The Commission on the Protection of the Black Sea Against Pollution

BLACK SEA
STATE OF ENVIRONMENT REPORT
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PREFACE AND ACKNOWLEDGEMENTS

This Report on the State of the Black Sea Environment (further referred to as BS SoE Report) for the years 2009-2014 is a scientific marine environmental assessment report undertaken periodically to trace the state of knowledge and to propose measures for improvement of the quality of environment and protection of ecosystems from impact of anthropogenic activities in the Black Sea basin[1.] This Report synthesizes the collected and evaluated data/information in this period. Its main findings demonstrated by smart indicators and, where possible, visualized on maps.

Therefore, the purpose of this assessment is to provide decision-makers, relevant stakeholders and public with comprehensive summary of contemporary knowledge on the state of the Black Sea environment in the selected period and to assess the efficiency of implemented policy and management measures. This Report also aims at identifying significant gaps in knowledge and to serve as basis for judging the effectiveness and adequacy of environmental protection measures, in particular, proposed in the Strategic Action Plan for the Environmental Protection and Rehabilitation of the Black Sea (BS SAP) adopted in 2009 and for making any necessary adjustments in national environmental policies and elaboration of scenarios for tackling environmental consequences of the human activities in the Black Sea basin.

This BS SoE Report is the third assessment prepared by the Commission on the Protection of the Black Sea Against Pollution[2] (further also referred to as Black Sea Commission or BSC), steps on the previous BSC SoE reports[3, 4] as well as on the reports and deliverables of the different international projects, such as SESAME, PERSEUS, KnowSeas, PEGASO, MISIS, EMBLAS, EMODNet and other relevant projects , as well as national projects and initiatives. It also refers to and utilizes to a certain extent relevant publications prepared for the Black Sea by various experts working in the Black Sea basin and beyond. This Report is prepared with financial contribution from EC/UNDP EMBLAS Project[5].

A lot of experts contributed to the elaboration of this SoE Report. These include representatives of the Black Sea scientific institutions; experts from projects and national programs of the Black Sea importance; individual scientists and research teams; partner organizations that have proven dedication and reached significant scientific results in the Black Sea environmental studies.

A dedicated Expert Working Group (WG) on elaboration of draft BS SoE Report was established under the auspices of the Black Sea Commission. The members of the WG met on 29th October, 2015 in Istanbul (Turkey) in order to discuss the modalities of report preparations in accordance with outline of the report which incorporated both existing approaches to ocean assessment - UN World Ocean Assessment approach (also called

1 Elaboration of this Report is in line with and contributes to the implementation of provisions of the Convention on the Protection of the Black Sea Against Pollution (Bucharest Convention), Strategic Action Plan for the Environmental Protection and Rehabilitation of the Black Sea (BS SAP) signed in 2009, relevant decisions and Annual Work Programmes of the Commission on the Protection of the Black Sea Against Pollution

2 http://www.blacksea-commission.org/

3 BSC, 2008. State of the Environment of the Black Sea (2001-2006/7). Edited by Temel Oguz. Publications of the Commission on the Protection of the Black Sea Against Pollution (BSC) 2008-3, Istanbul, Turkey, 421 pp.

4 http://www.blacksea-commission.org/_publ-SOE2002-eng.asp

5 EC/UNDP Project "Improving Environmental Monitoring in the Black Sea, http://emblasproject.org/

Regular Process)[6] and European approach reflecting provisions of the EU Marine Strategy Framework Directive (MSFD)[7]. The preparation of this meeting was partialy financed within the work of the EU PERSEUS Project[8].

Chapter 1 of the Report, within three sub-chapters, presents the state and dynamics of the Black Sea, geographical, physico-chemical characteristics and features of its biological community. Chapter 2 describes the state, dynamics and status of exploitation of the living and non-living resources in the Black Sea. Chapter 3 incorporates data on the state of Black Sea coast and socio-economic pressures and factors.

To conclude, I would like to extend my gratitude to colleagues from Permanent Secretariat, Kiril Iliev for his help in formatting and in particular Iryna Makarenko (PMA Officer) for her efforts throughout the production of the Report, all authors and especially to members of Working Group on elaboration of SoE Report for their scientific contributions, to the members of Black Sea Commission and its Advisory Groups for their valuable comments and proposals, all other organizations and individuals who kindly provided relevant data and information for this Report.

Let me wish all of us success in our efforts to preserve the unique and precious ecosystem of the Black Sea - our common heritage!

Prof. Dr. Halil İbrahim Sur
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6 The Black Sea Commission supported the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socio-economic Aspects, established under the UN General Assembly at its 28th BSC Regular Meeting (22nd October, 2012)

7 Two out of six Black Sea riparian countries (Bulgaria and Romania) are members of the European Union committed to implement the EU environmental legislation

8 http://www.perseus-net.eu/site/content.php

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2.1. MAIN BIORESOURCES

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EXECUTIVE SUMMARY

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The Black Sea, surrounded by the six coastal countries the Republic of Bulgaria (Bulgaria), Georgia, Romania, the Russian Federation (Russia), the Republic of Turkey (Turkey), and Ukraine. The location of the Black Sea Basin together with its climatic conditions has created a unique ecological system. Today, many of the Black Sea species are threatened by over-exploitation, habitat destruction, pollution and climate change. It reflects negatively on human well-being, social and economic sectors, and environmental services. By 1994, all Black Sea littoral states ratified the Convention on the Protection of the Black Sea Against Pollution of the Black Sea (the Bucharest Convention).

Being the first regional and legally binding instrument signed by all six Black Sea littoral states, the Bucharest Convention serves as an overarching framework laying down the general requirements and the institutional mechanism for the protection of the marine environment of the Black Sea.

Concrete commitments are determined and dealt with in protocols to the Convention. Negotiations on three protocols have been concluded. They focus on the protection of the marine environment of the black sea from land-based sources and activities, cooperation in combating pollution of the black sea marine environment by oil and other harmful substances in emergency situations, the protection of the black sea marine environment against pollution by dumping.

At the Meeting of the Parties to the Convention, held in Istanbul, the Republic of Turkey, 2013, the Conference of Parties (COP) requested the preparation of the second State of the Environment (SoE) of the Black Sea Report for distribution among Parties. Pursuant to that and other related requests by Parties, the Permanent Secretariat of the Convention organized a meeting of the leaders of Working Groups, in Istanbul, the Republic of Turkey, 28-31 October 2015. The Meeting agreed that the Report to be based, inter alia, on reports and documentation developed by the Working Groups and adopted by the Permanent Secretariat of the Black Sea Commission Against Pollution during 2009 - 2014. The content and the outline of the Report and distribution of responsibilities were also agreed.

For the assessment of the Black Sea status during 2009-2014 and its comparison with the previous period several data sources were used. The major source of the chemical data is the joint Regional Database on Pollution (RDB-P) of the Black Sea Commission. Additional important sources of environmental information for the Assessment are the Annual State Reports to the Secretariat of the Black Sea Commission Working Groups – Pollution Monitoring Assessment (PMA) and Land Base Sources (LBS).National scientific expeditions and environmental research activities also were used for the analysis of Sea condition and preparation of the assessment.

In the preparation of the report, due account was furthermore taken of other relevant scientific national and regional reports and publications and the development of a reporting format for the implementation of the Bucharest Convention and its Protocols. In order to increase the understanding and enhance the information on the state and trends of the marine environment of the Black Sea, there is a clear need to get a better insight about emerging environmental concerns.

The report summarizes the findings of the different assessments and includes existing updated figures. It is based on the latest information on policy and legislative measures, institutional setup, stakeholder engagement, future challenges and barriers to the improvement of the state of the environment in the region. The report is an effort to highlight the main trends in the marine and coastal environment of the Black Sea. It provides a gap analysis, showing the needs and requirements of the countries, individually and collectively, in the areas of monitoring, information collection and management related to policy, decision-making and implementation of the Bucharest Convention and its Protocols.

This report is based on materials and documents of the Permanent Secretariat of the Black Sea Commission Against Pollution, and does not reflect the official position of governments of the Black Sea states. It should not be regarded as a comprehensive analysis taking into account the consensus of all stakeholders and developed with their participation, but rather as a blueprint to help pave the way ahead, indicating what is needed to establish a monitoring network and programme capable of systematically measuring the state of the environment of the Black Sea, in light of the requirements of the Convention and its Protocols.

There are three chapters in the Report to reflect the state and dynamics of the Black Sea ecosystem, the state and dynamics of the living and non-living resources and their exploitation in the Black Sea region, and the state of the Black Sea coast and socio-economics.

It was suggested by the Meeting of the leaders of the Working Groups and coordinated by the PS BSC that the Report should focus on the scientific analysis of the Black Sea state.

The Report partially presents a regional picture reflecting the state of environment country by country but does not reflect the regional perspective.

Chapter 1 provides an overview of the Black Sea circulation and stratification characteristics, calculated characteristics of wind and waves, the Black Sea Water balance, chemical features, including nutrients dynamics and water and bottom sediments pollution, as well as land-based sources of pollution characterization.

The Chapter presents first the properties of the water column structure followed by the overall water balance and the long-term climatic variations. Finally, the circulation characteristics are summarized by emphasizing its energetic mesoscale variability. Based on the all available information related to the Black Sea circulation system it was suggested that the most notable quasi-persistent and/or recurrent features of the circulation system include (i) the meandering Rim Current system cyclonically encircling the basin, (ii) two cyclonic sub-basin scale gyres comprising four or more gyres within the interior, (iii) the Bosphorus, Sakarya, Sinop, Kizilirmak, Batumi, Sukhumi, Caucasus, Kerch, Crimea, Sevastopol, Danube, Constantsa, and Kaliakra anticyclonic eddies on the coastal side of the Rim Current zone, (iv) bifurcation of the Rim Current near the southern tip of the Crimea; one branch flowing southwestward along the topographic slope zone and the other branch deflecting first northwestward into the shelf and then contributing to the southerly inner shelf current system, (v) convergence of these two current systems near the southwestern coast, (vi) presence of a large anticyclonic eddy within the northern part of the northwestern shelf. All of these are well known characteristics of the Black Sea for decades, which means that despite of certain occasional variations in the vertical structure of the Black Sea ecosystem due to climatic or anthopogenic influence, the general hydrological and hydrophysical features of the Black Sea remain the same during the studied period.

Yet, the regime of wind waves in the Black Sea-Azov basin has a pronounced multiannual variability. This is most fully manifested in the regime of extreme sea swells. Usually strong storms with waves of more than 5 m heights are extremely rare on the Black Sea. Because of this, one or two strong storms can lead to the fact that a particular year will be perceived as a "stormy". This was *2013*, when, according to calculations, wave heights of more than 5 m were recorded in the centre of the sea. A different picture was observed in 2015, when waves of more than 2 m heights were observed only in the south-west of the sea. For the mean wave heights for a year, the opposite picture was observed. The height of extreme waves for 2013-2015 decreased but average of the height of waves for the year grew. Changes in the wave regime over these years are characterized by a decrease in extreme storms and an increase in the average wave strengths.

The wave regime for 2013-2014 was characterized by an increase in the average for the year wave periods in the west part of the sea. The average wave periods in the open water areas in the western part of the sea was increased by one second over the year. In the eastern part of the sea, the situation remained within the limits of the climatic norm.

According to climatic data, the direction of wind wave on the Black Sea has a north-easterly direction for the western part of the sea. The northern direction of wind wave is typical for the central water area and the north-western, western and south-western for its eastern part. North-eastern sea swells dominated the northeast of the sea as well as in its west in 2014 and 2015. Generally, this type of sea swells was typical until the 60s of the 20th century, when the winter northeast wind dominated the entire north-western part of the sea. The border of this domination was along the line of Novorossiysk-Bosporus.

The Black Sea is a semi-enclosed sea, surrounded by many industrialized countries, with important shipping routes, various fisheries and touristic areas. In addition it has a dynamic surface circulation and hosts a large drainage basin. All of the above factors make the Black Sea a particularly sensitive area for marine litter pollution (BSC, 2007; UNEP, 2009). A large number of rivers discharge into the Black Sea, including the second, third and fourth longest rivers in Europe. It is well acknowledged that rivers transport large amounts of natural and anthropogenic debris from in-land sources to the ocean and coastal beaches (Rech et al., 2014) and it is proven that high a percentage of marine litter, including micro-plastics, are introduced by river currents to the Black Sea (Tuncer et al., 1998; Topçu et al., 2013; BSC, 2007; Lechner et al. 2014).

This Chapter also provides a brief and easy understand information on waste water discharges from the riparian countries to the Black Sea and includes selected land based sources (LBS) data reported by the Black Sea (BS) countries for 2009-2015. According to the agreed classification, data were aggregated by countries. Municipal sources include discharges from wastewater treatment plants (WWTP). Four indicators of municipal pollution sources were included in this report. The parameters are: BOD5, total Nitrogen (TN), total Phosphorus (TP), total Suspended Solids (TSS), and waste waters discharged into the Black Sea. These indicators were selected to keep the possibility to comparing of the conceivable impact of the riparian countries.

Chapter 1 presents also model assessment of HM and POPs atmospheric input to the Black Sea pollution for the period 2009-2014. Modelling of atmospheric transport and deposition of selected HMs and POPs, namely, Cd, Pb, Hg, and benzo(a)pyrene (B(a)P), was carried out using MSC-E Eulerian transport models for Heavy Metals MSCE-HM (Travnikov and Ilyin, 2005) and for Persistent Organic Pollutants MSCE-POP (Gusev et al., 2005). Latest available official information on B(a)P emission from the EMEP countries was used in model simulations (Ilyin et al., 2016; Gusev et al., 2016).

The literature across international reports and scientific papers highlights that plastics are the most abundant type of marine litter worldwide. While plastic constitutes to around 75% of all litter items found in EU (Kershaw et al., 2013), the proportion found in both the Black sea's seafloor and coastal environments increased up to 90% (Topçu et al., 2013). Therefore, in accordance with global data, plastic waste has a worldwide predominance in the marine environment (Suaria et al., 2015). In regards to micro-plastics, the studies conveyed that the Black Sea is prone to micro-plastic accumulation, both in the pelagic and benthic habitats, which make it as a micro-plastic hotspot. In regards to the marine litter density, the Kerch Strait and Azov Sea each contain an extensive marine litter density relative to the rest of the Black Sea. It should also be highlighted that there are differences between each countries methodology and units when collecting and reporting marine litter densities; this makes it hard to compare the results between countries. There is therefore an urgent need for basin-wide surveys following similar observation techniques and to allow comparisons on marine litter composition and accumulation within and between countries. The majority of the marine litter data comes from coastal surveys followed by seabed studies. There were only two surveys focused on the presence of micro-plastics, one in Romania and one in Turkey. It is clear that all six Black Sea countries are on the pioneering stage of marine litter pollution management.

- Analysis of the information collected from the annual reports of the riparian countries delivered by LBS AG and presentations delivered during 21st LBS AG meeting 8–9 September 2016 allowed to make the following conclusions about the content of the waste waters discharged into the Black Sea:
- Bulgaria: there was an increasing tendency observed in the content of organic matters indicated in BOD5, total nitrogen, and suspended solids. At the same time, there was a decreasing tendency in the discharge of total phosphorous in the Bulgarian waste waters;
- Georgia: the waste waters discharged into the Black Sea from LBSs almost tripled from 2008 to 2014 with the volume of untreated waters decreased up to 40% in 2014 as compared with 2009. There was an increasing tendency in concentration of total nitrogen and total organic matters with the decreasing tendency in total suspended solids in Georgian waste waters;
- Romania: the volume of Romanian waste waters discharged into the Black Sea decreased by over 15% and the volume of untreated waters discharged into the Black Sea decreased almost by50% from 2008 to 2013. There was a decreasing tendency of content of total nitrogen and total suspended solids and an increasing tendency of total phosphorous and organic matters (BOD5);
- Russian Federation: there was a decreasing tendency in the volume of total nitrogen, phosphorous, organic matters, and suspended solids in Russian waste waters;
- Republic of Turkey: there was a substantial decrease of the volume of total discharge of pollutants in waste waters from Turkey's municipal source and there was a slight increasing tendency in BOD5, total suspended solids load, and total phosphorous, and visual increasing tendency in total nitrogen discharges in river waters;
- Ukraine: the total nitrogen discharge had slight increasing tendency and discharge of total phosphorous and organic matters had decreasing tendency in Ukrainian waste waters. There were decreasing tendencies in the content of total phosphorous and organic matters and slight increasing tendency in total nitrogen in Ukrainian waste waters.

Dynamics and over the years changes of Nutrients (C, N, P, Si), as well as the Black Sea eutrophication, and pollution, in particular by oil and oil products, are discussed in Subchapter

2. It was noted that information about pollution was largely fragmented and in most of the cases was not comparable.

Chapter 2 assesses the marine living resources status for the period of 2009-2014 and compares with the earlier period to explain the changes occurred. It first informs on anadromous fishes, and then about pelagic fishes.

It was noted that the lack of sufficient information concerning fishing activity, catch quantities, composition and its impact on the current state of the fish stocks are the critical issues for the Black Sea region. It is due to the fact that there are different techniques were and currently are in place for recording, evaluating, controlling and monitoring of the fishing activities as well as a number of surveys of the current state of the fishing stocks performed.

The analysis of data collected shows that:

- there is only one stock - sprat, which is considered sustainably exploited;
- most of fish stocks in the Black Sea are overexploited to the extent that some of them are nearly to depletion.

Therefore, there is the need to put more efforts in recovery and sustainable development of the fishing stocks to targeted levels of abundance identified. Measures, being developed and implemented, could mitigate the impact of the fishing activities endangering reproductive capacity and jeopardizing the fish stocks (EC, 2009).

Main conclusions to Chapter 2 are that the Black Sea is indeed exposed to many threats that need to be addressed urgently. Overfishing, illegal, unreported and unregulated (IUU) fishing, pernicious discarding practices, ghost fishing, marine pollution, uneven development of aquaculture and invasive species are the most important threats, although not the only ones. The declines of marine living resources were generated by: eutrophication (sources from agriculture, municipal waste, industry, etc.); harmful substances (sources from agriculture, industry, municipal waste, etc). In summary, the main causes for the Black Sea current status are hydraulic works; commercial fisheries; alien species; and climatic changes. Therefore, the causes of this situation are multiple, the independent effect of each being very difficult to be assessed:

- The high value of the percentage of the species sprat and their constancy within the catches explain the high oscillations of the annual catches on the Romanian coast. These oscillations occur even more as the fishing is done in a restricted area of coast where the conditions of maintaining fish shoals are extremely variable;
- The passive fishery uses pound nets and has suffered the strongest impact due to the change of the ecological conditions near the coast zone. Moreover, there are observations attesting the fish migration routes changed during the last 6-7 years. The fish has the tendency to remain in the offing, at a certain distance from the coast zone with the isobaths of 5-13 m where the pound nets are located;
- The environmental conditions existing to the Romanian littoral allowed formation and maintaining of very large agglomerations of gelatinous species, especially jellyfish. Jelly fish and ctenophore agglomerations making difficult the trawl fishery on all hauling level in some years and periods;
- Heavy fishing on small pelagic fish predominantly by the Soviet Union, and later also by Turkey, was carried out in a competitive framework without any agreement between the countries on limits to fishing. Depletion of the small pelagic stock appears to have led to increased opportunities for population explosion of planktonic predators (jelly

fish and ctenophores) which have competed for food with fish, and preyed on their eggs and larvae;

- The reduction of the fishing effort as a consequence of the economic changes occasioned by the transformation of the state capital into private capital;
- The limitation of market demands for some periods of the year, mainly amplified by the fact that more than 90% of the production was delivered as salted fish;
- The free market and imported products have caused the limitation of the traditionally prepared products and the reduction of their price until the limit of the profitableness (Radu et al., 2012).

Chapter 3 is devoted to the state of the coastal zone of the Black Sea and is based on the information presented annually by the Black Sea countries to the Permanent Secretariat of the Black Sea Commission Against Pollution for the period 2009 - 2013.

Economic activity at the coastal zone impacts on the state of the entire marine ecosystem. Therefore, it is important to take into consideration and discuss drivers, pressures, state, impact, and response analyzing the state of the Black Sea environment. Based on this approach the ICZM Advisory Group at its meeting decided to base its reports on general information of the Black Sea coastal zone as well as on data about population, including demographic trends, water and wastewater management, solid waste management, and information on protected areas. It was also decided that the Report should reflect coastal erosion, land use and economic activities.

Black Sea countries agreed that the Coastal Zone is the geomorphological area either side of the seashore in which the interaction between the marine and land parts occurs in the form of complex ecological and resource systems made up of biotic and abiotic components coexisting and interacting with human communities and relevant socio-economic activities.[9]

Analysis of information available related to the State of the Coast and Socio-economics allows to draw the following conclusions:

1. Due to the lack of important information a deep analysis of the state of the coast was impossible. To overcome the problem, ICZM Advisory Group of the Black Sea Commission decided to introduce new indicators for assessment of the state of the Black Sea coast. They were tested and ICZM Advisory Group agreed to use these indicators for future activities.

2. Black Sea coast is the zone of many types of activities. The most part of the coastal zones in Bulgaria, Romania and Ukraine are used for agriculture. In Russia biggest part of the coast is covered by forest and protected.

3. The number of population in the coastal zone is growing in Bulgaria, Russia and Turkey and decreasing in Romania and Ukraine.

4. There is a sustainable growth in access to drinking water and sanitation in all countries.

5. There is an increase in the amount of municipal wastes. The number of landfills has increased in Romania, Turkey and has decreased in Russia and Bulgaria. There is only one incineration plant. It locates in Turkey.

6. Erosion of the coast is increasing. However, there are very few projects implemented to prevent it.

9 Protocol on Integrated Coastal Zone Management in the Mediterranean, 2008

7. There are activities going on to improve protection of the coastal zone environment, including marine.

8. Since previous report the structure of economic activities was not changed. The leading sectors are tourism, food processing, agriculture and transport, including shipping.

9. Oil transshipment sufficiently impact on environment.

CHAPTER 1: STATE AND DYNAMICS OF THE BLACK SEA ECOSYSTEM

THE STATE AND DYNAMICS OF THE BLACK SEA PHYSICAL AND CHEMICAL FEATURES

1.1 Physical Features

1.1.1 Coastline characteristics, topography and bathymetry, geology of the Black Sea

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Abstract

The present section provides an overview of the Black Sea flow and stratification characteristics. It presents first the properties of the water column structure followed by the overall water balance and the long-term climatic variations. Finally, the circulation characteristics are summarized by emphasizing its energetic mesoscale variability.

Introduction

The Black Sea is a nearly enclosed and zonally elongated basin with the zonal dimension of about 1200 km and the meridional dimension varying from 500 km on the western side to 250 km towards the eastern side (Figure 1.1.1.1). With a surface area of 423,000 km2, it is approximately one-fifth of the surface area of the Mediterranean. It has a limited interaction with the Aegean Sea through the Turkish Straits System. Its main bathymetric feature is the presence of a narrow shelf (generally less than 20 km) and steep topographic slope (generally less than 30 km) around deep interior basin having maximum depths of 2200m (Figure 1.1.1.1). The north-western part of the sea, occupying ~20% of the total area, is characterized by a fairly wide shelf and its connection to the deep western basin through a wider topographic slope zone. The width of the western shelf gradually reduces towards south and finally terminates to the east of the Bosphorus Strait exit region (Figure 1.1.1.1). The Black Sea receives fresh water inflows all around the basin but the important ones (Danube, Dniepr and Dniestr) discharge into the north-western coastal waters. The River Danube being one of the largest rivers in Europe introduced dramatic effects on the Black Sea ecosystem.

Physical characteristics

Stratification characteristics

The Black Sea is a strongly stratified system; its stratification within the upper 100 m layer (10% of the entire water column) varies up to σt ~ 5 kg m-3 (Figure 1.1.1.2) and is an order of magnitude greater than, for example, in the neighboring Mediterranean Sea. The pycnocline corresponding to the density surface σt ~16.2 kg m-3 approximately conforms to 100-150 m depth within the interior cyclonic cell or may extend to 200 m within coastal anticyclones. The deep homogenous layer that has a thickness of 2000m within the abyssal plain of the sea possesses almost vertically uniform characteristics below 200 m within the range of values of T ~ 8.9-9.1oC, S ~ 22-22.5, σt ~ 17.0-17.3 kg m-3. The deepest part of the water column approximately below 1700 m involves homogeneous water mass formed by convective mixing due to the bottom geothermal heat flux during the last several thousands of years (Murray et al., 1991).

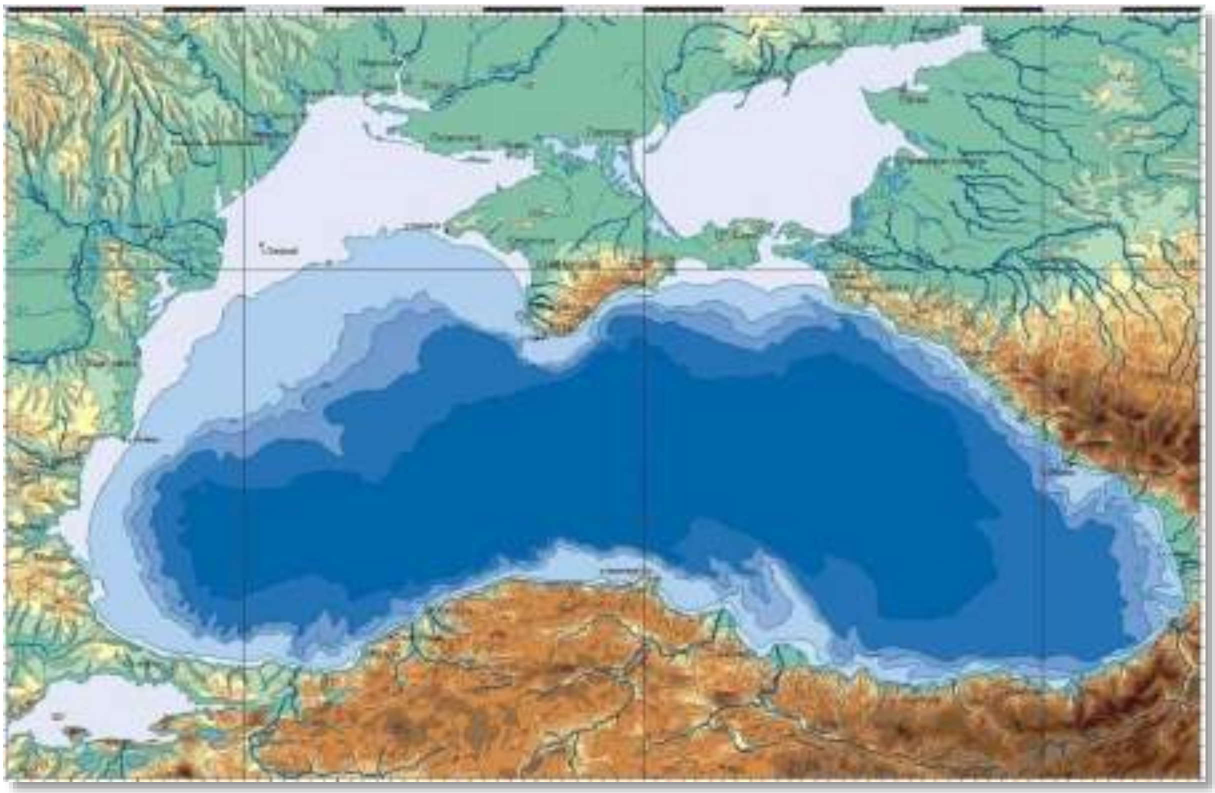

Figure 1.1.1.1. The location and bathymetry of the Black Sea.

The upper 50-60 m is homogenized in winter with T~6-7 oC, S ~18.5-18.8, σt ~14.0-14.5 kg m-3 when the north-western shelf and near-surface levels of the deep basin exposed to strong cooling by successive cold-air outbreaks, intensified wind mixing, and evaporative loss. As the spring warming stratifies the surface water, the remnant of convectively-generated cold layer is confined below the seasonal thermocline and forms the Cold Intermediate Layer (CIL) of the upper layer thermohaline structure. Following severe winters, the CIL may preserve its structure for the rest of the year, but it may gradually warm up and loose its character in the case of warm winter years. Stratification in summer months comprises a surface mixed layer with a thickness of 10-20 m with T~22-26oC, S~18-18.5 and σt ~10.5-11.5 kg m-3.

A distinct feature of the SST is the strong spatial variability as inferred by the long-term mean distribution (Figure 1.1.1.3). The temperature difference as high as 3oC extends diagonally from its lowest values (~13.5oC) within the north-western shelf region and relatively higher values (~16.5oC)within the eastern part of the eastern basin. This is related to the more frequent exposition of the western part to the cold air outbreaks from the continental Europe. On the contrary, the eastern basin is protected from such cold outbreaks by the mountain chains along the southern and eastern coastlines. Thus, the eastern basin favours milder winters and warmer winter temperatures in the surface mixed layer. Thus the decadal warming signature was felt more pronouncedly in the eastern basin during the 1990s. The relatively deep interior part of the sea is also slightly cooler than the peripheral zone due to the persistent upwelling motion associated with the cyclonic circulation system.

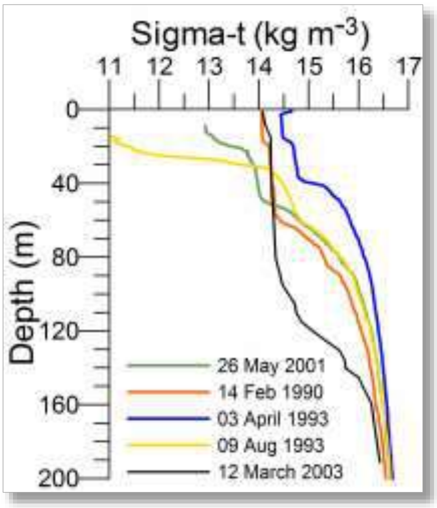

Figure 1.1.1.2. Vertical variations of density (expressed in terms of sigma-t, kg m-3) at various locations of the interior basin during different months representing different types of vertical structures.

An important feature of the upper layer physical structure is the intensity of diapycnal mixing that controls ventilation of the CIL and oxygen deficient zone and nutrient entrainment from its subsurface source in winter months. According to the recent microstructure measurements (Gregg and Yakushev, 2005 and Zatsepin et al. 2007), the vertical diffusivity attains its maximal values on the order of 10-3–10-4 m2 s−1 in the surface mixed layer (0–15 m), but decreases to 10-5–10-6 m2 s−1 across the seasonal thermocline (15–30 m). An increase in the diapycnal diffusivity is observed in the CIL to the range 2–6 x 10-5 m2 s−1. Below the base of the CIL, it rapidly decreases to its background values of 1–4×10-6 m2 s−1. Consequently, turbulent fluxes near the base of CIL are too weak to renew the oxygen deficient Suboxic Layer (SOL).

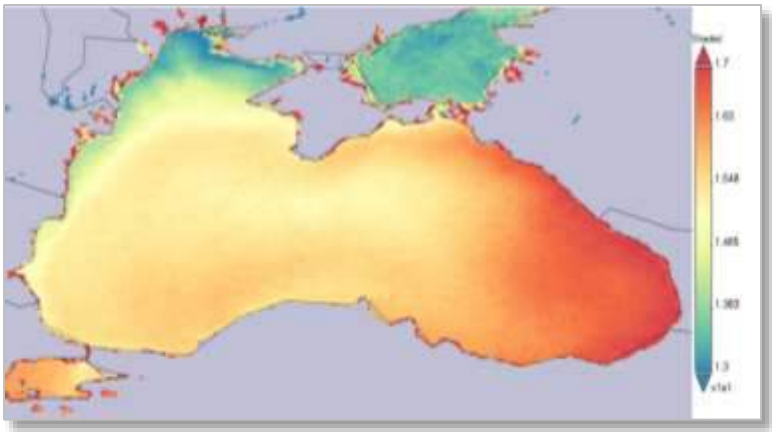

Figure 1.1.1.3. Time averaged (2002-2016) SST distribution over the Black Sea provided by the 4km resolution monthly mean MODIS satellite products.

The Mediterranean underflow that is characterized typically by T~13-14 oC and S~35-36 upon issuing from the Bosphorus modifies considerably by mixing with the upper layer waters and enters the shelf with T~12-13 oC and S~28-30. In the shelf, its track is regulated by small scale topographic variations. As it spreads out as a thin layer along the bottom, it is diluted by entrainment of relatively colder and less saline CIL waters and is barely distinguished by its slight temperature and salinity differences from the ambient shelf waters up on issuing the shelf break. The modified Mediterranean water is then injected in the form of thin multiple layers at intermediate depths (150-250 m) (Hiscoock and Millero, 2006; Glazer et al, 2006). Signature of the Mediterranean inflow within the interior parts of the basin can be best monitored up to 500 m, where the residence time of the sinking plume varies from ~10 years at 100 m depth to ~400 years at 500 m (Ivanov and Samodurov, 2001; Lee et al., 2002).

On the basis of available data since the 1920s (Ilyin et al., 2005), the total river discharge and precipitation into the sea show weak but opposite trends that compensate each other and therefore their sum remain uniform at ~550 km3 y-1. Evaporation varied slightly around 400 km3 y-1 up to the mid 1970s (except 15% increase in the 1940s), and then decreased steadily to ~300 km3 y-1 during the subsequent 15 years and stabilized at this value afterwards. The net fresh water flux into the sea, therefore, revealed an increasing trend from ~120 km3 y-1 in the early 1970s to ~300 km3 y-1 in the mid-1990s. This freshwater excess is balanced by the net outflow through the Bosphorus defined as the difference between the transports of its two layers and implies a nearly two-fold change from the 1960s to the 1990s.

Climatic variations

The physical characteristics of the upper layer water column above the base of the permanent pycnocline experienced distinct decadal-scale oscillations (Oguz et al., 2006; Piotukh et al., 2011). The sea surface temperature (SST) is used here as a proxy for describing climatic variability. It indicates a relatively mild cooling phase (0.5oC) during 1960-1980 and a subsequent more pronounced cooling phase identified by the winter (December-March) mean sea surface temperature (SST) changes as high as 1.5oC during 1980-1993 (Figure 1.1.1.4). Similar variations are also observed in the summer-autumn (May-November) mean subsurface cold intermediate layer (CIL) temperature field (Figure 1.1.1.4). They are followed by an equally pronounced warming phase during 1993-2014. They imply a clear signal of climatic changes within the upper 100m water column above the permanent pycnocline. The climate-induced temperature changes are related to strengthening of the NAO; its positive phase resulting in colder, drier, and more severe winters contrary to the simultaneous wetter, warmer, and milder winters over the northwestern Europe and the Eastern North Atlantic Ocean (Oguz et al., 2006). The subsequent warming trend starting by 1993 up to 2001 increases the SST and CIL temperature back to their former levels prior to the 1980. Afterwards, both SST and CIL temperature undergoes to a decadal scale oscillation with an amplitude of ~1.5oC between the minimum at 2005-2006 and the maximum at 2010-2011, followed by a decreasing trend.

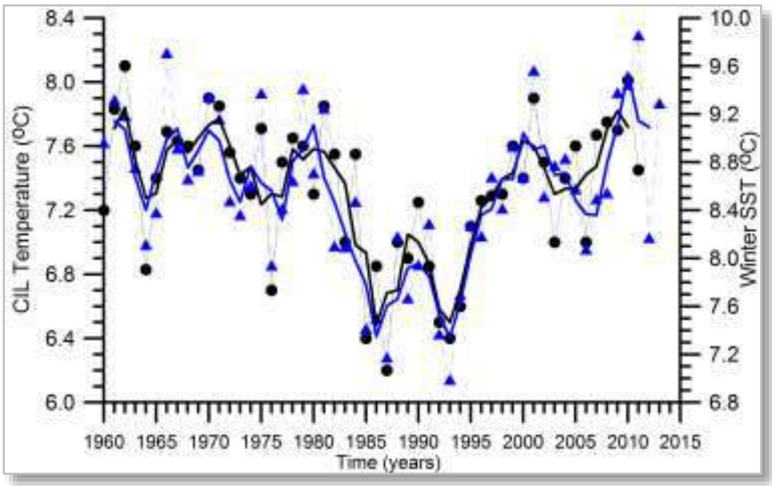

Figure 1.1.1.4. Long term variations of the winter (December-March) mean sea surface temperature and the summer-autumn (May-November) mean Cold Intermediate Layer (CIL) temperature below the seasonal thermocline.

The thin lines with symbols refer to the original data whereas the thick lines represent their smoothed variations by three point running averaged.

Sea level changes provide best response of the physical climate to atmospheric forcing, because the link includes an overall response of the changes in the surface atmospheric pressure through the inverse barometer effect, water density changes in response to temperature and salinity variations (steric effects), precipitation, evaporation and river runoff. The detrended sea level anomaly time series at Poti tide gauge site located at the southeastern corner of the sea (Figure 1.1.1.5) reveals higher (lower) SLA values coinciding with the warm (cold) cycles of the SST and exhibits a rising trend up to the mid-1999 (~3 cm y-1) followed by -3.0 cm y-1 declining trend 07/1999–12/2008 in consistent with the cooling phase indicated by the winter SST data and a rising trend afterwards. Good agreement between the SLA changes and the temporal variation of the Danube discharge suggest its predominant role on the basin-scale sea level oscillations.

The general consistency between periods of positive (negative) NAO index and relatively low (high) sea surface and air temperatures, higher (lower) surface air pressures supports the presence of a teleconnection between the regional atmospheric conditions and the NAO-driven large scale atmospheric motion (Oguz et al., 2006, Kazmin and Zatsepin, 2007). In terms of duration and intensity of events, the sequence of mild and severe winter cycles follows the temporal pattern of the negative and positive NAO cycles, respectively. In particular, the strong cooling trend during 1980-1993 characterizes an extended strongly positive NAO phase. The subsequent warming trend in SST coincides with the waekening of positive NAO index and its decreasing trend. The NAO climatic control of the Black Sea may be further modulated by the EAWR oscillation (Oguz et al., 2006).

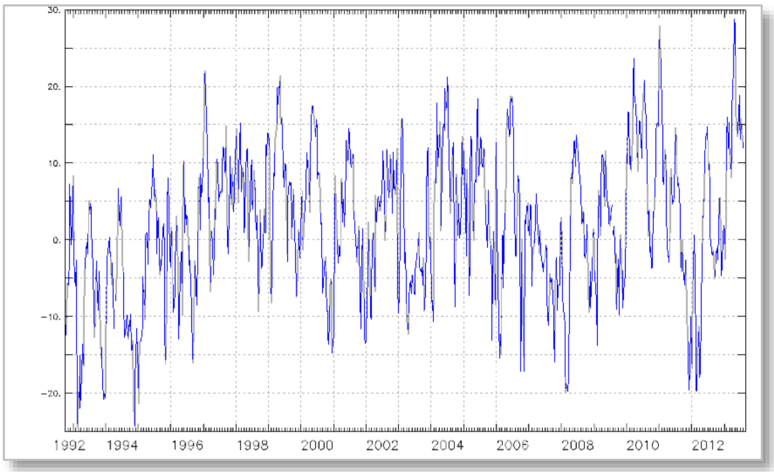

Figure 1.1.1.5. The sea level anomaly time series at Poti tide-gauge site located at the southeastern corner of the sea.

Circulation characteristics

The upper layer (100-150m) water column of the Black Sea above the permanent pycnocline reveals a complex, eddy-dominated circulation (Figure 1.1.1.6). It comprises different types of structural organizations of water masses within the interior cyclonic cell, the Rim Current jet is confined mainly along the abruptly varying continental slope and margin topography around the basin, and a series of anticyclonic eddies along its onshore side (Oguz et al., 1994; Besiktepe et al., 2001; Blockhina and Afanasyev, 2003; Korotaev et al., 2003; Zatsepin et al., 2003; Kubryakov and Stanichny, 2015). The interior circulation consists of several sub-basin scale gyres, each of which is formed by several cyclonic eddies. They evolve continuously by interactions among each other, as well as with meanders and filaments of the Rim Current. The overall basin circulation is primarily forced by the curl of wind stress throughout the year, and further modulated by the seasonal evolution of the surface thermohaline fluxes and mesoscale features arising from the basin’s internal dynamics. The strong topographic slope together with the coastline configuration of the basin governs the main pattern of the Rim Current system. It changes seasonally from a more coherent structure in the winter and spring to more a turbulent, eddy-dominated structure in the late summer and autumn.

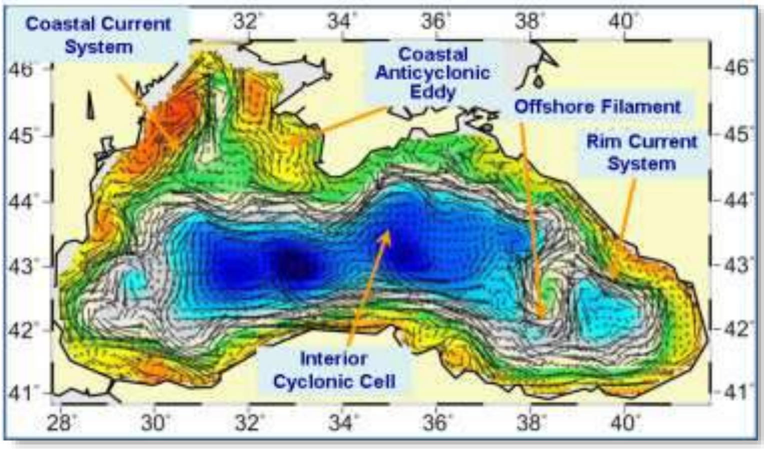

Figure 1.1.1.6. A typical structure of the upper layer circulation field deduced from a circulation model using assimilation of altimeter sea level anomaly data as described by Korotaev et al. (2003).

Larger scale characteristics of the upper layer circulation system possess a distinct seasonal cycle (Korotaev et al., 2003; Poulain et al., 2005). The interior cyclonic cell in winter months involves a well-defined two-gyre system surrounded by a rather strong and narrow jet without much lateral variations. This system gradually transforms into a multi-centered composite cyclonic cell surrounded by a broader and weaker Rim Current zone in summer. The interior flow field finally disintegrates into smaller scale cyclonic features in autumn (September-November) in which a composite Rim Current system is hardly noticeable. The turbulent flow field is rapidly converted into a more intense and organized structure after November-December.

The circulation is accompanied by a well-defined, meandering salinity front separating relatively less saline and dense coastal waters from more saline and denser interior basin (Figure 1.1.1.7). The fresh water discharge from the Danube contributes to buoyancy-driven component of the basin-wide cyclonic circulation system. Baroclinic instability processes are responsible by introducing considerable variability of the Rim Current in the form of eddies, meanders, filaments, offshore jets that propagate cyclonically around the basin. Over the annual time scale, westward propogating Rossby waves further contribute to the complexity of basinwide circulation system. Eddy dynamics and mesoscale features evolving along the periphery of the basin as part of the Rim Current dynamic structure appear to be the major factor for the shelf-deep basin exchanges. They link coastal biogeochemical processes to those beyond the continental margin, and thus provide a mechanism for two-way transports between nearshore and offshore regions.

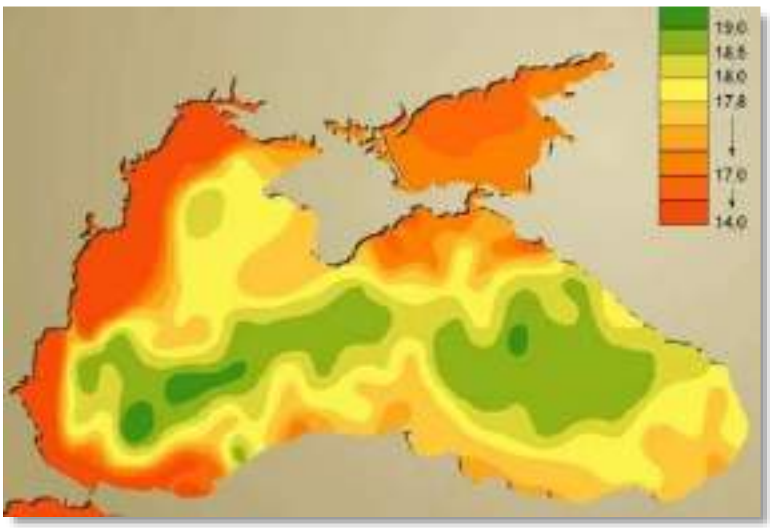

Figure 1.1.1.7. Surface salinity distribution determined by the July 1992 multi-ship basinwide survey.

The distribution possesses a meandering frontal structure between the relatively high interior basin salinity (> 18.0 psu) compared to lower salinity values around the basin maintained by the coastal fresh water discharges and outflow from the Azov Sea.

The Ship mounted Acoustic Doppler Current Profiler (ADCP) and CTD measurements in the western Black Sea (Oguz and Besiktepe, 1999), carried out soon after an exceptionally severe winter conditions in 1993, has shown a vertically uniform current structure in excess of 50 cm/s (maximum value ~100 cm/s) within the upper 100 m layer, followed by a relatively sharp change across the pycnocline (between 100 and 200 m) and the vertically uniform sub-pycnocline currents of 20 cm/s (maximum value ~40 cm/s) up to 350 m being the approximate limit of ADCP measurements. The cross-stream velocity structure exhibited a narrow core region (~30 km) of the Rim Current jet that was flanked by a narrow zone of anticyclonic shear on its coastal side and a broader region of cyclonic shear on its offshore side. Such exceptionally strong sub-pycnocline currents of the order of 20-40 cm/s should be largely related with the severity of the winter conditions that was indeed one of the most severe winters of the last century (Oguz et al., 2006). The corresponding geostrophically-estimated currents from the CTD measurements were relatively weak due to the lack of ageostrophic effects and barotropic component of the current.

Lagrangian subsurface current measurements by the autonomous profiling floats deployed into the intermediate layer and deep layers provided direct, quantitative evidence for strong currents and a well organized flow structure, that changed the traditional views built on a rather sluggish deep circulation of the Black Sea (Korotaev et al., 2006). The data suggested active role of mesoscale features on the basin-wide circulation system at 200m similar to the case observed in the upper layer (<100m) circulation system. The currents reach a maximum intensity of 15 cm s-1 along the Rim Current jet around the basin, which is consistent with the findings of ADCP measurements (Oguz and Besiktepe, 1999).

The magnitudes of deep currents may reach to 5 cm s-1 at 1500 m depth along the steep topographic slope (Korotaev et al., 2006). The combination of float and altimeter data suggests that deep currents are steered by the steep topographic slope and well-correlated with the structure of surface currents at seasonal and longer time scales. The deep layer currents flow along the strong topographic slope following constant potential vorticity isoclines due to the topographic β-effect. The wind stress, as the main driving force, can introduce a barotropic flow on the order of 5 cms-1 as further supported by the numerical modeling studies (Stanev, 1990; Oguz et al., 1995; Stanev and Beckers, 1999). The floats at the intermediate (750 m) and deep (1550 m) layers also delineate the importance of mesoscale eddies on the flow field.

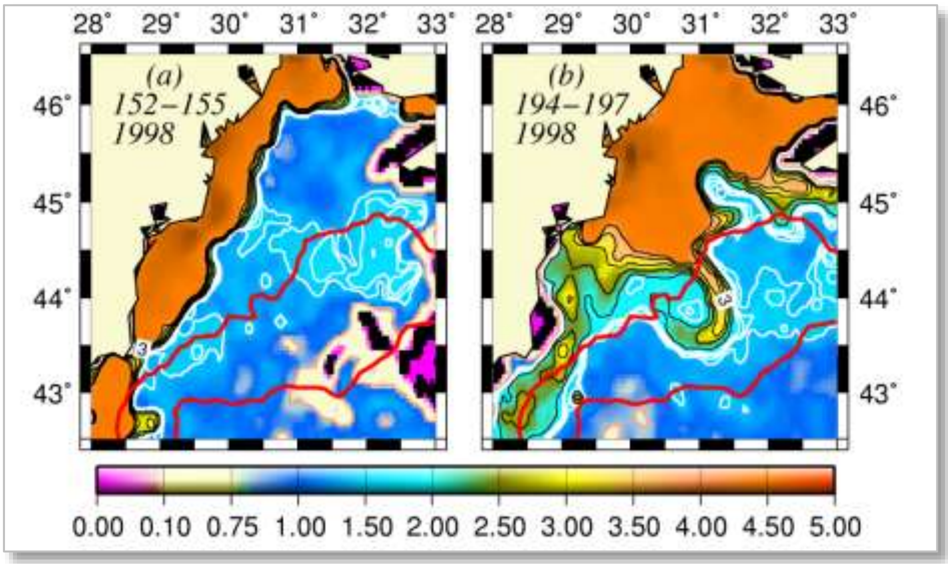

Figure 1.1.1.8. SeaWiFS chlorophyll distributions showing two alternative forms of circulation structure in the northwestern shelf; (a) a southward coastal current system during

days 152-155 (early June) and (b) a closed circulation system confined into its northern sector during days 194-197 (mid-July), 1998 (taken from Oguz et al., 2002).

The basic mechanism which controls the flow structure in the surface layer of the northwestern shelf is spreading of the Danube outflow. Wind stress is an additional modifier of the circulation. The Danube anticyclonic eddy confined within a narrow band along the coast between Odessa and Constantsa and often introduced by the wind forcing prevails for almost half of the year during spring and summer months (Figure 1.1.1.8). It sometimes expands and occupies almost the whole NWS region (Figure 1.1.1.8b). The Constanta and Kaliakra anticyclones located further south have a typical lifespan of 50 days are observed for about 190 days per year. An alternative configuration of the River Danube plume is the southward coastal current system (Figure 1.1.1.8a). The leading edge of this plume protrudes southward (i.e downstream) as a thin baroclinic boundary current along the western coastline. The flow system is separated from offshore waters by a well defined front as inferred from the large constrast between the chlorophyll concentrations in the figure. Its offshore flank may display unstable features, exhibits meanders and spawns filaments extending across the wide topographic slope zone (Figure 1.1.1.8b). Except such small scale features, there is almost no exchange between shelf and interior basin.

All available finding of the Black Sea circulation system suggest that the most notable quasi-persistent and/or recurrent features of the circulation system include (i) the meandering Rim Current system cyclonically encircling the basin, (ii) two cyclonic sub-basin scale gyres comprising four or more gyres within the interior, (iii) the Bosphorus, Sakarya, Sinop, Kizilirmak, Batumi, Sukhumi, Caucasus, Kerch, Crimea, Sevastopol, Danube, Constantsa, and Kaliakra anticyclonic eddies on the coastal side of the Rim Current zone, (iv) bifurcation of the Rim Current near the southern tip of the Crimea; one brach flowing southwestward along the topographic slope zone and the other branch deflecting first northwestward into the shelf and then contributing to the southerly inner shelf current system, (v) convergence of these two current systems near the southwestern coast, (vi) presence of a large anticyclonic eddy within the northern part of the northwestern shelf.

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1.1.2 Wind and waves calculations

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The quality of wind wave computation in the sea is primarily determined by the quality of atmospheric exposure calculation. Within the framework of this article, there were two regional atmospheric models were used, i.e. RegCM and WRF. It should be noted that the RegCM model is being applied in many foreign and national centres for the reproduction and forecast of regional atmospheric circulation because of its high quality and ease of use. Version RegCM4.3.5.6 of the regional hydrostatic model of atmospheric circulation was developed at ECMWF (European Centre for Medium-Range Weather Forecasts) (Elguindi, et. al., 2013). This version was adapted to the of the Black Sea region conditions.

Model RegCM was used to calculate fields of a driving wind for 1979 - 2013 on the grid of 138 × 74 in steps of 0.11 degrees, both in latitude and longitude. Applied step by time was 6 hours. Fields of the driving wind were calculated at the Marine Hydrophysical Institute and transmitted to SOI within the framework of the interinstitutional cooperation. Starting from 2014, calculation of driving wind fields was conducted in SOI with WRF model on a 194 × 94 grid in steps of 0.08 degrees both in latitude and longitude with the time step of 6 hours. It was done because interaction between institutions was ceased in 2014. Fields of wind-generated waves for 1979 - 2013 were interpolated into the WRF grid.

Wind wave fields were based on the corresponding driving wind fields. The model of the Russian Atmospheric-Wave Model (RAWM) based on the same type of the grid was used to calculate the directional spectrum of wind waves in the Black and Azov Seas. "Narrow-directional" simplification of Hasselmann’s kinetic integral which describes the nonlinear interactions in the spectrum of wind waves was used in the model. The average wave height was used in the system for the analysis of wave heights. Further, this mode detail will be omitted for brevity.

Wave climate of the Black Sea was calculated for 1979 - 2013. Weibull’s distribution was used to approximate the empirical distribution of wave heights for each grid point. A quantile which corresponds to the probability of occurrence of the event once a year was shot from it (Fig. 1.1.2.1) Climate data will be used to compare with calculations for a specific year. Separately, the highest wave heights for 2013, 2014 and 2015 were obtained (Fig. 1.1.2.2 – 1.1.2.4). These maps were obtained by sampling the highest wave height according to calculations for a particular year.

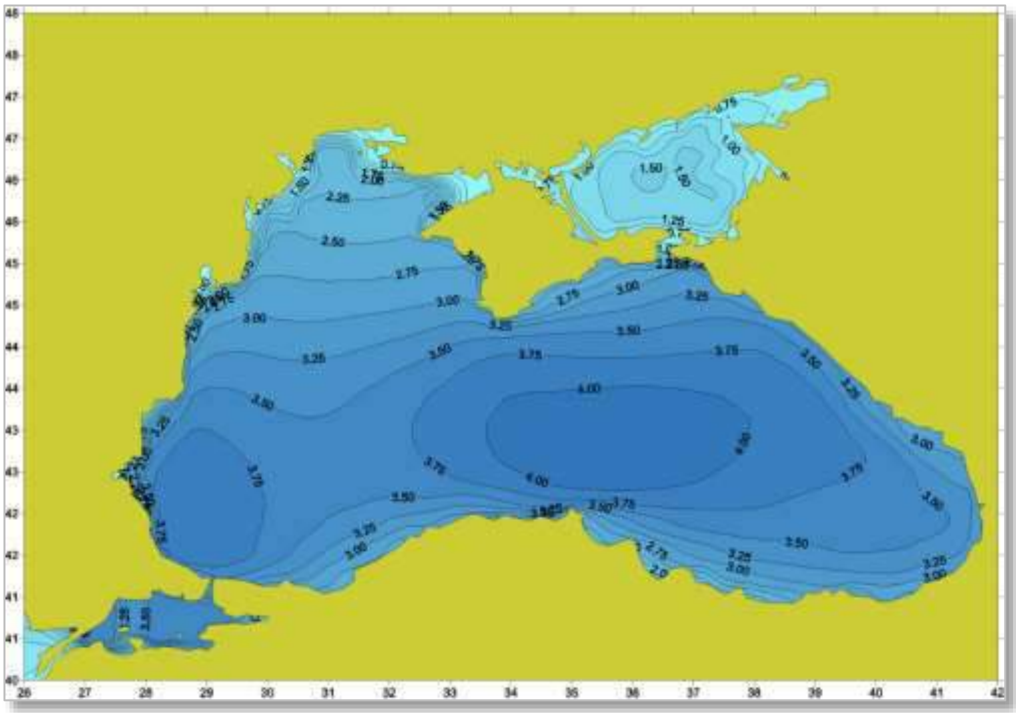

Figure 1.1.2.1. Average wave heights, possible occur once a year in the Azov-Black Sea basin (according to 1979-2013 data).

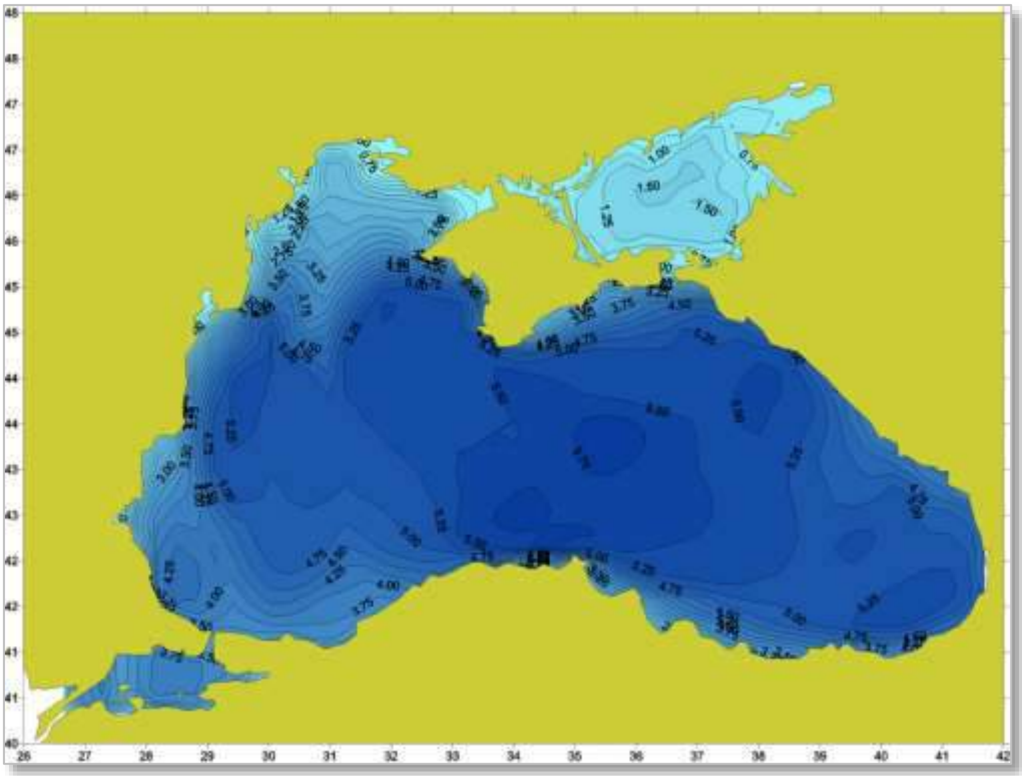

Figure 1.1.2.2. The highest average wave in the Azov-Black Sea basin (according to 2013 data).

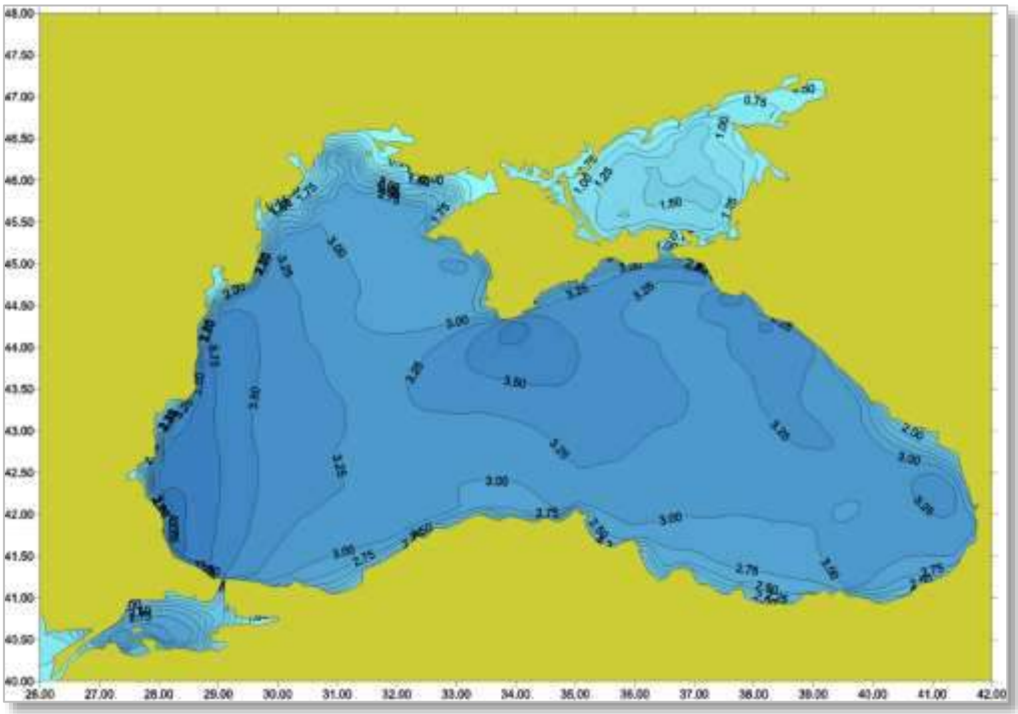

Figure 1.1.2.3. The highest average wave in the Azov-Black Sea basin (according to 2014 data).

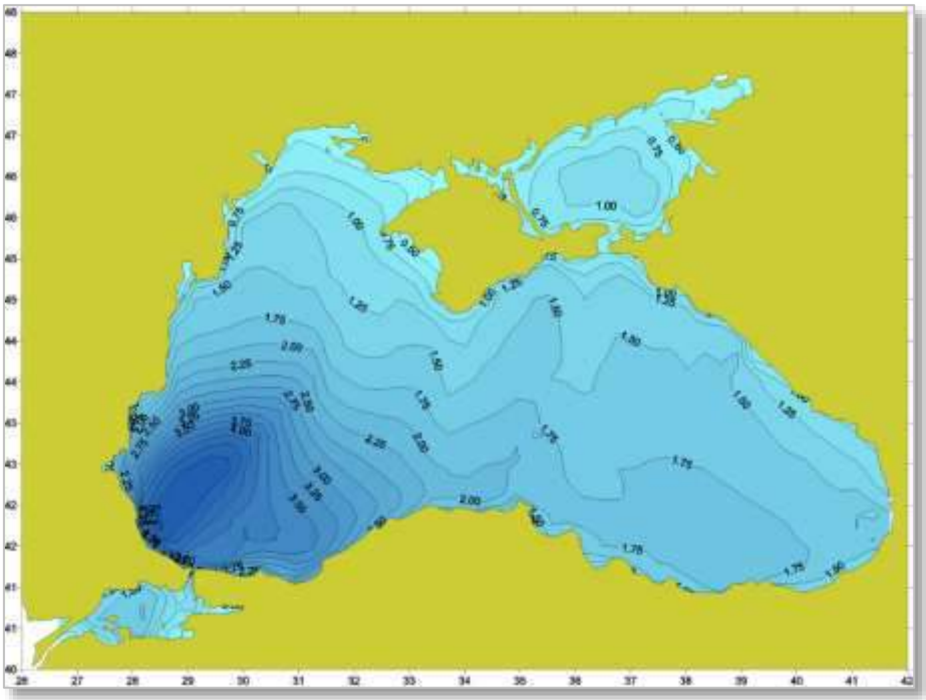

Figure 1.1.2.4. The highest average wave in the Azov-Black Sea basin (according to 2015 data).

According to the studies conducted, it can be argued that storm surges on the Black Sea have a strong interannual variability. The average long-term conditions are characterized by the presence of a strip in the centre of the sea with greater waves (more than 3.5 m). However, the picture is more variegated during some years. 2013 can be considered relatively "stormy". The highest wave heights exceeded by more than a meter the average annual during this year. The following years (2014 and 2015) are marked by the fact that storms of such force were not observed as in 2013. In its "storm" conditions, 2014 was close to the average for many years, then 2015 can be considered relatively "quiet". Wave conditions close to the average annual were observed in the south-west of the sea only. Figures 1.1.2.5-1.1.2.8 show the average wave heights for this year.

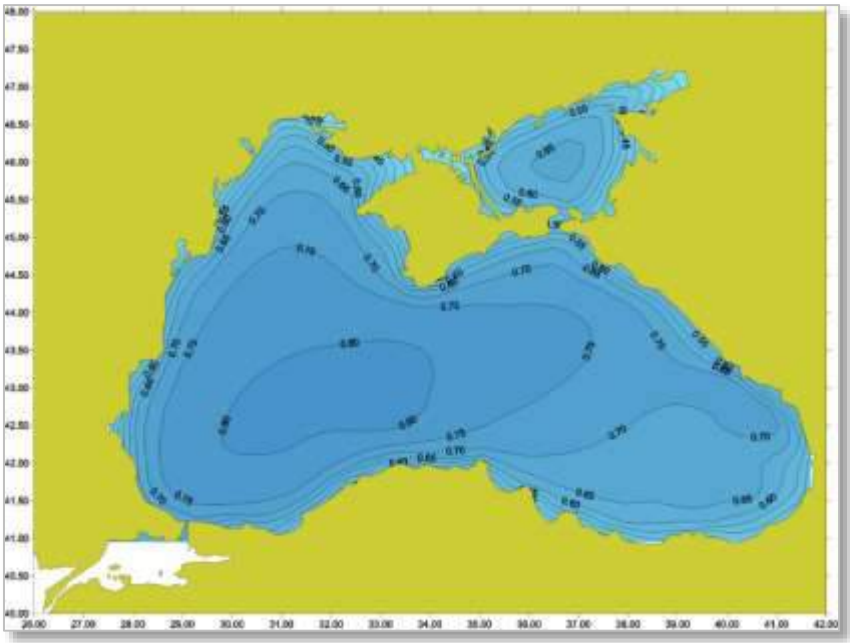

Figure 1.1.2.5 Mean annual wave heights in the Azov-Black Sea basin (according to 1979-2013 data)

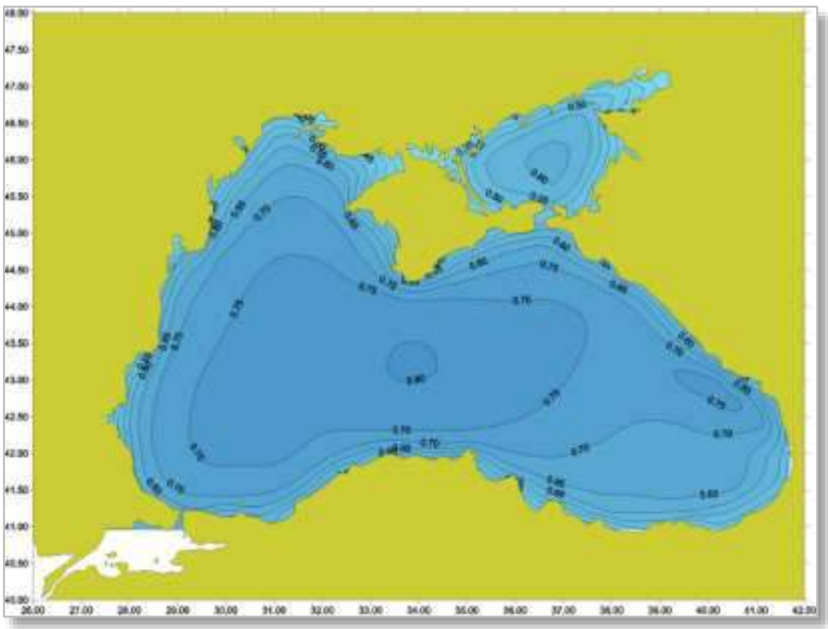

Figure 1.1.2.6 Mean annual wave heights in the Azov-Black Sea basin (according 2013 data)

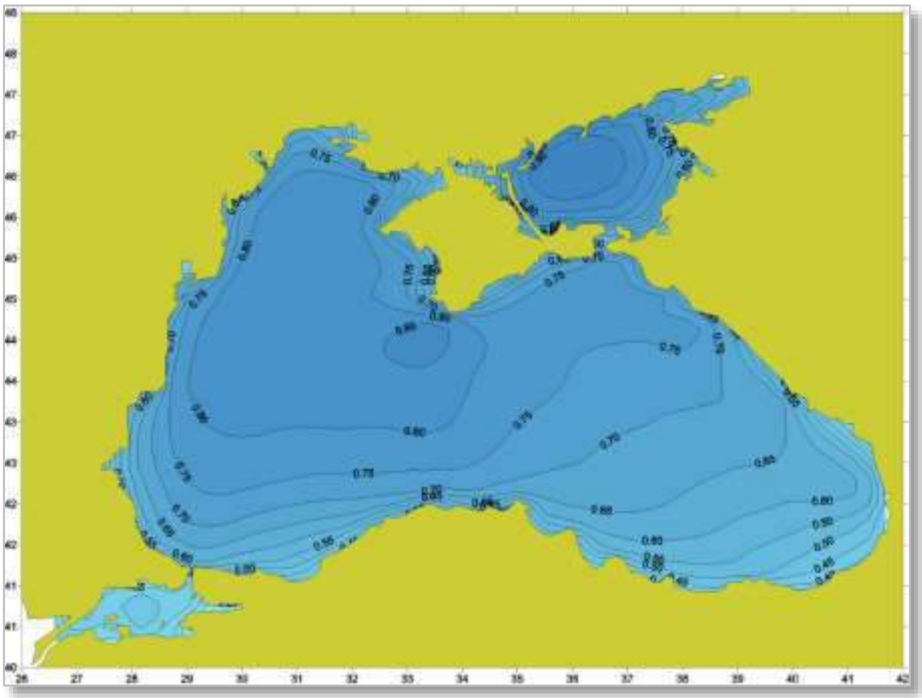

Figure 1.1.2.7 Mean annual wave heights in the Azov-Black Sea basin (according 2014 data)

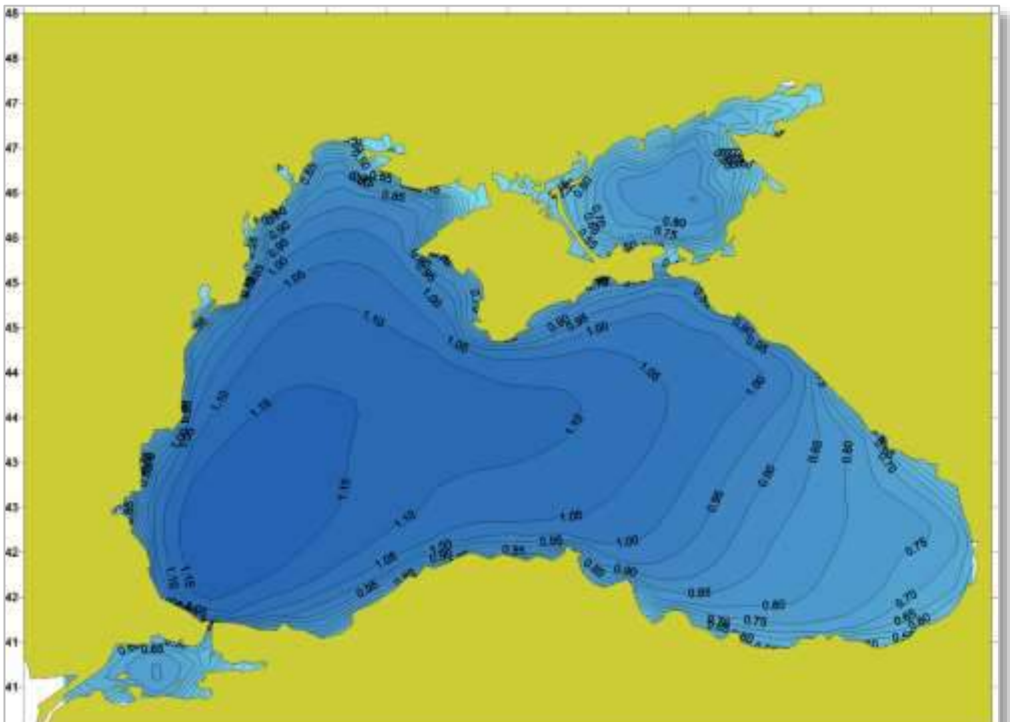

Figure 1.1.2.8 Mean annual wave heights in the Azov-Black Sea basin (according 2015 data)

Figure 1.1.2.5 shows the average wave heights for the years 1979 - 2013. Figures 1.1.2.6-1.1.2.8 show average values of wave heights for specific years: 2013, 2014 and 2015. It can be seen from the figures that the mean annual heights have a lower interannual variability than the "storm" values. Usually the average for a year the heights of waves more than 0.75 m occupy the central regions of the sea, decreasing to the shore. This effect is explained by smaller fetches for coastal commotion. A similar pattern was observed in 2013 and 2014. Somewhat apart is 2015. The average height of waves in it is 20 cm above the usually observed. In this year, large waves were not observed over the entire sea, except for the south-west (see Figure 1.1.2.4). In other words, the frequent appearance of "medium" wave conditions is not always accompanied by extreme storms.

The result of comparing the wave characteristics of the wave periods obtained over the entire data archive (Figure 1.1.2.9) and for specific years (2013, 2014 and 2015) (Figures 1.1.2.10-1.1.2.12) demonstrate that this regime characteristic varies little from year to year.

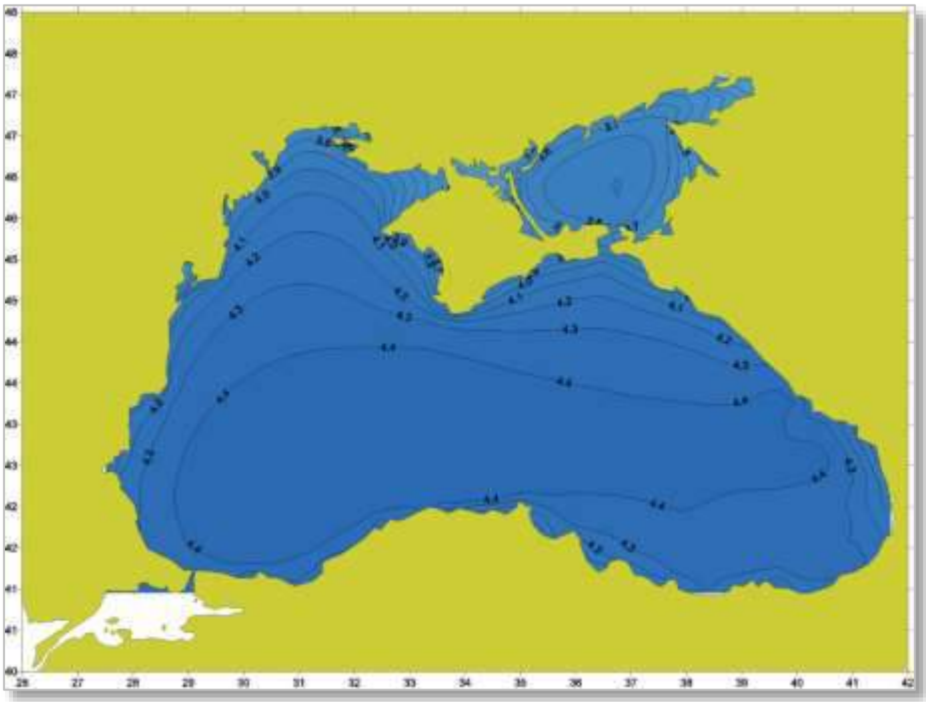

Figure 1.1.2.9 Average periods of waves in the Azov-Black Sea basin (according to 1979-2013 data).

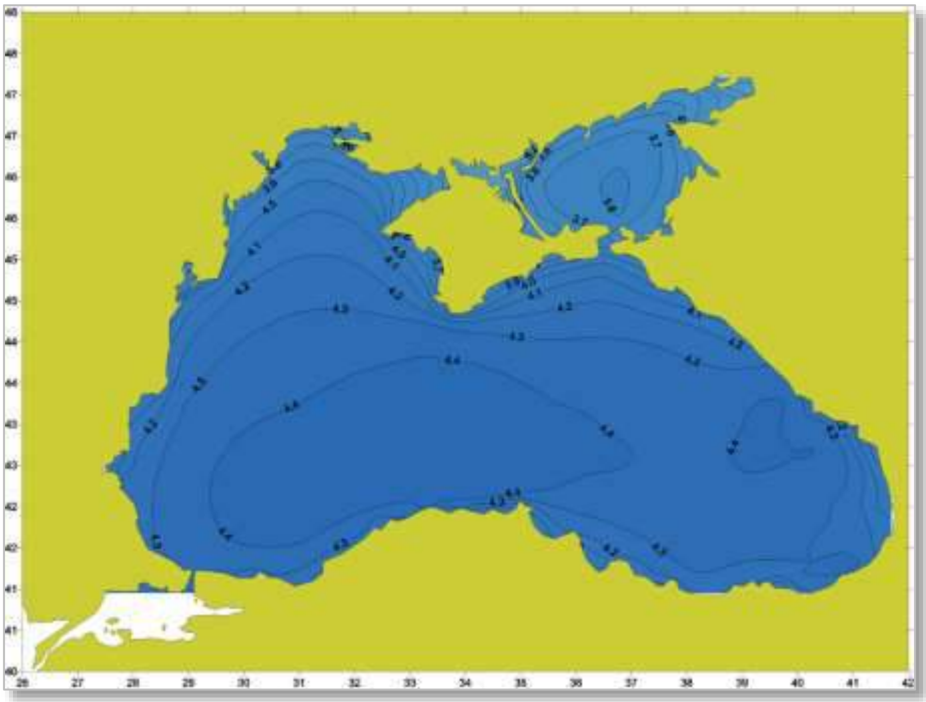

Figure 1.1.2.10 Average periods of waves in the Azov-Black Sea basin (according to 2013 data)

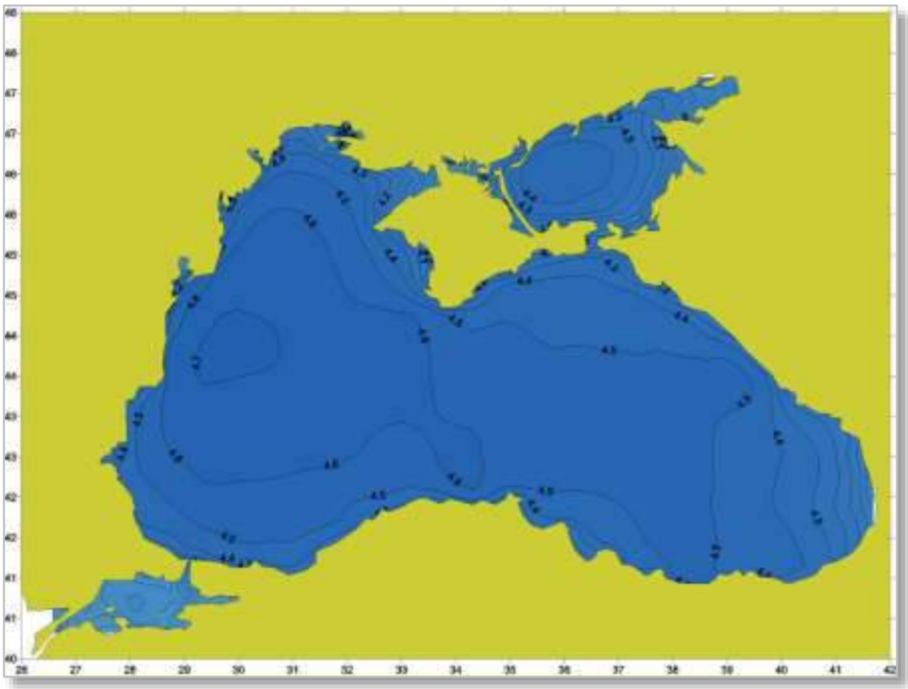

Figure 1.1.2.11 Average periods of waves in the Azov-Black Sea basin (according to 2014 data)

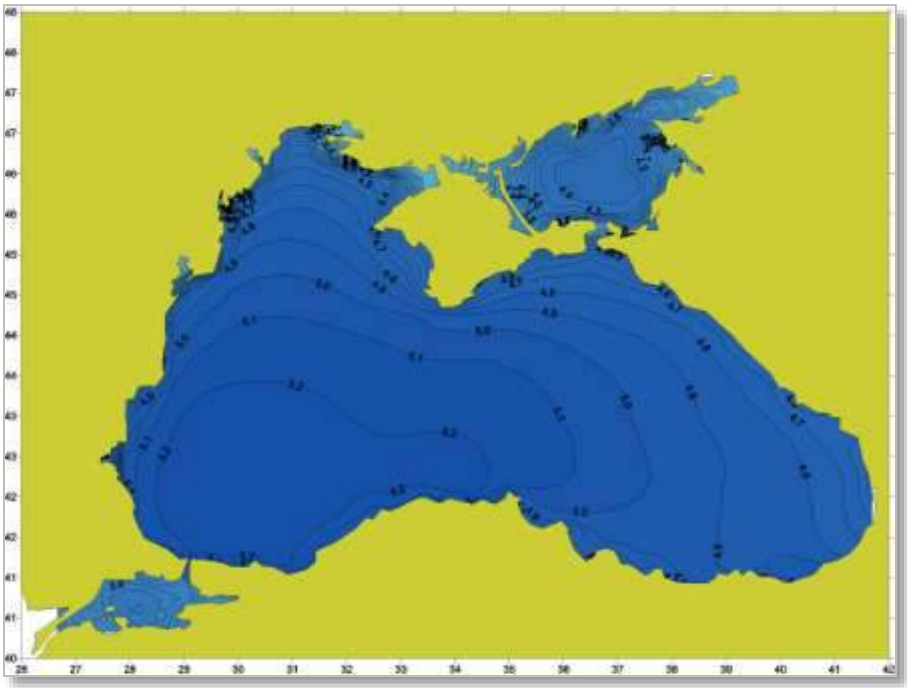

Figure 1.1.2.12 Average periods of waves in the Azov-Black Sea basin (according to 2015 data)

In general, the average annual periods of waves is above 4.4 s in the central parts of the sea and with the tendency to decrease towards the northern part of the sea. This is due to the fact that over the sea is usually dominated by the northern winds and, therefore, for the southern regions of the sea, fetches are greater. It should be noted that there is an increase in the average for the annual wave periods in the west of the sea over the last 3 years. 2013 was little different from the average multi-year conditions. In the west of the sea, the average wave periods over the year were more than 4.7 s in 2014 and more than 5.2 s in 2015.

Significant changes in the mode of wind wave (Figure 1.1.2.8) occur in the direction of wind wave in recent years (2014 and 2015), recall that it is counted in compass. The average direction of the wave (***θ₀***) was calculated according to the time data on wind wave energy $\boldsymbol{E_i}$ and the angle $\boldsymbol{\theta_i}$:

$$\theta_0 = arctg \frac{\sum_{i=1}^{n} E_i \ \sin(\theta_i)}{\sum_{i=1}^{n} E_i \ \cos(\theta_i)},$$

Here n – total number of terms of observations (calculations). Especially note that in the coastal zone the waves tend to unfold to the shore line. So the following reasoning will be true for open sea areas. On the average (Figure 1.1.2.13), the direction of wind waves has a north-easterly direction for the western water area of the sea. The northern direction is typical for the central water area and the north-western, western and south-western for its eastern part. A similar picture (Figure 1.1.2.14) was observed in 2013 as well. In 2014 and 2015 (Figures 1.1.2.15 and 1.1.2.16) in the northeast of the sea, as well as in its west, north-eastern wave directions began to dominate. Generally, this type of sea swells was actual until the 60s of the 20th century, when the northeast wind dominated the entire north-western part of the sea during the winter time. The border of this domination was along the line of Novorossiysk-Bosporus.

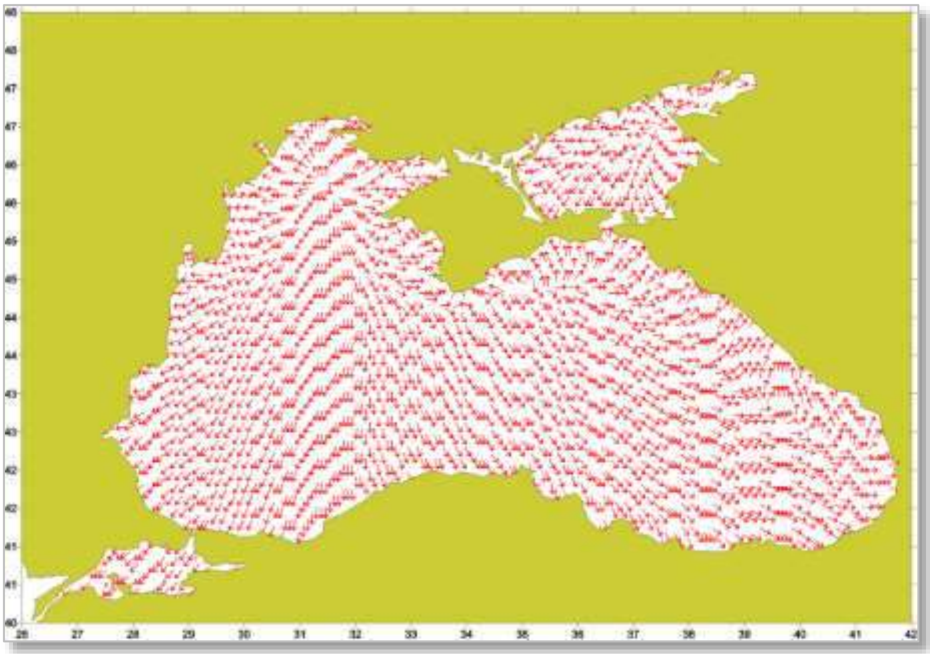

Figure 1.1.2.13 Average directions of sea swells in the Azov-Black Sea basin (according to 1979-2013 data).

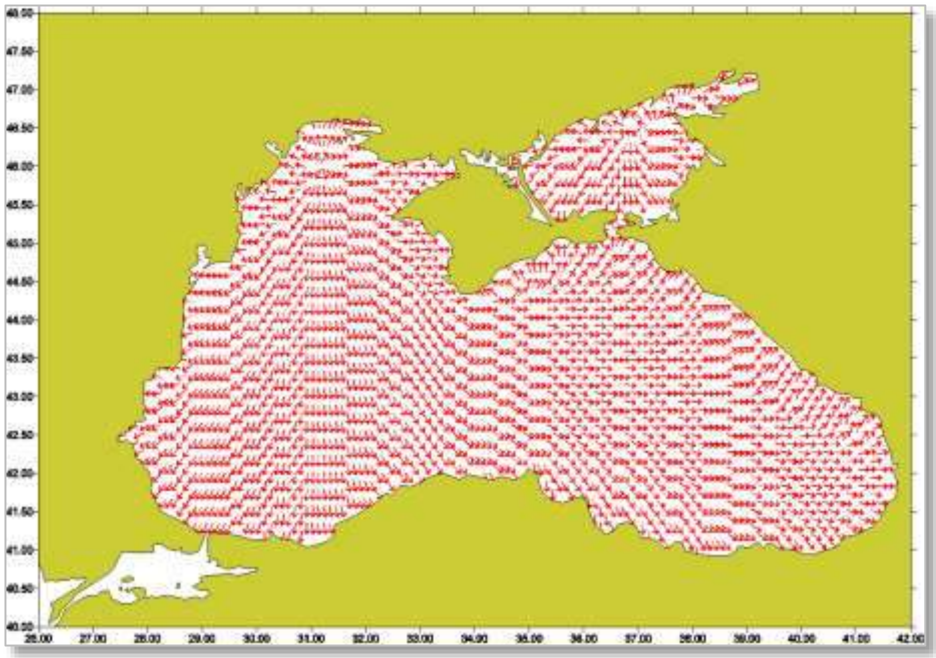

Figure 1.1.2.14 Average directions of sea swells in the Azov-Black Sea basin (according to 2013 data).

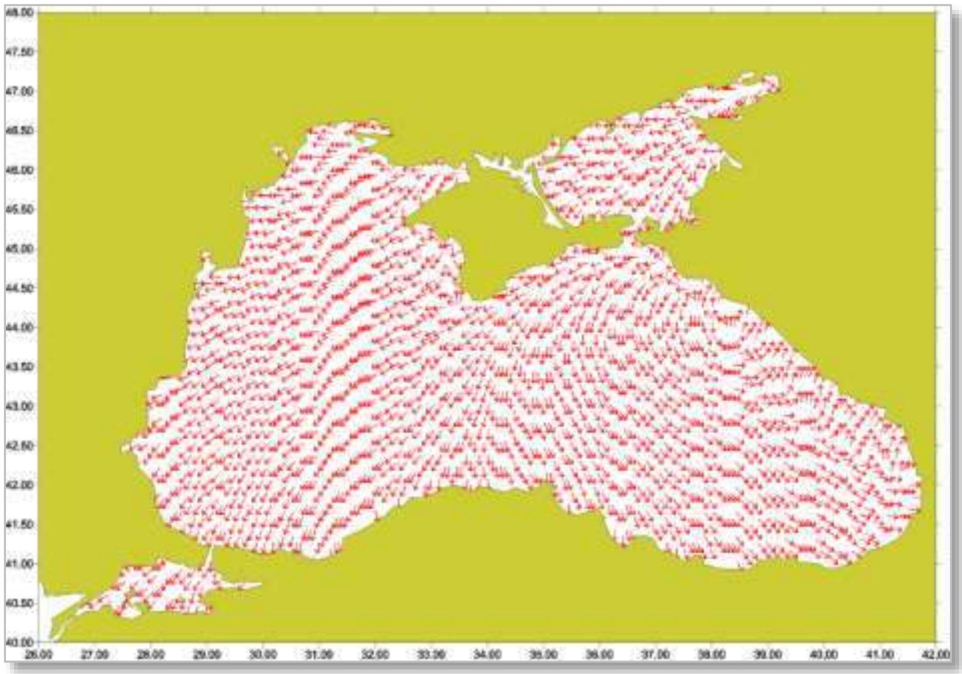

Figure 1.1.2.15 Average directions of sea swells in the Azov-Black Sea basin (according to 2013 data).

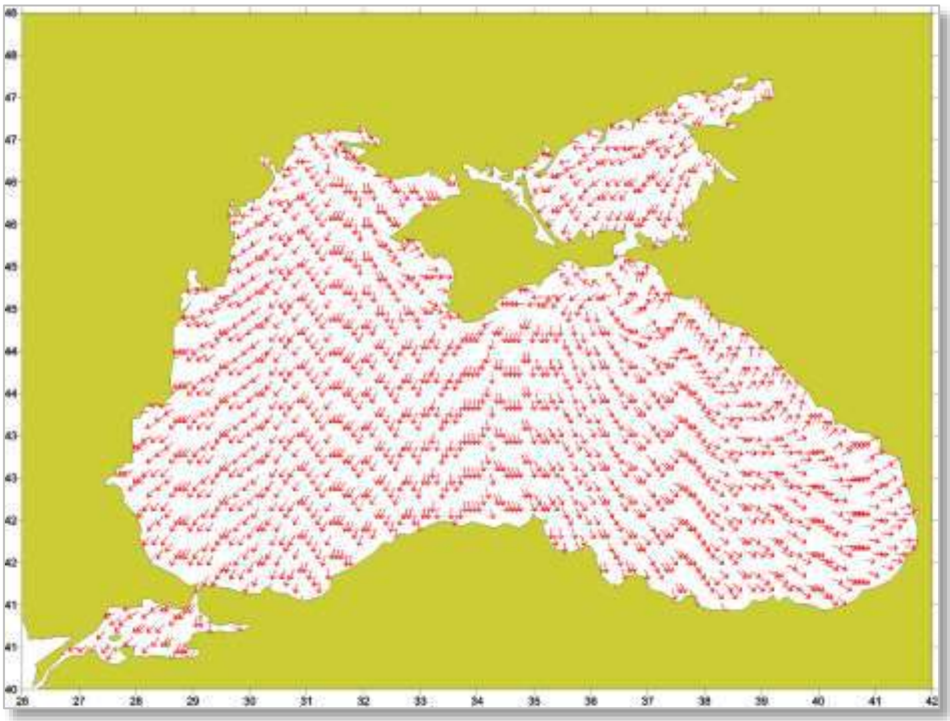

Figure 1.1.2.16 Average directions of sea swells in the Azov-Black Sea basin (according to 2015 data).

Conclusions

The regime of wind waves in the Black Sea-Azov basin has a pronounced interannual variability. This is most fully manifested in the regime of extreme sea swells. Usually strong storms with waves of more than 5 m heights are extremely rare on the Black Sea. Because of this, one or two strong storms can lead to the fact that a particular year will be perceived as a "stormy". This was 2013, when, according to calculations, wave heights of more than 5 m were recorded in the centre of the sea. A different picture was observed in 2015, when waves of more than 2 m heights were observed only in the south-west of the sea. For the mean wave heights for a year, the opposite picture was observed. Если The height of extreme waves for 2013-2015 decreased but average of the height of waves for the year grew. Changes in the wave regime over these years are characterized by a decrease in extreme storms and an increase in the average wave strengths.

The wave regime for 2013-2014 was characterized by an increase in the average for the year wave periods in the west part of the sea. The average wave periods in the open water areas in the western part of the sea increased by one second over the year - from 4.2 to 5.2 seconds. In the eastern part of the sea, the situation remained within the limits of the climatic norm.

According to climatic data, the direction of wind wave on the Black Sea has a north-easterly direction for the western part of the sea. The northern direction of wind wave is typical for the central water area and the north-western, western and south-western for its eastern part. North-eastern sea swells dominated the northeast of the sea as well as in its west in 2014 and 2015. Generally, this type of sea swells was typical until the 60s of the 20th century, when the winter northeast wind dominated the entire north-western part of the sea. The border of this domination was along the line of Novorossiysk-Bosporus.

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1.1.3 Black Sea Water Balance

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The water balance is the most important factor impacting on the Black Sea regime. Scales of annual and seasonal fluctuations of the water balance determine hydrological and hydrochemical characteristics of the sea waters.
Following [9, 16] the equation of the water balances:

$$(Q_p + Q_o + Q_{нБ} + Q_A) – (Q_и + Q_{вБ} + Q_Ч) = \pm \Delta B, \qquad (1)$$

Here Q_p – total river flows; Q_o – precipitations; $Q_{нБ}$ – inflow from Marmara Sea through Bosporus Strait (bottom flow); Q_A – inflow from Azov Sea through Kerch Strait; $Q_и$ – evaporation; $Q_{вБ}$ – outflow to Marmora Sea through Bosporus Strait (surface flow); $Q_Ч$ – outflow to Azov Sea; ΔB – Sea volume change.
Equation (1) could be simplified:

$$F + Q_Б + Q_К = \pm \Delta B, \qquad (2)$$

Here: $F = Q_p + Q_o – Q_и$ is the fresh water balance; $Q_Б = Q_{нБ} – Q_{вБ}$ is the result of the water flow through Bosporus Strait; $Q_К = Q_A – Q_Ч$ is the result of the water flow through Kerch Strait.

The precision of water volume balance depends on the precision of identification of the mentioned above characteristics as well as of the level of the Sea [9].

River flows. According [12], there are 211 rivers flowing directly into the Sea or via lagoons (limans). Following the geographical location, the total river flow consists of North-Western one ($Q_{СЗ}$), Crimea ($Q_{Кр}$), Caucasus ($Q_{Кз}$), Turkey (Q_T), Bulgaria ($Q_Б$) and Romania costs (Q_P) [9]. So that:

$$Q_p = Q_{сз} + Q_{Кр} + Q_{Кз} + Q_T + Q_Б + Q_P \qquad (3)$$

Long-time average annual river water flow varies widely from 287 to 480 km^3/year due to the lack of data about river water flows, in particular from Georgia and Turkey rivers, and certain difficulties related to the lack of regular hydrological information exchange on the interstate level [16].

According to [12], inaccuracy in determining the average annual of total river flows into the Black Sea is of ± 10% which is of 30–35 km^3/year. Following the latest information on the minor river flows from Turkey and Caucasus [15], average annual flow of rivers into the Sea for the period 1958-2014 can be estimated at 355.6 km^3/year, for the period 1958–2017 it is of 354.0 km^3/year which is very similar to the estimations of [16, 26]. Data on the average annual runoff (km^3/year) of the main rivers to the Black Sea during 1958-2014 are given in Table 1.1.3.1.

Table 1.1.3.1. Averaged over 1958 - 2014 (km^3/year) runoff of the Black Sea coast rivers.

River, area	Watershed, thousand km^2	River length, km	Water flow	
			Annual flow km^3/year	% of the total flow
North-Western area, including	**1500**		**263.2**	**74.0**
Danube	817.0	2860	208.0	58.5
Dnieper	503.0	2285	43.4	12.2
Dniester	72.1	1328	9.1	2.6
South Bug	63.7	857	2.2	0.6
Ingul	9.7	353	0.6	0.2
Crimea	**2.7**		**0.3**	**0.1**
Bulgaria	**14.5**		**1.8**	**0.5**
Veleka	1.0	147	0.3	0.1
Romania (without Danube)	**4.6**		**0.1**	**0.0**
Caucuses	**75.6**		**52.5**	**14.8**
Russian cost, including	5.1		6.5	1.8
Mzymta	0.9	89	1.6	0.4
Shakhe	0.6	59	1.2	0.3
Georgia, including	**50.4**		**46.0**	**12.9**
Rioni	13.3	228	13.4	3.8
Chorokh	22.1	438	8.7	2.4
Kodori	2.0	84	4.2	1.2
Bzyb	1.5	110	3.8	1.1
Turkey, including	**229.1**		**37.7**	**10.6**
Kyzyl-Irmak	78.6	1151	5.9	1.7
Sakaria	56.5	790	5.6	1.6
Eshil-Irmak	36.1	416	5.3	1.5
Total flow	**1857**		**355.6**	100.0

Source: [9, 13, 15, 21]

According to [9, 13, 15, 21], 74% of the total runoff to the Black Sea falls on its northwestern part (the Danube, Dnieper, and Dniester rivers) with 58.5% of the total runoff on the Danube River. According to [15, 26], the volume of the river flows from the Caucasus and from the territory of Turkey is 52.5 and 45.6 km^3/year respectively or 14.8 and 10.6% of the total river flows into the Black Sea. The flow of rivers in Bulgaria, Romania (without the Danube River) and the Crimea is about 2.2 km^3/year. Long-term and seasonal hydrographs of river runoff to the Black Sea from 1958 to 2017 are shown in Fig. 1.1.3.1.

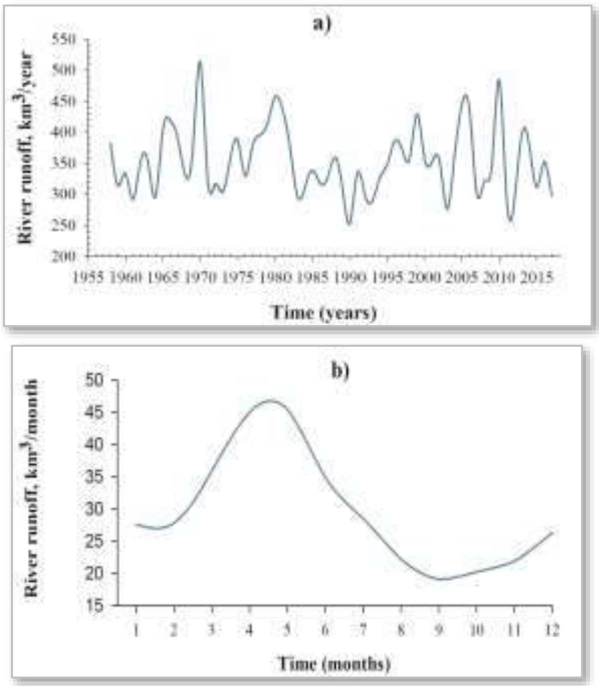


Figure 1.1.3.1. Long-term (a) and seasonal (b) hydrographs of river runoff into the Black Sea for 1958-2017.

According to [21], the maximum river flows into the Black Sea (529 km^3) was recorded in 1941, the minimum (230 km^3) in 1921. Analysis of the chronological course of annual and seasonal river runoffs in the Black Sea showed the presence of alternation of high and low water periods. The duration of the high-water periods for annual runoff varied more often from 1 to 3 or from 5 to 6 years. The following periods can be attributed to the high water periods: 1926 (425.0 km^3/year), 1931-1933 (average runoff for the period was 392.7 km^3/year), 1937-1938 (394.5 km^3/year), 1940-1942 (482.7 km^3/year), 1955-1956 (418.5 km^3/year), 1965-1967 (404.2 km^3/year), 1970 (514.1 km^3/year), 1977-1982. (410.0 km^3/year), 1996-1999. (386.4 km^3/year), 2005-2006. (440.8 km^3/year), 2010 (484.8 km^3/year) and 2013-2014. (388.1 km^3/year).

The long-term runoff of rivers into the Black Sea, represented in the form of a normalized difference-integral curve, is shown in Fig. 1.1.3.2. The ordinate represents the quantities $\sum_{i}^{1}(Ki-1)/C_V$, here $K_i = \frac{Q_i}{Q_{ch}}$ is modular ratio and C_V is variation coefficient

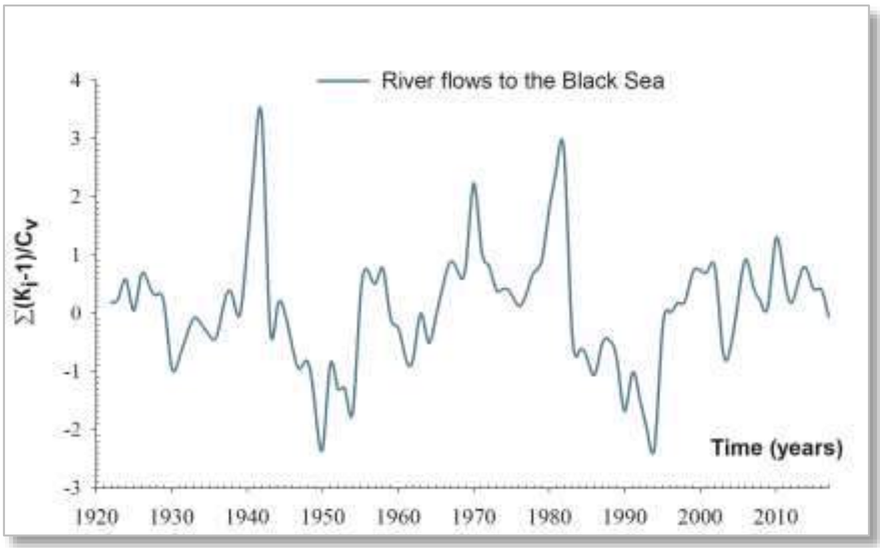


Figure 1.1.3.2. Normalized difference-integral curve of river flows to the Black Sea.

The integral curve of the annual runoff for 1921-2017 shows that there were three high water cycles: 1931 to 1942 (the average flow was 396.8 km^3/year); from 1965 to 1982 (the average flow was 383.7 km^3/year); 1995-2006 (the average flow was 373.0 km^3/year). Low-water cycles were observed in 1943-1964 (the average runoff for this period was 330.3 km^3/year) and from 1983 to 1994 (313.8 km^3/year). In the period from 2007 to the present, the average runoff amounted to 342.5 km^3/year, i.e. at 13.1 km^3/year is less than the average multi-year flow.

The duration of low-water periods was from 1 – 3 to 5 - 7 years. Periods with a small runoff were observed in 1921 (230.0 km^3/year), 1925 (291.0 km^3/year), 1927-1930 (average runoff was 308.3 km^3/year), 1943-1954 (314.8 km^3/year), 1959-1964 (323.4 km^3/year), 1983-1994 (313.8 km^3/year), 2007-2009 (322.9 km^3/year), 2011-2012 (289.4 km^3/year), 2015-2017. (320.6 km^3/year).

The river runoff to the Black Sea is affected by both climate variability and anthropogenic impact, The latest depends on the irretrievable seizure of a portion of the runoff and changes in its seasonal distribution. According to [21], the period from 1921 to 1955. reflects the close to natural conditions for the formation of river flow in the Black Sea basin, when irretrievable withdrawals from the rivers were insignificant, and the amount of runoff was determined by climatic variability only. In many rivers of the basin in the period from 1956 to 1974, regulation and withdrawal of flow began. It relates to the construction and commissioning of new reservoirs, canals, etc. [21]. From 1975 to the present, the magnitude of seizures in many basin rivers is significant and impact on the runoff. First of all, this refers to the River Dnieper, where by 1975 the construction and filling of the cascade from 6 reservoirs was completed. According to estimates [21, 23], the total withdrawals averaged about 10 - 13 km^3/year. According [6], the seizures of runoff in the Danube River basin reached 13-15 km^3/year, in the Dniester River basin - 1.1 km^3/year [15].

The river flows of the eastern part of the Black Sea are also actively used for household needs (irrigation, water supply, etc.). According to estimates [15], the irretrievable water consumption averages up to 2 - 3 km^3/year in Western Georgia. The total volume of irrecoverable seizures of the river flows in Turkey is about 3 - 5 km^3/year, in Bulgaria is about 0.5 km^3/year. Thus, the approximate volume of irrecoverable seizures of river runoff is at least 29.6-39.6 km^3/year (8-11% of the average long-term runoff).

The nature of the changes caused by anthropogenic activity is not only the irrecoverable seizures of the runoff, but also the reduction of its seasonal variability. The runoff of rivers has a spring flood in April-May and a low-water season in September-October (see Fig. 1.1.3.1b). The volume of spring and summer runoff decreased by 7-10% and the runoff in the winter season increased due to the regulation approximately by 11% (Fig. 1.1.3.3).

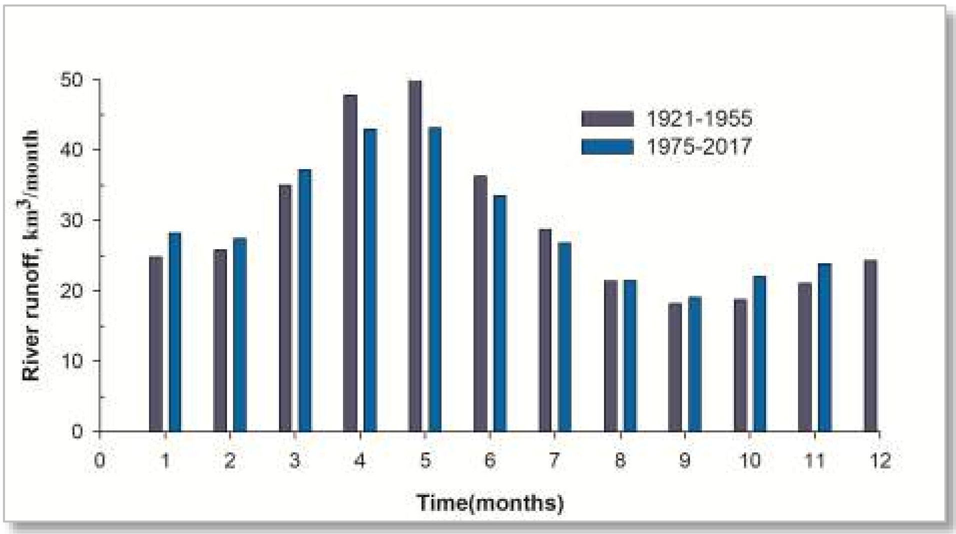


Figure 1.1.3.3. Intra-annual distribution of rivers flow (km^3 / month) with natural (1921-1955) and regulated (1975-2017) regimes. (Notes: x-axis of the plot – years, y-axis of the plot – river flows km^3/year).

It is difficult if impossible to obtain reliable information on underground runoff, Therefore, it was is either not taken into account [9, 13] in equations (1) - (3) or as in [15, 16], it was 5% of surface runoff (approximately 17 km^3/year) on the basis of a rather arbitrary analogy with other sea areas.

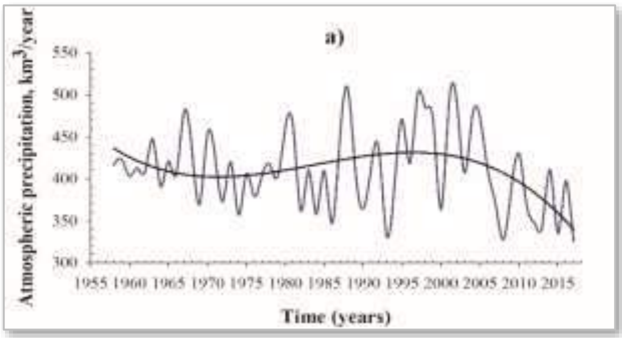
Atmospheric precipitation is an important contribution to the water balance of the Black Sea. Its volume comparable or exceeding the river runoff [12]. The traditional method [9] for calculating precipitations based on observations at coastal meteorological stations in the northern part of the sea and assuming the proportionality of the averaged modulus coefficients with the distribution of precipitation in the open seas is currently rejected [12, 13, 18, 19] due to an underestimation of the values of precipitation.

Modern methods for calculating the spatial distribution of atmospheric precipitation at synoptic, seasonal and multiannual scales are based on the joint use of instrumental measurements of precipitation at coast stations and the use of calculated values derived from a retrospective analysis of NCEP / NCAR [12, 18] or satellite information [13].

There is a difference in in the seasonal distribution of precipitation along the coast and over the open part of the Black Sea (Fig. 1.1.3.4b). The minimum of precipitation in the water area of the sea is observed in the summer period, when above the heated land convective rainfall prevails and over the sea convection is weakened. Maximum precipitation occurs in the autumn and early winter due to increased cyclonic activity as well as during intensification of vertical convective air currents over the open part of the sea due to an increase in the vertical instability of the atmosphere with the penetration of cold continental air masses onto the relatively warm water surface of the Black Sea. Such processes contribute to the formation of convective clouds over the sea and intense precipitation.

The difference in the amount of precipitation on the coast and in the open part of the sea calculated in [13] is observed in the autumn when the precipitation exceeds the open part of the sea more than on the coast. Underestimation of the above processes in the traditional method [9] resulted in an underestimation of precipitation on the Black Sea water area. According to calculations carried out using various methods [9, 12, 13, 16, 18], in all seasons region with maximum precipitation is the southeastern part of the sea (Anatolian and Caucasian coasts).

Depending on the data and methods used, the average annual precipitation for the entire sea area of the Sea varies widely, from 119 to 662 km^3 / year [16]. The precipitation averaged over the period from 1958 to 2017, calculated by the method of [13], was 411 km^3 / year. The long-term and seasonal distribution of precipitation are in Fig. 1.1.3.4.



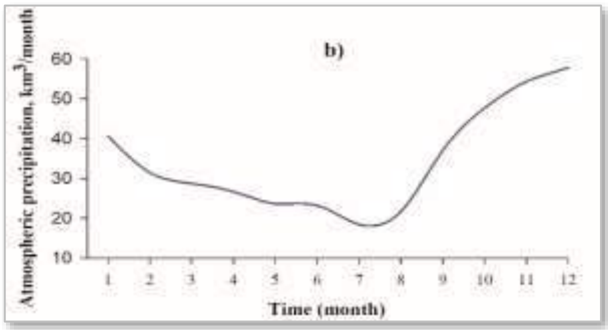


Figure 1.1.3.4: Long-term (a) and seasonal (b) distribution of atmospheric precipitation (km^3 / year) for the period 1958 – 2017.

To the rainy/wet, over the past 60 years, the following periods can be attributed: 1967-1968 (average amount of precipitation on the surface of the sea was 458.5 km^3 / year), 1980-1981 (461.8 km^3 / year), 1987-1988 (477.5 km^3 / year), 1995-1999 (468.8 km^3 / year) and 2001-2005. (467.0 km^3 / year). Dry periods were recorded in 1969 (369.5 km^3 / year), 1972-1977 (389.7 km^3 / year), 1982-1986 (377.1 km^3 / year), 1993-1994. (361.2 km^3 / year), 2000 (363.3 km^3 / year) and from 2007 to the present (367.4 km^3 / year). There is a 30-year wet period (1977 – 2006) and there is lowering period (last decade 2007 – 2017).

One of the most important part of the water balance of the Sea is ***evaporation*.** According to the standard methodology [9], the basis of its calculation is the semi-empirical formula by V.S. Samoylenko based on the Dalton law:

$$E = C_z V_z (e_0 - e_z), \qquad (4)$$

Here:E – amount of evaporating moisture, (mm); e_0 – the partial pressure of water vapor at a certain temperature of the surface layer of water, taking into account its salinity,(hPa); e_z – partial pressure of water vapor at height z, (hPa) (in our case, absolute air humidity over the sea); V_z – wind velocity at height z, m/sec; C_z = 3,5 is the coefficient for monthly evaporation values, taking into account the height of measurement of air humidity and wind speed over the sea.

The calculation of monthly and annual values of evaporation was based on the assumption that the annual modular evaporation coefficients in the coastal regions and on the sea area are proportional and was calculated by squares of the sea based on the data collected from coastal hydrometeorological stations and long-term ship observations [9]. Total evaporation was calculated by summation taking into account the ratio of the areas of the regions. The disadvantage of the method [9] as well as the calculation of atmospheric precipitation on the sea surface is the use of a limited number of weather stations located mainly on the northern and eastern coast of the Black Sea as well as the lack of wind velocity, temperature and salinity of sea water on the surface, temperature and humidity of air [12].

Remote sensing control allows to calculate latent heat fluxes (LHF) in the driving layer of the atmosphere with an acceptable accuracy. In [13], the LHF data set of the JRA-55 JMA-55 retrospective analysis was used to calculate the evaporation on a 1.25-degree grid. Data on the calculation of evaporation and other components of the Black Sea water balance according to the method [13] for different averaging periods are given in Table 1.1.3.2, the long-term and seasonal variations of evaporation values from the Black Sea surface are shown in Fig. 1.1.3.5.

According to the estimates of various authors, evaporation from the sea varies from 232 to 441 km^3 / year. According to [9], the average long-term value of evaporation from the surface of the Black Sea in 1923 - 1985 amounted to 395.6 km^3 / year, a fairly close value (413.2 km3 / year) for 1958 - 2017 was obtained in [13].

In the multi-year prospective (Fig. 1.1.3.5), the evaporation value periods of increased wind activity and more intense evaporation were recorded in 1967-1969 (441.4 km^3/year), 1991-1995 (424.4 km^3 / year), 2000-2004 (431.2 km^3 / year) and 2012-2017 (467.0 km^3 / year). The decrease in wind speed and, as a consequence, the lowered evaporation values from the sea surface were observed in 1960 (209.2 km^3 / year), 1964-1966 (400.4 km^3 / year), 1987-1991 (392.1 km3 / year), 1996-1999 (395.4 km^3 / year) and 2005-2011 (402.9 km^3 / year).

The spatial distribution of evaporation in the sea area depends mainly on the distribution of maximum winds in the driving layer. The regions of maximum evaporation are located in the northwestern and northeastern regions of the Sea [9, 16].

In the annual prospective (Fig. 1.1.3.5b), the maximum evaporation is recorded in July-September and the minimum in the spring (April-May). Reduction of evaporation in the spring is associated with a decrease in wind speed after the winter period of strong winds at a sufficiently low water temperature [16].

Table 1.1.3.2: The averaged over periods components (in km^3 / year) of the Black Sea water balance

(Q_p – total runoff, Q_{oc} и Q_u – precipitation and evaporation, $Q_{нБ}$ и $Q_{вБ}$ – flows through the Bosporus, F – balance).

Black Sea				
Components	Averaging period			
	1958-2017	1977-2006	2007-2012	2013-2017
Q_p	354	357	339	348
Q_{oc}	411	426	368	363
F	352	369	302	293
$Q_{нБ}$	206	201	226	225
$Q_{вБ}$	570	584	543	527
Q_u	413	414	405	417

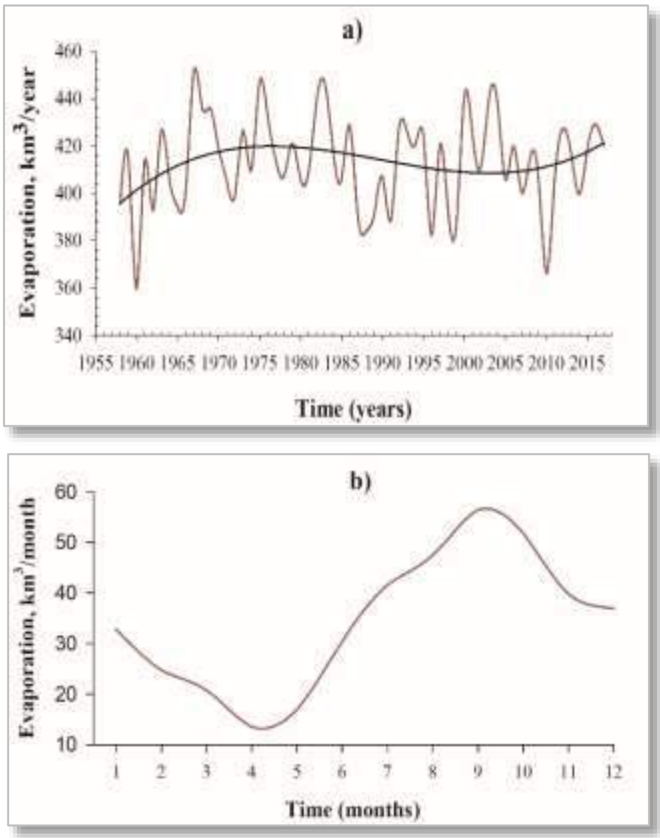


Figure 1.1.3.3. Multiannual (a) seasonal (b) evaporation (km^3/year) for the period from 1958 to 2017.

According to (2), the water balance is the sum of the river runoff and atmospheric precipitation minus evaporation. Analysis of variability the water balance components of the Black Sea showed that the regional features of global climate change in the Black Sea basin for 1977 – 2006 came out of in a significant increase in precipitation, river flow, and reducing evaporation. All this led to an increase of the fresh water in the balance of the Black Sea.

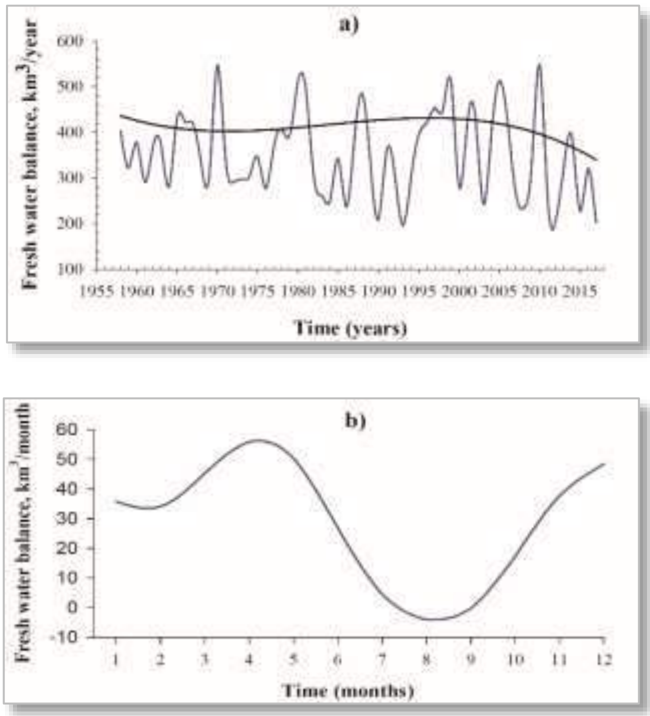


Figure 1.1.3.4. Long-term (a) and seasonal (b) changes in the freshwater balance of the Black Sea (km3 / year) for 1958-2017.

In subsequent years (2007-2012), the Black Sea fresh water balance was reduced by 67 km^3 / year primarily due to a decrease in precipitation. From 2013 to 2017, the fresh water balance decreased by 9 km3 and amounted to 293 km^3 / year. This decrease was primarily due to an increase in of the evaporation rate. The average annual evaporation rate for the period increased up to 417 km^3 / year with the decreased precipitation (the deviation from the average annual rate was 38 km^3 / year). The maximum changes in the incoming and outgoing parts of the balance are in April – May when there is the biggest runoff of rivers and low evaporation. The smallest changes are observed in August-September when the water runoff is low accompanied with intensive processes of evaporation.

Water flow through the Kerch Strait. Various approaches are in use to calculate currents and water flow for the determination of water exchange across the strait. The most famous method is by E.N. Altman [1, 2]. It takes into account the average daily difference in levels in the precarious areas of the Azov and Black Seas (Temryuk, Feodosia, Mysovoye, Anapa), as well as the average per day projection of the wind on the axis of the strait and the position of the level in its northern narrowness.

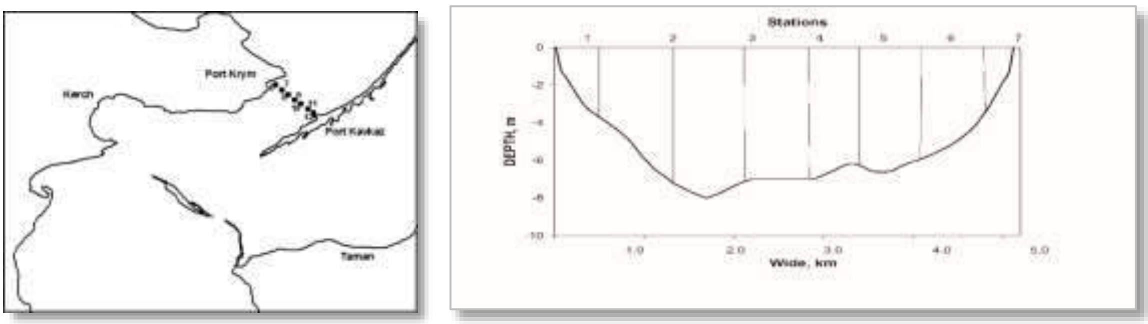
Another approach to obtaining water exchange values is the method of joint solution of the equations of water and salt balance of the Azov Sea for the steady state with the aim to obtain dependencies of water exchange on the balance of fresh water or on the flow of the rivers of the Azov Sea [3, 7, 8, 9, 11, 13, 20]. Most often for calculating the components of water exchange (Q_a – Azov, $Q_ч$ – Black Sea) a simplified E.N. Altman method is used [9]. It is based on the empirical dependence of water exchange components on the flow of rivers (Q_{Azp}) into the Azov Sea:

$$Q_a = 0{,}64 Q_{Azp} + 25{,}27, \quad (5)$$

$$Q_ч = \frac{Q_a}{0{,}024 Q_{Azp} + 0{,}59}. \quad (6)$$

There are also methods for calculating currents and water exchange through the strait based on numerical modeling [17, 22, 24].

In some articles [11, 13, 14], water exchange in the Kerch Strait was determined on the basis of regular observations at the section Port Crimea - Port Caucasus at the so-called northern narrowness of the Strait. The location of stations along the alignment is given in Figure 1.1.3.7a. Calculation of water exchange in this place is quite convenient because there is a large array of regular current measurements available. There are about 800 water flows were determined during the period from 1981 to 2017. With an insignificant width of the strait at this point (4.0 - 5.1 km), stability and predominantly unidirectional flows are observed throughout the entire cross section (mainly along the strait axis).



a) b)

Figure 1.1.3.5. Scheme of stations (a) and the cross-section (b) port Crimea - port Caucasus in the Kerch Strait.

The difficulties in accounting of main factors impacting both the Azov Sea and the Black Sea flows lead to the difference in the results of calculations. The main deficiency of the so called balance method is that it is impossible to calculate precise figures of the balance components, and evaporation in the first place.

In general, all methods considered reflect well common factors of the interannual fluctuation of the water flow through the Strait. The main differences are in the value of water flow from the Black Sea. Calculations showed that the inflow from the Azov Sea ($Q_a - Q_ч$) on average over a period of many years (1923 – 2017) prevails and is of 13.2 km^3/year. However, during the years (1973, 1975) with high anthropogenic withdrawals the value of $Q_a - Q_ч$ was negative, i.e. there was a small flow (up to 2.0 km^3/year) from the Black Sea. Before the construction of the Tsimlyansky reservoir in 1952, the flow from the Azov Sea was at least 20.1 km^3/year increasing to 38 – 43 km^3/year in 1929, 1941, 1942. After the regulation of the river flow, its discharge into the Azov Sea decreased on the average by 6.8 km^3/year which is very close to the volume of the irretrievable seizure [13]. The volume of the flow from the Black Sea increased up to 0.8 km^3/year during the same period. There were no linear trends discovered in the flows through the Kerch Strait during the period from 1952 to 2017. However, there is a negative trend in the flow from the Azov Sea (0.109 km^3/year) for the period from 1927 to 2017, and a positive trend in the flow from Black Sea (0.019 km^3/year) shown in Fig. 1.1.3.8.

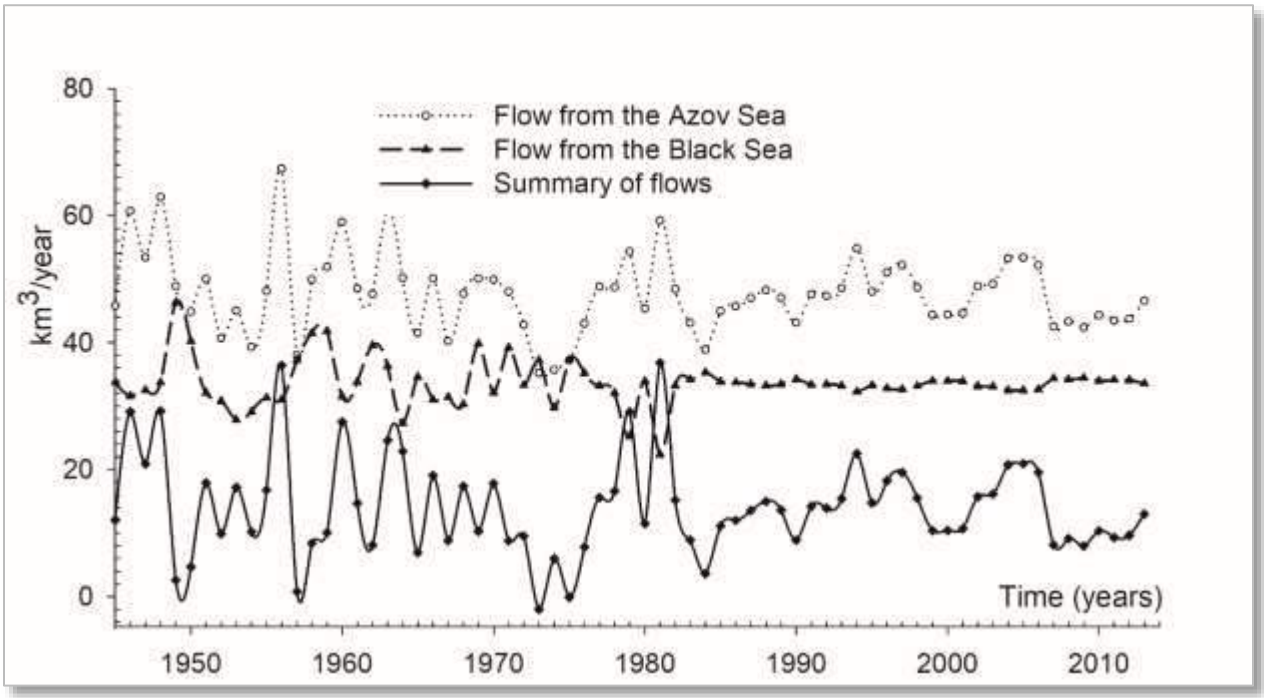


Figure 1.1.3.6. Multiyear water flows through the Kerch Strait (km^3/year). Notes: x-axis of the plot years, y-axis of the plot – flow; ……. flow from the Azov Sea, - - - - flow from the Black Sea, ____ summary of flows.

Measured long-term runoff components through the Kerch Strait ($Q_a, Q_ч$) about 1.5 times higher than those calculated according to the methodology [9]. But, the final figures of the total flow($Q_a - Q_ч$) is almost the same [13, 16].

The main 'regulator' of the level in the sea system (the Black Sea - Marmara Sea - Mediterranean Sea) is the Bosporus Strait. The ***water flow through the Bosporus Strait*** was calculated in [9] following to:

$$Q_Б = Q_{нб} - Q_{вб} = \Delta h + Q_K - F; \quad (7)$$

$$Q_{вб} = f_1(Q_Б); \quad Q_{нб} = f_2(Q_Б), \quad (8)$$

Here Δh – change in the average Black Sea level according to level posts; $Q_K = (Q_a - Q_м)$ – the resulting flow through the Kerch Strait; $F = (Q_p + Q_o - Q_u)$ – fresh water balance.

Empirical functions (8) were developed [4, 5] and verified according to the observation data at Bosporus region of the Black Sea. It was found that errors in determining the average level of the Black Sea and the components of the balance of fresh water significantly affect the precision of calculations of the water flow through the Bosporus Strait. On top of this, the hydraulic peculiar features of the Strait (water level, wind, and etc.) were not taken into consideration in (8). As the result, the measured discharge of the upper stream of Bosporus are always bigger then calculated according to [9]. The most important fact is that instrumental measures do not confirm the seasonal predominance of the Lower Bosporus currents over Upper Bosporus currents during the deficit of the fresh water flow from July to October [12, 16].

The biggest discrepancy in the calculations by different scientists (almost an order of magnitude from 190 to 1,028 km^3/year) is in the fresh water flow of the Upper Bosporus currents which makes the largest contribution into the expenditure side of the water balance [16].

Calculations of the Lower Bosporus currents over Upper Bosporus currents taking into consideration the peculiar features of the Strait were made in [25]. The results were used in the new methodology [13] to calculate the water balance of the Black Sea. A good correspondence between the variability of fresh balance and the components of water exchange through the Bosporus were obtained for the mean monthly water balance values calculated by this method (Fig. 1.1.3.9, Table 1.1.3.3).

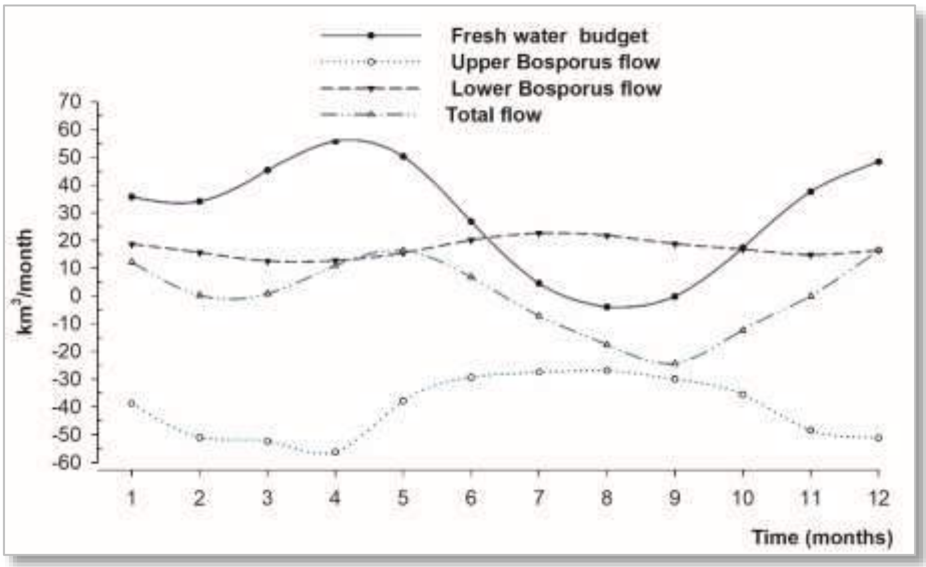


Figure 1.1.3.7. The intra-annual distribution of mean annual monthly values of the components of the Black Sea water balance (km3 / month), calculated according to [13] for 1958 - 2017. Notes: x-axis of the plot months, y-axis of the plot – flow; ……. Upper Bosporus flow, - - - - Lower Bosporus flow, ____ fresh water flow, -A-A- total flow.

Table 1.1.3.3. Seasonal average long-term (1958 - 2017) values (km^3) of the components of the Black Sea water balance.

Components/seasons	**Winter**	**Spring**	**Summer**	**Autumn**
Q_p	83	124	84	64
Q_{oc}	130	79	63	139
F	118	151	27	55

Components/seasons	Winter	Spring	Summer	Autumn
$Q_{нБ}$	51	41	65	50
$Q_{вБ}$	144	168	113	145
$Q_{и}$	95	51	120	148
ΔB	29	28	-18	-37

The maximum value of the fresh balance components are in spring and the minimum in summer. The difference is 124 km^3. The water volume of the Black Sea has it maximum during winter and spring and minimum in autumn (the difference reaches 66 km^3). The flow of the Black Sea waters into the Marmara Sea through the Bosporus Strait prevails in the spring.

The increase in the water volume of the Black Sea arrives to its maximum from February to May and is about 30 km^3. In April, there is an intensive flow of fresh water into the Sea and the biggest runoff of the Black Sea waters across the Bosporus Strait. The Black Sea level reaches its maximum in May. In this case, as a rule, the rate of increase in the volume of water in the sea basin exceeds the rate of its flow through the Bosporus Strait.

From May to July, there is a significant decrease in the volume of sea water (and level) associated with a significant decrease in fresh water inflow at this time of year. In August and September, the levels of the Black Sea are minimal, while the evaporation exceeds the intake of fresh water with rivers and atmospheric precipitation in this period. It should be noted that similar processes are also observed in the Mediterranean Sea, which is a basin of evaporation. In this case, the level of the Black Sea remains higher than the level of the Mediterranean Sea during this period of the year. Such level differences in the seas' system contribute to the intensive drainage of the Black Sea waters through the Strait in July-September, and in July and August, the Upper Bosporus stream even exceeds the Lower Bosporus by 15 km^3/month (see Figure 1.1.3.9). The above-described mechanism of water exchange through the Bosporus, obtained by calculation methods, is confirmed by the data of instrumental measurements of currents in the Strait [12].

In autumn and winter, the freshwater intake in the Sea with precipitation and rivers as well as the resulting flow through the Bosporus Strait is almost the same. Nevertheless, the volume of the Sea in winter is maximal and in autumn it is minimal (the difference is 66 km^3). Such differences are explained by the difference in evaporation volumes in winter and autumn, which reaches 53 km^3. In spring, the sea level has a second maximum which is also due to a decrease in evaporation from the sea surface in this season (evaporation in the spring is about 100 km^3 less than the autumn one).

The variability of the annual values of the resulting water flow across the Bosporus Strait is shown in Fig. 1.1.3.8. There is a predominance of Black Sea water flow into the Marmara Sea. At the same time, the difference in annual volumes of water participating in water exchange through the Strait during the period 1958 - 2017 reached 363.4 km^3 / year. The maximum excess of runoff of the Black Sea waters over the influx of the Marmara Sea was observed in 1970 (531.9 km^3 / year), 1980-1981 (average for the period - 489.8 km^3 / year), 1997-1994 (494.5 km^3 / year), 2005 (561.3 km^3 / year) and 2010 (496.7 km^3 / year), and the minimum in 1974-1976 (average for the period - 300.0 km^3 / year), 1983-1987 (292.9 km^3 / year), 1990-1994 (294.0 km^3 / year), 2007-2009 (289.0 km^3 / year), 2012-2013 (227.2 km^3 / year), 2015-2017 (265.4 km^3 / year). In 2012, there was an absolute minimum of the resulting water exchange across the Bosporus Strait ($Q_Б$). It was 168.6 km^3/year. Maximum (561.3 km^3/year) was observed in 2005.

Over the last decade (2007 - 2017) there was a significant decrease in the resulting water exchange across the Bosporus Strait (by 53.5 km^3 / year compared to the average annual value). This can be explained by a decrease in the intake of fresh water with precipitation, while the intensity of evaporation from the sea surface increases at the same time.

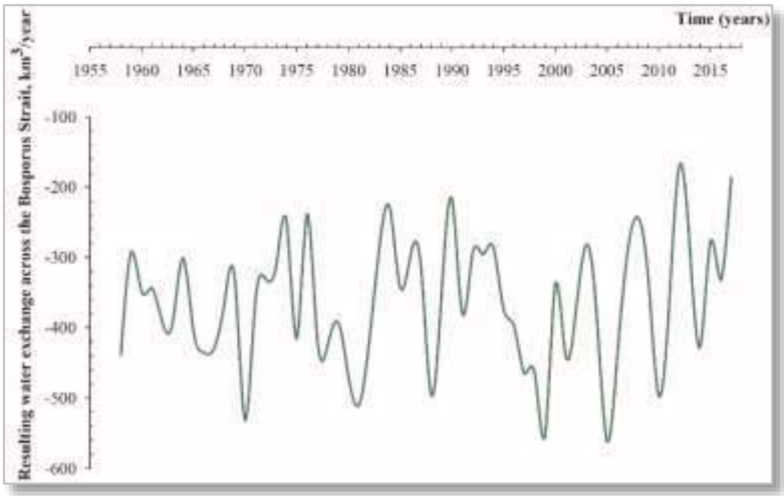


Figure 1.1.3.8. Interannual variability of the resulting water exchange (km3 / year) across the Bosporus Strait. Notes: x-axis of the plot years, y-axis of the plot – flow.

Interannual changes in the water volume of the Black Sea (Fig. 1.1.3.9) are quasi-periodic in the period 1958 – 2017. There is no significant trend in the balance (the angular coefficient of the linear trend is minus 0.05 km^3 / year). Interannual changes in the water volume of the Black Sea reach 190 km^3. The maximum losses were observed in 1983 (-105.8 km^3 / year), 1993 (-84.4 km^3 / year), 2011 (-105.2 km^3 / year), and the minimum is in 1974 (62.8 km^3 / year), 1987 (84.3 km^3 / year) and 2002 (78.5 km^3 / year), 2012-2013 (50.9 km^3 / year).

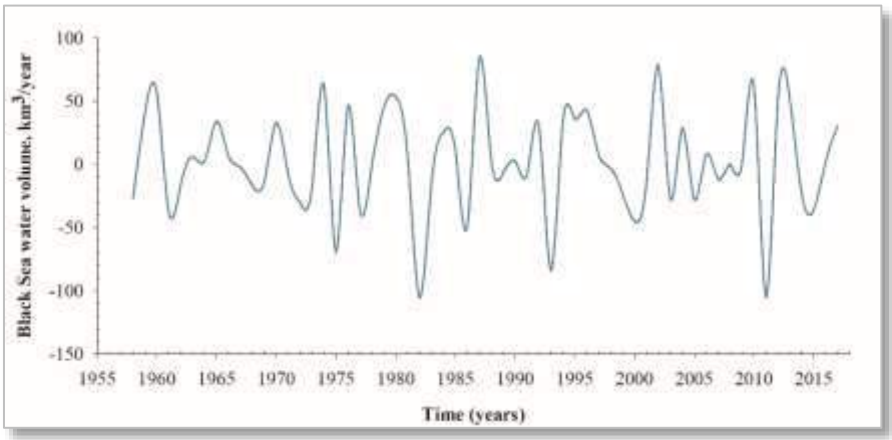


Figure 1.1.3.9 Interannual variability of the Black Sea water volume (km^3 / year).

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1.2. Hydrochemistry and pollution

Alexander Korshenko (Editor)

Content

Introduction

Data sources for chemical assessment

For the Assessment of the Black Sea status during 2009-2014 and its comparison with the previous period several data sources were used. The major source of the chemical data is the joint Regional Database on Pollution (RDB-P) of the Black Sea Commission currently managed in the Ukrainian Scientific Center of Ecology of the Sea (UkrSCES, Odessa). This center collects the raw data from all Black Sea riparian countries. Standard hydrochemical parameters and nutrients concentration are the most abundant in this DB (Fig.1.2.1.A), while the pollutants concentration in the bottom sediments (Fig. 1.2.1.B) and in the biological organisms rather poor in space and time (Fig.1.2.1.C).

Figure 1.2.1.A. Samples sites of marine waters from the RDB-P for period 2009-2014.

Figure 1.2.1.B. Samples sites of the bottom sediments from the RDB-P for period 2009-2014.

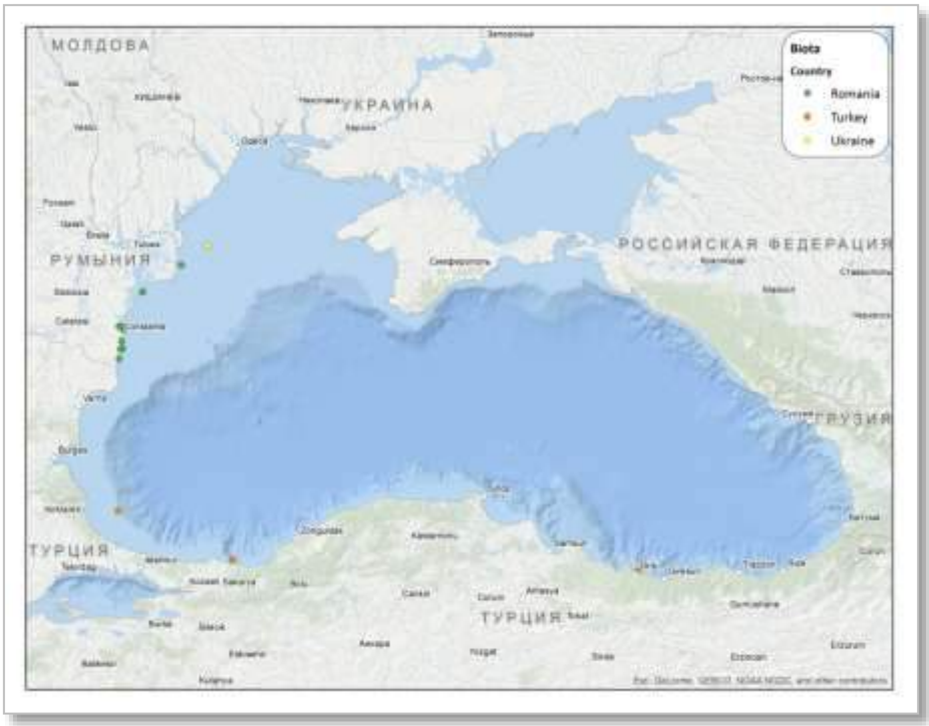

Figure 1.2.1.C. Samples sites of the biota from the RDB-P for period 2009-2014.

Additional important sources of environmental information for the Assessment are the Annual State Reports to the Secretariat of the Black Sea Commission Working Groups – Pollution Monitoring Assessment (PMA) and Land Base Sources (LBS).

National scientific expeditions and environmental research activities also were used for the analysis of Sea condition and preparation of Assessment.

1.2.1. Pollution sources

1.2.1.1. Land Base Pollution Sources (Anatoly Krutov*)

** State Oceanographic Institute (SOI, Moscow)*

This section provides brief and easy understand information on waste water discharges from the riparian countries to the Black Sea and includes land based sources (LBS) data reported by the Black Sea (BS) countries for 2008-2014. According to the agreed classification, data were aggregated by countries. Municipal sources include discharges from wastewater treatment plants (WWTP). There are four indicators of municipal pollution sources were used in this report. The parameters are: BOD_5, total Nitrogen (TN), total Phosphorus (TP), total Suspended Solids (TSS), and waste waters discharged into the Black Sea. These indicators were selected to keep the possibility to comparing of the conceivable impact of the riparian countries.

Bulgaria

According to information provided, there are 18 wastewater treatment plants which were reported as the potential sources of pollution. Those WWTP are: 1. Balchik municipal; 2. Varna; 3. Kavarna; 4. Albena; 5. Golden sands; 6. Sunny day; 7. Grand hotel Varna; 8. Evksinograd; 9. Elenite; 10. Asparuhovo municipal; 11. Tsarevo municipal; 12. Sozopol sewage; 13. Pomorie municipal; 14. Ravda - Sunny beach - Nessebar municipal; 15. Obzor-Byala municipal; 16. Meden Rudnik municipal; 17. Bourgas municipal; 18. Kiten - Primorsko municipal. According to the information extracted from Year Reports (Table 1.2.1.1.1) the lowest volume of wastewaters was discharged in 2012, the highest in 2014.

Table 1.2.1.1.1. Total volume of waste waters and selected indicators of waters discharged.

Years	2008	2009	2010	2011	2012	2013	2014
Total volume of waste waters discharged	95,690,106	67,534,238	95,388,331	82,396,388	40,036,211	75,248,832	67,065,117
Volume of untreated waters	587,460	1,387,070	2,381,613	1,219,850	2,623,688	2,685,418	2,938,722
BOD_5 (ton*1000)	0.6991	0.4045	2.0777	1.0835	2.5964	1.1213	0.8855
Total nitrogen (TN) (ton*1000)	0.3224	0.1838	0.8084	0.4921	1.0851	1.0436	2.7314
Total phosphorus (TP) (ton*1000)	0.2097	0.0744	0.2705	0.1051	0.1853	0.1055	0.1316
Total suspended solids (TSS) (ton*1000)	2.6578	1.4010	4.1486	3.3381	45.1297	58.8117	86.8843

Source: LBS 2007 BG Report.

The inter-annual change of the indicators, which characterize the water quality, discharged shows that there was an increasing tendency observed in the discharge of organic matters indicated in BOD_5 slightly and drastically in total nitrogen and total suspended solids (TSS). At the same time, there was a moderate decreasing tendency in the discharge of total phosphorous (Fig.1.2.1.1.1.-1.2.1.1.4).

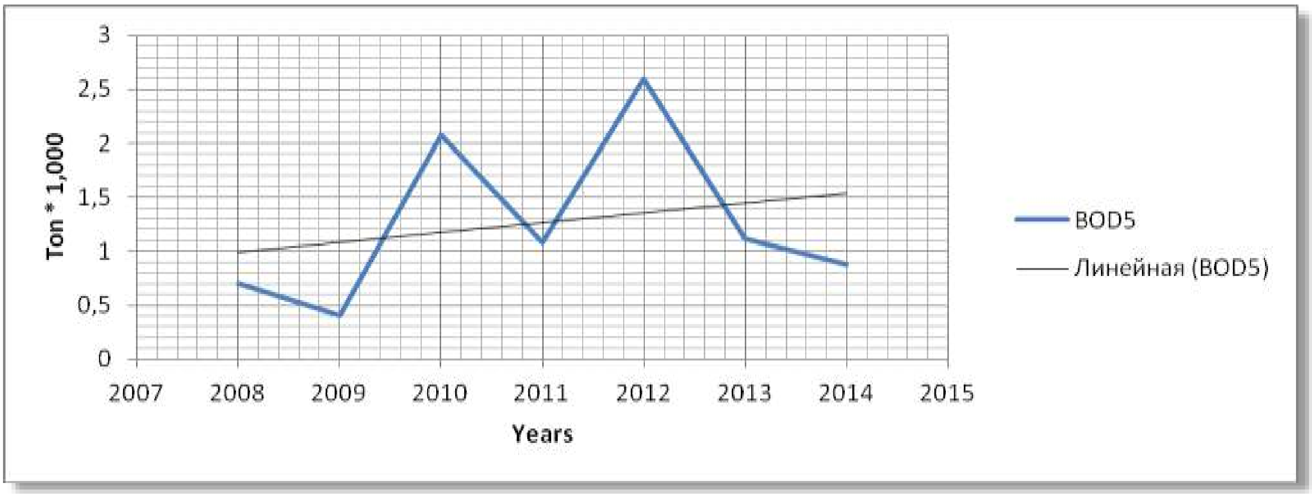

Figure 1.2.1.1.1. Changes of total organic matters indicated in BOD_5 discharged.

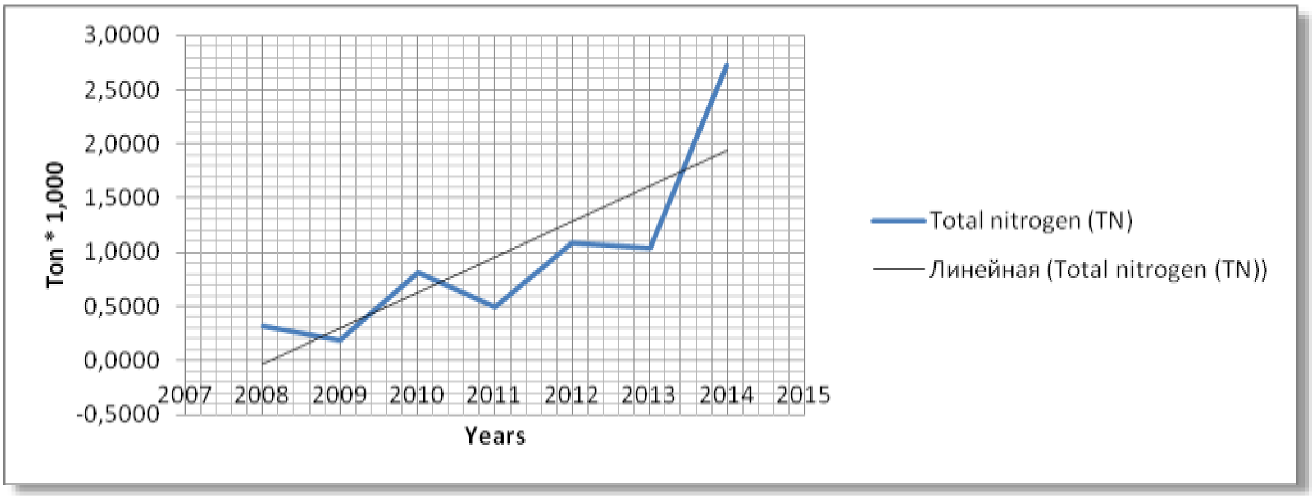

Figure 1.2.1.1.2. Changes of total nitrogen discharged.

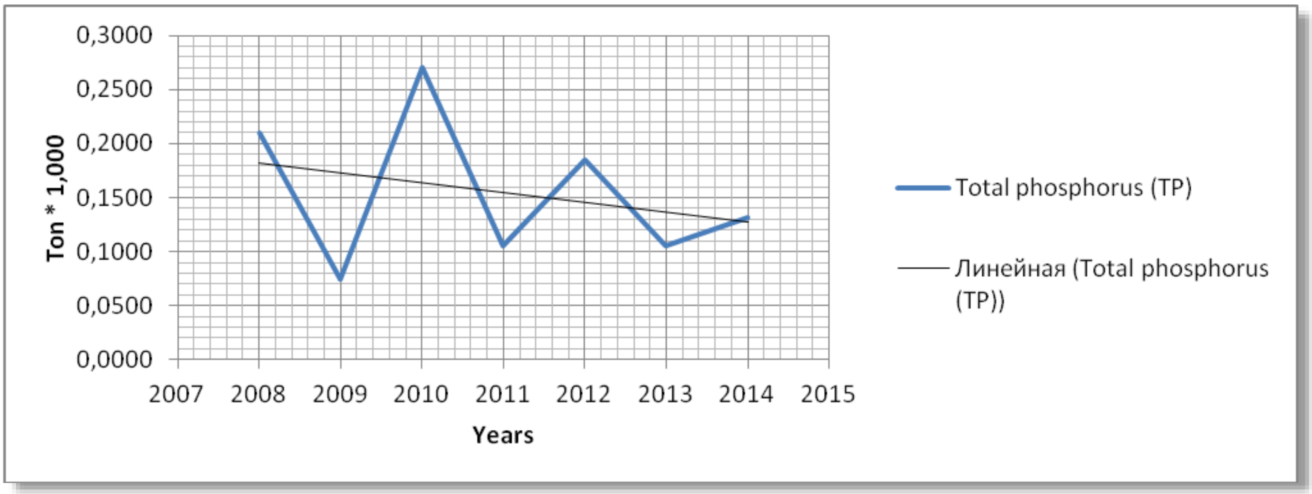

Figure 1.2.1.1.3. Changes of total phosphorus discharged.

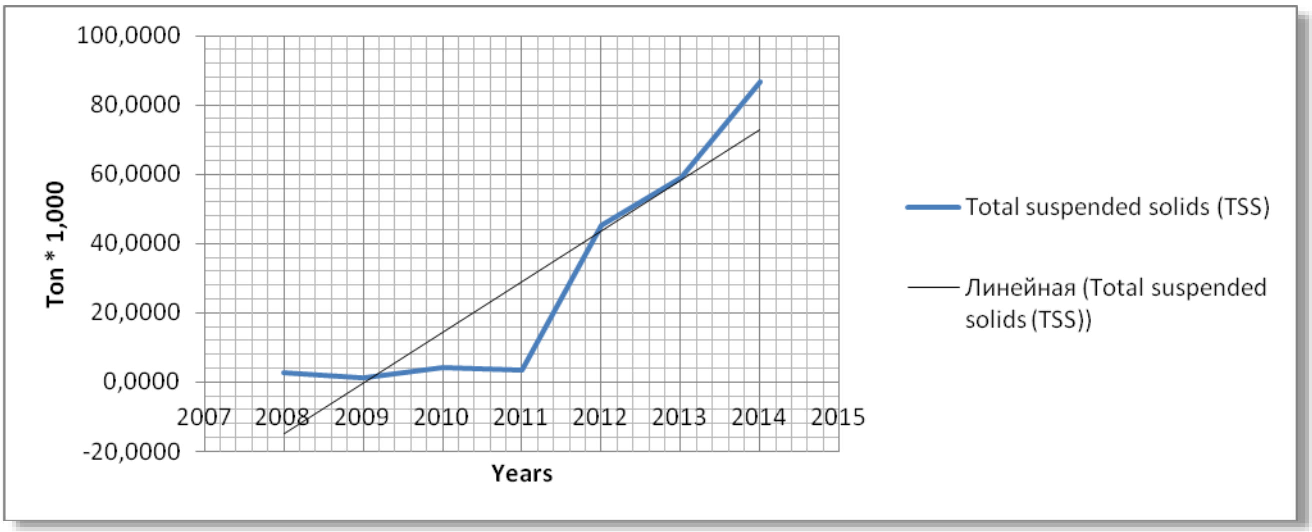

Figure 1.2.1.1.4. Changes of total suspended solids discharged.

Romania

Romania reports about four main municipal WWTP: 1. Constanta Sud; 2. Constanta Nord; 3. Eforie Sud; 4. Mangalia. During the period from 2008 to 2013 years the total and untreated volume of wastewaters discharged from Romanian's WWTP into the Black Sea varied insignificantly (Table 1.2.1.1.2).

Table 1.2.1.1.2. Volume of wastewaters discharged from Romania into the Black Sea at 2008-2013.

Years	2008	2009	2010	2011	2012	2013
Total volume of waste waters discharged into the Black Sea	76,488	63,284	70,020	69,185	68,478	63,936
Volume of untreated waters discharged into the Black Sea	69,175	57,990	61,987	41,420	39,190	35,895

Source: LBS 2007 RO Report.

The table shows that the volume of wastewaters discharged into the Black Sea decreased over 15% and that the volume of untreated waters discharged into the Black Sea decreased almost 50% from 2008 to 2013. The changes of the contamination of the wastewaters discharged from main sources is not significant within investigated period. There was a decreasing tendency of total nitrogen and TSS and an increasing tendency of total phosphorous and organic matters (BOD_5) in the wastewaters discharged from Romania into the Black Sea (Fig. 1.2.1.1.5-1.2.1.1.8).

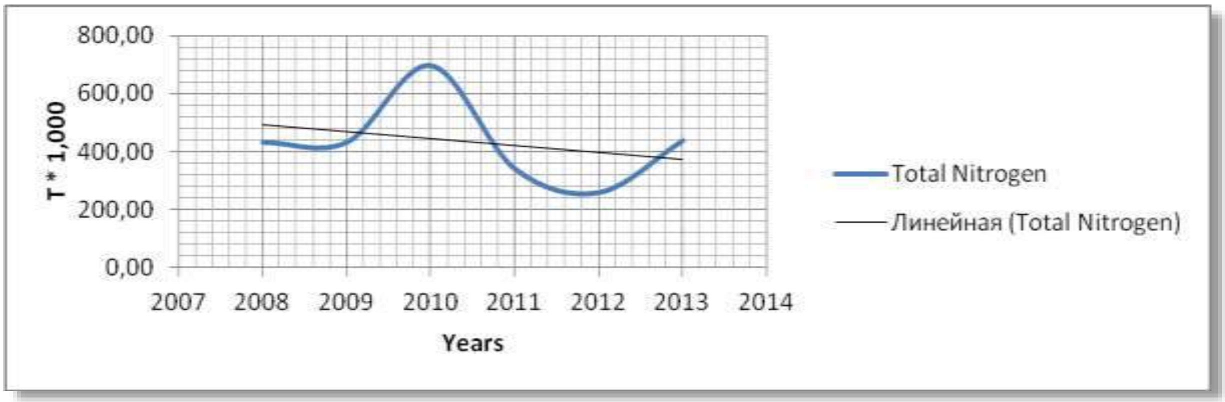

Figure 1.2.1.1.5. Changes of total nitrogen discharged and annual flow.

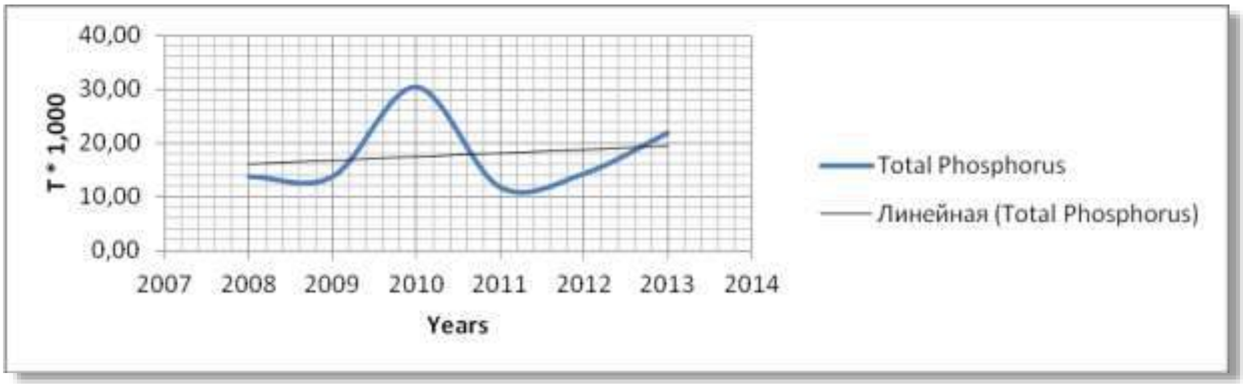

Figure 1.2.1.1.6. Changes of total phosphorous discharged and annual flow.

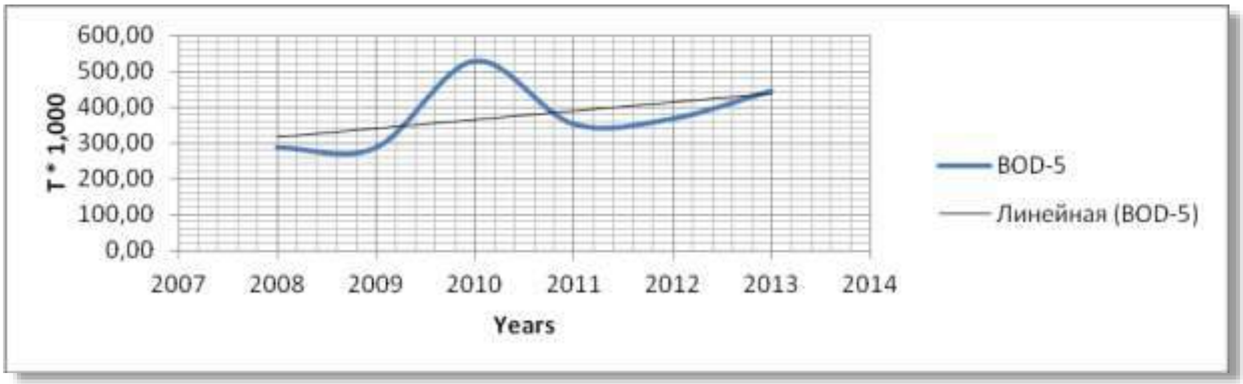

Figure 1.2.1.1.7. Changes of organic matters in BOD_5 discharged and annual flow.

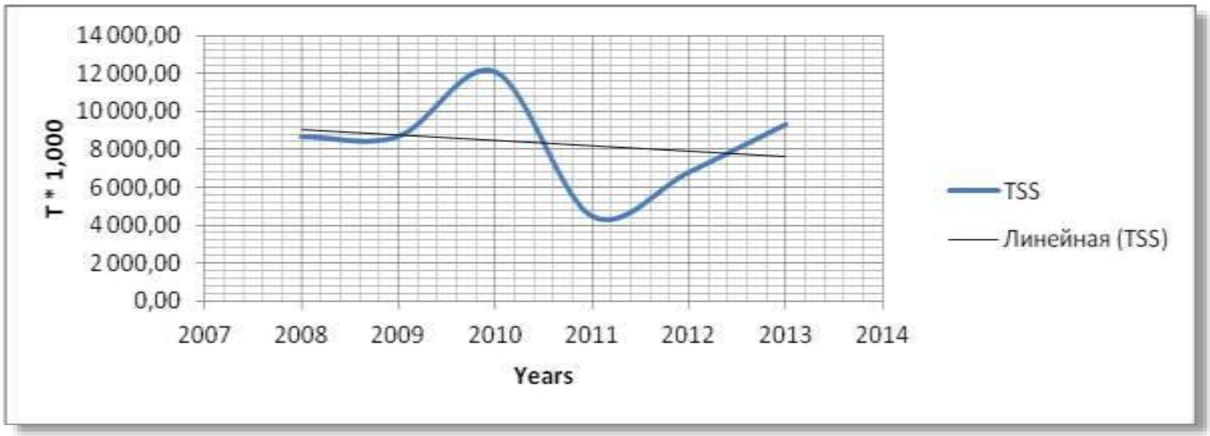

Figure 1.2.1.1.8. Changes of TSS discharged and annual flow.

Turkey

Turkey reported about seven municipal sources, including: 1. Trabzon; 2. Samsun; 3. Zonguldak; 4. Giresun; 5. Ordu; 6. Bafra; 7. Ereğli. The main contribution to the polluting of the Black Sea clearly belongs to Samsun, Giresun and Bafra WWTPs as the main LBS into the Black Sea. This tendency could be mentioned for the individual nutrient elements and certain pollutants (Fig. 1.2.1.1.9-1.2.1.1.15). The figures show that there was substantial decrease of the total discharge of pollutants in wastewaters from municipal sources.

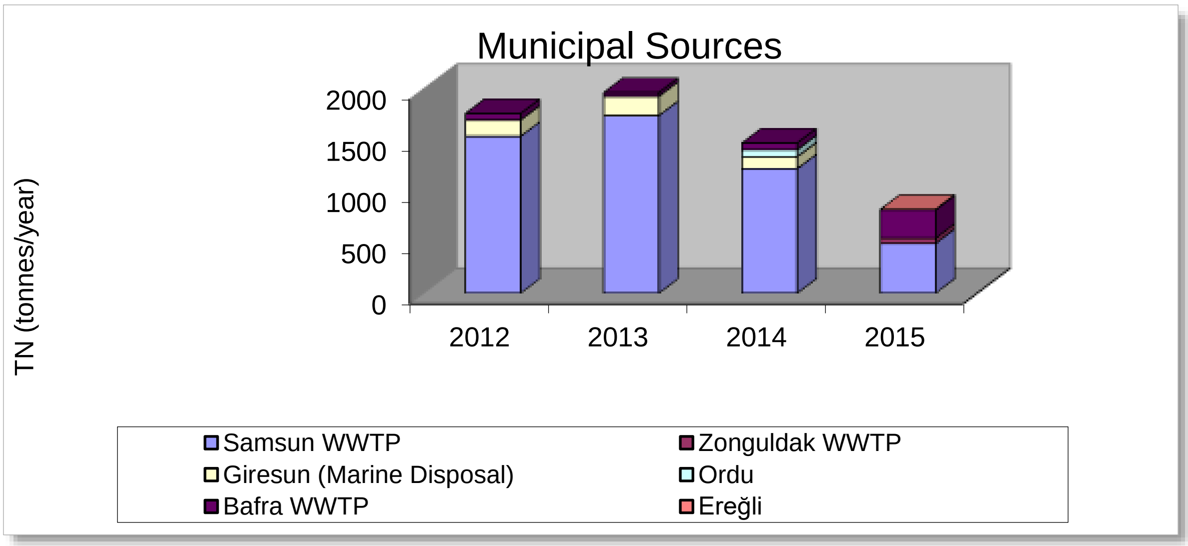

Figure 1.2.1.1.9. Changes of the total nitrogen discharges from the main LBS into the Black Sea.

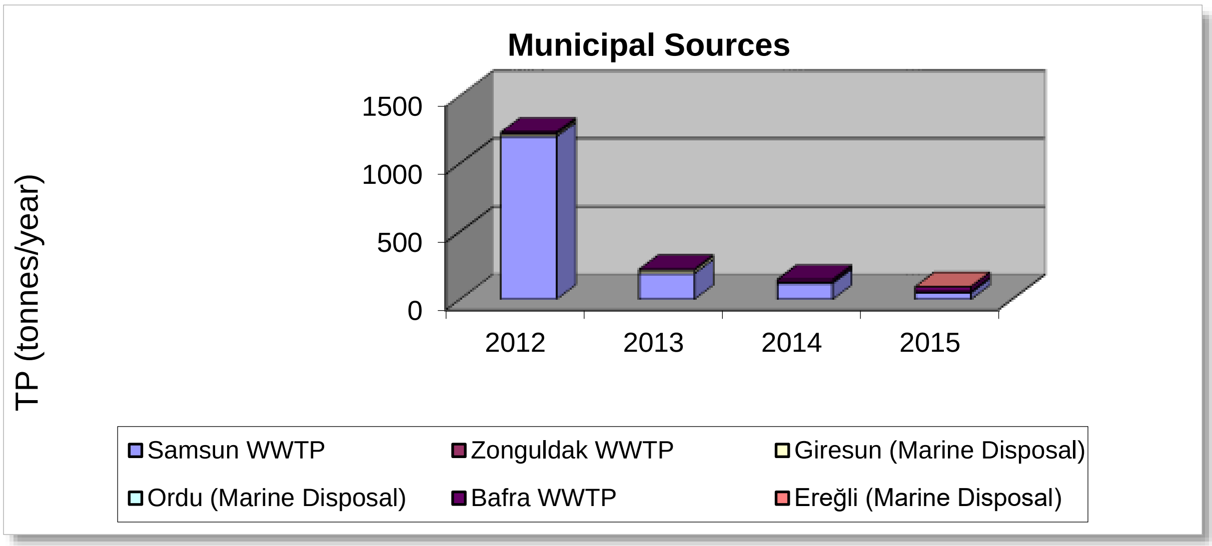

Figure 1. 2.1.1.10. Changes of the total phosphorus discharges from the main LBS into the Black Sea.

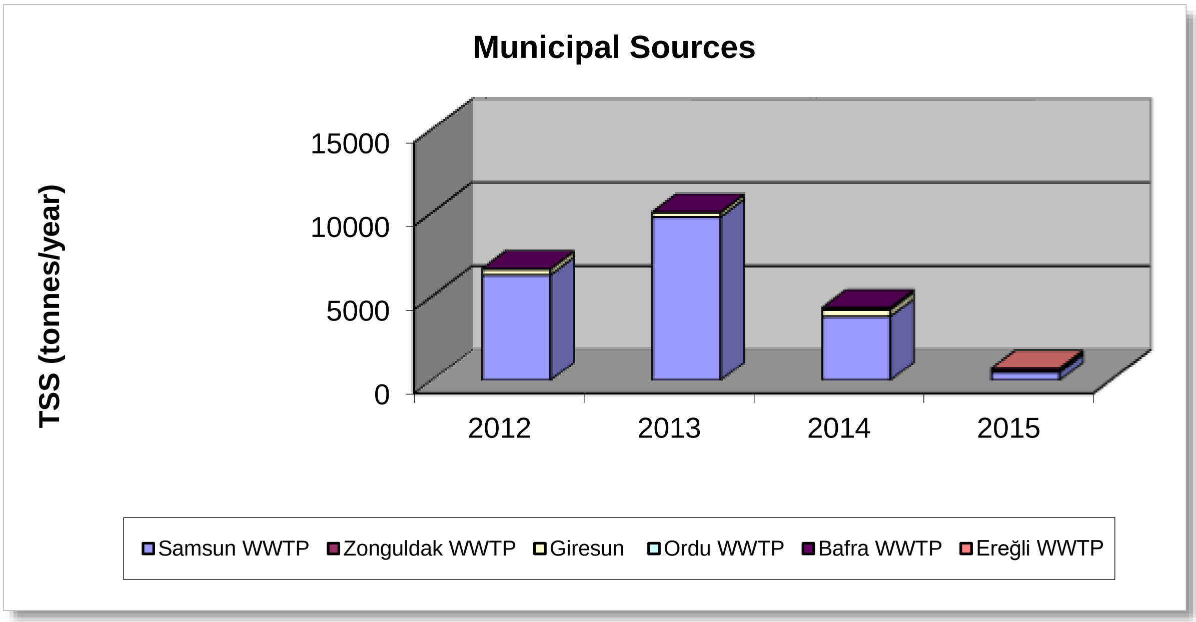

Figure 1.2.1.1.11. Changes of the total suspended solids (TSS) discharges from the main LBS into the Black Sea.

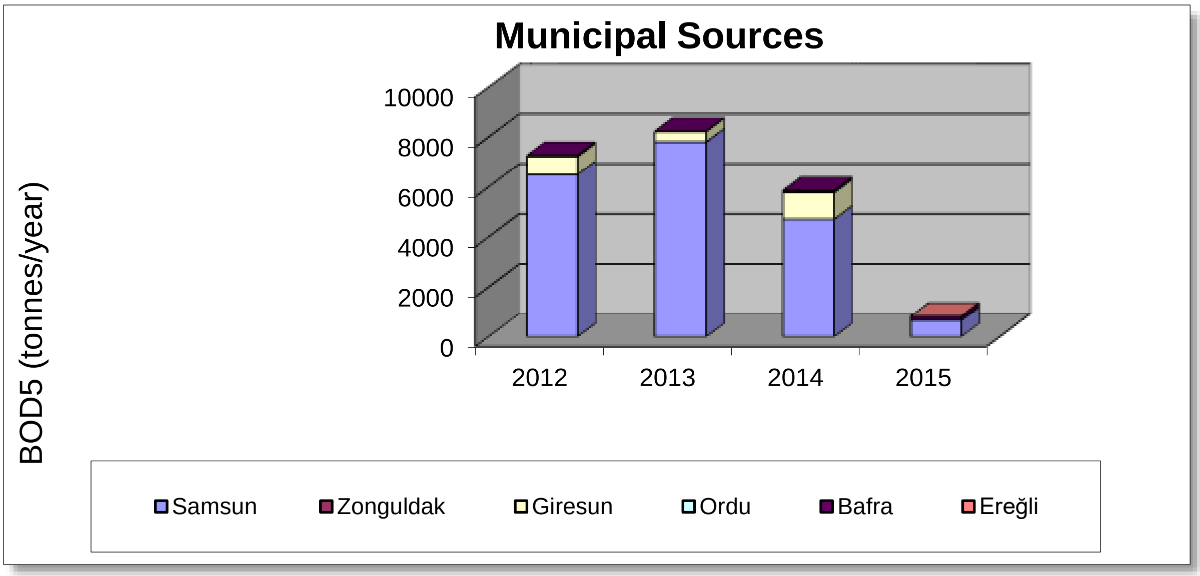

Figure 1.2.1.1.12. Changes of organic matters (BOD_5) discharges from the main LBS into the Black Sea.

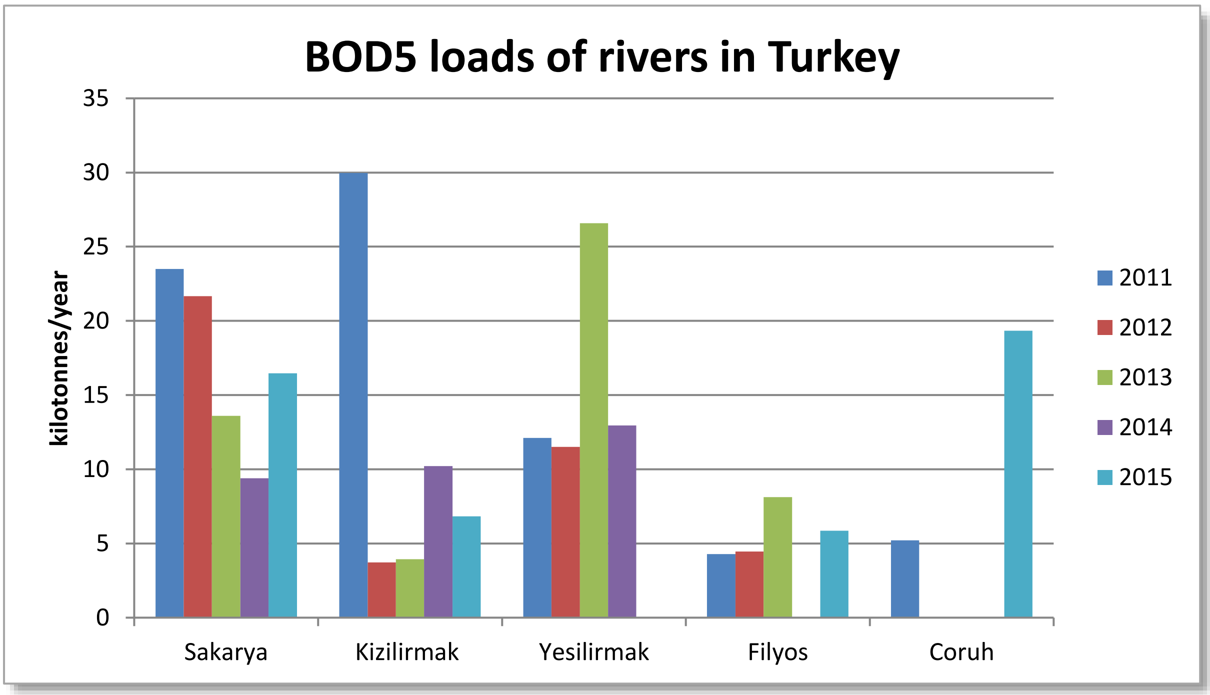

Figure 1.2.1.1.13. Changes of organic matters in rivers discharging into the Black Sea.

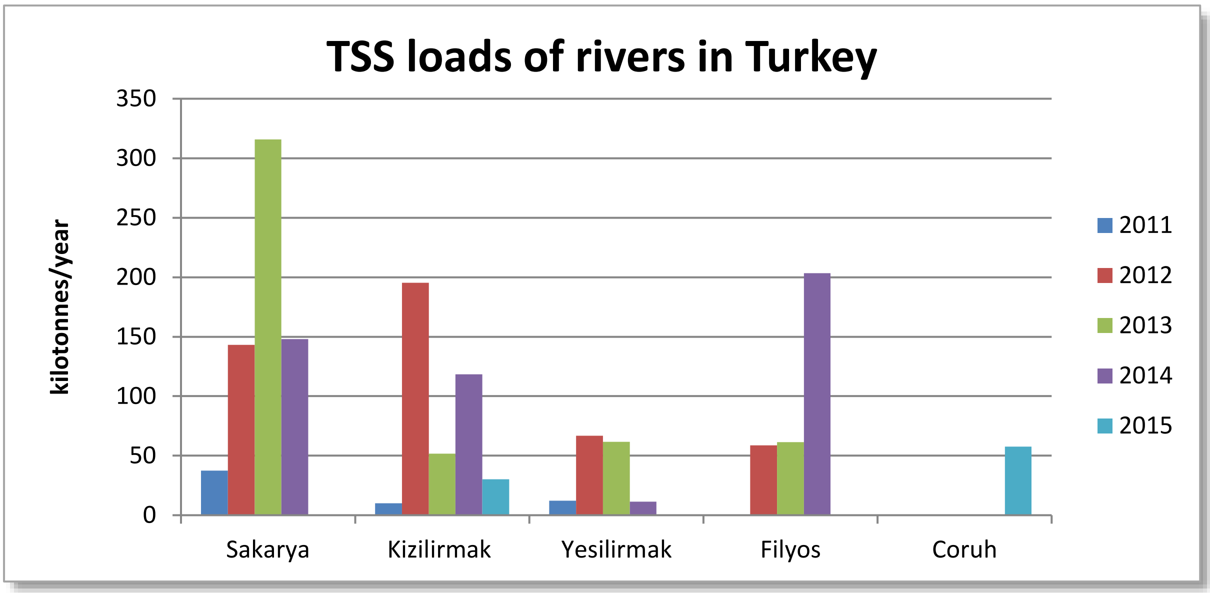

Figure 1. 2.1.1.14. Changes of TSS in rivers discharging into the Black Sea.

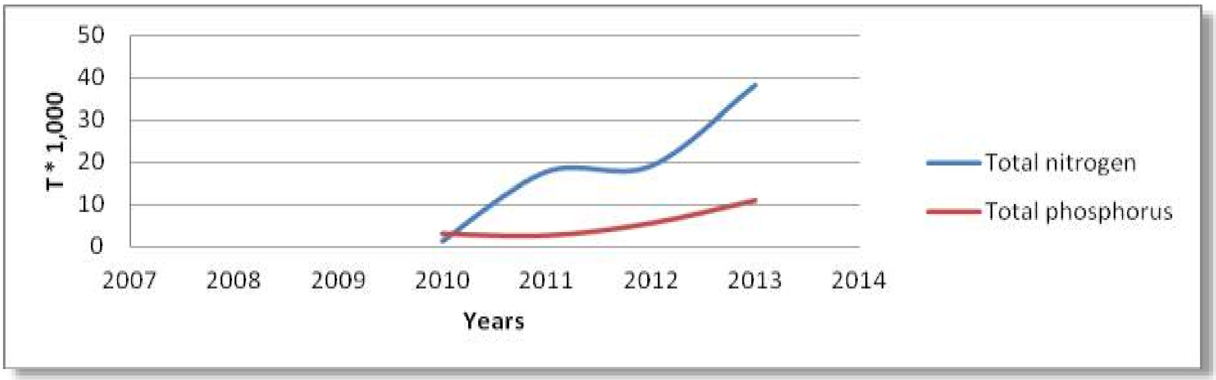

Figure 1.2.1.1.15. Changes of total nitrogen and total phosphorous discharged into the Black Sea.

The figures show that there was a slight increasing tendency in BOD_5, TSS load, and total phosphorous, and visual increasing tendency in total nitrogen discharges in river waters entering the Black Sea.

Georgia

The six municipal sources reported by Georgia are Kobuleti, Kutaisi, Poti, Tskhaltobo, Zugdidi and Batumi. The table below illustrates the changes of volume of waste waters discharged into the Black Sea from LBSs. It almost tripled from 2008 to 2014 (Table 1.2.1.1.3). At the same time, the volume of untreated waters decreased up to 40% in 2014 compare with 2009.

Table 1.2.1.1.3. Total volume of wastewaters discharged.

Years	2008	2009	2010	2011	2012	2013	2014
Total volume of waste waters discharged into the Black Sea	71.413	82.760	84.860	82.100	123.000	126.100	202.000
Volume of untreated waters	42.668	46.280	46.029	28.020	22.020	28.020	28.300

Source: LBS 2009 GE Report.

The Figures below illustrate the volume of pollution discharged in to the Black Sea from LBS. (Fig. 1.2.1.1.16-18).

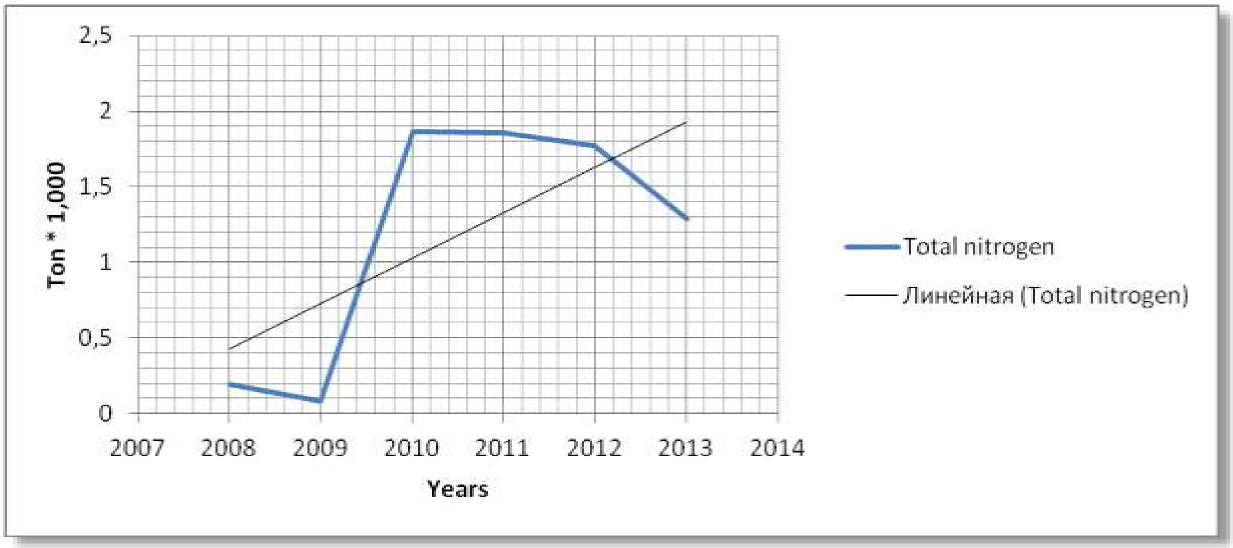

Figure 1.2.1.1.16. Changes of total nitrogen discharged.

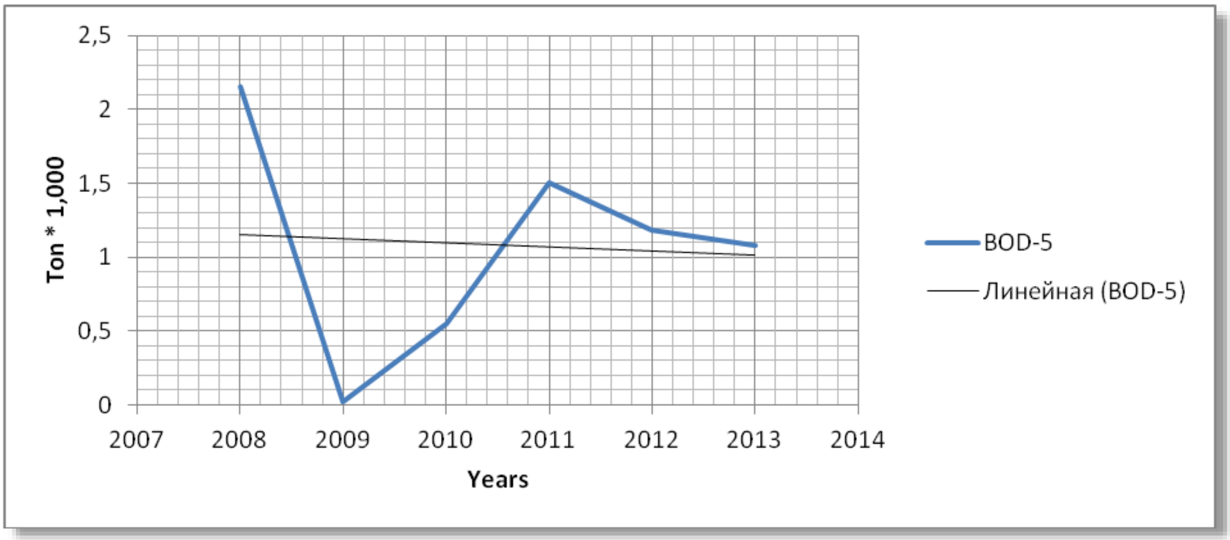

Figure 1.2.1.1.17. Changes of total organic matters indicated in BOD5 discharged.

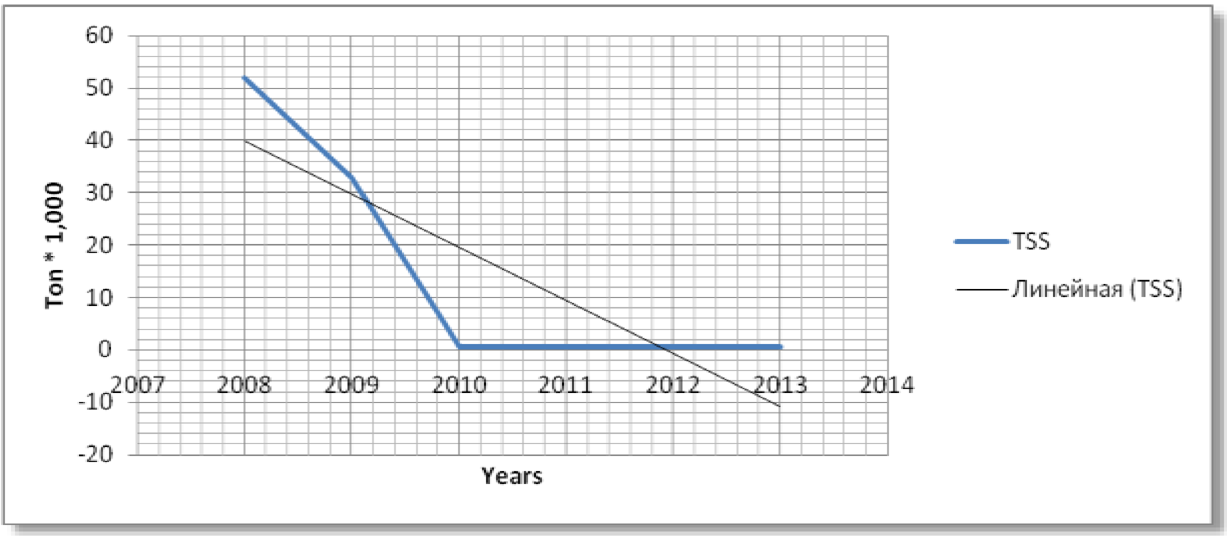

Figure 1.2.1.1.18. Changes of total suspended solids discharged.

The figures show that there is an increasing tendency in the discharge of total nitrogen and total organic matters with the decreasing tendency in total suspended solids discharged into the Black sea. The tables below illustrate the volume of major pollutants and main sources which discharged wastewaters into the Black Sea in 2014 (Table 1.2.1.1.4-5).

Table 1.2.1.1.4. Wastewater quality discharged from Georgian rivers into the Black Sea in 2014.

Indicator	Unit *1,000	River/Station			
		Rioni-Poti	Chorokhi Mirveti	Supsa Khidmagala	Khobi Kulevi
Nitrate	Ton	0,42	0,3	0,001	
Nitrite	Ton	0,02	0,55		
BOD-5	Ton	0,81	0,24		0,01

Source: LBS 2009 GE report.

Table 1.2.1.1.5. Distribution of pollution loads between main sources in 2014.

Indicator	Unit* 1.000	Kutaisi	Batumi	Chiatura	Poti	Zugdidi
Nitrate	Ton	0.052			0.0501	
Nitrite	Ton	0.012				
TSS	Ton	32.20	5.14	46.86	0.19	0.12
BOD-5	Ton	0.5153	0.3770		0.1328	0.01
Total P	Ton		0.291			
Total N	Ton		0.0510			

Source: LBS 2009 GE Report

Russia

Russia did not report on the number and location of main sources discharging waste waters into the Black Sea. However, according to the last report the volume of waste waters discharged into the Black Sea increased by 15% from 2014 to 2015. Information about the relevant indicators of pollution is shown in Table 1.2.1.1.6 and Figures 1.2.1.1.19-23. The figures below show that the volume of total nitrogen, phosphorous, organic matters, and suspended solids was decreasing in the wastewaters, which discharged into the Black Sea.

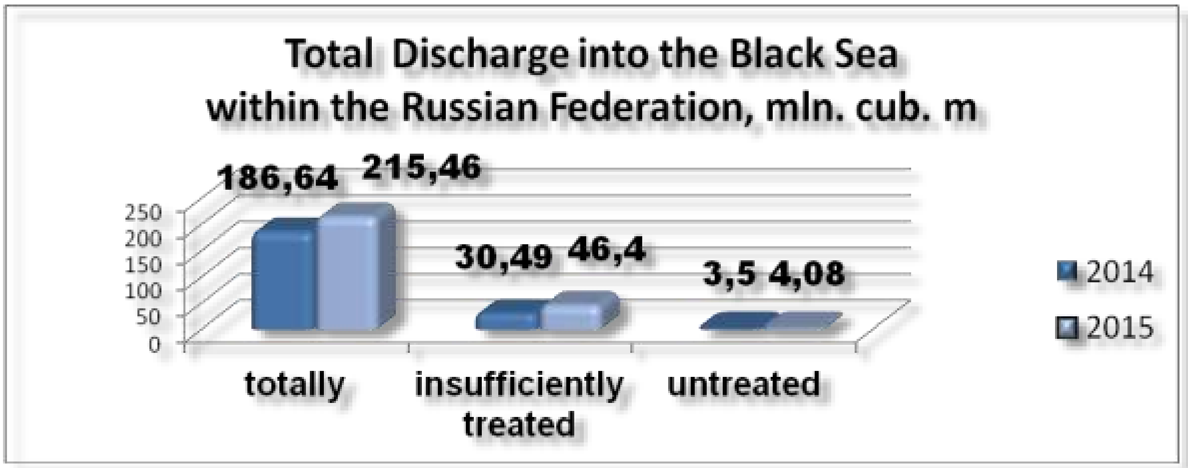

Figure 1.2.1.1.19. Discharges into the Black Sea from LBS at Russian coast in 2014 and 2015.

Table 1.2.1.1.6. Comparison of contaminants indicators of wastewaters discharged into the Black Sea.

River	Year	Water Flow, km^3	Nitrogen (mineral)	Phosphorus (total)	Organic (BOD_5)	TP	Suspended Solids
Vulan	2014	0.092	44	3.0	295	1.2	2383
	2015	0.075	39	2.0	290	1.65	1860
Tuapse	2014	0.366	481	58	414	17.2	36271
	2015	0.249	226	22	1450	12.4	7694
Sochi	2014	0.417	105	11	576	5.42	5796
	2015	0.427	163	10	632	5.12	68747
Khosta	2014	0.167	42	3	401	2.17	3223
	2015	0.157	41	2	162	1.57	1994
Mzimta	2014	1.55	316	121	2790	35.7	77500
	2015	1.51	331	41	1860	10.6	100264
Derekoyka	2014	0.009	8	1	26	0.117	288
	2015	0.016	6	2	53	0.288	333
Demerdzhi	2014	0.004	4	0.9	8	0.12	48.4
	2015	0.005	2	0.3	9	0.1	102

Source: LBS 2009 RU Report

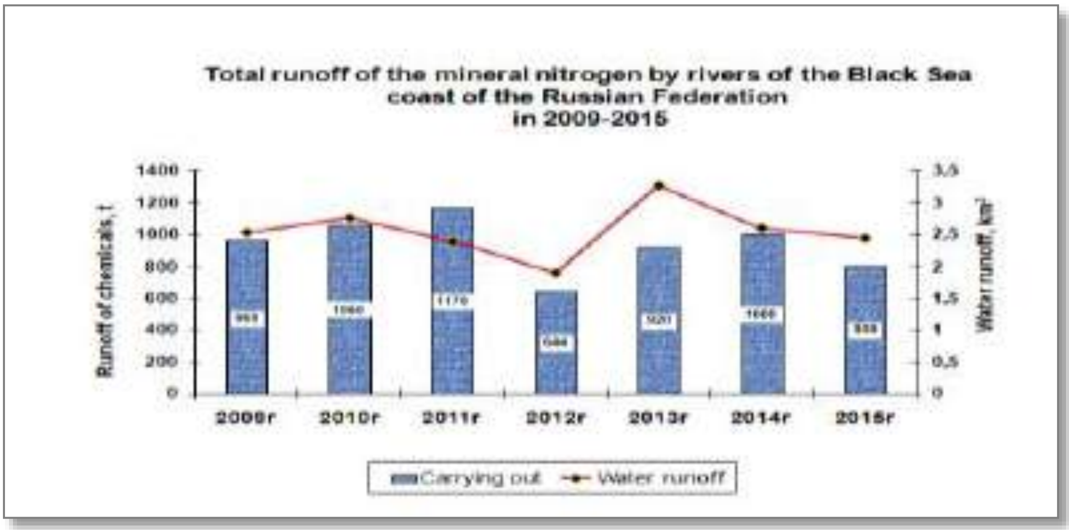

Figure 1.2.1.1.20. Changes of mineral nitrogen runoff into the Black Sea.

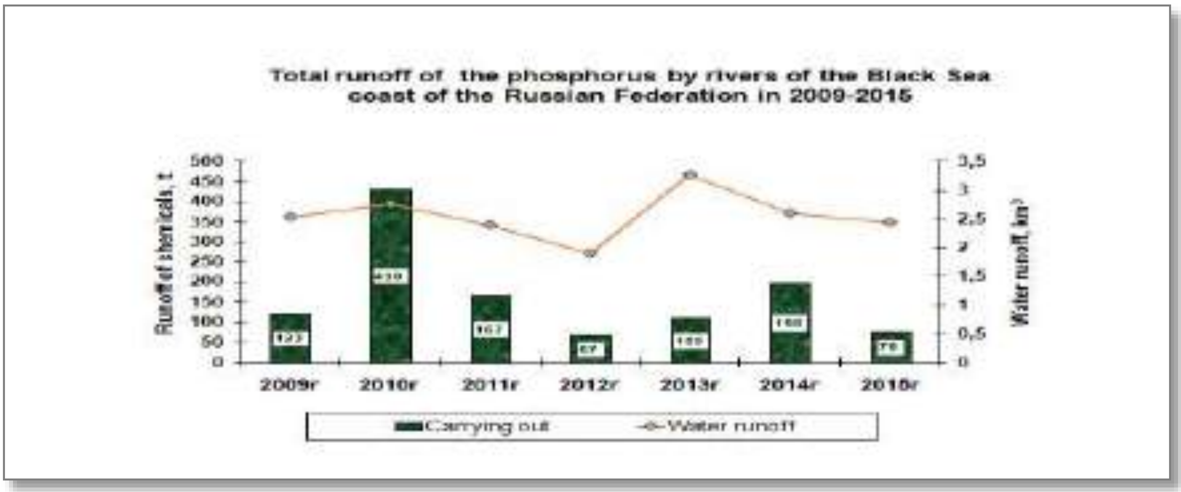

Figure 1.2.1.1.21. Changes of phosphorous runoff into the Black Sea.

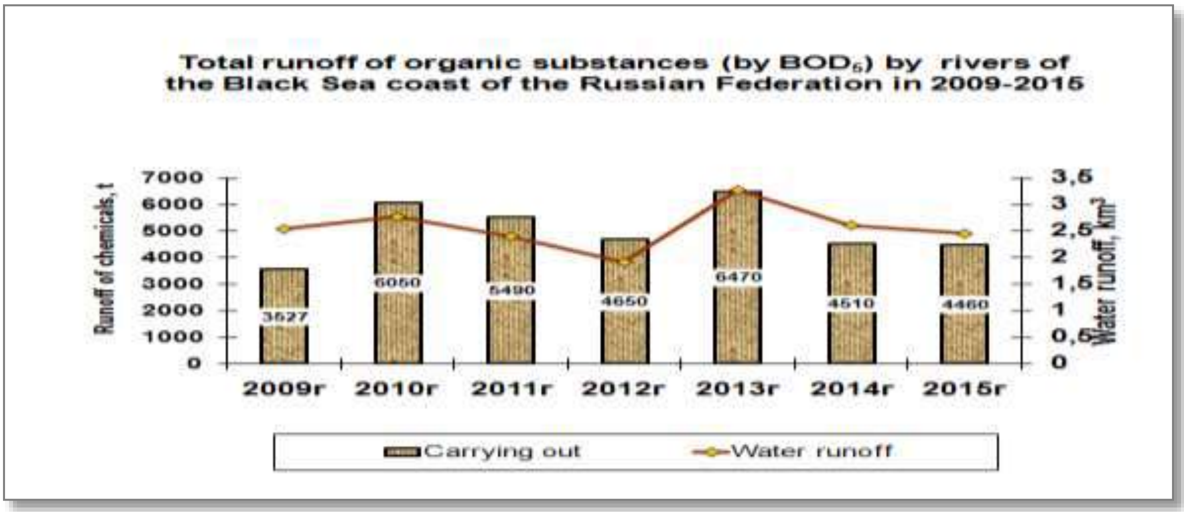

Figure 1.2.1.1.22. Changes of organic substances indicated in BOD_5 runoff into the Black Sea.

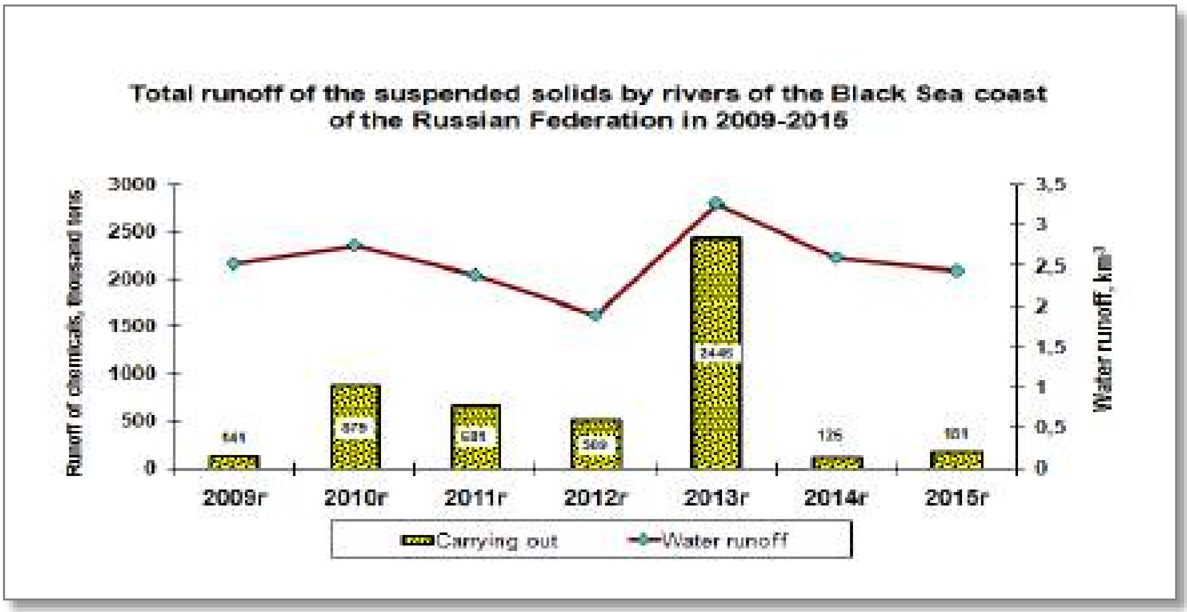

Figure 1.2.1.1.23. Changes of suspended solids runoff into the Black Sea.

Ukraine

Ukraine reported that Pivdenni is the main source, which contributes over 30% of wastewaters discharged into the Black Sea. There are some more sources to be accounted. The Figures below show that the total nitrogen discharge has slight tendency to increase at the same time discharge of total phosphorous and organic matters have decreasing tendency (Fig. 1.2.1.1.24-26). The figures show that there were decreasing tendencies in total phosphorous and organic matters and slight increasing tendency in total nitrogen discharged into the Black Sea.

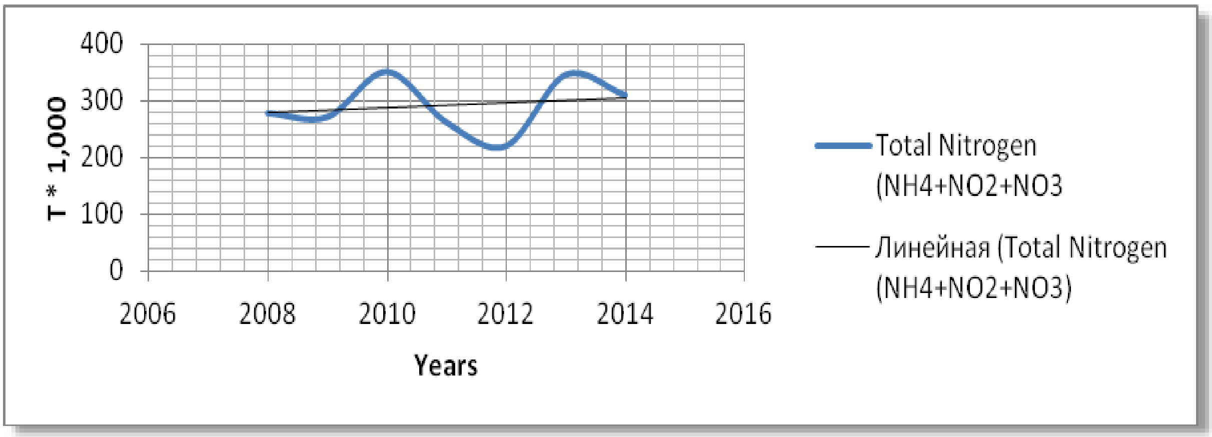

Figure 1.2.1.1.24. Changes of total nitrogen discharged into the Black Sea.

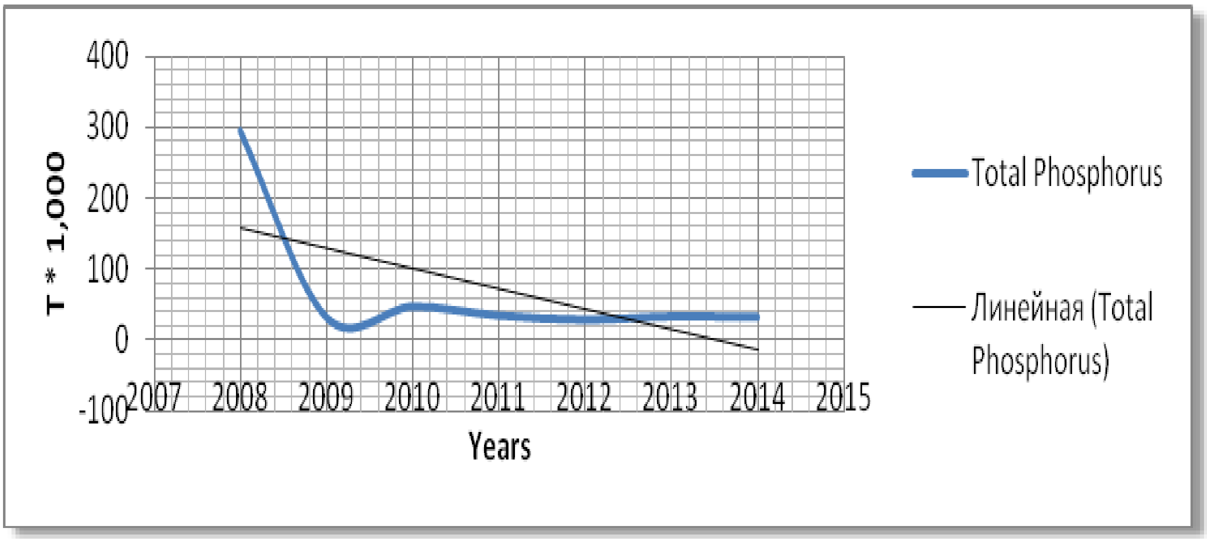

Figure 1.2.1.1.25. Changes of total phosphorus discharged into the Black Sea.

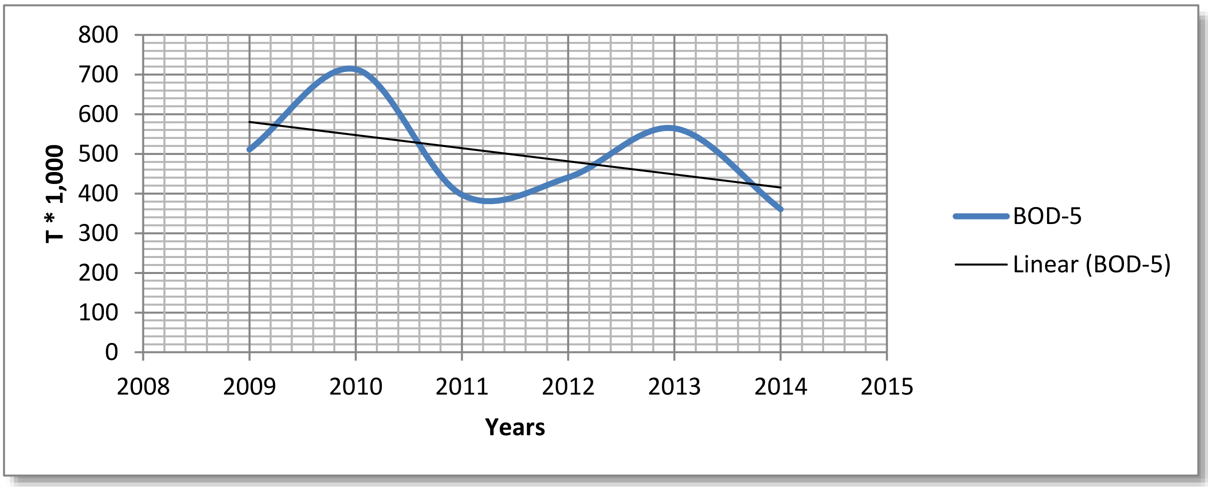

Figure 2.1.26. Changes of total organic matters discharged into the Black Sea.

Conclusions

Rapid analysis of the information collected from the annual reports of the riparian countries delivered by LBS AG and presentations delivered during 21st LBS AG meeting 8–9 September 2016 allowed to make the following conclusions about the content of the wastewaters discharged into the Black Sea:

- there was an increasing tendency observed in the volume of organic matters indicated in BOD5, total nitrogen, and suspended solids. At the same time, there was a decreasing tendency in the discharge of total phosphorous in the Bulgarian wastewaters;
- the waste waters discharged into the Black Sea from LBSs almost tripled from 2008 to 2014 with the volume of untreated waters decreased up to 40% in 2014 compare with 2009 in Georgian waste waters. There was an increasing tendency in concentration observed of total nitrogen and total organic matters with the decreasing tendency in total suspended solids in Georgian waste waters;

- the volume of Romanian waste waters discharged into the Black Sea decreased over 15% and the volume of untreated waters discharged into the Black Sea decreased almost 50% from 2008 to 2013. There was a decreasing tendency of content of total nitrogen and total suspended solids and an increasing tendency of total phosphorous and organic matters (BOD_5);
- the volume of total nitrogen, phosphorous, organic matters, and suspended solids was decreasing in Russian wastewaters;
- there was a substantial decrease of the volume of total discharge of pollutants in waste waters from Turkey's municipal sources and there was a slight increasing tendency in BOD_5, total suspended solids load, and total phosphorous, and visual increasing tendency in total nitrogen discharges into the river waters;
- total nitrogen discharge had slight increasing tendency and discharge of total phosphorous and organic matters had decreasing tendency in Ukrainian wastewaters. There were decreasing tendencies in the content of total phosphorous and organic matters and slight increasing tendency in total nitrogen in Ukrainian wastewaters.

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6. LBS UA Report. Land Based Sources Ukraine Report, 2007- 2015

6.2.1.2. Atmospheric deposition

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Heavy metals and POPs

This section presents model assessment of HM and POPs atmospheric input to the Black Sea for the period 2009-2014. Modelling of atmospheric transport and deposition of selected HMs and POPs, namely, Cd, Pb, Hg, and benzo(a)pyrene (B(a)P), was carried out using MSC-E Eulerian transport models for Heavy Metals MSCE-HM (*Travnikov and Ilyin*, 2005) and for Persistent Organic Pollutants MSCE-POP (*Gusev et al.*, 2005). Latest available official information on B(a)P emission from the EMEP countries was used in model simulations (*Ilyin et al., 2016; Gusev et al.*, 2016).

Temporal variations of annual total atmospheric input of lead, cadmium, mercury, and B(a)P to the Black Sea was not significant in the period 2009-2014 (Fig. 1.2.1.2.1). In general, the pattern of inter-annual deposition of considered pollutants depends on changes of emissions in the surrounding countries as well as changes of precipitation amount and atmospheric circulation. In case of B(a)P, additional effect on level of deposition can be related to inter-annual variations of temperature and concentrations of atmospheric reactants. Changes of lead and mercury deposition to the Black Sea have similar pattern with the increased amount of deposition in 2010 and gradual decrease towards 2013 that, in general, follow the changes of precipitation amount. Cadmium deposition flux to the Black Sea had maximum value in the considered period in 2012. For all three metals total deposition in 2014 was higher comparing to 2013. The pattern of inter-annual changes of B(a)P deposition differs from heavy metals by the maximum of deposition flux in 2013.

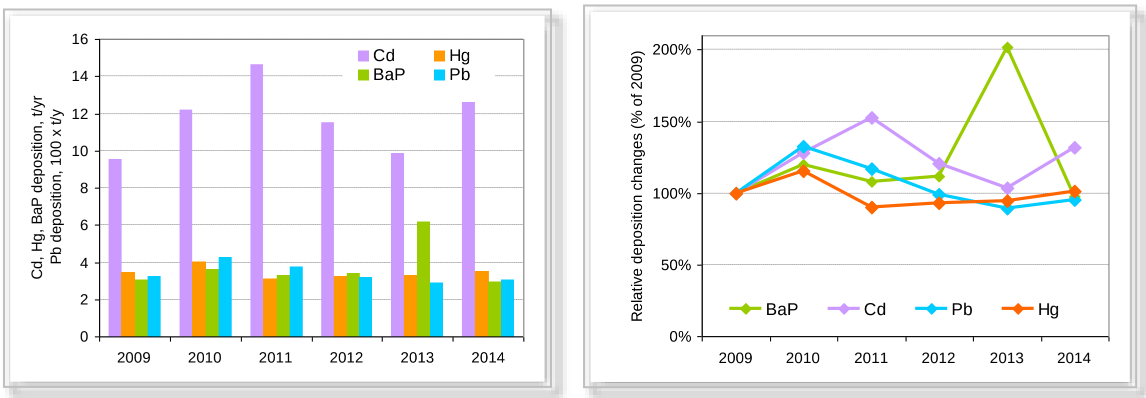

Figure 1.2.1.2.1. Temporal changes of annual total deposition of cadmium (ton/year), mercury (t/y), lead (100*t/y), and benzo(a)pyrene (t/y) to the Black Sea in the period from 2009 to 2014 (a) and their relative changes in comparison to the level of deposition in 2009 (%).

Spatial distributions of annual deposition fluxes of Cd, Pb, Hg, and B(a)P, measured as grams per km^2 in year, was not completely similar in different years, for instance in 2009 and 2014 (Fig. 1.2.1.2.2-5). The pattern of deposition fluxes in different parts of the Black Sea depends on spatial distribution of major emission sources located in the surrounding areas. In general, higher values of heavy metal deposition fluxes are subject of the western part of the sea.

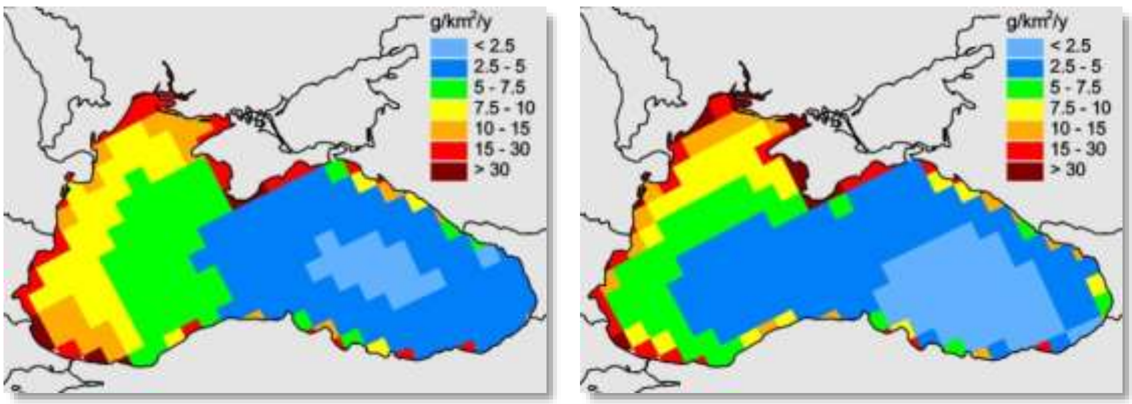

Figure 1.2.1.2.2. Annual deposition of benzo(a)pyrene (g/km^2/year) to the Black Sea in 2009 and 2014.

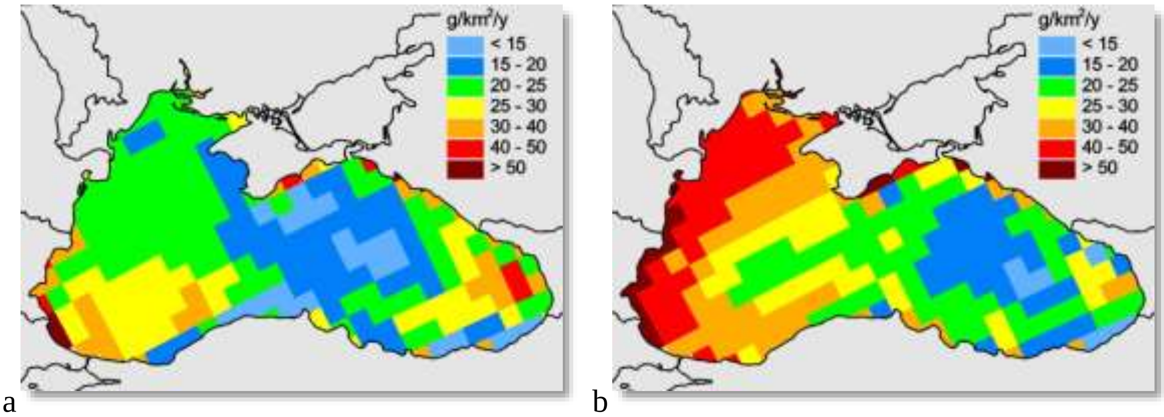

Figure 1.2.1.2.3. Annual deposition of cadmium (g/km^2/year) to the Black Sea in 2009 and 2014.

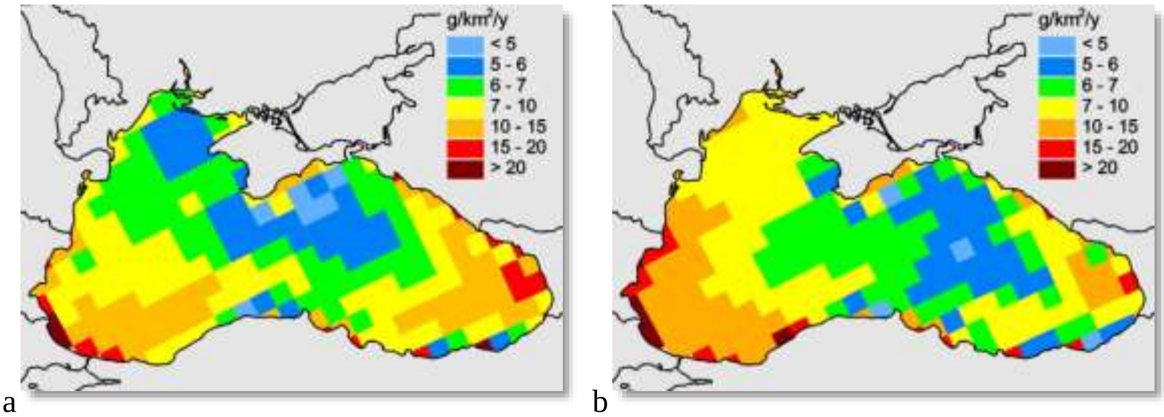

Figure 1.2.1.2.4. Annual deposition of mercury (g/km^2/year) to the Black Sea in 2009 and 2014.

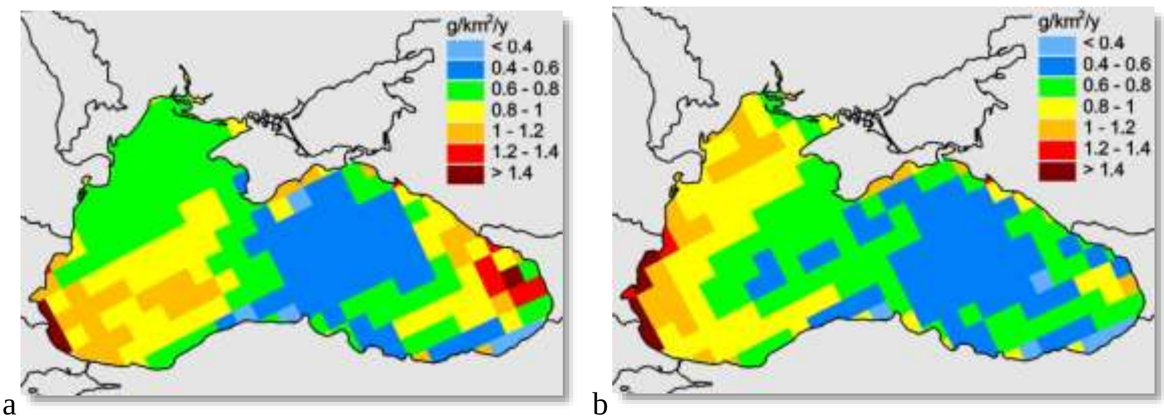

Figure 1.2.1.2.5. Annual deposition of lead (g/km^2/year) to the Black Sea in 2009 and 2014.

Nutrients atmospheric deposition in Sevastopol

During 2014 about 50 analyses of phosphates and total phosphorus, inorganic nitrogen and silicates concentration, and value of pH indicator were done from the atmospheric deposition. Samples were collected manually at meteorological station at Pavlovsky Cap in Sevastopol. The samples were taken only during raining and snowing. Hydrogenium ion concentration (**pH** indicator) in these samples varied between 4.77-7.76 with average 6.78 pH. In 26% of samples it was in range 4.77-6.50 pH. In winter the acidity of the rain was slightly increased till about pH 6.50 in contrary with warm period which had a range pH 6.5-7.5 and average about pH 7.0 (Fig. 1.2.1.2.6). Probably the reason of that is increasing release of main acidification elements sulphur and nitrogen into the atmosphere.

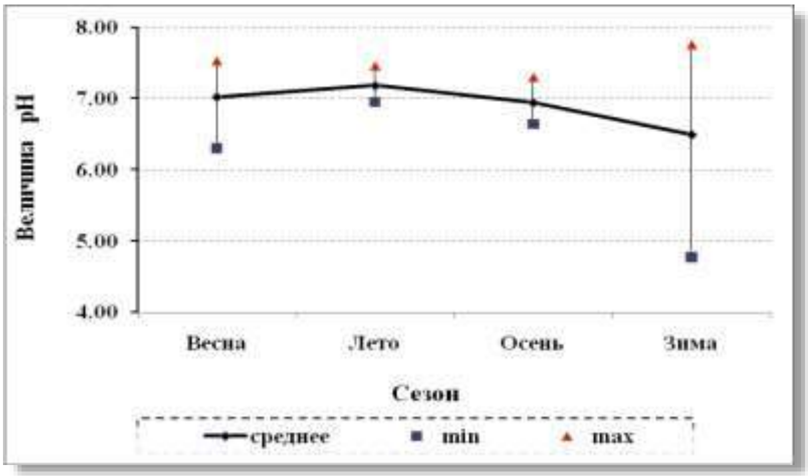

Figure 1.2.1.2.6. Average and maximum pH values in precipitation for different seasons in 2014.

The values of the concentrations of various **phosphorus** forms were characterized by strong seasonal heterogeneity which, in the first example, was connected with unequal distribution of precipitations during the year. The distribution diagram of the average value of phosphorus in precipitation samples is shown in Fig. 1.2.1.2.7.

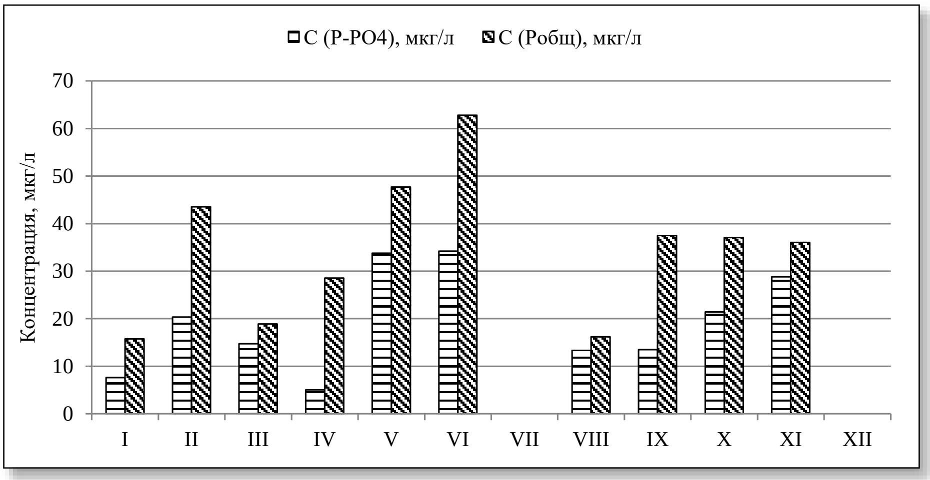

Figure 1.2.1.2.7. The average values of concentration of various forms of phosphorus (phosphates and total phosphorus, µg/l) in precipitation samples in 2014.

The most intense flows of phosphorus were identified in May and June linked to the decrease of precipitations. The increase of concentration during autumn and winter is also due to the meteorological conditions. The same during February, September, and October depending on the release of phosphorus in the form of a fine spray because of wind erosion of topsoil.

The flux of phosphates from January to November was 3550 µgP/m^2 which is almost 50% less than the same value fixed in 2013. Most probable, it depends on the climatic conditions of the year and, in particular with the reduced total volume of precipitations. The most intense precipitation of phosphorus is accompanied by winds from continental areas. This confirms the hypothesis of lack of flux with the sea's sprays.

The distribution of the total phosphorus deposition also depends on the wind flows. Similarly to phosphates, the most intensive fluxes were identified with winds of continental directions. The summary year flux was about 30% less than in previous years. This decrease could be partially explained by the lack of precipitations related to the South-East winds blowing across the areas with intensive agriculture.

The priority forms of inorganic **nitrogen** are nitrites and ammonium (Fig. 1.2.1.2.8). The concentration of inorganic nitrogen in atmospheric deposits of Sevastopol varied form 0.36 mgN/m^3 to 6.04 mgN/m^3 with the average of 2.80 mgN/m^3. The highest concentration of inorganic nitrogen concentration in the samples of atmospheric deposits was fixed during the cold period – from November to March and during warmer months the concentrations were decreased. The mentioned increase may also depend, for example, on the increase of the volume of fuel burned during the winter period. This fact could be proved by the distribution of nitrates concentration which is the major contributors of nitrogen concentration in atmospheric deposits. The variation range of nitrogen flux calculated as the multiplication of summary of inorganic nitrogen in precipitation sample on quantity of deposits on the unit area for the certain time period was from 0.93 to 230.12 mgN/m^2 x month.

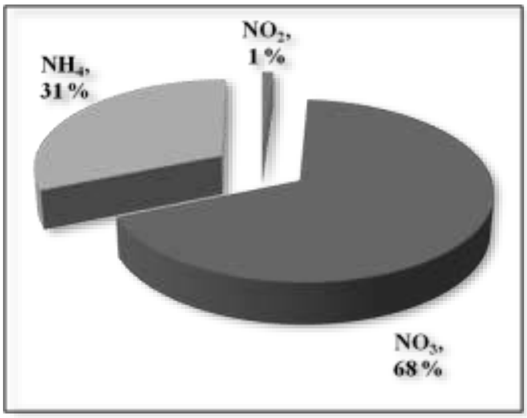

Figure 1.2.1.2.8. Relative contributions of nitrogen ions in general nitrogen content in atmospheric deposits during 2014.

The average content of **Synthetic Anionic Surfactants** (**SAS**) in atmospheric deposits was 26.9 µg/dm^3 and varied from 10 to 177.3 µg/dm^3. An analysis of concentration variations as a function of the quantity of deposits was conducted. It showed that concentration decreases with the quantity of precipitation increase (Fig 1.2.1.2.9).

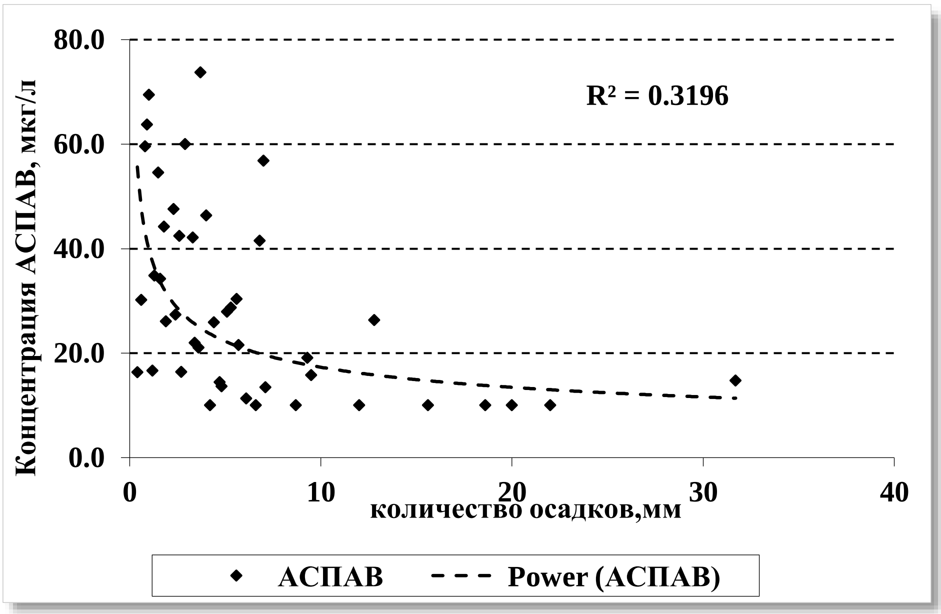

Figure 1.2.1.2.9. Link between concentration of SAS and quantity of wet atmospheric precipitation in 2014.

Air quality assessment is based on the results of the permanent monitoring of **particle size** distribution of aerosols from March to September which is the base for norms of the content (mass concentration) for ultrafine aerosols size groups <2.5 µm and <10 µm (PM2.5 и PM10). Air quality monitoring of ultrafine aerosols particles sizes 2.5 and 10 µm is the challenge for Russian Federation as well as for other countries like USA and EU Member states. The new task required the development of new methodology for the definition of indicators because the recommended gravimetrical method GN 2.1.6.1338-03 (MAC 2003) does not possesses the required assay sensitivity and selectivity for size of particles. On top of this, the majority of detectors measure the number of aerosols particles according to the interval of the particles sizes but concentration should be measured to compare with MAC.

A background point for continuous measurement of the size spectrum was organised in Sevastopol. It was located in the building at 105 m above sea level. The low-angle laser measuring instrument (IDL-1M) used there is the one of those commercially available devices allowing to measure the concentration of the particles as well as bulk concentration. This allows to correlate the results obtained with the value of the MAC with high discretisation resolution. The main obstacle for application of this measuring instrument and similar is still the lack of coordinated methodology to convert volume fraction (e.g., 1 million or ppm) in concentration (mg/m^3). To perform calculations, the density of the most common types of aerosols - sulphate aerosol (□=1.65 g/cm^3) was taken as the base. For single values, PM2.5 value changes in the range of 0-0.03 mg/m^3 and PM10 from 0 to 0.25 mg/m^3 during the whole period of observation. Such a large spread of suspended solids concentrations is due to the presence of large amounts of suspended solids revenue sources into the atmosphere among which the most important sources are the water surface and transboundary transport.

The phenomenon of spontaneous increasing of aerosols against the backdrop of the rapid temperature rise observed in spring was fixed while analysing the data on the change in particle size distribution of aerosols in time. In summer, the average diameter of aerosols most of the day has a value of >3 microns. An increase in the proportion of aerosols 5-6 microns in diameter occurs when the temperature reaches its maximum. Therefore, there is short period of time (approximately 1 hour) when there is a short-term reduction in the magnitude of 3-5 microns. Then, index value reaches the daily maximum. The described features of the change in size distribution probably relates to the filled of air of coastal areas with marine aerosols and their displacement under the influence of breeze winds.

Carrying out continuous monitoring of particle size distribution of aerosols allowed to capture and describe the case of transboundary transport of particulate matters of soil upper layer in the Atlantic cyclones frontal area 14–15 March and 22–23 March 2013. Fall of occluded particles was visually observed and noted by local media.

The increase of the average diameter of aerosols was registered at the curves of particles composition and was characterised by a relatively higher stability and lasted from 2 to 12 hours. The growth of the indicator mainly depended on reducing the relative concentration of small particles with diameter <5 microns. Thus, the studies have shown that the size distribution of aerosols is a highly informative indicator. And, the concentration particles of size groups of PM2.5 and PM10 varied over a wide range and in some cases approached MAC.

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1.2.2. Hydrochemistry

2.1. Nutrients

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Introduction

Nutrients (C, N, P and Si) are one of the most necessary chemical species on earth, making all life possible. Nutrient-poor areas cannot support much biodiversity. The introduction of nutrients into an environment can make the ecosystem healthy and fertile10. Thus, until 60s, the Black Sea was known as one of the most productive seas, with luxuriant pelagic fauna, being an example of natural eutrophic ecosystem due to permanent Danube's nutrients input (Gomoiu, 1981). Nevertheless, the worldwide development of the human activities altering the environment (e.g. Vitousek et al. 1997) mobilized the nutrient elements (mainly nitrogen and phosphorus) by land using, production and applications of fertilizers, discharge of human waste, animal production, and combustion of fossil fuels (e.g. Nixon, 1995). The enhanced use of N and P has accelerated their fluxes to coastal waters, and fertilization of coastal ecosystems became a serious environmental problem because it stimulates plant growth and disrupts the balance between the production and metabolism of organic matter in the coastal zone11, at which point too much nutrients are polluting the waters through eutrophication, and even worse, its effects. With a hydrographical basin six times higher than its surface and other natural features, the Black Sea has an enhanced vulnerability to anthropogenic pressures, too. Together with the increased use of fertilizers, wastewater discharges, detergents, etc. the nutrients regime has undergone significant changes in the Black Sea basin. These changes were found into the river nutrients input which increased significant (Mee and Topping, 1999, Cociaşu et al., 2008) and led to alterations in the North-Western Black Sea's coastal waters. Thus, at the beginning of 80s, phytoplankton has developed excessive and intense blooms became annually and extended in time and frequency. The algae species with more than 100000 cells/L abundance increased to 54 in 1983-1988 from 34 in 1960-1970 (Bodeanu et al., 2004, Gomoiu, 1992), first symptoms of an intense eutrophicated ecosystem. Other eutrophication effects appeared soon: transparency decreasing, oxygen depletion due to organic matter decomposition (Gomoiu, 1992), and seasonally hypoxic or even anoxic bottom sea (ICPDR – ICBS, 1999) transforming the North-Western part of the Black Sea into a highly eutrophic one (Zaitsev in Mee, 1999).

In the early 1990s have found decreasing nutrients input resulted in first recovery signs (decreasing of phytoplankton blooms, improvement of bottom oxygen regime, increasing of benthic macro fauna (Gomoiu, 1992). Thereby, in 2005, the North-Western part of the Black Sea seems to have a strong altered ecosystem, but relative functional. Malfunction symptoms like incapacity of recycling high organic matter input from river or biological activity or dominant monospecific phytoplankton blooms were still evident. Black Sea coastal and shelf waters have being still predominant eutrophic (BSC, 2008). Recently, the emphasized spatial

10 http://www.nationalgeographic.org/encyclopedia/nutrient/

11 Mar Ecol Prog Ser 210: 223-253, 2001

and seasonal variability and the extreme phenomena from the NW Black Sea coast makes the current eutrophication state definable as a moderate - good, based on the Romania's Initial Assessment equivalent to an eutrophic - mesotrophic state which, under the action of climatic factors and human impact more pronounced in the coastal zone, can easily pass to extreme states like unsatisfactory (hypertrophic) or very good (oligotrophic), conditions occasionally encountered in the waters of the NW Black Sea, often seasonally (Lazar et al., 2013, Daskalov et al, 2016).

Thus, in recent years, a slight improvement of the water quality has been observed, but also a system change (Oguz and Velikova, 2010; Daskalov et al., 2016). Hence, the highly productive and eutrophic coastal ecosystem was transformed into a less productive but degraded state during the early 1990s, significantly different from the pristine state, and does not really represent a recovery (Oguz and Velikova, 2010). The major ecosystem regime shift of the early 1990s resulted from a combination of environmentally-induced scarcity of planktivorous fish, persistent overfishing and an invasion by an alien species (Daskalov et al., 2016). All these findings lead us to the evaluation of eutrophication and the criteria that, by excellence, refer to the well-known effects without considering recent changes to alternative states and much different from the original, pristine state from 60s (Lazar et al., 2018).

As for the future, the decreasing trend in nutrient pollution will continue in the Danube region as a result of the implementation of the EU's environmental policies. In the catchment areas of the Dnieper and Don Rivers, however nutrient loading is expected to increase as a result of the development of the agriculture sectors of Ukraine, Russia and Byelorussia. As a result, the North-Western part of the Black Sea, the Azov Sea and the lower parts of the Danube, Dnipro and Don Rivers will reach the maximum level of eutrophication, or very close to it. This signifies that efforts for rehabilitation of the Black Sea aquatic ecosystem should be strengthened in implementation measures to decrease eutrophication in order to avoid the loss of this unique ecosystem (Borysova et al., 2005).

The eutrophication reduction (EcoQ3) is the subject of both Black Sea Strategic Action Plan (2009) implemented by the Black Sea Commission and the Marine Strategy Framework Directive through the Descriptor 5. The latter consider that the Good Environmental Status (GES) has been achieved when *human-induced eutrophication is minimized*, the biological community remains well-balanced and retains all necessary functions in the absence of undesirable disturbance associated with eutrophication (e.g. excessive algal blooms, low dissolved oxygen, declines in sea grasses, kills of benthic organisms and/or fish) and/or where there are no nutrient-related impacts on sustainable use of ecosystem goods and services (Borja, 2013).

Material and methods

The Black Sea monitoring network stations covered all riparian countries between 2009-2014 and consist of 453 stations and 3806 water column samples (Fig.1.2.2.1).

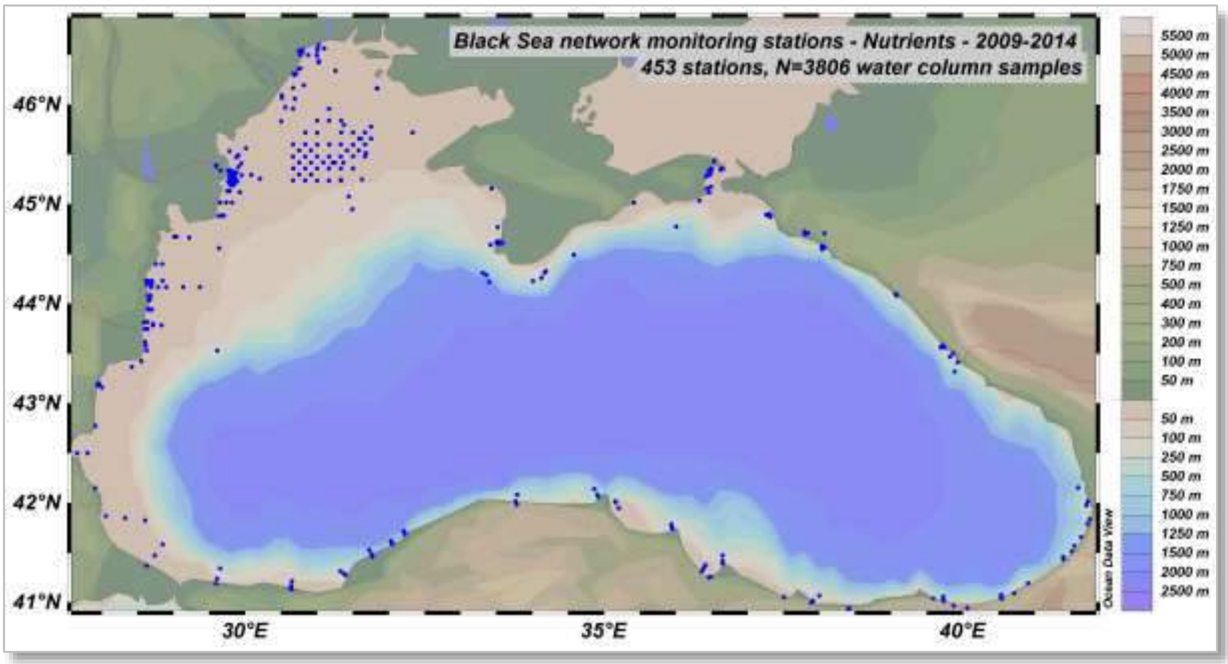


Figure 1.2.2.1. Map of the Black Sea's network of monitoring stations – nutrients in seawater – 2009-2014.

All maps were made with Ocean Data View (ODV) software version 5.12. ODV is a computer program for the interactive exploration that displays data in two basic ways: (1) either by showing the original data at the data locations as colored dots of user-defined size or by projecting the original data onto equidistant or variable resolution rectangular grids and then displaying the gridded fields. Method 1 produces the most elementary and honest views of the data, instantly revealing occasional bad data values and regions of poor sampling. In contrast, method 2 produces nicer plots and avoids the overlapping of the colored dots that occurs with method 1, especially for large dot-sizes. The gridded fields of method 2 are actually data products and that small scale or extreme features in the data may be modified or lost as a consequence of the gridding procedure (weighted-average gridding) (Schlitzer, 2016). All ODV representations done within the scope of this assessment have used method 2 with sampling stations marked as black dots.

Results and discussions

The data from the joint Black Sea Database allow to get descriptive statistics of nutrients concentration (µM) in the surface layer (0-5 m) of the Black Sea for 2009-2014 (Table 1.2.2.1).

Table 1.2.2.1. Descriptive statistics of nutrients – surface layer (0-5m), Black Sea, 2009-2014 (data from Black Sea Database).

	N	Min.	Max.	Median	Average	Standard deviation	95th percentile
Phosphates, $(PO_4)^{3-}$, µM	*2366*	*undetected*	1764.3	0.32	27.70	141.84	4.42
Total Phosphorus, TP, µM	*1389*	*undetected*	7238.5	0.71	48.11	357.34	5.80

	N	Min.	Max.	Median	Average	Standard deviation	95th percentile
Nitrates, $(NO_3)^-$, µM	2071	*undetected*	16561.6	1.86	59.70	566.65	96.74
Nitrites, $(NO_2)^-$, µM	2381	*undetected*	1734.1	0.22	9.44	63.18	5.90
Ammonium, $(NH_4)^+$, µM	2371	*undetected*	9810.1	2.50	107.8	576.54	92.90
Silicates, $(SiO_4)^{4-}$, µM	1541	*undetected*	401050.0	7.12	2269.90	17748.17	7121.11

Phosphates

Phosphate surface distribution highlights the north-north western rivers (Danube, Dniester, Dnieper, Bug) dominance for the inorganic phosphorus intake. Higher values and less variability were also observed in Kerch area and on eastern coast. Thus, with median between 0.08 µM and 0.54 µM, countries reported slightly increased concentrations compared to the reference period 1960s (0.25 µM). Several were outliers and extremes generating high variability possibly linked to changes in rivers hydrological regime (NNW areas) or point sources direct discharging in the sea (E area). Seasonally, winter median (0.23 µM) is the lowest, being significant diminished than other seasons (0.32 µM). The highest variability (standard deviation 0.60 µM) was observed in autumn (Fig. 1.2.2.2).

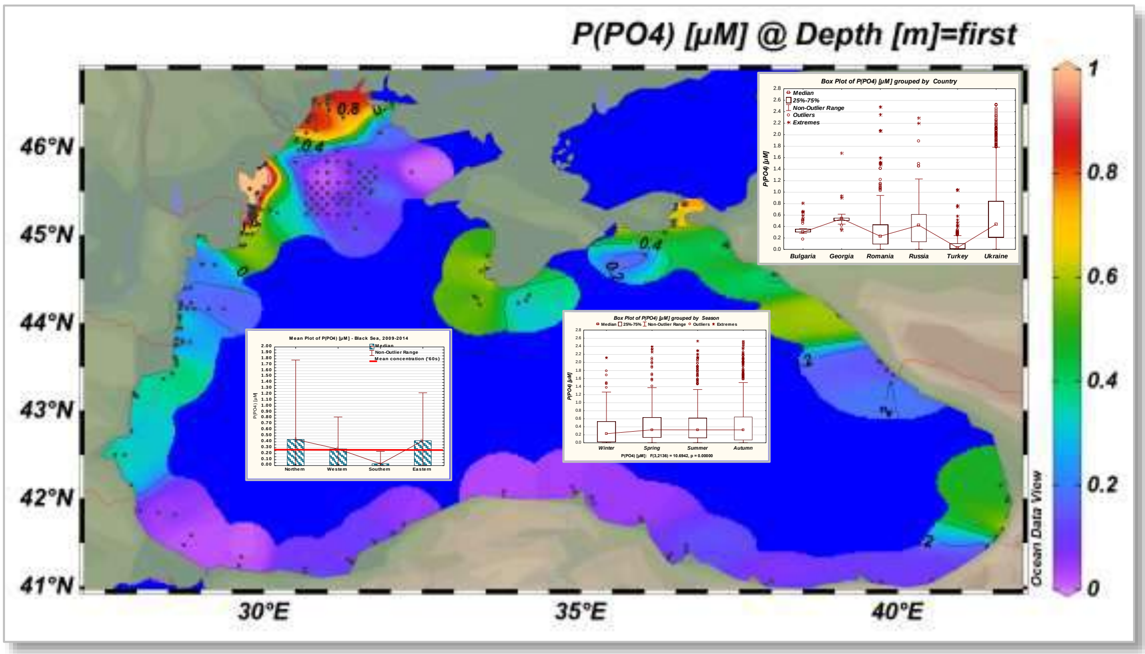


Figure 1.2.2.2. Surface distribution of phosphates concentration in the Black Sea, 2009-2014.

Phosphates concentrations in the water column (0-130 m) reveal the role of phosphorus in the biological activity enhanced in the warm season (spring and summer). Thus, if winter is characterized by the most homogenous and lowest concentrations, together with the increasing temperature and surface input, from spring to autumn looms a homogenous, oxic layer (approx. depths 10-40 m) with average concentrations 0.25 µM. Below, at 40-50 m, and just above the oxycline, was observed the minimum average concentration, 0.1 µM, regardless of season, although in spring and summer this layer is thinning due to Cold intermediate Layer (CIL – the layer with average temperature 6°C delimited in summer at depths 30-50 m) (Fig. 1.2.2.3). The layer 60-100 m, containing the oxycline (60-70 m) has the increasing gradient most evident in summer when mean concentrations reach 1 µM at 100 m. Higher concentrations were found in autumn both in the mixing layer (0-10 m) due to the increased supply and in anoxic waters (130 m) where average concentrations reach 1.5 µM (Fig. 1.2.2.4).

Figure 1.2.2.4. Seasonal variations of vertical distribution – phosphates (L) and oxygen saturation (R), Black Sea, 2009-2014.

Whitout any significant trend, the temporal variation (2009-2014) showed homogenous means between 0.39 µM (2012) and 0.48 µM (2009 and 2013) representing approx. 50-100% more than '60s average concentration (Fig. 1.2.2.5).

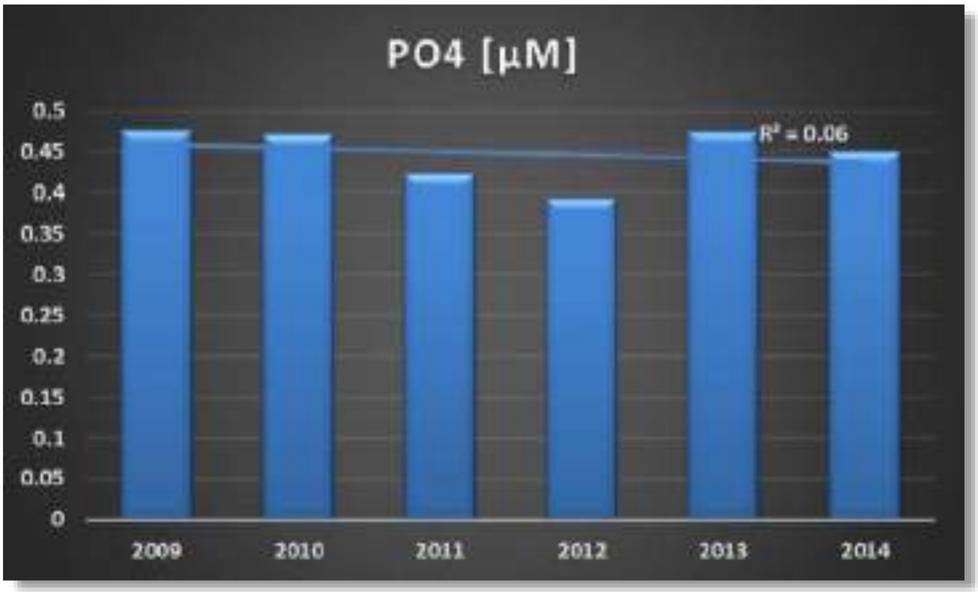


Figure 1.2.2.5. Phosphates annual mean concentration in the surface - Black Sea (2009-2014)

Silicates

Horizontal distribution (surface) of the silicate concentrations outlined the Danube as the major silica supplier followed by the eastern coast. However, currently was found the average concentration of 1960s (42.5 µM) as an extreme value all-over (sub region, country or season). Therefore, all average median concentrations reported by countries, in the range 2.2–11.0 µM, highlighted the Black Sea's silicate stock depletion (Fig. 1.2.2.6).

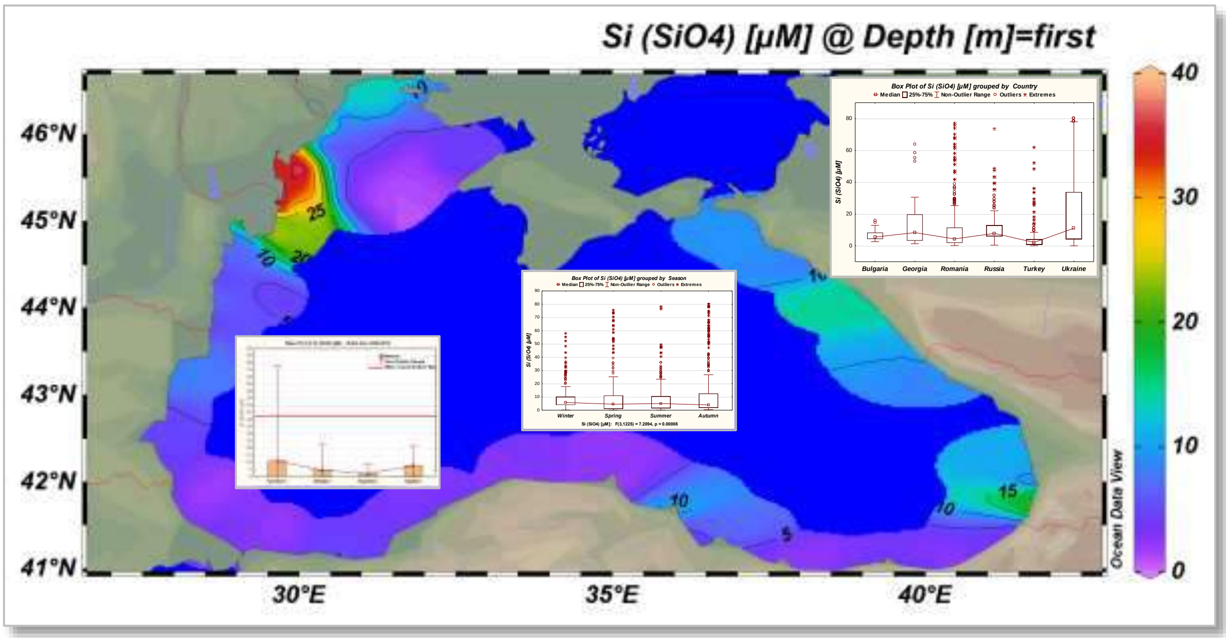


Figure 1.2.2.6. Surface distribution of silicates concentration, Black Sea, 2009-2014.

As diatoms have an absolute requirement for silicon (as silicic acid), its supply into the photic zone — largely by silica dissolution and upwelling — controls diatom production (and consequently the biological uptake of atmospheric CO_2 by the ocean) over vast oceanic areas.12. Silicates concentrations in the water column (0-130 m) reveal also the role of silicone in the biological activity enhanced in the warm season (spring and summer). Like phosphates, winter is characterized by the most homogenous and lowest concentrations (approx. 5µM). Together with the increasing temperature and surface input, from spring to autumn looms a homogenous, oxic layer (approx. depths 10-40 m), with concentrations around 10µM. Below the oxycline, concentrations started to increase from spring to autumn reaching maximum at bottom in autumn (50µM)(Fig. 1.2.2.7). The layer 60-100 m, containing the oxycline (60-70 m) has the increasing gradient most evident in autumn (Fig. 1.2.2.8).

12 http://www.nature.com/nature/journal/v397/n6719/full/397508a0.html#B4

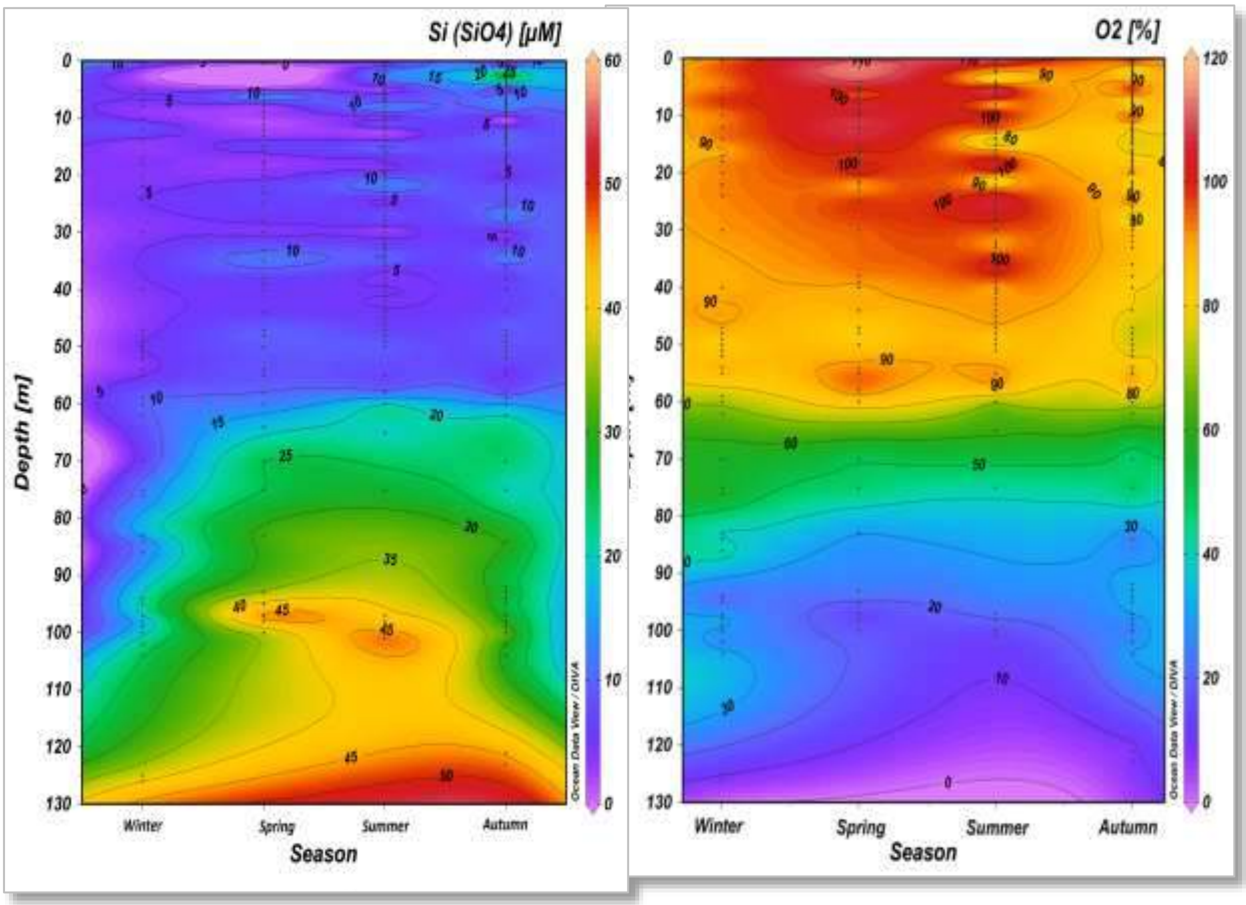


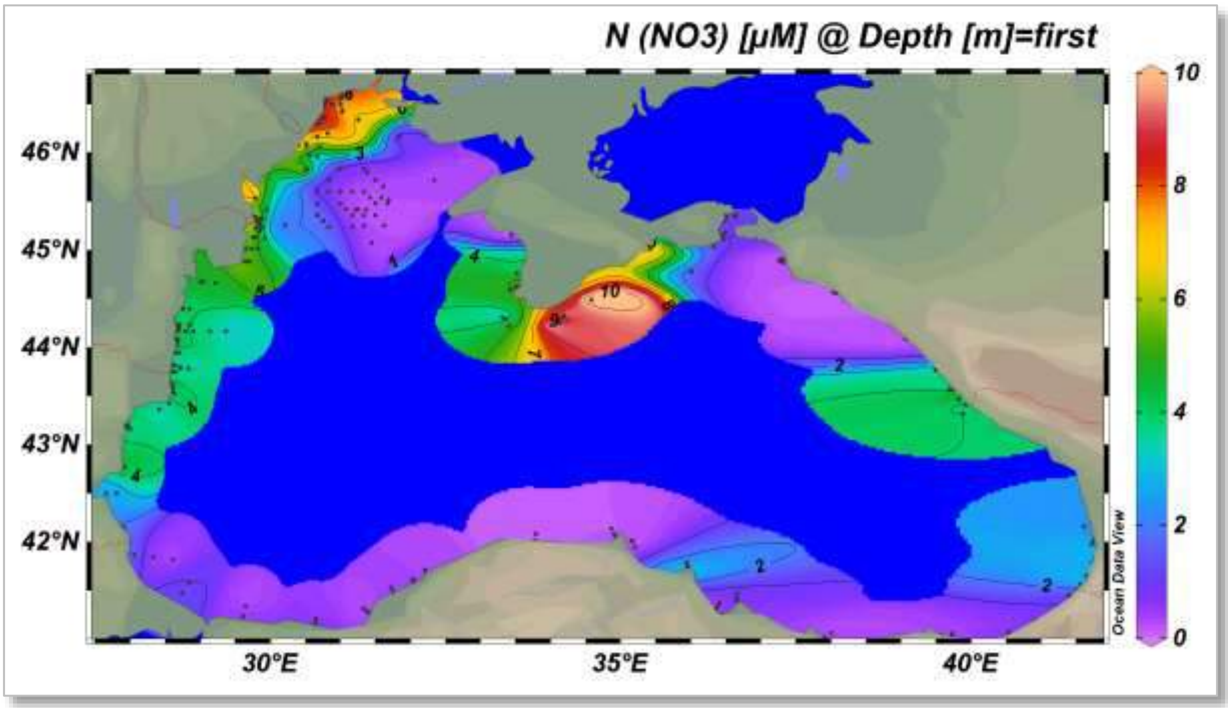
Figure 1.2.2.7. Seasonal variations of vertical distribution - silicates (L) and oxygen saturation (R) - Black Sea, 2009-2014.

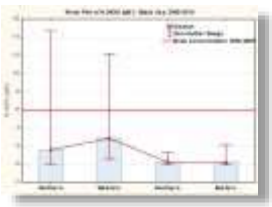
Figure 1.2.2.8. Silicates annual mean concentration in the surface - Black Sea (2009-2014)

The temporal trend (2009-2014) showed slightly increased means between 8.27 µM (2009) and 12.48 µM (2013) representing only about 20-30% from the ‘60s average (Fig. 1.2.2.8).

Nitrates

Nitrate concentrations showed lower values compared with the mean of 1990-2000 and highest variability in Northern and Western part suggesting the rivers input as an important influencing factor. The seasonal variability highlighted winter with the lowest surface average (5.55µM) (Fig. 1.2.2.9) when the maximum was observed below the oxycline (Fig. 1.2.2.10). For all other seasons, "activity" in the oxic zone was observed. Thus, together with the increasing temperature and surface input, in spring and summer looms a layer (approx. depths 10-40 m) with average concentrations 2-3 µM. Below, at 40-50 m, and just above the oxycline, was observed the minimum average concentration, 1 µM, excepting autumn, situated in the Cold intermediate Layer (Fig. 1.2.2.10). The layer 60-100 m, containing the oxycline (60-70 m) has another maximum average, 2 µM around 70 m. Higher concentrations were found in autumn both in the mixing layer (0-10 m) due to the increased supply and in hypoxic waters (30% saturation and 130 m) where average concentrations reach 4 µM.





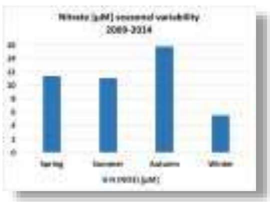


Figure 1.2.2.9. Surface distribution of nitrates concentration, Black Sea, 2009-2014.

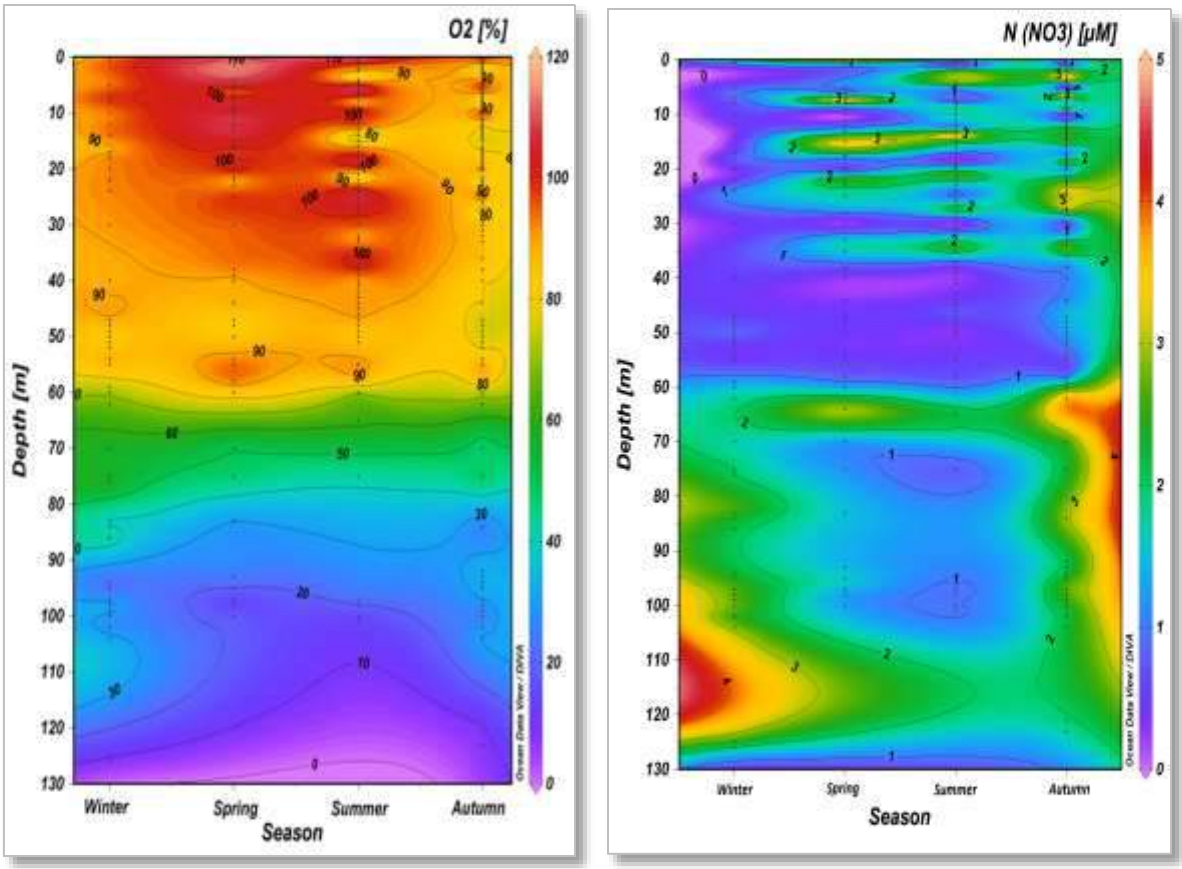


Figure 1.2.2.10. Seasonal variations of vertical distribution - nitrates (L) and oxygen saturation (R), Black Sea, 2009-2014.

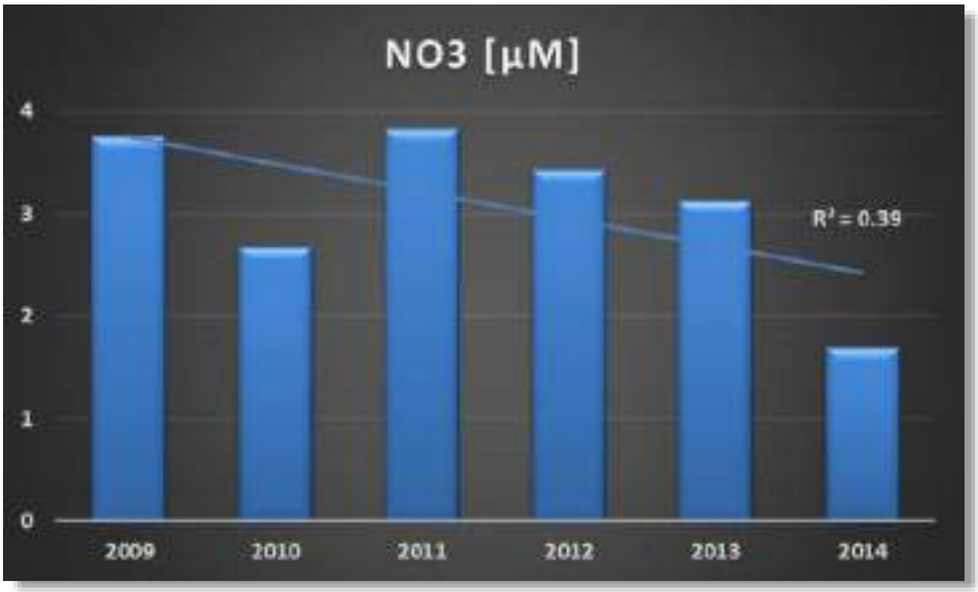


Figure 1.2.2.11. Nitrates annual mean concentration in the surface - Black Sea (2009-2014)

The temporal trend (2009-2014) showed decreased concentrations from 3.75 µM (2009) and 3.83µM (2011) to 1.69µM µM (2014) (Fig. 1.2.2.11). Thus, the value of 2014 represents a reduction with 64% of the 1990-2000 average concentration.

Nitrite

Comparing with other inorganic forms, nitrites do not have a pronounced spatial and seasonal variability. However, it is observed a slightly decreased trend in autumn and winter (Fig.1.2.2.12). In the water column, the homogenous layer found below the oxycline has less than average concentration of 0.1μM (Fig.1.2.2.13).

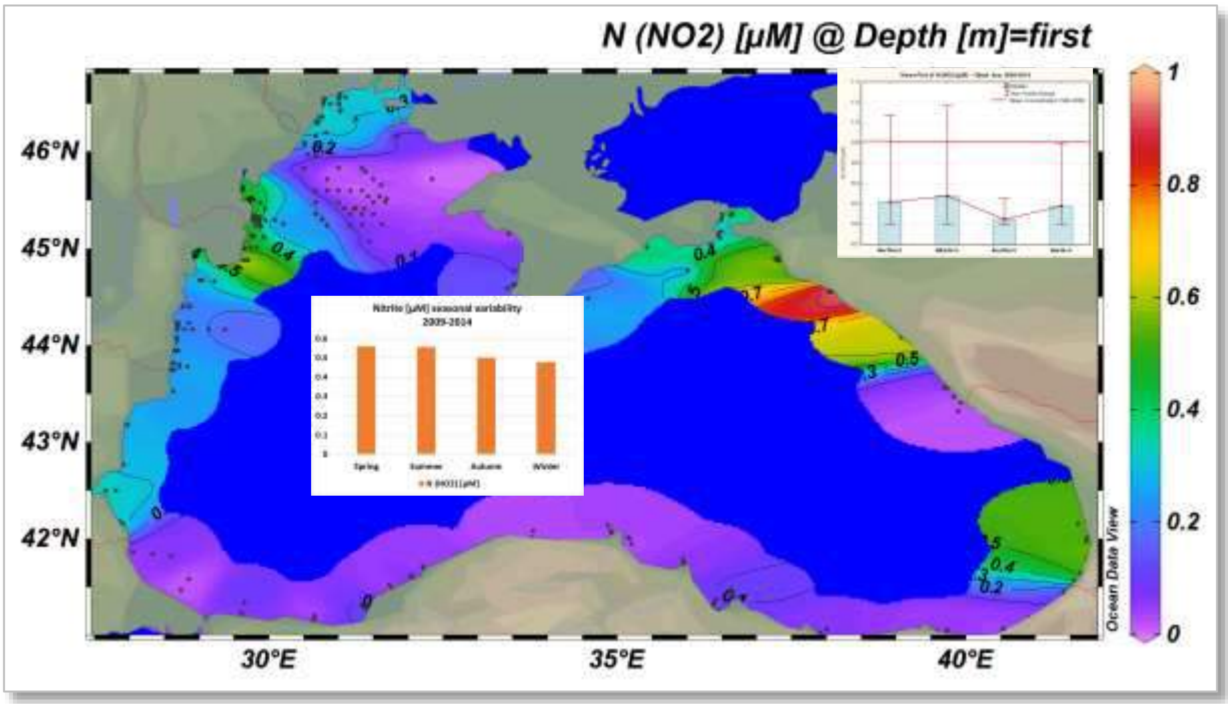


Figure 1.2.2.12. Surface distribution of nitrites concentration, Black Sea, 2009-2014.

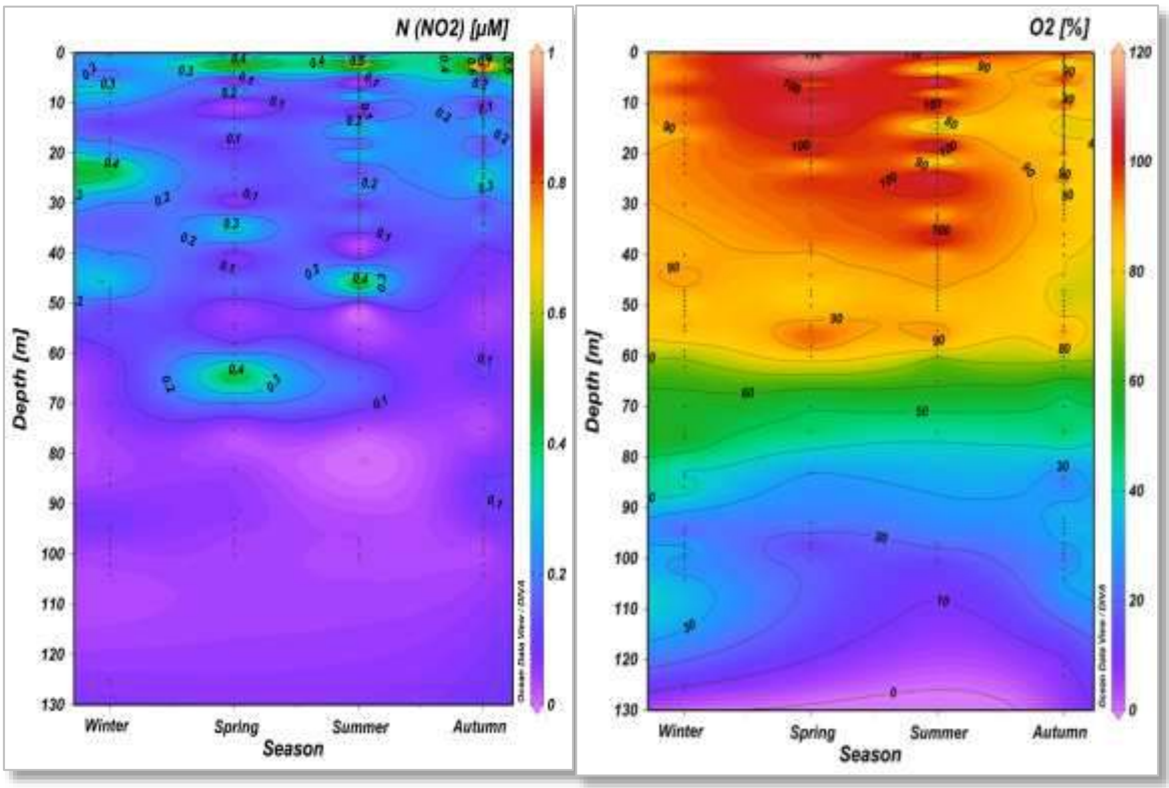


Figure 1.2.2.13. Seasonal variations of vertical distribution - nitrites (L) and oxygen saturation (R), Black Sea, 2009-2014.

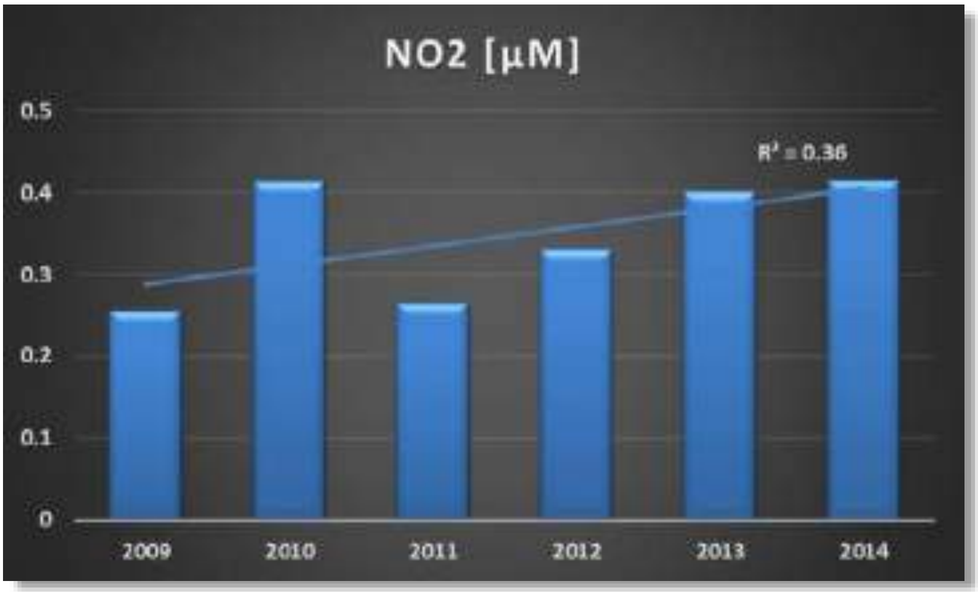


Figure 1.2.2.14. Nitrites annual mean concentration in the surface - Black Sea (2009-2014)

The temporal trend (2009-2014) showed increased means between 0.25 µM (2009) and 0.41 µM (2014) (Fig. 1.2.2.14).

Ammonium has its peak in spring and autumn following highest rivers flows and algal blooms (Fig. 1.2.2.15). The water column is highly enriched in the autumn, below the thermocline which is still shaped (layer 20-30m) (Fig. 1.2.2.16).

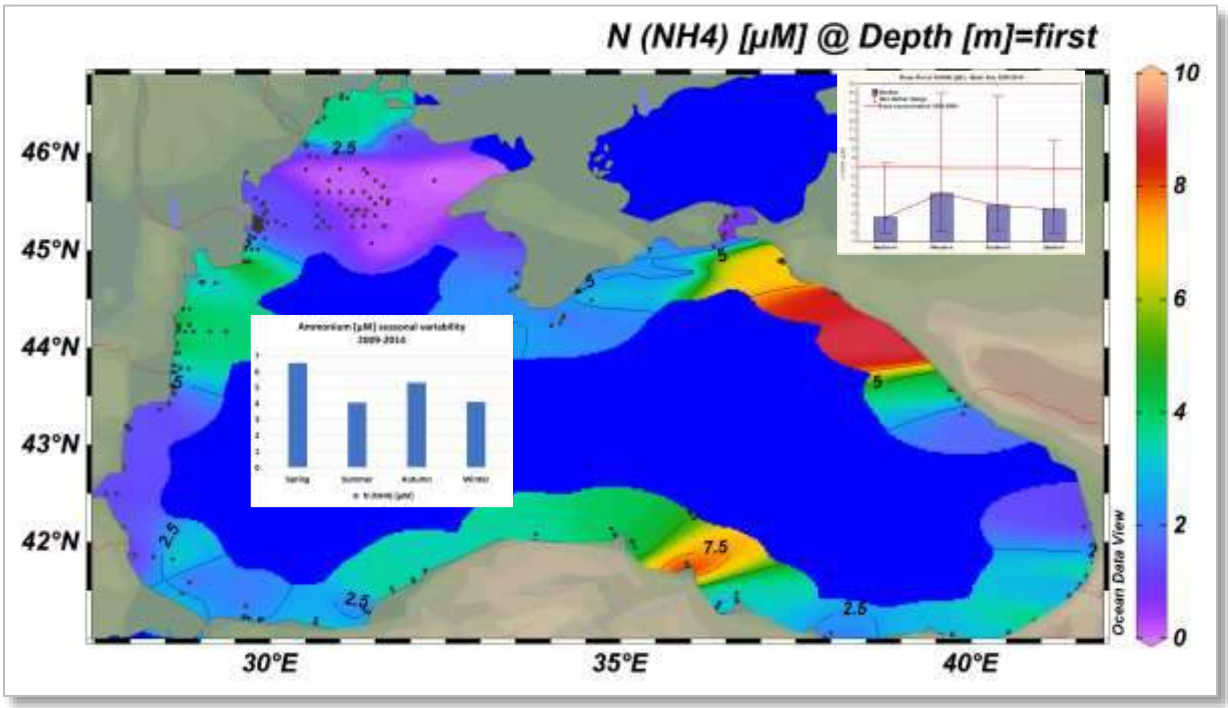


Figure 1.2.2.15. Surface distribution of ammonia concentration, Black Sea,2009-2014.

Then, once the oxygen depletion started, the ammonium concentrations were continuously went up due to remineralization processes and reached maximum values (10µM).

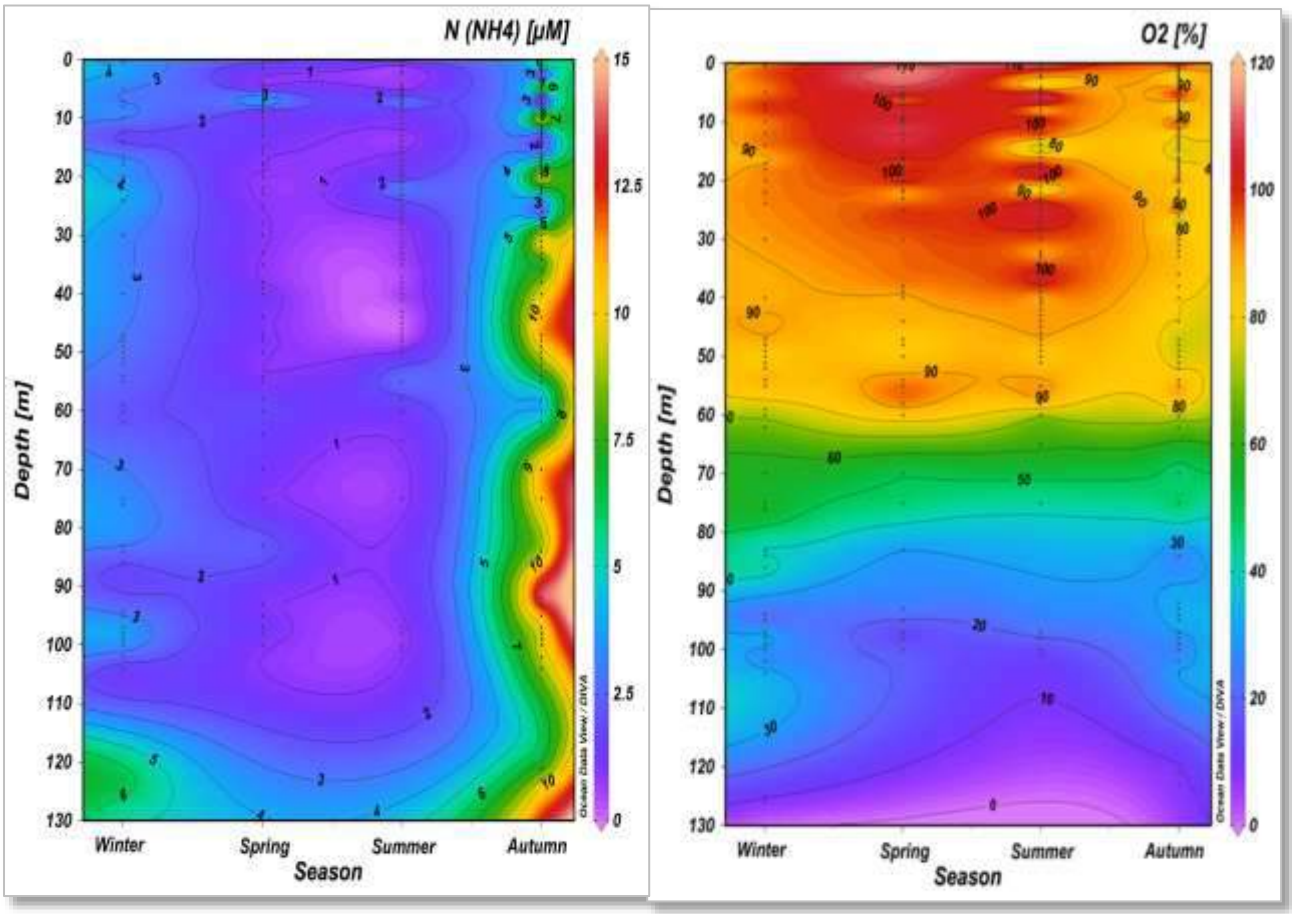


Figure 1.2.2.16. Seasonal variations of vertical distribution - ammonia N-NH_4 (L) and oxygen saturation (R), Black Sea,2009-2014.

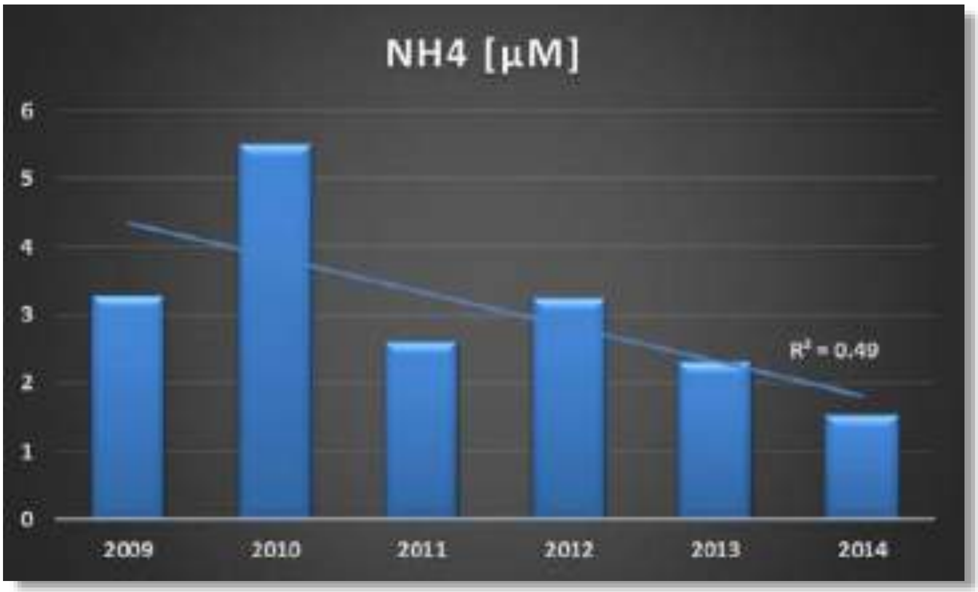


Figure 1.2.2.17. Ammonia annual mean concentration in the surface - Black Sea (2009-2014)

The temporal trend (2009-2014) showed decreased means between 5.50 µM (2010) and 1.54 µM (2014) (Fig. 1.2.2.5).

During 2009-2014 nutrients concentrations in the Black Sea's surface waters decreased, excepting phosphates. But, in the context of the vulnerability to future changes of flow regime and water quality of the largest South European watersheds which are differently impacted by anthropogenic and climatic forces (Cozzi et. al, 2019) and as the main causes of a complex phenomenon - eutrophication, nutrients research need a regional approach which took into consideration the following needs:

- estimate the critical nutrient loads from terrestrial sources, in relation to transitional/coastal retention, and chemical and biological target indicators using coupled atmosphere-river-coastal sea models
- research on natural background nutrient enrichment (e.g. import by upwelling; import from pristine/good status rivers) for determination of pristine state and separation of natural productive status from
- study of anthropogenic impacted eutrophic status; climate change impacts on availability and transformation of nutrients and organic matter from land to the sea.
- identification of critical nutrient loading thresholds beyond which the whole system is changing into an alternative steady state;
- research on factors that govern the occurrence and extension of hypoxic/ anoxic sediment surface.

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1.2.2.2. Black Sea Eutrophication Assessment Tool (BEAST)

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BEAST Method. The integrated indicators BEAST and TRIX were used for assessment of marine waters status and euthrophication level. BEAST (Black Sea Eutrophication assessment Tool) was developed in the frame of Baltic2Black project based on the HELCOM Eutrophication Assessment Tool (HEAT 2.0). HEAT 2.0 is based on the OSPAR "Common Procedure" and taking the requirements of the MSFD Commission Decision into consideration. Thus, BEAST categories are divided into three criteria: C1 - level of nutrients, C2 - direct effects and C3 - indirect effects. Each criterion could have a set of indicators (based on availability and expert choice). The result of each indicator status is done by EUT_Ratio. It is included, according to its own weight chosen by expert, into a qualitative response: high, good, moderate, poor and bad. For evaluation of EUT_Ratio are used:

RefCon - background value for the parameter from reference sources;

Target - target concentration parameter;

AcDev - permissible deviation from background values (RefCon), if the value of the indicator is in direct dependence to eutrophication, i.e., its value increases with increasing levels of eutrophication, we accepted AcDev = +50%; if the value of the indicator decreases with increasing eutrophication, we accepted AcDev = - 20%;

AcStat – actual values of parameter obtained by observation.

Background values and target concentrations for Romania, Turkey, Bulgaria, Georgia and Russian Federation were taken from the Final Report «Environmental monitoring of the Black Sea with focus on nutrient pollution» (Acronym: baltic2black), for Ukraine were taken from the Report «Referents and Target concentration Eutrophication and Estimate the state of waters», (Acronym: baltic2black) UA, 2013.

Value of EQR (rating of environmental quality) is calculated for each indicator, but a complete classification of the status of water depends on a combination of indicators. To begin with, the value of EQR for indicator are combined to determine the limits of class for each indicator, and also the boundaries of classes are combined for determining of the class boundaries for groups of indicators. The share of contribution for each indicator is accepted from 25% to 75%. The final assessment of water quality varies in the range from 0.5 to 2 and corresponds to 5 classes (Table 1.2.2.2).

Table 1.2.2.2. Range of water quality according to BEAST method.

Environment Quality Rate	Value of BEAST	Water quality	MFSD
EQR «RefCon»/«High»	<0,5	Hight	GES
EQR «High»/«Good»	0,5 – 1,0	Good	
EQR «Good»/«Moderate»	1,01 - 1,5	Moderate	not GES
EQR «Moderate»/«Poor»	1,51 – 2,0	POOR	
EQR «Poor»/«Bad»	>2	BAD	

The BEAST Index calculations for the period 2009-2014 based on national monitoring data clearly indicate the strong difference between Black Sea coastal zones (Fig. 1.2.2.18).

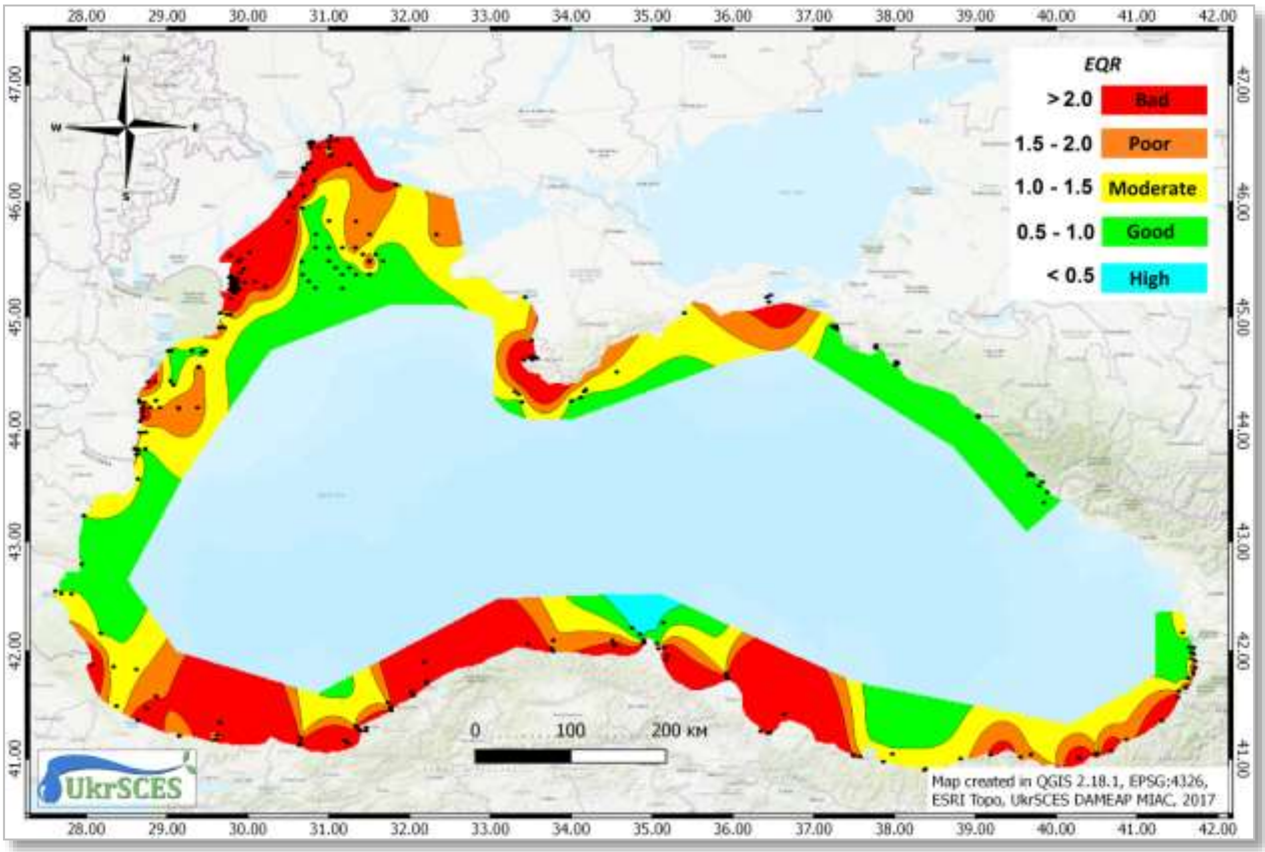

Figure 1.2.2.18. Black Sea coastal water quality assessed by the BEAST for period 2009-2014.

According Index “Bad” water quality is typical for the area influenced by Danube and Dnieper-Bug fresh-water discharge. This result clear coincide with expectation of high water turbidity, high nutrients concentration, algae blooms and color anomalies of water, anoxia of bottom waters and death of benthic organisms as typical for this parts of North-West shelf. Another bad quality local zone registered for Batumi area probably connected with quasi-stationary anticyclonic gyre. The third zone is located near Turkish coast eastward to Bosphor Strait. The rest part of coastal waters preferably estimated as “good” or ”moderate” on water quality and “moderate” and “high” concerning trophic level.

Ukraine

For a complex assessment of the surface waters quality the BEAST method was used for following areas of Ukrainian part of the Black Sea: the coastal waters of the Odessa region, transitional waters - area of the Danube seaside, sea water – Zernov's Fillofora field region (Fig. 2.2.19). The following indicators were used in assessment: inorganic nitrogen and phosphorus, suspended solids, oxygen percent saturation, phytoplankton biomass.

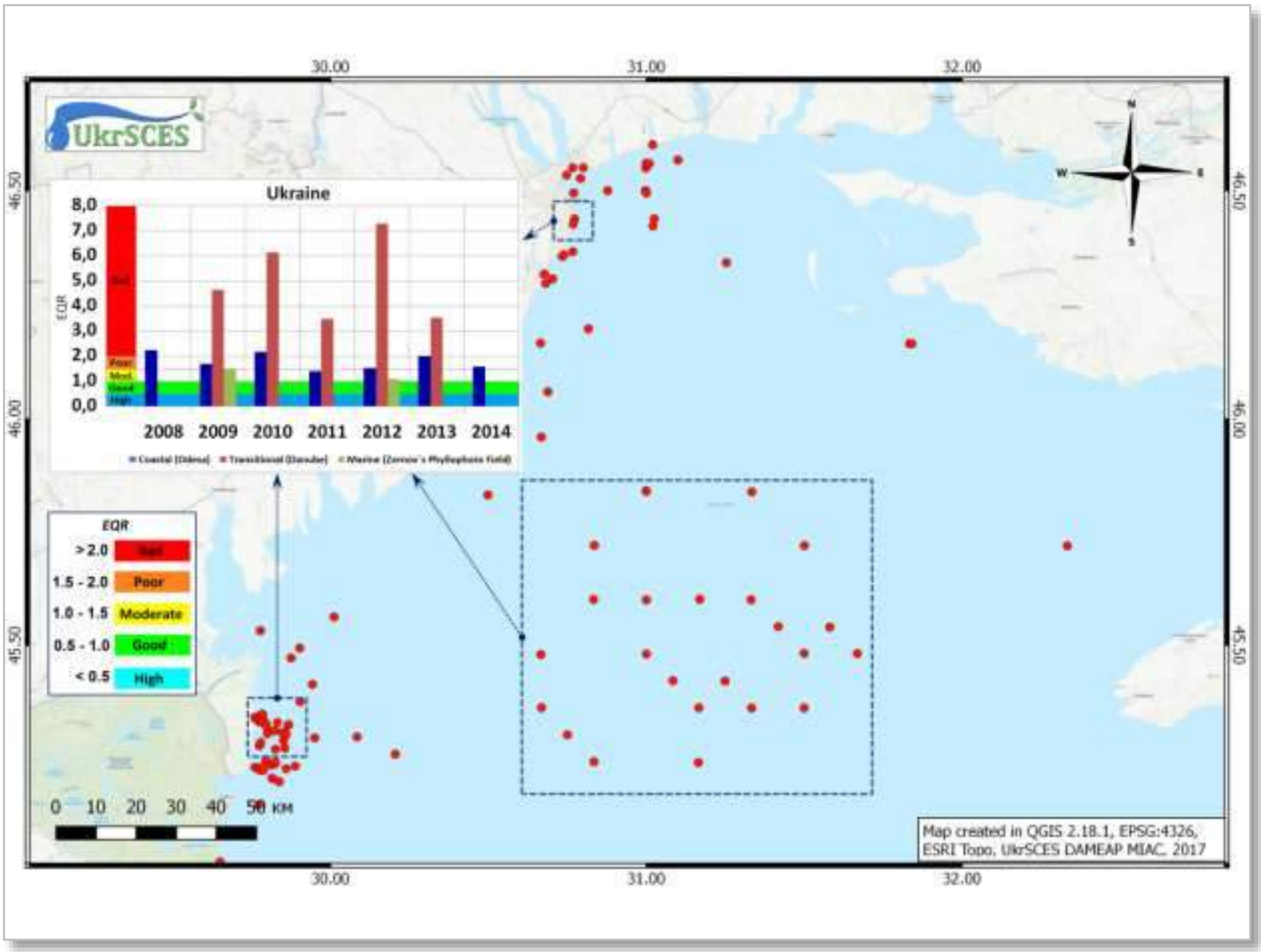

Figure 1.2.2.19. Average annual long-term changes in water quality state of Ukraine region by the BEAST method in 2008-2015.

The average EQR value of Odessa region coastal waters was 1.8 units. Particularly poor water quality was noted in 2008 and 2010 when EQR units were 2.3 and 2.2 respectively, which characterizes the water quality as "Bad". This state was observed mainly due to the increased content of mineral forms of nitrogen in sea waters, as well as in 2010 by the "bloom" of water caused by the mass development of blue-green algae *Nodularia spumigena* (Ukrainsky V.V., 2010; Grandova M.A., 2010). Transitional waters in the Danube region, on average, corresponded to "Bad" water quality with a value of 5 units of EQR due to the high concentration of nutrients. The highest ecological status were characterized Zernov's Fillofora field waters with an average value of EQR 1.5 units in 2009 and 1.1 units in 2012, which corresponds to the "Moderate" water quality.

Romania

For a complex assessment of the surface waters quality the BEAST method was used for following areas of the Romanian part of the Black Sea: the coastal waters of Mangalia, Costinesti, Mamaia, and Constanţa (Fig. 1.2.2.20). The following indicators are taken into assessment: inorganic nitrogen and phosphorus, Secci disk, oxygen percent saturation.

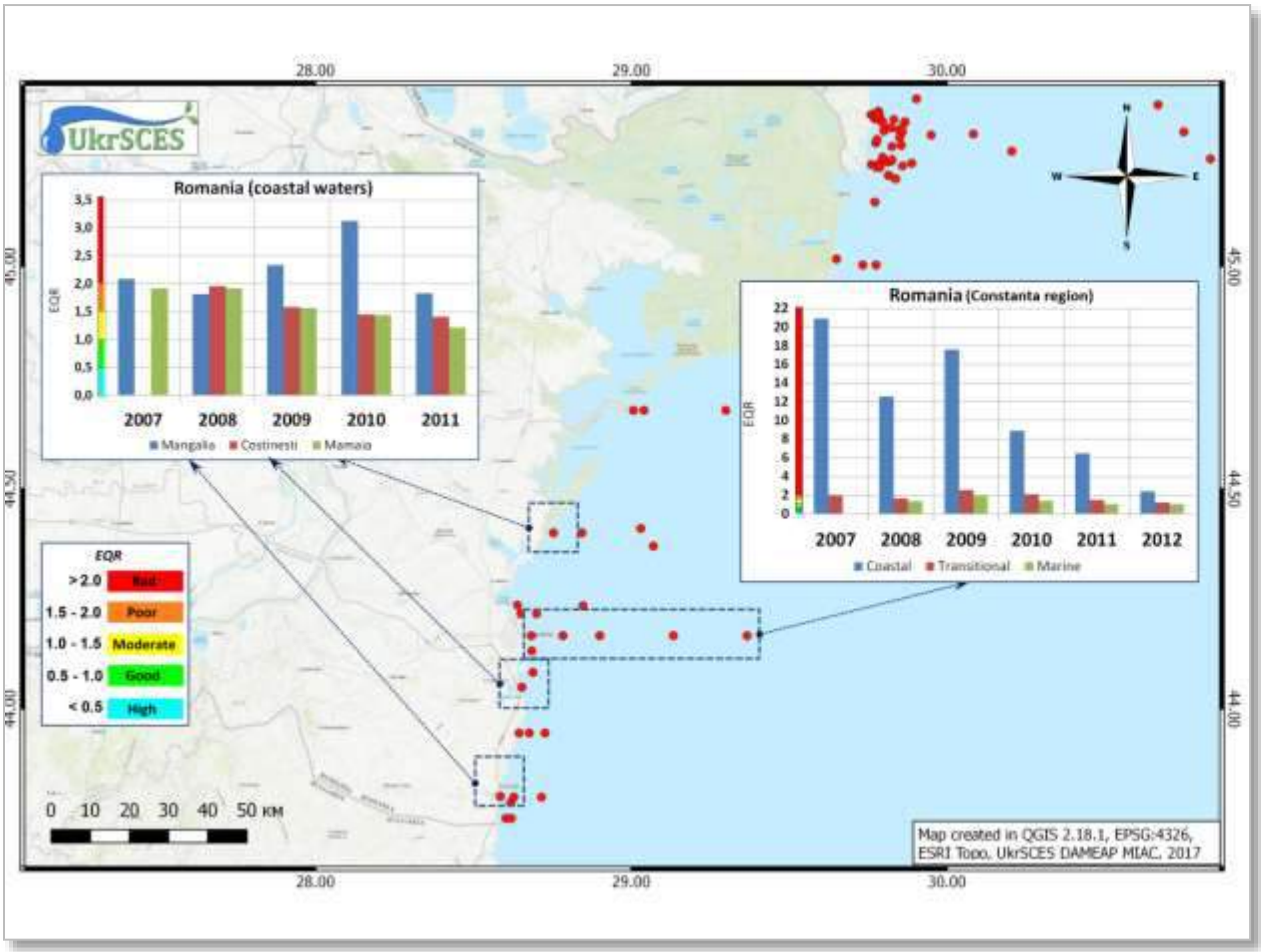

Figure 1.2.2.20. Average annual long-term changes in water quality state of the Romanian region by the BEAST method in 2007-2012.

