ROLE OF FISHING IN THE BLACK SEA ECOSYSTEM

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Abstract. The Black Sea anchovy has experienced the most severe decline of the past 50 years and the responsible factors are not yet clearly understood. This is mainly due to the possible existence of several factors which may be equally probable. Some of these factors are: the increased eutrophication which changed the oligotrophic character of the Black Sea into a dystrophic one; the introduction of ctenophore medusa, *Mnemiopsis* sp; the outstanding exploitation pressure of the over-capitalised fishing fleet, and alterations in river discharges and hydrologic conditions at the straits. In this study, the contribution of fishery to anchovy collapse has been evaluated. For this purpose, **i)** the increase of fishing power by the recent introduction of purse seiners and sonars and their effects on over-wintering stocks along the Turkish coasts, **ii)** the condition index as an indicator of starvation of anchovy for pre and post *Mnemiopsis* period, **iii)** the spawning behaviour of anchovy, and **iv**) the coexistence of anchovy and *Mnemiopsis* during the anchovy spawning season, have been reviewed. It was concluded that effects of over-capitalisation of the fishing sector, especially of Turkey, on anchovy collapse and to an extent on the catastrophic changes in the Black Sea ecosystem, should not be overlooked as secondary.

2. Introduction

The state of the Black Sea, with its unique features, such as being the largest enclosed catchment basin, sets an excellent example demonstrating the adverse human impact on a marine ecosystem in regard to what could happen in the very near future to the other parts of the world oceans. Since the early fifties noticeable alterations have been observed at various levels of the Black Sea ecosystem. These changes, such as manipulation of hydrologic regimes of the out-flowing rivers (Bondar, 1977), changes in nutrient composition (Bologa et al., 1984; Gomoiu, 1990), introduction of exotic species (Vinogradov et al., 1989; Mutlu et al., 1994), selective and excessive fishing (Ivanov and Beverton, 1985; Stepnowski et al., 1993; Bingel et al., 1993), are well studied and reviewed by various authors (Sorokin, 1983; Tolmazin, 1985; Caddy and Griffiths, 1990; Mee, 1992; Zaika, 1992; Niermann et al., 1994). The rivers, such as the Danube, Dnepr, Denstr, Don and Kuban, constitute llinks between land and sea,

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and play a crucial role in the modification and in the later deterioration of the ecosystem. These rivers are loaded by anthropogenic wastes from various sources in Central and Eastern Europe and drain them into northern part of the Black Sea. Their influence is, therefore, more pronounced in the Northwestern Shelf area and the Azov Sea, compared with other areas such as the Turkish Coast. Figure 1 is an arbitrary representation of different zones subjected to different types of changes.

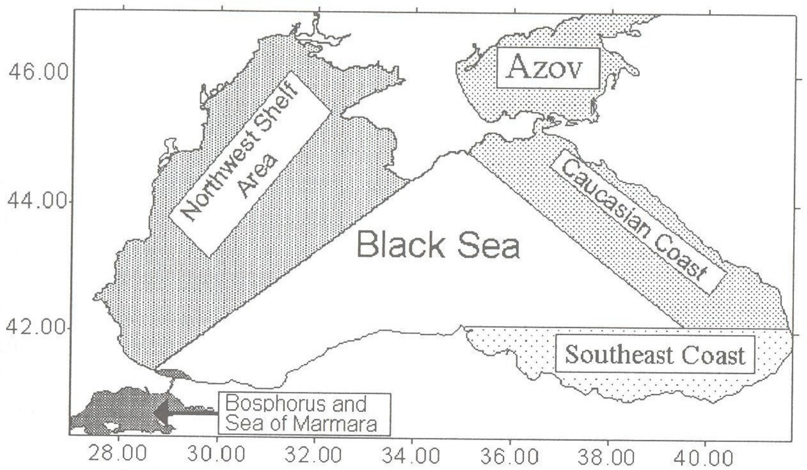

Figure 1 Arbitrary zones of the Black Sea used in the text.

In 1989, the *Mnemiopsis sp.*, which is an introduced species, suddenly appeared in the Black Sea in huge quantities. Its appearance has been synchronously followed by a sudden decline in various fish stocks. The purpose of this study is to evaluate the changes in the Black Sea ecosystem from the fisheries point of view and review -the catalysing effects of excess fishing on *Mnemiopsis* outbreak and on the deterioration in the ecosystem.

