EMBLAS
Environmental Monitoring
in the Black Sea

Funded by the European Union

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Joint Black Sea Surveys 2016

National Pilot Monitoring Studies and Joint Open Sea Surveys in Georgia, Russian Federation and Ukraine, 2016

REVEALING THE SECRETS OF THE BLACK SEA

photo by Oksana Savenko

This document has been prepared in the frame of the EU/UNDP Project: Improving Environmental Monitoring in the Black Sea – Phase II (EMBLAS-II) ENPI/2013/313-169

Date: April 2017

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About the Project

The project 'Improving Environmental Monitoring in the Black Sea" (EMBLAS-II) is aimed to improve the protection of the Black Sea environment. It is achieved through: i) improving availability and quality of Black Sea environmental data in line with the Marine Strategy Framework Directive (MSFD) and Black Sea Strategic Action Plan (2009) needs; ii) improving partner countries' ability to perform marine environmental monitoring along MSFD principles.

The project activities are dealing with national marine monitoring systems and tools for environmental data assessment, development of relevant programmes for harmonized chemical and biological monitoring, national needs assessment for equipment and training, as well as organization of Joint Black Sea Survey and further development of web-based Black Sea Water quality database and public awareness raising.

The Project is co-financed by the European Union (EU) and United Nations Development Programme (UNDP).

The Project implementation started on 1 April 2014 and will end on 31 May 2018.

It is implemented in Georgia, Russian Federation and Ukraine. The Ministries of Environment in these countries are project beneficiaries.

The project partners:

УкрНЦЕМ
ІМБ НАНУ
1865
ბათუმის ეროვნული სააგენტო
Commission on the Protection of the Black Sea Against Pollution

More information at

http://emblasproject.org/

Fans of the Black Sea

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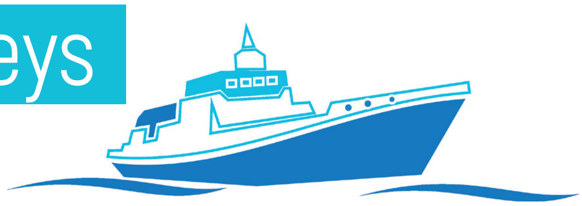
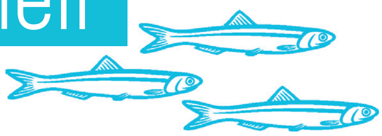




1.1. What are the Joint Black Sea Surveys?

Joint Black Sea Surveys, known also as JBSS, was **historically the biggest research expedition in the northern part of the Black Sea.** JBSS consisted of several interconnected and harmonised surveys in the Ukrainian shelf, Russian and Georgian coastal zones (called National Pilot Monitoring Studies (NPMS)) and expeditions in the open sea (called Joint Open Sea Surveys (JOSS)). JOSS were carried out on a transects between Odessa and Batumi by a common team of Georgian and Ukrainian experts, and from the coastal city of Gelendzhik to the middle of the sea by Russian scientists. Additionally, several stationary sites were investigated in each participating country within longer-term (12-months) NPMS and eight rivers flowing into the sea were monitored for the amounts and types of marine litter floating on the surface.
JBSS brought together researchers from the three Northern Black Sea countries and seven EU Member States. Expeditions in Ukraine and Georgia took part in May - June 2016 on the largest EU research vessel Mare Nigrum from Romania and a wide range of on-site measurements and sampling were performed at 15 sampling stations in Ukrainian waters, 15 sampling stations in Georgian waters and 25 sampling stations in the open sea. The open sea survey in Russian waters was carried out at 12 stations in the end of May 2016 and 40 stations were investigated in the Kerch Strait and Sochi-Adler regions in August and November 2016, respectively, using three smaller ships Impuls, Peleng and Ashamba. Special chemical analyses were carried out by selected leading laboratories across Europe. The chemical pollution and marine litter investigations were supported by the DG Joint Research Centre of European Commission. Beach litter monitoring was carried out with methodological support of the European Environment Agency (EEA).

1.2. Why are these surveys so important?

Unique terrestrial and aquatic habitats of the Black Sea are under threat, though during the last 10 years certain signs of improvement of the Black Sea state were observed. Yet, the Black Sea remains fragile, with low potential to withstand anthropogenic pressures, especially if they increase compared to today due to recovery of the region economy. The framework of the regional cooperation in the Black Sea environmental protection is provided by the 'Convention on the Protection of the Black Sea Against Pollution' (Bucharest Convention), which entered into force in 1994. It is expected, that the political commitment of the Black Sea countries to comply with the EU legislation will increase over the next years and there will be a need for building capacities and sharing the information and knowledge. The Black Sea Commission and the Bucharest Convention are the regional platform through which the EU legislation, particularly the **Marine Strategy Framework Directive** (MSFD; for territorial waters up to 12 nautical miles from the sea shore) and the **Water Framework Directive** (WFD; including coastal waters up to one nautical mile from the sea shore) can be efficiently implemented. The above is of particular urgency to **Georgia and Ukraine** who **signed the Association Agreement with the EU and are on the way of transposing all EU water legislation into the national policies**.

The EMBLAS project, financed by the European Commission and UNDP, **was designed to tackle deficiencies and limitations in availability of accurate reliable and comparable marine data**, as well as to build capacities of the involved countries to perform integrated environmental monitoring and assessment of the Black Sea according to the **MSFD, WFD** and the needs of the **Black Sea Strategic Action Plan** adopted by Black Sea countries in 2009. Relevant results and experiences of previous and ongoing projects have been taken into account. This holds in particular for an experience from the EU-funded MISIS project carried out in 2013, whose objectives match those of EMBLAS when it comes to marine environmental monitoring in 'the other three Black Sea countries' Bulgaria, Romania, and Turkey. **Combined results from EMBLAS, MISIS and recent monitoring efforts in Bulgaria and Romania using harmonised methods for sampling, analysis and assessment of results will for the first time allow for obtaining a big picture on how healthy is the Black Sea at present and provide an indication what to do to improve its status.**

The MSFD requires all EU marine waters to achieve 'good environmental status' by 2020. The criteria for assessing the extent to which good environmental status is being achieved are specified in relation to each of **the eleven descriptors of good environmental status set out in the MSFD**. The criteria are accompanied by a list of related **indicators** to make such criteria operational and allow subsequent progress. An overview of what the descriptors are dealing with is as follows:

Descriptor 1: Biological diversity
Descriptor 2: Non-indigenous species
Descriptor 3: Populations of all commercially exploited fish and shellfish
Descriptor 4: All elements of the marine food webs
Descriptor 5: Human-induced eutrophication
Descriptor 6: Sea-floor integrity
Descriptor 7: Permanent alteration of hydrographical conditions
Descriptor 8: Concentrations of contaminants

Descriptor 9: Contaminants in fish and other seafood for human consumption
Descriptor 10: Properties and quantities of marine litter
Descriptor 11: Introduction of energy, including underwater noise

Each EU Member State (MS) needs to consider each of the above criteria and related indicators in order to identify those which are to be used to determine good environmental status. On the basis of **the 'initial assessment'**, when a MS considers that it is not appropriate to use one or more of the criteria, it needs to provide the Commission with a justification, considering also comparison between regions and sub-regions. Current environmental legislations in Georgia, Ukraine and Russian Federation do not recognise yet the 'descriptors' and 'indicators' and thus do not allow for harmonised assessment of data and their comparison with other European seas. **JBSS was the first big step towards the completion of the 'initial assessment' in the region** as it tackled **eight out of 11 descriptors** (cf. those in bold above).

The WFD requires all EU surface inland waters, and transitional and coastal waters, to achieve 'good chemical and ecological status'. 'Good chemical status' basically means that the water should be clean from toxic chemicals. However, it is not enough to only have clean water without anything living in it. That is why the WFD also requires 'good ecological status' whereby waters must provide good conditions for animals and plants to live healthily. The WFD also requires countries to develop a River Basin Management Plan (RBMP) each six years (2009, 2015, 2021 and the last one in 2027) and to identify 'measures' they should take to achieve good status. Such 'measures' in each EU MS are in a range of billions of EUR investments. **JBSS contributed significantly to assessment of the current chemical status in the region by measuring the full list of (45) EU WFD priority substances, of whose many were monitored for the first time in the coastal waters of Georgia and Ukraine.** Using the terminology of the WFD, **four out of five Biological Quality Elements characterising water fauna (benthic invertebrates) and flora (phytoplankton, phytobenthos, macrophytes) were indicatively assessed based on the results of JBSS.** Consequently, the first steps were made to **revise the obsolete monitoring programmes** in the region.

Considering the above, goals, supported with the first outcomes of JBSS, have been officially placed among the governmental priorities of Ukraine in 2017 and highly esteemed by the Ministry of Environment and Natural Resources Protection of Georgia.

1.3. What was tested during the Joint Black Sea Surveys and how?

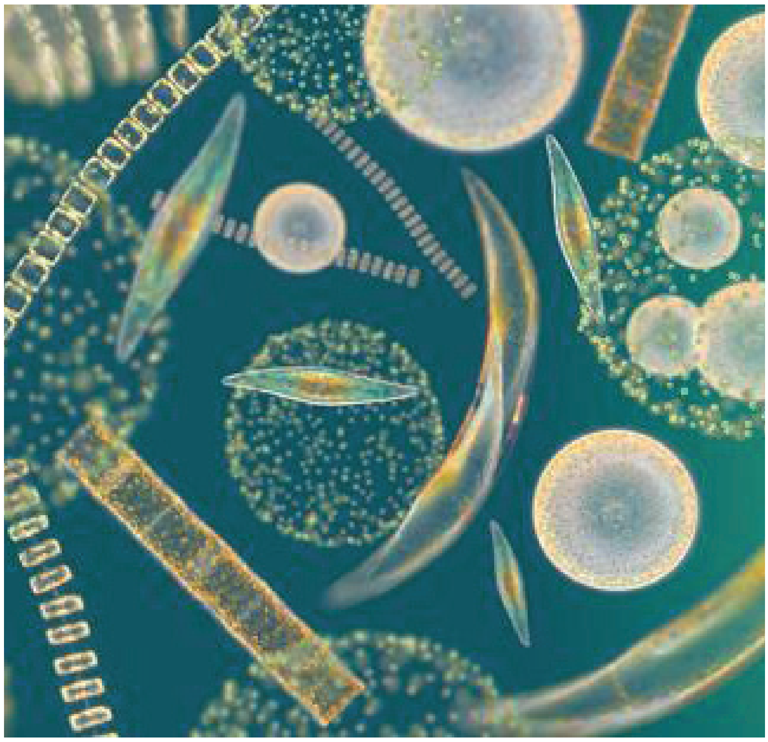
After a long period of no systematic monitoring in the north part of the Black Sea (GE, RF, UA) due to a lack of funds, ships, obsolete equipment and legislation dating back to the times of Soviet Union, a holistic analysis of all relevant chemical and biological parameters (water fauna and flora) together with relevant supporting general physico-chemical and hydrological parameters took place using sampling and analysis **methodologies harmonised among the countries**. Several training workshops were organised before the surveys and commonly accepted Standard Operational Procedures for each monitored parameter were developed.

Sampling at JBSS stations could include up to four different 'sample types' – water, sediment, biology, and biota (molluscs). Fish for chemical analyses were collected at the 12-months NPMS stations. Biological investigations were focused on sampling of phytoplankton (small floating algae-like particles), zooplankton (miniature up to large living organisms floating in water), benthic invertebrates (bugs, mussels etc. living at the sea bottom) and macrophytes (underwater plants). A specific methodology was used for sampling and analysis of 'gelatinous macrozooplankton' - unpleasant jellies often met by swimmers in the Black Sea when overpopulated. Underwater robot with a camera (Remote Operated Vehicle (ROV)) was employed to get the pictures of the sea bottom to check for the presence and abundance of water flora in depths not accessible to humans. The experts conducted numerous tests, looking for animals and plants, from marine mammals such as dolphins to microscopic bacteria. *Physico-chemical* parameters such as temperature, pH, salinity and oxygen concentration were monitored at various depths down to 2000 m depth with a special CTD probe, allowing also for sub-sampling of water at selected depths. Next to repeated grab sediment samples also multiple sediment samples were collected at selected stations by so-called 'multi-corer' device to check for presence of various bigger living organisms (benthic invertebrates) and obtaine samples for additional chemical analyses. Large chunks of sediments were taken from deep sea bottom sites using a large steel tube (gravity corer). A team of scientist from the BENTHOX project led by the University of Liege, Belgium, were on board at the sampling in the Ukrainian shelf studying hypoxia. Concentration of chlorophyll-a was measured by traditional methods but also with an aid of satellite monitoring.

JBSS included a globally unique programme for monitoring of chemical and hazardous substances. Large volume (up to 20 l) samples of sea water were taken using a special 'Mariani box' device provide by the DG JRC for target screening of substances selected as relevant for all European Seas. In parallel a 2 l water samples were sampled for screening of presence of additional more than 2000 substances and non-target screening of suspect or unknown (hundreds/thousands of) substances potentially present in each sample. **The JBSS samples were the first ones globally stored in a 'digitally frozen' state according to the protocol developed by the NORMAN network protocol** (www.norman-network.net; more than 75 organisations in Europe and North America dealing with emerging substances; **'Digital Sample Freezing Platform'**). This allows for **retrospective analysis of any of the thousands of pollutants potentially present in the samples** without the need for (expensive) re-sampling or their storage in Environmental Specimen Banks at extremely low temperature (with a need for defrosting, re-analysing, freezing again...). An 'active-**passive sampling'** took place during the survey employing a system of continuous pumping of water on board of the ship as it moved and adsorbing all pollutants on a battery of sorbents, revealing presence of those pollutants which were in the water collected during 3-4 days periods (covering hundreds of km long stretches). The fish and mussels samples were pre-processed and analysed for presence of metals and a wide range of organic toxicants, many of them being monitored for the first time in the region.

2. Results overview and key findings

2.1. Phytoplankton



Phytoplankton, as the **basis of the food chains of the ocean**, is immediately reflecting on the changes of nutrient concentration in the water column, which may lead to **eutrophication**, *i.e.* a process in which the enrichment of a water body with an excess amount of nutrients induces growth of plants and algae, that may result in oxygen depletion of the water body. To simplify the consequences - **no oxygen, no life**. Considering the above a careful balance between the occurrence of various species of pytoplankton and their excess biomass must be sought. During the surveys were identified 356 species from 15 classes of single-celled algae, with the highest species diversity found in the Ukrainian shelf (224 species); 126 species have been identified on Georgia's continental shelf. In the open waters number of identified species decreased. Indicative assessment of the ecological status of the investigated areas showed that **the most favourable environmental conditions were observed in the Ukrainian open sea water, whereas the worst ecological status was recorded in the Ukrainian shelf and in the region impacted by the Danube river.** To quantify the long-term trend of the phytoplankton occurrence in the Black Sea based on (to be collected) historical data is one of the major tasks in the remaining period of the EMBLAS project.

2.2. Zooplankton

Zooplankton plays a pivotal role in aquatic ecosystems and global biogeochemical cycles. The impact on zooplankton is diverse and largely depends on **climatic signals with concurrent changes** in the **phytoplankton**, physico-chemical conditions of the environment as a result of **eutrophication** and the introduction of **alien (non-indigenous) species**. Investigations within the framework of the MISIS project in 2013 were one of the first attempts to assess possibility of using the zooplankton as an indicator of the Black Sea water quality. Separate categories of zooplankton (micro-, meso-, macro-zooplankton and ichtyoplankton; microzooplankton being also termed as bacterioplankton) were investigated in JBSS. When assessing indicatively **mesozooplankton** results from the common Georgian - Ukrainian cruise, **ca. 93% of the (42) investigated sites** were in '**Not Good Environmental Status'** ('poor' and 'moderate' category according to the WFD). Open sea habitats differed significantly from the shelf zone, where the latter is usually in worse status. Regarding **microzooplankton**, **76% sites was indicatively in 'Not Good' status and the best environmental status was observed in the Ukrainian shelf** (5 out of 15 stations in 'good' status).

In general, the characteristics of the selected threshold values have been developed for the western half of the Black Sea and their further improvement will be addressed by EMBLAS in JBSS 2017.

Macrozooplankton was represented by **four gelatinous species** - *Aurelia aurita, Pleirobrachia pileus, Mnemiopsis leidyi and Beroe ovate*. All diversity indices showed low values because of low taxa numbers and abundance. The biomass of *Aurelia aurita* is changing seasonally and is reported to reach maximum by the end of the summer or beginning of the autumn. The total biomass of *A. aurita* has increased with intensifying eutrophication of the Black Sea and reached to 1 million tons wet weight in the early 1960s. The population size of *A. aurita* exploded in the late 1970s, making a peak at a total stock of 300-500 million tons in 1980s. The peak biomass is equivalent to about 1.5 kg·m^{-2} of *A. aurita*. In the JBSS investigations the maximum biomass was reached on the Station No. 16 of the JOSS GE-UA survey and was estimated as 1.2 kg·m^{-2}. There is an indication of a potential intense competition between *M. leidyi* and *A. aurita*.

