Ecological Monitoring of the New Dumping Area on the Belgian Continental Shelf.

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ABSTRACT

Since 1985 a new area for the dumping of industrial waste has replaced all previous dumping grounds on the Belgian continental shelf. Epibenthic and demersal fish species were sparsely distributed in the area and occurred in low numbers. No important commercial fisheries or spawning and nursery grounds were located.

Results of an ecological monitoring programme emphasize the relationship between benthic and demersal communities and the sediment. The overall abundance of epibenthic species never exceeded 3 000 individuals per 10^5 m^2. *Pagurus bernhardus, Ophiura albida* and *Spisula solida* were common but not dominant. The total abundance of demersal fish never exceeded 2 000 individuals per $10^5 m^2$. *Trachinus vipera, Callionymus lyra, Limanda limanda* and *Pomatoschistus spp.* displayed sometimes seasonal dominance. A comparison with previous investigations is discussed.

RESUME

Depuis 1985 une nouvelle zone pour l'immersion de déchets industriels a remplacé toutes les autres sites d'immersion sur le plateau continental belge. Les espèces épibenthiques et les poissons démersaux y étaient clairsemées et leurs abondances étaient plutôt faibles. Aucune pêcherie commerciale importante, ni aucune aire de ponte ou de frais y était localisé.

Les résultats d'une étude écologique de surveillance mettent en evidence la relation entre les communautés benthiques et démersaux et le sédiment. En général, l'abondance des espèces épibenthiques ne dépassait jamais 3.000 individus par 10^5 m^2. *Pagurus bernhardus, Ophiura albida* et *Spisula solida* étaient courantes mais aucune de ces espèces ne prédominait. L'abondance totale des poissons démersaux n'exédait jamais 2.000 individus par 10^5 m^2. *Trachinus vipera, Callionymus lyra, Limanda limanda* et *Pomatoschistus spp.* manifestaient quelquefois une prédominance saisonnière. Les résultats de cette étude sont comparés avec ceux d'investigations antérieures.

1. INTRODUCTION

On May the 15th, 1985 a new dumping area for industrial waste was established about 30 km off the Belgian coast, to replace all previous dumping grounds on the Belgian continental shelf. Until then industrial waste had been dumped at three different sites.

Two areas in the vicinity of the Goote Bank (Fig. 1) were abandoned because of their nearshore location, enhancing dispersion of waste to the coastal area.

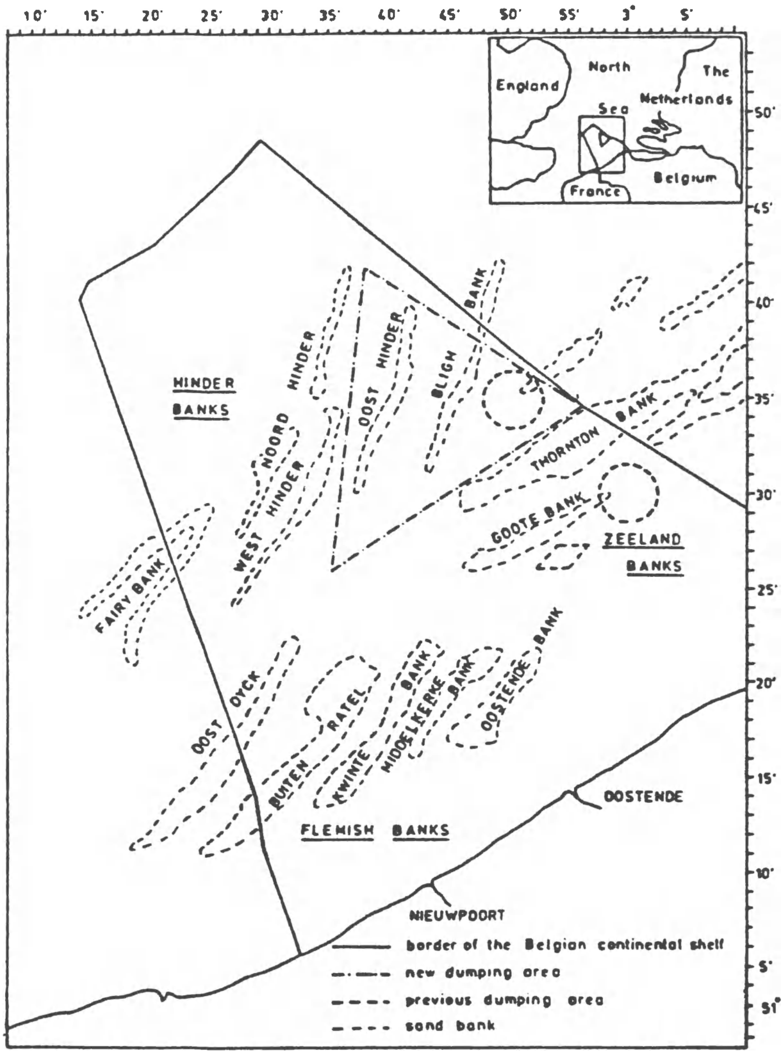

Figure 1. New and previous dumping areas for industrial effluents on the Belgian continental shelf.

(Nihoul, 1974; Bastin, 1974; Ronday, 1976) and because of the proximity of fishing areas and nursery grounds for flatfish (Maertens, 1984).

A third zone, incorporated in the new dumping area, featured favorable hydrodynamic conditions, for quick dispersion and transport of the disposed waste to the central part of the North Sea (Ronday, 1976; Gullentops et al., 1977; Mommaerts and D'Hondt, 1986). Moreover no important fisheries or spawning and nursery grounds were located in the surrounding area and benthic species were sparsely distributed (Maertens, 1987). The main reason for this poor community is the lack of nutrients in the water column (Baeteman and Vyncke, 1989) and sediments (Houbolt, 1968; Gullentops, 1974; Maertens, 1987) resulting in unsuitable conditions for the development of benthic biota (Maertens and Vanhee, 1985; Maertens, 1987). No recreational or other human activities were recorded in this area, except for trawling by Dutch fishing vessels.

Therefore in 1984 an extension of this third dumping area was proposed to become the present-day disposal site for all industrial effluents.

2 DESCRIPTION OF THE STUDY AREA

2.1 General situation

The Southern Bight of the North Sea, about 30 km off the Belgian coast is characterized by a complex of parallel sandbanks (ridges), known as the "Hinder Banks" (Fig. 1). They are separated from the "Flemish Banks" by a narrow depression used as a navigation channel to Zeebrugge and the Western Scheldt. The "Hinder Banks" form an angle of about 30° with the nearby "Zeeland Banks".

The Hinder Banks run from south-south-west to north-north-east. They are 17-30 km long, separated by channels 3-7 km wide, and rise about 25-30 meters above the surrounding seabed. The banks are isolated quaternary sand-bodies of glacial origin in immediate contact with a sub-layer of tertiary clay (Houbolt, 1968; Bastin, 1974).

The new dumping area, covering 300 km^2, incorporates two banks (Oosthinder and Bligh Bank) and is flanked by the West- and Noordhinder banks to the west and by the Thornton bank (a so-called "Zeeland Bank") to the south. There are no sand-banks to the north or to the east.

The disposed effluents include waste from the production of titaniumdioxide (about 6 10^5 tonnes/year), thiocarbamate (about 2 10^3 tonnes/year) and aniline (about 2.5 10^3 tonnes/year).

2.2 Hydrodynamic features

The North Sea is a tidal basin with a complex hydrodynamic pattern produced by the interaction of three tidal waves. The Southern Bight, however, is influenced by only two of these waves: one coming from the south, entering the North Sea through the English Channel, and another from the north, running along the Scottish coast and the Shetland Islands (Laevastu, 1963; Houbolt, 1968; Nio and Nelson, 1982).

