CHAPTER 17

Zoobenthos

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ABSTRACT

The present paper gives an overview on the macrozoobenthos species composition in the southern part of the Baltic based on about 100 000 data with origin between 1839 and 2006. More than two thirds of these data were collected after 1980. Both the historical data and those from more recent investigations have been combined in a common database. Sixteen different subareas with different salinity regimes (0–30 psu) have been defined and their faunistic inventory is described. The subareas are: Kiel Bight, Mecklenburg Bight, Plate of Rugia, Arkona Sea, Pomeranian Bay, Flensburg Fjord, Schlei Estuary, Eckernförde Bay, Kiel Fjord, Trave Estuary, Wismar Bay, Warnow Estuary, Darss-Zingst Lagoon, Rugia Lagoons, Greifswald Lagoon, and Stettin Lagoon. In total, 667 species of 29 higher taxonomical groups were recorded. As a consequence of decreasing salinities from west to east and from offshore to inshore respectively, the number of marine species is significantly decreased or has been displaced by limnic species in the inner coastal waters. As expected from previous work salinity was one major correlate to species richness in the estuaries and open sea areas. Another factor of potential importance for species richness is seasonal hypoxia in the bottom waters, a phenomenon common in several fjord like estuaries and deeper basins.

Furthermore, several populations inside the estuaries and in the offshore waters are only sustained over the life span of the established individuals (mainly a few years, e.g., *Ophiura albida* in the Mecklenburg Bight). Moreover, colonization is a frequent process, mediated by water influx from adjacent areas.

17.1 INTRODUCTION

In brackish water systems such as the Baltic Sea two main environmental variables (salinity and oxygen supply) affect the composition of the benthic community and species' abundance (e.g., Rönnberg and Bonsdorff, 2004). The Baltic Sea, formed after the latest glaciation, is a young ecosystem continuously undergoing postglacial successional changes (Jansson and Jansson, 2002). It is an enclosed, nontidal ecosystem and has steep latitudal and vertical salinity gradients (see also Chapter 2). The southern parts including the Belt Sea are closely connected to the Kattegat and Skagerrak and show salinities between 25 and 30 psu. Within a few 100 km toward the east or the north the values drop down to 5 psu and, finally, in the most northern part to more or less freshwater conditions. As a consequence, the number of marine species is significantly decreased or has been displaced by limnic species in the North and inner coastal waters (Bonsdorff, 2006).

State and Evolution of the Baltic Sea, 1952–2005, edited by Rainer Feistel, Günther Nausch, and Norbert Wasmund

Oxygen availability also limits species' distribution as most benthic organisms are sensitive to long term low oxygen conditions (Diaz and Rosenberg, 1995). Therefore, benthic life is often absent in the deeper basins below the halocline particularly after longer periods without any saline water inflows (see also Chapter 10). In the shallow parts of the Baltic (e.g., Mecklenburg Bight) hypoxia may occur during the summer months due to high water temperatures.

Even though the Baltic is a young ecosystem, species-poor and vulnerable to the threat of invasive marine and exotic species, both the strong gradient and the rapid change in salinity conditions especially in the southern Baltic inhibit an unhindered colonization. As a result, the Baltic benthic fauna is still largely characterized by species with obvious opportunistic life history traits (Rumohr et al., 1996).

The salinity gradient is particularly pronounced in the transition zone ranging from the euhaline Skagerrak and Kattegat to the brackish Baltic Proper (down to 5 psu).

In this chapter we

- describe the macrozoobenthic diversity within the southern Baltic Sea based on analysis of historical and recent data,
- demonstrate the variability of benthic colonization relative to salinity, and
- assess the long term development of macrozoobenthos at selected monitoring stations.

17.2 HOW DIVERSE IS THE MACROZOOBENTHOS IN THE SOUTHERN BALTIC SEA? ANALYSIS OF HISTORICAL AND MORE RECENT (IOW) DATA

17.2.1 History of Macrozoobenthic Research in the Southern Baltic Sea

The beginning of the study of macrozoobenthos in German Baltic waters dates back to the end of the eighteenth century when Detharding (1794) listed some molluscs and "molluSciform species." However, no information regarding the locality was given. In the nineteenth century some studies on several taxa groups, mainly on molluscs (e.g., Pfeiffer, 1839; Boll, 1852; Friedel, 1870; Lehmann, 1873) and sponges (Lieberkühn, 1857) have been performed but besides those, information on macrozoobenthos for this period of time is rare. The systematic observation of species and their distributions in the Baltic has began with Meyer and Möbius (1865, 1872) and Möbius (1873) who published different papers on molluscs and other invertebrates. Another famous scientist of this time period was Lenz (1875, 1882), who worked in the 1860s and 1870s on the macrozoobenthos of the Travemünde Bay and the Trave Estuary. Many other papers exist from this time period but in most cases these studies only deal marginally with macrozoobenthic species or they were mainly motivated by fisheries related questions. Especially at the beginning of the twentieth century the famous research cruises of Petersen (1913, 1918), Hagmeier (1926, 1930) and Hertling (1928) were focused on food of commercial fishes. Nevertheless, some hundred data are available covering approximately 50 macrozoobenthic species. In the 1930s Krüger and Meyer (1937) studied the macrozoobenthos of the Wismar Bay and 80 species were recorded. Seifert (1938) delivered the first comprehensive inventory of the Greifswald Lagoon. Similar studies were done by Remane (1937) and Jaeckel (1937) in the Schlei Estuary. They have summarized the results of own observations and data of colleagues and almost 140 species were listed. The next period of intensive faunistic research in German Baltic waters was during 1950s and 1960s. Regarding the Kiel Bight the studies of Kühlmorgen-Hille (1963, 1965) have to be stressed. The Mecklenburg Bight was intensively investigated by Schulz (1969a, b) and the basic knowledge concerning the macrozoobenthos in the Arkona Sea and the Pomeranian Bay was established by Löwe (1963). At the end of the 1970s and the beginning of the 1980s the studies of Gründel (1982), Brey (1984), and Weigelt (1986) are of importance. The latter have summarized the data collected by several scientists (Arntz, Gröhsler, Rumohr, Weigelt). As a result of diploma and doctoral theses, the well-known identification keys for polychaetes (Bick and Gosselck, 1985), molluscs (Jagnow and Gosselck, 1987), and crustaceans (Köhn and Gosselck, 1989) were developed.

Recently, macrozoobenthos inventories have been published for the Pomeranian Bay (Kube, 1996; Glockzin and Zettler, 2008), Mecklenburg Bight (Zettler et al., 2000) and for the Arkona Sea (Zettler et al., 2006). A comprehensive overview of historical and current literature on macrozoobenthos in the German Baltic is given in the reports of Gerlach (2000) and Zettler and Röhner (2004). In these bibliographic reports about 1085 literature sources were analyzed.

In the following we give an overview on the macrozoobenthos species inventory of the southern Baltic based on literature data that were digitalized, georeferenced, and combined with own recent data. In total, about 100 000 data originating between 1839 and 2006 have been analyzed.

17.2.2 Investigation Area

The macrobenthos inventory presented here represents the entire German Baltic sector including the Exclusive Economic Zone (EEZ), inner coastal waters up to the limnic border and the waters off the EEZ up to the mainland of Denmark and Sweden in the North and to 14.7 longitude degree in the East (Fig. 17.1). For better comparison of the macrofauna, and in respect to the strong salinity gradient (1–30 psu) the investigation area was divided into 16 subunits.

Generally, in water depths < 20 m the main sediment type consists of sand. The deeper areas, for example, depths > 20 in the Mecklenburg Bight or >35 m in the Arkona Basin, are characterized by muddy substrates. Gravel, stones, and boulders are typical for underwater glacial banks or exposed shore lines. When the narrow Little and Great Belt connect the Kattegat to the southern Belt Sea, the narrow Sound connects the Kattegat and the Arkona Basin directly. Because of these narrow connections, each sliced through sills, the inflow of highly saline and oxygen-rich water into the Baltic Sea is limited resulting in occasional stagnation periods over weeks up to months (see also Chapter 10). Along the German Baltic coast bottom water salinity ranges between about 25 psu in the West and 7 psu in the East (Fig. 17.2). A second strong gradient occurs from the offshore waters to the inner coastal waters and estuaries. Especially stations within the Darss-Zingst Lagoon (with salinities between 1 and 8 psu) and the Stettin Lagoon (1–5 psu) were taken into account. The overall salinity range in the investigation area was 1–30.2 psu.