3. Zones of the Black Sea

3.1. NORTHWESTERN SHELF AREA, NWS

Until recently, the Northwestern Shelf Area was the most important zone in the Black Sea for the majority of the fish fauna. This area was reported as the main spawning and nursery ground for commercial species, like anchovy (*Engraulis encrasicolus ponticus*), turbot (*Psetta maxima)*, Atlantic bonito (*Sarda sarda*) and blue fish (*Pomatomus saltator*) (Slastenenko, 1956; Ivanov and Beverton, 1985). The primary reasons for the high preference of this region were the river induced productivity; and the underlying shallow and broad shelf area inhabited by macrophytes, which were

abundant enough to oxygenate the water column down to 60 meters (Ivanov and Beverton, 1985; Zaitsev, 1993).

As the level of nutrient enrichment increased gradually, primary production and in turn, the carrying capacity of the ecosystem for planktivorous species has increased (Caddy, 1990). In the 1980's a significant drop in the stocks of large pelagic fish, like *Scomber scombrus*, *Sarda sarda*, *Pomatomus saltator* was observed. As a result of improved food availability and removal of predation control by large pelagics, the ecological situation in the NWS area turned in favor of the small pelagic fishes like *Engraulis encrasicolus ponticus* and *Sprattus sprattus balericus*. On the other hand, stocks of some other commercial demersal species, such as *Psetta maxima* declined considerably (GFCM, 1993).

By further increase in the nutrient enrichment, the frequency and extent of phytoplankton blooms and consequently turbidity in the waters have also increased. Light attenuation by the particles increased and this resulted in regression of macrophyta meadows. Today, human induced excess autotroph production, which is not transferred to higher trophic level sediments at the bottom; are decomposed by bacterial activity and cause high level of oxygen utilization. Due to lack of oxygen, hypoxia and even local anoxia became common phenomena in the shallow coastal waters of NWS. Along with macrophytes, mussels, other demersal invertebrates and fish either died or were reduced drastically. In summary, this precious habitat for almost all living resources was dystrophied (Zaitsev, 1993).

3.2. THE AZOV SEA

Although it a has different hydrological and biological structure than Black Sea, from the fishery point of view, the Azov Sea is in close connection with the Black Sea. Like the NWS area, the Azov Sea, with its shallow, less saline waters supplied with suitable nutrients, formerly served as important nursery and spawning grounds for commercial fishes such as anchovy (*Engraulis encrasicolus ponticus*) and kilka (*Clupea cultrivensis*). Starting from the early fifties, due to the construction of reservoirs, dams, diversion of river water for irrigation, dumping of industrial, agricultural and domestic wastes into water bodies, the water quality and hydrological regime of the Azov Sea has been changed. Eutrophication and desalination of the water has eventually adversely affected fish stocks (Volovik et al, 1992; 1993a; 1993b).

3.3. THE BOSPHORUS AND THE SEA OF MARMARA

Apart from being a strait between the Sea of Marmara and the Black Sea, the Bosphorus is also a passage for the warm water components of the fish fauna, which spawn and feed in the Black Sea and over-winter in the Marmara and the Aegean Seas. During their seasonal migrations, these fish become extremely vulnerable to the fishery activities in the Turkish Straits, and hence they are over-fished. Moreover, domestic and industrial pollution, heavy sea traffic and coastal erosion in the Bosphorus are other important factors preventing annual fish migration between the two seas. Several authors (Caddy and Griffiths, 1990; Zaitsev, 1993) have attributed total disappearance of large pelagics from NWS area to a combination of these factors.

3.4. THE SOUTHERN COAST

The man-made disturbances listed above for the NWS and Azov Sea and their influences on ecology, are not yet at a recognisable level along the Turkish coast. Turkish rivers discharging into the Black Sea are not utilised for energy generation, and human-induced changes in their hydrological regimes are not significant. The nutrient load and industrial or domestic wastes are not as concentrated as in the other two basins (Balkas et al., 1990). Until the fishery crisis in 1989 when anchovy catch collapsed from some 300 thousand tons to 96 thousand tons (Anon, 1993), Turkey had not been faced with a serious problem concerning drastic changes of the ecosystem as reported in NWS area and Azov Sea.

