DISTRIBUTION AND FLUCTUATION OF DOMINANT ZOOPLANKTON SPECIES IN THE SOUTHERN BLACK SEA IN COMPARISON TO THE NORTH SEA AND BALTIC SEA

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Abstract. The fluctuation of dominant pelagic species >300µm (copepoda, chaetognatha, scyphozoa, ctenophora and ichtyoplankton) of the southern Black Sea were compared with that of dominant species of the North Sea and Baltic Sea. In all three seas similar changes in the zooplankton compositon took place in end of the 1980's, beginning of the 1990: - decreasing or increasing abundances of certain species, - occurrence of new species (North Sea: *Muggiaea atlantica* Lusitanean fish species; Black Sea: *Mnemiopsis leidyi*), - changes of the blooming period of certain species, which starts earlier and last longer, - high interannual fluctuations of some species, which were obvious since end of the 1980's. The changes in the zooplankton of all three seas could be related to a rise in temperature during 1988/89 (North Sea, German Bight: sudden rise in the annual average temperature and salinity during 1988/89; Baltic Sea, Kiel Bight: rise in the temperature of the subthermocline water during 1988/89; Black Sea: extraordinary cold winter 1987/88 followed by an extraordinary warm winter during 1988/89. It was concluded, that the changes in the zooplankton community since end of 1980's in the Black Sea, North Sea and Baltic were triggered in all probability by climatic variability.

1. Introduction

The Black Sea, North Sea and Baltic Sea faced similar environmental problems since 1960 [40], [Zaitsev, this volume], as high fishery exploitation, eutrophication, oxygen deficiencies, which led to changes in marine communities [23],[4],[11]. The outburst Ff the accidentally introduced species *Mnemiopsis leidyi* 1988 [37],[39],[18] and the collapse of the anchovy fishery during 1989 [4] draw the attentions of many researchers to the Black Sea. The Institute of Marine Sciences started the investigation and monitoring of zooplankton and ichthyoplankton in the southern Black Sea in June 1991.

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This paper attempts to trace some common features of the distribution and fluctuation of dominant zooplankton (>300 µm) in the southern Black Sea in comparison with the fluctuation of same or similar species in the North Sea and Baltic Sea. To compare the abundances of the species in the different seas is difficult, since the numbers and biomasses of the species are strongly dependent on the methods of collecting. In the southern Black Sea the zooplankton was collected by vertical Hensen Net (mesh size 300 µm, opening diameter: 0.7 m) hauls from the anoxic layer to the surface.

2. Zooplankton Species

The considered dominant zooplankton species (>300µm) occurring in the southern part of the Black Sea are shown in Figure 1. The species, which are living most time above the thermocline are placed in the upper part, the species living most time below the thermocline are drawn in the lower part of Figure 1.

These species, *Sagitta setosa*, *Pleurobrachia pileus* and the copepods *Pseudocalanus elongatus*, *Calanus euxinus* and the North Sea *C. finmarchicus*, display diel vertical migrations [36]. During night these species are concentrated in the upper water, mostly just below the thermocline. In the early morning the species migrate down to the deep layers, stay there during day and rise again to the surface in the late afternoon / early evening. During day these species are concentrated in a narrow horizon just above the HS_2-layer in depths between 80 - 150 m with oxygen concentrations between 0.4-0.5 ml O_2 l^{-1}.

Many species, occurring in the Black Sea occur in the North Sea and Baltic Sea as well. Some Black Sea species are represented in the other seas by species of the same genus with similar behaviour. Due to the low salinity many zooplankton species occurring in the Black Sea and in the North Sea are not present or very rare in the Baltic Sea. Many species are present only in the south western more saline area with a salinity S > 7 [1]. Other species, which are dependent on a higher salinity, serve as indicator species for an inflow of higher saline North Sea water and are distributed only in the southern part of the Baltic Sea.