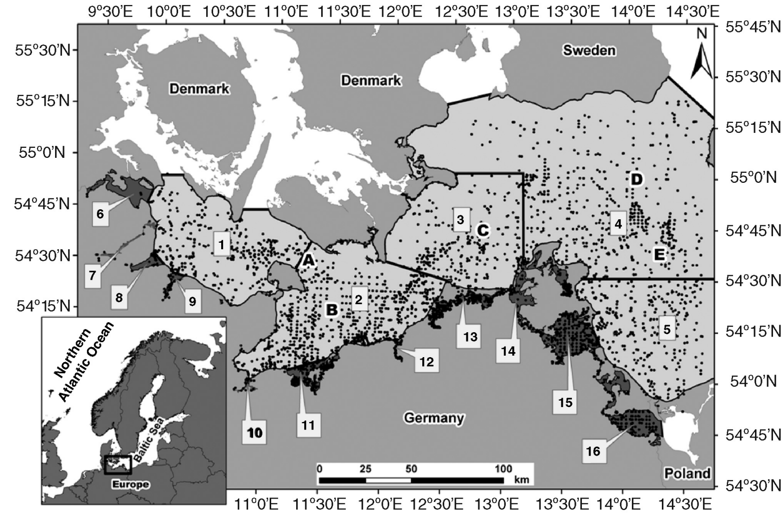

FIGURE 17.1 Investigation area in the southern Baltic Sea. In total 7200 stations (dots) were sampled between 1839 and 2006, including five long-term monitoring stations (A: 010, B: 012, C: 030, D: 109, E: 152). The numbers 1–16 indicate the subunits [1: Kiel Bight, 2: Mecklenburg Bight, 3: Plate of Rugia, 4: Arkona Sea, 5: Pomeranian Bay, 6: Flensburg Fjord, 7: Schlei Estuary, 8: Eckernförde Bay, 9: Kiel Fjord, 10: Trave Estuary, 11: Wismar Bay, 12: Warnow Estuary, 13: Darss-Zingst Lagoon, 14: Rugia Lagoons, 15: Greifswald Lagoon, 16: Stettin Lagoon].

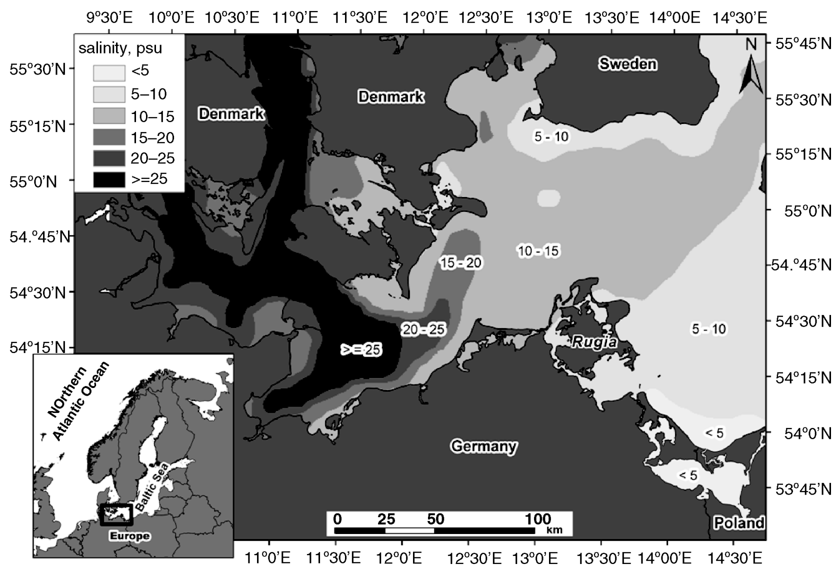

FIGURE 17.2 Distribution map of the modeled mean bottom water salinity (period 1980–2000) in the southern Baltic Sea derived by kriging of 1652 single data points (Dippner et al., 2005). The difference between highest and lowest measured values was 26.3 psu.

17.2.3 Literature Sources

Almost all relevant literature sources given in the reports of Gerlach (2000) and Zettler and Röhner (2004) were analyzed in respect to information on macrozoobenthos distribution. Only data were geographic coordinates could be assigned to have been considered. Other more general literature information (e.g., "is distributed in the Kiel Bight") was neglected.

17.2.4 IOW Data

These data sets are based on approx. 900 stations sampled by the Leibniz Institute for Baltic Sea Research (IOW) during the past 15 years as part of the regular monitoring or within different research programmes. Benthic samples were taken with a 0.1 m^2 van Veen grab. Depending on sediment composition, grabs of different weights were used. Three (or two) replicates of grab samples were taken at each station. Additionally a dredge haul (net mesh size 5 mm) was taken in order to obtain mobile or rare species. Exceptionally, in the shallow inner coastal waters a hand corer with an area of 78.5 cm^2 was applied. All samples were sieved through a 1 mm screen and animals were preserved in the field with 4% formaldehyde. For sorting in the laboratory, a stereomicroscope with 10–40× magnification was used.

17.2.5 Taxonomy

All macrofauna samples were identified to the lowest taxonomic level possible. The nomenclature was checked following the European Register of Marine Species (Costello et al., 2001). The taxonomic nomenclature used in the historical studies was revised before including the species into the comparison. For some species the taxonomic assignment was highly doubtful or not possible when following present day taxonomical understanding. In these cases the data were not included. Some difficult taxonomic groups (e.g., hydrozoans, turbellarians, nemertines, bryozoans, sponges, oligochaetes) are likely to be underrepresented because of the different expertises of the authors.

17.2.6 Database

Both the historical (literature) data and the recent (IOW) data were stored within one common database. One "data" point means one species at a distinct date and a distinct location (geographic coordinates) with a mean abundance (if replicates were taken) or at least its presence. In total approx. 100 000 data were included and analyzed. The chronological development in terms of investigation activity is reflected in Fig. 17.3. For the period before 1920 only single data or a few hundred per two decades are available. Between 1921 and 1960 more than 6 000 data were recorded. Since the beginning of the 1960s the amount of data has increased rapidly, up to several ten thousands. Generally, more than two thirds of all macrobenthic data were collected after 1980.

17.2.7 Macrozoobenthic Diversity in the Southern Baltic

The absolute number of macrozoobenthic species and the percentage of limnic species in the 16 subunits of the southern Baltic Sea is shown in Fig. 17.4. In general the number of

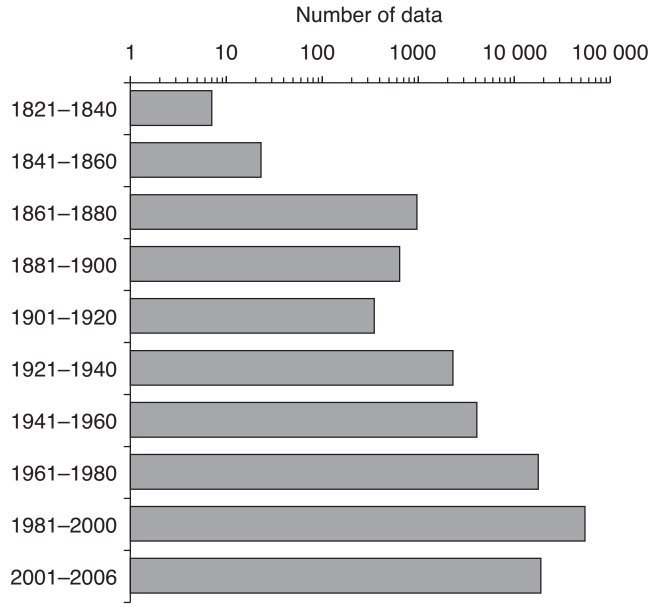

FIGURE 17.3 The progressive development of macrozoobenthos investigation activity and data collection in the southern Baltic Sea within the past 180 years. The first and the last data entry year were 1839 and 2006, respectively. (Note the logarithmic scale of *x* axis!).

