hore (*Mnemiopsis*) in relation to variable
n and assimilation efficiency. Journal of
on History of Comb Jelly Beroe Ovata
erties of Its Black Sea Representative,
nd its impact on the pelagic community.
g as a Management Tool for the Black
), v. 1, (Kluwer Academic Publishers),
A. I. Dudkin, 2001. The new invader
orth eastern Black Sea. Hydrobiologia
, I. Siokou-Frangou, S. Zervoudaki,
evelopment of the invader ctenophore
erranean basin. Marine Biology 139:
B. Dulimov & E. I. Musaeva, 2001b.
nitial effect on the pelagic ecosystem.
assessment. European Environment
55.Luxembourg: Office for official
gy 24: 69-76.
989. Ctenophore *Mnemiopsis leidyi*
Oceanology, Institute of Oceanology
phic Commission, no. 3, UNESCO,
is macroplankton (Jellyfish *Aurelia*
k Sea ecosystem (Important aspects
ntal Programme (CEP) Mnemiopsis
cyphomedusa *Aurelia aurita* in the
on Research 22: 223-239.
study of change and decline/GEF,
Fisheries Oceanography 1: 180-189.

Chapter 6

Decreased levels of the invasive ctenophore *Mnemiopsis* in the Marmara Sea in 2001

MELEK ISINIBILIR, AHMET N. TARKAN & AHMET E. KIDEYS[1]
Istanbul University, Faculty of Fisheries,
Laleli, Istanbul, TURKEY
[1]*Institute of Marine Sciences, Middle East Technical University,*
Erdemli, TURKEY

Keywords: *Mnemiopsis leidyi, Beroe* cf *ovata*, Marmara Sea, population dynamics, predation

Mnemiopsis leidyi, an endemic ctenophore of the western Atlantic, was first reported in the Marmara Sea in summer 1992, at an average abundance of 27 ind. m^{-3}. We investigated its abundance and distribution together with that of the mesozooplankton (most species are prey organisms of *M. leidyi*) at eight stations during August 2001, in order to evaluate recent population developments with regard to the impact of its predator, *Beroe* cf *ovata*. The abundance of *M. leidyi* was found to be quite low (range 0.5-8.8 ind. m^{-3}, average 1.62 ind. m^{-3}) compared to 1992. *B.* cf *ovata* was, although at very low abundance (0.1-1.1 ind. m^{-3}), only present at stations where *M. leidyi* occurred. The zooplankton abundance was higher during our investigation than in previous years, which should at least partly be due to a decreased predation impact by *M. leidyi*.

1. Introduction

The Marmara Sea is an inland sea which, together with the Bosporus and Dardanelles, forms the Turkish Strait Systems. The water column has two different layers; whilst the top 20-30 m has low saline (around 22 ppt) Black Sea waters, saline Mediterranean waters (38 ppt) occupy the lower layers which can be as deep as 1390 m.

Inland seas are more sensitive to impact than open seas. Many dramatic changes took place in recent years in the Marmara Sea, all connected with antropogenic stress. This includes the release of industrial and agricultural wastes into the rivers that drain into the sea, water transfer from the eutrophic Black Sea, an increase in the level of marine pollution, and heavy exploitation of the fish stocks in the last few years. The Marmara Sea ecosystem has also been damaged in the past by opportunistic invasions of temperate and subtropical animal and plant species. The introduction of a new species is often

H. Dumont et al. (eds.),
Aquatic Invasions in the Black, Caspian, and Mediterranean Seas, 155–165.

harmful for the recipient ecosystem. It is important to know the degree of tolerance of the invader to a new environment, peculiarities of its biology in the new habitat, and the relationship between introduced and indigenous species, its prey and competitors. All these factors determine the abundance and distribution of the invader, and its impact on the ecosystem.

