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 INTERCONNECTOR gas pipeline on the Belgian Continental Shelf

Final report

GENT

Report - Mai 1999

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SUMMARY (final campaign)

In autumn 1998, samples were taken along the trajectory of the INTERCONNECTOR gas pipeline in the Belgian coastal waters of the Southern North Sea. This third and final survey, carried out one year 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 72 macrobenthos species were found, half of them polychaetes, with an average density of 931.4 ind./m² per sampled station. The average density along the pipeline trajectory (1095.3 ind/m²) was considerably higher than those from the reference sampling sites (521.6 ind./m²).

The epibenthos communities ranged between 378 ind./10^5m² and 101,053 ind./10^5m² and were dominated by *Ophiura* spec. (brittle stars), *Liocarcinus holsatus* (flying crab) and *Asterias rubens* (starfish), with high densities respectively near the coast and the sandbanks. The brown shrimp (*Crangon crangon*) was predominantly present in the coastal stations. The flying crab (*Liocarcinus holsatus*) and the starfish (*Asterias rubens*) reached very high biomass values in both sampled areas (*L. holsatus* equalled up to 74,668 g ww/10^5m² at the reference area, *A. rubens* reached 771,568 g ww/10^5m² along the pipeline).

The fish densities in the different observed areas varied from 1161 ind./10^5m² to 22,124 ind./10^5m². The most common ones were sand gobies (*Pomatoschistus* spec.), dragonet (*Callionymus lyra*), hooknose (*Agonus cataphractus*) and lesser weever (*Trachinus vipera*). The fish communities near the sandbanks were in general more divers. The highest densities were caught near to the coast. *Pomatoschistus* spec., *Agonus cataphractus* and *Solea solea* reached their highest abundancies in the coastal areas. Commercial fish species (*Limanda limanda*, *Pleuronectes platessa*, *Trisopterus* spec. and *Gadus morhua*) were frequently caught, but never in very high numbers.

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. With reference to the construction of the INTERCONNECTOR gas pipeline, partly embedded in the sea bottom, three periods of sampling were carried out: before, immediately after and one year after the execution of the project. Underwater TV video recordings were initiated to monitor the position and the condition of the pipe. Additionally, a survey was conducted amongst 140 Belgian and Dutch fishermen, reflecting their views and experiences with the presence of the pipeline on the seafloor bottom.

This final report presents the results of:

- the third survey, done in autumn 1998, of the biotic environment along the trajectory of the planned pipeline, one year after the completion of the works
- previous campaigns, done in the framework of the ongoing biomonitoring projects as reference
- underwater video recordings
- a survey amongst Belgian and Dutch fishermen (See appendix p. 67)

Finally, this report contains also a synopsis (cf. General summary, p. 21) of the three periods of sampling and its final conclusions.

2. MATERIAL AND METHODS

All sampling programmes are carried out on board of the Belgian oceanographic research vessel A.962 'R.V. BELGICA' and the training vessel "O29- Broodwinner". The grids of the sampling cruises are shown in figures 1-3. The geographical positions, the sampling periods and the type of area of the sampling stations are summarised in tables 1-2.

2.1. Description of the study area

Compared to other oceans, the North Sea is very shallow, the average depth being about 60 metres, at some places only 20 metres. Because of the shallowness, the marine fauna and flora are very abundant, whereas there is a relatively small volume of water. The flow of nutrients combined with good spawning grounds have made the North Sea into a rich fishing area. Whereas the North Sea covers less than 0.2 per cent of the world's oceans, as much as 4.3 per cent of the world's total fish catches comes from there. The North Sea has also the busiest marine traffic in the world, and many of Europe's major ports are located around it. Therefore it is very vulnerable to all sorts of pollution. Tidal currents on one hand and oceanic currents on the other however, create a constant flushing of water and result into a circulation along the different coasts of the countries that surround it. The flushing time of the sea water varies from six months to three years for the different parts of the North Sea. These tidal currents are also responsible for the present geomorphology of the region.

In the framework of the installation of a gas pipeline that crosses the Southern Bight of the North Sea - from Bacton (UK) to Zeebrugge (B) - a large area along the planned trajectory is sampled. This survey confines itself to that part of the pipeline that currently is being laid on the bottom of the Belgian Continental Shelf. As shown in figures 1-3, the pipeline passes also several sandbanks (Bligh Bank, Thornton Bank and Wenduine Bank), before reaching its final destination, the Zeebrugge terminal. At some places (e.g. at the crossing of the shipping lane near the western Scheur) the pipeline will be buried and stabilised in the bottom. Most of the time however it will be laid on a preswept sea floor bed.

2.2. Sampling and sorting

2.2.1. Macrobenthos

Ten sites (H4-H8, 435, 700, 710, 780 and 140) along the pipeline trajectory were chosen for monitoring, on each site, 4 replicates were taken for macrobenthic analysis. All sampling was done during autumn 1998. In order to compare this data with other macrobenthic data, 4 reference stations were considered (120, 315, ZG02 and 330). 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.

In the present survey only the ones taken in autumn '98 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 per species, diversity and dominance were determined.

2.2.2. Epibenthos

Thirteen sites on the Belgian Continental Shelf, of which 9 (H4-H8, 435, 340, 710 and 780) lay in the vicinity of the pipeline, have been chosen as additional samples, investigating the changes in epibenthic population. Stations 120, 140, 215 and 315 were considered as reference.

Therefore 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 per species, biomass (wet-weight g/$10^5 m^2$) and diversity were determined.

2.2.3. Fish

A total of 13 stations were sampled in the context of this pipeline project. Nine of these lay along the trajectory or in its near vicinity, while the others were scattered over the Belgian Continental Shelf (cf. Epibenthos).

Another 12 stations, sampled during the period September '98, with the training vessel "029- Broodwinner" and 10 stations, sampled during August '98, 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.

2.2.4. Underwater TV video recordings

Underwater video recordings were initiated to monitor the position and the condition of the pipe, one year after its completion. Using a small underwater camera attached to a line, the seafloor bottom was filmed.

Efforts were made to get a glimpse of the pipeline itself or of signs of where the pipe was buried in the sediment. Unfortunately, due to bad weather conditions and to bad visibility on the seafloor bottom (too much suspended material), no video images could be made.

Several attempts were made at different positions, but with no satisfactory result.

2.2.5. Survey

In addition to the analysis of sediment and biota, the Fisheries Research Station also conducted a survey under 140 Belgian and Dutch fishermen to find out whether they had experienced any difficulties in fishing since the pipeline was laid.

The results of the survey are presented in the appendix p. 67.

2.3. Mathematical analysis

2.3.1. 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.

2.4. 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

The three sampling campaigns are in the following referred to as t(0), t(1) and t(2) representing respectively the consecutive surveys done in spring '97, autumn '97 and autumn '98.

3.1. Sediment

Sediment characteristics of sampling stations along the pipeline at t(2)

Station	reference	Med. gr.	grain fraction						
		(µm)	>2000µm	<2000µm	<1000µm	<500µm	<250µm	<125µm	<63µm
700	Pipeline	95.0	3.96	1.61	4.15	8.90	21.34	25.30	34.74
710	Pipeline	173.0	1.12	0.68	2.34	18.51	51.34	13.66	12.35
780	Pipeline	178.0	0.86	1.20	1.19	11.25	72.87	5.98	6.65
H4	Pipeline	226.0	3.68	1.01	1.65	36.66	48.19	3.21	5.60
H5	Pipeline	362.0	0.40	1.06	8.28	86.16	2.99	0.08	1.04
435	Pipeline	314.0	1.31	2.58	4.32	62.44	27.54	0.63	1.18
H6	Pipeline	325.0	0.72	1.25	3.14	72.18	21.57	0.15	0.99
H7	Pipeline	400.0	0.77	2.96	25.96	62.84	6.45	0.13	0.89
H8	Pipeline	401.0	12.13	1.35	15.50	66.13	4.03	0.10	0.76

All sampled stations along the pipeline, were characterised by a sediment with a median grain size varying between 95 and 401 µm. The fractions 250-500 µm, which are defined, according to the Wentworth scale, as medium coarse sand, dominated the sediment in all offshore stations. The stations closer to the coast tended to have a finer substrate, dominated by finer sand and silt fractions. A significant gradient in median grain size was noticed from the coastal area towards the open sea.

Generally, a decrease in medium grain size was reported in all samples sites compared to autumn '97. Although these changes were not always as radical as in H6, they showed a clear tendency towards a finer sediment. It was difficult to determine whether these changes at the pipeline stations were caused by either antropogenic or as a result of natural processes (Fig. 4).

When comparing the sediment types of some of the reference stations for the last three years, clear changes were also observed (figs. 5 & 6). 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.

As there was only one major disturbance in a short period of time, it is obvious that the sediment would have undergone some changes. Although this phenomenon was not distinctly observed in our samples. But shortly after these changes it would have evolved towards a new equilibrium, similar to that of the surrounding area depending on the local natural processes.

The chemical characteristics (Organic material, Interstitial water, $CaCO_3$ and TOC content) of the sediment samples of the pipeline at t(1), showed some clear changes in comparison with the initial situation t(0), but no general trends were found. At t(1) we would have expected a decrease of organic material and TOC in comparison with t(0). The disturbances of the sediment caused by the construction works would have created a resuspension of organic matter and minerals into the water column and therefore leaving the sediment with lower concentrations. This phenomenon was recorded for organic matter in stations H4, H8, 700 and 780. One year after the pipeline completion a recovery in organic material in the sediment was noted in the coastal area. At H5-H8 the amount of organic material was even lower than the initial situation before the pipeline works t(0).

The $CaCO_3$ content showed many fluctuations at the sampled stations, but no general trends were registered. The TOC content increased in the final survey. The changes in interstitial water content at the pipeline stations were comparable in all three sampling periods (See fig. 7).

Chemical sediment characteristics (in %) along the pipeline

Chemical sediment characteristics (in%)												
	spring '97				autumn '97				autumn '98			
Station	Org. mat.	Int. H2O	TOC	CaCO3	Org. mat.	Int. H2O	TOC	CaCO3	Org. mat.	Int. H2O	TOC	CaCO3
H4	1.83	20.33	0.30	5.01	1.70	22.00	0.26	5.91	1.86	22.67	0.13	4.59
H5	0.49	17.33	0.07	2.77	0.66	17.00	0.07	5.20	0.19	17.50	0.31	1.97
H6	0.47	18.33	0.11	2.58	1.33	16.50	0.04	0.67	0.31	17.17	0.19	2.14
H7	0.40	17.33	0.00	1.59	0.37	16.67	0.07	2.41	0.09	16.67	0.09	1.35
H8	0.74	17.83	0.16	3.34	0.48	16.50	0.06	3.07	0.28	16.50	0.14	2.59
700	6.77	40.83	1.83	10.13	5.16	37.00	1.27	8.69	6.78	41.83	1.08	12.10
710	0.59	17.67	0.11	12.64	0.75	19.67	0.28	7.90	2.50	25.50	0.27	6.17
780	2.14	26.67	0.35	7.45	0.80	19.67	0.15	5.62	1.95	24.00	0.21	5.59
435	0.47	14.83	0.07	3.24	0.45	16.33	0.07	3.69	0.45	17.67	0.12	2.02

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. 8).

3.2.1. Density

Densities of the macrofauna, taken in autumn 1998 along the trajectory of the INTERCONNECTOR pipeline, ranged from 216.7 ind./m² (station 435) to 3596.7 ind./m² (station 710). The mean was 1095.3 ind./m². All sampling stations were dominated by polychaetes (>50% of the population). The most common ones were the species : *Magelona mirabilis*, *Scoloplos armiger*, *Spio* spec., *Spiophanes bombyx*, *Chaetozone setosa* and *Polygordius* species.

Magelona mirabilis reached his highest density in station 710 (2683.3 ind./m²) dominating the whole macrobenthos community. The *Scoloplos armiger* species dominated the macrobenthic populations in H4, but were absent in the more offshore stations H6-H8. *Spio* spec. and *Spiophanes bombyx* were frequently found in the samples and reached their highest abundancies in respectively stations H4 and 780. The offshore stations were characterised by the presence of two interstitial polychaet species (*Hesionura elongata* and *Polygordius* spec.). In station H7, *Polygordius* spec. became the most abundant macrobenthic species. The more opportunistic polychaet, *Chaetozone setosa*, was only noticed in large quantities in stations 140 and 700. The polychaet species which occurred only once in the sampled pipeline stations were: *Aricidea suecica*, *Eusyllis blomstrandi*, *Lanice conchilega*, *Microphthalmus similis*, *Owenia fusiformis*, *Sthenelais boa*, *Streblospio benedicti* and *Protodorvillea kefersteini*.

The crustaceans, mainly amphipods from the genera *Bathyporeia* and *Urothoe*, were the most common species along the trajectory of the pipeline. Also present were different kinds of cumacea species (*Diastylis*, *Bodotria*, *Iphinoe* and *Pseudocuma*). They were always well represented but never dominated the macrobenthos community. Highest densities were reached in H5 and H6 (respectively 126.7 ind./m² and 113.3 ind./m²). Rare species were *Ampelisca brevicornis* and a Cirolaninae spec.

For the remaining macrobenthos groups, e.g. the echinoderms, low densities were recorded, except for the echinoderms, *Echinocyamus pusillus* and juvenile Ophiura species (respectively 130.0 and 250.0 ind./m² in resp. station H8 and station 780). The molluscs were only well represented in the stations nearest to the coast (780, 710, 700 and 140) but hardly noticed along the actual pipeline (H5-H8) except in H4. The most common species were *Abra alba*, *Ensis* species and *Mysella bidentata*.

Finally, anthozoa species were only found in stations 780 and H4. In the latter however, high densities were reached. Another species, *Branchiostoma lanceolatum* (Lancelet) out of the Chordata phylum, reached high abundancies in the more offshore stations (max. of 153.3 ind./m² in station H7).

In the reference stations (120, ZG02, 315 and 330), densities varied between 163.3 ind./m² (ZG02) and 1260.0 ind./m² (120). Similar to the pipeline stations there was a clear dominance of polychaetes (except in ZG02 and 330). The latter were however dominated by crustaceans (mainly amphipods from the genera *Urothoe* and *Bathyporeia*).

At station 120 no crustaceans were found in the sediment samples. The macrobenthos population consisted mainly out of a large fraction of polychaetes and a smaller fraction of molluscs. Molluscs were only present in high abundancies in the coastal stations 120 and 315. Especially *Abra alba* and *Ensis* species reached relatively high densities. Hardly any echinoderms were found in the reference samples.

All basic data are listed in figures 9-13 and tables 3 & 5.

3.2.2. Diversity

A total of 72 species were found during the autumn of 1998. Of that total, 67 species were found along the pipeline. The Shannon-Wiener diversity index reached its highest value at the reference station 120 and the pipeline station H5 (respectively 3.88 & 3.37). Along the trajectory of the pipeline, divers populations were recorded in all sampled sites (Fig. 9; Tab. 3). Generally, the diversity index reached high values. In one station (710) however a clear dominance was noticed (0.57). The mean number of species present near the pipeline (19.0) exceeded even that of the reference stations (18.5).

3.2.3. Comparison of the three sampling campaigns: t(0), t(1) & t(2)

a) General considerations

↳ The first sampling campaign offered an inventory of the macrobenthic populations present along the trajectory of the pipeline and of different reference stations before the construction works. The next survey, after the development of the pipeline, an impoverished macrobenthic community was expected. With lower diversities, as the normal living conditions were disturbed. Therefore a lot of species would have disappeared and the communities would be taken over by surface-dwelling errant deposit feeders and other opportunistic species who recolonised the soil, feeding on dead material. Also predation by demersal fish or epibenthic species (e.g. crabs and echinoderms) on dead macrobenthic species would in general result in lower densities.

A year after the completion a recovery was anticipated of the overall densities and perhaps also of the diversity. We had to take in account that the first survey was completed in the spring, during which the macrobenthic densities are at their lowest. The latter campaigns were both conducted during the autumn period.

↬ Another thing to consider was the fact that the sediment composition had changed during and after the works. And as most macrobenthos species are closely related to a certain sediment type, this could result into a totally different population composition. The densities could be comparable but the number of species and the similarity of species between the first two campaigns could differ a lot. Finally, as the disturbance was only noticeable over a limited area around the pipeline trajectory, the chance that some of our samples were taken beyond that area also had to be considered.

b) density

In general a increase in macrobenthos densities was recorded at t(1) considering the whole pipeline area (Fig. 13). Only in one pipeline station (H4) there was a deterioration in abundancy, just after the laying of the pipe (t1). In the other nine sampling sites the total density was nearly twice as high in comparison with the initial situation (t0). One should expect in this situation a macrobenthic community consisting mainly out of opportunistic, short living species who colonised the disturbed area. However in most of those nine sampling sites (except in 140 and 700) the populations were characterised by mainly long-living sedentary species (large polychaetes, bivalves and echinoderms). The presence of opportunistic species and large amounts of silt-loving bivalves, in 140 and 700, were more related to the radical sediment conditions (very high silt concentrations) rather than the result of a serious mechanical disturbance. In the third and final campaign t(2), the overall macrobenthos communities of the pipeline area showed even higher densities than at t(1). However in four stations a decrease in abundancy was reported, but remaining always higher than the initial density at t(0).

Three of four reference stations showed a status quo or a slight decrease in density at t(1) (except station 120). This was unusual if we take into account the recruitment that had taken place within the macrobenthic communities during the early summer until the beginning of autumn. The results of the third campaign showed no clear trends. Whereas in three of the reference stations (ZG02, 315 and 330) there was a minor increase in density recorded, an opposite effect was seen in reference station 120.

c) diversity

Slight differences in diversity, between the first two periods of sampling t(0) and t(1), were reported (Fig. 13). Five of the pipeline stations and three reference stations revealed higher Shannon-Wiener indices in the second sampling campaign. This was surprising, because after disturbances of the sediment there normally is a decrease in diversity observed. The macrobenthic communities appeared to be more divers after the pipe was laid than before. Also the number of species lay higher in most of the sampled pipeline stations. In the third and final campaign, the diversity indices decreased considerably in most of the offshore pipeline stations and remained even below the initial situation t(0). The pipeline stations closer to the coast showed no clear trends.

The diversity index of the reference stations at t(2) showed no significant changes in comparison with the sampling campaign just after the pipeline works t(1). While one remained at the same level of the second survey, the others showed a minor in- or decrease. The number of species present at the different sites revealed the same trend as for the diversity index. Similar situations were observed in the ongoing biomonitoring campaigns, especially at stations which are liable to variable natural processes.

It is clear that in the case of a single disturbance (e.g. the laying of a pipeline), it shows to 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 coastal areas and 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. 14).

3.3.1. Density

The total abundancy of the epibenthos population, sampled during autumn 1998 along the pipeline, ranged from 378 ind./10^5m² in H6 to 101,053 ind./10^5m² in H4.

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

The pipeline area was dominated by the echinoderms, *Ophiura* species (65.1 %). High densities were recorded near stations H4 (79,158 ind./10^5m²), 780 (49,941 ind./10^5m²) and 340 (9678 ind./10^5m²). *Asterias rubens* was commonly found and represented about 9.2 % of the total density. Densities varied from 69 ind./10^5m² in H8 up to 7931 ind./10^5m² in 780.

Other important species that were regularly caught were the crustaceans *Crangon crangon* (11.2 %), *Liocarcinus holsatus* (9.8 %) and *Pagurus bernhardus* (3.9 %). High densities of brown shrimps (*Crangon crangon*) were found in the pipeline stations near the coast and in the vicinity of sandbanks. The flying crab, *Liocarcinus holsatus,* prefers clean sands to bury themselves in (Verwey, 1978). The highest concentrations were found near the pipeline stations H4 and 710. 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 were always present in the samples. They reached their highest density in 780 and H4.

The reference area was characterised by a different epibenthos population. In comparison with the pipeline area (Table 10), large fractions (57 %) of *Crangon crangon* (brown shrimp) dominated the epibenthos catches in the coastal stations (120 & 140). Also the flying crab (*Liocarcinus holsatus*) was vastly present (31 %) especially around station 120. The echinoderm, *Ophiura* spec. never reached high abundancies as recorded in the pipeline area. They represented only 5.3 % of the total epibenthos community. Other epibenthos representatives occurring in lesser abundancies were : *Liocarcinus depurator*, *Alloteuthis subulata* and *Asterias rubens*.

3.3.2. Biomass

The highest biomass along the pipeline track was recorded in station 780 (439,854 g wet weight/10^5m^2), the lowest in H6 (3776 g ww/10^5m^2). The reference stations showed lower biomass in comparison with the pipeline stations (up to 93,273 g ww/10^5m^2 in 120).

High biomass values were recorded in both pipeline and reference area for the starfish (*Asterias rubens*) (respectively 771,5678 g ww/10^5m^2 & 37,185 g ww/10^5m^2). They represented about 70 % and 25 % of the entire biomass. In the reference area, the flying crabs (*Liocarcinus holsatus*) reached even higher biomass in the coastal area (50 %) (Fig. 9). The *Crangon crangon* (brown shrimp) fraction was also considerably high in the reference area (19 % of the total biomass).

3.3.3. Diversity and dominance

A total of 23 epibenthos species were found in autumn 1998 at the different sampling stations of the pipeline. The Shannon-Wiener diversity index varied from 1,16 (710) to 2,95 (435). The number of species varied between 7 (in 710 and 780) and 18 (in H5). With the exception of station 710 there was no clear dominance noted.

In the reference area 18 different species were caught during the third campaign. The diversity index varied between 1,03 (140) and 2,76 (215). *Crangon crangon* dominated the epibenthos populations in the coastal stations 120 and 140.

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

All densities, diversity and biomass are listed in figs. 15-18 and tables 7-10.

3.3.4. Comparison of the three sampling campaigns: t(0), t(1) & t(2) (Figures 19-20)

a) General considerations

➭ 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, consisting mainly out of smaller individuals.

In a next stage, one year after the pipeline works, the amount of smaller species diminished probably due to predation by larger animals or moved to other regions. Resulting in a smaller population containing mainly bigger species.

↬ 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 t(1), it is possible that during that period a new population was reinstalled.

That would also explain the higher diversity in the latter campaign. The even higher diversity and amount of species in the last survey t(2) could indicate that the presence of the gas pipe gave rise to a new and favourable biotope for epibenthic species.

b) density and biomass

The epibenthic populations caught at t(1) differed considerably from those at t(0), not only in their abundancy but also in their biomass and diversity. Nearly all sampling sites at t(1) were characterised by larger and more divers populations, with higher biomass values. At t(2) the density showed a slight decline but still revealed much higher abundancies than reported in t(0). The biomass values at t(2) rose to a very high level, implying that the epibenthos community at t(2) mainly consisted out of larger species in comparison with t(1).

A similar evolution was observed in the reference area for sampling periods t(0) and t(1). At t(2) however density and biomass were comparable with the t(1) situation.

The relative species composition of the pipeline stations was also liable to drastic changes. However, the dominant presence of brittle stars was clearly observed in all sampled campaigns t(0), t(1) and t(2). Other important species, like *L. holsatus*, *A. rubens*, *C. crangon* and *P. bernhardus* showed more variations in their abundancy. At t(1), the flying crab reached very high densities (30 % of the total density), at t(0) and t(2) they represented respectively 5 and 10 % of the total epibenthos population. The starfish populations were in the first two sampling periods comparable but rose to a maximum in the last one t(2). The brown shrimps and the hermit crabs revealed similar fluctuations in their abundancies. At t(1) low densities were recorded for both species in comparison with the initial situation, at t(2) a recovery was noted. The brown shrimps became even the second most common species of the epibenthos population at t(2).