Coastal waters were corresponded to "Bad" quality, an average of 2.1 units. The worst coastal water quality was observed in Constanta area in 2007, in average for this area EQR to exceed 11 units. This is due to the presence of high concentrations of dissolved inorganic forms of nitrogen and phosphorus. The best quality of coastal waters was noted in Mamaia region, on average, it corresponded to 1.57 units of EQR. Transitional waters of Constanta area was better than coastal, was 1.8 units EQR, which corresponds to the "Poor" quality. Sea waters in the area of Constanta were characterized by "Moderate" quality, which corresponds to an average of 1.37 EQR units. This state is mainly due to the low water transparency.

Bulgaria

For a complex assessment of the surface waters quality the BEAST method was used for following areas of the Bulgarian part of the Black Sea: the coastal waters of Shabla, Varna and Obzor (Fig. 1.2.2.21). The following indicators are taken into assessment: inorganic nitrogen and phosphorus, dissolved oxygen. On average, all coastal waters were estimated with value of EQR 1.03 units as "Moderate" waters. This water quality is caused by the concentration of dissolved oxygen.

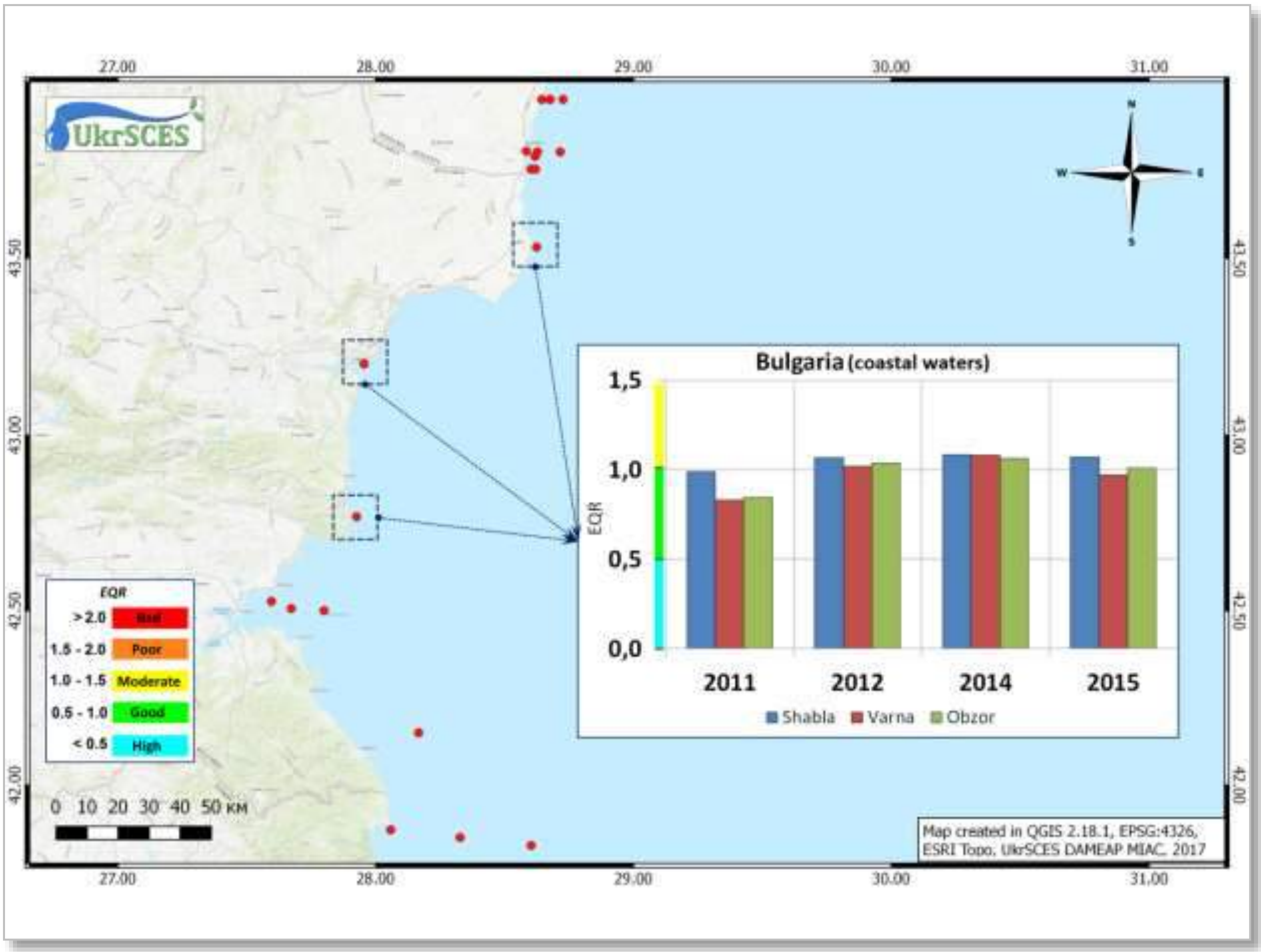

Figure 1.2.2.21. Average annual long-term changes in water quality state of the Bulgarian region by the BEAST method in 2011-2015.

Turkey

For a complex assessment of the surface waters quality the BEAST method was used for following areas of the Turkish part of the Black Sea: Western part, Central part and Eastern part (Fig. 1.2.2.22).

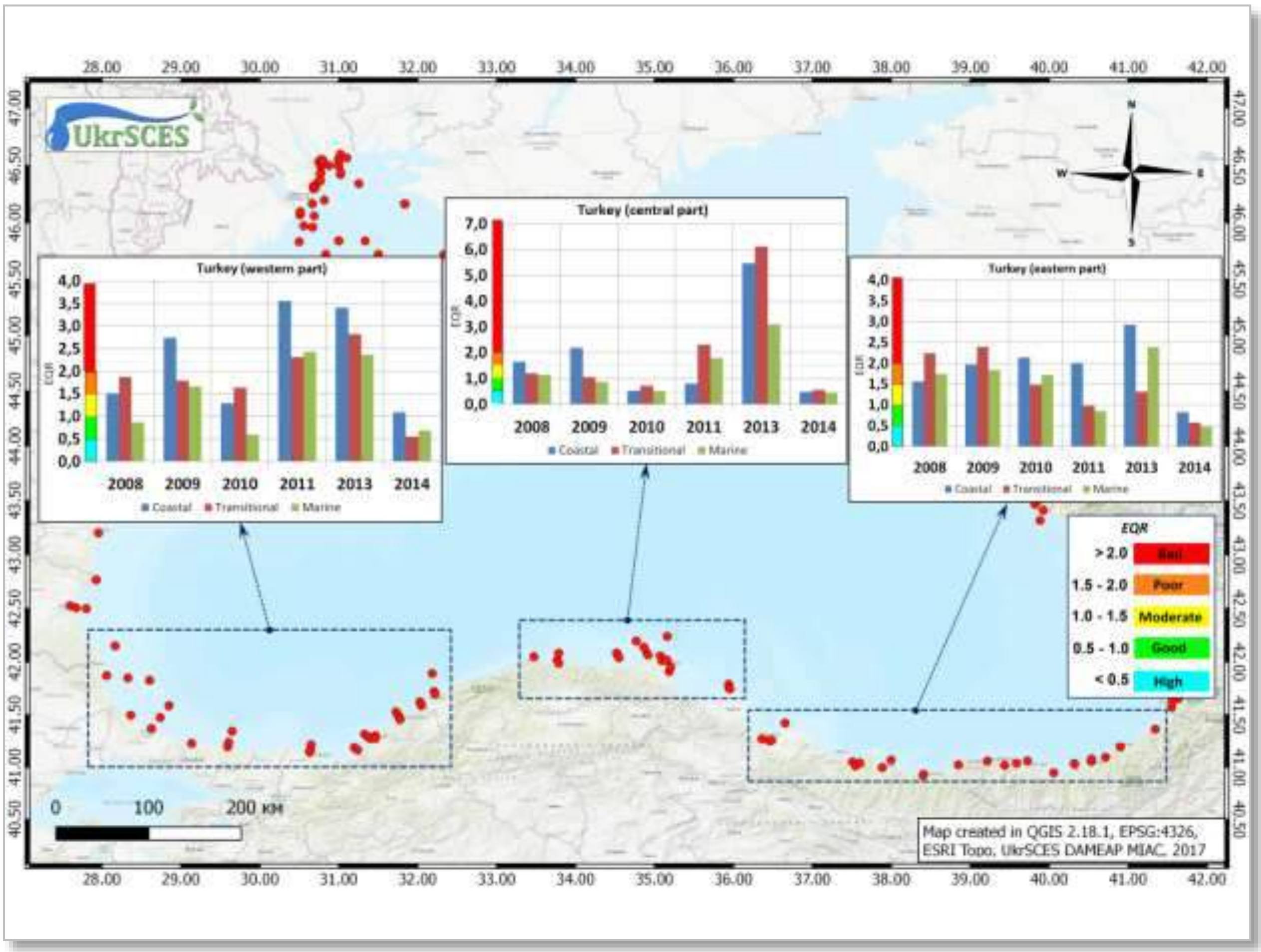

Figure 1.2.2.22. Average annual long-term changes in water quality state of the Turkish region by the BEAST method in 2008-2014.

The following indicators were used in the assessment: the amount of nitrites and nitrates, mineral phosphorus, the percentage of oxygen saturation. The coastal waters of the Western part for the period 2008–2014 are characterized by a "Bad" quality, with an average value of 2.25 EQR units. The worst water quality was noted in 2011, which corresponds to "Bad", with value of EQR 3.5 units. This level of quality is due to the high content of nutrients in the water. The coastal waters of the Central part for the period 2008–2014 are characterized by a «Poor» quality, with an average value of 1.85 EQR units. The worst water quality was noted in 2013, the value was 5.47 of EQR units, which corresponds to "Bad". Mainly, bad water quality caused by high content of nutrients in the water. The coastal waters of the Eastern part for the period 2008–2014 are characterized by a «Poor» quality, with an average value of 1.9 EQR units. The worst water quality was noted in 2013, the value was 2.9 of EQR units, which corresponds to "Bad". Mainly, bad water quality caused by high content of nutrients in the water.

The transitional waters of the Western part for the period 2008–2014 are characterized by a «Poor» quality, with an average value of 1.8 EQR units. The worst water quality was noted in 2013, the value was 2.8 of EQR units, which corresponds to "Bad". Mainly, bad water quality caused by high content of nutrients in the water. The transitional waters of the Central part are characterized by a «Moderate» quality, with an average value of 1.5 EQR units. The worst water quality was noted in 2013, the value was 6.1 of EQR units, which corresponds to "Bad". Mainly, bad water quality caused by high content of nutrients in the water. The transitional waters of the Eastern part are characterized by a «Poor» quality, with an average value of 1.99 EQR units. The worst water quality was noted in 2009, the value was 2.39 of EQR units, which corresponds to "Bad". Mainly, bad water quality caused by high content of nutrients in the water.

The marine waters of the Western part for the period 2008–2014 according to the estimate of BEAST on average were 1.44 EQR units and characterized by a «Moderate» quality. The worst water quality was noted in 2011, the value was 2.43 of EQR units, which corresponds to "Bad" due to high content of nutrients in the water. The marine waters of the Central part according to the estimate of BEAST on average were 1.31 EQR units and characterized by a «Moderate» quality. The worst water quality was noted in 2013, the value was 3.1 of EQR units, which corresponds to "Bad" due to high content of nutrients in the water. The marine waters of the Eastern part according to the estimate of BEAST on average were 1.5 EQR units and characterized by a «Moderate» quality. The worst water quality was noted in 2013, the value was 2.38 of EQR units, which corresponds to "Bad" due to high content of nutrients in the water.

Georgia

The following indicators were taken into assessment: mineral phosphorus, nitrites, silicium and percent saturation of dissolved oxygen. The coastal waters of the Georgia shelf for the period 2007–2013 averaged 2.74 EQR units according to the BEAST method, and characterized by a «Bad» quality (Fig. 1.2.2.23). The worst water quality was noted in 2008, the value was 3.6 of EQR units, which corresponds to "Bad" due to high content of silicium in the water. The transitional waters of the Georgia shelf for the period 2007–2013 averaged 1.29 EQR units and characterized by a «Moderate» quality. The worst water quality was noted in 2011, the value was 1.85 of EQR units, which corresponds to "Poor". Mainly, due to high silicium content in the water. Sea water of the Georgia for the period 2007–2013 according to BEAST was of 0.82 EQR units that characterizes the water quality as "Good".

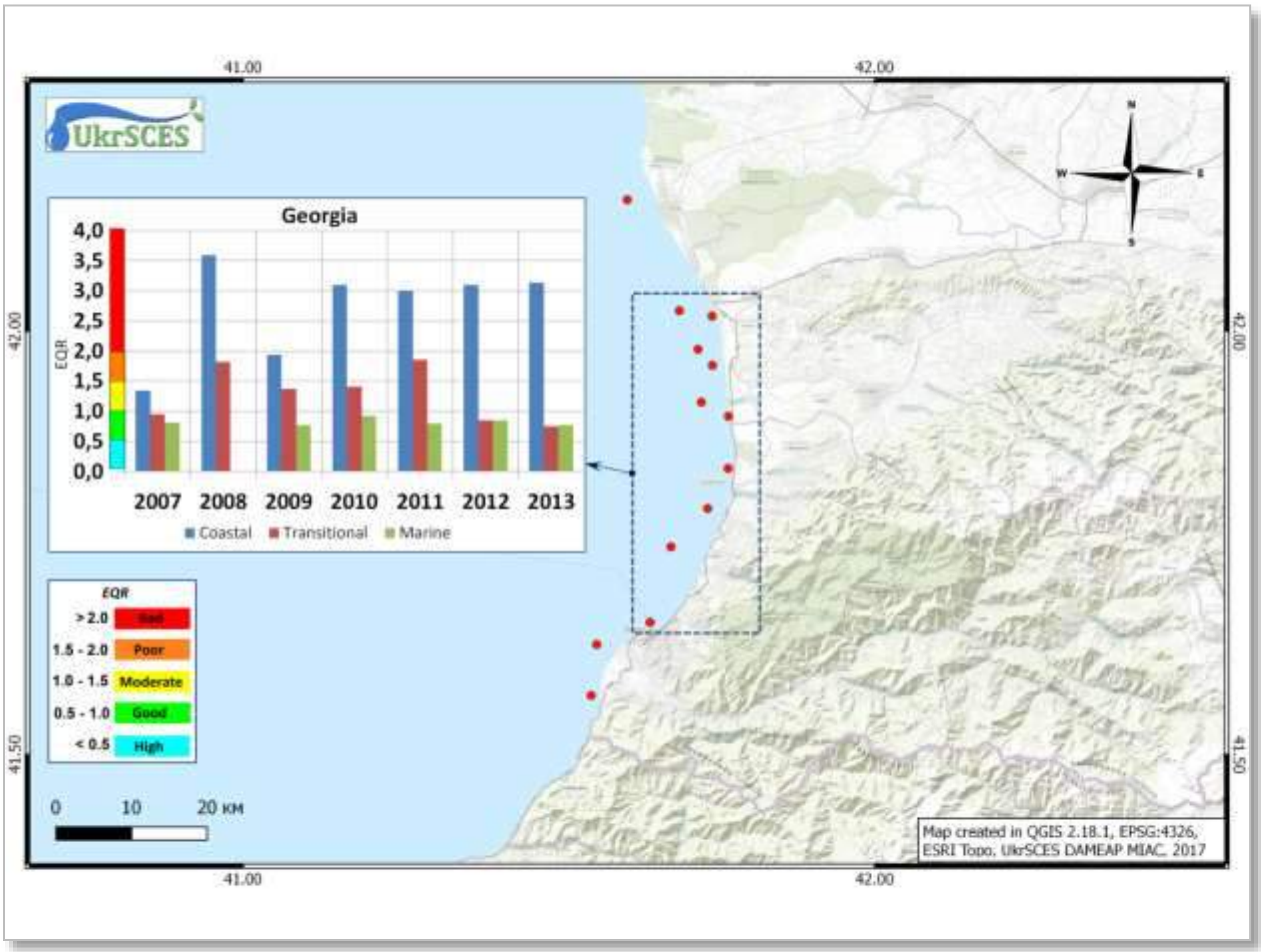

Figure 1.2.2.23. Average annual long-term changes in water quality state of the Georgia region by the BEAST method in 2007-2013

Russian Federation

For a complex assessment of the quality of surface marine water by BEAST were studied following areas: Anapa in the North and Sochi-Adler in the South (Fig. 1.2.2.24). The following indicators were taken into assessment: mineral phosphorus, nitrates, ammonium nitrogen, dissolved oxygen. Coastal waters in Anapa area for the period 2008–2014 with average value of 0.99 EQR units were characterizes as "Good" quality. The worst water quality was noted in 2011, the value was 1.59 of EQR units, which corresponds to "Poor" due to high content of mineral phosphorus in the water. Transitional waters in Anapa area with average value of 1.02 EQR units were characterizes as "Moderate" quality. The worst water quality was noted in 2011, the value was 1.23 of EQR units, which corresponds to "Moderate" due to high content of mineral phosphorus in the water. Sea water in Anapa region for the period 2008–2014 according to BEAST was of 0.81 EQR units that characterizes the water quality as "Good".

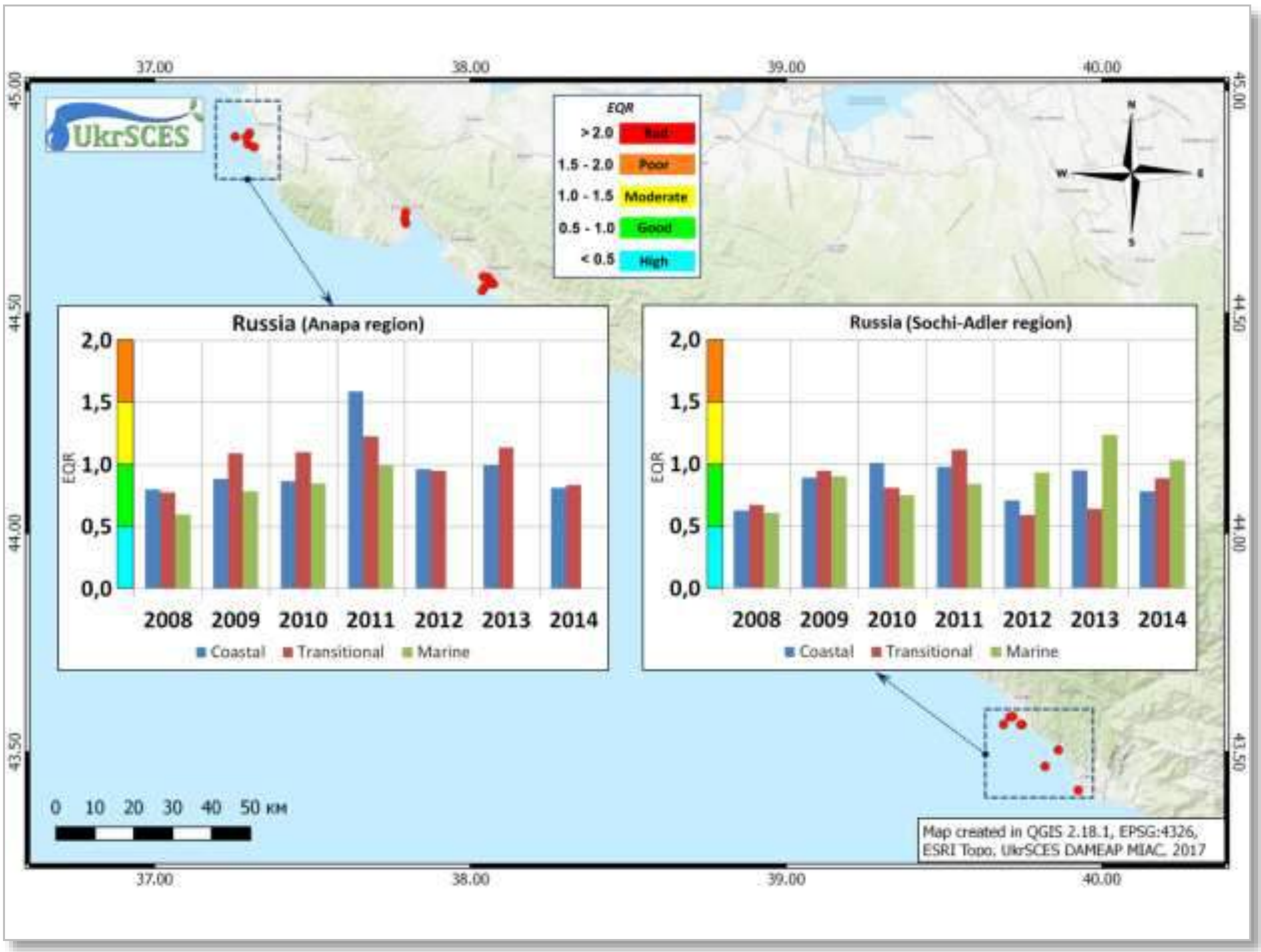

Figure 1.2.2.24. Average annual long-term changes in water quality state of Anapa and Sochi-Adler regions by the BEAST method in 2008-2014.

Coastal waters in Sochi-Adler area for the period 2008–2014 with average value of 0.85 EQR units were characterizes as "Good" quality. The worst water quality was noted in 2010, the value was 1.01 of EQR units, which corresponds to "Moderate" due to high content of mineral phosphorus in the water. Transitional waters in Sochi-Adler area with average value of 0.81 EQR units were characterizes as "Good" quality. The worst water quality was noted in 2011, the value was 1.12 of EQR units, which corresponds to "Moderate" mainly due to high content of mineral phosphorus in the water. Marine waters in Sochi-Adler area with average value of 0.9 EQR units were characterizes as "Good" quality. The worst water quality was noted in 2013, the value was 1.23 of EQR units, which corresponds to "Moderate" mainly due to high content of mineral phosphorus in the sea water.

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1.2.3. Oil pollution

1.2.3.1. Total petroleum hydrocarbons (TPHs)

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Materials and methods

The major source of the petroleum pollution data is the joint Regional Database on Pollution (RDB-P) of the Black Sea Commission. There are 1859 samples with numbers on concentration of total petroleum hydrocarbons in marine waters for the period of 2009-2014. These samples were collected in Ukrainian waters through the year from January to December, in Romania from February till October, in Turkey only in May-June and in Russian Caucasian coastal waters over the whole year (Table 1.2.3.1). In the joint BSC Database there is no data on petroleum hydrocarbons concentration from Bulgaria and Georgia for studied period. Collected samples are distributed unequally within studied years, the difference amounts to more than three times. All data were received during state monitoring programmes of the Black Sea riparian countries. The major part of the sampling sites is situated near the coast line and close to the main sources of pollution – rivers mouth, ports, large cities and municipal discharges, oil transportation routs etc. In Turkey during later spring monitoring cruise-2009 stations were rather randomly distributed along all coastal line in vicinity of main rivers and point sources. In Russian Federation eight stations in the south of Caucasian cost covered the estuaries of main rivers Mzumta, Khosta and Sochi, as well as port area and few “background” points at the distance of 2-3 nm from the shore. Northward routine monitoring stations are in the vicinity of large recreational cities and ports Tuapse, Gelendzhik, Novorossiysk and Anapa. In Crimea sampling places are situated near the underwater outlets of main WWTP almost in all parts of the coast from Kerch at the eastern side to Eupatoria in the west. Special attention was paid to the investigation of water quality in the Kerch Strait and Sevastopol bights. At the North-Western shelf permanent monitoring stations were situated in Odessa Bay (7 stations), one site at Zmeinyi and 13 in the very important for the Black Sea area – Danube delta branches and estuarine water seaside coastal line. Some additional data came from the irregular scientific cruises in the Kerch Strait and at Zernov’s Phyllophora Field. The Romanian waters are covered by routine monitoring stations rather dense, especially in Danube area and near important port Constanta.

For relative comparison of marine water pollution, the level of Maximum Allowable Concentration equal 50 µg/dm^3 (MAC) was established in some Black Sea riparian countries and will be used here (Annual Report 2015).

Table 1.2.3.1. Number of samples with Total Petroleum Hydrocarbons concentration presented in the joint Regional Data Base for period 2009-2014.

Country	2009	2010	2011	2012	2013	2014	Sum	Number of stations
1. Romania	65	68	72	61			266	44
2. Turkey	65						65	65
3. Russia	92	164	160	117	178	133	844	28
4. Ukraine	143	159	299	38	27	18	684	93
Sum	365	391	531	216	205	151	1859	

The concentration of TPHs in bottom sediments was studied significantly less intensive, only 487 samples were analysed: from Ukraine (212), Romania (220) and Turkey (55). The position of sampling sites coincides with the major part of standard water monitoring stations. Turkish coast was covered once in May-June 2009. Romanian studies were concentrated at Danube delta and estuarine area and Constanta region at southern coast. At the Northern-Western shelf the Ukrainian bottom sediments sampling sites mainly coincide with the water monitoring stations. At Crimea coast only four stations in the Kerch Strait were sampled in December 2009. For assessment of bottom sediments pollution by TPHs the Allowable Concentration = 50 µg/g (AC) historically was used in some European and Black Sea countries.

Results

The average concentration of TPHs varied in the very wide range from lowest value 1.9 µg/dm^3 in Turkish waters in 2009, averaged 65 samples of May-June, to extremely high value 2188.7 µg/dm^3 (44 MAC, further on both TPHs units could be used: 1 mg/dm^3=1000 µg/dm^3) in the Danube Delta at 21 July 2009 (Fig. 1.2.3.1). Unfortunately, there is no more available data on TPHs from Turkey coast in the joint Black Sea Database. Extremely high petroleum content in the Romanian waters reduced more then two times throughout next years. In other coastal waters the annual average concentration was significantly lower than MAC.

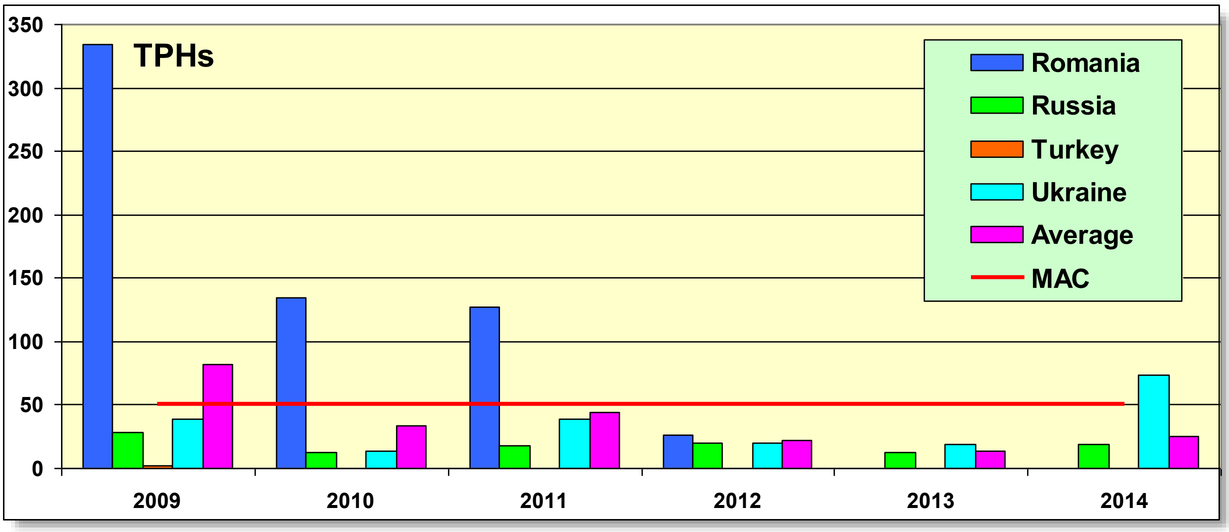

Figure 1.2.3.1. The average of total petroleum hydrocarbons concentration (µg/dm^3) in the coastal waters of the Black Sea countries in 2009-2014.

The maximum concentration recorded in costal waters varied significantly from year to year (Table 1.2.3.2). In all cases except Turkey the numbers strongly exceed MAC. While in Romanian waters decreasing trend was very clear, in Russian sampling area the level of pollution was rather stable in the range 1-2 MAC and only last year was increased four times. At the Northern-Western shelf waters annual significant changes were very clear.

Table 1.2.3.2. Maximum TPHs concentration (μg/dm^3) in the costal waters during the period 2009-2014.

	2009	2010	2011	2012	2013	2014
1.Romania Max	2189	652	355	86		
2.Turkey Max	9					
3.Russia Max	110	60	190	80	80	410
4.Ukraine Max	570	200	160	120	70	470

Romania

All thirteen sampled sites along Romanian coast could be divided into five large regions: Danube Delta and branches (Sulina, Mila, Sf.Gheorghe), Coast north to main port Constanta (Portita, Gura Buhaz, Mamaia), Constanta, Coast to south (Eforie Sud and Costinesti) and South (Mangalia and Vama Veche). The conciderable difference is strongly visible from year to year, when general level decreased ten times during three years (Fig. 1.2.3.2, Fig. 1.2.3.3). Strong decreasing trend was clear for all parts of the coastal line. If first two years the leader in petroleum pollution was Danube delta, but in 2012 the level of pollution was equal and significantly less in all investigated areas.

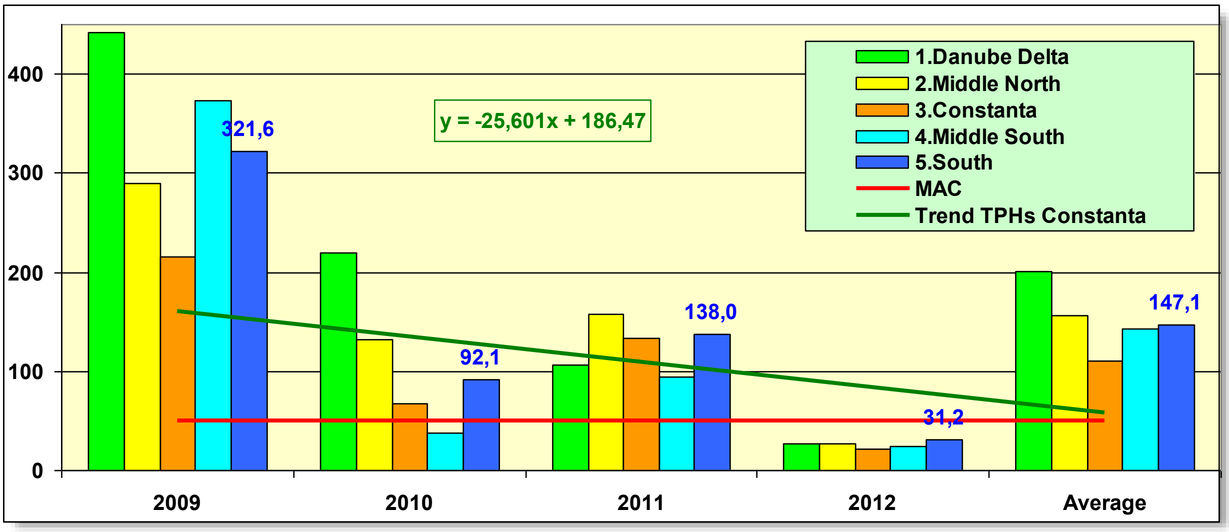

Figure 1.2.3.2. The average of total petroleum hydrocarbons concentration (μg/dm^3) in the coastal waters of Romania in 2009-2012.

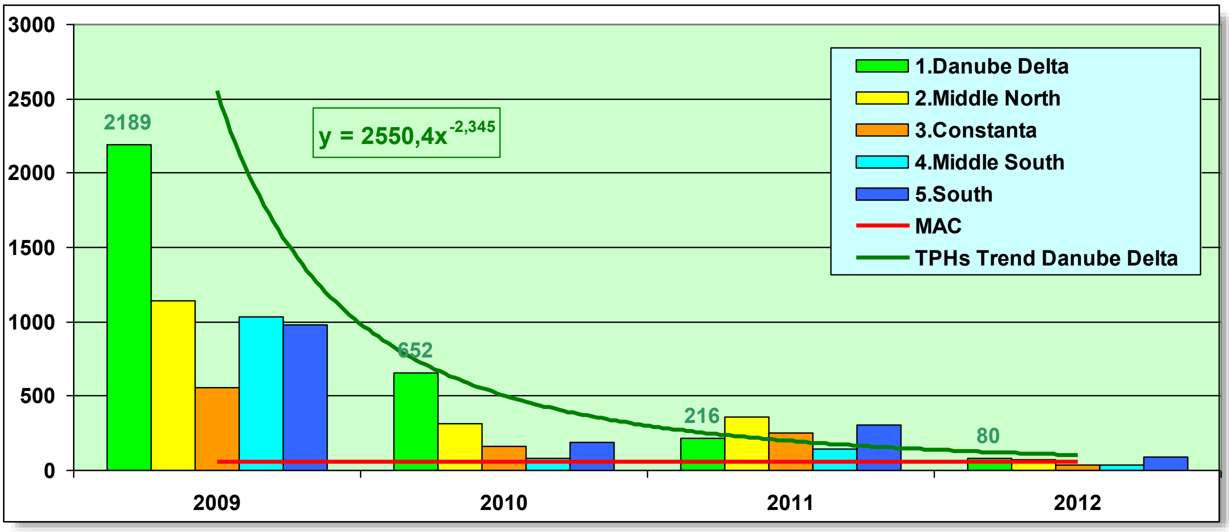

Figure 1.2.3.3. The maximum of total petroleum hydrocarbons concentration (µg/dm^3) in the coastal waters of Romania in 2009-2012.

The maximal concentration of petroleum hydrocarbons in Romanian coastal waters showed extremely quick decreasing from enormous high numbers of about 44 MAC down to 1 MAC or even less. There is no clear explanation for such unusual changes in all country's coastal waters. The highest pollution by TPHs could be expected near the city of Constanta with the large chemical complex of oil processing, but it is not the case. It is important to note that the average and extremes in previous few years were much higher than the level of 2012, it could be estimated from the picture as follows: 2006 – 400 and 1200 µg/dm^3, 2007 – 700 and 1400 µg/dm^3, 2008 – 300 and 3600 µg/dm^3 (Report 2015). In the year 2005 in different parts of coastal waters the average TPHs concentration varied from 140 to 280 µg/dm^3, the minimal level was in the Danube Delta and maximum in the south near Vama Veche (SoE 2008). The maximum value was in the range 200-470 µg/dm^3 and again the lowest TPHs content was in the Danube area, while maximum was recorded near Mamaia. In the previous period 2001-2004 the distribution of petroleum hydrocarbons was different: average value reached 220 µg/dm^3 in shallow waters near Portita and Mangalia; in the same places the highest numbers were 1280 and 2270 µg/dm^3 correspondingly. It was noted that only 72 samples from 344 tested from Romanian coastal waters in the period 2001-2004 have TPHs concentration less than MAC=50 µg/dm^3 (SoE 2008). In general, the data from the beginning of the century indicated a very high level of petroleum pollution of the Romanian coastal waters.

Turkey

In Turkish waters TPHs concentration was estimated in 65 water samples collected in May-June 2009 at small coastal transects with 1-3 stations and situated in 27 sites along the coast line from Bulgarian to Georgian borders. All samples were collected from the near-surface depth 0.5m. Most of stations (42) were in the range of 10-100 m depth, and only seven were deeper 200 m. Total petroleum concentration in Turkish marine coastal waters was very low during period of investigations and varied between 0.6 near Sinope and 8.6 µg/dm^3 slightly to the west near Eregli, the average was 1.92 µg/dm^3. These numbers allow to make a conclusion about lowest level of marine waters pollution by petroleum hydrocarbons among others (Fig. 1.3.1.1). No significant difference along Turkish coastal line was found.

In previous period monitoring cruises in Turkish coastal waters were performed in 2003-2005 (SoE 2008). In winter 2003 near the outlet of the Bosphorus Strait the concentration at 3 shallow stations was in the large range of 6-255 µg/dm^3 and the mean was 92 µg/dm^3. In the end of summer next year, the level of pollution was rather low and varied between 1 and 77 µg/dm^3 with the average value of 11 µg/dm^3. In April 2005, the average level of petroleum hydrocarbons content in 63 samples from the Turkish waters was 20 µg/dm^3: maximum reached the level of 163 µg/dm^3 in Ordu area. Half year later in September-October 2005 the petroleum hydrocarbons concentration in Turkish waters increased drastically almost everywhere. In the western part of the coast the extremely high values were recorded in surface waters probably of Danube origine. The mean level for four stations situated here was 757 µg/dm^3. In Central and Eastern parts, the TPHs concentration also was very high and reached values 571-1279 µg/dm^3. According the monitoring data Turkish coastal water could be considered as unpolluted by petroleum hydrocarbons with exception of one case in 2005 when marine waters in some places were heavily polluted (SoE 2008).

Russian Federation

In the Caucasian coastal waters during the whole period of routine monitoring investigations the annual average concentration of Total Petroleum Hydrocarbons (TPHs) never exceeded the MAC of 50 µg/dm^3 (Fig. 1.2.3.4). The most usual value could vary around 10-30 µg/dm^3. In long-term period the slight decreasing trend is rather visible. In the Northern part of the coast between cities Tuapse and Anapa in period 2009-2014 among 592 collected samples about third part (209; 35.3%) had very low hydrocarbons concentration below Detection Limit and showed analytical zero. The annual average value for the whole set of data was 16 µg/dm^3, and maximum reached level of 410 µg/dm^3 (8.2 MAC) in Tuapse port on 25.12.2014. Over the whole monitoring period the waters in the vicinity of Tuapse were more polluted than other controlled northern sites. To some extend the slightly higher pollution of Tuapse waters by hydrocarbons could be the consequence of increased frequency of sampling each ten days. This allows to record surface patches of local oil spills in the area where “storm station N2” is situated inside the port area. From the other side, the small-scale oil discharges from the refinery factory, oil transportation and ships activity in Tuapse port could be another reason of increasing TPHs values here.

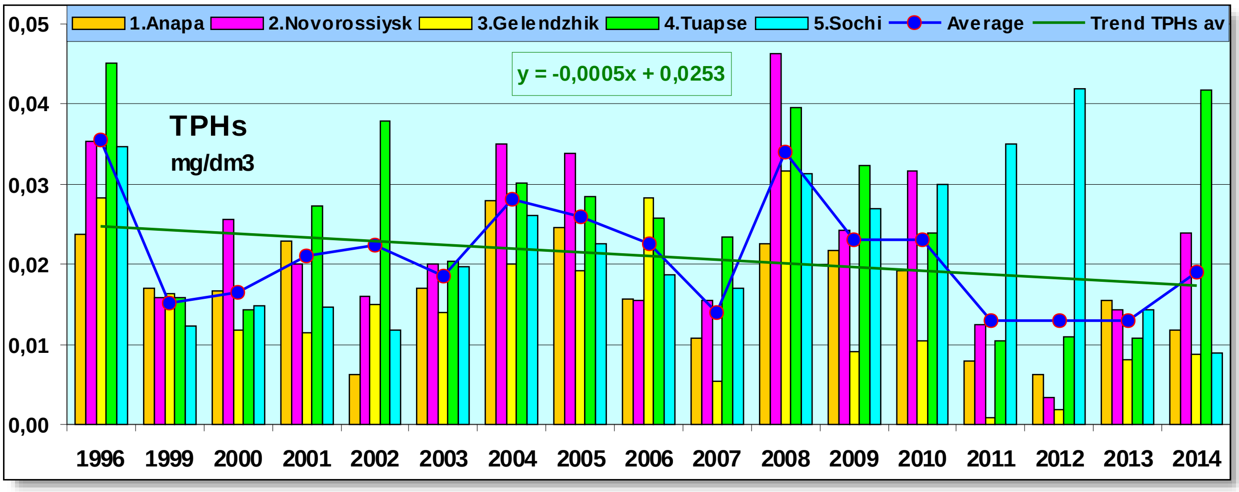

Figure 1.2.3.4. The average of total petroleum hydrocarbons concentration (mg/dm^3) in the coastal waters of Russia in 1996-2014 and long-term trend.

In the same period of time in the Southern part of the Russian coast between towns Adler and Sochi (estuaries of rivers Mzumta and Sochi) the TPHs concentration reached or exceeded the 1 MAC in 75 samples from 368 analysed. In 135 samples hydrocarbons concentration was lower than Detection Limit. The average value for the area Adler-Sochi for the period 2009-2014 was 25 µg/dm^3. The maximum (190 µg/dm^3, 3.8 MAC) was recorded twice 19.10.2010 and 17.03.2011 in the same place at 2 nm seaside from the river Mzumta estuary, notably at 50 m depth in both cases. The concentration over 1 MAC was noted for all stations of this region despite their position in the port, or in the rivers estuaries, or 2 nm off the coastal line (Fig. 1.2.3.5). Within last 6 years the petroleum content in marine environment had significant decreasing tendency and waters here could be considered as unpolluted in general.

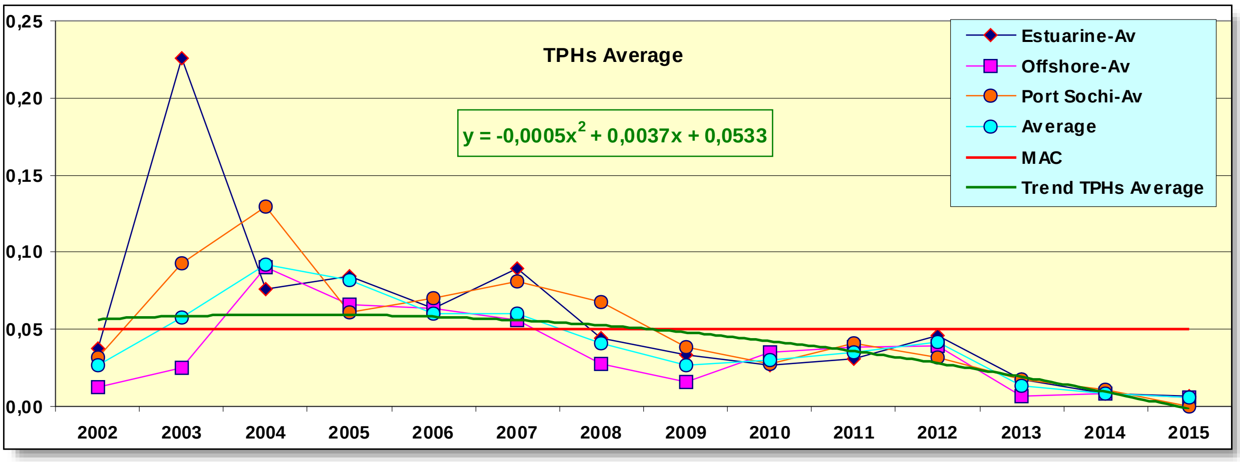

Figure 1.2.3.5. The annual average of total petroleum hydrocarbons concentration (mg/dm^3) in the coastal waters between Adler and Sochi in 2002-2015 and long-term trend.

Ukraine

As it could be expected, the average TPHs concentration in waters along the long coastal line of Ukraine should be very variable in space and time (Fig. 1.2.3.6). For instance, petroleum hydrocarbons were not recorded in nine samples received in 2009 from surface layer along the Southern Coast of Crimea (Feodosya, Sudak, Yalta, Simeiz and Foros Cup), the Detection Limit is 2.0 µg/dm^3. In the same year in the Central part of North-Western Shelf at two stations situated approximately in the middle of the transect between tinny village Chernomorskoe in Crimea and Shaganu Lagoon the hydrocarbons content reached the enormous high value of 570 and 260 µg/dm^3, 11.4 MAC and 5.2 MAC correspondingly. In general, the major part of annual averages was significantly lower than Maximum Allowable Concentration in coastal waters, as well as at the NWS and Danube Delta areas. Among other regions slightly increased concentration was recorded in the Kerch Strait waters and inside of small and narrow Balaklava Bight. From the dataset of 684 samples collected only in 56 the hydrocarbons content was higher than MAC, forty of them were received in the Kerch Strait, 5 samples from Sevastopol Bights, and 11 samples from the NWS.

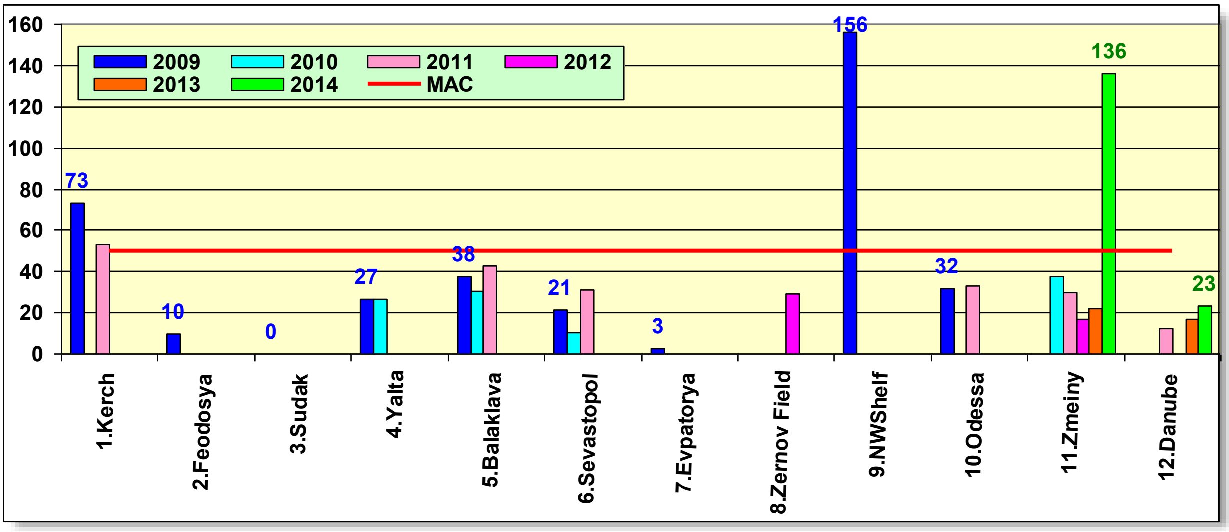

Figure 1.2.3.6. The annual average of total petroleum hydrocarbons concentration (µg/dm^3) in the marine coastal waters in 2009-2014.

The maximal numbers of TPHs concentration in different years almost in all studied regions exceeded the MAC. The highest numbers occurred in the central part of the North-Western Shelf (570 µg/dm^3, 2009) and near the Zmeiny Island at the western Ukrainian coast (470 µg/dm^3, 2014). In the Kerch Strait (2011), Yalta harbour (2010), Balaklava Bight (2011), Sevastopol Bight (2011), Zernov's Phyllophora Field (2012) and estuarine waters close to the Danube Delta (2013) the maximum hydrocarbons concentration was 160; 200; 80; 90; 120 and 70 µg/dm^3. It is important to note the decreasing amount of processed and presented in the BSC DataBase samples from 143/159/299 in 2009-2011 to 38/27/18 in 2012-2014. Taking into account high variability of oil/hydrocarbons appearance in the marine waters due to so called "patchiness" distribution, one could expect rather wider range of TPHs pollution in the costal waters during reporting period.

Historically the petroleum hydrocarbons concentration was observed in the frame of state monitoring system and in special scientific cruises which show more or less the same level of pollution. In period 1992-1999 in almost 1.5 hundred samples collected in Ukrainian waters average TPHs content was exactly 50 µg/dm^3 (1 MAC) and maximum 1200 µg/dm^3 (SoE 2008). The most intensive spatial investigations of the TPHs distribution over the whole Black Sea were carried out during two IAEA cruises onboard of RV "Professor Vodyanitsky" during 11-20 September 1998 and 22.09-11.10 2000 **(**SoE 2008). The first cruise in the western part of the sea showed rather uniform spatial distribution and the level of pollution was low. The average concentration for all sampled area was 84 µg/dm^3 and the maximum reached 230 µg/dm^3 in the Romanian shallow waters southward of Constanta. Suddenly the lowest concentrations (30 µg/dm^3) were recorded near the entrance of Bosphorus Strait and near Odessa where obviously there are many intensive shipping routes. Next time in 2000 hydrocarbons were measured at 32 stations in the Eastern and Central parts of the Sea. TPHs average concentration was 97 µg/dm^3 and varied from analytical zero to extremely high concentration of 3270 µg/dm^3 (65 MAC) that was recorded in the surface layer at shallow station near Feodosya in Crimea. Few other stations near the Southern Coast of Crimea also had quite high TPHs concentrations, probably due to local oil spill or municipal discharge of large tourist centers. In Eastern Gyre, as well as in Georgian and Turkish waters the level of pollution was relatively low; the averages in range were 30-50 µg/dm^3.

According to monitoring data from the period 2000-2005 the average concentrations of total petroleum hydrocarbons in Ukrainian waters were very low and varied in different parts in the narrow range 10-50 $\mu g/dm^3$ (SoE 2008). Relativelly unpolluted waters were recorded in Odessa Bay, in the Dnieper estuarine area, and in harbours Yuzhny and Illyechevsk. The maximum numbers were significantly higher in all regions. They varied from 50 to 80 $\mu g/dm^3$ with exception of Kerch Strait – 180 $\mu g/dm^3$ in September 2004.

In general, there is no visible trend in TPHs concentration in different parts of Ukrainian coastal waters. The level of petroleum hydrocarbons pollution in 2008-2014 was similar to previous decade.

Kerch Strait spill (November 2007)

Severe conditions during a very strong storm on 11 November 2007, when winds exceeding 30 m/sec produced over 5-meter-high waves in the Kerch Strait waters, where the depth varied from 7 to 12 meters only, were the reason of thirteen boats to suffer an accident, and among them four dry-cargo carriers and one tanker Volgoneft-139 sank (Kerch Spill 2011, Korshenko, Panova 2009). This tanker had carried a total of 4777 tons of heavy oil, about 1300 leaked out into the sea. It happened approximately five km to the West from the Tuzla Spit. This accident became the most studied oil spill event in the world, about 60 complex cruises were organized. Before the catastrophy 2075 samples in the strait waters were taken in the period 1981-2007. The absolute maximum for the whole period of investigations reached 2960 $\mu g/dm^3$ (59 MAC) and was recorded in October 1982 in the surface waters. In the late 1990s, petroleum pollution of the Kerch Strait has significantly increased up to 3 MAC in average in comparison with that in the early 1990s, and petroleum hydrocarbons were detected in all collected samples. Maximal average values in long-term run were recorded in the period 1995-1998, there is no evidence whether this high level of pollution was related to land-based sources or to shipping. Since 2000, the level of TPHs has decreased to 1-2 MAC with repetition of above 1 MAC concentration in 44% of all collected samples (Kerch Spill 2011).

After the accidental oil spill in Kerch Strait in November 2007 the highest petroleum hydrocarbons concentration was observed during the first several days after catastrophy. The maximum concentrations of 2500 $\mu g/dm^3$ (50 MAC) and 1740 $\mu g/dm^3$ (34.7 MAC) were recorded at the shorelines of the Chushka Spit (4 km to the North-East from the port of Caucasus) and of the port of Caucasus respectively. In general, the pollution level was high during a short period of two months including its extreme levels in the first few days, in average for all parts about 1-3 MAC. Later TPHs content in the strait waters decreased and average concentration was at the level of 1.0 MAC and quite stable. From different sources the average value in 2007-2009 varied in the range 50-67 $\mu g/dm^3$. Later the general level of hydrocarbons pollution was about the same, while the maximum numbers usually increased the MAC several times practically with no correlation with the flow in the strait (from the Azov Sea or back), (Fig. 1.2.3.7). The monitoring data and special observations allowed to make a conclusion on chronical petroleum hydrocarbons pollution of the Kerch Strait waters during the last three decades, as well as during the years after the Kerch Strait accident. The accidental spill most likely had a very short-time influence on the area.

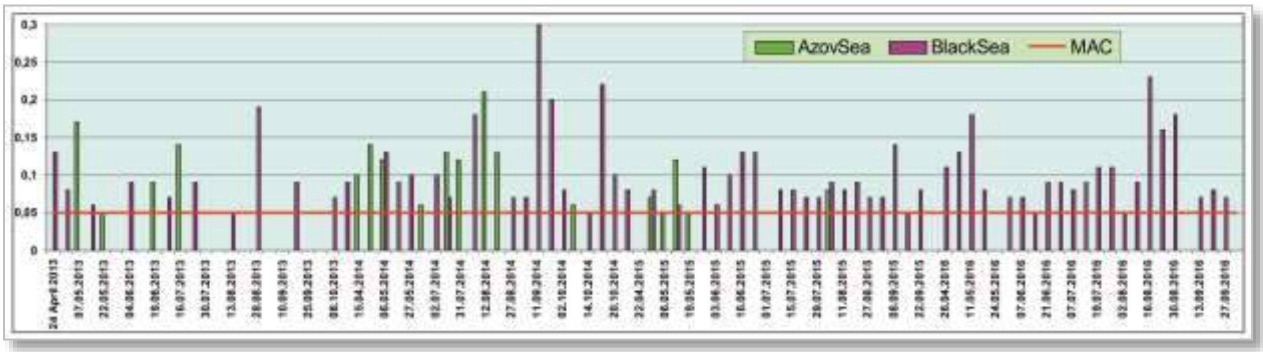

Figure 1.2.3.7. Maximum of total petroleum hydrocarbons concentration (µg/dm^3) in the Kerch Strait waters in different sampling time.

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1.2.3.2. Satellite images: Oil Pollution in the Black Sea

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The Black Sea Surface Oil Pollution

Satellite monitoring is an effective way of monitoring sea surface outside of ports and oil terminals. It allows for continuous monitoring of oil pollution over a vast area of offshore waters including territorial waters of neighboring countries (Kostianoy, Lavrova, 2014). The latter is particularly important for monitoring trans-border transport of the pollution by sea currents (Grishin, Kostianoy, 2012). The availability of satellite information (especially at low or no cost) has significantly broadened its application in scientific and applied research and has largely contributed to the development of remote sensing systems.

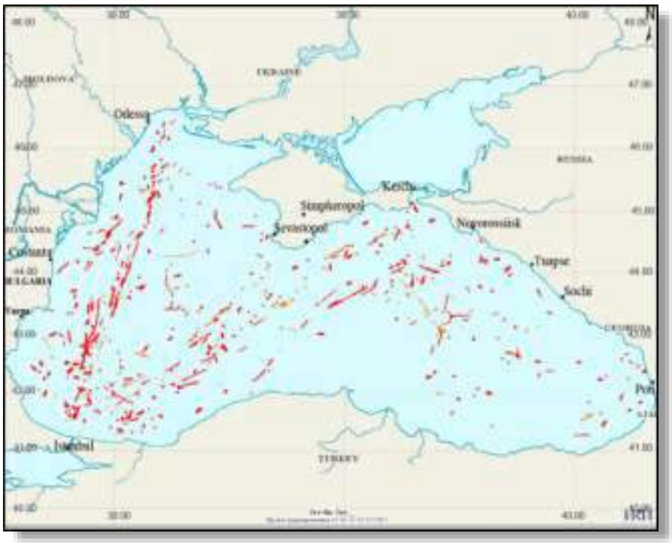
In the sea, oil pollution may result from releases of crude oil and oil products from tankers, offshore platforms, drilling rigs, wells, pipelines as well as from releases of bunker fuel, waste oil, and bilge water from other types of ships (cargo, ferry, tourist, military, fishery, etc.). This may occur accidentally or during routine operations at sea or in ports. Oil comes to the sea also with river runoff and from the ocean bottom due to natural seepages (Lavrova et.al, 2011, Mityagina et al., 2015).

The Black Sea Surface Oil Pollution Due to Ship Spillages

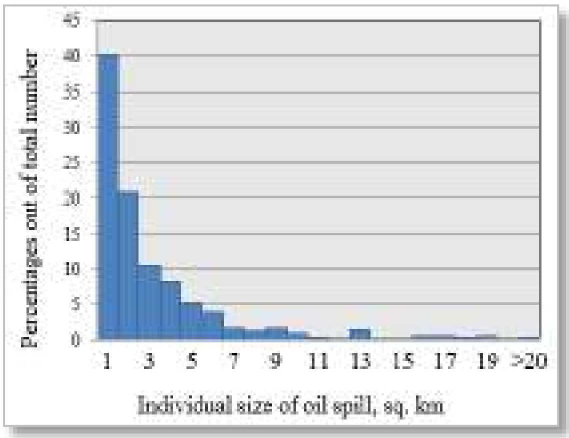
Ship-related operational discharges of oil include:

- • discharges of bilge water from machinery spaces;
- • operational discharges of oil from machinery spaces;
- • discharges of tank-washing residues and oily ballast water.

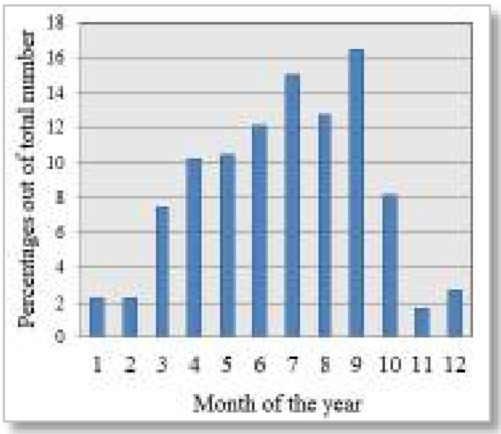
Figure shows the cumulative map of oil-containing spills in the Black Sea revealed from SAR data for the years 2009–2011. Year-by-year numbers of oil spills detected are 219, 253, and 234 correspondingly, total polluted areas being 790, 806, and 768 sq. km. All these pollution events are caused by spills of oil-containing waters from moving ships. As expected, the spills are concentrated along the main shipping routes such as Istanbul—Novorossiysk, Istanbul—Odessa and Istanbul—Tuapse. Besides, a large amount of spills is observed near the major ports of Bulgaria, Turkey, Romania and Ukraine (Fig. 1.2.3.8a).



(**a**)



(**b**)



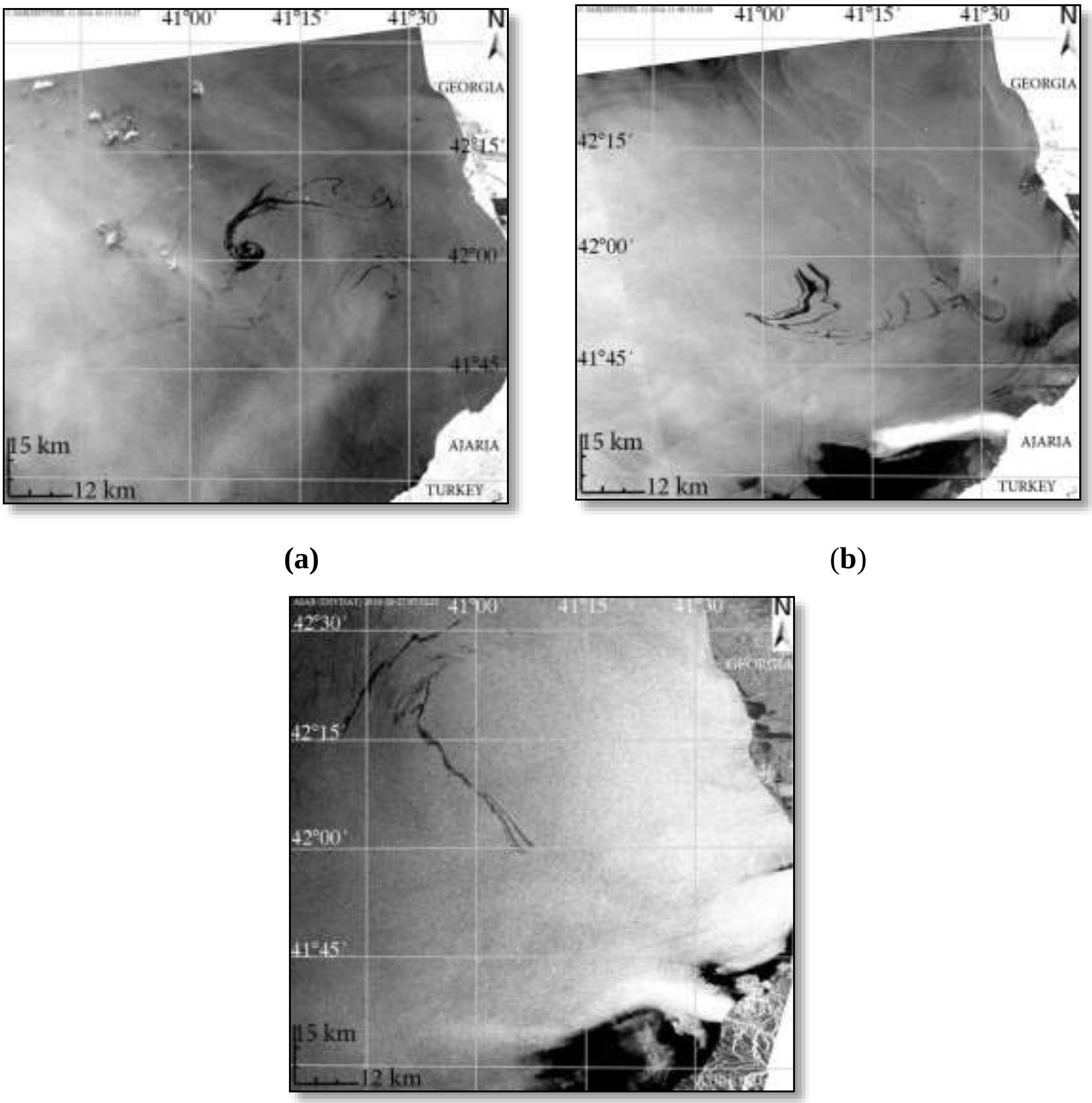
(**c**)

Figure 1.2.3.8. (**a**) Map of oil spills on the Black Sea surface revealed from satellite SAR imagery in 2009–2011; (**b**) individual spill size distribution; (**c**) monthly distribution of spills.

Some numerical data on oil spills in the Black Sea revealed from satellite data are presented in Figure 1.2.3.8b,c. The area of individual detected oil spill varied from 0.1 to 40 sq. km. It can be seen from the histograms that over 40% of spills did not exceed 1 sq. km, and 80% were less than 5 sq. km. Note that quite often ships discharge wastewaters several times along route over distances of dozens of kilometers. Larger numbers of spills registered during warm season (March–October) could be explained by weather conditions more favorable for the recognition of spills in SAR images.

Black Sea Surface Oil Pollution Due to Natural Hydrocarbon Showings

Characteristic slick structures caused by natural hydrocarbon can be frequently observed in satellite data of the Black Sea south-eastern continental slope. The geographical distribution of these surface films is characterized by their persistent locations that correlate with geographical locations of natural hydrocarbon sources in this region. Some examples of film pollution detected in SAR images taken over the continental slope in the south-eastern part of the Black Sea are shown in Figure 1.2.3.9. In most cases, surface film pollutions manifest themselves in this region as filamentary slicks, similar to biogenic films.



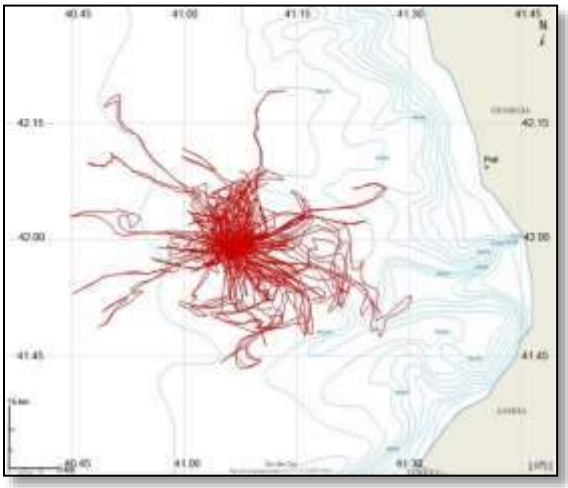
(a) (b)

(c)

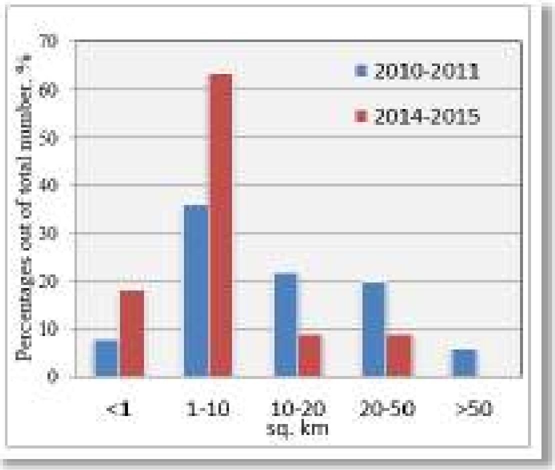
Figure 1.2.3.9. Surface slicks in the continental slope area offshore Georgia as seen in SAR imagery: (**a**) Sentinel-1 SAR, 15 October 2014, 15:10 UTC; (**b**) Sentinel-1 SAR, 8 November 2014, 15:10 UTC; (**c**) Envisat ASAR, 27 September 2011, 07:21 UTC.

In the majority of radar images, these slicks appear as "coupled" structures. Comparison of slick locations detected in satellite imagery and methane seepage locations depicted in Figure 1.2.3.9b makes it possible to draw the conclusion that such coupled character is caused by natural hydrocarbons showings from the two closely-spaced methane seepages on the sea bottom: Colkheti Seep and Pechori Mound. These surface films can stretch along the flow lines of surface currents and reproduce the shape of local circulation pattern.

We analyzed all ERS-2 SAR and Envisat ASAR images of the Black Sea taken over the south-eastern continental slope in the period from January 2010 to December 2011 as well as Sentinel-1 SAR images taken from October 2014 to April 2015. A consolidated map of seepage slicks revealed in the SAR imagery in the study area is shown in Figure 1.2.3.10a. It was found that 49.5% of the radar images of the area for the period of 2010–2011 contained slick structures, whereas in the period of October 2014–April 2015 the slick structures were registered in 64% of images (Fig. 1.2.3.10b). The total surface area exposed to oil contamination in the vicinity of the seepages reaches approx. 800 sq. km, which is a real danger to the ecology of the region. The slicks may drift distances up to 40 km driven by wind and local hydrodynamic processes. We can conclude from the analysis of the SAR data, that natural hydrocarbon showings occurred in the region more often in 2014–2015, but individual sizes of oil patches were bigger in 2010–2011 (Fig. 1.2.3. 10b,c).



(**a**)



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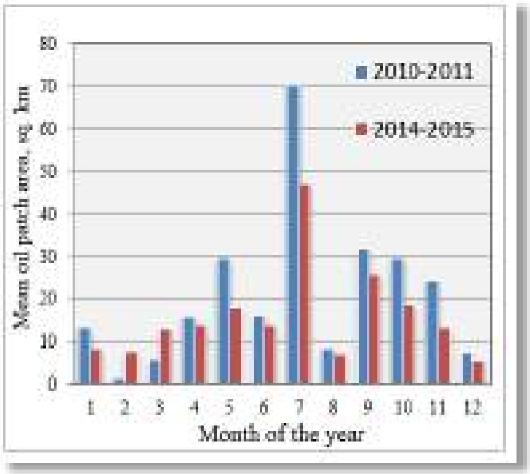

(**c**)

Figure 1.2.3.10. Analysis of SAR imagery of sea surface oil pollution due to seabed seepages in the south-eastern continental slope area: (**a**) consolidated map of oil patches; (**b**) size distributions of individual oil patches; (**c**) monthly means of oil patch sizes.

Public interest in the problem of oil pollution mainly arises during dramatic tanker catastrophes. Nevertheless, oil and petroleum products spills at sea take place all the time, and it would be a delusion to consider tanker accidents the main environmental danger. Oil spills cause contamination of seawater, shores, and beaches, which may persist for several months and represent a threat to marine resources. Today one can speak about largely fragmented information available on the parameters of surface oil pollution of the Black Sea. Therefore, mapping of the pollution, identification of its sources and spreading forecast are currently of extreme importance.

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1.2.4 Polycyclic aromatic hydrocarbons – PAHs

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1.2.4.1. PAHs in the water

Polycyclic aromatic hydrocarbons (PAHs, also polyaromatic hydrocarbons or polynuclear aromatic hydrocarbons) are organic compounds containing only carbon and hydrogen that are composed of multiple aromatic rings. The simplest such chemicals are naphthalene, having two aromatic rings, and the three-ring compounds anthracene and phenanthrene. PAHs are neutral, nonpolar molecules found in coal and in tar deposits. They are also produced by the incomplete combustion of organic matter, e.g. in engines and incinerators, forest burns, etc. Some studies suggest that PAHs account for a significant percentage of all carbon in the universe, and PAHs are discussed as possible starting materials for abiologic syntheses of materials required by the earliest forms of life. PAHs are nonpolar and lipophilic. Larger PAHs are generally insoluble in water, while some PAH's are soluble and known contaminants in drinking water.[ ] The larger members are also poorly soluble in organic solvents as well as lipids. They are usually colorless. PAHs can result from the incomplete combustion of organic matter and dominant sources in the environment are thus from human activity. Wood-burning and combustion of other biofuels contributed more than half of annual global PAH emissions. Industrial processes and the extraction and use of fossil fuels (oil and coal) made up slightly more than one quarter of global PAH emissions, dominating outputs in industrial countries. Wild fires are another notable source. PAHs typically disperse from urban and suburban non-point sources through road run-off, sewage, and atmospheric circulation and subsequent deposition of particulate air pollution. Soil and river/marine sediments near industrial sites can be highly contaminated with PAHs. Oil spills, creosote, coal mining dust, and other fossil fuel sources can also distribute PAHs in the environment. Two- and three-ring PAHs can disperse widely while dissolved in water or as gases in the atmosphere, while PAHs with higher molecular weights can disperse locally or regionally adhered to particulate matter that is suspended in air or water until the particles land or settle out of the water column. PAHs have a strong affinity for organic carbon, and thus highly organic freshwater and marine sediments can be a substantial sink for PAHs. Algae and some invertebrates such as protozoans, mollusks, and many polychaetes have limited ability to metabolize PAHs and bioaccumulate disproportionate concentrations of PAHs in their tissues. PAHs transform slowly to a wide range of degradation products. Biological degradation by microbes is a dominant form of PAH transformation in the environment. Abiotic degradation in the atmosphere and the top layers of surface waters can produce nitrogenated, halogenated, hydroxylated, and oxygenated PAHs; some of these compounds can be more toxic, water-soluble, and mobile than their parent PAHs.

Romania-2009. In the Black Sea within period of 2009-2014 in the first year only 65 water samples studying PAHs concentration were taken in Romania coastal waters in July, September and November. Analysis indicates the presence some of 13 individual polycyclic aromatic hydrocarbons (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]antracen, chrysene, benzo[b]fluorantene, benzo[k]fluoranthene, benzo[a]pyrene) in all samples analyzed. Among individual PAHs the most abundant were two aromatic rings naphthalene and 3-rings anthracene and phenanthrene, followed by fluorine and fluoranthene (Table 1.2.4.1). The maximum level reached for naphthalene 4700 ng/l at surface near Sf.Gheorghe, anthracene 7200 ng/l near Mila. The main part of extremes was recorded in July samples from two mentioned above sites. Other individual hydrocarbons were much less abundant in the coastal waters: average concentration of acenaphthene was 8.43 ng/l and maximum 61 ng/l; pyrene 2.36/20 ng/l; chrysene 2.02/20 ng/l; benzo[a]antracen 0.52/6 ng/l; benzo[b]fluorantene 0.47/20 ng/l; benzo[k]fluoranthene 0.48/20 ng/l and acenaphthylene 0.44/5 ng/l correspondingly. The most famous and poison benzo[a]pyrene was not recorded in the samples.

Table 1.2.4.1. Concentration (ng/l) of most abundant polycyclic aromatic hydrocarbons in the Romanian coastal waters in July-October 2009.

	1.Naphthalene	2.Anthracene	3.Fluorene	4.Fluoranthene	5.Phenanthrene
13.Sulina	1703.33	103.33	46.67	36.83	35.83
12.Mila	1298.00	1200.00	277.00	31.50	118.33
11.Sf.Gheorghe	1240.00	1585.50	154.00	127.83	50.33
10.Portita	802.00	1053.33	83.00	0.00	6.67
9.Gura Buhaz	0.00	213.75	74.50	2.50	0.00
8.Mamaia	0.00	0.00	37.00	1.67	0.00
7.Constanta N	550.00	0.00	0.00	0.00	38.33
6.Constanta E	0.00	0.00	0.00	0.00	0.80
5.Constanta Sud	2615.00	1141.25	343.75	109.20	24.50
4.Eforie Sud	0.00	0.00	0.00	39.00	12.50
3.Costinesti	0.00	0.00	0.00	10.00	0.00
2.Mangalia	1544.83	1482.67	227.67	80.60	11.33
1.Vama Veche	1316.00	1445.00	253.25	9.00	0.00
Maximum (ng/l)	4700 Sf.Gheorghe 21.07.2009	7200 Mila 21.07.2009	600 Mila 21.07.2009	369 Sf.Gheorghe 16.09.2009	455 Mila 21.07.2009
Average (ng/l)	875.43	673.06	117.51	36.30	24.65

In general, most polluted by five dominate in the group PAHs in 2009 regions of the Romanian coastal waters were detected at northern (Sulina-Mila-Sf.Gheorghe) and southern (Mangalia-Vama Veche) parts (Fig. 1.2.4.1). The only important exception is site in vicinity large port Constanta Sud where all hydrocarbons concentration strongly increased in comparison with neighbours.

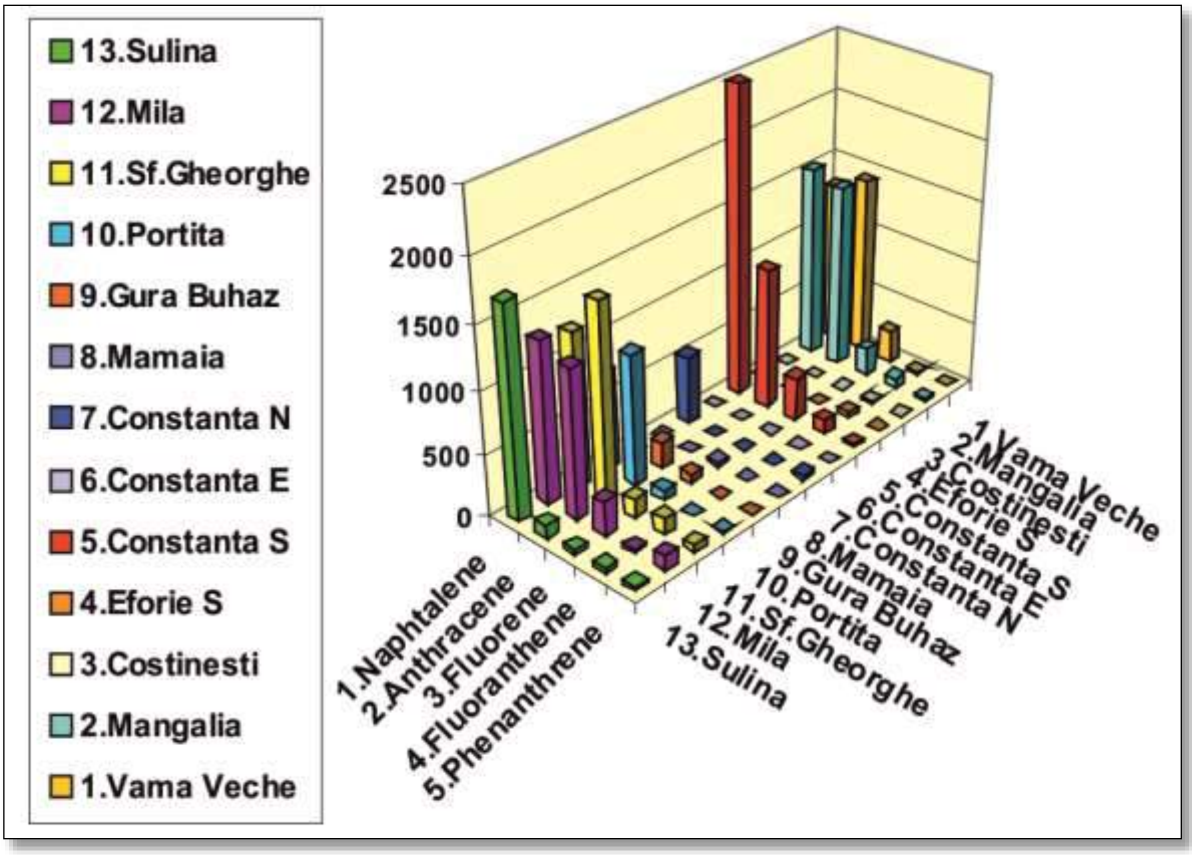


Figure 1.2.4.1. Average concentration of the PAHs in the Romanian coastal waters in July-October 2009.

In different months 2009 the structure of PAHs concentration and spatial distribution were similar to annual averages (Fig. 1.2.4.2). The area in Danube delta at North and close to Turkey border at South dominated in PAHs concentration, while some visible increasing also marked for Constanta region.

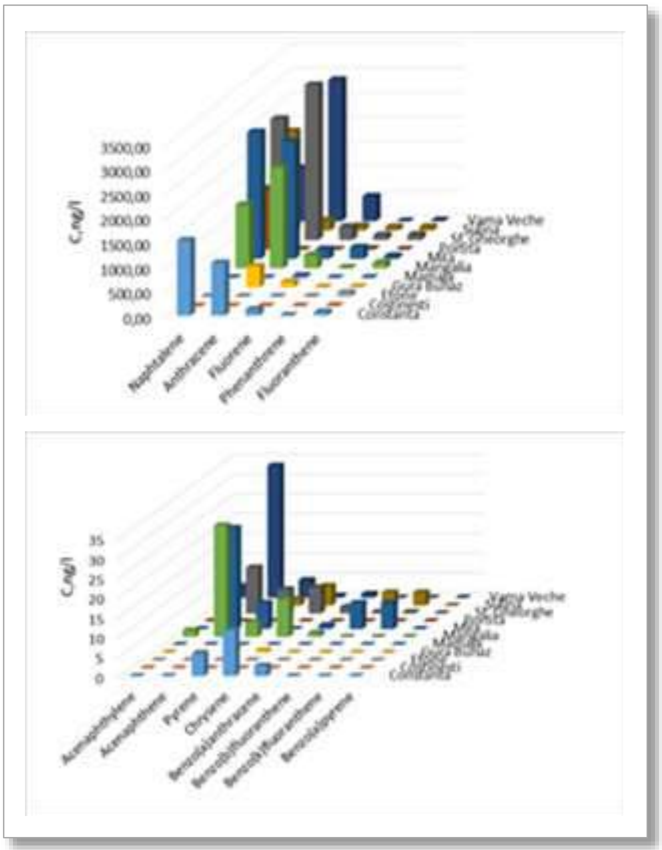


Figure 1.2.4.2. Average concentration of the PAHs in the Romanian coastal waters in July 2009.

Among individual PAHs in Autumn 2009 in highest average concentration (2045.00 ng/l) naphthalene (2106.67 ng/l) and anthracene are present (Fig. 1.2.4.3). The concentration of some individual PAHs (benzo(b) fluoranthene, benzo(k) fluoranthene, benzo(a) pyrene) were below the detection limit.

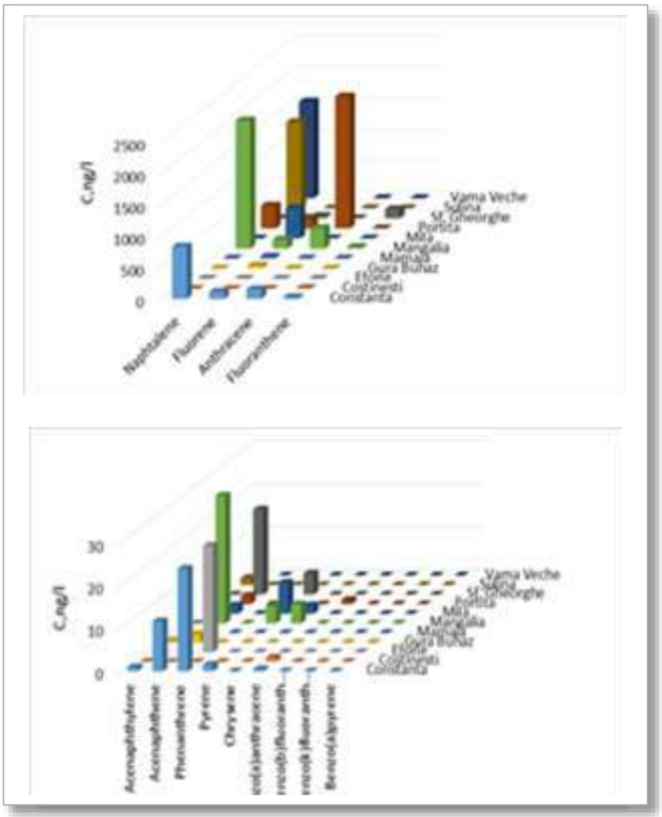


Figure 1.2.4.3. Average concentration of the PAHs in the Romanian coastal waters in September-October 2009.

Romania-2010. PAHs analysis indicates the presence of 16 priority hazardous organic contaminants (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)antracene, chrysene, benzo(b)fluorantene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(g,h,i)perylene, dibenzo(a,h)antracene and indeno(1,2,3-c,d)pyrene) in all samples analyzed. The level of contamination by polycyclic aromatic hydrocarbons in Romanian waters in 2010 is shown in Figures and Tables. The total concentration of the parameter “PAHs total” presented in Fig. 1.2.4.4.

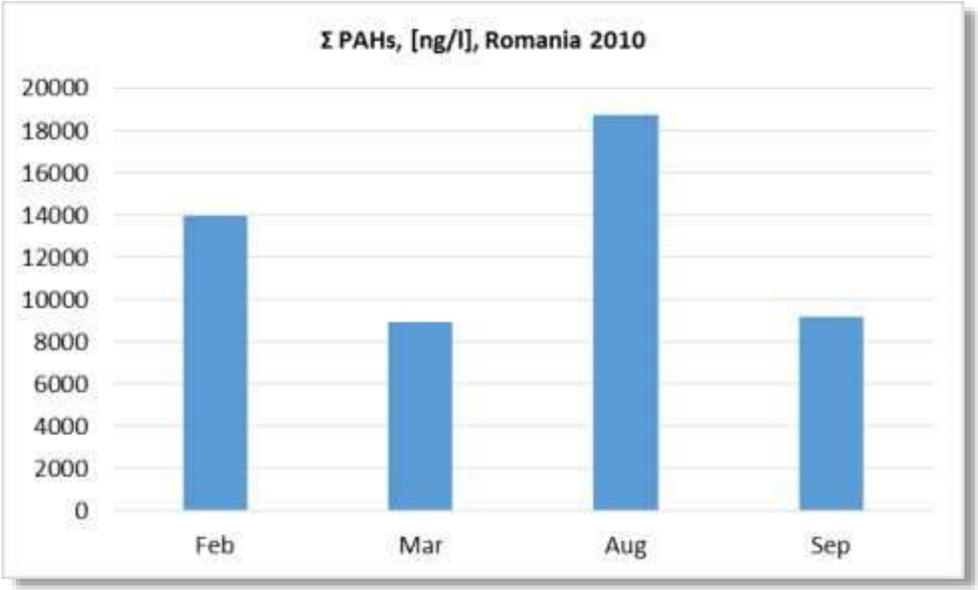


Figure 1.2.4.4. Concentration of the PAHs total in water, (Romania 2010).

The total polycyclic aromatic hydrocarbons - ∑16PAH (ng/l) content in water samples ranged from 7.10 to 3181.25 ng/l (Table 1.2.4.2, Figure 1.2.4.5). Of the total PAHs, the 2-3-ring PAHs contributed to about 90%, except area Gura Buhaz (58%), while 4-6-ring PAHs accounted for 10% (Figure 1.2.4.6). Naphthalene, Phenanthrene, Anthracene were found as the most dominant compounds.

Table 1.2.4.2. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the Romanian waters in February 2010.

Area	Σ PAHs, ng/l	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv. ng/l
Constanta	7.10	8	10.83	0.0
Gura Buhaz	492.76	15	1.34	7.0
Mangalia	1372.59	3	21.87	13.1
Mila	422.29	0	36.63	0.3
Portita	354.99	0	56.37	0.2
Sf. Gheorghe	1392.67	14	5.23	6.1
Sulina	3181.25	11	7.11	43.9

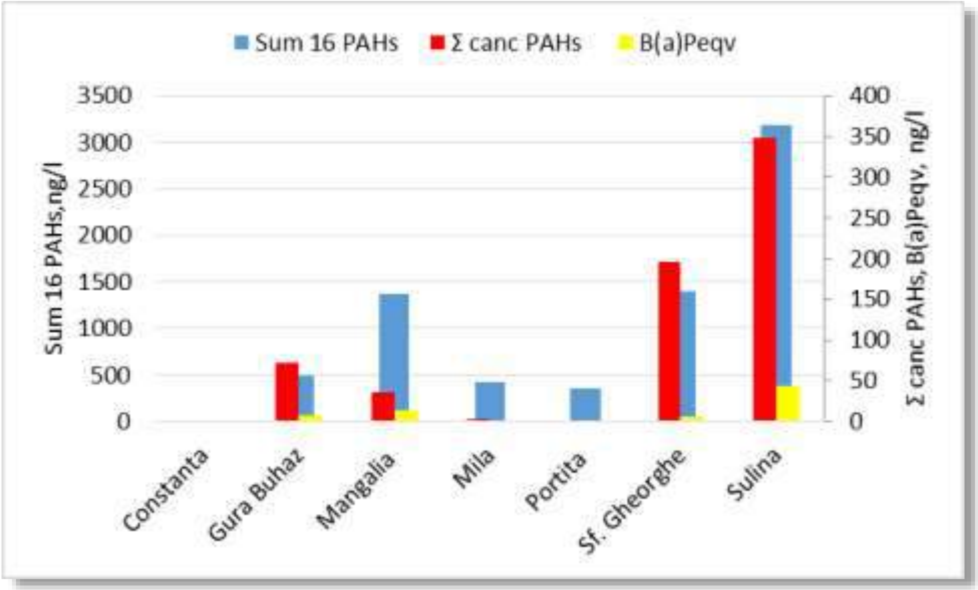


Figure 1.2.4.5. The level of water contamination by PAHs in the Romanian part of the Black Sea in February 2010.

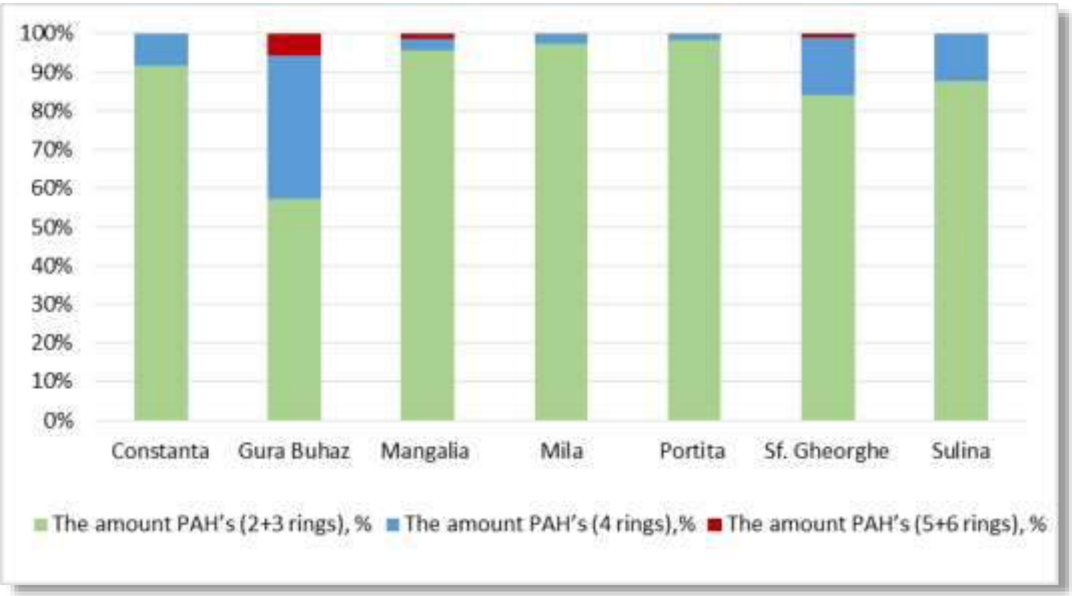


Figure 1.2.4.6. The ratio of 16 PAHs in water by the number of rings in the molecules.

The total polycyclic aromatic hydrocarbons - ∑16PAH (ng/l) content in water samples ranged from 71.82 to 1146.56 ng/l (Table 1.2.4.3, Fig. 1.2.4.7). Of the total PAHs, the 2-3-ring PAHs contributed to about 85%, except area Constanta (60%), while 4-6-ring PAHs accounted for 15% (Fig. 1.2.4.8). Naphthalene, Phenanthrene, Anthracene, Fluorene were found as the most dominant compounds.

Table 1.2.4.3. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the Romanian waters in March 2010.

Area	Σ PAHs, ng/l	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, ng/l
Constanta	71.82	17	1.49	1.0
Mila	573.90	0	13.09	0.2
Portita	478.94	9	6.84	0.9
Sf. Gheorghe	700.56	9	3.63	2.2
Sulina	1146.56	2	18.54	3.2

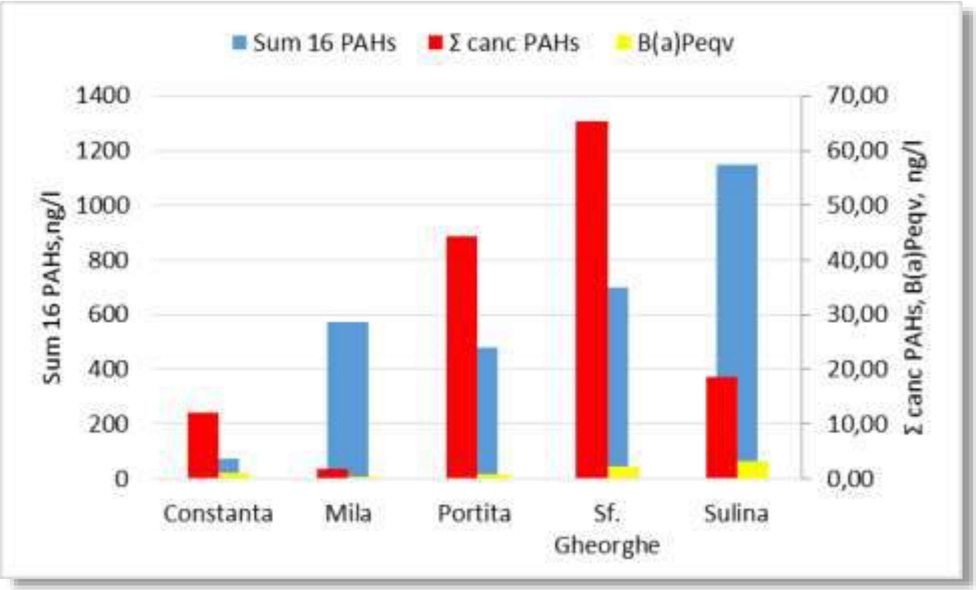


Figure 1.2.4.7. The level of water contamination by PAHs in the Romanian part of the Black Sea in March 2010.

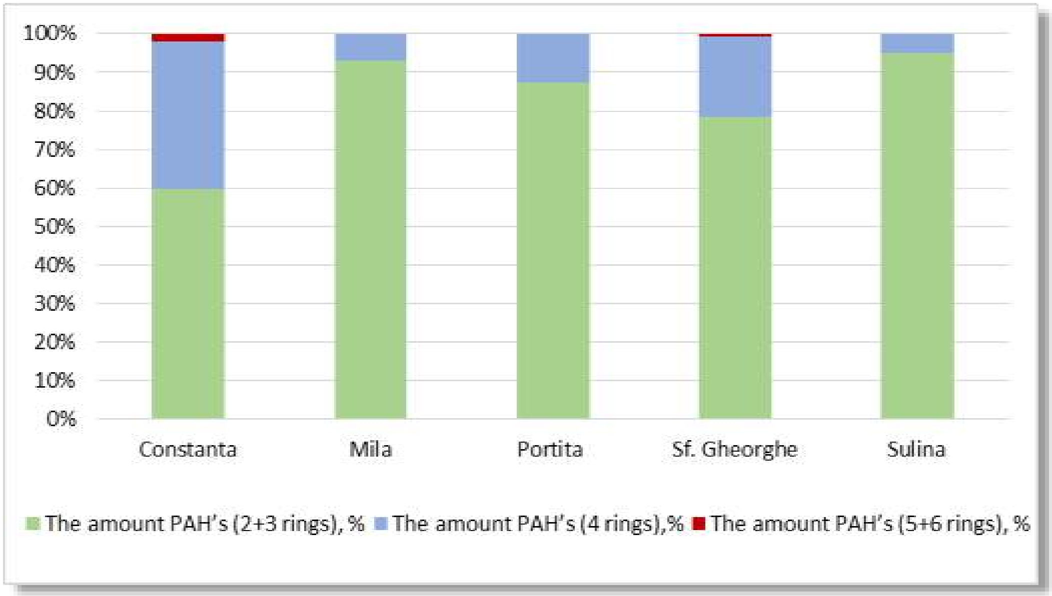


Figure 1.2.4.8. The ratio of 16 PAHs in water by the number of rings in the molecules.

The total polycyclic aromatic hydrocarbons ∑16PAH (ng/l) content in the water samples ranged from 82.07 to 1239.28 ng/l (Table 1.2.3.4., Fig. 1.2.4.9). Of the total PAHs, the 2-3-ring PAHs contributed to about 90% while 4-6-ring PAHs accounted for 10% (Fig. 1.2.4.10). Naphthalene, Phenanthrene, Anthracene, Fluorene were found as the most dominant compounds.

Table 1.2.4.4. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the Romanian waters in August 2010.

Area	Σ PAHs, ng/l	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, ng/l
Constanta	1239.28	6	12.79	5.3
Mamaia	82.07	0	92.53	0.0
Mangalia	1041.18	2	27.64	4.6
Vama Veche	1060.53	10	4.66	18.7

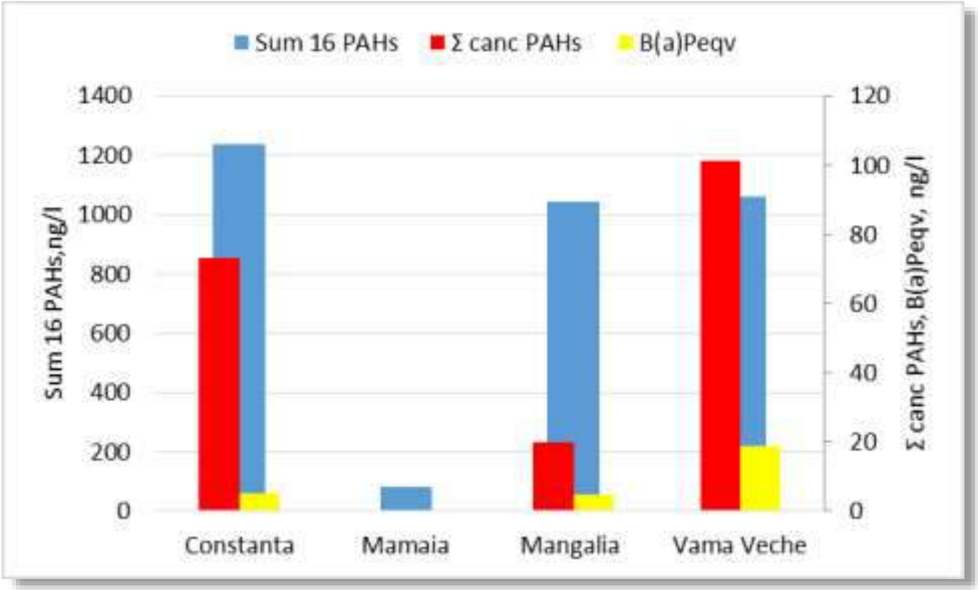


Figure 1.2.4.9. The level of water contamination by PAHs in the Romanian part of the Black Sea in August 2010.

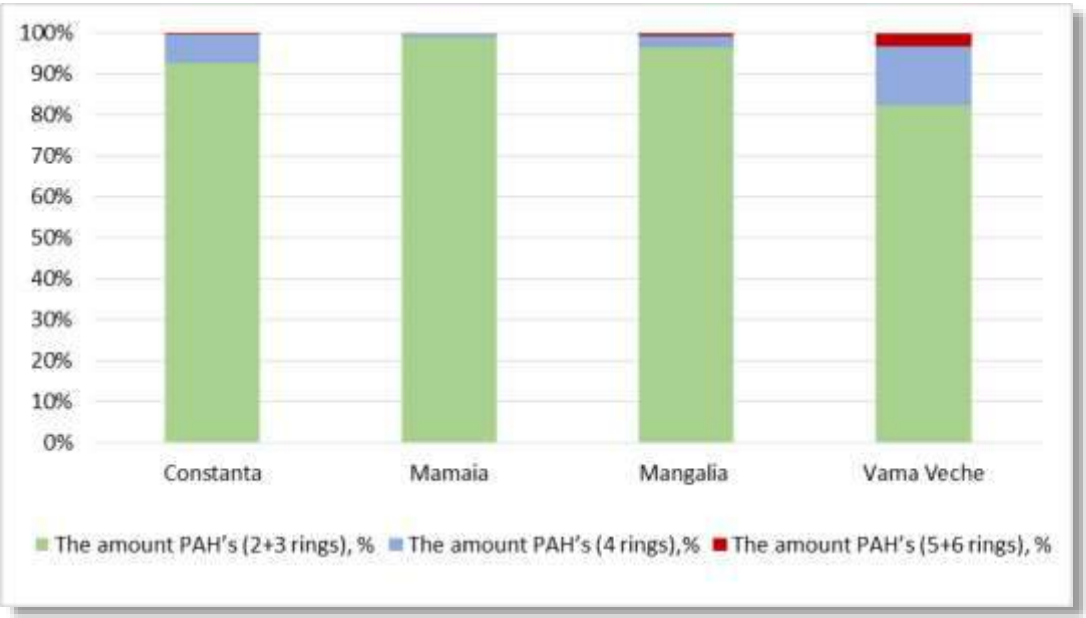


Figure 1.2.4.10. The ratio of 16 PAHs in water by the number of rings in the molecules.

The total polycyclic aromatic hydrocarbons - ∑16PAH (ng/l) content in water samples ranged from 39.25 to 1129.50 ng/l (Table 1.2.4.5, Fig. 1.2.4.11). Among others the 2-3-ring PAHs contributed to about 90%, except area Sf. Gheorghe (83%), while 4-6-ring PAHs accounted for 10% (Fig. 1.2.4.12). Naphthalene, Acenaphthylene and Anthracene were found as the most dominant compounds.

Table 1.2.4.5. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the Romanian waters in September 2010.

Area	Σ PAHs, ng/l	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, ng/l
Gura Buhaz	39,25	1	9,47	0,1
Mila	561,43	0	16,87	0,4
Portita	556,41	4	16,53	0,7
Sf. Gheorghe	785,37	9	5,03	7,8
Sulina	1129,50	1	42,03	1,9

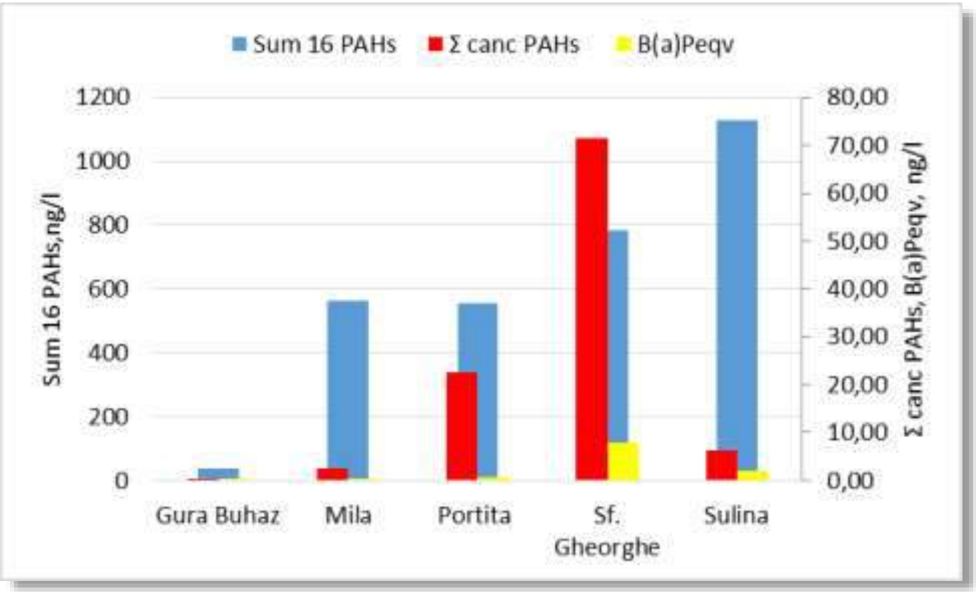


Figure 1.2.4.11. The level of water contamination by PAHs in the Romanian part of the Black Sea in September 2010.

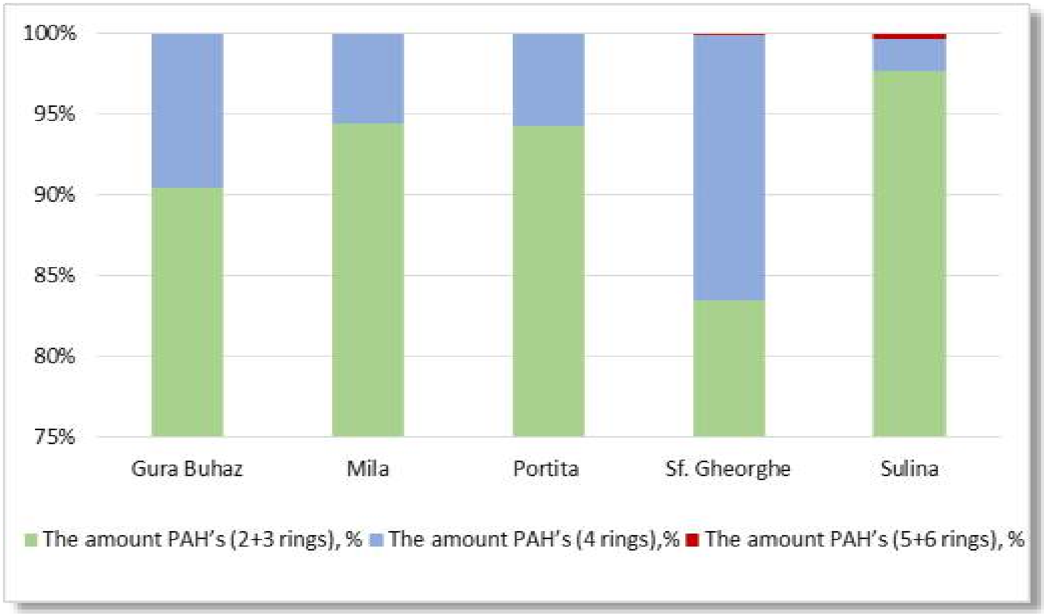


Figure 1.2.4.12. The ratio of 16 PAHs in water by the number of rings in the molecules.

Ukraine-2010. In Ukrainian marine waters the level of water contamination by individual PAHs was studied near Zmeiny Island (Fig. 1.2.4.13). Among individual PAHs in the highest concentration Indeno(1,2,3cd)pyrene (75.6 ng/l), Fluoranthene (52.9 ng/l), and Benzo(k)fluoranthrene (50.0 ng/l) were presented in the water samples.

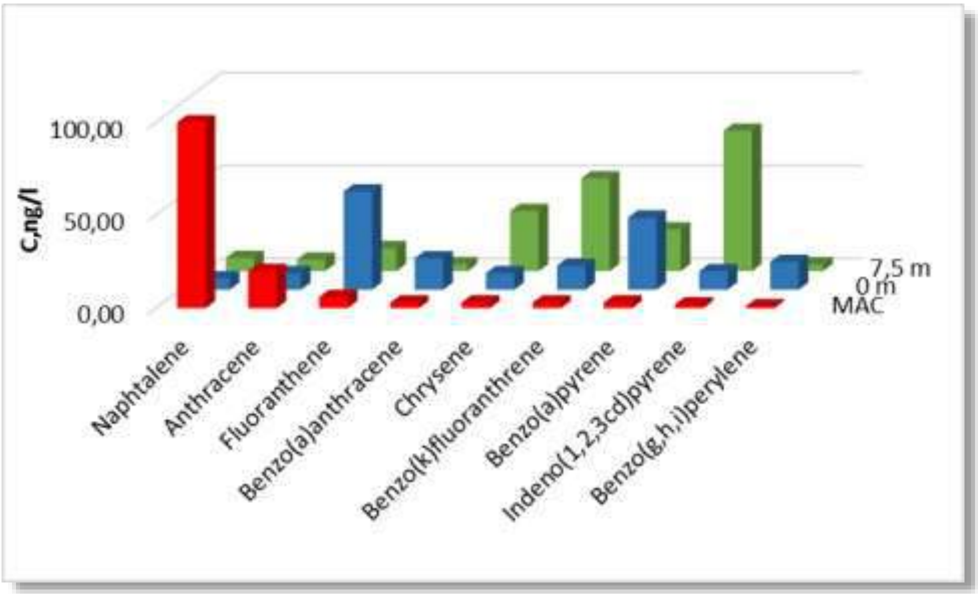


Figure 1.2.4.13. Concentration of the PAHs in marine waters near Zmeiny Island in 2010.

The sum of 16 polycyclic aromatic hydrocarbons in the water samples ranged from 649.40 to 748.40 ng/l (Table 1.2.4.6, Fig. 1.2.4.14). Among the PAHs, the 2-3-ring compounds contributed to about 60% while 4-6-ring PAHs accounted for 40% (Fig. 1.2.4.15). Phenanthrene, Benzo(b)fluoranthrene and Indeno(1,2,3cd)pyrene were found as the most dominant compounds.

Table 1.2.4.6. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in Ukrainian marine waters near Zmeiny Island in 2010.

Depth, m	Σ PAHs, ng/l	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, ng/l	Total PAHs index
0	649.40	24	1.75	71.3	4.83
7.5	748.40	41	1.30	51.5	7.16

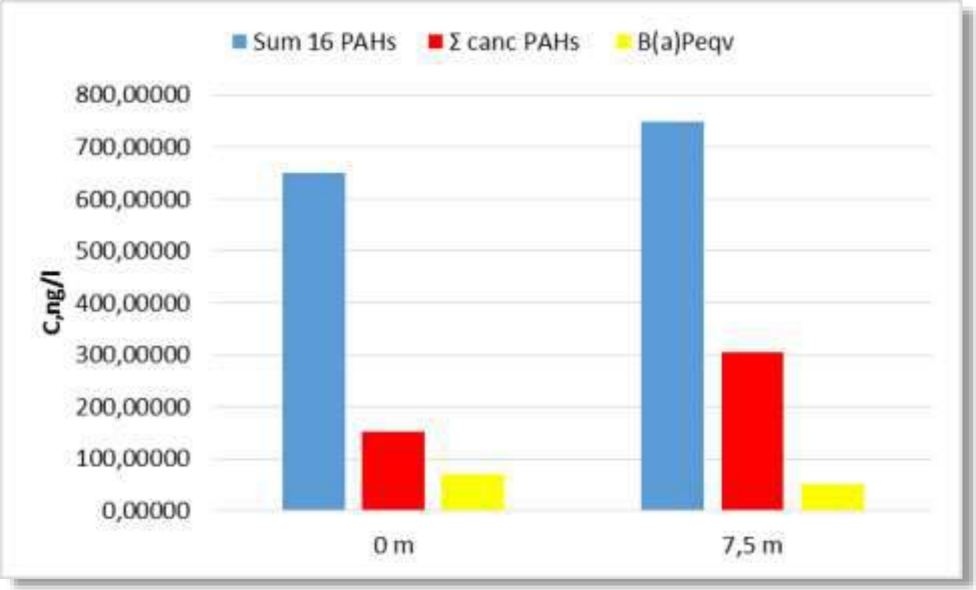


Figure 1.2.4.14. The level of marine waters contamination by PAHs near Zmeiniy Island in 2010.

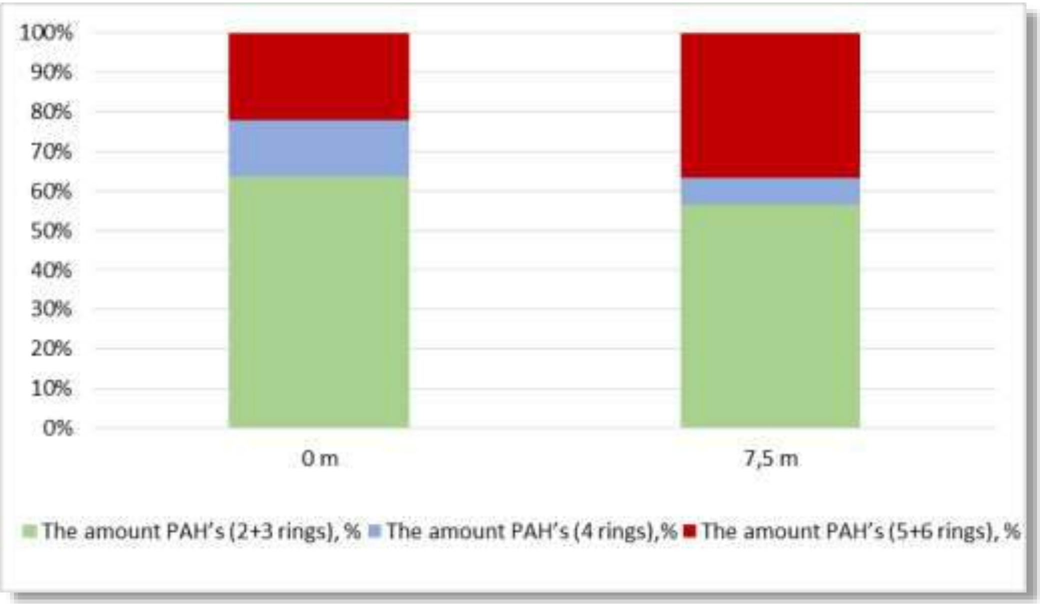


Figure 1.2.4.15. The ratio of 16 PAHs in the waters by the number of rings in the molecules.

Romania-2011. PAHs analysis indicates the presence of 16 priority hazardous organic contaminants (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]antracene, chrysene, benzo[b]fluorantene, benzo[k]fluoranthene, benzo[a]pyrene, benzo(g,h,i)perylene, dibenzo(a,h)antracene and indeno(1,2,3-c,d)pyrene, in all samples analyzed. The level of contamination by polycyclic aromatic hydrocarbons - PAHs in the Romanian Black Sea waters in 2011 is shown in Figures 1.2.4.17-20 and Tables 1.2.4.7-8. The total concentration of the parameter “PAHs total” presented in Fig. 1.2.4.16.

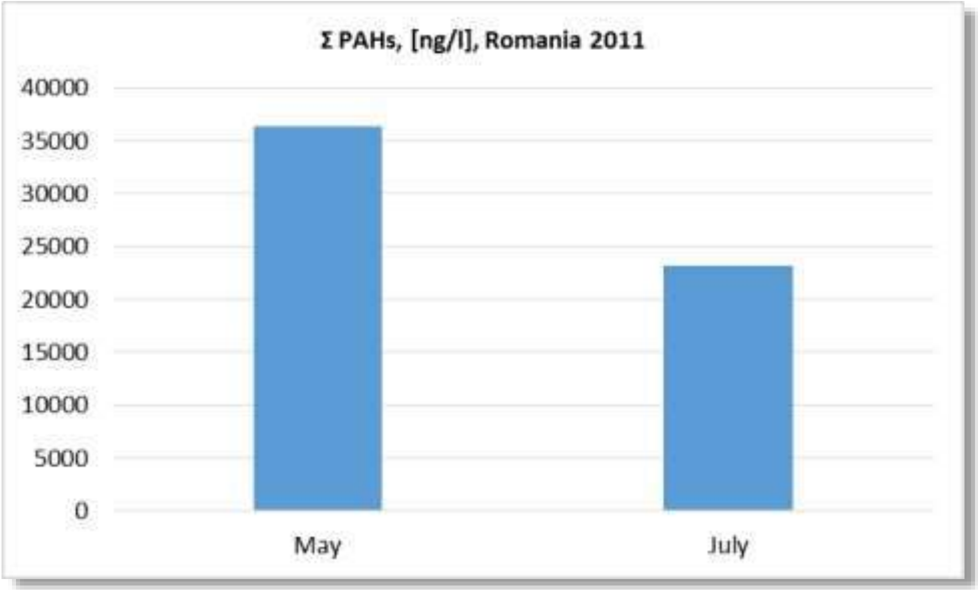


Figure 1.2.4.16. Total concentration of the PAHs in the waters of the Romanian part of the Black Sea in 2011.

The total concentration of 16 polycyclic aromatic hydrocarbons in the water samples ranged from 235.95 to 3422.27 ng/l (Table 1.2.4.7, Fig. 1.2.4.17). Among 16 priority PAHs, the 2-3-ring compounds contributed to about 95% while 4-6-ring PAHs accounted for 5% (Fig. 1.2.4.18). Naphtalene, Anthracene, Phenanthrene and Fluorene were found as the most dominant compounds.

Table 1.2.4.7. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the Romanian waters in May 2011.

Area	Σ PAHs, ng/l	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, ng/l
Constanta	1726.25	1	34.63	4.8
Costinesti	235.95	0	39.16	0.1
Eforie	253.36	0	15.24	0.1
Gura Buhaz	710.75	0	188.53	2.8
Mamaia	190.35	0	122.78	0.0
Mangalia	2322.29	1	32.69	9.0

Area	Σ PAHs, ng/l	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, ng/l
Mila	753.68	0	30.59	0.4
Portita	530.27	3	23.87	0.3
Sf. Gheorghe	1057.21	3	10.23	3.9
Sulina	1900.45	3	19.40	8.9
Vama Veche	3422.27	1	65.97	20.3

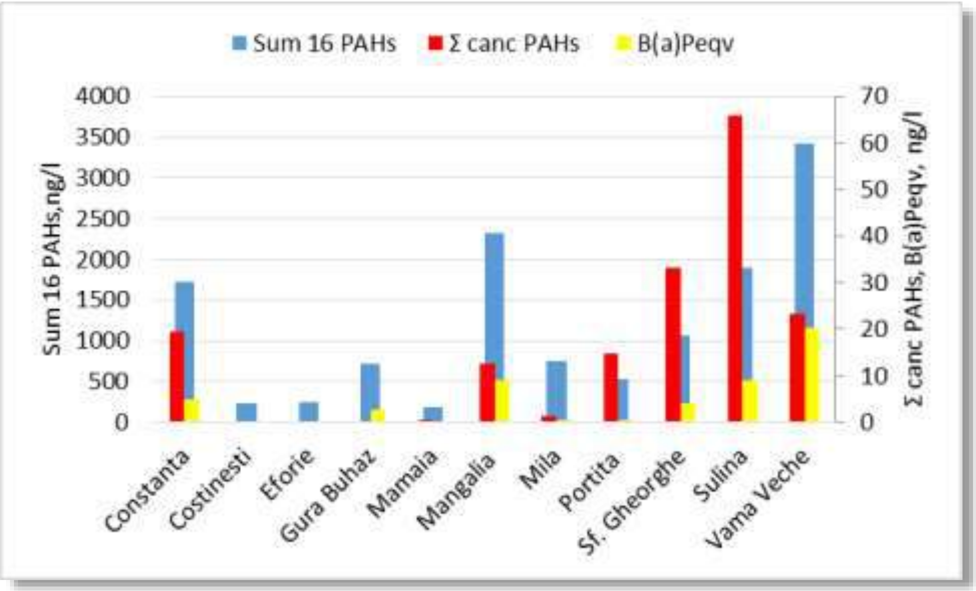


Figure 1.2.4.17. The level of water contamination by PAHs in the Romanian part of the Black Sea in May 2011.

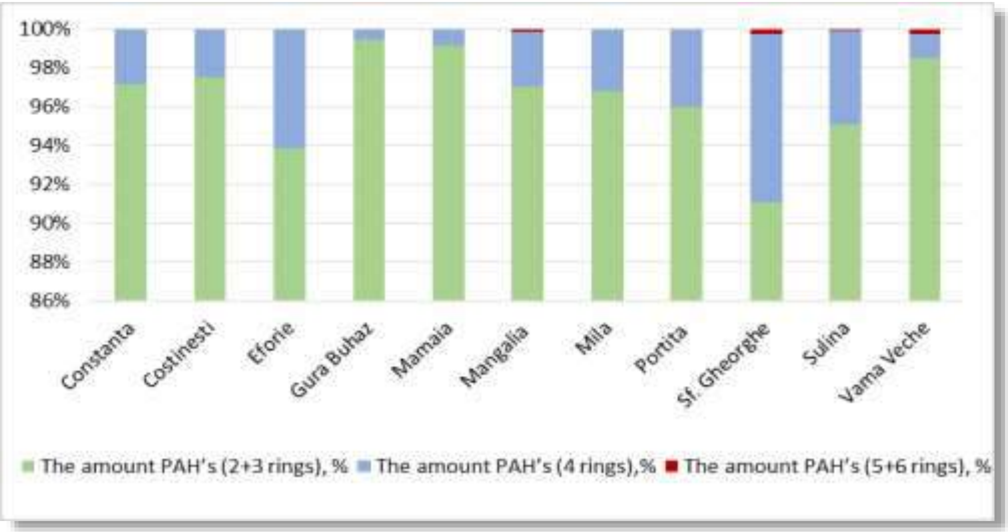


Figure 1.2.4.18. The ratio of 16 PAHs in the waters by the number of rings in the molecules.

The total concentration of 16 polycyclic aromatic hydrocarbons in the water samples ranged from 80.00 to 2650.16 ng/l (Table 1.2.4.8, Fig. 1.2.4.19). Among 16 priority PAHs, the 2-3-ring compounds contributed to about 98%, except area Gura Buhaz (72%), while 4-6-ring PAHs accounted for 2% (Fig. 1.2.4.20). Naphtalene, Anthracene, Phenanthrene and Fluorene were found as the most dominant compounds.

Table 1.2.4.8. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the Romanian waters in July 2011.

Area	Σ PAHs, ng/l	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, ng/l
Constanta	1325.42	0	51.74	3.9
Gura Buhaz	130.70	9	2.60	1.2
Mamaia	80.00	0		0.0
Mangalia	2650.16	0	50.82	12.2
Mila	404.73	0	78.33	0.2
Portita	180.76	0		0.0
Sf. Gheorghe	651.69	0	13.64	0.4
Sulina	1190.53	0	91.65	0.1
Vama Veche	1135.01	0		0.0

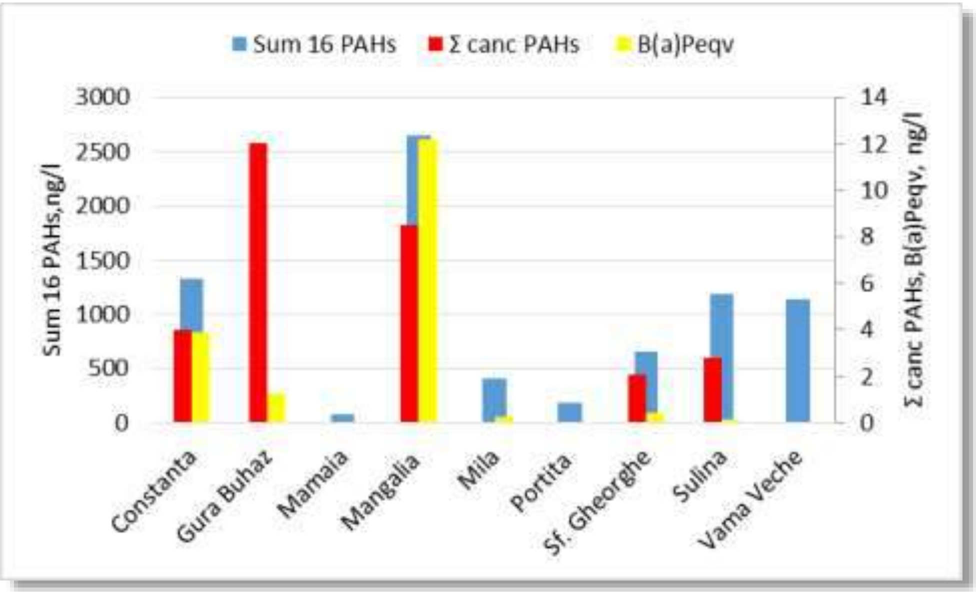


Figure 1.2.4.19. The level of water contamination by PAHs in the Romanian part of the Black Sea in July 2011.

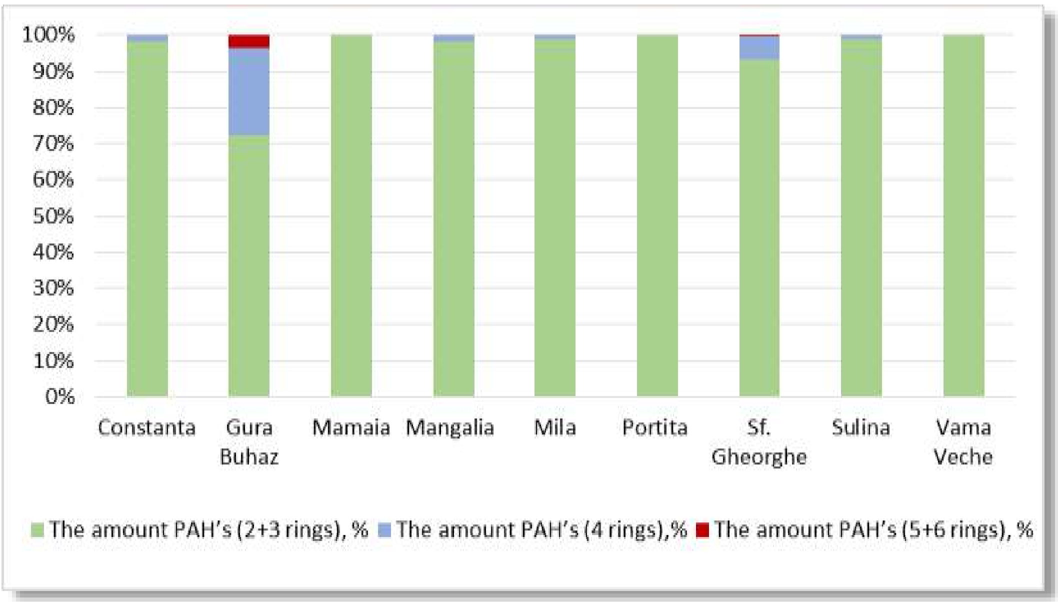


Figure 1.2.4.20. The ratio of 16 PAHs by the number of rings in the molecules in the Romanian waters in July 2011.

Romania-2012. The total concentration of 16 polycyclic aromatic hydrocarbons in the water samples ranged from 1683.42 to 28976.24 ng/l (Table 1.2.4.9, Fig. 1.2.4.21). Among 16 priority PAHs, the 2-3-ring compounds contributed to about 80%, except waters near Mila (47%), while 4-6-ring PAHs accounted for 20% (Fig. 1.2.4.22). Anthracene, Fluorene, Phenanthrene and Naphtalene were found as the most dominant compounds.

Table 1.2.4.9. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the Romanian waters in March-April 2012.

Area	Σ PAHs, ng/l	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, ng/l	Total PAHs index
Constanta	1712.25	10	3.90	29.5	35.08
Costinesti	2158.27	6	7.06	38.4	32.26
Eforie	2451.01	5	14.19	25.3	55.47
Mamaia	2202.95	7	3.38	29.9	57.84
Mangalia	1830.06	8	4.85	21.8	36.02
Mila	28976.24	6	0.86	279.0	354.92
Portita	1917.48	9	3.28	26.9	42.15
Sf. Gheorghe	1683.42	9	4.84	19.7	25.87
Sulina	2186.74	6	2.92	24.0	51.49
Vama Veche	2129.17	7	5.12	22.5	57.82

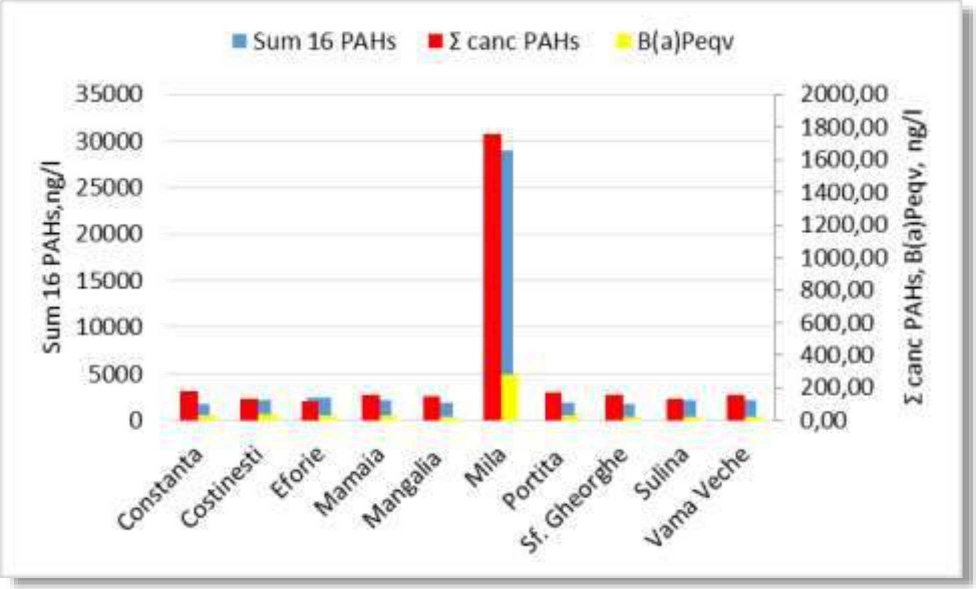


Figure 1.2.4.21. The level of water contamination by PAHs in the Romanian part of the Black Sea in March-April 2012.

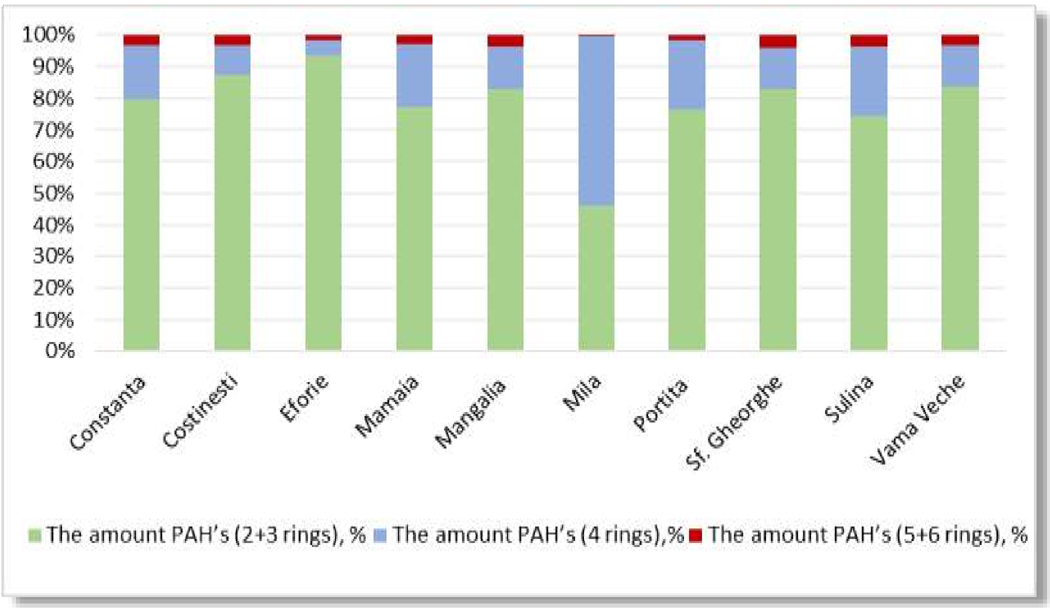


Figure 1.2.4.22. The ratio of 16 PAHs by the number of rings in the molecules in the Romanian waters in March-April 2012.

The total concentration of 16 polycyclic aromatic hydrocarbons content in the water samples ranged from 206.68 to 911.28 ng/l (Table 1.2.4.10, Fig.1.2.4.23). Among 16 priority PAHs, the 2-3-ring compounds contributed to about 60%, except waters near Eforie (35%), while 4-6-ring PAHs accounted for 40% (Fig. 1.2.4.24). Phenanthrene, Naphtalene and Anthracene were found as the most dominant compounds.

Table 1.2.4.10. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the Romanian waters in October 2012.

Area	Σ PAHs, ng/l	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, ng/l	Total PAHs index
Constanta	562.20	27	3.17	51.0	10.82
Costinesti	384.13	45	1.23	35.1	
Eforie	206.68	55	0.54	24.5	
Gura Buhaz	740.03	23	2.84	36.7	10.15
Mamaia	819.45	52	1.08	124.0	8.61
Mangalia	828.68	20	3.34	49.5	19.02
Mila	776.14	24	2.68	49.7	8.92
Portita	485.16	31	1.99	42.8	6.10
Sf. Gheorghe	470.32	41	1.68	65.1	5.16
Sulina	911.28	22	2.79	63.4	9.40
Vama Veche	708.40	26	2.80	49.9	9.27

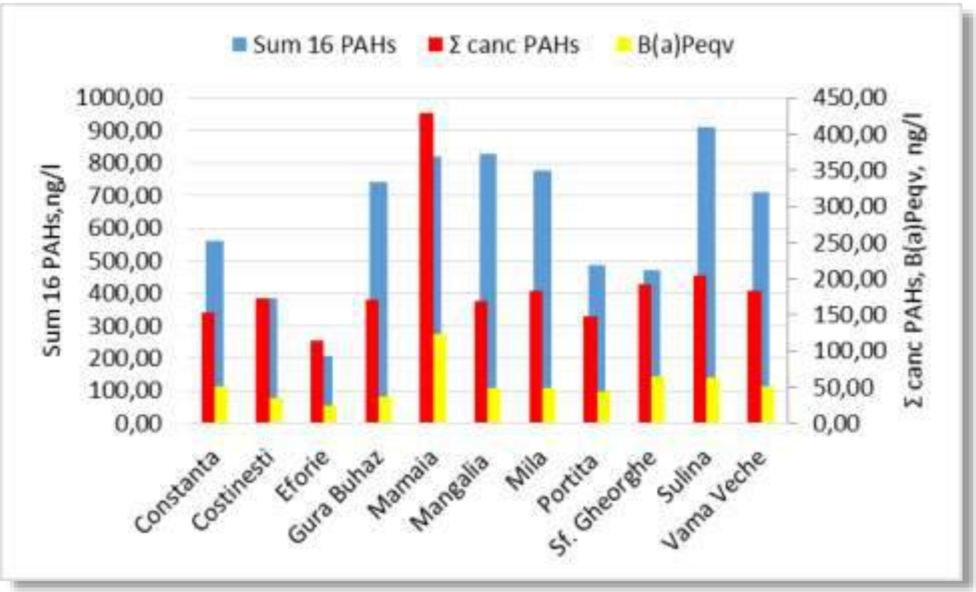


Figure 1.2.4.23. The level of water contamination by PAHs in the Romanian part of the Black Sea in October 2012.

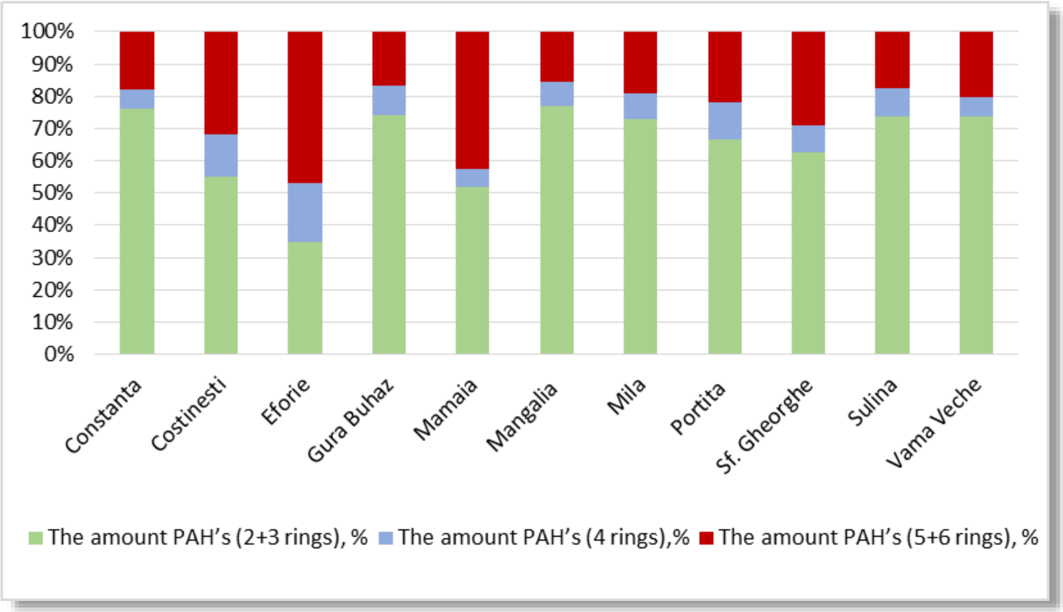


Figure 1.2.4.24. The ratio of 16 PAHs by the number of rings in the molecules in the Romanian waters in October 2012.

Ukraine-2012. In the samples collected in Ukrainian waters in 2012 at 13 stations from the near-bottom layer the largest concentration of 16 priority PAHs was recorded at stations №14, 15, 23 and 28 (Fig. 1.2.4.25). The highest amount of carcinogenic PAH (4.9-52 ng/l) was recorded at stations №14 and 15. At other stations the concentration of carcinogenic PAH was lower and varied in the range from analytical zero (st. 34) to 3.3 ng/l (st. 24). Benzo(a)pyrene equivalent (BaPekv) was in the range of 0.1 to 0.9 ng/l, with a maximum at station 14 (Table 1.2.4.11). In general, concentration of individual PAHs in water samples were significantly below MAC for benzo(a)pyrene (5 ng/l). The results of calculating the index value phenanthrene/anthracene and fluorantene/pyrene indicate that at the stations №28, 34, 35 and 45 the PAHs are likely to have anthropogenic sources of emission (phenanthrene/anthracene <10 and fluorantene/pyrene> 1).

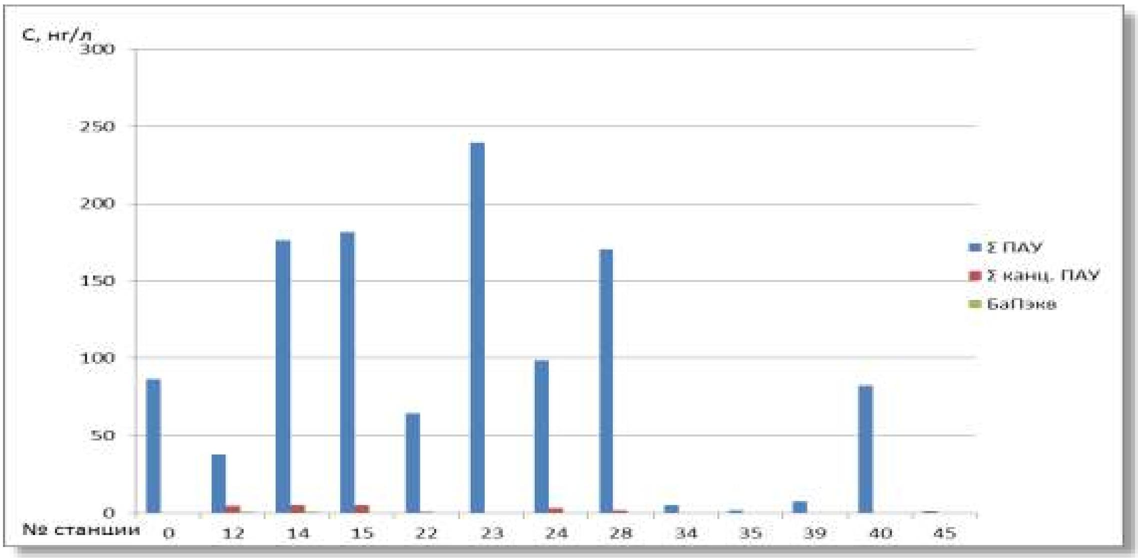


Figure 1.2.4.25. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the Ukrainian waters in 2012.

The total concentration of 16 polycyclic aromatic hydrocarbons in the water samples ranged from 1.4 to 239.7 ng/l (Table 1.2.4.11). Among 16 priority PAHs, the 2-3-ring compounds contributed to about 90%, except station 12 (80%), where 4-6-ring PAHs accounted for 10% (Fig. 1.2.4.26). Fluorene, Naphtalene and Phenanthrene were found as the most dominant compounds.

Table 1.2.4.11. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the Ukrainian waters in 2012.

No St.	ΣPAHs, ng/l	arc.PAHs, ng/l	carc.PAHs/ PAHs·100 %	henathrene/ nthracene*	uoranthene/ Pyrene*	a)Peqv, ng/l
0	86,6	0,5	1	13,0	1,0	0,2
12	37,6	4,9	13	25,5	25,5	0,7
14	176,4	5,2	3	37,8	1,6	0,9
15	181,7	5,1	3	44,0	1,1	0,5
22	64,6	1,0	2	31,7	1,7	0,3
23	239,7	0,4	0	41,0	2,6	0,3
24	98,4	3,3	3	22,3	1,2	0,4
28	170,3	1,8	1	9,3	1,1	0,3
34	5,2	0,0	0	8,0	2,0	≤0,1
35	1,6	0,0	0	2,0	1,0	≤0,1
39	7,6	0,2	3	11,0	2,0	≤0,1
40	82,3	0,0	0	47,0	2,3	0,1
45	1,4	0,0	0	1,0	2,0	≤0,1

* Value Phenanthrene/Anthracene>10 and Fluorantene/Pyrene<1, indicating the origin of petroleum PAHs, and the ratio Phenanthrene/Anthracene<10 and Fluoranthene/Pyrene>1 indicate anthropogenic emission of PAHs as a result of combustion products.

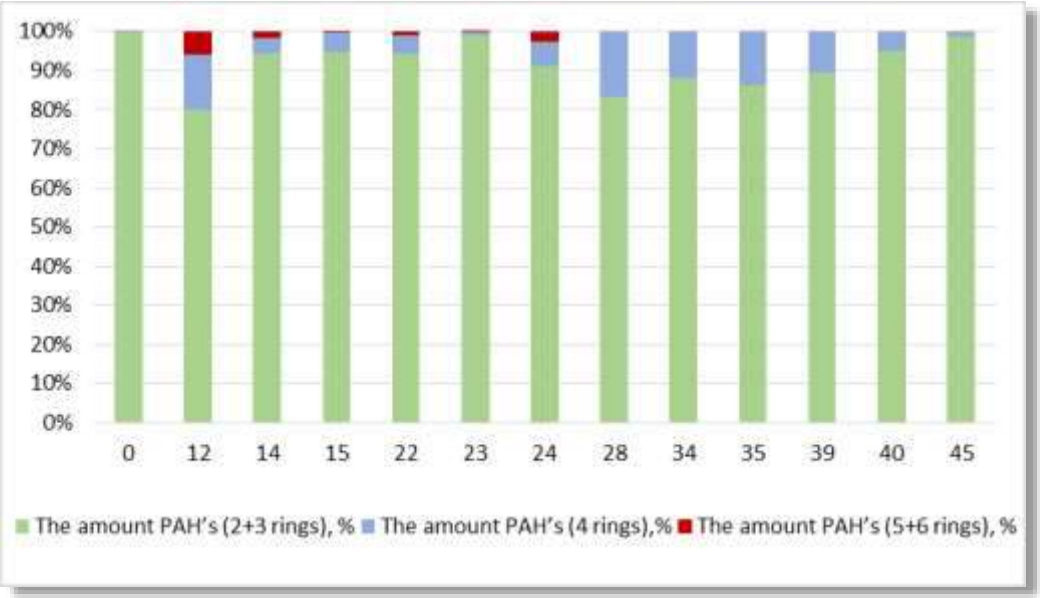


Figure 1.2.4.26. The ratio of 16 PAHs by the number of rings in the molecules in the Ukrainian waters in 2012.

Romania-2013. The level of contamination by polycyclic aromatic hydrocarbons in transitional, coastal and marine waters in 2013 is shown in Table 1.2.4.12. PAHs analysis indicates the presence of 16 priority hazardous organic contaminants (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)antracen, crisen, benzo(b)fluoranten, benzo(k)fluoranten, benzo(a)pyren, benzo(g,h,i)perilen, dibenzo(a,h)antracen and indeno (1,2,3-c,d)pyrene) in all samples analysed.

Table 1.2.4.12. Content of total PAHs Σ_{16} PAHs (µg/l) and various indices of toxicity in transitional, coastal and marine waters in Romanian part of the Black Sea in May-August 2013.

Pollution indices	**Typology**					
	coastal (n=34)		**marine (n=30)**		**transitional (n=20)**	
	range	mean	range	mean	range	mean
HAPMm/HAPMM	0.32 - 5.21	1.4	0.20 - 11.72	2.86	0.39 - 6.03	2.55
Total-B(a)Peqv (µg l^{-1})	0.02 - 0.42	0.07	0.03 -0.13	0.06	0.04 - 0.38	0.09
∑CHAPs %	16.1 - 75.5	48.0	7.9 - 83.3	35.2	14.2 - 71.7	36.6
$\sum_{16}$*HAP-uri* (µg l^{-1})	0.19 - 1.78	0.51	0.09 - 2.10	0.68	0.23 - 2.33	0.83
Benzo [a] piren (µg l^{-1})	0.01 - 0.36	0.05	0.01- 0.09	0.04	0.02 - 0.25	0.06

$\sum_7 carHAP/\Sigma_{16} HAP \cdot 100$ - The percentage of possibly carcinogens compounds;
HAPMm/HAPMM - the concentration ratio of low molecular weight hydrocarbon (2-4 aromatic rings) relative to the high molecular weight (4-6 aromatic rings);
Total BaP_{eqv} - total equivalent toxicity of benzo(a)pyrene.

Total polycyclic aromatic hydrocarbon content (Σ_{16} PAHs) in water samples ranged from 0.0932 to 2.325 µg/l, with an average value of 0.642 ± 0.400 µg/l (Fig. 1.2.4.27). In 65% of samples analyzed concentration are <0.6 µg/l, a value accepted as indicative of moderate pollution (Gonzalez, 2006 and Zakaria, 2002). The level of PAHs pollution recorded in 2013 is significantly lower compared to that in the period 2006-2012 (Fig. 1.2.4.28). High concentration was determined for phenanthrene, anthracene, benzo(a)anthracene and benzo(k)fluoranthene, average values of these compounds exceeding the maximum permitted by Order No.161/2006.

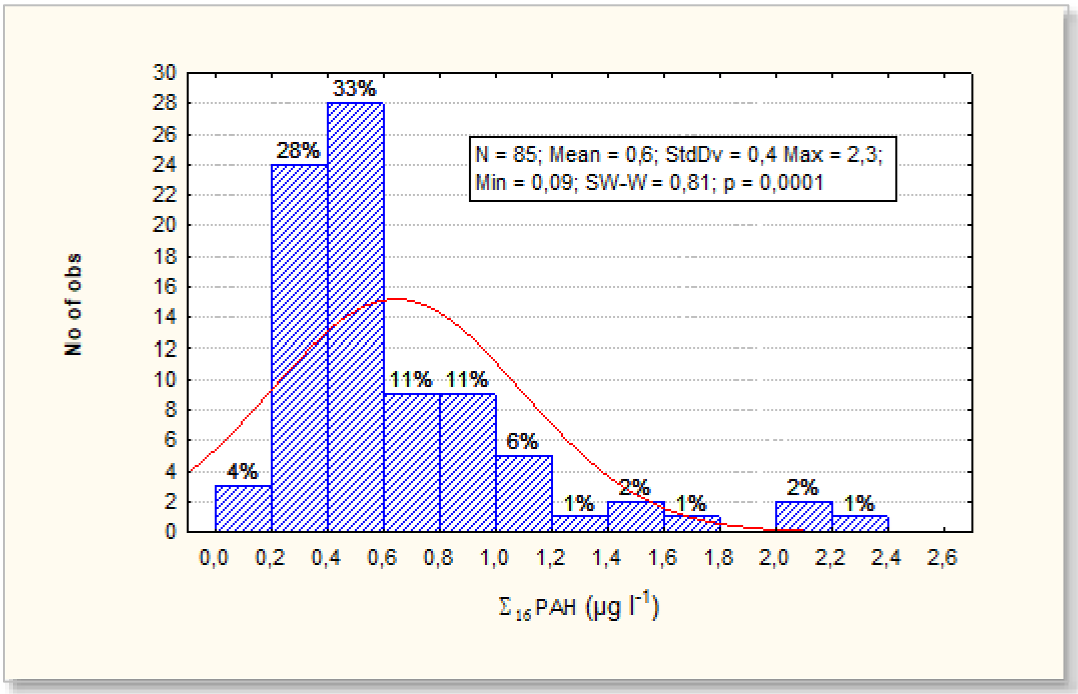


Figure 1.2.4.27. Histogram of total content of polynuclear aromatic hydrocarbons - Σ_{16} PAHs (µg/l) in the Romanian Black Sea waters in 2013.

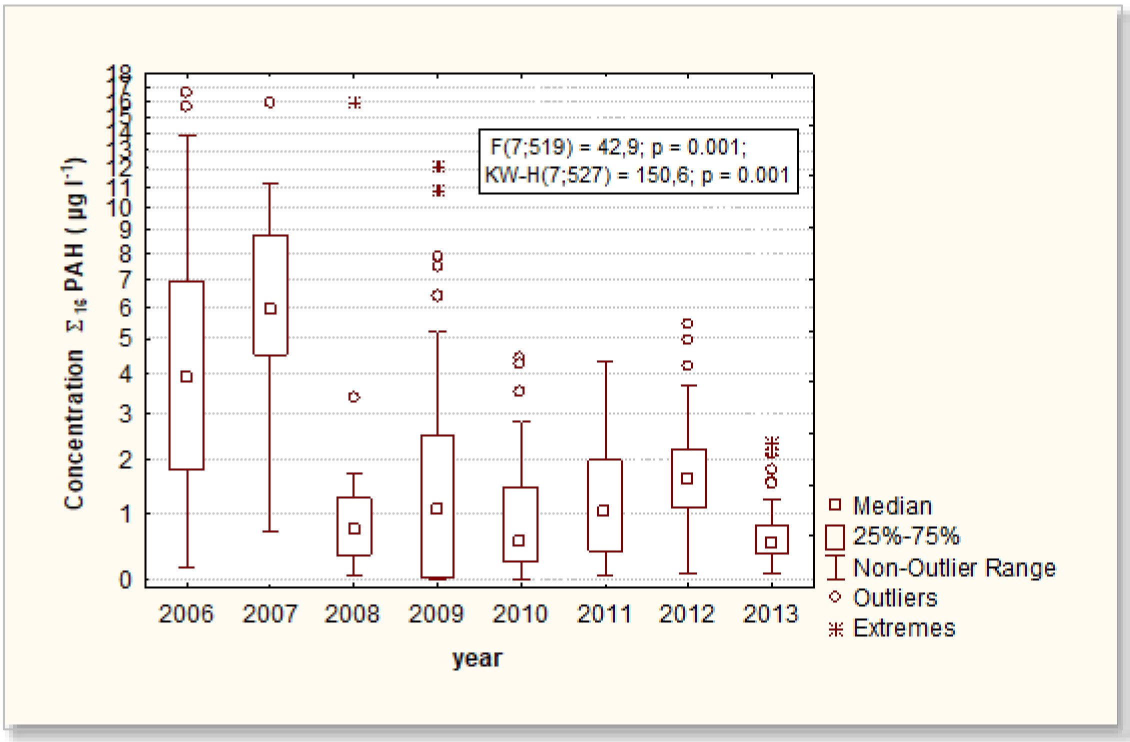


Figure 1.2.4.28. Distribution of polynuclear aromatic hydrocarbon concentrations - Σ_{16} PAH (µg/L) in the Romanian Black Sea waters during period 2006–2013.

Frequency of 88% of the report **HAPMm/HAPMM> 1** in marine waters show the presence of low molecular weight hydrocarbons (2-3 aromatic rings), indicative for oil or petroleum products pollution. Generally, PAHs of petroleum origins are more abundant in the water column due to their solubility (Farrington et al., 1983). Thus, the results of 2013 monitoring shows that phenanthrene - HAPMm (3 aromatic rings) is the dominant compound in marine waters with concentration in the range from 0.0020 to 0.4747 µg/l.

In conclusion, the level of water pollution recorded in 2013 is significantly lower compared to period of 2006-2007 and continuing trend of polynuclear aromatic hydrocarbons concentration decreasing in recent years (2008-2012). The low total toxicity equivalent of benzo(a)pyrene - Total B(a)Peqv (µg/l) and the concentration of benzo(a)pyrene not exceeding the maximum permissible limit of 0.05 µg/l established by Regulation (EC) no. 105/2008 indicates a low level of carcinogenic polycyclic aromatic hydrocarbon in all water samples.

1.2.4.2. PAHs in the bottom sediments

Methodical approaches to the assessment PAHs

According to the recommendations, the marine bottom sediments can be classified into three categories depending on the total content of PAHs:

- slightly polluted (ΣPAHs <250 µg/kg)
- polluted (ΣPAHs from 250 to 500 µg/kg)
- highly polluted (ΣPAHs > 500 µg/kg).

The degree of the PAHs anthropogenesis is usually estimated as the ratio of so-called "technogenic" PAHs to the "natural" ones. High molecular PAHs with a large number of aromatic rings are considered as technogenic ones, and low molecular PAHs with the 2-3 aromatic rings are natural ones. Polycyclic aromatic hydrocarbons formed under natural conditions are characterized by the dominance of relatively low molecular PAHs, whereas the concentration of macromolecular compounds is low. LMW/HMW Indexes: low molecular weight PAHs (2-3 rings) / high molecular weight PAHs (4-6 rings)). Values LMW/HMW <1 suggest PAH contamination pyrolytic origin, but more "technogenic" origin.

International Agency for Research on Cancer (IARC) has classified seven PAHs: (benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene) as probable (2A) and possible (2B) carcinogens. Benzo(a)pyrene is the only one PAH out of the sixteen determined polyarenes for which the toxicological data for the calculation of the carcinogenicity factor are available. Therefore, to assess PAHs total toxicity, the total B(a)Peqv was calculated as total equivalent of concentration by benzo(a)pyrene, using the toxicity equivalent (TE) for each PAH (Table 1.2.4.13), according to the formula:

$$\text{Total B}(a)P_{eqv} = \sum_{\mathrm{i}} \mathrm{C_i} \times TE_i$$

where: C_i - concentration of the respective PAHs µg/kg; TE_i - the toxicity equivalent of the corresponding PAHs.

Table 1.2.4.13. PAHs toxicity equivalent.

Compound	TE	Compound	TE
Acenaphthalene	0.001	Benzo(a)antracene	0.100
Acenaphthene	0.001	Chrysene	0.010
Fluorene	0.001	Benzo(b)fluranthene	0.100
Phenantren	0.001	Benzo(k)fluranthene	0.100
Antracene	0.010	Benzo(a)pyrene	1.000
Fluoranten	0.001	Indeno(1,2,3-cd)pyrene	0.100
Pyrene	0.001	Dibenzo(a,h)antracene	1.000
Benzo(g,h,i)perylene	0.010		

Indices PAHs

Possible sources of PAH emissions to the environment can be established through the use of indexes, which are the ratio of the concentrations of PAHs in some object. It is assumed that the ratio Fl/(Fl+Py) <0.4 indicates the pollutions by polyarenes of petroleum origin. The values of this ratio within the range from 0.4 to 0.5 are typical for the pollution by combustion products of liquid fuel and oil, >0.5 indicates pollutions that will occur as a result of combustion of kerosene, coal, creosote, etc. Ratio An/178 (Anthracene/(Anthracene+Phenanthrene)) may also characterize the nature of the PAHs formation in the environment. Ratio An/178 <0.1 indicates the PAHs formation as a result of low temperature processes (oil) while Ratio An/178 >0.1 indicates a dominance of combustion processes at the PAHs formation. Ratio BaA/228 (Benzo(a)Anthracene/(Benzo(a)Anthracene+Chrizen)) <0.2 indicates pollutions of bottom sediments by PAHs of petroleum origin, values from 0.2 to 0.35 points to a mixed pollution source (oil or combustion) while values >0.35 indicates pollution by polarizes formed as a result of paralytic processes. Ratio IP/IP+BghiP (Indeno(1,2,3-cd)pyrene/(Indeno(1,2,3-cd)pyrene+Benzo(g,h,i)perylene)) <0.2 indicates a petroleum origin of PAHs, values from 0.2 to 0.5 points - to liquid fossil fuel combustion and values >0.5 – suggest grass, wood and coal combustion. The calculated ratios indicate on anthropogenic sources of PAHs, as result of emissions of the products of incomplete combustion of hydrocarbons. In some cases, the ratio of the contents of polycyclic aromatic hydrocarbons (Fl/Fl+Py, An/178, IP/IP+BghiP and Baa/228) are not consistent with each other as sources of PAH emissions may be different, random and irregular.

Romania-2009

PAHs analysis indicates the presence of 11 hazardous organic contaminants in marine sediments in 2009 (naphthalene, acenaphthylene, fluorene, acenaphthene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene). Among individual PAHs in July 2009 the highest average concentration recorded for Pyrene (500 µg/kg), Phenanthrene (428.67 µg/kg) and Chrysene (324.67 µg/kg), (Fig.1.2.4.29).

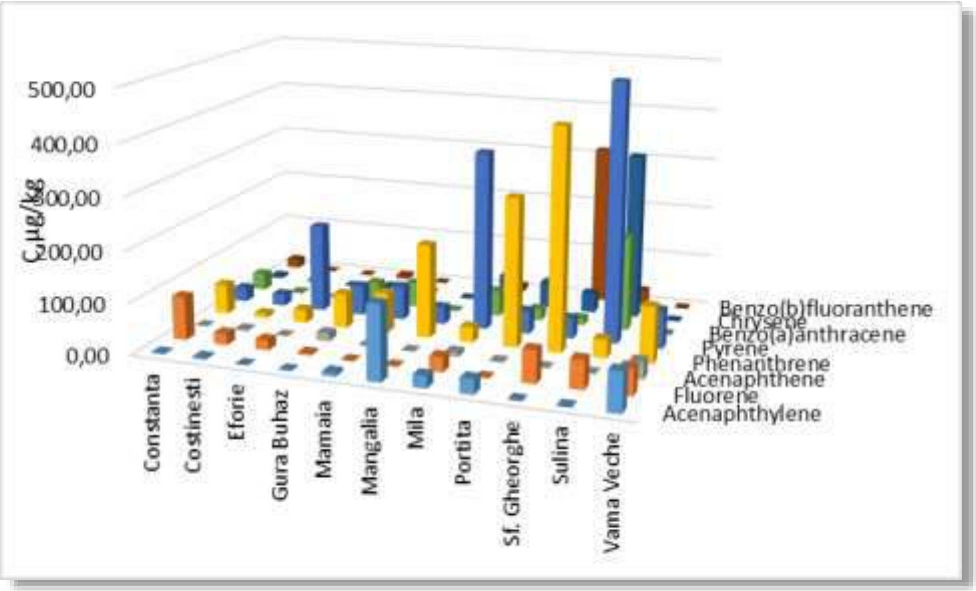


Figure 1.2.4.29. The average concentration of the PAHs in bottom sediments of the Romanian part of the Black Sea in July 2009.

Among individual PAHs in Autumn 2009 the highest average concentration noted for Benzo(b)fluoranthene (560 µg/kg) and Fluoranthene (456 µg/kg), (Fig. 2.4.30).

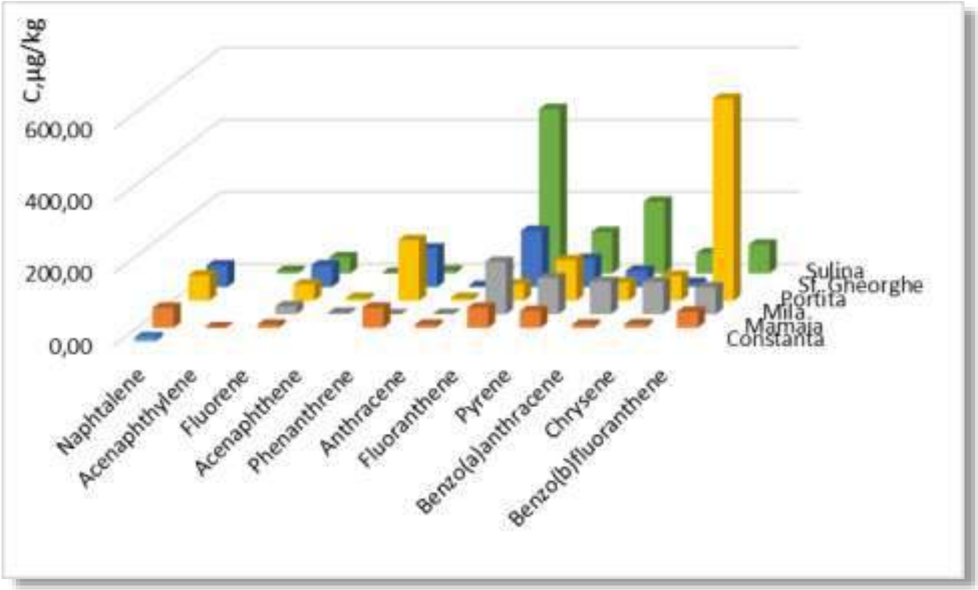


Figure 1.2.4.30. The average concentration of the PAHs in bottom sediments of the Romanian part of the Black Sea in Autumn 2009.

Ukraine-2009

The average concentration of organic polluting substances in bottom sediments in the Kerch Strait and Northern-Western Shelf of the Black Sea in 2009 in many cases was over established MAC (Table 1.2.4.14). The level of pollution by different PAHs usually was higher in the Strait.

Table 1.2.4.14. Average concentration of organic pollutants in bottom sediments in the Kerch Strait and NW Shelf of the Black Sea in 2009.

Pollution substances	Unit	Range of concentration	Average value		MAC
			NWS open sea	Kerch channel	
Polycyclic Aromatic Hydrocarbons (PAHs)					
Naphtalene	µg/kg	7.4 - 90	50	34	
Acenaphthylene	µg/kg	1.8 – 7.0	4.5	5	
Acenaphthene	µg/kg	1.8 – 10.2	5.2	4.8	
Fluorene	µg/kg	30 - 79	40	45	
Phenanthrene	µg/kg	138 - 368	**170**	**229**	45
Anthracene	µg/kg	0.9 – 9.7	4.2	7.3	50
Fluoranthene	µg/kg	20 - 239	**87**	**122**	15
Pyrene	µg/kg	10 - 127	54	75	
Benzo(a)anthracene	µg/kg	1.4 - 164	**39**	**45**	20
Chrysene	µg/kg	6.5 - 107	**45**	**61**	20
Benzo(b)fluoranthrene	µg/kg	4.1 - 131	81	77	
Benzo(k)fluoranthrene	µg/kg	9.0 - 188	**76**	**84**	25
Benzo(a)pyrene	µg/kg	4.8 - 86	**35**	**46**	25
Indeno(1,2,3cd)pyrene	µg/kg	5.1 - 243	**84**	**49**	25
Dibenzo(a,h)anthracene	µg/kg	1.0 - 36	14	10	
Benzo(g,h,i)perylene	µg/kg	6.1 - 250	**85**	**51**	20

Priority PAHs in bottom sediments are present at essential concentration that are an direct consequence of permanent chronic pollution. From 16 PAHs in the greatest concentration was found Phenanthrene and Fluoranthene (Fig. 1.2.4.31). The concentration of all observed PAHs exceeds the Norms.

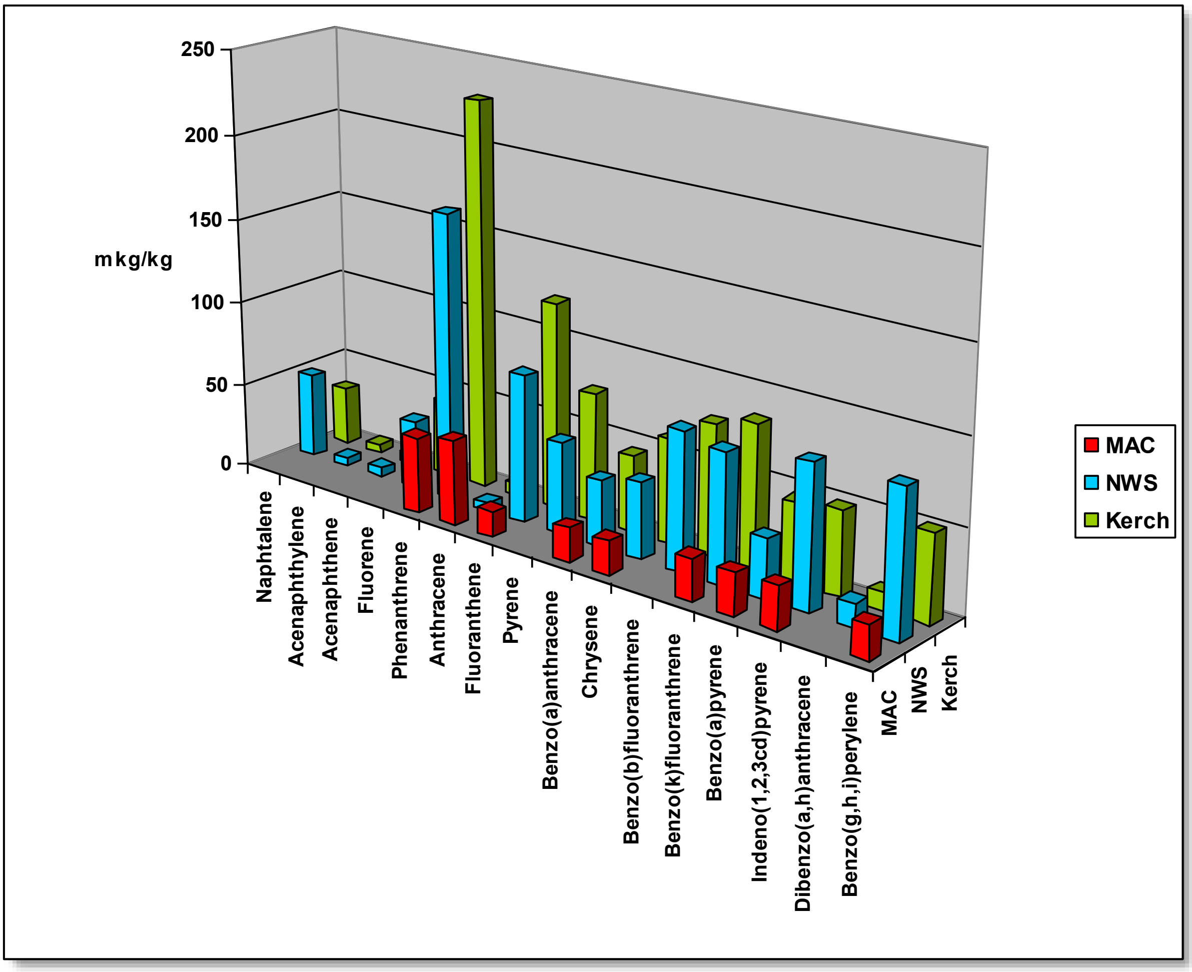


Figure 1.2.4.31. The average concentration of the PAHs in the bottom sediments of the Kerch Strait and NW Shelf of the Black Sea in 2009.

The total polycyclic aromatic hydrocarbons content in the bottom sediment samples (n=13) ranged from 285.7 to 1674.6 µg/kg (Table 1.2.4.15, Fig. 1.2.4.32). From all PAHs, the 2-3-ring compaunds contributed to about 70% at stations №4 and 7, while 4-6-ring PAHs accounted for 30%. At one station average concentration of 2-3-rings PAHs contributed to about 30%, while 4-6-rings PAHs accounted for 70% (Fig. 1.2.4.33). Phenanthrene, Fluoranthene, Indeno(1,2,3-cd)pyrene, and Benzo(b)fluoranthene were found as the most dominant compounds.

Table 1.2.4.15. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the bottom sediments of NW Shelf in 2009.

№ of station	Σ PAHs, µg/kg	Σ cancinogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, µg/kg	Total PAHs index
4	456.6	14	2.24	12.1	4.13
5	1674.6	46	0.26	161.2	5.47
6	987.3	49	0.46	75.6	8.67
98	680	36	0.67	56.2	4.64
99	422.6	30	0.84	24.4	4.39
100	1643.2	42	0.40	164.9	5.82
7	285.7	12	2.98	8.4	4.10
97	1505.2	48	0.51	152.7	4.72
96	633.3	35	0.72	43.4	4.44
1	1002.15	52	0.35	130.8	7.30
2	363.57	28	1.19	29.4	5.61
3	1157.93	56	0.30	175.0	7.31
99t	491.06	47	0.35	41.8	5.58

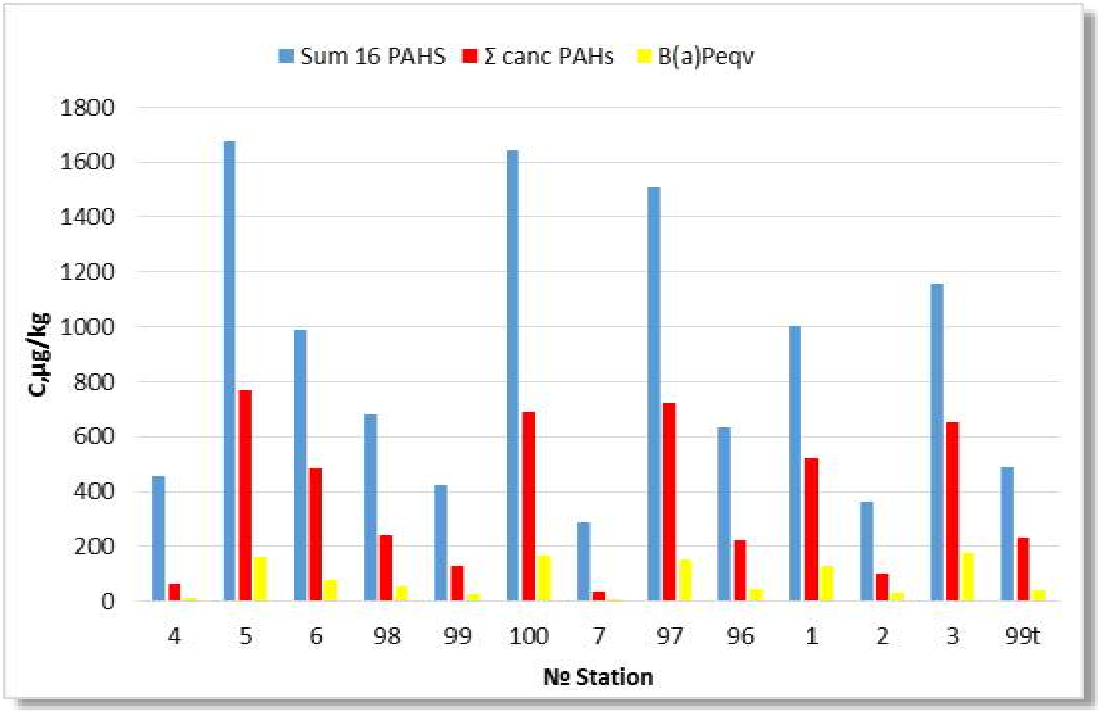


Figure 1.2.4.32. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the bottom sediments of NW Shelf in 2009.

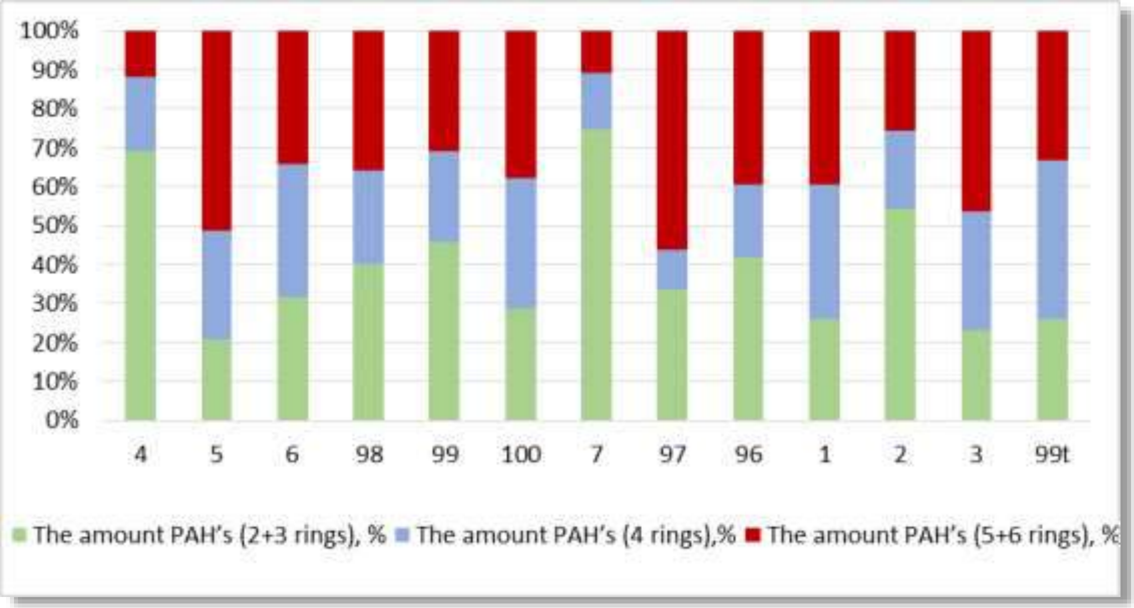


Figure 1.2.4.33. The ratio of 16 PAHs by the number of rings in the molecules in the bottom sediments of NW Shelf in 2009.

In the bottom sediment of the Kerch Strait total content 16PAHs in four collected samples ranged from 332.59 to 526.65 µg/kg (Table 1.2.4.16, Fig. 1.2.4.34). Compounds with 2-3-rings contributed to about 55% at stations №21 and 38, while 4-6-rings have about 45%. At other stations the average concentration of the 2-3-rings lowered to about 32%, while 4-6-rings PAHs occupied till 68% (Fig. 1.2.4.35). Phenanthrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene and Benzo(g,h,i)perylene were found as the most dominant compounds.

Table 1.2.4.16. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the bottom sediments of the Kerch Strait in 2009.

№ of station	Σ PAHs, µg/kg	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, µg/kg	Total PAHs index
21	369.12	22	1.28	17.5	5.82
28	526.65	51	0.46	50.7	7.27
38	332.59	28	1.16	24.6	5.69
39	506.46	47	0.57	24.5	7.21

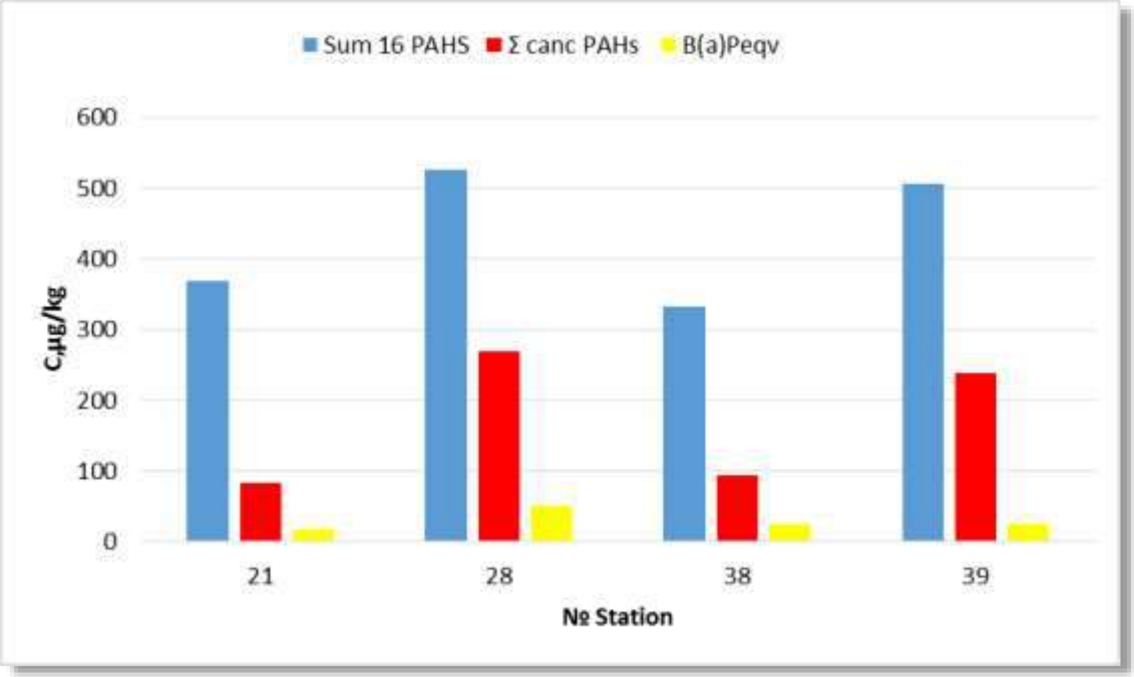


Figure 1.2.4.34. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the bottom sediments of NW Shelf in 2009.

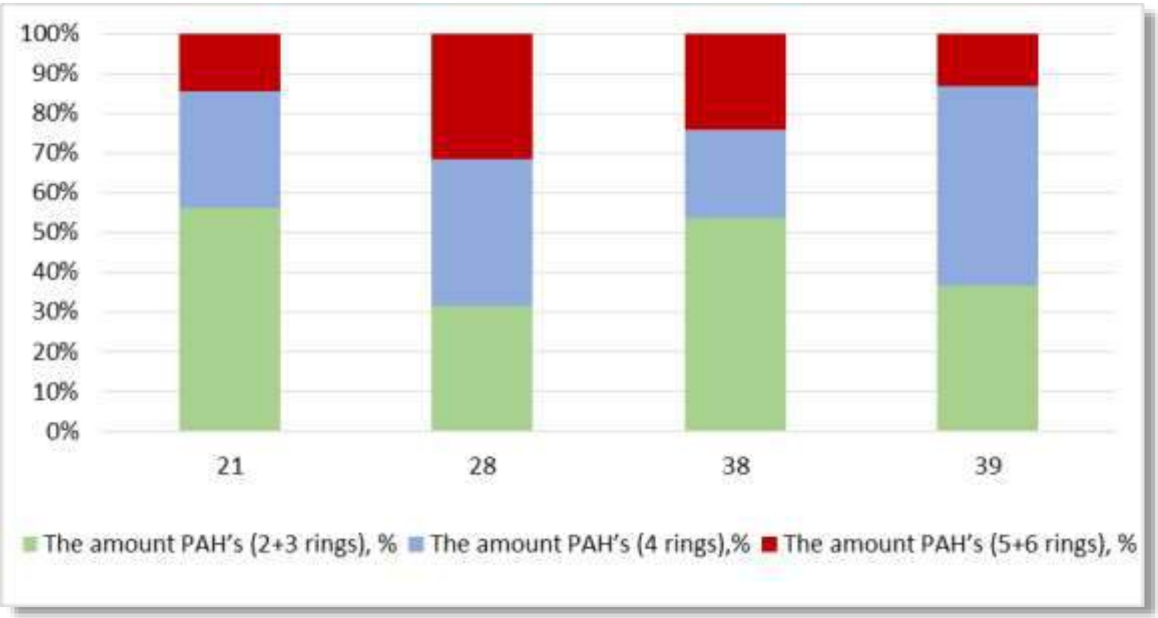


Figure 1.2.4.35. The ratio of 16 PAHs by the number of rings in the molecules in the bottom sediments of Kerch Strait in 2009.

Romania-2010

In the bottom sediments of the Romanian coastal area all 16 priority hazardous organic contaminants (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)antracene, chrysene, benzo(b)fluorantene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(g,h,i)perylene, dibenzo(a,h)antracene and indeno(1,2,3-c,d)pyrene) were analyzed in 2010 four times. The sum of PAHs concentration varied between seasons about two times (Fig. 1.2.4.36).

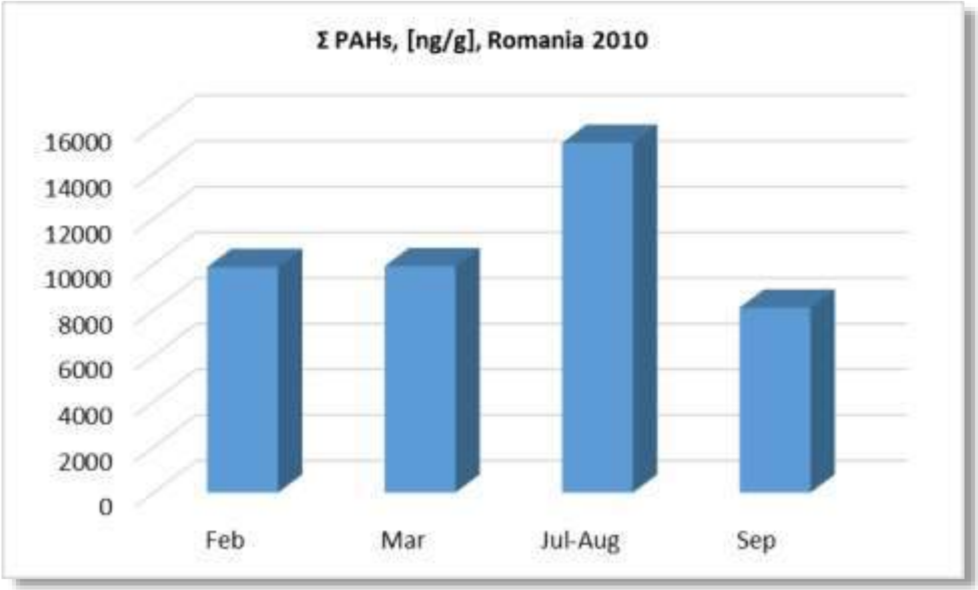


Figure 1.2.4.36. The sum of 16 PAHs concentration in the bottom sediments in the Romanian coastal area in 2010.

The total polycyclic aromatic hydrocarbons - ∑16PAH content in bottom sediment samples ranged from 602.23 to 1346.04 µg/kg (Table 1.2.4.17, Fig. 1.2.4.37). From all PAHs, the 2-3-ring PAHs contributed to about 20% except area Portita (58%) and area Sf. Gheorghe (40%), while 4-6-ring PAHs accounted for 80% (Fig. 1.2.4.38). Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Phenanthrene and Naphtalene were found as the most dominant compounds.

Table 1.2.4.17. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the bottom sediments in the Romanian coastal area in February 2010.

Area	Σ PAHs, µg/kg	Σ canc PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, µg/kg	Total PAHs index
Mangalia	1346.04	64	0.25	434.2	10.86
Mila	602.23	53	0.30	188.0	4.83
Portita	830.93	32	1.40	171.9	10.80
Sf. Gheorghe	963.18	46	0.66	286.5	10.08
Sulina	1097.93	53	0.28	286.4	6.80

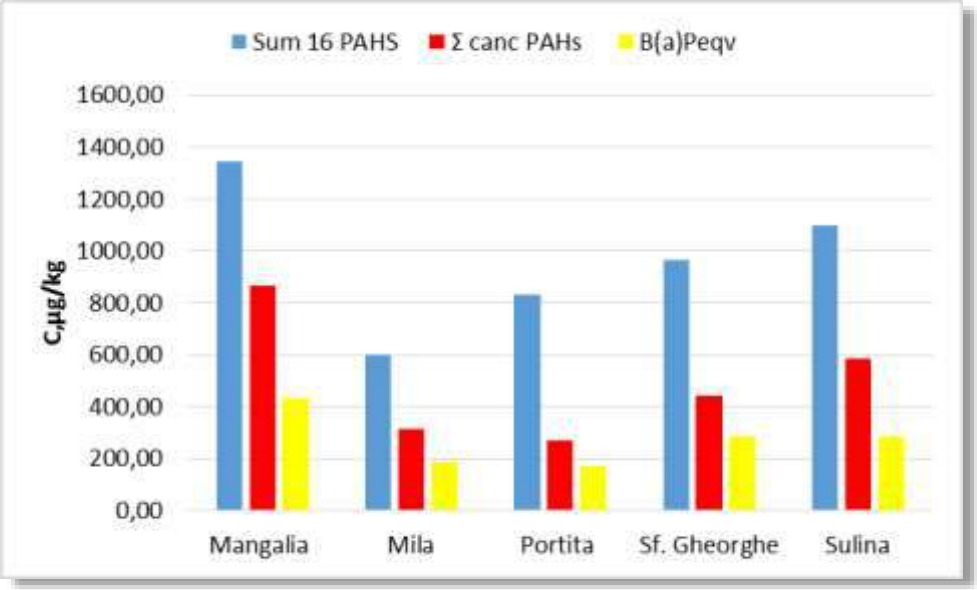


Figure 1.2.4.37. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the bottom sediments of the Romanian coastal area in February 2010.

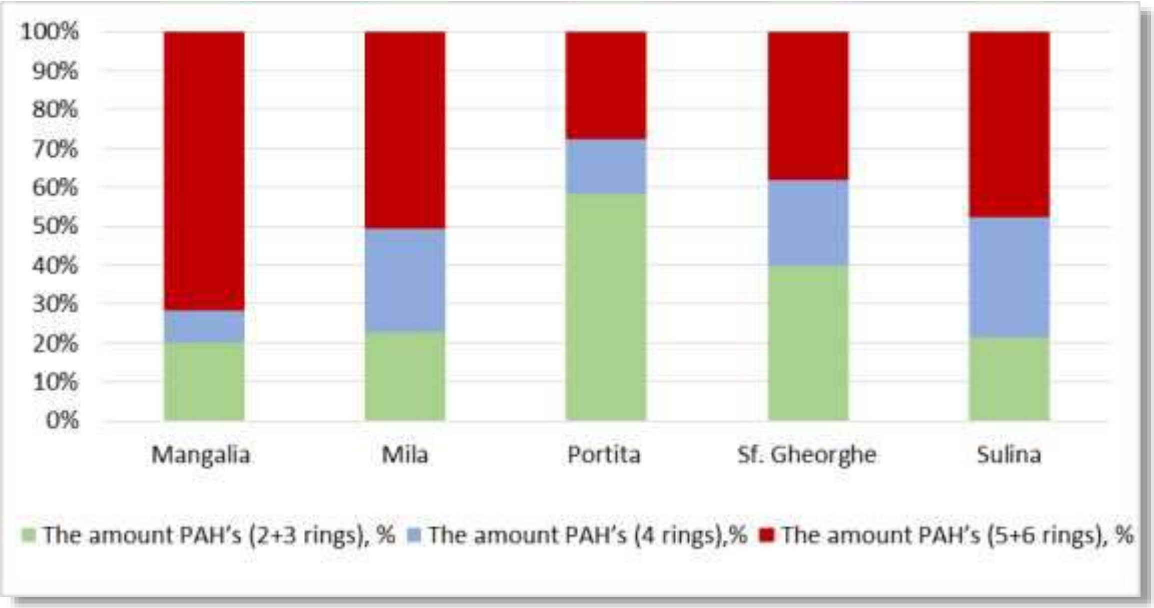


Figure 1.2.4.38. The ratio of 16 PAHs by the number of rings in the molecules in the bottom sediments of the Romanian coastal area in February 2010.

The total polycyclic aromatic hydrocarbons - ∑16PAHs content in bottom sediment samples ranged from 436.24 to 1118.81 µg/kg (Table 1.2.4.18, Fig. 1.2.4.39). From all PAHs, the 2-3-ring PAHs contributed to about 12% except area Portita (45%) and area Sf. Gheorghe (55%), while 4-6-ring PAHs accounted for 88% (Fig. 1.2.4.40). Indeno(1,2,3-cd)pyrene, Benzo(a)pyrene, Fluoranthene and Phenanthrene were found as the most dominant compounds.

Table 1.2.4.18. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the bottom sediments in the Romanian coastal area in March 2010.

Area	Σ PAHs, µg/kg	Σ canc PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, µg/kg	Total PAHs index
Constanta	597.93	64	0.19	160.1	6.57
Mila	436.24	44	0.16	80.4	5.21
Portita	755.46	37	0.85	160.7	9.43
Sf. Gheorghe	597.23	27	1.26	91.5	11.04
Sulina	1118.81	51	0.13	150.0	7.02

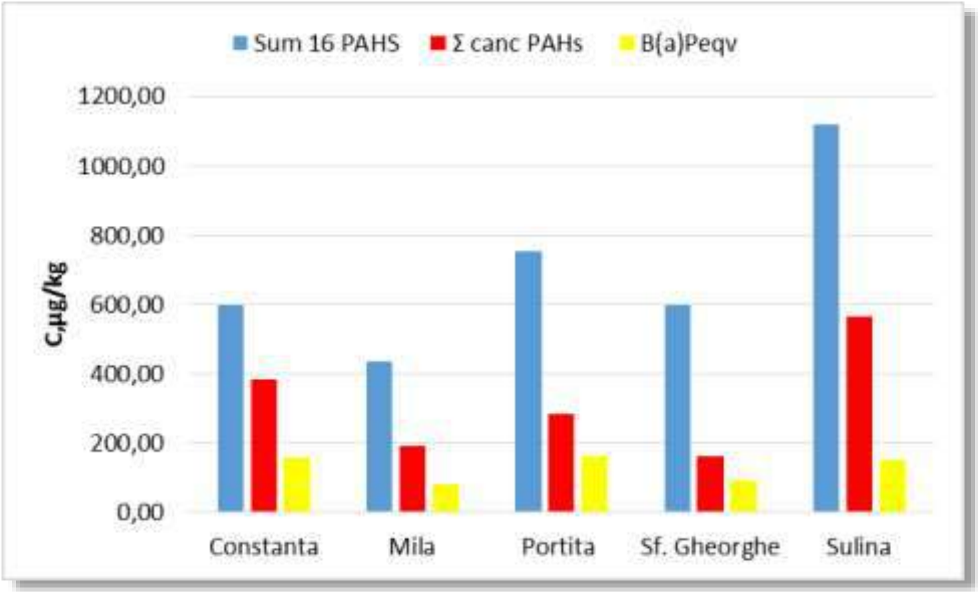


Figure 1.2.4.39. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the bottom sediments of the Romanian coastal area in March 2010.

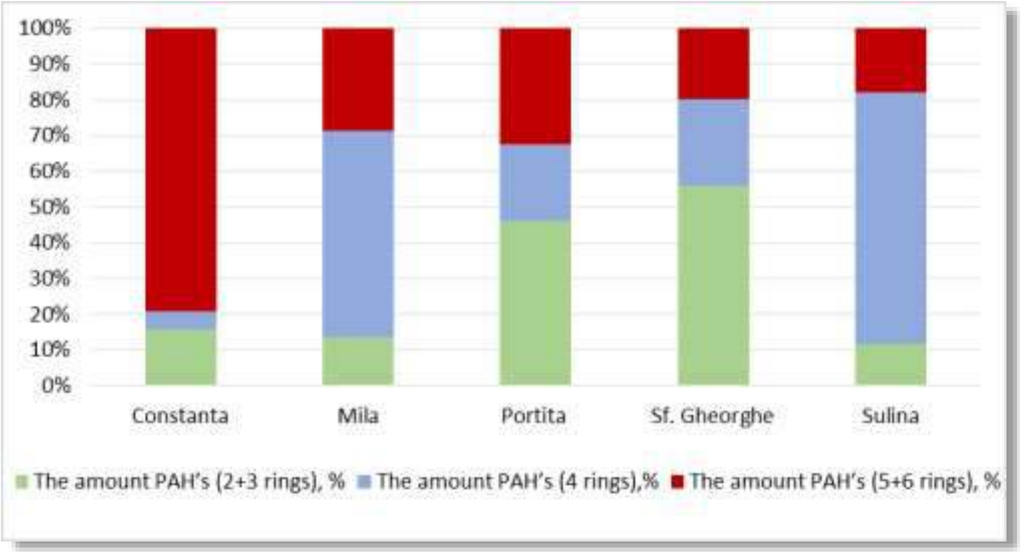


Figure 1.2.4.40. The ratio of 16 PAHs by the number of rings in the molecules in the bottom sediments of the Romanian coastal area in March 2010.

In July-August 2010 in samples of bottom sediments off the Romanian coast the total concentration of 16 PAHs varied from 147.98 to 1785.03 µg/kg (Table 1.2.4.19, Fig. 1.2.4.41). From all PAHs, the 2-3-ring PAHs contributed to about 80% except area Constanta (46%), while 4-6-ring PAHs accounted for 20% (Fig. 1.2.4.42). Naphtalene, anthracene and benzo(a)pyrene were found as the most dominant compounds.

Table 1.2.4.19. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the bottom sediments in the Romanian coastal area in July-August 2010.

Area	Σ PAHs, µg/kg	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, µg/kg	Total PAHs index
Constanta	525.64	40	0.86	122.9	8.42
Costinesti	147.98	11	5.89	1.7	4.66
Eforie	1271.00	3	9.75	7.2	23.39
Mamaia	105.07	7	3.44	1.5	2.62
Mangalia	1785.03	22	2.08	167.1	22.20

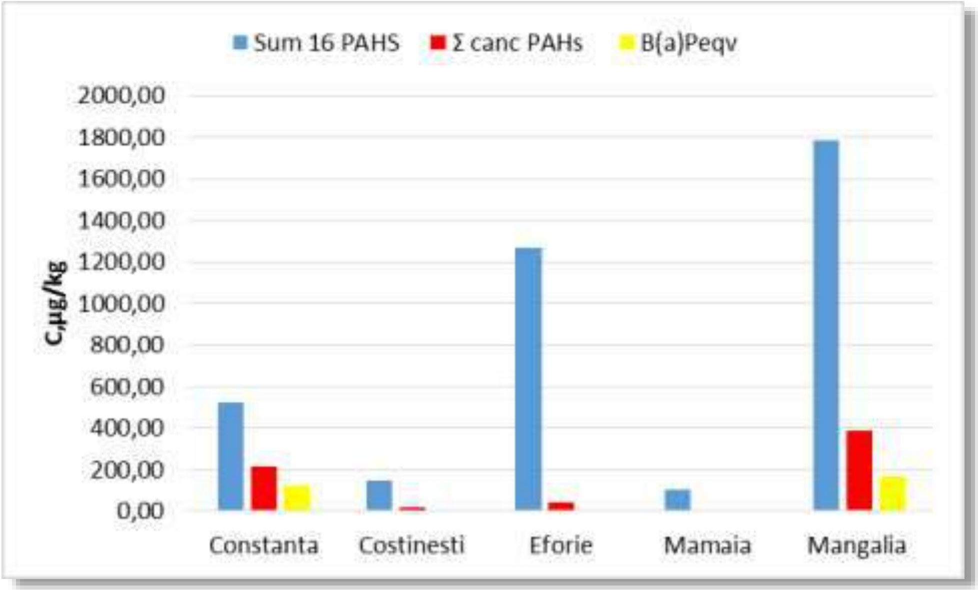


Figure 1.2.4.41. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the bottom sediments of the Romanian coastal area in July-August 2010.

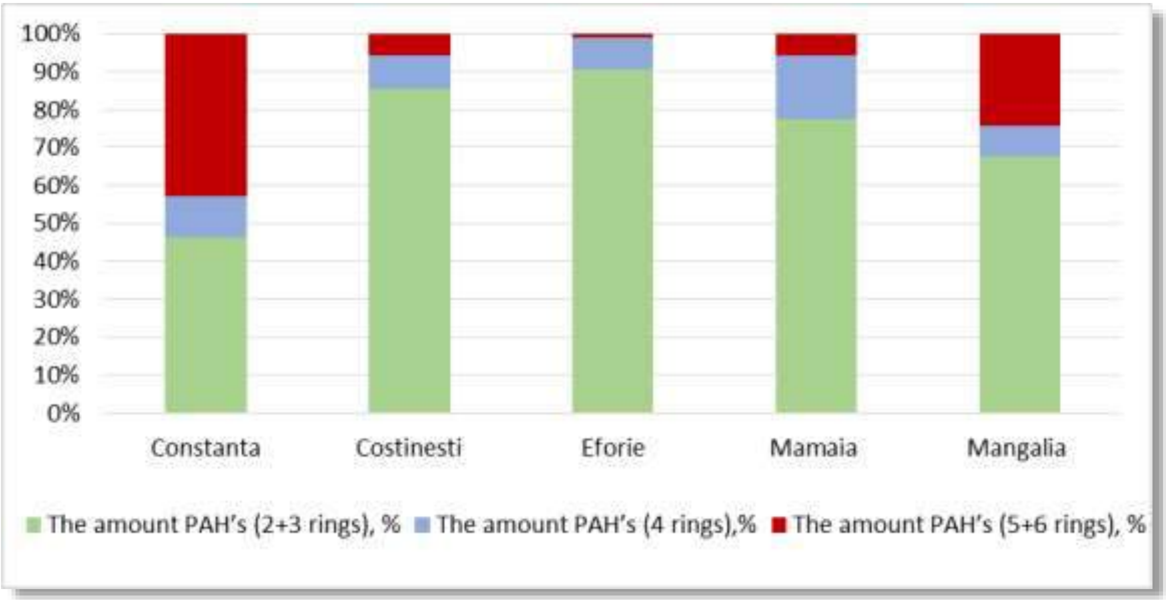


Figure 1.2.4.42. The ratio of 16 PAHs by the number of rings in the molecules in the bottom sediments of the Romanian coastal area in July-August 2010.

In September 2010 in bottom sediments off the Romanian coast the total concentration of 16 PAHs was in the range from 503.57 to 798.00 µg/kg (Table 1.2.4.20, Fig. 1.2.4.43). From all PAHs, the 2-3-ring PAHs contributed to about 45% except area Sulina (23%) and area Gura Buhaz (60%), while 4-6-ring PAHs accounted for 55% (Fig. 1.2.4.44). Fluoranthene, Pyrene, Naphtalene and Phenanthrene were the most dominant compounds.

Table 1.2.4.20. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the bottom sediments in the Romanian coastal area in September 2010.

Area	Σ PAHs, µg/kg	Σ cancirogenic PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, µg/kg	Total PAHs index
Gura Buhaz	563.46	7	1.56	15.6	9.36
Mila	560.74	27	0.89	69.1	9.26
Portita	503.57	29	0.81	42.4	10.10
Sf. Gheorghe	729.06	31	0.79	147.5	11.02
Sulina	798.00	25	0.32	66.6	4.85

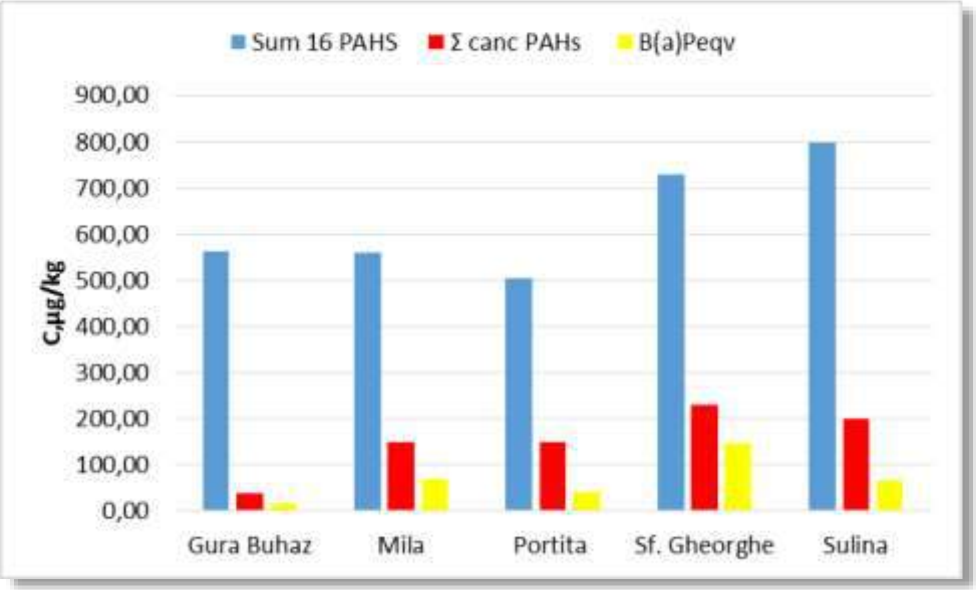


Figure 1.2.4.43. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the bottom sediments of the Romanian coastal area in September 2010.

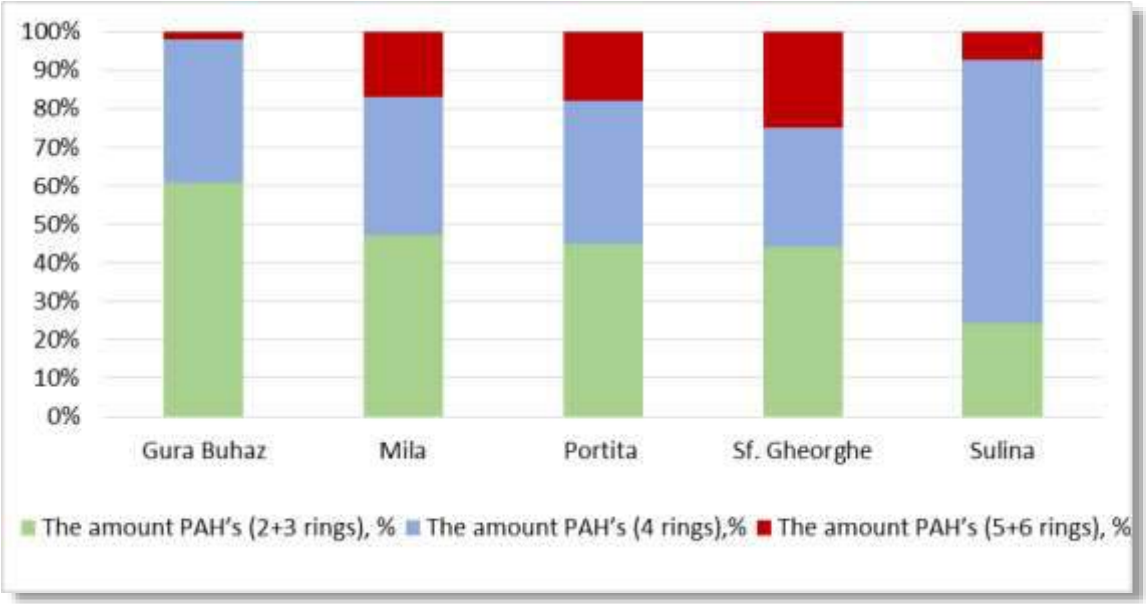


Figure 1.2.4.44. The ratio of 16 PAHs by the number of rings in the molecules in the bottom sediments of the Romanian coastal area in September 2010.

Turkey-2010

During short-time cruise along Turkish coast at 4-11 November 2010 samples of bottom sediments were collected at 26 stations. In major part of the samples the concentration of benzo(a)pyrene was in the range of 0.62-0.67 ng/g, and only in two places near Hopa (1.30 ng/g, station depth 21 m) and Giresun (2.04 ng/g, 25 m) significantly increased (Fig. 1.2.4.45). The average value for the whole set of samples was 0.72 ng/g. Among others PAHs naphthalene, acenaphthylene, acenaphthene, phenanthrene, anthracene, benzo(a)anthracene, chrysene, benzo(k)fluoranthene and benzo(g,h,i)perylene are not recorded in the samples. The concentration fluorene was 0.88 ng/g in one sample, fluoranthene - 1.35 ng/g (1 sample), pyrene – 5 samples with similar level of 1.35 ng/g, benzo(b)fluoranthene – 5 samples in the range of 0.73-2.22 ng/g, dibenzo(a,h)anthracene – 4 samples 1.10-1.12 ng/g and indeno(1,2,3cd)pyrene - 4 samples 1.12-1.18 ng/g. In general the level of polycyclic aromatic hydrocarbons in the Turkish bottom sediments was very low.

Ukraine-2010

PAHs in marine sediments have been monitored in 2010, especially in front of the Danube Delta. The total polycyclic aromatic hydrocarbons - ∑16PAHs content in bottom sediment samples (n=10) ranged from 329.6 to 1093.3 µg/kg (Table 1.2.4.21, Fig. 1.2.4.45). From all PAHs, the 2-3-ring PAHs contributed to about 20% except stations 4 and 6 (33%), while 4-6-ring PAHs accounted for 80% (Fig. 1.2.4.46). Benzo(a)pyrene, Fluoranthene, Pyrene Phenanthrene were found as the most dominant compounds.

Table 1.2.4.21. The results of determination of 16 PAHs in the bottom sediments in front of the Danube Delta.

№ of station	Σ PAHs, μg/kg	Σ canc PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, μg/kg	Total PAHs index
1	809.8	46	0.32	124.7	6.28
2	1093.3	50	0.23	195.1	6.15
3	1078.2	46	0.31	156.8	6.13
4	789.6	47	0.31	121.4	6.14
5	352.7	47	0.31	48.7	6.14
6	462.5	46	0.30	65.5	6.56
7	341.1	40	0.52	37.9	4.72
8	622.5	52	0.25	103.5	8.58
9	329.6	40	0.52	34.9	4.92
10	557.8	43	0.28	69.6	5.47

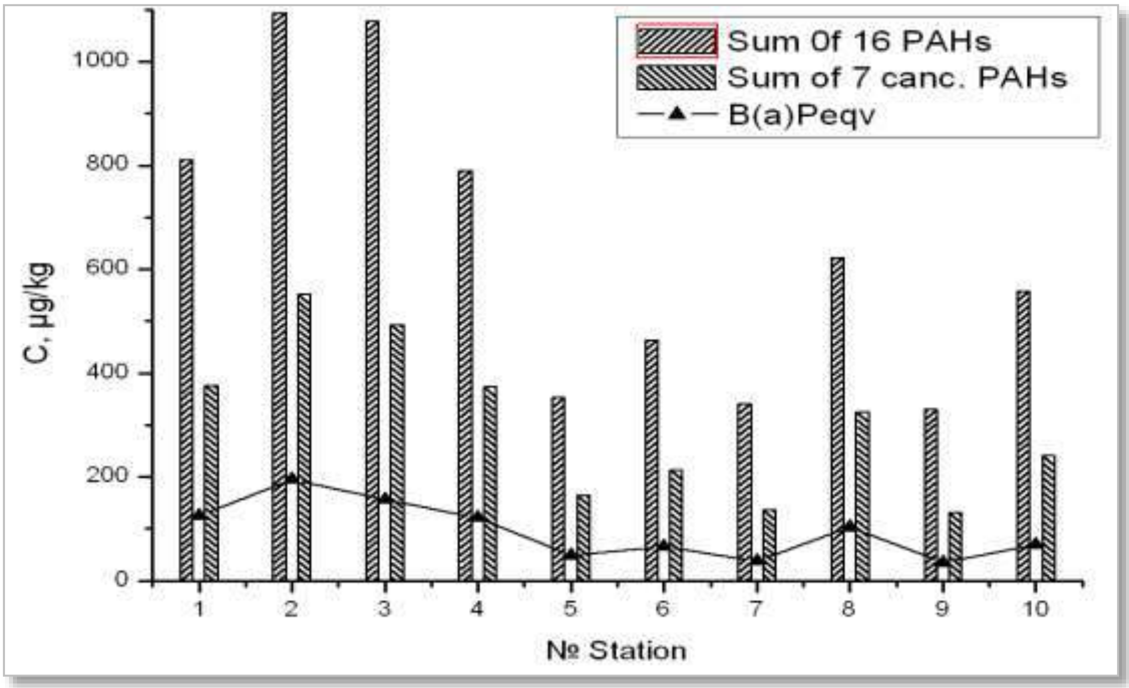


Figure 1.2.4.45. The level of sediment contamination PAHs in front of the Danube Delta in 2010.

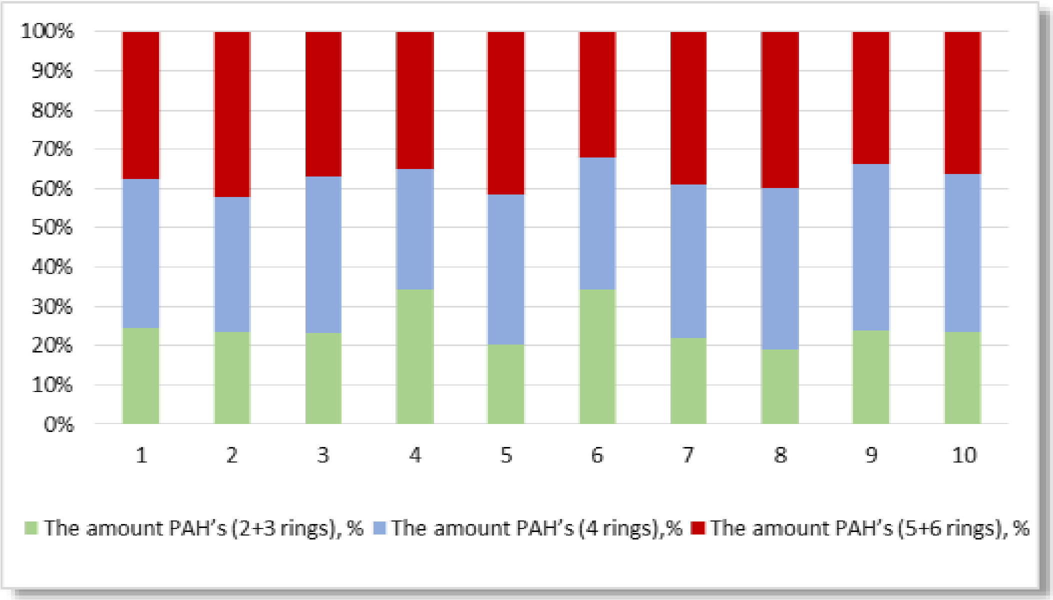


Figure 1.2.4.46. The ratio of 16 PAHs in the bottom sediments in front of the Danube Delta by the number of rings in the molecules.

Romania-2011

The total polycyclic aromatic hydrocarbons - ∑16PAHs content in bottom sediment samples ranged from 321.08 to 3045.24 µg/kg (Table 1.2.4.22, Fig. 1.2.4.47). From all PAHs, the 2-3-ring PAHs contributed to about 80% except area Mila (5%), Portita (55%), Sf. Gheorghe (47%), Sulina (23%), while 4-6-ring PAHs accounted for 20% (Fig. 1.2.4.48). Naphthalene, Anthracene Phenanthrene, Fluoranthene were found as the most dominant compounds.

Table 1.2.4.22. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the bottom sediments in the Romanian coastal area in May 2011.

Area	**Σ PAHs, µg/kg**	**Σ canc PAHs / Σ PAHs·100 (%)**	**LMW/HMW**	**B(a)Peqv, µg/kg**	**Total PAHs index**
Constanta	2229.42	7	20.76	51.4	19.93
Costinesti	321.08	3	18.29	1.4	5.46
Eforie	1593.13	0	12.01	3.6	17.14
Gura Buhaz	563.46	7	1.90	15.6	9.36
Mamaia	444.47	7	1.96	16.9	8.62
Mangalia	2038.28	19	9.18	233.6	32.24
Mila	2592.08	5	0.06	78.8	9.67
Portita	782.76	23	1.51	137.7	11.86
Sf. Gheorghe	814.96	27	0.87	159.1	9.09
Sulina	978.11	32	0.46	132.4	8.21

Area	Σ PAHs, µg/kg	Σ canc PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, µg/kg	Total PAHs index
Vama Veche	3045.24	4	4.80	23.8	14.52

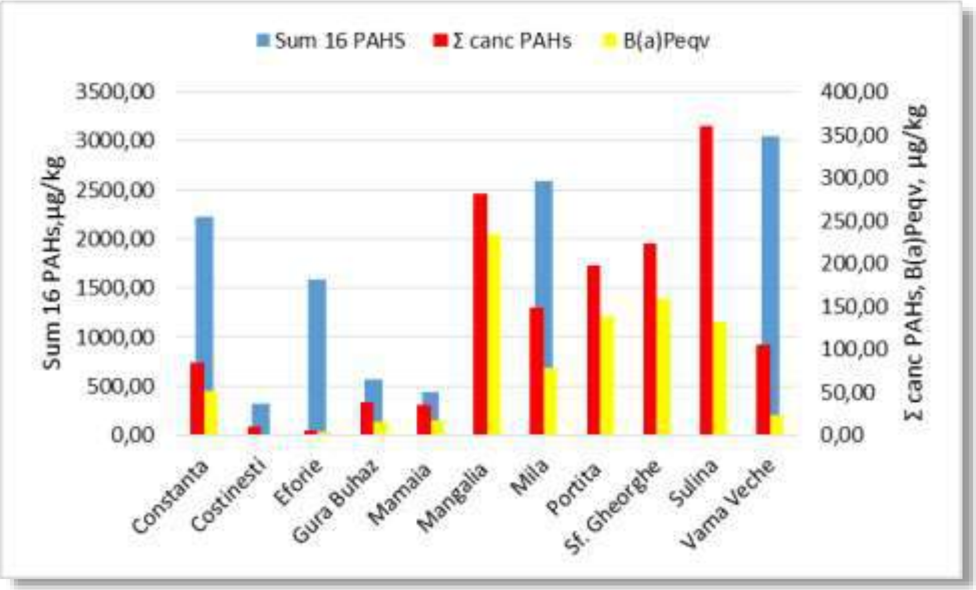


Figure 1.2.4.47. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the bottom sediments of the Romanian coastal area in May 2011.

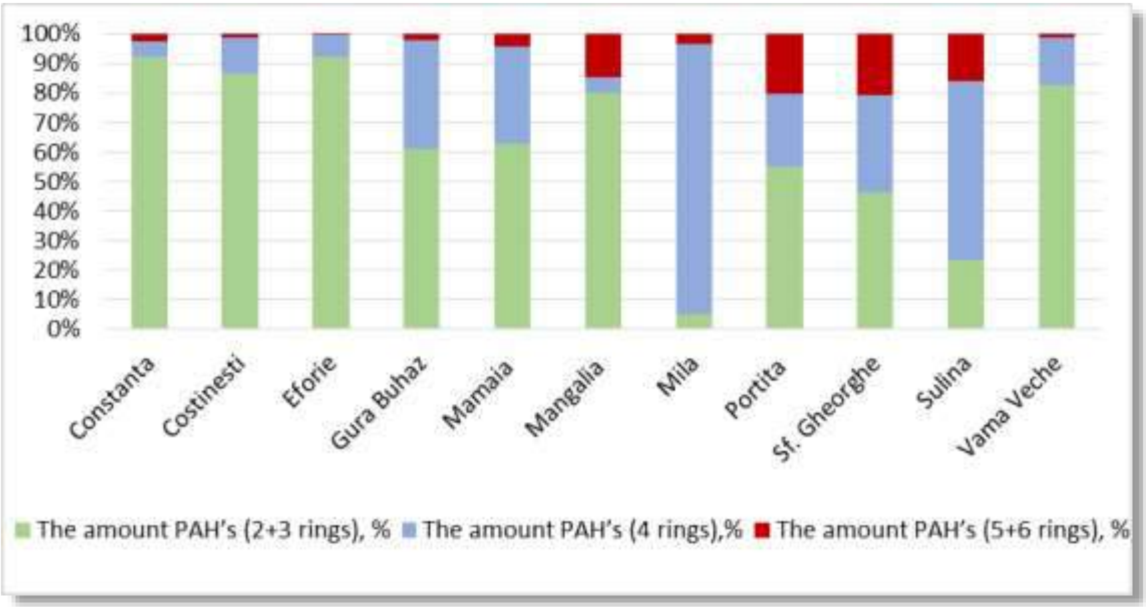


Figure 1.2.4.48. The ratio of 16 PAHs by the number of rings in the molecules in the bottom sediments of the Romanian coastal area in May 2011.

July 2011. The total polycyclic aromatic hydrocarbons - ∑16PAHs content in bottom sediment samples ranged from 220.57 to 2297.91 µg/kg (Table 1.2.4.23, Fig. 1.2.4.49). From all PAHs, the 2-3-ring PAHs contributed to about 90% for area Constanta, Costinesti, Eforie and Vama

Veche, while 4-6-ring PAHs accounted for 10%. From all PAHs, the 2-3-ring PAHs contributed to about 12% for area Mila, while 4-6-ring PAHs accounted for 88%. From all PAHs, the 2-3-ring PAHs contributed to about 55% for area Gura Buhaz, Mamaia and Portita, while 4-6-ring PAHs accounted for 45% (Fig. 1.2.4.50). Naphthalene, Anthracene, Fluoranthene, Phenanthrene were found as the most dominant compounds.

Table 1.2.4.23. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the bottom sediments in the Romanian coastal area in July 2011.

Area	Σ PAHs, µg/kg	Σ canc PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, µg/kg	Total PAHs index
Constanta	973.93	6	7.74	37.7	13.95
Costinesti	220.57	3	7.43	0.8	3.31
Eforie	2022.50	1	12.64	5.1	21.97
Gura Buhaz	341.76	6	1.19	7.7	4.30
Mamaia	207.14	7	1.38	6.2	2.33
Mangalia	1654.15	15	3.45	107.1	27.97
Mila	394.51	32	0.16	51.1	3.47
Portita	584.42	25	1.28	106.6	6.43
Sf. Gheorghe	462.31	24	0.63	58.2	3.90
Sulina	483.32	29	0.45	56.6	3.50
Vama Veche	2297.91	2	17.04	4.2	4.69

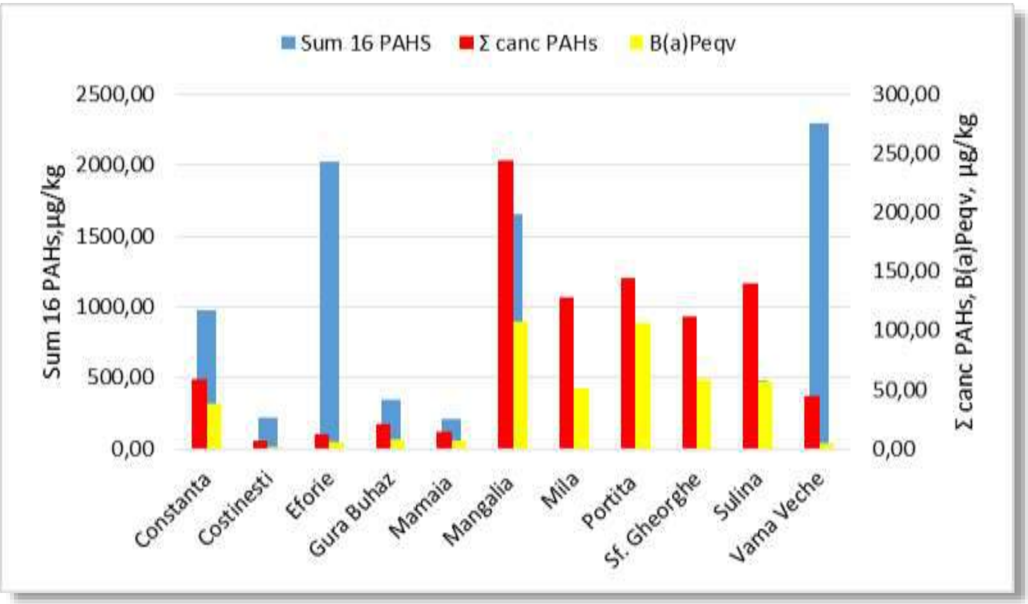


Figure 1.2.4.49. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the bottom sediments of the Romanian coastal area in July 2011.

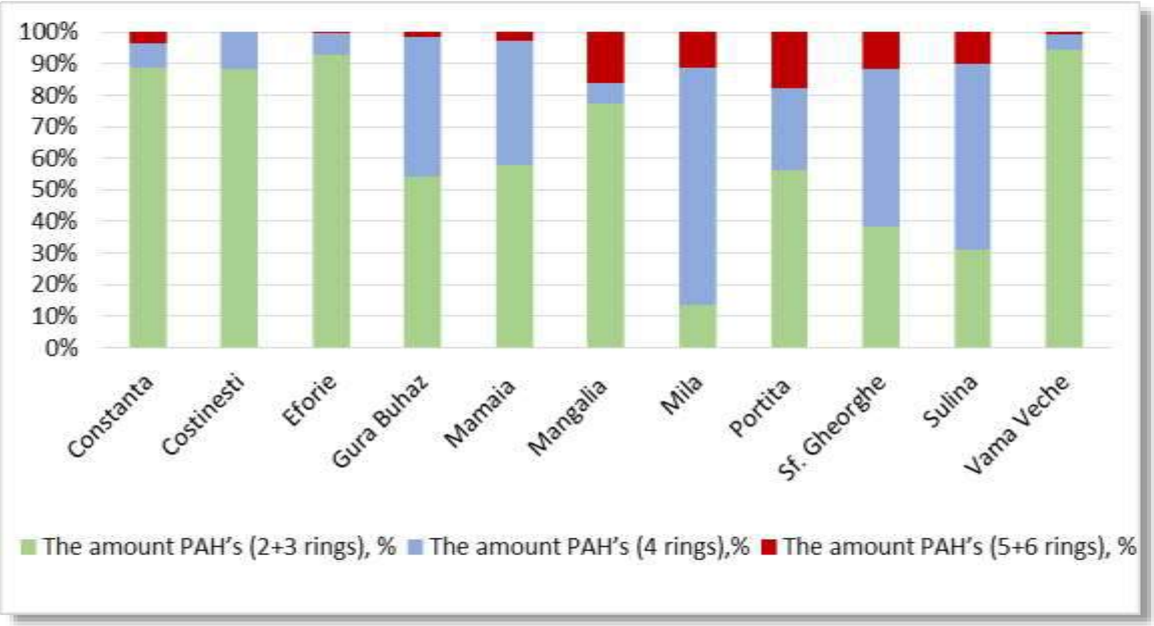


Figure 1.2.4.50. The ratio of 16 PAHs by the number of rings in the molecules in the bottom sediments of the Romanian coastal area in July 2011.

Ukraine-2011

16 polyarenes were identified and determined quantitatively in bottom sediments of the Danube estuarine coast and Odessa region. The results are given in the Table 1.2.4.24, where ΣPAHs is a sum of 16 individual PAHs, Σcarc.PAHs/ΣPAHs 100 - the carcinogenic PAHs percentage to the total PAHs, $B(a)P_{eqv}$ - the total equivalent of toxicity by benzo(a)pyrene.

№ of station	ΣPAHs, µg/kg	Σcarc PAHs/ ΣPAHs·100 %	B(a)Peqv, µg/kg
1	339.4	45	50.2
2	310.2	33	31.9
4	422.9	46	60.9
5	428.7	45	63.0
6	579.3	49	91.8
7	432.8	48	68.2
8	1001.1	39	98.2
9	884.4	43	103.1
10	318.6	37	31.2
11	293.8	37	27.1
16	317.8	37	34.1
17	356.3	40	38.3
18	451.5	43	49.8
24	940.2	43	125.6
25	763.0	42	86.7
26	711.6	40	66.9
28	662.1	40	73.1

Table 1.2.4.24. The results of GC/MS determination of PAHs in bottom sediments of Danube area.

Samples №8, 9 and 24 contains the highest concentration of ΣPAHs. The sum of 16 PAHs at these stations ranged from 884 to 1001 µg/kg. The following individual compounds are dominant at all stations (µg/kg):

- phenanthrene (from 30 to 172)
- fluoranthene (from 30 to 162)
- pyrene (from 30 to 148)
- benzo(a)anthracene (from13 to 105)
- chrysene (from 14 to 85)
- benzo(b)fluoranthene (from 265 to 60)
- benzo(k)fluoranthene (from 16 to 56)
- benzo(a)pyrene (from 17 to 79).

Maximum allowable contaminant levels (MAC) of polyarenes in marine bottom sediments are not regulated in Ukraine. However, according to the norms accepted in former time in the Netherlands, MAC in bottom sediments for benzo(a)pyrene is 25 µg/kg, for chrysene is 20 µg/kg and for fluoranthene – 15 µg/kg.PAHs with the 4-6 aromatic rings are dominant in the bottom sediments from the estuarine Danube area and Odessa region (Fig. 1.2.4.51).

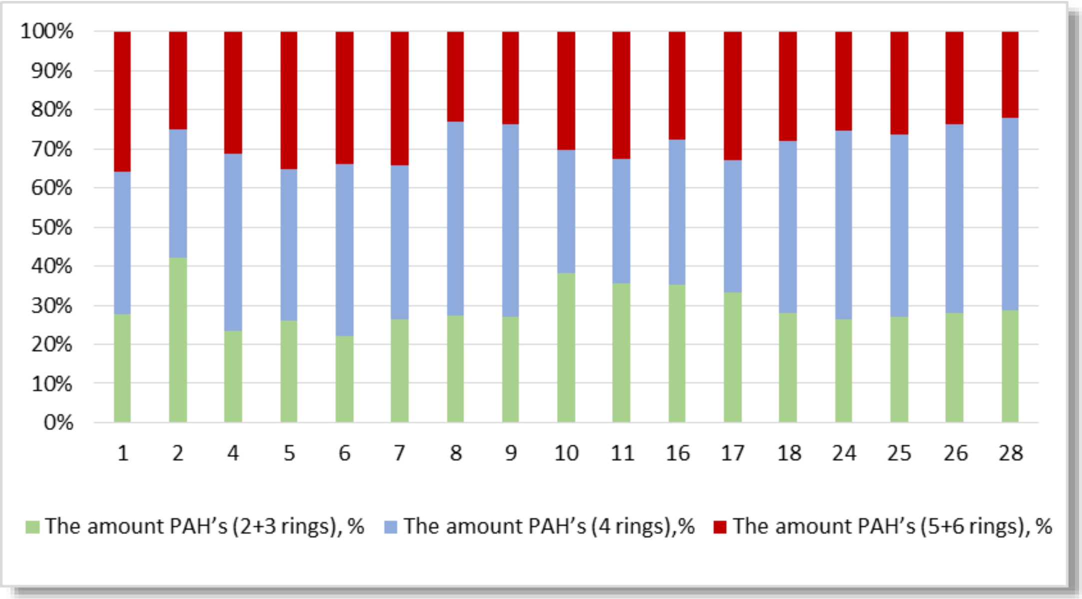


Figure 1.2.4.51. The ratio of 16 PAHs in the bottom sediments of Danube estuarine by the number of rings in molecule (the number of stations is located along the vertical axis; the PAHs percentage of on the number of rings is located along abscissa).

The obtained data indicate that the most significant technogenic PAHs pollution was at stations №8, 9 and 24. Figure 1.2.4.52 shows the distribution of total concentrations of 16 PAHs, seven carcinogenic PAHs and total toxicity equivalent by B(a)Peqv mkg/kg in each station. The amount of carcinogenic PAHs in samples of sediments №№1-10 varies from 100 to 400 µg/kg, representing 33% and 49% of the total concentration of polyarenes. The largest percentage of carcinogenic PAHs was in bottom sediments from stations №6 and №7 (49% and 48%, respectively). The calculated total B(a)Peqv at sampling stations was within the range 27.1 to 125.6 µg/kg. The largest B(a)Peqv was found at stations №№9 and 24 (103 and 125.6 µg/kg).

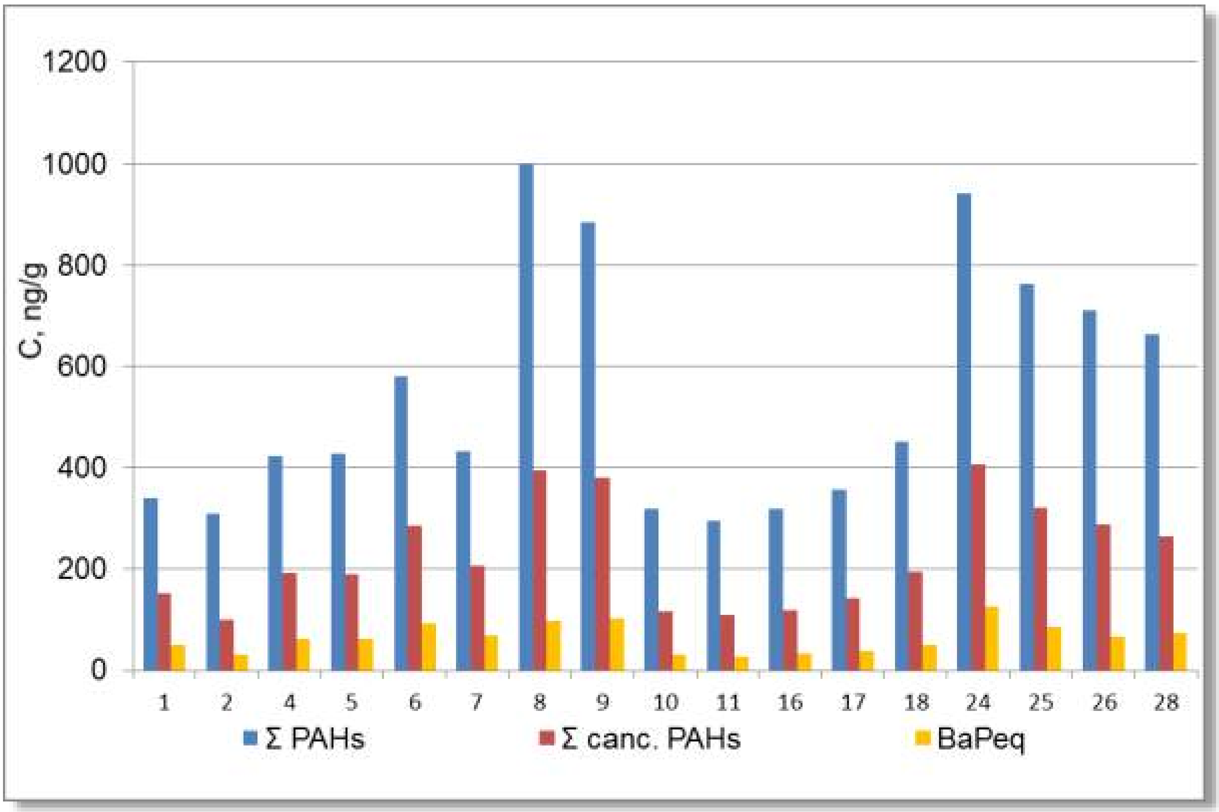


Figure 1.2.4.52. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the bottom sediments from the Danube estuary in 2011.

Possible sources of the PAHs emission into environment can be found through the use of indices, which are the ratio of concentrations of some PAHs in the sample. The values of the ration Fl/Fl+Py (fluoranthene/fluoranthene+pyrene) vary from 0.40 to 0.60 (Fig. 1.2.4.52). For samples from Danube estuarine ares the An/178 ratios varies from 0.1 to 0.4 and the values of the BaA/228 ratio varies from 0.4 to 0.65. The established relations IP/IP+BghiP for the studied bottom sediments vary within the range from 0.1 to 0.5 (Fig. 1.2.4.53). The results of research can be indicators of anthropogenic pressure to the shallow waters in the Danube area exerted by industrial and municipal waste emission and economic activity of the ports and dumping.

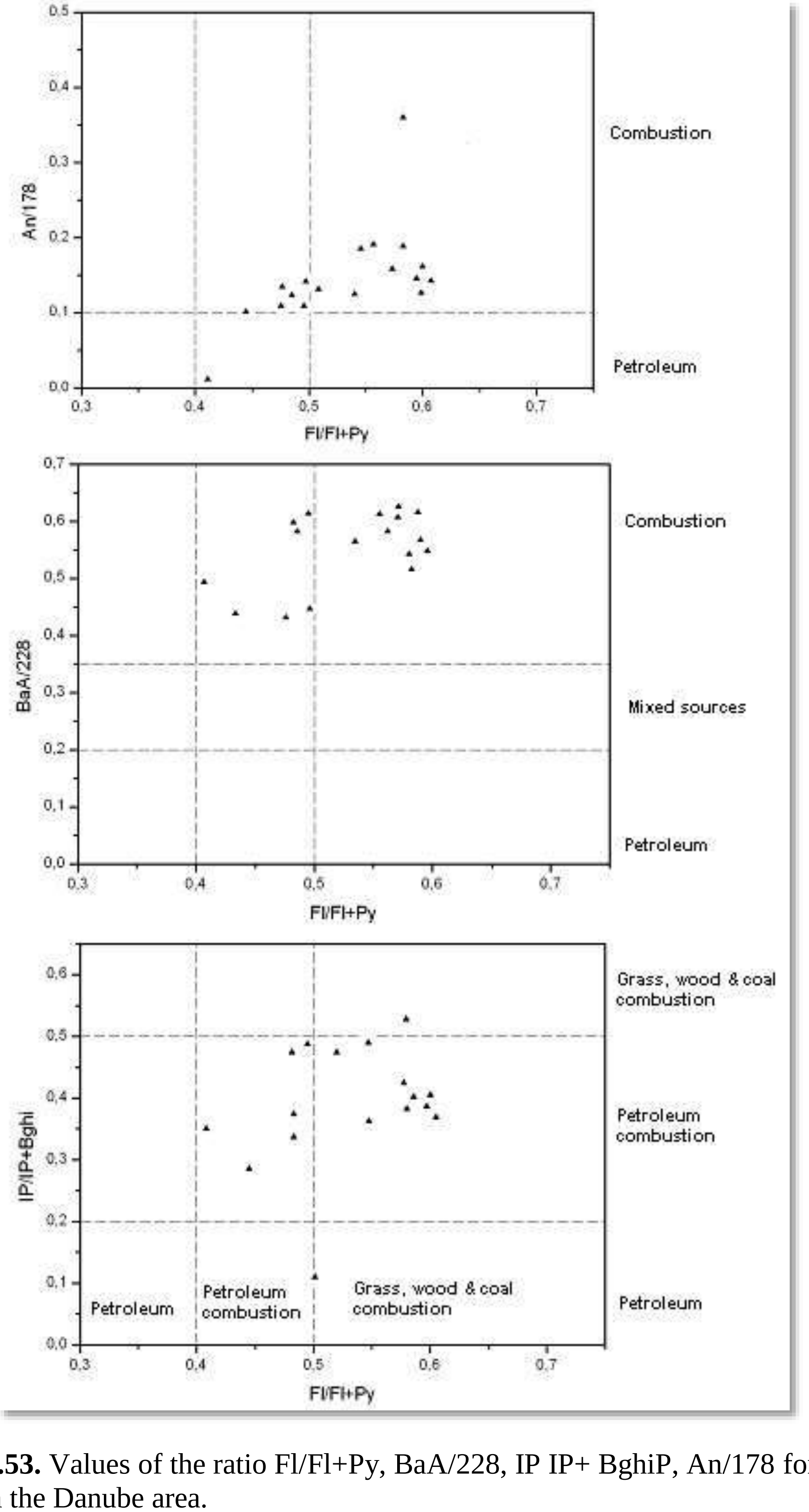


Figure 1.2.4.53. Values of the ratio Fl/Fl+Py, BaA/228, IP IP+ BghiP, An/178 for the stations from the Danube area.

Romania-2012

March-April 2012. The total polycyclic aromatic hydrocarbons - ∑16PAHs content in bottom sediment samples (n=4) ranged from 304.26 to 20994.81 µg/kg (Table 1.2.4.25, Fig. 1.2.4.54).

From all PAHs, the 2-3-ring PAHs contributed to about 10% except area Mamaia (75%) and area Sf. Gheorghe (40%), while 4-6-ring PAHs accounted for 90% (Fig. 1.2.4.55). Fluoranthene, Pyrene, Chrysene and Anthracene were found as the most dominant compounds.

Table 1.2.4.25. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the bottom sediments in the Romanian coastal area in March-April 2012.

Area	Σ PAHs, μg/kg	Σ canc PAHs / Σ PAHs·100 (%)	LMW/HMW	B(a)Peqv, μg/kg	Total PAHs index
Constanta	20994.81	9	0.24	586.4	179.77
Costinesti	3313.17	4	0.06	13.1	14.97
Mamaia	304.26	7	0.71	4.1	12.64
Mangalia	1409.29	6	0.35	6.5	5.96
Mila	5611.30	5	0.30	34.5	28.07
Portita	3939.00	4	0.31	13.9	30.98
Sf. Gheorghe	967.21	4	0.59	6.4	11.86
Sulina	6475.18	1	0.05	15.9	21.83

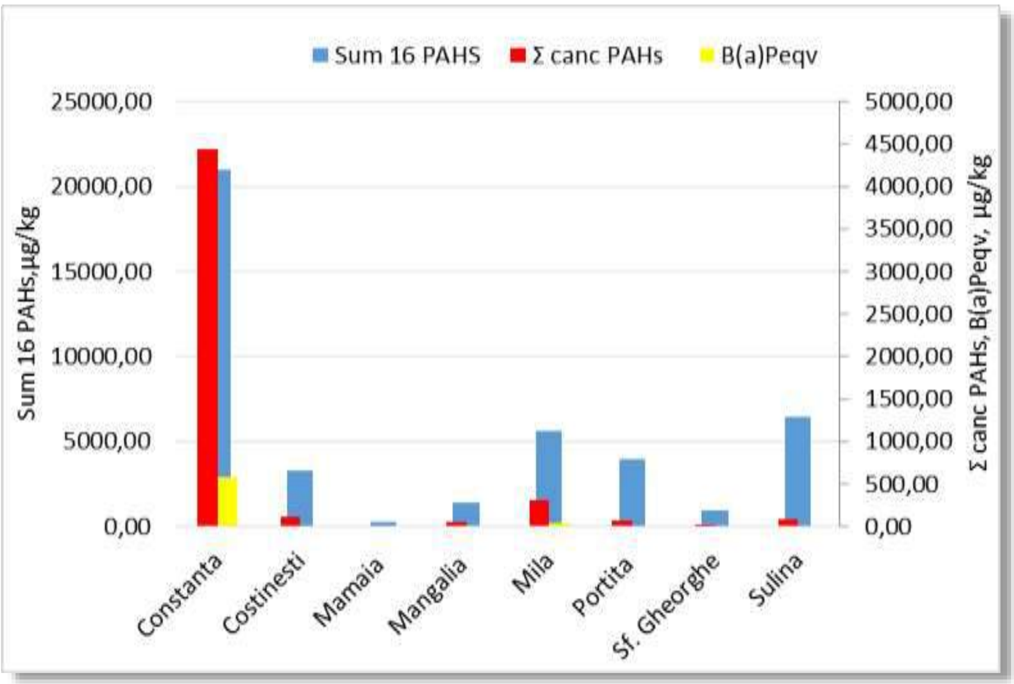


Figure 1.2.4.54. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the bottom sediments of the Romanian coastal area in March-April 2012.

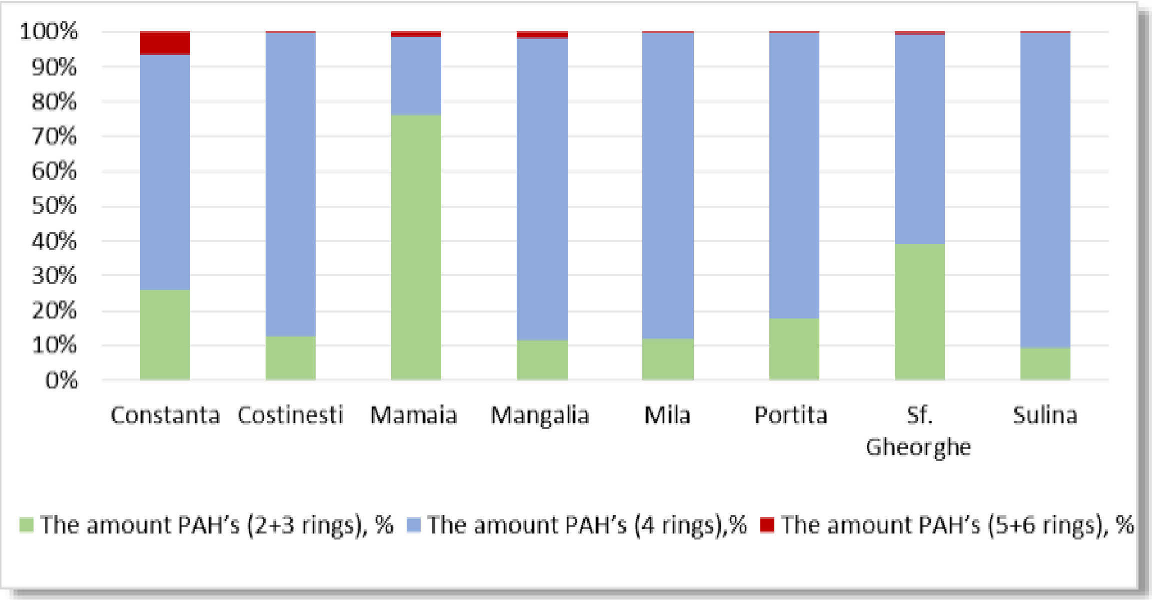


Figure 1.2.4.55. The ratio of 16 PAHs by the number of rings in the molecules in the bottom sediments of the Romanian coastal area in March-April 2012.

October 2012. The total polycyclic aromatic hydrocarbons - ∑16PAHs content in bottom sediment samples (n=4) ranged from 333.57 to 1817.47 µg/kg (Table 1.2.4.26, Fig. 1.2.4.56). From all PAHs, the 2-3-ring PAHs contributed to about 70% except area Sulina (34%) and area near Vama Veche (47%), while 4-6-ring PAHs accounted for 30% (Fig. 1.2.4.57). Phenanthrene, Naphtalene, Fluorene and Fluoranthene were found as the most dominant compounds.

Table 1.2.4.26. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the bottom sediments in the Romanian coastal area in October 2012.

Area	**Σ PAHs, µg/kg**	**Σ canc PAHs / Σ PAHs·100 (%)**	**LMW/HMW**	**B(a)Peqv, µg/kg**	**Total PAHs index**
Constanta	942.86	16	0.53	18.8	12.67
Costinesti	333.57	13	0.54	14.1	4.22
Eforie	518.73	6	0.60	5.9	5.51
Gura Buhaz	1316.37	5	0.81	23.0	4.06
Mamaia	687.35	10	0.69	15.2	4.60
Mangalia	1470.92	8	0.67	36.9	5.71
Mila	1127.35	10	0.48	11.8	7.96
Portita	797.84	14	0.62	15.6	10.57
Sf. Gheorghe	379.50	20	0.56	19.9	5.09
Sulina	563.83	26	0.45	34.9	5.08
Vama Veche	1817.47	21	0.32	36.0	13.24

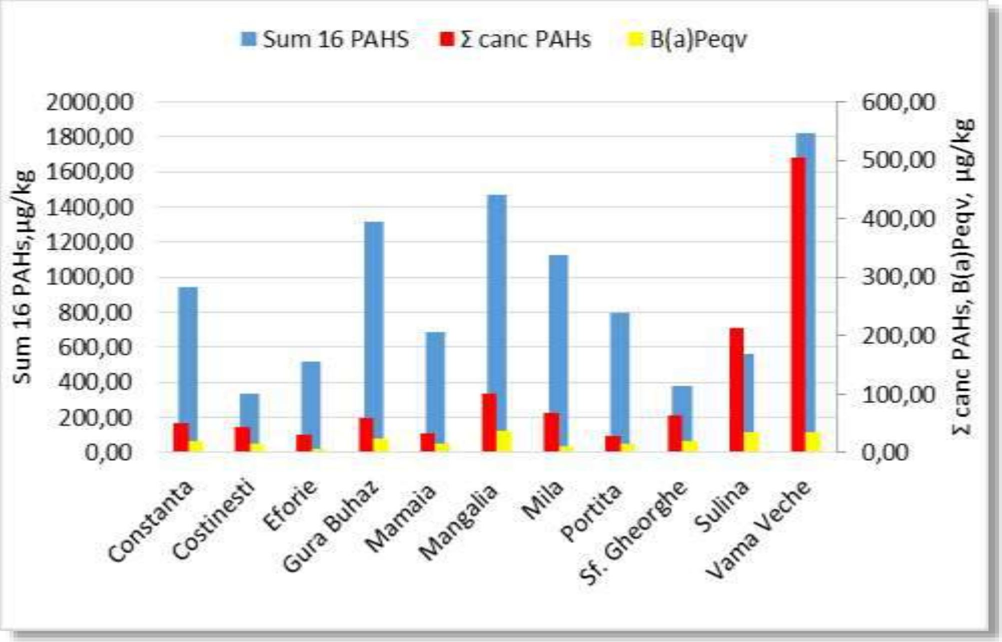


Figure 1.2.4.56. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the bottom sediments of the Romanian coastal area in October 2012.

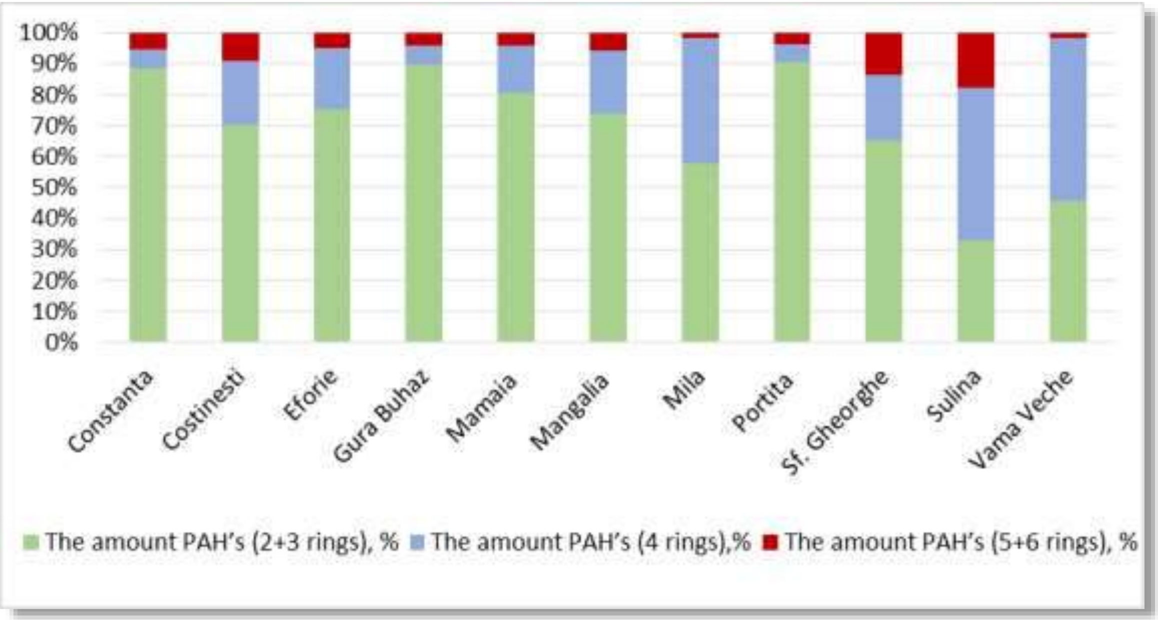


Figure 1.2.4.57. The ratio of 16 PAHs by the number of rings in the molecules in the bottom sediments of the Romanian coastal area in October 2012.

Ukraine-2012

From the 16 priority PAHs in bottom sediments of Zernov's Phyllophora Field (ZPF) in the largest concentrations were present naphthalene, the range of which oscillation was 10.4-32.8 µg/kg with an average value 22.8 µg/kg, which exceeds the value of ecological standard (ES), and fluorantene with range 0.16 – 23.1 µg/kg and the average concentration – 8.7 µg/kg.

From the 8 carcinogenic PAHs (benzo(a)anthracene, Chrysene, benzo(b)fluorantene, benzo(k)fluorantene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene and Benzo(g,h,i)perylene) in higher concentration in the sediments were found Benzo(b)fluorantene and benzo(a)pyrene, which average concentration were 7.95 µg/kg and 5.85 µg/kg, respectively. The average content of other carcinogenic PAHs did not exceed 5 µg/kg.

16 polyarenes were identified and determined quantitatively in bottom sediments of the Zernov's Phyllophora Field. The results are given in the Table 1.2.4.27, where ΣPAHs is a sum of 16 individual PAHs, Σcarc.PAHs/ΣPAHs 100 - the carcinogenic PAHs percentage to the total PAHs, $B(a)P_{eqv}$ - the total equivalent of toxicity by benzo(a)pyrene. The results of calculations of the origin of priority PAHs are present in Table 1.2.4.27 and Fig. 1.2.4.58.

Table 1.2.4.27. Total concentration of 16 priority PAHs and calculation of Indexes describing their origin in the bottom sediments of Zernov's Phyllophora Field in 2012.

Io t.	ΣPAHs, µg/kg	carc. AHs ıg/kg	carc PAHs/ ΣPAHs·100 %	henathrene/ nthracene*	luoranthene/ Pyrene*	a)Peqv, µg/kg
0	29.4	0.6	2	21.8	1.4	0.1
1	78.7	22.5	29	10.2	1.8	5.6
2	73.1	30.0	41	9.5	1.5	7.3
4	54.2	9.0	17	15.6	1.4	2.2
5	75.7	25.2	33	9.1	1.5	5.3
9	73.2	20.2	28	10.0	1.7	5.6
0	150.9	92.0	61	10.3	1.5	23.5
1	88.8	29.6	33	10.2	1.5	9.0
2	73.1	7.4	37	10.2	1.5	8.9
4	43.8	20.0	46	10.5	1.5	5.0
6	14.4	0.1	1	8.5	1.3	0.1
1	105.2	49.6	47	74.8	1.4	13.1
2	153.8	71.3	46	8.2	1.5	24.2
5	107.0	52.3	49	7.9	1.4	17.7
8	48.7	11.2	23	11.3	1.6	3.6
3	174.2	74.1	42	8.2	1.5	24.4
9	72.1	23.9	33	10.4	1.5	7.5
0	71.1	27.6	39	11.6	1.4	7.7
3	153.2	69.2	45	7.9	1.4	23.2
6	54.6	18.1	33	9.9	1.5	5.4
8	54.3	8.5	16	11.9	1.4	2.9
0	58.3	25.0	43	11.9	1.5	7.1

* Value Phenanthrene/Anthracene>10 and Fluorantene/Pyrene<1, indicating the origin of petroleum PAHs, and the ratio Phenanthrene/Anthracene<10 and Fluoranthene/Pyrene>1 indicate anthropogenic emission of PAHs as a result of combustion products.

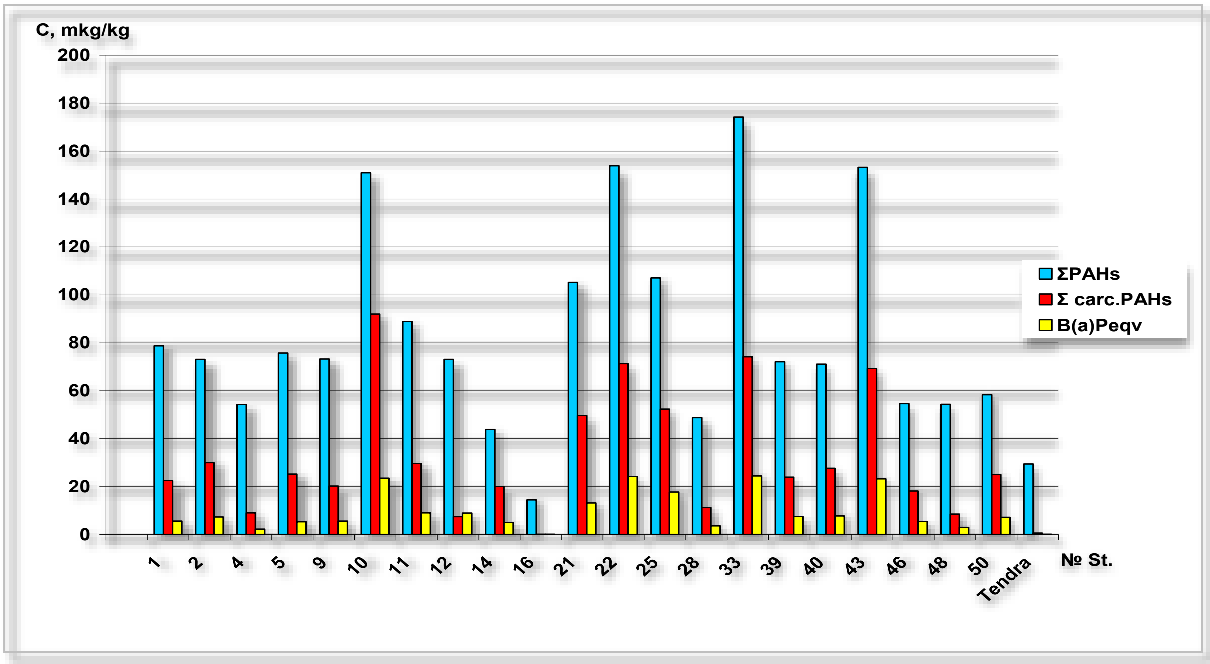
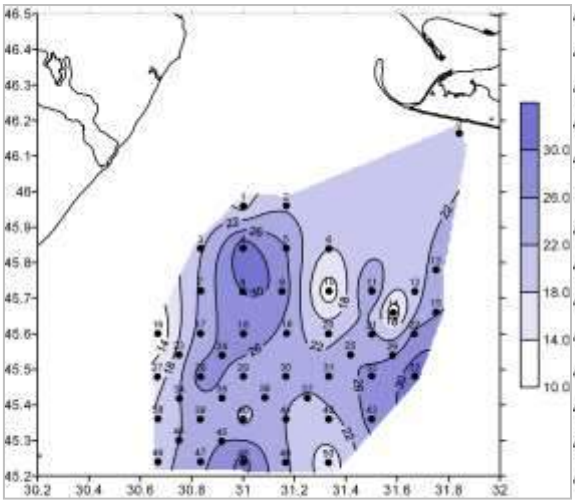
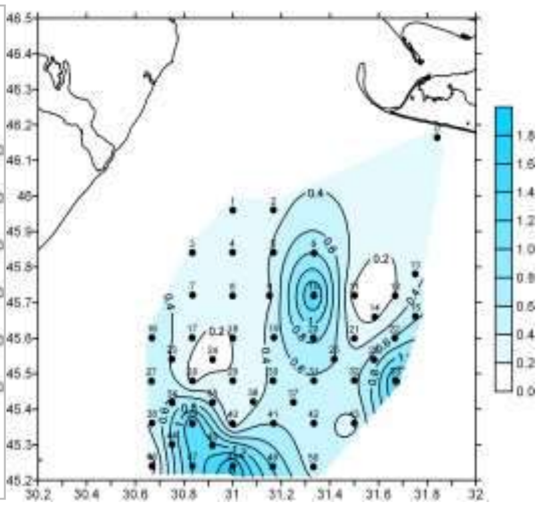


Figure 1.2.4.58. Concentration of the sum of 16 individual PAHs, and 7 carcinogenic PAHs, and total B(a)Peqv in the bottom sediments of Zernov's Phyllophora Field in 2012.

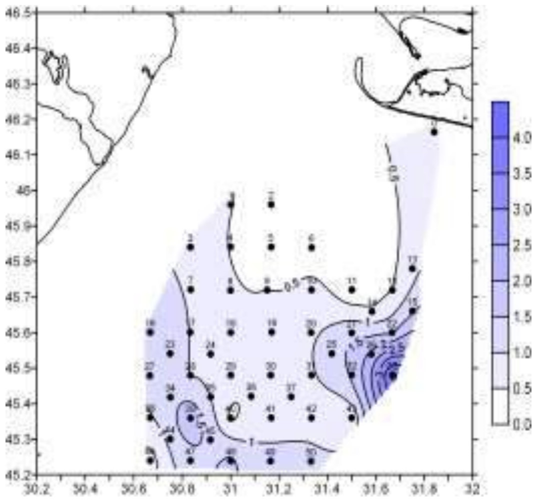
Calculating the index ratios fenanthrene/anthracene and fluorantene/pyrene showed that PAHs in sediments station number 2, 5, 16, 22, 25, 33, 43 and 46 of anthropogenic origin. MAC of PAHs in sediments in Ukraine are not regulated, but under former Netherlands Lists the content of benzo(a)pyrene should not exceed 25 µg/kg. The analysis of sediment samples from 22 stations of the study area showed that the excess of this ratio for BAP or BaPeqv. were not recorded, but at 4 stations in the southeastern part of the ZPF (Stations №10, 22, 33, 43) BaPeqv values ranged from 23 to 24 µg/kg and almost reached the MAC (Fig. 1.2.4.59).



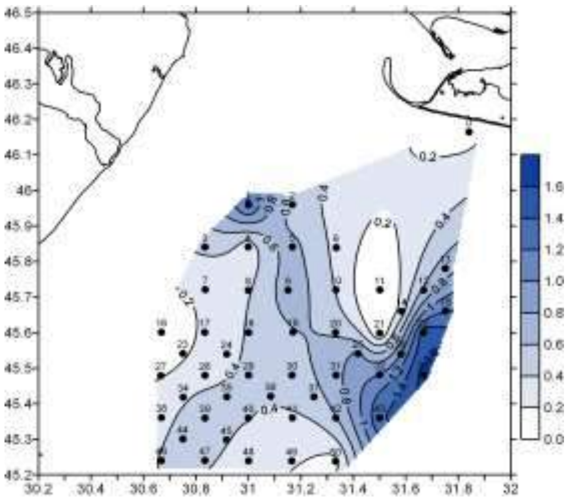
Naphtalene



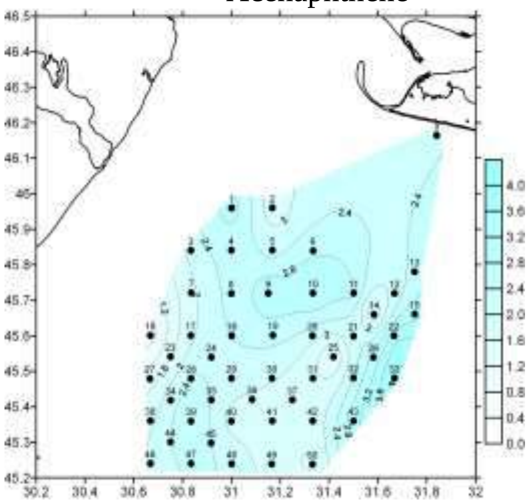
Acenaphthylene



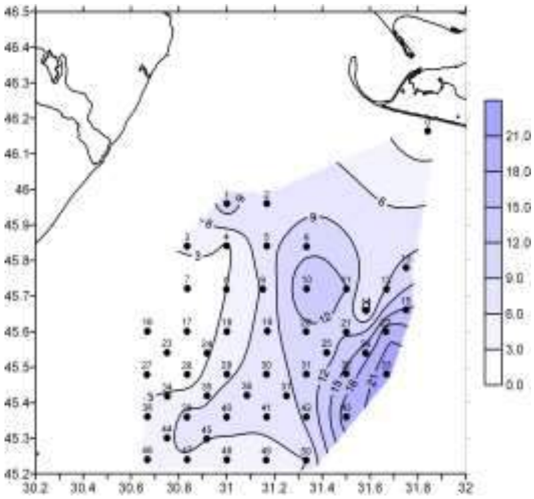
Acenaphthene



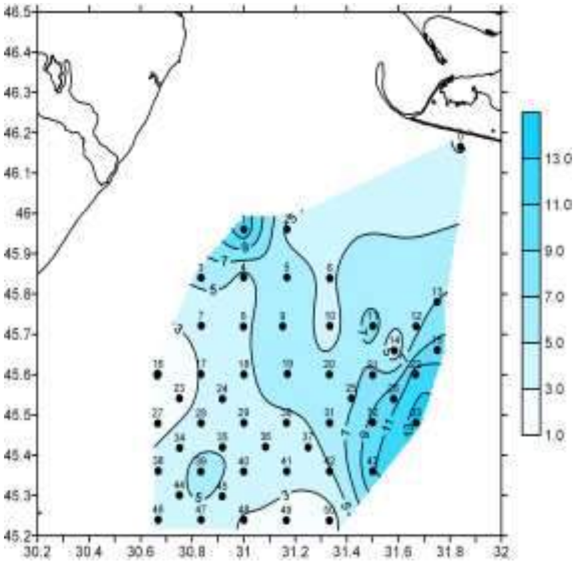
Anthracene



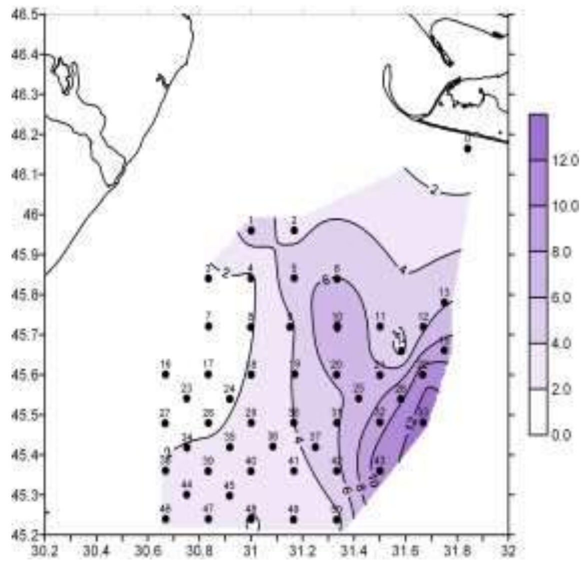
Fluorene



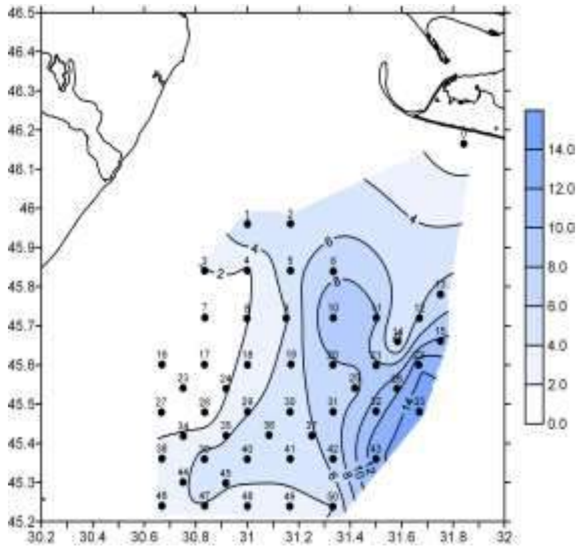
Fluoranthene



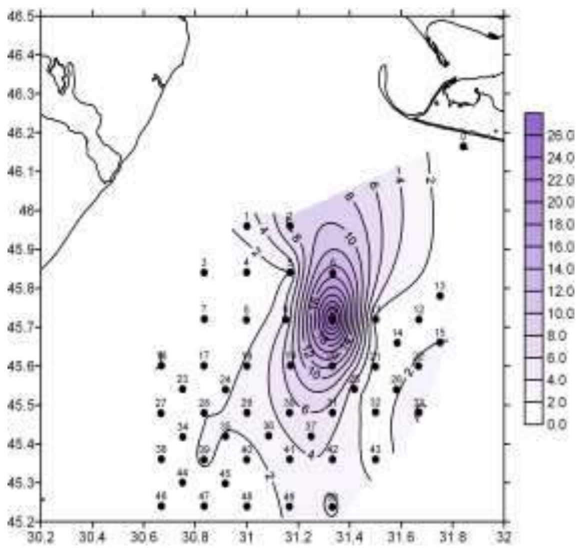
Phenanthrene



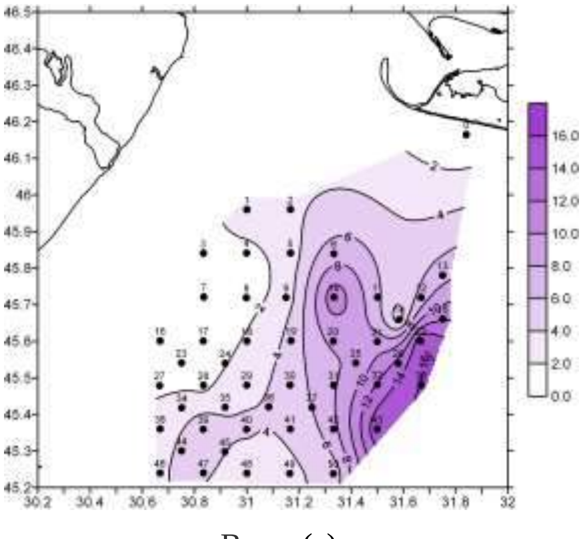
Chrysene



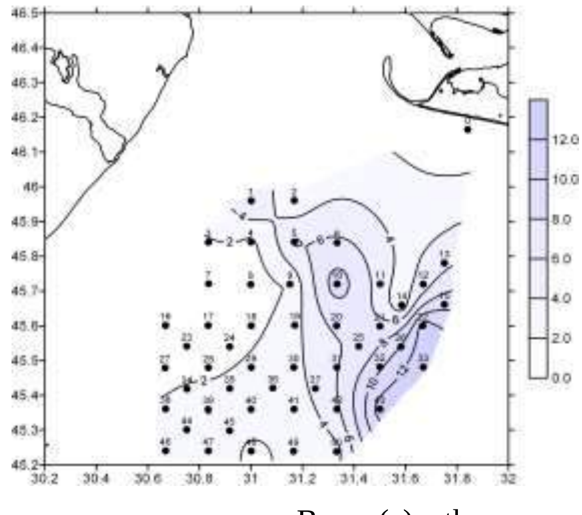
Pyrene



Indeno(1,2,3cd)pyrene



Benzo(a)pyrene



Benzo(a)anthracene

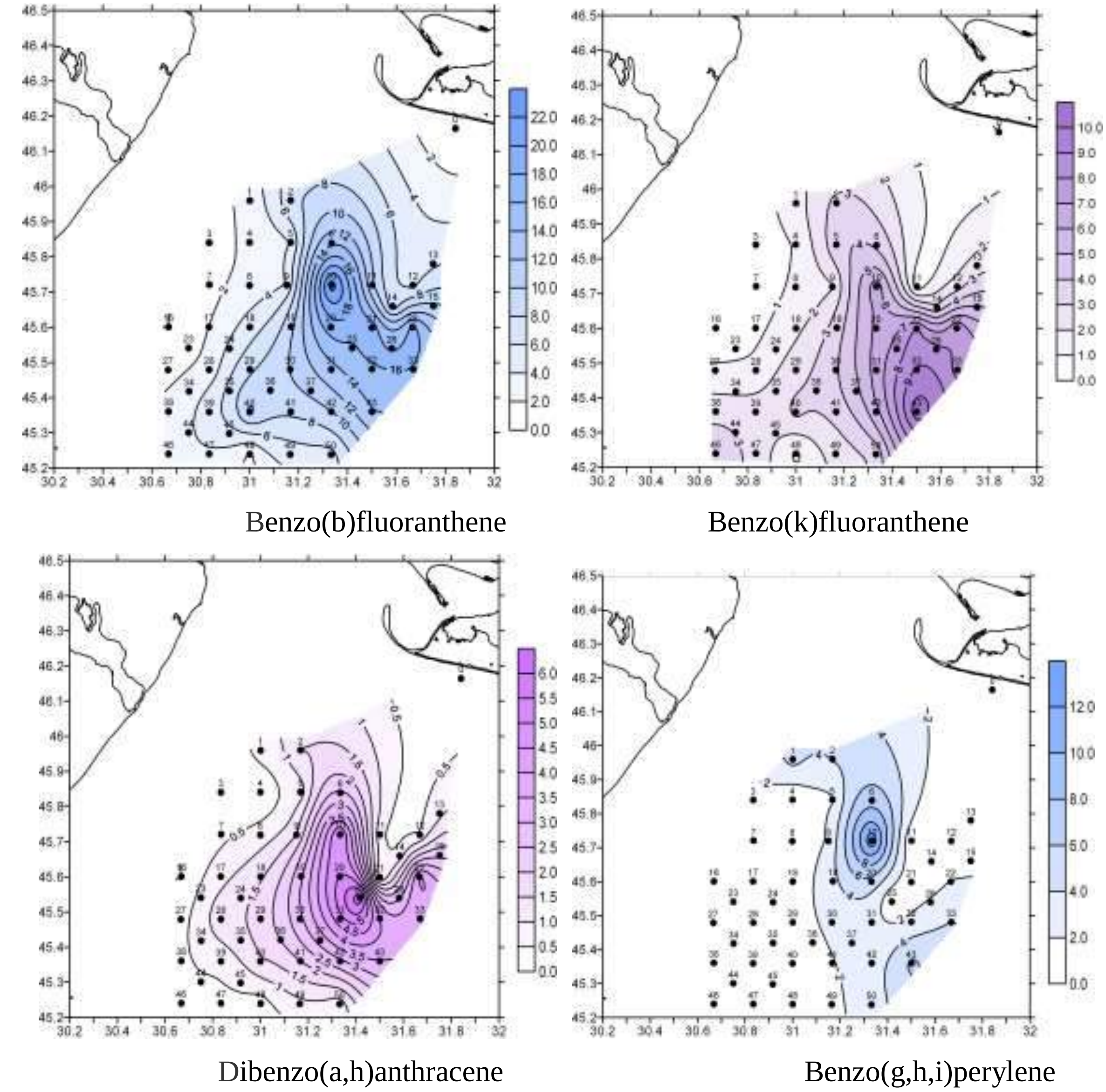


Figure 1.2.4.59. Spatial distribution of individual PAHs (μg/kg) in the the bottom sediments of Zernov's Phyllophora Field in 2012.

Romania-2013

The level of contamination by polycyclic aromatic hydrocarbons - PAH of sediment from Romanian Black Sea sector, May and August 2013, is presented in Table 1.2.4.16. The total content of polynuclear aromatic hydrocarbons - Σ_{16}PAH ranged from 27.1 to 3629 (μg/kg dry weight) with the highest values both in sediments collected from the northern sector (Sf. Gheorghe- 30 m) and from the southern (Constanta South WWTP – 5 m).

Table 1.2.4.27. Statistical results of the total content of polycyclic aromatic hydrocarbons –Σ_{16} PAH (µg/kg) in sediments from the Romanian sector of the Black Sea in 2013.

Compound	n	mean	mediane	min.	max.	std. dev.	percentile 25th	percentile 75th
Naphtalene	61	45.2	6.5	1.2	634.7	3.7	20.4	104.5
Acenaphthylene	52	4	2.1	0	78.9	1.8	2.7	10.7
Acenaphthene	54	10.2	2.9	2.2	292.2	2.7	3.5	39.7
Fluorene	61	24.1	4.3	1.6	976	2.6	7	124.4
Phenanthrene	58	41.1	15.5	4.8	409.7	8.5	38.8	77.3
Anthracene	60	16.7	7.4	0.3	294.5	3.5	14.3	39.5
Fluoranthene	56	24.2	7.6	1	272.7	3.4	27.7	41.2
Pyrene	58	34.4	11.2	1	325.8	4.8	37.4	60
Benzo(a)anthracene	57	14.4	2.4	0.1	295.1	0.6	9.6	41.3
Chrysene	56	6.1	2.2	0.2	85.8	1.6	6.2	12.6
Benzo(b)fluoranthene	50	14.7	2.2	0.1	255.1	0.7	4.2	43.9
Benzo(k)fluoranthene	59	4.3	4.2	0.7	21.2	2.9	5	2.8
Benzo(a)pyrene	61	8.4	3.4	0.8	141.3	2.4	5.9	20.9
Benzo(g,h,i)perylene	50	13.1	2.6	0.4	312.2	1.9	3.2	48.8
Dibenzo(a,h)anthracene	52	11.3	3	0.4	269.8	2	4	39.6
Indeno(1,2,3cd)pyrene	53	7	1.7	0.3	131	1.2	2.8	22.5
Σ_{16} HAP (µg/kg)	61	**262.1**	**93.2**	**27**	**3629.9**	**64.7**	**274**	**499.6**

The total content of polycyclic aromatic hydrocarbons is compared to the maximum allowed limit by Order №161/2006 (Σ_{16} PAH <1000 µg/kg dry weight) for assessing the sediments quality. Thus, for defining GES the following thresholds were proposed:

Ecological status	**Very good**	**Good (GES)**	**Bad**
$\sum_{16}$PAHs (µg/kg)	**< 150**	**150-1000**	**> 1000**
Pollution level	reduced	moderate	high

Monitoring results in 2013 allow to make classification of sediments based on total PAHs content -Σ_{16} PAH (µg/kg) as: only 18% of stations in front of Danube mouth or inside Costanta harbour are chronically polluted (>1000 µg/kg), 31% are moderately polluted (GES) (150-1000 µg/kg) and 51% with reduced pollution level (<150 µg/kg).

1.2.4.3. PAHs in biota

Among individual PAHs in Phyllophora in highest concentration (35 µg/kg) Naphthalene is present (Fig. 1.2.4.60), which is slightly lower than in 2000 year (43 µg/kg). The concentrations of Fluorene and Phenanthrene in Phyllophora are an average 3 µg/kg, which is much lower than in 2000 year.

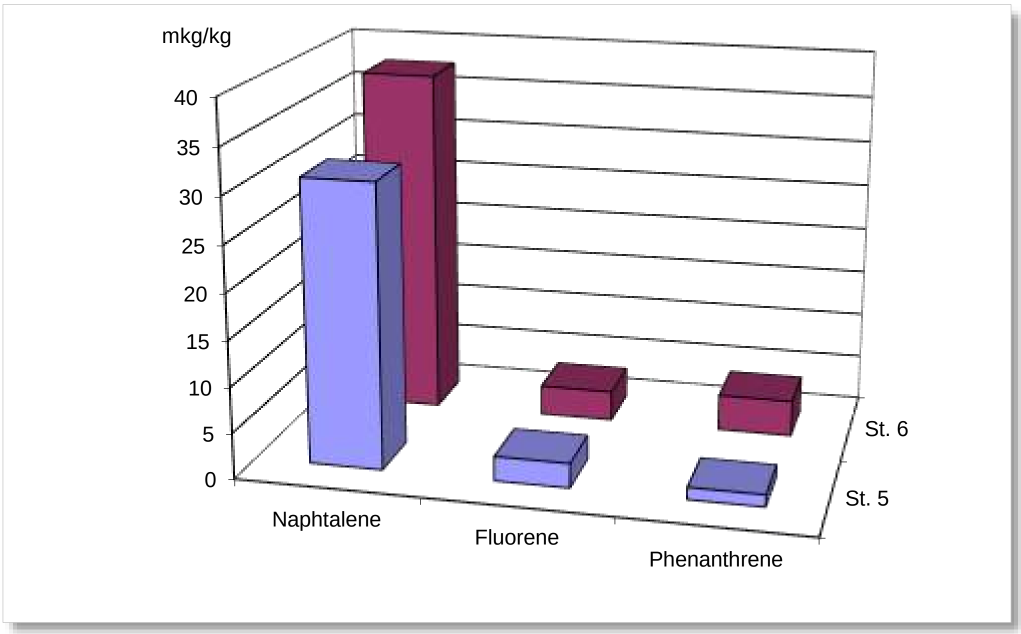


Figure 1.2.4.60. The concentrations of Naphtalene, Fluorene and Phenanthrene in Phyllophora.

The content of other 13 PAHs in Phyllophora (Fig. 1.2.4.61), including 8 carcinogenic PAHs did not exceed 1 µg/kg and decrease on 1-2 orders compared with 2000 year.

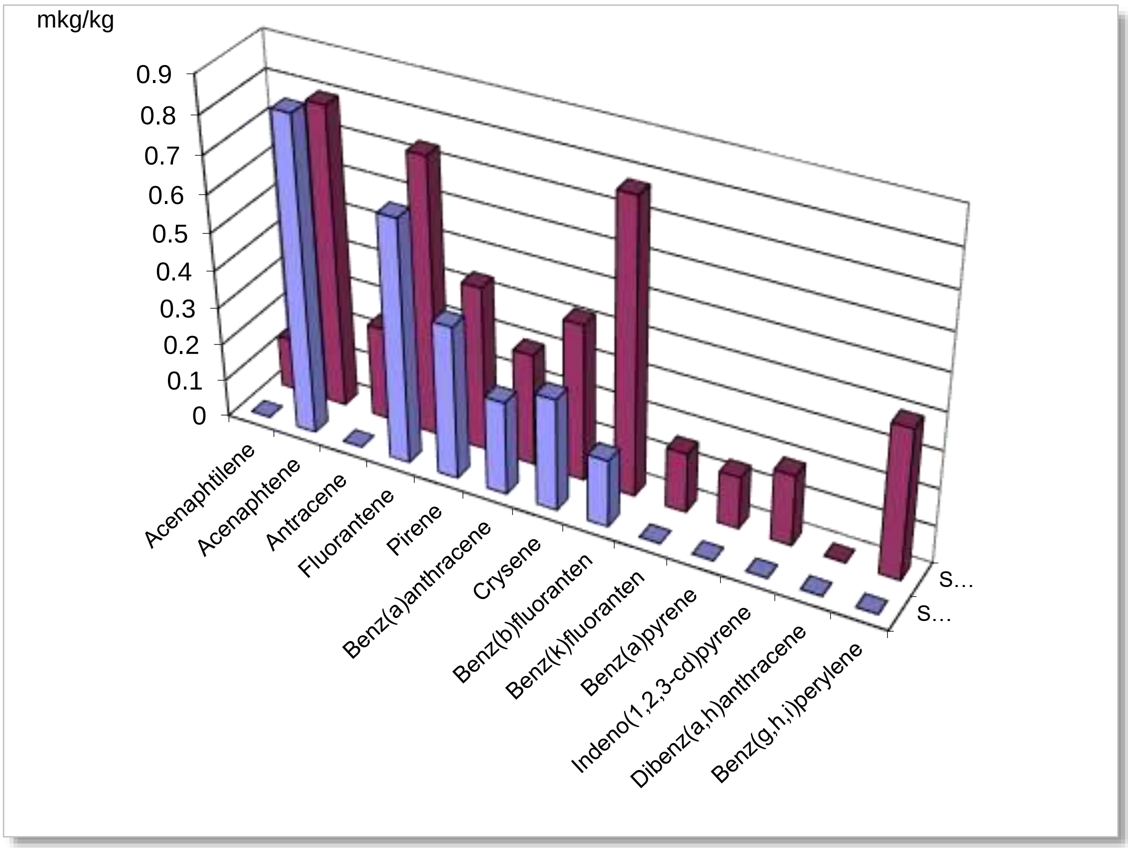


Figure 1.2.4.61. Concentrations of other individual PAHs in Phyllophora.

The results of calculations of the origin of priority PAHs are present in Table 1.2.4.28 and Figure 1.2.4.62.

Table 1.2.4.62. The results of calculations of the origin of priority PAHs in Phyllophora.

No St.	ΣPAHs , μg/kg	Σ carc. PAHs μg/kg	Σcarc PAHs/ ΣPAHs·100 %	Phenathrene/ anthracene*	Fluoranthene/ pyrene *	B(a)Peqv, μg/kg
5	**37.6**	**0.7**	**2**	**13.2**	**1.6**	**0.1**
6	**49.8**	**2.0**	**4**	**16.0**	**1.7**	**0.3**

* Value Phenanthrene/Anthracene>10 and Fluorantene/Pyrene<1, indicating the origin of petroleum PAHs, and the ratio Phenantrene/Anthracene<10 and Fluoranthene/Pyrene>1 indicate anthropogenic emission of PAHs as a result of combustion products.

The calculation results showed that the carcinogenic PAHs in Phyllophora present in minor concentrations and not exceeding 4% of all priority PAHs (Fig. 1.4.4.62). On this fact also indicates B(a)Peqv, whose value is less than 0.3 μg/kg (Fig.1.2.4.63).

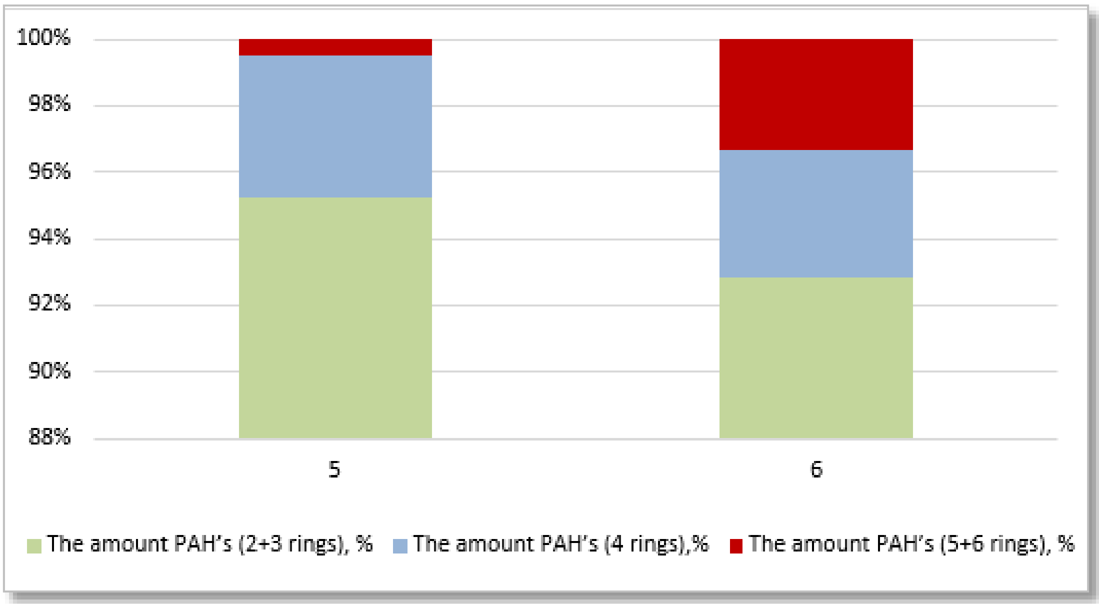


Figure 1.2.4.62. The ratio of 16 PAHs in Phyllophora from the NWS by the number of rings in the molecules.

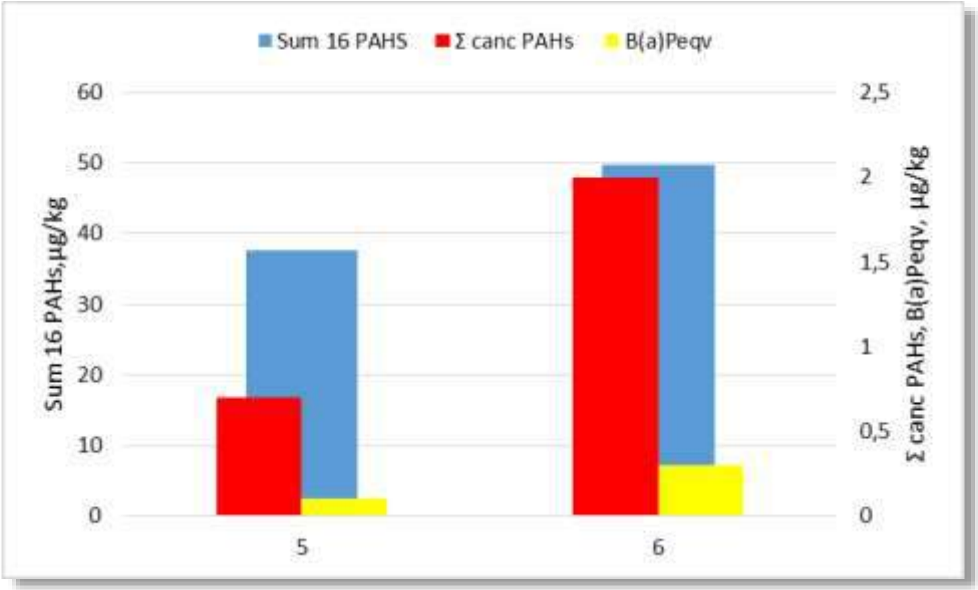


Figure 1.2.4.63. Concentrations of sum PAHs, carcinogenic PAHs and B(a)Peqv. in Phyllophora.

1.2.5 Persistent Organic Pollutants (Pesticides, PCBs and other Chlorinated Organics)

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POPs description

POPs are chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of living organisms and are toxic to humans and wildlife. POPs include organochlorine pesticides and polychlorinated biphenyls. Organochlorine pesticides are widespread in the environment due to their application directly into the environment.

DDT is a persistent organochlorine insecticide which is degraded primarily to DDE (1,1-dichloro-2,2-bis(chlorophenyl)ethylene) or DDD (1,1,-dichloro-2,2,-bis(p-chlorophenyl)ethane). DDT was used widely to control insects on agricultural crops and those carrying diseases such as malaria. Lindane (γ-HCH) was one of the most widely utilized insecticides on a worldwide scale. HCH has been used, e.g., as an insecticide and in wood treatment. Technical HCH contains various isomers: 60–75% α-HCH, 15% γ-HCH, 7–10% β-HCH, 7% δ-HCH, and 1–2% ε-HCH. The γ-isomer, lindane, is the most toxic isomer of the HCHs, 500 to 1000 times more active than the α-isomer. Aldrin, dieldrin, endrin and isodrin, also known as "the drins", have been used extensively throughout the world on a wide variety of crops and pests. Hexachlorobenzene (HCB) is a fungicide used, among others, in seed protection and wood preservation. Significant sources of HCB to surface waters are the chemical industry (production of chlorinated substances such as perchloroethylene) and the metal industry, where HCB occurs as an unintentional by-product. PCBs are synthetic chemicals that have been used in a wide variety of manufacturing processes especially as plasticizers and as insulators and flame-retardants. They are widely distributed in the environment through, for example, inappropriate handling of waste material or leakage from large condensers and hydraulic systems.

Stockholm Convention on Persistent Organic Pollutants is an international environmental treaty, signed in 2001 and effective from May 2004, that aims to eliminate or restrict the production and use of persistent organic pollutants (POPs). In most countries of the Black Sea the use of this POPs has been banned or restricted. The Stockholm Convention "dirty dozen" POPs includes eight organochlorine pesticides: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex, toxaphene, hexachlorobenzenes (HCBs), polychlorinated biphenyls (PCBs) and two groups of industrial by-products - dioxins and furans. Bulgaria, Georgia and Romania have signed and ratified this convention, while the remaining three Black Sea countries are signatories. Public health use of DDT is allowed under the Stockholm Convention, but only for the control of mosquitoes (the malaria vector) [BSC 2008a]. Anyway, they are still used in many developing countries (HELCOM 2001, Bignert et al. 2009). One of the primary transport routes into the marine and coastal environments is atmospheric deposition [Oehme &Manø 1984, Welch et al. 1991]. In addition, there is continued leaching from contaminated soil and river sediments into the aquatic environment and are transported to the sea (Green & Künitzer 2003), where they may bioaccumulate and biomagnify in food webs.

Regional assessment of POPs was done based on national monitoring programmes data reported by countries to the Black Sea Commission collected in Black Sea Database, period

2009–2014 and information gathered as result of scientific cruises carried out in the frame of international projects MISIS and PERSEUS Projects.

1.2.5.1. Seawater

The main chlorinated compounds investigated in the Black Sea waters were chlorinated pesticides. Most of the samples are collected in the north half of the Black Sea: Romania, Russia and Ukraine. Eight samples were collected in Bulgarian waters in 2011, in the frame of the national monitoring programme. No data were available to make an assessment of water pesticides pollution along the Turkish and Georgian coasts.

The pesticides concentration varied in large limits (Table 1.2.5.1). High values were reported in the west part of the Black Sea, while pesticides concentration was at analytical zero value in the eastern part.

Table 1.2.5.1. Concentrations of organochlorine pesticides in Black Sea surface waters, 2009-2014 (data from Black Sea Database)

Descriptive Statistics (Organochlorine pesticides _2009-2014_Surface water), Black Sea region						
	Valid N	**Mean [ng/l]**	**Median [ng/l]**	**Percentile - 10- [ng/l]**	**Percentile - 90- [ng/l]**	**Std.Dev. [ng/l]**
DDT	784	7.680	0.000	0.000	10.000	44.534
DDD	584	6.386	0.000	0.000	10.201	31.017
DDE	788	5.733	0.000	0.000	13.000	26.611
DDT total	469	12.915	0.000	0.000	21.015	75.556
Hexachlorobenzene	348	19.862	4.000	0.000	59.607	40.840
Heptachlor	340	20.260	3.000	0.000	44.869	66.836
Aldrin	333	14.546	3.000	0.000	37.380	36.265
Dieldrin	252	12.861	2.000	0.000	22.033	46.073
Endrin	251	13.210	3.361	0.000	31.390	28.002
ϒ -HCH (Lindane)	735	21.540	0.000	0.000	77.015	60.419
α-HCH	547	0.024	0.000	0.000	0.0800	0.0914
β-HCH	344	0.452	0.000	0.000	1.6400	0.8596
HCH total	292	0.649	0.000	0.000	2.1900	1.1166

The main investigated compounds were HCB, DDT and its metabolites. HCB concentrations varied between analytical zero and 5 ng/l in Bulgaria and Ukraine, while in Romania the average concentration for 2009–2012 was 29.16 ng/l. The average of DDT and its metabolites DDE and DDD in different areas varied from 0.23 to 24.74 ng/l with the range 0.0–52.21 ng/l; 0.0–37.39 ng/l and 0.0–32.34 ng/l, respectively. The highest values are reported in Romania area where, in some locations, are measured extreme values.

As in previous assessments (SoE 2008) DDTwas predominate in comparison with its metabolites (Fig. 1.2.5.1.). This suggests recent and ongoing water pollution in west and north-west part of the Black Sea.

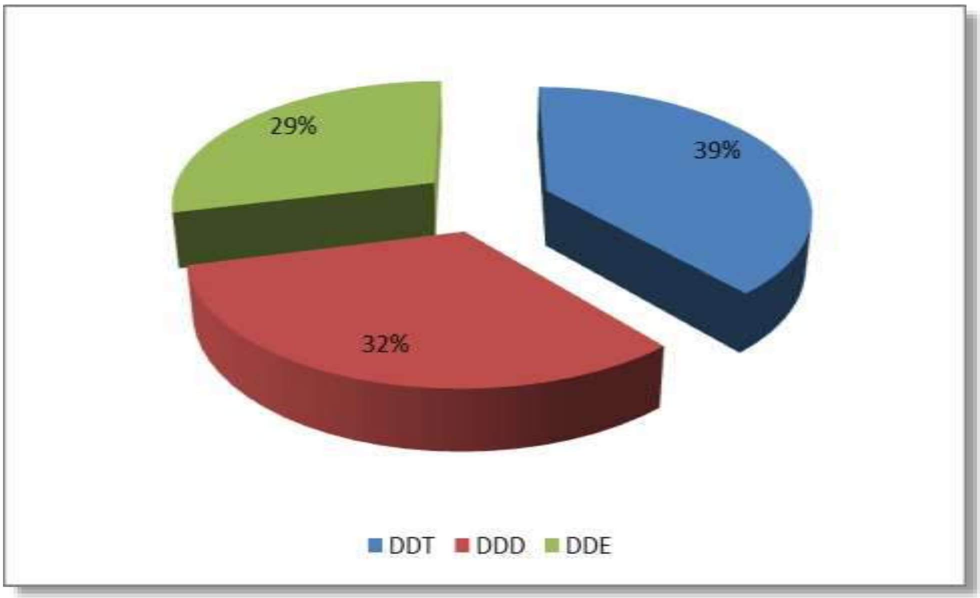

Figure 1.2.5.1. Share of DDT and its metabolites concentrations in Black Sea surface waters, 2009-2014 (data from Black Sea Database).

Ukraine and Romania monitored some other chlorinated pesticides: heptachlor, cyclodiene pesticides (aldrin, dieldrin, endrin) and HCH group. Their values were rather low in the north part of the Black Sea. Concentrations varied between 0.0 and 7.18 ng/l for HCH group; 0.0 to 2.4 ng/l for cyclodiene group and 0.0 to 6.07 ng/l for heptachlor. In the west area the concentrations in the period 2009 – 2012 were high: 0.0 to 63.95 ng/l for cyclodiene group, 0.0 to 63 ng/l for heptachlor and 0.0 to 129 ng/l for γ-HCH (Lindane).

In relation with European environmental quality standards (EQS) for water (Directive 2013/39/CE), concentrations of hexachlorobenzen, lindane, DDT, DDT total and sum of cyclodiene in surface waters complied in general with threshold values, while for heptachlor 80% of values were higher. This is probably due because most of the detection limits are higher than the threshold value (Table 1.2.5.2.).

Table 1.2.5.2. Percentage of observations exceeding threshold values stipulated by Directive 2013/39/CE, in surface waters, 2009-2014.

	Environmental Quality Standard Directive 2013/39/CE	Number of observations	Percentage of observations surpassing EQS
HCB	MAC: 0.05 µg/L	348	11.5%
Lindane	MAC: 0.02 µg/L	735	21%
Heptachlor	MAC: 0.00003 µg/L	340	80%
Sum Cyclodiene	AA: 0.005 µg/L	225	19%
DDT	AA: 0.01 µg/L	88	20.5%
Total DDT	AA: 0.025 µg/L	50	18%

PCBs were measured in the west and north-west part of the Black Sea. In Romanian waters these pollutants were measured, as total PCBs in 2009. The average concentration of total PCBs in 2009 in Romania waters was 259.31 ng/l. In Ukraine waters PCBs were measured as individual compounds (21 individual compounds); total PCBs AR-1260 and total PCBs AR-1254. The PCBs levels were rather low: average concentration of individual compounds varied in the range 0.0 to 3.943 ng/l; average of PCBs total AR-1254 was 25.22 ng/l and average of PCBs total AR-1260 was 7.52 ng/l.

Other regional information

In the framework of the project DG ENV MISIS (MSFD Guiding Improvements in the Black Sea Integrated Monitoring System), a Joint Cruise was carried out onboard R/V Akademik in the Western Black Sea, in July 2013, 18 samples (7 in RO waters, 6 in BG water, and 5 in the TR waters) along transects of Constanta, in the Romanian waters, Galata, in the Bulgarian waters, and Igneada, in the Turkish waters, were collected, covering the coastal, shelf and open waters. Results showed that concentrations of organochlorine pesticides were higher or comparable with those reported in the Black Sea region in previous researches.

For Bulgarian transect, the results for organochlorine contaminants are comparable with BSBD results [Annual reports, BSBD, 2006-2011], except for HCB and lindane for which were measured higher concentrations. For Turkey area, the results for organochlorine pesticides levels are comparable with previous results reported in Black Sea Turkish waters [Ozkoc, et al., 2007], except for lindane for which were measured higher concentrations. The concentrations of organochlorine pesticides are comparable with those reported in the previous period in Romanian waters [NIMRD, 2012].

The BS waters were dominated by the presence of HCB, lindane, and heptachlor. [Soe MISIS ch. V]. More than 75% values for aldrin, dieldrin, p,p' DDE, p,p' DDD and p,p' DDT were under detection limit (Table 2.5.3). Lindane and cyclodiene often exceeded the threshold values set out by Directive 2013/39EU.

Table 1.2.5.3. Concentrations of OCPs (µg/L) in water samples collected from the Romanian, Bulgarian and Turkish area, MISIS cruise, 2013.

Stations	HCB	Lindane	Heptachlor	Aldrin	Dieldrin	Endrin	p,p' DDE	p,p' DDD	p,p' DDT
MO1(RO32m)	0.028	0.039	<0.003	<0.003	<0.002	0.010	<0.002	<0.002	<0.002
MO2(RO47m)	0.027	0.051	<0.003	<0.003	<0.002	0.008	<0.002	<0.002	<0.002
MO3(RO52m)	0.015	0.028	<0.003	<0.003	<0.002	0.009	<0.002	<0.002	<0.002
MO4(RO65m)	0.037	0.030	<0.003	<0.003	<0.002	0.007	<0.002	<0.002	<0.002
MO5(RO100m)	0.050	0.020	<0.003	<0.003	<0.002	<0.003	<0.002	<0.002	<0.002
MO6(RO496m)	0.047	0.058	0.037	<0.003	<0.002	<0.003	<0.002	<0.002	<0.002
MO7(RO1000m)	0.063	0.049	<0.003	<0.003	<0.002	0.013	<0.002	<0.002	<0.002
MO8(BG1167m)	0.042	0.044	<0.003	<0.003	<0.002	0.003	<0.002	<0.002	<0.002
MO9(BG92m)	0.051	0.134	<0.003	<0.003	0.010	0.012	<0.002	<0.002	<0.002
M10(BG77m)	0.028	0.032	<0.003	<0.003	<0.002	0.009	<0.002	<0.002	<0.002
M11(BG40m)	0.111	0.169	0.075	<0.003	<0.002	0.026	<0.002	0.007	0.038
M12(BG23m)	0.009	<0.003	<0.003	<0.003	<0.002	0.007	<0.002	<0.002	<0.002
M13(BG1000m)	0.007	<0.003	<0.003	<0.003	<0.002	0.008	<0.002	<0.002	<0.002
M14(TR1118m)	0.019	0.023	<0.003	<0.003	<0.002	0.011	<0.002	<0.002	<0.002
M15(TR101m)	0.021	0.034	<0.003	<0.003	<0.002	<0.003	<0.002	<0.002	<0.002
M16(TR75.6m)	0.057	0.127	0.281	<0.003	0.009	<0.003	0.006	0.007	0.010
M17(TR54m)	0.079	0.284	<0.003	<0.003	0.092	<0.003	0.020	0.017	0.096
M18(TR27m)	0.023	0.065	0.185	<0.003	0.021	0.011	0.099	<0.002	<0.002

PCBs data obtained following MISIS cruise pointed out PCB 52 as major PCB compound. More than 85% values for the other investigated PCBs were under detection limit (Table 1.2.5.4). In Bulgarian area values of PCB 153 were higher than prevoius concentrations reported by BSBD [Annual reports, BSBD, 2006-2011].