As an outcome of the cruises carried out in the **north-eastern Black Sea** (Russian Federation), the **indicative environmental status** based on macro-and meso-zooplankton parameters was **mainly 'not good',** in spite of great decrease of population *Mnemiopsis leidyi*, which is usually responsible for worsening of the status. **Similar to GE-UA survey, an open sea water status was better compared to the situation at the coast.**

The JBSS GE-UA investigations of **ichtyoplankton** resulted in finding eggs and larvae of eight fish species on the shelf of Georgia, Ukraine and in the open sea areas. **On the sampling station No. 4 within the JOSS GE-UA was caught an adult individual of the unique *Syngnathus schmidti* (Black Sea Pelagic Pipefish, Schmidt's Pipefish), which is on the IUCN Red List.** Maximum biodiversity and abundance of ichthyoplankton were recorded at the Georgian coast (NPMS GE, Station No. 6). The greatest number of anchovy eggs were found on the Black Sea shelf in Georgia and Ukraine. Here, it should be mentioned that the sampling was carried out in May, while spawning of the two most popular Black Sea fishes - sprat, has already passed, and it had not started yet for the anchovy. It was concluded that the best sampling time for sampling ichtyoplankton is summer-autumn period when the maximum species diversity is expected, and therefore better results can be expected from the JBSS 2017 which is scheduled for August - September period.

photo by Mikhail Son

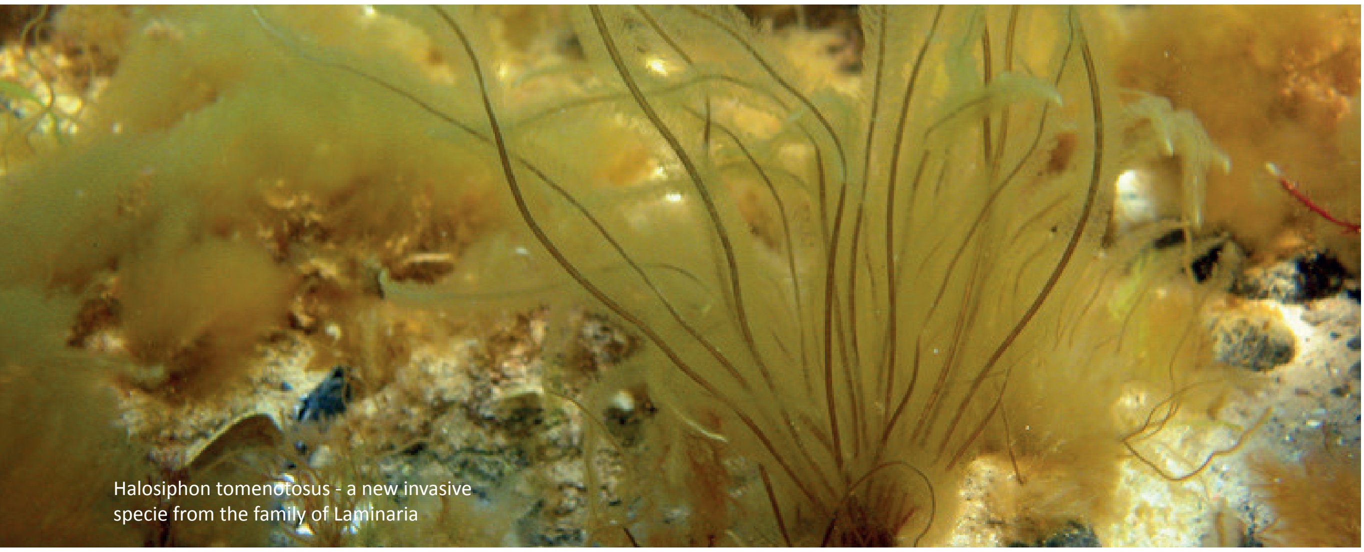
2.3. Benthic habitats

Benthic habitats play an important role in some of the key ecosystem processes such as primary production (basis of the food chain), food webs and recycling, but they are subject to many human pressures which put in risk their functionality. **Eight distinct benthic habitats have been identified** based on the results of NPMS GE and NPMS UA with one habitat common to both Ukrainian and Georgian shelf. In the period of time the survey had been conducted, the investigated area was indicatively assessed mostly as being in **Good Environmental Status (GES)** (78%), whereas 22% of the studied area was in *not-GES*. The ratio of GES/not-GES was 73 : 27% in the Ukrainian region and 83 : 17% in the Georgian region. The reliability of assessment of environmental status (e.g. by the used AMBI and M-AMBI indices) can be further increased by means of a joint effort to set common thresholds for ecological status assessment by EMBLAS (and possibly all) Black Sea countries.

2.4. Macrophytes

Macrophytes (submerged aquatic vegetation; also termed **macrophytobenthos**) community fulfils basic environmental function in coastal ecosystems – create primary organic matter with which the cycle of matter and energy transformation in trophic (food) chains begins. In total, 51 species of macrophytes were found on the investigated sites in Ukraine, Russian Federation and Georgia. The results suggest that the **north-western part of the Black Sea and areas adjacent to the Kerch Strait are in lower indicative ecological status categories compared to the east coast (Sochi and Batumi regions).** This might be due to the influence of big rivers (Danube, Dnieper, Dniester) and the Azov Sea as well as secondary eutrophication of the shelf zone. Lowest categories of the ecological status were recorded for the Ukrainian sector in the Dniester region (NPMS UA, St. No. 2) and the Waste Damping region (NPMS UA, St. No. 14; 'poor' status).


Philophora. Photo by Oksana Savenko


Halosiphon tomenotosus - a new invasive specie from the family of Laminaria

2.5. Non-indigenous species

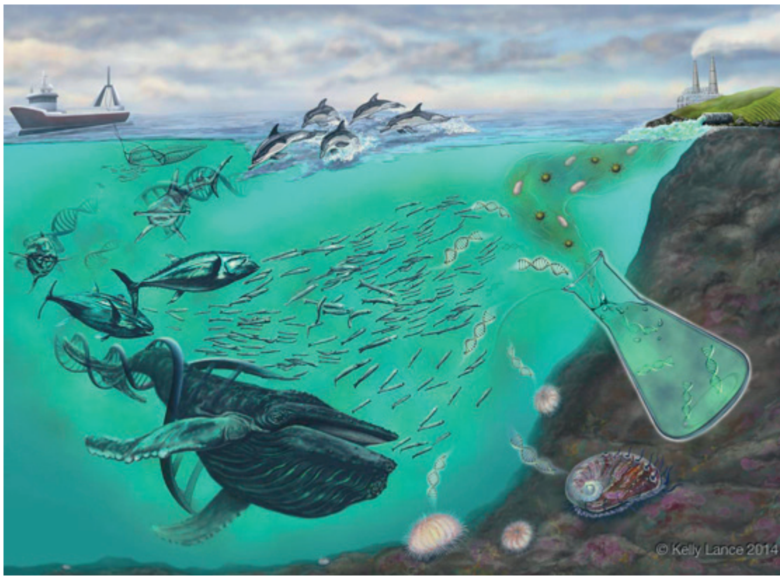
An increased probability of introduction of new organisms in the aquatic ecosystems is not only connected with the development of shipping and aquaculture, but also with eutrophication. It is known that eutrophication causes an increase in primary production (of food). When the total volume of the food increases, the number of species in the ecosystem is reduced and thus shortening the food chain. Reduction in the number of predators and herbivores and release of trophic niches create favourable conditions for the invasion by new species of plant and animal origin. According to the Black Sea Strategic Action Plan (BS SAP, 2009), eutrophication and **biological pollution topped the list of key threats for the Black Sea ecosystem**. One of the Advisory Groups at the BSC monitors appearance of new species in the sea and created a register of allien organisms that includes 365 marine, brackish and freshwater species from fungi and unicellular algae to the marine mammals. The results of JBSS allowed for assessment of impact of **non-indigenous (invasive) species,** which are becoming an increasingly disturbing factor for maintaining the balance in marine biodiversity. For **mesozooplankton**, **Not-Good Environmental Status** was recorded at **all (100%) sampling stations in Ukrainian shelf and Georgian waters**, and at **42% of stations in the open sea area**. This was despite the most notorious Black Sea invasive species comb jelly *M. Leidye* was not present in any of the samples during the JBSS. It is expected that the situation will be even worse when the sampling would take part in late summer - autumn when *M. Leidye* presence is at its peak.

Two species of the Black Sea **invasive macrophytes** were recorded on the shelf zone of the Ukrainian sector and on the Zernov's Phyllophora Field. **Rather alarming is the discovery of *Ch. tomentosa* at St. No. 2 of the NPMS UA as it was found only second time in the Black Sea ecosystem.** A systematic analysis of invasive species from other groups of organisms - phytoplankton, macrophytobenthos and macrozoobenthos, was not yet completed and it is planned that the Final EMBLAS-II report will be supplemented by these data.

The obtained results indicate there is a need to improve methods used for setting the threshold values for biological indicators, which are then applied for characterising water quality in different areas of the Black Sea. For non-indigenous species, the immediate task would be to develop integrated indicators bringing together characteristics reflecting the status of 'living zones' for marine organisms in the open sea and at the sea bottom. Similar changes are currently taking place in the process of implementing the EU MSFD.

2.6. Microorganisms (bacteria)

Microorganisms (bacteria) are ubiquitous in marine environment and known to be the drivers of biogeochemical processes, such as carbon and nutrient cycling. Their ability to rapidly respond to the changes in the environment, such as **climate change–associated shifts in temperature, oxygen and nutrient content, carbon chemistry, and alterations in ocean stratification** makes them promising indicators. Microorganisms harbour a vast genetic diversity and occur in extremely high numbers - it is known that 1 ml of ocean water can contain up to 1 million of microbial cells. The important role of microorganisms in biogeochemical processes can be illustrated by the fact that marine phototrophic microorganisms (*Cyanobacteri*a) are responsible for more than 50% of the oxygen production on Earth and heterotrophic bacteria consume the amount of carbon equivalent to approximately 20–60% of total primary production. Marine microorganisms occupy the bottom trophic level of marine food webs. The JOSS GE-UA data on microbial communities offered a unique opportunity to describe Black Sea marine microorganisms on different depths in relation to chemical parameters. In total 69 sea water samples from 12 stations and 30 sediment samples from 5 stations were collected during the JOSS GE-UA. This was the first large-scale metagenomic survey of microbial communities in the region, and the development of novel efficient monitoring techniques and improvement of databases sets additional perspectives to such study. **The metagenomics analyses** of sediment samples taken at more than 2000 m depth has shown that there are **bacteria able to degrade organic pollutants**, which was confirmed by relatively low levels of pollution by organic chemical pollutants in those samples. In other words - we might not be afraid of a chemical time bomb being build up at the bottom of the Black Sea for this kind of pollutants.



2.7. Marine mammals

The **marine mammals** (cetacean fauna) of the Black Sea includes three species which are recognized as endemic subspecies – **the Black Sea harbour porpoise** (*Phocoena phocoena relicta*), **the Black Sea common dolphin** (*Delphinus delphis ponticus*) and **the Black Sea bottlenose dolphin** (*Tursiops truncatus ponticus*). The Black Sea harbor porpoise and the Black Sea bottlenose dolphin are now listed as '**Endangered'** by the IUCN and the Black Sea common dolphin is listed as '**Vulnerable'**. A systematic marine mammals monitoring, as an important part of the MSFD implementation, took off finally within the EMBLAS-II. In total 2561 cetaceans were encountered during the EMBLAS-II research cruises in 2016 with the common dolphin as the most common species (2220 encounters). The data on distributional patterns of cetaceans were obtained for the territorial waters and exclusive economic zones of all three countries as well as for the deep open sea waters. **Joint group of common dolphins and juvenile harbour porpoise was detected in the offshore waters of the southeastern part of the Black Se), which is highly unusual – neither short- nor long-term associations between common dolphins and harbour porpoises have been documented before the recent sightings occurred in Scotland in 2017.** The pilot study allowed for identification of areas of predicted high density of marine mammals. This knowledge will be used in the design of the future line transect surveys for the Black Sea cetacean abundance estimates. The collected photographs of the individually distinguished common dolphins will contribute to the photo-identification catalogues of the Black Sea cetaceans.


photo by Oksana Savenko

2.8. Eutrophication

Eutrophication is a result of the process caused by increasing of nutrients, leading to high growth of microalgae (phytoplankton), so-called algal bloom. Unwelcome result of this process is the increasing of phyto biomass and production, that is well illustrated by chlorophyll-a concentration. High levels of chlorophyll-a concentration are good marker of eutrophication and point the part of sea harmed by it. **Comparison of chlorophyll-a concentration in the upper mixed layer from the satellite data and the measured values during the JBSS demonstrated high positive correlation.** The spatial reduction in the concentration of chlorophyll-a was observed with the increasing distance from the coast and increase of the chlorophyll-a concentration was recorded in the areas under the influence of river flow. Modification of the vertical distribution of chlorophyll-a and the displacement of its maximum were observed in the bottom layers in areas with high anthropogenic load (Dnieper region, Odessa Bay, Poti and Batumi transects). However, this may also be related to the hydrological characteristics of the port areas. Thus, the hot spots of the shelf zone under the influence of river flow and port zones require constant monitoring.

The results of JOSS RF gave grounds to assume that in the investigated season ecosystem of the Black Sea functioned in a normal mode without any features of eutrophication, however, an increase of concentrations of silicate and ammonium were noted in 2016 compared to previous years.

The analysis of average concentration of chlorophyll-a within a long-term period showed that the highest concentrations of chlorophyll-a in the north-western Black Sea shelf were determined by the influence of waters from the Dnieper estuary. To the greatest extent the downward trend of chlorophyll-a concentration with an angular factor in 0.12 $\mu g \cdot L^{-1}$ per year was marked in the Dnieper-Bug region. **A general trend of gradual chlorophyll-a concentration decrease for all of the north-western Black Sea shelf has been observed.**

Black Sea eutrophication integrated assessment was carried out with two methods - **BEAST** (Black Sea Eutrophication Assessment Tool; developed in the frame of Baltic2Black project based on the HELCOM (Baltic Sea) and OSPAR (North Sea) taking into consideration the requirements of the MSFD) and **E-TRIX** (an integral indicator associated with the characteristics of the primary production of phytoplankton and food factors (i.e., concentration of nutrients)). While the major part of the investigated areas were in 'GES', both in the surface and deep waters (e.g., Georgian waters, Gelendzhik area at 5-miles transect, southern part of the Kerch Strait area and the large part of the North-Western Shelf UA) some waters were in 'not-GES'. These were mainly surface waters influenced by the Danube discharge in May 2016, which strongly 'jumped over' the 'not-GES' threshold due to the large diatom bloom. Another non-compliance was recorded in the northern part of the Kerch Strait on 8 - 9 August 2016. In this case it was not due to the phytoplankton bloom, but high concentration of nutrients coming from the Azov Sea which was responsible for exceeding the 'GES' threshold. In general, **it can be concluded that the Black Sea coastal and open waters are mostly in 'GES' with several special exclusions connected with intensive inflow from large rivers and the Azov Sea.**

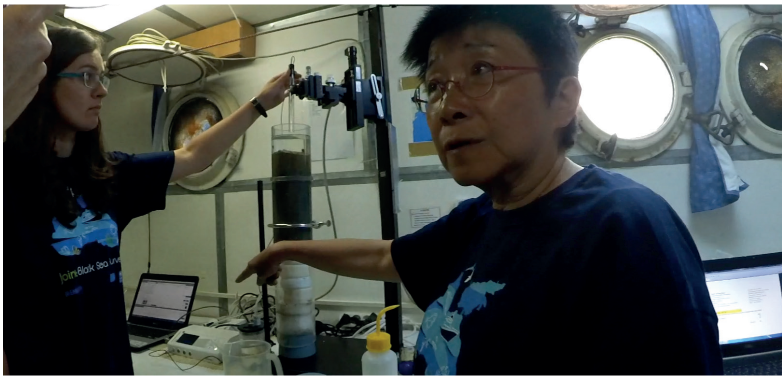
A general level of **eutrophication** of the Black Sea seems to get better, however, there are signs that **the overall level of the oxygen saturated layer** where most of the 'Black Sea life' is maintained **is decreasing** over the time (the 'dead zone' of anoxic H_2S layer from under ca. 100 m down to 2000+ m depth possibly moving up), which might cause an environmental disaster if not properly monitored, understood and prevented on time.

The Black Sea turned turquoise due to phytoplankton (NASA, June 2017).

