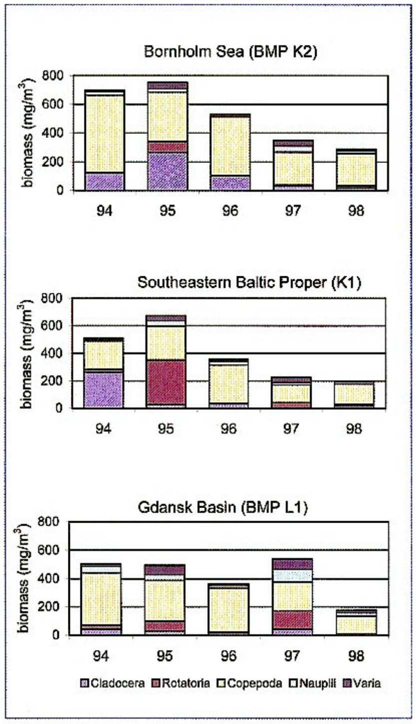
CEDERWALL, H., V. DIZIULIS, A. LAINE, A. OSOWIECKI, M. L. ZETTLER 2002: Eutrophication and related fields: Baltic Proper: benthic conditions. In: Environment of the Baltic Sea area 1994-1998. Helsinki: Helsinki Commission - Baltic Marine Environment Protection Commission (Baltic Sea Environment Proceedings; 82B): 50-55

*Figure 5.13*
*Mean biomass of mesozooplankton in the southern part of the Baltic Proper.*



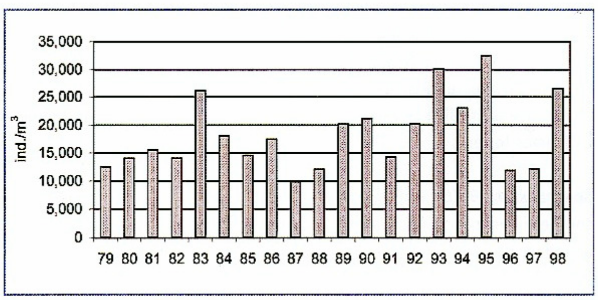




*Figure 5.14*
*Long-term changes in annual mesozooplankton abundance in the southern part of the Baltic Proper.*

layer. The opposite tendency is clearly visible for other calanoids and for less abundant cladocerans. The waters of the northern part of the Eastern Gotland Sea differ in origin and hence contain species indicative of various water masses. Besides common forms, representatives of the fresh-brackish-water assemblage such as *Limnocalanus macrurus* and *Keratella quadrata* and of the marine group such as *O. similis* and *Paracalanus parvus* are also present.

***Interregional comparison.*** In the southern part of the Baltic Proper (Arkona, Bornholm, Gdansk and Gotland Seas) a clear trend towards decreasing annual mean abundance and biomass of mesozooplankton was seen during the assessment period (Figure 5.13, Figure 5.14). In 1998, mesozooplankton biomass was three times lower than in 1994.

In June 1998, mean mesozooplankton abundance and biomass varied from 3,948 ind./m³ (111 mg/m³) in the Bornholm Sea to 13,186 ind./m³ (371 mg/m³) in the Arkona Sea. Maximum total abundance in the water column ranged from 343 to 1,144 000 ind./m³, productivity being highest in the Arkona Sea. Mesozooplankton was less abundant in the Gotland, Gdansk and Bornholm Seas, but the differences were not large – 3-fold at maximum.

***Changes in the community.*** Zooplankton species composition in the southern part of the Baltic Proper has not changed significantly compared to the previous assessment periods (1979-93) (Wolska-Pys and Ciszewska, 1991; HELCOM, 1996; Ciszewska 1990).