These tidal waves create a complex pattern of net sand and water transport. Tidal transport vectors alternate between north-east and south-west (Gullentops et al, 1977; Johnson et al, 1981), and residual velocity is to the north-east. As a result effluents and fines (e.g. mud, organic matter) are moved along the coast of the Netherlands and Germany to the central part of the North Sea, at an average speed of 0.05 $m.s^{-1}$ under calm weather conditions (Nihoul and Runfola, 1980; Moens, 1974; Mommaerts and D'Hondt, 1986).

Simulation models involving waste dispersion showed that hydrodynamics at the new disposal site are likely to create much more favorable conditions for the dispersion of dumped waste as opposed to any other site on the Belgian continental shelf (Nihoul, 1974; Ronday, 1976; Nihoul and Runfola, 1980; Mommaerts and D'Hondt, 1986).

2.3 Superficial sediments and topography

Superficial sediments mainly consist of median quaternary quartz sand with a small coarse sand fraction. The gravel content is strikingly high in the valleys between the sand banks, especially in the western part of the area (Fairy Bank). The extremely low mud and organic matter contents show that, in general, current energy on the sea-bed is sufficiently high to prevent permanent deposition (Gullentops, 1974; Maertens, 1987).

Houbolt (1968) reported marked geographical differences in the topography of the sea-bed. To the north and west the sand banks are bordered by a more or less flat sea-bed. The swales between the banks and the eastern part of the area are covered with asymmetrical mega-ripples. These extensive transverse mega-ripples indicate the existence of a regular sand transport system corresponding to rand sediment renewal and a high sedimentation rate. Previous work (Maertens, 1987) in the eastern part also discovered a vast sandwave field of 2-9 meters high sandwaves, at regular distances of about 150 meters.

2.4 <u>Benthic and dermersal fish communities.</u>

Prior to the seventies no analyses of the epibenthic or demersal fish communities were made in the Hinder Bank area. The only investigation on this subject was merely faunistic and covered a more inshore area (Leloup and Gilis, 1965a,b). From 1973 to 1978, however, an irregular sampling programme at six stations along the West Hinder bank was carried out by Redant (personal communication), revealing a poor community with a peculiar faunistic composition.

Since 1978 a regular monitoring programme has been prosecuted at three sampling stations east of the Bligh Bank (Maertens, 1980, 1982, 1983; Maertens and Vanhee, 1985; Maertens, 1987). Macro- and epibenthic fauna and demersal fish in this area belong to the same community. In general, however, species were distributed sparsely and in low numbers. *Pagurus bernhardus* and *Asterias rubens* were more abundant than *Macropipus holsatus*, *Crangon crangon*, *Ophiura texturata*, *Ophiura albida* and *Spisula solida*. All other epibenthic species occurred in very small numbers. Among fishes, no clear dominant species could be identified, although *Trachinus vipera*, *Callionymus lyra, Sprattus sprattus, Trisopterus luscus* and *Ammodytes lancea* frequently showed seasonal dominance (Maertens, 1987).

3 MATERIALS AND METHODS

3.1. Sampling

(i) Sampling grid. Since residual currents sweep the disposed effluents to the north-east any long-range impact of the dumping actions could be expected to occur mainly into that direction. Therefore four sampling stations (Table 1 and Fig. 2 : 440, 545, 640 and 800) were chosen to the north-east of the dumping site on the continental shelf of the

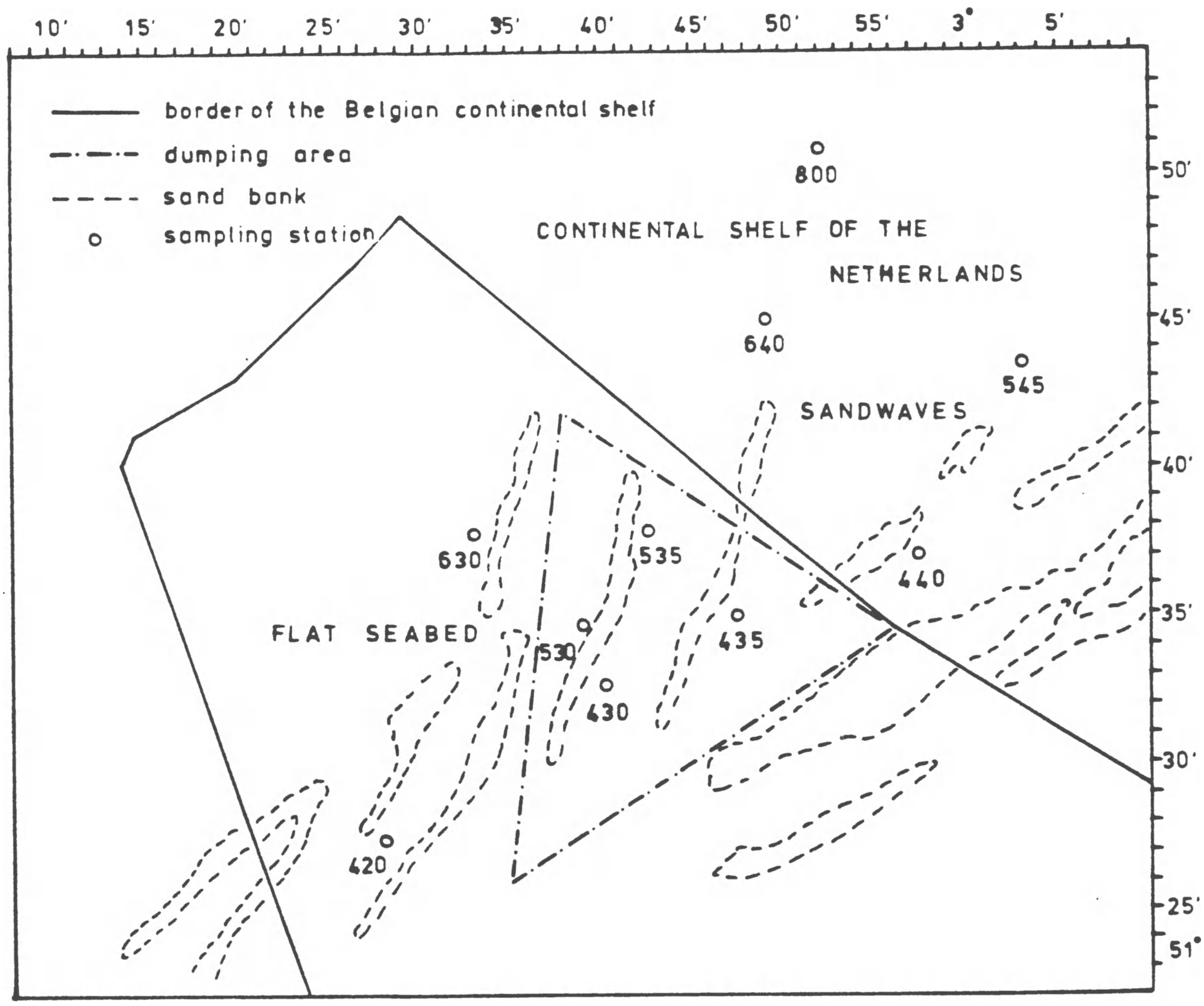

Figure 2. Sampling grid for the assessment of the effects of industrial effluents disposed on the Belgian continental shelf.

Netherlands. Four other stations (430, 435, 530 and 535) were situated within the dumping area, where immediate contact with the waste was likely. Finally two sampling stations were chosen to the north-east of the disposal site (420 and 630), in an area which was presumed not to be affected by waste disposal.

The extension of the sampling grid was sufficient to monitor and eventually to predict long-term effects, because of the overall similarity of the biotopes in the area (Houbolt, 1968; Moens, 1974; Gullentops, 1974; Nihoul and Runfola, 1980; Maertens and Vanhee, 1985; Mommaerts and D'Hondt, 1986; Maertens, 1987).

(ii) Sampling equipment. Sea-bed topography was recorded by a Furuno echosounder (FE 824) and a Furuno color video sounder (FCV 121).

Sediment samples were taken with a modified Van Veen grab (weight about 65 kg; surface sampled 0.1 m^2).

Demersal fish and epibenthic fauna were captured by a small meshed 8 meter beam trawl (20 mm mesh at the cod-end) (Maertens, 1988a).

