Monitoring the invertebrate benthic fauna in the Dutch sector of the North Sea 1991 – 2005: an overview

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Contents

Summary

In the framework of 'BIOMON', a national program for biological monitoring of marine waters, the invertebrate benthic fauna of the Dutch Continental Shelf (DCS) has been monitored from 1991 onwards. The monitoring is based on a boxcore sampling program yearly carried out in spring at 100 stations on the DCS. The aim is to generate a time series that can form a basis to detect possible trends in the development of the fauna in different areas within the DCS.

From the very beginnng it became clear that in the fauna of the DCS four clusters could be discerned that are geographically well defined: the Dogger Bank, the Oyster Ground, the southern offshore area and the coastal area. At the community level there were no trendwise changes over the period of monitoring. Species diversity was consistently highest at the Dogger Bank and in the Oyster Ground, on average twice as high as in the southern offshore and coastal areas. Faunal densities were generally the highest in the Oyster Ground. The highest biomass values were found in the coastal area, due to the presence of banks of bivalves (*Spisula subtruncata* and *Ensis americanus*). At the species level a few trends were observed: the disappearance of the polychaete *Aricidea minuta* from the DCS around 2000 and a dip in the densities of the brittle star *Amphiura filiformis* in the Oyster Ground during the second half of the nineties. A rather strong decrease of silt contents of the sediment in the latter area after 2001 was not reflected in a change in the abundance of one or more common species.

A comparison of the monitoring data with data collected in the period 1975 – 1981 appeared to be possible for only a few (mainly mollusc) species in the Oyster Ground, but indicated that the gastropod *Turritella communis* has strongly decreased since those years whereas there was a significant increase in the abundance of several small bivalve species.

Introduction

In 1989 the national program 'BIOMON' was started for biological monitoring of the waters in the Dutch sector of the North Sea, the Wadden Sea and the Delta area in the southwestern part of the Netherlands. The program was initiated by the National Institute for Coastal and Marine Management (RIKZ). It comprises monitoring of various trophic levels in the food web, from plankton to birds and mammals. We contributed to the program with monitoring of the macrozoobenthos in the Dutch sector of the North Sea.

The aim of the benthos monitoring is to obtain insight in the spatial and temporal variation in the fauna composition and to detect possible temporal trends which could reflect changes in environmental conditions. Benthic invertebrates are assumed to be particularly suitable for monitoring because of their limited mobility, making them unable to migrate in order to avoid stressful situations (Dauer & Llanso, 2003). Therefore the benthic fauna composition is thought to reflect environmental conditions which may vary over time.

In this report we give an overview of the methods used and the major results obtained between 1991 and 2005. Detailed descriptions of methods and results can be found in a series of 15 reports (Duineveld, 1992, Duineveld *et al.*, 1993, 1994; Holtmann et al., 1995, 1996, 1997, 1998; Daan & Mulder, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006). Further, for some of the commonest echinoderm and mollusc species we

compare our data with those collected by colleagues at our institute in previous years.
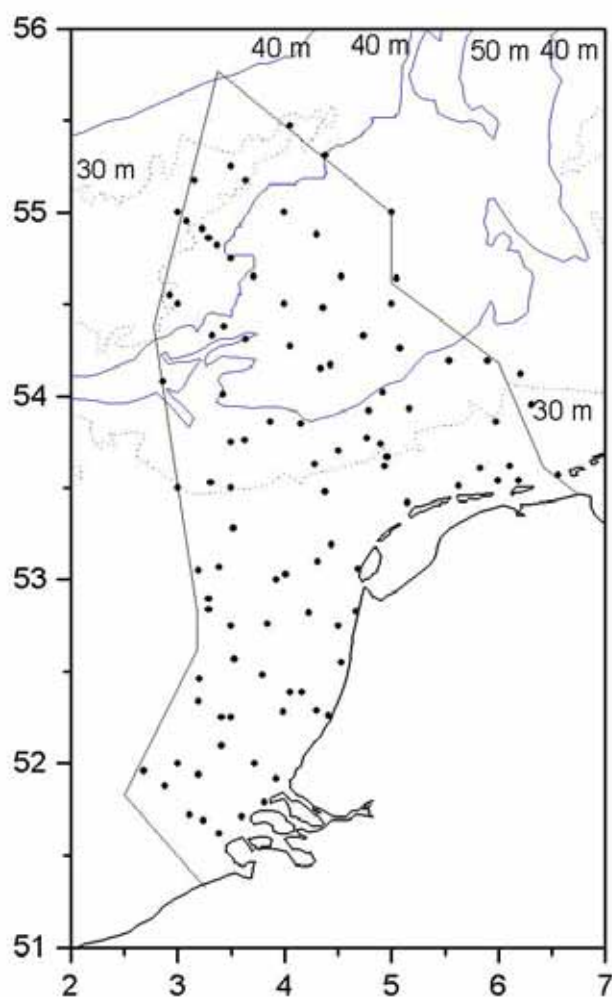

Fig. 1. Positions of the stations sampled within the BIOMON program between 1991 and 2005.