In the reference area similar changes were reported, but with different species. Brittle stars dominated the epibenthos at t(0) and t(1), but where hardly present in the last campaign. At t(2) the brown shrimp became the most common species (57 % of the total density). The flying crab fractions rose to a maximum density at t(1). A comparable amount was caught in the next sampling campaign t(2). Other species like *Asterias rubens* and *Pagurus bernhardus* showed a slight deterioration in their abundancy during the consecutive surveys.

The relative biomass of the six most important species showed also some variations over the sampled periods. The flying crab proved to be well represented during the autumn campaign t(1), despite the area of sampling (pipeline of reference). The starfish biomass fluctuated similar in both areas and reached its lowest value at t(1), just after the construction works. The hermit crabs were in the last two surveys comparable in density and size. In the first campaign more, but smaller, individuals were counted. The brittle stars followed a downward trend in biomass in both areas.

c) diversity

During the consecutive sampling campaigns along the pipeline the mean diversity showed an upward trend. The number of species present in the samples showed a similar course. A similar trend was observed for the diversity and the amount of species at the reference area over the sampled periods.

3.4. Fish

3.4.1. Density

In autumn 1998, the total density of the sampling sites varied between 1161 ind./10^5m² (station H7) and 22,124 ind./10^5m² (station 120). The total amount of fish caught, equalled 63,916 ind. The most common ones were sand gobies (*Pomatoschistus* species), dragonet (*Callionymus lyra*), hooknose (*Agonus cataphractus*), lesser weever (*Trachinus vipera*), dab (*Limanda limanda*), bib (*Trisopterus* species) and sole (*Solea solea*). Practically all stations (pipeline and reference) are dominated by either one or several of these species (fig. 21).

The average density in the reference area was considerably higher than in the pipeline area. This phenomenon was mainly caused by the enormous amount of sand gobies that was caught at reference station 120 (15,562 ind./10^5m²).

3.4.2. Length-frequency of the commercial fish species

Pipeline area

The plaice, common sole and whiting populations were clearly separated into different year classes (length classes). The place population was characterised by a vast juvenile fraction around 9 cm with a max. of 152 ind./10^5m² and a adult fraction around 25 cm with a max. of 43 ind./10^5m². A similar distribution was noted for the common sole, with a juvenile fraction around 11 cm and an adult fraction around 21 cm. The amount of whiting caught was considerably lower than the other commercial fish but still there was a clear distinction noticed between a juvenile fraction around 19 cm and a adult fraction around 27 cm. The remaining commercial fish populations (bib, dab and cod) were characterised by a large fraction of juveniles and lacked a distinct adult fraction. Furthermore the cod catches were very low.

Reference area

Similar as in the pipeline area, the whiting, plaice and common sole populations showed clear separated juvenile and adult fractions in their length-frequency distributions. For the whiting population the juveniles fraction reached a max. of 65 ind./10^5m² around 18 cm. The adult fraction situated around 28 cm and was less abundant (max. of 17 ind./10^5m²). Higher densities were found for the plaice species. Here, the juvenile fraction reached a max. around 11 cm (88 ind./10^5m²); the adult fraction showed a peak around 22 cm with a max. of 62 ind./10^5m². The common sole distribution was characterised mainly by the presence of juveniles with a max. of 185 ind./10^5m² around 8 cm. Within the adult fraction low densities were reported (max. 22 ind./10^5m² around 21 cm).

The other populations (bib, dab and cod) lacked an adult fraction. Especially within the dab catches a very large juvenile fraction was observed (around 6 cm with a max. of 1069 ind./10^5m^2). The cod and bib populations showed a juvenile fraction both with a max. around 17 cm with respectively 6 and 26 ind./10^5m.

3.4.3. Diversity and dominance

A total of 30 species were found at the different sampling sites (table 11). The diversity index ranged from 0.95 (in 140) to 2.74 (in H5). Station 140 was characterised by a high dominance of sand gobies (*Pomatoschistus* spec.) what kept the diversity value very low. The average number of fish species caught along the pipeline area amounted to 14. The surrounding reference areas showed comparable quantities of species (13,8).

A list of all species found during the autumn campaign can be found in table 11.

All densities, diversity and length-frequencies are listed in figs. 22-24 and tables 12 & 13.

3.4.4. Comparison of the three sampling campaigns: t(0), t(1) & t(2) (figures 25-27)

Considering the total fish catches (commercial and non-commercial) of all three sampled periods, a positive trend was recorded. During the period after the construction works a vast amount of fish was caught in the pipeline area. One year after at t(2), this amount had dropped to a lower level but still was fairly high in comparison with the reference area.

However, by making the distinction between commercial and non-commercial fish densities, other trends were found. Generally, the commercial fish catches showed a downward trend during the consecutive sampling periods t(0), t(1) and t(2). Actually, on species level two opposite trends in density were recorded. Dab, whiting and cod catches revealed a downward trend, while plaice, common sole and bib showed an upward trend. The loss of especially dab and whiting could not be compensated by the higher common sole and bib catches. Therefore the overall balance staid negative. These trends were also recorded in the reference area, except for bib.

The non-commercial fish showed an overall upward trend in both pipeline and reference areas. In the pipeline area this was especially the case for the hooknose and both dragonet species (*Callionymus lyra* and *C. reticulatus*). Sand gobies and lesser weever reached both a maximum at t(1) but showed in the last sampling campaign (t2) a drastic fall. In the reference area only two species showed a gradual upward trend, the sand gobies and the hooknoses. The sand gobies reached in the final campaign t(2) remarkable high abundancies and dominated the fish community.

The diversity and the number of species present in the catches in the pipeline area were comparable with the reference area and did not show significant changes.

3.4.5. Results from other fish campaigns in 1998

(1) 0.29 Broodwinner (Fig. 28)

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

A comparison was made between the total densities (mainly juveniles) of commercial fish caught in September '96 (13,591 ind./10^5m^2), in September '97 (7370 ind./10^5m^2) and in September '98 (17,826 ind./10^5m^2).

The total density dropped to a minimum in September '97, but recovered back in September '98 and reached again similar abundancies as in September '96. All commercial fish, except for dab, revealed a steep decline in density in September '97 in that area. The common sole and whiting populations diminished for more than 50 % compared with the year before. The loss in plaice was not so dramatic. All commercial fish species showed however a clear recovery in September '98. The dab population even exceeded their previous maximum.

Whether these fluctuating densities were caused by the construction of the Interconnector pipeline is questionable, because there are yearly density oscillations within the juvenile 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 14.

(2) A.962 Belgica

Ten sites were sampled, with a 40 mm meshed bottom trawl, scattered all over the Belgian Continental Shelf

The total densities per sampled station varied from 856 ind./10^5m^2 in station P3 to 15,944 ind./10^5m^2 in station 40a. In comparison with the catches from the year before (August '97) there was a considerable increase in abundancy recorded. Four sampling sites near to the pipeline (1, 39, P1 and P3) showed higher densities, except for station 2.

Although the number of species was similar, the diversity went down. This was due to the fact that some species were dominantly present in the catches (e.g. *Trachinus vipera*).

The amount of commercial fish: dab (*Limanda limanda*), common sole (*Solea solea*) and plaice (*Pleuronectes platessa*) fluctuated in all sampled stations. No direct effect (positive or negative) coming from the pipeline construction on the existing populations could be detected.

All basic data are listed in figure 29 and table 15.

4. FINAL CONCLUSIONS

The aim of this study was to evaluate the impact of the construction of a gas pipeline 'INTERCONNECTOR' on the composition and abundance of the macro- and epibenthos invertebrates and the fish populations within an area on the Belgian Continental Shelf.

The sediment composition showed some changes, but could not be related to the pipeline works, as similar changes were also recorded at the reference stations. The latter were probably due to natural processes in situ. The construction and laying of the pipeline would certainly have caused severe disturbances to the sediment composition. The sampling techniques used did not show any substantial changes in sediment composition close to the pipeline area.

The macrofaunal response, immediately following the pipeline works, was characterised by an increase in macrobenthic density and diversity. These populations were however not dominated by opportunistic short-living organism, as we would have expected, on the contrary. One year later we encountered a small loss in density whereas the diversity stayed at a status quo. The results of the various pipeline stations however showed sometimes opposite trends. This made it very difficult to assess the exact impact of such an installation on the local fauna. It is clear that in the case of a single disturbance (e.g. the laying of a pipeline), it shows to be very complex to predict 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 coastal areas and around the sandbanks. As there were sometimes large variations in density and diversity within the consecutive replicates, the assumption was made whether some of them were taken from an adjacent, not so disturbed area in the neighbourhood of the pipeline. Thereby causing a general increase in the total abundancy and diversity.

The epibenthos communities showed very high densities and biomass in the period immediately after the pipe was installed. This was also reflected in the number of species and the overall diversity. The assumption was made that the high epibenthos densities could be related to their scavenging nature. Their high mobility enabled them to colonise the disturbed area and feed on the damaged or killed fauna. The even higher diversity and amount of species in the last survey could indicate that the presence of the gas pipe gave rise to a new and favourable biotope for epibenthic species (cf. shipwrecks). These assumptions are based only on one observation and could therefore not be verified.

The fish populations caught along the pipeline trajectory were comparable in density and diversity with other sampled areas. The higher abundancies near the coast were seasonally occurring phenomena. It is difficult to assess the possible damage to the fish stock near the pipeline, because it ranges over different kinds of biotopes (coast, sandbanks, open sea) where the various physical conditions characterise the different benthos communities. But most fish have the ability to migrate from unfavourable situations and return when the conditions are again normalised.

GENERAL SUMMARY

The environmental impact of the installation of the gas pipeline 'INTERCONNECTOR', crossing the Belgian Continental Shelf, on the benthic and fish communities in situ, was monitored. Dredging operations had to be carried out to enable the pipeline to be installed on a firm and safe seabed and to protect the pipeline in the shallow coastal waters. The end of the works was scheduled for August 1998.

Three periods of sampling were carried out: before t(0), immediately after t(1) and one year after the completion of the construction works t(2).

Densities and species composition of the macro- and epibenthos as well as the fish populations along the pipeline trajectory were recorded. In addition to that, reference stations were chosen to monitor the environmental changes in more detail. Furthermore sediment characteristics were determined for each sampled pipeline station.

The changes in sediment at the pipeline stations showed no clear indication of mechanical disturbances, as the reference stations revealed similar variations in their sediment composition.

The macrobenthos communities near the pipeline, sampled just after the pipeline constructions t(1), showed in general higher densities in comparison with the first survey t(0). A year after the pipe laying t(2), a small loss in density was recorded. The diversity however rose to a maximum in the second campaign. Also the number of species present in the samples were in general higher compared with t(0). The last campaign revealed a decrease in diversity and number of species. This phenomenon was however not as such detected at the reference stations. In all three sampling periods polychaetes and crustaceans dominated the macrobenthos communities.

The epibenthos showed a larger and more divers population at t(1), with higher biomass values. At t(2) the total density showed a slight decline, but still revealed much higher abundancies than reported in t(0). The biomass remained high, resulting in an epibenthos community consisting out of larger species in comparison with t(1). The higher diversity and amount of species in the last survey could indicate that the presence of the gas pipe gave rise to a new and favourable biotope for epibenthic species. (cfr. shipwrecks)

In all three periods comparable quantities of fish were caught. However, the amount of commercial fish caught during the successive sampling campaigns showed large variations. Generally, the commercial fish catches showed a downward trend during the consecutive sampling periods t(0), t(1) and t(2). On species level two opposite trends in density were recorded. Dab, whiting and cod catches revealed a downward trend, while plaice, common sole and bib showed an upward trend. The decrease of especially dab and whiting was not equivalent to the observed increase of common sole and bib catches. Therefore the overall balance staid negative. This phenomenon was seen mainly in the coastal area and was probably due to seasonally fluctuations. The non-commercial fish showed an overall upward trend in both pipeline and reference areas.

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Figures and Tables

Fig. 1. - INTERCONNECTOR - Positions of sampling stations for macrobenthos research

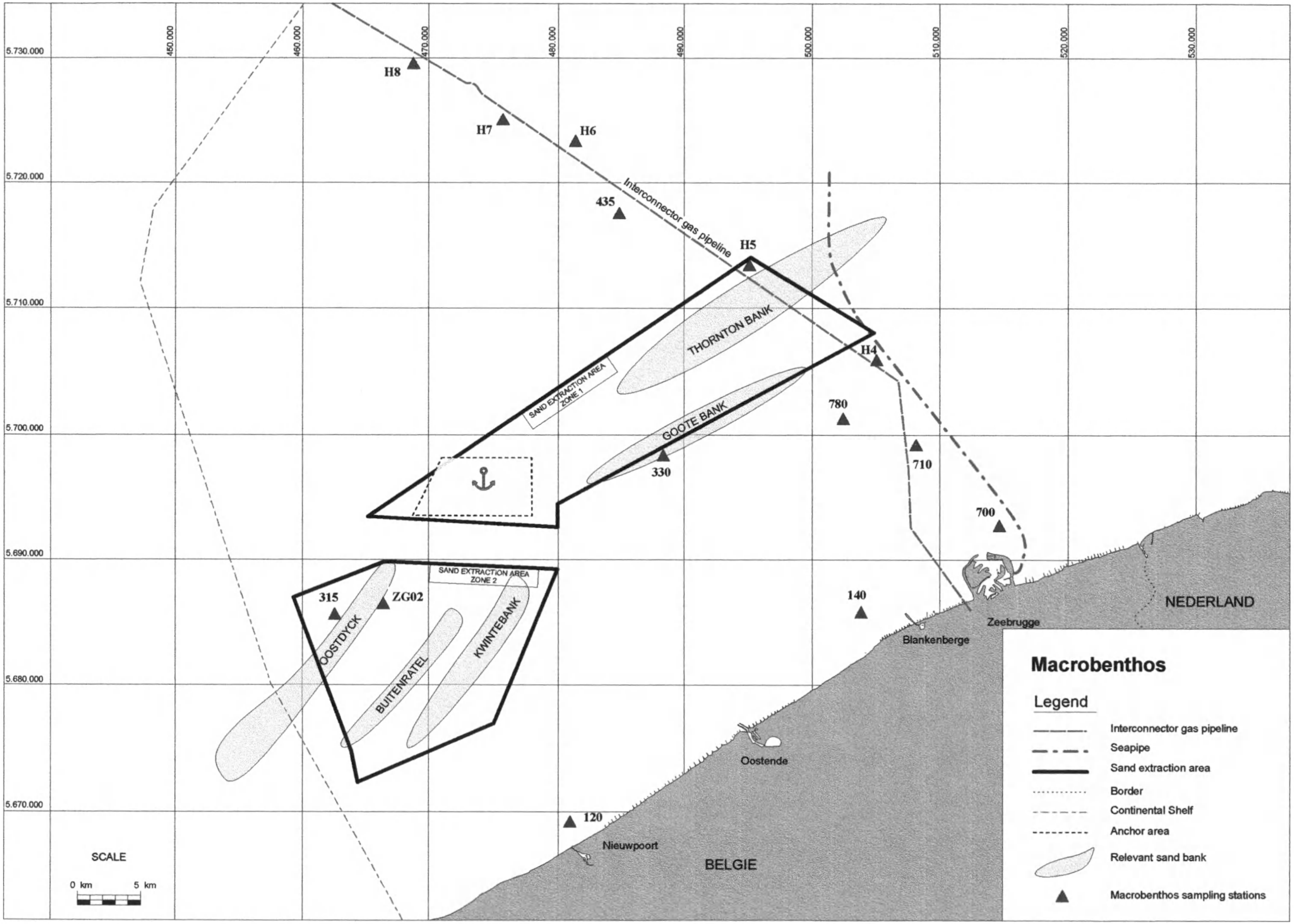


Fig. 2. - INTERCONNECTOR - Positions of sampling stations for epibenthos research

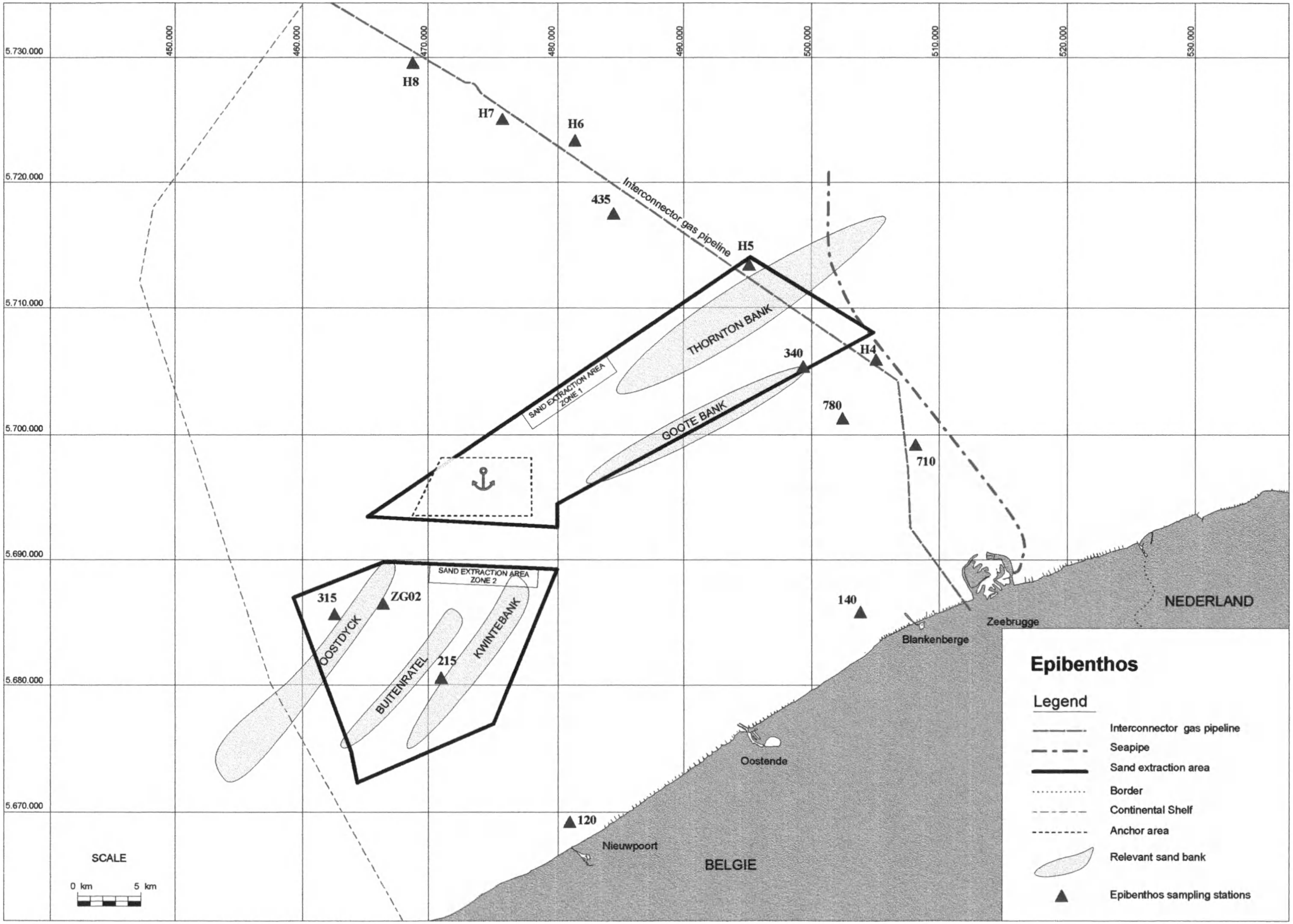


Fig. 3. - INTERCONNECTOR - Positions of sampling stations for fish research

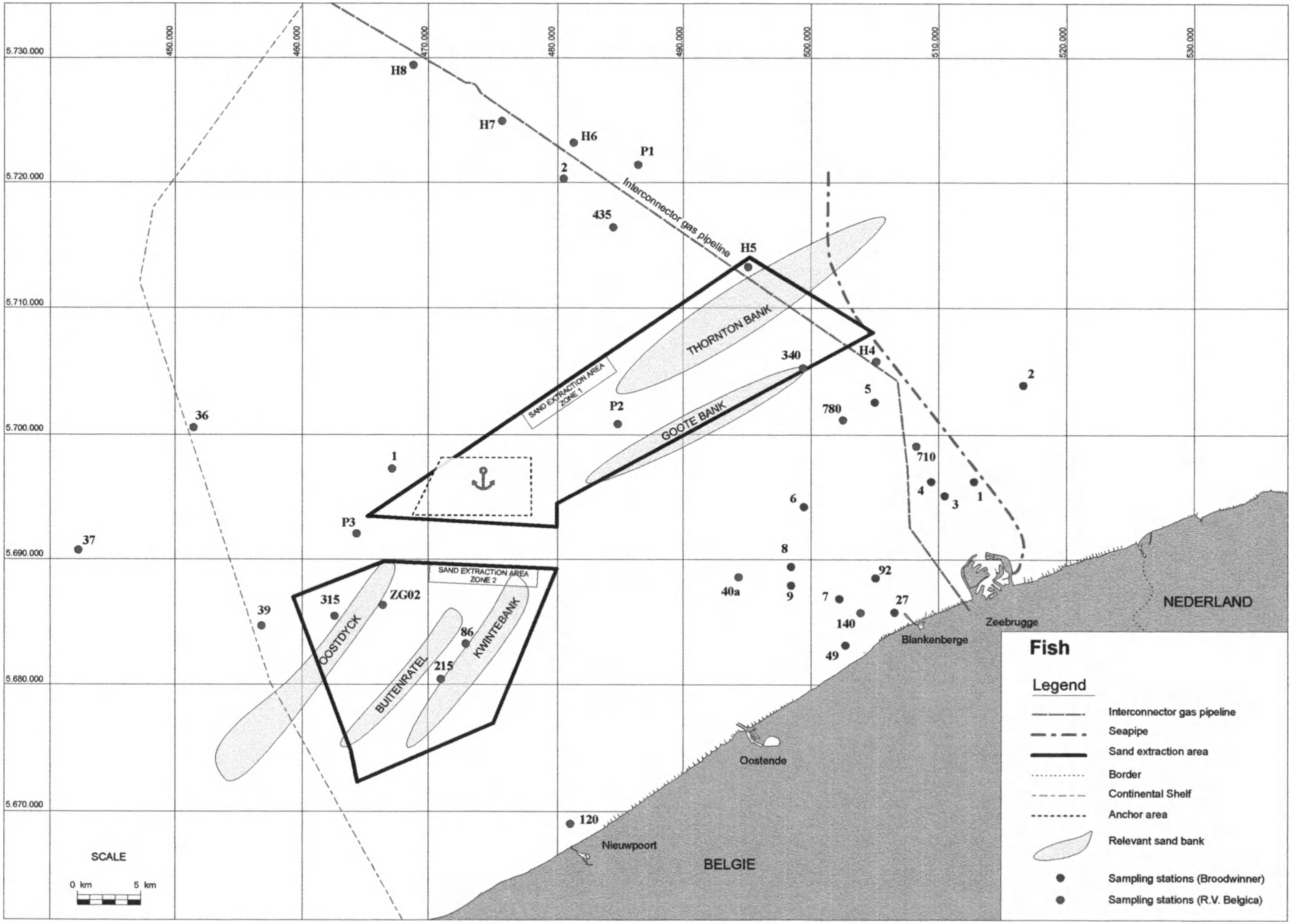


Table 1. Sampling positions epi-and macrobenthos and fish (Interconnector)