M. leidyi, a voracious zooplanktivorous ctenophore, was accidentally introduced in the early 1980's to the Black Sea, almost certainly with ballast water from the northwestern Atlantic coastal region (Vinogradov et al., 1989). Via the surface currents flowing from the Black Sea through the Bosporus, *Mnemiopsis* invaded the Marmara Sea as well. Documented was the appearance of *Mnemiopsis* at first in 1992 by (Shiganova 1993), when the levels of *M. leidiy* were already lower in the Black Sea than in 1988 and 1989. Later, several other investigators provided data on the abundance of this ctenophore in the Marmara Sea (Kıdeys and Niermann 1994, Shiganova et al., 1995; Isinibilir and Tarkan, 2001; Yuksek et al., 2002). In early October 1992, the average numbers of *M. leidyi* were 27 ind. m^{-3} (Shiganova et al., 1995), but in July, 1993, these numbers were as low as 0.1 ind. m^{-3} (Kıdeys and Niermann, 1994). In August 2000, higher values of *M. leidyi* were reported again from the Marmara Sea, (12.9 ind. m^{-3}) (Isinibilir and Tarkan, 2001). However, a new era started with the appearance of a predator of *Mnemiopsis*, the ctenophore *Beroe ovata* sensu Mayer, in the Marmara Sea in the late 1990s. This ctenophore feeds almost exclusively on other ctenophores, especially on *Mnemiopsis* (GESAMP, 1997). *B. ovata* was supposed to be of American origin, too and it seems to be different from the native species *Beroe ovata* sensu Chun which is not rare in the Mediterranean. (R. Harbison and K. Bayha, personal communication). *Beroe ovata* was found in the Marmara Sea as early as summer 1992 (Shiganova et al., 1995), but if it was already the new invader species could not clarified.

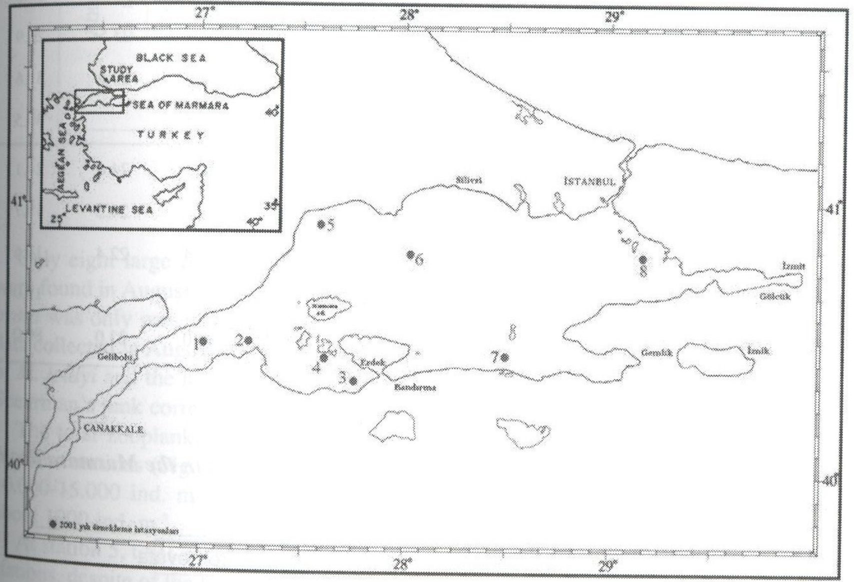
A new era started with the appearance in the Marmara Sea in the late 1990s of a predator of *Mnemiopsis*, the ctenophore *Beroe ovata* sensu Mayer. This ctenophore feeds almost exclusively on other ctenophores, especially on *Mnemiopsis* (GESAMP, 1997). *B.* cf *ovata* is currently supposed to be of American origin too, and molecular methods have revealed that it is different from the species *Beroe ovata* sensu Chun, which is not rare in the Mediterranean. (Bayha et al., this volume). Because of this unsettled taxonomic situation, we will henceforth refer to it as *Beroe* cf *ovata*. This ctenophore was found in the Marmara Sea as early as summer 1992 (Shiganova et al., 1995); whether it was already present there earlier could not be clarified.

Our purpose is to evaluate the abundance and distribution of *Mnemiopsis leidyi* after the arrival of *Beroe ovata* in the Marmara Sea.

