The macrobenthic community of gravel deposits in the Dutch part of the North Sea (Klaverbank): ecological impact of gravel extraction

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november 1989

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PREFACE

In 1988 research was carried out on the gravel beds of the Klaverbank/Botney Cut area in the Dutch part of the North Sea as part of a programme to establish the sediment characteristics and the composition of the macrofauna of the area and the impact of gravel extraction.
The project was initiated by the Ministry of Transport and Public Works, North Sea Directorate (RWS) and conducted in co-operation with the Geological Survey of the Netherlands (RGD) and Bureau Waardenburg b.v. .
Bureau Waardenburg b.v. was responsible for the biological part of the programme and the present report.
The project was headed by Dr. W. Zevenboom (North Sea Directorate).

The authors wish to thank the following persons:
Captain and crew of the research vessel 'Mitra' and the participants of the North Sea Directorate (section VTL) and the Geological Survey (RGD) for their assistance during the fieldwork and, especially, Ton van Schie, North Sea Directorate (section CZO), for his help in collecting and selecting the samples.
Mr. Ch. Dijkshoorn for his information concerning actual gravel extraction
Dr. C. Laban (Geological Survey) for the provision of geological data.
Dr. S.J. de Groot and dr. A. Corten, Netherlands Institute for Fishery Investigations (RIVO) for supporting this study with fruitful discussions and the provision of literature. Dr. R.J. Leewis, dr. W.A. Zevenboom and drs. H.R. Bos for critically reading the manuscript and Ms. R. Guicherit for assisting with the translation of the manuscript.

1. INTRODUCTION

The growing interest of mining industry in extracting marine gravel deposits, as a consequence of the diminished supply of terrestrial gravel deposits, demands the assessment of the ecological impact on the marine environment. As stated in several reports of the ICES Working Group on the Effects of Sand and Gravel extraction (ICES, 1975; 1977 &1985) and in papers of de Groot (1979, 1980), gravel extraction may offer a serious threat to the gravel-bound benthic community as well as to fish species like herring and sandeel, which use gravel-beds as spawning sites. The present report deals with the sediment characteristics and macrobenthos of a gravel area and evaluates the potential effects of mining.

In the Dutch sector of the North Sea, gravel deposits are found in the Klaverbank-Botney Cut area (blocks K1 and E15) on the southeast edge of the Doggerbank (Figure 1a). It is estimated that the reserves of exploitable gravel are 40 - 50 million m^3 (Schüttenhelm & Oele, 1982; de Groot, 1986). Several gravel deposits were extracted as part of experiments by the mining industry in 1987. In 1985 a research programme was initiated by the Ministry of Transport and Public Works, North Sea Directorate, in order to describe the species composition of the area and its relation to the gravel content of the seabed. According to the preliminary results of this study the gravel beds are characterised by a variety of benthic fauna, however, quantitatively good data were not obtained (Baptist, 1986; Sips & Waardenburg, 1988a).

In co-operation with the Geological Survey of the Netherlands and Bureau Waardenburg the programme was continued in 1988, geared towards the following questions:
- Which organisms live (permanently or temporarily) in the gravel area?
- Which of these species depend on gravel in such a way that gravel extraction will affect their abundances?
- What is the ecological significance of the gravel deposits of the Botney Cut-Klaverbank area in the North Sea?
- What is the impact of gravel extraction on the adjacent area?
- Is it possible to adjust the extraction technique in order to limit the expected negative effects?
- How much gravel can be extracted?

In order to obtain the relevant data concerning seabed morphology and macrobenthos a sampling programme was carried out with the North Sea Directorate research vessel Mitra in September, 1988. Inventories of samples and recordings were conducted in the laboratory of Bureau Waardenburg and are reviewed in the following paragraphs. Additional data of the Geological Survey and the North Sea Directorate have been included.

2. METHODS

2.1 Fieldwork

The fieldwork was confined to three transects, two in an area where extraction was supposed to have taken place in 1987 and 1988 (A and B) and one transect (C) at an undisturbed location (Figure 1b). Each transect had a length of about 1 km and was made up by two rows of five stations, with a distance of 250 m between them (Figure 1c). The location of the tracks and the stations was checked by means of the ships' DP-autotrack mode, based on the Hyperfix navigation system.

The following activities were planned:

- Sampling of the stations by means of a Grab andcore-sampler.
- Recordings of the seabed by Video surveys along the transects.
- Side Scan Sonar surveys.

The research was carried out in weeks 30 and 31, August - September, 1988. Because of bad weather it was not possible to complete the whole programme. The Side Scan Sonar surveys were cancelled and the video programme was half-done.

2.2 Sampling techniques

In contrast to sand-bottoms, gravel beds are not suited to boxcore sampling. Therefore, a so-called Hamon Grab sampler was applied, with a shovel moving circularly through the sediment. Additional samples, representing a fixed surface and undisturbed stratification, were obtained by use of a pneumatic Core sampler (Zenkowich).

