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Recent dramatic changes in the Black Sea ecosystem: The reason for the sharp decline in Turkish anchovy fisheries

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Abstract

As a result of eutrophication caused by increased nutrient input via major rivers during the last few decades, the Black Sea ecosystem has been subject to extreme changes in recent years. These changes first became evident in the 1980's, with abnormal phytoplankton blooms and a large increase in medusae (*Aurelia aurita*) biomass. Then, the introduction of a new species (a lobate ctenophore, *Mnemiopsis* sp.) into the Black Sea radically affected the whole ecosystem. This species competes with anchovy for the edible zooplankton as well as possibly consuming anchovy eggs and larvae in the Black Sea. The mass occurence of *Mnemiopsis* appears to be one of the most important reasons for the sharp decrease of anchovy and other pelagic fish stocks in the Black Sea. Although the future of the Black Sea ecosystem seems rather bleak, it is suggested that in addition to reducing anthropogenic impact, systematic studies are essential if the Black Sea fisheries are to recover.

1. Definition of the problem

Since 1981, the highest annual fish catches among all Mediterranean and Black Sea countries has been achieved in Turkey (GFCM, 1993). In fact, the Black Sea fisheries have a special importance in Turkish fisheries. The largest proportion of national fish yields (over 70% since 1970) were from the Black Sea where anchovy (*Engraulis encrasiccolus*) was the dominant fish in caught (60–72% of the total catch between 1980 and 1988; Fig. 1). Until recently there has been a gradual increase in the catches of anchovy (Fig. 1) and other plankton-eating pelagic fishes. However, the sudden decrease in anchovy landings since 1988 is striking (Fig. 1). The anchovy catch decreased from 295×10^3 tonnes in 1988 to 97×10^3 tonnes in 1989 and to 66×10^3 tonnes in 1990 (SIS, 1968–1991). The catch was still very low in 1991 (79×10^3 tonnes). This is almost a four fold reduction in the catches between 1988 and 1991.

The second most important fish with respect to Turkish statistics is the horse mackerel (*Trachurus mediterraneus*). Similar to anchovy, catches of horse mackerel gradually increased until 1986 when they reached 101×10^3 tonnes. The catch of this fish was still high (over 90×10^3 tonnes) between 1986 and 1989 but sharply decreased to 65×10^3 tonnes in 1990 and to only 20×10^3 tonnes in 1991. This presents more than a four-fold decrease between 1988 and 1991.

In the last a few years, dramatic reductions have been reported not only for Turkish Black Sea fisheries, but also in the fisheries of other riparian countries. For example, anchovy catches for the USSR consistently dropped in the same period; 237×10^3 tonnes in 1988, 65×10^3 tonnes

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in 1989, 29×10^3 tonnes in 1990 and only 6×10^3 tonnes in 1991 (GFCM, 1993). Anchovy along the Romanian coasts had almost disappeared by 1989 with landing figures of less than 61 tonnes as compared to 1.5×10^3 tonnes in 1987 and 3.2×10^3 tonnes in 1988. Unlike the years preceeding 1988, there are no records for anchovy catches since 1989 for Bulgaria (GFCM, 1993). The total catches of the Azov Sea fisheries dropped to 2.8×10^3 tonnes in 1990 from 42.4×10^3 tonnes in 1989 and 89.5×10^3 tonnes in 1988 (Volovik et al., 1992). Stocks of the economically important fish *Clupeonella cultriventris* had virtually disappeared by 1990 in the Azov Sea (Harbison and Volovik, in press; Volovik et al.. 1993). Similarly, in Romania, sprat (*Sprattus sprattus*) catches dropped to 3.2×10^3 tonnes in 1990 and to 729 tonnes in 1991, from $6–9 \times 10^3$ tonnes in the late 1980's (GFCM, 1993).

Since these anchovy fisheries were extremely important sources of income and protein, their collapse will have adverse effects on the economy and protein consumption of people, particularly those inhabiting the Black Sea coasts of Turkey.

The decline of these anchovy and other pelagic fisheries undisputedly shows the seriousness of the Black Sea problem. In this paper, we investigate two interrelated problems: the sharp decrease in the anchovy fisheries and the recent dramatic changes in the Black Sea ecosystem. Although several pollutants such as pesticides, PCB's, metals and radionuclides are becoming increasingly problematic in the Black Sea (Mee, 1992), they are unlikely to be the cause of the decrease in anchovy stocks, as there were no sudden changes in land-based activities during the period of decline. Therefore the effects of these pollutants are not discussed here.

