

## I - Executive Summary of CIESM Workshop 39

### “Climate forcing and its impacts on the Black Sea marine biota”

by

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*This synthesis was written by all participants of the workshop, under the coordination of Cemal Turan and with the support of Paula Moschella. Frédéric Briand, the Monograph Series Editor, reviewed and edited this chapter along with the entire volume, whose physical production was carried out by Valérie Gollino.*

#### 1. INTRODUCTION

In welcoming the participants Dr Frédéric Briand, Director General of CIESM, remarked that Trabzon – the famed, mythical Trebizond – marked the first, long-delayed encounter of a CIESM Workshop with the Black Sea shore and that there would be many further returns to a Sea that was an essential part of the Commission scientific and geographic scope. This specific meeting would extend to the Pontic region a brainstorming exercise engaged one year earlier, with CIESM Workshop 35, for the Mediterranean ecosystem, and would be carried out in the same integrative spirit as reflected by the presence around the table of marine biologists and physicists. After presenting the two co-Chairs of the CIESM Committee on Living Resources and Marine Ecosystems, Drs Cemal Turan and Ferdinando Boero happily reunited on this occasion, he expressed his gratitude to Dr Bayram Öztürk, Turkish Representative on CIESM Board for his very efficient assistance in helping prepare the ground logistics.

##### 1.1. Black Sea climate change and hemispherical teleconnection

The global warming observed since the end of the 19th century has been caused not only by natural climate changes on the decades-centuries scale but also by the impact of human activities on the Earth's climate system, expressed in greenhouse effect. According to IPCC (2007), mean global surface air temperature rise for the last century (1907-2006) was on average about 0.7 °C, and the trend of temperature for the last 50 years was almost twice as much (+ 0.13 °C/10 years). One of the most significant processes in the ocean-atmosphere system that influence climate fluctuations in Eurasia is the Atlantic Multi-decadal Oscillation (AMO) of sea surface temperature, with periods of 50-100 years (more often reported as 60-80 years), represented also by the low-frequency mode of North-Atlantic Oscillation (NAO) of surface pressure field (Polonsky, 2008) (Figure 1).

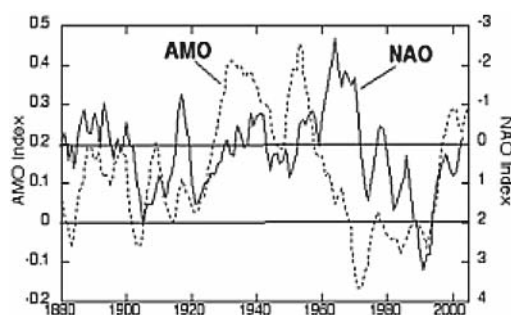


Figure 1. Atlantic Multidecadal Oscillation (AMO) and North Atlantic Oscillation (NAO), 5-yr running means, 1880-2005.

In general, positive NAO indexes correspond to more northern tracks of cyclones, bringing more heat/ cold in winter/ summer and more precipitations to northern Europe, whereas southern regions experience opposite conditions. Negative NAO phases mean more southern cyclone trajectories, toward the southern Europe areas, including the Mediterranean and Black seas. Estimation of climatic variations of these oscillations on a timescale over 30-years, and of related anthropogenic impacts such as the greenhouse effect and river hydraulic controls, contribute to determine long-term variability (trends and fluctuations) of the Black Sea ecosystem.

Regional atmospheric processes are under the influence of external climatic changes and they, in turn, affect processes on sea surface and in water column. The observed changes in the physical compartments determine in many respects the present and future changes of marine ecosystem state and productivity.

## 2. CLIMATE VARIABILITY (HYDROMETEOROLOGICAL PARAMETERS) AND ITS EFFECT IN THE BLACK SEA REGION

Based on secular observations from marine hydro-meteorological stations along the northern and eastern Black Sea shores, linear trends and long-term oscillations reveal annual, seasonal and monthly air temperature (AT) trends. Significant long-term secular linear trends of annual mean AT in most studied Black Sea regions are positive, with slopes (0.4-0.8 °C/100 years) that correspond to the secular rise of mean global surface air temperature (Ilyin and Repetin, 2006a). However, on the decadal scale, the long-term trend is interrupted by severe departures on the order of 1-3 °C (Figure 2), which corresponds to variations also seen in the sea-surface temperature (SST) as well as sub-surface (Figure 3). These decadal fluctuations agree with AMO and NAO signals (Figure 1).

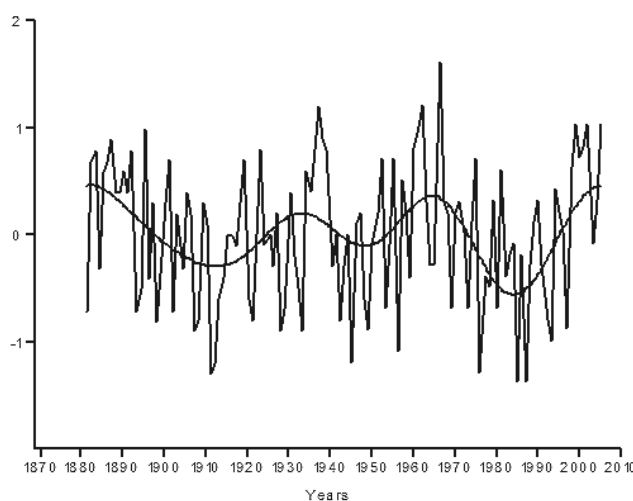


Figure 2. Long-term variability of AT anomalies (°C) in Yalta (Ukraine) approximated by superposition of harmonic functions having periods 31, 41 and 62 yr.

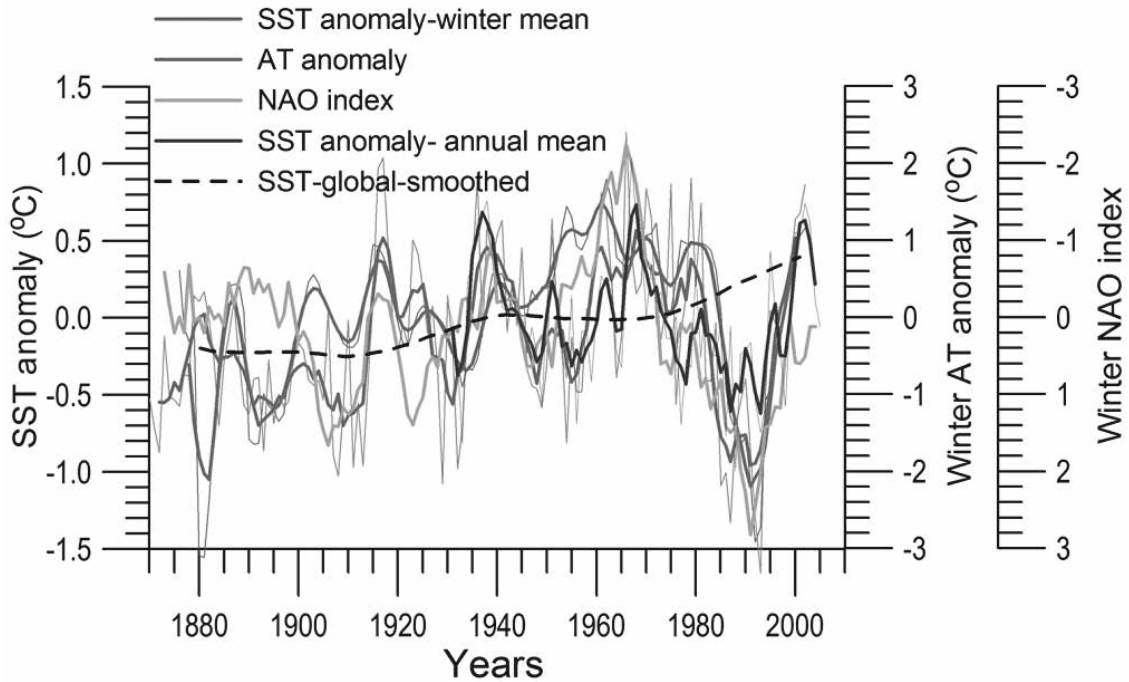


Figure 3. Annual trends in air temperature (AT), sea-surface temperature (SST) and the winter NAO index, 1870-2006.

The uniform response of the Black Sea drainage basin to AMO/NAO can also be seen in the closeness of temporal variations in river discharge throughout the area, ranging from the Sakarya in the south, to Don in the north-east, to Danube and Dnieper in the west (Figure 4). Changes in freshwater input also have been observed (Figure 5) together with a weakening in wind activity, which is manifested as a general deceleration of horizontal circulation and vertical mixing of surface waters in the Black Sea (Ilyin, 2008b). This in turn leads to changes in the transport of heat and chemical constituents, including nutrients and pollutants, as well as a change in self-cleaning processes, such as surface water renewal by wind-driven coastal upwelling.

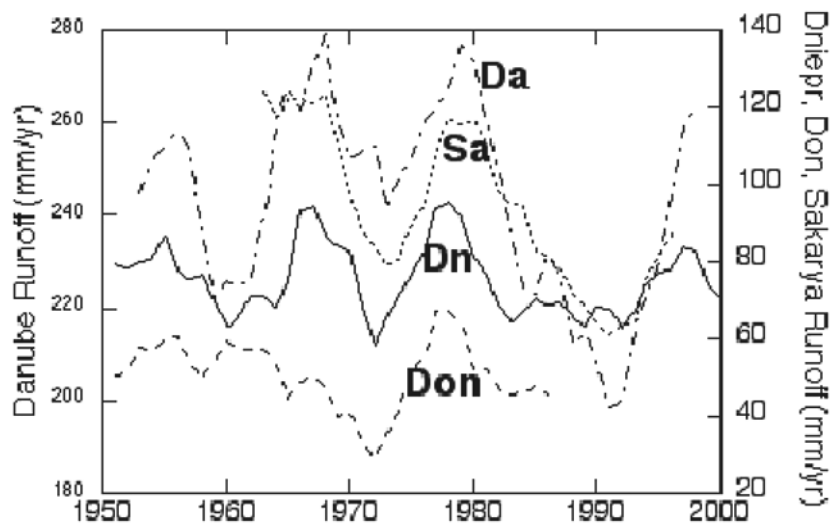


Figure 4. Annual discharge (5-yr running means) from the Danube (Da), Sakarya (SA), Dnieper (Dn) and Don rivers to the Black Sea.

