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Occurrence of *Mnemiopsis* along the Turkish coast

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The presence of *Mnemiopsis* along the Turkish coast, from the north-eastern Mediterranean to Istanbul, was investigated with horizontal net tows during a survey between 28 July and 1 August 1993. From the north-eastern Mediterranean and the Aegean Sea, only one station situated off Kusadasi in the southern Aegean contained *Mnemiopsis*, the first record of this ctenophore in the Aegean Sea. However, *Mnemiopsis* was present in all of the eight stations sampled between the Dardanelles and the Sea of Marmara, with a range of abundance from 0.2 33.9 individuals 100 m^{-3}.

Key words: Ctenophore, *Mnemiopsis*, distribution.

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Introduction

Mnemiopsis sp. is a western Atlantic ctenophore transported to the Black Sea in the 1980s, possibly in the ballast waters of ships (Harbison and Volovik, in press). This species is sometimes reported as *M. leidyi* (Vinogradov *et al.*, 1989; Uysal and Mutlu, 1993) and sometimes as *M. mccradyi* (Zaika and Sergeeva, 1990; Kideys and Niermann, 1993) due to the continuing controversy as to whether these two species are separate or the same (M. R. Reeve, pers. comm.). In this predator- and parasite-free new environment, *Mnemiopsis* had reached remarkable biomass figures by the summer of 1988, in some areas greater than all other zooplankton combined (Vinogradov *et al.*, 1989). It has been suggested that the mass occurrence of *Mnemiopsis* was one reason for the drastic decrease in catches of anchovy and other plankton-eating pelagic fishes in the Black Sea (Niermann *et al.*, 1993; Kideys, 1994; Harbison and Volovik, in press).

In late May 1992, the presence of *Mnemiopsis* was also reported in Turkish Mediterranean coastal waters between Erdemli and Mersin (Kideys and Niermann, 1993; see Fig. 1), where Uysal and Mutlu (1993) investigated some biometric characteristics of this ctenophore. According to Kideys and Niermann (1993) the transport of *Mnemiopsis* to Mersin Bay in the north-eastern Mediterranean was possible either via ships transporting ballast water from Black Sea ports or via currents through the Bosphorus, the Sea of Marmara, the Dardanelles, and the Aegean Sea. It is already reported to be present in consistently high numbers in the Sea of Marmara (Shiganova, 1993). In order to understand the mode of transport and geographical extent of *Mnemiopsis*, its distribution from the Mediterranean to the Bosphorus was investigated in this study.

Material and methods

The occurrence of *Mnemiopsis* was investigated along the Turkish coasts from eastern Mediterranean (Silifke) to Istanbul between 28 July and 1 August 1993 with RV "Bilim". Fifteen stations which are situated in the Mediterranean, Aegean, and the Marmara Seas were sampled for *Mnemiopsis* (Fig. 1). Ctenophores were sampled with a WP2 net (Hydro-Bios, Kiel, Germany; aperture 500 μm, diameter 1 m) which was towed horizontally at a speed of ~1.5 knots, 1-2 m below the sea surface for 15 min. However, at one station in the Dardanelles Strait (Station 9; see Table 1), the towing period was restricted to 5 min due to heavy shipping traffic. The volume of sea water filtered was calculated as 545 m^3 (182 m^3 in the 5-min tow), assuming 100% filtering efficiency. When *Mnemiopsis* occurred, their numbers and those of other gelatinous macrozooplankton (exclusively *Aurelia aurita*) caught were recorded. The total volume of each species was also measured using a graduated cylinder. No hydrographic measurements were made.

Results

The sampling data, including the biomass of other gelatinous organisms, are presented in Table 1. No