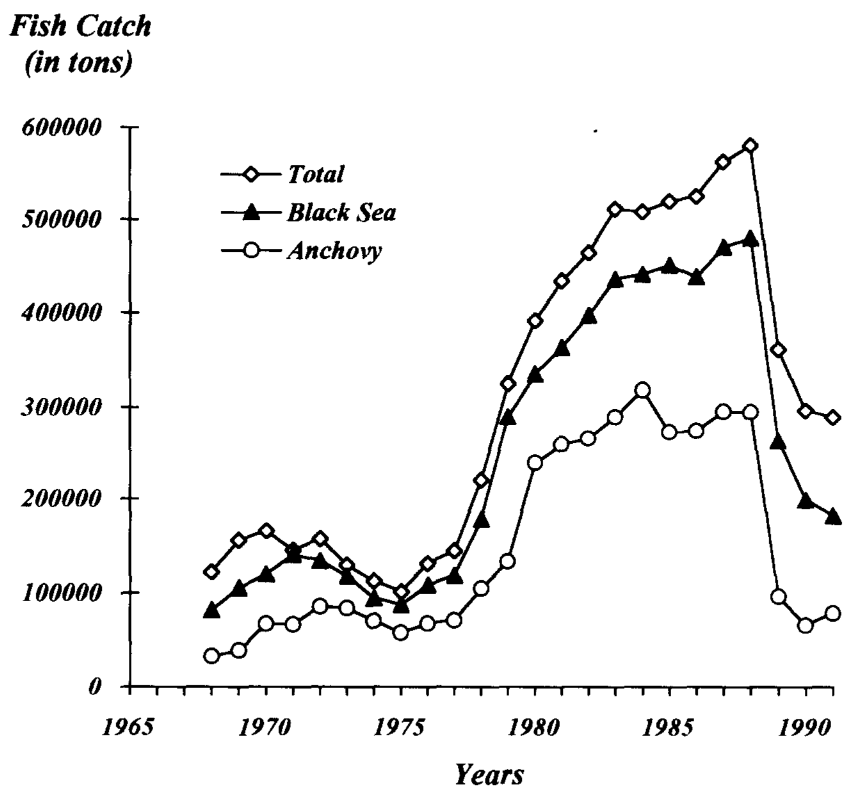

Fig. 1. Importance of anchovy fishing in the total Turkish catch between 1968 and 1991 (source SIS, 1968–1991).

2. The role of major rivers in the changing ecological characteristics of the Black Sea

The Black Sea (Fig. 2) contains the largest anoxic water body in the world (Tolmazin, 1985). The surface of the Black Sea is 423,500 km^2, volume 537,000 km^3, greatest depth 2245 m and average depth 1271 m (Zenkevitch, 1963). Its only water exchange occurs via the narrow (0.76–3.60 km) and shallow (32–34 m at its sill) Bosphorus Strait which is a significant factor for waters deeper than 150–200 m (90% of its total volume) being permanently anoxic.

In contrast to the rest of the Black Sea, the north-western continental shelf region comprising about 25% of its total area is relatively shallow at a depth of less than 200 m (Mee, 1992). Assuming an average depth of 75 m, the volume of this shelf area (approx. 100,000 km^2) can be calculated as $100{,}000 \times 0.075 = 7500$ km^3. Three rivers on the north-western shelf contribute about 67% of the total annual river inflow of 400 km^3 $year^{-1}$ to the Black Sea (Danube alone contributing about 203, the Dnieper 54 and the Dniester 9.3 km^3 yr^{-1}). The annual discharge of these three rivers amounts to about 4% of the total volume of the shelf area. A huge drainage basin fed by the agricultural and industrial areas of several European countries is responsible for the input to the aforementioned rivers.

Although there have been several other changes in the Black Sea over the last few decades (e.g. decrease in the discharge of northern rivers, increase in pollutant levels, etc.), the catastrophic events were triggered mainly by increased nutrient levels which then caused substantial changes in the plankton communities.

3. Changes in the nutrient input

In the last few decades, the nutrient concentrations, particularly in the northern and western parts of the Black Sea have increased significantly. While atmospheric input might play a substantial role in this increase, rivers are a very important source for nutrient loading in the Black Sea. Unfortunately nutrient levels via atmospheric input are not known, however, there are some studies on the annual nutrient flow transported by the major rivers.