4. *Aurelia Aurita* and *Mnemiopsis sp.* in the Context of the Changing Ecosystem of the Black Sea

Due to the induced eutrophication, the overall biomass at nearly all levels of the pelagic food web increased in the Black Sea (Zaitsev, 1993; Caddy, 1990; 1993; Kideys, 1994, Ivanov and Beverton, 1985). Many species which were formerly abundant disappeared and were replaced by their counterparts having higher ecological tolerance, such as *Noctiluca scintillans* and *Aurelia aurita*. In addition, some newly introduced opportunistic species, like *Mnemiopsis sp.* appeared, invaded the whole basin and reached to dramatic quantities in biomass.

Aurelia aurita is a common component of the Black Sea fauna. In 1959-1962 jellyfish total biomass in the 0-80m water layer of the Black Sea was 90-1600 thousands tons (wet weight; average ≈ 670 thousand tons). In 1978, in the 0-10m layer there were 47 million tons of *Aurelia aurita* with a total biomass of 300-450 million tons (wet weight) for the whole Black Sea (Gomoiu, 1981). Since there was no external control mechanism, such as predation or exploitation over *Aurelia aurita*, a considerable part of the biomass flow in the food-web was diverted in favour of *Aurelia aurita*. Consequently this species attained a biomass of 400 million tons just before the *Mnemiopsis* outburst in 1988 (Shushkina and Musayeva, 1983; Flint et al., 1989; Shushkina and Vinogradov, 1990; Vinogradov et al., 1985; Mutlu et al., 1994).

As opposed to *Aurelia aurita, Mnemiopsis* sp. is an introduced species first reported in 1982 (Shushkina and Musayeva, 1990; Zaika and Sergeeva, 1990) in the Black Sea. In 1989, this new species replaced *Aurelia aurita* by a sudden increase reaching to 800 million tons of total biomass and spread out all over the Black Sea. Later, between 1991-1993, the biomass leveled out and remained more or less stable around 100 million tons (Mutlu et al., 1994). A schematic representation of the fluctuation in the coexistence of these two species are depicted in Figure 2.

After the surprising outbreak of *Mnemiopsis sp.* in the Black Sea, coinciding with a drop in anchovy catch, the earlier studies disregarded the steadily increasing *Aurelia aurita*, and focused on possible predation of *Mnemiopsis sp.* on anchovy egg and larvae

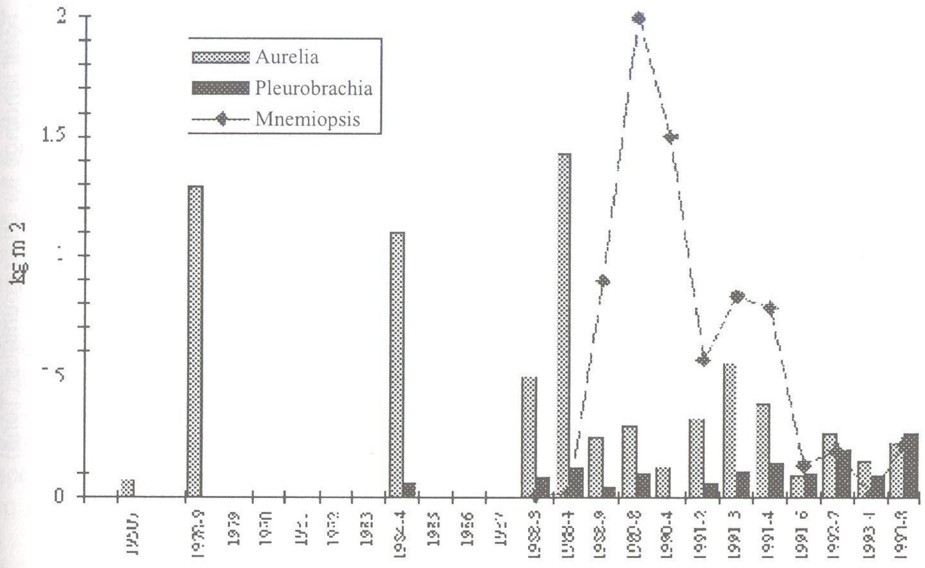

Figure 2. Fluctuation of the biomass (wet weight kg^{-2}) of *Mnemiopsis sp.*, *Aurelia aurita*, and *Pleurobrachia pileus* in offshore areas of the Black Sea from 1958-1993. Taken from Mutlu et al., 1994

and sought correspondence with collapse of anchovy fishery (Vinogradov, 1992; Zaika, 1992; Harbison and Volovik, in press). Recent studies, however, showed that anchovy egg and larvae constitute only a minor part of the *Mnemiopsis* diet (Tsikhon-Lukanina et al., 1990; Tsikhon-Lukanina and Reznichenko, 1991; Mutlu, in prep.). Both anchovy and *Mnemiopsis* feed mainly on copepods, hence compete for the same food source.