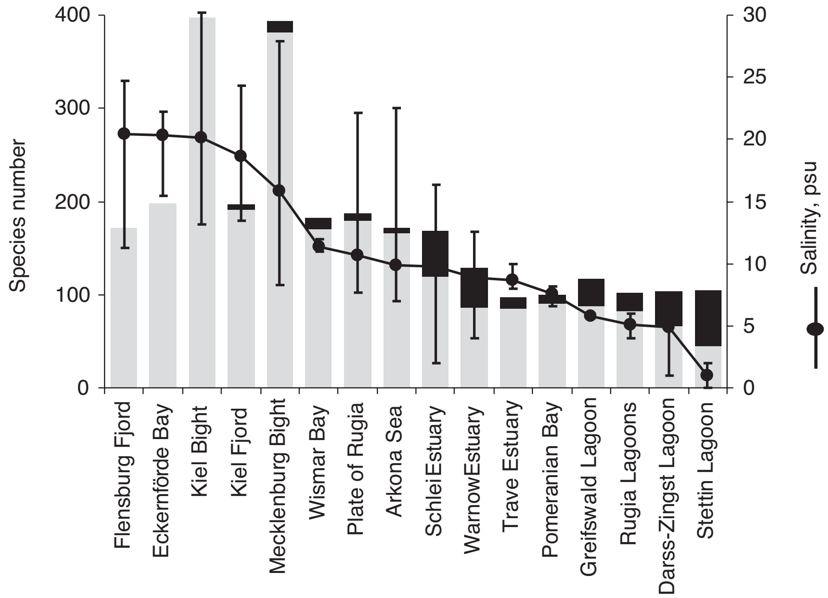

FIGURE 17.4 Total number of macrozoobenthic species in the 16 subunits (see Fig. 17.1) of the southern Baltic Sea and mean salinities (± maximum and minimum). The percentage of limnic species is indicated by dark gray color.

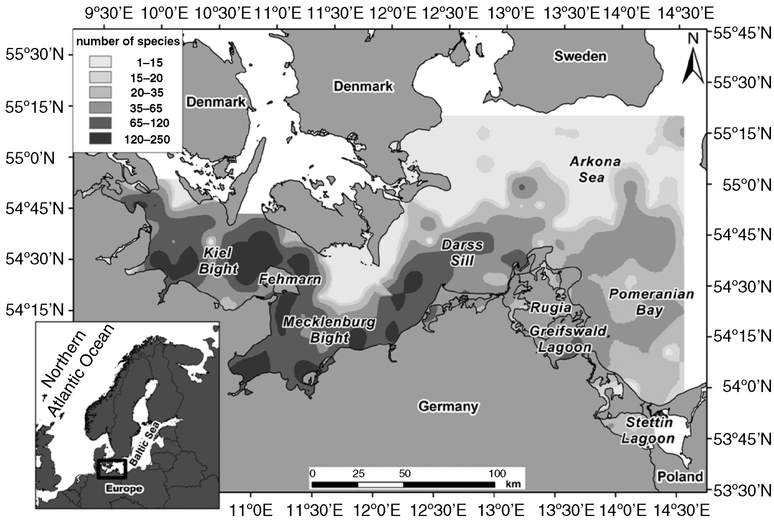

FIGURE 17.5 Macrozoobenthic species richness and distribution of "hot spots" in the southern Baltic Sea derived by kriging of centered-point-data acquired via fishnet (cell size: 10 km × 10 km, SURFER and ArcView). The species numbers are indicated by different color steps. (Note that the areas off the mainland of Denmark and Sweden are not representative, because of lower sampling density!) (See color plate).

marine species decreased continuously with decreasing salinities. With approx. 400 species, Kiel and Mecklenburg Bight showed the highest macrobenthic diversity. Mean salinity ranged between 15 and 20 psu with maximum values of 28–30 psu. In areas with oligohaline to freshwater conditions the number of marine species was clearly reduced (e.g., Pomeranian Bay) or has been replaced by limnic species (e.g., Stettin Lagoon). The comparable low numbers in the fjords and estuaries, such as estuaries Flensburg Fjord, Eckernförde Bay, and Kiel Fjord are likely due to periodical oxygen deficiencies (e.g., Bluhm, 1990) thus no stabile macrozoobenthic communities could be developed.

The decreasing macobenthic diversity with decreasing salinities from west to east and from offshore to inshore is also visible in Fig. 17.5. The most biodiverse areas were situated at the entrance of the Great Belt off the Island of Fehmarn. Moreover, in most of the 16 subunits diversity "hot spots" were localized. It means that in high saline as well as in oligohaline waters areas exist where the species richness is higher than in the surrounding areas. These "biodiversity centers" or "hot spots" are mainly linked with good oxygen supply, well structured bottom surface (e.g., macrophytes, boulder grounds, mussel beds) as shown by underwater video, and continuous supply with recruitment larvae due to present currents (Zettler et al., 2000).

Regarding the macrobenthos composition in the southern Baltic, in total 667 species representing 29 higher taxonomical groups were observed (Fig. 17.6). Among those, polychaetes showed the highest biodiversity (155 species), followed by gastropods (90 species) and amphipods (75 species). Bivalves, oligochaetes, hydrozoans, and bryozoans belong to species-rich groups as well whereas the diversity of other groups was clearly lower. The total amount of limnic species from all taxonomical groups was 98.

In a comparable Danish study (3602 samples distributed on 26 Danish areas over 4 years) a total of 510 taxa were found (Josefson and Hansen, 2004). As in German Baltic waters, annelids were also the most abundant taxon followed by arthropods and molluscs. Owing to

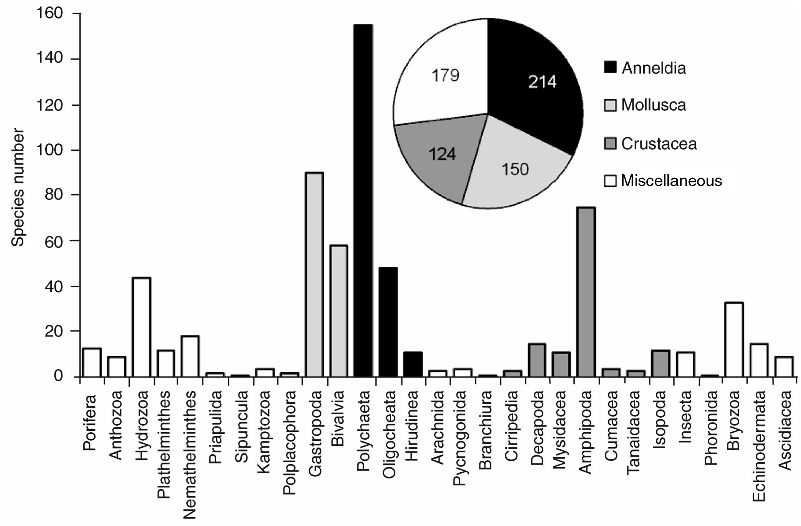

FIGURE 17.6 Macrozoobenthos composition in the southern Baltic Sea based on historical (literature) and recent (IOW) data collected between 1839 and 2006.

higher salinities in the Danish waters echinoderms played a more important role than in the southern Baltic.

Concerning the representiveness of the different species present in the southern Baltic, it has to be pointed out that more than half of all species were single records or were found only 2–10 times in the past 180 years (Fig. 17.7). Only 9% were recorded more than 500 times.

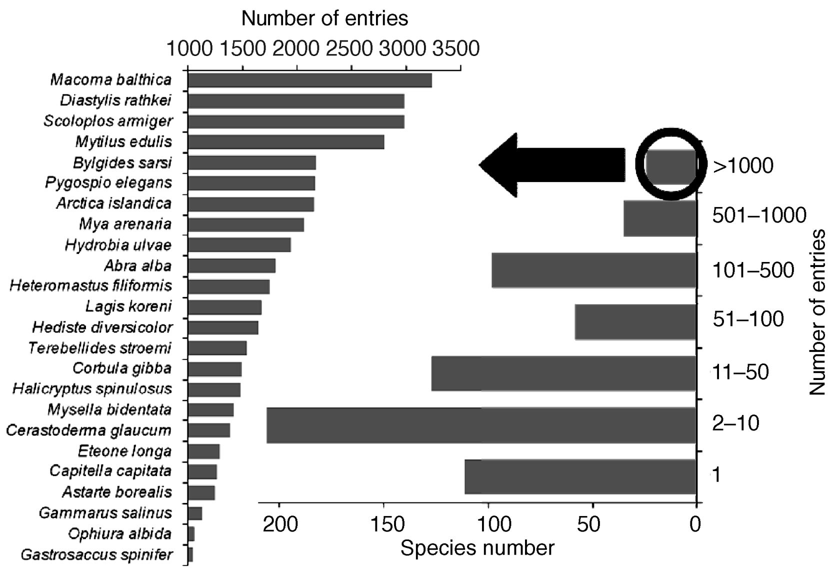

FIGURE 17.7 From about 100 000 data entries only 24 species have entries more than one thousand (left hand). More than the half of the species in the southern Baltic Sea are rarely sporadic or less frequent (right hand).