With a catchment basin of 817,000 km^2 the Danube is the most important fertilization source

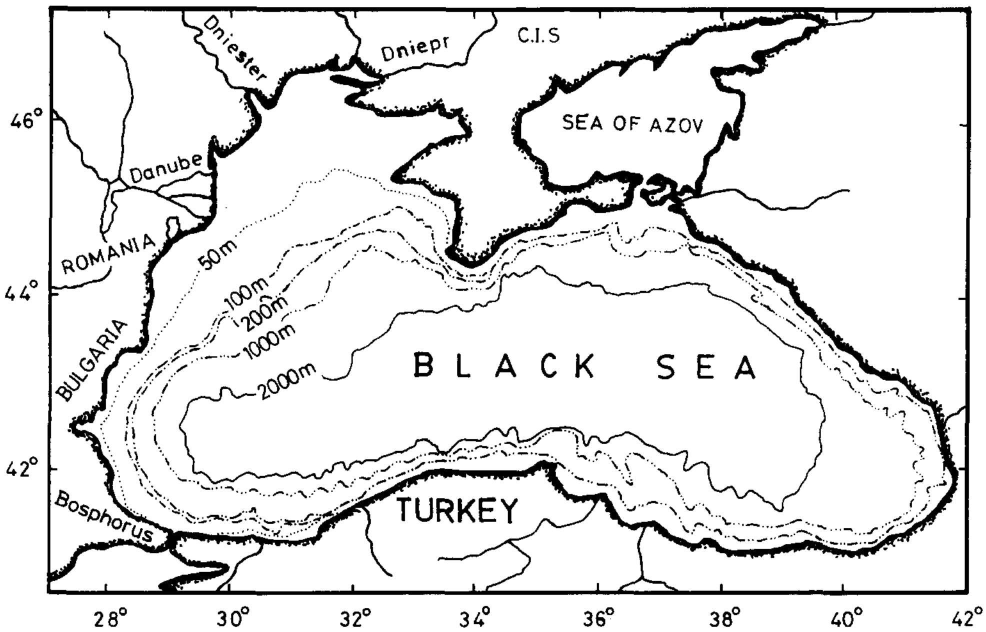

Fig. 2. The Black Sea (depth contours are labeled in meters).

Table 1
Long term mean values of nutrients ($\mu g\ l^{-1}$) in Constanza coastal waters, off Romania (from Bodeanu, 1989)

Period	P-PO_4	N-NO_4	Si-SiO_4
1960-1970	10.5	22.5	1029
1971-1975	177.5	-	1714
1976-1980	197.5	188.8	857
1981-1985	138.8	93.7	361
1986-1988	262.0	112.2	341

for the Black Sea. The quantities of phosphorus from phosphates carried every year by the Danube into the Black Sea, increased from 12.6 thousand tonnes in the 1950's to 30.4 thousand tonnes in 1987 (see Bodeanu, 1989). The annual nitrogen content showed an even greater increase: from 143 thousand tonnes in the 1950's to 741 thousand tonnes in 1988. While phosphorus and nitrogen compounds were increasing, the annual quantities of silicon carried by the Danube river showed a decreasing trend. Given that silicon has a strong affinity with particulate matter in water, this decreasing trend observed could be linked to a diminution of solid flow due to the numerous dams built in the river and its tributaries.

Similar trends were observed in the nutrient load of other rivers, too. For example, between 1952 and 1977, in the lower section of the Dniestr which has a catchment basin of 75,200 km^2, the concentrations (in $\mu g\ l^{-1}$) of nitrite, nitrate, phosphate and silicon increased from 0-20 to 36-150, 0-1000 to 400-3000, 0-50 to 15-260 and from 1000-5200 to 2300-9200, respectively (Tolmazin, 1985).

The changes in the nutrient load of the rivers in the last three decades are manifested particularly in the north-western coastal waters of the Black Sea (Table 1). Between 1960 and 1970 the phosphorus content (P-PO_4) was 10.5 $\mu g\ l^{-1}$. This value increased 17 fold in 1971-1975 and 26 fold in 1986-1988. Similar changes can be found for nitrates (N-NO_3): 22.5 $\mu g\ l^{-1}$ in 1960-1970, 112.2 $\mu g\ l^{-1}$ in 1986-1988. In contrast to these nutrients, silicon levels showed a decreasing trend in the respective periods (Table 1).