Methods
The benthic fauna in the Dutch sector was sampled with a boxcorer each year in March – April. During the first years (1991 – 1994) there were 25 stations located along 5 transects perpendicular to the Dutch coast. At these stations 5 replicate boxcore samples were collected each year. However, in order to obtain a better picture of (changes in) the fauna composition in the Dutch sector as a whole or in larger parts of it, it was decided in 1995 to change the sampling design according to the strategy recommended by van der Meer (1997). This strategy says: spread sampling over a large number of stations, with little sampling effort per station. From 1995 onwards 100 stations were visited each year, i.e. the 25 existing stations and 75 more or less randomly chosen new stations (Fig. 1). At each station only 1 benthos sample was taken. An additional boxcore sample was collected for sediment analysis.

Benthos samples were collected with a Reineck boxcorer ($\varnothing$ 0.078 m^2, minimal depth 15 cm). Each sample was washed on board through a 1mm mesh sieve and the residual macrofauna was preserved in a 6% neutralized formaldehyde solution for later analysis in the laboratory.

In the laboratory the samples were stained with rose-bengal and washed over a set of nested sieves with 0.7 mm as the smallest mesh size, to facilitate sorting. The separate sieve fractions were sorted under a magnifier. Then the various taxonomic groups were identified under a stereomicroscope. Major taxa like polychaetes, crustaceans, molluscs, echinoderms and sipunculids were generally identified to species level, but difficult taxa like anthozoans, phoronids, nemerteans and others were recorded on a higher taxonomic level.

Biomass values were obtained in 3 different ways for the various taxonomic groups. Molluscs and echinoids were measured to the nearest 0.5 mm and the ash-free dry weight (AFDW) was calculated according to empirically determined length-AFDW relationships. For polychaetes, larger crustaceans, ophiuroids and other taxa the wet weight measured on a balance was converted into AFDW according to factors provided by Rumohr *et al.* (1987) and Ricciardi & Bourget (1998). Small amphipods and cumaceans were assigned an average individual AFDW of 0.2 – 0.5 mg (Holtmann & Groenewold, 1992).

Sediment samples (from the 10 cm top layer) were always collected at each station for analysis of the grain size distribution. The grain size was analyzed with a Malvern particle analyzer by the RIKZ laboratory in Middelburg. The parameters derived from the grain size data are median grain size and percentage silt (fraction < 63 μm).
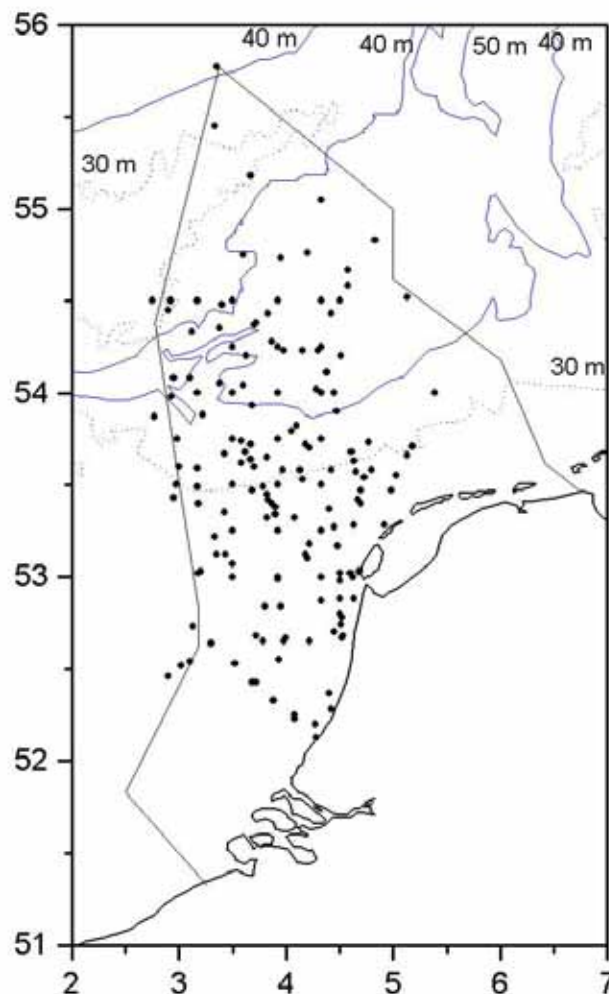

Fig. 2. Positions of the stations sampled by Creutzberg and Cadée in the period 1976 – 1981.