The most common and most frequent species are the bivalves *Macoma balthica* and *Mytilus edulis*, the cumacean *Diastylis rathkei*, and the polychaete *Scoloplos armiger*. In addition to those, 20 other species have more than one thousand entries in the data base. For the inner coastal waters some genuine brackish water species like *Marenzelleria neglecta* and *Hediste diversicolor* and some freshwater species like *Theodoxus fluviatilis* or *Radix balthica* belong to the most common benthic representatives.

Another pool of benthic species with increasing importance are neozoans, that have been introduced into the Baltic by shipping and other artificial vectors. At the beginning of 2001, about 100 nonindigenous species had been recorded in the Baltic Sea (Leppäkoski et al., 2002). Principally, most of these allochthonous species inhabit the inner coastal waters where they find optimal living conditions. About 10% of the benthic inventory of the Stettin Lagoon, for instance, invaded the Baltic Sea basin during the last decades (e.g., Gruszka, 1999). Among these introduced species is the polychaete worm *Marenzelleria* spp. that first appeared in German coastal waters in the mid-1980s. Since then it has become an important component of the coastal benthic fauna (Zettler et al., 2002).

Meanwhile it has been shown that three polychaete sibling species of the genus *Marenzelleria*, (*M. viridis*, *M. neglecta*, *and M. arctia*) have invaded the Baltic Sea during the past 20 years (Bastrop et al., 1997; Bastrop and Blank, 2006; Blank, et al., 2007. Lab experiments and field studies revealed the species' high ecophysiological adaptability, for example, to low oxygen, hydrogen sulfide and low salinity (Schiedek, 1997a, b). Besides its high tolerance to variations in environmental variables, and its genetic variability, short generation time, early sexual maturity, high reproductive capacity and a broad diet are typical features of this neozoan (Zettler et al., 2002).

The IOW database offers the opportunity for comparisons on a larger temporal scale to assess temporal trends or changes. An example is given in Fig. 17.8 for *Arctica islandica*, which is widely distributed in the high saline areas of the southern Baltic. In comparison to 1950–1970 its abundance has been higher in 1996–2006.

Long term trends using selected benthic species have also been studied in the Arkona Basin by comparing recent data (2001–2004) with those from different studies performed during the past 80 years (Zettler et al., 2006). In general no distinct changes in the distribution patterns and relative abundance of the six most important species are apparent. In the shallow parts (<35 m) species composition was very similar in both time periods. Only in the deeper parts of the Arkona Basin temporal differences were found that probably are due to variations in the hydrographic conditions (e.g., salinity, oxygen). In both depth ranges, however, a 3–10-fold increase in abundance from the 1920s to the period 2001–2004 has been observed that might have been caused by eutrophication (Zettler et al., 2006).

17.3 MACROZOOBENTHIC PATTERNS AND DYNAMICS IN THE SOUTHERN BALTIC SEA AT SELECTED MONITORING STATIONS DURING THE PAST 15 YEARS

As documented in the first part of this chapter, distribution patterns of benthic species in the southern Baltic Sea are clearly linked with the salinity gradient (Fig. 17.5). Hydrographic conditions, on the contrary, are highly variable (see Chapter 10) showing short term (seasonal or interannual) or long term fluctuations (e.g., saline water inflows). In

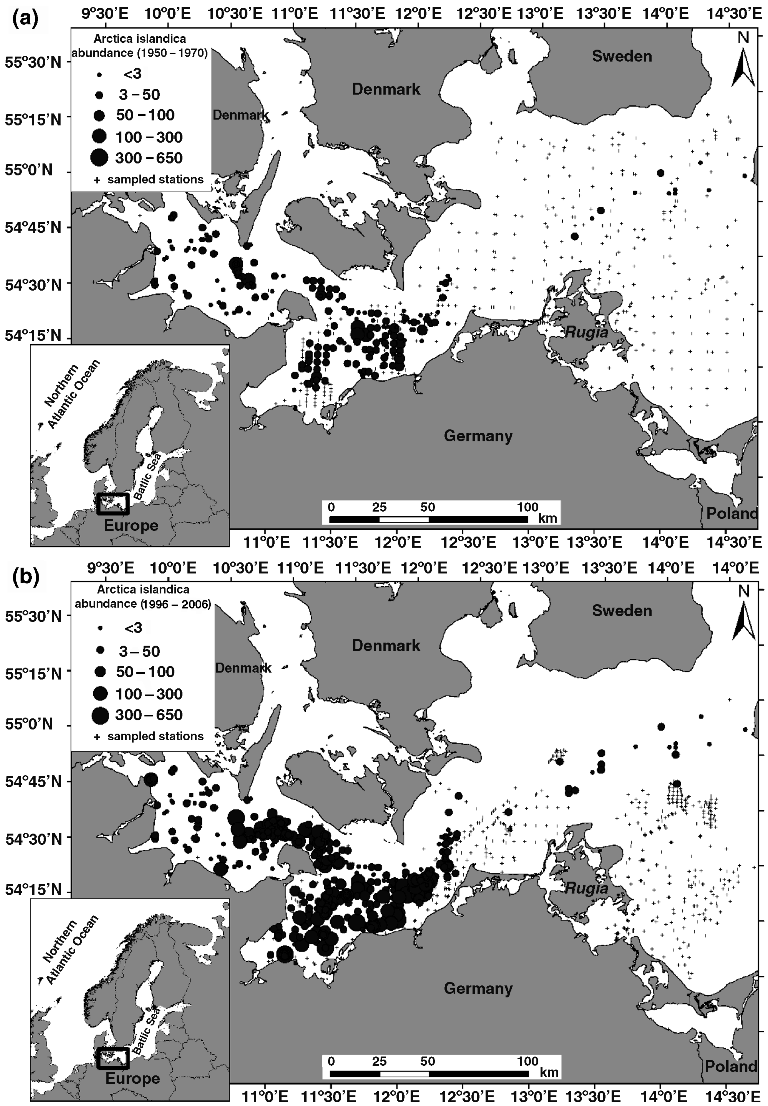

FIGURE 17.8 Distribution of the ocean quahog *Arctica islandica* (Bivalvia) in the southern Baltic Sea during two time periods (**a**) 1950–1970 and (**b**) 1996–2006).

addition, human impacts have increased (Helcom, 2003). In order to assess how natural parameters (salinity, oxygen availability) or pollution (eutrophication) may affect the benthic realm in the southern Baltic Sea a regularly monitoring was launched in the beginning of the 1980s at a few selected stations. At the beginning of the 1990s this monitoring programme was expanded. For the past 15 years, five stations, more or less equally distributed in the south-western Baltic Sea (see Fig. 17.1 for details), have been sampled annually by the Leibniz Institute for Baltic Sea Research (IOW). These locations have been chosen as they cover high (Fehmarn Belt and Mecklenburg Bight, S $>$ 20 psu) and low salinity areas (stn. 152, S 8–9 psu) and intermediates (Darss Sill and central

TABLE 17.1 Mean Abiotic Features, Biomass (afdw = Ash Free Dry Weight) and Frequency (%) of Macrozoobenthic Species at the Monitoring Stations. Only Frequency Values >65% are Indicated.

	Station 010	Station 012	Station 030	Station 109	Station 152
Water depth/m	29	25	22	48	31
Salinity (±stdev)/psu	23.2 (±2.4)	20.9 (±2.8)	14.3 (±4.0)	16.2 (±1.9)	8.6 (±0.8)
Organic content/%	3.2	10.2	0.5	16.0	0.3
Medium grain size/μm	129	10	221	9	239
Total species number	131	80	88	42	50
Max. biomass (afdw g/m^2)	90	50	45	7	28
Halicryptus spinulosus	69	71	93	69	93
Abra alba	65	65			
Arctica islandica	100	100		69	
Astarte borealis			100		
Corbula gibba	85	93			
Hydrobia ulvae			100		
Macoma balthica			100	85	100
Mya arenaria			100		
Mytilus edulis	69		100		100
Ampharete baltica			93		
Aricidea suecica			79		
Bylgides sarsi	77	79	86	85	93
Eteone longa			86		
Hediste diversicolor			79		
Heteromastus filliformis	77	86			
Lagis koreni	77				
Nephtys hombergiI	69	71			
Pygospio elegans			93		100
Scoloplos armiger			100	69	
Crangon crangon			86		
Diastylis rathkei	100	100	86	85	93
Gammarus salinus			71		71
Gammarus zaddachi					71
Jaera albifrons					71
Saduria entomon					71

Arkona Sea, see Table 17.1). In addition, the stations differ in the sediment composition (organic content or grain size) as shown in Table 17.1. The depth ranges covered are between 22 to 48 m, with the deepest station in the Arkona Sea.