The grab and core samples were numbered chronologically 88GH/A 501 up to 88GH/A 587 (GH = Hamon Grab sample; A = Core), in accordance with the Geological Survey. Grab samples analysed by the Geological Survey were annotated with the characters GS; those analysed by Bureau Waardenburg with the code BW. Station numbers and sample numbers can be found in the appendices.

2.2.1 Hamon Grab samples

All 30 stations indicated in Figure 1c were sampled twice with the Hamon Grab sampler (28 x 30 x 27/50 cm). One sample was collected to obtain sediment data only (GS-samples), the other was washed through sieves, with meshes of 8 and 1 mm respectively, to allow survey of macrofauna (BW-samples). To prevent damage, all the organisms of the coarsest fraction and part of the animals of the residue-fraction (1 - 8 mm) were separated from the sediment aboard by rolling gravel during transportation and, subsequently, preserved in a 5% neutralised formaldehyde solution. The residue-fraction itself was stored and preserved completely or, in case of very large samples, for a quarter part.

The gravel content of the grab samples analysed by the Geological Survey (GS) was measured as mass percentage of the fraction >2 mm (empty shells included), in accordance with the common definition of gravel. The grain-size distribution of the BW grab samples was expressed as the volume percentage of the fractions 1-8 mm and >8 mm (empty shells excluded). N.B. the sum of separated volume fractions may exceed the total volume, because of the packing of smaller grains in the interstitial spaces of coarser gravel.

2.2.2 Core samples

On 27 stationscore samples were taken with the Zenkowich Pneumatic Hammer (Ø 9 cm). The sampling method failed at three of the last stations (C7, C9 and C10), possibly because of the diminished accuracy of the Hyperfix navigation system at the late hour, and the subsequent instability of the ships' DP-autotrack mode. The Core was probably pulled over by the ships' movements. Once a core sample was brought to deck, the total length and gravel/boulder-clay boundaries were measured to serve geological typology. Surveys of grain-size distribution and faunal contents were limited to the upper part of the core, which was divided in four slices of 5 cm. Subsequently, each sub-sample was preserved and stored.

2.3 Treatment of the samples in the laboratory

In the laboratory the macrofauna of each grab and core sample was identified and counted using a stereo microscope. Organisms in the residue-fractions (1-8 mm) could not be separated by sieving or washing and had to be picked out by hand while carefully examining the sediment. Ashfree dryweights (ADW) of the larger or very common organisms were measured at the species level. The specimens were dried till constant weight at 70° C, and burned at 525° C (ICES recommendation). Small species in low densities were lumped in higher taxa first, before measuring

ADWs. Subsequently, species' ADW values were obtained by interpolation, using wet weight ratios.

To relate number and ADW of the species to density and biomass, the sediment contents of the Hamon Grab samples had to be converted to surface area (m^2). Because of the large variables in volume of the samples, no standard factor could be applied and, therefore, in this study, volumes have been converted to surfaces by circle-segment calculation, according the formula:

$$\mathbf{W R^2 \arcsin (S/2WR) - 0.5\, S \sqrt{(R^2 - 0.5\, S^2/W^2)} - V = 0}$$

in which **W** is the width of the shovel, **R** is the radius of the circular movement of the shovel, **V** is the volume of the sediment-content of the grab sample and **S** is the sampled surface (Figure 2). Because the thickness of the sediment layer varies over the calculated surface intersection, reaching zero at both ends, densities and ADWs of the deeper living species have been underestimated.

2.4 Video-survey

By means of the ROHP (Remote Operated Hoisting Platform), a propelled underwater camera system, dropped and towed by the research vessel) the seabed was monitored and recorded on video tape along three tracks with lengths of about 1500 m. Each track connected five station numbers of a sampled transect (Figure 1c). While moving over the surface a general impression was obtained of some bottom characteristics, e.g. patchiness of gravel and large stones, distance and direction of ripple-marks and the density of large sessile species. Detailed observation of the surface was only allowed by bringing the ROHP to a standstill and zooming the camera in maximally. Stops were made at the station sites along the tracks and on several seemingly interesting places en route. Because of the limited manoeuvrability of the ROHP good close-ups of surface dwelling species were made rather randomly.

3. RESULTS

3.1 Sediment data

According to the video protocol and the measured gravel contents, the sediment characteristics of transects A and B show some similarity (Appendix 1 and 3, Figure 3). Homogeneity (e.g. patchiness), however, depends on the scale being regarded. Comparing the mass-fractions of the GS-samples (>2 mm) with the volume-fractions (>1mm) of the BW-samples taken at the same station (within a few meters), the correlation coefficients of transect A, B and C are respectively 0.21, 0.75 and 0.84 From these figures the conclusion may be drawn that, on a smaller scale, track A is more heterogeneous than track B and C, which is probably caused by the more pronounced ripple marks at transect A, with alternating gravel/sand ratios in ridges and dips, as shown on the video recordings.

The gravel percentages of the BW grab samples were divided into fractions 1-8 mm and >8 mm. The ratio of both fractions, averaged over the transects, appears to be rather similar for transect A and B (transect A ; 41% of 1-8mm and 30% >8mm; transect B ; 42% of 1-8mm and 32% >8mm) Transect C is differentiates itself by its greater share of the coarsest fraction (; 42% of 1-8mm and 26% of >8mm)). The video recordings show that the gravel beds of transect C are less sorted than A and B, with gravel of varying dimensions and stones up to 1 m in diameter randomly scattered over the surface.