Four species of gelatinous animals are common in the Black Sea: two scyphozoans, *Aurelia aurita* and *Rhyzostoma pulmo* and two ctenophores, *Pleurobrachia pileus* and *Mnemiopsis leidyi*. While *Rhyzostoma pulmo* is most common in coastal areas, the three other species are distributed in all parts of the Black Sea [37]. *Mnemiopsis leidyi*, which originated from eutrophic lagoons in North America, was accidentally introduced into the Black Sea in the mid 1980's and affected radically the entire pelagic fauna of the Black Sea [37],[39],[4],[25]. *Aurelia aurita* is a very common jelly fish in the Black Sea and Baltic Sea, but is rare in the North Sea, where it is controlled by the jelly fish *Chrysaora quinquecirrha*. *Pleurobrachia pileus* exhibits a single dominant population maximum in the German Bight (North Sea) from mid of May till the end of June [13]. In the Baltic Sea the occurrence of *Pleurobrachia pileus* is strongly dependent on the inflow of North Sea water. In the Kiel Bight the variations

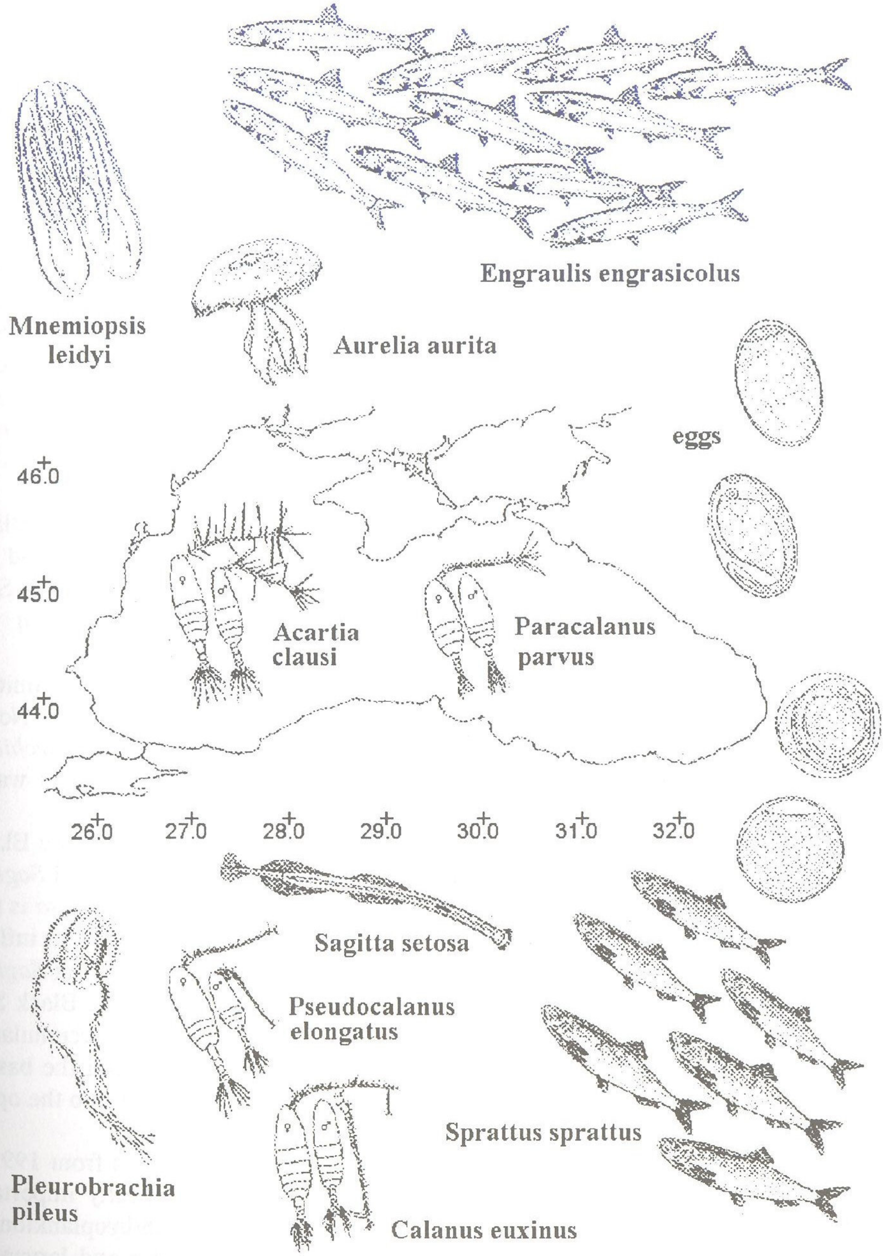

Figure 1: Dominant species (>300µm) of the southern Black Sea

of the ctenophore stock are primarily caused by advection and did not reflect the biological population cycle of this species [34].

Apart from *Oithona nana*, a species which is to small to be caught with a 300 µm gauze, *Acartia clausi* is one of the most abundant copepod species in the upper water layers of the Black Sea. The blooming period is during midsummer all 3 enclosed seas under concideration [37],[3],[19]. *Centropages kröyeri* (*ponticus*) and the cosmopolitan species *Paracalanus parvus* are typical species of the upper layer. They are not very common species in the southern Black Sea, occuring only in low numbers during summer [10]. In the North Sea *Paracalanus parvus* is very abundant in the central North Sea and in the coastal waters of Netherlands and Germany [19]. The distribution of *Paracalanus parvus* in the Baltic Sea is restricted to the south western part dependent on the salinity [1]. Below S = 7.8 this species does not occur. *Centropages kröyeri* does not occur in the North Sea and Baltic Sea. In the North Sea the genus is represented by the species *C. hamatus* and the Atlantic species *C. typicus* [19]. In the Baltic Sea *Centropages hamatus* occurs in low abundance in areas with a salinity S > 7 [1],[35].