2. Material and methods

The occurrence of *Mnemiopsis leidyi* and *Beroe ovata* were investigated in the Marmara Sea between 12 and 18 August 2001 aboard the R/V "YUNUS". Sampling was conducted at 8 stations (Fig. 1). Ctenophores and zooplankton samples were collected by vertical towing of a WP2 plankton net with a diameter of 57 cm and mesh size of 200 micrometers between the sea surface and the halocline, where water of the Black Sea and the Mediterranean Sea mixes (15-30m). The total volume of seawater filtered was calculated as 32.5 m^3. Ctenophore samples were identified and their total lengths measured on board. Zooplankton samples were preserved in 4% buffered formalin and qualitative and quantitative analyses were performed in the laboratory under a binocular microscope. Some basic environmental variables of the seawater (e.g. temperature and salinity) were also measured.

Figure 1. Location of 8 stations in the Marmara Sea, sampled between 12 and 18 August 2001



3. Results

Temperature and salinity data are presented in Table 1. The two-layer structure of the Marmara Sea was clear from the salinity and temperature values: whilst the salinity was around 22 ppt at the surface, much more saline Mediterranean water (about 36 ppt) was found at 30 m depth. The temperature also sharply decreased from >22 °C at the surface to around 15 °C at 30 m. Thus, it is clear that both a halocline and a thermocline occur between 20-30.

In total, 51 *Mnemiopsis leidyi* individuals were counted at the 8 stations with a mean abundance of 1.62 ind. m^{-3} (Fig. 2). The abundance varied spatially, No individuals were found at station 3, 8, and the offshore station 6, while the maximum of 8.8.ind. m^{-3}

were recorded at station 5, consisting of almost all small individuals collected during the survey. The majority of animals were found between 20 and 30 m. Generally the smallest individuals (10 mm in length) were occupying the calm and near-coastal areas of the Sea. Maximum length of *Mnemiopsis leidyi* was 130 mm and average length was 30 mm (Fig. 3).

Table 1. Temperature and salinity at eight stations in the Marmara Sea between 12 and 18 August 2001

		Stations							
		1	2	3	4	5	6	7	8
Date		12.08.01	12.08.01	14.08.01	14.08.01	15.08.01	17.08.01	17.08.01	18.08.01
Salinity‰	Surface	22.5		24.1	24.1	22.5	22.8	23.2	23.8
	10	22.8		24.3	24.2	24.9	24.9	23.5	25.9
	20	23.0		24.3	25.7	26.6	34.4	24.9	31.6
	30	35.9		36.5	36.5	33.6	36.8		36.5
T (°C)	Surface	27.0		25.4	25.7	25.4	22.8	24.6	24.1
	10	26.5		25.1	25.7	25.2	20.7	24.5	18.7
	20	25.4		24.3	21.5	16.3	14.4	22.4	14.6
	30	15.2		15.3	15.3	15.4	15.1		15.0
Total depth (m)		33.5	62.5	37.0	38.0	60.0	90.0	23.0	80.0

Figure 2. Abundance of Mnemiopsis leidyi and Beroe ovata in the Marmara Sea in August 2001

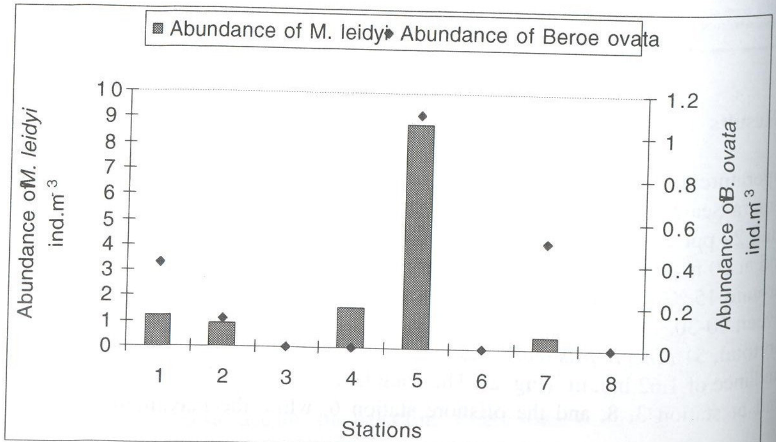
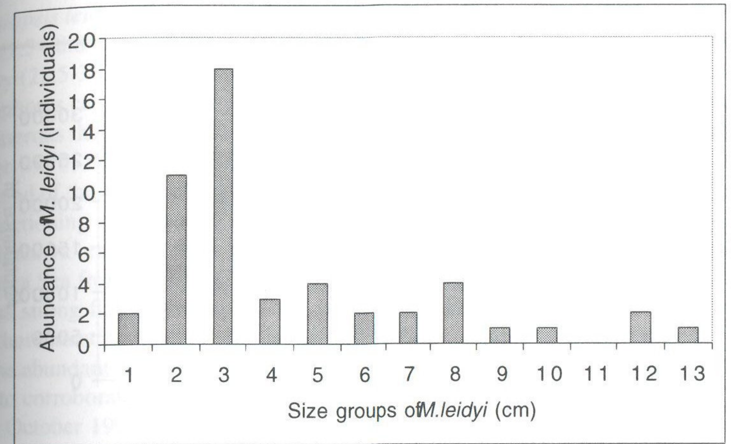