Gravel fractions of the Core samples taken at transect A and B (Figure 4) do not show a set pattern which corresponds to depth into the bottom surface. However, at transect C the coarsest fraction (>8 mm) is mainly found at the upper surface layer, which is probably due to the reduced thickness of the gravel deposit. In some samples the gravel/boulder-clay boundary reaches the upper 20 cm of the core. On the video recordings of transect C, chunks of boulder-clay were incidentally seen at the bottom surface.

3.3 Species data

Of the grab samples 59 species were identified, of which 15 molluscs, 9 echinoderms and 29 polychaetes (Appendix 4 and 5). 10 species were found in more than one third of the samples. The echinoderms *Ophiura albida* and *Echinocyamus pusillus* are wide-spread, as are the molluscs *Dosinia exoleta* and, to a lesser extent, *Thracia phaseolina*. Common polychaetes are *Notomastus latericeus*, *Glycera* *alba*, *Ophelia limacina*, *Chone duneri* and *Lumbrineris latreilli*. The chordate *Branchiostoma lanceolatum* was found in 11 grab samples (out of 30).

As to what extent the collected macrofauna can be considered to be representative for the species richness of the area is indicated by the rarefaction curves of Fig. 5, which show the cumulative increment of the number of species in subsequent samples. A good coverage may be expected when, after a certain number of samples, no new species are found. The graphics of the cumulative increase of the number of species found along the three transects (A, B and C) tend to level off in horizontal direction. This suggests that the majority of the macrobenthic species were collected. However, if many species occur in only very low densities, which seems to be the fact in the area observed, a good view of the species richness can hardly be achieved. For example, almost half of the 59 species counted were found in only one or two samples (respectively 11 and 15 species). Moreover, most of the surface dwelling and sessile species, as identified on the video recordings, were not collected at all, e.g. *Alcyonium digitatum*, *Metridium senile*, *Tealia felina*, *Buccinum undatum, Aequipecten opercularis* as well as some tunicates, hydroids and sponges (Appendix 3).

When a comparison is made of the composition of species at the three localities (Appendix 5), it appears that transects A, B and C have only 18 species in common (out of total of 59 species). Despite the relatively large distance between transect C and the transects A and B and the difference in the sediment composition, no great variation can be established in species' composition between transect C and the transects A and B , as well as between the latter two. At transect C 9 species were found, which were not found at the transects A and B. At the transects A and B, 5 and 8 species, respectively, were found which were not found at other transects.

In contrast with species richness, the species densities show a clear contrast between the localities, with the lowest concentrations found at transect C (Appendix 6). Here, the densities of the above-mentioned echinoderms and molluscs are found to be less than half; the chordate *Branchiostoma lanceolatum* by 80% and the polychaetes *Glycera alba*, *Chone duneri* and *Lumbrineris latreilli* even by more than 90%. The polychaete *Pectinaria spp.* however, can be considered typical of transect C. This species was not found at transect A and B, whereas at transect C it was found in 8 samples.

The results of the species ashfree dryweights (ADW; in grammes) and biomass (ADW/m^2) have been listed in Appendix 7. Figure 6 compares total biomass and shows the relative importance of different species groups. From this figure it is clear that biomass is dominated by molluscs (70%, averaged over the three transects). At transects A and B one single species, the bivalve *Dosinia exoleta*, accounts for these high values. At the less gravelly transect C, *Dosinia* is less common. *Arctica* and *Ensis* add however, add to the high biomass total. Because total biomass is mainly accredited to a few large species which have been sampled in only small quantities (e.g. only 4 specimens of *Arctica* have been found), the measured ADWs vary extremely among the different stations (e.g. 0.2 g at station C4 and 14.1 g at station A7), resulting in high standard errors of the mean biomass values.

4 THE HABITAT OF THE KLAVERBANK

4.1 Seabed morphology

According to the mapped isoconcentration boundaries of Figure 1b the gravel deposits of the Klaverbank (>30% gravel) cover a surface area of about 150 - 200 square kilometres. The depth of the water column is 30 - 40 meters. The maximum current velocity of the tidal stream reaches 0.5 m/s (surface values; Anonymous, 1976).

The results of sampling and video-recording allow the following remarks concerning seabed morphology:

The gravel beds have a thickness of approximately 0.5 - 1 meter, covering the boulder-clay which occasionally reaches the surface. The deposits consist of badly sorted, slightly angular stones, indicating its glacial origin (gravel of river deposits is generally well sorted and more rounded in shape).
The gravel composes of flints, sandstone, quartz, quartzite and other crystalline material, including some siliconized Jurassic fossils (the oyster *Gryphaea* spp. and belemnites). The maximum gravel concentration of the sample was 79% (mass % >2 mm). 5 - 20% of the gravel volume consists of calciumcarbonates: i.e serpulid tubes and recent or sub-fossil shell fragments of mainly *Dosinia exoleta*, *Acropagia crassa*, *Arctica islandica*, *Aequipecten opercularis* and *Ensis* spp..