However, there have been clear quantitative changes in the abundance of some copepod populations during the last two decades. Although *P. minutus elongatus* was markedly dominant from 1979 to 1988, it is decreasing in abundance in the southern parts of the sea. In the subsequent five-year period it was partly replaced by crustaceans with a higher tolerance to temperature and salinity changes, e.g. *T. longicornis* and *A. bifilosa* (Wolska-Pys, 1994). A small increase of Pseudocalanus population between 1995 and 1997 is probably attributable to improvement in hydrological conditions in the deep waters due to inflows from the North Sea in 1993 and 1994.

The increase in copepod biodiversity in the southern part of the Baltic Proper could be related to the occurrence of the new species *Acartia tonsa* from 1996 to 1998. The large calanoids *Limnocalanus grimaldii* were also noted in the waters in 1995 after a long-term absence (Wolska-Pys, 1996). The continuous increase of the population of halophilous *O. similis* in the deep waters of Gdansk Basin over the last five years is also important. The increase in Copepoda biodiversity was directly related to the reduction in the number of Cladocera species, which has decreased in the southern Baltic over the last five years from 4-5 (in 1994-96) to 1-3 (1997 and 1998) depending on the region. This decrease was especially notable in the Gotland Sea and in the Bornholm Sea.

In addition to the interregional difference in abundance and species composition, marked inter-annual variation in average abundance of mesozooplankton was also noted within regions (Figure 5.14).

## 5.1.4. Benthic conditions

### Macrozoobenthos

*By: H. Cederwall, V. Diziulis, A. Laine, A. Osowiecki, M. Zettler*

***Arkona Basin.*** Due to its proximity to the Danish

Straits the fauna of the Arkona Basin is very much influenced by minor inflows from the Kattegat, which often take place several times a year. Depending on the time of year and the conditions in the Kattegat, these inflows bring different kinds of pelagic larvae that settle in the Arkona Basin. The fauna in the deeper areas of the basin is therefore very variable, species turning up one year and then disappearing one or two years later to be replaced by other species.

At station BMP K4 (48 m) in the eastern part of the basin, the fauna increased in species richness and abundance as well as in biomass during the early 1990s. In the mid 1990s the fauna declined, but in 1997 increased strongly again following more than a year without any episodes of low oxygen (Figure 5.15), species number and abundance reaching the highest levels since 1982. Because of the low number of bivalves, the increase in biomass was less dramatic.

At this station the fauna has changed markedly since the early 1980s, at which time bivalves accounted for nearly 100% of the biomass (HELCOM, 1990). During the 1990s they often accounted for 50% or less of the biomass, and sometimes for only a few percent.

The change from a bivalve-dominated to a worm-dominated community is a response to deteriorating oxygen conditions in the deep area of the Arkona Basin.

The changes recorded at station BMP K4 during the 1990s are supported by results from national Swedish monitoring stations in the central part of the Arkona Basin (Cederwall and Sjöberg, 1995).

In the southern Arkona Basin (station BMP K3; 31 m) macrozoobenthos abundance, biomass and species richness increased until 1995. Whereas abundance only reached about 7,000 ind./m² in 1993, it increased to about 12,000 ind./m² in 1995. The dominant members of the community were the Polychaeta *Pygospio elegans*, the bivalve *Macoma balthica* and the crustacean *Diastylis rathkei*.

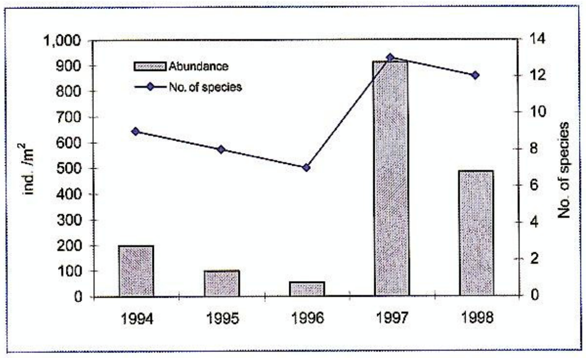
In 1997 the fauna declined, with abundance only reaching 5,000 ind./m² and only 11 species being present. In 1998, colonization occurred and species number increased again to 25.