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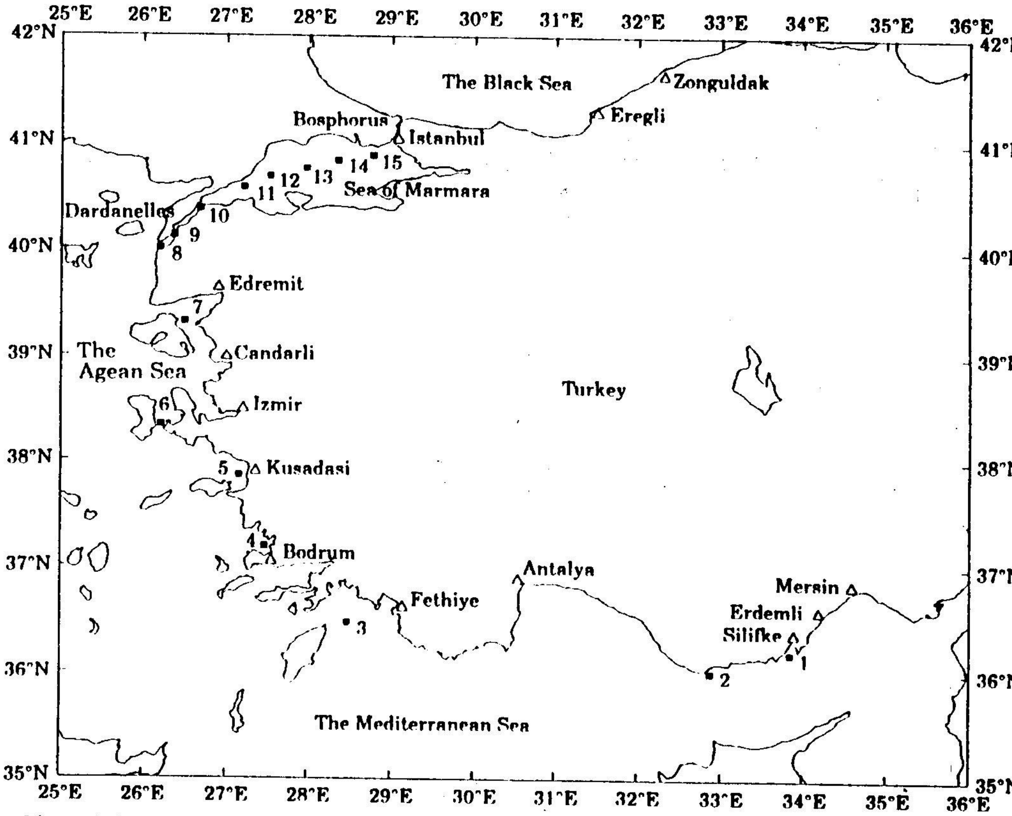

Figure 1. Location of 15 stations along the Turkish coast sampled between 28 July and 1 August 1993.

gelatinous organisms were obtained in the three tows made in the north-eastern Mediterranean. Among the four stations sampled in the Aegean Sea, only one station (Station 5), situated off Kusadasi, had two adult ctenophore specimens, namely one *Mnemiopsis* and one individual of an unidentified ctenophore species (order Cestida). One *Aurelia* was also found at the same station.

On crossing from the Aegean to the Dardanelles (Station 8), an abrupt change in the water colour from blueish to green was apparent, and the same colour, being characteristic of the eutrophic waters of the Sea of Marmara, prevailed at all stations along the sea. All eight stations sampled in the Dardanelles and the Sea of Marmara contained only adult specimens of *Mnemiopsis*. However, the numbers varied greatly, from 1 to 185 individuals per tow. The concentration of the *Mnemiopsis* gradually increased in stations sampled in the afternoon (15:25, Station 8) until around midnight (22:02, Station 11), when the maximum density of 33.9 individuals 100 m^{-3} value was observed. From midnight until morning a gradual decrease in *Mnemiopsis* concentration was also evident. With the exception of Stations 8 and 9, which were situated at the entrance to the Dardanelles from the Aegean Sea, all Marmara stations also contained low numbers of *Aurelia* (maximum 15 individuals per tow).

Discussion

There are a few previous observations on the occurrence of *Mnemiopsis* in the Sea of Marmara. Dense assemblages of the ctenophore were reported by some divers in June 1992 (pers. comm.). We also observed *Mnemiopsis* in the Bosphorus region during a cruise in July 1992. In October of the same year, Shiganova (1993) found this ctenophore to be distributed over the whole of the Sea of Marmara. In the present study, all Dardanelles and Sea of Marmara samples contained the ctenophore, but the total abundance (0.2–33.9 ind. 100 m^{-3}) of *Mnemiopsis* was much lower than that in their native location or in the Black Sea. Kremer and Nixon (1976) report a figure of >5000 ind. 100 m^{-3} during the peak summer densities in Narragansett Bay on the north-east coast of the USA. During its first mass occurrence in the summer of 1988 in the Black Sea, the maximum abundance of *Mnemiopsis* was around 3100 ind. 100 m^{-3} (Vinogradov *et al.*, 1989). A maximum value of 110 ind. 100 m^{-3}, obtained in the late spring of 1992 in Mersin Bay, was also higher than that found in the present

Table 1. Sampling data, number of individuals (no. 100 m^{-3}), and total volume (ml 100 m^{-3}) of *Mnemiopsis* and *Aurelia* at each station between 28 July and 1 August 1993. The salinity and temperature values for Aegean stations are those of Artuz and Korkmaz (1976) during August. All other salinity and temperature data were obtained by RV "Bilim" during July 1993 (unpublished data from Dr S. Besiktepe) at equivalent locations.