During the last 25 years, maximum nitrate concentrations in the open Black Sea have also risen gradually from 2-4 μM (0.1-0.3 $\mu g\ l^{-1}$) in the 1960's to 5-7 μM (0.4-0.5 $\mu g\ l^{-1}$) in 1978-1980 and finally to 8-9 μM (0.6-0.7 $\mu g\ l^{-1}$) during 1988-1991 (Codispoti et al., 1991).

This increase in nutrient levels in the Black Sea would inevitably lead to eutrophication hence increasing the growth of algae and organic matter.

4. Structure of phytoplankton

Even the slightest change in the nutrient balance may cause changes initially in the phytoplanktonic community, and subsequently in the whole ecosystem's food web.

The response of phytoplankton communities to eutrophication in the Black Sea has been reflected by qualitative and quantitative changes in their structures, including intensified blooms and red tides. For example, the ratio of diatoms:dinoflagellates in several localities has changed during the last few decades. Diatoms decreased from 92.3% in 1960-1970 to 62.2% in 1983-1988 in the phytoplankton off Romania and the proportion of dinoflagellates increased from 7.6 to 30.9% in the same periods (Table 2). Unfortunately there are only a few published studies on phytoplankton in the southern Black Sea (Tuncer and Feyzioglu, 1989; Feyzioglu, 1990; Uysal, 1993), and therefore, it is difficult to make sound deductions on the changes of phytoplankton community structure along the Turkish coast.

Bologa (1986) reported a qualitative change in the phytoplanktonic groups at the onset of intense eutrophication when the diatom proportion decreased from 67% (209 species) between 1960-

Table 2
Temporal changes in proportions (% of numerical density, cells l^{-1}) of the main algal groups in phytoplankton off Romania (from Bodeanu, 1989)

Algal group	Proportions (%)		
	1960-1970	1971-1982	1983-1988
Diatoms	92.3	84.1	62.2
Dinoflagellates	7.6	11.8	30.9
Other groups	0.1	4.1	6.9

Table 3
Distribution of taxonomic groups of the phytoplankton off the Romanian Black Sea coast (from Bologa, 1986)

Taxonomic group	1960–1970		1972–1977	
	No. of species	%	No. of species	%
Bacillariophyta	209	67	172	46
Pyrrophyta	60	19	77	21
Chlorophyta	15	5	68	18
Cyanophyta	11	3	32	8
Chrysophyta	14	4	19	5
Euglenophyta	2	1	5	1
Xanthophyta	3	1	2	1
Total	314	100	375	100

70 to 46% (172 species) between 1972–77 period (Table 3). For the same periods the number of dinoflagellate species increased from 60 to 77. Such qualitative changes in the phytoplankton denote that new species appeared for the first time in the ecosystem. Among them, *Gonyaulax polygramma* (Dinophyceae), *Raciborshiella salina* (Volvocales) and *Eutroptia lanowii* (Euglenineae) were recently reported in high densities in the Black Sea (Mihnea, 1985). The diatom *Hemialus hauckii* was observed in epidemic proportions in the south-east coast of the Black Sea by Feyzioglu (1990). It is reported to be a transitory species between oligotrophic and eutrotrophic waters (Kimor, 1985).

Another inevitable result of eutrophication is the increase in cell numbers and biomass of the phytoplankton. Mihnea (1985) reported that the cell number of the diatom *Skeletonema costatum* increased from 1×10^4–4×10^6 in 1962–1965 to 8.3×10^7 in 1984. The dinoflagellate *Prorocentrum cordatum* also increased from a few million in the 1960's to 1×10^7–1×10^8 cells l^{-1} in 1975–1983 (Mihnea, 1985). Several studies undertaken over the last decade in the Romanian littoral zone of the Black Sea report extensive phytoplankton blooms (Bodeanu, 1989). For instance, medium biomass of phytoplankton was ten times greater in 1983–1988 than in 1959–1963. The number of species with high numerical densities (over 100,000 cells l^{-1}) increased periodically reaching 72 in 1983–1988, compared with 61 in 1971–1982 and only 38 in 1960–1970. For the same period a collection of data was compiled by Soviet and Bulgarian authors with respect to this escalation of phytoplankton in the western part of the Black Sea (see Bodeanu, 1989; Prof. G. Dechev, pers. commun.).

