Climate Change: A Challenge for the Black Sea Biodiversity, Requires International Cooperation

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Abstract: The Black Sea is a direct link between the European Union and Asia, being a complex geopolitical region. Mutual respect through good neighborly treaties and continued cooperation are needed to achieve regional environmental goals. This paper reflects the importance of ongoing cooperation in resolving new issues that have arisen in recent decades. Coastal erosion followed by the collapse of rocks as a result of small earthquakes in deep water, water pollution due to maritime accidents or municipal and industrial wastewater discharges, eutrophication, pelagic fishing and climate change with thermal, chemical and biological changes in the composition of seawater , these are just a few issues that need to be addressed. At the beginning of the paper, some experimental measurements are briefly presented to highlight the current situation regarding the sources of pollution. The high concentration of hydrocarbons and ions is the cause of the appearance and overdevelopment of invasive marine species. A special paragraph illustrates in parallel some endangered species and some invasive species. New rules on fisheries regulation need to be implemented. A healthy Black Sea environment is a priority for the whole of Europe.

1 INTRODUCTION

The Black Sea, with an area of about 440,400 km^2, is considered a deep sea with a maximum depth of 2,212 m. Located between Europe and Asia it is surrounded by the Pontic Mountains, the Caucasus and Crimea to the south, east and north, the Strandzha Mountains to the southwest and Dobrogea plateau in the northwest. Romania, Bulgaria, Turkey, Ukraine, Russia and Georgia are the countries bordering the Black Sea, (EU Commission, Black Sea, 2018). Some large rivers, such as the Danube, the Southern Bug, the Dnieper, the Rioni and the Dniester, which flow here, are the main source of fresh water (Black Sea Commission, 2021). The Black Sea through the Bosphorus Strait is connected to the Marmara Sea and through the Dardanelles Strait to the Aegean Sea, the Crete Sea and the Mediterranean Sea. On the opposite side through the Kerch Strait is connected to the Sea of Azov (EU Climate ADAPT, 2017).

In the last two decades, the Black Sea has faced some unexpected problems caused either by natural causes or by human interference. An increase in the number of small earthquakes recorded in deep waters, on the border between Romania and Bulgaria, has led to the appearance of freshwater currents that locally affect the composition of seawater. Additionally, there was local erosion, followed by sand deplacement and landslides of 2-3 m high shores in the area of Mangalia, 2 Mai, and Vama Veche, and even 10 m near Eforie Nord (Black Sea Diagnostic Report, 2010). As a result, the beaches have shrunk and the number of tourists has decreased, even in normal years, but especially now during the pandemic, when it is necessary to maintain social distance.

Thus, new ecological problems have arisen due to unsustainable development and inadequate freshwater quality management in the main rivers Danube and Dnieper (Zaitsev 2006). Wastewater and solid waste discharged as a result of urban and industrial activities, inadequate land management and agricultural practices play a major role in the Black Sea environment (Boltachev, Karpova, and Danilyuk, 2006). They have direct consequences on surface and groundwater pollution, eutrophication and

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accelerated biodiversity degradation in the area (Dobrovolov, Ivanova, and Apostolu, 2003). Discharges into the seawater of residual substances from urban wastewater treatment plants of petroleum substances from ports and shipyards or from shipwrecks have also affected the quality of seawater (O'Higgins, Farmer and Daskalov, 2014).

Over the last decade, growing areas have been affected, often leading to numerous fish and dead jellyfish appearing on the surface of the sea, associated with massive amounts of destroyed marine vegetation. For example, in Romania, the beaches were impossible to use in 2005 and 2007, in the coastal area between Mamaia and Mangalia, for more than three weeks in each case, even in the middle of the summer season.

Finally, it should be noted that the Black Sea region has become an area of interest for entire Europe, representing the eastern border for the EU and NATO, and a transit area for oil and gas resources from Russia and the Caspian Sea. Due to its strategic importance, the area has recently been subjected to political tensions, as was the case in Crimea. The Black Sea area is bordered by two EU member states, Romania and Bulgaria, one candidate state-Turkey and other non-EU countries. Consequently, each country must abide by good neighborly and environmental treaties in order to maintain the regional balance and social prosperity of the Black Sea countries, but mainly to restore the specific biological balance (Black Sea, Ecolex Protocol, 1994).