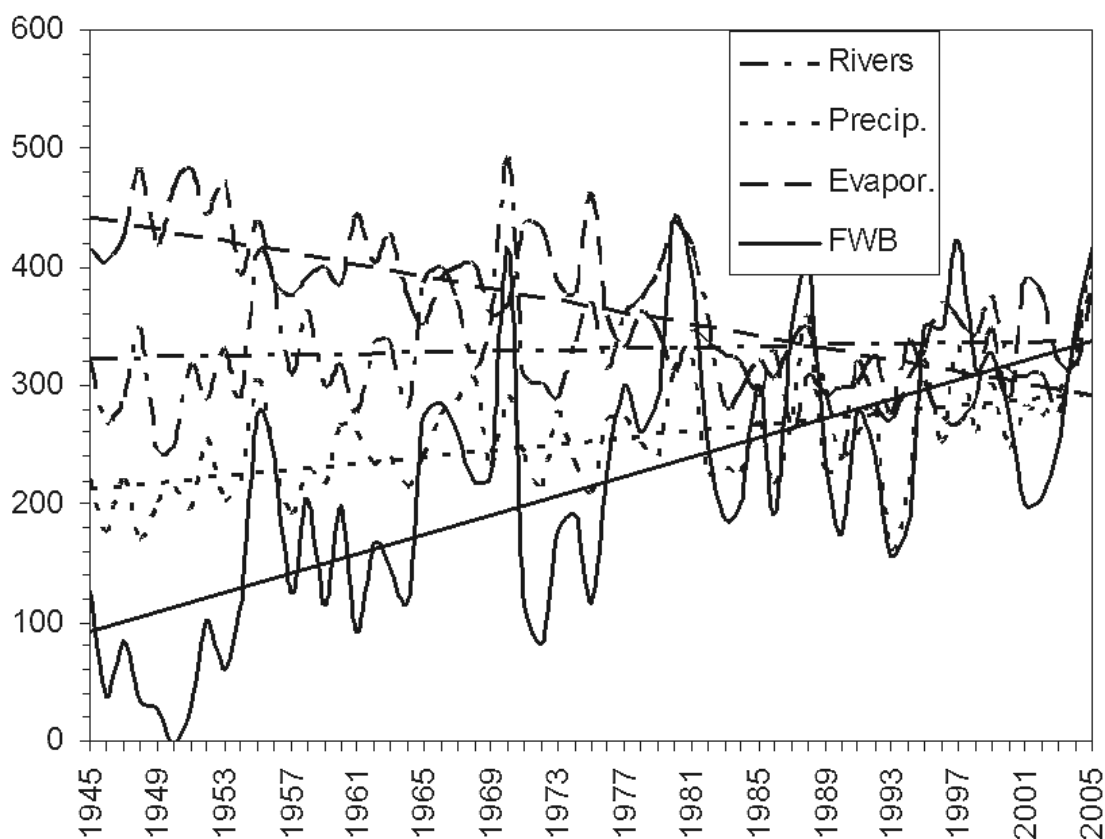


Figure 5. Interannual variability and trends of the Black Sea fresh water budget (FWB) and its components ( $\text{km}^3$ ).

In addition to lowering the salinity of surface waters, increased rainfall can lower SST, especially on the eastern coasts of the Black Sea. Moreover, pollutants and nutrients brought about via increased precipitation are comparable with those derived by riverine input; in fact, the atmospheric input of nutrients is estimated in ten-thousands (nitrites, phosphates) and hundred-thousands (nitrates, sulfates, chlorides) tons per year (Chaykina *et al.*, 2008; Voitsekhovich *et al.*, 2004).

River-derived nutrient discharge of nitrogen and phosphorus to the Black Sea rose sharply in the 1950s-1960s, in response to increased agricultural activity in the Danube, Dnieper and Don watersheds. Nitrogen and phosphorus fluxes, however, declined abruptly in the late 1980s, following the economic recession which affected the former eastern block countries in that period (Figure 6). Silica discharge declined in the 1970s in part due to river damming (e.g., Iron Gates Dam; Humborg *et al.*, 1997), and shifts from siliceous (mainly diatoms) to non-siliceous phytoplankton (Petrova-Karadjova, 1984; Humborg *et al.*, 1997; Bodeanu *et al.*, 2002). Data from the NE Black Sea reveal similar trends to those observed in the NW Black Sea, but with only a slight shift in the phosphate content (Figure 7).

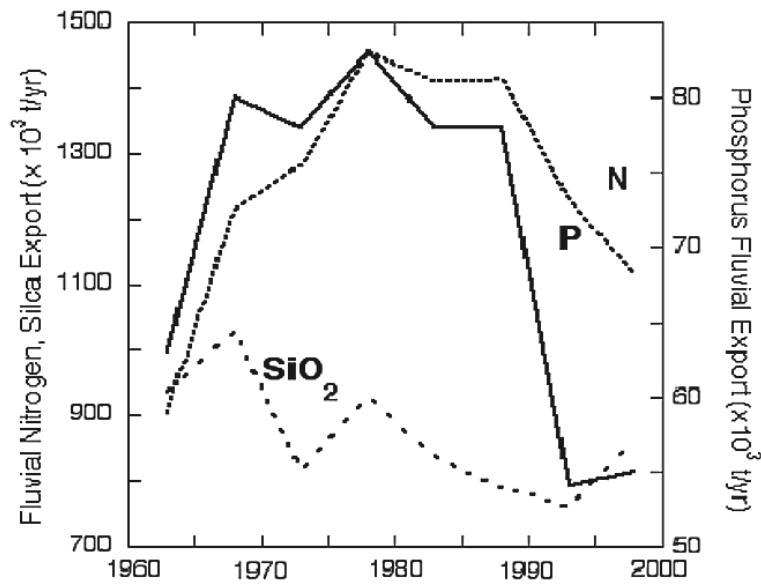


Figure 6. Five-year means fluvial flux of nitrogen (N), phosphorus (P) and Silica (SiO<sub>2</sub>) to the Black Sea (data from Ludwig *et al.*, 2009).

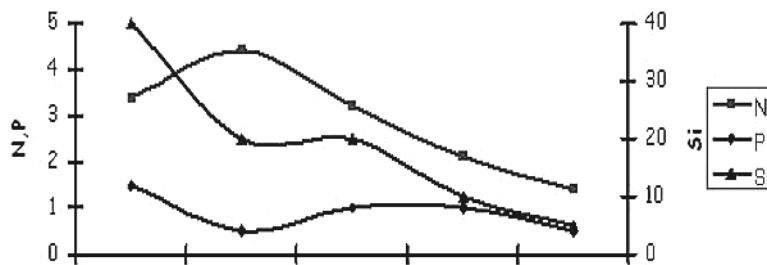


Figure 7. Interannual changes of upper layer concentrations of inorganic species of N, P, Si in the North-Eastern Black Sea averaged for the 5-years intervals.

In the open waters, the low NO<sub>3</sub>/ PO<sub>4</sub> ratio in the nutricline below the euphotic zone resulted in nitrogen limited phototrophic production in the surface layers. This can be explained by intensive loss of inorganic nitrogen under suboxic conditions. According to Cociasu *et al.* (1996) and Yilmaz *et al.* (2006), the NO<sub>3</sub>/ PO<sub>4</sub> ratio in the euphotic zone and the upper nutricline is very low (2 - 6.5) in the open sea. The same tendency can be observed in the NE Black Sea, where the N:P ratio decreased during the last 10-15 years from 30 to 5.

One of the indicators of the Black Sea biogeochemical system recovery should be the reappearance of the nitrogen fixation. The process of production of gaseous nitrogen through denitrification and anammox is a well known feature in oxygen-deficient basins. In terms of budgeting, this loss of bound nitrogen should be compensated by nitrogen fixation (Yakushev *et al.*, 2007). Denitrification and anammox were measured in the Black Sea during the last decades (Murray *et al.*, 2003; Kuypers *et al.*, 2003), whereas N-fixation was not observed in the 1980s-1990s. In contrast, in 1950s, before the initiation of intensive eutrophication, N-fixation in the Black Sea was well-developed (Pshenin, 1963). As shown above, the low N/P ratios in the different parts of the Black Sea testify to nitrogen-limited primary production, which favors N-fixation as part of the normal functioning of the ecosystem. Recently, N-fixation was again measured in the Central Black Sea in 2003 (McCarthy *et al.*, 2007). We thus can conclude that there are present positive signs of recovery of the Black Sea ecosystem after several decades of decline in anthropogenic impact (Black Sea Commission Report, 2008).

### 3. COASTAL OXYGEN DEPLETION AND HYPOXIA, OXIC ZONE VOLUME

Seasonal development of low oxygen zones (oxygen concentrations below 2 mg/l, oxygen concentrations <30% saturation value) in bottom waters of the Black Sea (e.g., northwestern shelf, Anapa shelf, Sea of Azov) depends on the intensity of eutrophication as well as circulation, stratification and meteorological conditions (wind, heat flux, etc.). In the Black Sea, the development of hypoxia typically begins in June-July and attains maximum coverage in August. There is a relationship between the rate and timing of river discharge and the scale of hypoxic conditions (Berlinskii, 2003). In years with high river discharge, hence high nutrient input and organic matter production, oxygen concentrations in bottom layers are ~20% lower than in years of low river discharge.