In recent years there have been increasing *Exuviella cordata* red tide intensities over the entire area of the sea. During the period of bloom in 1986, the biomass of *Exuviella* in the Burgas Bay attained to 1×10^9 cells l^{-1} (1 g l^{-1}) (Sukhanova et al., 1988). There have been even denser occurences of another red tide causing dinoflagellate, *Noctiluca miliaris*, reaching a level of about 100 g l^{-1} in the mouth of the Danube river (Polishchuk, 1988, cited in Vinogradov et al., 1989). Since 1976–1977, *Noctiluca* blooms became a common feature in some areas at times (Caddy and Griffiths, 1990). Phytoplankton blooms affect vertical light transmission and deplete dissolved oxygen content leading to a rise in the upper limit of the anoxic layer of the Black Sea. In 1986, during the bloom of *Exuviella cordata*, dissolved oxygen (DO) depletion zone was recorded at 4 m from the surface waters off Burgas, Bulgaria, resulting in mass mortalities of benthic organisms (Prof. G. Dechev, pers. commun.).

The effects of eutrophication were not limited only to inshore waters, but also to the open waters in the Black Sea. For example, chl *a* values measured in 1989 were 1.5–3 times higher than in the 1970's (Vinogradov, 1990). Accordingly, microbial population had increased 2–3 times compared with 20–30 years earlier in the open areas (Vinogradov, 1990).

5. Structure of zooplankton

Unfortunately there are only a few observations on the direct effect of eutrophication on zooplankton in the Black Sea. Red tide patches produced by the ciliate *Mesodinium rubrum* at concentrations greater than 280 g m^{-3} were found off the Bulgarian coast near Varna in 1984 (Tumantseva, 1985). However, the qualitative and quantitative changes in phytoplankton due to eutrophication would undoubtedly affect zooplankton composition. Petran et al. (1977, cited in Balkas et al., 1990) reported that the biomass of the zooplankton community increased from 2.6 mg m^{-3} in 1961 to 18.3 mg m^{-3} in 1967 and 17.0 to 155.6 mg m^{-3} during 1976–1977. Whilst all neustonic copepods (*Pontella mediterranea*, *Anomalocera patersoni*, *Labidocera brunescens*) have disappeared from the north-western region, many large species of crustacean plankton have been replaced by smaller species (Zaitsev, 1992). The number of some copepods, such as *Acartia clausi*, *Paracalanus parvus*, *Oithona nana*, increased considerably (Porumb, 1980, 1984 cited in Balkas et al., 1990; Zaitsev, 1992) until the 1980's, but decreased again recently, due to high predation pressure caused by an increasing biomass of gelatinous organisms (i.e. mainly the medusa *Aurelia aurita* and ctenophore *Mnemiopsis* sp.; Shuskina and Musayeva, 1990a). It has been observed that when there is no predation pressure some copepods are able to increase in substantial quantities. For example, a dense layer of *Calanus ponticus* was strikingly evident just above the anoxic layer (Vinogradov and Shuskina, 1982; Vinogradov et al., 1992) where the main predators are absent.

Two jelly-like zooplankton species warrant special attention due to their great biomass. Before analysing the problem in an attempt to provide a solution, it is also important to remember some biological and ecological aspects of these gelatinous organisms which play very important roles in the Black Sea ecosystem.

5.1. *Aurelia aurita*

Aurelia aurita is a member of the phylum Cnidaria (class Scyphomedusae) of which a characteristic feature is the presence of nematocysts or stinging cells. Although there is no statistical proof, *A. aurita* seems particularly abundant in eutrophicated regions.

Although *Aurelia aurita* is characteristic of the Black Sea pelagic fauna (Zenkevitch, 1963), its population has recently increased substantially. In 1950–1962, jellyfish biomass was estimated as 1.4 g live weight m^{-3} (Mironov 1971, cited in Shuskina and Musayeva, 1983). By using the 1.4 g live weight m^{-3} value, Shuskina and Musayeva (1983) calculated the total jellyfish biomass as 30,000,000 tons for the 0–50 m sea layer in which the main mass of Aurelia occurs (Vinogradov and Shuskina, 1982) in the Black Sea. In the early 1980's, the biomass of *Aurelia* was found to be 25 g live weight per m^3 which amounts to 350–400 million tons for the entire sea (Shuskina and Musayeva, 1983). Assuming an average daily ration of 6% body weight, expressed in calories, Shuskina and Musayeva (1983) calculated that jellyfish can consume up to 25% of the zooplankton production available to fish.