17.3.1 Spatial Distribution of Macrozoobenthic Species

As to be expected benthic species composition varied considerably in this part of the Baltic (Table 17.1). The most western stations 010 and 012 at the Fehmarn Belt and the Mecklenburg Bight are characterized by the bivalves *Abra alba* and *Arctica islandica* and the cumacean *Diastylis rathkei*, whereas the area around the Darss Sill (stn. 030) were most frequently colonized by the gastropod *Hydrobia ulvae*, the bivalve *Mytilus*

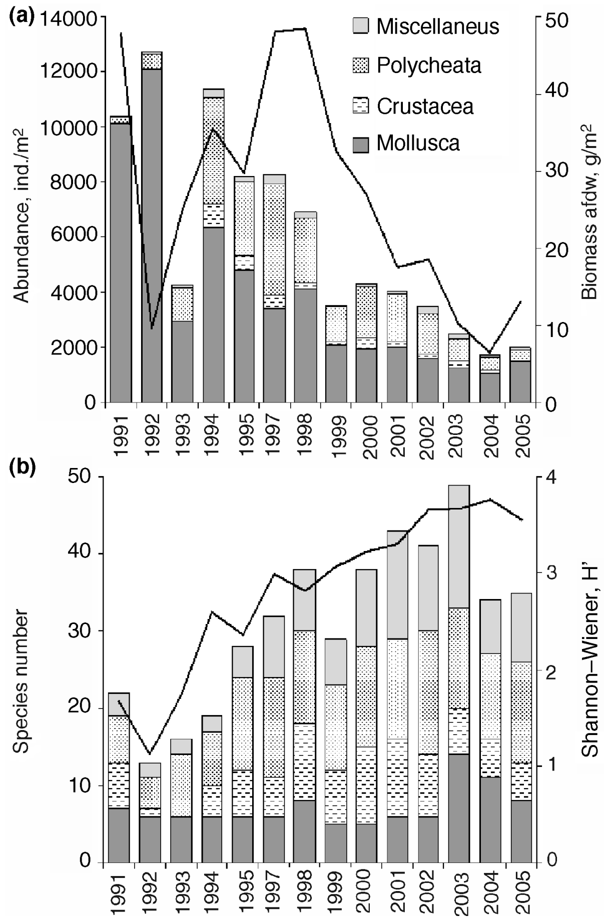

FIGURE 17.9 Development of abundance and biomass (**a**) and species number and Shannon diversity (**b**) at the monitoring station 030 (K8) in the Darss Sill area 1991–2005. The water depth is 22 m. [1996 no data exist.]

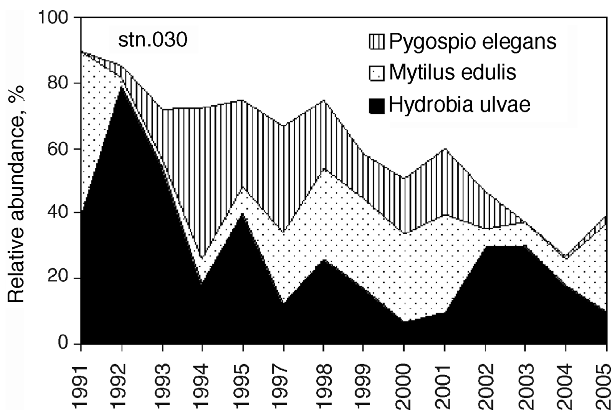

FIGURE 17.10 Relative abundance of most dominant species at station 030 (Darss Sill, C in Fig. 17.1) during the past 15 years. [1996 no data exist.]

edulis und the polychaete *Pygospio elegans*. With 131 recorded species, the total number is highest at Fehmarnbelt and lowest in the central Arkona Sea. Because of the uniform muddy sediments and occasional occurence of hypoxia/anoxia the total species number reached there is only 42. The bivalve *Macoma balthica*, the polychaete

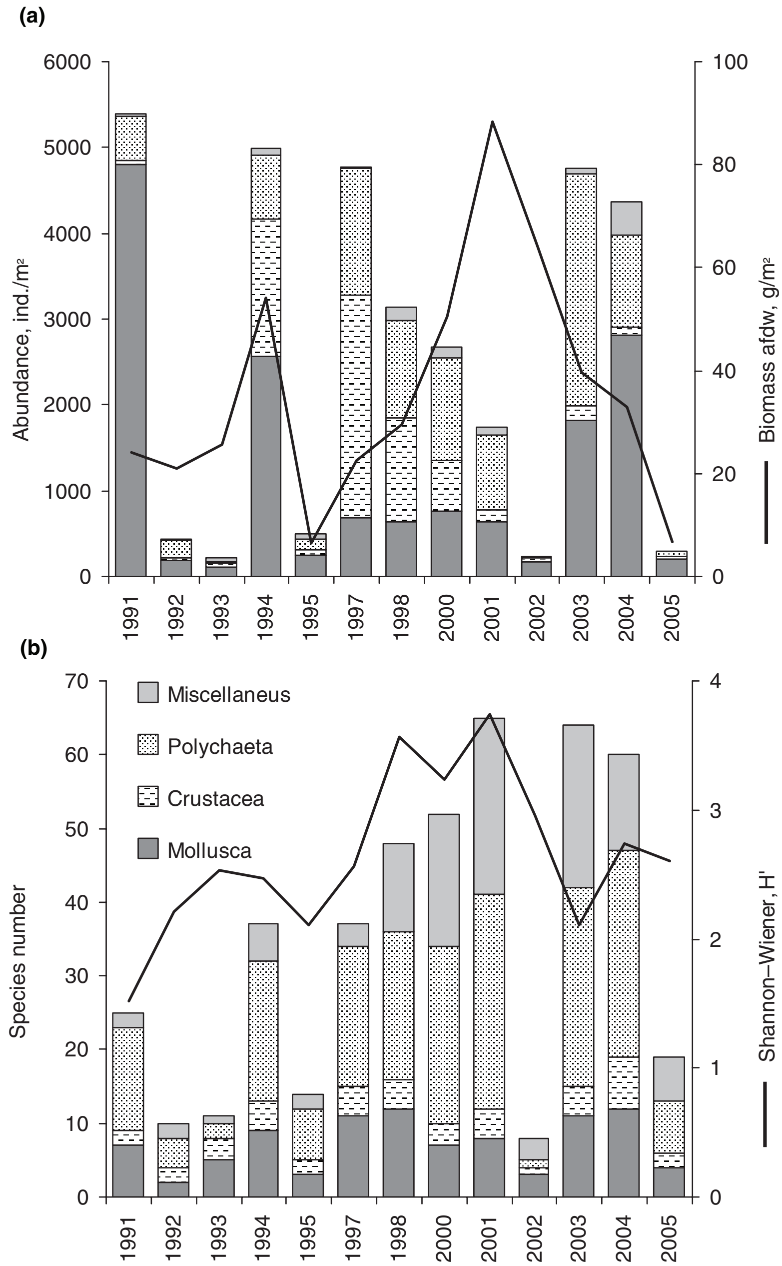

FIGURE 17.11 Development of abundance and biomass (**a**) and species number and Shannon diversity (**b**) at the monitoring station 010 (N1) in the Fehmarnbelt area 1991–2005. The water depth is 29 m. [1996 and 1999 no data exist.]

Scoloplos armiger and the cumacean *Diastylis rathkei* compose dominantly the station 109 in the central Arkona Sea. Though the polychaete *Bylgides sarsi* is very frequent at all stations it reached only minor abundances in most years. The southern Arkona Sea (stn. 152) differs completely from the other locations. The low salinity regime allows only euryhaline species to live here. The total species number is 50 (most of them occur only sporadically) and characteristic species are both the bivalves *Macoma balthica* and *Mytilus edulis* and the polychaete *Pygospio elegans*. In regard to maximum biomass, also clear differences are visible.