***Bornholm Basin.*** In the deepest part of the Bornholm Basin, new recruitment of fauna occurred as a consequence of water inflow from the Kattegat in 1993-94. This is exemplified by the findings at station BMP K2 (90 m, Figure 5.16). Species number, abundance and biomass increased, mainly due to settlement of polychaetes, of which several species had not been found there in over 12 years. A single specimen of *D. rathkei* and one small specimen of *Astarte sp.* were also found.

After 1994 the macrozoobenthos became successively impoverished, and by 1996 no animals were present. In 1997, recruitment of two polychaete species (*Harmothoe sarsi* and *Scoloplos armiger*) occurred. Two species were also detected in 1998 (surprisingly though the crustacean *D. rathkei* and the bivalve *Astarte borealis*), but in very low numbers.

In the shallower (70-80 m) northern part of the basin at Hanö Bay, polychaete recruitment occurred in 1994 followed by faunal decline in 1995 and an absence of fauna in 1996. In 1997, a few specimens of *H. sarsi* were found at a depth of 80 m, but no fauna was present at 70 m. In 1998, both depths were devoid of fauna. At a depth of

***Figure 5.15***
***Variation in total macrozoobenthos abundance and species number in the Arkona Basin (BMP K4).***



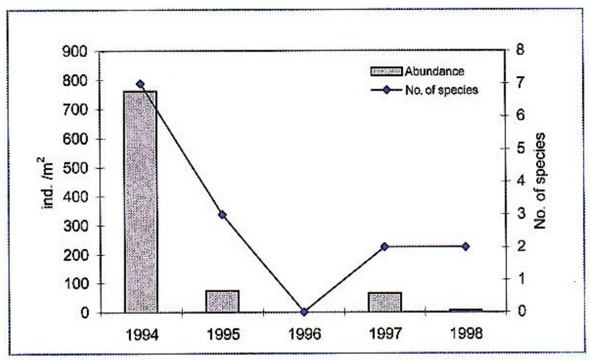




***Figure 5.16***
***Variation in macrozoobenthos abundance and species number in the Bornholm Deep (BMP K2).***

50-55 m the macrozoobenthos was normally rich during the whole assessment period.

At three Polish coastal stations - BMP K12 (19 m), BMP K13 (34 m) and BMP K14 (13 m) - the number of taxa was lower during the period 1994-98 than during the period 1989-93. At all stations the biomass was dominated by molluscs. At station BMP K14 located in the Pomeranian Bight, total biomass exhibited a negative trend during the 1980s, while no trend was detected during the 1990s. At station BMP K13, total biomass tended to decrease during the 1990s. At station BMP K12, no biomass trend is detectable, although

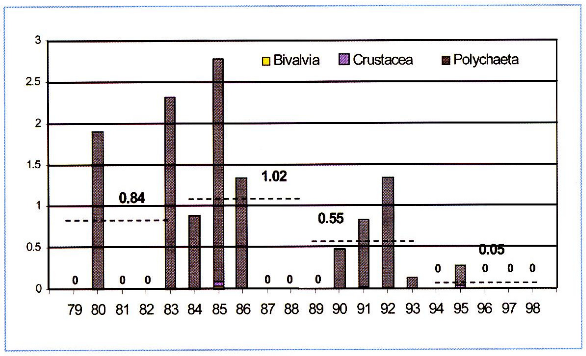



*Figure 5.17*
*Variation in macrozoobenthos biomass and taxonomic composition in the Gdansk Deep (BMP L1). 0 indicates that no fauna was found. The figures above the horizontal bars are the mean values for the period in question.*

total biomass was lower in the 1990s than in the 1980s.