In general, gravelly deposit were found arranged in large waves (1.0 - 1.2 meter across), interspersed with more or less flat sand areas. Relatively large stones lay scattered around, either upon gravel or sand. At all three transects the observed gravel waves ran parallel to the east-west direction, indicating the occasional occurrence of a north-south transport. The ridges and dips of the waves often show alternating gravel/sand ratios. Either sand waves may lay upon gravel, or gravel ridges may have been washed free from the finest fractions. Shell fragments often accumulate in the lower parts of the gravel waves.

4.2 Gravel-allied macrofauna

4.2.1 Species composition related to gravel contents

Obviously, sessile species need solid substratum to attach themselves. Besides man-made structures like wrecks, pipelines, drilling platforms and dike-slopes, solid substratum in the North Sea is limited to shells, gravel and stones. The instability of loose shell material due to its low specific gravity makes this type of substratum to be suitable for the attachment of sessile fauna (rare exceptions to this rule may be reserved for *Hydractinia*, a hydroid which covers snail-shells occupied by hermit crabs, and some shell-burrowing species like the polychaete *Polydora*). Therefore, the sessile species of the Klaverbank area, almost by definition, depend on gravel and stones and, hence, may be considered as typical of the area.

In the Hamon Grab samples sessile species have hardly been found besides serpulid tubes (empty or occupied by sipunculids) and some tiny sprigs of hydroids. However, the video recordings show the occurrence of a rich and varied sessile fauna. Two reasons may account for this discrepancy. First, it should be noted that the 30 Hamon Grab samples represent a sediment surface of only 6 square meters. The recorded video tracks amount to a total length of about 5 kilometres. Furthermore, the video recordings show a correlation between the coverage of sessile species and the size of individual stones. The sampled sediment may show a disproportionate lack of large stones.

The observed sessile fauna is composed of coelenterates, tunicates and probably sponges. Most conspicuous are *Metridium senile* (Plumose Anemone), single or in groups, and the soft coral *Alcyonium digitatum* (Dead Men's Fingers). *Alcyonium* has often been found detached, floating over the surface as free-living colonies. Other identified coelenterates are *Tealia felina* (Dahlia Anemone), mainly occurring on less gravelly patches, and hydroids of the genera *Hydractinia*, *Halecium* and *Sertularia*. Large stones are often covered by several of these species, occasionally including groups of the tunicate *Ascidiella* sp.

Non-sessile surface dwelling species such as the gastropods *Buccinum undatum*, *Colus gracilis*, *Aporrhais pes-pelecani*, *Natica* spp.and *Neptunea antiqua* are recorded on video, but were hardly or not found in the samples.This was also the case with the bivalve *Aequipecten opercularis* and the echinoderm *Asterias rubens* as well as some brittle-stars which could not be identified. The sea-urchin*Psammechinus miliaris* was the only species frequently found on the video recordings as well as in the samples. Fish species which were seen on the video recordings are Cod (*Gadus morhua*), Dragonet (*Callionymus lyra*), Sandeel (*Ammodytes* spp.) and flat-fishes (Pleuronectidae).

The density of 18, more or less numerous species, out of the 59 species in the Hamon Grab samples, has been plotted against total gravel percentages and different gravel fractions (Figure 7). Correlation coefficients have been calculated to assess the significance of positive or negative relationships at the levels $P<0.05$ and $P<0.01$ (Appendix 8).
The densities of 8 species show a significant positive correlation with gravel percentages: the bivalve *Dosinia exoleta*, the polychaetes *Glycera alba*, *Notomastus latericeus*, *Lumbrineris latreilli*, *Poecilochaetus serpens*, the echinoderms *Ophiura albida* and *Echinocyamus pusillus* and the chordate *Branchiostoma lanceolatum*. Two species, the bivalve *Gari fervensis* and the polychaete *Pectinaria*, have a significant negative correlation. Regarding the different gravel fractions, it appears that

density shows a much better correlation with the fraction 1-8 mm than with the fraction >8 mm. Intermediate gravel fractions may largely determine the presence of these macrobenthic species.

4.2.2 Comparison with adjacent areas

In 1988 the results of the Synoptic Mapping Programme, in which the macrofauna of the Dutch Continental Shelf had been sampled systematically by means of a rather coarse grid (de Wilde & Duineveld, 1988) became available. The data of four of the sampled stations of this programme, laying around the Klaverbank at a distance of 20 - 40 kilometres North, East, South and West, have been tabled in Appendix 9. Unfortunately, sediment data of these stations are lacking. However, it may be assumed that the sediment did not contain gravel, because otherwise no boxcore sampler could have been applied.

Some very clear differences in the faunal composition emerge when comparing the species densities of the Klaverbank with the surrounding area (Appendix 6 and 9), The most conspicuous species of both the Klaverbank and the adjacent area are listed below.