Figure 3. Size groups of Mnemiopsis leidyi in the Marmara Sea in August 2001



Only eight large *Beroe ovata* specimens with an average abundance of 0.3 ind. m^{-3} were found in August 2001 (Fig. 2). Their total lengths ranged from 125 to 200 m. *Beroe ovata* was only present at stations where *Mnemiopsis leidyi* was abundant. Analysis of data collected in August 2001 showed a modest positive correlation between the number of *M. leidyi* and the number of *Beroe ovata* (n = 8, r = 0.643, $p < 0.05$, non-parametric Spearman's rank correlation analysis).

The total zooplankton abundance varied between 20.000 and 27.000 ind. m^{-3} at the southern stations (Fig. 4). At the more northern stations 4,5,7,8 the abundance was less, 10.000-15.000 ind. m^{-3}. The most offshore station 6 displayed the lowest abundance, about 1000 ind. m^{-3}.

At station 5, total zooplankton abundance was in the same range as the other northern stations, despite of the local abundance of the *Mnemiopsis leidyi* (Figs 2, 4). The number of *M. leidyi* and the number of zooplankton were not correlated in the Marmara Sea during August 2001 (n = 8, r = 0.239, $p < 0.05$, non-parametric Spearman's rank correlation analysis).

The zooplankton of the Marmara Sea was found to consist of five groups. These were the Copepoda, Cladocera, Meroplankton, *Noctiluca miliaris* and "Others", consisting of Nauplii, Appendicularia, Chaetognatha and Ichthyoplankton. Compared to all other zooplankton groups, copepods were the dominant taxon (Fig. 5). The maximum abundance of Copepoda (13 440 ind. m^{-3}) was recorded at the station 3, in Erdek Bay, where no *Mnemiopsis* occurred.

Figure 4. Abundance of the total mesozooplankton (except Noctiluca miliaris) and Mnemiopsis leidyi in the Marmara Sea during August 2001