Calanus euxinus exhibits the highest biomass of all copepod species in the Black Sea. In the North Sea *Calanus euxinus* is replaced by *C. finmarchicus* and *C. helgolandicus*. *C. finmarchicus* is very common in the deeper northern North Sea, while *Calanus helgolandicus*, a summer/autumn species, occurres mainly in the southern more shallow areas [19].

Pseudocalanus elongatus, a cold water species, with a upper temperature limit of occurrence of about 13°C is very common in the whole Black Sea and in the North Sea. In the low saline Baltic Sea this species acts together with *Calanus finmarchicus* and *Calanus helgolandicus* as indicator of inflows of higher saline North Sea water into the Baltic Sea [1],[34].

The chaetognath *Sagitta setosa* is the dominant chaetognath species in the Black Sea with a peak occurence in July/August. In the North Sea the peak bloom of *Sagitta setosa* is between September and November [27]. In the Baltic Sea *Sagitta setosa* is not common. Its presence in the south western Baltic Sea is always related with an inflow of high saline water of the Kattegat [1]. The distribution of the deep dwelling *Sagitta setosa* reflects the topography and the overall hydrographic situation in the Black Sea (Fig. 2a). Thus the abundance is low at the shelf area. The individuals are accumulated in the rim current and drifting as big clouds along the shelf edges around the basin. The numbers of *Sagitta setosa* coincides with the branches of the current into the open sea, but the numbers are low in the central gyres (Fig. 2b).

A total of 29 taxa of ichthyoplankton were caught during all cruises from 1991 - 1994 in the southern Black Sea. The eggs of the two most economically important species *Engraulis encrasicolus* and *Sprattus sprattus* dominated the ichthyoplankton in summer and winter respectively (Fig. 1). From other fish species eggs and larvae in considerable amounts were only present of *Merlangius merlangus*, *Platichthys flesus*, *Mullus barbartus* and *Mugil sp.* (IMS, unpublished data).