Hypoxia is also subject to longer-term variations, and a simple correlation to environmental factors may not always hold. For instance, a two-fold increase in hypoxia occurred in the northwest shelf in the 1980s, but has since decreased in its Ukrainian sector. In contrast, no hypoxia was reported in Bulgarian waters or off other Black Sea states, other than an intensive summer anoxia in the Sea of Azov in 2001 (Yakushev *et al.*, 2003). A long-term detailed study of the anoxic zone in the northeastern Black Sea near Gelendzhik (Podymov, 2008; Yakushev *et al.*, 2008) (Figure 8) show that the depth of disappearance of hydrogen sulphide was characterized by values  $\sigma_{\theta}\sigma_{\theta}=16.15-16.25 \text{ kg m}^{-3}$  in 1991-1998. In 1999-2000 the shoaling of this boundary appeared. The value of this shoaling of ~5-15 m was about  $\sigma_{\theta}=0.05-0.15 \text{ kg m}^{-3}$ . After the year 2000 the position of hydrogen sulphide stabilized, as also seen in ammonia, total manganese and methane (Yakushev *et al.*, 2006). These oscillations can be connected with the corresponding winter weather conditions. For example, the two warm winters in 1998-1999 may have affected the winter formation of the oxygen-rich cold intermediate layer (CIL). These years were remarkable for the increase in SST (Figure 8), increase in temperature in the core of CIL (Oguz *et al.*, 2006; Krivosheya *et al.*, 2002), and shoaling of CIL in the density field (Murray *et al.*, 2003). The decrease of intensity of CIL formation should lead to an increase in temperature and a decrease in oxygen content in its core. To check these assumptions we calculated the average concentrations of dissolved oxygen in CIL (defined as the layer from  $\sigma_{\theta}=14.45 \text{ kg m}^{-3}$  to  $-\sigma_{\theta}=14.60 \text{ kg m}^{-3}$ ) (Figure 8). In 1999-2000, when the shoaling of reluctant occurred, the oxygen content declined. The minimal concentrations were registered in 2001-2002. In 2003-2004 the oxygen content in this layer returned to values typical of the early 1990s.

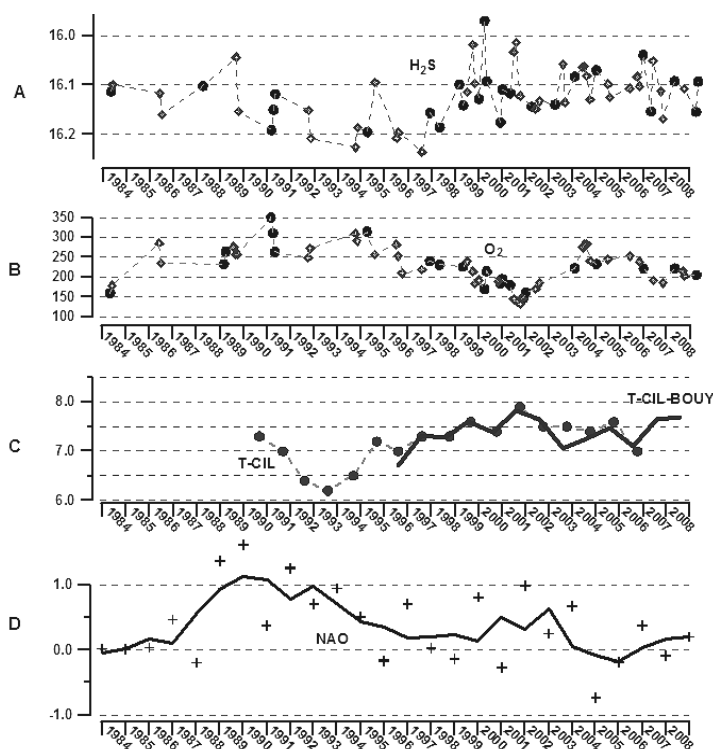


Figure 8. Onsets in the density field of hydrogen sulphide (A), averaged concentration of oxygen in the CIL (in the layer  $\sigma_{\theta}=14.45-14.60 \text{ kg m}^{-3}$ ) (B), temperature in CIL core in the Northeastern Black Sea (data of V.G. Krivosheya); averaged temperature in the CIL core (data of the MHI oceanographic database and ARGO floats) (C) and interannual variability of the winter NAO index (crosses - averaged for February-April, lines - averaged for three successive years (D).

The variability in the Black Sea hydrophysical-biogeochemical system can be connected with the weather conditions change as it follows from the NAO index behaviour (Figure 8). The results obtained illustrate the mechanism of reaction of the natural system of the Black Sea on the Global Climate changes. The correlated changes in the decadal NAO index behaviour under winter weather conditions result in larger or smaller cooling of the upper layer waters. As it follows from the analyzed estimates, the changes in sea surface temperature lead to changes in winter CIL formation intensity and to oxygen renovation there. The oxygen inventory in the CIL acts as a specific accumulator that supports the consumption of oxygen for the organic matter decay and downward diffusive flux during the whole year. The interannual variations of this oxygen renovation in CIL lead to changes in the suboxic layer hydrochemical structure and, in particular in the position of the anoxic boundary in the density field. Therefore, the distribution of the chemical parameters in the density field in the Black Sea might be a good indicator of the Global Climate variations. Another factor that might affect the interannual dynamics of the hydrogen sulphide position is eutrophication. It should be emphasized that one result of 5-10 m oscillations in the anoxic boundary is a 5-10% change in the volume of the oxic waters. Such oscillations are considered vitally significant and should be studied further.

#### **4. THE HISTORY OF BLACK SEA BIODIVERSITY**

##### **4.1 Mediterraneanization of the Black Sea biota**

Low species diversity (i.e. low competition) combined with high habitat diversity (i.e. availability of potential niches) in the Black Sea provides favorable conditions for the introduction of alien species. Some of these species become invasive, altering the stability and functioning of the ecosystem and threatening the indigenous species. There have been increasing numbers of Mediterranean species in the Black Sea since the first records in 1920s. This is particularly true for the fish fauna. The diversity of the Black sea ichthyofaunas has increased due to the intrusion of fish from the Mediterranean Sea, a process that has been defined as “mediterraneanization” (Pusanov, 1967; Boltachev and Yurakhno, 2002). In addition, fish species of Indo-Pacific origin naturally migrated to the Mediterranean Sea via the Suez Canal (Lessepsian migrants) along with those introduced accidentally (via ballast waters) and intentionally (e.g. for farming purposes) further modify the Black Sea fish diversity. The water mass exchange between the two seas also facilitates the introduction of species which may become later established in the Black Sea.

Any comparison between Black Sea and Mediterranean biota is however impaired by the fact that the Mediterranean fauna is itself still incompletely known. Caspers (1957) estimated the Black Sea metazoans at ca 21% of the Mediterranean fauna. Later research in both seas showed that the Black Sea fauna is only about three and a half times poorer (see Bianchi and Morri, 2000). Comparing the Mediterranean and the Black Sea - the decrease in total number of species is paralleled by disappearance and a decline in many oceanic groups, such as Sponges, Salps, Doliolids, Pteropods, Siphonophores, Euphausiids, Nemertini, etc. These changes are undoubtedly salinity-driven. Salinity ranges from 33 to 39‰ in the Mediterranean Sea, from 17 to 22 ‰ in the Black Sea. However, the degree of faunal impoverishment is not directly proportional to salinity. Between the Mediterranean and the Black Sea, salinity drops by more than a factor two, while the number of animal species decreases by a factor 3-3.5.

Indeed, 80% of the Azov-Black Sea fauna is of Atlantic-Mediterranean origin, and its share continues to increase; only 10.4% and 9.6% of species are of freshwater and Ponto-Caspian origin, respectively. The species of Atlantic-Mediterranean origin mainly come from the Mediterranean Basin, the Lusitanian province, and the boreal zone of the Atlantic Ocean. The biota of the Black Sea shares more similarities with the biota typical of higher latitudes, that is few species with high biomass, whereas the Mediterranean Sea is characterized by many species with low biomass (Table 1).

Table 1. Numbers of marine species in the World Ocean, the Mediterranean and the Black Sea.

Taxa	World	Medit.	M/W(%)	BS	BS/M(%)
<b>Phytoplankton</b>	~4375	673	15.4	746	110.8
Red algae	5250	867	16.5	143	16.5
Brown algae	1500	265	17.7	75	28.3
Green algae	1200	214	17.8	83	38.7
Sea grasses	50	5	10	6	120.0
<b>Total Macrophytes</b>	<b>12375</b>	<b>2024</b>	<b>16.4</b>	<b>1053</b>	<b>52.0</b>
Sponges	5500	600	10.9	25	4.2
Cnidarians	11 000	450	4.1	44	9.8
Bryozoans	5000	500	10	12	2.4
Annelids	8000	777	9.7	153	19.7
Molluscs	32 000	1376	4.3	125	9.1
Arthropods	33 600	1935	5.8	288	14.9
Echinoderms	6500	43	2.2	5	11.6
Tunicates	1350	244	18.1	16	6.6
Other invert.	~13 550	~550	4.1	278	50.5
<b>Total invert.</b>	<b>~116 500</b>	<b>~6475</b>	<b>5.6</b>	<b>946</b>	<b>14.6</b>
Cartilage Fishes	1170	84	7.2	12	14.3
Bony Fishes	13 151	532	4.1	180	33.8
Reptiles	~6700	355	5.3	175	49.3
Mammals	114	21	18.4	4	19.1
<b>Total vertebrates</b>	<b>21 135</b>	<b>992</b>	<b>4.7</b>	<b>371</b>	<b>37.4</b>
<b>Grand Total</b>	<b>~137 635</b>	<b>~7467</b>	<b>5.4</b>	<b>1317</b>	<b>17.6</b>

#### 4.2. The diversity of Black Sea fish fauna

The current Black Sea ichthyofauna is the result of a long process started after the last junction of the Black Sea to the world ocean and continued for about eight thousand years. At present, the Black Sea only connection with the Mediterranean Sea is the Turkish Strait system, comprising the Istanbul Strait, the Sea of Marmara, and the Dardanelles. Therefore the Black Sea can be considered as the 'arm' of the Mediterranean and many of its species are common to both seas.