Automatic data acquisition and processing of physical, chemical, meteorological and navigational parameters were done by a Hewlett Packard mainframe (1000, model 21 MXF).

(iii) Sampling frequency. As a rule routine sampling was carried out every year in March and September. Additional samples were taken at the "hot spot" biotopes, which were monitored four times a year.

Routine sampling as described above failed in 1985 and 1986 due to major technical and co-ordination problems. The trawling, in particular, produced poor results, and as a consequence only part of the sampling grid could be fully monitored in these years.

3.2. Analysis

(i) Sediments. Sediment samples for macrobenthos analysis were preserved with a 10% formaldehyde solution in seawater and stained with 0.1% eosine to facilitate subsequent sorting by microscope. Sediment was washed through a 1 mm sieve to separate organisms from the sand fraction. Organisms were classified by taxonomical groups to determine abundance and wet weight.

Gravel and mud content were measured by sieving the sediment through a 2000 µm (dry sieving) and a 63 µm sieve (wet sieving). After elimination of the gravel and mud, approximately 20 g of the remaining sediment was divided into fractions using Buchanan and Kain's method (1971) and classified according to the Wentworth (1922) scale. Organic matter was determined by loss of weight on ignition at 450 °C (Walkley and Black, 1934 ; J.M.G., 1981) and carbonate ($CaCO_3$) by loss of weight (CO_2) at 1050 °C (J.M.G., 1981).

(ii) Community structure. Basic laboratory analysis included identification of all species and length measurements of the fishes. Densities were converted to comparable surface areas (10^5 m^2).

Relative abundance data were used to calculate ranking classifications, which give an idea of the dominance and the distribution of each species. For this purpose a modification of Spearman's ranking method was elaborated.

Community structure was analyzed using several disturbance indices (Maertens, 1988b). Species diversity was calculated from Shannon and Weaver's (1949) formula. Sørensen's (1948) association coefficient was used to compare stations over periods of time and to define spatial similarities. In a preliminary evaluation (Maertens, 1987) community affinities were clustered using a proportional linkage strategy (Sokal and Michener, 1958) based on similarity indices (Légendre and Légendre, 1979). Further clustering techniques, based on species abundance and using the Lance and Williams' (1966) distance between values. Two strategies, nl. complete linkage and Ward's method (1963), were found to yield satisfactory dendograms.

4 RESULTS AND DISCUSSION

4.1 Sea-bed topography

A major difference in sea-bed topography was found between the sandbank area and the area North and East of the Bligh Bank.

Although Houbolt (1968) reported mega-ripples in the swales between the banks, the sea-bed appeared to be more or less flat. At the approach of the banks sandwaves could be detected as a sub-structure of the banks' slope. On a few occasions echograms showed sandwaves at station 530, especially when sampling was carried out close to the Oosthinder bank. Topographical sketching at sampling stations 420, 430, 530, 535 and 630 (Fig. 3) most often revealed small pits, slopes, mega-ripples and a single sandwave-like structure.

The sea-bed in the northern and eastern part was covered

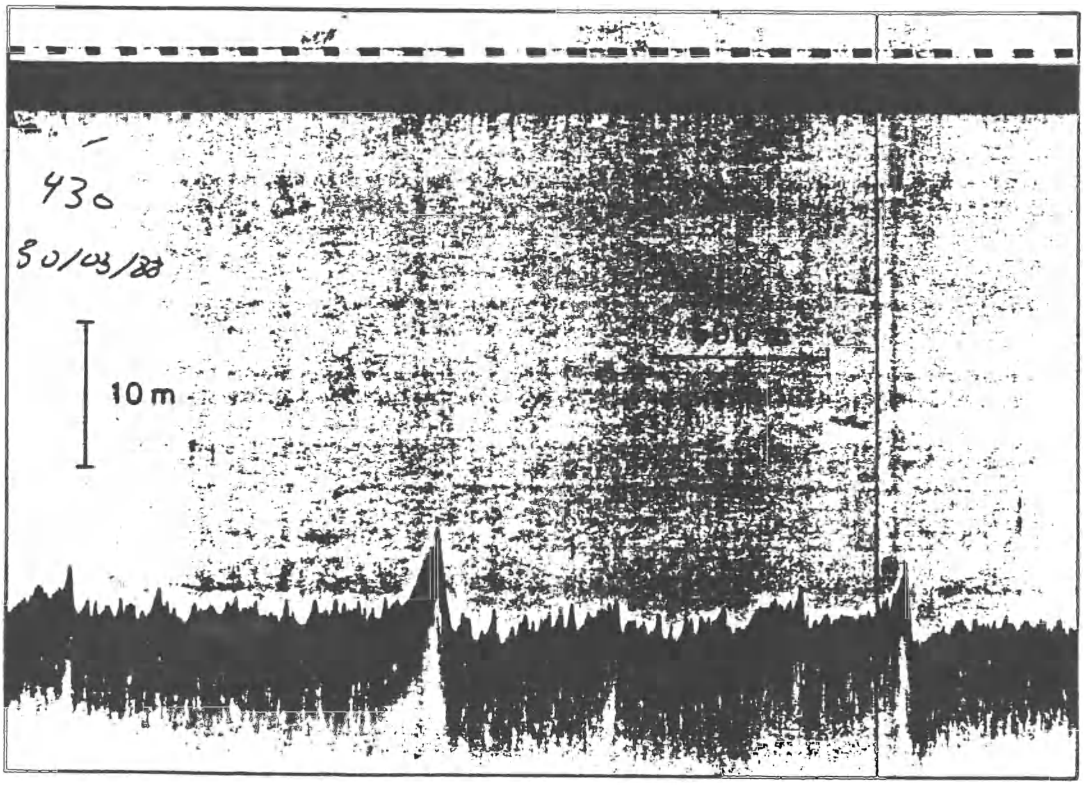

Fig. 3. Echogram of the sea-bed (station 430) of the disposal site on the Belgian continental shelf.

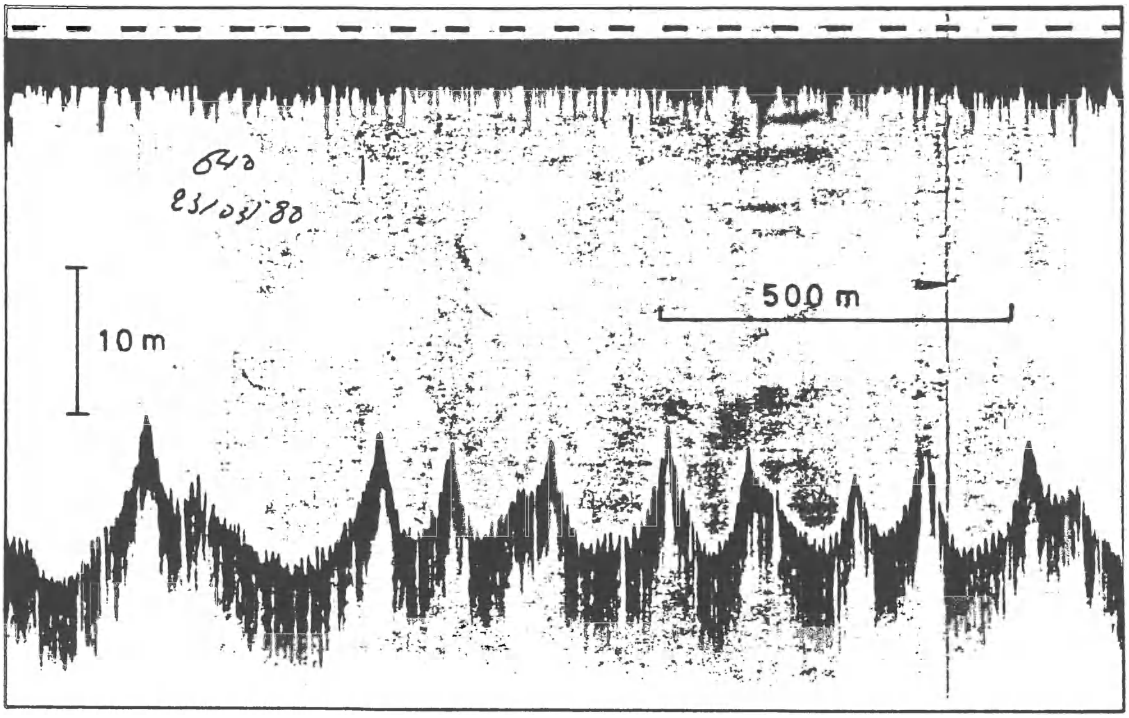

Fig. 4. Echogram of the sea-bed (station 640) in the sand-wave area.

