MINISTRY OF SMALL ENTERPRISES, TRADERS AND AGRICULTURE

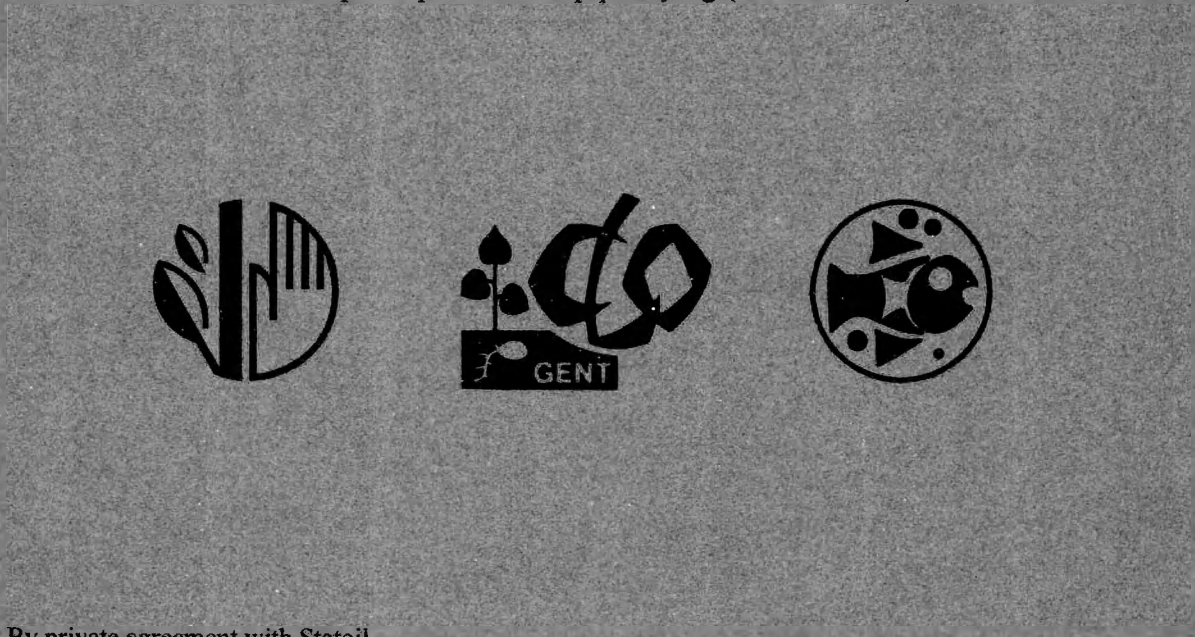
Agricultural Research Centre - Ghent

DEPARTMENT SEA FISHERIES

OSTEND

Environmental Impact Study in the framework of the construction of the NORFRA gas pipeline on the Belgian Continental Shelf

Second report : period after pipe laying (autumn 1997)



By private agreement with Statoil

Report - April 1999

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CONTENTS

SUMMARY

In autumn 1997, samples were taken along the trajectory of the NORFRA gas pipeline in the Belgian coastal waters of the North Sea. This second survey, carried out shortly after the construction works, was performed to assess the environmental impact of such an installation on the benthic and fish communities in the area. In addition to that, reference stations were chosen to monitor the environmental changes in more detail.

Density and species composition of the macro- and epibenthos as well as the fish populations were recorded. Furthermore sediment characteristics were determined for each sampled pipeline station.

In total 77 macrobenthos species were found, half of them polychaetes, with an average density of 573 ind./m^2 per sampled station. The average density along the pipeline trajectory was considerably lower than those from the reference sampling sites.

The epibenthos communities ranged from 1594 ind./10^5m^2 to 48,798 ind./10^5m^2 and were dominated by *Ophiura* species (brittle stars), with high densities near the sandbanks. The flying crab (*Liocarcinus holsatus*) reached very high biomass values in the reference stations (up to 214,688 g/10^5m^2).

The fish densities in the different observed areas varied from 814 ind./10^5m^2 to 11,806 ind./10^5m^2. The most common ones were sand gobies (*Pomatoschistus* spec.), dab (*Limanda limanda*), lesser weever (*Trachurus vipera*), dragonet (*Callionymus lyra*) and bib (*Trisopterus* spec.). The fish communities near the sandbanks were in general more divers.

This second report is, like the first one, to be considered as a basis for later comparison with results of the final survey, which will be carried out one year after the completion of the works, i.e. in the fall of 1998.

1. INTRODUCTION

In compliance with the Oslo and Paris Conventions the Fisheries Research Station evaluates the quality of the marine environment and the possible harmful effects of the laying of pipelines, dumping of dredge spoils and sand extraction.

This research includes biological, granulometric and chemical studies. Three periods of sampling will be carried out: before, during and after the execution of the NORFRA project. In addition underwater TV video recordings will take place to monitor the position and the condition of the pipe. The end of the research is scheduled for 1998.

This second of three reports presents the results of:

- the second survey, done in autumn 1997, of the biotic environment along the trajectory of the planned pipeline, just after the installation.
- previous campaigns, done in the framework of the ongoing biomonitoring projects as reference.

2. MATERIAL AND METHODS

All sampling programmes were carried out on board of the Belgian oceanographic research vessel A.962 'R.V. BELGICA'. Additional fish samples were taken with the training vessel 'Broodwinner'. The grids of the sampling cruises are shown in figures 1 to 3. The geographical positions, the sampling periods and the type of area of the sampling stations are summarised in tables 1 to 3.

2.1. Sampling and sorting

2.1.1. Macrobenthos

Eight sites (NF1-NF6, 315 and 435) along the pipeline trajectory were chosen for monitoring, of which each 3 replicates were taken for macrobenthic analysis. Due to a rocky underground no representative samples could be taken at stations NF1 and NF2.

In order to compare our findings with other macrobenthic data, 5 other sampling stations were considered as reference (120, 140, ZG02, H5 and H6). These stations are scattered all over the Belgian Continental Shelf. Twice a year—once in spring and once in autumn—ten replicate samples of each station are analysed in the framework of a biomonitoring project. Here in this survey only the ones taken in autumn '97 were considered.

Van Veen grabs were used at all these sampling stations with a surface sample of 0.1 m^2. The samples were stored in individual recipients and preserved in a 10% formaldehyde-seawater solution. In the laboratory the sediment was washed through a 1 mm sieve to collect the macrobenthic fauna. After sieving, the residue of the macrobenthos was stained with 0.1% eosin to facilitate subsequent sorting by microscope and identification to species level.

Total number of species, diversity and dominance were determined.

2.1.2. Epibenthos

Fifteen sites on the Belgian Continental Shelf, of which 8 lay in the vicinity of the pipeline, were chosen as sampling stations, investigating the changes in epibenthic populations. Stations NF1 en NF2 could not be sampled due to bad weather conditions. Besides that, the presence of big rocks, at these sites, also caused many difficulties for sampling. Therefore a selection was made of four sampling sites from the biomonitoring projects, which lay near the pipeline (315, 435, H5 and H6). In addition to that, six complementary reference stations were also incorporated in the study (120, 140, 215, 340 and 230).

A small meshed 8 meter beam trawl with a 22 mm mesh size at the cod-end was used. The hauls took about 30 minutes. Automatic data acquisition of the ship's position enabled the exact swept surface to be calculated. For comparison, all data were then converted to a reference surface of $10^5 m^2$.

A representative sub-sample of 6 l was taken after determination of the total volume of the catch. Samples were deep frozen at -18°C on board and later sorted and identified in the laboratory. Total number of species, biomass (in g WetWeight/$10^5 m^2$) and diversity were determined.

2.1.3. Fish

Apart from the NF stations, 7 other sites from the biomonitoring projects, which lay near the pipeline or in its vicinity (215, 315, 340, 435, H4, H5 and H6) were also sampled. In addition to that, 3 complementary reference stations, near the coast, were also included in this survey (120, 140 and 230).

Another 12 stations, sampled during the period September '97, with the training vessel "029- Broodwinner" and 9 stations, sampled during August '97, with the oceanographic research vessel Belgica, were also considered in this study as reference.

An 8 meter and/or a 4 meter beam trawl with respectively 20 mm and 40 mm mesh size in the cod-end were used. The duration of each haul was 30 minutes, with a velocity of 4 knots. All data were converted to a reference surface of $10^5 m^2$.

Total number per species, diversity and length-distribution were measured.

2.2. Mathematical analysis

2.2.1. Diversity

Beside the species density (number of ind./10^5 m^2), the diversity of the benthic communities is calculated.

Diversity is a measure that takes into account the number of species and the relative abundance of those species. It is a parameter that characterises interspecific relationships, stability of the community and the complexity of the environment.

The diversity is represented by three variables:

- species richness (i.e. the number of species per sample)
- Shannon-Wiener index
- Simpson's index for dominance

↳**Shannon-Wiener's diversity index** (H') is calculated as follows:

$$H' = -\sum_{i=1}^{s} \frac{n_i}{N} \times \log_2\left(\frac{n_i}{N}\right)$$

with n_i = number of individuals of species I

N = total number of individuals

s = number of species

A high H' indicates a rich and diverse community.

↳**Simpson's dominance index** (SI) is calculated as follows:

$$SI = \sum_{i=1}^{s}\left(\frac{n_i}{N}\right)^2$$

with n_i = number of individuals of species I

N = total number of individuals

s = number of species

A high SI-value indicates a low diversity with one or more species being very dominant in the community.

2.3. Sediment analysis

The sediment sampling scheme exists of one Van Veen grab per site, stored in individual recipients and deep frozen at -18°C. The equipment used is a modified Van Veen grab with a weight of about 50 kg taking a surface sample of 0.1 m^2. The grab has heavier arms with improved level action. Gravel and mud content are 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 is divided into fractions, using Buchanan and Kain's method (1971) and classified according to the Wentworth (1992) scale. Total organic carbon content (TOC) is 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). Interstitial water content is calculated by subtracting the weight after drying the sample at 100°C, from the weight of the wet sample.

Wentworth scale:

Phi	Med. grainsize in µm	description
-1 - 0	1000-2000	very coarse sand
0 - 1	500-1000	coarse sand
1 - 2	250-500	medium coarse sand
2 - 3	125-250	fine sand
3 - 4	62.5-125	very fine sand
< 4	<62.5	silt

Sediment samples were taken only at the macrobenthic sampling stations.

3. RESULTS

3.1. Sediment

Sediment characteristics of sampling stations along the pipeline

Station	reference	Med. gr.	Med. gr. (µm)	grain fraction						
		(phi)	(µm)	>2000µm	<2000µm	<1000µm	<500µm	<250µm	<125µm	<63µm
NF1	Pipeline	1.5	345.0	0.81	0.89	4.23	82.36	10.49	0.11	1.11
NF2	Pipeline	1.2	435.5	35.80	2.48	3.57	40.92	13.64	0.83	2.77
NF3	Pipeline	1.4	383.5	28.04	1.21	2.79	46.92	20.05	0.28	0.71
NF4	Pipeline	1.6	342.3	0.06	0.01	0.33	90.71	7.93	0.04	0.91
NF5	Pipeline	1.6	322.9	0.10	0.31	6.34	68.58	23.46	0.18	1.05
NF6	Pipeline	1.5	353.2	4.78	0.47	5.16	78.96	9.70	0.13	0.79

(See figure 4.)

All sampled stations along the pipeline (NF1-NF6), were characterised by a sediment with phi values between 1-2, and a median grain size varying between 323 and 436 µm. The fractions 250-500 µm, which are defined, according to the Wentworth scale, as medium coarse sand, dominated the sediment in all stations. In NF2 and NF3 however there was a considerable amount of bigger particles (> 2000µm) present.

Generally, an increase in medium grain size was reported in nearly all samples sites (except NF5) compared to spring '97. Although these changes were not always as radical as in NF2, they show a clear tendency that the sediment samples were characterised by the larger fractions of particles. Whether this was a direct result of the works that coincided with the pipe laying, could not be determined. But the laying of the pipe and the preparation of the seabed (presweeping) might have caused at some stage some disturbances to the sediment.

When comparing the sediment types of reference stations for the last two years, clear changes were also observed. These changes were not the result of mechanic disturbances, but were probably caused by natural oceanographic processes. This made it difficult to assess, at this stage, how big the actual impact of the pipeline was on the bottom and in a next stage, on its biota.

The chemical characteristics (Organic material, Interstitial water, $CaCO_3$ and TOC content) of the sediment samples of the pipeline, also showed no clear changes in comparison with the initial situation (spring '97).

Chemical sediment characteristics (in %) along the pipeline

	Spring '97				Autumn '97			
	Org. mat.	**Int. H_2O**	**$CaCO_3$**	**TOC**	**Org. mat.**	**Int. H_2O**	**$CaCO_3$**	**TOC**
NF1	0.47	17.67	3.45	0.19	0.50	17.67	3.73	0.85
NF2	0.43	17.50	2.84	0.20	0.71	16.17	3.87	0.15
NF3	×	×	×	×	0.41	15.67	2.88	0.12
NF4	0.69	19.00	4.05	0.11	0.30	18.00	1.48	0.14
NF5	0.53	17.67	2.37	0.11	0.40	17.33	2.00	0.10
NF6	0.42	18.17	1.80	0.08	0.23	16.93	1.40	0.13

3.2. Macrobenthos

Benthos comprises all organisms living on or in the sediment. The term macrobenthos as used in this study, refers to the animal fraction of the benthos larger than 1 mm and living on or in the sediment. They represent a major component in the trofic organisation of the marine environment, as food for the epibenthic- and demersal fish communities. The major faunistic groups represented in these samples are bristle worms (Polychaeta), crustaceans (mostly sea hoppers, Amphipoda and cumaceans, Cumacea), molluscs (particularly bivalves, Bivalvia; and sea snails, Gastropoda) and echinoderms (particularly brittle stars, Ophiuroidea; and sea urchins, Echinoidea) (Fig. 5).

3.2.1. Density

Densities of the macrofauna, taken in autumn 1997 along the trajectory of the NORFRA pipeline, ranged from 89.8 ind./m² (NF6) to 753.3 ind./m² (NF4). The mean value was 388.1 ind./m². Nearly all of the sampling stations were dominated by polychaetes (>50% of the population). The four most common ones were the species : *Spiophanes bombyx, Spio* species, *Nephtys* species and *Poecilochaetus serpens*.

Spiophanes bombyx reached his highest density in NF4 (286.7 ind./m²) resulting in a dominance in the polychaet community. The *Spio* species were never dominant (except in NF5), but always present with a average density of 46.7 ind./m². The polychaetes species which occurred only once in the sampled pipeline stations were: *Aricidea suecica*, *Exogone hebes*, and *Travisia forbesii*.

The crustaceans, mainly amphipods from the genera *Bathyporeia* and *Urothoe*, were the most common species along the trajectory of the pipeline. They were always well represented but never dominated the macrobenthos community. Highest densities were reached in NF3 (66.7 ind./m²) and 435 (133.3 ind./m²). Rare species were *Leucothoe incisa*, *Scopelocheirus hopei* and *Stenothoe marina*.