	Klaverbank:	**Adjacent area:**
echinoderms	*Ophiura albida*	*Amphiura filiformis*
	Echinocyamus pusillus	*Acronida brachiata*
	Psammechinus miliaris	*Echinocardium cordatum*
molluscs	*Dosinia exoleta*	*Dosinia lupinus*
	Acropagia crassa	*Mysella bidentata*
	Arctica islandica	*Tellina fabula*
	Ensis arcuatis	*Nucula turgida*
	Spisula elliptca	*Venus striatula*
Polychaeta	*Chone duneri*	*Magelona papillicornis*
	Glycera alba	*Pholoe minuta*
	Notomastus latericeus	*Spiophanes bombyx*
	Lumbrineris latreilli	*Nephtys hombergii*
Chordata	*Branchiostoma lanceolatum*	

The number of mollusc and polychaete species found in the 4 Synoptic Mapping stations (20 samples with a total surface of 1.4 m^2) is markedly greater than the number of species identified from the 30 Klaverbank samples (total surface 6 m^2), indicating a greater species richness in the adjacent areas. However, the Synoptic Mapping samples represent 4 locations which lay further apart than the three Klaverbank transects. If stations cover a larger area, a greater range of abiotic parameters may be expected and, hence, more different species. Furthermore, the comparison of species numbers may be obscured by the differences in densities of species (many species of the Klaverbank occur in only small densities) and by the possibly greater heterogeneity of gravel areas, calling for a more extended sample programme to fit all macrofauna. Regarding the discrepancy between the collected species and the fauna shown on the video recordings, the species richness at the Klaverbank is probably comparatively high.

With regards to biomass, the average total value is 1.5 times higher at the Klaverbank than in the surrounding area (20.1 respectively 13.4 g/m^2), which can be ascribed to the large bivalve species of the gravel area (Appendix 9 and Figure 6). From the circle diagrams it can be deduced that biomass of the adjacent area is dominated by Echinoderms (49%; at the Klaverbank 5%). Molluscs account for 33% of the biomass (70% at the Klaverbank).

For several reasons the real biomass figure of the Klaverbank may be higher than the calculated 20.1 g/m^2:

- The applied method of converting sampled volumes to surfaces (Chapter 2.3) results in an underestimate of densities and biomass of species inhabiting deeper sediment layers. For instance, many collected *Ensis arcuatis* were cut by the Hamon Grab sampler.
- The absence of larger stones in the samples accounts for an underestimate of the biomass of sessile fauna. Solid substrata of wrecks of the North Sea, with a coverage of nearly 100%, carry a mean biomass of 1600 g/m^2. Hence, it may be assumed that the sessile species of the Klaverbank attribute considerably to the total biomass figure, even with an estimated coverage of 0.5 - 1.0%.
- Calculating biomass the bottom surface was assumed flat. However, since gravel beds are characterised by large wave marks, the surface increases, and subsequently the species densities and biomass. Large stones add to the total surface, too.

4.3 The gravel community

The data obtained from the fauna of the Klaverbank is well in accordance with the results of the first sample programme in the area, conducted in 1985 (Sips & Waardenburg, 1988a). Although the data of that study had not been well suited for quantitative analysis, the biomass was estimated to lie between 7.5 and 25.0 g/m^2 (20.1 g/m^2 according the present study). Only a few species which were sampled before were not found again. These are the bivalves *Laevicardium crassum* and *Venerupis rhomboides*, the gastropods *Colus gracilis* and *Epitonium clathrus* and the polychaetes *Lagisca extenuata* and *Pomatoceros triqueter* (serpulid). On the other hand, the present study yielded 17 new species (excluding species shown on the video recordings).

The macrofaunal characteristics of the Klaverbank may be summarised as follows:

- The gravel deposits of the Klaverbank form a patchy combination of both solid substratum and sediment and, hence, offer a rich and varied habitat for sessile, surface dwelling and burrowing species.

- The species richness is high and its densities are low in comparison with the surrounding area.

- The Klaverbank is exceptional in its high biomass values, which can be accredited to several large bivalve species, notably *Dosinia exoleta*.

- The predominant species of the gravel beds are typical of the area in that they are not or only scarcely found in adjacent regions.
  Distinctive species are:

Dosinia exoleta	(bivalve)
Acropagia crassa	(bivalve)
Psammechinus miliaris	(echinoderm)
Alcyonium digitatum	(soft coral)
Metridium senile	(anemone)
Tealia felina	(anemone)
Chone duneri	(polychaete)
Branchiostoma lanceolatum	(chordate)

The characteristics of the Klaverbank give reason to refer to its macrofauna as the 'gravel community', which stands for a gravel dependent aggregate of species as a distinct element of the North Sea ecosystem.

The significance of the 'gravel community' to the larger North Sea environment is hard to define due to the lack of knowledge concerning the biology of the individual species.
The community's high biomass values may be indicative of a relative important role of the area as a food source for other species, assuming production is correlated with biomass. Large bivalves, for instance, may add to a considerable production by way of releasing eggs and, possibly, by the growth of siphons, bitten off by fish. Most sessile species feed on zooplankton (e.g. *Metridium*) and produce eggs as plankton again. Echinoderms and crustaceans may prey upon these species and may in turn serve as an important food source for fish. To determine the importance of the different faunal elements to the ecosystem, more should be known about inter-specific relationships.