2 ENVIRONMENTAL MEASUREMENTS, WATER CHARACTERISTICS

The Black Sea has distinct natural conditions. Over 90% of the deep water is anoxic, marked by the absence of oxygen. It is the largest body of water in Europe with a meromictic basin, without movements and water exchanges between the lower and upper layers of the sea. It is a rare phenomenon, hard to find in other parts of the world. There is thus a considerable difference in temperature between these two layers. The lower oxygen deprivation layer is inactive. The interaction between oxygen-rich surface water and the deep zone is practically limited. This stratified structure affects the diversity of Black Sea organisms. Due to these natural factors, the diversity of Black Sea fauna species is about three times less than that of the Mediterranean Sea, making it vulnerable to environmental disturbances affecting its ecosystem.

In recent decades, sea currents have partially changed their direction, pollution has steadily increased, sandbanks have shifted, and the coastal area is constantly changing. Thus, a modification in the local balance of the marine bio-system has occurred, leading to a slow but continuous degradation. Interference between water layers mainly affects the upper layer in which life exists, disrupting the aquatic bio-system.

The Black Sea ecosystem is currently the subject of intense discussion. Changes in its ecosystem over the last 50 years clearly indicate its vulnerability to anthropogenic effects. Black Sea marine resources have declined due to overfishing, unplanned coastal development and heavy maritime traffic. Due to the economic interests of the whole of Europe, the Black Sea Commission has been set up to monitor this area on an ongoing basis. Examples of monitoring and reporting are shown in Figure 1-a, b, c.

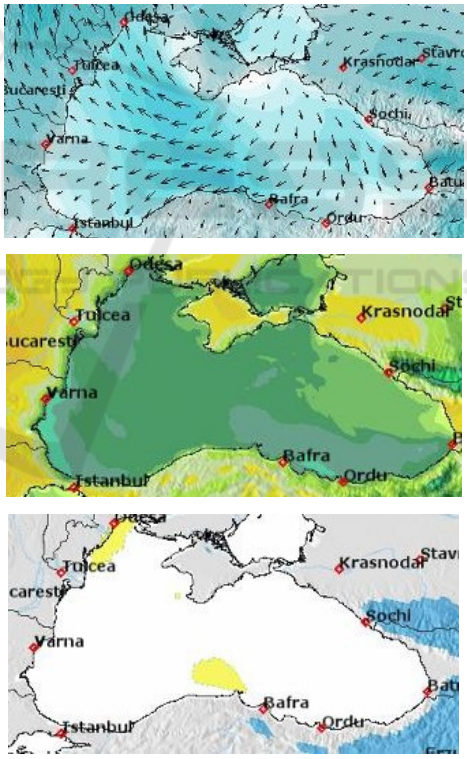


Figure 1: Monitoring reports: a-air currents, b-temperature evolution, c- accidental algae bloom development.

According to international good neighborly relations, a commission with international experts from Bulgaria, Romania and Turkey, called CP-BSP, the Commission for the Protection of the Black Sea against Pollution, was set up in 2000. Its purpose is to

systematically measure and create a database needed to monitor this bio-system. Measurements are stored and reported monthly, including temperature, humidity, precipitation, wind speed and direction, Figure 2-a, b, c.

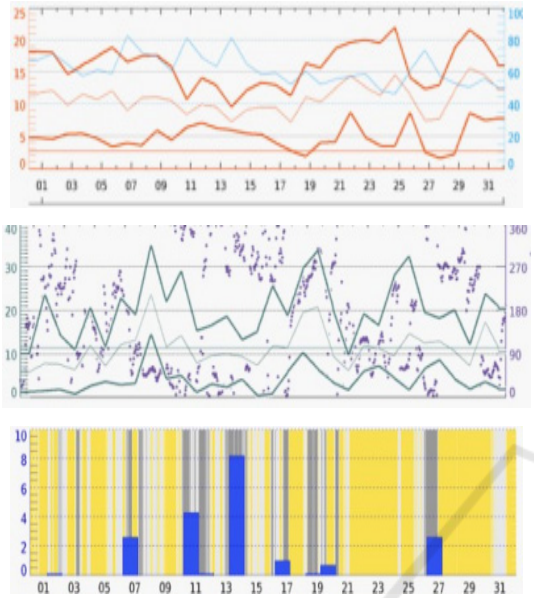


Figure 2: Recorded measurements: a- temperature and humidity, b- precipitations, c- wind velocity and direction.

In order to understand the changes, sand samples were collected from the coastal area from different depths, dates and places, considered important from an economic and social point of view. Each sample was subjected to optical and physical-chemical measurements and analysis as mentioned below for November 15, 2017 in the Mangalia area. Table 1 indicates the depth of sample collection: P1= 21-25 cm, P2= 54-78 cm, and P3= 160-200 cm in percentages.