2.9. Hypoxia

The Black Sea is a wide Oxygen Minimum Zone (OMZ) which results from natural and anthropogenic factors. Its semi-enclosed character makes it a naturally poorly ventilated region. Only the first ca. 100 m of the water column is enriched in oxygen by photosynthesis and winter mixing and waters below 100 - 150 m (ca. 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. 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 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. $O_2 < 63$ µmol/l). It would be more appropriate to speak about specific threshold since each species has its own level of tolerance to deoxygenation. The BENTHOX project (http://labos.ulg.ac.be/mast/) is dedicated to the development of tools to understand and mitigate bottom hypoxia on the north-western shelf of the Black Sea and, in cooperation with EMBLAS, to collect oxygen data throughout the shelf area in order to understand the impact of benthic hypoxia on biogeochemistry and ecosystem functioning. The occurrence and extension of OMZ may compromise the GES (Good Environmental Status) 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.

Preliminary results indicate that hypoxia has not been observed during the JBSS 2016. To make sure that the processes are well understood, it is proposed to study hypoxia in the Ukrainian shelf waters also in the surveys in 2017, however, in the warmer period of the year (August - September).



2.10. Chemical pollution

A **state-of-the-art chemical analyses** required by the EU water legislation (MSFD, WFD) were performed with the assistance of leading EU laboratories involving also the EC DG JRC laboratory in Ispra, Italy. Next to the detailed study on the occurrence of the EU WFD priority substances in water, sediment and biota (fish and mussels) samples a first attempt has been made to identify the **Black Sea Specific Pollutants**. Samples from 55 sampling sites spread across the sea were screened for presence of more than 2000 chemicals by the latest available analytical techniques and pollution patterns were established for a wide range of industrial chemicals, pharmaceuticals, personal care products, flame retardants etc. **Exceedances of toxic threshold concentrations of several EU WFD priority substances** in water and biota samples analysed within the project are certainly of high environmental concern regionally and should be verified in order to decide if (expensive) corrective programmes of measures are to be applied.

2.11. Marine litter

First trials in **marine floating litter** monitoring have shown that the Black Sea may be one of the most polluted European seas, however, this should be confirmed using harmonised methodologies. Also, test sites monitoring of an input of the **floating litter from the major rivers entering the sea** was carried out. More data are needed to come with any specific conclusions and recommendations. An urgent need to extend the monitoring for microplastics in the marine environment was identified. An overview of the **pollution of Black Sea beaches by marine litter** has been obtained via screening campaigns using European Environment Agency (EEA) methodological support.

2.12. Classification schemes

For the first time a coordinated effort has been made to assess the indicative ecological (Water Framework Directive - WFD; coastal waters) and environmental (Marine Strategy Framework Directive - MSFD; territorial waters) status based on the commonly agreed status classification schemes. A map of the Black Sea was created with areas highlighted indicatively as not being in 'good status' and thus deserving further attention of environmental authorities in GE, RF and UA.

All of the above are indicative results and should be re-confirmed by more data from future monitoring campaigns. This holds also for the assessments based on these preliminary data.

Next to JBSS, the EMBLAS project organised educational campaign on **Environmental Sentinels** in each country in summer-autumn 2016. A tradition of **Black Sea Clean Beach Day** in each of the project countries has been launched, connected with training sessions on Environmental Sentinels monitoring, clean-up of beaches and restoration activities in selected natural parks locations.

2.13. Joint Black Sea Survey - map of sampling sites

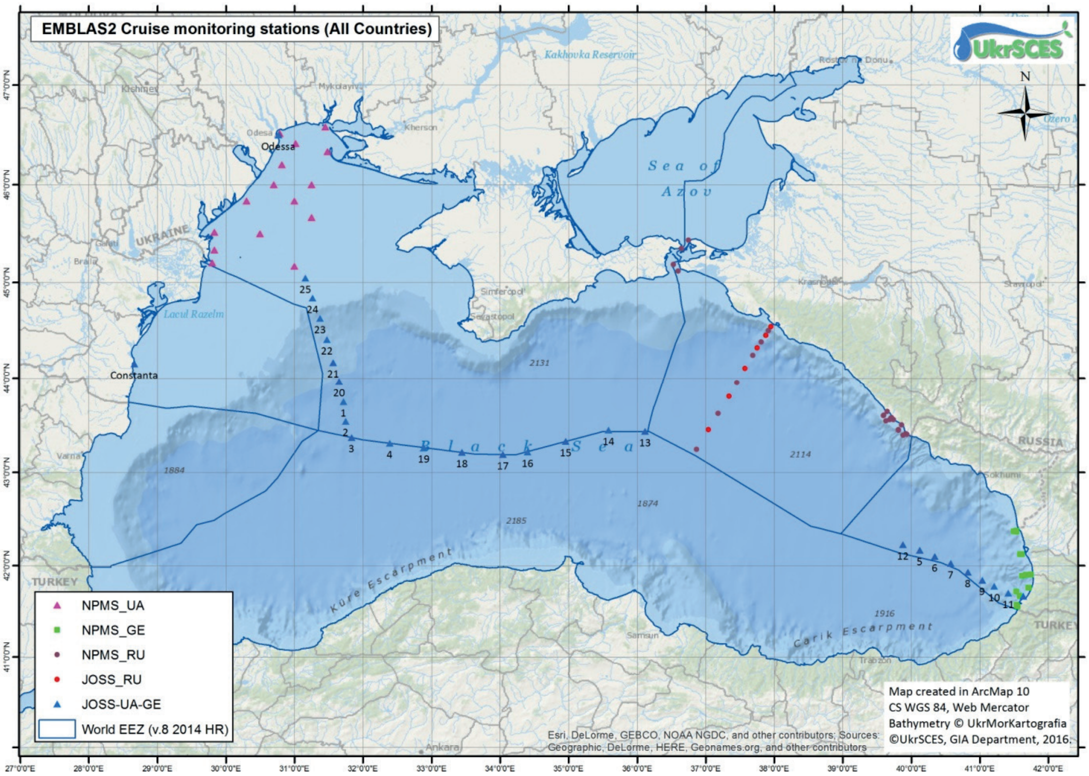


Figure 1a.
An overview map of sampling stations in the Joint Black Sea Survey including NPMS UA, NPMS GE, JOSS UA-GE and JOSS RF.

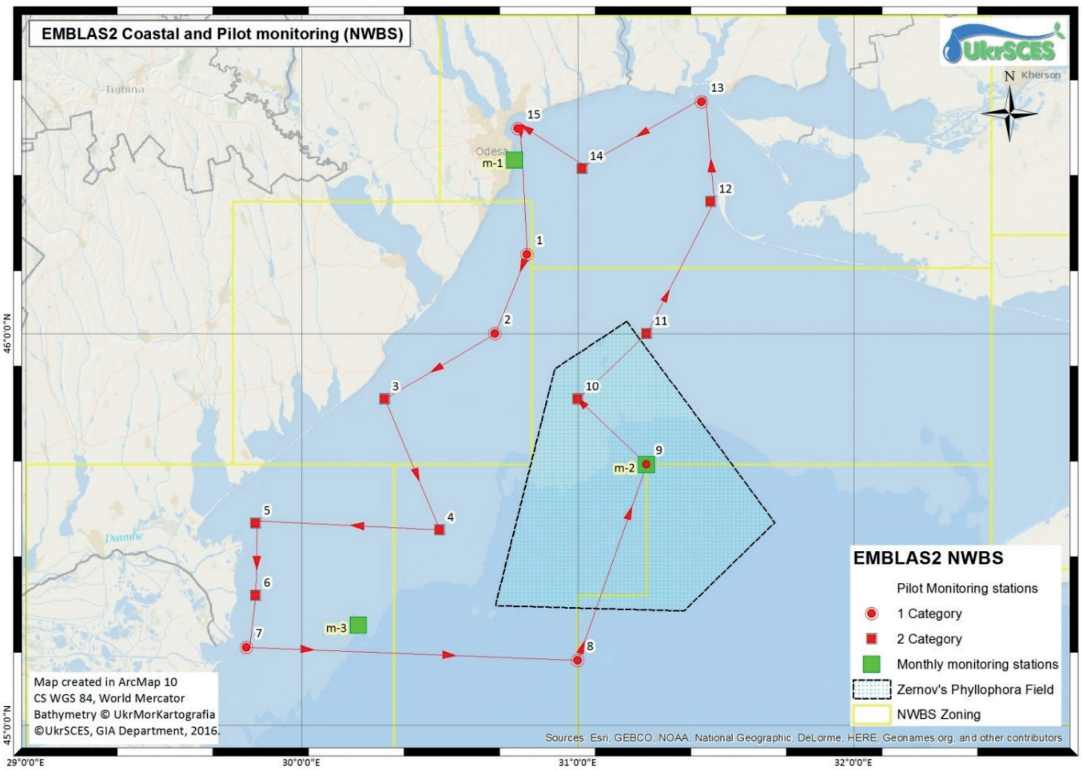
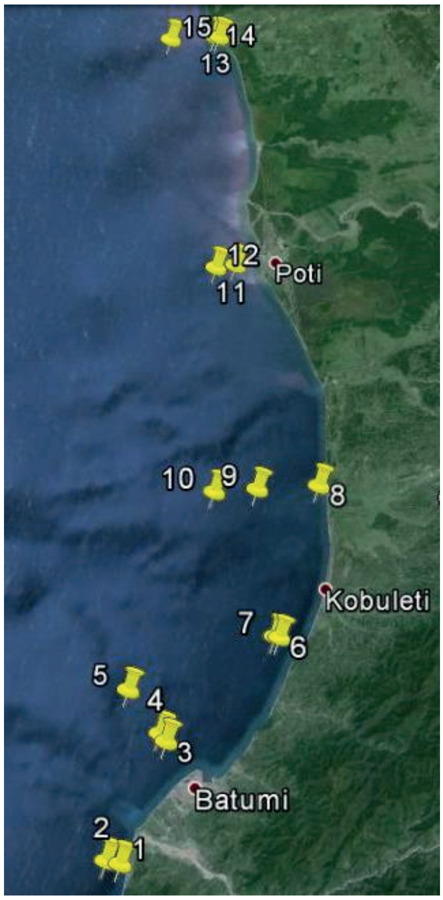


Figure 1b.
An overview map of NPMS UA sampling stations.

Figure 1c.
An overview map of
NPMS GE sampling
stations.



a)

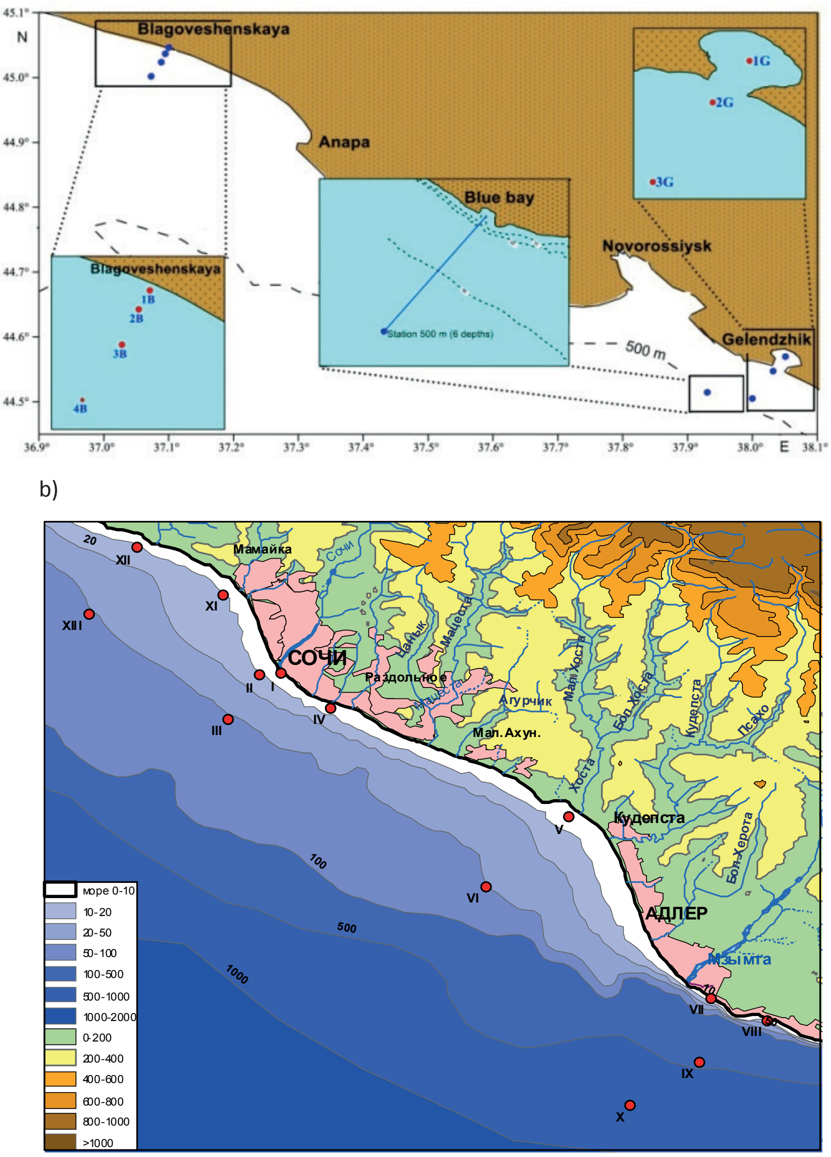


Figure 2.
An overview map of NPMS RF-III sampling stations: a) pilot monitoring study in Anapa Bay (left insertion), Gelendzhik Bay (right insertion) and 12-months monitoring study near Blue Bay (central insertion); and b) NPMS RF-II in Sochi-Adler region.

3. Joint Black Sea Surveys - preliminary scientific results

Tens of thousands results from JBSS were statistically processed in order to obtain an overall picture on what is the present 'MSFD' or 'WFD' status of the investigated Black Sea areas. It should be clarified here that the **MSFD requires two status assessment categories 'good environmental status' (GES; green) and 'not good environmental status' (Not-GES, red); whereas the WFD distinguishes five ecological status assessment categories (high - blue; good - green; moderate - yellow; poor - orange; bad - red).** In the WFD the critical border is between 'good' and 'moderate' status. When below 'good' (WFD) or 'Not-GES' (MSFD) a programme of measures is required by the law! Traditionally, the WFD approach with five categories is more accommodated in Europe and being frequently used also for the MSFD assessments. A general scheme of understanding and converting 'GES/Not-GES' and 'WFD five-colours scheme' is below.

WFD - ecological status (coastal waters)	**High**	**Good**	**Moderate**	**Poor**	**Bad**
MSFD - environmental status (territorial waters)	**GES**		**Not - GES**		

The results of JBSS discussed below were based primarily on the requirements of the MSFD according to individual descriptors. The Final Scientific Report and its excerpt presented here deliberately follow structure of the **'State of Environment Report of the Western Black Sea based on Joint MISIS cruise'** in order to compare obtained assessments of the Black Sea environmental status with those obtained by Romania, Bulgaria and Turkey in 2013. Also deliberately, the terminology used by the researchers is maintained throughout the text despite it might differ from that in the MSFD.

3.1. Data and methods

3.1.1. DESCRIPTOR 1: Biodiversity

Descriptor 1. *Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climate conditions.*

Phytoplankton

The WFD and the MSFD consider phytoplankton a necessary component of the assessment of the ecological/environmental status of water bodies. Various indicators of marine phytoplankton can provide valuable information on ecological processes which are important for the viability and quality of life of coastal countries. Structural indicators of phytoplankton, immediately reflecting the changes of nutrient concentration in the water column, have the advantage in the analysis of such environmentally significant process as eutrophication.

To assess the ecological status of habitats phytoplankton biomass and chlorophyll-a were used. Assessment of the Ukrainian shelf revealed differences for these indicators (see Figs. 3 and 4). The most favourable environmental conditions for phytoplankton were observed in the open Ukrainian shelf water. The worst status was observed in the Danube impacted region. The status of the Georgian shelf area and open sea water stations close to the Georgian coast by chlorophyll-a indicator was classified as «high» for both the surface (Figs. 5 and 6) and the bottom layer (not shown).