In this report, the faunistic data obtained during the BIOMON program are also compared to older data from the same area. The most important source of information appeared to be available in the form of unpublished data collected by the late dr. F. Creutzberg between 1976 and 1981 and by dr. G.C. Cadée between 1978 and 1981. These data originate from van Veen grab samples collected in the Oyster Ground and in the northern part of the offshore area (Fig. 2). Unfortunately, the data do not comprise such detailed taxonomic information as collected during the BIOMON program. Polychaetes, for example, were not identified in those years and of the crustaceans only a few larger species were recorded at the species level. In the Oyster Ground, the mud shrimps *Callianassa subterranea* and *Upogebia deltaura* were the only crustaceans that were identified. Both are deep digging species and are not efficiently sampled by a van Veen grab compared to a boxcorer (Beukema, 1974, Mulder et *al.* 1988). We, therefore, cannot use these data to unravel possible long-term changes. In the southern offshore area larger crustaceans like crabs are too sparse to be adequately sampled by a van Veen grab or boxcorer. In fact,
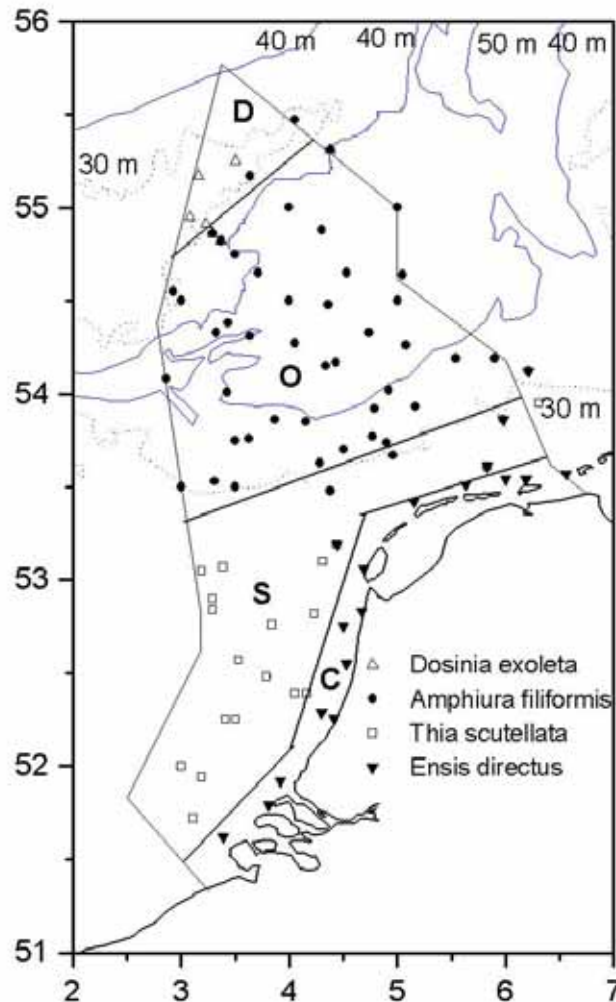
Fig. 3. The Dutch sector with its four main faunistic regions: the Dogger Bank (D), the Oyster Ground (O), the southern offshore area (S) and the Coastal zone (C). The distribution patterns are plotted of four species that are each characteristic of one of the four regions.

molluscs and a few echinoderms appear to be the only taxa for which suitable data are available for a comparison with the BIOMON data. Since the species specific densities calculated by Creutzberg and Cadée are based on much larger samples (sampling surface 0.18 m^2; 1, 5 or 10 grabs per station) than the boxcore samples collected during BIOMON (sampling surface 0.078 m^2; 1 or 5 boxes per station), we may expect that the variances in both data sets are quite different. For statistical comparison we therefore used a two-sample t-test with unequal variances.

Results and discussion
From the very beginning it became clear that, on the basis of fauna composition, four spatially well defined regions could be discerned within the monitoring area. Statistical analysis (TWINSPAN) carried out by Duineveld (1992) showed that the Dogger Bank, the Oyster Ground, the southern offshore area and the coastal area (Fig. 3) each had their own characteristic fauna composition. The different regions are roughly separated from each other by isobaths. The Oyster Ground is the deepest region and is separated by the 30-m depth contour from the Dogger Bank and the southern offshore area. The border between the latter and the coastal area is roughly marked by the 20-m depth contour.
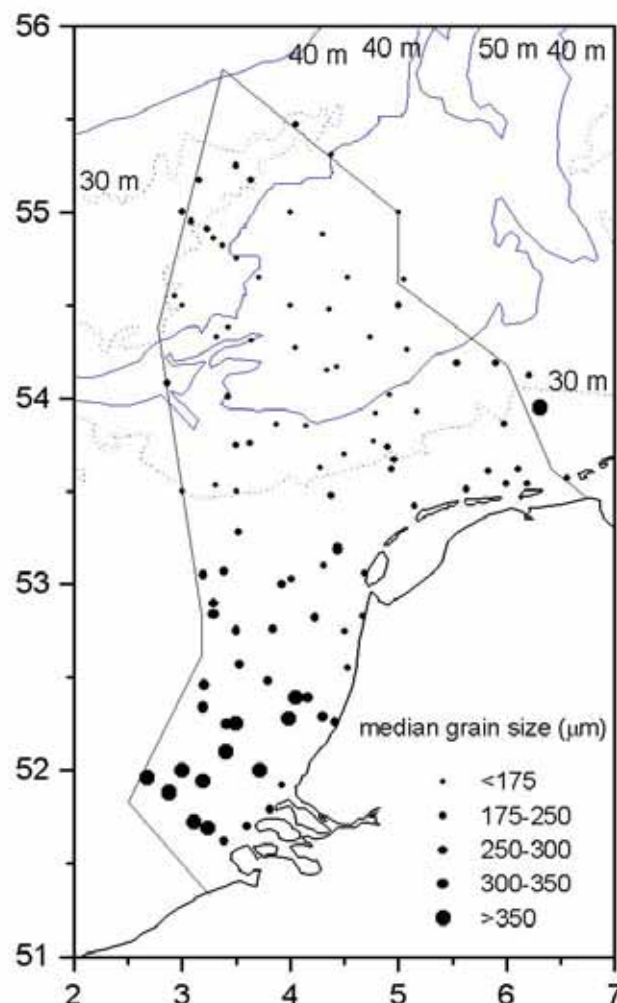