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

STATION	POSITION SHOT		TYPE
H4	51°30.00'	3°03.00'	Pipeline
H5	51°34.00'	2°55.00'	Pipeline
H6	51°40.00'	2°43.50'	Pipeline
H7	51°42.50'	2°38.50'	Pipeline
H8	51°45.00'	2°32.50'	Pipeline
120	51°11.05'	2°42.15'	reference
140	51°19.65'	3°03.05'	dredging
315	51°19.35'	2°27.80'	reference
215	51°16.75'	2°36.95'	reference
330*	51°26.00'	2°48.50'	sand
340	51°30.00'	3°00.10'	sand
435	51°34.80'	2°47.40'	reference
700*	51°22.60'	3°13.20'	dredging
710	51°26.00'	3°08.00'	dredging
780	51°28.30'	3°03.55'	dredging
ZG02*	51°20.00'	2°30.00'	reference

(*) no epibenthos and fish catches

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 2. Sampling periods (Interconnector)

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

Station	macrobenthos	epibenthos	Fish
H4	Autumn 1998	Autumn 1998	Autumn 1998
H5	Autumn 1998	Autumn 1998	Autumn 1998
H6	Autumn 1998	Autumn 1998	Autumn 1998
H7	Autumn 1998	Autumn 1998	Autumn 1998
H8	Autumn 1998	Autumn 1998	Autumn 1998
315	Autumn 1998	Autumn 1998	Autumn 1998
215	-	Autumn 1998	Autumn 1998
340	-	Autumn 1998	Autumn 1998
120	Autumn 1998	Autumn 1998	Autumn 1998
710	Autumn 1998	Autumn 1998	Autumn 1998
780	Autumn 1998	Autumn 1998	Autumn 1998
140	Autumn 1998	Autumn 1998	Autumn 1998
435	Autumn 1998	Autumn 1998	Autumn 1998
700	Autumn 1998	-	-
330	Autumn 1998	-	-
ZG02	Autumn 1998	-	-

Ship : 0.29 "Broodwinner"

Station	Fish
1	1996-1998
2	1996-1998
3	1996-1998
4	1996-1998
5	1996-1998
6	1996-1998
7	1996-1998
8	1996-1998
9	1996-1998
27	1996-1998
49	1996-1998
92	1996-1998

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

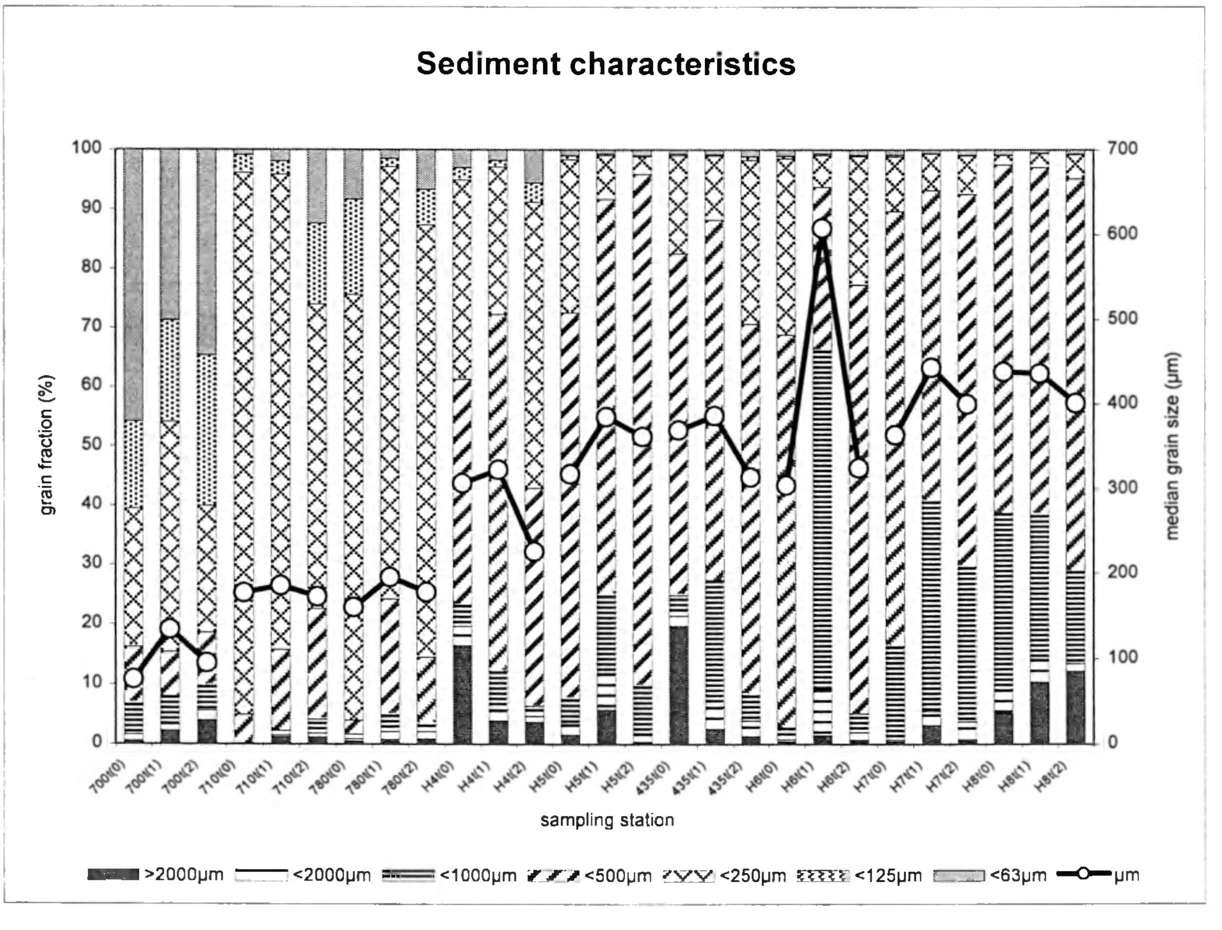


Fig. 4. Sediment characteristics Interconnector pipeline before t(0), just after t(1) and one year after the completion of the pipeline t(2) (spring, autumn 1997 and autumn 1998)

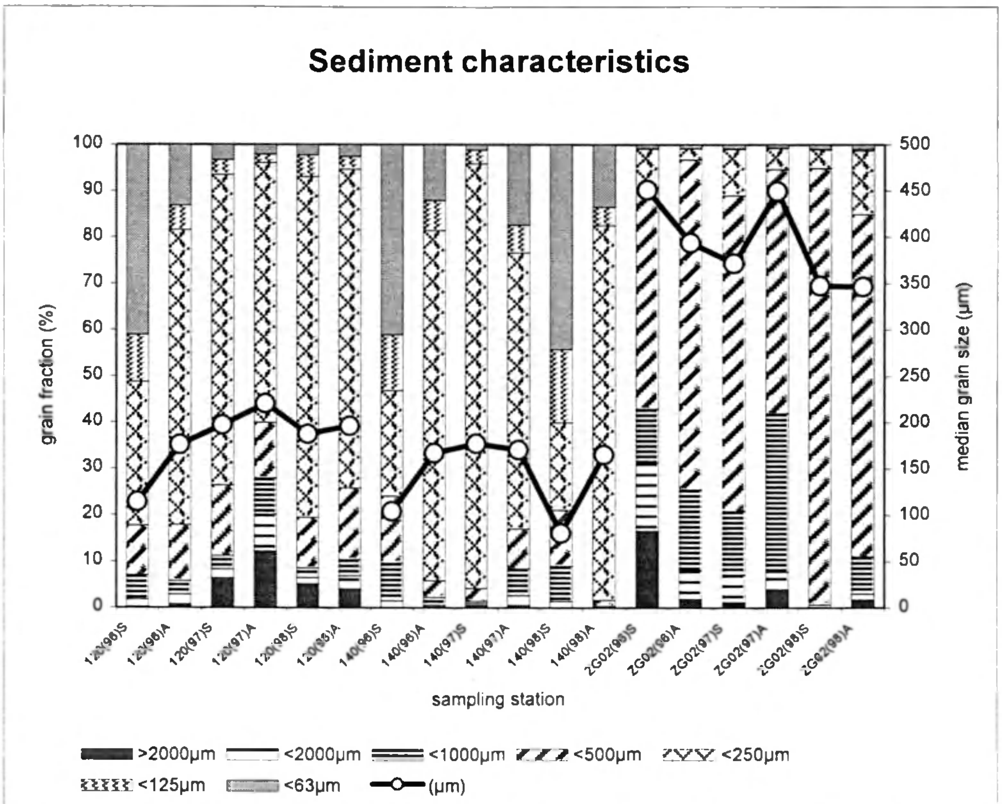
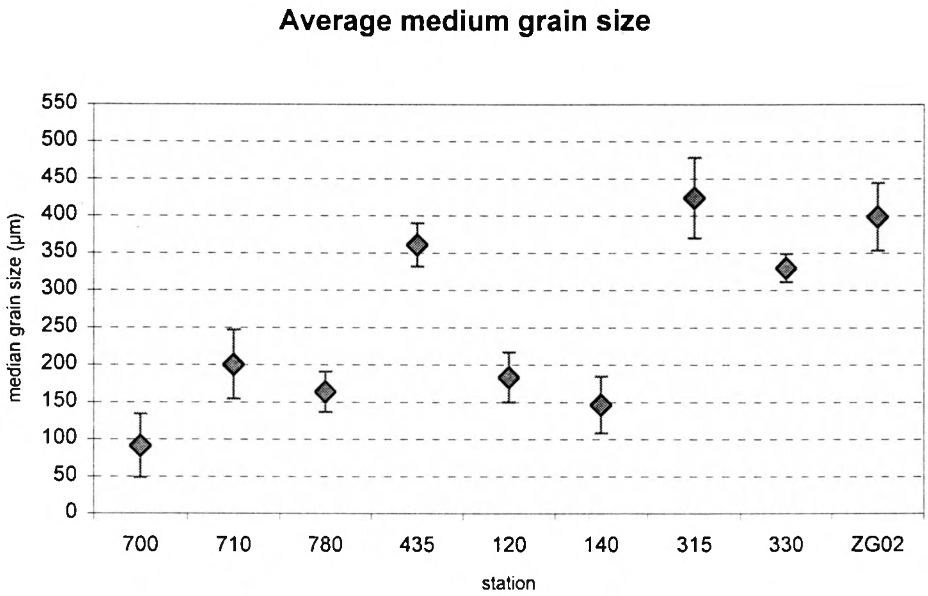


Fig. 5. Sediment characteristics of reference stations for the last three years (S) spring & (A) autumn



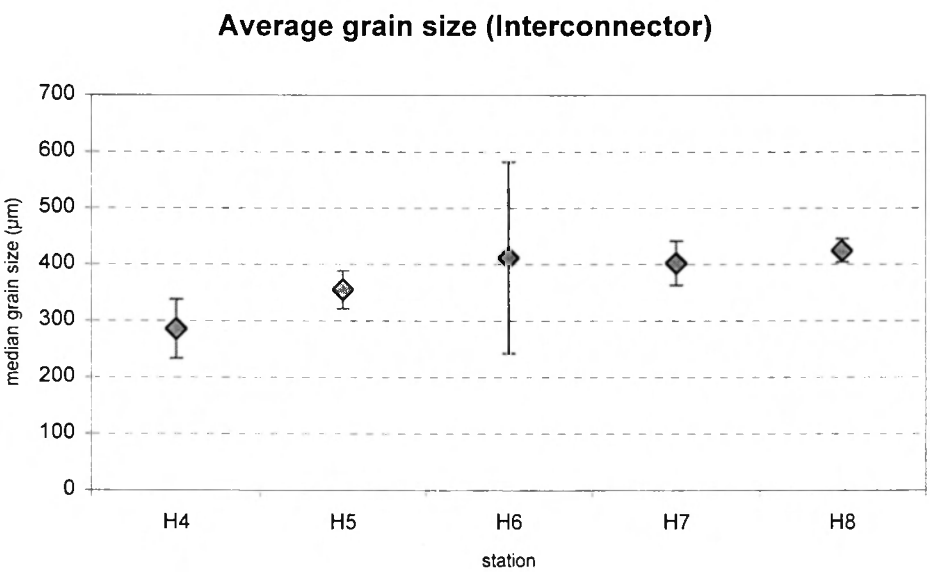


Fig. 6. Average median grain size and standard deviation of 9 sampling sites scattered over the Belgian Continental Shelf (period '95-'98) and five pipeline stations

Chemical sediment characteristics (in%)												
	spring '97				autumn '97				autumn '98			
Station	Org. mat	Int. H2O	TOC	CaCO3	Org. mat	Int. H2O	TOC	CaCO3	Org. mat	Int. H2O	TOC	CaCO3
H4	1.83	20.33	0.30	5.01	1.70	22.00	0.26	5.91	1.86	22.67	0.13	4.59
H5	0.49	17.33	0.07	2.77	0.66	17.00	0.07	5.20	0.19	17.50	0.31	1.97
H6	0.47	18.33	0.11	2.58	1.33	16.50	0.04	0.67	0.31	17.17	0.19	2.14
H7	0.40	17.33	0.00	1.59	0.37	16.67	0.07	2.41	0.09	16.67	0.09	1.35
H8	0.74	17.83	0.16	3.34	0.48	16.50	0.06	3.07	0.28	16.50	0.14	2.59
700	6.77	40.83	1.83	10.13	5.16	37.00	1.27	8.69	6.78	41.83	1.08	12.10
710	0.59	17.67	0.11	12.64	0.75	19.67	0.28	7.90	2.50	25.50	0.27	6.17
780	2.14	26.67	0.35	7.45	0.80	19.67	0.15	5.62	1.95	24.00	0.21	5.59
435	0.47	14.83	0.07	3.24	0.45	16.33	0.07	3.69	0.45	17.67	0.12	2.02

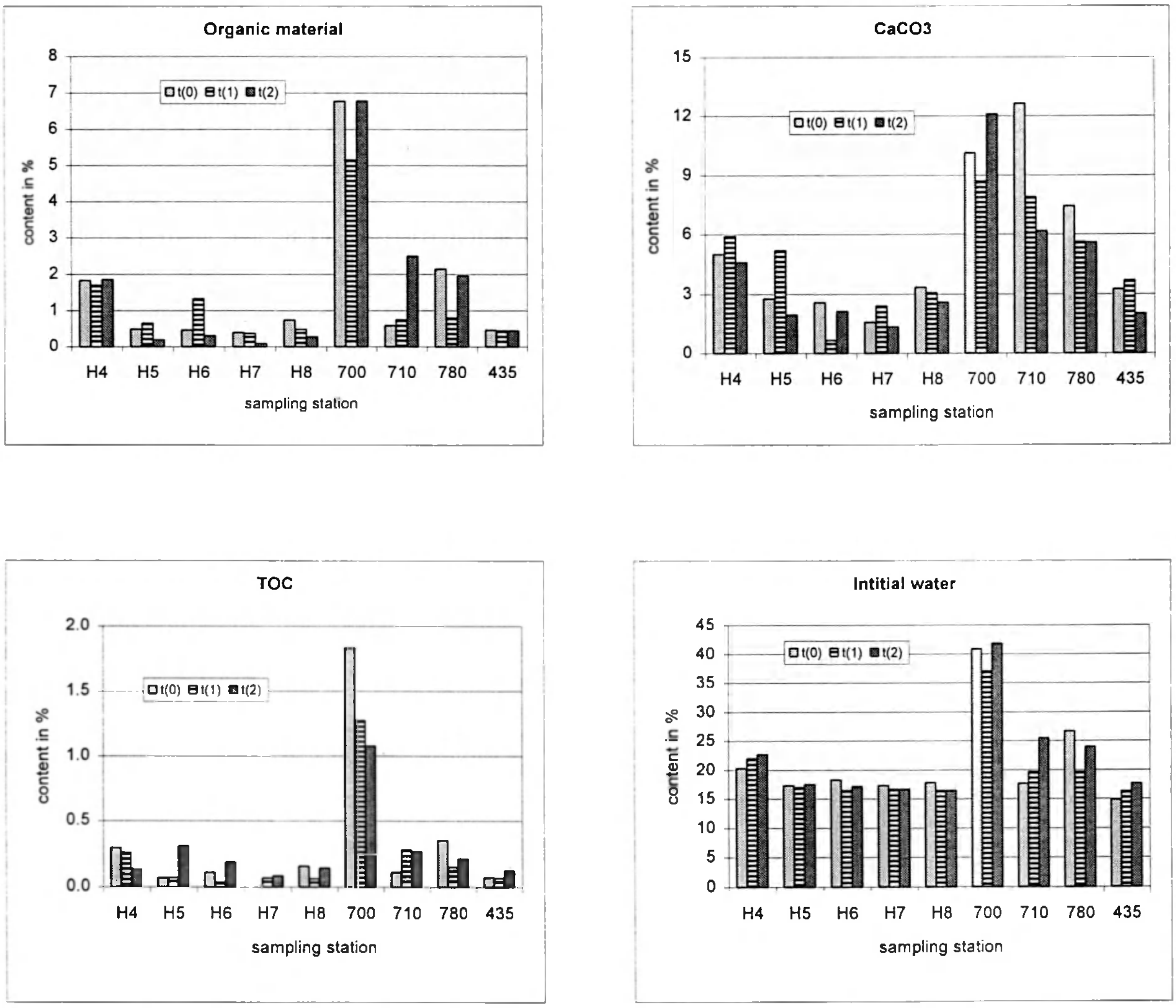
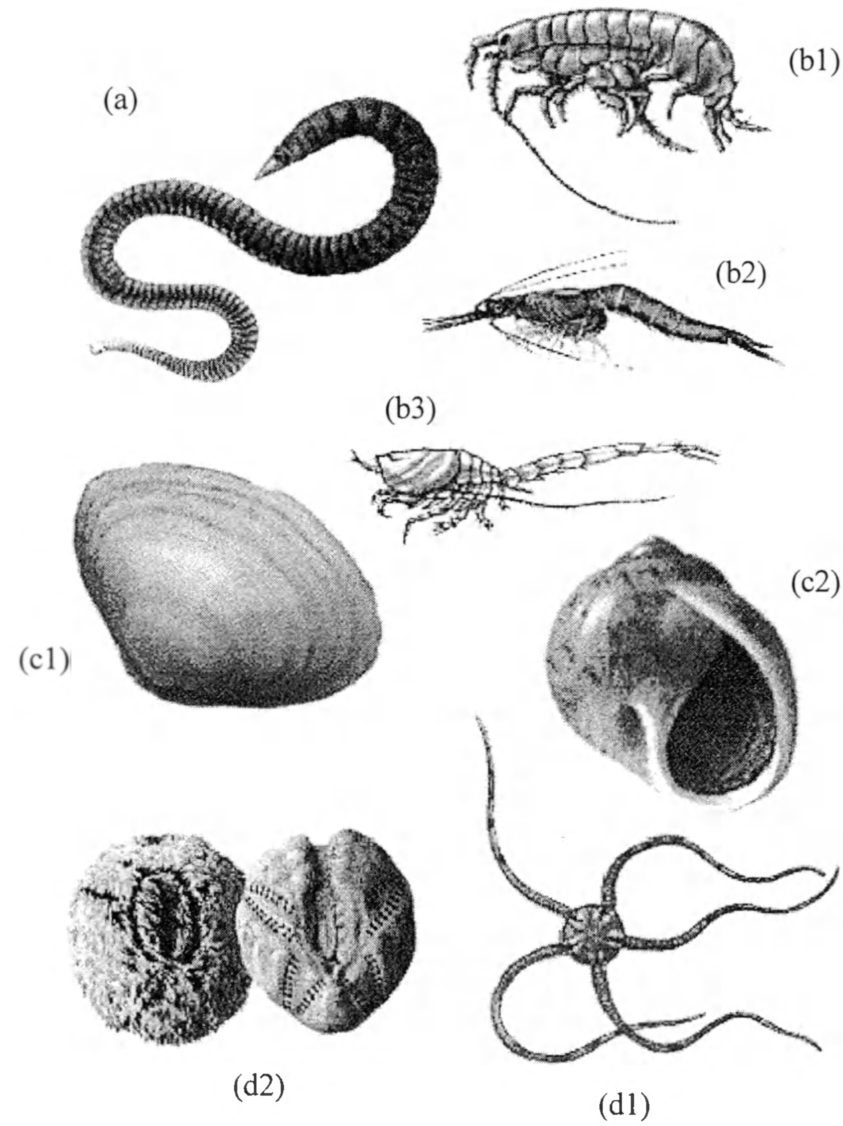


Fig. 7. The chemical characteristics of the sediment samples of the pipeline during the consecutive sampling campaigns t(0), t(1) and t(2)

Macrobenthos

Fig. 8. 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.