The Black Sea fish fauna accounts for about 200 species and subspecies, including occasional freshwater and marine fish, recorded as single individuals in the Black Sea (Svetovidov, 1964; Oven, 1993; Boltachev, 2003). However, a considerable decrease in the numbers of many native Black Sea fish is observed; some of them have not been recorded since several decades largely due to the effects of anthropogenic pressures, namely: chronic pollution, in particular eutrophication, which increases fish mortality, overfishing and poaching, the physical destruction of spawning grounds, of nursery and feeding areas, and the invasion of new hydrobionts.

According to their phylogenetics gene, ecological traits, and life cycles, in the Black Sea Basin four main fish groups can be singled out.

The fully marine fish – about 140 species and subspecies – make the core of the Black Sea ichthyofauna. The most representative species of this group, are of Atlantic – Mediterranean, tropic and sub-tropic origin. They are euryhaline and inhabit mainly the upper warmer layer in the water column. Among them, 60 naturalized completely, and formed endemic subspecies, all stages of their life cycle being spent in the Black Sea. The other species migrate regularly at the warm time of the year from different areas of the Mediterranean Basin (Vodyanitsky, 1930). Boreal–Atlantic fish are represented by 12 species, inhabiting mainly the cool subsurface layer in the warm season and penetrating the surface layer during the winter period (Svetovidov, 1964; Oven, 1993).

Brackish water fish count 22 species including species endemic of the Black Sea or species and subspecies shared with the Caspian Sea, which are autochthonous relicts of the ancient brackish-water Pontic lake – sea (Rass, 1949). Many of these species are distributed in the brackish-coastal waters and river estuaries, mostly in the north-western part of the Sea or near the Kerch Strait.

The diadromous and semi-diadromous group includes 25 species, which are of quite ancient origin – about 1.5-2 million years. This is related with fast migrations of these fish (with the exception of the eel fish, *Anguilla anguilla*) from the northern rivers into the Pontic lake basin and then returning back to the rivers for spawning (Oven, 1993). This group is affected by the mostly negative influence of human economic activities, which result in the destruction of reproduction sites, blockage of the migration pathways in rivers and over-catches, as many species are of high commercial value, such as sturgeons, salmon and herrings.

Typical freshwater taxa count only 15 species, occasionally reaching the Black Sea Basin coastal area usually during high water in the rivers (Oven, 1993).

**New records in the last 20 years:** up till now one observes a trend of increasing arrival of exotic species into the Black Sea; often resulting in the establishment of the new species (see Tables 2 and 3). The native Black Sea ichthyofauna also registers an increase of certain commercial and/or rare species (Boltachev, 2003; Boltachev, 2009). For example, there is an increase in frequency of round sardinella (*Sardinella aurita*), bogue (*Boops boops*) and salema (*Sarpa salpa*) in Turkish costal waters, and, in the coastal zone of the south-western Crimea, of “previously endangered” species such as Black Sea salmon (*Salmo trutta labrax*), common bass (*Dicentrarchus labrax*), dotted dragonet (*Callionymus risso*), bearded umbrine (*Umbrina cirrhosa*), yellow gurnard (*Chelidonichthys lucernus*), puntazzo (*Diplodus puntazzo*) and green wrass (*Labrus viridis*) (Table 4). The sea horse (*Hippocampus hippocampus*), which practically disappeared in the middle of the 1990s, suddenly increased in abundance in 2002 and 2008 along the coasts of Crimea, the north-western part of the Black Sea and the Northern Caucasus.

Table 2. Exotic fish species recorded in the Black Sea.

Species	Origin	Presence in the 60s	Reappearance in BS	Location first record	Established in Black Sea	Abundance	Habitat	Geographic distribution	Vector	References
<i>Sardinella aurita</i>	Med Mar	yes	1997	Sile	yes	abundant	pelagic, Turkish coast	Atlantic-Mediterranean	natural migration	B. Öztürk
<i>Boops boops</i>	Med Mar	yes	1989	Sile	yes	abundant	pelagic, Turkish coast	Atlantic-Mediterranean		B. Öztürk
<i>Thalassoma pavo</i>	Med Mar	yes	2006	Igneada	partially	abundant	pelagic, Turkish coast	Mediterranean		B. Öztürk
<i>Sarpa sarpa</i>	Med Mar	yes	2001	Igneada	yes	abundant	pelagic, Turkish coast	Mediterranean		B. Öztürk
<i>Sphyreana pinguis</i> <i>Sphyreana sphaena</i>	Med	yes	2004 2005	Sile Sile	a few individuals migrant	a few ind. a few ind.	pelagic, Turkish coast	Indo-pacific migrant	Lesseps	B. Öztürk
<i>Centracanthus cirrus</i>	Med	no	1988	off Odessa, littoral zone of Romania, common in Turkish area	a few individuals, eggs in 1988 2 adults off Romania in 2004	a few ind.	pelagic	Mediterranean		Tsokur, 1988; Radu, 2006 (pers. com.)
<i>Micromesistius poutassou</i>	Med	no	1999	coastal area of Crimea, common for Turkish area	a few ind.	a few ind.	pelagic	Mediterranean, Marmara	Med Mar	Boltachev, 2006
<i>Gobius auratus</i>	Med	no		common for Crimea			pelagic	Atlantic-Mediterranean	Med	
<i>Gobius cruentatus</i>	Med	no	2007	for Crimea, Turkish area	a few ind.		pelagic	Atlantic-Mediterranean	Med Mar	Boltachev, 2006 Engin et al., 2007
<i>Gobius xanthocephalus</i>	Med	no	2004	for Crimea, Turkish area	a few ind.	a few ind.	pelagic		Med Mar	Boltachev, 2006 Vasilyeva and Bogorodski, 2004
<i>Parablennius incognitus</i>	Med	no	2005	Common for Crimea, Abhazya, Turkish area	a few ind.	a few ind.	pelagic, Turkish coast	Atlantic-Mediterranean	Med Mar	Boltachev, 2006 Bogorodskii, 2006
<i>Zebus zebus</i>	Med	no	2008	Turkish area	a few ind.	a few ind.	pelagic, Turkish coast	Atlantic-Mediterranean	Med Mar	Kovacic and Engin, 2008
<i>Sphyraena chrysotaenia</i>	Med	no	1999	Turkish area	a few ind.		pelagic, Turkish coast	Indo-pacific pelagic, migrant	Lesseps	Boltachev, 2006

Table 3. Total number of Mediterranean plankton, algae and invertebrate species recorded in the southern Black Sea (mainly off Bosphorus).

Taxa	<1960s	1960-1970	1971-1980	1981-1990	1991-2000	2001-2009
Phytoplankton		37				
Copepoda		15	19	12	7	51
Gelatinous plankton						1
Macrophytes					26	
Benthos	1	45	30	56		5
<b>Total</b>	<b>1</b>	<b>97</b>	<b>49</b>	<b>68</b>	<b>33</b>	<b>57</b>

Table 4. Historical trends of Mediterranean fish species in the Black Sea.

Species names	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010s
<i>Sardinella aurita</i>	+	+	+	+	+	not present	+	+	+	+
<i>Boops boops</i>	+	+	+	+	+	+	+	+	+	+
<i>Thalassoma pavo</i>	+	+	+	+	+	+	+	+	+	+
<i>Sarpa salpa</i>	+	+	+	+	+	+	+	+	+	+
<i>Sphyraena sphyraena</i>	+	+	+	+	+	+	+	+	+	+
<i>Centracanthus cirrus</i>	-	-	-	-	-	-	-	-	+	
<i>Micromesistius poutassou</i>	-	-	-	-	-	-	-	-	+	+
<i>Gobius auratus</i>	-	-	-	-	-	-	-	-	+	-
<i>Gobius cruentatus</i>	-	-	-	-	-	-	-	-	+	+
<i>Gobius xanthocephalus</i>	-	-	-	-	-	-	-	-	+	-
<i>Parablennius incognitus</i>	-	-	-	-	-	+	+	+	+	+
<i>Zebrus zebrus</i>	-	-	-	-	-	-	-	-	-	+
<i>Sphyraena chrysotaenia (obtusata)</i>	-	-	-	-	-	-	-	-	+	-

The barfish (*Chromis chromis*), the lettered perch (*Serranus scriba*), the blotched picarel (*Spicara maena*) and the bogue, (*Boops boops*), are recorded again in the Black Sea. The European pilchard (*Sardina pilchardus*), though in small number, is frequently found in fixed nets and trawl catches along the whole Black Sea shelf of the Crimea. Catches of two Mediterranean migrant fishes, such as the thin-lipped grey mullet (*Liza ramada*) in 2006 and the European barracuda (*Sphyraena sphyraena*) in 2007 near Sevastopol are unique, because these species had not been encountered there since 1930 and 1950 respectively.

In the last decade, 15 fish species, new to the Black Sea ichthyofauna, or whose presence was previously doubted, were recorded in the coastal zone of the southwestern and southern Crimea. Among them, seven Atlantic-Mediterranean species: the thick-lipped mullet (*Chelon labrosus*), dorado (*Sparus aurata*), salema (*Sarpa salpa*), yellow-headed goby (*Gobius xanthocephalus*), red-mouthed goby (*G. cruentatus*), incognito blenny (*Parablennius incognitus*), and greater pipefish (*Syngnathus acus*). It is possible, that the abundance of some aforementioned bottom resident species (gobies, blennies) was so reduced in the past that they were just not recorded before. The chameleon goby *Tridentiger trigonocephalus*, endemic of the far Eastern seas, has naturalized in Sevastopol Bay. Four invasive species, freshwater by origin, were recorded in estuaries of the peninsula: far Eastern species – stone morocco (*Pseudorasbora parva*) and goldfish (*Carassius auratus*); and North American species – pumpkinseed (*Lepomis gibbosus*) and Eastern mosquitofish (*Gambusia holbrooki*).