For the remaining macrobenthos groups (echinoderms and molluscs), low densities were recorded, except for the juvenile echinoderm, *Ophiura* species (43.3 and 33.3 ind./m², in respectively stations NF3 and 315).

In the reference stations (120, 140, ZG02, H5 and H6), densities varied between 89.7 ind./m² (ZG02) and 2999.5 ind./m² (120). Similar to the pipeline stations there was a clear dominance of polychaetes. The macrobenthos community of station 140 consisted entirely out of two species of polychaetes (*Chaetozone setosa* and *Nephtys* species). Station H5 was however dominated by two amphipods (*Bathyporeia guilliamsoniana* and *Urothoe brevicornis*). They represented up to 66% of the total population density.

All basic data are listed in figure 6 and tables 4 & 5.

3.2.2. Diversity

A total of 77 species were found during autumn 1997. Of that total, 43 species were found along the pipeline. The Shannon-Wiener diversity index reached its highest value at the reference station 120 and the pipeline station 315 (respectively 4.34 & 4.26). Along the trajectory of the pipeline divers populations were recorded in all sampled sites (Fig. 6; Tab. 4). The mean number of species present near the pipeline exceeded even that of the reference stations. In one of the reference stations (140) however, there was a nearly 100% dominance of one polychaet. This resulted in a very low diversity.

General considerations

The overall macrobenthos densities, recorded in the autumn of 1997, from the two sampling areas (pipeline and reference) showed different trends. At the pipeline stations the total number of individuals per m^2 was lower than in the first survey, except in NF4 and in 435. The reference stations were all characterised by a increase of their total densities. This is not unusual if we take into account the recruitment that has taken place within the macrobenthic communities during the early summer until the beginning of autumn. The lower abundancies at the pipeline stations could coincide with the construction works that took place in late summer of '97.

Considerable differences in diversity between the two periods of sampling were reported. All of the pipeline stations and three reference stations revealed higher Shannon-Wiener indices in the second sampling campaign. Possible explanations for these phenomena will be discussed in the third and final report.

As a final consideration it is clear that in the case of such a single disturbance (e.g. the laying of a pipeline), it might be very difficult to assess the exact effect on the surrounding biota, especially in those areas where the variation in density and diversity is liable to natural processes. This is certainly the case in the areas around the sandbanks.

3.3. Epibenthos

The term epibenthos as used in this study, refers to the animal fraction of the large benthos living on the sediment. The major faunistic groups represented in these samples are sea anemones (Anthozoa), crustaceans (particularly crabs, Brachyura; hermit crabs, Paguridae; shrimps and prawns, Caridea), molluscs (mostly sea snails, Gastropoda; squid and cuttlefish, Cephalopoda), and echinoderms (mostly brittle stars, Ophiuroidea; and starfish, Asteroidea) (Fig. 7).

3.3.1. Density

The total abundancy of the epibenthos population, sampled during autumn 1997 along the pipeline, ranged from 2264 ind./10^5m^2 in NF6 to 7785 ind./10^5m^2 in NF3 (Tab. 7).

The most common species were *Ophiura* species (brittle stars); *Liocarcinus holsatus* (flying crab); *Asterias rubens* (starfish) and *Pagurus bernhardus* (hermit crab).

Their relative densities (in %) are shown in figures 8 and 9.

All the epibenthic communities were dominated by the echinoderms *Ophiura* species. The highest densities were found at stations near or in the vicinity of sandbanks (H5 & NF3). The *Ophiura* species are considered to be the most successful group of the living echinoderms ; they attribute this success in part to their motility, small size, and ability to utilize the protective cover of crevices, holes spaces beneath stones, and other natural retreats. Also *Asterias rubens* was a common known echinoderm species in our coastal waters. It lives mainly on sandy or muddy bottoms. Densities varied from 26 ind./10^5m^2 in NF5 up to 558 ind./10^5m^2 in 315.

Other important species that were regularly caught were the crustaceans *Liocarcinus holsatus* and *Pagurus bernhardus*. The flying crab, *Liocarcinus holsatus,* prefers clean sands to bury themselves in (Verwey, 1978). The highest concentrations were found near the pipeline stations NF3 and NF4. This crab species has the tendency of migrating every year from deeper water to the littoral zone as result of changing salinity/water temperature ratios (Adema, 1991).The scavenging hermit crabs reached their highest density in 315 & NF3.

The reference area was characterised by a similar epibenthos population, although some differences were noticed (Tab. 8). Both areas appeared to be dominated by the *Ophiura* species (respectively 66,4% and 60,3% of the total population). But taking only the separate stations into account showed that only stations 215 and 340 lived up to the latter. At the reference stations near the coast (120,140 and 230), the *Ophiura* species was hardly of not found in the samples.

The flying crab, *Liocarcinus holsatus,* reached very high densities in the reference stations during the second campaign (33,351 ind./10^5m^2).

The absence of *Anthozoa* species in the pipeline area was also striking. In the reference area this species was very common and abundantly present in all stations (except 340). Other species like *Pagurus bernhardus* and *Asterias rubens* were more abundant along the pipeline.

3.3.2. Biomass

The highest biomass along the pipeline track was recorded in station 315 (17,927 g ww/10^5m^2), the lowest in NF5 (5777 g ww/10^5m^2). The reference stations showed even higher biomass values in comparison with the pipeline stations (from 23,665 g ww/10^5m^2 in 140 to 73,382 g ww/10^5m^2 in 340).

Although the flying crabs (*Liocarcinus holsatus*) nearly always were outnumbered by the *Ophiura* species, their biomass was always considerably higher (39% of the entire epibenthos population near the pipeline). The same was true for the reference area , where the flying crab biomass reached up to 82% of the total population (Fig. 9).

The biomass of other important species, like Asterias rubens (starfish) and *Pagurus bernhardus* (hermit crab), were also considerably high in both sampled areas.

3.3.3. Diversity and dominance

A total of 22 epibenthos species were found in autumn 1997 at the different sampling stations of the pipeline. The Shannon-Wiener diversity index varied from 1.30 (315) to 2.09 (NF6). These values seem very low in comparison with the macrobenthos diversity.

A high density however does not necessarily correspond with a high diversity. The community is often dominated by one or more species and a fall of the diversity is the result.

In the reference area 14 different species were caught during the second campaign. The diversity index varied between 0.06 (140) and 1.96 (120). Stations 140 and 230 were both dominated by a large fraction of flying crabs (*Liocarcinus holsatus*).

A list of all species found during the autumn campaign can be found in table 6.

General considerations

The epibenthic populations caught in autumn differed considerably from those in spring, not only in their abundancy but also in their biomass and diversity. Nearly all sampling sites were characterised by larger and more diverse populations, with higher biomass values. Whether this phenomenon was the direct result of the construction of the NORFRA pipeline is doubtful, because the same density and biomass ratio's between both periods of sampling were reported in the reference stations.

In the following paragraphs a few feasible hypotheses are proposed :

- As most of the epibenthic species have the ability to move quickly and over greater distances than e.g. the macrobenthic species, the possibility exists that they temporarily left their territories due to the disturbances caused by the laying of the pipeline on the bottom of the seafloor bed.

After the completion of the works (thereby damaging the local flora and fauna), they recolonised the site and benefited from the greater food availability, that mainly consisted of dead macrobenthos and epibenthos species and resuspended organic material (detritus). In a following stage they reproduced, resulting in a large epibenthic community.

↳ Another possibility is that the local epibenthos community could not escape in time and was killed or damaged as the construction of the pipeline continued. In a second phase epibenthic species and demersal fish species from outside the construction area colonised the damaged area, feeding on the dead organic organisms. As the pipeline was completed in August and the samples were taken in September, it is possible that during that period a new population was reinstalled. That would also explain the higher diversity in the latter campaign.

3.4. Fish

3.4.1. Density

In the first campaign (spring '97) there were no fish catches at the specific pipeline stations (NF1-NF6). So the information concerning the fish stock around the trajectory of the NORFRA pipe was limited and thereby collected from other sampling sites in the vicinity of the pipeline track. In this second report however the NF stations along the pipeline were indeed sampled. So following four sampling areas could be considered :

- coastal area (stations 120, 140 and 230)
- western area (stations 215 and 315)
- eastern area (stations 435, 340, H4, H5 and H6)
- pipeline area (stations NF3-NF6)

The data retrieved from the coastal, western and eastern areas were referred to as reference (Fig. 10). All species names are mentioned in table 9.

In autumn 1997, the total density of the sampling sites varied between 814 ind./10^5m^2 (station 315) and 11,806 ind./10^5m^2 (station 230). The total amount of fish caught, equalled 64,187. The most common ones were sand gobies (*Pomatoschistus* species), lesser weever (*Trachurus vipera*), dab (*Limanda limanda*), dragonet (*Callionymus lyra*), bib (*Trisopterus* species), whiting (*Merlangius merlangus*) and plaice (*Pleuronectes platessa*). Practically all stations (pipeline and reference) are dominated by either one or several of these species.

By taking the average density of the different zones, a comparison in densities could be made. The coastal area represented the highest catches, followed by the eastern area. The pipeline area and the western area appeared to have comparable mean densities. (coastal: 6705 ind./10^5m^2; eastern area: 5245 ind./10^5m^2; western area: 2811 ind./10^5m^2 and pipeline area: 3048 ind./10^5m^2).

The coastal area was characterised by species like: *Anguilla anguilla*, *Ciliata mustela*, *Clupea harengus*, *Myoxocephalus scorpius*, *Pomatoschistus* spec., *Solea solea* and *Sygnatus* acus.

The eastern area, with many sandbanks, showed different species: *Hyppoglossoides platessoides*, *Limanda limanda*, *Mustelus mustelus*, *Trachurus trachurus*, *T. vipera* and *Trigla gurnardus*.

The pipeline area contained species from both coastal and eastern areas. As the pipeline lay along a depth gradient, following species showed a positive trend in their density along the pipeline track: *Callionymus lyra*, *Trachurus trachurus*, *T. vipera* and *Trigla gurnardus*. The opposite effect was noticed with *Pomatoschistus* spec.

3.4.2. Length-frequency of the commercial fish species

(Figs. 11-14)

(1). Coastal area

The plaice and common sole populations were clearly separated into a juvenile (around 10, with a max. of respectively 42 and 414 ind./10^5m^2) and a adult fraction (around 20 cm, with a maximum of resp. 126 and 56 ind./10^5m^2). Both populations were furthermore characterised by a small fraction of bigger species; up to 34 cm for the common sole. The whiting and cod catches consisted mainly out of semi-adult individuals. The whiting population reached its highest density at 18 cm. The cod distribution showed different maxima, but never exceeded 10 individuals. Finally a considerable juvenile fraction of dab, with a maximum of 304 ind./10^5m^2 around the 5 cm range, was recorded.

(2). Western area

In the western area the densities of commercial fish caught were considerable lower compared with the coastal area.

The dab population, caught near the western sandbanks, showed a clear juvenile, semi-adult and adult fractions in his length frequency distribution. High densities were only reported within the semi-adult fraction (maximum of 145 ind./10^5m^2, around 15 cm).

The other populations lacked on the one hand a juvenile or an adult fraction or on the other hand a clear distinction between the different age groups. The sole population, although only 24 individuals caught, reached a maximum of 12 ind./10^5m^2 around 20 cm. The whiting catches were also very low. Their length varied between 16 and 34 cm. The plaice population was characterised only by an adult fraction with 2 maxima of 40 ind./10^5m^2 around resp. 20 and 24 cm.

(3). Eastern area

All populations, except cod, showed clear length-frequency distributions. The abundant dab population reached its highest density (2069 ind./10^5m^2) around 6 cm. Besides a large juvenile fraction the dab population also consisted out of a smaller semi-adult and a minimal adult fraction. A comparable distribution was noted for plaice, with the difference that the semi-adult fraction was the most abundant one. The whiting and cod distribution were comparable with those described in the coastal area. The sole catches were generally low, with a small juvenile fraction but a clear adult fraction around 20 cm.

(4). Pipeline area

The pipe line area was characterised by low catches of commercial fish. Only dab was regularly caught and had therefor a distinct length-frequency distribution of a juvenile (max. 112 ind./10^5m^2 around 6 cm) and a semi-adult fraction (max. 109 ind./10^5m^2 around 15 cm). The sole, cod, whiting and plaice populations showed no clear separations between the different age groups.

3.4.3. Diversity and dominance

A total of 30 species was found at the different sampling sites (Table 9). The diversity index ranged from 1.29 (in 140) to 3.11 (in NF5). Station 140 was characterised by a high dominance of sand gobies (*Pomatoschistus* species) what kept the diversity value low. The average number of fish species caught along the pipeline area amounted to 15.5. The surrounding reference areas showed comparable quantities of species (14.4).

3.4.4. Results from other fish campaigns in autumn 1997

(1) 0.29 Broodwinner

Twelve stations are sampled, with a 18 mm meshed bottom trawl, situated along the Belgian coast.

A comparison of the total densities (juveniles & adults) of commercial fish caught in September '96 (13,591 ind./10^5m^2) and the catches of September '97 (7370 ind./10^5m^2) revealed a steep decline in density for most of the commercial fish species in that area, except for dab. The common sole and whiting populations diminished for more than 50% in comparison with the year before. The loss in plaice was not so dramatic. Whether these lower densities were caused by the construction of the NORFRA pipeline is questionable, because there are yearly density fluctuations within the fish communities. Furthermore, this sampling area is situated between de coast and the sandbanks and therefore far away from the pipeline trajectory.

Totals of the fish densities are shown in table 10.

(2) A.962 Belgica

Ten sites are sampled, with a 40 mm meshed bottom trawl, scattered all over the Belgian Continental Shelf (Table 11).

The total densities per sampled station varied from 236 ind./10^5m^2 in station 40a to 3189 ind./10^5m^2 in station 2. In comparison with the catches from the year before (August '96) there was a considerable increase in abundancy recorded. Four sampling sites near to the pipeline (1, 2, 39 and P3) showed higher densities, except for station P1. Although the number of species rose, the diversity went down. This was due to the fact that some species became more dominant (e.g. *Trachurus vipera*).

The amount of commercial fish: dab (*Limanda limanda*), common sole (*Solea solea*), plaice (*Pleuronectes platessa*) and flounder (*Platichthys flesus*) fluctuated in all sampled stations. No direct effect of the pipeline construction on these populations could be detected.