The sprat *Sprattus sprattus* occurs in all three seas. The sprat spans throughout the whole year. In the southern Black Sea and southern North Sea the main spawning time

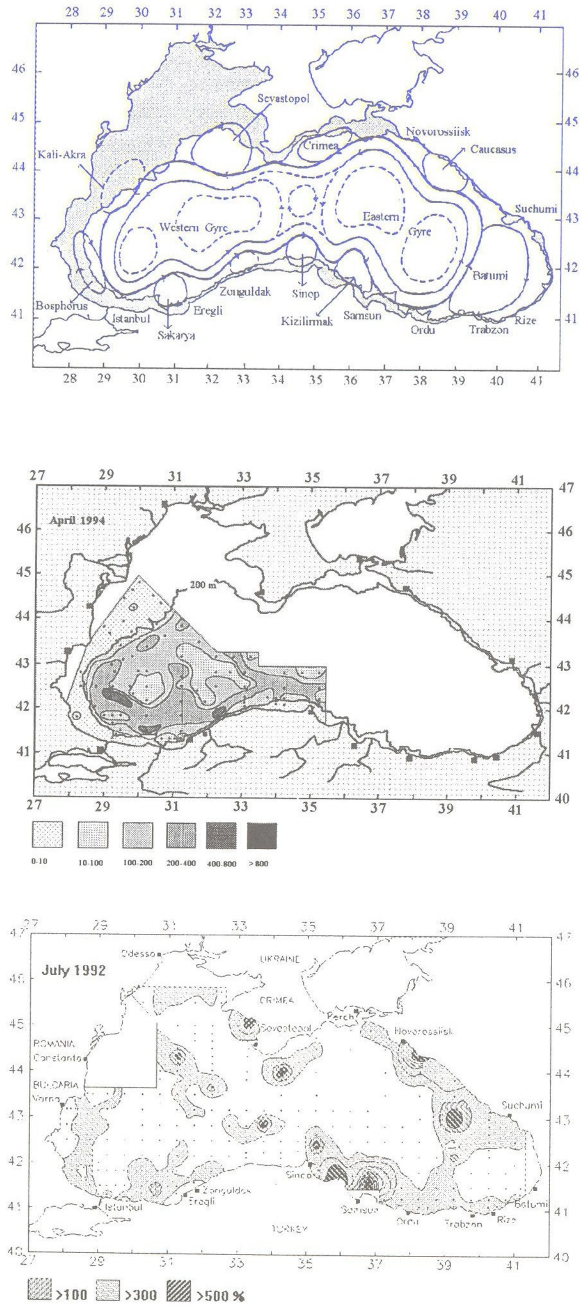

Figure 2 a: General circulation of surface currents in the Black Sea. The bold line shows the rim current. b: *Sagitta setosa*: Distribution in April 1994. c: Distribution of anchovy eggs in comparison to the current system in July 1992 [26]. Indicated are the areas with egg numbers 100 % of the average of the total number.

is in winter, with a peak in January/February. In the northern North Sea the peak spawning season starts with one month delay [17],[32].

The anchovy *Engraulis engrasicolus* is the most dominant fish in the Black Sea [5], but it is not frequent in the North Sea, and it does not occur in the Baltic Sea. In contrast to the sprat, anchovy eggs and larvae are very common during summer from mid of July to mid September. Due to their ellipsoid shape anchovy eggs are very easy to identify [9]. The distribution of anchovy eggs, which are drifting in the upper water layer, reflects as well the hydrographical features of the Black Sea [26]. The bulk of eggs is distributed in the main spawning areas between shelf areas and the rim current (Fig. 2c). After spawning the eggs are transported with the rim in open waters. This is obvious in the area between the eastern gyre and Batumi eddy and in the western area. Regions with no or very small abundances are the cyclonic gyres in the central part and the Batumi eddy in the eastern part of the Black Sea. No anchovy eggs as well were found in the upwelling region west of Sinop with surface temperatures of 12°C. In contrast to the anchovy eggs the cold water species *Pseudocalanus elongatus* was 15 times higher in the upwelling area compared to the average value of 2210±720 individuals m^{-2} of the whole southern Black Sea area (Ergün, 1994).