Zooplankton is the main food taken by *Aurelia* and includes young and adult individuals of *Paracalanus*, *Pseudocalanus*, *Calanus*, *Acartia*, *Oithona*, *Cladocerans* and *Appendicularians* in the Black Sea (Mikhaylov, 1962; Mironov, 1967 cited in Shuskina and Musayeva, 1983).

It is not clear whether *Aurelia* feeds on eggs and larvae of anchovy, this might well be so and needs investigating. However, *Aurelia aurita* has been shown to be an important predator on smaller species of several other fish larvae (e.g. cod *Gadus morrhua*, flounder *Platychthys flesus*, plaice *Pleuronectes platessa* and herring *Clupea harengus* etc.; Bailey and Batty, 1983, 1984; Zhong, 1988). Moller (1984) similarly found that this jelly-fish consumes large amounts of yolk-sac herring larvae in the Kiel Bight, Germany. But the fact is that there was no sudden decrease in the anchovy catches with increasing *Aurelia* biomass, until the mass appearance of *Mnemiopsis* in the Black Sea in 1987.

5.2. *Mnemiopsis sp.*

Mnemiopsis is a member of phylum ctenophora. Main (1928 cited in Vinogradov et al., 1989) points that whilst the medusae are microphages, *Mnemiopsis* is a macrophage capable of consuming fairly large prey (up to 1 cm or more in length).

Mnemiopsis, like all other ctenophores, are hermaphroditic. Ctenophores, particularly members of genus *Mnemiopsis*, have a very high reproductive capacity. *Mnemiopsis mccradyi* is able to produce 8000 eggs within 23 days, after 13 days of its own birth (Baker and Reeve, 1974). The growth rate of this species is comparable to that of phytoplankton (daily doublings, Reeve et al., 1978). Naturally such high growth rates can only be achieved with a high feeding rate.

Abundance of *Mnemiopsis* has been observed to fluctuate throughout the year where it occurs. In the Narragensett Bay, Kremer and Nixon (1976) found that while the overwintering population of *Mnemiopsis* was extremely low (1–2 animals per 10^4 m^3), they could reach a peak density of over 50 individuals m^{-3} in summer. An equally sharp decline took place in the early autumn. In the north Atlantic, the maximum abundance of *Mnemiopsis leidyi* has been found to occur between April and September by several investigators (Ziegenfuss and Cronin, 1958; Burrell, 1968; Hirota, 1974, all cited in Kremer and Nixon, 1976). It is worth noting that this period coincides with the spawning season of anchovy in the Black Sea.

Mnemiopsis has long been reported as an effective predator on zooplankton (Burrell and Van Engel, 1976; Mountford, 1980). Reeve et al. (1978) state that perhaps the most significant aspect of the feeding behaviour of *Mnemiopsis* is that their ingestion rate is proportional to food concentration. This is why concominant with their appearence, a dramatic decrease in the number or biomass of copepods and other food zooplankton is often observed. For example, Burrell (1968, cited in Kremer, 1979) suggested that predation by *Mnemiopsis leidyi* was responsible for a large fraction (73%) of total zooplankton mortality in the York River estuary of Chesapeake Bay. *Mnemiopsis leidyi* has also been shown to feed on eggs and larvae of fishes (Purcell, 1985; Tsikhon-Lukanina and Reznichenko, 1991), including anchovy *Anchoa mitchilli* (Monteleone and Duguay, 1988; Govoni and Olney, 1991).

It is believed that *Mnemiopsis* sp. reached the Black Sea in the ballast water of ships cruising between the western North Atlantic and the Black Sea (Prof. V.E. Zaika, pers. commun.). In the autumn of 1987, this ctenophore was first recorded off the northern coast of the Black Sea (Vinogradov et al., 1989). There has been confusion about the species name of this ctenophore. It was initially described as *M. leidyi* but redefined as *M. mccradyi* (Zaika and Sergeeva, 1990). This is not surprising since there is some controversy as to whether even these two species are separate or the same (M.R. Reeve, pers. commun.). By 1988, *Mnemiopsis* had spread all over the Black Sea with a remarkable biomass of 1.5–2 kg m^{-2} in the open waters. The total biomass of *Mnemiopsis* in the Black Sea was calculated as 800 million tons (live weight) in the summer of 1989 (Vinogradov, 1990). A great alteration of the structure in the planktonic community has resulted from this mass development. The quantities of copepods and other forage zooplankters have diminished 15–40 fold (Shuskina and Musayeva, 1990a). This remarkable increase in *Mnemiopsis* biomass caused the biomass of the *Aurelia* to drop to less than 1/20 of levels previously observed over the last 10 years (Vinogradov et al., 1989; Shuskina and Musayeva, 1990b; Shuskina and Vinogradov, 1991). The sharp decrease in the concentration of anchovy eggs and larvae observed since 1989 has been suggested to be due not only to eutrophication but also to *Mnemiopsis* predation or competition in the northern Black Sea (Niermann et al., 1993). All the available evidence indicates that either by consuming eggs and larvae of the anchovy or perhaps more importantly its food, *Mnemiopsis* has played an important role in the sharp decline of Black Sea pelagic fisheries.