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Figures and Tables

Fig.1 — NORFRA — Positions of sampling stations for macrobenthos research

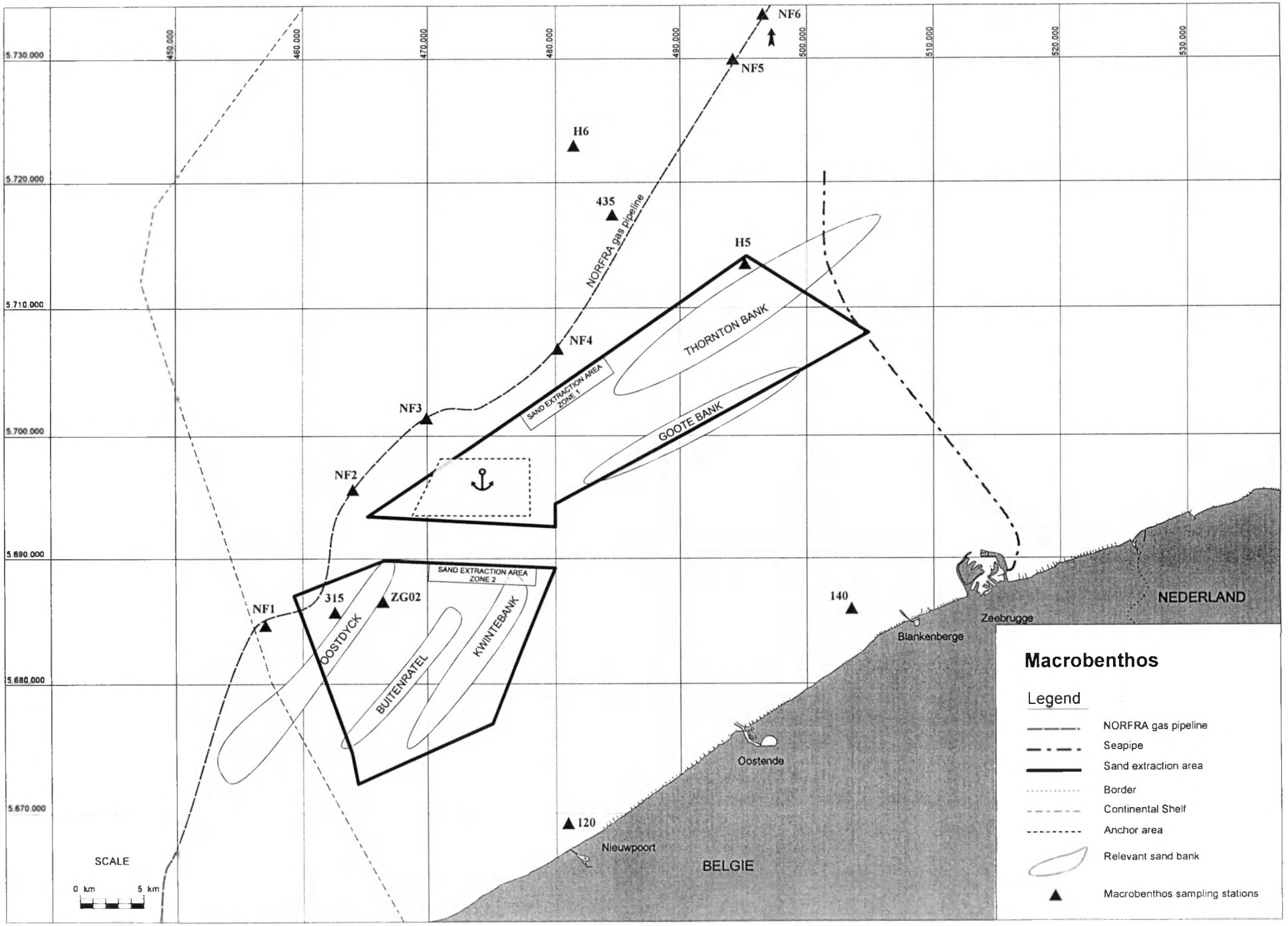


Fig.2 — NORFRA — Positions of sampling stations for epibenthos research

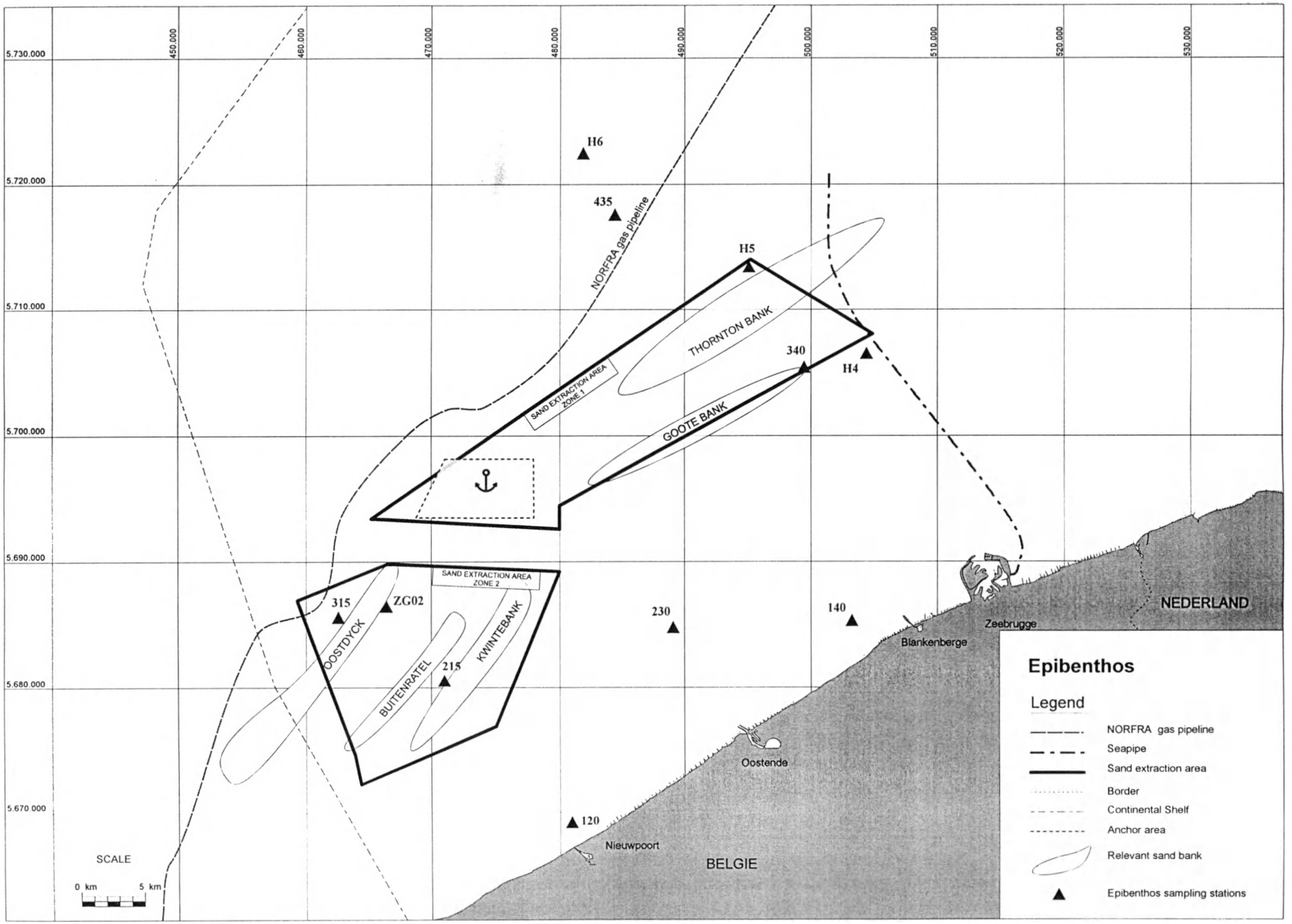


Fig.3 — NORFRA — Positions of sampling stations for fish research

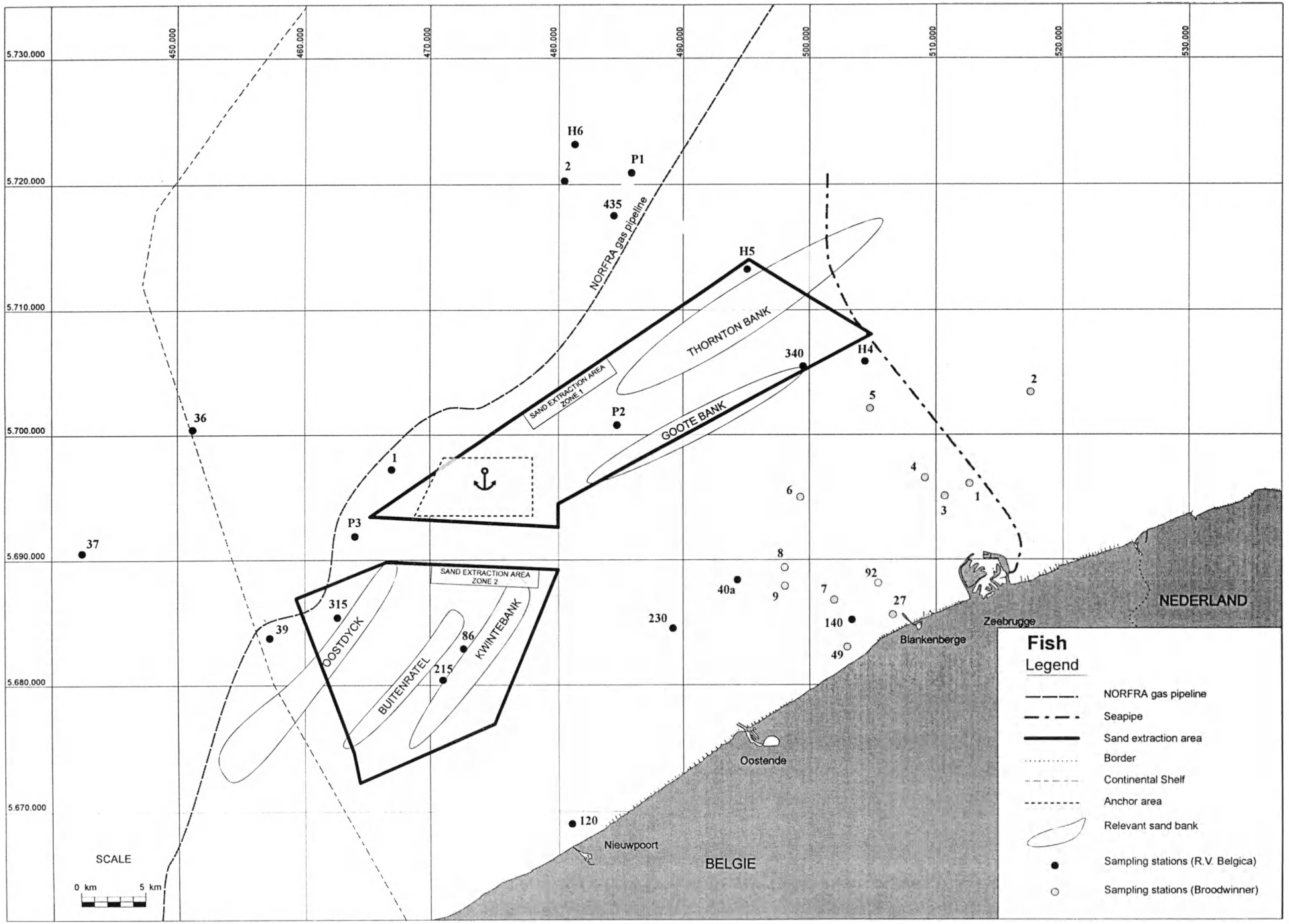


Table 1. Sampling positions epi-and macrobenthos and fish in 1997 (A.962 "R.V. Belgica")

Macrobenthos autumn 1997

STATION	POSITION SHOT		AREA
NF1	51°21' 30"	2°10' 93"	Oostdyck
NF2	51°24' 00"	2°29' 00"	Westhinder
NF3	51°28' 00"	2°34' 00"	Westhinder
NF4	51°30' 30"	2°42' 45"	Bligh-Bank
NF5	51°43' 15"	2°56' 15"	
NF6	51°48' 30"	3°03' 00"	
120	51°11' 03"	2°42' 09"	Westdiep
140	51°19' 39"	3°03' 03"	Wenduine Bank
315	51°19' 21"	2°27' 48"	Oostdyck
435	51°34' 48"	2°47' 24"	Bligh-Bank
ZG02	51°20' 00"	2°30' 00"	Oostdyck
H5	51°34' 00"	2°55' 00"	Thorton-Bank
H6	51°40' 00"	2°43' 30"	Oosthinder

Epibenthos and fish autumn 1997

STATION	POSITION SHOT		AREA
120	51°11' 03"	2°42' 09"	Westdiep
140	51°19' 39"	3°03' 03"	Wenduine Bank
230	51°18' 33"	2°51' 00"	Oostendebank
215	51°16' 45"	2°36' 57"	Kwinte Bank
315	51°19' 21"	2°27' 48"	Oostdyck
ZG02	51°20' 00"	2°30' 00"	Oostdyck
H4	51°30' 00"	3°03' 00"	Goote Bank
H5	51°34' 00"	2°55' 00"	Thorton-Bank
H6	51°40' 00"	2°43' 30"	Oosthinder
435	51°34' 48"	2°47' 24"	Bligh-Bank
340	51°30' 00"	3°00' 06"	Goote Bank

Table 2. Sampling positions fish in 1997

Ship : A.962 "R.V. Belgica"

STATION	POSITION SHOT		AREA
1	51°24' 07"	2°31' 37"	Westhinder
2	51°38' 73"	2°44' 78"	Oosthinder
36	51°27' 78"	2°20' 66"	Fairy-Bank
37	51°22' 70"	2°10' 93"	Fairy-Bank
39	51°17' 80"	2°20' 49"	Oostdyck
40a	51°21' 14"	2°55' 45"	Wenduine Bank
P1	51°34' 02"	2°45' 54"	Bligh-Bank
P2	51°27' 44"	2°43' 16"	Goote Bank
P3	51°23' 26"	2°30' 36"	Oostdyck

Ship : 0.29 "Broodwinner"

STATION	POSITION SHOT	
1	51°25' 47"	3°12'21"
2	51°29' 17"	3°15'36"
3	51°25' 02"	3°09'17"
4	51°25' 83"	3°08'58"
5	51°28' 45"	3°03'43"
6	51°23' 86"	2°59'56"
7	51°19' 69"	3°01'51"
8	51°21' 45"	2°58'50"
9	51°20' 29"	2°57'64"
27	51°18' 88"	3°04'54"
49	51°17' 23"	3°07'32"
92	51°20' 62"	3°04'50"

Table 3. Sampling periods (NORFRA)

Ship : A.962 "R.V. Belgica"

STATION	MACROBENTHOS	EPIBENTHOS	FISH
NF1	-	-	-
NF2	-	-	-
NF3	Autumn 1997	Autumn 1997	Autumn 1997
NF4	Autumn 1997	Autumn 1997	Autumn 1997
NF5	Autumn 1997	Autumn 1997	Autumn 1997
NF6	Autumn 1997	Autumn 1997	Autumn 1997
120	Autumn 1997	Autumn 1997	Autumn 1997
140	Autumn 1997	Autumn 1997	Autumn 1997
315	Autumn 1997	Autumn 1997	Autumn 1997
435	Autumn 1997	Autumn 1997	Autumn 1997
ZG02	Autumn 1997	-	-
H5	Autumn 1997	Autumn 1997	Autumn 1997
H6	Autumn 1997	Autumn 1997	Autumn 1997
215	-	Autumn 1997	Autumn 1997
230	-	Autumn 1997	Autumn 1997
340	-	Autumn 1997	Autumn 1997
H4	-	-	Autumn 1997
1	-	-	Aug-97
2	-	-	Aug-97
36	-	-	Aug-97
37	-	-	Aug-97
39	-	-	Aug-97
40a	-	-	Aug-97
86	-	-	Aug-97
P1	-	-	Aug-97
P2	-	-	Aug-97