Fig. 4. Spatial distribution of the median grain size of the sediment in 2005.

The spatial pattern in sediment composition shows that each of the four areas is distinguished by its own sediment characteristics. Coarse to very coarse sand occurs in the southern offshore area with a median grainsize always well beyond 200 µm and generally beyond 350 µm in the southern part (Fig. 4). Finer sand occurs at the Dogger Bank and in the coastal area with a median grain size of about 200 µm. Very fine sand is found in the Oyster Ground. The average median grain size in the four areas did hardly change over the monitoring period (Fig. 5). Considerable silt contents
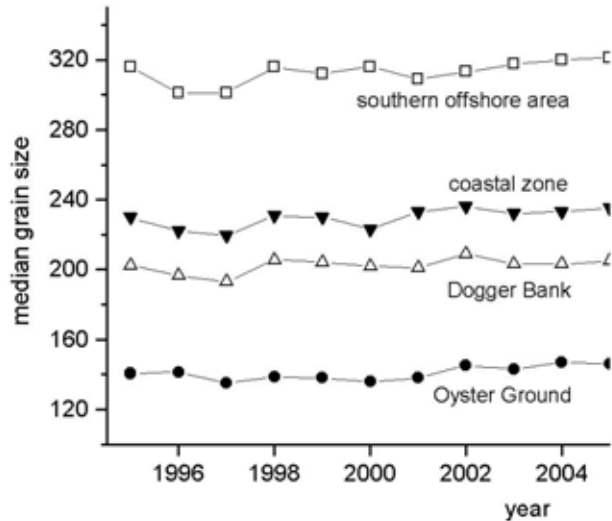

Fig. 5. Temporal patterns in the mean median grain size in the four regions of the Dutch sector of the North Sea.
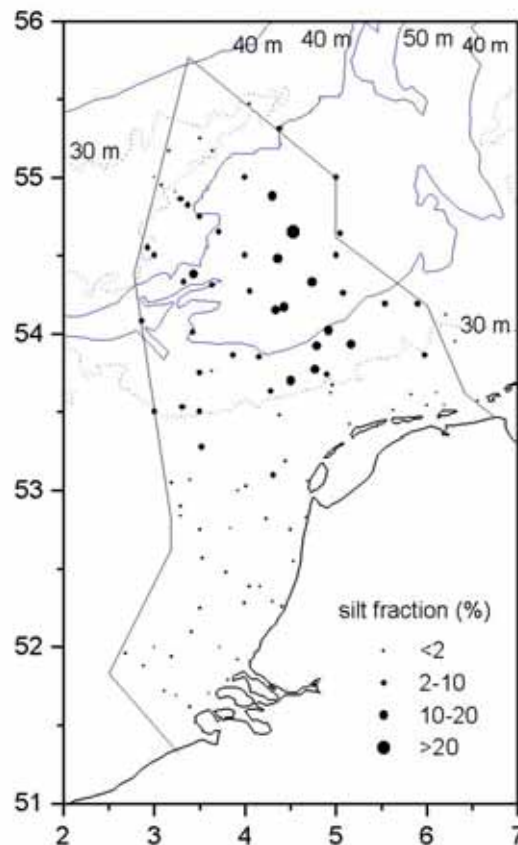

Fig. 6. Spatial distribution of the silt content (fraction < 63 µm) of the sediment in 2005.