Table 1.2.5.4. Concentrations of PCBs (μg/L) in water samples collected from the Romanian, Bulgarian and Turkish area, MISIS cruise, 2013.

Stations	PCB 28	PCB 52	PCB 101	PCB 118	PCB 153	PCB 138	PCB 180
MO1(RO32m)	<0.004	<0.006	<0.006	<0.004	<0.006	<0.007	<0.003
MO2(RO47m)	<0.004	<0.006	<0.006	<0.004	<0.006	<0.007	<0.003
MO3(RO52m)	<0.004	<0.006	<0.006	<0.004	<0.006	<0.007	<0.003
MO4(RO65m)	<0.004	<0.006	<0.006	<0.004	<0.006	<0.007	<0.003
MO5(RO100m)	<0.004	<0.006	<0.006	<0.004	<0.006	<0.007	<0.003
MO6(RO496m)	<0.004	0.007	<0.006	<0.004	<0.006	<0.007	<0.003
MO7(RO1000m)	<0.004	<0.006	<0.006	<0.004	<0.006	<0.007	<0.003
MO8(BG1167m)	<0.004	<0.006	<0.006	<0.004	<0.006	<0.007	<0.003
MO9(BG92m)	0.006	0.160	<0.006	<0.004	<0.006	<0.007	<0.003
M10(BG77m)	<0.004	<0.006	<0.006	<0.004	<0.006	<0.007	<0.003
M11(BG40m)	<0.004	0.042	<0.006	<0.004	<0.006	<0.007	<0.003
M12(BG23m)	<0.004	<0.006	<0.006	<0.004	<0.006	<0.007	<0.003
M13(BG1000m)	<0.004	<0.006	<0.006	<0.004	<0.006	<0.007	<0.003
M14(TR1118m)	<0.004	<0.006	<0.006	<0.004	<0.006	<0.007	<0.003
M15(TR101m)	<0.004	<0.006	<0.006	<0.004	<0.006	<0.007	<0.003
M16(TR75.6m)	<0.004	0.498	<0.006	<0.004	<0.006	<0.007	<0.003
M17(TR54m)	0.009	0.555	<0.006	0.113	0.014	<0.007	0.023
M18(TR27m)	<0.004	0.319	<0.006	<0.004	<0.006	<0.007	<0.003

National reports

Romania

Data on organochlorine compounds were obtained along relevant monitoring transects, in Danube mouths and Constanta area, strongly influenced by Danube in the northern area, or various land-based sources in the southern one, in 2012–2014 period, in the framework of the FP7 PERSEUS (Policy-oriented Marine Environmental Research for the Southern European Seas). Trends were assessed in comparison with 2006-2011 monitoring data.

In 2012–2014, although the variation of organochlorine pesticides was broad in the western part of the Black Sea, more than 50% of the values for most investigated compounds were under detection limit [Oros et al, 2016b]. Exception was represented by HCB and lindane, which often exceed European environmental quality standards (EQS) for water (Directive 2013/39/CE). Frequent (20–30%) exceeding of the EQS was recorded also for HCB, heptachlor, sum DDT and sum cyclodiene, mainly in 2013. For p,p' DDT, concentrations over the EQS are occasionally (Fig. 1.2.5.2). OCPs trend analysis for 2006–2014 show an obviously decreasing tendency in 2012–2014 period (Fig. 1.2.5.3).

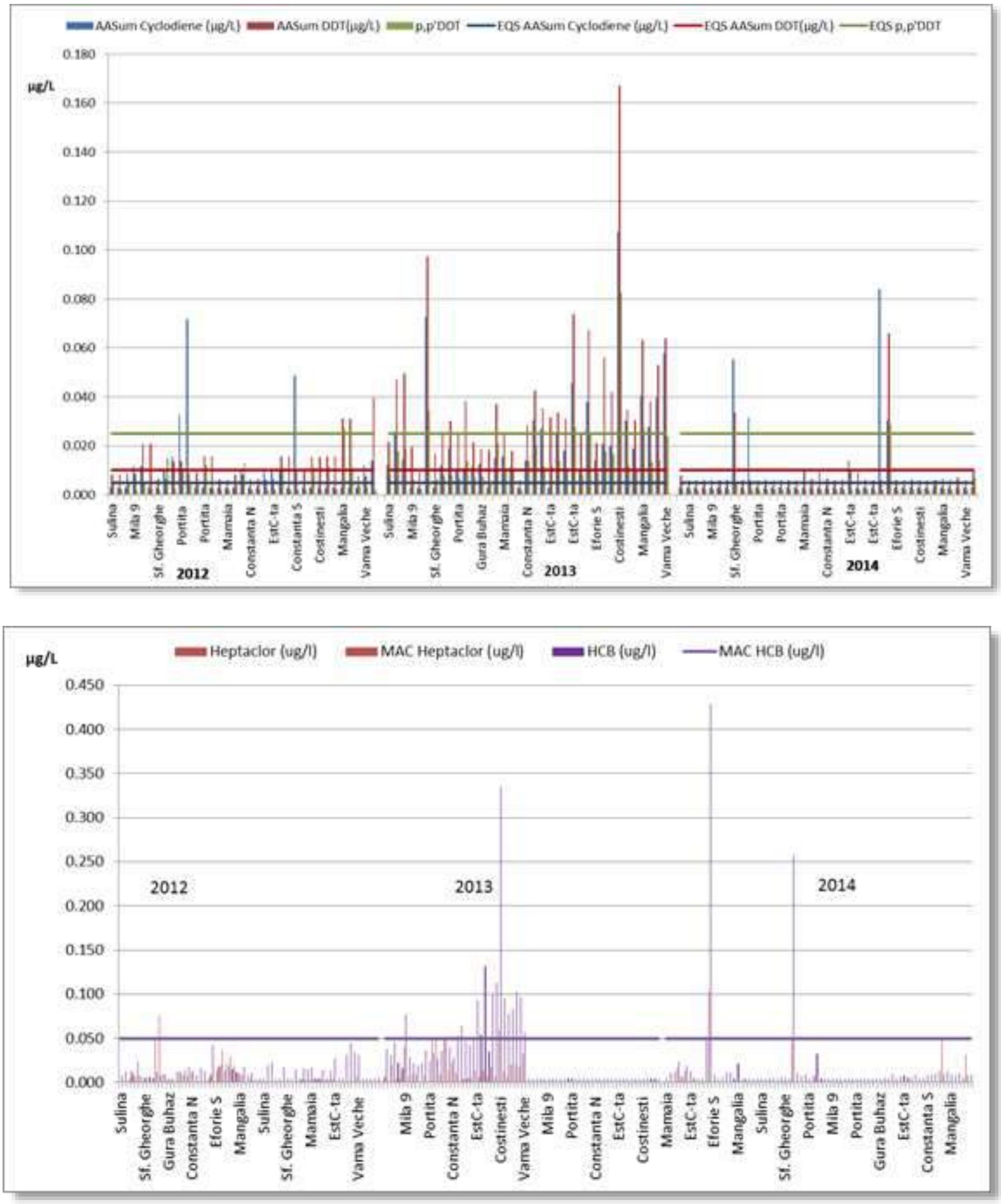

Figure 1.2.5.2. Concentrations of organochlorine pesticides in water, 2012 – 2014, in Constanţa and Danube mouth area, in relation to the proposed values for the definition of good environmental status.

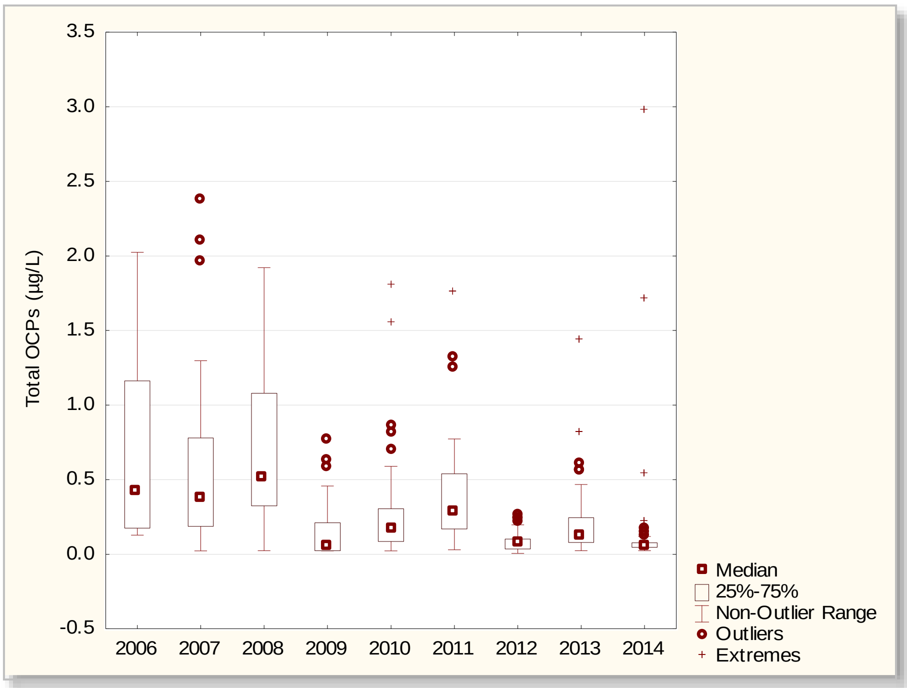

Figure 1.2.5.3. Trend analysis of OCPs in the west part of the Black Sea, in water, 2012 – 2014.

Concentrations of polychlorinated biphenyls, in 2012–2014, were low in the west part of the Black Sea. Except PCB52 that varied in the range 0.006 and 0.467 µg/l, 75% of the concentrations for PCB28, PCB101, PCB118, PCB153, PCB138, PCB180 were under detection limit. Some extreme values of these compounds were recorded in 2014 in Constanta and Portita area (Fig. 1.2.5.4). As no polychlorinated biphenyls data are available before 2012 is difficult to make a trend analysis for these compounds.

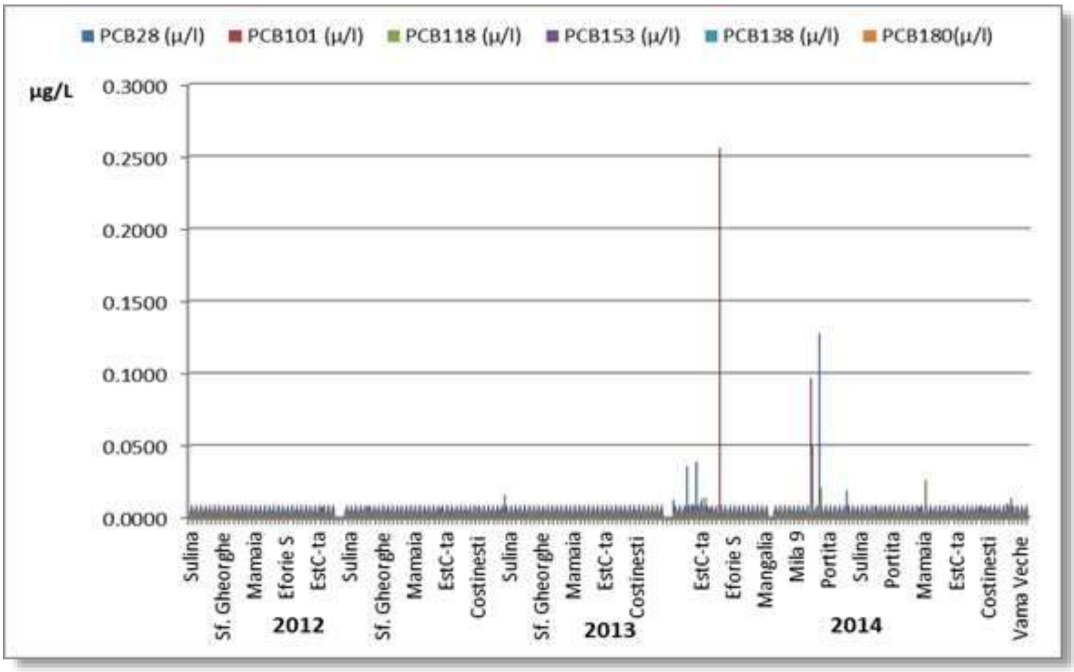

Figure 1.2.5.4. Concentrations of polychlorinated biphenyls in water, 2012 – 2014, in Constanţa and Danube mouth area.

1.2.5.2. Sediment

Sediment for POPs analysis was collected in the west (227 samples) and north – west (151 samples) part of the Black Sea as part of national monitoring programmes. The level of organochlorine pesticides fluctuated in a large range. Average concentrations varied from 0.319 ng/g dry sediment to 11.055 ng/g (Table 1.2.5.5).

Table 1.2.5.5. Concentrations of organochlorine pesticides in Black Sea surface sediments, 2009-2014 (data from Black Sea Database).

Descriptive Statistics (Organochlorine pesticides _2009-2014_Surface sediment), Black Sea region						
	Valid N	Mean [ng/g]	Median [ng/g]	Percentile - 10- [ng/g]	Percentile - 90- [ng/g]	Std.Dev. [ng/g]
DDT	378	4.812	0.700	0.000	12.198	12.719
DDD	378	4.152	0.450	0.000	8.090	18.244
DDE	378	6.289	0.755	0.000	7.104	53.319
DDT total	267	10.318	3.570	0.570	24.350	23.153
Hexachlorobenzene	378	4.251	0.300	0.000	8.175	15.758
Heptachlor	378	7.966	0.210	0.000	16.118	41.486
Aldrin	378	11.056	0.050	0.000	28.857	39.186
Dieldrin	243	6.594	0.333	0.000	10.761	21.387
Endrin	243	8.665	0.300	0.000	6.544	43.351
ϒ -HCH (Lindane)	378	4.455	0.300	0.000	11.230	14.762
α-HCH	151	0.320	0.080	0.000	0.830	0.678
β-HCH	151	1.869	0.470	0.000	3.170	5.437
HCH total	151	2.447	0.960	0.120	5.020	5.805

Most values for DDT and its metabolites DDE and DDD varied within the range 0.0–12.72 ng/g; 0.0–7.104 ng/g and 0.0–8.09 ng/g, respectively. The highest values were recorded in the western part. Other investigated compounds, lindane, hexachlorobenzene, heptachlor, aldrin, dieldin, endrin also had higher values in the western part comparative with the north-west. Most of the values varied from 0.0 to 11.23 ng/g for lindane, 0.0 to 8.175 ng/g for hexachlorobenzene, 0.0 to 16.118 ng/g for heptachlor, 0.0 to 28.85 ng/g for aldrin, 0.0 to 10.76 ng/g for dieldrin and 0.0 to 6.54 ng/g for endrin (Fig. 1.2.5.5). Extreme values were measured especially in the western part of the Black Sea. Pesticides α-HCH and β-HCH were investigated only in the North-West part of the Black Sea. Their values were rather low. Most values varied in the range 0.0 to 0.83 ng/g for α-HCH and 0.0 to 3.17 ng/g for β-HCH. Some extreme values were measured for these compounds.

PCBs were measured as total PCBs in Romanian area in 2009 in the frame of the monitoring programme. Average concentration of total PCBs was 30.62 ng/g. In Ukraine area PCBs were measured as individual compounds (21 individual compounds); total PCBs AR-1260 and total PCBs AR-1254. The PCBs concentration of individual compounds varied in a large range, from 0.0 to 17.37 ng/g; average of PCBs total AR-1254 was 21.47 ng/g and average of PCBs total AR-1260 was 6.69 ng/g. Higher values were detected for PCB44, PCB149, PCB105 and PCB129.

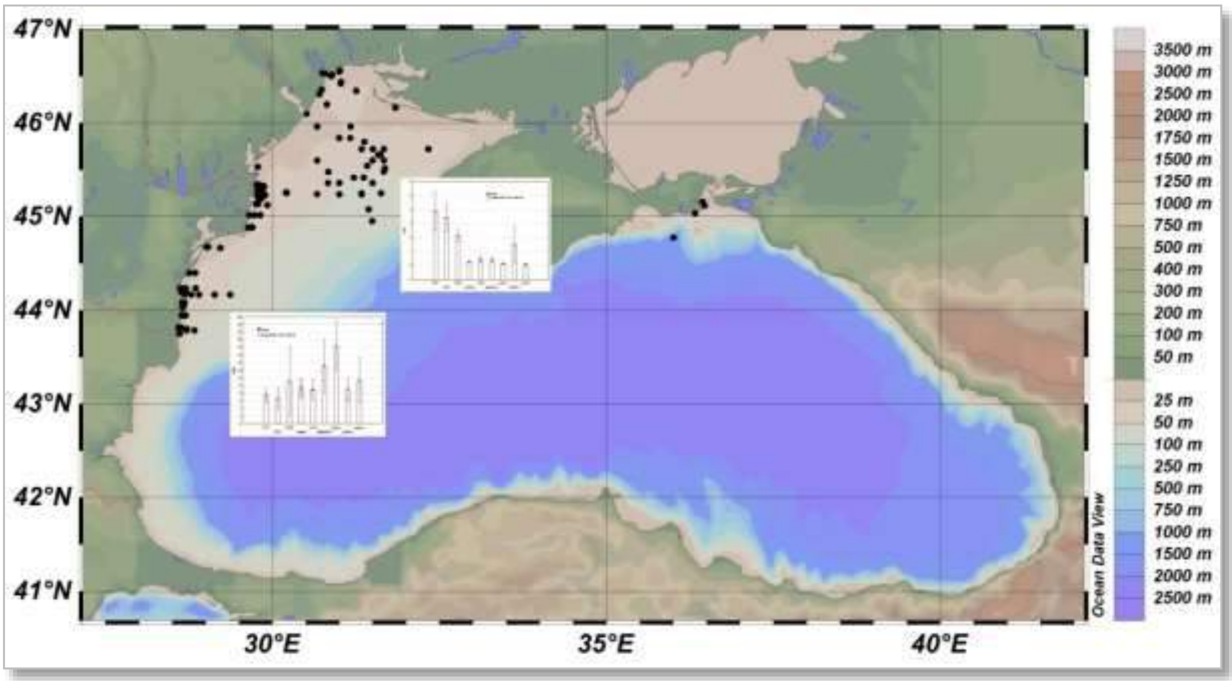

Figure 1.2.5.5. Mean plot of organochlorine pesticides in north and north –west part of the Black Sea surface sediments, 2009-2014 (data from Black Sea Database).

In relation with sediment quality criteria (ERL: Effects Range – Low and EAC: Environmental Assessment Criteria), percentages of observations surpassing ERL and EAC values varied, depending on the element, between 2% and 38% (Tab. 1.2.5.6). Environmental Assessment Criteria (EACs) was proposed by OSPAR as a means for assessing the significance of concentrations of hazardous substances in the marine environment and if EACs were not available with Effects Range Low (ERLs) developed by the United States Environmental Protection Agency for assessing the ecological significance of sediment concentrations [OSPAR Commission, 2008]. EACs (lower) are concentrations below which it is reasonable to expect that there will be an acceptable level of protection of marine species from chronic effects from specific hazardous substances. Concentrations below the ERL rarely cause adverse effects in marine organisms.

Table 1.2.5.6. Percentage of observations surpassing sediment quality criteria (EAC, ERL), 2009-2014.

	Sediment Quality Criteria (ERL, EAC)	Number of observations	Percentage of observations surpassing ERL / EAC
HCB	ERL: 20 ng/g	378	4%
Lindane	ERL: 3 ng/g	378	23%
DDE	ERL: 2 ng/g	378	32%
Dieldrine	ERL: 2.2 ng/g	243	23%
PCB 28	EAC: 1.7 ng/g	51	2%
PCB 52	EAC: 2.7 ng/g	151	6%
PCB 101	EAC: 3 ng/g	151	3%
PCB 118	EAC: 0.6 ng/g	151	38%
PCB 138	EAC: 40 ng/g	151	5%
PCB 153	EAC: 7.9 ng/g	151	0%
PCB 180	EAC: 12 ng/g	94	0%

Other regional information

In the framework of the project DG ENV MISIS (MSFD Guiding Improvements in the Black Sea Integrated Monitoring System), a Joint Cruise was carried out onboard R/V Akademik in the Western Black Sea, in July 2013, 18 samples (7 in RO waters, 6 in BG water, and 5 in the TR waters) along transects of Constanta, in the Romanian waters, Galata, in the Bulgarian waters, and Igneada, in the Turkish waters, were collected, covering the coastal, shelf and open waters. Results showed that concentrations of organochlorine pesticides in surface sediments were comparable with previous data [Ozkoc, H. B. et.al., 2007, Fillmann, G., 2002] obtained in the Black Sea region and emphasized PCB52 and PCB28 as major polychlorinated byphenil compounds.

Data obtained following MISIS cruise in July 2013 highlighted some overruns of ERL and EAC values (Table 1.2.5.7, Table 1.2.5.8) for p, p' DDT, p, p' DDE, lindane, PCB 28, PCB 52, PCB 101, PCB 118 and PCB 138.

Table 1.2.5.7. Concentrations of OCPs (ng/g dry weight) in sediment samples collected from the Romanian, Bulgarian and Turkish area, MISIS cruise, 2013.

Stations	HCB	Lindane	Heptachlor	Aldrin	Dieldrin	Endrin	p,p' DDE	p,p' DDD	p,p' DDT
MO1(RO32m)	<0.300	<0.300	<0.200	<0.200	<0.200	<0.300	0.711	<0.200	<0.200
MO2(RO47m)	<0.300	<0.300	<0.200	<0.200	<0.200	<0.300	1.727	<0.200	<0.200
MO3(RO52m)	<0.300	<0.300	<0.200	<0.200	<0.200	<0.300	0.509	<0.200	<0.200
MO4(RO65m)	<0.300	<0.300	<0.200	<0.200	<0.200	<0.300	**2.214**	<0.200	<0.200
MO5(RO100m)	2.504	**4.868**	1.421	<0.200	0.494	<0.300	**11.438**	0.985	0.583
MO9(BG92m)	<0.300	<0.300	0.200	<0.200	0.200	<0.300	1.786	<0.200	<0.200
MO10(BG77m)	4.349	**4.661**	2.577	0.287	**2.401**	0.397	**7.401**	2.533	15.679
MO11(BG40m)	<0.300	<0.300	<0.200	2.854	<0.200	<0.300	0.984	<0.200	<0.200
MO12(BG23m)	3.056	<0.300	<0.200	<0.200	<0.200	<0.300	**2.678**	<0.200	<0.200
MO15(TR101m)	<0.300	<0.300	<0.200	<0.200	<0.200	<0.300	0.641	<0.200	<0.200
MO16(TR75.6m)	<0.300	<0.300	<0.200	<0.200	<0.200	<0.300	1.961	<0.200	<0.200
MO17(TR54m)	<0.300	<0.300	<0.200	<0.200	<0.200	<0.300	0.738	<0.200	<0.200
MO18(TR27m)	<0.300	<0.300	0.506	0.526	0.903	1.544	0.788	3.170	1.854
ERL	20.00	3.000	-	-	2.00	-	2.20	-	-

Table 1.2.5.8. Concentrations of PCBs (ng/g dry weight) in sediment samples collected from the Romanian, Bulgarian and Turkish area, MISIS cruise, 2013.

Stations	PCB 28	PCB 52	PCB 101	PCB 118	PCB 153	PCB 138	PCB 180	∑ PCBs
MO1(RO32m)	**2.74**	0.63	**7.06**	0.56	0.61	<0.70	1.92	14.23
MO2(RO47m)	1.42	**28.16**	**10.63**	**11.46**	5.08	**14.06**	3.47	74.29
MO3(RO52m)	**24.80**	**59.03**	**24.43**	**1.07**	0.68	**14.86**	6.07	130.95
MO4(RO65m)	1.28	**7.55**	1.52	0.09	<0.60	<0.70	<0.30	12.03
MO5(RO100m)	<0.40	**139.87**	<0.60	<0.40	<0.60	<0.70	<0.30	142.87
MO9(BG92m)	**13.58**	**30.40**	**3.66**	<0.40	<0.60	<0.70	0.94	50.28
M10(BG77m)	<0.40	1.62	1.09	0.60	0.80	4.79	2.49	11.79
M11(BG40m)	<0.40	**5.08**	1.21	<0.40	<0.60	<0.70	1.65	10.05
M12(BG23m)	<0.40	**82.98**	1.48	**1.05**	<0.60	5.49	1.01	93.02
M15(TR101m)	<0.40	<0.30	2.56	**7.26**	3.00	<0.70	<0.30	14.52
M16(TR75.6m)	<0.40	<0.30	0.71	<0.40	<0.60	<0.70	<0.30	3.41
M17(TR54m)	<0.40	**12.79**	1.98	<0.40	<0.60	<0.70	0.49	17.35
M18(TR27m)	<0.40	1.77	<0.60	<0.40	<0.60	<0.70	0.45	4.92
EAC	1.7000	2.7000	3.0000	0.6000	40.0000	7.9000	12.0000	-

National reports

Romania

Data on organochlorine compounds in surface sediments were obtained along relevant monitoring transects, in Danube mouths and Constanta area, strongly influenced by Danube in the northern area, or various land-based sources in the southern one, in 2012–2014 period, in the framework of the FP7 PERSEUS (Policy-oriented Marine Environmental Research for the Southern European Seas). Trends were assessed in comparison with 2006-2011 monitoring data.

The average concentration of organochlorine pesticides and polychlorinated biphenyls in surface sediment in 2012–2014 varied in the range 0.4–5.8 ng/g and 1.5–31.2 ng/g, respectively. Although the variation of organochlorine pesticides was broad in the western part of the Black Sea, more than 50% of the values for most investigated compounds were under detection limit [Oros et al, 2016b]. The highest values were recorded for PCB28 and PCB52 [Oros et al, 2016b]. More than 50% of the values (except PCB28 and PCB52) were under detection limit.

Overruns of ERL values, were frequently observed for PCB28 (56% of the measurements), PCB52 (54% of the measurements), PCB118 (29% of the measurements), PCB101 (25% of the measurements), lindane (21% of measurements) and p,p' DDE (16% of measurements) (Fig. 1.2.5.6; Fig. 1.2.5.7). For HCB, dieldrin, PCB153, PCB138 and PCB180 concentrations surpassing ERL values were occasional (1–10%).

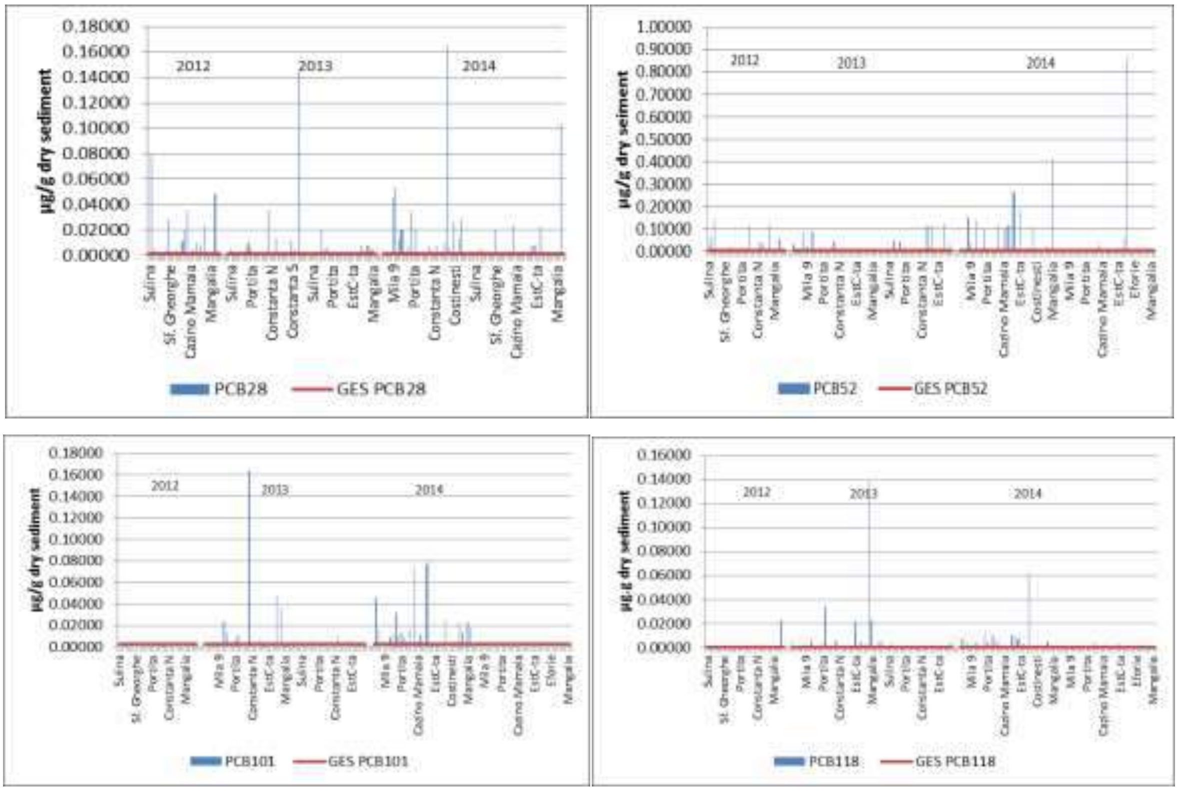

Figure 1.2.5.6. Concentrations of PCB28, PCB52, PCB101 and PCB118, in sediment, 2012–2014, in Constanta and Danube mouth area, in relation to the proposed values for the definition of good environmental status (ERL).

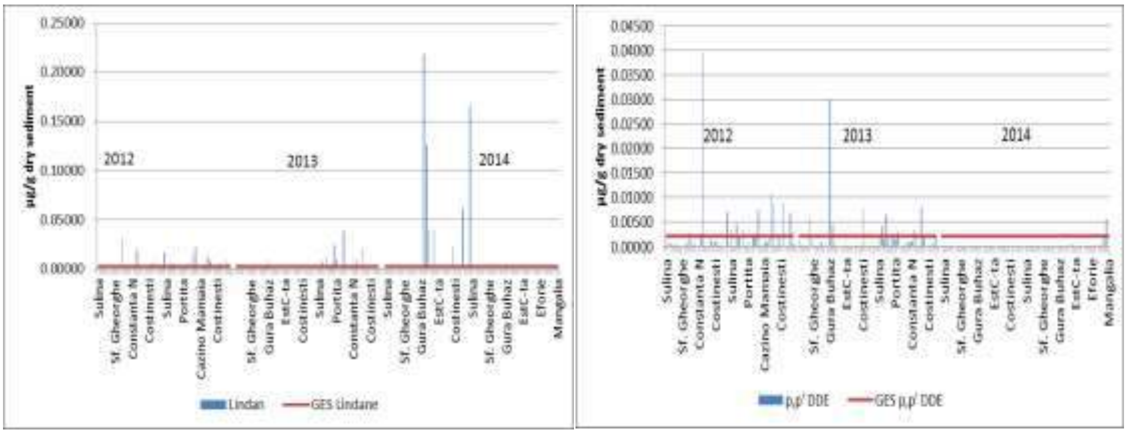

Figure 1.2.5.7. Concentrations of organochlorine pesticides in water, 2012–2014, in Constanta and Danube mouth area, in relation to the proposed values for the definition of good environmental status (ERL).

OCPs trend analysis for 2006–2014 show an obviously decreasing tendency in 2012–2014 period (Fig. 1.2.5.8). As no polychlorinated biphenyls data are available before 2012 is difficult to make a trend analysis for these compounds.

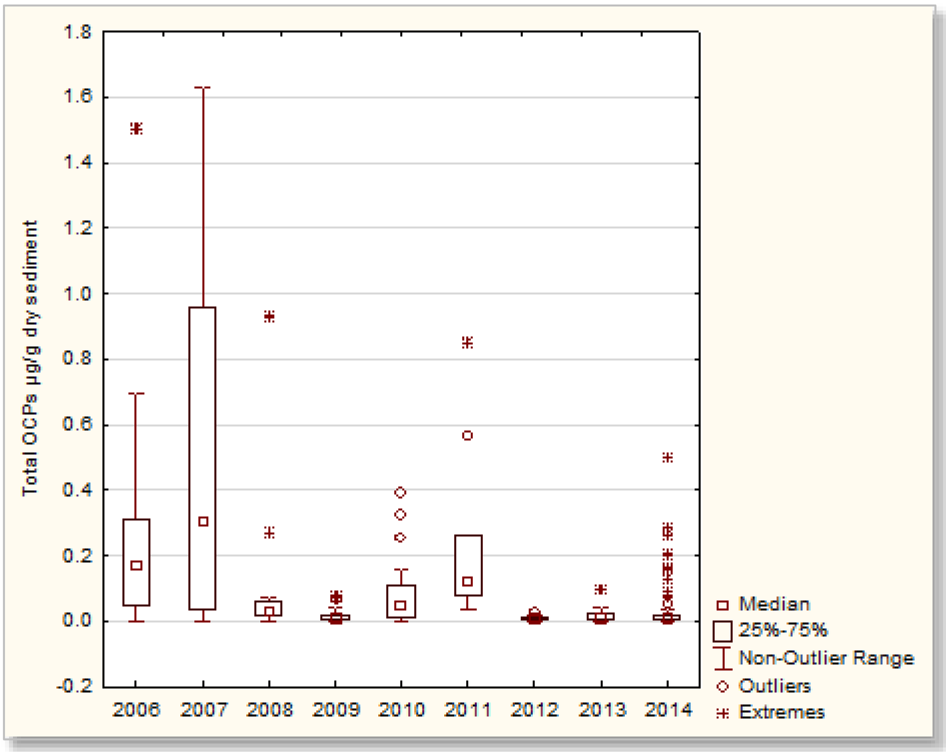

Figure 1.2.5.8. Trend analysis of OCPs in the west part of the Black Sea, in water, 2012 – 2014.

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1.2.6. Trace Metals

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Trace metals (TM) and rather often used as synonym name “heavy metals” (the difference mainly connected with including of iron and manganese) are elements that occur naturally in the environment and concentrations vary between areas of different geological origin, but human activities have drastically altered their geochemical cycles and biochemical balance, resulting in accumulation of metals in various ecosystem components (Bradl, 2002). The marine environment of the Black Sea is susceptible to pollution by hazardous substances because its typical features such as high water residence times, shallowness, and the large catchment area that predispose the Black Sea to the accumulation and effects of hazardous substances (Basturk et al, 1999). Heavy metals, emitted or discharged by households, traffic, agriculture and industries (mines, metal smelters, coal fired power plants, etc.) are transported to the sea via point sources, rivers, atmospheric deposition. Maritime transport and other maritime activities carried out at sea also add to the pollution burden of the sea. Heavy metals past pollution load is often buried in soils and sediments and does not disappear from the ecosystem, even in case of reduction in discharges or cessation of production, and this is particularly confirmed in shallow areas (Windom, 1992).

Studies in various marine regions confirm that atmospheric emissions from traffic, shipping, energy production, incineration of wastes and even small scale household represent important sources of heavy metals, which become dispersed in the marine environment after being deposited onto the sea surface (Knuuttila, 2009). Thus, for some heavy metals (eg. lead, mercury, cadmium), atmospheric deposition could be a major component of their inputs to the Black Sea and their sources may be located far away from the catchment area.

Regional assessment was primary conducted based on processing the heavy metals data reported by countries to the Black Sea Commission, gathered in the Black Sea Joint Data Base, period 2009–2014. Other relevant information was compiled from regional assessments conducted in the framework of major projects, like DG ENV MISIS, FP7 PERSEUS. Also national reports were included, for additional information and long-term trends.

1.2.6.1. Seawater

Eleven heavy metals (Fe, n=730; Zn, n=93; Hg, n=311; As, n=84; Cu, n=416; Cd, n=413; Pb, n=537; Cr, n=378; Ni, n=369; Mn, n=86; Co, n=84) were monitored and reported by countries to Black Sea Database, period 2009-2014, surface waters. Also data regarding concentrations along water column were reported. Mean and median concentrations, and variation ranges, excluding outliers, for the whole region and sub-regions, are presented in Tab. 1.2.6.1–1.2.6.6.

In relation with European environmental quality standards (EQS) for water (Directive 2013/39/CE), concentrations of Cd, Pb and Hg in surface waters complied with recommended values in majority of samples, while for Ni no surpassing of maximum admisible level was recorded (Tab. 1.2.6.1).

Differences among spatial distribution of average values among sub-regions could be related with the influence of rivers or various industrial effluents discharges - mining, smelters (Unsal, 2001), (Fig. 1.2.6.2; Fig. 1.2.6.3).

Distribution of heavy metals along water column (0-100m) evinced for Cu and especially Cd an accumulation in the middle of water column (between 40 and 60 m), while Pb presented increased concentrations at higher depth (>70m), (Fig. 1.2.6.1). This could be considered a typical behaviour, since the lateral transport is more important for the metals (Cd, Cu, Zn) with “nutrient-like” behaviour than vertical sedimentation, while for particle reactive elements like Pb, sinking associated with particles, and lateral transport as much as atmospheric input are in the same order of magnitude (Pohl et. al, 2006).

Inter-annual variability of heavy metals concentrations in surface waters shows a decreasing trend in recent period (2013-2014) for Cu, Cd, and Pb (Cu and Pb presented higher values in 2011, and Cd in 2012), while Ni and other elements didn’t show specific tendencies (Fig. 1.2.6.4).

Table 1.2.6.1. Concentrations of heavy metals in Black Sea surface waters, 2009-2014 (data from Black Sea Database).

Descriptive Statistics (Trace metals_2009-2014_Surface water), Black Sea region						
	Valid N	**Mean**	**Median**	**Percentile – 10th**	**Percentile – 90th**	**Std.Dev.**
Fe [μg/l]	730	39.06	30.00	10.00	60.42	53.43
Zn [μg/l]	93	7.92	4.60	0.00	15.60	12.27
Hg [μg/l]	311	0.05	0.00	0.00	0.10	0.18
As [μg/l]	84	1.61	1.04	0.00	4.60	2.18
Cu [μg/l]	416	7.33	3.33	0.68	17.41	10.39
Cd [μg/l]	413	1.84	0.82	0.03	4.93	3.35
Pb [μg/l]	537	6.51	3.12	0.16	11.87	12.07
Cr [μg/l]	378	2.20	1.09	0.00	6.12	3.13
Ni [μg/l]	369	3.06	1.74	0.01	7.66	4.16
Mn [μg/l]	86	12.48	7.35	1.50	30.10	13.19
Co [μg/l]	84	0.97	0.64	0.00	2.66	1.14

Table 1.2.6.2. Percentage of observations surpassing EQS (Directive 2013/39/CE) in surface waters, 2009-2014.

Element	Environmental Quality Standard (MAC) Directive 2013/39/CE	Number of observations	Percentage of observations surpassing EQS
Cadmium	1.50 μg/L	413	25%
Lead	14 μg/L	537	10%
Nickel	34 μg/L	369	0
Mercury	0.07 μg/L	311	20%

Table 1.2.6.3. Concentrations of heavy metals in Western Black Sea surface waters, 2009-2014 (data from Black Sea Database).

Descriptive Statistics (TM_2009-2014_Surface water), Western Black Sea						
	Valid N	**Mean**	**Median**	**Percentile – 10th**	**Percentile – 90th**	**Std.Dev.**
Fe [μg/l]	34	25.02	10.00	10.00	75.00	24.72
Hg [μg/l]	5	1.30	1.50	0.50	1.50	0.44
Cu [μg/l]	284	8.02	3.33	0.89	22.78	11.63
Cd [μg/l]	288	1.20	0.88	0.08	2.58	1.29
Pb [μg/l]	284	5.24	3.15	1.03	10.61	6.85
Cr [μg/l]	279	2.52	1.25	0.27	6.25	3.01
Ni [μg/l]	286	3.13	1.92	0.87	7.66	3.81
Mn [μg/l]	33	20.06	23.65	1.50	36.55	16.75

Table 1.2.6.4. Concentrations of heavy metals in Eastern Black Sea surface waters, 2009-2014 (data from Black Sea Database).

Descriptive Statistics (TM_2009-2014_Surface water), Eastern Black Sea						
	Valid N	**Mean**	**Median**	**Percentile – 10th**	**Percentile – 90th**	**Std.Dev.**
Fe [μg/l]	120	56.33	29.71	4.87	109.22	106.17
Hg [μg/l]	177	0.002	0.00	0.00	0.01	0.006
Pb [μg/l]	120	4.69	3.68	0.68	9.80	4.18

Table 1.2.6.5. Concentrations of heavy metals in North-Western Black Sea surface waters, 2009-2014 (data from Black Sea Database).

Descriptive Statistics (TM_2009-2014_Surface water), North-Western Black Sea						
	Valid N	**Mean**	**Median**	**Percentile – 10th**	**Percentile – 90th**	**Std.Dev.**
Fe [μg/l]	268	39.40	30.00	10.00	60.00	46.19
Zn [μg/l]	86	8.26	4.82	0.00	16.70	12.70
As [μg/l]	78	1.66	0.55	0.00	4.65	2.24
Hg [μg/l]	86	0.03	0.00	0.00	0.11	0.06
Cu [μg/l]	86	4.46	2.30	0.00	8.75	7.09
Cd [μg/l]	78	0.51	0.12	0.00	1.26	0.98
Pb [μg/l]	86	1.66	0.00	0.00	6.16	2.50
Cr [μg/l]	85	1.39	0.00	0.00	3.47	3.54
Ni [μg/l]	83	2.83	1.20	0.00	7.69	5.23
Mn [μg/l]	41	6.50	5.47	1.48	13.10	5.90
Co [μg/l]	81	0.95	0.39	0.00	2.66	1.16

Table 1.2.6.6. Concentrations of heavy metals in Southern Black Sea surface waters, 2009-2014 (data from Black Sea Database).

Descriptive Statistics (TM_2009-2014_Surface water), Southern Black Sea						
	Valid N	**Mean**	**Median**	**Percentile – 10th**	**Percentile – 90th**	**Std.Dev.**
Fe [µg/l]	12	46.18	39.11	32.05	64.04	15.97
Hg [µg/l]	41	0.17	0.10	0.09	0.41	0.12
Cu [µg/l]	44	8.80	7.42	2.09	15.58	5.32
Cd [µg/l]	45	8.34	6.40	0.38	17.11	6.59
Pb [µg/l]	45	28.92	12.92	3.12	71.96	28.89
Cr [µg/l]	12	0.96	0.75	0.57	1.55	0.45
Mn [µg/l]	12	12.07	9.00	4.03	17.53	9.83

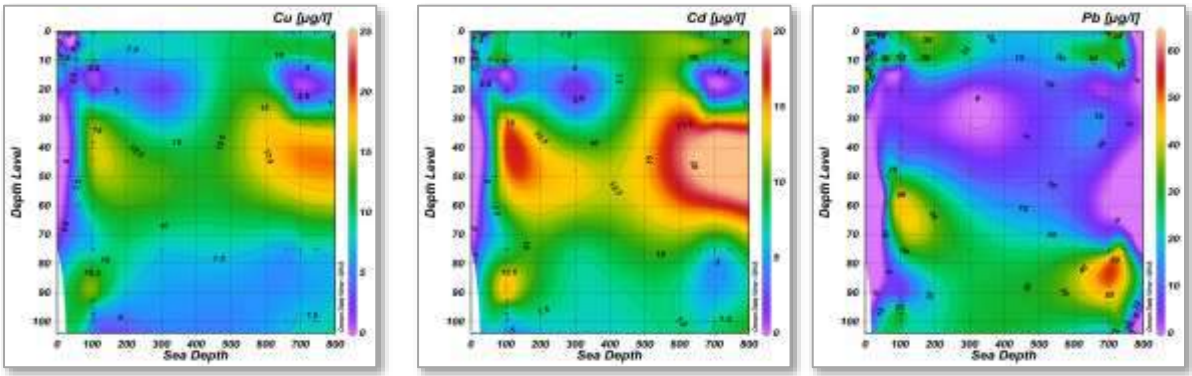


Figure 1.2.6.1. Distribution of Cu, Cd and Pb along water column, Black Sea Database, 2009-2014.

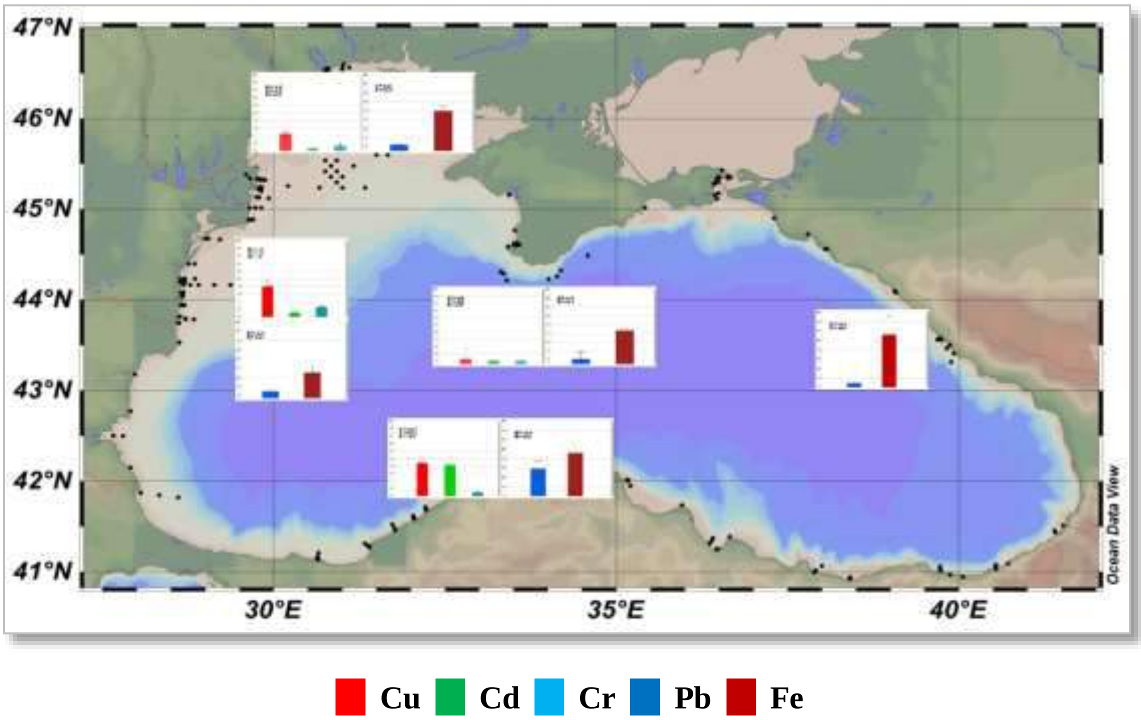


Figure 1.2.6.2. Black Sea monitoring stations and spatial distribution of average values of heavy metals in surface waters, 2009-2014.

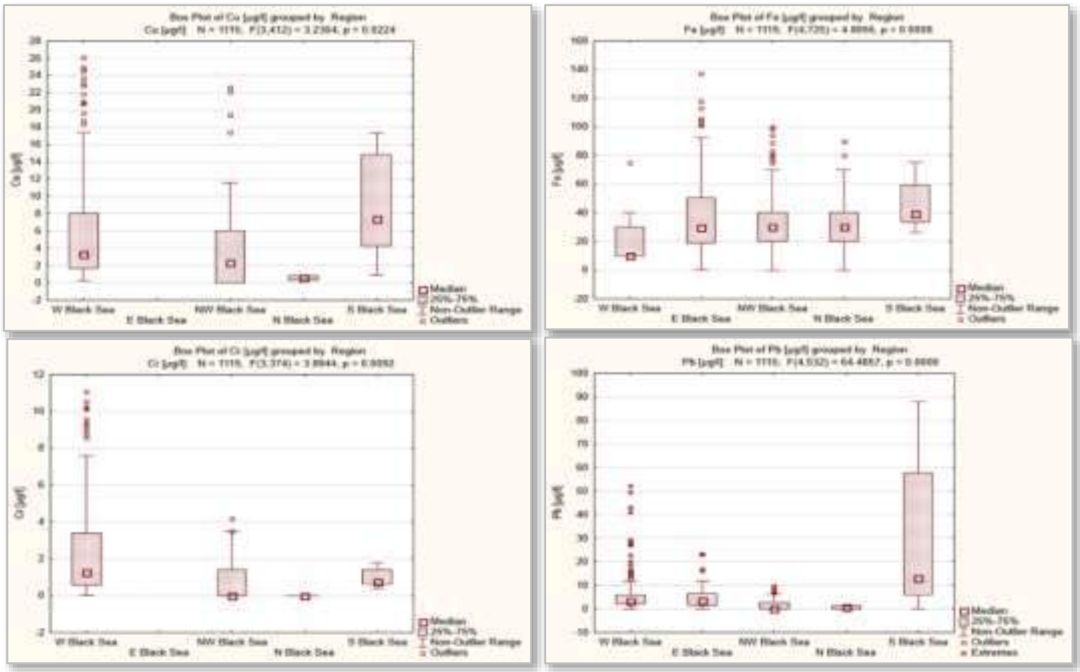


Figure 1.2.6.3. Spatial distribution of heavy metals concentrations in surface waters, 2009-2014.

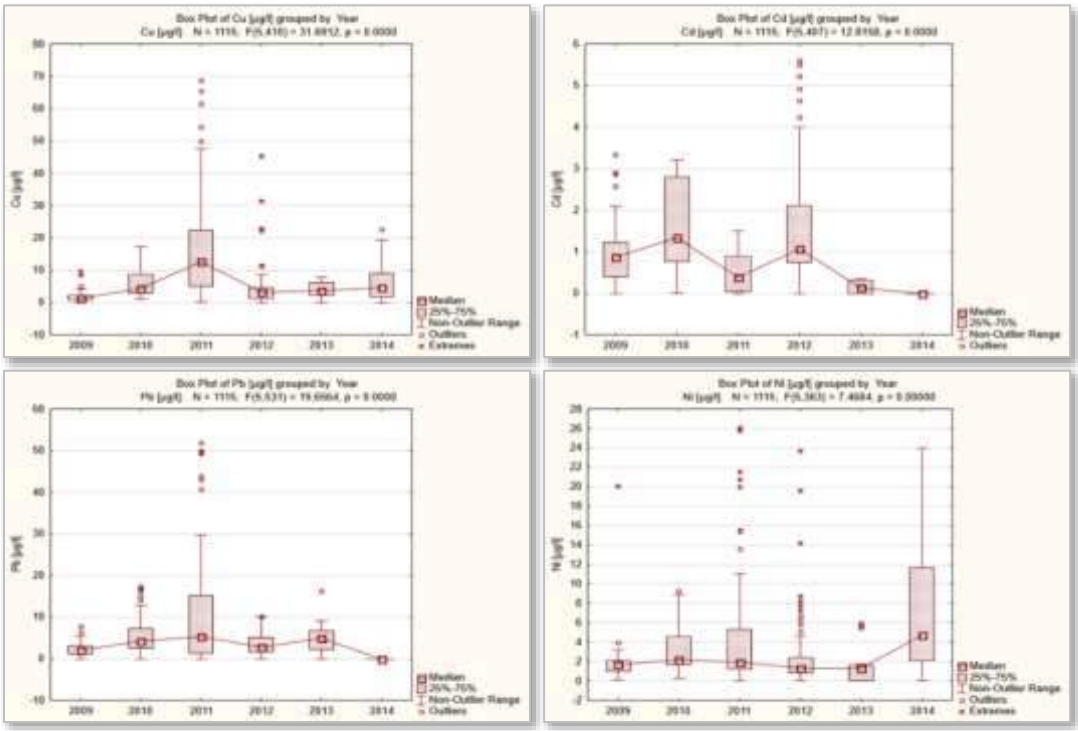


Figure 1.2.6.4. Trends of heavy metals concentrations in Black Sea surface waters, 2009-2014.

Other regional information (MISIS Project)

In the framework of the project DG ENV MISIS (MSFD Guiding Improvements in the Black Sea Integrated Monitoring System), a Joint Cruise was carried out onboard R/V Akademik in the Western Black Sea, during 22-31 July 2013. The selected transects were: Constanta, in the Romanian waters, Galata, in the Bulgarian waters, and Igneada, in the Turkish waters, 18 stations covering the coastal, shelf and open waters (Fig. 1.2.6.5). Results showed that heavy metals concentrations in surface seawater collected during July 2013 from all transects were found to be rather low, being comparable and included within typical ranges reported for Black Sea coastal or open waters (Table 1.2.6.7). Generally, a slight decreasing gradient from coastal to open sea was noticed for most analysed metals, with the exception of lead and chromium, but with no statistically significant differences (Fig. 1.2.6.6). These measurements from July 2013 indicated a low level trace metal pollution of marine waters, concentrations of cadmium, lead and nickel being much below recommended EQS from European Legislation (Directive 2013/39/EU), (Oros et al, 2016a).

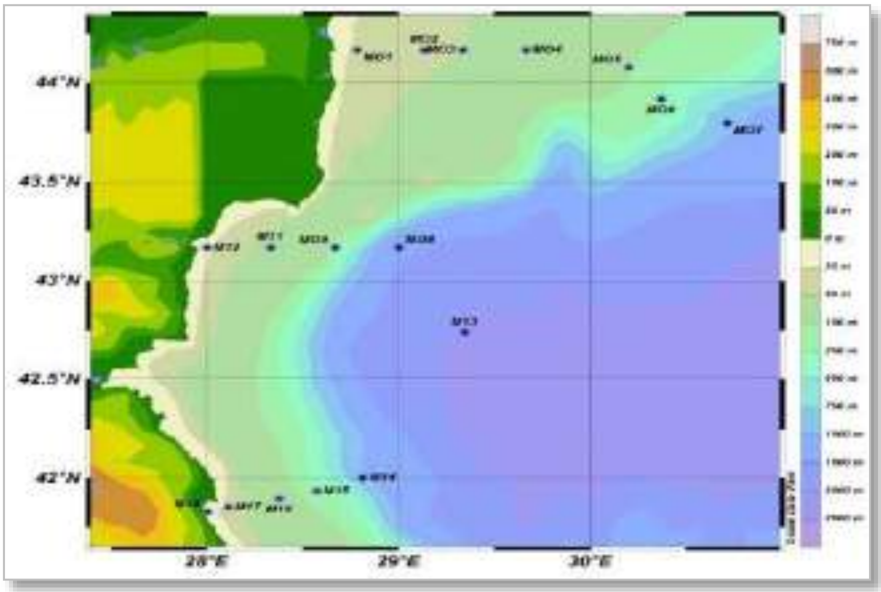


Figure 1.2.6.5. Map of study area, MISIS Joint Cruise, 22-31 July 2013.

Table 1.2.6.7. Comparative data on heavy metals in seawater of the Black Sea region.

	Cu (µg/L)	Cd (µg/L)	Pb (µg/L)	Ni (µg/L)	Cr (µg/L)
MISIS cruise, July 2013 (RO, BG, TR transects) (total metals)	0.65 (0.10-2.99)	0.20 (0.05 - 0.76)	2.45 (1.16-3.70)	4.38 (0.14-12.38)	2.54 (1.14-6.06)
IA RO Transitional, Coastal and Marine Waters (2006-2011) (total metals) (Boicenco et al, 2012)	10.02	0.99	3.78	3.65	3.84
RO Coastal and Marine waters (2013 Monitoring data) (total metals)	1.14 (0.37 - 4.14)	0.56 (0.16 - 2.87)	2.40 (0.04 - 7.04)	1.42 (0.24 - 8.13)	2.45 (0.37-10.34)
Ukrainian coastal Black Sea waters (total metals) (BSC. 2008)	0.40 - 3.00	0.05 - 0.15	1.00 - 9.30		

	Cu (µg/L)	Cd (µg/L)	Pb (µg/L)	Ni (µg/L)	Cr (µg/L)
MISIS cruise, July 2013 (RO, BG, TR transects) (total metals)	0.65 (0.10-2.99)	0.20 (0.05 - 0.76)	2.45 (1.16-3.70)	4.38 (0.14-12.38)	2.54 (1.14-6.06)
BG coastal Black Sea waters (Andreev et al, 1994)	0.60 - 0.85	0.018 -0.026	0.40 - 0.87	0.61 - 0.82	
BG coastal Black Sea waters (BSBD, 2006-2011)		0.84 - 0.97	1.70	3.8 - 5.9	
TR coastal Black Sea waters (total metals) (Coban et al, 2009)	7.75	1.68	8.08	8.33	5.82
W Black Sea (dissolved metals) (Tankere et al, 1996)	1.78	0.016	0.037	0.94	
NW Black Sea (dissolved metals) (Zeri et al, 2000)	1.19 – 218.11	0.15– 1.59		0.23 – 11.15	

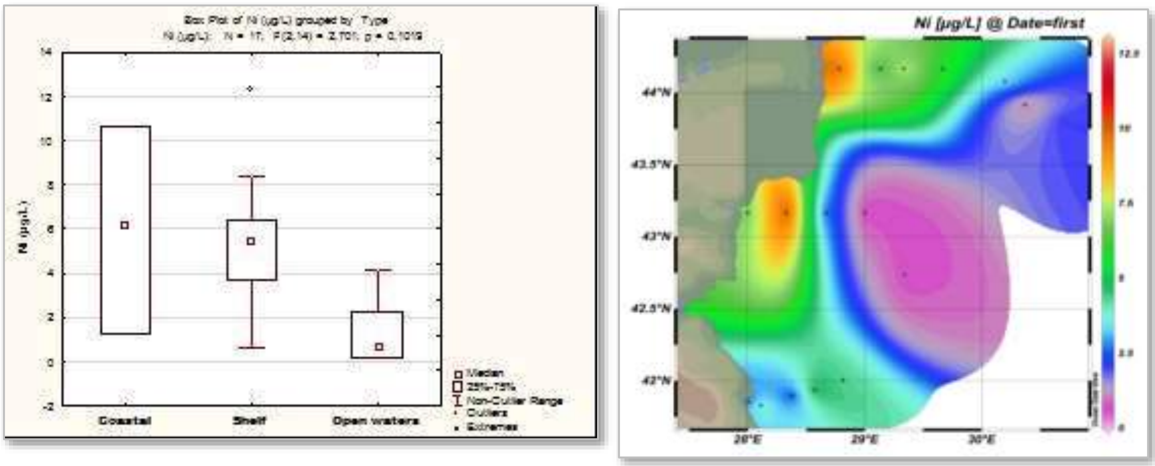


Figure 1.2.6.6. Distribution of nickel (µg/L) in coastal, shelf and open sea waters from the Romanian, Bulgarian and Turkish area, July 2013.

National reports (status, long-term trends)

Romania

In the framework of the FP7 PERSEUS (Policy-oriented Marine Environmental Research for the Southern European Seas), new data (2012-2014) on heavy metals in surface seawater samples from the Romanian Black Sea were obtained. Gradient of pollution was assessed along relevant monitoring transects, covering two study areas (Danube mouths and Constanta area), in order to improve knowledge on the various influences upon the quality of the Romanian Black Sea waters, either Danube in the northern area, or various land-based sources in the southern one. Trends were assessed in comparison with 2006-2011 monitoring data. Concentrations of heavy metals (Cu, Cd, Pb, Ni, Cr) measured in seawater (surface horizon) along the Romanian Black Sea coast during 2012-2014 were characterized by an increased spatial and temporal variability, under influence of various natural and anthropogenic pressures. Overall, the majority of samples (percentile 75th of all data series) were situated below environmental quality standards for seawater. Although occurred with a low frequency, higher variation ranges, even outliers and extreme values, were noticed especially in the area under the influence of Danube, and in specific locations, situated in the vicinity of big harbours (Constanta, Mangalia) or WWTP outlets. In comparison with 2006-2011 monitoring data, in the recent years heavy metals concentrations were situated in general within the same variation ranges, in some cases with slightly decreasing trends (Fig. 1.2.6.7), (Oros et al, 2016b).

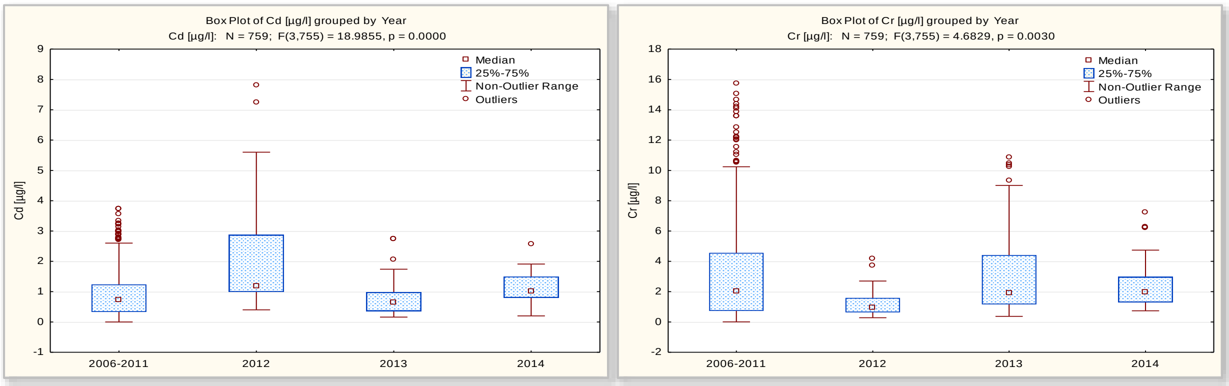


Figure 1.2.6.7. Trends of heavy metals in the Romanian Black Sea waters during 2006–2014.

Ukraine

In 2009, the concentration of most toxic metals in marine waters of the studied areas (NW Black Sea and Kerch Strait) were negligible and average values of about one order of magnitude below the established national standards (MAC). The absolute concentrations of the metal content in marine waters decreased in the following order: Zinc> Arsenic> Copper> Lead> Chromium> Cadmium> Mercury (Fig. 1.2.6.8)**.**

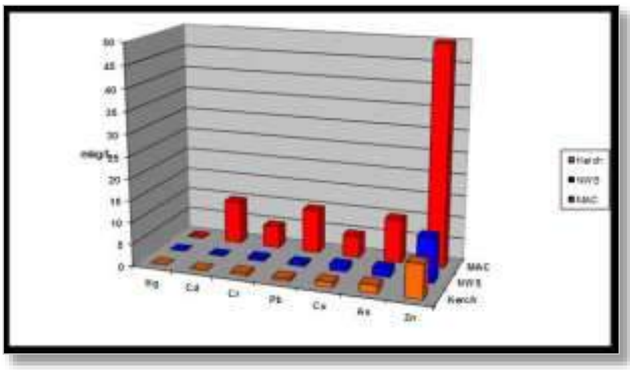
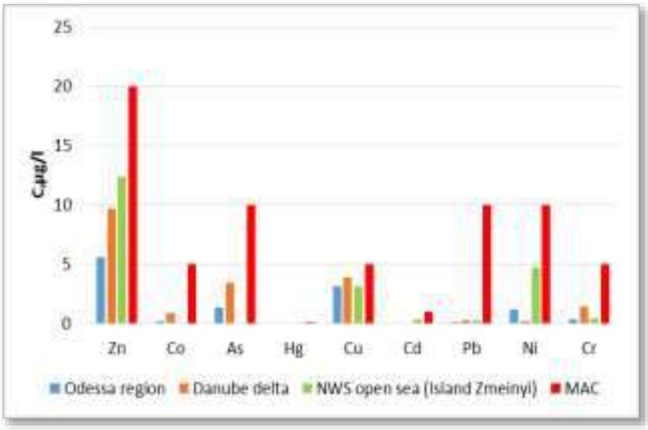


Figure 1.2.6.8. Average concentration of trace metals in seawater of NW Black Sea and Kerch Strait in 2009.

In 2011, the concentration of most toxic metals in marine waters of the studied areas (Odessa region, Danube Delta and NW open sea - Zmeinyi island) were negligible, with average values 10 time less than MAC (Fig. 1.2.6.9). The absolute concentrations of the metal content in marine waters decreased in the following order: Zinc> Copper > Arsenic > Nickel > Chromium> Lead> Cobalt> Cadmium> Mercury. The maximal concentrations of trace metals in three regions are presented in Fig. 1.2.6.10.



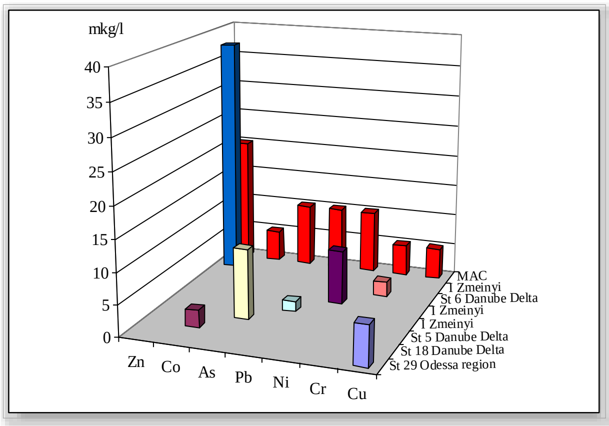


Figure 1.2.6.9. Average concentrations of trace metals in Ukrainian waters in 2011.

Figure 1.2.6.10. The maximal concentrations of trace metals in Ukrainian marine waters.

Average concentration of iron on the stations of Odessa bay, Sevastopol and Kerch areas did not exceed MAC (50 µg/l), but in the Danube delta area and in Odessa region (NW) concentration of iron was in 2-3 times more than MAC, in 2011.

In 2012, the concentration of most toxic metals in marine waters of the studied areas (Odessa region, Danube Delta, NW open sea - Zmeinyi island, Zernov's Phyllophora field) were negligible, with average values 10 time less than MAC (Table 1.2.6.8; Fig. 1.2.6.11). The absolute concentrations of the metal content in marine waters decreased in the following order: Zinc> Nickel> Copper> Manganese> Lead> Cobalt> Arsenic> Chromium> Cadmium> Mercury.

Table 1.2.6.8. Average concentrations of trace metals in Ukrainian marine waters in 2012.

Region	Zn	Cu	As	Ni	Cr	Pb	Co	Cd	Hg	Mn
	µg/L									
Odessa region	17,7	**18,9**	0,44	0,94	1,34	2,26	2,33	0,28	**0,107**	8,81
Danube delta	7,04	0	0	**15,65**	1,63	0	0	0	0,027	
NWS open sea (Island Zmeinyi)	2,18	0,84	1,52	6,93	0	2,52	0,53	0,73	0,093	1,71
Zernov's Phyllophora Field	4,95	1,00	1,50	1,03	0,18	2,99	1,94	**1,24**	0,05	6,78
MAC	**20**	**5,0**	**10**	**10**	**5,0**	**10**	**5,0**	**1,0**	**0,100**	**50,0**

Bold indicates a concentration above the MAC

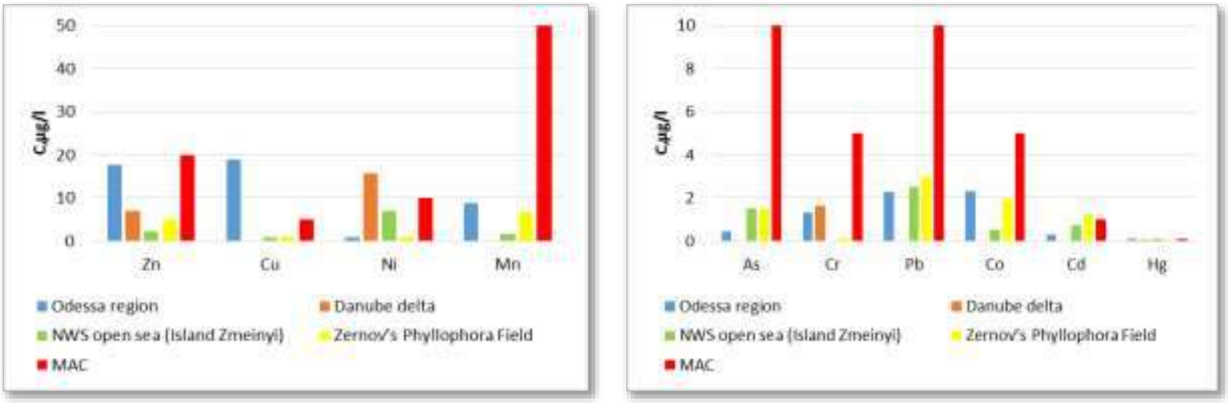


Figure 1.2.6.11. Average concentrations of trace metals in Ukrainian marine waters in 2012.

In 2013 the concentration of most toxic metals (except Cu) in marine waters of the studied areas was negligible, with average values less than MAC. The absolute concentrations of the metal content in marine waters decreased in the following order: Zinc> Copper > Nickel > Lead> Arsenic > Cadmium> Chromium> Cobalt> Mercury (Fig. 1.2.6.12).

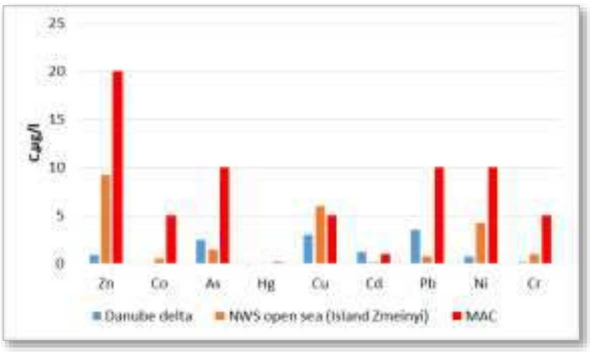


Figure 1.2.6.12. Average concentrations of trace metals in Ukrainian marine waters in 2013.

In 2014, the concentrations of most toxic metals (except Cu, Ni, Cr) in marine waters of the studied areas (Danube Delta, NW open sea – Zmeinyi Island) were negligible, with average values less than MAC. The absolute concentrations of the metal content in marine waters decreased in the following order: Nickel > Zinc> Copper > Chromium> Arsenic > Lead> Cobalt> Cadmium> Mercury. Toxic metals content in near-Danube coastal water close to the Bystriy mouth distributed as follows: 7.5 times as high as maximum concentration limit (MAC) for copper, 3.5 times as MAC for zinc, 2.5 times as MAC for chrome, 3.1 times as MAC for iron, and 22.4 as MAC for nickel, which indicates a significant toxic metal pollution. (Fig. 1.2.6.13)

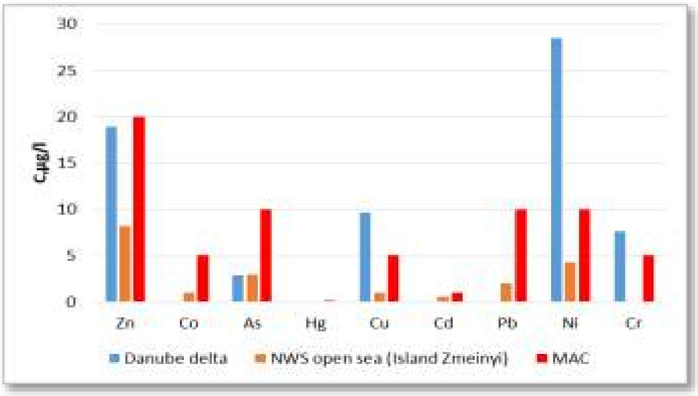


Figure 1.2.6.13. Average concentrations of trace metals in Ukrainian marine waters in 2014.

Russia

Region of Large Sochi. During the last decade the only measurements of mercury, lead and iron were provided four times per year in the coastal waters of the region of Large Sochi. The eight sampling sites of routine monitoring are placed in the narrow stripe of 2 nm between estuaries of rivers Mzymta and Sochi (Fig.1.2.6.14). The stations were situated in the port Sochi harbour (st.I, MSFD "Coastal"), in the estuarine areas of large rivers Mzymta, Khosta, Sochi and small stream Malui (st.II, IV, V and VII, MSFD "Transitional"), and at distance 2 nm apart from the coast (st.III, VI and VIII, MSFD "Marine"). The water was sampled by bathometer at standard horizons up to depth 50 m. For the treatment of marine waters AAS method were used: Spectrophotometer Kvant-Z.ETA, Detection Range Pb - 2.0÷30.0 µg/l; DR Fe - 10÷200 µg/l.

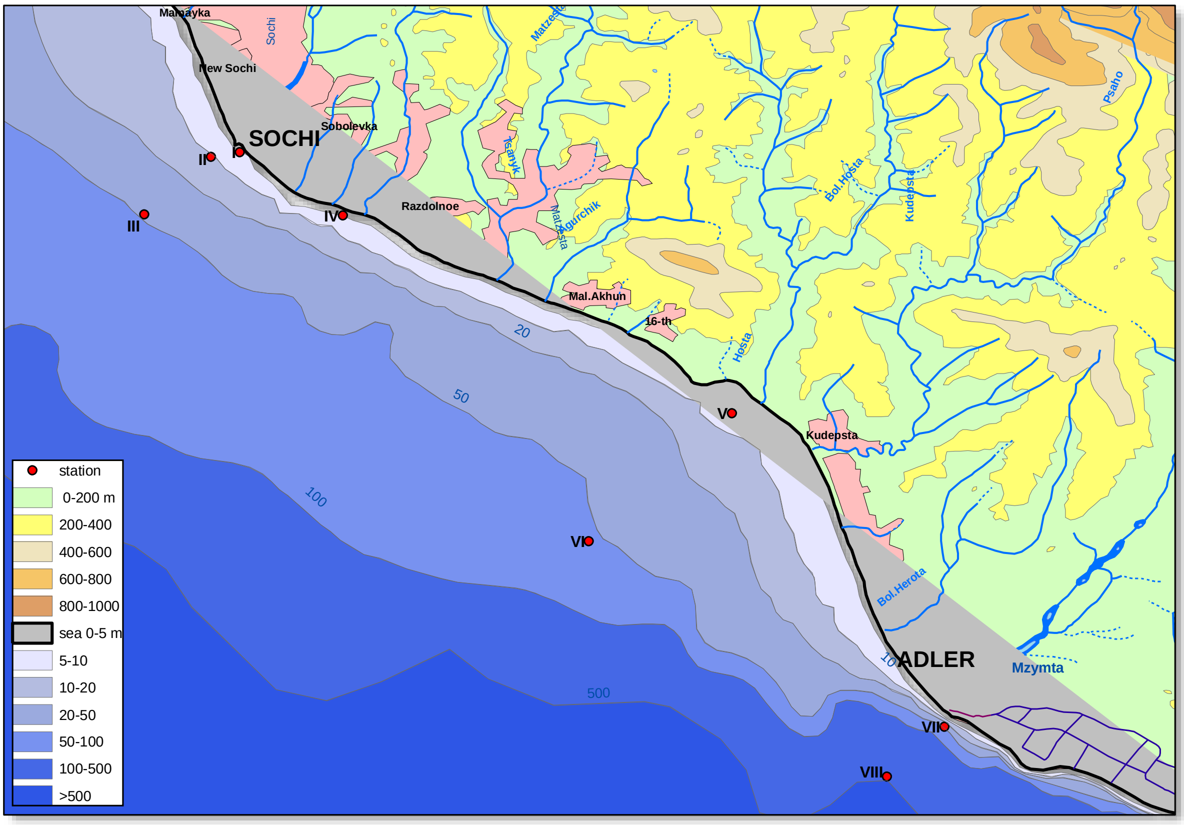


Figure 1.2.6.14. Routine monitoring stations in the coastal waters between estuaries of the rivers Mzymta and Sochi.

Hg. During the whole period of investigation since 2002 in the region of the Large Sochi the maximal concentration of mercury in marine waters exceeds the MAC=0.1 µg/l only four times – twice in July 2005 in close to Mzymta estuary (0.13 and 0.10 µg/l) and twice in June and December 2008 in Sochi harbour (0.11 and 0.12 µg/l). During the last five years in the coastal waters of studied region mercury in marine waters was recorded 26 times in concentration 0.01-0.02 µg/l (0.1-0.2 MAC) among 432 tested samples.

Pb. In 2015 the concentration of lead in the coastal waters was in the range 1.6-39.9 µg/l; the average value increased almost 4 times in comparison with previous year until 14,28 µg/l. The maximum also grow up four times till 4.0 MAC and recorded at surface of Sochi harbour at 11 March. In this year in 43 samples from 64 analysed (67%) the concentration of lead was above 1 MAC. In general, last decade the increasing of average and maximal concentration of lead was clearly recorded (Fig. 1.2.6.15). In 2015 the average first time over studied period exceeds MAC.

Fe. The iron concentration in 2015 in the coastal waters between estuaries of Mzymta and Sochi Rivers varied in the range of 7.1-123.0 µg/l. In contrary with previous year the concentration exceeds MAC in 16 samples (25%) mainly in the waters of Sochi harbour and rivers estuaries in March and November. In the Sochi harbour annual average iron concentration was 36.4 µg/l, in the open sea 33.8 µg/l. In the surface and near-bottom layers the difference of iron wasn't significant and reached 32.7 and 42.2 µg/l correspondingly while annual average for the whole region was 36,5 µg/l. During the last decade the short four-year period of extremely high iron concentration at 2008-2011 reaching 281-869 µg/l was recorded. Before and later the maximum usually was not exceeds 1-2 MAC. Therefore it isn't finding any significant trend in long-term dynamic of iron concentration in marine waters, but strong inter-annual variation is visible.

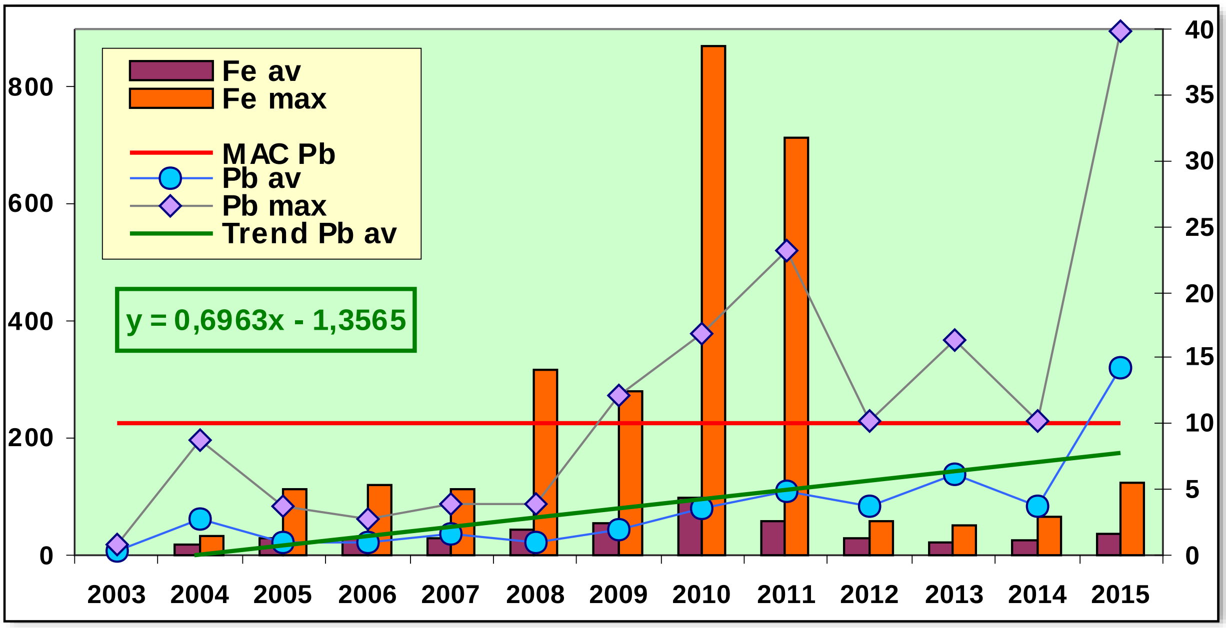


Figure 1.2.6.15. Average and maximal concentration of iron and lead (μg/l) in the coastal waters of region Adler-Sochi in period of 2003-2015.

1.2.6.2. Sediments

Sediments are an important repository for various pollutants and also play a significant role as sensitive indicators for monitoring contaminants in aquatic systems (Ozkan and Buyukisik, 2012). Sediments are considered to be an important carrier as well as a sink of heavy metals in the hydrological cycle and reflect the current quality of the system as well as provide information on the impact of pollution sources (Kruopiene, 2007).

Eleven heavy metals (Zn, n=274; Co, n=132; Hg, n=248; As, n=206; Cu, n=518; Cd, n=450; Pb, n=518; Cr, n=420; Ni, n=442; Mn, n=38; V, n=26) were monitored and reported by countries to Black Sea Database, period 2009-2014, in sediments. Mean and median concentrations, and variation ranges, excluding outliers, for the whole region and sub-regions, are presented in Tables 1.2.6.9-1.2.6.13. In relation with sediment quality criteria (ERL: Effects Range – Low) (Buchman, 2008), percentages of observations surpassing ERL values varied, depending on the element, between 3% and 65% (Table 1.2.6.10).

Differences in spatial distribution of heavy metals in sediments among Black Sea sub-regions were not so pronounced, and could be related, beside different background levels, with the influence of rivers or various industrial effluents discharges (mining, smelters) (Unsal, 2001) in some locations, where occasionally increased concentrations were reported during 2009-2014 (Fig. 1.2.6.16; Fig. 1.2.6.17).

Inter-annual variability of heavy metals concentrations in sediments shows a slight decreasing trend in recent period (2013-2014) for Cd, Pb and Ni (as reduced median values and variation ranges, and less extreme values), while Cu, Cr and Zn didn't show any trends, their concentrations being maintained between similar variation ranges along the assessment period (Fig. 1.2.6.18).

Table 1.2.6.9. Concentration of heavy metals in the Black Sea sediments, 2009-2014 (data from Black Sea Database).

Descriptive Statistics (Trace metals_2009-2014_Sediments), Black Sea region						
	Valid N	**Mean**	**Median**	**Percentile - 10th**	**Percentile – 90th**	**Std.Dev.**
Zn [µg/g]	274	78.85	69.00	28.00	137.00	55.60
Co [µg/g]	132	7.07	6.89	1.70	12.70	4.21
As [µg/g]	206	9.47	8.39	3.10	17.30	6.25
Cu [µg/g]	518	34.37	29.51	6.60	67.60	29.39
Cd [µg/g]	450	0.33	0.20	0.00	0.86	0.37
Pb [µg/g]	518	21.81	17.99	3.11	44.16	17.94
Ni [µg/g]	442	37.55	31.35	9.35	73.62	27.85
Cr [µg/g]	420	57.49	49.03	17.21	103.00	40.64
Hg [µg/g]	248	0.29	0.08	0.01	1.13	0.57
V [µg/g]	26	426.03	148.53	20.54	1104.69	467.11
Mn [µg/g]	38	577.57	464.50	98.70	1119.00	388.53

Table 1.2.6.10. Percentage of observations surpassing sediment quality criteria (ERL), 2009-2014.

Element	Sediment Quality Criteria (Effect Range – Low, ERL) *	Number of observations	Percentage of observations surpassing ERL
Zn [µg/g]	150	274	7%
As [µg/g]	8.2	206	50%
Cu [µg/g]	34	518	40%
Cd [µg/g]	1.20	450	3%
Pb [µg/g]	47	518	9%
Ni [µg/g]	21	442	65%
Cr [µg/g]	81	420	23%
Hg [µg/g]	0.15	248	34%

***** Buchman MF, 2008. NOAA Screening Quick Reference Tables (SquiRT), NOAA OR&R Report 08-1, Seattle WA, Office of Response and Restoration Division, National Oceanic and Atmospheric Administration, 34 p.

Table 1.2.6.11. Concentration of heavy metals in Western Black Sea sediments, 2009-2014 (data from Black Sea Database).

Descriptive Statistics (Trace metals_2009-2014_Sediments), Western Black Sea						
	Valid N	**Mean**	**Median**	**Percentile – 10th**	**Percentile – 90th**	**Std.Dev.**
Cu [µg/g]	218	38.10	32.99	8.05	74.57	28.12
Cd [µg/g]	218	0.45	0.41	0.00	1.00	0.42
Pb [µg/g]	218	22.49	16.00	5.07	54.25	19.63
Ni [µg/g]	218	43.16	40.05	13.62	86.05	27.88
Cr [µg/g]	218	50.39	43.52	17.00	89.00	31.12

Table 1.2.6.12. Concentration of heavy metals in Southern Black Sea sediments, 2009-2014 (data from Black Sea Database).

Descriptive Statistics (Trace metals_2009-2014_Sediments), Southern Black Sea						
	Valid N	**Mean**	**Median**	**Percentile – 10th**	**Percentile – 90th**	**Std.Dev.**
Zn [μg/g]	63	73.04	70.00	48.00	101.00	24.84
Cu [μg/g]	89	44.28	33.00	16.00	72.65	45.61
Cd [μg/g]	26	0.37	0.37	0.19	0.60	0.21
Pb [μg/g]	89	26.55	23.00	12.00	47.00	17.40
Ni [μg/g]	63	48.76	39.00	15.00	106.00	34.78
Cr [μg/g]	63	78.22	65.00	24.00	150.00	65.04
Hg [μg/g]	37	1.37	1.73	0.21	2.41	0.85
V [μg/g]	26	426.03	148.53	20.54	1104.69	467.11
Mn [μg/g]	11	835.18	849.00	435.00	1119.00	353.12

Table 1.2.6.13. Concentration of heavy metals in North-Western Black Sea sediments, 2009-2014 (data from Black Sea Database).

Descriptive Statistics (Trace metals_2009-2014_Sediments), North-Western Black Sea						
	Valid N	**Mean**	**Median**	**Percentile – 10th**	**Percentile – 90th**	**Std.Dev.**
Zn [μg/g]	206	81.04	68.45	22.90	142.00	62.43
Co [μg/g]	127	7.03	6.78	1.69	12.80	4.25
As [μg/g]	201	9.47	8.50	3.10	17.30	6.29
Cu [μg/g]	206	26.66	24.95	5.29	52.50	17.83
Cd [μg/g]	201	0.20	0.15	0.00	0.39	0.27
Pb [μg/g]	206	19.30	16.10	1.20	39.30	15.94
Ni [μg/g]	156	25.93	21.30	4.00	52.40	19.61
Cr [μg/g]	134	59.45	56.20	8.96	108.00	36.74
Hg [μg/g]	206	0.11	0.07	0.01	0.20	0.16
Fe [μg/g]	116	23828.10	24550.00	10000.00	37800.00	10844.48
Mn [μg/g]	27	472.62	368.00	84.00	960.00	356.87

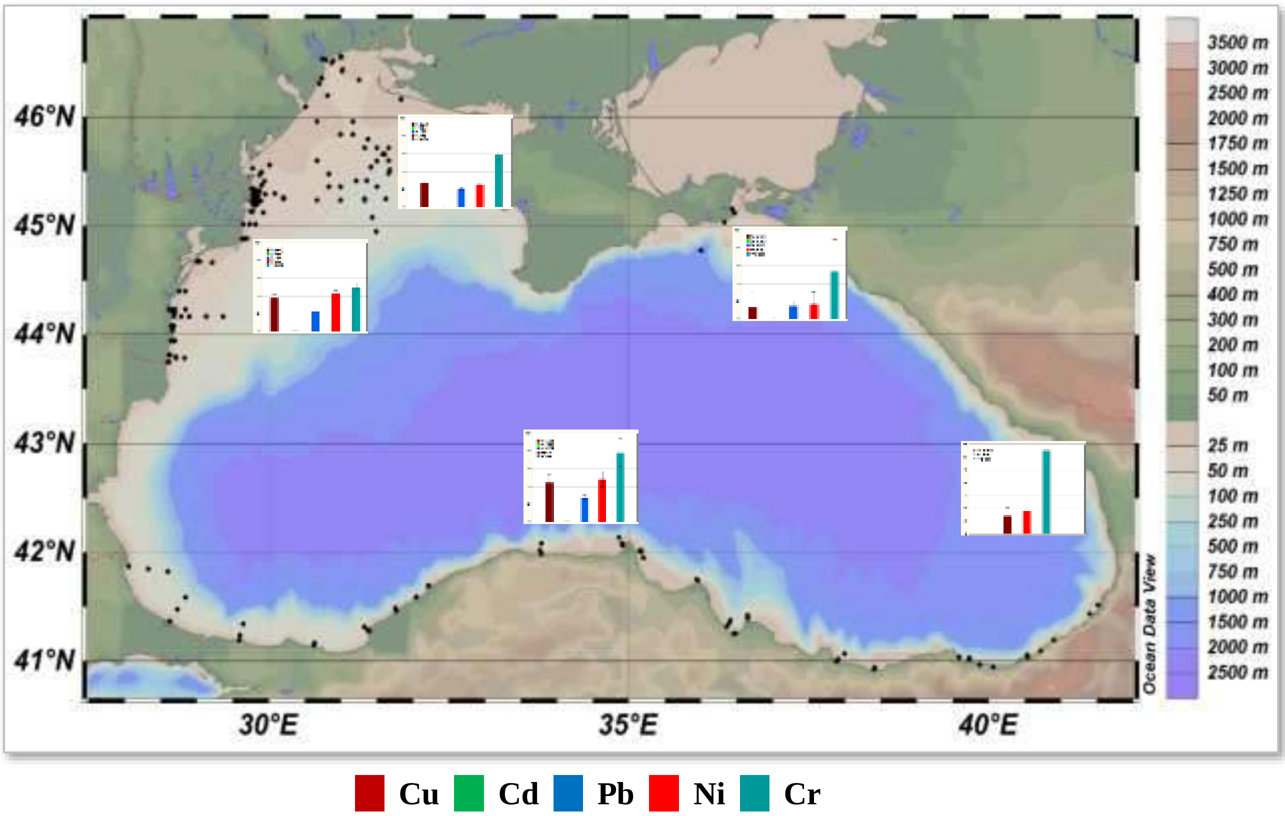


Figure 1.2.6.16. Black Sea monitoring stations and spatial distribution of average values of heavy metals in sediments, 2009-2014.

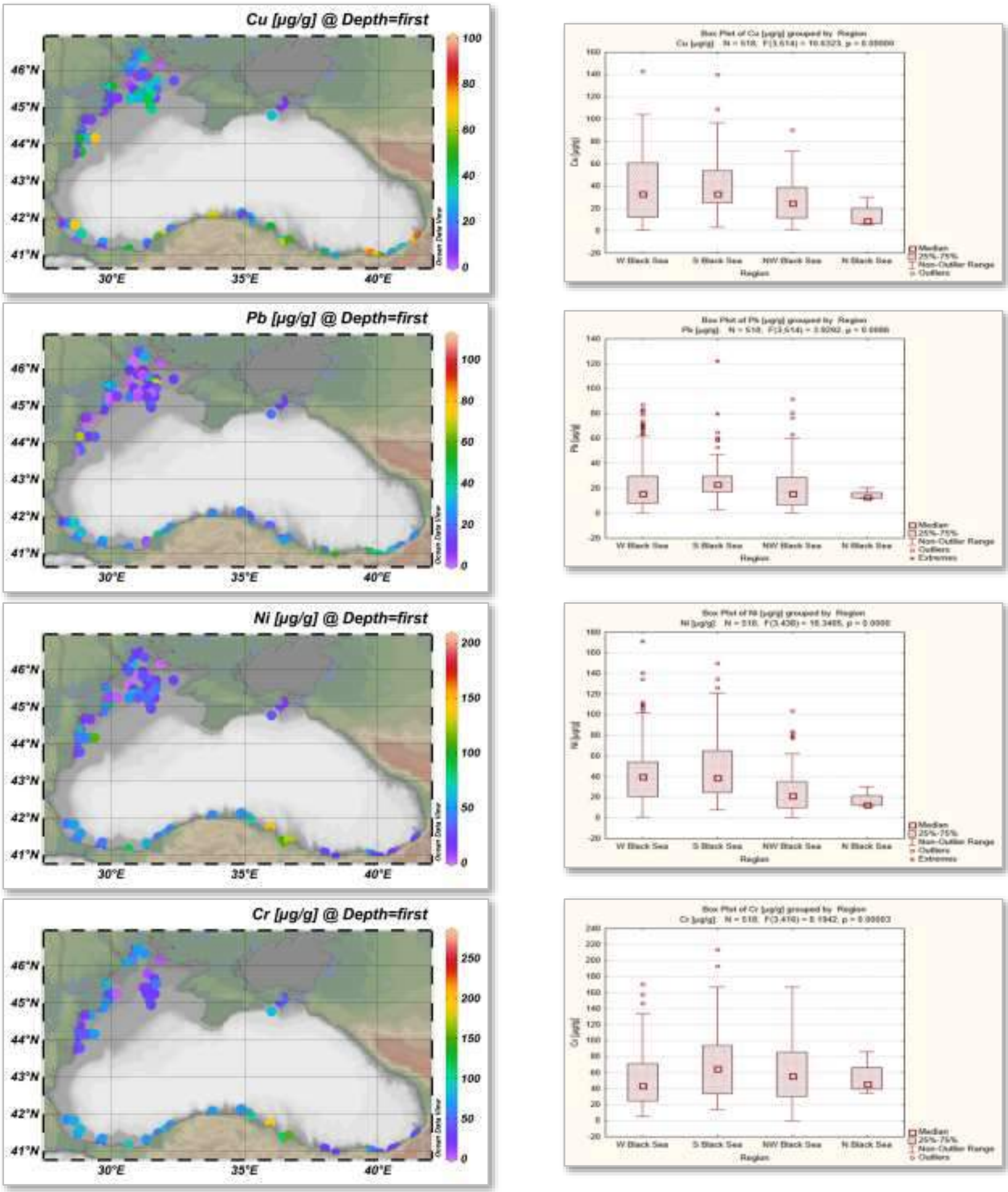


Figure 1.2.6.17. Spatial distribution of heavy metals concentrations in sediments, 2009-2014.

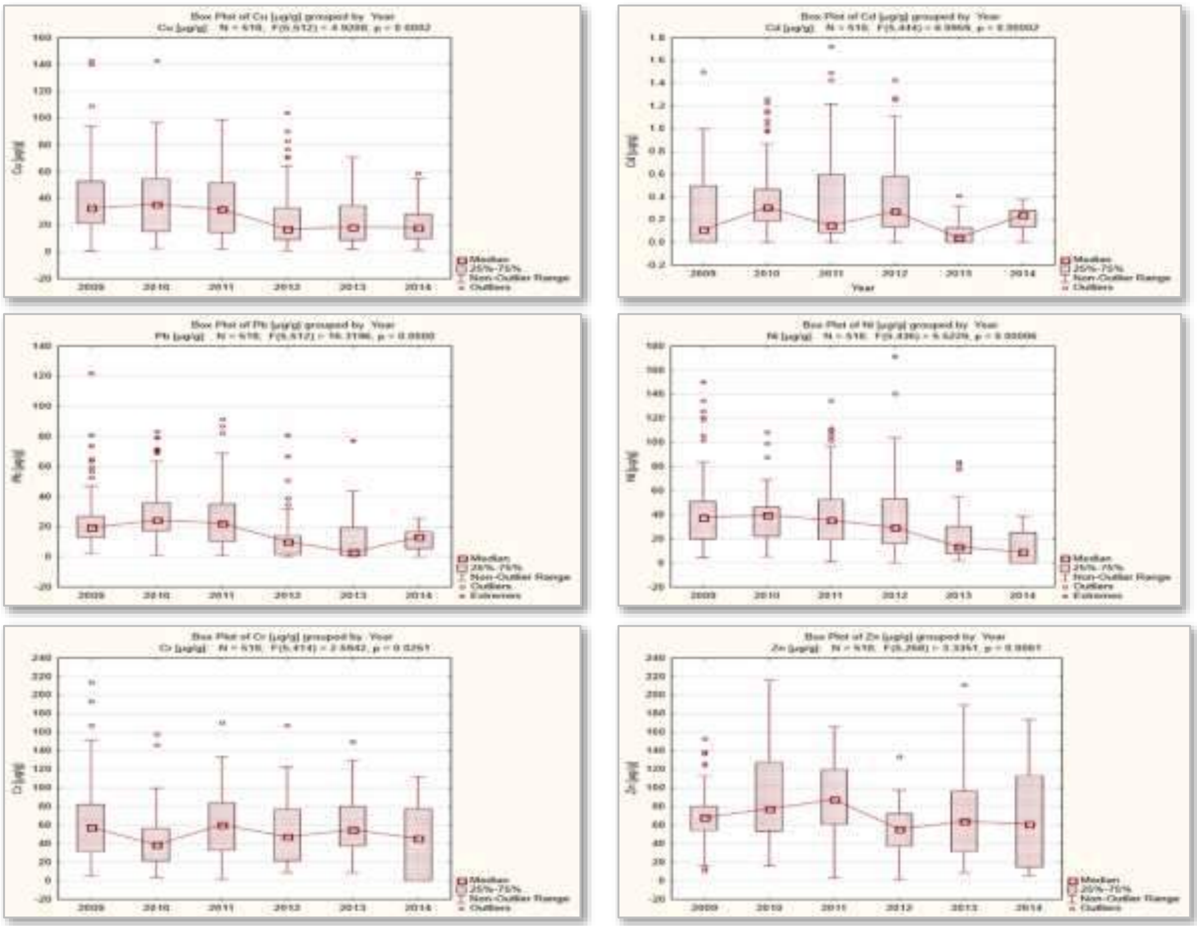


Figure 1.2.6.18. Trends of heavy metals concentrations in Black Sea sediments, 2009-2014.

Other regional information (MISIS)

In the framework of the project DG ENV MISIS (MSFD Guiding Improvements in the Black Sea Integrated Monitoring System) a Joint Cruise was carried out onboard R/V Akademik in the Western Black Sea, during 22-31 July 2013. The selected transects were: Constanta, in the Romanian waters, Galata, in the Bulgarian waters, and Igneada, in the Turkish waters, 18 stations covering the coastal, shelf and open waters (Fig. 1.2.6.5), (Oros et al, 2014; 2016a). The chemical characterization of the sediments show a rather high compositional variability (Table 1.2.6.14). Higher coefficients of variation (>50%) characterized the biogenic components (calcium carbonate, TOC, strontium), highly redox sensitive elements (V and Mn) as well as some technophyllic metals (Cu, Pb, Cd). Investigated components of terrigenous origin are introduced into the Black Sea mainly through the North-Western rivers, in both dissolved and particulate forms, with the Danube being the main contributor. Diffuse discharge and atmospheric input play probably a significant part in determining the sediment total concentrations for some heavy metals (Cd, Pb, Ni). (Secrieru et al, 2006). A comparison with available environmental quality standards and sediment quality guidelines showed that the concentrations of most metals were below the established limits. Frequent exceeding of the limits were identified for Ni and Cu, but a further analysis using Rb as a normalizing element demonstrated that this is mostly the result of a higher natural background.

Table 1.2.6.14. Main statistical parameters of the distribution of the inorganic chemical components of sediment in MISIS stations, July 2013 (Secrieru D data, in Oros et al, 2014; 2016a).

Component	C_{mediu}	C_{median}	C_{Min}	C_{Max}	C_v, %	n
$CaCO_3$, %	26.56	17.79	11.22	53.60	64.55	13
TOC, %	1.55	1.56	0.11	2.78	49.54	13
Fe_2O_3, %	4.49	5.09	2.27	6.23	32.90	13
TiO_2, %	0.35	0.31	0.03	0.84	78.21	13
Mn, µg/g	745.7	642.8	349	1425	41.11	13
Rb, µg/g	93.5	101	31	141	38.64	13
Zr, µg/g	162.6	148	121	327	33.93	13
Ba, µg/g	398.4	398	250	589	23.29	13
Sr, µg/g	514.1	349	215	1028	57.61	13
Ni, µg/g	39.36	41.63	15.7	57.8	37.17	13
Co, µg/g	8.94	8.58	4.371	12.82	29.16	13
Cr, µg/g	63.6	66.3	38	88	29.19	13
V, µg/g	46.0	39	5	91	55.38	13
Cu, µg/g	30.99	28.15	13.76	50.31	42.78	13
Pb, µg/g	26.32	23.57	9.21	45.18	40.04	13
Zn, µg/g	55.69	57.03	26.1	85.6	35.89	13
Cd, µg/g	0.236	0.247	0.057	0.386	40.29	13

C – concentration; C_v – coefficient of variation

National reports (status, long-term trends)

Romania

In the framework of the FP7 PERSEUS (Policy-oriented Marine Environmental Research for the Southern European Seas), new data (2012-2014) on heavy metals in sediments samples from the Romanian Black Sea were obtained. Gradient of pollution was assessed along relevant monitoring transects, covering two study areas (Danube mouths and Constanta area), in order to improve knowledge on the various influences upon the quality of the Romanian Black Sea ecosystem, either Danube in the northern area, or various land-based sources in the southern one. Trends were assessed in comparison with 2006-2011 monitoring data.

Concentrations of heavy metals (Cu, Cd, Pb, Ni, Cr) measured in sediments along the Romanian Black Sea coast during 2012-2014 were characterized by a high variability, reflecting not only the impact of various anthropogenic pressures, but also the diversity of mineralogical and granulometric characteristics of sediments, and consequently of the natural background levels of metals. Overall, concentrations of heavy metals in the majority of samples (percentile 75^{th} of all data series) were situated below sediment quality standards (ERL values), with the exception of Ni, which might have higher natural background levels. (Oros et al, 2016b).

Looking at spatial distribution along specific transects it could be observed significant differences between locations: higher heavy metals concentrations were observed especially in the area under the influence of Danube river, and in specific stations, situated inside or in the vicinity of big harbours (Constanta, Mangalia) or close to WWTP outlets. In comparison, moderate levels were measured in the central sector and in the southern extremity of the

Romanian coastal zone, areas with predominantly touristic activities (Fig. 1.2.6.19). In comparison with 2006-2011 monitoring data, in the recent years heavy metals concentrations were situated in general within the same variation ranges, in some cases with slightly decreasing trends (Fig. 1.2.6.20), (Oros et al, 2016b).

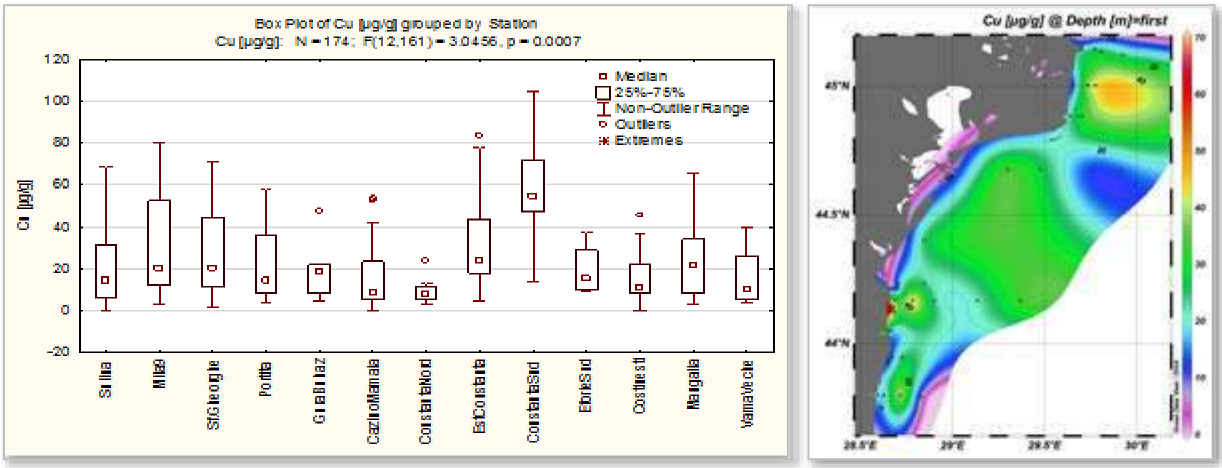


Figure 1.2.6.19. Distribution of copper in sediments along the Romanian Black Sea coast (13 transects), study areas – Danube (Sulina–Portita) and Constanta (Gura Buhaz–Vama Veche) in 2012-2014.

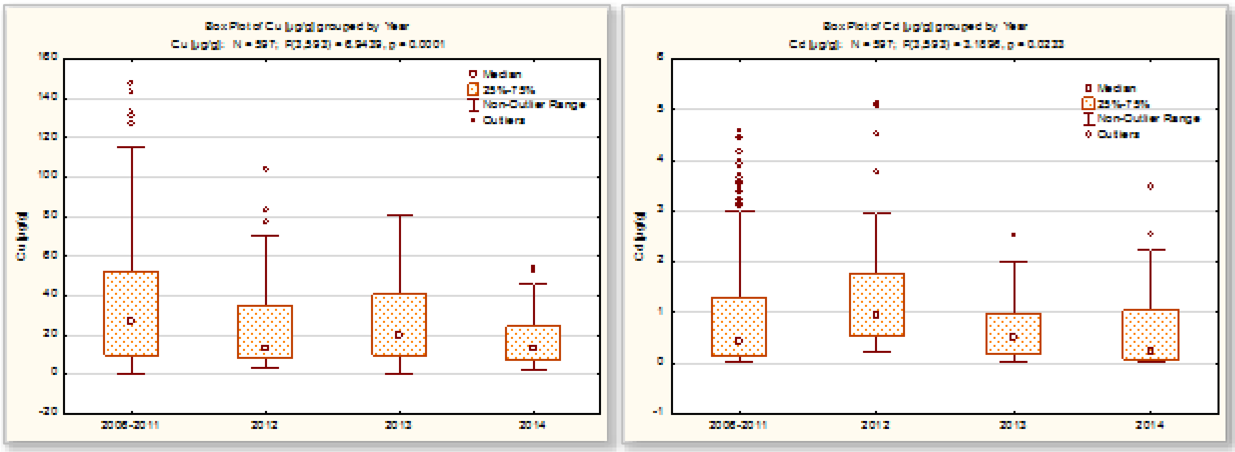


Figure 1.2.6.20. Trends of heavy metals in marine sediments at Romanian Black Sea coast during 2006–2014.

Georgia

Investigations of marine bottom sediments along the Georgian coastal zone in 2008–2009 were carried out in frame of a grant project of Georgian National Scientific Foundation. Design of sediment sampling is created with considering of existing research results concerning content and distribution of metals in bottom sediments of Georgian shelf zone. In total 74 stations were sampled and Zn, Cu, As, Cr, Mn. Fe, Al were determined. The sampling stations are located in close on river mouths, with consideration of morphological and sediment transport characteristics of shelf zone (Fig. 1.2.6.21). Also, in Poti Sea Area, content of heavy metals were investigated during the special research program in 2010 and 2011. Results of investigation allow to see the spatial difference in heavy metals distribution along Georgian coastal zones.

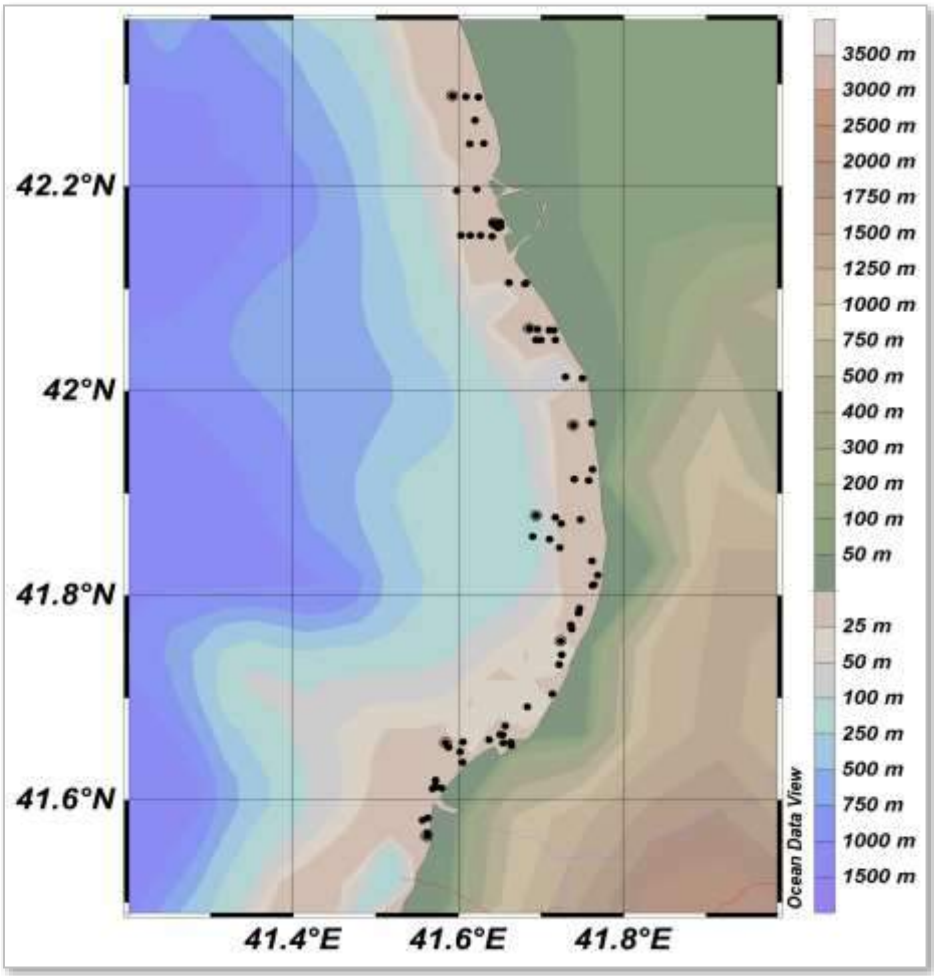


Figure 1.2.6.21. Sampling stations along Georgian coastal zone.

Fe. Average concentration of iron in the bottom sediments shows the stepwise decline from the South in Gonio vicinity to the North around Khobi, something from 7.5% to 4% (Fig.1.2.6.22). The maximum value of iron content has similar feature from about 14.5% 4.3%. Notable rather small variability in concentration in different sediment samples near Poti and Khobi where Max and Min shows similar values. This is huge contrast with the southern points where the difference between extremes very high.

Mn. Manganese in bottom sediments is distributed regularly. Ajara and Guria region concentration reaches 0.1%. In Rioni and Poti region it increased and average value was 0.25%, maximum – 0.35%. In this case increasing is caused by anthropogenic impact. High concentration of Mn is related with activity of the Chiatura mining factory. In Khobi region the sediments enriched with manganese are transported from Poti area.

Cu, Zn and As. In the bottom sediments of Batumi and Gonio areas the accumulation of these three elements was caused by discharge of Chorokhi River bringing sediments polluted with mining minerals. The tilling and wastes of Murgul Cooper Industry, contained high concentration of sulphide minerals, are transported from river Murgul to river Chorokhi and finally to sea mouth area, in Georgian coastal waters. Based on this fact it could be assumed the high influence of anthropogenic factor to the marine environment of southern part of Georgian coastal waters. Average concentration of Cu, Zn and As in Chorokhi River mouth area reaches 184, 212 and 25 µg/g respectively (with maximal content 560, 575 and 69 µg/g).

Further on, driving by alongshore transport, this bottom sediment are migrated to Batumi area. Here they flows into the underwater canyon situated right in front of Batumi seaport. Due to this reason metal-enriched sediments do not extends further more to north.

Ni and Cr. Nickel and chromium in the investigated area are distributed similarly: their concentration in the bottom sediments stepwise increased from Gonio mouth area to Chakvi – Natanebi, and then decreased northward. According current knowledge the concentration of these elements is not related with anthropogenic factors, but their occurrence and allocation are controlled with natural factors.

Poti Sea Area

Content of heavy metals were investigated during the special research program in 2010 and 2011. Average data of elements concentration and limits of variation were estimated (Tab. 1.2.6.15). Based on received results we can assume that content of all elements with the exception of Mn, remains in local background limits. Concentration of Mn (0.15–0.855%) is related with anthropogenic impact of manganese mining infrastructure. It could be noted the increased concentration of As compared to other regions.

Table 1.2.6.15. Content of metals in bottom sediments of Poti Sea Area.

	Zn, µg/g	Cu, µg/g	As, µg/g	Ni, µg/g	Cr, µg/g	Mn, %	Fe, %
average	80.97	44.07	12.13	55.60	88.33	0.373	4.06
Min	62.00	19.00	6.40	20.00	38.00	0.15	3.25
Max	132.00	109	26.20	89.00	220.0	0.855	4.85

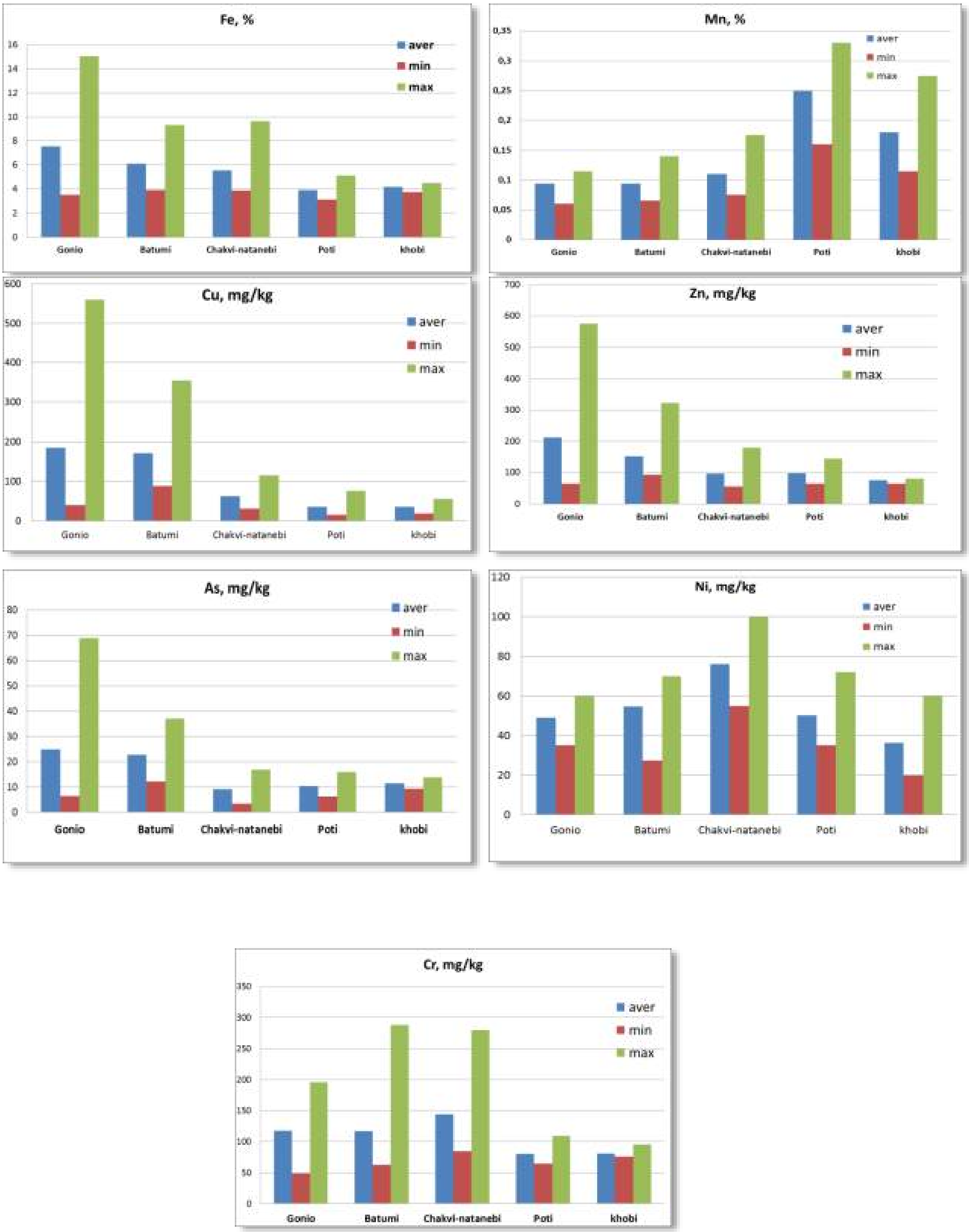


Figure 1.2.6.22. Heavy metals concentration (µg/g) in the bottom sediments along the Georgian coastal zone, 2008–2009.

Ukraine

Research of quality of marine bottom sediments, in comparison with sea water, allows a better an estimation of level of chronic pollution of the sea environment as bottom sediments are more conservative from the point of view of variability of the concentrations of polluting substances. As norms (MAC) for bottom sediments in Ukraine do not exist, such estimation was done in relation with the specifications operating in the countries of the European Union, in particular in the Netherlands. Level of the concentrations of different metals in bottom sediments depends from the nature of metal and structure of sediments.

In 2009, in study areas (NW open sea and Kerch channel) the highest concentration was noted for zinc and chrome, range of concentrations are 10-78 µg/g, and 5–91 µg/g, respectively. But in comparison with MAC, average concentration of these metals did not exceed recommended values (Tab. 1.2.6.16).

Table 1.2.6.16. Average concentrations of trace metals in the bottom sediments of Ukrainian part of the Black Sea.

Pollution substances	Unit	Range of concentrations	Average value		MAC
			NW open sea	Kerch channel	
Cadmium (Cd)	µg/g	0.045 – 0.852	0.13	0.13	0.8
Cobalt (Co)	µg/g	2.3 – 12.9	6.29	6.45	20
Mercury (Hg)	µg/g	0.010 – 0.028	0.009	0.036	0.3
Copper (Cu)	µg/g	3.90 – 39.3	23.7	20.5	35
Lead (Pb)	µg/g	4.40 – 30.0	10.9	21.7	85
Chromium (Cr)	µg/g	5.40 – 91.0	26.4	66.6	100
Zinc (Zn)	µg/g	10.7 – 78.4	39.1	70.5	140
Arsenic (As)	µg/g	2.7 – 20.7	10.3	9.8	29
Nickel (Ni)	µg/g	4.0 – 59.8	30.1	22	35

In NW area on 3 stations from 9 (33%) concentration of nickel were found 1.4-1.7 times above norm. Also in two stations from this area it was recorded a slight excess of norms (1.1 MAC) for the copper content in bottom sediments. In the area of the Kerch Strait, there were recorded isolated cases of exceeding the standards for nickel, copper and chromium.

The average concentrations of trace metals in bottom sediments in 2011 are presented in Fig. 1.2.6.23. Concentration of different metals in bottom sediments depends from the nature of metal and structure of sediments. The highest concentration was observed for zinc and chromium, range of concentration of 10-99 µg/g and 4–77 µg/g, respectively. Average concentration of these metals did not exceed MAC.

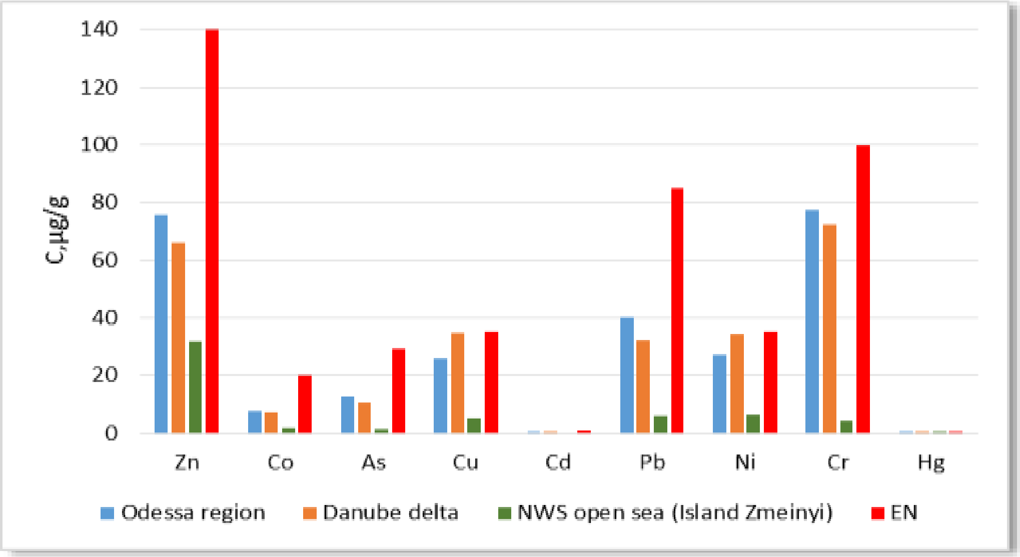


Figure 1.2.6.23. Average concentrations of trace metals (µg/g) in the bottom sediments of Ukrainian Black Sea in 2011.

In 2012, the highest concentration were observed for zinc and chromium, a range of average concentrations was 47-203 µg/g and 23–85 µg/g, accordingly. But in comparison with MAC, average concentration of these metals did not exceed recommended values, with the exception of zinc (Fig. 1.2.6.24).

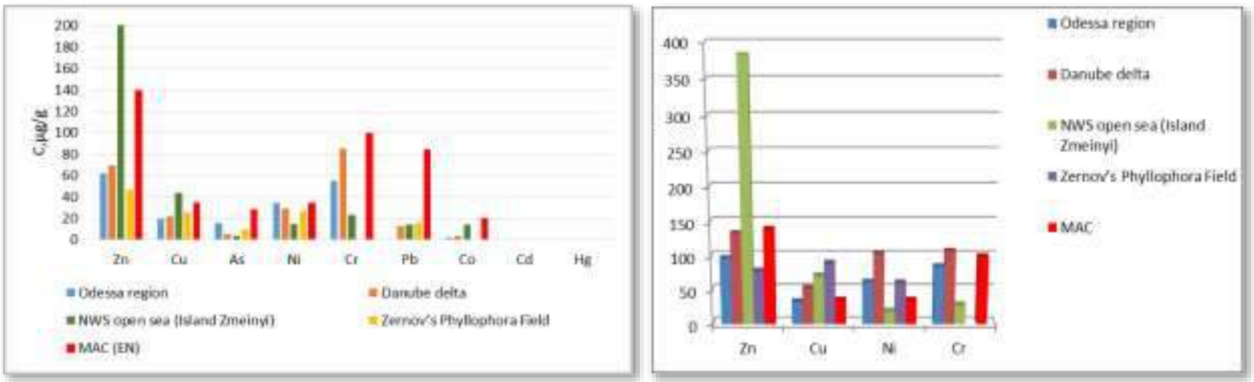


Figure 1.6.2.24. Average and maximal concentration of trace metals in bottom sediments of Ukraine in 2012.

In 2013, the average concentration of toxic metals in bottom sediments of the studied areas were less than MAC (Fig. 1.2.6.25). The absolute concentrations of the metal content in marine waters decreased in the following order: Zinc> Chromium> Copper > Nickel > Lead> Cobalt> Arsenic > Cadmium> Mercury.

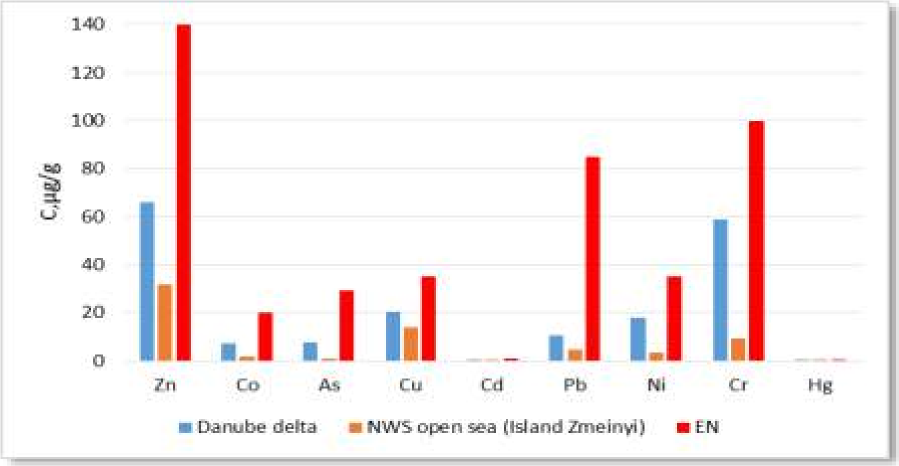


Figure 1.2.6.25. Average concentrations of trace metals in bottom sediments of Ukraine in 2013.

In 2014, the average concentration of toxic metals in bottom sediments of the studied areas were below MAC (Fig. 1.2.6.26). The absolute concentration of the metal content in bottom sediments decreased in the following order: Zinc> Chromium> Copper > Arsenic > Nickel > Cobalt> Lead> Cadmium> Mercury. In general, the quality of bottom sediments of the near-Danube coastal zone for a number of parameters (nickel, zinc, chrome, and cobalt content) corresponded to a «satisfactory» quality class, for some parameters (copper, mercury) — to a «poor» quality class.

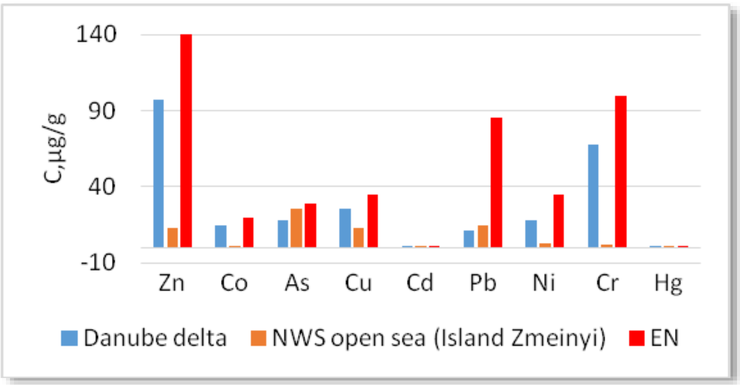


Figure 1.2.6.26. Average concentrations of trace metals in bottom sediments of Ukrainian Black Sea in 2014.

1.2.6.3. Biota

Rather few data were reported by countries to the Blak Sea Database concerning heavy metals in mussels, and only one country reported also for fish. Mussels sampling points are depicted in Fig. 1.2.6.27, and results are presented in Table 1.2.6.17.

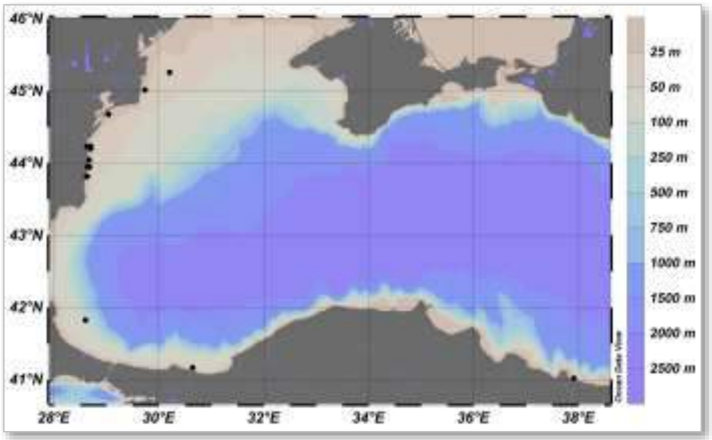


Figure 1.2.6.27. Mussels sampling points at 2009-2014.

Table 1.2.6.17. Descriptive statistics of heavy metals concentration in mussels in 2009-2014.

	Valid N	**Mean**	**Median**	**Percentile – 10th**	**Percentile – 90th**	**Std.Dev.**
Cd [µg/g]	27	0.698	0.300	0.085	2.950	0.958
Cu [µg/g]	25	4.532	2.580	1.490	15.000	5.587
Pb [µg/g]	27	2.434	0.890	0.040	5.640	4.270
Zn [µg/g]	7	82.385	26.300	13.100	311.00	111.288
As [µg/g]	7	2.738	1.430	0.000	8.760	3.168
Ni [µg/g]	24	5.816	0.980	0.290	12.500	17.513
Cr [µg/g]	24	1.145	0.765	0.150	2.140	1.453

Other regional information

In the framework of the project DG ENV MISIS (MSFD Guiding Improvements in the Black Sea Integrated Monitoring System), a Joint Cruise was carried out onboard R/V Akademik in the Western Black Sea, during 22-31 July 2013. The selected transects were: Constanta, in the Romanian waters, Galata, in the Bulgarian waters, and Igneada, in the Turkish waters, 18 stations covering the coastal, shelf and open waters (Fig. 1.2.6.5) Biota samples (mollusks, *Mytilus galloprovincialis*, *Rapana venosa* and *Scapharca inequivalvis*) were prelevated by dredging along relevant transect and investigated for heavy metals content (Coatu et al, 2014; 2016).

Heavy metals concentrations determined in the whole soft tissue of the molluscs species investigated in July 2013 registered the following averages and variation ranges (reported as wet weight tissue), (Table 1.2.6.18).

Table 1.2.6.18. Concentration of heavy metals in three species of marine mollusks from the Western Black Sea, July 2013 (Oros Andra data, in Coatu et al, 2014; 2016).

Species	Station	Cu (µg/g ww)	Cd (µg/g ww)	Pb (µg/g ww)	Ni (µg/g ww)	Cr (µg/g ww)
Mytilus galloprovincialis	RO/M01-M02	2.20	0.37	0.216	1.95	0.14
Mytilus galloprovincialis	RO/M04-M05	1.75	0.45	0.072	0.97	0.07
Mytilus galloprovincialis	BG/M12-M11	4.48	0.84	0.092	1.00	0.17
Mytilus galloprovincialis	BG/M11-M10	1.17	0.21	0.072	2.69	1.31
Mytilus galloprovincialis	BG/M10-M09	1.51	1.05	0.172	6.00	0.15
Mytilus galloprovincialis	TR/M17-M16	1.13	1.12	0.002	2.30	0.22
Rapana venosa	RO/M01-M02	7.48	1.23	0.138	0.33	0.23
Rapana venosa	BG/M12-M11	4.76	5.40	0.086	0.65	0.24
Rapana venosa	BG/M11-M10	7.68	4.36	0.254	0.92	0.57
Rapana venosa	TR/M18-M17	9.35	5.42	0.019	0.66	0.14
Scapharca inequivalvis	RO/M01-M02	2.15	2.20	0.018	1.85	0.22
Scapharca inequivalvis	BG/M12-M11	2.03	2.47	0.050	4.47	0.47
Scapharca inequivalvis	TR/M18-M17	1.93	2.86	0.004	1.10	0.19

With respect to interspecific differences, *Rapana* samples (whole soft tissue) had a higher bioaccumulation capacity for copper and cadmium, whereas nickel levels were diminished, in comparison with the other mollusks. For mussels (*Mytilus edulis*) from North Sea and Baltic Sea the following threshold values, corresponding to normal background for metals, were proposed: Cu 2.0 µg/g ww; Cd 0.4-0.8 µg/g ww; Pb 0.4-1.0 µg/g ww; Ni 0.8-1.0 µg/g ww; Cr 0.4-0.6 µg/g ww (EPA, 2002). In reference to these values, concentrations of heavy metals in mussels investigated in July 2013 were included in their variation range, with the exception of nickel.

Data obtained during MISIS cruise, July 2013, concerning heavy metals in molluscs are comparable with other data reported for the Black Sea or other marine regions, even showing diminished levels, as in case of lead (Table 1.2.6.19). In comparison with Commission Regulation (EC) no. 1881/2006 regulatory value for cadmium in bivalve molluscs (1 µg/g ww), all *Mytilus* samples were below the limit, whereas *Scapharca* and *Rapana* from all transects presented higher bioaccumulation level. We should mention that *Rapana* was also analysed as whole soft tissue, i.e. including viscera, where metals have the tendency to accumulate. In case of lead, all three species of molluscs were much below regulatory value (1.5 µg/g ww), (Fig. 1.2.6.28).

Table 1.2.6.19. Comparative heavy metal concentrations (µg/g wet weight tissue) in bivalve molluscs worldwide.

	Cu (µg/g ww)	Cd (µg/g ww)	Pb (µg/g ww)	Ni (µg/g ww)	Cr (µg/g ww)
MISIS Cruise, July 2013, Black Sea (RO, BG, TR)	2.04 (1.13 - 4.48)	0.68 (0.21 - 1.12)	0.104 (0.002 - 0.216)	2.48 (0.97- 6.00)	0.34 (0.07- 1.31)
IA RO Black Sea (2006 – 2011) (Boicenco et al, 2012)	2.61 (0.91 – 10.77)	0.36 (0.05 – 1.98)	0.98 (0.02 – 10.29)	1.05 (0.11 – 2.66)	0.97 (0.01 – 6.07)
TR Black Sea coast (Bat, 2014) (2002 – 2012)	0.48 - 38.00	0.05 - 1.28	0.21 - 4.20	0.40 - 8.76	
BG Black Sea (Stancheva *et al*., 2012)		0.04 – 0.09	0.11 – 0.18		
Mediterranean Sea (Conti and Cecchetti, 2003)	0.85 - 1.77	0.05 - 0.08	0.26 - 0.38		0.08 - 0.20
North Atlantic Ocean (Besada, 2002)	0.88 - 1.93	0.07 - 0.57	0.10 - 1.64		
North Atlantic Ocean (Ugur, 2002)	2.41 – 5.83		0.77 – 6.02		
Sea of Japan (Shulkin, 2003)	0.78 – 23.80	0.28 – 5.20	0.20 – 56.60	0.14 – 0.80	

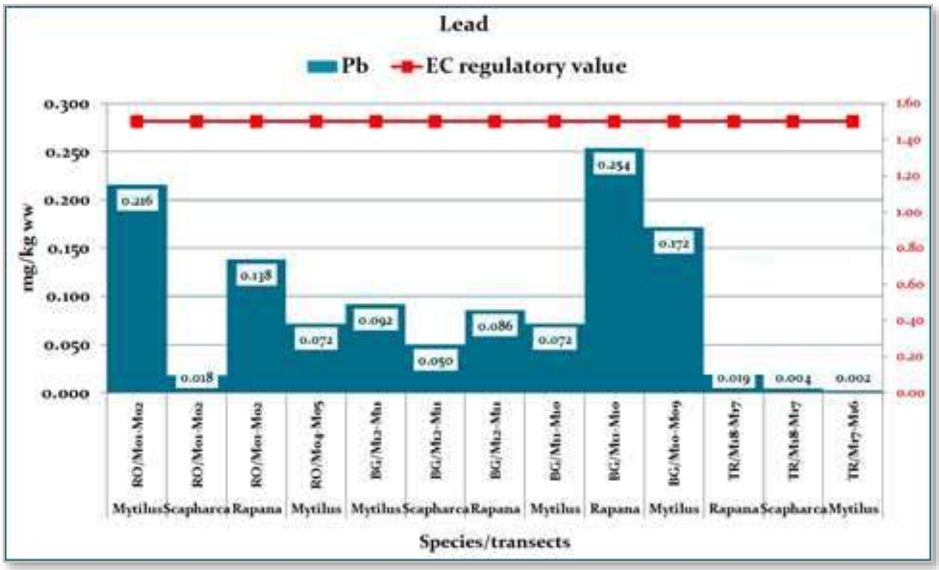


Figure 1.2.6.28. Lead concentrations (µg/g) in mollusks from the Romanian, Bulgarian and Turkish waters, July 2013, in comparison with EC regulatory values.

National reports (status, long-term trends)

Romania

In the framework of the FP7 PERSEUS (Policy-oriented Marine Environmental Research for the Southern European Seas), new data (2012-2014) on heavy metals in biota (mollusks/whole soft tissue, fish/muscle) samples from the Romanian Black Sea were obtained (Oros et al, 2016b). Trends were assessed in comparison with 2006-2011 monitoring data. Levels of Cd and Cu in mussels (*Mytilus galloprovincialis*) belonging to the length class 4.5-5 cm, sampled from different locations along Romanian coast, were compared against Background Assessment Concentrations (BAC/OSPAR) and Maximum Allowable Levels from European legislation (EC nr. 1881/2006). Whereas Cd BAC were slightly exceeded in all samples, only one value higher than MAC was noticed, all the other samples presenting Cd concentrations below MAC. As for Pb, this element presented low values of accumulation in mussels, all samples being much below MAC. Background levels for Pb were exceeded in only 2 samples, from the locations situated in the vicinity of Constanta Port (East Constanta, Constanta South), (Fig.1.2.6.29).

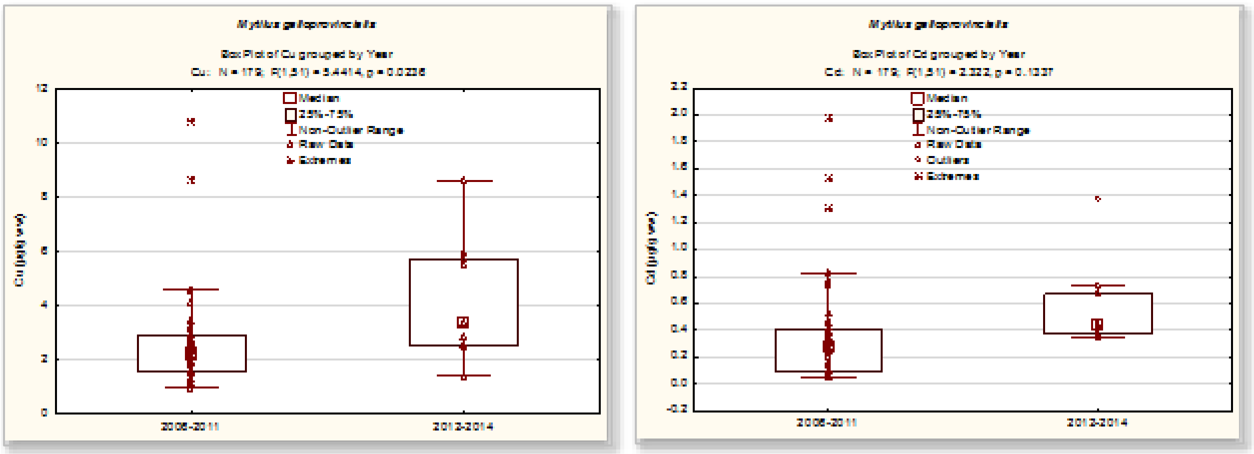


Figure 1.2.6.29. Levels (µg/g) of Cd and Cu in mussels along Romanian Black Sea coast (2012-2014) against background assessment concentrations (BAC/OSPAR) and maximum allowable concentrations (MAC/EC nr. 1881/2006).

Over the period 2006-2014 no specific decreasing trends of accumulation of heavy metals in mussels were noticed. Overall, recent data (2012-2014) were included in similar variation ranges, even in some cases with slight increasing tendencies (Fig. 1.2.6.30).

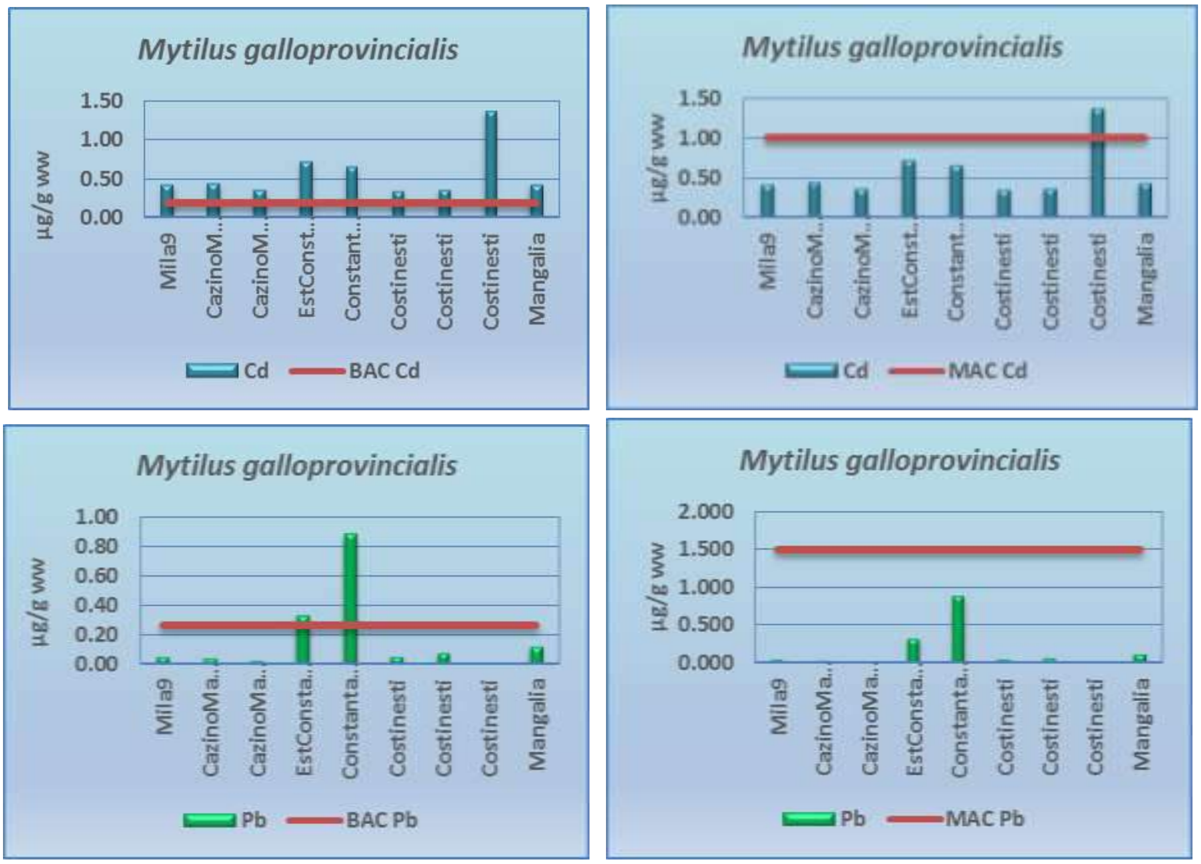


Figure 1.2.6.30. Trends of heavy metals concentration (µg/g) in mussels along the Romanian Black Sea coast during 2006–2014.

Fish samples belonging to 9 species frequently encountered in Romanian marine waters were investigated for heavy metals levels in their muscle tissues during 2012-2014. Determined concentrations presented high variability, interspecific differences between pelagic and demersal species being noticed (Fig.1.2.6.31). For instance, many elements presented higher concentrations in whiting, anchovy and sprat.

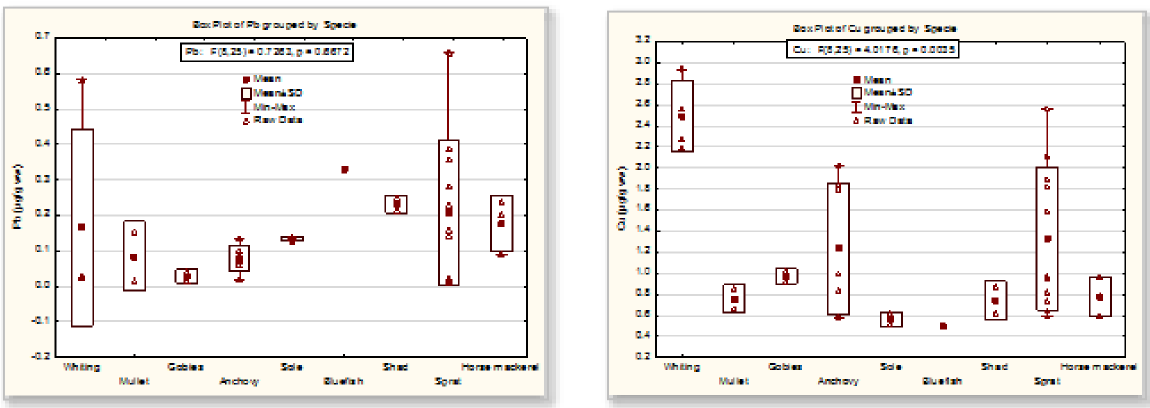


Figure 1.2.6.31. Interspecific differences of heavy metals accumulation in 9 species of pelagic and demersal fish from Romanian Black Sea waters during 2012-2014.

Long-term data on period 2001-2014 regarding accumulation of heavy metals in small pelagic fish, namely anchovy and sprat, shows stabilisation with similar variation ranges or even slight decreasing trends for the recent years (Fig. 1.2.6.32).

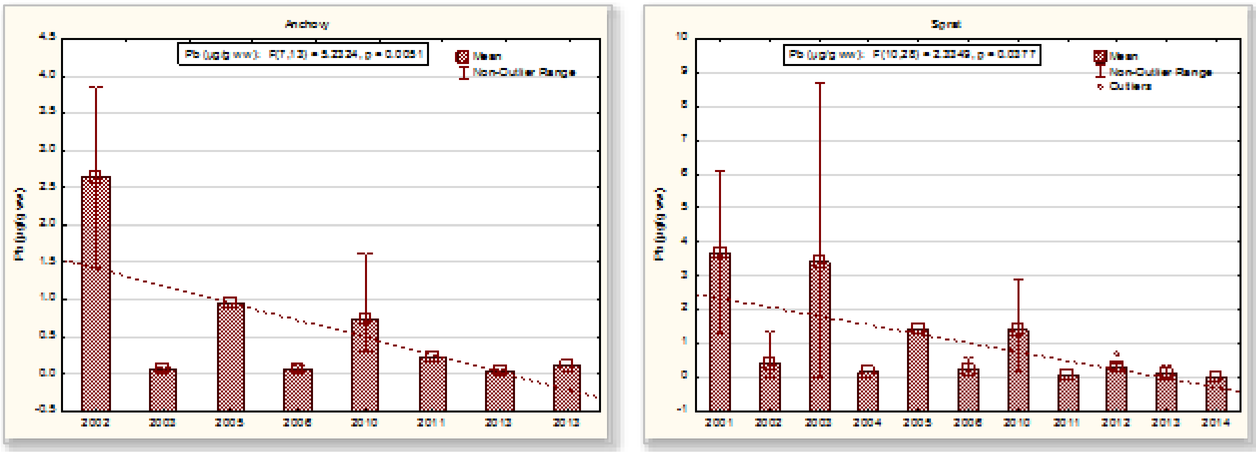


Figure 1.2.6.32. Trends of heavy metals content in small pelagic fish (anchovy, sprat) from the Romanian Black Sea waters during 2001–2014.

Ukraine

In 2012, two samples of *Phyllophora* collected at stations 5 and 6 of Zernov *Phyllophora* field were investigated. Among the toxic metals, zinc and nickel are present in the largest concentrations (40-50 µg/g), which is about 3-4 times lower than the results of research in 2000. Average levels of accumulation of cadmium (0.32 µg/g) and copper (16 µg/g) as compared to 2000, decreased by 3-3.5 times (Fig. 1.2.6.33). Concentrations of macro components (iron and manganese) in *Phyllophora* much higher other toxic metals.

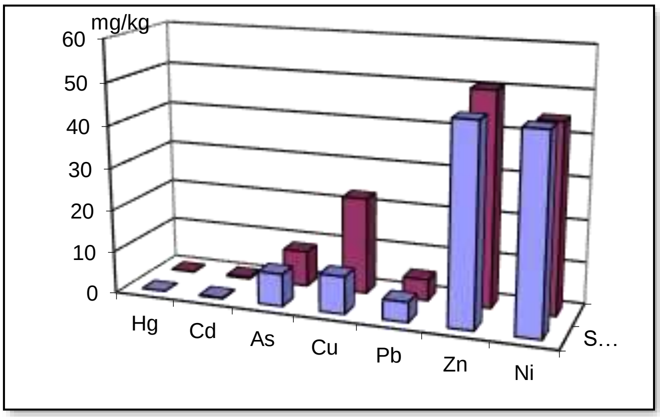


Figure 1.2.6.33. Concentrations of metals (µg/g) in the taloms of *Phyllophora* seagrass.

The analysis of fish tissue in 2012 revealed the accumulation of certain toxic metals (Zn, Pb and Hg) in a concentration above the national MAC (Fig. 1.2.6.34).

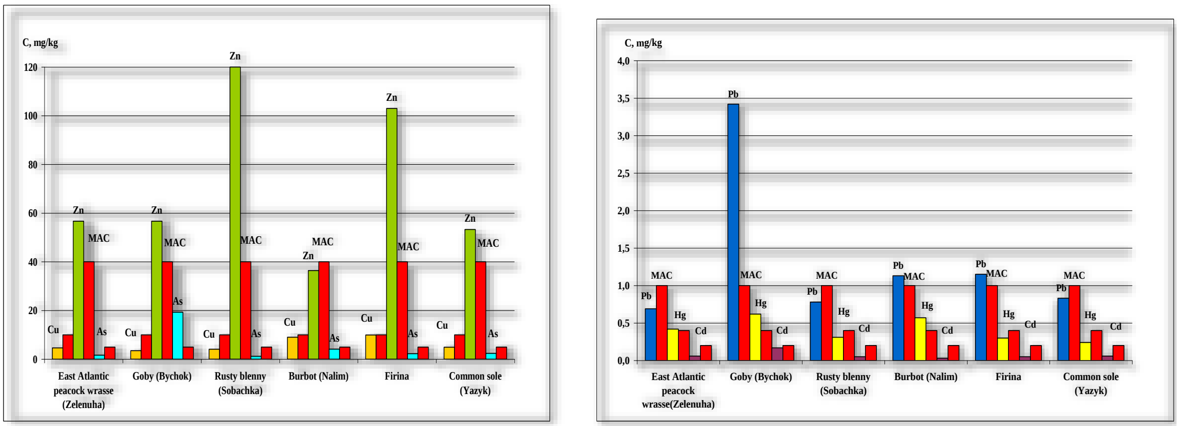


Figure 1.2.6.34. Concentrations of Cu, Zn, As, Pb, Hg and Cd (µg/g) in fish tissues from waters of Zmeinyi Island in 2012.

It was also revealed the accumulation of Zn, Cu, As, Hg and Cd in some shellfish (mussels and Rapana) in concentration above MAC (Fig. 1.2.6.35).

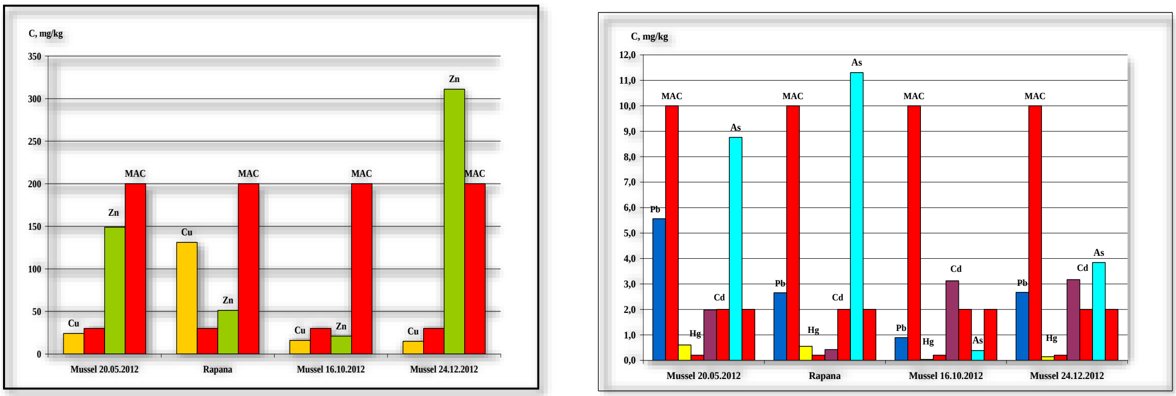


Figure 1.2.6.35. Concentrations of trace metals Cu, Zn, As, Pb, Hg and Cd (µg/g) in mollusks tissue in 2012.

In 2013, the analysis of fish tissue revealed the accumulation of certain toxic metals in a concentration above the MAC (Fig. 1.2.6.36, Fig. 1.2.6.37).

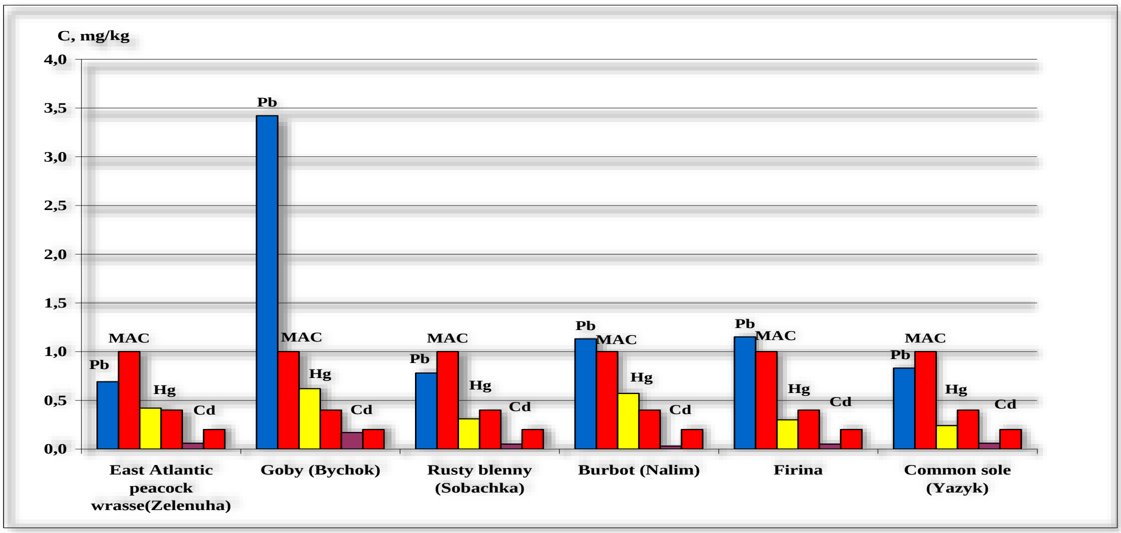


Figure 1.2.6.36. Concentrations of trace metals Hg, Cd and Pb (μg/g) in fish tissue (I. Zmeinyi) in 2013.

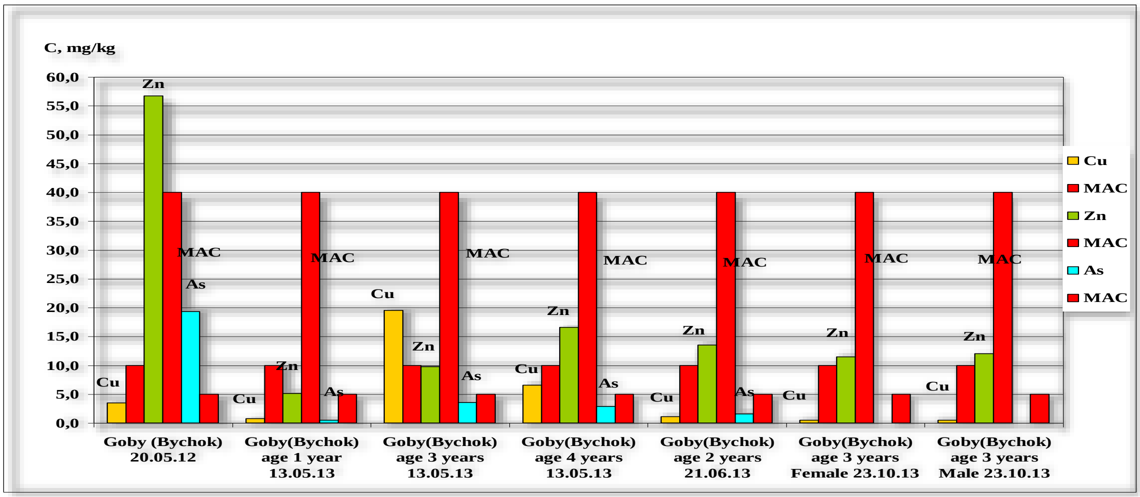


Figure 1.2.6.37. Concentrations of trace metals Cu, Zn and As (μg/g) in fish (goby) tissue near Zmeinyi Island in 2013.

Investigations carried out in 2014 revealed decreasing trends for some metals in mussels in comparison with previous data (Fig. 1.2.6.38).

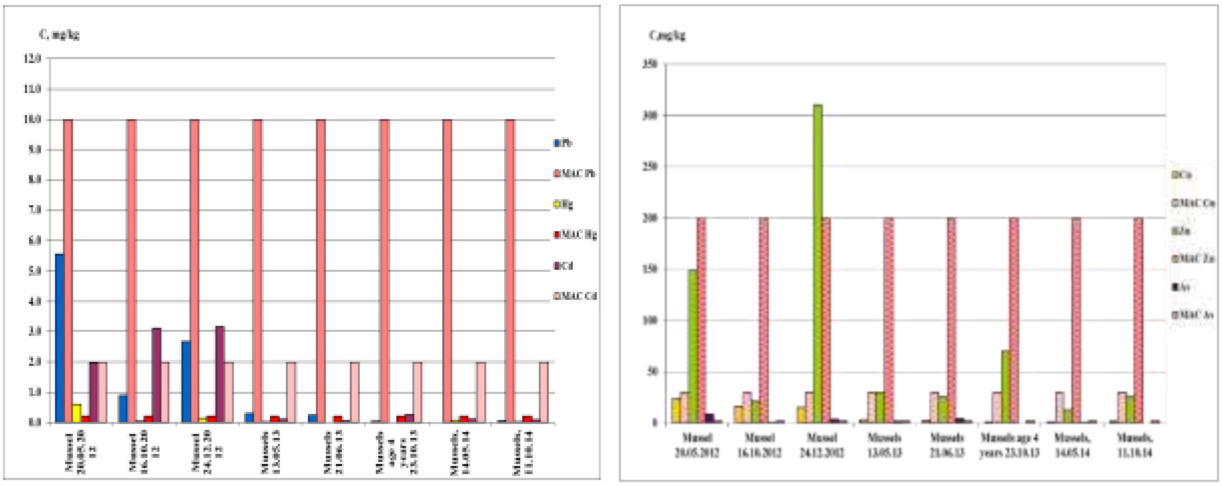


Figure 1.2.6.38. Concentrations of trace metals Pb, Hg, Cd, Cu, Zn and As (μg/g) in mussels tissue near Zmeinyi Island in 2012-2014.

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1.2.7 Marine Litter

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Introduction

Marine litter forms one of the most widespread pollution problems of our time with a worldwide demonstration (Galgani *et al*. 2013) due to poor practices, insufficient infrastructures and lack of public awareness. Transboundary dissemination of waste through currents and winds increase the dimensions of the issue from a local to a global scale (BSC, 2007). Due to its global threat statues, many international, regional and national legal instruments focus on marine litter pollution such as the International Maritime Organisation (IMO), United Nations Environment Programme (UNEP), Intergovernmental Oceanographic Commission (IOC-UNESCO), Food and Agriculture Organisation (FAO) and The European Union Marine Strategy Framework Directive (MSFD, 2008/56/EC). Among them, MSFD establishes a framework within which EU Member States shall take action to achieve or maintain good environmental status (GES) of their marine waters by 2020. In addition, all the neighbouring countries of the Black Sea have signed various conventions for preventing the marine pollution within it. Bucharest Convention is the most effective one regarding to the land-based marine litter, whereas International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) is the basic regulation instrument for shipping-related litter. Furthermore, there were numerous international campaigns carried out to combat the marine litter on the Black Sea during last years: MARLISCO, MARELITT, CleanSea, LIFE+ BALKWASTE, PERSEUS. The detailed information on thses projects is given on the relevant web-sites.

Turkey

Marine litter composition and density has been studied from the western to the eastern Turkish Black Sea. The majority of studies focus on coastal litter and also the benthic habitat to a lesser extent. Furthermore, there are few studies carried out in regard to the sea surface and there has only been a single study dedicated to microplastics. In addition to the scientific studies, there are various campaigns and projects running, covering the topics ranging between public awareness to active litter collection.

To reduce the amount of floating marine litter, the Sea Surface Marine Litter Cleaning Operation has been carried out in Turkey by three metropolitan municipalities, namely İstanbul, Kocaeli, and İzmir, and the district municipality of Beşiktaş since 1999. While 29.300 m^3 of solid waste was collected from 2005-2012 in Istanbul, 5122 tonnes of solid waste was collected between 2006 and 2012 in Izmir and 329 tonnes of solid waste was removed from 2007 to 2012 in Kocaeli Metropolitan Municipality (http://www.marlisco.eu/sea-surface-marine-litter-cleaning-operation-turkey.en.html).

Cleaning apparatus, to collect litter from the sea surface and to encourage the fishing community to collect and recycle, was designed under the program of The Waste Free Oceans (WFO) “Happy Fish” or the Mutlu Balıklar in 2012 (https://www.marinelittersolutions.com/projects/waste-free-ocean-turkey-happy-fish/). The Turkish Marine Research Foundation (TÜDAV) have also been running continous surveys on marine litter and coastal clean ups for over 10 years. TUDAV is a partner organisation of a diverse range of projects such as "Clean up the Med", "MARLISCO" and "Lets Clean Up Europe".

In regards to the scientific surveys, the marine litter composition in Istanbul has been studied through a series of 11 diving surveys for marine litter in different sites in 2005, also covering the adjoining regions of Marmara Sea. The number of litter items collected accumulated to 1606 and the majority of these were manufactured from glass (31%), plastic (25%) and metal (21%) with a tendency to accumulate in certain areas (e.g. in Ortaköy at a depth of 8-13 m). Solid waste was also recorded within local benthic communities. Additionally, the remains of submerged constructions have caused a countless number of fishing lines to get caught which poses a serious threat to marine animals (STH 2005).

The Turkish Marine Environment Protection Association (TURMEPA) has organised coastal cleanup operations in the populated areas along the Turkish coasts of the Mediterranean, Aegean, Black Seas and Turkish Straits System since 2002. In 2003 and 2004, eight locations throughout the Black sea coast (Akçakoca, Ereğli, Giresun, Hopa, Inebolu, Rize, Samsun and Trabzon) were cleaned up. 8215.4 kg of marine litter along 21,3 km of the Black Sea shore was collected in 2003. The average weight of marine litter collected acorss these locations was therefore 385.7 kg/km (ranging from 58.4 kg/km in Rize to 1.395,1 kg/km in Trabzon). Shoreline and recreational activities coupled with smoking related activities constituted to the two major sources of marine litter, responsible for 95.5-96.8% of items found on the seashore.

A case study on a municipal solid waste landfill site which is within close proximity with the shoreline near Zonguldak, Turkey has been studied by Yıldırım *et al.*, (2004). The municipal solid waste (72.4 ton per day at the average) was deposited on the landfill site located in Kozlu suburb, between a main coastal roadway and the seashore over a period of 30 years. The area and bulk volume of the landfill was estimated to be 2.5 ha and 75.000 m^3, respectively. An important but unfortunately undefined amount of deposited items were dumped into the sea and scattered along the coastline (Yıldırım *et al*., 2004). The highest composition of Zonguldak solid wastes were organic waste (31%), paper (20%) and carton and plastic (16%), respectivelly. Yıldırım *et al*., (2004) proposed that sea currents posed a threat to the dissemination of marine litter and other contaminants not only in Zonguldak but also throughout the Black Sea region. Moreover, the increase of solid waste due to an increase in population and consumption was estimated to increase by 545.000 m^3 by 2018 (Yıldırım *et al.*, 2004). However, active measures have been undertaken recently by the Municipality with support from the government through constructing a wall as a barrier to avert waste washing from the landfill into the sea as well as constructing regular storage facilities. Currently, the problem of solid waste is under the control of the Turkish Ministry of Environment and Forestry, and is being taken seriously.

The South-western Black Sea coast has been recently studied by Topçu and Öztürk 2010 and, Topçu *et al*., 2013. The initial study employed trawlers between 25 and 100 m water depths in October 2007 and in February and April 2008 to investigate the density and composition of marine litter on the sea floor in this study area. Marine litter density ranged from 8 to 217 items/km^2 with plastic being the most dominant litter type by 90%. Additionally, four out of six readable labels were foreign originated, highlighting the trans-boundary nature of marine litter. Topçu *et al*., (2010) concluded that the amount of benthic litter was higher than the litter density in the Mediterranean Sea. The study conducted a few years later by Topçu *et al*., (2013) concentrated on coastal litter. Ten coastal stations were surveyed for marine litter in April, June, October 2008 and January 2009. Litter density were found to be between 0.085 to 5.058 items/m^2 and the most abundant type of debris was found to be comprised of artificial materials, of which plastic was the most dominant (around 79%) and up to 75% of total debris was smaller than 10 cm. It is also important to note that unidentifiable items made up 52% of the collected litter and listed as mesoplastics followed by beverage packaging by 19%. Recreational and fishery related items comprised of only 2% and 0.5% of the litter, respectively. Although most of the litter collected in the study area was clearly of land-based origin; about half of the identifiable labelled litter was foreign. The highest marine litter density was recorded for the autumn season. According to Topçu *et al.*, (2013), the Turkish western Black Sea Coast was highly polluted by marine litter when compared to the touristic beaches in southern Turkey (Balas *et al.,* 2003).

The Turkish waters of the eastern Black Sea have also been studied by various researchers. Güneroğlu *et al.*, (2010) studied the marine litter transportation and composition between Trabzon to Rize, with a total coverage of 180 km. 15 different streams were surveyed on three separate occasions in order to estimate the marine litter composition within them. Plastic has been found to be the most dominant litter item at 56%. Yomra Stream has the highest ratio of plastic litter by an estimated 64% due to its location and proximity of industrial establishments alongside stream banks. He concluded that the South Eastern Black Sea region was suffering from environmental pollution despite all the legal regulations and authorities. He recommended that illegal dumping along the stream networks and banks must be strongly prohibited. In addition, solid waste cleaning and removal must be strictly coordinated and organized within the region. Moreover, implementing litter collecting nets should be considered, at least for major streams, to slow down the marine litter pollution.

Erüz *et al.*, (2010) has studied the east coast of the Black Sea and classified the land based marine litter in 10 different beaches in Trabzon, in 2010. The amount of marine litter collected ranged from 2304 items to 33140 items. Trabzon had significantly more marine litter on its beaches than the rest of the stations. Plastic had the highest encountered at 49%, followed by textile, metal, styrofoam, glass and paper (28%, 12%, 5%, 5%, 1% respectively).

More recently, Terzi and Seyhan (2013) studied the amount and composition of marine litter in the eastern coast of Black Sea and in the trawling areas between Sinop to Rize, in 2012-2013. A total of 36,880 m^2 of beach was surveyed and 5,690 items of litter with a total weight of 108.28 kg was collected during the study. Marine litter density was highest in autumn months. During the beach surveys, 70.49 kg of litter was collected with a density between 0.0001-0.015 kg/m^2. Plastic was the most dominant marine litter type by almost 72%, followed by nylon at 16%. The most common usage category was foam boxes (possibly used by the fishermen) (26.43%), followed by beverages (24.38%). Terzi and Seyhan (2013), has also been studied in Samsun to define the benthic litter composition via trawl surveys and found 121 to 366 marine litter $items/km^2$ with nylon being the most dominant litter type by 66%, followed by plastic at 19%. The most common usage category was general packaging (25.80%) followed by beverage (12.90%), and fishing gear (6.95%) (Terzi and Seyhan 2013).

A pilot assessment of bottom marine litter in the Black Sea during the MISIS Project Joint Black Sea along 3 transects (Bulgaria, Romania and Turkey) in the NW Black Sea were conducted in 2013 for the aim of providing a quantitative assessment of bottom (Moncheva et al. 2014). The marine litter density was found at 7.956 $items/km^2$ in the southwest Black Sea waters of Turkey, with plastic being the most dominant type in all study transects by 68% and the abundance of marine litter was higher in coastal areas than the continental shelf (Moncheva et al. 2014).

Only recently, Aytan *et al.*, (2016) assessed microplastic presence from zooplankton samples during two cruises along the south eastern coast of the Black Sea in 2014 and 2015. About 92% of all samples were contaminated by micro-plastics and the dominant origins were fibres (49.4 %) followed by plastic films (30.6%) and fragments (20%); no micro beads were found. The highest concentrations of micro-plastics were observed in offshore stations during November samplings. According to the paper, the relatively high micro-plastic concentrations could be a result of the study methodology or the semi-enclosed nature of the Black Sea, which can hold high densities of plastics (Barnes *et al*., 2009); thus the Black Sea was defined as a hotspot for micro-plastic pollution.

Bulgaria

Bulgaria implements the provisions of the EU Marine Strategy Framework Directive and they actually use landfill taxes and part of the revenue goes towards waste management and environmental initiatives (Newman et al. 2015). Bulgaria and Romania, which were accepted into the EU in January 2007, transpose relevant EU directives and standards into their national legislation. Therefore, national policies exist on waste minimization, reuse, recycling and recovery of landfills. Additionally, plastic products are charged and taxed in Bulgaria and these schemes are generally considered successful (Oosterhuis et al. 2014). Bulgaria is a partner of many different EU projects, focusing mainly on public awareness campaigns, beach cleaning, landfills and waste management, however to our knowledge, there are few scientific reports on the marine litter density and composition from Bulgarian region.

The only scientific survey that highlights was carried in July 2013 by Moncheva *et al*., (2014) which covered Bulgaria, Romania and Turkey in its study sites. Marine debris density was found to be 9.598 item/km^2 in Bulgaria. The high marine litter density could be a result of intensive fishing and shipping activities and/or their natural dispersal. The paper concluded that the natural dispersal of floating and suspended marine litter by wind and sea currents represents a transboundary problem that needs a basin scale concerted management strategies of different sectoral activities.

Romania

In Romania, sea surveys for seabed marine litter monitoring, beach marine litter monitoring surveys along Romanian Black Sea coast, laboratory analyses for macro- and micro-plastics, participation in actions to identify the main polluters, developing proposals for measures to reduce litter pollution of the marine environment (MSFD), awareness raising campaigns through beach cleaning activities and education, are actively in place (Golumbeanu et al. 2015).

In regard to the scientific surveys, the monitoring of the existing waste on the seabed is in the pioneer stage in Romania however the National Institute for Marine Research and Development (NIMRD) conducted sampling trawlings to collect and assess types and quantities of marine litter on the seabed through voluntary monitoring in 2011 and 2012 under The National Pelagic and Demersal Fish Species Status Evaluation Program. It was concluded that the abundance and distribution of marine litter has a considerable spatial variability and is strongly influenced by hydrodynamics, geomorphology and human related factors. Moreover, the increasing presence of plastics (PET containers, bags, sacks, linoleum, buckets, canisters etc.) on the seabed were confirmed (Percentages of trawling hauls with plastic presence was 57% in 2011, 58% in 2012 and raised to 60% in 2013). Metal and rubbers were collected in almost 100% of cases from vessels. Most of the litter items were discards of vessels/boats going out of harbors and the ones traveling along trade routes. In addition, the Danube River has a significant input in bringing plastic litter into the sea through its outflows (Anton *et al*., 2013). The study concluded that there is a considerable amount of marine litter on the seabed, coming from discards or losses, many of them having a negative impact on biodiversity, as well as on activities such as fisheries and tourism and furthermore mentioned the importance of litter GIS mapping to avoid trawler to haul in the same areas (Anton *et al*., 2013). The experiences from the current survey have been put together for the definition of the national monitoring programme for marine litter in the context of MSFD implementation (http://www.cleansea-project.eu/drupal/?q=en/node/192).

Lechner et al. (2014) provided the first evidence that large rivers transport significant amounts of micro-plastics and contribute substantially to the marine plastics pollution. He placed Stationary driftnets to investigate the marine litter pollution in Danube River between 2010 and 2012. A total of 17,349 plastic items have been counted and mean plastic abundance and its mass in the river were higher than the drifting larval fish (Lechner et al. 2014). Approximately 900 plastic items/m^3 in 2010 and 50 items/m^3 in 2012 between the sizes of 0.5 to 50 mm were reported. Industrial raw materials as in pellets, flakes and spherules represented the 70.4% of the plastic debris in the river. The plastic input via the Danube into the Black Sea was estimated as 4.2 ton per day (Lechner et al. 2014) which is an estimation showing that litter load in Black Sea is more than the total plastic load of the whole North Atlantic Gyre (Wagner et al. 2014).

In July 2013, Moncheva *et al.*, 2014 carried out pilot marine litter assessment study covering Romania, Bulgaria and Turkey. In total, the marine litter density ranged from 304 to 20.000 item/km^2 (mean of 6359 items/km^2) with Romania holding the highest marine litter density. About 68% of all the marine litter was identified as plastic. Moreover it was found that the amount of marine litter was considerably higher in the coastal zones then in the continental shelf in Romania.

According to the study conducted by ARCADIS, beaches near Constanta have considerably more litter from recreational and touristic activities (both land and sea-based). 45% of the marine litter originated from recreational fishing, followed by household and sanitary sources. While shipping and ports represent only 8% of the total marine litter (ARCADIS 2013).

Recently, Ioakeimidis *et al.*, (2014) has studied the marine litter on the seafloor of the Eastern Mediterranean and Black Sea in 2013. The objective of the study was to determine the abundance, spatial distribution and qualitative composition of benthic marine litter as well as to investigate the factors affecting benthic litter accumulation and distribution (external sources *vs* internal transport mechanisms) in five selected study areas in the Eastern Mediterranean (Saronikos, Echinades, Patras Gulfs of Greece, Limassol Gulf in Cyprus) and Black Seas (Constanta Bay in Romania). In total 16 trawlers were conducted in Constanta Bay with a survey area of 75.6 km. 210 items with an average of 87 kg had been collected from the bay, which corresponds to 0.8-23.5 kg/trawl in Constanta Bay. Mean marine litter density was found to be 291±237 items/km^2 with the highest density on plastic by 45% followed by glass and metal (both 22%). The highest marine litter density was recorded in front of Danube mouth by 1068 items/km^2. In conclusion, the marine litter load was affected by a series of factors including; i) the proximity of big cities, ii) the intensity of marine traffic, iii) the riverine inputs into the sea and (v) the geomorphology of the area (semi-enclosed *vs* open - shelf environment). Additionally, small size items (<5x5 cm) had a significant proportion in Constanta Bay by 22%.

Ship-based marine litter visual surveys were carried out by the EU Project CoCoNet between the Danube delta and the port of Constanta, Romanian waters, to provide the first preliminary data on floating debris (Fig.1.7.1).

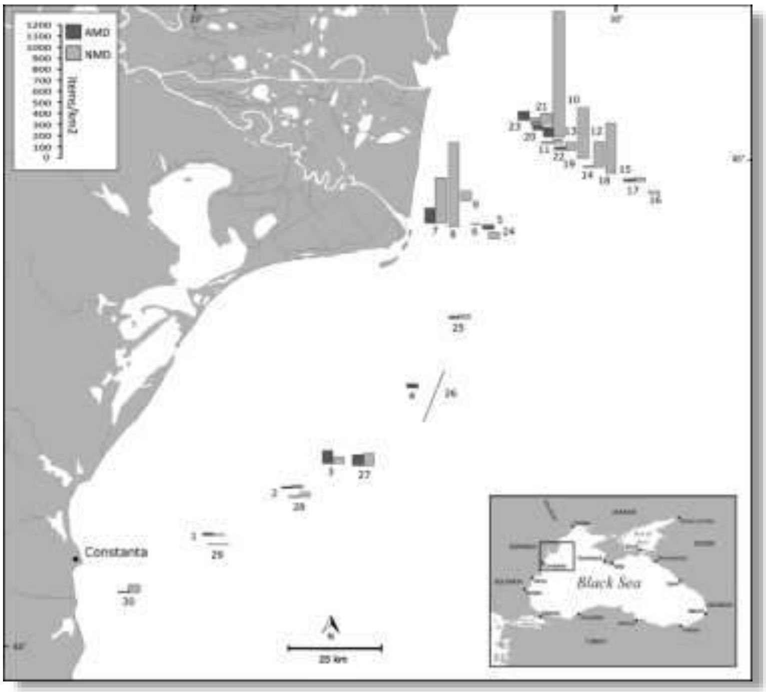

Figure 1.7.1. Map of the study area (North-western Black Sea) showing the distribution of Anthropogenic Marine Debris (AMD-dark bars) and Natural Marine Debris (NMD-light bars) densities (expressed as number of items/km).

High man-made litter densities peaking to 135.9 items/km^2 were found with a mean of 30.9 ± 7.4 items/km^2. However, natural debris was more abundant than anthropogenic litter, which can be a result of the proximity of the Danube delta to the survey sites. 75.5% of the sightings were wood and other riparian debris, however plastic items (mainly fragments, bags, containers and packaging) remained the most abundant type of manmade litter items by 89.1%. No previous data on the abundance of floating debris in Romanian waters exist (Suaria *et al.*, 2015).

Ukraine

Marine litter studies are scarce in Ukraine. For the scientific surveys, there are studies from the beginning of 2000, mainly focusing on floating debris and coastal litter. On the other hand, early surveys weren't originally focused on marine litter. However floating marine litter density was also noted during the surveys and recorded according to their cumulative appraisal. In 2002, aerial surveys have been conducted originally for a marine mammal surveys in Kerch Strait, southern portion of the Azov Sea and adjoining Black Sea shelf which are located in Ukraine and Russia in 2002. While moderate number of plastic items was detected in the Azov Sea along all tracklines surveyed, in the Kerch Strait numerous litter sightings were concentrated in the central and southeastern portions – mainly within the anchorage area abundant with large vessels. However, the homogenized valuation of marine litter pollution in the Kerch Strait turned out to be almost as high as in the Azov Sea (66 item/km^2) and twice as high as those from the Black Sea area (BSC, 2007).

A year after the initial study, vessel-based line transects surveys was carried out in 2003 during a marine mammal survey in the Kerch Strait and in the territorial waters of Ukraine. During the marine mammal survey, the numerical values of floating marine litter were again estimated. The coastal waters of Crimea peninsula have the highest records. The general density of floating plastic was estimated as 6.57 items/km^2 in the Ukrainian Sea and 65.7 items/km^2 in the Kerch Strait, while in total 158,620 floating plastic items were counted during the study, of which 5.25% were plastic bottles (Birkun and Krivokhizhin, 2006). Lastly, it was estimated that aggregate the mass of plastic floated upon the entire surface of the Ukrainian Black Sea 18.559 kg.

The marine litter presences in coastal zones were also investigated in 12 pedestrian surveys in Crimea, Ukraine by the Brema Laboratory and Crimean Medical University in 2002 and 2003. The sites were relatively unmanaged, sandy and pebble beaches of the western (outskirts of Shtormovoye), south-western (outskirts of Lyubimovka) and south-eastern (outskirts of Privetnoye) Crimea. The density of beachfront pollution by polymeric garbage varied from 333 to 6.250 kg/km^2, while the density of glass fluctuated between 222 and 1,455 kg/km^2 (BSC 2007). Additionally, while the density of plastic objects was found to be 16.348±5.076 pieces/km^2, it was 674±107 pieces/km^2 for glass bottles (Birkun and Krivokhizhin, 2006). In conclusion, plastic predominance was found to be considerably higher than glass by 80-98% to 2-20% on the unmanageable beaches under different seasons.

There are a couple of recent projects where Ukraine is a partner country. The EMBLAS project (Improving Environmental monitoring in the Black Sea) carried out by EU and UNDP is conducted with the aim of strengthening capacities of Georgia, Russian Federation and Ukraine to monitor the water quality of Black Sea, in line with EU marine environmental legislation (MSFD) (http://emblasproject.org). Ukrainian Scientific Center of Ecology of the Sea, Institute of Marine Biology of National Academy of Sciences of Ukraine and Odessa National I.I. Mechnikov University are involved in the project's implementation. The main objectives of the survey conducted in 2016 in the frame of the EMBLAS project were to determine the parameters for good environmental states, to screen the emerging organic pollutants, to study marine litter according to the EU Marine Strategy Framework Directive in part of the initial assessment of marine waters and the EU Water Framework Directive in part of the status assessment of the coastal zones (http://www.ua.undp.org/content/ukraine/en/home/presscenter/articles/2016/05/25/ukrainian-and-georgian-scientists-join-forces-in-unique-environmental-researching-black-sea-basin.html). During EMBLAS activities one beach near Odessa (Chernomorka) was observed according to the 'Guidance on Monitoring of Marine Litter in European Seas (JRC 2013). Furthermore during EMBLAS cruises floating litter monitoring was conducted with the help of Joint Research Center Floating Litter Mobile Application (JRC App) in Ukranian territorial waters and on the large transect through the center of the sea from Odessa to Batumi. The results of these observations are going to be published soon in EMBLAS Scientific report. A good tradition to celebrate the Black Sea Clean Beach day with major cleanups was set in automn within the EMBLAS project in all Black Sea countries.

Russia

Even though there is a wide range of studies, campaigns and projects on the Russian Baltic Sea and Russian Far East, covering the Northwest Pacific, specifically Primosky Kray which is known as hot spot for marine litter, there are few studies focusing on the marine litter issue in the Russian Black Sea. Until now, aerial surveys were the most dominant survey type that was carried out for marine litter studies. The majority of the studies focused on marine litter distribution and hotspots while there were no records of marine litter compositions. Visual aerial surveys were conducted by Ukrainian and Russian scientists in 2002, focusing on the Kerch Strait, Azov Sea and the coastal Russian Black Sea. As mentioned previously, concentrations of marine litter in the Kerch Strait and the Azov Sea were found comparable at 66 items/km^2 and twice as high as those from the Black Sea (BSC 2007).

In later years, aerial surveys have been carried out in the internal and territorial waters of Russian Black and Azov Seas in 2003, 2004 and 2005 by the Centre of Hydrometeorology and Environment Monitoring of the Black and Azov Seas (CHEMBAS, Sochi, Russia). While marine litter distribution, relative density, hot spots, seasonal and daily trends were mapped, no precise information was collected regarding its composition, other than indicating that it usually consisted of human-produced materials (BSC, 2007). In total, 150 and 160 days were allocated in 2004 and 2005, respectively. Marine litter accumulation sizes were roughly estimated which varied widely from 1-5 m^2 to more than 100.000 m^2. A total of 918 and 949 marine litter sightings were recorded in 2004 and 2005, respectively, with a maximum number of marine litter sightings in the southern part of the Russian Black Sea near Sochi and between Sochi and Tuapse (Psou–Loo, Loo–Magri and Magri-Inal areas). The number of sightings decreased in the northern parts. Marine litter pollution depends mainly on the level of river run-off in this area. The study concluded that numerous "spontaneous heaps" of marine litter items have been sighted during the surveys and the eastern Azov Sea was less polluted with marine litter than the north-eastern and eastern Black Sea within the territorial borders of Russia during spring, summer and autumn. However, this conclusion may be strongly biased due to different observation effort applied in different areas (BSC, 2007).

Lastly, the Black Sea Commission (2007) noted that marine litter deposits are known to be present on sandy north-eastern coast of the Kerch Strait (Choushka spit), and also in Taman–Anapa (Blagoveshchenskaya and Vityashevskaya spits), Anapa–Novorossiysk (Abrau peninsula), Novorossiysk–Gelendzhik, and Divnomorskoye–Dzhoubga areas. However, no quantitative information was collected and analysed (BSC, 2007).

A recent programme was launched in 2016 covering the Russian territorial waters within the EMBLAS project (Improving Environmental monitoring in the Black Sea) with the aim of strengthening capacities of Georgia, Russian Federation and Ukraine to monitor the water quality of Black Sea, in line with EU marine environment legislation (MSFD) (http://emblasproject.org). In the frame of the project for beach litter monitoring four different sites (near Taman', Anapa, Gelendzhik, Sochi) were observed according to the 'Guidance on Monitoring of Marine Litter in European Seas' (JRC 2013) in 2016. The last one in Sochi region was made with the help of European Environmental Agency Mobile Application (MarineLitterWatch App) on the Black Sea Clean Beach day combined with public awareness rising campaign and involving large amounts of volunteers. Floating litter observations were conducted with the help of Joint Research Center Floating Litter Mobile Application (JRC App) in Kerch strait and Sochi-Adler region. Futhermore the riverine floating litter was observed regulary during the year with the same mobile application on rivers Don, Ashamba and Aderbievka as collaboration with RIMMEL project. The results of all these observations are going to be published soon in EMBLAS Scientific report.

Georgia

Even though Georgia was a partner of several EU funded projects, to our knowledge no previous information on marine litter has been reported so far from the Georgian Black Sea coast. Recently in 2016, Georgia togather with Russia and Ukraine have started to run an EMBLAS project (Improving Environmental monitoring in the Black Sea), covering the territorial waters of these countries with a wide range of survey topics. Some of the main aims of the surveys related to marine litter are to determine the parameters for good environmental states, to screen the emerging organic pollutants, to study marine litter according to the EU Marine Strategy Framework Directive in part of the initial assessment of marine waters and the EU Water Framework Directive in part of the status assessment of the coastal zones. (http://www.ua.undp.org/content/ukraine/en/home/presscenter/articles/2016/05/25/ukrainian-and-georgian-scientists-join-forces-in-unique-environmental-researching-black-sea-basin.html). Since 2015 regular observations of beach litter according to the 'Guidance on Monitoring of Marine Litter in European Seas (JRC 2013) have started by Tbilisi State University (TSU) which continued in 2016. The obtained results showed in 2015 the volume of plastic litter about 95–96% (without natural wood waste) (Machitadze et al., 2015). In 2016 two different sites for monitoring were chosen (Sarpi and Kobuleti) with different anthropogenic impact which showed 61.1% and 91.2% of plastic found as a result. Furthermore during EMBLAS cruises floating litter monitoring was conducted with the help of Joint Research Center Floating Litter Mobile Application (JRC App) in Georgian territorial waters. This Application also allows to monitor the riverine floating litter which was tested on four Georgian rivers as well (Chorokhi, Supsa, Natanebi and Rioni). The results of all these observations are going to be published soon in EMBLAS Scientific report. A good tradition to celebrate the Black Sea Clean Beach day with major cleanups was set in automn in the frame of EMBLAS project in all Black Sea countries.

Conclusion

The Black Sea is a semi-enclosed sea, surrounded by many industrialized countries, with important shipping routes, various fisheries and touristic areas. In addition it has a dynamic surface circulation and hosts a large drainage basin. All the above factors make the Black Sea a particularly sensitive area for marine litter pollution (BSC, 2007; UNEP, 2009). A large number of rivers discharge into the Black Sea, including the second, third and fourth longest rivers in Europe. It is well acknowledged that rivers transport large amounts of natural and anthropogenic debris from in-land sources to the ocean and coastal beaches (Rech *et al*., 2014) and it is proven that high a percentage of marine litter, including micro-plastics, are introduced by river currents to the Black Sea (Tuncer *et al*., 1998; Topçu *et al*., 2013; BSC, 2007; Lechner *et al.* 2014).

The literature across international reports and scientific papers highlight that plastics are the most abundant type of marine litter worldwide. While plastic constitutes to around 75% of all litter items found in EU (Kershaw *et al.*, 2013), the proportion found in both the Black sea's seafloor and coastal environments increased up to 90% (Topçu *et al*., 2013). Therefore, in accordance with global data, plastic waste has a worldwide predominance in the marine environment (Suaria *et al.*, 2015). In regard to micro-plastics, the studies conveyed that the Black Sea is prone to micro-plastic accumulation, both in the pelagic and benthic habitats, which make it as a micro-plastic hotspot. In regard to the marine litter density, the Kerch Strait and Azov Sea each contain an extensive marine litter density relative to the rest of the Black Sea. It should also be highlighted that there are differences between each country's methodology and units when collecting and reporting marine litter densities; this makes it hard to compare the results between each country. There is therefore an urgent need for basin-wide surveys to follow similar survey techniques and to allow comparisons on marine litter composition and accumulation within and between countries. The majority of the marine litter data comes from coastal surveys followed by seabed studies. There were only two surveys focused on the presence of micro-plastics, one in Romania and one in Turkey. It is clear that all six Black Sea countries are on the pioneering stage of marine litter pollution management.

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1.3. THE STATE AND DYNAMICS OF THE BIOLOGICAL COMMUNITY

1.3.1 Microbial Communities

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Microbial communities such as *Bacteria*, *Archaea*, viruses, *Fungi*, and protists constitute the bulk (up to 90%) of diversity and biomass of marine ecosystems (Glockner et al., 2012). These microbes play crucial roles in all marine ecosystems functioning and productivity, and can include pathogens that cause diseases in marine organisms and humans (Gasol et al., 2008). They are sensitive to environmental and anthropogenic impacts and respond quickly (often in few hours) to natural perturbations and environmental stress, acting as early warning indicators of changes in the health of marine ecosystems. This allows microbial analyses to discriminate marine environment quality status, and shifts in microbial communities and activity could be used as an indicator of changes in quality of marine ecosystem and each of its compartments such us water, sediments and biota (Coelho et al., 2013).

Although microorganisms have proven to provide an integrated measure of marine environment quality, an aspect that cannot always be obtained with physical and chemical measures and/or analysis of higher organisms, they are included in the Black Sea monitoring programs only as microbial pathogens (BSC, 2002). The assessments of the quality of the Black Sea marine environment currently are performed at national level monitoring programs under the Bathing Water Directives 2006/7/EC, 76/160 EEC and the Shellfish Water Directive 2006/113/EC in most of the countries in the region. Intestinal enterococci and Escherichia coli for bathing waters, as well as total fecal coliforms, Escherichia coli and Salmonella spp. for designated shellfish growing areas are determined, on an annual basis, to assess the microbiological pollution of surface seawaters with the purpose of protecting human health and the Black Sea environment (Alecu et al., 2015). Thus, microbial community composition and function, two important metrics that can be used to monitor and predict marine environmental changes highly relevant to global economy and health are largely ignored by the current national monitoring programs of the Black Sea countries. However the Black Sea, ***the largest landlocked and vulnerable sea in the world,*** necessarily requires a deeper understanding of diversity and function of their microbial communities and a clear defining of their role in marine ecosystems quality status indicators (BSC, 2008).

Development/improvement of cost-effective tools for monitoring microbial communities of the Black Sea, not only microbial pathogens, should be considered as a management target of high priority to better inform policy makers and the public on its value in environmental, social (including cultural) and economic terms. Further coordination in policies and legislation between the six Black Sea countries is also required to fill those gaps found in the current EU Marine Strategy Framework Directive 2008/56/EC (MSFD) descriptors which don't integrate the most important microbial variables within the set of GES (Good Environmental Status) indicators of marine environmental quality (Caruso et al., 2015).

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1.3.2 Phytoplankton

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Introduction

Phytoplankton is the base of the food web ,that plays a key role in the biological economy of the ocean, e.g. via photosynthesis converts the inorganic nutrients and the solar energy, as the only energy source, into relatively stable organic substances that drive life in the marine ecosystems through complicated web of feeding interactions. As a component of the aquatic biota strongly affected by multiple variables it is the "first target" of the environmental perturbations, including those induced by the anthropogenic pressure (pollution and eutrophication) and climatic changes. Thus, alterations in phytoplankton communities biodiversity, dominant species, taxonomic structure, abundance, biomass, primary production, seasonal succession and mode of function are considered relevant indicators of the ecosystem health. The Water Framework Directive (Directive 2000/60/EC) and the Marine Strategy Framework Directive (Directive 2008/56/EC) of the European Union, as well as the Black Sea Commission Strategic Action Plan (SAP, 2009) refer to phytoplankton as an important biological component to be addressed in the assessment of the ecological status of the sea. Plankton indicators may provide valuable information about the condition and "health" of the pelagic habitats for Descriptor D1 – Biodiversity, D2- Non- indigenous species, D5- Eutrophication, D4-Food web.

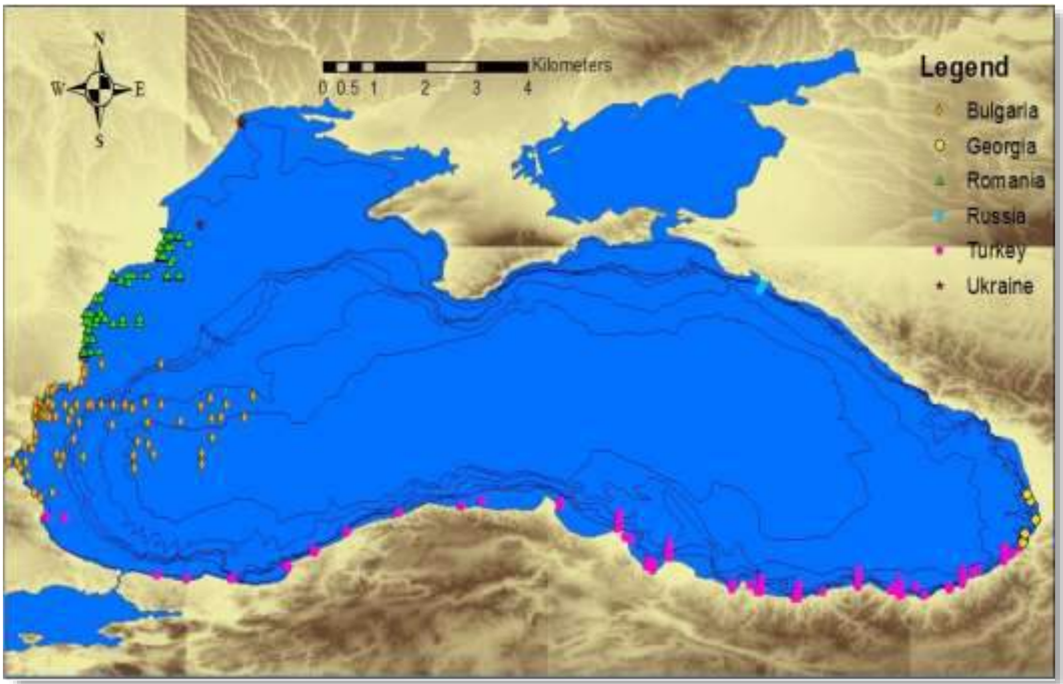
The **Objective** is to produce a coherent basin scale assessment of the recent (2008-2014) trends in phytoplankton community biodiversity, taxonomic structure and seasonal patterns of growth, based on common indicators (community traits), proposed by the Black Sea CBD AG and approved by the Black Sea Commission, for assessment of Black Sea ecosystem ecological state (Table 1.3.2.1).

Table 1.3.2.1. Phytoplankton parameters/indicators

Parameters - BS State	BG	GE	RO	RU	TR	UA
Phytoplankton biomass (seasonal trends)	x		x	x	x	x
Phytoplankton abundance (seasonal trends)	x	x	x	x	x	x
Max concentration of blooming species	x	x	x	x	x	x
Diatoms/Dinoflagellates biomass ratio (only for spring)	x					

Data and methods

The assessment is based on data collected during the period 2008-2014 by the Black Sea countries within national monitoring programs and projects funded by different sources. The inventory of sampling stations is presented on Fig. 1.3.2.1.



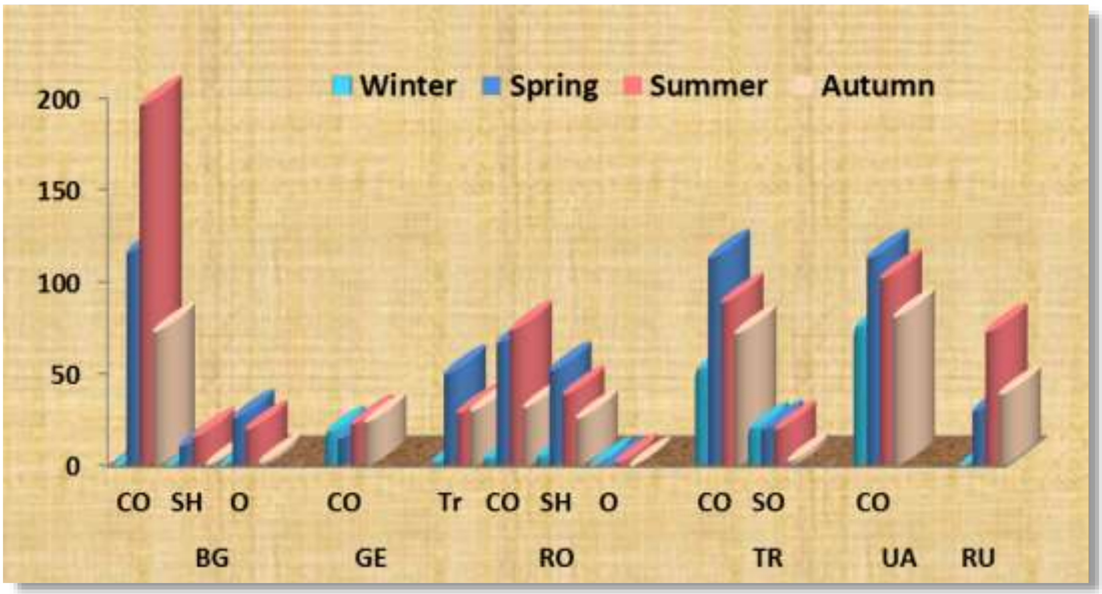


Figure 1.3.2.1. Map of sampling station and distribution of number of stations by seasons and pelagic habitats per country: BG-Bulgaria, GE-Georgia, RO-Romania, TR- Turkey, UA-Ukraine; RU-Russia (Tr- transitional, CO-coastal (depth <30m), SH- shelf (depth >30-<200m and O-open sea (depth >200m), SO- shelf-open sea)

The inventory shows a very uneven spatial distribution of the stations, majority centered in the coastal zone (~ 70%), lower number of sampling stations located in the shelf (~20%), while the stations in the open sea are mostly in the BG EEZ (in total 50 sampling cases). The same pattern stands for the frequency of sampling and spatial distribution by seasons - very few data in winter (176 sampling cases), the highest frequency and spatial coverage being in summer (683 sampling cases ~37 % of the total) and spring (613~ 33%). Another feature of the data set is the disproportion and unevenness of sampling between years within the period and by countries, which has a bearing on the comparison between the different habitats.

Laboratory analysis reveal some differences in counting methods mainly regarding the microscopes and counting chambers used (Table 1.3.2.1). How these differences affect the final estimates were documented in the Intercomparisson Reports produced within the intercomparisson excercises conducted between Bulgaria, Romania and Turkey (Moncheva et al., 2014 - MISIS Project) and between Ukraine, Georgia and Russia (Zotov, 2017- EMBLAS II Project).

Table 1.3.2.2. Methods for phytoplankton laboratory analysis by countries

Country	Sample fixation	Sample concentration	Counting chamber	Type of microscope	Volume of sub-subsample, ml	Magnification	No cells counted per sample	Biomass calculation
BG	4 % buffered formaldehyde	Decantation Utermol	Segwick Rafter Utermol	Nicon inverted+ immage analysis	1	20X; 40X	400 cells	geometric shapes
GE	4 % buffered formaldehyde	Inverse filtration	Segwick Rafter	KRUSS, inverted	0.05	20X; 40X		geometric shapes
RO	4 % buffered formaldehyde	Decantation , Utermol	Utermol	Olympus Inverted +image analysis	0.1	20X, 40X	entire chamber	geometric shapes
RU	2% buffered formaldehyde2 % buffered glutar-aldehyde	Inverse filtration; Double Decantation	Najotte Nayman ; Nucleopore 0.2 µ	LOMO, Ergoval light microscope; epifluorescent	0.05; 1.0	16X; 40X; 1000x picoplankton	400 cells	geometric shapes
TR	4 % buffered formaldehyde	Decantation , Utermol	Segwick Rafter Utermol	Nikon inverted+epiflourescense attachment	0.1	20X, 40X	entire chamber	geometric shapes
UA (ONU)	4 % buffered formaldehyde	Inverse filtration; Decantation		HUND 600, light	0.01; 1.35	20X; 40X; 60X		geometric shapes
UA	4 % buffered formaldehyde	Inverse filtration; Decantation		LOMO, Carl Zeiss, light	0.05, 1.0	20X; 40X; 60X		geometric shapes

Trends in phytoplankton biodiversity

Although phytoplankton diversity is extremely important for the stability and functioning of the marine ecosystem and biogeochemical cycles (Ptacnik et al., 2008) the indicator role bear a number of constrains, that should be taken into consideration in the comparative assessments. On the one hand our knowledge of marine phytoplankton biodiversity is limited due to both methodological constrains of species identification techniques the effort and expense of gaining appropriate data sets by traditional microscopic methods (Cermeño et al., 2013, Dromph et al., 2013) and mismatches between sampling and the scales of phytoplankton natural variability, for which species identity concepts within Biodiversity Ecosystem Functioning are rather vague (Strong et al., 2015). On the other hand mechanisms regulating patterns of phytoplankton biodiversity still remain debated and largely unexplored (Garmendia et al., 2012, Cermeno et al., 2013). Albeit the great effort to explain the factors that determine the distribution, community assembly, blooms, and succession of species the macroecological and morphospecies approaches are not properly scaled to the ecophysiology and niche requirements of the phytoplankton phylogenetic groups and species present (Smayda, 2011).

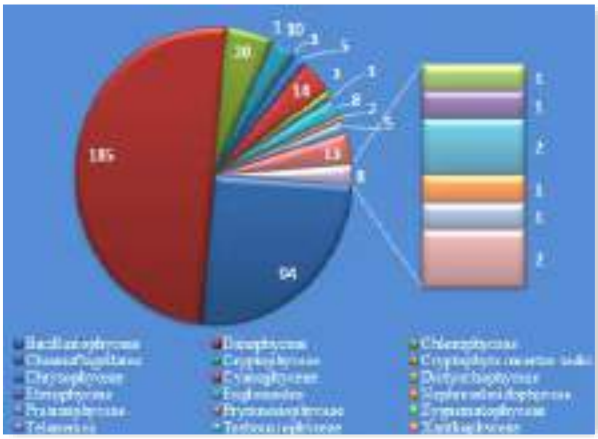
Irrespective of the differences in the phytoplankton community biodiversity profile and number of species reported, during 2008-2014 a high species diversity and richness was a common trend for all pelagic habitats basinwide.

In **Bulgarian** (BG) waters a total of 370 species, varieties and forms were identified in the study area, from 21 taxonomic classes and a numerous small flagellates that could not be identified to species level under light microscope. Dinoflagellates were the most diverse - 185 species (merely 50% of the total), diatoms ranked second with 94 species (~25% of the total species pool). While the species diversity among the other classes was much lower, the relatively high species richness of Cryptophyceae - 20, Cyanophyceae - 14, Prymnesiophyceae - 13, Euglenophyceae – 8 should be outlined (Fig. 1.3.2.2a).

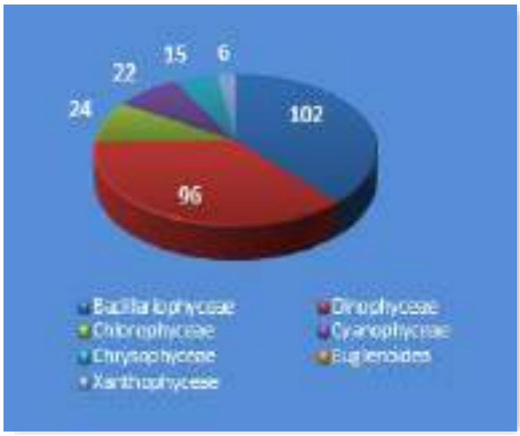
Among dinoflagellates genus Protoperidinium (25 species), Gymnodinium (27 species) and Gyrodinium (15) were represented by the highest variety. Among diatoms genus Chaetoceros contributed by high diversity followed by *Pseudonitzschia complex*. A specific feature of phytoplankton assembly diversity was the increased share of Cryptophyceae (*Hemiselmis sp., Hillea fusiformis, Plagioselmis sp*.), Prasinophyceae (*Pyramimonas sp.)* and microflagellates especially in summer.

Irrespective of the season and the habitat the phytoplankton community was represented by rich species pool – between 79 and 260 per sampling campaign. In conformity to the trend outlined after 2000 the species richness per station was high (41-73), the highest number was traditionally recorded at the surface homogenious and thermocline layers and the lowest bellow the thermocline. The open sea stations accommodated relatively high diversity similar to that of the costal phytoplankton assemblages (Moncheva et al., 2013).

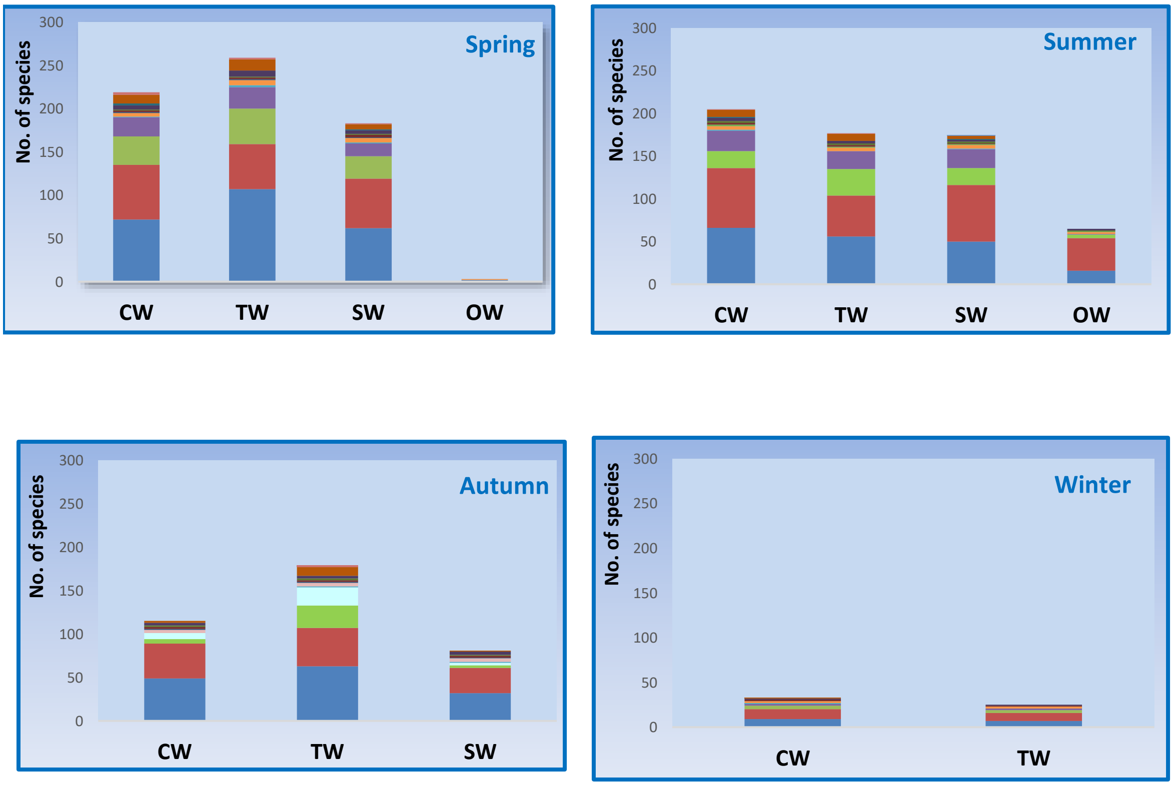
As a general trend in addition to the traditional and common diatoms (Cerataulina pelagica, Chaetoceros species, Sceletonema costatum, Pseudonitzschia delicatissima, Thalassionema nitszchioides, Cyclotella choctawhatcheeana, Pseudosolenia calcar-avis) and dinoflagellates (Prorocentrum cordatum, Prorocentum micans, Heterocapsa triquetra, Glenodinium paululum and Glenodinium pilula, Protoperidinium bipes, Protoperidinium pellucidum), the recently recorded dinoflagellate Lessardia elongata was common for all stations. Genus Scrippsiella composed by several species was reported as Scrippsiella complex in support of the recent finding by Robino et al. (2010).



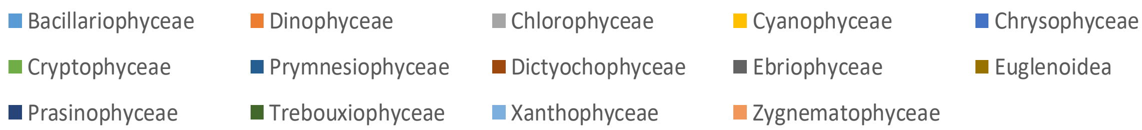
a)Bulgaria

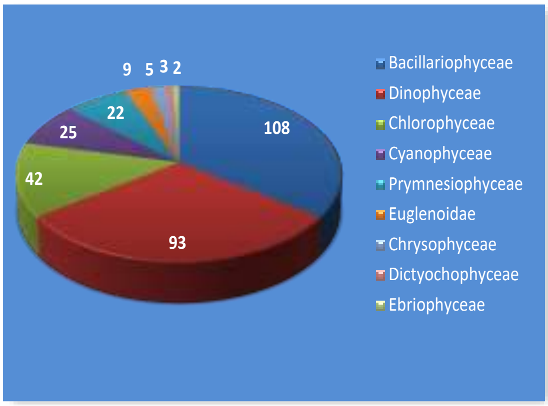


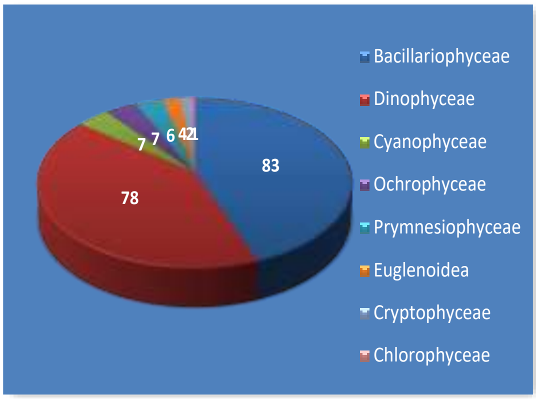
b) Georgia



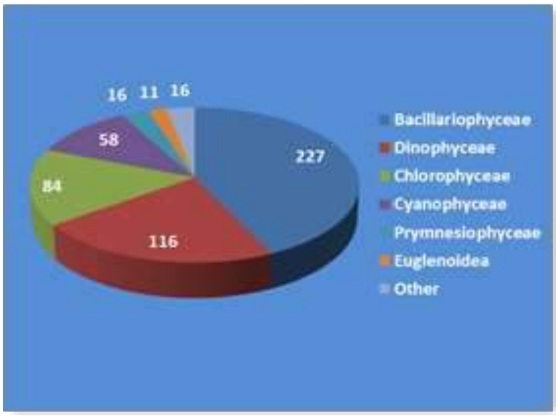
Romania

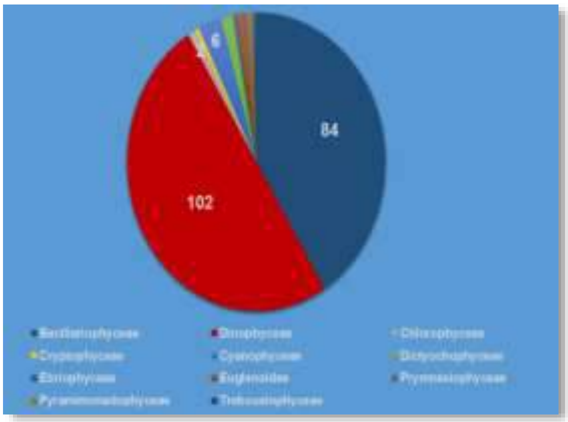






d) Zmiiny (Ukraine) e) Russia





f) Odessa (Ukraine) g) Turkey

Figure 1.3.2.2. Phytoplankton biodiversity by taxonomic classes for the period 2008-2014 by countries: a) BG pelagic habitats; b) Georgia coastal habitat; c) Romanian pelagic habitats (CW-coastal waters, TW-transitional waters, SW-shelf waters, OW-open waters) d) island Zmiiniy e) Russia waters f) Odessa coastal habitat g) Turkish waters

The phytoplankton assembly was enriched with recently detected or very rare dinoflagellates such *as Cystodinium sp., Gyrodinium cochlea, Gyrodinium flagellare, Gyrodinium varians, Gymnodinium nanum*, the euglenophyte *Euglena acusforme* and species recorded for the first time in the Bulgarian waters, such as *Glenodinium pulvisculus* (Ehrenberg) Stein 1883, *Polyblepharides amylifera* (Conrad) H.Ettl, 1982, *Amphidinium flagellans*, Schiller *Borodinellopsis texensis* R.F. Dykstra 1971 (Chlorophyceae), signifying further diversification of the phytoplankton community, predisposing further changes in the community taxonomic structure (Table 1.3.2.3).

The application of novel techniques such as Massive Parallel Sequencing (aplicon sequence of the 18S rRNA gene) reveal the presence of new species for BG waters, out of which 24 species not reported for the Black Sea, some of which are listed as potentially toxic (Dzhembekova, Moncheva, 2014, Dzhembekova et al, 2017a, b) (Table 1.3.2.3). The application of genus specific large subunits ribosomal DNA (LSU rDNA) primer resulted in the first detection of *Pseudonitzschia linea* Lundholm, Hasle and G. A. Fryxell, 2002 in the Black Sea and first confirmation of the presence of the cryptic *Pseudonitzschia calliantha* Lundholm, Moestrup & Hasle, 2003 and *Pseudonitzschia pungens* var. *aveirensis* Lundholm, Churro, Carreira & Calado, 2009 in BG waters.

Table 1.3.2.3. List of phytoplankton species new for the BG waters and the Black Sea

Phyllum	Bulgaria	Black Sea
Bacillariophyceae	*Chaetoceros aequatorialis Cleve, 1873*	
	Chaetoceros calcitrans (Paulsen) Takano, 1968	
	Halamphora coffeaeformis (Agardh) Levkov, 2009	√
	Hyalodiscus scoticus (Kützing) Grunow, 1879	
	Cyclotella atomus Hustedt, 1937	√
	Thalassiosira lundiana Fryxell, 1975	√
	Lennoxia faveolata H.A.Thomsen & K.R.Buck, 1993	√
	Pseudonitzschia linea Lundholm, Hasle and G.A.Fryxell, 2002	√
	Pseudonitzschia calliantha Lundholm, Moestrup & Hasle, 2003	
	Pseudonitzschia pungens var. aveirensis Lundholm, Churro, Carreira & Calado, 2009	
	Thalassiosira antiqua var. septata Proschkina-Lavrenko 1955	
Dinophyceae	*Alexandrium margalefii, Balech, 1994*	√
	Alexandrium mediterranenum U. John, 2014	√
	Amphidinium acutissimum Schiller, 1933	
	Amphidinium curvatum Schiller, 1928	√
	Amphidinium herdmanii Kofoid & Swezy, 1921	√
	Biecheleria cincta (Siano, Montresor & Zingone) Siano, 2012	√
	Cochlodinium geminatum (Schütt, 1895) Schütt, 1896	
	Dinophysis punctata Jörgensen, 1923	
	Glenodinium caspicum (Ost.) Schiller, 1937	
	Glenoaulax inaequalis (Schmarda) Diesing, 1866	√
	Gonyaulax turbynei Murray & Whitting, 1899	
	Tovellia coronata (Woloszynska) Moestrup, Lindberg & Daugbjerg 2005	√
	Gymnodinium elongatum Hope, 1954	√
	Gymnodinium nanum Schiller, 1928	√
	Gymnodinium opressum Conrad 1926	√
	Gymnodinium dorsalisulcum (E.M.Hulbert, J.J.A.McLaughlin & P.A.Zahl) Shauna Murray, M. de Salas & G. Hallegraeff, 2007	√
	Gyrodinium dominans Hulbert, 1957	
	Gyrodinium gutrula J.Larsen, 1996	√
	Margalefidinium polykrikoides (Margalef, 1961) F.Gómez, Richlen & D.M.Anderson, 2017	

Phyllum	Bulgaria	Black Sea
	Lessardia elongata Saldarriaga & F.J.R.Taylor, 2003	
	Pfiesteria piscicida K.A.Steidinger & J.M.Burkholder, 1996	√
	Peridiniopsis penardii (Lemmermann) Bourrelly, 1968	
	Protoperidinium bulla (Meunier ,1910) Balech 1974	
	Protoperidinium nux (J. Schiller 1937) Balech 1974	√
	Peridiniopsis niei G.X.Liu & Z.Y.Hue, 2008,	√
	Pelagodinium beii (H.J.Spero) Siano, Montresor, Probert & Vargas, 2010;	√
	Woloszynskia pascheri (Suchlandt) von Stosch, 1973	
Euglenophyceae	*Euglena acusformis J.Schiller*	
Trebouxiophyceae	*Trochiscia multispinosa (Möbius) Lemmermann*	
Chlorophyceae	*Chlamydomonas pulsatilla H.Wollenweber, 1926*	√
Prymnesiophyceae	*Pontosphaera haeckelii Lohmann, 1902*	
	Corymbellus aureus J.C.Green, 1976	√
Chlorophyceae	*Chlamydomonas raudensis Ettl, 1976,*	√
	Chlorogonium capilatum H.Nozaki, M.M.Watanabe & K.Aizawa, 1995	√
Cyanophyceae	*Phormidium bulgaricum (Komárek) Anagnostidis & Komárek, 1988*	√
	Spirulina meneghiniana Zanardini ex Gomont, 1892	
Choanoflagellatea	*Caliacantha natans (Grøntved) Leadbeater, 1978*	√
Nephroselmidophyceae	*Nephroselmis astigmatica Inouye & Pienaar, 1984*	√
	Nephroselmis pyriformis (N.Carter) Ettl, 1982	√
Prasinophyceae	*Pachysphaera sp. Ostenfeld, 1899*	√

The algal flora of **Georgian (GE) Black Sea coastal waters** was represented by 6 main classes of phytoplankton – Bacillariophyceae, Dinophyceae, Chlorophyceae, Cyanophyceae, Chrysophyceae, Euglenoidea with more than 250 species, out of which 102 species of Diatoms and 96 species of dinoflagellates, Chlorophyceae – 24 species, Cyanophyceae – 22 species Chrysophyceae and Xantophyceae were represented by relatively low diversity (15 and 6 species) (Fig. 1.3.2.2b).

The species composition increased almost twice between 2008 and 2014, mainly on the account of diatoms. If in 2008 only 18 species were recorded, in 2014 the species identified were 45. The number of dinophytes increased from 13 to 25 species, while Chlorophyceae and Cyanophyceae species richness fluctuated insignificantly. Several species of Xantophyta were periodically detected (Fig.1.3.2.3).

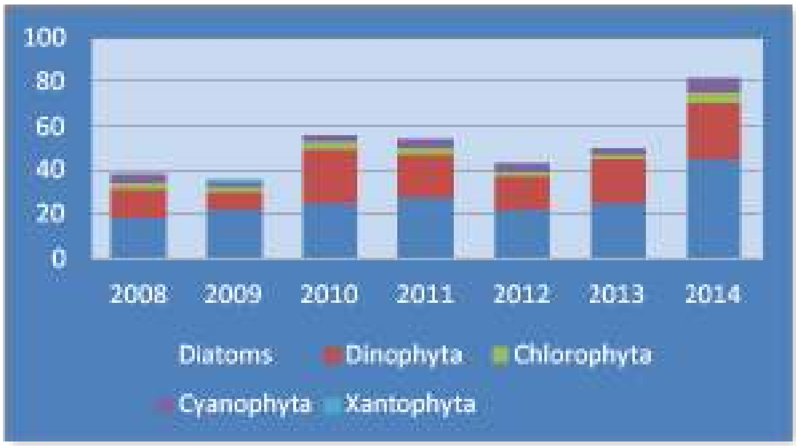


Figure 1.3.2.3. Number of phytoplankton species by taxonomic classes for the period 2008-2014 in Georgian coastal waters

Bacillariophyceae and Dinophyceae, central to the community taxonomic structure were represented by the following dominant and sub-dominant species: *Sceletonema costatum, Thalassionema nitzschioides, Chaetoceros sp., Tripos furca, Ceratium fusus, Prorocentrum micans* etc. An increasd number of *Chlorophyceae* and *Cyanophyceae* with the most frequent species *Anabaena flos-aquae, Microcystis aeruginosa, Merismopedia punctata* occurred in some locations during the warm months (Batumi, Poti and river Sufsa) associated to point sources of eutrophication.

In the **Romanian (RO) marine waters** 348 species, varieties and forms of microalgae were identified in the phytoplankton composition, belonging to fourteen classes (Fig. 1.3.2c). The highest diversity was found in spring in transitional waters (259 species) and the lowest diversity in open waters.

Diatoms remained the best represented group (with 37.4% of all species), followed by dinoflagellates with 25%, Chlorophyceae (13.8%) and Cyanophyceae (10.1%). The remaining classes (Chrysophyceae, Cryptophyceae, Prymnesiophyceae, Dictyochophyceae, Ebriophyceae, Euglenoidea, Prasinophyceae, Trebouxiophyceae, Xanthophyceae, Zygnematophyceae) account for only 13.8% of the total.

The number of diatoms building the community had a relatively small oscillation between years and also between coastal, transitional and shelf habitats. The largest number of diatoms, 118, was found in spring, in transitional waters under the influence of fresh waters of the Danube. Freshwater species brought by the Danube usualy develop in waters of low salinity (up to 2-3 $^{0}/_{00}$) together with the local marine species. The most diverse genus was Chaetoceros with 25 species and 3 varieties (out of a total of 40 species and 8 varieties, that were found in the entire Black Sea basin (Sorokin, 2002). The highest frequency of occurrence had *Chaetoceros socialis, Ch. curvisetus, Ch. affinis, Ch. similis* var. *solitarius*, some of them often producing blooms in summer, from June to September. A genus almost as rich in species as Chaetoceros was Nitzschia respectively Pseudo-nitzschia, with 15 species, the most common being *N. tenuirostris, Pseudo-nitzschia delicatissima, Pseudo-nitzschia seriata*. Melosira and Navicula genus (each with 2 and 8 species) are mostly freshwater, growing particularly in the waters influenced by the Danube. Thallassiosira genus was represented by 8 species and one variety and the most common (21.4%) - *Thalassiosira parva*. With two of its species – *Skeletonema costatum* and *Sk. subsalina*, Skeletonema genus was less important for diversity, but is the most common genus, present in all habitats, with major growth in spring and autumn.

Dinoflagellates were the second important group of planktonic algae for diversity and abundance, contributing with a number of species between 37 in 2009 and 63 in 2013. This group surpasses the number of diatoms and often their abundances and played a more important role in summer when the temperature and photosynthetically active radiation (PAR) values were higher.

The key genera were Protoperidinium (16), Peridinium (4 species), Glenodinium (2 species) and Gonyaulax (5 species), Gymnodinium (8 species), Dinophysis (7 species), Prorocentrum (4 species); Amphidium, Neoceratium, Phallacroma were represented by 2-3 species. Widespread were species of over 50µm, such as *Tripos fusus*, *Ceratium tripos*, *Tripos furca, Protoperidinium depressum* etc., but most were microalgae, with average size of 20-40µm, or nanoalgae of 5- 20µm. The most common microalgae were *Protoperidinium granii, Prorocentrum micans, Gonyaulax ceratocoroides*, *G. polygramma* and among nanodinoflagellates - *Prorocentrum cordatum, Scripsiella trochoidea* and species of the genera Glenodinium and Gymnodinium.

Although dinoflagellates prefer warm waters typical in summer,some species of the genera Tripos, Protoperidinium, Prorocentrum grow all year-round.

The class Chlorophyceae ranked third with a total of 48 species, but on yearly basis the number was much lower, between 16 and 35 species; the highest frequency of occurrence had Desmodesmus, Scenedesmus, Monoraphidium and Tetrastrum genera.

Among the most important species from Prymnesiophyceae was the coccolithophore *Emiliania huxleyi*, from Dictyochophyceae - *Dictyocha speculum*, from Ebriophyceae - *Ebria tripartita* and from Cryptophyceae - *Hillea fusiformis*.

In Russian waters 188 species and varieties of plankton algae belonging to 8 systematic groups were identified in the phytoplankton (Fig. 1.3.2.2e). Diatoms were the richest by number of genera (38) and species (83 species; 44% of the total number of species). Genus Chaetoceros (17 species) was the most diverse, followed by genus Coscinodiscus (5) and Pseudo-nitzschia (5), genus Thalassiosira was represented by four species. Three species were identified from each of the following genera: Achnanthes, Bacteriastrum, Cyclotella, Licmophora, Navicula, Nitzschia and Pleurosigma. Two species were determined in genera Leptocylindrus, Thalassionema and Melosira. Other genera Amphiprora, Aulacosiera, Cerataulina, Cylindrotheca, Dactyliosolen, Detonula, Ditylum, Fragilaria, Gomphonema, Grammatophora, Guinardia, Gyrosigma, Hemiaulus, Paralia, Pinullaria, Planktoniella, Proboscia, Pseudosolenia, Skeletonema, Synedra were represented by one species. The share of littoral-benthic species in phytoplankton was relatively high (17 genera, 38 % of all genera; 23 species, 28% of all diatoms) confined to the coastal habitat.

Dinoflagellates were second rich by number of genera (28) and species (78 species; 42% of the total number of species), highest species richness observed in genus Protoperidinium (17 species), genus Dinophysis (7) and Prorocentrum (7). Genera Amphidinium, Gonyaulax, Gymnodinium and Gyrodinium were represented by 5 species, genus Alexandrium by 3 species; genera Cochlodinium, Ceratium, Heterocapsa and Oxytoxum - by two species. Other genera Akashiwo, Diplopsalis, Glenodinium, Katodinium, Lingulodinium, Noctiluca, Oxyrrhis, Peridinium, Phalacroma, Polykricos, Protoceratium, Pyrophacus, Scrippsiella, Spatulodinium, Torodinium, Tripos were represented by one species. Dinoflagellates in the area were composed of predominantly marine pelagic species, with exclusion of the limnetic *Peridinium latum* and littoral *Prorocentrum lima*.

The other phylla were less diverse: coccolithophores (6 species), cyanophytes (7), Ochrophyta (Dictyochophyceae - 5, Chrysophyceae - 2), euglenophytes (4), cryptomonades (2) and 1 species of green algae.

In general, according to taxonomic composition, ecological and bio-geographic features phytoplankton of the north-eastern shelf belonged to typical marine plankton communities with a low presence of brackish assemblages.

The data allowed to identify assembly of dominant phytoplankton species typical for the different months of the year cycle. In March-April the phytoplankton biomass was formed by dinoflagellate *Scrippsiella trochoidea* and small-celled diatoms *Pseudo-nitzschia delicatissima* complex and *Chaetoceros curvisetus.* In late spring/early summer in May-June the dominant species was *Emiliania huxleyi,* with sub-dominant diatoms *Pseudo-nitzschia delicatissima* complex, *Chaetoceros curvisetus, Proboscia alata* and dinoflagellates *Scrippsiella trochoidea and Akashiwo sanguenea.* The invasive species *Chaetoceros throndsenii* and *Chaetoceros minimus* were recorded in May–June, i.e. during the period of the coccolithophore dominance. In summer, in July–August the phytoplankton biomass was composed of large-celled diatoms *Proboscia alata* and *Pseudosolenia calcar-avis,* dinoflagellates *Prorocentrum micans* and *Prorocentrum cordatum.* In September, the same diatoms *Proboscia alata* and *Pseudosolenia calcar-avis* were dominant with addition of the large-celled dinoflagellates from genera *Tripos* and *Ceratium* as well as coccolithophore *Emiliania huxleyi.*

In **Ukrainian waters** 527 species of algae have been identified in the phytoplankton of the **Odessa coast**, Bacillariophyceae similar to Romanian and Russian waters of the highest contribution to species diversity, followed by dinoflagellates (Fig. 1.3.2.2f). A specific feature was the high species richness among Chlorophyceae and Cyanophyceae due to the high presence of freshwater species while *Aphanocapsa salina*, *Aphanothece salina*, *Dolichospermum affine*, *Anabaenopsis elenkinii*, *A. seriata*, *Pseudanabaena limnetica*, *Oscillatoria limosa*, *Microcystis wesenbergii* and *Planktothrix sp.* - found for the first time in the Black Sea (Terenko, Nesterova, 2015). In **Zmiiny island** alone 319 phytoplankton species were identified from 11 taxonomic classes (Fig 1.3.2.2d). The increased importance of Dinophyceae species in phytoplankton composition was related to the appearance of typically marine species, including the newly identified Harmful species (HS), such as *Azadinium spinosum* Elb. et Till. and *Dinophysis fortii* Pavillard, 1923 *Prorocentrum scutellum* Schr., 25% of new species appeared in the Zmiinyi Island area, which had not been registered there before, including harmful species (Dereziuk et al., 2015).

In the **Turkish waters** species belonging to eleven classes have been recorded (Fig. 1.3.2.2g). A total of 204 species was determined in which Bacillariophyceae was represented by 41 genus and 84 species; Dinophycaeae by 24 genera and 102 species; Chlorophyceae by 2 genus and 2 species, Cyanophyceae by 6 genera and 6 species, Dictyochophyceae by 2 genera and 3 species; Euglenoidea by 2 genera and 2 species and the other classess by 1 genus and 1 species. From the total number of species, 50% was represented by dinoflagellates, 41% by diatoms and the remaining 9% by the other classes.

1.2.1.1- 4. Seasonal trends in phytoplankton abundance and biomass

The distribution of phytoplankton abundance and biomass in the **Bulgarian pelagic habitats** was featured by a very high spatial heterogeneity in all seasons and very high intra-seasonal, intra-annual and inter-annual variability (Fig. 1.3.2.4). On the one hand this could be associated with the spatial and temporal disparity of data (irregular monthly sampling) and on the other hand with the heterogeneity of the year specific environmental conditions as a main driver of phytoplankton assembly taxonomic composition. A decrease of both phytoplankton abundance and biomass along the coastal-open sea pelagic habitats was a common patern of spatial distribution with a tendency of higher total abundance relative to the total biomass (Fig. 1.3.2.4, Fig. 1.3.2.32) and a decline on long-term bases both of the abundance and biomass after 2000 (Moncheva et al., 2012, Moncheva et al., 2014, Mavrodieva et al., 2017).

The spring intra-annual variations of total phytoplankton abundance was highest in the coastal waters ranging between 1-3x10^6 cells/l, between 0.5 – 1.3x 10^6 cells/l in the shelf, and between 0.15-0.5 x 10^6 cells/l in the open sea. The average spring density for the entire period in the coastal and shelf waters were slightly higher than the proposed GES thresholds (Fig. 1.3.2.3, Table 1.3.2.4). The summer abundance mirrored the spring trends with the exception of the very coastal waters (CO-WFD) where the average was in the range of the GES threshold but with a high variability (high standard deviation) (Fig. 1.3.2.4, Table 1.3.2.4a).

The common pattern of total biomass manifested in all habitats both in spring and summer was a decreasing trend (exception the 1.n.m. coastal zone) and similar to the abundance the averages for the period remain within the GES thresholds (with high standard deviation) (Fig. 1.3.2.5, Table 1.3.2.4a).

Typical for the Black Sea seasonal phytoplankton dynamic the summer abundance and biomass in average were about 2 times lower that the spring averages. However, cases of high values exceeding GES threshold were observed in all habitats - in the coastal waters (max density 6-9 x10^6 cells/l in spring and between 2.4-4x10^6 cells/l in summer) and in range 1-2x10^6 cells/l in the shelf. High spring abundance measured in 2012 in all habitats was associated to the large basin scale bloom of coccolithophore *Emiliania huxleyi* and *Pseudonitzschia delicatissima* in some coastal water bodies (WFD).

Table 1.3.2.4. Basic statistic of phytoplankton abundance and biomass (2008-2014)

a) Bulgarian waters

		Spring		
N, 10^3 cells/l	**CO-WFD**	**CO**	**SH**	**O**
Average	1240.4	1687.0	955.9	401.2
Stdev	835.8	1270.1	559.8	712.3
Max	6648.9	9343.3	2569.1	3291.5
Median	1130.8	1580.7	846.8	161.1
B, mg/m^3	**CO-WFD**	**CO**	**SH**	**O**
Average	561.82	1358.50	435.94	144.98
Stdev	470.99	556.63	376.58	132.56
Max	3605.13	2443.26	1723.53	521.81
Median	452.03	1392.65	283.21	115.41
		Summer		
N,10^3cells/l	**CO-WFD**	**CO**	**SH**	**O**
Average	755.1	936.5	564.5	340.7
Stdev	682.3	778.1	286.6	286.1
Max	4020.1	2414.3	1446.6	597.4
Median	649.6	583.3	578.1	343.9
B, mg/m^3	**CO-WFD**	**CO**	**SH**	**O**
Average	379.72	594.31	270.97	176.07
Stdev	251.34	505.25	155.38	85.05

Max	1185.12	2050.14	839.30	386.62
Median	337.29	332.87	216.40	173.85

b) Georgian waters

N, 10^3 cells/l	**winter**	**spring**	**summer**	**autumn**
Min	394.6	932.8	812.5	477.3
Max	5770.5	11273.3	11933.3	12023.3
Average	2437.7	5695.2	3286.0	4301.9
Stdev	2068.5	5301.9	4343.4	4352.7

c)Romanian waters

Month	**II**	**III**	**IV**	**V**	**VII**	**VIII**	**IX**	**X**	**XI**
Density (10^3 cells/l)									
Min	119.4	45.7	6.7	165.4	10	21	108.1	81.8	169.7
Max	2439.9	19635.6	15412.1	16624.2	1984.8	1115.1	5336.8	1751.2	1284
Average	741.7	4768.6	1292.4	2909.6	325.3	218.8	1035.2	390.5	582.4
Median	483.5	3474.9	135.5	1914.8	188.1	132.9	585.5	234.8	293.4
Stdev	854.9	4721.4	3378.8	2964.2	401.8	246.1	1179.1	389.3	610.8
Biomass (mg/m^3)									
Min	320	70	10	130	10	140	180	170	810
Max	1810	6010	5400	9190	9750	3460	9290	1870	4940
Average	760	1560	530	1980	1140	1000	1450	650	2480
Median	540	1170	140	1470	660	690	650	460	1690
Stdev	550	1430	1160	1660	1600	860	2080	470	2180

d)Russian waters (N & B without nanoflagellates 2-4 µm)

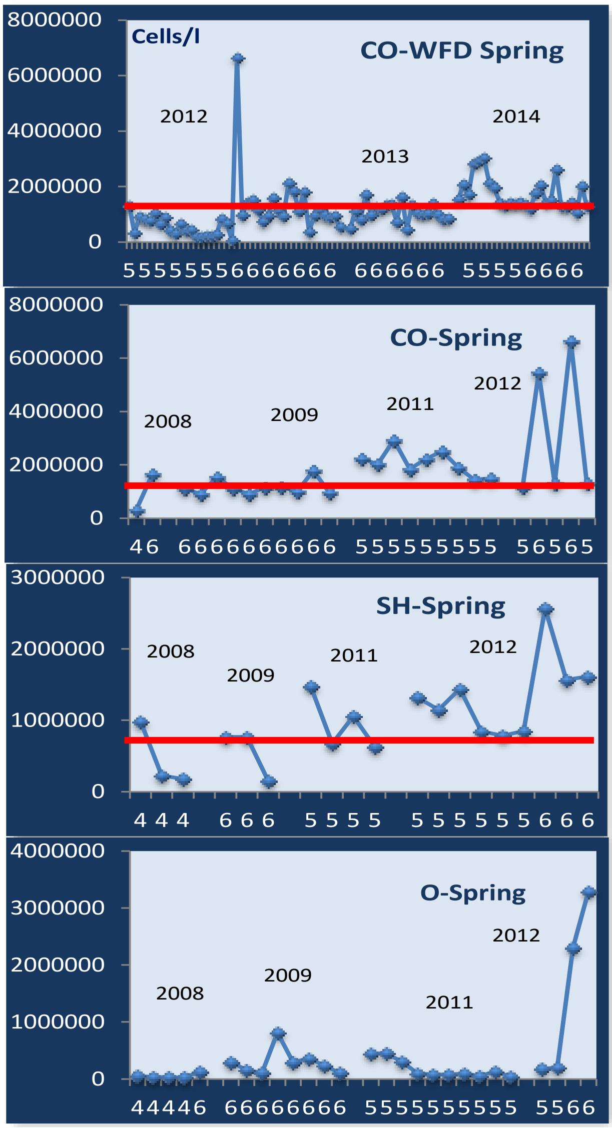
Month	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
N,10^3cells/l								
Mean	229.2	718.8	2654.3	1201.2	1975.0	605.3	513.0	108.9
Stdev	296.2	933.4	3396.2	735.6	1190.1	339.3	651.7	32.8
Max	757.9	4222.8	9756.4	3140.7	2808.9	1214.0	2895.8	143.4
Median	113.1	515.7	793.0	1282.5	2407.6	472.8	259.1	113.8
B, mg/m^3 (N and B – average for either the upper 50-m water column or the layer above the sea bottom)								
Mean	97	182	396	556	409	374	289	16
Stdev	90	204	577	919	433	470	459	13
Max	217	688	1639	3568	1032	1325	1826	33
Median	61	79	105	203	288	103	61	13

e) Ukrainian waters (Odessa region)

	spring	summer	autumn	winter
N, 10^3cells/l	**CO**	**CO**	**CO**	**CO**
Average	1537	973	144	435
Stdev	5928	3469	285	675
Max	51405	16138	1986	3778
Median	122	42	55	156
B, mg/m^3	**CO**	**CO**	**CO**	**CO**
Average	506	6466	321	680
Stdev	690	27073	467	1953
Max	3950	126750	2762	11826
Median	228	238	205	182

f) Ukrainian waters (Zmiiniy island)

N, 10^3 cells/l	spring	summer	autumn	winter
Average	8469	1686	1807	23542
Stdev	10101	1274	1726	31011
Max	46685	4959	7611	67929
Median	4029	1376	1573	5030
B, mg/m3	**spring**	**summer**	**autumn**	**winter**
Average	5886	2100	2509	4115
Stdev	5497	2049	4092	5440
Max	21406	10228	19118	12408
Median	4319	1459	1153	930



Cells/l
CO-WFD Spring
8000000
6000000
4000000
2000000
0
2012
2013
2014
5555555666666 666666 55556666
CO-Spring
8000000
6000000
4000000
2000000
0
2008
2009
2011
2012
46 6666666666 555555555 56565
SH-Spring
3000000
2000000
1000000
0
2008
2009
2011
2012
4 4 4 6 6 6 5 5 5 5 5 5 5 5 5 5 6 6 6
O-Spring
4000000
3000000
2000000
1000000
0
2008
2009
2011
2012
44446 66666666 5555555555 5566

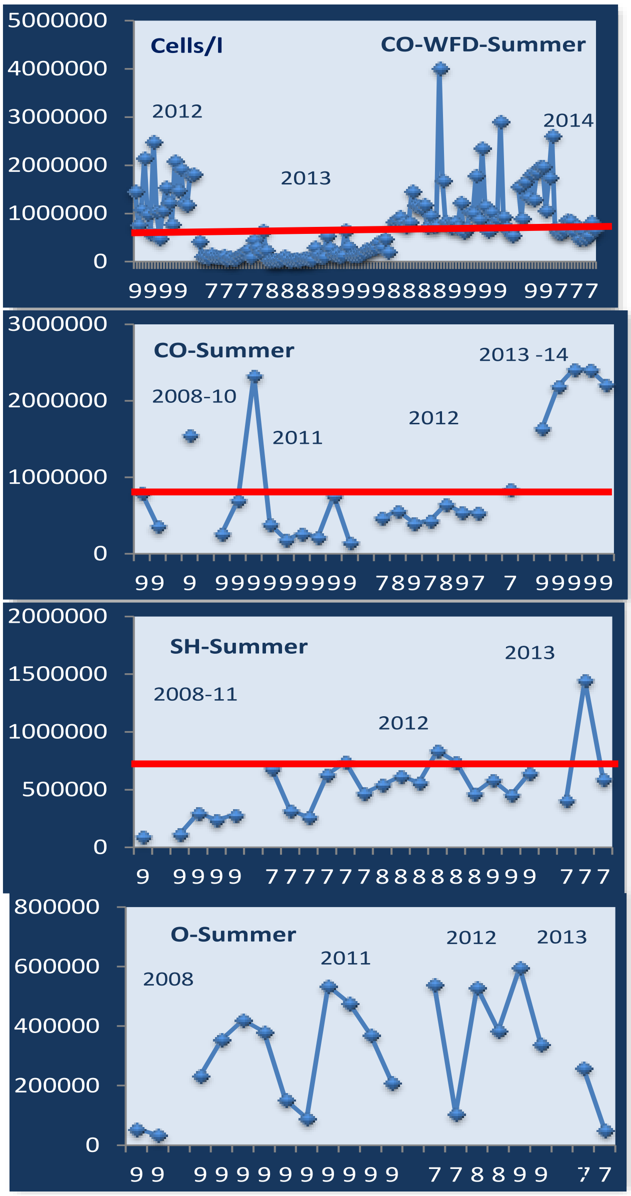


Figure 1.3.2.4. Trends in phytoplankton Total Abundance (cells/l) during 2008-2014 in spring and summer by habitats (BG-Bulgaria); CO-WFD – 1n.m. coastal, CO-coastal, SH-shelf, O-open sea; on the x axes are given the months of sampling

Cases of maximum biomass – in the range 2.4-3.6 g/m^3 in the coastal waters in spring and 1.0-2.0 g/m^3 in summer were also registered, but both the highs of abundance and biomass were an order of magnitude lower than the ones recorded during the high eutrophication phase of the ecosystem (Moncheva et al, 2001, Moncheva et al., 2012).

Higher abundances relative to low biomasses, emerging as a general trend in the current period was associated to an increase of the small-size species fraction in the community and structural reorganization (Moncheva et al, 2012, 2013, 2014). The latter could well be a response to the progressive climatic changes, increase in temperature and alterations in the intensity of hydrological processes in the Black Sea (Kubryakov et al., 2016) in synergy to the relative reduction of anthropogenic pressure from land based sources – both the Danube nutrients input that impact substantially BG shelf habitat along with the recent reconstruction of WWTPs along the Bulgarian coast (National Report, MOEW, 2016).

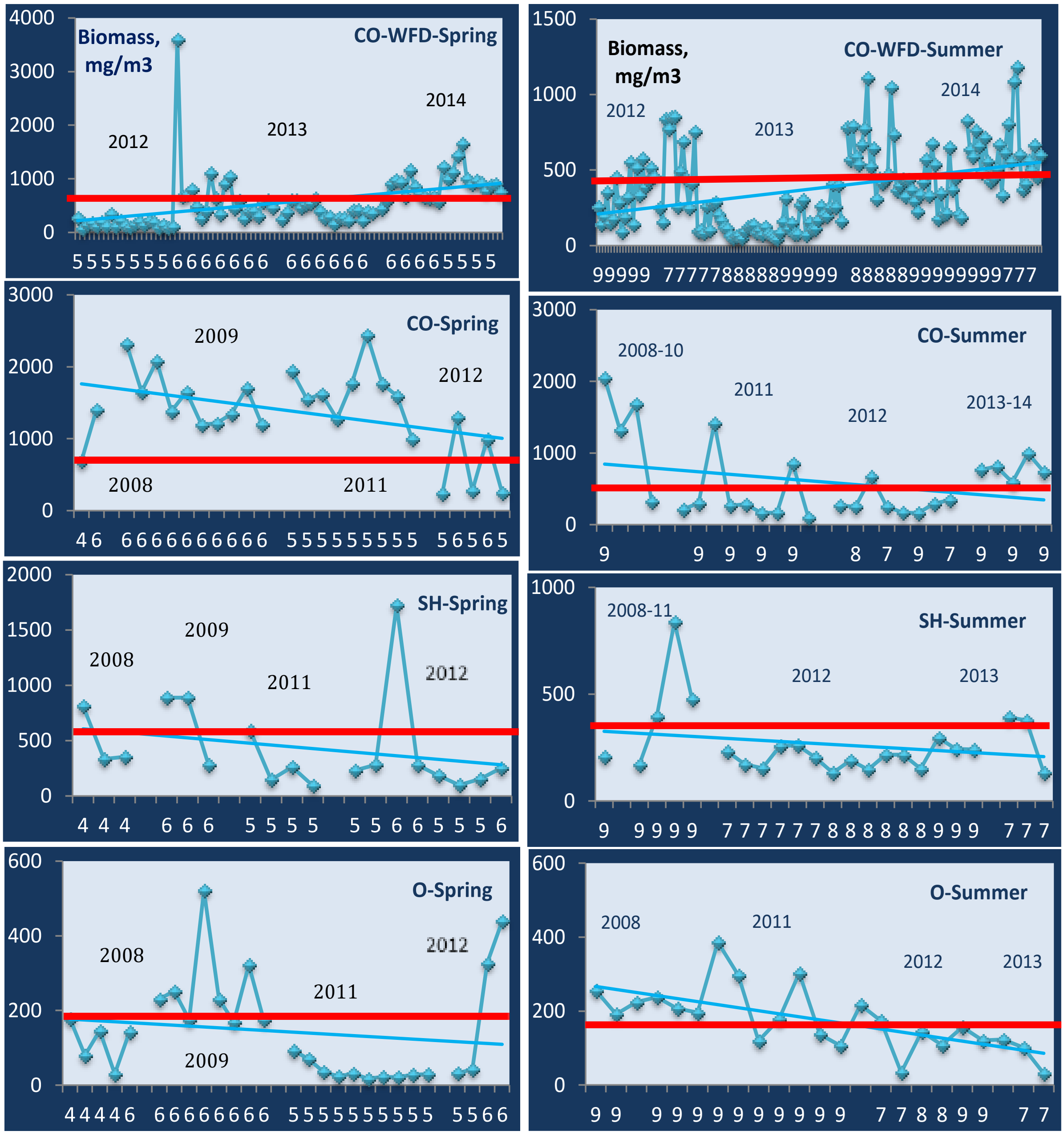


Figure 1.3.2.5. Trends in phytoplankton Total Biomass (mg/m^3) during 2008-2014 in spring and summer by habitats (BG-Bulgaria); CO-WFD – 1n.m. coastal, CO-coastal, SH-shelf, O-open sea; x axis-months of sampling

Literature reviews provide evidence that climate trends could affect phytoplankton abundance (Richardson and Schoeman, 2004), phenology (Edwards and Richardson, 2004) and induce shifts in taxonomic composition (Leterme et al., 2005).

In the **Georgian coastal waters** also a decreasing trend was observed in the total phytoplankton abundance with an average for the period of 3930 x10^{3}cells/l especially pronounced in summer (Fig.1.3.2.6, Table 1.3.2.4).

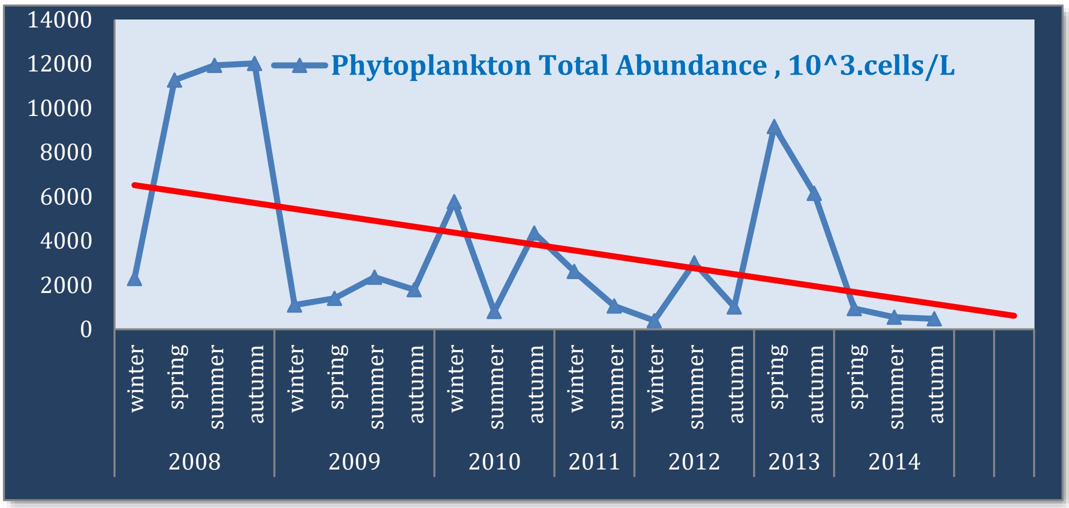


Figure 1.3.2.6. Trends in phytoplankton Total abundance (10^3 cells/l) during 2008-2014 in the Georgian coastal waters

In 2008, the average annual density reached $9382x10^3$cells/l, while in 2014 it averaged an order of magnitude less - $652x10^3$cells/l. The minimum abundance occurred in winter - averaged $394x10^3$cells/l, and the maximum was recorded in autumn – 12.023 $x10^6$cells/l (Table 1.3.2.4b).

In **Romanian water**s regardless of the season phytoplankton distribution and dynamics is influenced by the nutrient input of the Danube, salinity and the direction of transport by currents (Bodeanu, 1966, 1968, 1979). Due to the heterogeneity of environmental conditions on the continental shelf and the existence of strong gradients associated to discharge of the Danube, a division of the Romanian coastline into three areas was considered:

- Northern area or the transitional waters (Sulina profiles stations, Mila 9, St. George, Portiţa) - strongly influenced by the Danube with the lowest salinity (0.38 -17.81PSU); this area covers the 30m isobaths within the one nautical mile from the shore baseline;
- Central and southern area or coastal waters (Gura Buhaz profiles stations, Casino Mamaia, Constanta North, South and East Constanta, South Eforie, Costineşti, Mangalia, Vama Veche) - with salinities ranging from 8.5 to 19.32 PSU;
- continental water area or shelf waters (the area between 30m isobaths and 200m isobath) - salinity values between 9.26 to 19.37 PSU.

The distribution of phytoplankton density and biomass showed a great seasonal variability (Fig.1.3.2.7). Thus, **spring** was the season of the most significant phytoplankton growth, both in coastal waters (up to $13.78x10^6$ cells/l for density and up to 9187 mg/m^3 for biomass), and in transitional waters (up to $19.63x10^6$ cells/l for density and up to 7313 mg/m^3 for biomass). In shelf waters both density and biomass were of lower values, up to $4.46x10^6$ cells/l and 2597 mg/m^3.

During **summer**, although the density did not exceed 1-$2x10^6$ cells/l the biomass in transitional waters was high - up to 9747 mg/m^3, due to the development of large-size diatom - *Cerataulina pelagica* - 7704 mg/m^3), and the dinoflagellates *Preperidinium meunieri* (537.6 mg/m^3) and *Akashiwo sanguinea* (528 mg/m^3).

In **autumn**, phytoplankton reached 4-5x10^6cells/l and 8-9000 mg/m^3 in both coastal waters and transitional waters, values higher than in shelf waters where the peaks were about 581x10^3cells/l and 1390 mg/m^3 (Fig. 1.3.2.7).

Distribution maps of monthly averages of phytoplankton densities (Fig. 1.3.2.8) and biomasses (Fig. 1.3.2.9) in the Romanian coastal waters for the water column showed that they fluctuated signifficantly between months. Thus, in **February** (data limited to 2009 from Constanta and Portiţa profile) the average density of 741.6x10^3 cells/l and biomass - 7.598 g/m^3 were high enough for this winter month. Maximum density of 2.4 x10^6 cells/l (1.8 g/m^3) was reached at Portita, station 2, 30m isobath (Fig. 1.3.2.8).

In **March**, phytoplankton showed maxima of average density and biomass both in waters under the influence of the Danube and to the south. Values over 10x10^6 cells/l were recorded at Sulina, 30m isobath and Constanta (Station 1), 15.7x10^6 cells/l and 10.6x10^6 cells/l. In the remaining stations, average densities ranged between 1.6x10^6 cells/l and 9.1x10^6 cells/l, phytoplankton blooms being common for March phytoplankton community (Fig. 1.3.2.8).

In **April**, in the waters from the central area the communities gradually reduced densities to not exceeding one million cells per liter. Maximum values were recorded at Portița (15.4x10^6 cells/l) (Fig. 1.3.2.8) at Mangalia the average density being 3.74x10^6 cells/l. On the offshore stations of the northern area the higher phytoplankton densities were associated with the influence of the cyclone, which on the Romanian continental shelf was of a north-south direction.

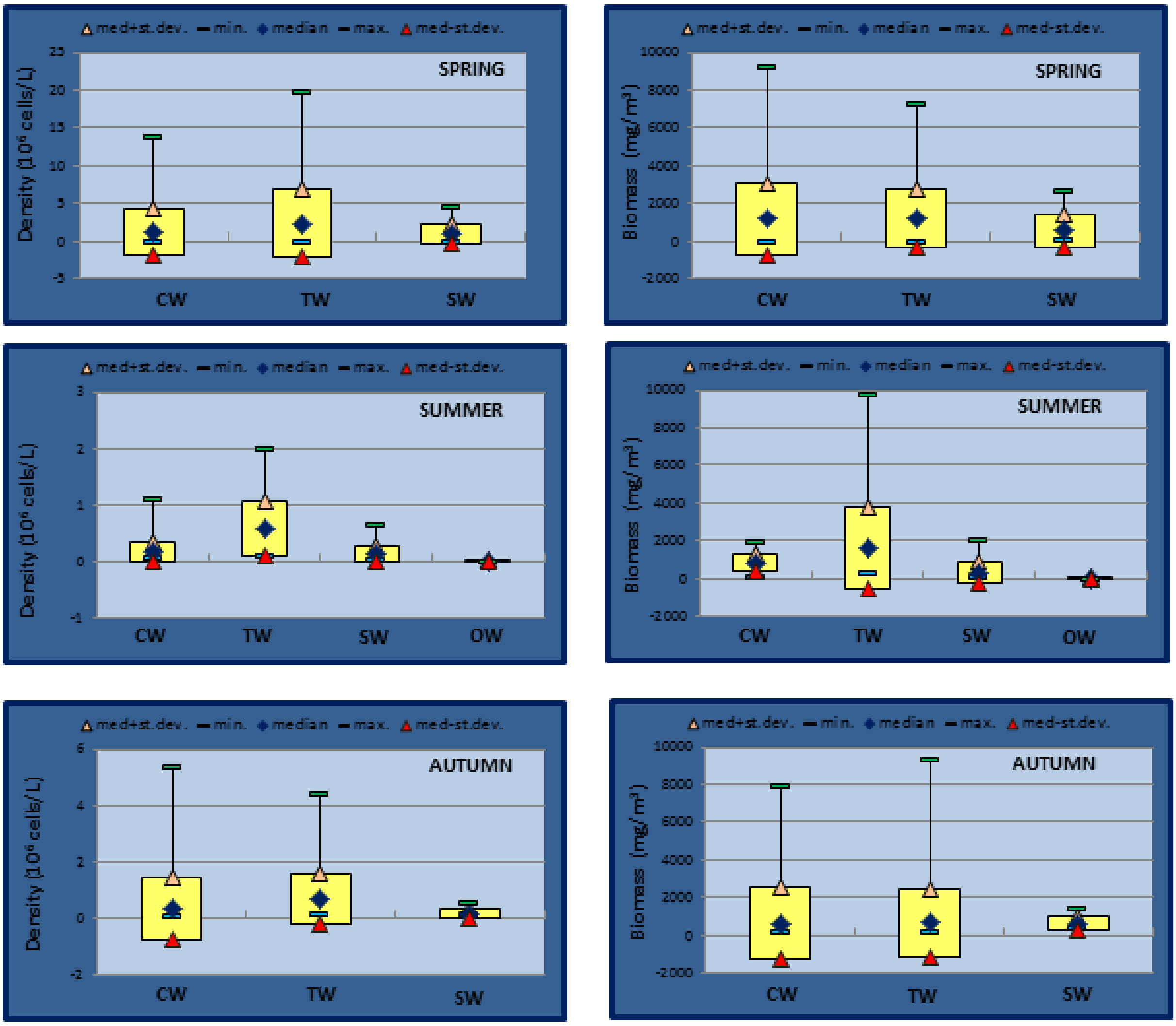


Figure 1.3.2.7. Variation of total phytoplankton abundance (cells/l) and biomass (mg/m^3) by seasons and habitats in the period 2008-2014 in Romanian waters

In **May**, the northern and central coastal waters were characterized by very abundant phytoplankton communities exceeding far those encountered in previous months (density varying between 0.16 and 16.6x10^6 cells/l and biomass between 0.4 and 7.3 g/m^3). Phytoplankton abundance fall below one million cells per liter at Sulina profile, and in the rest of the water the average densities were twice as high compared to the average multiannual for April. Diatom *Pseudo-nitzschia delicatissima* dominated the shelf waters in 2014, the diatom *Cyclotella choctawhatcheeana* (maximum density – 3.18x10^6 cells/l, Portiţa, 30m isobaths) - in 2013 and *Skeletonema costatum* in 2008 (maximum density – 4.23x10^6 cells/l, Mila 9, 30m isobath).

In **July**, phytoplankton populations declined compared to May, the averages ranging between 9.9x10^3 and 1.9x10^6 cells/l and 0.95 and 9.74 g/m^3 distributed more evenly in the central area (Fig. 1.3.2.8, Table 1.3.2.4c). Diatoms *Cerataulina pelagica* (maximum density - 2.15x10^6 cells/l and biomass of 1.4 g/m^3 in 2008) and *Pseudosolenia calcar-avis* (maximum biomass – 1.4 g/m^3 in 2011) together with the dinoflagellate *Scripsiella trochoidea* (maximum biomass – 1.03 g/m^3) dominated the coastal waters.

In **August**, the northern and southern areas of the Romanian coast were featured by modest phytoplankton growth as compared to July (maximum density of 706.4x10^3 cells/l in north and

236.5x10^3 cells/l in the south) (Fig. 1.3.2.8). Although the densities were not high, the biomass recorded (average – 2.3 g/m^3) was mainly due to the dinoflagellates *Prorocentrum micans* (maximum biomass – 10.7 g/m^3), *Akashiwo sanguinea* (maximum biomass – 1.14 g/m^3), *Lingulodinium polyedrum* (maximum biomass – 1.2 g/m^3) and large diatoms *Cerataulina pelagica* (maximum biomass – 0.69 g/m^3) and *Pseudosolenia calcar-avis* (maximum biomass – 1.53 g/m^3) (Fig. 1.3.2.9).

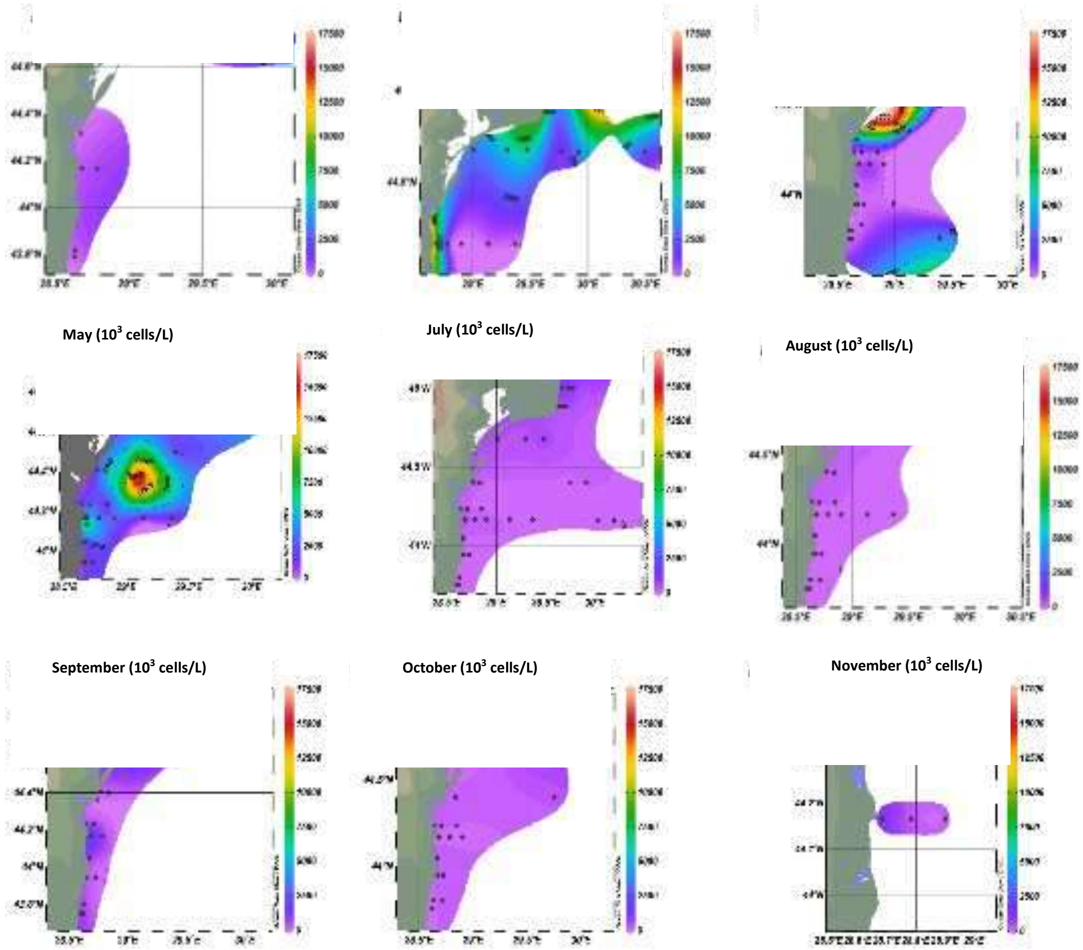


Figure 1.3.2.8. Spatial distribution of mean monthly abundance (10^3 cells/l) of phytoplankton in the waters along the Romanian shore, between 2008 – 2014

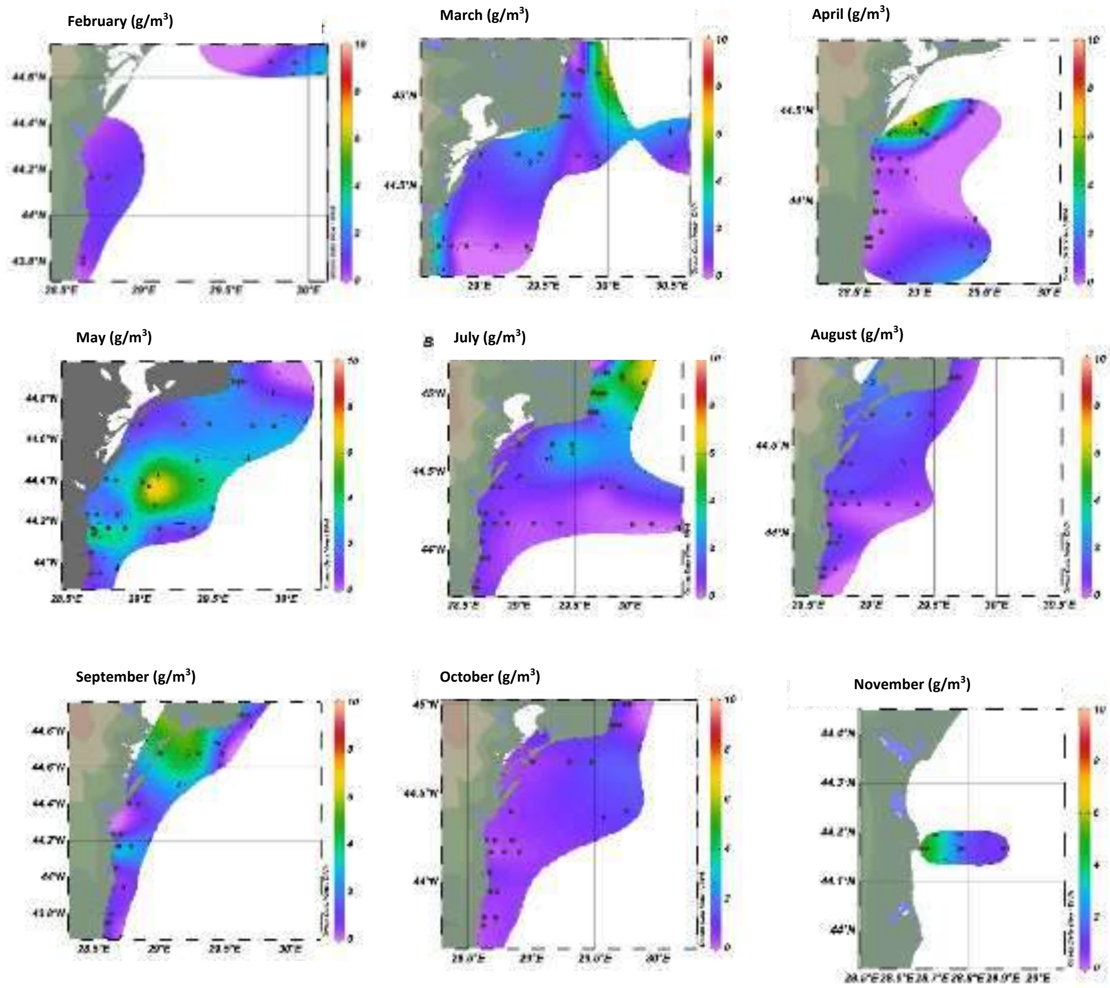


Figure 1.3.2.9. Spatial distribution of mean monthly biomass (g/m^3) of phytoplankton in the waters along the Romanian shore during 2008 – 2014

In **September**, was recorded the second highest phytoplankton development after the one in May, the highest average density observed in the northern area (maximum of 2.79x10^6 cells/l) in the central area, in Constanta (maximum density - 2.47x10^6 cells/l) (Table 1.3.2.4c). Biomass values were approx. 50% lower than in July when were registered the maximum biomasses, mostly because of the diatoms *Chaetoceros affinis* (maximum biomass – 2.7 g/m^3), *Ch. socialis* (maximum biomass – 1.4 g/m^3) and *Proboscia alata* (maximum biomass -2.02 g/m^3) in 2009.

October and **November** were characterized by modest phytoplankton population standing stock (maximum density of 1.7x10^6 cells/l in October and 1.2x10^6 cells/l in November). The October diatoms outcompetitors *Skeletonema costatum*, *Pseudo-nitzschia delicatissima*, *Chaetoeros socialis* and *Aulacoseira italic* were replaced in November by the diatom *Leptocylindrus minimus* and the dinoflagellate *Heterocapsa triquetra*.

In **Russian waters** May-June months were sampled most regularly which allowed to trace the interannual variations during 2008-2014. The mean monthly phytoplankton total abundance changed by a factor of 2.5 from 0.6 to 1.5x10^6 cells/l (Fig. 1.3.2.10). In 2012 the total cell abundance was very high due to the proliferation of coccolithophore *Emiliania huxleyi* and nanoflagellates (2-4 µm). Maximum phytoplankton abundance reached 18x10^6 cells/l. By contrast, the total phytoplankton biomass changed between years in a broader range from 117 to 1748 mg/m^3 (Fig 1.3.2.10). In 2008 and 2009 the biomass highs were formed due to development of diatoms, while in 2012 due to the intensive growth of coccolithophores.

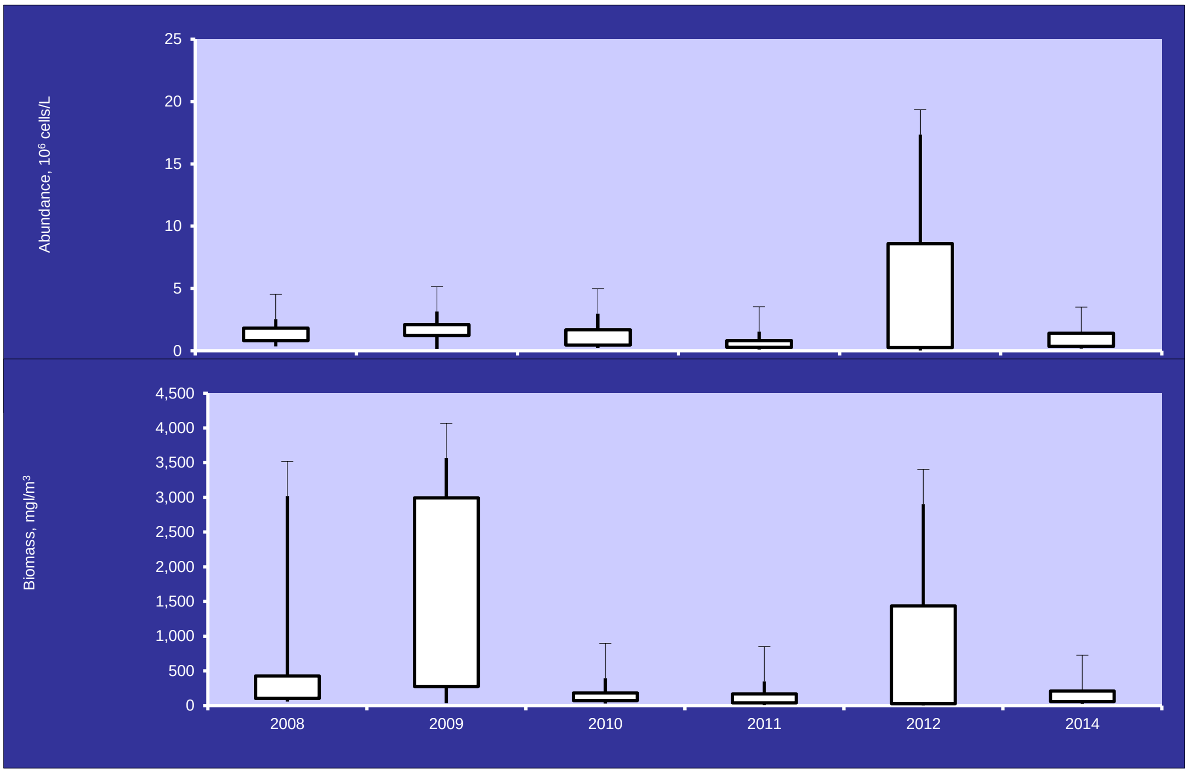


Figure 1.3.2.10. Changes in the monthly mean pytoplankton total abundance (top panel) and biomass (bottom panel) during 2008-2014 in May-June in Russian waters . Minimum, maximum, 25% and 75% percentiles are shown

In the **coastal Ukrainian waters (Odessa area)** the maximum abundance in 2008 was associated with spring algal blooms in (May - June) (Fig. 1.3.2.11). Abnormally high biomass of cyanobacteria determined the maximum summer biomass in 2010 and the maximum summer biomass for he entire period 2008-2013 (Fig. 1.3.2.11).

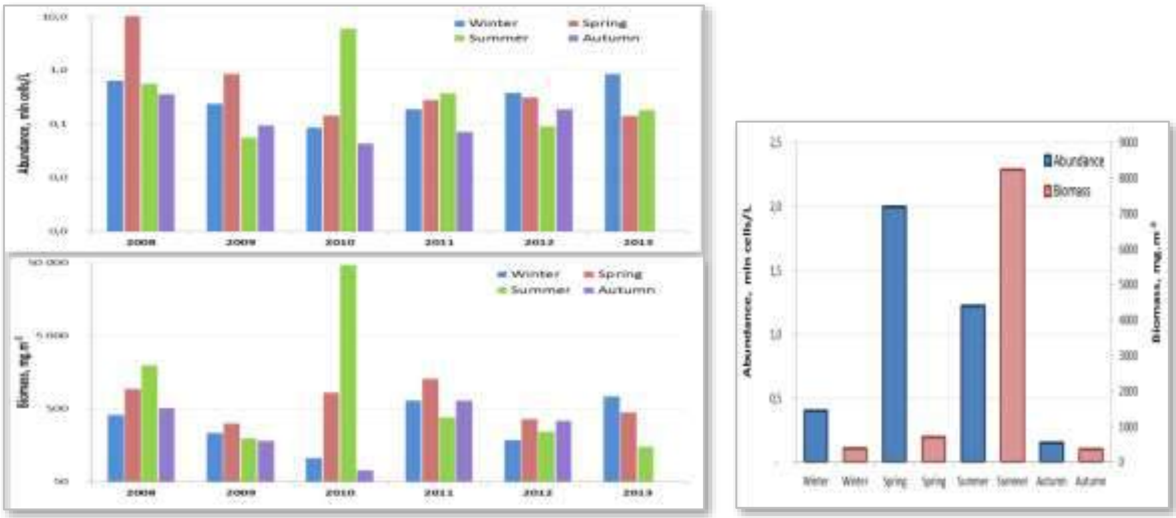


Figure 1.3.2.11. Seasonal variability of phytoplankton abundance (10^6 cells/l) and biomass (mg/m^3) by years (left) and seasonal averages for the entire period (2008-2013) (right) in the Odessa coast

In the waters of **Zmiiniy island** the total abundance of microalgae at the surface ranged between 63x10^3 - 67.93x10^6 cells/l, and at the bottom between 73 x10^3 – 46.7x10^6cells/l, and the total biomass – between 60 - 19120 mg/m^3 and between 59 -21410 mg/m^3 (Fig. 1.3.2.11a). The averaged monthly phytoplankton total abundance and biomass showed a trend towards reduction. The highest abundance was observed in 2008 and 2009 (1.5 higher than the "average value" for 2008-2014).

Marine species constituted the main input in the phytoplankton assembly (212 species, including cosmopolitans), while fresh water species were mainly observed in the upper layers (0-2 m depth) their development controled by hydrodynamic processes. Comparison between the average values for 2008-2014 and the data published earlier (Smyntyna et al., 2008) for 2003-2007 has shown that current values of phytoplankton abundance and biomass varied within the ranges typical for the period 2003-2007.

Over the last years a trend of decrease in Dinophyta average monthly abundance and biomass was observed, while by 2011 the average number of Dinophyceae species exceeded that of the Bacillariophyceae, during 2012-2014 the number of diatoms prevailed.

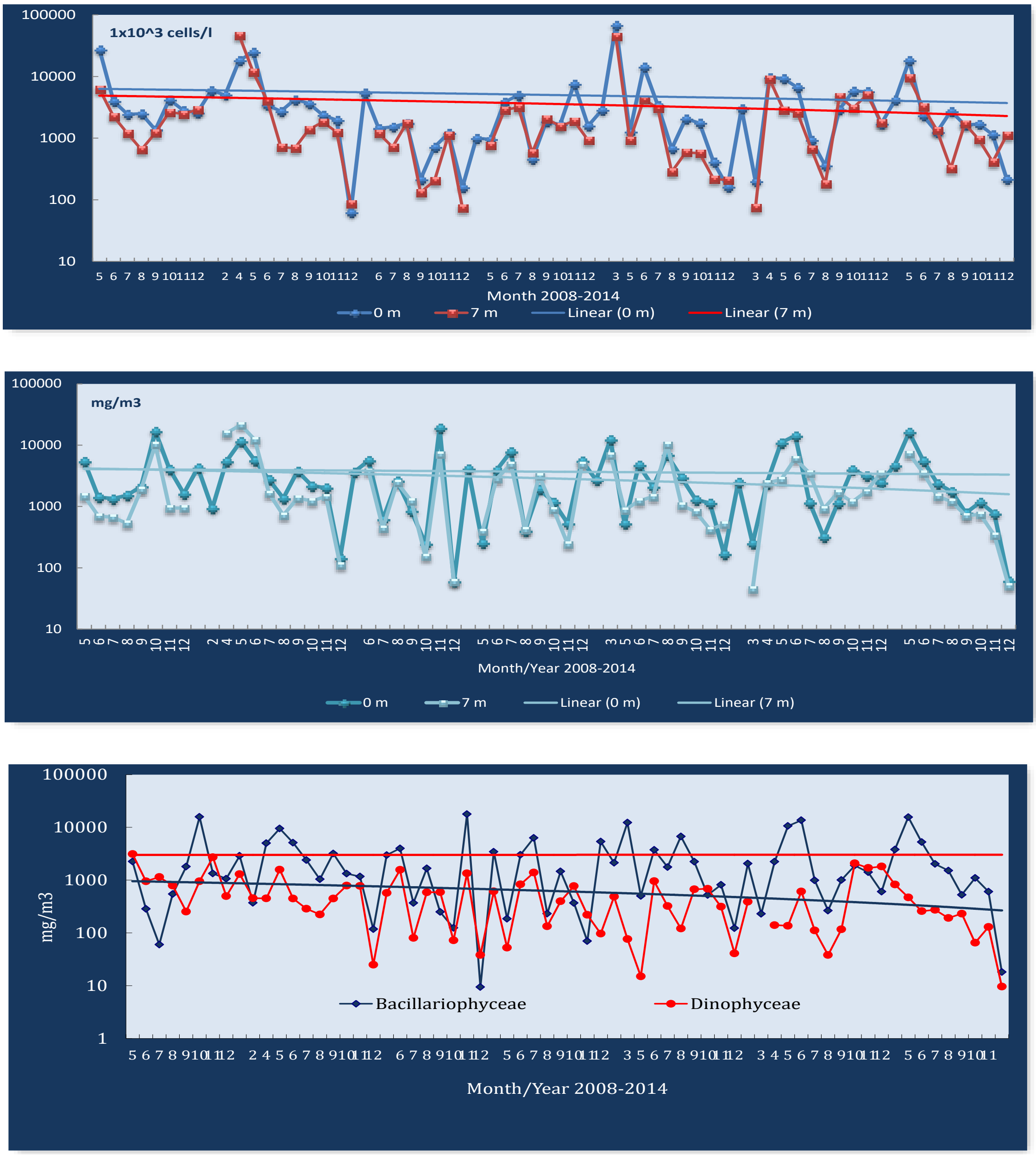


Figure 1.3.2.11a. Variability of phytoplankton monthly abundance (10^3 cells/l) and biomass (mg/m^3) and diatoms and dinoflagellates biomass (mg/m^3) during 2008-2014 in Zmiiniy island

1.2.1.1-5. Seasonal trends in the taxonomic structure by habitats

The lack of synchronized systematic monitoring by pelagic habitats and frequency of sampling adequate to the scale of natural variability of phytoplankton (days to weeks) and the ununiform environmental conditions make it impossible to elucidate concise assessment of phytoplankton seasonal succession and generalize phenology patterns. In addition, the taxonomic identity alone fail to explain a direct cause-effect response to the multiple environmental factors due to the non-linearity of the processes that depend on species specific functional traits (Cloern and Dufford, 2005, Litchman et al. ,2010). There are no species (the occurrence or abundance of which) that can be used as universal indicators and there is no unique fixed assemblage of species each with its own abundance that is representative enough of a given ecological state of the environment, which underline the complexity in definition of robust phytoplankton taxonomic related indicators (Garmendia et al., 2012). Nonetheless even if fragmented the data show particular trends associated to both climatic changes and local environmental conditions.

In **Bulgarian** marine waters the variation of phytoplankton quantitative metrics was associated with a high variability of the community taxonomic structure and a diverse taxonomic profile.

A specific feature of the spring assembly by abundance during 2008-2014 was the recurrent growth of the prymnesiophyte *Emiliania huxleyi* in all pelagic habitats, more apparent in the shelf and open sea domains (Fig. 1.3.2.12). The proportion of *Prymnesiophyceae* in the total spring abundance (in %) varied within the range 11-61% in the coastal waters (40% - 2008, 61%-2009, 53%- 2012 respectively), in the shelf – 43% -in 2011, 53%-2012 and 75%- in 2009 and in the open sea it dominated in 2009 – 82%, 2011-68% and 2012 -86%. Another peculiarity of the spring assembly was the increased share of species form classes “other” including microflagellates (65% in the coastal waters in 2013; 74% in the shelf in 2008 and ~ 50% in 2011 at selected stations).

The proportion of diatoms was in the range 25 - 49% in the coastal area (max in 2012 and 2014), about 18% in the shelf and less than 2% in the open sea with the most frequent outcompetitors from genus Chaetoceros (*Ch. decipiens, Ch. Lorenzianus*), *Pseudo-nitzschia seriata, Ps. delicatissima, Cyclotella choctawhatcheeana*, *Thalassionema nitzschioides.* The proportion of dinoflagellates did not exceed 11-18 % (Fig. 1.3.2.12).

The summer assembly manifested even higher variability. A specific feature was the dominance of species from the classes “other” in all habitats (in the range 42-73% in the coastal habitats and between 27- 53% in the shelf and open waters), a relatively high share of *E.huxleyi* (more apparent in the shelf and open sea domains), and emerging high proportions (between 20-45 % at selected stations) of species from Nephroselmidophyceae (*Nephroselmis pyriformis*), Cryptophyceae (*Hemiselmis* sp.)Prasinophyceae (*Pyramimonas* sp.)(Fig. 1.3.2.12).

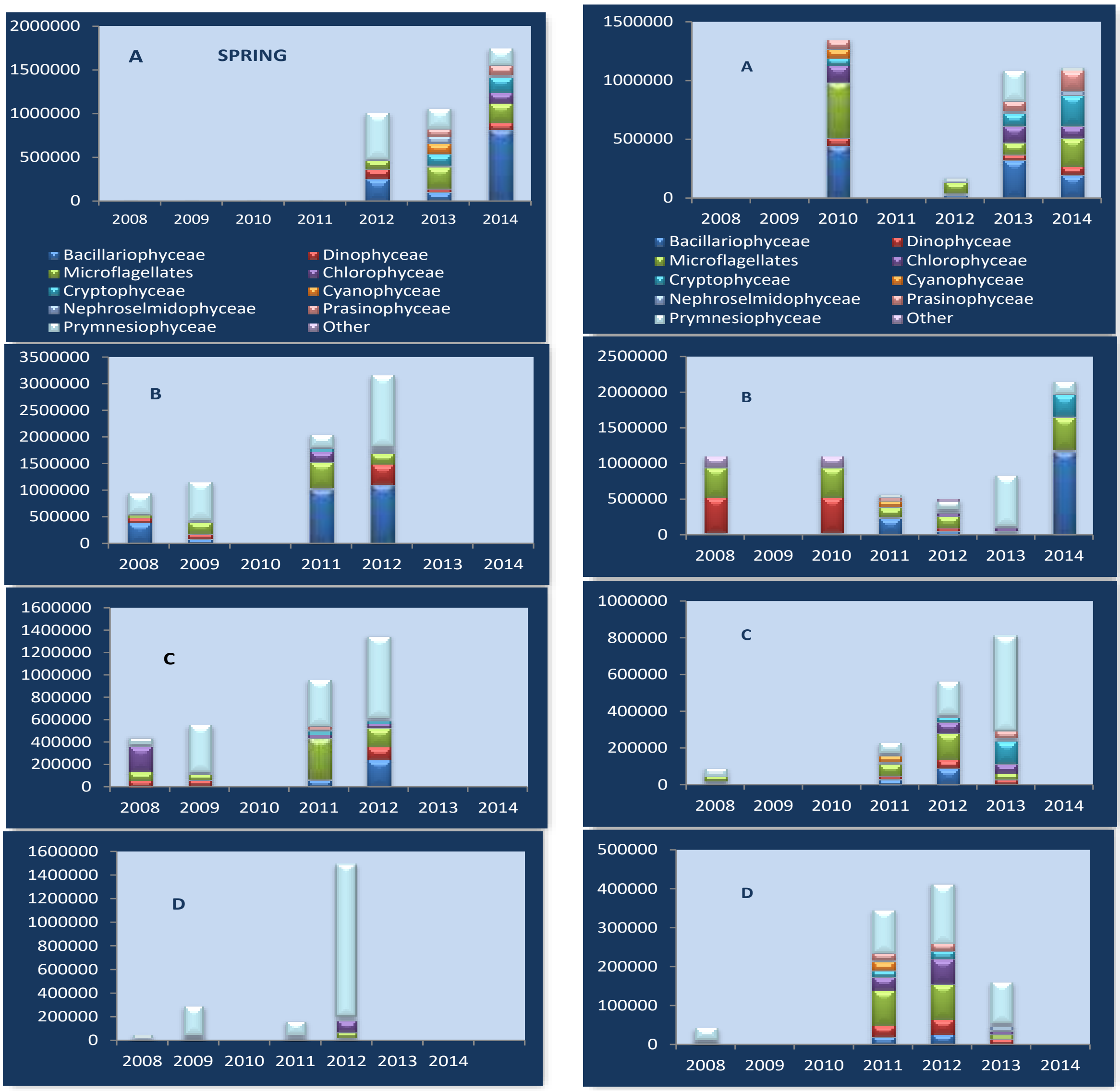


Figure 1.3.2.12. Taxonomic structure by phytoplankton abundance (cells/l) in spring and summer in the coastal (a, b), shelf(c) and open sea habitats (d) in the Bulgarian marine waters

The taxonomic structure by biomass was more homogenious shared mainly between diatoms and dinoflagellates. Dinoflagellates dominated the biomass in all habitats in 2008 (75-89%) in the CO-WFD waters in 2012-2014 (44-65%) in the shelf in 2012 and in the open sea in 2009 with key species *Scrippsiella trochoidea*, *Prorocentrum micans*, *Gonyaulax spinifera* and *Protoperidinium*. The proportion of diatoms was high in 2011-2014 (32-81% in coastal wates), 2009, 2011 in the shelf (43-44%) while in the open sea Prymnesiophyceae contributed between 25-71% (2009, 2011, 2012) concomitant to the abundance (Fig. 1.3.2.13). The typical feature for the period, the relatively high biomass of large-size diatom *Pseudosolenia calcar-avis* in summer was associated most likely to its unpalatability to graizers, that allow the accumulation of this species irrespective of its relatively low species specific growth rate and the efficiency of nutrients uptake under the condition of nutrient injections in the water column (Silkin et al., 2013), but of low effectiveness for the food web. Originally cryptophytes and prasinophytes are fueling the microbial – loop functional mode in the ecosystem, lowering the efficiency of energy transfer that thrives under different from the classical nutrient ratios environment

(Šupraha et al., 2014), which along with the dominance of unpalatable large size diatoms altogether could trigger cascading changes down the food-web (Zingone et al., 2011).

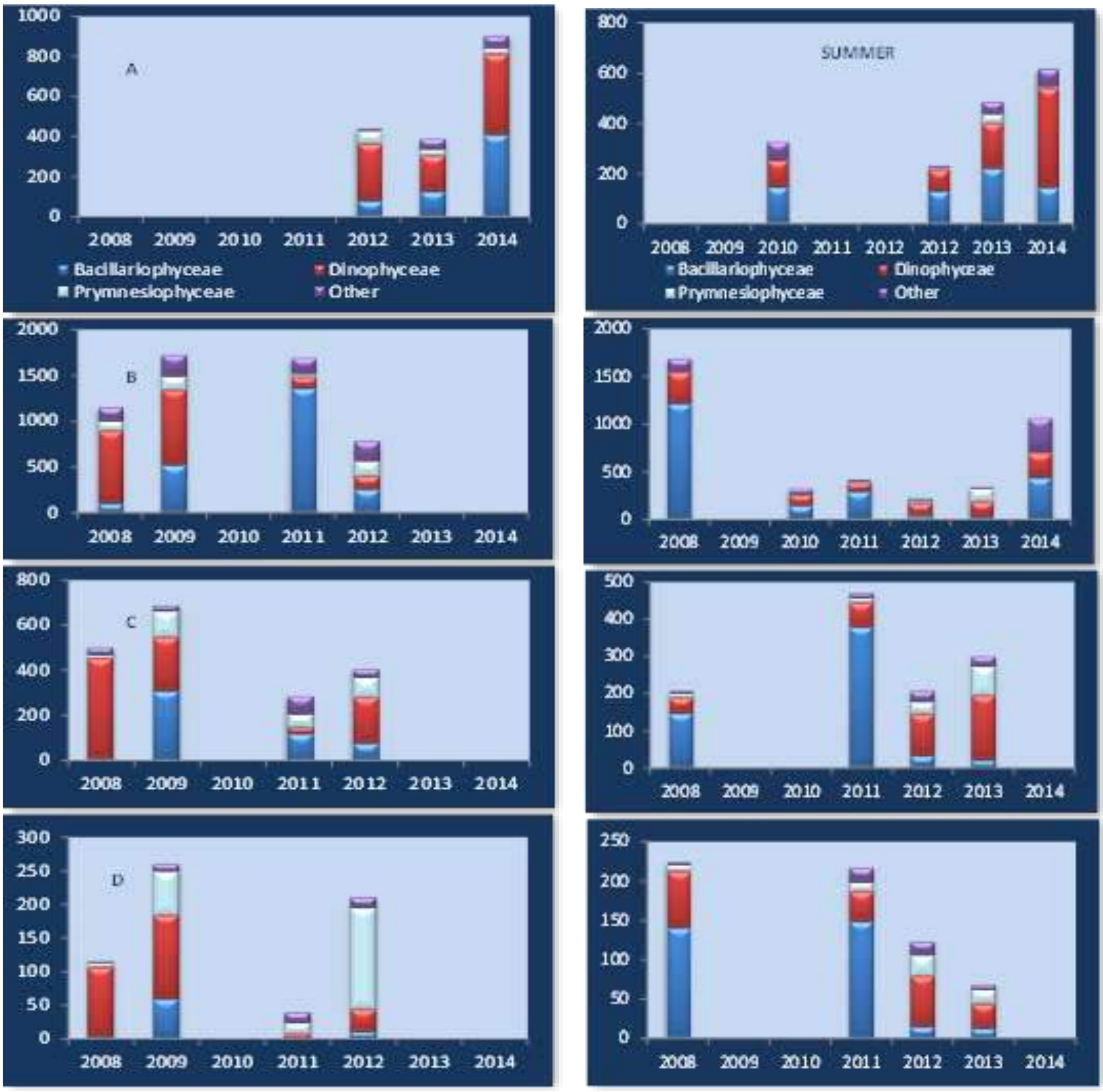


Figure 1.3.2.13. Taxonomic structure by phytoplankton biomass (mg/m^3) in spring (left) and summer (right) in the coastal (a, b), shelf(c) and open sea habitats (d) in the Bulgarian marine waters

On a long-term bases for the period after 1996 both the share of diatoms in the total biomass as well as the biomass ratio diatoms to dinoflagellates (Bac:Din) in spring albeit the increasing trend oscilated at a level much lower relative to the 70-ies (Fig. 1.3.2.14).

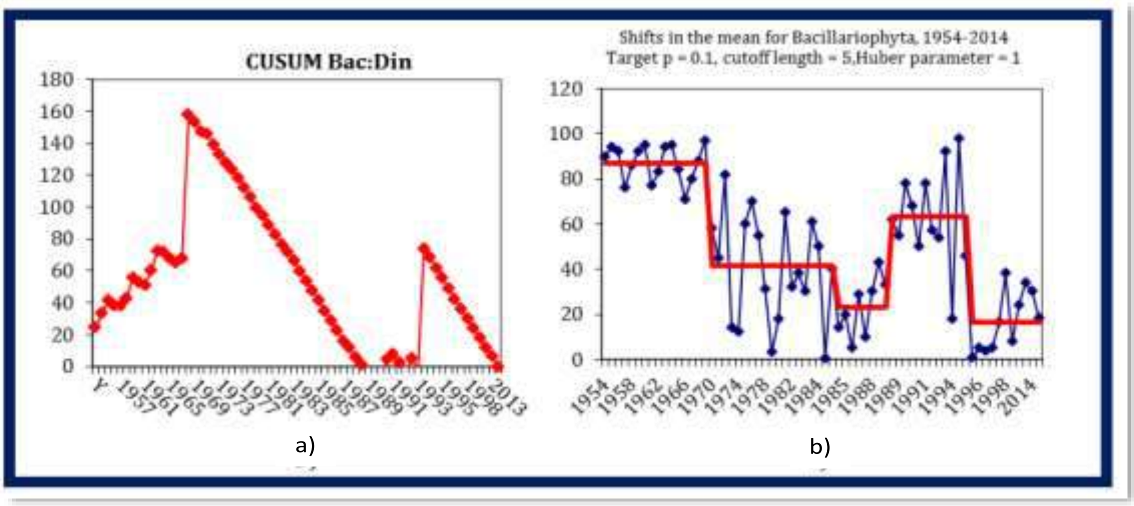


Figure 1.3.2.14. Long- term variation of spring Bac:Din biomass ratio: a) CUSUM curve and b)Regimeshift in the coastal BG waters (Moncheva et al., 2017).

In the **Georgian coastal waters** in 2008 the dominant group in the total density was Bacillariophyceae (~54% of the total abundance). In spring due to active growth diatoms reached density 10.52x10^6cells/l at the station located near the mouth of the Chorokhi River and in summer - 9.2 x10^6 cells/l in the waters of Batumi. The species dominating the community were *Skeletonema costatum*, *Proboscia alata*, *Pseudosolenia calcar- avis*, and a number of species of genus Chaetoceros (Fig. 1.3.2.15).

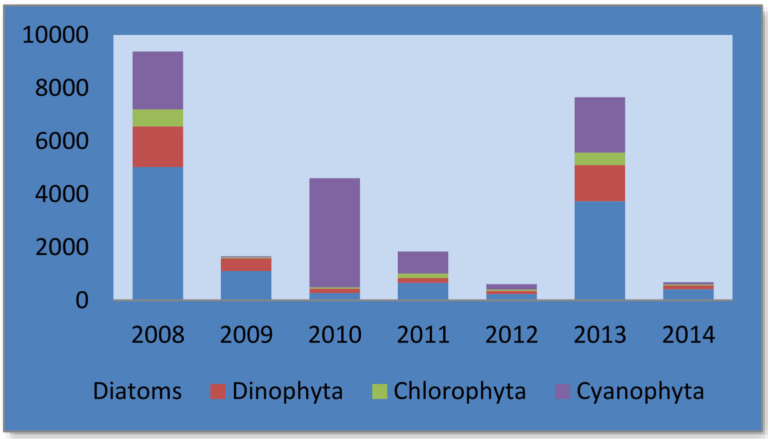


Figure 1.3.2.15. The average annual phytoplankton abundance (10^3cells/l) by taxonomic classes for the period 2008-2014 in the Georgian coastal waters

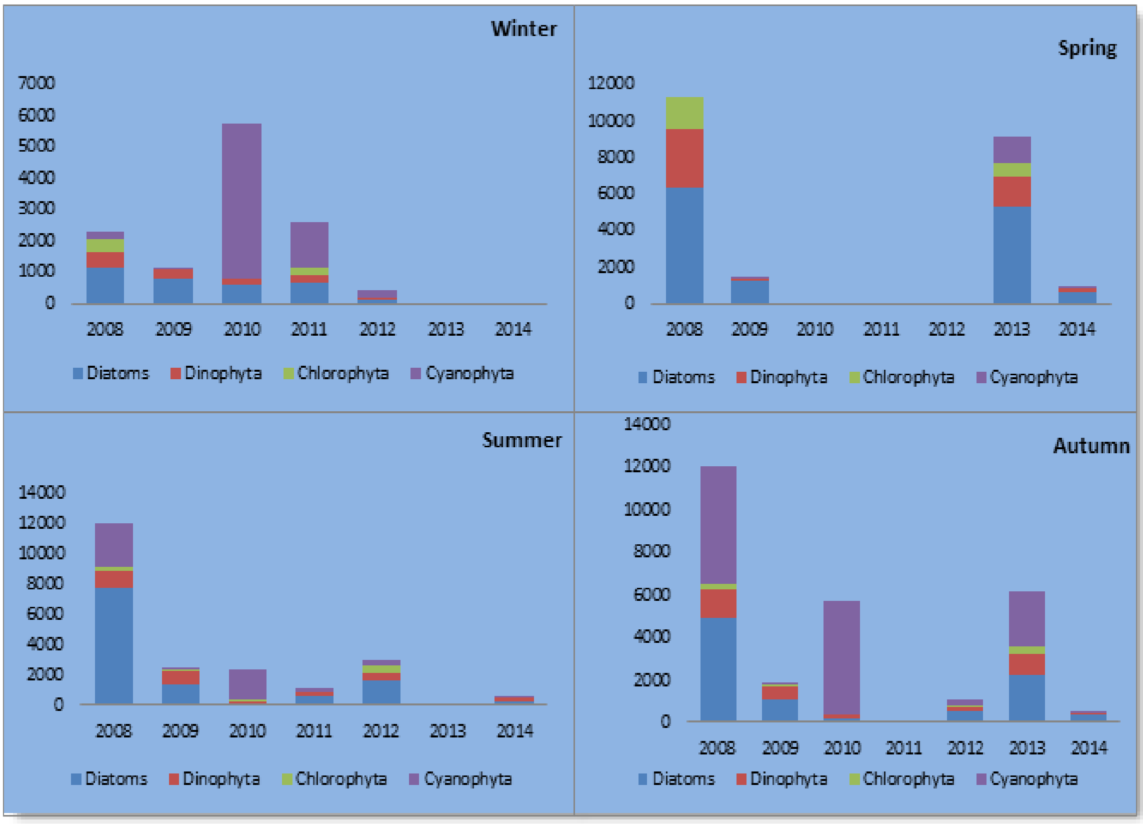


Figure 1.3.2.16. Taxonomic structure by phytoplankton abundance (10^3cells/l) in spring and summer in the coastal habitats in the Georgian marine waters

In 2009, the total phytoplankton abundance decreased to 1665x10^3cells/l and the predominance of diatoms (66%) remained (Fig.1.3.2.15). The picture changes dramatically in 2010 -2011, when a massive bloom of blue-green algae was recorded, especially at Batumi stations (7878x10^3cells /l) and Poti (8020 x10^3cells /l) in winter (Fig.1.3.2.16).