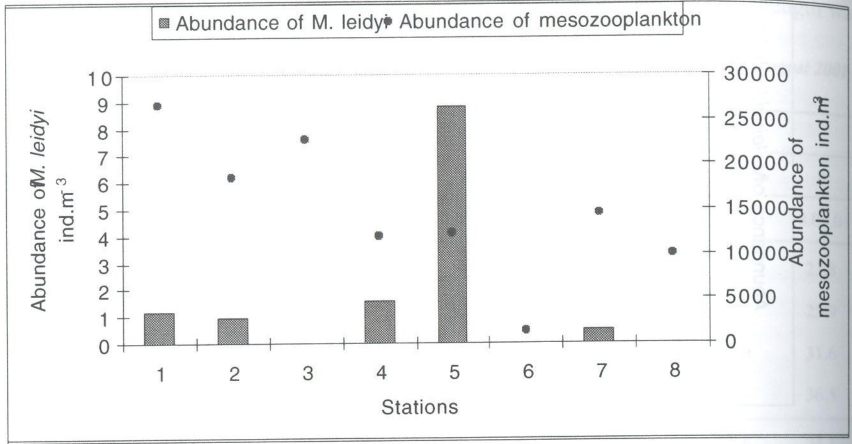
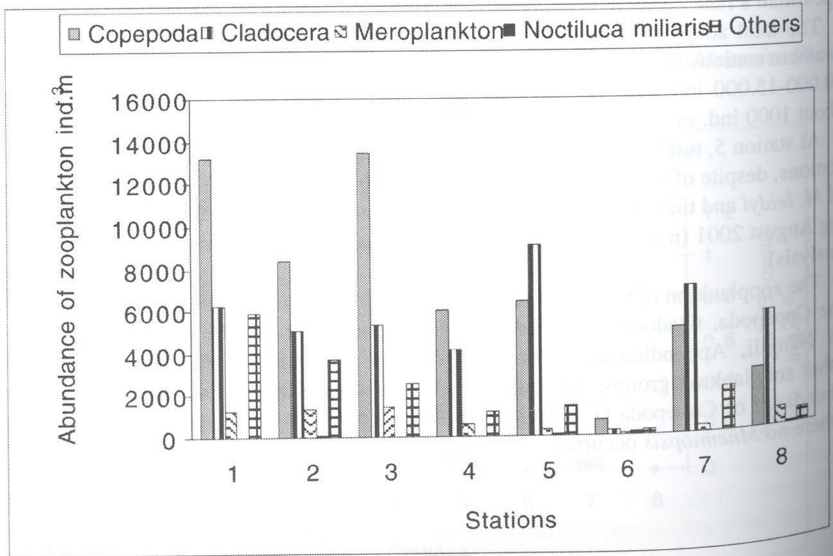


Figure 5. Abundance of different groups of zooplankton at eight stations in the Marmara Sea during August 2001



4. Discussion

Mnemiopsis leidyi is known to tolerate a wide range of salinities (10-70‰) and temperatures (1.3-28.8°C) (Burrell & Van Engel, 1976). Thus, the Marmara Sea has a suitable salinity (22.5-36.8‰) and temperature (27-15°C) for *M. leidyi* to survive and reproduce. Ctenophores can be important carnivores in planktonic food chains. They are sometimes so numerous that they drastically modify the structure of an otherwise stable community (Fraser, 1970; Bishop, 1967). The outburst of the ctenophore *M. leidyi* in the Black Sea at the end of the 1980s, changed the structure of the planktonic communities and affected the functioning ecosystem in an essential way (Vinogradov et al., 1989).

Shiganova et al. (1995) assumed that *Mnemiopsis leidyi* first penetrated to the Marmara Sea from the Black Sea with the upper Bosporus current. Considering the continuous strong flow from the Black Sea towards the Sea of Marmara, the arrival of *M. leidyi* here must have occurred long before 1992, presumably as soon as the ctenophores became abundant in the Black Sea, in 1987 or 1988. Unfortunately no data existed before 1992 to corroborate this hypothesis.

By October 1992, *Mnemiopsis leidyi* was present in the Marmara Sea, at an average abundance of 27 ind. m^{-3} (Shiganova et al., 1995). Shiganova et al., 1995 suggested that *M. leidyi* occurs all year round in the upper water layer of the Marmara Sea, similar to the situation in the Black Sea. However in the subsequent years the density of *M. leidyi* decreased considerably. In July 1993, the average density of *M. leidyi* was only 0.1 ind. m^{-3} (Kıdeys and Niermann, 1994), in July 1999 the abundance was 0.06 ind. m^{-3} (only Bosphorus data; Tarkan et al., 2000), in August 2000, the numbers increased to 12.9 ind. m^{-3} (Isinibilir and Tarkan, 2001) and dropped again to 1.62 ind. m^{-3} in August 2001 (present study).

These data demonstrate that *Mnemiopsis leidyi* populations show marked interannual variation in the Marmara Sea, probably resulting from environmental interactions and food availability and spawning season.

In 1992, medium-sized individuals (10-45 mm) of *Mnemiopsis leidyi* were dominant in the Marmara Sea (Shiganova et al., 1995), but later in 2000, small individuals were found the dominant group in the northern part of Marmara Sea (Isinibilir and Tarkan, 2001). These small individuals, occupying the calm and coastal areas of the Sea, may suggest either that spawning of *Mnemiopsis leidyi* occurs in the coastal regions of the Sea or that the ctenophores here are starving more than those in the offshore regions (it is known that they shrink with starvation).