Ship : 0.29 "Broodwinner"

STATION	FISH
1	Autumn 1997
2	Autumn 1997
3	Autumn 1997
4	Autumn 1997
5	Autumn 1997
6	Autumn 1997
7	Autumn 1997
8	Autumn 1997
9	Autumn 1997
27	Autumn 1997
49	Autumn 1997
92	Autumn 1997

Wentworth scale

Phi	ed. grainsize in µm	description
-1 - 0	1000-2000	very coarse sand
0 - 1	500-1000	coarse sand
1 - 2	250-500	medium coarse sand
2 - 3	125-250	fine sand
3 - 4	62.5-125	very fine sand
< 4	<62.5	silt

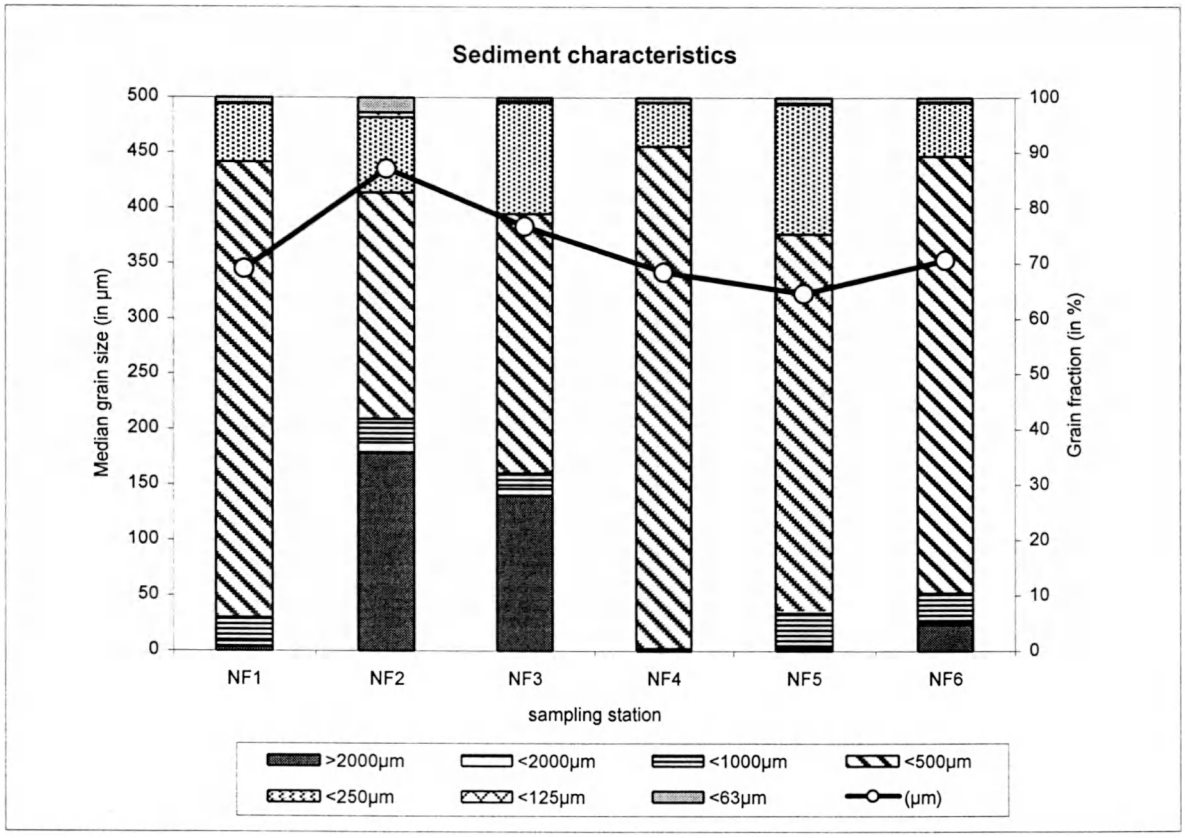
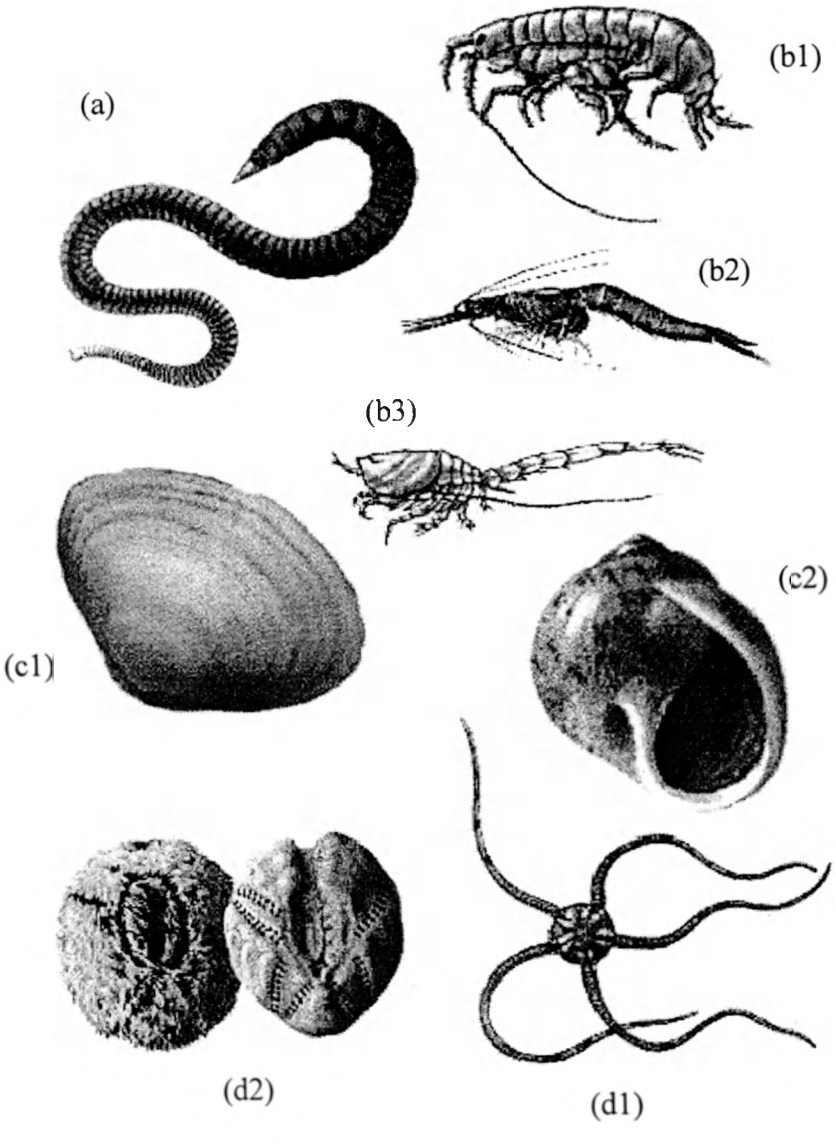
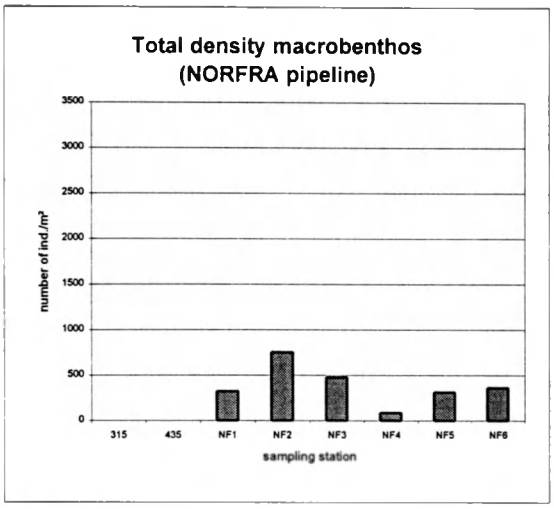


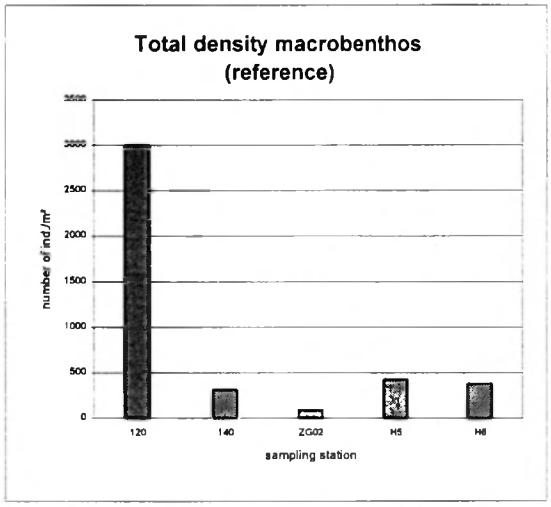
Fig. 4. Sediment characteristics Norfra pipeline (autumn 1997)

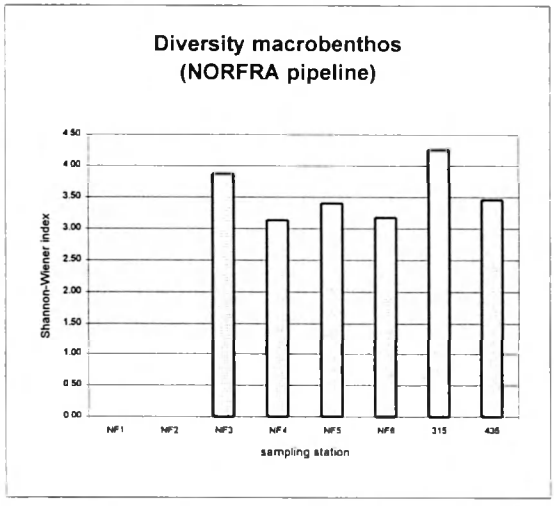
Macrobenthos

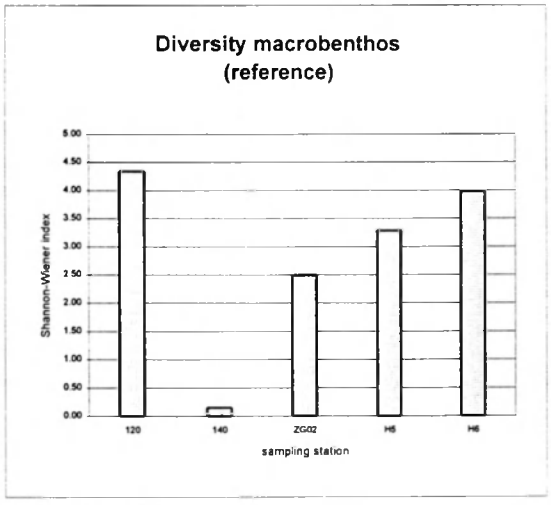
Fig. 5. The major faunistic groups of a macrobenthic community: (a) Polychaeta (bristle worms); (b) Crustacea: (b1) Amphipoda, (b2) Mysidacea and (b3) Cumacea; (c) Mollusca : (c1) bivalves and (c2) sea snails; (d) Echinodermata: (d1) brittle stars and (d2) sea urchins.

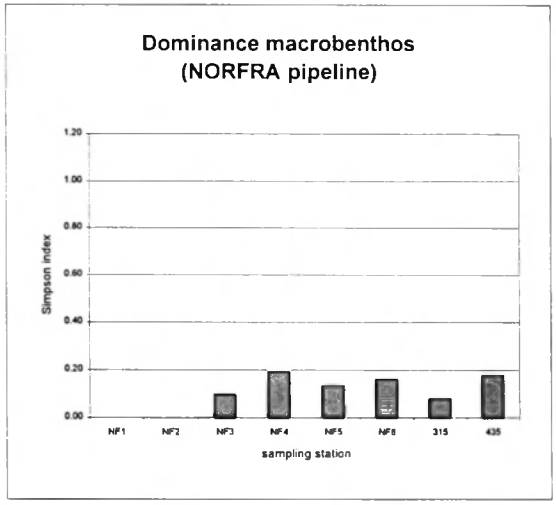












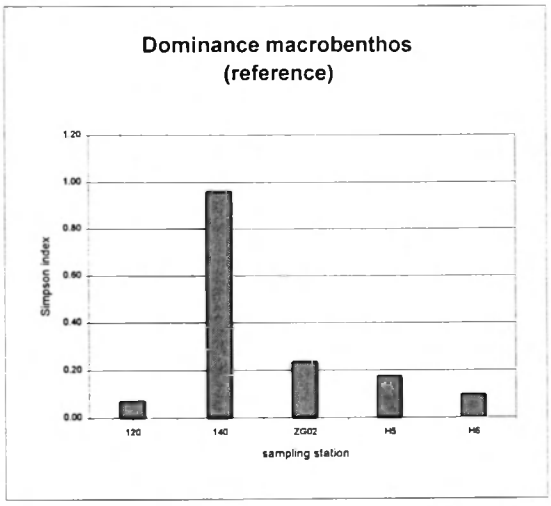
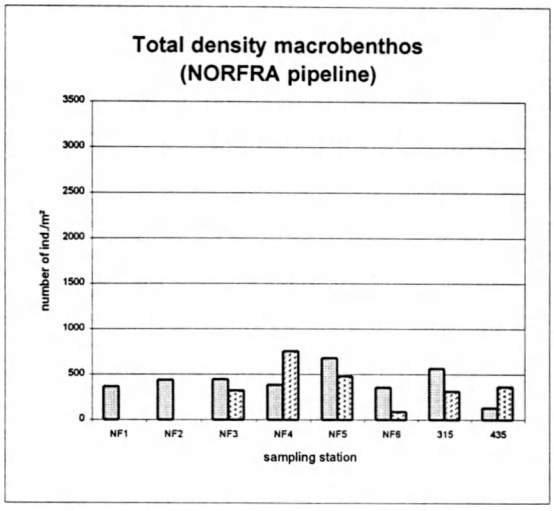
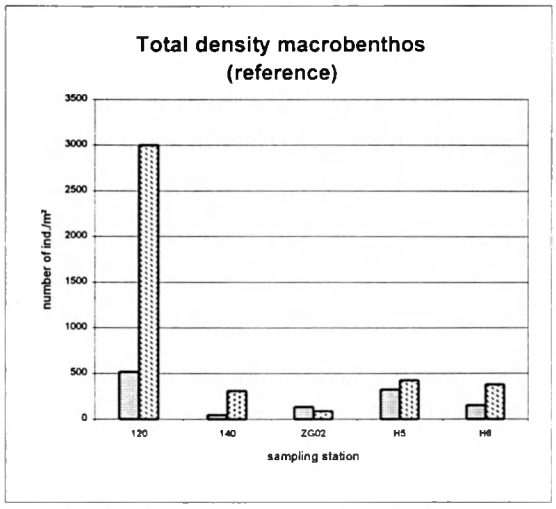
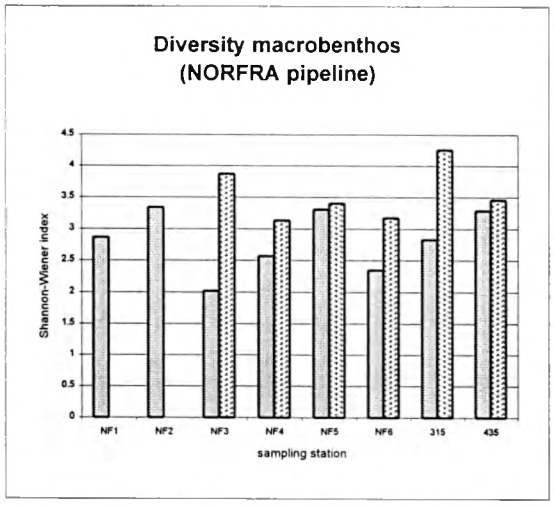
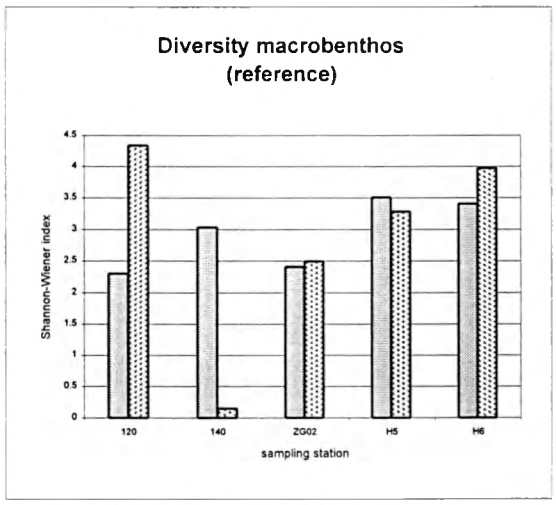