Station no.	Area	Position	Date	Time	Salinity	T (°C)	Per 100 m^3 *Mnemiopsis* no.	*Mnemiopsis* ml	*Aurelia* no.	*Aurelia* ml
1	Med.	36°16′N-33°51′E	28.7	21:10	39.2	28.3	0	0	0	0
2	Med.	36°00′N-32°52′E	29.7	02:25	39.3	27.0	0	0	0	0
3	Med.	36°28′N-28°29′E	29.7	21:25	40.0	22.4	0	0	0	0
4	Aeg.	37°10′N-27°28′E	30.7	11:03	~38	23–24	0	0	0	0
5*	Aeg.	37°51′N-27°09′E	30.7	19:02	~38	23–24	0.2	2.1	0.2	10.4
6	Aeg.	38°20′N-26°13′E	31.7	00:42	~38	23–24	0	0	0	0
7	Aeg.	39°19′N-26°30′E	31.7	08:15	~38	23–24	0	0	0	0
8	Dar.	40°01′N-26°12′E	31.7	15:25	25.4	21.1	0.2	2.1	0	0
9†	Dar.	40°06′N-26°22′E	31.7	16:58	26.6	22.9	0.5	5.1	0	0
10	Dar.	40°22′N-26°41′E	31.7	19:43	22.4	22.3	7.3	55.0	0.9	18.3
11	Exit	40°34′N-27°12′E	31.7	22:02	22.4	21.2	33.9	348.6	0.4	20.2
12	Mar.	40°40′N-27°31′E	1.8	01:03	22.1	22.6	22.2	256.9	1.5	91.7
13	Mar.	40°45′N-27°58′E	1.8	03:27	—	—	7.3	53.2	0.2	4.6
14	Mar.	40°49′N-28°21′E	1.8	05:29	22.0	22.5	5.1	25.7	0.2	36.7
15	Mar.	40°54′N-28°46′E	1.8	07:35	21.5	22.6	0.2	2.1	2.8	91.7

*One unidentified ctenophore specimen (order Cestida) was also obtained at this station.
†Five-minute tow.

study. Shiganova (1993) calculated for the Sea of Marmara the average density of *Mnemiopsis* to be 4.2 kg m^{-2}, where the ctenophore was exclusively confined to the upper 15–30 m (i.e. depth of thermocline). Unfortunately, those results were not presented in terms of individuals (or volume) per cubic metre and it is therefore difficult to compare them with our findings. However, using the regression equation of weight (g)=0.981 volume (ml) − 0.945 of Uysal and Mutlu (1993) and assuming the depth of the water column sampled to be 30 m, the average density value of *Mnemiopsis* obtained by Shiganova (1993) can be calculated to be at least 14 000 ml 100 m^{-3}, which is about 40 times higher than our maximum density value (348.6 ml 100 m^{-3}; Table 1). Seasonal fluctuations and variations in biomass between one year may account for the large difference in biomass values obtained for October 1992 and July 1993. Vinogradov and Tumantseva (1993) found that the biomass of *Mnemiopsis* in Gelendzhik in the northern Black Sea displayed marked seasonal fluctuation, with numbers lowest in May–June and highest in October. It may also be suggested that *Mnemiopsis* had attained its peak biomass by 1992, whilst by 1993 numbers had decreased to a more stable level. Such a pattern occurred in the Black Sea, where the biomass of *Mnemiopsis* peaked in 1989 and has shown a 4–6-fold reduction since then (Vinogradov and Tumantseva, 1993).

The concentration of *Mnemiopsis* was found to increase gradually in tows performed after dark towards midnight and to decrease in those towards morning, implying a diel vertical migration in response to light. This finding contrasts with those in the north-western Atlantic. For example, the luminescence meter results of Kremer and Nixon (1976) suggested that in most areas *Mnemiopsis* showed no clear vertical distribution. On the other hand, Miller (1974) observed all sizes of *M. leidyi* were most abundant at the surface during the day, while large individuals showed no depth preference at night. He stated, however, that there was no obvious advantage for *Mnemiopsis* to congregate near the surface in daylight as its most important food component, estuarine Entomostraca, are negatively phototactic. Unfortunately, no studies exist on the vertical migration of *Mnemiopsis* in the Mediterranean.

Mnemiopsis occurs in the entire Black Sea throughout the year (Mutlu *et al.*, 1994) and there is a continuous surface flow of Black Sea waters with low salinity (around 18) towards the Sea of Marmara via the Bosphorus. A consistent occurrence of *Mnemiopsis* in the Sea of Marmara was therefore to be expected. It is worth noting that, except for one individual found in Kusadasi Bay (Aegean), *Mnemiopsis* was only present in the Sea of Marmara and the Dardanelles, up to the Aegean exit of the Dardanelles strait.