6. Possible future scenario in the Black Sea

Unfortunately, the immediate future of the Black Sea does not seem a good one. For example, even "turning off" nutrient sources completely (which is almost impossible) would not stop eutrophication for years due to nutrient recycling particularly from the continental shelf areas (Mee, 1992).

If necessary steps are not taken immediately, the increasing input of nutrients will cause a further increase in the organic matter production by phytoplankton. With only a very small quantity of pelagic fish to utilize this organic production, most of it will be eaten by *Mnemiopsis* or will accumulate by sedimentation on the sea bed. Dying *Mnemiopsis* will also reach the sediment due to an absence of their natural predators. An increase in organic matter sedimentation combined with a decrease in light penetration (which adversely affects photosynthesis and hence oxygen production) will boost H_2S production, thus causing a rise in the upper level of anoxic deep waters. This may cause further mass mortalities of benthic organisms, severely diminishing the marine fauna and biodiversity along the continental margin of the Black Sea.

Aurelia aurita biomass could be expected to continue decreasing due to a few reasons. Firstly, the benthic stage of *Aurelia* is confined to relatively shallow water on substrates of rock or gravelly sand. Suitable areas for this benthonic stage in the Black Sea are therefore limited to the narrow shelf areas mainly in the northern region (Caddy and Griffiths, 1990). According to these authors the existence of a benthonic stage in the life cycle could make *Aurelia* populations vulnerable to the effects of rising anoxic bottom water in the Black Sea. Secondly, the reproductive and growth potential of monosexual *Aurelia* is ,very low (only 10 ephyrae on average from one single *Aurelia* polyp per year, Thiel, 1962 cited in Moller, 1984) compared to hermaphroditic *Mnemiopsis* as mentioned previously. *Mnemiopsis* has long been reported to have a competitive advantage at high food densities in eutrophicated areas (Reeve et al., 1978; Kideys and Niermann, 1993). Therefore it could be suggested that the biomass of *Aurelia* may continue to drop in the Black Sea.

Since there is no natural enemy in the Black Sea to feed on *Mnemiopsis*, a decline in the biomass of this ctenophore is not expected if no reduction in organic matter production (= eutrophication) takes place. Moreover, the present biomass level of this ctenophore may not allow any increase in pelagic fish stocks from their already very low level. Thus, the future for plankton-eating pelagic fish seems bleak in the Black Sea.

One further inevitable result of the present decrease of the anchovy and other pelagic fish stocks will be a high rate of mortality among Black Sea dolphins as they are mainly dependent on these fish (Celikkale et al., 1988). In the last stock assessment carried out in 1987, roughly 500,000 dolphins were estimated to occur in the Black Sea (Celikkale et al., 1988). Unfortunately, it would not be pessimistic to expect a sharp decrease in this number by now due to the collapse of pelagic fisheries in the Black Sea despite no dolphin fishing being allowed by all riparian countries since 1983.

7. Action needed

7.1. Reducing nutrient input

The fate of the Black Sea is dependant upon those countries whose rivers directly affect it, therefore cooperation between Black Sea and Danube riparian countries is vital for a promising outlook. Only by their collaboration can nutrient loads be substantially reduced. Some collaboration activities have already started by riparian countries (see Mee, 1992). However the application of such cooperation seems difficult; for the sake of riparian countries and also the world's benefit, all necessary enforcing legistlation must be put into action. The role of atmosphere in the transport of nutrients should also be taken into account in the agenda for any Black Sea cooperation. Because, for example, atmospheric deposition of N occurs as nitrogen oxides and originates from the combustion of fossil fuels, e.g. from car engines and power stations (Rosenberg, 1985).