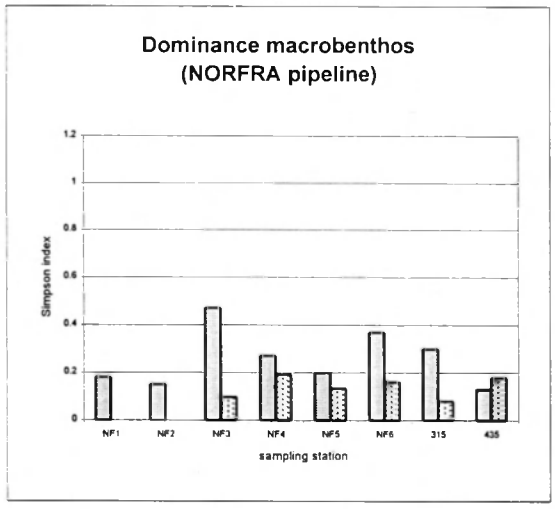
Fig. 6. Total density, diversity and dominance of sampled macrobenthos stations along the trajectory of the pipeline and some reference stations (autumn 1997)











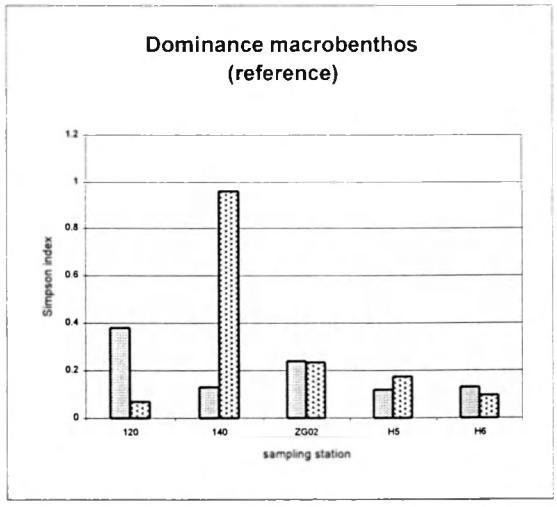


Fig. 6.bis Total density, diversity and dominance of sampled macrobenthos stations along the trajectory of the pipeline and some reference stations before and just after the installation (spring and autumn 1997)

Table 4. Macrobenthos density (# ind./m²) and diversity along the trajectory of the NORFRA pipeline just after installation (autumn 1997)

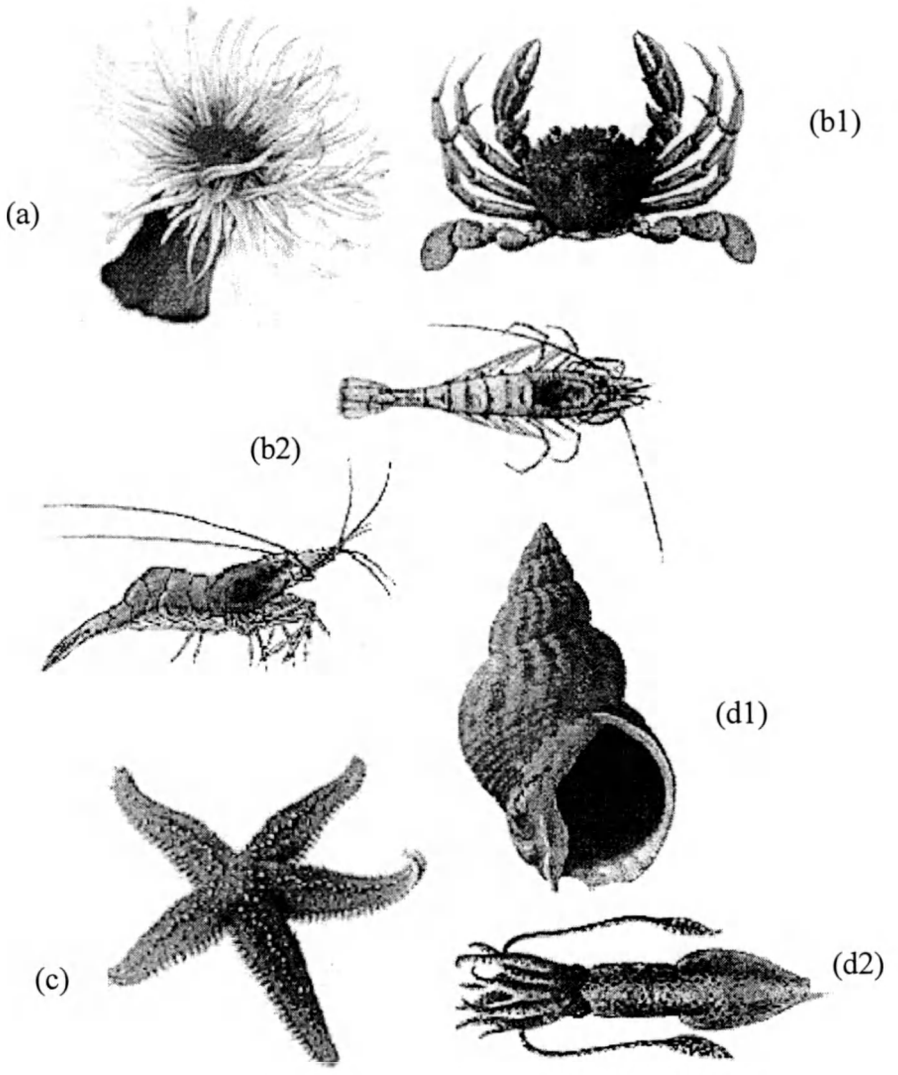
STATION	NF3	NF4	NF5	NF6	315	435	Total
Polychaeta							
Aonides paucibranchiata	0.0	0.0	0.0	3.3	13.3	0.0	16.6
Aricidea suecica	0.0	0.0	6.7	0.0	0.0	0.0	6.7
Eteone species	0.0	36.7	0.0	3.3	3.3	0.0	43.3
Exogone hebes	6.7	0.0	0.0	0.0	0.0	0.0	6.7
Glycera species	3.3	0.0	40.0	30.0	23.3	6.7	103.3
Harmothoe glabra	0.0	0.0	3.3	0.0	3.3	0.0	6.6
Hesionura elongata	3.3	13.3	10.0	3.3	3.3	6.7	39.9
Lanice conchilega	13.3	0.0	0.0	0.0	3.3	3.3	19.9
Nephtys cirrosa	16.7	90.0	36.7	6.7	36.7	33.3	220.1
Nephtys species	0.0	13.3	0.0	0.0	3.3	13.3	29.9
Ophelia limacina	3.3	0.0	3.3	3.3	3.3	0.0	13.2
Pectinaria koreni	0.0	3.3	0.0	0.0	33.3	0.0	36.6
Phyllodoce maculata	0.0	0.0	0.0	0.0	0.0	3.3	3.3
Poecilochaetus serpens	40.0	3.3	3.3	6.7	50.0	3.3	106.6
Polygordius species	3.3	0.0	36.7	3.3	3.3	0.0	46.6
Scolelepis species	0.0	23.3	6.7	0.0	0.0	33.3	63.3
Scoloplos armiger	3.3	13.3	13.3	0.0	3.3	6.7	39.9
Spio species	20.0	86.7	106.7	13.3	20.0	33.3	280.0
Spiophanes bombyx	13.3	286.7	13.3	6.7	3.3	16.7	340.0
Travisia forbesii	0.0	0.0	0.0	0.0	0.0	3.3	3.3
Crustacea							
amphipoda species	0.0	0.0	3.3	0.0	6.7	0.0	10.0
Atylus species	0.0	0.0	3.3	0.0	3.3	0.0	6.6
Bathyporeia guilliamsoniana	23.3	90.0	106.7	0.0	6.7	133.3	360.0
Bodotria species	0.0	0.0	0.0	0.0	3.3	0.0	3.3
Diastylis bradyi	3.3	6.7	0.0	0.0	0.0	3.3	13.3
Diastylis species	0.0	0.0	0.0	0.0	3.3	0.0	3.3
Leucothoe incisa	0.0	0.0	0.0	0.0	6.7	0.0	6.7
Perioculodes longimanus	3.3	6.7	0.0	0.0	3.3	3.3	16.6
Pontocrates altamarinus	0.0	3.3	0.0	0.0	0.0	0.0	3.3
Pseudocuma species	0.0	3.3	0.0	0.0	0.0	0.0	3.3
Scopelocheirus hopei	3.3	0.0	0.0	0.0	0.0	0.0	3.3
Stenothoe marina	0.0	0.0	0.0	0.0	0.0	3.3	3.3
Thia scutellata	0.0	16.7	3.3	0.0	3.3	3.3	26.6
Urothoe brevicornis	66.7	20.0	56.7	0.0	6.7	10.0	160.1
Echinodermata							
Echinocardium cordatum	0.0	10.0	0.0	0.0	3.3	16.7	30.0
Echinocyamus pusillus	16.7	0.0	0.0	3.3	3.3	6.7	30.0
Ophiura albida	13.3	0.0	6.7	0.0	3.3	0.0	23.3
juvenile ophiura species	43.3	6.7	6.7	0.0	33.3	0.0	90.0
Mollusca							
Arca tetragona	0.0	0.0	0.0	0.0	3.3	0.0	3.3
Lunatia alderi	0.0	0.0	0.0	0.0	0.0	6.7	6.7
Moerella pygmaea	0.0	0.0	0.0	3.3	0.0	0.0	3.3
Spisula subtruncata	0.0	3.3	0.0	0.0	0.0	0.0	3.3
Miscellaneous							
anthozoa species	3.3	0.0	0.0	0.0	0.0	3.3	6.6
Branchiostoma lanceolatum	6.7	10.0	10.0	0.0	10.0	0.0	36.7
Total # ind./m²	309.7	746.6	476.7	86.5	306.1	353.1	2278.7
Diversity							
Number of species	24	22	21	13	33	24	
Shannon-Wiener	3.70	3.09	3.37	3.06	4.14	3.34	
Simpson dominance	0.11	0.20	0.14	0.17	0.08	0.18	

Table 5. Macrobenthos density (# ind./m²) and diversity of 5 reference stations after the installation of the pipeline (autumn 1997)