Table 1: Characteristics of the sand in Romania coast.

Probes	Sand	Silt	Clay
P1	38.79	54.7	6.51
P2	30.6	58.9	10.5
P3	48.3	47.1	4.6

The measurements also consisted of biological, physical and chemical tests performed in different parts of the Black Sea. Until 2012, there was a steady increase in eutrophication, more pronounced after 2009, when the naval accident off the coast of Turkey was recorded. Recently, as a result of the implemented measures, some positive signs have been observed, but some problems still persist. At the international level, a report by the Black Sea countries highlighted the main factors of water pollution, listed in Table 2. The main disturbance of the last two decades was due to massive oil spills, especially in 1997, 2007 and 2009. They produced some chemical and biological changes.

Table 2: Factors of water pollution.

Types of pollution	Sources of pollution				
	Stationary land-based outfalls[1]	River run-off[2]	Coastal diffuse sources[3]	Atmospheric fall-out[4]	Ships and marine platforms[5]
Contamination with chemicals					
- Nutrients and organic matter	+	+	+	+	+
- Oil and petroleum products	+	+	+	+	+
- Persistent organic pollutants	+	+	+	+	+
- Trace elements	+	+	+	+	+
Radioactive contamination		+		+	
Marine litter (solid waste pollution)	+	+	+	?	+
Biological pollution					
- Microbial contamination	+	+	+		+
- Introduction of invasive species	+	+	+		+

[1] - Insufficiently treated or untreated industrial liquid waste and sewage from coastal cities and settlements;

[2] - Inputs from agriculture, industry, mining and municipal sewerage from the entire drainage area of the Black Sea;

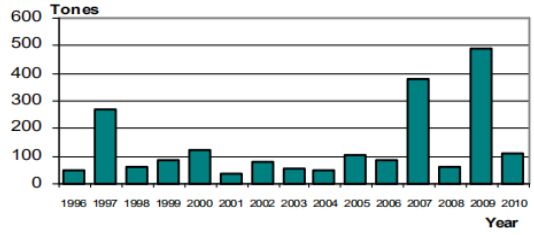
[3] - Contributions from agriculture, animal husbandry and unmanaged tourism, mainly through land leaks (coastal rainwater effluents and groundwater);

[4] - Inputs from various sources of air pollution (smoke, volcanic fumes, dust and exhaust fumes) regardless of their place in the world, deposited on the Black Sea water;

[5] - Disposal of solid waste and dredged materials; wastewater discharge and untreated ballast, oil spills, lost fishing nets, introduction of new organisms due to biofuel.

In 2018, according to the reports of the European Environment Agency, the following chemical composition was registered: Oxygen 0.8 -17.6 mg/l, average value 6.96 mg/l, dissolved oxygen 5.36 - 10.28 mg/l , average value 7.66 mg/l, nitrates 0.03 - 7.40 mg/l, average value 1.25 mg/l, total organic carbon 0.05-3.15 mg/l with average value 0.23 mg/l. The maximum values of nitrates detected were reached in 1997 and 2009. In the coastal waters of Romania, in the period 2014-2018, there was a slight decrease in nitrogen concentrations, due to the decrease in fertilizer use in the last decade and the application of the EU Directive. on Nitrates in the Danube Basin.

Figure 3-a shows the amount of oil spilled in the Black Sea in the period 1996-2010 as a result of accidents or improper handling on shipyards, reported by the EEA-European Environment Agency. Since 2002, satellite and more recently drone surveillance of oil fields has been established. Figure 3-b shows the oil spill following the accident off the coast of Turkey in 2009. Oil spills cause eutrophication of the Black Sea over time.



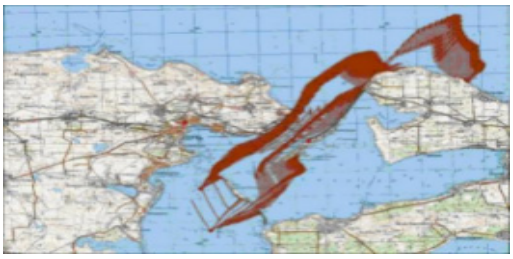


Figure 3: The main oil spills.

