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REVIEW ARTICLE

Present state and evolution trends of biodiversity in the Black Sea: decline and restoration

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Abstract

The biological diversity, including the marine one, and its advanced and continuous decline, respectively, range among priority issues at planetary level, *y compris* the Black Sea, nowadays. As to the Black Sea and its biodiversity, among the other concerns on present ecological disequilibrium, pollution, living resources, the problem consists of its five times larger watershed than the sea surface itself, totalizing about 350 km^3 of freshwater, originating in the hydrographic basins of the Danube, Dneper, Dnester and Don, each year. The six Black Sea coastal states Bulgaria, Georgia, Romania, Russian Federation and Turkey themselves affect marine biodiversity directly through their land-based pollution sources. This review reveals the present state and evolution trends of Black Sea macrophytobenthos, zoobenthos, phytoplankton and related blooms, zooplankton, ichtyofauna and cetaceans, with some examples of changes occurring in the Romanian coastal and marine ecosystem during the last seven decades. The main conclusions highlight that the Black Sea ecosystem is different from that documented in the former reference periods, a slight improvement and rehabilitation tendency of the ecosystem since 1995, the considerable improvement of the pelagic ecosystem especially due to weakening of anthropic pressure. But it is still out of balance by its biodiversity and fish stocks due to eutrophication, overfishing and alien species invasion. The long lasting processes of ecosystem restoration, of qualitative improvement of environmental factors and of fishery resources depend on the efficiency of conservation, protection and management measures to be undertaken together by Danube riparian countries and Black Sea coastal states. There is still a strong need for continuing regional co-operation in the fields of monitoring, research and legislation, by developing scientifically sound data bases and communication networks, for decision makers and end-users.

Keywords: Black Sea, biodiversity, changes, decline, restoration

Introduction

All major environmental issues refering to the Black Sea, before and now, relate to its hydrographic basin five times larger than its own surface (Figure 1).

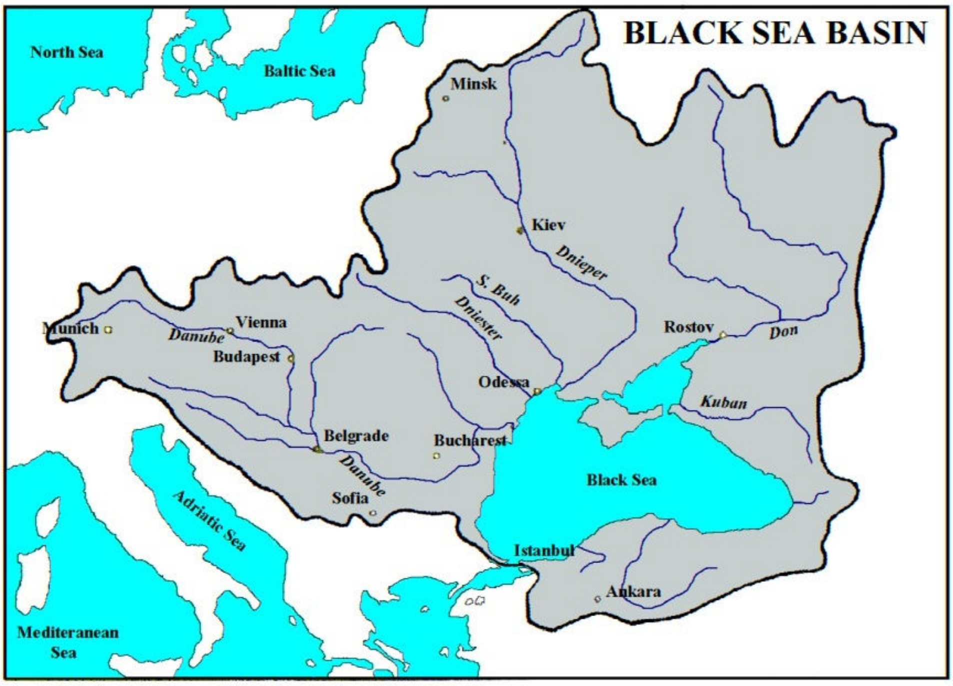

Figure 1. The Black Sea hydrographic basin.

These problems concern all six coastal states (Figure 2). The unique nature of this particular sea has been emphasized by marine scientists with time. A Russian oceanographer Nikolay M. Knipovich considered it certainly most concisely and inspired as “unicum hydrobiologicum”. A Romanian biologist Grigore Antipa stressed later on that “the Black Sea, because of entirely different conditions from those prevailing in other seas, represents a real natural laboratory”. A Contemporary US scientist Jane Lubchenco resumed more recently “The problems of the Black Sea are not so different as elsewhere, but they are more obvious, in part of isolated, contained nature of the Black Sea”.