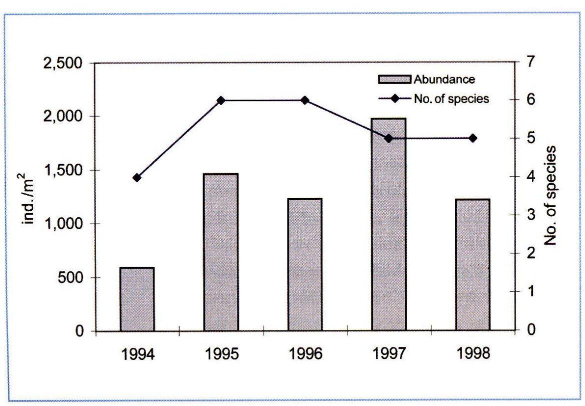
A new polychaete species of North American origin, *Marenzelleria viridis,* which appeared in Polish waters during the second half of the 1980s (Gruszka, 1991), was found at stations BMP K12 and BMP K14 for the first time in 1994–95. The biomass of the species increased between 1994 and 1998.

***Gdansk Basin.*** On the bottom of the Gdansk Deep, periods lacking in benthic fauna alternate with periods with a species-poor fauna of low abundance. The macrofauna recolonizes irregularly due to inputs of denser, oxygen-rich water originating from the North Sea (HELCOM, 1996).

Macrozoobenthos investigations have been carried out in the Gdansk Deep (station BMP L1; 108 m) since 1979. During this time, macrozoobenthos was absent on ten sampling occasions (Figure 5.17). Over the period 1994–98, macrozoobenthos was only present in 1995 and consisted of small numbers of two species of polychaetes, *H. sarsi* and *S. armiger,* and one crustacean *Pontoporeia femorata.*

At station BMP K11 (19 m) in the coastal area near Zarnowiec, the total number of species present was higher in 1994–98 than in 1989–93. Molluscs dominated the total biomass. The species present in the greatest biomass were *Cardium glaucum* until 1991 and *M. balthica* from 1992 onwards. The shift in mollusc domination was very marked.

*Figure 5.18*
*Variation in macrozoobenthos abundance and species number in the southern part of the Eastern Gotland Basin (BMP K1).*




The biomass of all the macrozoobenthos phyla, with the exception of polychaetes, whose biomass oscillated irregularly, exhibited a significant decreasing trend.

The Gulf of Gdansk is far more eutrophic than other shallow areas in the open Polish coastal zone (Dubrawski *et al.*, 1998; Kruk-Dowgiallo and Dubrawski, 1998). At station BMP K10 (36 m) the number of taxa was approximately the same during 1994–98 as during 1982–93.

This station exhibited the greatest taxonomic diversity of the Polish coastal stations and the highest average biomass, which was strongly dominated by molluscs. Biomass increased at this station during the 1990s, with the highest values in 1995 and 1997. Between 1997 and 1998, however, the biomass declined considerably.

***Eastern Gotland Basin.*** At station BMP K1 (90 m) in the southern part of the Eastern Gotland Basin, the effect of the 1993–94 inflow of water was only detected in 1995 when the marine species *D. rathkei* and *S. armiger* were found for the first time in many years, although only in low numbers. The species typical for the central and northern Baltic Proper (*P. femorata* and *M. balthica*) remained dominant, though. Abundance and biomass increased from 1994 onwards (Figure 5.18), peaking in 1997 at the highest values ever recorded.

At station BMP J2 (47 m) off the Lithuanian coast, biomass and abundance are mainly accounted for by *M. balthica*. Total biomass increased from 1981 until 1991, but has since decreased (Figure 5.19). After a period of increase during the period 1981–87, total abundance has been decreasing. Moreover, the number of species has been decreasing slightly since 1989.

Biomass and abundance of the crustacean *Monoporeia* affinis have fluctuated strongly: After an increase in the 1980s, the species has decreased drastically since 1989. *Halicryptus spinulosus* and *H. sarsi* have decreased since 1987 and *M. balthica* has decreased since 1988. All observed decreases occurred after a period of increase.