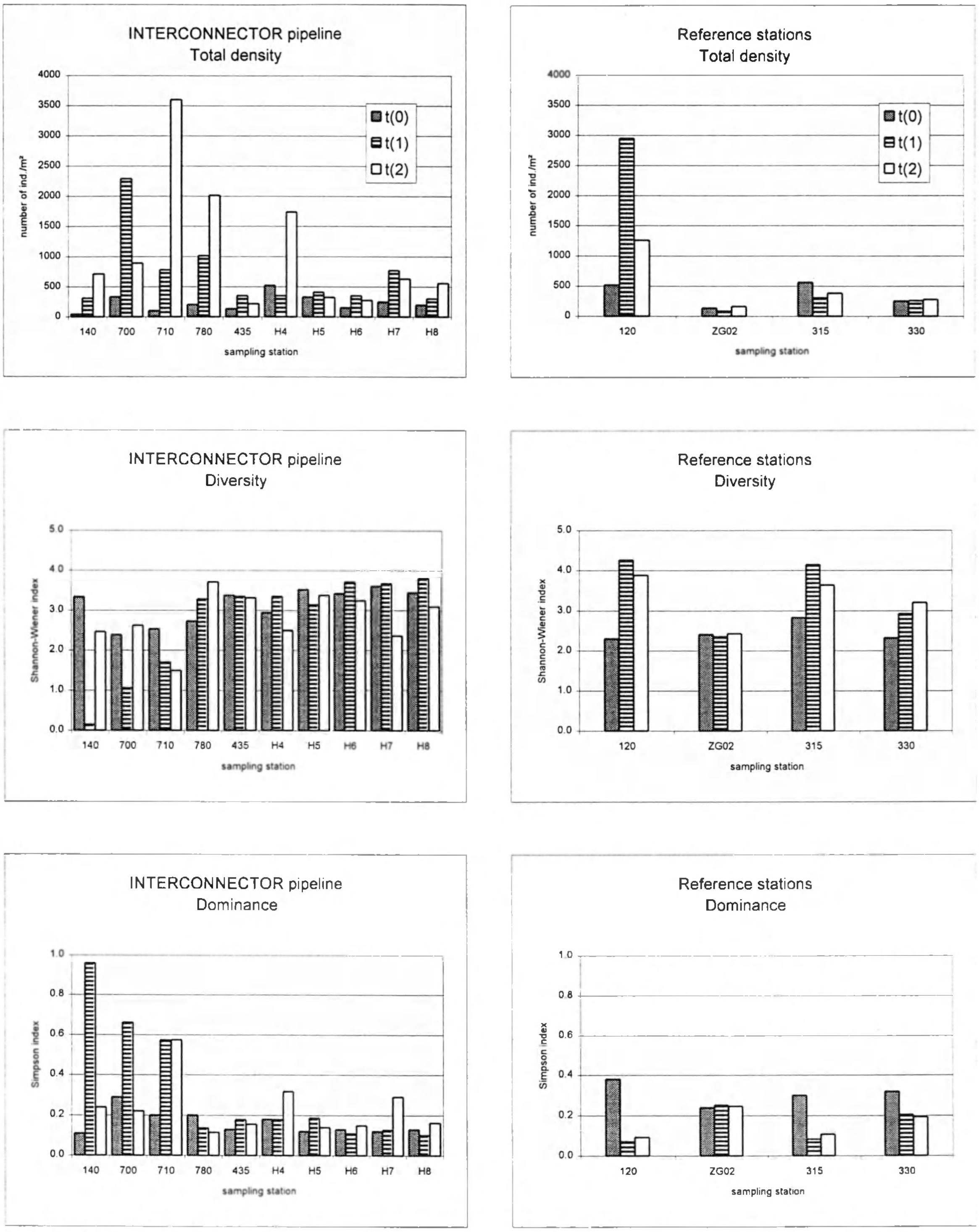
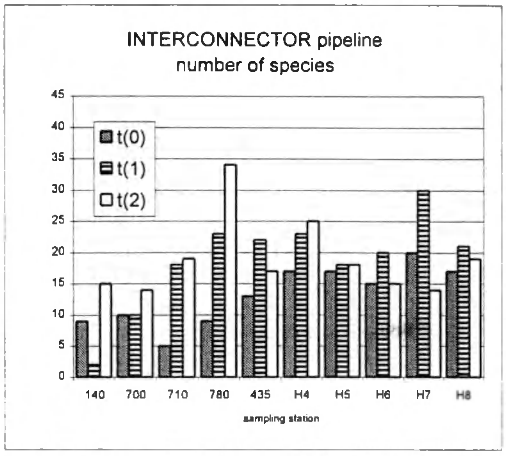


Fig. 9. Total density, diversity and dominance of the sampled macrobenthos stations along the trajectory of the pipeline and some reference stations before t(0), just after t(1) and one year t(2) t(2) after the installation of the INTERCONNECTOR pipeline (resp. spring, autumn 1997 and autumn 1998)



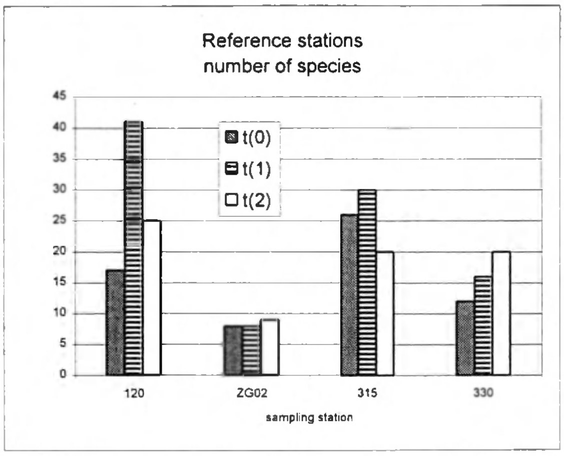


Fig. 10. Number of species along the trajectory of the pipeline and some reference stations before t(0), just after t(1) and one year after t(2) the installation of the INTERCONNECTOR pipeline (resp. spring, autumn 1997 and autumn 1998)

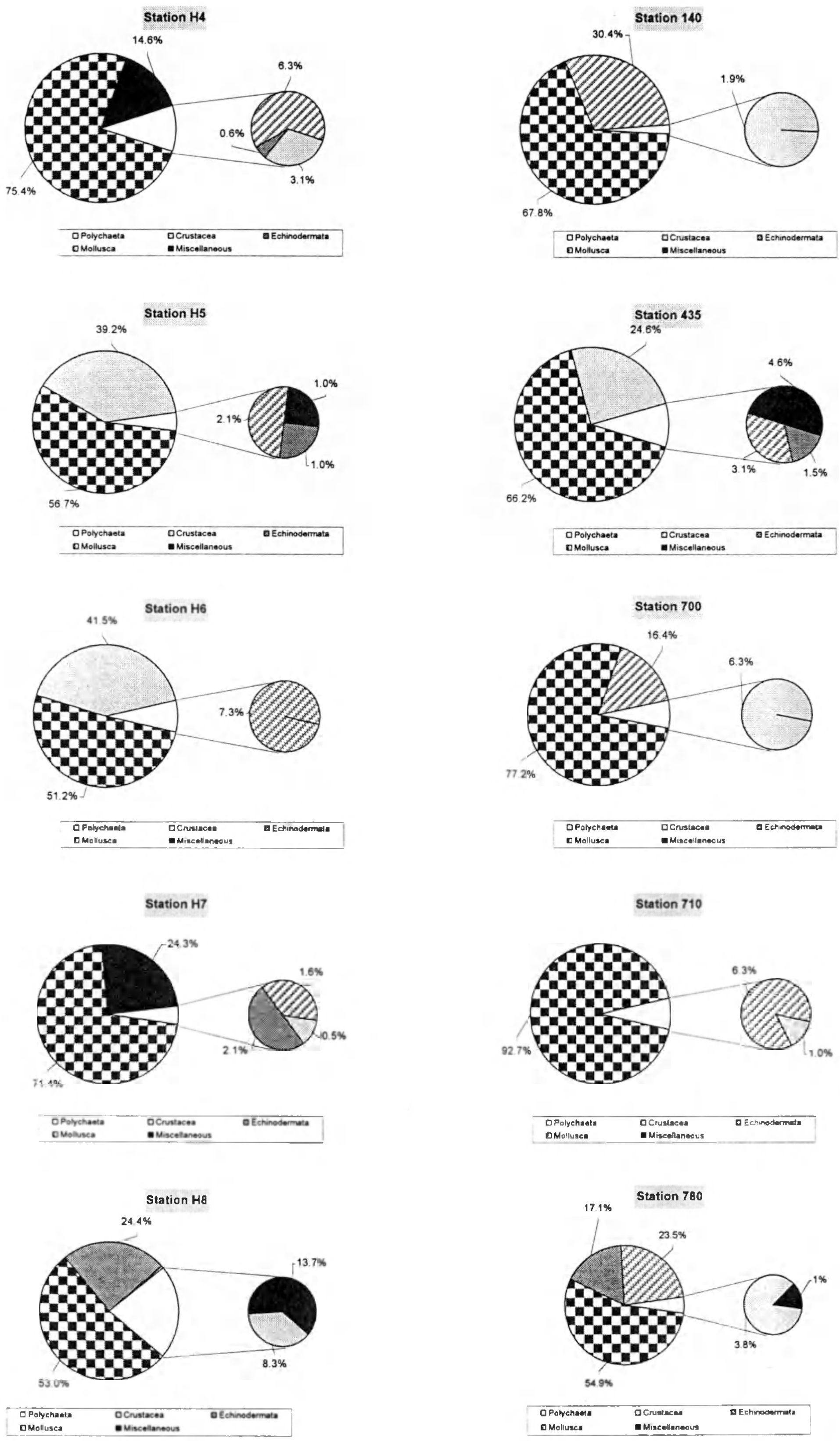


Fig. 11. Mean macrobenthos composition of the sampling sites along the Interconnector pipeline (autumn 1998)

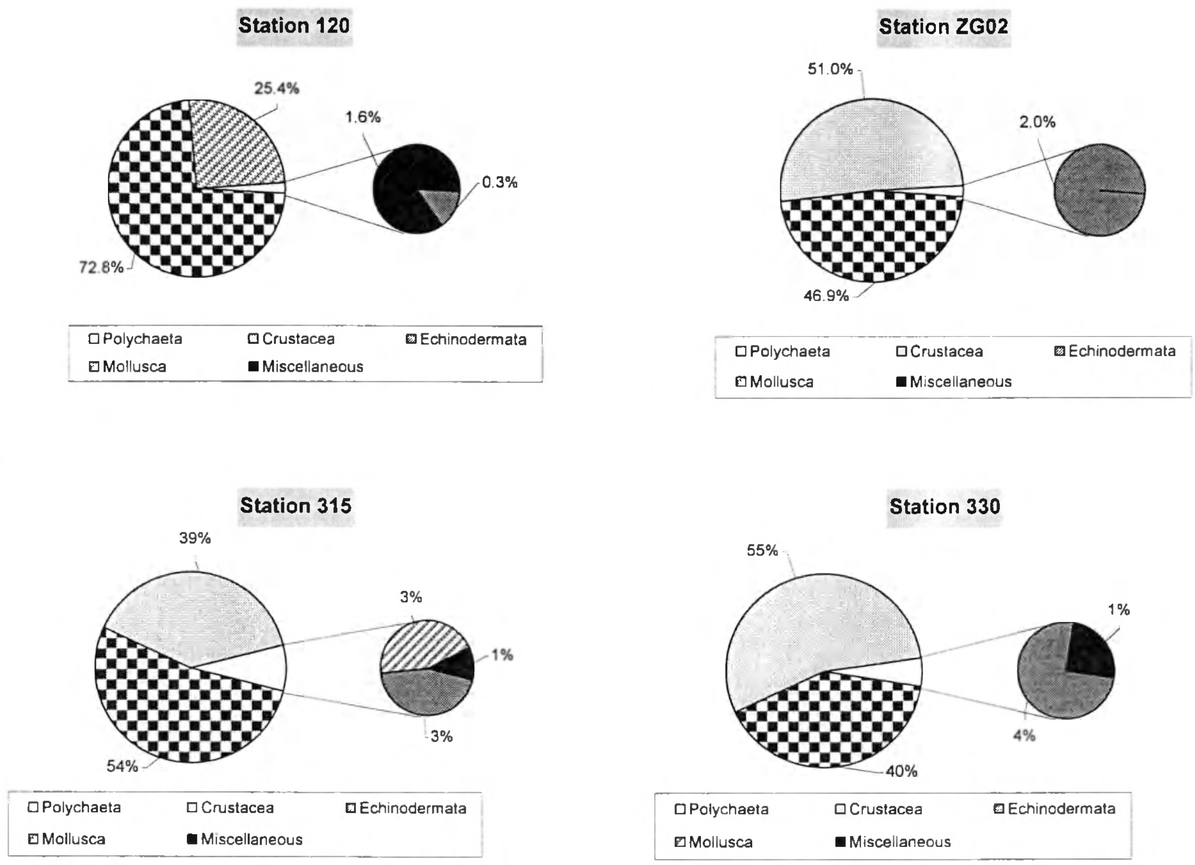


Fig. 12. Mean macrobenthos composition (in % values) of the reference sampling sites (autumn 1998)

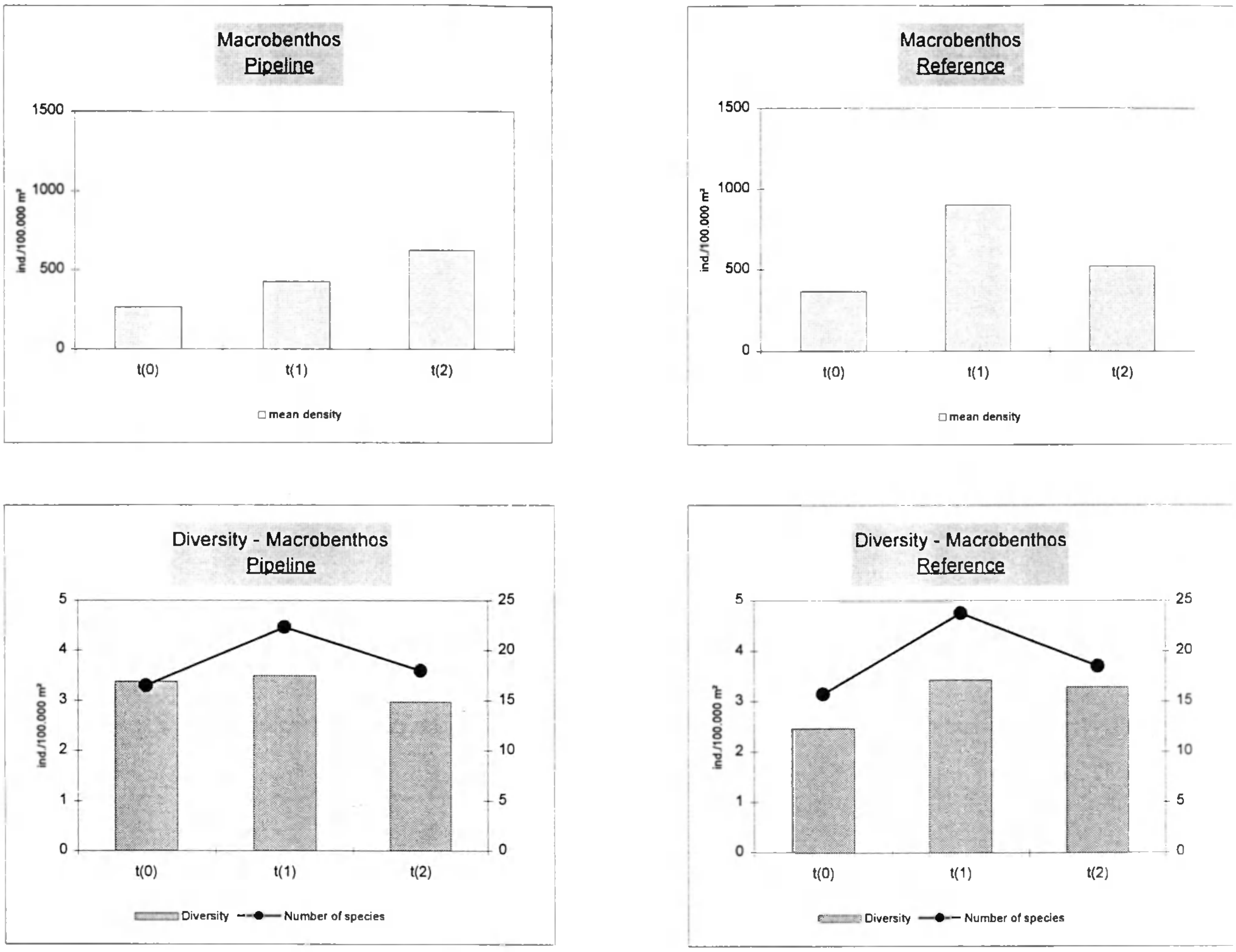


Fig. 13. Mean macrobenthos density and diversity of both pipeline and reference stations, during the consecutive sampling campaigns t(0), t(1) and t(2).

Tabel 3. Species composition

A total of 72 macrobenthos species was found during the sampling campaign t(2) of which 38 bristle worms (Polychaeta), 16 crustaceans (Crustacea), 12 molluscs (Mollusca), 1 anemone (Cnidaria), 4 echinoderms (Echinodermata) and one chordate (Chordata)

POLYCHAETA

Aonides paucibranchiata
Aricidea suecica
Capitella spec.
Chaetozone setosa
Eteone spec.
Eumida sanguinea
Eusyllis blomstrandi
Glycera spec.
Harmothoe spec.
Hesionura elongata
Lanice conchilega
Magelona mirabilis
Microphthalmus similis
Nephtys cirrosa
Nephtys hombergii
Nephtys spec.
Nereis longissima
Nereis spec.
Notomastus latericeus
Ophelia limacina
Owenia fusiformis
Pectinaria koreni
Phyllodoce maculata
Pisione remota
Poecilochaetus serpens
Polydora spec.
Polygordius spec.
Pomatocerus triqueter
Protodorvilea kefersteini
Pygospio elegans
Scolelepis spec.
Scoloplos armiger
Spio spec.
Spiophanes bombyx
Sthenelais boa
Streblospio benedicti
Syllidae spec.
Syllis gracilis

CRUSTACEA

Abludomelita obtusata
Ampelisca brevicornis
Amphipoda spec.
Atylus falcatus
Bathyporeia spec.
Bodotria spec.
Cirolaninae spec.
Diastylis rathkei
Gammarus spec.
Iphinoe trispinosa
Pariambus typicus
Perioculodes longimanus
Pontocrates altamarinus
Pseudocuma spec.
Stenothoe marina
Urothoe poseidonis

CNIDARIA

Niet gespecifieerd

ECHINODERMATA

Echinocardium cordatum
Echinocyamus pusillus
Ophiura albida
Ophiura juv.

MOLLUSCA

Abra alba
Donax vittatus
Ensis spec.
Fabulina fabula
Lunatia alderi
Macoma balthica
Moerella pygmaea
Mysella bidentata
Spisula solida
Spisula subtruncata
Striarca lactea
Tellimya ferruginosa

CHORDATA

Branchiostoma lanceolatum

Table 4. Macrobenthos density (# ind./m²) and diversity along the trajectory of the **Interconnector pipeline.** one year after the installation (autumn 1998)

STATION	H4	H5	H6	H7	H8	140	435	700	710	780	Total
Polychaeta											
Aonides paucibranchiata	6.7	0.0	3.3	0.0	23.3	0.0	0.0	0.0	0.0	0.0	33.3
Aricidea suecica	0.0	0.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3
Capitella species	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	6.7	16.7
Chaetozone setosa	0.0	0.0	0.0	0.0	0.0	226.7	0.0	250.0	0.0	3.3	480.0
Eteone species	3.3	0.0	0.0	0.0	0.0	0.0	0.0	6.7	3.3	0.0	13.3
Eumida sanguinea	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	20.0
Eusyllis blomstrandi	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	3.3
Glycera species	0.0	13.3	23.3	80.0	140.0	0.0	0.0	0.0	0.0	3.3	260.0
Harmothoe species	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	3.3
Hesionura elongata	0.0	26.7	20.0	20.0	13.3	0.0	30.0	0.0	0.0	0.0	110.0
Lanice conchilega	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	10.0
Magelona mirabilis	3.3	0.0	0.0	0.0	0.0	13.3	0.0	0.0	2683.3	46.7	2746.7
Microphthalmus similis	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	3.3
Nephtys cirrosa	0.0	56.7	50.0	0.0	0.0	3.3	3.3	0.0	0.0	0.0	113.3
Nephtys hombergii	16.7	0.0	0.0	0.0	0.0	10.0	0.0	13.3	76.7	23.3	140.0
Nephtys species	6.7	10.0	0.0	6.7	3.3	16.7	6.7	73.3	20.0	290.0	433.3
Nereis longissima	23.3	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	33.3
Nereis species	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	3.3
Notomastus latericeus	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0	0.0	6.7	13.3
Ophelia limacina	0.0	13.3	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7
Owenia fusiformis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	20.0
Pectinaria koreni	13.3	0.0	0.0	0.0	0.0	0.0	0.0	296.7	0.0	16.7	326.7
Phyllodoce maculata	6.7	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	23.3	33.3
Pisione remota	0.0	0.0	0.0	16.7	6.7	0.0	0.0	0.0	0.0	0.0	23.3
Poecilochaetus serpens	50.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	60.0
Polygordius species	0.0	26.7	10.0	290.0	80.0	0.0	70.0	0.0	0.0	0.0	476.7
Protodorvillea kefersteini	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0
Pygospio elegans	0.0	3.3	0.0	0.0	0.0	0.0	0.0	23.3	73.3	0.0	100.0
Scolelepis species	0.0	0.0	3.3	0.0	0.0	0.0	10.0	0.0	0.0	0.0	13.3
Scoloplos armiger	910.0	16.7	0.0	0.0	0.0	0.0	3.3	10.0	3.3	406.7	1350.0
Spio filicornis	0.0	0.0	0.0	3.3	3.3	0.0	0.0	0.0	0.0	0.0	6.7
Spio species	30.0	0.0	6.7	0.0	0.0	203.3	13.3	3.3	426.7	36.7	720.0
Spiophanes bombyx	233.3	10.0	6.7	0.0	0.0	0.0	3.3	6.7	43.3	176.7	480.0
Sthenelais boa	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3
Streblospio benedicti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	3.3
Syllidae species	0.0	0.0	0.0	16.7	16.7	0.0	0.0	0.0	0.0	0.0	33.3
Syllis gracilis	0.0	0.0	0.0	3.3	3.3	0.0	0.0	0.0	0.0	0.0	6.7
Crustacea											
Abludomelita obtusata	26.7	6.7	0.0	0.0	3.3	0.0	0.0	0.0	0.0	13.3	50.0
amphipoda species	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0	6.7
Ampelisca brevicornis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	16.7
Atylus falcatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3	0.0	13.3
Bathyporeia species	0.0	30.0	80.0	0.0	30.0	3.3	26.7	0.0	10.0	0.0	180.0
Bodotria species	20.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	3.3	26.7
Cirolaninae species	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	3.3
Diastylis rathkei	0.0	0.0	0.0	0.0	0.0	3.3	0.0	56.7	3.3	20.0	83.3
Gammarus species	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	3.3
Iphinoe trispinosa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	6.7
Pariambus typicus	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	23.3
Pontocrates altamarinus	0.0	0.0	0.0	0.0	10.0	3.3	0.0	0.0	6.7	0.0	20.0
Pseudocuma species	0.0	0.0	10.0	0.0	3.3	3.3	6.7	0.0	0.0	0.0	23.3
Urothoe brevicornis	0.0	90.0	20.0	0.0	0.0	0.0	13.3	0.0	0.0	0.0	123.3
Echinodermata											
Echinocardium cordatum	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	13.3	16.7
Echinocyamus pusillus	0.0	3.3	0.0	13.3	130.0	0.0	0.0	0.0	0.0	0.0	146.7
juvenile ophiura species	6.7	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	250.0	260.0
Ophiura albida	3.3	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	80.0	86.7

Table 4bis. Macrobenthos density (# ind./m²) and diversity along the trajectory of the Interconnector pipeline, one year after the installation (autumn 1998)

STATION	H4	H5	H6	H7	H8	140	435	700	710	780	Total
Mollusca											
Abra alba	40.0	3.3	0.0	0.0	0.0	43.3	0.0	123.3	3.3	306.7	520.0
Donax vittatus	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.0	10.0	0.0	16.7
Ensis species	53.3	0.0	0.0	0.0	0.0	163.3	3.3	0.0	140.0	3.3	363.3
Fabulina fabula	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.7	0.0	46.7
Lunatia alderi	3.3	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	13.3
Macoma baltica	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	3.3
Moerella pygmaea	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	10.0	20.0
Mysella bidentata	6.7	0.0	0.0	0.0	0.0	0.0	0.0	23.3	26.7	66.7	123.3
Spisula subtruncata	6.7	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	80.0	90.0
Tellimya ferruginosa	0.0	0.0	20.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	23.3
Miscellaneous											
anthozoa species	253.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3	266.7
Branchiostoma lanceolatum	0.0	3.3	0.0	153.3	76.7	0.0	10.0	0.0	0.0	0.0	243.3
Total # ind./m²	1736.7	323.3	273.3	630.0	560.0	713.3	216.7	893.3	3596.7	2010.0	10953.3
Diversity											
Number of species	25	18	15	14	19	15	17	14	19	34	
Shannon-Wiener index	2.50	3.37	3.23	2.36	3.09	2.46	3.31	2.62	1.50	3.70	
Simpson's index	0.32	0.14	0.15	0.29	0.16	0.24	0.16	0.22	0.57	0.11	

Table 5. Macrobenthos density (# ind./m²) and diversity of 4 reference stations one year after installation of the Interconnector pipeline (autumn 1998)