with sandwaves. At stations 435 and 440 sandwaves lined at regular distance of 150-200 metres, some of them rising almost 10 metres above the sea-bed. This structure already was discribed in previous work (Maertens, 1987). At stations 545, 640 and 800 an irregular pattern of alternating high and small sandwaves was discovered (Fig. 4). Most of these were asymmetrical, with the steeper slope to the south. All sand-waves were covered with mega-ripples. Echograms resembled those recorded by Houbolt (1968). This sandwave field covers a vast area on the Dutch continental shelf.

4.2 Superficial sediment

As for sea-bed topography (see section 4.1) sampling stations can be divided into two groups on the basis of grain size and carbonate content (Table 1). Moderately sorted median sand was the largest sediment fraction in the whole area : less than 70 %, on average, of the sediment in the flat sea-bed dumping site area (Fig. 5) and more than 70 % in the sandwave sampling site (Fig. 6). In the former area about 30 % of the sediment was coarser than 500 µm, especially at sampling stations 420 (34 %), 530 (37 %) and 630 (36 %).

According to Houbolt (1968) and Veenstra (1964) the coarse gravel occurring in the swales between the sandbanks in the dumping area consists of "flint", not rounded enough to be considered as beach gravel. Very often organisms were found to be attached to only one side of the pebbles, indicating that these are not currently being displaced.

Gullentops (1974) reported a definite trend in the gravel content from the north-east (no gravel) to the south-west (high gravel percentages). The gravel content in the former area (stations 435, 440, 545 and 640) was less than 2 % (Table 1). Fig. 5 and 6 show the difference in median sand and the coarse fraction at the disposal site and in the sandwave area.

All over the area the average mud fraction (< 63 µm) was

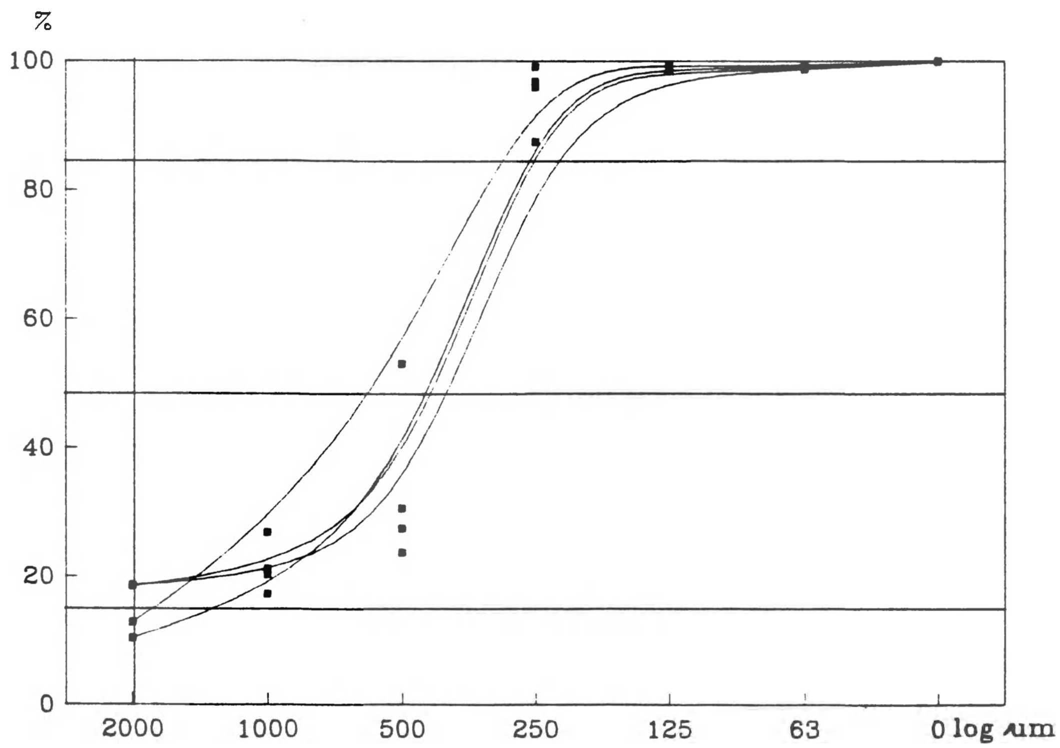

Figure 5. Cumulative grain size analysis of the sediment of station 420 (flat sea-bed dumping site area).

extremely low (about 1 %) and the organic matter content never exceeded 1%. These low values were already mentioned by Gullentops (1974), and by Baeteman et al. (1987) and in previous work (Maertens, 1987).

The carbonate content closely reflects variations in the coarse fraction. Sediments with a small coarse fraction (sandwave area) contained only about 5 % carbonate, whereas sediments in the dumping area sometimes contained more than 20 % carbonate (420 : 20 %, October 1987 ; 430 : 30 %, November 1986 ; 530 : 21 %, September 1985 and 1986 ; 30 %, November 1986). Station 435 in the eastern part of the dumping area, is located in a transitional sediment zone, with a higher amount of coarse sand a and higher carbonate content (Table 1) than at the other sandwave area stations.

The observed carbonate levels agree with those reported in previous studies on this area: 4.5-12.5 % (Bastin, 1974); > 12 % in the south and < 4 % in the north (Gullentops, 1974); 4.2-8.9 % in the north (Maertens, 1987); 11.6-23.8 %

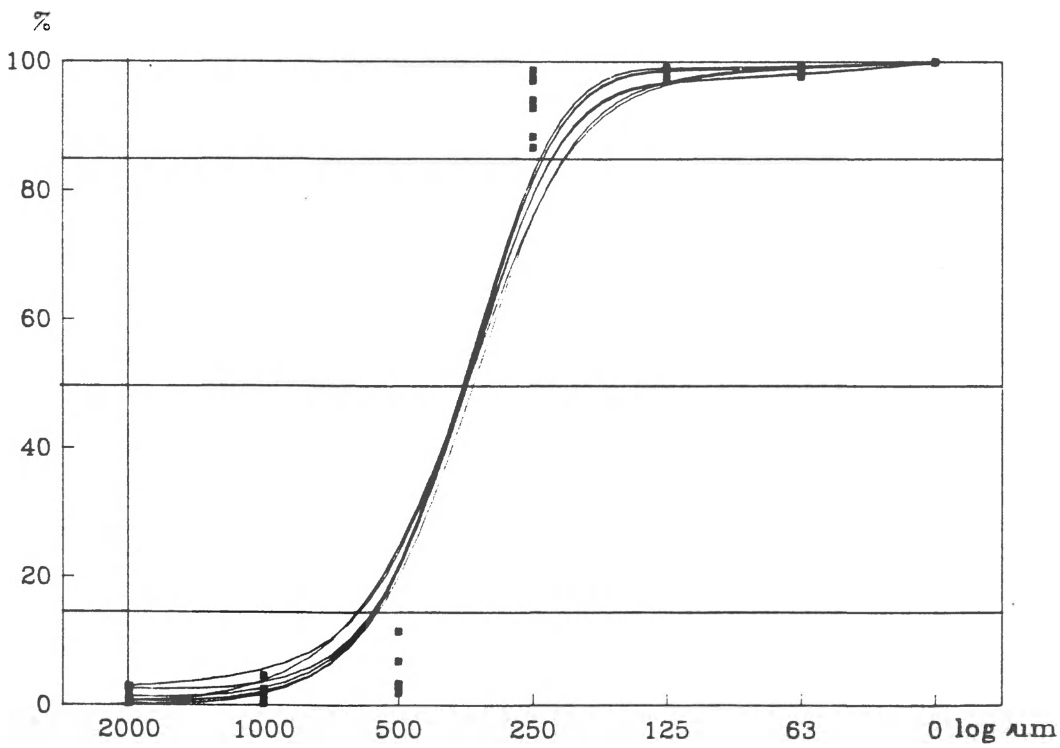

Figure 6. Cumulative grain size analysis of the sediment at station 440 (sandwave area).

in the south and 3.9-14.2 % in the north (Baeteman, 1987). The higher values recorded by Baeteman can be explained by methodological differences. Baeteman analyzed the sediment as a whole, whereas the other authors measured carbonate content on the fraction < 2 mm only.