The remaining three species are known from single findings and apparently belong to the category of accidental records.

### 5. MEDITERRANIZATION BARRIERS AND GENETIC ASPECTS OF SPECIES INTRODUCTION AND ESTABLISHMENT IN THE BLACK SEA

Global climate change is causing shifts in the geographical distribution of species, associated with local extinction and expansion of their distribution ranges. Natural and artificial transport pathways contribute to such redistribution of species. Transportation in ballast water is increasingly eliminating geographical barriers and separation of species.

#### 5.1. Adaptation to local conditions

Species distribution more and more depends on whether specimens sustain transport conditions, at least passively, and then find suitable living conditions in their new environment. Within a given species and its original functional and genetic diversity, only resistant phenotypes and genotypes may survive, thereby reducing genetic diversity compared to the parent population and defining the starting point for successful settlement of suitable environments by selected, pre-adapted specimens.

The newcomers are “filtered” during the process of introduction, or after they arrive at their destination. The conditions in ballast tanks, for instance, might select particularly strong specimens that have proper characters to face the new conditions. The passage through a turbulent environment, like the Bosphorus Strait, acts also as filter.

Bottlenecks in transport to the Black Sea are set by the transport conditions in ballast water or by the acute conditions in or at the exit of the Bosphorus current system. Taking into account the hydroclimatic differences between the Mediterranean (hosting the parent population) and the Black Sea (receiving the newcomers), the physical factors that particularly challenge the survival of the specimens undergoing migration are water currents, shifts to lower salinities at the surface and lower temperatures coinciding with hypoxia and elevated CO<sub>2</sub> in the intermediate layer and anoxia in the depth. Furthermore, transport or migration may only be successful in a limited seasonal time window. Limiting factors not only act individually but also interact synergistically as in the case of temperature extremes, CO<sub>2</sub> and hypoxia, thereby exacerbating stress levels (Figure 9). Oxygen-deficient (less than 80% of saturation), hypoxic (less than 30%) and anoxic conditions are typical for the coastal shelf zones of the Black Sea and the Sea of Azov in the summer period and oxygen depletion will probably become more intense in the future (Diaz and Rosenberg, 2008).

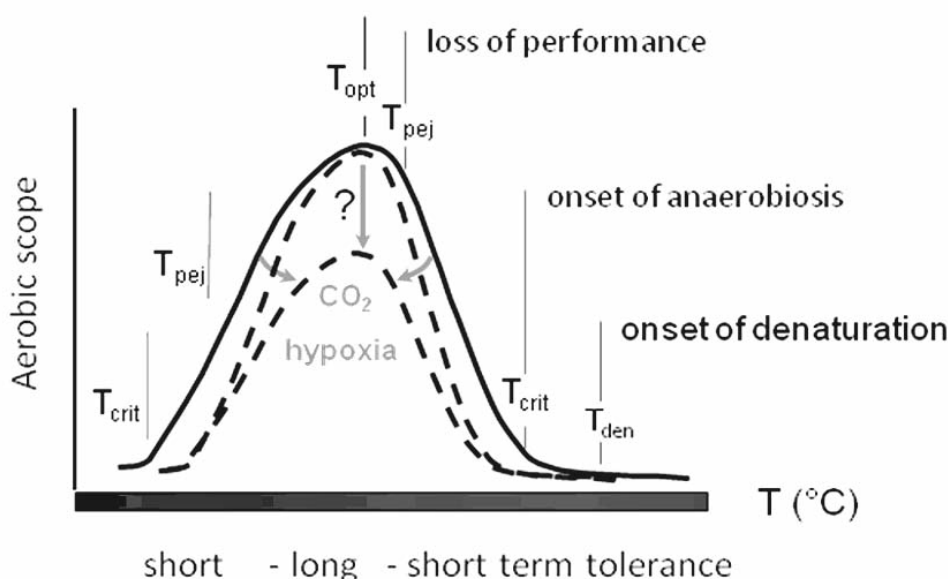


Figure 9. Organisms thermal windows: optima, limits (|) and acclimation/ adaptation (↔). Modified from Pörtner and Farrell (2008).

A Mediterranean species entering the Black Sea might become successful not because Black Sea conditions match Mediterranean ones, but because that species contained, in its genetic variability, the traits that allow for the colonization of the Black Sea Basin, in spite of its differences from the Mediterranean Sea. Turan (2006) reported that the amount of genetic divergence of *Mullus barbatus ponticus* in the Black Sea is high enough to be considered as a subspecies of *M. barbatus* in the Mediterranean Sea. This genetic analysis also indicated that *M. b. ponticus* could be an incipient species in the Black Sea. The seagrass *Posidonia oceanica* is a stenohaline species endemic to the Mediterranean Sea, where it normally lives at a salinity of between 36.5 and 39.5 ppt. Meinesz *et al.* (2009) reported large *P. oceanica* beds in the Marmara Sea, where salinity ranges between 21.5 and 28 ppt. They carried out a genetic analysis on these low-salinity tolerant *P. oceanica* beds, and found different signs of genetic isolation: excess of heterozygosity and a presence of fixed alleles, which are rarely found in the whole distributional range of the species.

It is important, at this point, to investigate on differences in the limits of tolerance between Mediterranean populations that became newly established in the Black Sea and those of the Mediterranean populations.

## 5.2. The Turkish Straits System as an acclimatization/adaptation corridor

The Turkish Strait System is a very important biological corridor for many migratory species of fish, birds and mammals from both the Black Sea and the Mediterranean Sea and it is the feeding and breeding ground for the pelagic fish of Atlantic origin during their migrations from the Black Sea to the Sea of Marmara or vice versa. Additionally, the Turkish straits form an “acclimatization zone” for transiting species, allowing those from the Mediterranean to adjust to the different environmental conditions in the Black Sea, and vice versa.

### 5.2.1 Physical characteristics of TSS

The Turkish Strait System (TSS) constitutes a two-layer system, where a sharp halocline of a thickness of 10-20 m separates brackish waters (22-26 psu) in the thin upper layer of the Marmara Sea (15-30 m) from the saltier waters (38.5-38.6 psu) in the lower layer throughout the year. Temperature of the upper layer varies seasonally within the range of 7-27°C whereas temperature of the lower layer remains around 14.5-15.0 °C. The relatively dense Mediterranean underflow enters into the Çanakkale Strait below the depths of 15-20 m with salinity of 38.9-39.0 psu and temperature of 16-17 °C and undergoes gradual changes along the Strait and its transition region to the western Marmara Basin. They eventually sink in the form of a dense water plume with S~38-38.5 psu and T~15.0-16 °C toward the density levels where they reside, whereas a part of it continues to flow within a narrow zone immediately below the interface. The sinking plume subsequently takes part in the renewal of the sub-halocline waters of the Marmara Sea by spreading isopycnically in the form of intrusive layers.

The underflow spends about 6-7 years in the deeper layers of the Marmara Basin (Besiktepe *et al.*, 1994). Upon reaching the Bosphorus-Marmara junction region, the lower layer waters flow into the Istanbul Strait through the submarine canyon. Thereafter, the underflow interacts with local topography at the southern and northern sill regions, becomes progressively diluted due to strong entrainment into the upper layer flow, and enters into the Black Sea junction region as a thin plume.

In terms of mixing characteristics of the Mediterranean underflow, five distinct regions are evident within the TSS: the first one occurs within the Nara section of the Çanakkale Strait where the internal hydraulic adjustment of the flow causes strong entrainment of the lower layer flow with the upper layer that then goes back to the Aegean Sea. Similar abrupt mixing occurs at the southern and northern sill regions of the Istanbul Strait. The Bosphorus-Black Sea junction region imposes further mixing on the underflow. Moreover, the wind-induced mixing within the Sea of Marmara affects the properties of the sub-halocline waters of the lower layer during autumn-winter months.

### 5.2.2 Persistent geographic barriers of TSS for mediterraneanization

Depending on the mixing and transport characteristics of the Mediterranean underflow through the TSS, Oguz and Öztürk (unpub.) recently proposed a set of successive geographic barriers that may control migration success of Mediterranean species on their way to the Black Sea. These barriers mostly apply to pelagic and benthic planktonic species and fish larvae whose transports are mostly

passive and introduced by hydro-physical conditions. The present discussion therefore excludes the migration of fish species between the Mediterranean and Black Sea ecosystems that are largely independent from such persistent hydro-physical geographic barriers.

The planktonic species and fish larvae face the first barrier in the Nara Passage zone of the Çanakkale Strait where the strong turbulence and mixing of upper and lower water masses may likely cause a part of their population to be transported back to the Aegean Sea with the upper layer flow and may introduce as well physiological shocks due to abrupt temperature change of about 7-10 °C and salinity change of about 10-15 psu. The region therefore has long been considered as an acclimatization zone for marine organisms migrating to the Black Sea (Öztürk and Öztürk, 1995).

The second barrier occurs along the junction region to the Sea of Marmara where the major part of the Mediterranean underflow sinks into intermediate and deep layers of the suboxic-anoxic western Marmara Basin. Only those individuals able to follow the narrow sub-halocline layer below the interface with sufficient oxygen (Figure 10) will be able to survive their passage.