5. Review of Total Landings of Black Sea Countries

Figure 3 represents total fish landings from the Black Sea reported by the riparian countries. The collapse of fisheries was not only experienced in Turkey. Other countries faced the same problem even earlier. The Bulgarian fishery was ahead of the party confronted with a fishery crisis. In the seventies, moderate degree of nutrient enrichment increased the over-all production, reflected in the fishery by increased landings. The highest catch was obtained in 1981 and in the following period, landings decreased with nearly the same trend of the former increase. An almost similar picture was observed in Romania and former USSR, whose highest catches were obtained in 1986 and 1982, respectively. Along the Turkish coast, the increase in total fish landings kept its pace until 1988, thereafter underwent a very sharp decline in 1989.

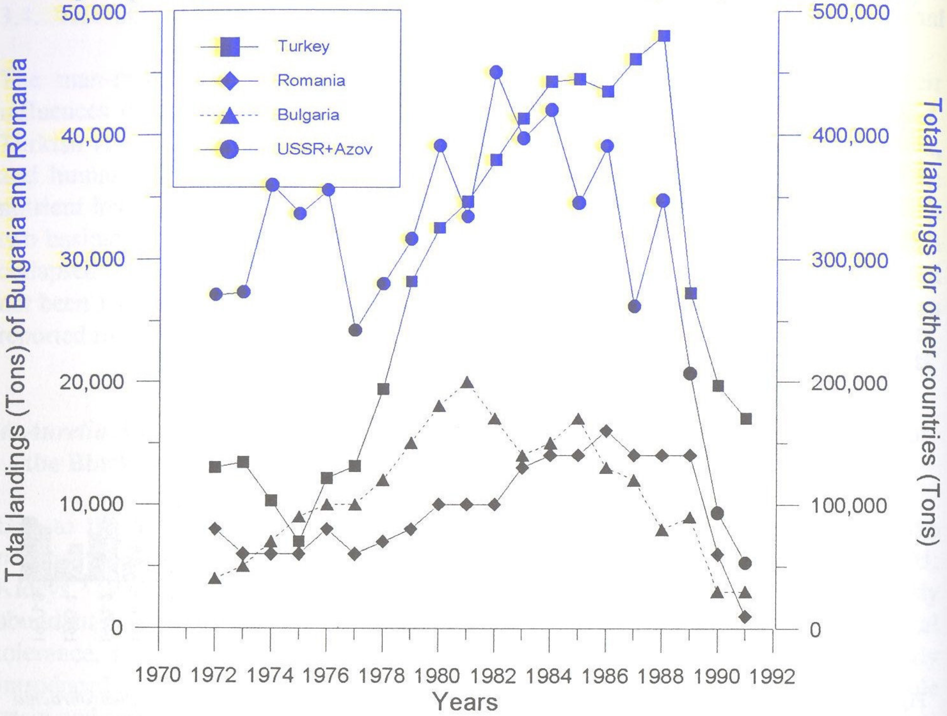

Figure 3. Total landings of Black Sea riparian countries (GFCM, 1993).

5.1. TURKISH FISHERY AND CHANGES IN THE CATCH COMPOSITION

Today, the Turkish fishing fleet operating in the Black Sea is characterised by three distinct categories: purse seining, trawling and artisanal fishery. The latter one is carried out with small wooden boats 4-10 m in length, using beach seine, trammel and gill nets. Their contribution to the total landing is quite insignificant.

Trawl nets are designed and rigged to work on the bottom. Considering the complex topography, i.e. narrow and steep continental shelf, canyons, and troughs, the Turkish coast of the Black Sea, in general is not suitable for trawling activity. Moreover, trawling is completely banned at the eastern-most section of the coast.