7.2. Regulating fisheries

Overfishing of anchovy stocks is clear from the decrease in the average length of fishes over the years. For example Bingel et al. (1993) found that the majority (> 50%) of anchovy caught were below 11.5 cm in 1987/1988 fishing season, 9 cm in 1988/1989, 7.5 cm in 1989/1990 and 8 cm in 1990/1991. In other words, the ratio of anchovy > 1 year old (about 9.5 cm) to the total stock had decreased sharply, 88.8% in 1987/1988, 22.6% in 1988/1989, 1.7% in 1989 to 1991, indicating heavy fishing pressure on this fish. In Turkey, the influence of some fishermen in decreasing the permitted minimum size caught is unfortunately considerable. Recently in the winter of 1992, following a lobby, this was reduced to 8 cm allowing the capture of 0 year class stock. For the long-term rational exploitation of anchovy stocks to be feasible, the decisions on the management of stocks should be based on scientific results.

7.3. Control of gelatinous macrozooplankton using biological methods

Although biologists loathe to suggest introducing new species into the marine environment, there are few alternatives to offer for this ecologically devastated environment (i.e. Black Sea). Unfortunately only very few predators or parasites are known for both *Aurelia* and *Mnemiopsis*. Additionally neither species is cannibalistic. The only predator described for *Aurelia* (in the scyphistoma stage) is a benthonic opisthobranch mollusc, *Coryphella verrucosa* which is absent in the Black Sea (Caddy and Griffiths, 1990). Parasitization by the amphipod *Hyperia galba* may be important for *Aurelia*'s death in the Kiel Bight (Moller, 1980).

There are some reviews on the predators of gelatinous zooplankton (Harbison, 1993), including *Mnemiopsis* (Harbison and Volovik, in press). It seems that the only fish which could be considered to be predatory on *Mnemiopsis* is the butterfish *Peprilus triacanthus*. It has been suggested that these fish exerted substantial predation pressure on this ctenophore during the late summer and autumn in Narragansett Bay, Atlantic coast of United States of America (Kremer, 1976). However, an additial observation exists regarding the consumption of *Mnemiopsis* juveniles by the horse mackerel (*Trachurus mediterraneus*) off the Bulgaria coast (Prof. V.E. Zaika, pers. commun.). Two less important predators of *Mnemiopsis* are another ctenophore *Beroe ovata* (Kremer, 1976) and a cnidarian *Chrysaora quinquecirrha* (Burrell and Van Engel, 1976). However, introducing these organisms with no known predator on them does not help, but may increase, the problem of gelatinous organisms in the Black Sea. Only one parasite, the coelenterate *Edwarsia leidyi* (= *Fagesia lineata*), has been observed to infest *Mnemiopsis leidyi* in the north-western Atlantic waters (Kremer, 1976) where a single ctenophore may contain more than ten large individual parasites of which potential influence is considerable.

A gigantic fish, the basking shark *Cetorhinus maximus*, feeds exclusively on plankton. Although little is known on any aspects of their biology, including feeding habits, these fish have been observed to filter seawater containing substantial amounts of a tentaculate ctenophore (most probably *Pleurobrachia pileus*) in the Irish Sea (pers. obs.). The use of biological methods in the control of *Mnemiopsis* is worth investigating.

7.4. Fundamental investigations

It is obvious that systematic investigations are fundamental in understanding the consequences of this event in the Black Sea. A continuous monitoring of the biological characteristics of primary importance in this ecosystem is vital in determining a sound rescue operation. Therefore the quality and quantity of major components of the ecosystem e.g. benthos, phytoplankton, zooplankton, jelly-like organisms (i.e. *Aurelia*, *Mnemiopsis*, *Pleurobrachia*, *Noctiluca*), pelagic fish (mainly anchovy, sprat and horse mackerels) and dolphins, should be closely monitored.

Although there are several studies on food preferences and quantities taken by different anchovy species in different regions of the world (Hunter, 1972; Scura and Verde, 1977 Mendiola, 1980; Mendiola and Gomez, 1980; Mendiola and Lopez, 1980), the feeding ecology of the larval, juvenile and adult anchovy is not known in the Black Sea. This problem, in the context of the food web, requires immediate investigation in order to understand the damage done to its food sources by other main predators or by the changing abiotic characteristics of the Black Sea.

The feeding ecology of *Mnemiopsis* should also be enlightened in the Black Sea. A determination of the ecological energetics parameters of this ctenophore will primarily help in the assessing the importance of its predation on zooplankton, including eggs and larvae of anchovy.

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