In Autumn in Batumi and Poti waters high abundance of *Microcystis aeruginosa* colonies (2280x10^3cells/l) was measured. In winter along with *Microcystis aeruginosa* (5453x10^3cells/l and 4560x10^3cells/l) (Table 1.3.2.5b) at the same stations a bloom of *Merismopedia punctata* (2100x10^3cells/l and 2040x10^3cells/l) co-dominated the community. Cyanobacteria in 2010 contributed to an average of 89% of the total phytoplankton abundance, and in 2011 - 45% (Fig. 1.3.2.16).

Since 2012, there has been a decline in the abundance of blue-green algae and an increase in the proportion of diatoms and dinophytes. In 2014, the number of diatoms was 63%, dinophyte - 20%, and blue-green 11% of the total phytoplankton. The proportion of Chlorophyceae was insignificant and averaged about 5-6%.

Along the **Romanian waters** analysing the phytoplankton taxonomic composition it was found that the average density and biomass had high values in 2008-2014, especially in coastal and transitional waters, where species diversity was higher. In density, diatoms were dominant in all habitats (58-99.8%), followed by species from other groups (up to 27%) and dinoflagellates in ratios much lower (by 13.5%). In the biomass, diatoms maintained their annual dominance over 70% in most of the study period, with few exceptions (2008 and 2012) due to the development of dinoflagellates in the spring-summer seasons (*Heterocapsa triquetra*, *Lingulodinium polyedrum*, *Akashiwo sanguinea*, *Scrippsiella trochoidea*).

In **coastal waters**, the annual average densities were in most years below $1.5x10^6$ cells/l with the exception of 2009 (density 2.46 $x10^6$ cells/l) and 2014 (density $3.15x10^3$ cells/l) (Fig. 1.3.2.17). In biomass, 2009 was also peculiar with high biomass and the annual average of 2700mg/m^3, at least 2.5 times higher than in the rest of the period. The analysis by taxonomic groups showed the dominance of diatoms in the densities (over 80%), and in the biomass, (over 85%) only in 2009, 2013 and 2014.

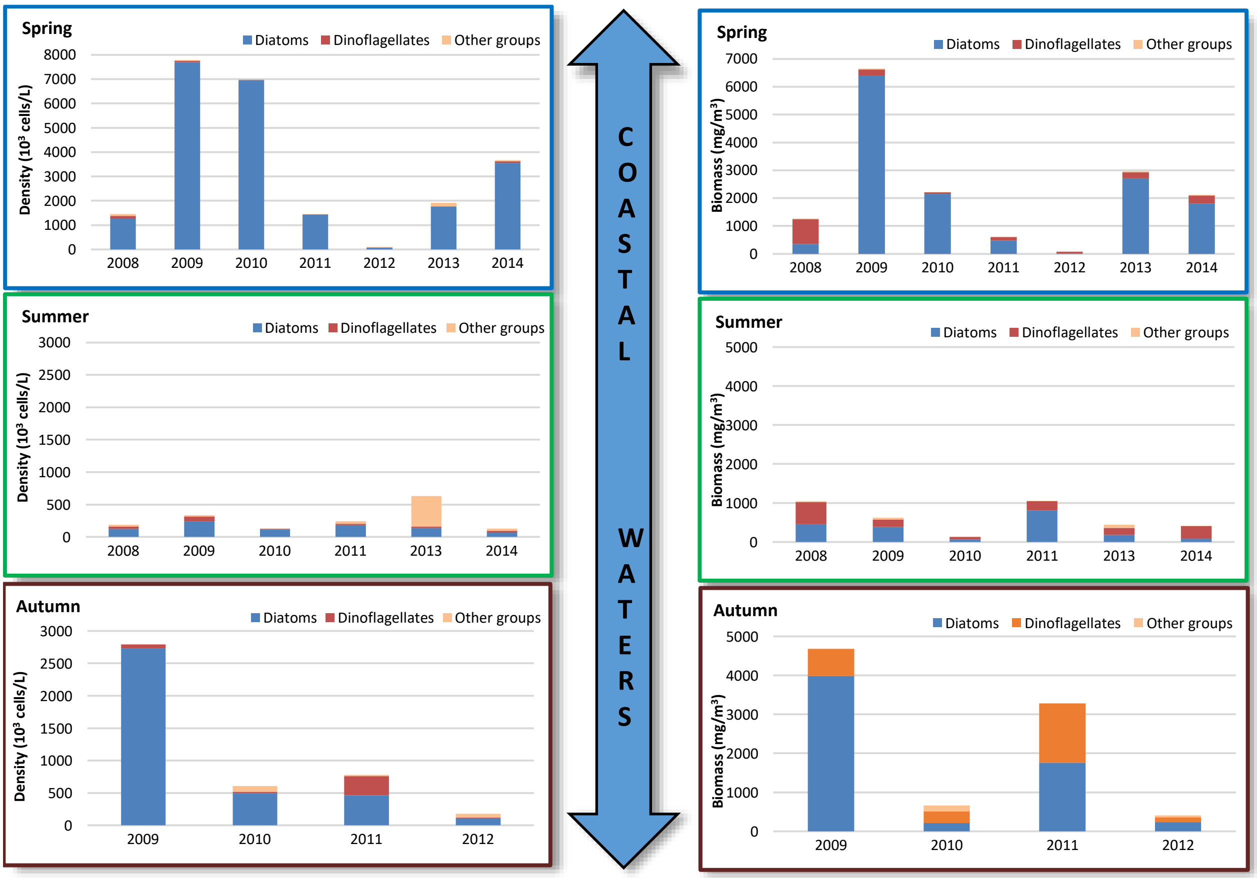


Figure 1.3.2.17. Taxonomic structure of phytoplankton densities (cells/l, left) and biomasses (mg/m^3, right) in the Romanian coastal waters, between 2008 – 2014

In **transitional waters**, phytoplankton amounts were the highest compared with those of coastal and shelf waters ranging from $920x10^3$ cells/l (2008) and $4.06x10^6$ cells/l (2014). Biomass values fluctuated considerably between years, 2009 and 2011 recorded the maximum average values (2770 mg/m^3 and 2520 mg/m^3 respectively), while the remaining years had the average biomasses below 2000 mg/m^3 (Fig. 1.3.2.18). During the 5 years of the 2008-2014 period diatoms dominated the taxonomic structure both in density and biomass in percentage of over 90%, only in 2008 and 2013, the share of diatoms in biomass was less than 55%.

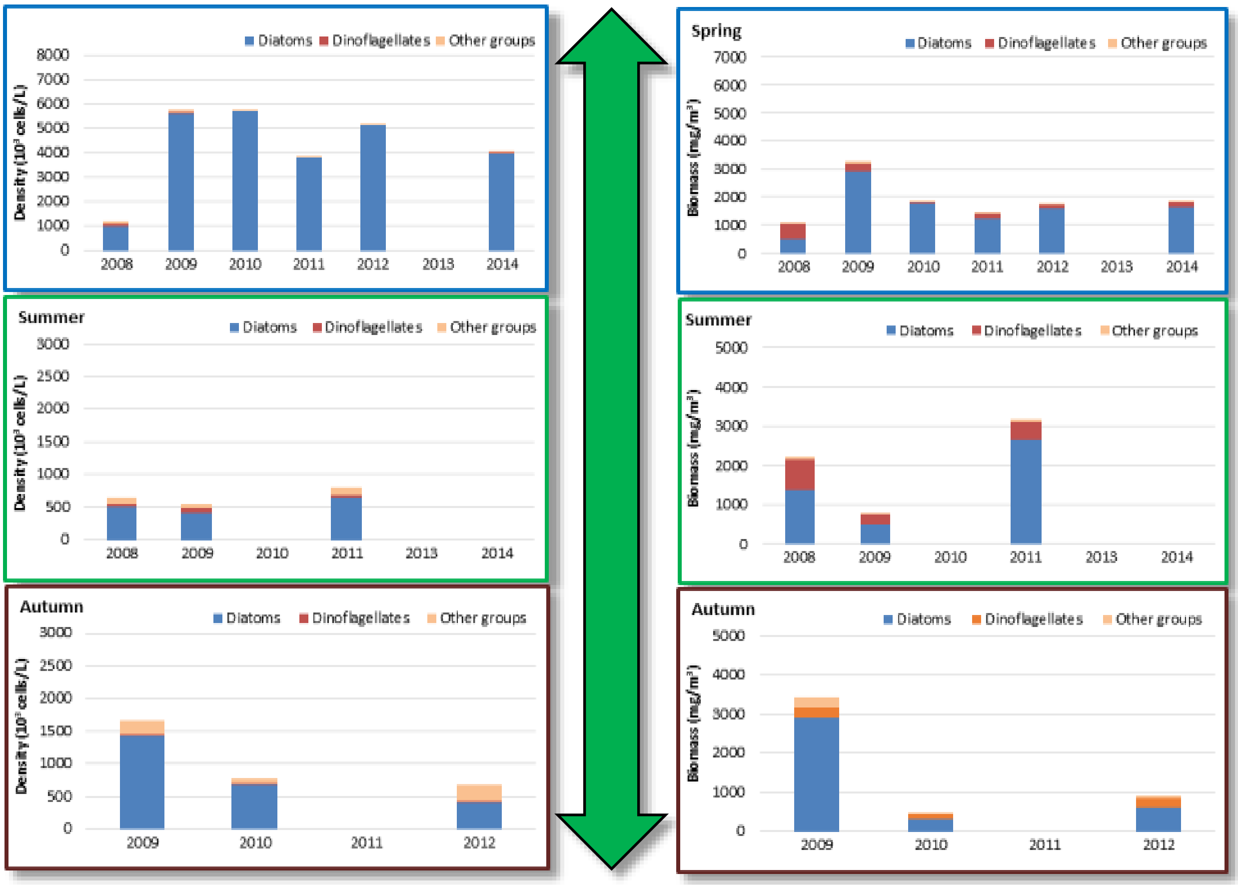


Figure 1.3.2.18. Taxonomic structure of phytoplankton densities (cells/l, left) and biomasses (mg/m^3, right) in the Romanian transitional waters, between 2008 – 2014

In **shelf waters**, phytoplankton quantities were lowest compared to coastal and transitional waters, the average densities in most years standing below 500x10^3 cells/l, ranging between 137x10^3 cells/l (2012) and 1.86x10^6 cells/l(2014) (Fig. 1.3.2.19). Diatoms dominated between 2011 and 2014 in shelf waters, and only the yaer 2010 was featured by a higher development of dinoflagellates and species belonging to other groups.

Dinoflagellates contributed to lower %, as compared to diatoms and to species belonging to "other groups". Higher dinoflagellates proportions (42 -43 %) were observed in 2008 and 2010 in shelf waters, at average annual density of 346x10^3 cells/l and 197x10^3 cells/l. In the biomass, dinoflagellates contribution in the shelf was higher than in coastal or transitional waters.

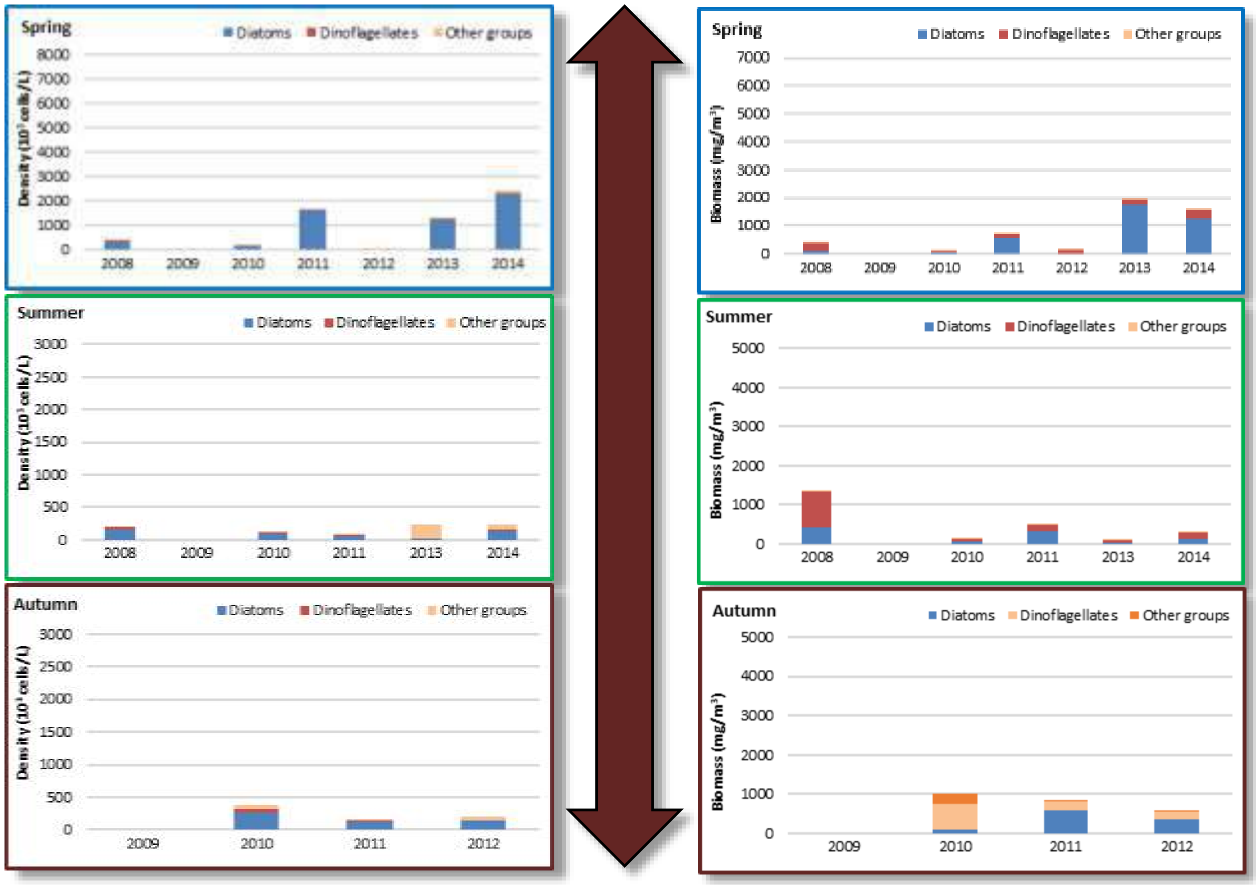


Figure 1.3.2.19. Taxonomic structure of phytoplankton densities (cells/l, left) and biomasses (mg/m^3, right) in the Romanian shelf waters, between 2008 – 2014.

In **Russian waters** the seasonal dynamics of phytoplankton communities taxonomic profile differed substantially between 2008 and 2012 and 2009, 2010, 2011 (Fig. 1.3.2.20). A key difference between these two groups of years was in the winter air and sea surface temperatures (SST). The first group of cold years was characterized by low February SST from 6.5 to 7.3 ^{0}C, while during the warm years group the February SST was higher and varied from 7.9 to 8.5 ^{0}C.

During the cold years, the maximum biomass (on the average of 610 mg/m^3) in the water column was observed in May (Fig. 1.3.2.20a) and was formed by coccolithophores represented mainly by *Emiliania huxleyi*. The coccolithophores made up about 85% of the total phytoplankton biomass in May and 45% in June. Diatoms predominated in phytoplankton in August and September (240 – 275 mg/m^3), comprising 85% and 45% of the total phytoplankton biomass, respectively. Peaks in biomass of dinoflagellates were observed in April (122 mg/m^3) and September (147 mg/m^3), when they contributed 55% and 37% to the total phytoplankton biomass. In the year-round cycle the biomass of flagellates (3-41 mg/m^3) and their proportion in the total phytoplankton biomass (6 – 15%) were not substantial. On average, coccolithophores, diatoms, dinoflagellates and flagellates contributed 43, 33, 17 and 7% to the annual (warm period of the year) total phytoplankton biomass.

In the warm years, the maximum biomasses (230-417 mg/m^3), formed by large-cells diatoms *Proboscia alata* and *Pseudosolenia calcar-avis*, occurred in June, July and August when these algae made up 57 – 88% of the total phytoplankton biomass (Fig. 1.3.2.20b). Coccolithophores were most abundant in June and July (76-78 mg/m^3) while their share in the total phytoplankton biomass was maximal in May (33%). Biomass of dinoflagellates was highest in March (42 mg/m^3) and June (47 mg/m^3). The maximum contribution of this group to the total phytoplankton biomass was in March (45%). The contribution of flagellates was essential with a biomass maximum in July (59 mg/m^3). Their proportion in the phytoplankton standing stock varied in a broad range - in some month when the total phytoplankton biomass was very low (April), their share reached 78%. On average, coccolithophores, diatoms, dinoflagellates and flagellates contributed 13, 74, 8 and 6% to the annual (warm period of the year) total phytoplankton biomass.

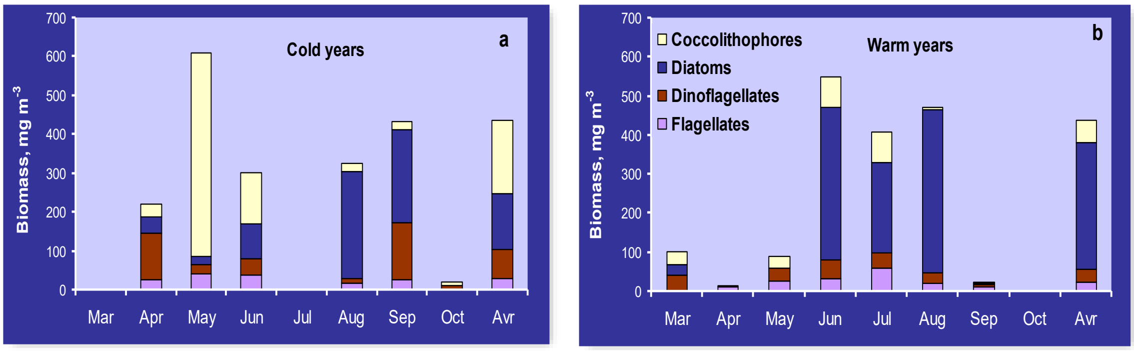


Figure 1.3.2.20. Changes in phytoplankton taxonomic structure: average monthly biomass and annual averages (Avr) during cold (a) and warm (b) years

The seasonal dynamics of phytoplankton reavealed a mass development of diatoms in August, September (Fig. 1.3.2.20a), July-August (Fig. 1.3.2.20b). It is assumed that, typically, diatoms dominate in spring and autumn (Sorokin, 2002). Nevertheless, in the near-coastal waters of the north-eastern Caucasian shelf, summer blooms of diatoms were reported earlier. In August 1978, the mass development of *Pseudo-nitzschia delicatissima* was recorded in the Gelendhzhik region (Zernova, 1980). In 2004 – 2005, mass development of the diatom *Chaetoceros subtilis* var. *abnormis* f. *simplex* (with the maximal abundance of 0.9 x10^6 cells/l) was observed along all Caucasian shelf from Gelendzhik to Sochi (Pautova et al., 2007). In these years the wind-induced near-shore upwelling stimulated diatoms growth. One can assume that similar events were responsible for the diatoms bloom in June 2008 – 2009. The autumn development of diatoms typically occurred in October and November (Morozova-Vodyanitskaya, 1954, 1957; Belogorskaya and Kondratieva 1965). According to our data a high diatom growth was not observed in October. Moreover, the very low biomass of phytoplankton in October seems atypical and may be explained by the restricted data (only 2 years during the period).

Another peculiarity of the phytoplankton seasonal dynamics was the absence of the typical spring peak (Fig. 1.3.2.20b), a feature of the Black Sea ecosystem reported earlier. In 1950's Morozova-Vodyanltskaya (1957) found that "biological spring" in the open waters may not be pronounced. After mid-1990's the decrease of magnitude of the spring bloom or its complete disappearance led to assumption that the reason for such decrease was the global warming which reduced intensity of winter convection and respectively the amplitude of spring bloom (Oğuz et al., 2003). Recently, the suggested Pulsing Bloom Hypothesis gave another theoretical explanation for the regular nonappearance of spring bloom in the open waters (Mikaelyan et al., 2017). During warm winters phytoplankton develops in the temporal subsurface turbulent layers that result in exhausting of nutrients at the end of winter which prevents the classical spring diatom bloom. In addition, the results indicated that during warm years a spring bloom did not occure in the near-shelf waters too. For example, in March 2009 the biomass of diatoms was 26 mg/m^3 whereas the biomass of dinoflagellates and coccolithophores was 43 and 34 mg/m^3, respectively. It is likely however that the expected spring bloom in the cold years was missed due to lack of March observations.

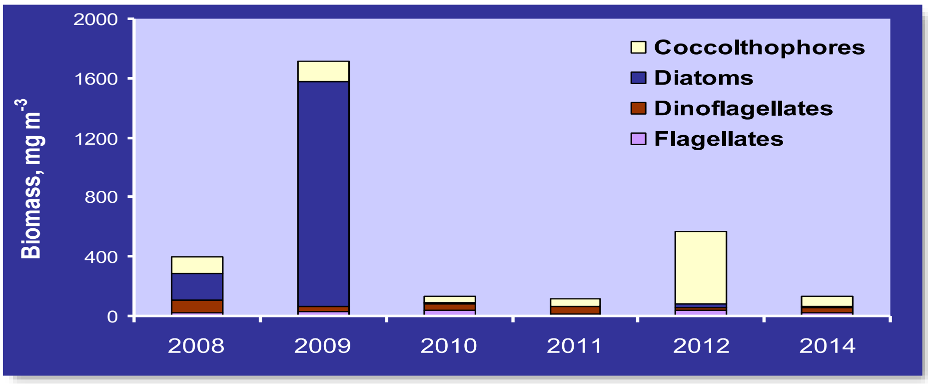


Figure 1.3.2.21. Interannual changes of phytoplankton biomass taxonomic structure in May-June 2008-2014 in Russian waters

In contrast in May–June samples were collected more regularly during most years (Fig.1.3.2.21). This period of the year is characterized by prevalence of coccolithophores (Cokacar et al., 2001; Mikaelyan et al., 2011) due to the high abundance of *Emiliania huxleyi*. Maximum cell numbers (8.4x10^6 cells/l) was observed in 2012, contributing to the total phytoplankton biomass ~ 86%. During the other years, the species did not exceed 1x 10^6 cells/l. Their share in the total phytoplankton was low and varied from 8 to 45%. As it was shown earlier, the shares of diatoms and coccolithophores in the total phytoplankton biomass changed inversly (Mikaelyan et al., 2015). The same relationship was found in this study (r=-72, n=6, p=0.1) and the results confirmed the massive growth of coccolithophores in May–June. During the period from 2003 to 2007 similar maximum abundances were recorded twice. In 2004 and 2006 the maximum cell density reached 8 and 4.5x10^6 cells/l and the average input to the total phytoplankton biomass reached 70% (Mikaelyan et al., 2011). From 2008 to 2014 such strong bloom was observed only in 2012. It can be assumed, that in the near-shelf waters of Caucasian coast, the frequency of the coccolithophores exeptional blooms in May-June decreased.

In the **Odessa coast** the largest relative contribution to the abundance and biomass of phytoplankton communities in 2008-2011 was formed by Bacillariophyceae species. The second largest relative contribution both in the abundance and in the biomass was associated with Dinophyceae species. Cyanophyceae and Chlorophyceae proportion was also high, more pronounced in the abundance (Fig. 1.3.2.22).

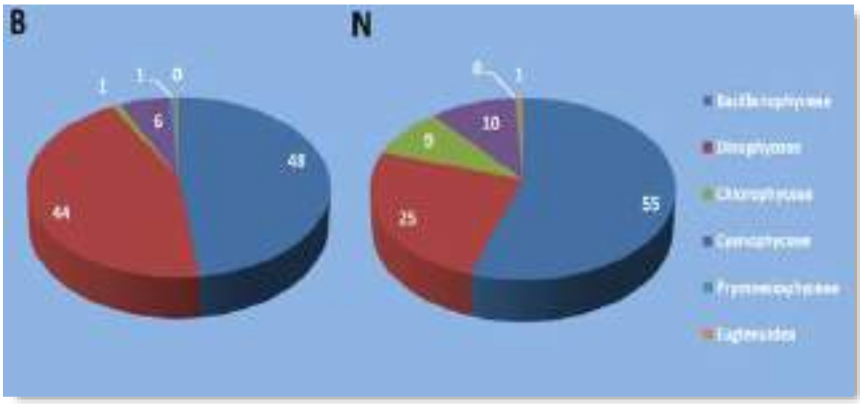


Figure 1.3.2.22. Average contribution of number of species per taxon in the abundance (N) and biomass (B) in the Odessa coastal phytoplankton communities during 2008-2011

In contrast to the relative contribution, the highest average biomass was due to Dinophyceae contribution - about 2 times higher than that of Bacillariophyceae. In the abundance the maximum for the entire period was due to the dominant Cyanophyceae species, exceeding diatoms abundance ~4 fold (Fig. 1.3.2.23).

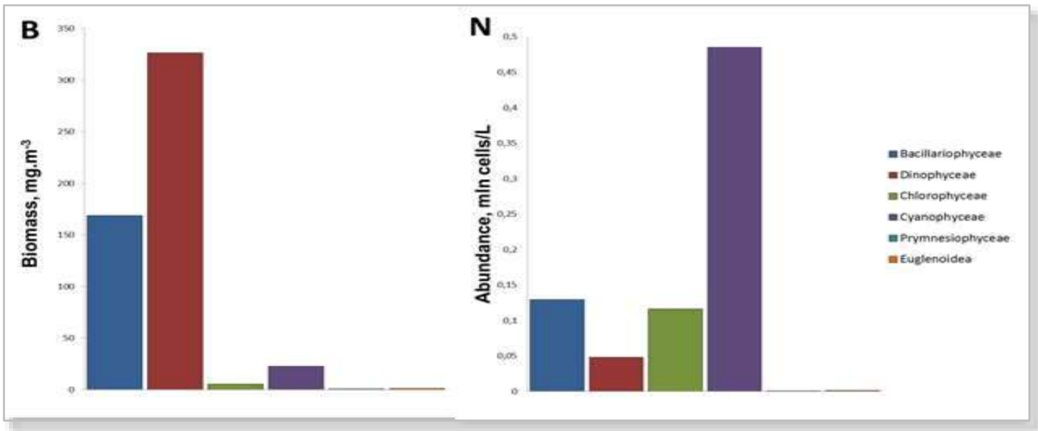


Figure 1.3.2.23. Average abundance (10^6cells/l) and biomass (mg/m^3) of phytoplankton taxa on the Odessa coast during 2008-2011

While in 2006-2007 Bacillariophyceae species dominated not only in relative (Fig. 1.3.2.24), but also in absolute average phytoplankton abundance and biomass (Fig. 1.3.2.25), taxonomic restructuring towards Dinophyceae dominance occurred in 2010, most likely related to the abnormal climatic conditions in 2010 - high temperature, high rainfall (Minicheva et al., 2013). The proportion of dinophytes increased to ~60% in the biomass in 2011 (Fig. 1.3.2.24).

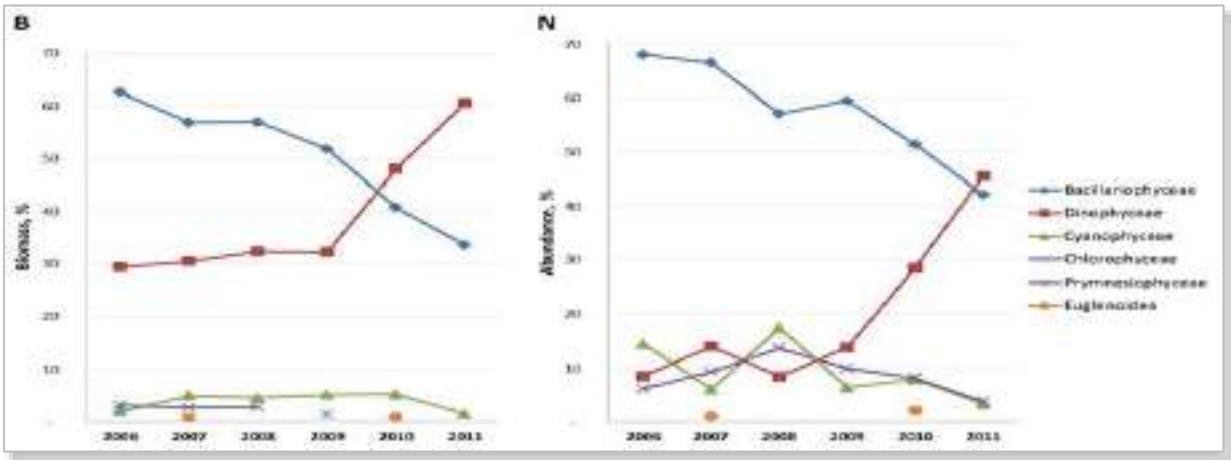


Figure 1.3.2.24. Interannual variability of average relative contribution of phytoplankton taxa in the biomass (%) and abundance (%) in the Odessa coast (2006-2011)

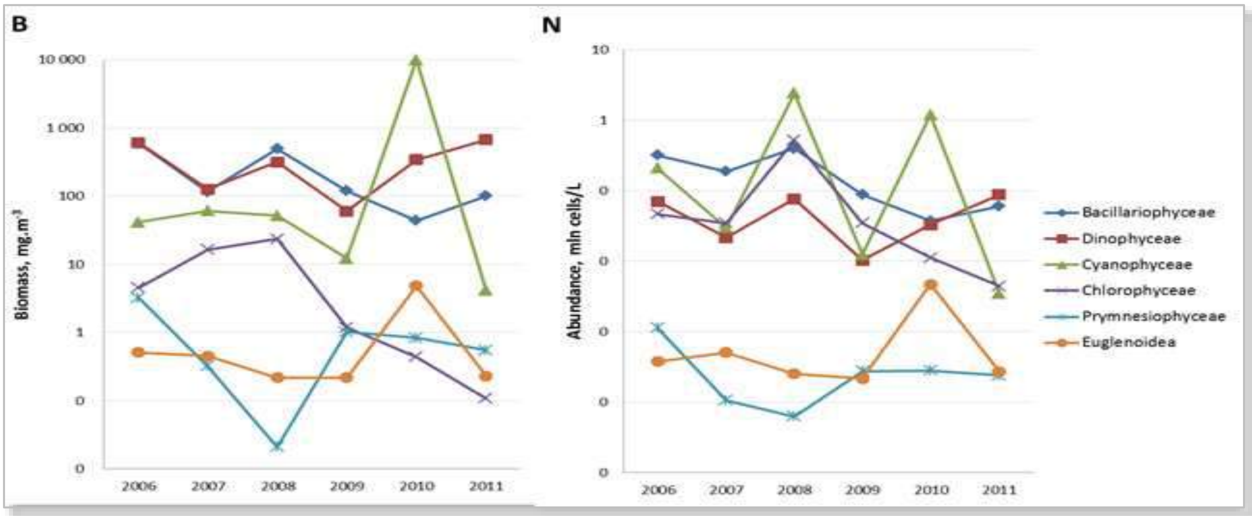


Figure 1.3.2.25. Interannual variability of average contribution of phytoplankton taxa in the biomass (mg/m^3) and the abundance (1x10^{6}cells/l) in Odessa coast (2006-2011)

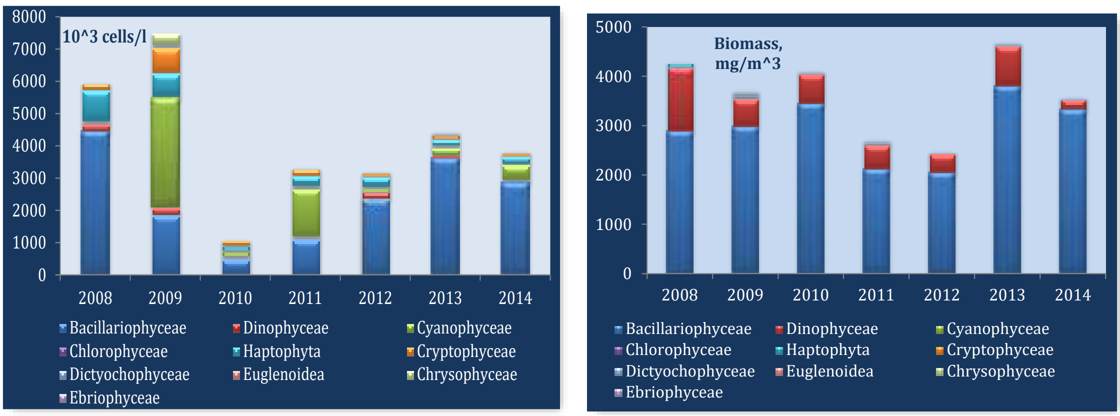


Figure 1.3.2.25a. Taxonomic structure of phytoplankton abundance (cells/l, left) and biomasses (mg/m^3, right) in the Zmiinyi island during 2008 – 2014

In 2008 **in the area of Zmiinyi island** the total phytoplankton abundance was dominated by diatoms and haptophytes, whose abundance exceeded the average values for 2008-2014 almost twice (Fig. 1.3.2.25a, Table 1.3.2.4f). In 2009 the dominant taxa were more diverse, and the abundance exceeded the average 2-8 times. The biomass was dominated mostly by diatoms with far lower proportion of dinoflagellates, the highest total biomasses of phytoplankton were measured in 2008 and in 2013. The total abundance of Bacillariophyceae on the surface ranged between $6x10^3$cells/l (in winter) to $66.3x10^6$cells/l (in spring) (Fig. 1.3.2.11a). The most frequent diatoms that reached the values of “blooms” (more than 80% of biomass or abundance) were *Skeletonema costatum,* numerous species belonging to genera Chaetoceros, Nitzschia and Pseudonitzschia, *Cerataulina pelagica*, *Pseudosolenia calcar- avis*. In 2013-2014 the list of “blooming” species was enriched with *Dactyliosolen fragilissimus, Cyclotella choctawhatcheeana*, *Cylindrotheca closterium*, *Stephanodiscus hantzschii* and other species. The number of Bacillariophyta blooms increased after 2010 and the average monthly abundance of diatoms was 2-3 higher than that of Dinophyta.

Among dinoflagellates genera Ceratium, Dinophysis, Gonyaulax, Prorocentrum and *Heterocapsa triquetra* developed annually during summer-autumn season, their abundance not reaching critical values. The total abundance of Dinophyceae on the surface ranged between 0.46 - $1480x10^3$cells/l (in June 2012) (Fig.1.3.2.11a).

The biomass of diatoms (contributing to ~ 90% of total phytoplankton biomass) on the surface ranged from 10 mg/m^3 to 17800 mg/m^3, while the biomass of dinoflagellates varied within 3 to 2720 mg/m^3.

The Chlorophyceae microalgae appeared generally during periods associated to high river inflow to the island and were represented by few freshwater species belonging to genera Monoraphidium and Scenedesmus, as well as the species *Desmodesmus communis* (Hegew.) and *Coenochloris pyrenoidosa* Korsch. The average monthly values did not exceed $320x10^3$ cells/l and their average biomass – 220 mg/m^3.

Significant role in the structure of phytoplankton in summer-autumn was played by cyanobacteria, sometimes proliferated to blooming densities. Average monthly abundance on the surface ranged from 0.5×10^3 to $12.56x10^6$ cells/l (in May 2009) and the average monthly biomass ranged between 0.1- 240 mg/m^3 (in November 2011) with a decreasing trend observed after 2011. Similar to green algae, the cyanobacteria were most often brought to the area of the island by the Danube freshwater flow with the most common genera Anabaena, Oscillatoria, Spirulina, as well as *Aphanizomenon flos-aquae* (L.) Ralfs and *Microcystis viridis* (A.Br.) Lemm. In summer irrespectively of river influence the autochthonous cyanophyte *Limnothrix planktonica* (Wol.) Meff. was recurrently observed.

Cryptophytes *Leucocryptos marina* (Braar.) Butcher and *Rhodomonas* were observed annually from spring till autumn, most often by insignificant share in the phytoplankton composition. Only in February and July 2009 these species reached the level of a bloom ($4320-1600x10^3$ cells/l) (Table 1.3.2.5b).

1.2.1.1-6. Trends in phytoplankton blooms

In **Bulgarian waters** typical for the recent period co-dominance of several species was the main feature of the phytoplankton assemblages over the two seasons (spring and summer). The most frequent out-competitors were a mix of species of different taxonomic assignment. Prymnesiophite *Emiliania huxleyi* was the most common and frequent species proliferated to a bloom density but far bellow the max blooming density recorded in the area (Fig. 1.3.2.26, Table 1.3.2.5a). However this is the species that continue to produce basin- scale blooms in spring (May-June 2016, 2017) (Fig. 1.3.2.26a) in all Black Sea habitats and local blooms in different months during the year predominantly in coastal and shelf waters, while the mechanisms of bloom initiation are different (Churilova et al., 2017, see comments bellow). A monospecific bloom of the emblematic for the period of high eutrophication dinoflagellate *Prorocentrum cordatum* (*Prorocentrum minimum*) was not observed after June 2012 and since 2000 it's concentrations declined sharply (Fig. 1.3.2.26).

Prorocentrum minimum

Month	4	5	6	7	8	9	10	11
1954		0.2						
1955								
1956		0.2						
1959		0.05						
1967		1						
1968		1.6						
1969		5.4						
1973		86.3						
1983			4.31					
1984				8.6				60.17
1985								
1986		11.2	481.3					
1987		30.5		31.8				
1988			3.1					
1989			96.8		280			
1990		1.7		2				
1991			5.7					
1992						2.2		
1993								
1994		5						1.5
1995				5.3		5.9		
1996		1.5					4.8	
1997		6.3		206				
1998				105.2				
1999					4.6			
2000		3.7						3.4
2001								1.1
2002		1.3		1.4				
2003		0.3			3.2			
2004		0.5						
2006								
2007		1						
2008		<1						
2010		<1	<1					
2012		<4						

<1   <4   >4   1x10^6 cells/l

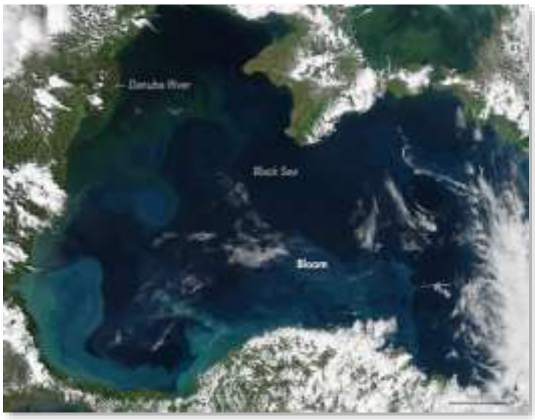
Emiliania huxleyi

month	5	6	7	8	9	10
1983				1.1		
1984						
1985						
1986	2.9	4.14				
1987	3.2		3.2	5.9		
1988						
1989				3.8	1.5	
1990			10.5	3.2		
1991				2		
1992	2.9		3.8'		4.5	
1993	1.1	2		6		
1994			5.4	13.7		
1995				3.2		
1996					3.1	
1997	1.1					
1998					2.2	
1999				1.7		
2000	1.4	14		1.2		4.1
2001	4.33					
2002	3.1	4.8		2.9		
2003				1.7		
2004	8.2	3.88			1.7	
2005	1.6	2.7				
2006	4.4					
2007		1.3				0.32
2008		1.1				
2009		1.9				
2010						
2011						
2012		9.2			1.8	
2013					1.3	1.6
2014		1.1				

1-4   >4   1x106 cells/l

Figure 1.3.2.26. Long-term record of blooms of *Prorocentrum minimum (=cordatum)* and *Emiliania huxleyi* in BG waters

Relatively few species attained bloom concentrations in 2008-2014 or contributed alone to more than 1000 mg/m^3 in the biomass - *Cerataulina pelagica* in October 2008, *Prorocentrum cordatum* in June 2012, *Proboscia alata* in April 2009, *Dactylosolen fragilissimus* in July 2014 (Table 5a). More often it was an aggregate of several species that structured the dominant phytoplankton seasonal communities. Thus, for example in June 2009 the high biomass was composed of several species *Cerataulina pelagica* (555.75 mg/m^3), *Pseudo-solenia calcar-avis* (648.06 mg/m^3), *Proboscia alata* (775.04 mg/m^3), *Dactyliosolen fragilissimus* (542.07 mg/m^3), *Heterocapsa triquetra* (651.08 mg/m^3), *Prorocentrum micans* (982.90 mg/m^3) and *Ceratium fusus* (744.71 mg/m^3). In August 2014 it was a polyphyletic mix of species that contributed to the high total abundance - dinoflagellate *Lessardia elongata*, diatom *Lennoxia faveolata*, cryptophytes (*Chroomonas* sp., *Hemiselmis* sp.), species from Nephroselmidophyceae (*Nephroselmis astigmatica*, *Nephroselmis pyriformis* and Prasinophyceae (*Pyramimonas amylifera*, *Pyramimonas* sp.)



a) 3 June 2012 c) 7 May

a) 9 May 2013 d) 4 June 2008

Figure 1.3.2.26a. Satelite images of Basin scale bloom of *Emiliania huxleyi* during 2008-2016

a) NASA GSFC http://modis.gsfc.nasa.gov/gallery)

b) https://earthobservatory.nasa.gov/IOTD/view.php?id=88017&eocn=image&eoci=related_image

c)https://eoimages.gsfc.nasa.gov/images/imagerecords/88000/88017/BlackSea_amo_2016128.jpg

d) https://eoimages.gsfc.nasa.gov/images/imagerecords/8000/8817/BlackSea_AMO_2008156.jpg

The general trend of bloom dynamics along the BG waters was towards reduction as compared to the 80-90ies, majority of the blooms reported in Table 1.3.2.5a being local of low magnitude. Albeit the relatively high uncertainties due to the low frequency of field monitoring campaigns, the reduction especially in the summer blooms was well supported by application of remote sensing chlorophyll data for assessment of bloom intensity and magnitude in the shelf and open sea 1998-2013 (Slabakova et al., 2014) (Fig. 1.3.2.26b).

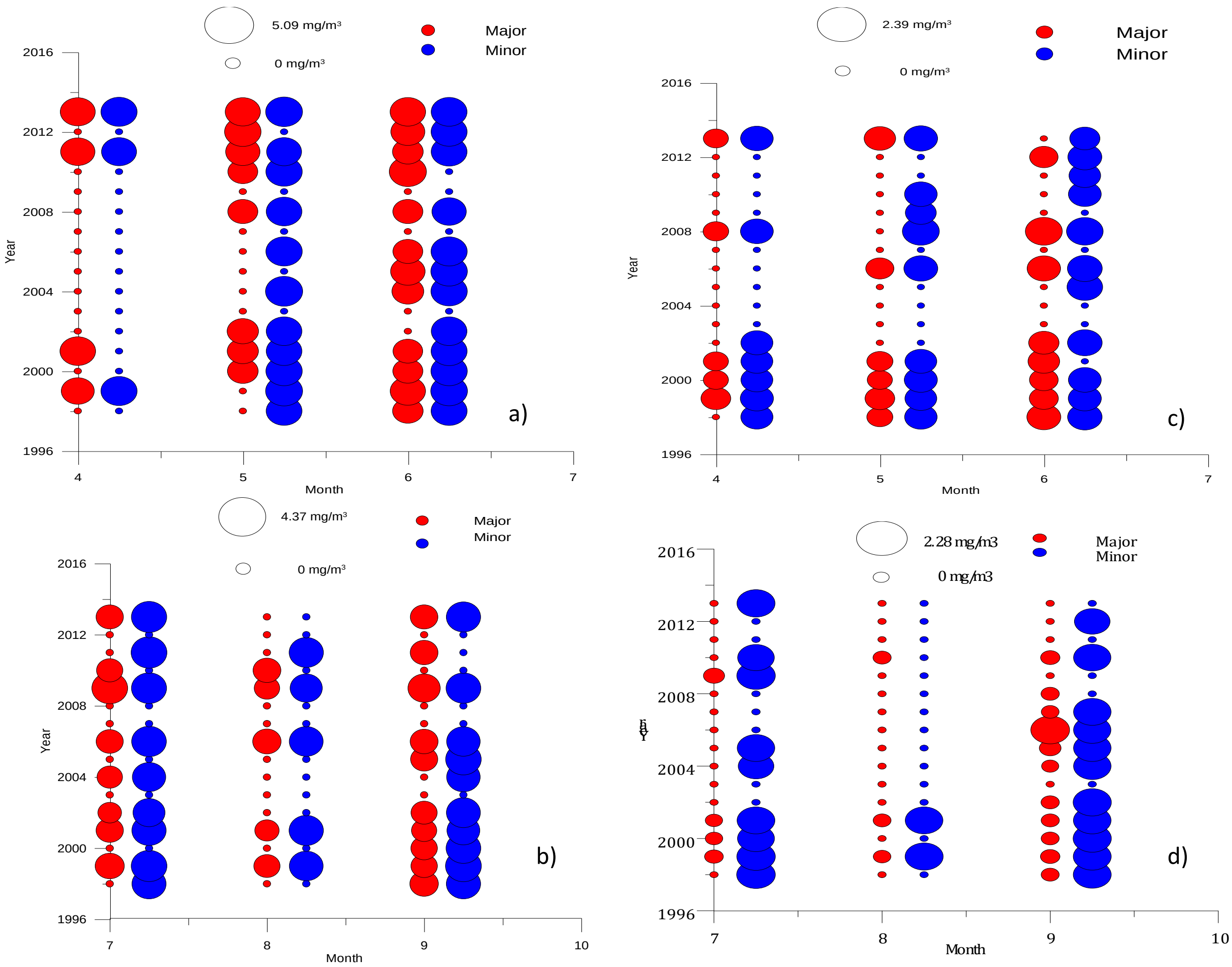


Figure 1.3.2.26b. Monthly averaged spring (a) and summer (b) phytoplankton blooms magnitude (mg/m^3) in the shelf and open sea (c-spring and d-summer) (Slabakova et al., 2014)

The intensity of the major and minor blooms in the shelf region as an average result for the period 1998-2013 did not differ significantly between the two phases (1998-2005 and 2006-2013) in summer, in contrary to spring when a steady increasing trend of major blooms magnitude was observed (Fig. 1.3.2.26b).

Generally, decreasing mid-term trend of average bloom spatial extent for both seasons and regions was found (Fig. 1.3.2.26c). In the shelf, a decline of bloom area was explicitly noticeable for minor blooms in spring (about 2 times) while in open sea the recent spatial extent decreased more than 5.5 fold for major and 2 fold for minor blooms, a common trend for the two seasons but at different rates by months. The overall analysis featured the spring blooms in the shelf region as intensive, while viewed as weaker and widespead in summer, quite in line to the trend of summer blooms decline inffered from field studies.

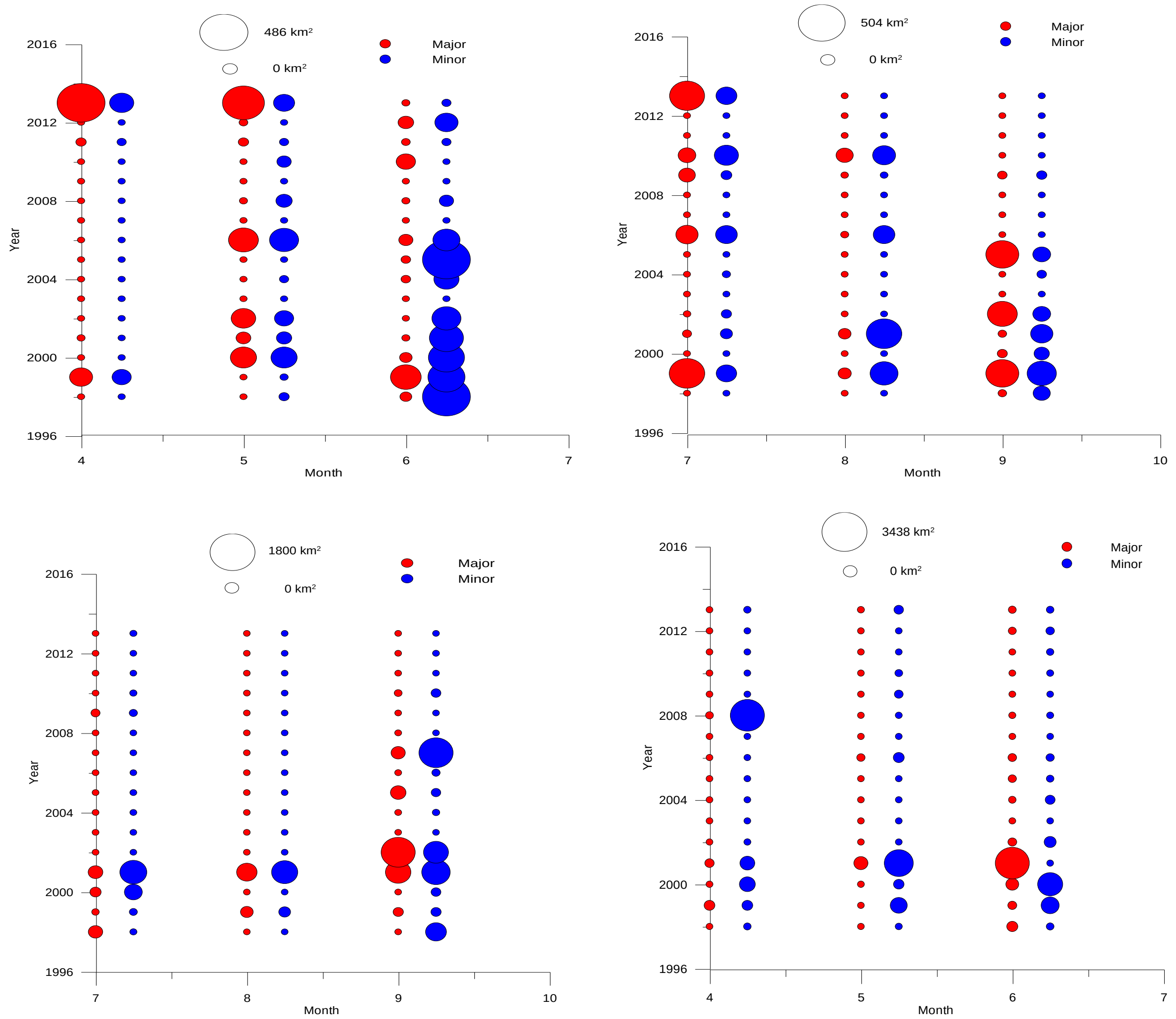


Figure 1.3.2.26c. Monthly averaged bloom area (km2) in the shelf (upper left) in spring, and summer (upper right) and open sea (spring (right) and summer (left)) by years) (after Slabakova et al., 2014)

In **Romanian waters** during 2008-2014 there were 21 blooming events (with densities of over $1x10^6$ cells/l), of which more than half were small scale (with abundances not exceeding $5x10^6$ cells/l), 4 events were abundant - densities up to $10x10^6$ cells/l, 4 - with abundance up to $20x10^6$ cells/l and 2 significant events with species proliferation to densities $40x10^6$ cells/l (Table 1.3.2.5c). Out of the 10 dominant species identified the diatoms *Pseudo-nitzschia delicatissima* ($15.5x10^6$ cells/l) and *Skeletonema costatum* ($39.5x10^6$ cells/l) showed the most significant proliferation during 2008-2014, especially in the spring season (Table 1.3.2.6). Diatoms *Cerataulina pelagica*, *Nitzschia tenuirostris*, *Thalassionema nitzschioides* were found in quite variable abundance with decreasing trend, from over $4.5x10^6$ cells/l in 2001 to $1.2x10^6$ cells/l in 2011 (Table 1.3.2.5c).

Table 1.3.2.5. Maximum concentrations of blooming phytoplankton species between 2008 - 2014 in the Black Sea in different waters

Bulgarian waters

Year	Month	Species	N[cells/l]	B[mg/m³]
2008	IV	*Emiliania huxleyi*	153096	
2008	VI	*Emiliania huxleyi* *Prorocentrum cordatum* *Scrippssiella trochoidea*	1044363	
2008	IX	*Cerataulina pelagica* *Nitzschia* sp.	1689795	1761.74
2009	IV	*Pseudonitzschia delicatissima* *microflagellates*	4821600	
2009	IV	*Proboscia alata* *Heterocapsa triquetra*		1452.63 491.57
2009	VI	*Emiliania huxleyi*	1875717	
2011	V	*Chaetoceros diadema*		1986.08
2012	VI	*Emiliania huxleyi*	1014300	
2012	XI	*Emiliania huxleyi*	1857868	
2012	VI	*Pseudonitzschia delicatissima*	3495680	
2012	VI	*Prorocentrum cordatum*		3379.47
2013	VIII	*Lenoxia faveolata*	2200000	
2013	IX	*Emiliania huxleyi*	1300000	
2013	XI	*Emiliania huxleyi*	1600000	
2014	V	*Pseudonitzschia delicatissima*	1100000	
2014	VI	*Emiliania huxleyi*	1100000	
2014	V	*Pseudo-nitzschia delicatissima*	1300000	
2014	VII	*Dactylosolen fragilissimus*		1815.41
2014	IX	*Lenoxia faveolata*	1552642	

b) Georgian waters

Year	Month	Species	N[cells/l]
2008	IV	*Skeletonema costatum* *Chaetoceros lorensianus*	1440000 1093000
2008	VI	*Proboscia alata*	1324000
2008	VII	*Pseudosolenia calcar avis* *Chaetoceros lorensianus*	3020000 2253000
2008	VIII	*Pseudosolenia calcar avis*	2040000
2008	IX	*Skeletonema costatum* *Proboscia alata*	1336000 1080000
2009	IV	*Melosira moniliformis*	1124000
2009	V	*Pseudo-nitzschia delicatissima*	1021600

Year	Month	Species	N[cells/l]
2009	IV	*Skeletonema costatum*	1260000
2010	II	*Navicula pennata v.pontica*	2680000
2010	XI	*Microcystis aeruginosa* *Prorocentrum cordatum*	2280000 1012000
2010	XII	*Microcystis aeruginosa*	5453000
2012	VII	*Pseudosolenia calcar avis*	1306000
2013	IV	*Skeletonema costatum* *Melosira moniliformis*	1180000 1020000
2014	III	*Thalassionema nitzschioides* *Skeletonema costatum*	1460000 2060000
2014	VII	*Prorocentrum micans* *Ceratium furca*	1120400 1031000
2014	X	*Chaetoceros insignis*	1640000

c) Romania waters

Year	Month	Species	N [cells/l]	B [mg/m^3]
2008	III	*Skeletonema costatum*	7240000	2172.00
	V	*Skeletonema costatum*	3140000	942.00
	V	*Pseudo-nitzschia delicatissima*	7372000	1489.14
	V	*Nitzschia* sp.	2626000	
	V	*Heterocapsa triquetra*		1647.07
	VII	*Scrippsiella trochoidea*		1034.88
	VIII	*Melosira moniliformis*		1774.08
	VIII	*Pseudosolenia calcar-avis*		1536.00
	VIII	*Lingulodinium polyedrum*		1209.60
	VIII	*Akashiwo sanguinea*		1142.40
2009	II	*Skeletonema costatum*	1814000	
	V	*Pseudo-nitzschia delicatissima*	15528000	3136.66
	V	*Chaetoceros curvisetus*	1216000	6080.00
	V	*Cerataulina pelagica*		1682.46
	IX	*Chaetoceros socialis*	2850000	1425.00
	IX	*Chaetoceros affinis*		2796.80
	IX	*Proboscia alata*		2028.00
2010	III	*Skeletonema costatum*	39540000	11862.00
	VIII	*Skeletonema costatum*	30360000	6072.00
	VIII	*Cyclotella choctawhatcheeana*	6500000	1664.00
	VIII	*Nitzschia tenuirostris*	1440000	
	IX	*Nitzschia tenuirostris*	1122000	
2011	IV	*Skeletonema costatum*	15184000	4555.20
	VII	*Cerataulina pelagica*	2156000	14005.38
	VII	*Chaetoceros curvisetus*		1194.90
	VII	*Pseudosolenia calcar-avis*		1452.00

Year	Month	Species	N [cells/l]	B [mg/m³]
	XI	*Ditylum brightwellii*		2420.60
	XI	*Heterocapsa triquetra*		1744.96
	XI	*Ceratium fusus*		920.92
2012	III	*Skeletonema costatum*	18440000	5532.00
	X	*Chaetoceros curvisetus*		1063.80
	X	*Ceratium fusus*		1293.60
2013	V	*Pseudo-nitzschia delicatissima*	2082000	
	V	*Cyclotella choctawhatcheeana*	3188000	
	V	*Pseudanabaena limnetica*	1344000	
	V	*Chaetoceros curvisetus*		4400.00
	V	*Oblea rotunda*		1185.10
	VII	*Emiliania huxleyi*	1324000	
	VIII	*Prorocentrum micans*		10756.70
2014	V	*Skeletonema costatum*	4232000	
	V	*Pseudo-nitzschia delicatissima*	8928000	2258.78
	V	*Cerataulina pelagica*		3215.66

d) Russian waters

Year	Month	Species	N, cells/l	B, mg/m³	Depth, m
2008	X	*Proboscia alata*	65000	1306	0
	XII*	*Proboscia alata*	290000	1653	0
2009	VI	*Proboscia alata*	160000	4750	0
	VI	*Emiliania huxleyi*	1728000	311	10
	VI	*Flagellates 4-6 µm*	2176000	69	10
	VII	*Proboscia alata*	223000	3233	0
	VIII	*Proboscia alata*	500000	2850	0
	IX	*Proboscia alata*	110000	1850	0
	X	*Proboscia alata*	180000	3042	0
2010	V	*Flagellates 4-6 µm*	1920000	61	30
	VI	*Flagellates 4-6 µm*	1536000	42	0
2012	V	*Flagellates 2-4 µm*	18144000	72	0
	V	*Flagellates 4-6 µm*	1024000	32	0
	VI	*Emiliania huxleyi*	8630458	1553	10

*samples from the sea surface

e) Ukrainian waters (Odessa coast)

Year	Season	Species	N, cells/l	Specific surface (SW)c $m^2 \cdot kg^{-1}$
2 008	spring	*Coenococcus planctonicus*	2961000	1765
2 008	spring	*Merismopedia sp.*	5050000	2609
2 008	spring	*Microcystis aeruginosa*	34168000	7692
2 008	spring	*Microcystis sp.*	18757000	7500
2 008	spring	*Monoraphidium contortum*	2026000	4287

Year	Season	Species	N, cells/l	Specific surface (SW)c $m^2 \cdot kg^{-1}$
2 008	spring	*Thalassiosira sp.*	1622000	751
2 008	spring	*Thalassiosira subsalina*	2532000	1190
2 010	summer	*Nodularia spumigena*	16138000	400
2 013	winter	*Skeletonema costatum*	3620000	1138

The dominant species registered values between 4-8x10^6 cells/l in the years 2008 and 2009. Starting with spring 2010, the blooming events of Skeletonema constantly exceeded 10x10^6 cells/l, with the maximum value of 39x10^6 cells/l (Table 1.3.2.6).

Table 1.3.2.6. Maximum densities (>10^6 cells/l) of dominant phytoplankton species between 2008 -2014 in Romanian waters

Season	Spring							Summer			Autumn		Winter
Species/Year	2008	2009	2010	2011	2012	2013	2014	2010	2011	2013	2009	2010	2009
Cerataulina pelagica									● (grey)				
Chaetoceros curvisetus		● (grey)											
Chaetoceros socialis											● (grey)		
Cyclotella choctawhatcheeana						● (grey)		● (green)					
Emiliania huxleyi										● (grey)			
Nitzschia sp.	● (grey)												
Nitzschia tenuirostris								● (grey)				● (grey)	
Pseudanabaena limnetica						● (grey)							
Pseudo-nitzschia delicatissima	● (green)	● (yellow)				● (grey)	● (green)						
Skeletonema costatum	● (green)		● (red)	● (yellow)	● (yellow)		● (grey)	● (red)					● (grey)

● (red)	20-40·10^6 cells/l	● (yellow)	10-20·10^6 cells/l	● (green)	5-10·10^6 cells/l	● (grey)	1-5·10^6 cells/l

In Russian waters only one diatom *Proboscia alata*, the coccolithophore *Emiliania huxleyi* and two non-identified to species level groups of nanoflagellates with cell size of 2-4 µm and 4-6 µm formed blooms in the shelf and near-shelf areas (Table 1.3.2.5d). *E. huxleyi* exceeded 1x10^6 cells/l in June 2009 and 2012. In June 2012 the maximum cell density was 8.6x10^6 cells/l, with similar high abundance of coccolithophores (8.4x10^6 cells/l) observed in the eastern Black Sea only in May-June 2004 (Mikaelyan et al., 2011).

Nanoflagellates regularly developed in high abundance reaching 1-2x10^6 cells/l in May-June 2009, 2010 and 2012. An absolute density record was observed in May 2012 when they reached 18x10^6 cells/l. Interestingly, blooms of nanoflagellates occurred during exactly the same May-June period, concomitant to those of coccolithophores.

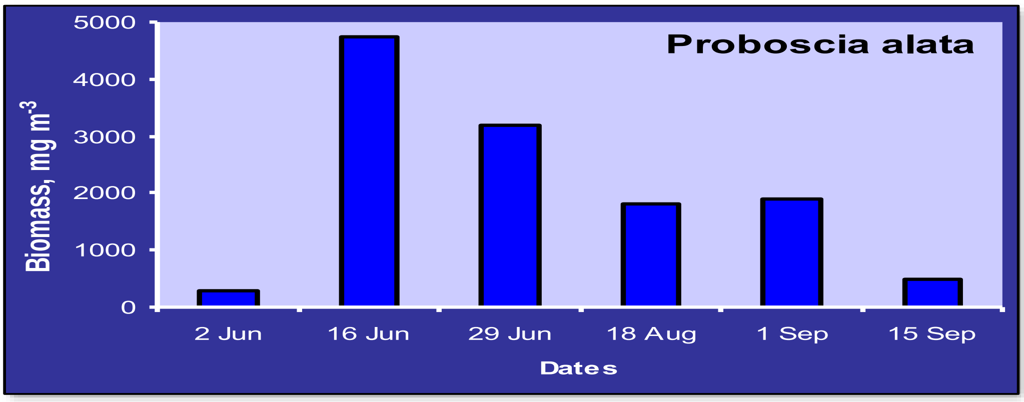


Figure 1.3.2.27. Dynamics of the *Proboscia alata* bloom on the north-eastern shelf area with sea bottom depths from 10 to 100 m in 2009 (surface biomass)

Blooms of diatom *Proboscia alata* were observed in 2008 and 2009 (Table 5d). In December 2008 several samples taken from the sea surface showed maximum cell numbers of 0.29x 10^6 cells/l and high biomass of 1653 mg/m^3. In 2009 a strong bloom of *P. alata* developed during summer in the shallow upper mixed layer 0-15 m (Fig. 1.3.2.27). Its biomass reached 4750 mg/m^3. Maximum cell number was 0.16x10^6 cells/l. The growth started from beginning of June and population reached the maximum biomass within 2 weeks. Bloom specific increase rate was rather high and was equal to 0.2 day^{-1}. Population doubling time was 3.4 day. Further, the bloom gradually decreased to mid-September. The cell volume changed as the bloom progressed. In June-July cell volume was about of 30 000 µm^3. A high abundance of these cells resulted in the maximum biomass in July. Further, due to intense cell division, cell volume decreased to 5 700 µm^3. As a result, the maximum cell numbers (500 000 cells/l) observed in August did not coincided with the maximum biomass.

In general, for the period 2008-2014 there were no obvious trends in phytoplankton blooms in the north-eastern shelf. Some authors found an increasing bloom of coccolithophores in the bays of Caucasian coast (Yasakova et al., 2017). The data reported here did not reveal the same trend. In the shelf and near-shelf open waters the meteo- conditions of a year were responsible for the development of these plankton algae. Therefore, trend in coccolithophore blooms is determined by weather or climate change. The current 7-year period of observations is too short to trace these changes.

Along the Odessa coastal waters in 2008, the May blooms were formed by Cyanophyceae species (*Merismopedia* sp. – 46.5% from the total abundance, 9.1% - from the biomass), Chlorophyceae species (*Monoraphidium contortum* (Thur) Kom. -Legn.; *Coenococcus planctonicus* Korsch.- 33.2% & 4.5% respectively) and Bacillariophyceae (*Thalassiosira baltica* (Grunow in P.T. Cleve , Grunow) Ostenfeld – 18.3%, 29.5%). In June the bloom was initiated by the small- size Cyanophyceae (*Microcystis sp.; Microcystis aeruginosa* Kütz -. 94% & 38%) (Table 1.3.2.5e).

Analysis of the average surface water temperature in the Odessa coast has showed that in the last decade it has increased by 1.7 °C. While no significant relationship was reported between average annual temperature and average annual values of abundance, biomass, and the index of coastal phytoplankton (Minicheva et al., 2010), the variability of abiotic factors and their anomalies seem to cause much stronger responses in algal communities. In the last decade, due to climate change, the frequency and strength of weather anomalies have increased. As an example, a high degree of weather anomalies in the NWBS was observed in 2010. Precipitation exceeded the annual by 200-350%, and temperature in August was above normal by more than 5 times. Climatic conditions in 2010 radically changed the morphology and function of the phytoplankton communities of the Odessa coast. As a result of the temperature anomaly in summer 2010, the entire area of the NWBS was covered by a bloom of cyanobacteria *Nodularia spumigena* Mertens ex Born. Et Flah. It was the first case of a water bloom caused by *Nodularia spumigena* in the Black Sea. Mass development of the species was observed in mid July 2010 at 24.9–27.0° C SST temperature and 12.9–14.5 salinity. The maximum abundance of the species in the bloom patch was $585.6 \cdot 10^6$ of filaments (conventional units with length 100 μm)/l, and biomass – 6.2 kg/m^3 (Alexandrov et al., 2010). This abnormal biomass of the cyanobacteria accounted for the maximum average biomass in 2010 and the max observed during the entire period 2008-2013 (Fig. 1.3.2.28). Yet in the long-term context the most significant changes concern the biomass of phytoplankton. While during the period of "intensive eutrophication" it increased 16.5-fold (from 1.03 to 17.02 g/m^3), since 2000 to 2010 surface phytoplankton biomass had decreased 14 times (Minicheva et al., 2013).

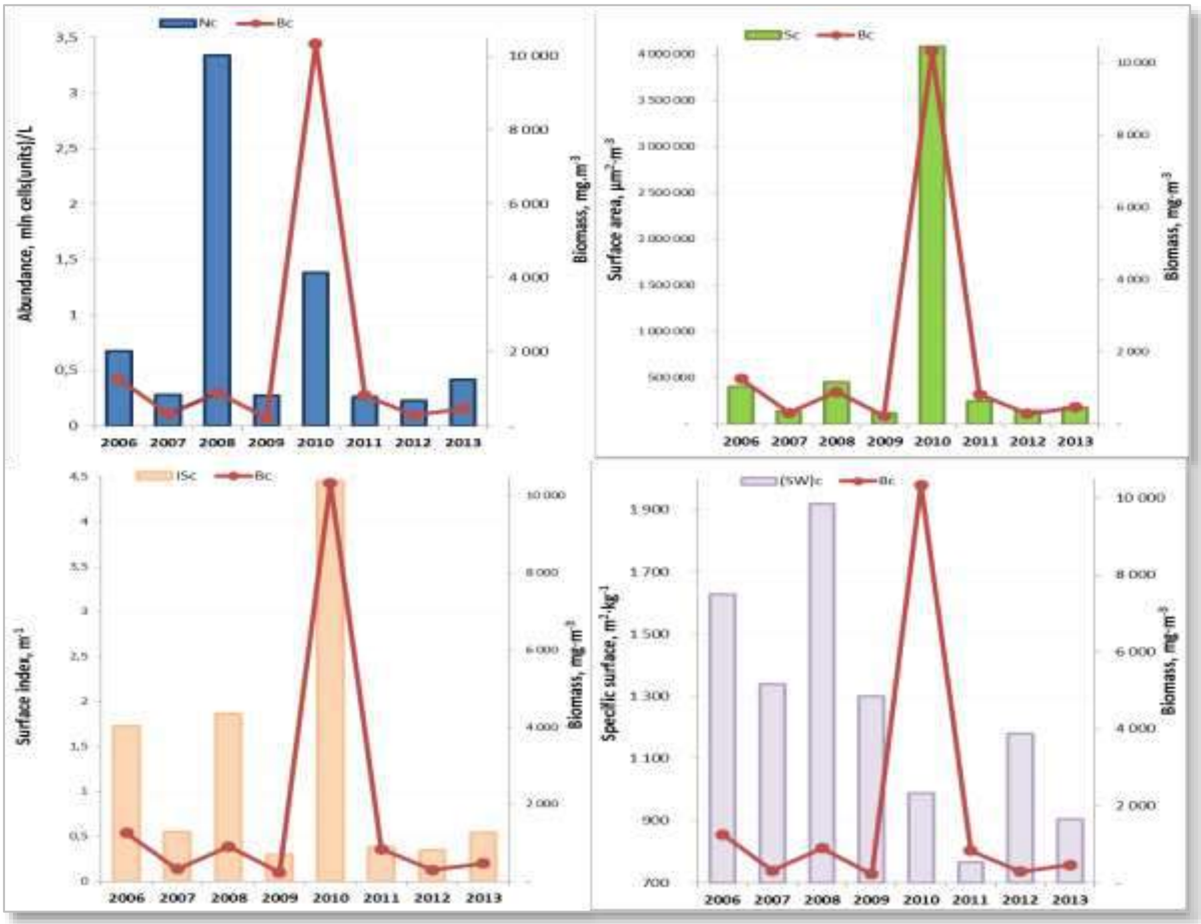


Figure 1.3.2.28. Interannual variability of the abundance (Nc, 1x10^{6}cells/l), biomass (Bc, mg/m^3), surface area (Sc, μm^2/m^3), surface index (ISc, m^{-1}) and specific surface ((SW)c, m^2/kg^1) of the of phytoplankton communities of the Odessa coast (2006-2013)

In 2010 maximum values were recorded for the morphofunctional indices of phytoplankton assemblages - surface area (Sc) and surface index (ISc) (Fig. 1.3.2.28), which has been accompanied by a decrease in the community specific surface ((SW) c), a trend which continued in 2011.

In the area of Zmiiniy island phytoplankton community over the last seven years exhibited some peculiar characteristics such as the increase in maximal abundance and biomass for the species *Cerataulina pelagica* (summer 2013), *Chaetoceros curvisetus* (Spring 2014), *Skeletonema costatum* (Spring 2012) etc., which exceeded significantly (10-100 times) the maxima of previous years. During 2012-2014 diatoms manifested a trend towards extension of the periods of maximal development in spring and summer.

Among dinoflagellates *Heterocapsa triquetra* and *Lessardia elongata* (1150x10^3cells/l produced a bloom (spring of 2008) and among Cyanobacteria short-term blooms of *Microcystis aeruginosa* and *M. viridis* occurred in spring 2009 (12.6x10^6 cells/l). The massive *Nodularia spumigena* bloom was also observed in the coastal waters of the island, brought in by notherly winds (Fig. 1.3.2.29).

Figure 1.3.2.29. Fragment of MODIS Aqua space image with fields of *Nodularia spumigena* blooms (July 2010) in the in North-western part of the Black Sea from Dnieper estuary till Zmiinyi island

Over the period 2008-2014 Haptophyta species (*Emiliania huxleyi, Acanthoica, Rhabdosphaera, Syracosphaera*) abundance varied within 2–1900 10^3cells/l, while the blooms were occasional, except in October 2012, when a bloom of *E. huxleyi* was observed (2.940x10^6 cells/l). The increase in the total number of harmful Dinophyta species, which originated from other parts of the sea, is also raising a concern since adaptation of these species to the island coastal water conditions could impair ecosystem’s trophic structure and fuction (Ryabusko, 2003; Dereziuk, 2012).

In **Turkish waters** high abundance of *Emiliania huxleyi* (5x10^5 cells/l) in April and 4.6xx10^5 cells/l, *Proboscia alata* (2x10^5 cells/l) in October were observed in 2008 *Pseudonitzshia delicatisima* (6.6x10^5 cells/l) in April was the most important species for 2009. Spring high densities of diatoms *Proboscia alata*, *Pseudosolenia calcar-avis*, *Pseudo-nitzschia pungens* were observed in 2010 with numerical abundance about 3x10^5 cells/l. A high cell density of coccolithophore *E. huxleyi* was observed in November (2x10^5 cells/l).

The blooms species were *Emiliania huxleyi* (1.17x10^6 cells/l), *Ceratium furca* (11.4x10^5 cells/l), *Heterocapsa triquedra* (7x10^5 cells/l) and *Pseudonitzshia delicatissima* (6.92x10^5 cells/l), *Nitzshia longisima* (5.7x10^5 cells/l) in spring 2013. During the summer 2013 *Heterocapsa rotundata* (1.1x10^5 cells/l), *Protoceratium reticulatum* (1.25x10^5 cells/l) Prorocentrum micans (1.45x10^5cells/l), *Cerataulina pelagica* (2x10^5cells/l), *Thallassionema* *nitzschioides* ($5.3x10^5$ cells l-1), *Pseudonitzshia delicatissima* ($2.4x10^6$ cells/l) were dominant in the community.

Ecological state evaluation (WFD)

The ecological status of coastal waters (WFD) in RO and BG was assessed by the Integrated Biological Index (IBI) (Moncheva S., L. Boicenco, 2011/Com Dec. 2013). The composite indicators in IBI algorithm for final ecological status of coastal water bodies are: density (cells/l), biomass (mg/m^3), taxonomic indicators –(Microflagellates+Euglenophyceae+ Cyanophyceae (MEC, %), heterotrophic dinoflagellates (DE, %), biodiversity indicators Menhinick and Sheldon and chlorophyll *a* (mg/m^3).

After applying IBI for the period 2011-2014, out of the 31 stations analyzed, 12 were found in the "good" category, 7 - in "moderate" and just one station in category "poor", which confirms the recovery trend of the coastal ecosystem environmental status of the Romanian Black Sea waters recorded in recent years (Fig. 1.3.2.30).

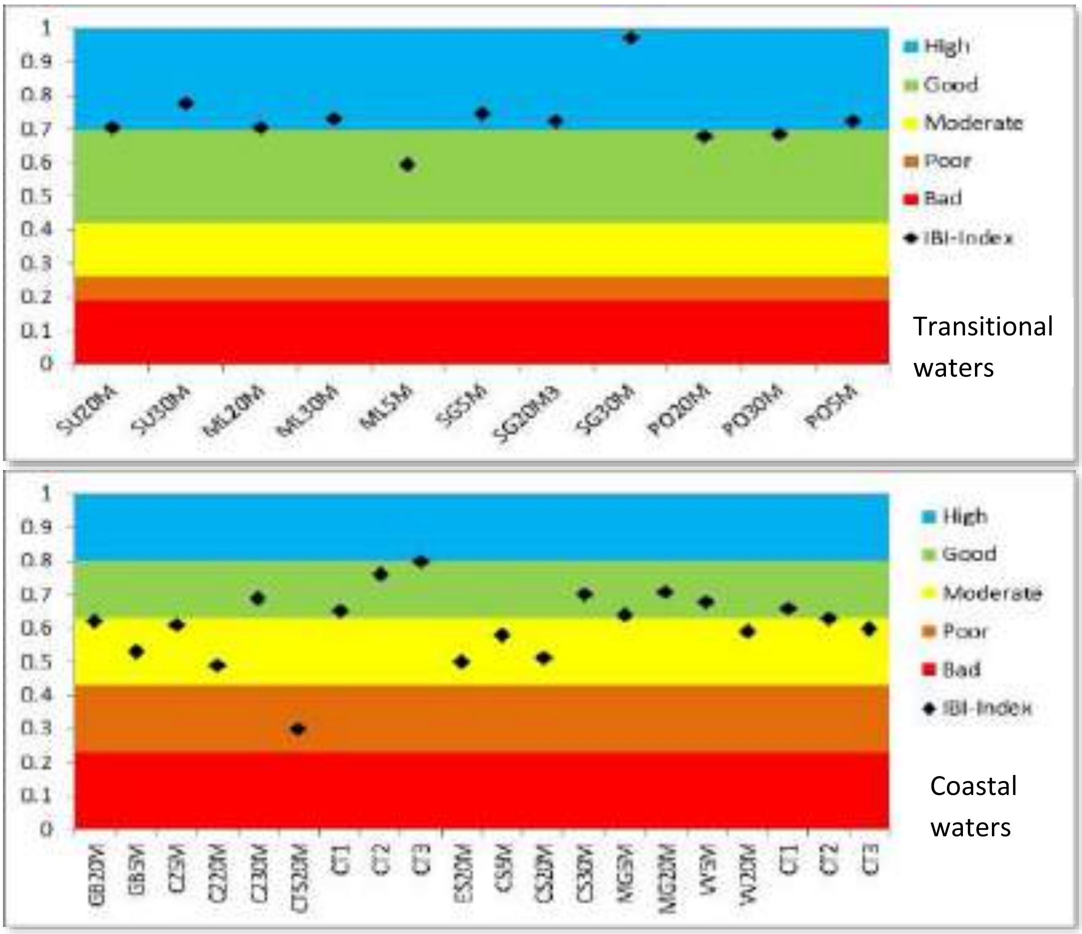


Figure 1.3.2.30. Ecological quality status of coastal waters based on phytoplankton Integrated Biological Index (IBI) between 2011– 2014 in RO waters (color codes according WFD)

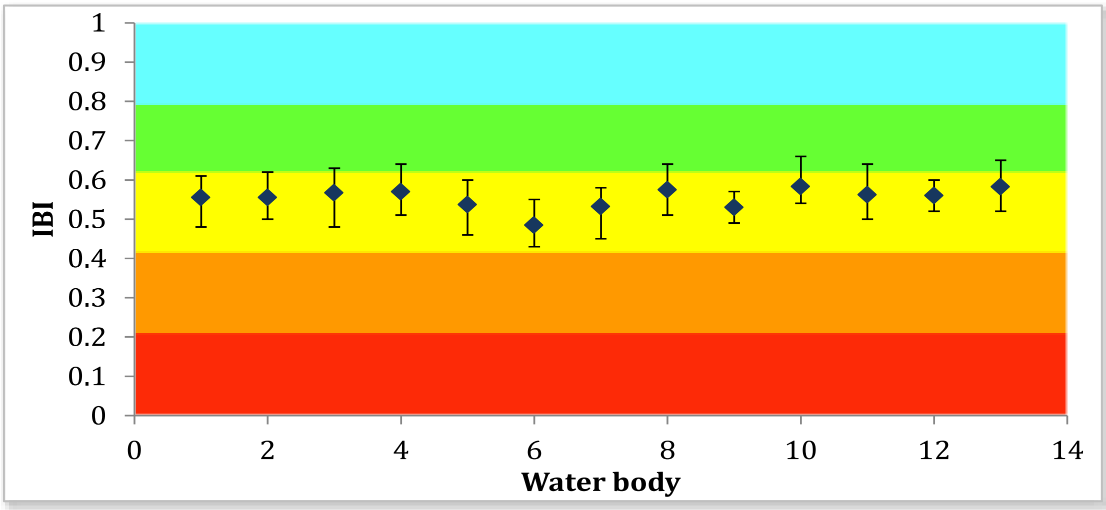


Figure 1.3.2.31. Ecological quality status of BG coastal water bodies based on phytoplankton Integrated Biological Index (IBI) between 2011– 2014 (color codes according WFD)

Similarly out of 13 coastal water bodies in the Bulgarian coastal waters between 2011-2014, the ecological status of 12 WB varied between moderate-good and only one (Varna Bay) between moderate-poor (Fig. 1.3.2.31).

1.2.1.1-7. Basin scale major trends for the period 2008-2014

For the period 2008-2014 the common features of phytoplankton community diversity at basin scale were increased species richness - the highest shared by diatoms and dinoflagellates with an increased contribution to biodiversity of the taxonomic classes Chlorophyceae, Cyanophyceae, Cryptophyceae and Prymnesiophyceae, yet the results of molecular analysis call for a wider application in the Black Sea monitoring especially regarding the taxonomic identity of potentially toxic and cryptic species.

The detailed analysis of phytoplankton comunity traits by countries show a common trend of reduction of all indicator-parameters (Table 1.3.2.7).

Table 1.3.2.7. Trends of phytoplankton parameters/indicators during 2008-2014

Parameters - BS State	BG	GE	RO	RU	TR	UA
Phytoplankton biomass (seasonal trends)	↘	↘	↘	↘		↘
Phytoplankton abundance (seasonal trends)	↘	↘	↘	↘		↘
Max concentration of blooming species	↘	↘	↘	↘		↘
Diatoms/Dinoflagellates biomass ratio (only for spring)	→					

Based on the data available it is not possible to plot a reliable spatial basin-scale assessment map, as the averages cover hardly comparable habitats (transitional, coastal and marine in RO, coastal and shelf in RU, transitional in UA, coastal in GE and coastal, shelf and open sea in BG) (Fig. 1.3.2.32). As expected the maximum values observed were associated to riverine flow (UA, RO and GE) more pronounced in spring, it is noteworthy to underline the relatively high abundance and biomass also in summer, including summer blooms, but in much lower amplitude and frequency as compared to the period of intensive anthropogenic eutrophication. In addition to the common for the entire basin dominant/blooming species, there were regional differences associated to both riverine impacts (contribution of freshwater species) and local land based specific pressures.

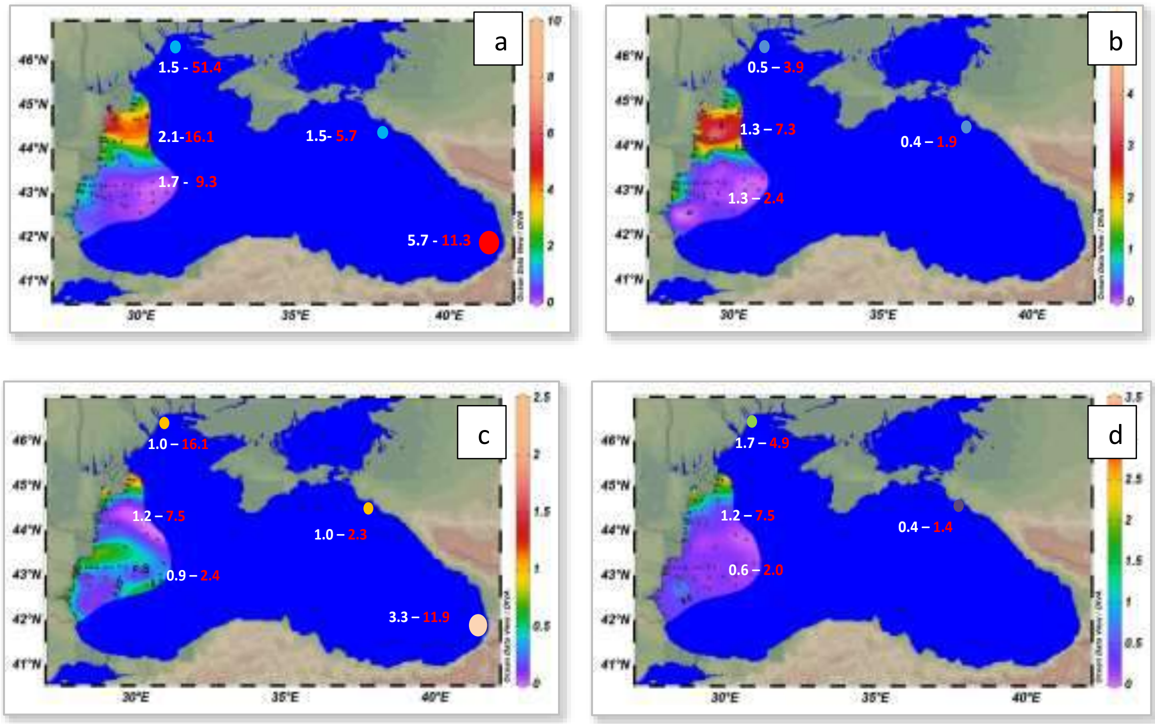


Figure 1.3.2.32. Spatial distribution of phytoplankton abundance (10^6 cells/l) and biomass (g/m^3) in spring (a, b) and summer (c, d); the numbers in white denote averages and in red- maximum values (based on data in Table 1.3.2.4).

The inherent feature of phytoplankton composition and abundance, a high spatio-temporal natural variability is a function of multiple drivers - both top-down and bottom up controls, physical, chemical, and biological parameters, such as hydrodynamics and circulation, light, nutrient availability and their stoicheometry, temperature and salinity, and biotic interactions to which the responses are non-linear, although different controlling mechanism operate in coastal, shelf and open sea waters. While coastal phytoplankton communities are mostly affected by the intensity of local land – based anthropogenic pressures (municipal and industrial discharges, recreational activities, alteration of coastal biotopes etc.) and regional (nutrients loads of river discharge; invasion of alien species) in synergy with global climatic changes (increased temperature and frequency of weather anomalies), in the shelf, especially in the North-Western Black Sea the pattern of growth and distribution is affected by the features of lateral transport and the interplay with the main Black Sea current and the position and intensity of quasipermanent eddies located in the area, the cross-shelf exchange being an important driver of the biodiversity and variability of the basin ecosystem associated to the transfer of nutrient conditions from the shelf to the deep sea. The eddy horizontal advection of nutrients can play a major role in conditioning the state of the Black Sea ecosystem on interannual time scales compared with a vertical entrainment of nutrients via winter convective mixing as a major mechanism preconditioning phytoplankton dynamics in the open sea.

In the coastal/shelf waters of NW Black Sea the reduction trends of phytoplankton indicator traits could be associated to the relative decline of nutrients loads introduced by the big rivers (Danube, Dnieper, Dniester and Southern Bug). The data show that nutrient loads into Danube river compared to ones of eutrophication period (1970th-1980th) decreased by 5-10 fold for PO_4, NO_2, NH_4 and by 1,5 fold for NO_3 associated to nutrients emission reduction by 12 % for N, 34% for P and for organic matter (BOD5) about 50% (DANUBE Declaration, 2016) that resulted in relative reduction of nutrients input into the Black Sea, more pronounced after 2000 (EMBLAS II Reports-Eutrophication,2017). Trends of some nutrients and the river flow decline are reported also for the rivers Rioni, Chorokhi and Ajaristskhali along the Georgian coast especially after 2010, but the rate of reduction is not uniform for the different nutrient species. Riverine nutrients loads still represent one of the major source of eutrophication (Kresin et al., 2014) along with the municipal discharges and various anthropogenic activities that define localities of ecological risk along all Black Sea coastal waters (HOTSPOT Project, http://bs-hotspots.eu/). It was noted the risk of not achieving the target values for GES of Romanian Black Sea waters in the context of eutrophication in transitional waters (due to phosphates) and coastal and marine waters (due to inorganic nitrogen). These higher levels were associated to both riverine and land-based anthropogenic influence and extreme climate phenomena (Nicolaev et al, 2015). In Bulgarian coastal waters phytoplankton extremes were also associated with local anthropogenic pressures (Varna Bay) and global/regional climatic impacts (Moncheva et al, 2012, 2015). Recently it was found that the amplitudes of a seasonal cycle of current velocity variability from 2002 to 2012 were two times higher than the amplitudes from 1998 to 2001, the reduction of the eddy horizontal transport and cross-shelf exchange causing a significant decline (~25%) of the surface chlorophyll a concentration in the shelf/open Black Sea after 2002 (Kubryakov et al., 2016) caused by a more organised basin-scale circulation,which decreases the number of mesoscale eddies and strengthens the frontal barrier between the coastal waters and deep sea waters. During a period of intense mean currents from 2002 to 2013, the Black Sea dynamics show a distinct quasi-biannual signal: 2003, 2006, 2008, 2010, and 2012 are characterised by significantly more intense winter circulation compared with 2002, 2004, 2005, 2007, 2009 and 2011. Thus, the variability of the cross-shelf transport may serve an important role in regulating the nutrient fluxes and the state of the basin ecosystem in different trophic stages, that affect phytoplankton development, explaining the pattern of interannual and interseasonal phytoplankton variability along the NW shelf (Fig. 1.3.2.32). In the open sea the alteration of cold/warm winters regime was reported to affect the succesion of phytoplankton taxonomic composition and alternative blooms of diatoms/coccolithophores in spring and diatoms proportion in summer-autumn (Mikaelyan et al., 2011, 2015, 2017, Churilova et al., 2017). Climate warming observed during the last 25 years and the associated decrease of frequency of cold winters most likely resulted in a decline of the annual phytoplankton standing stock in the open sea (Mikaelyan et al., 2017) and reduction of primary productivity by ~ 15-20% (Yunev et al., 2016).

The analysis suggest that during 2008-2014 phytoplankton dynamics was strongly controled by climate variations, and even if the reduction of phytoplankton abundance and biomass, including blooms could be considered a positive sygnature of ecological state improvement as a response to the relative nutriens loads reduction, these trends should be treated in the context of climatic variability. Increasing frequency of global climate anomalies becomes an important driver that may considerably change the rate of environmental processes and structural-functional organization of phytocoenoses of the NW Black Sea (Minicheva et al., 2013).

Given the high interannual variability and the lack of systematic harmonized basin-scale integrated monitoring and the fact that at this stage there are no defined threshold for Good environmental status (GES), not ignoring the positive trends in phytoplnakton communities, yet the answer to the question how far is the ecosystem to achieve GES (related to phytoplankton) remains uncertain.

1.2.1.1-8. Gaps and recommendations

- The analysis of available data underline the need for adequate monitoring frequency and extent to capture the natural time-spatial variability of phytoplankton communities as a prerequisite to further advance our understanding of the associated key drivers. During the observed 7-year period most of research activities were conducted in the coastal - shelf waters, while the vast deep sea area including all eastern part was not covered by observations. This is a crucial problem for understanding phytoplankton development of the deep basin as the patterns and drivers there differ from those in coastal regions. Joint international programs like PERSEUS, MISSIS or EMBLAS-II which support field observations in the sea interior are strongly recommended for implementation in the Black Sea region. A concerted integrated monitoring program would be essential for the adequate assessment of phytoplankton community basin scale patterns.
- There is a lack of advanced genetic and genomic investigations for taxonomic revisions especially critical for phytoplankton potentially toxic species. There is not enough knowledge of the capacity of Black Sea harmful algae to produce toxins and their biogeography, a lack of official statistics on possible phycotoxin poisonings due to lack of targeted monitoring.
- Despite the Black Sea regional initiatives such as Black Sea GOOS (ARGO floats and other drifters in the Black Sea), the bio-ecological operational oceanography is still poorly developed and the results inefficiently explored.
- The results of the intercalibration exercises (MISIS and EMBLAS II Projects) call for more frequent ring tests and intercalibration campaigns in order to improve the comparability of generated data as an important prerequisite for adequate ecological state assessment at basin-wide scale
- Satellite-borne remote sensing is crucial in providing the necessary spatio-temporal scales of observation required to proper measure and understand phytoplankton time-spatial patterns of distribution and variability and overcome scale mismatches, options that should be more efficiently exploited and employed in the Black Sea regional monitoring. However the importance of in situ data should not be ignored as they prove essential for validation and thus the advance of the new emerging technologies.
- Infrastructure improvements and effective introduction of less applied approaches such as remote sensing, dron observations, Continuous Plankton Recorders, Ship of opportunity / FerryBox system, should be considered as overarching and critical issues for better understanding phytoplankton dynamics and implementation of relevant monitoring practices.
- In the context of global climate change it is now recognised that a partition of the marine phytoplankton species pool into a suite of functional types (PFT), would increase our understanding of the role of phytoplankton in the global carbon cycle and biogeochemistry, thus incorporation of PFTs into the monitoring programs and

biogeochemical models may improve our predictive capabilities and the capacity for a better ecosystem management.

- Integration of pressure data (fluxes of nutrients from various sources including non-point sources) and relevant meteorological information would be crucial for the adequacy of the assessments.

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1.3.2.1. Algae: Species Composition

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Species belonging to eleven classes of algae (Bacillariophyceae, Dinophyceae, Chlorophyceae, Cryptophyceae, Cyanophyceae, Dictyochophyceae, Ebriophyceae, Euglenoidea, Prymnesiophyceae, Pyramimonadophyceae and Trebouxiophyceae) have been recorded. A total of 204 species was determined in which Bacillariophyceae was represented by 41 genus and 84 species; Dinophycaeae by 24 genera and 102 species; Chlorophyceae by 2 genus and 2 species, Cryptophyceae was represented by 1 genera and 1 species, Cyanophyceae was represented by 6 genera and 6 species, Dictyochophyceae was represented by 2 genera and 3 species; Ebriophyceae e was represented by 1 genera and 1 species; Euglenoidea was represented by 2 genera and 2 species; Prymnesiophyceae was represented by 1 genera and 1 species; Pyramimonadophyceae was represented by 1 genera and 1 species and Trebouxiophyceae by 1 genus and 1 species.

Among these classes, Dinophycaeae was found to be dominant in terms of number of species. From the total number of species, 50% was represented by dinoflagellates, 41% by diatoms and the remaining 9% by the other classes.

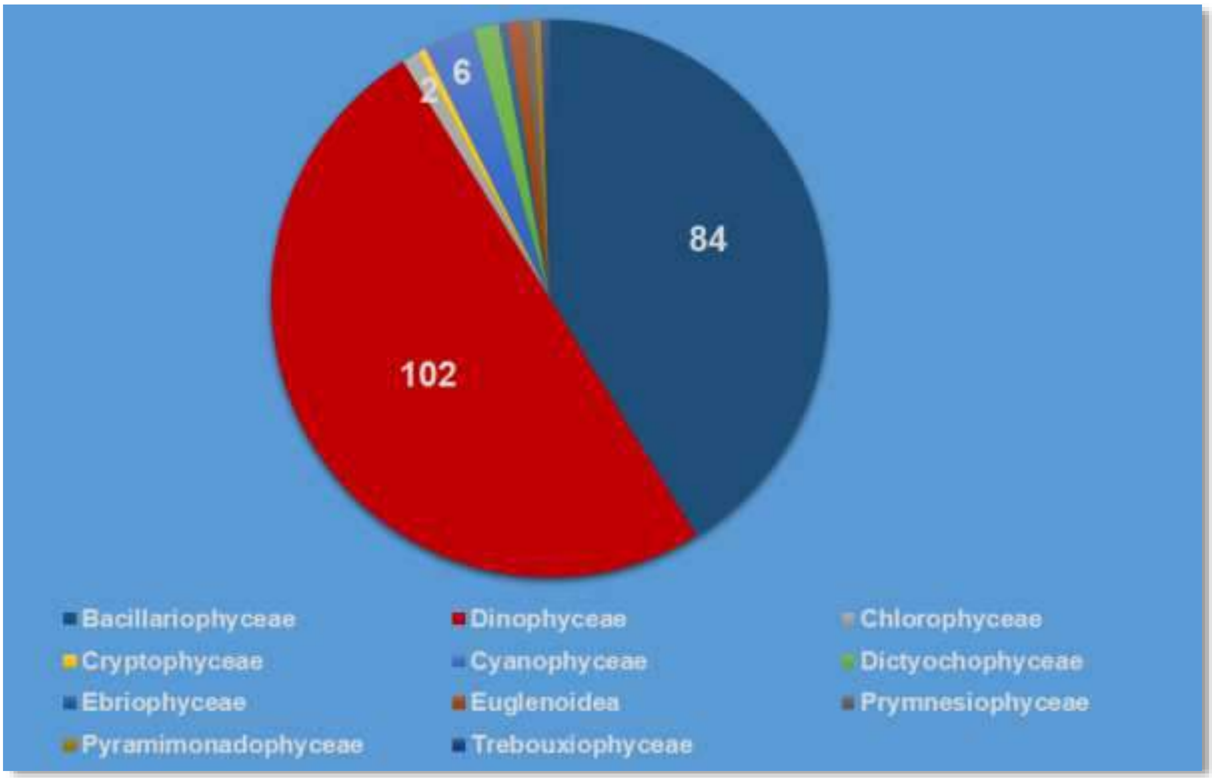

Figure 1.3.2.1.1. Number of species distribution of phytoplankton classes sampled in 2008-2014.

Trends in phytoplankton blooms

Bloom of *Emiliania huxlei* ($5x10^5$ cells l^{-1}) in April and 4.6 x $x10^5$ cells l^{-1} *Proboscia alata* (2 $x10^5$ cells l^{-1}) in October were observed in 2008.

Pseudonitzshia delicatisima (6,6 $x10^5$ cells l^{-1}) in April was the most important bloom species for 2009 season.

Spring bloom of diatoms consist of *Proboscia alata*, *Pseudosolenia calcar-avis*, *Pseudo-nitzschia pungens* in 2010. Their cell numbers were about $3x10^5$ cells l^{-1}. The bloom of coccolithophore *E. huxleyi* was in November and their cell concentration was approximately 2 $\times$ 10^5 cells l^{-1} in the same yeas.

The blooms species were *Emiliania huxlei* ($1.17x10^6$ cells l^{-1}), *Ceratium furca* (11.4 $x10^5$ cells l^{-1}), *Scrippsiella triquedium* ($7{,}2x10^5$ cells l^{-1}) *Heterocapsa triquedra* 7× 10^5 cells l^{-1} and *Pseudonitzshia delicatessima* ($6{,}92x10^5$ cells l^{-1}), *Nitzshia longisima* ($5{,}7\times10^5$ cells l^{-1}) in spring 2013. During the summer 2013 period *Heterocapsa rotundata* ($1.1x10^5$ cells l^{-1}), *Protoceratium reticulatum* (1,25 × 10^5 cells l^{-1}) *Prorocentrum micans* (1,45 × 10^5 cells l^{-1}), *Cerataolina pelagica* (2 x 10^5 cells l^{-1}), *Thallassionema nitzschioides* (5.3 x10^5 cells l^{-1}), *Pseudonitzshia delicatissima* (2,4 x10^6 cells l^{-1}) were the bloom species.

1.3.3 Mesozooplankton

[1]Kremena Stefanova, [1]Elica Stefanova, [1]Valentina Doncheva, [2]Marina Mgeladze, [2]Mary Khalvashi, [3]Elena Arashkevich, [3]Anastasia Amalina, [4]Alexandra Gubanova, [5]A. Muzaffer Feyzioglu, [6]Ilknur YILDIZ, [7]Funda Üstün, [8]Boris Alexandrov, [8]Ruslana Migas, [8]Vladimir Adobovskiy, [9]Svetlana Kovalishina, [9]Dmitriy Dudnik

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Introduction

The previous report on the state of the Black Sea ecosystem covered the period 2001-2006/7 (BSC, 2008). In this regard, present report also included data for 2007-2008. Unfortunately, data on the state of mesozooplankton in the Romanian shelf area were not provided and were not included in this report. The characteristics of the state of zooplankton of the Romanian waters in comparison with the data obtained on the shelf of Bulgaria and Turkey can be found for the investigated period for the summer of 2013, when the integrated international expedition to the EU MISIS project (MISIS Joint Cruise Scientific Report, 2014) was carried out.

Since the distribution of plankton is significantly influenced by the volume of river runoff, which have significant interannual fluctuations, the dynamics of hydrometeorological elements in the northwestern part of the Black Sea (NWBS) for the period 2007-2014 was presented. This attention was paid to NWBS due to the fact that 84.6% of the total river flow of the Black Sea flows here (Zaitsev, 2008) to the Danube, the Dniester, the Dnieper and the Southern Bug.

The average annual volume of river flow to the NWBS from the Danube, Dniester and Dnieper-Bug Estuary (DBE) was 260 km^3. Of the total volume, the share of the South Bug was 0.8%, the Dniester 3.7%, the Dnieper 15.5% and the Danube 80.0% (data on river runoff were provided by the Danube Hydrometeorological Observatory - DHMO and the Mykolaiv Regional Hydrometeorological Center – MRHMC). Changes in river runoff in 2007-2014 occurred basically synchronously, with the peak of the maximum flow in 2010, significant decrease in 2011-2012 and overall growth in 2013-2014. However, if the runoff of the Danube in 2013-2014 were 226-227 km^3, the runoff from the DBE varied from the maximum (56.76 km^3) in 2013 to the minimum (31.84 km^3) in 2014 (Fig. 1.3.1.1).

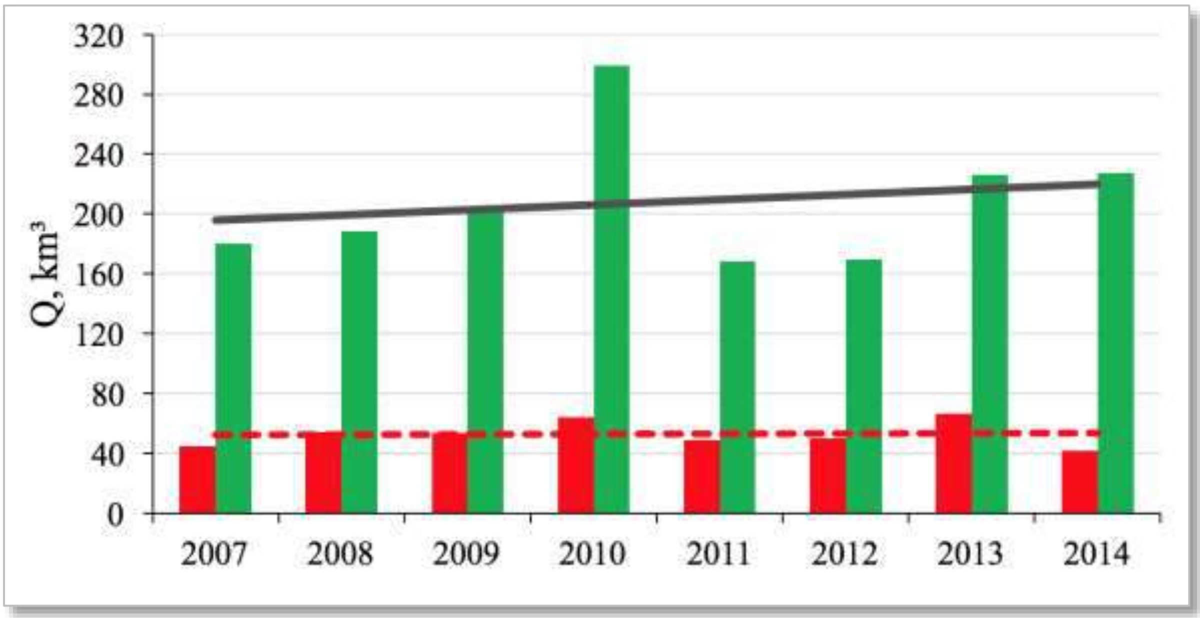


Figure 1.3.3.1. The course of annual values of the rivers runoff in 2007-2014 (data of DHMO and MRHMC).

Note. South Bug, Dniester and Dnieper - in Red, Danube - in Green.

In 2010, due to the large amounts of precipitation in river basins (https://rp5.ru/weather archive in Odessa), the total annual runoff of rivers was 360 km^3, which is 1.4 times higher than the average value for the period 2007-2014. The bulk of the water with the Danube drain enters the sea in the first and second quarters of the year, but there are exceptions: in the fourth quarter of 2014, the runoff was even greater than in other periods of this year (Fig. 1.3.3.2).

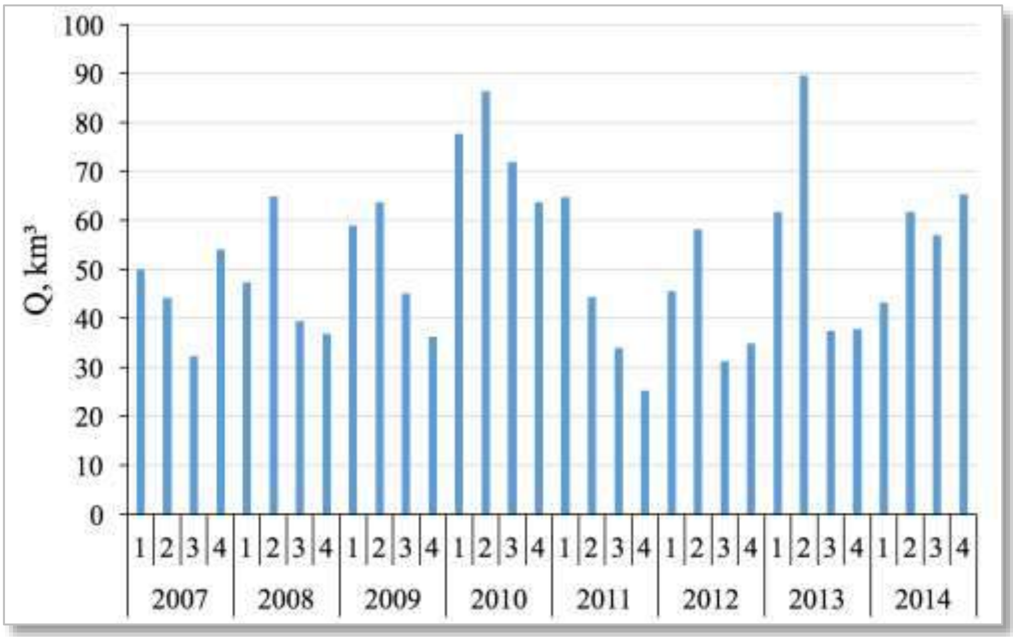


Figure 1.3.3.2 Distribution of the Danube discharge (Q) by quarters in 2007-2014 (data of DHMO).

The water temperature in the coastal zone of the sea has a well-defined seasonal character with maximum values in August and minimal in February. The course of the mean values of the surface water temperature for the year has a tendency towards growth since the beginning of the 21st century. According to the results of observations of the Marine Geophysical Laboratory of the Odessa State Environmental University (MGL OSEU) for the period 2007-2014 the maximum annual temperature of water is 13.6° C in 2010, which is 1.1° C above the average (12.5° C) in the first 16 years of this century (Fig. 1.3.3.3).

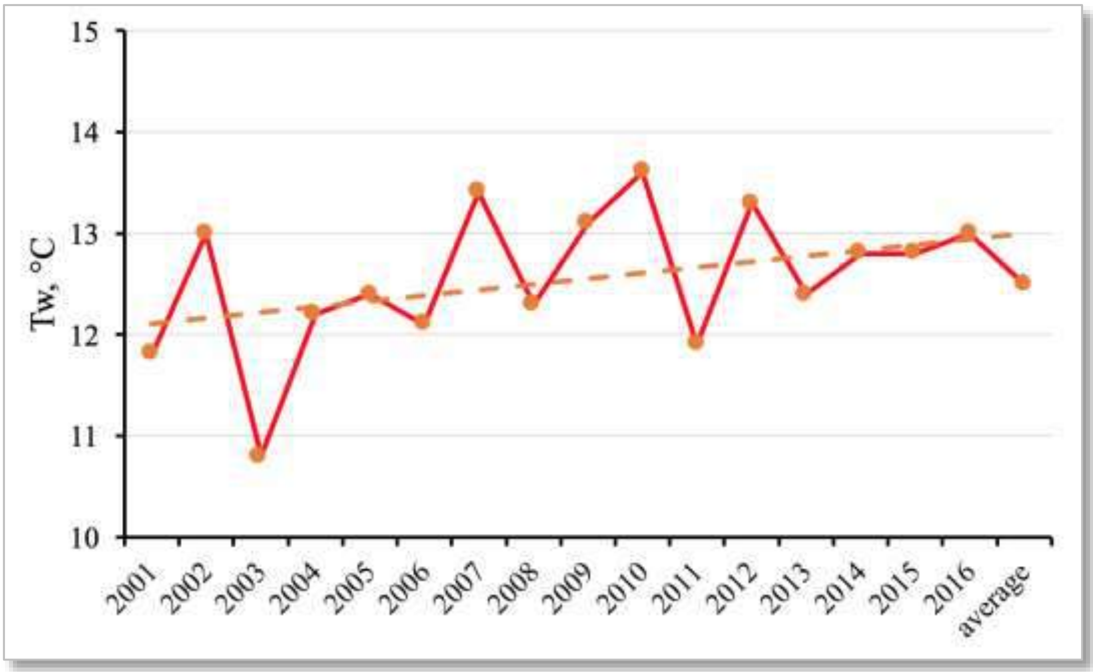


Figure 1.3.3.4. The course of average values of the water temperature in 2001-2016 (data of MGL OSEU).

Similar results in the long-term dynamics of the upper layer temperature were obtained in the study of the northeastern part of the Black Sea in the period 2005-2014 (Fig. 1.3.3.4).

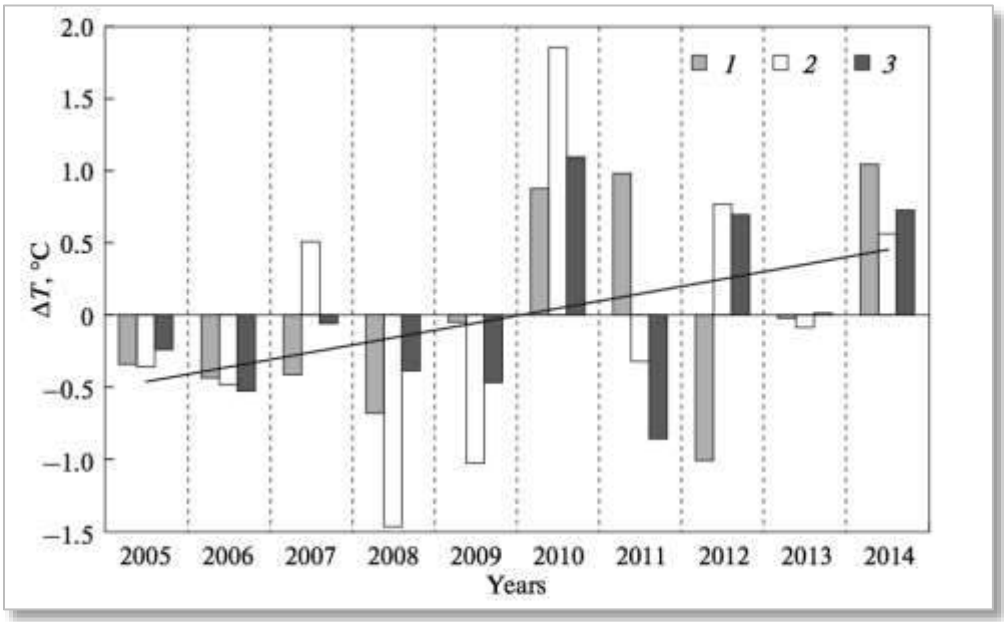


Figure 1.3.3.4. Shifts in sea surface temperature (ΔT) from the average values for 2005-2014: (1) winter temperature; (2) summer temperature; and (3) annual average temperature. Line shows linear trend of annual average temperature (Arashkevich et al., 2015).

The salinity of water is largely determined by the amount of fresh water entering the sea with river runoff, the average salinity value of the surface layer in 2007-2014 was 13.21 ‰, which practically differs from the average (13.51 ‰) for 2001-2016. Danube runoff in 2007-2014 had a weak tendency to increase, while the total runoff of other rivers flowing into the NWBS, there was no tendency to change their volumes (see Fig. 1.3.3.1). Wind regime which has a great influence on the distribution and transformation of fresh waters in the sea had significant changes in 2007-2014. According to the data of the Hydrometeorological Center of the Black and Azov Seas (Odessa) during this period the frequency of south winds (S, SE, SW) decreased from 44% in 2007 to 29% in 2017, and the frequency of winds of the 1st quarter (N, NE, E) increased from 26% to 43%. In this case the frequency of winds with W and NW remained at the same level, amounting to about 30% (https://rp5.ru/weather archive in Odessa). There is a great difference in wind speeds in different parts of the NWBS. In 2007-2014 years. The average for the period value of wind speed in the area of Odessa was 2.9 $m \cdot s^{-1}$ (https://rp5.ru/weather archive in Odessa), and in the Sulina area it is 2 times larger - 5.9 $m \cdot s^{-1}$ (https://rp5.ru/weather archive in Sulina). During this period, there was no decrease or increase in the average values of wind speeds at both points of observation.

1.3.3.1. Bulgarian shelf area

The study area was restricted to Bulgarian Exclusive Economic Zone (Fig. 1.3.3.5) locked between min. lat: 41° 58' 41.5'' N (41.9782), min. long 27° 26' 58.5'' E (27.4496°) and max. lat 43° 44' 52'' N (43.7478°), max. long 31° 20' 43'' E (31.3453°). Twenty eight surveys were conducted in the frame of multidisciplinary oceanographic cruises within various projects and programmes during the spring-summer-autumn period 2007-2014. Detailed information on the sampling stations is given in Table 1.3.3.1, 1.3.3.2. Three pelagic habitats were under consideration: coastal (< 30 m), shelf (30-200 m) and open sea (>200 m) distinguished according to the Initial Assessment report of Bulgaria (Moncheva, Todorova et al., 2013).

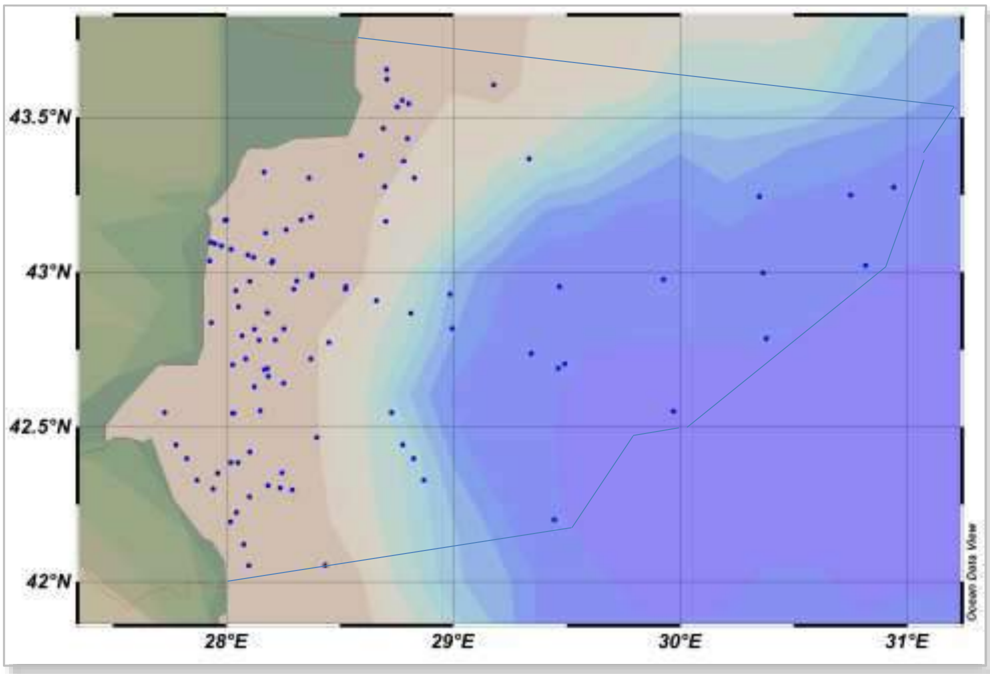


Figure 1.3.3.5. Location of stations corresponding to the sampling programmes during the monitoring exercises in 2007-2014.

A total of 671 zooplankton samples were collected from 154 monitoring stations in 2007-2014 (Tables 1.3.3.1, 1.3.3.2). Samples were collected by vertical plankton Juday net, 0.1 m^2 mouth opening area, 150 μm mesh size, from 2 meters above the bottom or oxygen minimum zone to the surface at integral sampling layers or districted layers depending of water stratification and thermocline depth (Alexandrov et al., 2015). Before sample preservation, the gelatinous species (*Aurelia aurita, Pleirobrachia pileus, Mnemiopsis leidyi, Beroe ovata*) were removed, rinsed, measured and counted on board (Shiganova et al., 2014). The samples were preserved in final 4% formalin solution buffered to pH 8-8.2 with disodiumtetraborate (borax) ($Na_2B_40_3 \cdot 10\ H_20$) (Alexandrov et al., 2015). In the laboratory, the samples were settled before being divided into sub-samples. Bogorov's chamber was used for quantitative assessment (abundance and biomass calculation) and qualitative (taxonomic structure) processing of sub-samples (Alexandrov et al., 2015). The sub-samples were examined by using an Olympus SZ30 Stereoscopic Zoom Microscope. Species were identified according to Morduhay-Boltovskoy (1968, 1969, 1972) manuals. Biomass values as wet weight were estimated based on the number of individuals and the individual weight given per taxon and size class in Petipa (1959).

Table 1.3.3.1. Sampling inventory and data sources

Year, Date	**Number of stations**			**Data source (Programme, Project)**
	coast	shelf	open sea	
2007, 29.05.2007	3	1		GEF
2007, 05-08 October	1	2	2	SESAME Project
2008, 16-21 April	3	6	4	SESAME Project
2008, 10-12 June	2		1	SESAME Project
2008, 29 September - 4 October	3	6	4	SESAME Project
2009, 04-19 May	4	5	3	JRC-NATO

Year, Date	Number of stations			Data source (Programme, Project)
	coast	shelf	open sea	
2009, 05-11 June	5	5	5	National Monitoring
2010, 19-29 June		17		Data collection *Sprattus sprattus*
2010, 17 August	7			National Monitoring
2010, 07-12 December		5		Data collection *Sprattus sprattus*
2011, 09-15 September	6	7	10	National Monitoring
2011, 15-23 November	1	17		Bioacoustic of *Sprattus sprattus*
2012, 14-19 May	13	12	2	National Monitoring
2012, 07-12 June	13	12	2	National Monitoring
2012, 18-27 July	13	12	2	National Monitoring
2012, 14-20 August	13	12	2	National Monitoring
2012, 29 September - 04 October	13	12	2	National Monitoring
2012, 05-10 November	13	12	2	National Monitoring
2013, 23-30 June	11	9		National Monitoring
2013, 24-27 August	11	9		National Monitoring
2013, 26-29 September	11	9		National Monitoring
2013, 07-10 November	11	9		National Monitoring
2013, 26-29 July	1	3	2	MISIS Project
2014, 31 October - 07 November	1	21		Bioacoustic of *Sprattus sprattus*
2014, 29-31 May	5	1		National Monitoring
2014, 19-20 June	5	1		National Monitoring
2014, 14-17 July	5	1		National Monitoring
2014, 08-09 September	5	1		National Monitoring

Table 1.3.3.2.. Coordinates and depth of the routine monitoring stations.

STATION	LATITUDE	LONGITUDE	DEPTH, m
105	43° 37' 59.88"	29° 40' 0.12"	91
201	43° 22' 0.12"	28° 30' 0"	28
202	43° 22' 0.12"	28° 40' 0.12"	70
203	43° 22' 0.12"	28° 49' 59.88"	79
204	43° 22' 0.12"	29° 0' 0"	93
206	43° 22' 0.12"	29° 19' 59.88"	1100
302	43° 10' 0.12"	28° 10' 0.12"	23.5
303	43° 10' 0.12"	28° 19' 59.88"	41
304	43° 10' 0.12"	28° 30' 0"	78
305	43° 10' 0.12"	28° 40' 0.12"	92
306	43° 10' 0.12"	28° 49' 59.88"	352
307	43° 10' 0.12"	29° 0' 0"	1187
308	43° 10' 0.12"	29° 10' 0.12"	1542

STATION	LATITUDE	LONGITUDE	DEPTH, m
BG2BS00000MS001	43° 34' 51.96"	28° 36' 47.16"	22
BG2BS00000MS102	43° 31' 59.88"	28° 36' 24.12"	37
BG2BS00000MS002	43° 25' 27.48"	28° 33' 12.24"	27
BG2BS00000MS003	43° 22' 0.12"	28° 25' 0.12"	16
BG2BS00000MS104	43° 22' 45.12"	28° 11' 59.9994"	17
BG2BS00000MS105	43° 19' 30"	28° 5' 48.12"	17
BG2BS00000MS004	43° 10' 0.12"	28° 0' 0"	23
BG2BS00000MS005	43° 12' 6.12"	27° 57' 17.9994"	17
BG2BS00000MS006	43° 11' 6"	27° 56' 12.12"	16
BG2BS00000MS007	43° 1' 29.9994"	27° 54' 33.12"	19
BG2BS00000MS008	42° 46' 5.88"	27° 55' 33.5994"	30
BG2BS00000MS009	42° 40' 47.9994"	27° 46' 41.88"	22
BG2BS00000MS010	42° 30' 22.68"	27° 40' 19.92"	28
BG2BS00000MS011	42° 27' 47.88"	27° 31' 0.12"	17
BG2BS00000MS109	42° 38' 48.12"	27° 53' 12.12"	19
BG2BS00000MS012	42° 30' 1.08"	27° 48' 0"	36
BG2BS00000MS111	42° 25' 59.88"	27° 43' 21"	38
BG2BS00000MS110	42° 20' 10.32"	27° 49' 9.12"	47
BG2BS00000MS112	42° 8' 59.9994"	27° 54' 45"	47
BG2BS00000MS013	42° 4' 59.88"	28° 0' 0"	53

Species composition

The zooplankton community was featured by increased species diversity and richness during 2007-2014 relevant mainly to key ecological groups - Copepods, Meroplankton, Cladoceras (Fig. 1.3.3.6). A total of 58 species and forms were identified in the study area from 10 phyla (Mysozoa, Ciliophora, Cnidaria, Ctenophora, Rotifera, Annelida, Mollusca, Arthropoda, Chaetognatha, Chordata). Arthropoda was the most diverse – 28 species/taxa (49% of the total) among which subclass Copepoda (14 species) was represented by the highest variety and followed by Cladocera (7 species) and larvae forms of benthic organisms (7 species/taxa). During the all investigated period zooplankton community was represented by relatively rich species pool between 28 to 44 species/taxa per sampling cruise. The last three years (2012-2014) species diversity was maintained in equal level (26±6) and pattern in comparison with previous years (2007-2011). The highest number of species traditionally was registered at the coastal and shelf habitats (average 26) at the surface and above the thermocline layers and the lowest below them (Fig. 1.3.3.7.). The open sea area is characterized with lower diversity (18 ± 3) similar at both layers above and below thermocline.

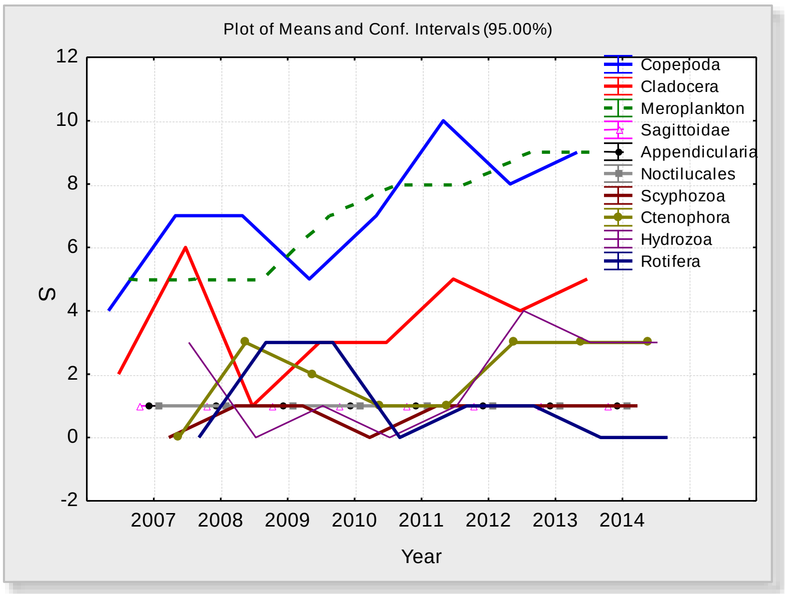


Figure 1.3.3.6. Zooplankton species number by taxa and groups from 2007 to 2014.

Ecologically key groups of Copepods, Meroplankton and Cladocera could be classified as the most important component of plankton fauna. In general, genus *Acartia*, *Paracalanus*, *Oithona*, *Centropages* were mostly presented inshore and above the thermocline, while *Pseudocalanus* and *Calanus* at offshore and below the thermocline. Recently found (2009) cyclopoid species *Oithona davisae* in Bulgarian waters (Mihneva, Stefanova 2011, 2013) was a frequent species along with other copepods. Meroplankton was more divers at coastal and shelf waters (Polychaeta, Cirripedia, Bivalvia, Gastropoda, Isopoda, Cumacea, Mysida) in comparison with open sea where the larvae stages of Polychaeta and Molluscs are the main representatives. Cladocerans (*Evadne spinifera*, *Pseudevadne tergestina*, *Penilia avirostris* and *Pleopis polyphemoides*) co-dominanted the zooplankton assemblages (see Fig. 1.3.3.7.).

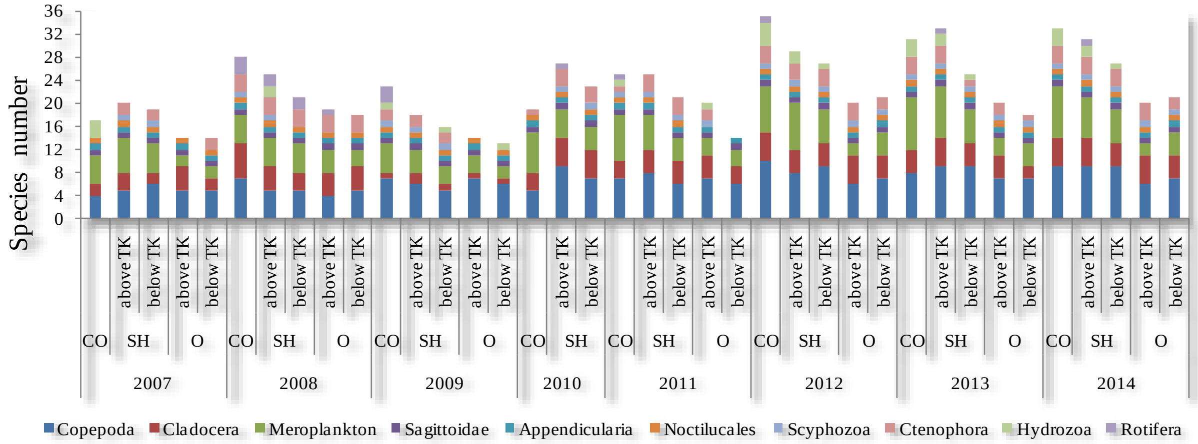
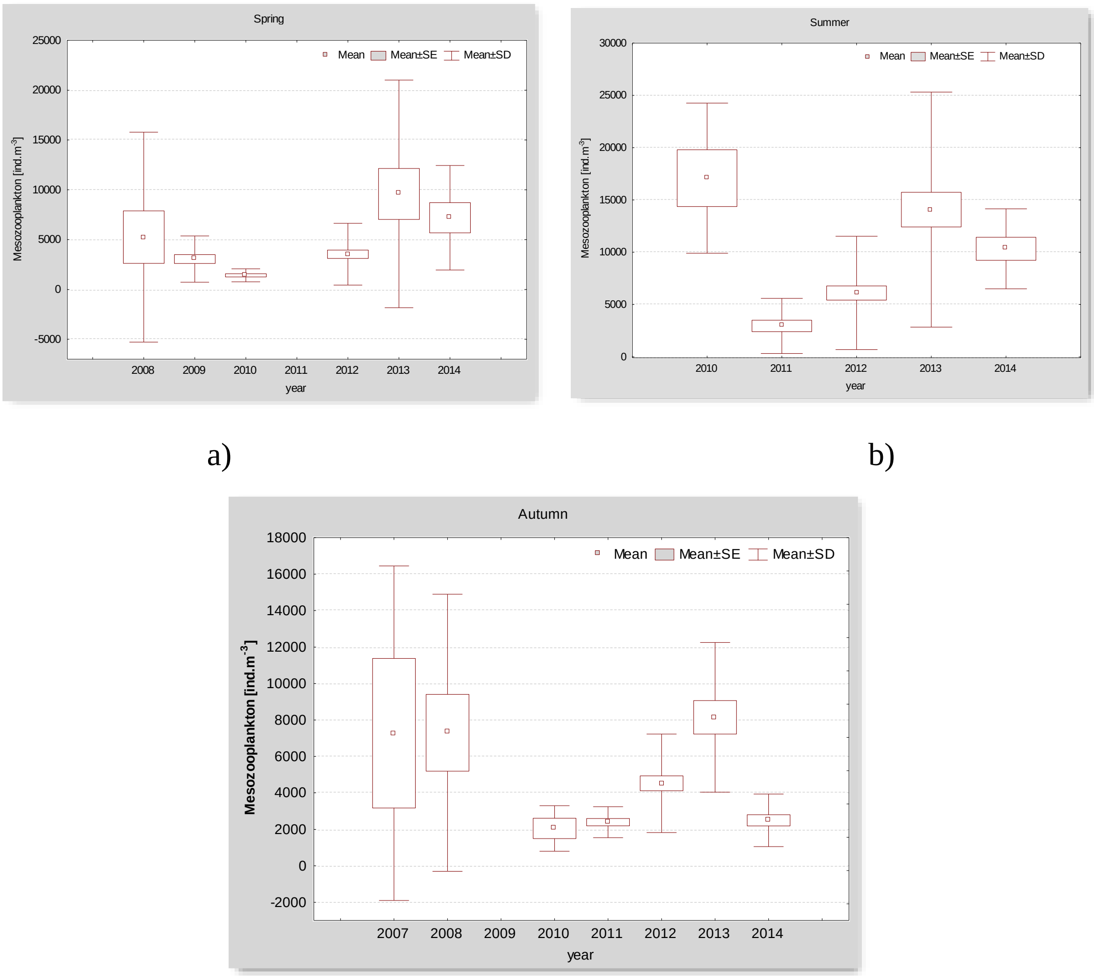


Figure 1.3.3.7. Zooplankton species number by taxa and groups at coastal (CO), shelf (SH) and open sea (O) habitats above and below thermocline (TK).

Seasonal dynamic

Changes in zooplankton structure were examined in terms of the bulk of biomass and the numerical abundance of major taxa. During the whole period, mean mesozooplankton numerical abundance was 6144 ± 7084 ind·m^{-3} (mean ± SD) and varied by four orders of magnitude. Zooplankton abundance was greater than average in the summer (8880 ind·m^{-3}) and lower than average in the spring and fall (4522 ± 6423 ind·m^{-3} and 4736 ± 4294 ind·m^{-3}). The lowest zooplankton abundance was found in autumn 2010 with 109 ind·m^{-3} and the highest in summer 2013 with 49475 ind·m^{-3} (Fig. 1.3.3.8). Copepod abundance reached its maximum in summer (33866 ind·m^{-3}) and minimum in late autumn (77 ind·m^{-3}), it was lower than average (3066 ind·m^{-3}) in spring (1866 ind·m^{-3}), nearly average in the fall (2753 ind·m^{-3}), and higher in the summer – 4483 ind·m^{-3} (Fig. 1.3.3.9). Cladocera demonstrated similar seasonal pattern with maximum in summer (18403 ind·m^{-3}) and equal average density in spring (495 ± 827 ind·m^{-3}) and autumn (501 ± 1301 ind·m^{-3}).



a) b)

c)

Figure 1.3.3.8. Seasonal interannual dynamic of total mesozooplankton (*N. scintillans* is not included) abundance (ind·m^{-3}) during the period 2007-2014: a) spring, b) summer, c) autumn.

Meroplankton seemed to reach annual maxima during the spring (43273 ± 5324 ind·m^{-3}) followed by summer and fall (see Fig. 1.3.3.9). *N. scintillans* exhibited positive anomalies in spring (5284 ± 5988 ind·m^{-3}) especially during the last three years (see Fig. 1.3.3.9.a). Generally, numerical abundance decreased from coast to offshore and maintained classical distribution pattern with density 3 and approximately in 6-fold more than shelf and open sea habitats (see Fig. 1.3.3.9).

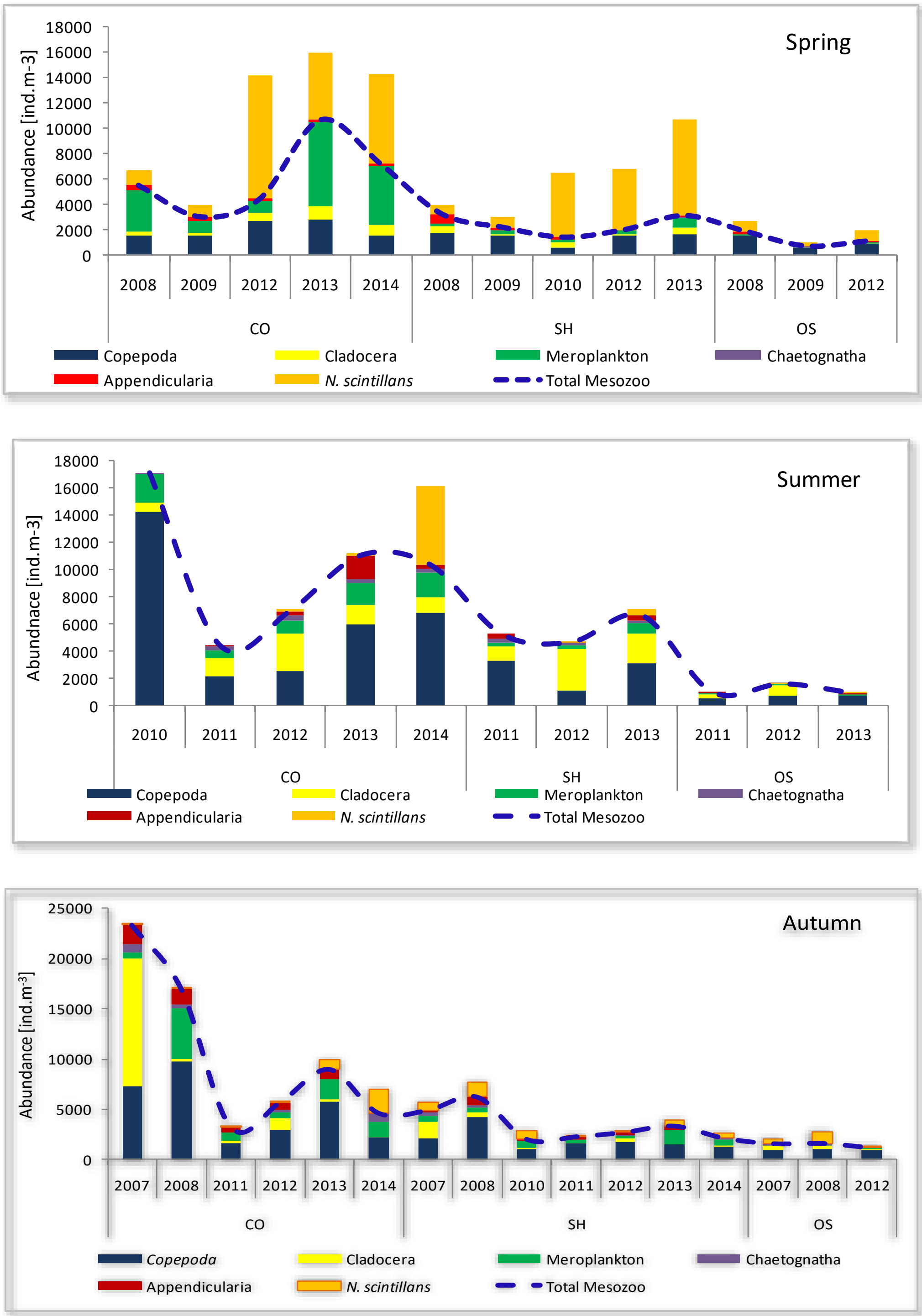
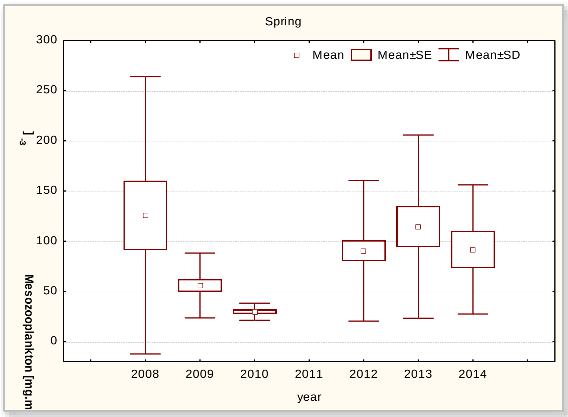
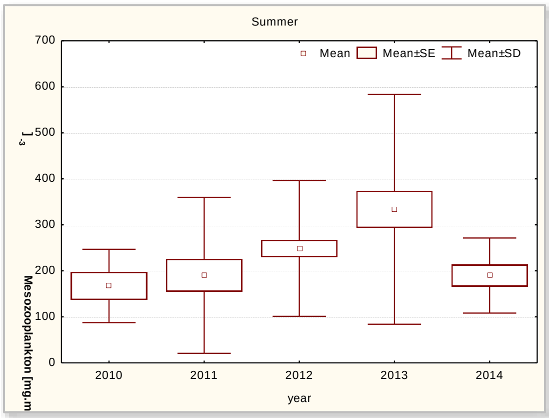


Figure 1.3.3.9. Seasonal annual fluctuations of taxonomic structure in abundance (ind·m^{-3}) at different habitat type during the period 2007-2014: a) spring, b) summer, c) autumn. *N. scintillans* is not included in the total mesozooplankton abundance.

When examining interannual and seasonal patterns (Fig. 1.3.3.10, 1.3.3.11), the lowest zooplankton biomass was found in spring at open sea station (2011) with 7.31 mg·m^{-3} and the highest in autumn 2012 with 1229.39 mg·m^{-3} at coastal area due to *Parasagitta setosa* dominance. In contrast of the relevant figure of abundance, biomass in summer showed insignificant alterations among the years (see Fig. 1.3.3.10). Copepods, Cladoceras and benthic larvae exhibited high temporal variability from year to year and spatially, although they were most abundant in terms of biomass in summer/autumn.



a)



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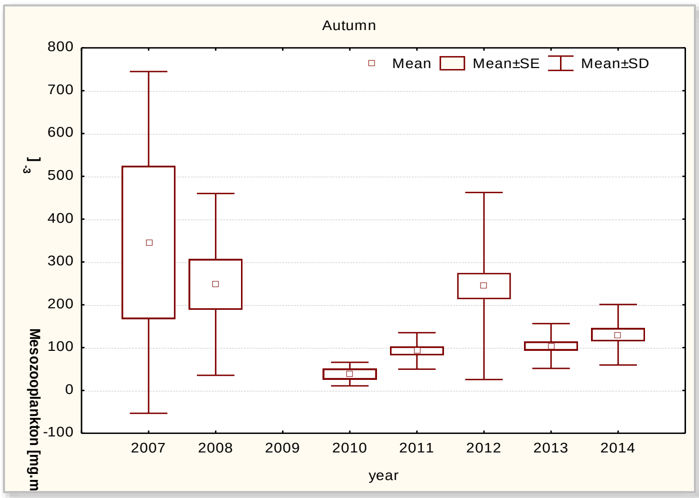
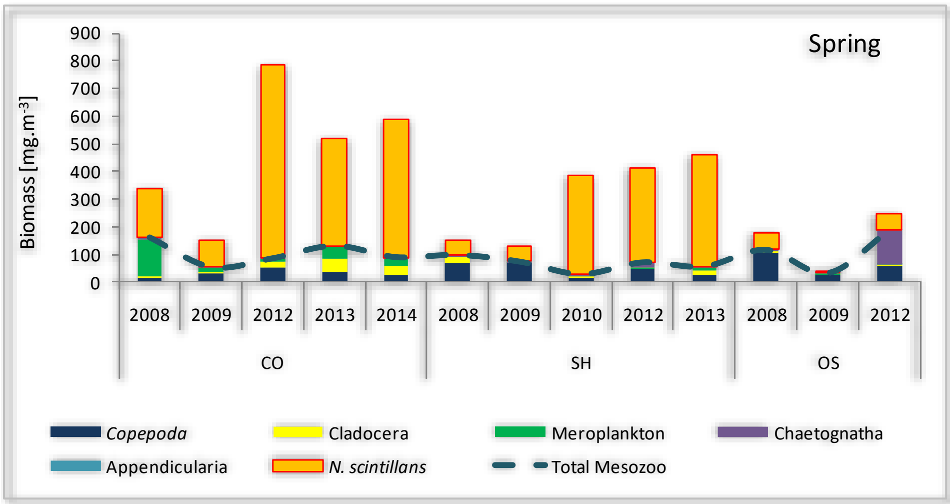
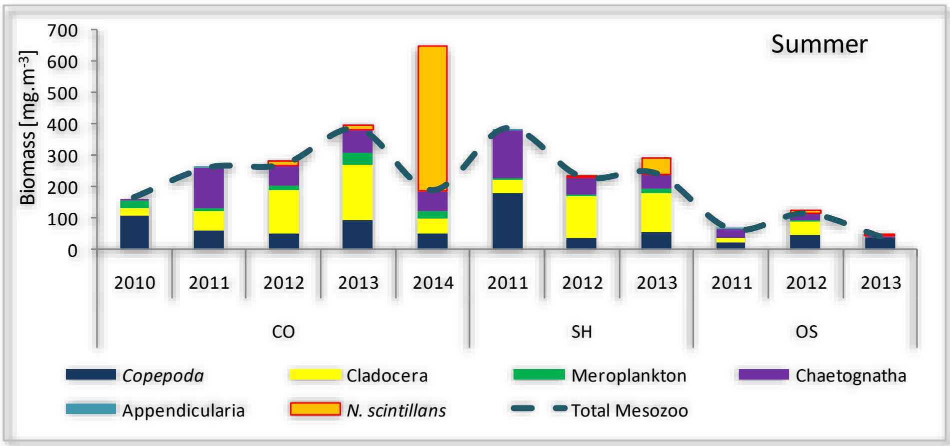


c)

Figure 1.3.3.10. Seasonal annual dynamic of total mesozooplankton (*N. scintillans* is not included) biomass ($mg \cdot m^{-3}$) during the period 2007-2014: a) spring, b) summer, c) autumn.



a)



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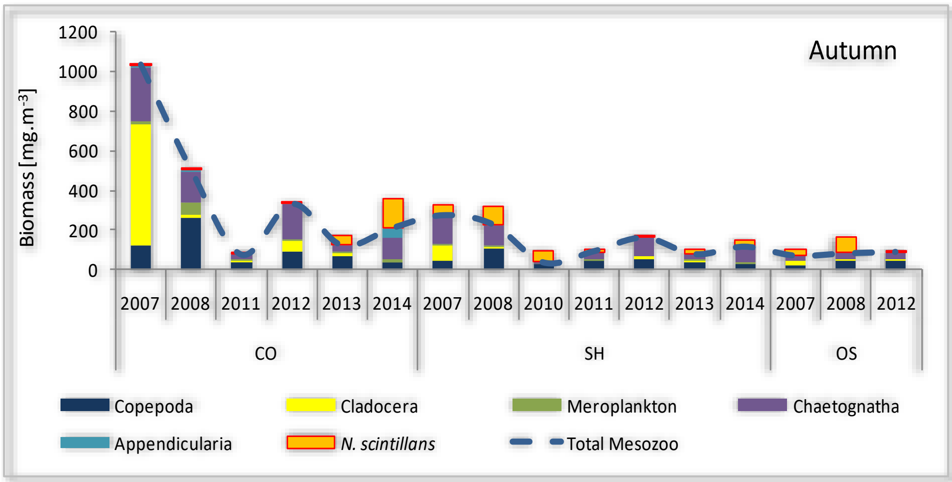


c)

Figure 1.3.3.11. Seasonal fluctuations of taxonomic structure in biomass (ind·m^{-3}) at different habitat type during the period 2007-2014: a) spring, b) summer, c) autumn. *N. scintillans* is not included in the total mesozooplankton biomass.

Development of *N. scintillans* in spring and *M. leidyi* in summer reflected indirectly on mesozooplankton biomass, since both negatively correlated with the biomass of planktonic fauna. Seasonal successions and development of various key species and groups are very well demonstrated in Fig. 1.3.3.12. *N. scintillans* dominated in spring (May-June), with an average of 78%, thermophilic representatives of Cladocera prevailed in summer (45 %), *P. setosa* - mainly in the fall (48%) when is the peak in reproduction processes. Copepods are presented all year-round with a slight excess to the summer-autumn period.

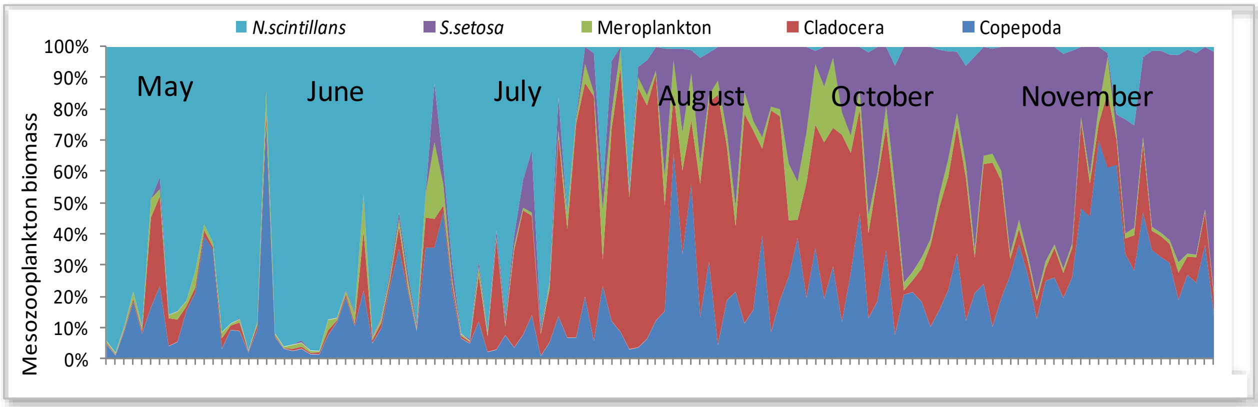


Figure 1.3.3.11. Seasonal succession zooplankton community from May to November 2012.

Spatial distribution

As examples of spatial distribution pattern here are presented spring and autumn model of zooplankton community displacement. Inshore-offshore variations of zooplankton biomass were shown in Fig. 2.1.9, 2.1.10. Inshore (shelf) is regarded as zone between coast and 200 m isobath and offshore as the zone beyond this isobaths while coast is limited to 30 m. There were marked inshore-offshore differences in the biomass in any of the three habitats. Maximum along the horizontal gradient in 2008 was register at coastal stations in spring 163.83 ± 253.29 mg·m^{-3} and autumn 503.40 ± 339.45 mg·m^{-3}, which is almost two times more than shelf and six fold higher than open sea.

The vertical pattern reflects the decrease in food availability due to light-limited primary production in deeper waters, and the decrease in temperature from the surface to the meso- and bathypelagic layers (Rutherford et al. 1999), but it was also suggested importance of large coldwater species as *Pseudocalanus elongatus*, *Calanus euxinus* in the zooplankton assemblages and biomass. These offshore distribution patterns are in agreement with observations made by Coetzee (1974), Hutchings (1979, 1985), Pillar (1984), Beshiktepe (2001), Mutlu (2003) with respect to copepods. These authors showed that, while the majority of copepods remained in the upper mixed layer and performed limited vertical migration, a few copepod species (two mentioned above) were either closely associated with the thermocline or oxygen minimum zone. In spring and autumn 2008 *P. elongatus* and *C. euxunus* contributed 80-90% of copepod biomass or 60-70% of total mesozooplankton biomass.

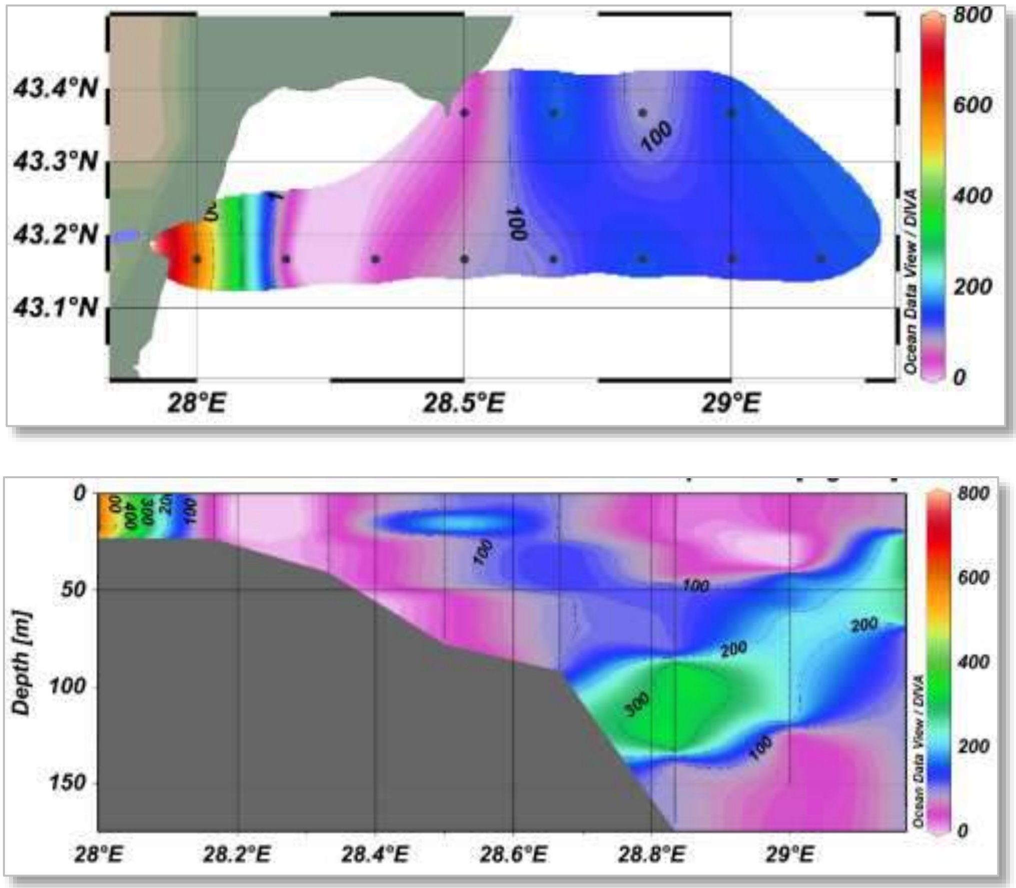


Figure 1.3.3.13. Spatial distribution of zooplankton biomass, horizontal (upper panel) and vertical (lower panel) - SESAME project cruise, April 2008.

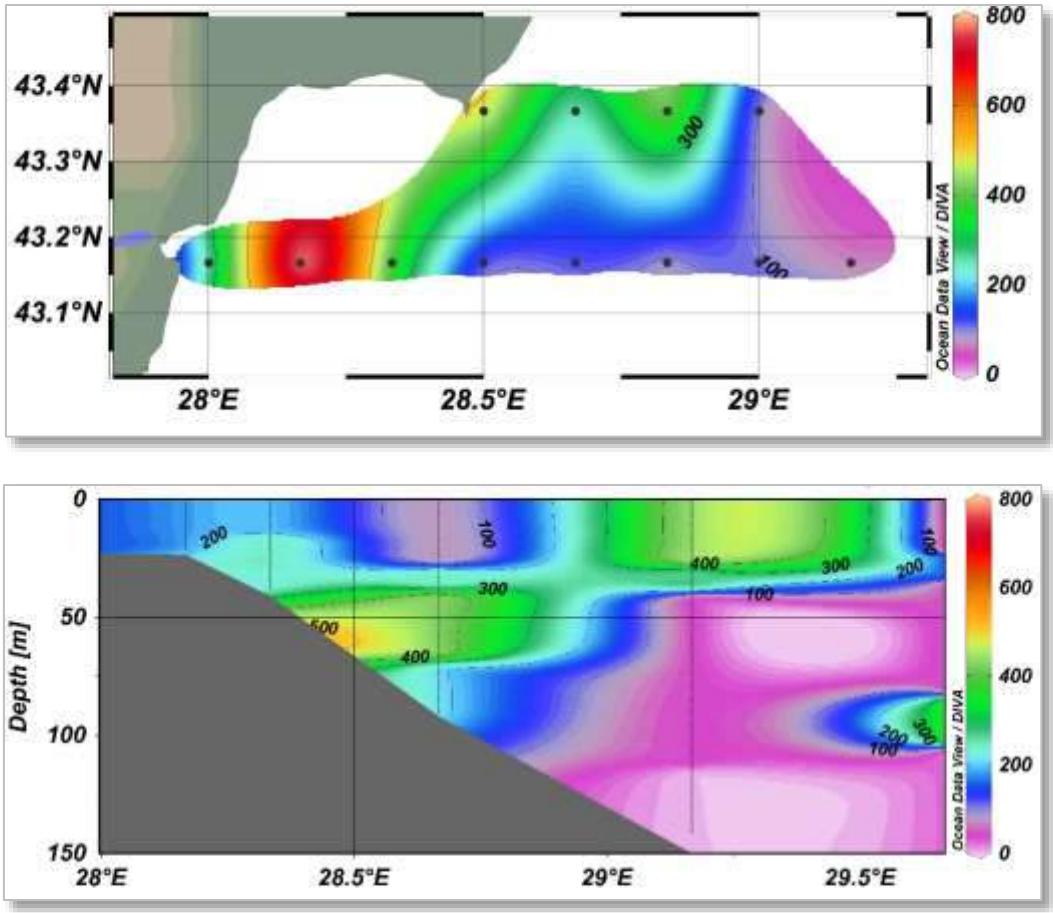


Figure 1.3.3.14. Spatial distribution of zooplankton biomass, horizontal (upper panel) and vertical (lower panel) SESAME project cruise October 2008

Another example is the campaign for *Sprattus sprattus* data collection in November 2014, where no clear mesozooplankton distribution pattern in direction from coast to open sea was discerned in front of Bulgarian coast. The main feature for the study period was patchiness of zooplankton distribution with high concentration of the fodder zooplankton in the area between capes Kaliakra and Emine (Fig. 1.3.3.15). Generally, plankton fauna density and biomass decreased in direction from the North towards South. Higher biomass was recorded at area closed between 30 to 60 m meter isobaths.

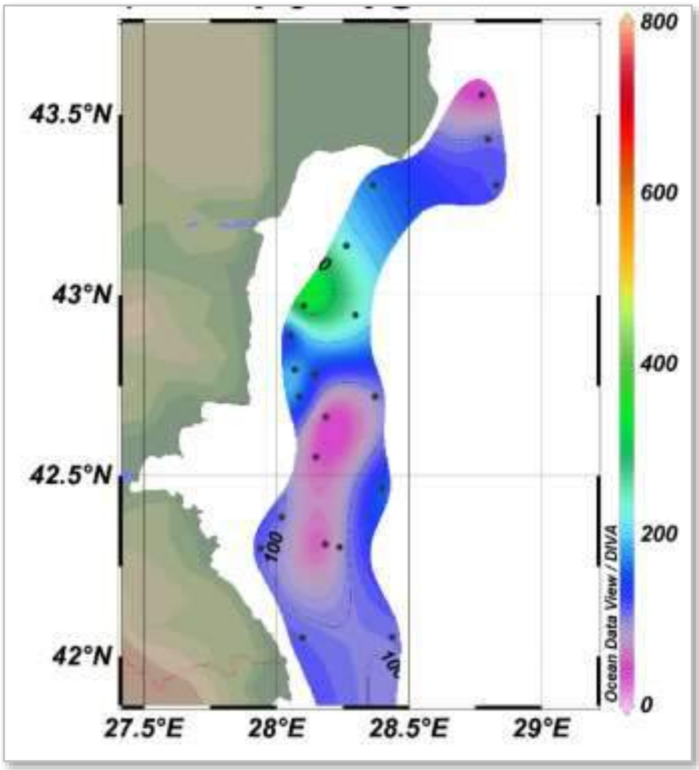


Figure 1.3.3.15. Spatial distribution of zooplankton biomass, November 2014 – data collection *Sprattus spratus.*

Assessment of water quality

Zooplankton indicators agreed within BSC expert group

- Mesozooplankton biomass (for 3 years)
- Biomass of Noctiluca scintillans (%)
- Biodiversity index Shannon-Weaver (abundance and biomass)

The importance of zooplankton as an indicator of ecological conditions stems from its position in the food web, sandwiched between the top-down regulators (fish or jellyfish) and bottom-up factors (phytoplankton), thus providing information about the relative significance of top-down and bottom-up controls and their impact on water clarity (Jeppesen et al., 2011). Zoooplankton is mentioned in the WFD CIS Monitoring guidance (2003) and in the Bulgarian legislation, Ordinance № 1/11.04.2011 (Article 56) as a 'supportive/interpretative parameter''. We applied the WFD approach to zooplankton and develop a classification system for the ecological state assessment of coastal marine waters. The list of selected zooplankton metrics (indicators) tested during the National Monitoring Programme included: a) Mesozooplankton biomass ($mg \cdot m^{-3}$), b) *Noctiluca scintillans* biomass ($mg \cdot m^{-3}$), c) *Mnemiopsis leidyi* biomass ($g \cdot m^{-3}$), d) Shannon-Weaver index ($ind \cdot bit^{-1}$). Additionally, for implementing of MSFD candidate indicators were developed and proposed in the Initial Assessment report of Bulgaria, 2012. GEnS thresholds based on long-term zooplankton data (1967-2006) available for cape Galata transect and reference period (1967-1973) were applied. Indicators relevant to Descriptor 1 (Biodiversity) and Descriptor 5 (Eutrophication) are as follow:

- Mesozooplankton biomass - Biomass is calculated using abundance of species/taxa present in mesozooplankton community and their individual weights. The indicator reflects composition of zooplankton community. Mezozooplankton indirectly exposed to eutrophication process (in case the amount of food composition and size) and catches of commercially exploited fish (through changes in the pelagic food chain), while the direct impact is shaped by climate change (temperature and salt mode), predation on fish and gelatinous plankton. Proposed threshold values above which GEnS are achieved needed further validation (Table 1.3.3.3).

Table 1.3.3.3. Threshold values of mesozooplankton biomass.

Habitat/season	**Spring**	**Summer**	**Autumn**
Coastal	50	250	40
Shelf	35	75	25
Open sea	30	45	25

Mesozooplankton biomass during the last 3 years of research at coastal and shelf habitats showed similar trends of decrease from 2012 to 2014 (Fig. 1.3.3.16). According to GEnS boundaries spring and autumn at shelf and summer at coast in 2010 were below the limit most probably due to mass development and domination of small copepod species *Otihona davisae* after its appearance in the Black Sea along the Bulgaria coast (Fig. 1.3.3.16, Table 1.3.3.4).

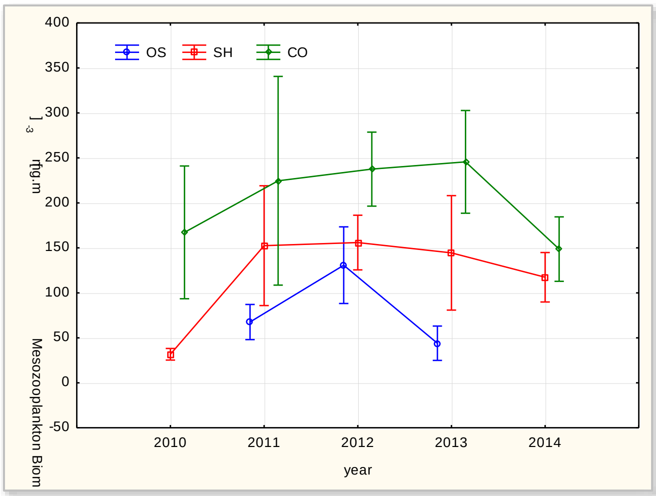


Figure 1.3.3.16. Mesozooplankton biomass dynamic from 2010 to 2014 at three habitats.

Shannon-Weaver index – reflects the number of species in a dataset, taking into account how evenly the basic entities (such as individuals) are distributed among species. The values of a diversity index depend both the number of species and evenness increase. The boundary for good status was accepted 3 bit·ind^{-1} for coastal and shelf habitats, while 2.5 bit·ind^{-1} was for open sea. The index is strictly area specific and differentiation was required to avoid the risk of not achieving good status due to higher defined threshold. The number of species is generally lower in offshore due to the specific conditions.

Although the index is not presented seasonally, the variations were higher in spring and summer while in autumn in 60% of the cases the values corresponded mainly to a good ecological status (Table 1.3.3.4). The lowest values were in spring, which probably correlated with the *N. scintillans* prevalence in mesozooplankton complex.

Noctiluca scintillans biomass (N.sci %) - contribution of *N. scintillans* biomass to total mesozooplankton biomass. The wide feeding spectrum (phytoplankton, zooplankton and detritus) of the species, development in high bloom concentrations, usually after the mass development of phytoplankton, determines its ecological importance for the pelagic ecosystem (Kiørboe, Titelman 1998; Dela-Cruz et al., 2003). *N. scintillans* density is usually higher in coastal areas where maximum phyto- and zooplankton were registered. For detection of classification limits the period of intensive eutrophictaion (1980-1993) was selected as “low” ecological state. Established threshold for good environmental status is % N. sci < 30%. The threshold is relevant for three areas – coastal, shelf and open sea.

Heterotrophic dinoflagellate maintained lower concentrations in summer and autumn with some exclusion in autumn of 2008 and 2014 where were registered values above the selected limit. Generally, more than 68 % of zooplankton community was presented by *N. scintillans* especially after 2012 at coastal area (see Fig. 1.3.3.16). Noctiluca expanded in bloom concentrations under favorable conditions (calm weather, phytoplankton blooms, low salinity) (Al-Azri et al., 2007).

Taking into account all the quality indicators of the environment that were used there were no any cases have GES status in coastal stations. The quality of the environment in the shelf area reached the "Good" status in only 13% of cases (see Fig. 1.3.3.4).

Concluding remarks

The year-to-year variation of the seasonal succession of the zooplankton community was similar to the overall general seasonal pattern, although the different zooplankton groups exhibited variability in their biomass during the study period.

Coastal and shelf habitats are characterized by non-steady community pattern - in more than 50% of occasions is in “lower” quality in respect of indicators. Opens sea habitat revealed a rather homogenous structure of zooplankton community composition and standing stock corresponding to GEnS characteristic

Table 1.3.3.4. Indicators: mesozooplankton biomass (mg·m^{-3}), *N. scintillans* (% N.sci), Shannon index H (A) and H (B) at three habitats in the period 2007-2014. Blue color cells correspond to GEnS values.

	2007	2008		2009	2010			2011		2012			2013			2014		
mg.m-3	Autumn	Spring	Autumn	Spring	Spring	Summer	Autumn	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn
Coastal	1032.3	164.8 ± 253.9	503.4 ± 260.6	56.2 ± 29.6		167.2 ± 79.8		261.4 ± 160	77.5 ± 58.4	87.8 ± 68.6	271.1 ± 154.7	333.1 ± 267.1	133.4 ± 98.6	383.5 ± 259.9	124.6 ± 44.2	92.8 ± 64.2	190.3 ± 81.3	208.6 ± 110
Shelf	275.5 ± 79.3	100.3 ± 47.2	229.1 ± 140.0	75.6 ± 33.8	29.8 ± 8.5		38.3 ± 27.5	385.7 ± 169.1	94.2 ± 42.4	71.6 ± 44.5	231.8 ± 130.2	162.7 ± 89.0	57.7 ± 13.6	242.8 ± 170.2	79.9 ± 27.5			115.6 ± 57.4
Open sea	72.6 ± 5.8	118.6 ± 40.8	83.7 ± 16.7	33.3 ± 22.2				67.7 ± 29.1		188.6 ± 103.7	116.3 ± 29.8	91.0 ± 32.1		44.0 ± 2.1				

	2007	2008		2009	2010			2011		2012			2013			2014		
%N.sci	Autumn	Spring	Autumn	Spring	Spring	Summer	Autumn	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn
Coastal	0.2	39 ± 43	0.3 ± 0.3	32 ± 31		0		0	3 ± 4	85 ± 9	3 ± 9	3 ± 5	68 ± 25	5 ± 12	26 ± 21	73 ± 24	37 ± 42	40 ± 29
Shelf	17 ± 19	24 ± 25	24 ± 29	34 ± 24	85 ± 20		56 ± 17	0	7 ± 13	67 ± 27	3 ± 4	3 ± 5	85 ± 9	12 ± 28	22 ± 21			19 ± 13
Open sea	27 ± 9	27 ± 33	48 ± 10	12 ± 18				0		20 ± 9	4 ± 7	4 ± 2		2 ± 0.2				

	2007	2008		2009	2010			2011		2012			2013			2014		
H'(A)	Autumn	Spring	Autumn	Spring	Spring	Summer	Autumn	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn
Coastal	2.0	1.7 ± 0.8	2.1 ± 0.7	2.9 ± 0.4		2.2 ± 0.3		2.7 ± 0.4	2.7 ± 0.2	1.8 ± 0.6	2.6 ± 0.6	3.0 ± 0.3	2.4 ± 0.5	2.8 ± 0.4	2.8 ± 0.3	2.0 ± 0.7	2.3 ± 0.5	2.8 ± 0.3
Shelf	3.2 ± 0.1	2.6 ± 0.3	2.4 ± 0.4	2.7 ± 0.3	1.6 ± 0.7		2.8 ± 0.2	2.9 ± 0.2	2.8 ± 0.2	1.9 ± 0.7	2.3 ± 0.9	3.3 ± 0.2	2.0 ± 0.4	2.8 ± 0.6	2.8 ± 0.2			2.8 ± 0.4
Open sea	2.9 ± 0.3	2.2 ± 0.5	2.5 ± 0.2	2.7 ± 0.2				2.7 ± 0.4		2.5 ± 0.4	2.6 ± 0.5	3.2 ± 0.2		2.8 ± 0.3				

	2007	2008		2009	2010			2011		2012			2013			2014		
H'(B)	Autumn	Spring	Autumn	Spring	Spring	Summer	Autumn	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn
Coastal	1.7	1.4 ± 0.9	2.1 ± 0.6	2.5 ± 0.8		2.8 ± 0.2		2.0 ± 0.3	2.4 ± 0.1	0.9 ± 0.5	2.2 ± 0.5	2.2 ± 0.4	1.6 ± 0.8	2.6 ± 0.6	2.7 ± 0.4	1.4 ± 0.9	2.0 ± 0.9	1.9 ± 0.3
Shelf	2.3 ± 0.02	2.2 ± 0.5	1.8 ± 0.5	2.2 ± 0.5	0.8 ± 0.5		2.0 ± 0.5	2.2 ± 0.3	2.5 ± 0.4	1.3 ± 0.7	2.0 ± 0.7	2.2 ± 0.5	1.1 ± 0.5	2.4 ± 0.6	2.7 ± 0.4			2.1 ± 0.5
Open sea	2.5 ± 0.2	1.5 ± 0.4	2.2 ± 0.3	2.0 ± 0.2				2.4 ± 0.2		1.9 ± 0.3	2.5 ± 0.4	2.3 ± 0.4		2.0 ± 0.6				

1.3.3.2. Georgian shelf area

During the period 2008-2014 zooplankton was sampled mainly at three coastal monitoring areas in Georgia (Gonio, Batumi and Kobuleti) and in 2010 and 2014, samples were also taken in Supsa and Poti area (Fig 1.3.3.17, Table 1.3.3.5). Unfortunately, sampling was not carried out in all seasons, mainly in spring and summer.

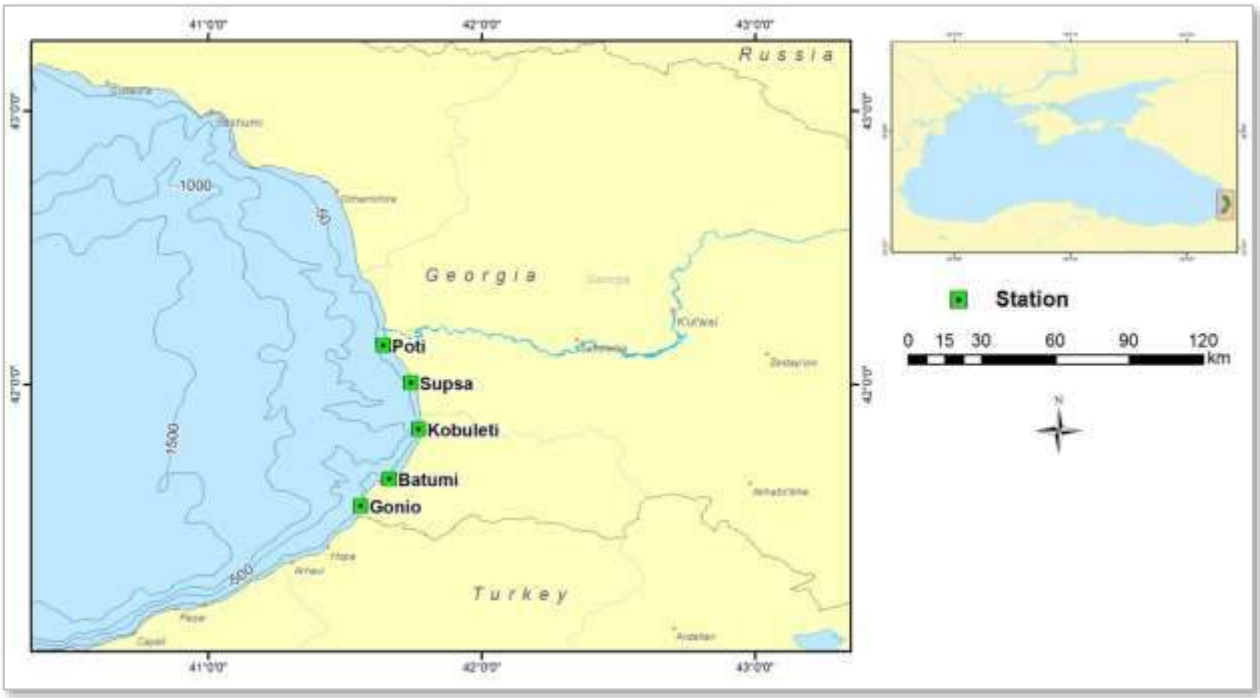


Figure 1.3.3.17. The map of monitoring stations in the Georgian Black Sea coastal zone during the 2008-2014.

Table 1.3.3.5. Coordinates of monitoring stations in the Georgian Black Sea coastal zone.

Areas	Coordinates of monitoring stations	
	Latitude	Longitude
Gonio	41°33'29.34"N	41°33'23.40"E
Batumi	41°39'23.09"N	41°39'43.13"E
Kobuleti	41°50'17.72"N	41°46'4.21"E
Supsa	42° 0'32.17"N	41°44'25.57"E
Poti	42° 8'39.65"N	41°38'23.16"E

Samples were taken at a distance of 1-1.5 miles from the shore on board the research vessel by the vertical plankton Judey net (inlet area 0.1 m^2, mesh size 150 μm), in the depth range 2-20 m. The samples were fixed with 4% formalin and processed in the Department of Fishery and Monitoring of the Black Sea, Batumi. Qualitative and quantitative treatment of samples was carried out using a Bogorov camera, binocular and Leica microscope. To identify the species composition of zooplankton were used various key books (Morduhay-Boltovkoy, 1968, 1969, 1972). Biomass was calculated using standard weights of the Black Sea main zooplankton forms (Petipa, 1959).

Species composition

Totally during the period of 2008-2014 were founded 30 species of zooplankton on the Georgian shelf area. An average it was about 22 taxons per year. Maximal number of the species was registered in 2010 (Table 1.3.3.6).

Crustaceans (Copepoda and Cladocera) was the dominant group of mesozooplankton on abundance. They accounted for over 40% of the total number of species, of which the copepods was about 27%, the number of species ranged from 6 to 10. Other numerous zooplankton group was the meroplankton (larvae of benthic invertabrates), they accounted for 18% of the total number of zooplankton species. The most common were larvae of bivalve mollusks and polychaetes (Fig. 1.3.3.18).

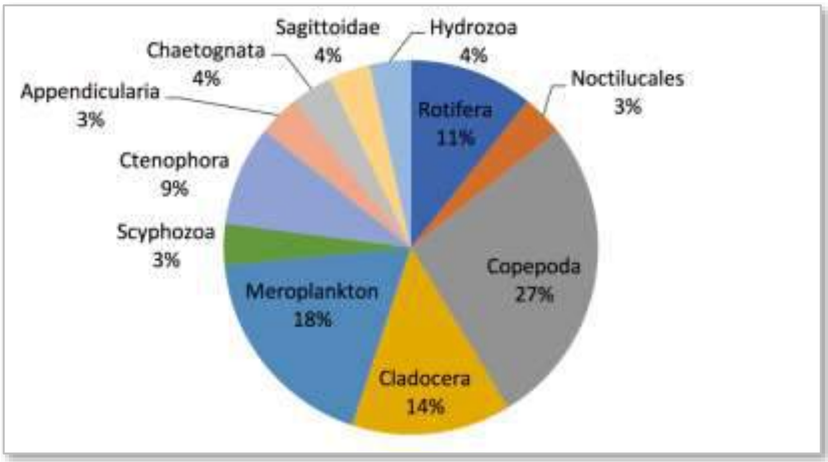


Figure 1.3.3.18. Average diversity of zooplankton in the Georgian Black Sea coastal zone (2008-2014).

Table 1.3.3.6. The biodiversity of mesozooplankton groups in the Georgian Black Sea coastal zone (2008-2014).

Species (taxon)	Investigated years						
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
DINOFLAGELLATA							
Noctiluca scintillans Kofoid & Swezy, 1921	+	+	+	+	+	+	+
APPENDICULARIA							
Oikopleura (Vexillaria) dioica Fol, 1872	+	+	+	+	+	+	+
CLADOERA							
Bosmina longirostris O.F. Müller, 1785	+	+	+				
Diaphanosoma brachyurum Liévin, 1848	+	+					
Evadne spinifera P.E. Müller, 1867	+	+	+				+
Penilia avirostris Dana, 1849	+	+	+	+	+	+	+
Pleopis polyphaemoides (Leuckart, 1859)	+	+	+	+	+	+	+
Podonevadne trigona (G.O. Sars, 1897)	+	+					
Podon leuckartii (Sars G.O., 1862)	+						

Pseudevadne tergestina (Claus, 1877)	+						
CHAETOGNATHA							
Parasagitta setosa (Müller, 1847)	+	+	+	+	+	+	+
COPEPODA							
Acartia (Acartiura) clause Giesbrecht, 1889	+	+	+	+	+	+	+
Acartia tonsa Dana, 1849		+	+	+			+
Calanus euxinus Hulsemann, 1991	+	+	+	+	+	+	+
Centropages ponticus Karavaev, 1895	+	+	+	+	+	+	+
Cyclopina gracilis Claus, 1863			+	+			
Oithona davisae Ferrari F.D. & Orsi, 1984	+	+	+	+	+	+	+
Oithona similis Claus, 1866		+	+	+			+
Paracalanus parvus (Claus, 1863)	+	+	+	+	+	+	+
Pontella mediterranea (Claus, 1863)			+				
Pseudocalanus elongates (Boeck, 1865)	+	+	+	+	+	+	+
Copepoda egg	+	+	+	+	+	+	+
Copepoda nauplii	+	+	+	+	+	+	+
MEROPLANKTON							
Bivalvia larvae	+	+	+	+	+	+	+
Cirripedia larvae	+	+	+	+	+	+	+
Decapoda larvae			+	+	+	+	+
Gastropoda larvae		+			+		+
Ostracoda	+	+			+		
Polychaeta larvae	+	+	+	+	+	+	+
Fish egg			+	+		+	+
TOTAL NUMBER	**23**	**24**	**24**	**21**	**19**	**18**	**22**

During the study period, the species composition of zooplankton changed insignificantly. It should be noted a slight decrease in the number of Cladocera. If in 2008, about 8 species of Cladocera were registered (Gvarishvili et al., 2010). In 2014 there were only three species: *Penilia avirostris* (mass species in the summer), *Pleopis polyphaemoides* and *Evadne spinifera* (Fig. 1.3.3.19).

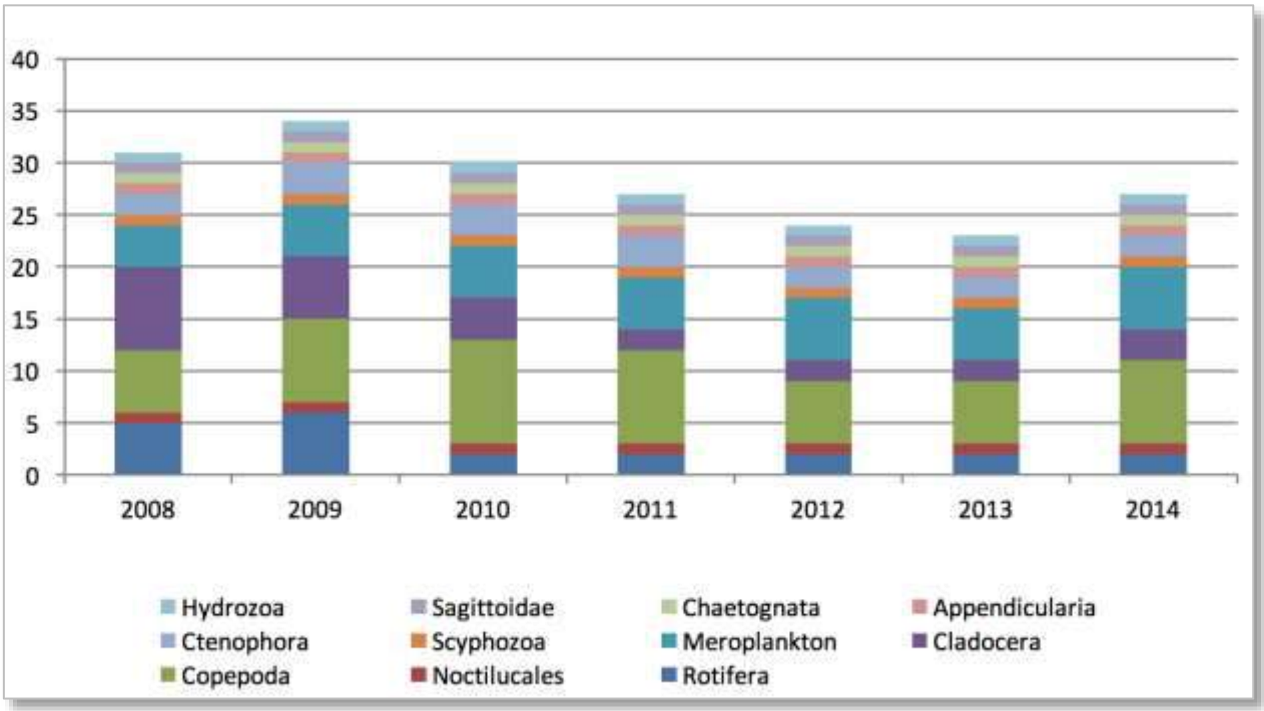


Figure 1.3.3.19 Zooplankton species number by taxa and groups at Black Sea Georgian coastal zone in 2008-2014.

Seasonal dynamic and spatial distribution

Seasonal dynamics of quantitative development of zooplankton showed its absolute dominance in the summer. At this time of the year zooplankton abundance and biomass reached 46 and 44% respectively from the annual value in average. Seasonal biomass of plankton will correspond in average as 29%, 44%, 22% и 5% (Table 1.3.3.7).

Table 1.3.3.7. Seasonal dynamics of quantitative development of zooplankton in the shelf zone of Georgia (2008-2014)

Year	Season	Average abundance, ind·m^{-3}	Average biomass, mg·m^{-3}
2008	Spring	4810±1947	355,6± 45,5
	Summer	37644±3179	820,5± 36,2
	Autumn	16241±4517	285,4± 32,6
	Winter	678± 59	59,3± 14,5
2009	Spring	9353± 969	120,5± 54,1
	Summer	14454±4068	274,6± 46,8
	Autumn	11653±3822	168,2± 20,9
	Winter	3845±1818	69,5± 17,5
2010	Summer	11236±2851	175,6± 51,9
	Autumn	10565±2176	95,6± 26,3
	Winter	3566±1353	18,4± 3,1
2011	Summer	18428± 962	185,4± 82,0
	Winter	3222± 698	47,6± 29,6
2012	Summer	26258±6377	448,5±134,0

Year	Season	Average abundance, ind·m^{-3}	Average biomass, mg·m^{-3}
	Autumn	15682±1252	386,4±113,4
	Winter	2461±1516	76,2± 19,3
2013	Spring	14580±2526	385,6±101,1
	Autumn	16771±2397	203,9± 54,8
2014	Spring	8453±1081	244,5± 46,2
	Summer	25740±8191	604,6±261,9
	Autumn	16431±3588	114,7± 25,8

Note. The blue color indicates the values of biomass which correspond to a good ecological status – GES; in yellow cells are marked for which threshold values are not defined (correspond to winter). For more detail explanation see section "Assessment of water quality" below.

During the year the leading position in plankton has *Acartia clause* and *Paracalanus parvus*. In spring-summer period mass development has new Black Sea non-indigenous species *Acartia tonsa* and *Oithona davisae*. Abundance of these species in August near Batumi have reached 14000 ind·m^{-3}. In the summer, one of the leading positions has thermophilic copepod *Centropages ponticus*. In the autumn and winter this species was replaced by cold-water copepod *Pseudocalanus elongates*. Its numbers at some stations (Gonio, Batumi) reaches 500-650 ind·m^{-3}. In cold season as usually was registered copepod *Oithona similis* in abundance 40-200 ind·m^{-3}.

Meroplankton the second most frequent group of zooplankton have maximal development in summer. During this period abundance of Bivalvia and Polychaeta larvae reached 3500 and 1500 ind·m^{-3} respectively. Their biomass were 30 and 15 mg·m^{-3}. In spring and summer, the nauplial forms of copepods were found in large numbers, their abundance varied from 500 to 35000 ind·m^{-3} and the biomass comprised almost 30% of the total biomass of zooplankton.

Noctiluca scintillans was registered throughout the study period, but a significant proportion in the biomass of zooplankton was in the spring. At Batumi and Poti stations *N. scintillans* biomass exceeded 90% and at Gonio station an average of 30-40% of the total biomass. This peculiarity has reflected the water quality in investigated areas, because *N. scintilans* is indicator of Non-Good Ecological Status if their biomass is bigger than 30% of total zooplankton biomass.

As well as species diversity maximal development of mesozooplankton reached in summer. During this period zooplankton abundance varied from 10660 to 37644 ind·m^{-3}, biomass varied from 175 to 820 mg·m^{-3} on the Georgian coast. Minimal development of pelagic invertebrates were observed in January and February. Their numbers varied from 600 to 3000 ind·m^{-3} and the biomass ranged from 47.6 to 76.4 mg·m^{-3}. The average annual number of zooplankton varied from 8455 to 16874 ind·m^{-3}, and biomass - from 96 to 380 mg·m^{-3}. At the same time, the average annual abundance was 13043 ind·m^{-3}, biomass - 240 mg·m^{-3} (Fig. 1.3.3.20). The minimal quantitative development of zooplankton was recorded in 2010 when anomalous hydrological conditions were recorded in the northwestern part of the Black Sea (Adobovsky et al., 2012).

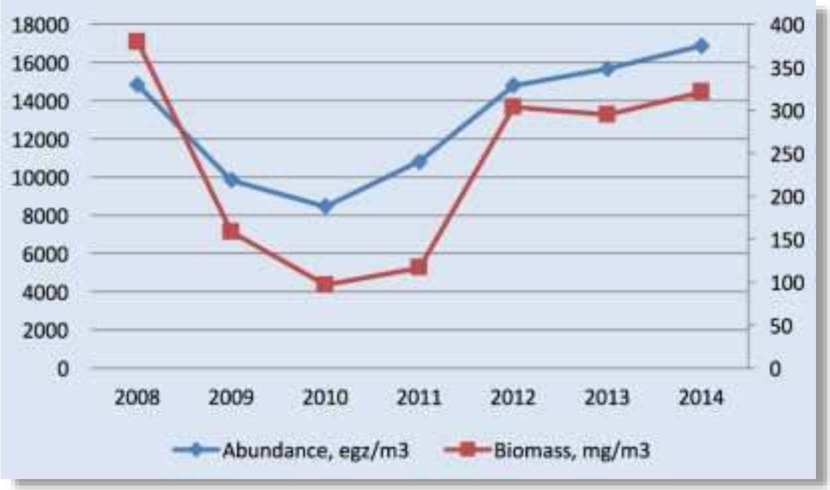


Figure 1.3.3.20. Mean abundances and biomasses of mesozooplankton in the Georgian Black Sea coastal zone.

The quantitative development of mesozooplankton in the investigated regions of the coastal zone of the Black Sea off the coast of Georgia showed: 1) the absolute dominance of plankton biomass in the surface layer of water (0-5 m) throughout the year; 2) the maximum development of plankton in the summer season, regardless of the area of research; 3) the maximum values of biomass are marked, regardless of the season of the year, for the Gonio area, and the minimum values for Supsa and Poti, which is related to local anthropogenic impact (Fig. 1.3.3.21).

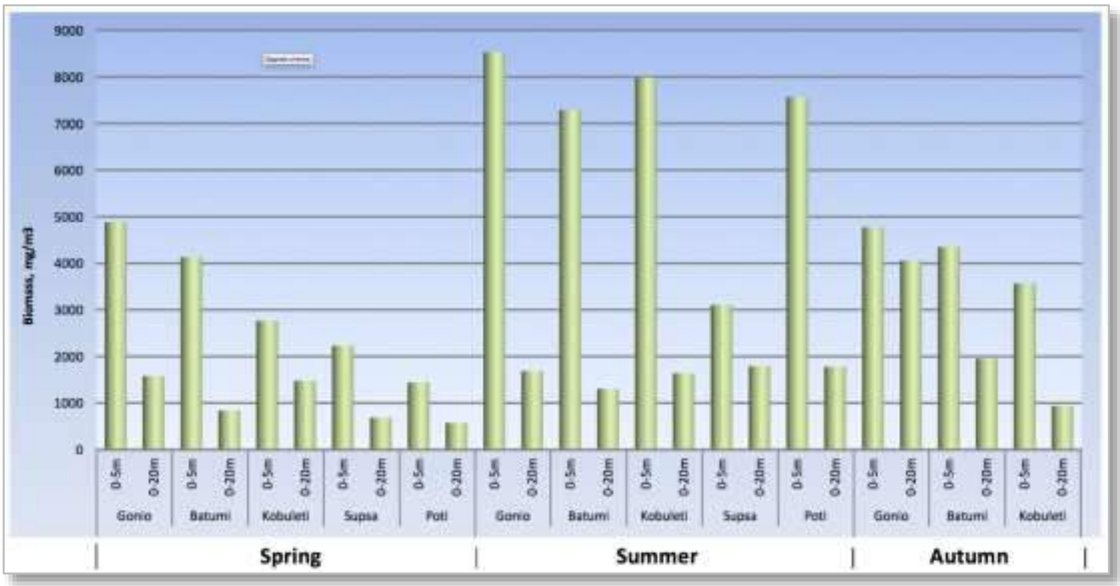


Figure 1.3.3.21. Spatial distribution of mesozooplankton biomass in Georgian coastal waters (2014).

Research station in Gonio area is located between the rocky shore of Sarpi and the left bank of the Chorokhi River. This is the cleanest coastal region of the Black Sea in Georgia. The Chorokhi River does not have a negative impact. Its current, connecting with the flow of the main Black Sea current, moves from Gonio towards Batumi. During the Soviet period, this was a closed zone for the population, as it was adjacent to the Turkish border. In recent years, recreational tourism is intensively developing here.

Research station in Supsa is located at the mouth of the Supsa River. This is a zone of strong anthropogenic impact. In 2011, in the Supsa village, “Heidelberg Cement AG” opened a cement plant. Not far from the village is the Supsinsky oil terminal, which receives oil from Azerbaijan via the Baku-Supsa oil pipeline with subsequent loading oil onto vessels with the help of no berthing loading. The coastal zone of the sea is under the influence of Supsa and Natanebi rivers.

Research station in Poti is located in the Rioni River mouth. Rioni is one of the largest rivers of Transcaucasia, as well as the Maltakva River. Both these rivers carry a large volume of urban sewage (Janelidze et al., 2011). On the shore is the port of Poti - one of the largest ports in the Black Sea basin.

Assessment of water quality

The quality of the aquatic environment for the studied areas of the Georgian coast can be estimated from the total mesozooplankton biomass (see Table. 1.3.3.7) and its established threshold values (Table 1.3.3.7).

Table 1.3.3.7. Threshold values of mesozooplankton biomass (B) for determination of the coastal marine water quality in the Black Sea (Stefanova et al., 2016).

Season	B, $mg\cdot m^{-3}$*
Spring	70
Summer	200
Autumn	70

*Threshold GES ≥ B

Analysis of obtaining results (see Table 1.3.3.6) showed that in 87.5% of the cases studied shelf regions correspond to a high water quality with GES. The only exception is the average biomass of mesozooplankton in summer of 2010 and 2011. Since these results are based on the threshold values developed for the coastal waters of Bulgaria, in the long term it is advisable to develop threshold values for the coastal waters of Georgia, which would be based on the data of long-term observations of national experts.

1.3.3.3. Romania shelf area

National data for the period 2008-2014 were not provided.

1.3.3.4. Northeastern (Russian Federation) shelf area

The state of the shelf pelagic ecosystem has been assessed based on multidisciplinary monitoring performed in the northeastern Black Sea on 17 standard stations (Fig. 1.3.3.4.1) in 2005–2014. The study area was locked between min. lat.: 42°29.51" N, min. long. 36°59.41" E and max. lat. 44°30.82" N, max. long. 39°37.75" E (Table 1.3.3.4.1).

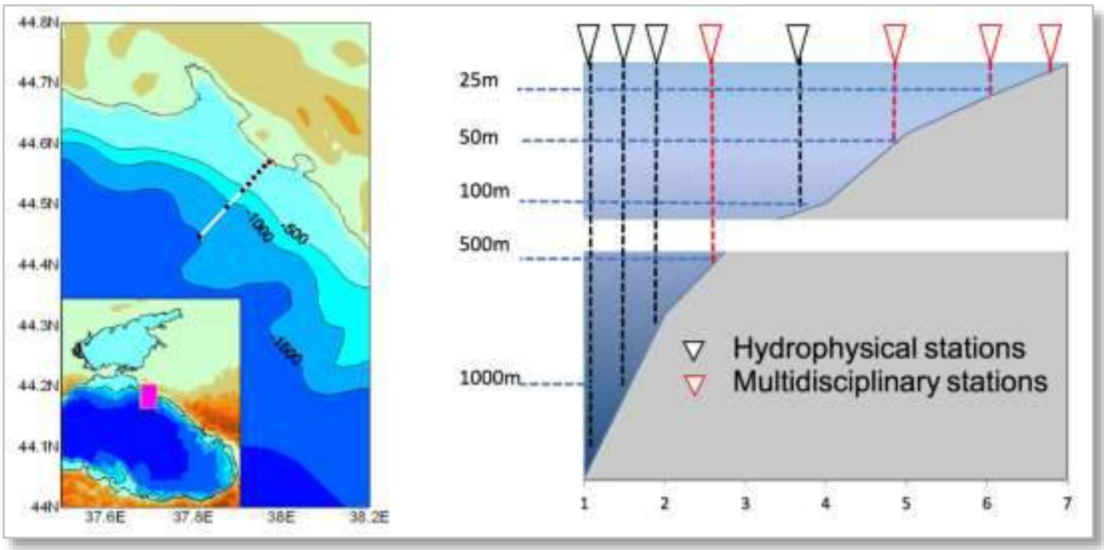


Figure 1.3.3.4.1. Location of mesozooplankton sampling station on northeastern shelf area of Russian Federation.

Table 1.3.3.4.1. Coordinates and depth of the routine monitoring stations.

STATION	**LATITUDE**	**LONGITUDE**	**DEPTH,** m
22	43°53.53	37°30.37	>2000
23	43°39.88	37°20.53	>2000
24	43°25.15	37°9.612	>2000
25	43°11.83	36°59.41	>2000
27	43°04.17	37°23.89	>2000
28	42°54.66	37°49.93	>2000
29	42°45.85	38°13.87	>2000
30	42°37.37	38°38.05	>2000
31	42°29.51	39°00.13	>2000
32	42°49.47	39°12.55	2000
33	44°07.59	37°40.81	1900
34	44°14.95	37°46.58	1700
35	44°21.58	37°51.43	1000
36	44°30.82	37°55.92	510
37	43°06.06	39°23.16	1800
38	43°19.93	39°33.52	1700
39	43°28.27	39°37.75	900

The features of the quantitative development of mesozooplankton for investigated period are analyzed considering hydrologic changes, biogenic load, phytoplankton and gelatinous microzooplankton (Arashkevich et al., 2015). Field material was collected in the mid shelf of the northeastern Black Sea (near Gelendzhik) at a station with a water column depth of 50 m from the RV “Akvanavt” in 2005–2008 and RV “Ashamba” in 2009–2014. Sampling was performed on a monthly basis from March and April to October and November. Zooplankton was sampled by vertical net tows from the bottom to surface. Mesozooplankton was sampled with a Juday net (opening area 0.1 m^2 and mesh size 180 μm). The samples were fixed with 4% formalin neutralized with borax. Individual animal weight in carbon units was determined using the corresponding equations (Arashkevich et al., 2014).

Species composition

During investigated period, total number of taxon/species fluctuated within 10-18 on average. At the same time larvae of Bivalvia, Gastropoda, Cirripedia, Polychaeta, Decapoda and Amphipoda were identified at the level of the class or order. The maximum variety was noted in 2008, 2009 and 2011, the minimum was 2014. The autumn period (October-November) has always had a large number of taxon/species than the spring (March-April), on average 33.5 ± 2.5% (Table 1.3.3.4.2).

Plankton crustaceans (Cladocera, Copepoda) were absolutely dominant over other mesozooplankton groups by biomass, averaging 65.6 ± 2.9%. In this case, their contribution, in most cases, was in equal proportion (Fig. 1.3.3.4.2).

Interannual and seasonal dynamic

The interannual changes in mesozooplankton biomass are shown in Fig. 1.3.3.4.2. It is evident that the total biomass considerably decreased in 2013–2014 (3.5 ± 2.2 mg C·m^{-3}) as compared with previous years (8.2 ± 2.3 mg C·m^{-3}) with the herbivorous zooplankton, accounting for over 80% of the total mesozooplankton biomass, as the major contributors to this decrease. No considerable interannual changes in the taxonomic structure of zooplankton community were observed, except for 2011, when a mass development of *Noctiluca scintillans* was recorded, and 2013, when cladocerans almost completely disappeared. Correlation analysis failed to find any significant correlation between the biomass of zooplankton in general and of individual taxonomic groups with temperature, chlorophyll concentration, and total phytoplankton biomass. The only positive correlation found was between the biomass of herbivorous zooplankton and diatom biomass (r = 0.55, p = 0.05).

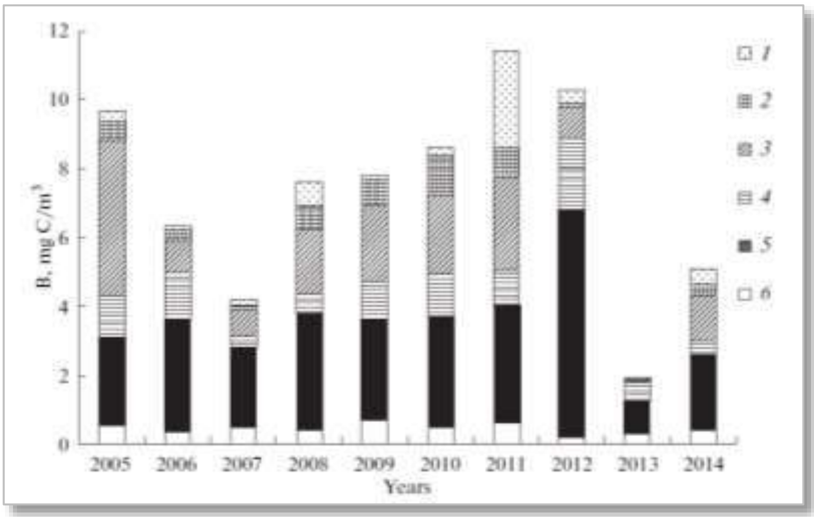


Figure 1.3.3.4.2. Interannual variation in biomass (B, mg C·m^{-3}) and taxonomic structure of mesozooplankton in 0–50 m layer of the mid shelf of the northeastern Black Sea: (***1***) *Noctiluca*; (***2***) meroplankton; (***3***) cladocerans; (***4***) chaetognaths; (***5***) copepods and (***6***) others. Traditionally for the Black Sea, the heterotrophic dinoflagellate *Noctiluca scintillans* is regarded as a component of mesozooplankton because of its large size and omnivorous diet.

Spatial distribution

Distribution of biomass of the dominant mesozooplankton groups along the cross-shelf transect is shown in Fig. 1.3.3.4.3. Stations located at the 25 m, 50 m and 500 m depths are corresponded to the different coastal zones, inner-shelf, mid-shelf, and continental slope, respectively. The biomass values were averaged for spring and autumn 2008-2014.

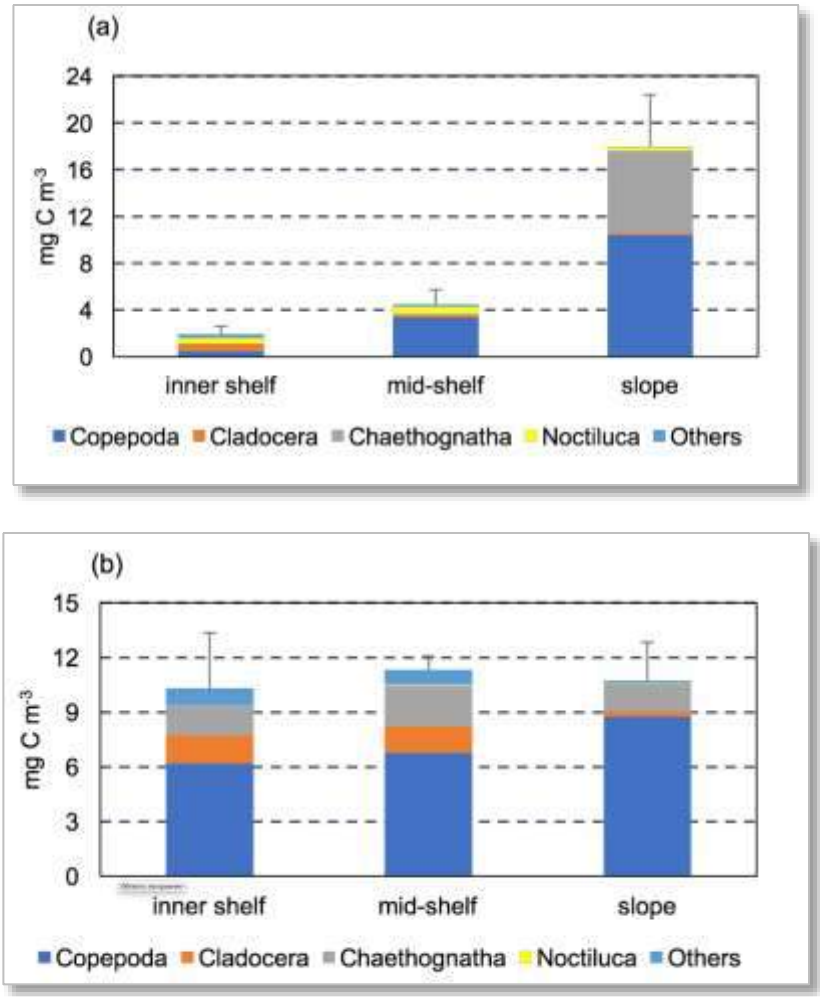


Figure 1.3.3.4.3. Cross-shelf distribution of mesozooplankton biomass (mg C·m^{-3}) in the northeastern Black Sea in (a) spring and (b) autumn. The average values of the total biomass for each coastal zone are reported with the standard error bars.

In spring, the average values of the total mesozooplankton biomass in the different coastal areas (see Fig. 1.3.3.4.3 a) differed significantly (ANOVA, p=0.002) and equaled 1.9, 4.5 and 17.9 mg C·m^{-3} over the inner-shelf, mid-shelf, and slope, respectively. Biomass of cladocerans and *N. scintillans* decreased from the shore to the deep sea while biomass of copepods and chaetognaths were higher significantly over the slope as compared with the shelf. Over the inner-shelf, zooplankton biomass was dominated by cladocerans (34% of total biomass) followed by noctiluca and copepods (26 and 25% of the total biomass, respectively). On the mid-shelf, zooplankton was dominated by copepods (75% of total biomass) while over the slope the share of copepods in the total biomass was equaled to 58% and 38 % of the biomass were made by chaetognaths.

In autumn, the average mesozooplankton biomass did not differ significantly over the cross-shelf transect (ANOVA, p=0.94) making up 10.4-11.4 mg C·m^{-3} (see Fig. 1.3.3.4.3 b). In all coastal areas copepods were dominant making up 60-82% of total biomass. The main difference between the shelf and deep areas was the higher biomass of cladocerans and meroplankton ("others") in the shallow stations as compared with the continental slope. In this season the value of *N. scintillans* biomass was negligible in all areas.

The different pattern of zooplankton distribution over the cross-shelf transect in the different seasons can be caused by the peculiarities of the hydrodynamic regime. In spring, the distinguishing feature of the water dynamics in the northeastern coastal zone is the development of the fast boundary (Rim) current over the continental slopes while in autumn, the circulation is usually characterized by a weakening of the Rim current and by extensive formation of eddies from small to mesoscale size (Kubryakov et al., 2014). Earlier it has been shown that intensification of the Rim current can result in an increase of mesozooplankton abundance over the slope, and opposite, a weakening of the current and increase in the vortex activity facilitate the cross-shelf exchange and result in more homogenous distribution of zooplankters over the shelf and slope (Arashkevich et al., 2005).

Assessment of water quality

Such characteristics of mesozooplankton as the percentage of *N. scintillans* and Copepoda from its total biomass were used to assess water quality. Unfortunately, due to the fact that the values of the total biomass of mesozooplankton were expressed in organic carbon units rather than in wet weight, it was impossible to use the adopted standards for this indicator. The threshold values of the used indicators, which correspond to Good Ecological Status (GEnS), for *N. scintillans* should be < 30%, for copepods > 42%. All of these thresholds are the same for three areas: coastal, shelf and open sea (MISIS Joint Cruise Scientific Report, 2014). Using the averaged results of all observations for the investigation period (see Table 1.3.3.4.2) and the adopted threshold values of the indicators, the quality of the marine environment in the northeastern part of the Black Sea was assessed (Table 1.3.3.4.3).

For the period 2008-2014 the GEnS was registered in 71.4% of cases. Non-GEnS water quality was observed in 2008, 2009, 2011 and 2014 (see Table 1.3.3.4.3).

Concluding remarks

The decrease in *Mnemiopsis* biomass coincided with the general trend of an increase in SST, although any statistically significant correlation between this biomass and temperature was undetectable. No correlation between the biomass of gelatinous predators and biomass of both the overall mesozooplankton and its individual taxonomic groups was observed.

Thus, the state of the pelagic system of the examined region in the last decade can be regarded as rather stable despite a high rate of increase in sea temperature. However, several negative signals are observed, which are associated with both direct and mediated influences of warming. First and foremost, this refers to the lower components of the trophic chain, in particular, a decrease in diatom biomass, which, in turn, has a negative effect on the biomass of herbivorous plankton. The decrease in biomass rerecorded during the last 2 years and the changes in taxonomic compositions of phytoplankton and zooplankton currently appear as interannual fluctuations; however, considerable rearrangements in the structure and functioning of the shelf pelagic system are expectable with further temperature elevation if this trend is retained.

Table 1.3.3.4.2. Distribution of total number of registered mesozooplankton taxon's and biomass (mg C·m^{-3}) on northeastern (Russian Federation) shelf area

Mesozooplankton components	**2008**		**2009**		**2010**		**2011**		**2012**		**2013**		**2014**	
	Spr	**Aut**	**Spr**	**Aut**	**Spr**	**Aut**	**Spr**	**Aut**	**Spr**	**Aut**	**Spr**	**Aut**	**Spr**	**Aut**
Number of taxon's	11	17	10	18	10	16	11	17	10	14	11	15	11	15
Total biomass	5.34	12.49	3.08	12.38	5.27	7.79	7.04	11.90	11.71	5.44	2.34	1.43	1.93	5.79
Noctiluca	1.97	0.02	0.28	0.002	0.38	0.16	1.79	0.02	1.94	0.01	0.01	0	0.79	0/23
Copepoda	1.42	7.82	2.56	4.39	3.80	3.58	4.32	4.39	7.86	3.61	1.34	1.05	0.69	3.95

Note: **Spr** (March-April), **Aut** – autumn (October-November). Larvae of Bivalvia, Gastropoda, Cirripedia, Polychaeta, Decapoda and Amphipoda were identified at the level of the class or order.

Table 1.3.3.4.3. Distribution of some indicators of mesozooplankton expressed in their percentage of total biomass (mg WW·m^{-3}) and water quality (WQ)*

Mesozooplankton components	2008		2009		2010		2011		2012		2013		2014	
	Spr	Aut	Spr	Aut	Spr	Aut	Spr	Aut	Spr	Aut	Spr	Aut	Spr	Aut
Noctiluca	37	0	9	0	7	2	25	0	17	0	0	0	41	4
Copepoda	27	63	83	35	72	46	61	37	67	66	57	73	36	68
Integral WQ														

Note: **Spr** (March-April), **Aut** – autumn (October-November). Larvae of Bivalvia, Gastropoda, Cirripedia, Polychaeta, Decapoda and Amphipoda were

*Threshold values which correspond to Good Ecological Status (blue color): for *N. scintillans* should be < 30%, for copepods should be > 42%.1.3.3.5.

Turkish shelf area

Zooplankton is the main component of the pelagic environment. Zooplankton studies along the Turkish Black Sea coast started at mid of 20th century (Demir, 1954; Einarsson and Gürtürk,1959). Studies mostly focus on taxonomic structure, diversity and zooplankton ecology, species distribution and abundance. Zooplankton studies in Turkish Black Sea shelf area has recently focused on Sinop, Samsun and Trabzon (Erkan et al, 2000; Besiktepe and Unsal, 2000; Besiktepe, 2001, Feyzioglu and Yıldız, 2010; Yıldız and Feyzioğlu 2014; Ustun et al 2008; Deniz and Gönülol, 2016).

Present data were collected from 2008 to 2013 monthly and seasonal period in Sinop (southern area of Turkish coast) and southeastern Black Sea continental shelf area from Samsun to Hopa during the various cruises. Sampling point and region were given in Fig. 1.3.3.5.1, Table 1.3.3.5.1.

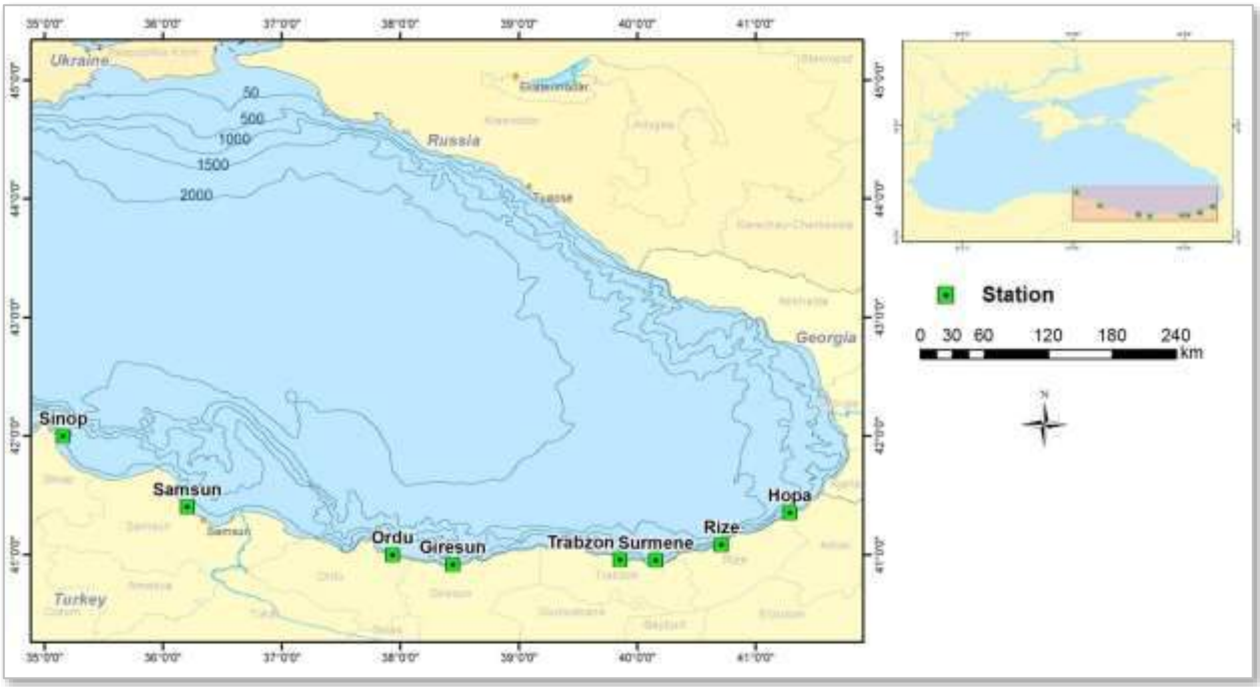


Figure 1.3.3.5.1. Location of mesozooplankton sampling station on shelf of Turkey.

Table 1.3.3.5.1. Geographic coordinate, station depth, sampling period and location.

Sampling Location	Depth (m)	Lat	Long	Sampling Period
Sinop off-shore	50	42° 00' 21" N	35° 09' 32" E	2008-2009
Samsun Coast	12	41° 45.120 N	35° 58.205 E	2012-2013
Samsun off-shore	950	41° 54.195 N	35° 58.205 E	2012-2013
Ordu Coast	18	41° 00.010 N	37° 56.100 E	2007-2009,2012-2013
Ordu Off-shore	560	41° 09.090 N	37° 56.100 E	2012-2013
Giresun Coast	15	40° 55.245 N	38° 26.600 E	2012-2013
Giresun Off-shore	870	41° 04.830 N	38° 26.600 E	2012-2013
Trabzon coast	12	40° 57.562 N	39° 51.310 E	2007-2009,2012-2013
Trabzon off-shore	600	41° 07.605 N	39° 51.311 E	2007-2009,2012-2013
Rize coast	10	41° 05.212 N	40° 42.686 E	2007-2009,2012-2013
Rize off-shore	>2000	41° 15.330 N	40° 42.932 E	2012-2013
Hopa Coast	12	41° 21.393 N	41° 17.272 E	2012-2013
Hopa Off-shore	>1500	41° 31.263 N	41° 17.500 E	2012-2013
Surmene Time Series Station	300	40° 57.190 N	40° 09.410 E	2008-20014

Zooplankton sampling near Sinop was carried out from 50 m to 0 m (sea surface) via vertical net hauls aboard the “Araştırma I” research vessel. All zooplankton samples were obtained during daytime with a single vertical haul by using a plankton net of 50 cm diameter mouth opening (opening area 0.2 m^2) and 112 µm mesh size. Following the vertical tow, contents of the cod ends were filtered using a 2 mm sieve to retain gelatinous organisms.

The samples in southeastern Black Sea continental shelf were taken with help of Hensen plankton nets (200 µm mesh size) in Sürmene Bay from 2007 to 2014 (see Table 1.3.3.5.1). The other samplings were conducted in 7 locations with monthly intervals between Samsun - Hopa during the period of 2007 - 2008 - 2009 and between 2013-2014 seasonal periods (see Fig. 1.3.3.5.1).

The samples were preserved in borax buffered formalin solution (final concentration 4%) until laboratory analysis. Sub-samples of 1 ml taken with a Stempel pipette (two replicate) were used for analysis. For species, which did not appear during subsampling and for rare groups (like Chaetognatha, Decapod larvae), all samples were analyzed. Results were averaged and extrapolated to the whole sample. Holoplanktonic groups included Copepod, Cladocera, Chaetognatha and Appendicularia. Although *Noctiluca scintillans* is an unicellular organism, it is considered as the holoplankton because of its large size: 500-800 µm (Deniz and Gönülol, 2016).

Species composition

Mesozooplanktonic species in southeastern part of Turkey Black Sea coast is given in Table 1.3.3.5.2. Holoplaktonic community includes 10 Crustacea, 1 Chaetognatha and 1 Appendicularia species. Among the zooplanktonic groups Crustacea is dominant. Species which is belong to the copepod included *Calanus euxinus, Acartia clausii, Paracalanus parvus, Pseudocalanus elongates, Acartia tonsa, Centropages ponticus* and *Oithona similis* (see Table 1.3.3.5.2). A more detailed study of mesozooplankton was conducted on the southern coast in the Sinop area. 37 taxa / species were recorded here. The total list of the registered number of species was increased first of all due to pelagic larvae of benthic organisms and fish. More species of Cladocera and Copepoda (totally 15 species of pelagic Crustacea) were identified (Table 1.3.3.5.3).

Table 1.3.3.5.2. Main Mesozooplanktonic groups and species registered in southeastern Black Sea continental shelf area of Turkey.

Calanoid Copepod
Calanus euxinus
Acartia clausii
Paracalanus parvus
Pseudocalanus elongatus
Acartia tonsa
Centropages ponticus
Cyclopoid Copepod
Oithona similis
Oithona davisae (after 2010 in Southeastern Black Sea)
Cladocera
Penilia avirostrist
Evadne tergestina
Chaetognatha
Sagitta setosa
Oikopleuridae
Oikopleura dioica

Species richness is the relative abundance of the species and Species diversity is the number of species that are represented in a given community. Species diversity and richness are a useful parameter for the comparison of communities. Table 1.3.3.5.4-7 presents the Margalef Species Richness (d') and The Shannon-Wiener diversity index (H') results. The Shannon-Wiener index (H') of the mesozooplankton collected from the 12 stations range from 0.44 (Samsun off-shore station in summer) to 3.02 (Giresun off-shore station in winter) and there were no significant difference ($P<0.05$) among the 12 sampling stations. But statistical significans were observed between the sampling season ($p<0.05$). Winter season species diversity (H') were significantly differs than summer and spring species diversity. Diversity is low in spring period (mean H'=1.50) and its higher in winter (mean H'=2,64)

Table 1.3.3.5.3. Annual mean abundances and biomasses of mesozooplankton groups in Sinop area (standard deviation values given after ±).

Taxon / Species	Abundance, ind·m^{-3}		Biomass, mg·m^{-3}	
	2008	**2009**	**2008**	**2009**
APPENDICULARIA				
Oikopleura (Vexillaria) dioica Fol, 1872	107±88	258±119	1.04±0.9	4.05±1.66
CLADOERA				
Evadne spinifera P.E.Müller, 1867	9±32		0.04±0.13	
Penilia avirostris Dana, 1849	109±236	138±270	3.06±6.61	3.87±7.57
Pleopis polyphaemoides (Leuckart, 1859)	74±97	10±18	0.66±0.87	0.09±0.16
Pseudevadne tergestina (Claus, 1877)	0.3±0.9	9±21	0.001±0.004	0.03±0.09
Total	**193±242**	**156±287**	**3.76±6.51**	**3.99±7.63**
CHAETOGNATHA				

Parasagitta setosa (Müller, 1847)	6±5	73±186	0.87±0.71	10.90±18.77
COPEPODA				
Acartia (Acartiura) clausi Giesbrecht, 1889	293±30	316±235	3.30±3.5	3.56±2.60
Calanus euxinus Hulsemann, 1991	8±10	20±41	0.77±0.63	5.12±11.45
Centropages ponticus Karavaev, 1895	1±2	12±25	0.04±0.07	0.33±0.8
Cymbasoma sp.		0.01±0.03		
Oithona davisae Ferrari F.D. & Orsi, 1984		176±441		0.35±0.86
Oithona similis Claus, 1866	45±34	119±101	0.14±0.11	0.38±0.33
Paracalanus parvus (Claus, 1863)	347±572	753±428	1.89±3.32	3.87±2.52
Pontella mediterranea (Claus, 1863)	0.004±0.01		0.003±0.01	
Pseudocalanus elongatus (Boeck, 1865)	97±44	250±406	1.36±0.81	4.37±6.93
Unidentified Harpacticoida	2±4	0.1±0.2	0.07±0.13	0.003±0.006
Unidentified Copepoda		1±1		0.02±0.04
Copepoda egg	63±76	61±81	0.06±0.07	0.05±0.07
Copepoda nauplii	307±145	465±440	0.35±0.19	0.47±0.44
Total	**1163±708**	**2172±1248**	**7.98±5.44**	**18.53±18**
FORAMINIFERA	0.06±0.22	0.2±0.1	0.0002±0.001	0.0003±0.001
TINTINNIDA	6±13	2±5	0.006±0.01	0.002±0.005
MEROPLANKTON				
Actinotroch larvae	0.03±0.05			
Amphipoda	0.02±0.07		0.0003±0.001	
Ascidiacea larvae	0.2±0.3	0.01±0.03	0.0002±0.000	0.0001±0.000
Bivalvia larvae	355±269	296±156	1.78±1.34	1.48±0.78
Byrozoa larvae		0.5±1.5		0.0007±0.002
Cirripedia larvae	8±6	3±3	0.14±0.11	0.07±0.11
Coelenterata larvae	4±9	0.5±1.5	0.02±0.07	0.003±0.009
Decapoda larvae	1±1	1±2	0.04±0.06	0.06±0.12
Gastropoda larvae	23±29	15±15	0.25±0.31	0.17±0.16
Isopoda	0.3±0.6	0.1±0.1	0.01±0.03	0.003±0.005
Ostracod		0.01±0.03		0.0003±0.001
Polychaeta larvae	6±8	16±29	0.08±0.12	0.59±1.09
Fish egg	0.1±0.4	0.5±0.9		
Fish larva	0.05±0.16	0.2±0.3		
Total	**398±258**	**332±181**	**2.33±1.24**	**2.38±1.87**
Total Mesozooplankton Average m^{-3}	**1873±740**	**2994±1330**	**15.99±8.53**	**39.84±29.57**

DINOFLAGELLATA				
Noctiluca scintillans (Macartney) Kofoid & Swezy, 1921	104±123	155±207	9.16±10.81	13.68±18.22

Table 1.3.3.5.4. Distribution of zooplankton diversity index in investigated areas along the southeastern Black Sea in **winter**.

Location	Distance	d'	H' (log_2)
Hopa	Coastal	1.48	2.63
	Off-shore	1.73	2.62
Rize	Coastal	1.31	2.73
	Off-shore	1.27	2.57
Trabzon	Coastal	1.63	2.47
	Off-shore	2.00	2.63
Giresun	Coastal	1.46	2.02
	Off-shore	1.96	3.02
Ordu	Coastal	1.49	2.73
	Off-shore	1.81	2.87
Samsun	Coastal	1.42	2.59
	Off-shore	1.96	2.89

Table 1.3.3.5.5. Distribution of zooplankton diversity index in investigated areas along the southeastern Black Sea in **spring**.

Location	Distance	d'	H' (log_2)
Hopa	Coastal	1.49	1.77
	Off-shore	1.68	1.67
Rize	Coastal	2.13	1.59
	Off-shore	2.00	1.47
Trabzon	Coastal	1.35	2.26
	Off-shore	1.14	1.58
Giresun	Coastal	1.98	1.24
	Off-shore	2.18	1.04
Ordu	Coastal	2.64	1.81
	Off-shore	1.49	1.44
Samsun	Coastal	1.23	1.32
	Off-shore	1.05	0.91

Table 1.3.3.5.6. Distribution of zooplankton diversity index in investigated areas along the southeastern Black Sea in **summer**.

Location	Distance	d'	H' (log_2)
Hopa	Coastal	2.48	2.04
	Off-shore	1.73	1.81
Rize	Coastal	2.27	1.85
	Off-shore	2.18	1.99
Trabzon	Coastal	2.19	2.60
	Off-shore	1.98	2.21
Giresun	Coastal	1.28	1.48
	Off-shore	1.13	1.21
Ordu	Coastal	1.69	1.52
	Off-shore	1.46	1.73

Samsun	Coastal	2.21	0.60
	Off-shore	1.58	0.44

Table 1.3.3.5.7. Distribution of zooplankton diversity index in investigated areas along the southeastern Black Sea in **autumn**.

Location	Distance	d'	H' (log_2)
Hopa	Coastal		
	Off-shore		
Rize	Coastal		
	Off-shore		
Trabzon	Coastal	1.57	2.37
	Off-shore	1.50	2.54
Giresun	Coastal	1.79	2.28
	Off-shore	1.63	2.34
Ordu	Coastal	1.71	2.37
	Off-shore	1.60	2.54
Samsun	Coastal	1.70	2.86
	Off-shore	1.22	2.30

Margalef Species richness (d') was calculated as 1.64 and 1.75 coastal stations and off-shore stations respectively. Significant statistical differences were not observed between seasons. The lowest species richness was in Samsun (1.54) and the highest was in Rize location (1.86). According to index results Samsun region is less divers and has low species richness than easter part of the South eastern Black Sea continental shelf areas. In general, off-shore area is more divers than the coastal area. Although the lowest species richness observed in the winter, the species diversity is the highest in the same period.

Due to the large number of registered species, the total biological diversity in the Sinop area was almost twice as high. The Shannon index calculated according to Table 1.3.3.5.3 for 2008 was 3.713, and for 2009 3.537 ind·bit^{-1}.

Seasonal dynamic

Most of the seasonal changes were characterized by an increase in the biomass of zooplankton in spring and autumn. Its biggest quantitative development according to observations in the southeastern part of the Turkish shelf (Table 1.3.3.5.9) was noted in 2008. At the same time, in the south in the Sinop area (Table 1.3.3.5.8), the total biomass of zooplankton was on average lower than in the southeast in 4.2 times, if we express the value of biomass in wet weight (Fig. 1.3.3.5.2).

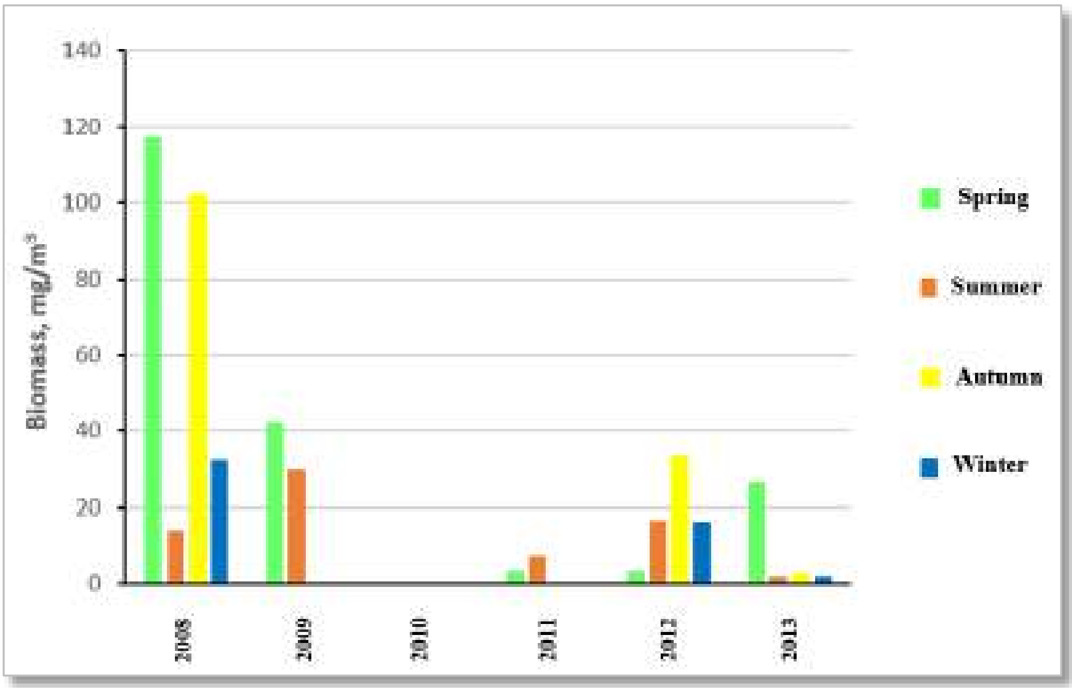


Figure 1.3.3.5.2. Interannual and seasonal dynamics of the total biomass of mesozooplankton in the southeastern part of the Turkish coast of the Black Sea. To biomass value conversion from dry to wet weight, the following dependence was used: 1 mg DW = 5 mg WW (Cushing et al., 1958).

Copepods were dominant group of mesozooplankton organisms in every season but their abundance reach the maximum population size during the winter and spring periods (Fig. 1.3.3.5.3).

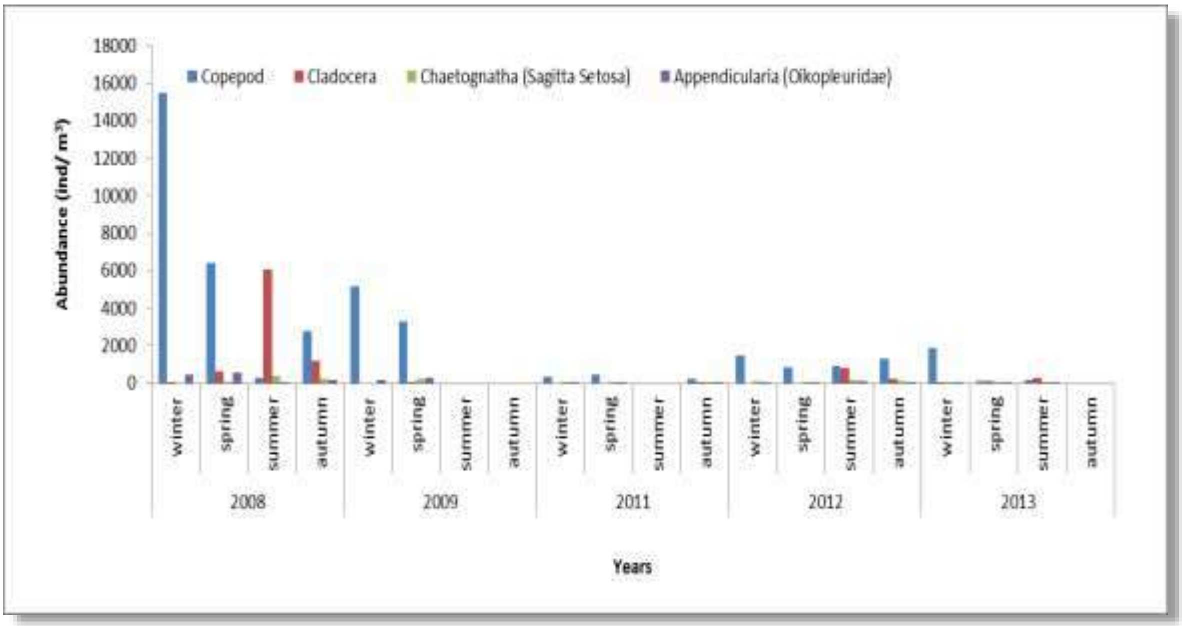


Figure 1.3.3.5.3. Seasonal changes of the zooplankton groups in net samples.

Biomass belong to the copepod species was the highest in the end of winter and early spring 2008 (Fig. 1.3.3.5.4). Through the observation period *Acartia spp.* and *Calanus euxinus* were the most dominant species in the Southeastern Black Sea continental shelf area. *Calanus euxinus* is the

largest copepod species in the Black Sea. Throughout the sampling period winter copepod composed of mostly *Calanus euxinus* except 2008 sampling period. In this period *Acartia spp* biomass as dry weight was 18.73 mg·m^{-3}. *Paracalanus pavrus* biomass was almost equal the other copepod species autumn 2008 and winter 2009 sampling period. Copepod biomass was lower between 2009-2013 when compared copepod biomass of 2008. The reason for this may be higher phytoplankton biomass. Because, our unpublished data showed that the highest winter chlorophyll-a maximum were measured as 2.33 µg·l^{-1} in the same region so far.
Second important group in summer period is Cladocera.

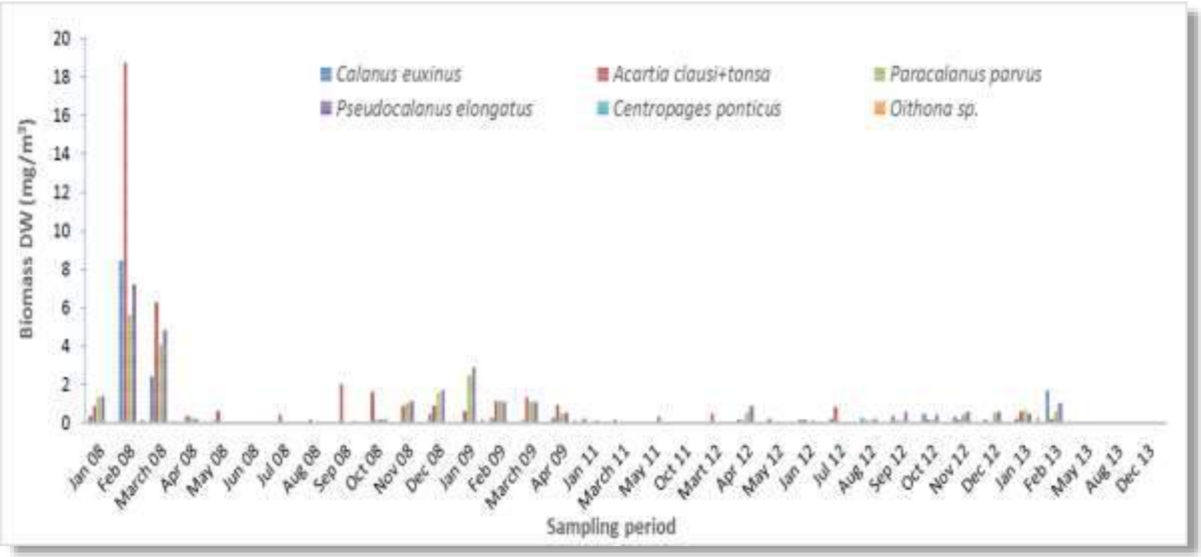


Figure 1.3.3.5.4. Biomass of the Copepod species throughout the sampling period.

N. scintillans important organism for the Black Sea pelagic ecosystem. It sometimes reaches the bloom condition. It was observed 10^{6} ind·l^{-1} (10^{9} ind·m^{-3}) and caused the red-tide in the sea surface of coastal areas (Kopuz et al, 2014). In water column, their biomass and abundance was the highest in spring and the lowest in winter season between the 2008-2013 sampling periods. Maximum cells member and biomass was 56500 ind·m^{-3} and 19.90 mg C·m^{-3} respectively (Fig. 1.3.3.5.5, 1.3.3.5.6). Their biomass gradually decrease years by years from 2008 to 2013.

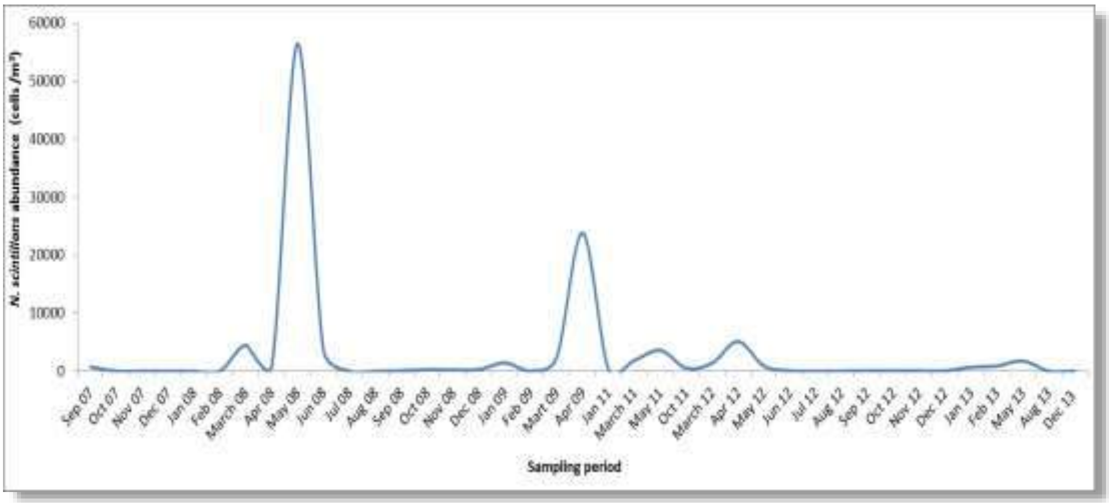


Figure 1.3.3.5.5. Monthly changes of *N. scintillans* abundance (ind·m^{-3}) in net samples.

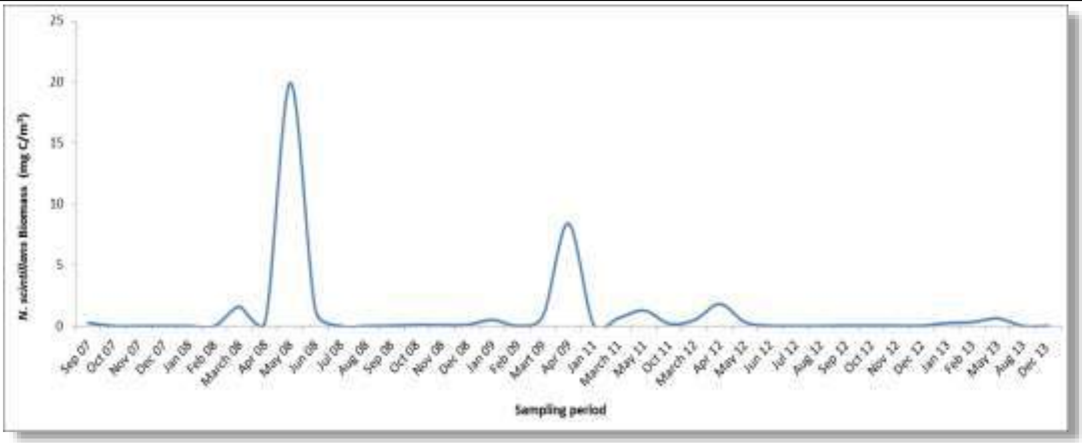


Figure 1.3.3.5.6. Monthly changes of *N. scintillans* biomass (mg C·m^{-3}) in net samples.

Spatial distribution

Mean Zooplankton abundancy in winter for six years were higher in Samsun, Rize and Hopa (Artvin) than Giresun and Trabzon sampling area (Fig. 1.3.3.5.7). But Samsun was the highest in winter biomass. Although abundance was the highest in Samsun region. The biomass as dry weight in winter was higher in Rize and Hopa (Artvin) regions. Giresun and Samsun had the lowest zooplankton biomass and the abundance in the spring respectively. During the summer time the zooplankton biomass shows almost uniform distribution along the South eastern Black Sea continental shelf area (Fig. 1.3.3.5.8). In spring period the lowest and the highest abundance is observed in Ordu and Hopa (Artvin) regions. But the biomass was the highest in Trabzon region in the same period.

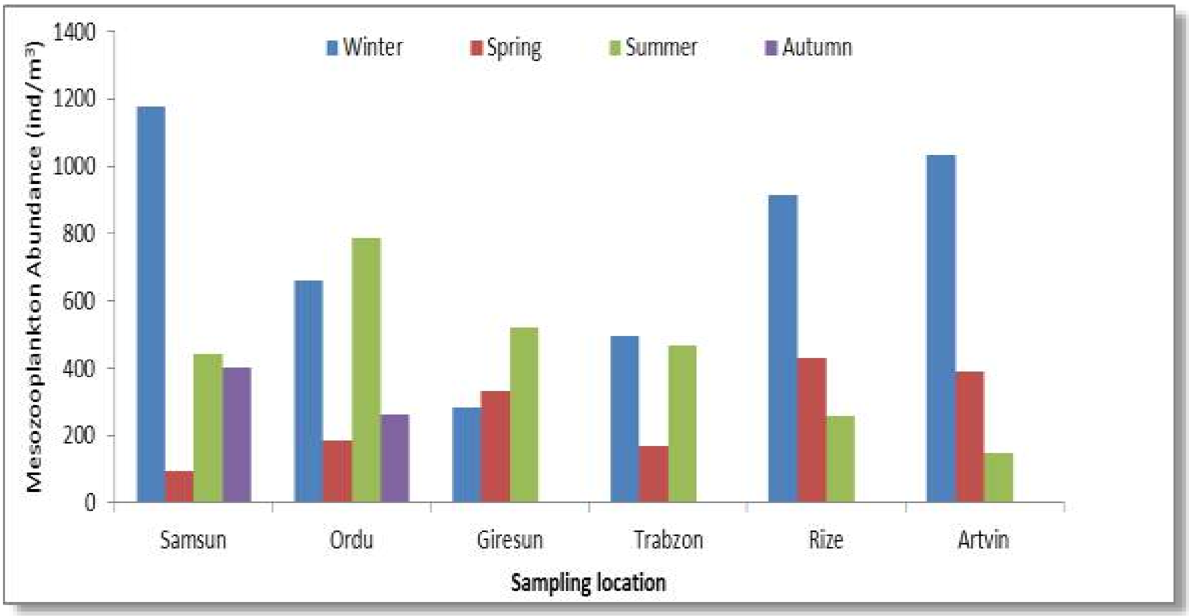


Figure 1.3.3.5.7. Geographic variation of mean mesozooplankton abundance along the southestern Black Sea coast.

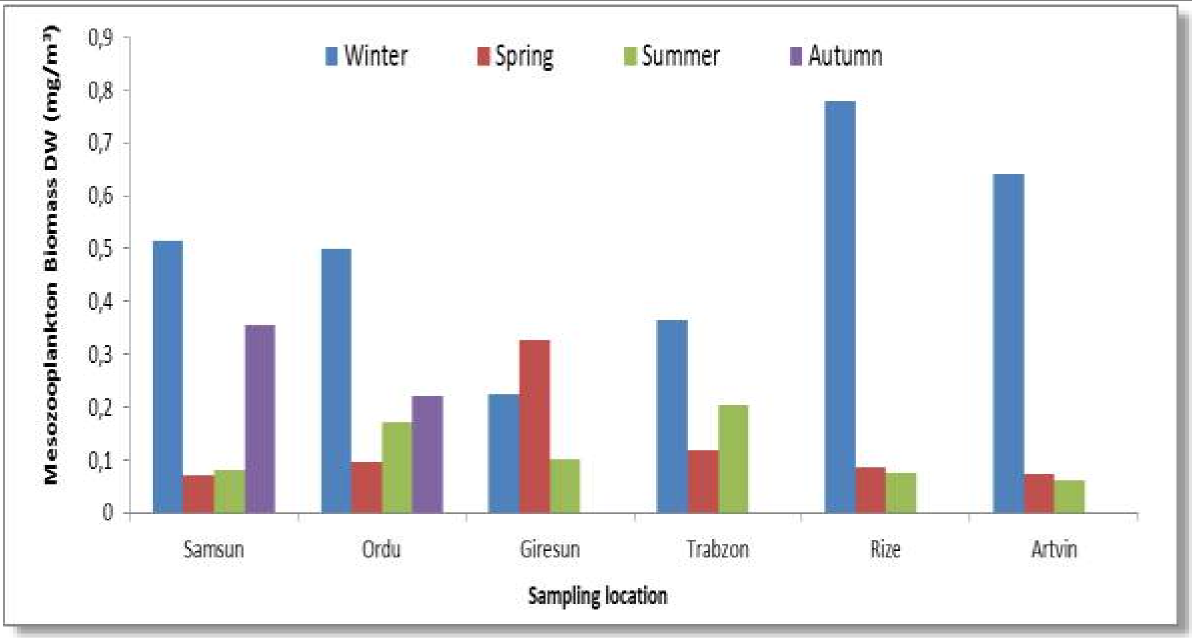


Figure 1.3.3.5.8. Geographic variation of mean mesozooplankton biomass along the southeastern Black Sea coast.

N. scintillans was more abundant in Samsun, Ordu and Giresun than Trabzon, Rize and Hopa (Fig. 1.3.3.5.9).

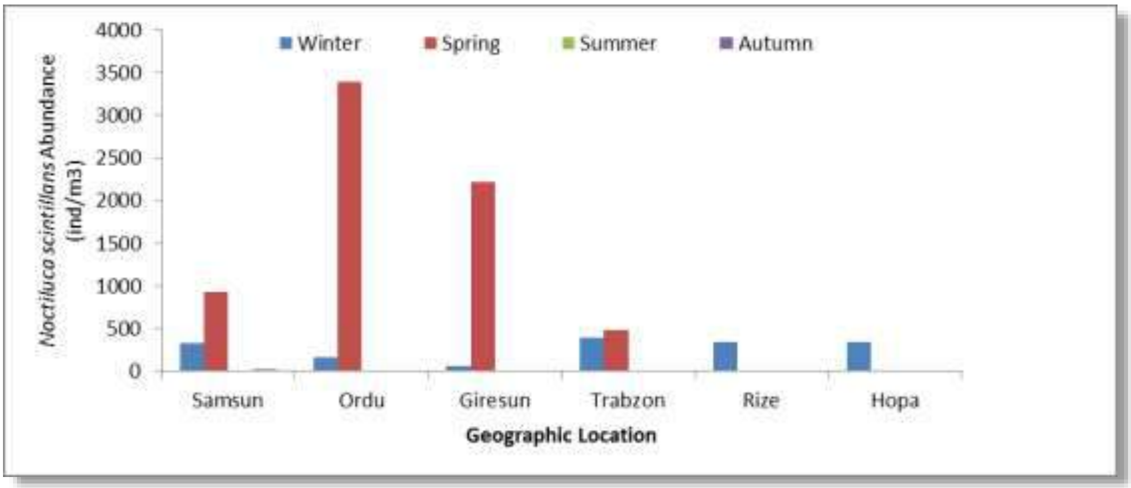


Figure 1.3.3.5.9. Geographic variation of mean *N. scintillans* abundance along the southestern Black Sea coast.

Comparison the results of mesosooplankton qualitative and quantitative development near Sinop area (see Table 1.3.3.5.8) with southeastern part of Turkish coast from Samsun to Hopa (see Table 1.3.3.5.9) allows to draw several important conclusions on biological diversity, the development of the total abundance and biomass of zooplankton, and, finally, in assessment of water quality.

Assessment of water quality

The main part of water quality indicators for zooplankton are related to its total biomass, expressed in terms of wet weight (WW). Due to the fact that most of the data collected in shelf area of Turkey during 2008-2014 were presented in the form of biomass, expressed either in dry weight (DW) or in organic carbon (C), it was impossible to calculate them, due to the lack of corresponding threshold values. Despite the data available in the literature for the conversion of

Table 1.3.3.5.8. Distribution of mesozooplankton biomass in Sinop coastal zone (southern Black Sea).

Mesozooplankton components	Months											
	Jen	**Febr**	**March**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2008												
Total biomass, mg WW·m^{-3}	8.26	7.94	12.44	10.91	8.64	4.45	16.03	31.77	21.50	25.74	22.71	21.45
Noctiluca, mg WW·m^{-3}	0.72	0.13	0.36	4.04	35.96	16.41	3.77	16.38	1.70	9.15	3.05	18.30
Copepoda, mg WW·m^{-3}	3.05	5.70	6.70	3.35	4.87	1.57	6.17	5.44	10.02	16.91	15.42	16.53
2009												
Total biomass, mg WW·m^{-3}	15.39	28.94	25.15	77.53	3.79		41.59	21.87	99.46	25.33	29.51	69.71
Noctiluca, mg WW·m^{-3}	55.38	41.25	15.25	4.48	9.19		0.67	3.58	15.47	4.26	0.22	0.67
Copepoda, mg WW·m^{-3}	11.39	20.14	20.09	68.65	1.54		6.72	6.62	16.71	9.47	20.21	22.25

Note. WW – wet weight

Table 1.3.3.5.9. Distribution of mesozooplankton biomass on southeastern Black Sea continental shelf area of Turkey.

Mesozooplankton components	Months											
	Jen	**Febr**	**March**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2008												
Total biomass, mg DW·m^{-3}	4.177	42.780	23.317	1.711	4.321	2.320	22.015	20.964	18.529	4.722	8.244	6.618
Noctiluca, mg C·m^{-3}	0.180	0.119	1.520	0.304	1.912	1.204	0.203	0.125	0.024	0.080	0.075	0.094
Copepoda, mg DW·m^{-3}	4.177	40.228	17.873	1.105	0.953	0.095	0.497	0.179	2.205	2.388	3.260	4.736
2009												
Total biomass, mg DW·m^{-3}	7.183	4.065	14.153	5.976								
Noctiluca, mgC·m^{-3}	0.482	0.142	0.799	1.750								
Copepoda, mg DW·m^{-3}	6.408	3.820	4.016	2.521								
2011												

Total biomass, mg DW·m^{-3}	0.717		0.604		1.508					0.937		
Noctiluca, mgC·m^{-3}	0.128		0.630		0.220					0.182		
Copepoda, mg DW·m^{-3}	0.461		0.395		0.639					0.286		
2012												
Total biomass, mg DW·m^{-3}			0.608	2.840	0.551	6.635	8.669	4.343	7.307	2.462	3.188	4.026
Noctiluca, mgC·m^{-3}			0.461	1.731	0.099	0.020	0.041	0.037	0.309	0.241	0.022	0.022
Copepoda, mg DW·m^{-3}			0.608	1.839	0.326	0.657	1.367	0.952	1.358	1.534	1.675	1.559
2013												
Total biomass, mg DW·m^{-3}	5.360	5.393			0.437			0.552				0.439
Noctiluca, mgC·m^{-3}	0.230	0.301			0.197			0.034				0.022
Copepoda, mg DW·m^{-3}	2.443	3.854			0.129			0.115				0.288

Note. DW – dry weight, C – biomass in carbon

Table 1.3.3.5.10. The percentage of copepods from the total biomass of mesozooplankton as an indicator of water quality (WQ)* in the Black Sea shelf area of Turkey.

Years	Months											
	Jen	**Febr**	**March**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Southern Black Sea (Sinop)												
2008	37	72	54	31	56	35	38	17	47	66	68	77
2009	74	70	80	88	41		16	30	17	37	68	32
Southeastern Black Sea (Samsun, Ordu, Giresun, Trabzon, Surmene, Rize, Hopa)												
2008	100	94	77	65	22	4	2	1	12	51	40	72
2009	89	94	28	42								
2011	64		65		42					31		
2012			100	65	59	10	16	22	19	62	53	39
2013	46	71			30			21				66

*Threshold values which correspond to Good Ecological Status (blue color) for copepods should be > 42% (MISIS Joint Cruise Scientific Report, 2014).

zooplankton biomass from DW or C to WW (Cushing et al., 1958, Smayda, 1966, Alexandrov et al., 2015), the error of such calculations is very large. Therefore, the baseline data (see Tables 1.3.3.5.8, 1.3.3.5.9) was used only for such a water quality indicator as the percentage of copepods from the total biomass of mesozooplankton (Table 1.3.3.5.10). The analysis of the received materials led to the following conclusions:

1. Monthly monitoring was not always provided with regular observations. In 26 cases, out of 84 observations were not provided. In 2010 and 2014 studies were not organized. In the Sinop area, monitoring was interrupted after 2009.

2. On an average for the year, the percentage of copepods over the period 2008-2013 off the coast of Turkey ranged from 45 to 63%, that is, corresponded to a good ecological status (GES).

3. According to this indicator, the southern coast in the Sinop area was practically no different from the southeastern part of Turkey.

4. The highest GES (average 63 ± 16%) was found in 2009.

5. The seasonal dynamics of changes in the percentage of copepods over the period under study changed on the average as follows: spring - 73 ± 6%, summer - 40 ± 5%, autumn - 20 ± 5% and winter - 53 ± 6%.

In general, the quality of water in the shelf zone of Turkey in terms of the state of zooplankton can be characterized as good.

1.3.3.6. Ukrainian shelf area

Offshore water area of Ukraine in the Black Sea can be divided into two zones that differ significantly in terms of hydrological conditions. It is a shallow northwestern part of the Black Sea (NWBS), which is heavily influenced by the largest rivers of the Black Sea and the narrow shelf of the Crimean Peninsula with extremely limited river flow and a sharp increase in depth beyond the coastal zone one mile wide. Another natural factor is the prevalence of sandy beaches in NWBS and rocky shores in Crimea.

The Odessa Gulf is experiencing the strongest anthropogenic pressure in NWBS, which is affected by the ports of Big Odessa (Ilyichevsk now Chernomorsk, Odessa and Yuzhniy) with an annual cargo turnover about 90 million tons per year (the second one after the port of Novorossiysk, Russia in the Black Sea). In the narrow coastal zone of the Odessa region, hydrotechnical structures to protect the coast from landslides are located. Creation of this constructions were started in 1959. Their total length is 14.5 km. In the area of hydrotechnical structures there are 12 releases of fresh drainage water with a total debit (water discharge) of 50-60 thousand $m^3 \cdot day^{-1}$. The daily volume of sewage from Odessa with population more than one millionth in to the sea from two biological treatment stations exceeds 1 million m^3 per day (Dotsenko et al., 2009). A high anthropogenic impact is experienced in the Crimea Sevastopol Bay, which houses the largest naval base in the Black Sea.

As already mentioned in the introduction to the section "Mesozooplankton" during the last 20 years (1988-2008) a stable tendency of warming and simultaneous freshening of waters is observed in the narrow coastal zone of the Odessa region, as evidenced by a constant increase in the average annual water temperature and the same decrease an average salinity in this period (Dotsenko et al., 2009).

In contrast to the above-mentioned regions of the Ukrainian shelf, the least affected, except for eutrophication, is anthropogenic impact in the Danube region, opposite the Ukrainian part of the Danube Delta, where the Danube Biosphere Reserve is located.

Three categories of research areas were used to assess the Black Sea water quality in Ukraine shelf area: 1) marine coastal waters, which included 9 coastal stations in the Odessa Gulf and two stations in the Sevastopol Bay; 2) transition waters (the Danube and Odessa regions, whose stations are located more than one nautical mile away, 3) the shelf zone (off-shore st. 1 in the Crimea, which was located outside the Sevastopol Bay).

Northwestern part of the Black Sea that was investigated includes Danube Delta area and Odessa regions which was divided into the shelf (Fig.1.3.3.6.1) and coastal (Fig.1.3.3.6.2) zones.

Research on NWBS shelf area of Ukraine was carried out with the help of R/V "Sprut". In Odessa region have been organized 7 expeditions and 12 expeditions in Danube region during 2008-2014. Totally of 326 zooplankton samples were collected from 28 monitoring stations (140 samples) in Odessa region and 23 stations (186 samples) in Danube region in 2008-2014 (Tables 1.3.3.6.1, 1.3.3.6.2). Investigations were conducted in spring, summer and autumn. Samples were collected by vertical plankton Juday net, 0.1 m^2 mouth opening area, 150 µm mesh size. At each station was carried out one haul with a net from the bottom to the sea surface. The samples were preserved in final 4% formalin. In the laboratory the samples were settled before being divided into sub-samples. Bogorov's chamber was used for quantitative assessment (abundance and biomass calculation) and qualitative (taxonomic structure) processing of sub-samples (Alexandrov et al., 2015).

Within the Odessa region, hydrobiological monitoring was carried out on the basis of regular observation, periodically once a week, at stations in the cape Maliy Fontan and city beach "Arcadia", once in a season (spring: May-June and autumn: August-September) at the stations in port Yuzhniy and Odessa (oil terminal), city beaches "Luzanovka", "Delfin ", "Chkalov", cape Bolshoy Fontan (Table 1.3.3.6.3). Totally were taken 596 samples of mesozooplankton during 2008-2014 on these stations, including 283 samples in cape Maliy Fontan, 272 in city beach "Arcadia" and 42 stations in Odessa region. Zooplankton sampling was carried out by Apshtein plankton net with inlet diameter 37 cm and mesh size 200 µm. Sampling was carried out in a layer of water from the bottom to the surface, in shallow places through the grid passed 100 liters of water. To Zooplankton samples was conserved by formalin. Light microscope MBS-9 was used for calculation the abundance of plankton organisms. Species were identified according to Morduhay-Boltovskoy (1968, 1969, 1972) manuals. Biomass values as wet weight were estimated based on the number of individuals and the individual weight given per taxon and size class in Petipa (1959).

For optimal analysis of a large base of initial data (total 922 stations), results of investigations in northwestern part of the Black Sea were averaged not only for all stations of each individual survey, but also for seasons (Table 1.3.3.6.4, 1.3.3.6.5).

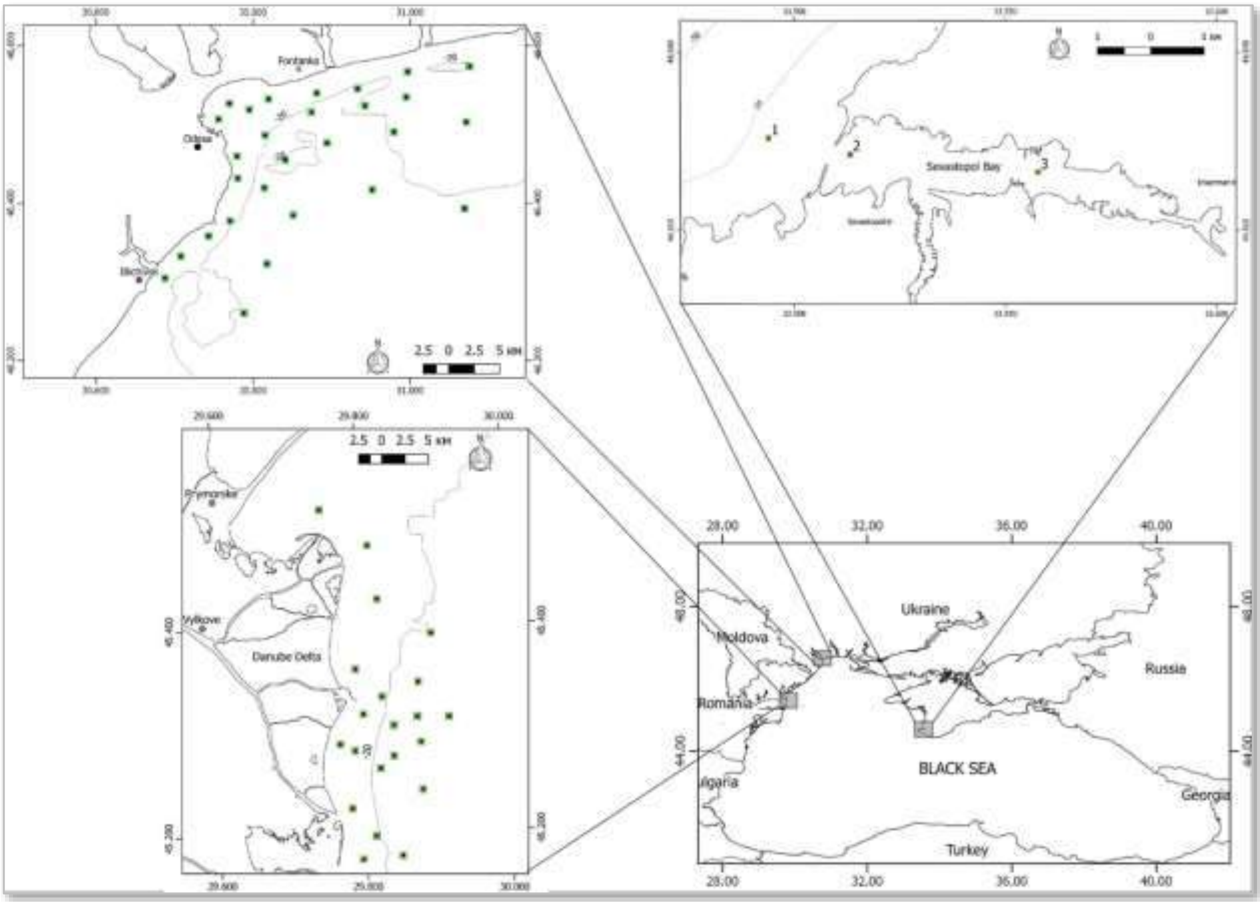


Figure 1.3.3.6.1. Investigated polygons and research stations in Ukrainian shelf area of the Black Sea.

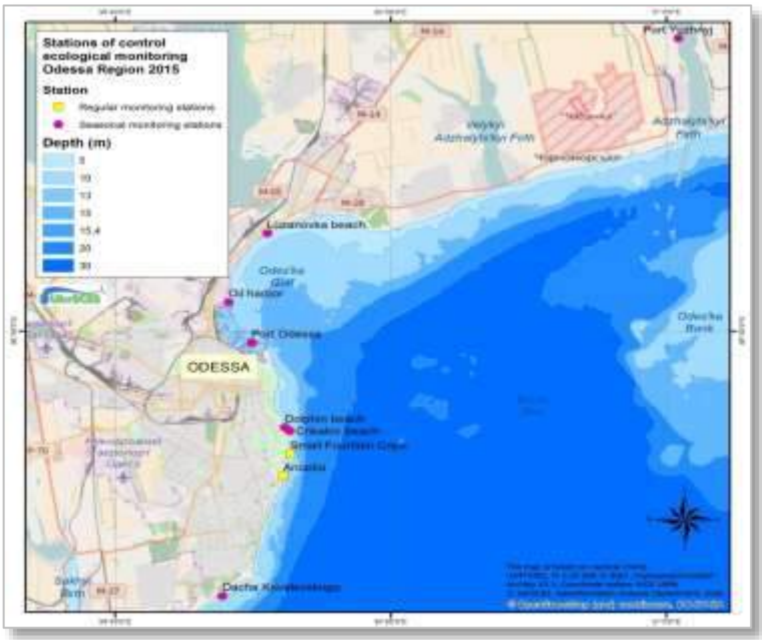


Figure 1.3.3.6.2. Marine coastal stations in Odessa region (northwestern part of the Black Sea).

Table 1.3.3.6.1. General characteristics of expeditions on RV "Sprut" in northwestern Black Sea shelf.

Year	Odessa region		Danube Delta region	
	Data	Total number of the stations	Data	Total number of the stations
2008	02–05.08.	26	03–05.06.	14
	14–15.10.	16	15–18.08.	18
			23–27.10.	18
2009	07–09.07.	15		
2010	23–28.06.	21	27–29.04.	15
			24–30.08.	18
			30.11– 04.12.	9
2011	08–09. 15.07.	24	29–30.06.	19
			13–15.10.	18
2012	26–27.09.	19	07–09.11.	18
2013	07–08.08.	19	01–02.08.	19
2014			11–12.09.	10
			09–10.11.	10

Table 1.3.3.6.2. Location of mesozooplankton sampling station on the shelf area of Ukraine in northwestern part of the Black Sea.

St.	Odessa region		St.	Danube region	
	Latitude	Longitude		Latitude	Longitude
1	46º 34.80' N	31º 00.30' E	1	45° 31.35' N	29° 44.68' E
2	46º 33.70' N	30º 55.05' E	2	45° 29.15' N	29° 48.03' E
3	46º 32.10' N	30º 57.00' E	3	45° 26.00' N	29° 49.00' E
4	46º 28.60' N	30º 54.20' E	4	45° 22.977' N	29° 53.014' E
5	46º 30.90' N	30º 52.20' E	5	45° 22.060' N	29° 48.154' E
6	46º 32.80' N	30º 52.60' E	6	45° 21.20' N	29° 51.97' E
7	46º 32.20' N	30º 49.60' E	8	45° 19.330' N	29° 47.923' E
9	46º 31.85' N	30º 46.35' E	9	45° 18.652' N	29° 50.404' E
12	46º 30.30' N	30º 45.20' E	10	45° 19.377' N	29° 52.258' E
13	46º 30.90' N	30º 47.40' E	10-1	45° 19.839' N	29° 52.274' E
15	46º 29.10' N	30º 49.40' E	10-2	45° 19.370' N	29° 52.946' E
16	46º 27.30' N	30º 49.30' E	10-3	45° 18.957' N	29° 52.171' E
17	46º 28.10' N	30º 46.70' E	10-4	45° 19.409' N	29° 51.626' E
18	46º 25.80' N	30º 46.80' E	12	45° 17.00' N	29° 50.00' E
19	46º 25.00' N	30º 49.30' E	13	45° 17.773' N	29° 52.111' E
20	46º 22.60' N	30º 50.80' E	14	45° 14.027' N	29° 46.314' E
21	46º 22.30' N	30º 45.80' E	15	45° 12.532' N	29° 48.158' E
22	46º 21.80' N	30º 45.00' E	16	45° 11.085' N	29° 49.826' E
23	46º 18.90' N	30º 48.70' E	17	45° 15.010' N	29° 50.946' E
24	46º 19.50' N	30º 42.00' E	18	45° 16.362' N	29° 48.806' E
26	46º 32.64' N	31º 00.00' E	19	45° 17.379' N	29° 47.170' E
27	46º 29.10' N	30º 58.40' E	21	45° 10.863' N	29° 47.592' E
29	46º 25.00' N	30º 57.60' E	25	45° 19.236' N	29° 54.171' E
30	46º 35.00' N	31º 05.00' E			
31	46º 30.80' N	31º 05.00' E			
33	46º 24.00' N	31º 05.00' E			

St.	Odessa region		St.	Danube region	
	Latitude	Longitude		Latitude	Longitude
41	46º 17.80' N	30º 40.60' E			
42	46º 15.00' N	30º 47.30' E			

Table 1.3.3.6.3. Location of mesozooplankton sampling station in coastal stations of Odessa region.

St.	Coordinates		Description of the area
	Latitude	Longitude	
1	46° 38.79' N	31° 00.42' E	Port Yuzhniy
2	46° 32.93' N	30° 45.52' E	City beach «Luzanovka»
3	46° 30.87' N	30° 44.12' E	Port Odessa (oil terminal)
4	46° 29.65' N	30° 44.96' E	Port Odessa (passenger terminal)
5	46° 27.10' N	30° 46.16' E	City beach «Delfin»
6	46° 26.64' N	30° 46.33' E	City beach «Chkalov»
7	46° 26.03' N	30° 46.07' E	Cape Maliy Fontan (city beach)
8	46° 26.00' N	30° 46.03' E	City beach «Arcadia»
9	46° 22.04' N	30° 43.89' E	Cape Bolshoy Fontan (wastewater discharge)

Table 1.3.3.6.4. Distribution of mesozooplankton characteristics on the shelf area of Ukraine in northwestern part of the Black Sea.

Year	Seasons	Odessa region (shelf area)					Shelf area in front of Ukrainian part of the Danube Delta				
		Total abundance ind·m^{-3}	Total biomass, mg·m^{-3}	Noctiluca biomass, %	Copepoda biomass, %	Shennon index, bit·ind^{-1}	Total abundance ind·m^{-3}	Total biomass, mg·m^{-3}	Noctiluca biomass, %	Copepoda biomass, %	Shennon index, bit·ind^{-1}
2008	Summer						17027± 2374	334.506± 114.876	87.7	2.1	2.111
	Autumn	8882± 1415	428.682± 77.747	97.4	1.6	1.036	13580± 3359	806.470± 206.547	92.9	4.2	1.298
	Winter	10321± 744	260.373± 37.830	65	24.6	3.000	16882± 2254	375.364± 77.626	60.4	10.7	3.078
2009	Autumn	6242± 620	279.448± 49.684	14	13.5	2.380					
2010	Summer	13913± 2131	107.175± 17.805	1.31	56.5	2.810	4142± 565	157.226± 63.650	19.5	7.3	2.326
	Autumn						32906± 4417	462.841± 57.642	1.6	43.7	2.603
	Winter						18701± 4836	98.465± 24.622	6.7	52.2	1.938
2011	Summer						11427± 3125	282.288± 42.175	62.9	2.3	2.056
	Autumn	6072± 1325	54.101± 10.446	0.02	10.0	3.066					
	Winter						36835± 4362	441.102± 66.543	7.7	31.1	2.247
2012	Autumn	63838± 6962	1099.829± 332.193	0.05	15.6	2.137					
	Winter						108599± 16460	1439.636± 393.797	1.6	8.0	1.735
2013	Autumn	28310±	295.707±	0.28	19.7	2.826	113749±	1234.392±	11.5	54.6	1.776

Year	Seasons	Odessa region (shelf area)					Shelf area in front of Ukrainian part of the Danube Delta				
		Total abundance ind·m^{-3}	Total biomass, mg·m^{-3}	Noctiluca biomass, %	Copepoda biomass, %	Shennon index, bit·ind^{-1}	Total abundance ind·m^{-3}	Total biomass, mg·m^{-3}	Noctiluca biomass, %	Copepoda biomass, %	Shennon index, bit·ind^{-1}
		2574	60.141				30734	313.589			
2014	Autumn						142829± 39282	426.078± 80.376	0	36.2	2.142
	Winter						5759± 1725	982.917± 546.852	0	1.1	1.620

Table 1.3.3.6.5. Average values for mesozooplankton characteristics of marine coastal zone in Odessa region.

Year	Season	Total number of taxon	Total biomass. mg·m^{-3}	Noctiluca biomass (%)	Copepoda biomass (%)
2008	Winter	10	0.509	0	24
	Spring	16	7.613	0	3
	Summer	16	3.816	0	8
	Autumn	8	10.548	7	1
2009	Winter	9	6.616	75	2
	Spring	12	2.672	20	15
	Summer	13	3.654	2	14
	Autumn	17	31.948	0	1
2010	Winter	5	0.820	0	5
	Spring	12	26.154	0	1
	Summer	19	36.938	0	7
	Autumn	14	22.476	25	15
2011	Winter	8	28.198	0	0
	Spring	23	55.692	0	1
	Summer	14	30.597	0	7
	Autumn	9	22.357	0	13
2012	Winter	10	1.861	0	45
	Spring	14	15.966	0	3
	Summer	15	12.348	5	6
	Autumn	16	13.971	27	7
2013	Winter	8	2.382	0	26
	Spring	18	84.985	0	1
	Summer	19	41.842	0	16
	Autumn	17	13.796	33	4
2014	Winter	7	0.316	0	34
	Spring	17	12.295	0	4
	Summer	22	20.421	6	7
	Autumn	13	87.393	0	10

Sevastopol Bay (Crimea, Northern Black Sea) is about 7000 m long and 850 m wide, with an average depth of 12 m. Regular studies of plankton communities in the bay waters were performed in 2008-2014. Samples were usually collected twice a month (with gaps due to technical or meteorological conditions) at three stations located within and adjacent to Sevastopol Bay (st. 1–3, see Fig. 1.3.3.6.1).

A total of 457 zooplankton samples were collected from 3 monitoring stations in Sevastopol Bay during 2008-2014. Samples were in the morning taken using a Juday plankton net (mouth area 0.1 m^2 and mesh size 150 μm) by vertical hauls through the whole water column (from the bottom to the sea surface): 40-0 m at the st. 1; 10-0 m at the st. 2; 9-0 m at the st. 3. Samples were fixed with buffered formaldehyde solution (4% final conc.). Before sample preservation, the gelatinous species (*Aurelia aurita*, *Pleurobrachia pileus*, *Mnemiopsis leidyi*, *Beroe ovata*) were removed, measured and counted. Zooplankton was processed by the methodology for zooplankton studies in the Black Sea (Alexandrov et al., 2015). Copepods of all copepodite developmental stages (I-VI) were identified at species level, except *Acartia* genus. Due to closely morphological features and sizes a copepodite stages (I-V) *A. clausi* and *A.tonsa* were counted together as copepodite stages of the genus *Acartia*. Adult females and males of *A. clausi* and *A. tonsa* were counted separately. Species were identified according to Morduhay-Boltovskoy (1968, 1969, 1972) manuals, taxonomic keys of Shuvalov (1980), Nishida (1985) and Sazhina (1969) as well as Razouls et al. (2005–2014). Abundance of zooplankton was calculated per cubic meter.

Species composition

In ***northwestern part of the Black Sea*** totally were found 59 representatives of the holoplankton and 7 representatives of the meroplankton. Of this number Noctilucales were represented 1 species, Calanoida - 11 species, Cladocera - 12 species, Sagittoidea - 1 species, Appendicularia -1 species and Hydrozoa - 2 species. The biggest species diversity was noted in 2011 (total 47 taxon / species), and the smallest in 2012 (total 11 taxon / species). During 2008-2014, the presence of *Noctiluca scintillans*, *Synchaeta* sp., *Parasagitta setosa*, *Oicopleura dioica*, as well as some representatives of the meroplankton of the larvae Cirripedia, Polychaeta, Bivalvia and Gastropoda was registered every year. The rest of the species did not meet regularly. The most numerous in terms of species composition, as well as frequent were representatives of Rotatoria, Cladocera and Copepoda. It should be noted that there is a significant reduction in the quantitative development of mesozooplankton. The development of one of the dominant species *Noctiluca scintillans* was decline since 1989 from 94.8 to 27.9% from total zooplankton biomass (Table 1.3.3.6.6). Among the invasive species were found *Beroe ovata*, *Oithona davisae* and *Acartia tonsa*.

Table 1.3.3.6.6. Long-term changes of *Noctiluca scintillans* biomass (B) and its percentage from the total biomass of mesozooplankton (%).

Years	Biomass, mg·m^{-3}	Percentage, %
1951-1974*	148.1 ± 14.9	38.3 ± 3.5
1975-1989*	3986.3 ± 637.9	94.8 ± 0.7
1990-2007*	1240.7 ± 404.0	73.6 ± 12.7
2008-2014	122.1 ± 44.4	27.9 ± 8.3

* Data from BSC, 2008

In ***Sevastopol Bay*** mesozooplankton is represented by a relatively small number of species, as it happens also in the entire Black Sea. Its key groups are Copepods, Meroplankton and Cladocera. The species composition was same at all stations during 2008-2014. The difference was observed in the frequency of appearances and abundance of some species in the Bay (st. 2 and 3, see Fig. 1.3.3.6.1) in comparison with open coastal area (st.1).

As few as eight species of Copepoda were found regularly in zooplankton samples throughout the period of observation: *Acartia clausi* Giesbrecht, 1889; *A. tonsa* Dana, 1849; *Calanus euxinus* Hulsemann, 1991; *Centropages ponticus* Karavaev, 1894; *Oithona similis* Claus, 1866; *Paracalanus parvus* Claus, 1863; *Oithona davisae* Ferrari and Orsi, 1984 and *Pseudocalanus elongatus* Boeck, 1865. In addition single individuals of pontellids (*Anomalocera patersoni* and *Pontella mediterranea)* were found. Apparently, Pontellidae abundance is underestimated when sampling by vertical hauls of a Juday net is performed (Alexandrov et al., 2015; Zaitsev, 1983). With the exception of *A. tonsa* and *O. davisae*, all of these species are indigenous to the Black Sea.

A. clausi and copepodite stages of the genus *Acartia* were present all year around at the all three stations as well as another eurythermous species *P. parvus*. Psychrophilic copepods *C. euxinus, O. similis* and *P. elongatus* were found all year round at st. 1 and were absent in the most of the samples in June-September at st. 2 and st. 3. In the summer months, the psychrophilic species in the open coastal area inhabit below the thermocline, which according to our data in 2010-2011 was at the depths of 9-28 m at st.1 while in the bay this one was not found. The thermophilic *C. ponticus* was reported as rule in all samples in May-November and absent from January till March. In the population of another thermophilic copepod *A. tonsa* significant interannual changes were observed during period of investigation. The copepod was found in all samples in the bay from June to October in 2008. Some individuals of the species were recorded also in May, November and December. A frequency of appearance of *A. tonsa* decreased significantly from 2009. *A. tonsa* was recorded from June to September with small abundance in 2010-2014. Only single individuals of the copepod were found in May and October. In the open coastal area (st. 1) *A. tonsa* was found in the samples in July-September 2008. It was not found in 2009 and single individuals were recorded in July-August in 2010-2014.

New non-indigenous species *O. davisae* has become one of the most abundant copepod species in the bay since its first appearance there in 2005 (Altukhov et al., 2014; Gubanova and Altukhov, 2008). The abundance of *O. davisae* increased steadily from 2008 till 2009 (Fig. 1.3.3.35). The sharpest growth of its average annual abundance was observed in 2010 at all stations. Next year the abundance of the invader decreased and since 2011 *O. davisae* population became in stabilization phase (Odum, 1975). In general, the population of *O. davisae* was more abundant in the centre of the bay (st. 3) than at its mouth (st. 2). In open coastal area (st. 1) the abundance of *O. davisae* was considerably less throughout the period of study. However, a slight increase in this species abundance was noticed in 2009 and in 2010 it increased significantly.

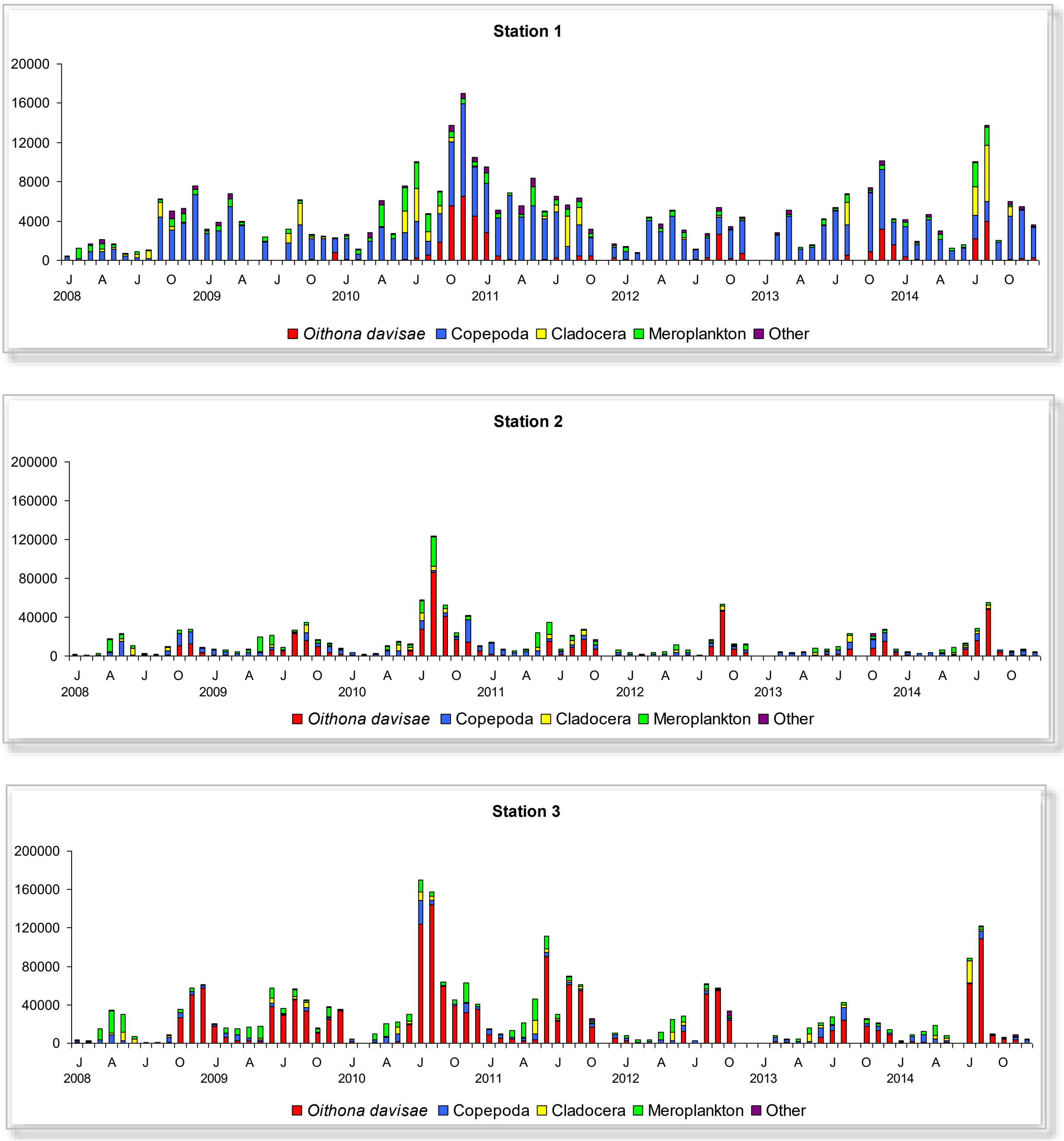


Figure 1.3.3.6.3. Seasonal and interannual variations in zooplankton taxonomic composition and abundance in the bay (st. 2, st.3) and open coastal area (st. 1).

Due to the significant differences in the abundance of zooplankton, the maximum value on the scale figure of station 1 is an order of magnitude smaller than at st. 1 and 3. Cladocerans were represented by species *Pleopis polyphemoides, Penilia avirostris, Pseudoevadne tergestina, Evadne spinifera*. *P. polyphemoides* is registered in the samples almost all year round. Other cladocerans are usually registered in summer – autumn period. Holoplanktonic species *Parasagitta setosa, Oikopleura dioica* and *Pleurobrachia pileus* were more abundant at the st. 1. Sometimes large concentrations of heterotrophic dinoflagellates *Noctiluca scintillans* are observed. Meroplankton is an important component of the zooplankton community. The larvae stages of bentic Cirripedia, Polychaeta, Decapoda and Mollusca contributed a lot to the total zooplankton abundance in the warm period of a year. In addition meroplanktonic larvae of Amphipoda, Bryozoa, Mysidacea, *Branchiostoma lanceolata* and Anisopoda, Ascidiacea, Cumacea, Foronidae, Isopoda, Nematoda, Nemertina, Turbellaria, fish larvae and eggs were recorded in some samples in negligible abundance.

Seasonal dynamic

In the ***northwestern part of the Black Sea***, seasonal dynamics of mesozooplankton was analyzed separately for the coastal and offshore zones of the sea. According to Tables 1.3.3.6.4 and 1.3.3.6.5, the averaged values for the period 2008-2014 were calculated (Table 1.3.3.6.7).

Table 1.3.3.6.7. Seasonal dynamics of the mesozooplankton total biomass (mg·m^{-3}) in the northwestern part of the Black Sea (2008-2014).

Area	Spring	Summer	Autumn	Winter
Coastal	29.3 ± 11.4	21.4 ± 5.9	28.9 ± 10.1	5.8 ± 3.8
Shelf		220.3 ± 53.0	565.3 ± 132.1	599.6 ± 207.7

Since regular studies of the seasonal dynamics of zooplankton were investigated in the coastal zone of the sea, the most general regularities could be found only here. The probability of forming the maximum biomass in spring and autumn for the 2008-2014 was the same, respectively 43% (see Table 1.3.3.6.5). In absolute value during these seasons were also close, respectively 29.3 and 28.9 mg·m^{-3}. The established feature concerned both the abundance and biomass of mesozooplankton. In spring, the maximum abundance and biomass were registered in May, and in autumn the maximum biomass was in September, and the maximal abundance was observed in October (Fig. 1.3.3.6.4). In offshore area maximal biomass was registered in winter, but unfortunately there were now any observations in spring (see Table 1.3.3.6.7).

The interannual dynamics of quantitative development of zooplankton was most detail studied in the coastal zone of the sea. The maximum abundance and biomass were recorded in 2011 and 2014, their minimum values were in 2008 and 2012 (Fig. 1.3.3.6.5).

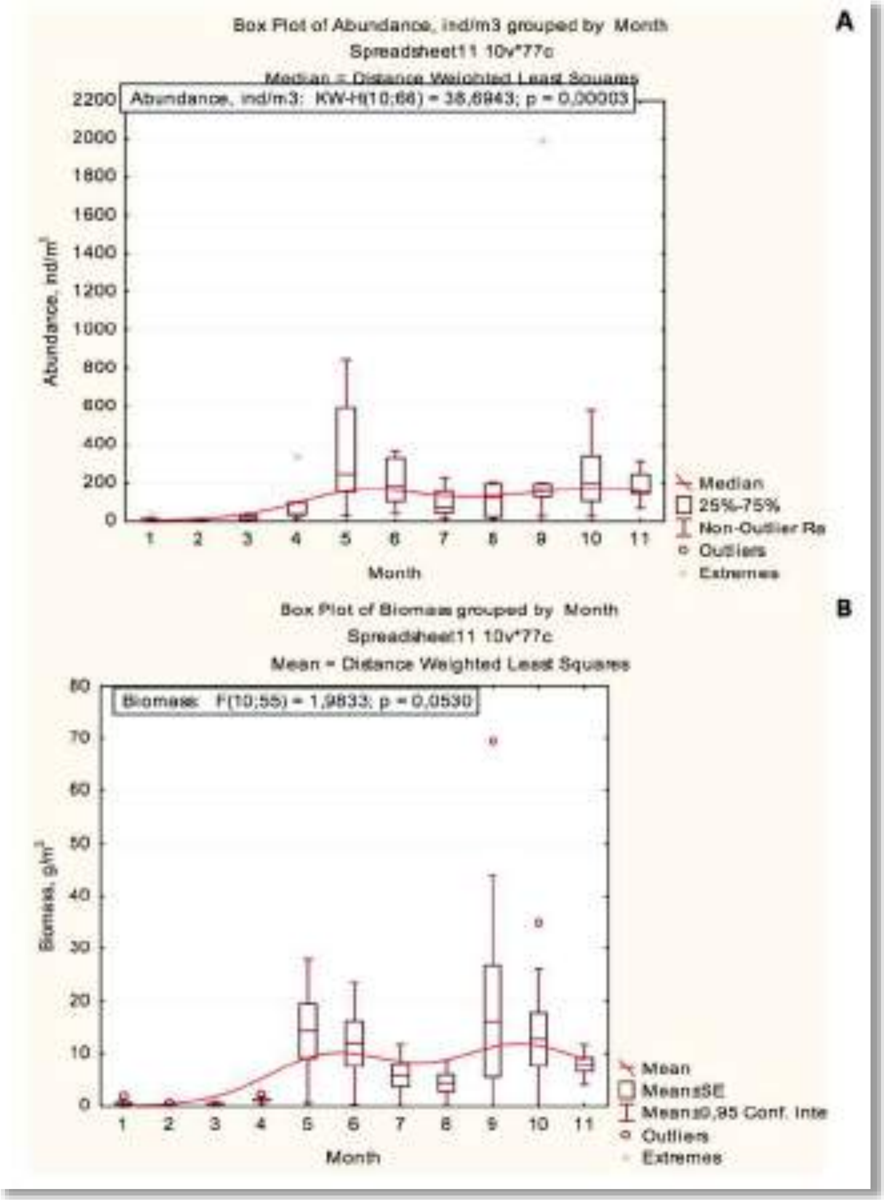


Figure 1.3.3.6.4. Average monthly changes in abundance (A) and biomass (B) of mesozooplankton in the coastal zone of the Odessa region (2008-2014).

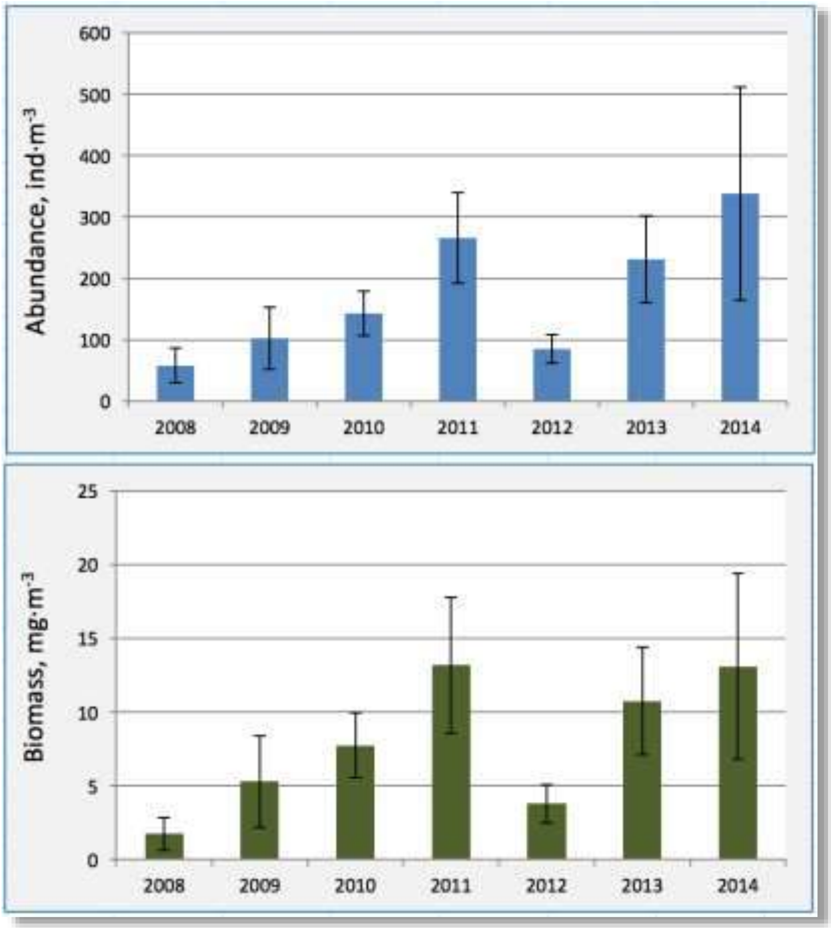
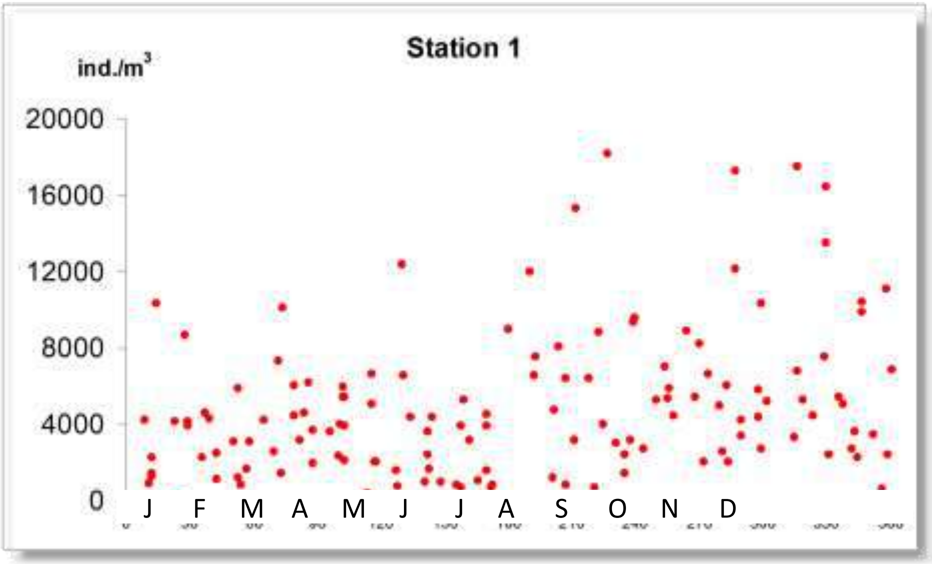
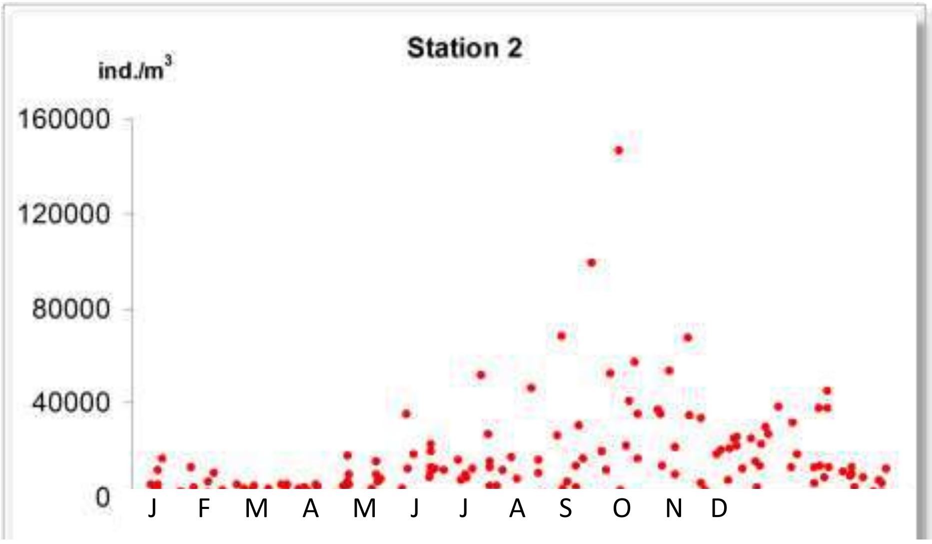


Figure 1.3.3.6.5. The interannual dynamics of changes in the total abundance and biomass of mesozooplankton in the coastal zone of the northwestern part of the Black Sea.

For the ***Sevastopol Bay*** seasonal variation in the abundance of total zooplankton in 2008-2014 shows on Fig. 1.3.3.6.6. It was similar in the bay (st. 2, 3) and differed at station in the open coastal area (st. 1). The seasonal dynamics was characterized by low values from July till April and maximum during the summer-autumn at st. 2 and st. 3. At st. 1 maximum of abundance occurred in February-April and in August-November. Copepods were the dominant group within mesozooplankton throughout the period of study. They accompanied by cladocerans and meroplankton (see Fig. 1.3.3.6.3). The zooplankton was significantly abundant in the bay (st. 2, st.3) in comparison with open coastal area (st.1). In particular, the maximum abundance that was recorded at all stations in 2010, reached 17256 ind·m^{-3} at st. 1; 146540 ind·m^{-3} at st. 2, 29700 ind·m^{-3} at st. 3 (see Fig. 1.3.3.6.6). This is due to the mass development and huge abundance of *O. davisae* attaining up to more than 90% of total abundance of overall copepods in the bay. Thus *O. davis*ae affected considerably the seasonal fluctuations of total zooplankton abundance at st. 2 and st. 3. While *P. parvus* was the more numerous at st.1 most part of the year. It was co-dominated by *P. elongatus* in winter – spring and *O. davisae* in the end of summer and autumn.

Up to 90% of the cases, the mesozooplankton abundance at the monitoring stations of the Sevastopol Bay was distributed as follows: st. 3 did not exceed 60,000 ind·m^{-3}, st. 2 - 40,000 ind·m^{-3} and st. 1, which was located in the shelf, was 10,000 ind·m^{-3} (see Fig. 1.3.3.6.6). That is, in contrast to the Odessa region, there was directly the opposite picture in Sevastopol Bay. The accumulation of plankton in the coastal zone of the sea was in 4-6 times bigger than on the shelf.


Station 1
ind./m3
20000
16000
12000
8000
4000
0
J F M A M J J A S O N D


Station 2
ind./m3
160000
120000
80000
40000
0
J F M A M J J A S O N D

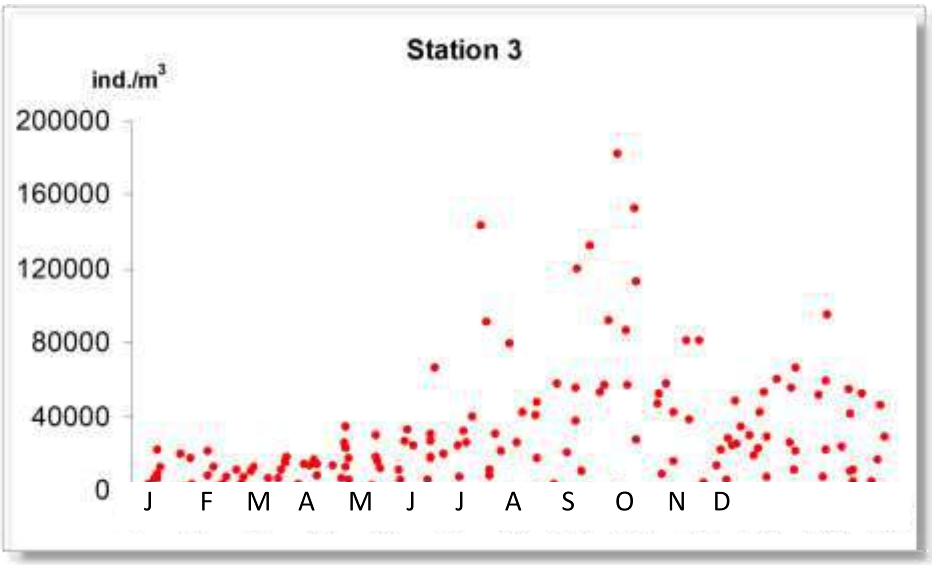

Station 3
ind./m3
200000
160000
120000
80000
40000
0
J F M A M J J A S O N D

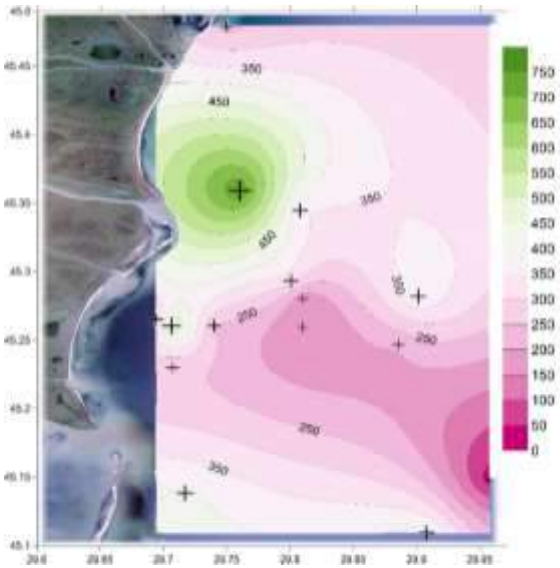
Figure 1.3.3.6.6. Seasonal variations of total zooplankton abundance (without *Noctiluca scintillans*) during 2008-2014.