17.3.2 Temporal Changes in the Macrozoobenthos Distribution in the Southern Baltic

The beginning of the 1990s was characterized by a stagnation period caused by missing major saline water inflows to the Baltic Sea for more than 10 years (Matthäus, 2006). Only at the beginning of 1993 a major inflow occurred (Chapter 10) bringing higher saline oxygen-rich water into the southern Baltic and the Baltic Proper. More than two thirds of the inflowing water reached the Baltic via the Great Belt, passing the Darss Sill. The macrozoobenthic species composition at the monitoring station near the Darss Sill (stn. 030) in the centre of the Plate of Rugia (see Fig. 17.1) reflects these inflow events with a certain time delay. Shortly after the 1993 inflow event species numbers started to increase, reaching a more or less stable value in 1998. At the same time overall abundance decreases (Fig. 17.9). Similar to that the biomass dropped with some exceptions in the past 7 years. Only 20–30% of maximum values (in 1997 and 1998) were recorded in the last years. Responsible for this decrease in abundance and biomass is the drastic decline of populations of the gastropod *Hydrobia ulvae* and the spionid polychaete *Pygospio elegans* (Fig. 17.10). Both species established large populations until the mid-1990s. Afterwards, especially the latter disappeared almost completely and is presently only observed sporadically. The reasons for this development are not known yet (Wasmund et al., 2006).

The distribution areas for many marine species are restricted to a salinity higher than 12 psu (e.g., Kinne, 1964). The Fehmarnbelt area and Mecklenburg Bight with a salinity range of 15–23 psu form a natural border regarding the distribution of these species. As

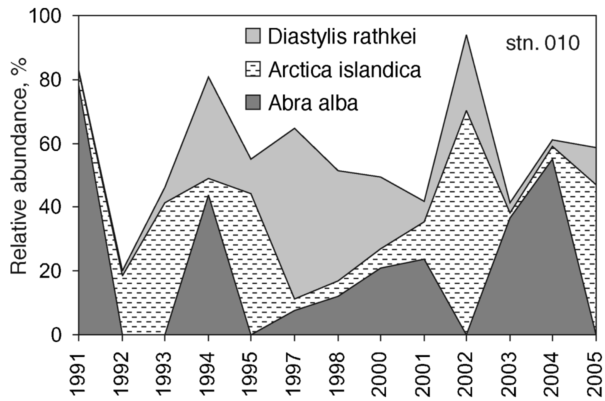

FIGURE 17.12 Relative abundance of most dominant species at station 010 (Fehmarnbelt, A in Fig. 17.1) during the past 15 years. [1996 and 1999 no data exist.]

shown in Fig. 17.4 this part of the Baltic has a potential macrozoobenthic inventory of about 300–400 species.

An increase in the overall species number after 1993 saline water inflow is also obvious in the Mecklenburg Bight (stn. 012) and in the Fehmarnbelt area (stn. 010). This is not surprising since the greater amount of the saline water inflow from the North Sea enters the Baltic Sea via the Great Belt, the Fehmarnbelt and the Mecklenburg Bight.

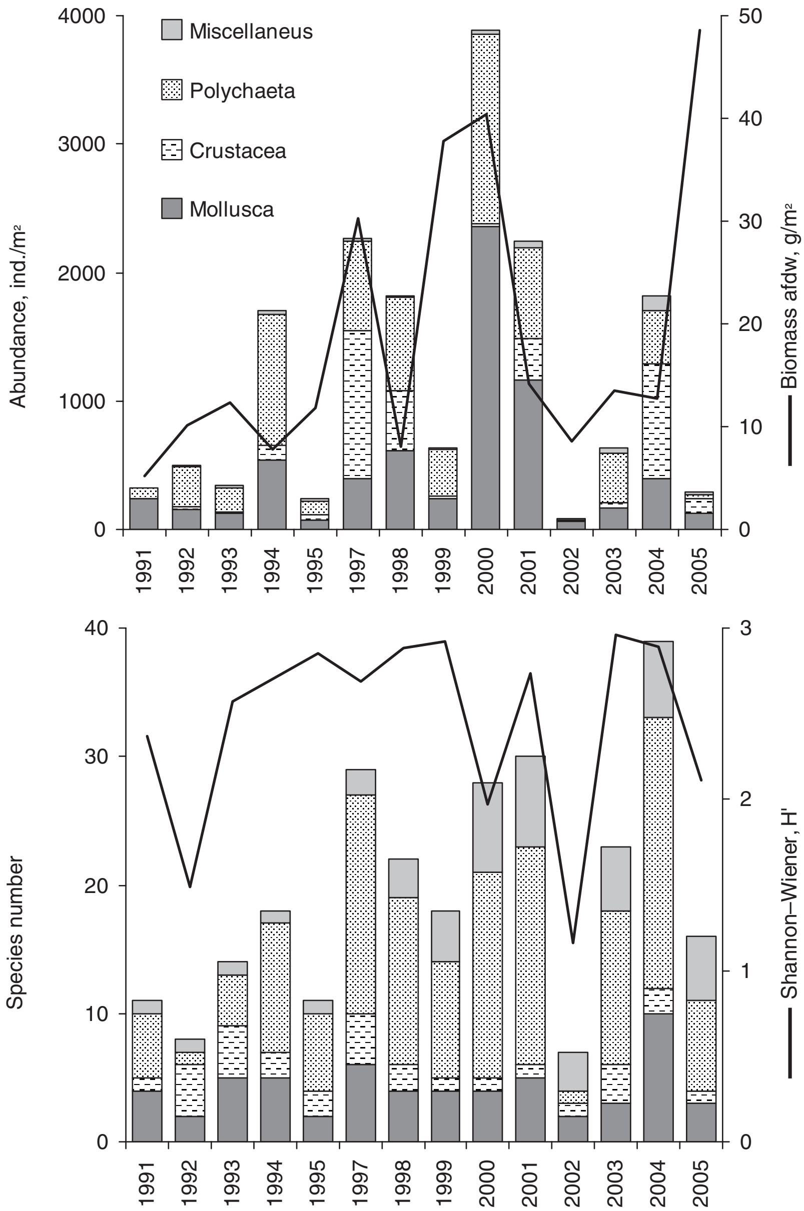

FIGURE 17.13 Development of abundance and biomass (**a**) and species number and Shannon diversity (**b**) at the monitoring station 012 (M2) in the Mecklenburg Bight 1991–2005. The water depth is 25 m. [1996 no data exist.]

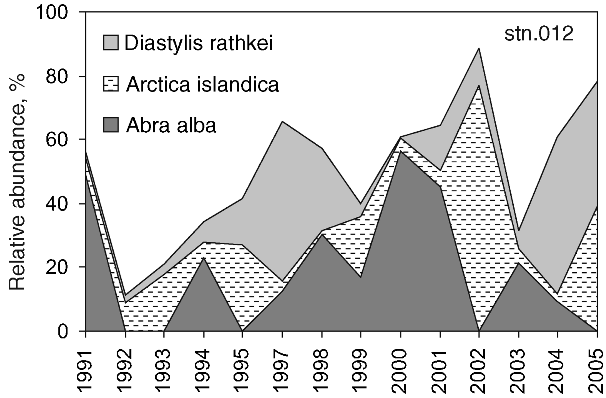

FIGURE 17.14 Relative abundance of most dominant species at station 012 (Mecklenburg Bight, B in Fig. 17.1) during the past 15 years. [1996 no data exist.]

Previous studies have shown that the benthic dynamic below the halocline is not only affected by periodic saline water inflow events but also by intermittent hypoxia (Arntz, 1981; Kölmel, 1978; Weigelt, 1991). The temporal composition and abundance of macrofauna communities reflect the interaction of these major factors at both locations (Figs.17.11–17.14). Especially in 2002 and to a smaller extent in 2005 the macrozoobenthos was influenced by long lasting hypoxic conditions. Both, abundance and species number decreased strongly thereafter. Only larger bivalves (e.g., *Arctica islandica*) and some opportunistic species (e.g., *Halicryptus spinulosus* and *Heteromastus filiformis*) were able to survive or to recolonize rapidly. However, within a relatively short time after the disturbance, species number has increased showing that in this well fluxed area it takes only a few months up to a year for the regeneration of the benthic community. The recruitments (i.e., larvae supply) are likely to be provided by the adjacent areas (Kattegat region via Great Belt) or the continuously oxygenated margin of the Mecklenburg Bight itself (Zettler et al., 2000). However, several populations inside the Bight are only able to sustain over the life span of the established individuals (mostly a few years, e.g., *Ophiura albida*). Thus colonization is a dynamic process, mediated by water influx from adjacent areas. Populations of other species, for example, *Arctica islandica* find optimal living conditions within the Mecklenburg Bight, allowing them to build a recruitment pool for the adjacent waters (Zettler et al., 2001).