Purse seine nets used by the Turkish fishing fleet are about a kilometer long and approximately 150 meters high (Anon, 1992). These nets catch the fish by surrounding them from the sides. The sea bottom or the underlying permanent H_2S layer prevents the fish from escaping in deep waters by diving downwards. Boats operating purse seine nets are usually equipped with powerful sonars having one kilometer scanning range on each side of the boat, which enables them to point precisely the position of

fish schools. Once the school of fish is encircled, an auxiliary skiff equipped with a fish pump comes alongside and empties the catch in a short time. This fishery setup, is extremely suitable to exploit dense school forming pelagic species, such as anchovy. As reported by the fishermen, a single set of purse seiner may catch up to 300 tons of anchovy in a single operation.

Although the total landing of fishery collapsed in 1989 and remained low since then, not all the species exploited by Turkish fishing fleet showed the same trend. Table 1 represents the main commercial fishes exploited by the Turkish fishing fleet along with their catch records of the past 12 years. It is evident that main pelagic species like *Engraulis encrasicolus*, *Pomatomus saltator* and *Sarda sarda* decreased during that period, some others, such as *Merlangius euxinus*, *Scomber japonicus* and *Sprattus sprattus* increased. Like anchovy, the other species lay pelagic eggs and they are strictly dependent on copepods for feeding during their early life stages. Here, one of the most important argument requires the settlement of the question as to why only the pelagic fish have declined, while others have increased or did not change.

The species which shows a negative trend is mostly school forming pelagic species and they are the target species of purse seines. On the contrary, most of the species, which increased or remained unchanged during the past 12 years, are either demersal or do not form dense schools, hence are not vulnerable to purse seines. As an example, whiting is a demersal species caught mainly by trawlers. Similarly sprat is a pelagic species, but because it does not form dense school during the fishing season (November to April), it is not effectively caught by purse seine nets.

5.2. FISHING POWER OF THE TURKISH FISHING FLEET

As a consequence of man-induced eutrophication, the carrying capacity of the Black Sea, and in turn, the surplus production of small pelagics have increased. The purse seines, introduced in late 50's, rapidly developed in the later years. The number of boats, usage of sonars and fish finders, fish pumps and number of auxiliary skiffs increased very sharply (Figure 4). All these factors have increased the fishing power of the Turkish purse seine fleet by the factor of ten (Gücü, in prep.).

Due to poor coordination in the sector and lack of reliable stock estimates, the same reasons misled the policy makers to encourage investments on fish processing factories, such as fish oil and meal plants. Today, the fishing and processing capacities are not properly matched, i.e., the total capacity of fish processing factories have reached 6700 tons/day which is 4 times higher than the total annual production of the whole country, including catches from Mediterranean, Aegean, Marmara Sea and inland waters (Bingel et al., 1995).

6. Anchovy as an Indicator of the Ecological Changes in the Black Sea

The anchovy is the dominant species of the Black Sea. It comprises more than 50% of the total landings from the Black Sea. The anchovy has two subspecies in the Black

Sea. The Black Sea anchovy, *E. encrasicolus ponticus* and the Azov anchovy, *E. encrasicolus maeoticus*. Until recently, the Black Sea anchovy was mainly spawning in the Northwestern Shelf area in summer. During winter, the whole population was