3. Changes in the pelagic ecosystems

The present state of the Black Sea, North Sea and Baltic Seas are determined by a continuing eutrophication process, which effect especially coastal communities [4]; Lancelot, this volume). Eutrophication effects in the open waters are obvious as well, but still moderate. In the Black Sea changes in the ecosystem started in the sixties with increasing eutrophication, pollution and exploitation of the fish stocks [40]. How these changes are reflected in the life patterns of single species should be highlighted exemplary for the anchovy stock.

The two subspecies of the Black Sea anchovy *Engraulis engrasicolus ponticus and Engraulis engrasicolus euxinus* undergo extensive migrations all over the Black Sea from the overwintering to the spawning areas [17],[6]. According to earlier surveys the anchovy spawns throughout the whole of the Black Sea but mainly in the northern half, especially in the shelf area [17].

Changes in the spawning areas of anchovy were noticeable off the Crimea coast by 1988, when the areas observed to be most abundant with anchovy eggs and larvae were towards the open sea rather than the typical distribution at the shelf areas found during 1950 to 1980. In 1992 and 1993 the bulk of anchovy eggs were obtained from the southern and particularly the south-eastern Black Sea and not from the northern Black Sea as usual. Comparison of the egg numbers found during an earlier survey about 40 years ago in July 1957 showed, that the northern part of the Black Sea displayed nearly the same numbers of anchovy eggs as in 1957, whilst the egg numbers for the southern region were significantly higher in 1992 than in 1957 [26].

The authors concluded, that the low egg and larvae numbers in 1957 and 1959 possibly reflect the mesotrophic state of the Black Sea in the late 1950s. With

increasing eutrophication, the anchovy stock enlarged in the early 1960s, and consequently egg and larval numbers increased. The decrease in spawning of the anchovy in the northern Black Sea during the 1980s is consistent with the northern area of the Black Sea having become excessively eutrophic and more polluted than the southern area over the last two decades as a result of major rivers flowing into this region. It was suggested, that the environmental deterioration of the shelf area due to dystrophication and the improved food conditions in the open sea due to eutrophication, has resulted in a shift of the spawning grounds to the open sea. Increasing eutrophication of the former mesotrophic coastal areas of the southern Black Sea could also be assumed as reason for the expansion of the spawning grounds from the Bosphorous area to the eastern Black Sea coast of Turkey.

A sudden decline of anchovy eggs and larvae, reflecting the collapse of anchovy catches for the whole of the Black Sea, were recorded in 1989, coinciding with the outburst of *Mnemiopsis leidyi*. This species competes for zooplanktonic food with the anchovy and is an important potential predator of anchovy eggs, and, especially, of yolk-sac larvae [8]. *Mnemiopsis* could, therefore, be a threat to fishery year-class recruitment [24].

Why the outburst of *Mnemiopsis leidyi* happened just at the end of the eighties and its relationship to the decline of the zooplankton biomass and the collapse of anchovy stock is still under discussion [37], Zeitsev, 1992; Prodanov, this Volume; Shiganova, this volume). Mny authors put the outburst of *Mnemiopsis leidyi* in connection to overfishing and to eutrophication effects, which caused changes in the planktonic species composition. Comparing the fluctuations of the zooplankton in all enclosed seas under consideration it is striking that major changes in the zooplankton community happened in the end of the 1980's as well in the Baltic Sea and in the North Sea.

3.1 BALTIC SEA

The comparison of the August months from 1953 - 1988 (data of the Baltic Sea Fishery Research Institute in Riga) showed a steep increase of zooplankton biomass in the Baltic Proper during the 1970's [35]. The increase of the zooplankton biomass was caused especially by the high increase of *Pseudocalanus elongatus* and *Acartia sp.* After maintaining of a high level during the 1980's the population of *P. elongatus* and *Acartia sp.* declined rapidly in 1988, while small zooplankton species as Bosmina increased (Fig. 3).