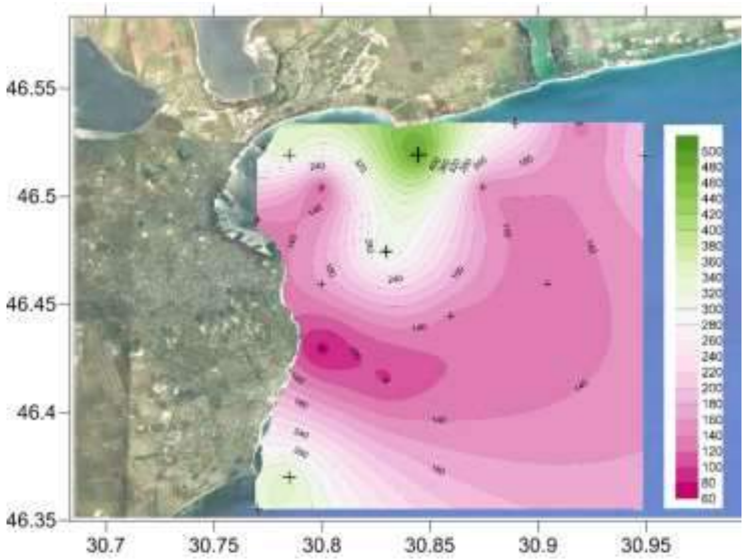
Spatial distribution

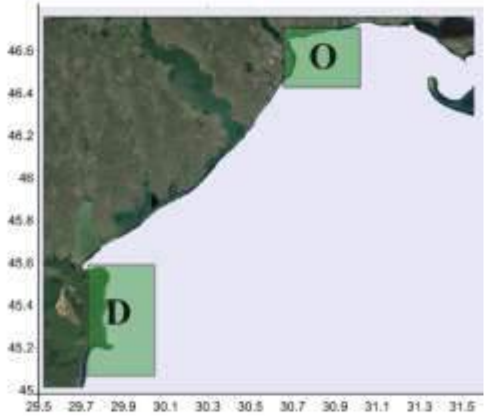
In the ***northwestern part of the Black Sea*** for analysis of the spatial distribution of zooplankton were used the data that have been received when expeditionary studies in the Danube and Odessa regions coincided in time, so was organize at the same year and season (see Table 1.3.3.6.4, 1.3.3.6.5). Most often under the influence of the Danube, the biomass of mesozooplankton was higher. On average, for the investigated period the biomass in the Danube region was 565.8 ± 116.2 mg·m^{-3} and in the Odessa region - 360.8 ± 131.8 mg·m^{-3} (see Table 1.3.3.6.4). Thus, the biomass in the zone of influence of the Danube was in 1.6 times larger. Its maximum value was recorded directly near the Danube Delta in the zone of the river runoff influence. Another explanation of the high quantitative development of plankton in this region of the sea compared to the Odessa region can be a high level of anthropogenic impact associated with Odessa port activities and the discharge of urban waste water as it was said in the introduction. In 2013, the second maximum of zooplankton biomass was located in hydrofrontal zone at the boundary between mixing fresh and sea waters. This peculiarity was previously shown for the seashore of the Danube (Alexandrov, 1998). In the Odessa region, the maximum biomass of mesozooplankton was noted near the cape Severniy (Fig 1.3.3.6.7-1.3.3.6.9).

Comparison of the results of coastal (see Table 1.3.3.6.5) and shelf (see Table 1.3.3.6.4) zone investigation in the Odessa region showed that the average biomass of mesozooplankton in the coastal zone during investigated period was 21.4 ± 4.4 mg·m^{-3} and on its shelf - 360.8 ± 131.8 mg·m^{-3}, which in comparison was about 17 times lower. This is another evidence of the high anthropogenic impact on the coastal zone of Odessa Gulf.

2008







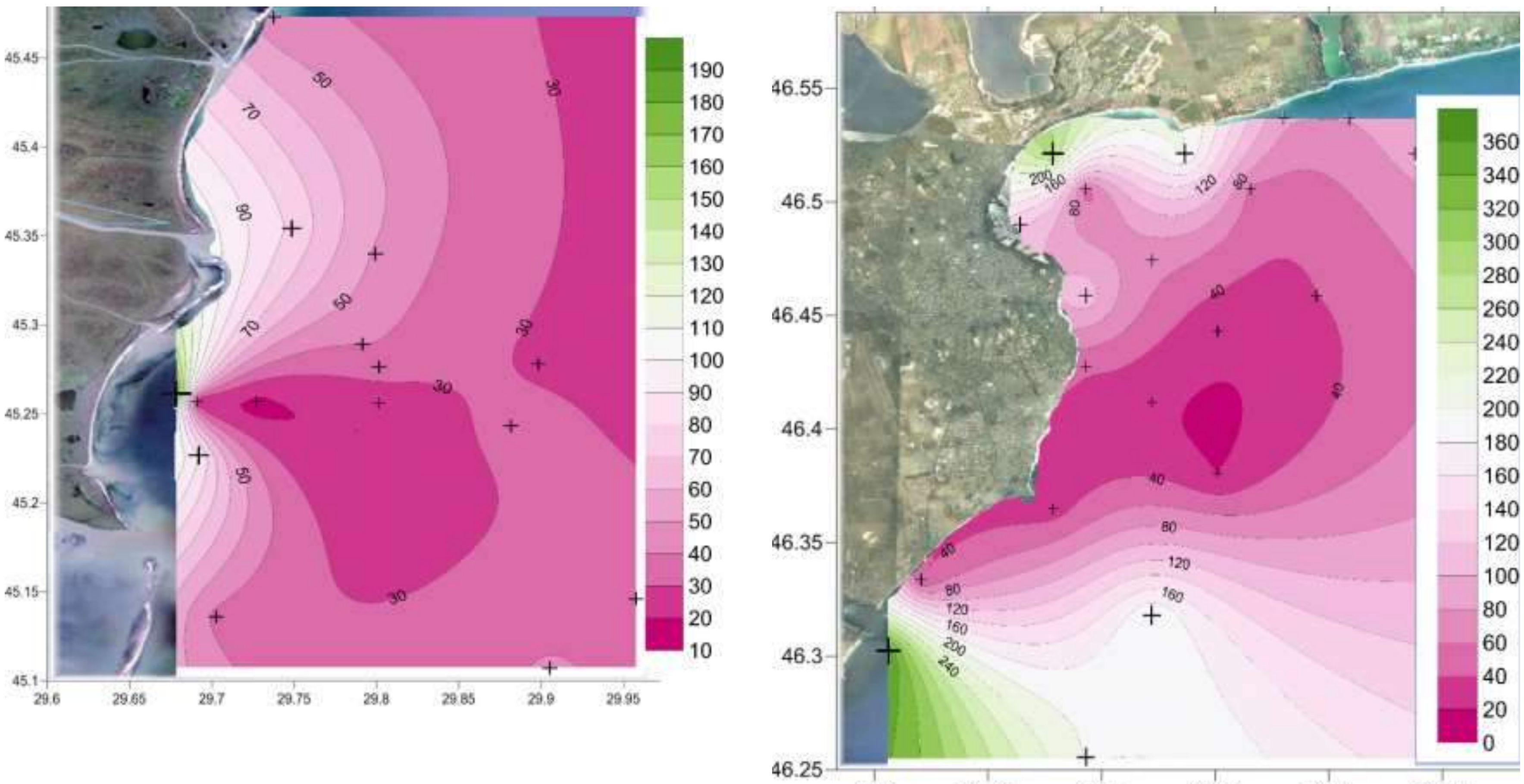
Location map of research areas:
D-Danube region, O- Odessa region

Danube region

Odessa region

Figure 1.3.3.6.7. Spatial distribution of zooplankton biomass (mg·m^{-3}) on the shelf area of Ukraine in northwestern part of the Black Sea (2008).

2010



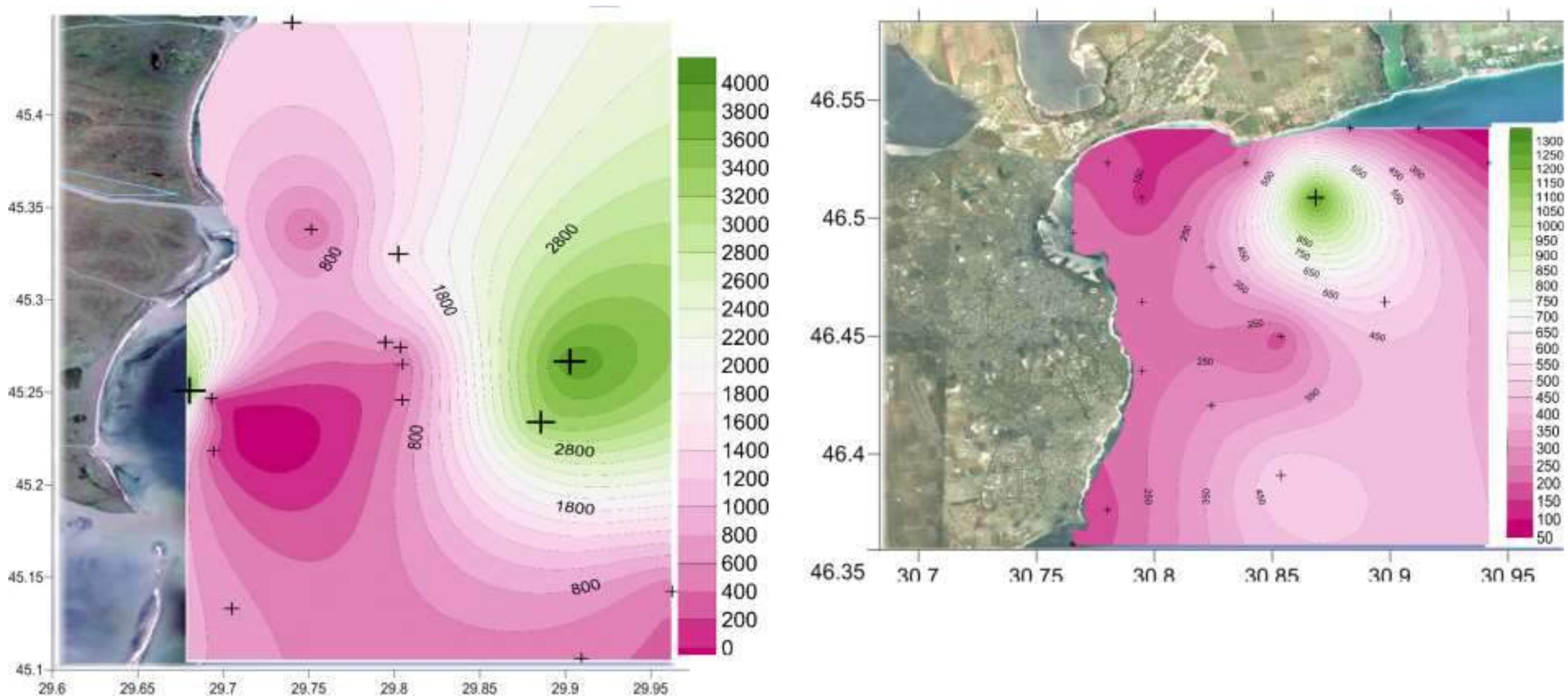
Danube region

Odessa region

Figure 1.3.3.6.8. Spatial distribution of zooplankton biomass (mg·m^{-3}) on the shelf area of Ukraine in northwestern part of the Black Sea (2010).

Location of research area see on Fig. 1.3.3.6.7.

2013



Danube region

Odessa region

Figure 1.3.3.6.9. Spatial distribution of zooplankton biomass (mg·m^{-3}) on the shelf area of Ukraine in northwestern part of the Black Sea (2013).

Location of research area see on Fig. 1.3.3.6.7.

Assessment of water quality

As was said at the beginning of this section three categories of research areas were used to assess the Black Sea water quality in Ukraine shelf area: 1) marine coastal waters, which included 9 coastal stations in the Odessa Gulf and two stations in the Sevastopol Bay; 2) transition waters (the Danube and Odessa regions, whose stations are located more than one nautical mile away, 3) the shelf zone (st. 1 in the Crimea, which was located outside the Sevastopol Bay). The already published threshold values for the characteristics of the state of zooplankton (Stefanova et al., 2016) have been used for marine coastal stations and the shelf. The threshold values of the characteristics of zooplankton for transition waters with salinity below 14.5‰ have not yet been published but were discussed during special workshop of participants of the Black Sea countries on methods of biological monitoring in assessing water quality (Alexandrov, 2016).

The threshold values of the investigated characteristics of zooplankton, which correspond to Good Ecological Status (GEnS) are presented in Table 1.3.3.6.8.

Table 1.3.3.6.8. Threshold values of mesozooplankton indicators that correspond to Good Environment Status of the Black Sea.

Indicators	Season	Coastal water	Transitional water	Shelf waters
Total biomass, mg·m^{-3}	Spring	70-400	> 59	130-300
	Summer	200-900	> 11470	
	Autumn	70-350	> 164	
Copepod biomass, %	All year round	> 30	> 10	> 30
Noctiluca biomass, %		< 42	< 69	< 42
Shennon index, bit·ind^{-1}		≥ 3		

Due to the fact that the data for the Sevastopol Bay for the investigation period were not recalculated to biomass values, the assessment of marine water quality was made only for the northwestern part of the Black Sea within Ukraine (for the coastal and offshore zone separately). The averaged data from Table 1.3.3.6.4 and 1.3.3.6.5 were used. In connection with the fact that the threshold values of mesozooplankton characteristics were not established for winter (see Table 1.3.3.6.3) this season was excluded from the final table for assessing of water quality. Finally, due to the fact that the Shannon index for coastal stations was not calculated this metric was also excluded from the characteristics of water quality. The analysis of the obtained results on the assessment of the quality of the aquatic environment in Ukrainian part of NWBS (Table 1.3.3.6.9) allowed to the following conclusions:

1. For the selected mesozooplankton characteristics, on average for the entire investigated period (2008-2014) there were not founded any case Good Ecological Status (GEnS) in marine coastal zone of Odessa.

2. In about 1/3 of cases (in the Odessa region 33%, in the Danube region 29%), a GEnS of shelf water was recorded in the Ukrainian part of the Black Sea. Most often (in 86% of cases) a GEnS was recorded in autumn.

3. The most favorable marine water quality was registered in 2009, 2013 and 2014.

Table 1.3.3.6.9. Mesozooplankton indicators at two habitats (marine coastal area and marine shelf area: shelf 1 – Odessa region, shelf 2 – Danube region) in northwestern Black Sea.

Area	2008			2009			2010			2011			2012			2013			2014		
	Spr	Sum	Aut	Spr	Sum	Aut	Spr	Sum	Aut	Spr	Sum	Aut	Spr	Sum	Aut	Spr	Sum	Aut	Spr	Sum	Aut
Total mesozooplankton biomass, B mg·m^{-3}																					
Coast	8	4	10	3	4	32	26	37	22	56	31	22	16	12	14	85	42	14	12	20	87
Shelf 1			429			279		107				54			1010			296			
Shelf 2		334	806					157	463		282							1234			426
Copepoda biomass, %																					
Coast	3	8	1	15	14	1	1	7	15	1	7	13	3	6	7	1	16	4	4	7	10
Shelf 1			2			13		56				10			16			20			
Shelf 2		2	4					7	44		2							55			36
Noctiluca biomass, %																					
Coast	0	0	7	20	2	0	0	0	25	0	0	0	3	6	7	0	0	33	4	7	10
Shelf 1			97			14		1				0			0			0			
Shelf 2		88	93					19	2		63							11			0
Total water quality																					
Coast																					
Shelf 1																					
Shelf 2																					

Note. **Spr** – Spring, **Sum** – Summer, **Aut** – Autumn. Blue color cells correspond to GEnS values.

Concluding remarks

The key impacts on the mesozooplankton development in the investigated regions of Ukraine are volume of the river flow, in particular the Danube, and the level of anthropogenic load.

The maximum abundance and biomass of mesozooplankton were recorded in 2011 and 2014, and their minimum values were in 2008 and 2012.

Only about 30% of the cases of water quality on the shelf of the northwestern part of the Black Sea corresponded to GEnS.

Due to the strong anthropogenic load in the coastal zone of the Odessa region, the quality of water did not meet the standards and, unlike Sevastopol Bay, quantitative development of plankton was suppressed here and was significantly lower than on the shelf, at a distance of more than 1 nautical mile from the shore.

Conclusion

Characterizing in general the investigated period, it should be noted that in 2008-2014 there was a further increase in water temperature in the surface layer of the northwestern and northeastern parts of the Black Sea. At the same time, in the northwestern shelf, the increase in the volume of the Danube of the largest river of the Black Sea influenced on the mesozooplankton state, which led to a decrease in the salinity of the water.

Mesozooplankton, in contrast to other ecosystem components, is characterized by low species diversity. The difference in the number of species registered by specialists from different countries was primarily due to the number of taxa taken into account, or by the presence in the sea of freshwater and brackish water species that enter the sea with river runoff. The total number of registered taxa ranged from 12 to 59. The most representative components of zooplankton such as Copepoda and Cladocera were most clearly considered. During investigated period under 14 species of Copepoda and 12 species of Cladocera were founded. Their maximum diversity is noted in Bulgaria and Ukraine. Among the interesting feature that influenced to the ratio of the composition of zooplankton should be noted the decline in the development of one of the dominant representatives of zooplankton, the dinoflagellates *Noctilluca scintillans*. This was especially evident in the northwestern part of the Black Sea where its percentage in the composition of mesozooplankton decreased from 95 to 28% of the total biomass from 1989, were registered maximal eutrophication in northwestern shelf.

The quantitative development of zooplankton in different parts of the sea did not coincide. For example, most often the minimum annual average biomass was recorded in different areas of the sea in 2008 and 2012, and the maximum in 2011 and 2013. Anthropogenic impact had an overwhelming effect on the development of zooplankton, which was convincingly demonstrated in Georgia and Ukraine.

Depending on the peculiarities of the temperature regime of the various regions of the sea, the maximum biomass development of zooplankton was observed in summer in Bulgaria and Georgia, in spring and autumn in Ukraine and in winter in Turkey.

Due to the differences in the available data base for the assessing of water quality, different indicators (as well as their total number) were used by experts from different countries. Despite this, the final assessment of the water quality of the Black Sea countries is as follows: Bulgaria - coastal and shelf habitats are characterized by non-steady community pattern - in more than 50% of occasions is in “lower” quality in respect of indicators; Georgia - in 87.5% of the cases studied shelf regions correspond to a high water quality; Russia – water with high quality was registered in 71.4% of cases; Turkey – all investigated areas corresponded to a good ecological status; Ukraine - for the entire investigated period (2008-2014) there were not founded any case Good Ecological Status (GEnS) in marine coastal zone of Odessa and in about 1/3 of cases a GEnS of shelf water was recorded in Ukrainian part of the Black Sea.

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1.3.4 State of Zoobenthos (Turkish Shelf)

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The coastline of Turkey which is surrounded by the Mediterranean, Aegean, Marmara and Black Seas is about 8,500 km in length, excluding islands. This extensive marine and coastal fringe supports a rich and important biodiversity. However, the coastal and marine biodiversity of the Turkish Black Sea is constantly under serious threat due to the pressures exerted by mankind. The major threats are posed by the destruction of marine habitats and ecosystems, over-exploitation of marine resources and the loss of coastal habitats through mass urbanization (Öztürk et al. 2013).

The Turkish coast of the Black Sea was poorly investigated in terms of zoobenthic groups. The studies carried out on the Black Sea coast of Turkey were mainly focused on the pre-bosphoric region published by various authors (Jakubova, 1948; Demir, 1952; Marinov, 1959; Dimitrescu, 1960; 1962; Rullier, 1963; Caspers, 1968; Kiseleva, 1981; Gillet and Ünsal, 2000; Uysal et al., 2002). The Anatolian Region of the Black Sea was studied by Kocatas and Katagan (1980), Ates (1997), Mutlu et al. (1992; 1993), Sezgin et al. (2001), Gonlugur (2003), Ozturk et al. (2004), Çinar and Gonlugur-Demirci (2005), Gonlugur-Demirci (2006), Kirkim et al. (2006), Sezgin and Katagan, 2007, Bilgin et al. (2007), Agirbas et al. (2008), Gozler et al. (2009), Dagli (2012), Kurt-Sahin and Çinar (2012), Kus and Kurt-Sahin (2015), and Kurt-Sahin et al. (2016).

When the up-to-present studies at the Black Sea coasts of Turkey (Açik, 2014; Bakir et al., 2014; Çinar, 2014; Çinar et al. 2014a, b; Evcen et al., 2016; Koçak and Onen, 2014; Kus and Kurt-Sahin, 2015; Kurt-Sahin et al., 2016; Oztoprak et al., 2014; Ozturk et al., 2014; Topaloglu and Evcen, 2014) are considered, 767 species belonging to 12 zoobenthic taxa (Porifera, Cnidaria, Platyhelminthes, Nematoda, Nemertea, Bryozoa, Sipuncula, Annelida, Phoronida, Arthropoda, Mollusca and Echinodermata) have been recorded at the samplings by 2015 (Figure 1.3.4.1 - 2). According to the 2001-2007 State of Environment Report, 385 species were reported in 2000-2007 period and 731 species were reported until 2014 (Figure 1.3.4.3).

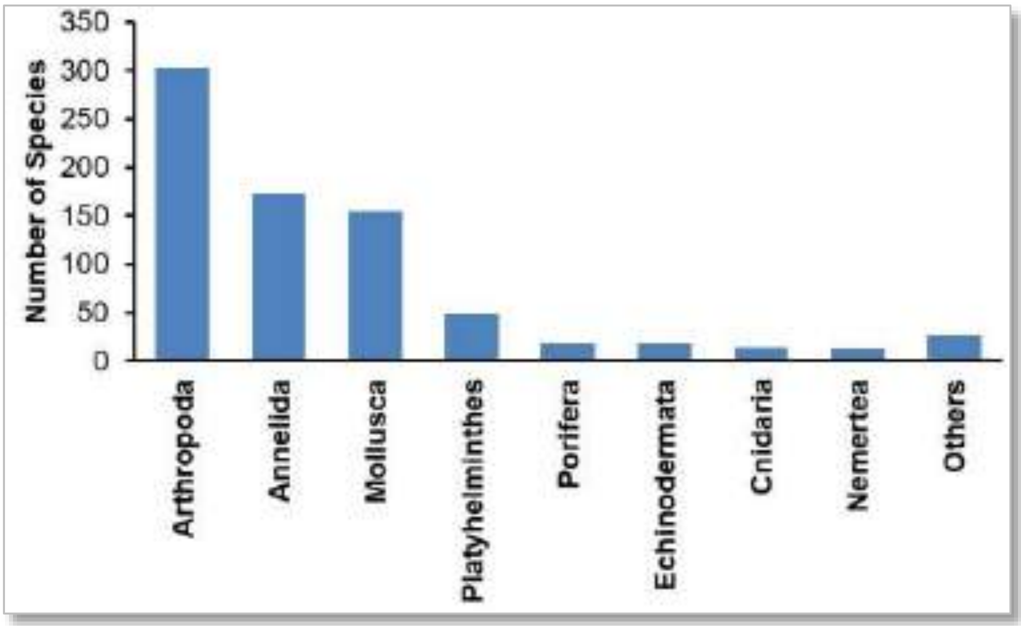

Figure 1.3.4.1. Number of species in the zoobenthic taxa reported from the Turkish coasts of the Black Sea

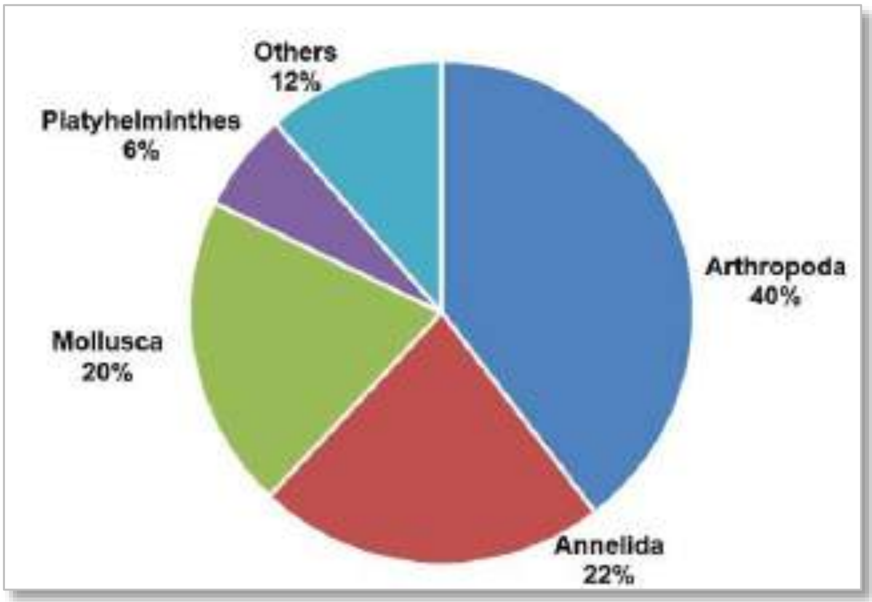

Figure 1.3.4.2. Relative percentages of the zoobenthic taxa reported from the Turkish coasts of the Black Sea

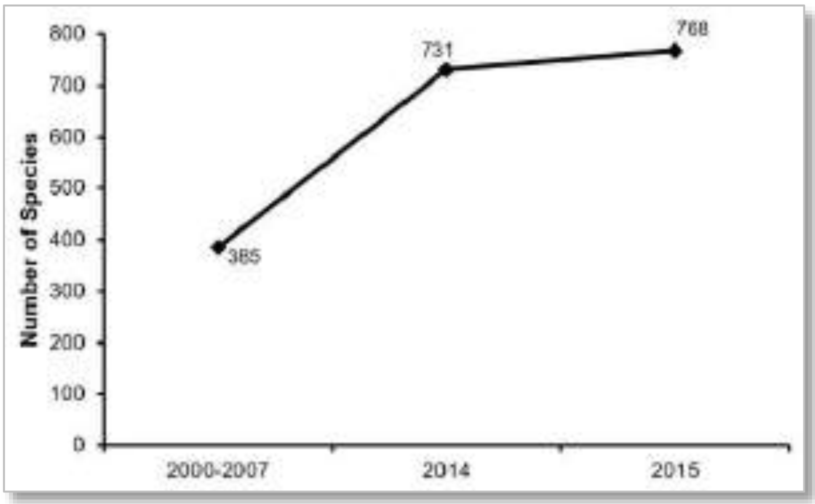

Figure 1.3.4.3. Annual changes in the number of species of macrozoobenthos along the Turkish coasts of Black Sea.

Among these species, 11 alien species were reported from the Turkish coast of the Black Sea up to date (Table 1.3.4.1). Besides, *Cerithium vulgatum* Bruguière, 1792 and *Pholas dactylus* Linnaeus, 1758 are recognized as endangered or threatened according to the IUCN Red List and Barcelona/ Bern Conventions (Ozturk et al., 2014).

Table 1.3.4.1. Alien species reported from the Turkish coasts of the Black Sea

Polychaeta	**References**
Capitellethus dispar (Ehlers, 1907)	Rullier, 1963
Polydora cornuta Bosc, 1802	Kurt-Sahin et al. 2016
Prionospio pulchra Imajima, 1990	Dagli & Çinar, 2011
Crustacea	
Callinectes sapidus Rathbun, 1896	Yaglioglu et al., 2014
Pilumnus minutus De Haan, 1835	Gonlugur-Demirci, 2006
Mollusca	
Anadara inaequivalvis (Bruguière, 1789)	Aydin et al., 2014
Anadara kagoshimensis (Tokunaga, 1906)	Albayrak, 2003
Mya arenaria Linnaeus, 1758	Uysal et al., 1998
Rapana venosa (Valenciennes, 1846)	Fischer-Piette, 1960
Teredo navalis Linnaeus, 1758	Gonlugur-Demirci, 2005
Echinodermata	
Asterias rubens Linnaeus, 1758	Karhan et al., 2008

Total 20 stations located at 8-55 m water depths were investigated along the Black Sea coasts of Turkey between 2013 and 2014 in the scope of the Black Sea Monitoring Project for the Determination of Ecological Quality Status within the Integrated Monitoring Activities in Turkish Seas (a cooperation between Republic of Turkey Ministry of Environment and Urbanization and TÜBİTAK-MAM). As a result of this study, ecological qaulity status of the coasts were identified according to m-AMBI index (Figure 1.3.4.4). A general evaluation inferred from the map prepared according to the index values of the stations implies that the ecological quality status of the stations are at good and moderate level.

Figure 1.3.4.4. m-AMBI results of the stations along the Turkish coast of the Black Sea

Habitat structure of the Turkish Black Sea coasts was presented by European Marine Observation and Data Network (EMODnet) in their 2015 report. Accordingly, the infralittoral rocky substratum of the benthic zone is covered by photophilic algae and the main components are *Cystoseira barbata, Ulva rigida, Polysiphonia subulifera, Cladophora spp., Ulva rigida, Ulva intestinalis* and *Gelidium* spp. Key components of the infralittoral sandy and muddy-sand substrata are listed as follows: shallow fine sands with *Lentidium mediterraneum, m*edium to coarse sands with *Donax trunculus,* infralittoral sand with *Chamelea gallina* (with *Cerastoderma glaucum, Lucinella divaricata, Gouldia minima*) (depends on the region), muddy sand with burrowing thalassinid *Upogebia pusilla/Pestarella candida*. The circalittoral rocky substratum is reported to be composed of Scyaphilic algae *(Phyllophora* spp., *Polysiphonia* spp., *Zanardinia* spp., *Gelidium* spp.), sponges and hydroids. Shallow circalittoral mud and organogenic sandy mud at the circalittoral zone is characterized by muds with *Abra prismatica - Pitar rudis - Spisula subtruncata, Acanthocardia paucicostata and Nephtys hombergii* and sandy muds with *Dipolydora* meadows and *Mytilus*. Deep circalittoral coarse mixed sediments are known to be composed of shelly muds with *Modiolula phaseolina*. It is obvious that more areas and depths should be investigated in order to clearly reveal the zoobenthic diversity and the community structure of the Black Sea coasts of Turkey.

The Black Sea is an enclosed system encompassing the largest anoxic basin on the planet, due to the limited water renewal and exchange with the Mediterranean Sea and Atlantic Ocean through the Istanbul (Bosphorous) Strait This unique property renders the Black Sea ecosystem rather vulnerable to anthropogenic pressures and require special protection for its biodiversity. One of the most effective solutions for the recovery of a marine ecosystem is to designate Marine Protected Areas (MPAs) in certain areas of ecological or biological significance in the given sea according to the Convention of Biological Diversity (CBD). The main goals of assigning such protected areas are to preserve biological diversity and maintain essential ecological processes to both ensure the sustainable use of species and ecosystems and to protect environmental quality, the health and safety of coastal communities and of resource users (Öztürk et al. 2013).

Özturk et al. (2013) recommended five ecologically important sites (İğneada, Şile-Kefken, Doğanyurt, Kızılırmak and Yeşilırmak, Mezgit Reef) to be designated as Marine Protected Areas (MPA) along the Turkish Black Sea coast, where currently no MPAs exist.

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1.3.5 State of Macrophytobenthos

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Introduction

The modern Black Sea macrophytes check-list has 456 species and subspecies of the seaweeds and flowering plants which relate to phylums: *Chlorophyta* (112); *Charophyta* (7); *Xanthophyta* (3); *Phaeophyta* (99); *Rhodophyta* (229); *Tracheophyta* (6). It was prepared by experts of the Black Sea countries for the Black Sea Ecological Commission at support of projects MISIS and EMBLAS (Minicheva, et al., 2015). The given list can be reduced on risen to disappearance of sensitive species to ecological conditions, and vice versa to fill up by new invasions species, which can become mass, as it happened with *Desmarestia viridis* (O.F.Müller) J.V.Lamouroux. (Minicheva & Eremenko, 1993) and *Chorda tomentosa* Lyngbye (Minicheva, 2015).

The macrophytes communities form a coastal vegetative belt practically on all perimeter of the Black sea. Special conditions for intensive development of macrophytobenthos are created in bays, as well as on north-western shelf where now except of red seaweeds from a genus *Phyllophora*, also began to develop red, green and brown filamentous seaweed. Presently on territory of Ukrainian botanical reserve of national significant «Zernov's Phyllophora Field" grows of 24 macrophytes species: *Phaeophyta* (6), *Rhodophyta* (12) and Chlorophyta (Trachenko & Tretyak, 2015). In the last decade there is a tendency of renewal the populations of *Phyllophora truncate* (Pall.) Zinova on the depths of 15-30 m, also increase of floristic diversity of macrophytobenthos. However, due to the processes of secondary eutrophication which connection with higher concentration of nutrients that have accumulated in the bottom sediments in the habitats of Zernov's Phyllophora Field observed the intensive development of small-size filamentous algae with high rates of surface area (Minicheva, et al., 2009).

In coastal zones of Black Sea the macrophytobenthos communities bring the basic contribution to the autophyte function of marine ecosystem, related to the production of organic substance. In the coastal belt the bottom vegetation determines speed of ecological processes and transformation of organic substance on higher tropic levels. This property did macrophytes the sensible indicators of estimation of the ecological state of ecosystem. Recently the macrophytes began to be used as indicators of estimation the ecological status class of marine ecosystems in accordance with the requirements of Marine Strategy Framework Directive (MSFD, 2008/56/EC), (Berov et al., 2010; Dencheva, 2010; Marin et. al., 2013; Minicheva, 2013).

The modern state of macrophytobenthos of national coasts of the Black Sea, with accent on floristic structure, spatial distribution by seasonal and interannual dynamics characteristic in the period of 2009-2014 is afford in this chapter. Also first for the series of monographs of Black Sea State of Environment, these assessment of Black Sea's ecological status class with using as Ecological Evaluation Index the different parameters of macrophytobenthos communities.

BULGARIAN SECTOR

Species composition

Along the Bulgarian Black Sea coast were registered 157 macrophytobenthos species, which constituted 53% of the total Black Sea macroflora. They belonged to 82 genera, 43 families and 25 classes of *Rhodophyta*, *Phaeophyta* and Chlorophyta (Dimitrova-Konaklieva, 2000). The first group was the richest with about 55% of all species, followed by the rest with approximately even number of species (Table 1.3.5.1). In comparison with the Russian (75%), Romanian (40.7%) and Turkish coast (24%), the Bulgarian Black Sea coast ranked second regarding to macroflora species diversity (Kalugina-Gutnik, 1975). In the period of 2007-2014 years, 72 species were found from investigated transects (Dencheva, 2010, 2014). Other 10 species reported from literature (Deyanova, Berov, Stoyneva, 2010) in the same period could be added and the total number of species is 81. In present period (2007 - 2014) *Rhodophyta* and *Ochrophyta* number of species are 2 times and more than 2 times lower respectively in comparison with pristine period 1904-1932 years. *Chlorophyta* number of species is 0.5 times lower in present period (2007-2014).

Table 1.3.5.1. Species composition along the Bulgarian coast in different periods of investigation. * - literature data

Group	1969-1972	2007-2014
Rhodophyta	86	39+6*
Phaeophyta	37	12+3*
Chlorophyta	34	21+1*
Total	**157**	**71+10***

The long-term observations in the Varna Bay region indicated a decreasing trend of macrophyte species in general and of oligosaprobic species in particular in response to increased level of eutrophication (Dimitrova, 1978). The total loss of macrophyte species accounted for more than half as compared to the first half the last century in the period 1994-2002, particularly in the *Phaeophyta* and *Rhodophyta* species and little increased in 2009-2014 period whereas *Chlorophy*ta species increased by 50% during the same period (Fig. 1.3.5.1). For example, the average biomass of the *Phaeophyta* species *Cystoseia barbata* was estimated as 7 kg·m^{-2} in 1966-1969 with respect to 1.1 kg·m^{-2} in 1997 up to 2 m depth. It was mostly substituted by *Ulva spp., Cladophora spp., Ceramium virgatum*. In the last years (2009-2014), species from all the tree phylums little increased their number.

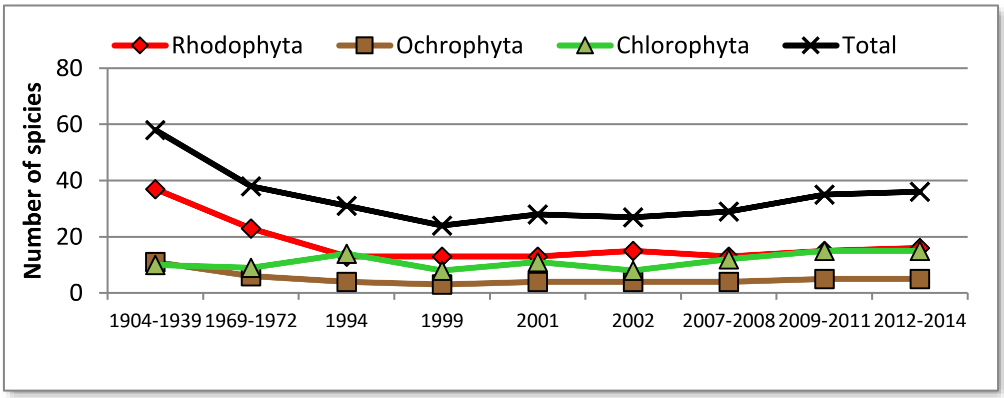


Figure 1.3.5.1. Changes in species structure of phylums of macrophytes in Varna Bay through different time periods

The comparison of the floristic indices of macrophytobenthic coenoses for 1904-1972 and 1994-2002 and 2007-2014 periods may be used to assess the level of eutrophication along the Bulgarian coast. The floristic index increases with enhancement of the level of eutrophication. For example, in Varna Bay being the most eutrophic part of the Bulgarian coastline, it was increased from 4.3 during 1904-1939 to 5.3 in 1969- 1972 and to more than 6.0 in the 1990s and the present decade.

Floristic index of Cheney, very well reveals changes through the years and it could be seen that there is lowering of the index values in last years compared with 1994-1999 (high eutrophication level period). Lowering of the floristic index values is result of decreased level of eutrophication (Table 1.3.5.2).

Table 1.3.5.2. Changes in floristic index of macrophytes in Varna Bay in the years of investigation

Period	1904-1939	1969-1972	1994	1999	2001	2002	2007-2008	2009-2011	2012-2014
Floristic index	4.27	5.3	6.75	7	6	5.75	6.25	6.0	6.2

In terms of saprobic structure of macrophytes in Varna Bay, major loss occurred in oligosaprobic species which became almost extinct since the 1990s (Table 1.3.5.3). Typical oligosaprobic species such as *Ralfsia verrucosa, Stilophora tuberculosa, Nereia filliformis, Dictiota dichotoma, Cladostephus verticillatus* were not registered during the last two decades in this region. The most dominant species, in terms of their biomass, are the polysaprobic and mesosaprobic species such as *Ceramium virgatum, Callithamnion corrymbosum, Ulva spp., Cladophora spp., Bryopsis plumosa* in larger part of the bay. This floristic structure was similar to the Odessa Bay (Minicheva, 1998). Olygosaprobic species from genus *Cystoseira* declined in period of strong eutrophication. The depth limit distribution of these species was reduced up to 5m depth and in central and south area of Varna bay near the Varna channels, *Cystoseira* disappeared. In last years some restoration of this community was registered.

Table 1.3.5.3. Changes in saprobic structure of macrophytes in Varna Bay in the years of investigation

Saprodic structure	1904-1939	1969-1972	1994	1999	2001	2002	2007-2008	2009-2011	2012-2014
Olygosaprobic	5	4	3	3	3	3	3	4	4
Mesosaprobic	37	11	21	13	18	17	15	17	18
Polysaprobic	16	23	7	8	7	7	12	15	15

Comparison of the species composition of macroalgae in the Sozopol Bay from 1980-1981 with that for 2009-2010, showed no significant difference in the presence of species in the two periods despite the noted period of significantly higher nutrient concentrations and eutrophication impacts between the two periods. (Berov, 2013; Berov et al., 2012).

Recently, the taxonomic status of *C. bosphorica* Sauvageau was reevaluated by comparing specimens of *Cystoseira* spp. . collected in Bulgaria with data from the literature, the lectotype of C. *bosphorica*, old collections of *Cystoseira* spp. from the Black Sea and several large collections of *Cystoseira* species from the Mediterranean Sea (Berov et al, 2015 a).Specimens of *Cystoseira* spp. were sampled along the Bulgarian coast, in shallow benthic assemblages (0-3 m depth). The material was compared with the almost exhaustive collection of

Mediterranean *Cystoseira* species deposited in the Herbaria of HCOM (see Berov et al., (2015 a) for detailed list).

The material collected along the Bulgarian coasts belongs to two species of *Cystoseira*: *C. barbata* and the species identified as *C. crinita*.The specimens of *C. barbata* agree well with the previous descriptions and illustrations of large Black Sea individuals of *C. barbata*. The characteristics of the species identified as *C. bosphorica* Sauvageau or *C. crinita* f. *bosphorica* (Sauvageau) A.D. Zinova and Kalugina were as follows: thalli, 30-50 cm high, caespitose, with 8-17 axes, up to 20 cm high and 3-4 mm in diameter; apex of axes prominent and smooth; primary branches not spinose, 15-23 cm long and 1 mm in diameter, with bases broadened and persistent; adventitious branches on the base of dropped primary branches; ultimate branches cylindrical; cryptostomates numerous and slightly prominent; aerocysts frequent, oval to subconical broader at the apex, 9-10 mm x 3-4 mm, with 2 or more outgrowths that can produce other aerocysts; receptacles cylindrical tuberculate, simple to bifid, 5-12 mm x 1.5-2 mm, with apices blunt and sometimes a short sub-apical lateral spine-like appendage; conceptacles slightly prominent. This material agrees well with the diagnosis (Sauvageau, 1912), the lectotype, other specimens from the Black Sea, and the published descriptions and illustrations of *C. bosphorica, C. crinita* f. *bosphorica* and *C. crinita* f. *crinita* from the Black Sea (see Berov et al., 2015 for detailed list).The analysis of literature data and the examination of large Mediterranean collections showed that, except for the caespitose character and the absence of spine-like appendages on branches, no other determinant character could justify the taxonomical reduction of *C. bosphorica* to a form of *C. crinita* proposed by Zinova & Kalugina (1974). *Cystoseira crinita* differs significantly from *C. bosphorica*, especially by a smaller size, the presence of spinose parts (apex of axes and receptacles), the constant absence of distinctive aerocysts, and by the location close to the surface: 0-0.5 m depth versus 0.5-10 m depth for *C. bosphorica*. The Black Sea specimens attributed to *C. crinita* f. *crinita* by Zinova & Kalugina (1974) possess apex of axes smooth and distinctive aerocysts, consequently they cannot be a form of *C. crinita*.

On the basis of literature data and new morphological and ecological studies, Berov et al. (2015 a) proposed the reinstatement of species rank for the Black Sea endemic species *Cystoseira bosphorica* Sauvageau (homotypic synonym *C. crinita* f. *bosphorica*). *C. crinita* is considered a strictly Mediterranean endemic species that is absent from the Black Sea. The implications of this taxonomical reinstatement are important in terms of biological conservation. The habitat dominated by *C. bosphorica* becomes a major feature of the Black Sea region and its conservation constitutes a new challenge in the current efforts in setting up marine habitat classification schemes in the framework of the EU Habitats Directive, the Marine Strategy Framework Directive and the creation of networks of marine protected areas ensuring the conservation of European marine environments.

Sea grasses biodiversity was not severely affected during the period of increased eutrophication impacts, as recent surveys in the Burgas Bay (Berov et al., 2015 b) have shown the presence of all five species, that were described in the early 1980s in the same region (Petrova-Karajova, 1982) – *Zostera marina* L. , *Zostera noltei* Hornem., *Zannichellia palustris* L., *Ruppia maritima* L., and *Potamogetom pectinatus* L.

Seasonal dynamic

The seasonal dynamics of the *Cystoseira bosphorica* Sauv. (previously identified as *C. crinita* Bory, see (Berov et al., 2015 a) community structure in the highly dynamic environmental conditions of the Black Sea is not well studied. In order to study the impact of anthropogenic factors on these fragile infralittoral communities, it is essential to establish the effects of natural variations in seasonal temperatures, light intensity and dynamics of nutrients on the species diversity and quantitative changes in communities. A seasonal biological sampling of *C. bosphorica* was carried out between 2009 and 2011 at a sampling location near the town of Sozopol, combined with monthly water chemistry sampling and analysis of nutrient concentration and continuous monitoring of seawater temperature Macroalgal samples were collected seasonally between 7.2009 and 7.2011 from a *C. bosphorica* community at depth of 1 m located on a flat rocky terrace on an exposed coast.

The dynamics of temperature of sea waters at the study site followed the typical seasonal dynamics for the Black sea (Fig. 1.3.5.2). The highest temperatures were measured in August (29,49 °C on 17.8.2010 и 26,28 °C on 7.8.2009), and the lowest in February and March (3,25 °C on 5.2.1010 и 4,06 °C on10.3.2011). Severe positive temperature anomalies were measured in the summer of 2010. The maximum temperature measured in the summer of 2010 is higher than the maximum seawater temperatures measured around Sozopol between 2009 and 2015. The reason for this positive temperature anomaly was the presence of a persistent area of high pressure and extremely high temperatures over Russia and Ukraine throughout the spring and summer of 2010 (Sedlacek et al., 2011).Concentrations of nutrients in the study area have seasonal maximum values during the winter (01-04.2010 and 01-04.2011) and significantly lower during the rest of the year. NO_3 varies in the range between 0,17 and 6,78 μM, NH_4 between 0,2 and 2,25 μM, $N_{tot.}$ between 4,38 and 30,85 μM, and PO_4 between 0,01 and 0,27 (see Berov, 2013 for details).

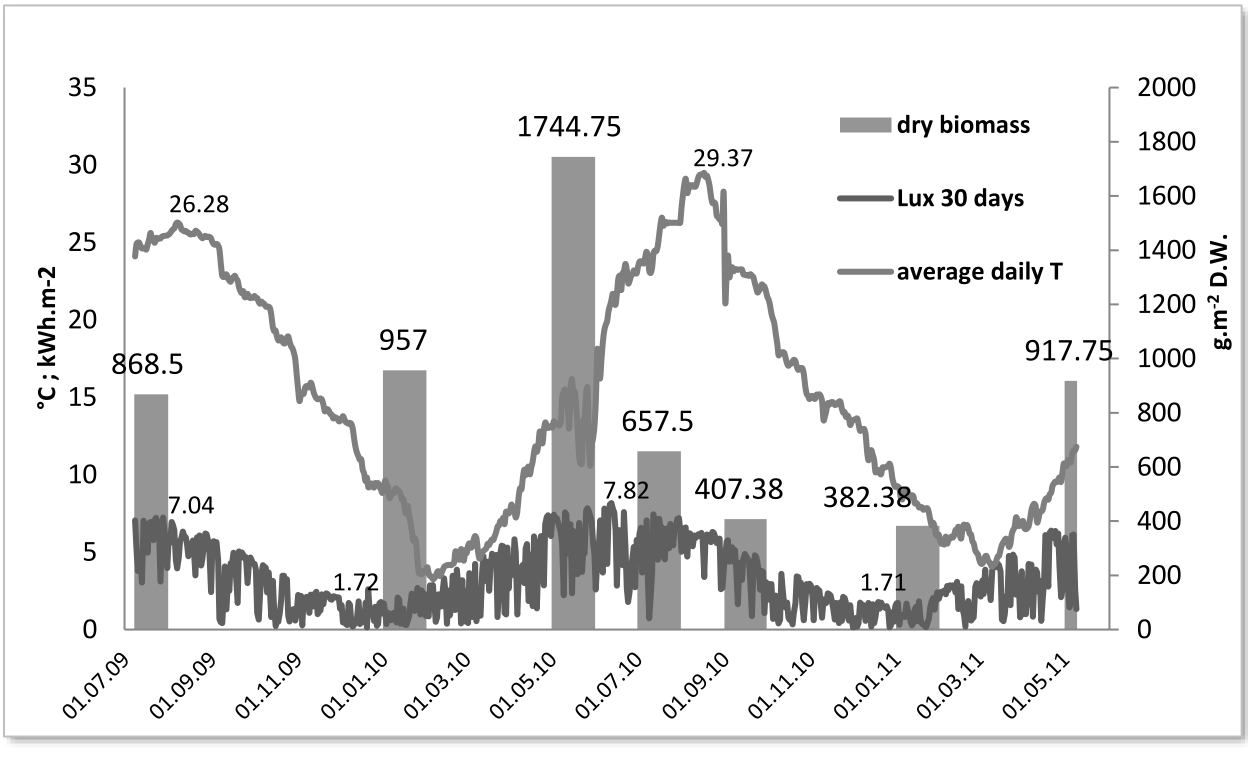


Figure 1.3.5.2. Average dry biomass of a C. crinita [g·m^{-2} D.W.] of samples from the coast of Sozopol town , average daily temperature (°C, grey line) and average monthly solar illumination (kWh.m^{-2}, black line)

During the period of the study, a total of 19 macroalgal species were identified, including 7 Rhodophyta, 3 Ochrophyta и 9 Chlorophyta. Typical seasonal species were identified, including winter-spring species such as – *Porphyra leucostica* (01.2011 и 05.2011), и *B. plumosa* (05.20110), and typical summer-autumn species such as the red macroalgae

G. crinale, *P. subulifera*, *C. corymbosum*, the green *Chaetomorpha linum*, *Cladophora sericea*, *C. albida*, *Ulva intestinalis* и *U. linza*, as well as the brown *S. cirrosa* .Shannon's H' biodiversity index had maximum values in the spring season (07.2010 – 1,83; 05.2011 – 1,73; 09.2009 – 1,56), and minimum during the winter (01.2010 –0,21).

C. bosphorica's biomass at the study site undergo significant changes during the study period (see Fig 1.3.5.2). In both years of the study, the biomass of the species increases between the winter and spring, reaching its maximum values in 01.2010 (957 g·m^{-2} D.W.), 05.2010 (1744,7 g·m^{-2}D.W.; 82,3% increase from 01.2010) and 05.2011 (917,75 g·m^{-2} D.W.; 140% increase from 01.2011). The period of increase of the biomass is followed by a gradual decrease in the summer and autumn – a decrease by 62,3% between 05.2010 and 07.2010 and by 76,6% between 05.2010 and 09.2010. The lowest biomass values were reached in 09.2010 and 01.2011, which followed the period of extremely high sea water temperatures in the Black Sea during July-August 2010. The seasonal changes in the biomass of *C. bosphorica* are similar to those described by Kalugina-Gutnik (1975) along the coast of Odessa, and to differ from tin the NE part of the Black Sea (Sevastopol).

The quantitative structure of the *C. bosphorica* community undergoes pronounced changes during the different seasons and years of the study (Figure 1.3.5.3).The spring and summer periods of maximum biodiversity are characterized with the presence of large quantities of epiphytes, including the red *Ceramium tenuicorne*, *Polysiphonia subulifera* и *Acrochaetium secundatum*, and the brown *S. cirrosa*, as well as some green macroalgae such as *U. rigida*, *C. albida*, *C. sericea*. During the winter, the epiphytic flora consists of minimal quantities of *C. tenuicorne*, as well as the cold-water species *Porphyra leucostica*. The drastic decrease in the quantities of *C. bosphorica* in the summer of 2010 is accompanied by an untypical change in the community structure – the dominant epiphyte in this period is the warm-water opportunistic species *Cladophora albida*. These green filamentous algae had completely overgrown the branches of *C. bosphorica* and had displaced the typical summer epiphytes *P. subulifera* и *C. tenuicorne*. The mass development of *C. albida* during this period is probably due to the fact that seawater temperatures at that time reached the optimal for the growth of the species ((25-30°C, acc. to Breeman, Oh, Hwang, & Van Den Hoek, 2002). The exceptionally high seawater temperatures were probably also the reason for the complete absence of the otherwise very abundant green *Ulva rigida*, which has an optimal growth at temperatures between 12 and 23°C (De Casabianca and Posada, 1998). Similar changes in *C. bosphorica* and *C. barbata* community structure were observed during the same period in adjacent areas (see Berov, 2013).

Data reviews that the severe changes in community structure in 09.2010 are produced by the high seawater temperatures and further strengthened by the increased concentrations of NH_4^+ and NO_3^+ (see Berov (2013) for detailed discussion). The observed recovery of the *C. bosphorica* communities to their 'normal' seasonal state by the spring of 2011 indicates that the stress by the combined extreme summer temperatures and elevated nutrient concentrations was within the limits of their resilience.

Given the predictions of the International Panel for Climate Change (IPCC, 2013) for a possible increase in global temperatures in the coming decades, it can be speculated that extreme temperature events such as that of the summer of 2010 will occur frequently in the near future, which in combination with increased eutrophication impacts in the coastal zone, could possibly lead to a gradual degradation of Cystoseira communities along the Black Sea coast.

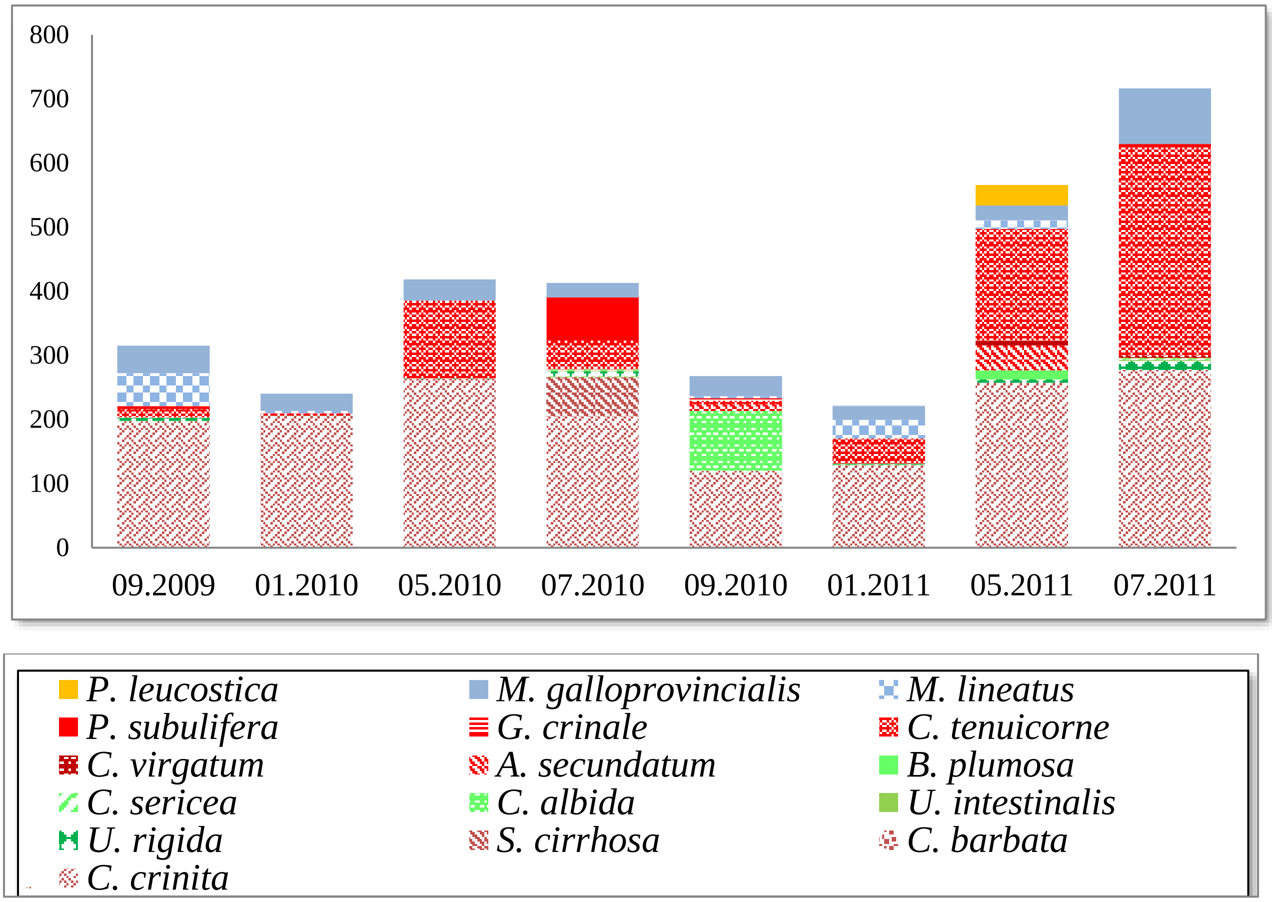


Figure 1.3.5.3. Averaged horizontal projected cover of samples from the coast of Sozopol town

Between the two seasons (spring and summer) could not be seen substantial differences in total biomass values in different polygons (Fig. 1.3.5.4). Highest total biomass again was calculated in Sveta Paraskeva polygon in south part of Bulgarian Black Sea coast. Lowest one was registered in Galata and Pochivka polygons (Varna bay).

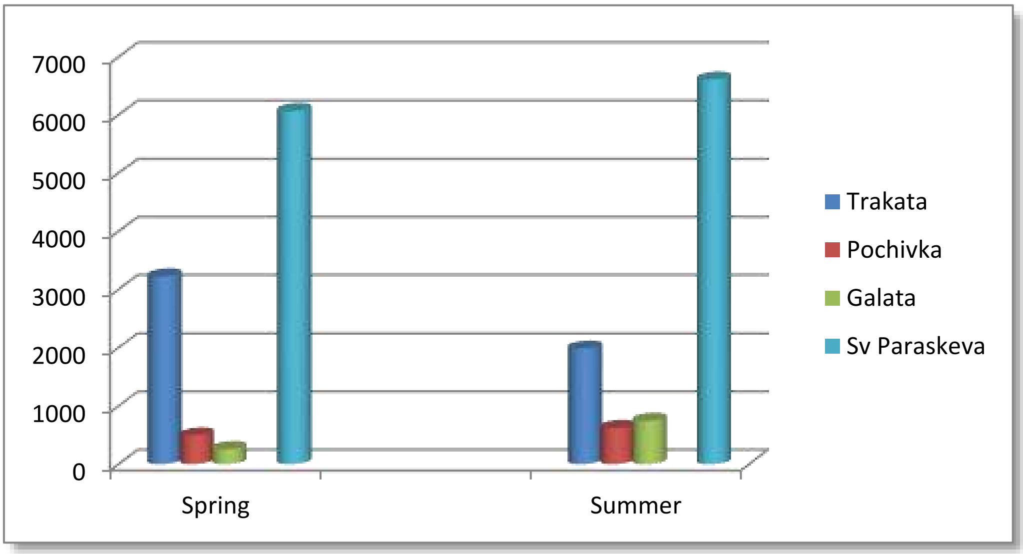


Figure 1.3.5.4. Seasonal changes of biomass (g·m^{-2}) for some polygons along the Bulgarian Black Sea coast (spring and summer, 2012 year)

Spatial distribution

Typical phytobenthic associations

Recent studies of the structure and distribution of the macrophytobenthos along the Bulgarian Black Sea coast established the presence of a number of typical Black Sea macroalgal and sea grass plant associations (Vasilev et al., 2005, Berov et al., 2010; Dencheva, 2010; Holmer et al., 2016). As a part of the implementation of European environmental policies, these predominant phytobenthic habitat have been classified in a scheme based on the EU Habitats Directive (92/43/EEC) and further developed under the EU Marine Strategy Framework Directive (2008/56/EC) (Table 1.3.5.4). This classification scheme follows the zonation of the littoral introduced by Peres and Picard (1964), where benthal is subdivided in zones, depending on substrate type, depth, exposure, the presence of typical morphological forms of plants and light availability. Table 1.3.5.4 presents the classification of the typical phytobenthic communities for the Bulgarian coast of the Black Sea in accordance with the EU Habitats Directive, the EU Marine Strategy Framework Directive, EUNIS, as well as the classification of Kalugina-Gutnik (1975).

Figure 1.3.5.4. Classification of typical phytobenthic habitats found along the Bulgarian Black Sea coast according to different classification schemes

Habitats Directive Annex 1	**National subtypes (biotopes) (MSFD initial assessment Table II.2.1.1.) +**	**Kalugina-Gutnik (1975) associations correspondence**	**EUNIS**	**Reference**
1110	**Underwater Seagrass meadows**		**A1.165**	(Berov et al., 2015 b; Holmer et al., 2016; Todorova et al., 2012)
	Zostera marina	*Zostera marina*		(Berov et al., 2015 b; Holmer et al., 2016)
	Zostera marina-Zannichellia palustris-Zostera noltii			(Berov et al., 2015 b; Holmer et al., 2016)
	Zostera noltii	*Zannichellia palustris - Zostera noltii*		(Berov et al., 2015 b; Holmer et al., 2016)
1170	**Rocky reefs**			
	3.Mediolittoral rocks with Corallina, Nemalion, Scytosiphon and other macroalgae :			
	3.a Exposed to moderately exposed lower mediolittoral rock with *Corallina* spp.			(BSBD, 2013; Todorova et al., 2012)
	3.b Mediolittoral rocks with *Nemalion helmninthoides*	*Nemalion helmintoides - Laurencia papilosa*		(BSBD, 2013; Todorova et al., 2012)
	3.c Mediolittoral rocks with *Scytosiphon lomentaria*	*Scytosiphon lomentaria*		(BSBD, 2013; Todorova et al., 2012)
	3.d Mediolittoral rocks with *Ceramium virgatum* and *Mytilus galloprovincialis*		A3.23 A3.237	(BSBD, 2013; Todorova et al., 2012)

Habitats Directive Annex 1	**National subtypes (biotopes) (MSFD initial assessment Table II.2.1.1.) +**	**Kalugina-Gutnik (1975) associations correspondence**	**EUNIS**	**Reference**
	9. Infralittoral rocky bottom with perennial brown macroalgae from the genus Cystoseira :			(BSBD, 2013; Todorova et al., 2012)
	9.a Exposed upper infralittoral rocks with *Cystoseira crinita f. bosphorica Kalug. et Zin. (=C. bosphorica Sauv.)*	*Cystoseira crinita + C. barbata - Cladostephus verticillatus - Corallina mediterranea*	A3.23A	(Berov, 2013; Berov et al., 2015; Vasilev et al., 2005)
	9.b Moderately exposed infralittoral rocks with *Cystoseira barbata + Ulva rigida+ Polysiphonia subulifera*	*Cystoseira barbata f. hoppii - Ulva rigida*	A3.23M	(Berov, 2013; Vasilev et al., 2005)
	9.c Sheltered, shaded, upper infralittoral rock with *Phyllophora crispa*		A3.23O; A3.741	(Todorova et al., 2012)
	10. Infralittoral rocky bottom with seasonal green and red macroalgae :			(Berov, 2013; Dencheva, 2010; Todorova et al., 2012)
	10.a Infralittoral rocks with *Ulva rigida + Gelidium spinosum*	*Ulva rigida - Ceramium rubrum*		(Berov et al, in prep.)
	10.b Infralittoral rocks with Cladophora spp. + *Ulva rigida + Ulva intestinalis +* Gelidium *spp.*	*Cladophora vagabunda + Ulva intestinalis + Callithamnion corymbosum*	A3.23 A1.241 A1.242	(Berov, 2013)
	11. Lower infralittoral with association of the scyophylic algae *Phyllophora crispa*	*Phyllophora nervosa* subf. breviarticulata		(Todorova et al., 2012)
	11.a Lower infralittoral rocks with *Phyllophora crispa +Apoglosium ruscifloium + Gelidium spinosum+ Zanardinia typus*	*Phyllophora nervosa* subf. breviarticulata		(Berov et al., in prep.)
	11.b Lower infralittoral rocks with *Polysiphonia elongata +Cladophora albida+ Antithamniom cruciatum + Lomentaria clavellosa*	*Polysiphonia elongata + Zanardinia typus; Antithamniom cruciatum + Ectocarpus siliculosus*		(Todorova et al., 2012; Berov et al., in prep.)

Spatial distribution along the national sates

The coastal zone around C. Maslen Nos within the Ropotamo-Kiten Natura 2000 zone in the S section of the Bulgarian Black Sea coast is considered as a relatively undisturbed from anthropogenic impacts and serves a referent area in the national marine monitoring programs. The structure of macroalgal communities in this area can be considered as representative for the natural undisturbed state of macroalgal habitats in this region of the Black Sea (Berov, 2013; Vasilev et al., 2005; Berov et al., in prep.)

The upper infralittoral belt in the zone (0,5-1 m depth) is populated by *M. galloprovincialis* on bare rocks, overgrown by *Ceramium virgatum*, *Gelidium spinosum* and *Gelidium crinale*, with small patches of *Corallina mediterranea*, *Ulva linza*, *U. intestinalis* and *Chaetomorpha aerea*. At depths between 1 and 3-5 m the upper-infralittoral is dominated by *Cystoseira bosphorica* Sauv. communities, followed by *C. barbata* Bory communities at depths between 3-5 and 7-10 m (see Fig. 1.3.5.5). This low depth limit of distribution of the perrennial *C. barbata* marked the depth limit between the upper and lower infralittoral, as defined by Peres and Picard (1964).

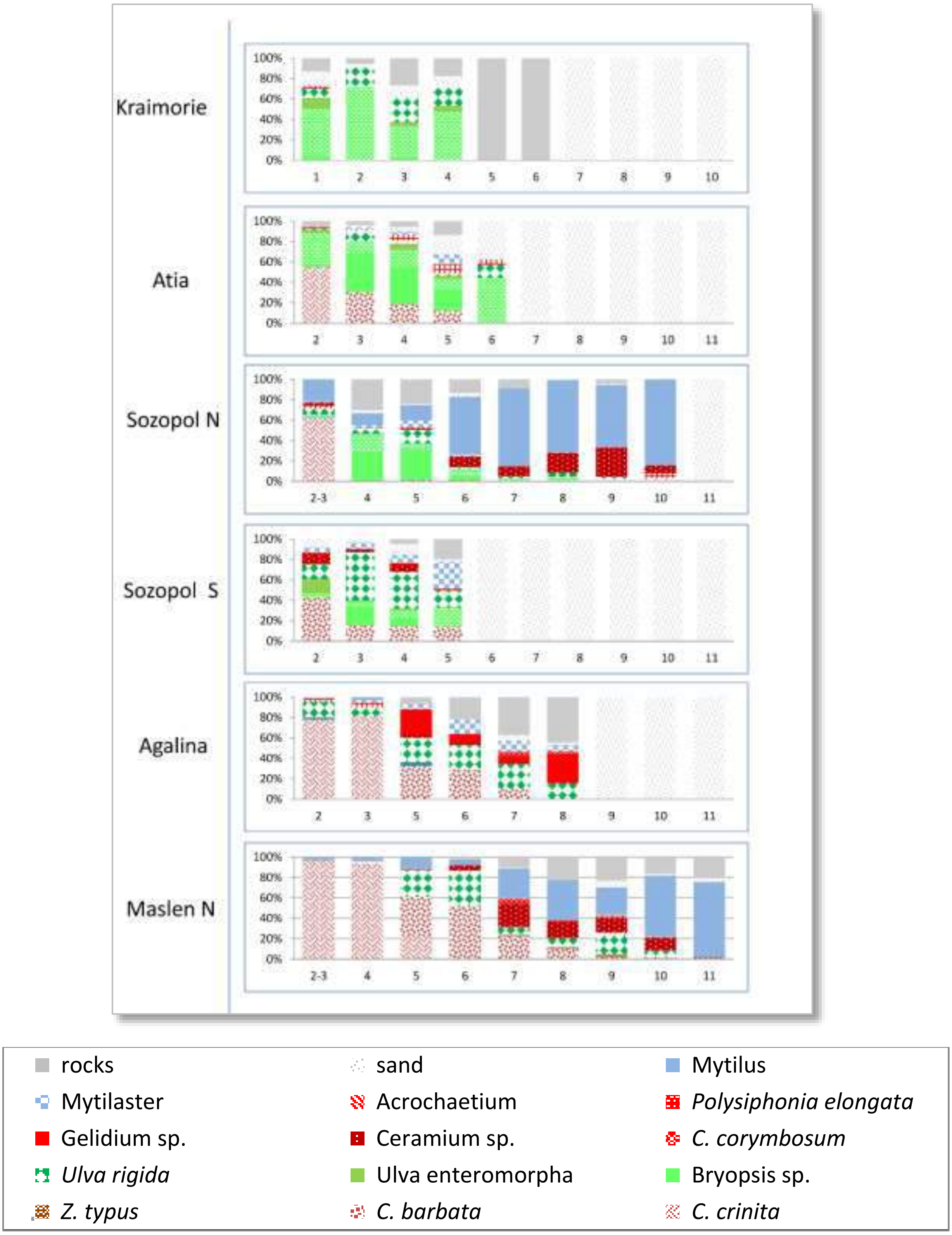


Figure 1.3.5.5. Average per meter-depth intervals photo cover of the benthos by dominant benthic organisms at study stations along the S coast of Burgas Bay in 06.2010

Rocky reefs below this depth are dominated by a mixture of macroalgal assemblages, with abundant presence of the scyiophylic red and brown macroalgae – *Phyllophora crispa*, *Zanardinia typus*, *Apoglosium ruscifloium* as well as the widely adaptive turf-forming green macroalgae *Cladophora albida* and *Cladophora coelothrix*, as well as the red macroalgae *Gelidium spinosum*, and *Gelidium crinale*. The depth limit of the lower infralittoral rocky bottom zone formed by these assemblages is at 15-18 m, depending on local conditions and substrate availability. Below 15-18 m, which marks the upper depth limit of the circalittoral, the only prominent macroalgal species is the red sciaphylic species *Antithamnion cruciatum*.

The long-lasting anthropogenic pressures in the coastal zone of Bulgaria determine the different state of phytobenthic habitats in the well-established long-term gradients of impact in the Burgas and Varna Bays. Studies of the changes in the diversity and depth structure of macroalgal communities these areas showed a typical picture of change in the depth distribution of the dominant habitats depending on the distance from the main sources of local impacts (Berov, 2013; D. Berov et al., 2012; Dencheva, 2006; Orfanidis et al., 2012). The decreasing eutrophication impacts in these coastal zones are paralleled with gradual decrease in the presence of green macroalgae from the genus Cladophora, Ulva and Chaetomorpha, and red opportunistic macroalgal species (e.g. *Ceramium virgatum*, *Callithamnion corymbosum*), increase in the presence of sensitive K-selected red and brown macroalgal species, an increase in the overall biodiversity, as well as an increase in the depth of occurrence of the dominant brown macroalgal species – *Cystoseira barbata* and *Cystoseira bosphorica*.

This process is well described along the S coast of Burgas Bay, where a study conducted in 2009-2010 showed a clear decrease in nutrient, sestone and chlorophyll-a concentrations, as well as increase in water transparency was noted between the inner Burgas Bay (Kraimorie) and Cape Maslen Nos area (see Berov et al. (2012) for details). The gradient of eutrophication impact in the Burgas Bay had a strong impact on the taxonomical structure of the studied macroalgal communities– decrease in the number of Ochrophyta and Rhodophyta, an increase in the numbers of Chlorophyta (**Error! Reference source not found.**6).

Figure 1.3.5.6. Overall number of red, brown and green macroalgae in samples from study stations along the Sea coast of Burgas Bay

This improvement in water quality was paralleled with a gradual change in the species structure, biodiversity depth limit of distribution of dominant species and change in ecological status quantified using different Water Framework indices (see see Fig. 1.3.5.5).

Surveys conducted along the S coast of Varna Bay conducted reviewed similar processes of improvement in the structure of the phytobenthic communities with increasing distance from the sources of local eutrophication impacts and the improvement in water quality (Todorova et al., 2012). With increasing distance from the inner Varna Bay between Cape Galata and the Galata Natura 2000 area, located 8-10 km outside of the immediate zone of impacts in the Varna Bay), a gradual decrease in the presence of opportunistic green and red species was observed. The phytobenthos in the upper infralittoral gradually shifts from *Ulva rigida* – Cladophora spp. – dominated communities to communities of *Cystoseira barbata-Ulva rigida* (see Figure 1.3.5.7.). A gradual increase in the depth of distribution of macroalgae e is also observed – from as little as 5-6 m at Cape Galata, down to 10-11 m at Rodni Balkani area.

These changes in community structure of macroalgae along eutrophication gradients are not unique cases and are probably representative for the whole Black Sea coastal area, where the interaction of natural and anthropogenic factors shape the distribution of marine macroalgae.

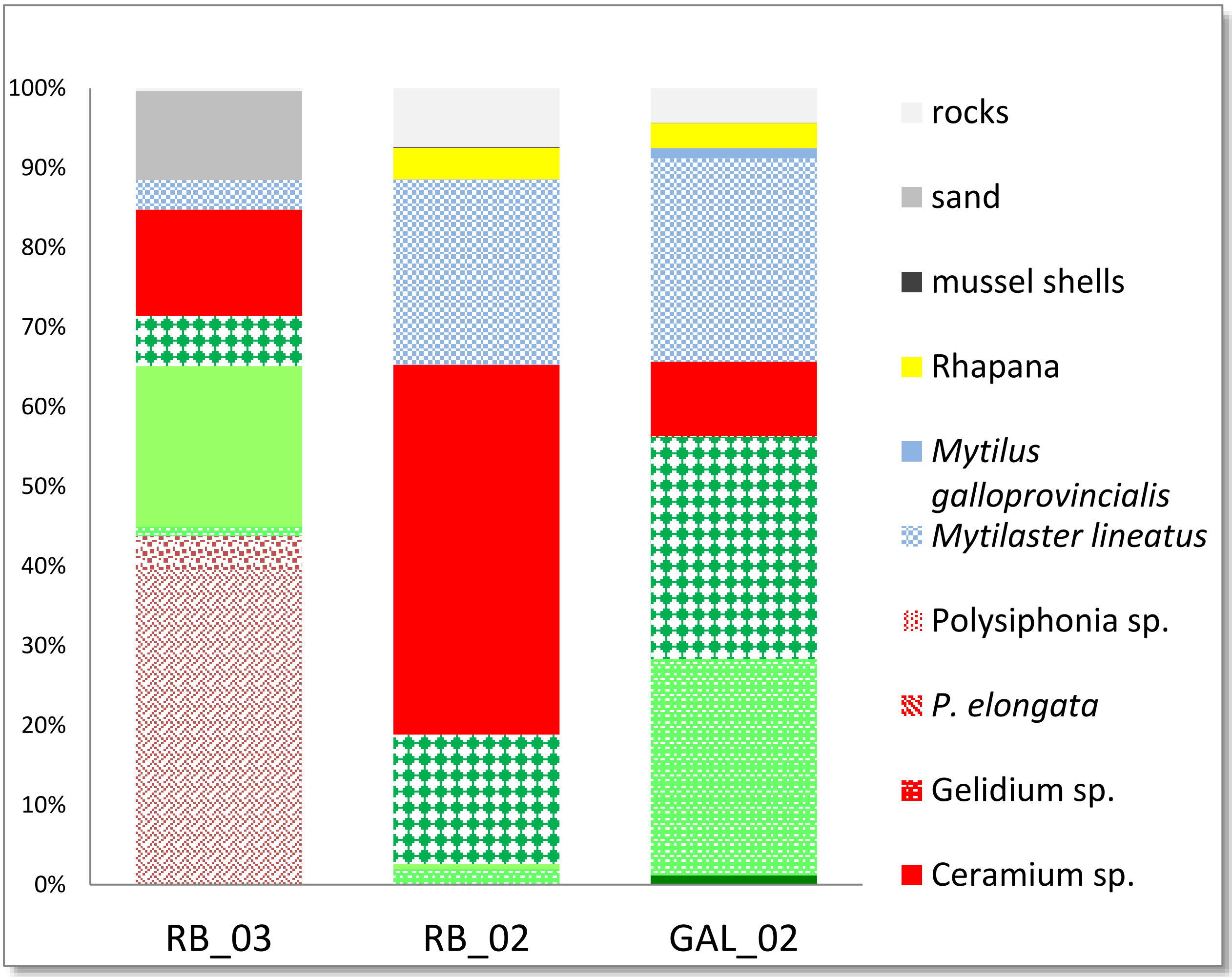


Figure 1.3.5.7. Upper infralittoral macroalgal communities structure at depths 2-3 meters at stations at Cape Galata (Gal_02, 2 km from the inner Varna Bay), Rodni Balkani 2 (RB_02 9 km from the inner Varna Bay), and Rodni Balkani 3 (RB_03, 10 km from the inner Varna Bay) in the summer of 2011 (Todorova et al., 2012)

In Pochivka, Galata, Veteran and Pasha dere poligons, prevail green and red algae and dominant in species number was Rhodophyta phylum. Dominance of red and green algae in Pochivka, Galata, Veteran and Pasha dere polygons (Fig. 1.3.5.8) are consequence of described below in the text reasons. Average number of species was highest at Star korab, Rodni balkani and Trakata. The lowest average number of species was estimated for Galata, Pochivka, Pasha dere polygons.

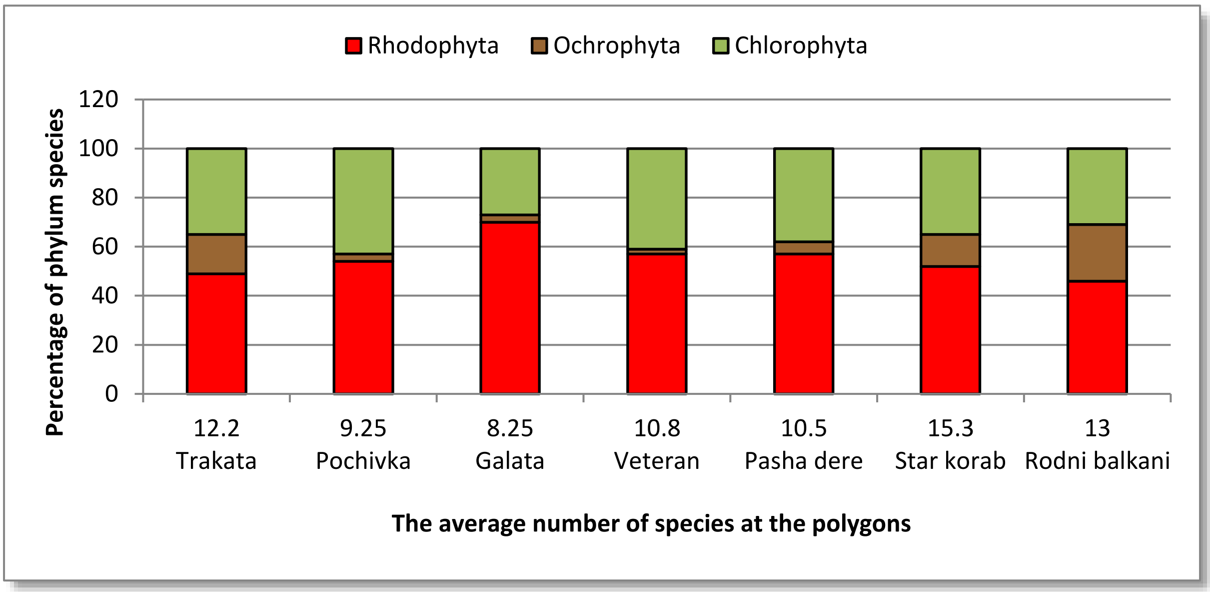


Figure 1.3.5.8. Percentage of species of Chlorophyta, Ochrophyta and Rhodophyta phylums from polygons in Varna bay and average species number through different years of investigation (2007-2014)

As a whole, differences between species within a given phylum along the Bulgarian coast are small. The highest number of species is registered for Rhodophyta phylum (15) and it is obvious that the representatives of this phylum are most numerous. With lowest number of species are characterized brown algae (Ochrophyta phylum), followed by Chlorophyta (green algae). Ochrophyta (ranged from 3 to 4) and Rhodophyta (12 - 15) prevailed in southern part of the Bulgarian coast and in the northern part in Rusalka polygon (Fig. 1.3.5.9). Chlorophyta species numbers were lower (3 - 4 species) in the same zones. It is in conformity with fact that in these zones there are no or minor sources of pollution exist.

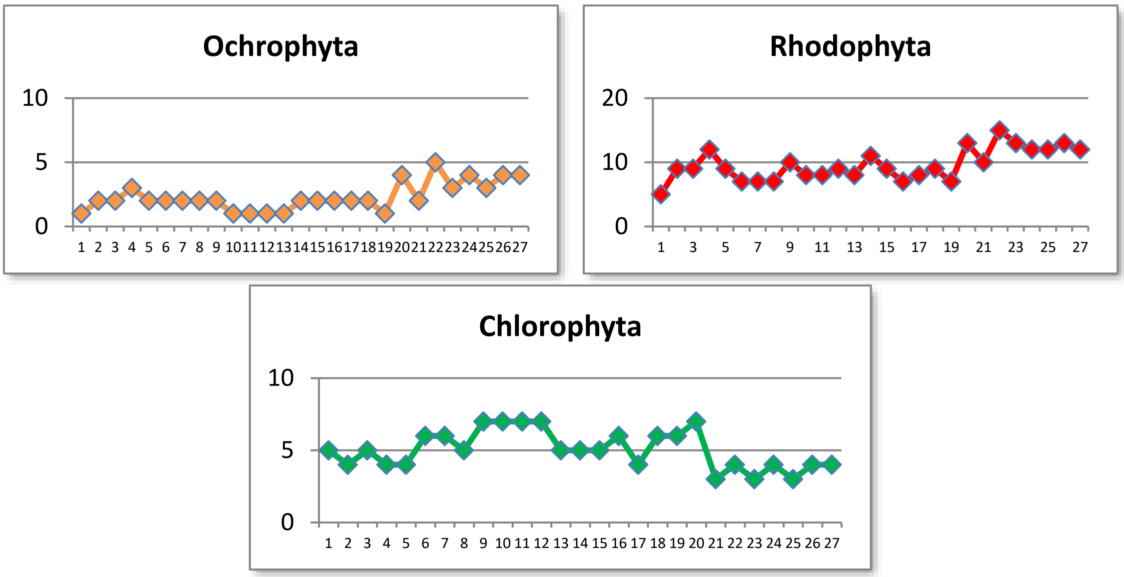


Figure 1.3.5.9 Changes in species number of Chlorophyta, Ochrophyta and Rhodophyta phylums along the Bulgarian coast from investigated polygons (from north to south) in the period 2007-2014 years, summer - autumnal season.

1.Krapetz, 2. Shabla, 3. Tiulenovo, 4. Rusalka, 5.Tauk liman 6. Kavarna, 7. Balchik-Tuzla, 8. Kranevo, 9. Trakata, 10, Pochivka, 11. Galata. 12.Veteran, 13. Pasha dere, 14. Star korab, 15. Rodni balkani, 16. Biala, 17. Irakly, 18. Nesebar, 19. Kraymorie, 20. Sozopol, 21. Agalina, 22. Sv. Paraskeva, 23. Arapia, 24, Varvara 25. Before Ahtopol, 26. Sinemoretz, 27. Rezovo

Low Floristic index values represent more pure waters, while higher values are characteristic of more polluted waters. In south part of the Bulgarian coast from Sozopol to Rezovo, the indices are low. The highest values are registered in Varna bay (Pochivka, Galata, Veteran, Pasha dere) Krapetz, and Kraymorie (Burgas bay) (Fig. 1.3.5.10).

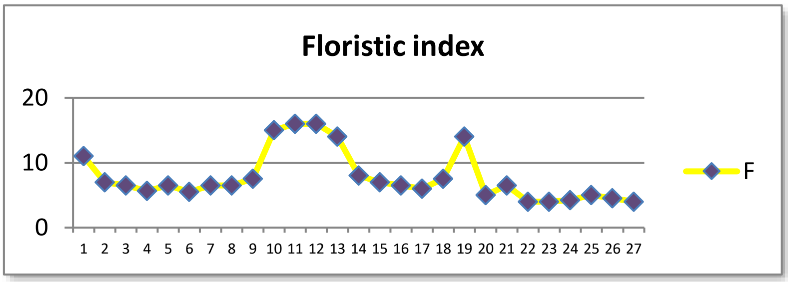


Figure 1.3.5.10. Changes in the Floristic index (F) along the Bulgarian coast from investigated polygons (from north to south) in the period 2007-2014 years, summer - autumnal season (symbols correspond to Fig. 1.3.5.9).

In Varna bay the following gradient of eutrophication was revealed according to percent biomass proportion of green, red and brown algae (Fig. 1.3.5.11).

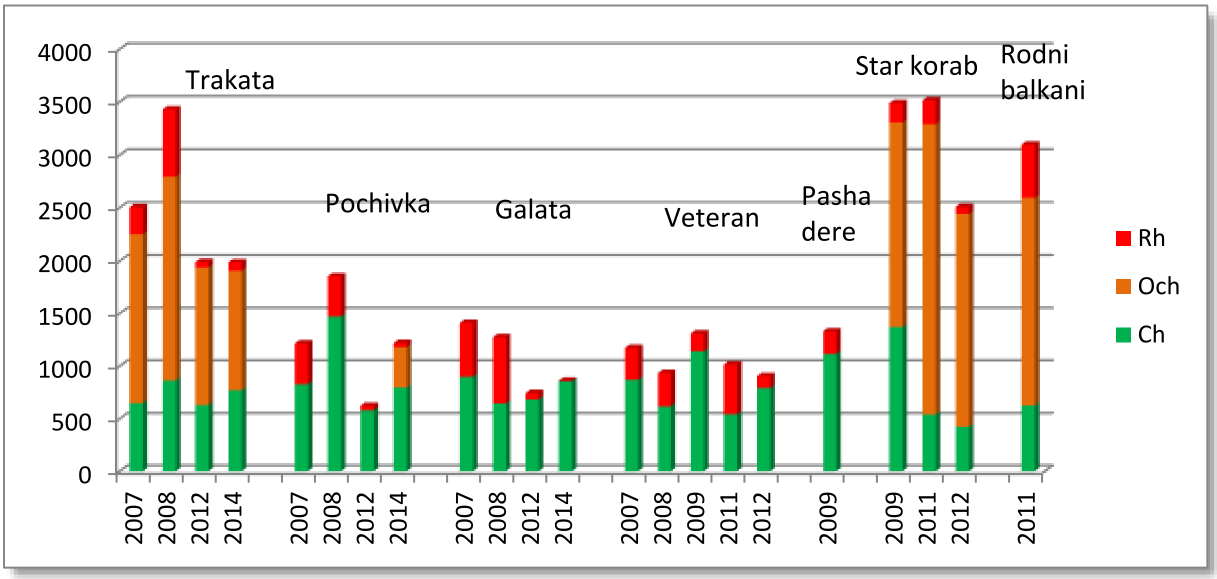


Figure 1.3.5.11. Biomass (g·m^{-2}) proportion of Chlorophyta, Ochrophyta and Rhodophyta phylums from investigated polygons in Varna bay through different years of investigation

Trakata, Star korab and Rodni balkani were characterized with dominance of Ochrophyta phylum. These polygons are in the northern and southern part of the bay and are in highest distance from channels through which, the contaminants enter the bay while in Pochivka, Galata, Veteran and Pasha dere polygons, dominant was Chlorophyta phylum biomass (see Fig. 1.3.5.11). The Pochivka and Galata, Pasha dere and Veteran are closer to the channels and are influenced by the pollution entering trough. With higher eutrophication level, expressed with nutrients inflow increase and transparency decrease in water column, Chlorophyta phylum representatives well adapted for growth in these conditions with their high surface/volume area and short life cycle enhance their quantity and Ochrophyta olygothrophic perennial species lower their quantity or disappear. These processes are well described for seas and oceans. (Borowitzka, 1972; Benedetti-Cecchi et al, 2001; Eriksson, Bergstrom, 2005; Orfanidis et all., 2003, 2011; Kalugina-Gutnik, 1975; Minicheva, 1998; Dencheva 2010; Diez et al., 2012)

In eutrophicated areas such as Varna bay, depth distribution decrease in algal communities is observed because of lowering of transparency and quantity of light with depth. Phaeophyta species biomass is distributed to 5 m depth and other Rhodophyta and Chlorophyta species are restricted to 14-15 m with low biomass and just 2-3 species mainly *Polysiphonia elongata, Bryopsis plumosa, Callithamnion corymbosum.* In different years of investigation some fluctuations in proportions of different phylums exist, but no big differences were established.

At the end points of Varna Bay in south (Star korab, Rodni balkani) and north (Trakata), biomass values were higher because of higher distance from main sources of pollution, which is spread with current from Varna lake to Galata and Veteran direction and central part of the bay (Pochivka) (Fig. 1.3.5.12). It is in conformity with the results from other parameters (species composition and biomass proportions of different phylums).

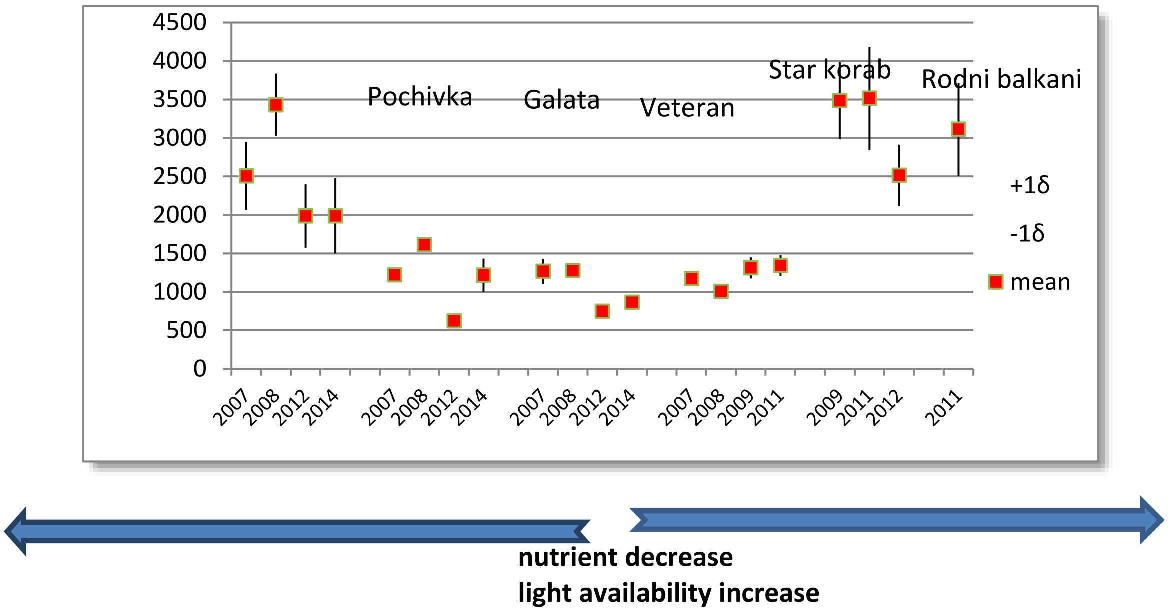


Figure 1.3.5.12. Total biomass (g·m^{-2}) values of macropohyte communities in Varna Bay (summer season) from the years of investigation (2007-2014). Vertical lines show standard error from average biomass values (quadrates)

Highest biomass was measured in south part of the Bulgarian coast from Sozopol to Rezovo (Fig. 1.3.5.13) and in Shabla, Tiulenovo, Irakli (2014 year). These polygons are characterized with good conditions and good and high ecological status. Lowest biomass values were registered in Krapetz and Krajmorie (Burgas bay) respectively. Highest biomass value was measured in Sveta Paraskeva polygon 6609.3 g·m^{-2}(2012 year). In Sveta Paraskeva polygon, south part in 2012 year first time for the Bulgarian Black Sea coast, the species *Vausheria dichotoma* f. *marina* was registered at 3 m depth. The species was found in big quantity as epiphyte on *Cystoseira* spp.

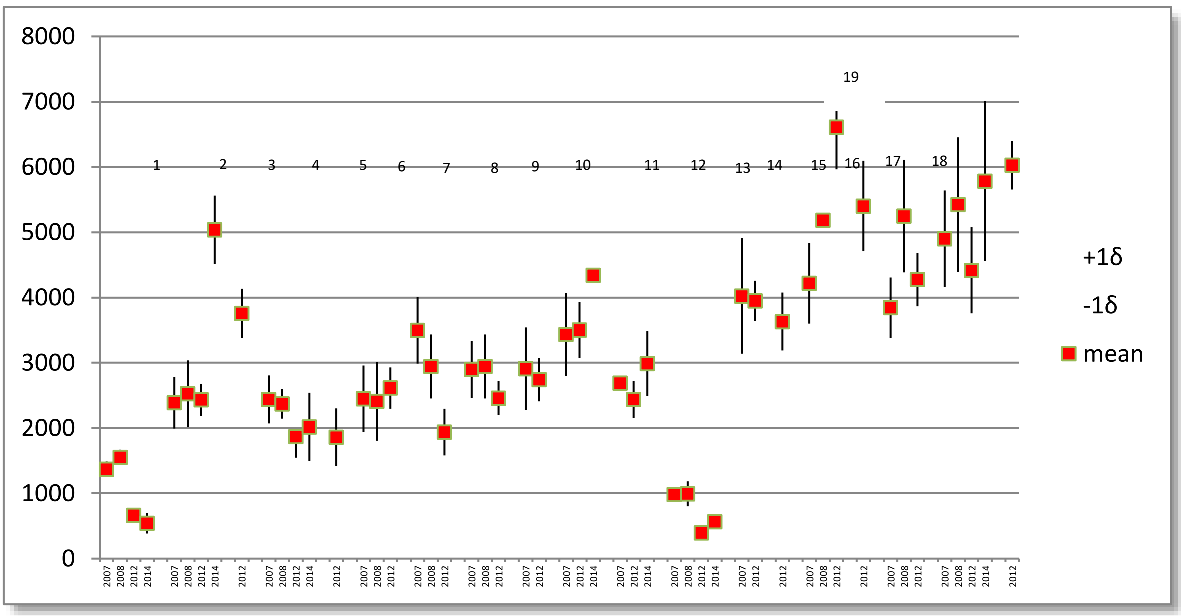


Figure 1.3.5.13. Total biomass (g.m^{-2}) values of macropohyte communities in Bulgarian coast (summer season) from the years of investigation (2007-2014).

Vertical lines show standard error from average biomass values (quadrats). 1. Krapetz. 2. Shabla; 3. Tiulenovo. 4. Rusalka. 5.Tauk liman.6. Kavarna. 7. Balchik. 8.Kranevo. 9.Biala. 10. Irakli. 11. Nesebar. 12. Kramorie. 13. Sozopol. 14. Sveta Agalina.15. Sv. Paraskeva. 16. Tsarevo(Arapia). 17. Varvara. 18. Sinemoretz. 19. Rezovo

Sea grass communities

Seagrass communities found along the Bulgarian Black Sea coast have a clearly depth-related change in community structure, with *Zostera noltei* dominating between 1-3 m depth range, followed by mixed *Z. noltei – Zannichellia palustris - Zostera marina* communities (3-4 m) , and dominance of *Z. marina* between 4 and 7 m. The lower depth limit of distribution of the meadows is smaller in areas under increased eutrophication pressures (e.g. inner Burgas Bay)

Historically, seagrass communities were widely spread along the Bulgarian Black Sea coast with the majority of the meadows found in sheltered and semi-sheltered coastal areas in the Burgas Bay (Petrova-Karajova, 1982). Recent studies confirmed the presence of most of these seagrass meadows within the areas surveyed in the 1980s (Berov et al., 2015 b; Holmer et al., 2016; Vasilev et al., 2005), and confirmed that the majority of these phytobenthic communities are located within the Burgas Bay, where they have an area of over 300 hectares. Smaller patches of Zostera spp. meadows have also been located in several sheltered bays north of Cape Emine (Dencheva, 2010; Todorova et al., 2012).

Assessment of water quality

Along the Bulgarian Black Sea Coast, following polygons were investigated for assessment of the ecological status on the base of macrophytobenthic communities in period 2007-2014 years (Fig. 1.3.5.14).

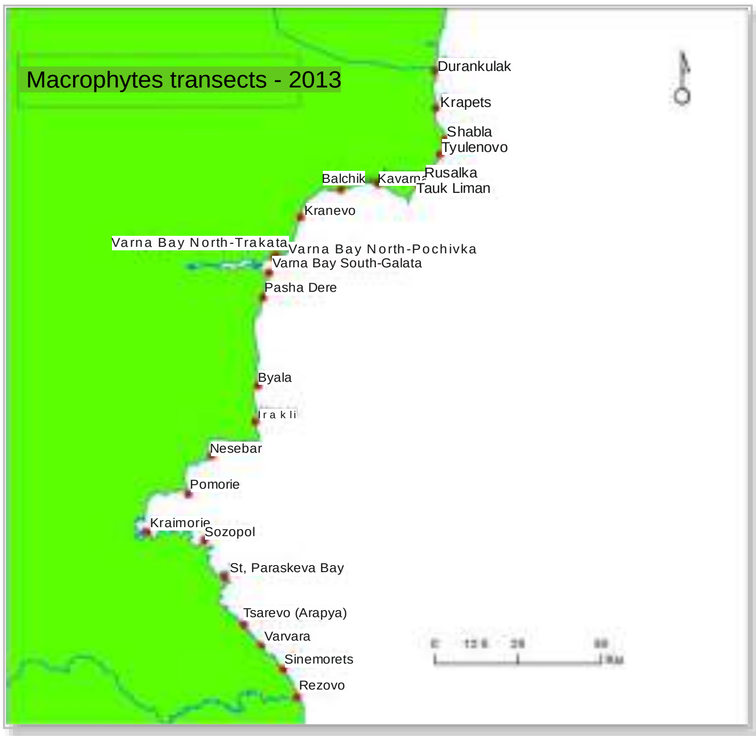


Figure 1.3.5.14. Map with the investigated polygons along the Bulgarian Black Sea coast

Ecological index was based on the biomass proportion of sensitive (ESGI) and tolerant (ESGII) species. The conceptual model that the anthropogenic pressures can produce a decrease or even disappearance of the most sensitive species, while the most tolerant taxa flourish, is proved very well in the literature. (Kalugina-Gutnik 1975; (Minicheva 1998,1993; Orfanidis et al., 2003, 2011; Pinedo, 2007; Mangalajo et al., 2007; Ballesteros, 2006; Borowitzka, 1972; Diez et al., 1999, 2012; Dencheva, 1994).

Highest values of the index and ecological quality ratio were registered in Trakata, Pasha dere (Star korab) and Rodni balkani polygons. They are at higher distance from main sources of pollution which enter the bay from Varna lake with main current in directon Galata and central part of the bay. That is the reason in Galata, Veteran, Pasha dere and Pochivka polygons, the lowest values of ecological index and ecological quality ratio values to be measured (Table 1.3.5.5).

Table 1.3.5.5. Ecological index, Ecological Quality Ratio and ecological status of investigated polygons in Varna bay: 2007-2014 years. Ecological Status Class: red-bad status; orange-poor; moderate-yellow; good-green; high-blue

Polygon	EI-EQR	EI	Year
Trakata	0.55	5.11	2007
	0.48	4.5	2008
	0.59	5.47	2012
	0.53	4.92	2014
Pochivka	0.04	0.42	2007
	0.05	0.48	2008
	0.22	2.05	2012
	0.38	3.57	2014
Gala(Romantika)	0.06	0.6	2007
	0.25	2.52	2008
	0.07	0.64	2012
	0.11	1	2014
Veteran	0.26	2.39	2007
	0.26	2.4	2008
	0.11	1	2009
	0.05	0.5	2011
	0.21	2	2012
Pasha dere	0.11	1	2009
Pasha dere (Star korab)	0.52	4.82	2009
	0.67	6.25	2011
	0.69	6.44	2012
Rodni balkani	0.65	6.1	2011

Ecological quality status was moderate in Trakata and Pasha dere (Star korab) and good ecological status was established in Rodni balkani. In Pochivka, Galata Veteran and Pasha dere, bad and poor ecological status was calculated.

Varna bay and Burgas bay were defined as water bodies at risk along the Bulgarian Black sea coast. On table 1.3.5.6 could be seen that Krajmorie, which is in Burgas bay has the lowest values of the Ecological index and Ecological Quality Ratio (EQR) and is characterized in bad status class. Another site with low values of Ecological index (0.43; 0.48; 2.85; 0.75) and EQR (0.05; 0.05; 0.31; 0.08) is Krapetz. The influence of Danube river many years ago is probably one of reasons for these low values. Another main reason are natural conditions (high turbidity, high abrasion, soft clay plates as substrate, exposed coast). In these conditions, *Cystoseira* which is the main genus which is sensitive to pollution and forms high biomass, can not attach and grow. In south part of Bulgarian Black Sea coast (from Sozopol to Rezovo), very good conditions exist for growing of sensitive macrophyte species mainly *Cystoseira spp*. Pure waters, very good rocky substrate, spread in large areas allow to extensive *Cystoseira* meadows to grow. That is the reason here to be measured the highest values of Ecological index and EQR and these sites are classified in high ecological status. In the last two years, little improvement in ecological status was registered. It is proved with higher values of Ecological index and EQR (Table 1.3.5.6).

Table 1.3.5.6. Ecological quality ratio, Ecological index values of investigated polygons along the Bulgarian Black Sea coast. Ecological Status Class: red-bad status; orange-poor; moderate-yellow; good-green; high-blue

Polygon	EI-EQR	EI	Year
Krapetz	0.05	0.43	2007
	0.05	0.48	2008
	0.31	2.85	2012
	0.08	0.75	2014
Shabla	0.57	5.3	2007
	0.58	5.42	2008
	0.68	6.29	2012
	0.92	8.61	2014
Tiulenovo	0.88	8.23	2012
Rusalka	0.77	7.13	2007
	0.73	6.85	2008
	0.86	8.05	2012
	0.75	7	2014
Tauk liman	0.86	8	2012
Kavarna	0.68	6.33	2007
	0.78	7.23	2008
	0.87	8.15	2012
Balchik	0.65	6.1	2007
	0.73	6.83	2008
	0.85	7.91	2012
Kranevo			
	0.67	6.24	2007
	0.67	6.2	2008
	0.65	6.09	2012
Biala	0.78	7.2	2007
	0.84	7.8	2012
Irakli	0.65	6.1	2007

Polygon	EI-EQR	EI	Year
	0.87	8.2	2012
	0.9	8.4	2014
Nesebar	0.65	6.13	2007
	0.62	5.75	2012
	0.69	6.41	2014
Krajmorie	0.06	0.56	2007
	0.05	0.48	2008
	0.11	1	2012
	0.12	1.16	2014
Sozopol	0.86	8.1	2007
	0.89	8.33	2012
Sv. Agalina	0.74	6.88	2012
Sv. Parashkeva	0.99	9.25	2007
	0.89	8.23	2008
	0.93	8.67	2012
Arapia	0.97	9.05	2012
Varvara	0.87	8.16	2007
	0.88	8.2	2008
	0.92	8.62	2012
Sinemoretz	0.95	8.9	2007
	0.88	8.2	2008
	0.93	8.67	2012
	0.99	9.25	2014
Rezovo	0.98	9.18	2012

From Shabla to Nesebar mainly good ecological status was established with fluctuations through the years and from Sozopol to Rezovo high ecological status was assessed, wth exception of Sv. Agalina (good ecological status). In Krapetz, Kraymorie (Burgas bay), bad ecological status was registered.

GEORGIAN SECTOR

The national data of macrophytibenthos state are absent for the period 2009-2014 years.

ROMANIAN SECTOR

Species composition

The submerse vegetation from the Romanian Black Sea waters represents a very important ecosystem component, being a substrate for the epiphytic algae, feeding and breeding area for invertebrates and fish, which carry-out their vital processes within the thickets formed by macrophytes.

Romanian sampling area

During 2009 – 2014, the samples were collected from the following stations along the coastal strip Năvodari - Vama Veche, considered representative for the development of the algal flora: Năvodari, Mamaia, Pescărie, Constanta North, Casino Constanta, Agigea, Eforie North, Eforie South, Tuzla, Costineşti, Saturn, Mangalia, 2 Mai and Vama Veche (Fig. 1.3.5.15). These stations have a favorable substrate for the development of phytobenthic communities, both natural (hard, rocky substrate) and sandy substrate (suitable for phanerogams development). The quantitative data (average data for each species, at each sampling station) used in the present report belong to summer season, the other seasons were only analyzed from a qualitative point of view.

During the past years, at the Romanian shore the photophylic associations *Ulva* sp. – *Cladophora* sp. - *Ceramium* sp. dominates, especially during summer season. For the cold period, the characteristic association is *Ulva* sp. – *Pyropia* sp. – *Scytosiphon* sp., enriched with various seasonal elements, with important development between 0-5 m depth range.

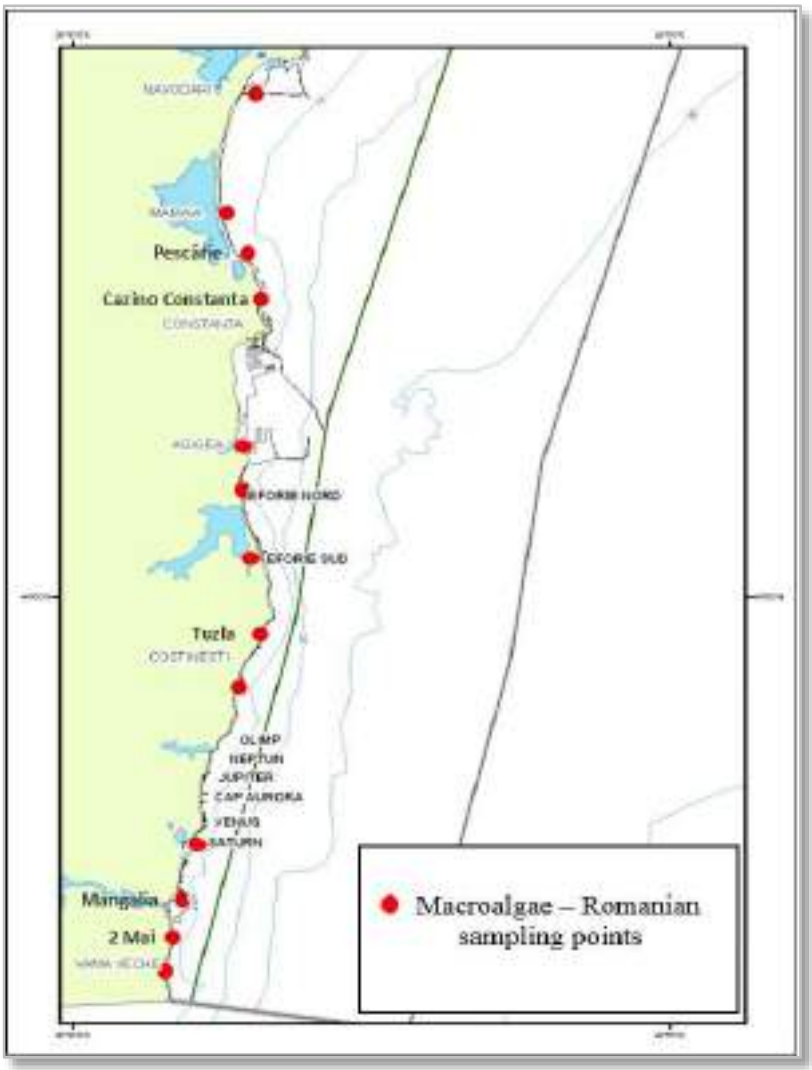


Figure 1.3.5.15. Romanian phytobenthos sampling map

The algal populations from the Romanian coastal waters have undergone radical changes over decades, the most important being the reduction of *Cystoseira* fields and the intense development of algal populations with short life cycle. These particular situations changed also the zoobenthic associated communities (Tiganus V., 1979). This situation characterized also the last years, especially during the summer season, when a few number of species dominates the rocky substrate (*Ulva, Cladophora, Ceramium*) and develops appreciable fresh biomasses.

In present (including the analyzed period), at the Romanian coast, macroalgae develop up to 5-7 m depth, rarely 10 m, where there is enough light for the photosynthesis process (Sava D., 2000). As a general idea, for the Romanian coast of the Black Sea, the most important change suffered by the submerse vegetation over decades, is considered to be its qualitative decline, the disappearance/decline of perennial species with ecological value and the reducing areal of marine phanerogams. The present situation compared to the one of the last decades ('60 -'70) is characterized by the decrease of the perennial species number, but a positive aspect can be noticed, namely the regeneration of perennial brown algae *Cystoseira barbata* (Stackhouse) C.Agardh and the marine phanerogam *Zostera (Zosterella) noltei* Hornemann along the Romanian Black Sea coast (Marin O. et al., 2013).

Although, nowadays it is not possible to speak of a high species number comparing to the one recorded in the previous decades, during the past years the study showed a slight improvement of this situation. In the past years, was noticed a higher taxa, compared to the period 1996 – 2005 (Table 1.3.5.7):

Table 1.3.5.7. Romanian phytobenthic species evolution over decades

	Period			
Number of species	**1962 – 1972** (Bavaru A.,1972)	**1976 -1995** (Vasiliu F.,1984)	**1996 – 2005** (Sava D. & Bologa A.,2008)	**2005-2014** (Marin O.et al, 2011)
	86	**55**	**31**	**35**

Cystoseira and *Zostera* communities are currently dominated by the key species *Cystoseira barbata* (Stackhouse) C.Agardh, 1820 and *Zostera (Zosterella) noltei* Hornemann, These are species that influence the structure and functioning of benthic communities, a substrate for other plants and refuge, feeding and breeding area. They are nowadays in a regeneration period at the Romanian Black Sea coast, but remain highly sensitive to anthropogenic factors and associated activities (e.g. dams constructions, harbors excavations).

During the considered period (2009-2014), based on the qualitative analysis, 35 taxa were identified, assigned to the following phyla: 14 species of Chlorophyta, 4 of Ocrophyta, 13 Rhodophyta taxa and 4 of Tracheophyta (Table 1.3.5.8):

Table 1.3.5.8. Romanian species list (2009 – 2014)

Chlorophyta	Ocrophyta	Rhodophyta	Tracheophyta
Bryopsis plumosa (Hudson) C.Agardh, 1823	*Cystoseira barbata* (Stackhouse) C.Agardh, 1820	*Acrochaetium secundatum* (Lyngbye) Nägeli, 1858	*Zannichellia palustris L.*
Chaetomorpha aerea (Dillwyn) Kützing, 1849	*Ectocarpus siliculosus* (Dillwyn) Lyngbye, 1819	*Callithamnion corymbosum* (Smith) Lyngbye, 1819	*Zostera (Zosterella) noltei Hornemann*
Cladophora albida (Nees) Kutzing, 1843	*Punctaria latifolia* Greville, 1830	*Ceramium diaphanum* (Lightfoot) Roth, 1806	*Ruppia cirrhosa (Petagna) Grande, 1918*
Cladophora laetevirens (Dillwyn) Kützing, 1843	*Scytosiphon lomentaria* (Lyngbye) Link, 1833	*Ceramium diaphanum var. elegans* (Roth) Roth, 1806	*Stuckenia pectinata (L.) Börner, 1912*
Cladophora sericea (Hudson) Kützing, 1843		*Ceramium virgatum* Roth, 1797	
Cladophora vagabunda (Linnaeus) Hoek, 1963		*Coccotylus truncatus* (Pallas) M.J.Wynne & J.N.Heine, 1992	
Ulva compressa Linnaeus, 1753		*Colaconema thuretii* (Bornet) P.W.Gabrielson, 2000	
Ulva flexuosa Wulfen, 1803		*Corallina officinalis* Linnaeus, 1758	
Ulva intestinalis Linnaeus, 1753		*Gracilaria gracilis* (Stackhouse) M.Steentoft, L.M.Irvine & W.F.Farnham, 1995	
Ulva linza Linnaeus, 1753		*Hildenbrandia rubra* (Sommerfelt) Meneghini, 1841	
Ulva prolifera O.F.Müller, 1778		*Lomentaria clavellosa* (Lightfoot ex Turner) Gaillon, 1828	
Ulva rigida C.Agardh, 1823		*Polysiphonia denudata* (Dillwyn) Greville ex Harvey, 1833	
Ulothrix flacca (Dillwyn) Thuret, 1863		*Pyropia leucosticta* (Thuret) Neefus & J.Brodie, 2011	
Urospora penicilliformis (Roth) Areschoug, 1866			

At the Romanian shore, the qualitative dominant are the green algae, due to a nutrient enrichment of marine shallow waters, thus favourizes a reduced number of resistent genera (see Table 1.3.5.7). The red algae are the most sensitive to pollution: as a matter of fact, about 30 species are missing nowadays, compared to 1977; they are also the most numerous on the list of disappeared, extinct or rare species (Sava D., Bologa A., 2008) for the Romanian shore.

During 2009-2014, high biomasses of red algae are almost entirely owed to *Ceramium* Roth, 1797 species, found on rocky bottom. This can be explained by the fact that *Ceramium* Roth, 1797 has a high reproductive capacity, both asexuate and sexuate, so they can easily and quickly populate the rocky bottoms, sometimes even completely (Sava D., Bologa A., 2008).

Among the green algae, at the Romanian coast, the eurithermal and opportunistic species belonging to the phylum *Chlorophyta* have dominated, both quantitatively and qualitatively, characterized by a fast development cycle and abundant proliferation. The species of the *Ulva* genus are among the first macrophytes to colonize the substrate from coastal waters with a high content of nutrients. This may due to their simple morphology and remarkable reproductive capacity (Sava D., 2006). Along all study period, during summer, *Ulva rigida* C.Agardh, 1823 was a constant presence, both in the northern and in the southern part, but developed considerable biomasses along the coastal strip 2 Mai – Vama Veche, where it forms the association *Cystoseira barbata* (Stackhouse) C.Agardh – *Ulva rigida* C.Agardh, 1823, particularly important for the marine ecosystem, enriched with various faunal elements.

During cold season, the following stenothermal species were identified at the Romanian shore: *Urospora penicilliformis* (Roth) Areschoug, 1866, *Ulothrix implexa* (Kützing) Kützing, 1849, *Punctaria latifolia* Greville, 1830, *Ectocarpus siliculosus* (Dillwyn) Lyngbye, 1819, *Scytosiphon lomentaria* (Lyngbye) Link, 1833, *Pyropia leucosticta* (Thuret) Neefus & J.Brodie, 2011. Some of them, with the onset of warm season, showed an interesting stenothermy behavior. Thus, as the water temperature increased, these species have retreated to deeper horizons where the environment was still favorable to their physiological processes (the case of *Scytosiphon lomentaria* (Lyngbye) Link, 1833, *Bryopsis plumosa* (Hudson) C.Agardh, 1823, found at 5 metres depth in early summer).

The phanerogam associations play an important ecological role at the Romanian Black Sea coast. In the last 6 years, 4 phanerogams have been identified at the Romanian coast. These species form monospecific meadows or associations of 2-3 of these species. Regarding these marine plants, at the Romanian shore can be found: 3 compact monodominant association *Zostera (Zosterella) noltei* Hornemann (at Mangalia, between 1-3 m), the association *Zostera (Zosterella) noltei* Hornemann – *Stuckenia pectinata* (L.) Börner, 1912 – *Ruppia cirrhosa* (Petagna) Grande, 1918 (at Năvodari), and also small areas covered with *Zannichelia palustris* L. (in the extreme southern part, at Vama Veche).

In the extreme southern part, Vama Veche, the sensitive species – *Corallina officinalis* Linnaeus, 1758 can be found. Also, among the encrusted species, nowadays the most frequent is *Hildenbrandia rubra* (Sommerfelt) Meneghini, 1841, found on mussels shells (*Rapana* and *Mytillus*) and on shallow waters rocky substrate (especially in the northern part, at Cazino Constanta and in the southern part, at 2 Mai – Vama Veche).

Seasonal dynamic

During the period 2009-2014, the clear quantitative dominance of the green algae followed by the red ones, can be noticed, a tendency maintained in past 6 years at the Romanian Black Sea coast. This fact is due to the proliferation of a small number of species characterized by a high reproductive capacity and a high degree of opportunism. Species with short vegetation period have dominated from a quantitatively point of view, since the early 70s, developing high fresh biomasses, frequently exceeded 2,000 kg·m^{-2} (Tiganus V., 1979).

In 2009, the species that dominated the shallow hard substrate were *Ulva rigida* C. Agardh, 1823 and *Ceramium diaphanum* var. *elegans* (Roth) Roth, 1806, able of developing important fresh biomass of more than 1,000 kg·m^{-2}: *Ulva rigida* C.Agardh, 1823 – 1,600 kg·m^{-2}, *Ceramium diaphanum var. elegans* (Roth) Roth, 1806 – 2,100 kg·m^{-2}. Generally, *U. rigida* C.Agardh, 1823 developed the highest biomass in the southern part, where it forms an important association for the shallow marine life, with the brown alga *Cystoseira barbata* (Stackhouse) C.Agardh. The intense proliferation of *Ulva* species is due to its ability to populate various artificial substrates in absence of the rough natural ones. It’s able to populate hard compact rocks, gravels, shells and even fine or coarse sands (Vasiliu F., 1984). The red algae presented a lower biomasses compared to the green ones; a single genus proliferated during the warm seasons, the *Ceramium* genus. *C. diaphanum* var. *elegans* (Roth) Roth, 1806 developed both on rocky substrate and as principal epiphyte on the *Cystoseira barbata* (Stackhouse) C. Agardh thalli. In 2009, the highest quantities of *Ceramium* (*C. virgatum* Roth, 1797 in association with *C. diaphanum* (Lightfoot) Roth, 1806) were recorded in the northern part of the Black Sea coast, at Constanta North (up to 2,000 kg·m^{-2}).

Regarding the dominant species, the 2010 summer situation was similar to the one described above for 2009. In 2010, as in previous years, the green algae dominated quantitatively, due to a small number of opportunistic species with a high proliferation ability: *Ulva rigida* C.Agardh, 1823 – 1,300 kg·m^{-2} fresh biomass, *Cladophora albida* (Nees) Kutzing, 1,843 – 0,300 kg·m^{-2}.

During the summer of 2009, *Cladophora* did not develop considerable biomasses along the Romanian shore, but starting with 2010 until 2012, this genus had a particularly intense development, covering (at some profiles even completely) the hard substrate at depths between 0 and 5 m. *Cladophora vagabunda* (Linnaeus) Hoek, 1963, *C. albida* (Nees) Kutzing, 1843, *C. sericea* (Hudson) Kützing, 1843 were the dominant species (from a quantitatively point of view):

2011 – *C. vagabunda* (Linnaeus) Hoek, 1963+ *C. albida* (Nees) Kutzing, 1843 (1,700 kg·m^{-2} average fresh biomass) at Costinetti

2012 – *Cladophora vagabunda* (Linnaeus) Hoek, 1963 (1,600 kg·m^{-2} average fresh biomass) at 2 Mai

2013 – *Cladophora sericea* (Hudson) Kützing, 1843 (0,700 kg·m^{-2} average fresh biomass) at Agigea

As a consequence, the shore deposits formed during the summer season were dominated in proportion of 80% of *Cladophora* species. Starting with 2012, a decrease of the fresh biomass for *Cladophora* genus was observed, so the dominant genus for 2013 and 2014 was *Ulva* (namely *Ulva rigida* C.Agardh, 1823 and *Ulva intestinalis* Linnaeus, 1753). In addition, in 2010, an abundant development of *Chaetomorpha aerea* (Dillwyn) Kützing, 1849 at Mangalia, was noticed. The phenomenon was observed inside *Cystoseira* fields, forming a dense layer, preventing this key species to carry out its photosynthetic activity. During the following periods this phenomenon has not been observed.

The biomass of opportunistic species (both green and red algae) generated by a limited number of species, but with a very high developing capacity, decreased gradually with the depth. Thus, for the Romanian shore, between 0 and 3 m, the recorded values were the highest, knowing that this is a normal response of benthic vegetation to seasonal environmental conditions (high water temperature, large amount of nutrients, favorable water transparency). Starting with 4 m depth the macroalgae distribution is sparser, and at 5 m only red algae, scattered distributed on mussels shells, were identified. The following taxa were reported at those deeper horizons: *Callithamnion corymbosum* (Smith) Lyngbye, 1819, *Ceramium virgatum* Roth, 1797, *Ceramium diaphanum* (Lightfoot) Roth, 1806, *Polysiphonia denudata* (Dillwyn) Greville ex Harvey, 1833, but with low biomasses, up to 100 g·m^{-2}.

As mentioned above, in 2011 the genus that dominated quantitatively was *Cladophora* sp. with fresh biomasses exceeding on some profiles 1,700 kg·m^{-2}. High biomass values were reported at Eforie South (where the dominant species was *C. sericea* (Hudson) Kützing, 1843 (1,300 kg·m^{-2}) and Costineşti. At the latter station the hard substrate between 0 and 3 m depth was covered by *C. vagabunda* (Linnaeus) Hoek, 1963 in association with *C. albida* (Nees) Kutzing, 1843, with biomass values over 2,000 kg·m^{-2} between 0-2 m, decreasing to about 1,000 kg·m^{-2} at deeper horizons. *U. rigida* C.Agardh, 1823 associated to *Cystoseira barbata* (Stackhouse) C.Agardh field developed more intensely along the 2 Mai – Vama Veche coastal strip. Along the other sampling stations, the *Ulva* genus was quantitatively poorly represented and the substrate has been widely covered by *Cladophora* species.

Also in 2012 a trend of the previous years was maintained, respectively the intense proliferation of *Cladophora* species during summer season. It has been a constant presence throughout the sampling period, with higher biomasses in the southern part (along Eforie North – Eforie South) where at some depths the biomass values exceeded 1,600 kg·m^{-2}. Like in the previous years, high biomass values were developed by *Cladophora vagabunda* (Linnaeus) Hoek, 1963 (1,800 kg·m^{-2}) and *C. sericea* (Hudson) Kützing, 1843 (1,700 kg·m^{-2}).

During the summer season 2013 the photophylic associations *Cladophora vagabunda* (Linnaeus) Hoek, 1963 – *C. sericea* (Hudson) Kützing, 1843, *Ulva* sp. – *Ceramium* sp., and in the south *Cystoseira barbata* (Stackhouse) C. Agardh – *Ulva rigida* C.Agardh, 1823 were a constant presence between 0 and 5 meters depth. It is known that opportunistic species of *Ulva, Cladophora* and *Ceramium*, are more resistant to unfavorable environmental factor and develop appreciable biomasses during the warm season: *C. vagabunda* (Linnaeus) Hoek, 1963 – 670 g·m^{-2}, *Ceramium virgatum* Roth, 1797 – 600 g·m^{-2}, *Ulva rigida* C.Agardh, 1823 – 900 g·m^{-2}.

During summer 2014, the phytobenthic communities at depths between 0-3 m were dominated by the opportunistic species *Ulva rigida* C.Agardh, 1823 and *Ceramium virgatum* Roth, 1797, *U. rigida* C. Agardh, 1823 was collected between 0-3 m depth range, with high biomasses at Agigea and Costineşti (over 1,000 kg·m^{-2}). *Ulva rigida* C.Agardh, 1823 along with *Ceramium virgatum* Roth, 1797 form the photophylic association (characteristic for the Romanian shore) *Ulva* sp. – *Cladophora* sp. – *Ceramium* sp. Another characteristic association, as mentioned above is *Cystoseira barbata* (Stackhouse) C.Agardh – *Ulva rigida* C.Agardh, 1823, with numerous zoobenthic elements, creating areas with special ecological role.

As a conclusion regarding the opportunistic species, the following *Cladophora* species were identified in the Romanian coastal waters: *Cladophora vagabunda* (Linnaeus) Hoek, 1963, *C. sericea* (Hudson) Kützing, 1843, *C. laetevirens* (Dillwyn) Kützing, 1843, *C. albida* (Nees) Kutzing, 1843. These species have experienced an intense development in the past years at the Romanian shore. They were also encountered as epiphytes on *Cystoseira barbata* (Stackhouse) C.Agardh and *Zostera (Zosterella) noltei* Hornemann, having sometimes a negative effect on the development of these species, suffocating and preventing the photosynthesis processes of these two key species. Among all of the green algae, *Cladophora vagabunda* (Linnaeus) Hoek, 1963 (for 2009-2011 period) and *Ulva rigida* C.Agardh, 1823 (for 2012-2014 period) ware a constant presence throughout the study period in both northern and southern sector. Red algae were dominated by *Ceramium* species, annual elements that thrive on rocky substrate during summer, sometimes found in association with green algae of the genus *Ulva* (often *Ulva rigida* C.Agardh, 1823 and *U. intestinalis* Linnaeus, 1753) (Fig.1.3.5.16). Another constant presence throughout the study was *Callithamnion corymbosum* (Smith) Lyngbye, 1819, with no notable biomasses, commonly recorded at depths between 3 to 5 m, both on hard substrate and as epiphyte on *Zostera (Zosterella) noltei* Hornemann leaves.

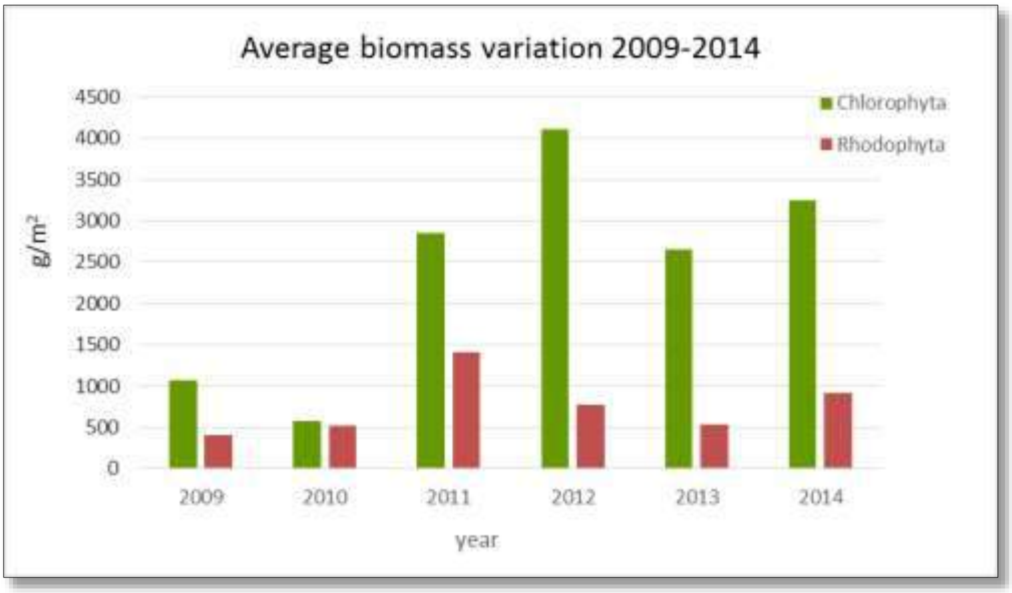


Figure 1.3.5.16. Opportunistic species – average fresh biomass values (summer seasons 2009-2014)

At Mangalia, the average fresh biomass of *Zostera (Zosterella) noltei* Hornemann showed a slight increase during the past 3 years (Fig. 1.3.5.17)

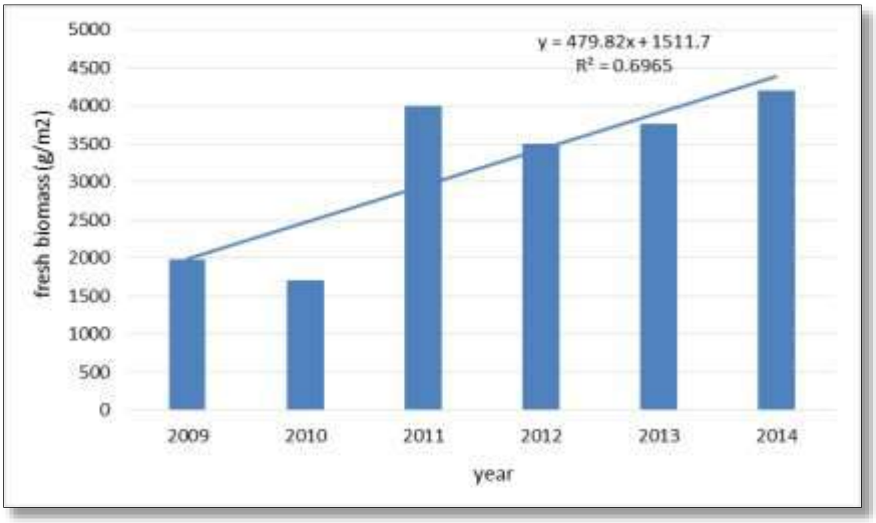


Figure 1.3.5.17. *Zostera noltei* – fresh biomass variation between 2009–2014

The regeneration process of *Zostera (Zosterella) noltei* Hornemann, noticed after 2000 is maintained and the qualitative analysis of the collected specimens presented certain indicative features in this regard: long leaves, of a deep green colour, fresh aspect, few epiphytes (*Colaconema thuretii* (Bornet) P.W.Gabrielson, 2000 – the dominant characteristic epiphyte), strong rhizomes and long rhizoids system (for a good anchorage in the sandy substrate).

Spatial distribution

At the Romanian shore the perennial sensitive species are particularly located in the southern part, respectively along coastal strip Mangalia – 2 Mai – Vama Veche.

The small red alga *Acrochaetium secundatum* (Lyngbye) Nägeli, 1858 was observed as epiphyte on *Cystoseira barbata* (Stackhouse) C.Agardh thalli collected from Vama Veche. This is considered a species that suffered a serious decline over decades at the Romanian shore, due to the reduced habitat of the host species.

Compact *Cystoseira barbata* (Stackhouse) C.Agardh fields are found between 1-3 m depth. The lower and upper absolute depth limits during the maximum development period (meaning the 60s-70s), range between 0.5-6 m, but compact populations did not exceed 2-3 m depth. In the 70s, the largest *Cystoseira* fields were placed in the southern part of the Romanian shore, between Tuzla and Vama Veche, with a total surface, in 1971, of about 2.68 km^2. Following the prolonged sea frost during 1971-1972 winter (48 days), much of *Cystoseira* stock was destroyed even in a proportion of 70-80%, producing also a 5 to 10 times reduction in the number of macrofauna populations.

In the past years (2009–2014), *Cystoseira barbata* (Stackhouse) C.Agardh is considered to be in a stable condition at the Romanian shore. Although the developed biomasses are incomparable with the ones existing before the '70s (between 1970 and 1971 the stocks were estimated at 4,900-5,500 tons fresh biomass – Vasiliu F., 1984), in the current environment conditions, both natural and anthropogenic, *Cystoseira barbata* (Stackhouse) C.Agardh is in a continous recovery process. *Cystoseira barbata* (Stackhouse) C.Agardh is present in the southern part of the Romanian coast, gradually increasing its biomass towards Vama Veche. The average biomass values ranged between 1,100 $kg \cdot m^{-2}$ (at Mangalia) up to 9,000 kg m^{-2} (at Vama Veche). The highest biomass values for *Cystoseira* were recorded at Vama Veche, knowing that in this part a large regenerated *Cystoseira* field exists. Currently, *Cystoseira barbata* (Stackhouse) C.Agardh has recovered to a certain extent and forms true underwater thickets that provide shelter for fish larvae and juveniles, and feeding and breeding place for various other species. By its presence, *Cystoseira* increases the plant primary production, influence the composition of fish and benthic fauna (Müller et al., 1969), and all this recommends this alga as a key species for the benthic life.

An important occurrence in the past years was *Lomentaria clavellosa* (Lightfoot ex Turner) Gaillon, 1828, a species identified at Constanta North, Costinești and 2 Mai. The occurrence of this species, considered rare for the Romanian waters, which in the past used to form a complex association, is particularly important, indicating a slight regeneration of benthic vegetation. In the past, these red alga formed the association *Lomentaria clavellosa* (Lightfoot ex Turner) Gaillon, 1828 – *Antithamnion cruciatum* (C.Agardh) Nägeli, 1847, which used to mark the lower limit of the attached algal macrophyte vegetation in the Romanian coastal waters. This lower depth varies from 7-8 m in the nouthern part, down to 13-15 m in the southern part of the Romanian Black Sea.

Along the Romanian continental shelf, in the 70s, the following *Phyllophora* species were found: *Coccotylus truncatus* (Pallas) M.J.Wynne & J.N.Heine, 1992, *Phyllophora crispa (Hudson)* P.S.Dixon, 1964, *Phyllophora pseudoceranoides* (S.G.Gmelin) Newroth & A.R.A.Taylor, 1971. Nowadays, at the Romanian shore, can no longer speak of a *Phyllophora* agglomeration, due to the dredging operations, eutrophication and low water transparency, negative factors that led to a drastic decline of *Phyllophora* population over the years. During the 70s, the dominant species (in proportion of almost 100 % in the northern part) was *Coccotylus truncatus* (Pallas) M.J.Wynne & J.N.Heine, 1992 (Marin O., Timofte F., 2011). In the last 2 years, at Constanta Nord, various *Coccotylus truncatus* (Pallas) M.J.Wynne & J.N.Heine, 1992 thalli were found along the beach, fixed on *Mytilaster*, an indicator of a slight regeneration of this species at the Romanian coast (Fig. 1.3.5.18).

Figure 1.3.5.18. *Coccotylus truncatus* was found along the beach at Constanta Nord

Assessment of the water quality

The macroalgae are a unique domain able to maintain the ecological balance in the marine coastal environment. Macrophytobentic communities answer to marine environment changes by modifying their qualitative and quantitative structure and can be used as indicators of changes in the marine environment. Anthropogenic activities produce the nutrient enrichment of coastal waters, a direct effect being the development of macroalgae opportunistic species and an indirect one, sometimes with long-term consequences, the reduction and disappearance of perennial sensitive species. In order to assess the ecological state of coastal waters, the ecological index (EI) was developed (according to WFD and MSFD criteria), based on the theory that the anthropogenic impact changes the state of an ecosystem, and turns it into an area where opportunistic *r*-selected species dominates instead of the *k*-selected sensitive ones (Littler, M. M., & Littler, D. S.,1980).

The EI was applied to the 2009-2014 data set, providing an overview of the ecological status of the Romanian coastal zone according to the Biological Quality element - Macroalgae and Angiosperms. 3 replicates at each depth (1,2 and 3 m) were collected by means of a square frame with a side of 20 cm. Species with a lower biomass of 0.5 g•m-2, have only accidental presence in that area, or have no significant input to the structure and functioning of the phytobenthic community, and are not considered for the index application (Dencheva K., Doncheva V., 2014; Berov D. et.al, 2015).

All of the 5 ecological classes, as required by the WFD can be adapted to establish good environmental status (GES) under the MSFD, according to the biological element 'macroalgae and marine phanerogams'. It can be considered that 'High Ecological Status' and 'Good Ecological Status' represent GES, while the other categories of ecological status classes, namely Moderate, Poor and Bad Ecological Status characterize an environment included in non-GES (according to Table 1.3.5.9).

Table 1.3.5.9. Ecological Index (EI) and Ecological Quality Ratio (EQR) of macrophytobenthic communities for different status classes (Berov D. et.al, 2015)

Biomass proportions of sensitive and tolerant species	EI	Ecological state class (acc. WFD)	EI-EQR	Ecological state class (acc. MSFD)
80-100% Ecological Status Group I	7.8-10	High	0.837 – 1	

Biomass proportions of sensitive and tolerant species	**EI**	**Ecological state class (acc. WFD)**	**EI-EQR**	**Ecological state class (acc. MSFD)**
60-80% Ecological Status Group I	**6-7.8**	**Good**	**0.644 – 0.837**	**Good Environmental Status (GES)**
40-60% Ecological Status Group I	**4-6**	**Moderate**	**0.429 – 0.644**	**Non-Good Environmental Status (non-GES)**
0-40% Ecological Status Group I	**2-4**	**Poor**	**0.214 – 0.429**	
0% Ecological Status Group I	**< 2**	**Bad**	**< 0.214**	

Each species identified was included in ecological groups according to its tolerance to environmental conditions, namely Ecological Status Group I **(**ESG IA, ESG IB, ESG IC – perennial species indicator of less eutrophic areas – *Cystoseira*, *Zostera*), and Ecological Status Group II **(**ESG IIA, ESG IIB, ESG IICa, ESG IICb – opportunistic species able to thrive in eutrophic areas with a high reproductive capacity – *Ceramium*, *Cladophora*, *Ulva*). Main criteria in differentiating the species into sensitivity groups was species morphology, biology and growth rates, as well as observational and experimental evidence of their sensitivity to eutrophication in the specific conditions of the Black Sea (Berov D., 2013; Marin. O. et al., 2013).

The average biomass of sensitive (ESGI) and tolerant (ESGII) species from all the samples collected from replicate transects is calculated. The index is expressed as the proportion of sensitive and tolerant species average biomasses at each transect. As a value of EI, the biomass proportion of the most sensitive group is taken into consideration. The applied index methodology was according to Marin O., et al., 2015.

After the application of the EI (according to EQR) for the Romanian coast (assesed along 11 sampling sites), all of the 5 ecological classes – Bad, Poor, Moderate, Good, High Ecological Staus were fully covered (Fig. 1.3.5.19).

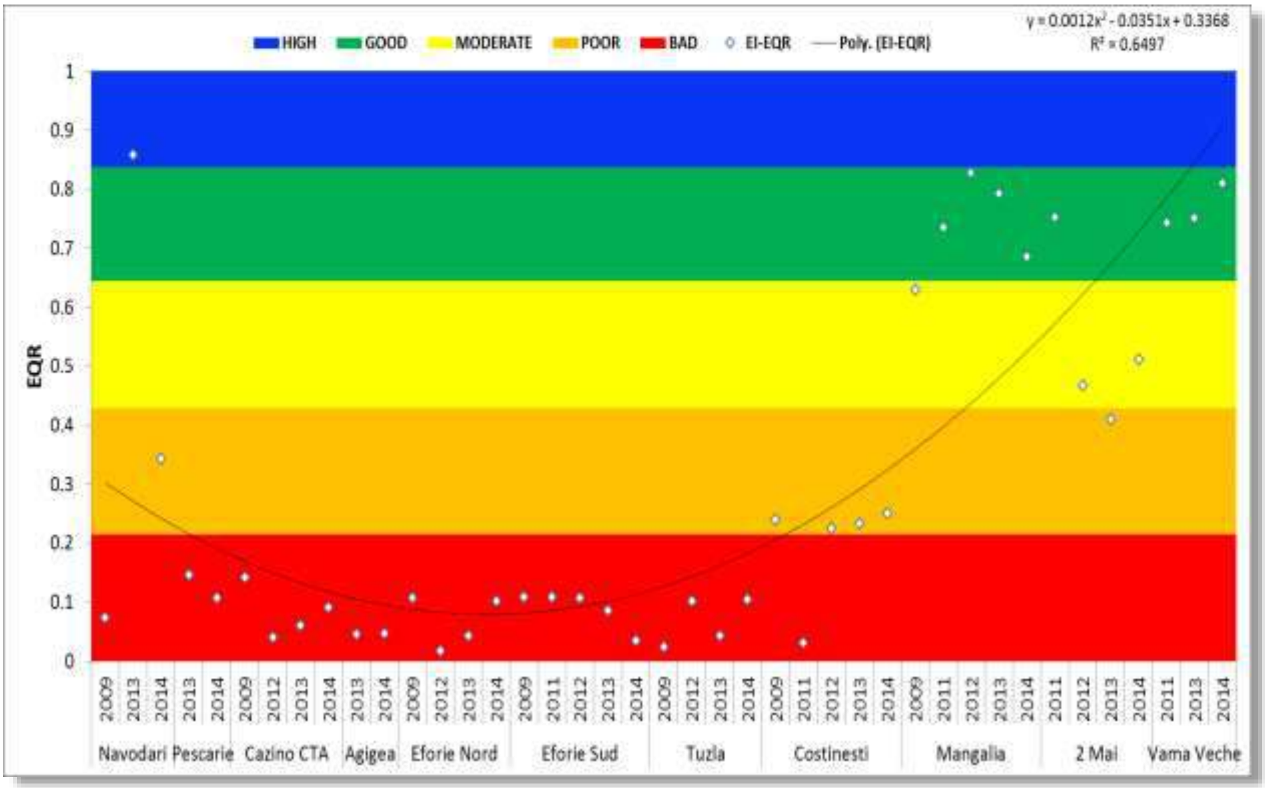


Figure 1.3.5.19. Ecologial state class (between 2009–2014) for Romanion coast

For the norhern part of the Romanian shore (Năvodari, Pescarie, Cazino Constanta) the obtained index values were low, higher only at Năvodari, due to the presence of the *Zostera-Stuckenia-Ruppia* association. For the southern part, from Agigea to Vama Veche, as a result of increased nutrient inputs from harbour and treatement plants influences, opportunistic species dominate, hence lower index value and Bad Ecological Status (see Fig. 1.3.5.19). In highly eutrophic conditions, macrophytobenthic communities obtain a very simplified patchy structure, with monospecific character, with a lower number of opportunistic species, that thrive, especially during the summer season (the opportunistic genera *Ulva*, *Cladophora* and *Ceramium*). Higher values were obtained for the Romanian shore from Costinesti to Vama Veche, due to the presence of the perennial species *Cystoseira barbata* (Stackhouse) C.Agardh, 1820 and *Zostera (Zosterella) noltei* Hornemann. The extreme southern part 2 Mai – Vama Veche is shelter for some important phytobenthic species (*Cystoseira barbata* (Stackhouse) C.Agardh, 1820, *Corallina officinalis* Linnaeus, 1758, *Lomentaria clavellosa* (Lightfoot ex Turner) Gaillon, 1828, *Zannichellia palustris* L.) and a rich associated fauna, hence it has a marine protected area status (Marin O. et. al, 2015)

The increase of the index value from North to South can be noticed (towards a higher ecological state), with the highest values at Vama Veche, where the anthropogenic activity is low, and the natural, rocky substrate offers good conditions for the development of typical Black Sea macrophytobenthic communities, in particular of the *Cystoseira barbata* (Stackhouse) C.Agardh, 1820 – *Ulva rigida C.Agardh, 1823* association. Although the High Ecological Status has not been reached until 2014 at Vama Veche, a tendency for a gradual increase of the EI – EQR value was noticed and the improvement of the ecological state. Taking into account the lower pressure index value, and the presence of well-developed *Cystoseira barbata* fields, the high ecological state was reached in 2015. A good ecological state was achieved at Mangalia, an area that offered favorable conditions for the development of key perennial species, respectively *Cystoseira barbata* (Stackhouse) C.Agardh, 1820 and *Zostera (Zosterella) noltei* Hornemann (see Fig.1.3.5.19).

TURKISH SECTOR

Many lists of macroalgal taxa along the Turkish coast of the Black Sea was given by the several authors (Aysel et al., 1996, 2000a, 2004, 2005; Erdugan et al., 1996; Dural et al., 2006; Karaçuha and Gönülol, 2007). With new additions of algal taxa, this number increased later to 297 by Aysel et al (2004). A list of algal taxa and macrophytes along the Turkish coast of the Black Sea is given by Aysel et al. (2005). The list of algal taxa and macrophytes along the Turkish coast of the Black Sea (Fig. 1.3.5.20) is given in the Table 1.3.5.10, and their relative dominancy is given in the Table 1.3.5.11. According to Taşkın et al. (2008) have been reported 285 algal taxa from the Black sea coast of Turkey. However it is essential to prepare an actual checklist based on "htpp://www.algaebase.org" due to the some omitted, undetermined and synonym species (Bat et al., 2011).

Figure 1.3.5.20. Map of the macrophytes samplieng places along the Turkish coast of the Black Sea

Table 1.3.5.10. Macrophytes diversity from different areas in the Black Sea of Turkey (Aysel et al., 2005).

Region	Seaweeds				Magnoliophyta	Total
	Cyanophyta(CY)	Rhodophyta (R)	Ochrophyta (O)	Chlorophyta (C)		
Rize, Artvin	3	43	15	27	3	91
Trabzon	1	23	8	23	3	58
Giresun	18	109	33	30	3	193
Ordu	14	93	27	26	4	164
Samsun	20	106	27	22	3	178
Sinop	22	136	52	55	3	268
Kastamonu	22	133	56	48	3	262
Bartın	12	116	43	39	3	213
Zonguldak	20	100	42	43	3	208
Kocaeli/Sakarya/Düzce	30	126	50	46	3	255
Kırklareli	23	71	24	30	3	151
Total	30	142	57	58	4	297

Table 1.3.5.11. Dominancy in division level among of Black Sea coast of Turkey (Aysel et al., 2005)

Region	Division					
	R/O	R/C	R/CY	0/C	O/CY	C/CY
Rize, Artvin	2.90	1.60	14.3	0.60	5.00	9.00
Trabzon	2.90	1.00	23.0	0.30	8.00	23.0
Giresun	3.30	3.63	6.05	1.10	1.83	1.66
Ordu	3.44	3.58	6.64	1.04	1.93	1.86
Samsun	3.92	4.81	4.30	1.22	1.35	1.10
Sinop	2.60	2.50	6.50	0.96	2.50	2.59
Kastamonu	2.37	2.77	6.04	1.16	2.54	2.18
Bartın	2.70	3.00	9.70	1.10	3.60	3.30
Zonguldak	2.40	2.30	5.00	1.00	2.10	2.20
Kocaeli, Sakarya, Düzce	2.52	2.73	4.20	1.08	1.66	1.53
Kırklareli	3.00	3.70	3.10	0.80	1.00	1.30

The numbers of taxa periodically increases from west to east until Sinop (see Table 1.3.5.10). The number then decreases in Samsun, but increases again in Giresun, which is the following station. R/C and R/O rates along the coast of the Black Sea of Turkey are higher than Aegean and Mediterrenean coasts. With regard to Table 1.3.5.11 in terms of O/CY and C/CY rates are lower because of high taxon number of blue-green bacterias. According to Güner and Aysel (1996), this can be the result of the interior currents of Black Sea. The strong current of Mediterrenean carries the algae spores through the Aegean Sea, Dardanelles, the Marmara Sea and Bosphorus to the Black Sea. This current changes its direction towards the Azak Sea. A following current from Azak Sea to Ukraine, Rumenia, Bulgaria, Thrace (Turkey) is combined to another one coming through Bosphorus. All these currents help the circulation of algae and stand as a major factor for the attendance of algae at the Black Sea. Smaller circulated flows at the east of Sinop play an important role for the marine algal flora. These smaller flows get back to Sinop after completing their circle from Caucausia Eastern Azak Sea. In addition, these smaller flows play a limited role in algal variety of the region. This issue is also observed at the decreasing numbers of taxa numbers from west to east (Aysel et al., 2005).

Seagrass (Magnoliophyta)

The first studies with the combination of algae and sea grass have been made in the Black Sea coast of Turkey, mainly around Sinop, between 1996-2003 years. Aysel et al., (2000b) has been investigated algae in detail in a project by all Black Sea coast of Turkey. This was later followed by other project that began in 2003. This project also maps and other flowering plants phenology for all three areas besides the distribution of all western Black Sea, it was investigated seasonally (Dural et al., 2006). According to this; for the first time in Black sea coast of Turkey seagrass flora, *Potamogeton pectinatus* and *Ruppia cirrhosa* have been reported (Dural et al., 2006). Gönlügür-Demirci and Karakan (2006) reported *Cymodocea nodosa* (Ucria) Ascherson in a study conducted in around Sinop, particularly Akliman lagoon is located. But this taxon has not been living in the sea at low salinities. While the researcher were offering this taxon, it is noticed that they considered Aysel et al. (2004) records. However, it was noted that distribution of taxa was incorrect and there was a need to make adjustments started in 2003 with the Western Black Sea Project (Dural et al., 2006). According to this project; this species that can be confused with *Z. noltii* due to thin leaves, because of their wrong determination, the same incorrect description have been repeated by Gönlügür-Demirci and Karakan (2006), too. Finally, the flowering plant taxa number have been detected as 6 (*Zostera marina*, *Zosterrella noltii*, *Ruppia cirrhosa*, *Potamogeton pectinatus*, *P. gramineus*, *Zannicheli palustris*) for Black sea coast of Turkey (Dural et al., 2006).

Generally the vertical distribution of *Zostera* beds in the Turkish self area is mainly between 0.7 m and 6 m but low-density patches can grow down to 17 m. Besides, *Zostera marina* compared to the inner part of the bay, facing the open sea, the coast is found sometimes in pure populations with *Zosterella noltii*. However, *Zosterella noltii* have been reported more shallow depths according to *Zostera marina*. In this case, the leaf of *Z. marina* weakened the competitiveness of eective because shorter plants can be connected. *Z. marina*, with *Potamogeton pectinatus* often does not create community. Therefore, in Akliman (Sinop region), *Potamogeton* has been very close and intense the point where the fresh water input. Natural sheep from the central part of the sea species are found only Zosteracea to the correct output. Often striking case, *Ruppia* and *Potamogeton* species in the harbor or shelter, particularly calm and landed close enough to be common in areas, outside the port or open to the right; it is the dominant feature of the show Zosteracea species. However, *Ruppia cirrhosa* not many nested with communities (Dural et al., 2011).

Seagrass constitute of an important part of the Black Sea coastal zone. *Zostera* meadows are an important source of food and shelter for the juvenile stages of many fish and crustacean species. The network of roots and leaves in a *Zostera* bed provides ecological nichs for a wide range of associated with fauna and flora, so that the biotopes are important in maintaning coastal biodiversity. In Turkey, as in other Black Sea countries, the negative impact on the seagrass ecosystems is increasing due to a growing coastal population, pollution, and overexploitation of resources.

Seasonal dynamic and spatial distribution

There have been various studies on macroalgae during the last ten years. However, the changes in the biomass of the macroalgae is poorly known in Turkish coast of the Black sea. The first study on the biomass of the macroalgae, only with *Ulva linza* Linnaeus, 1753 and *Ulva lactuca* Linnaeus, 1753, which collected from the seawage pollution area of Sinop coast, has been studied by Bat et al. (2001). Recently, more comprehensive macroalgal biomass study have been reported by Karaçuha and Ersoy-Karaçuha (2013) in Turkish coast of the Black sea (from Sinop). In this study, seasonal variations in seaweed biomass were examined to determine the ecological status of macroalgae around the Sinop Bay of the Black Sea. In this study, algal samples were collected monthly from five stations at zero to 0.5 m depth on rocky substrata with a quadrat (20x20 cm) (Fig. 1.3.5.21). As a result of this study, a total of 30 taxa were identified, comprising 9 Chlorophyta, 8 Ochrophyta and 13 Rhodophyta. According to this study, the maximum average macroalgal biomass value was reported in spring (484.20±116.44 g dry weight m^{-2}), followed by summer with 445.40±64.63 g dry weight m^{-2} and winter with 358.80±107.15 g dry weight m^{-2}, the lowest value was obained in Autumn (320.00±99.36 g dry weight m^{-2}) (Fig.1.3.5.22a). Generally, Ochrophyta had the largest macroalgal biomass in all seasons in Sinop coasts, followed by Chlorophyta and then Rhodophyta (Fig.1.3.5.22b). The biomass of Ochrophyta showed a maximum value of 1539.16±194.27 g dry weight m^{-2} in spring and the lowest value (1207,73±80,64 g dry weight m^{-2}) in winter. The highest biomass of Chlorophyta was obtained from summer (721.48±261.98 g dry weight m^{-2}) and spring (575.11±115.8 g dry weight m^{-2}). Besides, the total biomass of Ochrophyta reached its maximum value of 7218.94 g dry weight m^{-2} in Hamsilos station, followed by Karakum and Akliman. However, the maximum total biomass of Chlorophyta was calculated in Dışliman (2175.96 g dry weight $m^{- 2}$), then Öztürkler (1898.08 g dry weight m^{-2}), all the year round (Fig.1.3.5.23). On the contrary, the minimum biomass values in taxa were taken from Rhodophyta. The maximum Rhodophyta biomass value of 941.5 g dry weight m^{-2} was obtained in Hamsilos and the lowest value of 290.01 g dry weight m^{-2} in Dışliman.

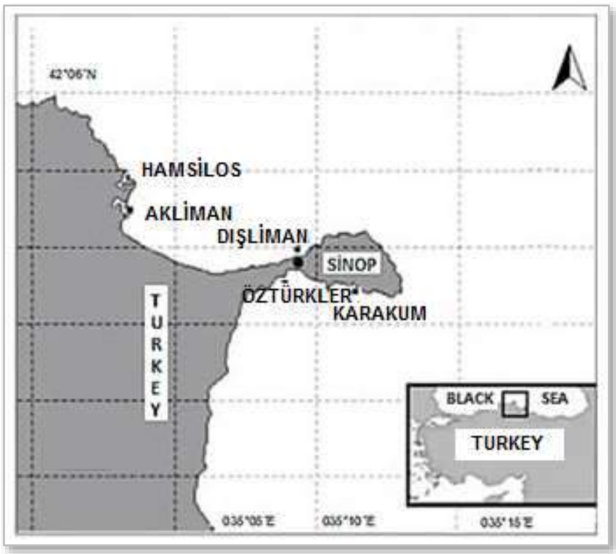
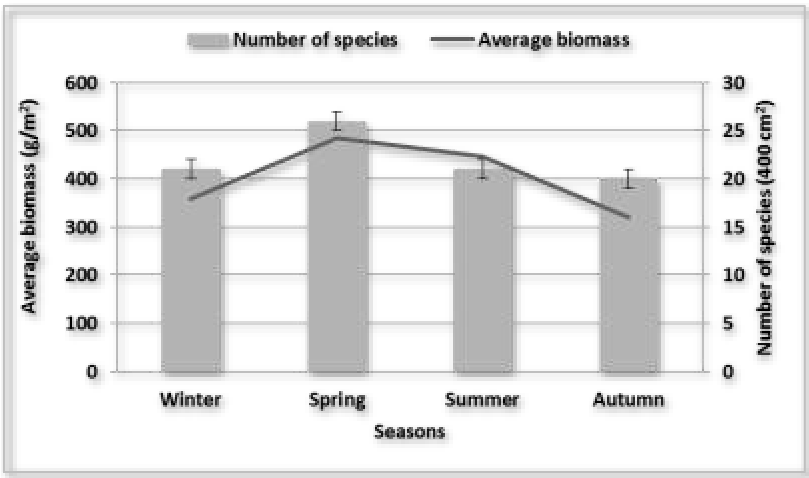
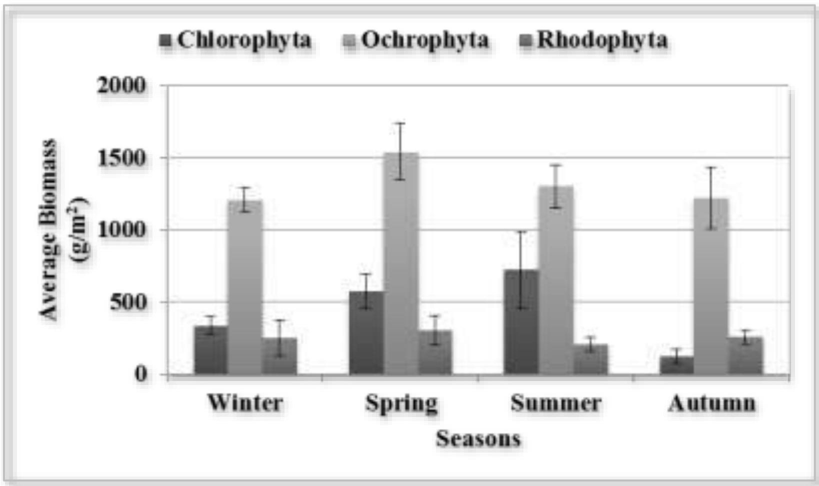


Figure 1.3.5.21. Study area (Karaçuha and Ersoy Karaçuha, 2013)



(a)



(b)

Figure 1.3.5.22. Seasonal variations of average biomass (g dry weight m^{-2}) of macroalgal taxa (a) and the average biomass (g dry weight m^{-2}) of each class in each season (b) (Karaçuha and Ersoy Karaçuha, 2013)

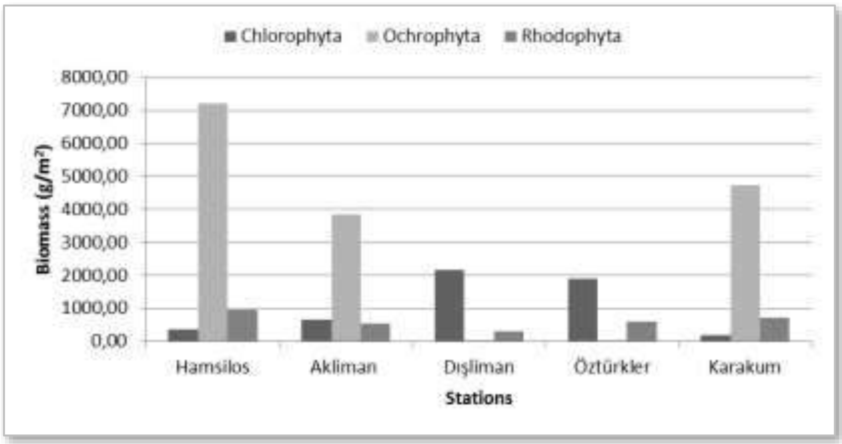


Figure 1.3.5.23. The total biomass (g dry weight m^{-2}) of macroalgae taxa according to the station during a year (Karaçuha and Ersoy Karaçuha, 2013).

Benthic macroalgae communities play an important ecologically functional role in coastal ecosystems as they are essential for many organisms as habitat (Cacabelos et al., 2010), mating and nursery grounds (Shaffer, 2003) and feeding areas (Lorentsen et al., 2004). They have an important contribution to primary production (Mohammed and Fredriksen, 2004), the sediment stabilization and coastline protection (Madsen et al., 2001), and are a suitable indicator on the ecological status of coastal communities (Juanes et al., 2008). One of the most conspicuous results of eutrophication in shallow coastal waters is the mass development of macroalgae. In general, the process of eutrophication leads to a shift in the macrophytobenthic community from slow-growing seagrasses and macroalgae to phytoplankton and fast-growing macroalgae such as *Ulva*, *Enteromorpha* and *Cladophora* spp. (Duarte, 1995). Because of these properties they are the most important organisms maintaining the ecosystem's stability.

According to Borum and Sand-Jensen (1996), nutrient availability for biological uptake is an important factor controlling algae species composition and biomass in shallow coastal waters, and various algae show different growth strategies, life forms and distribution along nutrient gradients. According to Karaçuha and Ersoy Karaçuha (2013), the maximum biomass of Chlorophyta was calculated in Dışliman (2175.96 g dry weight m^{-2}), followed by Öztürkler (1898.08 g dry weight m^{-2}) and these were dominated by the opportunistic species *Ulva rigida, U. intestinalis, Ceramium* spp. and *Enteromorpha linza var. crispata*. On the other hand, it is clear that organic pollution acts as a physical stress in *Ulva* and *Enteromorpha* communities, changing their biomass and species composition. However, anthropogenic nutrient inputs into the Dışliman area of Sinop have increased rapidly in recent years with enhanced inputs of sewage effluent (Bat and Öztürk, 1997). It has been shown that the macroalgae biomass and species number directly related to antropogenic affects.

UKRAINIAN SECTOR

Species composition

Macrophytobenthos floristic composition of Ukrainian Black Sea sector was studied in the following water bodies: Odessa Bay, the shallow waters - coastal lakes in northwestern Black Sea region, marine botanical reserves ("Zernov's Phyllophora Field", "Small Phyllophora Field" (Karkinitskiy Bay), zoological reserve "Zmiiniyi island", and along the Crimean Black Sea coast.

49 macrophyte species (23 species of *Chlorophyta* (44,2%), 18 species of *Rhodophyta* (34,6%), 8 species of *Ochrophyta* (15,5%) and 3 species of *Magnoliophyta*) were discovered in Odessa Bay during the reporting period.

24 macrophyte species (*Ochrophyta* – 6, *Rhodophyta* – 12 and *Chlorophyta* – 6) were discovered in "Zernov's Phyllophora Field" marine botanical reserve in 2012.

In 2009 - 2010 48 macrophyte species (*Ochrophyta* – 9, *Rhodophyta* – 26, *Chlorophyta* – 10, *Magnoliophyta* – 3) were identified in coastal waters of "Small Phyllophora Field" (Karkinitskiy Bay) reserve. The area was dominated by *Phyllophora crispa*, *Cystoseira barbata*, *C. crinita*, *Dasya baillouviana*, *Chondria dasyphylla* and *Polysiphonia subulifera* (Tkachenko et al., 2009, 2012).

46 macrophyte species (*Chlorophyta* – 18; *Rhodophyta* – 23; *Ochrophyta* – 5) were found in coastal waters of Zmiiniyi island in 2003 - 2013. Interestingly, *Cladophora hutchinsiae*, which is the new species for Ukrainian algal flora, was discovered. Phytobenthic communities of the survey area include 4 rare algae specie, which are listed in the Red Book of Ukraine: *Punctaria latifolia, Chroodactylon ornatum, Stylonema alsidii* and *Ulva maeotica* (Tkachenko & Kovtun, 2014).

The only population of *C. barbata* in northwestern Black Sea has been preserved on the rocky bottom in the southern part of Tyligul liman. The total area covered by *Cystoseira* is relatively small, 3 – 5 m in width and 2 km in length, while the projective cover is 10%. The total number of macrophyte species discovered in *Cystoseira* plant community during the reporting period was 19, out which 8 – *Rhodophyta*, 9 – *Chlorophyta* and 2 – *Ochrophyta* (Tkachenko& Maslov, 2014).

182 macrophyte species belonging to 3 phyla (*Chlorophyta* – 45 species coming from 19 families and 10 orders, *Rhodophyta* – 92 species from 18 families and 7 orders) and 1 species of *Magnoliophyta* (*Zostera noltei*) were identified at exposed coasts of Crimea peninsula during the period of 2008 - 2013. The average ratio of red algae to brown algae was 2,09 for Crimea water area (from Feodosia Bay to Tarhankut Cape), which indicates generally warm-water composition of algal flora. The most taxonomically abundant green algae belonged to the *Ulvacea* genus, including 7 *Ulva* species, 6 *Chaetomorpha* species and 9 *Cladophora* species. Brown algae were dominated by the *Ectocarpus* genus (5 species), *Feldmannia* and *Entonema* (3 species) and *Cystoseira* (2 species) genus. In red algae the highest species richness was observed for *Ceramium* (11 species), *Polysiphonia* (9 species), *Laurencia* and *Acrochaetium* (6 species in each) (Kostenko et al., 2007a, 2008a; 2010).

Temporal dynamic

The temporal dynamics of the communities macrophytobenthos closely related with natural and anthropogenic conditions which are determine the primary production process in marine ecosystems. The most significant cyclically changes in floristic composition and functional characteristics of macrophytes are observed as a result of seasonal changes of solar radiation flow and temperature of marine water. Distinctions in the interannual organization of macrophytes phytocenouses are connected with climatic features of year. Precipitation, temperature and wind regime influence on the concentration of nutrients which entering to ecosystems from a catchment area, salinity and hydrological terms of marine environment. Tendencies in long-term dynamic of structural-functional organization of macrophytobenthos communities can are the indicators of regional natural and anthropogenic processes. The seasonal, interannual and long-term dynamics of macrophytes communities of the Ukrainian sector of the Black Sea in the period 2009-2015 years can are not only description of the state of benthos vegetative component but also to testify the ecological state of the given region of Black Sea ecosystem.

Seasonal dynamic

In the Ukrainian sector of the Black Sea, the seasonal changes in solar radiation and sea water temperatures to create conditions for the change regularity of floristic composition and production characteristics of macrophyte communities throughout the year. In the region of northwestern part of the Black Sea two floristic complexes of macrophytobenthos are distinguished: cold-water species which are developing at the temperature of marine water is lower 10 C° and warm-water species – at the temperature of marine water is higher than 10 °C.

The peak of the cold period communities there is March, at that the cold-water macrophytes can continue to develop until the end of June. The peak of development of the warm-period communities there is September, at that the warm-water macrophytes can continue to develop until the end of December.

During the period 2009-2015, the representatives of the mass species of the cold period in the coastal zone of the Danube-Dniester interfluves coast at the depth of 0-3 meters were: *Pyropia leucosticta* Thuret, *Scytosiphon lomentaria* (Lyngbye) Link, *Ectocarpus siliculosus* (Dillw.)

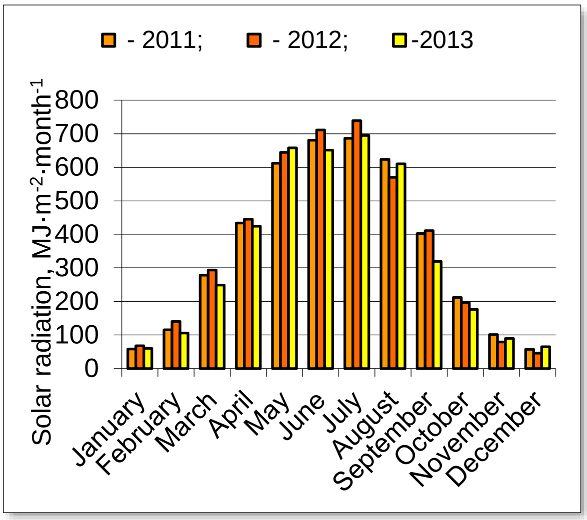
Lyngb., *Urospora penicilliformis* (Roth) Areschoug, *Punctaria latifolia* Grev. In the horizons deeper than 3 meters the Polysiphonia elongata (Hudson) Sprengel and the Desmarestia viridis (O.F.Müller) J V. Lamouroux were mass developed. The arctic-boreal brown seaweeds – D . viridis was moved in the north-west part of Black Sea in 90th years of the last century (Minicheva & Eremenko, 1993) and now there is a mass species in the cold-period year on horizon of the 3-10 m. Average biomass of the *D. viridis* reaches to 0,811 $kg \cdot m^{-2}$ under the maximum 1,800 $kg \cdot m^{-2}$. In March-April, 2015 on the Odessa coast in associated with the D. viridis found out another arctic invasion species – brown seaweeds from the Laminariales genus – *Chorda tomentosa* Lyngb. (Minicheva, 2015).

During the cold period of 2011-2013 in the Tiligul liman which having water exchange with the sea and located near to Odessa, intensive developments of brown macrophytes which have the low ecological activity indicated by the value of specific surface of populations (S/W_p) were discovered. In the winter-spring periods of 2011 and 2012 were characterised by untypically high development of brown algae *E. siliculosus, P. latifolia* and *S. lomentaria*, being indicators of good environmental state of ecosystem. In the coastal zone of the Tiligul liman mass development of new species for its ecosystem (they were first discovered in the estuary about 10 years ago: (Tkachenko & Kovtun, 2004) were registered. They included *Striaria attenuata* (C.Agardh.) Grev. (S/W_p – 18 $m^2 \cdot kg^{-1}$), and *Leathesia marina* (Lyngbye*)* Decaisne (S/W_p – 9 $m^2 \cdot kg^{-1}$). In April–May 2013 in the Tiligul liman, development of the new species not only for this water body but also first cited for the northwestern area of the Black Sea – *Liebmannia leveillei* J. Agardh (S/W_p – 15 $m^2 \cdot kg^{-1}$) was observed.

Through the warm period in the north-western part of the Black Sea, at a high level of the primary production process intensive development the finely branched green, red and blue-green macrophytes having high coefficients of S/W_p from 50 to 150 $m^2 \cdot kg^{-1}$ is characteristic such as: *Cladophora vagabunda* (Linnaeus) Hoek, *Ulva clathrata* (Roth) C.Agardh, *Polysiphonia denudata* (Dillwyn) Greville ex Harvey, *Callithamnion corymbosum* (Smith) Lyngbye, *Spirulina tenuissima* Kützing, etc.

Except the strongly representatives of warm or cold seasons, in the Ukrainian sector of a northwestern part of Black Sea there are the species register during the all seasons of the year, it mainly representatives of genius: *Ceramium* and *Ulv*a. In August – September intensity of their development can raise significantly. To macrophytes which also development throughout the all year, belongs the red algae that is found at a depth of 3-10 m in the Danube-Dniester interfluves – *Lomentaria clavellosa* (Tourn.) Gail. After the 60th of the last century, this species did not meet in the northwestern region of Ukraine more than 40 years. Currently the significant of its development and widely the spatial distribution is recording.

Cyclically dynamics of seasonal factors influencing on intensity of autotrophic process, is natural reason of changing, both floristic structure and intensity of development of macrophytobenthos communities. Increase from winter to the summer period in 8-9 times of the flow of solar radiation for the latitude 46°30´ N (Fig 1.3.5.24a) and increase in 4-5 times of water temperature (Fig 1.3.5.24b), leads to appropriating increase of macrophytes Surface Indexes from a few to 40-50 m^2 the photosynthesizing surface of tally per the m^2 substrate (Fig 1.3.5.24c).



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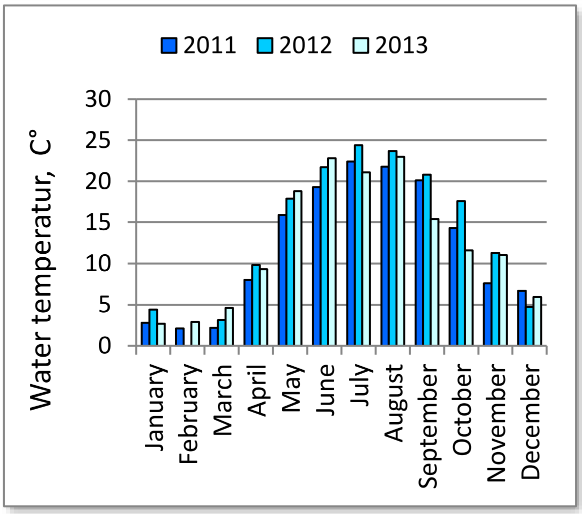

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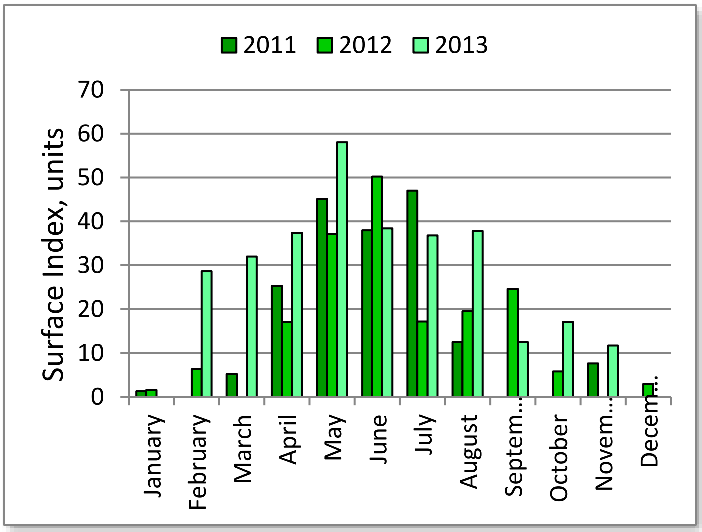


c

Figure 1.3.5.24. Comparison of the seasonal dynamics of the solar radiation (a), water temperature (b) and functioning intensity of macrophytes communities – Surface Index (c) for the period 2011-2013 on the Odessa coast

This correlation confirms the main reason of seasonal changes of the structural-functional organization of macrophytes communities; there are natural factors that determine primary production process in aquatic ecosystems.

Interannual dynamic

During of the reporting period the interannual differences in the structure of phytobenthos communities of Ukrainian sector of the Black Sea were determined abnormal climatic conditions. Among years of the review period the 2010 was differed anomaly high values of the water temperature (16% higher in comparison with the average level in the period 1981-2010), as well as abnormally high precipitation (67% higher in comparison with the average level in the period 1981-2010). Abnormally high precipitation in 2010 was brought a big volume of nutrients from the catchment area to the northwestern part of the Black Sea. Increase the nutrients and water temperatures have caused to grow the level of autotrophic process. Under these conditions, the first time in the north-western part of the Black Sea ultra-high concentration of phytoplankton, which reached the value of 6,2 $kg \cdot m^{-3}$ was registered in July 2010. Water-bloom was caused by the outbreak of development the blue-green algae *Nodularia spumigena* Mertens ex Bornet et Flahault, under the seawater temperature 24,9-27,0 °C and salinity 12,9-14,5 ‰. (Adabovsky et. all, 2012). Such intensive phytoplankton bloom is a natural mechanism for the quickly dispousal of the aquatic ecosystem from the overflow of organic matter. Under these conditions, phytoplankton (*r*-strategists) takes advantage of development before macrophytes (*k*-strategists) (Minicheva, Zotov et. all, 2014). Components of the autotrophic system - "phytoplankton - phytobenthos" which respectively have high and low functional activity in the anomalous 2010 showed the opposite response. Communities of coastal phytobenthos, in contrast of phytoplankton, significantly reduced the parameters of grows. The dominance shifted from the green and red macrophytes (species of genus: *Ceramium, Polysiphonia, Ulva, Cladophora*) to the colonial blue-green algae (species of genus: *Lyngbya, Oscillatoria, Spirulina*). This change has led to increased the ecological activity populations $(S/W)_p$ of mass species on order (from 30 to 300 $m^2 \cdot kg^{-1}$). The specific surface $(S/W)_{cm}$ and surface indices (SI) of the Odessa coast phytobenthos communities increased in two times and reached respectively 147 $m^2 \cdot kg^{-1}$ and 78 units. At the same time, the average biomass of macrophytes phytocenoses bring down to a few tens of grams per m^2 (Fig. 1.3.5.25). The decline of phytobenthos biomasses happened by reason of replacement the low functional forms of macrophytes with large talus by high functional forms with a small weight.

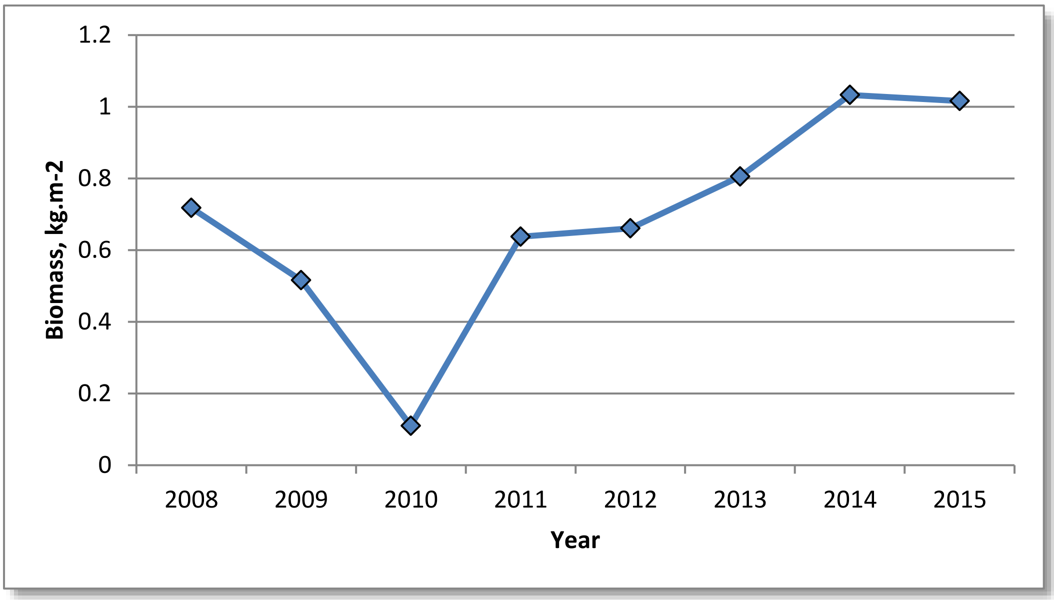


Figure 1.3.5.25. The decline of phytobenthos biomass on the Odessa coast in climatically anomalous 2010

Post anomalous periods 2011-2014, in contrast, was characterized by decrease of development the phytoplankton community and increase of development the macrophytes communities. Significant release of the coastal and offshore areas of the north-western part of the Black Sea in 2010, from the excess of organic matter as a result of intensive phytoplankton bloom, led to an increase in transparency. Increased transparencies allowed to develop macrophyte not only in the coastal area, but also on hard substrates are located deeper than 10 m. In 2011, from the Danube Delta to the Crimean peninsula was recorded outbreak of green filamentous algae growing on the offshore hard substrates. The floristic composition and ecological activity of macrophytes growing on banks (Odessa, Dniester) of the northwestern part were significantly different from the coastal communities (Table 1.3.5.12).

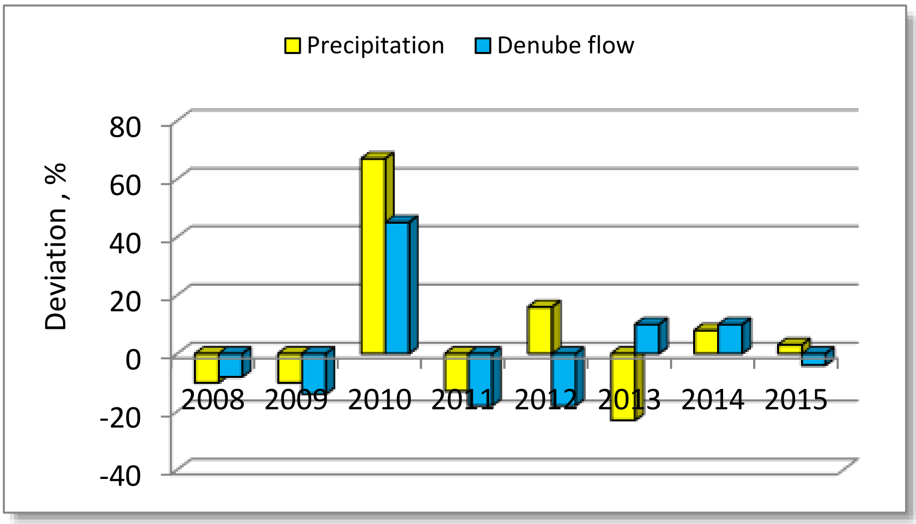
Table 1.3.5.12. Comparative characteristics of the floristic composition and ecological activity of macrophytes in the offshore and coastal zones of the north-western part of the Black Sea in 2011

Offshore		Coastal	
Species	S/W, $m^{2}\cdot kg^{-1}$	Species	S/W, $m^{2}\cdot kg^{-1}$
Cladophora albida (Nees) Kutzing	99,1	*Cladophora vagabunda* (L.) C. van den Hoek	54,9
Ulva clathrata (Roth) C. Agardh	85,0	*Ceramium siliquosum* var. *siliquosum* (Kütz.) Maggs et Hommers	30,9
Ulohtrix implexa (Kütz.) Kütz.	282,8	Ulva intestinalis Linnaeus	35,2
Average:	**155,6±63,7**		**40,35±9,05**

The wrack in coastal zone of the deep-water macrophytes resulted in a significant accumulation in July 2011 plant biomass in the area between the Dniester and the Dnieper rivers. In different parts of the 40 km of the Odessa coast extension concentration of the green filamentous algae on a depth 0,5-1,0 m reached in average 17,5 $kg\cdot m^{-3}$ with a maximum of 92,55 $kg\cdot m^{-3}$ (Fig. 1.3.5.26).

Figure 1.3.5.26. Discharge of deep-water macrophytes on the Odessa coast in July of 2011

Thus, in the northwestern part of the Black Sea is under significant influence of the river flow of three major rivers: the Danube, Dnieper and Dniester, interannual variations in the amount of precipitation and runoff, to a great extent determine the development of phytobenthos. Synchronicity deviations from the mean regional values for the period 1981-2010 Precipitation and Danube flow (Fig. 1.3.5.27a) with the Surface Indices and Production of phytobenthos (Fig. 1.3.5.27b) confirms, that the decrease in the intensity of the functioning of the bottom vegetation and the related process of restoring the floristic structure are determined the low-water period 2008-2015. And only the abnormally full water and warm 2010 caused the abrupt increase in the intensity of the phytobenthos functioning and shift dominance from red and green to blue-green algae.



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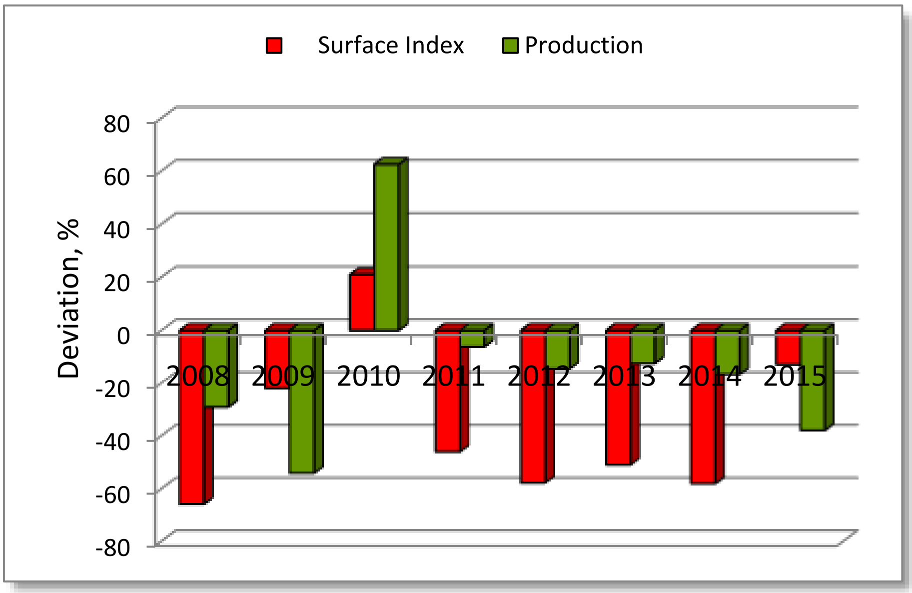

b

Figure 1.3.5.27. Synchronicity deviations from average value of the period of 1981-2010 for Precipitation and Danube flow (a) and Surface Index and Production of macrophytes community (b) in 2008-2015

Long- term dynamic

Long-term dynamics of macrophytes communities for some decades makes it possible to judge about the historical stages of benthic vegetation changes which were connected with the regional trends of the ecological status of the marine ecosystem. Four periods were distinguished during the north-western part of the Black Sea eutrophication dynamics assessment: *natural state* (before the 1970th), *intensive eutrophication* (early 1980th), *immobility* (mid 1990th) and *sustainable tendency of deeutrophication* at the turn of the millennium (Minicheva et al., 2008). The values of morphofunctional parameters of aquatic vegetation connected with the ecosystem's trophic status show that at present the north-western part of Black Sea is in the period of *sustainable tendency of deeutrophication.* The long-term dynamic of the biomass and production of the macrophytobenthos community in the Danube – Dnieper interfluves (Fig. 1.3.5.28) confirmed the decreasing of functional processes and opening possibility to restoration of floristic structure of benthic vegetation in the Ukrainian sector of the Black Sea.

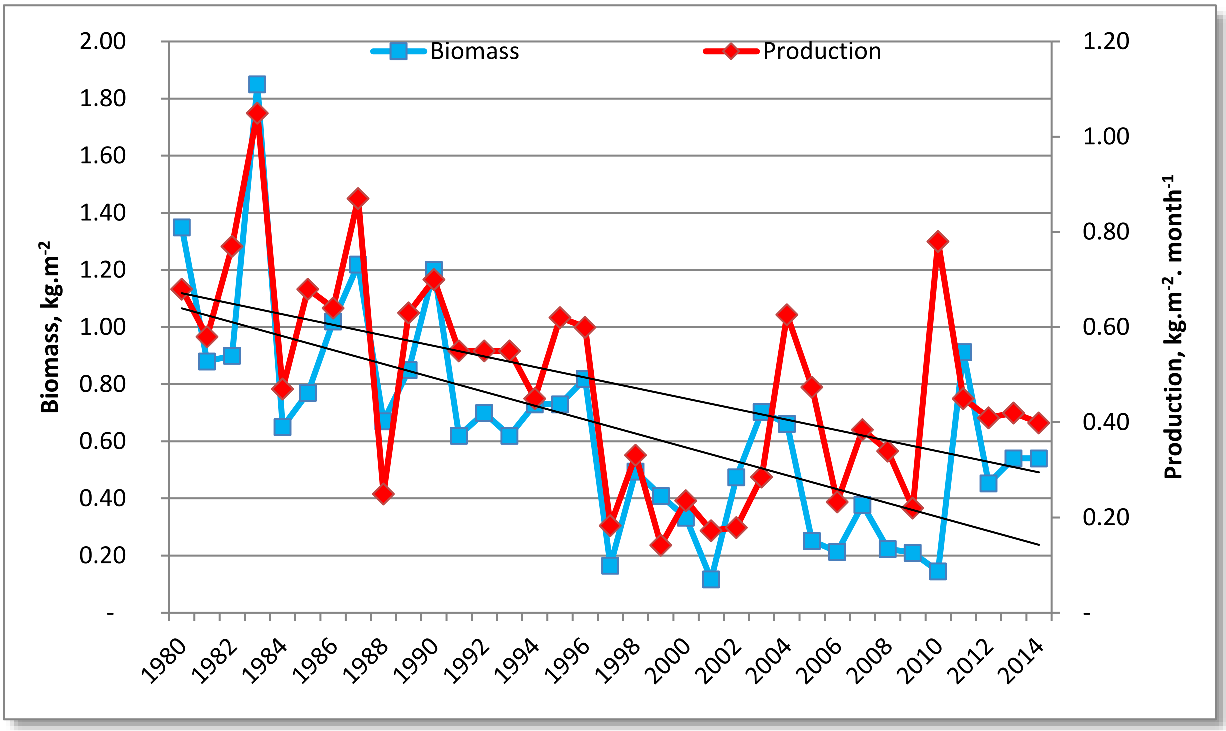

Figure 1.3.5.28. Long-term dynamic of the biomass and production of the macrophytobenthos community in the Danube – Dnieper interfluves

Analysis of long-term dynamics (1960s - 2010) of macrophytobentic communities in Karkinitskiy bay revealed the following trends: emerence of previously absent polysaprobic species and increase in the proportion of mezosaprobic species accompanied by the decrease in the proportion of oligosaprobic species. The total amount of discovered algae species went up by 20, out of which 11 are red algae, 7 are green algae and 2 are brown algae; yet 5 brown algae species, 5 red algae species and 2 green algae species from those present in 1960s have disappeared. The proportion of green algae in floristic composition has increased by 8% owing to the reduction of brown algae proportion. The ratio of macrophytes according to their vegetation time has changed as well, so that the annual algae proportion has gone up by 20% accompanied by the respective reduction of perennial algae proportion. The fraction of tropical boreal elements in macrophytes' phytogeographical composition increased by 14%, whereas the proportion of wide-boreal and lower-boreal elements decreased (Tkachenko et. al., 2009, 2012).

Some significant floristic composition changes occurred in algal communities of "Zernov's Phyllophora Field" botanical reserve. Those included: Sorensen similarity index calculated for macrophyte composition of the reserve as to 1960s compared to macrophyte composition as to 2012 was 39,9%. Yet, there were significant positive changes observed during the period of 2005 - 2012. The total macrophyte species richness increased from 8-17 (according to different sources) to 28 species, in particular 8 new red algae species (including the red-listed ones, such as *Phyllophora pseudoceranoides*), 6 new green algae species (including the red-listed *Cladophora vadorum*) and 2 new species of brown algae were detected (Tkachenko & Tretyak, 2015).

Multiyear dynamics of bottom vegetation was explored in the water area of Karadag nature reserve, where the first quantitative studies of macrophytobenthos on the depth ranging from 0 to 15 m were conducted in 1970 and repeated in 1980 - 1984, in 1993 - 1995 and yearly in 2001 - 2013. Survey of macrophytobenthos on the standard geobotanical transects comprising the depth of 0 – 15 m located along the Crimea coast (from Feodosia bay to Tarhankut cape) conducted in 2008 - 2013, showed that the trends and patterns discovered for Karadag water area can be extrapolated to the most of Crimea water area.

Plant communities dominated by perennial brown algae of *Cystoseira* genus (*C. barbata* and *C. crinita* (which is now known as *C. bosphorica* (Berov et al., 2015) and subdominated by *Cladostephus spongiosus f. verticillatus* (Lightfoot) Prud'homme van Reine, that are substituted by algal communities dominated by *Phyllophora crispa* (Hudson) P.S.Dixon red algae and subdominated by *Polisyphonia elongata* (Hudson) Sprengel and *Gracilaria dura* (C.Agardh) J.Agardh with the increase of depth, prevailed in Karadag water area and in southeastern Crimea in 2009 - 2015. The distribution of macrophyte biomass with depth has undergone significant changes compared to 1980. Thus, the total macroalgae biomass has decreased by 2 - 5 times within the depth range of 1 – 10 m and by 5 - 10 times within the depth of 10 – 15 m. Macrophytobenthos is almost absent at the depth of more than 15 m, except in some water areas near southern Crimea, where macrophytobenthos can be observed at the depth of 17 – 20 m, whereas in 1970s - 1980s it could was present at more than 25 m. Biomass maximum has shifted as well: nowadays the maximum of macrophytobenthos biomass is associated with the depth of 1 – 2 m, while in 1970s - 1980s it was at the depth of 3 – 5 m. The basiphyte/epiphyte biomass ratio has also changed considerably: annual epiphyte biomass is now equal to the basiphyte biomass or, frequently, higher. The decrease in water transparency results in general reduction of macrophytobenthos production and biomass, in decrease of algal community surface index; leads to the shift of heliophilous species (*C. barbata, C. crinita*) distribution boundary towards the shallow depth, while pushing the heliophobic species (*Cladostephus spongiosus f. verticillatus, P. crispa, Codium vermilara* (Olivi) Delle Chiaje, *Nereia filiformis* (J.Agardh) Zanardini, *Zanardinia typus* (Nardo) P.C.Silva etc.) towards the shallow and mid depth. At the same time an increase in water body trophicty is the main factor of plant community development on the shallow depth, where the growth of macrophytes is not limited by the reduction of water transparency. This process leads to an increase of total macrophytobenthos biomass on the shallow depth, of algal community surface index and of annual epiphytes/perennial basiphytes ratio. An increase in water trophicity near the southeastern coast of Crimea is significantly determined by the intermixing of Black Sea water with nutrient rich Azov Sea water coming through the Kerch Strait, and is not dependent on the local sources of pollution. As to the transparency reduction, it is majorly caused by anthropogenic factor, and is associated with an increase of particulate matter amount in water due to the massive construction work on the coast; yet it also depends on the other factors, such as phytoplankton development and ctenophores reproduction (Kostenko et al., 2007 a,b,c,d, 2008 a,b,c; 2010).

Spatial distribution

Spatial distribution of macrophytes in Ukrainian Black sea is determined by several ecological factors. The first one is the substrate type - the availability of rocky substate and soil texture. The second important factor is water transparency and trophicity. Salinity plays a significant role in the areas of river inflow into the sea. Rocky substrates and sandy boulders of Crimea from Chauda cape and Feodosia bay to Tarkhankut cape, and of Karkinitskiy bay are represented by plant communities dominated by the brown algae of Cystosera genus (*C. barbata, C. crinita*) and sub-dominated by *Cladostephus spongiosus f. verticillatus.* The red algae *Phyllophora crispa* is dominating the community with the increase of depth and *Polisyphonia elongata and Gracilaria dura* are sub-dominating. The bays with sandy and clayey soil feature plant communities dominated by the sea grasses of *Zostera* genus (*Z. marina* Linnaeus, *Z. noltei* Hornemann) in the areas of increased salinity and by *Stuckenia pectinata* (L.) Börner, 1912 in less saline waters. The sea grasses' dominated communities are most widespread in the shallow bays that are protected from the storms – Dzharylgachskiy, Tendrovskyy and Yagorlytskiy.

The open part of north-western Black Sea is characterized by the presence of unique plant communities dominated by the red algae from *Phyllophora* and *Coccotylus* genera, which exist either as sessile forms attached to the shells (mainly, *Coccotylus truncatus* (Pallas) M.J.Wynne & J.N.Heine) or as floating forms carried by the currents and accumulating in topographic lows (*Phyllophora crispa*). The confervoid green and brown algae are sub dominating these communities. These unique communities are preserved in "Zernov's Phyllophora Field" botanical reserve, created in 2008. According to the data of 2012 survey, the projective cover of macrophytes in "Zernov's Phyllophora Field" is lactated in the range of 1 - 76%. The main limiting factors are water transparency and trophicity. As a result of the light limit, there were only a few algae specimens at 50 m, the macrophytobenthos projective cover was 1 - 6% (5% on average) at 45 m and 30 - 76% at 20m (45% on average). It is worth mentioning that the confervoid red, brown and green algae with high specific surface index were dominating at 20 m, whereas *Phyllophora* projective cover was not exceeding 10 -15%, which is the result of the secondary eutrophication occurring due to nitrogen- and phosphorus leaching from the soft sediments of the northwestern shelf (Langmead et al., 2009). The optimal growth conditions for *Phyllophora* were detected at the depth range of 37 – 43 m, where *Phyllophora* domainates algal communities with the projective cover of 10% - 35% and accumulate in topographic lows (Fig. 1.3.5.29) (Tkachenko & Tretyak, 2015).

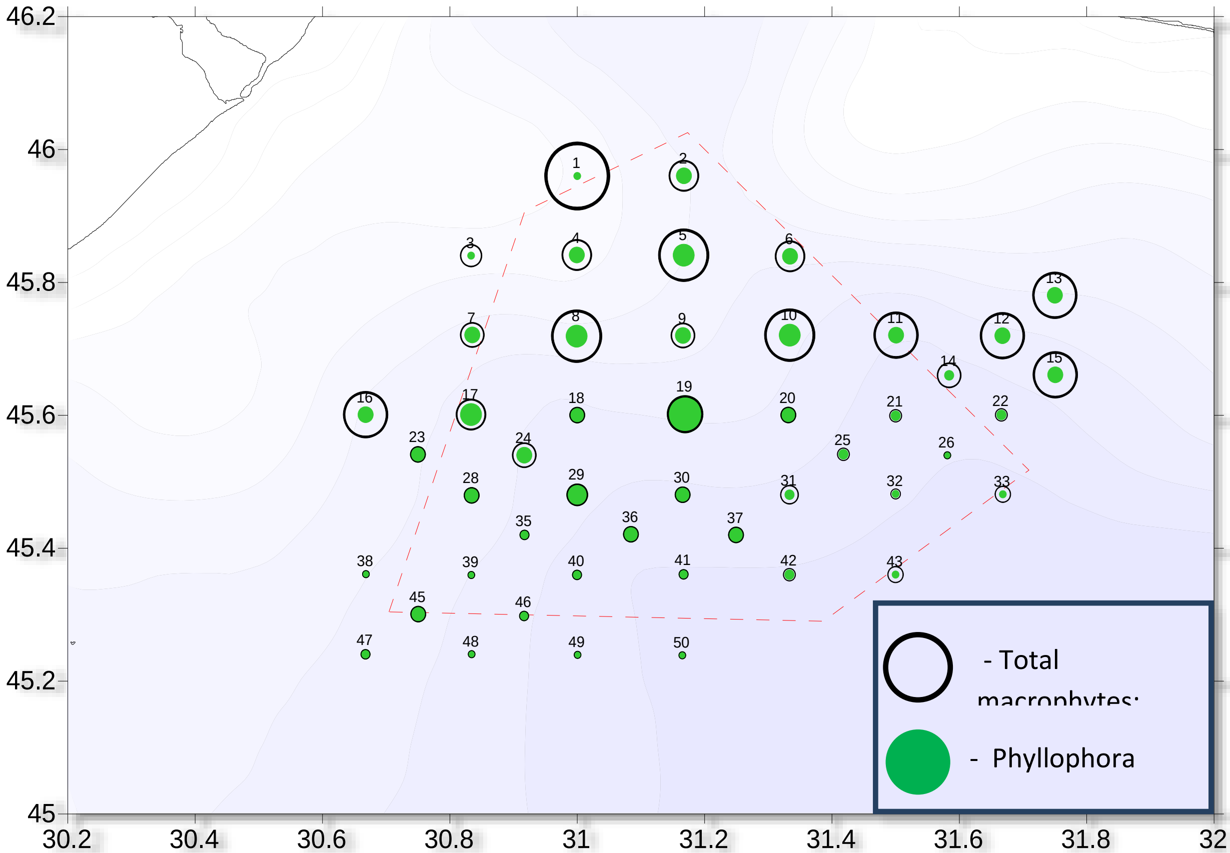

Figure 1.3.5.29. The percentage of bottom cover of the total macrophytes and *Phyllophora spp*. populations at "Zernov's Phyllophora Field"according to survey by UkrSCES in 2012 (Komorin V., UkrSCES, unpublished)

Assessment of water quality

Assessment the Ecological Status Class (ESC) of water bodies of the Ukrainian sector of the Black Sea conducted with use of the Ecological Evaluation Index (EEI): Three Dominants Ecological Activity (S/W_{3Dp}) and Phytocenosis Surface Index (SI_{ph}) and cclassification scheme for determination of the five categories of ESC of Ukrainian sector of the Black Sea (Minicheva, 2013).

Classification scheme of the $(S/W)_{3Dp}$ index has been used for spatial assessment of the ESC for 26 water bodies in Ukrainian sector of the Northern Black Sea in the reporting period (Table 1.3.5.13, Fig. 1.3.5.30). The picture received shows that maximal number of water bodies having the lowest ecological status classes is located in the north-western area. «Bad» status class (EQR: 0.11-0.07) correspond to ecosystems of the Kujalnitskiy and Hadzhibeyskiy Limans. Low ecological status of those sites has resulted from combination of unfavourable natural conditions and human impact: limans are shallow ecosystems having no free water exchange with the sea. Besides, they are situated within the boundaries of Odessa – the city with million populations. These water bodies suffer all kinds of municipal pressures, including sewer discharge into the Hadzhibeyskiy Liman. On the other side, 5 sates having «High» status class (EQR: 0.98-0.85) enjoy combination of favourable natural conditions and minimal human pressure: the Tendrovskiy Bay, the Karkinitskiy Bay, the Egorlytskiy Bay and the Karadag coast are marine protected areas of international and national significance (Biosphere and Nature Reserves). The Donuzlav Lake had no high human pressures for a long time as it used to be out-of-bounds military site.

Table 1.3.5.13. Ukrainian water bodies' ESC assessment by macrophytes morphofunctional EEI the Three Dominants Ecological Activity (S/W_{3Dp})

Water Body	Ecological Status Class	EEI, $(S/W)_{3Dp}$, $m^2 \cdot kg^{-1}$	Ecological Quality Ratio
Tendrovskiy Bay	High	11.2	0.98
Karkinitskiy Bay	High	11.7	0.96
Donuzlav Lake	High	11.9	0.92
Egorlytskiy Bay	High	12.5	0.89
Karadag coast	High	13.4	0.85
Tiligul Liman	Good	18.6	0.81
FeodosijaBay	Good	19.7	0.78
Sebastopol Bay	Good	22.3	0.74
Dnister Liman	Good	23.4	0.70
Kerchenskiy Channel	Good	24.2	0.67
Zmiinyi Island coast	Good	25.7	0.63
Dofinovskiy Liman	Moderate	32.0	0.59
Zernov's Phyllophora Field	Moderate	32.5	0.56
Tuzlopvskie Limans	Moderate	32.6	0.52
Zhebrijanovskiy Bay	Moderate	35.2	0.48
Grigorievskiy Liman	Moderate	36.7	0.42
Odessa Bay	Moderate	36.7	0.42

Water Body	**Ecological Status Class**	**EEI, (S/W)$_{3Dp}$, m^2·kg^{-1}**	**Ecological Quality Ratio**
Kalamitskiy Bay	Moderate	41.9	0.37
Dnipro-Bugskiy Liman	Moderate	43.3	0.33
Berezanskiy Liman	Moderate	44.7	0.30
Shabolatskiy Liman	Poor	45.7	0.26
Suhoy Liman	Poor	46.8	0.22
Danube Delta Front	Poor	54.2	0.18
Sasyk Lake	Poor	62.1	0.15
Kujalnitskiy Liman	Bad	119.0	0.11
Hadzhibeyskiy Liman	Bad	209.4	0.07

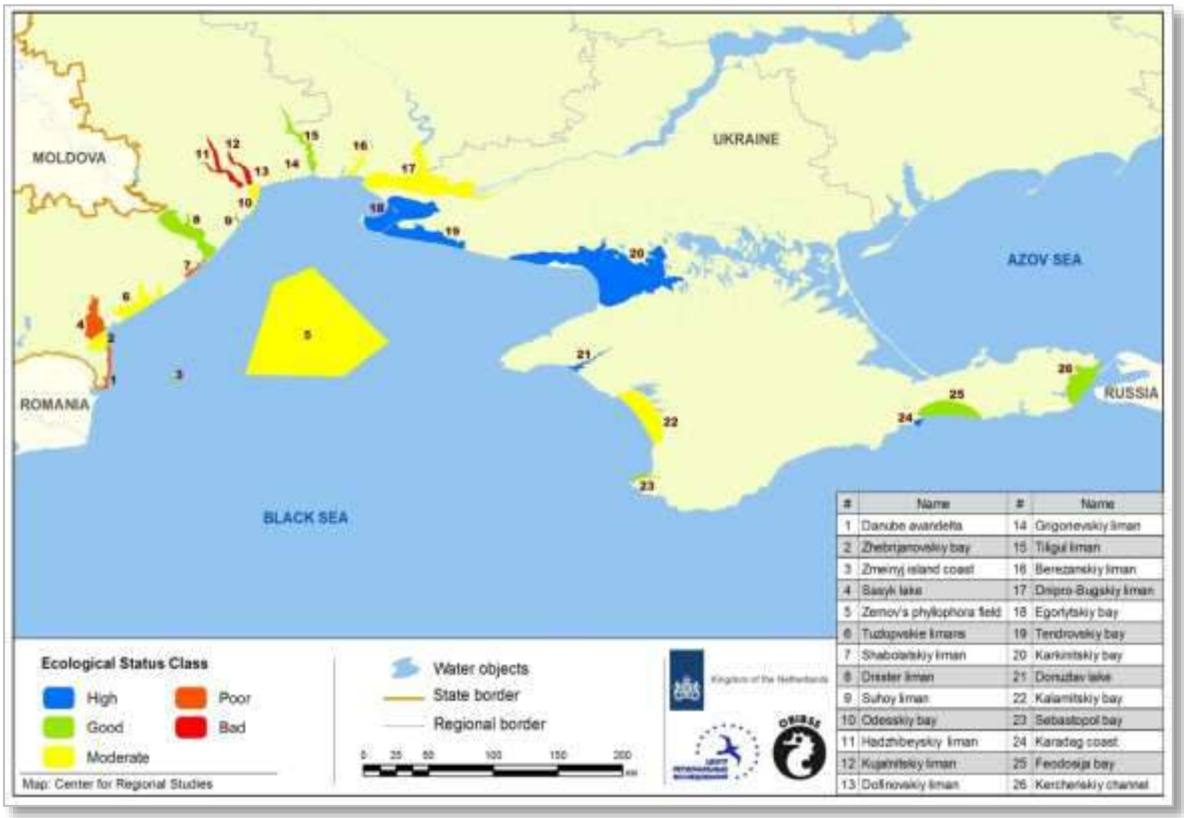

Figure 1.3.5.30. Assessment of ESC of different water bodies in the Ukrainian Northern Black Sea sector by macrophytes morphofunctional EEI the Three Dominants Ecological Activity (S/W$_{3Dp}$)

The dynamics of ESC for the same water body to change under the influence of abiotic factors which are operating for a year. Estimation the ESC of Odessa coast with using sensitive to temporal dynamics EEI – Phytocenosis Surface Index (SI$_{ph}$) reflected the climatic interannual features of reporting period, about which it was mentioned higher (see *Interannual dynamic*). The lowest category of the reporting period of ESC – "Poor" was characteristic of the climatic anomalous 2010 (Fig. 1.3.5.31). At low ecological status of ecosystems in 2010 year development advantage was with phytoplankton. In good ecological conditions of 2011-2013, at the increase of transparency of the water habitat was observed the mass development of green macrophytes at a depth of 10-15 m. Obviously, this process has cyclic character and under the conditions of 2010 year (abnormally high levels of precipitation, river flow and temperature), this situation could be repeated.

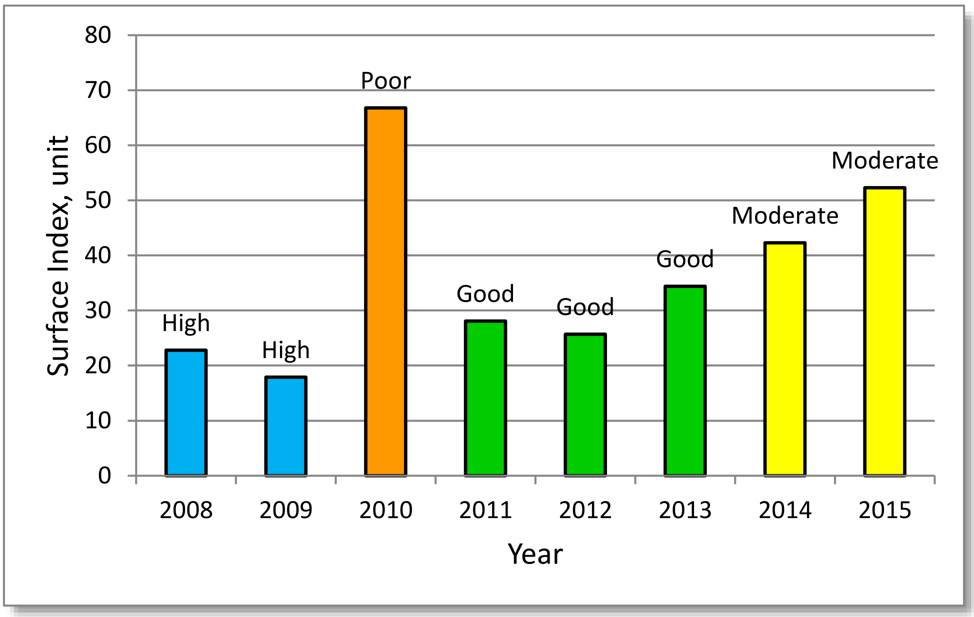

Figure 1.3.5.31. Temporal dynamic of the ECS categories on the Odessa cost (northwestern part of Black Sea) in period 2008-2015 year have assessment by macrophytes morphofunctional EEI the phytocenosis – Surface Index (SI_{ph}).

Conclusions

The analysis of the Black Sea ecosystem's macrophytobenthos in the period of 2009-2014 indicates to continuation of the restoration processes in structural-functional organization of bottom vegetation community in a new millennium. Especially expressive this process is observe in the north-western part, being under the influence of major European rivers Danube, Dniester and Dnieper.On the coasts of Bulgaria, Romania and Ukraine the tendencies of increase of floristic diversity of macrophytes and renewal the populations of key species such as *Cystoseira* and *Zostera* are registered. In the Zernon's Phyllophora Field recorded the development of numerous species of filamentous algae belonging to the divisions: *Chlorophyta*, *Rhodophyta* and *Ochrophyta*. Outline the tendency of increasing development of the *Coccotylus truncatus* population, talus which it was begun to meet on the Romanian coast. Restoration processes in the macrophytobenthos communities are obviously related with decline of the eutrophication level and improvement the ecological state of Black Sea rivers catchment basins.

The main feature of the development of aquatic vegetation in the examined period, there is a reaction of macrophytes and phytoplankton on climatic anomalous by temperature and precipitation 2010 year and subsequent post-anomalous period. In 2010, due to high temperatures and intensive development of phytoplankton the macrophytes communities were depressed. In a post-anomalous period 2011-2014 there was a peak of development on the national coasts of north-western part of the Black Sea the green algae from the geniuses: *Cladophora, Ulva, Ulothrix*. Thus, the rapid and prolonged effects on climatic anomalies of the Black Sea macrophytobenthos was observed.

For the first time in this report, macrophytes of the Black Sea have been considered as a Biological Quality Elements (Macroalgae and Angiosperm) to assess the Ecological Status

Class (ESC) in accordance with requirements of the Marine Strategy (MFSD). The long-term estimation of ESC on the basis of the macrophytobenthos indicators, also confirms that against the background improvement the ecological state which related with the decline of eutrophication, the strongest factor of worsening of it became the anomalous climatic conditions of 2010 year. Under influence of different degrees of local anthropogenic impacts on the coasts of Bulgaria, Romania, Ukraine there are sites which by macrophytobenthos indicators have the low categories: «Moderate», «Poor» and «Bad». At the same time for most of the Black Sea Marine Protected Areas, such as: Mangalia, Vama Veche (Romania) Tendrovskiy, Yagorlytskiy, Karkinitskiy Bays, Karadag (Ukraine), Balchik (Bulgaria) by macrophytobenthos indicators have the high ESC categories: «Good» and «High».

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1.3.6 State of Gelatinous Plankton

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During the last decades, native and invasive gelatinous species have become the main drivers of the Black Sea ecosystem functioning subjected to its disturbance.

With respect to their origin, all the Black Sea species including gelatinous may be subdivided on the cold water, warm-water, eurythermic. Native gelatinous species belong to moderately cold-water species: the ctenophore *Pleurobrachia pileus* O. Muller, two scyphomedusae *Aurelia aurita* (L) and *Rhizostoma pulmo* **(**Macri) (Shiganova, 2009).

First a sharp growth of the *Aurelia aurita* abundance was recorded in the late 1970s. It was triggered by the supply of large amounts of detritus that is consumed by medusas and by the eutrophication, which also provided additional food for *Aurelia aurita* (Mironov, 1971). Significant growth of the *A.aurita* population became one more factor that led to the deterioration of the Black Sea ecosystem even before the appearance of invader *Mnemiopsis leidyi* (Anninsky, 1989; Lebedeva and Shushkina, 1991).

The warm-water invader ctenophore *Mnemiopsis leidyi* A. Agassiz 1865 arrived in Black Sea in 1982 and spread around the sea in 1986-88 (Vinogradov et al., 1989). It was transported to the Black Sea in ballast waters of the ships from Tampa Bay of the Gulf of Mexico (Ghabooli et al., 2010; Reusch et al. 2010). There were no any its predators and *M. leidyi* could establish under optimal temperatures and food (zooplankton) concentration of the Black Sea, spread around the sea, and reached high abundances. Its main food is zooplankton, fish eggs and small larvae (Tzihon-Lukanina et al., 1991; Shiganova et al., 2001a). Its larvae feed on microzooplankton (Sullivan & Gifford, 2004; 2007). As a result in following years cascading effects were observed at the most levels of the ecosystem. Bottom-up effects were included collapsing planktivorous fish populations, drop of large pelagic fish and dolphins stocks were following. Top-down effects were included decreased zooplankton species diversity and stocks (maximum annual zooplankton biomass declined to ca. 0.5 mg C m^{-3}, which was almost two orders of magnitude lower than during the previous period); increased phytoplankton biomass released from zooplankton pressure. In addition bacterioplankton increased growing on the high production of mucus released by *M.leidyi* and its degradation fragments, heterotrophic flagellates and ciliates increase follow, which fed on the overgrown biomass of bacteria (Shiganova et al., 2004, 2019). By the late 1980s, the pelagic ecosystem had become dominated by gelatinous plankton, where *M.leidyi* comprised of the most of biomass (Shiganova et al., 2003).

The sizes of *M. leidyi* populations were not controlled by any predator until 1997. In that year, another carnivorous ctenophore *Beroe ovata* sensu Mayer 1912 (named by Bayha et al., 2004 after his first genetic analyses of this species), arrived in the Black Sea in ballast waters from North American coastal areas (Konsulov & Kamburska, 1998, Seravin et al., 2002). Our genetic analyses made recently with usage ITS-1; COI and 18 S primers confirmed arrival *B.ovata* in the Black Sea from the same area as *M.leidyi* from Tampa Bay (Florida) (Johansson et al., 2018). *B. ovata* is a predator of zooplanktivorous ctenophores, mostly *M. leidyi* in Northern and Southern American waters (Bayha et al., 2004; Mianzan, 1999). In the upper layer of the Black Sea *B. ovata* feeds on *M. leidyi*. Although it may also feeds on the native ctenophore *Pleurobrachia pileus*, which generally lives in deeper waters offshore and is not available for *B.ovata* occurring in surface layer during active period of its life (Shiganova et al., 2001b). After the arrival of *B. ovata*, the Black Sea ecosystem began to recover progressively (Shiganova et al., 2014; 2018). An additional factor that favored the recovery of the ecosystem was a decrease level of eutrophication, which resulted from reduced anthropogenic nutrient inputs (Cociasu et al., 2008). That was accompanied by decreasing in total phytoplankton biomass and harmful algae blooms. The combination of these factors in the late 1990s led to a general improvement of the Black Sea ecosystem (Oguz and Velikova 2010; Shiganova et al., 2014).

The interannual variability of the *M. leidyi* abundance depends on changes in surface water temperature and its food concentration, i.e. edible micro- and mesozooplankton and level of control by *B.ovata* after its arrival (Shiganova et al., 2014; 2018).

Recently we have investigated the mechanisms by which the populations of *M. leidyi* are controlled by *B. ovata* (Shiganova et al., 2014). Understanding these mechanisms in the Black Sea is especially important because *M. leidyi* distributions are rapidly expanding in the waters around Eurasia (e.g. Faasse & Bayha 2006, Javidpour et al. 2006, Boero et al. 2009, Fuentes et al., 2010, Galil et al. 2009, Shiganova & Malej 2009; Shiganova et al., 2014). Here we describe interaction of these two ctenophores and variability of competitor of *M.leidyi* jellyfish *Aurelia aurita* abundance in conditions increasing temperature during last years and level of *M.leidyi* impact on zooplankton in presence of its predator *B.ovata* .

Material and methods

Study area

Samples were collected along transect from the Blue Bay (northeastern Black Sea) towards the open waters up to 500 m depth (Fig. 1.3.6.1). In the Blue Bay temperature varies from 6°C in winter to up to 30°C in summer during last years, and salinity varies from 17 to 18. Meandering of the Rim Current (cyclonic contour current on the continental slope of the Black Sea) frontal zone generates eddies, mainly anticyclonic, which migrate offshore and exchange water and plankton between coastal and offshore areas. In addition, wind-driven Ekman transport affects the numerical abundance and biomass of plankton in the coastal zone (Zatsepin et al., 2010; Shiganova et al., 2014).

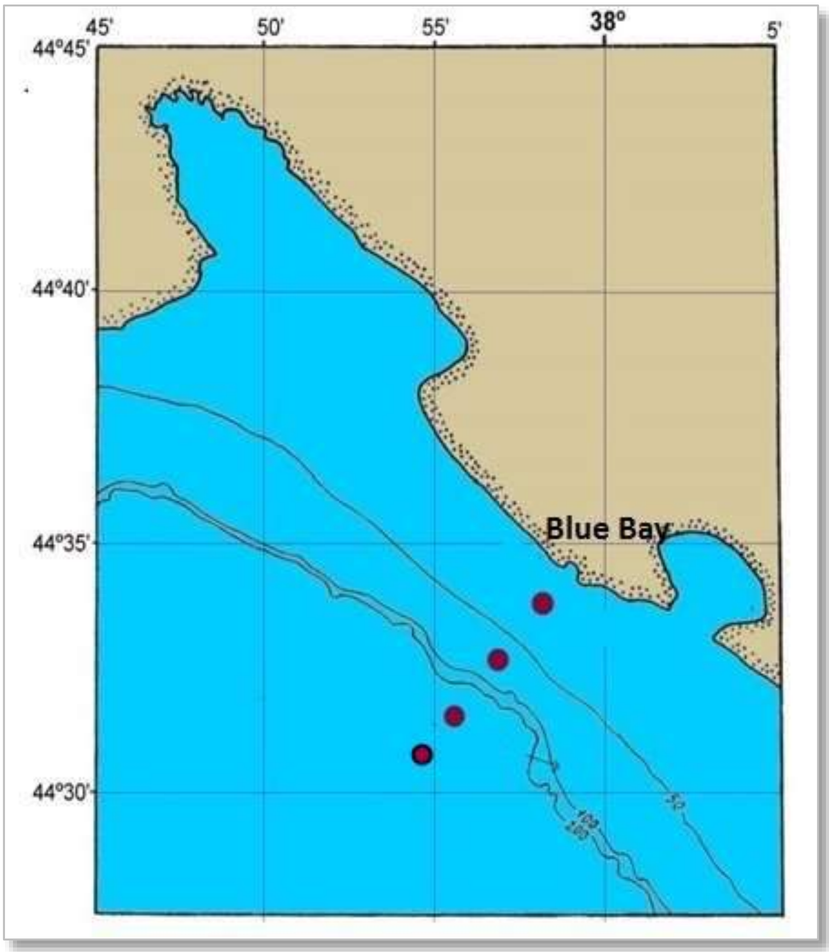

Figure 1.3.6.1. Map of the north-eastern Black Sea, showing the locations of Blue Bay and the sampling transect.

Data collection

Samples were collected monthly with some excursions along transect from the Blue Bay to offshore at the stations above 10, 50, 100 m and 500 m depth (Fig. 1.3.6.1).

Temperature and salinity were recorded vertically with a SeaBird CTD probe. Zooplankton (including eggs and larvae of ctenophores) was collected with a Juday plankton net (0.1 m^2 opening, 180 µm mesh size), and gelatinous plankton and ichthyoplankton with a smaller size modification of the Bogorov Rass net (0.2 m^2 opening, 500 µm mesh size). All samples in the coastal area were collected using vertical hauls from bottom to surface, and at the station above 500 m from the boundary of anoxic layer to the surface and from thermocline to the surface.

The ctenophores obtained from the vertical net hauls were immediately separated from other organisms using a 2 mm mesh sieve. All ctenophores including the smallest larvae and the eggs were measured alive immediately after collection by size groups. Small organisms of both *M. leidyi* and *B. ovata* were counted and measured under the binocular microscope. For *M. leidyi*, the size groups were: <2, 3-5, 6-10, 11-20, 21-30, 31-40, 41-50, and >50 mm. The life stages of the Black Sea *M. leidyi* were defined as follows: <2 mm, hatched larvae; 3-5 mm, larvae; 6-10 mm, cydippid larvae; 11-20 mm, transition of juveniles from cydippid to lobate; 21-30 mm, lobate juveniles; 31-40 mm, beginning of maturity and reproduction, accepted as adults; and >40 mm, adults. For *B. ovata*, the size groups were: <4, 4-8, 9-30, 31-40, 41-50, and >50 mm. In the Black Sea under favorable conditions, *B. ovata* can reach maturity and start reproduction at a length of 40 mm. Its life stages are: <8 mm, larvae; 8-40 mm, juveniles; and >40 mm, adults (Shiganova et al., 2014). The smallest larvae and eggs were also counted and measured alive from the zooplankton samples, and then preserved in 2% formaldehyde.

The total numbers of individuals of *M. leidyi* and *B. ovata* were used to estimate their total abundances. The individual ctenophore biomass was estimated by the displacement volume method and then total biomass was estimated.

Statistical analyses. In statistical analyses we applied for Statistics VII software.

We also measured metrics and used classification system for the coastal marine waters on the base of macro- and mesozooplankton characteristics according to WFD (Table 1.3.6.1).

Table 1.3.6.1. Metric and classification system for the coastal marine waters on the base of zooplankton characteristics (according to WFD).

Season	High	Good	Moderate	Poor	Bad
Mesozooplankton biomass, mg.m^{-3}					
Spring	400-300	300-150	150-70	70-10	<10
Summer	900-600	600-350	350-200	200-40	<40
Autumn	350-250	250-150	150-70	70-10	<10
Noctiluca scintillans biomass mg.m^{-3}					
All the year	<50	50-100	250-500	500—2500	>2500
Mnemiopsis leidyi biomass g.m^{-3}					
All the year	0	1-4	4-20	20-50	>50
Shanon-Weaver index.ind.bit^{-1}					
All the year		>3.5	3.5-2.5	2.5-1.5	<1

RESULTS

Seasonal and interannual variability of *M. leidyi* and *B. ovata*

With the arrival of *B. ovata* in the Black Sea in 1997 (in 1999 in the north-eastern area considered here, as a time of beginning monitoring which includes the Blue Bay), the period of the year during which *M. leidyi* was present changed drastically: until 1998, *M. leidyi* occurred in sizable concentrations during spring, summer, autumn and warm winters. However since 1999, it has occurred in sizable concentrations (i.e. ≥5 ind. m^{-3}) only during late spring and summer. *B. ovata* appeared in upper water column late summer when *M.leidyi* reached peak in abundance and reproduction rate until the last years (Fig. 1.3.6.2).

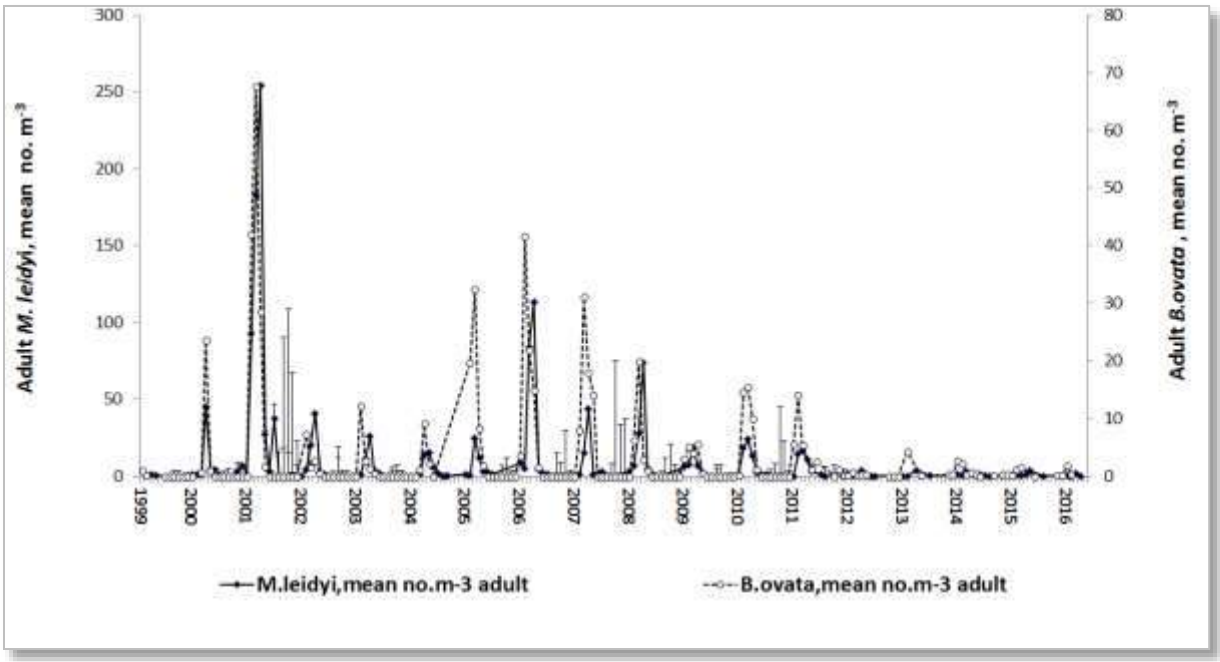

Figure 1.3.6.2. Abundances of adult *M. leidyi* and *B. ovata* along transect in the north-eastern Black Sea from 1999 to 2016 in the coastal waters up to 100 m depth. Error bars: standard deviations. (A) Interannual variations of mean values during each sampling survey along transect in Figure 1.3.6.1.

The abundances of adult *M. leidyi* and *B. ovata* varied from year to year (Fig. 1.3.6.2). Their dynamics is determined by temperature and food availability (zooplankton for *M.leidyi* and *M.leidyi* for *B.ovata*). The maximum annual abundances ranged over more than one order of magnitude for two species, i.e. *M. leidyi* from 26.2 to 254 ind. m^{-3} in 2003 and 2001, respectively, and *B. ovata* from 6 to 68 ind. m^{-3} in 2009 and 2001, respectively. During last years the abundance of both species dropped and ranged from 3.4 ind.m^{-3} to 0.91 ind.m^{-3} of *M.leidyi* , and *B.ovata* from 1.4 ind.m^{-3} to 0.43 ind.m^{-3} in 2015 and 2017 respectively.

The observed succession of peaks (maximum annual values) of *M. leidyi* and *B. ovata* within each year suggests that the maximum annual abundance of *B. ovata* predator was related to that of its *M. leidyi* prey. This was indeed the case as the two variables showed a significant positive relationship (Fig. 1.3.6.3).

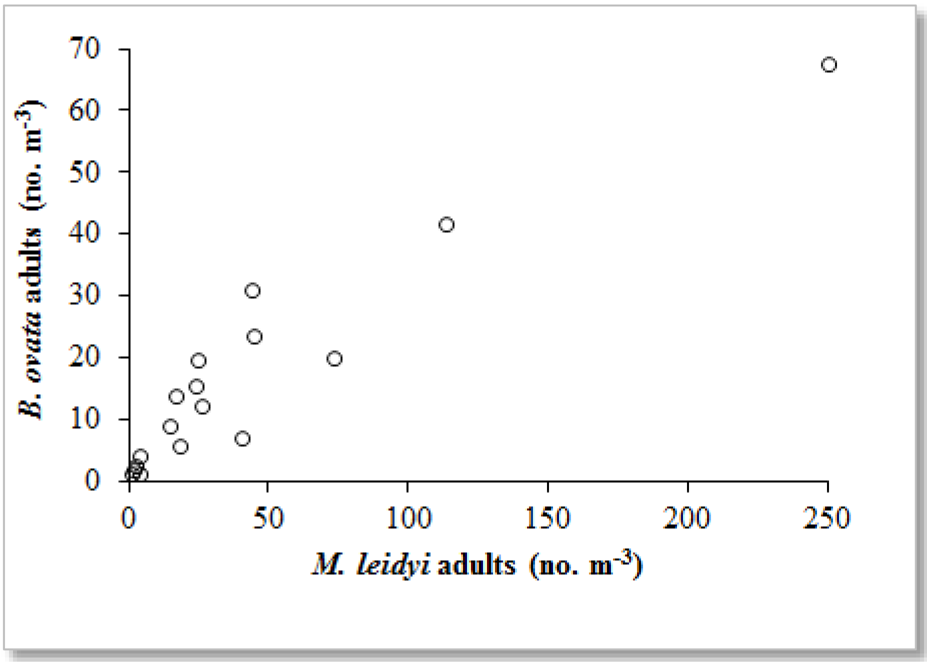

Figure 1.3.6.3. Maximal annual number of adult *B. ovata* in 1999-2016 plotted as a function of maximum annual number of adult *M. leidyi*. The coefficient of linear correlation between the two variables is $r^2 = 0.95$ (prob. < 0.001).

From the beginning of year, the maximal annual abundance of *M. leidyi* depends on springtime temperature (average of March to May), with a threshold effect of temperature (at 11.8°C, see Shiganova et al., 2014). In previous observations, we tested this effect by assigning the data to a 2 x 2 contingency table where the cells contained the number of observations corresponding to two temperatures (i.e. <11.8 and ≥11.8°C) and two maximum annual abundances of *M. leidyi* (i.e. ≤33 and >33 ind.m^{-3}) (Shiganova et al., 2014). This is a first crucial period for creation of *M.leidyi* annual abundance in population.

The second crucial period is the date of starting reproduction of *M. leidyi*. Between 1999 and 2011 the starting date was significantly and inversely related to the average temperature in the surface layer, i.e. the reproduction of *M. leidyi* started earlier in warmer years, and at the highest June temperatures (>22°C), which were recorded after 2005 in June and even in May during last years (Fig. 1.3.6.4). The earlier reproduction of *M. leidyi* after 2005 was accompanied by a rising temperature and earlier appearance and reproduction of *B. ovata* (Fig. 1.3.6.2, 1.3.6.4, 1.3.6.5).

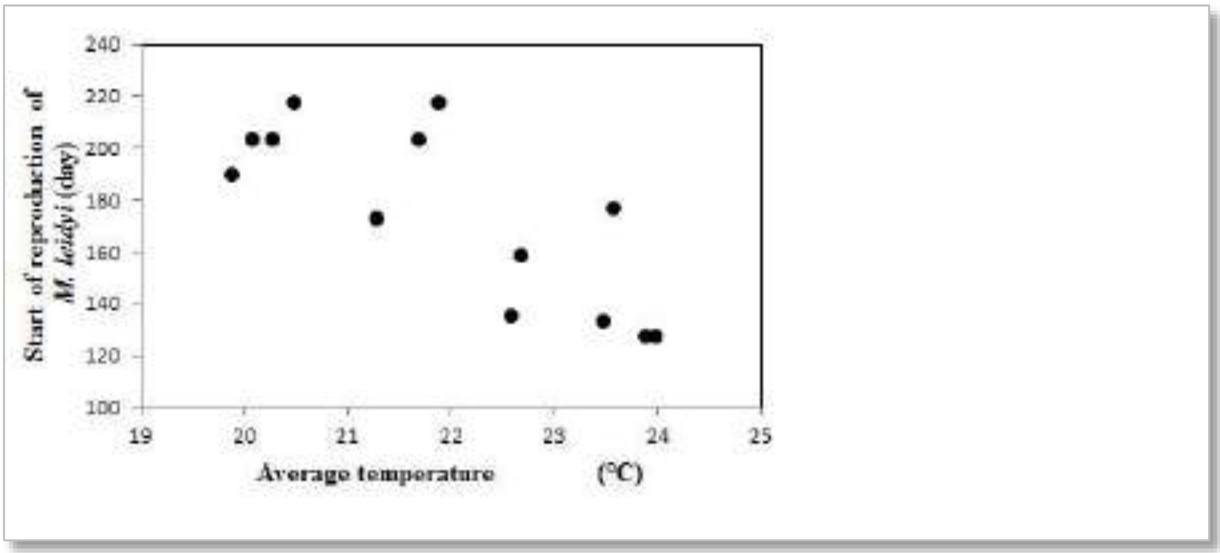

Figure 1.3.6.4. Starting date of reproduction of adult *M. leidyi* plotted as a function of average temperature in the surface layer in inshore waters within and off Blue Bay from 1999 to 2017.

The coefficient of linear correlation between the two variables is $r^2 = -0.78$ ($p < 0.01$).

In addition, the maximum annual abundance of *M. leidyi* and time of beginning of reproduction depends on spring and particularly on early summer (June-July) zooplankton biomass, with a significant positive linear relationship between the two variables. This is third crucial period for creation of *M.leid*yi size of population. Foods based on optimal temperature stimulate the beginning of reproduction and its intensity (Fig. 1.3.6.4)**.** Our statistical analyses snow also significant dependency *M.leidyi* abundance on zooplankton biomass before *B.ovata* appearance (Fig. 1.3.6.5, 1.3.6.6).

During first years period of high *M.leidyi* abundance lasted up to 3.1 month between 2000 and 2005 from August to late September. However in 2006-2009 from June to August since increasing temperature in spring and summer and particularly in August duration of high *M.leidyi* abundance decreased to maximal 2, 4 months. At that time temperature increased from May to late July-early August 2006-2017 *M.leidyi* , and reproduction rate decreased, total abundance also decreased due to increasing temperature particularly in August to average 26, 22±2,1^0C with maximal up to 30^0 C (Fig. 1.3.6.5). According to our experimental data *M.leidyi* stops to reproduce when temperature reaches about 27 ^{0}C (Shiganova et al., 2004).

1

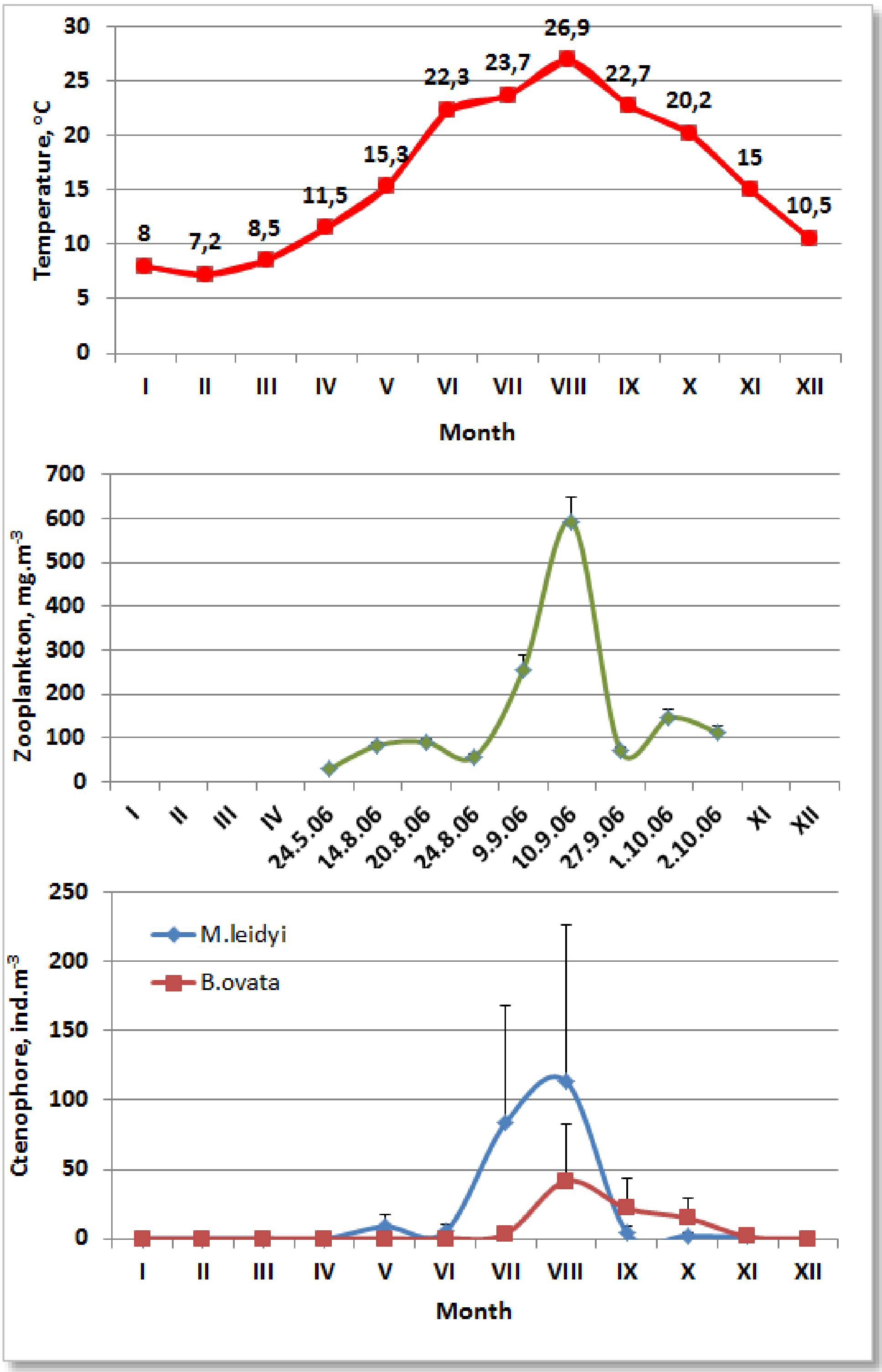

Figure 1.3.6.5. 1- Annual change temperature °C, 2-seasonal development of edible zooplankton, **3-***M.leidyi* and *B.ovata* in in coastal waters (10-100 m depth) in 2006.

Error bars: standard deviations. (The coefficient of linear correlation between the zooplankton biomass and *M.leidyi* abundance is $r^2 = 0.5$ (prob. <0.05); between *M.leidyi* and *B.ovata* is $r^2=1$ (prob.<0.001)

Our observations during last three years (Fig. 1.3.6.6) in the costal area from 10 m up to 100 m depths showed continuation of decreasing trend of *M.leidyi* abundance, particularly when temperature rose higher than 26,4^0 C and duration of *M.leidyi* presents became shorter from year to year up to one month in 2016-2017 (Fig 1.3.6.2, 1.3.6.6).

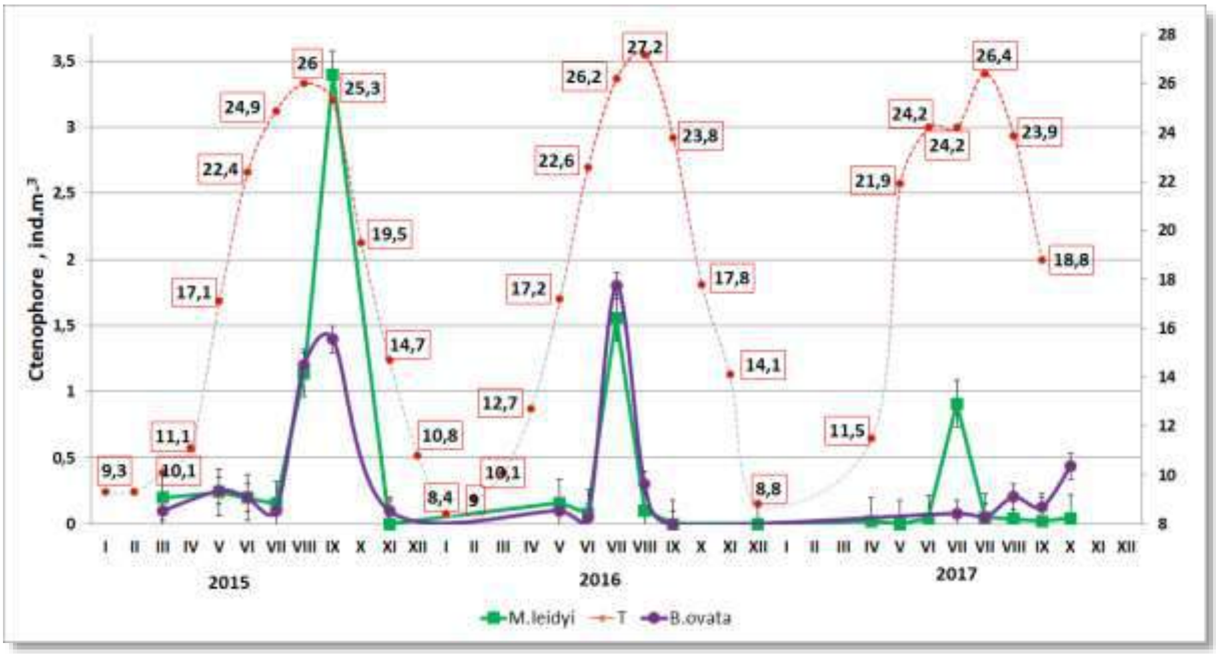

Figure 1.3.6.6. Seasonal development of *M.leidyi* and *B.ovata* in the coastal waters (10-100 m depth) in 2015-2017.

Error bars: standard deviations (between *M.leidyi* and temperature significant positive dependency in spring and negative when temperature higher 26.6^0 C; between *M.leidyi* and *B.ovata* is r=0.78 (prob.<0.04); between *B.ovata* and temperature in May is r^2=0.9 (prob.<0.001).

One more reason for decreasing *M.leidyi* abundance is that since 2012 seasonal dynamics of *B.ovata* also changed due to increasing temperature in May at 2^{o}C up to 17.1-17.17 ^{o}C, which show significant dependency (Fig. 1.3.6.6). As a result *B.ovata* began to appear in upper layer of water column earlier in April - June and even single individuals were recorded in March in 2015. Resulting in seasonal dynamics of both ctenophores began to coincide. Consequently *M. leidyi* did not reach high abundance grazed by *B. ovata* from the beginning of development (Fig. 1.3.6.6).

As showed our observations, reproduction of *M.leidyi* started already in late May-June now, reaches peak in June-July then dropped when larvae of *B.ovata* grazed by larvae *M.leidyi*, which now also starts reproduction earlier in July (Fig. 1.3.6.7).

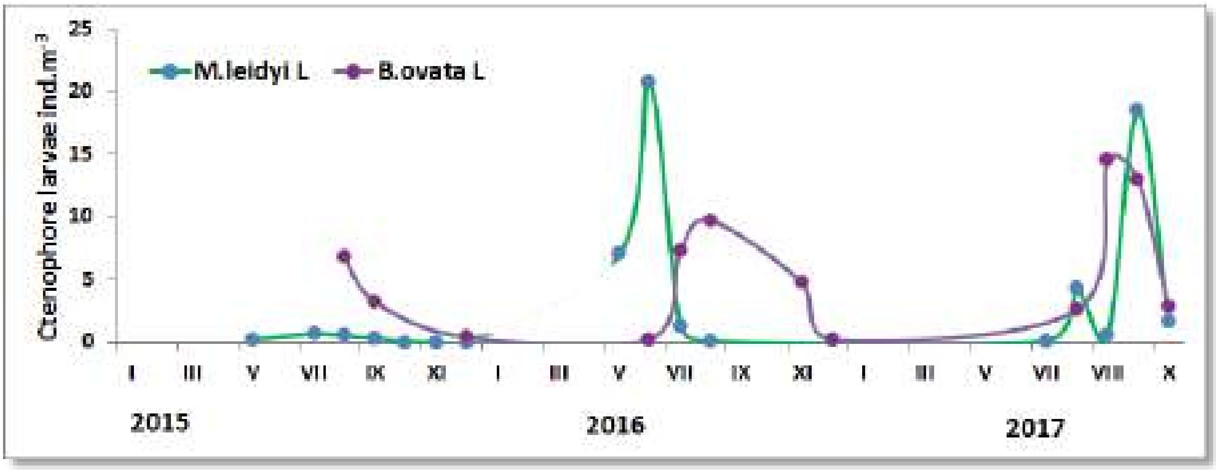

Figure 1.3.6.7. *M.leidyi* and *B.ovata* larvae occurrence above the depth 10-100 m in 2015-2017.

The main area of occurrence and reproduction of both ctenophores is the coastal waters up to boundary of the shelf. Our observations in the open sea above 500 m. during last three years support this statement.

Adult *M.leidyi* and *B.ovata* may spread with the currents in open waters in the months,

particularly when they reach high abundance in shelf waters but sporadically and in very low abundance (Fig. 1.3.6.8).

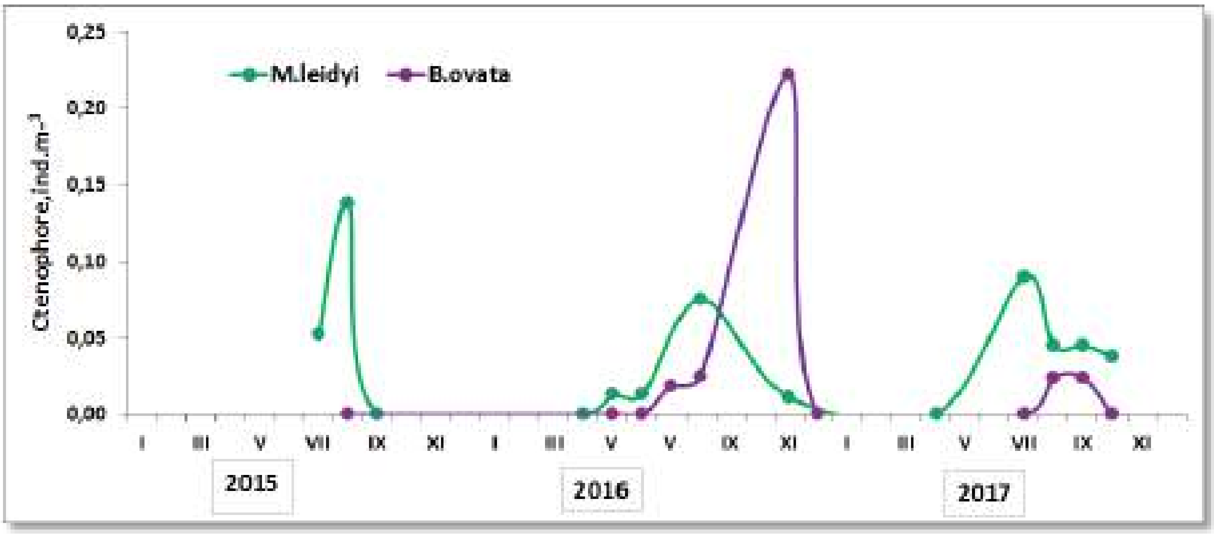

Figure 1.3.6.8. Occurrence of adult *M.leidyi* and *B.ovata* above the depths 500 m above the anoxic layer .

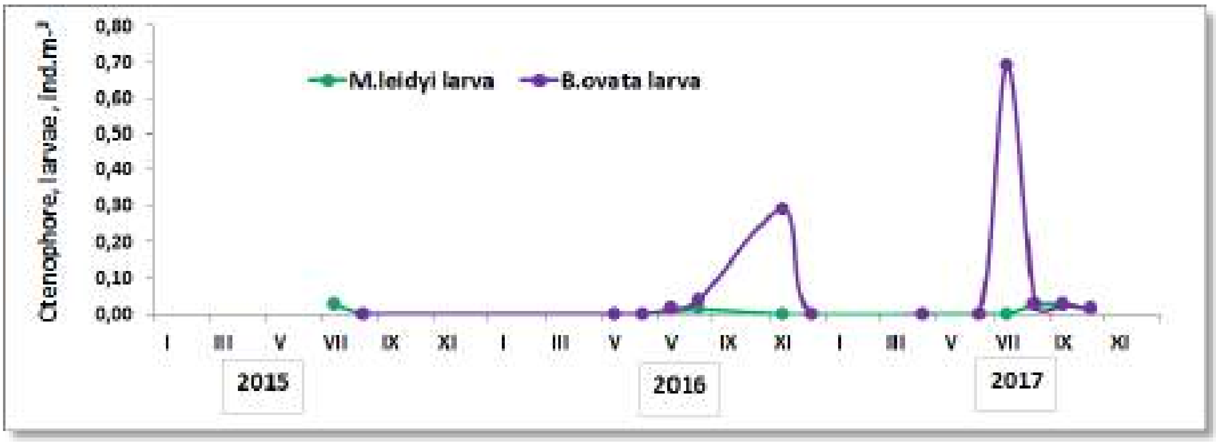

Figure 1.3.6.9. Occurrence of larvae *M.leidyi* and *B.ovata* at the depths 500 m above anoxic layer .

Larvae of both species also can be transported in the deep waters in very low abundance (Fig. 1.3.6.9). However transported adults of both species may also release eggs in deep waters and larvae may develop.

Effect *M. leidyi* on zooplankton after appearance *B.ovata*.

There is a strong dependence zooplankton biomass and *M.leidyi* abundance before seasonal development *B.ovata* (Fig. 1.3.6.5, 1.3.6.6), The coefficient of linear correlation between the zooplankton and *M. leidyi* is $r = 0.5$ (prob. <0.05) in 2006, $r = 0.71$ (prob. < 0.005) in 2015 and $r = 0.9$ (prob. < 0.001) in 2016. However during last years with increasing temperature in July and August *M.leidyi* abundance is low also due to decreasing intensity of its reproduction at high temperature (>26, 6^0C) even without *B.ovata* grazing (Fig. 1.3.6.2). Therefore zooplankton biomass is still high during seasonal development of *M. leidyi*. In addition zooplankton biomass may increase after disappearance *M.leidyi* grazed by *B.ovata* and reached rather high biomass (Fig. 1.3.6.9). However it depends when *B. ovata* completely decreased *M. leidyi* abundance during current year, and if summer zooplankton species still continues reproduction and development (Fig. 1.3.6.9).

Nevertheless as it is noticeable from Fig. 1.3.6.9, the range of zooplankton biomass variation is still very high. Positive sign is that summer zooplankton peak now exists during last years as it was before *M.leidyi* arrival (Fig. 1.3.6.9).

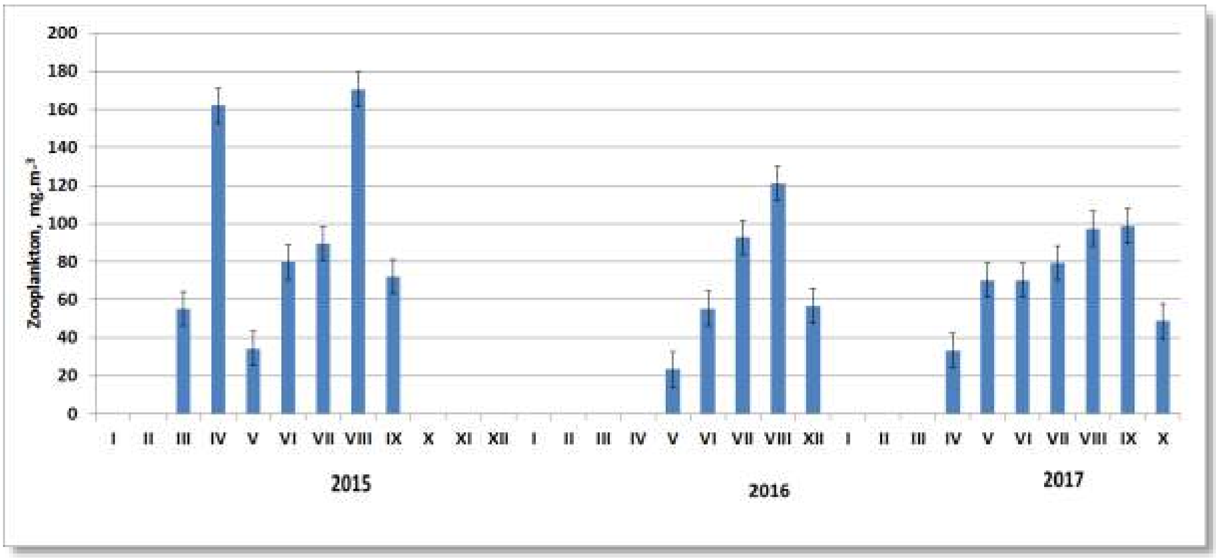

Figure 1.3.6.9. Seasonal dynamic of edible (without *Noctiluca scintillans*) zooplankton biomass

(Error bars: standard deviations) in coastal waters (10-100 m depth) in 2015-2017.

Seasonal and interannual variability of *Aurelia aurita* during last years.

Aurelia aurita is one of the most abundant common species of Scyphozoa that is encountered in the near-shore waters of all the oceans between 70° N and 40° S. Recent genetic analyses showed that the Black Sea *Aurelia aurita* belong to clade Borealis (Ramsak et al., 2012). Both spatial and vertical distributions of medusas are extremely irregular. The spatial heterogeneity in the medusa stage distribution is caused by their transport by currents and manifests itself in the form of accumulations observed as individual patches or bands, sometimes extended along the shore or, in open regions, along the direction of the wind. The sizes of these kind of accumulations may be rather significant (Fig. 1.3.6.10)

Figure 1.3.6.10. Aggregations of *Aurelia aurita* in the open waters in May.

Although, according to the data of Anninsky (Anninsky, 1989), the maximal rates of all the processes in medusas are observed at temperature of 19–20°C, which is observed in the upper mixed layer in the late spring-early summer. Their commitment to the cool waters may be explained that *Aurelia aurita* is more common in boreal waters. Medusas eat out 34–67% of the total production of mesozooplankton or 47–90% of the copepod production (Anninsky, 1989). These calculations suggest a strong negative influence of the increased *Aurelia aurita* population on the edible zooplankton.

An analysis of the our data and previous data (Mironov, 1967) allow to suppose that, in the Black Sea, *Aurelia aurita* has annual two generations: the winter generation that develops for approximately 6 months (from November –December to May) and the spring generation that develops over about 5 months (from April–May to August–September). The individuals of the winter and spring generations reach their maximal sizes and weights at the end of May and at the end of September, respectively. According to our observations, the peaks of the ephyra strobilation and medusa development in the Black Sea occurs in April –May depending on the temperature and November and, probably, in December (Shiganova, 2009). This seasonal dynamic was observed also in the previous studies (Mironov, 1967). In that period, ephyrae were encountered, the mean size of medusas were the least (3 to 8 mm).

First increase of *A.aurita* population was recorded in late 1970s. During *M.leidyi* mass development before *B.ovata* arrival, abundance of *A.aurita* dropped since *M.leidyi* was found to be more successful competitor for food, mainly for edible zooplankton.

Now when *M.leidyi* abundance decreased after arrival *B.ovata* and increase temperature for unfavorably high level for *M.leidyi*, abundance of *A.aurita* began to increase in spring and autumn during seasonal development its medusas and when *M.leidyi* population is very low or absent (Fig. 1.3.6.11).

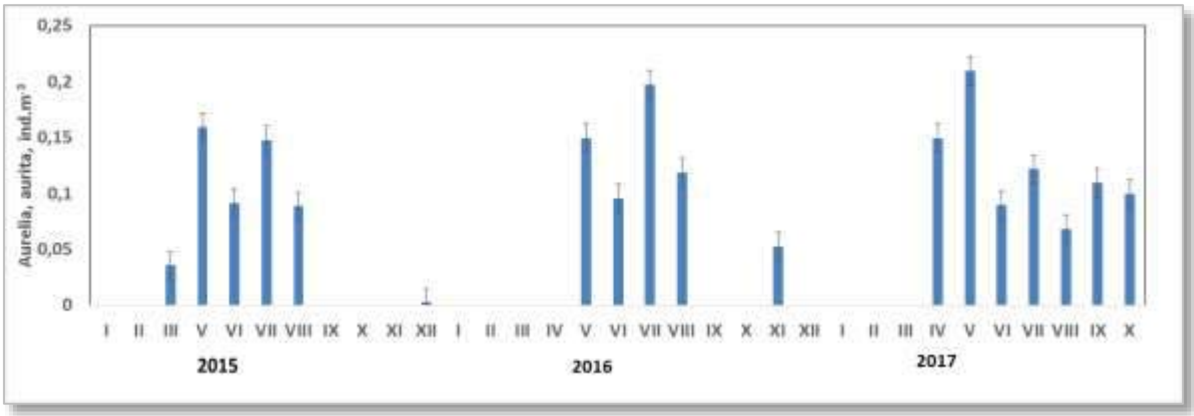

Figure 1.3.6.11. Seasonal dynamic of *Aurelia aurita* in the coastal waters (10-100 m) I 2015-2017.

In open sea above 500 m abundance *A.aurita* was higher particularly in April-May with bloom in April 2017 (Fig. 1.3.6.12).

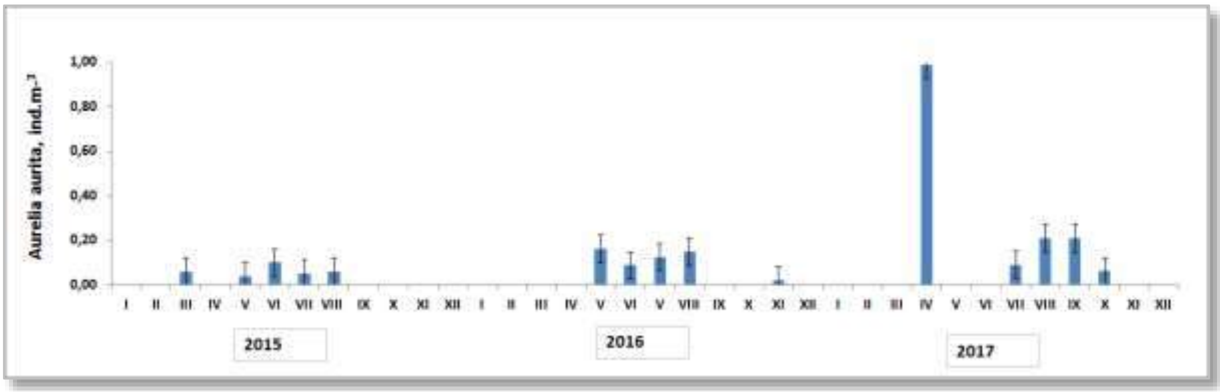

Figure 1.3.6.12. Seasonal dynamic of Aurelia aurita above 500 m in the layer from anoxic layer to the surface.

Discussion and conclusion.

Summarizing our results we may conclude that the source area of *M.leidyi* occurrence and reproduction is the coastal waters of the Black Sea from where aggregations both adult and larvae may be transported in deeper waters with the currents but in much lower abundance. Abundances of the two ctenophores, time and duration of their development depends on environmental conditions. Although the same combined reproductive sequences of *M. leidyi* and *B. ovata* take place every year from 1999 until 2017 (Fig. 1.3.6.2) but value of abundances depends on temperature and zooplankton biomass of current year.

After 2006 with increase temperature in spring *M.leidyi* starts to reproduce earlier and reached pick of reproduction earlier, *B.ovata* consequently appears also earli1er (Fig. 1.3.6.5). Since 2012 *B.ovata* appears much earlier almost simultaneously with *M.leidyi* as a consequence *M.leidyi* could not reach high abundance due to its grazing by *B. ovata. M.leidyi* reaches peak now in July, although its peak is much lower and shorter about one month duration due to increasing surface water temperature and decrease intensity of *M.lei*dyi reproduction (Fig. 1.3.6.6).

One more negative event appeared during last years. *Aurelia aurita* abundance again increases in spring and autumn before spring development of *M.leidyi* population and after its drop grazed by *B.ovata* in autumn.

In spite of recovering of some trophic levels of pelagic ecosystem both invasive ctenophores and native jellyfish *Aurelia aurita* still act as the main stressors of pelagic ecosystem functioning of the Black Sea.

We estimate ecological status of marine environment (GES) based on state of studied parameters (Table 1.3.6.2).

Table 1.3.6.2 Ecological status of marine environment (GES), in the northeastern Black Sea on the base macro- and mesozooplankton parameters as indicators in 2016.

Month	Mean edible zoo.B, mg·m^{-3}	GES	Mean *M.leidyi* ind.m^{-3}	**GES**	**Cop**, %	**GES**	Mean **Sh**, bit·ind^{-1}	**GES**
		Coastal waters 10-100 m						
May	15,5	Bad	0,26	Good	1,9	Bad	0,1-0,012	Bad
June	23,2	Bad	0,288	Good	1,2	Bad	0,1-0,28	Bad
July	164,9	Good	1,56	Good	8,0	Bad	0,25-0,3	Bad
August	163	Moderate	0,1	Good	2,8	Bad	0,35-0,5	Bad

Note. Mesozooplankton indicators: **B zoo**- total edible zooplankton biomass, Cop,% Percent of Copepoda in total biomass of edible zooplankton, **Sh**- Shennon-Weaver index.

Thus, according to our observations and assessment of macro-and mesozooplankton parameters environmental status is still mainly not good in the north-eastern Black Sea, in spite of great decrease of population *M.leidyi*. Species diversity and share of Copepoda are still low in the coastal waters. So, according Water Framework Directive (WFD):

biomass of copepods (%) - contribution of copepods biomass to total mesozooplankton biomass comprised only 0.5-5% in the coastal waters. Particularly low percent of Copepoda was recorded during peak of *M.leidyi* development in July and early August 1. 2-4% in shelf waters, which is not corresponded to GES. Shannon-Weaver index (bit·ind^{-1}) – reflects the number of species in a dataset, taking into account how evenly the basic entities (such as individuals) are distributed among species. So this index reflected total biodiversity of mesozooplankton. The boundary for good status was accepted 3 bit·ind^{-1} for coastal habitats, The index was low 0.3 in coastal waters.

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1.3.7. State of Seabirds

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Species diversity and conservation status

There are at least 35 regularly occurring seabird species in the Black Sea, representing 9 families (see Table 13.7.1). Twenty one species breed along the Black Sea coast, while 28 are present during winter or on passage. Four globally threatened species, all classified as 'Vulnerable' (VU) in the Global Red List (BirdLife International 2017a) use the Black Sea during the non-breeding season: Long-tailed Duck, Velvet Scoter, Yelkouan Shearwater (all 'Vulnerable' also in Europe) and Horned Grebe ('Near Threatened' in Europe). The Common Eider (globally 'Near Threatened' and 'Vulnerable' in Europe) also breeds here. Another two species of seabirds occurring in the Black Sea are 'Near threatened' in Europe – Red-breasted Merganser and Little Gull (BirdLife International 2017b).

Important Bird and Biodiversity Areas

There are 9 marine IBAs (Important Bird and Biodiversity Areas13) of global importance for seabird species in the Black Sea (Figure 1.3.7.1). These sites were mostly designated for the importance for the Vulnerable Yelkouan Shearwater *Puffinus yelkouan* (Raine et al. 2012, Péron et al. 2013). The Yelkouan Shearwater is a Mediterranean endemic with a population estimated between 46.000 and 90.000 individuals (BirdLife European 2017c; Derhé 2012). Birds from different colonies congregate in the Black Sea during the non-breeding period, one of the most critical of the life-cycle of the species, when most of the mortality of adult birds (the major cause of the population decline) occurs (Oppel et al. 2011). Recent tracking studies have revealed that between 26% and 42% of the global population of the Yelkouan Shearwaters migrate to this region (Raine et al. 2012, Péron et al. 2013, Seabird Tracking Database 2017), which results in an estimate of approximately 30.000 individuals. Coastal counts at the Bosphorus have shown that up to several thousands of individuals can pass the straight in one single day (Şahin et al. 2012; 14). During coastal counts along the Bulgarian Black Sea coast in May 2015, over 21.000 individuals were counted in only 6 hours, flying north and presumably following the spring migration of fish (unpublished source). The phenomenon is observed regularly since 2010. At-sea surveys and studies of habitat suitability have also confirmed the importance of the Black Sea for the species (Ortega & İsfendiyaroğlu 2017).

Most of these IBAs include also the feeding sites for the Mediterranean endemic subspecies of European Shag *Phalacrocorax aristotelis desmarestii* during the breeding season (Doğa Derneği 2014). Several colonies of the species can be found both around the coasts of the Black Sea, with population estimates of several hundred breeding pairs estimated to breed here (Doğa Derneği 2014).

Several other species occur in these IBAs, many of which are also listed on Annex I of the EU Birds Directive; apart from the Vulnerable species mentioned above, other species are Slender-billed Gull *Larus genei*, Black Tern *Chlidonias niger*, Arctic Loon *Gavia arctica*, Red-throated

13 https://maps.birdlife.org/marineIBAs/default.html

14 http://www.osme.org/content/monitoring-yelkouan-shearwaters-bosphorus

Loon *Gavia stellata*, Audouin's Gull *Larus audouinii*, Mediterranean Gull *Larus melanocephalus*, Great White Pelican *Pelecanus onocrotalus*, Red-necked Phalarope *Phalaropus lobatus*, Caspian Tern *Hydroprogne caspia*, Common Tern *Sterna hirundo*, Common Gull-billed Tern *Gelochelidon nilotica* and Sandwich Tern *Thalasseus sandvicensis*.

Monitoring

In general, Seabirds in the Black Sea are poorly studied. The International Waterbird Census (IWC 2017) is the main source of information about the numbers of waterbirds at wetland sites in the region, ongoing already for over 40 years and covering the territories of all 6 countries of the Black Sea (e.g. Kostiushyn et al. 2011). Nevertheless, there are major knowledge gaps on population size and trend, distribution, migration, important feeding and resting sites, as well as anthropogenic and natural threats.

Under art. 12 of the EU Birds Directive, Bulgaria and Romania are required to assess the status and trend of breeding and wintering populations of birds every six years. Similarly, the Marine Strategy Framework Directive requires from Member States to take the necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest15, including initial assessment, monitoring and reporting (every six years). Under the project "Preparing the basis for an inventory of Marine Important Bird Areas along the southern Black Sea Coast"16 (2012-2014), Bulgaria, Romania and Turkey have adopted and implemented for first time in the Black Sea, standardized ESAS methodology and coastal counts for seabird monitoring.

Threats

Coastal and water pollution, eutrophication, oil extraction and oil spills, light pollution, on shore and off shore constructions, declining food resources, by-catch in fisheries and human disturbance are among the main threats for seabirds in the Black Sea.

15 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:EN:PDF

16 http://ec.europa.eu/environment/marine/international-cooperation/regional-sea-conventions/bucharest/pdf/bsp_final_report_150228.pdf

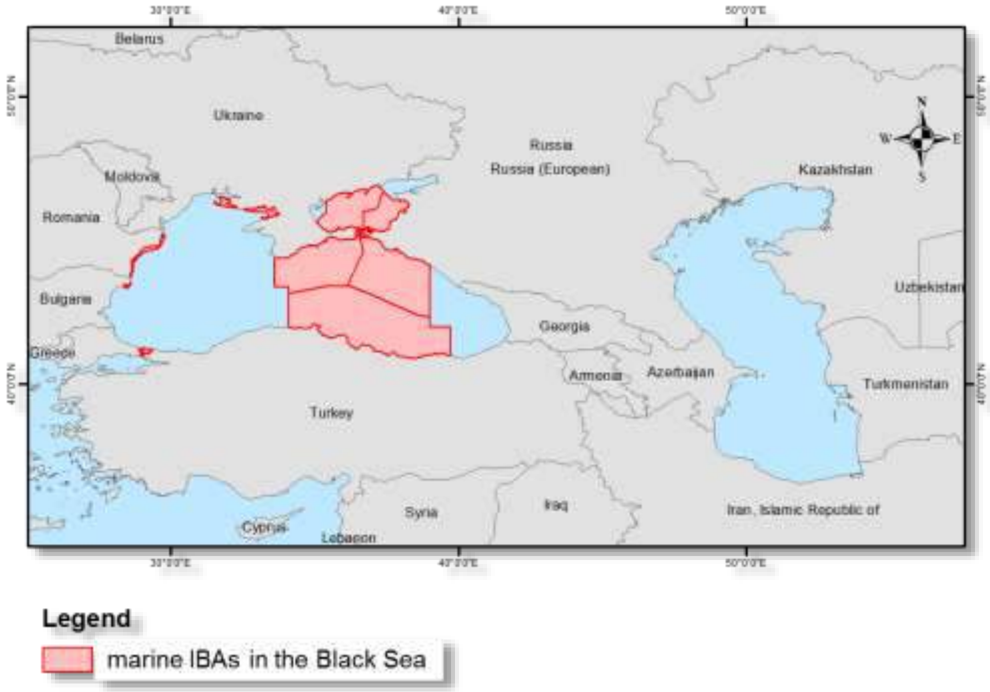

Figure 1.3.7.1. Marine IBAs of global importance in the Black and Caspian Seas.

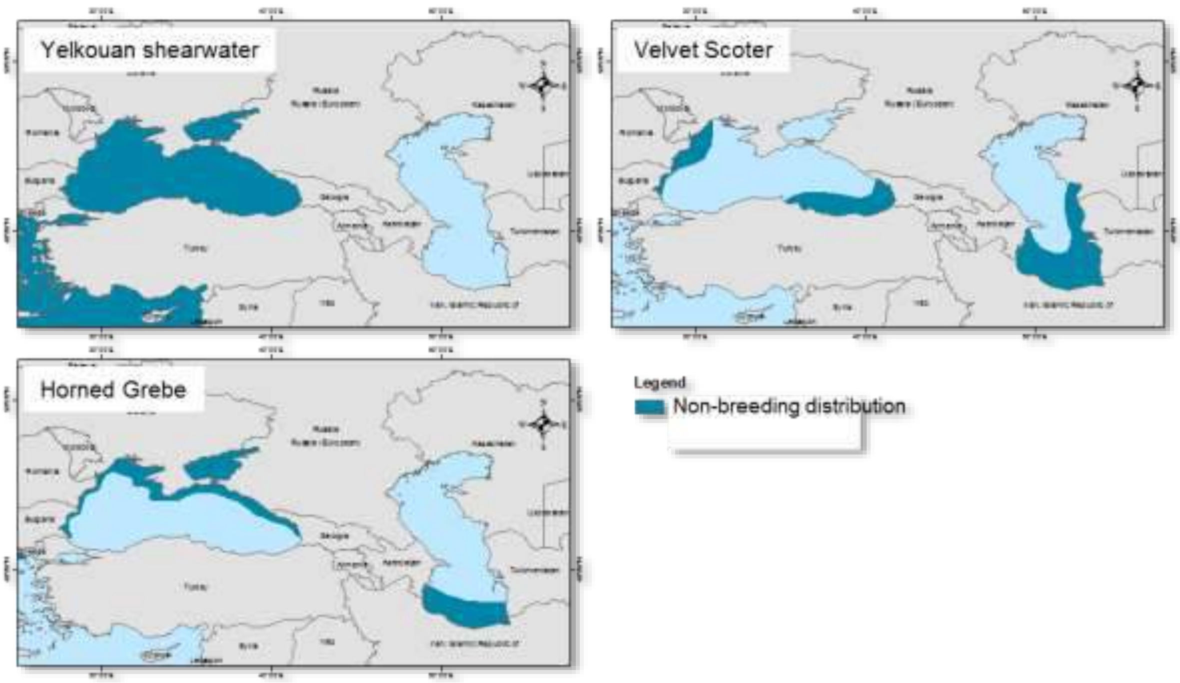

Figure 1.3.7.2: Distribution of the globally threatened seabird species occurring in the Black Sea and in the Caspian Sea (Yelkouan shearwater *Puffinus yelkouan*, Velvet Scoter *Melanitta fusca* and Horned Grebe *Podiceps auritus*)

Table 1.3.7.1: List of seabird species occurring in the Black Sea, including the countries where they occur. SPEC category corresponds to the "European birds of conservation concern" of BirdLife International (2017).

Family	English name	Scientific name	breeding (B)/ wintering (W)/ on passage (P)	Global IUCN Red List Category 2017	SPEC category 2017	BG	RO	UA	RU (Europe)	GE	TR
Anatidae	Greater Scaup	*Aythya marila*	W	LC	3	●	●	●	●		●
Anatidae	Common Eider	*Somateria mollissima*	B, W	NT	1	●	●	●	●		
Anatidae	Long-tailed Duck	*Clangula hyemalis*	W	VU	1	●	●	●	●		
Anatidae	Common Goldeneye	*Bucephala clangula*	B, W	LC	Non-SPEC	●	●	●	●	●	●
Anatidae	Red-breasted Merganser	*Mergus serrator*	B, W	LC	3	●	●	●	●		●
Anatidae	Goosander	*Mergus merganser*	W	LC	Non-SPEC	●	●	●	●		●
Anatidae	Common Scoter	*Melanitta nigra*	W	LC	Non-SPEC	●	●	●	●		●
Anatidae	Velvet Scoter	*Melanitta fusca*	W	VU	1	●	●	●	●	●	●
Podicipedidae	Red-necked Grebe	*Podiceps grisegena*	B, W	LC	Non-SPEC	●	●	●	●	●	●
Podicipedidae	Great Crested Grebe	*Podiceps cristatus*	B, W	LC	Non-SPEC	●	●	●	●	●	●
Podicipedidae	Horned Grebe	*Podiceps auritus*	W	VU	1	●	●	●	●	●	●
Podicipedidae	Black-necked Grebe	*Podiceps nigricollis*	B, W	LC	Non-SPEC	●	●	●	●	●	●
Gaviidae	Red-throated Loon	*Gavia stellata*	W	LC	3	●	●	●	●	●	●
Gaviidae	Arctic Loon	*Gavia arctica*	W	LC	3	●	●	●	●	●	●

Family	English name	Scientific name	breeding (B)/ wintering (W)/ on passage (P)	Global IUCN Red List Category 2017	SPEC category 2017	BG	RO	UA	RU (Europe)	GE	TR
Procellariidae	Yelkouan Shearwater	*Puffinus yelkouan*	W, P	VU	1	●	●	●	●	●	●
Pelecanidae	Great White Pelican	*Pelecanus onocrotalus*	B	LC	3	●	●	●	●	●	●
Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo*	B, W	LC	Non-SPEC	●	●	●	●	●	●
Phalacrocoracidae	European Shag	*Phalacrocorax aristotelis*	B, W	LC	2	●		●	●		●
Scolopacidae	Red-necked Phalarope	*Phalaropus lobatus*	P	LC	Non-SPEC			●	●		●
Laridae	Mew Gull	*Larus canus*	W	LC	Non-SPEC[E]	●	●	●	●	●	●
Laridae	Lesser Black-backed Gull	*Larus fuscus*	P	LC	Non-SPEC[E]	●	●	●	●		●
Laridae	Pallas's Gull	*Larus ichthyaetus*	B	LC	Non-SPEC		●	●	●	●	●
Laridae	Black-headed Gull	*Larus ridibundus*	B, W, P	LC	Non-SPEC[E]	●	●	●	●	●	●
Laridae	Slender-billed Gull	*Larus genei*	B, W, P	LC	Non-SPEC	●	●	●	●		●
Laridae	Mediterranean Gull	*Larus melanocephalus*	B, W, P	LC	Non-SPEC[E]	●	●	●	●		●
Laridae	Little Gull	*Hydrocoloeus minutus*	W, P	LC	3	●	●	●	●		●
Laridae	Caspian Tern	*Hydroprogne caspia*	B	LC	Non-SPEC	●	●	●	●		●

Family	English name	Scientific name	breeding (B)/ wintering (W)/ on passage (P)	Global IUCN Red List Category 2017	SPEC category 2017	BG	RO	UA	RU (Europe)	GE	TR
Laridae	Sandwich Tern	*Thalasseus sandvicensis*	B, W	LC	Non-SPEC[E]	●	●	●	●		●
Laridae	Common Tern	*Sterna hirundo*	B	LC	Non-SPEC	●	●	●	●	●	●
Laridae	Little Tern	*Sternula albifrons*	B	LC	3	●	●	●	●	●	●
Laridae	Black Tern	*Chlidonias niger*	B	LC	3	●	●	●	●	●	●
Laridae	Caspian Gull	*Larus cachinnans*	B, W	LC	Non-SPEC	●	●	●	●	●	●
Laridae	Common Gull-billed Tern	*Gelochelidon nilotica*	B	LC	3	●	●	●	●		●
Laridae	Yellow-legged Gull	*Larus michahellis*	B, W	LC	Non-SPEC[E]				●	●	●
Stercorariidae	Arctic Jaeger	*Stercorarius parasiticus*	P	LC	Non-SPEC	●	●		●		●

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1.3.8 Deoxygenation in the Black Sea

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Summary

The Black sea is a wide Oxygen Minimum Zone (OMZ) which results from natural and anthropogenic factors. Its vertical structure (i.e. presence of a permanent halocline) and semi-enclosed character make it a naturally poorly ventilated region. Only the first ~100m of the water column is enriched in oxygen by photosynthesis and winter mixing and waters below 100-150 m (~87 % of the volume) are deprived from oxygen. Next to this huge anoxic reservoir located in the deep basin, recurrent OMZs have been identified on the bottom of the north-western shelf. In this case, the formation of an OMZ is seasonal and results from anthropogenic eutrophication combined to warming.

Although the investigation of the Black sea biogeochemical structure has been at the core of many research initiatives, still there were a lot of uncertainties on the fate of the deoxygenation process and on its impact on ecosystem functioning and biogeochemistry. For instance, there are still controversies on the possible long term stability of the deep basin's chemical structure and in particular, on the vertical extension of the oxygenated layer. On the northwestern shelf, the discussions concern the occurrence of bottom OMZ after the decrease of eutrophication in the 90's.

We have used model simulations and data analysis in order to investigate the deoxygenation process in the Black sea north-western shelf and deep basin. On the north-western shelf, we show that seasonal hypoxic events still occur in the northern part in summer. This finding is in agreement with local Ukrainian data sets but is against the idea that hypoxia does not occur anymore when eutrophication decreases in the 90s. This study leads to two important recommendations: 1) future monitoring strategies have to be focused on areas and during periods when low oxygen events are expected; 2) eutrophication has to be managed considering the global warming of the environment.

For the deep sea, we show that between 1955 and 2015, the oxygen penetration depth decreases from 140 m in 1955 to 90 m in 2015 which means an average rising of 7.9m per decade. This trend has been interpreted as follows in the 70s and 80s as already pointed out by Konovalov and Murray (2001), the eutrophication process that affected the Black sea north-western shelf led to an increased input of organic matter to the deep sea and higher oxygen consumptions . After 1996 climate warming led to a reduction in the volume of Cold Intermediate Layer (CIL) formation which acts as a (the) main vector for ventilation. We expect that the ARGO program will provide essential dataset to monitor this worrying trend that may accelerate in the context of global warming.

Introduction

The problem of decreasing oxygen content (deoxygenation) of coastal and oceanic waters worldwide has worsened in recent decades, primarily as a result of climate change, agricultural runoff and inputs of human waste. Deoxygenation of marine waters is predicted to further worsen with continued increases in global temperatures and human population size, with widespread consequences. Low oxygen environments have been at the core of important international conferences and for instance the Euro-Ocean conference on oxygen (http://www.eur-oceans.eu/conf-oxygen), the 44th international Liege colloquium on Low Oxygen Environment in marine, estuarine and fresh water systems (http://modb.oce.ulg.ac.be/?page=colloquium&year=2014) and London Royal Society conference on Ocean ventilation and deoxygenation in a warming world. Recently, the International Oceanographic Commission of Unesco (IOC-Unesco) has launched a global oxygen network

(GO_2NE) in order to raise awareness about the deoxygenation issue and to crystallize the disparate efforts that are taken worldwide.

Below a given threshold, low oxygen conditions impact biogeochemistry and the degradation of organic matter uses an alternate oxidant than oxygen. It is usually considered that suboxic conditions prevail when O2<20 µmol/l which is when denitrification starts. Low oxygen values also affect ecosystem functioning and the generic term of hypoxia is used to refer to oxygen concentrations that will be detrimental for living communities (e.g. O2< 63 µmol/l). It would be more appropriate to speak about specific threshold since each species has its own level of tolerance to deoxygenation (e.g. Vaquer-Sunyer and Duarte, 2008). Although deoxygenation is a worldwide phenomenon of global concern that may compromise the Good Environmental Status (GES) of marine waters there are still a lot of uncertainties on its dynamics, fate, causes, impacts…. It is thus urgent to tackle hypoxia through a holistic approach combining field work, laboratory experiments and the development of science-based tools targeted towards the understanding and prediction of deoxygenation.

Towards that aim, various international and national initiatives have been conducted in the Black Sea in order to investigate its vertical chemical structure and in particular its oxygen conditions (e.g. KNORR and Geotraces expeditions, EU FP7 Hypox project, INCO-VENTIL). Recently, the BENTHOX project (link) is completely dedicated to the development of tools to understand and mitigate bottom hypoxia on the north western shelf and in cooperation with EMBLAS (i.e. Environmental Monitoring in the Black Sea; http://emblasproject.org/) to the collection of oxygen data throughout the shelf in order to understand the impact of benthic hypoxia on biogeochemistry and ecosystem functioning.

These initiatives have provided essential information on the understanding of the oxygen dynamics (e.g. Murray et al., 1992; Gregoire et al., 2001) but still uncertainties remain on for instance the long term fate of the anoxic and suboxic layer, vertical oxygen content, extension and management of shelf hypoxia, the adequate deployment of a monitoring system that could serve as an alarm in case of hypoxic conditions, the impact of hypoxia on ecosystem and in particular aquaculture.

Here, we investigate the deoxygenation process on the shelf and deep sea. In the deep sea, we assess the long term dynamic (60 years) of the integrated oxygen content and the upper suboxic interface and on the shelf we show that seasonal hypoxic events still occur in the northern part and identify its drivers.

Materials and Methods

The dynamics of coastal hypoxia has been investigated using a tri-dimensional coupled hydrodynamic-biogeochemical model that describes biogeochemical processes from the surface to the bottom. The model has been described in Grégoire et al., 2004, 2008 and Capet et al., 2012. Its application to the study of the occurrence of hypoxic events on the Black sea north-western shelf is described in Capet et al., 2013.

The long term evolution of the oxygen profile characteristics in the deep basin between 1955 and 2005 is investigated using the analysis of 4385 ship-based vertical combined with that of recently collected ARGO profiles data. This analysis is realized with the DIVA advanced data analysis software and details can be found in Capet et al., (2016). From each profile we derived (1) the depth and (2) the potential density anomaly σ_θ where oxygen concentration went below 20µM and (3) the oxygen inventory, integrated above this limit (Fig. 1). The threshold value of 20µM used to define the upper interface of the suboxic layer was suggested to compare oxygen observations issued from sensors with different detection limits (Konovalov and Murray, 2001).

Results

Deoxygenation in the deep basin

Variability of oxygen profiles on a density scale

Controversies still exist on the long term fate of the oxygenated, suboxic and anoxic layers. These controversies result from the difficulties in obtaining meaningful diagnostics at basin scale and over several decades. In order to remedy to the lack of data, past works that have investigated the long term change of the Black sea vertical chemical structure have preferentially used vertical profiles on a density scale because this presentation reduces data scatter seen in depth coordinates and is assumed to render the vertical profiles quasi-independent from geographical location and time of the year (e.g., Codispoti et al.,1991; Saydam et al., 1993; Tugrul et al., 1992, Konovalov and Murray, 2001). The long term variability is then assessed by combining data profiles indifferently of the time and place of collection. However, very few studies have attempted to assess the spatial and seasonal variability of O2 and H2S profiles on a density scale. We can cite the studies of Glazer et al., (2006) and Stanev et al (2013) that show that, over the year and over the basin, the variability of the O2 profile on a density scale may have an order of magnitude comparable to that of identified long term trends. This complicates the differentiation between possible long term trends and spatial/temporal variability. Hence, the analysis of density profiles calls for the use of advanced methodologies to combine profiles taken in different places and time. In Capet et al. 2016, we use an advanced interpolating tool to analyze oxygen profiles on a density and depth scales over the period 1955-2015 (the tool is described in Capet et al. 2014). We confirm that the use of isopycnal coordinates does not overcome the significant spatial variability of oxygen penetration depth. For instance, we find that the spatial distribution of the potential density anomaly of the upper suboxic layer (defined as O2=20µM) presents a variability of 0.35 km/m3 with higher density values in coastal areas, especially in the Bosphorus region (σ_θ= 16.1 kg/m3) and lower values in the central parts (σ_θ=15.75 kg/m3). This variability of oxygen profiles when expressed on a density scale may be explained by the fact that biogeochemical processes that do not occur along isopycnal surface like specific motions of biological populations, light penetration, vertical sinking and aggregate formation may also impact the distribution of chemical variables and hence introduce a scattering in density chemical profiles. Additionally, the convective sinking of the oxygenated Bosphorus plume and its advection, as well as diapycnal mixing processes arising from the interaction of the Rim current with the coastline induce spatial variability in the ventilation rates (e.g. Zatsepin et al., 2007; Stanev et al., 2013).

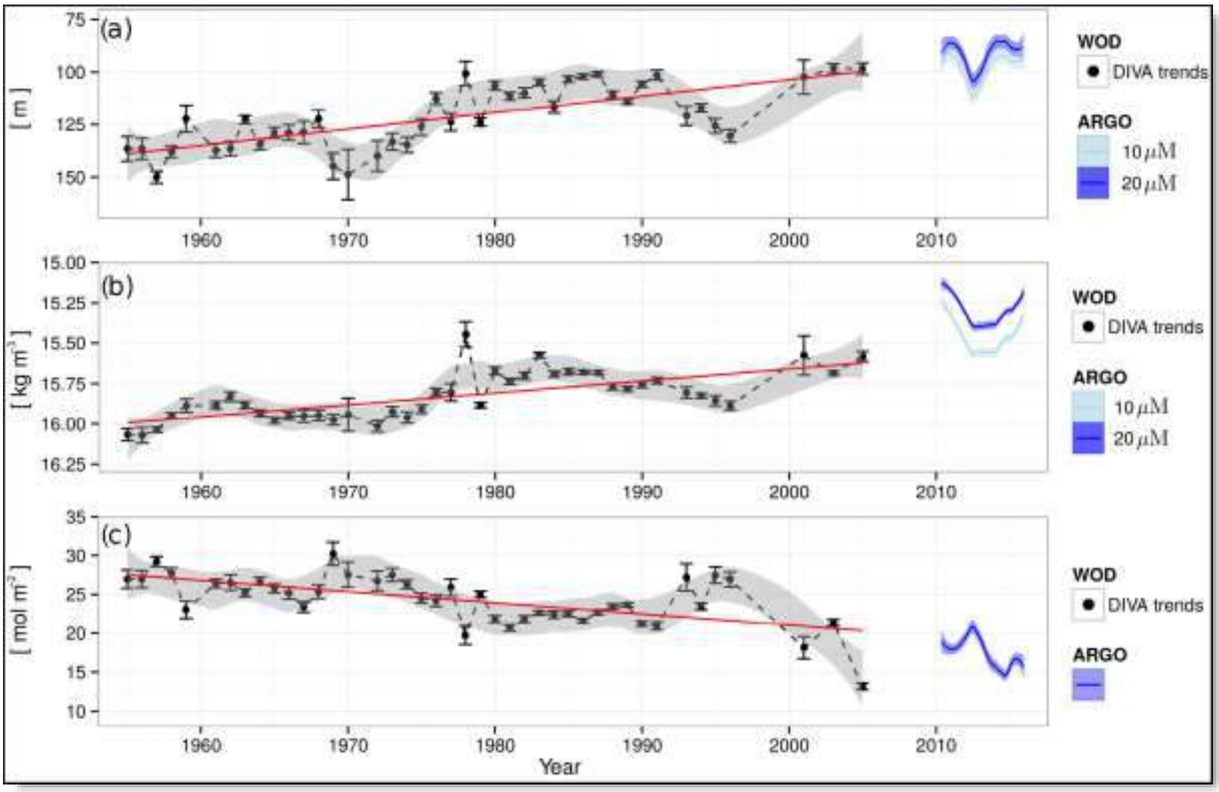


Figure 1.3.8.1: Trends of (a) oxygen penetration depth, (b) oxygen penetration density level (σ_θ) and (c) oxygen inventory deduced from (dots) DIVA analysis of ship-based casts and (blue) ARGO floats.

In (a) and (b), the diagnostics from ARGO are also shown for the lower threshold of 10μM to acknowledge a potential bias between Winkler and Argo data. Red lines: the linear trends assessed from the ship-based data set are -7.9 m decade^{-1}, -0.074 kgm^{-3} decade^{-1} and -1.44 molOm^{-2} decade^{-1} for (a), (b) and (c), respectively. Error bars on DIVA estimated trends indicate the standard error associated with the estimation of the mean misfit for each year (Figure taken from Capet et al., 2016).

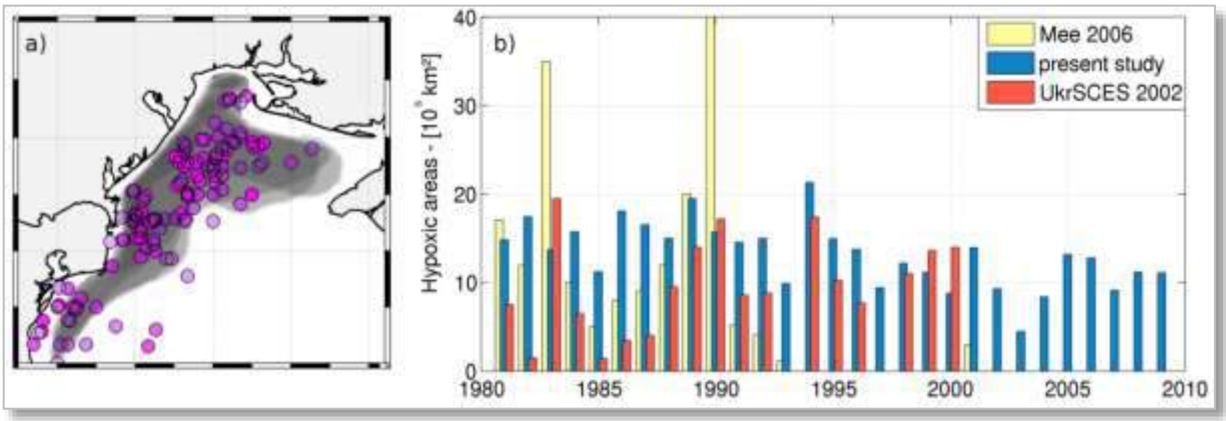
Long term evolution of the vertical oxygen content

Figure 1.3.8.1 shows the evolution over the last 60 years of the depth of the upper interface of the suboxic layer and the vertical oxygen content. Between 1955 and 2005, the oxygen penetration depth rose at an average rate of 7.9m per decade (Fig. 1.3.8.1a). The basin average was of 140m in 1955 (ship-based), 100m in 2005 (ship-based) and 90m in 2015 (Argo). This shoaling was also observed on a density scale. The oxygen inventory, integrated from the surface down to the suboxic upper interface, decreased by 44% during the last 60 years (Fig. 1.3.8.1c) considering the ship-based estimate for 1955 (27 molOm^2) and the Argo estimate for 2015 (15 molOm^2). The few ship-based profiles available after the mid-1990s revealed the lowest oxygen inventories recorded during the time frame 1955-2015. This shoaling was more intense between 1970-1985 and from 1996 onwards. Capet et al (2016) found a positive correlation between the intensity of CIL formation (CIL cold content) and the vertical oxygen content during the whole period. In the early 1990s, the transient recovery of the three oxygenation diagnostics (Figs. 1.3.8.1a, b, c) provided arguments supporting the stability of the oxic interface (Tugrul et al., 1992; Buesseler et al., 1994). This stabilization matched the convenient perception of a general recovery of the Black Sea ecosystem after the reduction of nutrient load around 1990 (Kroiss et al., 2006). However, we show that this transient recovery during the period 1986–1998 was associated with much higher ventilation rates (i.e., higher

CIL cold content) during that period than during the previous periods which masked ongoing high oxygen consumption. The fact that the relationship between oxygen inventories and CIL content for the last period 1999–2015 is similar to that of 1986–1998 indicates a stabilization in the biogeochemical oxygen consumption terms. Higher air temperature in this last period (Oguz and Cokacar, 2003; Oguz et al., 2006; Pakhomova et al., 2014), by limiting winter convective ventilation events (Capet et al., 2014) led to the lowest oxygen inventories ever recorded for the Black Sea.

Deoxygenation on the northwestern shelf

In his seminal paper on reviving Dead Zones, Mee (2006) raises awareness on the occurrence of hypoxia along the Romanian and Ukrainian coasts in the 70s and 80s. The occurrence of these dead zones is thought to kill an estimated 60 million tons of bottom living species. Mee estimates that this dead zone extends up to a surface of 40,000 km2 at its extreme in the 90s which represents more than half of the shelf surface and is almost twice the extension of the dead zone in the Gulf of Mexico off the Mississippi River delta. Eutrophication has been identified as the main driver of the hypoxic events that occurred from the end of the 70s until early 90s. Indeed, the increased nitrogen and phosphorus inputs to the northwestern shelf intensify the phytoplankton blooms whose a significant fraction reaches the bottom to be degraded by bacteria. From the end of spring until late summer, the shelf circulation is anti-cyclonic and hence the Danube's discharges are first transported to the northern shelf where they lead to huge blooms. During that period, the water column is strongly stratified by the formation of the seasonal thermocline but also by the presence of a halocline associated to the river discharges. This strong stratification prevents the ventilation of bottom waters and leads to the occurrence of an OMZ on the bottom. In the 90's, nutrient runoff sharply dropped off due to the agricultural and industrial activities that slowed down due to the collapse of the communist regime in eastern Europe and it was often argued that the Black sea shelf recovered from bottom hypoxia after the decrease of eutrophication. However, Capet et al., (2013) show that bottom hypoxia still occurs in summer in the northern part of the shelf. This finding has been corroborated by Ukrainian data sets (Figure 1.3.8.2). The cause of this prolongation of hypoxia is the sediment that continues to consume large oxygen quantities to remineralize the organic matter accumulated during the previous years. Sediment inertia has already been pointed out as a factor that delays the recovering from hypoxia and complicates the prediction of the time scale necessary to restore the system. Capet et al. (2013) estimate an inertia-timescale of ~9 years. During the last decade, climate warming with the reduced spring ventilation (due to lower oxygen solubility) and the extension of the summer stratification period is the main driver of seasonal hypoxia (Capet et al., 2013).



fig

Figure 1.3.8.2: (a) Area affected by hypoxia, redrawn from Zaitsev (1997), and locations of hypoxic records from the WOD database. (b) Extension of the surface affected by bottom hypoxia,

as reported in the literature (Mee, 2006; UkrSCES, 2002) and simulated by the 3-D model (Capet et al., 2013).

Managing Hypoxia

The Black Sea needs an integrated observing system targeted towards the monitoring of the Good Environmental Status (GES) of its ecosystem. The occurrence and extension of OMZ may compromise the GES and hence should be carefully monitored. In the northern part of the shelf the occurrence of seasonal hypoxic events may be detrimental for the benthic ecosystem and marine resources. An alarm system is needed in targeted places (e.g. aquaculture, sensible species). In the deep sea, the ARGO program will provide a wealth of information to monitor the position of the oxygenated layer as well as the possible incursion of anoxic waters on the northwestern shelf. The contradicting conclusions on the recovering from hypoxia on the shelf can be explained by the lack of data collected after 1995 in places and where we expect to have hypoxia.

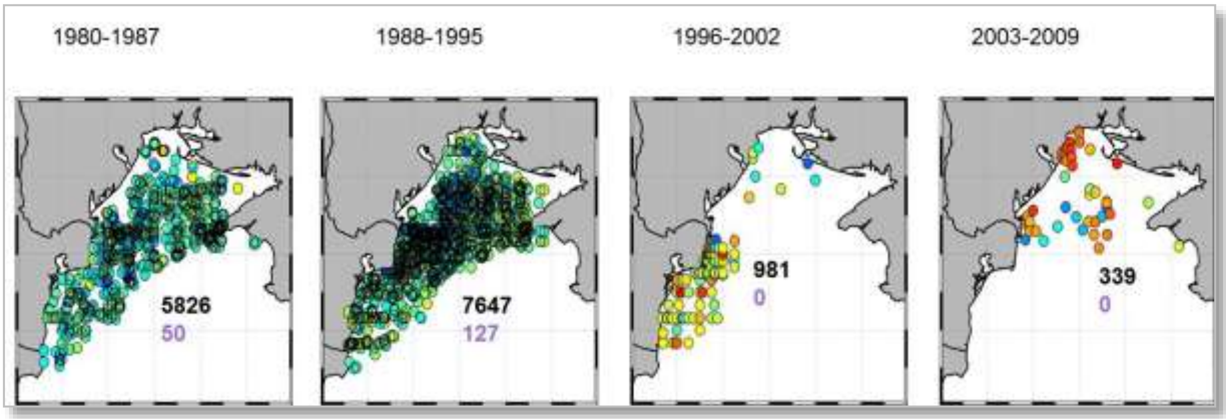


Figure 1.3.8.3: Distribution of data collected during the last decades and available in the World Ocean data base. After 1995, no data has been collected in areas and during periods of occurrence of hypoxia.

The Millennium Ecosystem Assessment report released by the United Nations in 2005 reported that the supply of nitrogen-containing compounds to the sea is expected to grow by 65 percent by mid-century. Climate warming will add another threat because higher temperatures will reduce the ventilation mechanisms by extending the length of the stratification period and reducing the solubility of oxygen in warmer waters. In the case of the Black Sea, governments of riparian countries aided by the United Nations Global Environment Facility have agreed to pursue an initiative to maintain nutrient runoff levels at those of the mid-1990s. The definition of an "acceptable" level of nutrient discharges is of course a challenging issue that depends on the level of hypoxia that can be tolerated. We start to realize how hypoxia may affect ecosystem functioning, biogeochemistry, marine resources but still significant efforts are needed in order to better quantify and value the impact hypoxia may have on the goods and services provided by the sea at the scale of the shelf. Robust science-based tools that make the link between the different processes and scales at stake combined with a targeted observing system are needed. Towards that aim, Capet et al., (2013) proposes the definition of a H index that can been seen as an environmental indicator of the severity of hypoxia. This index integrates the spatial and temporal dimension of the problem. Figure 1.3.8.4 shows the evolution of this H index as a function of the amount of nutrients discharged by the Danube (here nitrogen) for climate conditions typical of 1981-2009 (black curve) and 2015-2020 (red curve). We can see that if one wants to keep the level of hypoxia unchanged (H constant) in the 2015-2020 climate, the nutrient discharged has to be decreased. If not, the level of hypoxia will increase because in a warming world the solubility of oxygen will decrease and the stratification will intensify. The key message is that the management of hypoxia has to take into account the warming of the climate.