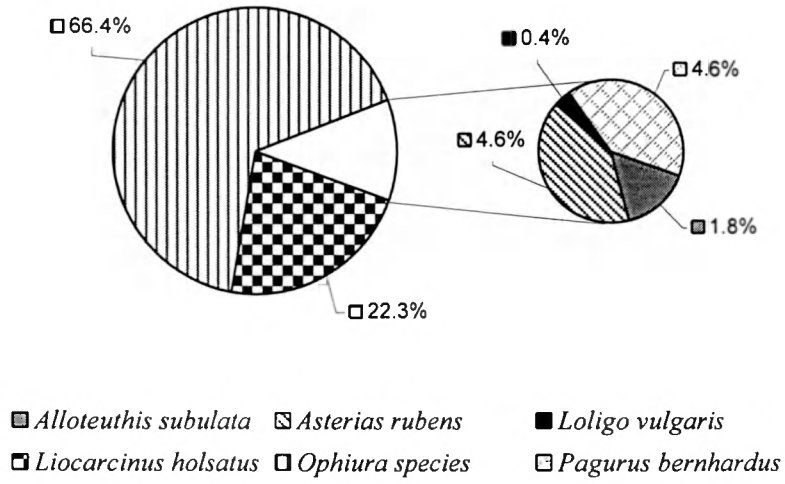
STATION	120	140	ZG02	H5	H6	Total
Polychaeta						
Ampharete species	3.3	0.0	0.0	0.0	0.0	3.3
Aonides paucibranchiata	0.0	0.0	0.0	0.0	0.0	0.0
Autolytus prolifer	156.7	0.0	0.0	0.0	0.0	156.7
Capitella species	113.3	0.0	0.0	0.0	0.0	113.3
Chaetozone setosa	293.3	303.3	0.0	0.0	0.0	596.6
Eteone species	33.3	0.0	0.0	10.0	6.7	50.0
Eumida sanguinea	110.0	0.0	0.0	0.0	0.0	110.0
Glycera species	0.0	0.0	0.0	20.0	13.3	33.3
Harmothoe species	16.7	0.0	0.0	0.0	0.0	16.7
Hesionura augeneri	0.0	0.0	23.3	0.0	6.7	30.0
Lanice conchilega	193.3	0.0	0.0	0.0	0.0	193.3
Magelona mirabilis	3.3	0.0	0.0	0.0	0.0	3.3
Nephtys caeca	26.7	0.0	0.0	0.0	0.0	26.7
Nephtys cirrosa	0.0	0.0	33.3	30.0	23.3	86.6
Nephtys hombergii	6.7	0.0	0.0	0.0	0.0	6.7
Nephtys species	253.3	6.7	0.0	0.0	6.7	266.7
Nereis species	3.3	0.0	0.0	0.0	0.0	3.3
Ophelia limacina	0.0	0.0	3.3	6.7	0.0	10.0
Pectinaria koreni	16.7	0.0	0.0	0.0	0.0	16.7
Pholoe minuta	10.0	0.0	0.0	0.0	0.0	10.0
Phyllodoce maculata	13.3	0.0	0.0	0.0	0.0	13.3
Poecilochaetus serpens	3.3	0.0	0.0	3.3	0.0	6.6
Polydora species	3.3	0.0	0.0	0.0	0.0	3.3
Polygordius species	0.0	0.0	0.0	6.7	6.7	13.4
Scolelepis species	0.0	0.0	3.3	0.0	3.3	6.6
Scoloplos armiger	56.7	0.0	0.0	6.7	16.7	80.1
Spio filicornis	0.0	0.0	3.3	0.0	13.3	16.6
Spio martinensis	3.3	0.0	0.0	10.0	23.3	36.6
Spio species	0.0	0.0	13.3	0.0	0.0	13.3
Spiophanes bombyx	193.3	0.0	3.3	10.0	76.7	283.3
Crustacea						
Abludomelita obtusata	100.0	0.0	0.0	0.0	0.0	100.0
Amphilochus manudens	30.0	0.0	0.0	0.0	0.0	30.0
amphipoda species	3.3	0.0	0.0	0.0	13.3	16.6
Bathyporeia guilliamsoniana	0.0	0.0	0.0	136.7	66.7	203.4
Bathyporeia species	0.0	0.0	0.0	0.0	16.7	16.7
Bodotria arenosa	26.7	0.0	0.0	0.0	0.0	26.7
Bodotria scorpioides	43.3	0.0	0.0	0.0	0.0	43.3
Bodotria species	16.7	0.0	0.0	0.0	0.0	16.7
Corophium bonelli	3.3	0.0	0.0	0.0	0.0	3.3
Corophium volutator	3.3	0.0	0.0	0.0	0.0	3.3
Diastylis rathkei	0.0	0.0	0.0	13.3	0.0	13.3
Diastylis species	10.0	0.0	0.0	0.0	0.0	10.0
Microprotopus maculatus	303.3	0.0	0.0	0.0	0.0	303.3
Pariambus typicus	240.0	0.0	0.0	3.3	0.0	243.3
Phtisica marina	30.0	0.0	0.0	0.0	0.0	30.0
Pseudocuma longicornis	0.0	0.0	0.0	0.0	3.3	3.3
Thia scutellata	0.0	0.0	0.0	6.7	3.3	10.0
Urothoe brevicornis	0.0	0.0	0.0	100.0	13.3	113.3
Echinodermata						
Echinocyamus pusillus	0.0	0.0	0.0	6.7	0.0	6.7
juvenile ophiura species	53.3	0.0	0.0	20.0	10.0	83.3
Mollusca						
Abra alba	56.7	0.0	0.0	0.0	0.0	56.7
Crepidula fornicata	13.3	0.0	0.0	0.0	0.0	13.3
Ensis species	53.3	0.0	0.0	0.0	0.0	53.3
Lunatia alderi	0.0	0.0	0.0	0.0	3.3	3.3
Mysella bidentata	23.3	0.0	0.0	0.0	0.0	23.3
Spisula subtruncata	403.3	0.0	0.0	10.0	0.0	413.3
Venerupis pullastra	3.3	0.0	0.0	0.0	0.0	3.3
Miscellaneous						
anthozoa species	16.7	0.0	0.0	0.0	0.0	16.7
Branchiostoma lanceolatum	0.0	0.0	0.0	10.0	26.7	36.7
chaetognatha species	0	0	3.3	0	6.7	10.0
Total # ind./m²	2946.2	310.0	86.4	410.1	360.0	4112.7
Diversity						
Number of species	45	2	9	22	26	
Shannon-Wiener index	4.25	0.15	2.36	3.14	3.76	
Simpson's index	0.07	0.96	0.25	0.19	0.11	

Epibenthos

Fig. 7. The major faunistic groups of the epibenthic community: (a) Anthozoa (sea anemones); (b) Crustacea: (b1) crabs and (b2) shrimps; (c) Echinodermata (starfish) and (d) Mollusca: (d1) sea snails and (d2) cuttlefish.



(a) pipeline stations
(NF3-NF6, 315 & 435)



(b) reference stations
(120,140, 215, 230 & 340)

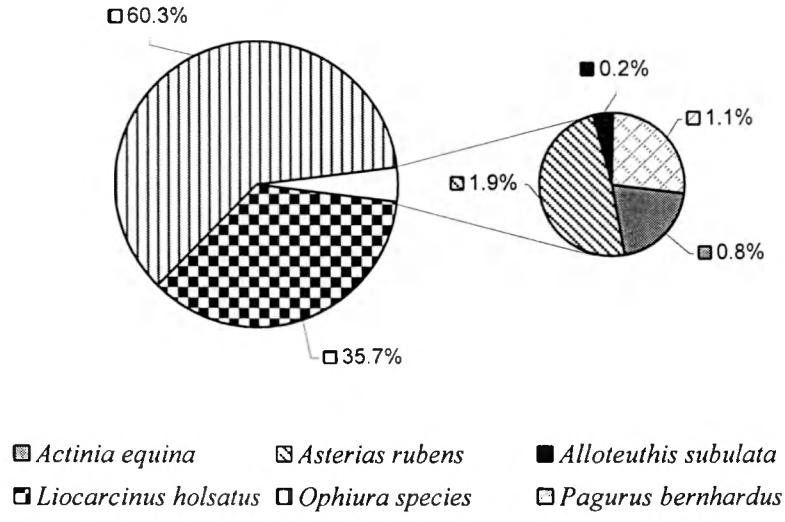
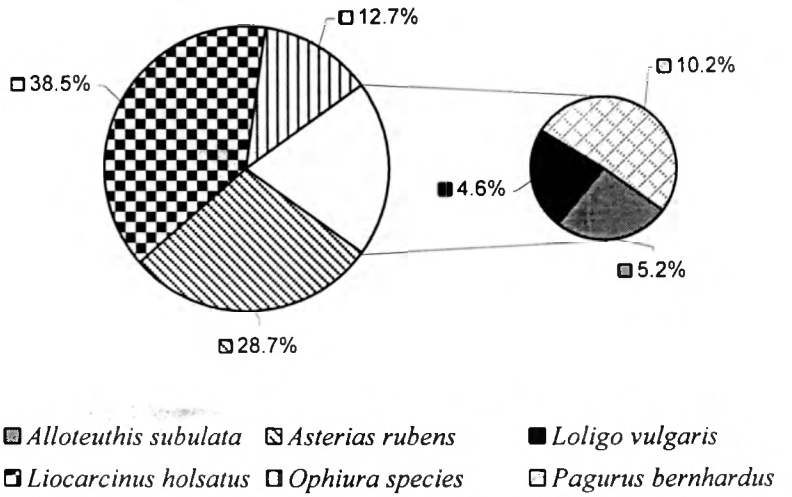


Fig. 8. Mean densities (in % values) of the most common epibenthic species along the pipeline (a) and of some reference stations (b) (autumn 1997).

(a) pipeline stations
(NF3-NF6, 315 & 435)



(b) reference stations
(120,140, 215, 230 & 340)

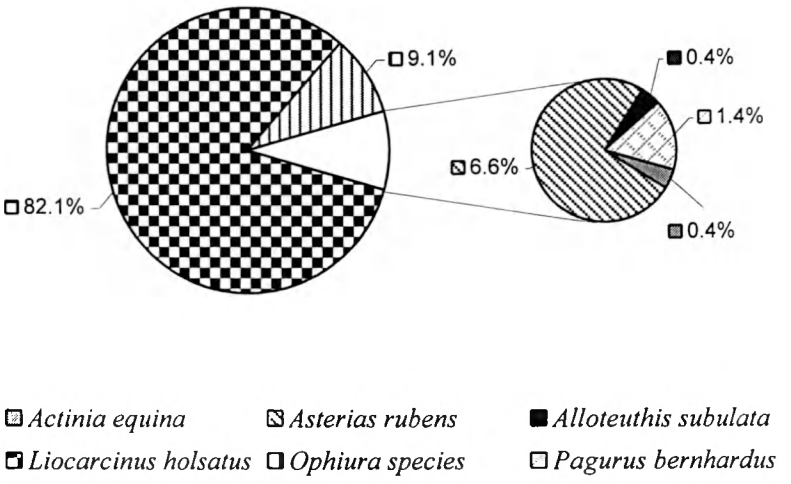


Fig. 9. Mean biomass (in % values) of the most common epibenthic species along the pipeline (a) and of some reference stations (b) (autumn 1997).

Table 6. Epibenthos species

Scientific name	English name
Anthozoa species	Sea anemones
Alloteuthis subulata	Squid
Asterias rubens	Starfish
Cancer pagurus	Edible crab
Carcinus maenas	Shore crab
Corystes cassivelaunus	Masked crab
Crangon allmanni	Shrimp
Crangon crangon	Shrimp
Echinocardium cordatum	Heart urchin
Hyas coarctatus	Contracted crab
Loligo vulgaris	Squid
Liocarcinus arcuatus	Arch-fronted swimming crab
Liocarcinus depurator	Blue-leg swimming crab
Liocarcinus holsatus	Flying crab
Liocarcinus marmoreus	Marbled swimming crab
Macropodia rostrata	Long legged spider crab
Necora puber	Velvet swimming crab
Ophiura albida	Brittle star
Ophiura texturata	Brittle star
Pagurus bernhardus	Heremit crab
Pontophilus trispinosus	Shrimp
Psammechinus miliaris	Sea urchin
Sepia officinalis	Cuttle fish
Sepiola atlantica	Lesser cuttle fish
Spatangus purpureus	Sea urchin
Thia polita	Polished crab

Table 7. Total density and biomass of epibenthos along and in the vicinity of the NORFRA pipeline (autumn 1997) (density in ind./100.000m²; biomass in g ww/100.000m²)

DENSITY

STATION	NF3	NF4	NF5	NF6	435	315	Total	H5	H6	Total
Anthozoa species	13	6	7	0	0	0	26	0	10	10
Alloteuthis subulata	7	23	137	101	92	78	438	68	34	102
Asterias rubens	394	79	26	45	41	558	1143	90	68	158
Cancer pagurus	0	0	0	6	0	0	6	0	0	0
Crangon allmanni	0	0	33	0	0	0	33	0	34	34
Crangon crangon	0	0	7	0	0	0	7	0	0	0
Echinocardium cordatum	0	6	0	6	0	0	12	0	15	15
Hyas coarctatus	0	0	0	0	13	0	13	0	0	0
Loligo vulgaris	71	0	0	0	35	0	106	0	0	0
Liocarcinus holsatus	2088	1031	793	676	730	262	5580	7978	926	8904
Liocarcinus marmoreus	0	0	7	28	0	0	35	0	39	39
Macropodia rostrata	26	0	39	95	19	0	179	23	15	38
Necora puber	7	0	0	0	0	0	7	0	0	0
Ophiura albida	4862	1881	1365	1072	2739	3871	15790	39146	270	39416
Ophiura texturata	13	682	20	34	32	34	815	90	5	95
Pagurus bernhardus	278	135	124	190	117	296	1140	407	154	561
Pontophilus trispinosus	0	0	7	0	0	0	7	0	0	0
Psammechinus miliaris	7	0	0	0	3	23	33	0	0	0
Sepia officinalis	0	0	0	0	0	10	10	0	0	0
Sepiola atlantica	19	0	20	11	6	0	56	90	19	109
Spatangus purpureus	0	11	0	0	0	0	11	0	0	0
Thia polita	0	0	0	0	35	0	35	23	5	28
Total	7785	3854	2585	2264	3862	5132	25482	47915	1594	49509
Diversity										
Number of species	12	9	13	11	12	8		9	13	
Shannon-Wiener index	1.49	1.84	1.88	2.09	1.42	1.30		0.80	2.08	
Simpson index	0.47	0.34	0.38	0.32	0.54	0.59		0.70	0.38	

BIOMASS

STATION	NF3	NF4	NF5	NF6	435	315	Total	H5	H6	Total
Anthozoa species	16	9	11	0	0	0	36	0	10	10
Alloteuthis subulata	15	660	602	208	207	1497	3189	77	55	132
Asterias rubens	2581	1764	119	499	780	11956	17699	457	592	1049
Cancer pagurus	0	0	0	64	0	0	64	0	0	0
Crangon allmanni	0	0	16	0	0	0	16	0	0	0
Crangon crangon	0	0	7	0	0	0	7	0	33	33
Echinocardium cordatum	0	86	0	66	0	0	152	0	402	402
Hyas coarctatus	0	0	0	0	12	0	12	0	0	0
Loligo vulgaris	1949	0	0	0	872	0	2821	0	0	0
Liocarcinus holsatus	6766	5675	3443	3310	3187	1348	23729	38190	4923	43113
Liocarcinus marmoreus	0	0	60	203	0	0	263	0	439	439
Macropodia rostrata	40	0	35	57	10	0	142	2	15	17
Necora puber	152	0	0	0	0	0	152	0	0	0
Ophiura albida	1748	790	560	494	1495	1291	6378	16235	84	16319
Ophiura texturata	28	1001	59	125	156	105	1474	249	7	256
Pagurus bernhardus	1166	959	809	1344	556	1478	6312	3469	1376	4845
Pontophilus trispinosus	0	0	3	0	0	0	3	0	0	0
Psammechinus miliaris	206	0	0	0	50	154	410	0	0	0
Sepia officinalis	0	0	0	0	0	98	98	0	0	0
Sepiola atlantica	47	0	53	25	18	0	143	213	41	254
Spatangus purpureus	0	570	0	0	0	0	570	0	0	0
Thia polita	0	0	0	0	34	0	34	45	6	51
Total	14714	11514	5777	6395	7377	17927	63704	58937	7983	66920

Table 8. Total density and biomass of epibenthos for reference sampling stations (120, 140, 215, 230 & 340) (autumn 1997) (density in number of ind./100.000m²; biomass in g ww/100.000m²)

DENSITY

STATION	120	140	215	230	340	Total
Anthozoa species	381	16	148	210	0	755
Alloteuthis subulata	0	0	49	0	110	159
Asterias rubens	180	0	641	23	964	1808
Crangon allmanni	0	0	0	0	0	0
Crangon crangon	0	0	0	0	0	0
Liocarcinus arcuatus	43	0	0	0	0	43
Liocarcinus depurator	0	0	0	0	28	28
Liocarcinus holsatus	2761	2402	9126	9369	9693	33351
Macropodia rostrata	27	0	0	0	55	82
Ophiura albida	147	0	17513	0	35937	53597
Ophiura texturata	841	0	222	0	1735	2798
Pagurus bernhardus	284	0	444	71	193	992
Sepia officinalis	70	0	25	0	0	95
Sepiola atlantica	0	0	0	0	83	83
Total	4734	2418	28168	9673	48798	93791
Diversity						
Number of species	9	2	8	4	9	
Shannon-Wiener index	1.96	0.06	1.29	0.24	1.16	
Simpson index	0.38	0.99	0.49	0.94	0.58	