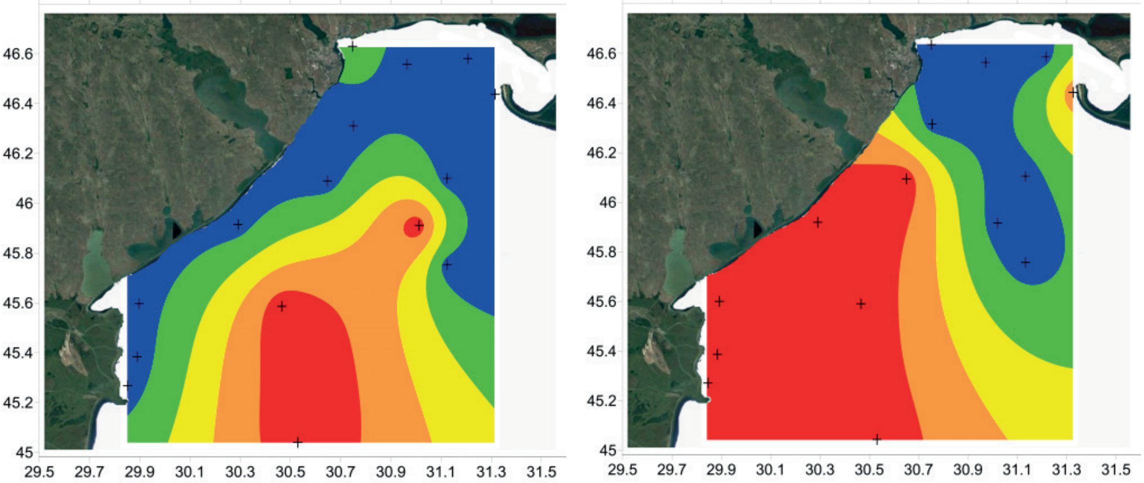


Figure 3.
Map of ecological status in NPMS UA based on phytoplankton biomass (mg/m3, left) and chlorophyll-a (µg/l, right), upper mixed layer (X-axis - longitude; Y-axis - latitude; crosses- stations).

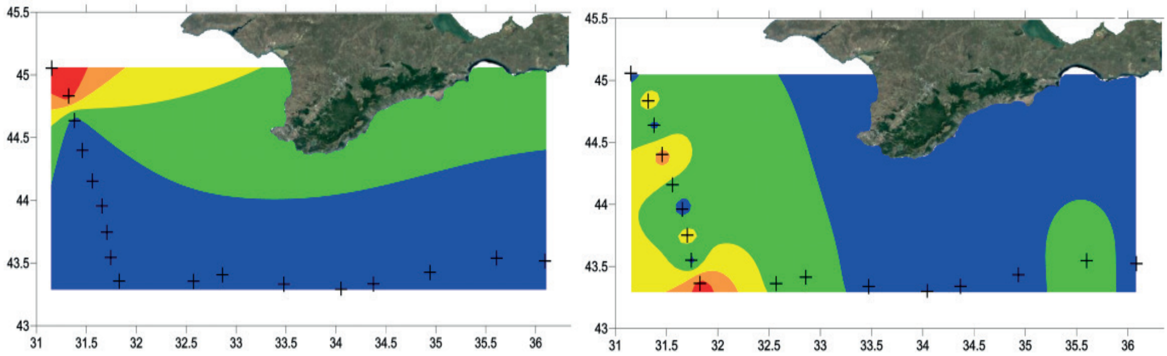


Figure 4.
Map of ecological status in JOSS GE-UA based on phytoplankton biomass (mg/m3, left) and chlorophyll-a (µg/l, right), upper mixed layer (X-axis - longitude; Y-axis - latitude; crosses- stations).

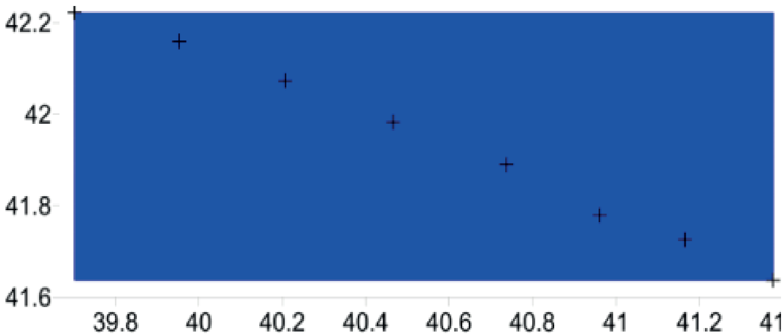


Figure 5.
Map of ecological status in JOSS GE-UA (in the south-east part of the sea) based on chlorophyll-a (µg/l), upper mixed layer (X-axis - longitude; Y-axis - latitude; crosses - stations).

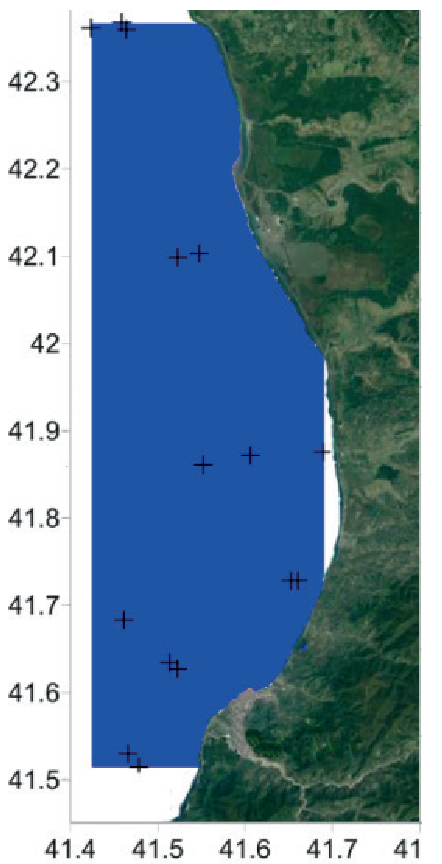


Figure 6.
Map of ecological status in NPMS GE based on chlorophyll-a (µg/l, right), upper mixed layer (X-axis - longitude; Y-axis - latitude; crosses - stations).

In the studied area 14 potentially toxic species of phytoplankton were identified. The highest average abundance ($302 \cdot 10^3$ cells/L) and biomass (143 mg/m^3) was registered for *Pseudo-nitzschia delicatissima*. The relatively high average biomass was found for *Phalacroma sphaeroideum* (57.12 mg/m^3) and *Gonyaulax spinifera* (47.09 mg/m^3). All potentially toxic species demonstrated higher abundance and biomass in the shelf waters in comparison with the open waters.

Zooplankton

In total, 36 samples from 15 NPMS UA stations; 42 samples from 14 stations NPMS GE and 43 samples from 12 stations JOSS GE-UA were analysed and reported. The results of indicative ecological status assessment of the sub-selection of investigated areas are shown for microzooplankton in Fig. 7 and for mesozooplankton in Fig. 8.

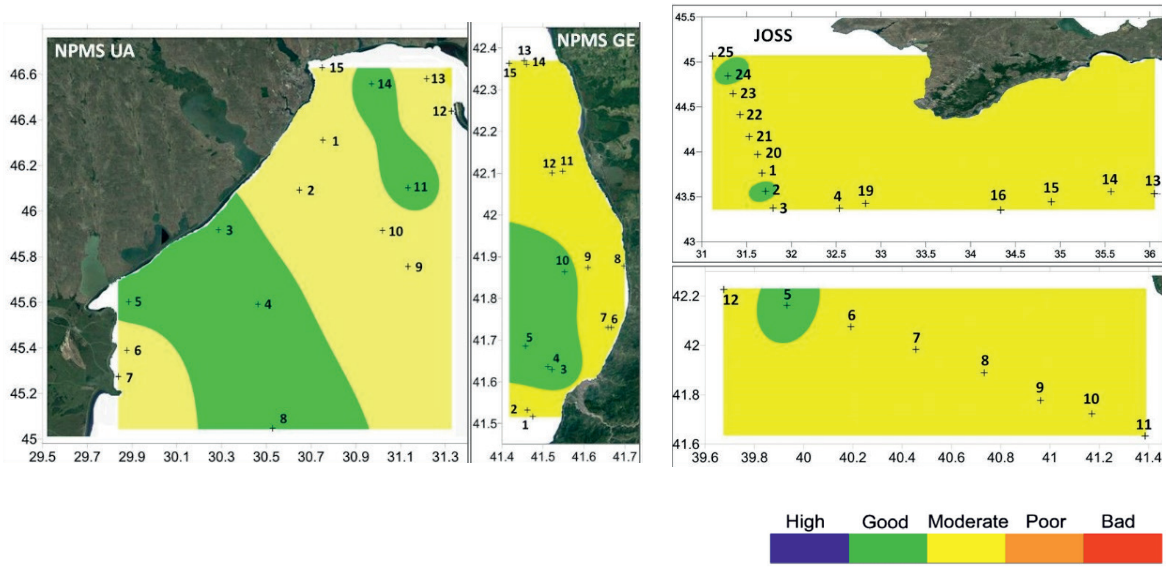


Figure 7.
Indicative assessment of the ecological status in the studied regions on the basis of microzooplankton indicator.

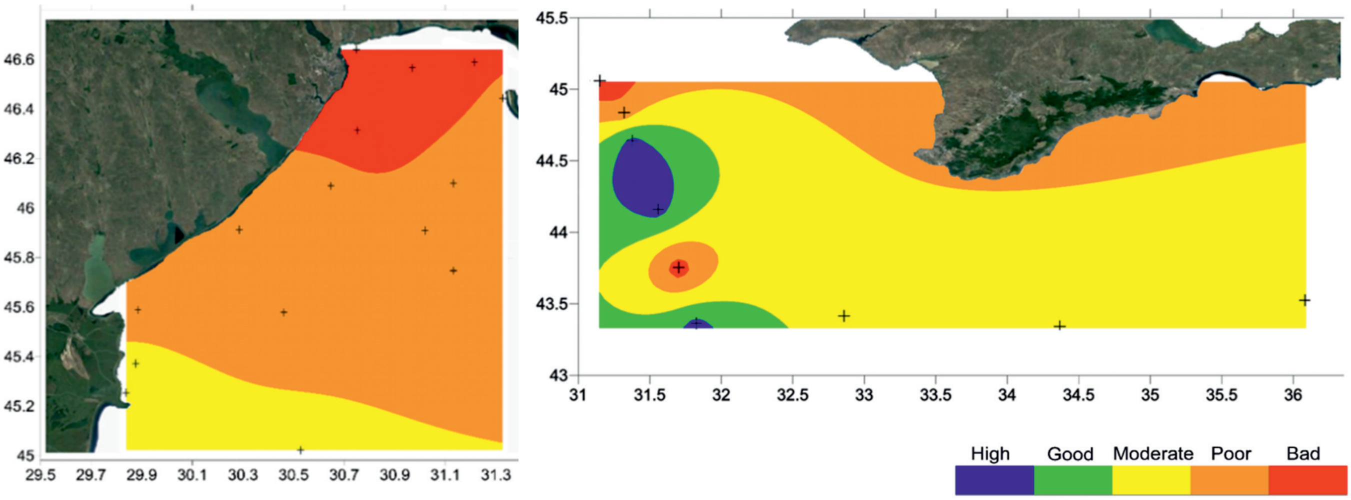


Figure 8.
Indicative assessment of the ecological status using mesozooplankton biomass in the surface layer of the Black Sea: a - north-western shelf (NPMS UA), b - open sea area.

Benthic habitats

One of the main objectives of the EMBLAS-II project is the ecological assessment of the Black Sea, taking into consideration the requirements of the WFD and the descriptors of the MSFD and providing general overview on the status of habitats. In order to respond to the objectives raised by the project, JBSS in the north-western and eastern part of the Black Sea have been performed, at which occasion the **macrozoobenthos** samples were collected.

Achieving a Good Environmental Status requires knowing about the marine ecosystems, of which seabed habitats are an integral part. The assessment of the condition of benthic habitats is one of the evaluation criteria both in the WFD (as biological quality element) and in the MSFD descriptors **(D1 - biodiversity & D6 - sea floor integrity).**

Descriptor 6. *Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.*

Regarding the Descriptor 6 and its requirement to assess the 'condition of benthic community', multi-metric indices AMBI and M-AMBI have been agreed to be used by all EMBLAS partners. The AZTI Marine Biotic Index (AMBI) was designed to establish the ecological quality of European coasts and used also for the determination of the ecological quality status within the context of the WFD. AMBI takes into consideration the proportion of species within each Ecological Group (EG) in relation with their sensitivity to pollution, while M-AMBI besides these categories (AMBI) integrates also two other indices: diversity (H') and species richness (S). Based on this, AMBI will always differentiate the stations nearby rivers' mouth, characterised by high sedimentary and pollutant inputs.

EMBLAS-II project aimed to assess the ecological state of benthic habitats. The typology of main habitats within the Black Sea classified after European Nature Information System (EUNIS) developed within the project EUSeaMap 2 has been applied (http://www.emodnet-seabedhabitats.eu). Currently, in the Black Sea there are two classification systems of habitats in different development stages: NATURA 2000 and EUNIS. NATURA 2000 is the most used, but given the general European tendency to classify all habitats after EUNIS, it gives more reasons to analyse and align to EC requirements.

Eight benthic habitats have been found in the study area (Ukrainian and Georgian waters) based on samples analysis. As a result of specific features of the analysed areas, the assessment of benthic ecological status has been performed which differentiated on each of the two regions. There were 105 and 98 macrozoobenthic taxa identified in the studied zones of the Ukrainian and Georgian shelf, respectively, most of them being taxonomically determined at species level.

The investigated area was assessed mostly as being in Good Environmental Status (GES) (78%), whereas 22% of the studied area was in 'not-GES'. The ratio of GES/Not-GES was 73 : 27% in Ukrainian region and 83 : 17% in Georgian region. Nevertheless, it is still problematic to propose how some habitats should be approached in further studies, especially those coming under strong riverine influence. The current assessment of these habitats both in Ukrainian and Georgian waters revealed 'bad' ecological status, which might be misleading. The multivariate indices used (AMBI, M-AMBI) for ecological quality assessment are very sensitive to tolerant and opportunistic species and these species are dominant in habitats undergoing high inputs of terrigenous sediments.

photo by Mikhail Son

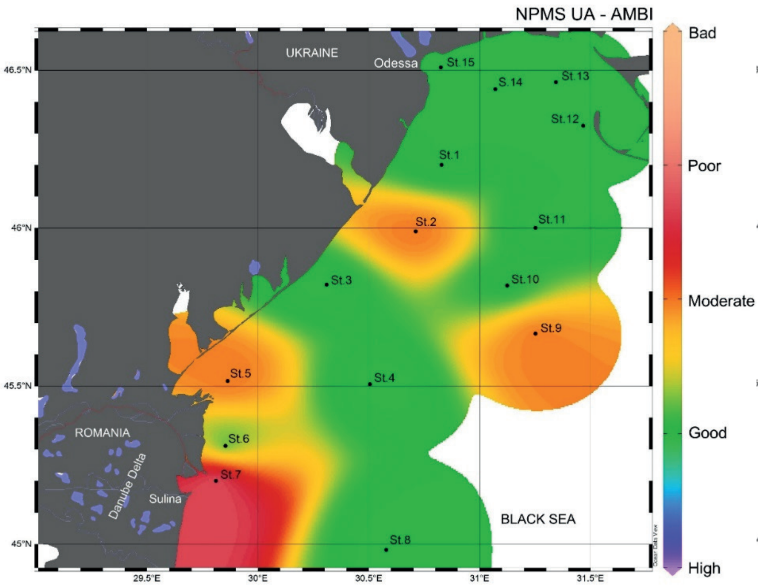


Figure 9.
Distribution map of AMBI values and ecological status of habitats on the Ukrainian shelf.