At least three species of the predatory, large-sized genus *Beroe* inhabit the Mediterranean Sea: *Beroe cucumis* Fabricius (in Campbell, 1982), *B. ovata* Esch and *B. forskalii* Chun (in Tregouboff and Rose, 1957). *Beroe ovata* sensu Chun was till end of the 1990's not distributed the Black Sea. Thinkable is, that for this species the low salinity of the Black Sea was a barrier. The recently introduced *Beroe ovata* censu Mayer, possibly of western Atlantic origin, seems to be adapted to low salinity.

In 1992 *Beroe ovata* was recorded in the Marmara Sea (Shiganova et al., 1995), however it was uncertain, which species of *Beroe* it was. In 1999, two individuals of *B. ovata* were found near the Bosphorus (Tarkan et al., 2000). During 2000 *B. ovata* was not found in the Marmara Sea (Isinibilir and Tarkan, 2001). In August 2001 we caught eight mostl ividuals with an average abundance of 0.3 ind. m^{-3}. But still uncertain is, which f *Beroe* was collected, the Mediterranean or the newly introduced one. The of large individuals in the Marmara Sea during August 2001 may suggest t *ovata* is transported to the Marmara Sea by currents from the adjacent Black

Fi l. (2001, 2002) and Kideys (2002) demonstrated for the Black Sea area off S that *Beroe ovata* sensu Mayer could control the *M. leidyi* stock. With the o of *B. ovata* in the Black Sea end of the 1990's the previous year-round distri *M. leidyi* became limited to a very short period in summer (Finenko et al., 20

It t the appearance of its predator, *Beroe ovata* had an effect on the stock of *M.* he Sea of Marmara in recent years, as it was observed for the Black Sea, but fr ited data we can not make such a statement.Compared to earlier investigatio ndance of copepods was high in August 2001. In 1977 the abundance of copep northern Marmara was 257 ind. m^{-3}, in the southern Marmara 360 ind. m^{-3} (C Tarkan, 1990). In August 1992, the zooplankton was drastically reduced to 33 d. m^{-3} in the northern and southern Marmara respectively (Shiganova et. al., 1 00 the food zooplankton increased in the northern Marmara to 2935 ind. m^{-3} an (present study) to 14751 ind. m^{-3}.

M is a voracious feeder on zooplankton, especially on copepods. It was often in the Black Sea, that in areas with high abundance of *M. leidyi* the copep rs were harshly reduced (Niermann et al, 1999). This was not found in the M a during August 2001. There was no significant correlation between the abund pepods and *Mnemiopsis*. Despite of that, by comparing long-term trends in the and Marmara Sea, is seems that the fluctuation of mesozooplankton was simila eas, low numbers at the beginning of 1990's and high numbers of zooplank end of the 1990's and beginning of the 2000's. It could be assumed that there n between the decrease in the amount of zooplankton and the extraordinary i *Mnemiopsis leidyi* and vice versa. Unfortunately we do not have weight data kton which would be a better measure for analysing long-term changes.

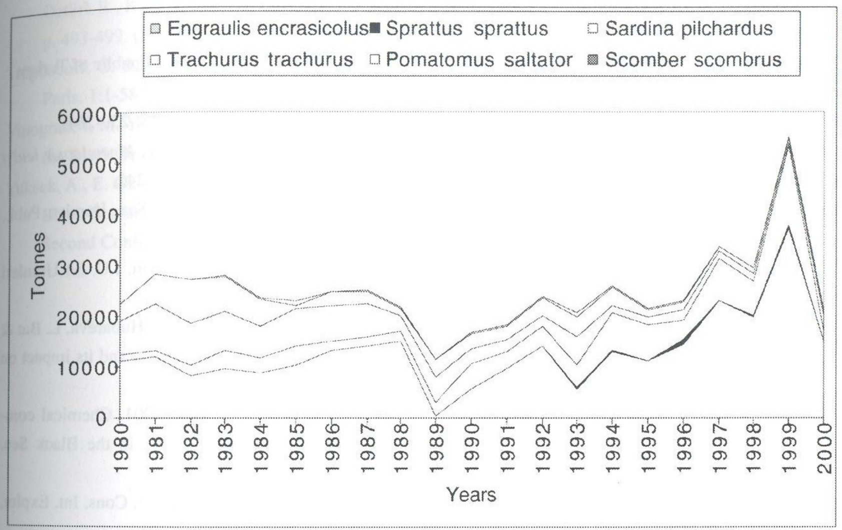
Si t of the Black Sea the fish catch of the Marmara Sea was the lowest in the late 1 6), in the period of highest *M. leidyi* impact in the Black Sea. According to sev rs the high density of *Mnemiopsis leidyi* in the Black Sea during 1989 and subse s could be responsible for the decline of the anchovy, because *M. leidyi* feeds s and larvae and is a strong competitor for the mesozooplankton food of the ju adult anchovy (Kideys, 2000, Shiganova, 1998).