Figure 2. The Black Sea coastal states.

In fact, the Black Sea, No. 62 on LMEs map of World and Linked Watersheds, has been appreciated as being "the most seriously degraded sea on our planet" (GEF, 1992).

Among the most dramatic changes, obvious in all neighbouring countries, affecting this tideless, brackish water, 90% H_2S saturated water body, are mainly coastal erosion, eutrophication, decline of biodiversity, loss of living resources, and degradation of landscapes. For various natural and anthropogenic reasons, the Black Sea is particularly sensitive to land-based pollution (Bologa 2001a).

The above mentioned topics led to the installment of a severe ecological disequilibrium during the last five to seven decades. This is especially illustrated by the long-term evolution of chemical (nutrients, heavy metals, oil), micro- and biological pollution (BSC 2008, NIMRD 2009, 2010, 2011). As to the last one, the matter of harmful exotic vegetal and/or animal biota is still questionable.

The visible degradation of the Black Sea has been often claimed (e.g. Black Sea TDA 1997; Beşiktepe *et al*. 1999; Sorokin 2002), including destruction of its biodiversity (GEF BSEP National Reports of Romania 1997, Bulgaria 1998; Georgia 1998; Turkey 1998; Ukraine 1998; Zaitsev and Mamaev 2001; Bologa 2001b), endangered species (Dumont 1999) and exotic species (Zaitsev and Öztürk 2001). The modifications of the benthic and planktonic biota in the Romanian Black Sea sector have been focused on the period between 1970 and 1990 (Bologa *et al*. 1995). General environmental problems concerning the Black Sea continue to be of present interest (Bologa 2011).
This review summarizes the present state and evolution trends of macrophyto- and zoobenthos, phyto- and zooplankton, fishery resources and cetaceans, with

respect to major changes in biodiversity at the end of the 20th century and beginning of the 21st century.

Results

Macrophytobenthos

Macrophytobenthos is a good bioindicator for the state of eutrophication and of radioactive pollution.

Usually 331 macrophytes have been inventoried for the whole Black Sea, namely 80 green (Chlorophyta), 76 brown (Phaeophyta), 169 red algae (Rhodophyta) and six seagrasses (Phanerogama/Magnoliophyta); more recently a total number of 332 species has been reported (Milchakova 2011). A guide with most common seaweeds off the Romanian littoral has also been published (Sava 2008); 16 Chlorophyta, five Phaeophyta and 10 Rhodophyta have been identified nowadays (Sava and Bologa 2010).

Typical is the domination of small-size taxa with fast growth rate. But species number and community biomass considerably decreased during last decades especially compared, e.g. along the Romanian shore, with the '40ies. The increase of Chlorophyta and the decrease of Phaeophyta became obvious.

A special attention deserves the massive disappearance of the perennial brown alga *Cystoseira barbata* on the Black Sea shelf, e.g. along the Romanian shore, due to intense eutrophication started in the early '70ies; a certain restoration of this ecologically and economically very valuable species becomes visible in the southern Romanian coastal waters within the Marine Natural Reserve 2 Mai – Vama Veche after 1990. Very recently a population-based approach to assessing the state of *Cystoseira* as an environmental indicator near Crimean and Caucasian shores has been proposed (Milchakova and Vilkova 2011).

The present state of the three *Phyllophora* species in the Zernov's field has been up-dated by Ukrainean investigators.

Generally common findings evince a replacement of former much richer macroflora with tolerant eutrophic species of the genera *Enteromorpha*, *Cladophora* and *Ceramium*. The development of other species, such as *Desmarestia viridis*, *Polysiphonia sanguinea*, *Pylaiella littoralis*, was signalized in Ukrainean and Romanian coastal waters in the '90ies. Morphological and ecological changes of certain macrophytes under prolonged influence of eutrophication (different branching of *Cystoseira* and *Gelidiella*), two shallow water forms of *Phyllophora nervosa*) can also be noticed.

Occasional but often extremely strong macroalgal blooms, dominated by opportunistic green and red algae, have marked the spring and summer seasons along the Romanian littoral in the last two decades. They might indicate an improved water quality, even if the stranded biomasses have created tremendous problems to beach owners in order to get rid of them due to created environmental discomfort even if not at all toxic. These huge algal biomasses extended, for instance, to 25,000 t in 2008, and are simply a loss as natural resource, at present, with considerable costs for their removal; it would certainly deserve an economical usage in near future, e.g. for pharmaceutical needs.

The sensitivity of this component of biodiversity to contemporary climatic changes is also expressed by the domination of either winter or summer species.