occur in the sediment of the Oyster Ground (Fig. 6). Here the silt fraction is generally well beyond 2%. However, in this area a decrease of silt concentrations was observed after 1999. The average percentage silt decreased from 13% in 1999 to 7.5 % in 2004. Particularly at stations where silt concentrations were very high before 2000 the decrease was considerable. In 1999 there were 12 stations with silt contents of more than 20%, but in 2003 and 2004 such high values were no longer found and in 2005 a concentration of more than 20% occurred at only one station. In the other regions the silt contents of the sediments were consistently low during the period of monitoring, generally below 2%. The distribution of most benthic species appeared generally to be concentrated in one or two of the four regions. Fig. 3 shows the distribution of four species, that were found almost exclusively in one region. The bivalve *Dosinia exoleta* was found only at the Dogger Bank. The brittle star *Amphiura filiformis* is a characteristic species of the Oyster Ground and is hardly found outside that area. The thumbnail crab *Thia*
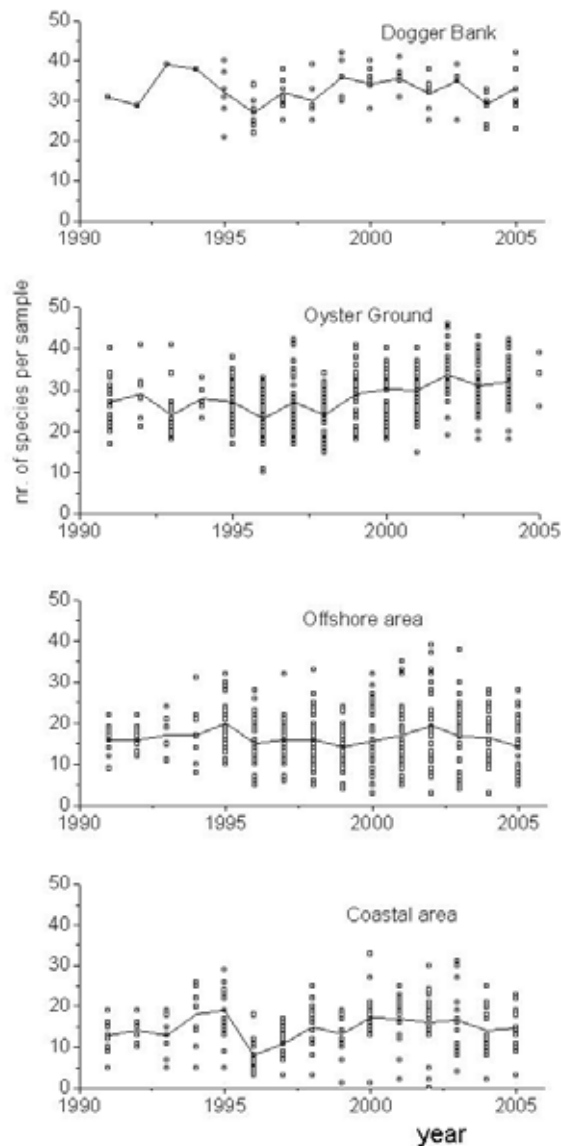

Fig. 7. Temporal patterns in species richness between 1991 and 2005. The drawn lines connect the annual means.

scutellata is a typical dweller of the southern offshore area and the American razor clam *Ensis americanus*, which invaded European waters in the early eighties, has colonized particularly the coastal zone.

Species richness, here expressed as the number of species per boxcore sample, was always the highest at the Dogger Bank and in the Oyster Ground and the lowest in the southern offshore and coastal areas (Fig. 7). There seemed to be no trendwise changes over the period of monitoring. In the Oyster Ground there might be a tendency for a slight increase in species richness in recent years, but particularly the large spatial variation does not allow to decide that this was a consistent trend.

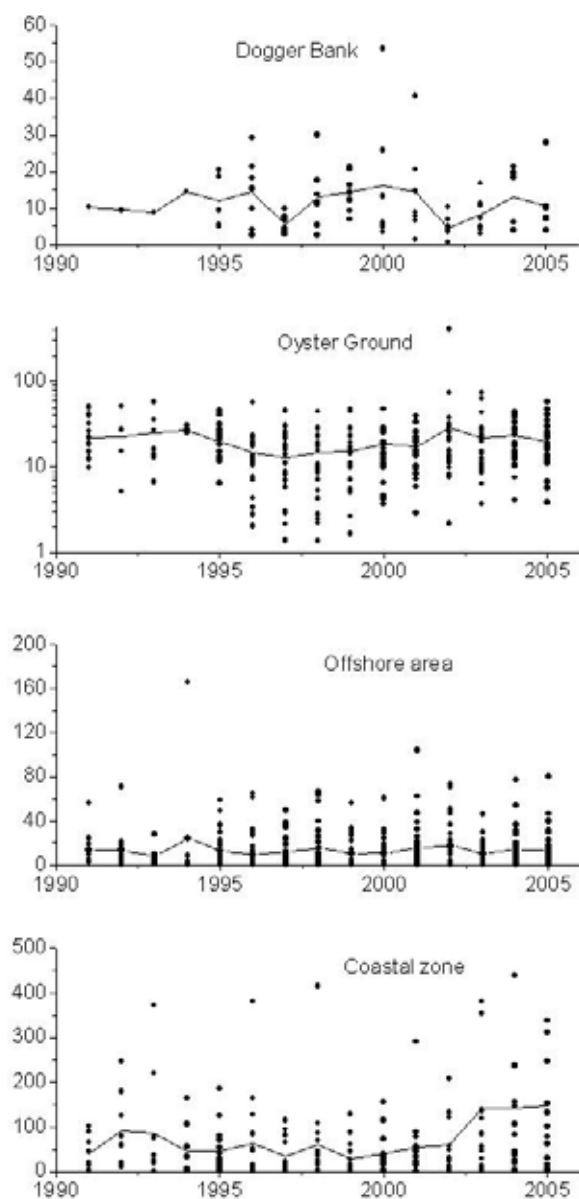Biomass values were always the highest in the coastal area (Fig. 8). Over

Fig. 8. Temporal patterns in biomass between 1991 and 2005. The drawn lines connect the annual means.

the whole period of monitoring an average of 75 g AFDW.m^{-2} was found in this area. This high value was largely caused by the presence of banks of the bivalves *Spisula subtruncata* and *Ensis americanus*. Particularly at the end of the monitoring period (2003 – 2005) very high biomass values (on average 145 g AFDW.m^{-2}) were found as a result of a succesful spatfall of *E. americanus* in 2001.