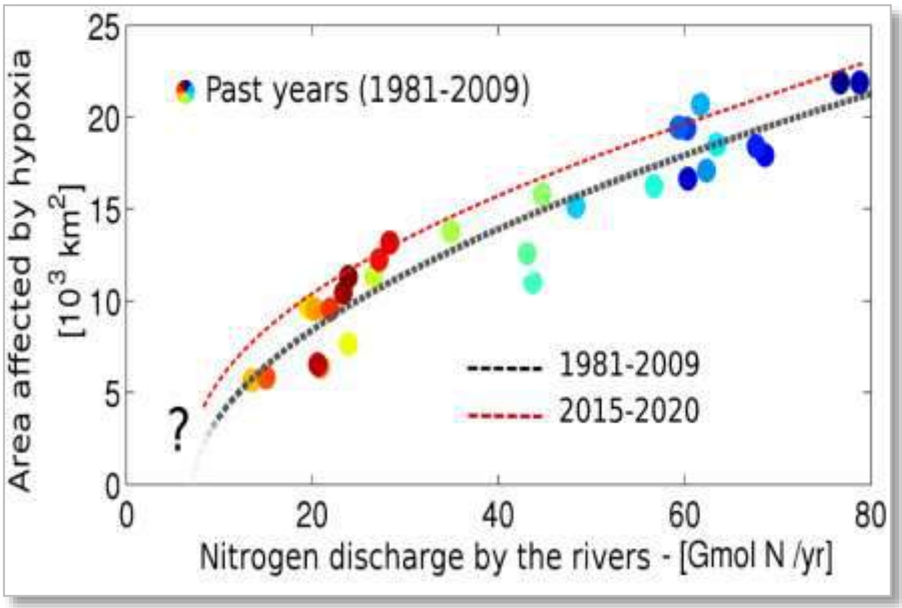


Figure 1.3.8.4: Level of hypoxia, H, reached at "equilibrium" for a range of nitrate riverine load, N.

Coloured dots: results from the tridimensional physical-biogeochemical model; dotted lines: results from a statistical non-linear model obtained by fitting 3D model predictions. The black dotted line represents the relationship obtained for a climate typical of 1981-2009 while the red one shows results for a climate typical of the period 2015-2020. (Figure reproduced from Capet et al., 2013, for further details please refer to this paper).

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CHAPTER 2. STATE AND DYNAMICS OF THE LIVING AND NON-LIVING RESOURCES AND THEIR EXPLOITATION IN THE BLACK SEA REGION

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This Chapter is to assess conditions of the marine living resources for the period of 2009-2014 and compare with the earlier period to explain the changes occurred. It is to inform on anadromous fishes, and then about pelagic fishes.

Lack of sufficient information concerning the fishing activity, catch quantities, composition and its impact on the current state of the fish stocks are the critical issues for in the Black Sea region though there are a number of techniques which have been and currently are in place for recording, evaluating, controlling and monitoring of the fishing activities as well as a number of surveys of the current state of the fishing stocks performed.

The analysis of data collected shows that:

- there is only one stock – sprat which is considered sustainably exploit;
- most of fish stocks in the Black Sea are overexploited to the extent that some of them are nearly to depletion.

Therefore, there is the need to put more efforts in recovery and sustainable development of the fishing stocks to targeted levels of abundance identified.

Common Fishery Policy of EU (CFP) aimed at protection measures to prevent the over exploitation of the fish stocks. Measures, being developed and implemented, could mitigate the impact of the fishing activities endangering reproductive capacity and jeopardy the fish stocks (EC, 2009).

Acknowledgement

The main body of the chapter represents a compilation from STECF EWGs Black Sea assessments, AG FOMLR, BSC annual reports and GFCM WGBS and SGSABS reports. The results obtained, for the purposes of analysis of SOE report, are as a result of common efforts of many scientists from Black Sea, Mediterranean Sea countries and JRC EC. Thanks to M&E and partners and study Lot No. 2: Adverse Fisheries Impacts on Cetacean Populations in the Black Sea.

2.1. MAIN BIORESOURCES

The following indicators were used to acknowledge the status of main bioresources:

- Long-term dynamics of recruitment, biomass and catches, population structure; relevant indicators - e.g. body size or age class structure, sex ratio, fecundity rates, survival/ mortality rates, genetic structure where appropriate, spawning stock, proportion of fish larger than a given length, size at full sexual maturation, etc.- to be demonstrated
- Spatial distribution of biomass (abundance)

2.1.1 Anadromous fishes

Black Sea is Pontic Shad (*Alosa immaculata* E. T. Bennett, 1835)

For Bulgarian catches, Rodionov method (2004) for regime shifts was applied for differentiation of periods with sharp alteration in values of landings (Fig.2.1.1.1.). Results show regime shift in landings during the period 1951 – 1955, when average catch reached 217.50 t. using the 6 years cut off period. In case of 10 years cut off period, regime shift was not detected. For the previous years (1925 – 1950), average landings amounts at 77.15 t. and after period with regime shift (1956-2010), mean landings decreased to 39.93 t.

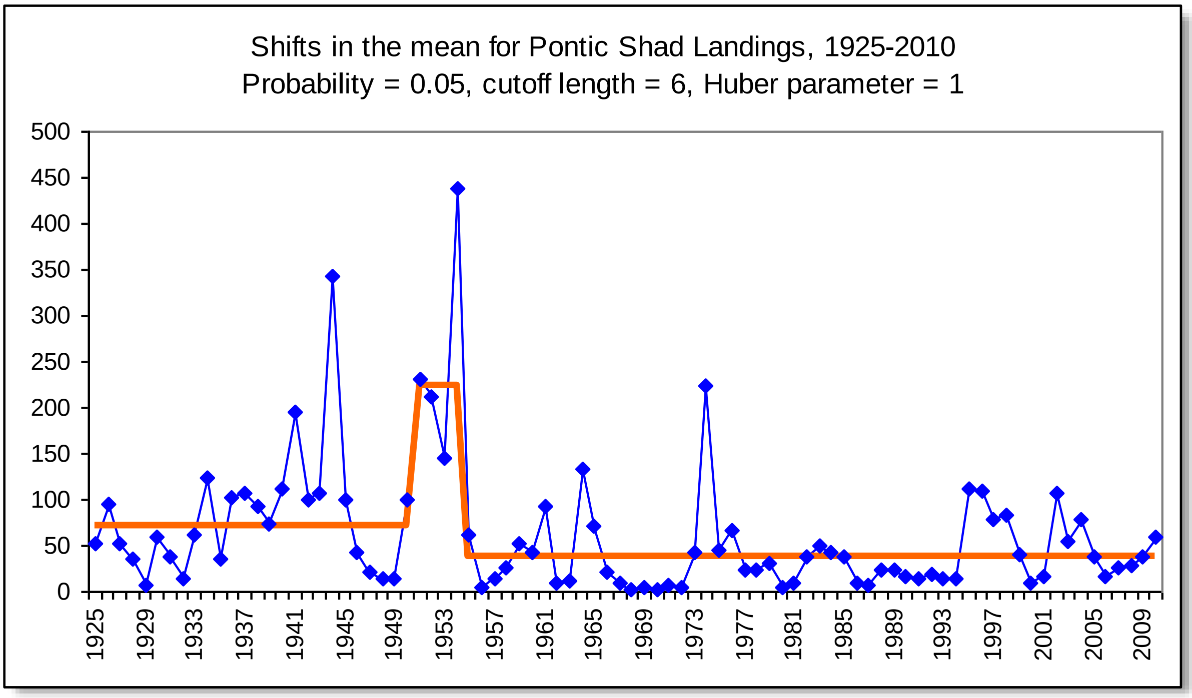


Figure 2.1.1.1. Shifts of the mean landings of pontic shad, 1925-2010 (Panayotova et al., 2012)

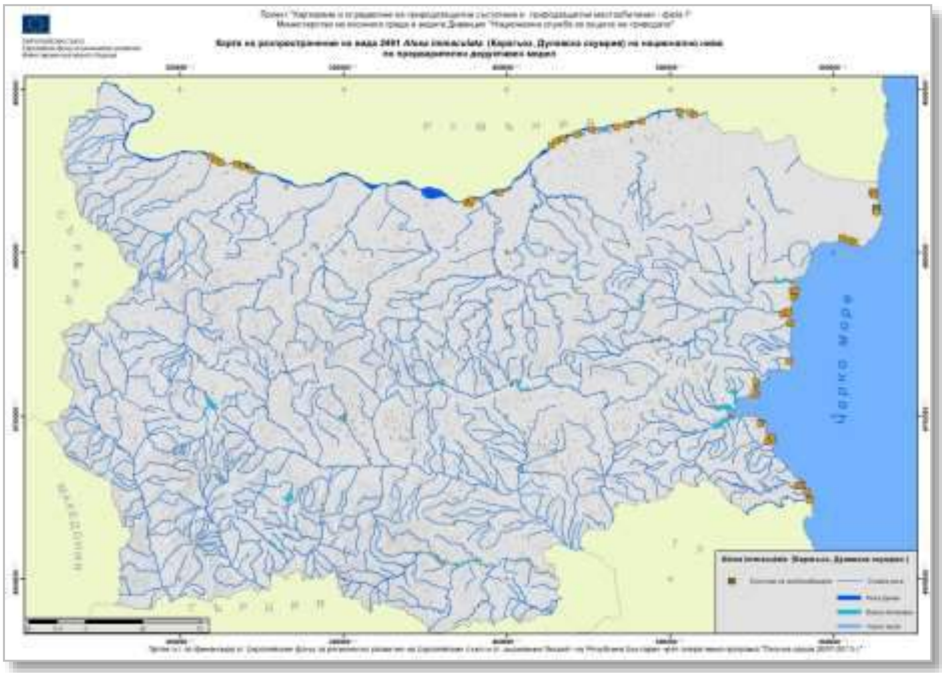


Figure 2.1.1.2. Map of Alosa immaculata distribution in Danube River and marine area (Bulgarian part)
(http://natura2000.moew.government.bg/PublicDownloads/Auto/SDF_REF_SPECIES/4125/4125_Species_102.pdf)

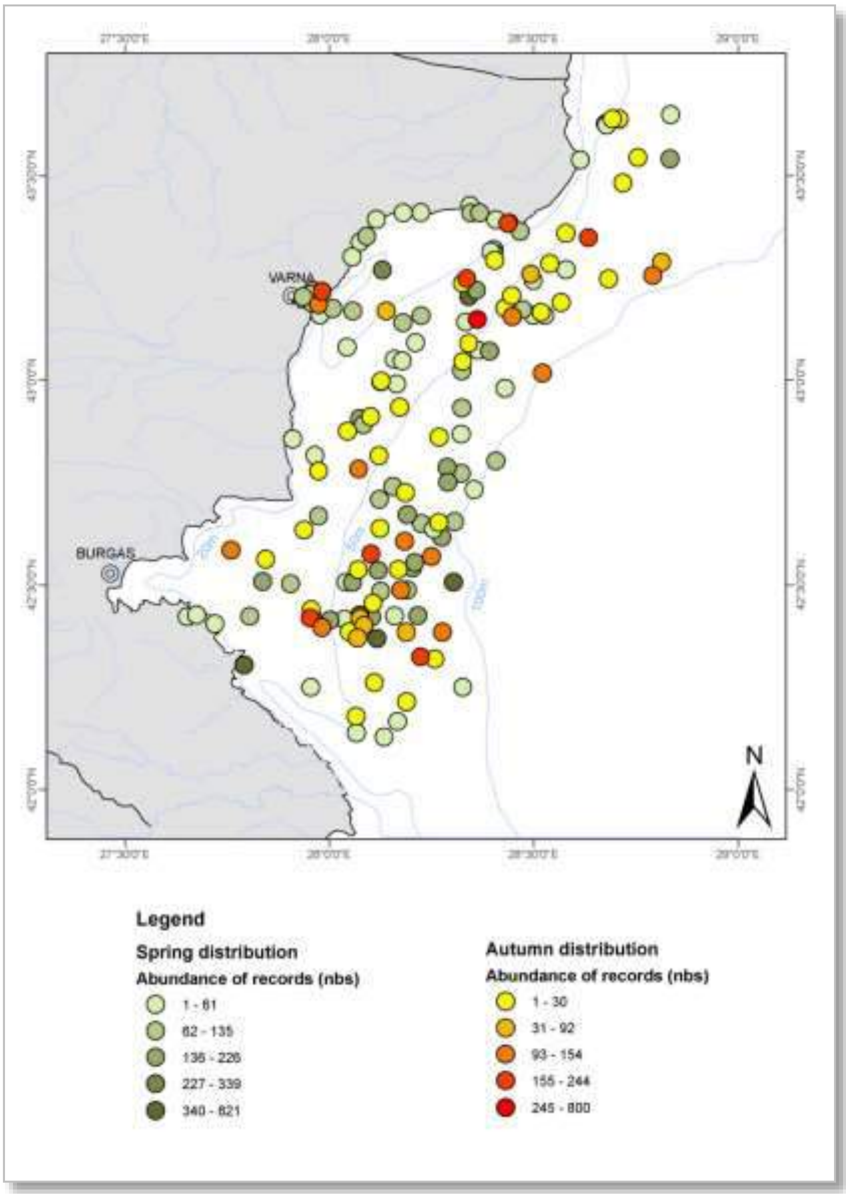


Figure 2.1.1.3. Shad distribution in spring and autumn season in 1956-2011 (Panayotova et al., 2012)

Analysis of all shad records in spring season during the period 1956 – 2011 show dispersed distribution of species in both coastal and open sea areas up to 100 m. Because research cruises cover only area up to 100 m, presence of shad in deeper waters is still unknown. Shads present in trawl and pound net catches. Most abundant records during the spring season were observed in front of Varna, cape Emine and Sozopol (Fig.2.1.1.3.). In autumn season, shads inhabit whole marine area, but fish were withdrawn after 20 m isobath. Most abundant records were made off Varna, Kaliakra and Burgas Bay. Because the shad population, migrating along Bulgarian Black Sea coast is relatively low abundant, special measures and designation of marine protected areas are required for conservation of this valuable species (Panayotova et al., 2012)

Size structure.

Length-Weight relationship of shad for the period 2010-2011 was $W=0.0037L3.3453$ .The growth in this period was positive alometric, as the coefficient of alometry was $n>3$.

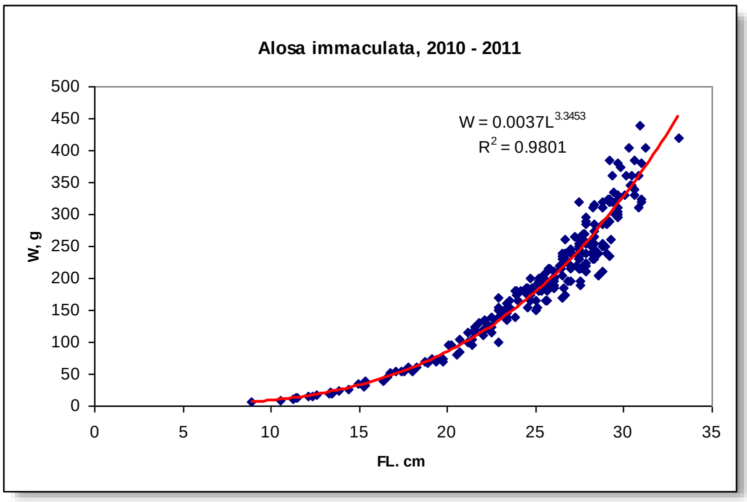
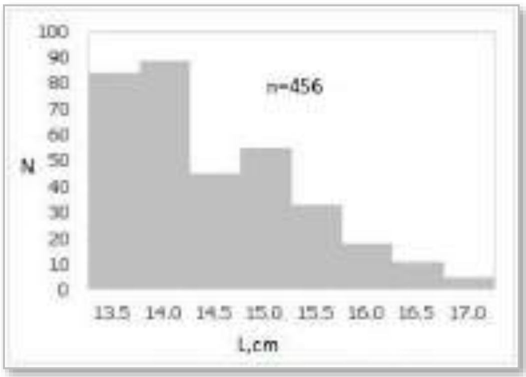


Figure 2.1.2.4. Length – weight relationship of Pontic shad (2010-2011)

The histogram of *Alosa immaculata* size structure, caught in uncovered trap nets (in September, 2014) reveals bi-modal distribution on the left side of the histogram with a preponderance of size groups 13.5-14 cm. 14.5 -15.0 length groups have lower numbers, as the smaller numbers have 15.5-17cm groups. There are no individuals larger than 17 cm, which indicates the presence of young, not sexually mature individuals aged 1+ years. The state according to this criteria is estimated to be "unfavorable unsatisfactory". The number of caught specimen in autumn (n=320) were lower, as clear bi-modal distribution and lack of individuals with higher than 15 cm size, reveals the state according to this criteria as "unfavorable unsatisfactory"(Raykov et al., 2016).



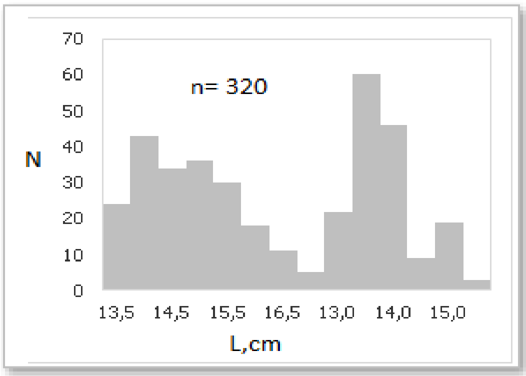


Figure 2.1.2.5.(a) A. immaculata, Spring-summer, Length groups (cm) (b) A. immaculata, Autumn, Length groups (cm) (Raykov et al., 2016)

Clupeidae is one of the world's most commercially important families of fishes. Despite their importance, little is known about the phylogenetic relationships within Genus Alosa, resulting in systematic and taxonomic uncertainty, which may undermine the establishment of adequate conservation measures (Ivanova et al. 2012). Using starch gel electrophoresis 19 protein fractions are present, but polymorphism in the species compared was not found. The analysed Atlantic anadromous shad species from Genus Alosa (A. *sapidissima*, *A. aestivalis*, *A. pseudocharengus* and A. sp., close to the *A. sapidissima* showed differences in their electrophoretic and morphologic characteristics, while the Black Sea shads (*A. immaculata* and *A. caspia*) are not good distinguished. The Black Sea shads, electrophoretically analyzed in the present study were preliminary morphologically determined as A. immaculate and *A. caspia.(*Ivanova et al.,2012). The isoelectric focusing spectra on thin and ultrathin polyacrilamide Ampholine and Servalite gel plates showed 40-41 general protein fractions. Differences between the elctrophoretical spectra of the two species analysed in the Black Sea were not found, with exception of several samples. The same rare specters were established also in *A. immaculata* and *A. caspia*. In view of the absence of correlation between morphological and genetical differences between the species compared we decided to mark all Black Sea shads as *A. immaculata* complex. Using isoelectric focusing (IEF) on muscle tissue, polymorphic variations in three loci (PROT-1*, PROT-2* and PROT-3*) were detected. Polymorphism on *A. immaculata* complex was observed in Varna Bay and Kaliakra The criteria $\chi 2$ didn't increase 3.84, which is evidence for equilibrium in the populations analyzed. Only in one sample a higher value of $\chi 2$ (4.883) was registered, which indicate that we are analyzed at least two mixed populations (Ivanova et al., 2012)

The conservation status of the shads in the Black Sea

The most European anadromous fish species are endangered and listed in the habitats fauna directive, the Bern convention and the IUCN Red List. Alosa species (Genus Alosa) are extremely vulnerable to anthropogenic changes, especially related to access and quality of their spawning grounds (Faria et al. 2006). The major threats to these species and communities include industrial and domestic pollution, acidification, land use changes, river barriers, drainage, fish farming, fishery management and the introduction of new species. Recently, restoration and conservation programs including the protection of spawning areas should be initiated. The current threat to the species is overfishing, at sea and in the rivers during the migration runs, which is causing a population decline of unknown levels. The area of the remaining spawning grounds is estimated to be less than 2,000 km² (Freyhof & Kottelat, 2008). Alosa spp. has relatively low share in the total marine yield from Bulgarian Black Sea area (337.1 t). Its trophic level is 3.93 (±0.63) (www.fishbase.org), and major catch of the species in the last years has been realized by Turkey (10 210 t). In other Black Sea countries the share of the species in the landings is insignificant. Expert assessments show that real catch of the species in Black Sea is highly underestimated and still unknown. In view of the difficulty to identify shad species (included in the catches) in the Black Sea it is impossible to estimate their stocks assessments and conservation status. For species determination of the shads genetical analyses are needed and to find correlation between genetical and morphological characters. All Black Sea shads were marked in the IUCN as vulnerable species. The data deficient for all of them present the necessity to additional carefully study of these species. For proper fishery management conservation measures should be applied in the Black Sea. Priority areas for further research should include ecology of the juvenile (freshwater) and marine phases, genetical identification and monitoring of species and populations and detailed population dynamics research (Ivanova et al., 2012)

2.1.2 Key pelagic fishes

Black Sea anchovy (Engraulis encasicolus ponticus) and Azov anchovy (Engraulis encasicolus maeoticus)

The assessments conducted in GFCM and as well as in STECF, assume that the anchovy exploited by countries providing data are of a single stock. On the other hand it is well documented that there are at least two different subspecies in the Black Sea, *Engraulis encrasicolus ponticus, and E. e. maeticus*. (Chashchin 1996, Ivanova et al., 201X). According to (Chashchin et al., , 2015), the character differences typical for the subspecies are growing again several years after a massive populations mixing in the Black Sea. This is likely to result from the inheritance linkage of the most characteristic subspecies' characters to the eggs shape (Chashchin, 1995, 1996). The maintenance of the subspecies' differences is facilitated by the anchovy immigration from the Mediterranean through the Bosporus Strait, as the Mediterranean anchovy has even more significant differences from Azov anchovy. It is similar to the Black Sea anchovy in longer body, lower body fat rate and by other characters.

Azov anchovy matures and spawns in the second year of life. Black Sea anchovy also mainly spawns at age 1 +. A small part of each new generation of the Black Sea anchovy (less than 3%) reaches sexual maturity and spawns two-three months after hatching, at the end of the spawning season. Tables 2.1.2.1 and 2.1.2.2 are shown the characteristics of growth and maturity for both subspecies of anchovy.

Table 2.1.2.1 Maximum size, size at first maturity and size at recruitment of Azov anchovy

Somatic magnitude measured – FL, cm		Unit – Azov anchovy	
Maximum size observed (historical)	13.0	Reproduction season	May-July
Size at first maturity	6.5	Reproduction areas	Sea of Azov
Recruitment size	6.5	Nursery areas	Sea of Azov

Table 2.1.2.2 Maximum size, size at first maturity and size at recruitment of Black Sea anchovy

Somatic magnitude measured – FL, cm		Unit – Black Sea anchovy	
Maximum size observed (historical)	20.0	Reproduction season	May-August
Size at first maturity	6.0	Reproduction areas	The Black Sea
Recruitment size	6.0	Nursery areas	The Black Sea

In Northern part of Black Sea the share of *E.e.maeoticus* increased after 2009 and reached its peak in 2014.Simultaneously, landings of *E.e.ponticus* decreased significantly towards 2014. (Fig. 2.1.2.1 a,b).

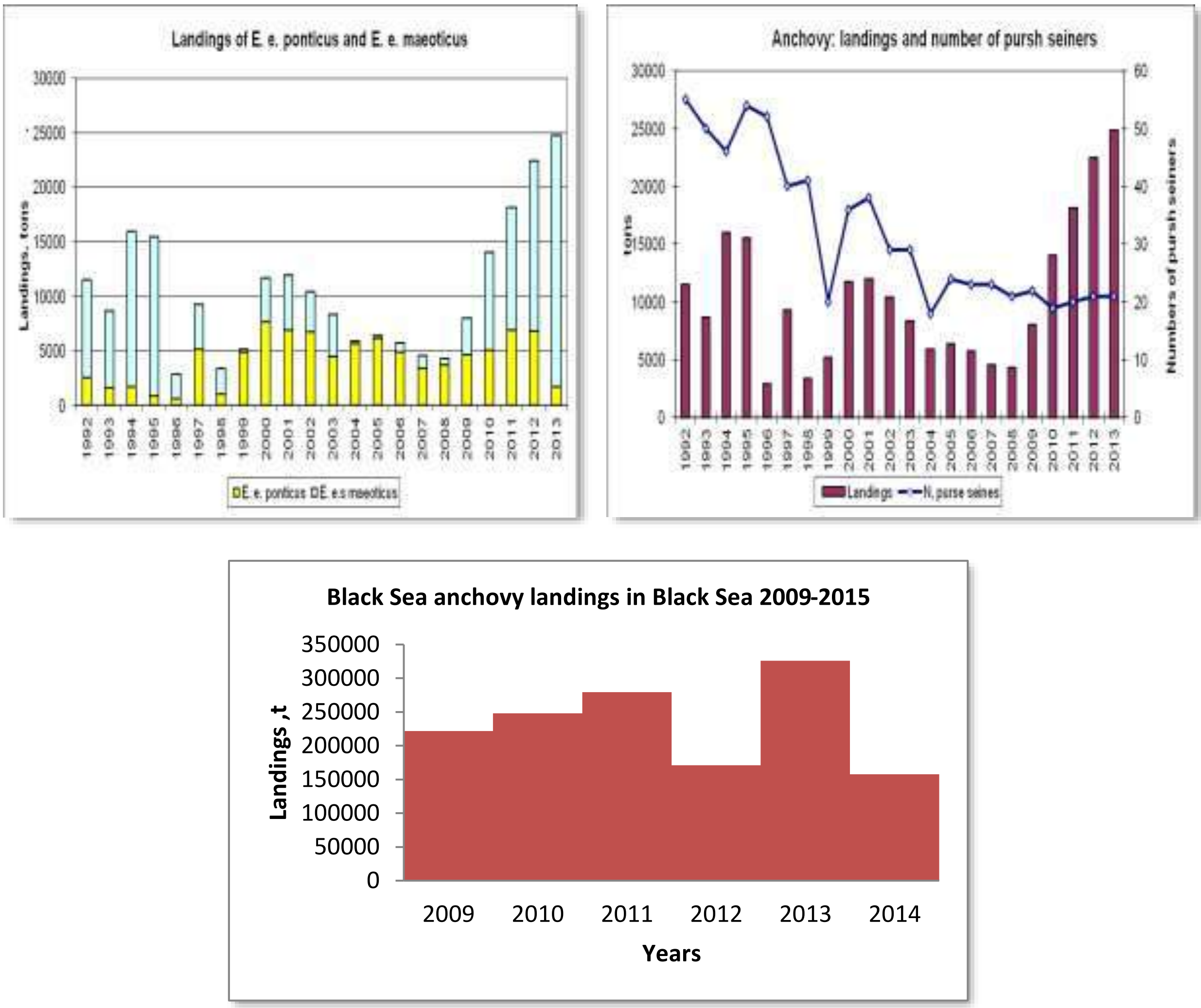


Figure 2.1.2.1 (a) Landings of *E.e.ponticus* and *maeoticus*; (b) anchovy landings and number of purse seiners; (AG FOMLR, 2014) (c).landings 2009-2015

The asymptotic length of Anchovy (*E. e. ponticus*) was calculated as parameter of von Bertalanffy equation as 13.9 cm, with very high rate of growth (k=0.985) (Table 2.1.2.3).

Table 2.1.2.3. Population parameters of *E.e.ponticus* (STECF, 2015; GFCM, 2015)

MLR	Parameters of von Bertalanffy's equations			Mortality		
	L∞, cm	k	t0	M	F	Z
Anchovy (*E. e. ponticus*)	13.26	0.66	-0.81475	0.84		

Natural mortality (M vector) proportion of matures by size or age for males and females are shown on Table 2.1.2.4. and Table 2.1.2.5.

Table 2.1.2.4. M vector and proportion of matures by size or age (Males)

Size/Age	Natural mortality	Proportion of matures
0	1.32	0
1	0.81	1
2	0.56	1
3	0.48	1

Table 2.1.2.5. M vector and proportion of matures by size or age (Females)

Size/Age	Natural mortality	Proportion of matures
0	1.32	0
1	0.81	1
2	0.56	1
3	0.48	1

Table 2.1.2.6. Landings in Black Sea of sprat 2009-2014 (AG FOMLR, 2015)

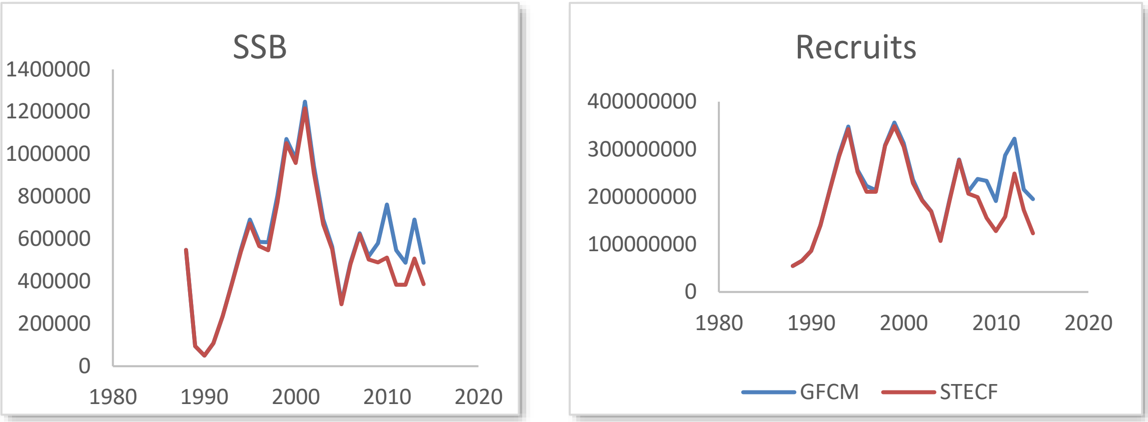
Year	Bulgaria	Georgia[1]	Romania	Russian Federation	Turkey	Ukraine[2]	USSR[2]	Total
2009	42	39857	21		185606	4653		221660
2010	65	25918	50		203026	5051		248049
2011	18	11006	41		246390[2]	6932		279300
2012	7	56777	18		109187[2]	6823		171036
2013	10	70795	111		255309[2]	0		326130
2014	370	66000	62	300	71530[3]	200		157462

1. The national experts recognized inconsistency in the Georgian landing data used previously and provided official landings

2. The landing data has been corrected by the Ukrainian experts by removing the landings of Azov anchovy caught in the Black Sea by the former USSR and Ukrainian fleets

3. The Turkish landings were taken from TurkStat, however for the last four years the landing figures were taken from the reports of a national anchovy monitoring program carried out in Turkey

Graphs of SSB, Recruitment of the stock assessment model are presented on Fig.2.1.2.2. The assessments (STECF and GFCM) of SSB and Recruitment from 2008-2014 differ as GFCM assessments show higher SSB and recruitment in this investigated period (GFCM, 2015).



A B.

Figure A. 2.1.2.2. Spawning stock biomass SSB, t; B. Recruitment, mil (GFCM, 2015)

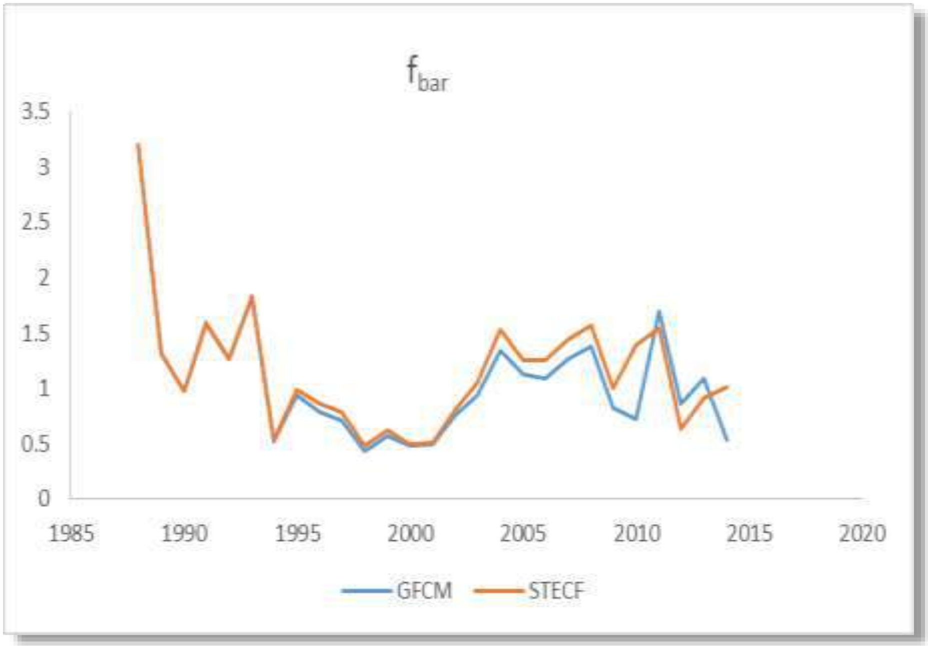


Figure 2.1.2.3. Model estimated harvest and comparison with STECF (2015)(GFCM, 2015)

The results of the analysis display a very strong year class entry in 2012, which, as all assessment results agrees, increased the SSB in the following year. The F, however, which had been dropped noticeably, slightly increased in 2013 and dropped again in 2014. The current exploitation rate (E=0.53), estimated based on the average F [1:3] of the last 3 years, exceeds the precautionary threshold 0.4 recommended for small pelagic fish (Patterson, 1992). On the other hand, the high variance of the F estimates averaged over the last 5 years hampers to make meaningful short term predictions. General trend in the last ten years, however, indicates a slight decrease in the fisheries mortality (STECF, 2015; GFCM, 2015).

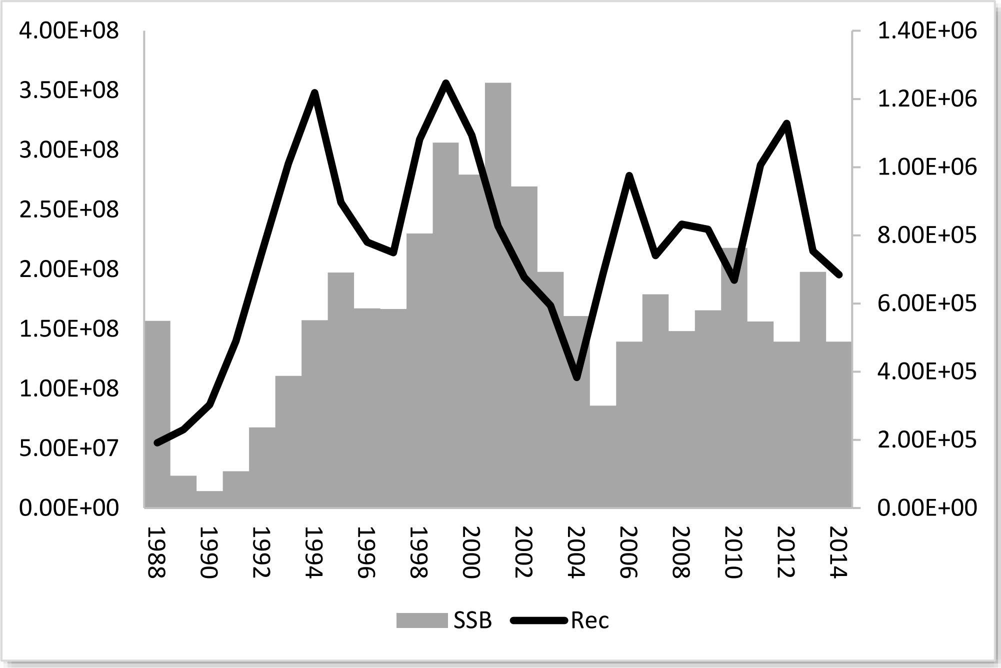


Figure 2.1.2.4. SSB,t and recruitment of anchovy in Black Sea (STECF,2013)

In all model runs recruitment displayed a cyclic pattern with peaking values for 2009-2014 observed in 2012, followed by decrease in the 2013 1nd 2014. (Figure 2.1.2.4.) which usually followed by a drop within the last 25 years. The pulse of a strong year class usually effects the next year's SSB. This is what happened in 2013; the strong recruitment gave rise to the number of spawners next year. The same pattern has been observed, at varying degrees, few years after the strong recruitment years. In relation to anchovy, a hypothetical biomass trend was reconstructed from total landings from the Black Sea assuming a constant harvest rate of 60% (Biomass / landings = 0.6). The maximum value of this series was used as an estimator of a potential maximum biomass (e.g. as an estimator of Bvirgin); limit and precautionary biomass reference points were estimated following FAO (1995) and Serchuk et al. (1997): Blim = 0.2 Bvirgin and Bpa = 0.5 Bvirgin (see figure below) (GFCM, 2015).

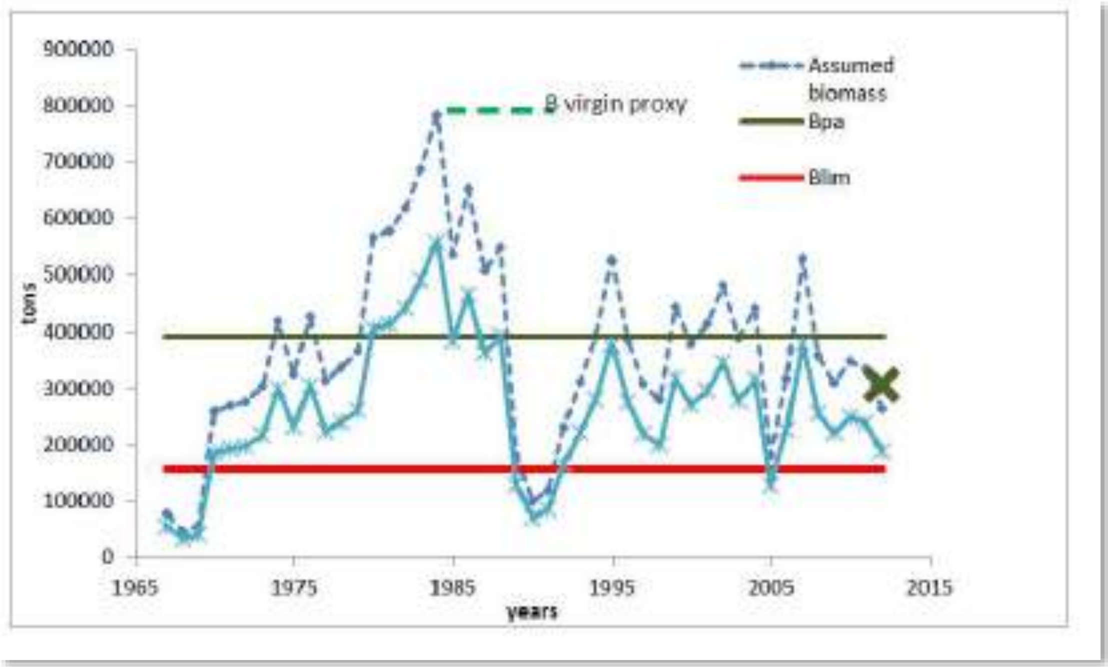


Figure 2.1.2.5. Limit and precautionary biomass reference points for Black Sea anchovy (GFCM, 2015)

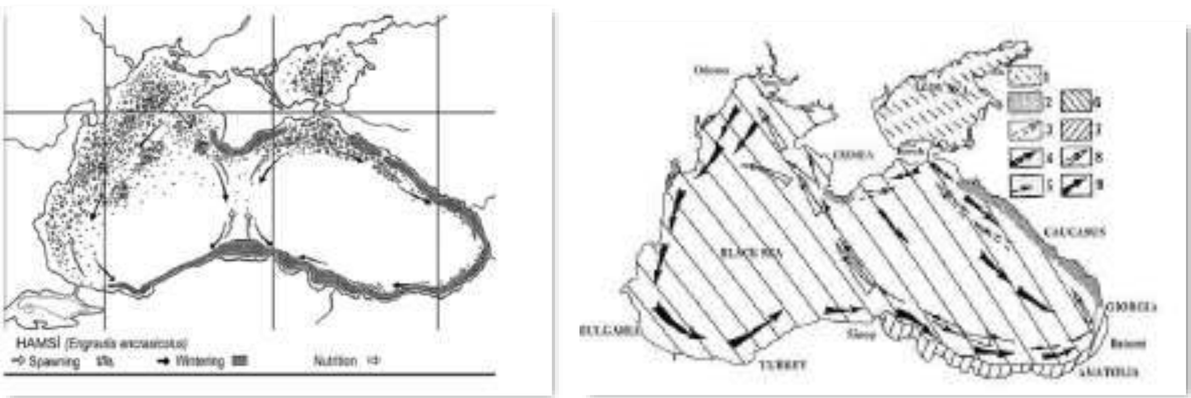
The estimated reference points could only be considered as an exercise, considering the assumed constant harvest rate was not supported by previous studies. However, the estimated maximum biomass could be considered as a minimum indicator of the biomass existing in the middle 80's (as landings were not expected to be overestimated and a higher harvest rate is unlikely for anchovy stocks), and therefore Bpa could be considered as a minimum precautionary biomass. Under such scenario, the current anchovy stock biomass could be considered to be below precautionary threshold. Given existing uncertainties in previous analytical assessments for this stock (GFCM, 2015), it was suggested to collect additional information on potential harvest rates to develop precautionary advice as an alternative to more formal assessment based on validated numerical assessments.

Table. 2.1.2.7. Indicators of anchovy stock derived from analytical assessments (STECF, 2015; GFCM,2015)

Based on	Indicator	Analytic all reference point (name and value)	Current value from the analysis (name and value)	Empirical reference value (name and value)	Trend (time period)	Status
Fishing mortality	Fishing mortality		E_{curr} = 0.53	E = 0.4	N	IO_L
	Fishing effort		F_{curr} = 0.54 $F_{[2012-14]}$= 0.83		D	
	Catch				D	

Based on	Indicator	Analytic all reference point (name and value)	Current value from the analysis (name and value)	Empirical reference value (name and value)	Trend (time period)	Status
Stock abundance	Biomass					
	SSB				D	
Recruitment					C	
Final Diagnosis		In intermediate level of overfishing				

The reference points produced by FLBRP, such as F0.1 or F_{max} were quite unrealistic and high. Therefore Patterson's (1992) precautionary exploitation rate of E=0.4 is used to evaluate the status of the stock. The average of the last three years F was used for the calculation of F used in the estimation of exploitation rate.



A. B.

Figure 2.1.2.6. A. Spawning, feeding and overwintering grounds of anchovy in the Black Sea (upper: black arrows: overwintering, empty arrows: spawning migration; shaded area: overwintering; dots: spawning areas; taken from Ivanov and Beverton, 1985; B. lower: the Azov anchovy 1= spawning and foraging region; 2 = wintering region; 3 = spring migrations; 4 = autumnal migrations; 5 = periodical migrations of a mixed population. The Black Sea anchovy: 6 = spawning and foraging region; 7 = wintering region; 8 = spring migrations; 9 = autumnal migrations taken from Chashchin (1996) (in Gucu et al., 2016)

Since 2011, the Middle East Technical University Institute of Marine Sciences, together with the Trabzon Institute of Central Fisheries Research of Turkey conducted 15 scientific fisheries surveys in the Black Sea targeting anchovy. Although the main objective of the surveys was to understand the spawning, migration and overwintering behaviour of the species on the southern half of the Black

Sea, the data and the results of the surveys raised some imported issues for the assessment of Black Sea anchovy stock.

Three ichtyoplankton surveys conducted successively in July 2013, 2014 and 2015 indicated that the size of the southern stock has increased remarkably when compared to 1990s. An additional survey conducted in October 2014, showed that the eggs spawned on the south survive and recruit to the stock. These finding are important for the definition of the stock units. As for the migration studies, results showed that the anchovy do not necessarily follow their classic route every year and that they may display remarkable changes depending on the cooling rate and pattern over the entire basin.

The most striking case has been experienced in 2015 when the first schooling anchovies, which are usually sighted on the Turkish western-central Black Sea coast, were spotted at the Turkish-Georgian border. The migration models developed on the basis of the field observations suggested that due to the cooling pattern experienced in autumn 2015, the anchovies might have followed an offshore route, not approaching the Turkish coast and heading directly east, towards Georgia. As a consequence of this unusual situation, Turkey, which used to exploit the largest part of the stock by far, lost its share to Georgia. In fact, unexpected drop in the Turkish landings has been experienced several times in the past and, disregarding the rest of the basin, it was considered collapse of the stock associated with some other factors, such as exotic invaders, or predators.

These observations clearly show that anchovy has to be monitored and assessed jointly, at least by Georgia and Turkey (Gucu et al., 2016).

Egg and larvae distributions

The results of the ichthyoplankton survey conducted in 2013 are given in Table 2.1.2.8.

Table 2.1.2.8. Results from ichthyoplankton survey in 2013 (Gucu et al., 2016)

Year	Month	Egg-range	Egg-mean	Egg-CV	Larvae-range	Larvae-mean	Larvae-CV	Survival	References†
1957	July	0–321	≈18	–	–	≈2	–	–	(1)
1991	June	0–29	≈6	213%	0–2	≈1	–	–	(2)
1992	July	0–1167	72	171%	0–55	3.5	196%	5%	(2)
1993	August	0–718	39	233%	0–39	3.1	222%	11%	(3)
1996	June–July	0–577	90	106%	0–44	4.3	166%	5%	(3)
2013	**July**	**60–3051**	**385**	**101%**	**3–359**	**60**	**79%**	**16%**	**(4)**

†References: (1) Einarsson and Gürtürk, 1960; (2) Niermann et al., 1994; (3) Kideys et al., 1999; (4) This study.

Additionally, the results of the surveys conducted in the same area in 1991, - 1993 and 1996, which were reanalysed in order to improve comparability, are also depicted in the same table.

As the table displays, there is more reproductive activity in the south compared with the past as the number of eggs found in July 2013 is by far greater than for any of the surveys conducted previously. The difference is most striking in the mean number of larvae, which is almost 15-fold greater than the nearest number previously recorded.

The increased egg vitality shows that were more not only eggs spawned in the south but also survival rates of the eggs to larvae have improved over the last two decades. Mortality was estimated based on the decay in the number of larvae in the length-converted age classes and depicted the instantaneous mortality between 2 and 15 mm length classes (0–18-day-old larvae) (Table 2.1.2.8.).

As the ranges exhibit, anchovy eggs and larvae were found at every station sampled in 2013, whereas, in the previous surveys, no planktonic anchovy were present at certain stations. This shows that the spawning site selection is not localized to specific areas but that the anchovy spawn over the entire basin. This can also be seen in Figure 2.1.2.6, where a series of maps are presented to evaluate spawning site selection. In general, numbers are higher in coastal regions; however, the eggs are distributed throughout the study area. There are no clear aggregation areas representing the core of spawning in the resulting distribution map (Fig. 2.1.2.6. b).

Larval distribution in the eastern region is relatively similar to egg distribution. The highest numbers of larvae, however, were found offshore in the west yet there is a huge distance between this region and the site where the highest numbers of eggs were observed (Fig. 2.1.2.6. c). With regards to the viability of the eggs, the percentages of live eggs are noticeably low in the easternmost range of the study area (Fig. 2.1.2.6. d). In contrast, a fairly large number of larvae were observed in the same area (Fig. 2.1.2.6. c).

In the west, the percentage of live eggs was quite high at the station where the highest number of eggs was found; this was also the case for neighbouring stations but dropped remarkably at the eastern and western sides of the core. Although a somewhat high egg density was present at those stations located in the area under the Danube influence, the majority of these eggs were not viable (Fig. 2.1.2.6.). Taking this into account, a path can be recognized moving from the Istanbul strait offshore in a north-easterly direction, as the high numbers of eggs, the percentage of viable eggs and numbers of larvae are considered (Gucu et al.,2016).

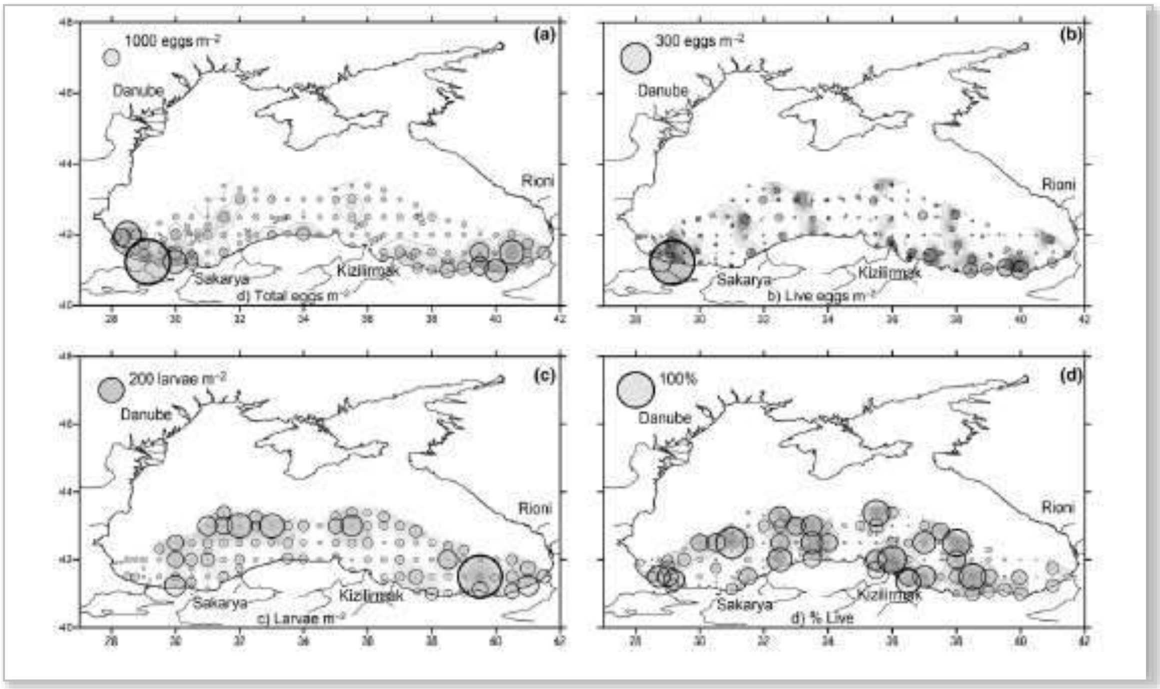


Figure 2.1.2.6. Results of ichthyoplankton survey conducted in July 2013 (a) density of anchovy (viable and non viable) eggs (b) live eggs only (advection accounted); (c) density of larvae;(d) percentage of live eggs (Gucu et al.,2016).

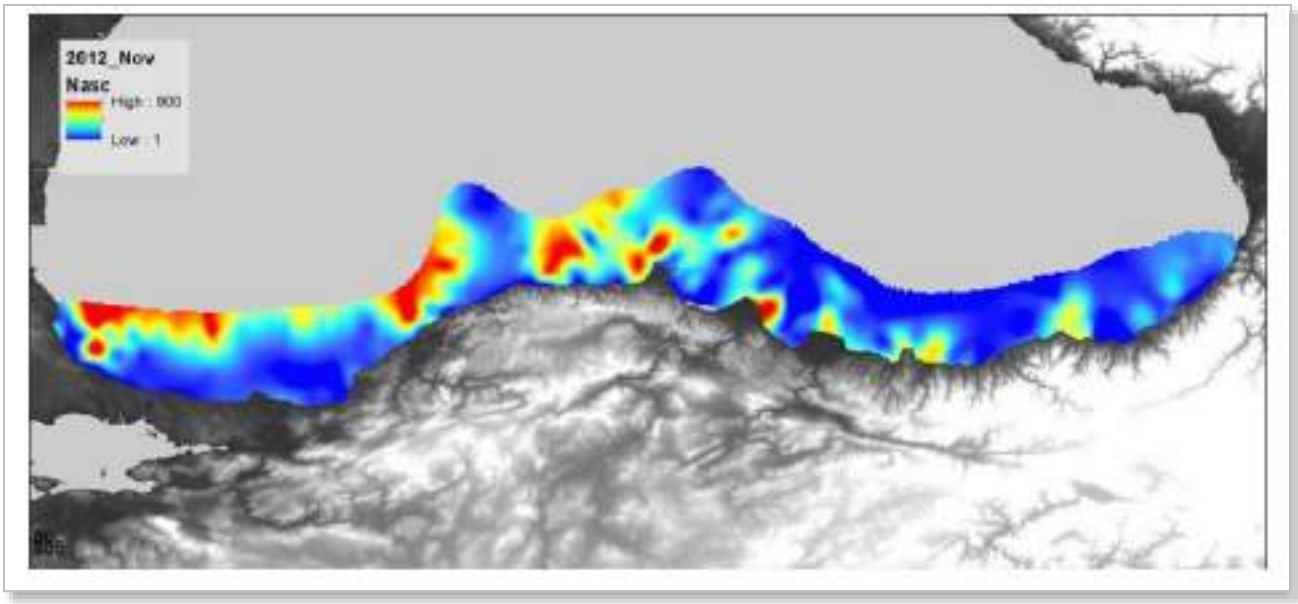


Figure 2.1.2.7. Spatial distribution of anchovy in November 2012 in Turkish Black Sea waters (STECF, 2013)

No scientific survey on anchovy was reported by the countries, except Turkey. The Turkish Ministry of Food, Agriculture and Livestock has launched a fisheries project on Black Sea anchovy. The project initially aimed to conduct acoustic surveys on the Turkish continental shelf during the overwintering season of the species. Until now four surveys were carried out in 2011 (November-December) and 2012 (January-February; November, December; Figure 2.1.2.8. In each survey, complementary pelagic trawl sampling was also performed to determine size/age distribution of anchovies. The net used in the pelagic trawl sampling designed to catch both fast swimming adults and small sized recruits at the same time. It has very fine mesh size (14 mm stretched) and equipped with a pair of SIMRAD trawl sensors attached to head rope and bottom line.

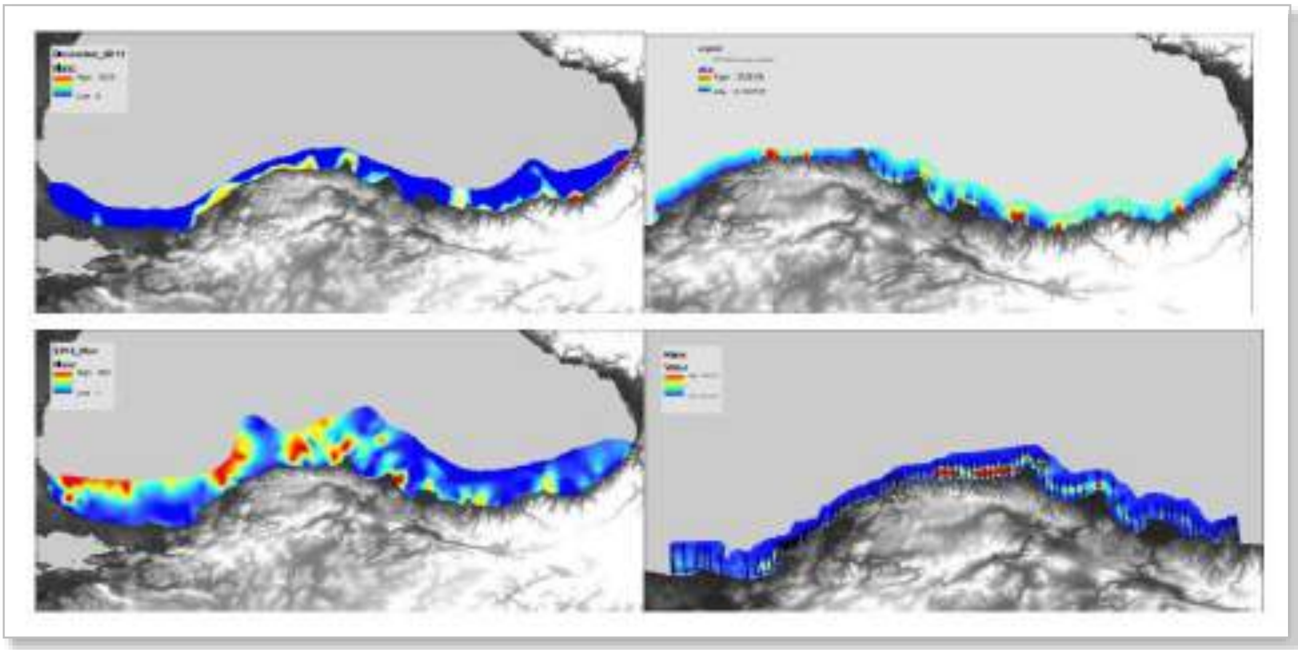


Figure 2.1.2.8. Distribution maps of anchovies in November-December 2011 (upper left); January-February2012 (upper right); November 2012 (lower left) and December 2012 (lower right) (STECF, 2013)

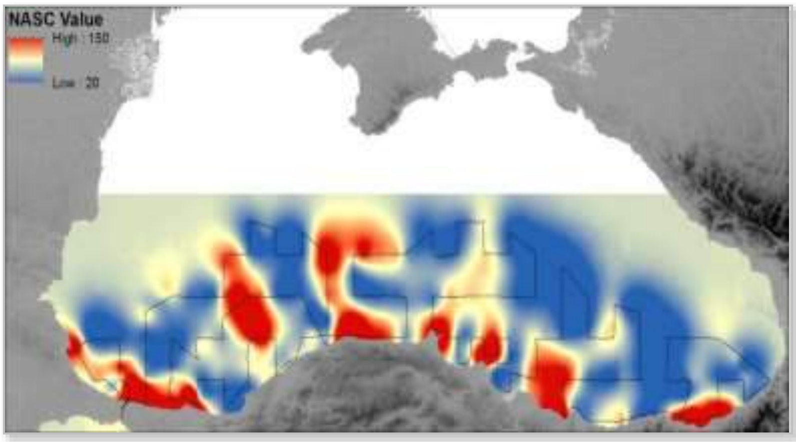


Figure 2.1.2.9. Distribution of spawning stock acoustically detected in July 2013 (STECF, 2014)

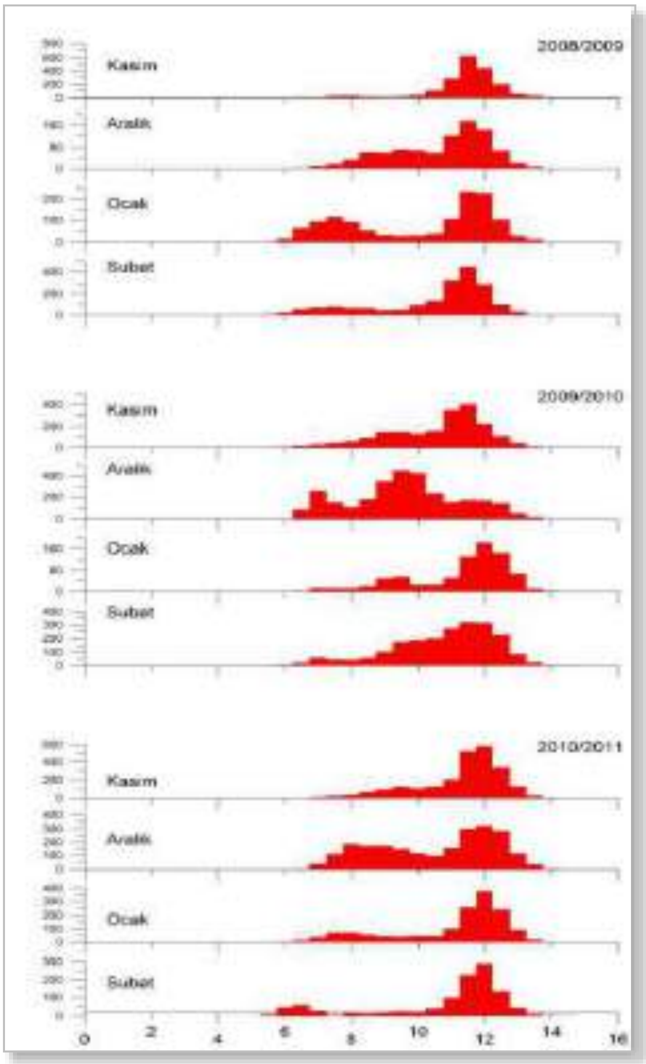


Figure 2.1.2.10. Time series of the length frequency distributions of the Black Sea anchovy sampled at the Turkish landing sites by SUMAE (STECF, 2013)

Anchovy is an object of both artisanal (with and Ukraine), and commercial purse-seines both subspecies of anchovy - the Black Sea and Azov Sea anchovy. Their regulation and registration of national statistics of Ukraine, as well as Russian Federation, are made separately. Anchovy length groups varied from 9 to 13.5 cm (age: 1-3 years +.). Minimum size for catch of the species identified in FAA is 8 cm. The state in 2001 is estimated as 'favourable' as regards parameter sized structure.

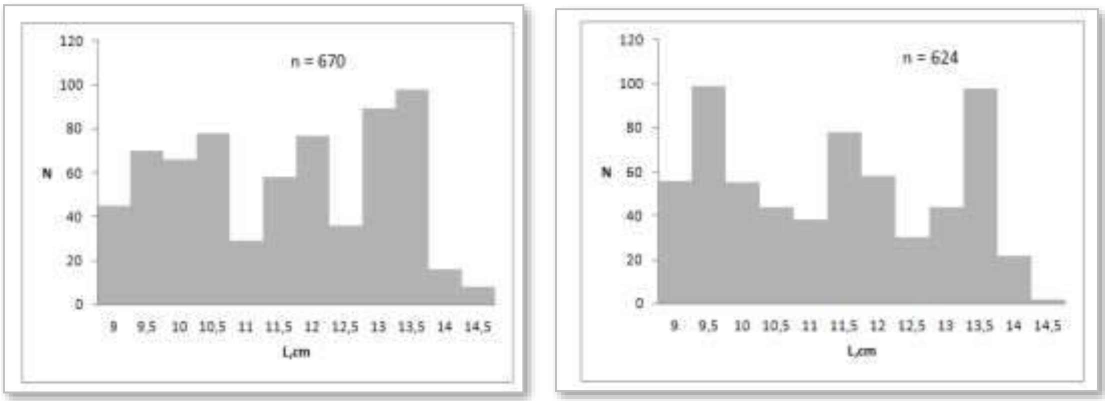


Figure 2.1.2.11. Anchovy, Engraulis encrasicolus, spring-summer, length groups (cm), sampling gear: uncovered pound net (FPO) - a; anchovy, Engraulis encrasicolus, autumn, length groups (cm), sampling gear: uncovered pound net (FPO) – b (Raykov et al., 2016).

On Fig.2.1.2.12. Length classes of anchovy in 2009 in Romanian marine area have been presented. The bulk of individuals were between 85-91 and 120-121cm classes.

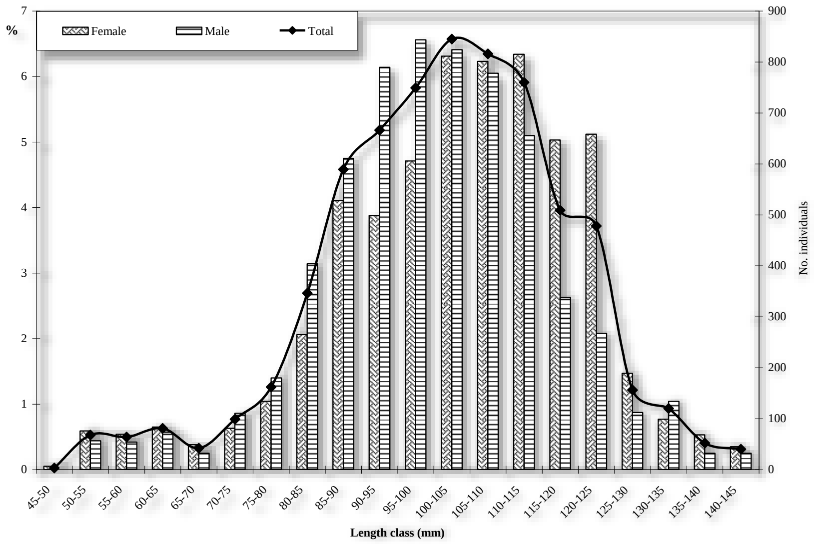


Figure 2.1.2.12. Structure on length classes for anchovy in 2009, total catches (STECF, 2010)

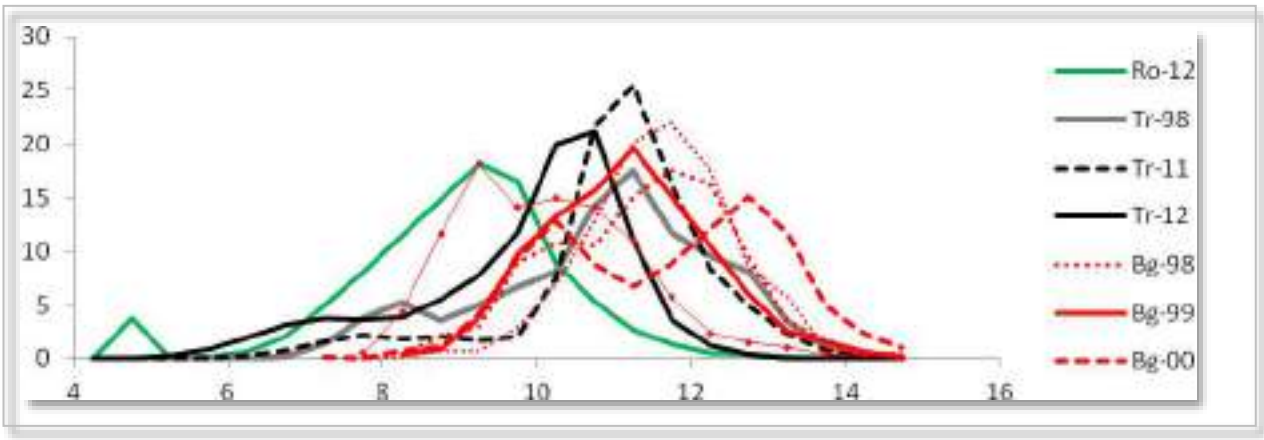


Figure 2.1.2.13. Length distributions (TL, cm) in Black Sea 1998 – 2012 (STECF, 2015)

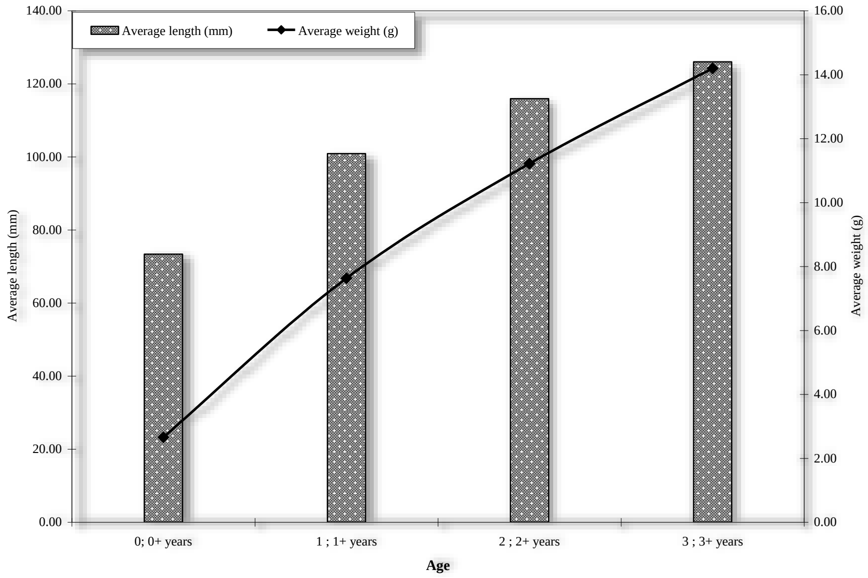


Figure 2.1.2.14. Mean length and weight on age classes for anchovy in 2009, total catches (STECF, 2010)

Table 2.1.2.9. Anchovy -*Engraulis encrasicolus*, gonad maturity stages (STECF, 2010)

Year	Month	Sex	maturity stages										*Total*
			II	II-III	III	III-IV	IV	IV-V	V	V-VI	VI	VI-II	
2009	V	F				11.3	25.6	28.1	23.5	11.5			**317**
		M			12.7	31.3	38.6	15.9	1.5				**332**
	VI	F					16.7	12.9	34.7	10.3	16.7	8.7	**597**
		M				9.8	11.3	45.8	23.7	6.6	2.8		**450**
	VII	F						4.7	41.2	36.8	12.3	5.0	**460**
		M					3.3	21.2	37.7	33.2	4.6		**370**
	VIII	F							24.5	11.7	33.5	30.3	**639**
		M					4.4	12.3	45.4	23.7	5.7	8.5	**798**
	IX	F							14.2	10.3	14.7	60.8	**176**
		M						9.9	35.5	42.8	11.8		**224**
	XI	F	12.3								9.8	77.9	**1184**
		M	5.6							3.7	10.0	80.7	**1098**

Spatial distribution

Anchovy were acoustically registered only in the northern part of Bulgarian coast in November 2014 of the surveyed area and the schools were composed by young fish (0+- 1+). (Panayotova et al., 2014)

Table 2.1.2.10. Estimated number of anchovy (millions) by age group and polygon, October - November 2014 (Panayotova et al., 2015)

Polygon	Total (millions)	Age	
		0	1
7	2760.61	2286.57	474.04
8	4091.86	3389.22	702.64
Total (millions)	**6852.47**	**5675.79**	**1176.69**

Table 2.1.2.11. Estimated relative biomass (tones) of anchovy by age group and polygon, October - November 2014. (Panayotova et al., 2015)

Polygon	Total (t)	Age	
		0	1
7	3213.35	2661.56	551.79
8	4762.93	3945.05	817.88
Total (t)	**7976.28**	**6606.61**	**1369.66**

Table 2.1.2.12. Estimated number of anchovy (millions) per size classes and polygons, October - November 2014 (Panayotova et al., 2015)

Size class (cm)	Abundance (millions)		Total (millions)
	Polygon 7	Polygon 8	
8	119.74	177.48	297.22
8.5	123.29	182.74	306.04
9	95.56	141.65	237.21
9.5			
10	10.91	16.17	27.08
10.5	10.64	15.77	26.42
11	3.69	5.47	9.16
Total (millions)	2760.61	4091.86	6852.47

Size class (cm)	Abundance (millions)		Total (millions)
	Polygon 7	Polygon 8	
4	540.97	801.84	1342.81
4.5	772.81	1145.49	1918.30
5	369.87	548.23	918.11
5.5	140.36	208.04	348.40
6	201.32	298.41	499.73
6.5	142.50	211.22	353.72
7	81.96	121.49	203.46
7.5	146.98	217.86	364.84

Table 2.1.2.13. Estimated relative biomass (tonnes) of anchovy by size classes and polygons, October - November 2014 (Panayotova et al., 2015)

Size class (cm)	Biomass (t)		Total (t)
	Polygon 7	Polygon 8	
4	162.29	240.55	402.84
4.5	324.58	481.10	805.68
5	227.21	336.77	563.98
5.5	129.83	192.44	322.27
6	227.21	336.77	563.98
6.5	194.75	288.66	483.41
7	162.29	240.55	402.84
7.5	389.50	577.32	966.82
8	357.04	529.21	886.25
8.5	454.41	673.55	1127.96
9	421.96	625.43	1047.39
9.5			
10	64.92	96.22	161.14
10.5	64.92	96.22	161.14
11	32.46	48.11	80.57
Total (t)	3213.35	4762.93	7976.28

Maximum values of estimated relative biomass of anchovy were concentrated between 20 and 80m depths in the area in front of cape Kaliakra and Varna (Fig. 2.1.2.13.). Total estimated biomass amounted at 7 976.28 t. (Panayotova et al., 2015).

No evidence for the existence of subspecies differentiation between anchovy populations from the European coast of the Mediterranean and the Atlantic Ocean was found. However, based on genetic-biochemical data, the existence of two anchovy subspecies, European and African, is suggested. The former inhabit the Atlantic and Mediterranean coasts of Europe and the Aegean, Marmora, Black, and Azov Seas. The latter inhabits the Cape Blank region in the Atlantic Ocean and, probably, the northwestern part of the African coast (Mediterranean). The Aegean anchovy is a hybrid population as a result of introgressive hybridization between the European and the African anchovies. The Black, Marmora, Azov, Adriatic, and Mediterranean (Nice and Valencia) populations are genetically close to the European anchovy, caught north of the Canary Island. The genetic distance between the Azov and Black Sea populations show that the former probably entered the Black Sea during the Karangad period and the latter during the last connection of the Black Sea to the Mediterranean (Ivanova and Dobrovolov, 2006).

Sprat (Sprattus sprattus L.)

Due to the lack of information about the structure of sprat (Sprattus sprattus) population in the Black Sea, this stock was assumed to be confined within the GSA 29 boundaries. The species is fast growing with the population constituted by 5 age groups. The von Bertlanffy Growth Parameters VBGF by countries are given in Table 2.1.2.14. In Romanian waters asymptotic length is comparable with the growth parameters derived in Bulgarian and Ukrainian Black Sea waters. In Turkish waters the asymptotic length significantly differs for 2014. On Table 2.1.2.14. the maximum estimated L asymptotic in Black Sea were presented.

Table 2.1.2.14.a Growth and length weight model parameters (GFCM, 2015)

			Sex			
		Units	**female**	**male**	**Combined**	**Years**
Growth model	**L_∞**	Cm			13.69	
	K	year			0.32	
	t_0	Year			-0.83	
	Data source					
Length weight relationship	**a**				0.0059	
	b				2.96	
	M (scalar)				0.95	
	sex ratio (% females/total)					

Table 2.1.2.14.b Growth and length weight model parameters of sprat in Black Sea (STECF, 2015)

	L∞	K	t_0	a	b
Bulgaria	12.05	0.41	-0.01	0.0009	2.77
Romania	12.60	0.25	-1.58	0.0117	2.70
Ukraine	12.33	0.34	-0.78	0.0134	2.67
Turkey	13.69	0.32	-0.83	0.0059	2.96

Landings of sprat in Black Sea for 2009-2014 varied from 27 355 t (2013) to 120708 t (2011).The majority of landings were in Turkey, as the highest catch was 87141 t in 2011.

Table 2.1.2.15. Landings of sprat in Black Sea for 2009-2014. AG FOMLR, 2015

Year	Bulgaria	Romania	ian Federa	Turkey	ne with Cr	Total
2009	4551	92	8744	53385	24603	91375
2010	4041	39	5839	57023	24652	91594
2011	3958	131	5099	87141	24379	120708
2012	3157	88	3937	12092	15751	35025
2013	3784	99	842	9764	12866	27355
2014	2279	85	5577	41648	8791	58380

In 2014, SSB is estimated at 277 720 t, which is around the average of the time series (200 000-300 000 t). Recruitment has been relatively low in 2010-2011 but has increased in 2012. The current exploitation rate (E = 0.32, which corresponds to an F = 0.45) is smaller than EMSY (0.40, which corresponds to an F = 0.64), indicating that sprat in GSA 29 is being fished below EMSY (STECF, 2015).

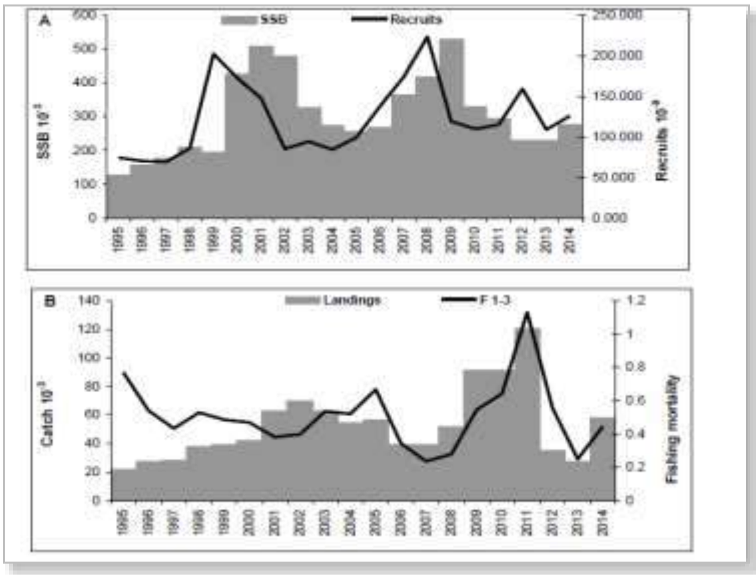


Figure 2.1.2.14. Spawning stock biomass, t (SSB, t), recruits (10-9), landings and fishing mortality 1-3 of Black Sea sprat (STECF, 2015)

The stock estimates reveal the cyclic nature of sprat population dynamics. The years with strong recruitment were followed by years of low to medium recruitment which leads to corresponding changes in the Spawning Stock Biomass (SSB). High fishing mortalities (F1-3) were observed in 2010-2012. In 2011 the highest ever total catch of 120 708t was recorded mainly due to the intensive development of the Turkish sprat fishery. Over 2007-2010 periods the levels of biomass and catches were comparable with the highest figures reported, but in 2009-2011 a decreasing trend in recruitment becomes evident (Fig. 2.1.2.14). In 2012-2013 catches dropped more than 3 times, and SSB is estimated at the level of about 200 000t. The last year (2014) catch and biomass show some increase reflecting the positive influence of the relatively strong year-class 2012 (Fig. 2.1.2.14.).

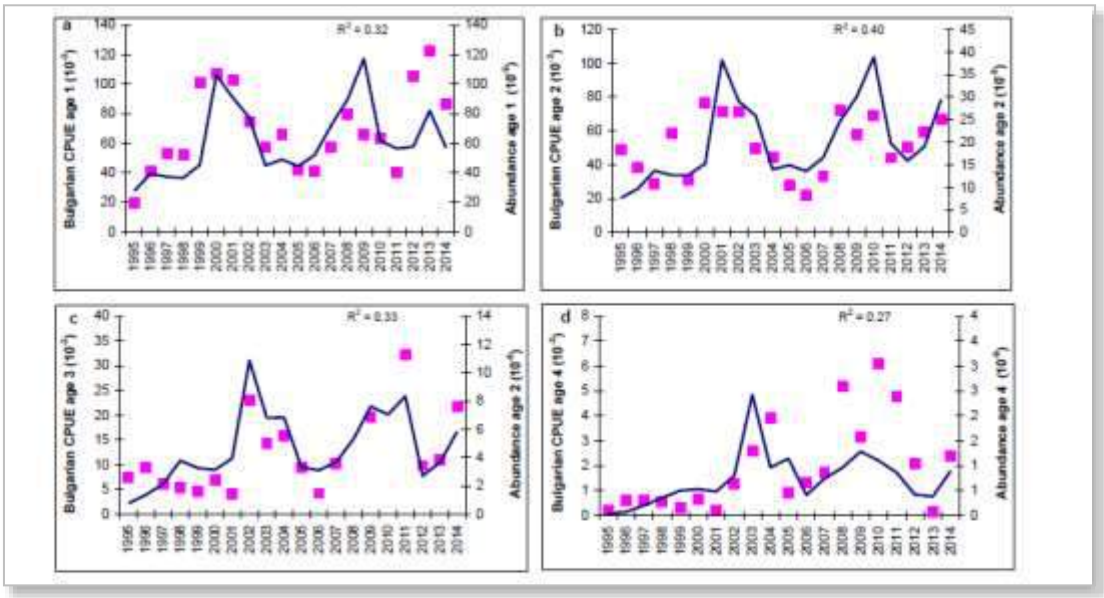


Figure 2.1.2.15. Sprat in GSA 29. Time-series of estimated and observed abundance-at-age and age-structured Bulgarian CPUE (best fit is given by linear relationships and r2 are displayed): (a) Age 1. (b) Age 2. (c) Age 3. (d) Age 4 (STECF, 2015)

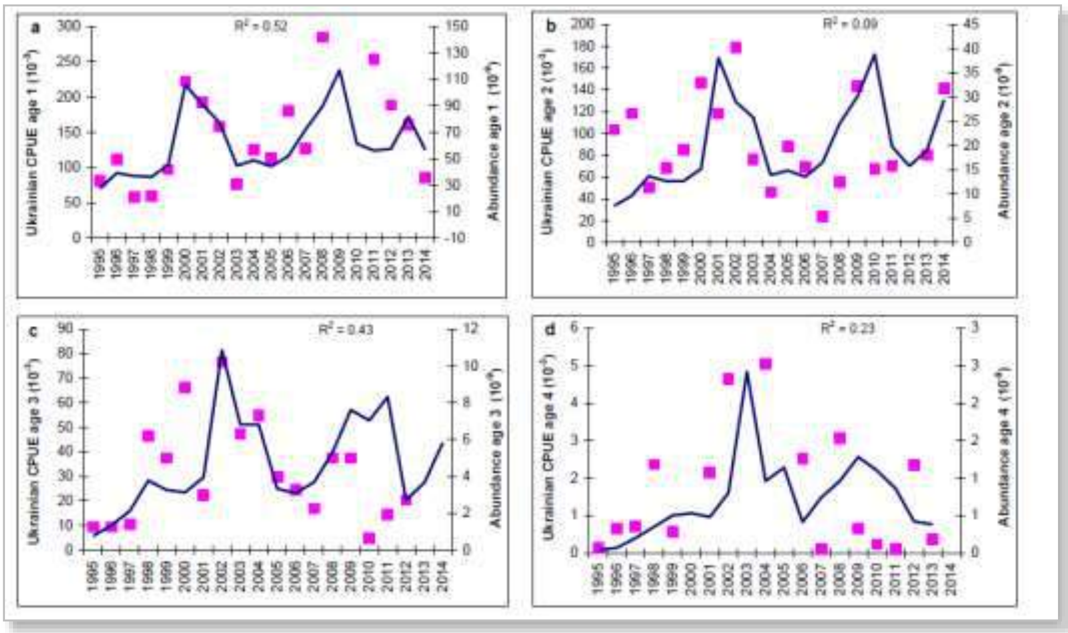


Figure 2.1.2.16. Sprat in GSA 29. Time-series of estimated and observed abundance-at-age and age-structured Ukrainian CPUE (best fit is given by linear relationships and r2 are displayed): (a) Age 1. (b) Age 2. (c) Age 3. (d) Age 4.(STECF, 2015)

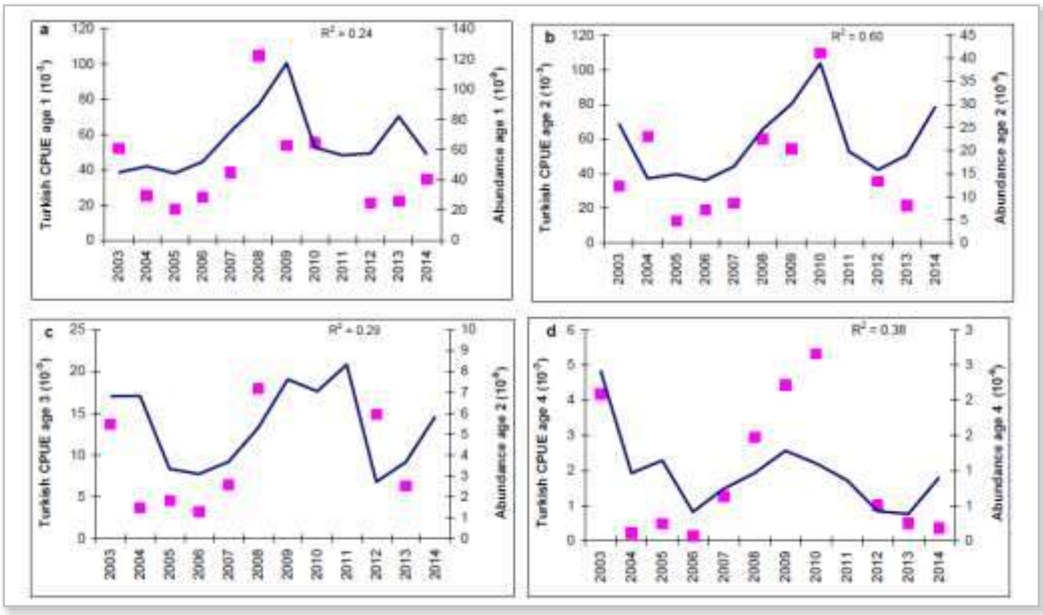


Figure 2.1.2.17. Sprat in GSA 29. Time-series of estimated and observed abundance-at-age and age-structured Turkish CPUE (best fit is given by linear relationships and r2 are displayed): (a) Age 1. (b) Age 2. (c) Age 3. (d) Age 4. (STECF, 2015)

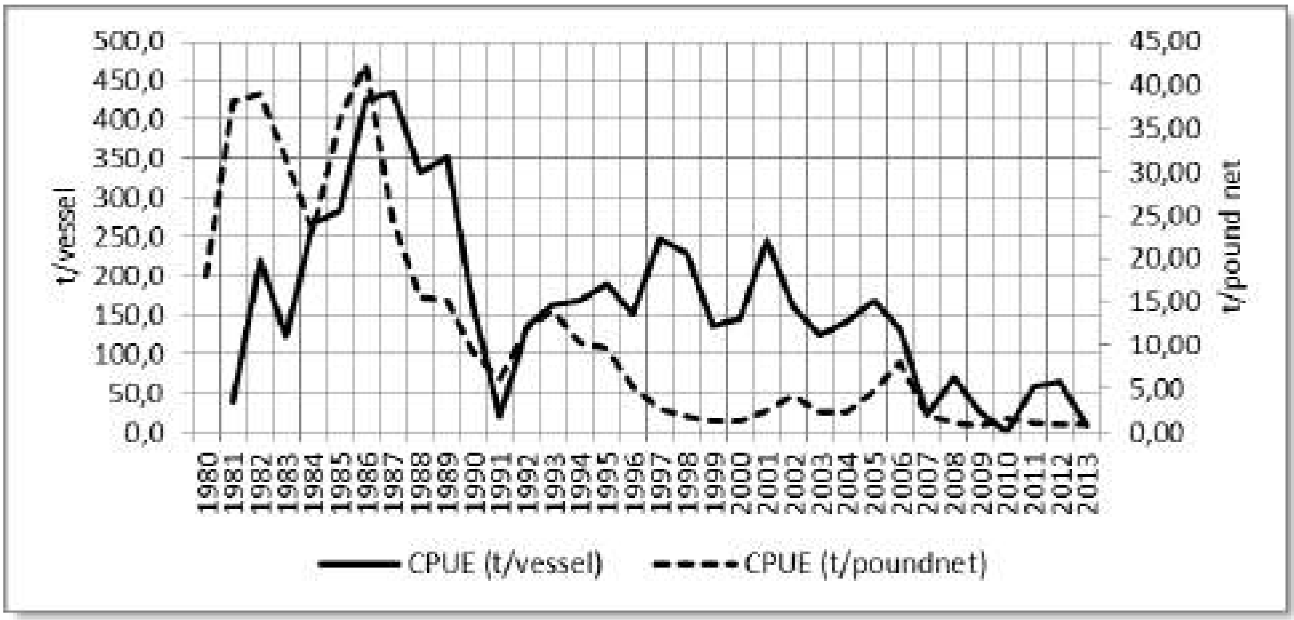


Figure 2.1.2.18. Trend of CPUE from active and passive fishing gears in Romanian marine area (Totoiu et al., 2016)

The biomasses (t) of sprat (2008-2014) are presented for Bulgarian and Romanian marine areas. In Bulgarian area the biomass varied from 32718 t to 75080 t ; in Romanian area varied from 39277 to 68886 t. The highest biomass was detected in 2010 (75080 t) in Bulgarian part, and in 2012 (68886 t) in Romanian part. (STECF, 2015) (Table 2.1.2.15.)

Table 2.1.2.15. Biomass (t) of sprat in Bulgarian and Romanian marine areas (estimations from surveys) AG FOMLR, 2015

	2008	2009	2010	2011	2012	2013	2014
Bulgarian waters	32718	41761	75080	48202	-	-	55 361
Romanian waters	60000	60000	59600	-	68886	56428	39277

Spatial distribution

In the Bulgarian marine area, in field A15 northwest of Chernomorets depth (30-50) catch per unit effort kg. per hour showed the greatest value - 2200kg/hour. In the field D9 to Kamchia river catch per unit effort showed the value of 1.500 kg / hour west of Sozopol at depths of 75-100 m. The field F16 CPUE kg/h is 1440kg/h.

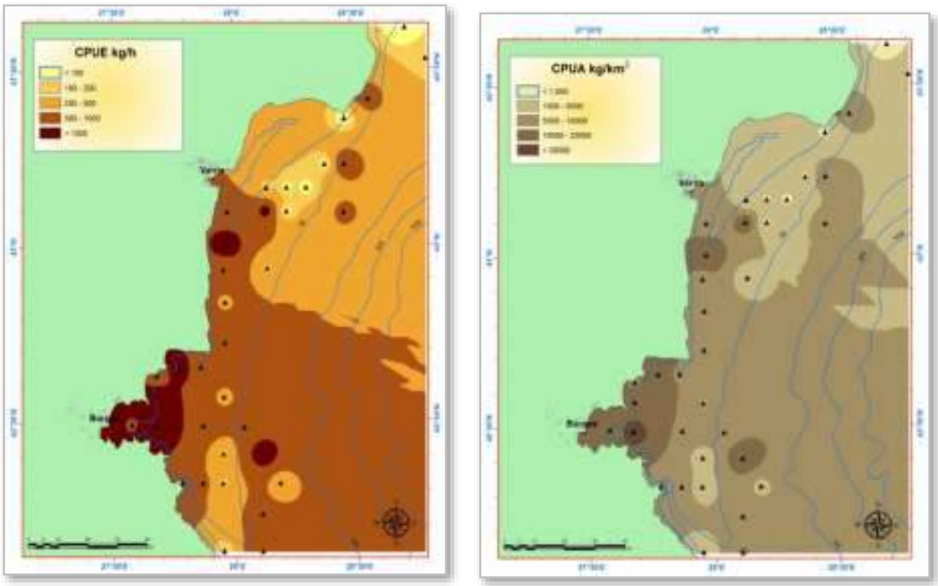


Figure 2.1.2.18. (a.)CPUE kg / h on fields (2009). (b.) CPUA kg / km2 in fields (2009) (Raykov, 2012)

A14 station before Pomorie 1200 kg / hour station F8 west of Pasha Dere at a depth of 30-50m -1170 kg / hour. Relatively high catch per unit effort was southwest of Tsarevo depth of 75-100 in field F19 920 kg / h from the southwest cape of the same depth in the station J6 780 kg / h. High levels of catch per unit effort (Fig.2.1.2.18.a) in the limits of 280-680 kg / h had studied in a number of fields in limits of 3rd stratum. In the northernmost tested station west of Krapec station M1 stratum II 50-75m was not realized catch. In fields J4- forty-eight kg / h (at Kaliakra) G8- 40 kg / h (west of Pasha Dere), I6-60 kg / h (west of Golden Sands), H7-50 (west of Galata), G7 -60 kg / h (west of Galata) immediately before cape catch was low and was 48 kg / h. The highest values of catch per unit area were in the fields A15, F16, B13, A14, D9, F8 (Figure 2.1.2.18b). In the spring season of 2009 makes impression high values of catch per unit area, or momentary clusters of sprat in greater proximity to the shore, respectively, in stratum I. The average catch per unit area in stratum I (30-50m) was 9696.306 kg / km2. In stratum III has lower: 7900.637 kg / km2, and the minimum yield per unit area found in the stratum II: 1593.405 kg / km2 (Raykov, 2012).

The densest sprat aggregations in autumn 2010 were detected in the shallowest stratum 10-35 m with average value of catch per unit area of 16 404 kg.km-2 and with average CPUA of 7428.6 kg.km-2 from all investigated stratums. During the survey the highest biomass indices were established in the stratum localized close to the shore -10 – 35 m in Bulgarian marine area. The biomass index in this stratum was 30 796.5 t. In the rest of the stratums the biomass was 2-3 times lower than in the shallowest stratum. The size composition ranged from 4.0 to 12.0 cm, the age ranged from 0+ to 4-4+, as oldest age groups and young-of-the-year was presented with low percentage. In Romanian waters sprat biomass was very high (at almost 10 times) in shallowest waters (stratum 10-35 m) in comparison with the stratums more distant from the coast - 35-50 m and 50-75 m (Raykov et al., 2012).

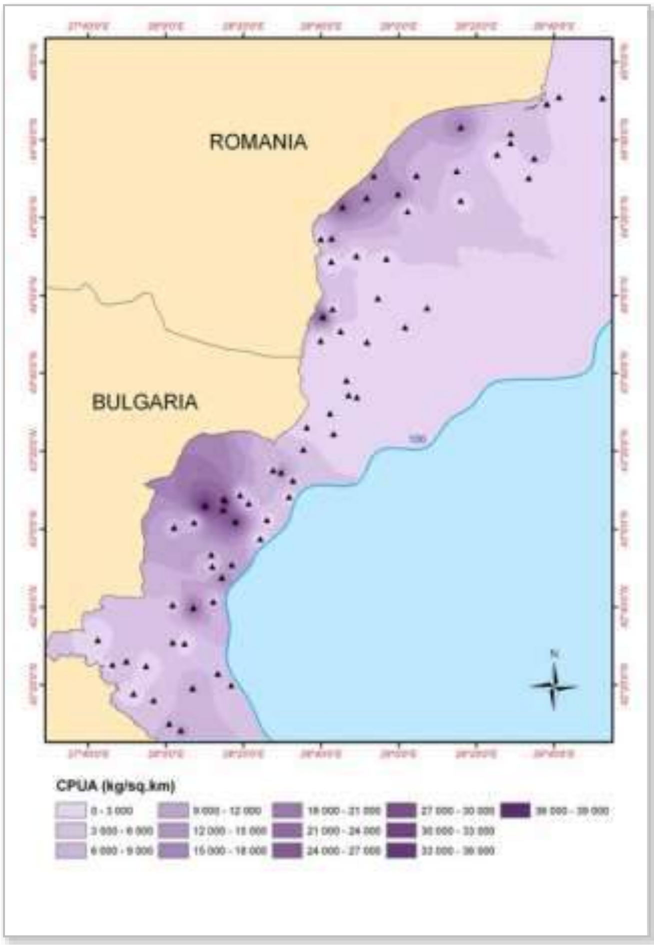


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Figure 2.1.2.19. Catch per unit area (kg/sq.km) of sprat in Western part of Black Sea (Raykov et al., 2012)

Commercial catch in Bulgaria was composed from 1-1+ and 2-2+ old specimen, mainly. Similar trends were observed in scientific surveys. Samples collected from Turkish pelagic trawls operating in shallow waters (40-60 m) also confirm the tendency that larger/older fish (Age 3 and 4) is distributed mostly in deeper waters (Fig.2.1.2.20.).

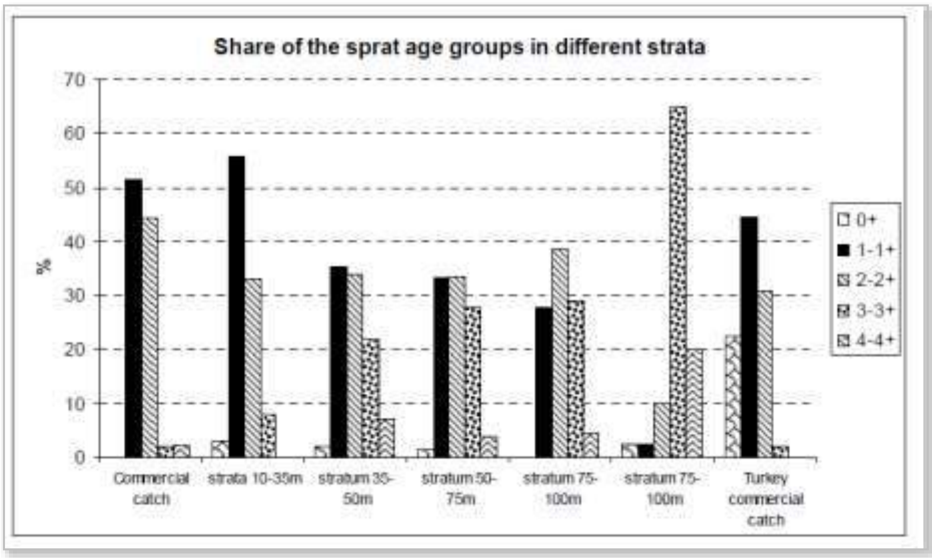


Figure 2.1.2.20. Share (%) of the sprat age groups in different strata compared with commercial catch in Bulgaria and Turkey (Raykov,2012).

Sprat distribution pattern was studied during the acoustic surveys in 2010 and 2011. In 2011, sprat schools were found scattered over most of the surveyed area. Their main concentrations were found on northern (Kaliakra – Shabla) and central (Obzor – Kamchia) areas with NASC values range between 12 – 31 (m2 .nm^{-2}) and, to a lesser extent, in the southern (Fig. 2.1.2.21.).

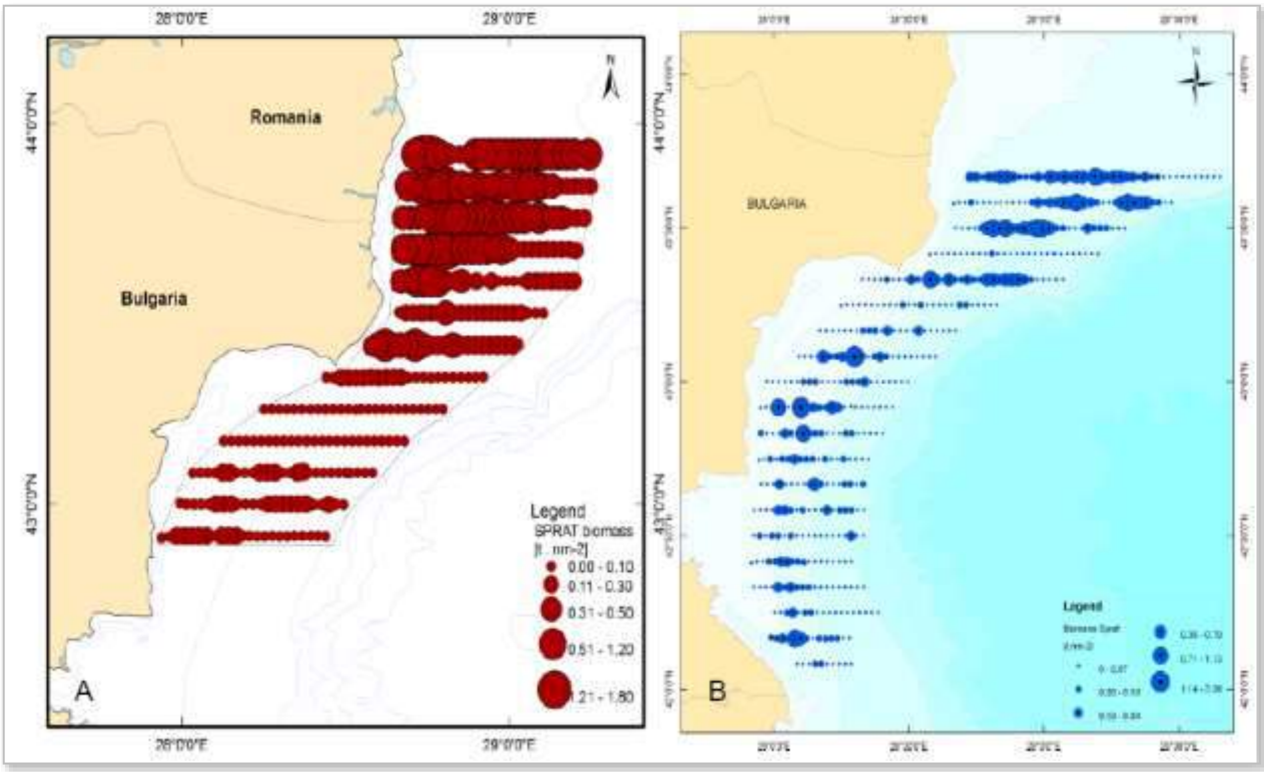


Figure 2.1.2.21. Distribution map of sprat relative biomass along Bulgarian coast in 2010 and 2011 (STECF,2013)

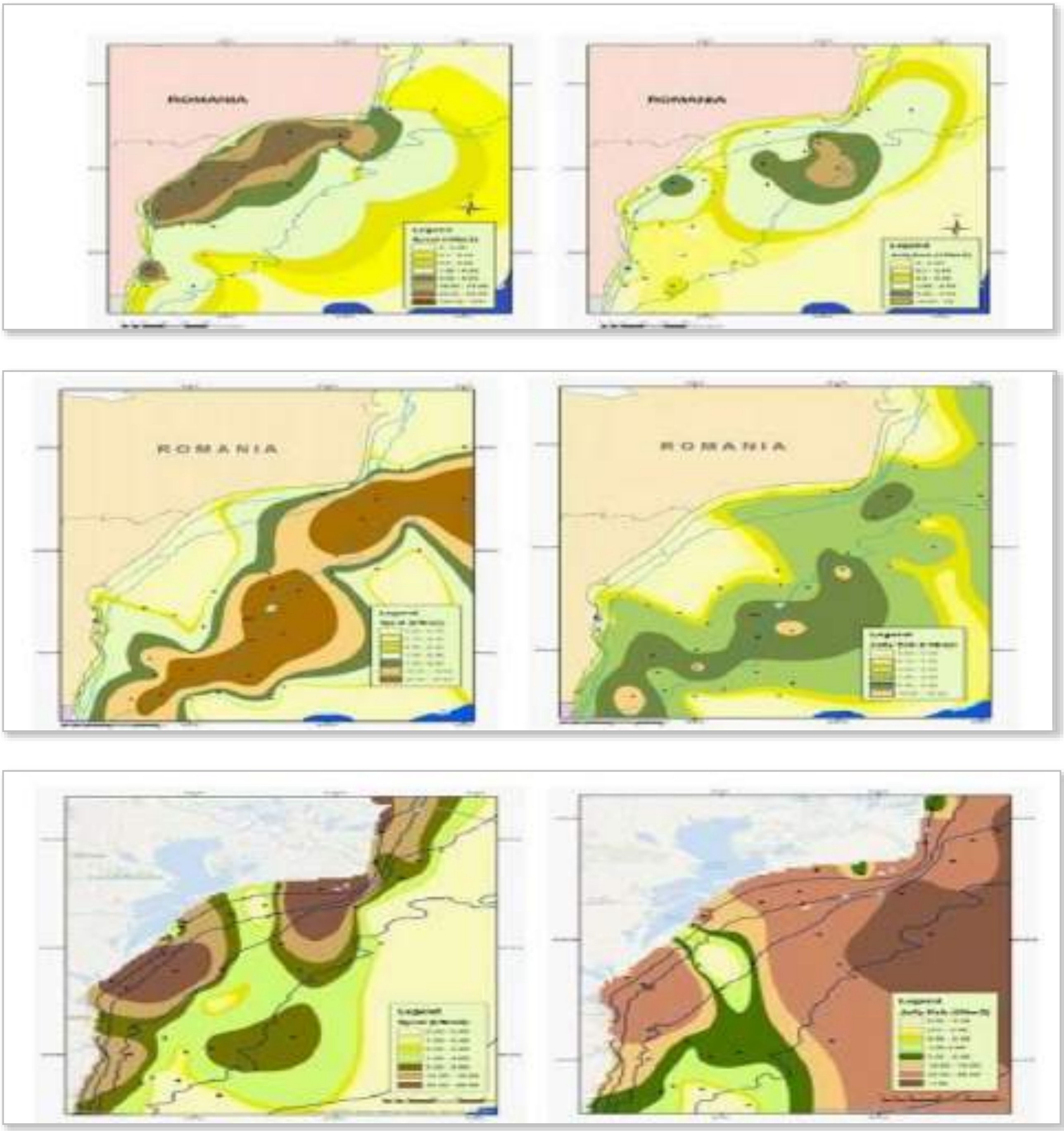


Figure 2.1.2.22. Distribution and abundance of sprat 2010, 2012 and 2013 in Romanian Black Sea waters (STECF,2014).

Size structure of sprat catches during the survey encompasses fish with total lengths between 5 and 11 cm. Two maxima of abundance in length classes were distinguished - in 7 cm and 9 cm, which correspond mainly to age groups 1 and 2 – Fig. Figure 2.1.2.23. The average length of all measured fish over all hauls was estimated at 8.59 cm

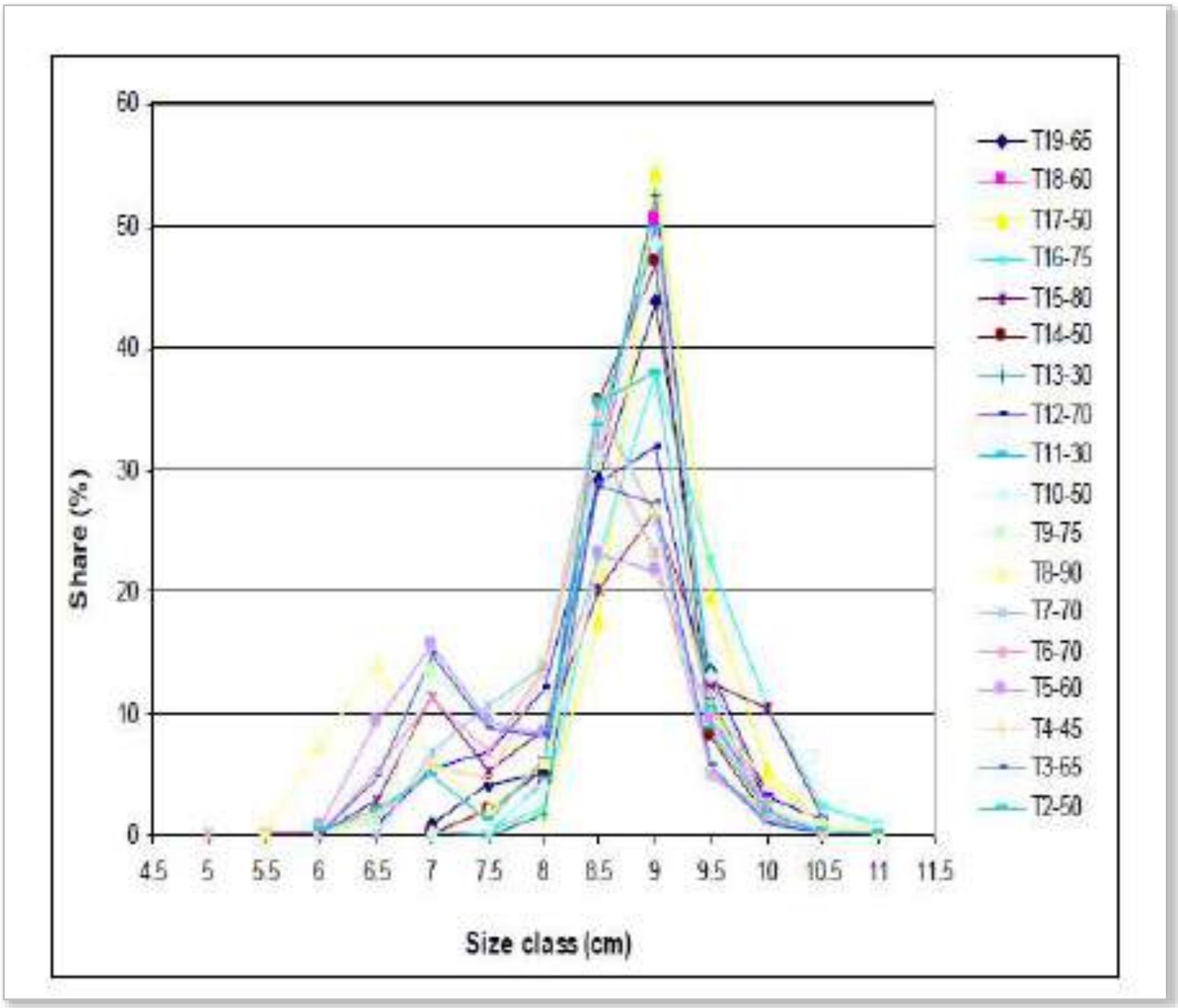


Figure 2.1.2.23. Length distribution of Sprat (*Sprattus sprattus*) by hauls during acoustic survey along Bulgarian coast in 2011 (STECF, 2012)

Table 2.1.2.16. Descriptive data regarding abundance indices of sprat for spring 2011 in Samsun shelf area (Turkey).

Mean Abundance index (kg/km^2)	Minimum-maximum kg/km^2	Standard error	No of hauls (N)	Depth range (m)
4178.3	820.7-15917.1	±1018.3	14	50-100

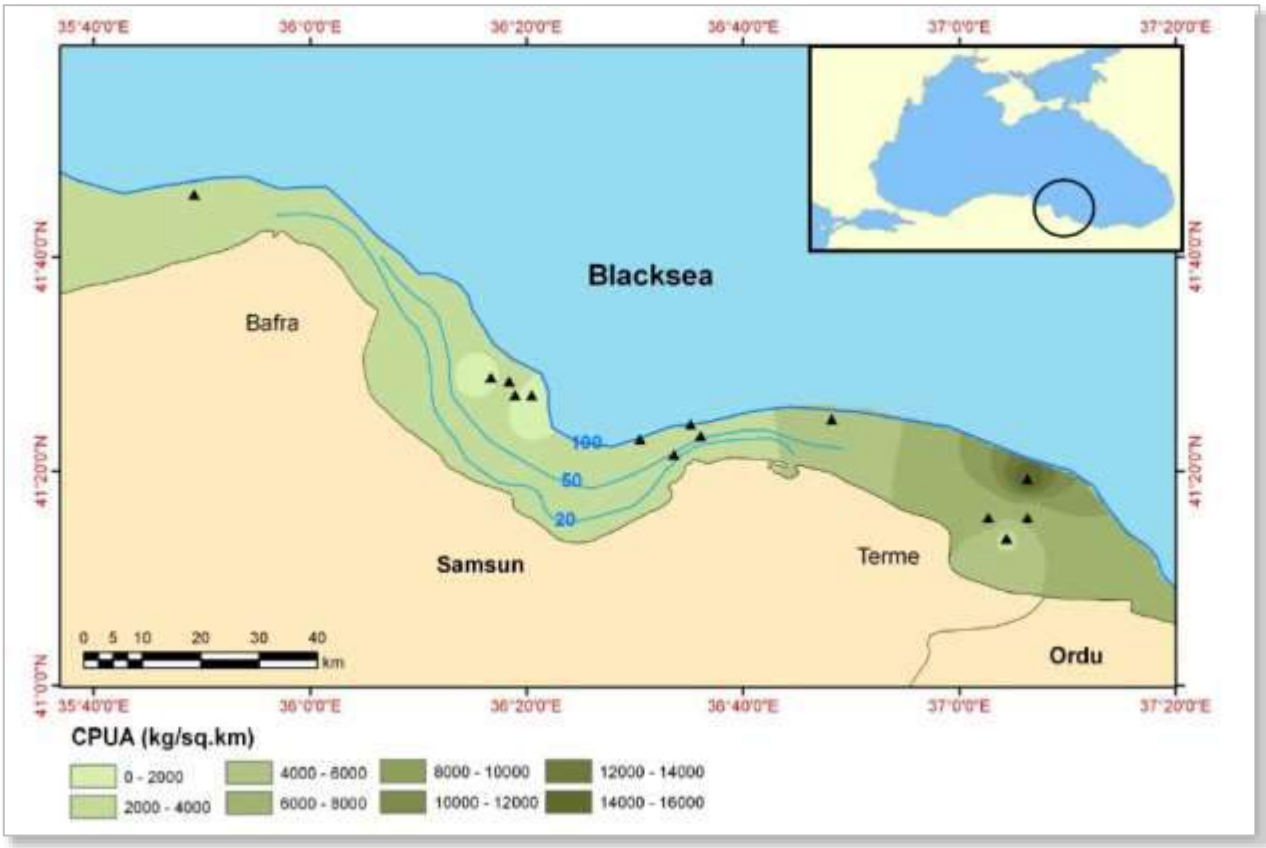


Figure 2.1.2.24. Distribution of sprat CPUA kg/km2 for spring 2011 along Samsun Shelf Area (Turkey) (STECF, 2015)

Mean abundance index (kg/km2) is presented on (Table 2.1.2.16.). The bulk of the biomass were distributed between age 1 and 2. The oldest age group estimated in this research belong to 4 years. No five years old specimens were found in this research. The species is fast growing; age comprises 4-5 age groups.

The three modal distributions of lengths from commercial sampling were recorded, as the highest percentage belong to the class of 8 cm. The length from 9.5 to 11 cm have subdominant role (Fig. 2.1.2.25).

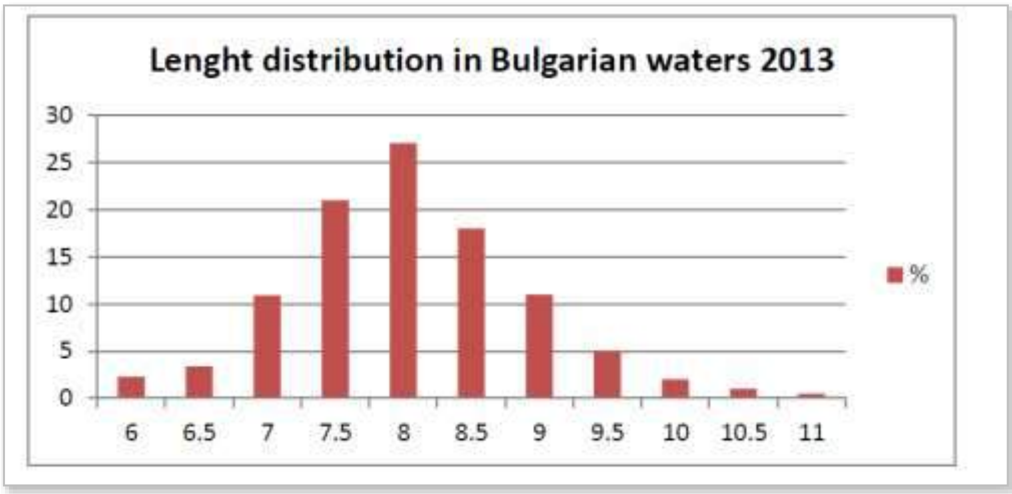


Figure 2.1.2.25. Length distribution from commercial sampling in 2013 (Bulgarian area)(STECF,2014)

Share (%) of age groups from Romanian marine area (1980-2014) are shown on Fig. 2.1.2.26. it is evident that in the last couple years the prevailing age class is 1+.In 1998-2009 the highest share belong to the 2-2+ years old individuals.

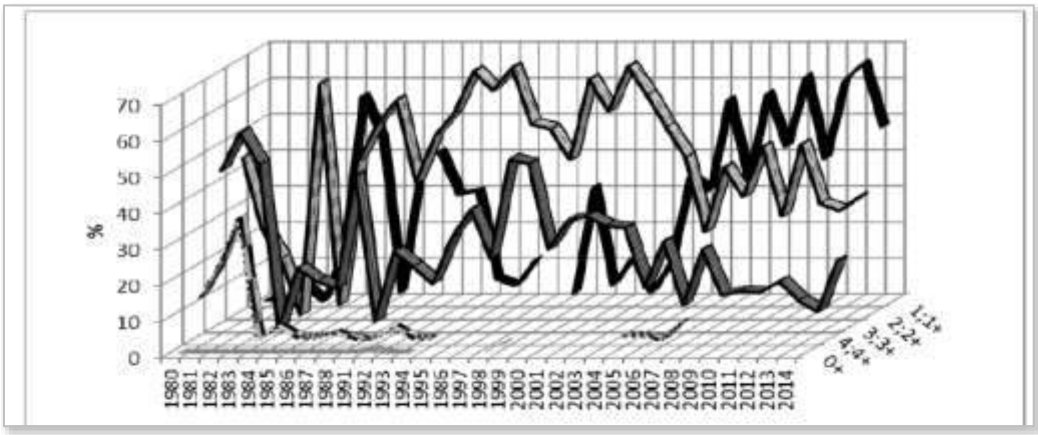


Figure 2.1.2.26. Age classes of sprat (share %) in Romanian marine area (Totoiu et al. 2016)

The maximum age was reported as 5 years within a variety of studies carried out in Samsun Shelf Region and in other sub regions of the Black Sea basin (Figure 2.1.2.27). The sprat has a high recovery rate with strong recruitments (Avsar and Bingel, 1994; Prodanov et al., 1997). In the sampling studies with the commercial vessels in Samsun Shelf Region, in 2013, it was observed that a large extent of landings (86.3%) were of 1 and 2 age groups that attained sexual maturity. Age 3 was represented by 12.3% of the sampling and age 4 and 5 by 6% and 0.5%, respectively.

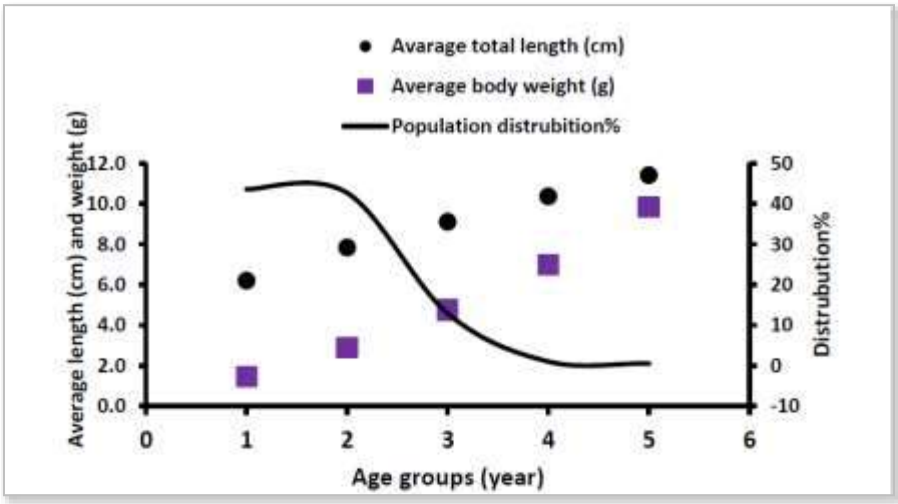


Figure 2.1.2.27. Age groups and average length and weight distribution of *Sprattus sprattus* in the Samsun Shelf Area in 2013 (STECF, 2014)

The length and weight frequency distributions were presented in Figure 2.1.2.27a, b. The mean length and body weight is found respectively 7.74 (4.5-12.17) cm, and 3.08 (0.10-12.98) g. The age range was determined as 1-5 years. The von Bertalanffy growth parameters were estimated as L∞ = 13.09 cm, K=0.477 year-1 and t0= -1.199 year and the constant and slope in length - weight relationship were calculated as 0.004 and 3.29 (Rsq= 0.92) respectively, for whole sub sampling (n=3819) periods in 2013 (Figure 2.1.2.27a,b.)

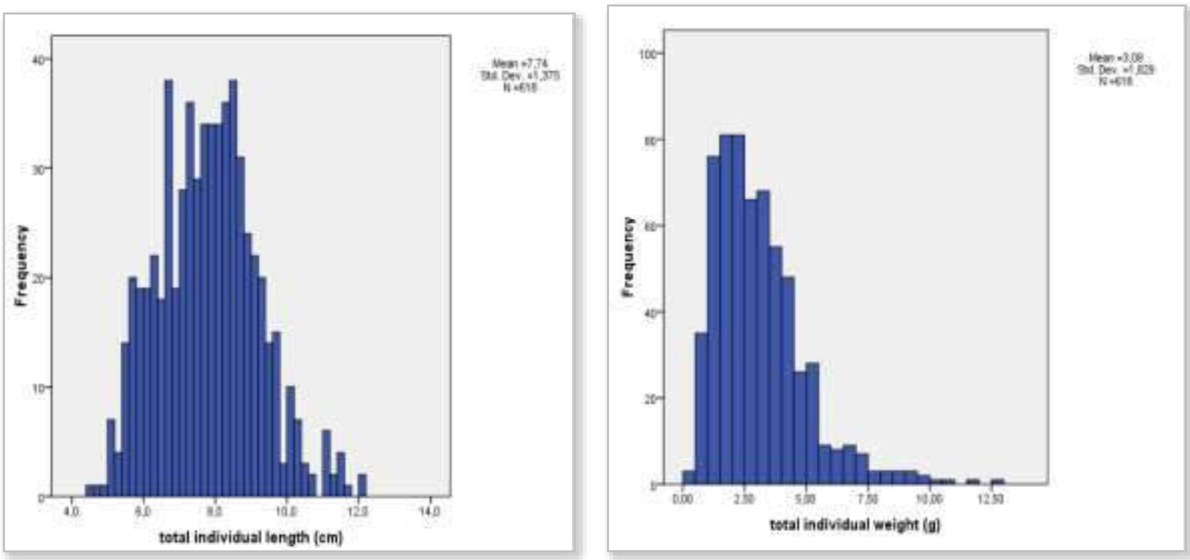


Figure 2.1.2.27. Length (a) and weight (b) frequency distributions of sprat I Turkey (STECF, 2014)

The acoustically detected distribution sprat within the Turkish EEZ during summer 2013 is

presented in the Figure 2.1.2.27.. The biomass of the species is remarkably higher in the eastern part of the area surveys. The averaged biomass is estimated at 6.4 tons/na2 (423 552 tons within the Turkish EEZ). However these values should be treated with caution. Hydroacoustically estimated biomass is 6.4 tons/na2. The biomass extrapolated over the Turkish EEZ is

Wmean = 0.58 g

Lmean = 4.9 cm

TSmean = - 57.4 (based on B20=-71.2)

Table 2.1.2.17. Spatial distribution of sprat in Turkish waters in 2013

Depth range (m)	0 - 30m	30 – 50m	50-70 m	Total
Investigated area (Nm^2)	625	887.5	87.5	1600
Variation of the catches (t/ Nm^2)	1.755-89.977	0.00 – 16.894	0.00 – 6.74	0.00 – 89.977
Average catch (t/ Nm^2)	23.96618	4.943529	3.37	11.2857
Biomass of the fishing agglomerations (t)	14978.86	4387.382	294.875	18057.266
Biomass extrapolated the Romanian shelf (t)				56428.955

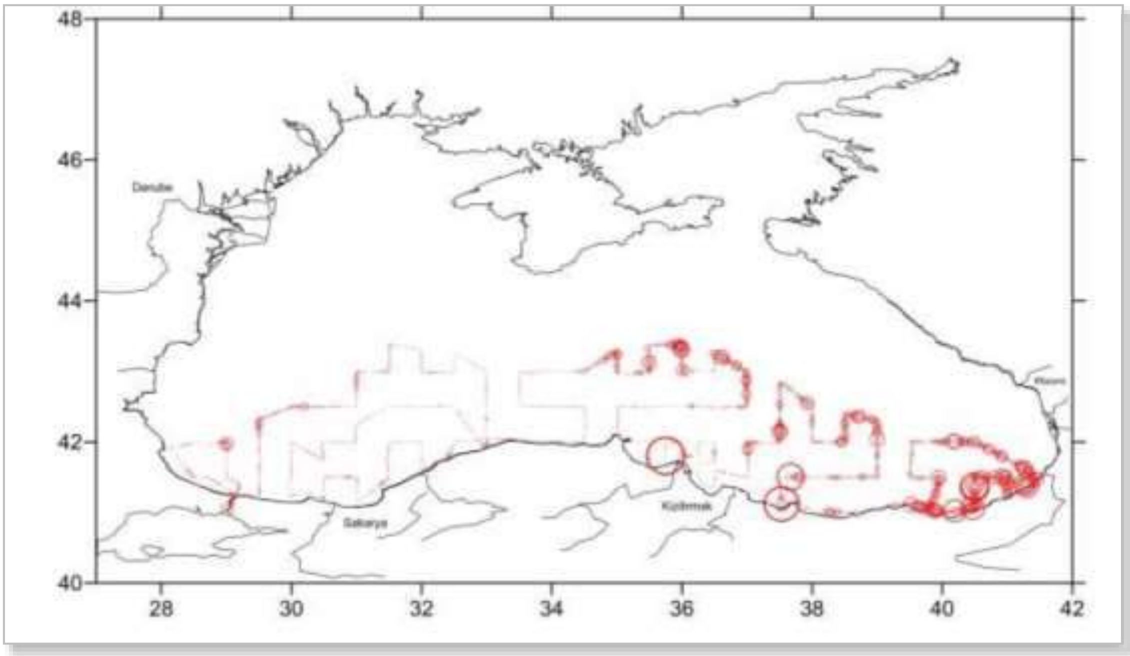


Figure 2.1.2.28. Hydro acoustic survey in Turkish waters conducted in 2013 with corresponding sprat agglomerations (STECF, 2014)

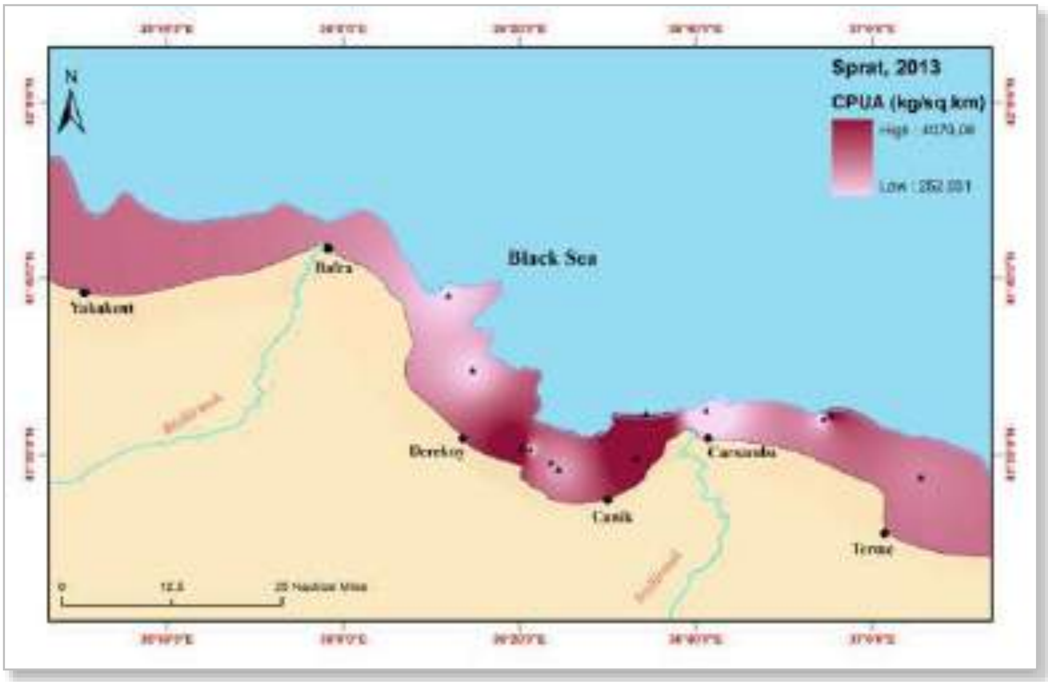


Figure 2.1.2.29. CPUA kg/sq.km of sprat in Turkish waters, 2013 (STECF, 2014)

Biomass indices in Bulgarian marine area (November 2014) were presented on Figure 2.1.2.30 (STECF, 2015). Sprat schools were found scattered over the most of the surveyed area, predominantly in the deeper waters after 50 m isobaths. Only in front of the area between Varna and Kamchia River mouth, sprat agglomerations were observed in the shallow waters at depths between 20 and 50m. The main sprat concentrations were found in front of Kaliakra-Shabla and between Varna and Ahtopol, forming a layer between 50 and 100 m depths with NASC values range between 7.80-28.51 ($m2.nm^{-2}$). The point map of distribution of sprat NASC values ($m2.\ nm^{-2}$) obtained during the acoustic survey of R/V "Akademik" in October-November 2014 (STECF, 2015).

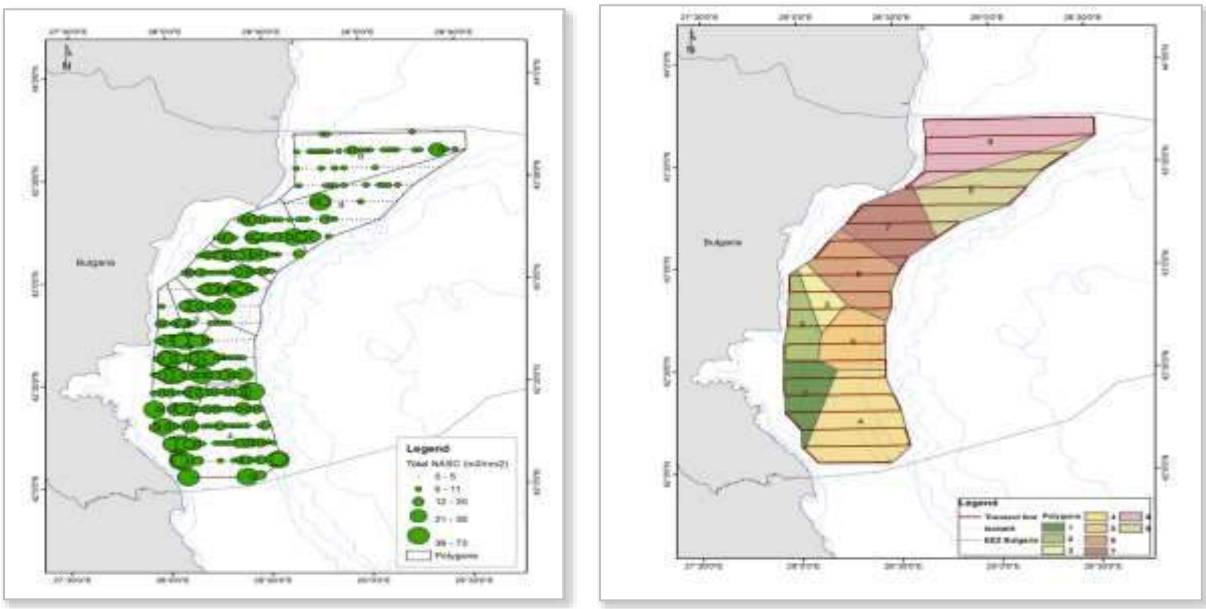


Figure 2.1.2.30. Total fish NASC values per EDSU in October – November 2014 (STECF, 2015)

Table 2.1.2.18. Estimated abundance of sprat (millions) by age groups and polygons, October - November 2014 (Panayotova et al., 2015)

Polygon	Total (t)	Age				
		1	2	3	4	5
3	1225.06		816.75	408.31		
4	23205.22	150.03	12302.77	9152.06	1500.34	100.02
5	9619.04	1180.58	4507.67	3447.83	482.96	
6	12384.90	4751.44	4439.87	2901.49	292.10	
9	8926.28	3250.61	4867.31	808.35		
Total (t)	**55360.49**	**9332.66**	**26934.36**	**16718.05**	**2275.40**	**100.02**

The observed size and age distributions of turbot catches during the survey in May, 2012 along the Bulgarian Black Sea coast are presented on Fig. 2.1.2.30. Due to very low number of individuals caught (n=26), the observed distributions are not representative for the population in front of Bulgarian coast. The individuals caught have lengths between 26 and 70 cm. Undersized turbots with total lengths under 45 cm represent 38.46 % of all caught specimens and the standard sized fish represent 61.54 % respectively. The average length over all caught specimens was estimated at 47.10 cm. The maxima in abundance were observed in size classes 44.5 – 53.5 cm, but all classes were low abundant. The larger size classes were represented by few individuals, which make up 19.23 % of total observed abundance.

Age structure of specimens caught in the Bulgarian area encompassed 2 - 7 years old individuals. The catches were dominated by 4 - years old fish (30.77%) - Fig. 2.1.2.30. During the survey in May 2012, the share of recruitment (2 - 3- years old individuals) represent 34.62 % from all caught fish, the 4 - 5 years old fish- 46.15% and the 6 - 7 years old individuals composed 19.23 % of total abundance (STECF, 2013)

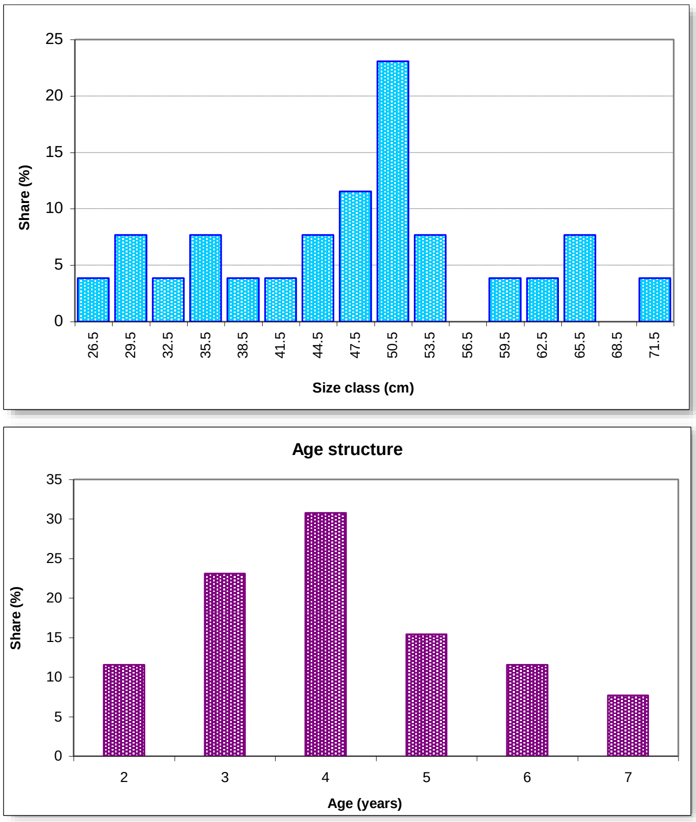


Figure 2.1.2.30. Length and age frequency data for turbot, obtained during the survey along the Bulgarian Black Sea coast in May, 2012 (STECF, 2013).

In Romanian area, the turbot catches were low in spring survey 2012. The size structure was composed of mature specimens with total lengths between 21 - 81 cm / 633.0 – 9155.0 g, aged 2-7 years. The dominant size classes were 41.5 - 68.5 cm / 1,650 - 5,507.27 g, 3 - 5 years (76.0%). Average body length was estimated at 54.44 cm and the average weights - 3 425.24 g, respectively. The sex ratio indicates a clear dominance of females (53.96%) than males (43.56%) and juveniles (2.48%). The age composition of turbot catches reveals the existence of specimens between 1 to 7 years. Most of the individuals are 4 years old (31% of all specimens analyzed) and of 3 years old (30%), followed closely by those of 5 years old (15%), 6 years (9%), 7 years (8%) and of 2 years old (7%) (Maximov, 2012).

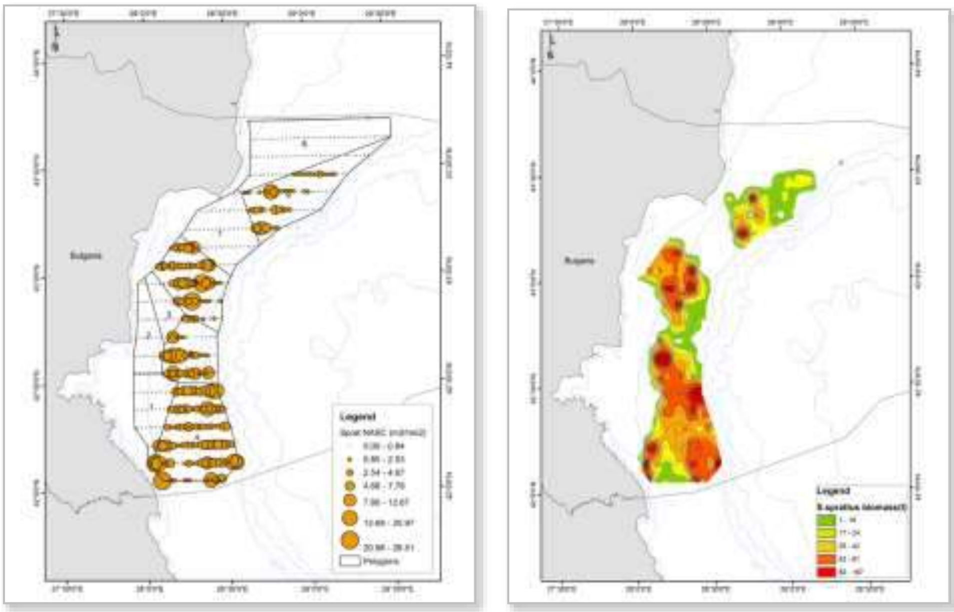


Figure 2.1.2.31. Distribution map of sprat biomass values in October - November 2014 (Panayotova et al., 2015)

Table 2.1.2.19. Biomass of sprat by age groups in 2014, Bulgarian marine area (Panayotova et al., 2015)

Polygon	Total (t)	Age				
		1	2	3	4	5
3	1225		817	408		
4	23205	150	12303	9152	1500	100
5	9619	1181	4508	3448	483	
6	12385	4751	4440	2901	292	
9	8926	3251	4867	808		
Total (t)	55360	9333	26934	16718	2275	100

The length distribution of sprat is given on Figure 2.1.2.32.The 3 modal distributions were observed for the investigated period.

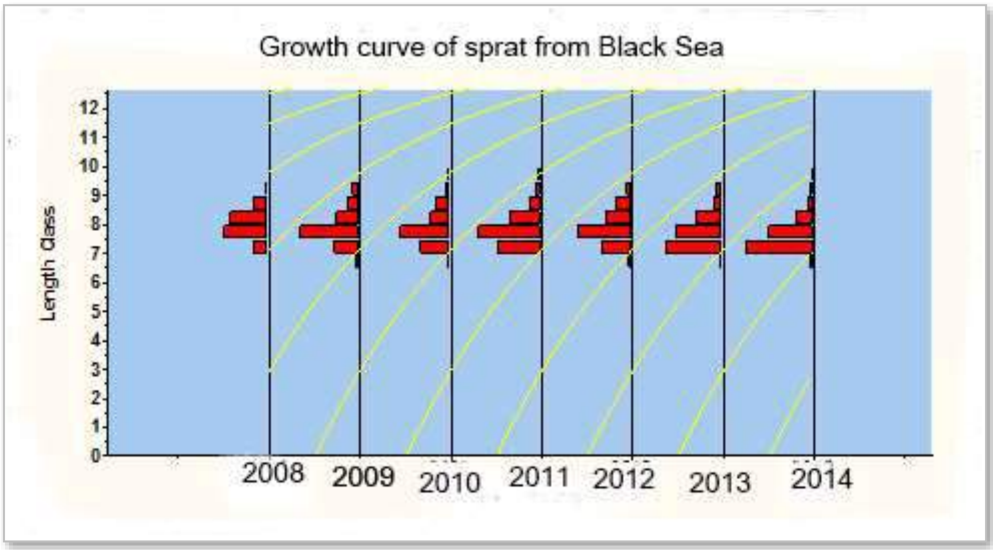
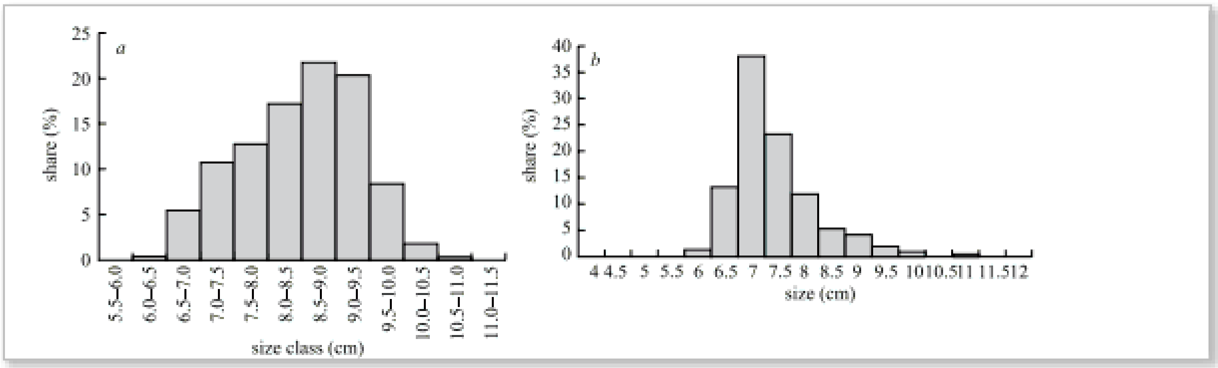


Figure 2.1.2.32. Length frequencies of sprat for 2008-2012 periods.

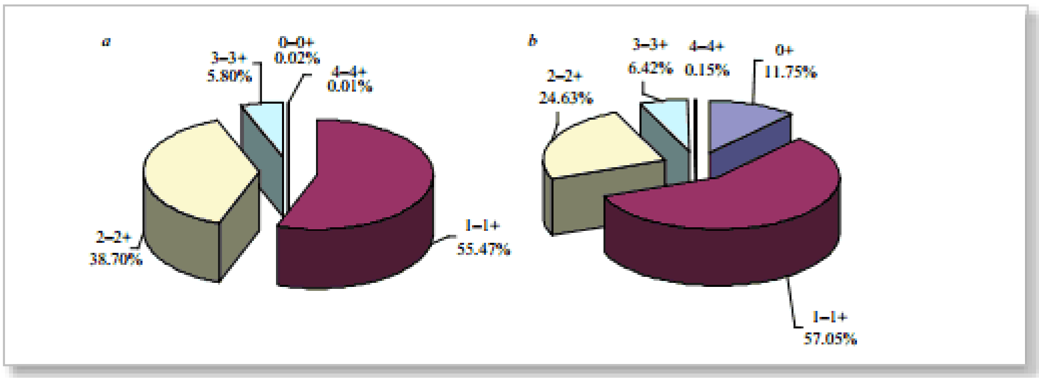
Table 2.1.2.20. Sprat means length (L_{mean}) by years in the shelf zone with corresponding min-max values and CI (95%)

	L mean	min	max	CI (95%)	Zone
2009	7.94	4.99	12.46	0.8122	Shelf
2010	7.99	4.92	11.72	0.2531	
2011	8.33	5	10.6	0.546	
2012	8.21	4.98	11.66	0.458	
2013	8.19	4.82	11.82	0.774	
2014	8.33	4.77	11.77	0.822	



A B.

Figure 2.1.2.33. Length distribution of sprat from scientific survey in 2010 (A. Romania; B.Bulgaria) (Raykov et al., 2014)



A B.

Figure 2.1.2.34. Age distribution of sprat from scientific survey in 2010 (A. Romania; B.Bulgaria) (Raykov et al., 2014)

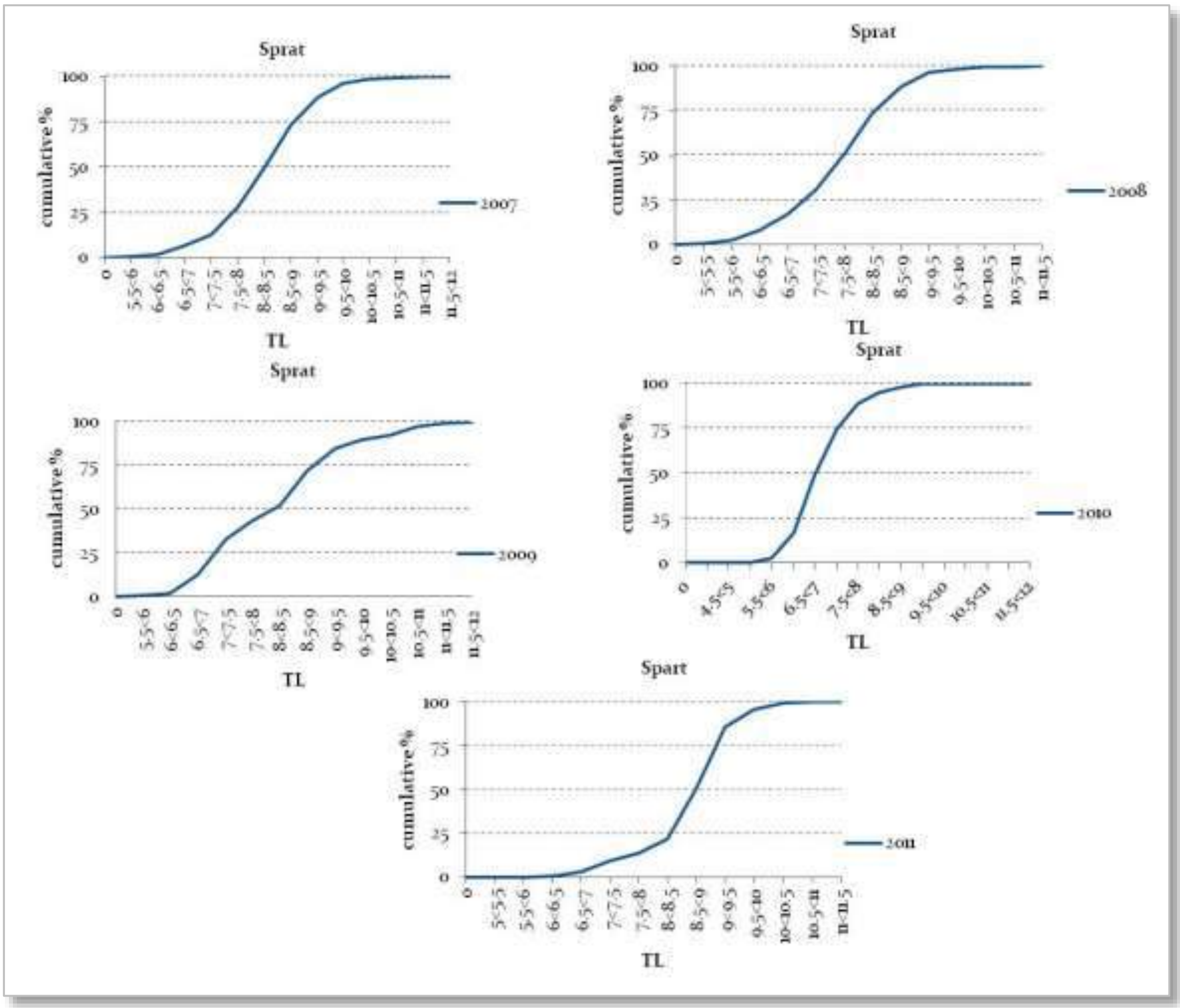


Figure 2.1.2.35. Indicator based on length-frequency distributions of sprat: 95% percentile of the population length distribution for 2007-2011 in Bulgarian marine area (Raykov, 2015)

Analysis of the equilibrium yield-per-recruit as fraction of unexploited biomass is presented in fig. 2.1.2.36. The plot shows that the median Y/R, as a fraction of unexploited fishable biomass, reaches a maximum or close to values of F above about 1.4. The value of F close to natural mortality M = 0.95, which shows that sprat stock is not overexploited. The upper 97.5% confidence band 15–17 for relative Y/R is still rising as F reaches 2.0, while the lower 2.5% confidence band may have reached a maximum for F somewhere around 0.42. In lower confidence band the model suggests that towards fishing mortality F=2 the stock is nearly extinction.

Medium confidence band shows that at fishing mortality rates around 0.8 the ratio yield and fishable biomass at unexploited level is around 0.25. Increasing fishing mortality above values of 0.8–1 decreases relative yield and at F≥2 could lead to stock depletion. From the Y/R analysis it is clear that levels of F that produces Y/R at or near the maximum will also reduce the SSB (Fig. 2.1.2.36) to levels that are a tiny fraction of its unexploited level. Determination values of F that produce an equilibrium SSB-per-recruit that is 20% of its unexploited level.

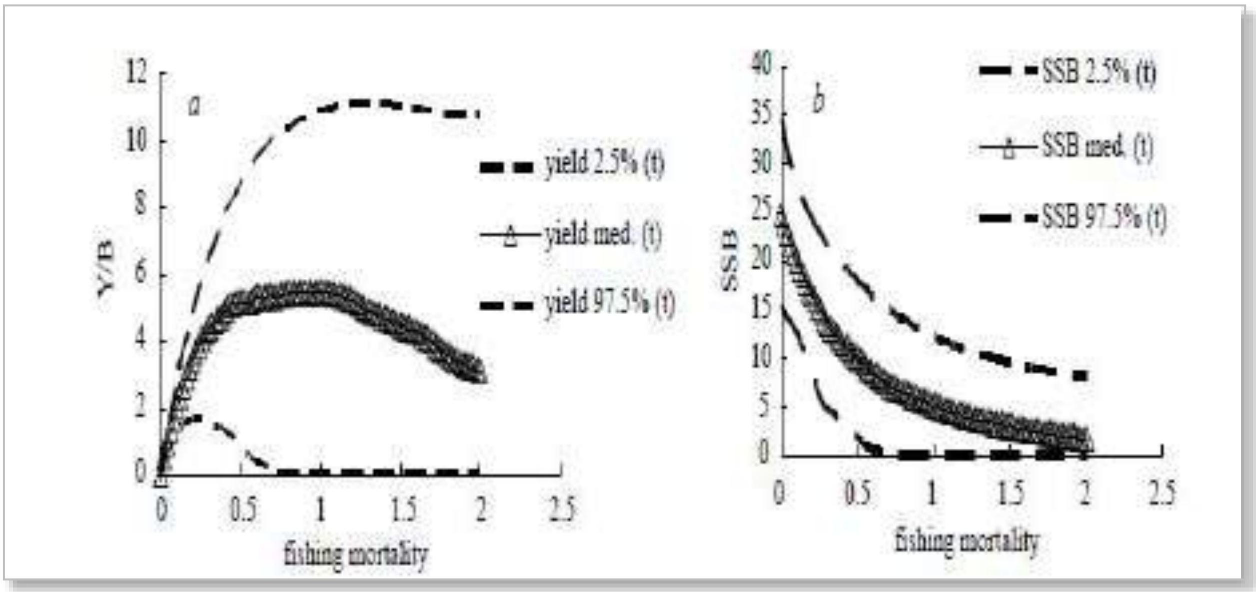


Figure 2.1.2.36. Equilibrium yield-per-recruit as fraction of unexploited Biomass (Raykov et al., 2011)

The candidate reference points for the sprat stock in the western part of the Black Sea F0.1 and corresponding SSB, yield, fishable and total biomass per recruit is presented in Fig. 2.1.2.37. According to the analysis, F0.1 criteria advice to keep the fishing mortality rates in the range of 0.75 to 1.0 with bell-shaped histogram, after simulation run performed (Fig. 2.1.2.37.a). The other tested variables (Fig. 2.1.2.37. b, c, d and e) show similar trends, as the taller bars are on the left side of the histograms.

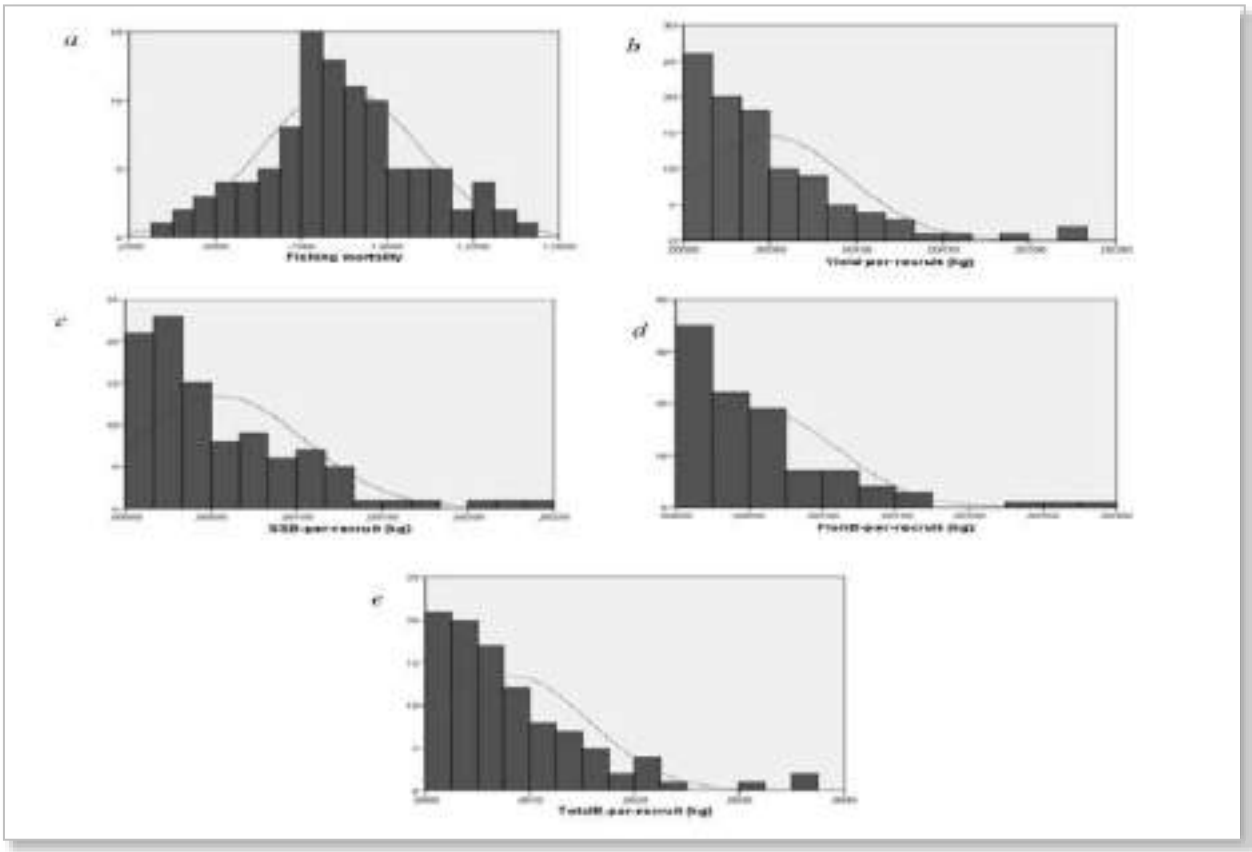


Figure 2.1.2.37. F0.1 reference points of sprat: reference fishing mortality (a); reference yield per recruit, kg (b); reference SSB per recruit, kg (c); reference fishable biomass per recruit, kg (d); reference total biomass per recruit, kg (e)

Scad (Trachurus mediterraneus ponticus)

The Black sea horse mackerel is a subspecies of the Mediterranean horse mackerel *Trachurus mediterraneus*. Although in the past the Black sea horse mackerel has been attributed to various subpopulations, in a more recent study Prodanov et al. (1997) brought evidence that the horse mackerel rather exists as a single population in the Black sea, and thus all Black sea horse mackerel fished across the region should be treated as a unit stock. The genetic analysis demonstrated that two scad shoal groups migrate in the Bulgarian adulatory sector of the Black Sea (Dobrovolov, 2000). The horse mackerel is a migratory species distributed in the whole Black Sea (Ivanov and Beverton, 1985). In the spring it migrates to the north for reproduction and feeding. In summer the horse mackerel is distributed preferably in the shelf waters above the seasonal thermocline. In the autumn it migrates towards the withering grounds along the Anatolian and Caucasian coasts migration (Ivanov and Beverton, 1985). The horse mackerel population in the Black Sea mainly winters along the Crimean, Caucasian and Anatolian coasts and warm sections of the Marmara Sea. They winter at a depth ranging between 20 and 90 meters off Crimea and between 20 and 60 meters off the Caucasian coasts. The horse mackerel population continuously remains in the eastern Black Sea winters in an area north-east of Trabzon. The population migrating between Marmara and the eastern Black Sea spend the winter in the Bosphorus area and off the Marmara Sea at optimal depths ranging between 30 and 50 meters. Depending on water temperature, feeding migration starts in mid-April or towards the end of that month (Demir, 1958). Horse mackerel groups migrate from the Bosphorus to the Bulgarian and Romanian coasts in the north. They are also believed to migrate from Crimea to the north-west and from the Caucasian and north-eastern Anatolian coasts to the Crimean coasts. Autumn migration starts in September and reaches a peak in October and November (Ivanov and Beverton, 1985).

The horse mackerel (*Trachurus mediterraneus*) fishery operates mainly on the wintering grounds in the southern Black Sea using purse seine and mid -water trawls. The horse mackerel of age 1-3 years generally prevails in the commercial catches, but strong year classes (for example, the 1969-year class) may enter into exploitation at age of 0.5 year and may prevail up to age 5 -6 years. Over the last 40 years, highest horse mackerel catches were reported in the years preceding *M. leidyi* outbreak (1988-1990) (Prodanov et al., 1997; FAO, 2007). The maximum catch of 141 thousand tons was recorded in 1985, from which ~100 thousand tons were caught by Turkey (Prodanov et al., 1997). Upon 1994 the amounts of catches decreased especially in 1998-1999 period. In 2013 decrease in catches of horse mackerel was reported, at the level of 20213.51t. The catches of Black Sea horse mackerel were realized by active (pelagic trawls and purse seine) and passive fishing gears (gill netting, trawl net, trap nets). Horse mackerel stocks in the Black Sea are usually caught by Turkish fishermen by using active (bottom trawler, pelagic trawler and large purse seine) and passive (extension and longline) nets. Almost the whole horse mackerel catch (98.2%) in Turkish waters is caught by large purse seine (STECF, 2015).

The scad landings in Black Sea (2009-2014) are presented on table 2.1.2.21. Turkey hold the first place as regards quantities of scad, as the highest landings have been recorded in 2012 (23911 mt) and highest in Black Sea, respectively.

Table 2.1.2.21. Landings of Scad in Black Sea AG FOMLR, 2015

Year	Bulgaria	Georgia	Romania	Rus. Federation	Turkey	Ukraine	Total
2009	176.91	106.397	16.783	124.04	15905	260	16589.13
2010	165.27	26.7673	7.228	108.86	12929	190	13427.1253
2011	394.84	445.1816	22.82	87.21	17746	264	18960.0516
2012	381.37	709.3929	20.005	87	23911.2	539.713	25648.6809
2013	271.38	730.7505	26.325	89	18979.4	847.405	20944.2605
2014	113.07	730.7505	6.611	64.765	10824.9	597.242	12337.3385

Table 2.1.2.22. Growth and length weight model parameters

COUNTRY	YEAR_PERIOD	SPECIES	SEX	L_INF	K	t_0	a	b
Bulgaria	2007-2008	HMM	C	19.75	0.3020	-0.830	0.0035	3.3046
Bulgaria	2007-2008	HMM	M	18.785	0.3373	-0.825	0.0034	3.3123
Bulgaria	2007-2008	HMM	F	19.661	0.3075	-0.836	0.0038	3.3029
Bulgaria	2013	HMM	C	20.98	0.2839	-0.71	-	-
Bulgaria	2014	HMM	C	20.45	0.3126	-0. 813	0.0199	3.2421
Romania	2000	HMM	C	18.6	0.224	-1.430	0.0380	2.3552
Romania	2001	HMM	C	18.95	0.268	-0.630	0.0470	2.3501
Romania	2009	HMM	C	18.42	0.42	-0.410	0.0450	2.3469
Romania	2010	HMM	C	20.03	0.302	-0.467	0.0111	2.9065
Romania	2011	HMM	C	17.37	0.371	-0.445	0.0101	2.9101

COUNTRY	YEAR_PERIOD	SPECIES	SEX	L_INF	K	t_0	a	b
Romania	2012	HMM	C	16.84	0.2686	-1.811	0.01075	2.883
Romania	2013	HMM	C	16.842	0.47	-1.1078	0.01788	2.6774
Romania	2014	HMM	C	16.80	0.503	-1.11	0.008849	2.961
Turkey	1991 – 1992	HMM	M	19.9	0.396	-1.020	0.0110	3.18
Turkey	1991 – 1992	HMM	F	20.6	0.356	-1.110	0.0080	2.993
Turkey *	2005	HMM	C	20.237	0.3181	-1.603	0.0081	2.9983
Turkey *	2006	HMM	C	22.394	0.241	-1.932	0.0064	3.0986
Turkey *	2007	HMM	C	22.232	0.2554	-1.828	0.0085	2.984
Turkey *	2008	HMM	C	22.244	0.2538	-1.80	0.0069	3.1018
Turkey *	2009	HMM	C	24.023	0.2082	-2.075	0.0062	3.1024
Turkey *	2010	HMM	C	25.002	0.187	-2.11	0.0052	3.1654
Turkey *	2011	HMM	C	24.44	0.235	-1.767	0.0056	3.1402
Turkey *	2012	HMM	C	21.36	0.287	-1.84	0.0059	2.8831
Turkey *	2013	HMM	C	19.804	0.4516	-0.8235	0.0050	3.1862
Turkey *	2014	HMM	C	21.805	0.2926	-0.9344	0.0045	3.2422
Ukraine	2008	HMM	C	18.5	0.343	-0.66	-	-

XSA main outputs (Fig. 2.1.2.38.) showed that F values ranged between 0.501 and 2.328. Recruitment is indicated to have decrease in the mid part of the series and is now in a high period. Assessment formulations indicate that the SSB in 2014 was lower compare to the previous year but is fluctuating since 2005 (STECF, 2015; GFCM, 2015)

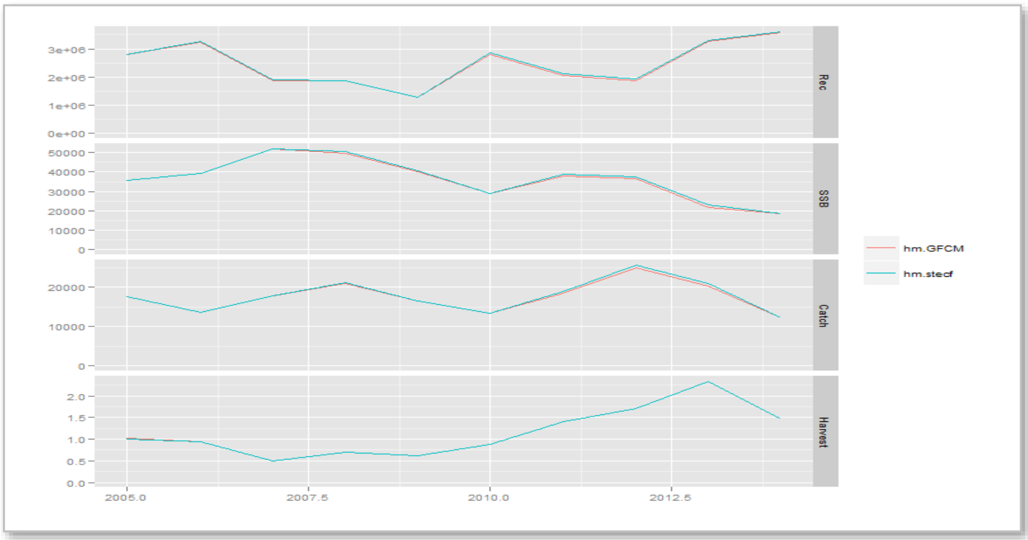


Figure 2.1.2.38. Mediterranean Horse Mackerel in GSA 29. XSA summary results. SSB and catch are in tons, recruitment in thousands of individuals (STECF, 2015)

Since the stock is pelagic as reference point to be consistent with long term exploitation of the stock, the Patterson Exploitation E=0.4 was selected. Since the current E value of horse mackerel was E2014=0.787 and it was almost two times higher than the reference point, the stock was considered in a state of overexploitation in 2014 (Figure 2.1.2.39) (STECF, 2015; GFCM, 2015).

Table 2.1.2.23. Results of the best assessments Spawning Stock Biomass (SSB), F over age 1-4 (F_{bar}), Recruitment (REC), catch and landings (STECF, 2014)

Year	SSB	F_{bar}	REC	CATCH	LANDINGS
2009	37647.47	0.7154386	1255322	16489.06	16489.06
2010	26970.41	1.0172681	2820623	13405.50	13405.50
2011	36771.91	1.5578679	2543753	18558.87	18558.87
2012	40405.69	1.7370362	3142292	24931.36	24931.36
2013	34530.60	1.4231011	3244748	20213.51	20213.51

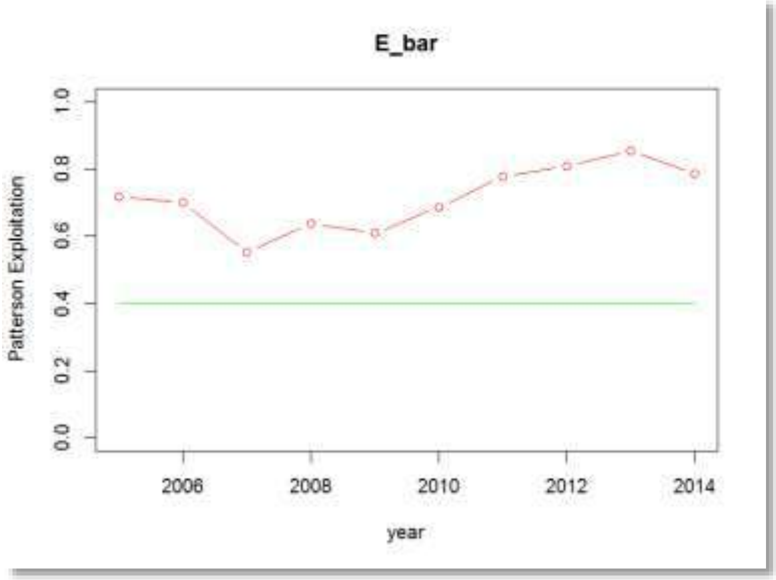


Figure 2.1.2.39. Mediterranean Horse Mackerel in GSA 29. Patterson Exploitation in relation to reference point E=0.4 (STECF, 2015)

The calculated value for the growth performance index of *T. Mediterraneus* during the present study were 2.196. The application of the Bhattacharya method determined model lengths of *T. mediterraneus* ranging from August, with satisfactory separation index (Yankova, 2013).

Table 2.1.2.22. Identified age groups from length-frequency analysis of *T. mediterraneus* during the monthly sampling using the Bhattacharya method (Yankova and Raykov 2012; Yankova, 2013).

Months	Age groups	Mean total length (TL) (cm)	SD	SI
May	1	14.65	0.730	–
	2	16.62	0.300	2.120
June	1	13.20	1.200	–
	2	16.88	1.210	2.180
July	1	13.69	0.470	–
	2	15.10	0.380	2.080
August	1	9.93	0.450	–
	2	15.30	1.170	2.720
September	1	14.06	0.730	–
	2	15.53	0.450	2.040
October	1	13.63	0.640	–
	2	16.12	0.900	2.130
November	1	11.04	0.460	–
	2	13.85	0.870	2.260
December	1	13.10	0.760	–
	2	14.90	0.610	2.060

The length range obtained in the horse mackerel was 8 to 19 cm, the majority of the catch being between 12 and 16 cm. The length frequency distribution of *T. mediterraneus* for the study period is shown in Figure 2.1.2.40. The ELEFAN-I analysis gave the following VBGF parameters: cm and The Powell-Wetherall plots are shown in Figure 2.1.2.41. The corresponding estimates of and for *T. mediterraneus* are 19.73 cm and 2.35 respectively. This additional estimate of is slightly smaller than the one estimated through ELEFAN-I (Yankova, 2013).

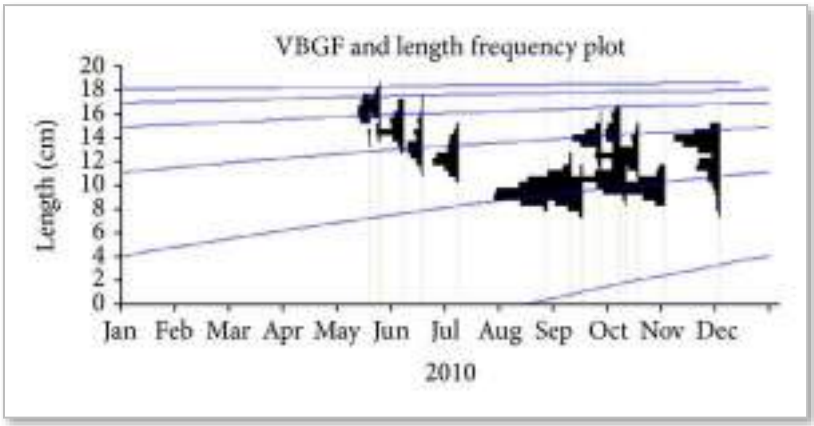


Figure 2.1.2.40. VBG curve of *T. mediterraneus* with normal length frequency histograms. Lines superimposed on the histograms link successive peaks of growing cohorts as extrapolated by the model.

Table 2.1.2.23. Various growth parameter estimates of *T. Mediterraneus* along the Bulgarian coast

(cm)				Method		Locality
19.25	0.35	−0.59	8.57[1]	Otolith	2.113	Bulgarian coast [9]
19.99	0.31	−0.49	9.67[1]	Otolith	2.093	Bulgarian coast [32]
19.99	0.34	−0.46	8.82[1]	Otolith	2.134	Bulgarian coast [31]
20.00	0.24	−0.98	12.5[1]	Otolith	1.975	Bulgarian coast [31]
19.45	0.23	−0.93	13.04[1]	Otolith	2.031	Bulgarian coast [31]
19.99	0.33	−0.29	9.09[1]	Otolith	2.077	Bulgarian coast [31]
20.00	0.28	−0.81	10.7[1]	Otolith	1.739	Bulgarian coast [31]
17.55	0.45	−0.19	6.66[1]	Otolith	2.142	Bulgarian coast [33]
18.78	0.34	−0.82	8.82[1]	Otolith	2.079	Bulgarian coast [34]
19.95	0.64	−0.55	4.7[1]	ELEFAN I	2.406	Bulgarian coast[2]

[1]Based on the Taylor's [17] assumption

[2]Present study

Results of the analysis of the recruitment pattern of *T. mediterraneus* during the investigation are shown in Figure 2.1.2.41. The recruitment pattern showed one annual pulse of recruitment for horse mackerel (around June). This pulse produced 23.86% of the recruits. Our asymptotic length value compares favourably with those obtained by others researchers.

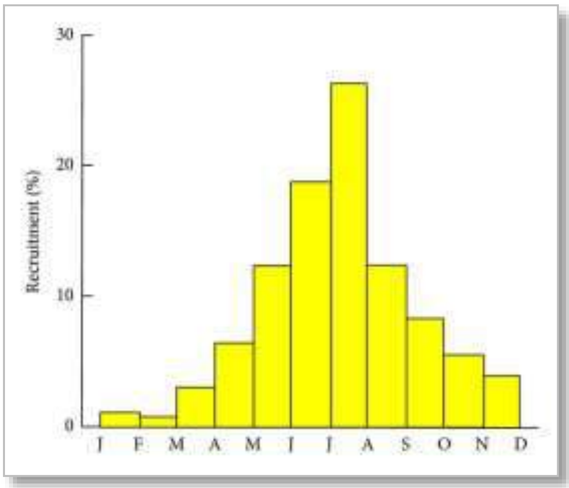


Figure 2.1.2.41. Recruitment pattern of horse mackerel. The recruitment pattern showed one annual pulse of recruitment for horse mackerel (Yankova, 2013)

Spatial distribution

The distribution of horse mackerel in September and October is in a peculiar manner, during the day shoals usually, kept at 7-12 m below the water surface and at 1 to 3 m above the bottom, and at night in the middle layer from 5 to 10 m from the bottom. The autumn migration from the northern Black Sea region towards the south is usually carried out in November. During the autumn migrations starts at the end of November and the first half of December from north to south forming offshore aggregations in the southern Bulgarian coastal area. This work provides a first description of the migrations of horse mackerel, along the Black Sea territorial waters. Fig. 2.1.2.42. Chart of summer migration of horse mackerel in Black and Azov seas after Aleev (1959). Legend: 1- south-western (Bosporic) shoal; 2- northern (Crimean) shoal; 3- eastern (Caucasian) shoal.

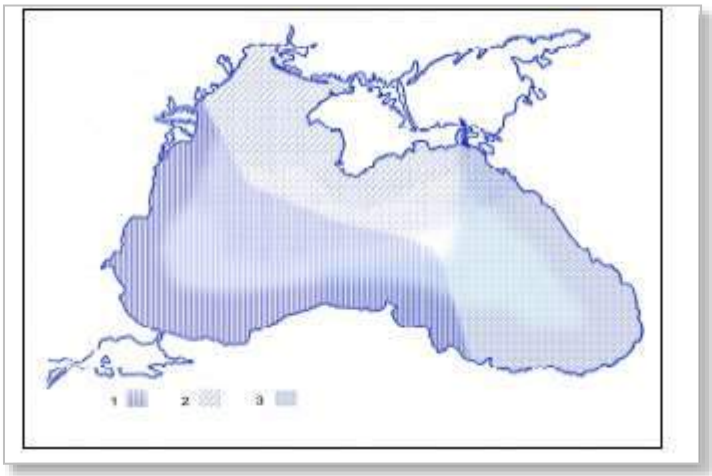


Figure 2.1.2.42. Chart of summer migration of horse mackerel in Black and Azov seas after Aleev (1959). Legend: 1- south-western (Bosporic) shoal; 2- northern (Crimean) shoal; 3- eastern (Caucasian) shoal.

Survey period coincided with the wintering migration of pelagic fish and horse mackerel agglomerations were acoustically distinguished in the whole area, but with the highest abundance in front of cape Emine at depths between 20 and 50m.

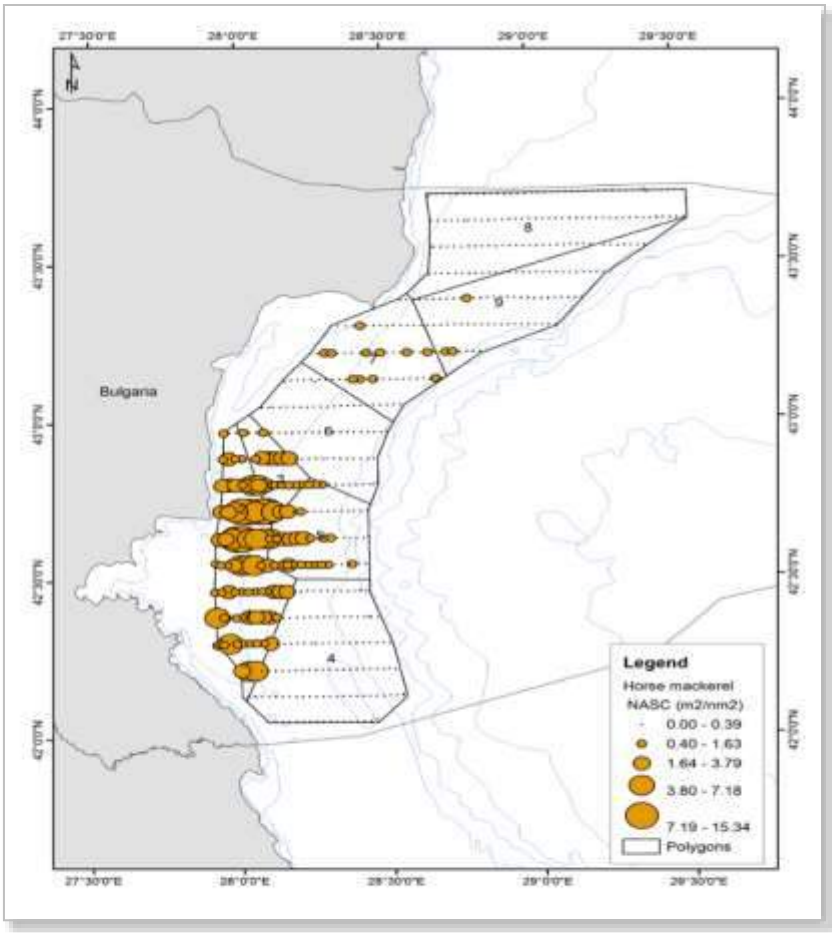


Figure 2.1.2.43. Point map of horse mackerel NASC values (m2.nm-2)(Panayotova et al.,2015)

Table 2.1.2.24. Estimated relative biomass (tonnes) of horse mackerel by age group and polygon, October - November 2014 (Panayotova et al.,2015)

Polygon	Total (t)	Age				
		0	1	2	3	4
1	4547.04	3025.02	1464.95	57.08		
2	6280.34	1684.46	3244.15	748.65	457.51	145.57
3	2183.21	545.80	1472.64	144.17	20.60	
5	3625.79	2120.75	1459.44	45.61		
7	3469.98	2050.44	1104.08	157.73		157.73
9	4150.72	4150.72				
Total (t)	**24257.07**	**13577.19**	**8745.25**	**1153.23**	**478.10**	**303.30**

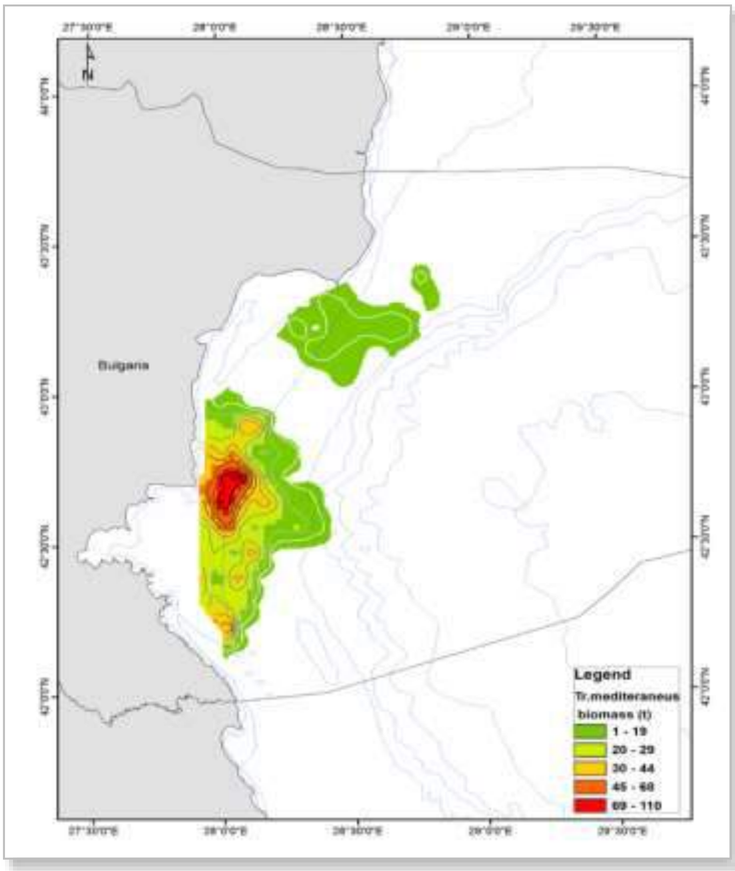


Figure 2.1.2.44. Distribution of horse mackerel biomass values, obtained during the acoustic survey of R/V "Akademik" in October - November 2014 (Panayotova et al., 2015)

Bluefish - Pomatomus saltatrix

Bluefish schools migration was observed in the study area and the schools follow the horse mackerel movements. The agglomerations were composed from the recruitment (0+ - 1 years old fish) (Panayotova et al., 2015).

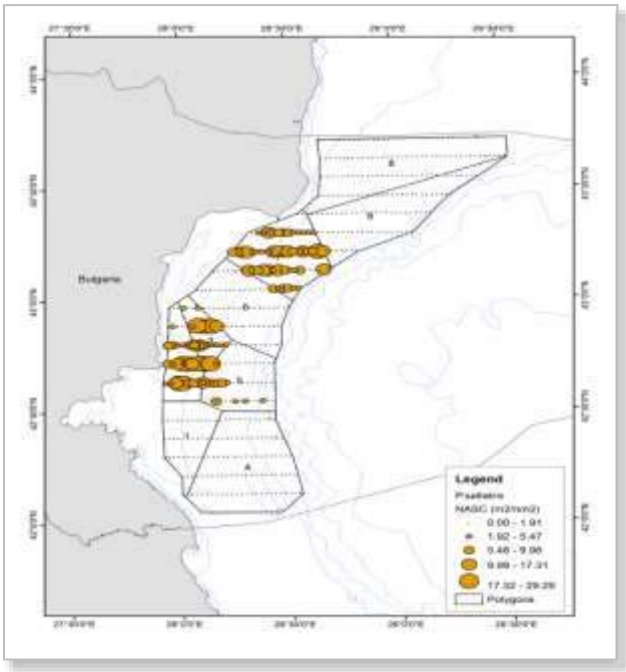


Figure 2.1.2.45. Estimated number of bluefish (millions) by age groups and polygons, October - November 2014 (Panayotova et al., 2015)

Table 2.1.2.26. Distribution of bluefish at age 0 and 1 in Bulgarian marine area, 2014

Polygon	Total (millions)	Age	
		0	1
2	337.11	331.03	6.07
3	196.79	189.76	7.03
5	218.60	218.60	
7	264.90	264.90	
Total (millions)	**1017.39**	**1004.29**	**13.10**

Atlantic Bonito (*Sarda sarda*)

Atlantic bonito (Sarda sarda Bloch, 1793), which is a member of Scombridae, exhibiting wide distribution in temperate and tropical coastal areas, coasts of the Atlantic Ocean, the Mediterranean, and the Black Sea (Collette and Chao,1975; Collette and Nauen, 1983; Sabatés and Recasens, 2001; Yoshida, 1980). It is an oceanodromous species which lives in schools along the neritic area and may enter in estuaries. It can be found from 80 to 200 meters depth (Collette and Nauen, 1983). Temperature is one of the most important environmental factors determining the distribution of tuna fish. This species can adapt to different temperatures 12°C to 27°C and salinities 14 to 39‰ (STECF, 2015). Atlantic bonito plays a major role as top predator in the Black Sea ecosystem and has high commercial importance, especially for the Turkish fishery since 1950 (Prodanov et al., 1997; Cengiz, 2013; FAO, 2014). While total catches of Atlantic bonito from all Black Sea coastal states reached the maximum of 20.000 tons in 1969, thereafter have no Atlantic bonito catches recorded from these countries, except Turkey and Bulgaria. This was mainly due to pollution in northwest Black Sea, problems with migration routes (Changing of oceanographic conditions) and heavy fishing impact occurred in the Black Sea on Atlantic bonito stocks (Daskalov, 2002; Eremeev and Zuyev, 2007).

- While egg hatched, pre larva, post larva and juvenile periods getting to increase, which cause the decrease in natural mortality rate? The favorable water temperature and alterations in pelagic food web have positive effect on bonito population.
- The spawning period may be prolonged compared to the period before 2000.
- Migrating population into Black Sea spend more time than before and feed on small pelagic species as anchovy, horse mackerel and sprat.

Data on landings of Atlantic bonito in the Black Sea are available primarily for Turkey. The other Black Sea nations, except for Bulgaria, have no reported landings for this species. No discard data for bonito are available. Length and weight data for bonito landed in Turkey were collected during the period 2000-2013, except for the years 2002-2004, from the Turkish border with Bulgarian to border with Georgia. In the available length frequency data almost all the fish were relatively small (<50cm) and there were very few large mature individuals, which suggests that the adult portion of this population is unavailable to fishing operations in the Black Sea and may not reside in the Black Sea. However, reported Turkish landings of bonito are relatively low for the Aegean and Mediterranean Seas. Similarly, landings of bonito in Greece (Aegean Sea) are relatively low, implying that neither the Aegean nor the Mediterranean Seas are the parental source for bonito in the Black Sea (STECF, 2015). Fishing activity for bonito takes place in the Black Sea generally between September and November, and landings reach their highest levels during September in 2013. The vast majority of the bonito catches are by Turkish purse seine vessels (85%) and small fisheries vessels (15%) (STECF, 2015; GFCM, 2015).

Table 2.1.2.27. M vector and proportion of matures by size or age (Males) (GFCM, 2015)

Size/Age	Natural mortality	Proportion of matures
0+		2.259936
1+		0.954501
2+		0.743604
3+		0.679564

Table 2.1.2.28. M vector and proportion of matures by size or age (Females) (GFCM, 2015)

Size/Age	Natural mortality	Proportion of matures
0+		2.259936
1+		0.954501
2+		0.743604
3+		0.679564

Table 2.1.2.29. Growth and length weight model parameters (GFCM, 2015)

			Sex			
		Units	female	male	Combined	Years
Growth model	L_∞	69.24			C	2013
	K	1.08			C	2013
	t_0	-0.17			C	2013
	Data source					
Length weight relationship	a	0.0024			C	2013
	b	3.4115			C	2013

M (scalar)	0.917			C
sex ratio (% females/total)				

Age determination and growth of Atlantic bonito have been studied by means of different methodologies: otholiths, vertebrae, spines and size frequency. The species is fast growing and the age range of bonito is found between 0-3 years by size frequency for the 2000-2013 periods, in the Black Sea. A total of 477 individuals were studied in 2013 years from market sampling, purse seine and gill nets off the Turkish coast of Black Sea (from the border of Bulgaria to the border of Georgia). The von Bertlanffy Growth Parameters (VBGF) is given for Black Sea in Table 2.1.2.27 and for other seas in Table 2.1.2.28 (Genç et al., 2014). The length–weight relationship was estimated for all years (Figure 2.1.2.47; Table 2.1.2.29 and 2.1.2.30). While the b-values and t-test results indicated positive allometric growth for all samples, the b-values showed no significant difference for years ($P > 0.05$) (Figure Table 2.1.2.29.). Table 2.1.2.30 VBGF parameters were calculated for caught Atlantic bonito (Sarda sarda) in the Turkish coast of Black Sea between 2000-2013 (TL: total length), (L_∞ in cm, k in y-1, t0 in y) (GFCM, 2015).

Table 2.1.2.30. Growth parameters of bonito 2000-2013 (GFCM, 2014)

Parameters	2000	2001	2005	2006	2007	2008	2009	2010	2011	2012	2013
K	0.76	0.39	0.57	0.71	0.68	0.70	0.34	0.72	1.19	0.92	1.08
L_∞	72.89	95.26	77.00	73.64	82.55	73.87	99.70	73.62	65.90	72.60	69.24
To	-0.23	-0.34	-0.29	-0.25	-0.23	-0.25	-0.38	-0.25	-0.17	-0.20	-0.17
A	0.0044	0.0034	0.0027	0.0034	0.0037	0.0063	0.0021	0.0038	0.0038	0.0037	0.0024
B	3.3282	3.3607	3.3871	3.3109	3.2831	3.2040	3.4464	3.2705	3.2873	3.2806	3.4115
M	0.717	0.432	0.583	0.688	0.643	0.679	0.388	0.689	0.989	0.812	0.917
N	1110	673	40	391	304	284	275	610	491	907	477

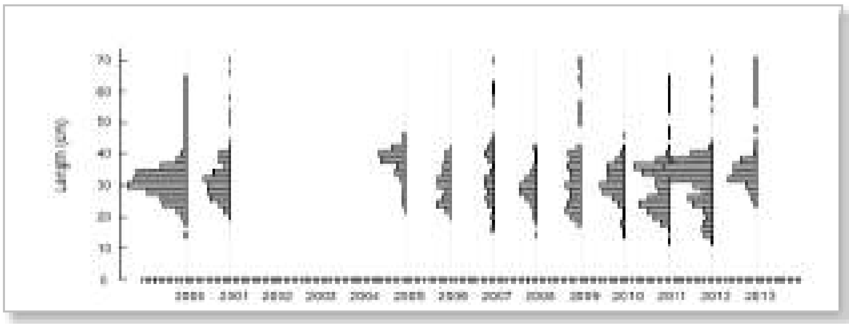


Figure 2.1.2.46. Growth curve of Atlantic bonito (*Sarda sarda*) in the Turkey waters of Black Sea and Sea of Marmara between 2001-2013 years (GFCM, 2015)

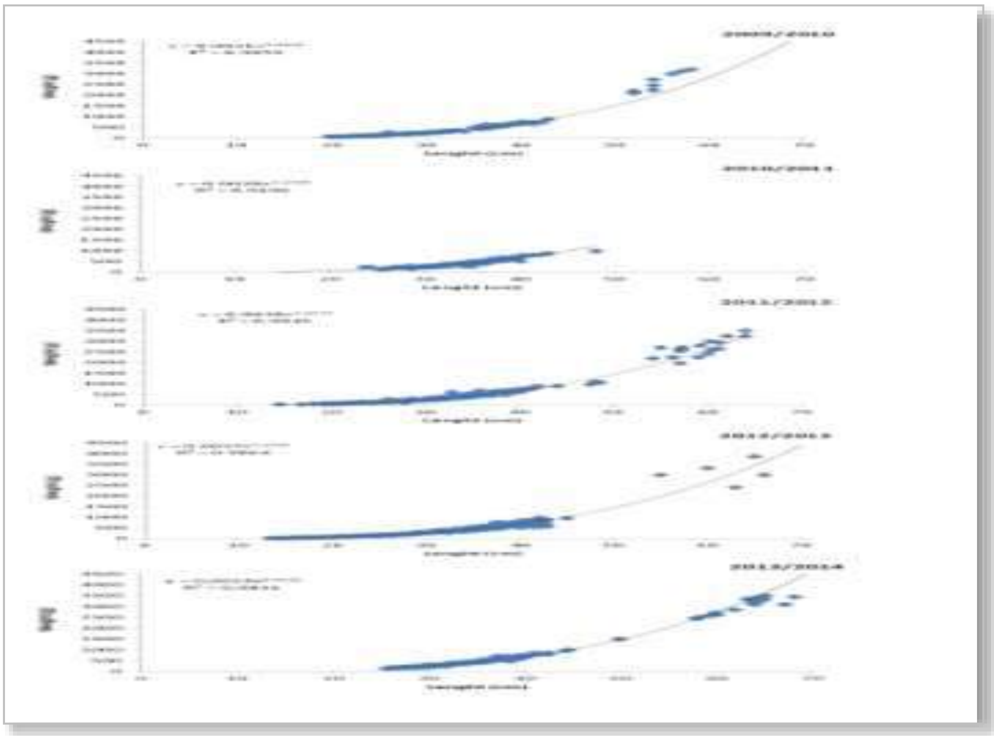


Figure 2.1.2.47. Length-weight relationship of bonito 2009-2014 in Black Sea (GFCM, 2015)

Table 2.1.2.26. Landings of Bonito 2009-2014 in Black Sea (GFCM, 2015)

Year	Turkish Seas (Tones)					Country (Tones)		
	West Black Sea	**East Black Sea**	**Marmara Sea**	**Aegean Sea**	**Mediterranean Sea**	**Turkey**	**Greece**	**Bulgaria**
2009	2.535	1.681	983	754	1.083	7.036	476	5
2010	3.408	2.914	1.304	809	966	9.401	531	16
2011	3.555	3.171	1.054	1.004	1.235	10.019	277	8
2012	14.991	14.863	3.008	2.015	886	35.763	555	96
2013	6.671	3.930	1.180	732	645	13.158	615	0

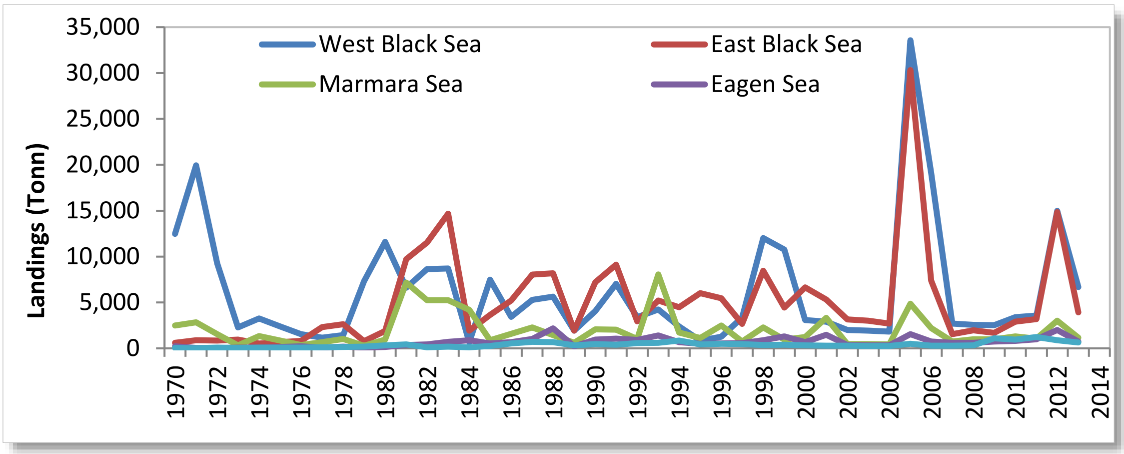


Figure 2.1.2.48. Landings of Bonito in Black Sea

In Turkey, the declared landings of Atlantic bonito in the last years are the following: 6322 tons in 2010; 6726 tons in 2011; 29854 tons in 2012; 10601 tons in 2013.

Time series analysis (if available) and graph of the observed trends in abundance, abundance by age class, etc. for each of the directed methods used.

Table 2.1.2.27. Aggregated catch at age in number 10-3 of Turkey (GFCM, 2015)

Year	Age-0+	Age-1	Age-2	Age-3
2009	4044.66	3960.605	2276.431	465.6385
2010	6199.694	10633.11	0	0
2011	4665.997	10457.62	2866.445	497.8718
2012	9842.11	56652.81	1296.113	1382.787
2013	2420.415	8916.019	246.9811	197.5849

Table 2.1.2.28. Weight at age in the catch (in g).

Year	Age-0+	Age-1	Age-2	Age-3
2009	206.3588	580.5513	2627.75	4300
2010	260.2305	506.4648		
2011	153.7717	544.0284	2594.667	3380
2012	178.7153	542.6042	3240	3456.667
2013	5748.035	12248.25	64449.73	82862.17

Table 2.1.2.29 Table of indicators of Bonito in Black Sea (GFCM, 2015).

Based on	Indicator	Analytical reference point (name and value)	Current value from the analysis (name and value)	Empirical reference value (name and value)	Trend (time period)	Status
Fishing mortality	Fishing mortality	($F_{0.1}$, = value, F_{max}= value)			N	IO_L
	Fishing effort				D	
	Catch					
Stock abundance	Biomass			33_{th} percentile		O_L
	SSB					
Recruitment					D	
Final Diagnosis		Example: In intermediate level of overfishing and overexploited with low level of biomass				

2.1.3. Key demersal fishes

Turbot – *Psetta maxima*

Turbot (*Psetta maxima/Scophthalmus maximus*) is a demersal species and occurs in local shoals all over the shelf area of all Black Sea countries at depths up to 100 m -140 m. Species inhabits different habitats, but mostly on sandy and silty bottoms and mussel beds. The reproduction occurs during the spring season – between April and June. Turbot in the Black Sea is represented by several local populations, which migrate and mix in the adjacent zones. Local populations are independent units of the stock, and have to be covered in order to ensure an accurate assessment of the stock at regional level. The gaps in available information regarding distribution of different stock unit, accurate fisheries statistics, estimates of discards and by-catch, availability of biological data and share of IUU fisheries continue to exist. The present assessment is based on the analysis of the best available information, obtained from combined data of all Black Sea countries and assuming the stock as representing a single unit in the entire Black Sea (STECF, 2015).

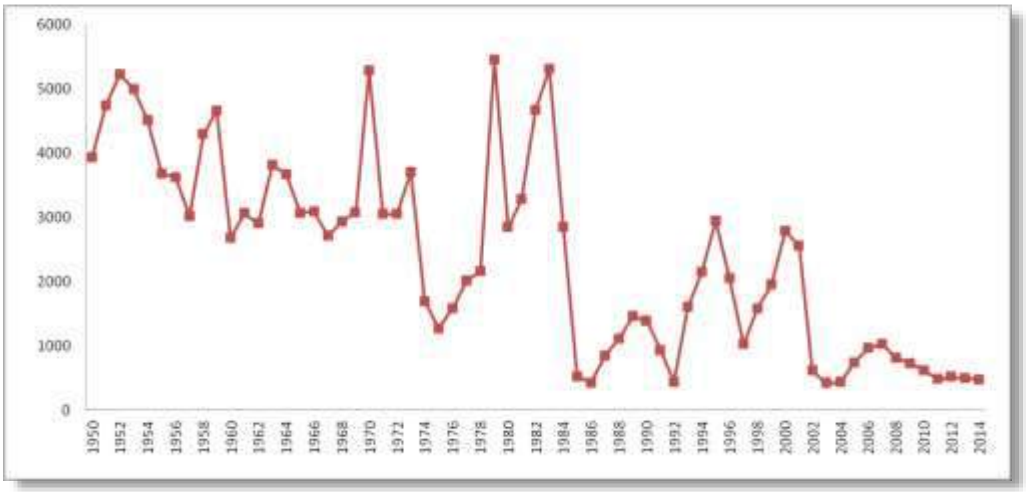


Figure 2.1.3.1. Landings and IUU estimates of turbot in the Black Sea during the period 1950 – 2014.

Growth

Turbot is a long living species with a slow growth rate. The parameters reported here by countries are considered appropriate for the description of an average growth performance of the species in GSA 29 – Tab. 2.1.3.1. Growth parameters of turbot by countries and periods (STECF, 2015).

Tab. 2.1.3.1. Growth parameters of turbot by countries and periods

COUNTRY	AREA	YEAR_PERIOD	SPECIES	SEX	L_INF	K	t_0	*a*	*b*
ROM	***29***	***2003-2005***	***TUR***	***C***	***80.98***	***0.15***	***-1.37***	***0.000018***	***3.01***
ROM	***29***	***2006-2008***	***TUR***	***C***	***72.5***	***0.212***	***-1.15***	***0.00806***	***3.22***
ROM	***29***	***2009-2011***	***TUR***	***C***	***86.3***	***0.19***	***-2.1***	***0.030088***	***2.87***
BGR	***29***	***2007-2008***	***TUR***	***C***	***77.81***	***0.242***	***0.152***	***0.000431***	***2.21***
BGR	***29***	***2008-2009***	***TUR***	***C***	***120.4***	***0.076***	***-2.811***	***0.000011***	***3.13***
BGR	29	2008-2009	TUR	F	129.81	0.065	-3.351	0.000013	3.11
BGR	29	2008-2009	TUR	M	67.38	0.246	-1.217	0.000041	2.78
BGR	29	2007-2008	TUR	M	57.6	0.507	0.458	0.000918	1.96
BGR	29	2007-2008	TUR	F	80.31	0.213	-0.136	0.000424	2.22

COUNTRY	AREA	YEAR_PERIOD	SPECIES	SEX	L_INF	K	t_0	*a*	*b*
BGR	29	2006-2007	TUR	M	77.49	0.158	-1.975	0.000022	2.92
BGR	29	2006-2007	TUR	F	124.27	0.08	-2.136	0.000021	2.94
BGR	***29***	***2006-2007***	***TUR***	***C***	***79.26***	***0.173***	***-1.561***	***0.000008***	***3.17***
UKR (NE)	29	2000 - 2006	TUR	C				0.000216	2.48
UKR (NW)	***29***	***2008 - 2009***	***TUR***	***C***	***74***	***0.106***	***-1.73***	***0.001437***	***1.94***
TR	**29**	**1990 - 1991**	**TUR**	**C**	**82.57**	**0.17**	**-0.93**	**0.0085**	**3.18**
TR	**29**	**1990 - 1996**	**TUR**	**C**	**96.24**	**0.119**	**-0.01**	**0.0112**	**3.12**
TR	**29**	**1998 - 2000**	**TUR**	**C**	**95.9**	**0.104**	**-1.55**	**0.0106**	**3.14**
BGR-RO	29	2010	TUR	M	73.36	0.194	-1.779	0.00004	2.799
BGR-RO	29	2010	TUR	F	113.553	0.089	-2.489	0.0000007	3.795
TR	29	2010	TUR	C	60.57	0.218	0.25	0.12	3.081
BGR	29	2011	TUR	C	69.98	0.395	1.043	0.000033887	2.837
TR(west)	29	2011	TUR	C	96.376	0.112	-1.304	0.014	3.059
TR(east)	29	2011	TUR	C	101.12	0.11	-1.24	0.01	3.17
RO	29	2011	TUR	C	86.32	0.242	-1.971	0.06254606	2.66
BGR	29	2012	TUR	C	88.44	0.17	-0.34	0.0000338	2.86
RO	29	2012	TUR	C	86.32	0.2179	-0.486	0.03502439	2.842
TR	29	2012	TUR	C	82.41	0.342	-3.73	0.012	3.09

The Turkish data (in bold) were used to estimate growth parameters for the historical part of the time series (1950-1999) while Romanian, Bulgarian, Ukranian and Turkish data (in bold italics) from 2003 to 2012 were used to estimate growth parameters for the modern part of the times series (2000-2012). Therefore, the average k, Linf, t0, a and b were estimated for sex combined.

Maturity

The species reaches sexual maturity at ages between 3 and 5. The maturity ogive for 2012 was prepared based on data, collected during different surveys (DCF, from commercial fisheries, national monitoring programs, etc.) from Bulgaria, Romania, Ukraine and Turkey, averaged by age groups. The proportions of mature individuals by age groups for the period 1970 – 2012 are given in Table 2.1.3.2. Maturity ogives were calculated as the average for the period 2007 – 2009 due to good data consistency for these years and applied over the whole time series.

Table 2.1.3.2. Common maturity ogive of turbot by ages and years.

Year/Age	1	2	3	4	5	6	7	8	9	10+
1970-2006	0	0	0.75	1	1	1	1	1	1	1
2007	0	0	0.38	0.61	1	1	1	1	1	1
2008	0	0	0.51	0.76	1	1	1	1	1	1
2009	0	0	0.41	0.67	1	1	1	1	1	1
2010	0	0	0.22	0.83	1	1	1	1	1	1
2011	0	0.06	0.20	0.86	1	1	1	1	1	1
2012	0	0.13	0.52	0.92	1	1	1	1	1	1

The Black Sea turbot (*Psetta maxima*/*Scophthalmus maximus*) historically has been fished by all coastal states, using both stationary and mobile fishing gears (gillnets and bottom trawls). The species is often caught as a by-catch of otter trawls, long lines and purse seiners' fishery. Total annual landings in the Black Sea present a decreasing trend during the last years - from 1035 t in 2007 to 486 t in 2011, but in 2012 slight increase was observed – 528 t. IUU fisheries on turbot also occur.

Turbot commercial fishery in Turkey is realized by two methods – gillnets fishery (70% of total landings) and by bottom trawls (30%) (Zengin et al., 1998). Thus, 38.64 t of total turbot landings in

2012 are obtained by gill nets and 16.56 t by bottom trawls in Eastern Black Sea in 2012. In the Western Black Sea - 81.9 t were realized by gillnets fishery and the 35.1 t - by bottom trawls. For both regions, the distribution of fishing effort according to the vessel length and engine power was presented in Fig. 2.1.3.2.

Country	**Species**	**Metier**		**CPUE**				
		Gear	**Gear**	**2008**	**2009**	**2010**	**2011**	**2012**
Bulgaria	**TUR**	**GNS**	LOA > 0 < 6	30.4	32.5	21.86	20.22	16.48
			LOA => 6<12	58.32	53.91	34.5	43.29	29.44
			LOA => 12<18	125.26	71.62	65.48	46.49	42.78
			LOA => 18<24	83.05	95.86	102.95	34.47	69.89
			LOA => 24<40	-	-	250	110.69	104.6
		OTM	LOA => 12<18	139.17	145.1	9.68	-	
			LOA => 18<24	45	137.83	--	-	
			LOA => 24<40	251.67	95	84.38	-	

Table 2.1.3.4. CPUE data for Romania in 2012.

Gear	**No.vessels**	**Landings, t**	**No. gillnets**	**Days fishing**
LOA > 0 < 6	7	1.646	275	85
LOA => 6<12	55	31.678	2534	1321
LOA => 12<18	2	3.945	300	143
LOA => 18<24	1	4.250	200	31
LOA => 24<40	1	1.694	206	127
Total	**66**	**43.213**	**3515**	**1577**

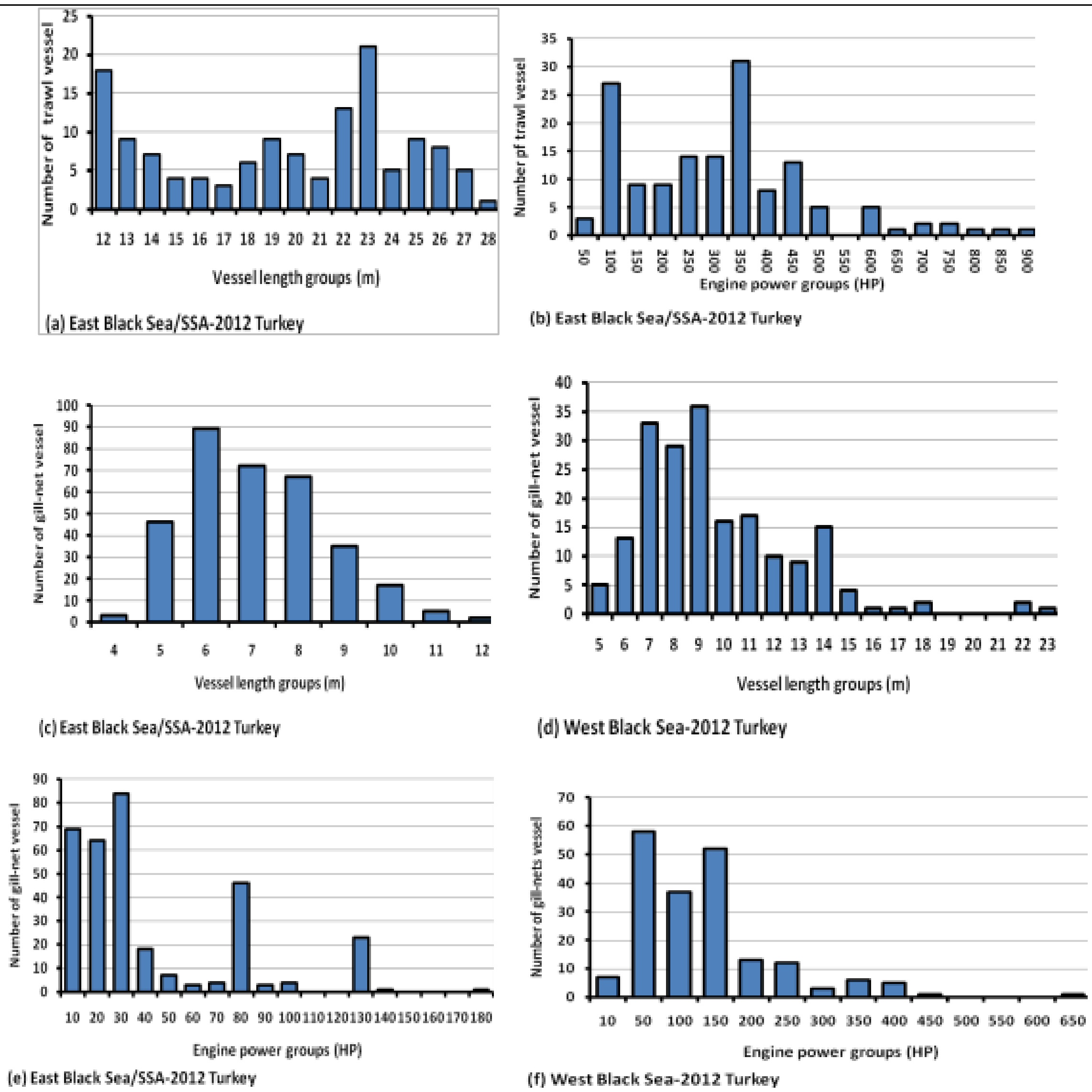


Figure 2.1.3.2. Distribution of fishing effort in turbot fisheries by vessel length and engine power in the East and West Turkish Black Sea Region (STECF, 2013)

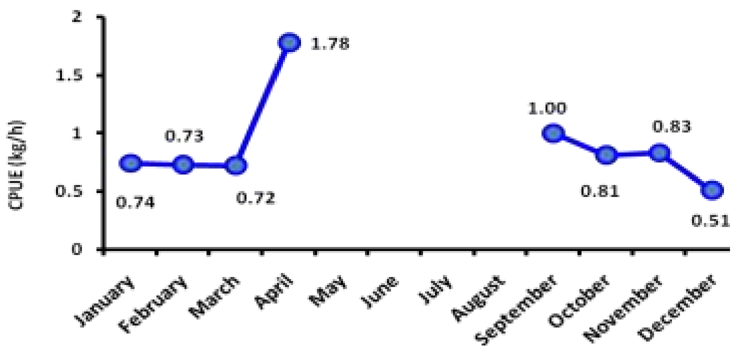


Figure 2.1.3.3. Monthly average CPUE (kg/h) of turbot for commercial trawl in the Turkish Black Sea area (STECF, 2013)

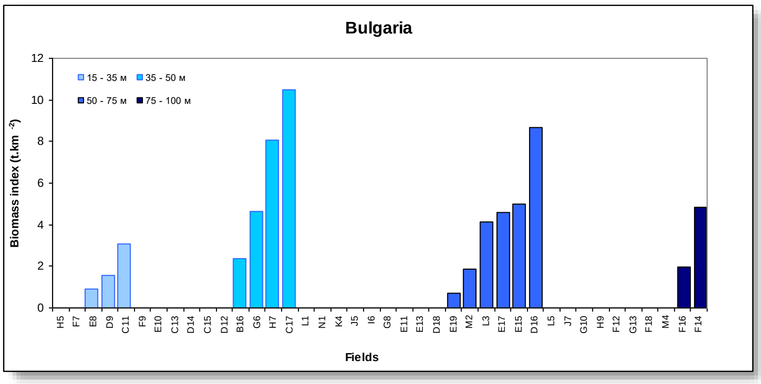


Figure 2.1.3.4. Relative biomass of *S. maximus* by strata in front of Bulgarian Black Sea coast in May 2012 (Panayotova, Raykov, 2013).

Spatial distribution

Distribution of turbot CPUA (kg.km-2) for the Bulgarian waters in spring season is shown in Fig. 2.1.3.4. The maxima of CPUA during the survey was observed in front of cape Maslen nos with value of 167.69 kg.km^{-2} at depths around 40 - 45 m. Higher values of catches per unit area were observed off Varna area. In the northern region, another area with higher CPUAs was observed in front of Kamen bryag. In the southern region, the maximum values of CPUA were concentrated in the area enclosed between depths 40 m and 75 m in front of cape Maslen nos. The average estimated CPUA value for the whole Bulgarian area during the survey was 25.15 kg.km^{-2} (Panayotova, Raykov, 2013).

Table 2.1.3.5. Assessment of turbot agglomerations in t May 2012, demersal trawl survey, and Romanian area.

Depth range (m)	**0 - 30m**	**30 – 50m**	**50-70 m**	**Total**
Investigated area (Nm^2)	663.62	1065	517.37	2245.99
Variation of the catches (t/ Nm^2)	0.00-0.45	0.00-0.68	0.00-0.47	0.00-68
Average catch (t/ Nm^2)	0.142	0.167	0.108	
Biomass of the fishing agglomerations (t)	94.28	178.648	56.051	328.98
Biomass extrapolated the Romanian shelf (t)				**627.35**

In autumn season, 38 demersal trawlings were conducted on an area of 2 555.75 nm2. The observed distribution of turbot agglomerations was different, compared to spring season. The average values of turbot catches varied between 0.056 and 0.147 t/nm2. Higher catches have been recorded between 30 and 50 m depth in Corbu – Sulina and Costinesti – Vama Veche. In autumn survey, the estimated turbot biomass was 627.35 tonnes for the area of 2 245.99 nm2, (Table 2.1.3.6.).

Table 2.1.3.6. Assessment of turbot agglomerations in the period October -November 2012, demersal trawl survey, Romanian area.

Depth range (m)	**0 - 30m**	**30 – 50m**	**50-70 m**	**Total**
Investigated area (Nm^2)	607.75	930.5	1017.5	2555.75
Variation of the catches (t/ Nm^2)	0.00-0.192	0.00-0.408	0.00-0.37	0.00-0.41
Average catch (t/ Nm^2)	0.056	0.147	0.089	
Biomass of the fishing agglomerations (t)	34.07	137.065	91.056	262.19
Biomass extrapolated the Romanian shelf (t)				**480.91**

Distribution of turbot CPUA (kg.nm-2) in Romanian waters by seasons (Maximov et.al, 2013) is shown on Fig. 2.1.3.5.

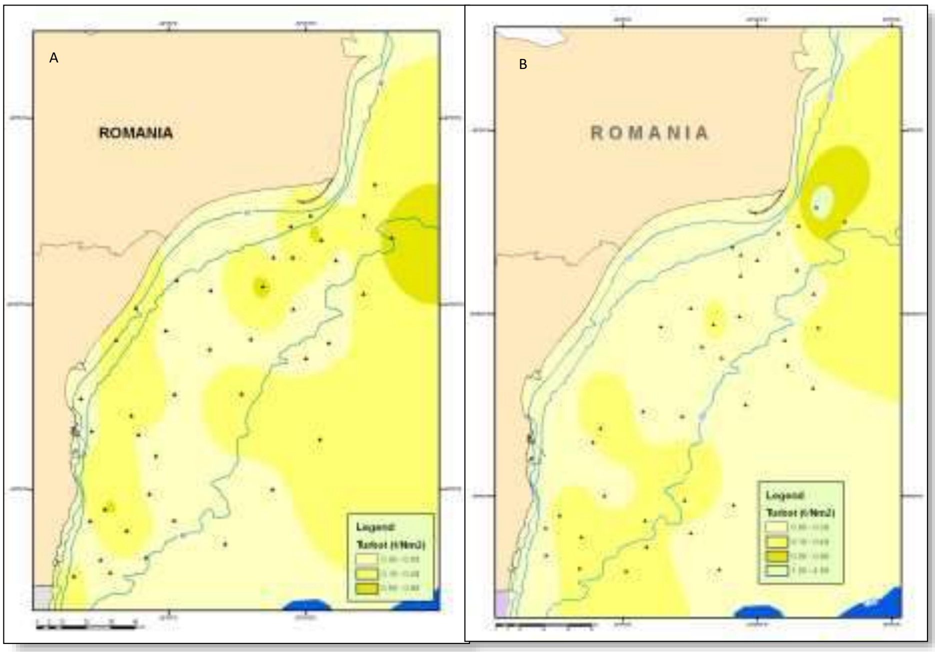


Figure 2.1.3.5. Distribution of turbot CPUA (kg/Nm^2) from surveys along the Romanian Black Sea coast in spring (A) and autumn (B) seasons of 2012 (Maximov et.al, 2012).

In the period of the biomass index continues to decrease in Bulgarian area with the lowest value of 191.47 t in 2012. Same decreasing trend was observed in Romanian area in 2012.

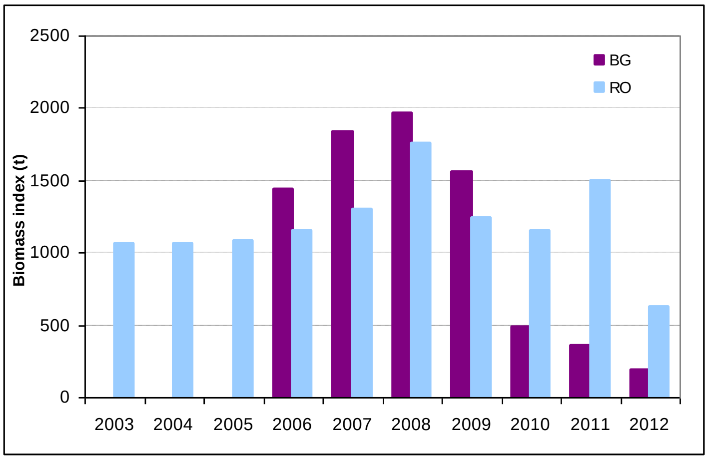


Figure 2.1.3.6. Biomass indices derived from national surveys in Bulgaria and Romania) for turbot in the Black Sea in the period 2003 – 2012 (Panayotova, Raykov, 2013).

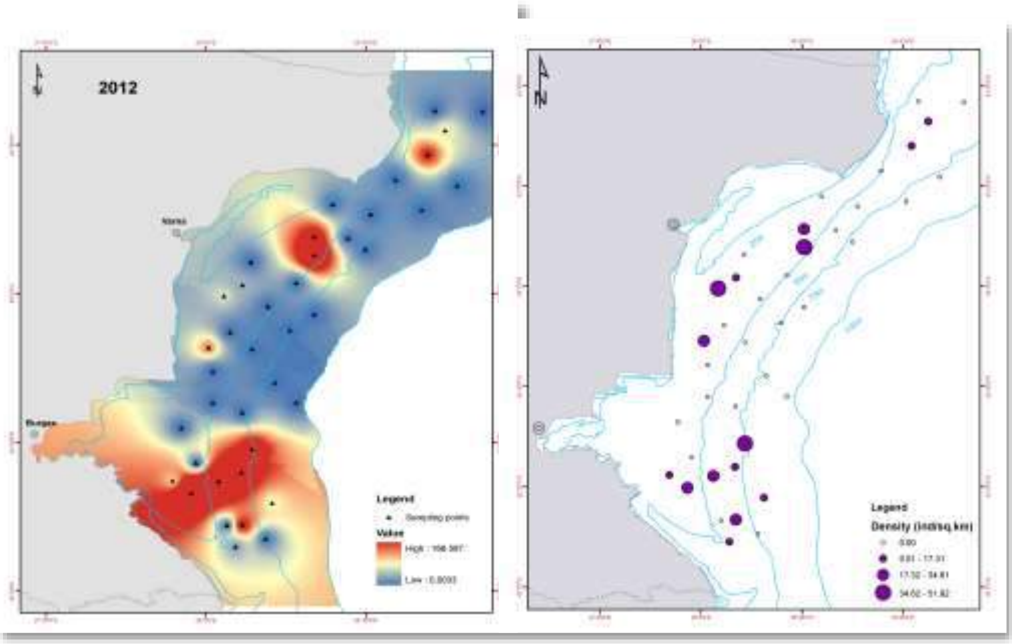


Figure 2.1.3.7. Distribution of turbot CPUA (kg/km^2) and density, obtained from research survey along the Bulgarian Black Sea coast in May 2012 (Panayotova, Raykov, 2013).

The biomass of the main fish species with commercial value along Romanian Black Sea coast was asessed by swept area method. During the research survey in spring season, the turbot population was wide distributed in the area between Mangalia and Sulina, with a higher density between Vama Veche – Constanta. The agglomerations reached an average value of 0.108 - 167 t/nm2 (Maximov et al, 2012). During the 40 hauls covering the area of 2 245.99 nm2; the distribution of turbot agglomerations was variable. The average values of the turbot catches ranged between 0,001 t/nm^2 and 1.782 t/nm^2. Significant catches were recorded between 35 and 50 m depth, in the Corbu - St. Gheorghe (the change of abundance 0.167 t/nm2). During the spring survey, the turbot biomass was estimated at 627.35 tonnes in the studied area of 2 245.99 nm2, (Table 2.1.3.6.).

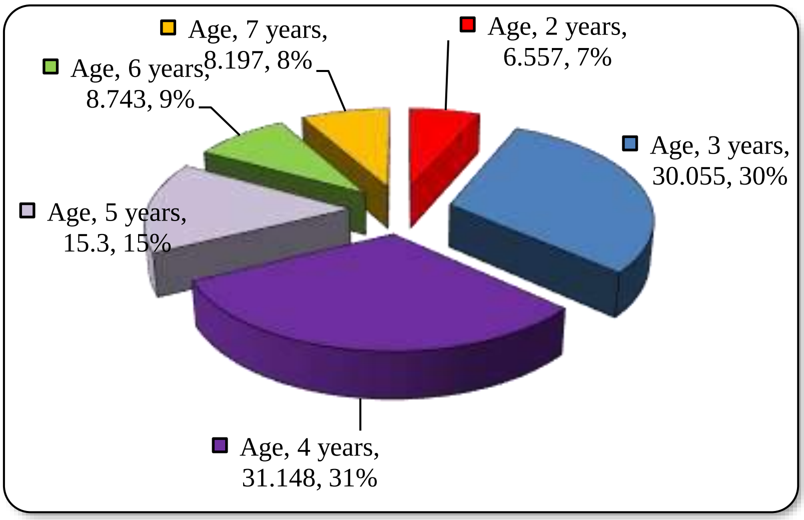


Figure 2.1.3.8. Size and age structure of turbot, obtained during the spring survey along the Romanian Black Sea coast in 2012 (Maximov 2012).

During the autumn survey in 2012, the catches were composed by specimens with lengths of 17.5 – 71.5 cm / 400.0 – 6 410.12 g. The dominant size classes were 50.5 - 68.5 cm / 2 289, 21 – 4 854.14 g (Figure 2.1.3.8). Average body length was estimated at 54.36 cm and the average weight – 3 299.75 g. The sex ratio indicates a clear dominance of females (52.5%) than males (36.25%) and between 1 to 6 years. Most of the individuals are 4 years old (26% of all specimens analyzed) and of 5 years old (25%), followed closely by those of 6 years (19%), 3 years (19%), and of 2 years old (11%)(Maximov, 2012).

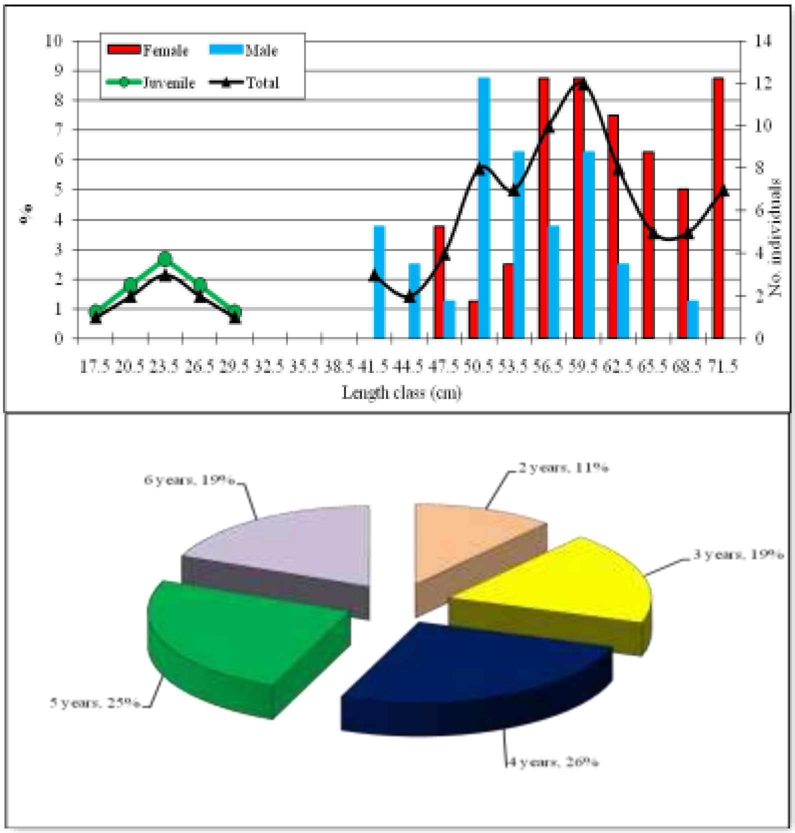


Figure 2.1.3.9. Size and age structure of turbot, obtained during the autumn survey along the Romanian Black Sea coast in 2012. (Maximov, 2012).

Trends in growth

Due to very low number of caught turbots (n=26) in Bulgarian area, statistically reliable estimation of growth rate during the spring season of 2012 could not be obtained. The calculated values of the parameters in von Bertalanffy growth function, estimated by least square method are given in Table 2.1.3.7. The linear growth of both genders in 2012 at age 2 – 7 years old is according to the relationship represented on Fig. 2.1.3.7.(STECF,2013)

Table 2.1.3.7. Values of parameters in VBGF for both genders (STECF, 2013)

Parameters	VBGF
L_∞ (cm)	125.597
k	0.104
t0	-0.516
a	0.000017750
b	3.004

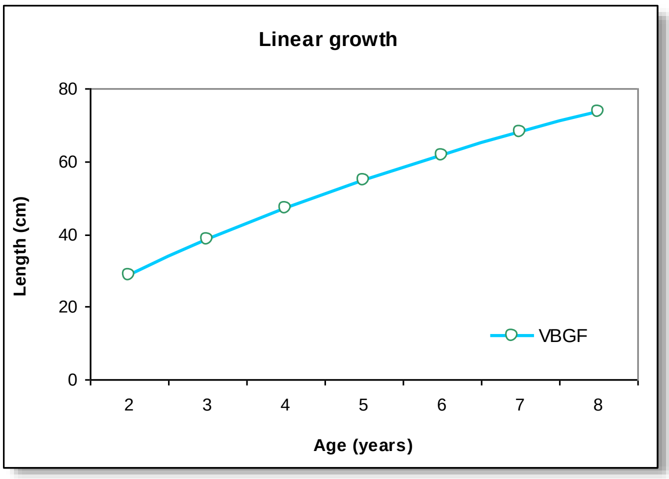


Figure 2.1.3.10. Linear growth of turbot by ages (STECF, 2013)

Spatial distribution

In 2012, survey on commercial fishing vessels was executed in Turkey. Estimated biomass indices of pooled data for the Eastern and Western Turkish Black Sea are given on Figure 2.1.3.11.

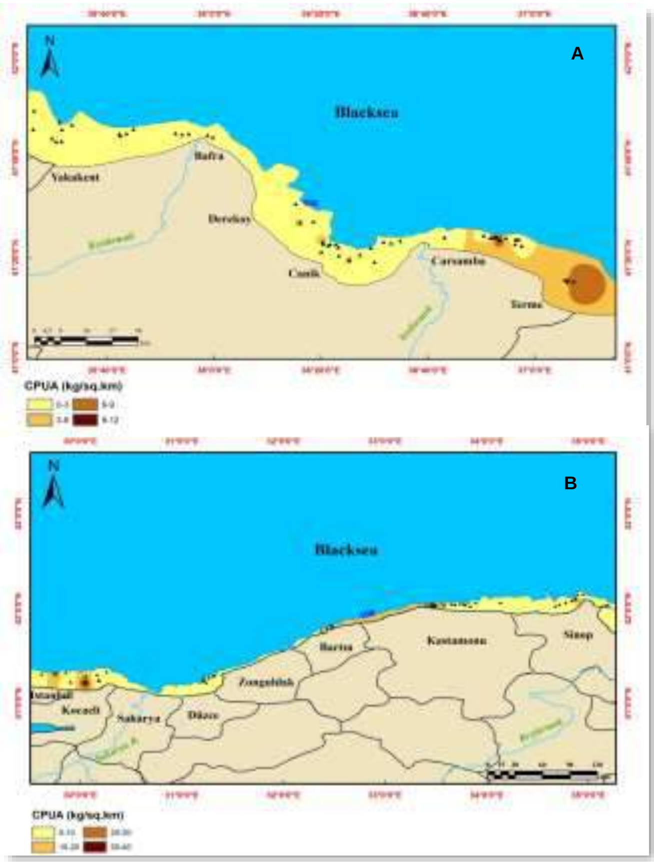


Figure 2.1.3.11. Distribution of turbot CPUA (kg.km-2) from surveys along the Turkish East (A) and West (B) Black Sea coast in 2012 (Zengin, Gumus, 2013).

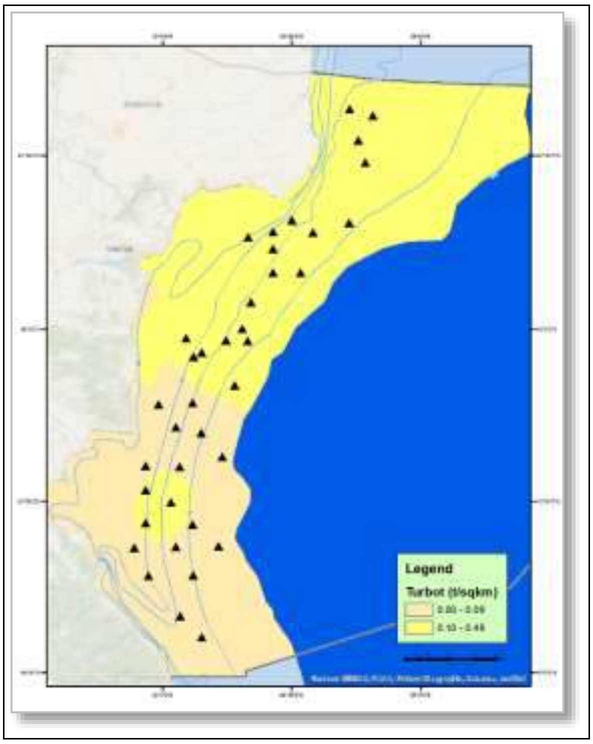


Figure 2.1.3.12. Turbot distribution off the Bulgarian coast in November 2014(Tserkova et al., 2015)

Taking into account that only two stations included depth < 30 m, for technical reasons statistical analysis was performed on stratum 15 – 50 m. Also, the strata - 50 – 75 m and 75 – 100 m have been analyzed. However, up to 30 m depth, biomasses at the two stations were - 181.129 kg/Km2 and 39.622 kg/km2, abundance -113 specimens/km2 and 38 specimens/km2.

Table 2.1.3.8. CPUE of turbot in 2008-2011 by métier in Bulgaria

Country	Species	Metier		CPUE			
		Gear	Gear	2008	2009	2010	2011
Bulgaria	TUR	GNS	LOA > 0 < 6	30.4	32.5	21.86	20.22
			LOA => 6<12	58.32	53.91	34.5	43.29
			LOA => 12<18	125.26	71.62	65.48	46.49
			LOA => 18<24	83.05	95.86	102.95	34.47
			LOA => 24<40	-	-	250	110.69
		OTM	LOA => 12<18	139.17	145.1	9.68	-
			LOA => 18<24	45	137.83	--	-
			LOA => 24<40	251.67	95	84.38	-

Distribution of turbot CPUA (kg.km^{-2}), merged for the Bulgarian and Turkish waters by seasons is shown in Figure 2.1.3.13.

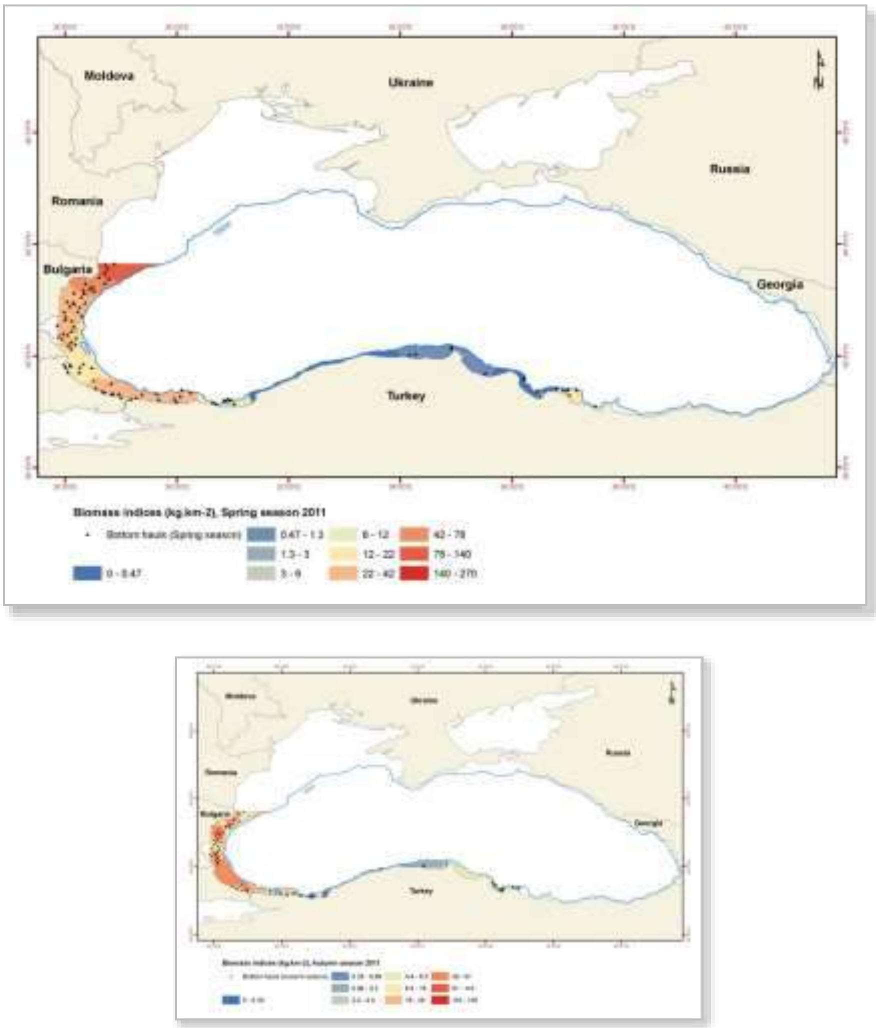


Figure 2.1.3.13. Distribution of turbot biomass (kg.km-2) in Bulgarian and Turkish waters (STECF, 2013)

Distribution of turbot CPUA (kg.Nm-2) in Romanian waters by seasons (Maximov et.al, 2011, 2012) is shown on Figure 2.1.3.14.

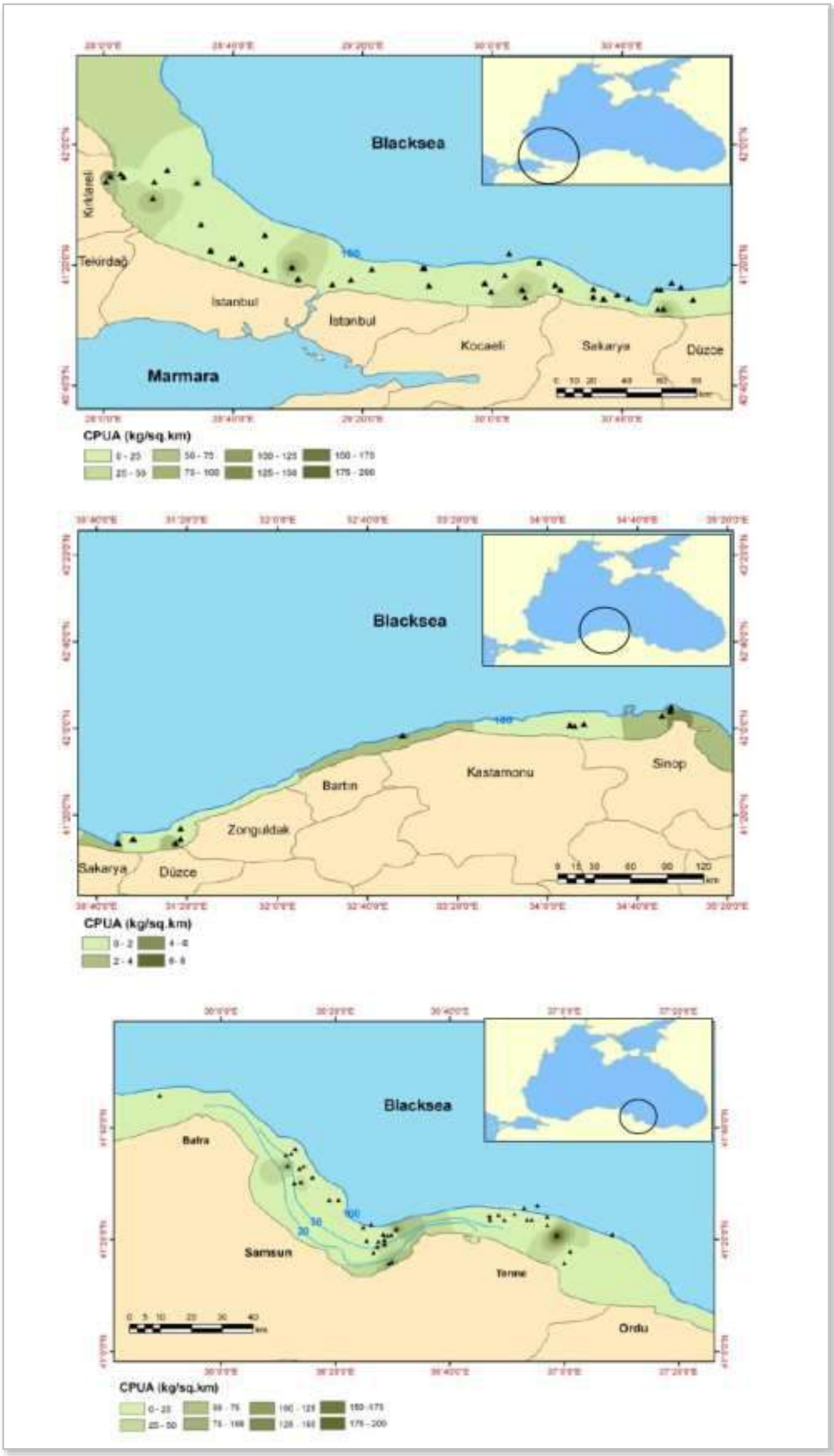
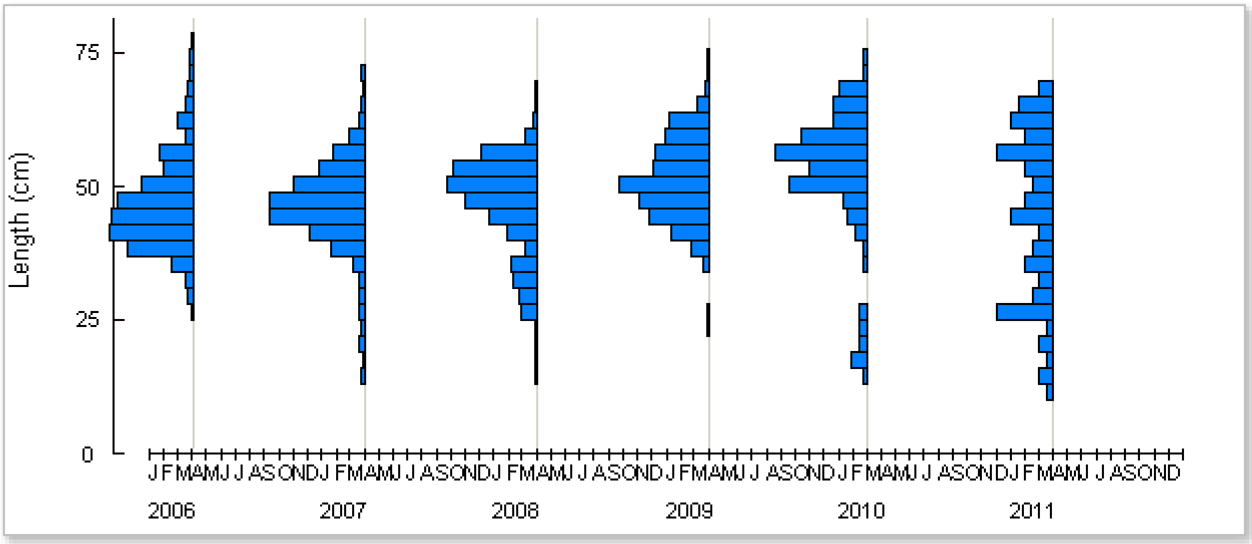

Blacksea
Kırklareli
Tekirdağ
İstanbul
İstanbul
Kocaeli
Sakarya
Düzce
Marmara
CPUA (kg/sq.km)
Blacksea
Kastamonu
Sinop
Bartın
Zonguldak
Sakarya
Düzce
CPUA (kg/sq.km)
Blacksea
Bafra
Samsun
Terme
Ordu
CPUA (kg/sq.km)

Figure 2.1.3.14. Distribution of turbot CPUA (kg.km^{-2}) from surveys along the Turkish Black Sea coast in 2011 (STECF, 2012)

The trends in abundance at length and at age during the period 2006 - 2011, according to the survey data along the Bulgarian Black sea area, are presented on Figure 2.1.3.15.



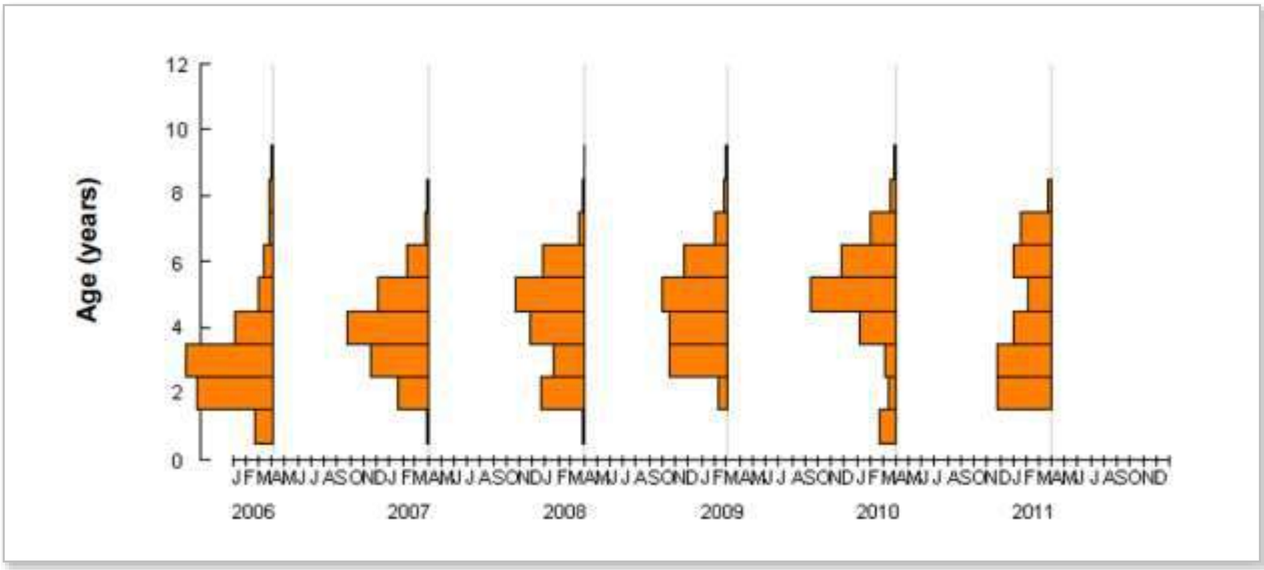


Figure 2.1.3.15. Length and age frequency data for turbot, obtained during the surveys along the Bulgarian Black Sea coast in the period 2006 – 2011. (STECF, 2012)

The trends in abundance at length during the surveys in Romanian area during the period 2002 – 2010 and 2011 are presented on Figure 2.1.3.16.

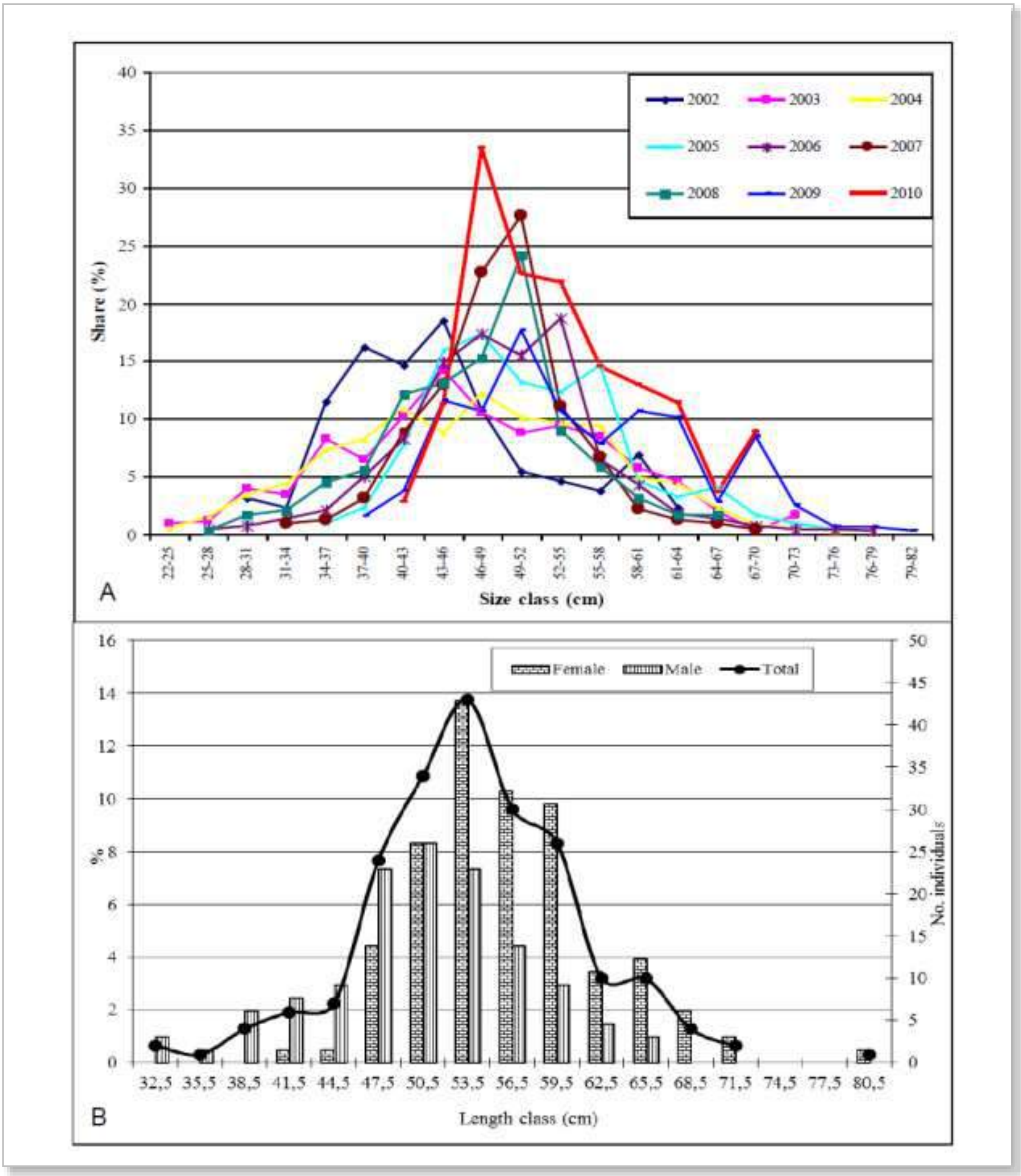


Figure 2.1.3.16. Length frequency data for turbot, obtained during the surveys along the Romanian Black Sea coast in the period 2002 – 2010 (A) and 2011 (B) (STECF, 2012).

Maximum values on L∞ =129.8 cm were detected for 2008-2009 period in Bulgarian waters and minimum values (L∞ = 60.6 cm) in Turkish waters for 2014.

Table 2.1.3.9. Growth parameters of turbot in Black Sea for different periods (STECF,2012)

COUNTRY	AREA	YEAR_PERIOD	SPECIES	SEX	L_INF	K	t_0	A	B
ROM	29	2003-2005	TUR	C	81.0	0.15	-1.37	0.00002	3.010
ROM	29	2006-2008	TUR	C	72.5	0.21	-1.15	0.00806	3.220
ROM	29	2009-2011	TUR	C	86.3	0.19	-2.10	0.03009	2.870
BGR	29	2007-2008	TUR	C	77.8	0.24	0.15	0.00043	2.210
BGR	29	2008-2009	TUR	C	120.4	0.08	-2.81	0.00001	3.130
BGR	29	2008-2009	TUR	F	129.8	0.07	-3.35	0.00001	3.110
BGR	29	2008-2009	TUR	M	67.4	0.25	-1.22	0.00004	2.780
BGR	29	2007-2008	TUR	M	57.6	0.51	0.46	0.00092	1.960
BGR	29	2007-2008	TUR	F	80.3	0.21	-0.14	0.00042	2.220
BGR	29	2006-2007	TUR	M	77.5	0.16	-1.98	0.00002	2.920
BGR	29	2006-2007	TUR	F	124.3	0.08	-2.14	0.00002	2.940
BGR	29	2006-2007	TUR	C	79.3	0.17	-1.56	0.00001	3.170
UKR (NE)	29	2000 - 2006	TUR	C				0.00022	2.480
UKR (NW)	29	2008 - 2009	TUR	C	74.0	0.11	-1.73	0.00144	1.940
TR	29	1990 - 1991	TUR	C	82.6	0.17	-0.93	0.00850	3.180
TR	29	1990 - 1996	TUR	C	96.2	0.12	-0.01	0.01120	3.120
TR	29	1998 - 2000	TUR	C	95.9	0.10	-1.55	0.01060	3.140
BGR-RO	29	2010	TUR	M	73.4	0.19	-1.78	0.00004	2.799
BGR-RO	29	2010	TUR	F	113.6	0.09	-2.49	0.00000	3.795
TR	29	2010	TUR	C	60.6	0.22	0.25	0.12000	3.081
BGR	29	2011	TUR	C	70.0	0.40	1.04	0.00003	2.837
TR(west)	29	2011	TUR	C	96.4	0.11	-1.30	0.01400	3.059
TR(east)	29	2011	TUR	C	101.1	0.11	-1.24	0.01000	3.170
RO	29	2011	TUR	C	86.3	0.24	-1.97	0.06000	2.660
BGR	29	2012	TUR	C	88.4	0.17	-0.34	0.00000	2.860
RO	29	2012	TUR	C	86.3	0.22	-0.49	0.04000	2.840
TR	29	2012	TUR	C	82.4	0.34	-3.73	0.01000	3.090
BG	29	2013	TUR	C	97.2	0.14	-0.61	0.00000	2.580
TR	29	2013	TUR	C	86.0	0.14	-1.15	0.01000	3.070
RO	29	2013	TUR	C	76.8	0.39	-0.48	0.01000	3.150
BG	29	2014	TUR	c	108.6	0.12	-0.25	0.00003	2.853
BG	29	2014	TUR	c	69.5	0.36	-0.48	0.00840	3.180
RO	29	2014	TUR	c	89.4	0.20	-1.11	0.01330	3.051

The maturity ogive for 2014 was estimated based on data collected during surveys (DCF, from commercial fisheries, national monitoring programs, etc.) from Bulgaria and Romania, averaged by age groups. No data were available from other countries. The proportions of mature individuals by age groups for the period 1970 – 2014 are given in Table 2.1.3.10.

Table 2.1.3.10. Common maturity ogive of turbot by ages and years (STECF, 2015)

Year/Age	1	2	3	4	5	6	7	8	9	10+
1970-2006	0	0	0.75	1	1	1	1	1	1	1
2007	0	0	0.38	0.61	1	1	1	1	1	1
2008	0	0	0.51	0.76	1	1	1	1	1	1
2009	0	0	0.41	0.67	1	1	1	1	1	1
2010	0	0	0.22	0.83	1	1	1	1	1	1
2011	0	0.06	0.20	0.86	1	1	1	1	1	1
2012	0	0.13	0.52	0.92	1	1	1	1	1	1
2013	0	0.04	0.69	0.93	1	1	1	1	1	1
2014	0	0.70	0.90	0.99	1	1	1	1	1	1

The gonad somatic index (GSI, %) of females was 1.45% on the average, with maximum and minimum values - 2.97 and 0.33%, respectively (Fig. 2.1.3.17.). The average GSI,% of male turbots was 0.36%, with maximum/minimum values - 0.84 and 0.15%. GSI variation was markedly pronounced in females vs males, which could be attributed to the relatively consistent weight structure of the collected male individuals (3000-1000 g) in comparison to that of females (7300-900 g). The ovary and testis were in the second degree of maturity, with predominance of previtellogenic oocytes and spermatids fractions.

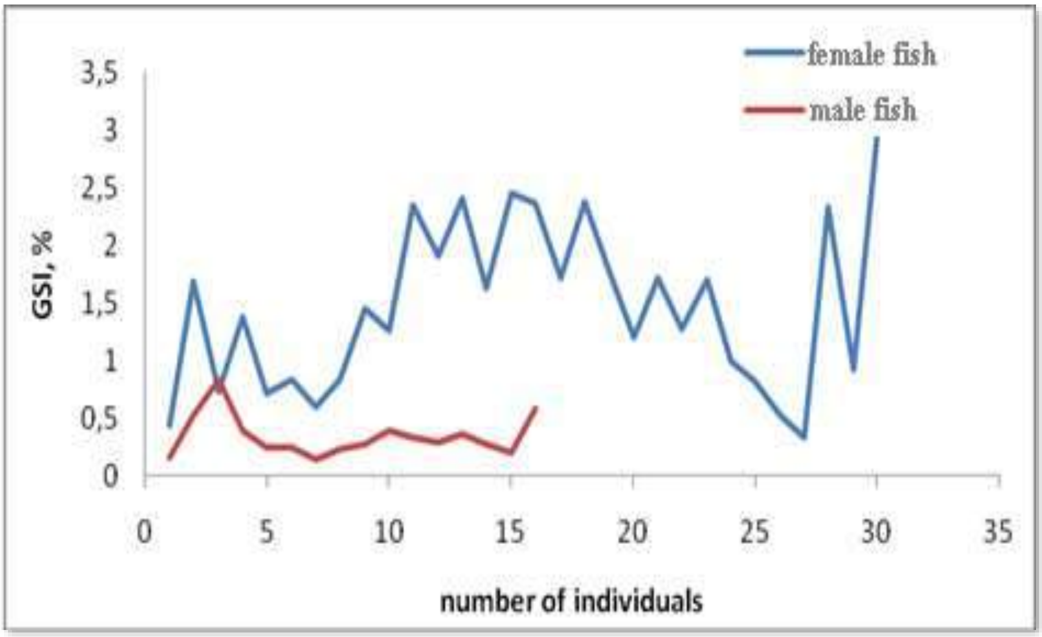


Figure 2.1.3.17. Dynamics of GSI (%) in female and male turbots caught in December 2014 (GFCM, 2015)

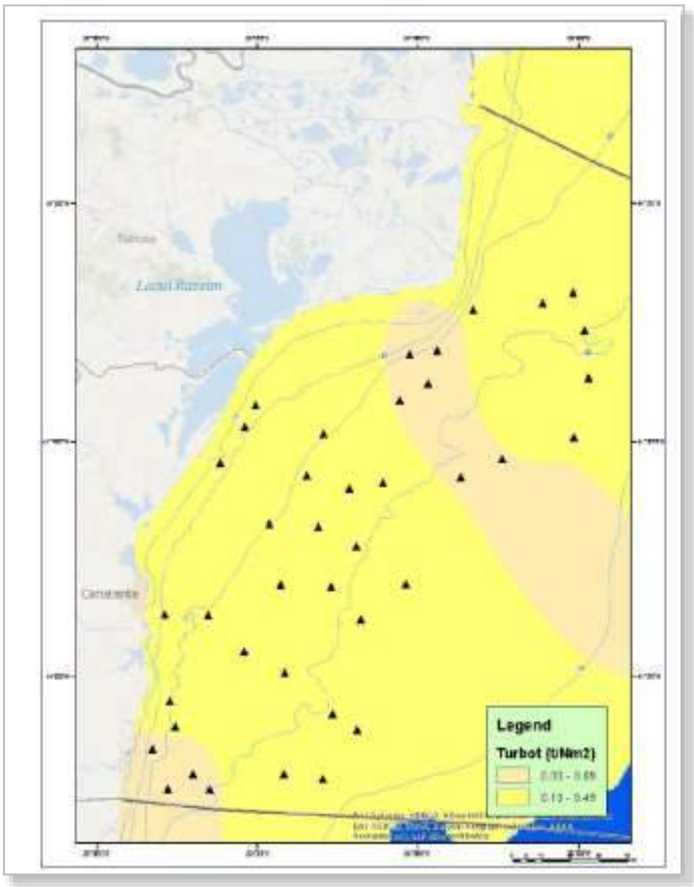


Figure 2.1.3.18. Distribution of spring turbot biomass (t/km2) in Romanian waters in 2014 (STECF, 2015)

In spring season, the survey covered almost the entire Romanian shelf area between St. Gheorghe and Vama Veche at depths between 13.8 m and 80 m with a total surveyed area of 2600 Mm2. Low average turbot catches (0.00 - 0.395 t/Nm2) were observed. The lowest values were recorded in the shallower areas between Cap Midia – Cap Tuzla (depth 0 -30 m / 0.000 – 0.136 t/Nm2 and depths 30 - 50 m / 0.00 – 0.395 t/Nm2) and the highest – in the Constanta – Sf. Gheorghe area (depth 30 - 75 m / 0.0 - 0.286 t/Nm2).

Autumn survey covered the Romanian shelf area enclosed between St. Gheorghe and Vama Veche at depths between 20 m and 65 m with total coverage of 2 650 Nm2. The observed distribution of turbot agglomerations was different. The average values of turbot catches ranged between 0.040 and 0.067 t/Nm2.

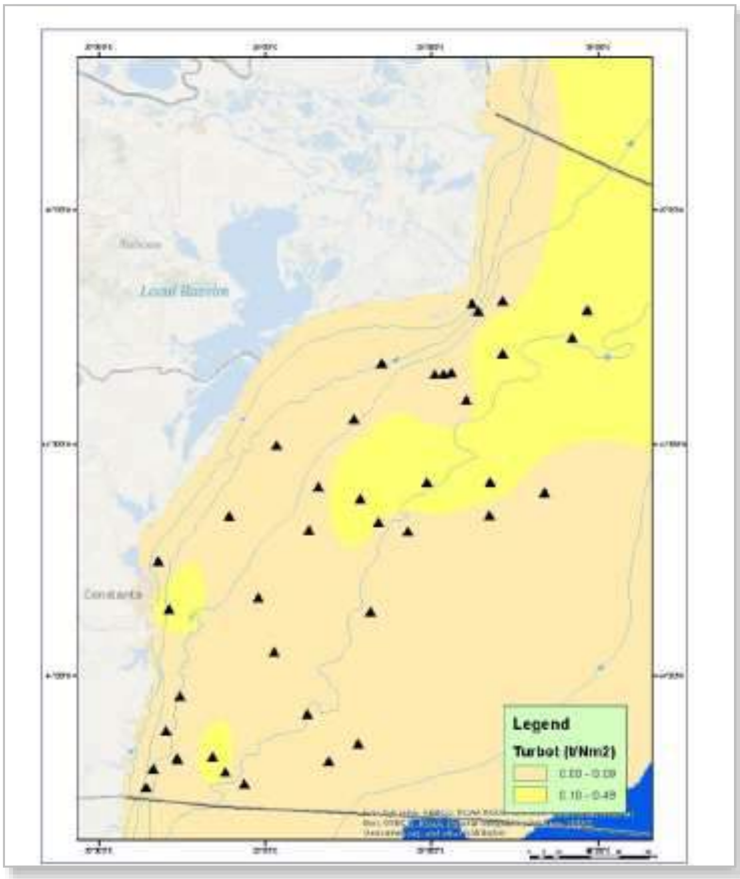


Figure 2.1.3.19. Turbot in GSA 29. Distribution of biomass indices in autumn season, as estimated by the Romanian survey 2014 (STECF, 2015)

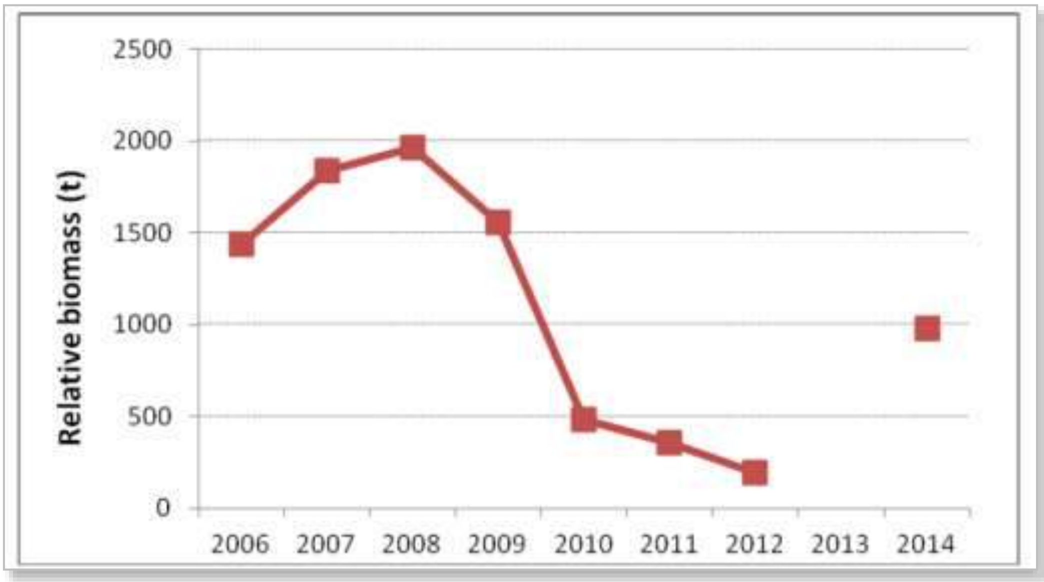


Figure 2.1.3.20. Trends in relative biomass (t) of turbot derived from surveys in Bulgarian marine zone (STECF, 2015)

Analysis of the trend in the survey indices during the period 2006 – 2014 indicated a decreasing trend in turbot biomass since 2008. However, the estimated biomass in 2014 is 5 times higher compared to 2012 (STECF, 2015; GFCM, 2015).

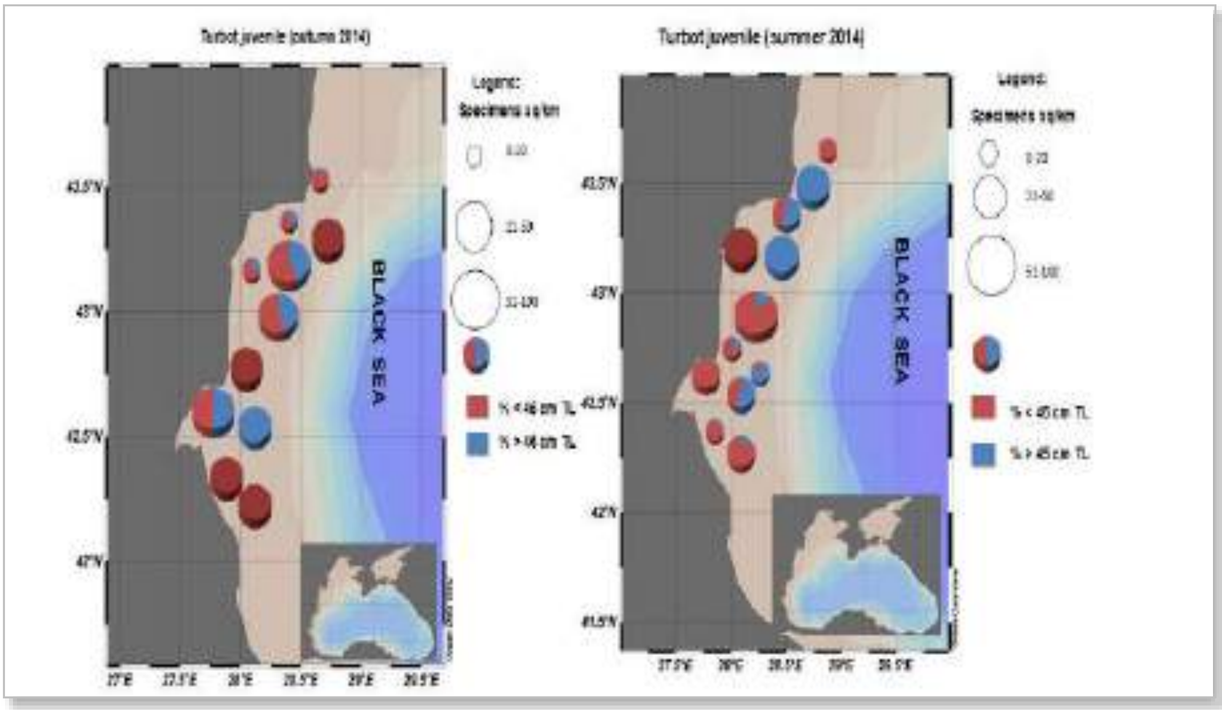


Figure 2.1.3.21. Distribution of turbot juveniles in spring and autumn 2014 (STECF, 2015;Raykov, et al., 2016

In July turbot immature individuals (<45 cm TL) were predominant in the Bulgarian marine area, especially in shallow waters (Fig.2.1.3.23 A). The maximum length observed was 56.2cm. Turbot individuals ranged from 22 to 40 cm in summer in the near shore area between 22 and 65.3 m depth. In September 2014 (Fig. 2.1.3.21.) the bulk was composed by length groups 33-40cm, distributed in depths of 26.6 to 68.1m, as the specimen with total length of 15-28 cm were less in terms of abundance in the near shore zone with depths of 21 to 58.2m. In Romanian Black Sea waters spring and autumn surveys were conducted (Fig. 2.1.3.23.). It is evident that in summer 2014, the percent of immature specimen in the area between 10 and 30m depth is limited. In autumn 2014, the immature individuals significantly increased.

The size structure of catches was analyzed in agreement with the Bulgarian low regulations (Fisheries and Agriculture Act, 2005), determining the minimum allowable total length for turbot fishing. Thus, the individuals with absolute length < 45 cm are indicated as small and those > 45 cm – as standard. The distribution of turbot size groups off the Bulgarian coast in November 2014 is represented on a map (Figure 2.1.3.21.), where the diameter of circles reflects the total abundance of turbot, caught in the respective area, while the colours - green/red appoint the abundance of small and standard size specimens.

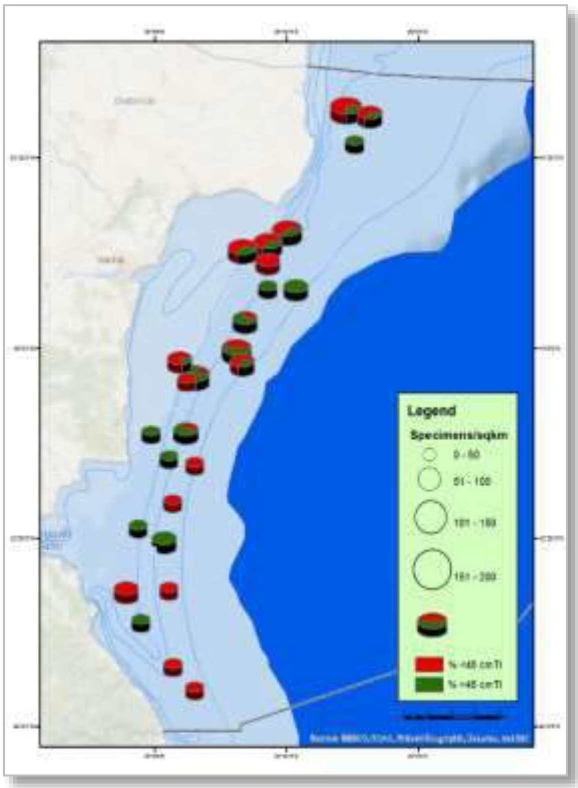


Figure 2.1.3.22. Number of turbot specimens/Km2 and ratio between the specimens with small and standard sizes.

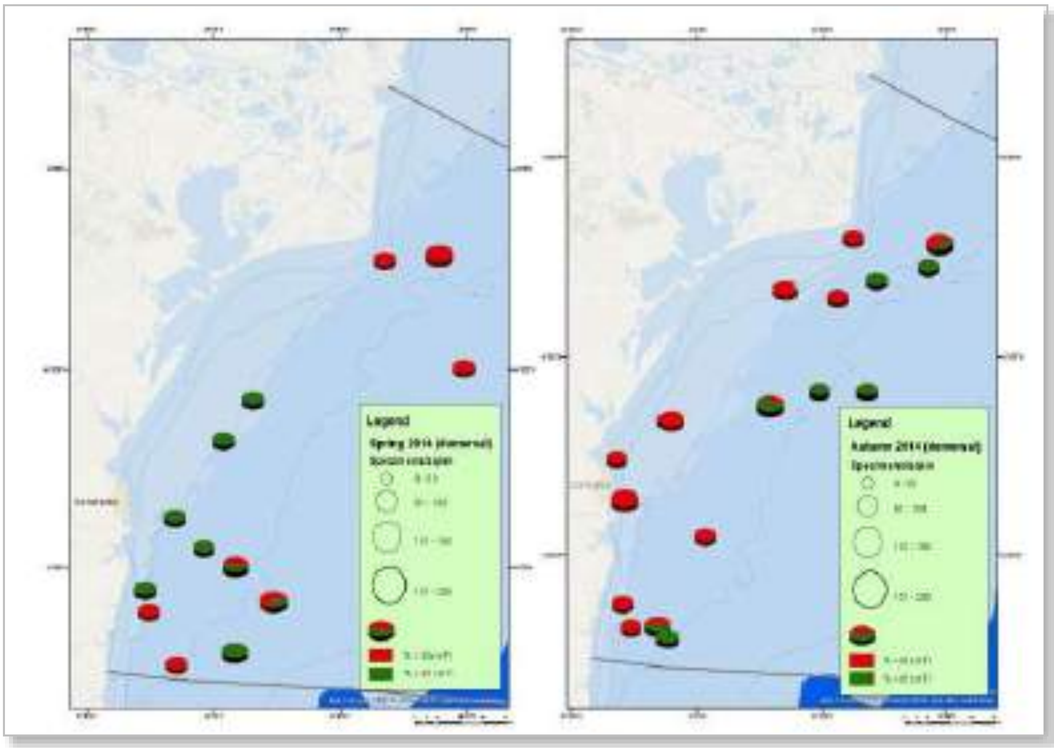


Figure 2.1.3.23. (A). Map of distribution of mature and immature individuals in Romanian Black Sea waters in spring 2014 and in autumn 2014 (B) (STECF, 2015)

Mapping of distribution of turbot (BSERP, 2006) juveniles and larvae in the Ukrainian sector was estimated on the basis of YugNIRO summer ichthyoplankton surveys with Bongo nets and Danilevsky's pelagic trawl. In the Ukrainian sector two main areas of spawning are located. They are as follows: coastal waters adjacent to the western extremity of the Crimea peninsula, including the Karkinitsky Bay and the eastern coast of the Crimea. The most intensive spawning is observed in May. Eggs are pelagic; they keep in the upper layers of water; due to this it may spread by currents far from spawning sites. However, grounds with increased density of juveniles and larvae of turbot are located in the immediate vicinity of major spawning sites – near western and eastern coasts of the Crimea within the shelf zone (Fig. 2.1.3.24). Turbot juvenile distribution in Bulgarian and Ukrainian waters is presented in Fig. 2.1.3.23 B.

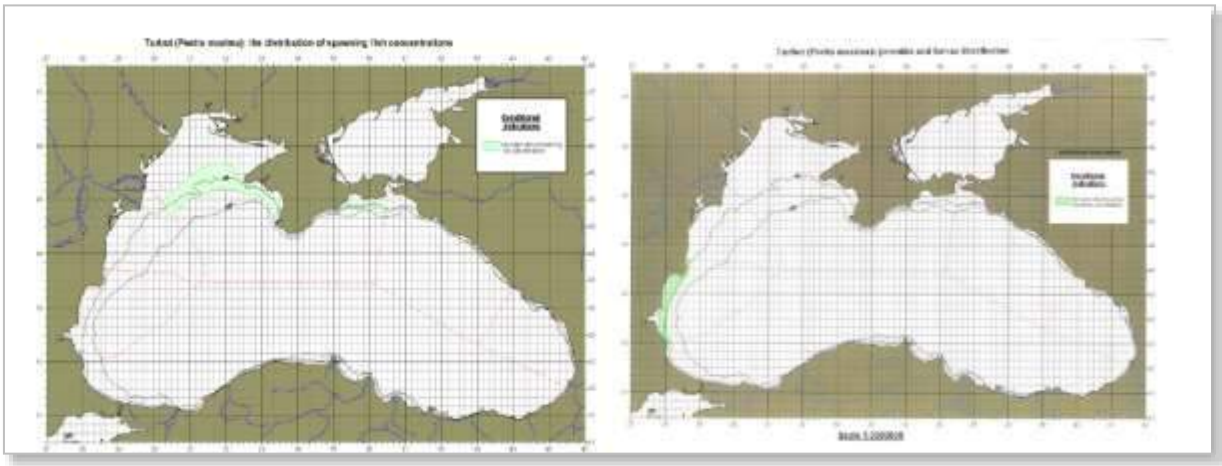


Figure 2.1.3.23. A: distribution of spawning turbot in Ukrainian waters B; juvenile and larvae distribution in Bulgarian waters (BSERP, 2007;STECF, 2015)

The sex structure of turbot catches is represented on Figure 2.1.3.24. In the Bulgarian Black Sea waters the juvenile turbot specimens represent 30.80% of all collected individuals, the females formed 40.7 %, whereas the percent share of males was lowest - 28.6 %.

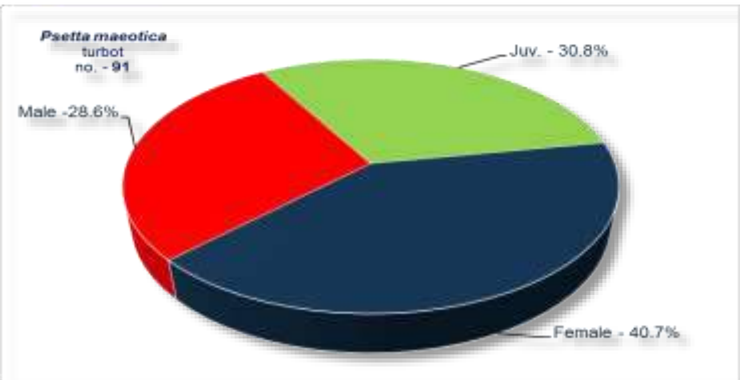


Figure 2.1.3.24. Sex structure of turbot catches in November 2014 (STECF, 2015)

The sex structure of turbot in the investigated area is presented on Figure 2.1.3.25

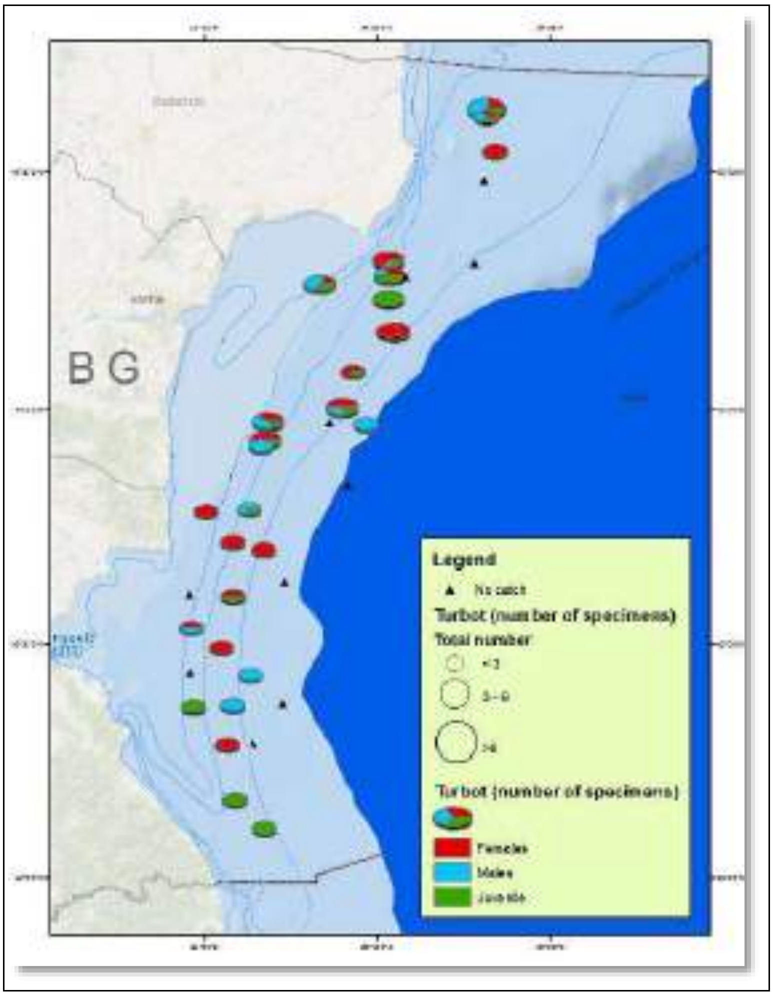


Figure 2.1.3.25. Sex structure of *Psetta maxima* in November 2014 (Tserkova et al., 2015)

The estimated catch per unit effort (CPUE) and biomass indices (CPUA) for the Turkish area during the autumn, winter and spring seasons in the active period for bottom trawls in both regions (turbot fishery is allowed between 15 September and 15 April and out of 3 miles), are presented in Table 2.1.3.11.

Table 2.1.3.11. Turkish Black Sea turbot catch per unit effort (kg/h) and biomass indices (kg/km2) in 2012 (STECF, 2013)

Region	N	Minimum	Maximum	Mean	Std. Error	Std. Deviation
CPUE/GENERAL	101	0.00	6.10	0.78	0.13	1.27
CPUA/GENERAL	101	0.00	12.79	1.66	0.28	2.81
CPUE/SSA (EBS)	59	0.00	6.10	0.90	0.17	1.32
CPUE/ WBS	42	0.00	4.00	0.61	0.19	1.19
CPUA/ SSA (EBS)	59	0.00	12.79	1.88	0.38	2.92
CPUA/WBS	42	0.00	8.73	1.36	0.41	2.65

The mean abundance index is estimated as 1.66±0.28 kg/km2 in trawl hauls in depths between 50-100 m (minimum 24.7 m, maximum 113.1 m) along Samsun shelf area in spring 2012 (Table

2.1.3.11.). Abundance indices were estimated by 'swept area method' for the period of intense fishing (January-April and September-December) from commercial vessels (Sparre and Venema, 1992).

Trends in abundance at length or age

The average length (Fig. 2.1.3.26.) and weight frequency distributions were presented in Table below. The age range was determined as 0-8 years.

Age group	Length (cm)	Weight (g)	N
0	7.5	6.6	1
1	21.1	165.2	7
2	28.6	462.2	17
3	37.8	926.3	17
4	42.9	1374.9	29
5	49.1	2014.4	23
6	57.1	3190.0	2
7	63.3	4831.3	4
8	68.1	6216.7	3
Average	41.3±11.12 (7.9-69.0)	1506.4±1286.91 (6.6-7050.0)	101

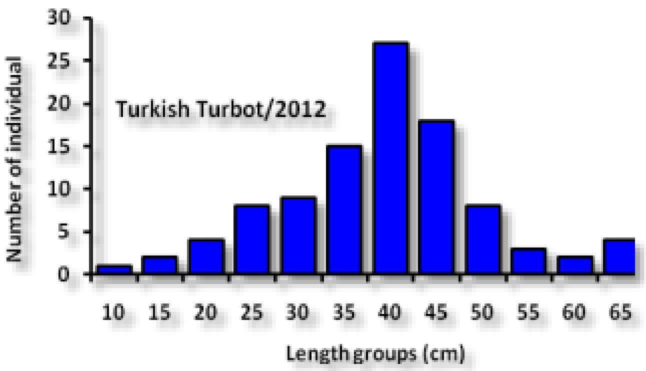


Figure 2.1.3.26. The length frequency distribution of turbot population along Turkish Black Sea Coasts, 2012 (STECF,2013).

Trends in growth

The growth parameters were estimated as Loo= 82.41 cm, K=0,342 year-1 and t0=-3.731 year and the constant and slope in length-weight relationship were calculated as 0,012 and 3,093 (Rsq = 0.99) respectively, for spring sampling 2012 (Fig. 2.1.3.27.)

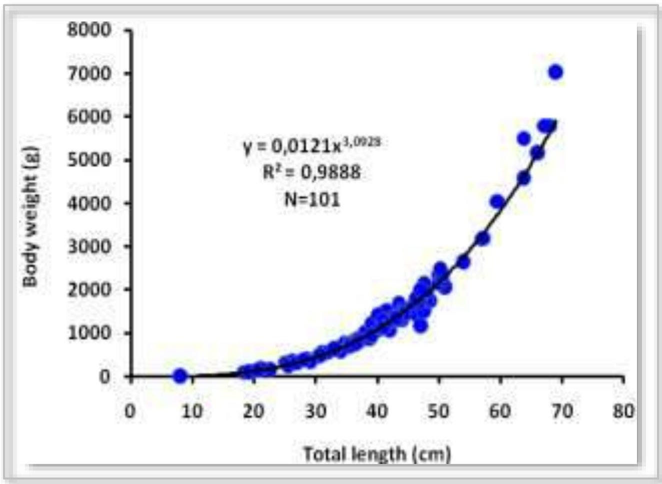


Figure 2.1.3.27. Turbot length-weight relationship in 2012 (STECF, 2013)

Multiple SAM model runs were done to test the effect of different combinations between tuning series on SSB, recruitment and fishing mortality. Among the others, a run excluding the Romanian tuning fleet was performed. The observed effects were large in terms of SSB (i.e. around 60% lower SSB in the last year) but not significant in F and recruitment, and nevertheless do not affect the perception of the stock status. Thus, STECF EWG 13 12 Black Sea assessments decided to use the all available tuning series in the analysis.

The SAM estimated recruitment has four peaks in 1965 – 1968, 1974 – 1977,1991 – 1994 and 2003 – 2006 and three lows in 1982-85, 1996 – 1997 and 2004 - 2006. Correspondingly, SSB attained higher values up to 14 255 t in 1976 – 1982 and very low values after 1989. For the recent period however the STECF EWG 13 12 Black Sea assessments is aware that misreporting of actual catches might be larger than assumed in the assessment (around 1.82 the official catches) especially for Bulgaria and Ukraine. Fishing mortality F4-8 has a peak of F~1.25 in 2000-2001 and keeps as high as F = 0.6 - 0.86 thereafter (Figure 2.1.3.28.).

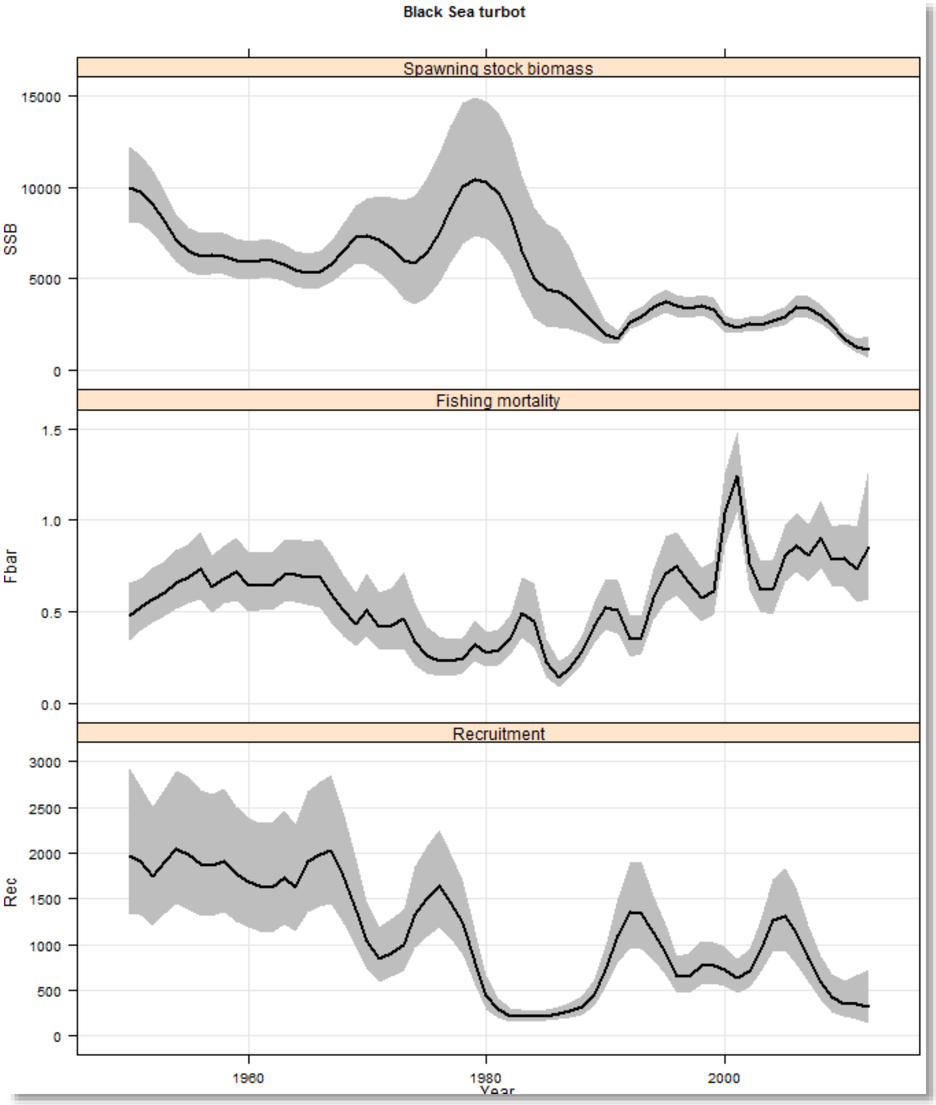


Figure 2.1.3.28. Time-series of population estimates of Black Sea turbot (SAM final model): SSB, F (ages 4–8) and recruitment with estimate of uncertainty (STECF, 2015).

Red mullet Mullus barbatus

In the vicinity of the Crimean and Caucasian coasts, two particular forms of red mullet are distinguished: "settled" and "migratory" ones. "Migratory" red mullet moves to the Kerch Strait and the Sea of Azov for fattening and spawning in spring and returns to the coasts of the Crimea for wintering. Along coasts of Romania and Bulgaria in September-November red mullet migrates to the Turkish waters of the Black Sea and Sea of Marmara for wintering. The "migratory" form of red mullet is considered as different stock and excluded from the current analysis. Subsequently the catches by Ukraine, which are dominated by the "migratory" form of red mullet, are excluded from this assessment (STECF, 2015).

The population parameters (Table 2.1.3.27. and 2.1.3.28) from VBGF are presented on the following table:

Table 2.1.3.27. Red mullet in GSA 29. Parameters of VBGF and L-W relationship

COUNTRY	YEAR- PERIOD	SPECIES	SEX	L_INF	K	t_0	a	b	Reference
Ukraine	1988-1990	MUT	C	17.97*	0.316	-1.876	0.0085	3.338	Domashenko (1990)
Turkey	1991-1996	MUT	F	25.55	0.238	-1.324	0.0064	3.177	Genç (2000)
	1991-1996	MUT	M	23.83	0.227	-1.624	0.0074	3.114	Genç (2000)
Turkey	2004-2006	MUT	M	25.25	0.154	-1.590	0.0700	3.170	Süer (2008)
Turkey	2004-2006	MUT	F	39.36	0.082	-1.920	0.0700	3.140	Süer (2008)
Turkey	2004-2005	MUT	C	20.15	0.330		0.0107	2.972	Aksu et al, 2011
Turkey	2010	MUT	C	18.97	0.486	-0.961	0.0070	3.150	Zengin et al.(2012)
Turkey	2011	MUT	C	20.66	0.442	-1.327	0.0070	3.150	Zengin et al.(2012)
Turkey	2012	MUT	C	21.37	0.409	-1.479	0.0060	3.210	Zengin et al.(2012)
Turkey	2013	MUT	C	21.97	0.287	-1.086	0.0080	3.110	Gumus et al (2013)
Romania	2013	MUT	C	12.63	0.411	-2.273	0.0050	3.270	NDCP, 2013
Turkey	2014	MUT	C	21.71	0.403	-1.834	0.0080	3.150	

* - standard length (SL)

Table 2.1.3.28. Growth and length weight model parameters (GFCM, 2015)

			Sex			
		Units	female	male	Combined	Years
Growth model	L∞	cm			21.71	2014
	K				0.403	2014
	t_0				-1.834	2014
	Data source	STEFC,2015				
Length weight relationship	a				0.008	2014
	b				3.15	2014
	M (scalar)					
	sex ratio (% females/total)					

An important issue was raised by a Turkish expert on possible misclassification of two Mullid species in the Black Sea; namely Red mullet (*Mullus barbatus*) and Striped mullet (*Mullus surmuletus*). The reasons behind misclassification seem to be two; the first is different names given to the species locally in Turkey. The second reason is the different minimum individual size regulation applied to two species; according in Black Sea EU waters there is no size limit for the M. surmuletus and in Turkey the minimum legal landing size of *M. barbatus* (13 cm) is larger than that of *M. surmuletus* (11 cm). Given that the two species have very identical morphological features, it was evidenced that undersized *M. barbatus* is intentionally reported as *M. surmuletus*. This issue has been discussed in depth and based on various research carried out in the Turkish coast of the Black Sea (Keskin, 2012; Gümüş and Zengin, pers.com.), in which no *M. surmuletus* has never been reported, it was concluded that there is only one Mullid species in the Black Sea, which is abundant enough to be exploited at commercial scale, and this is Red mullet (*M. barbatus*). Nevertheless, the EWG noted the exception of the local population confined to the area around Istanbul (Strait of Boasphorus), where the majority of the Mullids landed by gillnet fishery is composed of *M. surmuletus* (Karakulak, pers. com). Therefore for the assessment, the landings data of *M. surmuletus* and *M. barbatus* were merged and further treated as *M. barbatus* (Red mullet) only, and the exception noted above is considered as minor and not affecting the outputs of the analysis (STECF, 2015).

Table 2.1.3.29. Landings of red mullet in Black Sea

Years	**Bulgaria Red mullet**	**Bulgaria Striped mullet**	**Georgia**	**Romania**	**Russian Federation**	**Turkey Red mullet**	**Turkey Striped mullet**	**Ukraine**
2009	**48**	**24**			**292**	**799**	**1790**	**65**
2010	**72**	**38**			**200**	**507**	**3373**	**68**
2011	**176**	**33**	**22**	**2**	**291**	**326**	**2994**	**58**
2012	**131**	**12**			**144**	**347**	**2868**	**76**
2013	**256**	**15**		**3**	**180**	**318**	**1743**	**96**
2014	**314**	**15**		**9**	**161**	**438**	**2973**	**188**

On Table 2.1.3.29. are presented the landings of the Red mullet and Striped mulled reported by the Black Sea countries. Trends in red mullet landings differ between countries (Figure 2.1.3.29.). Reported red mullet landings of Turkey (Fig.2.1.3.29.) have significantly decreased in the last 15 years, whereas landing of the rest of the countries have increased.

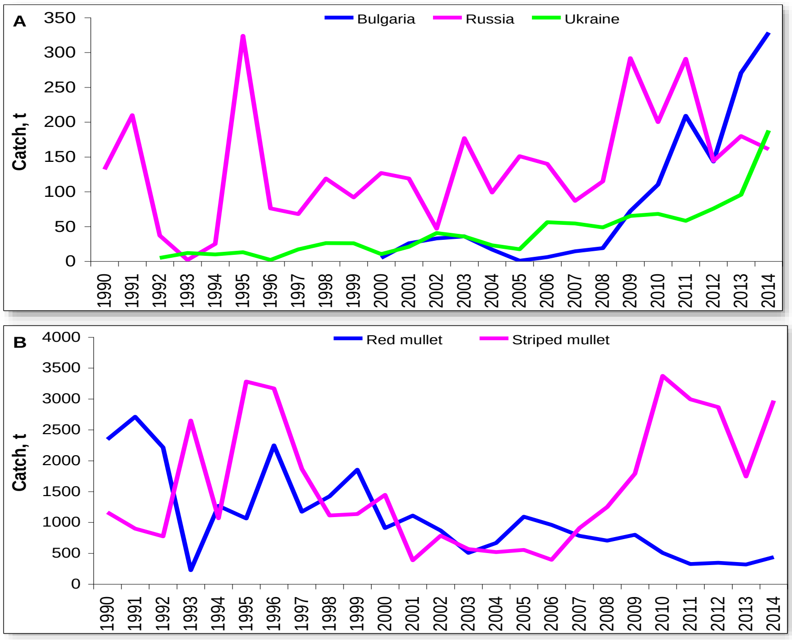


Figure 2.1.3.29. Catches of Red mullet in Bulgaria, Russia, and Ukraine. B: Catches of Red mullet and Striped mullet in Turkey. Note the divergent trends after 2003 (STECF, 2015)

Spatial distribution

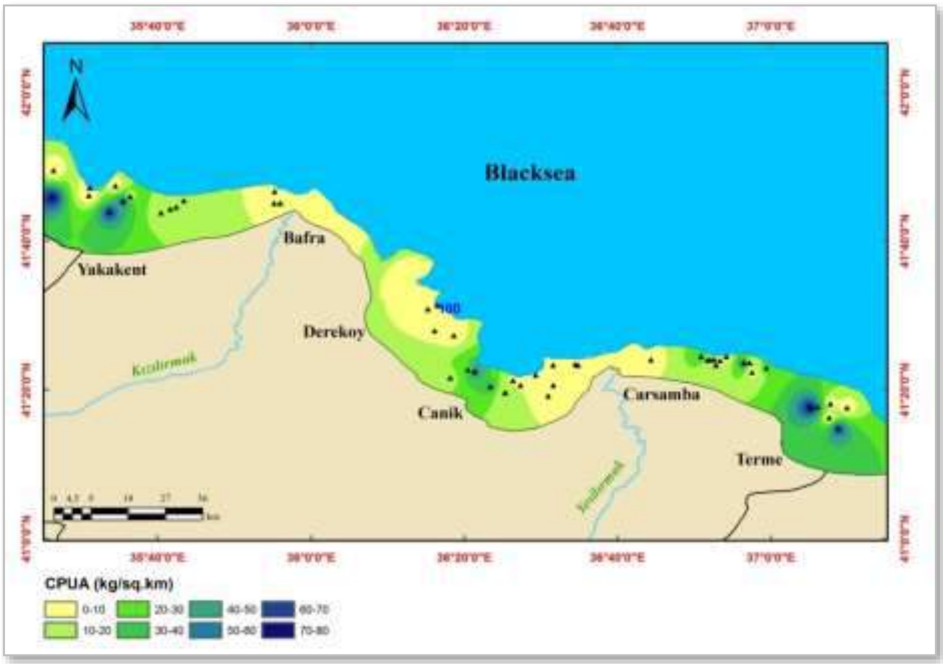


Figure 2.1.3.29. Red mullet in GSA 29. Map of biomass indices in the Samsun Shelf Area (upper) and West Black Sea (lower) for 2013 (STECF, 2014)

Table 2.1.3.30. Tuning fleet data (CPUE kg/h)

Year/age	1	2	3	4	5
2009	672	282	58	13	3
2010	531	261	61	13	1
2011	718	250	40	11	4
2012	387	130	35	16	1
2013	363	171	47	19	1
2014	533	135	39	7	0.4

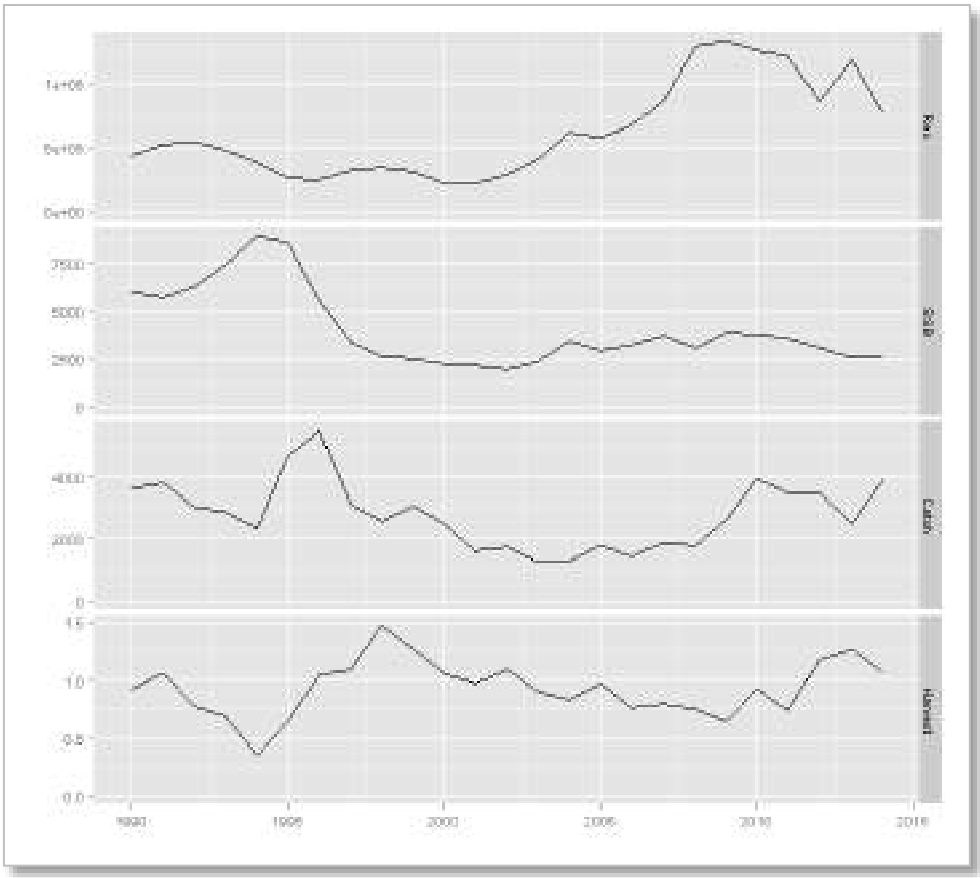


Figure 2.1.3.30. Red mullet in GSA 29. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals (STECF, 2015)

The SSB drops in the late 1990s and has some increase over 2004-2010. After 2010, SSB decreased again to 2500 t. Estimates of recruitment are rather imprecise due to the lack of survey data. Recruitment shows an increasing trend after 2000 that is reflected by the dominant amount of younger fish in the catches. Fishing mortality is consistently high: 0.8 - 1.4 except in 1994 when the catch dropped suddenly about 10 time compared to the previous years.