BIOMASS

STATION	120	140	215	230	340	Total
Anthozoa species	559	46	225	227	0	1057
Alloteuthis subulata	0	0	382	0	606	988
Asterias rubens	2949	0	5054	1182	8171	17356
Crangon allmanni	0	0	0	0	0	0
Crangon crangon	0	0	0	0	0	0
Liocarcinus arcuatus	48	0	0	0	0	48
Liocarcinus depurator	0	0	0	0	308	308
Liocarcinus holsatus	21412	23619	52752	69771	47134	214688
Macropodia rostrata	18	0	0	0	52	70
Ophiura albida	59	0	5671	0	11739	17469
Ophiura texturata	1280	0	602	0	4458	6340
Pagurus bernhardus	725	0	1754	526	746	3751
Sepia officinalis	677	0	289	0	0	966
Sepiola atlantica	0	0	0	0	168	168
Total	27727	23665	66729	71706	73382	263209

Fish

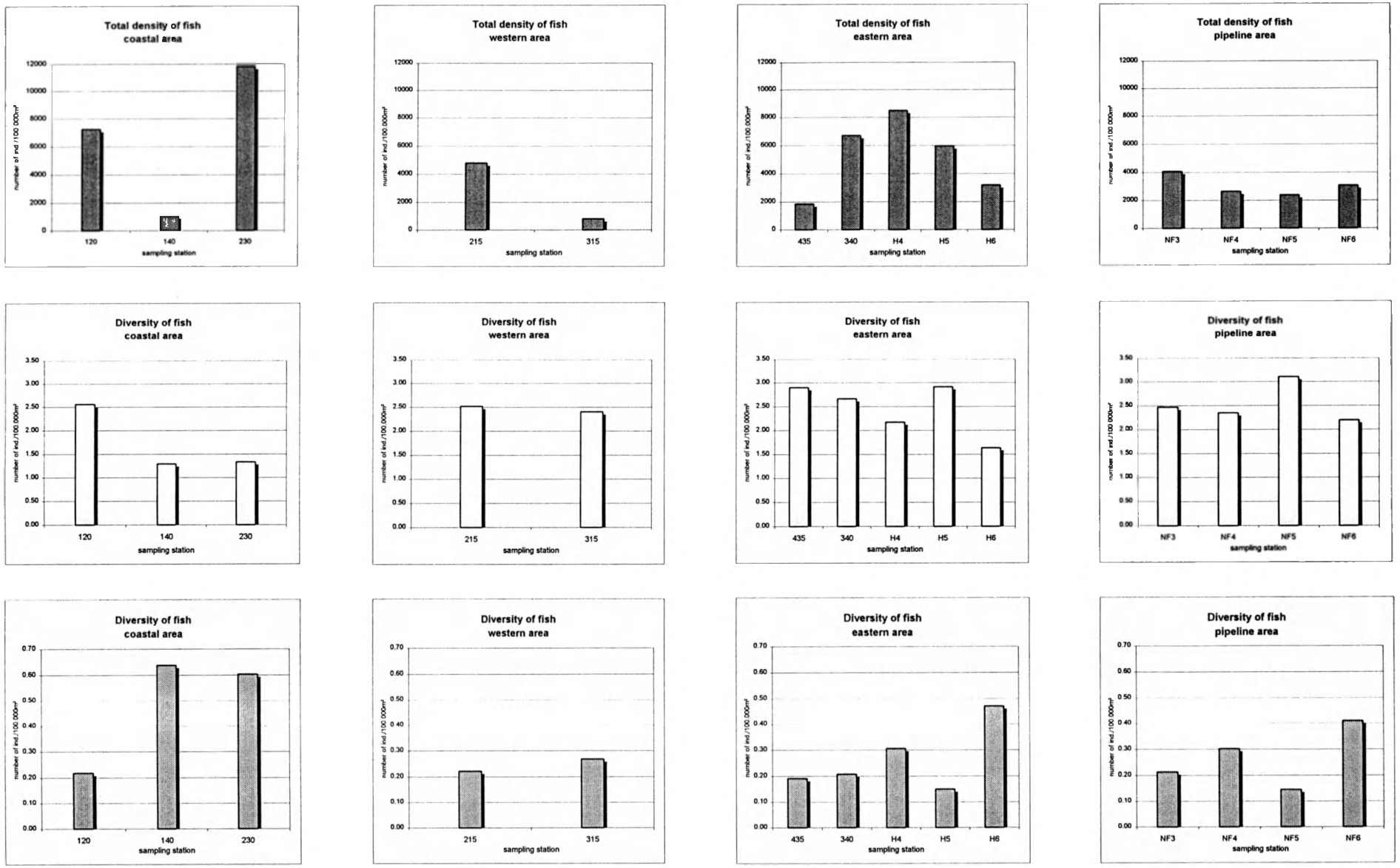
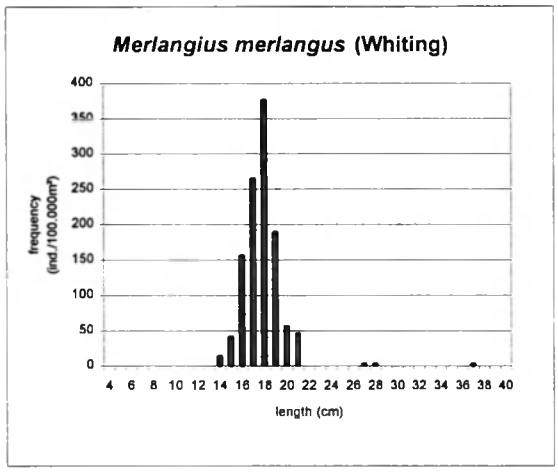
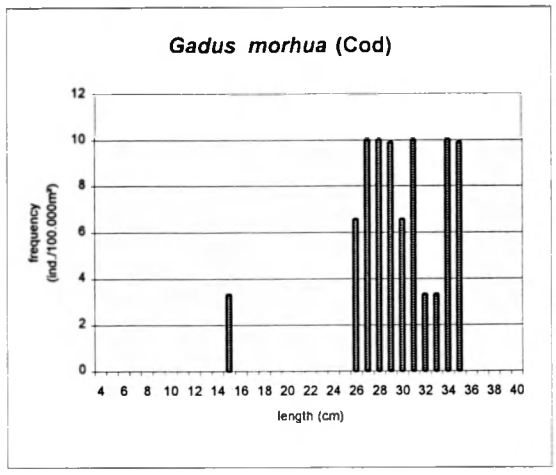
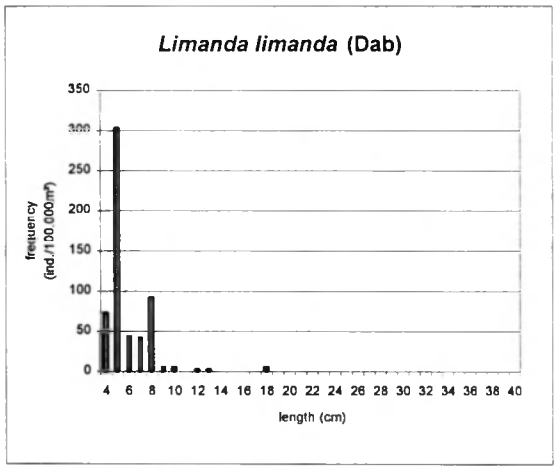
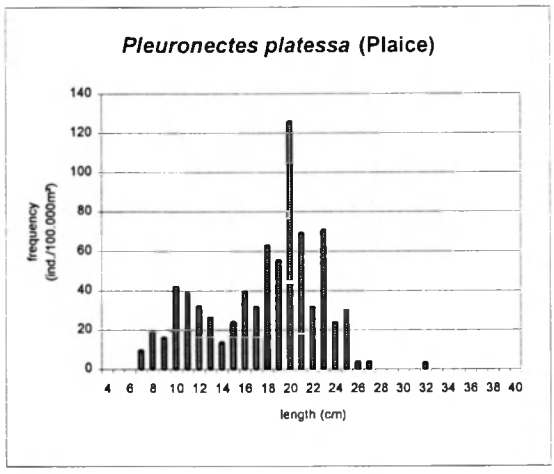


Fig. 10. Density and diversity of fish stock of the different sampled areas (autumn 1997)









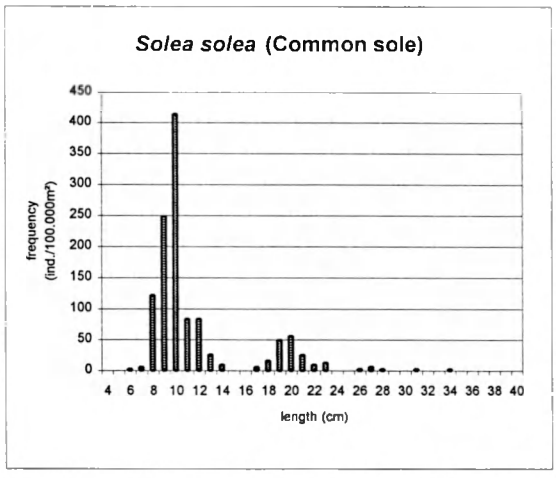
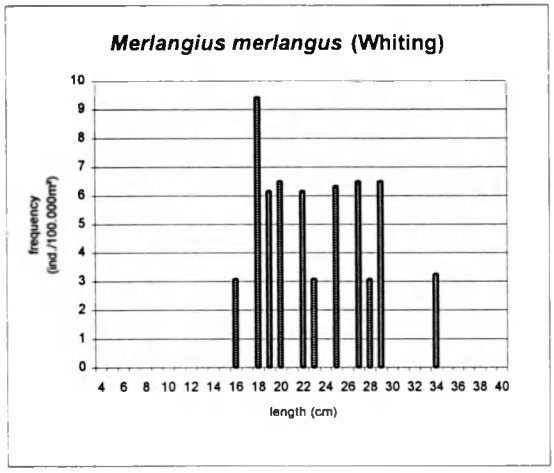
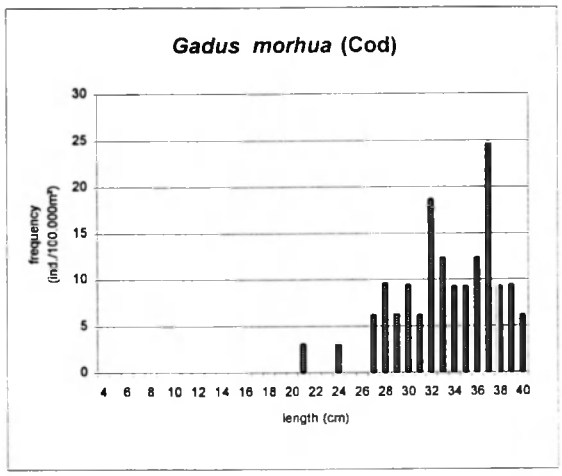
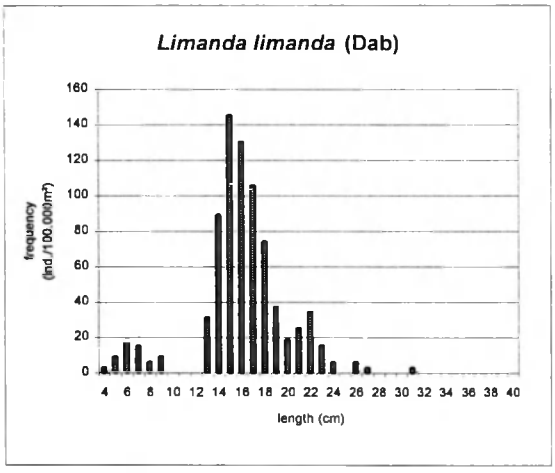
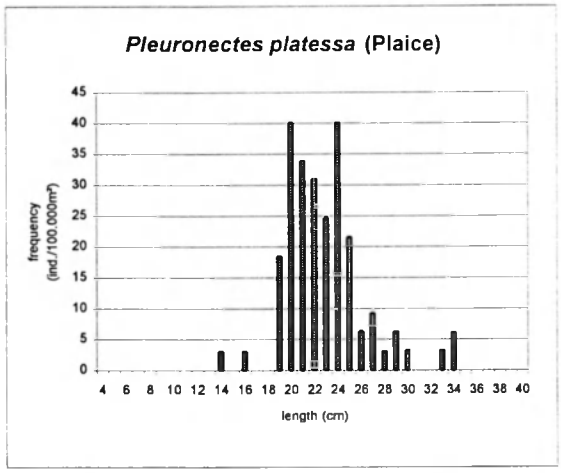


Fig. 11. Length-frequency distribution of the commercial fish species in the **coastal area** (sampling stations 120-140-230) (autumn 1997)









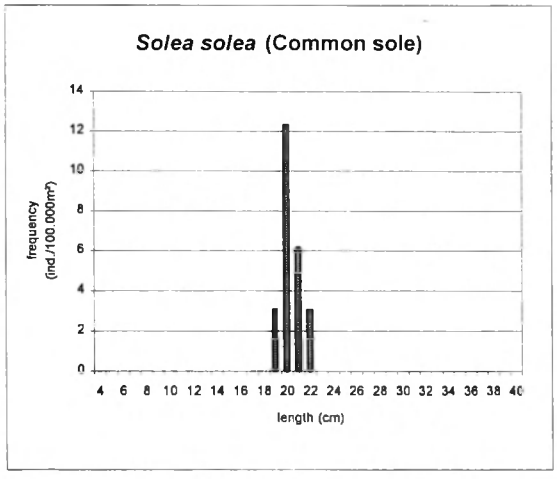
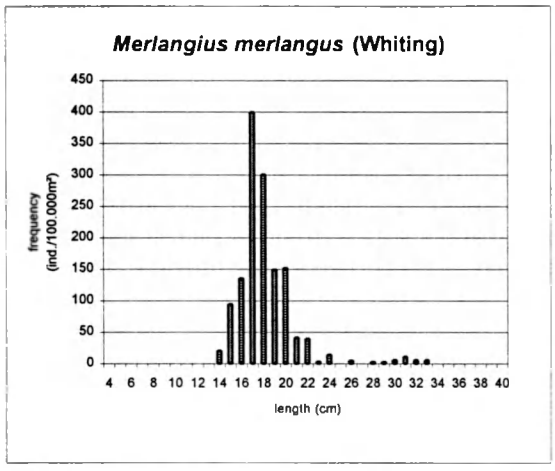
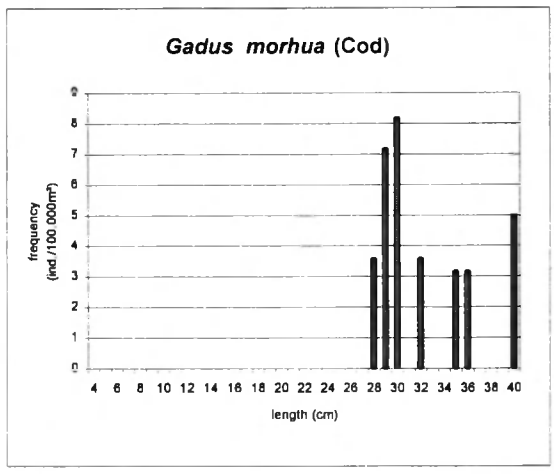
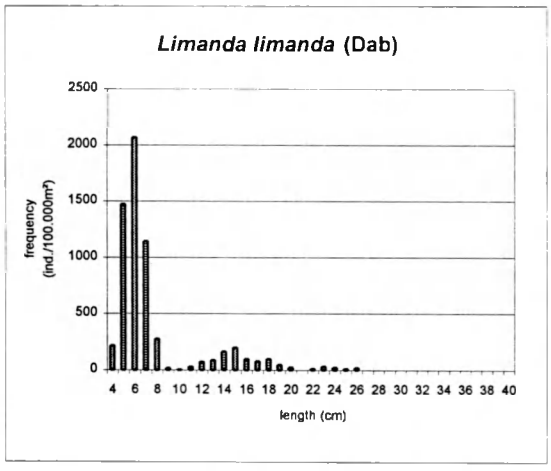
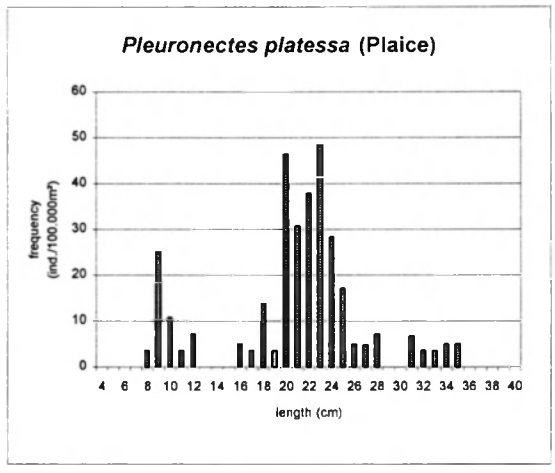