Du ck of data on *Mnemiopsis* for this time period, we only can assume that beside pacts (see Niermann in this volume) probably *Mnemiopsis,* could have affect hovy in the Sea of Marmara as well.

Si burst of *Mnemiopsis* during 1989 in the Black Sea (which could probably assum Marmara Sea as well), fish catches were increasing steadily until 1999 (up to alm usand tonnes). In 2000 the catches decreased to 21 thousand tonnes.

Wh were the reasons for the recovery of the catches during the 1990's, the ste se in 1999 and the drastic decrease in 2000 can not be answered by our invest

Figure 6. ***Catches of fish species in the Marmara Sea (Fisheries Statistics. State Institute of Statistics Prime Ministry Republic of Turkey.1980-1999) and GFCM Capture Production 1970-2000 Fishstat Plus Version 2.30 FAO***



According to Kideys (2000), Shiganova (1998), Finenko et al. (2003) the extermination of *M. leidyi* by *B. ovata* could be an important factor for the recovery of the anchovy in the Black Sea by end of the 1990's. To what extents *Beroe ovata* sensu Mayer played a role by the fast increase of the catches in the Marmara Sea from 1997-1999 can not be answered yet.

In conclusion, it is once more clear that for a better understanding of the ecosystem of the Marmara Sea, long-term monitoring data on the important biological components, and particularly on the quality and quantity and of plankton are essential.

According to Kideys (2000), Shiganova (1998), and Finenko et al. (2003), the extermination of *M. leidyi* by *Beroe* cf *ovata* was an important factor in the recovery of the anchovy in the Black Sea by end of the 1990's. However, to what extent this *B. ovata* sensu Mayer played a role in the fast increase of the catches in the Marmara Sea during 1997-1999 cannot be answered yet.

In conclusion, it is once more clear that for a better understanding of the ecosystem of the Marmara Sea, long-term monitoring data on the important biological components, and particularly on the quality and quantity and of plankton are essential.

5. Acknowledgements

We are grateful to Dr. Ulrich Niermann for his constructive comments.

References

Anonymous, 1980-1999. Fisheries Statistics. State Institute of Statistics Prime Ministry Republic of Turkey.

Anonymous, 1970-2000. GFCM Capture Production, Fishstat Plus Version 2.30, FAO

Bishop, J. W., 1967. Feeding rates of the ctenophore *Mnemiopsis leidyi*. Chesapeake Sci. 8: 259-264.

Burrell, V. G. and Van Engel, W. A. 1976. Predation by and distribution of a ctenophore, *Mnemiopsis leidyi* A. Agassiz, in the York River estuary. Estuarine and Coastal Marine Science, 4: 235-242.

Campbell A. C. 1982. The Hamlyn guide to the flora and fauna of the Mediterranean Sea. Hamlyn Publ., London, 320 p.

Cebeci,M. and Tarkan, N. 1990. Marmara Denizinde zooplankton organizmaların dağılımı. I.U. Su Urunleri Dergisi 4(1) 69.

Finenko G. A., Z. A. Romanova, G. I. Abolmasova, *B.* E. Anninsky, L. S. Svetlichny, E. S. Hubareva, L. Bat & A. E. Kideys, 2003. Ingestion, growth and reproduction rates of the alien *Beroe ovata* and its impact on plankton community in Sevastopol Bay (the Black Sea). J. Plank. Res. (accepted).