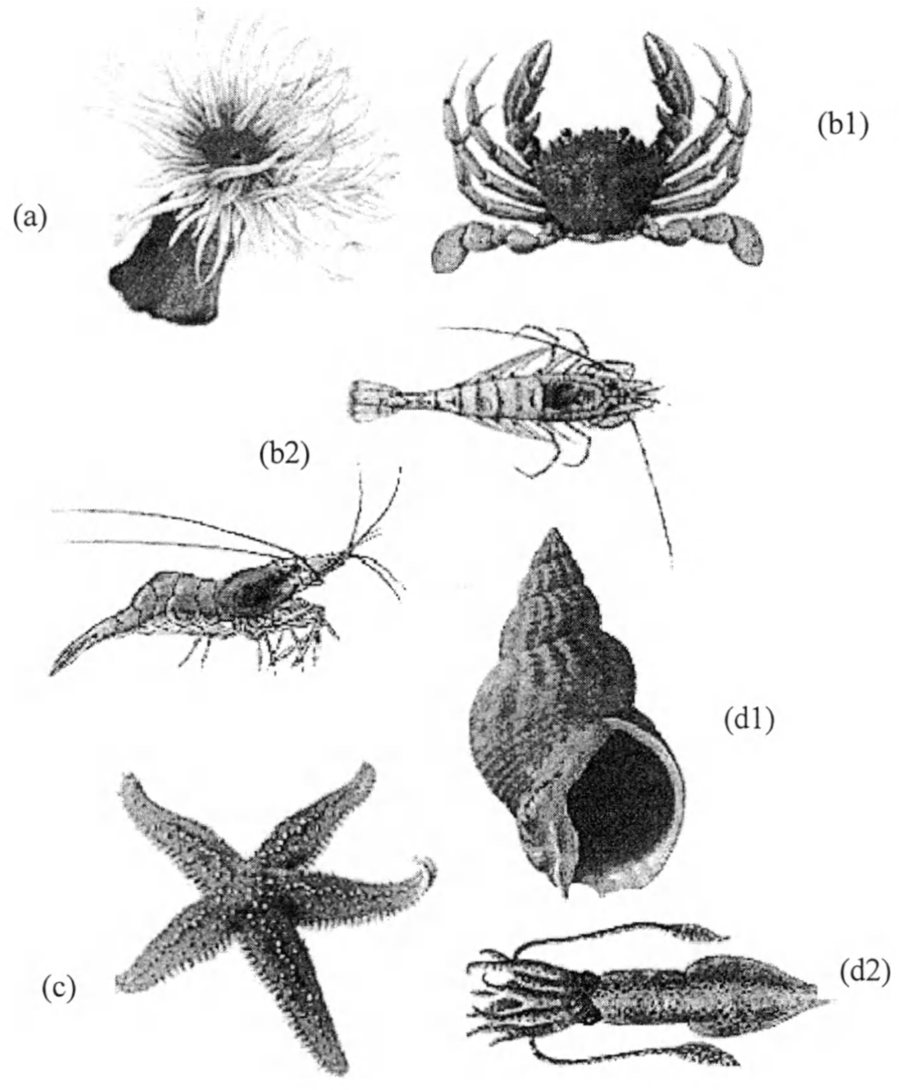
STATION	120	ZG02	315	330	Total
Polychaeta					
Ampharete species	0.0	0.0	0.0	0.0	0.0
Aonides paucibranchiata	0.0	0.0	30.0	0.0	30.0
Autolytus prolifer	0.0	0.0	0.0	0.0	0.0
Capitella species	46.7	0.0	0.0	0.0	46.7
Chaetozone setosa	153.3	0.0	0.0	0.0	153.3
Eteone species	16.7	0.0	0.0	0.0	16.7
Eumida sanguinea	0.0	0.0	0.0	0.0	0.0
Glycera species	16.7	3.3	43.3	6.7	70.0
Harmothoe species	0.0	0.0	0.0	0.0	0.0
Hesionura elongata	0.0	30.0	3.3	0.0	33.3
Lanice conchilega	3.3	0.0	0.0	0.0	3.3
Magelona mirabilis	23.3	0.0	0.0	0.0	23.3
Nephtys caeca	0.0	0.0	0.0	0.0	0.0
Nephtys cirrosa	0.0	30.0	30.0	20.0	80.0
Nephtys hombergii	16.7	0.0	0.0	3.3	20.0
Nephtys species	10.0	0.0	6.7	40.0	56.7
Nereis longissima	26.7	0.0	0.0	3.3	30.0
Nereis species	6.7	0.0	0.0	0.0	6.7
Notomastus latericeus	46.7	0.0	0.0	0.0	46.7
Ophelia limacina	0.0	0.0	16.7	0.0	16.7
Pectinaria koreni	86.7	0.0	0.0	0.0	86.7
Pholoe minuta	0.0	0.0	0.0	0.0	0.0
Phyllodoce maculata	93.3	0.0	0.0	0.0	93.3
Poecilochaetus serpens	16.7	0.0	26.7	0.0	43.3
Polydora species	0.0	0.0	0.0	3.3	3.3
Polygordius species	0.0	0.0	20.0	0.0	20.0
Pomatocerus triqueter	0.0	0.0	0.0	6.7	6.7
Scolelepis species	0.0	0.0	0.0	0.0	0.0
Scoloplos armiger	210.0	0.0	0.0	0.0	210.0
Spio filicornis	0.0	0.0	0.0	0.0	0.0
Spio martinensis	0.0	0.0	0.0	0.0	0.0
Spio species	30.0	0.0	13.3	16.7	60.0
Spiophanes bombyx	103.3	13.3	13.3	13.3	143.3
Sthenelais boa	10.0	0.0	0.0	0.0	10.0
Crustacea					
Abludomelita obtusata	0.0	0.0	0.0	3.3	3.3
Amphilochus manudens	0.0	0.0	0.0	0.0	0.0
amphipoda species	0.0	0.0	3.3	0.0	3.3
Atylus species	0.0	0.0	0.0	0.0	0.0
Atylus swammerdami	0.0	0.0	0.0	0.0	0.0
Bathyporeia guilliamsoniana	0.0	0.0	0.0	0.0	0.0
Bathyporeia species	0.0	10.0	60.0	16.7	86.7
Bodotria arenosa	0.0	0.0	0.0	0.0	0.0
Bodotria scorpioides	0.0	0.0	0.0	0.0	0.0
Bodotria species	0.0	0.0	0.0	13.3	13.3
Corophium bonelli	0.0	0.0	0.0	0.0	0.0
Corophium volutator	0.0	0.0	0.0	0.0	0.0
Diastylis bradyi	0.0	0.0	0.0	0.0	0.0
Diastylis species	0.0	0.0	0.0	0.0	0.0
Eurydice spinigera	0.0	0.0	0.0	0.0	0.0
Gammarus species	0.0	0.0	0.0	3.3	3.3
Leucothoe incisa	0.0	0.0	0.0	0.0	0.0
Microprotopus maculatus	0.0	0.0	0.0	0.0	0.0
Pariambus typicus	0.0	0.0	0.0	3.3	3.3
Perioculodes longimanus	0.0	3.3	0.0	0.0	3.3
Phtisica marina	0.0	0.0	0.0	0.0	0.0
Pseudocuma species	0.0	3.3	6.7	0.0	10.0
Stenothoe marina	0.0	0.0	0.0	3.3	3.3
Urothoe brevicornis	0.0	66.7	80.0	110.0	256.7
Echinodermata					
Echinocardium cordatum	0.0	0.0	0.0	3.3	3.3
Echinocyamus pusillus	0.0	0.0	13.3	3.3	16.7
juvenile ophiura species	0.0	3.3	0.0	3.3	6.7
Ophiura albida	3.3	0.0	0.0	0.0	3.3

Table 5bis. Macrobenthos density (# ind./m²) and diversity of 4 <u>reference</u> stations one year after installation of the Interconnector pipeline (autumn 1998)

STATION	120	ZG02	315	330	Total
Mollusca					
Abra alba	193.3	0.0	0.0	0.0	193.3
Arca tetragona	0.0	0.0	0.0	0.0	0.0
Crepidula fornicata	0.0	0.0	0.0	0.0	0.0
Ensis species	56.7	0.0	3.3	0.0	60.0
Fabulina fabula	6.7	0.0	0.0	0.0	6.7
Lunatia alderi	0.0	0.0	3.3	0.0	3.3
Mysella bidentata	13.3	0.0	0.0	0.0	13.3
Spisula solida	0.0	0.0	3.3	0.0	3.3
Spisula subtruncata	50.0	0.0	0.0	0.0	50.0
Striarca lactea	0.0	0.0	3.3	0.0	3.3
Venerupis pullastra	0.0	0.0	0.0	0.0	0.0
Miscellaneous					
anthozoa species	20.0	0.0	0.0	3.3	23.3
Branchiostoma lanceolatum	0.0	0.0	3.3	0.0	3.3
Total # ind./m²	1260.0	163.3	383.3	280.0	2086.7
Diversity					
Number of species	25	9	20	20	
Shannon-Wiener index	3.88	2.43	3.63	3.20	
Simpson's index	0.09	0.25	0.11	0.19	

Epibenthos

Fig. 14. 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.



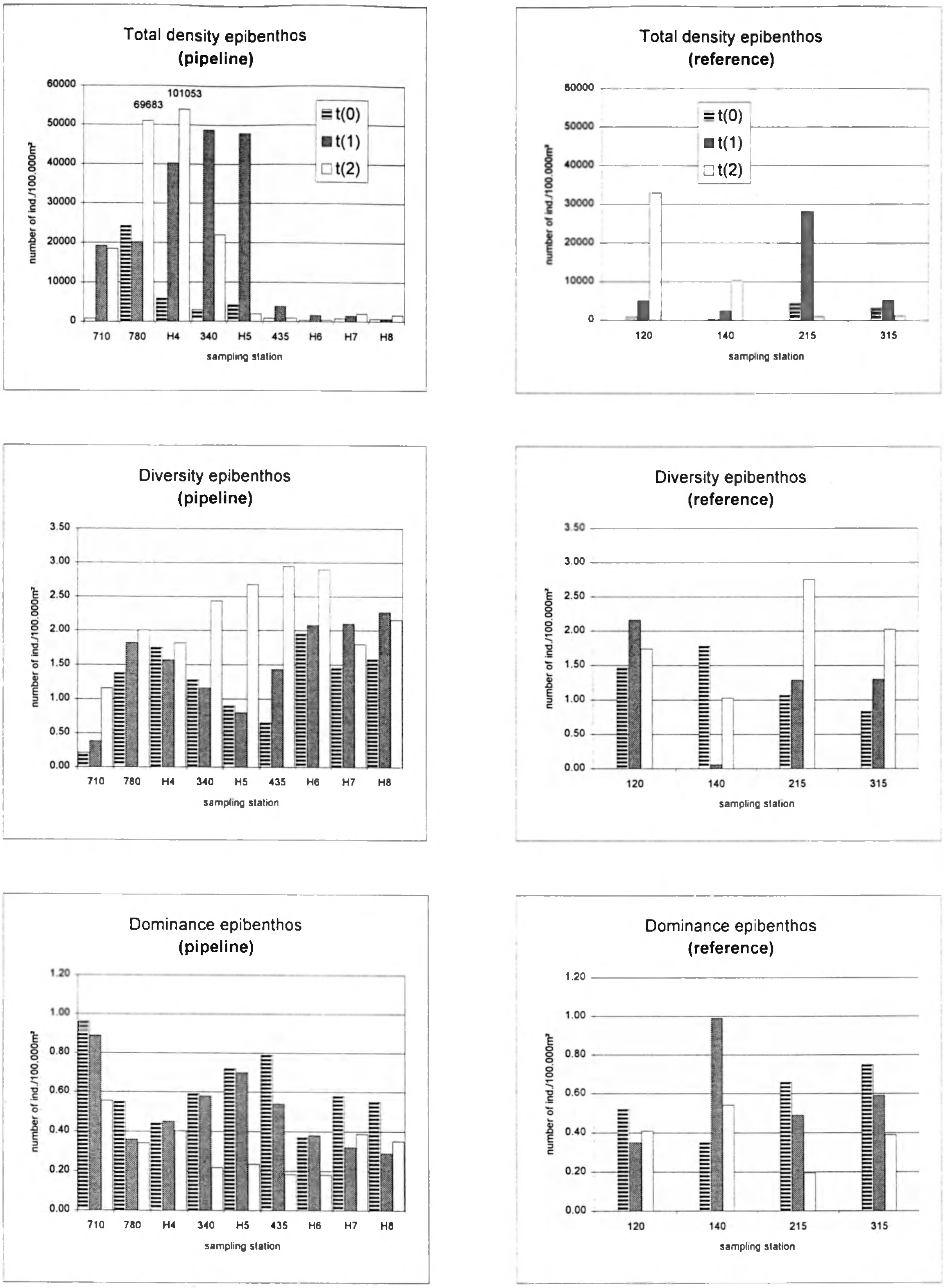
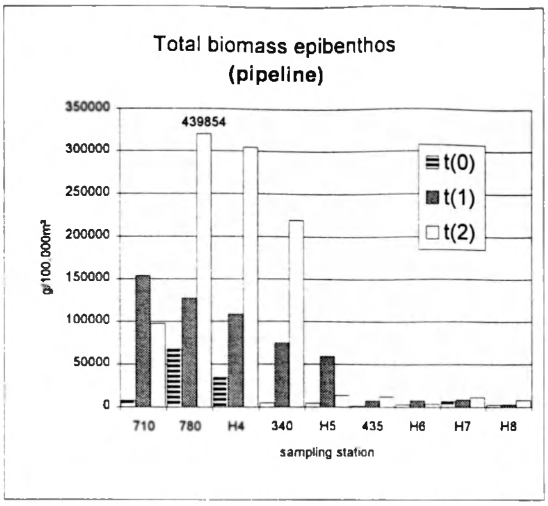


Fig. 15. Total density, diversity and dominance of sampled epibenthos stations before t(0), after t(1) and one year after t(2) the pipeline works



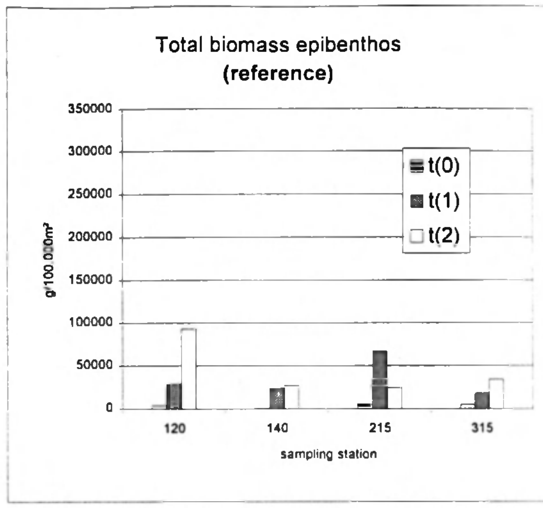
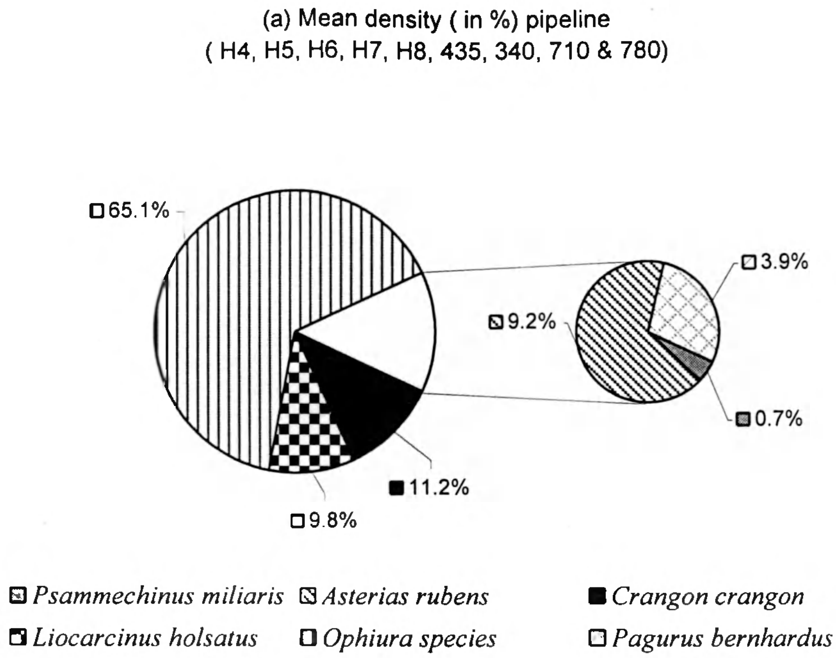


Fig. 16. Total biomass of sampled epibenthos stations before t(0), after t(1) and one year after t(2) the pipeline works



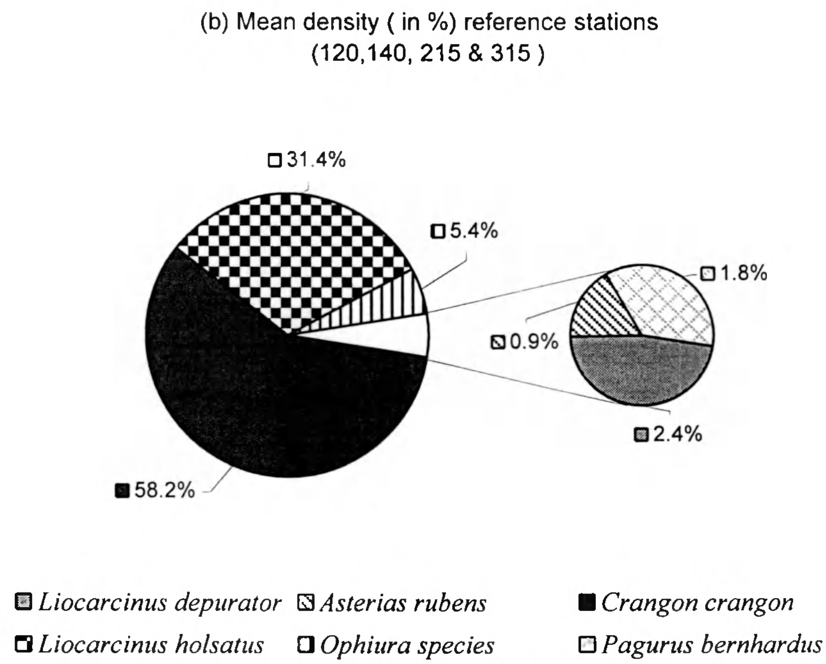
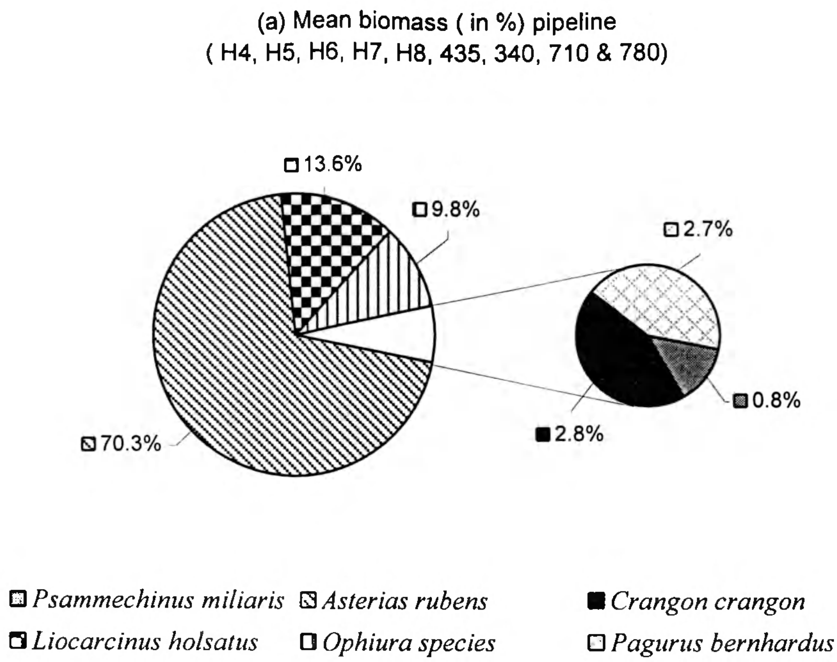


Fig. 17. Mean densities (in % values) of the most important epibenthic species along the Interconnector pipeline (a) and of some reference stations (b) (autumn 1998)



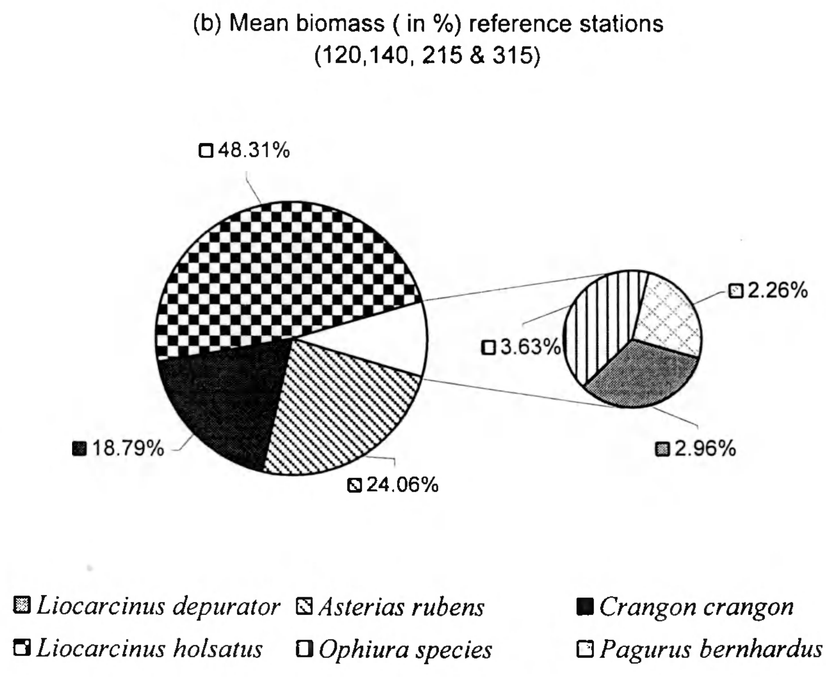


Fig. 18. Mean biomass (in % values) of the most important epibenthic species along the Interconnector pipeline (a) and of some reference stations (b) (autumn 1998)

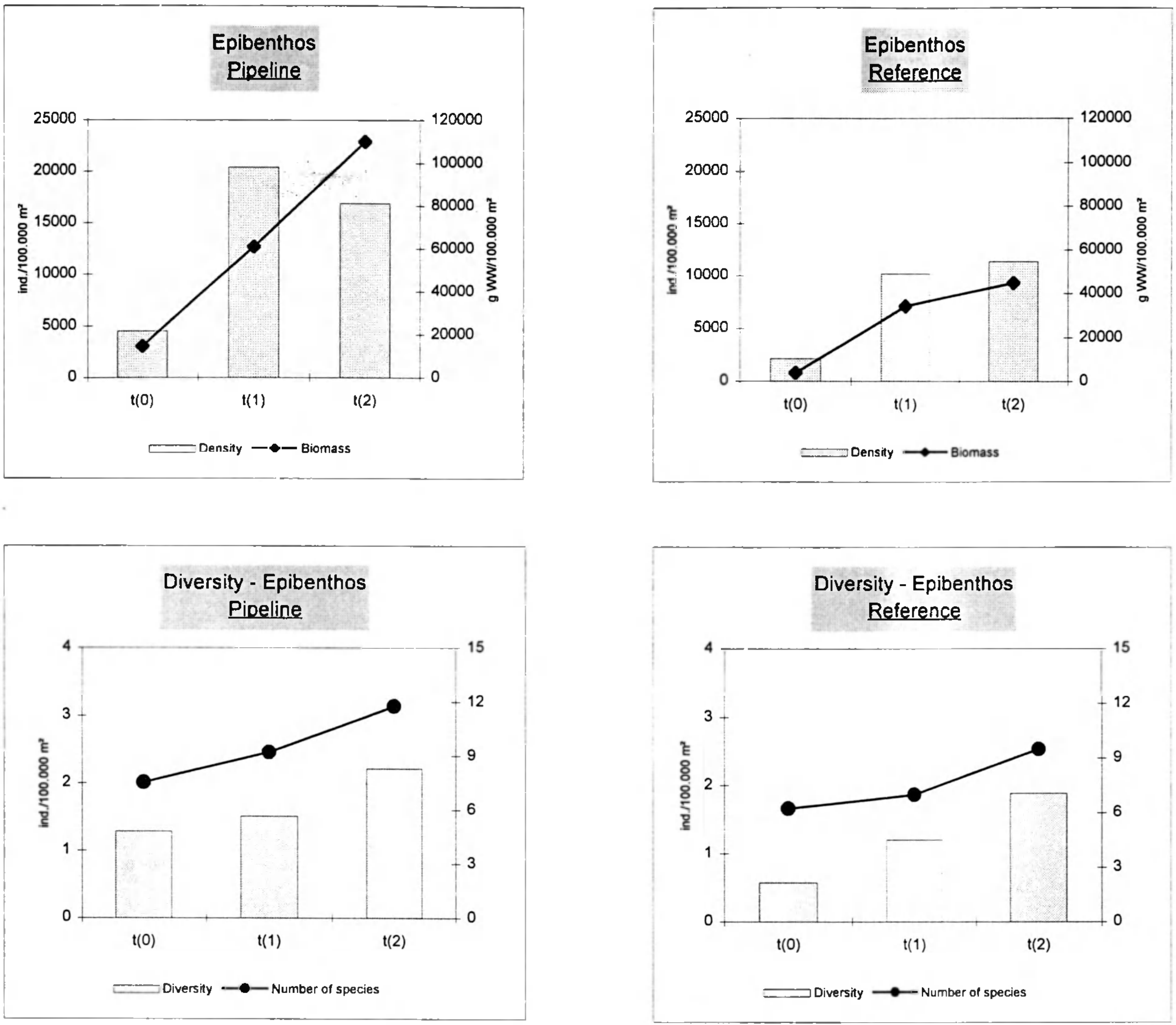


Fig. 19. Mean epibenthos density, biomass and diversity of both pipeline and reference stations, during the consecutive sampling campaigns t(0), t(1) and t(2).