This year assessment (2014) differs considerably from the previous (2013) assessment because different input catch data were used (catches reported as Red mullet and Striped mullet were pulled together). Resulting average F follows a similar trend to the 2013 assessment, except in the period 2004-2009, while SSB and recruitment differ considerably from the 2013 assessment (Fig. 2.1.3.31.)

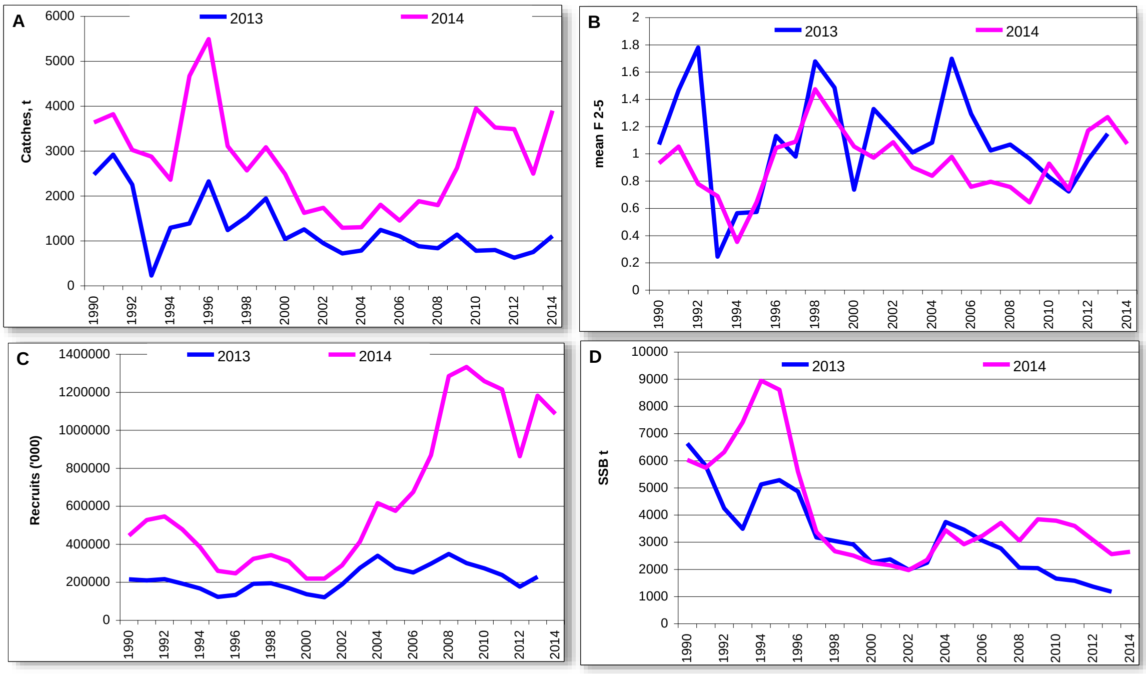


Figure 2.1.3.31. Catch, Recruitment, SSB and harvest of red mullet in 2013 and 2014 (STECF, 2015)

Red mullet was observed only in polygons 2, 3 and 5, situated in front of area between Obzor and cape Emine (Figure 2.1.3.31.)

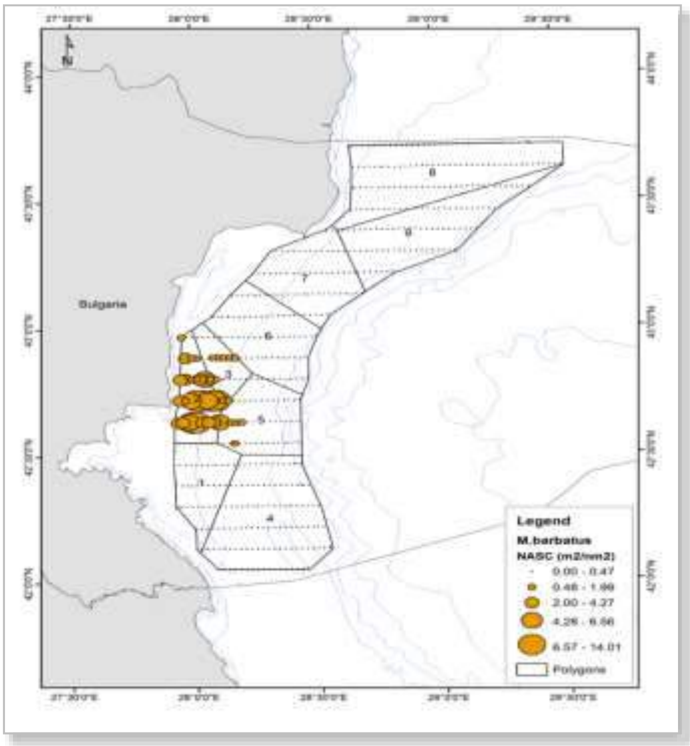


Figure 2.1.3.31. Spatial distribution of red mullet in November 2014, Bulgarian area (Panayotova et al., 2015)

Table 2.1.3.31. Estimated relative biomass (tonnes) of red mullet by size classes and polygons, October - November 2014 (Panayotova et al., 2015)

Size class (cm)	Biomass (t)			Total (t)
	Polygon 2	Polygon 3	Polygon 5	
8.5	54.00			54.00
9	54.00			54.00
9.5	54.00			54.00
10	162.00	48.52		210.52
10.5	215.99	97.04		313.04
11	485.99		248.32	734.31
11.5	108.00	48.52	496.64	653.16
12	971.98	48.52	248.32	1268.82
12.5	647.98	242.61	496.64	1387.23
13	647.98	339.65	496.64	1484.27
13.5	485.99	242.61	496.91	1225.51
14	269.99	194.09	248.32	712.40
14.5	215.99	48.52		264.52
15	269.99	145.56		415.56
15.5	215.99	48.52		264.52
16		145.56		145.56
Total (t)	4859.88	1649.73	2731.79	9241.40

Maximum values of estimated relative biomass of red mullet were distributed between 20 and 60m depths in the area in front of cape Emine (Fig. 2.1.2.32.). Total estimated biomass amounted at 9 241.40 t.

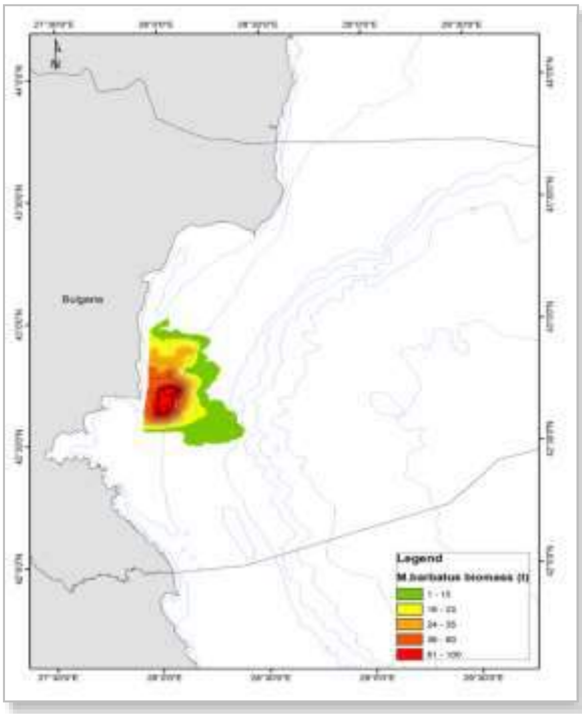


Figure 2.1.3.32. Distribution of red mullet biomass values, obtained during the acoustic survey of R/V “Akademik” in October - November 2014 (Panayotova et al., 2015)

WHITING *Merlangius merlangus*

In the Black Sea, the whiting is one of the most abundant species among the demersal fishes. It does not undertake distant migrations, spawning mainly in the cold season within the whole habitat area. The whiting produces pelagic juveniles, which inhabit the upper 10-meter water layer for about a year. The adult whiting is cold-living, preferring temperatures 6-10. C. Fishes at the age less than 6 years are predominant in the whiting populations, the older year classes are found in catches individually. It occurs all along the shelf, dense commercial concentrations are formed by 1-3 year old fishes in the water down to 150 m depth, most often at 60-120 m depths (Shlyakhov, 1983; Ozdamar et al, 1996). Such concentrations on the shelf of Bulgaria, Georgia, Romania, the Russian Federation and Ukraine not do from every year, appearing at periods of 4-6 years - in the years of appearance of highly productive year classes. In these countries, whiting is very rarely the target species for fisheries and yielded as by-catch during trawl fisheries for other fish species or while non-selective fisheries with fixed nets in the coastal sea areas (Shlyakhov and Daskalov, 2008). The problem of units for whiting stocks in the Black Sea has not been settled yet. Fisheries experts from the Black Sea Commission specify the stock as shared that is although this fish does not make long migrations; its whole stock (or two different stocks – Eastern and Western) is exploited by each Black Sea country in their waters. In this case, the part of the stock (or local stocks) that is distributed outside the Turkish waters, practically unexploited. Therefore, the estimates F and stock size obtained from the analysis of only the fishery and biological data does not have a lot of regional value for whiting (STECF, 2015; GFCM, 2015). The Turkish data for 2014 were derived from monthly sampled catches as in previous years. The length and weight range between 5.2 cm and 24.3 cm and 1.11g and 138.21g, respectively (Fig . 2.1.3.32.).). The average length was 11.84 (±0.07) cm and the average weight was 14.81 (±0.33) cm. Age groups range between 0 and 6 year. The most dominant age group was age 1 (78.39%) followed by age 2 (12.36%) and age 3 (4.19%) (Fig. 2.1.3.32.).

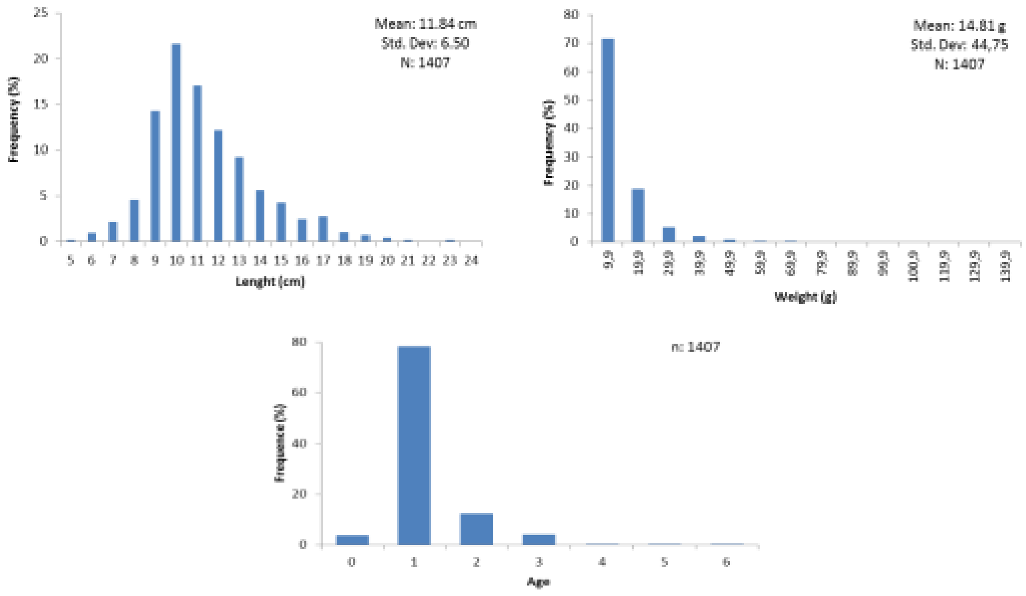


Figure 2.1.3.32. The length, weight and age frequency (n=1,407) distributions of whiting from Turkish coasts for 2014 (STECF, 2015; GFCM, 2015)

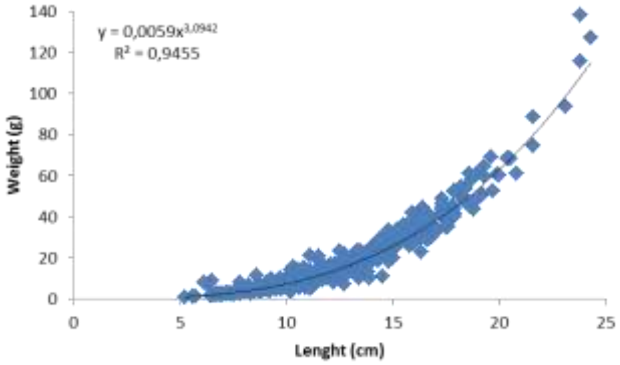


Figure 2.1.3.33. The length, weight and age frequency (n=1,407) distributions of whiting from Turkish coasts for 2014 (STECF, 2015; GFCM, 2015).

The constant and slope was calculated as 0.059 and 3.0942 (N=1407, R=0.945) for the L-W relationship. The growth parameters were estimated from 2014 sampling as L∞ = 31.60 cm, K= 0.186 cm/y and to=-1.428 year. The Growth performance index (Φ) was calculated 5.22. The mortality was estimated at 0.291 according to Pauly's equation (STECF, 2015; GFCM, 2015).

Table 2.1.3.32. Growth parameters of whiting in Black Sea (Raykov et al., 2008)

Country	L∞	K	t0	1	2	3	4	5	6
Bulgaria	29.83	0.157	-2.49	12.6	15.1	17.2	19.1	20.6	22.0
Romania	26.30	0.160	-2.19	10.5	12.8	14.8	16.6	18.0	19.2
Ukraine	39.00	0.106	-1.324	8.5	11.6	14.3	16.8	19.0	21.0

Table 2.1.3.33. Population parameters of whiting from Black Sea (STECF, 2015, GFCM, 2015)

Year	2013	2013	2014	2014	2014
Country	Romania	Turkey	Romania	Turkey	Bulgaria
length range (cm)	5.0-16.5	5.4 - 22.7	5.5 - 19.0	5.2 - 24.3	7-19.5
weight range (g)	1.15-46.12	1.17 - 82.99	1.125 - 42.397	1.11 - 138.21	
average length (cm)	10.38	12.37 (±0.07)	11.341	11.84 (±0.07)	
average weight (g)	8.58	16.07 (±0.27)	10.562	14.81 (±0.33)	

age groups range (y)	0-4	0-8	0-4	0-6	1-4
most relevant		age 2 (48.42%)	age 2 (48.42%)	age 2 (38.27 %)	age 1 (78.39%)
age group		age 3 (26,53%)	age 3 (26.53%)	age 1 (38,10%)	age 2 (12.36%)
		age 1 (20,59%)	age 1 (20.59%)	age 3 (13,44%)	age 3 (4.19%)

Sampling by month the commercial landings of the bottom trawls operating in 2013 and 2014 along Turkish waters (Samsun Shelf Area and west Black Sea Turkish coasts) and Romania waters allows collecting information on length. They are synthetized in table Table 2.1.3.33. (Radu and Maximov, 2013, 2014).

The Romania data for 2014 were derived from monthly sampled catches as in previous years. All samplings were provided from commercial bottom trawls operating in Romanian littorals of Black Sea coasts. The length and weight range between 5.5 cm and 19.0 cm and 1.125 g and 42.397 g, respectively. The average length was 11.341 cm and the average weight was 10.562 cm. Age groups range between 0 and 4 year. The most dominant age group was age 2 (38.27 %) followed by age 1 (38, 10%) and age 3 (13, 44%)(Figure 2.1.3.34.)

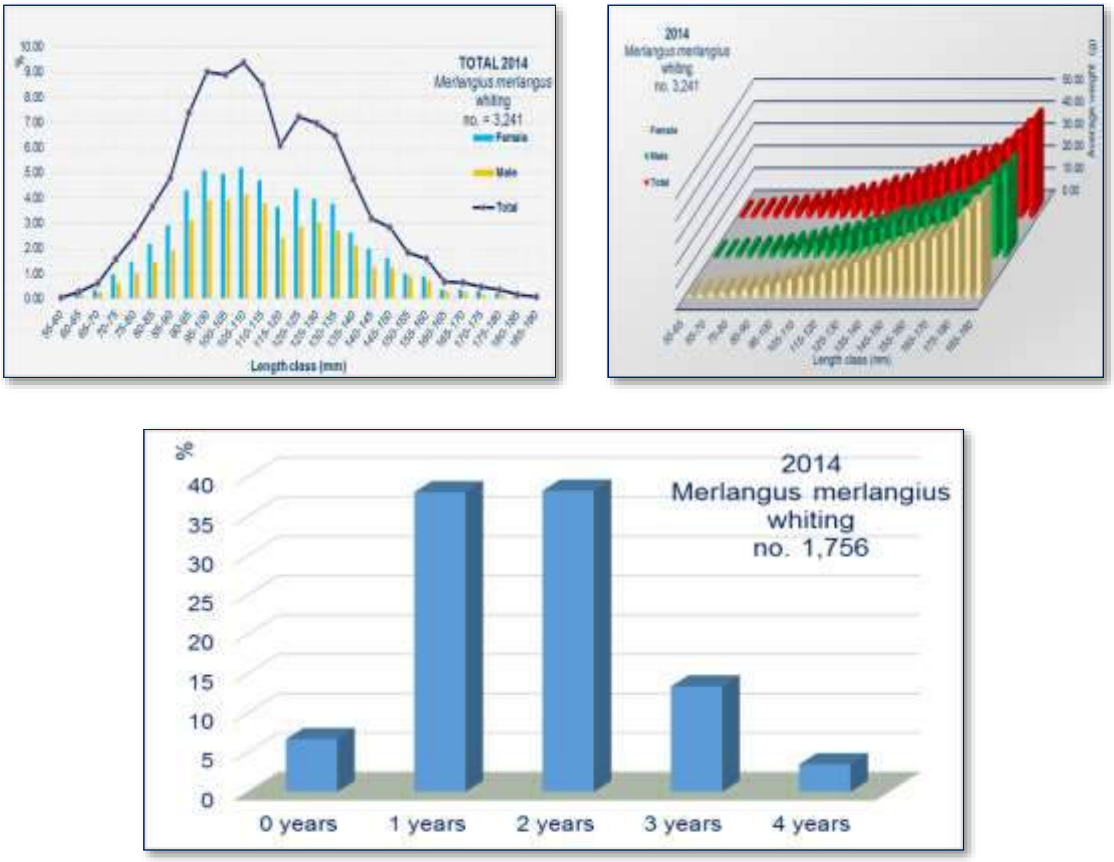


Figure 2.1.3.34. The length, weight and age frequency (n=3,241) distributions of whiting from Romanian coasts for 2014 (STECF, 2015; GFCM, 2015)

In Bulgaria, size structure of whiting was determined on the base of 1,184 fish, which were measured and aged. Size structure of M. merlangus, using 0.5 cm length class is presented on the Fig. 1.2.3.35.

The size structure of whiting catches includes individuals with lengths between 7 and 19.5 cm. Majority of the individuals has total lengths between 9.5 and 16 cm. Age structure of whiting includes 1 – 4 years old fish with major share of fish at age 1- 2 years old (Fig. 2.1.3.35.).

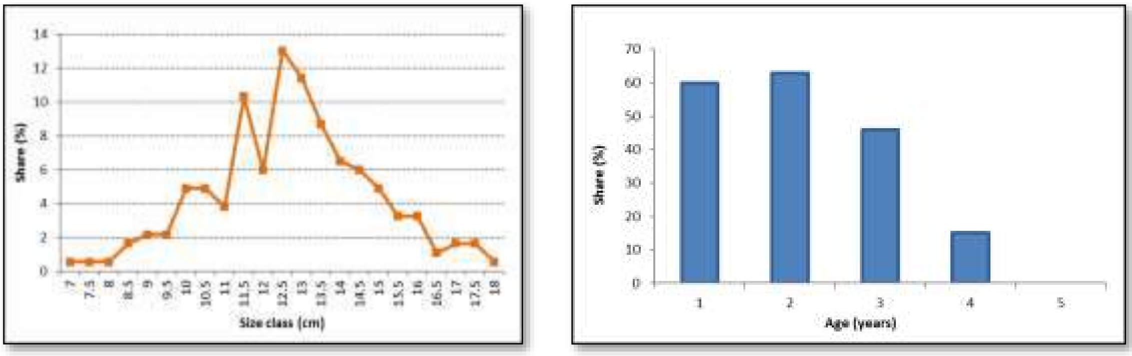


Figure 2.1.3.35. The length and age frequency (n = 1,184) distributions of whiting from Bulgarian coasts for 2014 (STECF, 2015; GFCM, 2015)

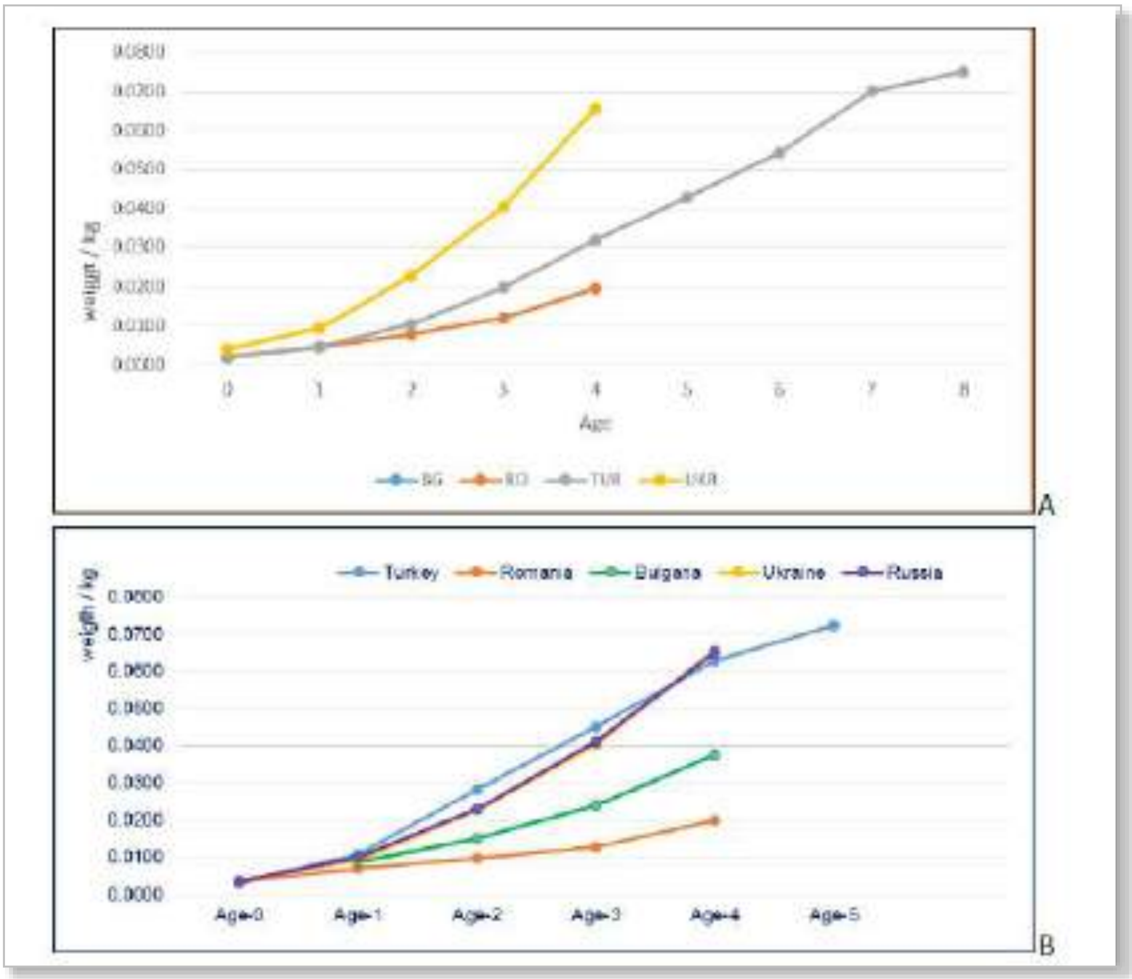


Figure 2.1.3.36. Whiting in GSA 29. Average weight at age by country (A=2013,B=2014) (GFCM, 2015)

Table 2.1.3.37. Landings of whiting in period 2009-2014

Year	Bulgaria	Georgia	Romania	Russian Fed.	Turkey	Ukraine	Former USSSR/Crimea	Black Sea
2009	2.3	15	39.5	52	8979	17	-	9105
2010	14.7	15	23.6	23	11894	17	-	11987
2011	1	42	0.1	20.9	8122	36	-	8222
2012	1.4	42	0.4	2.8	6251.4	34	-	6332
2013	5.3	-	1.1	15	8240	19.8	-	8281
2014	4.8	0	0.3	0.6	8805	0	9.1	8820

Spatial distribution

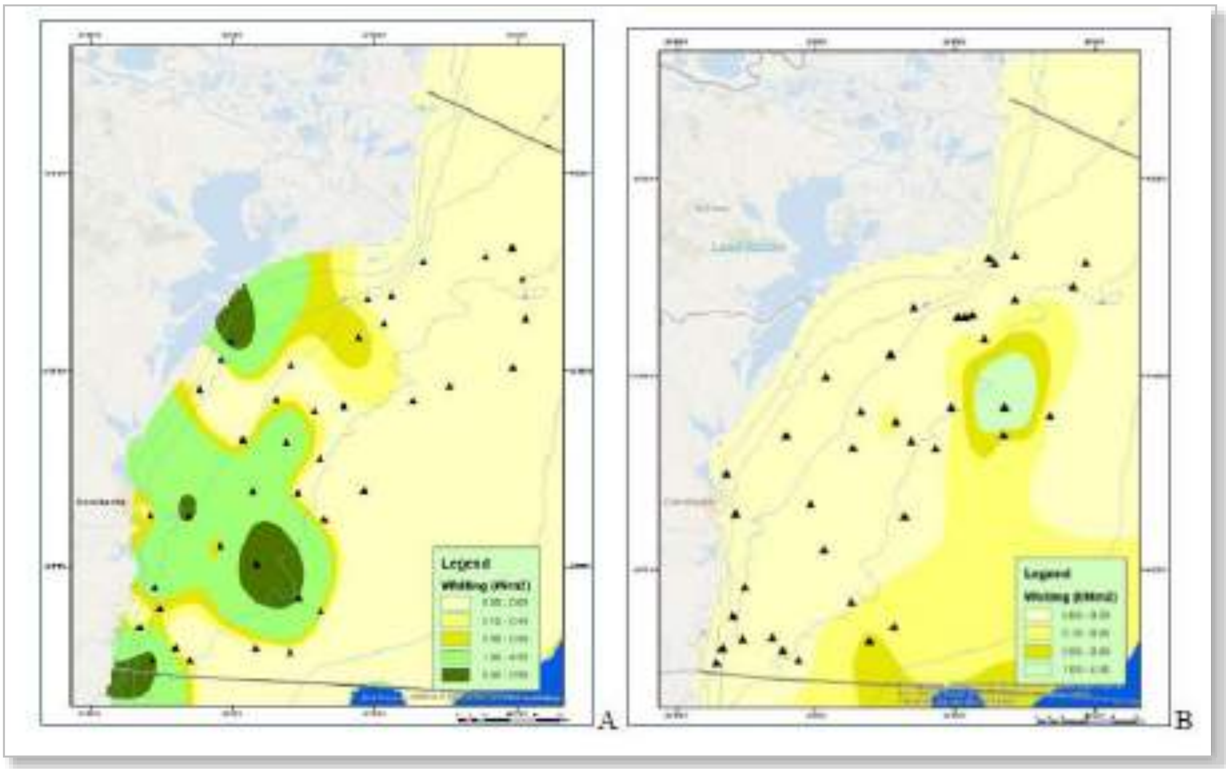


Figure 2.1.3.37. in GSA 29. Distribution along the Romanian littoral (2014)

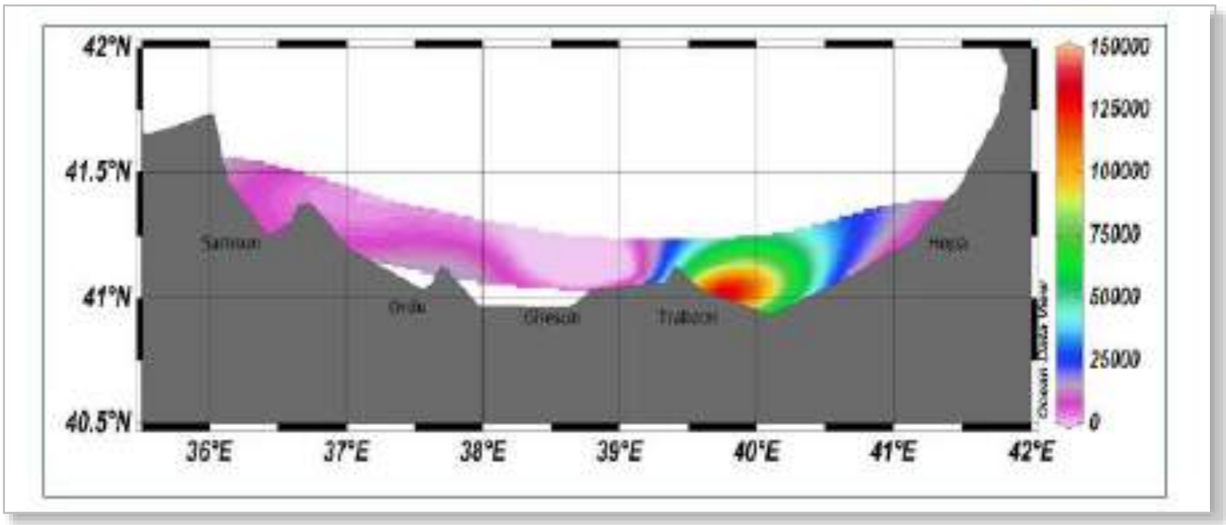


Figure 2.1.3.38. Whiting in GSA 29. Distribution along the Turkish littoral (August 2014).

Whiting was found mostly over the southern shelf area at depths between 40 and 60 m , where the sprat schools were concentrated. In the northern and central areas, the whiting schools were scarce or absent. The point map of the distribution of whiting NASC values (m2.nm-2) obtained during the acoustic survey of R/V "Akademik" in 2014 is presented on the Fig. 2.1.3.39.

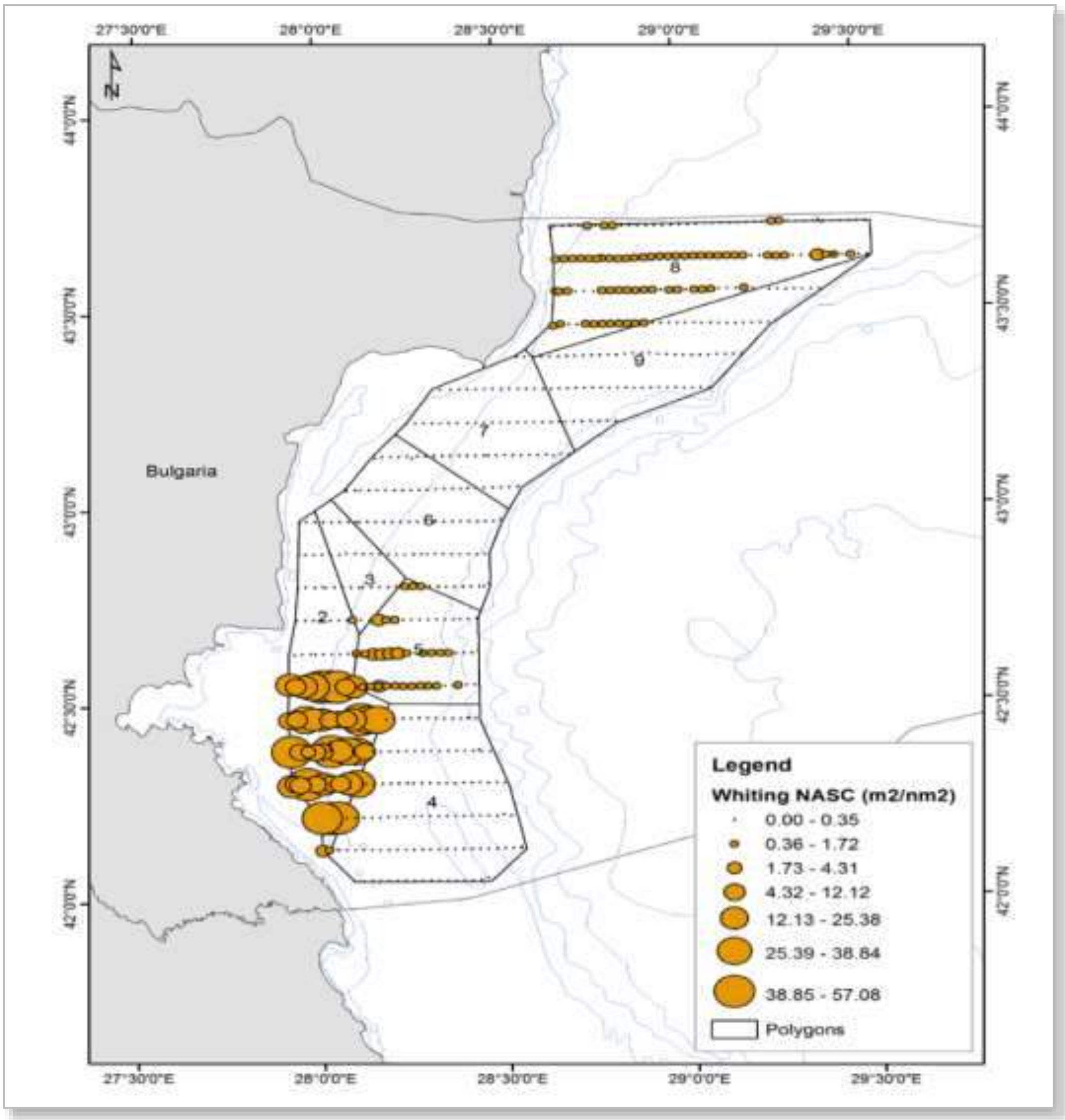


Figure 2.1.3.39. Point map of whiting NASC values (m2.nm-2)(STECF,2015)

Table 2.1.2.38. Estimated number of whiting (millions) by age groups and polygons, October - November 2014 (STECF, 2015)

Polygon	Total (millions)	Age			
		1	2	3	4
1	1976.70	560.77	644.88	560.77	210.29
2	163.58	46.41	53.37	46.41	17.40
5	237.13	67.27	77.36	67.27	25.23
6	202.36	57.41	66.02	57.41	21.53
8	446.42	126.65	145.64	126.65	47.49
Total (millions)	**3026.20**	**858.50**	**987.27**	**858.50**	**321.94**

Table 2.1.2.39. Estimated relative biomass (tonnes) of whiting by age groups and polygons, October - November 2014 (STECF, 2015)

Polygon	Total (t)	Age			
		1	2	3	4
1	30560.59	8669.67	9970.12	8669.67	3251.13
2	2529.08	717.47	825.09	717.47	269.05
5	3666.13	1040.04	1196.04	1040.04	390.01
6	3128.57	887.54	1020.67	887.54	332.83
8	6901.91	1957.99	2251.69	1957.99	734.25
Total (t)	**46786.28**	**13272.70**	**15263.61**	**13272.70**	**4977.26**

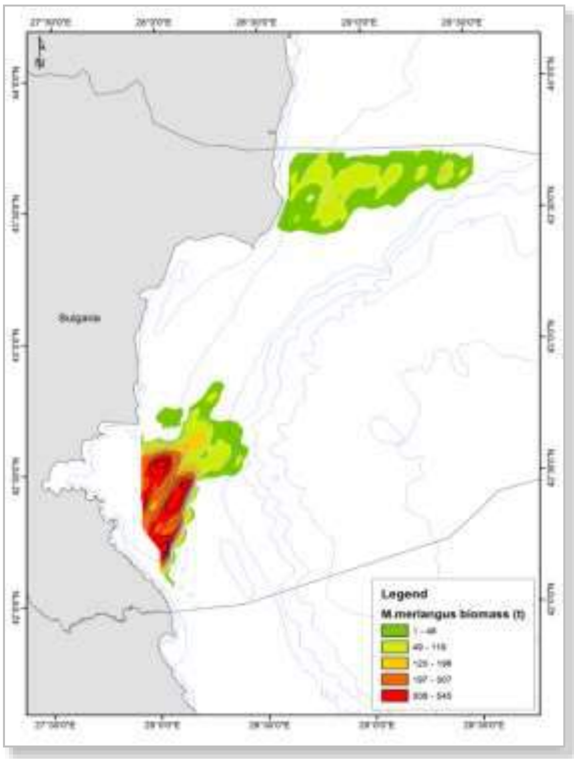


Figure 2.1.3.40. Distribution map of whiting relative biomass values, obtained during the acoustic survey of R/V "Akademik" in October - November 2014 (Panayotova et al., 2015)

Table 2.1.3.37.Catch at age of whiting in Black Sea (GFCM, 2015)

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Total
2009	85.34	431.12	286.88	65.12	18.17	0.00	887
2010	207.06	1145.08	483.52	51.51	14.56	0.00	1902
2011	452.01	1152.96	791.57	72.78	7.46	8.69	2485
2012	10.08	612.63	252.23	33.36	0.00	0.00	908
2013	568.89	1491.60	1107.72	240.51	57.81	0.00	3467
2014	48.56	275.28	276.56	97.10	25.11	0.00	723

Table 2.1.3.38.Whiting in GSA 29. Survey CPUE (kg/h) between 2011 to 2014 in the Samsun shelf area (SSA) and West Turkish Black Sea (GFCM, 2015)

Region	No of hauls	Minimum	Maximum	Mean	Std. Error	Std. Deviation
CPUE/GENERAL	102	0	150	31.03	2.72	27.46
CPUE/SSA (EBS)	60	0	150	30.59	3.64	28.2
CPUE/ WBS	42	0	100	31.66	4.12	26.69

Table 2.1.3.39.Whiting in GSA 29. Trend of abundance indices (N×10-3) and average CPUE (kg/h) by age according to the Turkish trawl surveys in 2009 – 2014 (GFCM, 2015)

Age	0	1	2	3	4	5	6	7	8	Total	Kg/h
2009	1015	232.4	438.7	138	31.6	3.7	0	0	0	1859.1	212.7
2010	14.4	507.1	768.1	244	52.5	9.3	0	0	0	1595.5	56.7
2011	115.6	765.1	852.4	352	50	26.5	0	0	0	2161.5	52.1
2012	12	276	558.2	217	27.9	17.5	1.9	0	0	1111.3	31
2013											
2014	22.81	465.84	73.49	2.49	2.96	2.53	1.69	0	0	594.23	24.2

Table 2.1.3.40. Whiting in GSA 29. Indices of abundance by length according to the Romanian research trawl surveys in 2011 - 2014 (106) (GFCM, 2015)

Class of length (cm)	2011	2012	2013	2014

4			1.2	
5	29.3	9.9	18.2	3.1
6	110.9	119.2	454.7	25.0
7	73.1	118.6	612.1	76.4
8	168.2	155.2	721.7	117.5
9	315.5	194.2	658.9	156.7
10	432.9	182.7	441.3	128.0
11	504.8	113.9	268.7	82.9
12	413.2	60.1	171.5	62.4

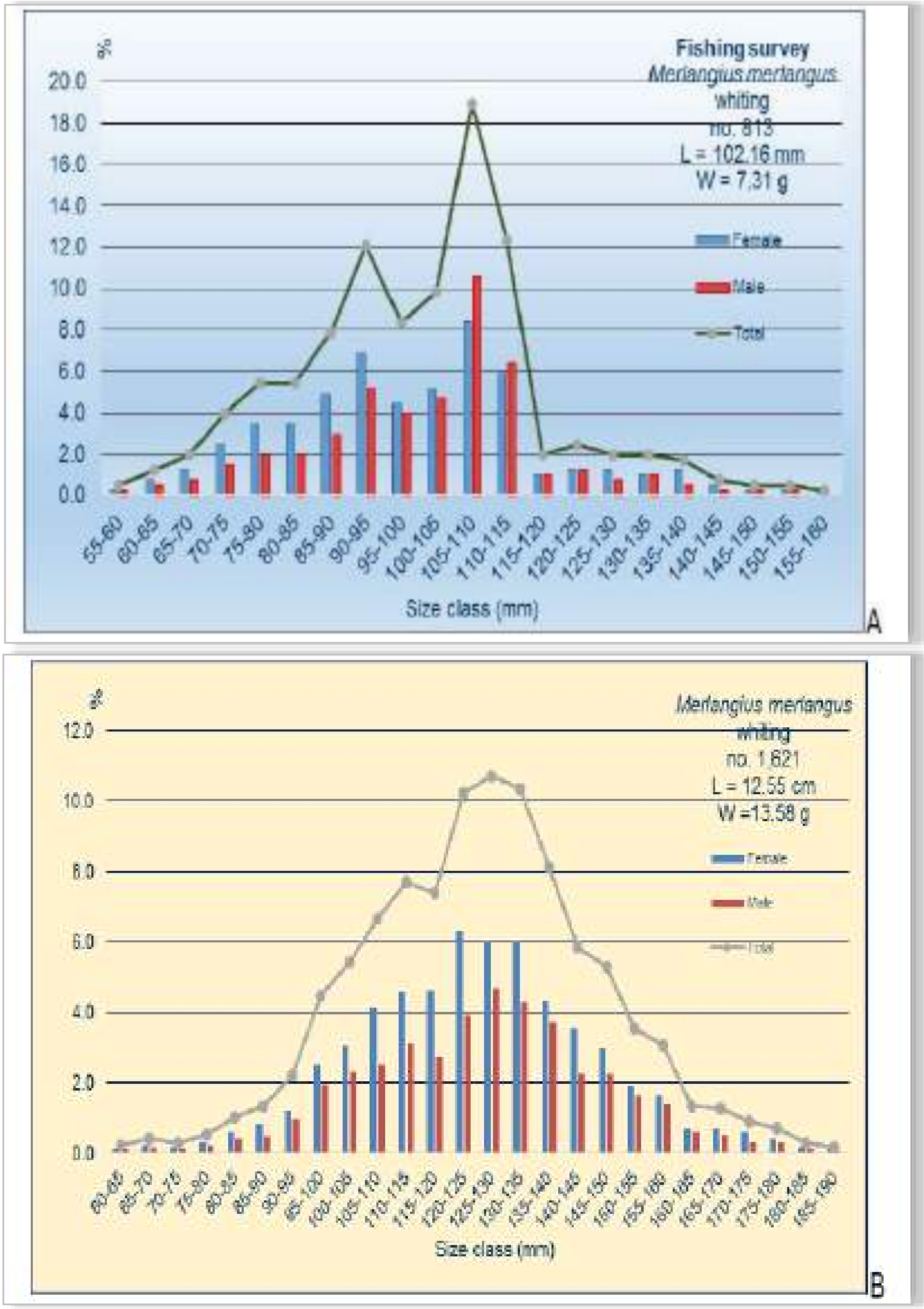


Figure 2.1.3.41. Length distribution by sex (A=spring, B=autumn) estimated by the Romania survey (GFCM, 2015)

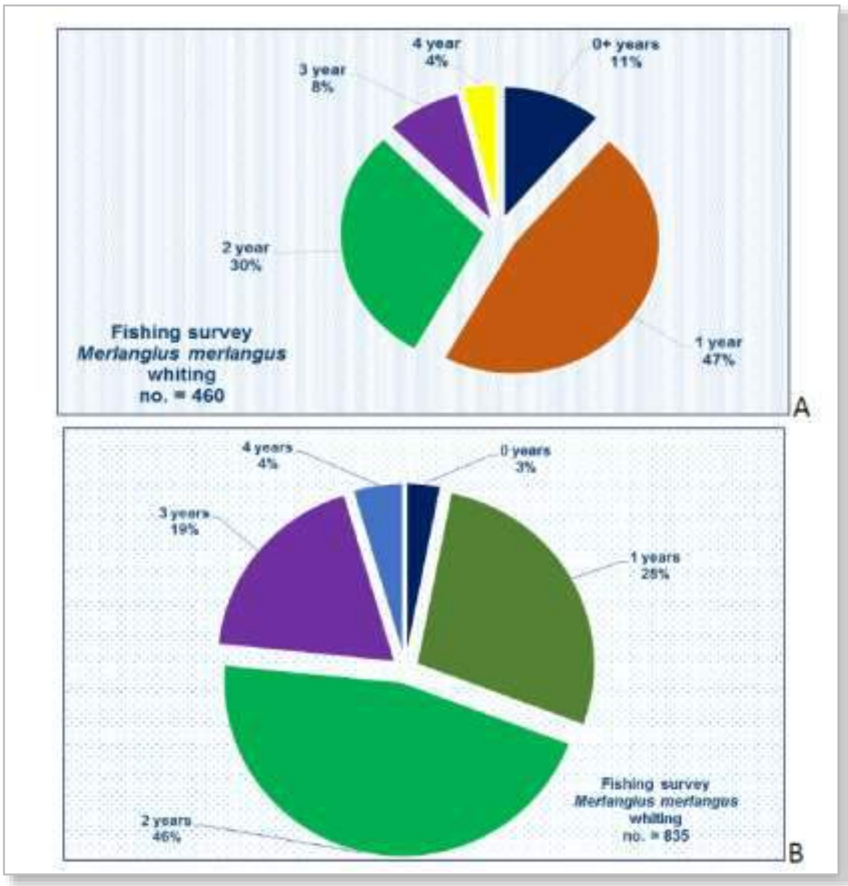


Figure 2.1.3.42. Whiting in GSA 29. Age composition estimated from the Romanian trawl survey (A=spring, B=autumn)(STECF, 2015)

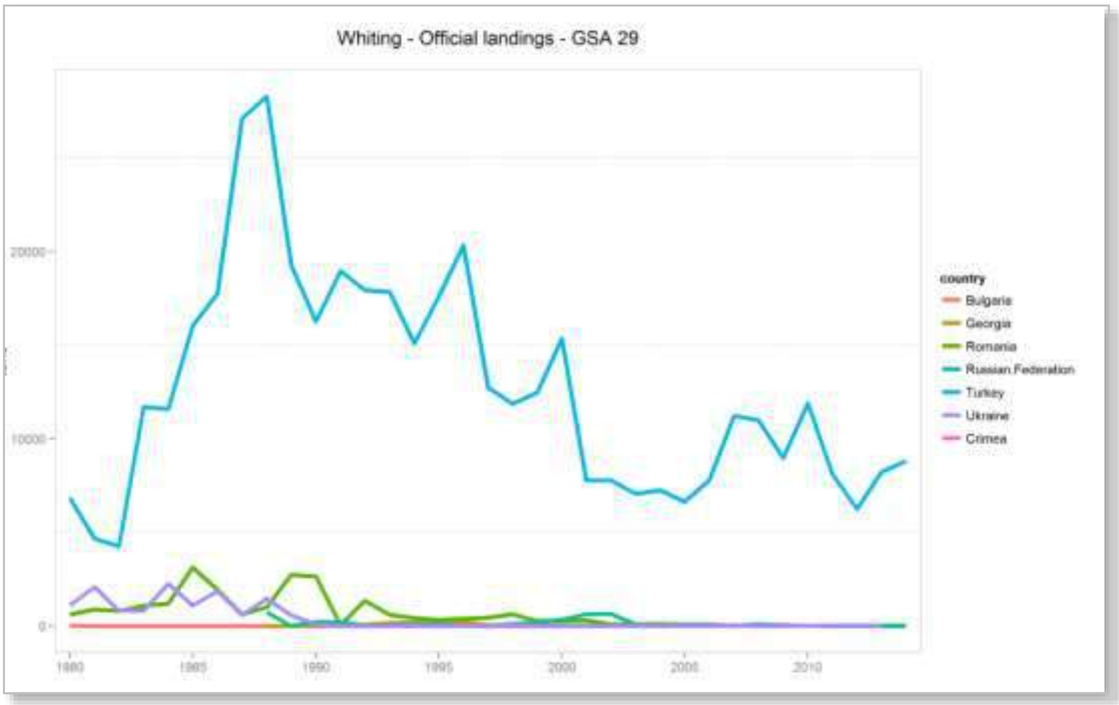
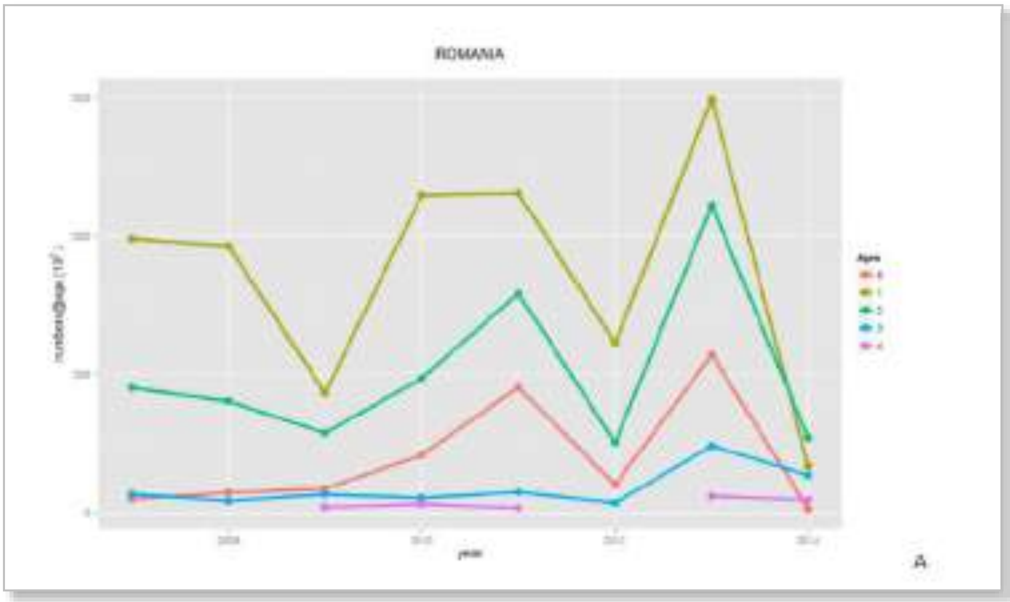


Figure 2.1.3.43. Whiting in GSA 29. Trends in catches by country (1980 – 2014) (STECF, 2015; GFCM, 2015)



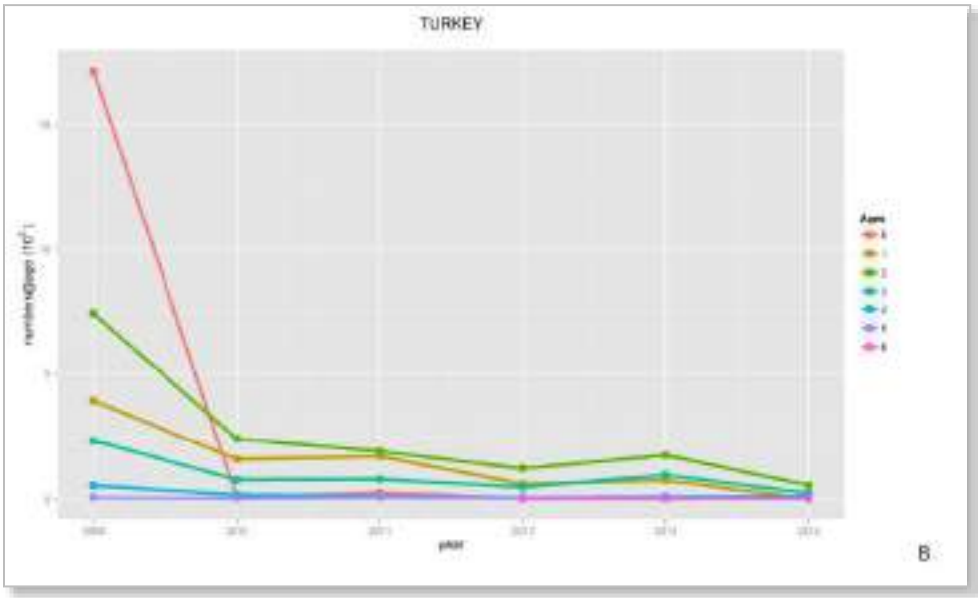


Figure 2.1.3.44. Whiting in GSA 29. A) Trends in the Romanian survey (2007 – 2014) and B) Turkish CPUE (2009 – 2014) series at age (STECF, 2015; GFCM, 2015)

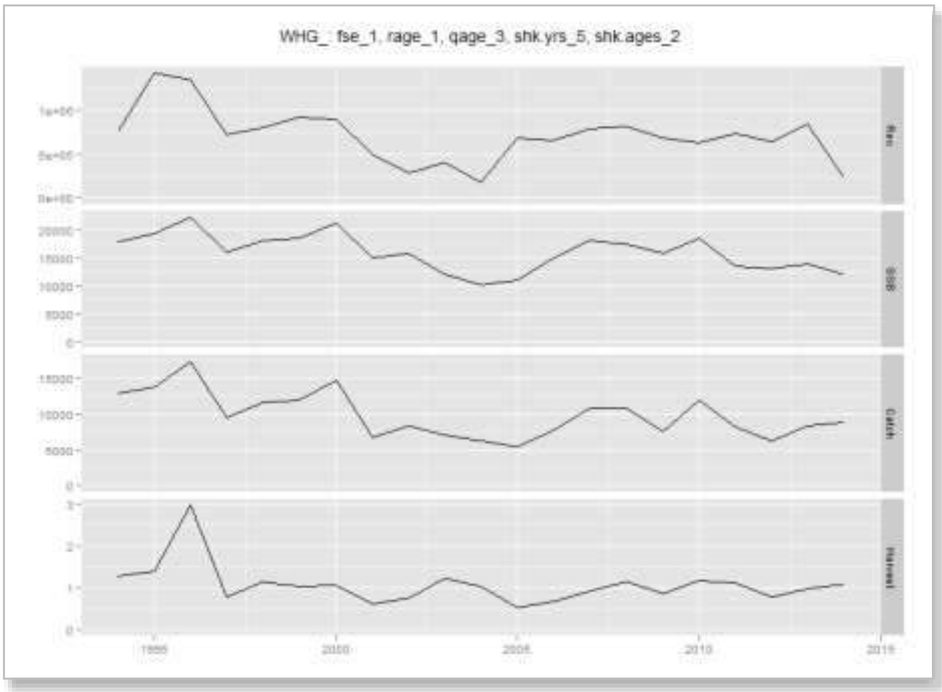


Figure 2.1.3.45. Dynamics of Recruitment, SSB, Catch and harvest of whiting in Black Sea (GFCM, 2015)

STECF (2015) and GFCM (2015) advises the relevant fleets' catches and/or effort to be reduced until fishing mortality is below or at the proposed EMSY level (0.40), in order to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan taking into account mixed-fisheries considerations. Catches of whiting in GSA 29 in 2016 consistent with EMSY cannot be estimated as the assessment is only indicative of trends.

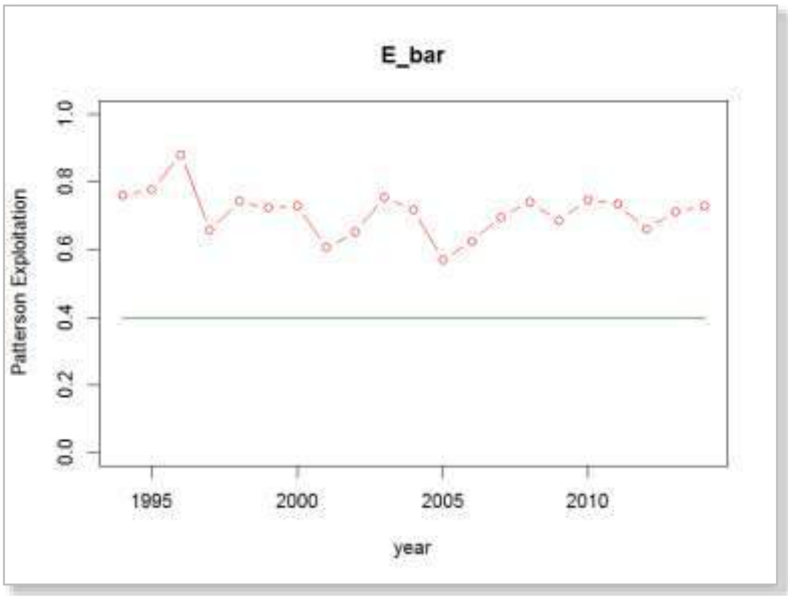


Figure 2.1.3.46. Whiting in GSA 29. Exploitation rate in relation to the reference point (E=0.4). STECF, 2015; GFCM, 2015)

Thornback ray – *Raja clavata*

Thornback ray, *Raja clavata*, is widely distributed in coastal waters of the eastern Atlantic, ranging from Norway and Iceland to Northwest Africa, including the Skagerrak, Kattegat and western Baltic Sea, Mediterranean and Black Seas (Stehmann and Bürkel, 1986; Stehmann, 1995). Thornback ray is a bottom-dwelling species on the shelf and upper slope from inshore to depths of 300 m (Stehmann and Bürkel, 1984), while mainly distributed from 10 to 70 m in the Black Sea (Aydin et al., 2009). The main factor affecting the distribution of this species is temperature (Jardas, 1973).

Length, width and weight ranges are given in Table 2.1.2.41. (Turkish data). Age is ranging between 1 and 12 years. The growth parameters were estimated from age reading using vertebrae. VBGF and L-W relationship parameters are shown in Table 2.1.2.41.

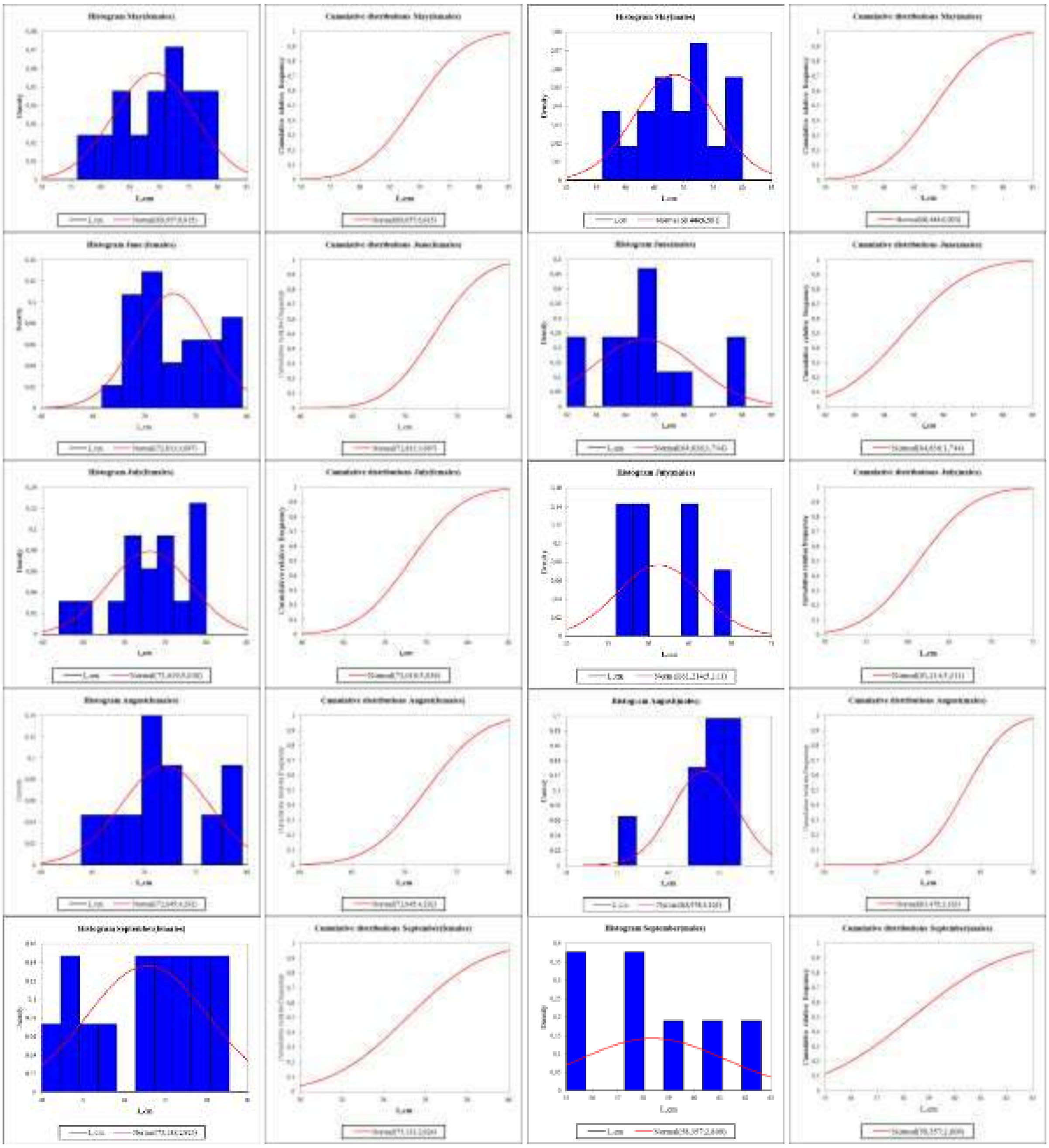
Table 2.1.3.41. Thornback ray in GSA 29. Mean, minimum, and maximum length, width, and weight.

Years	Length (cm)			Width (cm)			Weight (g)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2009	67.23±1.27	14.1	93	45.71±0.90	8.7	64.5	2500±89	14.8	5399
2010	58.84±1.75	14.3	88.4	40.21±1.24	9.4	64.5	1859±129	14.9	5004
2011	55.33±1.43	14.9	89	37.33±0.99	9.2	61	1487±94	14	4800
2013	51.94±1.35	16.5	92	35.54±0.96	10.2	62.5	1304±94	25	5150
2014	59.26±1.07	16.8	92	40.85±0.74	9.5	63.5	1865±87	25.5	5265

Table 2.1.3.42. Thornback ray in GSA 29. Parameters of VBGF and L-W relationship.

Parameters	Years				
	2009	2010	2011	2013	2014
a	0.0035	0.0025	0.0023	0.0029	0.0031
b	3.1421	3.2300	3.2356	3.1982	3.1864
L_∞ (cm)	119.12	119.31	128.93	124.26	121.39
W_∞ (g)	11669.77	12752.90	15487.78	13746.26	13565.5
k (cm/year)	0.119	0.113	0.100	0.107	0.112
t_0 (year)	-0.467	-0.436	-0.920	-0.511	-0.518
Φ	3.233	3.208	3.220	3.188	3.219

The monthly «n» parameter (fig. 2.1.3.42) of the length-weight relation varied from 1.7428 to 2.8299(males), from 1.1727 to 2.9278 (females), and from 2.1264 to 3.2613 (combined sexes). Meanwhile, exponent «n» was higher in females than males. General growth pattern was allometric in both sexes as shown by the monthly mean exponents (n = 2.98±0.51) for May, June (n = 3.11±0, 11), July (n = 2.13±0.66), August (n = 2.81±0.46), September (n = 3.51±0.38), October (3.08±0.16) and November (3.26±0.36). However, the low values of allometric coefficient in September-November 2008 were possibly due to the small sample size Monthly length distribution for females (fig. 2.1.2.43.) demonstrates the upper limit of 79 cm (total length) and lower limit of 62.3 cm of individuals. In contrast, males show lower values of the total body length as maximum as 77 cm and minimum as 56 cm. The maximum total length, known in the literature for the entire distribution area, is total length (TL) 95 cm for males and TL 88.2 cm for females Mean lengths, stated in our study (74.1 cm for females and 62.9 cm for males)(Raykov and Yankova, 2008).



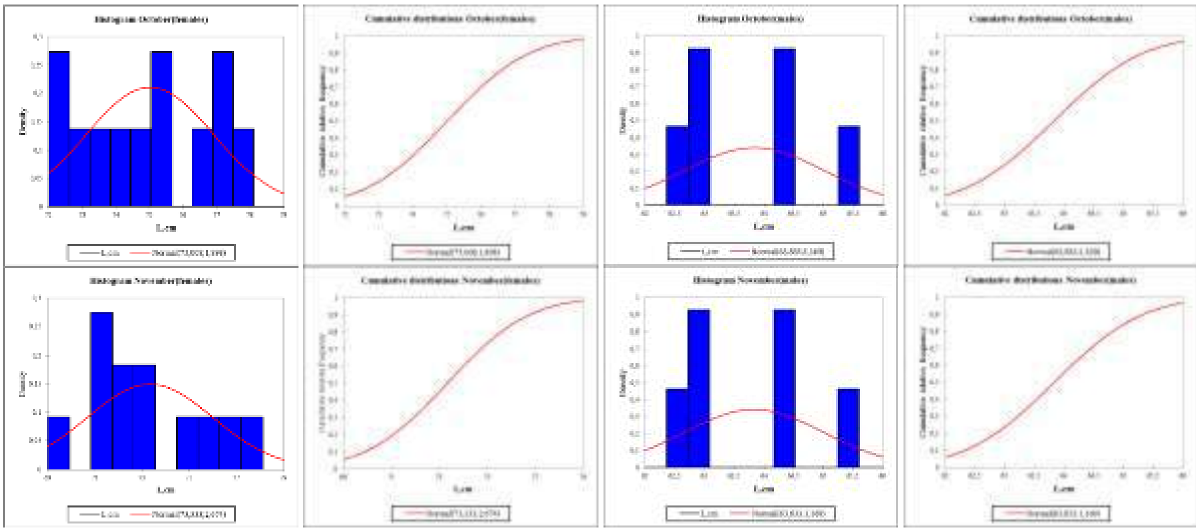


Figure 2.1.3.46. Histogram and % cumulative frequency of thornback ray (*Raja clavata* L.) by months and sex

Respectively, the mean weight of females (fig. 2.1.3.47) increased from May to November as the maximum was at 5.23 kg and minimum – at 1.85 kg.

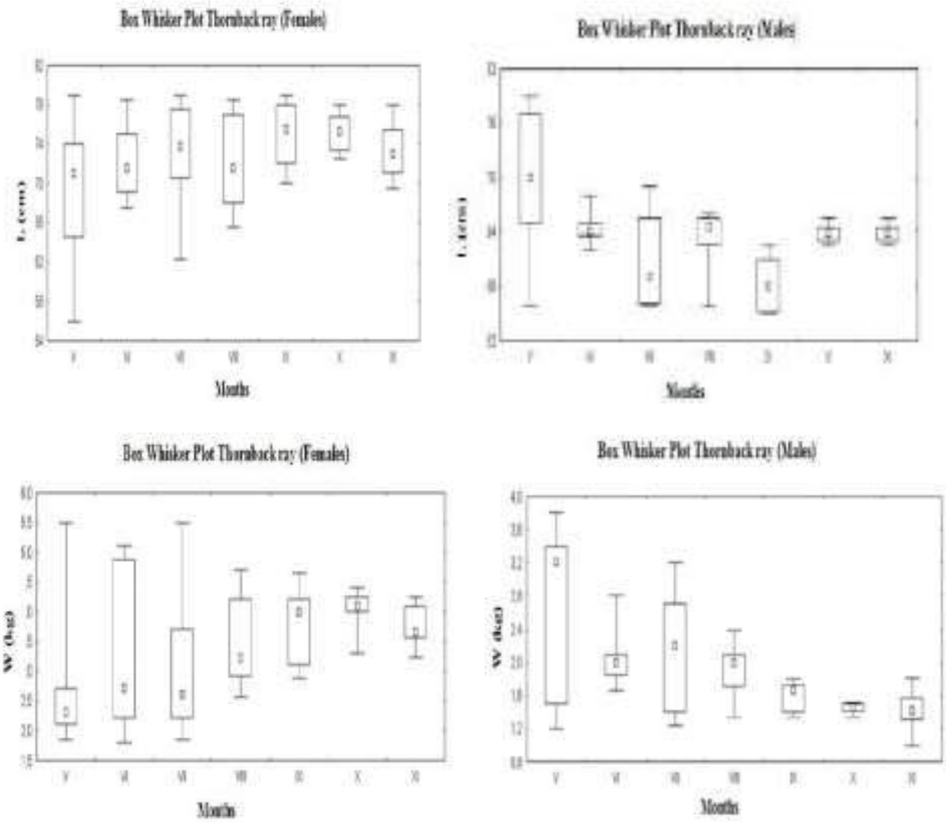


Figure 2.1.3.47. Box Plot Mean length and weight (kg) distribution by months (median, values hinge: 25-75 %, minimum and maximum value of percent participation)

(A) mean length of females by months; (B) mean length of males by months; (C) mean weight of females by months; (D) mean weight of males by months decreased toward September, slightly increased in October-November.

The minimum registered weight for males was 1.23 kg and the maximum weight was 3.82 kg. In the samples, the males with disk width ranging from 35 to 45 cm were predominant. Female individuals with disk width of 56-60 cm were predominant. The rest of the presented size groups consist of fewer male individuals and larger number of females (Raykov and Yankova, 2013).

Table 2.1.3.43. Thornback ray in GSA 29. Natural mortality.

Parameter	Years				
	2009	2010	2011	2013	2014
M	0.150	0.145	0.131	0.138	0.144

Table 2.1.3.44. Thornback ray in GSA 29. Landings by country.

Year	Bulgaria	Georgia	Romania	Russian Federation	Turkey	Ukraine	Total
2009	49	-	-	-	264	-	313
2010	72	-	-	-	102	-	174
2011	7	-	-	-	81	-	88
2012	48	-	-	-	94	-	142

R. clavata speciemens were collected under the project of "Investigation of Opportunities on Cultivation of Gurnard (*Chelidonichthys lucerna* L., 1758)" from Samsun to neighbor of Georgia border in August 2014. In previous years, some data were collected under the "Research on Bio-Ecological Properties and Aquaculture Possibilities of Flounder (*Platichthys flesus luscus* Pallas, 1811)" in the Trabzon area.

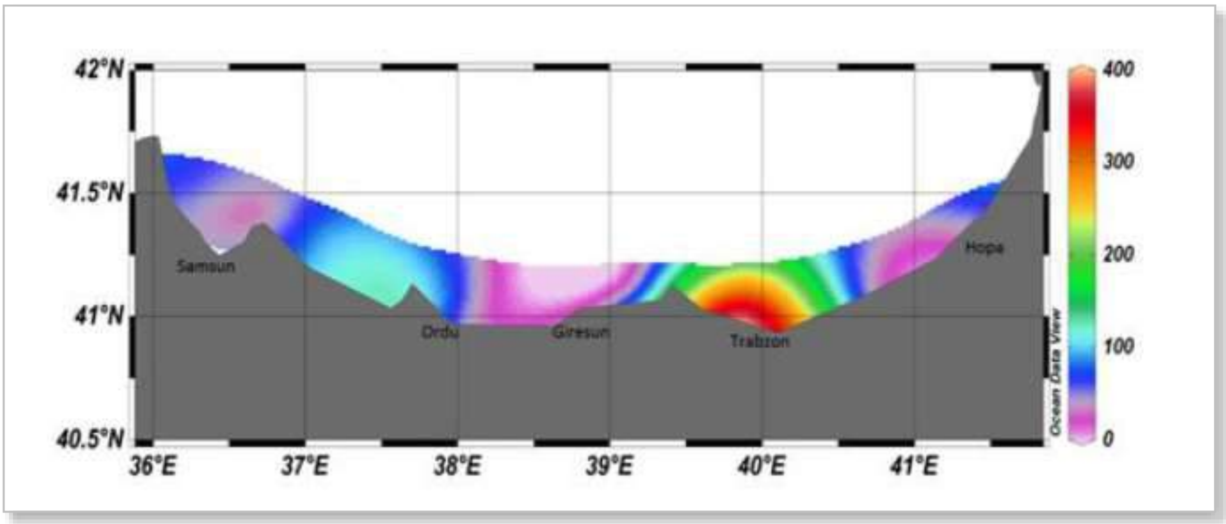


Figure 2.1.3.47. Thornback ray in GSA 29. The abundance of Thornback ray in the Turkish coasts in August 2014 (n. individuals/km2).

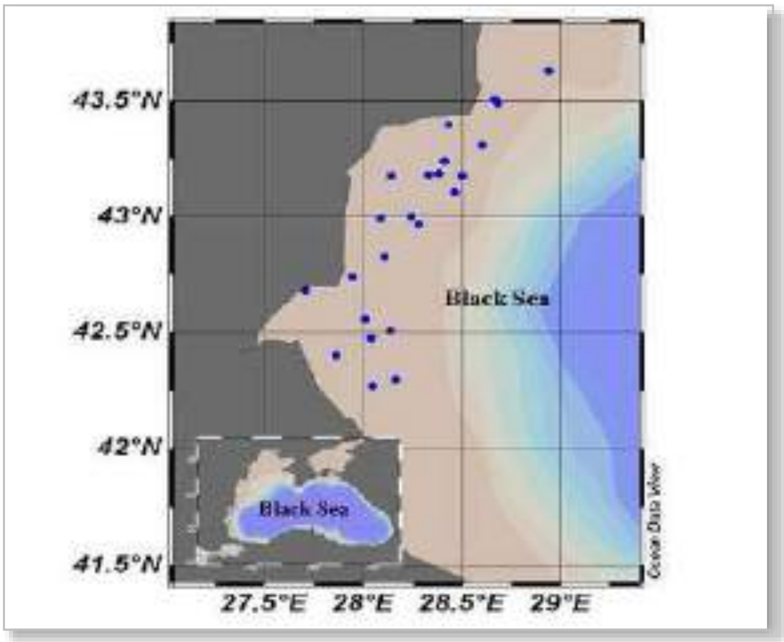


Figure 2.1.3.48. Thornback ray in GSA 29. Map showing area and localities of catches off the Bulgarian coasts.

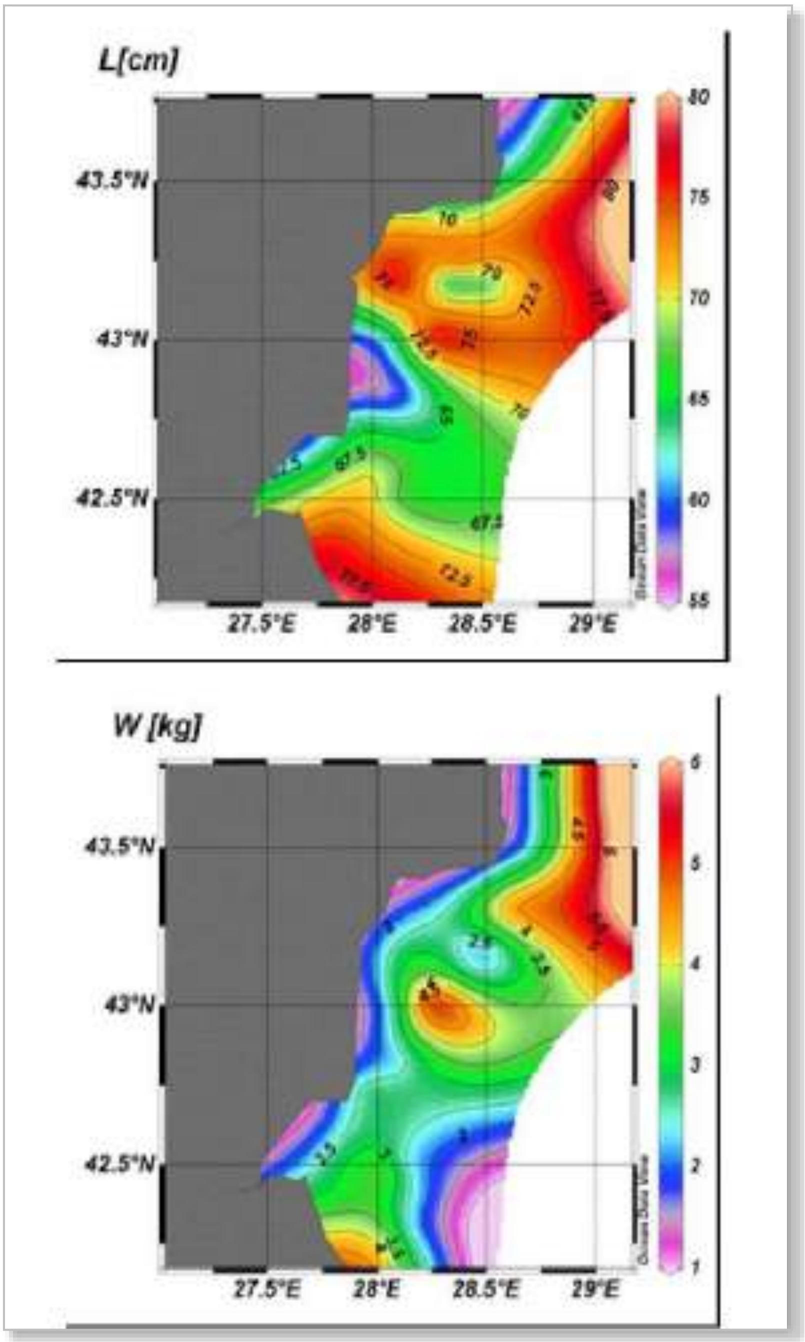


Figure 2.1.3.49. Thornback ray in GSA 29. Distribution by length, cm (A), and weight, kg (B).

Table 2.1.3.45. Thornback ray in GSA 29. Landings (t) by country.

Year	Bulgaria	Romania	Georgia, Russia, Ukraine	Turkey
2008	50.0	NA	NA	117.0
2009	49.0	NA	NA	264.0

2010	72.2	NA	NA	102.0
2011	6.7	NA	NA	80.8
2012	48.3	NA	NA	93.8
2013	56.1	NA	NA	77.1
2014	70.3	0.2	NA	26

Table 2.1.3.46. Thornback ray in GSA 29. Catch at age (thousands).

Age	2008	2009	2010	2011*	2012*	2013	2014
1	26.0	24.5	27.9	44.3	30.5	24.4	1.4
2	43.8	49.0	53.7	91.7	63.1	50.4	10.1
3	14.6	8.2	25.9	56.9	39.2	31.3	11.1
4	11.4	57.1	65.7	135.9	93.6	74.8	21.6
5	9.7	70.7	33.8	47.4	32.6	26.1	7.6
6	40.6	29.9	55.7	101.2	69.7	55.7	12.2
7	63.3	19.0	29.9	37.9	26.1	20.9	14.7
8	66.6	35.4	59.7	34.8	23.9	19.1	7.6
9	105.5	70.7	23.9	34.8	23.9	19.1	14.7
10	26.0	16.3	6.0	9.5	6.5	5.2	2.2
11	14.6	2.7	4.0	6.3	4.4	3.5	0.7
12	4.9	0.0	0.0	3.2	2.2	1.7	1.4
*Age structure for 2011 and 2013 was borrowed from 2013 data							

Yield-per-Recruit (Y/R) and Spawning Stock Biomass per recruit (SSB/R) output curves are illustrated in the figure below.

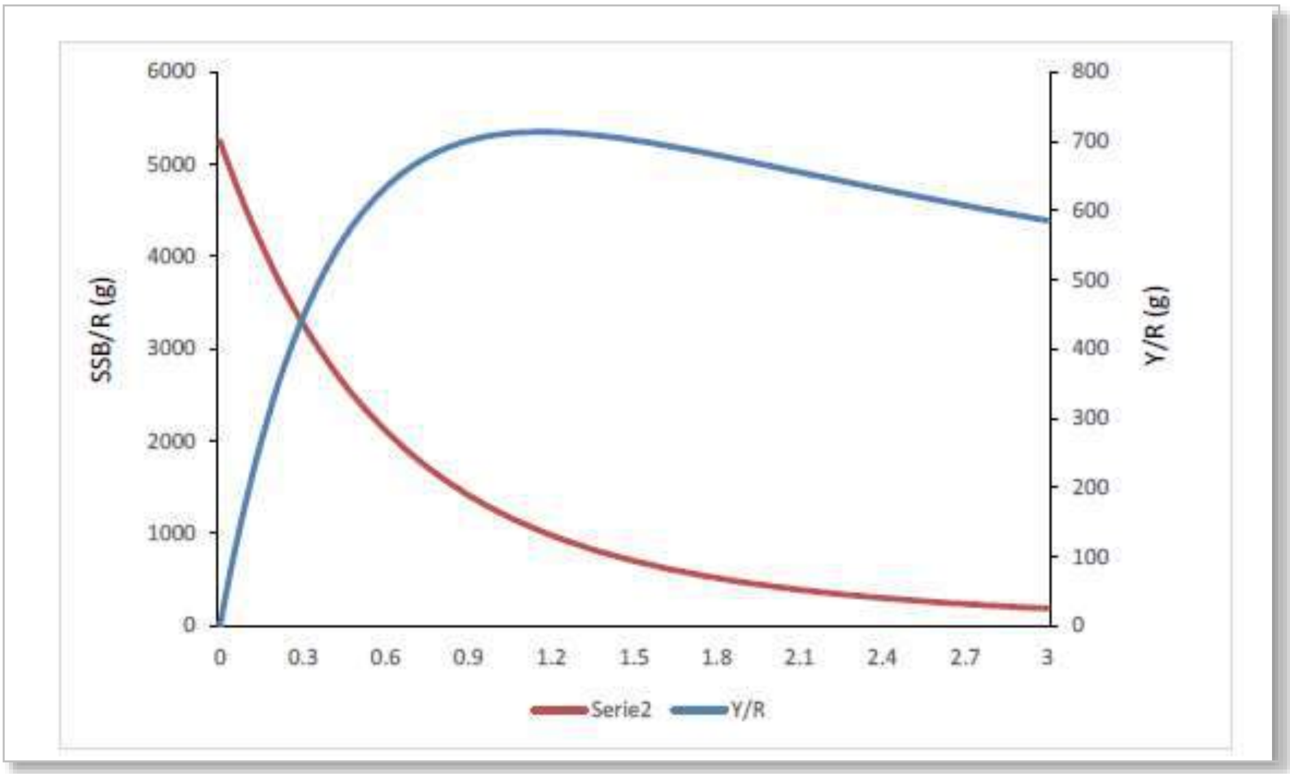


Figure 2.1.3.50. Thornback ray in GSA 29. Yield-per-Recruit (Y/R) and SSB-per-Recruit (SSB/R) curves (year 2014).

Table 2.1.3.47. Thornback ray in GSA 29. Main outputs of the pseudo-cohort analysis carried out by means of VIT program.

		F	Y/R
2008	F_0	0.00	0.0
	$F_{0.1}$	0.17	782.8
	F_{curr}	0.23	820.7
	F_{max}	0.29	828.9
2009	F_0	0.00	0.0
	$F_{0.1}$	0.17	715.4
	F_{curr}	0.29	750.1
	F_{max}	0.27	751.4
2010	F_0	0.00	0.0
	$F_{0.1}$	0.16	660.6
	F_{curr}	0.25	691.0
	F_{max}	0.25	691.1
2013	F_0	0.00	0.0
	$F_{0.1}$	0.15	633.5
	F_{curr}	0.27	655.6
	F_{max}	0.22	662.9
2014	F_0	0.00	0.0
	$F_{0.1}$	0.15	680.2
	F_{curr}	0.21	709.3
	F_{max}	0.24	713.7
Mean values	$F_{0.1}$	0.16	
	F_{curr}	0.25	
	F_{max}	0.25	

Picked dogfish – Squalus acanthias

Piked dogfish inhabits the whole Black Sea shelf at the water temperatures 6 – 15º C. It undertakes extensive migrations. In autumn feeding migrations are aimed at the grounds of the formation of the wintering concentrations of anchovy and horse mackerel in the vicinity of the Crimean Caucasus and Anatolian coasts. With their disintegration picked dogfish disperses all over the shelf. Reproductive migrations of viviparous picked dogfish take place towards the coastal shallows with two peaks of intensity – in spring and autumn. The autumn migration for reproduction covers more individuals usually. The major grounds for reproduction of picked dogfish in the Ukrainian waters are located in Karkinitsky Bay, in front of Kerch Strait and in Feodosia Bay. Piked dogfish belongs to long-living and viviparous fish; therefore reproduction process includes copulation and birth of fries. Near the coasts of Bulgaria, Georgia, Romania, Russian Federation and Ukraine the intense spawning season is in March-May. Two peaks of birth of juveniles can be distinguished – spring period (April-May) and summer-autumn (August-September, Serobaba et al., 1988). To give birth of juveniles the females approach the coastal zone in depth 10 – 30 m. (GFCM, 2015).

Growth

Romanian data for the last four years are presented in the table 2.1.3.48.

Table 2.1.3.48. Piked dogfish growth parameters in the Romanian marine area (STECF, 2015; GFCM, 2015)

Parameters	2011	2012	2013	2014
Linf	136	157	156	152.63
a	0.0117	0.016977	0.061086	0.0185
b	2.7694	2.696436	2.41368	2.672849
k	0.191	0.153	0.134	0.1343
to	-1.31	-1.13684	-0.9304	-0.975

Maturity

Life-history parameters and food diet of picked dogfish (*Squalus acanthias*) from the SE Black Sea were studied (Demirhan and Seyhan, 2007). Picked dogfish at age 1 to 14 years old were observed, with dominance of 8 years old individuals for both sexes. The length–weight relationship was $W=0.0040*L^{2·95}$and the mean annual linear and somatic growth rates were 7.2 cm and 540.1 g, respectively. The estimated parameters in VBGF were: $W\infty=12021$ (g), $L\infty=157$ (cm), K=0.12 (year−1) and t0=−1.30 (year). The size at first maturity was 82 cm for males and 88 cm for females. Mean biennial fecundity was also found to be 8 pups per female. The relationships fecundity–length, fecundity–weight and fecundity–age were found to be:

F=−17.0842+0.2369*L (r=0.93)

F=0.3780+0.0018*W (r=0.89)

F =−0.7859+1.1609*A (r=0.94), respectively.

In conformity with Ukrainian data, the maturity ogive for last years is the following:

Table 2.1.3.49.Maturity ogive after Ukrainian scientists (STECF, 2015; GFCM, 2015)

Year/ Age	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.25	0.45	0.55	0.75	0.95	1.0	1.0	1.0	1.0	1.0

Table 2.1.3.50.Maturity ogive from Romanian data (STECF, 2015; GFCM, 2015)

Year/ Age	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
2011	0.0	0.0	0.45	0.7	0.95	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Natural mortality

For calculation of natural mortality (M) has been utilized Poly's M empirical equation:
$\log(M) = -0.0066-0.279\log(L_\infty) + 0.6543\log(k) =+ 0.4634\log(T)$

where:

L_∞) is the asymptotic length measured in total length;

K is the VBGF growth constant;

T is the mean annual habitat.

The Romanian values used in the last years are presented in the table 2.1.3.51.

Table 2.1.3.51. Natural mortality for piked dogfish in the Romanian Black Sea area (STECF, 2015; GFCM, 2015)

Parameters	2011	2012	2013	2014
M	0.258	0.15	0.22	0.228

Fisheries

General description of the fisheries

In the Black Sea the largest catches of picked dogfish are along the coasts of Turkey, although this fish is not a target species of fisheries, being yielded as by-catch in trawl and purse seine operations mainly in the wintering period. In the 1989-1995 annual catches of Turkey are 1055-4558 t (Shlyakhov, Daskalov, 2008). In subsequent years, they have decreased about 2 times and did not exceed 2400 t. In the waters of Ukraine most of piked dogfish is harvested in spring and autumn months by target fishing with gill-nets of 100 mm mesh-size, long-lines, and as by-catch of sprat trawl fisheries. As in Turkish waters, in the last 20 years the maximum annual catches of picked dogfish are observed in 1989-1995, reaching 1200-1300 t. After 1994 the catches went down being between 20 and 200 t. In the rest of countries piked dogfish is harvested mainly as by-catch, annual catches are usually lower than the Ukraine.In Turkey piked dogfish lost its commercial importance in recent years. In the last 20 years, the decrease of dogfish landing may be may be due to over-fishing (Demirhan , Phd thesis,)

In the last years increased the importance of the catches in Bulgaria, these being around 40% from total Black sea catches.

Catches

For 2014 all Black Sea riparian countries reported the piked dogfish catches as landings.

Landings

The landings of Piked dogfish by countries are given in Table 2.1.3.52.

Piked dogfish landings by countries (FAO Fisheries Statistics, GFCM Capture Production, BSC data, input from experts).

Table 2.1.3.52. Picked dogfish landings 2009-2014 in Black Sea

Year	**Bulgaria**	**Georgia**	**Romania**	**Russian Federation**	**Turkey**	**Ukraine**	**Total**
2009	9.46	1.5	4	14	159	47	**234.960**
2010	42	1.5	3	8.54	16	27	**98.040**
2011	38.06	1.5	4	3.61	26.5	30.537	**104.207**
2012	28.67	1.5	2.14	4.000	25	9	**70.310**
2013	30.95	1.5	8.681	4	25	13.241	**83.372**
2014	34	1.5	2.06	4.523	3	30.095	**75.178**

After 2000 the catches of picked dogfish significantly dropped (fig.2.1.3.51.).

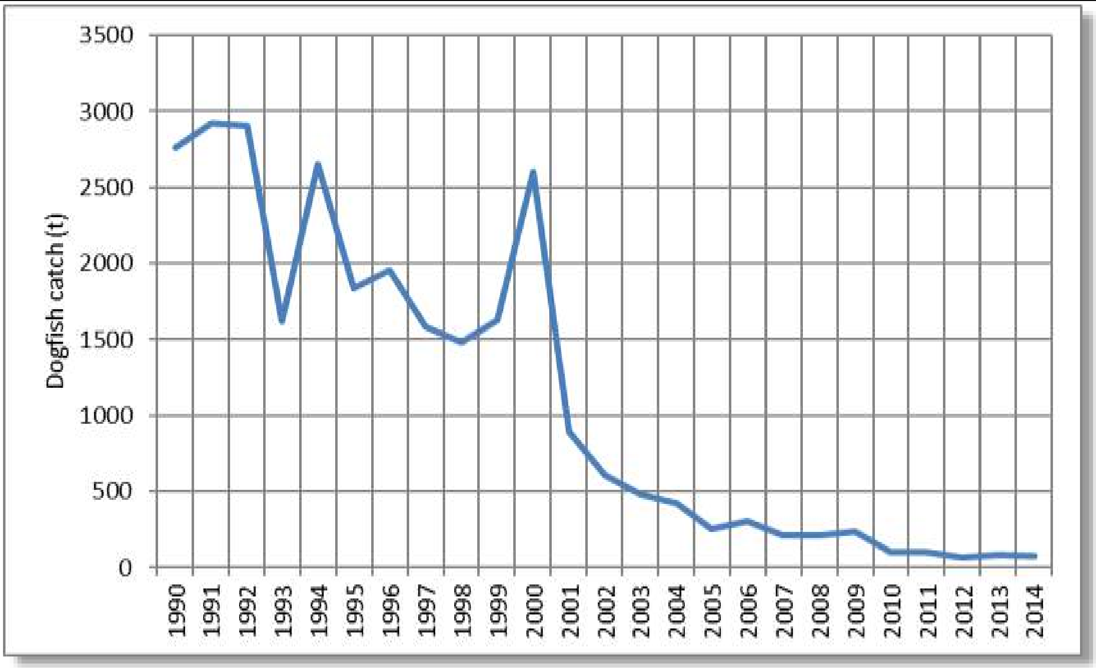


Figure. 2.1.3.51. Total landings of Picked dogfish in Black Sea for 1990 - 2014

Dynamics of dogfish catches in the Black Sea

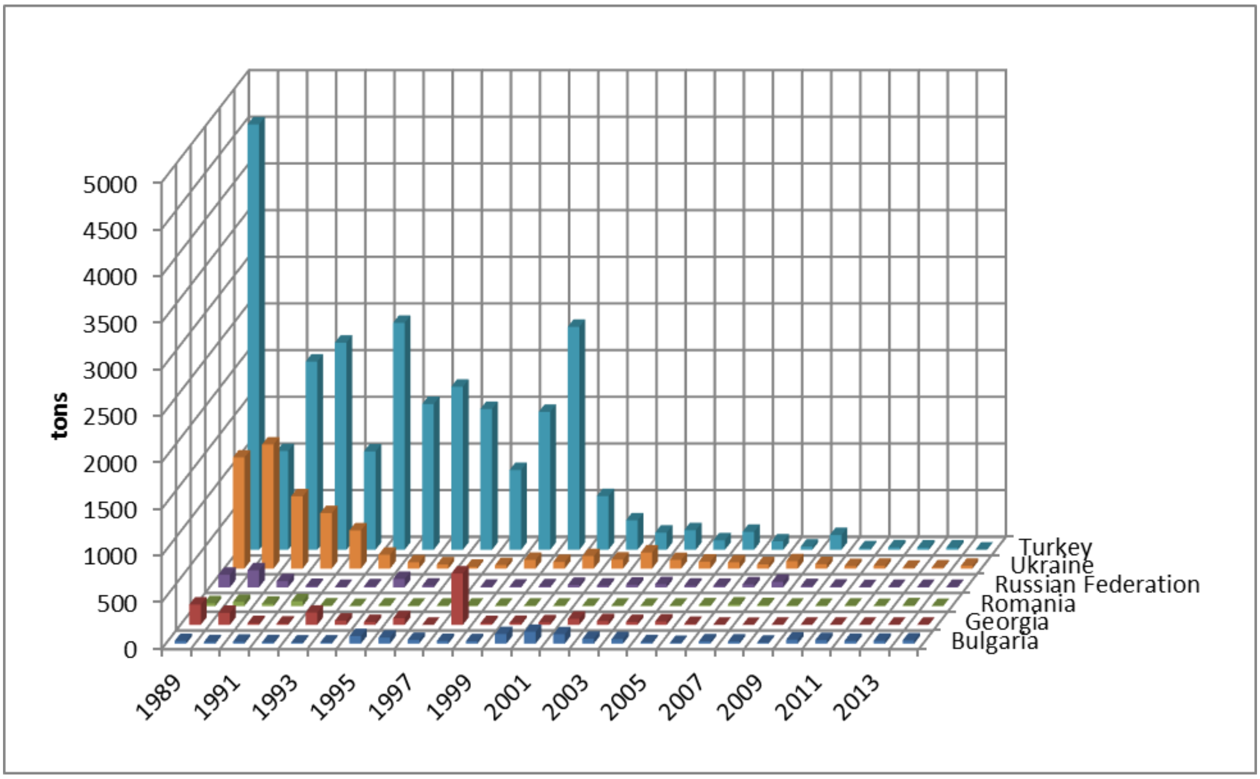


Figure. 2.1.3.52. Piked dogfish catches in the Black Sea area by countries (t) STECF, 2014;

Discards

Have not been reported discards for piked dogfish.

Fishing effort (by fleet if possible)

The EWG 15-12 was not provided with quantitative information on fishing effort by all riparian countries. In the last four years only Romania provided data regarding the number of gillnets by vessel length class. The number of vessels fishing gillnets for dogfish dropped from 265 in 2011 to 160 in 2012 and 25 in 2013.

Table 2.1.3.53. Number of fishing gillnets for dogfish in the Romanian area (STECF, 2015; GFCM, 2015)

Vessel length (m)	Number of gillnets for dogfish in 2011	Number of gillnets for dogfish in 2012	Number of gillnets for dogfish in 2013	Number of gillnets for dogfish in 2014
< 6m	10	-	-	2
6-12 m	205	110	-	10
18-24 m	50	50	-	20
24-40 m	-	-	25	-
Total	265	160	25	32

Table 2.1.3.54. Romanian CPUE in commercial fishing, 2009-2014 periods (STECF, 2015; GFCM, 2015)

YEAR	**Fishing gear**	**CPUE**
2009		
LOA 6-12 m	gillnets	0.24 kg/gear/day
LOA 18-24 m	gillnets	0.40 kg/gear/day
LOA 24-40 m	gillnets	0.89 kg/gear/day
2010		
LOA 6-12 m	gillnets	0.18 kg/gear/day
2011		
LOA 6-12 m	gillnets	0.248kg/gear/day
LOA 18-24 m	gillnets	0.91 kg/gear/day
2012		
LOA 6-12 m	gillnets	8.8 kg/gear/day
LOA 12-18 m	gillnets	8.5 kg/gear/day
18-24	gillnets	6.0 kg/gear/day
2013		
LOA 6-12 m	long lines	20.65 kg/gear/day /
LOA 24-40 m	pelagic trawl	123.45 kg/gear/day
LOA 24-40 m	gillnets	8.91 kg/gear/day
2014		
LOA <6m	gillnets	7 kg/gear/day
LOA 6m-12m	gillnets	1.066 kg/gear/day
LOA 6m-12m	long lines	1.125 kg/gear/day
LOA 12-18m	gillnets	1.443 kg/gear/day
LOA 12-18m	trawl	5.608 kg/gear/day
LOA 24-40m	trawl	3.867 kg/gear/day

Spatial distribution

In Romanian waters the agglomerations are distributed on the entire shelf, but especially at depth deeper than 20m. Two peaks of intense spawning and of birth of juveniles are in spring and autumn period at Romanian littoral. Figure. 2.1.2.53.

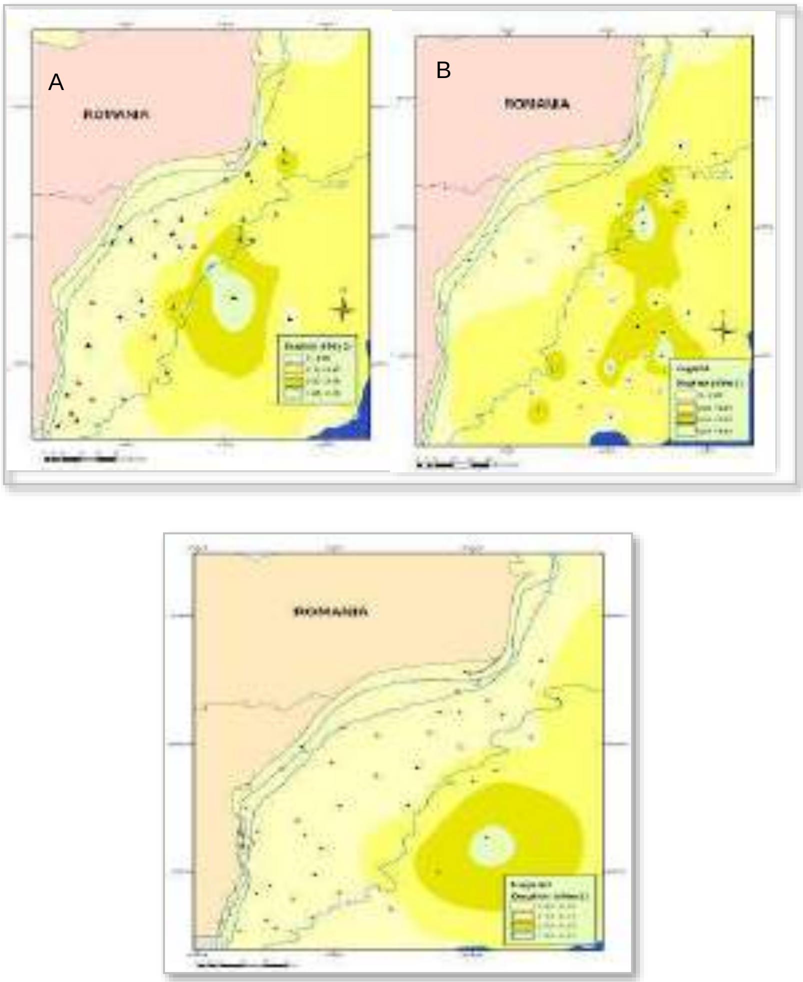


Figure. 2.1.3.53. Distribution of piked dogfish catches during demersal trawl survey in 2011 (A - spring season. B - autumn season), Romanian Black Sea area.

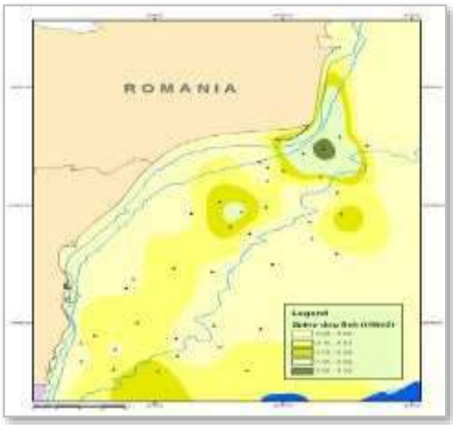


Figure. 2.1.3.54. Distribution of the dogfish agglomerations in demersal trawl survey, in May and October 2012, Romanian area

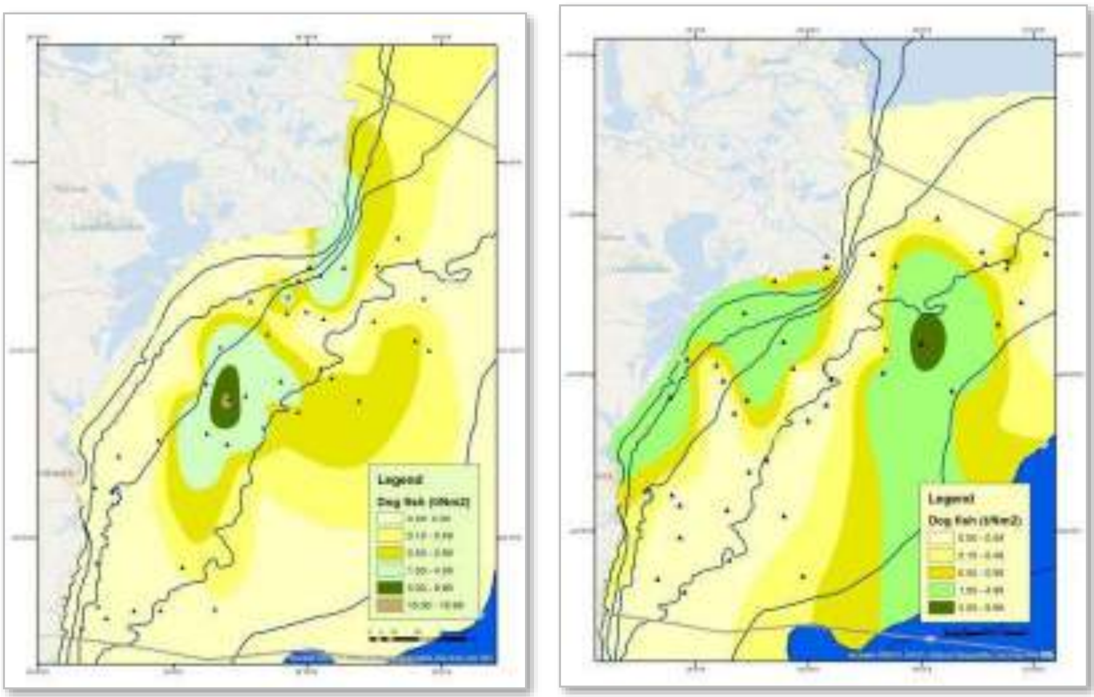


Figure 2.1.3.54. Distribution of the dogfish agglomerations in demersal trawl survey, in May and October 2013, Romanian area (STECF, 2014, GFCM, 2014)

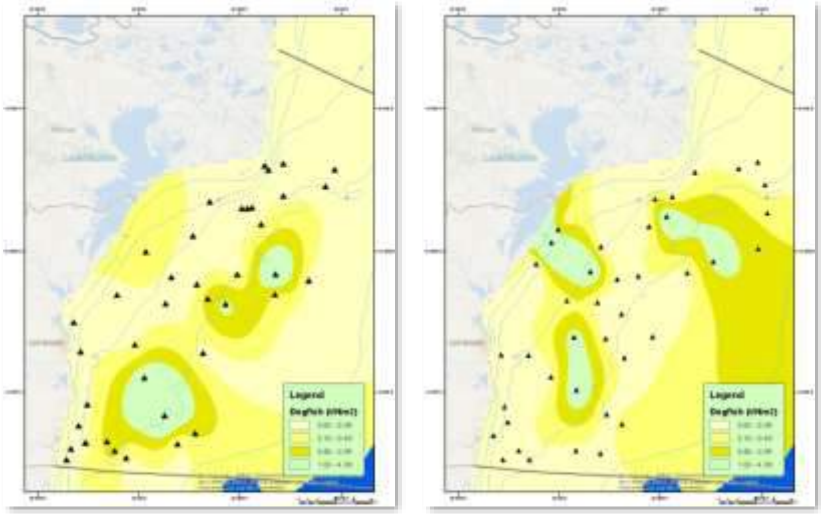


Figure 2.1.3.55. The distribution of the dogfish agglomerations in demersal trawl survey, in May and October 2014, Romanian area (STECF, 2014, GFCM, 2014)

Biomass

Results for estimated piked dogfish biomasses in May and November of 2009- 2013 in Romanian waters are given in the following tables.

Table 2.1.3.55. Estimated piked dogfish biomasses (t) in May and November of 2009- 2014 in Romanian waters (GFCM, 2015)

Species	2009	2010	2011	2012	2013	2014
Piked dogfish	967-2,509	5,635-13,051	1,173-1,690	1,436-1,159	3,181-4,483	1520-1267

Table 2.1.3.56. CPUE for the at sea surveys for Romanian Black Sea areas (GFCM, 2015)

YEAR	**2010**		**2011**		**2012**		**2013**		**2014**	
Period	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
Range (kg/hour)	3.6 – 98.63	4.5 – 106.22	5.8 – 24.9	5.0 - 24.83	1.1-19.2	1.5-134	5.5-115.8	0.95-200	4.25-50.3	5.45-39.21

Table 2.1.3.57. Assessment of dogfish agglomerations in the period May 2012, demersal trawl survey , Romanian area (GFCM, 2015)

Depth range (m)	0 - 30m	30 – 50m	50-70 m	Total
Investigated area (Nm^2)	663.62	1065	517.37	2245.99
Variation of the catches (t/ Nm^2)	0.00-0.062	0.00-0.365	0.00-0.75	0.00-0.75
Average catch (t/ Nm^2)	0.005	0.016	0.432	
Biomass of the fishing agglomerations (t)	3.468	17.69	223.81	244.97
Biomass extrapolated the Romanian shelf (t)				1436.34

Table 2.1.3.58. Assessment of dog fish agglomerations in the period October - November 2012, pelagic trawl survey , Romanian area (GFCM, 2015)

Depth range (m)	0 - 30m	30 – 50m	50-70 m	Total
Investigated area (Nm^2)	754.58	1294.12	807	2855.7
Variation of the catches (t/ Nm^2)	0.30-1.35	0.00-1.60	0.00-0.86	0.00-1.60
Average catch (t/ Nm^2)	0.736	0.372	0.161	
Biomass of the fishing agglomerations (t)	754.85	482.324	130.53.4	1169.086
Biomass extrapolated the Romanian shelf (t)				1515.883

Table 2.1.3.59. Assessment of dogfish agglomerations in the period May –June 2013, demersal trawl survey, Romanian area (GFCM, 2015)

Depth range (m)	0 - 30m	30 – 50m	50-70 m	70-100m	Total
Investigated area (Nm^2)	650	1225	1350	50	3300
Variation of the catches (t/ Nm^2)	0.325-2.264	0.00-4.272	0.00-6.878	0.013-0.019	0.00-6.878
Average catch (t/ Nm^2)	1.19033	0.530778	0.607833	0.015583	0.63622
Biomass of the fishing agglomerations (t)	773.7167	650.2028	820.575	1.16875	2099.53
Biomass extrapolated the Romanian shelf (t)					3181.119

Table 2.1.3.60. Assessment of dogfish agglomerations in October 2013, demersal trawl survey, Romanian area (GFCM, 2015)

Depth range (m)	0 - 30m	30 – 50m	50-70 m	Total
Investigated area (Nm^2)	625	1075	450	2150
Variation of the catches (t/ Nm^2)	0.00-0.308	0.00-11.404	0.00-1.32	0.00-11.40
Average catch (t/ Nm^2)	0.060333	1.5042	0.386714	0.896522
Biomass of the fishing agglomerations (t)	37.70833	1617.015	174.0214	1927.522
Biomass extrapolated the Romanian shelf (t)				4482.609

Table 2.1.3.61. Assessment of dogfish agglomerations in the period May –June 2014, demersal trawl survey, Romanian area (GFCM, 2015)

Depth range (m)	0 - 30m	30 – 50m	50-70 m	70-100m	Total
Investigated area (Nm2)	625	1150	825		2600
Variation of the catches (t/ Nm2)	0-2.86	0-1.64	0-1.1		0-2.86
Average catch (t/ Nm2)	0.65	0.343	0.149		0.304
Biomass of the fishing agglomerations (t)	406.62	394.23	123.27		790.22
Biomass extrapolated the Romanian shelf (t)					1519.67

Table 2.1.3.62. Assessment of dogfish agglomerations in October 2014, demersal trawl survey, Romanian area (GFCM, 2015)

Depth range (m)	0 - 30m	30 – 50m	50-70 m	Total
Investigated area (Nm2)	625	1150	875	2650
Variation of the catches (t/ Nm2)	0-0.33	0-1.56	0-2.23	0-2.23
Average catch (t/ Nm2)	0.048	0.143	0.532	0.2533
Biomass of the fishing agglomerations (t)	30.29	164.75	466.34	671.32
Biomass extrapolated the Romanian shelf (t)				1266.643

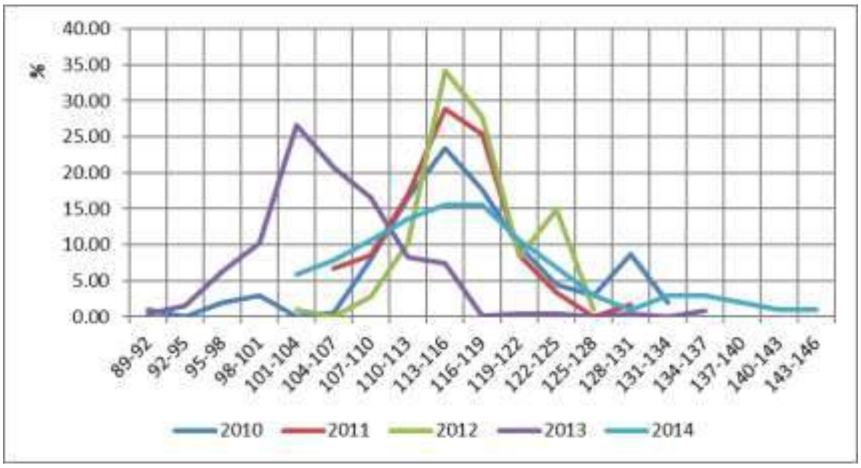


Figure 2.1.3.56. Percentage of total number of specimens on length classes for dogfish, Romanian area

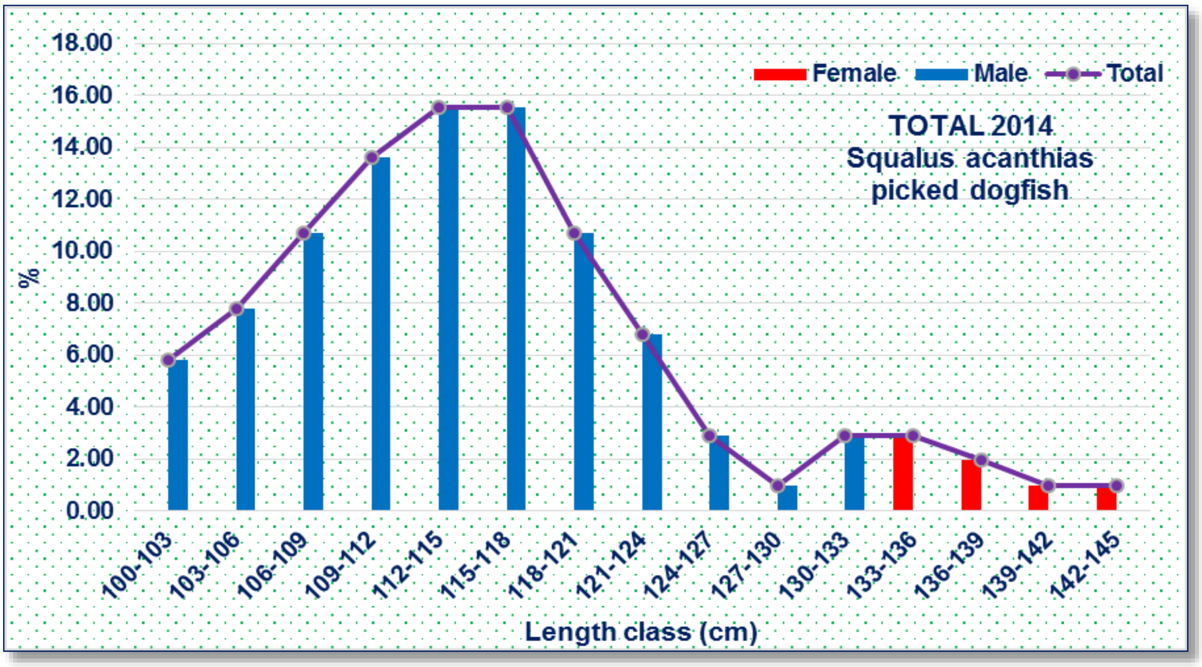


Figure 2.1.3.57. Structure on length classes for dogfish in 2014,Romanian area (STECF, 2015)

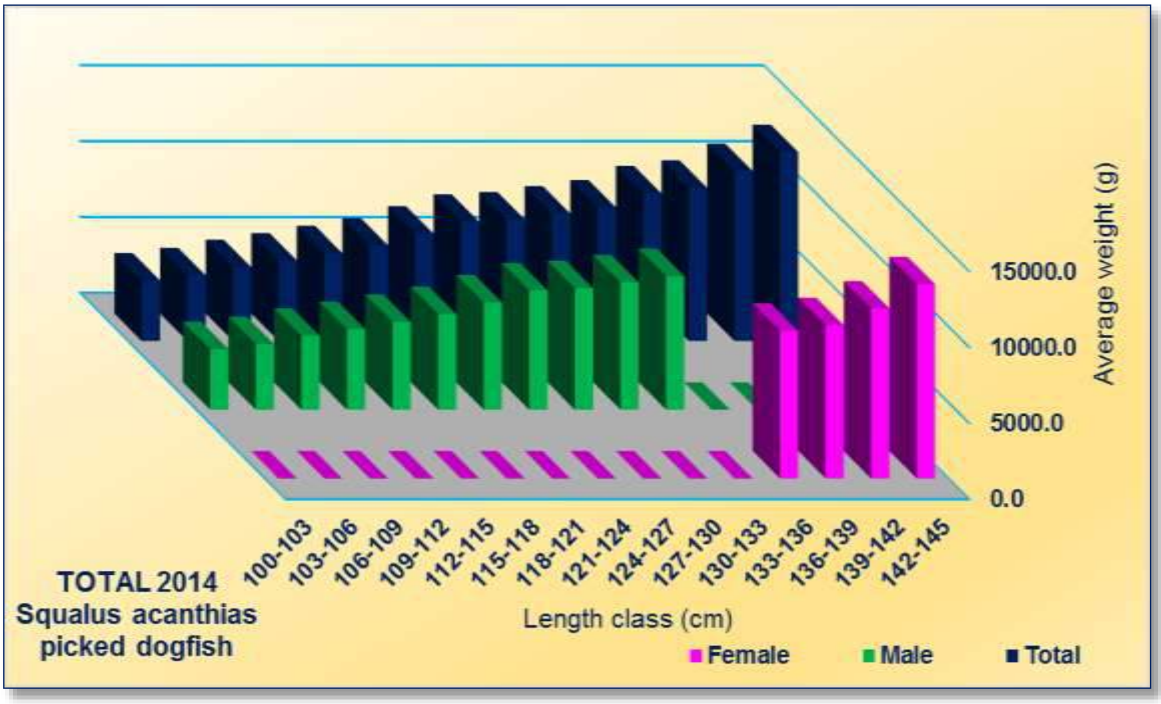


Figure 2.1.3.58. Mean weight on length classes for dogfish in 2014, Romanian area (STECF, 2015)

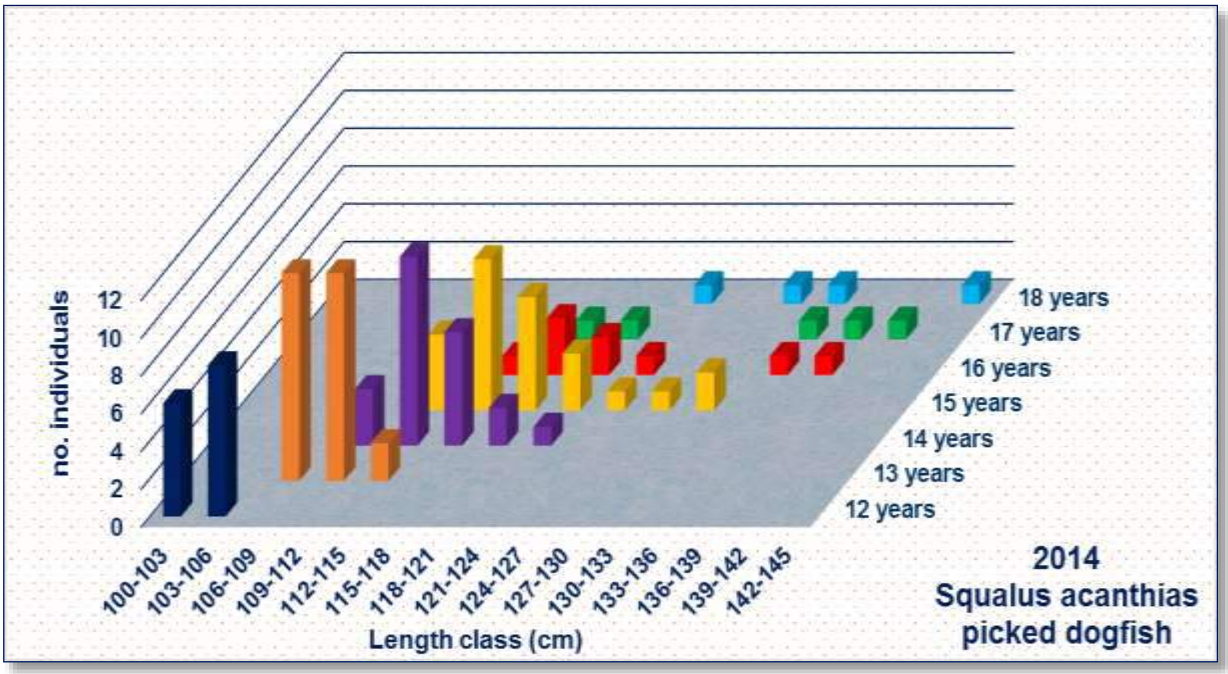


Figure 2.1.3.59. Age on length classes for picked dogfish 2014, Romanian area (STECF, 2015)

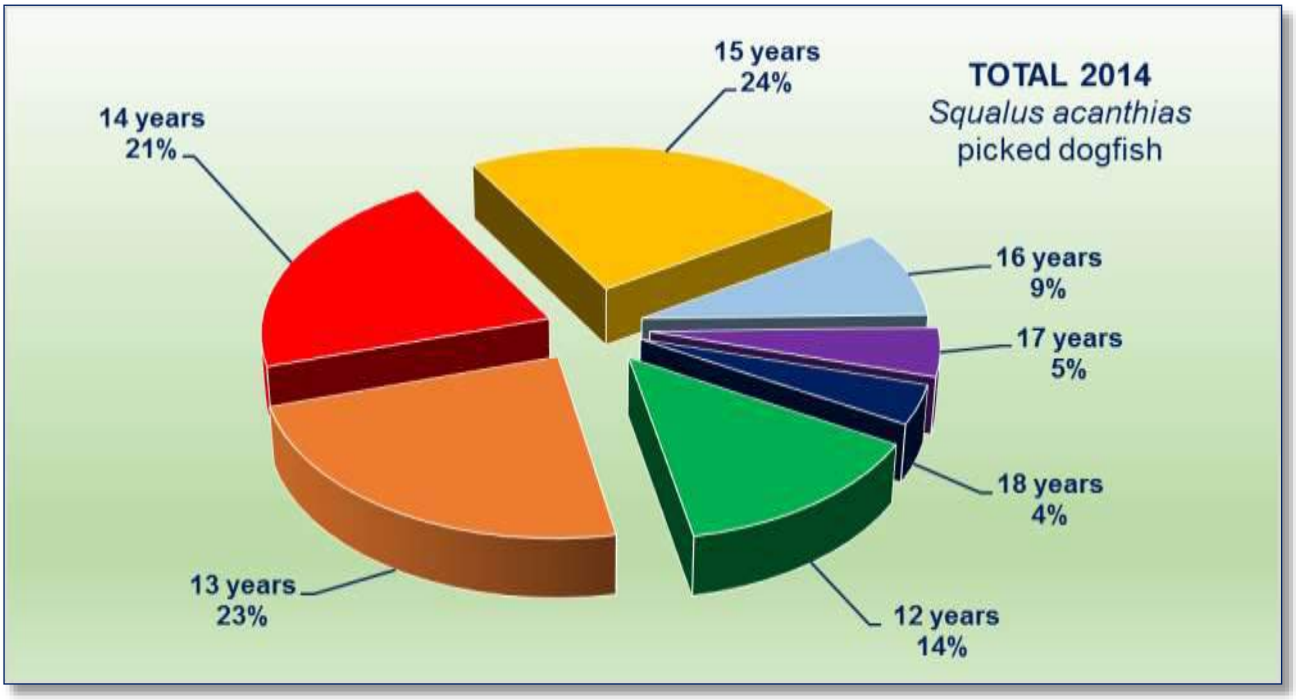


Figure 2.1.3.60. Percentage on age classes for picked dogfish 2014, total catches (STECF, 2015)

A fixed natural mortality (M) of 0.15 was used for each age class in the period 1989-2014. The following maturity vector was used in the whole investigated period.

Table 2.1.3.62.Proportion of maturity by age

Age	7	8	9	10	11	12	13	14	15	16	17	18	19+
Prop. Mat.	0.5	0.5	0.625	0.625	0.725	0.775	0.875	0.975	1.0	1.0	1.0	1.0	1.0

Results

The results indicated a steady and major reduction in the spawning stock biomass since 1989. The estimates of current rates of fishing mortality are high (~0.25) and estimates of F for past years were erratic, exceeding 0.7 four times between 1999 and 2009. Detailed outputs can be traced in the following figures and tables (STECF, 2015; GFCM,2015).

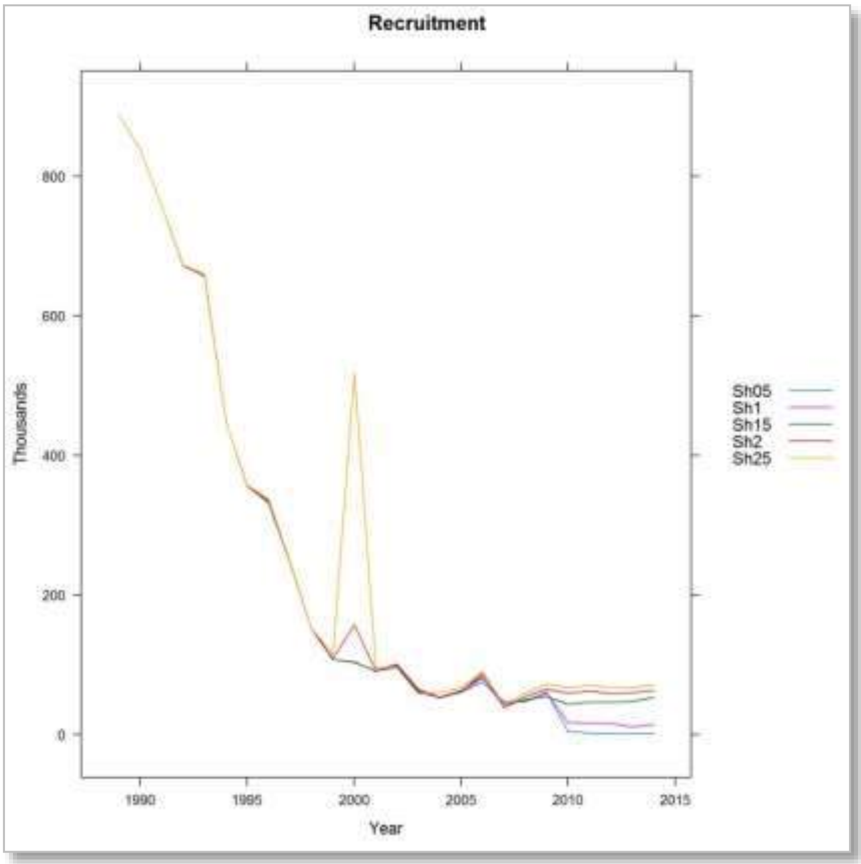


Figure 2.1.3.61. Piked dogfish in Black Sea. Recruitment trends obtained by means of XSA fitting with five shrinkage settings (STECF, 2015; GFCM,2015)

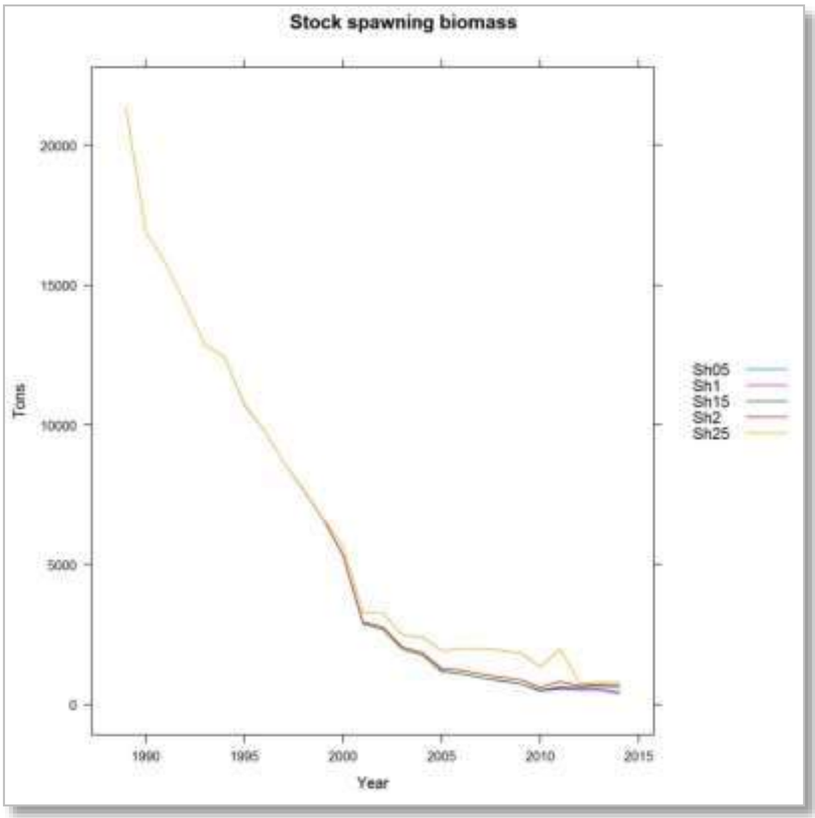


Figure 2.1.3.62. Piked dogfish in Black Sea. Spawning stock biomass (SSB) trends obtained by means of XSA fitting with five shrinkage settings (STECF, 2015;GFCM,2015)

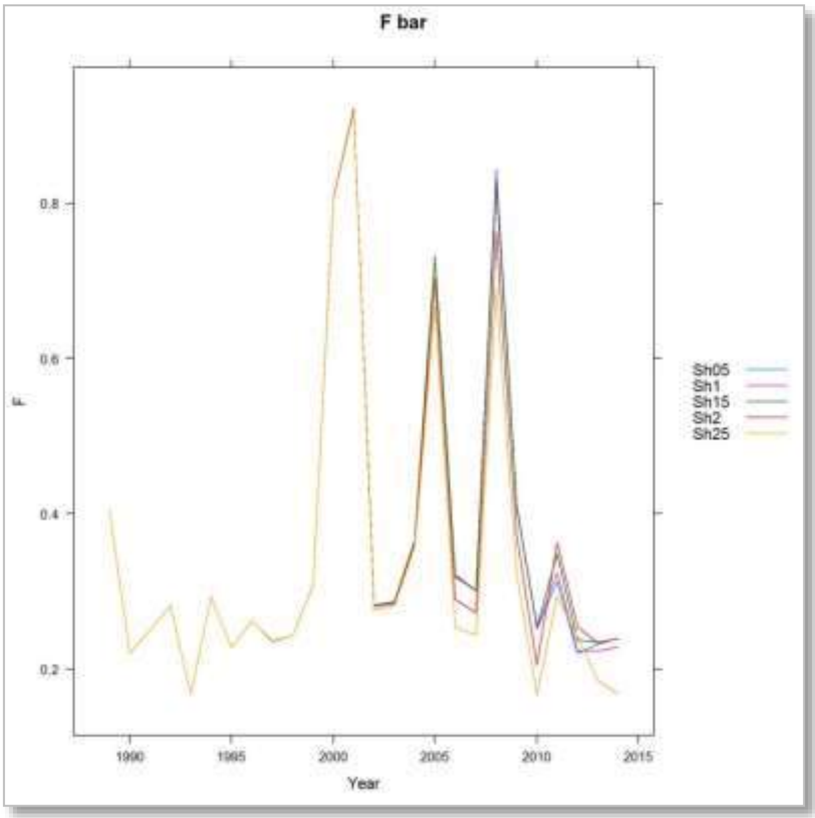


Figure 2.1.3.63. Piked dogfish in Black Sea. Fbar (10-17) trends obtained by means of XSA fitting with five shrinkage settings (STECF, 2015; GFCM, 2015)

Both log-catchability residuals and retrospective analysis indicate that the XSA model fitting with shrinkage 1.5 is providing the best results. Shrinkage 1.5 was not used in EWG14-14. However, it was decided to use this shrinkage at EWG15-12 because it was producing a more smoothed pattern in recruitment; therefore it was preferred to shrinkage 2 (and 2.5) that was producing an odd peak in recruitment around year 2000. The settings that minimized the residuals and showed the best diagnostic outputs were used for the final assessment, and are the following (STECF, 2015)

Table 2.1.3.63. Settings for minimizing the residuals (STECF, 2015)

Fbar	**Shrinkage**	**fse**	**rage**	**qage**	**shk.yrs**	**shk.age**
10-17	1.5	0.5	13	17	3	5

The outputs of the XSA final assessment are shown below.

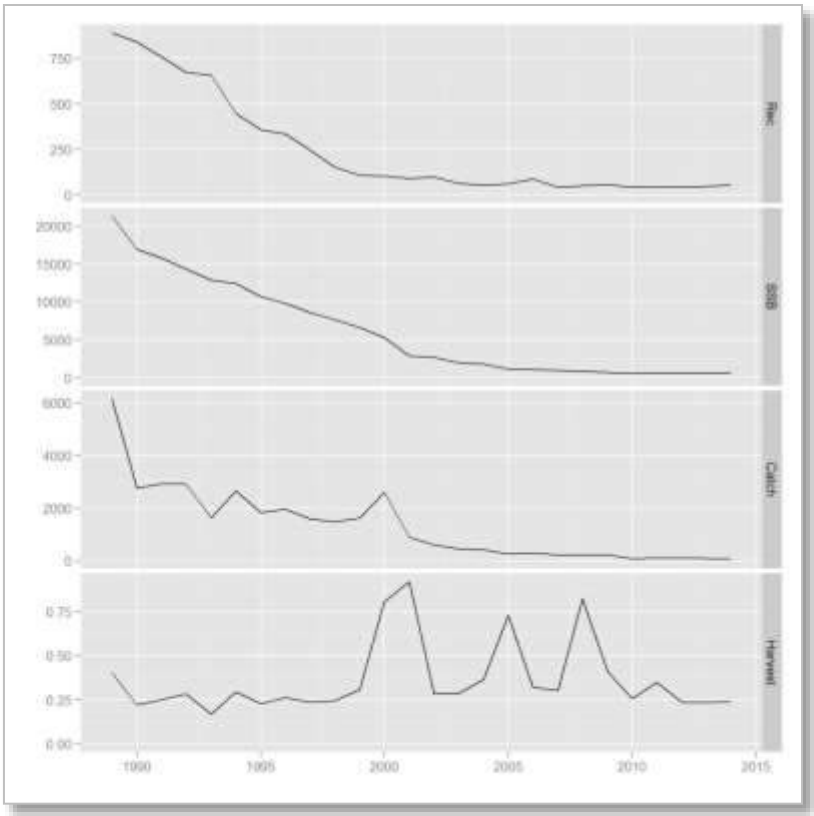


Figure 2.1.3.64. Piked dogfish in Black Sea. Results of the XSA best model (shrinkage 1.5) (STECF, 2015; GFCM, 2015)

Table 2.1.3.64. Piked dogfish in Black Sea. XSA summary results.

	Fbar10-17	**Recruitment (thousands)**	**SSB (t)**	**Catch (t)**	**Landings (t)**
2009	0.41	54.9	737.8	235	235
2010	0.26	43.1	510.5	75	75
2011	0.35	46.3	634.1	104	104
2012	0.24	46.0	625.4	70	70
2013	0.23	47.4	670.1	83	83
2014	0.24	52.9	616.1	75	75

Table 2.1.3.65. Piked dogfish in Black Sea. F-at-age matrix obtained from XSA.

	F at age						
	7	**8**	**9**	**10**	**11**	**12**	**13**
2009	0.00	0.00	0.09	0.31	0.43	0.39	0.39
2010	0.00	0.01	0.01	0.05	0.05	0.09	0.20
2011	0.00	0.01	0.01	0.04	0.10	0.06	0.18
2012	0.00	0.00	0.01	0.02	0.03	0.04	0.04
2013	0.00	0.00	0.00	0.00	0.02	0.06	0.14
2014	0.00	0.00	0.00	0.00	0.00	0.07	0.08
	F at age						

	F at age						
	7	**8**	**9**	**10**	**11**	**12**	**13**
	14	**15**	**16**	**17**	**18**	**19+**	
2009	0.49	0.43	0.44	0.40	0.34	0.34	
2010	0.17	0.27	0.67	0.53	0.36	0.36	
2011	0.24	0.28	0.71	1.17	0.40	0.40	
2012	0.37	0.64	0.42	0.34	0.47	0.47	
2013	0.13	0.69	0.62	0.22	0.57	0.57	
2014	0.49	0.26	0.43	0.57	0.49	0.49	

Reference points

Methods

YPR-LEN analyses estimated $F_{0.1}$ = 0.204 proxy for F_{MSY}. XSA estimates of current rates of fishing mortality are high (~0.25) and estimates of F for past years were erratic, exceeding 0.7 four times during 1999 to 2009. Given (a) the uncertainty in the VIT and YPR-LEN analyses, linked to the assumption of constant recruitment, (b) the preliminary nature of the XSA analysis, and (c) the absence of more reliable information, EWG considered precautionary to use the F_{MSY} value ($F_{0.1}$ = 0.03 as proxy for F_{MSY}) estimated by ICES (ICES, 2014) for piked dogfish in the North East Atlantic as an appropriate proxy for F_{MSY} for piked dogfish in the Black Sea (STECF, 2015)

Results

The current F estimated by XSA is 0.24. The results can be viewed as being uncertain, but indicative of the status of piked dogfish. The stock can be considered to be overexploited or even severely depleted, if the precautionary F_{MSY} value is to be taken into account (STECF, 2015)

Stock advice

The current F estimated by XSA is 0.24. The results can be viewed as being uncertain, but indicative of the status of piked dogfish. The stock can be considered to be overexploited or even severely depleted, if the precautionary F_{MSY} value is to be taken into account.

Spatial distribution

Mapping of distribution of piked dogfish juveniles in the Ukrainian sector was made on the basis of materials produced during YugNIRO register surveys, namely: piked dogfish surveys with bottom trawl in summer period (June), surveys for bottom fishes in spring (April-May) and autumn (September-October) periods and winter-spring surveys for whiting (February-March, December). In the north-western Black Sea the largest concentrations of piked dogfish juveniles in the warm period of a year are usually observed in depth from 40 m to 50 m, and in winter period – from 50 to 60 m. Although sometimes in February-March they may occur in large depths down to 90-100 m. The most typical distribution of juvenile concentrations of piked dogfish are characterized by depth 40 – 60 m with water temperature 7-12ºC from the border with the Romanian sector to the cape Tarkhankut and from the cape Chauda to the border with the Russian sector.

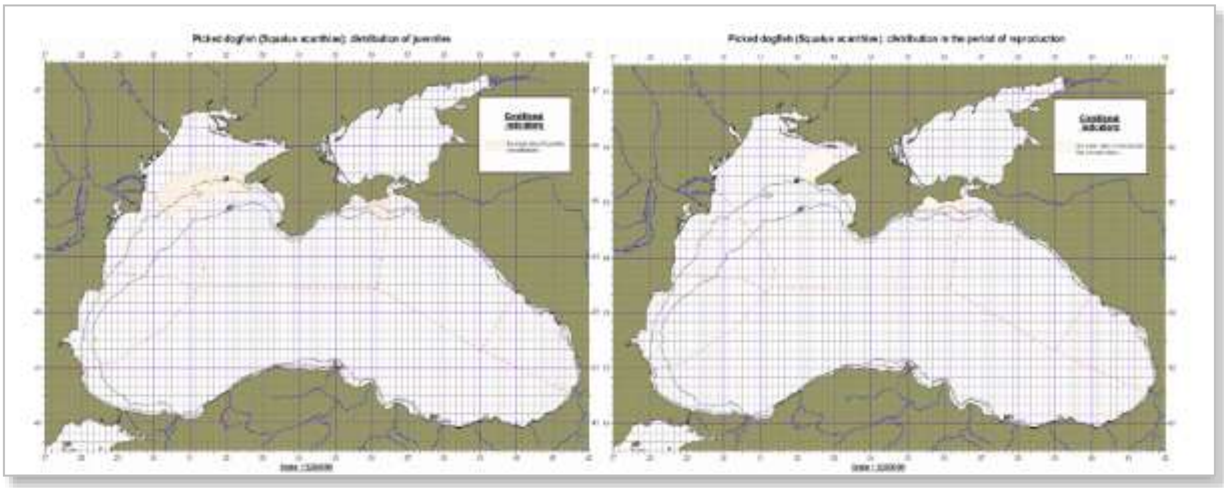


Figure 2.1.3.65. Piked dogfish distribution of juveniles and during the period of reproduction (BSERP, 2007)

2.1.4. Commercial molluscs

- Long-term dynamics of biomass and catches (relevant indicators to be demonstrated)
- Spatial distribution of biomass (abundance)

Rapa whelk - *Rapana venosa*

Rapana is one of the alternative fishery resources for the fishermen after the decline in many fish stocks. There are two options at present: either to maintain a good level of Rapa whelk stocks to maximise fishermen benefits by social and economic incentives or to reduce ecological impacts of Rapana for the future of Black Sea ecosystem. In order to reduce ecosystem losses due to Rapana, the unique way is the commercial fisheries. It means we should support fishermen to harvest Rapana as much as possible. On the other hand, the use of traditional dredges and bean trawls has an impact on the coastal habitat and the marine living organisms sharing the same environment. It is very essential to reduce bycatch rates in dredges and beam trawls, which are widely used in Bulgaria, Romania and Turkey.

The best solution is to promote the use of environmental-friendly harvesting methods and gears in the region. Traps are the best solution at present. In this presentation, several types of dredges and their bycatch rates will be summarised based on latest research studies. Information on Rapa whelk (*Rapana venosa*) was discussed although no analytical assessment was attempted, and SGSABS provided guidance on further research needs towards an assessment of rapa whelk in the area (GFCM, 2015).c Rapa (veined) whelk *Rapana venosa* Val., 1846) (syn. *Rapana thomasiana* Crosse, 1861) was introduced into the Black Sea in 1946 and distributed along the Caucasian and Crimean coasts and to the Sea of Azov within a decade. Its range extended into the northwest Black Sea to the coastlines of Romania, Bulgaria and Turkey from 1955 to 1969.

It is well established in the benthic ecosystem of all the Black Sea coastal states and has exerted significant predatory pressure on the indigenous malacofauna (Black Sea TDA, 2008). In the Black Sea, *Rapana venosa* occurs on sandy and hard-bottom substrates to 45 m depth. The highest abundance occurs in the Kerch Strait at the entrance to the Sea of Azov, near Sevastopol and Yalta (Ukraine), and along the Bulgarian coast (ICES, 2004). In the Black Sea coasts of Turkey, it was observed that 74% of the stocks were found up to10 m, 24% 10-20m and 2% more than 20 m depths (Duzgunes et al., 1992).

The investigations on the biology, abundance and stocks of *Rapana venosa* and its main food *Mytilus galloprovincialis* began after Rapana settlement in the Black Sea during the 1940-s. More recent data were obtained in 2005, when the stock of the both species was estimated along the Bulgarian Black Sea coast (Petrova and Stoykov, 2009, 2011). The species *Rapana venosa* and *Mytilus galloprovincialis* form dynamic balance, which require annual monitoring of the ongoing changes in their populations, separately and as functionally dependent components of the benthic community. In 2013 were carried out in Bulgarian waters with fishing vessel, equipped with beam trawl. The trawling activities were performed in area from Balchik to cape Emine.

The values in the different hauls varies from 50 to 600 kg and the largest quantities of Rapana venosa were registered in Galata and Byala fields followed by Balchik field (Petrova, E., 2014, Petrova, E., St. Stoykov, 2015). The average sizes of the individuals ranges and from 6.4 to 7 cm in 2013 and for comparison from 6.9 to 9.1 cm during 2005. As a result of the complete destruction of the black mussel in Balchik field, Rapana venosa had an extremely low growth rate and fed on other bivalve mollusks, such as *Chamelea gallina* and *Anadara inaequivalvis*. Similar results were obtained in the other investigated areas (GFCM, 2015).

Figure 2.1.4.1. *Rapana venosa*

Rapana venosa (Figure 2.1.4.1.) is known as a sea snail or a whelk. It is thought that from its home places of the Indian – Pacific oceans sea snail came to Black Sea with ballast waters (Sorokin, 1982). Larvae of sea snail feed on nano plankton algae and their adults feed mainly on bivalves. They travel over large distances for feeding (State of the Environment of the Black Sea, 2001-2006/7).

The oyster banks destroyed in the Ukrainian waters by the sea snail in the area of the Kerch Strait and in the Karkinitsky Bay; the biocenoses of other molluscs associated with depth down to 30 m has suffered as well. Bilecik, 1990 stated Turkey has been conducting large-scale harvesting of sea snails since the mid-1985s and other Black Sea countries have also started harvesting sea snail. Turkish catches much higher than other countries, followed by Bulgaria, which has also become a commercially important resource after 1994 that stated by Prodanov and Konsulova, 1995 as 2000 tons. According to information available at the FAO (http://www. fao.org/fi/oldsite/FCP/en/bgr/body.htm), the 2000 FAO reported data for rapa whelk equated to 90% of the total shellfish catch in Bulgaria. Considered the remaining 10% to be comprised equally of *C. gallina*, *Donax* spp. and miscellaneous marine molluscs (“marine molluscs nei”) for the 1994 to 2013 period. (Keskin, Ç., et al, 2017). Another recently *R. venosa* harvesting country is Romania. Landings of *R. venosa* in the Black Sea for 6 countries are given below as figure.

Sea snail catch has beed greatly increased in Turkey for the recent years. Knudsen and Zengin, 2006 claimed Tukey uses typical boats that combine sea snail dredging, bottom trawling and net fishing. Düzgüneş, E., 2006 stated event though the population of this mollusc is still withstanding, such high intensity of fisheries using a large-scale implementation of dredges has a destructive effect on the bottom biocenoses and on the ecosystems as a whole. However some studies have been initiated for new methods such as posts and surface supplied diving systems (Kideys, 2002; Saglam et al., 2007).

In the Ukrainian costs of the Black Sea snail was harvested to be used as fine shells souvenirs. The stocks were assessed at 2800 tonnes in 1990, 1500 tones in 1994 and 1300 tonnes in 1999 (State of the Environment of the Black Sea, 2001-2006/7). The difference in the stock of the whelk considered as the evidence of drag fisheries impact.

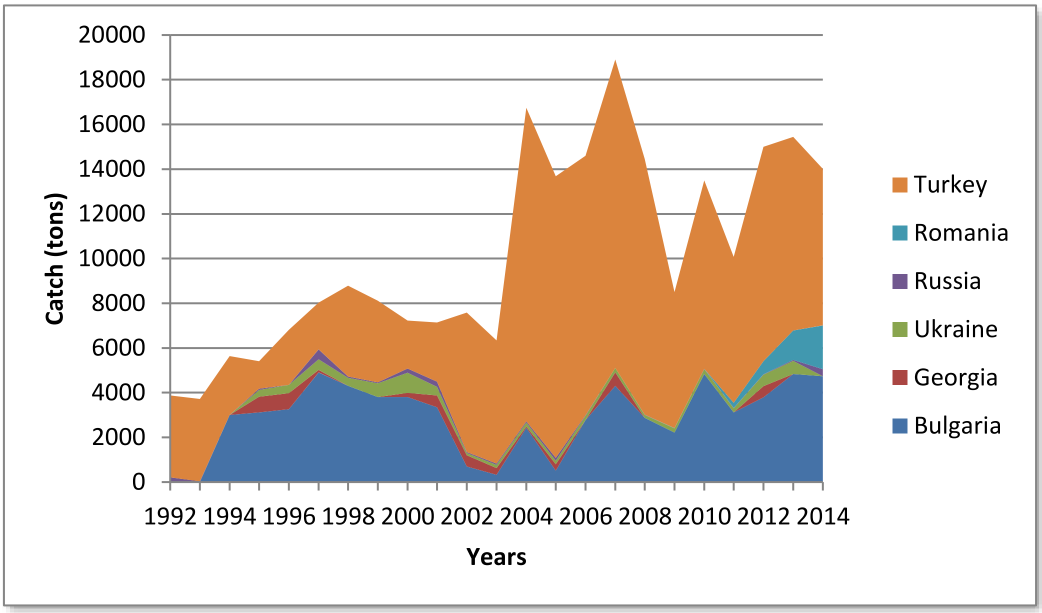


Figure 2.1.4.2. Landings of *R. venosa* in the Black Sea

According to the Fig 2.1.4.2, highest percentage of the total R. venosa catch belong to Turkey between 1992 and 2014. For the 6 countries there was a sudden drop in the catchment in 2003. The highest total catch was recorded in 2007 for Turkey, while it was 2014 for Romania and 1997 for Russia. This figure shows even though there some unexpected falls, the amount of total catch for R. venosa has an increasing trend in the Black Sea.

In 2015-2016, during the surveys under the frame of IFR Project - ECRAMON BLACK SEA, significant reduction of the abundance of both species was found. The species *Rapana venosa* was discovered mainly up to 35 m isobaths. Between 35 and 45 depth the presence of black mussel was observed, while rapana was not found at such depths. Due to overexploitation and lack of appropriate food, there is a trend of decreased size of Rapa whelk.

Growth and maturity

Table 2.1.4.1. Length, catch-at length and average weights in Romanian waters in 2014 Landings - 1,953.161 tons / 1953161 kg

Class (mm)	***Total catch*** (t)	***No. exemplary*** (thousands)	**average weight** (Kg)
3 – 3,99	0.716	38.813	0.0185
4 – 4,99	29.498	1435.74	0.0205
5 – 5,99	316.27	8654.982	0.0365
6 – 6,99	466.688	8138.737	0.0573
7 – 7,99	467.274	6352.074	0.0736
8 – 8,99	398.446	4063.494	0.0981
9 – 9,99	262.288	1922.805	0.1364
10 – 10,99	11.981	72.598	0.1651
Total	**1953.161**	**30679.243**	**0.0768**

Table 2.1.4.2..Discards Length, catch-at length and average weights in Romanian waters in 2014 DISCARD 2013 – 1.270 tons / 1270 kg (GFCM,2015)

Class (mm)	***Total catch*** (t)	***No. exemplary*** (thousands)	**average weight** (Kg)
3 – 3,99	0.001	0.025	0.0185
4 – 4,99	0.019	0.934	0.0205
5 – 5,99	0.206	5.628	0.0365
6 – 6,99	0.303	5.292	0.0573
7 – 7,99	0.304	4.130	0.0736
8 – 8,99	0.259	2.642	0.0981
9 – 9,99	0.170	1.250	0.1364
10 – 10,99	0.008	0.047	0.1651
Total	**1.270**	**19.948**	**0.0768**

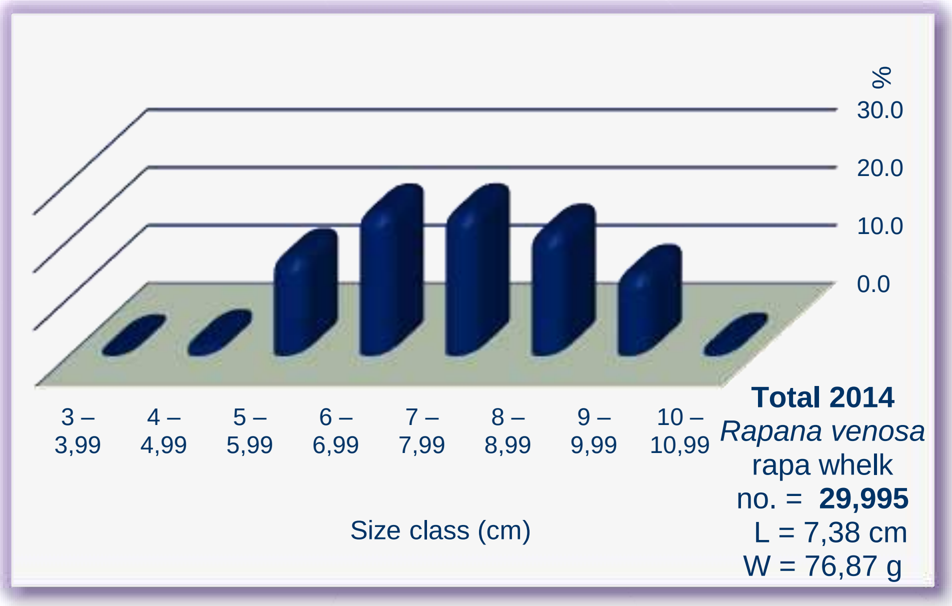


Figure 2.1.4.3. Structure by lengths and mass cards of Rapa whelk during commercial fishing

Table 2.1.4.3. Length, catch-at length and average weights in Romanian waters in 2015

LANDING - 4458.491 tons / 4458491 kg (GFCM,2015)

Class (mm)	***Total catch*** (t)	***No. exemplary*** (thousands)	**average weight** (Kg)
2 – 2.99	13.627	1214.616	0.0112
3 – 3,99	73.204	3605.375	0.0203
4 – 4,99	252.253	5910.946	0.0427
5 – 5,99	565.585	8551.773	0.0661
6 – 6,99	982.388	9782.876	0.1004
7 – 7,99	1293.126	8727.645	0.1482
8 – 8,99	1176.031	5542.714	0.2122
9 – 9,99	90.464	409.452	0.2209
10 –	11.814	49.464	0.2388
Total	**4458.491**	**43794.860**	**0.1018**

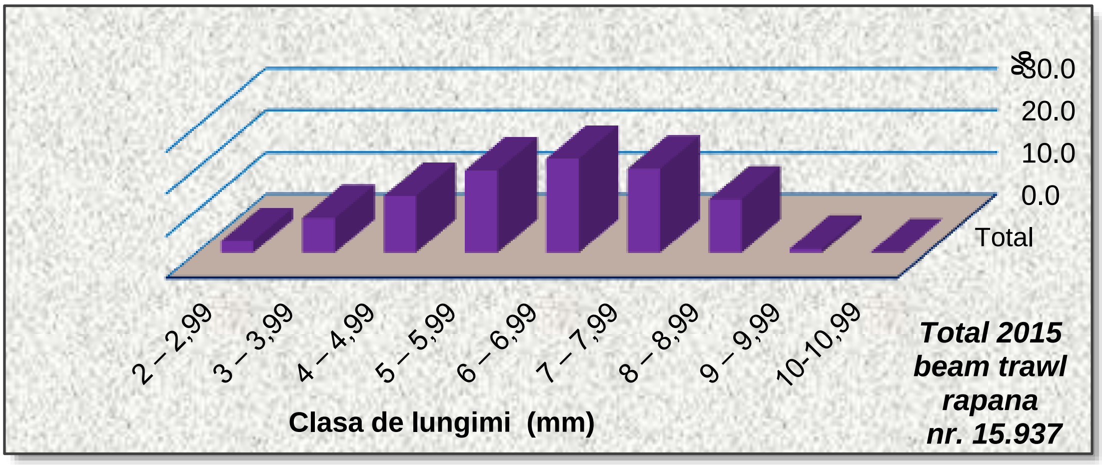


Figure 2.1.4.4. Structure by lengths and Mass cards of Rapa whelk during commercial fishing

(GFCM,2015)

Table 2.1.4.4. Time series of Rapa whelk landings (tons) in the Black Sea

Syear	Bulgaria	Georgia	Romania	Russian Federation	Turkey	Ukraine	TOTAL
2009	2214	0			6085	190	8489
2010	4381	0			5460	225	10066
2011		0			7770		7988
2012	3793	0			8893	509	13783
2013	4819	0	1357	50	8655	586	15467
2014	4732	0	1953	150	6199	200	13403
2015	4101	82	4459	1011	8795	369	18817

The catches in Turkey are the highest for 2015.The Romanian landings increased significantly since 2014 and the trend is positive. According to the intensions and investments of Romanian fishermen we could predict that the catches in Romanian area will possibly increase, and even double the catch of 2015.

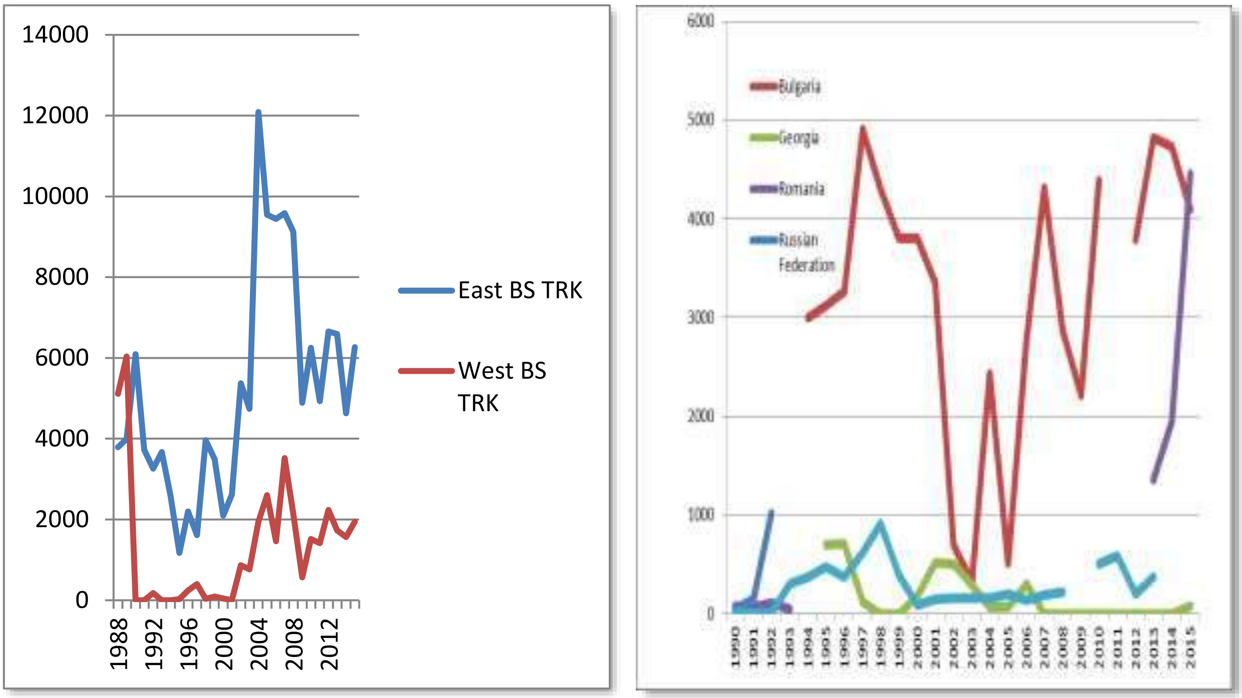


Figure 2.1.4.6. Trends of catches of Rapa whelk in Black Sea

Clams – *Chamelea gallina*

Chamelea gallina (L., 1758) is a well-known, small sized bivalve mollusck species widespread all over the coasts of the Mediterranean and the Black Sea, inhabiting sandy ground at depth up to 35 m (Fischer *et a*l., 1987, State of the Environment of the Black Sea, 2001-2006/7).

Fig 2.1.4.7. Geographic distribution of *Chamelea gallina* (URL-2, 2006)

Turkey is the only one to conduct regular striped venus harvesting among Black Sea countries due to there is no domestic consumption the majority of production is exported to EU countries as frozen or canned goods (Dalgıç G., *et al*., 2010). In 2006 the hydraulic dredge boats operated in clams fishing was 39, the most of them concentrated along the southwestern coast of the Black Sea (Dalgıç G., *et al* 2005). Between 1st of September and 30th of April fishing is available for clams.

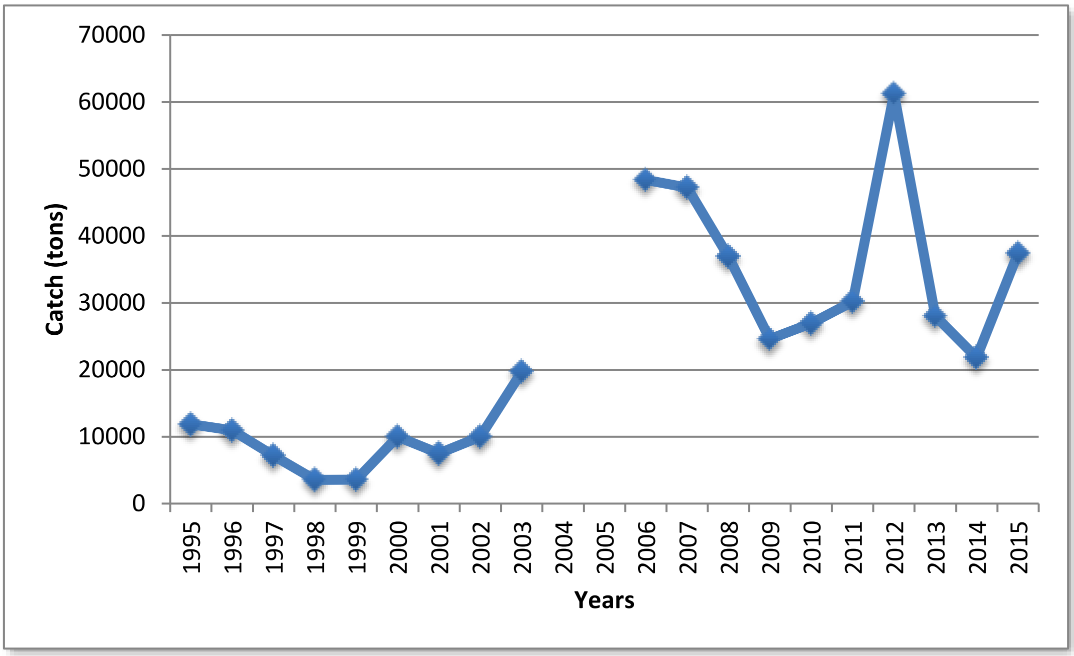


Figure 2.1.4.8. Harvest of striped venus in the Black Sea along the Turkish coasts (State of the Environment of the Black Sea, 2001-2006/7, Fisheries Statistics, Turkey)

According to Fig 2.1.3.72, the amount of harvested striped venus is increased more than three times in 2012 compared to 2000. Even there are few decreases after 2012 the amount of total catch of striped venus is always higher compared past 15 years.

The average length of *C. gallina* that caught in the Turkish waters defined as 27-30 mm with 10-11 average weights by Alpbaz and Önen, 1989.

Until now there is no research to understand the possible impact of fishing on growth of *C. gallina*. Even so, the number of studies investigating the impacts of fishing on growth rates of other aquatic organisms have increased, with some authors suggesting that fishing has caused declines in growth and size or age at maturity (Ricker, 1981; Olsen *et al*., 2004; Jorgensen *et al*., 2007; Koeller *et al*., 2007; Swain *et al*., 2007), conversely, others suggest the reverse (Rijnsdorp & van Leeuwen, 1996; Pastoors *et al*., 2000) Dalgıç G., *et al*., 2010.

Mediterranean mussel – Mytilus galloprovincialis

Mediterranean mussel (Mytilus galloprovincialis) is the one species with high commercial value among the Black Sea mollusks that forms communities along all the coasts from the shoreline to the depth of 60 meters (State of the Environment of the Black Sea, 2001-2006/7). Mediterranean mussel fisheries were first developed in the Turkey and Ukraine between 1989 and 2005 (also with much less amount in Bulgaria and the Russian Federation). Even thought the most abundant settlements were in the northwestern part of the Black Sea with 8-12 million tons in 1970's, the population of this species was exposed to massive death due to oxygen deficiency in near bottom water layer and reduced to 4-6 million tones in 1980's (Zaitsev, 1992).

2.1.5. Status Of Alien Species In The Black Sea

Main characteristics of the Black Sea

The Black Sea is one of the world's most isolated seas from a major ocean and the largest anoxic body of water on the planet (87 percent of its volume is anoxic). The Black Sea has a total surface of 423 000 km2 and its catchment area is over 2 million m2. It is surrounded by Turkey, Bulgaria, Romania, Ukraine, the Russian Federation and Georgia (Figure 2.1.5.1). In the north-eastern corner, the Black Sea is connected to the Sea of Azov through the Kerch Strait, and in the south-western corner to the Sea of Marmara through the Istanbul Strait (Bosphorus). The maximum depth is 2 212 m. The most striking characteristic of the Black Sea is probably its high level of hydrogen sulphide (H2S): the level of H2S is 150–200 m deep and has been relatively stable, although seasonal and annual fluctuations have been observed.

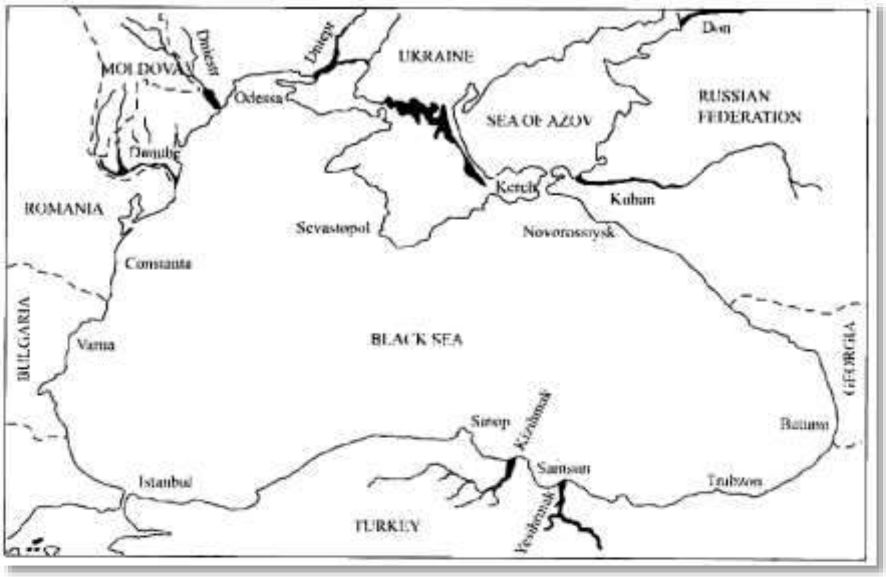


Figure 2.1.5.1. The Black Sea.

The presence of a permanent halocline between 150 and 200 m is another major distinguishing feature (Figure 2.1.5.2). Stratification is affected by the fresh water input and the Mediterranean inflow of highly saline water. The average surface salinity represents about 18–18.5 per mille during the winter, and increases by 1.0–1.5 per mille in summer. Temperatures show more variations than water salinity, seasonally and regionally. The mean annual surface temperature varies from 16°C in the south to 13°C in the northeast and 11°C in the northwest. While the upper 50–70 m water layer features seasonal fluctuations in temperature with considerable vertical variation, the temperature of deeper waters remains constant throughout the year. Typically, the temperature at a depth of 1 000 m is about 9°C and only shows a slight increase of 0.1°C per 1 000 m towards deeper sections (Balkas et al., 1990).

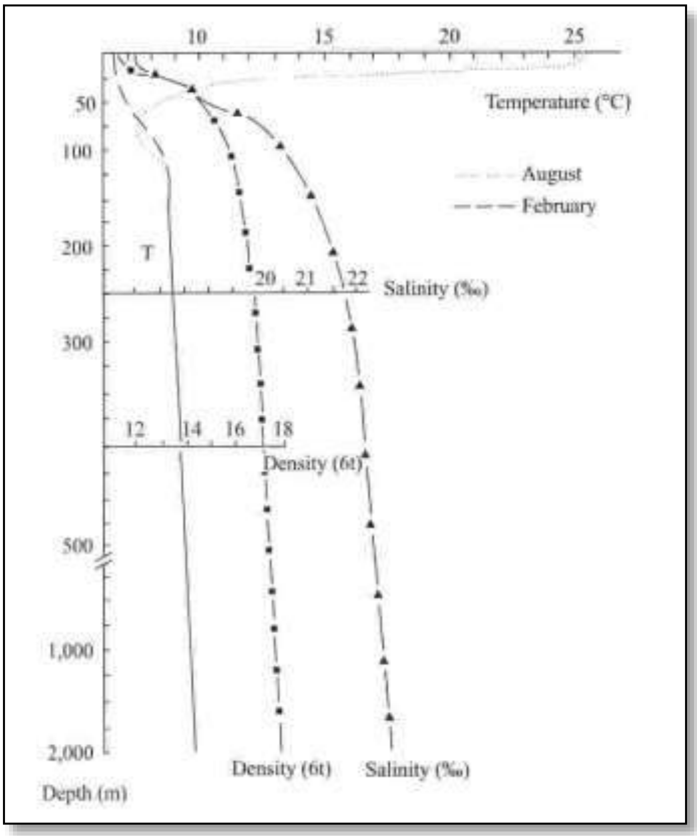


Figure 2.1.5.2. Vertical profile of salinity, temperature and density of the Black Sea.

The changes in the Black Sea ecosystem that have occurred since the 1960s due to the concurrent impacts of eutrophication, overfishing, climatic fluctuation and alien species invasions have been studied extensively. A synthesis provided in the State of the Environment Report (BSC, 2008) examines the changes occurred in pelagic and benthic ecosystems.

The biodiversity of the Black Seaclearly reflects its geological history. After the Istanbul Strait (Bosphorus) established a connection with the Mediterranean Sea, about 7 000–10 000 years ago, the salinity of the Black Sea rose gradually and Mediterranean species soon established in the Black Sea. Today, 80 percent of the total fauna of the Black Sea is of Mediterranean origin. According to Slastenenko (1959), the Black Sea has received more than one third and about one fifth of its fauna from the Aegean Sea and the Mediterranean Sea, respectively. The last group of species is called “alien species”, which includes those introduced either intentionally or unintentionally by human activities from the various seas and oceans of the world.

Vectors for alien species in the Black Sea

In recent years, the Black Sea has become home of a large number of alien plants and animals. There are three main vectors for alien species to reach the Black Sea: a) shipping activities, the most common vector; b) intentional or unintentional introduction by humans; c) Mediterranization, which means that Mediterranean originated species pass all ecological barriers in the Turkish straits and penetrate into the Black Sea.

Shipping activities

The invasion of alien species most commonly occurs via ocean-going ships. Marine organisms usually travel either as part of the fouling attached to ship hulls either in tank sediment or in ballast water (Zaitsev and Mamaev, 1997; Zaitsev and Öztürk, 2001; Öztürk 2002a, b; Gomiou et al., 2002; Streftaris et al., 2005). Shipping activities are intense in the Black Sea, mainly due to the transport of Caspian petrol from Novorossisk, in the Russian Federation, to the Mediterranean countries via the Turkish straits (Figure 2.1.5.3). It is also known that the largest unintentional pathway for the transport of marine organisms is the ballast water of commercial vessels; a typical commercial bulk vessel may carry over 30 000 metric tonnes of ballast water to provide for stability and trim adjustment during a voyage (cited in Wonham et al., 2000).

Hundreds of algal and animal species, either microorganisms or even smaller organisms, are known to travel by attaching themselves to the hulls of the ship. Most of them, like algae, clams and barnacles, are attached to the living substrate. Active non-sessile forms such as amphipods, shrimps, crabs and fish can also be found. When the ship is in motion they hide in barnacles and other similar shelters, so as not to be swept away by the current.

Ballast water is pumped into tanks to stabilize a ship when it is not carrying any cargo. When ships fill their ballast tanks in ports or sometimes in other areas, suspended matter and various planktonic organisms are also pumped into the tanks with the water. Many organisms, such as spores and eggs, sometimes survive the trip in the ballast water or sediment. Upon arrival at the ship's destination, the ballast water is discharged into the sea and the organisms find themselves in a new environment. If the conditions are favourable to their particular needs, these organisms may survive and even become naturalized. The huge number of ocean-going ships means that many new species are introduced into new environments constantly.

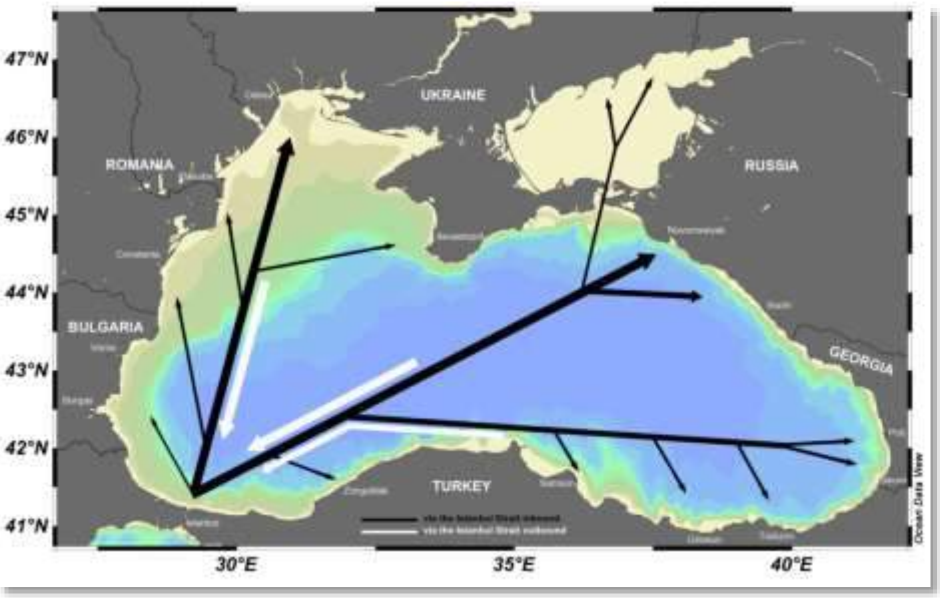


Figure 2.1.5.3. Main shipping routes in the Black Sea.

Intentional or unintentional introduction by humans

Several alien species have been introduced into the Black Sea for aquaculture or other reasons. The mosquito fish Gambusia affinis is a good example of this type of introduction. This fish is well known for its ability to feed on neuston larvae and mosquito eggs, including those species which transmit malaria. It has been thus introduced into the wetlands to combat malaria in the entire Black Sea basin. After the fish adapted and reproduced, Gambusia turned to a euryhaline species. Today Gambusia is widespread in the Black Sea basin.

Mediterranization effects

This is a relatively new phenomenon; the reason for the invasion of the Black Sea by Mediterranean-originated species seems to be related to water temperature rise as a consequence of climate change (Oğuz, 2005). Even though the Turkish straits (Istanbul and Çanakkale Straits) serve as an ecological barrier for these species, due to having totally different oceanographic peculiarities from the Black Sea and the Mediterranean Sea, some phytoplankton and zooplankton species penetrate into the Black Sea (Georgieva, 1993; Kovalev, 2006; Selifinova et al., 2008). Because of the temperature rise due to climate change, some Mediterranean fish species, such as sardine, bouge and wrasse have also penetrated into the Black Sea in recent years.

Alien species in the Black Sea

Zaitsev and Mamaev (1997) described 26 alien species from the Black Sea. According to Zaitsev and Öztürk (2001), 59 species of alien marine organisms were living in the Black Sea and only a few species, such as whelk Rapana and the ctenophore Mnemiopsis leidy, had been well studied in terms of their impacts on fisheries. Also, Çinar et al. (2005) reported 20 alien species from the Turkish part of the Black Sea and according to Alexandrov et al. (2007), there were 240 alien species originating from Ukrainian fresh, brackish and marine waters. Later, 156 alien species were reported by Shiganova and Öztürk (2009) in the Black Sea, most of these coming from the Mediterranean Sea. Alexandrov et al.(2014) reported that on the based on the decision of the secretariat of the Black Sea commission 263 non- indigenous species is included in world information system on aquatic non-indigenous and cryptogenic species Aquanis (www.corpi.ku.lt/databases/aquanis) .

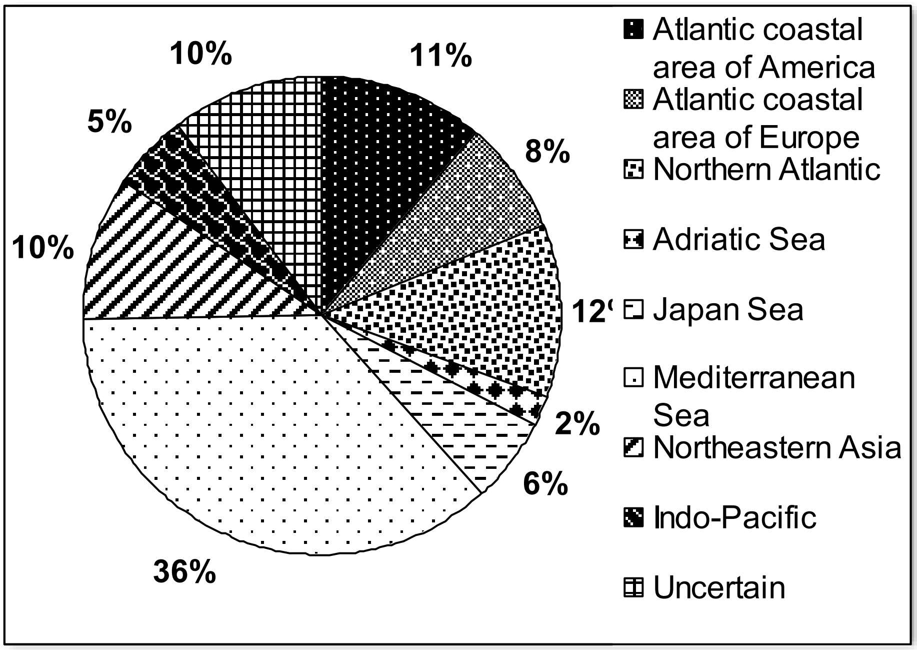


Figure 2.1.5.4. Donor areas of alien species and their proportions in the Black Sea (Shiganova and Öztürk, 2009).

Alien invertebrates in the Black Sea and their impacts on biodiversity

Over the last decades, numerous alien invasive species, among which a mollusc species, *Rapana venosa*, bivalve species, *Mya arenaria* and Anadara inaequivalvis,as well as gelatinous carnivorous species, *Mnemiopsis leidyi* and Beroe ovata, have developed mass populations and given rise to severe ecosystem transformations with considerable impacts on the pelagic and/or benthic food webs of the Black Sea.

Mnemiopsis leidyi

Mnemiopsis leidyi (Figure 2.1.5.5) is a carnivorous ctenophore. It is characterized by two big lobes referred to as lateral or oral lobes. The oral lobes are derived from the ctenophore body (spherosome). Four smaller lobes are situated under the two principal oral lobes. In the Black Sea, the size of the animal varies from 40 to 180 mm length. The adult animal is about 100 mm long; specimens larger than this are rare. There are four relatively short, simple auricles arising from the sides of the body immediately above the mouth and close to the sides of the oral lobes. The introduction of the ctenophore M. leidyi took place through ballast water by ships from the northern American Atlantic areas at the beginning of the 1980s (Shiganova, 1998; Zaitsev and Öztürk, 2001).

Figure 2.1.5.5. *Mnemiopsis leidyi*.

Mature specimens of M. leidyi spawn at night in summer temperatures of 20 to 23°C in the upper layer of the sea. Embryonic development takes about 20–24 hours. The size of the larvae is 0.3–0.5 mm (Zaika and Sergeeva, 1990). The average egg production of M. leidyi in the coastal zones of the Black Sea is very high and exceeds 1 000 eggs per individual in one day. The total number of eggs in one laying is comprised between 2 000 and 4 000. Equations to determine wet weight (W, mg) on the basis of the total length (L, mm) of the animal body are:

$W = 3.1 \cdot L2.22$ for $L < 45$ mm or $W = 3.8 \cdot L2.22$ for $L > 45$ mm (Vinogradov et al., 2000).

This species originally comes from the Atlantic coasts of North America. M. leidyi is found in the coastal waters of North America, from Cape Cod southwards to Carolina. It is abundant in the ports and harbours of these areas and can be pumped (presumably as larvae or small juveniles) or gravitated (in the case of adults as well) with ballast water into cargo ships. While sufficient zooplankton may be available to sustain this comb jellyfish in ballast water on a voyage lasting 20 or more days from the Americas to the Black Sea, food resources are not necessary, since M. leidyi can live for three or more weeks without food, reducing its body size at the same time (Reeve et al., 1989). Like other ctenophores, M. leidyi is a simultaneous hermaphrodite. This means, in theory, that a single animal could invade a new area.

The first record of M. leidyi occurrence in the coastal waters of the Black Sea dates back from 1982 (Pereladov, 1988). The first registration of this species in open water was made in winter 1986–1987 (Zaitsev et al., 1988). The massive growth of the Black Sea population started in 1988 and at first covered only bays, gulfs and coastal waters. Its abundance reached 10–12 kg m-2 in several coastal areas (e.g. Anapa, in the southwestern Bulgarian coast) although it did not exceed 1.5–3 kg m-2 in the open sea (Shushkina and Vinogradov, 1991). The maximal development of this species was registered in 1989 and 1990 (about 1 200 g m-3), but then its abundance started to decrease (Vinogradov et al., 2000). For example, the average biomass of Mnemiopsis during 1991–1994 along the Romanian littoral zone reached 2.2–3.5 g m-3 and decreased to 0.2 g m-3 in 1995 (Radu et al., 1996–1997). The same quantitative distribution was observed in the Dnieper River influence zone of the Black Sea. The average biomass of M. leidyi between 1993 and 1997 was 3.2–5.1 g m-3. Its population density during these years stabilized between 300 and 800 g m-2 in the Black Sea and betweent 500 and 600 g m-2 in the Sea of Azov (GESAMP, 1997).

Meanwhile, another ctenophore species, Beroe ovata, which is a predator of M. leidyi, was introduced into the Black Sea, presumably by ballast water, and observed in 1997. As explained below for B. ovata, this introduction helped mitigate the M. leidyi outburst.

Distribution maps of M. leidyi for the Black Sea have been established according to different years and seasons. To make a general map, the model description of this comb jellyfish has been used. This description was based on the peculiarity of its biology (reproduction, growth, mortality) and water mass transportation in the Black Sea (Lebedeva, 1998). The map showing the general distribution of M. leidyi was made for the water layer of 0–30 m (typically inhabited layer for this species) in September 1998 (Figure 2.1.5.6).

M. leidyi is usually found close to shore, in bays and estuaries, although they have occasionally been collected several hundred kilometres offshore. This species is able to tolerate a wide range of salinities and temperatures, it can live and reproduce in salinities ranging between 3.4 and 75 percent and in temperatures ranging between 1.3oC and 32oC and survive well in oxygen-poor environments. The species is most abundant in brackish waters with high levels of suspended materials and appears to be hardly affected by contaminants. The only factors which seem to restrict its rapid population growth are the temperature, the availability of food and the presence of predators (GESAMP, 1997).

Mnemiopsis leidyi is the most striking example of the negative impacts of alien species on the Black Sea ecosystem. After its invasion, the structure of the planktonic communities in coastal waters and the open part of the sea has significantly changed. The general abundance of subsurface mesozooplankton has declined on average 2–2.5 times or more, compared to the previous period. The biomass of some species (small copepods such as Oithona, Paracalanus, Acartia, and Pseudocalanus) has decreased 3–10 times or more. A sharp decrease (approximately 2–10 times) of meroplankton in summer has also been observed, demonstrating the grazing impact of M. leidyi upon the larvae of benthic animals. The subsequent decrease of the zoobenthos biomass has been estimated at about 30 percent (Volovik et al., 1993; Shiganova, 1998).

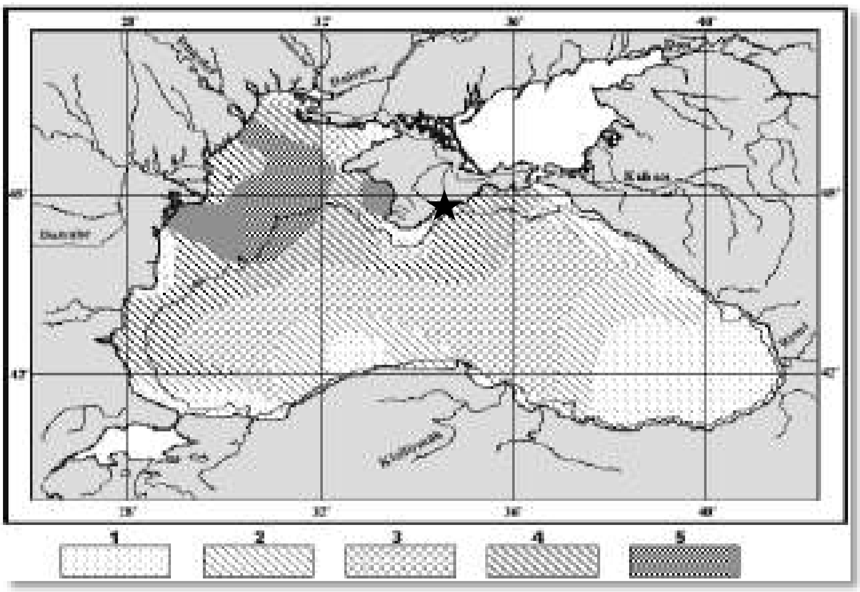


Figure 2.1.5.6. Distribution of Mnemiopsis leidyi in the Black Sea during its maximum development in September 1998.

Range of biomass (g m-2) – Area 1: <200; Area 2: 200–600; Area 3: 600–1000; Area 4: 1000–1400; Area 5: >1400.□: Place of the first registration (Zaitsev and Öztürk, 2001).

In summary, the three major impacts of M. leidyi on fisheries have been identified as follows:

1) Predation on fish eggs and larvae. For example, in shelf waters, M. leidyi has been estimated to graze up to 70 percent of total ichthyoplankton stock (Tsikhon-Lukanina et al., 1993);

2) Feeding on larvae and adult fish food, such as zooplankton, thus causing starvation;

3) Further accelerating ongoing ecological change, presently being experienced due to eutrophication. For example, direct environmental impacts on the pelagic and benthic systems (anoxia) due to a massive precipitation of mucus and dead ctenophores to the bottom on the shallow shelf.

All these events related to this new predator have resulted in a drastic decrease of fish production – 4–5 times for Black Sea shad and over 10 times for anchovy. Mass occurrence of M. leidyi appears to be one of the most important reasons for the sharp decrease of anchovy and other pelagic fish stocks in the Black Sea. There has been a decline in the biomass of both populations and catch in about the same proportions, which has caused large scale damage to the fisheries.

Indeed, the annual loss in fish catches attributed to the M. leidyi plague has been calculated at approximately US$ 200 million in the Black Sea and USD 30–40 million in the Sea of Azov (GESAMP, 1997).

Beroe ovata

Another alien ctenophore species, Beroe ovate (Figure 2.1.5.7), needs to be examined as it is a competitor of Mnemiopsis leidyi. This species is miter-shaped and its lateral compression is very marked, with a broad lateral diameter fully twice the width of the narrow one. The size of Black Sea *B.ovata's* eggs is 300–350 μm with gelatinous capsules of 0.9–1.0 mm in diameter. The abundance of eggs in one laying depends on the size of the comb jellyfish. Ctenophores that are 5–6 cm long lay approximately 2 000–3 000 eggs, while individuals that are 8–10 cm long can lay 5 000–7 000 eggs (Shiganova et al., 2000; Volovik, 2004).

Figure 2.1.5.7. Beroe ovata.

This species is circumpolar in its distribution. It extends along the coast of New Engand, Greenland and is common in the Labrador Current. It is abundant in the North Sea and off the coasts of Scotland and thePacific coast of North America. This species also inhabits the eastern coasts of Japan and also the Antarctic, Pacific and Indian Oceans (Mayer, 1912).

The possible mechanism of penetration of this comb jellyfish into the Black Sea is probably the same as for Mnemiopsis leidyi. In ballast water, B. ovata has been most likely transferred from the estuaries along the North Atlantic Ocean where this species is tolerant to lower salinity and is a native predator of M. leidyi. Another hypothesis is that B. ovata, which lives in the Mediterranean and Marmara Sea, has penetrated and had a chance to acclimatize itself in the Black Sea due to abnormal warm winters in 1997–1998 and 1998–1999 and, in particular, in summer 1999 in the north-eastern part of the Black Sea. Interestingly, comb jellyfish B. ovata has also been recommended to the Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) to combat the outburst of M. leidyi.

In 1998, the occurence in the Black Sea of B. ovata, a predator of the ctenophore M. leidyi, has led to a partial recovery of the planktonic food web structure by compensating the negative impacts of

M. leidyi. B. ovata predominantly inhabits 30 mile-width of the coastal zone of the Black Sea. Most probably the reproduction of this species takes place in open waters.

Most experts have considered that B. ovatafeeds exclusively on other comb jellies during all of its development stages (Nelson, 1925, Kamshilov, 1955). It is known that, over one month, one 35 mm long individual of B. ovatamay consume 44 individuals of 10–35 mm long Bolinopsis and grows up to 44 mm (Zaitsev and, Öztürk, 2001). Besides, B. ovatais a food web dead-end due to the lack of natural enemies in the Black Sea. Thus either direct or indirect impact through the entire food web could be expected, repeating for instance Mnemiopsis leidyi’s history and further adding to the problem of gelatinous species in the Black Sea.

Alien invertebrate species and impacts on biodiversity

With regards to non-indigenous plankton species from the Black Sea, the prymnesiophyte Phaeocystis pouchetii was extremely abundant and clogging the gills of fish along the Bulgarian coasts of the Black Sea. There is also a list of the non-indigenous species proposed by Moncheva and Kamburska (2002), although Gomez and Boicenco (2004) did not fully agree with this list.

The bivalve Mya arenaria, a native of the Northern Atlantic, was first detected in 1966 and became very abundant in a short period of time in the north western and western part of the Black Sea, reaching its peak abundance in 1972. Even though it was later adversely affected by the regular hypoxia-anoxia crises that destroyed the entire benthos in the 1980s, it still retains considerable abundance in the western coastal waters. This species is a competitor for habitats with the small local bivalve, Lentidium mediterraneum, which avoids sandy bottoms siltated by M. arenaria. Large amounts of washed molluscs on the beach attract their consumers, such as gulls and crows.

Another bivalve of Indo-Pacific fauna, Anadara inaequivalvis, was found in the Black Sea in 1968, and has spread to the whole basin. This species has a potential for commercial harvesting in Turkey (Sahin et al., 2006).

In 2001, two new non-native bivalve species were found in the Odessa Bay: edible Mytilus edulis and Mytilus trossulus (Alexandrov, 2004). M. edulis was probably brought with ballast water from the Mediterranean, where it is cultured off the Spanish and Italian shores. The Pacific species M. trossulus was probably brought with ships from the far east Russian coasts, where it is one of the main species for cultivation (Suprunovich and Makarov, 1990). The shipworm, Teredo navalis, one of the oldest alien bivalve species found in the Black Sea, is present in small numbers and its impacts are not significant at present because wood is replaced by concrete or metallic underwater constructions and also because shipworms are becoming rare.

Other alien species such as the ivory barnacle, Balanus eburneus, and the acorn barnacle, Balanus improvises, are typical organisms of fouling communities, which may have adverse effects on the net cages of sea bass aquaculture in Trabzon, along the Turkish Black Sea coasts.

A Mediterranean jellyfish has become a threat for humans in the Marmara and Black Sea. Compass jellyfish Chrysaora hysoscella (Linnaeus, 1767), a temperate planktophagous species, was firstly reported from the Sea of Marmara by Inanmaz et al. (2002). This species made a large bloom in the Marmara Sea, Istanbul Strait and Turkish part of the Black Sea in July 2009 (Öztürk and Topaloglu, 2009). Most of beach bathers used fishing nets to protect themselves from this stinging jellyfish. This species is venomous and needs to be monitored in the Black Sea in terms of impact on human health and interrelation with the entire Black Sea biota. It seems that C. hysoscella could establish its population in the Black Sea shortly. Moreover, in November 2009, a few individuals of a jellyfish from the Red Sea, Cassiopea andromeda (Figure 2.1.5.8), were found on the shores of Kilyos, just off the Istanbul Strait. New economical alien species such as Callinectes sapidus has been reported from the Black Sea i.e. Pashkov et al, 2012, Yaglıoglu et al; 2014.This species can gain economical importance such as Rapana venosa in the Black Sea .But ecological impacts to the native species is not known yet.

Figure 2.1.5.8. Impacts of alien species on pelagic fisheries in the Black Sea

Several studies have focussed on alien species in the Black Sea. There are, however, no accurate data to explain their impacts on the fisheries of some commercial pelagic fish, such as bluefish, mackerel, and bonito, and commercial demersal fish, such as whiting, turbot, red mullet, and striped mullet. On the other hand, the impacts of Mnemiopsis leidyi and Beroe ovata on small pelagic fish, such as anchovy and sprat, have been studied intensively as described below.

***Sprattus sprattus* (sprat)**

Sprat, Sprattus sprattus, is one of the most abundant and commercially important pelagic fish species in the Black Sea, and it also serves as an important food source for larger fish (Ivanov and Beverton, 1985). Sprat reaches its maturity at one year of age and reproduces during the whole year, but its peak spawning takes place between November and March.

Its spawning during winter and spring in deeper layers has been relatively unaffected by Mnemiopsis leidyi because of its low biomass in those deep layers. There is therefore little competition for prey and predation on sprat eggs and larvae (Shylakov and Daskalov, 2008).

In summer, the juvenile and adult sprats leave the upper warmed layer, avoiding severe competition for food with other plankton-consumers including M. leidyi. During this period, their preferred food mainly consists of the cold water Calanus and Pseudocalanus copepod species living below the cold intermediate layer of the water column. It should be noted that these preys are also available to M. leidyi as they migrate to the thermocline at night for their daily feeding where they can be consumed by the ctenophore. This can partly explain the reduction in sprat stocks during the population outburst of M. leidyi in the early 1990s. Like the other commercial stocks, heavy overfishing also took place before and during the M. leidyi outbreak, aggravating stock depletion (Prodanov et al., 1997).

***Engraulis encrasicolus* (Black Sea anchovy)**

The Black Sea anchovy, Engraulis encrasicolus, is the most important commercial pelagic fish species distributed all over the Black Sea. Between October and November, it migrates to the wintering grounds along the Anatolian and Caucasian coasts and forms dense wintering concentrations until March, when it becomes subject to intensive commercial harvesting.

Anchovy competes for food with Mnemiopsis leidyi (Grishin et al., 1994) and this competition has probably further affected the anchovy's population growth (Oğuz et al., 2008). The initial outbreak of M. leidyi was reported in 1988–1989 in the Black and Azov Seas. It appears that the catastrophic reduction of the Black Sea anchovy stocks in the late 1980s was due to the combined effects of two factors: excessive fishing and the M. leidyi outburst (Grishin et al., 2007). It is noteworthy that the sharp decline in anchovy catch happened after the outburst of M. leidyi at the end of 1980s and in the early 1990s (Niermann, 2004) (Figure 2.1.5.9.). Moreover, it has been mentioned by Kideys (2002) that as M. leidyi feeds on anchovy's eggs and larvae, it was mainly responsible for the collapse of the anchovy fisheries.

Catches increased after the outburst of the competitor species Beroe ovata at the end of the 1990s. In a way, B. ovata has helped the ecosystem to recover by feeding almost exclusively on *Mnemiopsis leidyi*. Catches of anchovy by Turkish fishers has stabilized from the 1990s to 2000s in the Black Sea (Figure 2.1.5.9). The total loss of anchovy catches between 1989 and 1992, due to the M. leidyi outbreak, can only be roughly estimated. According to Campbell (1993), the total annual loss of fish processing factories was estimated at US$11 million and the total annual loss in fishing itself was very roughly estimated at approximately US$330 million in 1992. The economic damage caused to the Turkish fishery sector is conservatively estimated at several hundred million dollars.

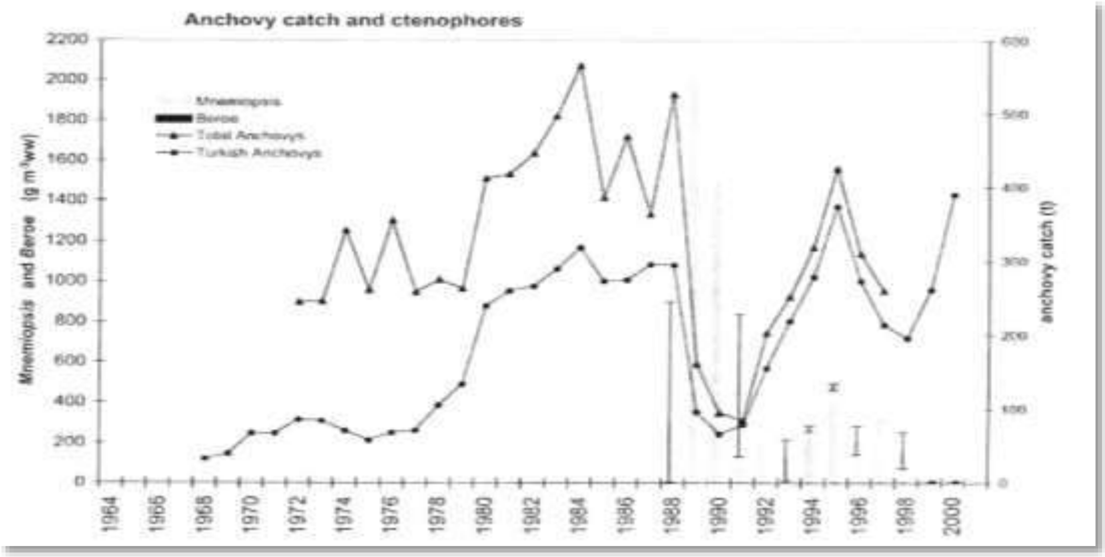


Figure 2.1.5.9. Anchovy catches and ctenophore biomass in the Black Sea (Niermann, 2004).

Damages caused by Mnemiopsis leidyi to the anchovy population has been most likely brought about through food competition, as unusually low levels of zooplankton biomass were observed in the top 50 m layer during summer in the early 1990s (Oğuz et al., 2008). Anchovy larvae could also be affected by M. leidyi predation, given that anchovy larvae peak in abundance in July and August when M. leidyi biomass also has a seasonal peak (Grishin et al., 2007). M. leidyi can consume a daily ration that is several times greater than its own weight (Lipskaya and Luchinskaya, 1990). Its food spectrum is quite wide and includes anchovy eggs as well as larvae. The distribution of anchovy larvae and M. leidyi, even though anchovy larvae were predominantly found in the narrow coastal zones while the ctenophore was distributed further offshore, shows and overlap. Oğuz et al. (2008) reported that the switch of a large marine ecosystem to a totally gelatinous invader-dominated state required an extremely strong environmental perturbation. More often, an environmental disturbance creates a suitable niche for an alien gelatinous invader to become a member of the food web structure and to share food resources with the native small pelagic fish communities.

***Trachurus* spp. (horse mackerel)**

Dietary studies on juvenile and adult horse mackerel Trachurus spp. have shown that both the habitats and the diet of juvenile horse mackerel and M. leidyi overlap with each other; therefore the strong feeding pressure exerted by M. leidyi on zooplankton directly affects larval and juvenile horse mackerel.

As the first outburst of *M. leidyi* occurred in autumn 1988, the maximum production of zooplankton in summer did not suffer much from the devastating effect of *M. leidyi*. The copepods Oithona nana and *Oithona similis*, which constituted the main food sources for larval horse mackerel (Revina, 1964), were especially abundant. However, favourable trophic conditions for larvae in summer 1988 failed to ensure the formation of a strong year-class because juveniles were faced with strong feeding competition from M.leidyi further in the year. A sharp decline in Oithona under the predation pressure of M. leidyi during the subsequent years further affected the survival of horse mackerel (Vinogradov et al., 1993). Nonetheless, recent data show that horsemackerel stocks have been stabilizing along the Turkish coasts over the last few years .

Alien fish species and their impacts

According to Slastenenko (1955–1956), a total of 189 fish species can be found in the Black Sea; 34 of them live in estuary and lagoon areas of the Black Sea. However, in recent years, a number of fish species which are ecologically tolerant to temperature and salinity have settled in the Black Sea. These species have migrated from the Mediterranean Sea and are extending their northern distribution up to the Crimian peninsula. Besides, Indo-Pacific species, such as the blunt barracuda Sphyraena pinguis and a coral-dwelling fish, Heniochus acuminatus, have recently extended their distribution ranges to the Black Sea (Boltachev and Astakhov, 2004; Bolthachev, 2009). These fish species are lessepsian migrants and, after the Aegean Sea, ultimately reached the Black Sea. Even though temperature is a primary factor for the dispersion of lessepsian fish and lower temperature is an impeding factor for tropical fish, these species have actually penetrated into the Black Sea. Nevertheless, only a few species of these lessepsian migrants need to be monitored in the Black Sea in terms of distribution and abundance.

An intentionally introduced fish, haarder, Mugil soiuy or Liza haematocheila, has become an important commercial species and is now distributed around all the coastal waters of the Black Sea, Azov Sea, Sea of Marmara and Mediterranean Sea, and even along the Algerian coasts. Its annual catch in the Black Sea exceeds 10 000 tonnes (Zaitsev and Öztürk, 2001). According to Okumus and Basçınar (1997), this fish appears to have an established population in the Black Sea; its growth rates seem to be much higher and it reaches its age of first sexual maturity earlier than native mullet species.

Age at first maturity has been estimated at 3–4 years for males and 4–5 years for females and the spawning period extends from the end of May to the beginning of July. Its pelagic eggs have a diameter of 0.8–0.9 mm and large oil droplets, which constitute for up to 23 percent of the egg volume. This is the reason behind the high floatability of haarder’s eggs, which can develop in low saline water in some coastal wetlands. Haarder fries e feeds on zooplankton and therefore can compete with local plankton-eating fish. This species feeds on small bottom-living organisms, mostly of meiobenthos, thus competing with plaice and turbot juveniles in coastal areas (Kazanskji, 1989; Ünsal, 1992). Some specific parasites (Trematoda, Monogenea) associated with haarder have been introduced into the Black Sea and found in the body of local grey mullets as well. The consequences of such on human health and on the biota of the Black Sea need to be further investigated. It is expected that in the next years this species will become more commercialized in the Mediterranean and the Black Sea.

A total of 42 marine species have been intentionally or unintentionally introduced into the Black Sea (Russian Federation, Romania, Ukraine and Turkey) (Table 2.1.5.1). The distribution of these organisms is scarcely known. Morevoer, many aspects such as parasites, genetic differentiation, etc. should be investigated. Most of other introduced species have failed to survive in the Black Sea for various ecological reasons.

Among the intentionally introduced species, rainbow trout, Onchorhynchus mykiss, and salmon, Salmo salar, are also commercially produced mostly in the Turkish part of the Black Sea. The sea trout production is estimated at approximately 2000 tonnes per year and the salmon production reaches 1 500 tonnes yearly (Okumuş and Deniz, 2007). The problem with intentionally introduced species is the risk of their hybridizing with native species when they escape from cages at sea.

Table 2.1.5 1.. Alien species intentionally or unintentionally introduced into the Black Sea (Zaitsev and Öztürk, 2001; Gomoiu et al., 2002; Alexandrov et al., 2007).

Species	Purpose of introduction	Years	Origin of the species	Inoculation places
Gambusia affinis (Mosquito fish)	To combat malaria	1925s	Mediterranean Sea, North America	Russia, Turkey
Lepomis gibbosus (Freshwater sun fish)	Aquarium	1920s	North America, Europe	Odessa Gulf
Pandulus kesleri (Far eastern shrimp)	Aquaculture	1960s	Far east	Odessa, Kizilcay Region
Roccus saxatilis (Striped bass)	Aquaculture	1965-1972	Atlantic Ocean	Dnestrovsky
Plecoglossus altivellis (Salmon)	Aquaculture (Failed)	1963	Sea of Japan	Odessa
Salmo gaidneri (Steelhead trout)	Aquaculture (Failed)	1960s	Atlantic Ocean	Dnesterovsky
Oryzias latipes (Japanese medeka)	Aquaculture	1970s	Sea of Japan	Black and Azov Seas
Panaeus japonicas (Japanaese shrimp)	Aquaculture	1970s	Japan	Romania
Oncorhyncus keta (Far Eastern keta)	Aquaculture	1970s	Europe	USSR
Lateolabrax japonicas (Sea perch)	Aquaculture	1978	Japan	USSR
Dicentrarchus labrax (Seabass)	Aquaculture	1979	Mediterranean Sea	USSR
Crassostrea gigas (Giant oyster)	Aquaculture	1980	Sea of Japan	USSR
Mugil soiuy (Lisa haematocheila)	Acclimatization	1972–1980	Sea of Japan	USSR
Salmo salar (Salmon)	Aquaculture	1990	Norway	Turkey, Ukraine
Onchorhynchus mykiss (Rainbow trout)	Aquaculture	1970	Denmark	Turkey, Ukraine
Carassius auratus	Aquaculture	1900s	Southeast Asia	Ukraine
Micropterus salmonides	Aquaculture	Late 19th century	North America	Ukraine
Ictalurus nebulosus	Aquaculture	1935	North America	Ukraine
Ictalurus puncatus	Aquaculture	1935	North America	Ukraine
Perccottus glehni	Aquarium trade	1948	South Asia	Ukraine
Channa argus argus	Aquaculture	1950s	South Asia	Ukraine
Coregonus albula	Aquaculture	1950s	Holarctic	Ukraine
Tribolodon brandtii	Unintentional	1950s	Pacific	Ukraine
Aristichytys nobilis	Aquaculture	1953	Southeast Asia	Ukraine
Hypophthalmichthys molitrix	Aquaculture	1953	Southeast Asia	Ukraine
Coregonus nasus	Aquaculture	1954	Holarctic	Ukraine
Coregunus peled	Aquaculture	1954	Holarctic	Ukraine

Species	Purpose of introduction	Years	Origin of the species	Inoculation places
Ctenopharyngodon idella	Aquaculture	1954	Southeast Asia	Ukraine
Coregonus autumnalis	Aquacultrue	1957	Holarctic	Ukraine
Coregonus lavaretus	Aquaculture	1960s	Holarctic	Ukraine
Salmo ischchan	Aquaculture	1960	Sevan Lake	Ukraine
Mylopharyngodon piceus	Aquaculture	1961	Southeast Asia	Ukraine
Orchynchus gorbuscha	Aquaculture	1961	Pacific, Asia	Ukraine
Pseudobrasbora parva	Unintentional introduction	1990	Asia	Ukraine
Oreochromis mossambicus	Aquaculture	1996	Africa	Ukraine
Coregonus laveratus	Aquaculture	1965	Holarctic	Ukraine
Morone saxatilis	Aquaculture	1965	North America	Ukraine
Oreochromis niloticus	Aquaculture	1970s	Africa	Ukraine
Tilapia zilli	Aquaculture	1970s	Africa	Ukraine
Ictiobus bubalus	Aquaculture	1975	North America	Ukraine
Ictiobus cyprinellus	Aquaculture	1975	North America	Ukraine
Ictiobus niger	Aquaculture	1975	North America	Ukraine

Alien marine mammal species in the Black Sea

The white whale or beluga, Delphinopterus leucas, was captured in the Sea of Okhosk and accidentally released from the Sevastopol Aquarium into the Black Sea in 1991. The northern fur seal, Callorhinus ursinus, has been captured from the Bering Sea and accidentally released into the Black Sea. The Steller sea lion, Eumetopias jubatus, originally coming from the Sea of Okhotsk has also been accidentally released into the Black Sea. It should be noted that, except for native dolphins, the Black Sea is not hospitable for large fish-eating marine mammals (Zaitsev and Öztürk, 2001).

Lessons learnt for the Black Sea

The introduction of alien species in the Black Sea is still an ongoing process and needs to be monitored at the national, regional and international levels. A special monitoring programme is crucial for key areas such as Istanbul, Canakkale and the Kerch Straits, in order to better understand the dispersion patterns of alien species.

The impact of the alien species is complex and most of the time unpredictable due to the lack of monitoring and the lack of scientific knowledge about those species. Experts on alien species, such as taxonomists, should be trained and encouraged. Capacity-building for Black Sea riparian countries is essential for the monitoring of alien species. Moreover, initiatives for the management of databases on Mnemiopsis leidyi and other jellyfish species should be pursued and promoted by international organizations such as, for instance, the Black Sea Commission.

As a consequence of recent climate change and water temperature rise, some Mediterranean species, such as sardine, bouge and wrasse, have also penetrated into the Black Sea and fishing catch amounts are likely to change in the future. Mediterranean-originated species need therefore to be monitored in the Black Sea. General trends show that a miniature Mediterranean Sea is going to be established within the Black Sea since several species penetrate into the Black Sea with various vectors. Besides, alien species penetration into the Black Sea is putting pressure on autochthonous Black Sea endemic species, which retreat to brackish water areas and take refuge in estuaries and deltas. Among the impacts of alien species on native species, there may be a loss of ecological niches mostly in the mouths of rivers, such as the Danube, Dnieper, Dniester, Kizilirmak, Yesilirmak and Sakarya. Because of the low salinity of brackish water in the Black Sea, euryhaline and eurytherm species are more suitable to settle.

Due to overfishing, at the end of 1980s, the reduction of total fish biomass in the Black Sea to less than one third of its maximum value in the 1970s has caused a partial emptiness of the occupied ecological niche. According to the general rule “Natura abhoret vacuum” they have been occupied by invader planktophagous Mnemiopsis leidyi. Overfishing, therefore, should be avoided for all fish species in order to minimize the risk of alien species invasion.

Public awareness and sensibilization programmes for local people, fishers, boat crews, harbour masters and coast guards are needed in order to explain alien species and their impacts on nature, human health and fisheries. Fisheries cooperatives should also benefit from special education programmes to inform local fishers on the impacts of alien species.

Legal measures regarding the intentional introduction of alien species into the Black Sea should be taken by national authorities and within international conventions, such as the Convention on the Protection of the Black Sea Against Pollution (the Bucharest Convention) and the Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention).Besides ,The international convention for the control and management of ships, Ballast water and Sediments(BWM Convention) will enter in to force on 8 September 2017. This global treaty to halt invasive aquatic species can be facilitate international cooperation. İndeed essential point to combat alien invasive species in the entire ecosystem. The significant impacts of climate change and Mediterranization should also be taken into account for the Black Sea. Finally , Black Sea Environment Commision should continue to lead regionally alien species database to monitor and to predict future risk of biodiversity in the Black Sea.

2.1.5. Aquatic plants (algae and angiosperms of commercial importance)

Macrophytes along the Bulgarian Black Sea coast are not used with commercial purposes. Cystoseira are mass species in Black Sea with highest biomass and have commercial value. But in Bulgarian Black Sea coast, they are not extracted for commercial purposes. Researches of their quantities were carried out, to know if there are enough resources for commercial use. V. Petrova first investigated the quantities of Cystoseira species in 1966-1969 years. (Petrova V., 1975). From 2007 year till now (Dencheva, 2010), monitoring along the Bulgarian Black Sea coast was conducted and data for Cystoseira biomass were collected. Different polygons were visited and many samples were gathered (Fig. 2.1.5.1). On figure 2.1.5.2. biomass of Cystoseira genus calculated from these polygons is presented.

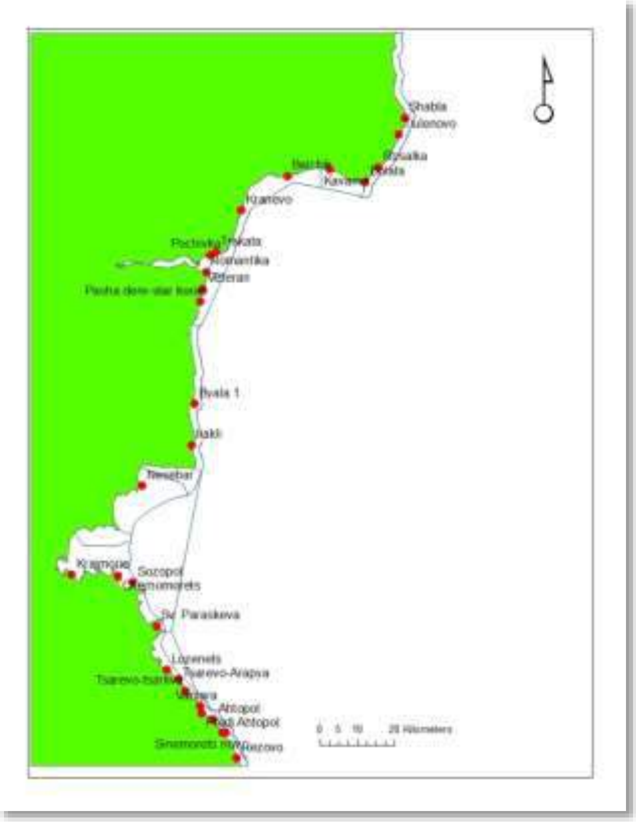


Figure 2.5.4.1. Sampling stations along the Bulgarian coast

The highest biomass was registered in south part of the Bulgarian coast.

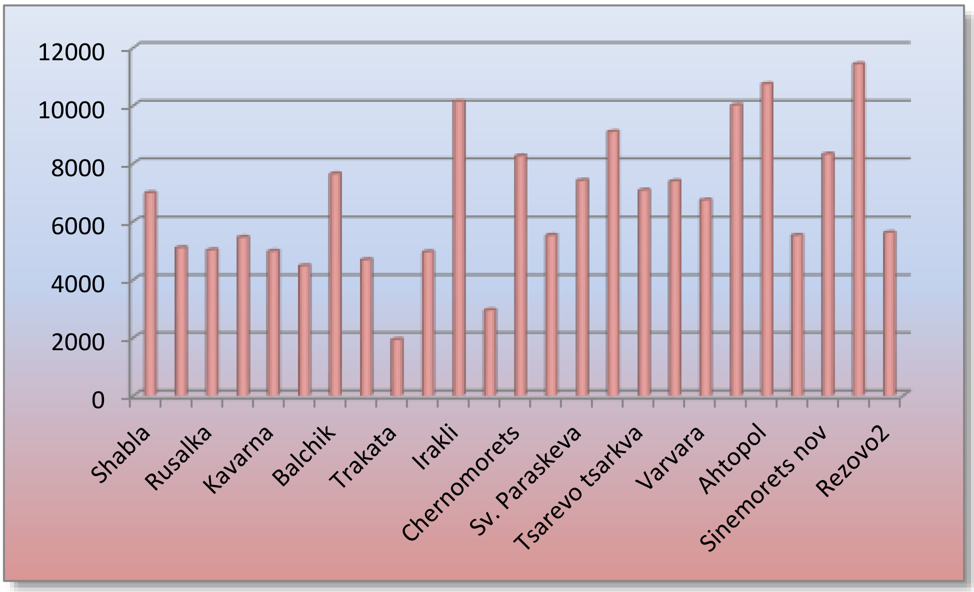


Figure 2.5.4.2. Biomass of Cystoseira genus (0-3m depth) from Bulgarian coast (2012-2016 years).

Petrova divided Bugarian coast to 5 main regions and the average biomass was calculated for them (Table 2.1.5.1). It is obvious that at present there is some degradation of Cystoseira biomass.

Table 2.5.4.1. Biomass of Cystoseira genus (0-3m depth) in kg.m-2 in different regions for two periods of investigation

▪ Region	▪ Dencheva(2012-2016)	▪ Petrova(1966-69)
▪ I	▪ 5.39	▪ 8.7
▪ II	▪ 4.2	▪ 7.4
▪ III	▪ 7.1	▪ 8.4
▪ IV	▪ 7	▪ 7.4
▪ V	▪ 8	▪ 9.7

Large meadows of Cystoseira with high quantities enough for some commercial purposes are spread especially in south part of Bulgarian Black Sea coast. But because of some degradation of Cystoseira biomass and lowering of depth distribution with increased eutrophication last decades, Cystoseira genus is protected from extraction with the Low of medicinal plants (http://lex.bg/laws/ldoc/2134916096).

2.2. BLACK SEA BIORESOURCES EXPLOITATION

Total catch in 2009-2014 is presented on fig.2.2.1.The peak of catches was in 2011, followed by the drop in 2012, rise in 2013 and then again drop in 2014. This fluctuation is most probably related to the changes in fishing effort in different countries, as well as with environmental conditions in the Black Sea and variations of fish stocks.

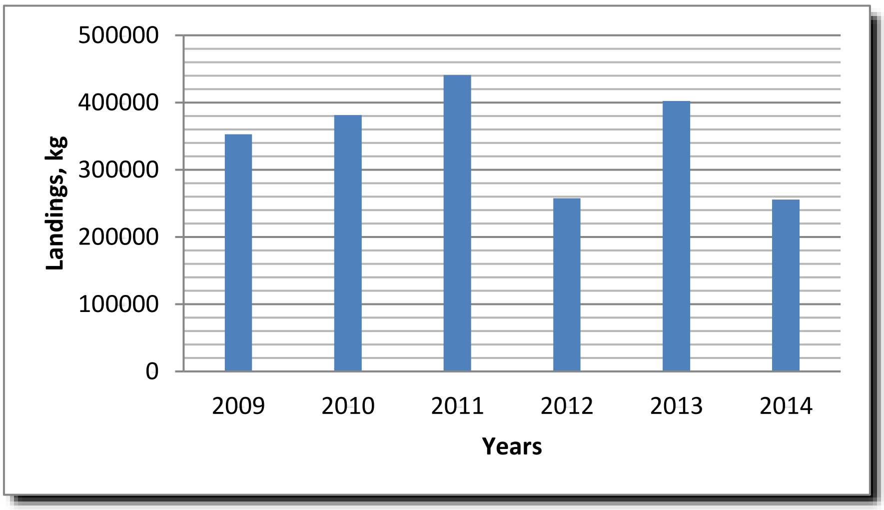


Figure 2.2.1. Total catch in Black Sea

In the following section, a summary of each country's fleet capacity is presented in terms of past and current operation. The gear types operated currently in these fleets are also discussed and classified according to the EU Metier Classification System where necessary (Birkun et al., 2014).

Romania (Birkun et al., 2014)Temporal Trends in Fleet Capacity

When searching for historical fleet capacity data for EU countries, various sources including the Eurostat database and viewable and downloadable data from the EU Community Fleet Register were utilised. Eurostat data refers to the situation of the national fleets on the 31st of December of the reference year and were last updated on the 18th of December 201317. Data from the Community Fishing Fleet Register can be searched by specific dates and are available from 2007 to the present day18 for Bulgaria and Romania. Length (LOA) of vessels is not used as an indicator of fleet capacity in this case as EU databases only publish summarised data on the number of vessels, power and tonnage.

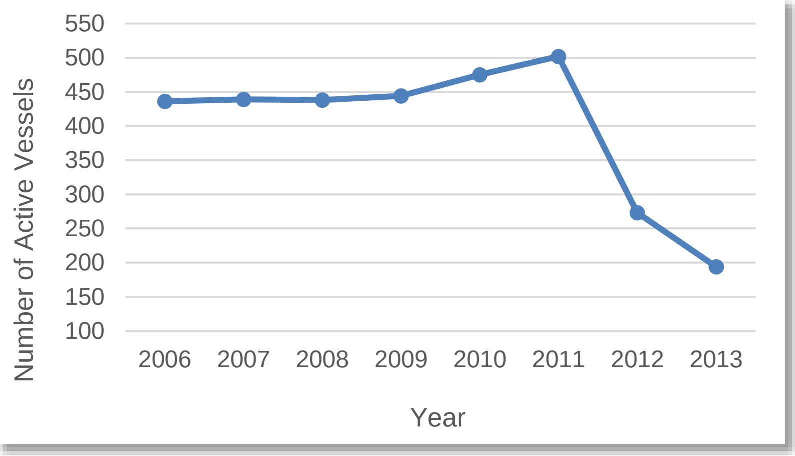


Figure 2.2.2.: Historical Trend in the Size of the Active Fleet in Romania. Source Eurostat. Data refers to the situation of the national fleets on the 31st of December of the reference year.

17 European Commission Eurostat Database: Select Agriculture, forestry and fisheries >> Fisheries (fish) >> and select the Fishing fleet (fish_fleet) data explorer. [Online] Available: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database [Accessed 15.08.2014].

18 European Commission Fleet Register on the Net: Select country under 'Simple search' option and filter results as necessary. [Online]. Available: http://ec.europa.eu/fisheries/fleet/index.cfm?method=Search.SearchSimple [Accessed 15.08.2014].

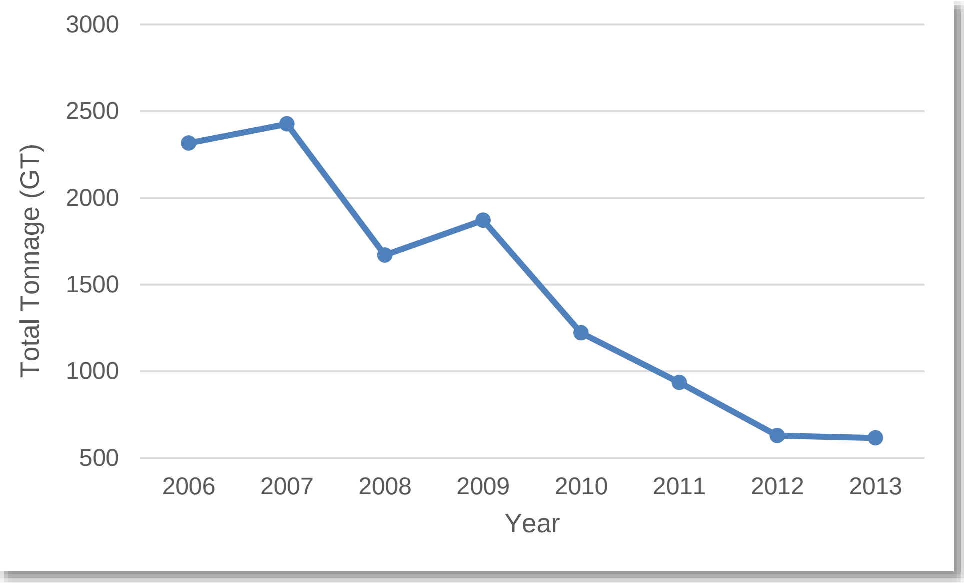


Figure 2.2.3. Historical Trend in Total Tonnage (GT) in the Romanian Active Fleet. Source Eurostat. Data refers to the situation of the national fleets on the 31st of December of the reference year.

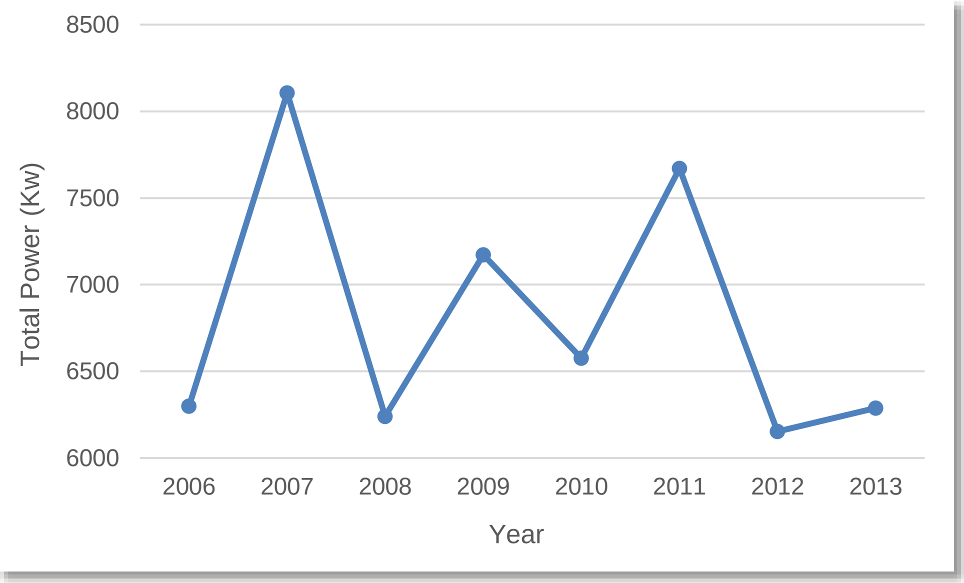


Figure 2.2.4: Historical Trend in Total Horsepower (Kw) in the Romanian Active Fleet. Source Eurostat. Data refers to the situation of the national fleets on the 31st of December of the reference year.

Figure 2.2.2 indicates that Romania's fleet has decreased in size since 2006 and particularly since 2011. The fleet in 2013 was at 38% of its size than in 2011.

Figure 2.2.3 shows that Romania's total tonnage (GT) has declined steadily since 2006, indicating that fish holding capacity has decreased over the years. There was no sharp decline in fish holding capacity in 2011, which suggests that the vessels that became inactive were those of the smaller tonnage classes.

Figure 2.2.4. shows peaks in total fleet horsepower in 2007, 2009 and 2011, indicating greater power available for fishing gear.

Generally, the capacity of Romania's fishing fleet and subsequently, the level of active fishing has declined. It has also been specifically reported that there are fewer larger fishing vessels in the active fleet. In 2010, there were 20 vessels with LOA between 24-40m registered, but in the past years, only one or two vessels were active for a very short period of time. Also depending on the years, only 1 or 2 vessels of LOA over 12m have been active in Romania[19].

Current Fleet Capacity

Table 2.2.1. below represents the current capacity of the Romanian active fleet. Data were obtained from the EU Fleet Community Register on 29/7/2014. This information is more up-to-date than that published in Romania's National Programme.

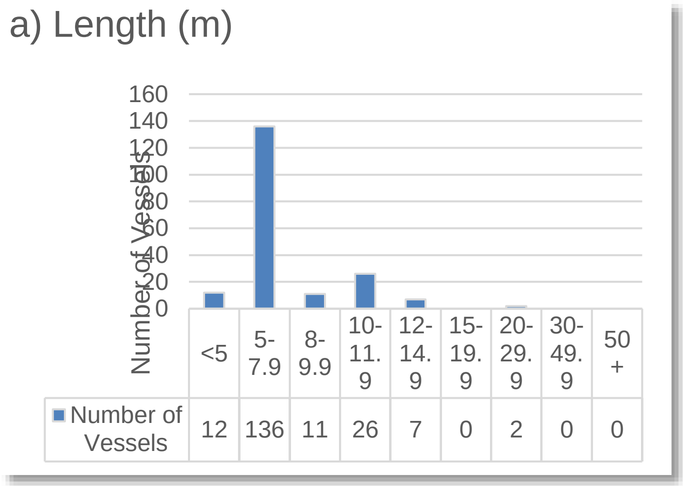
Note here that length, tonnage and power data have been grouped into categories based on those used by the Turkish Statistical Institute. Turkish vessel data are not available in raw form (i.e. individual vessel length, tonnage and power records are already published to grouped categories) so sorting by EU DCF categories was not possible.

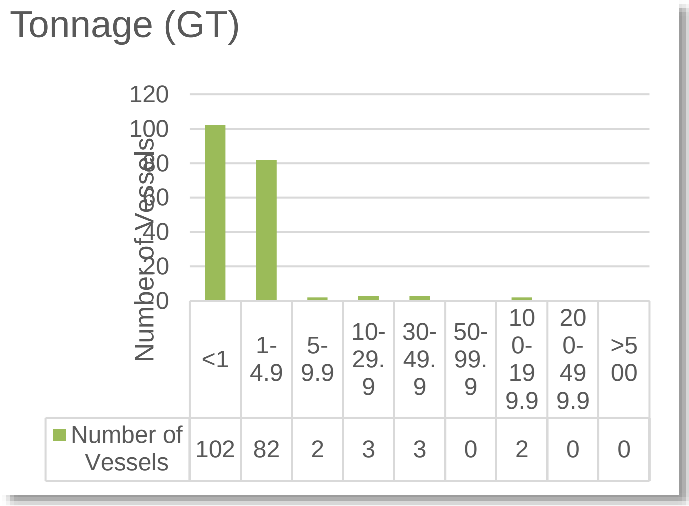
Table 2.2.1: Current Romanian Fleet Capacity (28/5/2014)

Length/LOA (m)	**Number of Vessels**
<5	12
5-7.9	136
8-9.9	11
10-11.9	26
12-14.9	7
15-19.9	0
20-29.9	2
30-49.9	0
50+	0
Tonnage (GT)	**Number of Vessels**
<1	102
1-4.9	82
5-9.9	2
10-29.9	3
30-49.9	3
50-99.9	0
100-199.9	2
200-499.9	0
>500	0
Kw	**Number of Vessels**
0	63

19 Cervera, J., Salz, P., Alberti-Schmitt, C., Petereit, C. and Azorin, E. (2014). Country Report: Fieldwork Mission to Romania. Contract: "Field work specific contract for Lithuania, Romania, Spain and United Kingdom", has been implemented within the framework contract, MARE/2009/08 "Assistance for the monitoring of the implementation of national programmes for the collection, management and use of data in the fisheries sector", funded by the DG Mare. [Online]. Available: http://ec.europa.eu/fisheries/documentation/studies/data/documents/romania-report_en.pdf [Accessed 15.08.2014].

1-9.9	53
10-19.9	17
20-49.9	26
50-99.9	14
100-199.9	17
200-499.9	3
>500	1
Total number of Active Vessels	**194**





Active Vessels: 194

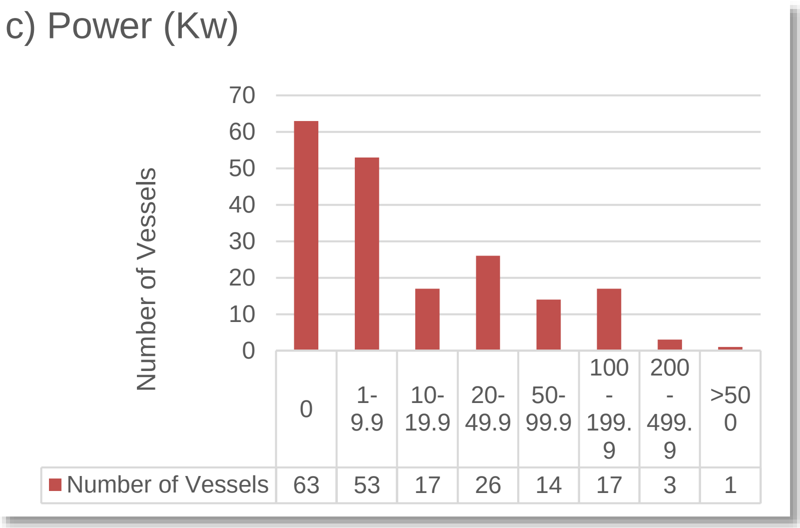


Figure 2.2.5.: Romanian Fleet Capacity: Length (m), Tonnage (GT) and Power (Kw) of the Active Fleet (as of 29/07/2014).

Figure 2.2.5.a above indicates that the majority (70%) of the fleet are between 5 and 7.9m in length, followed by a small number (13%) between 10 and 11.9 m. There are no vessels over 30m and very few under 5m. Figure 2.2.5.b indicates that the majority (94%) of the fleet have a gross tonnage less than 4.9, and no vessels with a GT of over 20. Figure 2.2.5.c indicates that the fleet exhibits a range of power across the categories but that most vessels (69%) are under 9.9 Kw.

Gear Types and Metiers

Figure 2.2.6. below represents the number of vessels operating specific gear types. They are presented as main and secondary gear types. Data were downloaded from the EU Fleet Community Register on 28/5/2014. See Table 2.2.2. for EU gear code descriptions.

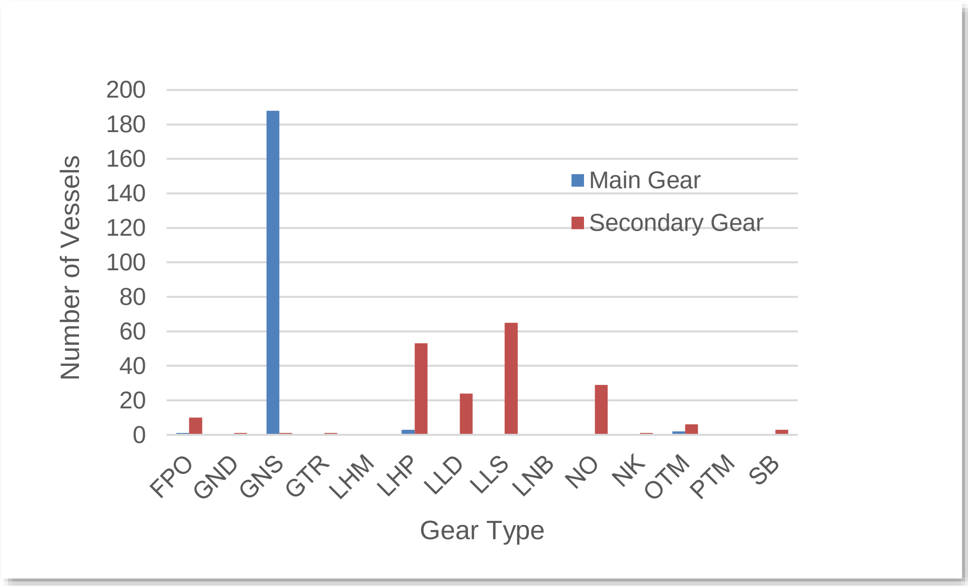


Figure 2.2.6. Gear Type Utilisation in the Romanian Active Fleet (As of 30th July 2014)

Table 2.2.2.: EU Gear Code Descriptions

EU Gear Code	Gear Type Description
FPO	Pots and traps
GND	Drift nets
GNS	Set gillnets (anchored)
GTR	Trammel nets
LHM	Hand lines and pole-lines (mechanised)
LHP	Hand lines and pole-lines (hand operated)
LLD	Drifting long lines
LLS	Set long lines
LNB	Boat-operated lift nets
PS	Purse seines
DRH	Hand dredges operating from a boat
NO	No gear

EU Gear Code	Gear Type Description
NK	Unknown gear
OTM	Mid-water otter trawls
OTB	Bottom otter trawls
PTM	Mid-water pair trawls
SB	Beach seines

Table 2.2.2. shows a peak in the GNS category, indicating that most of the active fleet (96%) are using set gillnets as their main gear type. Other common gear types are various types of hooks and lines.

According to the National Programme of 2013, the Romanian fleet uses only selected metiers. As active gears, mid-water otter trawls (OTM) and beach seines (SB) are used. As passive gears, stationary uncovered pound nets (FPN) and pots and traps (FPO) are applied. Other passive gear types are gillnets (GNS), long lines (LLS) and hand and pole lines (LHM).

Figure 2.2.6. above indicates that similar gear types are being utilised to those in 2013, except for uncovered pounds nets (FPN) that were reported in 2013 only, and drifting long lines that are now being operated in 2014. It must be noted that FPN does not exists as a gear type on the EU Fleet Register and may be grouped into the pots and traps (FPO) category.

Romania proposed the following metiers at level 6 of the EC's Mediterranean Sea and Black Sea Fishing Metier classification system**Error! Bookmark not defined.** in their National Programme of 2 013**[4]** (Table 2.2.3.).

Table 2.2.3.: Metiers operated in the Romanian Fleet (2013). Table adapted from that published in Romania's National Programme.

Metier Level 6	National metier	Target species	Space strata	Time strata
OTM_MPD_14_0_0	Mid-water otter trawls targeting mixed pelagic and demersal fish	Sprat	37.4.2	Quarterly, estimates between April and November.
'Misc._FPN_MPD_14_0_0	Stationary uncovered pound nets targeting mixed pelagic and demersal fish	Sprat, anchovy, horse mackerel	37.4.2	Quarterly, estimates between April and September.
GNS_DEF_400_0_0	Set anchored gillnets targeting demersal fish	Turbot	37.4.2	Quarterly, estimates between March and November.
LHP-LHM_FIF_0_0_0	Hand operated and mechanised hand-lines and pole-lines targeting finfish	Gobies	37.4.2	Quarterly, estimates between April and October.

Metier Level 6	National metier	Target species	Space strata	Time strata
LLS_DEF_0_0_0	Set long lines targeting demersal fish	Gobies and dogfish	37.4.2	Quarterly, estimates between April and October.

The metier level 6 code FPN_MPD_14_0_0 was changed to Misc_FPN_MPD because there were no combinations of the gear FPN with the target species MPD in the Commission decision 949/2008**[4]**

In summary, according to the latest EU Fleet Register data, the Romanian active fleet appears to consist mainly of small (<7.9m, <4.9 GT, <49.9Kw) boats operating set gillnets.

Bulgaria

Temporal Trends in Fleet Capacity

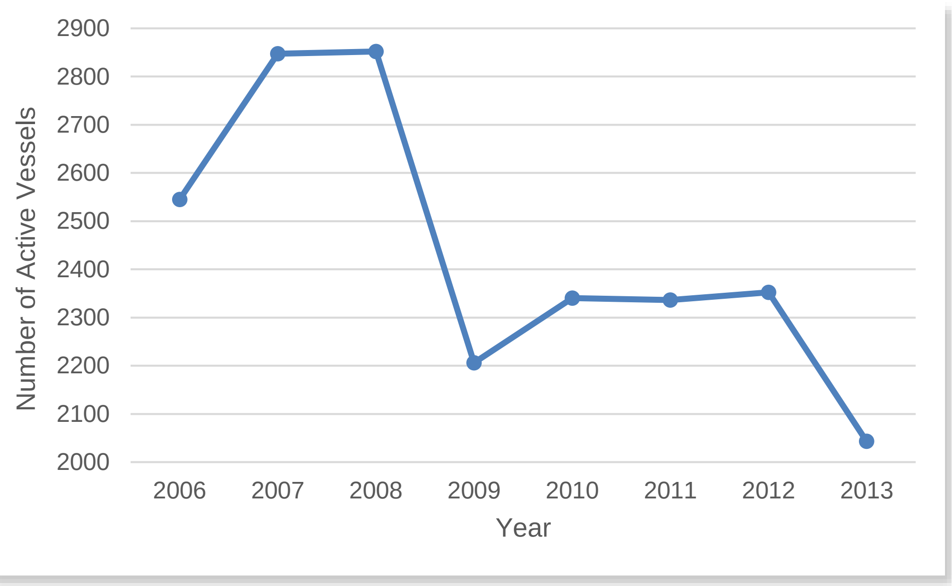


Figure 2.2.7.: Historical Trend in the Size of the Active Fleet in Bulgaria. Source Eurostat. Data refers to the situation of the national fleets on the 31st of December of the reference year.

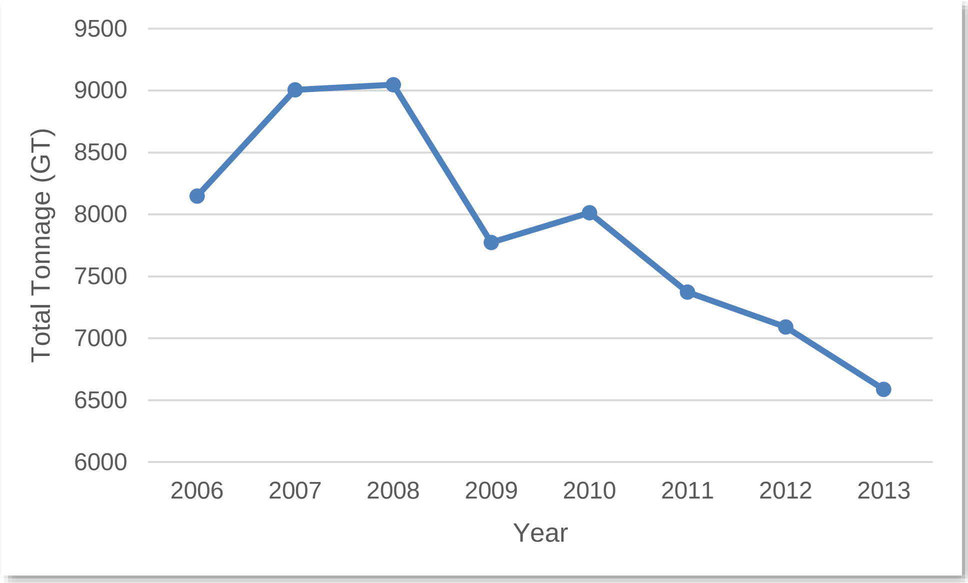


Figure 2.2.8.: Historical Trend in Total Tonnage (GT) in the Bulgarian Active Fleet. Source Eurostat. Data refers to the situation of the national fleets on the 31st of December of the reference year.

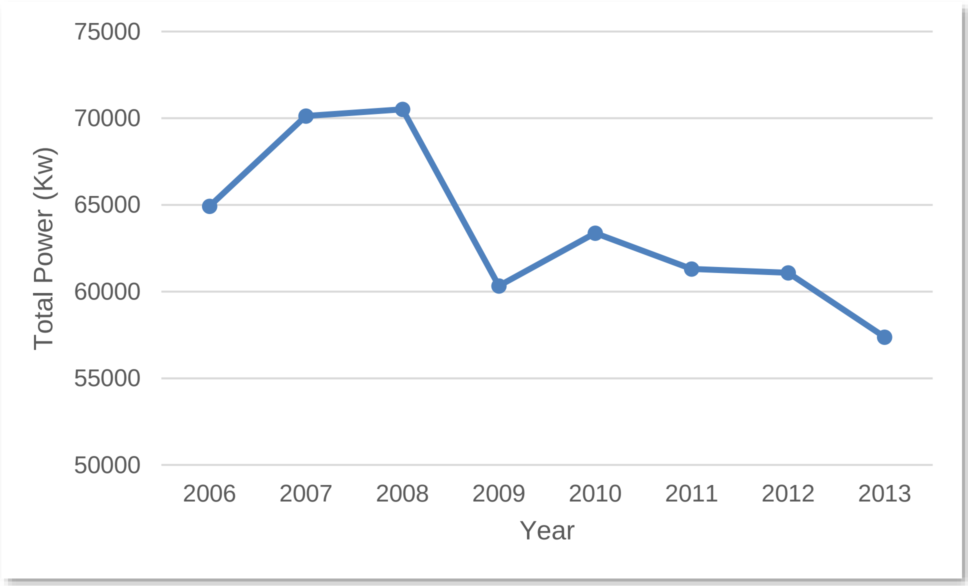


Figure 2.2.9. Historical Trend in Total Horsepower (Kw) in the Bulgarian Active Fleet. Source Eurostat.

Data refers to the situation of the national fleets on the 31st of December of the reference year.

Figure 2.2.7 indicates that overall, Bulgaria's fleet has decreased in size since 2006 by around 500 vessels. Fleet size increased since from 2006-2008 (the fleet contained a maximum of number of 2852 vessels) and from 2009 to 2011/12. Figure 2.2.8 and Figure 2.2.9 show similar trends, indicating that fish holding capacity and power available for fishing gear has decreased over the years in the Bulgarian fleet.

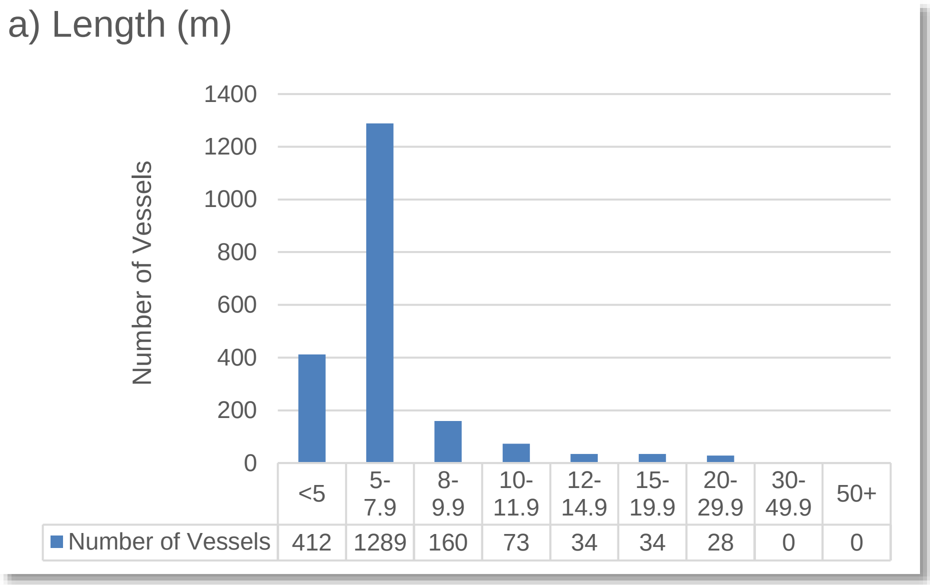
These figures must be interpreted with caution as it has been reported that in in 2008, only 716 vessels were actually active**Error! Bookmark not defined.**.

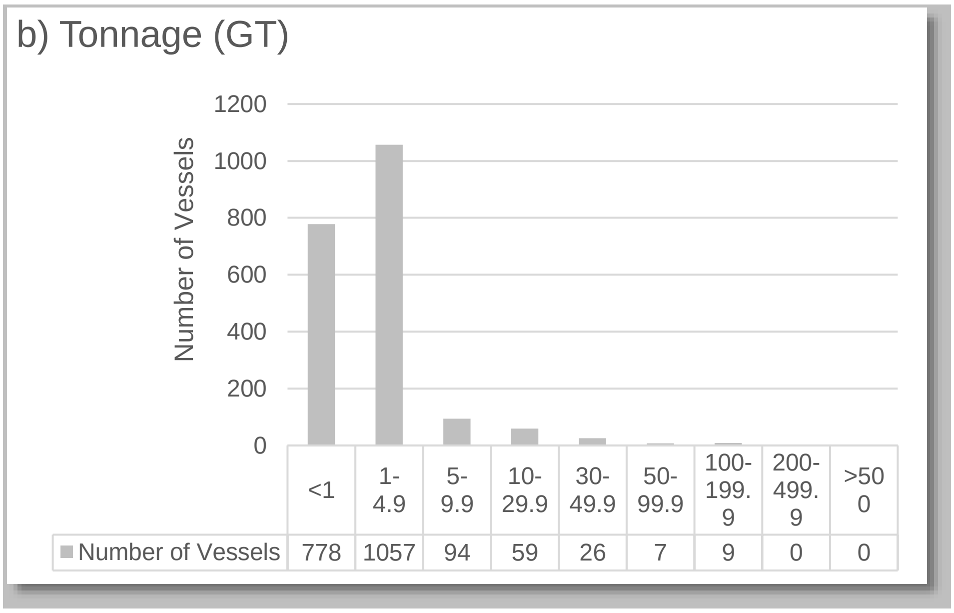
Current Fleet Capacity

Table 2.2.4. and Figure 2.2.10. below represent the current capacity of the Bulgarian active fleet. Data were obtained from the EU Fleet Community Register on 29/7/2014. This information is more up-to-date than that published in Bulgaria's National Programme, representing data from 2011-2013.

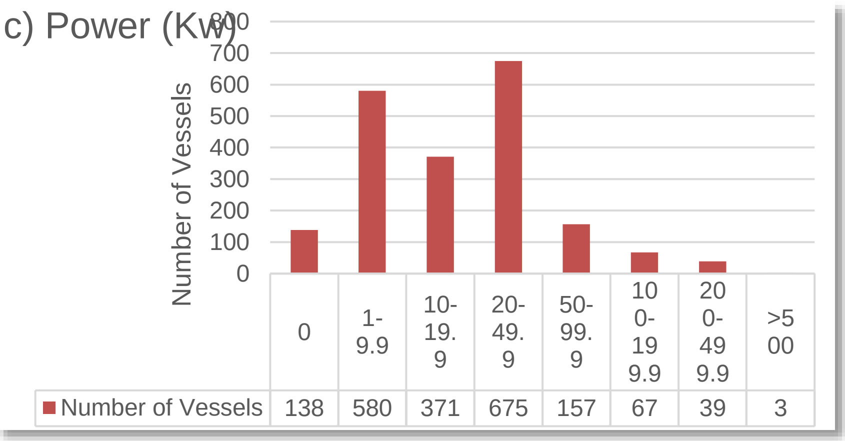
Table 2.2.4: Current Bulgarian Fleet Capacity (28/5/2014)

Length/LOA (m)	Number of Vessels
<5	412
5-7.9	1289
8-9.9	160
10-11.9	73
12-14.9	34
15-19.9	34
20-29.9	28
30-49.9	0
50+	0
Tonnage (GT)	**Number of Vessels**
<1	778
1-4.9	1057
5-9.9	94
10-29.9	59
30-49.9	26
50-99.9	7
100-199.9	9
200-499.9	0
>500	0
Kw	**Number of Vessels**
0	138
1-9.9	580
10-19.9	371
20-49.9	675
50-99.9	157
100-199.9	67
200-499.9	39
>500	3
Total number of Active Vessels	**2030**





Active Vessels: 2030



Figures 2.2.10. a-c: Bulgarian Fleet Capacity: Length (m), Tonnage (GT) and Power (Kw) of the Active Fleet (as of 29/07/2014)

Figure 2.2.10.a above indicates that the majority of the fleet (84%) are below 7.9m in length. There are no vessels over 30m. Figure 2.2.10.b indicates that nearly all vessels have a GT under 4.9. Figure 2.2.10.c indicates that the fleet exhibits a range of power across the categories but most vessels (80%) have values between 1 and 49.9 Kw.

Gear Types and Metiers

Figure 2.2.11. below represents the number of vessels operating specific gear types. They are presented as main and secondary gear types. Data were downloaded from the EU Fleet Community Register on 28/5/2014. See Table 2.2.5. for descriptions of EU gear codes.

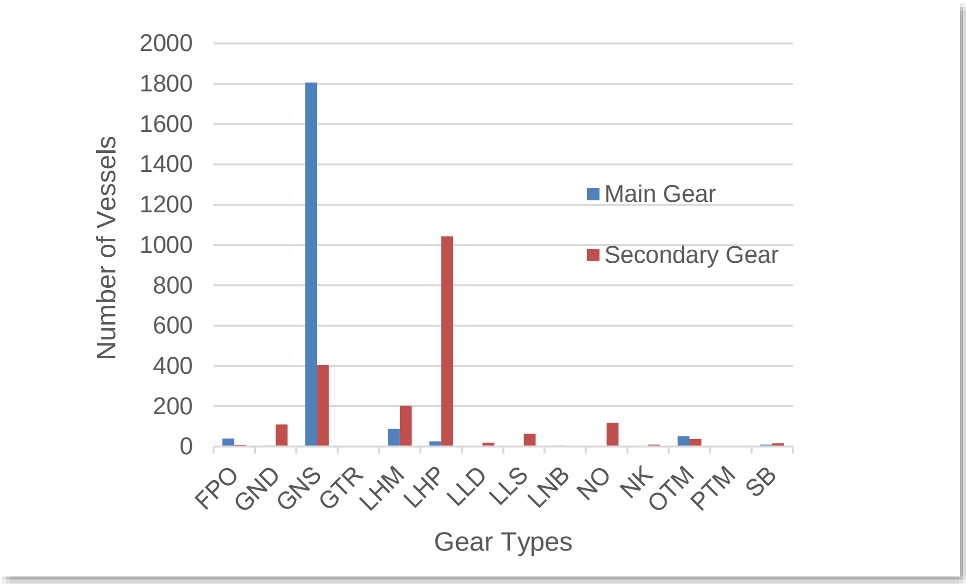


Figure 2.2.11.: Gear Type Utilisation in the Bulgarian Active Fleet (As of 30th July 2014)

Figure 2.2.11. shows a peak in the GNS category, indicating that most of the active fleet (89%) are using set gillnets as their main gear type. Other common gear types are hand-lines and pole-lines, as secondary gears.

Various metiers, based on Bulgaria's fishing activity were proposed in Bulgaria's latest National Programme (2013), but are based on 2009 data. In 2009, the majority of the active fleet (90%) operated set gillnets (GNS) as their main gear. Other gears in use included mid-water otter trawls (OTM), set long lines (LLS) and stationary uncovered pound nets (FPN). It was also reported that generally, vessels between 12 and 24m LOA were reported to perform pelagic trawling and gillnet fishing.

Figure 2.2.11. above indicates that set gillnets are still the most widely used gear type. The use of GNS has also increased since 2009 – currently 1805 vessels operate the gear type compared to 1307 vessels in 2009. Changes in gear types over the years are also seen whereby hand lines and pole lines are now widely used (1042 vessels using LHP as secondary gear, 2014), as opposed to the use of set long lines in 2009. The numbers of vessels using mid-water otter trawls has reduced from 67 in 2009 to 51 in 2014. See Table 2.2.5. below for the detailed 2009 segmentation of the Bulgarian active fleet.

Table 2.2.5.: Segmentation of the Bulgarian active Fishing Fleet per category of fishing technique (main fishing gear) and length. Data based on 2009.**[4]**

Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**LOA classes (m)**						
Activity	Gear classes	Gear group	Gear type	Target assemblage	Mesh size and other selective devices	< 6	6 > 12	12 > 18	18 > 24	24 > 40	40 +	Total
Fishing activity	Trawls	Pelagic trawls	Mid-water otter trawl [OTM]	Mixed demersal and pelagic species	13-20_0_0	0	9	31	17	10	0	**67**
	Hooks and Lines	Long lines	Set long lines [LLS]	Demersal fish	0_0_0	4	10	9	10	0	0	**33**
	Traps	Traps	Stationary uncovered pound nets [FPN]	Pelagic fish	12-16_0_0	11	27	0	0	0	0	**38**
	Nets	Nets	Set gillnet [GNS]	Small and large pelagic fish Demersal species	400_0_0	473	786	34	14	0	0	**1307**

Bulgaria proposed the following metiers at level 6 of the EC's Mediterranean Sea and Black Sea Fishing Metier classification system **[10]** in their National Programme of 2013 **[3]** These data are based on those from 2008 (Table 2.2.6.). The same level of detail is not given as it is for Romania.

Table 2.2.6. Metiers operated in the Bulgarian Fleet (2009). Table adapted from that published in Bulgaria's National Programme **[3]**

Metier Level 6	**National metier**	**Fishing ground**
OTM_MPD_13-20_0_0	Mid-water otter trawls targeting mixed pelagic and demersal fish.	GSA29

Metier Level 6	**National metier**	**Fishing ground**
GNS_DEF_400_0_0	Set anchored gillnets targeting demersal fish	GSA29
Misc_FPN_MPD	Stationary uncovered pound nets targeting mixed pelagic and demersal fish	GSA29
LLS_DEF_0_0_0	Set long lines targeting finfish	GSA29

In summary, according to the latest EU Fleet Register data, the Bulgarian active fleet appears to consist mainly of small (<7.9m, <4.9 GT, <49.9Kw) boats operating set gillnets and hand/pole lines.

Ukraine

Temporal Trends in Fleet Capacity

With no official or national data reporting in Ukraine relating to fleet capacity, historical changes in this sector can only be estimated from various reports. This is summarised in Table 2.2.7. below.

Table 2.2.7. Historical Estimates of Ukrainian Fleet Size.

Year	**Estimated Number of Fishing Vessels in the Black Sea**	**Source**
1991	600	World Fishing and Aquaculture**[20]**
1999	123 (industrial oceanic fleet only)	World Fishing and Aquaculture**[20]**
2006	142	GFCM **[18]**
2007	135	GFCM **[18]Error! Bookmark not defined.**
2008	123	GFCM. **[18]**
2008	2300	Duzgunes, E., & Erdogan, N. (2008) **[13]Error! Bookmark not defined.**
2013	3 (industrial oceanic fleet only)	World Fishing and Aquaculture **[20]**

Results are difficult to interpret as sometimes only sections of the fleets are reported (i.e. industrial oceanic sector). Estimates also vary dramatically for 2008, which may be due to the reported value of 2300 considering both inactive and active vessels. The original source of this value was not provided by Duzgunes, E., & Erdogan, N. (2008) **[13]** so cannot be validated.

One identifiable trend is seen in the GFCM data whereby estimates suggest that from 2006 to 2008, there was a reduction (13.4%) in the number of fishing vessels. It has also been reported that over the last few years the Ukrainian fishing fleet has almost disappeared, due to a lack of funding for its modernisation20.

It is therefore assumed that the Ukrainian fleet has limited capacity, which has been declining since at least 2006.

However, a new state program involving the restoration of natural fish spawning grounds and the reduction of taxes on domestic fishermen, amongst other plans, should create conditions for the recovery of the Ukrainian fishing fleet. If successful, the program will involve the construction of 5 trawlers before 2016, expected to operate in the Black Sea region20.

Current Fleet Capacity

Table 2.2.8. and Figure 2.2.12. below represent the capacity of the Ukrainian active fleet, as of 2012. Data were obtained from the Ukrainian national teams. Up-to-date information was not available.

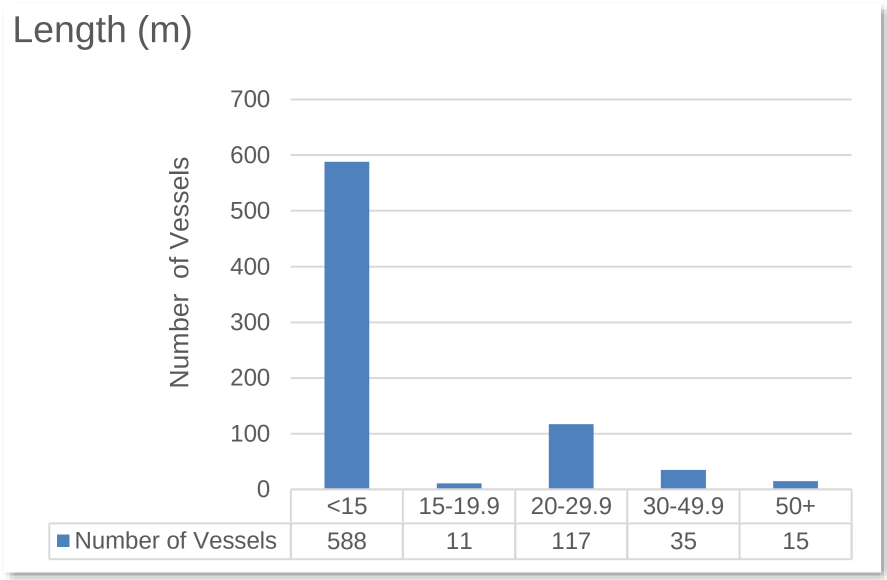
Table 2.2.8: Current Ukrainian Fleet Capacity (2012 **[14]**)

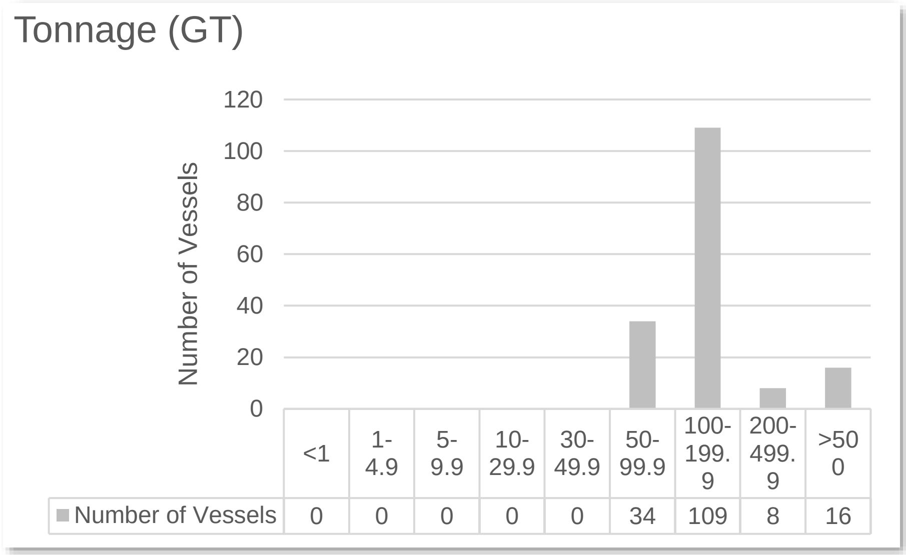
Length/LOA (m)	**Number of Vessels**
<5	
5-7.9	
8-9.9	
10-11.9	
12-14.9	588
15-19.9	11
20-29.9	117
30-49.9	35
50+	15
Tonnage (GT)	**Number of Vessels**
<1	
1-4.9	
5-9.9	No data
10-29.9	3
30-49.9	8
50-99.9	34
100-199.9	109
200-499.9	8
>500	16
Kw	**Number of Vessels**
0	
1-9.9	
10-19.9	
20-49.9	No data
50-99.9	2
100-199.9	103

20 World Fishing and Aquaculture (2013). Development Plans for Ukrainian Fisheries (Article) [Online]. Available: http://www.worldfishing.net/news101/regional-focus/development-plans-for-ukranian-fisheries [Accessed 18.08.2014].

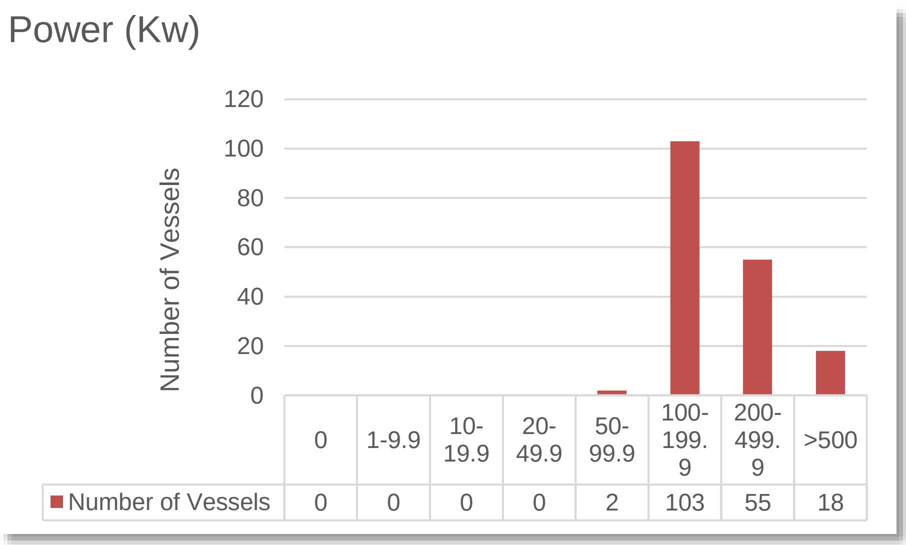
200-499.9	55
>500	18
Total number of Active Vessels	**766**

Note: the total number of active vessels differs between length, tonnage and power groupings as no data were given for the low power and low tonnage classes. The size of the active fleet has been estimated from the maximum given; 766





Active Vessels: 766



Figures 2.2.12. a-c: Ukrainian Fleet Capacity: Length (m), Tonnage (GT) and Power (Kw) of the Active Fleet.

Figure 2.2.12 a above indicates that the majority (76%) of the fleet are below 15m in length, although 15% of the fleet range between 20 and 29.9 m. There are very few vessels over 50m. There are no tonnage or power data for the under 15m sector of the fleet and the full active fleet is not presented in Figures 2.2.12b&c. However, the data provided indicate that a significant proportion of the fleet fall in the 100-199.9 GT and Kw category.

Gear Types and Metiers

Data regarding the possible gear types and metiers in use in the Ukrainian fleet have been estimated by national teams **[14].** Table 2.2.9. and Figure 2.2.13. below show this information.

Table 2.2.9.. The list of permitted for the Black Sea (except of Zones of Integral Protection) fishing gears **[14]**

No	Target species	Fishing grounds	Fishing gears
1	*Alosa pontica*	The Black Sea (except the Karkinitsky Bay), the Dniester, Dnieper and Bug Limans	Shad gillnets **(S)**
2	*A. caspia*	Dnieper and Bug Limans	Gill nets **(S)**
3	*Clupeonella cultriventris, Gobiidae*	Dnieper, Bug and Berezansky Limans	Burilo (small trawls) **(S)**
4	*Engraulis encrasicolus ponticus, Mugilidae, Mugil soiuy, Sarda sarda, Scomber scombrus, Pomatomus saltator*	The Black Sea (except the Karkinitsky Bay)	Purse seines **(PD)**
5	*E. e. maeoticus*	In the Black Sea eastwards of the meridian which passes through Khersones Cape	Purse seines **(PD)**
6	*Gobiidae*	The Black Sea, in the Black Sea estuaries	Trap nets **(S)**, beach seines **(S)**, gobies gillnets **(S)**
7	*Merlangius merlangus, Sprattus sprattus*	The Black Sea (except grounds closed for the trawl fisheries)	Midwater **(PD)** and midwater pair trawls **(PD)**
8	*Mugilidae*	The Black Sea	Trap nets **(S)**, beach seines **(S)**
9	*Mugilidae*	In the Black Sea limans, except Dniester, Dnieper and Bug Limans	Beach seines **(S)**
10	*Mugil soiuy*	The Black Sea	Trap nets **(S)**
11	*M. soiuy, Trachurus mediterraneus ponticus*	The Black Sea	Cast nets **(S)**
12	*M. soiuy, Platichthys flessus luscus*	The Black Sea (except the Karkinitsky Bay)	Gill nets **(S)**
13	*Mullus barbatus*	The Black Sea	Beach seines **(S)**
14	*Psetta maxima*	The Black Sea	Turbot gillnets **(PD)**
15	*Rajiformes, Squalus acanthias*	The Black Sea southwards the line joining Tarkhakut Cape and the Dniester-Tzargorod	Long lines **(PD)**, bottom nets for dogfish **(PD)**

No	Target species	Fishing grounds	Fishing gears
		Lighthouse and eastwards the meridian 30° 00′ E	
16	*T. m. ponticus*	The Black Sea from Meganom Cape to Cape Lukul	Lift cone-shaped nets with electric light attraction **(S)**,
17	*Mytilus galloprovincialis, Rapana venosa*	The Black Sea	Hand harvesting **(S)**
18	*M. galloprovincialis, R. venosa*	The Black Sea (except the Karkinitsky Bay)	Khizhyak's dredge **(S)**
19	*Natantia*	The Black Sea	Beach seines **(S)**, hand harvesting **(S)**
20	*Amphypoda*	The Black Sea, in the Black Sea Limans	Beach seines, hand harvesting **(S)**
21	*Phyllophora spp*	The Black Sea (except the Karkinitsky Bay)	Kitran's trawl **(PD)**
22	*Zostera marina, Cystoseira barbata*	The Black Sea	Reaping-hooks **(S)**, mowers **(S)**, hand harvesting of stormy discards **(S)**
23	Non target fishing	The Black Sea	Pound nets **(PD)**, Bottom trap nets **(S)**, Beach seines **(S)**

* **PD** – potential risk of cetacean by-catch; **S** – no risk of cetacean by-catch.

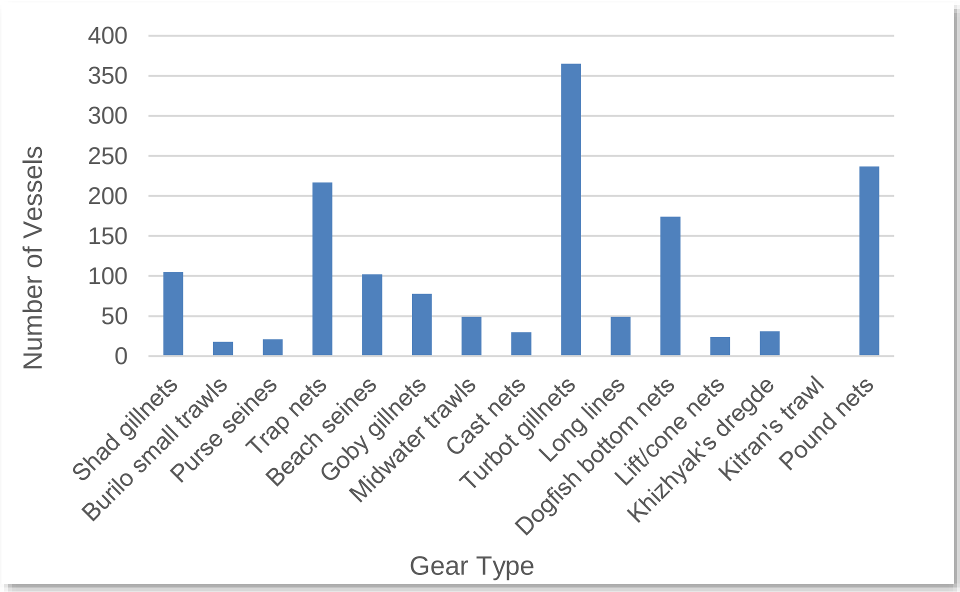


Figure 2.2.14.: Gear Type Utilisation in the Ukrainian Active Fleet (As estimated by national teams in May 2014)

Gear types have been matched to EU Gear Codes as closely as possible to enable subsequent comparison between countries. This is shown below in Table 2.2.10 and Figure 2.2.15.

Table 2.2.10.: Gear Types Utilised in the Ukrainian Fleet and Matched to EU Gear Codes.

Gear Type	Corresponding EU Gear Code	Number of Vessels
Shad gillnets	GNS – Set gillnets (anchored)	105
Burilo small trawls	OTB – Bottom otter trawls	18
Purse seines	PS – Purse seines	21
Trap nets	FPO – Pots and traps	217
Beach seines	SB – Beach seines	102
Goby gillnets	GNS - Set gillnets (anchored)	78
Mid-water trawls	PTM – Mid-water pair trawls	49
Cast nets	NK – Unknown gear	30
Turbot gillnets	GNS - Set gillnets (anchored)	365
Long lines	LLS – Set long lines	49
Dogfish bottom nets	GNS - Set gillnets (anchored)	174
Lift/cone nets	LNB – Boat-operated lift nets	24
Khizhyak's dredge	DRH – Hand dredges operated from a boat	31
Kitran's trawl	OTB – Bottom otter trawls	0
Pound nets	FPO – Pots and traps	237

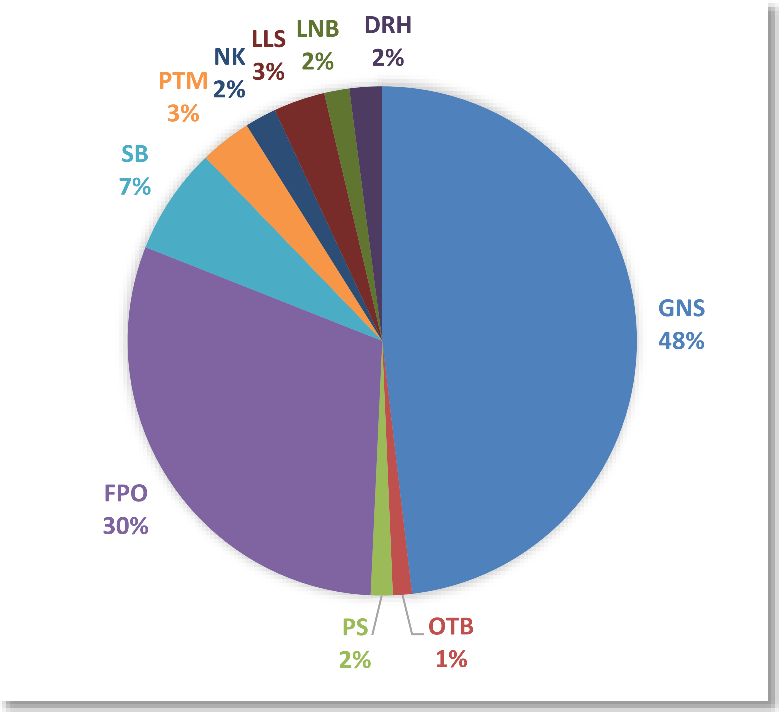


Figure 2.2.15. The Number of Vessels Utilising Different Gear Types (in terms of EU codes) in the Ukrainian Fleet.

It is important to note that the total number of vessels assigned to various gear types here (1500) exceeds the total given by national teams for fleet capacity data (788). These data rely on estimations from personal observations of the national teams and therefore, results must be interpreted with caution. The true size of the active fleet is unknown.

Figure 2.2.15. indicate that nearly half (48%) of the fleet are likely to be using set gillnets, mostly targeting turbot (24%), but also dogfish (12%), shad (7%) and gobies (5%). A significant proportion of the fleet appear to be operating gear in the FPO category (30%), which consist of pound nets and trap nets targeting mullet and other non-target demersal species. A small proportion of the fleet (7%) appear to operate beach seines targeting gobies, mullet, shrimp and other non-target demersal species.

National team members also provided data in greater detail, specifically for the number of turbot gillnets in use, as these nets are known to be the greatest risk to cetaceans in terms of by-catch. These estimates were based on a series of calculations using data obtained from the UFFS, YugNIRO and reports of the Ministry of Agrarian Policy and Food of Ukraine and are shown below in Table 2.2.11. (data selected for 2013).

Table 2.2.11. Distribution of boats by length and the number of gillnets in use with a mesh size of 180-200 mm **[14]**

Length (m)	**Vessel number**	**Number of Turbot Gillnets**
5-7,9	229	4580
8-9,9	66	1320
10-11,9	65	1300
12-14,9	1	100
15-19,9	2	200
20-29,9	2	200
Totals	365	7700

The following main metiers have been proposed for Ukraine's fleet, based on data provided by national teams and from the GFCM21 that has been matched to EU metier classification **[10]**:

Table 2.2.12. Proposed Metiers operated in the Ukrainian fleet (2012-14) based on the EU metier classification.

Metier Level 6	**National metier**	**Target Species**
GNS_DEF_100-200_0_0	Set anchored gillnets targeting demersal fish	Turbot, shad, dogfish, gobies.
FPO_ DEF_0_0_0	Pots and traps targeting demersal fish	Mullet and other non-target demersal species.

21 GFCM. Database on National Fisheries Legislation: Ukraine. [Online]. Available at: http://nationallegislation.gfcmsecretariat.org/index.php?title=Ukraine [Accessed: 01.08.2014].

Metier Level 6	National metier	Target Species
BS_DEF_0_0_0	Beach seines targeting demersal fish	Mullet and other non-target demersal species.
PTM_SPF_0_0_0	Mid-water pair trawls targeting small pelagic fish	Sprat and whiting

In summary, according to the data provided by the national team, the Ukrainian fleet appears to consist mainly of small boats under 15m, albeit without any data for tonnage and power. This sector of the fleet is likely to operate the set gillnet metier. The larger boats for which tonnage and power data have been provided, may operate other metiers, such as the mid-water trawls.

Turkey

Temporal Trends in Fleet Capacity

Historical data relating to fleet capacity is limited and is based on that published in various reports. This is summarised below.

Table 2.2.13.: Historical Estimates of Turkish Fleet Size.

Year	Estimated Number of Fishing Vessels in the Black Sea	Source
2007	6631	Saglam and Duzgunes (2010)22 via Turkish Statistical Institute
2008	7308	Duzgunes, E., & Erdogan, N. (2008)[13]
2008	6597	Turkish Statistical Institute [16]**Error! Bookmark not defined.**
2009	5973	Turkish Statistical Institute [16]**Error! Bookmark not defined.**
2010	5937	Turkish Statistical Institute[16]
2011	4993	Turkish Statistical Institute[16]
2012	5113	Turkish Statistical Institute[16]

22 Saglam, N. E., & Duzgunus, E. (2010). Comparative approach to analyze fishing fleet profile of Turkey and European Union as an indicator of fishing effort.*Scientific Research and Essays*, *5*(21), 3572-3584.[Online]. Available: http://www.academicjournals.org/article/article1380534981_Saglam%20and%20Duzgunes.pdf [Accessed 18.08.2014].

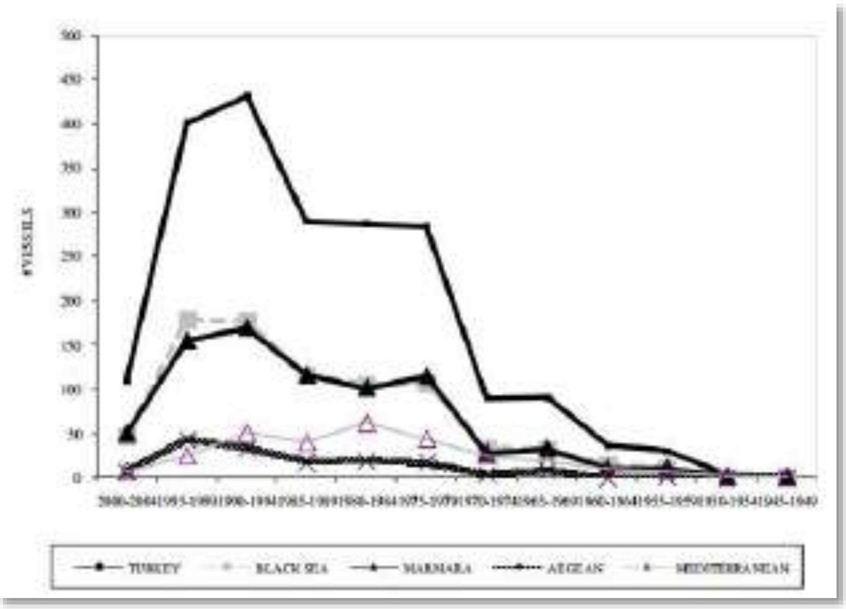


Figure 2.2.16. Historical Estimates of Turkish Fleet Size 1945-2000. Source: Saglam and Duzgunes (2010)22

Figure 2.2.16. shows that the Black Sea Turkish fleet experienced two main growth periods in the 1970s and from 1990 to 1994. In 1980, the abolition of custom duties and low interest credits induced the development of a trawl fleet, with larger vessels and fishing gear. This period of rapid expansion caused a dramatic decline in the target species of trawl fisheries (including whiting, red mullet and turbot) in the Black Sea region and the stocks collapsed in the 2000s23.

After 2000, subsidized fishery credits proved not to have been a driver for fishing pressure and since 2002, it has not been possible to obtain new licences **[18].** The more recent data provided by the Turkish Statistical Institute from 2008-2012 (Table 2.2.13.) show that the size of the fleet has decreased (by 1484 vessels), indicating a reduction in capacity over the years.

Current Fleet Capacity

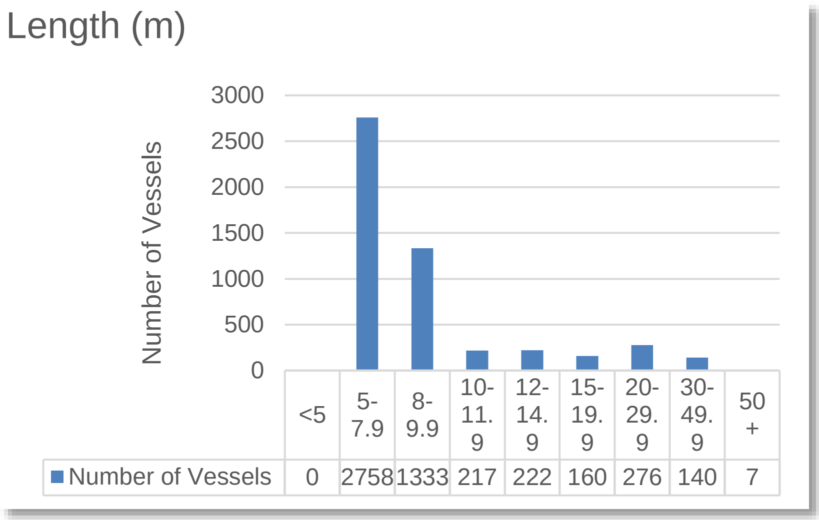
Table 2.2.14. and Figure 2.2.17. below represent the capacity of the Turkish active fleet, as of 2012. Data were obtained from the Turkish national teams, via the TurkStat Fishery Statistics Book, 2012. Up-to-date information was not available.

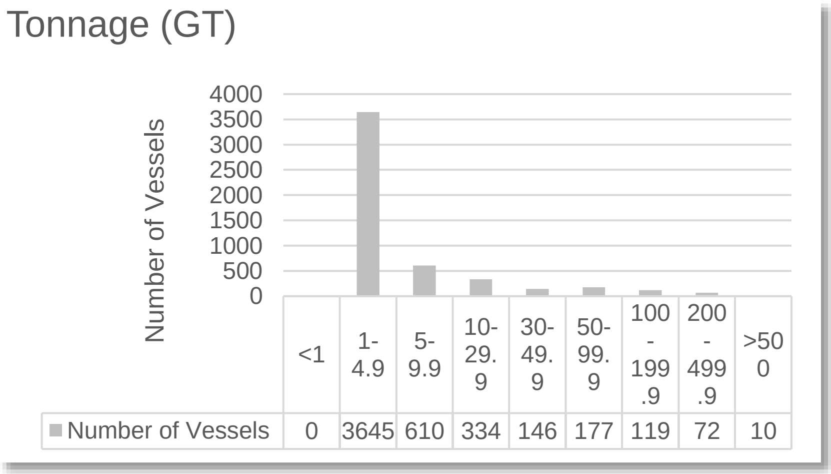
Table 2.2.14.: Turkish Fleet Capacity (2012 **[16]**)

Length/LOA (m)	Number of Vessels
<5	0
5-7.9	2758
8-9.9	1333
10-11.9	217
12-14.9	222
15-19.9	160

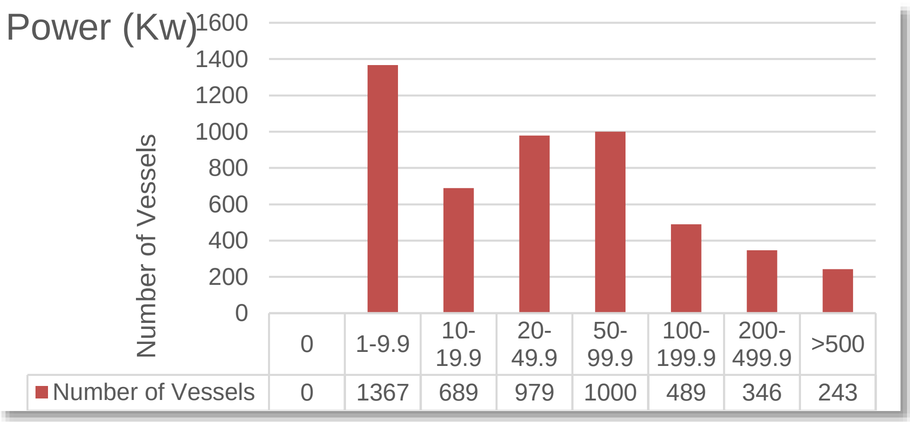
23 Zengin, M. (2014). Last Three Decades of the Turbot Fisheries in the Turkish Black Sea Coast. In: Duzgunes, E., Ozturk, B., and Zengin, M. (Eds) (2014). *Turkish Fisheries in the Black Sea*. Published by Turkish Marine Research Foundation (TUDAV), Publication number: 40, Istanbul, Turkey.

20-29.9	276
30-49.9	140
50+	7
Tonnage (GT)	**Number of Vessels**
<1	0
1-4.9	3645
5-9.9	610
10-29.9	334
30-49.9	146
50-99.9	177
100-199.9	119
200-499.9	72
>500	10
Kw	**Number of Vessels**
0	0
1-9.9	1367
10-19.9	689
20-49.9	979
50-99.9	1000
100-199.9	489
200-499.9	346
>500	243
Total number of Active Vessels	**5113**





Active Vessels: 5113



Figures 2.2.17. a-c: Turkish Fleet Capacity: Length (m), Tonnage (GT) and Power (Kw) of the Active Fleet

Figure 2.2.17.a above indicates that the majority of the fleet (80%) in 2012 was between 5 and 9.9m in length. There were no vessels under 5m and very few over 50m. Figure 2.2.17b indicates that the majority of the fleet (71%) have a gross tonnage of between 1 and 4.9, no vessels with a GT under 1

and none with a GT over 50. Figure 2.2.17c indicates that the fleet exhibit a wide range of power across the categories but that most vessels have a horsepower of between 1 and 99.9 Kw.

Gear Types and Metiers

The only data regarding gear types provided by the Turkish national teams is shown in Table 2.2.15. below. The data given refers to the Black Sea coast.

Table 2.2.15.: Turkish Vessel Operating Types (2012 **[16]**) on the Black Sea Coast.

Total	**2008**	**2009**	**2010**	**2011**	**2012**
Trawler	147	152	280	281	289
Purse seiner	374	323	241	195	158
Trawler-Purse seiner	192	160	168	189	181
Carrier vessel	130	107	80	112	112
Other	5744	5231	5168	4216	4373
Total	6587	5973	5937	4993	5113

The 'other' category is likely to be small boats operating mixed gears (gillnetters, anglers and small purse seiners)**Error! Bookmark not defined.**.

The GFCM also report the following: "The Turkish legislation (Fisheries Regulation 22223) regulates in particular the use of surrounding nets (Art. 16); light fishing (Art. 17); and seine nets, gillnets and other fishing nets (Art. 18). Mesh size of cod-end in trawl nets should be 44 mm (diamond) or 40 mm (square). The use of drift-net is also prohibited (Art. 21.k). At least a 40mm mesh size opening for the whole demersal trawl cod-end is implemented and the use of deep trawl nets fisheries at depths beyond 1000 m of depth is prohibited in accordance (Notification 2/1 Regulating Commercial Fishing, Art.10 (ç-2) and (ç-7))."24

Comparative Country Statistics

In this section, the fleet capacity and the gear types in use will be compared between countries to identify trends and differences in the current fishing activities of the Black Sea.

Temporal Trends in Fleet Capacity

Recent data (2006/8 to current) show that the capacity of all fleets have been in decline. This can be seen in terms of fleet size, horse power and gross tonnage for Bulgaria and Romania but not for Ukraine and Turkey, where declines are seen in terms of fleet size only.

In general, it is reported that the EU's fishing fleet capacity has declined fairly steadily since the 1990s, in terms of both tonnage and engine power25. In Turkey, this appears to have been caused by a decline in fisheries resources which is likely to have also affected fleet capacity in the other countries.

24 GFCM. Database on National Fisheries Legislation: Turkey. [Online]. Available at: http://nationallegislation.gfcmsecretariat.org/index.php?title=Turkey#Fishing_gear_and_methods [Accessed: 01.08.2014].

25 Eurostat (2013). Agriculture, forestry and fishery statistics, 2013. [Online]. Available: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-FK-13-001/EN/KS-FK-13-001-EN.PDF [Accessed 18.08.2014].

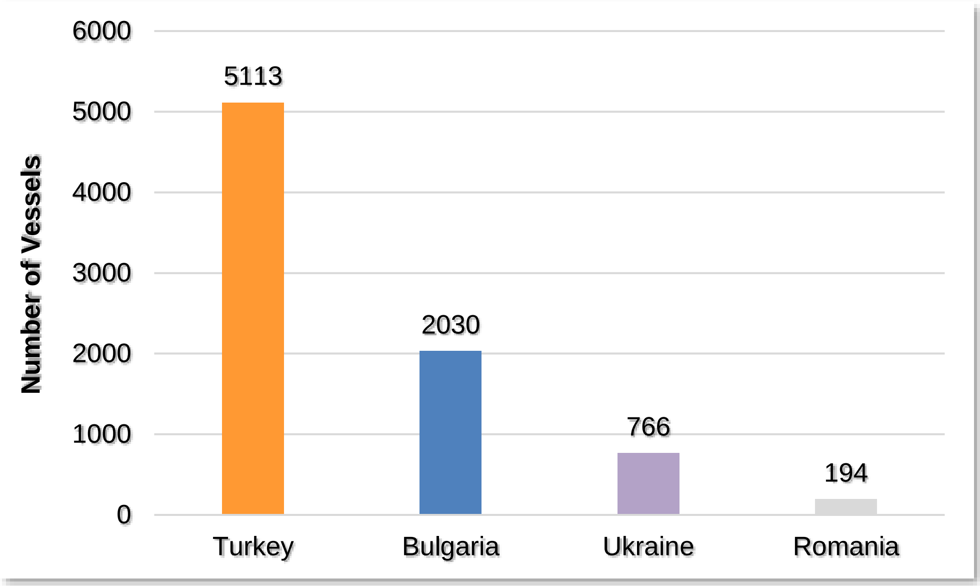


Figure 2.2.18.: Estimated Number of Active Vessels in All Countries.

Figure 2.2.18. above indicates that the Turkish active fleet is significantly larger than the active fleets in Bulgaria, Ukraine and Romania. The sizes of the active fleets presented here will not be fully representative of the current fleet activity, for reasons that vary between countries.

In Turkey the numbers are based on data from 2012 and are therefore not up-to-date.

In Bulgaria and Romania, the number of active vessels are up-to-date but can only be considered as estimates due to: a) fleet segments with low vessel numbers for which data is hard to obtain or for which there are confidentiality issues, b) only active fleets being submitted by Member States upon data call, as opposed to full fleets being represented on the Community Register, and c) differences in data representation from different sources (i.e. the Community Register and National Programmes).

In Ukraine, the numbers of vessels have been estimated by the national team, based on 2012 statistics, so are out-of-date.

Vessel Length

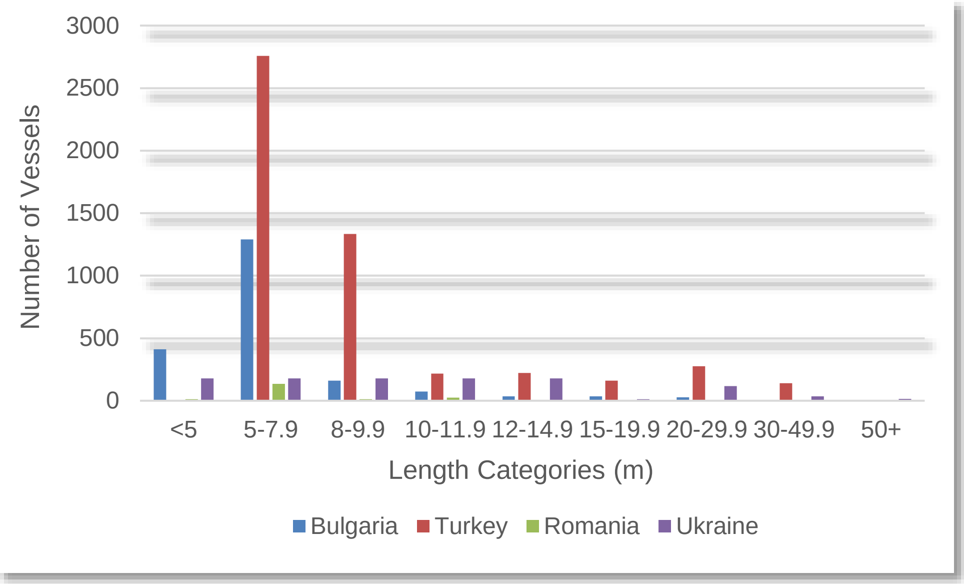


Figure 2.2.19.: Estimated Number of Active Vessels in All Countries Over Various Length Categories.

Figure 2.2.19.indicates that the majority of fleets are dominated by small sized vessels (5-9.9 m in length). Bulgaria's fleet has largest number (412) of <5m vessels and Ukraine's fleet have the largest number of >50m vessels. Note for Ukraine that national teams reported 588 vessels across the first 5 length categories, so equal numbers of vessels (177.6) have been placed in each of these categories, although the actual distributions of vessels are likely to vary between these categories.

Vessel Tonnage

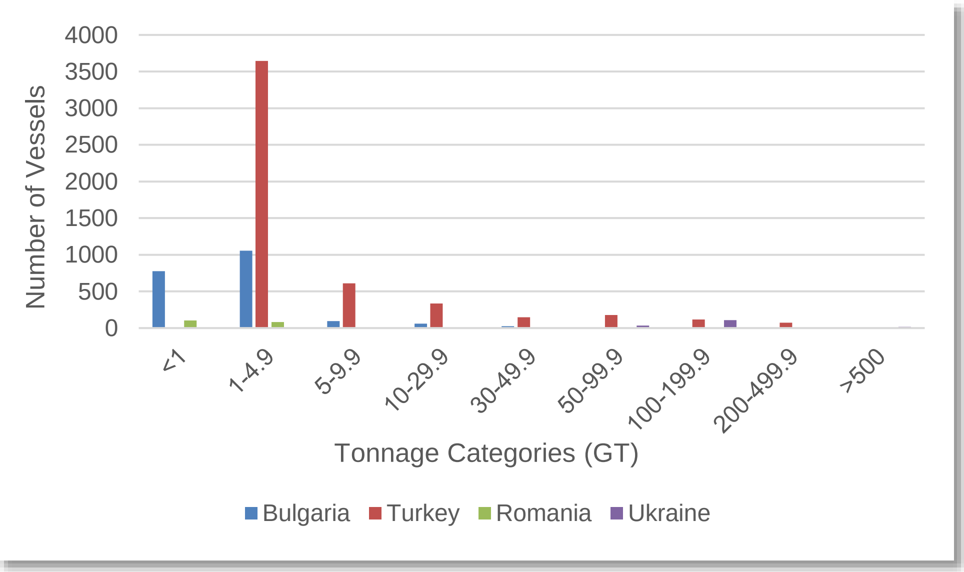


Figure 2.2.20.: Estimated Number of Active Vessels in All Countries Over Various Tonnage Categories.

Figure 2.2.20. indicates that the majority of fleets are dominated by small tonnage vessels (<1-9.9 GT). Bulgaria's fleet has largest number (778) of <1 GT vessels and Ukraine's fleet have the largest

number of >500 GT vessels. However the actual distribution of vessels in the Ukrainian fleets are not likely to represent the current situation as Ukrainian national teams reported that there were no data on the distribution of vessels in the GT categories below 9.9 GT.

Vessel Power

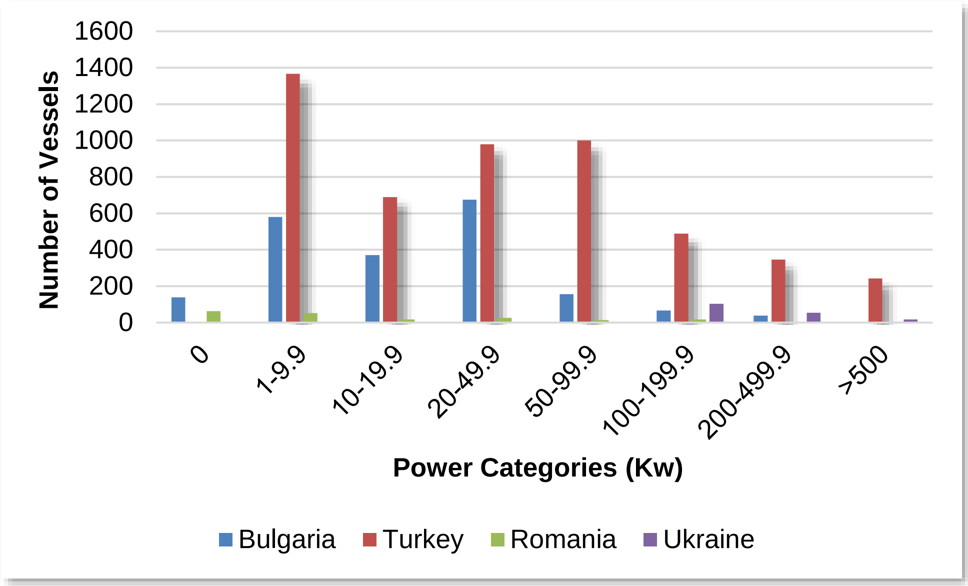


Figure 2.2.21.: Estimated Number of Active Vessels in All Countries Over Various Power Categories.

Figure 2.2.21. indicates that the all fleets demonstrate a wide range of horse power. This suggests that smaller boats in the Black Sea can operate a multitude of fishing practices and gears, as the majority of fleets appear to consist of small vessels (see above in this section). Bulgaria's fleet has largest number (138) of vessels with no horsepower and Turkey's fleet has the largest number of maximum power (>500 Kw) vessels. Note that Ukrainian national teams reported that there were no data on the distribution of vessels in the Kw categories below 49.9 Kw.