It is suggested that there is a flow of low salinity Black Sea water to the northern (Ozsoy *et al.*, 1986) and south-eastern Aegean (Zodiatis, 1993), and from there possibly to the Mediterranean, which would transport *Mnemiopsis* to these areas. The presence of one

Mnemiopsis individual in Kusadasi Bay is also evidence for such a current regime. Moreover, the occurrence of *Mnemiopsis* in Mersin Bay in the late spring of 1992 could have resulted from its transport by currents all the way from the Black Sea (Kideys and Niermann, 1993). It is difficult, however, to explain the almost total lack of *Mnemiopsis* (and *Aurelia*) in the Aegean and Mediterranean samples observed in this study.

It is well known that *Mnemiopsis* is a euryhaline organism tolerating a salinity range of ca. 5–75 (Perkins, 1974; Burrell and Van Engel, 1976). It survives and reproduces successfully in waters with low (<18 in the Black Sea) and high salinities (>37 in the north-eastern Mediterranean; Kideys and Niermann, 1993). The salinity along the Aegean and Mediterranean coasts of Turkey very rarely exceeds 40 (generally around 38) which is much lower than 75 reported in the Laguna Madre (Texas) where *Mnemiopsis mccradyi* naturally occur (Perkins, 1974).

Temperature could be another important factor in determining the distribution of *Mnemiopsis* along the Turkish coasts. This species is reported to survive and reproduce at a wide range of temperature (1.3–32°C; Harbison and Volovik, in press). Unfortunately, no temperature (or other hydrographic) measurements were taken during this survey. However, the temperatures measured approximately 3 weeks before our survey, close to our stations, showed a uniform temperature of 21.1–22.9°C (Dr S. Besiktepe, unpublished data) in the Sea of Marmara and the Dardanelles. Temperatures in the Aegean Sea during August were reported to be around 23–24°C (Artuz and Korkmaz, 1976), which is not very different from those measured in the Sea of Marmara or the Dardanelles. In the eastern Mediterranean higher temperatures were measured in July 1993 by RV "Bilim" (28.3, 27.0, and 22.4°C in Stations 1, 2, and 3, respectively; Dr S. Besiktepe, unpublished data). Thus, at least in the Aegean Sea, the temperatures are close to those measured in the Sea of Marmara, yet only one *Mnemiopsis* individual occurred in the Aegean Sea in this study. Therefore, we can conclude that temperature alone is not the sole factor in determining the near absence of *Mnemiopsis* in the Aegean Sea.

The food conditions differ greatly between all seas surrounding Turkey. In contrast to the oligotrophic structure of the north-eastern Mediterranean and the Aegean Sea (Salihoglu *et al.*, 1990), the Black Sea exhibits eutrophic characters. In addition to a high human population, substantial annual water input from the Black Sea sustains high productivity in the surface waters of the Sea of Marmara, providing favourable feeding conditions for *Mnemiopsis*. It is well known that *Mnemiopsis* is a voracious zooplankton predator (Burrell and Van Engel, 1976; Mountford, 1980). Reeve *et al.* (1978) state that perhaps the most important feeding characteristic of *Mnemiopsis* is that the consumption rate is proportional to ambient food concentration. So in the areas rich in food, *Mnemiopsis* is expected to be very competitive. However, if there is not sufficient food to sustain its high growth (see Reeve *et al.*, 1978) and reproduction rate (see Baker and Reeve, 1974), *Mnemiopsis* could be out-competed by other zooplankton. It has been observed that under food deficiency or starvation conditions *Mnemiopsis* decreases in size and weight (Deason and Smayda, 1982). Some bays along the Mediterranean and the Aegean Seas may provide favourable food conditions for *Mnemiopsis*, as was the case in Mersin Bay in the late spring of 1992 when the ctenophore dominated the macrozooplankton. Similar situations may have arisen in some other bays where possibly no investigation has been undertaken to detect the presence of this ctenophore. However, we did not observe *Mnemiopsis* even in Mersin Bay during 1993 and during spring and summer 1994.

The lack of *Mnemiopsis* in the Aegean and Mediterranean seas cannot be explained by any one of the factors mentioned above. Similarly, changes in food availability, temperature, and salinity do not explain the seasonal disappearance of *Mnemiopsis* in Narragansett Bay (Deason and Smayda, 1982). It is more likely that a combination of these factors is responsible for the distribution of *Mnemiopsis*. Miller (1974) indicated the synergistic effect of temperature and salinity in the accumulation of *M. leidyi* on a beach in South Creek, North Carolina. We suggest that the distribution of *Mnemiopsis* could be related to the combined effects of salinity, temperature, and food conditions along the Turkish coasts. Extensive laboratory experiments are essential in order to determine the importance of each factor and their combined effects on this introduced population.

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