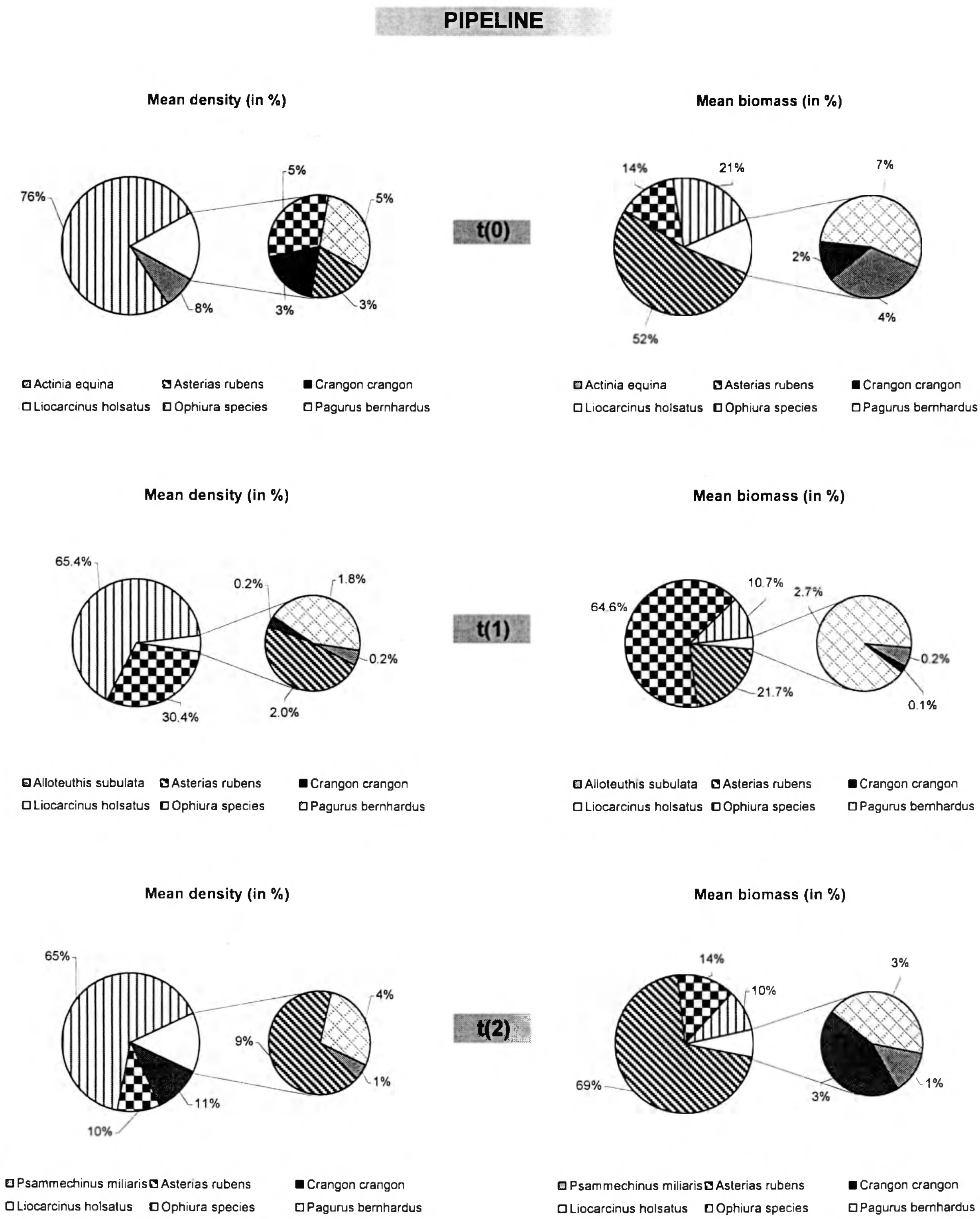


Fig. 20. Mean density and biomass of the most common epibenthic species (Pipeline)

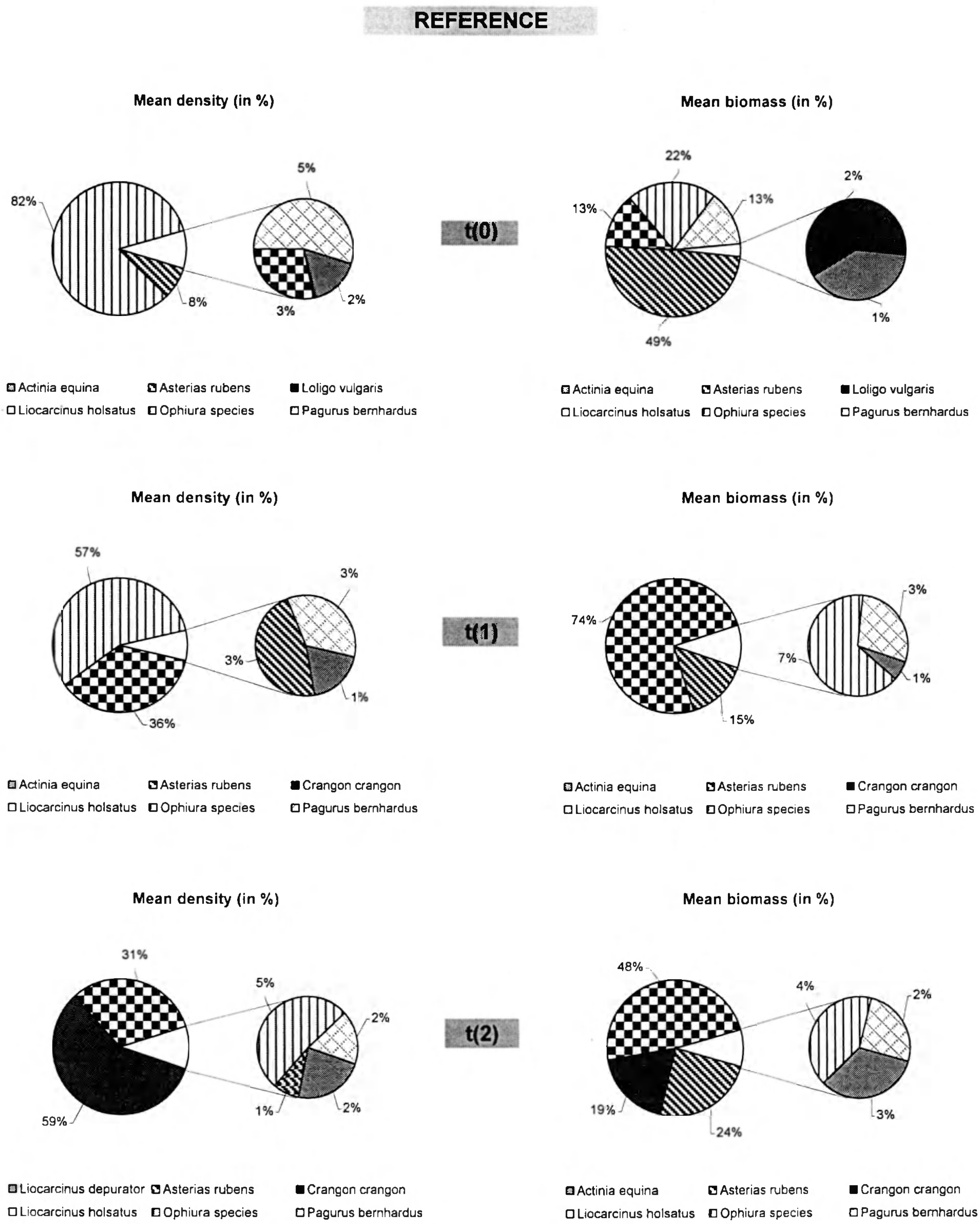


Fig. 20bis. Mean density and biomass of the most common epibenthic species (Reference)

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
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
Ophiothrix fragilis	Brittle star
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
Thia polita	Polished crab

Table 7. Total density of epibenthos for sampling stations along the trajectory of the Interconnector pipeline (density in # ind./100.000 m²)(autumn 1998)

STATION	H4	H5	H6	H7	H8	340	435	710	780	Total
anthozoa species	337	0	5	0	0	81	0	59	253	734
Alloteuthis subulata	0	98	47	61	93	0	123	0	0	422
Asterias rubens	5895	515	123	303	69	4513	298	224	7931	19870
Cancer pagurus	0	0	0	0	0	0	1	0	0	1
Carcinus maenas	0	0	0	0	0	0	0	10	0	10
Crangon allmanni	0	9	0	0	0	285	0	0	0	294
Crangon crangon	5558	94	0	0	0	2887	0	12963	2692	24194
Echinocardium cordatum	168	9	5	0	0	0	7	0	0	189
Hyas coarctatus	0	0	0	10	5	0	0	0	0	15
Loligo vulgaris	0	58	28	5	29	0	116	0	0	236
Liocarcinus holsatus	8505	139	24	10	78	4025	42	4613	3753	21189
Liocarcinus depurator	84	4	9	0	0	0	7	0	0	104
Liocarcinus marmoreus	0	18	0	10	5	0	7	0	0	40
Macropodia rostrata	253	9	0	10	15	41	7	0	0	335
Ophiothrix fragilis	0	4	0	0	0	0	0	0	0	4
Ophiura albida	59958	756	28	5	69	7482	32	0	12776	81106
Ophiura texturata	19200	31	0	0	0	2196	14	504	37165	59110
Pagurus bernhardus	1095	152	76	439	872	447	147	118	5113	8459
Pontophilus trispinosus	0	13	0	5	0	41	0	0	0	59
Psammechinus miliaris	0	4	9	1111	299	41	49	0	0	1513
Sepia officinalis	0	0	5	0	0	0	17	0	0	22
Sepiola atlantica	0	45	19	10	39	0	18	0	0	131
Thia polita	0	4	0	5	5	0	7	0	0	21
Total	101053	1962	378	1984	1578	22039	892	18490	69683	218059
Diversity										
Number of species	10	18	12	13	12	11	16	7	7	
Shannon-Wiener index	1.82	2.68	2.90	1.80	2.16	2.44	2.95	1.16	2.00	
Simpson index	0.40	0.24	0.18	0.39	0.35	0.22	0.18	0.55	0.34	

Table 8. Total density of epibenthos for reference sampling stations (density in # ind./100.000 m²)(autumn 1998)

STATION	120	140	215	315	Total
anthozoa species	228	204	0	19	451
Alloteuthis subulata	0	0	222	693	915
Asterias rubens	36	0	336	0	372
Carcinus maenas	179	0	0	0	179
Crangon crangon	18309	6840	26	94	25269
Liocarcinus holsatus	10249	3256	153	0	13658
Liocarcinus arcuatus	272	0	0	0	272
Liocarcinus depurator	962	0	29	37	1028
Liocarcinus marmoreus	0	0	20	37	57
Loligo vulgaris	0	0	20	0	20
Macropodia rostrata	36	0	10	0	46
Necora puber	0	0	3	0	3
Ophiura albida	804	0	16	56	876
Ophiura texturata	1259	0	33	169	1461
Pagurus bernhardus	599	0	179	0	778
Psammechinus miliaris	36	0	0	37	73
Sepia officinalis	0	0	20	19	39
Sepiola atlantica	0	0	7	0	7
Total	32969	10300	1074	1162	45505
Diversity					
Number of species	12	3	14	9	
Shannon-Wiener index	1.74	1.03	2.76	2.02	
Simpson index	0.41	0.54	0.19	0.39	

Table 9. Total biomass of epibenthos for sampling stations along the trajectory of the Interconnector pipeline (biomass in ww g/100.000 m²)(autumn 1998)

STATION	H4	H5	H6	H7	H8	340	435	710	780	Total
anthozoa species	160	0	21	0	0	28	0	327	538	1074
Alloteuthis subulata	0	279	97	268	118	0	370	0	0	1132
Asterias rubens	202104	9400	1989	2828	1053	182973	6313	16317	348592	771568
Cancer pagurus	0	0	0	0	0	0	800	0	0	800
Carcinus maenas	0	0	0	0	0	0	0	790	0	790
Crangon allmanni	0	4	0	0	0	110	0	0	0	114
Crangon crangon	6333	156	0	0	0	3403	0	16980	3388	30260
Echinocardium cordatum	1962	164	134	0	0	0	55	0	0	2315
Hyas coarctatus	0	0	0	21	5	0	0	0	0	26
Loligo vulgaris	0	752	389	40	645	0	2499	0	0	4325
Liocarcinus holsatus	41574	1107	134	10	267	22270	377	62321	21431	149492
Liocarcinus depurator	817	56	120	0	0	0	129	0	0	1122
Liocarcinus marmoreus	0	115	0	23	18	0	69	0	0	225
Macropodia rostrata	211	5	0	12	25	33	6	0	0	291
Ophiura albida	12615	167	6	2	26	1720	9	0	2003	16548
Ophiura texturata	36758	114	0	0	0	5457	53	426	48525	91333
Pagurus bernhardus	2173	1043	740	2244	3722	2525	901	617	15377	29341
Pontophilus trispinosus	0	5	0	1	0	4	0	0	0	10
Psammechinus miliaris	0	47	74	5860	2067	890	391	0	0	9329
Sepia officinalis	0	0	32	0	0	0	231	0	0	263
Sepiola atlantica	0	93	40	26	88	0	44	0	0	290
Thia polita	0	7	0	5	5	0	6	0	0	23
Total	304705	13514	3776	11338	8040	219413	12253	97778	439854	1110672

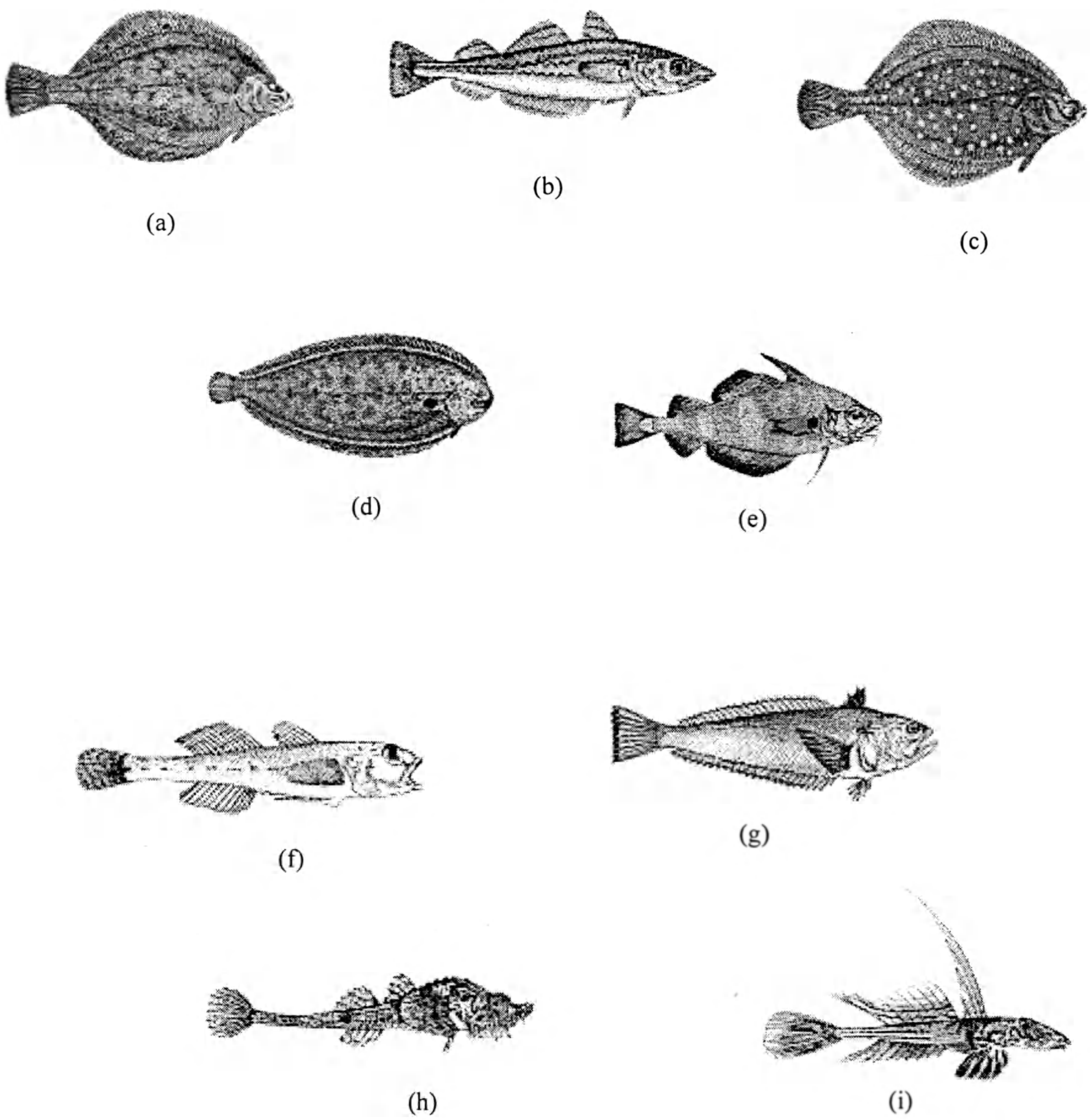
Table 10. Total biomass of epibenthos for reference sampling stations (biomass in ww g/100.000 m²)(autumn 1998)

STATION	120	140	215	315	Total
anthozoa species	387	584	0	0	971
Alloteuthis subulata	0	0	350	54	404
Asterias rubens	5072	0	20869	11244	37185
Carcinus maenas	4159	0	0	0	4159
Crangon crangon	20336	8674	25	0	29035
Liocarcinus holsatus	54559	17894	1201	1014	74668
Liocarcinus arcuatus	954	0	0	0	954
Liocarcinus depurator	4183	0	389	0	4572
Liocarcinus marmoreus	0	0	142	307	449
Loligo vulgaris	0	0	326	1743	2069
Macropodia rostrata	54	0	5	0	59
Necor puber	0	0	30	0	30
Ophiura albida	235	0	11	0	246
Ophiura texturata	1747	0	95	279	2121
Pagurus bernhardus	1254	0	840	1394	3488
Psammechinus miliaris	333	0	0	0	333
Sepia officinalis	0	0	236	17934	18170
Sepiola atlantica	0	0	16	45	61
Total	93273	27152	24535	34015	178914

Fish

Fig. 21. The most common fish species caught during the sampling campaigns

Commercial fish:	(a) Dab (*Limanda limanda*); (b) whiting (*Merlangius merlangus*); (c) plaice (*Pleuronectes platessa*); (d) common sole (*Solea solea*); (e) Bib (*Trisopterus* species)
Non-commercial fish:	(f) Sand gobies (*Pomatoschistus* species); (g) dragonet (*Callionymus lyra*); (h) lesser weever (*Trachinus vipera*); (i) hooknose (*Agonus cataphractus*)



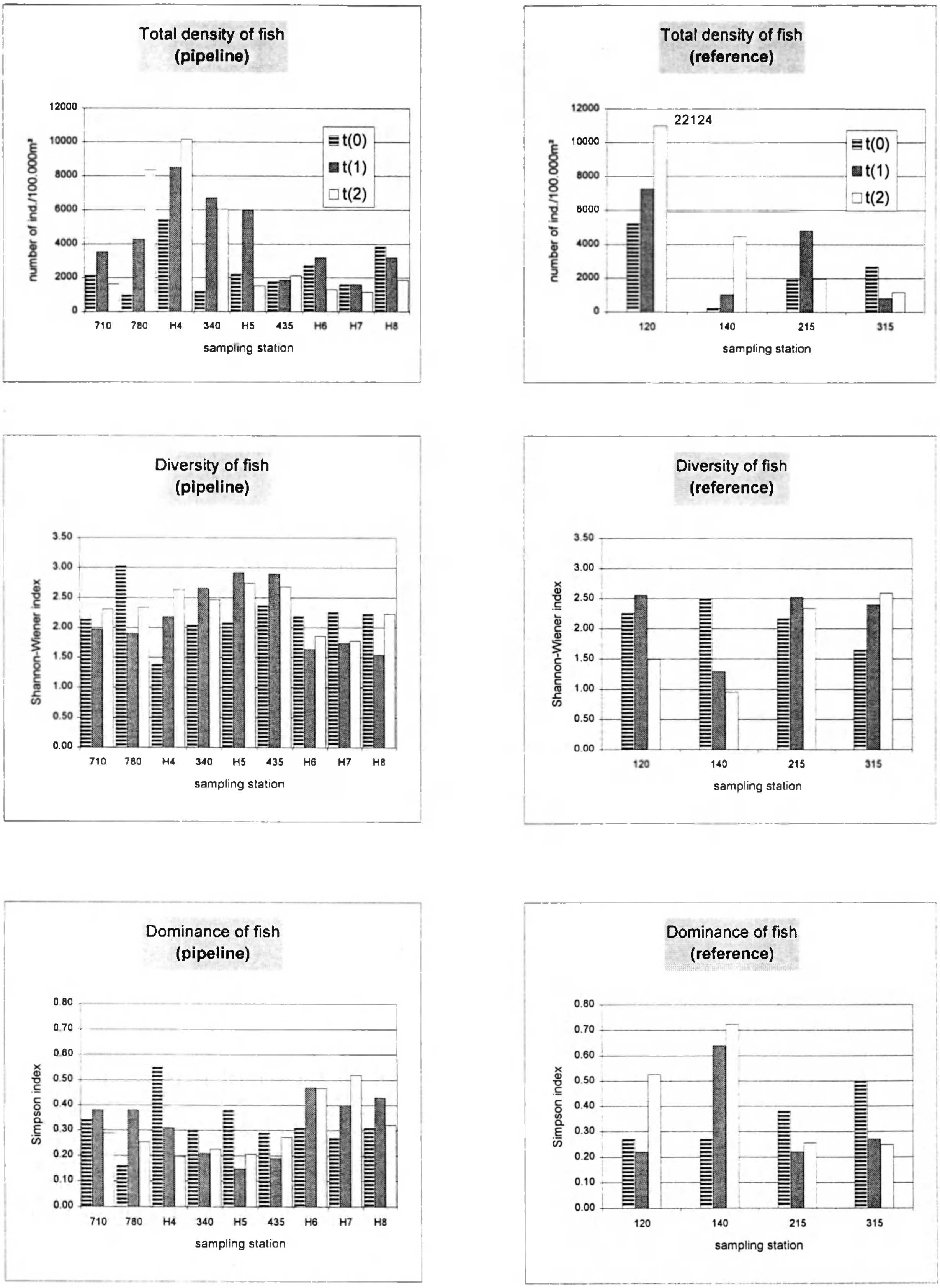
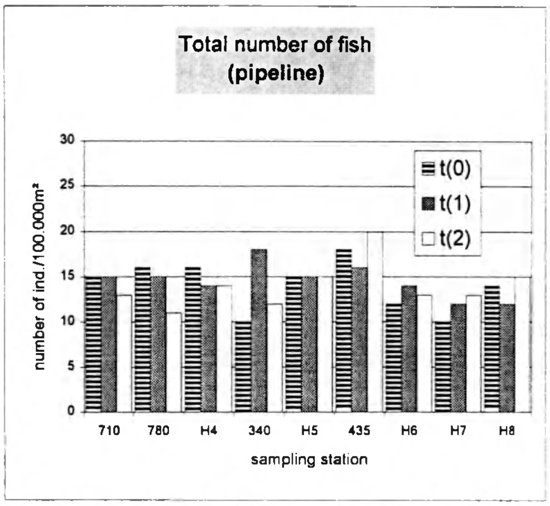