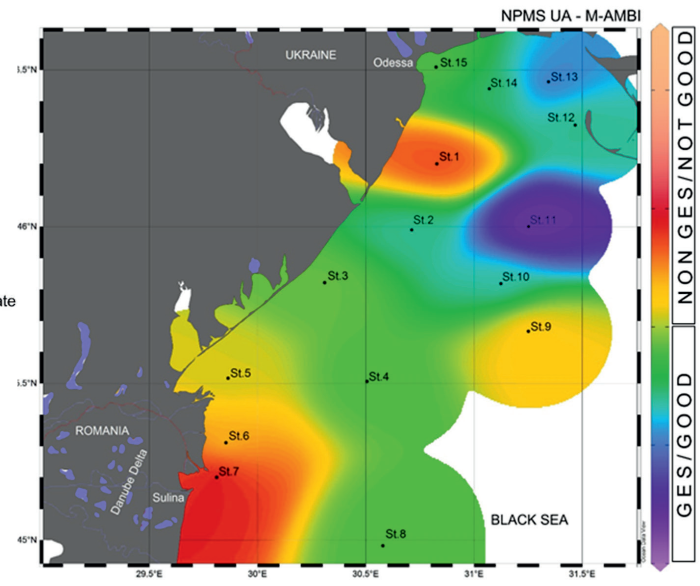
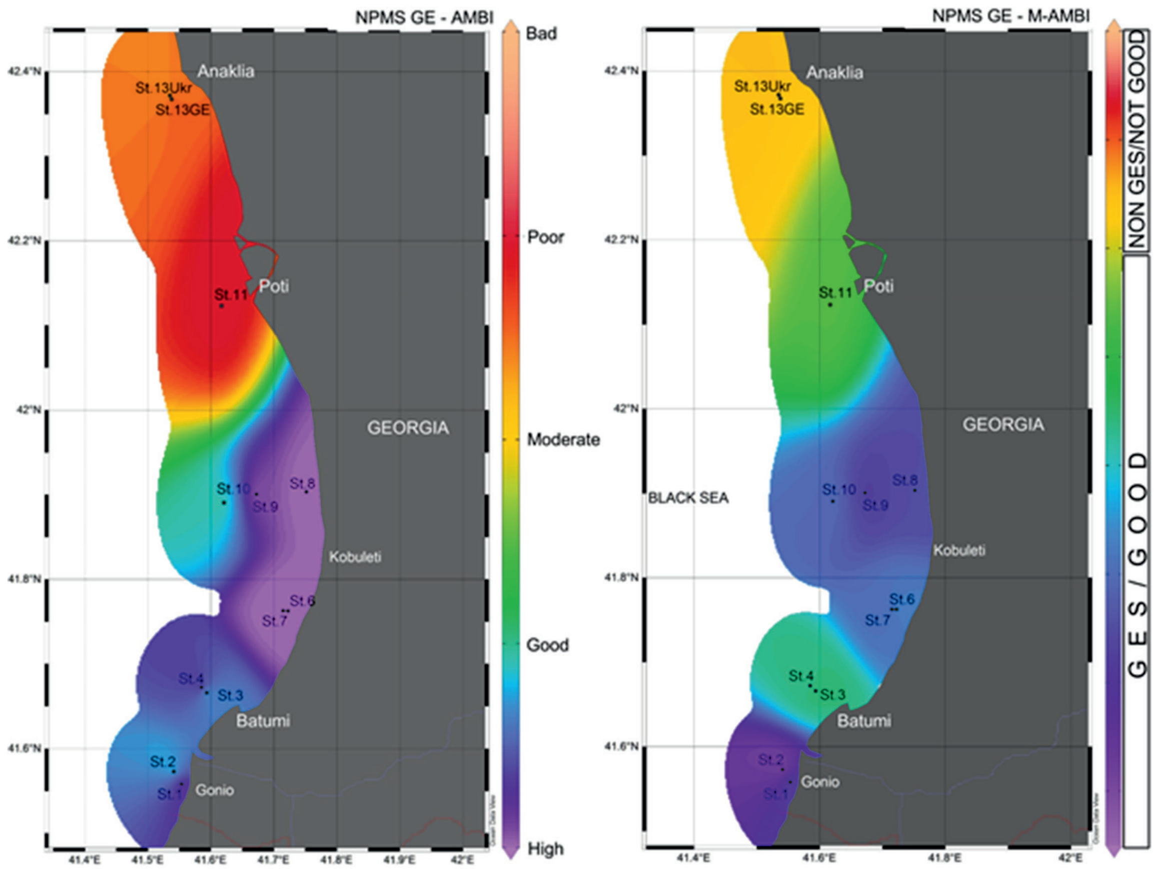


Figure 10.
Distribution map of M-AMBI values and ecological status of habitats on the Ukrainian shelf.

Figure 11.
Graphical representation of AMBI and M-AMBI values and ecological status of habitats on the Georgian shelf.



A separate assessment has been done on the basis of **meiobenthos,** which represents a distinct unit of benthic animals, with size varying from 32 µm to 1 - 2 mm. In the practice of monitoring studies meiobenthic organisms are usually defined to higher taxa. The meiobenthic community is rarely found in the absence of macrobenthic communities, except that living in very harsh conditions (low oxygen, very high or low temperatures, very polluted or disturbed environments) inappropriate for macrobenthos life. Overall, 70 samples of meiobenthos were taken during the NPMSs, of which 30 samples on the Ukrainian shelf, 30 on the Georgian shelf and 10 within the Kerch Strait. The habitats for meiobenthos sampling points were considered the same as for macrozoobenthos ones.

Table 1. Ecological status classification system based on meiobenthic communities.

(DDN% - dominance after nematodes density, DDF% - dominance after foraminifera density)

MSFD	Soft bottom sediments	
	Depth 20 - 50 m	
GES	Nematoda (DDN%) ≤ 50	Foraminifera (DDF%) ≤ 30
Non - GES/Not - GES	50 > Nematoda (DDN%)	30 > Foraminifera (DDF%)

In total, 15 taxonomic groups of meiobenthos were identified in Ukrainian waters. According to the proposed indicators for assessment the data indicated that four NPMS UA stations (Nos. 6, 7, 12, 15) are in poor condition (Not-GES), while the other NPMS UA stations are in good condition (GES). In the meiobenthic community of NPMS GE 13 taxonomic groups were found. The data indicated that NPMS GE stations Nos. 1, 4, 6, 7 are in the 'poor' condition (Not-GES), whereas the other stations were in good condition (GES). On the stations of NPMS carried out in the Kerch Strait were found 14 taxonomic groups. The data indicated that five stations in the Kerch Strait (Nos. 1, 4, 6, 10, 19) were in poor status (Not-GES) and the other stations were in good status (GES).

The multivariate indices AMBI and M-AMBI proved to be reliable tools suitable for assessment of environmental status of the investigated areas. They can be used to assess GES at various spatial scales (from station to habitat or ecosystem). AMBI and M-AMBI indices are largely used at the EU level and therefore intercomparison of assessments in a wider European scale is possible. The reliability of assessment by AMBI and M-AMBI would certainly further increase if there would be a joint effort to set common thresholds for ecological status assessment by all Black Sea countries.

Despite the macrozoobenthic populations in the Black Sea underwent critical periods especially in the 80 - 90's, based on the current results and similar studies carried out in recent years, it seems that the resilience capacity of macrobenthic communities has been mantained at a level that led to slight improvement of quality status of benthic habitats.

Macrophytes

Within the framework of the MFSD new approaches and indicators are being actively developed that give opportunity to use the macrophytobenthos community for assessment of Ecological Status Class (ESC) of Europe's seas coastal ecosystems. In the last decade two main approaches dealing with so called 'Ecological Status Groups' and 'morphofunctional indicators' have been applied to assessment of ESC for the national coasts of Bulgaria, Romania, Turkey and Ukraine. The first attempt for assessment of ESC with the use of morphofunctional indicators for national coasts of Georgia and the Russian Federation was conducted within the framework of EMBLAS-II project. A status of the precious Black Sea Zernov's Phyllophora Field (Fig. 12) was investigated as well.

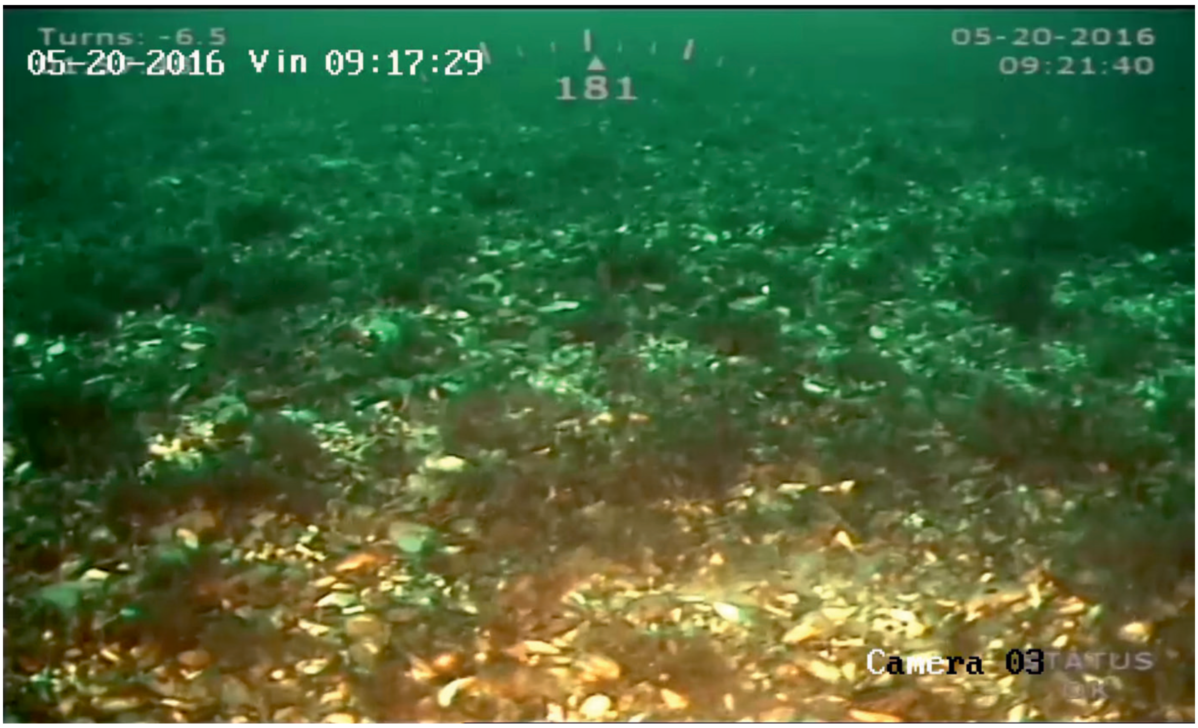
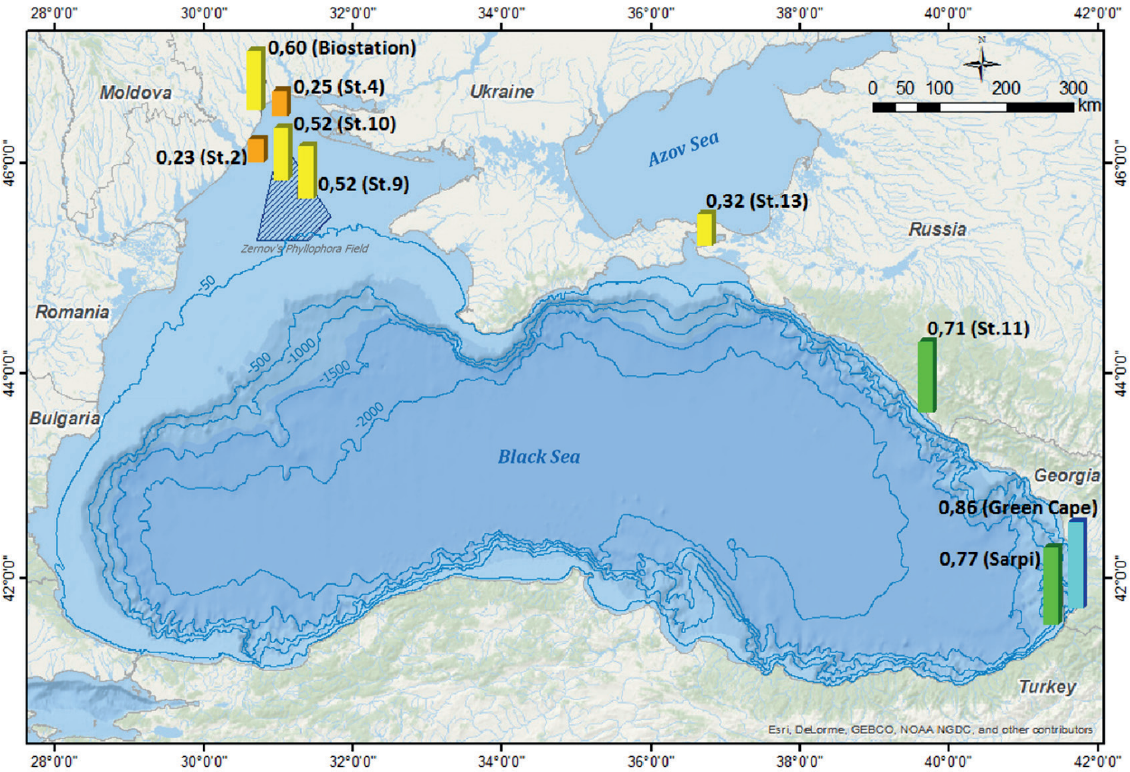


Figure 12. Distribution of macrophytes at the Zernov's Phyllophora Field (NPMS UA - Stations Nos. 9, 10).

Among the 51 species of macrophytes registered on the monitoring sites representing coastal and shelf habitats of Ukraine, Russian Federation and Georgia were noted 11 sensitive species macrophytes; the rest were tolerant.

Figure 13. Distribution of the Ecological Status Class (ESC) categories and Ecological Quality Ratio (EQR) values at the investigated sampling sites in Ukraine, Russian Federation and Georgia.

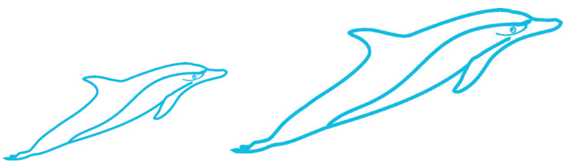


The ratio in the floristic composition of sensitive and tolerant species showed that the most favourable ecological conditions are characteristic for the eastern coast of the Black Sea (sampling sites in the Russian Federation and Georgia: Sochi and Batumi coasts; Fig. 13). The north-western part of the Black Sea and areas adjacent to the Kerch Strait are in lower ESC categories due to the influence of big rivers (Danube, Dnieper, Dniester) and the Azov Sea as well as secondary eutrophication of the shelf zone. Integrated ESC assessment shows that the most favourable environmental conditions among the studied sites were at Green Cape (Georgia; 'high'; EQR - 0,86). Lowest categories of the ESC were noted for the Ukrainian sector in the Dniester region (NPMS UA, St. No. 2) and the Waste Dumping region (NPMS UA, St. No. 14; 'poor'; EQR - 0,23-0,25).

Marine mammals

Large-scale studies of cetacean distribution in the Black Sea are required for scientific, conservation and management purposes according to the MSFD, complying with the defined indicators within the Descriptor 1: 'Marine mammals actual range', 'Marine mammals natural range', 'Marine mammals population dynamics' and 'Marine mammals status'.

During the JBSS were encountered 516 groups (2,561 individuals) of all three species of the Black Sea cetaceans (Fig. 14).



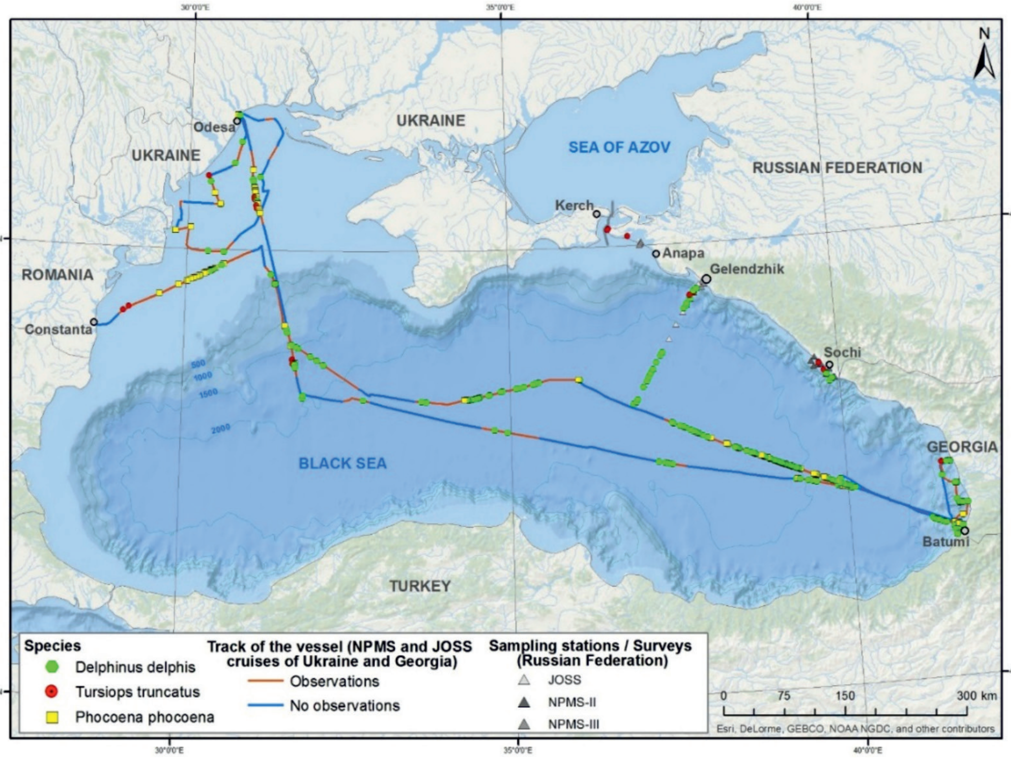


Figure 14.
Marine mammal encounters during the JBSS in 2016.

Cetaceans were encountered mainly in the single-species groups, but joint group of common dolphins and juvenile harbour porpoise was detected in the offshore waters of the southeastern part of the Black Sea (Fig. 15).

Figure 15.
Joint group of common dolphins and juvenile harbour porpoise encountered in the offshore waters of the southeastern part of the Black Sea.

The JBSS results inform the EU Member States and also the international organisations that have a responsibility for and interest in the conservation of cetaceans in the Black Sea waters. The low encounter rates of the endangered harbour porpoises and particularly bottlenose dolphins cause certain concern. The pilot study allowed to identify areas of predicted high density of marine mammals. This knowledge will be used in the design of the future line transect surveys for the Black Sea cetacean abundance estimates. Photographs of the individually distinguished common dolphins will contribute to the photo-identification catalogues of the Black Sea cetaceans.