In the Kiel Bight a change in the zooplankton community was apparent in 1988 as well: the abundances of many zooplankton species increased, the blooming time of late summer/autumn zooplankton species started earlier and some species show high interannual fluctuations [2]. Increasing abundances after 1988 were observed as well in ichthyoplankton [33] and in zoobenthic species [31] after an abundance and diversity minimum during 1985-1988.

In contrast to the zooplankton stock of the Baltic Proper the stock of *Pseudocalanus elongatus* in the Kiel Bight increased since 1988 after a period of

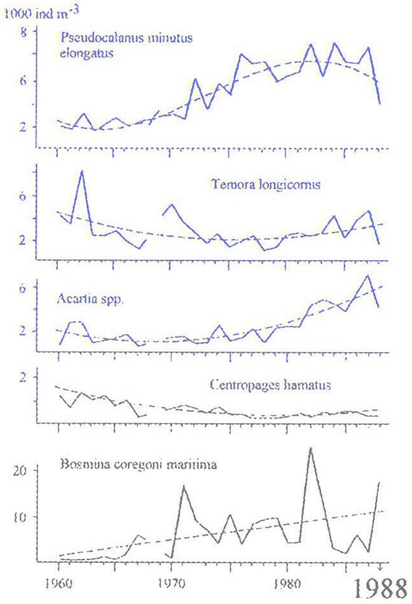

Figure 3: Fluctuation of main zooplankton species in the eastern and south eastern part of the Baltic Proper during August 1960 - 1988 in 0 - 100 m depth [35].

extremely low abundance between 1986 and 1987. The individual numbers of the copepod *Othiona similis* and the appendicularia *Oikopleura diocica* increased very strong since 1988/89 in the summer and displayed since then high seasonal fluctuation (Fig. 4a). Since 1988 the blooming period of *Oikopleura diocica* starts already in July, two month earlier than in previous years and continues as before till November (Fig. 4b).

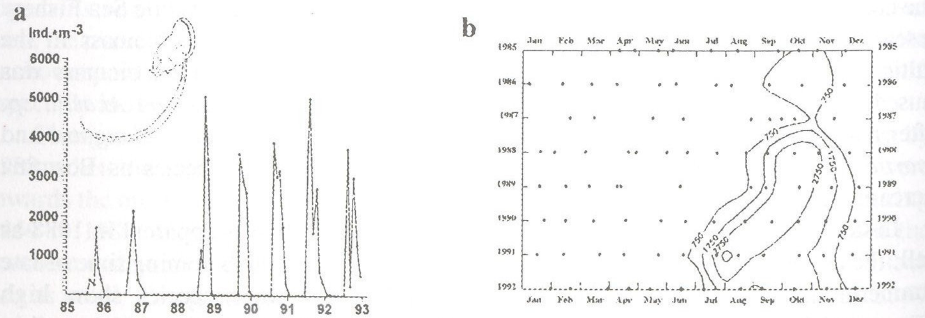

Figure 4: *Oikopleura diocia*: Fluctuation (a) and seasonal distribution (b) in the Kiel Bight, Baltic Sea during 1985 -1993 [2].

In the Kiel Bight the increase of *Oikopleura* and *Oithona* were significantly related with the rise in the temperature at the 20 m depth for the season July to December

1988, while the years with low densities of *Pseudocalanus elongatus* correspond to years with low salinity at 5 m and partly at 20 m depth before and during the reproduction season [2].

3.2 NORTH SEA

Sudden changes in the abundance of some species were detected as well in the German Bight (North Sea), at Heligoland Roads during 1988/89 [14]. For example the abundance of *P. elongatus* and *Paracalanus sp.* decreased after 1987-1992 after a blooming period from 1983-1986 (Fig. 5a). After a blooming period 1983-1989 the stock of and *Acartia sp.* declined rapidly till 1993 (Fig. 5b). After 1988 the actinotrocha, the larval stage of *Phoronis mülleri*, increased after a period of low abundance (Fig. 5c). The abundance of *Sagitta setosa* decreased as well end of the 80's after a blooming period (1983 - 1988). Since 1987 *Sagitta setosa* fluctuated with a high amplitude till 1991 (Fig. 5d).