In the Oyster Ground the annual average biomass varied between 13 and 29 g AFDW.m^{-2} with an overall mean of 19 g AFDW.m^{-2}. At the Dogger Bank and in the southern offshore area the overall mean biomass level was at 12 g AFDW.m^{-2} with yearly fluctuations between 5 and 17 g AFDW.m^{-2}. In neither of the areas a consistent temporal trend could be observed. It was observed that a few large species often contribute a major part to total biomass values. The sea urchin *Echinocardium cordatum* has a substantial share in the whole Dutch sector and the bivalves *Spisula subtruncata* and *Ensis americanus* particularly in the coastal area. If we assume that (the non-juvenile specimens of) these species cannot be considered as food available to fish and we subtract their share from total biomass, the remaining average biomass possibly available to fish is 16 g AFDW.m^{-2} in the Oyster Ground, 13 g in the coastal area, 9 g at the Dogger Bank and 6 g in the southern offshore area.
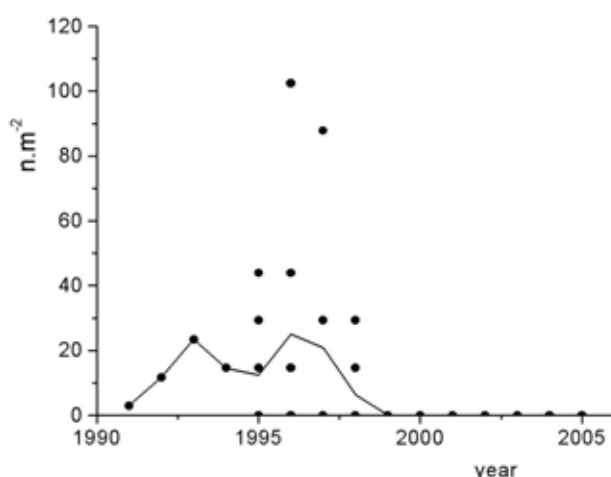

Fig. 9. Densities of the polychaete *Aricidea minuta* at the Dogger Bank between 1991 and 2005. The line connects the annual means.

At the species level a limited number of trendwise changes were observed. At the Dogger Bank the polychaete *Aricidea minuta* was a common species up to 1998, but it disappeared in 1999 and was never found again (Fig. 9). In the offshore area the species also showed a decreasing trend, which, however, started after 2001. In the other regions the species has always been rare.

In the Oyster Ground there was a period of low abundance of the brittle star *Amphiura filiformis* and the mud shrimp *Callianassa subterranea* in the second half of the ninetees, but the densities of both species recovered after 2000 (Fig. 10). Further the bivalve *Nucula nitidosa* showed an increase from 1999 onwards. Densities of other species showed (sometimes strong) year to year fluctuations without any consistent temporal trend.
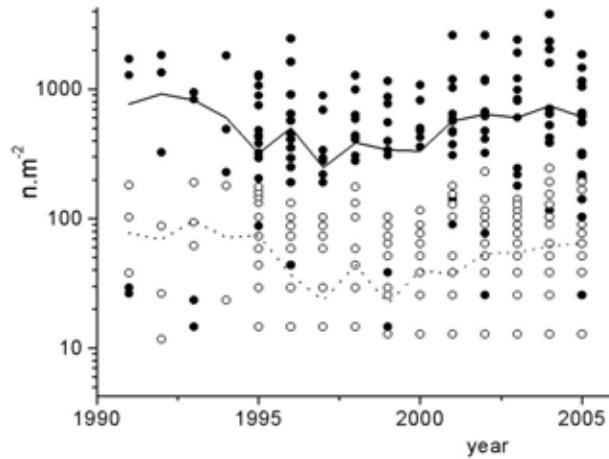
Fig. 10. Densities of the echinoderm *Amphiura filiformis* (solid circles) and the crustacean *Callianassa subterranea* (open circles) in the Oyster Ground between 1991 and 2005. The lines connect the annual means.