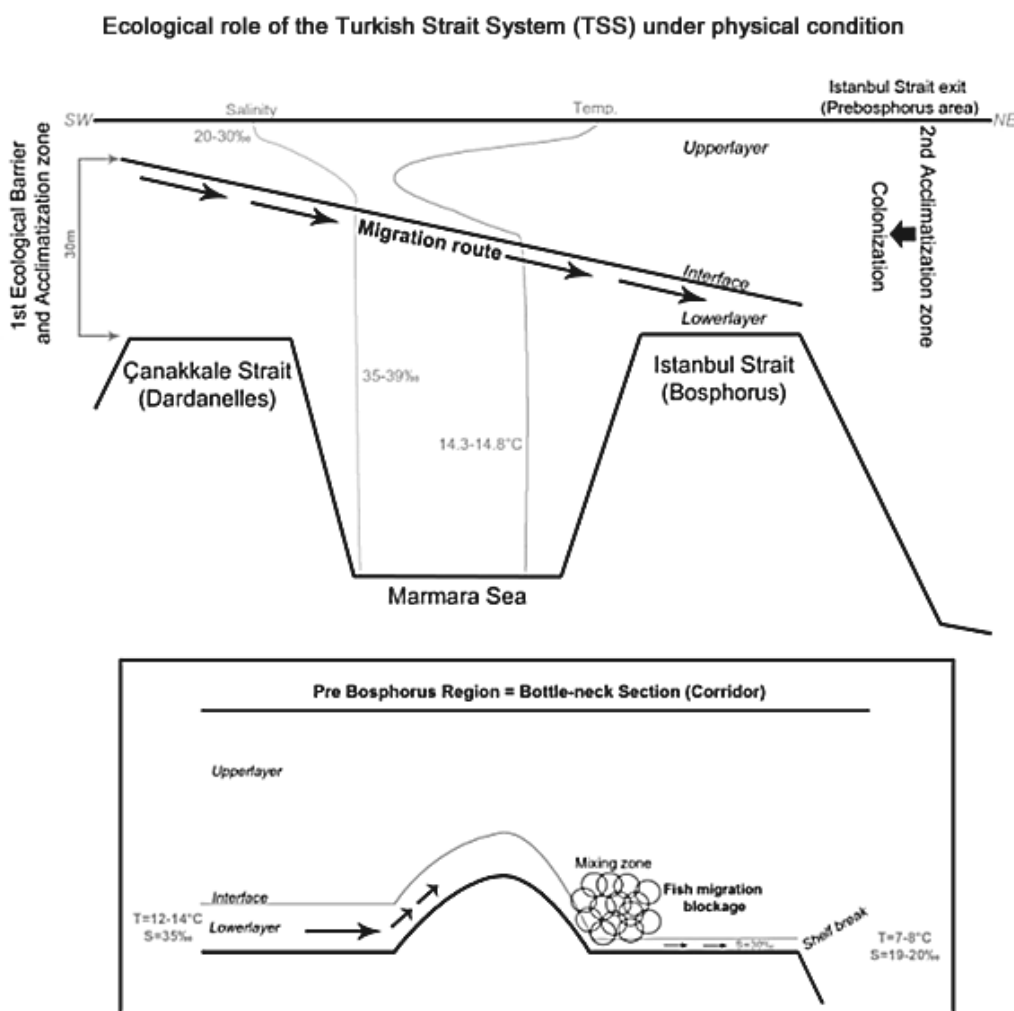


Figure 10. Schematic diagram, by T. Oguz and B. Öztürk, of the physical structure of the Turkish Strait System (TSS) controlling the migration success of Mediterranean species into the Black Sea. The lower panel displays in more detail the pre-Bosphorus channel region outside the northern exit of the Istanbul Strait as well as the Bosphorus-Black Sea junction region up to the shelf break. The temperature and salinity profiles in the upper panel are typical for the Sea of Marmara. The main migration route of Mediterranean species lies immediately below the interface zone (thick sloping line) between the upper and lower layers.

Mediterranean species which manage to enter the Bosphorus encounter three successive obstacles. The first is induced by the southern sill, the second by the constriction region near the Atatürk Bridge, and the third by the northern sill at the Black Sea exit. The underflow is characterized upstream of the northern sill roughly by  $S \sim 35-36$  psu and  $T \sim 11-13$  °C, but more importantly its thickness of at least 30-40 m at the Aegean end of the system declined to 5-10 m at most. Entrainment process of the underflow into the upper layer that prevails excessively downstream of the sill as well as further along the shelf introduces further dilution of the underflow. When it reaches to the shelf break of the southwestern Black Sea Basin the underflow is almost indistinguishable from ambient waters and has a thickness of less than 1 m. The species which are able to survive and reach the narrow shelf zone of the southwestern Black Sea are prone to settlement and acclimatization to the Black Sea conditions. There is also a possibility that some of them can sink across the shelf break into the anoxic waters of the Black Sea together with the Mediterranean underflow. These successive physical constrains may therefore explain the low species diversity of the Black Sea (Zaitsev and Mamaev, 1997) after its connection to the Mediterranean about 7,000 years ago.

### **5.2.3 Temporary geographic barriers of TSS for mediterrization**

While the physical constraints and bottle-necks described above along the TSS are persistent features of the system, some temporal physical features may exercise further adverse controls on the migration process. Almost every winter, under very strong northwesterly wind episodes, excessively large upper layer flow can temporally fill all depths of the Istanbul Strait with cold waters of about 5-7 °C, and temporally block the Mediterranean underflow. The abrupt mixing and sudden temperature changes between these two contrasting water masses lead to mass mortalities of commercial and immigrant fish species such as bonito, bluefish, anchovy, horse mackerel. This event is called “Orkoz” or “Ayna” by local fishermen and may even be extended into the southern half of the strait near the AnadoluHisar/Kandilli section.

To conclude, the mediterrization process is one of the subtle issues of the Black Sea ecosystem and it is likely to evolve in future decades under continuing global warming. The lack of clear understanding of this process mostly arises from the lack of systematic sampling and monitoring strategy along the TSS.

## **6. CLIMATE FORCING (AMO & NAO) OF BIODIVERSITY AND MEDITERRANIZATION**

The magnitude and variety of climatically forced changes in the physical environment provoke substantial proximate and emergent ecological responses. The direct effects of climate change impact occur at the individual level, at various stages in the life history cycle via changes in physiology, morphology and behaviour, at population level via changes in transport processes influencing dispersal and recruitment and at community level via interacting species (e.g., predators, competitors, etc.), including climate-driven changes in both the abundance and the per capita interaction strength of these species.

### **6.1. Examples from plankton and fish biomass**

During the period 1960-1980 the Black Sea status passed from low mesotrophy to high mesotrophy and eutrophy. The period 1960-1970 represents the Black Sea pristine conditions, with phytoplankton biomass less than 2-3 g m<sup>-2</sup> whereas 1970-1980 is the period of high nutrient enrichment of the system that is reflected in phytoplankton biomass by a gradual increase to more than 10 g m<sup>-2</sup> (Figure 11). The climate-induced changes are therefore not clearly seen due to more dominant signal of eutrophication-induced changes. However, the climate-induced changes appear to be well-marked during the 1980s and 1990s.

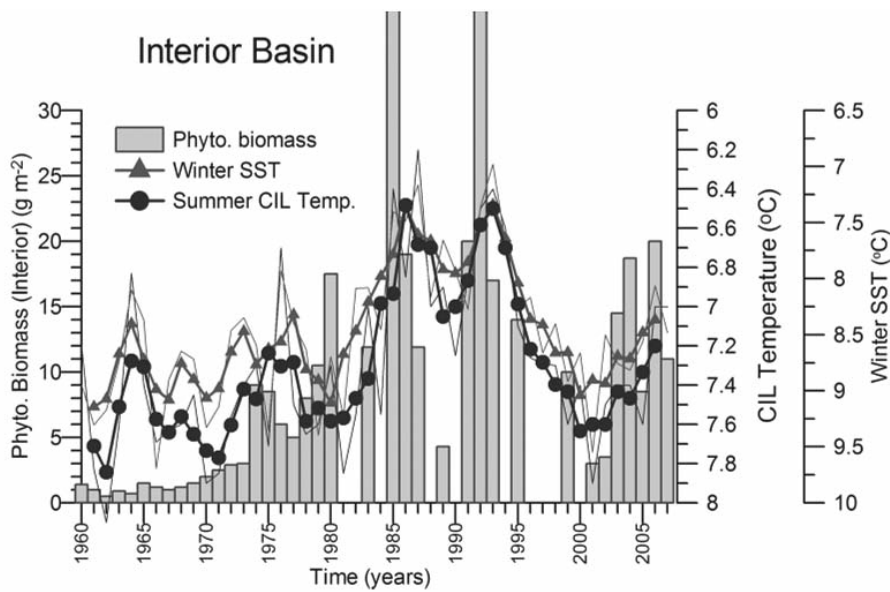


Figure 11. Long-term variations of summer-autumn mean phytoplankton biomass ( $\text{g m}^{-2}$ ) (vertical bars; after Mikaelyan, 2005), the mean CIL temperature ( $^{\circ}\text{C}$ ) (dots; after Belokopitov, 2005) averaged over all stations within interior basin and mean winter (December-March) sea surface temperature (SST) as an average of Hadley2, NCEP-Reynolds and Pathfinder5 data sets. The phytoplankton biomass is expressed in terms of euphotic zone integrated values.

Zooplankton biomass in the northeastern Black Sea is significantly correlated with the changes in water temperature. As shown in Figure 12, the biomass fluctuates with the annual mean sea surface temperature such that warm (cold) years attain higher (lower) biomass with clear increasing and decreasing trends of variations between cold and warm years. The corresponding phytoplankton biomass also follows the climatic changes as evidenced by close correlations between high (low) biomass and cold (warm) temperatures in Figure 11. Phytoplankton biomass has therefore out of phase variations with zooplankton biomass in regard to temperature dependence, perhaps linked with trophic cascade.