East of the Darss Sill salinity is clearly decreased and species number is generally lower. At the monitoring station 152 (31 m water depth and well sorted sandy substrates) total abundance increased until the mid-1990s (with a maximum of about 12 000 ind./m^2 in 1995) as at most of the other monitoring stations. However, in the southern Arkona Sea area this is mainly due to a strong increasing abundance of the spionid *P. elegans* (Figs. 17.15 and 17.16). Except in 2001 and 2002, *P. elegans* dominated the community with a relative abundance between 55% and 77% (300–9500 ind./m^2). Subdominant species were the bivalves *M. balthica* and *M. edulis*. The latter occurred rather patchy. Its abundance ranged between 12 ind./m^2 (1991) and 1800 ind./m^2 (1999). In some years the cumacean *D. rathkei* reached remarkable abundances (e.g., 600 ind./m^2 in 1995). Total biomass was mainly affected by the density of *M. balthica*, which dominated the biomass in all years with values of about 50% ot total biomass. Only *M. edulis* reached similar high values during some years.

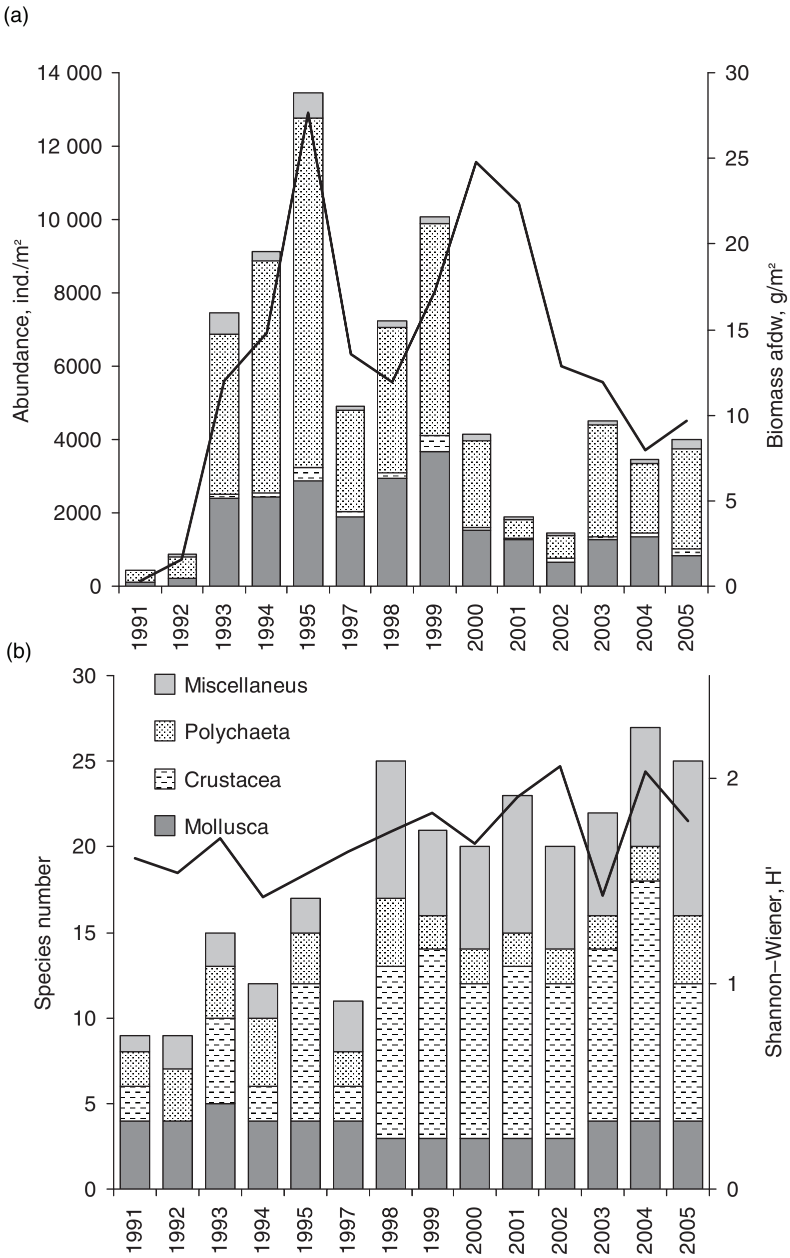

FIGURE 17.15 Development of abundance and biomass (**a**) and species number and Shannon diversity (**b**) at the monitoring station 152 (K3) at the junction between Arkona Sea and Pomeranian Bay from 1991 to 2005. The water depth is 48 m. [1996 no data exist.]

The Arkona Basin is regarded as a part of the transitional zone between the Kattegat and the deep basins of the Baltic Proper. About a quarter of this area is deeper than 40 m (maximum 53 m). Only the marginal zones are shallower than 20 m. The central Arkona Sea is Swedish and Danish territory in the North and German in the South. The main sediment

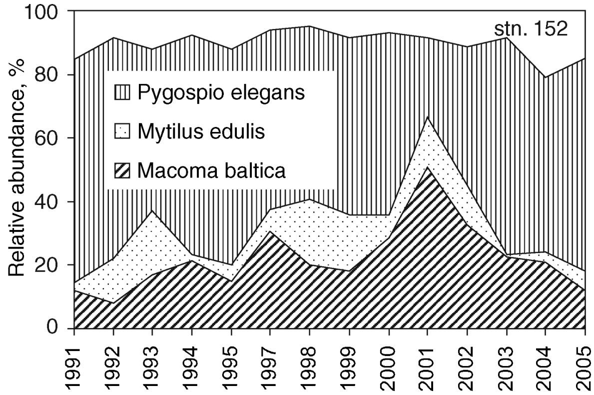

FIGURE 17.16 Relative abundance of most dominant species at station 152 (Arkona Sea/Pomeranian Bay, E in Fig. 17.1) during the past 15 years. [1999 no data exist.]

type in water depths >35 m is mud. The macrozoobenthos at station 109 (45 m water depth) showed a large interannual variability with respect to abundance and biomass (Fig. 17.17). The abundance varied between 38 ind./m^2 in 1995 and 1075 ind./m^2 in 1991.

Increasing abundance and all peaks were caused by high densities of the polychaete *S. armiger* (Fig. 17.19). This species reached values between 64% and 93% of the total abundance in years with high abundance (e.g., 1991–1993, 1998, 2002). The total biomass (ash free dry weight) ranged between 0.4 g/m^2 and 8.1 g/m^2 (Fig 17.17). In some years (1991, 1995, 1998, 2000) *A. islandica* dominated the biomass with 70%–97% of total biomass. Another "coaffecting" species is the bivalve *M. balthica* (2003 and 2004) with high biomass values as well. Since the beginning of the 1990s both the species number and the Shannon diversity increased rapidly to 23 and 2.9, respectively (Fig. 17.18).

17.3.3 Benthic Fauna, Ecological Status and Ecosystem Functions

The 15 years comprising monitoring data also show that the share of opportunistic species varies among locations and temporarily. Moreover, their abundances appear to be linked with disturbance events at least at locations with higher organic content in the sediment and low mean grain size (i.e., muddy sediments) such as in the Mecklenburg Bight or the Arkona Sea (Fig. 17.19). It is likely that in these areas low oxygen conditions are more persistent when compared to sandy well sorted sediments with higher dynamical changes.

The historic data reaching back 80 years together with the monitoring data allow to identify a group of about 25 macrobenthic taxa as being the most important species in this part of the Baltic Sea. However, their spatial distributions are not uniform and temporal variations are also visible. These species not only represent different taxonomic groups but also specific functional guilds. Their presence/absence will have an impact on ecosystem functions. Studies performed by Forster and Zettler (2004) have shown how the presence/absence of the bivalve *Mya arenaria* impacts pore water-exchange and thus bentho-pelagic matter transport and fluxes. In future one focus will be to further elucidate the relationship between species abundance and ecosystem functioning (Glockzin and Zettler, 2008).