Fig. 22. Total density, diversity and dominance of sampled fishstock before t(0), after t(1) and one year after t(2) the pipeline works



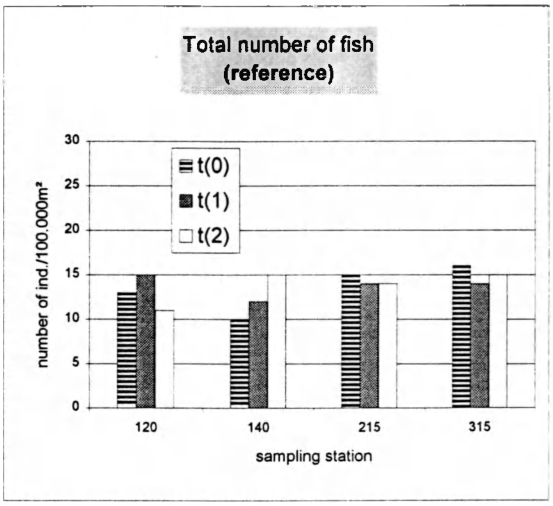


Fig. 22bis. Total number of fish before t(0), after t(1) and one year after (t2) the pipeline works

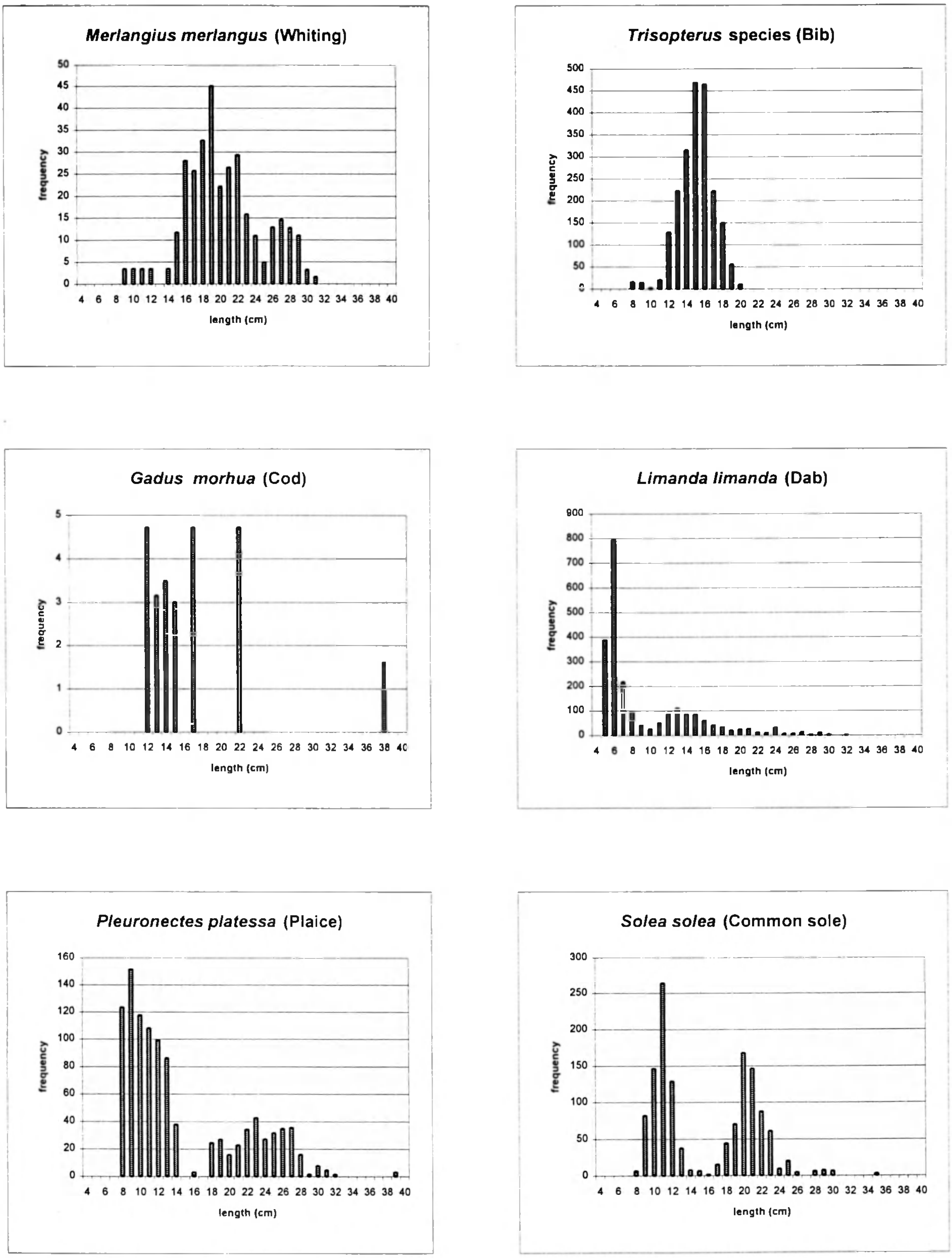
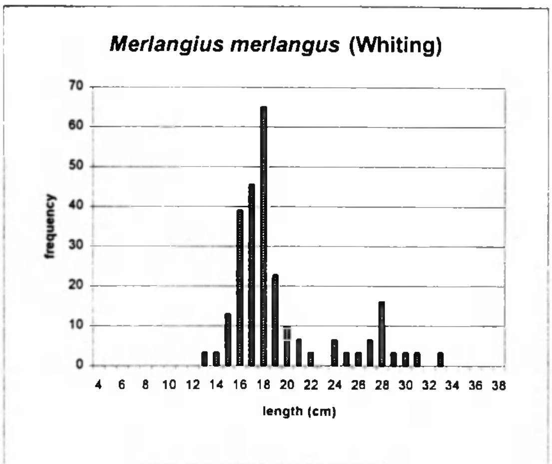
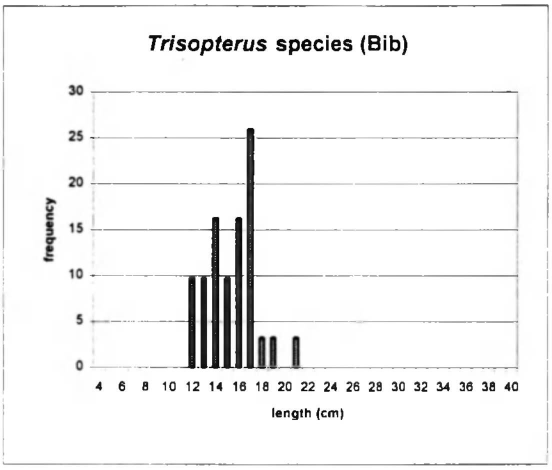
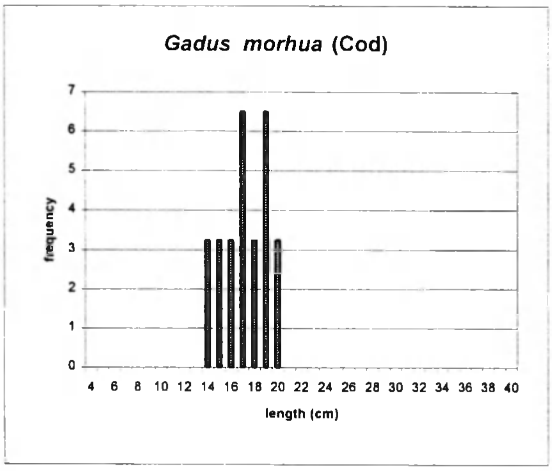
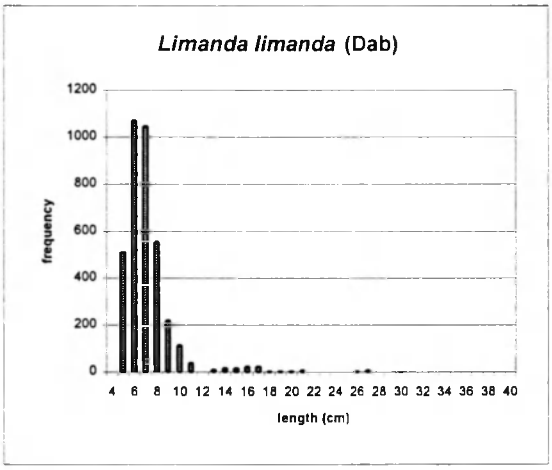


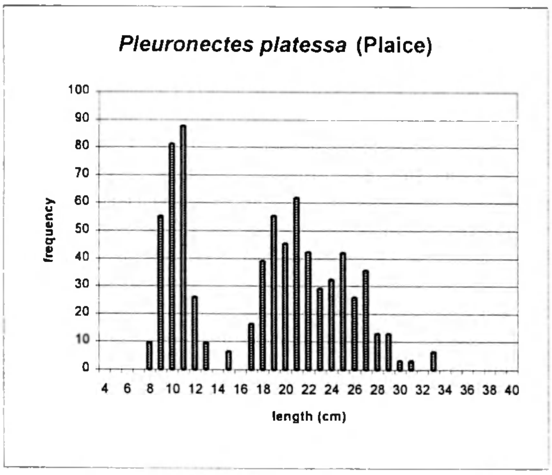
Fig. 23. Length-frequency distribution of the commercial fish species along the **Interconnector pipeline** (sampling stations 710-780-H4-340-H5-435-H6-H7-H8)(autumn 1998)











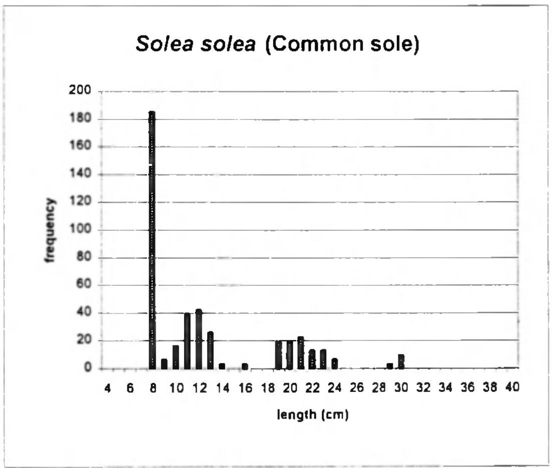


Fig. 24. Length-frequency distribution of the commercial fish species caught at the **reference** stations (sampling stations 120-215-315)(autumn 1998)

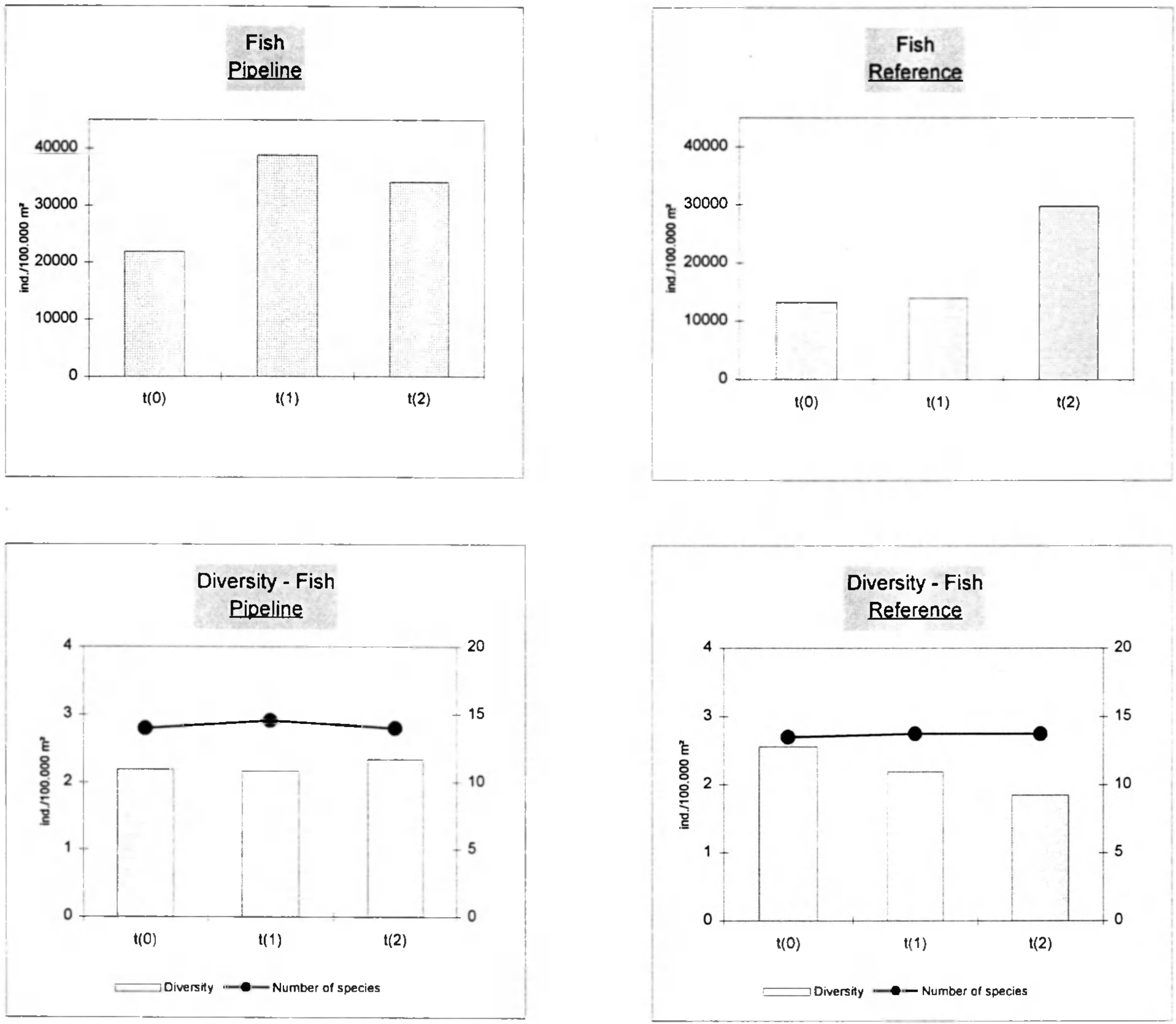
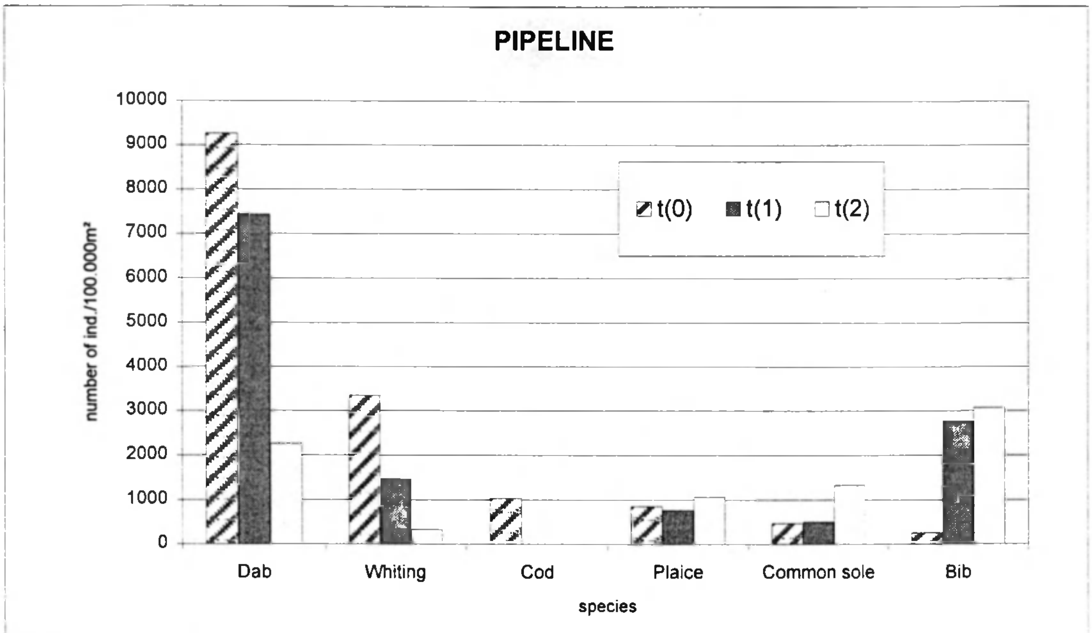


Fig. 25. Mean fish density and diversity of both pipeline and reference stations, during the consecutive sampling campaigns t(0), t(1) and t(2).



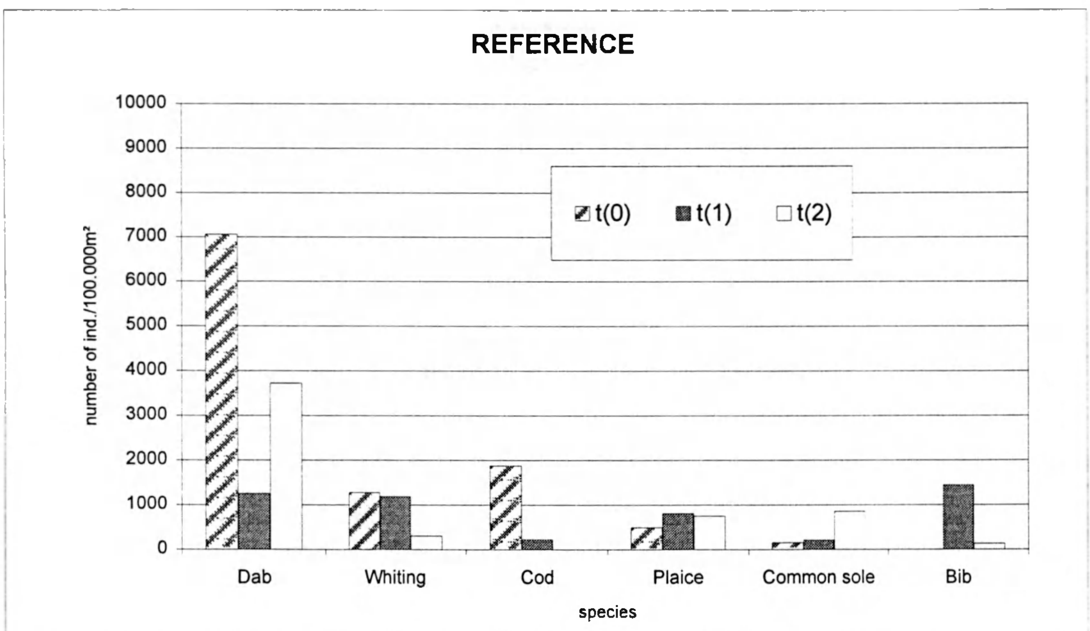
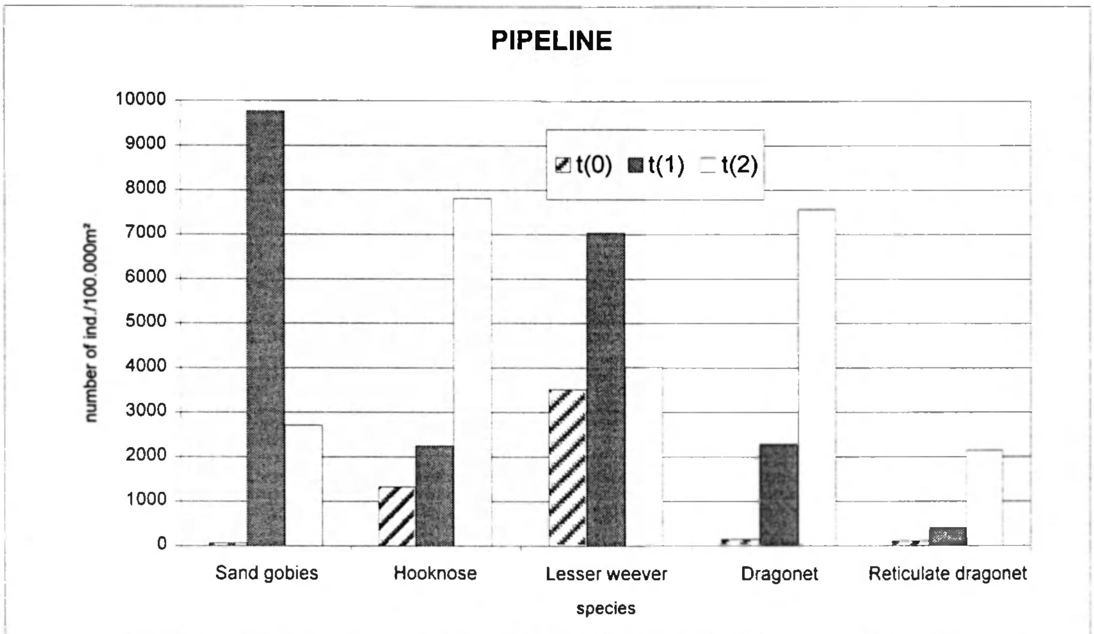


Fig. 26. Total densities of commercial fish during the consecutive sampling campaigns t(0), t(1) and t(2).