The abundance of *P. elegans* fell to a mean level after a three-year (1990–92) period of high abundance. No clear trend is evident in the abundance and biomass of oligochaetes and the crustacean *Saduria entomon.*

No occurrences of dead sea bottom were observed in the Lithuanian national monitoring region, but samples from station 5C (70 m) usually contained black mud with a strong smell of hydrogen sulphide. Some life was still present, however.

Within the Lithuanian national monitoring region, biomass and abundance have declined at depths below 40 m since 1990–91. At shallower nearshore stations, parallel fluctuations were observed but with less clear evidence of a decrease. At most stations, the number of species found has decreased since the mid 1990s.

At the Swedish coastal station BMP J10 (45 m), macrozoobenthos abundance is strongly dominated by *M. affinis,* and fluctuates markedly. During the period 1994–98, abundance was highest in 1995 (9,000 ind./m²) and lowest in 1997 (4,000 ind./m²). The number of species also varied. Thus eight species were found in 1994, but only four–five species during the following years. There is no clear long-term trend in abundance, but the values found during the period 1986–90 were higher than the ones found 1994–98.

In the late 1980s and early 1990s, gradual recovery of the communities was observed at bottoms deeper than 85 m in the Eastern Gotland Basin as a consequence of the positive effects of prolonged stagnation on the oxygen conditions in intermediate depths. The recovery of the benthic communities was most pronounced on the eastern slope of the basin extending down to about 155 m in the southern half of the basin (Laine *et al.*, 1997).

In 1994–98, the sampling sites at a depth of 90–100 m on the western slope were characterized by impoverished, *H. sarsi*-dominated communities. An exception was station HA1 (89 m) where *P. femorata* was observed in increasing numbers (abundance of up to 750 ind./m²).

On the eastern slope at 85–100 m (HA and HL transects), relatively abundant communities prevailed comparable to those at station BMP K1. These communities were dominated by *P. femorata*, *M. balthica* and *H. sarsi*, with a total abundance of 200 to more than 1100 ind./m².

*D. rathkei* occurred at one 101 m deep station (HL6) from 1994 to 1997. At a depth of 100–150 m only *H. sarsi* was occasionally found throughout the period. In 1998, the deeper stations (>100 m) were mostly devoid of macrofauna. An exception was station HL5 (135 m), where *S. armiger, H. sarsi*

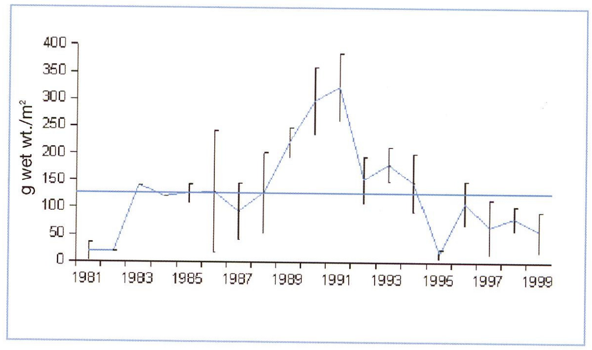
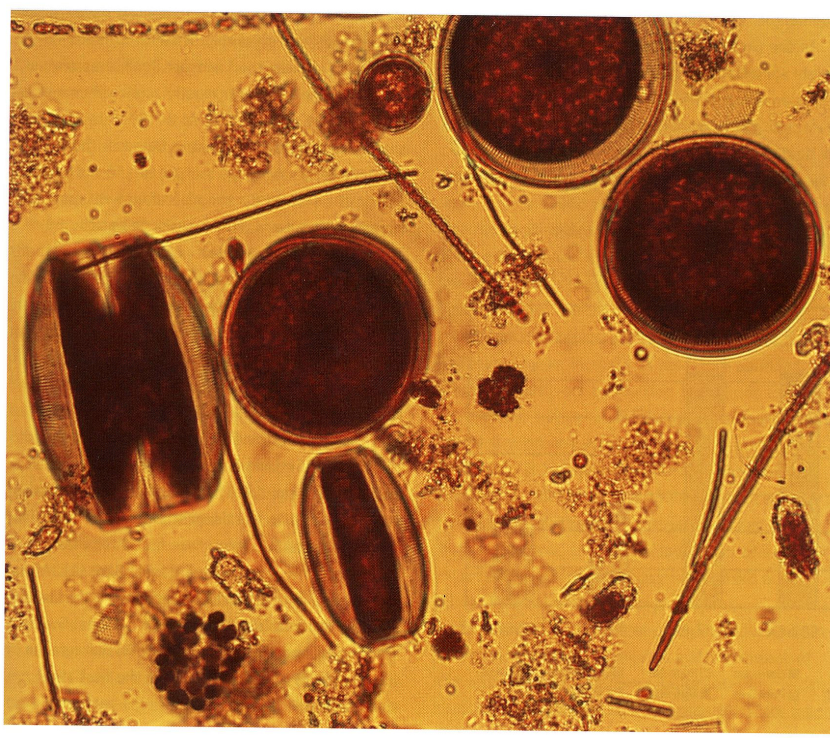