Finenko G. A., B. E. Anninsky, Z. A. Romanova, G. I. Abolmasova & A. E. Kideys 2001. Chemical composition, respiration and feeding rates of the new alien ctenophore, *Beroe ovata*, in the Black Sea. Hydrobiologia 451:177-186.

Fraser, H. F., 1970. The ecology of the ctenophore *Pleurobrachia pileus* in Scotish waters. J. Cons. Int. Explor. Mer. 33: 149-168.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on The Scientific Aspects of Marine Environmental Protection), 1997. Opportunistic settlers and the problem of the *Mnemiopsis leidyi* invasion in the Black Sea. Rep. Stud. GESAMP 58: 84 pp.

Isinibilir, M. & A. N. Tarkan, 2001. Abundance and distribution of *Mnemiopsis leidyi* in the northern Marmara Sea. *Rapp. Comm. int. Mer. Médit.36.* CIESM, Monte-Carlo. pp.*276*.

Kideys, A. E. 2002. Fall and rise of the Black Sea ecosystem. Science 297: 1482-1484.

Kideys, A. E. & U. Niermann, 1994. Occurrence of *Mnemiopsis* along the Turkish coast. ICES Journal of Marine Science, 51: 423-427.

Niermann, U., A. E. Kideys, A. V. Kovalev, V. Melnikov, V. Belokopytov, 1999. Fluctuation of pelagic species of the open Black Sea during 1980-1995 and possible teleconnections.- in: Besiktepe S., Ünlüata, Ü., Bologa, S. (eds), Environmental degradation of the Black Sea: Challenges and Remedies.- Kluwer Academic Publishers: 147-173.

Mayer, A. G., 1912. Ctenophores of the Atlantic coast of North America. Carnegie Institute Washington. Publication, 162.

Shiganova, T. A. 1993. Ctenophore *Mnemiopsis leidyi* and ichthyoplankton in the Sea of Marmara in October of 1992. Oceanology 33: 900-903.

Shiganova, T. A., A. N. Tarkan; A. Dede, & M. Cebeci, 1995. Distribution of the ichthyo-jellyplankton *M. leidyi* (Agassiz, 1865) in the Marmara Sea (October 1992). Turkish Journal of Marine Science 1: 3-12. Istanbul.

Shiganova, T. A., 1998. Invasions of the Black Sea by the ctenophore *Mnemiopsis leidyi* and recent changes in pelagic community structure. Fisheries and Oceanography 7:305-310.

Tarkan, A. N., Isinibilir, M., Benli, H. A. 2000. An observation on distribution of the invader *Mnemiopsis leidyi* (Agassiz,1865) and the resident *Aurelia aurita* (Linn.1758) along the Strait of Istanbul. Oztürk B., Kadıoğlu M. and Oztürk H. (eds), The Symposium of The Marmara Sea 2000, TUDAV. Istanbul p. 461-467.

Tarkan, A. N., Isinibilir, M., Ogdul, R. G. 2000. Mesozooplankton composition Sea of northern Marmara. Oztürk B., Kadıoğlu M. and Oztürk H. ed., The Symposium of The Marmara Sea 2000, TUDAV. Istanbul, p. 493-499. (in Turkish).

Tregouboff, G. & M. Rose, 1957. Manuel de Planctonologie Mediterraneenne. Centre Nat. de la Rech. Sci. Paris. 1:1-587

Vinogradov, M. Ye., E. A. Shushkina, E. I. Musayeva & F. Yu. Sorokin, 1989. A newly acclimated species in the Black Sea: The ctenophore *M. leidyi* (Ctenophora: Lobata). Oceanology 29: 220-224.

Yuksek, A., E. Okus, A. Uysal, N. Yılmaz, 2002. Distribution of *Mnemiopsis leidyi* in the Sea of Marmara and Black Sea and influence of environmental parameters (1995-2001). Yılmaz A., Salihoğlu İ., Mutlu E., Second Conference of Oceanography of the eastern Mediterranean and Black Sea. Ankara. 142 pp.