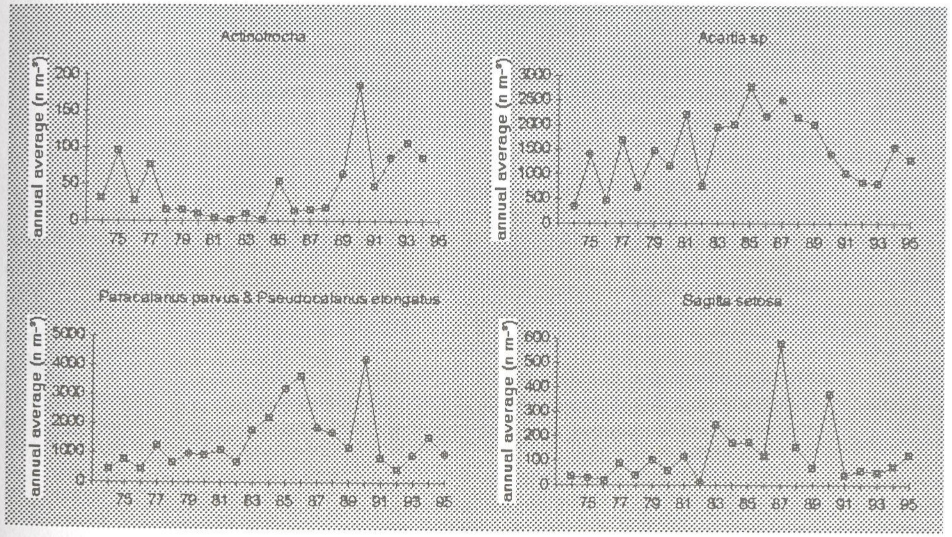

Figure 5: Fluctuation of dominant zooplankton species at Helioland Roads, German Bight, North Sea during 1974 -1995. Data from MABIS (Marine Biological Information System of the Biologische Anstalt Helgoland).

As in the Black Sea a new species *Muggiaea atlantica* (Siphonophora, lusitanian plankton) invaded the North Sea in 1989 and caused changes in the biocoenosis [12]. As evidence for a exceptional inflow of Atlantic water into the North Sea during 1989 an extraordinary population of *Doliolum nationalis* (Tunicata) was observed in the central an south eastern North Sea [21]. Lusitanian fish species *Trachurus vipera, Zeus faber, Mullus surmuletus* and other species where found in the North Sea since 1989 as well [15].

In the German Bight the temperature and salinity of the surface water increased in similarity to the Baltic Sea suddenly in the end of 1980's (Fig. 6). The average surface temperature was in the years 1984-1987 below 10°C. The temperature increased since 1988 and was about 11°C in 1989/90. After 1990 the average temperature varies between 10 and 10.5°C, on a higher level than in the mid 1980's. The salinity S > 33 as well was very high during 1988/89 and remained on a higher level as in the period 1977-1987 with salinities below S = 32.5.

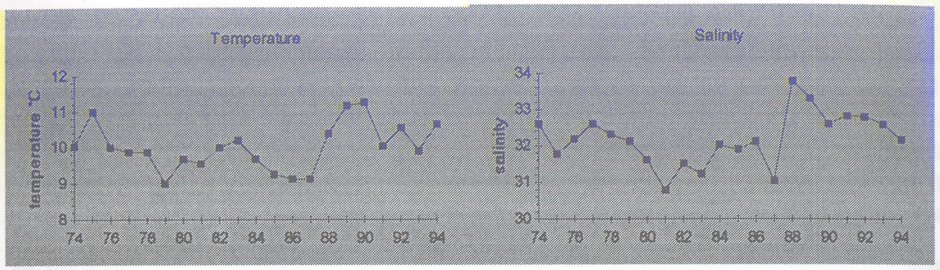

Figure 6: Changes in the mean annual temperature (a) and salinity (b) at Heligoland Roads during 1974 - 1994 according to [14].