5 IMPACT OF GRAVEL EXTRACTION

5.1 Extraction method

For the extraction of gravel at the Klaverbank the proposed method of excavation is to use a so-called hopper dredger (pers. comm. Ch. Dijkshoorn, North Sea Directorate). Mounted on the ship, one or two rear-facing suction-pipes are dragged across the sediment, lifting the aggregate into the cargo hold (Figure 8). This technique produces shallow furrows on the sea-bed. In order to collect an adequate volume of aggregates, a relatively large area needs to be dredged. Because of the small diameter of the gravel deposits, dredging at anchor, resulting in deep pits, can not be applied. The mixture of sand and gravel is stored as a whole, whereas only the overflow of water, loaded with suspended material, is rejected. Sorting is done ashore or omitted if the aggregate is used for foundations in off-shore construction.

The possible effects of gravel extraction may be summarised as follows:

temporal effects:

- direct damage to the benthic fauna at the suction sites
- suffocation of the sea-bed by redeposited sediment
- increase in turbidity, nutrient enrichment and contamination of the water column

permanent: effects:

- alteration of the sea-bed topography
- alteration of the sediment composition

The consequences for respectively macrofauna and fish are discussed below.

5.2 Effects on the macrofauna

Because the gravel deposits at the Klaverbank are rather thin (0.5 - 1.0 m) it may be assumed that, at the dredging trails, the aggregate will be removed entirely, including the inhabiting species, and the underlying sediment layer (boulder-clay) will become exposed. The damage to the 'gravel community' may be permanent and proportional to the extracted surface Unless the spontaneous transport of neighbouring gravel re-covers the dredged area. This may result in a diminished thickness of the gravel beds throughout the area and a restored, more or less original, composition at the surface. The 'gravel community' will eventually recolonise the sediment and damage may be temporary.

The question arises therefore, whether the natural transport of gravel occurs at the Klaverbank or not.

In this respect De Groot (1979) quotes several papers which state that, in the North Sea, restoration of a dredged gravel area is expected to be extremely slow. For instance, Dickson and Lee (1973a, b), when studying the impact of gravel extraction with a sector scanner, found that a test pit dredged in 22 m. water depth and 3,5 m deep,did not refill at all over a period two years. Based on calculations of bottom current velocity, Millner *et al* (1977) were able to calculate that material larger than about 6 mm. in diameter would not be moved even by the strongest tides, indicating that, on gravel substratum, the pits or trails will remain as long-lasting features.

Notwithstanding the statements about the supposed stability of gravel, factors given below, point to the possibility of occasional transport of gravel by natural causes at the Klaverbank:

- The morphology of the gravel beds show a regular pattern of large ripple which only could have originated from a strong wave action.

- If the gravel deposits were stable and solid, sessile fauna would settle at great densities all over the area. Conform artificial solid substrata (e.g. wrecks) a covering percentage of nearly 100% would be expected (Waardenburg & Sips, 1989). However, mainly larger stones carry sessile species. Apparantly survival on coarse material is reduced, indicating the occasional reworking of the seabed by an external force, i.e. wave action.

Therefore it is clear why so many sampled serpulid tubes were found dead. Another factor is that two species typical of solid substratum but often found at less gravelly patches (the anemone *Tealia felina* and the sea-urchin *Psammechinus miliaris*) are well known for their opportunistic settling behaviour, so-called 'pioneering species' (Waardenburg, 1988). Despite the considerable waterdepth (30-40 m) and the weak currents (max. 0,5 m/s) the top surface of the gravelbeds will be transported and remixed due to severe storms. The sand fraction will of course be moved easier. So this will happen more often and the transportation will be over greater distances than with the gravel.
Model calculations suggest that at wind force >6 Bft for longer than 24 hours, sediment transport occurs in the rather shallow (30-50m) Dutch part of the Continental Shelf (RWS, unpublished).

In the scope of naturally occurring bottom disturbances, the following remarks can be made on the impact of gravel extraction:

- The 'gravel community' has been accustomed to the reworking of sediment, in such a way that either the inhabiting species adapt to occasional disturbances and survive, or that they should naturally be opportunistic, never constituting a longlasting stable population.

- Permanent alteration of the seabed through dredging does not necessarily occur. Much of the restoration depend on how much gravel is extracted.

- Large and continuously extracted areas may recover more slowly than a reticulated pattern of isolated trails. Restoration of the surface of dredged narrow strips may be facilitated if the long axis of the strips run parallel to the wave marks, east to west (i. e. transverse to the currents main direction).

- If large gravel areas are replaced by sand, the faunal composition will change accordingly, resulting in a diminished biomass.
  The change may be rather drastic if large areas of boulder-clay become permanently exposed. Boulder-clay is a very 'fatty' and silty, more or less impenetrable substance, probably unsuit to settlement of a rich and varied fauna. Furthermore, disturbance of the boulder-clay may cause extreme turbidity.