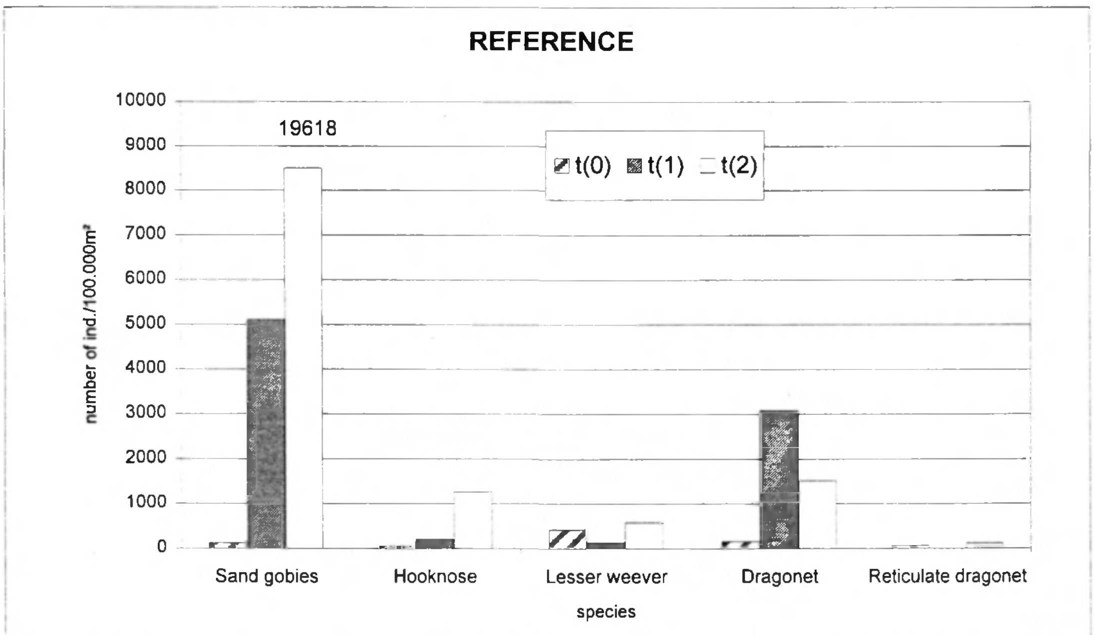


Fig. 27. Total densities of non-commercial fish during the consecutive sampling campaigns t(0), t(1) and t(2).

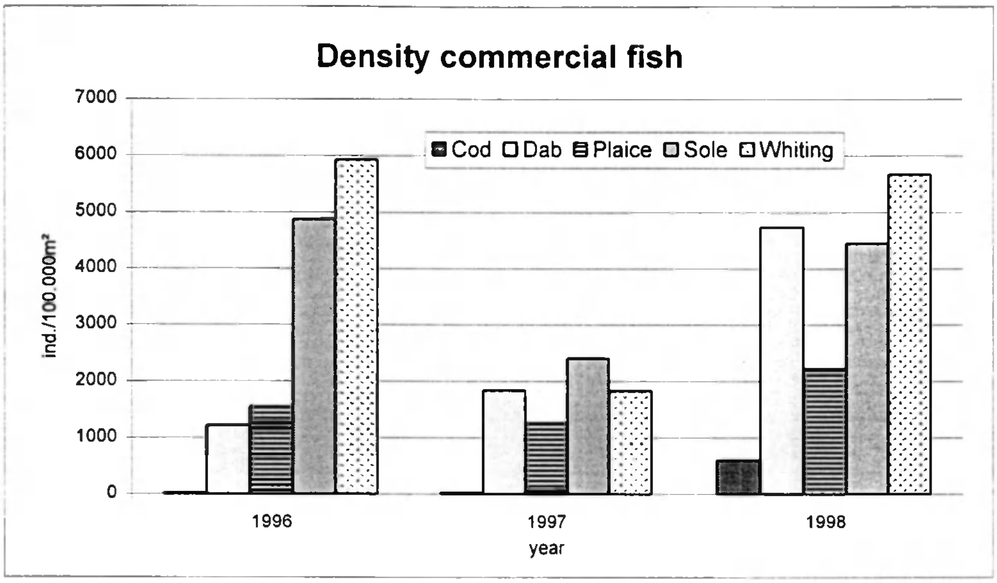


Fig. 28. Total density of the commercial fishes cod, dab, plaice, sole and whiting caught before the Belgian coast (Broodwinner campaigns, September '96, '97 & '98)

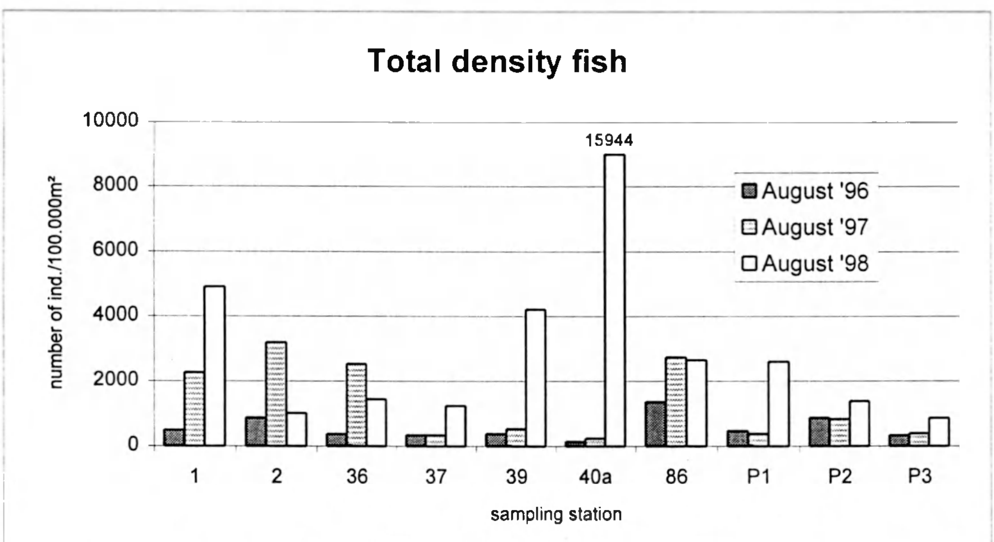


Fig. 29. Total density of the fishstock around the Belgian Continental Shelf (A. 962 R.V. Belgica campaigns August '96, '97 & '98)

Table 12. Density, diversity of fish species along the **Interconnector pipeline** (autumn 1998)

STATION	710	780	H4	340	H5	435	H6	H7	H8	Total
Agonus cataphractus	329	2237	2996	2238	0	3	5	0	0	7808
Ammodytes tobianus	0	0	0	0	27	15	0	10	25	77
Arnoglossus laterna	0	0	0	0	13	47	5	0	10	75
Buglossidium luteum	0	149	14	0	103	225	76	0	0	567
Callionymus lyra	4	3264	2359	1274	278	201	62	45	79	7566
Callionymus recticulatus	0	0	298	834	479	264	142	66	59	2142
Ciliata mustela	4	0	0	0	0	0	0	0	0	4
Clupea harengus	7	0	24	3	4	0	0	0	0	38
Cyclopterus lumpus	0	0	0	0	0	0	0	0	0	0
Gadus morhua	4	3	14	3	0	2	0	0	0	26
Gobius niger	0	0	0	0	0	2	0	20	5	27
Hyperoplus lanceolatus	0	0	0	0	0	16	28	20	30	94
Hyppoglossoides platessoides	0	0	0	0	0	0	0	0	0	0
Limanda limanda	273	1062	590	190	31	57	9	25	30	2267
Liparis liparis	0	3	0	0	0	0	0	0	0	3
Merlangius merlangus	63	25	61	63	36	53	0	5	20	326
Microstomus kitt	0	0	61	0	0	0	0	0	0	61
Mullus surmuletus	0	0	0	0	9	28	0	0	5	42
Mustelus mustelus	0	0	0	0	0	0	5	0	0	5
Myoxocephalus scorpius	0	0	0	0	0	0	0	0	0	0
Platichthys flesus	0	0	0	0	0	0	0	0	0	0
Pleuronectes platessa	28	831	24	6	54	58	5	15	39	1060
Pomatoschistus minutus	758	82	1095	488	49	39	38	45	113	2707
Scomber scombrus	0	0	0	0	0	0	0	0	0	0
Scophthalmus maximus	0	0	0	0	4	0	0	0	0	4
Solea lascaris	0	0	0	0	0	5	0	0	0	5
Solea solea	60	357	770	136	0	8	0	5	0	1336
Sprattus sprattus	49	0	5	0	0	0	0	0	0	54
Trachurus trachurus	0	0	0	0	22	34	33	61	556	706
Trachinus vipera	0	0	0	12	385	1025	876	829	891	4018
Trigla gurnardus	21	3	0	0	0	15	24	15	10	88
Trisopterus luscus	35	338	1852	792	22	26	0	0	5	3070
total	1633	8355	10163	6039	1516	2123	1308	1161	1877	34175
Diversity										
Number of species	13	11	14	12	15	20	13	13	15	
Shannon-Wiener index	2.31	2.34	2.63	2.46	2.74	2.68	1.86	1.78	2.23	
Simpson index	0.29	0.25	0.20	0.23	0.21	0.27	0.47	0.52	0.32	

Table 13. Density, diversity of fish species of **reference** sampling stations (autumn 1998)

STATION	120	140	215	315	Total
Agonus cataphractus	1172	78	7	6	1263
Ammodytes tobianus	0	3	3	495	501
Anguilla anguilla	0	6	0	0	6
Arnoglossus laterna	0	0	7	19	26
Buglossidium luteum	0	0	111	13	124
Callionymus lyra	497	0	743	267	1507
Callionymus recticulatus	0	0	29	90	119
Ciliata mustela	0	12	0	0	12
Clupea harengus	0	12	0	0	12
Gadus morhua	29	3	0	10	42
Gobius niger	0	0	0	0	0
Hyperoplus lanceolatus	0	0	3	55	58
Limanda limanda	3618	42	46	16	3722
Liparis liparis	0	3	0	0	3
Merlangius merlangus	208	45	0	51	304
Microstomus kitt	0	0	0	0	0
Mullus surmuletus	0	0	3	0	3
Mustelus mustelus	0	0	0	0	0
Myoxocephalus scorpius	0	0	0	0	0
Platichthys flesus	0	3	0	0	3
Pleuronectes platessa	449	12	261	32	754
Pomatoschistus minutus	15562	3765	179	112	19618
Solea lascaris	0	0	0	3	3
Solea solea	420	425	3	6	854
Syngnatus acus	72	12	0	0	84
Trachurus trachurus	0	0	7	0	7
Trachinus vipera	0	0	580	0	580
Trigla lucerna	3	0	0	0	3
Trisopterus luscus	94	36	0	3	133
total	22124	4457	1982	1178	29741
Diversity					
Number of species	11	15	14	15	
Shannon-Wiener index	1.49	0.95	2.34	2.59	
Simpson index	0.53	0.72	0.26	0.25	

Table 14. Total density for the commercial fish species cod, dab, plaice, common sole and whiting (period '94-'96 ; 0.29 Broodwinner)

September '94
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	0	0	0	0	0	0	0	0	0	0	0
Dab	*Limanda limanda*	360	223	171	212	15	103	69	617	177	0	311	17	2275
Plaice	*Pleuronectes platessa*	663	125	53	72	15	86	208	400	113	0	710	29	2474
Common sole	*Solea solea*	28	65	10	20	0	103	156	171	314	0	88	29	984
Whiting	*Merlangius merlangius*	0	0	0	0	0	172	0	251	0	0	0	0	423
	total	1051	413	234	304	30	464	433	1439	604	0	1109	75	6156

September '95
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	0	0	0	0	0	0	57	17	2	5	81
Dab	*Limanda limanda*	52	296	90	289	0	236	0	96	19	22	0	3	1103
Plaice	*Pleuronectes platessa*	6	8	30	0	0	22	0	5	0	0	0	5	76
Common sole	*Solea solea*	53	13	100	0	0	4	14	70	12	6	0	30	302
Whiting	*Merlangius merlangius*	0	33	0	198	5	35	9	0	12	106	13	50	461
	total	111	350	220	487	5	297	23	171	100	151	15	93	2023

September '96
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	6	0	0	0	0	0	8	0	11	0	0	25
Dab	*Limanda limanda*	194	269	151	55	429	0	0	0	17	74	27	0	1216
Plaice	*Pleuronectes platessa*	543	191	132	98	234	31	14	130	75	73	27	0	1548
Common sole	*Solea solea*	1002	173	305	192	2727	12	21	46	6	248	141	5	4878
Whiting	*Merlangius merlangius*	201	568	338	470	722	464	107	1088	878	369	571	148	5924
	total	1940	1207	926	815	4112	507	142	1272	976	775	766	153	13591

Table 14bis. Total density for the commercial fish species cod, dab, plaice, common sole and whiting (period '94-'96 ; 0.29 Broodwinner)

September '97
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

September '98
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	6	0	4	5	12	11	209	166	54	108	24	598.2
Dab	*Limanda limanda*	172	181	227	140	455	2793	17	565	32	24	113	24	4742
Plaice	*Pleuronectes platessa*	334	175	162	83	89	121	33	896	284	6	28	10	2222
Common sole	*Solea solea*	439	77	47	35	812	503	330	557	804	221	137	492	4451
Flounder	*Platichthys flesus*	5	0	0	0	0	6	0	96	27	6	5	0	144.1
Whiting	*Merlangius merlangius*	167	914	596	395	94	751	148	487	332	704	740	341	5668
	total	1117	1351	1032	658	1454	4186	539	2810	1645	1015	1131	890	17826

Table 15. Density and diversity of fishstock around the Belgian Continental Shelf and in the vicinity of the Interconnector pipeline (August 1998 ; A. 962 R.V. Belgica)(density in # ind./100.000m²)

Genus species		**sampling station**										
		1	**2**	**36**	**37**	**39**	**40a**	**86**	**P1**	**P2**	**P3**	**Total**
Bib	*Trisopterus* species	0	0	0	0	0	2080	0	0	200	384	2664
Brill	*Scophthalmus rhombus*	0	0	0	0	0	0	0	0	0	0	0
Cod	*Gadus morhua*	0	0	0	0	0	32	0	0	0	0	32
Common sole	*Solea solea*	56	8	8	16	24	936	128	8	88	64	1336
Dab	*Limanda limanda*	64	88	64	72	88	4440	400	0	352	184	5752
Dragonet	*Callionymus lyra*	192	136	0	144	104	2440	456	8	240	0	3720
Flounder	*Platichthys flesus*	0	0	0	0	0	0	0	0	0	0	0
Greater sand eel	*Hyperoplus lanceolatus*	64	0	8	0	40	0	0	8	8	0	128
Grey gurnard	*Eutrigla gurnardus*	0	0	0	0	0	0	0	0	0	0	0
Horse Mackerel	*Trachurus trachurus*	0	0	0	0	0	72	0	0	0	0	72
Lemon sole	*Microstomus kitt*	0	0	0	16	0	0	0	0	56	88	160
Lesser sand eel	*Ammodytes tobianus*	0	0	0	8	32	0	24	0	0	0	64
Lesser weever	*Trachinus vipera*	4232	0	1064	632	3600	0	840	2488	120	0	12976
Melt	*Osmerus eperlanus*	0	0	0	0	0	0	0	0	0	0	0
Plaice	*Pleuronectes platessa*	272	152	168	304	168	720	448	72	120	112	2536
Pogge	*Agonus cataphractus*	0	8	40	0	0	1776	152	0	56	0	2032
Ray	*Rajidae* species	0	0	0	0	0	0	8	0	0	0	8
Red gurnard	*Aspitrigla cuculus*	0	0	0	24	16	0	0	0	0	16	56
Sand gobies	*Pomatoschistus* spec.	0	504	0	0	0	888	0	0	120	0	1512
Scaldfish	*Arnoglossus laterna*	16	80	88	16	136	0	56	0	0	0	392
Smoothhound	*Mustelus mustelus*	0	0	0	0	0	0	0	0	0	0	0
Solenette	*Buglossidium luteum*	0	24	0	0	8	0	128	8	8	0	176
Sprat	*Sprattus sprattus*	0	0	0	0	0	0	0	0	0	0	0
Trigger fish	*Balistes carolinensis*	0	0	0	0	0	0	0	0	0	0	0
Tub gurnard	*Trigla lucerna*	16	8	0	8	0	0	0	0	8	8	48
Turbot	*Scophthalmus maximus*	0	0	0	0	0	0	0	0	0	0	0
Whiting	*Merlangius merlangus*	0	0	0	0	0	2560	8	0	0	0	2568
	total	4912	1008	1440	1240	4216	9000	2648	2592	1376	856	36232
	diversity											
	number of species	8	9	7	10	10	10	11	6	12	7	
	Shannon-Wiener diversity	0.89	2.19	1.36	2.04	1.00	2.81	2.70	0.30	3.03	2.17	
	Simpson dominance	0.75	0.31	0.57	0.34	0.73	0.16	0.19	0.92	0.15	0.28	

Appendix

SURVEY

A survey was conducted amongst 140 Belgian and Dutch ship-owners, fishermen and skippers (see letter, next page). They were asked to state their views and remarks concerning the presence and the works that coincided with the construction of both gas pipelines NORFRA and INTERCONNECTOR, while conducting their fishing activities.
A period of three weeks was given to provide us with practical information about possible obstacles that they had encountered while fishing during the past two years. They were also asked to record the exact positions where these problems were encountered. By not replying, the assumption was made that within those two years no serious problems had occurred while performing their professional duties.

Results

↬The vessel Z.80 from Breskens reported difficulties at different locations (see map):

- INTERCONNECTOR: near the sampling stations H7 and H8; south-east of Thorton Bank; south-east of Noordhinder Bank
- NORFRA: near the sampling stations NF2 and NF3; Bligh Bank to Westhinder Bank

The remark was made that the pipeline was not buried at these locations and in some cases even floating above the sea bottom, creating problems for fishing. Furthermore, he stated that a lot of the larger vessels from Vlissingen and Breskens had similar complaints.

Comments

However in the officially agreed proposal it was not required to bury the pipeline in these regions. Nevertheless it would be advisable for the construction companies to investigate this matter and if needed do the necessary fortifications to ensure a firm and permanent contact of the pipeline with the sea bottom. This could avoid unnecessary problems or accidents in the future.

MINISTERIE VAN MIDDENSTAND EN LANDBOUW - BESTUUR ONDERZOEK EN ONTWIKKELING

CENTRUM VOOR LANDBOUWKUNDIG ONDERZOEK - GENT

DEPARTEMENT ZEEVISSERIJ

Oostende 14 april 1999

Geachte heer reder, reder-schipper of schipper,

Ongeveer twee jaar geleden werden op onze Belgische kust twee pijpleidingen voor gastoevoer op en in de zeebodem gelegd, nl. de NORFRA en de INTERCONNECTOR gasleidingen. Het tracé is op kaart in bijlage vermeld. Vermits het Departement voor Zeevisserij (het vroegere Rijksstation voor Zeevisserij) zich indertijd had verbonden met een onderzoekingsproject om de gevolgen van deze inplanting te volgen wil ik u hierbij een advies terzake vragen.

De vraag doe ik u thans zou willen stellen is de volgende: **Hebt u of uw bemanning sedert het plaatsen van de leidingen in 1998 en meer bepaald tijdens de laatste maanden enige hinder of onverwachte verstoring van uw visserijactiviteit ondervonden?** Laat het ons weten in de vorm van praktische en vooral nauwkeurige informatie met betrekking tot hinder en (of) afwijkingen van het geplande tracé met bijgaande bodembedekking. Ik zal er van uit gaan dat ik bij ontstentenis van enig antwoord op 30 april dat u in de afgelopen twee jaar geen problemen in deze zaak hebt ondervonden bij het uitoefenen van uw beroepsactiviteiten.

Met vriendelijke groeten,

Rudy De Clerck
Afdelingshoofd

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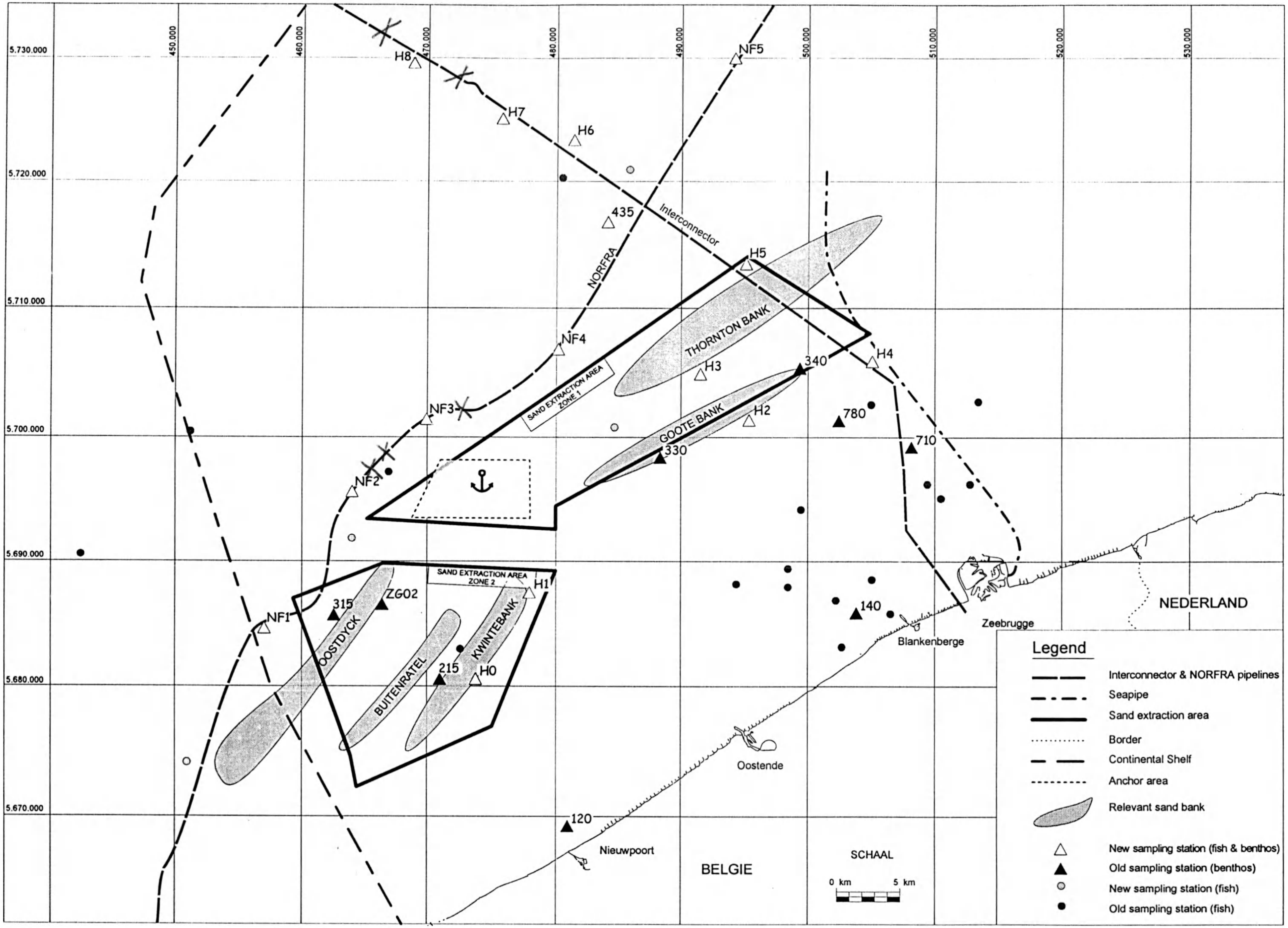
GSM 075/40 88 99 E-mail : rdeclerck@unicall.be



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H3
H2
H1
H0
NF5
NF4
NF3
NF2
NF1
435
340
330
780
710
315
ZG02
215
140
120
Interconnector
NORFRA
SAND EXTRACTION AREA ZONE 1
SAND EXTRACTION AREA ZONE 2
THORNTON BANK
GOOTE BANK
OOSTDYCK
BUITENRATEL
KWINTEBANK
NEDERLAND
Zeebrugge
Blankenberge
Oostende
Nieuwpoort
BELGIE
SCHAAL
0 km
5 km
Legend
Interconnector & NORFRA pipelines
Seapipe
Sand extraction area
Border
Continental Shelf
Anchor area
Relevant sand bank
New sampling station (fish & benthos)
Old sampling station (benthos)
New sampling station (fish)
Old sampling station (fish)