Microbial communities

The JOSS GE-UA data on microbial communities offered a unique opportunity to describe Black Sea marine microorganisms on different depths in relation to chemical parameters. This was the first large-scale metagenomic survey of microbial communities in the region, and resulted in the development of novel efficient monitoring techniques and establishment of regional databases. From a legal point of view the investigations of microbial communities were closely related to the below Descriptors/Indicators/Criteria relevant to the MSFD.

MFSD Descriptors		Indicators
1. Biodiversity	1.7. Ecosystem structure	1.7.1. Composition and relative proportions of ecosystem components (habitats, species)
4. Food webs	4.3. Abundance/distribution of key trophic groups/species	4.3.1. Abundance trends of functionally important selected groups/species

Descriptor 4. *All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.*

In total, 69 sea water samples from 12 stations and 30 sediment samples from 5 stations were collected during the JOSS GE-UA. The samples were taken from the following depths: surface, thermocline, deep chlorophyll-a maximum, nutrient maximum, oxygen minimum and H_2S zone. Nutrient maximum was defined as the layer, at which the concentration of nutrients (PO4) was particularly high relative to the other depths at the station, and oxygen minimum layer was at the depths, where the concentration of O_2 was less then 2 mg/l. The samples were processed at the National Institute for Marine Research and Development "Grigore Antipa", Constanta, Romania.

The data on microbial communities class and genera relative abundance suggested a clear pattern, which was in accordance with the distribution of chemical parameters at the different depths sampled (Table 2).

The genera abundant at surface and thermocline were responsible for carbon and nitrogen cycling and dependent on light and aerobic conditions. The samples from oxygen minimum were characterised by the presence of sulfur oxidising bacteria and green sulphur bacteria, which have narrow econiche and cluster at chemocline. The genera abundant in H_2S zone were characterised with varying metabolic strategies, yet they all benefit from the presence of H_2S. The microbial communities at this layer featured sulfate-reducing, denitrifying, anaerobic ammonium oxidating and organohalide-respiring bacteria. The sediments samples were strongly dominated with organohalide-respiring and sulphate reducing bacteria, and included genera known to play a role in carbon cycling. **In other words, good news - organic pollutants sinking into the bottom of the sea can be degraded and thus do not accumulate in sediments.**

Table 2.
Numbers of classes and genera observed at various sampling depths.

Layer	Number of classes	Number of genera
Surface	11	28
Thermocline	12	29
Fluorescence maximum	12	22
Nutrient maximum	12	25
Oxygen minimum	13	16
H2S	16	18
Sediments	20	15
Total	30	61

3.1.2. DESCRIPTOR 2: Non-indigenous species (NIS)

Descriptor 2. *Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem.*

The final report of the MISIS project suggested that the **biomass of comb jelly *Mnemiopsis leidye*** is used for the assessment of the quality of the marine environment. The poor quality of the environment ('Low Environmental Status' (LES) or not Good Environmental Status (Not-GES)) for the comb jelly biomass is considered when the threshold value of 3 $g \cdot m^{-3}$ (120 $g \cdot m^{-2}$) is exceeded. The threshold of the second indicator reflects the **ratio between NIS and native species as 10% of abundance or biomass of pelagic organisms** and this threshold should not be exceeded in order to suppose that the investigated area is in Good Environmental Status (GES). JBSS report focused on zooplankton data since the information on phytoplankton, macrophytes and macrozoobenthos was not fully processed yet. Despite that, two species of the Black Sea invasive macrophytes were recorded on the shelf zone of the Ukrainian sector and on the Zernov's Phyllophora Field of which, rather alarming is the discovery of *Ch. tomentosa* at St. No. 2 of the NPMS UA as it was found only second time in the Black Sea ecosystem (Figs. 16 and 17).

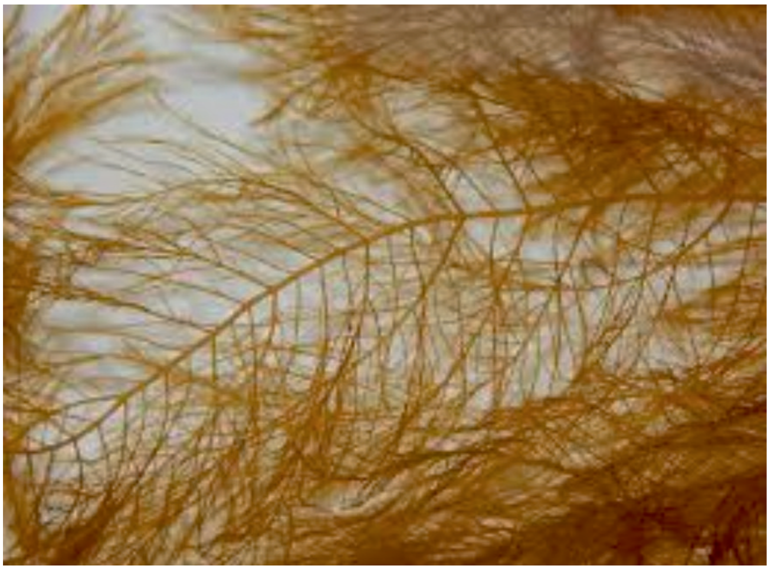


Figure 16.
Invasive species - Desmarestia viridis from St. Nos. 9, 14; NPMS UA.

Figure 17.
Invasive species - Chorda tomentosa from St. No. 2; NPMS UA.
Second official discovery in the Black Sea.

Several indices such as CB – biomass of Copepoda, N.sci. - biomass of *Noctiluca scintilans*, SH – Shennon-Weaver index (measure of total biodiversity) and NIS - biomass of non-indigenous species were tested. The results (Table 3) showed that for mesozooplankton, Not-Good Environmental Status was recorded at all (100%) sampling stations in Ukrainian shelf and Georgian waters, and at 42% of stations in the open sea area.

Table 3. Results of water quality assessment on various characteristics of zooplankton including biomass of non-indigenous species of copepods in the upper layer of the Black Sea.

Zooplankton characteristics	Stations with LES, %		
	NPMS UA	**JOSS**	**NPMS GE**
Mesozooplankton biomass, mg·m^{-3}	100	42	100
Copepoda biomass, %	60	58	43
N. scintillans biomass, %	27	58	14
Non-indigenous copepoda specias biomass, %	73	58	93
Non-indigenous comb jelly *M. leidye*, g·m^{-3}	0	0	0
Average	52±18	43±11	50±20

The results should obviously be complemented by observations of gelatinous plankton, first of all quantitative development of *Mnemiopsis leidye* and *Beroe ovata*. Their peak occurrence will hopefully be monitored during the EMBLAS August-September 2017 surveys.

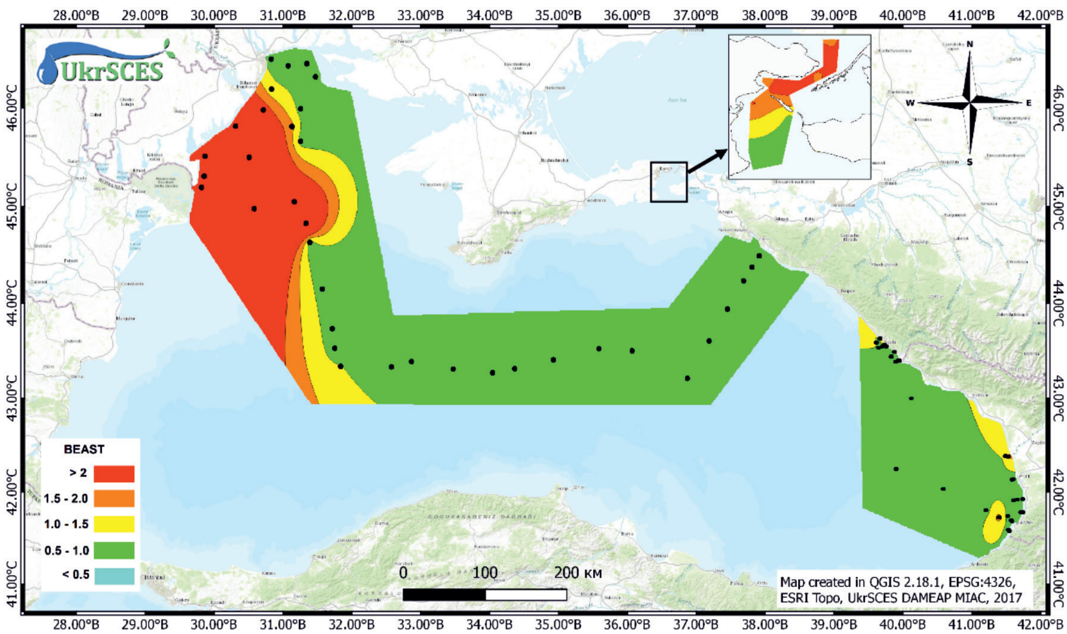
3.1.3. DESCRIPTOR 5: Eutrophication

Descriptor 5. *Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters.*

The application of **BEAST and E-TRIX methods** for the assessment of the level of euthrophication in the different regions of the Black Sea allowed to distinguish several areas which were in 'not GES'. While the major part of the investigated areas were in 'GES', both in the surface and deep waters (Georgian waters, Gelendzhik area at 5-miles transect, southern part of the Kerch Strait area and the large part of the North-Western Shelf UA) some waters were in 'not GES'. The surface waters influenced by the Danube discharge in May 2016 strongly 'jumped over' the 'not GES' threshold due to the large diatom bloom. Another non-compliance was recorded in the northern part of the Kerch Strait on 8 - 9 August 2016. In this case it was not the phytoplankton bloom, but high concentration of nutrients coming from the Azov Sea which was responsible for exceeding the 'GES' threshold. In general, it can be concluded that the Black Sea coastal and open waters are mostly in 'GES' with several special exclusions connected with intensive inflow from large rivers and the Azov Sea.

In long-term scaling the climate changes manifested through the alteration of the rivers hydrological regime, seawater temperature increase, intensification of the water masses stratification, winds and currents regime etc., are important influencing factors of the current eutrophication status of the Black Sea waters. The results of assessment by BEAST and E-TRIX methods of the studied area of the Black Sea are shown in Fig. 18.

a)



b)

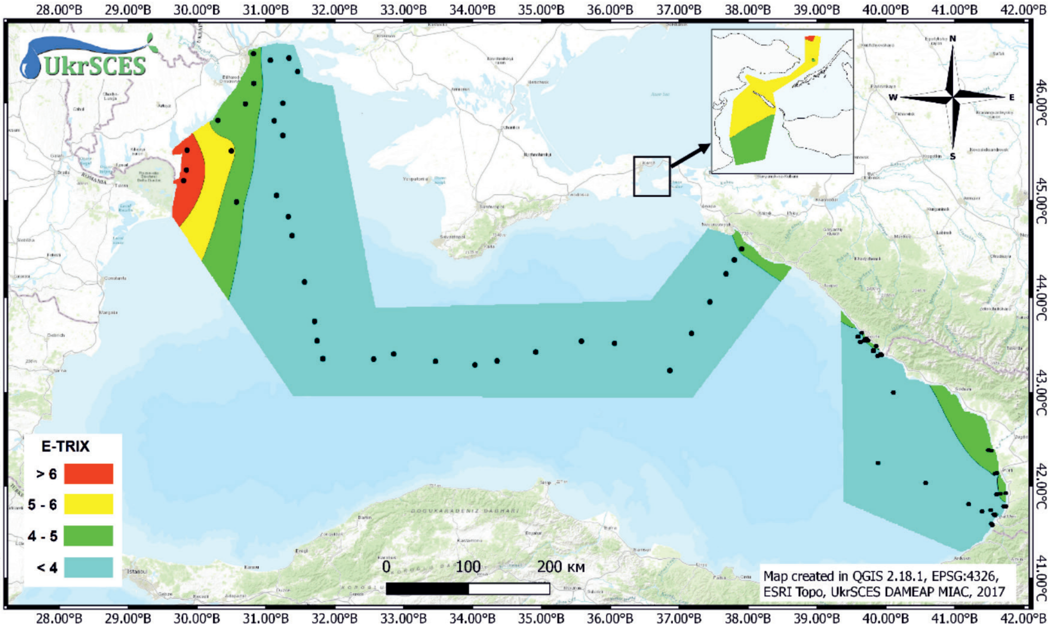


Figure 18. Assessment of the environmental status of the studied Black Sea areas in 2016 by BEAST (a) and E-TRIX (b) methods .

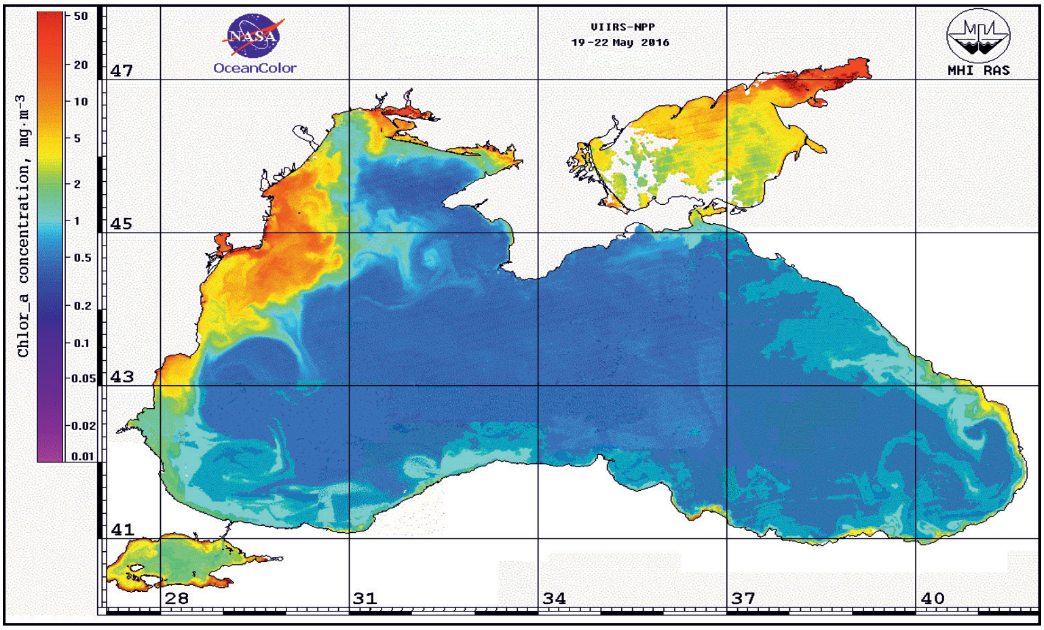


Figure 19. Composite satellite image of the chlorophyll-a concentration in the Black, Azov and Marmara Seas on 19-22 of May 2016. Red colour points represent the highest value of chlorophyll-a, yellow, green and blue show its gradual decreasing. Origin: JRC, http://marine.jrc.ec.europa.eu/.

High levels of chlorophyll-a concentration are good marker of eutrophication and point the part of sea harmed by it. **Comparison of chlorophyll-a concentration in the upper mixed layer from the satellite data (Fig. 19) and the measured values during the JBSS demonstrated high positive correlation and therefore further promoted usage of the satellite monitoring as a cost-effective monitoring tool.**

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 the Oxygen Minimum Zone (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). **There is a general lack of data in the past decades (Figure 20) to assess hypoxia and new data are badly needed.**

1980-1987 | 1988-1995 | 1996-2002 | 2003-2009

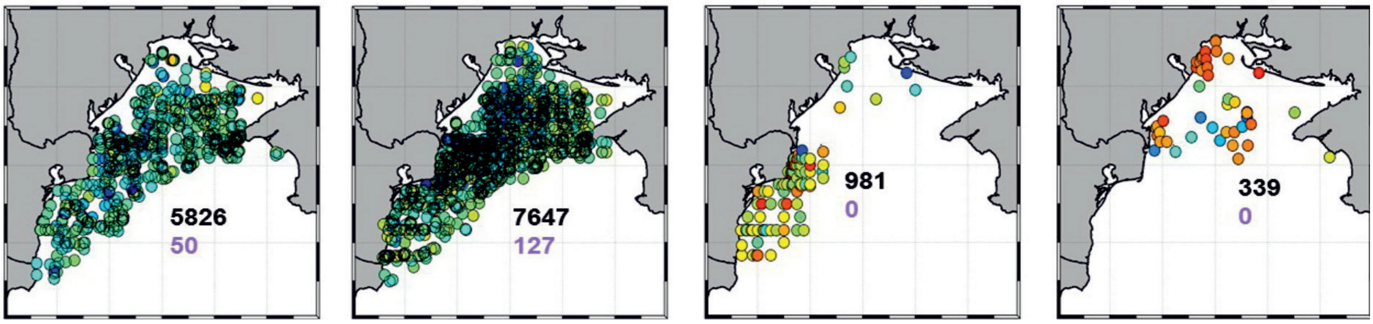
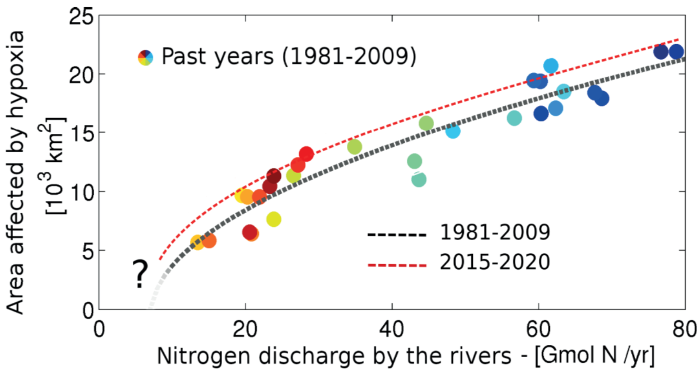


Figure 20.
Distribution of data collected during the last decades and available in the World Ocean data base. After 1995, no data has been collected in impacted areas and during periods of occurrence of hypoxia.