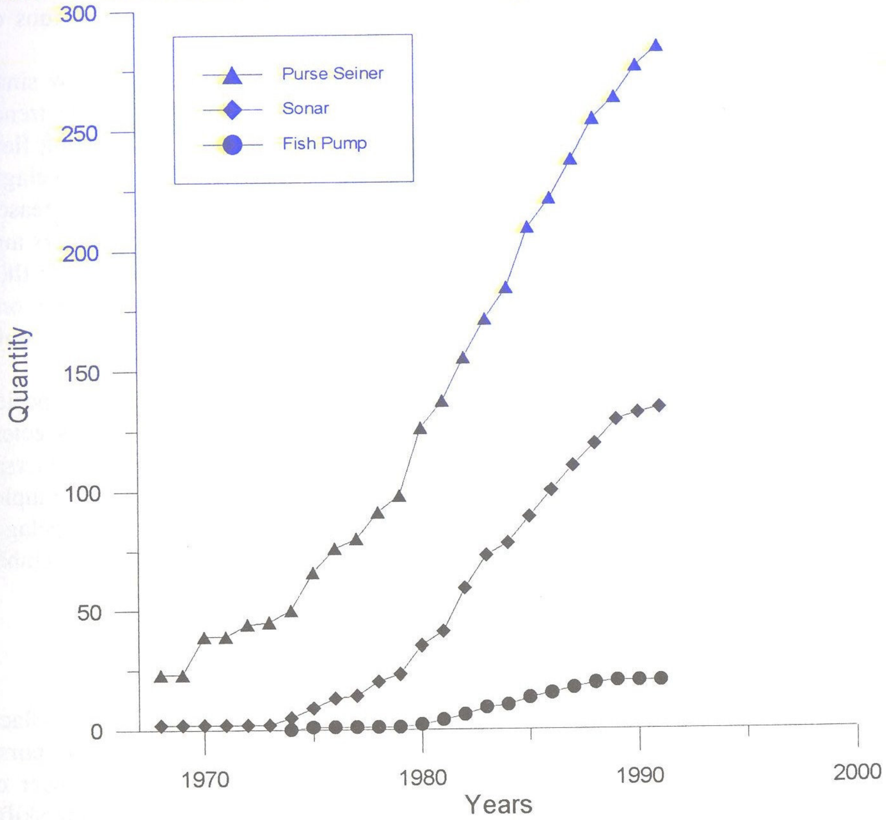

Figure 4. Number of Turkish purse seiners, boats with sonar and fish pump operated in the Black Sea (Anon., 1992).

migrating to the south and hibernating along the eastern part of Turkish Black Sea coast and Georgia (Ivanov and Beverton, 1985). Azov anchovy was spawning in the Azov Sea during summer and migrating to south for over-wintering. More recent studies carried out by joint efforts of various Black Sea countries, have revealed that there is an evident shift in the spawning grounds of the Black Sea anchovy, which are nowadays located in the southern part of the Black Sea, contrary to their past preferences (Niermann et al., 1994). Hydroacoustic studies in offshore waters support the hypothesis that major spawning and nursery grounds of anchovy have shifted to the south (Caddy, 1992).

The southward shift in the spawning ground of Black Sea anchovy is in good agreement with deterioration of the ecological features of the northwestern shelf area (Zaitsev, 1993). The period of summer algal blooms developing in the NWS area and

finally associating with hypoxia and even anoxia, coincides with the period when anchovy spawning reaches it maximum.

Similarly, a southward shift in the spawning ground of Azov anchovy has been reported by Chashchin (1995). The author explained this situation by desalination in the Azov Sea as a result of hydrological manipulation on the in-flowing rivers, like Kuban. Consequently moving south, the spawning grounds of the Azov and Black Sea anchovy have been overlapped, and the share of hybrids (Black Sea X Azov anchovy) in the Black Sea has increased considerably (Chashchin, 1995).

6.1. FACTORS RESPONSIBLE FOR THE ANCHOVY DECLINE

Several hypotheses for explaining the decline of anchovy stocks have been advanced, but only two appear scientifically sound: the impact of *Mnemiopsis sp.* and the effects of over-fishing. The effects of the latter is evident from the variations in length composition of anchovy landed by the Turkish fishing fleet, depicted in Figure 5 along with the total amount of fish caught. In the 1987/88 fishing season, relatively larger and older fishes were dominating the catch. This is an appreciable figure for fisheries management purpose, unless total catch exceeds the limit of "recruitment over-fishing" in which the size of the spawning stock is reduced so that they can not produce enough offspring to sustain former population size. However, as it is evident from a comparison of the 1987/88 and 1988/89 fishing seasons, the anchovy stock was over-fished and only small sized premature individuals dominated the catch during 1988/89 period. Neither fishermen nor governments recognised this obvious sign of "recruitment over-fishing", and due to mismanagement, potential spawners of the next year were removed from the system before they could spawn. Finally in the 1989/90 period, nearly no anchovy was left and Turkish fishing fleet could only catch 1/3 of the amount in the previous seasons (Anon, 1993).

As a consequence of drastic decline in the stocks, the catch per effort, and in turn, total income of the fishermen reduced. Faced with declining anchovy catches, Turkish fishing fleet of the Black Sea, which had attained enormous quantities, shrunk in size. Some of the people involved switched to alternative businesses, others moved to the Aegean and Mediterranean Sea regions to cope with crisis. According to the latest catch statistics of Turkey a slight recovery was experienced in 1994.

Another evidence on the role of over-fishing in anchovy fishery collapse is the condition index of the hibernating anchovies. In Figure 6, condition of different size groups of anchovy are depicted. This figure is contradictory with the concerns about the starvation of anchovy as a consequence of heavy predation of *Mnemiopsis* on calanoid copepods, which is the common food source of both species. The figure, on the other hand, is in good agreement with the feeding biology of the anchovy, such that they stop feeding during winter and consume fat deposited during summer, such that their condition index is decreased. As it is clear from the figure, the condition index of the over-wintering anchovy has decreased considerably in all examined fishing periods.