Table 1: Significant (*) and non-significant (n.s.) changes in the
densities of some echinoderm and mollusc species
between the
late seventies and the BIOMON period in the Oyster Ground
and the southern offshore area

Oyster Ground

	mean densities (n.m-2)			
	76 - '81	BIOMON	t-test	
Amphiura filiformis	466	513	0.460	n.s.
Echinocardium cordatum	21.2	18.3	0.590	n.s.
Abra alba	4.3	69.7	0.000	*
Corbula gibba	1.7	132.2	0.000	*
Chamelea striatula	4.1	6.9	0.150	n.s.
Mysella bidentata	59.3	212.8	0.000	*
Nucula nitidosa	12.5	34.1	0.000	*
Phaxas pellucidus	1.7	7.1	0.000	*
Tellina fabula	8.0	14.3	0.170	n.s.
Cylichna cylindracea	8.5	19.9	0.000	*
Euspira nitida	2.0	14.8	0.000	*
Turritella communis	5.9	0.9	0.005	*

offshore area

	mean densities (n.m-2)			
	76 - '81	BIOMON	t-test	
Echinocardium cordatum	15.8	14.8	0.730	n.s.
Euspira nitida	4.4	17.2	0.000	*
Tellina fabula	14.1	33.0	0.001	*
Donax vittata	1.7	11.2	0.002	*
Chamelea striatula	0.8	0.3	0.040	*
Abra prismatica	1.2	0.2	0.005	*

So far, the monitoring exercise did not reveal changes in the composition of the benthic fauna to such an extent that the assumption is justified that environmental conditions have changed. However, the duration of the period of monitoring may be too short to discern any substantial change. Therefore, it can be interesting to compare the data with older data collected in the same area.

In the Oyster Ground, the brittle star *Amphiura filiformis* has always been a numerically dominant species. The numbers found by Creutzberg and Cadée between 1976 and 1981 are only slightly lower than during BIOMON and the difference appears to be not significant (t-test, $p > 0.05$; table 1). The species has been intensively sampled also in 1986 by Duineveld et al. (1987) who found somewhat higher densities, but these were not significantly different ($p > 0.05$) too. Although, at a larger scale, there seemed to be no change in the abundance of *A. filiformis*, at a more local scale a rather dramatic decrease could be observed in the first half of the ninetees. In the Frisian Front area, at the southern border of the Oyster Ground, the densites declined in that period from over 1000 specimens per m^2 to a density of almost zero in 1995 (Fig. 11). Except for a temporary (and not successful) patch of spatfall in 1997 the densities remained low for several years and gradually seemed to recover only after 2000.
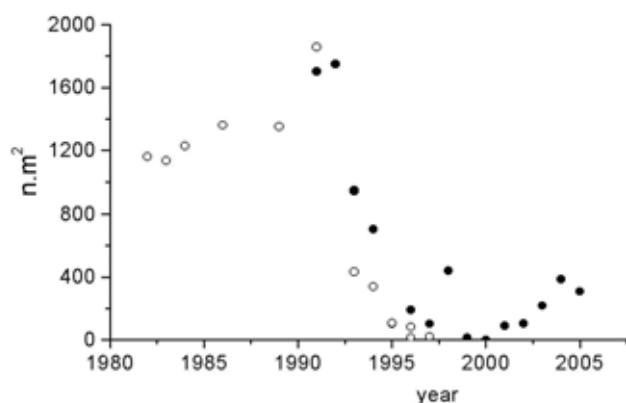

Fig. 11. Densities of the echinoderm *Amphiura filiformis* at Frisian Front station OYS-36 between 1982 and 2005. The data plotted stem from BIOMON (solid circles) and other programmes (open circles: Duineveld & van Noort, 1986, Duineveld et al., 1987, Holtmann & Groenewold, 1992, Verburg unpubl. data, NIOZ students course unpubl. data).

The average densities of the sea urchin *Echinocardium cordatum*, a species common in the whole Dutch sector, appeared to be almost the same in the late seventies as in recent years (Table 1). This holds for both the Oyster Ground and the southern offshore area. The small differences were not significant ($p > 0.05$). In the coastal area and on the Dogger Bank the numbers are too low to allow for a statistical comparison.

Molluscs form the major group of species for which densities in the late seventies can be compared with those found in the BIOMON period. For the Oyster Ground the statistical comparison was made for 7 bivalves and 3 gastropods that belong to the most abundant species in at least one of the two periods (Table 1). The abundances in both periods generally differed clearly. Except for the bivalves *Chamelea striatula* and *Tellina fabula,* which did not show a significant difference, the differences were in

all cases very highly significant (p<0.001). Most species appeared to be much more abundant in the BIOMON period than in the seventies. Only one species, the gastropod *Turritella communis*, showed higher densities in the seventies (Fig. 12).
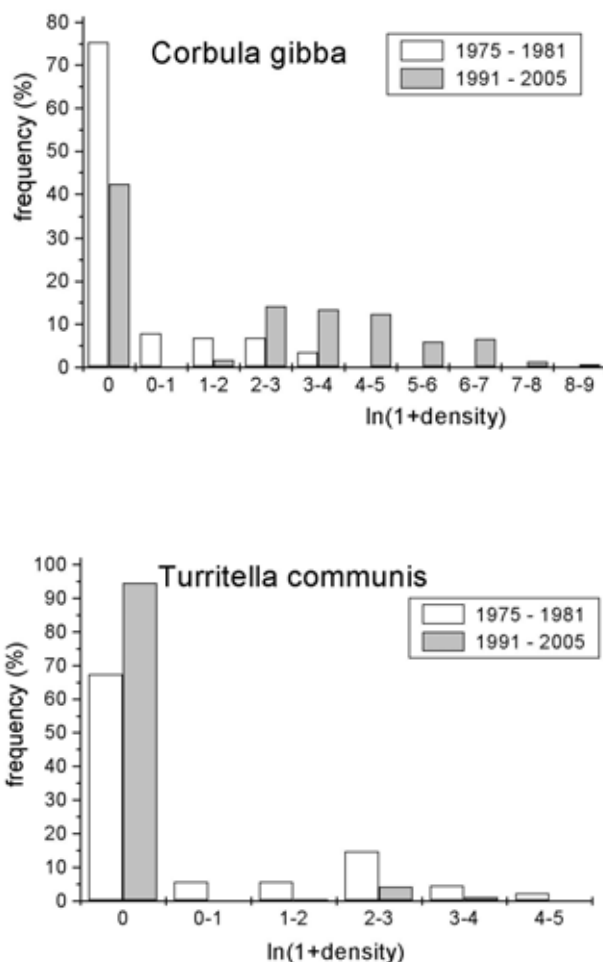