Microprofiling of dissolved oxygen concentration in the sediment during the JBSS 2016 showed that dissolved oxygen at the water-sediment interface, although above the hypoxic level (i.e. > 63 µmol/l), was only at about 55% saturation level at stations situated in the Danube delta area. It indicates also that on the Ukrainian shelf, the dissolved oxygen penetration depth is less than 10 mm below which the sediment is completely deprived of oxygen. This suggests high oxygen consumption rate in the benthic environment, probably due to high organic matter loading related to continental nutrient inputs.

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 assess 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 an 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 21 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). It has been shown that if one wants to keep the level of hypoxia unchanged (H constant) in the 2015 - 2020 climate, the nutrients discharged have 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 21.
Level of hypoxia, H, reached at “equilibrium” for a range of nitrate riverine load, N.



3.1.4. DESCRIPTOR 8: Contaminants in the environment

Descriptor 8. *Concentrations of contaminants are at levels not giving rise to pollution effects.*

During JBSS, a subset of 33 marine waters samples was analysed for a full range of 45 EU regulated substances - so called ‘priority substances’ and hundreds of other substances to find out potential **‘Black Sea Specific Pollutants’**. A special large-volume sampling device from DG Joint Research Centre of the EC was employed to obtain sufficient volume (20 l) of water samples to trap all substances at environmentally relevant concentration levels (see Fig. 22). Also, sediment samples (Fig. 23) were thoroughly screened for presence of pollutants in order to establish first baseline for determining ‘trends of pollution’ required by the EU legislation. **Majority of the priority substances were investigated in Ukrainian and Georgian waters, and generally in the Black Sea, for the first time.**

Leading national laboratories in Ukraine, Georgia and Russian Federation were involved in analysis of parameters included in their actual national legislation. These included metals, polyaromatic hydrocarbons, total petroleum hydrocarbons, chlorinated pesticides and PCBs which were analysed in all (55) samples. Three out of four EU regulated metals (cadmium, lead and mercury) were determined at concentrations above their toxicity threshold values (annual average environmental quality standards; AA-EQS) mainly in the samples taken from Ukrainian shelf area.

Figure 22.
Sampling device from DG JRC used for sampling of large volume (20 l) of sea water samples.

a)

b)

Figure 23.
DCh-0 sampler grab (a) and sediment samples collection (b).

Table 4. Exceedance of environmental quality standards (EQS) of WFD priority pollutants in 33 large volume water samples collected during NPMS UA, NPMS GE and JOSS GE-UA. Substances causing exceedance are listed in 'status'.

NPMS UA		Status	JOSS GE-UA		Status	NPMS GE		Status
UA_2	red	PFOS, benzo(a) pyrene, Hg	JOSS_1	yellow	Hg	GE_1	red	heptachlor/heptachlor epoxide
UA_5	red	PFOS, benzo(a) pyrene	JOSS_2	red	benzo(a)pyrene, Hg	GE_2	red	heptachlor/heptachlor epoxide, benzo(a)pyrene
UA_7	red	PFOS, benzo(a) pyrene	JOSS_9	yellow	Hg	GE_3	red	benzo(a)pyrene
UA_8	red	PFOS, benzo(a) pyrene	JOSS_10	yellow	Hg	GE_4	green	
UA_11	green		JOSS_11	yellow	Hg	GE_5	red	heptachlor/heptachlor epoxide, Hg
UA_12	red	PFOS	JOSS_13	red	benzo(a)pyrene, Hg	GE_7	yellow	Hg
UA_13	green		JOSS_16	yellow	Hg	GE_8	green	
UA_14	red	PFOS	JOSS_19	green		GE_9	red	heptachlor/heptachlor epoxide, benzo(a)pyrene
UA_15	green		JOSS_23	green		GE_10	green	
			JOSS_25	red	PFOS, benzo(a) pyrene	GE_11	red	benzo(a)pyrene
						GE_12	green	
						GE_13	red	benzo(a)pyrene
						GE_14	green	
						GE_15	red	benzo(a)pyrene

Hexachlorocyclohexane (HCH) - the sum of concentrations of all HCH isomers exceeded the limit value (annual average (AA)-EQS (2 ng/L)) at 27 out of 33 sampling stations (with the exceeption of stations Nos. NPMS GE 3, 14, JOSS 25, NPMS UA 5, 12, 13) - not shown since the limit value is established only for gamma isomer of HCH;

Concentrations of metals were below their AA-EQS in all cases; Hg - no water EQS in the Directive 2013/39/EU, Hg tested in biota samples exceeded EQS but sampling locations differ from those in the table;

Yellow colour - Hg assessed according to the Directive 2008/105/EC referring to its limit value in water (50 ng/L); this has changes in the update of the Directive in 2013, in which the limit value has been established only for concentration of Hg in biota;
Red colour - Not-GES;
Green colour - GES.

The results showed omni-presence of polyaromatic hydrocarbons (PAHs) originating from oil spills by ship traffic; they were represented by an indicator compound benzo(a)pyrene, which was determined in all samples and at thirteen stations quantified over its limit value. The toxic threshold value was often exceeded by the persistent and bioaccumulative perfulorinated substance **PFOS** with the highest concentrations recorded at sampling stations affected by the Danube river. This compound, frequently used as water repellent in outdoor textiles and shoes or as a coating of paper cups/boxes (e.g. pizza), was present at high concentrations also during the Joint Danube Survey carried out in 2013. Most of the searched for pesticides were determined below their toxic threshold values. However, in samples from Georgian coast were found high concentrations of **heptachlor and heptachlor epoxide,** which indicates local sources of these pesticides. The sum of old pesticide **hexachlorocyclohexane** (HCH), which is banned for use for a long time, exceeded the limit value at 27 out of 33 investigated sites and the presence of this substance in the Black Sea environment should be carefully monitored.

Despite the results from the surveys are only indicative, **all of the above exceedances of regulatory values should be re-confirmed in order to start with the programme of measures at the regional and national level.**

In order to find the region specific substances, next to those regulated at the EU level, were all water and sediment and biota samples screened for presence of additional **2041 target substances** of emerging concern. The list contained all substances considered important in the other European Seas and other most frequently detected substances in the European aquatic environment including pharmaceuticals, personal care products, pesticides, biocides, industrial chemicals, their transformation products etc. Out of these chemicals, **145 were detected** in at least one sample and subsequently toxicity threshold (PNEC) values were derived for all of them; 18 out of these 145 compounds were popping out when the concentrations of pollutants was close to or exceeded toxicity limit values. Among these substances was **imidacloprid,** which belongs to the group of a systematic pesticides/insecticides used for treatment of domestic pets to control fleas; **dinoterb**, a herbicide for controlling annual broad-leaved weeds post-emergence in cereals, and corn; **metolachlor**, a herbicide used for grass and broadleaf weed control in corn; **fipronil,** a broad-use insecticide, however, being toxic to fish and bees. Another group of compounds were pharmaceuticals: **adenosine**, as an antiarrhythmic agent; and **telmisartan**, used for the treatment of essential hypertension. Several industrial pollutants were determined at elevated concentrations: **bisphenol A**, an endocrine disruptor which is contained in a variety of common consumer goods, such as plastic bottles, sports equipment, CDs/DVDs etc.; **dibutyl phthalate**, which is a commonly used plasticizer and a suspected endocrine disruptor and **monobutyl tin compounds** often used as a polyvinyl chloride (PVC) stabilizer. Toxic threshold limits of flame retardant **tritolyl phosphate** (TMPP), sun screen agent **ethylhexylmethoxycinnamate** (EHMC; found close to the

Georgian coast at station No. NPMS GE 3) and **polychlorinated biphenyls** (PCBs) were exceeded at several stations and therefore these substances should be included in future investigative monitoring programmes. **Organophosphorus compounds** (OPCs), **new generation flame retardants** being commonly used instead of already regulated polybrominated compounds, were detected at each site. The sum of the concentrations of all OPCs was highest at the area close to the Danube estuary, however, the highest exceedances of the available PNEC values were observed for one of the OPCs (TMPP) at the Dniester region and in Georgian waters.

The results were useful also in terms of indicating pollution patterns by specific substances, e.g., increased concentrations at the estuaries of large rivers, next to large ports, country specific, etc. (see Figs. 24 and 25).

All mentioned compounds should be of interest for the policy makers to include it in the future monitoring programmes and, eventually, if adverse effects on fauna and flora are confirmed, into the legislation. The results might be of interest also for the wide public, because there is a clear correlation between our daily waste management behaviour and pollution in the sea.

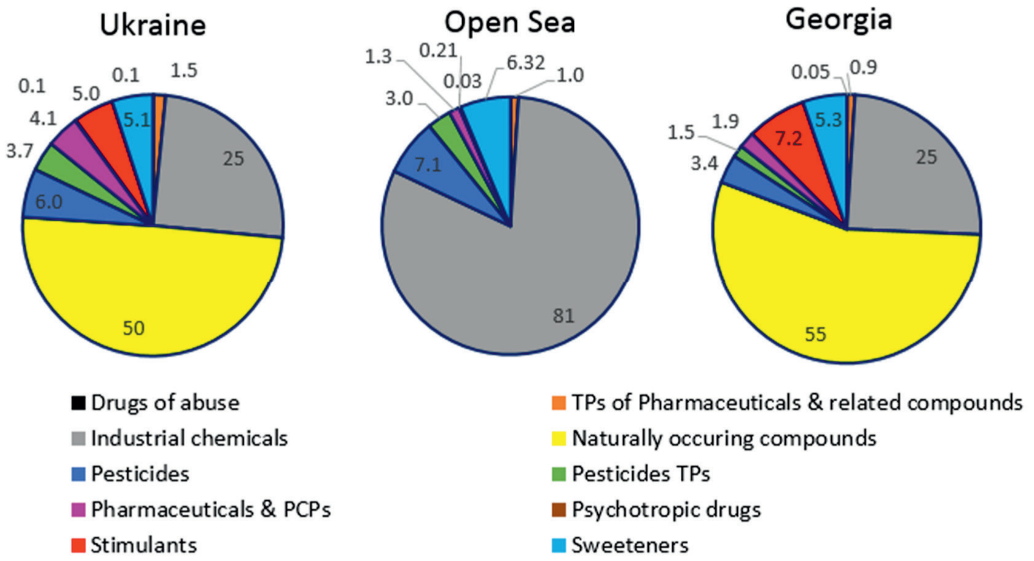


Figure 24. The distribution of the detected classes of emerging pollutants in seawater samples from Ukrainian, Open Sea and Georgian area, May/June 2016.

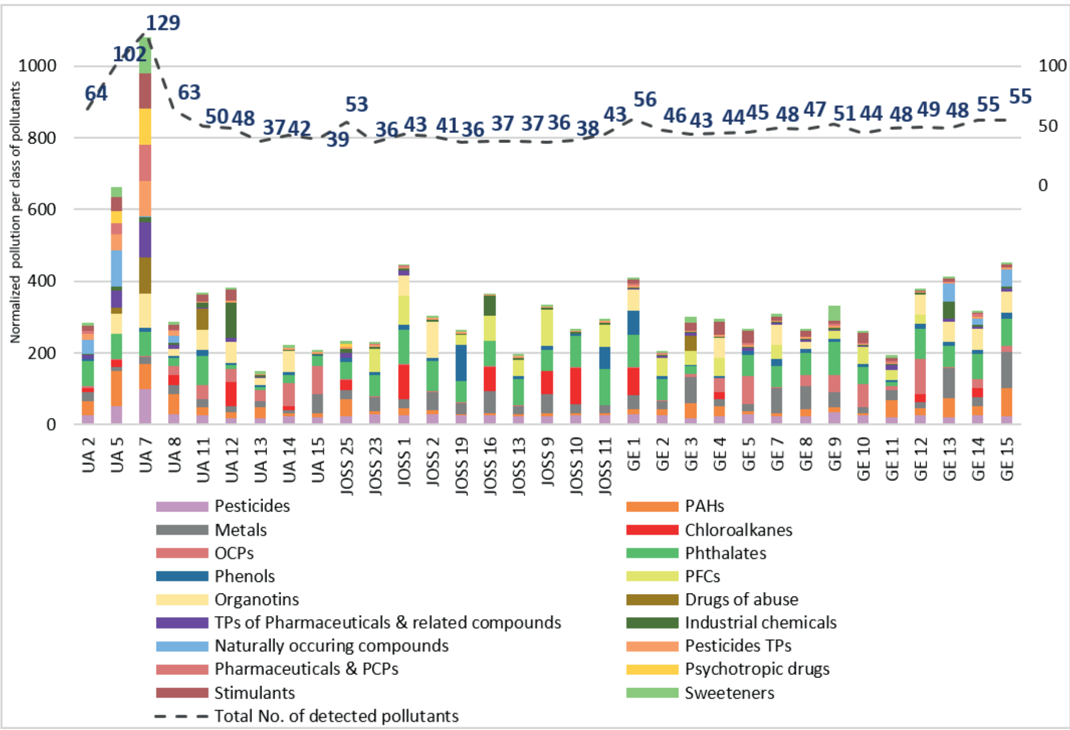


Figure 25. Normalized pollution cumulative chart for seawater samples from Ukrainian, Open Sea and Georgian area, May/June 2016.

Digital Sample Freezing Platform

Each environmental water sample contains typically several hundreds of substances. In order to preserve environmental samples (e.g. fish, top predators, sediments, leaves etc.) for the future, in some countries they are stored at very low temperatures for decades in Environmental Specimen Bank, so that later the samples can be re-analysed, e.g. in order to check if the policy banning the use of some of the toxic pollutants was successful. In JBSS a new way of preserving of the samples was developed, called **"Digital Sample Freezing Platform".** For this, samples of Black Sea water, sediment and biota were analysed with liquid chromatography – high resolution mass spectrometry and stored - not at low temperature but in a data storage place (cloud). The process is similar to **taking fingerprints** of all of the 2-3 thousand of substances which are typically present in each sample. Sometimes the name of the 'suspect' contaminant whose signal is recorded is not known, but we know that the substance is there (exact mass unique for each chemical compound) and we have its fingerprint (mass spectrum). Any of the thousands of 'digitally frozen' substances can be searched for retrospectively without the need for expensive re-sampling. Also, the samples can be put on the map to see **pollution patterns** of pollutants of interest, e.g. if the compound is everywhere (diffuse pollution) or just around one place – potential source of pollution, which can be then targeted by localised programme of measures. An example of a typical retrospective analysis is shown in Figure 26. Valtarsan - pharmaceutical of which we did not know it is present in samples and thus did not search for it was identified later on and then shown (via modelling) how is is distributed in the Ukrainian shelf.
Methodologies already exist how to identify an unknown contaminant **(to turn an 'unknown' to 'known')** and to see whether its measured concentration is above or below the toxicity threshold value. Pollutants exceeding the toxic threshold value should be then included into Surveys monitoring. Using the samples collected during Joint Black Sea Surveys, such repository of digitally frozen samples with fingerprints of toxic substances was initiated. The repository "Black Sea dataset", includes now more than 17000 'fingerprints' and its is **the first one available globally**. The dataset is planned be enlarged in the next years by the national datasets from France, Norway and Germany through NORMAN network (www.norman-network.net).