The ability of macrofauna to resettle after disturbance and to recover from redeposited sediment has widely investigated (e.g.: ICES, 1975; de Groot, 1979; Morton, 1977; Kaplan et al, 1974; Kiørboe & Møhlenberg, 1982; van Dolah et al, 1984). In general the original fauna will re-establish itself within 1 - 2 years, providing the bottom morphology has not altered. The outwash and deposition of fine sediment does not appear to be a serious problem.

Recolonisation of benthos may occur through active transport of the species itself, resulting in decreased mean overall densities, or through settlement and subsequent growth of recruits. Small species (e.g. most polychaetes) and sessile fauna may only resettle by reproduction. Large mobile species that grow relatively slowly will probablyre-establish. But they need of course more time to reach the original densities. A simple ad hoc aquarium experiment, conducted on board of the research vessel at the Klaverbank, showed that large bivalves (*Dosinia*, *Acropagia*, *Arctica* and *Ensis*) are well capable of moving through pure gravel, replacing stones much bigger than the specimen themselves. On account of this 'bioturbation' and the relatively large interstitial spaces between the grains of gravel beds, it can be supposed that the bottom surface is aerated continuously. Suffocation of the seabed is not likely to occur.

5.3 Effects on fisheries

5.3.1 Herring spawning grounds

In contrast with most pelagic fish, which spawn in the open water, herrings (*Clupea harengus*) need solid substratum (stones, gravel and occasionally algae and sea-grass) to attach their eggs. In the central part of the North Sea, herrings spawn on gravel beds from August to October. Several authors emphasise the possible negative effects of gravel extraction on spawning grounds (e.g.: ICES 1975, 1977; de Groot 1979, 1980, 1986; Kiørboe & Møhlenberg, 1982; Sips & Waardenburg, 1988b). In this respect questions arise to what extent the herring depends on Klaverbank deposits:

- Does the Klaverbank serve as a spawning ground or could it have this function in the future?

- If so, what are the criteria for herring to select a specific spawning ground?

- Does the disappearance of suitable spawning beds have influence on the size of the herring stock in thae North Sea?

The North Sea herring comprises of a number of self-contained populations, which are grouped in three units: the northern, central and southern North Sea stocks. Quoting Corten (1986), the southern stock declined in the 1950s, presumably as a result of overfishing, and it remained at a very low level until the late 1970s. The central and northern stocks gradually declined throughout the 1960s and early 1970s, due to overfishing and probably through recruitment failure caused by a temporally changed North Sea circulation. In 1976, the stock of the entire North Sea was estimated to stand at 100,000 tons at maximum (pers. comm. A. Corten, RIVO). After protective measures had been taken, and possibly because of the restored water circulation, the stock recovered slowly, up to 1.5 million tons in 1988.

The extreme changes in stock size have been accompanied by large shifts of the spawning grounds. Fig. 9 shows the spawning grounds used in the years 1955-1973, based on the point of capture of herring, on the verge of spawning (Postuma et al, 1975). The spawning sites at the central North Sea covers the area from the British coast to the Klaverbank, alongside of the 54° latitude. During the period of depletion of the herring stock, all western spawning grounds (between 1° and 4° longitude) were abandoned. This situation remained long until after the stock had recovered (Figure 10). The herring is conservative in exploring new spawning grounds. However, the increase in the herring population will probably necessitate the re-occupation of the formerly abandoned areas. From 1980 onwards, spawning grounds have gradually extended eastwards. In 1988 the first 'spawning' herring was captured on the Klaverbank (A. Corten; unpublished data). Should this tendency continue, it may be assumed that sooner or later the Klaverbank will regain its function as a spawning ground.

In order to establish the suitability of different types of gravel beds, the criteria for the herring to select a specific spawning grounds must be found. Unfortunately, the location of the spawning grounds is done by catching mature herring and newly hatched larvae. Research on spawn-gravel relationships, either by dredging or grabbing techniques or by direct observation, has hardly been done. De Groot (1979, 1980), quoting several papers, evaluates the criteria the herring may emplay when selecting a new spawning ground:

- Spawning beds are always small (a few hundreds meters across). Concentrated amounts of eggs adhere to the stones by an adhesive mucus, forming a more or less continuous carpet over the surface which lasts for about two weeks. The beds can be longitudinally shaped, the long axis parallel to the tidal stream (Bolster & Bridger, 1957).

- The boundary of a spawning bed may coincide with a change from gravel and small stones to large stones and rocks (Parrish et al, 1959). Hemmings (1965) and later Bowers (1969) and Dragesund (1970) confirm that the herring selects on gravel patches with distinct uniform grain-sizes, devoid of sand.

The available data suggest that herring indeed requires gravel with specific properties. It is proposed that these properties are strongly connected with the stability of the bottom surface and, hence, grain-size and maximum water current velocities. If the substratum is too stable, sessile fauna will occupy the surface, leaving no place for the herring to spawn. On the other hand eggs, if the sediment is too unstable-could well be lost. A certain degree of stability is therefore preferable and should assure the best recruitment (Sips & Waardenburg, 1988a).