It results that macrophytobenthos is evincing an improvement of the ecological state of the Black Sea, *i.a*. by the pronounced development of present taxa, some restoration of *Cystoseira barbata* belts along the western shore, and seaweed distribution in deep waters.

Zoobenthos

Zoobenthos is considered the most conservative bioindicator for ecosystem structural and functional changes and related ecological health.

Generally the NW sector of the Black Sea became recently poorer as fauna and nourishing places for ecologically valuable fish species compared to the 60's. E.g. in the Romanian coastal waters almost 800 taxa have been identified between 1960 and 1970.

This indicator has evinced a drastic decrease of specific diversity, abundance and biomass, a simplification of community structure, and a dominance of smaller-size hypoxia tolerant groups and opportunistic species.

Obviously the qualitative and quantitative worsening of zoobenthic resources, mainly mollusks, have altered/reduced the biofilter strength of the ecosystem. Crustaceans proved to be the most sensitive to oxygen deficiency, polychetes less sensitive, and bivalves most tolerant. Nevertheless significant changes of mussel (*Mytilus galloprovincialis*) populations occurred in Ukrainian and Romanian coastal waters (Bologa 2001; BSC 2008). Instead, the development of opportunistic worms has been signalized.

The increasing invasion rate by some exotic species, such as *Mya arenaria*, *Scapharca inaequivalvis* and *Rapana venosa*, in unoccupied ecological niches without competitors and/or predators, predacious enemies of littoral malacofauna (e.g. of oyster *Ostrea edulis* in Georgian waters) was relevant during the last decade (Black Sea Commission 2008). A consequent decrease of

R. *venosa* abundance by natural causes in Romanian coastal waters or due to commercial harvesting in Bulgarian ones, has also been observed.

So zoobenthos indicates only a relative increase in species diversity and recovery of hypoxia sensitive groups during the post-eutrophication period with an adjustment process of benthic communities towards a new quasi-stable equilibrium (slow recovery).

Phytoplankton

Phytoplankton is the best bioindicator for the state of eutrophication.

In the Black Sea 750 species have been recorded. Their composition (taxonomic structure) and abundance (numerical density, biomass) differ considerably in various marine areas. The main components consist of diatoms (Bacillariophyta) such as *Skeletonema costatum*, *Chaetoceros socialis*, *Cyclotella caspia* and dinophytes such as *Prorocentrum cordatum, Protoperidinium pellucidum*, *Heterocapsa triquetra*. The ratio of these components fluctuates with space and time.

The most important change of this parameter is its trend to shift from an earlier diatom dominant system to an apparent dominance of opportunistic dinoflagellates (mainly along the western shelf and in the southern Black Sea due to the modification in nutrient balance in addition to temperature regime of the sea water). A substantial basin-wide increase of coccolithophorids in spring became frequent. Occasional abundances of blue green, green and euglena microalgae took place in recent decades.

The prevailing phytoplanktonic blooms produced by *Prorocentrum cordatum*, *Cerataulina pelagica, Emiliania huxleyi*, much more intensive and frequent off the Romanian coastal waters before the early 90'ies), require a systematic, preferably monthly, monitoring.

Phytoplankton confirms the relative improvement of the ecological state of the Black Sea ecosystem, *i.a*. with less intense and frequent related blooms.

Zooplankton

Zooplankton is the critical link between autotrophic (phytoplankton) and next higher trophic levels.

It counts 150 species, out of which 70 mainly Ponto-Caspian brackish-water types and about 50 meroplanktonic ones.

It is consuming phyto- and microzooplankton, controlling directly their abundance, and constituting a major food resource for pelagic fish larvae and fish by controlling their stocks. More productive but showing a lower species diversity (compared, e.g., with the Mediterranean Sea). They are thermophylic and euryhaline (Mediterranean) and cold-water (North Atlantic boreal) species, both phytophagous and detritophagous.

A strong basin-wide interannual variability in composition and abundance is characteristic, evincing changes in the taxonomic structure, with temporary decline of diversity of edible zooplankton.

Prior an increased abundance of gelatinous species (scyphozoan jellyfish *Aurelia aurita*, cystoflagellate *Noctiluca scintillans*, opportunistic copepod *Acartia clausi*), indicators of eutrophication, especially in the NW Black Sea sector, due to regional hydrochemical characteristics (nutrient supply from the Danube, Dnieper, and Dniester runoffs) has been noticed.

An exceptional development of alien ctenophore *Mnemiopsis leidyi* (since 1988) praying on edible zooplankton, with major side-effects on all trophic levels (reduction of food resources for planktivorous and predator fish) has characterized the ecosystem in previous decades. The introduction of predator ctenophore *Beroe ovata* (from the Mediterranean or eastern coast of N Atlantic ballast waters) about 1997 has balanced the former outburst of *M. leidyi.* A reduction in abundance of certain sensitive zooplankton species, such as *Centropages ponticus* and *Penilia avirostra*, besides the disappearance of some species (e.g. the family Monstrillidae in Romanian coastal waters after the 80'ies) are also worth mentioning.