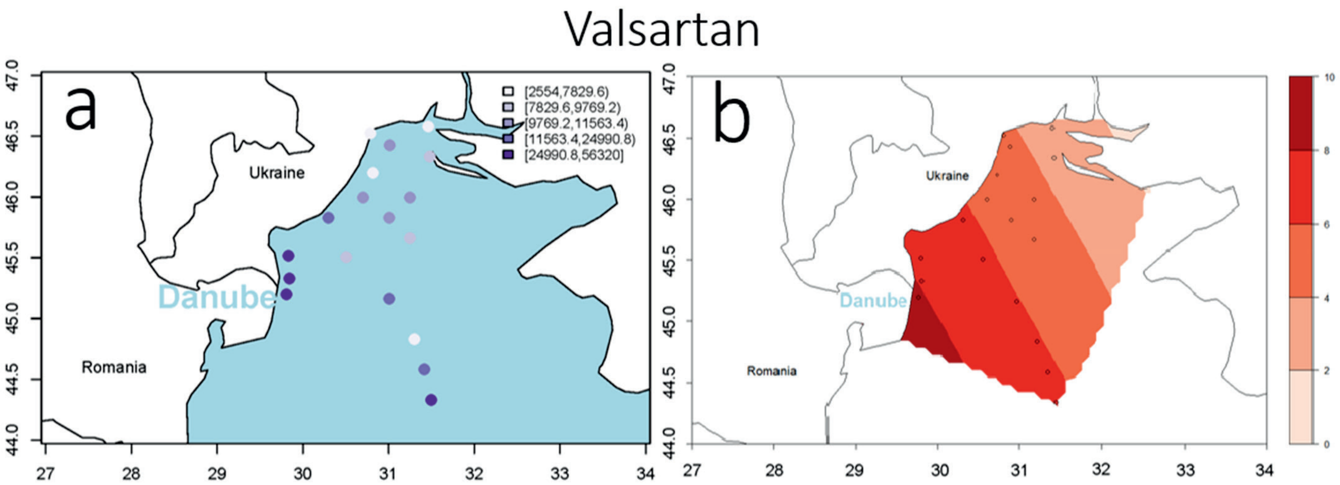


Figure 26.
a) Map of the NPMS UA sampling stations,
b) simulated distribution of concentrations of Valtarsan - the higher intensity of red colour, the higher the concentration.

Passive sampling of organic pollutants

The passive sampling data collected during the JBSS provided very useful information on the occurrence and typical levels of several classes of trace organic pollutants in surface seawater of the Black Sea. As the ship was moving across the sea, water was pumped on its board and pollutants present in the water were continously trapped on sorbents of the passive sampler (see Fig. 26). These sorbents containing 'chemical information' of several hundreds of km stretches of the Black Sea were sent later on for an analysis in a specialised laboratory. Additionally, passive samplers were submerged in the Odessa bay and at the Zmeiniy island in Ukrainian waters for several weeks to trap pollutants present in the water at that time.

Numerous perfluorinated substances were determined in the sea water samples; among them also **PFOS**, which is already a regulated substance in the EU. These compounds were also reported to be present in surface seawater in other studies. Pharmaceuticals such as **carbamazepine, paracetamol and sulphamethoxazole** were present in the samples, as well as the mosquito repellent DEET. Elevated concentrations of paracetamol were observed at the static sampling sites in the Ukraine`s territorial waters and higher levels of **caffeine** were found especially in the open sea areas. Also, quite some polar pesticides belonging to groups of herbicides, fungicides and insecticides were found to be present all around the investigated areas.

The study targeted also polybrominated diphenyl ethers (PBDEs) and **novel flame retardants (NFRs),** chemicals present in high amounts (tens of per cents of the total weight) in various products around as, such as textiles, plastics, furniture etc. The concentrations of already regulated PBDEs measured during the JBSS were somewhat lower than those measured by passive sampling in

2012 in the Aegean Sea. **Regarding NFRs, eight compounds** (pentabromobenzene, pentabromotoluene, hexabromobenzene, 1,2-bis (2, 4, 6-tribromophenoxy) ethane, syn- and anto-dechlorane plus, α- and β-tetrabromoethylcyclohexane) **were found in the samples. To our knowledge this was the first concentration data reported for NFRs in seawater using passive sampling.**

The concentrations of the notorious polychlorinated biphenyls and organochlorine pesticides were about one order of magnitude lower than those reported from passive sampling performed in the Danube river water during the Joint Danube Survey 3 (2013) and comparable with concentrations measured by passive sampling in 2012 in the Aegean Sea.

Passive sampling has been confirmed as a robust technique that enables to detect pollutants at sub ng/l level without the need of complex sampling equipment or laborious sampling operations (e.g. active extraction of large volumes of seawater). During the campaign local staff from the Ukraine and Georgia has been trained in deployment of passive samplers in surface seawater, which enables to perform further sampling studies according to a good practice without the need of on-site assistance from passive sampling experts. This first investigative monitoring campaign serves as a good starting point for future sampling campaigns. In future, data with an increased spatial resolution could be obtained by deploying passive samplers at multiple static sites or along defined transects using available infrastructure (e.g. buoys, offshore installations, opportunity ships).

Figure 27.
Above: passive samplers mounted in the onboard sampling device.
Right hand side: Passive samplers for static deployment (silicone rubber sheets, POCIS and Empore® SDB-RPS disks), mounted in their deployment frames.

3.1.5. DESCRIPTOR 8 and 9: Concentration of contaminants in fish and seafood

***Descriptor 9.** Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.*

Following the regulation, 11 out of the 45 priority substances were searched for also in biota (fish and mussels) samples. The maximum threshold levels were exceeded in fish samples for **dioxins and dioxin-like compounds** (Table 5) and **mercury,** which are persistent, bioaccumulative and toxic for mammals. The exceedance of mercury limit values in fish fits into an overall European picture received over the last few years. Exceedance of mercury concentrations was also observed in molluscs (*Rapana venosa*) samples at the Ukrainian shelf.

Table 5. Results of analyses of dioxins and dioxin-like compounds in biota samples, expressed as toxicity equivalent (TEQ).

Biota sample	µg/kg TEQ	EQS in the Directive 2013/39/EC (µg/kg TEQ)
Fish, GE (Batumi), muscle	0.631	0.0065
Round Goby, UA (Odessa bay), muscle	0.125	
Round Goby,UA (Zmiinyi island), muscle	0.158	

In order to find the region specific substances, next to those regulated at the EU level, were all biota samples screened for presence of additional **2041 target substances** of emerging concern. Numerous substances of environmental concern were detected in the fish tissue and molluscs (Figs. 28 and 29). Further analysis of this information is needed to find out which of the substances might be harmful to humans.

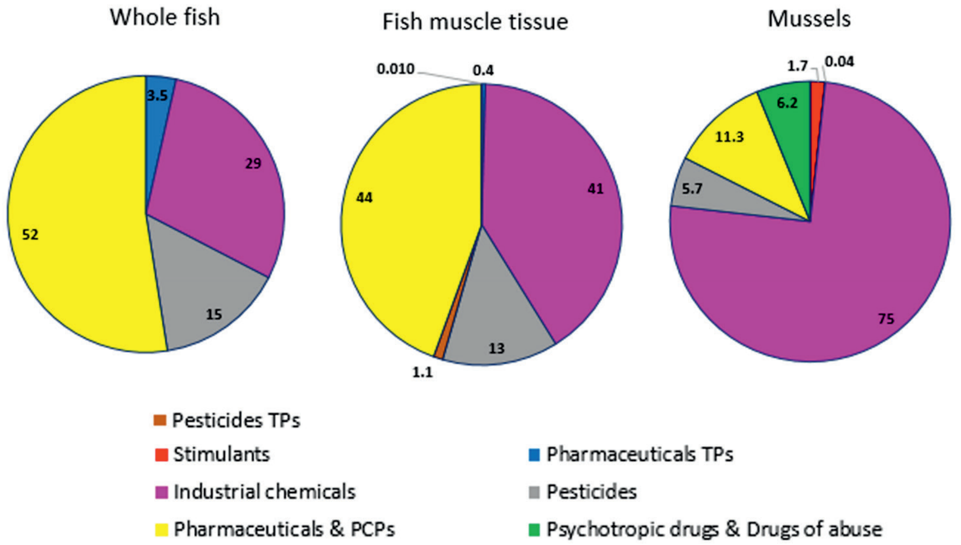


Figure 28.
The distribution of the detected classes of emerging contaminants in biota samples from Ukrainian and Georgian area, May/June 2016.

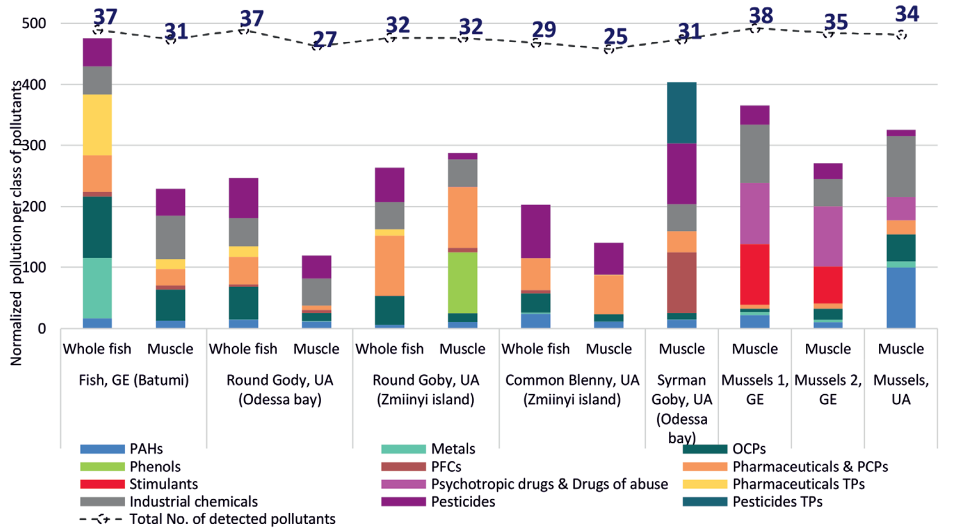


Figure 29.
Normalised pollution cumulative chart for biota from Ukrainian and Georgian area, May/June 2016.

3.1.6. DESCRIPTOR 10: Marine litter

Descriptor 10. *Properties and quantities of marine litter do not cause harm to the coastal and marine environment.*

Marine litter has been recognised as threat for marine wildlife by the MSFD, the Regional Sea Conventions and by international provisions, such as the UN Sustainable Development Goal 14. Monitoring data are needed in order to assess the spatial distribution of litter in the different environmental compartments and to identify the sources of litter in order to plan appropriate and efficient measures.

Litter can occur in the marine environment in different matrices. It can be deposited by local littering or be deposited by wave action from the sea to the seashore. Dense items can reach the seafloor, while floating litter can enter the sea also through rivers and stay afloat at sea. All are subject to physical degradation into micro litter. Most of the marine litter is plastic material from different sources. Through natural degradation the floating litter tends to decompose into small particles called microlitter (most of which consists of microplastics), which is then often consumed with the food by marine inhabitants causing harmful toxicological and physical effects. Here, the waste management behaviour of general public should be addressed.

Floating litter at sea was monitored during JBSS by observation from vessels, using the JRC Tablet Computer Application "Floating Litter" and according to the 'Guidance on Monitoring of Marine Litter in European Seas' (DG JRC), during the transect between sampling stations. The tablet application allowed for transmission of the recorded data into the BSC and JRC RIMMEL database.

Floating litter in rivers was monitored from bridges by trained observers every two weeks since September 2016, using the same JRC Tablet App, and contributing also to the BSC and Riverine Litter Observation Network organized by JRC RIMMEL project.

Beach litter monitoring was carried out by each country separately during summer activities and was combined as well with public awareness raising activities in autumn during the Black Sea Clean Beach Day on 23 - 24 September in Ukraine, 28 - 29 October in Russian Federation and 30 - 31 October 2016 in Georgia, where all EMBLAS countries had an opportunity to test the European Environment Agency (EEA) software application for beach litter monitoring (Marine Litter Watch App).

JBSS revealed that marine litter is present in all Black Sea areas (Fig. 30), being dominated by covers/packaging, plastic bags, small plastic pieces, polystyrene items and foam, and that the concentrations of litter in some areas are extremely high. In general, the pollution of Black Sea with marine litter seems to be significantly higher compared to other European seas. This requires urgent follow-up actions for confirmation and measures. Organisation of monitoring campaigns and rigid implementation of the agreed common monitoring protocol and reporting still need to be improved.

Figure 30.
Map of floating marine macrolitter observed during JOSS GE-UA.

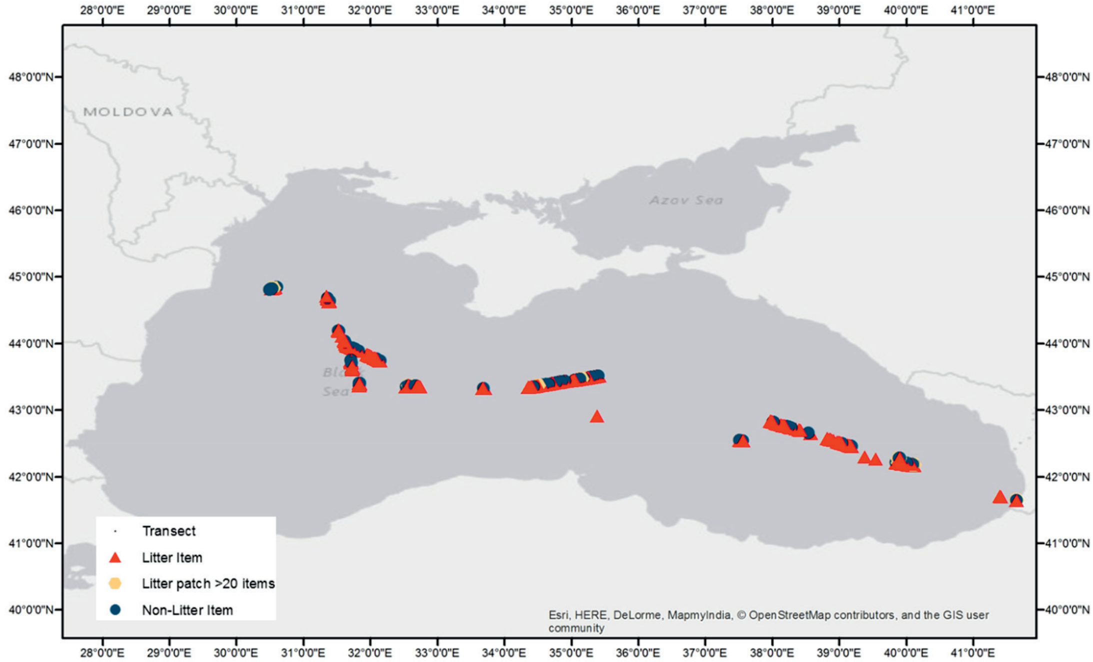
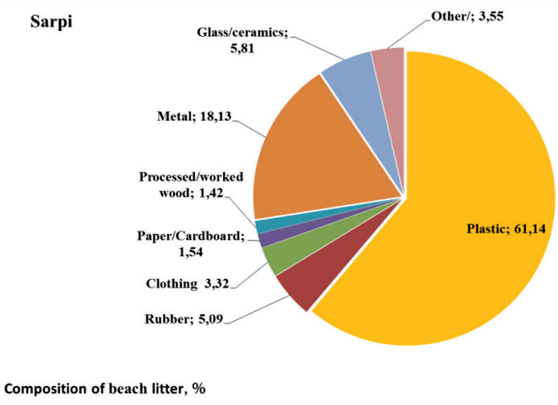


Figure 31.
Map with selected rivers monitored for input of the floating river into the Black Sea.

Concentrations on the beaches and the sea surface are very variable. A typical composition of the waste on Georgian beaches is shown in Figure 31.



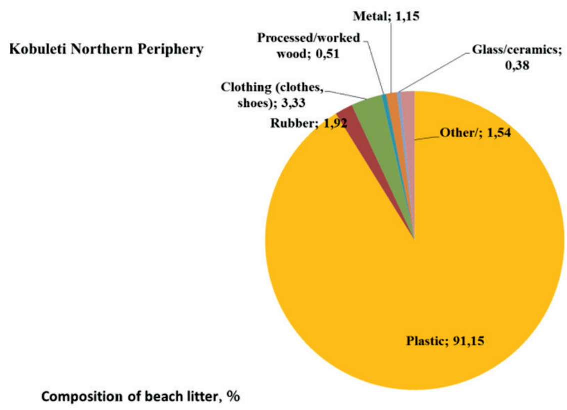


Figure 32.
Composition of beach waste atSarpi, Georgia.

Figure 33.
Beach waste composition at Kobuleti, Georgia.

Acknowledgements

The Joint Black Sea Surveys would not have been possible without the help of many institutions and passionate individuals. Technology, logistics and laboratory support were driven by their involvement and a comprehensive list of all the people that helped to conduct the survey would be longer than this report.

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Instead of Afterword

In 2017 the Joint Black Sea Surveys will be held again with new survey programme. A new automated marine litter counting device (camera on the bow of the ship) should be tested for the first time and a super-large sample volume collecting device (up to 500 l) water both from JRC Ispra would be applied. A link between bacteria and reduction of chemical pollution in deep parts of the sea (down to 2000 m) should be studied. The microplastics and eDNA studies will be conducted as well. Also, investigations in the coastal zones in the newly delineated water bodies will be a priority to find out about compliance of their chemical and ecological status with the requirements of the Water Framework Directive.

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