4.3 Epibenthic and demersal fish assemblages

As already mentioned, the results obtained by trawling should be considered as being preliminary, due to incomplete

TABLE 1

Physical and chemical properties of the sediment in the new dumping are on the Belgian continental shelf (1985-1988).

Sampling station	Co-ordinates	Number of samples	Grain size analysis (%) < 63 µm	63 - 2000 µm	> 2 mm	Org. matter (%)	$CaCO_3$ (%)
420	51°27.30 N 02°28.50 E	4	1.0	median sand (61) coarse sand (12)	15.0	0.66	13.63
430	51°32.40 N 02°40.30 E	8	1.0	median sand (64) coarse sand (16)	7.4	0.46	9.59
435	51°34.84 N 02°47.42 E	7	0.9	median sand (76) coarse sand (16)	1.5	0.38	7.62
440	51°37.10 N 02°57.30 E	7	1.2	median sand (89)	1.3	0.36	4.68
530	51°34.40 N 02°39.10 E	8	0.8	median sand (55) coarse sand (15)	13.2	0.74	17.30
535	51°37.70 N 02°42.60 E	6	1.0	median sand (67) coarse sand (21)	2.7	0.49	8.57
545	51°43.60 N 03°03.00 e	5	1.0	median sand (81) coarse sand (10)	1.4	0.29	3.73
630	51°37.50 N 02°33.00 E	7	1.0	median sand (61) coarse sand (19)	14.3	0.40	6:05
640	51°45.00 N 02°49.00 E	7	0.9	median sand (88)	0.7	0.35	3.99
800	51°50.83 N 02°52.00 E	7	1.1	median sand (71) coarse sand (14)	9.1	0.33	5.22

sampling of the proposed sampling grid. From sampling station 420 e.g. no data were available at all. The sea-bed at this station is covered with big stones (blocs), which continued damaging the fishing gear to such an extent that the catch was lost. Throughout the investigations minor changes in the location of several sampling stations appeared to be necessary to prevent damaging of the fishing gear.

(i) Epibenthic community structure. More than 95 % in numbers of the epibenthic organisms were Crustaceans (48 %), Echinoderms (28 %) and Molluscs (21 %). Overall abundance never exceeded 3 000 individuals per 10^5 m^2, except for some large catches of *Spisula solida* (N = 6 700, September 1985) and *Crangon allmanni* (N = 6 700, October 1987) at station 430, and large numbers of *Alloteuthis subulata* (N = 1 500, October 1987) at station 435. Some stations yielded very low mean abundances (station 530 : 825 individuals and station 640 : 634 individuals).

More than 60 species were identified, out of which *Pagurus bernhardus*, *Ophiura albida* (two ubiquitous species), *Spisula solida*, *Spisula elliptica* and *Asterias rubens* were common (Table 2). These five species largely accounted for the low diversity of the community. The Shannon diversity index never exceeded 2.20, except for station 440 in September 1986 (2.41 for 20 species). The lowest value (1.16) was recorded at station 640 in March 1985 (only 9 species).

Rare species were found on several stations : *Atelecyclus septemdentatus* at station 630, *Ebalia spp.* and *Corystes cassivelaunus* at station 440, and *Spatangus purpureus*, *Pandalina brevirostris*, *Hippolyte varians* and *Processa spp* at station 430. *Neopentadactylo mixta*, a new species for Belgium, was caught in summer 1986 at station 430.

The average species number was slightly lower in the sandwave area (16) than in the dumping site area (19). On average 21 species were caught at stations 430 and 630.

No significant differences in species composition, attributable to differences in sediment composition between the two sampling areas could be detected, although *Spisula solida, Psammechinus miliaris* and *Pontophilus trispinosus* were more abundant in the dumping site area, while *Spisula elliptica, Alloteuthis subulata, Macropipus holsatus* and *Macropodia rostrata* ranked higher in the sandwave area (Table 2).

TABLE 2

Ranking of common epibenthic species by occurrence and abundance in the dumping site area (11 samples) and the sandwave area (17 samples).

DUMPING SITE AREA			SANDWAVE AREA		
Species	Rank number	% Occ.	Species	Rank number	% Occ.
Pagurus bernhardus	2.00	100	Pagurus bernhardus	2.41	100
Ophiura albida	4.27	100	Ophiura albida	2.53	100
Spisula solida	4.45	91	Spisula elliptica	5.47	100
Asterias rubens	5.00	100	Asterias rubens	6.71	94
Psammechinus miliaris	6.64	82	Spisula solida	8.29	88
Crangon allmanni	6.91	82	Crangon allmanni	8.41	82
Spisula ellipica	7.45	91	Alloteuthis subulata	8.53	71
Anthozoa spp.	8.18	100	Anthozoa spp.	9.06	88
Pontophilus trispinosus	10.27	73	Macropipus h. holsatus	9.12	71
Crangon crangon	11.36	82	Crangon crangon	9.59	71
Alloteuthis subulata	12.09	73	Macropodia rostrata	10.29	82
Hyas coarctatus	12.18	73	Ophiura texturata	10.76	71
Macropipus h. holsatus	12.36	64	Pontophilus trispinosus	10.88	71
Pandalus montagui	12.91	45	Psammechinus miliaris	12.18	53
Buccinum undatum	13.18	73	Macropipus h. marmoreus	12.35	53
Macropodia rostrata	13.45	73			

A difference in sea-bed structure between the two areas could be the reason for this. Cluster analysis based on the abundance of common species and using several strategies (complete linkage, centroid and Ward) revealed no consistent patterns among stations. There are, however, strong indications of seasonal clustering (spring 1985 and 1988, autumn 1985 and 1987).

(ii) Demersal fish community structure. The demersal fish community is characterized by the seasonal dominance of non-commercial species and by the relative scarcity of gadoids and pleuronectoids. No important commercial fish stocks or nursery grounds were found in the area. Commercial fish species (*Merlangius merlangus, Gadus morhua, Trisopterus luscus, Limanda limanda* and *Pleuronectes platessa*) represented less than 30 % of the total catch, the majority being *Limanda limanda*.

Total abundance never exceeded 2 000 individuals per 10^5 m^2, except for large catches of species belonging to the *Pomatoschistus complex* (*P. minutus* and *P. lozanoi*) at station 430 (N = 2 800 in October 1987). Very low overall abundance values were recorded at station 435 (432 individuals/10^5 m^2), station 530 (550), station 535 (421) and station 630 (250).

Only 29 species were identified in the course of this study. *Limanda limanda, Trachinus vipera*, the *Pomatoschistus* complex and *Callionymus lyra* were common but not ubiquitous. Occassionaly they repretented more than 90 % of the overall abundance (stations 430 and 435 in October 1987 and stations 530 and 640 in June 1986).

Due to the seasonal dominance of these species and the small species numbers observed during most surveys, diversity was rather low. The Shannon species diversity index only once exceeded 2.10, nl. at station 630 in March 1985 (2.24 for 12 species). A very low value was recorded at station 640 in March 1985 (0.69 for two species only).

Two rare species should be mentioned, nl. *Arnoglossus laterna* at station 430 (September 1985) and *Cyclopterus lumpus* at station 435 (September 1985).