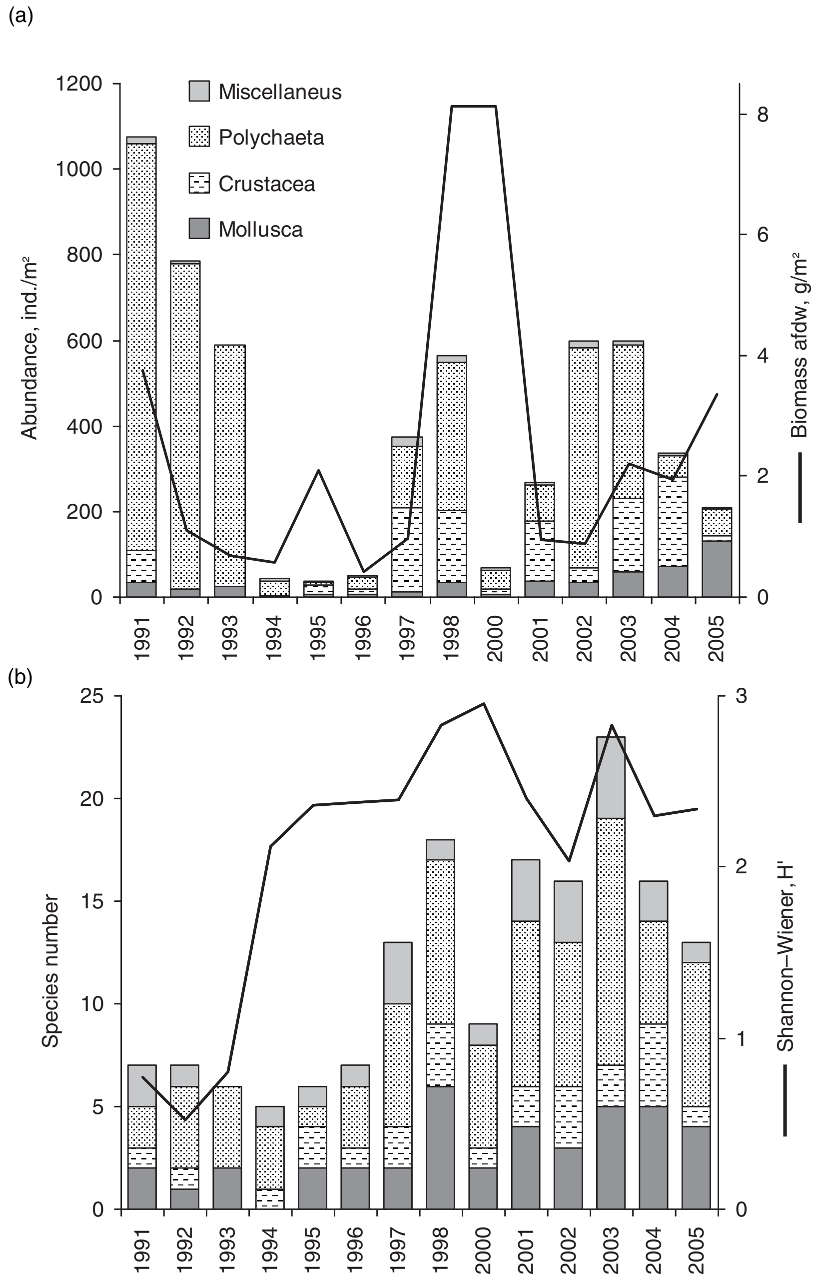

FIGURE 17.17 Development of abundance and biomass (**a**) and species number and Shannon diversity (**b**) at the monitoring station 109 (K4 or BY2) in the central Arkona Sea from 1991 to 2005. The water depth is 48 m. [For 1996 and 1999, no data exist.]

Benthic invertebrates are often used as bioindicators to detect and monitor environmental changes because of their rapid responses to natural and/or anthropogenic caused stress (e.g., Pearson and Rosenberg, 1978; Grall and Glémarec, 1997; Simboura and Zenetos, 2002; Perus et al., 2004). As sessile organisms with a relatively long life span they integrate water

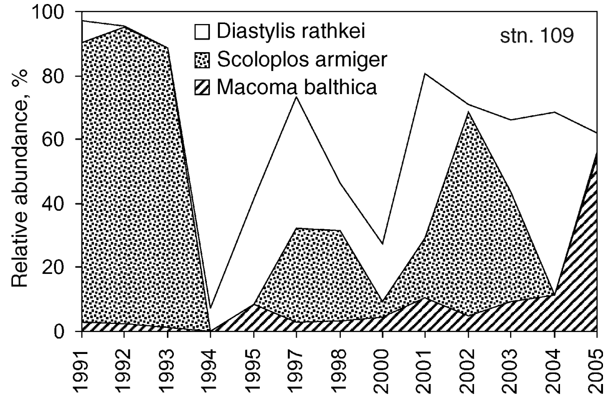

FIGURE 17.18 Relative abundance of most dominant species at station 109 (central Arkona Sea, D in Fig. 17.1) during the past 15 years. [For 1996 and 1999, no data exist.]

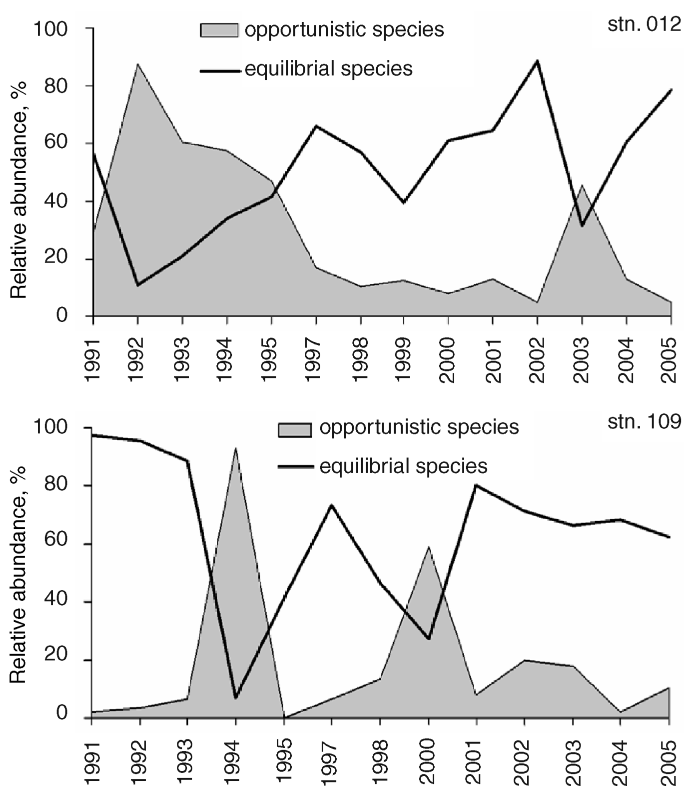

FIGURE 17.19 Development of opportunistic and equilibrial species at the monitoring stations 012 and 109 from 1991 to 2005. Opportunistic species 012: *Corbula gibba*, *Lagis koreni*, *Heteromastus filiformis*, *Polydora* spp. Opportunistic species 109: *Bylgides sarsi*, *Halicryptus spinulosus*, *Heteromastus filiformis*, *Polydora* spp. Equilibrial species 012: *Abra alba*, *Arctica islandica*, *Diastylis rathkei*. Equilibrial species 109: *Diastylis rathkei*, *Macoma balthica*, *Scoloplos armiger.*

and sediment quality conditions over time. In the Baltic as in other coastal seas their presence/absence indicates temporal as well as spatial disturbances (Reiss and Kröncke, 2005). This is also indicated by the Shannon diversity index and its temporal changes as shown in Figs. 17.9,17.11,17.13,17.15, and 17.17.

In the last years different other biotic indices have been designed to assess the ecological quality of coastal waters. The development of biological indicators as a tool for the assessment and hence protection of biological diversity in European coastal and marine ecosystems has been advanced due to the implementation of the Habitats Directive and the Water Framework Directive (WFD).

On the basis of the IOW data presented above, the traditional Shannon Wiener Index (H'), the more recently published AZTI' Marine Biotic Index (AMBI) as well as the Benthic Quality Index (BQI), were tested along the salinity gradient in the southern Baltic Sea (Zettler et al., 2007). The comparison of the three indices demonstrated that in the southern Baltic Sea the ecological quality (EcoQ) classification based on macrozoobenthic communities as indicator greatly depends on the biotic index chosen. A significant positive relation between species number, H', BQI and salinity were found resulting in EcoQ status of "Bad," "Poor" or "Moderate" in areas with a salinity value below 10 psu. The AMBI was less dependent on salinity but appear to partly overestimate the EcoQ status. Presently none of these biotic indices appear to be adjusted for application in a gradient system as given in the southern Baltic Sea (Zettler et al., 2007).

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