As the condition indices of the smallest size group of over-wintering anchovy are compared for pre- and post *Mnemiopsis* periods, they were less conditioned before *Mnemiopsis* outbreak during 1988/89 fishing season. In 1989/90, the condition index of the youngest individuals of hibernating anchovies increased considerably. It is crucial to note that this period coincides with the anchovy collapse. This is in contrast

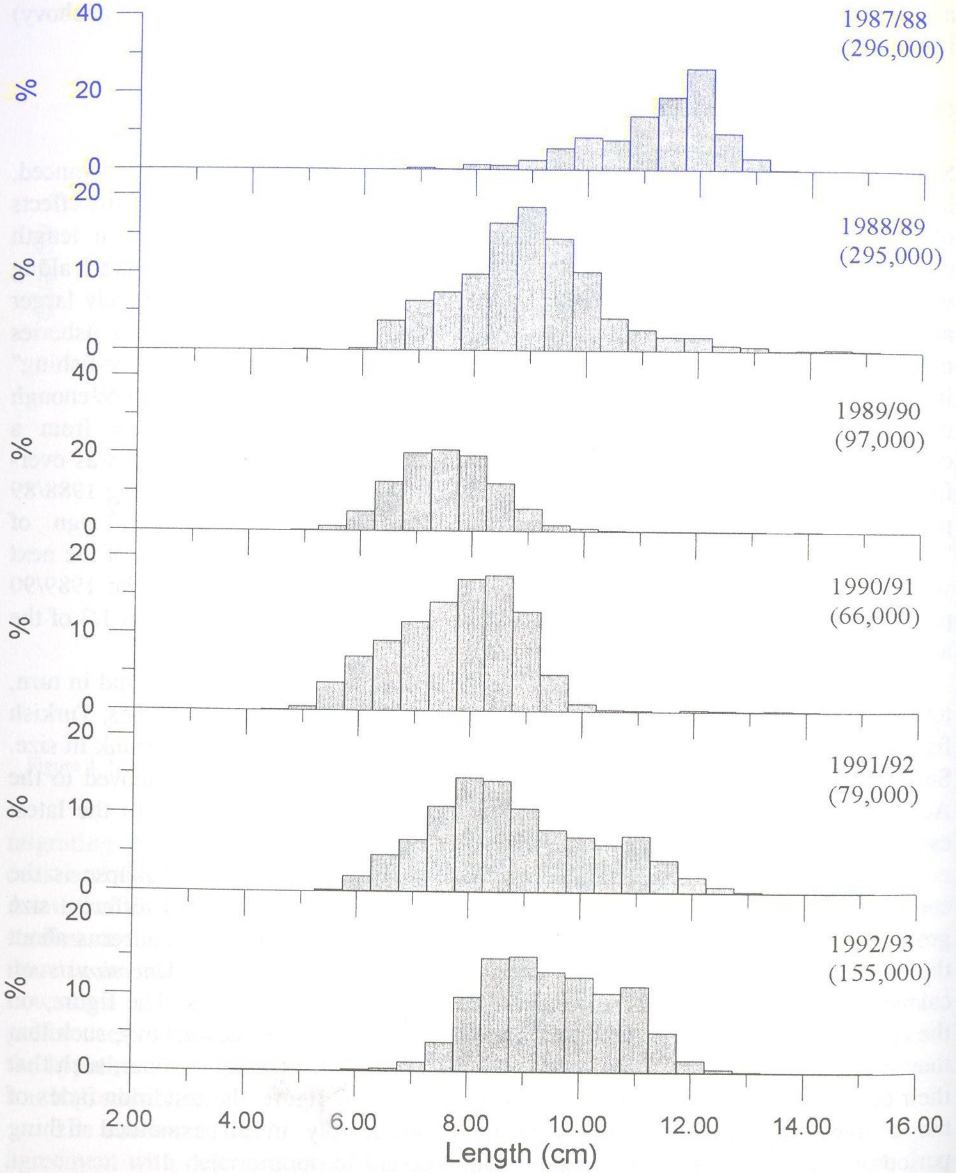

Figure 5. Length composition of the anchovy landed by the Turkish fleet during 1987-1993

with the expectations, because within this period *Mnemiopsis* attained the maximum biomass level ever recorded, during which predation of anchovy spawns by *Mnemiopsis*, if any, and competition between *Mnemiopsis* and anchovy for calanoid copepods should expected to be very high.