***Figure 5.19 Variation in macrozoobenthos biomass off the Lithuanian coast (BMP J2).***



***Plankton sample from south western Baltic. Photo: Susanne Busch, Baltic Sea Research Institute, Rostock.***

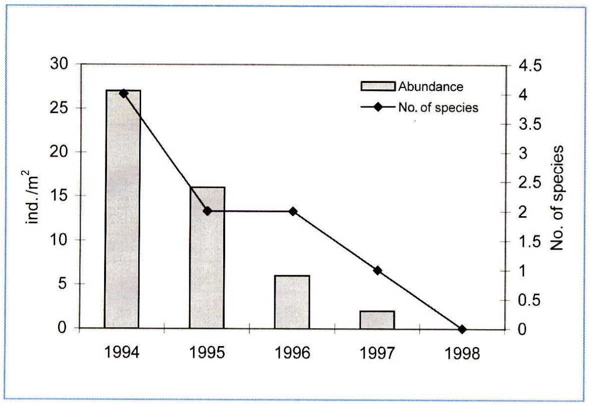



*Figure 5.20*
*Variation in macrozoobenthos abundance and species number in the Western Gotland Basin (BMP I1).*

and *P. femorata* were recorded in low numbers.

Identification of the positive effects of the 1993–94 inflows on this depth zone is complicated by the improved oxygen conditions already present prior to the inflows, although they are clearly reflected in the distribution of marine macrozoobenthos species.

In the central part of the Eastern Gotland Basin, at station IVb 2 (112 m), no macrofauna was found in 1994. In 1995, two species were found in modest numbers (*H. sarsi* and *P. femorata*). In 1996, four species were found, but total abundance was lower. The macrofauna then gradually became impoverished, and in 1998 only one species (*Monoporeia affinis*) was found, in low numbers.

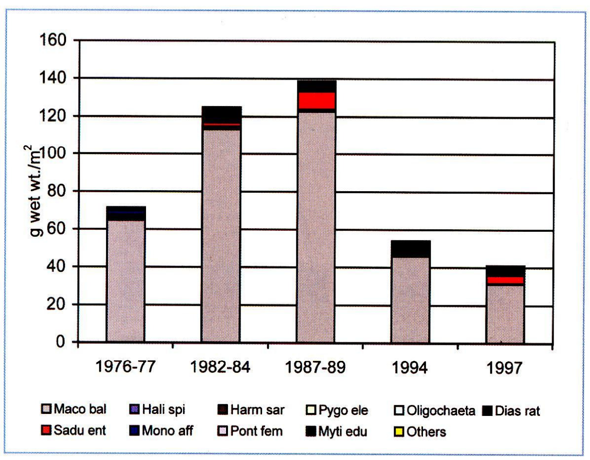
In the Gotland Deep (station BMP J1; 249 m), single specimens of *H. sarsi* were found in 1994 as a consequence of the inflow of new oxygenated water. *H. sarsi* (18 ind./m$^2$) was also recorded here in May 1995. The Gotland Deep was oxygenated in 1994–95, but hydrogen sulphide has been recorded annually in the deep layer since 1996.