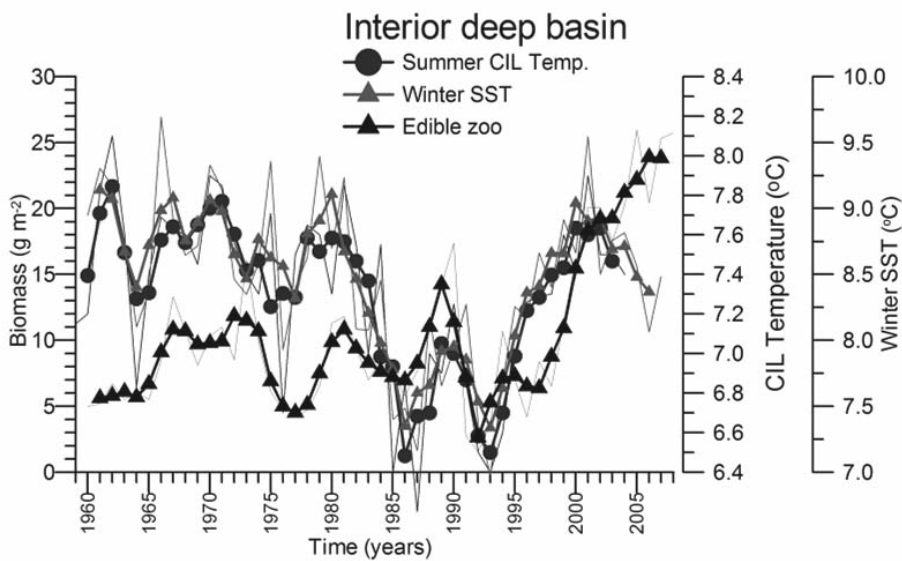


Figure 12. Long-term variations of the annual-mean edible zooplankton biomass in the northeastern basin ( $\text{g m}^{-2}$ ), and the mean CIL temperature ( $^{\circ}\text{C}$ ) (dots; after Belokopitov, 2005) averaged over all stations within interior basin and mean winter (December-March) sea surface temperature (SST) as an average of Hadley2, NCEP-Reynolds and Pathfinder5 data sets.

The sprat and anchovy stock estimates also follow closely the annual mean sea surface temperature and therefore reflect a clear signature of climatic modulations. Sprat as a cold water species attains much higher biomass during cold years and lower biomass in warm years (Figure 13). The sprat fluctuations overlap considerably with those of phytoplankton and are opposite to edible zooplankton, indicating therefore a trophic cascade pattern. Similar correlation is also evident for the sprat fat content in which a cooling (decreasing) trend coincides with increasing (decreasing) sprat fat content. In particular, sprat populations were able to maintain their highest fat content during the cold period of the 1980s. On the other hand, the anchovy stock follows an opposite trend having higher biomass during warm years.

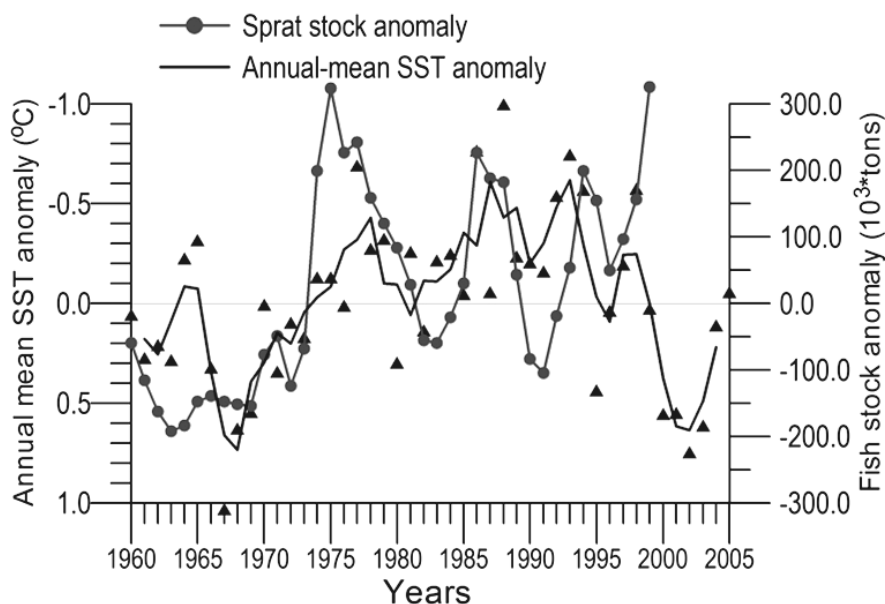


Figure 13. Long-term variations of annual-mean basin-averaged sea surface temperature and sprat stock anomalies. The figure shows positive correlation of the changes in sprat stocks with the climatically cold years.

Climatic fluctuation may affect the relative timing of food requirement and food availability (match-mismatch). Differences in the temporal and spatial match between predator and prey may thus generate variability in the predator survival rates. The ambient conditions in the Black Sea such as water temperature and large-scale climatic and hydrographic processes generate variation in the production, distribution, and abundance of organisms. A climate-induced delay in food production could thus create a mismatch between the prey production and the predator requirements with dramatic implications for reproduction success.

## 6.2. Interaction with anthropogenic factors

Pollution, destruction of hydrobionts stocks, introduction of invasive alien species and habitat loss and modification were indicated by the Global Ecological Fund (GEF) as the main factors threatening the world ocean. The Black Sea is a good example.

The mass development of gelatinous plankton organisms is a characteristic feature of marine zooplankton in condition of eutrophication (Figure 14). High numbers of the scyphozoan *Rhizostoma pulmo* were observed in the coastal zone of north-western Black Sea in the late 1960s and early 1970s. The population of *R. pulmo* gradually declined back to its former levels in 1973-1974. However, almost immediately a population of another scyphozoan jellyfish, *Aurelia aurita*, became highly abundant. The exotic ctenophore, *Mnemiopsis leidyi*, unexpectedly appeared in the early 1980s, and reached a total biomass of about one billion tons (Zaitsev and Mamaev, 1997). On the other hand, the *Aurelia* population collapsed almost immediately, and the biomass of other zooplankton and ichthyoplankton decreased sharply. As a result anchovy catches dropped and commercial fishing for anchovy in the Sea of Azov came to a complete halt (Zaitsev and Mamaev, 1997).

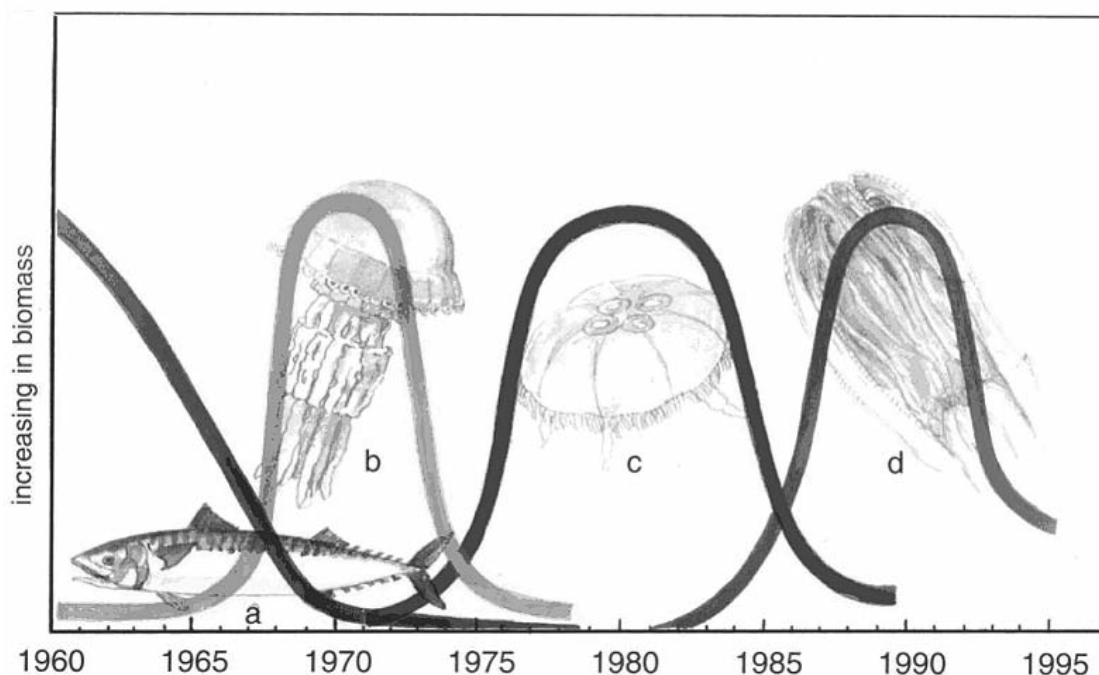


Figure 14. Successive blooms of jellyfish in the Black Sea between 1960-1995, after sharp decline of population of the jellyfish eating mackerel. a- *Scomber scomburus*, b- *Rizostoma pulmo*, c- *Aurelia aurita*, d- *Mnemiopsis leidyi* (after Zaitsev and Mamaev, 1997).

The Black Sea is a favourable habitat for many accidental invaders, some of which have become serious competitors for local species or even their predators. It is possible that the large volumes of phytoplankton and certain zooplankton that resulted from cultural eutrophication did facilitate the establishment of these exotics in the Black Sea (Zaitsev and Mamaev, 1997).