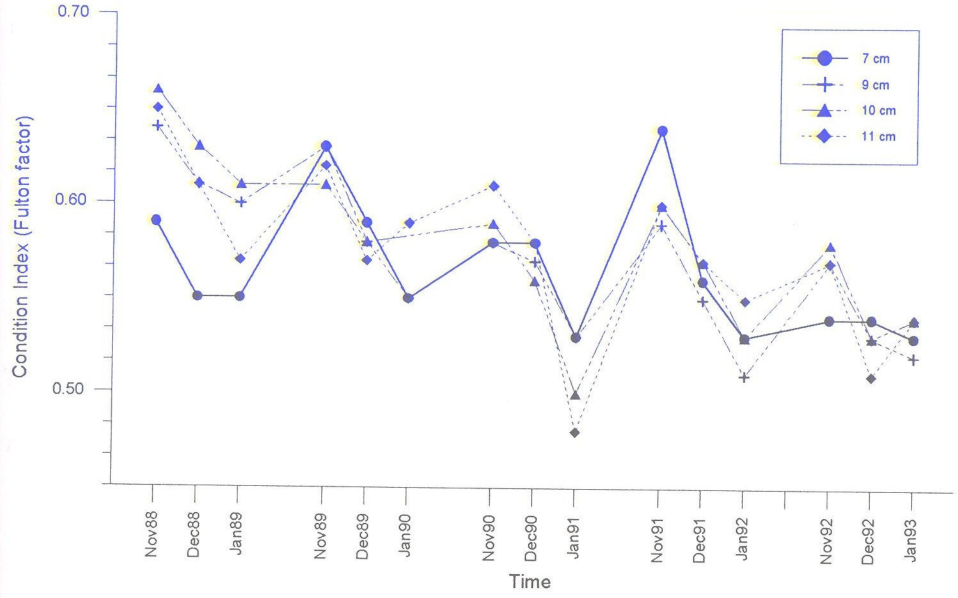

Figure 6. Condition index of anchovies caught during 1988-1993

7. Conclusion

Nutrient enrichment, in general, has raised the carrying capacity of the Black Sea for small pelagic fishes, hence the catch per unit effort increased and provoked governmental and private investments in the fishing sector. Towards the end of 1980's, the fishing sector reached a state that can catch and process more than the Black Sea could sustain.

As a result, over-wintering anchovy, which forms very dense schools and are concentrated in a narrow coastal band, became extremely vulnerable to the Turkish purse seiners. Finally size of the spawning stock was reduced to the extent that not enough young fish were produced to ensure the future of the stock. Following the abrupt decline in the stock, the niche formerly occupied by anchovy was re-occupied by *Mnemiopsis* sp.

The collapse of the fishery in the Black Sea, besides causing significant loss to economy, in terms of the value of catch, the value of vessels and plants, and employment, also had a significant side effect due to its contribution to enhance the eutrophication. Using the respective ratios of 1/417 and 1/35 for phosphorus and nitrogen in fish tissue, given by Anderson and Ursin (1977), Caddy (1992) has roughly calculated that the total removal of phosphorus and nitrogen simply by fishery activities to be on the order of 2158 tons and 26000 tons, respectively, in the pre-collapse period. At present, these values have decreased to 480 tons of phosphorus and 5760 tons of nitrogen. In other words, 1,700 tons of phosphorous and 20,000 tons of nitrogen have remained in the system.

As it was repeatedly emphasised by nearly all authors working on Black Sea ecological problems, to mitigate the situation in the Black Sea the following remedies are advisable:

–substantial reduction of flow of nutrient into the system,

–implementation of control measures over jelly predators,

–recovery of fish stocks through a sound international fishery management policy.

It is worth noting that the above listed remedies are often very costly and therefore nearly improbable to implement. On the other hand, by simply regulating the fishery and achieving a level exceeding the former catch records;

i) economic loss (human food, employment, re-utilization of waste, investment capital) can be retrieved,

ii) energy flow to jelly organisms can be diverted to fishes, and hence population of the former can also be controlled,

iii) considerable part of the excess nutrient pumped by the rivers into the Black Sea can be removed from the system in a very profitable way.

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