3.3 BLACK SEA

In the open Black Sea the average air temperature decreased after 1986, was extremely low in 1987, raised up in 1988 and decreased till 1994 [28] Ovchinnikov, unpublished). Obvious is, that sudden changes in the zooplankton community of the Black Sea occurred as well during 1987-1989 as seen in the North Sea and Baltic Sea. The abundance and biomass of many zooplankton species in the Black Sea, as *Aurelia aurita, Acartia sp., Oithona sp., Sagitta setosa* decreased during 1987/88 [37],[39], [Melnikov, this volume; Shiganova, this volume]. In the same period the combjelly *Mnemiopsis leidyi* stock increased suddenly and the anchovy stock collapsed in 1989 [4],[26].

4. Conclusions

Similar changes in the zooplankton community of the Black Sea were obvious in the North Sea and Baltic Sea:

- changes in the meso zooplankton community structure due to decrease or increase of the abundance of dominant species
- occurrence of new species (North Sea: *Muggiaea atlantica,* lusitanian fish species; Black Sea: *Mnemiopsis leidyi*)
- changes of the blooming periods of some species, which start earlier and last longer
- high interannual fluctuations of some species, which started since end of the 1980's

High fluctuation in communities indicate a period of instability, which often is induced by a change of environmental parameter [29]. The changes in the seas under consideration occurred in the Black Sea after a extraordinary cold winter 1987/88 and a very warm winter during 1988/89, in the German after a sudden increase in temperature and salinity during 1988/89 and in the Kiel Bight after a rise in temperature of the subthermocline water during 1988/89. It could be concluded, that the changes in the zooplankton community since end of 1980's in the Black Sea, North Sea and Baltic Sea are forced by the same overall climatic event.

Of course, the importance of eutrophication as a major forcing function for zooplankton, especially in coastal waters, e.g. in the German Bight [16], most bays of the Baltic Sea [35] and the shelf area of the Black Sea [40] should always be considered. But the effects of eutrophication can be override or masked by hydrographic changes [38], [Reed, this volume]. Besides the possible eutrophication effect the changes of temperature and salinity in the Baltic Proper had an overall influence on the composition of the zooplankton community. The years in cold water periods 1962-1970 and 1979-1988 with severe winters displayed lower level of zooplankton development, than those years of warm water periods with mild winters 1954-1961 and 1971-1978 [35].

Examples for sudden changes of the community structure due to climatic variability as extreme cold winters, changes in the strength of currents or due to or high wave action triggered by strong storms are well known in the North Sea and Atlantic [7], [30]. Mann & Lazier [22] summarized the biological consequences of major perturbation of the North Atlantic during 1960'-1980's which affected the North Sea as well. Influences of forcing conditions have been discussed by Lindeboom *et al.* [20], who stated sudden changes in the biota of the North Sea at the seventies to eighties. Changes in the same period were obvious as well in the composition of phytoplankton (Diatom/Dinoflagellate ratio) and in the duration of the blooming period of Diatoms, Fagellates and small copepods in the German Bight [11].

Up to now the events in the Black Sea after 1988, and especially the collapse of the anchovy fishery, were often related to pollution, overfishing and to the outburst of *Mnemiopsis leidyi* [37],[40],[39]. Keeping in mind, that changes in the zooplankton community in the late 80's were evident in all seas under consideration, a climatic impact could have triggered the changes in the zooplankton community in the Black Sea as well, which caused the conditions for the outburst of *M. leidyi* and the decline of the anchovy stock.

Up to now the approach to evaluate existing zooplankton long term data of the Black Sea in relation to climatic variability has not been carried out. Therefore more effort should be made in near future to evaluate the existing zoo- and phytoplankton data of the Black Sea in relation to physical and meteorologic changes.

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