Species numbers and composition were similar in the two sampling areas and varied from 2 at station 640 (March 1985) to 15 at station 430 (September 1985 and October 1987) with an overall average of 9.

Ranking of the most common species (Table 3) revealed no significant differences between the communities in the two areas. The major difference was for *Gadus morhua*, which ranked four numbers lower in the sandwave area than in the dumping site area. *Trisopterus luscus* was less important in the former area too. Community structure was not affected by the major differences in sea-bed morphology between the two areas.

TABLE 3

Ranking of common demersal fish by occurrence and abundance in the dumping site area (11 samples) and the sandwave area (17 samples).

DUMPING SITE AREA			SANDWAVE AREA		
Species	Rank number	% Occ.	Species	Rank number	% Occ.
Limanda limanda	3.36	100	Trachinus vipera	2.65	82
Pomatoschistus spp.	3.45	91	Limanda limanda	3.24	88
Trachinus vipera	3.64	91	Pomatoschistus spp.	4.29	88
Callionymus spp.	4.09	82	Callionymus spp.	4.35	76
Gadus morhua	5.64	82	Merlangius merlangus	5.65	76
Ammodytes lancea	6.00	73	Pleuronectes platessa	6.41	71
Merlangius merlangus	6.91	73	Ammodytes lancea	6.71	71
Trisopterus luscus	7.18	55	Trachurus trachurus	6.94	47
Pleuronectes platessa	7.18	73	Gadus morhua	7.00	65
Trachurus trachurus	7.45	45	Eutrigla gurnardus	7.94	35
Ammodytes lanceolatus	8.36	45	Trisopterus luscus	8.12	41
Eutrigla gurnardus	9.73	36	Ammodytes lanceolatus	8.18	53
Sprattus sprattus	9.73	27	Agonus cataphractus	8.82	18
Agonus cataphractus	9.82	27	Sprattus sprattus	8.88	24

Ward's clustering strategy revealed significant seasonal groupings of stations (Fig.7): cluster A comprises all stations sampled in March 1985, together with station 435 sampled in March 1988, cluster B all stations sampled in March 1988 (except for station 435), cluster C all samples taken in the summers of 1985 and 1986, and cluster D all autumn samples (1985-1987). The dissimilarity of the spring samples, being divided into two clearly different clusters, is striking. The main reason for this is supposed to be the lack of a routine sampling procedure during the March 1985 survey (cluster A), which may have affected the apparent community composition in that period. Therefore it seems preferable not to take these data into account in any further long-term monitoring studies or trend analysis.

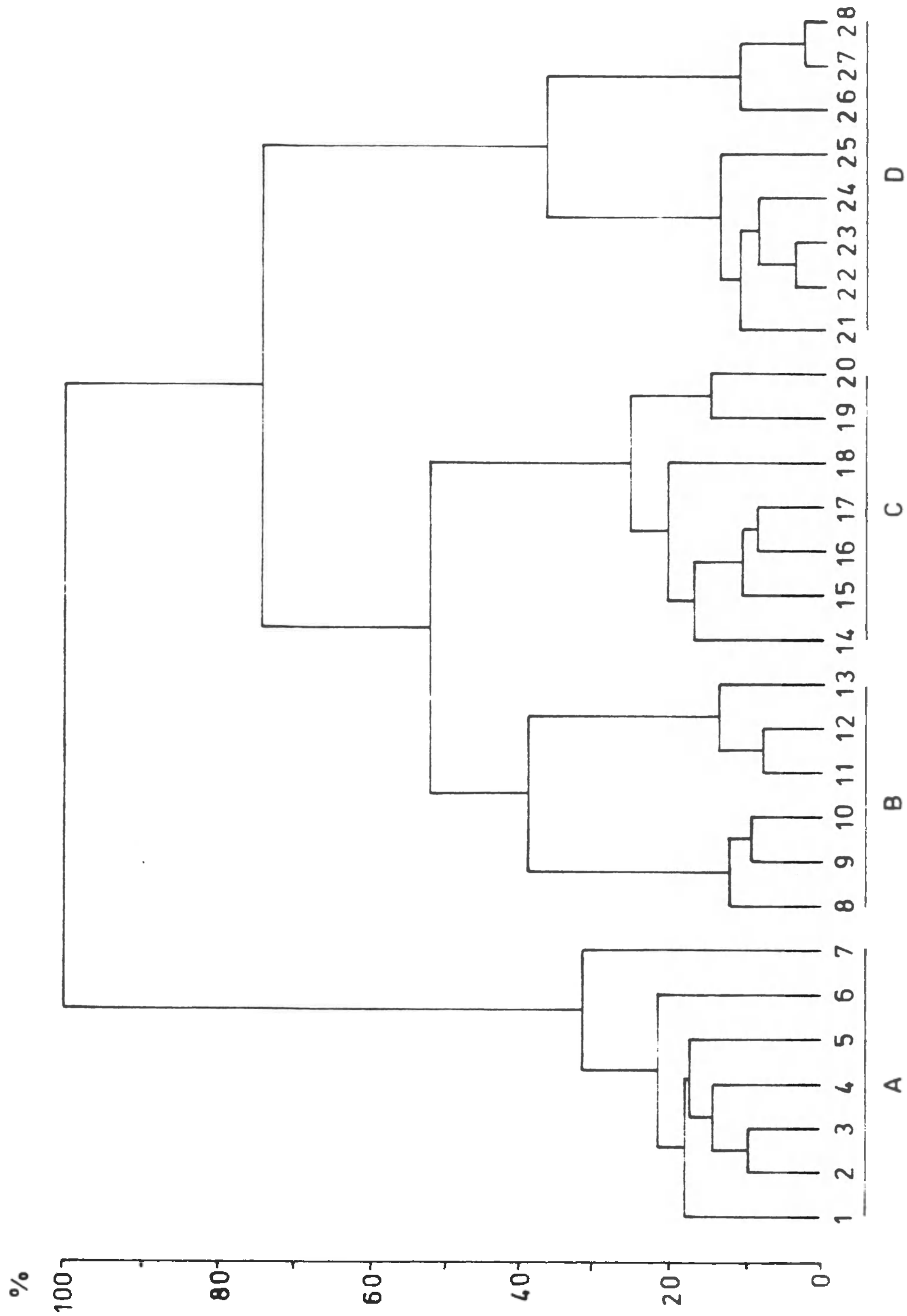

Figure 7. Cluster analysis of all samples (1985-1988) based on the abundance of ten most common demersal fish species.