*Figure 5.21*
*Variation in macrozoobenthos taxonomic composition and mean biomass at six stations within 30–70 m depth in the Western Gotland Basin.*

In the northern part of the Eastern Gotland basin, two intermediate depth stations – LF1 (67 m) and IBS5-10 (78 m) – exhibited species-rich but fluctuating communities with no clear trends in abundance. P. *femorata* and *M. balthica* dominated at these sites, with a lesser contribution by *M. affinis, H. spinulosus, H. sarsi* and *S. entomon.*

Somewhat deeper and more offshore, at stations LF2 (81 m), IBS5-9 (89 m) and LF3 (95 m), the increase, which had started earlier (Laine *et al.*, 1997), peaked in 1994–96 and was followed by a clear decline. The two first sites were strongly dominated by *P. femorata*, whereas *H. sarsi* was the most abundant species at the deeper station. Single specimens of *D. rathkei* were recorded at this site in 1996–97.

In the Fårö Deep area, single individuals of *H. sarsi* were occasionally present at 135 m (LF5). In 1995, the species was also recorded in the deep itself (F80; 193 m). Hydrogen sulphide has been recorded annually in the Fårö Deep at depths >150 m during 1994–98.



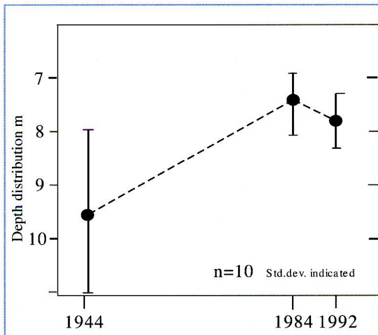

***Northern Central Basin.*** In 1994–98, no hydrogen sulphide was recorded at station BMP $H_2$ (170 m). The depth where oxygen concentration fell below 1 ml/l varied annually from 90 m to 125 m. The polychaete *H. sarsi* has occasionally been detected at this site since the late 1970s (Laine *et al.*, 1997) and was observed in low numbers (<15 ind./m$^2$) in 1995–97. In addition, *P. femorata* was recorded at this site in 1996. At another 130 m deep open sea station (LL15) in the northern central basin *H. sarsi* was recorded only once, in 1996.

At 125 m, near the Landsort Deep, macrofauna were found in 1994–97 (mostly a few specimens of *H. sarsi*), but not in 1998. At 80–90 m in the Landsort area, several species were found in the mid 1990s in levels ranging from 20 to 150 ind./m$^2$. During the late 1990s the macrofauna disappeared from the 90 m level and was reduced at the 80 m level. In the shallower parts of the Askö-Landsort area biomass tended to increase during the 1990s, and there was a statistically significant increase in *M. balthica* in the area.

***Western Gotland Basin.*** Some of the saline water that entered the Baltic Sea in 1993–94 flowed northwards from the Bornholm Basin and entered the Western Gotland Basin from the south (Cederwall and Sjöberg, 1995). This led to immigration of marine species to the deepest areas. Thus in 1994, the polychaete *S. armiger* was found for the first time in the Western Gotland Basin (BMP I1). After 1994 the fauna successively declined in the deepest part of the basin (BMP I1 and national Swedish stations) (Figure 5.20), and in 1998, macrofauna was absent at station BMP I1 for the first time since 1990.

In shallower (30–70 m) areas of the basin the faunal biomass decreased significantly in the beginning of the 1990s, following an increase during the 1970s and 1980s (Figure 5.21). In 1997, the situation was unchanged compared to 1994, with biomass being significantly lower than in the late 1980s.