Fig. 12. Length-frequency distribution of the commercial fish species in the **western area** (sampling stations 215-315)(autumn 1997)









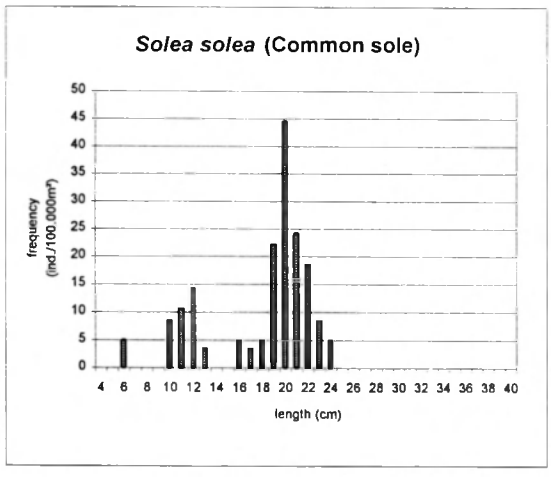
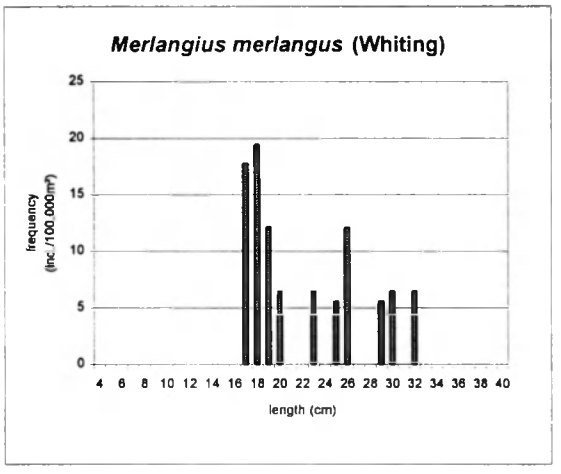
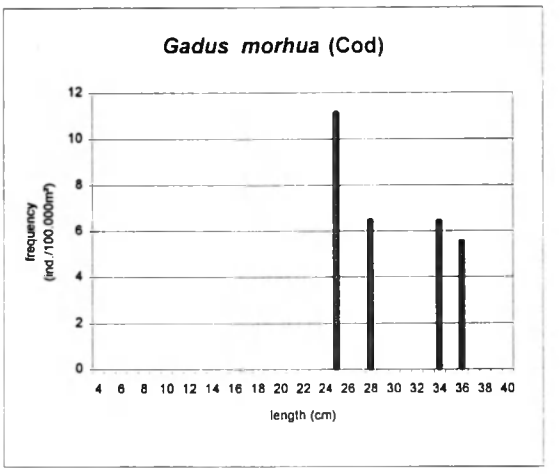
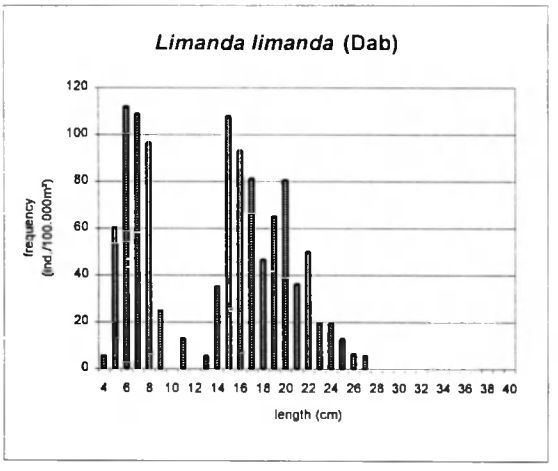
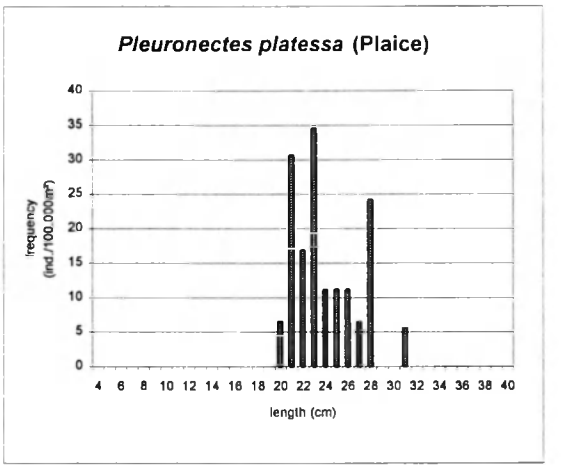


Fig. 13. Length-frequency distribution of the commercial fish species in the **eastern area** (sampling stations H4-H5-H6-340-435)(autumn 1997)









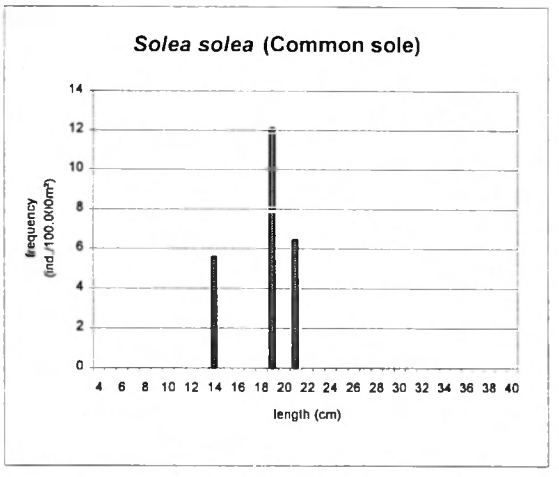


Fig. 14. Length-frequency distribution of the commercial fish species along the **NORFRA-pipeline** (sampling stations NF3-NF6)(autumn 1997)

Table 9. Density and diversity of fish species of different sampling stations on the Belgian Continental Shelf (autumn 1997)(density in ind./100.000m²)

	coastal area				western area			eastern area						NORFRA pipeline				
STATION	**120**	**140**	**230**	**Total**	**215**	**315**	**Total**	**435**	**340**	**H4**	**H5**	**H6**	**Total**	**NF3**	**NF4**	**NF5**	**NF6**	**Total**
Agonus cataphractus	53	20	456	529	136	3	139	3	65	704	0	0	772	19	39	6	22	86
Ammodytes tobianus	0	0	0	0	3	0	3	44	4	0	20	34	102	6	17	13	11	47
Anguilla anguilla	0	20	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arnoglossus laterna	0	0	0	0	0	0	0	3	0	0	10	0	13	0	0	0	11	11
Buglossidium luteum	0	0	23	23	9	3	12	19	32	5	55	19	130	13	28	123	173	337
Callionymus lyra	1676	0	6	1682	1036	364	1400	314	528	412	829	125	2208	743	282	253	151	1429
Callionymus recticulatus	0	0	0	0	0	7	7	16	14	0	377	0	407	6	11	13	22	52
Ciliata mustela	0	7	87	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clupea harengus	0	72	0	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gadus morhua	72	0	12	84	136	19	155	9	15	10	5	0	39	6	0	6	17	29
Gobius niger	0	0	0	0	6	0	6	0	0	0	0	0	0	0	0	0	0	0
Hyperoplus lanceolatus	0	0	0	0	0	7	7	0	0	0	0	48	48	0	0	6	0	6
Hyppoglossoides platessoides	0	0	0	0	0	0	0	0	0	45	0	0	45	0	0	0	0	0
Limanda limanda	460	7	115	582	654	128	782	95	1247	4176	958	58	6534	288	373	243	198	1102
Merlangius merlangus	1107	19	28	1154	30	30	60	100	209	250	835	0	1394	13	17	48	18	96
Microstomus kitt	7	0	0	7	40	3	43	0	0	15	0	0	15	0	0	0	0	0
Mullus surmuletus	0	0	0	0	0	3	3	0	4	0	35	19	58	26	11	130	56	223
Mustelus mustelus	7	0	0	7	0	0	0	57	7	0	0	0	64	0	0	0	0	0
Myoxocephalus scorpius	13	0	13	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Platichthys flesus	7	3	13	23	0	0	0	0	11	0	0	0	11	0	0	0	0	0
Pleuronectes platessa	552	3	222	777	237	15	252	63	211	10	30	15	329	6	52	44	58	160
Pomatoschistus minutus	2581	829	9069	12479	1708	0	1708	136	2342	1598	1291	39	5406	840	253	208	123	1424
Scomber scomber	0	0	0	0	0	0	0	0	4	0	0	5	9	0	0	0	0	0
Solea solea	127	56	1013	1196	24	0	24	0	106	40	30	5	181	12	6	0	6	24
Sprattus sprattus	13	3	0	16	6	0	6	0	0	0	0	0	0	0	0	0	0	0
Syngnatus acus	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trachurus trachurus	27	0	0	27	0	3	3	54	22	30	5	752	863	58	197	292	195	742
Trachinus vipera	0	0	0	0	0	137	137	660	1256	10	1010	2058	4994	1274	1341	650	1932	5197
Trigla gurnardus	0	0	6	6	0	0	0	3	0	0	0	14	17	0	0	6	17	23
Trisopterus luscus	564	6	740	1310	783	92	875	280	634	1200	492	10	2616	770	23	344	68	1205
total	7266	1045	11806	20117	4808	814	5622	1856	6711	8505	5982	3201	26255	4080	2650	2385	3078	12193
Diversity																		
Number of species	15	12	15		14	14		16	18	14	15	14		15	14	16	17	
Shannon-Wiener index	2.56	1.29	1.34		2.52	2.40		2.90	2.66	2.18	2.92	1.64		2.47	2.35	3.11	2.20	
Simpson index	0.22	0.64	0.60		0.22	0.27		0.19	0.21	0.31	0.15	0.47		0.21	0.30	0.15	0.41	

Table 10. Densities of commercial fish species observed during the juvenile fish survey (September '97; O29 'Broodwinner')

number of species (# ind./ 100.000m²)

Genus species		sampling station												
		1	2	3	4	5	6	7	8	9	27	49	92	Total
Cod	*Gadus morhua*	0	0	5	0	16	4	0	0	0	0	5	0	30
Dab	*Limanda limanda*	178	0	270	328	362	247	109	108	0	11	186	40	1839
Plaice	*Pleuronectes platessa*	248	0	152	749	16	30	19	33	0	5	0	10	1262
Common sole	*Solea solea*	81	0	30	180	205	86	201	104	43	874	216	388	2408
Whiting	*Merlangius merlangius*	43	0	98	82	117	273	337	332	31	163	201	154	1831
	total	550	0	555	1339	716	640	666	577	74	1053	608	592	7370

Table 11. Density and diversity of fishstock around the Belgian Continental Shelf and in the vicinity of the NORFRA pipeline (August '97 ; A. 962 R.V. Belgica)(density in # ind./100.000m²)

Station		1	2	36	37	39	40a	86	P1	P2	P3	Total
Bib	*Trisopterus* species	0	7	0	0	0	109	31	0	505	202	855
Brill	*Scophthalmus rhombus*	8	0	0	0	0	0	0	0	0	5	13
Cod	*Gadus morhua*	0	0	7	0	0	0	0	0	12	27	47
Common sole	*Solea solea*	99	86	22	17	7	34	328	48	12	98	750
Dab	*Limanda limanda*	0	158	30	80	60	0	555	154	208	16	1262
Dragonet	*Callionymus lyra*	152	647	30	114	235	0	929	0	0	0	2107
Flounder	*Platichthys flesus*	0	0	0	0	0	76	0	0	0	0	76
Greater sand eel	*Hyperoplus lanceolatus*	15	0	0	0	0	0	0	0	0	0	15
Grey gurnard	*Eutrigla gurnardus*	0	7	0	0	0	0	0	0	0	0	7
Lemon sole	*Microstomus kitt*	0	0	0	17	0	0	0	0	6	22	45
Lesser sand eel	*Ammodytes tobianus*	114	33	22	0	54	0	0	0	0	0	223
Lesser weever	*Trachinus vipera*	1673	1849	2094	0	0	0	523	0	0	0	6139
Melt	*Osmerus eperlanus*	0	0	22	11	7	0	0	0	0	0	41
Plaice	*Pleuronectes platessa*	137	73	75	40	60	0	226	166	36	16	829
Red gurnard	*Aspitrigla cuculus*	23	7	15	34	0	0	0	6	0	0	85
Scaldfish	*Arnoglossus laterna*	23	145	105	6	94	0	39	0	0	0	411
Smoothhound	*Mustelus mustelus*	0	0	0	0	0	0	0	0	0	0	0
Solenette	*Buglossidium luteum*	23	172	97	6	0	0	94	0	0	5	397
Sprat	*Sprattus sprattus*	0	0	0	0	0	8	0	0	0	0	8
Trigger fish	*Balistes carolinensis*	0	0	7	0	7	0	0	0	0	0	14
Tub gurnard	*Trigla lucerna*	0	7	0	11	7	0	8	0	0	0	33
Turbot	*Scophthalmus maximus*	0	0	0	0	0	0	0	6	0	0	6
Whiting	*Merlangius merlangus*	0	0	0	0	0	8	0	0	48	0	56
	total	2266	3189	2528	336	530	236	2734	380	826	394	13419
	diversity											
	number of species	10	12	12	10	9	5	9	5	7	8	
	Shannon-Wiener diversity	1.52	1.97	1.17	2.69	2.33	1.78	2.47	1.61	1.59	2.05	
	Simpson dominance	0.56	0.39	0.69	0.20	0.26	0.34	0.22	0.37	0.44	0.34	