Table 2.2.16. TACs and quota for sprat in Black Sea(STECF, 2015)

Year / National data	2008	2009	2010	2011	2012	2013	2014
Species	Sprat (SPR)	Sprat (SPR)	Sprat (SPR)	Sprat (SPR)	Sprat (SPR)	Sprat (SPR)	Sprat (SPR)
Quota, t	15 000[2]	12 750[2]	12 750[2]	11 475[2] 8032.51	11 475[2] 8032.51	11 475[2] 8032.51	11 475[2] 8032.51
Total catch, t	4 300.0363(BG) 234 (RO)	4 541.35 (BG) 92(RO)	4 039. 966 (BG) 39(RO)	3 957.895 (BG) 131.3 (RO)	3 156.832 (BG) 87.458(RO)	3784.191 (BG) 98.84(RO)	2279.3 (BG) 84.9 (RO)
Biomass, t	32 718.33 60 000[5]	41 761.398[3] 60 000[5]	75 080.20[4] 59 600[5]	48 201.7[4] -	- 68 886	- 56 428	55 360 39 277
Recommended TAC	average 13 746.57	11 469.9[3]	12 500[4]	-	-	-	-

1. Quota according to Regulation (EU) № 1579/2007, Regulation (EU) № 1139/2008,Regulation (EU) № 1287/2009,Regulation (EU) № 1004/2010,Regulation (EU) № 1256/2010, Regulation (EU) № 5/2012
2. EC's quota
3. Source of data: Institute of Oceanology – BAS, Bulgaria
4. Source of data: Institute of Oceanology – BAS, Bulgaria and NIMRD,Romania
5. National Institute for Marine Research and Development, Romania

A quota (Table 2.2.16.) is allocated in EU waters of the Black Sea (Bulgaria and Romania). No fishery management agreement exists among other Black Sea countries. In the EU Black Sea waters a global (both Romania and Bulgaria) TAC of 12 750 tons has been allocated in 2009 and 2010. In 2011 44 and in 2012-2014 allocated quota in Bulgarian waters was at the rate of 8 032.5 t sprat (Council Regulation 5/2012) and 3 442.49 t for Romanian waters. The decreasing trend in indices since 2008 was observed despite of quotas regime in force in Community waters. Because of insufficient national funding by NDCP, hydro acoustic survey (2012 and 2014) for the assessment of sprat stocks off the Bulgarian Black Sea coast has not been carried out. Sprat (Sprattus sprattus) is subject to national quotas for EU member states.

Table 2.2.17. Sprat total TAC (in thousands of tons) applied to vessels of Ukraine and Russian Federation.

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Russian Federation	42			21	21	21				
Ukraine	60	70	40	50	50	50	60	70	70	*)

*) A TAC was not set in Ukraine in 2014.

Turbot fisheries in Black Sea EU waters are being managed through the annual establishment of fishing opportunities (EU quotas) since 2008, by the adoption of Council Regulations. During the last four years, the EU turbot quota has been fixed at 86.4 t and equally allocated to Bulgaria and Romania (50 % each). The same Council Regulations set up every year the prohibition of fishing activities during reproduction period for turbot. The ban has been in force from 15 April to 15 June in European Community waters of the Black Sea. The same period of prohibition is fixed by Turkish National Legislation.

Figures 2.2.22, 23 and 24 below show the distribution of these sampling sites for various data categories in the survey. The large number of sites in Turkey was aggregated into east Black Sea and west Black Sea to reflect data representation in the Turkish National Fisheries Statistics.

Figure 2.2.22.: Number of vessels surveyed in each region in the Black Sea. CRS: WGS 84

Total Fishing Capacity and Fishing Effort Results

To summarise the results of this section (that estimates total fishing capacity and effort in the Black Sea) Table is provided on the following page.

Country	Metier	Number of vessels operating metier (as single or mixed gear)		Estimated average quantity of fishing gear per vessel (meters)	Estimated total quantity of fishing gear nationally (meters)	Estimated average no. of fishing days per year
		Reported	Estimated			
Turkey	GNS_DEF_>150		1119	11400	12,756,600	61
	GNS_DEF_<150		3148	4900	15,425,200	126
	GNS_LPF_<150		2589	650	1,682,850	64
	GNS_SPF_<150		140	650	91,000	41
	PS_LPF_14-60		355	600	213,000	56
	PS_SPF_<14		120	615	73,800	71
	OTM_SPF	470		n/a	n/a	140
	OTB_DEF					
	LLS_DEF	Not reported in the fishermen's survey, although this metier is used in Turkish waters				
Bulgaria	GNS_DEF_>150		812	12400	10,068,800	114
	GNS_DEF_<150		1173	2900	3,401,700	127
	GND_LPF_<150		1444	3200	4,620,800	96
	GNS_SPF_<150		1083	3200	3,465,600	49
	OTM_SPF	88		n/a	n/a	213
	LLS_DEF	65		2000	130,000	0
Romania	GNS_DEF_>150		118	7500	885,000	44

Country	Metier	Number of vessels operating metier (as single or mixed gear)		Estimated average quantity of fishing gear per vessel (meters)	Estimated total quantity of fishing gear nationally (meters)	Estimated average no. of fishing days per year
		Reported	Estimated			
	GNS_DEF_<150		88	1300	114,400	40
	GNS_SPF_<150		132	4200	554,400	98
	OTM_SPF	8		n/a	n/a	48
	LLS_DEF	65		2000	130,000	57
Ukraine	GNS_DEF_>150		543	7850	4,262,550	110
	GNS_DEF_<150		474	2200	1,042,800	97
	GNS_SPF_<150		139	1000	139,000	85
	PS_LPF_14-60		21	600	12,600	108
	PS_SPF_<14					
	OTM_SPF		49	n/a	n/a	154
	OTB_DEF		18	n/a	n/a	140
	LLS_DEF		49	2000	98,000	102

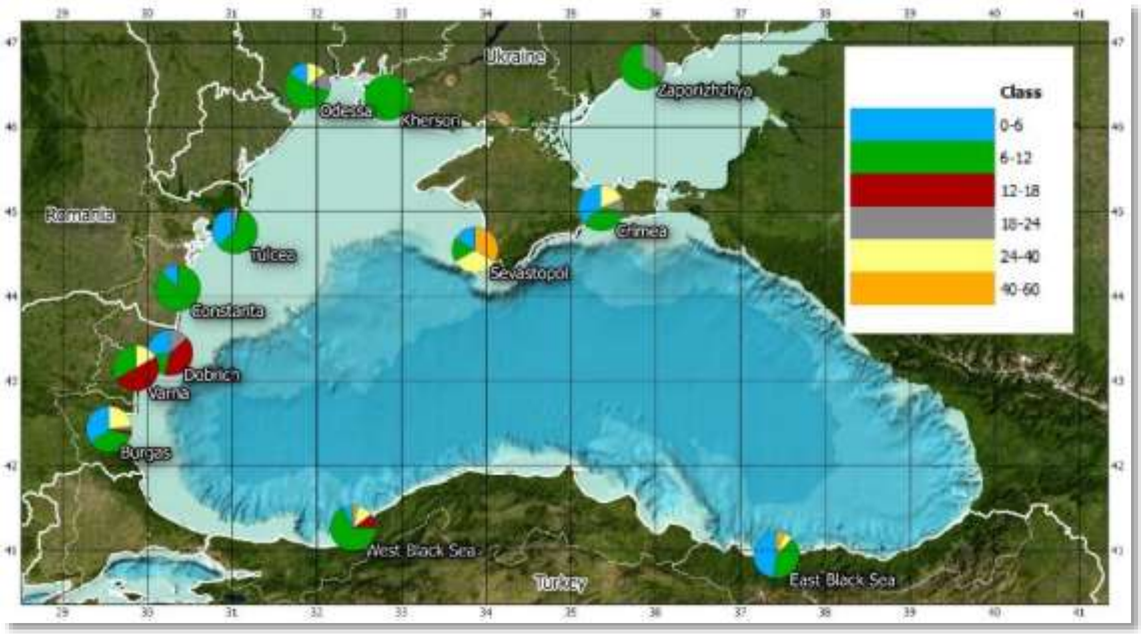


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Figure 2.2.23 Distribution of vessel size classes of all vessels surveyed in the Black Sea. CRS: WGS 84.

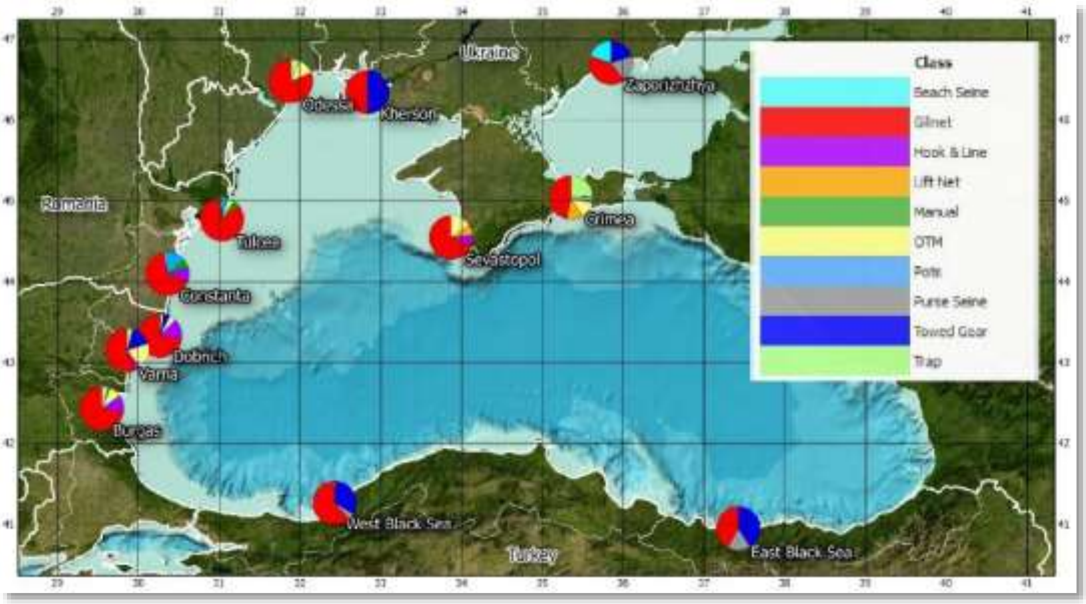

Figure 2.2.24.: Distribution of each gear class across the Black Sea. CRS: WGS 84.

Illegal, Unreported and Unregulated Fishing

Illegal, Unreported and Unregulated (IUU) fishing is one of the most serious threat for the sustainable fishing in the entire Black Sea. Due to IUU fishing, ghost fishing and by-catch, destruction of the benthic ecosystem has been witnessed. This issue has several socioeconomic, environmental and legal ramifications. Most of the riparian countries are reluctant to report IUU fishing and to analyze it for several reasons. From 1992 to 2012, a total of 65 IUU fishing cases have been reported in the various Exclusive Economic Zones (EEZs) of the Black Sea. Among these cases, 5 fishermen lost their lives and 2 were wounded in the EEZs. This excessive use of force should be stopped for the sake of fishermen livelihood and peaceful settlement of disputes should be pursued when confrontations, altercations or arrests occur. The main target fish in the Black Sea is turbot and stocks of turbot are decreasing. Consequently, regional stock assessment on a regular basis is requested. Enforcement of the existing fisheries regulations and laws is also necessary for all riparian countries to halt IUU 26 fishing. For this purpose, Monitoring, Control and Surveillance (MCS) system should be developed. Asipenceriform species (sturgeons) are endangered species in the Black Sea and IUU fishing and overfishing are most likely the cause of the collapse of the stocks. Illegal clam and rapana dredging is also a threat for the benthic ecosystem. Anchovy is the largest stock of small pelagic fish in the Black Sea and contribute for the major part of fisheries production in the region, especially for Turkey. Its unreported fishing should be seriously taken into consideration. Most of the countries do not have records of bycatch and ghost fishing in the Black Sea. Because IUU fishing in the Black Sea shows a decreasing trend in recent years, concerted actions and international cooperation are essential. Zero tolerance should be the main driver in policy formulated against IUU fishing in the Black Sea. In addition, transparency and good governance need to be taken into account by riparian countries. The General Fisheries Commission for the Mediterranean of the FAO (GFCM) is the regional fisheries management organization competent to manage fisheries in the Mediterranean, the Black Sea and connecting waters since its establishment (1949). Within its structure, it has a fully operational working group on the Black Sea. Among possible solutions to improve the fight against IUU fishing, there could be that of establishing a GFCM permanent working group for IUU fishing as a subsidiary body of the GFCM Compliance Committee (CoC). In addition, both the GFCM Agreement and the Bucharest Convention should be promoted, in terms of participation and compliance to enable optimum utilization of the living resources. The possibility of creating a technical cooperation project for the Black Sea to be executed under the GFCM Framework Programme, together with partners such as the Black Sea Commission and ACCOBAMS, should be considered.

Illegal fishing refers to fishing activities: (1) conducted by national or foreign vessels in waters under the jurisdiction of a State, without the permission of that State, or in contravention of its laws and regulations; (2) conducted by vessels flying the flag of States that are parties to a relevant Regional Fisheries Management Organization (RFMO) but operate in contravention of the conservation and management measures adopted by that organization and by which the States are bound, or relevant provisions of the applicable international law; or (3) in violation of national laws or international obligations, including those undertaken by cooperating States to a relevant regional fisheries management organization.

Unreported fishing refers to fishing activities: (1) which have not been reported, or have been misreported, to the relevant national authority, in contravention of national laws and regulations; or (2) undertaken in the area of competence of a relevant regional fisheries management organization which have not been reported or have been misreported, in contravention of the reporting procedures of that organization. Unregulated fishing refers to fishing activities: (1)in the area of application of a relevant regional fisheries management organization that are conducted by vessels without nationality, or by those flying the flag of a State not party to that organization, or by a fishing entity, in a manner that is not consistent with or contravenes the conservation and management measures of that organization; or (2)in areas or for fish stocks in relation to which there are no applicable conservation or management measures and where such fishing activities are conducted in a manner inconsistent with State responsibilities for the conservation of living marine resources under international law (GFCM,2014)

2.3. NON-LIVING RESOURCES AND THEIR EXPLOITATION

SAND EXTRACTION

Because of the marine sources are preferred over terrestrial sources, demand for marine aggregates have increased worldwide in recent years. Simons and Hollingham, 2001 claimed the annual extraction in Europe is about 50 million m3, which, also serves as supply sand for beach restoration projects. Even in İstanbul the sand demand is approximately 10 million m3 and half of this the amount is dredged from the Black Sea (especially from the of the western part of the entrance to the İstanbul Strait).

Sand dredging can have both direct and indirect effects on the beaches. For a direct effect, if a dredge hole is placed to the place where significant sediment movement occurs, the hole will eventually fill. To prevent being a part of the littoral cycle and creating shoreline erosion, the dredge hole traps the sediment. As an indirect effect, the opposite way occurs by not filled dredge hole and thereby interrupting the littoral cycle, which can still effect a shoreline indirectly by transforming the waves. This does represent long-term gains and losses along different sections of beach (Demir, H., 2002).

Oil/gas exploration and exploitation

In 2012, MV Petrom, and ExxonMobil Exploration and Production Romania announced a significant discovery under the Black Sea, with preliminary estimations speaking about a natural gas deposit of 42-84 billion cubic meters, equivalent to 3-6 times the annual consumption of Romania. The drilling operations were conducted by the two companies in the Black Sea started at the end of 2011 and are about to be finalised (OMV, 2012).

Analysis showed that first production could be obtained at the end of this decade, at the earliest. The Domino -1 rig is located in the Neptun block, 170 km off the Romanian coast, in water with the average depth of 1,000 metres, and is drilled with state-of-the-art technology. It is estimated that the total depth of the well will be 3,000 metres under the sea level, HotNews.ro informs. The Neptun perimeter has a surface of about 9,900 square km, with a depth of water between 50 and 1,700 metres. In November 2008, ExxonMobil Exploration and Production Romania Limited, and Petrom signed an accord through which ExxonMobil acquired a stake of 50 pc in the deep-sea zone of the Neptun perimeter. (http://www.roconsulboston.com/Pages/InfoPages/Businesspages/ExxonOMVGas.html).

Deepwater Champion was built in Korea and has been specifically designed for easy access to and from the Black Sea. Deepwater Champion is a double-hull sea drilling vessel that can operate in moderate environments, and down to a maximum depth of 3,000 metres. The ship was built in 2011 by Hyundai Heavy Industries, Korea. Deepwater Champion can operate in a maximum water depth of 3,000 metres (which can be extended to 3,600 m), and can drill wells with a maximum depth of 12,191 metres.

Petrom invested EUR 500 million in its 860 MW gas-fired plant in Brazil, having started construction work on the plant in 2008. It is the largest private greenfield power generation project in Romania. The plant was not yet inaugurated after Petrom announced earlier this year a delay in its opening, initially scheduled for this year. Petrom recently discovered, together with Exxon, a natural gas reserve in Romania's Black Sea, some 84 billion cubic meters of gas in the Neptune perimeter. Petrom, majority owned by Austrian OMV, expects a new record profit this year, of some EUR 867.8 million (RON 3.784 billion), higher than last year- when expressed in local currency- even if its turnover is forecast to drop in 2012. The budgeted turnover for 2012 is of EUR 3.6 billion, down 4.6 percent on 2011.

In 2013, Exxon Mobil, Petrom, Shell and the Ukrainian state company Nadra agreed to establish a partnership in exploiting a gas perimeter in the Black Sea.

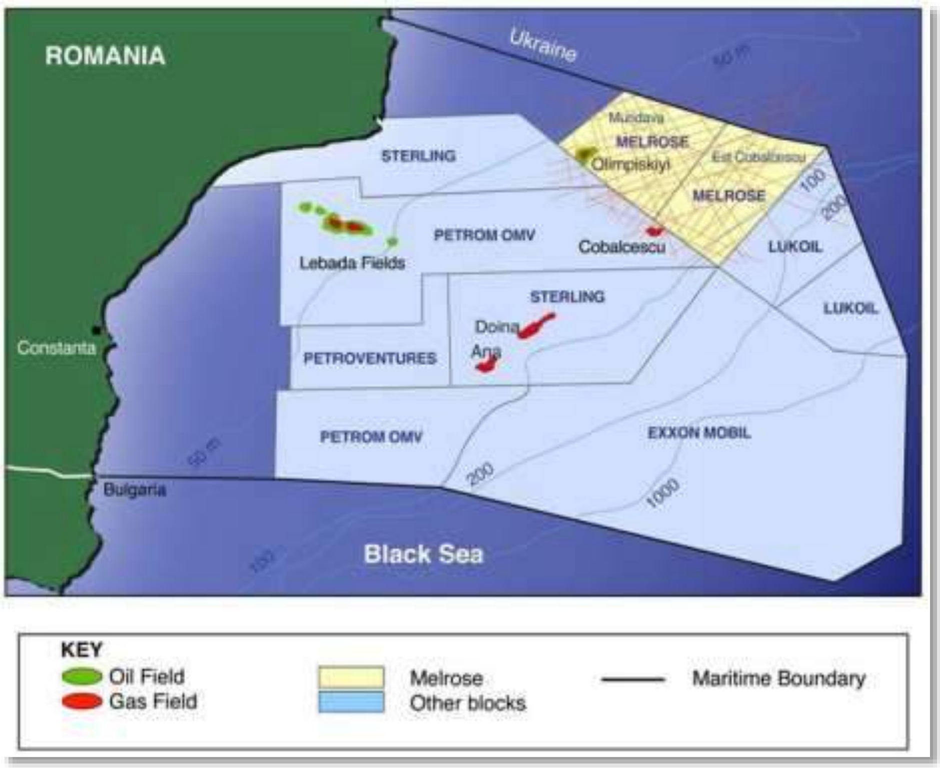

Figure 2.3.1. Oil and gas fields in Romanian waters with exploration and exploitation boundaries among different companies (http://www.roconsulboston.com/Pages/InfoPages/Businesspages/ExxonOMVGas.html)

In 2015, Canadian Oil Company Sterling Resources sold its Romanian business to Carlyle International Energy Partners, an affiliate of The Carlyle Group, the company has announced. The transaction, which includes oil drill license, blocks 13 Pelican, 15 Midia, 25 Luceafarul and 27 Muridava, structured as a corporate sale of the company's wholly-owned subsidiary Midia Resources SRL, will finalize around the end of the second quarter of 2015. CIEP paid USD 42.5 million to Sterling when the transaction is completed, prior to any Romanian tax liabilities. Sterling has decided to sell its Romanian business in order to focus its financial resources in the UK North Sea.

Block "Khan Asparuh" is located about 80 km from the coast near Varna. More detailed resource assessment will be made after interpretation of data from 2D and 3D seismic evaluation and after having made two planned exploratory drilling. The wells will be drilling to a depth of between 1,000 and 2,000 m. Drilling was planned in the period 2015-2016. In the best possible organization first gas production if expectations are confirmed deposits can be made in 2017-a. According to experts in proven reserves and skillful negotiation is possible Bulgarian side to get 55% of the extracted gas. The area for exploration of block "Khan Asparuh" is 14,220 square kilometers. Very close to it is the Romanian unit "Neptune", which was discovered deposit with reserves of about 84 billion sq.m. of gas. OMV holds 30% of the consortium, which received a license to search for gas field and is the operator of the completed studies. The other participants are the French "Total" (Total) with a share of 40 percent, which will be operator in the next phase of the project - drilling and Spanish"Repsol" (Repsol) holds 30%. In recent years, natural gas consumption in Bulgaria is below 4 billion. Sq.m. per year. In the period 2010-2025, it was envisaged crude demand to increase and reach expert predictions about 6.3 Bil.sq.m. at the end of the period.

Figure 2.3.2. Block "Khan Asparuh" for prospecting and exploration of oil and natural gas in Bulgarian marine area.

After February 2016 the consortium of "Total", OMV and "Repsol", which received permission for prospecting and exploration of oil and natural gas in Block "Khan Asparuh" Black Sea will make the first exploratory drilling. The window for the start of the first exploratory drilling between February and May 2016 (Fig.2.3.2) (http://www.monitor.bg/a/view/9378).

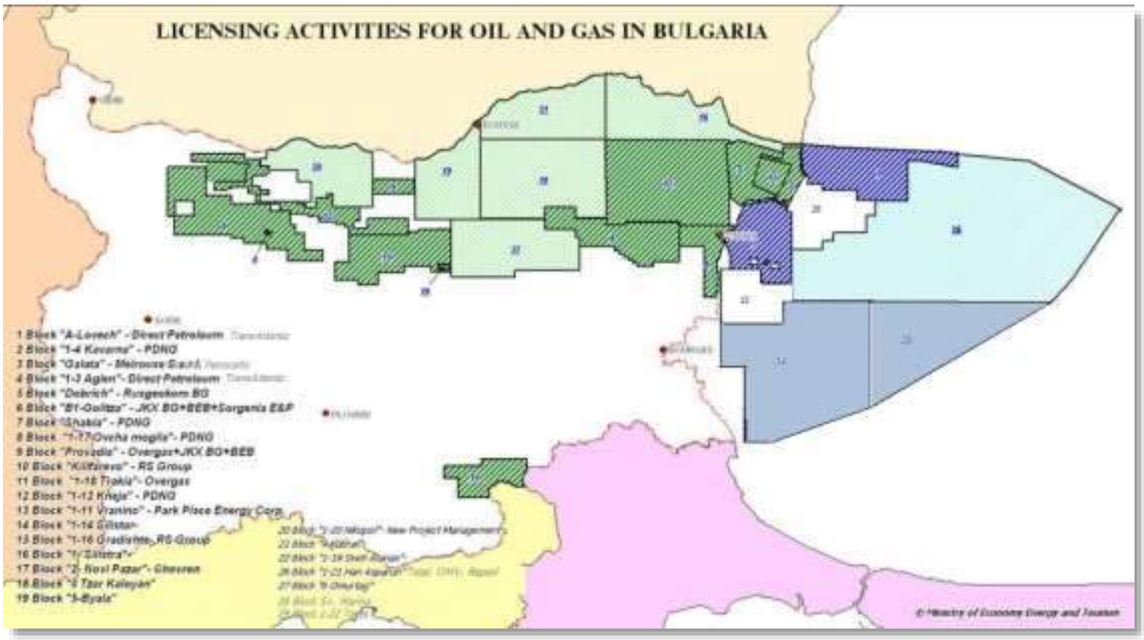

Figure 2.3.3. Licensing activities for oil and gas in Bulgaria http://www.monitor.bg/a/view/9378).

The block "Silistar"(Fig.2.3.3. – Block 14) is located in the continental shelf of the southern Black Sea coast (the northern part of the deposit is located between Biala and Nessebar, the southern end passes over Rezovo - Turkish border and in the north-western part of the water area of study is located miles south of Cape Emine) and has an area of 6893 square kilometres. - Approximately the size of Sofia District. It is less of the "Han Asparuh" but expected there to be discovered large quantities of oil. The same goes for the block "Teres". It is also located on the Southern Black Sea coast in the deep part of the Black Sea. So far, however, it calls for the selection of a company to make the study ended without success.

In practice, in the deep part of the Black Sea over the years have made only 7 wells (at several hundred, for example, in the Gulf of Mexico). They found the existence of reserves that remain unexplored. The first drilling discovered the deposit "Galata". It satisfied 15% of the needs of Bulgaria, but already exhausted. Alongside him were made more studies and were down 2-3 smaller deposits - Kaliakra Kavarna, Galata East. They continue to operate and satisfy currently 10% of the country's needs. At the same time, domestic production decreased the average price of gas for consumers around 8 to 10%.

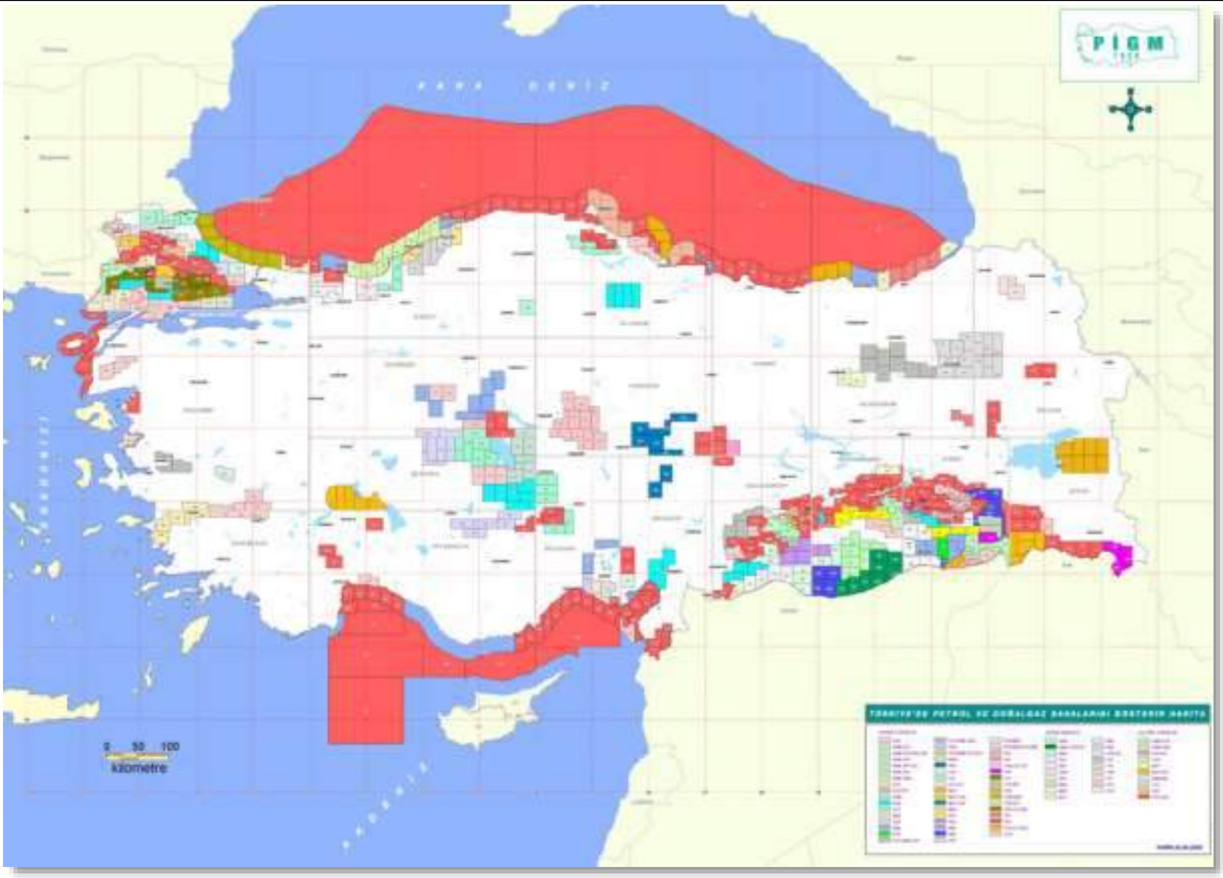

Figure 2.3.4. Oil and gas production fields in Turkey http://www.guneyyildizi.com.tr/en/oil-gas-in-turkey/

In table 2.3.1. and 2.3.2. the total Oil and gas production in Turkey was shown.

Table 2.3.1 Oil production in Turkey (2013)

Oil Production	2,4 million tonnes
Oil Consumption	30,1 million tonnes
Total Proved Reserves	1027 million tonnes
Total Recoverable Reserves	189,3 million tonnes
Cumulative Production	142,7 million tonnes
Remaining Recoverable Reserves	46,7 million tonnes
Number of Wells	173
Exploration Licences	527

Production Leases	117

Table 2.3.2. Gas production in Turkey (2013)

Gas Production	562 million bcm
Gas Consumption	45,6 bcm
Total Proved Reserves	24.4 bcm
Total Recoverable Reserves	19.4 bcm
Cumulative Production	14,1 bcm
Remaining Recoverable Reserves	5,4 bcm

Sources: PIGM & TPAO

OIL AND NATURAL GAS PIPELINES / PROJECTS in Turkey

A. CRUDE OIL PIPELINES

Kirkuk-Yumurtalık Crude Oil Pipeline (Iraq-Turkey Crude Oil Pipeline) The Iraq - Turkey Crude Oil Pipeline system was constructed pursuant to the Iraq-Turkey Crude Oil Pipeline Agreement signed on 27 August 1973 between the Governments of the Republic of Turkey and the Republic of Iraq in order to transport Iraqi crude oil to the Ceyhan (Yumurtalık) Marine Terminal.

The first line which is 986-km-long with an annual transport capacity of 35 Million tons was commissioned in 1976 and the first tanker was loaded on May 25, 1977. With the completion of the Second Pipeline, which is parallel to the first one, the annual capacity reached 70,9 Million tons as of 1987.

The agreement and related protocols and letters are renewed for 15 years by a further bilateral agreement signed on 19 September 2010.

Baku-Tbilisi-Ceyhan Crude Oil Pipeline (BTC)

Baku-Tbilisi-Ceyhan Crude Oil Pipeline was contructed to transport crude oil (particularly the Azeri crude), produced in the Caspian Region to Ceyhan Terminal via Georgia in an economically viable and environmentally sensitive manner and to export the crude to global markets by tankers.

BTC pipeline transports primarily the Azeri crude which is extracted in the Azerbaijan sector of the Caspian Sea as well as Turkmen and Kazakh crude to the Turkish Mediterranean oil terminal of Ceyhan.

Total length of the pipeline is 1.769 km of which 1.076 km is within the Turkish territories. The capacity of the pipeline which extends from Baku and Tbilisi to Ceyhan is around 50 Million tones annually (1 million barrels per day).

The very first crude which was transported to Ceyhan via BTC on 28th May, 2006 was loaded onto the tanker in the Ceyhan Terminal on 4 June 2006. The official inauguration ceremony of the pipeline was held in Ceyhan on 13 July 2006.

On 11 August 2014, BTC celebrated the loading of the 2 billionth barrel of oil at the Ceyhan terminal in Turkey. Since its commissioning, more than 2,3 billion barrels of crude oil have been transported via the BTC pipeline.

B. NATURAL GAS PIPELINES AND PROJECTS

a. CURRENT PIPELINES

Baku-Tbilisi-Erzurum Natural Gas Pipeline (BTE)

Baku-Tbilisi-Erzurum Natural Gas Pipeline is a 690-km-long pipeline which transports natural gas produced in the Shah Deniz field in the Azerbaijan sector of the Caspian Sea via Georgia to Turkey.

An Intergovernmental Agreement between Turkey and Azerbaijan and the Natural Gas Sale and Purchase Agreement between BOTAŞ and SOCAR (State Oil Company of Azerbaijan) were signed on 12 March 2001 to transport 6,6 billion cubic meters (bcm) of Shah Deniz Phase-I gas to Turkey.

The construction work was carried out between 2005 and 2007, and the pipeline has been operational since July 2007. The Azerbaijan and Georgian sections of the BTE pipeline were designed at larger capacities than the contracted volumes (6,6 bcm annually) so as to enable gas transportation to Europe via Turkey in the future. A small part of the gas carried through the BTE pipeline has been transported to Greece via the Turkey-Greece Interconnector which became operational on 18 November 2007.

Turkey-Greece Interconnector (ITG)

The Intergovernmental Agreement on natural gas transportation from Turkey to Greece was signed on 23 February 2003. The Agreement foresees interconnection of Turkish and Greek natural gas networks within the framework of the first phase of the Southern Gas Corridor, as developed under the EU's INOGATE (Interstate Oil and Gas Transport to Europe) Programme. Through the Turkey-Greece Interconnector, the construction of which started in 2005 and became operational on 18 November 2007, the Azeri gas was delivered to Europe for the first time through an alternative route.

Total length of the pipeline is approximately 300 km of which 209 km is within the Turkish territory. A part of the natural gas imported from Azerbaijan (Shah Deniz Phase-I) is exported to Greece via the mentioned pipeline.

Western Route (Russia-Turkey Natural Gas Pipeline)

An Intergovernmental Agreement was signed on 18 September 1984 between Turkey and the former Soviet Union on natural gas supplies to Turkey. The pipeline transits Ukraine, Romania and Bulgaria and enters Turkey at Malkoçlar border point and passes through Hamitabat, Ambarlı, İstanbul, İzmit, Bursa and Eskişehir before reaching Ankara. The pipeline is 845-km-long.

Gas imports which started in 1987 have gradually increased and reached peak level of 6 bcm/year by 1993. The capacity of the pipeline was later on expanded to 14 bcm/year.

Blue Stream Natural Gas Pipeline

The foundation of Blue Stream natural gas pipeline, the largest energy project ever between Turkey and Russia, was laid by the Intergovernmental Agreement on Russian Gas Supply to Turkey via Black Sea as signed on 15 December 1997. On the same date, BOTAŞ and Gazprom Export inked the "Gas Sales and Purchase Contract" which envisages annual deliveries of 16 bcm per year until the end of 2025.

The gas deliveries through the Pipeline started in February 2003 and the official inauguration ceremony was held on 17 November 2005.

Total length of Blue Stream is 1.213 km of which 396 km lies at the Black Sea offshore section. The pipeline enables direct Russian gas supplies to Turkey.

Iran – Turkey Natural Gas Pipeline

A “Gas Sales and Purchase Agreement” was signed between Turkey and Iran in 8 August 1996. According to this agreement, Iran started to deliver 3 bcm of gas per year to Turkey in 2001 and the gas deliveries are expected to reach 10 bcm/year.

b. NATURAL GAS PIPELINE PROJECTS

Trans-Anatolian Natural Gas Pipeline Project (TANAP) Turkey aims to contribute to its energy supply security and that of Europe through the Southern Gas Corridor which is envisaged to transport Middle East as well as Caspian Basin natural gas resources to Europe through alternative routes. Through Trans Anatolian Natural Gas Pipeline (TANAP), which is the backbone of Southern Gas Corridor, Azerbaijani and Caspian natural gas will be transported to the Western markets in vast quantities for the first time via an alternative route. The groundbreaking ceremony of TANAP project was held on 17 Mart 2015. The first gas transportation to Turkey through TANAP is expected in mid-2018 and to Europe in 2020. In the first phase, TANAP is foreseen to carry 16 bcm of natural gas to be produced from Shah Deniz Phase-II, of which 6 bcm will be distributed wihin the Turkish domestic market while the remaining 10 bcm will be exported to Europe. The capacity of the pipeline, which will be 16 bcm in 2020, is expected to reach 23 bcm by 2023 and 31 bcm by 2026. TANAP project is managed by a consortium led by Azerbaijan State Oil Company (SOCAR). The shareholders of TANAP project are as follows: SOCAR 58%, BOTAŞ 30%, BP 12%. Efforts for additional sources that can be directed to the pipeline are in progress.

On the other hand, Turkish Petroleum’s share in Shah Deniz Field, one of the largest gas fields in the world, was increased from 9% to 19% on 30 May 2014. The partners and their shares are currently as follows: BP (UK) 28,8%, TP 19%, SOCAR (Azerbaijan) 16,7%, Petronas (Malaysia) 15,5%, Lukoil (Russia) 10% and NICO (Iran) 10%.

Turkey – Bulgaria Interconnector (ITB)

Bulgaria’s natural sole gas provider, Bulgargaz, signed a gas purchase contract for 25 years with Shah Deniz consortium in September 2013. According to the contract, Bulgaria is expected to purchase 1 bcm of gas starting from 2019. Memorandum of Understanding regarding Turkey–Bulgaria Interconnector (ITB) was signed in March 2014. Preparations on ITB preliminary feasibility report are in progress.

According to the announcement by the EU Commission on 29 October 2014, Turkey–Bulgaria Natural Gas Interconnector (ITB) was included in the projects supported by EU members under the "Connecting Europe Facility (CEF)" fund.

OIL TRANSPORTATION THROUGH TURKISH STRAITS

Turkish Straits play a distinctive role in terms of energy supply security since 3% of the global oil consumption passes through the Straits. The total amount of oil and oil derivatives transported through Bosphorus was 60 million tons in 1996. This amount reached a record level of 150 million tons in 2008. During 2014, 125 million tons of oil was transported through the Straits.

Considering the busy traffic as well as the physical structure of the Straits; a maritime accident to be caused by oil tankers carrying hazardous material is highly probable risk. An accident in the Straits could cause not only a humanitarian and environmental disaster but also a disruption in the global oil supply. Therefore, alternative oil export options that by-pass the Straits should be developed.

The Ukraine is a net importer of both oil and gas. Per the BP statistical survey, precrisis Ukraine produced about 50 MBOPD of oil and consumed about 290 MBOPD, making it a net importer of approx. 240 MBOPD. It imported most of this oil from Russia. Again, per the BP statistical survey, the precrisis Ukraine produced about 1.8 BCFD of natural gas, and consumed between 5-6 BCFD, making it a net importer of between 3.2 - 4.2 BCFD. Almost all of this imported gas was sourced from Russia. The importance of the gas volumes for both residential and industrial use is the primary reason the Ukrainian government was aggressively seeking to expand domestic production through deepwater exploration and shale gas development.

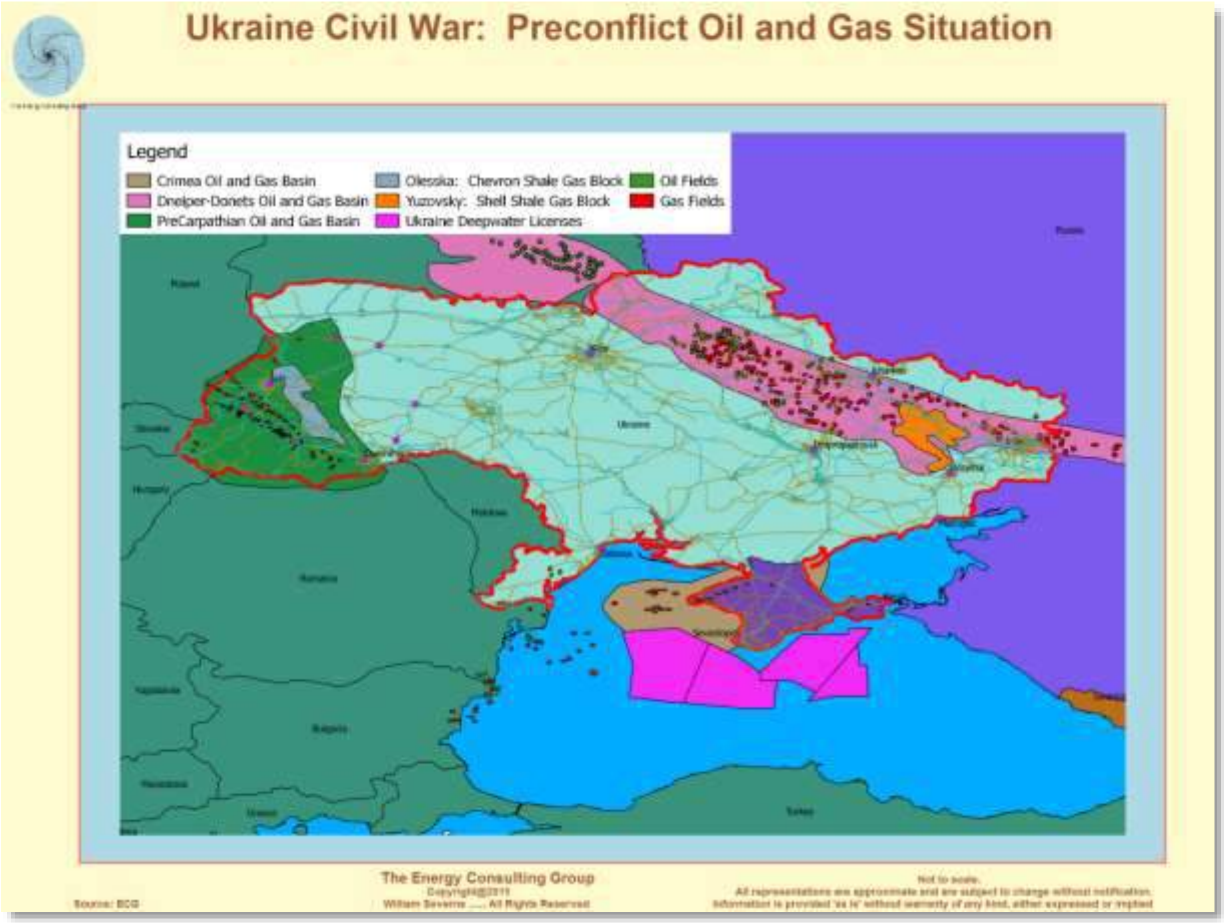

Figure 2.3.5. Oil and Gas map in Ukrain preconflict situation (http://www.energy-cg.com/Ukraine/Ukraine_preconflict_oilgas_situation_Jan15_EnergyConsutlingGroup_web.png)

Georgia

Georgia's oil and gas importance has always been as a transit country rather than a producer. Its oil reserves are tiny – just 35 million barrels – and unless serious payload is found in its acreage it is hard to see Georgia becoming a Black Sea producer any time soon.

Russia

Russia's main oil-related activity in the Black Sea recently has been cleaning it up – a leak on the major pipeline from the Tuapse oil refinery last Christmas sent nine cubic metres of crude into the sea, requiring a state of emergency and a 300-person cleanup operation. The shelving of South Stream has also pushed drilling off Russia's agenda, as efforts continue to develop an alternative route to get Russian gas to Europe.

In terms of Black Sea production, there had previously been plans to develop the 11,200 sq km Tuapse Trough acreage off the Krasnodar Region, with a joint venture with Eni signed in 2012, but although drilling was slated for the start of 2015 oil is yet to flow. A deal between Rosneft and ExxonMobil to drill in the Black Sea has been killed by sanctions, which in total have cost ExxonMobil over billion dollars in lost revenue.

Russia's Black Sea potential is considerable, but sanctions, a focus on LNG, and a drive to get major pipelines to China and Europe built may mean that drilling will have to wait.

2.4. CHANGES IN THE STATE OF THE BLACK SEA RESOURCES

Conclusions

The Black Sea is indeed exposed to many threats that need to be addressed urgently. Overfishing, illegal, unreported and unregulated (IUU) fishing, pernicious discarding practices, ghost fishing, marine pollution, uneven development of aquaculture and invasive species are the most important threats, although not the only ones. The decline of marine living resources were generated by: eutrophication (sources from agriculture, municipal waste, industry, etc); harmful substances (sources from agriculture, industry, municipal waste, etc).

The main causes are:

- Hydraulic works; commercial fisheries; alien species; climatic changes;
- Eutrophication
  - Alteration of ecological state in rivers, lagoons/limans and shelf areas;
  - Mass development of phytoplankton;
  - Mass mortalities of demersal species;
  - Disturbance of fish behaviour, mainly by keeping of fish shoals away from shallow waters.
- Hydraulic Works
  - Loss of valuable habitats for spawning and feeding habitats of fish due to transforming of lagoons/limans in freshwater reservoirs;
  - Affecting the shelf habitats important for spawning and feeding of living resources through siltation from building of port dams or civil coastal defence works;
  - Changing of fish behaviour in coastal areas due to modification of water currents by building of big ports.
- Alien Species
  - Outbreak of some alien species (such as *Mnemiopsis leidyi*) multiplied the ecological disturbance, especially at the food chain level of marine living resources and on fish behaviour.
  - Increase the natural sensitivity of the Black Sea ecosystem.
- Commercial Fisheries
  - Using of non-selective fishing gears allowing catching of non-target species (some of them endangered) and/or having undersize length;
  - Increasing of catches and fishing effort which permits exploitation of stocks outside safe biological limits;
  - Illegal fishing amplifies the effect of overfishing

So, the causes of this situation are multiple, the independent effect of each being very difficult to be assessed:

The high value of the percentage of the species sprat and their constancy within the catches explain the high oscillations of the annual catches on the Romanian coast. These oscillations occur even more as the fishing is done in a restricted area of coast where the conditions of maintaining fish shoals are extremely variable.

- The passive fishery uses pound nets and has suffered the strongest impact due to the change of the ecological conditions near the coast zone. Moreover, there are observations attesting the fish migration routes changed during the last 6-7 years. The fish has the tendency to remain in the offing, at a certain distance from the coast zone with the isobaths of 5-13 m where the pound nets are located.
- The environmental conditions existing to the Romanian littoral allowed formation and maintaining of very large agglomerations of gelatinous species, especially jellyfish. Jelly fish and ctenophore agglomerations making difficult the trawl fishery on all hauling level in some years and periods.
- Heavy fishing on small pelagic fish predominantly by the Soviet Union, and later also by Turkey, was carried out in a competitive framework without any agreement between the countries on limits to fishing. Depletion of the small pelagic stock appears to have led to increased opportunities for population explosion of planktonic predators (jelly fish and ctenophores) which have competed for food with fish, and preyed on their eggs and larvae.
- The reduction of the fishing effort as a consequence of the economic changes occasioned by the transformation of the state capital into private capital;
- The limitation of market demands for some periods of the year, mainly amplified by the fact that more than 90% of the production was delivered as salted fish;
- The free market and imported products have caused the limitation of the traditionally prepared products and the reduction of their price until the limit of the profitableness (Radu et al., 2012)

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CHAPTER 3: STATE OF THE BLACK SEA COAST AND SOCIO-ECONOMICS

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INTRODUCTION

This Chapter is devoted to the state of the coastal zone of the Black Sea and based on the information presented annually by the Black Sea countries to the Permanent Secretariat of the Black Sea Commission Against Pollution for the period 2009 - 2013.

Economic activity at the costal zone impacts on the state of the entire marine ecosystem. Therefore, it is important to take into consideration and discuss drivers, pressures, state, impact, and response analyzing the state of the Black Sea environment. Based on this approach the ICZM Advisory Group at its meeting decided to base its reports on general information of the Black Sea coastal zone as well as on data about population, including demographic trends, water and wastewater management, solid waste management, and information on protected areas. It was also decided that reports should reflect coastal erosion, land use and economic activities.

Black Sea countries agreed that the Coastal Zone is the geomorphological area either side of the seashore in which the interaction between the marine and land parts occurs in the form of complex ecological and resource systems made up of biotic and abiotic components coexisting and interacting with human communities and relevant socio-economic activities.[26]

3.1. STATE OF THE BLACK SEA COAST

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Based on the understanding that without the creation of an effective coastal zone management system, it is impossible to achieve a sustainable development of the Black Sea area, the Black Sea countries declared the necessity of implementation of Integrated Coastal Zone Management principles which targeted at both improving the living standards of the population and the preservation of unique

26 Protocol on Integrated Coastal Zone Management in the Mediterranean, 2008

ecosystems. It was acknowledged by signing the Ministerial Declaration on the Protection of the Black Sea (Odessa, Ukraine, 1993).

Implementation of ICZM principles and instruments acquired special significance after adoption by the European Union recommendation of the Committee of Ministers to Member States on the Guiding Principles for Sustainable Spatial Development of the European continent (30 January 2002). *Inter alia*, it reads:

"58. Europe's coastal regions are not only sensitive natural heritage areas but also important focuses of economic and commercial activities, prime locations for industry and energy conversion, a starting point for the exploitation of maritime and underwater resources and particularly attractive areas for tourism.

59. Since such a range of activities in coastal strips can generate numerous conflicts, an integrated and sustainable spatial development policy, covering not only the coastal strip but also the hinterland, is essential for such regions. The concept of the integrated management of coastal areas is intended to take into account the interaction between economic activities and social and environmental requirements when making use of natural resources in coastal areas and hence facilitate the decision-making process in assessing investments. Integrated coastal management should be a systematic component of regional planning at the various levels concerned. Cross-border and transnational co-operation beyond the sea are of particular importance in this respect."

3.1.1. State of the Black Sea Coast

Black Sea coastal area of countries basically is a combination of seaside valleys and mountain ranges. Mountain relief is typical for Georgia, Turkey and Russia and partially for Bulgaria, Romania, and Ukraine. The approaches to determine the area of the coastal zone (CZ) vary from country to country. There are three approaches in identification of coastal zones (CZ) used by the Black Sea countries. The approaches based on the following principles:

- Administrative division (Bulgaria, Romania, Turkey);
- Specified areas on the either sides of the seashore, including specified areas of rivers flowing into the sea (Georgia, Russia).
- Combination of traditions, specific economic regime, and requirements (Ukraine).

In all cases the coastal zone boundaries are not legally identified and coordinated. Therefore, countries have defined the area and boundaries of their coastal zones for the reporting purposes only.

The distribution of the estimated length of the countries coast is shown in Figure 3.1.1 below.

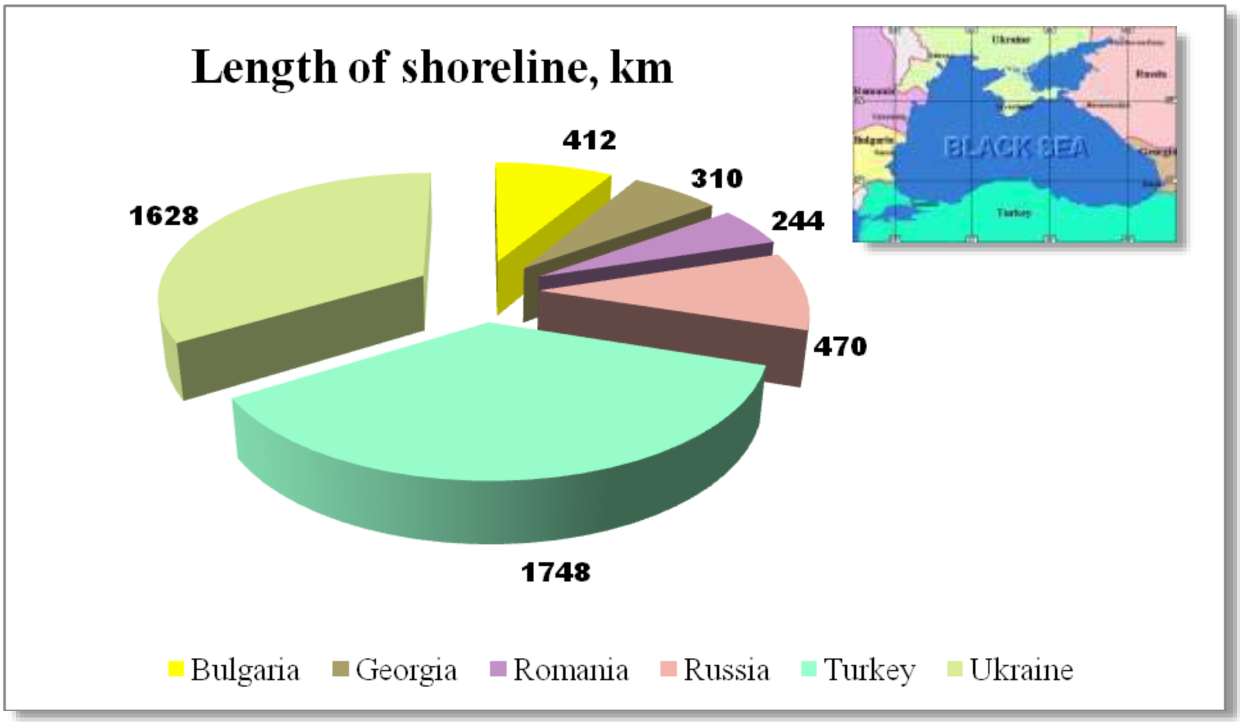


Figure 3.1.1. Length of the coast in the Black Sea countries

As it was stated above, Black Sea countries have defined their coastal zones differently. Bulgaria coastal area (Fig. 3.1.2) covers 16 municipalities that are located in 3 separate administrative districts, as follows:

- District of Dobrich: Municipalities of Shabla, Kavarna and Balchik;
- District of Varna: Municipalities of Aksakovo, Varna, Devnya, Beloslav, Avren, Dolni Chiflik, Byala.
- District of Burgas: Municipalities of Nessebar, Pomorie, Burgas, Sozopol, Primorsko, Tsarevo.

The estimated total area of coastal zone is 5951,3 km2, length of the coast is 412 km.

Figure 3.1.2. Coastal zone of Bulgaria.

The Georgian coastal zone is identified according to the Guidelines for the Integrated Coastal Zone Management in Georgia (http://sites.google.com/site/iczmgeo/Home/ICZM.pdf), a non-binding document, issued by the Ministry of Environment and Natural Resources Protection in 2006. The coastal zone extends to the outer limit of the territorial sea and comprises the coastal administrative units to a maximum distance of 3 km from the coastline and 5 km along the rivers flowing into the sea. Protected areas nearby the coast are also considered as the part of the coastal zone (Fig. 3.1.3).

The estimated total area of the coastal zone is 7,100 km2, the length of the coast is 310 km.

Figure 3.1.3. Coastal zone of Georgia.

The Romanian coastal zone is entirely located in the Dobrogea region (Fig. 3.1.4) and limited by the administrative boundaries of two counties – Constanta and Tulcea. The total estimated area of the costal zone is about 15 570 km2, which is almost 6,5 % of the entire territory of the country. The marine boundary of the coastal zone is running at the distance of 12 nautical miles from the coast and coincides with the boundary of the country's territorial waters.

The length of the Romanian Black Sea shore is of 244 km, extending from the Chilia branch on the Danube delta, in the north, to Vama Veche, (Bulgarian border) in the south. It is divided into two major units: the Northern sector (164 km length) and the Southern sector (about 80 km length).

Figure 3.1.4. Coastal zone of Romania.

The entire coastal zone lies in the Krasnodar Region of the Russian Federation of 5 municipalities: Anapa, Novorossiysk, Gelendzhik, Tuapse and Sochi (Fig. 3.1.5). It is accepted that the boundary of coastal zone coincides with the watershed, covers water basins and located between the sea and the Caucasus Mountain Range. The marine boundary of the costal zone coincides with the boundary of territorial waters. Total area of coastal zone is 8,950 km2. Its length is of 470 km.

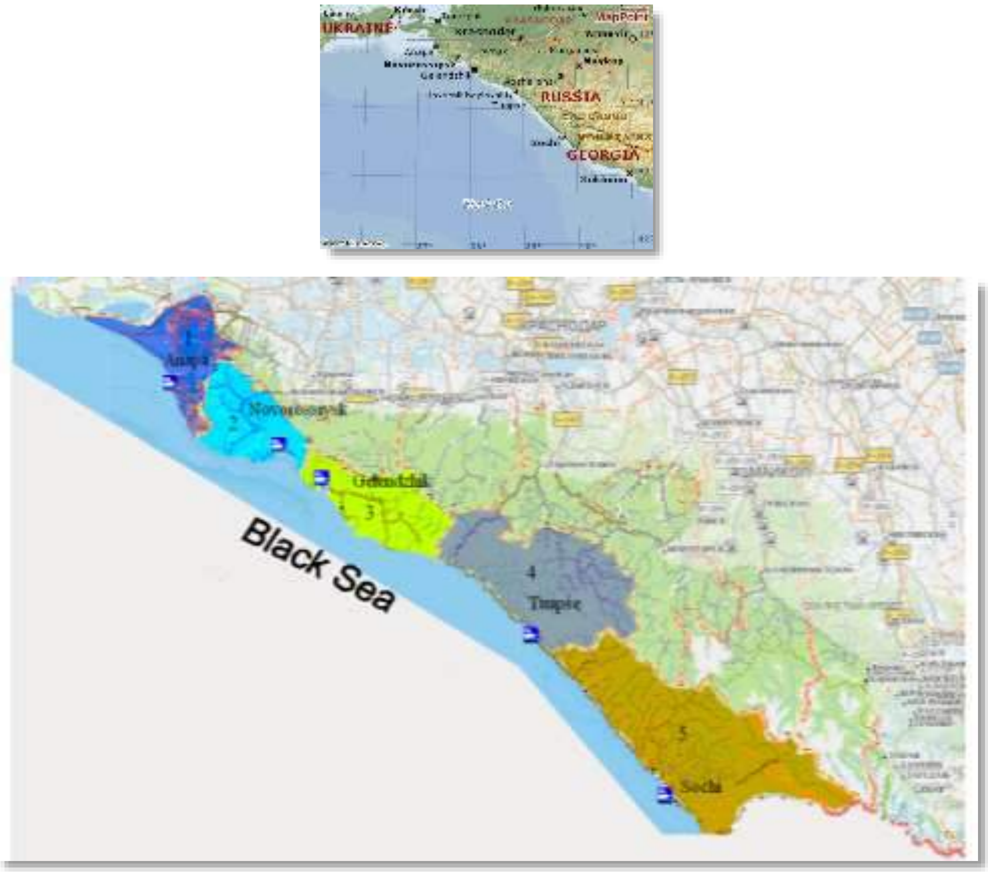


Figure 3.1.5. Coastal zone of Russia.

The costal zone of Turkey includes 14 provinces, namely: Artvin, Bartın, Düzce, Giresun, Kastamonu, Kırklareli, Kocaeli, Ordu, Rize, Sakarya, Samsun, Sinop, Trabzon and Zonguldak27. The total length of the Turkish the Black Sea coastline is of 1748 km (Fig. 3.1.6).

27 The area of Istanbul was excluded from the reporting by the decision of Advisory group (2002).

Figure 3.1.6. Turkish coastal zone

The Ukrainian Black Sea coastal zone is limited by borders of coastal regions (oblasts) and borders of the territorial sea waters. It includes territories of Autonomous Republic of Crimea, Mykolaiv, Kherson, Odesa regions and Sevastopol city (Fig. 3.1.7)28.

The total estimated area of the coastal zone is of113,400 km2. It is of 19% of the territory of the country area. The length of the coastal line from Danube Delta to the Cape Takil is of 1628 km.

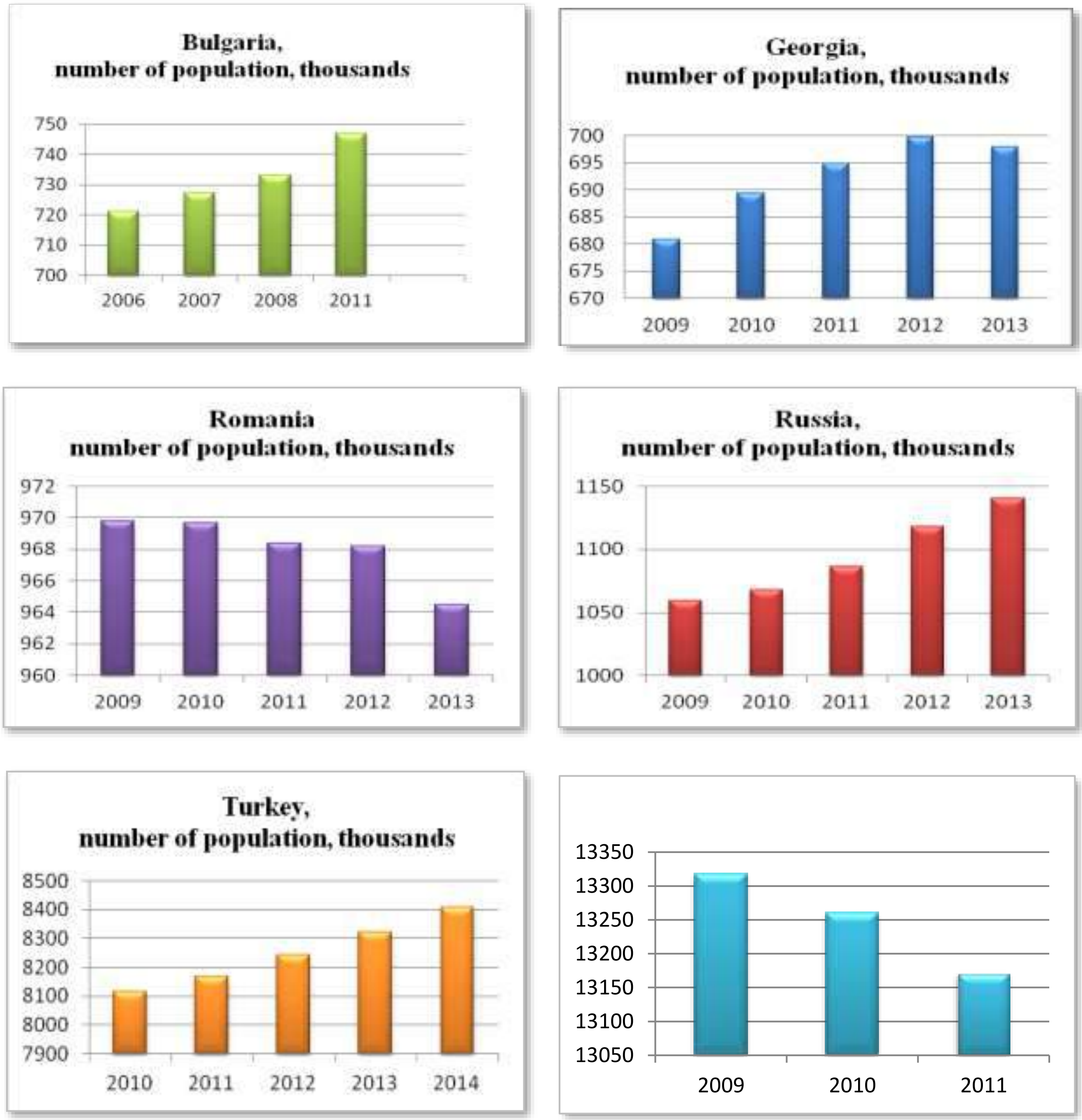
The costal zone includes 14 marine estuaries of large rivers (Danube, Dnipro, Dnister, Southern Bug) flow into the Black Sea and 8 gulfs. The total estimated area of estuaries is of 1,952 km2 and total of gulfs is 1770 km2.

Figure 3.1.7. Black Sea Region of Ukraine. Legend: 1 – 7 – watershed areas. (Source: State of the Black Sea Environment: National Report 1996 – 2000. – Odessa: Astroprint, 2002. – 80 p.)

28 AR of Crimea and Kherson Region partially belongs to the Azov Sea. However, for the consistency reason the total territory of both administrative units were considered as the Black Sea area in this report.

3.1.2. Population

Figure3.1.8. Population of the Black Sea countries.



For the reporting period the population growth was observed in coastal zone of Bulgaria, Russia and Turkey. The total number of population declined in Romania and Ukraine (Fig. 3.1.8).

In 2012, population density in the Black Sea coastal zone was: in Bulgaria – 140.21 people per km^2, Romania – 123.8 people per km^2, Russia – 123.8 people per km^2, in Ukraine it varied widely from 37.83 people per km^2 in Kherson region to 426.00 people per km^2 in Sebastopol region with the average 122.34 people per km^2 which is in the range of the rest of the Black Sea countries.

There is an indicator which is let one feel the real pressure on the coastal zone during tourism season. It is Population Density during Touristic Season”. As an example, the diagram of numerical values of the indicator for Russia is given in Fig. 3.1.9. The diagram shows that the population in the tourist season increases more than 8 times.

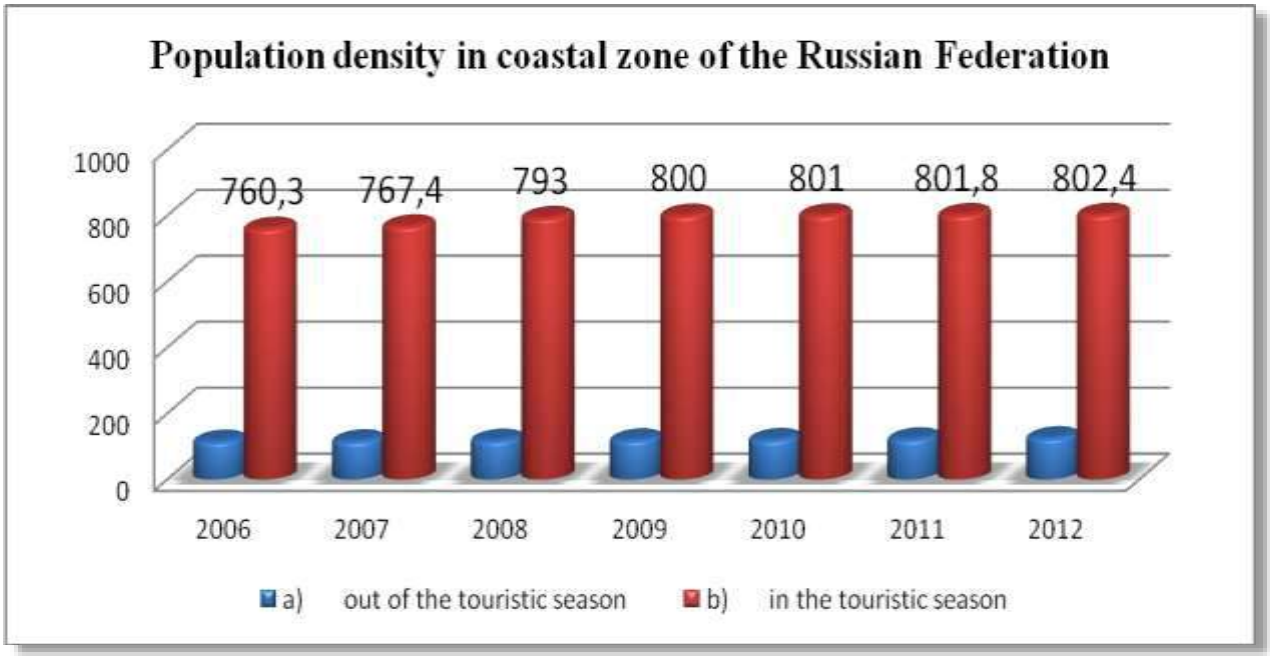


Figure 3.1.9. Population density in coastal zone of the Russian Federation, inhabitants per sq.km

There is another important indicator characterizing the pressure on the coastal zone. It is the ratio between urban and rural population. of city and rural residents, as well as data on urban and rural settlements from the year 2012 is listed in the table 3.1.1.

Table 3.1.1. Data on population, urban and rural settlements

Indicator	Bulgaria	Georgia29	Romania	Russia	Turkey30	Ukraine
No. of cities	21	3	17	5	173	55
No of cities over 100 000 inhabitants	3	1	1	3	17*	7
No of rural settlements	192	26	426	235	6630	3792
Total population in the coastal zone (thousands)	834.475	698.0	968,2	1117,7	8243	6995,5
Rural / urban ratio	75.87 / 24.13	N/A	40.65 / 59.35	33.45 / 66.55	48.52 / 51.48	34 / 66

3.1.3. Land use

The type of the land use in Black Sea counties varies from country to country and depends on climate, relief and other factors. The land use in the Black Sea countries according to the national reports is in Fig. 3.1.10 below.

29 Data limited to urban and rural settlements in the coastal zone only.

30 Istanbul area was excluded from consideration.

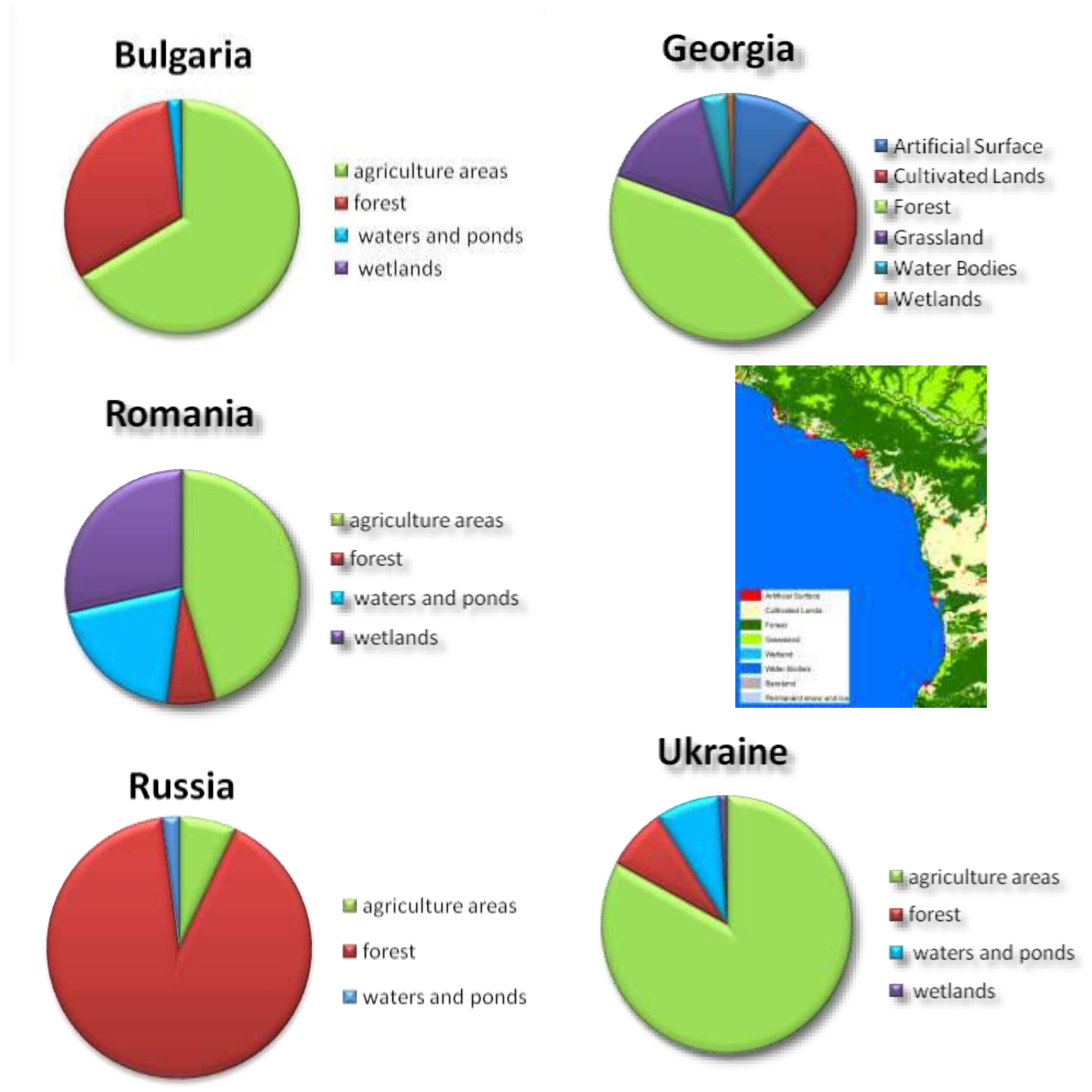


Figure 3.1.10. Land use in the Black sea countries

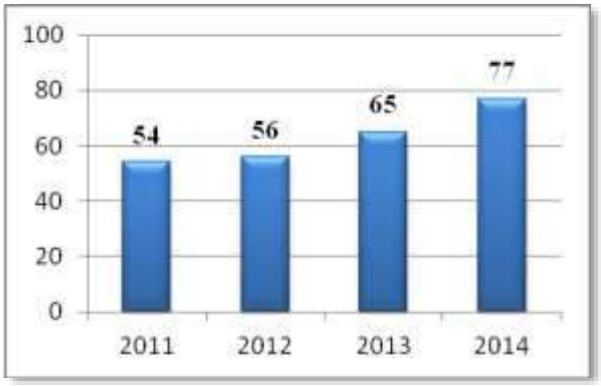
The coastal zones in Bulgaria, Romania and Ukraine are mostly used for agriculture. In Russia, the largest part of the coastal zone is covered by forests but there no wetlands at all. Forests also cover most of the coastal zone in Georgia (source: NGCC, http://www.globallandcover.org).

3.1.4. Water and waste water

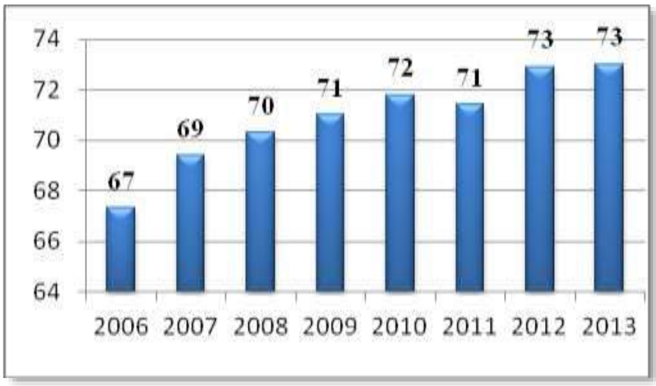
The limited access to drinking water and to sewage systems is common for the coastal zones. However, countries are putting sufficient efforts to address the problem, for example:

- In 2012 Bulgaria, almost 100% of population in its coastal zone has access to drinking water supply and about 76% of the population is connected to sewerage systems;

- Access to clean drinking water is steadily increasing in Romania from 63% in 2011 to 71% in 2013;
- There is a positive dynamic in Russia. The number of residents with access to drinking water changed from 85% in 2009 to almost 92% in 2013 and percentage of population provided with sewerage system changed from 71% in 2009 to 73% in 2013 (Fig. 3.1.11, b);
- In Turkey 77 % of population (urban and rural) was connected to the waste water treatment plants (WWTP) in 2014 (Fig. 3.1.11, a).



a)



b)

Figure 3.1.11. Percentage of Population connected to WWTP in Turkey (a) and Russia (b)

3.1.5. Solid Waste Management

Estimating the amount of solid waste processed is challenging because the Black Sea countries have various approaches for estimation and reporting. However, according to the national reports, at least the number of landfills has increased in Romania, Turkey and has decreased in Russia and Bulgaria. There is an incineration plant in Turkey and there are two in Romania. Russia reports about a steady rise of volume as industrial as well as of municipal wastes, the same tendency occurs in Turkey. It looks like that there were a lot of solid wastes were accumulated in the Black Sea countries. Therefore, the waste recycling, treatment and utilization has become an urgent task.

3.1.6. Protected Areas

The number of protected areas did not change since the issuing of the previous SOE Report in Romania, Russia, and Turkey. There are 92 protected sites with a total area of 16,940 ha, 48 sites of Nature 2000 with a total area of 5,300 ha, and 31 marine protected areas of 302, 200 ha in Bulgaria.

Kolkheti National Park (area 45,447 ha as of 2013) includes both a terrestrial part of 29,704 ha and a marine part of 15,743. It is the largest one and the only marine protected area in Georgia. Romania has 8 sites of Nature 2000 with the area of 138,700 ha and 2 marine protected areas with a total area of 108,000 ha. Russia reported increase of the total protected area. There is only 1 marine protected area (Utrish) in Russia with total area 9,848 ha. It includes 9,065 ha of forest land and 783 ha of the sea area. There are 11 natural reserves with a total area of 38,000 ha in Turkey.

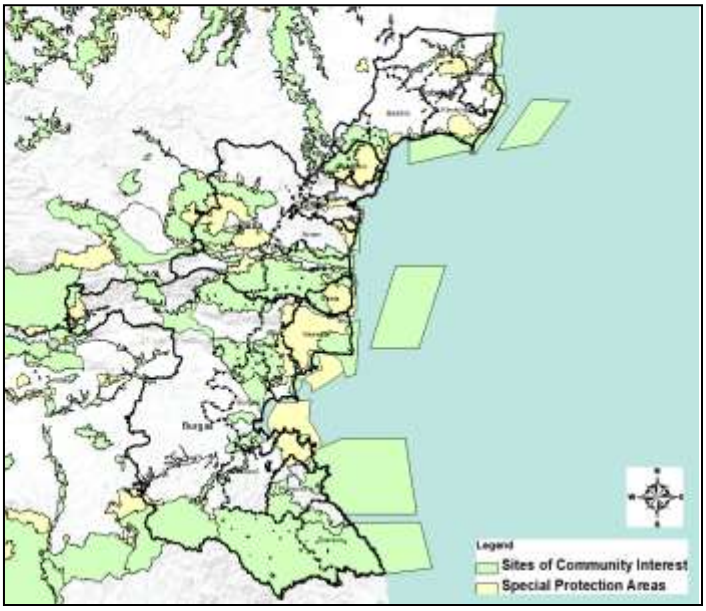


Figure 3.1.12. NATURA 2000 sites in Bulgaria

3.1.7. Coastal erosion

Coastal erosion is the common problem for all the Black Sea countries.

Beach erosion/abrasion surveys were carried out in Bulgaria from 1983 to 2003. According to the reports of the surveys, the landslides and erosion terraces cover about 13% of the coastal line of the country. The average rate of annual beach surface eroded along the Bulgarian Black Sea coast is 17,527 m^2/year. The average estimated rate of coastal erosion is 0.08 m/year. The average rate of retreat of cliffs is 0.36 m/year (Peychev, 2004): https://www.climatechangepost.com/bulgaria/coastal-erosion/

Coastal change tool of Georgian Data Cube (UNEP/GRID http://geodatacube.unepgrid.ch, GDC) was used in Georgia to estimate coastal dynamics in 2009-2013. The results for the area near Poti are in Fig. 3.1.14.

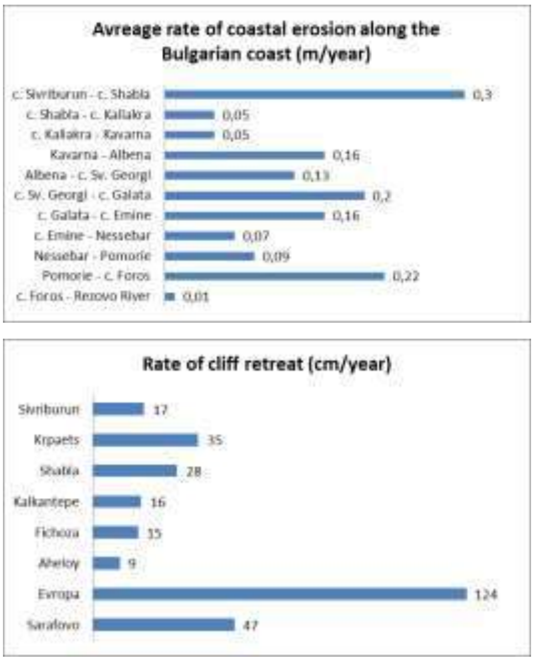


Figure 3.1.13. Average rate of coastal erosion and cliff retreats along the Bulgarian Black Sea coast

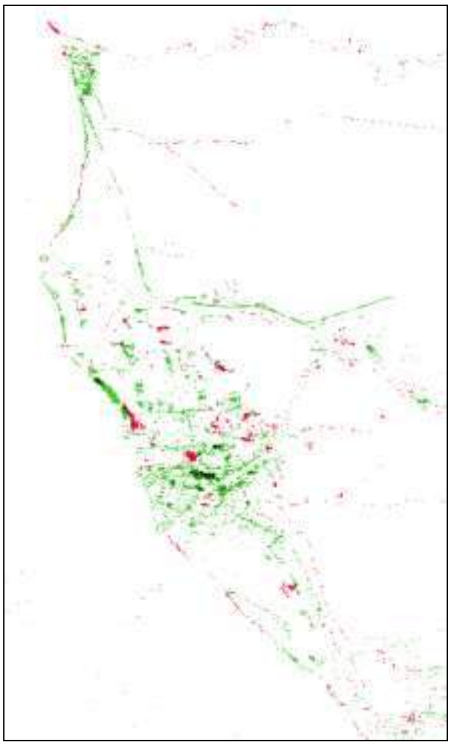


Figure 3.1.14. Dynamics of Poti (Georgia) coastline from Khobistskali to Supsa river mouths for period 2009-2013 (GDC, Landsat 7). Legend: red: land-to-water, green: water-to-land

About 50 ha with accumulation and about 80 ha with erosion process were identified (NIMRD, 2014) in the northern sector of Romania's cost (Fig. 3.1.14, 3.1.15). The shoreline advanced by more than 10 m on 10% of the total length of the coastline and recession by more than 10 m on 53% of the coastline. It is about 38% of the coastline is stable (retreated or advanced by less than 10 m). There are 5 coastline protection priority projects which started under the Coastal Zone Master Plan aiming at mitigating erosion and rehabilitating the coastal zone. The projects cover Mamaia South, Tomis

North, Tomis Center, Tomis South and Eforie North sites. There were 51 benchmarks in the area of the protection works (construction of dams/dikes) to continue erosion survey (NIMRD, 2014).

Figure 3.1.15. Accumulation/erosion 2011-2012

in Sulina – Sf. Gheorge – Zaton, Romania

Figure 3.1.16. Accumulation/erosion 2011-2012 in Perisor – Cape Midia sector, Romania

Source: NIMRD Report on the State of the Marine and Coastal Environment in 2011-2012

The average annual variation along the coast of Russia does not exceed 1 m. The average coastal recession is 0.7 m/year in the northern part of the coastline because it is formed with erodible rocks. In the south, there is a 50 km sand bay-bar system with dunes and beaches, then a flysch zone with abrasion cliffs and a mountainous coastline with gravel/pebble beaches. A longshore transport stream interrupted with a system of groins and breakwaters which intercept pebble and gravel material migration along the coast. Therefore, beaches are not restored naturally Average rate of beach surface erosion is 0,5 m.

Storms, in particular of the south, southwest and southeast directions have negative impact on the coastline in Ukraine. It is due to the dynamic impact of waves which could have 4 to 7 m heights. The estimated coastline retreat due to this impact is from 0.2 to 0.3 m per 1 cm of waves heights.

3.1.8. Tourism

Tourism is one of the most important sectors of economy in the Black Sea countries. However, different reporting criteria of visitors used by the states make the results incomparable. Nevertheless, due to accommodation capacity increase there is an assumption that there is an increasing trend for the number of visitors except Romania. The number of Blue flag beaches remains relatively low in all Black Sea countries (Bulgaria - 11, Romania - 1, Turkey – 4, Ukraine - 3,)31.

- Bulgaria reported about an increase in accommodation capacities and about general increase of visitors both national and from abroad (totally 2,432,000 visitors in 2012);
- Romania reported about fluctuation of the number of visitors during 2006-2010 (Fig. 3.1.16). At the same time there is an increase in accommodation capacities and visitors in 2011 and 2012; (there were 1,041,000 visitors registered in 2012);
- Russia observed a steady annual arrivals and accommodation capacity increase (there were 9,869,000 visitors in 2012);
- There is an increase in accommodation capacity and number of visitors in Turkey (3,671,000 visitors in 2012);
- There is a stable growth in accommodation capacity and fluctuating number of visitors observed in Ukraine (2,878,000 visitors in 2011).

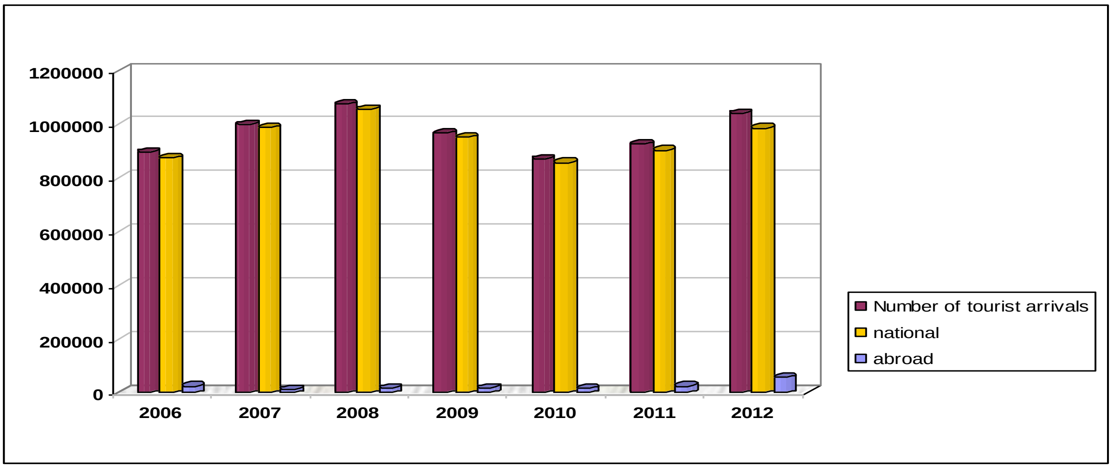


Figure 3.1.17. Number of visitors arrivals to the Romanian Black Sea coast in 2006-2012.

3.1.9. Energy

Renewable energy sector is growing in the Black Sea countries: For example, there is a positive developments in a wind-energy field in Romania. Constanța County has the highest potential for wind-energy production in the country. The biggest wind power plant was developed in at Dorobanțu in 2011. The wind park operates with 18 turbines with a total installed capacity of 54 MW. The largest coastal wind farm in Europe locates in Fântanele-Cogealac. It launched its operations in 2012. The wind park has the installed capacity of 600 MW. It operates with 240 turbines with an installed capacity of 2.5 MW each. The onshore wind farm can provide energy for 1 million households annually.

Turkey listed 2 wind farms in 2014.

31 Russia and Georgia do not apply Blue Flag Beach criteria.

3.1.10. Industry

Bulgaria reports about one refinery in coastal zone. There are also metallurgic, textile and food processing enterprises in the coastal zone of the country;

There is one refinery in Romania. There are also metallurgic, construction materials, textile and food processing enterprises;

Industry is not well developed in the coastal zone of Russia. There is only one refinery there. The most industrially developed city is Novorossiysk where cement industry is located.

Industry sector is more developed inTurkey. The diagram on fig. 3.1.18 illustrates the tendency in the sector development. Cement, paper, packaging, copper, mining and shipping plants are operating in the coastal zone of the country. There are textile and metallurgic enterprises besides the leading food processing industry.

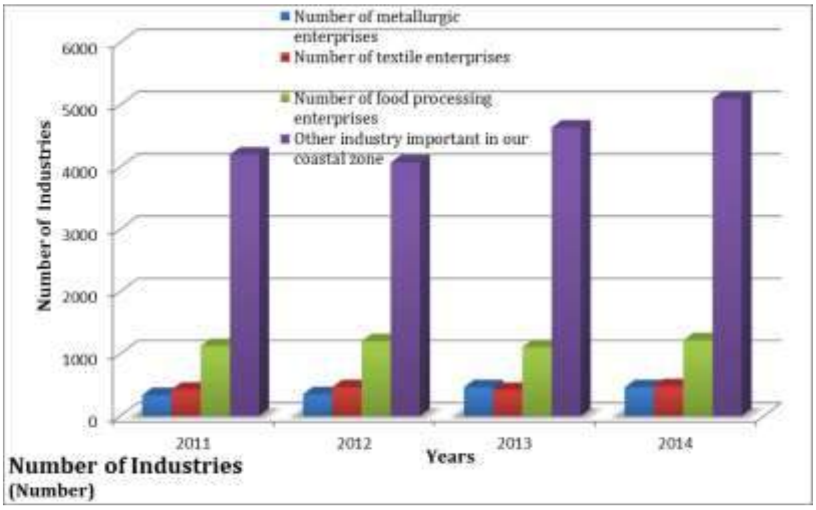


Figure 3.1.18. Industry in Black sea coastal zone of Turkey

3.1.11. Agriculture

There are very few figures provided by the countries about agriculture.

There is a decrease in the area of arable land in the coastal zone of Russia. It decreased from 50,500 to 36,600 ha during last 5 years. There is also a decrease in the number of heads of cattle, pigs, sheep and poultry;

Turkey reported about increase for the total land use of agricultural areas from 1,965,000 to 1,974,000 ha between 2011 and 2014. The number of heads of cattle, sheep and poultry is also increased.

Ukraine reported on a general decrease in the number of heads of farm animals except poultry in Kherson Region. Value of production generated by agricultural sector in the Black Sea Region increased in Kherson Oblast and decreased in two other Oblasts in 2014.

3.1.12. Transport (including port activities)

All Black Sea countries have harbors with different traffic capacity. There are oil terminals in the countries: Bulgaria – has one, Georgia – three, Romania -one, Russia – four, Turkey – eight terminals.

Density of the public road network differs from country to country, with Romania (Constanta county) having the highest (0.35 km/km^2) and Turkey having the lowest (0.115km/km^2).

3.1.13. Proposed Indicators to Report on the State of the Black Sea coast

Currently, a new set of indicators is being considered for the evaluation of the state of the Black Sea coast. In the framework of PEGASO Project (PEGASO, 2013), new methodological factsheets for indicators in support of comparable measurements and integrated assessment in coastal zones were introduced. ICZM National Focal Points from Georgia, Romania and Ukraine responded positively to this initiative and tested the indicators in the following case sites: Georgia selected Lanchkhuti and Ozurgeti Municipalities and Guria Region; Romania selected Constanta County as part of Dobrogea Region; Ukraine opted for Scadovsk Town (NUTS 5) and District (NUTS 4) in Kherson Oblast (NUTS 3).

The Romanian National Focal Point (NFP) reported about the following selected indicators for Constanta County as part of Dobrogea Region: *Area of built-up space*, *Added value per sector*, *Coastal dynamics*, *Economic production*, *Employment*, *Number of enterprises*, *Population size and density*, *Sea level rise*.

Area of built-up space in the coastal zone

Units: Coastal Administrative Unit LAU 2 (NUTS 5).

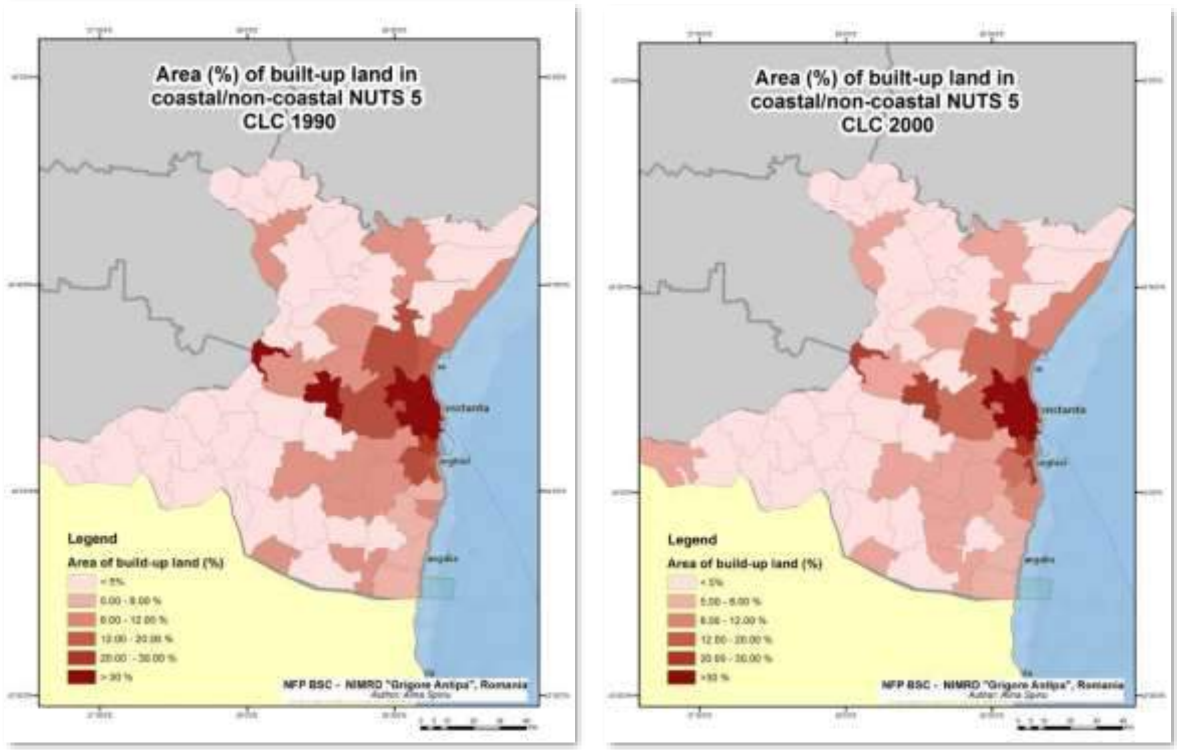


Figure 3.1.19. Area (km^2) of built-up land in coastal NUTS 5 as a proportion of the area of built-up land in the wider reference region for years 1990 and 2000 for Constanta County, Romania

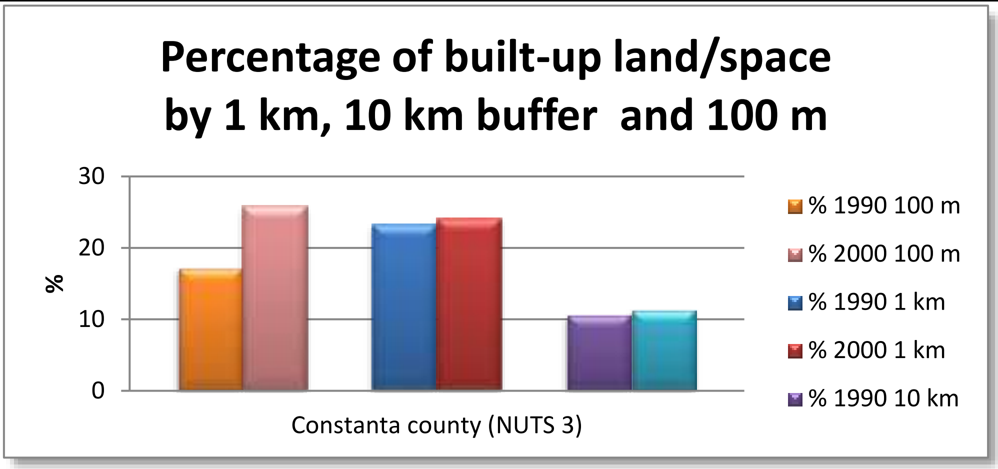


Figure 3.1.20. Percent of built-up land by distance from the coastline in 0-1km, 0-10km and 1-100 m buffers units, by NUTS 3 for years 1990 and 2000 for Constanta County, Romania.

Added value per sector

Coverage: Constanta County and regional level

Units: Coastal Local Administrative Units NUTS 2 and NUTS 3 levels.

Source: National Institute for Statistics – Constanta County Department for Statistics, Statistical yearbook of Constanta County 2012.

Sectors identified as relevant for ICZM: Agriculture, Extraction and processing, Manufacturing, Electricity power production and delivery, Water supply, sanitation, waste management activities, Constructions, Trade, Transport activity and warehouses, Hotels and restaurants.

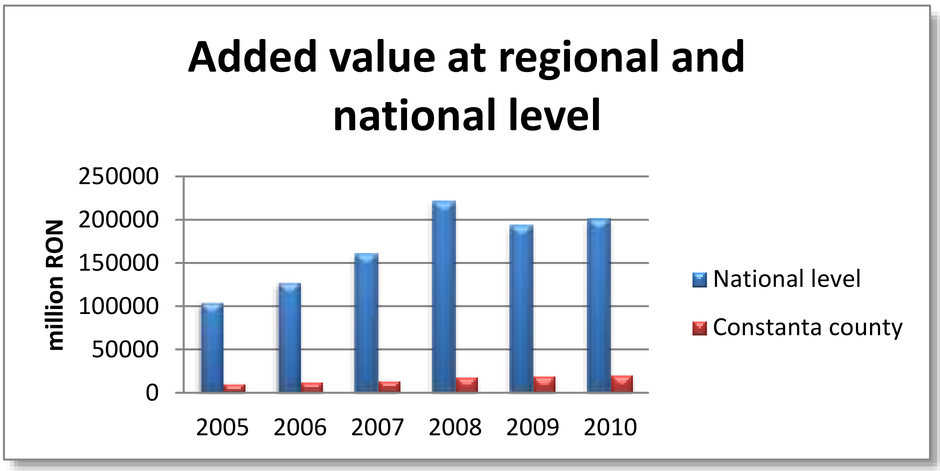


Figure 3.1.21. Added value per sectors relevant in relation to ICZM (Constanta County, Romania)

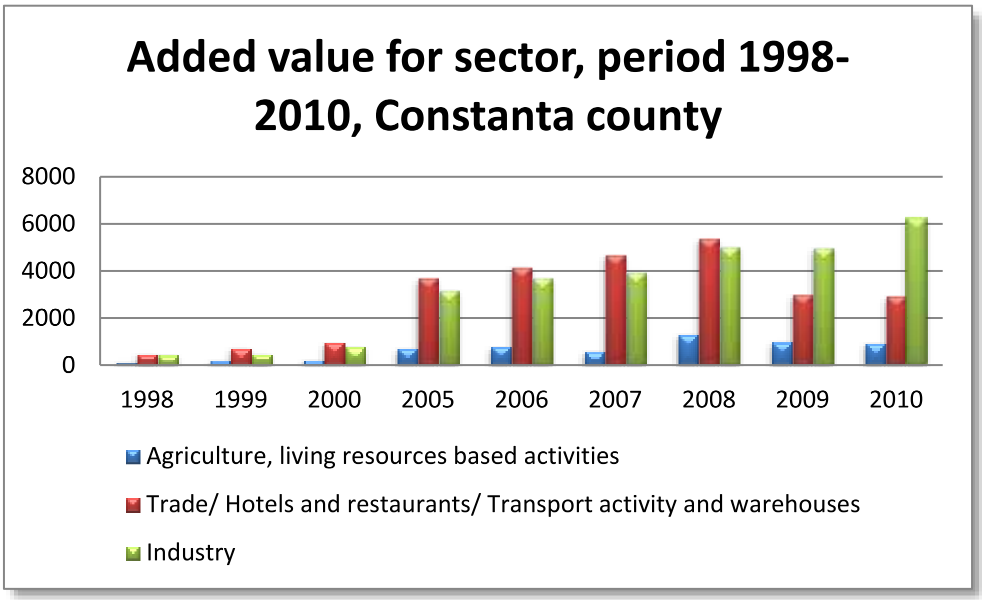


Figure 3.1.22. The dynamics of added value in the relevant sectors (Constanta County, Romania)

Areal extent of coastal erosion and coastal instability

Coverage: Romanian littoral

Source: Topographic map 1980 (NIMRD database), Aerial photos 2004 (NIMRD database), SPOT satellite image 2007 (NIMRD database)

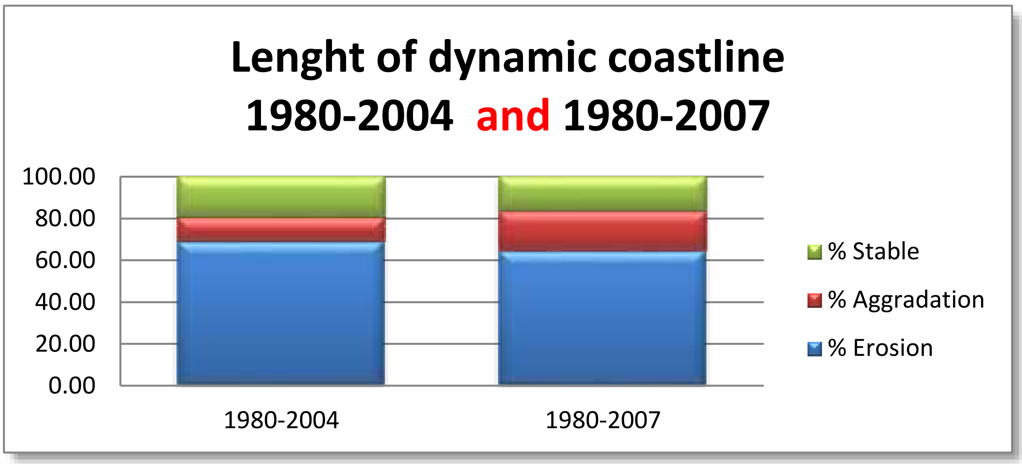


Figure 3.1.23. Coastline instability (Romanian littoral)

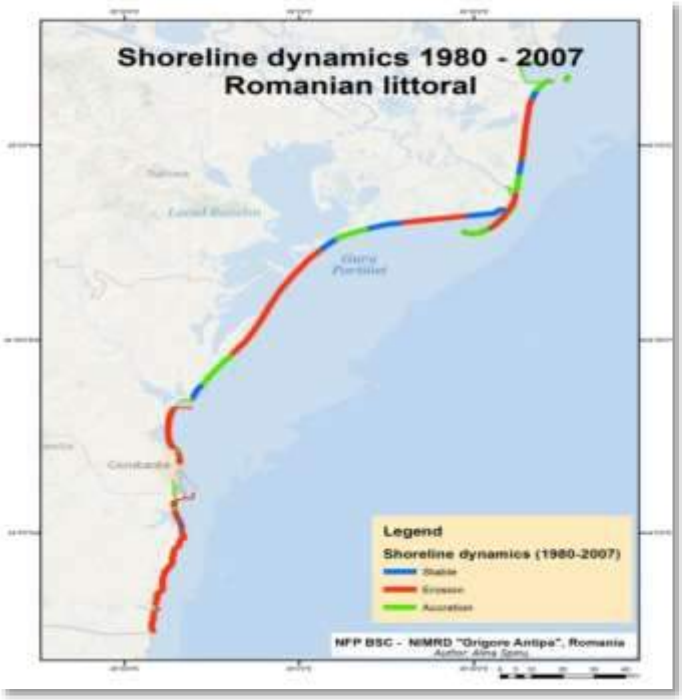


Figure 3.1.24. Coastline dynamics (Romanian littoral)

Economic production per sector (turnover)

Units: Coastal Local Administrative Units NUTS 2 and NUTS 3 levels.

Source: National Institute for Statistics – Constanta County Department for Statistics, Statistical yearbook of Constanta County 2012.

Sectors identified as relevant for ICZM: Extraction and processing, Manufacturing, Electricity power production and delivery, Water supply, sanitation, waste management activities, Constructions, Trade, Transport activity and warehouses, Hotels and restaurants.

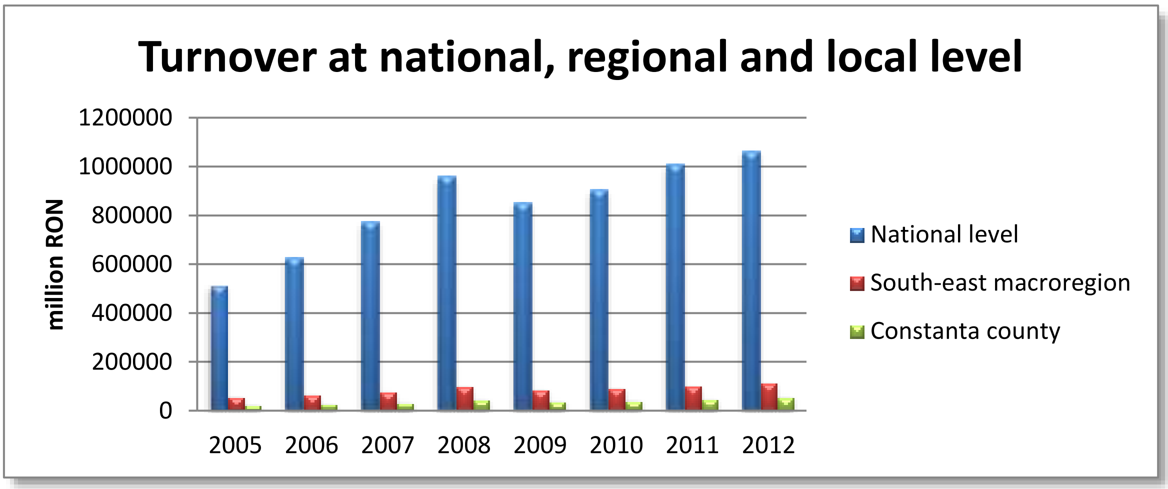


Figure 3.1.25. Economic production (turnover) per sectors that are relevant in relation to the ICZM (Constanta County, Romania)

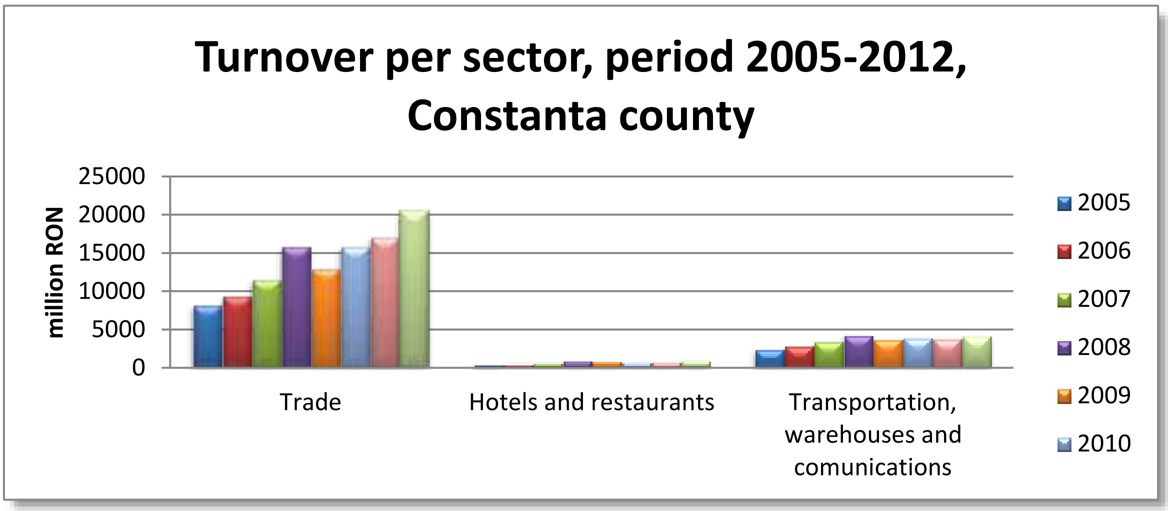


Figure 3.1.26. The dynamics of economic turnover in relevant sectors (Constanta County, Romania)

Employment structure (Active population structure)

Units: Coastal Local Administrative Units NUTS 2 and NUTS 3 levels.

Source: National Institute for Statistics – Constanta County Department for Statistics, Statistical yearbook of Constanta County 2012.

Sectors identified as relevant for ICZM: Agriculture, Extraction and processing, Manufacturing,

Electricity power production and delivery, Water supply, sanitation, waste management activities, Constructions, Transport activity and warehouses, Hotels and restaurants.

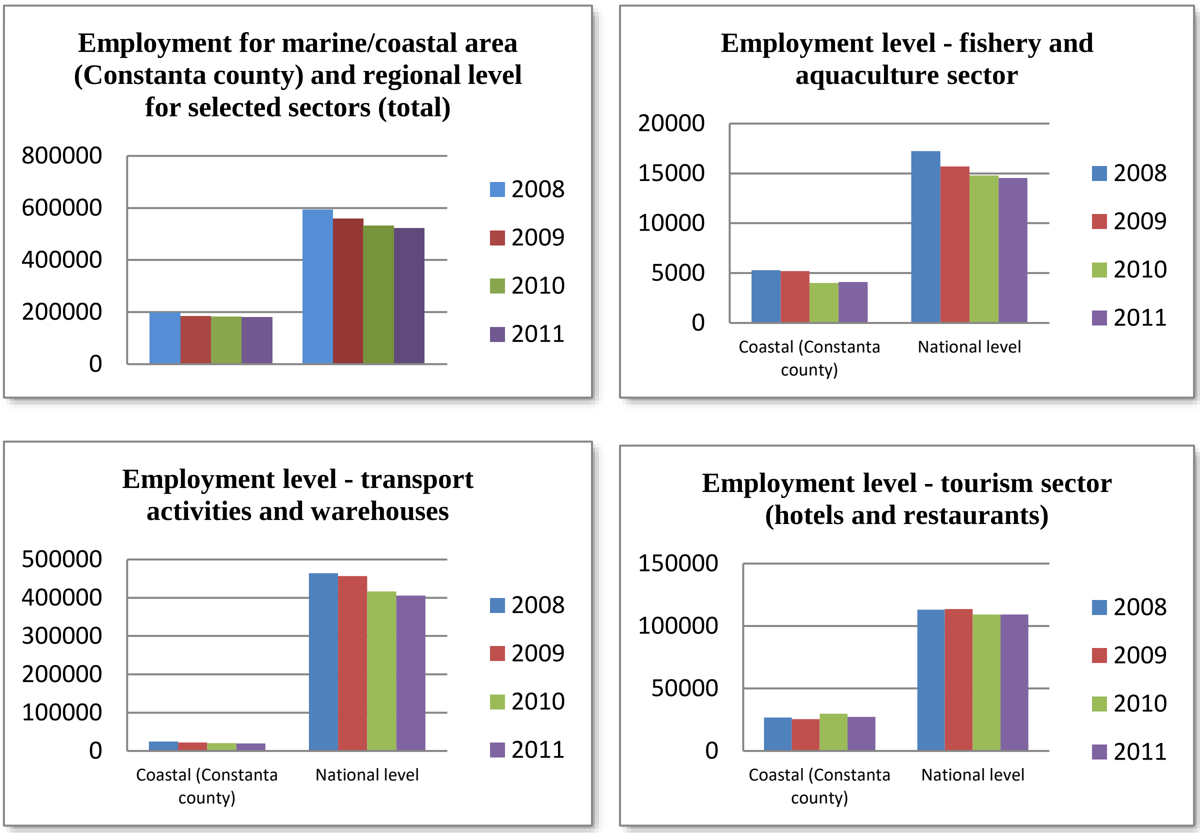


Figure 3.1.27. Employment level per sectors relevant in relation to the ICZM (Constanta Country, Romania).

Number of enterprises

Units: Coastal Local Administrative Units NUTS 2 and NUTS 3 levels.

Source: National Institute for Statistics – Constanta County Department for Statistics, Statistical yearbook of Constanta County 2012.

Sectors identified as relevant for ICZM: Agriculture, Extraction and processing, Manufacturing, Electricity power production and delivery, Water supply, sanitation, waste management activities

Constructions, Trade, Transport activity and warehouses, Hotels and restaurants.

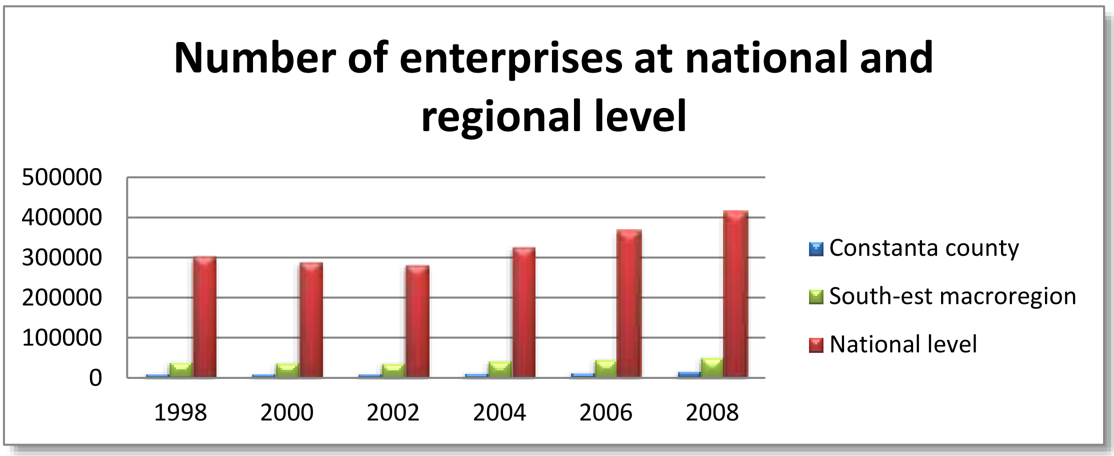
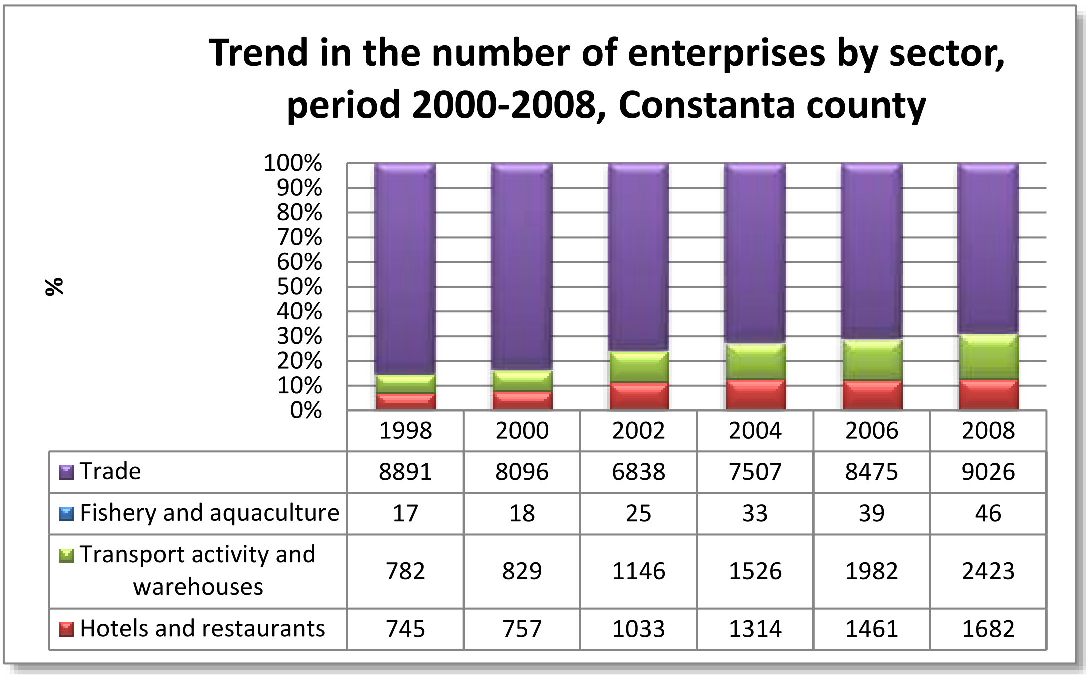


Figure 3.1.28. Percent Number of enterprises per sectors that are relevant in relation to the ICZM



	1998	2000	2002	2004	2006	2008
Trade	8891	8096	6838	7507	8475	9026
Fishery and aquaculture	17	18	25	33	39	46
Transport activity and warehouses	782	829	1146	1526	1982	2423
Hotels and restaurants	745	757	1033	1314	1461	1682

Figure 3.1.29. Percent Number of enterprises per sectors that are relevant in relation to the ICZM

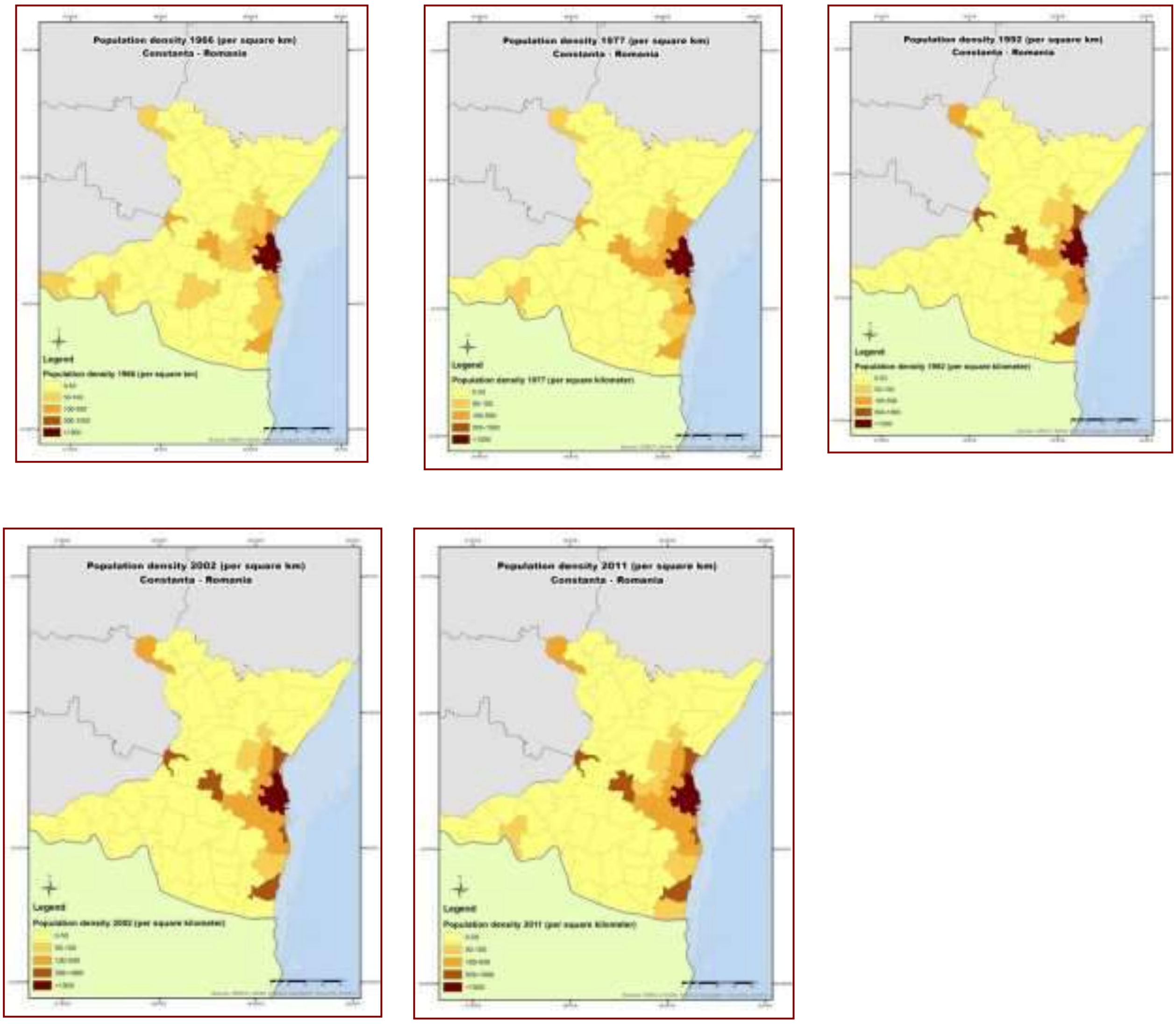
Size and density of the population living in the coastal area

Units: Coastal Local Administrative Unit LAU 2 (NUTS 5).

Source: National Institute for Statistics – Constanta County Department for Statistics, Statistical yearbook of Constanta County 2012.

Built-up area: Number of inhabitants per square kilometer in coastal LAU 2 compared to the number of inhabitants in non-coastal LAU 2.

Built in buffer: Population of the coastal LAU as a proportion of the total population of the wider reference region.



Figures 3.1.30. Number of inhabitants per square kilometre in coastal LAU 2 compared to the number of inhabitants in non-coastal LAU 2 for 1966, 1977, 1992, 2002 and 2011 (Constanta County, Romania)

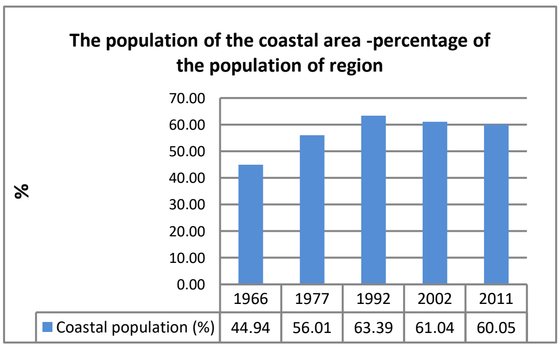


Figure 3.1.31. Population of the coastal LAU 2 as a proportion of the total population of the wider reference region (Constanta County, Romania)

Sea level rise and SLR relative to land

Units: Coastal gauges and sampling stations.

Parameter: Annual mean sea level relative to land (millimetres).

Spatial units: Time series for Constanta, Romania and Varna, Bulgaria from 1933 to till 1996.

Following source was used to provide indicator compilation as well as to see metadata:

Constanta: http://www.psmsl.org/data/obtaining/stations/379.php

Varna: http://www.psmsl.org/data/obtaining/stations/318.php

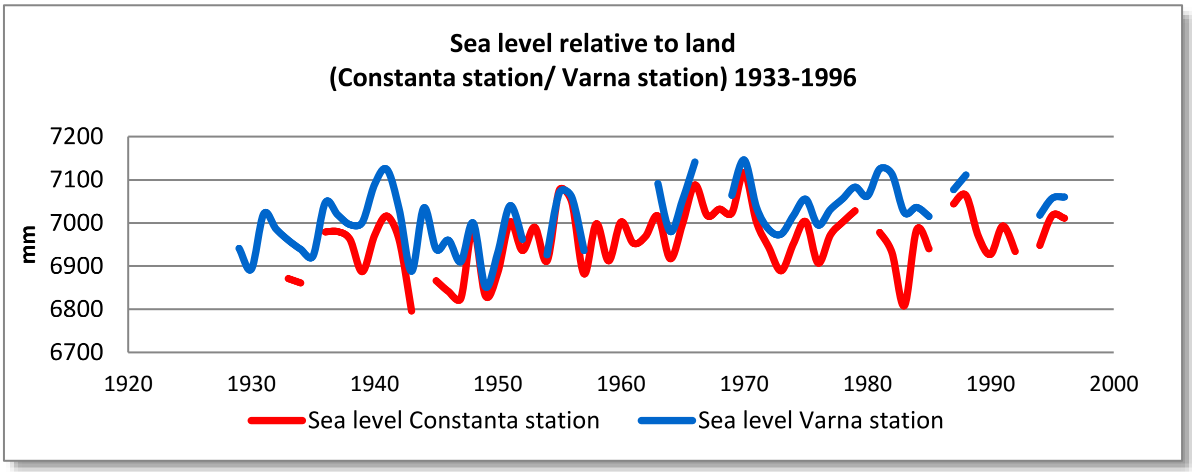


Figure 3.1.32. Sea Level relative to land for Constanta and Varna (source: http://www.psmsl.org)

3.1.14. Conclusions:

Analysis of information available allows to draw the following conclusions:

1. Due to the lack of important information a deep analysis of the state of the coast was impossible. To overcome the problem, ICZM Advisory Group of the Black Sea Commission decided to introduce new indicators for assessment of the state of the Black Sea coast. They were tested and ICZM Advisory Group agreed to use these indicators for future activities.

2. Black Sea coast is the zone of many types of activities. The most part of the coastal zones in Bulgaria, Romania and Ukraine are used for agriculture. In Russia biggest part of the coast is covered by forest and protected.

3. The number of population in the coastal zone is growing in Bulgaria, Russia and Turkey and decreasing in Romania and Ukraine.

4. There is a sustainable growth in access to drinking water and sanitation in all countries.

5. There is an increase in the amount of municipal wastes. The number of landfills has increased in Romania, Turkey and has decreased in Russia and Bulgaria. There is only one incineration plant. It locates in Turkey.

6. Erosion of the coast is increasing. However, there are very few projects implemented to prevent it.

7. There are activities going on to improve protection of the coastal zone environment, including marine.

8. Since previous report the structure of economic activities was not changed. The leading sectors are tourism, food processing, agriculture and transport, including shipping.

9. Oil transhipment sufficiently impact on environment.

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3.2 INTEGRATED COASTAL ZONE MANAGEMENT IMPLEMENTATION

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Introduction

This chapter reports on the implementation of Integrated Coastal Zone Management (ICZM) in the Black Sea region. Summary sub-section fist presents the main trends in the state of the coast in the Black Sea Basin with emphasis on the issues with management instruments to address them, followed by short description of ICZM activities of Black Sea riparian countries and existing arrangements for regional coordination. Sub-section is concluded with best practice recommendations for addressing the identified problems in the coastal zones through comprehensive application of ICZM within the long term governance. Summary sub-section is followed with detailed presentation of the application and implementation of ICZM in the Black Sea Region in the period of 2009-2014 and prospects for future action. Summary of main regional trends, activities and best practice findings are reported in subsection 3.2.1-3, followed by detailed presentation of ICZM in the Black Sea region in subsections 3.2.4-7.

3.2.1 Main trends

Illustration of the overarching issues with coastal governance arrangements and the trends in the state of coastal environment faced by the six littoral states around the Black Sea is certainly the expansion and encroachment of urbanised areas and infrastructure developments towards and along the coast. In all six countries, without exception, built-up spaces almost doubled within the 10-km strip buffer adjoining the Black Sea coastline (see Fig. 3.2.1) in the period since signing of the Bucharest convention (1992) and until the end date of the current reporting period (2015) on the State of the Black Sea Environment.

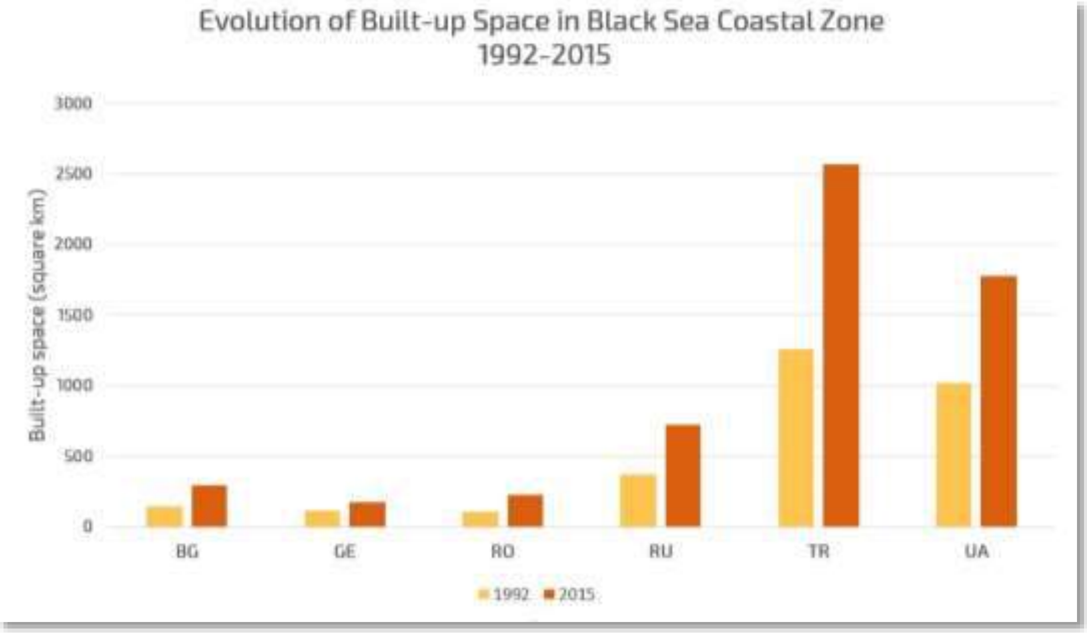

Figure 3.2.1. Evolution of built-up space in Black Sea 10-km coastal buffer during 1992-2015 (cf. Figure 3.2.3 below)

Governance issues identified with the Integrated Coastal Zone Management (ICZM), such as those revealed with the ICZM stock-taking and ICZM progress indicators confirm, that much needs to be done in the region internationally and at national and sub-national levels to improve coastal governance, so that rate of artificialisation of the Coastal Zone (CZ) is reduced and plethora of environmental consequences are addressed, therefore further efforts are indeed required to address management issues identified through stock-taking done in 2012, namely:

- All the Black Sea countries need either to improve or to define statutorily CZ boundaries.
- Coastal legislation either not available or not based on sound principles of ICZM.
- Mechanisms for vertical, horizontal and land-sea integration are weak or non-existent.
- Setback distances to control coastal developments are not established or not well enforced.
- Specific economic indicators related to sustainable use of the coastal zone are not applied.
- Progress was reported in all countries in designation of wetlands of international importance.
- No experience reported though with the restoration of degraded wetland habitats.
- Marine Protected Areas (MPA) designation insufficiently and is in need of concerted efforts.
- Insufficient regulations for coastal landscape/seascape protection at national & local levels.
- No mechanisms for meaningful communication in place with regard to the coastal strategies, plans, programmes and projects of local, national and transboundary nature.
- Training & education in ICZM implemented only on an *ad hoc* basis and not well sustained.
- National assessments of the coastal zone and its governance framework on *ad hoc* basis.
- No mechanisms exist of land and sea acquisition for coastal preservation or for providing public with access to and along the coast/coastline.
- No economic/financial incentives in place in support of ICZM – only command and control.

- Preference given to expensive investments (like combating rather than preventing coastal erosion and flooding) instead of management measures (such as setbacks or spatial plans).
- Various ICZM indicators set at the regional level not applied at the national/local level.
- Support for ICZM Regional Activity Centre is currently discontinued.
- Only two counties developed ICZM strategies, but non approved due to insufficient will.
- Pilot projects demonstrated ICZM spatial planning methodology only in non-EU countries.
- Black Sea regional transboundary EIA recommendations developed but not endorsed yet, while Protocol on EIA seems less feasible given the reservations of some countries.

3.2.2 ICZM activities and regional coordination

The Black Sea Commission, its Permanent Secretariat and the Advisory Group on the Development of Common Methodologies for Integrated Coastal Zone Management (ICZM AG), provide the international framework for the coordination and advancement of ICZM in the Black Sea Region.

Activities of ICZM AG since its inception in 1996 up to the reporting period till 2009 were well documented in Antonidze (2009), Kosyan and Velikova (2016) and further in BSC (2016). Key outputs, which were supported by GEF/UNDP and EU projects within the Black Sea Environmental Programme (BSEP), included National ICZM Reports (1996); National ICZM Policies & Strategies (1997); Coastal Code of Conduct (2000), Regional ICZM Strategy (2003) (not endorsed yet), ICZM Spatial Planning Methodology (2004), ICZM Pilot Projects (Russian Federation 2000, Ukraine 2000, Turkey 2007, Georgia 2009), Feasibility Study for the ICZM Instrument to the 1992 Bucharest Convention, Vinogradov (2007), ICZM Progress Indicators (2008). Regional ICZM activities in the current reporting period of 2009-2014 are briefly summarised below.

Particularly noteworthy in this period were European projects (such as http://pegasoproject.eu), supporting the Black Sea countries in taking the stock of ICZM achievements in the region; enhancing the implementation of management instruments such as various types of ICZM indicators; and notably developing the regional guideline for ICZM – fulfilling the key action mandated by the BS-SAP (2009).

Indeed, through coordinated efforts applied in the reporting period, a milestone was achieved in ICZM area with the endorsement of the 'Guideline on Integrated Coastal Zone Management in the Black Sea' by the 32nd Regular Meeting of the Commission on the Protection of the Black Sea Against Pollution, 12-13 October 2016, Istanbul, Turkey (BSC, 2016).

As an another important action in transboundary cooperation in the field of Environmental Impact Assessment (EIA), the ICZM Advisory Group, after several iterations, finalised the 'Recommendations on EIA in a Transboundary Context for the Black Sea Region', submitting the document for consideration by the Black Sea Commission. The document was developed in cooperation with the Espoo Convention Secretariat (UNECE) and once adopted, would provide guidance on transboundary EIA cooperation by means of notification, exchange of information and consultation.

3.2.3 ICZM best practice

Per approved 'Guideline on ICZM in the Black Sea' the Countries are advised to prepare and regularly update national inventories of coastal zones, covering information on resources and activities, as well as on institutions, legislation and planning that may influence coastal zones (section XVI, para. 1).

The Black Sea Countries are also invited to define and measure appropriate indicators, in order to evaluate the progress achieved in ICZM implementation (section XVIII, para. 4).

Six coastal countries reported on progress with ICZM under the auspices of the Commission, with initial results published in the previous SoE of the Black Sea (BSC, 2008). ICZM AG has further fine-tuned the progress reporting to their needs, expanding it to include the indexed reference system, communicating in textual format the reasoning for upgrading or downgrading colour coded markers. ICZM AG developed the concise user manual for filling ICZM progress indicators in the Black Sea Region and included it in the Guideline as Appendix 1.

ICZM Progress Indicators updated by ICZM NFPs from six Black Sea Countries is presented in the Attachment 2, where presentation first starts with the regionally agreed progress ratings.

Following the provisions of the 'Guideline on ICZM in the Black Sea' (Appendix 2), all six Black Sea Countries successfully completed stock-taking exercise individually as well as produced regional synthesis report documented in Antonidze et al. (2013).

In congruence with the issues identified upon stock-taking (listed above), the following were defined as the best practice recommendations for furtherance of ICZM in the Black Sea Region:

A harmonized delimitation of Coastal Zone boundaries is required.

Defining common principles would assist national initiatives to legislate ICZM.

Consultative fora should contribute into integration rather than dilute the focus.

Coastal development control, setback regulations and practical mechanisms for guaranteeing cross-shore and long-shore access provisions are required.

More attention needs to be paid to marine protected areas, wetland restoration and the protection of coastal landscapes as part of the ICZM agenda.

Participation should be seen as integral part of the ICZM governance process with genuine opportunities and mechanisms for the public to challenge the strategies, plans and projects prior to key decision-making steps.

ICZM centres of excellence are missing in the countries and at the regional level.

More effort is required to develop and deliver training and education in ICZM.

Monitoring & reviewing the progress with ICZM should be built in into the administrative arrangements.

Regional arrangements could prescribe common format to guide national ICZM strategies and plans.

Pilot projects and cases should be pursued to apply ICZM at all levels.

Some Black Sea countries need to upgrade their EIA systems to bring them in line with the best international practice, as well as to introduce SEA. Regional arrangements for EIA in transboundary context should be pursued and agreed for the Black Sea marine region.

Sound economic and financial instruments are evidently missing in the region.

Assessment and preparedness for climate change induced and other coastal hazards need advanced planning and time to start acting is now.

An easy to use and upgraded common set of coastal (including socio-economic) indicators and ecosystem accounts are warranted to monitor changes (statistical, spatial) in the coastal zones, as well as to observe the outcomes of the management efforts. Use of ICZM progress indicators should be continued on a permanent basis.

International cooperation within the BSC framework is the key driver for ICZM in the region. More visibility and functionality would support the process.

The Black Sea countries should use the opportunity of Turkey being the only Mediterranean and Black Sea country and promote, adapt and adopt the best management solutions available in the partner marine region, such as the ICZM Protocol.

The last recommendation and several other findings were indeed materialised by the endorsement of the 'Guideline on ICZM in the Black Sea' by the Black Sea Commission. The Guideline, which is a comprehensive document, very similar to Mediterranean ICZM Protocol, could indeed guide Black Sea coastal counties in the implementation of ICZM in the region, gradually addressing not only the governance issues and set-ups for necessary management arrangements, but could also help reverse the current decline and in the long run reflected into improvements of the indicator values, characterising the state of the Black Sea coastal zone.

3.2.4 ICZM Implementation in the Black Sea Region

Figure 3.2.2. Night lights can indicate the extent of artificialisation in the coastal zones around the Black Sea32

Cover image of this section (Fig. 3.2.2) illustrates the daunting task faced by the six littoral states in addressing a sustainable management and improvement of the state of coastal environment around the Black Sea, whereby strips and agglomerations of night lights can highlight that urbanised areas and infrastructure developments are indeed attracted towards the coast.

The Black Sea Commission, its Permanent Secretariat and the Advisory Group on the Development of Common Methodologies for Integrated Coastal Zone Management (ICZM AG), with support of the international partners, in the reporting period of 2009-2014 devoted a great deal of effort to advancing further the ICZM in the Black Sea Region. Particularly noteworthy in this regard are the

32 Source: http://earthobservatory.nasa.gov/Features/NightLights (Black Marble global composite derived from NASANPP VIIRS day-night band).

European projects (such as PEGASO33 and IASON34), supporting Black Sea countries in taking the stock of ICZM achievements in the region; enhancing the implementation of management instruments such as various types of ICZM indicators; and developing the regional guideline for ICZM, as was mandated by the BS-SAP (2009).

Indeed, through coordinated efforts applied in the reporting period, a milestone was achieved in ICZM area with the endorsement of the 'Guideline on Integrated Coastal Zone Management in the Black Sea' by the 32nd Regular Meeting of the Commission on the Protection of the Black Sea Against Pollution, 12-13 October 2016, Istanbul, Turkey (BSC, 2016).

Per Guideline the Black Sea Countries are advised to prepare and regularly update national inventories of coastal zones, covering information on resources and activities, as well as on institutions, legislation and planning that may influence coastal zones (section XVI, para. 1). The Black Sea Countries are also invited to define and measure appropriate indicators, in order to evaluate the progress achieved in ICZM implementation (section XVIII, para. 4).

Two approaches are currently suggested in the Annex, Explanatory and Reference Notes to the Sections of Guideline, to measure progress with ICZM: the ICZM Implementation Audit (in the format of national responses to ICZM Stock-Taking Questionnaires), as well as the Colour Coded ICZM Progress Indicators.

While stock-taking exercise is appropriate to be updated on a less regular basis (usually by the Ministerial or other important medium term milestone, with periodicity of 5 years or more), progress markers can be subjected to update on an annual basis with cumulative reporting to the regional millstone events such as Black Sea SoE Reporting. This chapter reports on ICZM implementation progress in the Black Sea Regions in these two complementary formats.

Above mentioned two progress monitoring tools were developed as online instruments with support of the European Commission's 7th Framework Programme IASON uptake project35.

At the same time, it is perfectly realised in the Black Sea region, that in addition to indicators measuring governance efforts, a common set of the state of the coastal environment (including socio-economic) indicators and ecosystem accounts are warranted to monitor changes (statistical, spatial) in the coastal zones, as well as to observe the outcomes of the management efforts. It is worth mentioning, that the Black Sea countries are more than a decade involved in reporting basic statistical parameters concerning national coastal zones, and this is reported elsewhere in this part of the SoE for the Black Sea, concerned with coastal processes.

It is welcoming development in this regard to observe the commitment of the European Space Agency (ESA) to engage in this region through Black Sea from Space Workshop series (http://eo4blacksea.info) and by supporting projects such as EO4SEE36 with use case for the Black

33 People for Ecosystem-based Governance in Assessing Sustainable development of Ocean and coast (abbreviated as Pegaso) is the Collaborative Project in the field of ICZM, supported by the European Commission within its 7th Framework Programme (FP7), coordinated by Universitat Autònoma de Barcelona (UAB), Spain (see http://pegasoproject.eu, now at http://vliz.be/projects/pegaso). 25 partners of Pegaso project include the Permanent Secretariat of the Commission on the Protection of the Black Sea Against Pollution (BSC PS, http://www.blacksea-commission.org).

34 IASON goal was to establish a network of institutions of the EU and neighborhood countries located in the Mediterranean and the Black Sea regions and concerned with the sustainable application of Earth Observation tools, building on the experiences gained by 5 FP7 projects, including PEGASO.

35 The tools described and available for use as part of the IASON Knowledge Base (http://eopower.grid.unep.ch/drupal_IASON/?q=node/22 - colour coded progress reporting) and at (http://eopower.grid.unep.ch/drupal_IASON/?q=node/18 - stock-taking on-line survey tool, accessible at this link http://iason-fp7.eu/survey)

36 EO4SEE (http://eo4see.terrasigna.com) "Pathfinder assessment for regional high volume data access, processing and information service delivery platforms - South East Region", financed by European Space Agency - ESA (2016 – 2018) and coordinated by TerraSigna (Romania).

Sea and its coastal zone under development by TerraSigna (Romania) and its project partners. Initial preview of such remotely sensed indicators and integrated indices utilising European Sentinel and other platforms is enclosed as a sample maps below, classifying and quantifying a range of development pressures from built-up to natural areas in coastal zones and catchments of the Black Sea countries. It is hoped that these initiatives will translate into fully fledged observation systems for the coastal areas of the Black Sea countries, and can be reflected in the next iteration of the SoE and SAPIR for the Black Sea.

In the meantime, reported hereby further below are the above mentioned two types of progress and implementation measuring indicators for ICZM in the Black Sea Region (cf. chart on Fig. 3.2.1 above in the summary sub-section, quantifying significant urban encroachment in coastal areas of all Black Sea countries, visualised on Fig. 3.2.3 maps).

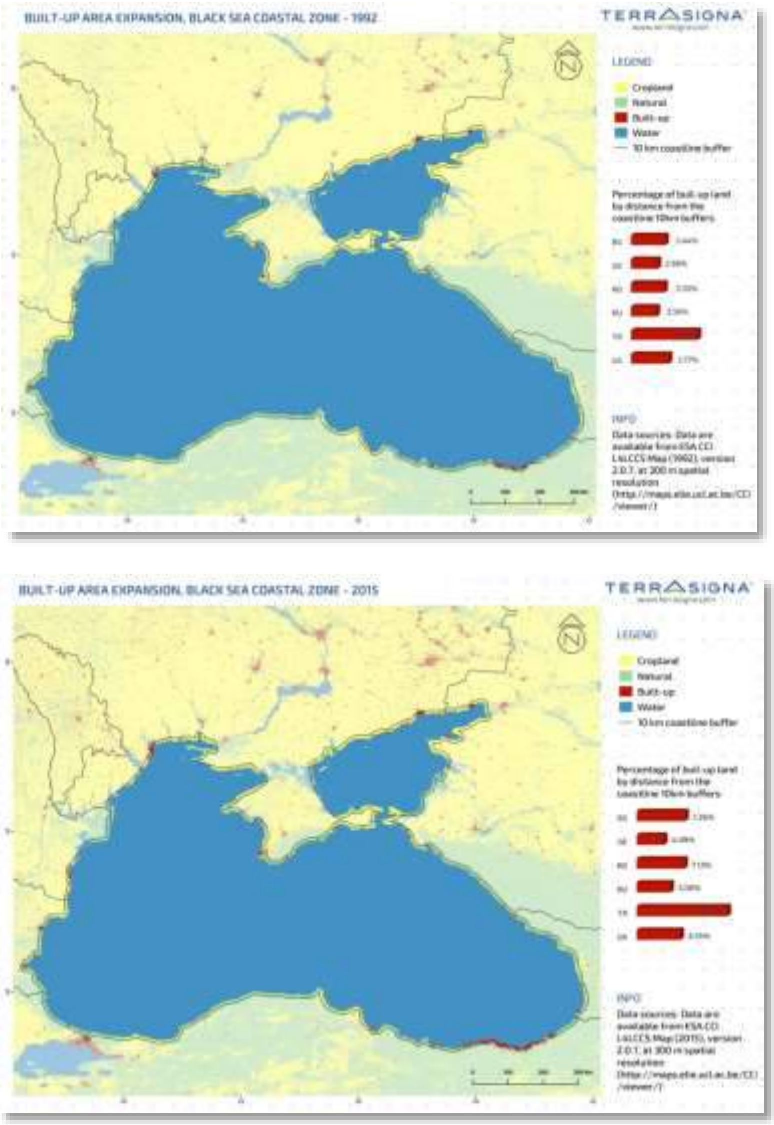

Figure 3.2.3. Colour coded maps illustrating integral indices for BS coastal zones & catchments (1992 and 2015). Expansion of built-up areas in entire 10 km buffer is most obvious at south-eastern Black Sea coastline.

3.2.5 ICZM colour coded progress indicators

Colour coded set of indicators to evaluate progress of ICZM implementation was first proposed by the ICZM Expert Group of the European Commission (EC, 2005; Pickaver et al., 2004). Similar reporting methodology was applied in the Black Sea region as well, initially with support of the EuropeAid funded ECBSea project (Environmental Collaboration for the Black Sea). Six coastal countries reported on progress with ICZM under the auspices of the Commission, with initial results published in the previous SoE of the Black Sea (BSC, 2008). ICZM AG has further fine-tuned the progress reporting to their needs, expanding it to include the indexed reference system, communicating in textual format the reasoning for upgrading or downgrading colour coded markers. ICZM AG developed the concise user manual for filling ICZM progress indicators in the Black Sea Region and included it in the Guideline as Appendix 1.

ICZM Progress Indicators updated by ICZM NFPs from six Black Sea Countries is presented in the Attachment 2, where presentation first starts with the regionally agreed progress ratings.

3.2.6 ICZM implementation audit (regional synthesis)

Another important test of the feasibility of Guideline proved to be the ICZM implementation audit inventory, performed through stock-taking questionnaires, organized by the BSC Permanent Secretariat within European FP7 PEGASO project, engaging ICZM National Focal Points from Black Sea Countries. Stock-taking questionnaire (Shipman, 2012), composed of over 50 questions on multiple coastal governance themes of institutional and legal nature, was modelled against the requirements of the Mediterranean ICZM Protocol (available at http://www.pap-thecoastcentre.org), content of which in basic terms is equivalent to the contents of the Black Sea ICZM Guideline.

All six Black Sea Countries successfully completed stock-taking exercise individually as well as produced regional synthesis report documented in Abaza et al. (2011) and Antonidze et al. (2013). Main findings are presented below for each key theme covered by the stock-taking, followed by the quantitative summary in Attachment 1.

Coastal Zone boundaries

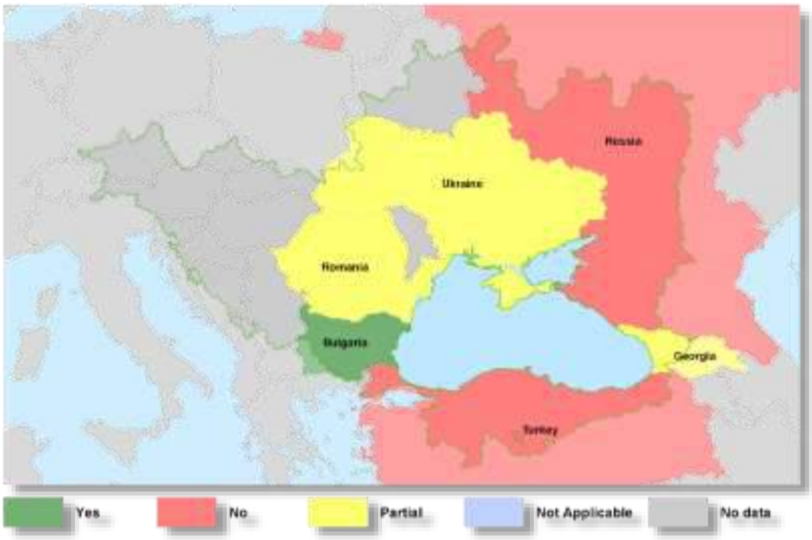

Figure 3.2.4.1. Coastal zone boundaries appropriately defined

The landward and the seaward limits of the coastal zone in the ICZM context have been formally defined essentially in only the two EU countries and even here, landward (RO) and seaward (BG) extents are very limited. Two countries (GE, UA) seem to have proposed adequate definitions for

Coastal Zone (CZ) boundaries, but their legislation is not yet under consideration. The Shore Law of TR defines boundaries for shoreline management, insufficient for ICZM. At regional level clearly there is room for harmonization of CZ definitions based on few km inland and 12 nm territorial sea seems plausible.

ICZM and/or coastal legislation

Only one country (RO) has legislation in force directly concerned with ICZM. Others either have certain sets of ICZM principles in place through spatial planning legislation (BG), or have developed draft legislation for ICZM (GE, UA), but political will is required to adopt and enforce the proposed legal measures. Certain principles of integrated management are provided in the Urban Planning Code of RU, but at federal level the work on the ICZM legislation is currently not being done. There is an effective Shore Law, but a comprehensive law for ICZM is not available in TR for the time being. None of the existing or draft legislation is ideal and therefore, a regional level legal instrument would be an indispensable mechanism in harmonizing approaches and principles.

Coordination

The proliferation of consultative committees or councils is not fully helpful yet. Streamlining is required. The collation of all existing or contemplated consultative fora concerned with marine and coastal affairs into a single, representative national forum with strong institutional memory and respected membership expertise would provide a solid foundation for rational decision-making in marine and coastal domains. International partnership at the regional level is facilitated by the BSC ICZM AG (see its terms of reference at http://www.blacksea-commission.org/_ag-tor-iczm.asp) with lead institutional support of BSC PS.

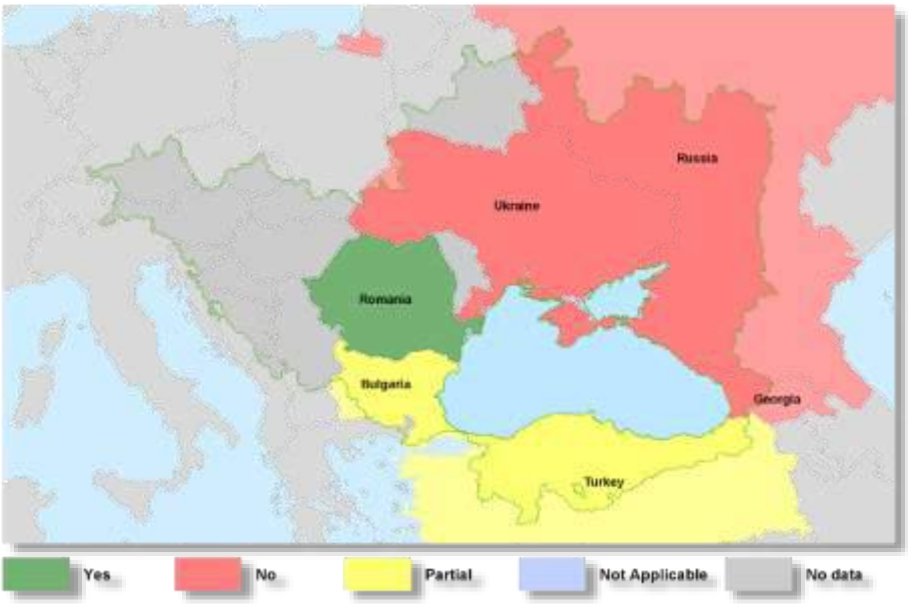

Figure 3.2.4.2. Coordination/integration mechanisms in place (horizontal)

Protection and sustainable use of the Coastal Zone

Perhaps TR has the best defined system for managing coastal setbacks through its Shore Law. In other Black Sea countries no universally applied coastal setback distances are established as such, though some countries report no-construction areas prescribed through coastal legislation (BG, RO). NATURA 2000 sites and protected areas are used in BG and RO to set an interesting precedence of safeguarding much of the coastal zone from urban sprawl and artificialisation, though coastal land

and ecosystem accounts are clearly needed to monitor performance in space and time. Freedom of access to and along the coast is 'guaranteed' in the same EU member countries and in TR by its Shore Law. Per Water Code of RU the public access is grated to public water bodies, except as otherwise provided in legislation. Access to the coastline by vehicles and vessels remains mostly unregulated beyond coastal protected areas, with only RO and TR reporting some rules.

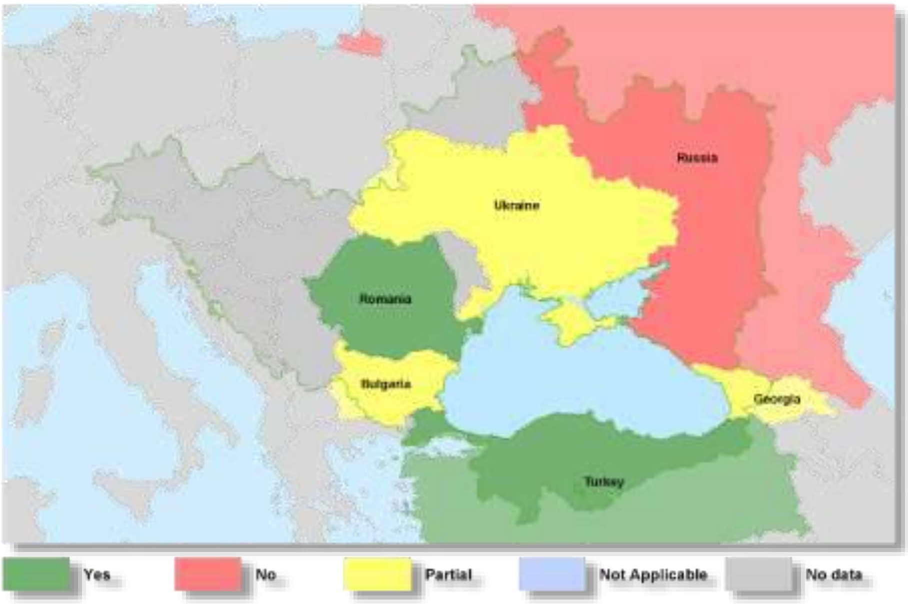

Figure 3.2.4.3. Setback zones for coastal development control claimed

Economic activities

There are no specific economic indicators related to sustainable use of the CZ applied and used in any of the Black Sea countries, except for the general economic development indicators applicable elsewhere, such as GDP, etc.

Coastal ecosystems, landscapes & cultural heritage

Strong progress is reported in all countries in the designation, protection and management of wetlands of international importance (RU has no designated wetlands in the Black sea coastal zone). TR has a by-law dealing solely with protection of wetlands. However, this does not seem to provide irreversible restraint against the major development projects (like the Kulevi oil terminal built next to Ramsar site and National Park in Kolkheti, GE) or other infrastructure, energy and transportation sectors projects in all countries (such as a major highway along the southern-eastern Black Sea coast of TR), threatening the viability of coastal ecosystems around the Black Sea. Experience with restoration of degraded wetland habitats is not a significant part of management practice. Progress with Marine Protected Areas (MPA) designation is lagging behind as well. All countries cited the Bucharest Convention, its Protocol on Black Sea Biodiversity and Landscape Conservation (except GE and RU) and provisions of the Strategic Action Plan for the Environmental Protection and Rehabilitation of the Black Sea, see BS-SAP (2009), as the international cooperation framework for marine conservation in the Black Sea, but still much needs to be done in terms of national implementation. The visibility and statutes of the Regional Activity Centre on Conservation of Biological Diversity (Georgia) essentially needs revival to enable it to support MPA work under the direction of BSC and PS. More efforts are also needed to establish and implement effective mechanisms for coastal heritage, landscape and seascape protection at the national and local levels.

Participation

Consultative bodies and their role in streamlining land-sea, vertical and horizontal integration of the governance were described above. The concept of ICZM partnerships is not practiced yet in the countries from the region. Mediation and conciliation procedures are still not part of the culture and regulations as well. Public participation and formal consultation mechanisms were used in GE when developing the national ICZM strategy with the support of the EuropeAid ECBSea project, but it seems that neither approaches motivated the Government to adopt the strategy. EU member Black Sea countries are obliged to implement public participation through EU Directives on Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA). Public rights to seriously challenge inadequacies in coastal plans and development projects are limited only to the combination of ecological expertise and EIA mechanisms in the former Soviet countries. EIA and SEA mechanisms for genuine participation are underutilised in TR as well. International consultations at the regional level are facilitated by the ICZM AG, and its role should probably be enhanced by including ICZM NFPs in the mechanisms of meaningful communication with regard to the strategies, plans, programmes and projects of transboundary nature.

Awareness raising, training, education & research

Countries report that training and education in ICZM is not systematic and mostly implemented on an ad hoc basis within the framework of some international funded projects, with education initiatives downscaling as projects close. Awareness raising is not targeting decision-makers and stakeholders at various levels, but rather addressed to general public and not specifically to ICZM needs. Research projects on ICZM governance are supported by the EU within its framework programmes, such as FP7 Pegaso (http://pegasoproject.eu) and enviroGRIDS (http://envirogrids.net), FP6 SPICOSA (http://spicosa.eu), INTERREG PlanCoast (http://plancoast.eu) and other projects. A centre with ICZM research capability exists in RO, where a marine research institute is serving as the secretariat to the National Coastal Zone Committee and its thematic working groups; while MEDCOAST of TR plays prominent role providing national and international ICZM conference series, research network and training programmes for both Mediterranean and Black Seas. TR has a National Committee for Coastal Zone Management since 1993 established under the Higher Educational Law. This committee has been organising national ICZM conferences bi-annually since 1997 in addition to networking and consulting services. There are no ICZM capability centres in other countries. It is noticeable that even an ICZM lead country such as RU discontinuously supported the ICZM Regional Activity Centre (RAC) despite its successful operation in the past, due to the strong international function and wealth of ICZM experience accumulated in the Research Institute of Applied Ecology (Krasnodar, RU). The experience of PAP/RAC in the Mediterranean clearly suggests that a regional centre of excellence in ICZM in the Black Sea region is undoubtedly needed to ensure the progress.

Monitoring & review

The first national level assessment, including inventory of institutions and legislation was provided in the National ICZM Reports prepared by the ICZM NFPs with the support of GEF/UNDP Black Sea Environmental Programme (BSEP) in 1996. Since 2001, annual updates on ICZM activities are being prepared for the BSC by NFPs. Some Black Sea countries performed recent comprehensive national assessments of ICZM as part of international (GE) or national (UA, RO) funded projects, or as part of the Mediterranean efforts (TR). But all countries need to revisit their assessments regularly taking into account the ever changing conditions in the coastal zone and those in the governance framework. The countries also agreed on the necessity to introduce a common set of coastal indicators addressing socio-economic, environmental and governance dimensions.

National coastal strategies, plans and programmes, transboundary cooperation

All Black Sea countries developed national ICZM policies & strategies documents as early as in 1997 as part of the BSEP, and it might be worth reviewing the progress against these documents. Up to date, only two Black Sea countries (GE, RO) reported the availability of valid national ICZM strategies, but their approvals are delayed due to various reasons, primarily the lack of political will and the ongoing uncontrolled development agenda for the national coasts. TR is currently engaged in the preparation of the National ICZM Strategy and Action Plan. As for the pilot projects, non-EU Black Sea countries have acquired some experience with ICZM at local implementation level, mostly through support of GEF and EU funding. These pilot projects (Gelendzhik-RU, Akçakoca-TR and Tskaltsminda-GE) have applied with quite positive feedback the Black Sea ICZM spatial planning methodology developed earlier by the ICZM RAC (Yarmak, 2004). TR has carried out integrated planning projects at the local scale for important bays that have been severely pressurised by unsustainable use. There were no ICZM pilot projects implemented in EU member Black Sea countries (CASES under FP7 PEGASO cover the Danube Delta, RO, but there is no partner from BG).

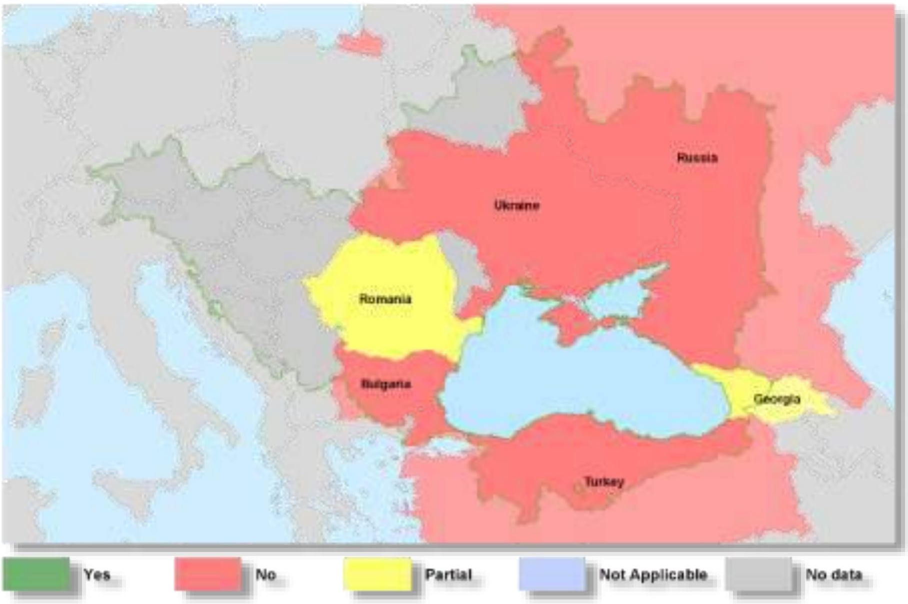

Figure 3.2.4.4. National ICZM strategy prepared

Environmental and strategic assessments

EU member countries report that EIA procedures include all traditional stages of assessment process, and that both EIA and SEA legislation and practices should comply with respective EU Directives. EIA process in GE, RU and UA are established as the so-called "ecological expertise procedure", inherited from the earlier Soviet system. There is no SEA system in place in these countries and even modest reference to plans and programs in national EIA legislation was removed after recent reforms in the spirit of uncontrolled development (GE), while in RU plans and programs are subject to ecological expertise, which provides for public hearing. UA signed in 2003 but not yet ratified the Espoo SEA Protocol. TR has been utilizing the EIA since 1993 and has also prepared a draft by-law recently for SEA in the EU accession process. None of the countries report on specific guidelines for EIA or SEA in the coastal context. A certain level of harmonization of EIA process in the transboundary context could be achieved with the adoption of the Black Sea regional EIA recommendations, prepared in cooperation with the Espoo Convention Secretariat and recommended by the ICZM AG for consideration of the BSC in 2010. A Protocol on EIA/SEA seems less feasible given the reservations of some countries.

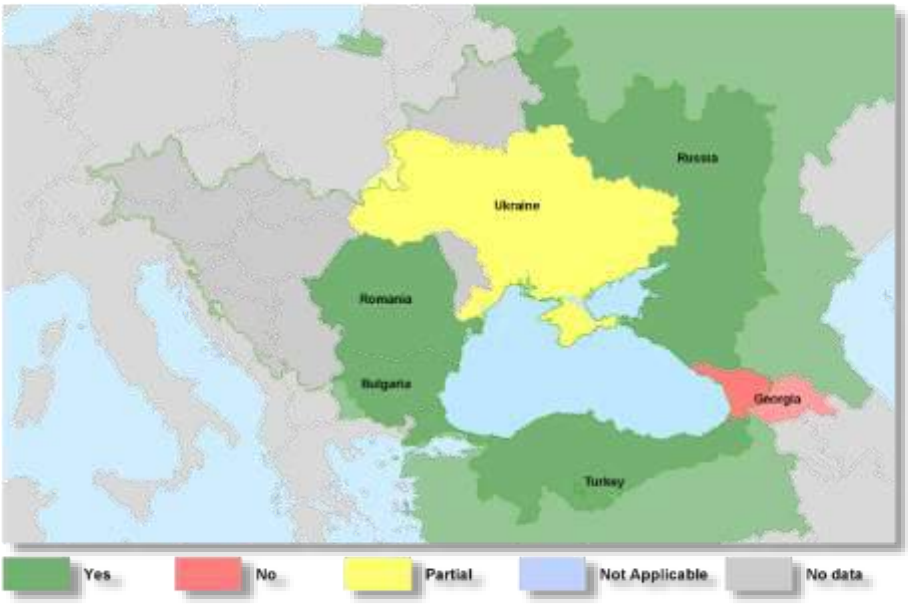

Figure 3.2.4.5. Environmental assessment procedures in place and adequate

Land policy

All countries have expropriation instruments for public works projects, but none has acquisition systems in place specifically for coastal preservation (in the spirit of the Conservatoire du Littoral, http://conservatoire-du-littoral.fr), and for providing the public with access to and along the coast/coastline. No data is available on land acquisitions even into public domain. No examples were cited for either private or non-governmental organizations being in charge of preservation of coastal lands through protective ownership. Land management functions are generally distributed among multiple governance levels and agencies, with the ministries of environment usually being the least influential in decision-making. The existing public (State) land ownership in all the countries could be converted from legacy into opportunities for coastal conservation if parties decide to opt for modern models of public acquisitions in support of coastal conservation, mentioned above.

Economic, financial & fiscal instruments

Economic instruments used in the countries are of command and control nature (like fees/penalties for environmental or land use violations) and economic and financial incentives in support of ICZM are clearly not applied. Some governments (GE) are creative in establishing blunt tax breaks to stimulate rapid development of the coastal tourism with no safeguards set for protecting coastal heritage, lands and environments. Countries should learn from experience of TR with setting biased incentives in support of tourism development in the Mediterranean, rectified subsequently.

Natural hazards & coastal erosion

Preference is given to expensive investments (like combating rather than preventing coastal erosion and flooding) instead of management measures (such as spatial and contingency plans). BG mentioned only landslide protection plan, while in UA emphasis is on coastal resilience through coastal conservation and protected areas. In RO the focus is on feasibility studies for coastal protection works. Some countries either participate (BG), or plan to attract (GE) projects of adaptation to climate change induced hazards (such as floods) in coastal areas and the implementation of early warning systems.

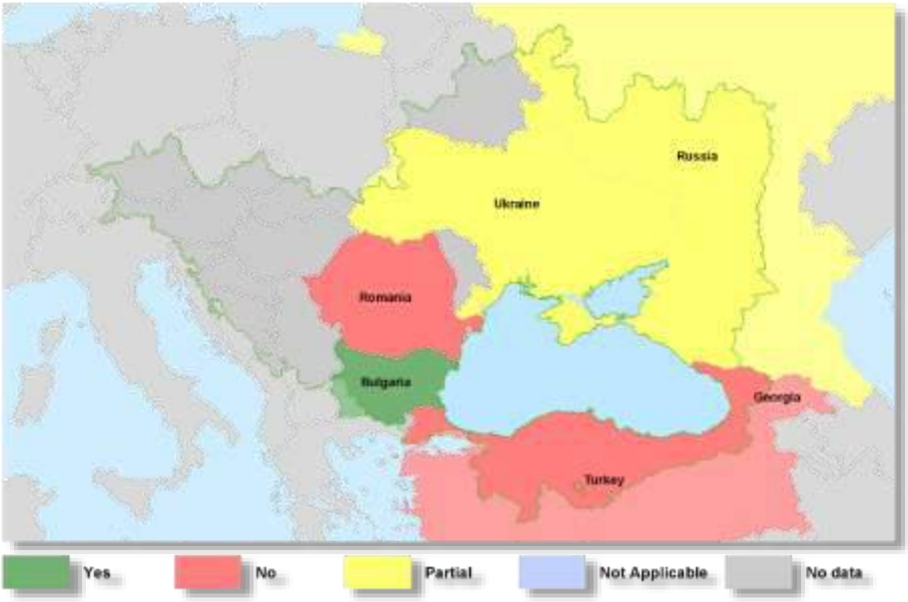

Figure 3.2.4.6. Coastal hazard prevention, mitigation & adaptation measures

Exchange of information and activities of common interest

Indicators for measuring ICZM progress in a format, compatible with EEA (2006) and Pickaver (2004), were defined and carried out by Black Sea NFPs within the ICZM AG work. These were reported to the BSC by including them into the 5-yearly BSC Report on the Implementation of the Strategic Action Plan for the Rehabilitation and Protection of the Black Sea 2002-2007 (http://www.blacksea-commission.org/_publ-BSSAPIMPL2009.asp). In addition, NFPs report annually to the BSC by statistical compilations on the state of the Black Sea coastal zone, covering various indicators: the general parameters of population and geography, energy, water and wastewater, biodiversity, coastal erosion, economy, tourism, health, solid waste management, agriculture, industry, transport, and climate, as well as basic facts about the ICZM coordination mechanisms, legislation, permitting and access to information. These figures were also reproduced in the BSC report cited above. However, NFPs report in the stock-taking that these indicators are not used in national coastal management practice, except for the EU member states, which have ICZM reporting obligations to European Community as well. Upgrading and harmonizing ICZM indicator sets was envisaged under the FP7 Pegaso project, which was a key ICZM activity in the reporting period.

Transboundary cooperation

ICZM activities and regional coordination were described in sub-chapter 3.2.2 above. As for the transboundary cooperation on EIA, the ICZM Advisory Group, after several iterations, recently finalised the Recommendations on EIA in a Transboundary Context for the Black Sea Region, submitting the document for BSC consideration. The document was developed in cooperation with the Espoo Convention Secretariat (UNECE), as mentioned above and, if adopted by the BSC, it would provide guidance for transboundary EIA cooperation by means of notification, exchange of information and consultation. Actually, the only earlier example of bilateral cooperation in relation to EIA was cited by UA for the Project on Development of the Deep-water Navigable Channel Black Sea – Danube (2004-2009).

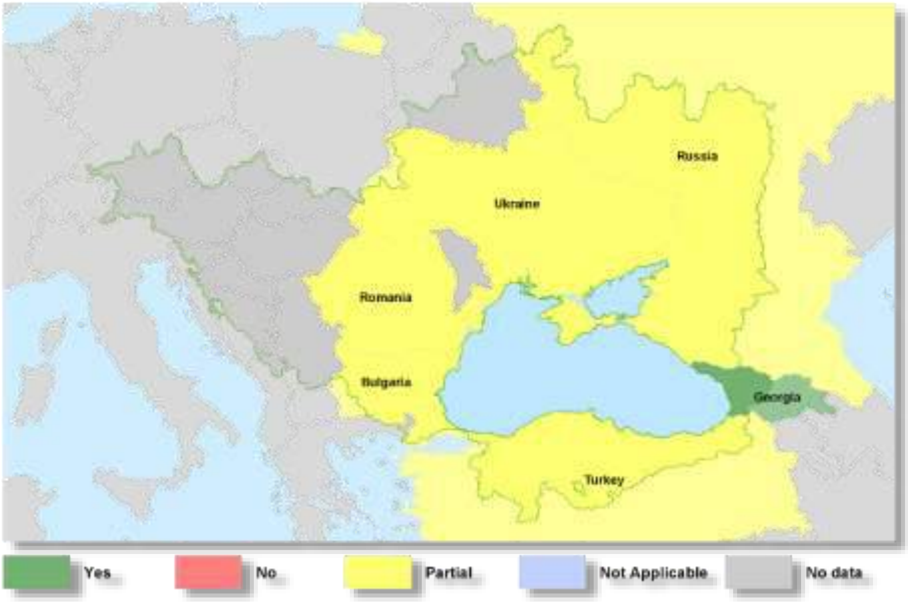

Figure 3.2.4.7. Coastal zone management and sustainability indicators

3.2.7 Conclusions and Recommendations

Analysing the national ICZM stock-taking responses, taking into consideration also the regional dimension, the following (non-exhaustive) set of issues can be drawn from the qualitative assessments provided above in this report (see Abaza et al., 2011 and Antonidze et al., 2013):

Stock-taking themes and key issues:

- A harmonized delimitation of Coastal Zone boundaries is required.
- Defining common principles would assist national initiatives to legislate ICZM.
- Consultative fora should contribute into integration rather than dilute the focus.
- Coastal development control, setback regulations and practical mechanisms for guaranteeing cross-shore and long-shore access provisions are required.
- More attention needs to be paid to marine protected areas, wetland restoration and the protection of coastal landscapes as part of the ICZM agenda.
- Participation should be seen as integral part of the ICZM governance process with genuine opportunities and mechanisms for the public to challenge the strategies, plans and projects prior to key decision-making steps.
- ICZM centres of excellence are missing in the countries and at the regional level.
- More effort is required to develop and deliver training and education in ICZM.
- Monitoring & reviewing the progress with ICZM should be built in into the administrative arrangements.
- Regional arrangements could prescribe common format to guide national ICZM strategies and plans.
- Pilot projects and cases should be pursued to apply ICZM at all levels.

- Some Black Sea countries need to upgrade their EIA systems to bring them in line with the best international practice, as well as to introduce SEA. Regional arrangements for EIA in transboundary context should be pursued and agreed for the Black Sea marine region.
- Sound economic and financial instruments are evidently missing in the region.
- Assessment and preparedness for climate change induced and other coastal hazards need advanced planning and time to start acting is now.
- An easy to use and upgraded common set of coastal (including socio-economic) indicators and ecosystem accounts are warranted to monitor changes (statistical, spatial) in the coastal zones, as well as to observe the outcomes of the management efforts. Use of ICZM progress indicators should be continued on a permanent basis.
- International cooperation within the BSC framework is the key driver for ICZM in the region. More visibility and functionality would support the process.
- The Black Sea countries should use the opportunity of TR being the only Mediterranean & Black Sea country and promote, adapt and adopt the best management solutions available in the partner marine region, such as the ICZM Protocol.

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3.3. SOCIO-ECONOMICS OF THE BLACK SEA COAST

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Introduction

This chapter focused on the reviewing of socio-economic drivers (sectors directly or indirectly related to the Black Sea) as well as on the pressure on the environment, social and economic consequences of environmental changes, and riparian countries (Bulgaria, Georgia, Romania, Russian Federation, and Ukraine) response to address challenges at national and regional levels and promote sustainable development of the Black Sea region. The chapter ends with the conclusions of socio-economic aspects.

Sources of data and information used for this chapter include but not restricted to i) ICZM national and BS Region reports for the BS Commission for 2009-2014; ii) reports and policy papers of international organizations and projects; iii) open statistic data produced by national and international agencies: and iv) scientific publications.

3.3.1. Socio-economic drivers

General overview

Conceptual framework for understanding environmental changes in the Black Sea marine and coastal ecosystem during last decades is based on the model D –> P –> S –> I –> R (Drivers –> Environmental Pressures –> Environmental State Changes –> Socio-Economic Impacts –> Policy Responses) and described in the previous report "The State of the Environment of the Black Sea (2001-2006/7)" (Kleschev K.A., 2003). However, this model application for the BS Region processes has some specific implications. First, socio-economic drives represented by sectors directly or indirectly related to the Black Sea were more than ever dependent on political processes impacting on the socio-economic conditions of the riparian countries.

The social and economic conditions of the riparian states are not homogeneous: Bulgaria and Romania are the EU member states, Turkey is negotiating its accession to the EU, the Russian Federation is implementing its own social-economic policy, Georgia and Ukraine have declared an intention to the accession to the EU. However, all of the riparian states make a significant investment to the enhancement of economic growth rates improve quality of life of their population (Papava V., 2010).

The coastal zone of the Black Sea littoral states comprises terrestrial and marine parts and represents an extremely complex social-ecological system, which is developing and functioning under pressure of interdependent political, social, environmental, economic, cultural, governance, and other factors. Socio-economic development of the coastal communities based on the exploration of valuable natural resources: land, water and their mineral, biological, recreational and other their constituents. At the same time, prosperity of the coastal communities sufficiently depends on the social-economic trends at national and international scale.

GDP (per capita) data for BS countries could demonstrate the difference in the development of their economy level. The Russian Federation demonstrated the best results during the reporting period. Bulgaria, Romania and Turkey comprise group of countries with similar GDP level and tendencies. Ukraine and Georgia are instantiated by the lowest GDP in the BS region. Global economic crisis of 2008 affected the socio-economic development of the Black Sea riparian states. Their GDPs dropped down in 2009 (Table 3.3.1).

Bulgaria was quite optimistic and did not expected an immense threat of the global financial crisis to its economy in 2008. However, the crisis affected Bulgaria rather significantly: in 2009, GDP declined by 4.7% as compared to the same period of 2008. About 95% of Bulgarian companies showed a drop in their sales. The industrial sector of the country was affected significantly. According to (Mee L.D., 2010), the gross value added decreased by 8% in 2009 compare to 2008. Crisis affected income generation (five largest companies of chemical industry have demonstrated decrease in income by 46.2% in the first quarter of 2009) and caused loss of jobs in main sectors of national economy, including those dependent on marine resources.

Table 3.3.1. Dynamic of the GDP of BS countries, 2007 – 2015.

GDP per capita, PPP (current international dollars, thousand)								
Country	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Bulgaria	12.898	14.396	14.133	14.963	15.676	16.208	16.647	17.406
Georgia	5.833	6.164	6.054	6.598	7.315	8.027	8.542	9.216
Romania	13.442	16.302	16.013	17.181	18.095	18.983	19.878	20.797
Russian Federation	16.649	20.164	19.387	20.498	24.074	25.317	24.165	25.095
Turkey	14.229	15.356	14.795	16.542	18.27	18.56	19.229	19.654
Ukraine	8.006	8.396	7.24	7.666	8.282	8.475	8.63	8.684

Source: Ivanciu Nicolae-Valeanu, 2013.

Situation in Georgia was more complicated. Negative impact on Georgia of the financial crisis was not expected to be high, however it was. Besides, the country had to avoid banking sector crisis, fighting with growth of the relatively high inflation rate, and protecting national currency from devaluation, and had to overcome the consequences of the military flare-up. After 2008, the summary economic indicators clearly reflected the implications of both the global financial crisis and the military flare-up (Mee L.D., 2010).

Since 2010, economies of all BS countries demonstrated tendencies to recovery. This process was ongoing without interruption through 2009 – 2014 (Ivanciu N.-V., 2013).

Sectors directly or indirectly related to the Black Sea

The sea and adjusted coastal regions are the area of various economic activities. During 2009 – 2014, similarly to the previous years, the economic activities directly connected to the Black Sea in all riparian countries comprised following key sectors:

- Shipping and ports;
- Fishery;
- Tourism;
- Oil and gas.

Most of maritime economic activities (MEAs) are typical for all of the Black Sea riparian countries in spite of possessing of different natural resources and different level of economic efficiency achieved. These MEAs have stimulated enhancing urban area development as well as some other supportive industries in coastal regions. As a result, there is quite intense expansion of urbanized areas and related infrastructures in all BS countries observed. As it follows above (see section 3.2), the built-up areas almost doubled within the 10-km strip buffer zone located along the Black Sea coastline in the period 1992 – 2014. Urban expansion towards and along the coast mainly adjusted to big cities is of 4% coastal area in Georgia and up to 12% in Turkey. This process is ongoing and is one of the main factors affecting environment. Therefore, urbanization was included in the list of key economic sectors in the coastal regions.

The Black Sea is divided into exclusive economic zones (EEZ) since years and exploration and exploitation of marine natural resources by riparian countries is restricted within the borders determined (Fig. 3.3.1) and regulated by national laws and international agreements (WB: Indicators).

Shipping and ports

The Black Sea is the cross-road of the East-West and North-South of interrelations of various nature, including political, economic, societal, religious, scientific and others. The BS provides many traditional and new opportunities for cooperation in various sectors for the riparian countries. The Sea is playing the role of geo-political, economic and trade hub and considering now as an access point to the coastal countries, as well as an entry point to the European Union, the Balkans, the Caucasus, Central Asia and other regions. Therefore economic activities, related to the exploitation of marine resources and the sea as a transitional route and the way connecting nations and states, are traditional and have long history.

Traditional maritime sectors are the most important providers of employment. In Bulgaria, shipping mainly is oil transportation and its growth depends on fleet renewal and on the development of infrastructures, including inland waterway transport.

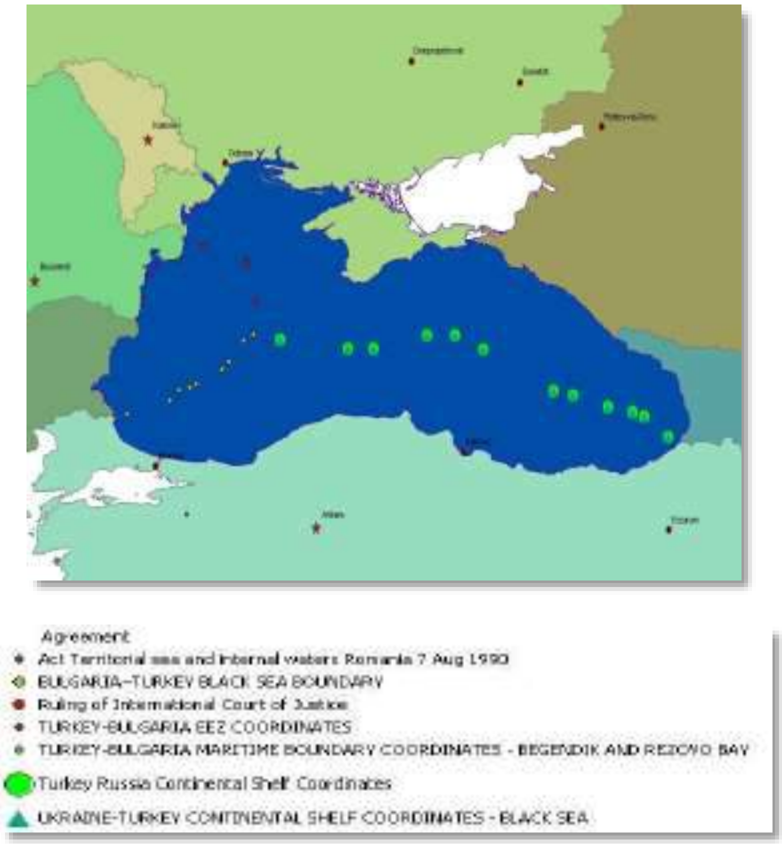

Figure 3.3.1. The map presenting delineation of the exclusive economic zones in the Black Sea (Oral N., 2018).

There are several seaports along Georgia's Black Sea coast. The largest one is the Port of Batumi. Chartered passenger ferry services the link between Georgia and Ukraine and Turkey. Shipping sector of Georgia plays an important role in the employment opportunities.

In Romania, shipbuilding industry has a long tradition and although affected by the economic crisis 2008. Recently, its competitiveness was improved by investing in green technologies and innovation capacity. Shipbuilding is mainly devoted to commercial transport vessels. Short-sea shipping is the fastest growing maritime activity in Romania and is concentrated in the Port of Constanta. Inland waterway transport sector in the Black Sea and the Danube River plays an important role in the national economy because of its size and positive contribution to the country’s economy.

The Modernization Program of Novorossiysk Commercial Sea Port (Russian Federation) was focused on the development of the port’s marine infrastructure. It includes dredging and construction of new cargo terminals. Inland waterways in the European part of the country form a network of channels connecting the basins of major rivers. There are plans to construct shipbuilding and ship-repair facilities at the Black Sea coast the Russian Federation.

In Turkey, maritime economic activities support of 280.000 jobs and reach a total Gross Value Added (GVA) of more than EUR 4.4 billion. The shipbuilding and ship-repair sector of Turkey (mainly concentrated at the Mediterranean Sea coast) contributes over 82% to GVA (World Bank, 2009). Turkey has the longest shoreline in the Black Sea. This provides it with the strong strategic position at the intersection of the East–West and North–South international transport corridors and provides with the potential for the development of offshore infrastructure.

Internal and international short-sea shipping is important and well developed in the country because of the unique geographic position.

The shipping sector in Ukraine makes a significant contribution to the country's economy. The country has 18 deep-sea merchant ports and 11 merchant river ports connected to the sea. The biggest sea ports, Odessa, Illichivsk, and Yuzhny. They occupy 60% share of the total cargo turnover through Ukrainian seaports (World Bank, 2009). Odessa offers regular passenger ferries to Istanbul, Varna, and Haifa. Intermodal sea-railway transport is well developed, connecting IlIichivsk to Varna and to Batumi. The capacity of Ukraine's merchant fleet was significantly decreased during period of economic recession in 1990th but the country is still training qualified specialists and supplies labour forces for merchant fleets and other maritime sectors abroad.

The region has also outstanding opportunities for the development of river/sea shipping: river and channel systems provides opportunities to achieve Rotterdam on the North Sea (through Danube and Rhine) or the Caspian Sea ports (through Volga and Don) from BS ports. These opportunities are to be utilized in the years to come. Regretfully, in reporting period, the river/sea shipping capacity was not utilized and contribution of the rivers' fleet for passengers and commodities transportation was minimal in Ukraine. In this regard, the Dnipro River, the third largest river of Europe, was not exploited as a transport route.

Fisheries and aquaculture

Fisheries is the traditional economic activity in the Sea since centuries. Nova days, it is supplemented with fast developing aquaculture. The fishery sector plays an important role in the region by providing various employment opportunities for local population: several hundred thousand people have found jobs in the fisheries and aquaculture. The sector supplies as well valuable seafood products for local consumption as well as for regional and international markets.

The BS sea food processing industry comprising industrial, semi-industrial and small-scale fisheries. Variety of fishing nets and techniques are being used here. Fisherman mainly exploit a benthic and pelagic stocks of fish, as well as mollusks and crustaceans. Dominated species are varying in landings by different countries. For example, European anchovy, sprat, whiting, mullet, red mullet, turbot, sea snail, flatfish, and dogfish caught in Georgia. Russia has a long tradition in fisheries based mainly on catches of anchovy, which constitute of 65% of the country's total catches in the basin.

The BS countries have different technical capacities for fisheries. As it follows from the Table 3.3.2, Turkey has largest fleet and demonstrates largest figures in landings.

Table 3.3.2. Fishing technical capacity and average landings by riparian countries in the Black Sea in 2000-2013.

Country	Number of vessels	Capacity (gross tonnage)	Reporting year	Average landings, [tonnes]
Bulgaria	704	3743	2015	7,715
Georgia	47	N/A	2015	12,600
Romania	159	790	2015	1,258
Russian Federation	33	N/A	2013	32,000
Turkey	16,447*	175,328*	2015	459,400*
Ukraine	135	N/A	2015	68,900

*Turkey: Total data for Mediterranean and Black Sea regions

Source: Tsikliras A.C.at al., 2016

For many reasons, landings in the Black Sea are showing a generally increasing trend however, during last three decades, have varied considerably from one year to the next. In 2013, the total reported landings in the Black Sea were 376 000 tonnes. The total value of these fish landings across the Black Sea is of USD 691 million (Tsikliras A.C.at al., 2016). What is important, the small-scale fisheries in the Black Sea play a significant social and economic role because of they provide jobs for at least 60 percent of the workers directly engaged in fishing activity and account for approximately 20 percent of the total landing value from capture fisheries in the region. Small-scale fisheries include recreational component, which is becoming more and more popular.

Due to semi-enclosed configuration of the Black Sea divided into exclusive economic zones between coastal states, fleets from different countries have to share the stocks. During 2008 – 2014, fisheries sector faced significant challenges due to decreasing of the fish stock. The status of the Black Sea fisheries was evaluated regularly for the period 1970-2016, using various indicators such as total landings, the number of recorded stocks, etc. (WB: Indicators, FAO, 2014, Tsikliras A.C. at al., 2016). All assessments confirmed that the fisheries resources of the Black Sea are at risk from overexploitation and impact of pollution from land based and off-shore pollution sources. The state of stocks assessments resulted in conclusion that the BS fisheries being in a worst shape as to compare to the Mediterranean and other sea regions (FAO, 2014). Therefore, sustainable management of stocks, one of the most significant issues in the region, requires urgent measures and strengthening cooperation at the Black Sea states level for these purposes.

In the reporting period, marine aquaculture has been one of the fastest growing activities in Turkey and in some other BS countries. By 2014, this sector has produced more than 88.000 tons annually in Turkey with a planned increase to 600.000 tons of sea products by 2023. Aquaculture production reached a 25% market share of the seabass and seabream trade in Europe. More than 96% of the production is located on the Aegean coast; however, being underdeveloped in Turkish Black Sea area (nine sea-cage farms operated with a production volume of just 8.500 tonnes), has potential for fast growth.

In general, marine aquaculture in the BS region has remained underdeveloped in 2008-2014. The farming of sturgeon and mussels dominated in the aquaculture industry.

Coastal and marine tourism.

Tourism plays an important role in the economies and generates significant contribution to the GDP of the BS countries. Turkey is a leader in tourism development among the BS countries followed by the Russian Federation and Ukraine (Fig. 3.3.3). In 2013, Turkey has received 37.8 million foreign visitors, Russian Federation – 28 million, Ukraine – 25 million. In 2013, Turkey is ranking 6th country in tourists’ arrivals and 12th in receipts (Panayotis G., Iorga G.A., 2009).

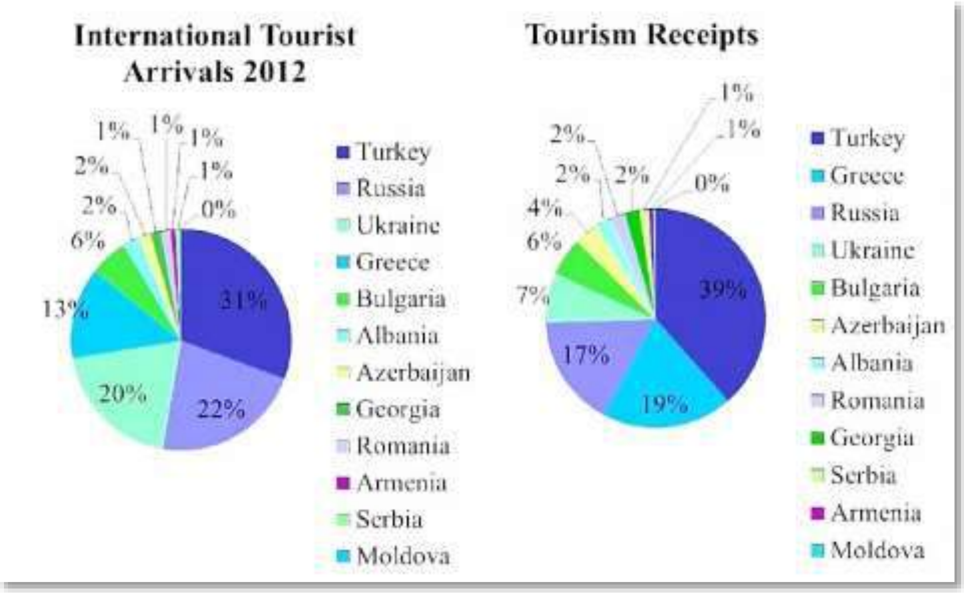

Figure 3.3.2. International tourist arrivals and receipts in 2012 in the BSEC Member states (Source: Panayotis G. and G.A. Iorga, 2009)

The Black Sea Basin favourable climate and outstanding natural features - including mineral springs and beautiful beaches – have made the region as an important destination for recreational and health tourism with the Crimea peninsula being the most important. Recreational infrastructure and seaside resorts in Bulgaria, Romania, Ukraine, Russia and Georgia are very active but are less developed on Turkey's BS coast (where tourism is focused mainly on the Aegean and Mediterranean). Tourism potential in the Black Sea Basin area is rich and diversified, including spa and medical tourism, culture, nature, eco and agro-tourism, adventure, cave and mountain tourism, and tourism related to cuisine, rivers, hunting and diving as well as winter tourism (skiing).

Coastal tourism constituted a significant economic sector in terms of number of visitors and income generated. In Bulgaria, Turkey, Romania the sector has significant contribution into regional GDP compare to other maritime activities. It is less developed in Georgia, Ukraine and the Russian Federation. However, it remains fast growing sector offering significant potential for future development. In Bulgaria, coastal tourism is encompassing of 80% of the total tourism sector. In Georgia, tourism is one of the fastest growing service sectors. The number of foreign visitors reached 4.430.000 in Georgia in 2012 or the 3,5-fold increase over 2008. Coastal tourism is one of the most promising economic sectors of Turkey's blue economy. Cruise tourism in the Black Sea, like coastal tourism, is noted for its potential. Coastal tourism in Ukraine has played an important role in the national economy and constitutes sufficient contribution to regional GDP. Odessa, Yalta, Sevastopol, and Kerch were among the main tourist centres on the Black Sea by 2014. Odessa area became the main coastal destination for those visiting Ukrainian from neighbouring countries.

The territories around Odesa, Sochi and Batumi are also well-established tourist destinations. However, the Black Sea tourism potential is not yet fully developed primarily due to the limited investments, insufficient transport infrastructure, inadequate tourist facilities, and relatively poor quality of services. In 2014, the conflict between Ukraine and the Russian Federation has affected the tourism sector in both countries. Coastal tourism activities has failed significantly in Crimea however attractiveness of other Black Sea destinations - Odesa and Sochi regions, Georgia coast etc. seems increased. Anapa, Gelendjik, and Sochi on the Caucasian coast of the Black Sea are the famous destinations for coastal tourism.

The common tendency in the sector is the increasing number of visits (see, for example, data for Bulgarian coast, Fig. 3.3.3). Economic crisis of 2008 has affected the sector but it is recovering.

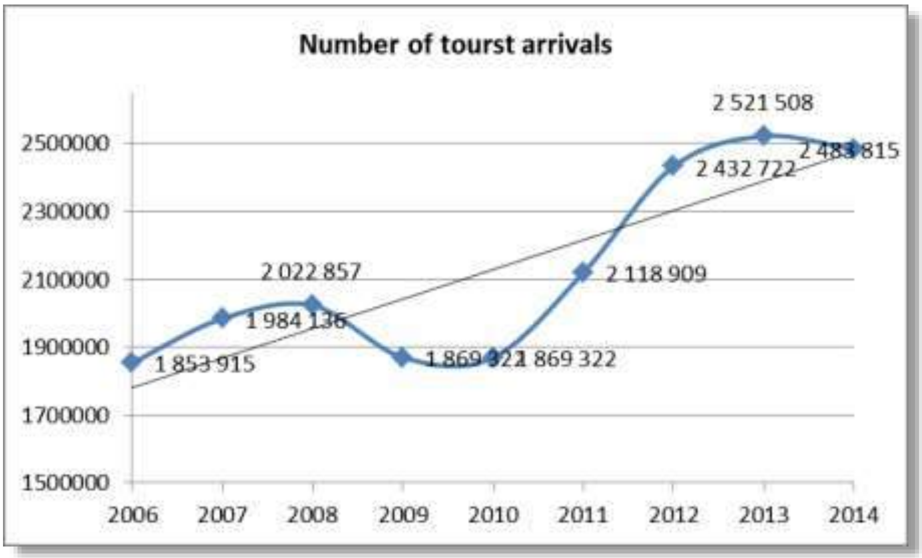

Figure 3.3.3. The number of tourist arrivals to the coastal zone of Bulgaria (Bulgarian Annual Reporting on Integrated Coastal Zone Management (ICZM, 2014).

Continued expansion and diversification of tourism over the past decades in the BS countries makes it as one of the largest and fastest-growing economic sectors. Regretfully, in spite of very positive impact on employment and income, growth of the tourism industry creates environmental challenges notably in the coastal areas and requires sustainable management approach.

Exploration and exploitation of oil and gas

This includes offshore hydrocarbon industries and pipelines, located both on the adjusted terrestrial areas as well as on the Black Sea aquatic area. Estimations of deposits are different. The West Black Sea Basin is considered as an area with most promised gas-oil deposits. It presents shelf with depth approximately 100 m for main part. The area is located mainly within the Ukraine water, covers about 50 thousand km2, and comprises Odessa Bay with the adjacent gas province. Area comprises one exploited deposit and six deposits in the stage of preparation for the exploitation or development. The total surveyed resources of gas in this area is of 1.5 trillion m3 (Panayotis G., Iorga G.A., 2009).

According to (UNDOC), deposits of the North-Western part of the BS are estimated at 495.7 billion m3 of natural gas and 50.4 million tonnes oil, Prikerchenskay zone - 321,2 billion m3 of natural gas and 126,8 million tonnes oil, continental slope - 766,6 billion m3 of natural gas and 232,6 million tonnes oil. It creates opportunities to meet the demand for energy.

Offshore oil and mainly gas exploration and production in the Black Sea is located in production fields (Ayazli off the Turkish coast, Galata and Kaliakra near the Bulgarian coast, the Ana, Doina, Delta, Pescarus and other fields off Romania, Odesa Bay off Ukraine fields; Russian Federation is running exploration and planning exploitation of the Tuapse oil field).

The recent discovery of new gas fields on the Romanian continental shelf of the Black Sea has the potential to strengthen this sector's role. Offshore oil and gas exploitation is already the third-largest employer in the coastal economy of Romania.

The Black Sea area is not only comprises hydrocarbon deposits, the Sea is an important transit route for gas-oil supply from Russia and the Caspian Region countries to the EU and a significant energy market in its own right. However, this situation creates not only opportunities for the region. The crossing interests and maritime power of the EU and non-EU countries in the region poses specific problems that require extra efforts for coordination achieving common vision.

Russian Federation is the world's leading natural gas exporter and one of the largest gas producers, as well as the largest oil exporter and producer. Russian Federation produces gas and oil mainly outside of the BS. In 2014, The Russian Federation companies has started gas exploitation in the Black Sea shelf after annexing Crimea and withdrawal Ukrainian offshore gas platforms. Meanwhile, The Russian Federation succeeded in oil transportation, and Russian container cargos, using well-developed cargo terminals, are the major transport segment in the short-sea shipping sector.

Natural gas and crude oil mainly transported by pipelines. Key pipelines in the BS region presented on the Fig. 3.3.5 and described below.

The Odessa–Brody pipeline is a crude oil pipeline connecting Ukrainian cities Odessa at the Black Sea, and Brody near the Ukrainian-Polish border (674 km). The pipeline was constructed to supply oil delivered to Odessa oil terminal from oil-exporting countries. Pipeline was used in reverse regime for oil transportation in both directions. There are plans to expand the pipeline to Płock, and furthermore to Gdańsk in Poland.

Famous Blue Stream is a major trans-Black Sea gas pipeline that carries natural gas from Russia to Turkey and to European Union countries. Operating at full capacity, it delivers 16 bcm gas per year. The pipeline was built with the intent of diversifying Russian gas delivery routes to Turkey and avoiding third countries. There is a plan to build the second section of the pipeline expanding Russia's gas export to the south (via Samsun-Ceyhan gas pipeline further to Israel and Lebanon).

The Baku–Tbilisi–Ceyhan pipeline is a 1,768 km long crude oil pipeline from the Azeri-Chirag-Guneshli oil field in the Caspian Sea to the Mediterranean Sea basin. In fact, it is located far away from the sea coast however it plays an important role for diversification of the energy sources supply. The pipeline connects Baku, the capital of Azerbaijan, Tbilisi, the capital of Georgia, and Ceyhan, a port on the south-eastern Mediterranean coast of Turkey. It was entered into operational on 10 May 2006 and has a capacity to transport 1 million barrels per day.

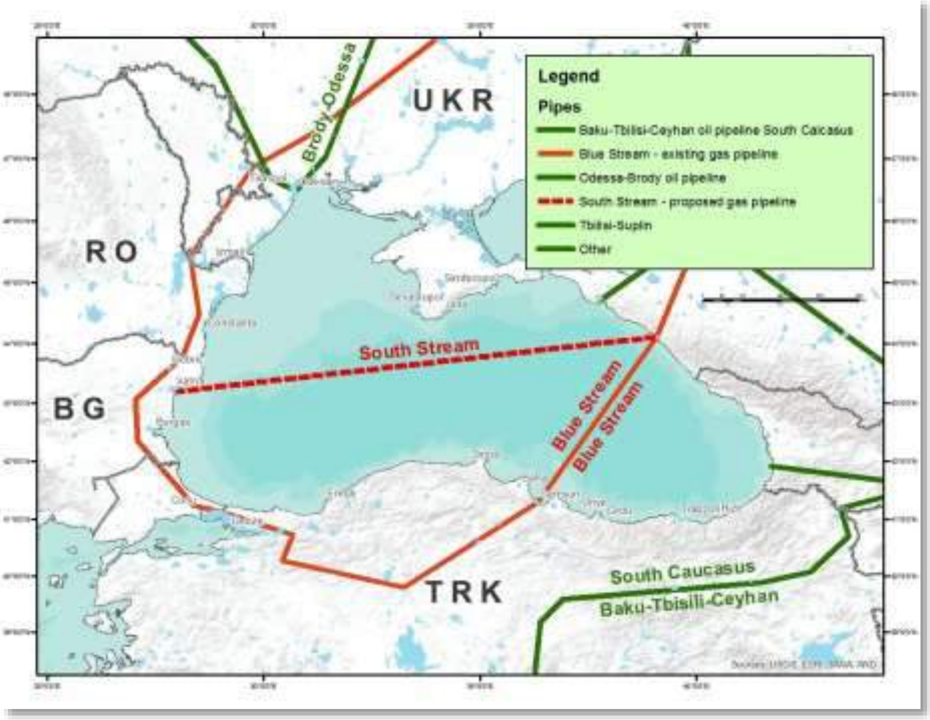

Figure 3.3.4. Oil-gas pipelines in the Black Sea Region (UNDOC).

South Caucasus Gas Pipeline (Baku-Tbilisi-Erzurum route) is under construction in the same corridor as the Baku-Tbilisi-Ceyhan oil pipeline. Its annual capacity is up to 16 billion m3. The 692-km-long pipeline is connecting the Shah Deniz gas field in the Azerbaijan sector of the Caspian Sea and Turkey port Ceyhan. The pipeline is constructed with the potential to connect Turkmen and Kazakh gas fields through the planned Trans-Caspian Pipeline. Its operation has been started in December 2006, supplying natural gas to Georgia and Turkey. Initially it was planned to use South Caucasus pipeline to supply Europe with Caspian natural gas from Iran and Turkmenistan producers through connection to other pipelines (e.g., Turkey-Greece and Greece-Italy pipelines). International consortium has attempted to develop and implement NABUCCO gas pipeline project with planned length 3.900 km and the transport capacity up to 31 bcm per year. It was expected to connect the Caspian region, Middle East and North Africa (Egypt) via Turkey, Bulgaria, Romania, Hungary and Austria and further Central and Western European gas markets. Project preparation has been started in 2002 however it was not implemented and closed in 2013 giving priority to the Trans Adriatic Pipeline (878 km) connecting Caspian region, Middle East, and Western Europe. Project preparatory activities started in 2003 and got approval of the European Commission in March 2016. The pipeline construction started in May 2016 and its operation is expected in 2019.

As we may see, the Black Sea region represents cross-road for significant transportation of energy sources from Caspian Region and Kazakhstan to Eastern and Central Europe. It promotes economic growth and makes significant contribution to the employment of the BS population. Pipeline construction and operation has significant social and environmental impact on the region.

Water projects

Water projects are vital to waterway maintenance, especially on the Danube River, and for improved access to maritime ports in the Black Sea. Such projects increased capacity of the commercial harbours in Ukraine (marine Odesa, Illichivsk, Yuzhny harbours as well as Danube and Dnipro rivers harbours), Georgia, and other countries.

Key marine economy sectors described above have promoted development the urban development sector to accommodate prevailed migration of population to the coast. In particularly, urban agglomeration of Odesa, Sebastopol, Novorossiisk-Sochi, Istanbul, Constanta, Varna provides more jobs, particularly during the summer season (UNDOC).

3.3.2 Major pressures related to human activities and impacts

Political transformation on the post-Soviet territory caused in 1990th significant economic decline resulted in the decreasing pressure on coastal and marine ecosystems (except Turkey). In late 1990th, recovery of the economies of the Black Sea countries increased pressure on the coastal and marine environment due to the fast development of regional infrastructure (urbanisation, enlargement of touristic centres, harbours, terminals and industrial complexes, energy generating installations, pipelines, etc.).

Economic and other kind of human activities in coastal region during 2009-2014 kept pressure on the marine and coastal environment ongoing. Natural features of the region has increased and effect of this pressure. The Black Sea is practically landlocked because has very narrow connection with the ocean and restricted opportunity to exchange marine waters with World Ocean. These circumstances make the region especially vulnerable and sensitive to influence different natural and economic pressures. The state of the natural component of the coastal zone of the Black Sea indicates that both terrestrial and marine ecosystems are suffering from massive anthropogenic influence (UNDOC) caused by different sectors of economic activities. In this regard, shelf area of the North-Western part of the Sea is an area of significant impact.

Severe degradation of the marine ecosystem has started in the 1980th and still ongoing in spite of undertaken efforts of the Black Sea countries and international community. Basic critical factors affecting the marine environment in the region, which were typical for late decades of the 20th century are still in place. They comprise but not restricted to extensive use of terrestrial and marine resources. In particular, in catchment Black Sea area land and water are used for intensive agriculture, forests for paper industry, and construction, rivers and the sea for navigation and commercial fishing, coastal resources for tourism, energy generation, transport infrastructure, constructing and other industries. To meet increasing demands for oil and gas, coastal and marine areas used for pipelines construction. As a result, natural landscapes are deteriorated and gradually replacing by anthropogenic landscapes.

Another problem is the water quality. Rivers run-offs, oil and gas extraction activities, atmospheric deposition, intentional and accidental discharged from vessels are the main sources of pollution. Rivers flows are polluted by agriculture, industries, communal wastewaters, transport and others sectors located in the Sea basin. Over 300 rivers running into the BS drain almost half of Europe and significant parts of Eurasia. The main rivers are the Danube, Dnieper and Don, which are the second, the third and the fourth major European rivers.

The estimated maximum annual river discharge entering the Black Sea and Azov Sea is of 480 km3 (ESPON, 2013). Polluted rivers' run-off cause sufficient deterioration of the marine ecosystem. Sources of pollution locate both at the coastal zone and the overall catchment area. Management of the impact requires consolidated efforts of the catchment area states.

Pollutions cause direct and indirect impact on marine ecosystem. In particularly, pollutions represented by heavy metals, oil and others harmful substances are causing toxic effect on biota directly. Suspended solid particles decrease sun rays penetration through water layer and thus depress development of benthic biocenoses and pelagic algae and other organisms. Mineral and organic fertilizers originated from agricultural fields stimulate microflora bloom (eutrophication) and in such a way cause destructive effect and damage coastal water biocoenosis.

In general, quality of coastal water is far away from the natural level due to the bad management and bays, golfs and harbour area of large cities in particular (e.g., Constanta, Odesa, Sebastopol, Novorossiysk, Poti, Batumi, Trabzon, Istanbul, Varna, etc.) are the most polluted areas in the Black Sea (UNDOC).

Other factors of effects on the marine environment related to harbour and coastal activities. Dredging, coastal and off-shore construction (e.g., construction of oil/gas facilities, pipelines, coastal protection installations, wave breakers, etc.) are harmful for benthic communities, and directly and indirectly deteriorate bottom landscapes and depress phytoplankton and benthic macrophytes as a result of damping huge amount of silty mud. Dredges and some fishing practices damage bottom landscapes biocenoses and have a significant impact on the ecosystem. Unsustainable fisheries and extraction of other living resources (e.g., biomass of Philophora algae) are destroying the fish stock and macrophytes fields. Decreasing of the population of fish species is provoking further negative processes in marine ecosystem and push ecosystem evolution in unpredictable way.

Depressing biota of the marine ecosystem and decreasing its productivity due to pollution of the coastal water, coastal and bottom landscapes transformation activities, and unsustainable exploitation of living resources still constitute one of the most problems of the BS environment.

Key economic activities and their impact on the marine and coastal environment summarized in Table 3.3.4.

Table 3.3.4. Anthropogenic activities affecting directly the marine environment.

Pressure	**Economic activity**	**Sub-activity / Marine water use**
Biological disturbances Deterioration of marine ecosystem	Fisheries	Living resources catches Fish / Mollusks
Deterioration of coastal and marine ecosystem: Damages to the physical environment (in terms of geological and geomorphological integrity, as well as constructed shoreline / infrastructure)	Anthropogenic origin structures (including the construction stage)	Coastal protection & protection against flooding
		Harbor operation
		Emplacing and operating offshore structures (other than those producing energy)
		Oil/gas extraction
Nutrient and organic substance enrichment	Human settlements, Industry, Agriculture	Waste water discharges from industry/emissions;

Pressure	Economic activity	Sub-activity / Marine water use
		Waste water discharges from municipalities; Nutrients discharged by the rivers
Hazardous substances contamination	Industry	Hazardous substances discharge by the rivers

Source: UNDOC

Climate change

Apart of the described factors of pressure on the environment in the BS region, there is a strong scientific evidences that the global warming in recent decades is becoming one more significant factor of influence on many physical, societal and biological systems. Key indicator of the global warming is rising surface air temperatures, and main consequences of this uncontrolled phenomena are retreating and melting glaciers, increasing average global sea levels and changing functioning ecosystems.

Climate change (CC) is natural process however there is a strong scientific consensus that human activity significantly contribute to this process accelerating temperature increase. Human-induced climate change is caused mainly by greenhouse gas emissions from industry, transport, agriculture and other vital economic sectors. Carbon dioxide makes one of the largest contribution to enhanced climate change. BS coastal activities promotes climate change by utilizing fossil fuels (coal, oil and gas), which are the greatest source of humanity's carbon dioxide and carbon oxide emission. Industry, agriculture, deforestation and other land-use changes also release large amounts of carbon dioxide and other green-house gases. Domesticated animals, rice paddies and waste management (in particular, the disposal and treatment of garbage and human waste) comprise other sufficient sources of methane emission. All these activities and processes are taking place in coastal zone.

The BS region is under impact of global climate change tendencies. Global temperatures continue to increase. The global average temperature is estimated to have risen by 0.6°C over the course of the 20th century, and there are few scenarios of following development (Stakeholders Conference, 2014). Although the rate of warming varies from year to year due to natural variability, the human-induced warming trend has continued. 2001-2010 was the warmest decade on record since modern temperature monitoring began around 160 years ago. The global combined land-air surface and sea-surface mean temperature for the decade is estimated at 0.47°C above the 1961-1990 average of 14.0°C. Globally, 2010 is estimated to be the warmest year ever recorded since modern measurement began, closely followed by 2005. No single year since 1985 has recorded a below-average mean. The 2001-2010 decade was also the warmest ever recorded for each continent. Europe and Asia recorded the largest average temperature anomaly for the decade (+0.97°C) (Stakeholders Conference, 2014). Climate processes have some specifics in the BS region. Short-term periods of increased temperature in summer, increased number of extra-ordinary meteorological phenomena, warmer in general winter seasons are typical features of the climate change consequences in the BS region.

Addressing climate change is focusing first of all at mitigation of this phenomenon, however CC creates as well some new opportunities. In particular, some areas of human activity may benefit taking advantage of CC. The prolongation of the warm season near the Black Sea coast (a season relatively short compared with the Mediterranean similar locations) caused by warming is beneficial for tourism sector. Tourist demand in mountain and coastal resorts, following the need of urban inhabitants to escape the city heat waves, is resulted as well from CC consequences.

At the same time the warming has explicit health implications. A lot of people are sensitive to sharp temperature and pressure drops and increases, and these obstacles are have to be controlled in order to prevent health disorders. Warming is to changing boundaries of habitats of animals and insects, including the peddlers of dangerous infectious diseases (e.g., tick-borne Lyme disease, tick-borne encephalitis, hemorrhagic fever, West Nile fever). Warming is a factor of fast induction of new and transformed viruses threatening health and life of human and other living organisms. Therefore, medical institutions of the BS region are considering approaches to prevention, diagnosis and treatment of atypical for the area of diseases.

3.3.3. Consequences of environmental change

Over the last decades an increase human (economic activities) and natural (climate change) drivers and pressures, described in the previous section, caused substantial degradation of Black Sea. The time were the Black Sea had a remarkably stable ecosystem past away in the second half of the 20th century. Economic depression in the 1990th in post-Soviet countries and consolidated measures undertaken by littoral countries and international communities promoted positive changes in the marine ecosystem. Environmental restoration created opportunities for economic activities.

- Acceleration of an economic activities at the end of 1990th and in the first decade of the 2000s on the BS coast area (in particular, constructing new hydrocarbon pipelines, developing energy, transport, military and industrial infrastructure) increased pressure on the marine and coastal environment after decade. During 2008-2014, monitoring activities and research programs showed similar consequences and tendencies, which were described for the Black Sea ecosystem in the second half of 1990th.
- • Decline in the Black Sea fisheries was irreversible. According to the modern estimation, about 85 percent of the Black Sea stocks are fished at biologically unsustainable levels (Tsikliras A.C. at al., 2016). In spite of the difference in sustainability of the demersal and pelagic fish stocks (demersal stocks experience higher fishing mortality rates than small pelagic stocks), the majority (85 percent) of stocks for which a validated assessment available are fished outside biologically sustainable limits (Tsikliras A.C. at al., 2016). Fish stocks are slowly decreasing. It has negative consequences for fishery sector and put it in face of losing sources of its existence and development.
- • Natural habitats, notably wetlands and shelf areas, supporting important biotic resources are still under anthropogenic impact (amount of polluted water discharged into the Sea has been decreased but not prevented and depends on economic activities on the coast; littering of coastal and marine environment represents increased threat for biota and human health). It means that developing tourism, recreation and health sectors have worse quality of ecosystem services.
- • Some progress was achieved in the field of the protection of coastal biodiversity, ecosystems and landscapes. In particular, in 2008-2014 several new national parks and natural reserves were established in the Ukrainian part of the BS coastal zone – in Odesa, Mykolaiv, Kherson oblasts and in AR Crimea. Ukraine has designated 2

exclusively marine protected areas – State Botanic Reserve Filophora Field (2008, Odesa Bay) and State Botanic Reserve Small Filophora Field (2012, aquatory between AR Crimea and Kherson region). At the same time these optimistic steps were not supported by strong management and appropriate resources for implementation of the effective protective programs and activities. The cumulative positive impact of these measures is in hindering ongoing degradation of natural landscapes and biodiversity, creating some job opportunities and preconditions for new touristic activities.

- • Dynamic quality of coastal water impacted by pollution from multiple coastal sources and off-shore installations and activities is an issue for rapidly developing touristic sector in all BS countries.
- Consequences of economic activities and environmental changes have not depressed value of the Black Sea goods and services, which remain key factors of socio-economic development of coastal communities.

Hydrocarbon Resources. In spite of political and military tensions between some BS countries (Russian Federation- Ukraine, Georgia –Russian Federation) and arisen from these processes economic difficulties and uncertainties, exploitation of hydrocarbon deposits in the North-West shelf and in other part of the BS is inevitable and will be accelerated. It will create new jobs and generate energy resources for littoral countries. Meanwhile, it creates significant threat to the marine environment and require responsible management and coordinated actions among BS countries.

Fish stock. The status of the Black Sea fisheries was evaluated for the period 1970-2010 (FAO, 201, Tsikliras A.C. at al., 2016). All indicators used for assessment (e.g., temporal variability of total landings, the number of recorded stocks, the mean trophic level of the catch, the fishing-in-balance index, the catch-based method of stock classification) confirmed that the fisheries resources of the Black Sea are exhausting and at risk from overexploitation. The pattern of exploitation demonstrates that the BS fisheries is in a worst shape. In the BS, total landings, mean trophic level of the catch and fishing-in-balance index were declining.

To make possible stocks recovering, the country need to introduce regular, more detailed and extensive stock assessments of all commercial and supportive species, which create background for reasonable conservation and management measures. Meanwhile, sensitivity of the fishery to human impact stimulates development more sustainable and less dependent aquaculture sector

To make possible stocks recovering, the country need to introduce regular, more detailed and extensive stock assessments of all commercial and supportive species, which create background for reasonable conservation and management measures. Meanwhile, sensitivity of the fishery to human impact stimulates development more sustainable and less dependent aquaculture sector.

Ecosystem services. Tourism is based on ecosystem services of the BS environment (recreational resources, beaches, sands, friendly water and sun, natural beauties and attractions, etc.) and developing very fast. Tourism is one of the most promising sectors in terms of sustainable use of coastal and marine goods and services. The coast and marine area still have huge but restricted potential to provide necessary goods (food and accommodation facilities) and services for local and foreign tourists. Developing tourism infrastructure in Georgia, northern part of Turkey, Odesa region in Ukraine, Krasnodar Krai in the Russian Federation, as well as improvement of coastal infrastructure of Bulgaria and Romania is expected to be the key trend in nearest decade.

Tackling issues like deterioration of natural habitats, pollution prevention, supporting fish and other living resources stock, irresponsible exploitation of hydrocarbon and mineral resources of the BS bed, and others will improve the quality of an environment and facilitate the development of those maritime activities that are dependent on a healthy environment, such as fisheries, aquaculture and tourism.

3.3.4. Responses: countries activities to address problems

In 2009-2014, the BS countries demonstrated economic growth accompanied with intensive expansion on the natural coastal areas and negative impact on the marine ecosystem. Response to changes in the BS environment affecting socio-economic landscapes of the littoral countries required coordinated and consolidated efforts at the national and regional level. Basis for regional cooperation was created by the Convention on the Protection of the Black Sea against pollution (Bucharest Convention, 1992) supplemented with its Protocols and follow-up non-legally binding acts (e.g., Black Sea Strategic Action Plan, 1996, 2009). The Convention remained as a key framework for cooperation in 2009-2014. Regional cooperation was supplemented with international cooperation among Black Sea riparian countries, European Union, UN agencies and international financial organizations.

One of the areas of such cooperation is climate change prevention and adaptation. All the Black Sea littoral states have signed and ratified the UN Framework Convention on Climate Change and the Kyoto Protocol to the Convention. Meanwhile, actual implementation of the provisions of these legal acts has been sporadic in 2008-2014, with little regional coordination. It makes sense to consider the possibility of a Black Sea countries to strengthen regional coordination of possible actions in terms of prevention and adaptation to CC including regional emissions trading scheme.

In spite of the limits of the coastal zone have not been formally defined in all riparian countries (actually, only Romania and Bulgaria has legal ground for coastal zone limitation), the ICZM concept and principles were introduced in BS countries. At the same time, common legal document or guidelines on methodology of the ICZM for the BS states is not developed and improved. Romania has legislation in force directly related to ICZM. Others countries apply certain ICZM principles through spatial planning legislation (Bulgaria), Shore Law (Turkey), Urban Planning Code (the Russian Federation). Georgia and Ukraine have developed draft legislation for ICZM but adoption and enforcement is suspended due to lack of political will. Therefore, adequate planning of coastal development and inter-sectoral coordination at national and regional levels are still required countries activities to address problems. In this regard, the Black Sea Commission and its bodies (Permanent Secretariat and the Advisory Group on the Development of Common Methodologies for Integrated Coastal Zone Management), provides the international framework for the coordination and advancement of ICZM in the Black Sea Region. The Commission considers ICZM methodology as key instrument for sustainable development of the coastal communities. Details of the context and activities of ICZM and its role in governance of the coastal development described in details in the following chapter.

Cooperation of the BS countries with EU promoted multi-dimensional development and made sufficient contribution to economic growth in the BS region. Such cooperation takes place largely on a bilateral basis, and is supplemented with multilateral cooperation, aimed at supporting and promoting mutually beneficial sectoral initiatives. In 2008 – 2014, such initiatives included but not restricted the Interstate Oil and Gas Transport to Europe (INOGATE), the Transport Corridor Europe-Caucasus-Asia (TRACECA), the Black Sea Pan-European Transport Area (PETrA), the Danube-Black Sea Task Force (DABLAS). These initiatives promoted deeper regional integration for the Black Sea region as a whole and strengthened capacities to prevent and overcome regional and global challenges.

Countries are planning framework for the “blue growth” in the BS region (Tsiaras K., 2010). “Blue Growth” is a new concept and an important element of the Integrated Maritime Policy (IMP), which is a cross-sectorial policy that seeks to provide a more coherent approach to maritime issues, with increased coordination between different ministries, with the public authorities and the private sector, with regions and with other countries. The EU has laid down objectives for the Black Sea basin as well as for other regional seas. Marine and maritime growth will be reflected in all EU funding instruments for 2014-2020 as well as in other maritime investment and research priorities. Blue Growth is a key component of this policy by addressing difficulties that hinder sustainable growth in a number of maritime sectors. In this regard, EU provides support to the projects clarifying maritime policies and developing instruments for implementation of such policies.

In particularly, for Bulgaria, Romania and Turkey, most promised and relevant sectoral activities were identified (Tsiaras K., 2010). Exercises were based on the analysis of maritime economic activities (MEAs) and the Countries’ Fiches. Identified four groups of activities, important for “blue growth”, are presented in the table below and can be applicable for planning development of coastal zones by other Black Sea countries.

<table>
<tr><td rowspan="2">SECTORAL THEMES (ACTIVITIES)</td><td>Increasing regional attractiveness
- Coastal tourism
- Yachting and marinas
- Cruise tourism</td><td>Ensuring regional energy security
- Offshore oil and gas
- Offshore renewable energy</td></tr>
<tr><td>Connecting the region
- Port and coastal / river infrastructure
- Inland waterway transport
- Ship-building and repair
- Short-sea shipping</td><td>Sustainable utilization of living aquatic resources
- Marine aquaculture
- Fishing for human consumption</td></tr>
</table>

In addition to these sector-driven thematic ‘pillars’, the proposed Black Sea sea-basin approach has been supplemented with important cross-cutting horizontal actions that are necessary to underpin the sustainable and balanced long-term growth of maritime economic activities. Identified four key groups of cross-cutting ‘Horizontal Actions’ are presented in the table below.

<table>
<tr><td>HORIZONTAL ACTIONS</td><td>Planning a blue economy
□ Maritime Spatial Planning and ICZM
□ Integrated local development</td><td>Developing knowledge
□ Joint data collection, monitoring and sharing</td></tr>
</table>

	Development of smart infrastructure	Capacity-building across individuals, institutions and society Sharing maritime culture and heritage
	Supporting business growth Facilitating access to finance Promoting innovation through applied Research and Development Development of maritime clusters	**Enhancing the Environment** Preserving, protecting and improving the quality of the coastal and marine environment and heritage Ecosystem monitoring Building resilience to the impacts of climate change

Through coordinated efforts applied in the reporting period, the BS countries demonstrated some progress in socio-economic development, which was not accompanied with expected improvement of the state of environment in the region.

Conclusion and Recommendations:

1. During reporting period the Bleak Sea countries have demonstrated steady economic growth. Socio-economic processes in Bleak Sea coastal area strongly depend on the local economic and societal activities as well as trends of national and global levels.

2. Global economic crisis of 2008 was not crucial for coastal economies and the BS littoral states demonstrated strong potential for rehabilitation and further grow.

3. Tourism is an accelerator for many other sectors of the BS littoral states economy.

4. Despite importance of the fisheries, this sector has historically lacked an integrated management strategy and sustainable development.

5. Natural habitats of coastal and marine environment remain under pressure of mainly land-based human activities. In spite on establishing new protected areas (national parks and natural reserves) on the coast and in open sea, degradation of ecosystems is not prevented and biodiversity decline is ongoing.

6. On-going urbanization, infrastructure development, offshore exploitation of hydrocarbon deposits are the key factors of economic development in the nearest future. Strengthening of cooperation, enhancement of political links, between the riparian states as well as the relevant technical assistance for them from international community are therefore needed in order to ensure implementation of the principles of sustainable development of the Black Sea region.

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ANNEX 1 QUANTITATIVE SUMMARY OF ICZM STOCK-TAKING FOR THE BLACK SEA COUNTRIES

Item Heading	Number	ICZM Instrument / Issue Item	Bulgaria	Georgia	Romania	Russia	Turkey	Ukraine
Boundaries	01	Coastal zone boundaries legally defined (landward, seaward)	1	0	0	-1	-1	0
Legislation	02	ICZM legislation or a coastal law approved	0	0	1	-1	1	0
Coordi-nation	03	Coordination / integration land and sea parts	1	-1	1	-1	-1	-1
	04	Coordination / integration horizontal	0	-1	1	-1	0	-1
	05	Coordination / integration vertical	0	-1	1	-1	0	-1
Protection and sustainable use of the Coastal Zone	06	Setback zone for coastal developments	0	-1	1	-1	1	0
	07	Other measures for coastal protection and sustainable use	1	-1	-1	-1	1	-1
	08	Urban coastal development restrained outside protected areas	-1	-1	1	1	1	0
	09	Linear coastal (transport) development restrained	-1	-1	1	0	-1	0
	10	Long-shore and cross-shore access for the public	1	-1	1	0	1	1
	11	Limiting vehicle and vessel access to fragile coast	1	-1	1	0	0	0
Economics	12	Economic indicators	-1	-1	-1	-1	-1	-1
Coastal eco-systems, landscapes & cultural heritage	13	Protection of coastal wetlands	1	1	1	na	0	1
	14	Restoration of coastal wetlands	1	-1	1	na	1	0
	15	Protection of marine habitats	1	0	1	0	0	1
	16	International cooperation in marine protection	1	0	1	-1	0	1
	17	Protection of coastal landscapes	-1	-1	0	0	1	0
	18	Islands	0	na	na	na	0	1
	19	Coastal cultural heritage protection	0	-1	0	1	1	0
Partici-pation	20	Consultative bodies	1	-1	1	1	0	-1
	21	Public rights on inquiries & hearings (plans, projects)	1	-1	1	1	0	0
	22	Coastal partnerships	1	-1	0	-1	-1	-1
	23	Mediation or conciliation procedures (plans, projects)	1	-1	-1	1	-1	-1
	24	Rights to challenge coastal plans, projects	-1	-1	1	1	1	1
Awareness, training, education & research	25	Education, training, awareness (national)	0	0	-1	0	0	-1
	26	Education, training, awareness (regional)	0	0	0	0	-1	0
	27	Education, training, awareness (local)	0	0	0	-1	0	0
	28	ICZM research centres of excellence	-1	-1	1	0	0	-1

Item Heading	Number	ICZM Instrument / Issue Item	Bulgaria	Georgia	Romania	Russia	Turkey	Ukraine
Monitoring & review	29	Observation / inventory of coastal resources and environments	0	0	0	0	0	1
	30	Stock-taking / inventory of institutions	0	0	1	0	-1	1
	31	Stock-taking / inventory of legislation and planning	0	0	0	0	-1	1
Strategies, plans and projects	32	National ICZM strategy	-1	0	0	-1	-1	-1
	33	Coastal use and management assessments	1	0	-1	0	0	1
	34	ICZM projects	0	1	1	0	1	0
EIA/SEA guidelines	35	EIA applied to coastal projects	1	-1	1	1	1	0
	36	SEA applied to coastal plans/programs	1	-1	1	1	0	-1
	37	SEA guidelines established for coastal plans/programs	-1	-1	-1	-1	-1	-1
Land policy	38	Land acquisition into public domain for coastal preservation	1	-1	0	0	-1	0
	39	Area or percentage of land acquired into public domain?	na	na	na	na	na	na
	40	Who is responsible for the management of the land?	na	na	na	na	na	na
	41	Land acquisition into private domain for coastal preservation	-1	-1	-1	-1	-1	-1
Economic instruments	42	Economic, financial, fiscal incentives for ICZM	-1	0	0	-1	-1	0
	43	Economic, financial, fiscal disincentives for ICZM	1	-1	1	-1	-1	0
Natural hazards & coastal erosion	44	Coastal vulnerability and hazard assessment	1	0	1	0	0	0
	45	Coastal hazard prevention, mitigation and adaptation measures	1	-1	-1	0	-1	0
	46	Measures to maintain and restore natural capacity of the coast	1	-1	0	1	-1	0
	47	Contingency plans to respond to coastal hazards	0	-1	1	1	0	0
Exchange of information	48	Coastal management indicators	0	1	0	0	0	0
	49	Up-to-date coastal use and management assessments	-1	0	0	0	-1	0
	50	ICZM demonstration projects	-1	1	0	1	1	1
	51	Centres of ICZM specific capacity	0	-1	0	0	0	0
Trans-boundary	52	Bilateral or multilateral cooperation in ICZM (plans, strategies)	-1	0	0	0	-1	0
	53	Transboundary EIA mechanisms	1	0	1	0	-1	0
TOTAL	#	Score	9	-25	17	-5	-8	-3

Note: "**1**" is **Yes**, "**0**" is **P**artial, "**-1**" is **No**, "**na**" is **N**ot **A**pplicable.

ANNEX 2 COLOUR CODED ICZM PROGRESS INDICATORS FOR THE BLACK SEA REGION COUNTRIES

These progress indicators are divided into 4 phases and 31 actions, closely following the approaches suggested in the EEA (2006) and Pickaver et al. (2004): updated to meet the needs of Black Sea littoral countries to complete the periodic self-assessments indicating the progress with implementation of ICZM through filling the colour coded marker tables.

Reporting milestones for measuring the progress with ICZM indicators correspond to Ministerial meetings and/or international cooperative actions of the Black Sea countries within the framework of the Bucharest Convention. The reporting milestones to date include the meetings convened for the adoption of Odessa Declaration in 1993, signing in Istanbul the Black Sea Strategic Action Plan of 1996, adoption of Sofia Declaration in 2002, and the signing of the updated Black Sea Strategic Action Plan at Kiev Ministerial in 2009. Results of ICZM progress assessments covering approximately 5 year period are to be included in the periodic State of the Black Sea Reports prepared by the Black Sea Commission and reported to the regular Ministerial meetings.

Operational updating of the ICZM progress indicators is to be performed annually and presented at the meetings of the ICZM AG. Results of the operational ICZM progress marker assessments should therefore be reported to the Black Sea Commission on an annual basis.

The progress markers and respective endnoted textual arguments are addressed at four administrative and spatial levels: international, national, sub-national and local. International level might include Black Sea regional, EU, regional seas, or other applicable international scales. Sub-national level might include coastal regions, large protected areas or similar units of sub-national designation, as determined by each country. Local level initiatives are to be considered in *ad hoc* manner as progress is monitored at local level and at this stage of development are not accounted for on a site-specific/geographic basis, though in future it is envisaged to introduce spatially explicit progress indicators.

Following are the steps to complete the indicator table:

1. Alongside each phase/action colour coded cell should indicate whether particular action is implemented (green), partially implemented (yellow), or not yet implemented (red).

2. In case of positive or negative changes in time, indicated with modifying the colour of the cell, an explanatory reason forcing this change should be explained with the numbered endnotes.

3. Endnote number should be prefixed with '+', '-' or no sign, indicating the direction of change (upgrade/downgrade/unchanged) of the particular phase/action.

4. In order to identify trend through time the colour coded table is to be filled at respective reporting milestone (Ministerial meeting) or at annual operational update (ICZM AG meeting).

5. Latest formal reporting period and current operation update dates should be inserted in the indicator table header.

6. Updated/modified endnote texts vis-à-vis previous reporting period should be highlighted in bold to show most recent changes in the colour coded progress marker status.

Colour coded indicators and triggering endnotes are presented below starting first with the regional synthesis table, followed by results for each of six Black Sea littoral countries.

	COUNTRY	REGION (BLACK Sea)	YEAR	1993	1996	2002	2009	2016
	PHASE	ACTION	#	INTERNATIONAL				
Annual Operational BSC 2016.09	I. Aspects of coastal planning & management are in place	Decisions about planning and managing the coast are governed by general legal instruments.	01					
		Sectoral stakeholders meet on an ad hoc basis to discuss specific coastal and marine issues.	02					
		There are spatial development plans which include the coastal zone but do not treat it as a distinct and separate entity.	03					
		Aspects of the coastal zone, including marine areas, are regularly monitored.	04					
		Planning on the coast includes the statutory protection of natural areas.	05					
Latest Ministerial Reporting Date: 2008.04.08	II. A framework exists for taking ICZM forward	Existing instruments are being adapted and combined to deal with coastal planning and management issues.	06					
		Adequate funding is usually available for undertaking actions on the coast.	07		+[1]	[2]	+[3]	[4]
		A stocktake of the coast (identifying who does what, where and how) has been carried out.	08		+[5]			+[6]
		There is a formal mechanism whereby stakeholders meet regularly to discuss a range of coastal and marine issues.	09			+[7]	+7	[8]
		Ad hoc actions on the coast are being carried out that include recognisable elements of ICZM.	10				+[9]	[10]
		A sustainable development strategy which includes specific references to coasts and seas is in place.	11					
		Guidelines have been produced by national, regional or local governments advising planning authorities on appropriate uses of CZ.	12				+[11]	+[12]
Downgrade	III. Most aspects of an ICZM approach to planning and	All relevant parties concerned in the ICZM decision-making process have been identified and are involved.	13					
		A report on the State of the Coast has been written with the intention of	14					

	COUNTRY	REGION (BLACK Sea)	YEAR	1993	1996	2002	2009	2016
	PHASE	ACTION	#	INTERNATIONAL				
		repeating the exercise every five or ten years.						
		There is a statutory coastal zone management plan.	15					
-		Strategic Environmental Assessments are used commonly to examine policies, strategies and plans for the coastal zone.	16					
Upgrade		A non-statutory coastal zone management strategy has been drawn up and an action plan is being implemented.	17			+[13]	+[14]	-[15]
		There are open channels of communication between those responsible for the coast at all levels of government.	18					
+		Each administrative level has at least one member of staff whose sole responsibility is ICZM.	19		+[16]			
Attained		Statutory development plans span the interface between land and sea.	20					
		Spatial planning of sea areas is required by law.	21					+[17]
		A properly staffed and properly funded partnership of coastal and marine stakeholders is in place.	22		+[18]		-[19]	
Partially		ICZM partnerships are consulted routinely about proposals to do with the coastal zone.	23					
		Adequate mechanisms are in place to allow coastal communities to take a participative role in ICZM decisions.	24					
	IV. An efficient, adaptive and integrative process is embedded at all levels of governance and is delivering greater sustainable use of the coast	There is strong, constant and effective political support for the ICZM process.	25	+[20]	+[21]		+[22]	+[12]
Not Attained		There is routine (rather than occasional) cooperation across coastal and marine boundaries.	26					
		A comprehensive set of coastal and marine indicators is being used to assess progress towards a more sustainable situation.	27				+[23]	[23]
		A long-term financial commitment is in place for the implementation of ICZM.	28					

LEGEND:	COUNTRY	REGION (BLACK Sea)	YEAR	1993	1996	2002	2009	2016
	PHASE	ACTION	#	INTERNATIONAL				
		End users have access to as much information of sufficient quality as they need to make timely, coherent and well-crafted decisions.	29					
		Mechanisms for reviewing and evaluating progress in implementing ICZM are embedded in governance.	30					
		Monitoring shows a demonstrable trend towards a more sustainable use of coastal and marine resources.	31					

Endnotes REGIONAL (BLACK Sea):

	COUNTRY	BULGARIA (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
Annual Operational BSC Reporting Date: 2016.09.07	I. Aspects of coastal planning & management are in place	Decisions about planning and managing the coast are governed by general legal instruments.	01															
		Sectoral stakeholders meet on an ad hoc basis to discuss specific coastal and marine issues.	02					+[1]			+[2]							
		There are spatial development plans which include the coastal zone but do not treat it as a distinct and separate entity.	03				+[3]	[4]			+[5]	[6]	[7]				+[8]	
		Aspects of the coastal zone, including marine areas, are regularly monitored.	04				+[9]	-[10]					+[11]					
		Planning on the coast includes the statutory protection of natural areas.	05			+[12]		+[13]										
Latest Ministerial 2008.04.08	II. A framework exists for taking ICZM forward	Existing instruments are being adapted and combined to deal with coastal planning and management issues.	06															
		Adequate funding is usually available for undertaking actions on the coast.	07				+[14]											
		A stocktake of the coast (identifying who does what, where and how) has been carried out.	08		+[15]			+[16]										
		There is a formal mechanism whereby stakeholders meet regularly to discuss a range of coastal and marine issues.	09				+[17]	[18]										

	COUNTRY	BULGARIA (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
		Ad hoc actions on the coast are being carried out that include recognisable elements of ICZM.	10				+[19]	[20]			+[21]	+[22]						
		A sustainable development strategy which includes specific references to coasts and seas is in place.	11				+[23]	[24]										
		Guidelines have been produced by national, regional or local governments advising planning authorities on appropriate uses of CZ.	12															
Downgrade	III. Most aspects of an ICZM approach to planning and managing the coast are in place and functioning reasonably well	All relevant parties concerned in the ICZM decision-making process have been identified and are involved.	13															
		A report on the State of the Coast has been written with the intention of repeating the exercise every five or ten years.	14															
		There is a statutory coastal zone management plan.	15															
-		Strategic Environmental Assessments are used commonly to examine policies, strategies and plans for the coastal zone.	16															
Upgrade		A non-statutory coastal zone management strategy has been drawn up and an action	17					+[25]										

Annex 2 Colour coded ICZM progress indicators for the Black Sea Region Countries

	COUNTRY	BULGARIA (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	**NATIONAL**					**SUB-NATIONAL**					**LOCAL**				
		plan is being implemented.																
		There are open channels of communication between those responsible for the coast at all levels of government.	18															
+		Each administrative level has at least one member of staff whose sole responsibility is ICZM.	19															
		Statutory development plans span the interface between land and sea.	20								+[26]		+[27]					
Attained		Spatial planning of sea areas is required by law.	21				+[28]	+[29]										
		A properly staffed and properly funded partnership of coastal and marine stakeholders is in place.	22					+[30]										
		ICZM partnerships are consulted routinely about proposals to do with the coastal zone.	23															
Partially Attained		Adequate mechanisms are in place to allow coastal communities to take a participative role in ICZM decisions.	24				+[31]											
	IV. An efficient, adaptive and integrative process is embedded at all levels of	There is strong, constant and effective political support for the ICZM process.	25															
Not Attained		There is routine (rather than occasional) cooperation across coastal and marine boundaries.	26															

	COUNTRY	BULGARIA (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
		A comprehensive set of coastal and marine indicators is being used to assess progress towards a more sustainable situation.	27															
		A long-term financial commitment is in place for the implementation of ICZM.	28															
		End users have access to as much information of sufficient quality as they need to make timely, coherent and well-crafted decisions.	29					+[32]										
		Mechanisms for reviewing and evaluating progress in implementing ICZM are embedded in governance.	30															
LEGEND:		Monitoring shows a demonstrable trend towards a more sustainable use of coastal and marine resources.	31															

Endnotes BULGARIA (BLACK Sea):

	COUNTRY	GEORGIA (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
Annual Operational BSC Reporting Date: 2016.09.07	I. Aspects of coastal planning & management are in place	Decisions about planning and managing the coast are governed by general legal instruments.	01				+1	-2			+3						+4	
		Sectoral stakeholders meet on an ad hoc basis to discuss specific coastal and marine issues.	02			+5	-6	+7				+8						
		There are spatial development plans which include the coastal zone but do not treat it as a distinct and separate entity.	03				+10				+9	+10					+11	12
		Aspects of the coastal zone, including marine areas, are regularly monitored.	04															
		Planning on the coast includes the statutory protection of natural areas.	05								+3	+10					+13	-14
Latest Ministerial 2008.04.08	II. A framework exists for taking ICZM forward	Existing instruments are being adapted and combined to deal with coastal planning and management issues.	06															
		Adequate funding is usually available for undertaking actions on the coast.	07			+15	-16				+17		+18			+19	+20	
		A stocktake of the coast (identifying who does what, where and how) has been carried out.	08		+21	+22	-23	+24			+25							
		There is a formal mechanism whereby stakeholders meet regularly to discuss a range of coastal and marine issues.	09			+5	-6											
		Ad hoc actions on the coast are being carried out that include recognisable	10					+26									+27	

	COUNTRY	GEORGIA (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	**NATIONAL**					**SUB-NATIONAL**					**LOCAL**				
		elements of ICZM.																
		A sustainable development strategy which includes specific references to coasts and seas is in place.	11			+[28]	[29]											
		Guidelines have been produced by national, regional or local governments advising planning authorities on appropriate uses of CZ.	12				+[30]			+[31]								
Downgrade	III. Most aspects of an ICZM approach to planning and managing the coast are in place and functioning reasonably well	All relevant parties concerned in the ICZM decision-making process have been identified and are involved.	13															
		A report on the State of the Coast has been written with the intention of repeating the exercise every five or ten years.	14															
		There is a statutory coastal zone management plan.	15								+9	+[10]					+[13]	-[14]
-		Strategic Environmental Assessments are used commonly to examine policies, strategies and plans for the coastal zone.	16															
		A non-statutory coastal zone management strategy has been drawn up and an action plan is being implemented.	17			+[32]	+[33]	-[34]										
Upgrade		There are open channels of communication between those responsible for the coast at all levels of government.	18				+[35]											
+		Each administrative level has at least one member of staff whose sole	19		+[36]	+[37]	-[38]					+[39]	[40]					+[41]

Annex 2 Colour coded ICZM progress indicators for the Black Sea Region Countries

COUNTRY	GEORGIA (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
PHASE	**ACTION**	**#**	**NATIONAL**					**SUB-NATIONAL**					**LOCAL**				
	responsibility is ICZM.																
	Statutory development plans span the interface between land and sea.	20								+9	+[10]						
	Spatial planning of sea areas is required by law.	21									+[10]						
	A properly staffed and properly funded partnership of coastal and marine stakeholders is in place.	22															
	ICZM partnerships are consulted routinely about proposals to do with the coastal zone.	23															
	Adequate mechanisms are in place to allow coastal communities to take a participative role in ICZM decisions.	24															
IV. An efficient, adaptive and integrative process is embedded at all levels of governance and is delivering greater sustainable use of the coast	There is strong, constant and effective political support for the ICZM process.	25		+[42]	-[43]	+[44]	-[34]										
	There is routine (rather than occasional) cooperation across coastal and marine boundaries.	26															
	A comprehensive set of coastal and marine indicators is being used to assess progress towards a more sustainable situation.	27				+[45]						+[46]					
	A long-term financial commitment is in place for the implementation of ICZM.	28			+[15]												
	End users have access to as much information of sufficient quality as they need to make timely, coherent and	29															

LEGEND: Not Attained (red) · Partially Attained (yellow) · Attained (green)

	COUNTRY	GEORGIA (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	**ACTION**	**#**	**NATIONAL**					**SUB-NATIONAL**					**LOCAL**				
		well-crafted decisions.																
		Mechanisms for reviewing and evaluating progress in implementing ICZM are embedded in governance.	30															
		Monitoring shows a demonstrable trend towards a more sustainable use of coastal and marine resources.	31									+[47]	-[48]					

Endnotes GEORGIA (BLACK Sea):

Annex 2 Colour coded ICZM progress indicators for the Black Sea Region Countries

Annual Operational BSC Reporting Date: 2016.09.07

Latest Ministerial 2008.04.08

COUNTRY	ROMANIA (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
I. Aspects of coastal planning & management are in place	Decisions about planning and managing the coast are governed by general legal instruments.	01			+[1]												
	Sectoral stakeholders meet on an ad hoc basis to discuss specific coastal and marine issues.	02				+[2]											
	There are spatial development plans which include the coastal zone but do not treat it as a distinct and separate entity.	03				+[3]											
	Aspects of the coastal zone, including marine areas, are regularly monitored.	04				+[4]										+4	
	Planning on the coast includes the statutory protection of natural areas.	05				+[5]											
II. A framework exists for taking ICZM forward	Existing instruments are being adapted and combined to deal with coastal planning and management issues.	06															
	Adequate funding is usually available for undertaking actions on the coast.	07			+[6]	+[7]	+[8]										
	A stocktake of the coast (identifying who does what, where and how) has been carried out.	08					+[9]										
	There is a formal mechanism whereby stakeholders meet regularly to discuss a range of coastal and marine issues.	09				+[10]											
	Ad hoc actions on the coast are being carried out that include recognisable elements of ICZM.	10															

	COUNTRY	ROMANIA (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
		A sustainable development strategy which includes specific references to coasts and seas is in place.	11				+[11]											
		Guidelines have been produced by national, regional or local governments advising planning authorities on appropriate uses of CZ.	12															
Downgrade	III. Most aspects of an ICZM approach to planning and managing the coast are in place and functioning reasonably well	All relevant parties concerned in the ICZM decision-making process have been identified and are involved.	13				+[12]											
		A report on the State of the Coast has been written with the intention of repeating the exercise every five or ten years.	14															
		There is a statutory coastal zone management plan.	15					-[13]										
-		Strategic Environmental Assessments are used commonly to examine policies, strategies and plans for the coastal zone.	16				+[14]											
Upgrade		A non-statutory coastal zone management strategy has been drawn up and an action plan is being implemented.	17															
		There are open channels of communication between those responsible for the coast at all levels of government.	18				+[15]											
+		Each administrative level has at least one member of staff whose sole responsibility is ICZM.	19				+[16]										+[16]	

Annex 2 Colour coded ICZM progress indicators for the Black Sea Region Countries

COUNTRY	ROMANIA (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
PHASE	**ACTION**	**#**	**NATIONAL**					**SUB-NATIONAL**					**LOCAL**				
	Statutory development plans span the interface between land and sea.	20															
	Spatial planning of sea areas is required by law.	21															
	A properly staffed and properly funded partnership of coastal and marine stakeholders is in place.	22															
	ICZM partnerships are consulted routinely about proposals to do with the coastal zone.	23															
	Adequate mechanisms are in place to allow coastal communities to take a participative role in ICZM decisions.	24				+[17]											
IV. An efficient, adaptive and integrative process is embedded at all levels of governance and is delivering greater sustainable use of the coast	There is strong, constant and effective political support for the ICZM process.	25															
	There is routine (rather than occasional) cooperation across coastal and marine boundaries.	26															
	A comprehensive set of coastal and marine indicators is being used to assess progress towards a more sustainable situation.	27															
	A long-term financial commitment is in place for the implementation of ICZM.	28															
	End users have access to as much information of sufficient quality as they need to make timely, coherent and well-crafted decisions.	29															

LEGEND: Not Attained | Partially Attained | Attained

COUNTRY	ROMANIA (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
	Mechanisms for reviewing and evaluating progress in implementing ICZM are embedded in governance.	30															
	Monitoring shows a demonstrable trend towards a more sustainable use of coastal and marine resources.	31															

Endnotes ROMANIA (BLACK Sea):

Latest Ministerial 2008.04.08 Annual Operational BSC Reporting Date: 2016.09.07

COUNTRY	RUSSIAN Federation (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
PHASE	**ACTION**	**#**	**NATIONAL**					**SUB-NATIONAL**					**LOCAL**				
I. Aspects of coastal planning & management are in place	Decisions about planning and managing the coast are governed by general legal instruments.	01		+[1]	+[2]	+[3]											
	Sectoral stakeholders meet on an ad hoc basis to discuss specific coastal and marine issues.	02			+[4]							+[5]					
	There are spatial development plans which include the coastal zone but do not treat it as a distinct and separate entity.	03					+[6]									+[7]	+[8]
	Aspects of the coastal zone, including marine areas, are regularly monitored.	04								+[9]							
	Planning on the coast includes the statutory protection of natural areas.	05					+[10]										
II. A framework exists for taking ICZM forward	Existing instruments are being adapted and combined to deal with coastal planning and management issues.	06					+6					+6					
	Adequate funding is usually available for undertaking actions on the coast.	07									+[11]						
	A stocktake of the coast (identifying who does what, where and how) has been carried out.	08															
	There is a formal mechanism whereby stakeholders meet regularly to discuss a range of coastal and marine issues.	09															
	Ad hoc actions on the coast are being carried out that include recognisable	10															

	COUNTRY	RUSSIAN Federation (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
		elements of ICZM.																
		A sustainable development strategy which includes specific references to coasts and seas is in place.	11															
		Guidelines have been produced by national, regional or local governments advising planning authorities on appropriate uses of CZ.	12															
Downgrade	III. Most aspects of an ICZM approach to planning and managing the coast are in place and functioning reasonably well	All relevant parties concerned in the ICZM decision-making process have been identified and are involved.	13															
		A report on the State of the Coast has been written with the intention of repeating the exercise every five or ten years.	14							+[12]								
		There is a statutory coastal zone management plan.	15										+[13]					
-		Strategic Environmental Assessments are used commonly to examine policies, strategies and plans for the coastal zone.	16															
Upgrade		A non-statutory coastal zone management strategy has been drawn up and an action plan is being implemented.	17															
		There are open channels of communication between those responsible for the coast at all levels of government.	18															
+		Each administrative level has at least one member of	19										+[14]					

Annex 2 Colour coded ICZM progress indicators for the Black Sea Region Countries

COUNTRY	RUSSIAN Federation (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
	staff whose sole responsibility is ICZM.																
	Statutory development plans span the interface between land and sea.	20		+1					+1								
	Spatial planning of sea areas is required by law.	21															
	A properly staffed and properly funded partnership of coastal and marine stakeholders is in place.	22															
	ICZM partnerships are consulted routinely about proposals to do with the coastal zone.	23															
	Adequate mechanisms are in place to allow coastal communities to take a participative role in ICZM decisions.	24														+15	
IV. An efficient, adaptive and integrative process is embedded at all levels of governance and is delivering greater sustainable use of the coast	There is strong, constant and effective political support for the ICZM process.	25															
	There is routine (rather than occasional) cooperation across coastal and marine boundaries.	26															
	A comprehensive set of coastal and marine indicators is being used to assess progress towards a more sustainable situation.	27															
	A long-term financial commitment is in place for the implementation of ICZM.	28															
	End users have access to as much information of sufficient quality as they need to make timely,	29		+16													

LEGEND: Not Attained, Partially Attained, Attained

	COUNTRY	RUSSIAN Federation (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	**ACTION**	**#**	**NATIONAL**					**SUB-NATIONAL**					**LOCAL**				
		coherent and well-crafted decisions.																
		Mechanisms for reviewing and evaluating progress in implementing ICZM are embedded in governance.	30															
		Monitoring shows a demonstrable trend towards a more sustainable use of coastal and marine resources.	31															

Endnotes RUSSIAN FEDERATION (BLACK Sea):

	COUNTRY	TURKEY (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
Annual Operational BSC Reporting Date: 2016.09.07	I. Aspects of coastal planning & management are in place	Decisions about planning and managing the coast are governed by general legal instruments.	01					+[1]										+1
		Sectoral stakeholders meet on an ad hoc basis to discuss specific coastal and marine issues.	02					+[2]										
		There are spatial development plans which include the coastal zone but do not treat it as a distinct and separate entity.	03									+[3]					+3	
		Aspects of the coastal zone, including marine areas, are regularly monitored.	04				+[4]	4									+4	4
		Planning on the coast includes the statutory protection of natural areas.	05	+[5]														
Latest Ministerial 2008.04.08	II. A framework exists for taking ICZM forward	Existing instruments are being adapted and combined to deal with coastal planning and management issues.	06					6				+[7]						
		Adequate funding is usually available for undertaking actions on the coast.	07				+[8]											
		A stocktake of the coast (identifying who does what, where and how) has been carried out.	08				+[9]											
		There is a formal mechanism whereby stakeholders meet regularly to discuss a range of coastal and marine issues.	09									10	+[11]					

	COUNTRY	TURKEY (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
		Ad hoc actions on the coast are being carried out that include recognisable elements of ICZM.	10										+[12]					
		A sustainable development strategy which includes specific references to coasts and seas is in place.	11					[13]										
		Guidelines have been produced by national, regional or local governments advising planning authorities on appropriate uses of CZ.	12									+[14]						
Downgrade	III. Most aspects of an ICZM approach to planning and managing the coast are in place and functioning reasonably well	All relevant parties concerned in the ICZM decision-making process have been identified and are involved.	13									+[15]						
		A report on the State of the Coast has been written with the intention of repeating the exercise every five or ten years.	14									+[16]						
		There is a statutory coastal zone management plan.	15									+[17]						
-		Strategic Environmental Assessments are used commonly to examine policies, strategies and plans for the coastal zone.	16					[18]										
Upgrade		A non-statutory coastal zone management strategy has been drawn up and an action	17															

	COUNTRY	TURKEY (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	**NATIONAL**					**SUB-NATIONAL**					**LOCAL**				
		plan is being implemented.																
		There are open channels of communication between those responsible for the coast at all levels of government.	18															
+		Each administrative level has at least one member of staff whose sole responsibility is ICZM.	19															
		Statutory development plans span the interface between land and sea.	20															
Attained		Spatial planning of sea areas is required by law.	21															
		A properly staffed and properly funded partnership of coastal and marine stakeholders is in place.	22															
		ICZM partnerships are consulted routinely about proposals to do with the coastal zone.	23															
Partially Attained		Adequate mechanisms are in place to allow coastal communities to take a participative role in ICZM decisions.	24															
	IV. An efficient, adaptive and integrative process is embedded at all levels of	There is strong, constant and effective political support for the ICZM process.	25				+19											
Not Attained		There is routine (rather than occasional) cooperation across coastal and marine boundaries.	26															

	COUNTRY	TURKEY (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	**NATIONAL**					**SUB-NATIONAL**					**LOCAL**				
		A comprehensive set of coastal and marine indicators is being used to assess progress towards a more sustainable situation.	27															
		A long-term financial commitment is in place for the implementation of ICZM.	28															
		End users have access to as much information of sufficient quality as they need to make timely, coherent and well-crafted decisions.	29															
		Mechanisms for reviewing and evaluating progress in implementing ICZM are embedded in governance.	30									+[20]						
LEGEND:		Monitoring shows a demonstrable trend towards a more sustainable use of coastal and marine resources.	31															

Endnotes TURKEY (BLACK Sea):

Annual Operational BSC Reporting Date: 2016.09.07

Latest 2008.04.08

COUNTRY	UKRAINE (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
I. Aspects of coastal planning & management are in place	Decisions about planning and managing the coast are governed by general legal instruments.	01			+clvii	+clviii	+clix				+clx			+clxi		+clxii	
	Sectoral stakeholders meet on an ad hoc basis to discuss specific coastal and marine issues.	02															
	There are spatial development plans which include the coastal zone but do not treat it as a distinct and separate entity.	03															
	Aspects of the coastal zone, including marine areas, are regularly monitored.	04															
	Planning on the coast includes the statutory protection of natural areas.	05	+clxiii	+clxiv	+clxv												
II. A framework exists for taking ICZM forward	Existing instruments are being adapted and combined to deal with coastal planning and management issues.	06			+clxvi												
	Adequate funding is usually available for undertaking actions on the coast.	07															
	A stocktake of the coast (identifying who does what, where and how) has been carried out.	08									+clxvii						
	There is a formal mechanism whereby stakeholders meet regularly to discuss a range of	09			+clxviii											+clxix	

	COUNTRY	UKRAINE (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
		coastal and marine issues.																
		Ad hoc actions on the coast are being carried out that include recognisable elements of ICZM.	10														+clxx	
		A sustainable development strategy which includes specific references to coasts and seas is in place.	11														+clxxi	
		Guidelines have been produced by national, regional or local governments advising planning authorities on appropriate uses of CZ.	12					+clxxii										
Downgrade	III. Most aspects of an ICZM approach to planning and managing the coast are in place and functioning reasonably well	All relevant parties concerned in the ICZM decision-making process have been identified and are involved.	13															
		A report on the State of the Coast has been written with the intention of repeating the exercise every five or ten years.	14			+clxxiii										+clxxiv		
		There is a statutory coastal zone management plan.	15															
-		Strategic Environmental Assessments are used commonly to examine policies, strategies and plans for the coastal zone.	16					-clxxv								+clxxvi		
Upgrade		A non-statutory coastal zone management strategy has	17															

	COUNTRY	UKRAINE (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
		been drawn up and an action plan is being implemented.																
		There are open channels of communication between those responsible for the coast at all levels of government.	18															
+		Each administrative level has at least one member of staff whose sole responsibility is ICZM.	19															
Attained		Statutory development plans span the interface between land and sea.	20															
		Spatial planning of sea areas is required by law.	21															
		A properly staffed and properly funded partnership of coastal and marine stakeholders is in place.	22				+clxxvii											
Partially Attained		ICZM partnerships are consulted routinely about proposals to do with the coastal zone.	23															
		Adequate mechanisms are in place to allow coastal communities to take a participative role in ICZM decisions.	24															
	IV. An efficient, adaptive and integrative process is	There is strong, constant and effective political support for the ICZM process.	25		+clxxviii													
Not		There is routine (rather than occasional) cooperation	26															

	COUNTRY	UKRAINE (BLACK Sea)	YEAR	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016	1993	1996	2002	2009	2016
	PHASE	ACTION	#	NATIONAL					SUB-NATIONAL					LOCAL				
		across coastal and marine boundaries.																
		A comprehensive set of coastal and marine indicators is being used to assess progress towards a more sustainable situation.	27															
		A long-term financial commitment is in place for the implementation of ICZM.	28															
		End users have access to as much information of sufficient quality as they need to make timely, coherent and well-crafted decisions.	29															
		Mechanisms for reviewing and evaluating progress in implementing ICZM are embedded in governance.	30															
LEGEND:		Monitoring shows a demonstrable trend towards a more sustainable use of coastal and marine resources.	31															

Endnotes UKRAINE (BLACK Sea):

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[1] Funding in support of regional ICZM efforts provided by EU (1995, TACIS ICZM Project) and some funding by UNDP/GEF.

[2] Funding in support of regional ICZM efforts provided by EU (1998, TACIS ICZM Project, 2002, EU ICZM project).

[3] 2006: Control of eutrophication, hazardous substances and related measures for rehabilitating the Black Sea ecosystem: Phase 2, funded by UNDP/GEF resulting in the development of

Vessel Traffic Oil Pollution Information System (VTOPIS), used for early warning and control of the oil spills in the coastal zone, coastal waters, and territorial sea.

2006: Regional Project “Plan Coast” (http://www.plancoast.eu) aimed at developing good practices and instruments for Integrated Coastal Zone Management. The project deliverable is a “Handbook on Integrated Maritime Spatial Planning”.

2007: SPICOSA, an EU integrated project, aimed to create a self-evolving, operational research approach framework for the assessment of policy options for the sustainable management of coastal zone systems.

2008: EU funded ECBSea project ICZM component provides certain minor resources for pilot activities.

[4] **EC funded FP7 Pegaso Project provides resources for Black Sea CASES in Sevastopol Bay (UA), Danube Delta (RO) and Guria Region (GE).**

[5] Countries prepared National ICZM Reports in 1996.

RAC prepared Black Sea Regional ICZM Report.

[6] **National ICZM Stock-Taking questionnaires filled within EC FP7 Pegaso Project. All countries have completed stock-taking questionnaires (2010), 5 counties updated (2012). Regional synthesis report completed. ICZM Stock-Taking survey tool up & running and is available online at IASON Knowledge Base.**

[7] Regional ICZM Advisory Group to the Black Sea Commission established since 2002 and meets regularly.

[8] **Regular Black Sea Stakeholder Conference promoting IMP established by EC/DG MARE (held on 2014 in Bucharest, Romania; in 2015 Sofia, Bulgaria; in 2016 Odessa, Ukraine)**.

[9] Pilot Projects implemented in RU (2003), UA (2003), TR (2006) and GE (2009).

[10] **EC funded FP7 Pegaso Project provides certain resources for ICZM in the Black Sea region.**

[11] Guidelines for marine protected areas produced for the Black Sea with EC EuropeAid ECBSea project support.

[12] **Preparation of ICZM Guideline for the Black Sea completed under PEGASO project. Draft ICZM Guideline, endorsed by members of the ICZM AG, was proposed for adoption during the 31st Regular Meeting of BSC in September, 2015. Revised draft was produced and finally the 'Guideline on Integrated Coastal Zone Management in the Black Sea Region' was endorsed by The Commission on the Protection of the Black Sea Against Pollution on its 32nd Regular Meeting of 12-13 October 2016 in Istanbul, Turkey.**

[13] National ICZM Policies and Strategies documents prepared by countries in 1997.

[14] Regional ICZM Strategy prepared by RAC in 2004.

[15] **Regional and national ICZM policies and strategies implemented with limited scope.**

[16] ICZM National Focal Points designated in each Black Sea country since 1994.

[17] EU adopted MSP directive (covering Bulgaria and Romania), but ICM was excluded.

[18] ICZM Regional Activity Centre (RAC) established in Krasnodar, RU.

[19] ICZM Regional Activity Centre ceased functioning in RU.

[20] Bucharest Convention signed/ratified (1992). Odessa Declaration (1993) issued with some provisions for ICZM.

[21] Black Sea Strategic Action Plan (1996) signed with some provisions for ICZM.

[22] Updated Black Sea Strategic Action Plan (2009) with certain provisions for ICZM signed by all countries.

[23] Annual national reports are being prepared for the Black Sea Commission. ICZM progress indicator tool was adopted as well and regular national reporting initiated. State of the coastal zone indicator collection initiated and tested by some BS countries (Georgia, Romania, Ukraine).

[1] 2013: Clean Rivers - Clean Sea - establishment of national focus groups, with a focus on the sources of water pollution and stakeholders' involvement in the water management processes.

2015: The Black Sea NGO network organized a stakeholder meeting under the project "Reduction of litter in the marine and coastal environment and sustainable use of natural resources — Marine Litter Watch — EEA Financial Mechanism".

2016: Project TEN ECOPORT aims at developing a permanent discussion platform among stakeholders for sustainable development of the marine transport corridors in the South-Eastern European Seas (http://www.tenecoport.eu).

[2] 2003: Yearly meetings of the River Basin Councils taking place since 2003 involve all the stakeholders, whose activities affect water resources in the Black Sea River Basin Management district.

[3] 2009: Development and adoption of National Strategy for Sustainable Development of the Tourism in Bulgaria and a National Strategic Plan for the Development of the Cultural Tourism, outlining the coastal tourism as a leading sector.

[4] 2015: National programme for prevention and limitation of the landslides on the territory of the Republic of Bulgaria, the coastal erosion and abrasion along the Danube and the Black Sea coast in 2015-2020.

[5] 2007: Municipal plans for development (2007-2013) for the 16 coastal municipalities (LAU 1 and LAU2).

[6] 2009: First "River Basin Management Plan" of the Bulgarian Black Sea coastal waters is developed, according to the requirements of the Water Framework Directive (Directive

2000/60/EC). The River Basin Management Plan is a complex instrument for implementation of some principles of the ICZM regarding the surface waters and groundwater in the coastal zone.

[7] **2013: In 2013 are updated the District Strategies for the development of the three coastal districts Dobrich, Varna and Burgas (NUTS 3). The strategies of the Burgas and Varna districts outline measures for addressing the landslides and coastal erosion along the coast.**

2015: Updating of the River Basin Management Plan of the Bulgarian Black Sea River Basin districts takes place in 2015, according to the requirements of the Water Act and the Directive 2000/60/EC.

[8] 2010: The master plans of the coastal municipalities Shabla, Avren, Primorsko, Sozopol, Pomorie and Tsarevo are updated in the period 2006-2010.

[9] 2007: Since 2007 the Executive agency “Maritime Administration” (EAMA) develops and maintains information systems: (1) Vessel Traffic Management Information Systems (VTMIS) (http://www.vtexplorer.com) and (2) Vessel Traffic Oil Pollution Information System (VTOPIS) (http://www.astrapaging.com/vtopis).

[10] **2015: The national monitoring programme of coastal waters under the Water Act and the Water Framework Directive not taking place in 2015 leading to loss of data on the state and the distance from achieving GES.**

2014: Five research and administrative capacity building projects are taking place aimed at filling in the monitoring gaps and develop programs of measures in Bulgaria and jointly between Bulgaria and Romania in 2015.

[11] **2011, 2013, 2015: Annual monitoring of the environmental status of the marine coastal waters since 2012 onwards to fulfil the requirements of the European water legislation (WFD, Marine Strategy Framework Directive and the relevant national legislation (the Water Act and the Regulation of the environmental protection of the marine waters)). The monitoring programme provides information on the driving forces, pressure, state and impact of the human activities on the inland surface waters (rivers, lakes) and groundwater in the coastal zone and the coastal marine waters and provides information on some aspects of the ICZM – marine litter, coastal structures, coastal biodiversity, pollution, etc., in a comprehensive manner, i.e. within the Driver-Pressure-State-Impact-Response (DPSIR) framework.**

[12] 2002: The Bulgarian Act for the Protection of Biodiversity establishes on-shore and off-shore NATURA 2000 zones with restrictions against any type of construction and economic development.

[13] **2012: The “Black Sea Seabirds Project” started the designation of Important Bird Areas in the Black Sea.**

[14] 2006: Bulgarian-Dutch project MyCOAST (EVD/PPA06/BG/7/3) aims at developing a vision and a strategy for integrated management of the Bulgarian coast.

[15] The annual report on the ICZM activities is prepared each year by the National Focal Point for Bulgaria in the Advisory Group on ICZM, refers to institutions but there is no special national coastal inventory of institutions.

[16] National stock-taking initiated, completed in 2011 and updated in 2012 with support of the EC funded FP7 project PEGASO.

[17] 2003: The Basin Council to the Black Sea River Basin Directorate was established in September 2003 as a collective body whose main task was to assist the Director in the process of formulating the Black Sea River Basin Management Plan (http://www.bsbd.org/v2/bg/BSPLAN2009.html).

[18] 2013: Project CleanSea (http://www.cleansea-project.eu) addressing problems with marine litter.

2013: Project "Integrated hotspots management and saving the living Black Sea ecosystem" aims to optimize and/or increase resources to regulatory and enforcement bodies responsible for pollution control and improve capacity through targeted training programmes.

[19] 2007: Project under the programme "Third maritime safety package" to support the work of the Bulgarian administration with the European institutions when addressing the problems of maritime safety and protection of the marine environment.

2008: Project MICORE (Morphological Impacts and Coastal Risks Induced by Extreme Storm Events) with the Institute of Oceanology-Bulgarian Academy of Sciences (IO-BAS) as Bulgarian partner.

2008: The state companies' hazard protection are equipped with a software to create a "Register of the landslides in the Republic of Bulgaria". Also, Ministry of Transport and Communications is a partner in the "International Network for Promotion of water and land multimodal transport" - WATERMODE.

2009: Bulgaria-Finland joint project for capacity building to prevent the oil and contaminants pollution from shipping in the Black Sea with the participation of Execute Agency "Maritime Administration".

[20] 2011: Tow projects started in 2009 with the participation of the Institute of Oceanology – BAS, as a Bulgarian partner: (1) THESEUS (Innovative technologies for safer European coasts in a changing climate) aimed at developing a systematic approach to deliver both a low-risk coast for human use and healthy coastal habitats for evolving coastal zones subjected to multiple factors; (2) Project "Dynamics of sea level in the western part of the Black Sea. Forecasts and impacts the characteristics of ecosystems; (3) "Innovative technologies for wind and wave energy utilization in the coastal zone" – INWECO. Project ДРНФ 02/7 15.12.2009.

2012: The research project IRIS-SES (2012-2015) ,with Bulgarian partner IO-BAS, aims to support management of human activities and their effects in EU waters by providing tools for integrated MSFD and other environmental legislation in selected regions and based on existing sampling across various disciplines.

2013: EU IASON project initiated with Bulgarian partner (IO-BAS) to uptake PEGASO and enviroGRIDS results.

2013: MARELITT project (http://www.marelitt.eu) with a Bulgarian NGO partner, which aim is cleaning the marine litter in the European seas.

[21] 2005: Bulgarian-Dutch project for improved management of the waste resulting from shipping and the residues of shipping cargo in the Bulgarian ports.

[22] 2008: Pilot project (BG2004/016-919.05.01.01.020, within the framework of the “Plan Coast” - Interreg III-B) takes place in 2008. Spatial planning of the Varna coastal zone from cape Ekrene to cape Paletsa, according to the Bulgarian legislation and in accordance with the principles of the ICZM.

2009: Pilot project "Efficient policies for the regional development of the South-eastern region", created by the Burgas municipality in 2010, aimed at supporting the partnership between the four district administrations in the south-eastern planning region.

[23] 2009: A draft National Strategy for Environmental Protection (2009-2018) has been developed including as a priority objective "integrated management of water resources and coastal areas in the Black Sea Basin, based on the ecosystem approach".

[24] 2012: National Strategy for the Regional Development of the Republic of Bulgaria (2012-2022) is adopted in 2012.

[25] 2015: A draft National Marine Strategy is under discussion.

[26] 2008: Regional plans for the development of the Northeastern and Southeastern level 2 regions for the period 2007-2013 are adopted. The plans are based on the Regional Development Act from 2004 and the National Strategy for Regional Development (2005-2015). The two plans are based on the principles of sustainable regional development and integrated territorial management, including the integrated management of the Black Sea coastal areas.

[27] 2013: Regional plans for the development of the Northeastern and Southeastern level 2 regions for the period 2014-2020 are adopted.

[28] 2007: Black Sea Coast Development Act (State Gazette No. 48/15.06.2007).

2008: There is a legislative setback zone, where the construction is not allowed (Law for the Black Sea Coast adopted on 1 Jan 2008, last updated 20 Nov 2009). In zone A (100 m from the sea coast), any construction on the beaches is banned, whereas, it is allowed in the coast strip of 100 m, outside the beaches. In Zone B (2 km from the border of Zone A), construction is legally allowed although potential investment proposals have to comply with numerous environmental and sanitary restrictions.

[29] 2014: Directive 2014/89/EU establishing a framework for maritime spatial planning. The Directive should be transposed in the Bulgarian legislation by 18.09.2016.

[30] 2010: A Consultative and Coordinating Council for the Protection of the Environment in Marine Waters of the Black Sea and Management of the Implementation of the Marine Strategy and Action Programme was established with a Ministerial Order No. 273, adopted on the 23rd of November, 2010.

[31] 2008: The Black Sea River Basin Management Plan was subject to public discussion and public hearings for more than two years before it was adopted at the beginning of 2010.

[32] 2010: Spatial Data Access Act (State Gazette No. 19/9.03.2010).

[1] Draft ICZM legislation prepared but not under formal consultation yet.

[2] **Adoption of ICZM legislation not included in EU-GE Association Agreement roadmap.**

Kolkheti National Park (KNP) legislation enacted in 1999 (but not yet enforced in its entirety).

[4] Shoreline management strips delimited (and approved); General Scheme for the Black Sea Coast of Georgia developed (but not approved yet).

[5] ICZM State Consultative Commission established by Presidential Decree (but irregular meetings; no decision-making power).

[6] ICZM State Consultative Commission abolished (ICZM Working Group reactivated, but still at inception stage).

[7] **IMP feasibility stakeholder meetings held in Tbilisi and Poti (2015.02.24-25).**

[8] Kolkheti National Park (KNP) Advisory Council established in 2005 (irregular meetings; no decision-making power, only advisory and consultative role).

[9] Preparation of the statutory KNP management plan initiated with substantial spatial planning/zoning component (¼ of Georgian CZ).

[10] Kolkheti Protected Areas (KPA) (KNP and Kobuleti Nature Reserve/KNR) management plans approved by the Ministry of Environment.

[11] Local zoning plans prepared for several coastal settlements but not yet approved statutorily (Kobuleti, Batumi, Poti).

[12] Development of Poti and Batumi land use plan (with USAID G3 project support). Ureki land use plan approved but without ICZM principles. Ureki-Shekvetili spatial scheme under development.

[13] Integrated Plan for Tskaltsminda Coastal Community approved by Lanchkhuti local municipality. Plan highlights the need to maintain natural habitats.

[14] Essential provisions of the Integrated Plan for Tskaltsminda Coastal Community violated by approval of port development in the mouth of the River Supsa.

[15] WB/GEF funded Georgia ICM Project (GICMP) appraised (1999) and implementation completed (2007).

[16] National stock-taking in need of updating due to changes in the governance systems.

[17] GICMP included component for Kolkheti wetlands establishment and management which can be considered as a regional initiative.

[18] **EC funded FP7 project PEGASO provides minor resources for CASES in Georgia (Guria Coastal Region). FP7 enviroGRIDS provides synergy with watershed modelling application case study in the same region. ILMM-BSE project with EU funding provides complementary support for Guria land use modelling.**

[19] Small community grant scheme was developed and international funding secured for 30 communities around the Kolkheti protected areas.

[20] EU funded project ICZM component provides certain minor resources for the local ICZM pilot project (Tskaltsminda).

[21] National ICZM Report prepared in 1996.

[22] ICZM component of GICMP undertook socio-economic assessment and other stocktaking tasks for Georgia's coastal zone management.

[23] National stock-taking in need of updating due to changes in the governance systems.

[24] **National stock-taking initiated, completed in 2011 and updated in 2012 with support of the EC funded FP7 project PEGASO.**

[25] KNP stakeholder analysis undertaken.

[26] **EU IASON project initiated with Georgian partner to uptake PEGASO and enviroGRIDS results.**

[27] ICZM Demonstration projects implemented in Kobuleti (combining community development, beach management and coastal/wetland interpretation).

[28] National ICZM Policies and Strategies document prepared, certain strategic actions implemented but others remain pending.

[29] ICZM Policy note and ICZM Work Program prepared and submitted for consideration of high level decision-makers.

[30] ICZM Guidelines prepared and endorsed by the Minister of Environment but implementation is at early stage of development.

[31] Kolkheti Wetlands management planning guidelines produced and implemented (Georgia joined Ramsar Convention, established KNP).

[32] National ICZM Policies and Strategies documents prepared by Georgia and all other Black Sea countries, as well as Regional ICZM Strategy by RAC.

[33] ICZM Strategy submitted by Ministry of Environment Protection and Natural Resources to interagency consultation and approval by Government of Georgia.

[34] **ICZM Strategy successfully passed through interagency consultation, but submission for approval to Government of Georgia delayed and pending, kept on halt due to insufficient administrative capacity (personal communication, Deputy Minister of MoE). Adoption of ICZM Strategy included in EU-GE Association Agreement roadmap.**

[35] ICZM webpage is up and running and maintained regularly at the national level.

[36] National ICZM Focal Point designated.

[37] ICZM Centre established in charge of implementing GICMP project.

[38] ICZM Centre dissolved. National ICZM Focal Point remains designated. Reportedly Monitoring and Prognosis Centre has ICZM staff with certain experience.

[39] Adjara Department of Natural Resources designated ICZM personnel, functions are yet limited. KNP administration could be considered as in charge of Kolkheti coast.

[40] CASE Coordinator selected and is in charge of implementation in Guria Coastal Region.

[41] Georgia CASES Coordinator elected as the Chairman of Lanchkhuti Municipal Council.

[42] Regional Black Sea Strategic Action Plan (1996) signed; Georgia joined Ramsar Convention and designated Kolkheti wetlands; Georgia ICZM Program initiated.

[43] Due to certain coastal developments and changes in the Government's policy directions support to integrated management approaches dwindled and remains subdued.

[44] Updated Regional Black Sea Strategic Action Plan (2009) signed by Georgia.

[45] Annual national reports are being prepared for Black Sea Commission. ICZM progress indicator tool was adopted as well and national reporting initiated.

[46] State of coastal zone spatial indicator testing initiated for Guria region of Georgia.

[47] Despite several drawbacks Kolkheti protected areas are functioning and contributing to improved protection of coastal resources.

[48] Lazika city and/or infrastructure idea promoted by GoG, presumably in Kolkheti wetlands.

[1] Governmental Emergency Ordinance no. 202/2002 on ICZM approved with further modifications and amendments through the Law no. 280/2003.

[2] National Committee of Coastal Zone (NCCZ) has been established based on the provisions of the Governmental Emergency Ordinance no. 202/2002 on ICZM approved with further modifications and amendments through the Law no. 280/2003. In June 2004 the operational and functioning regulation has been set up through the Government Decision 1015/2004. The Secretary of State for Water of the Ministry of Environment, chairs the committee in which approximately 40 central, local and regional authorities, institutions and stakeholders (including NGOs) are represented. The National Institute for Marine Research and Development "Grigore Antipa" (NIMRD) is the technical secretary of the Committee. NCCZ has the following responsibilities:

- Endorsing the plans regarding ICZM and local and regional spatial planning;
- Endorsing the studies regarding environment impact of activities having an important impact in the coastal zone as well as the environment audit for the existing ones;
- Endorsing the projects regarding establishing of natural parks and reserves.

- NCCZ through its Permanent Technical Secretariat is empowered to inform the competent organizations about critical situations in the coastal zone which need rehabilitation actions and initiating of specific projects.

[3] Territorial Development Plans – the legal framework for carrying out the spatial and urban planning activities was completed in 2001 through the approval of Law nr. 350/2001 on Spatial Planning and Urban Planning. The spatial planning activity is carried out on the entire Romanian territory based on the principle of hierarchisation, cohesion and spatial integration at national, regional, county, city and commune level, creating the appropriate framework for balanced development and sound use of territory and accountable management of natural resources and environmental protection. There is no Development (local or urban) plan set up only for the coastal zone.

[4] Monitoring programme – NIRM Constanta, financed by Ministry of Environment (and Climate Change).

[5] According to the Governmental Emergency Ordinance regarding ICZM no. 202/2002 approved with further modifications and amendments by ICZM Law 280/2003, chapter IV, Section 2, provides: (art 52 para (1) For the purpose of ensuring the sustainable protection of the coastal zone, of the biological and landscape biodiversity, of species productivity and of maritime and terrestrial habitat, reserves or coastal or maritime parks (protected areas) should be established, according to the legislation.

[6] JICA Feasibility Study on Southern Romanian Black Sea shore (2005-2006) – Coastal Protection Plan for the period 2007-2020 and beyond. (Aim of the study: coastal protection plan and preliminary design of the priority projects on the southern area. Coastal Protection Plan is to provide a long term strategy on protection and rehabilitation of the Southern Romanian Black Sea shore).

[7] Besides JICA Feasibility Study, in July 2008 - first phase of the Black Sea Coastal Erosion Programme COASTEROSION, (USTDA - grant) covering in particular the northern part of the Romanian coastline. The programme focused on designing and implementing an integrated coastal zone management system that will help to determine potential structural and non-structural coastal erosion control measures. Activities on identification, assessment and specification of all components of the spatial data monitoring stations, GIS and communication technology for implementation of the ICZM.

[8] Master Plan “Protection and rehabilitation of the coastal zone” for the entire Romanian coast – as a Technical Assistance developed by Halcrow (2010-2012) within the Sectoral Operational Programme (SOP) Environment 2007-2013 including an Action Plan for Project Implementation. Based on this Master Plan, investments for rehabilitation and protection of the Romanian Black Sea shore are secured through EU funding. Aim of the project: long term sustainable and strategic approach to the management of risks relating to the coastal erosion for the entire Romanian coast. Master Plan establishes the priorities for the rehabilitation and improvement of the environment. The Master Plan include assessment of priorities for implementing both urgent and long term coastal rehabilitation and protection works and establishes an action plan to put both structural and non-structural measures in place to manage the erosion and reduce the consequences.

[9] **ICZM implementation audit (Stocktaking) completed by Romania in 2012 under FP7 PEGASO project.**

[10] National Committee of Coastal Zone (NCCZ) – meets when needed, for debating and approval of the relevant projects developed within the coastal zone (such as Master Plan for rehabilitation and protection of coastal zone, urbanistic development plans, studies, coastal works, etc.). NCCZ meetings are convened when there are documents to be discussed and agreed or decisions to be taken.

[11] In 2006 Romania has submitted to the European Commission an "Outline Strategy for the Integrated Management of the Romanian Coastal Zone". This draft was developed within the MATRA Project "Institutional strengthening for implementation of the Water Framework Directive and ICZM Recommendations along the Romanian Black Sea coast" Project MAT05/RM/9/3.

As it is still an outline draft, it can be foreseen that many technical problems / conflicts shall appear during its future implementation. The strategy hasn't been public debated and adopted yet.

[12] National Committee of Coastal Zone (NCCZ). Approximately 40 authorities, institutions and stakeholders (NGOs) are represented within the NCCZ, out of which, authorities for agriculture, health, transport, regional development, economy, research, education, tourism, defence, administration and interior, representatives of the Romanian Academy as well as local authorities representatives (mayors, county council representatives, etc.), authorities for water management, Danube Delta Biosphere Reserve, and public institutions.

[13] **According to the Government Emergency Ordinance nr. 202/2002 – on Integrated Coastal Zone Management, the Implementation tool of the ICZM Recommendation is the National Plan for Integrated Coastal Zone Management (ICZM). Elements of this National Plan have been drafted but there is no integrated plan yet.**

[14] According to the national legislation, the Strategic Environmental Assessment is developed base on the provisions of the Government Decision no. 1076/2004 for establishing a procedure for carrying out environmental assessment for plans and programs, transposing the SEA Directive 2001/42/EC.

Other Legal Instruments and Guiding documents:

- Order no. 995/2006 for approving the list with plans and programmes concerned by GD 1076/2004, including those within coastal zone
- Order no. 117/ 2006 for approving the SEA methodology Handbook
- SEA Handbook for cohesion policy 2007 - 2013

[15] Communication channels through the National Committee of Coastal Zone (NCCZ) ensuring dealing with coastal management issues both horizontally (between administrations at the same level) and vertically (between administrations at different levels), from municipalities to central public authorities, due to the competence of the NCCZ.

[16] Members of the National Committee of Coastal Zone have responsibilities for ICZM implementation.

[17] The National Committee of Coastal Zone (NCCZ) ensures the mechanism of public consultation and debate for relevant projects and developments on the coastal zone.

[1] 1995, Law on Medical Resources and Resorts of the Russian Federation approved.

[2] 2002, Law on Environmental Protection of the Russian Federation approved.

[3] 2004, Urban Planning Code of the Russian Federation approved.

2006, Water Code of the Russian Federation approved.

[4] 2003, Law on General Principles of Local Government in the Russian Federation.

[5] 2012, Public Environmental Council of the Governor of the Krasnodar Territory established.

[6] 2013, Guidelines for preparation of territorial plans for the subjects of the Russian Federation.

[7] 2009, Spatial Plan for Sochi approved.

[8] 2012, Spatial Plan for Gelendzhik approved.

2013, Spatial Plan for Anapa approved.

2014, Spatial Plan for Novorossiysk approved.

[9] In 2006-2008 Monitoring of the environmental state of the coastal zone was implemented by Research Institute of Applied Ecology (Krasnodar)

[10] 2014, Project on Coastal Strip developed (under approval).

[11] 2008, Krasnodar Region Law on Target Program “Financial Support of Krasnodar Region Municipalities on preparation of Spatial Plans for 2008-2010 years".

[12] 1996, Decision on Annual State of the Environment Report for the Krasnodar Region issued.

[13] 2013, Spatial Plan for the Krasnodar Region approved.

[14] 2010, Department of Spatial Planning, Development and Investment support of Azov and Black Sea Coastal Zone established.

[15] 2003, Law on General Principles of Local Government in the Russian Federation includes procedure of public hearings.

[16] 1995, Law on Ecological Expertise.

[1] Article 43 of Turkish Constitution, the Coastal Code and the By-Law: The main approach of Turkey is to ensure a balanced usage of the coastal zones while strictly protecting them.

1985: Zoning Law Numbered 3194: The basic principles and procedures regarding planning and construction processes in all urban and rural settlement areas are regulated by this Law.

1990: Coastal Law Numbered 3621: The implementations regarding planning and construction processes in coasts of sea, natural/artificial lake and rivers are regulated by this Law and its implementation legislation.

2011: Statutory Decree numbered 644: Ministry of Environment and Urbanism has been established by this Decree. In the statutory decree, Article 7 indicates that the Ministry is responsible for conducting the studies on integrated coastal zone management and planning.

2014: Regulation of Making Spatial Plans has been announced and conducted. This Regulation has defined the hierarchy among plans in Turkey in order to eliminate the conflict in the planning system. The Regulation has described the procedures of the Integrated Coastal Zone Plans in detail. These plans are not stated in the spatial planning hierarchy, these plans are prepared with a strategic approach for coastal areas and their hinterlands and guide the zoning plans.

In addition, within the municipal areas, municipalities are responsible for the land management except the specially defined areas such as protected areas, tourism areas, etc. In other areas, the Ministries or their representative Provincial Governorates are responsible.

[2] **Ministry of Environment and Urbanism, Ministry of Culture and Tourism, Ministry of Transport, Maritime Affairs and Communications, Ministry of Forestry and Water Affairs, Republic of Turkey Ministry of Food, Agriculture and Livestock, Ministry of Port Operators Association of Turkey (TURKLIM), Chamber of Shipping, Marine Tourism Association, Yacht Tourism Association, Mediterranean Coastal Foundation (MED-COAST), Underwater Research Association, The Scientific And Technological Research Council of Turkey, Turkish Coast Guard Command, Naval Forces Guard Command, Union of Chambers of Turkish Engineers and Architects, Port Authorities, etc. are important sectoral stakeholders that gather in order to discuss several coastal and marine issues.**

[3] 2007, Territorial Development Plans have been prepared since year 2007 by Ministry of Environment and Urbanism and Metropolitan Municipalities. Territorial plan is a macro scale plan at NUTS-2 or NUTS-3 Level, that determines land-use decisions such as settlements, housing, industry, agriculture, tourism, transportation in accordance with the national and regional plan decisions. These plans produce land use decisions as a basis for Land-use Plans and Implementation Plans. %97 of Turkey is covered with Territorial Plans.

[4] **By Statutory Decree numbered 644 (2011), Urban Wastewater Treatment (2009), Water Pollution Control Regulation (2004), since year 2004 integrated pollution monitoring task is done by The Scientific And Technological Research Council of Turkey (TUBITAK) with Ministry of Environment and Urbanism in Black Sea Region. In addition, some municipalities monitor the coastal and marine areas with different methodologies specific to region.**

[5] 1990: Coastal Law Numbered 3621: There is an article in the Turkish Coastal Code that does not allow construction on the shore (beaches, dunes, wetlands etc.) and in the first 50 meters of the adjacent shore band, which is protected. In the remaining part of the shore band (at least another 50 meters wide), construction of public infrastructure (like roads, treatment plants) and facilities supporting public use of the shore for recreation (like pubs, kiosks etc.) without accommodation units are allowed. Private constructions like houses are not allowed.

[6] **2013: Project of National Strategy and Action Plan for Integrated Coastal Zone Management has been completed by the end of June 2013 that develops the main strategies for the efficient use of coastal areas while minimizing the threats and constituting a framework for the preparation and implementation of Integrated Coastal Zone Plans. However, this plan has not been approved legally by the Ministry of Environment and Urbanism yet.**

[7] 2007: Turkish Government has been carrying out Integrated Coastal Zone Management and Planning studies since 2007. The "Integrated Coastal Zone Plans (ICZP)" covering approximately 35 percent of coastal areas of Turkey are planned to be completed by the end of year 2016, ICZP covering 75 percent of coastal provinces are planned to be completed by the end of year 2017. For Black Sea Region, only for Samsun Province ICZM Plan is in effect, besides Sinop Province ICZM Plan and Rize-Artvin Provinces ICZM Plan have been completed, but not in effect yet.

[8] 2007: Republic of Turkey Ministry of Development ensures the finance for developing Integrated Coastal Zone Plans since year 2007 according to Investment Programme announced each year in the Official Letter.

[9] For integrated coastal zone planning and management, there are defined different duties, authorities and responsibilities for several central government authorities. On the other hand, there doesn't exist a unit that gathers all the relevant stakeholders.

[10] 2007: Since year 2007, the Integrated Coastal Zone Plans have been prepared with participation of several central, regional and local stakeholders. However, this was not defined officially in legislation.

[11] **With Statutory Decree numbered 644 announced in year 2011 and with the Regulation of Making Spatial Plans announced in year 2014, the integrated coastal zone plans in which a governance mechanism is defined legally by the planning statements, have been defined in detail by legislation. On the other hand, there are some deficiencies in ensuring coordination among different stakeholders that should be developed in time in the planning process.**

[12] **2013: Project on Determining and Classifying Quality Levels of Sea and Coastal Waters has been completed in year 2013. Within this project, 16 coastal water management unit were established in the Black Sea Region.**

[13] **2013: Project of National Strategy and Action Plan for Integrated Coastal Zone Management has been completed by the end of June 2013 that develops the main strategies for the efficient use of coastal areas while minimizing the threats and constituting a framework for the preparation and implementation of Integrated Coastal Zone Plans. However, this plan has not been approved legally by the Ministry of Environment and Urbanism yet.**

[14] 2007: Turkish Government has been carrying out Integrated Coastal Zone Management and Planning studies since 2007. The "Integrated Coastal Zone Plans (ICZP)" covering approximately 35 percent of coastal areas of Turkey are planned to be completed by the end of year 2016, ICZP covering 75 percent of coastal provinces are planned to be completed by the end of year 2017. For Black Sea Region, only for Samsun Province ICZM Plan is in effect, besides Sinop Province ICZM Plan and Rize-Artvin Provinces ICZM Plan have been completed, but not in effect yet.

[15] In integrated coastal zone plans, several stakeholders with different duties, power and responsibilities, also the citizens, are involved both in the planning process and implementation process. However, these responsibilities are not defined with legislation, mostly depend on Plan Statements.

[16] The integrated coastal zone plans are generally revised every five years if there are changes in the sectoral policies, plans and strategies for the region.

17 2007: Turkish Government has been carrying out Integrated Coastal Zone Management and Planning studies since 2007.
2014: With Regulation of Making Spatial Plans, announced and conducted in year 2014, the procedures of the Integrated Coastal Zone Plans have been described in detail.

18 Strategic Environmental Assessment Regulation has been preparing but not finished and approved yet.

19 Integrated coastal zone plans are under the responsibility of Ministry of Environment and Urbanism and are developed according to the related legislation mentioned above.

20 For implementation and monitoring the integrated coastal zone plans, Coastal Consultation Unit is assumed to be established if it is recommended by the related Governorship according to the Plan Statements.

[clvii] Law on General Scheme of Planning of the Territory of Ukraine of 07.02.2002 p. N 3059-III.

Law "On the Planning and Using Territories for Building up" # 1699-III of 20.04.2000.

[clviii] Draft Law of Ukraine «On the marine coastal zone", 2004. Ministry of Environment of Ukraine – EU Black Sea Collaboration Project.

[clix] **Since January 1, 2011, the Law "On Amendments to the Land and Water Codes of Ukraine Regarding Coastal Protective Zones" (approved in 2010) has entered into force. The Law envisages establishment of beach zone within the coastal protective stripe (not less than 2 km wide landward).**

Law "On regulation of Urban Construction Activity" (#3038-VI of 17.02.2011).

Regulation (restrictions) of human activities (including urban development) on coastal zone in resort areas are described in Law on Resorts of Ukraine #2026-III of 05.10.2000

[clx]State Strategy of Regional Development of Ukraine till 2015. Ordinance of the Cabinet of Ministers of Ukraine of 21.07.2006 p. N 1001.

[clxi] Ordinance of the Cabinet of Ministers of Ukraine "On the Approval of Procedures of Determination of the Size and Borders of Water Protective Zones and Regime of Economic Activities on these Zones" # 486 of 08.05.1996).

[clxii] State Administration of Odessa region has approved decision #70/A-2006 of 13.02.2006 "Measures aimed at setting up the borders of coastal protective zones". However, these decisions are being implemented only for restricted parts of coastal zone.

[clxiii] Law of Ukraine "On Natural Reserve Fund" # 2456-XII of 16.06.1992 (includes, inter alia, Regulations of the protection and use of wetlands of first type).

[clxiv] Water Code of Ukraine, 06.06.1995 p. № 213/95-BP, Land Code of Ukraine of 25.10.2001 p. № 2768-III (Law restricts or prohibits activities in beach zones along the sea however makes exclusion for hydro technological, hydrometrical and linear objects construction and related activities (Water Code, Article 90; Land Code, Article 62)).

[clxv] Law of Ukraine "On the Approval of the State Program of Protection and Rehabilitation of the Environment of the Black and Azov Seas", #2333-III of 22.03.2001.

Law on the State Program of Ukraine's National Environmental Network Development for years 2000-2015 of 21.09.2000 p. № 1989-III.

[clxvi] Law of Ukraine "On the Approval of the State Program of Protection and Rehabilitation of the Environment of the Black and Azov Seas" (#2333-III of 22.03.2001) includes special section of the Program "Establishment of the System of Integrated Natural Resources Use in the Marine Coastal Zone" and describes important tasks to be achieved in this area during 1st (by 2005) and 2nd (by 2010) phases of the Program implementation.

[clxvii] In 2006, Ukrainian State Research Institute of Urban Planning (DIPROMISTO) has completed project (funded by the Ministry of Construction, Architecture and Communal Services of Ukraine) and prepared report "Planning Scheme of the Black and Azov Seas' Coast for using in Donetsk, Zaporizhzhia, Kherson, Odessa, Mykolaiv Regions, and AR Crimea". This comprehensive document comprises extensive data about natural resources, economic activities, settlements, demography etc. of coastal regions of Ukraine.

Comprehensive overview of national legal, management and, in particularly, planning system was prepared in the framework of the PlanCoast INTERREG IIIB CADSES Project (Adriatic Sea

– Baltic Sea – Black Sea, 2006 – 2008). Report by V.Karamushka “Spatial Planning of the Development of Marine Coastal Zone of Ukraine”, 2008. See http://plancoast.sea.gov.ua/downloads.html.

clxviii Intersectoral Commission on the Protection of the Black and Azov Seas has been established and coordinated by the Ministry of Environment since 2000.

clxix Councils at local level in the framework of demonstrative pilot projects was established in Ovidiopol district (Odessa Region) in the framework of the Project “Introducing Integrated Coastal Zone Management for strengthening the sustainable development of local communities” (2006-2007).

clxx Project: Spatial Planning in Coastal Zones (Developing, introducing and implementing the new field of spatial planning of maritime areas).

Funding: EU (contribution - € 120,348).

Implementing organization: Ukrayinskiy Naukoviy Centr Ekologiyi Morya (Ukrainian Scientific Center of Ecology of the Sea), Odessa.

Implementation Period: 2008-2009 (18 month).

Location: Odessa Region (Oblast); Target Group: local governments, general population.

clxxi Cabinet of Ministers of Ukraine has approved the Conception of the Development of Marine Coast of Crimea (#789 of 22.08.2005).

State Program of Social-economic Development of AR Crimea until 2017 (Resolution of the Cabinet of Ministers # 1067 of 30.08.2007).

clxxii ICZM Guideline developed by the ICZM AG and adopted by the Black Sea Commission.

clxxiii Results of general assessments of vulnerability and hazard of entire marine coastal zone along Azov and Black Seas are presented in the National report prepared and published by the Ukrainian Scientific Center of Ecology of the Sea “State of Environment of the Black Sea: National Report of Ukraine, 1996-2000 “, Odesa, AstroPrint, 2002, 80 p.

clxxiv State and problems of Odessa coastal zone: Report. Edited by N.Barker, O.Diakov, I.Studennikov, and J.Toussik. – Odessa, 2002 // http://www.crs.org.ua/ru/11/19/60.html.

Assessments of the Azov Sea coastal zone were undertaken by Industrial-Ecological Union “Donbas-Azov XXI”, Donetsk (the Project: «Perspective Scheme of exploitation of natural resources of coastal zone of the Sea of Azov within the borders of Donetsk Region”, 1999 – 2003).

The State and Problems of the Odessa Coastal Zone: Produced within the SEPS 548 Project, Center of Regional Studies, Odesa, 2008. 152 p.

clxxv Law of Ukraine “On regulation of the Urban Construction Activity” has been approved in 2011 ((#3038-VI of 17.02.2011). After that, some legal acts (including Law “On Ecological Expertise”) were sufficiently changed. The law has strong impact on

environmental consequences of economic activity because it has restricted or eliminated at all procedures of Environmental Impact Assessment from planning processes and construction activities including those having place on coastal zones.

[clxxvi] Project: Adopting Integrated Coastal Zone Management as Good Practice for Sustainable Development of Odessa.

Funding: DFID, UK (contribution - 20000 £).

Implementing organization: Center of Regional Studies, Odessa.

Implementation Period: June – December 2002 (6 month).

Developing Integrated Coastal Zone Management for Tiligul Liman to Optimise Long Term Economic Opportunities.

Funding: DFID, UK.

Implementing organization: EuroCoast-Ukraine NGO, Odessa.

Implementation Period: 2002.

Location: Odessa Region (Oblast); Target Groups: local government, general population.

[clxxvii] EuropeAid Project "Environmental Collaboration for the Black Sea" (2007 – 2009).

[clxxviii] Legal Act "Concept of the Protection and Rehabilitation of the Environment of the Azov and Black Seas (approved by the Ordinance of the Cabinet of Ministers of Ukraine on July 10, 1998, #1057) stipulates "Creation of Integrated Management of Natural Resources Use within Coastal Zone of the Azov and Black Seas" and introduction of Integrated Coastal Zone Management.