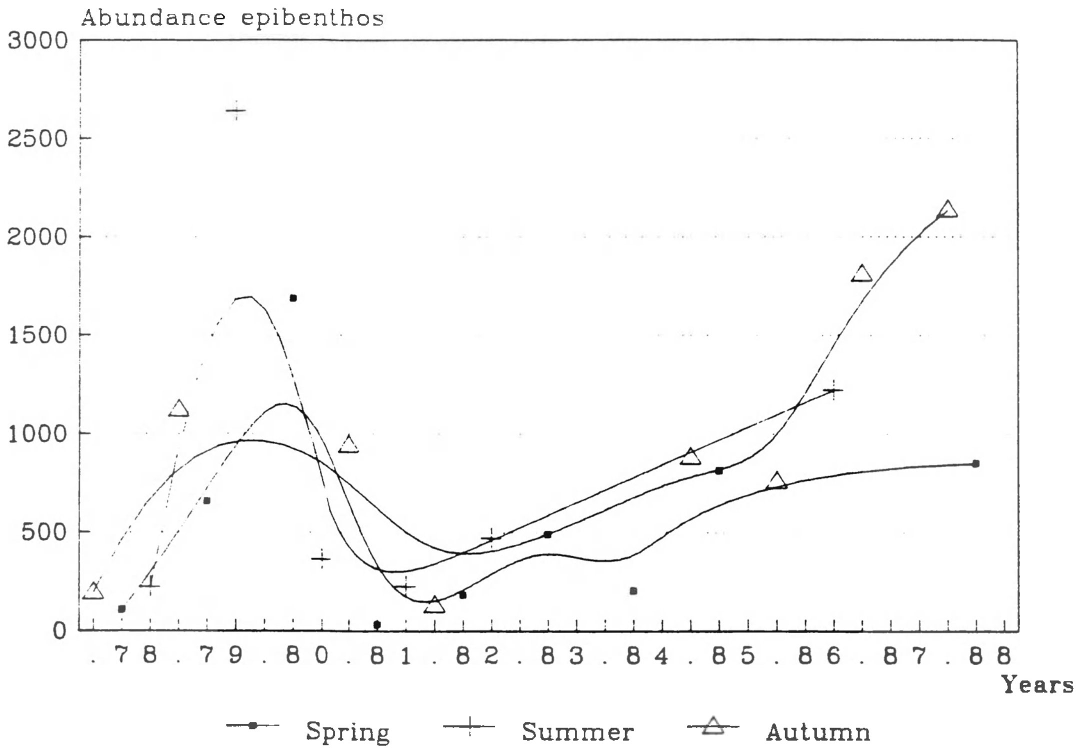

Figure 8. Total seasonal abundance of the epibenthic community at station 440.

4.4 Ten years ecological monitoring

Since 1978 two stations (435 and 440) of the present sampling grid have been monitored to assess the effects of the disposal of thio-carbamate waste material. A trend analysis of this ten years' study is discussed briefly.

As far as sea-bed morphology, granulometric properties, carbonate content and organic matter are concerned no major changes could be detected over the period 1977-1988.

An analysis of the abundance data for epibenthos and fish (Fig. 8 and 9) revealed a stable community structure, based on low overall densities. Total abundance of the epibentic community remained fairly stable with a short-term decline in 1981 and 1982. As a rule the abundance of the fish community was much higher in autumn than in spring and summer (Fig. 9). Total abundance of fish never exceeded 2 000 individuals/-10^5 m^2, except for station 440, sampled in March 1982, where a catch of 2 109 *Sprattus sprattus* accounted for a high overall abundance (2 180 individuals/10^5 m^2) and a low diversity value (0.19).

Exceptional catches of *Macropipus holsatus* on both stations (2 474 individuals at station 435 and 1 754 at station 440) in summer 1979 resulted in the highest abundance values ever recorded in that area. None of the other samples, throughout the period under review showed such high abundance values for *Macropipus holsatus* (maximum 400 individuals/ 10^5 m^2).

Due to the change in fishing gear in 1984 (from otter to beamtrawl) the apparent abundance values of several species suddenly changed. Since the vertical opening of the otter trawl was larger than that of the beamtrawl motile and semipelagic species were much more efficiently caught by the former method. As a result apparent abundances of gadoïd fishes have dropped since 1984, whereas those of *Pagurus bernhardus* (Fig. 10), *Trachinus vipera* and *Limanda limanda*

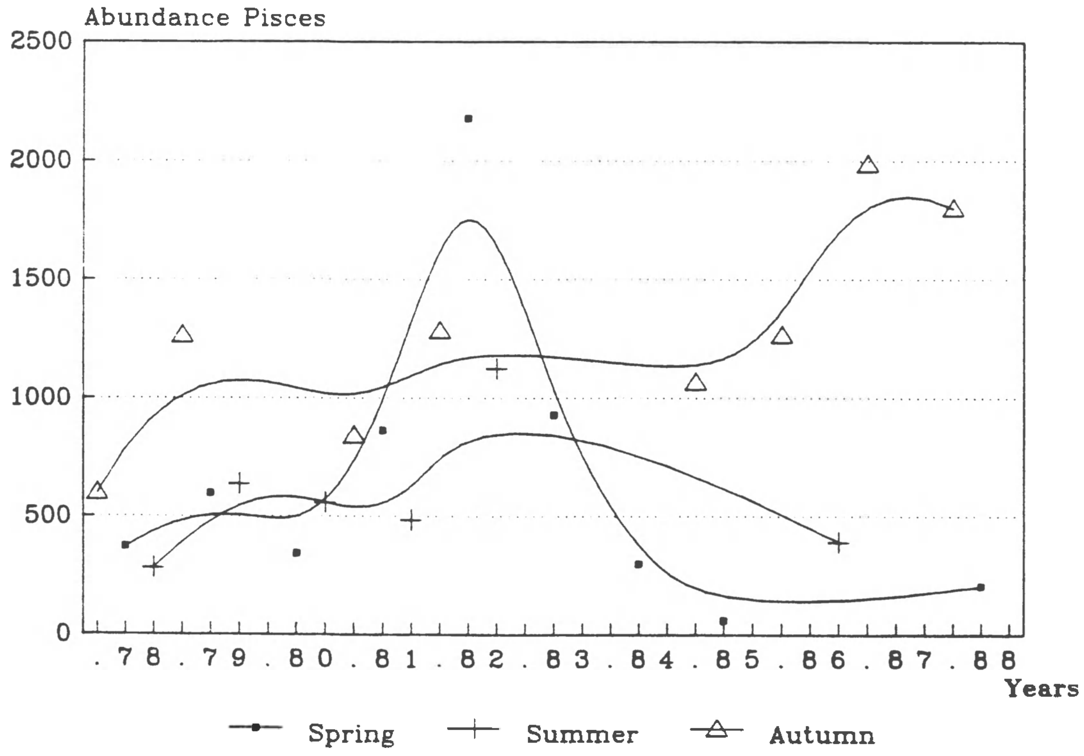

Figure 9. Total seasonal abundance of the demersal fish community at station 440.

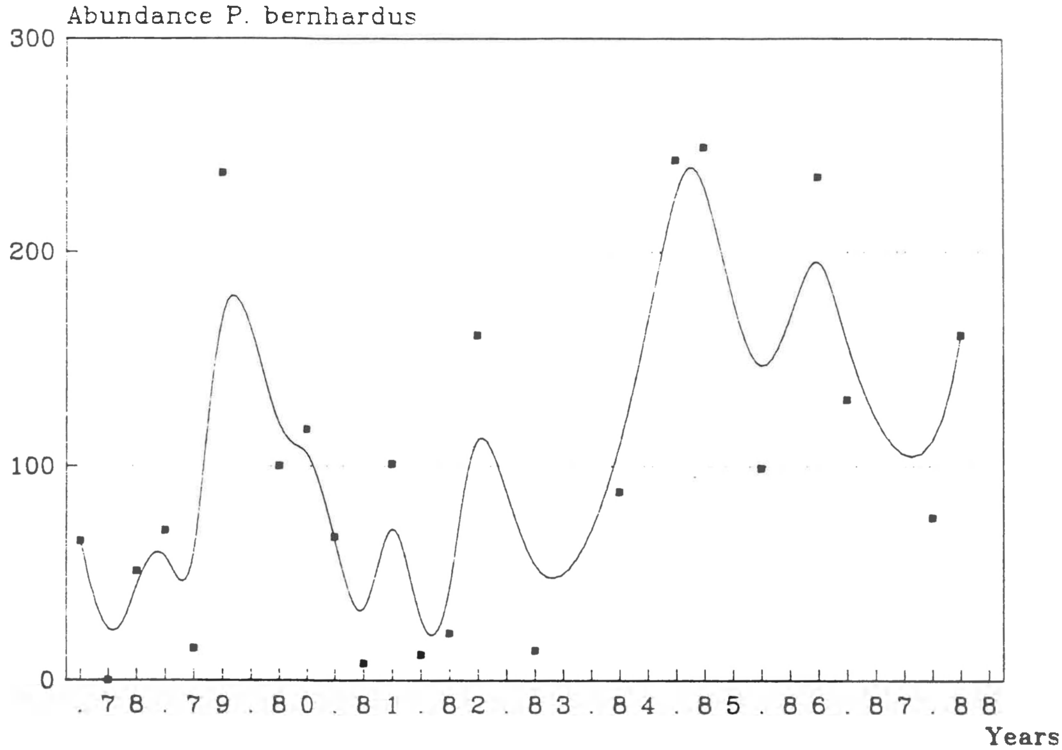

Figure 10. Abundance of *Pagurus bernhardus* at station 440.