One of the most important consequences of increased nutrient intake followed by eutrophication of water is the disruption of its oxygenation regime, usually followed by hypoxia and later anoxia. The development of the hypoxia phenomenon, the discharges of water from rivers with different hydro-chemical and biological conditions are all correlated with each other. As a result, the area with low oxygen content in the water recorded in the Black Sea in the N-V, after 2009 gradually expanded. Large areas were covered with aquatic vegetation due to eutrophication. In the worst case, the hypoxia and mass mortality of plants in the N-V area of the Black Sea could cover over 30-40 thousand km^2.

Areas with hypoxia and anoxia are characterized by abnormal sea conditions: temperatures of 15^{o}C, vertical gradients of density of 6 conventional units, salinity 6% at 1 m. A characteristic of nutrient distribution is the absence of zero values in the surface water layer. However, at the beginning of summer 2016, the surface pH level reached 9.25 being oversaturated with oxygen, 170%. In the lower layer, the pH level of the water dropped rapidly. Consequently, there is an intense development of this destructive process. The biochemical value of the oxygen requirement reaches 2-4 mg/l, and the rate of oxidation of organic matter exceeds 3-5 times the average allowed value.

3 ECOSYSTEM PROBLEMS, ENDANGERED AND INVASIVE SPECIES

As the Black Sea eutrophicated, the number of saprophytic bacterial plankton increased sharply, especially in the type of cocci and bacilli, due to the high level of dissolved organic matter. It represents a source of nutrition for saprophytic microorganisms. From the satellite can be seen the areas affected by the excessive growth of small plankton, such as Dinoflagellates, Cocolitophores and Euglenoids, representing about 148 species and subspecies.

Unfavorable conditions, such as strong solar radiation in the summer of 2001, led to a massive increase in algae (Funda, Bat, and Sahin, 2019). Their intensive development has increased the bio-sedimentation of decaying plants, further leading to a decrease in dissolved oxygen, reducing the transparency of seawater, thus preventing the penetration of light. Moreover, a drastic change in zooplankton communities has been caused by the outbreak of Cotylorhiza tuberculata, Cassiopea Andromeda and the largest jellyfish in the Black Sea, Rhizostoma pulmo and Aurelia aurita. Jellyfish with a diameter of 1-1.5 m, non-existent 10-15 years ago, were captured. All of these venomous species are shown in Figure 4.

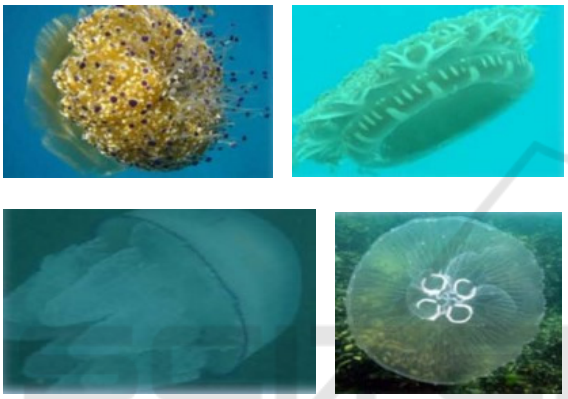


Figure 4: Invasive species of jellyfish.

In the Black Sea, there are about 200 species of fish, over 500 species of mollusks, and macrophyte aquatic plants (red, brown, blue, and green algae). Of these, only about two dozen fish have economic value, accounting for about 98% of catches in the period 1996-2019. These include bud, anchovy, Danube mackerel, turbot, cod, shark, lipac, mullet, mackerel and three species of sturgeon (Acipenser gueldenstaedtii, Acipenser stellatus and Huso huso). Some of them are shown in Figure 5.

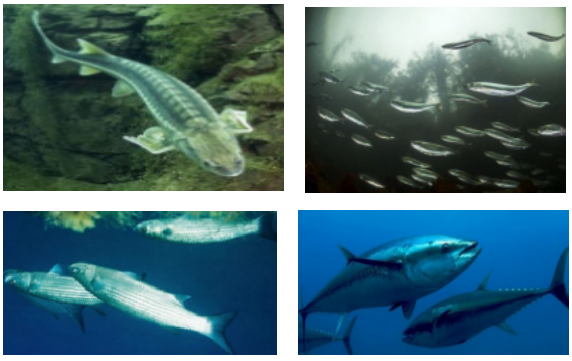


Figure 5: Specific species of fish: sturgeon, Danube mackerel, mullet, tuna, Huso huso sturgeon.

All these changes in the composition of the water caused the fish to move away from the shore, thus increasing the number and size of jellyfish. From this case, in 2016 the Romanian sea fishing achieved one of the smallest quantities recorded in the last 20 years.