### 6.3 Interaction with fisheries

#### 6.3.1 Fishery resources of the Black Sea

The Black Sea has a considerably limited variety of fishery resources compared to the Sea of Marmara, the Aegean Sea and the Mediterranean. Abundance and catch rate of pelagics such as anchovy, sardine, sprat, blue fish and bonito depend strongly on the recruitment success in their spawning grounds in the Sea of Marmara and NW Black Sea shelf. Turbot, whiting, red mullet, dogfish, skates, stingray, red gurnard, sole and plaice are the major demersal fish species and play an important role in the fisheries of Black Sea countries. *Rapana venosa*, *Venus gallina*, *Mytilus galloprovincialis* are the main species in demersal shellfish production

#### 6.3.2 Development of fishing industry (1970s-2005/8)

The intensive exploitation of Black Sea fisheries started at the end of 1960s – beginning of 1970s with the increase of number of vessels and fishing efficiency. The pressure on the stocks increased until the end of 1980s with a peak total catch of 800 kt in 1988, followed by a sharp decline in the subsequent years due to introduction of the comb-jelly *Mnemiopsis leidyi*, causing high predation on eggs and larvae of economically important fish species. The decline coincides with the two-decade-warming period of climatic cycle in the region. This period also coincided with major political changes in the countries bordering with the Black Sea, when the Russian Federation, Ukraine and Georgia emerged as new states after the collapse of the Soviet Union. During this transition period, due to the financial problems, the fishing fleets of these countries were not used efficiently opening the way to an increase in the fishing effort of the Turkish fleet. From 2000 onwards, over 80% of the total Black Sea catches have been obtained by Turkey (see Figure 15). This ratio is even higher for some species, e.g. bonito, horse mackerel, whiting, red mullet, and bluefish.

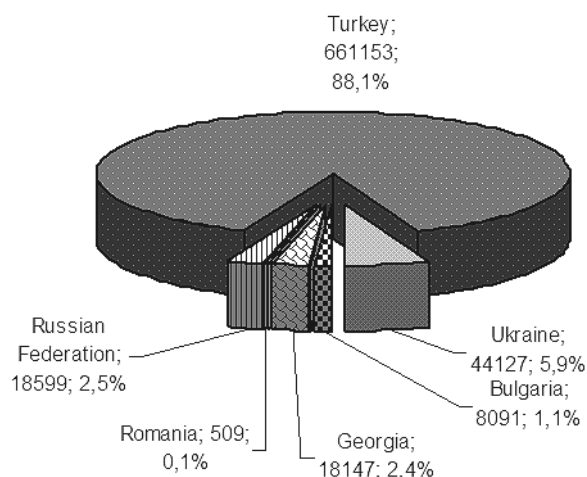


Figure 15. Share of the countries in capture fish production in the Black Sea in 2007 (FAO, Statistics 2008).

The number of Turkish fishing vessels in the Black Sea is 6,700 and new entries are not permitted since 2002. On the other hand old vessels can be replaced by new ones with the same license (20% length increase for cold storage and modern life spaces).

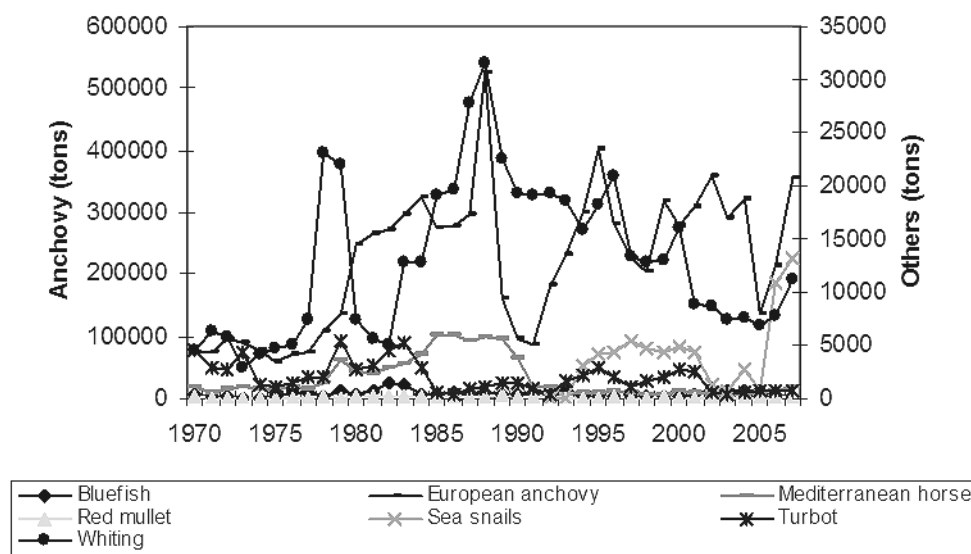


Figure 16. Production of some important fish species in the Black Sea in 2007 (FAO, Statistics 2008).

The main fish species in the catch are anchovy, horse mackerel, whiting, bluefish, Atlantic mackerel, sea snail and baby clam (Figure 16).

### 6.3.3 Recent changes in catch composition of native and alien species

The sea snail *Rapana venosa* is the one of the most important alien species affecting native species of the Black Sea. It has been introduced in the Black Sea in the 1940s from the Sea of Japan by merchant vessels. The absence of any direct predators facilitated the spread of *Rapana* all over the Black Sea coasts, causing the destruction of the mussel beds, its favourite prey. However, as its meat is very popular in the Far East countries, mainly in Japan, this mollusc has been the object of commercial fishing since 1990, for exportation to overseas markets. Similarly, *M. leidyi* became the most abundant jellyfish in the Black Sea and caused the collapse of anchovy stocks (Zaitsev and Mamaev, 1997).

The Pacific mullet, *Liza haematochilus* (= *Mugil so-iuy*) was intentionally introduced in the Seas of Azov and the Black Sea in the period 1972-1980. Native to brackish and marine waters of the Sea of Japan, *M. so-iuy* was introduced into the Azov Sea during the early 1980s by Soviet scientists (Zaitsev, 1991). This species started to reproduce in the Azov Sea and became very abundant along the south Crimean coast, before extending further (Unsal, 1992). At present, *M. so-iuy* is a commercial species in the Black and Azov Seas (Shiganova, 2008). After the introduction of this species the population of native mullet declined due to high level of food competition, to the point where four of five native mullet species are currently out of the commercial list.

## 7. CLIMATE CHANGE PROJECTIONS

Most of the existing climate models have reproduced much weaker trend of the positive NAO index than recently observed under increasing greenhouse gas concentrations (Gillett *et al.*, 2003). Ambaum and Hoskins (2002) demonstrated quantitatively the existence of a nonlinear feedback mechanism between the NAO and the stratospheric vortex located about 20-30 km above the earth's surface over the North Pole. Scaife *et al.* (2005) and Rind *et al.* (2005) have further extended the Ambaum and Hoskins (2002) model by showing that the unexplained strengthening of the NAO can be fully simulated in a climate model by imposing observed trends in the lower stratosphere. Considering the fact that the increase in greenhouse gas concentrations cools and strengthens the stratospheric winter vortex, this process translates at the surface as stronger westerly winds that promote a positive NAO index and further warming in the North Atlantic region. Reduced stratospheric temperatures over both poles mainly in late winter and spring, when sunlight comes back to the polar night area due to the substantial reduction of lower stratospheric ozone content over the last two decades (e.g. Graf *et al.*, 1998) also contribute to strengthening of the stratospheric winter vortex. Kodera *et al.* (2008) further pointed to the solar modulation of the stratospheric polar vortex, and hence promoting the positive NAO index over the Eurasia. Thus, the Eastern Mediterranean and Black Seas is expected to cool under increasing greenhouse gases which cause either to slow down the effect of global warming or to switch the regional climate into a cooling phase.

## 8. RESEARCH PRIORITIES AND RECOMMENDATIONS

Future research needs to address species-specific preferences and sensitivities to environmental factors, most importantly temperature, hypoxia, ocean acidification, and salinity changes, also in relation to the effect of biotic factors such as food availability. Such efforts will improve the cause/effect understanding of ongoing change and lead to the development of reliable mechanism-based projections of future scenarios. Physiological studies of sensitivities, stress levels and functional capacities in crucial life sustaining processes need to be combined with those of phenotypic plasticity, functional genomics and population genetics.

These physiological and genetic approaches must be completed by ecological studies on the biotic interactions among species. Ecological systems are historical and are governed by both constraints (e.g. the limits of tolerance of single species) and by contingencies (e.g. the arrival of an alien predator). Constraints are predictable, but contingencies are not. According to recent estimates, the oxygen-depletion processes might be intensified in the future resulting in the overall decrease of oxygen content in the oceanic water and formation of temporal dead zones (Diaz and Rosenberg, 2008). Regarding the Black Sea it may result in increasing frequency of hypoxia in the Shelf regions (Northwestern Shelf, Anapa Shelf, Azov Sea) and in changes of the volume of the oxygenated layer of the Black Sea (Yakushev *et al.*, 2008).

The Black Sea Basin is characterized by a complex political development during the past twenty years. It embraces six States engaged in different regional forms of cooperation, but also divided on a number of issues up to a point of military confrontation. This has inevitably left its stamp on the management of marine living resources as well. After almost two decades of regional cooperation, there are still no regular stock assessments for the most important commercial species. It is hard to move on to ecosystem-based fishery management with the existing serious data gaps.

The prevailing managerial approach is the implementation of national measures (mainly input controls, such as limitation of fishing effort through licensing of fishing gear and vessels, closed

seasons). Since 2007, Bulgaria and Romania, as new EU members, have followed the Community Fisheries Policy and applied quotas for turbot and sprat. There is no international convention covering fisheries management in the whole Basin, although different drafts have been discussed at technical level for over ten years under the auspices of the Black Sea Commission. Recently, the General Fisheries Commission for the Mediterranean, GFCM, has been put forward, mainly by the EU, as a suitable body for dealing with issues arising at regional level. While the agreement establishing GFCM covers the Black Sea area, Georgia, Russia and Ukraine are not parties to the Commission, which puts certain limits to the viability of such a solution. The issue of coordinating the management of migratory species (e.g. anchovy) within the Black Sea Basin remains open and an institutional setting acceptable to all coastal countries still lies in the future.