Yet zooplankton is also evincing an improvement of the ecological state of the Black Sea ecosystem, i.a. due also to some, even fluctuant, recovery of the edible zooplankton community.

Marine living resources

The Black Sea living resources count about 200 fish species, less than 500 molusks, and few seaweeds.

The highest economic value is to be attributed to not more than about 25 species producing about 98% of the total catch. 2% are common less important fish, mollusks, crustaceans and other aquatic biota. The main catches concern anadromous, pelagic and demersal fish species.

The total mean annual fish catch of 410,000 tons between 1996 and 2005 was more than 30,000 t higher than between 1989 and 1995: it consisted of anadromous fish (*Alosa pontica*, *Acipenser gueldenstaedtii*, *A. stellatus*, *Huso huso*), pelagic fish (*Engraulis encrasicolus*, *Sarda sarda*, *Potamotus saltatrix*), and demersal fish (*Squalus acanthia*s, *Psetta maxima*, *Merlangus merlangus*, two species of *Mullus*, four species of *Mugil*).

The relevant ecosystem effects of marine fisheries refer to leading anthropogenic stressor, overfishing, pollution, degradation of spawning and nursery, illegal fishing, use of destructive fishing gears, fluctuating climate, alien species (e.g. *Mnemiopsis leidyi*), phytoplanktonic blooms with usual related hypoxia, H_2S production; all these factors contributed together to the collapse of Black Sea fisheries in the '90ies.

As to the Black Sea living resources, besides most relevant fish species, only one commercial mollusk (*Mytilus galloprovincialis*), sea snail (*Rapana venosa*), clams (*Chamtea gallina*) and some water plants (*Cystoseira barbata*, *Phyllophora nervosa*, *Zostera marina*) can be added.

Thus the notable improvement in the state of Black Sea living resources between 2000 and 2005, compared to the collaps period (1989-1992) is still inferior to the baseline period (1970-1988).

Marine mammals

Three dolphins (*Phocoena phocoena relicta*, *Delphinus delphis ponticus*, *Tursiops truncatus ponticus*) and one pinniped (*Monachus monachus*) are known in the Black Sea; the monk seal is practically extinct.

There is still insufficient scientific information about cetacean abundance, distribution, migrations, critical habitats, natural and anthropogenic threats and pathology.

The commercial fishery practiced mainly between 1930 and 1950 was in fact banned in 1966 by former USSR, Romania and Bulgaria, and in 1983 by Turkey.

Main threats concerning these cetaceans refer to accidental mortality in fishing gears, habitat degradation, pollution and epizootics.

The need for multidisciplinary research and protection should take into consideration taxonomy and genetics, distribution, abundance, habitat and ecology, life history, past and ongoing threats, population trend, conservation tools and strategies, national, regional and international instruments, consideration of IUCN & Red List of Threatened Animals, and the Conservation Plan for Black Sea Cetaceans (2006).

The main issue regarding the Black Sea cetaceans are the major gaps in their knowledge.

Biodiversity changes and conclusions

1. The present Black Sea ecosystem is obviously different from that documented in the 1960's.
2. An improvement and rehabilitation tendency of the coastal Black Sea ecosystems has been registered after the mid 1980's.
3. Above mentioned improvement is visible for water quality parameters and for the structural and functional properties of biota (compared with the conditions from the mid 1970's to the early 1990's.
4. The considerable improvement of the pelagic ecosystem of the western Black Sea, due to the weakening of anthropogenic pressure, is sustained by the relative recovery of the benthic ecosystem even if still fragile, recovery of some macroalgal populations, increasing of phyto- and zooplankton diversity, less intensive and fewer phytoplanktonic blooms, increase of edible zooplankton, reappearance of some native fodder zooplankton species, and decline of opportunistic and gelatinous species.
5. A proposal of a new diagnostic method in order to asses long-term improvement of the pelagic ecosystem has been advanced by O. Yunev *et al.* (2008).
6. Fish stocks are still out of balance due to eutrophication, overfishing and exotic intruders.
7. The restoration of the ecosystem is a long-lasting process (depending on the accomplishment of conservation, protection and management measures.
8. There are still gaps in the scientific knowledge of biodiversity due to the absence of sufficiently comprehensive monitoring data in all coastal states.
9. The anthropic ecosystem damage shows a very slow recovery rate despite undertaken rehabilitation efforts (e.g. in comparison with the Baltic and North Seas).

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