The number of Pontic mackerel fish is steadily declining. The main threat is the same as in the case of sturgeon, the overfishing. Figure 6 shows images of endangered species. Other species are also affected by the changes of salinity and water quality, as example seahorses and crabs due to eutrophication, angel sharks, sturgeons and belugas due to pollution by oil, European eel and hammerhead sharks due to changing salinity.

Figure 6: Species of endangered fish: seahorse, angel shark, dog shark, hammerhead shark, sea cat.

Among the endangered species may be also mentioned Squatina (angel shark), Acipenser gueldenstaedtii (sturgeon), Acipenser nudiventris (visa), Acipenser persicus (Persian sturgeon), Acipenser stellatus (trout), Acipenser sturuso (sturgeon) Anguillael (anguillael), and the little guide from the Danube Delta. The situation of the Danube mackerel is better compared to sturgeons, due to its natural abilities of faster recovery.

4 GOOD NEIGHBOURHOOD AND FISHING POLICIES

Romania and Bulgaria, as EU Member States, have accepted and complied with all requirements regarding the CFF- Catch Fish Fund and the total allowable catches of mackerel and turbot. Fisheries management has very different aspects in the countries of the Black Sea region, with a certain tradition of applying CFF quotas and fishing vessels in the states of the former Soviet Union.

Turkey uses a different regulatory mechanism without specifying FFC for the Black Sea. With the exception of bilateral agreements, for example, between Georgia, Turkey and Ukraine on fishing for anchovy in Georgian waters, there is no general agreement on the regional management of Black Sea fish stocks.

In Russia, the 2007 CFF law provides for the establishment of quotas, defined as "a scientifically justified annual catch of aquatic biological resources of certain species in a fishing zone". The quota can vary greatly from year to year and is proposed by certain fishing institutes (rybvods). In Ukraine, the fishing quota has changed over the last decade, mainly in terms of quota allocation.

In 2002, a new fishing system was introduced for species such as anchovies and sprat, modeled after an Olympic system, to be fished as long as CFF is reached. Only valuable and rare species are regulated by individual quotas. In Georgia, there is currently no national fisheries policy governing certain fishing quotas.

On the other hand, the Black Sea is a transit route for oil and gas transportation. The risks associated with these activities, and accidental pollution, are expected to increase. About 50,000 ships sail through the Bosphorus each year, of which about 10,000 are oil tankers. Several Black Sea ports in Russia and Georgia are terminals for Caspian oil and gas pipelines. Although it brings jobs and economic development, the increase in oil transport, transit and handling operations, if not systematically regulated and monitored, could put additional pressure on the region's ecosystem.

5 CONCLUSIONS

The Black Sea Commitment provides a regional framework for cooperation to protect the area from pollution. Following the accession of Romania and Bulgaria to the EU, the Black Sea has become the focus of various EU fisheries policies and integrated coastal zone management.

Even if it is considered the ecological changes due to environmental factors such as the low level of oxygen content in the water, the water temperature and its pollution, the main factor that continues to affect the fish population is in fact overfishing. The fish stock has deteriorated dramatically over the last three decades. Local human communities, which are heavily dependent on fishing, are clearly affected.

In contrast, the diversity of commercially caught fish has declined during this period from about 26 species 20-30 years ago to six in the main, while the volume of fish caught has steadily increased. This represents a larger volume of specific fish species existing in the Black Sea, but not a sustainable development of the variation of the species caught.

This is almost entirely caused by the significant amount of anchovy fishing carried out by 2 states, accounting for almost 80% of the total catches of this species in the Black Sea.

Illegal fishing in the Black Sea is growing rapidly, with the development of remote sensing systems affecting both marine biodiversity and economic activities in the region.

In 2015, all riparian countries adopted an updated BS-SAP Strategic Action Plan for the rehabilitation and protection of the Black Sea. Based on a coherent approach, the plan aims to address cross-border environmental issues. It contains realistic objectives, including legal and institutional reforms, as well as suggestions for the investments needed to address key environmental issues.

A number of projects developed by international teams have restored some environmental issues. The number of algae is declining, with Mnemiopsis leidyi, biomass being less common. It was reduced after the invasion of Beroye ovata, which feeds on this destructive species of algae. The abundance of forage zooplankton is increasing, followed by an increase in small pelagic fish.

National efforts and international cooperation within BS-SAP have shown the first signs of recovery in the Black Sea ecosystem.

It is also recommended to adopt a unitary policy on the quality of wastewater that can be discharged into the Black Sea.

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