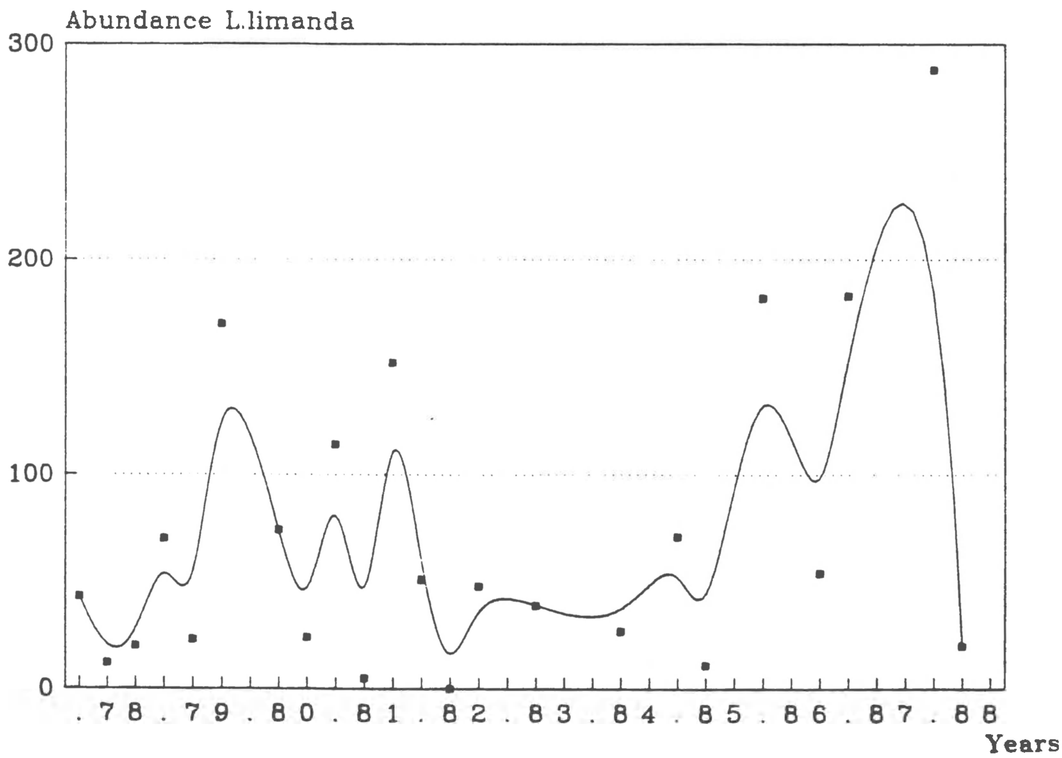

Figure 11. Abundance of *Limanda limanda* at station 440.

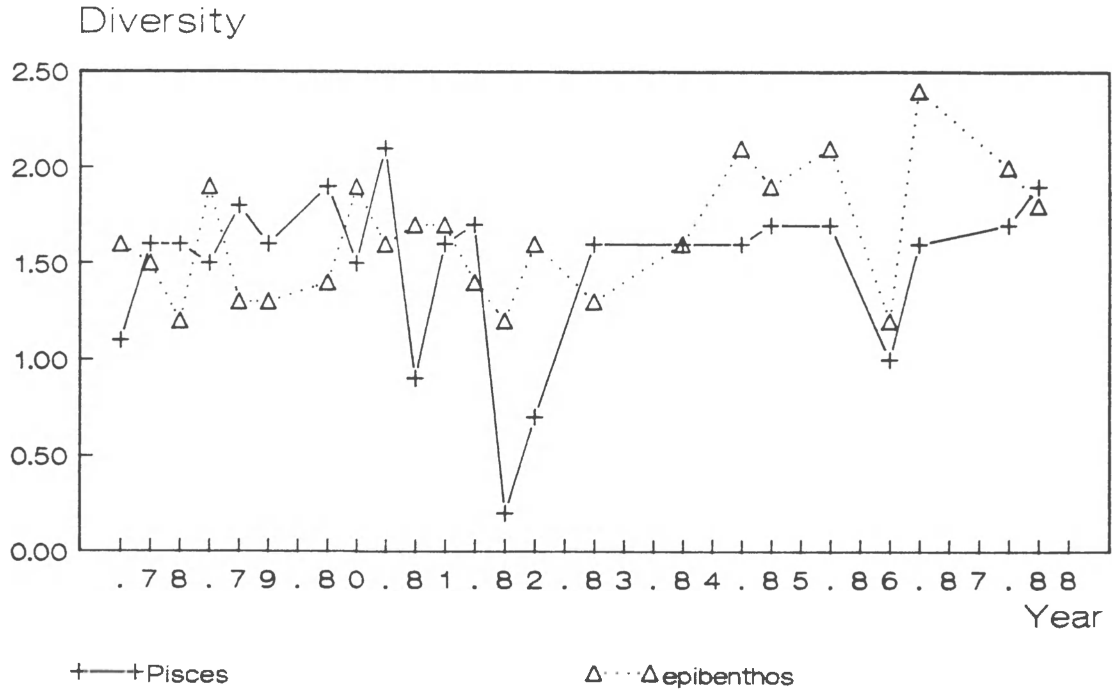

Figure 12. Trend in the Shannon species diversity index for the epibenthic and demersal fish community at station 440.

(Fig. 11) seem to have risen. Most species, however, remained more or less at the same abundance level.

Two species of *Spisula (S. solida* and *S. elliptica*), never caught before 1981, appeared in 1982 at both stations. This can not be explained by changes in the investigated environmental parameters, as no such changes were measured.
A similar boom was seen in a coastal dredging area, where the abundance of *Spisula subtruncata* reached one million individuals/10^5 m^2 in November 1985 (Maertens, in preparation). Most of these were pre-adults, with an average weight of 2.5 grams. Since this species prefers rather silty substrate the huge catches can possibly be explained by an increase in the dredging rate, exposing more mud over the area.

The diversity indices ranged from 1.0 to 2.0 (Fig. 12). Epibenthic species diversity seems to have risen since the introduction of the beam trawl as a sampling tool (1984), whereas demersal fish diversity remained at the same level. Species diversity for the fish community fell to very low values at station 440 in spring (0.19) and in summer (0.70)

1982 due to the dominance of *Sprattus sprattus* and *Ammodytes lancea* respectively.

5 CONCLUSIONS

In 1984 the Belgian Oceanographic Research vessel "Belgica" was launched. Trial fisheries were carried out in September 1984 and 1985. During these preliminary investigations a sampling procedure was marked out for 10 new sampling stations. Data had to be examined carefully, particularly those obtained by trawling, since abiotic, technical and antropogenic conditions changed markedly over the ensuing years. Fishery data from the March 1985 survey had to be excluded from further trend analysis because of the overall lack of conformity. Full-scale population and community analyses were not possible in 1985 and 1986 as a consequence of irregular and incomplete sampling.

Hydrodynamics and current velocity patterns in and around the dumping area prevented sedimentation of the disposed waste products. The almost complete absence of mud and organic matter in the sediment minimized accumulation.

The main reason for the poor development of the bentho-demersal communities in the area is the lack of nutrients in the water column and in the sediments. This appeared to be more effective in limiting their development than the differences in sea-bed morphology and the disposal of waste. The Seasonal appearance of certain species can be explained by natural fluctuations and migratory patterns. Only a few species seem to be able to subsist under these unfavorable nutritional conditions.

Station 430 can be mentioned as being the most diverse biotope, with the highest overall abundance values, exceptionally large catches and the appearance of rare species. There is as yet no evidence that this phenomenon is caused by peculiarities in the physical or chemical environment.

Over ten years of assessment no major changes in abiotic conditions or in benthic and demersal assemblages could be detected.

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