Fig. 12. Abundance class distributions of two species in the Oyster Ground in the late seventies and during the BIOMON period. Plotted are the percentages of samples in which each abundance class (density = $n.m^{-2}$) was present.

In the southern offshore area the comparison was made for 5 bivalve species. For all of them there were significant differences between the two periods and for two of them the difference was very highly significant (p<0.001). Three species had increased between the seventies and ninetees, whereas two species showed a decrease.
In view of the fact that most species that showed an increase between the two periods are either relatively small species or usually comprise a substantial fraction of small juvenile specimens it might be wondered whether the differences found could be artificial and caused by differences in sorting methods.However, from personal communication with Cadée it could be inferred that his sorting method did not differ substantially from the method we used. Just like we did, he stained the samples with Bengal rose and he used a magnifier during sorting to minimize the chance of missing some of the smallest organisms.

Also Creutzberg used a magnifier, but he did not stain his samples with Bengal rose. Still this does not seem to have affected his efficiency in sorting the smaller molluscs: when the abundance data for three of the smallest mollusc species (*Mysella bidentata, Nucula nitidosa* and *Euspira nitida*) are compared, there appears to be no significant difference between the average densities found by Creutzberg and Cadée. This indicates that the differences between the abundance data collected in the seventies and those collected during BIOMON cannot be reduced to methodological differences.

The fact that not all mollusc species tested were found in higher densities during BIOMON and that there were also species which showed higher abundance in the Creutzberg/Cadée-period also supports the view that methodological differences have played only a minor role in the observed changes. However, such methodological differences most probably would hamper a quantitative comparison of the BIOMON data with those collected by Eisma (1966) on molluscs in the coastal and nearby offshore area in the nineteensixties. Eisma sorted his van Veen grab samples on board straight from the 1 mm sieve, without using a magnifier. There is no doubt that this will lead to substantial underestimates of the smaller mollusc specimens. Moreover, since he gives no density estimates, any quantitative comparison is impossible. Nevertheless, from the presence data he presents, it can be inferred that the bivalve *Abra prismatica* must have been much more abundant in the sixties than in the BIOMON period. Eisma found *A. prismatica* in 27% of his samples, whereas during BIOMON the species was found in 1.4% of the samples taken in the offshore area and not at all in samples of the coastal zone.
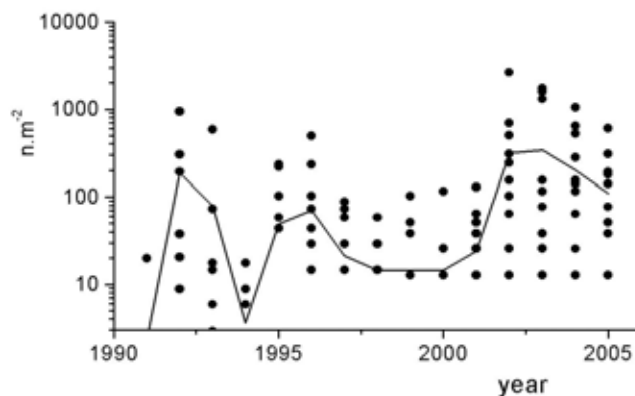

Fig. 13. Densities of the bivalve *Ensis americanus* in the coastal zone between 1991 and 2005. The line connects the annual means. Note that zero values are not plotted.

One might speculate about the causes of the species specific density changes observed, but it is postulated here that these changes do not necessarily reflect synchronous changes in environmental conditions. It is conceivable that even under overall stable environmental conditions population densities are not constant. Size and success of spatfall may largely determine the density of a population for a longer period following the settlement of larvae. During BIOMON we observed such a period of high densities in the american razor clam *Ensis americanus* after a succesful spatfall in the coastal zone in 2001 (Fig. 13). Before 2001 the densities of *E. americanus* had been at an average level of 10 to 20 specimens per m^2, whereas after the spatfall of 2001 the densities stayed

at a level of more than 100 specimens per m^2 for at least 4 years. This example may illustrate the importance of continuity in monitoring.

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