Since the bivalve *M. balthica* accounts for over 80% of the biomass, the changes observed are mainly due to variations in this species. The individual mean weight of this species increased during the 1970s and 1980s, but then decreased strongly in the early 1990s. It seems that the biomass increase during the 1970s and 1980s was due to growth of a few successful age classes, which died off in the early 1990s, followed by recruitment of young small *M. balthica* in the early 1990s. The old population of *M. balthica* possibly hindered successful recruitment of young specimens since it is known that large *M. balthica* can have a negative effect on small, young *M. balthica* (Bonsdorff *et al.*, 1986).




T-test comparison probability (n=10):

| | 1944 | 1984 | 1992 |
|---|---|---|---|
| 1944 | 1 | | |
| 1984 | <0.001 | 1 | |
| 1992 | 0.013 | 0.013 | 1 |

Wilcoxon signed ranks test (two sided probability using normal approximation)

| | 1944 | 1984 | 1992 |
|---|---|---|---|
| 1944 | 1 | | |
| 1984 | 0.007 | 1 | |
| 1992 | 0.012 | 0.022 | 1 |

***Figure 5.22***
***Depth penetration of Fucus vesiculosus in the Gräsö archipelago, Åland Sea. Comparison of ten localities in 1944, 1984 and 1992. Results of a t test and Wilcoxon signed rank test of changes within each locality are shown (from Kautsky, 1995).***

### Phytobenthic plant and animal communities

***By: H. Kautsky***

The maximal depth distribution of plants is a measure of the ambient light conditions over time. The trends in the distribution of perennial plants in particular thus integrate environmental change over long periods. A strong correlation thus exists between the Secchi depth, reflecting the turbidity of the water, and maximal depth distribution of the phytobenthos. With increasing water quality (i.e. less turbidity) and the presence of suitable substrate, the attached plant species spread to greater depths.

In the Gräsö area of the Åland Sea, the depth distribution of the bladder wrack (*Fucus vesiculosus)* decreased by 3 m from 11.5 m in the 1940s to 8.5 m in the mid 1980s. During the same period the mean Secchi depth in the region also decreased by 3 m. Since the 1980s the depth distribution has increased again (Figure 5.22). The maximum depth distribution of the bladder wrack also seems to be increasing in the Askö area.

Eutrophication enhances the growth of opportunistic, filamentous, annual algae and the percentage of the total biomass accounted for by annual plants is expected to increase with increased eutrophication, as has been the case in the Askö area since the mid 1970s (Figure 5.23a). However, this is due not to an increase in annual plant biomass, but rather to a decrease in perennial plant biomass (Figure 5.23b).

The decrease of perennials could be attributable to several factors, e.g. shading and competition for nutrients from an increasing biomass of filamentous epiphytes could hamper the growth and distribution of the bladder wrack (*F. vesiculosus*). No increase of filamentous algae can be seen in the Askö area, though (Figure 5.23b). However, there are anecdotal indications reported from several places along the coasts of the Baltic Proper of an increased and seasonally prolonged occurrence of epiphytes on *Fucus*. An alternative explanation might be the life cycle of this perennial alga. *Fucus* has an intricate life cycle with only a few, short opportunities each year to reproduce – mainly during full moon and calm weather. The chance of reproductive failure is thus high, and young *Fucus* plants are only present in high abundance in occasional years. The populations might disappear from large areas when their life cycle is completed. The *Fucus* germlings seem to be poor competitors if no empty space is found. Recolonization may therefore take a long time due to competition for space from filamentous algae.

The disappearance of *F. vesiculosus* could be explicable by an increase in herbivore abundance since the herbivore population is thought to benefit from the eutrophication-induced increase in the biomass of annual plants, which are a preferred food item. It has been shown that the herbivores *Idothea spp.* might change their preference when in dense populations and instead consume *Fucus* fronds. However, there is no indication of any increase in herbivore biomass in the Askö area since the mid 1970s (Figure 5.23c).

Eutrophication enhances pelagic production, thereby increasing the organic matter content of the water column and hence sedimentation. It can thus be expected that the phytobenthic filter feed-