If the properties of spawning beds are better understood, criteria may be developed which divide the Klaverbank area in unsuited and potentially adequate spawning grounds. Gravel extraction could be adjusted accordingly. Lacking this knowledge ICES (1977) has requested to abstain from gravel extraction in several regions where the herring is known to spawn (Figure 11). The Klaverbank is situated just eastwards of the restricted area. With the extension of the spawning sites in eastward direction it has become necessary to reconsider the regions' boundaries.

The stock-recruitment relation is still not clear (Corten, 1986). However, even if this relation proves to be obscure, a decline of spawning grounds remains undesirable because the herring will be more vulnerable to all types of local disturbances, e.g. pollution and anoxia.

5.3.2 Effects on the sandeel

Ecologically as well commercially the sandeel (*Ammodytes* spp.)is an important benthic species. It serves, for a large part, the diet of many larger fishes. It is also important for the fish-flour industry. Sandeels live in large quantities at the Klaverbank.

The behaviour of sandeels make them particularly vulnerable to dredging (ICES, 1977; de Groot, 1979). The species spends between four and six months completely buried in the sand. Even during periods of activity, the fish remains buried at night and leaves the seabed only during daylight hours to feed. Hence, the species was found in the grab samples several times. They also spawn in the seabed, and need a certain grainsize. When the eggs are fully covered with fine material, the development of the embryo will be impossible. The deposition of fine sediment released during dredging may impede the hatching. Gravel extraction during the spawning season (in winter) may be harmful to the sandeel stock.

5.4 Concluding remarks

The present study leads to the following statements:

- The macrofauna of the Klaverbank is distinct from adjacent regions and characterised by high biomass values of mainly molluscs.

- The ecological significance of the 'gravel community' is not yet understood, because of the lack of knowledge about inter-specific relationships.

- The occurrence of permanent negative effects of gravel extraction on the macrofauna largely depends on the degree to which the bottom topography will change. In this respect, Side Scan Sonar surveys will play a decisive role. If the morphology remains unchanged, no permanent effects can be expected .

- Replacement of gravel by sand leads to thane reduced species variety and a diminished biomass.This results in even more drastic effects if boulder-clay, after dredging, exposes the surface.

- Assuming that the bottom morphology does not alter, recovery of the macrofauna after disturbances will be fast and effective since the 'gravel community' has already been accustomed to occasional reworking of the seabed and anoxia is not likely to occur. However, recovery of large bivalves, removed by the hopper dredger, will take a considerable time.

- Restoration of the seabed is facilitated if extraction is conducted in narrow, isolated strips. The best direction is probably parallel to the sediment ripples, i.e. east - west.

- The Klaverbank has formerly served as a spawning ground for herring and as such it is likely to function again. More knowledge about the exact locations and characteristics of spawning beds is urgently needed.

- Changes of the morphology of the Klaverbank may negatively affect the return of the herring to the spawning sites, and therefore their successful reproduction. In principle, these changes are irreversible and permanent.

- Turbidity of the water column through dredging operations may have negative effects on spawning sites not only in the direct vicinity but also in adjacent spawning sites. Gravel extraction should be avoided during the spawning seasons of sandeel (winter) and herring (August-October).

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Appendices

Station number	Sample number BW	% vol. fraction > 8 mm	% vol. fraction 1 - 8 mm	% restvolume	Sample number GS	% mass fraction > 2 mm
A1	88GH501	38%	31%	31%	88GH502	66%
A2	88GH511	33%	44%	23%	88GH510	60%
A3	88GH505	34%	43%	23%	88GH504	52%
A4	88GH508	6%	21%	71%	88GH507	54%
A5	88GH514	38%	18%	44%	88GH513	37%
A6	88GH517	41%	45%	14%	88GH516	64%
A7	88GH523	28%	50%	22%	88GH522	56%
A8	88GH520	37%	50%	13%	88GH519	56%
A9	88GH526	25%	56%	19%	88GH525	46%
A10	88GH529	21%	52%	27%	88GH528	36%
B1	88GH532	14%	27%	59%	88GH531	48%
B2	88GH535	30%	44%	26%	88GH534	65%
B3	88GH541	15%	40%	45%	88GH540	45%
B4	88GH537	38%	42%	20%	88GH538	79%
B5	88GH544	25%	53%	22%	88GH543	61%
B6	88GH547	20%	45%	35%	88GH546	65%
B7	88GH550	42%	40%	18%	88GH549	68%
B8	88GH553	42%	42%	16%	88GH552	66%
B9	88GH559	47%	36%	17%	88GH558	67%
B10	88GH556	42%	53%	5%	88GH555	65%
C1	88GH562	32%	24%	44%	88GH562	36%
C2	88GH565	2%	2%	96%	88GH564	7%
C3	88GH572	33%	13%	54%	88GH571	27%
C4	88GH568	40%	11%	49%	88GH567	24%
C5	88GH574	15%	10%	75%	88GH573	28%
C6	88GH577	4%	14%	82%	88GH576	19%
C7	88GH583	19%	12%	69%	88GH582	42%
C8	88GH580	42%	27%	31%	88GH579	46%
C9	88GH585	39%	31%	30%	88GH584	57%
C10	88GH587	38%	31%	31%	88GH586	50%

Appendix 1: gravel percentages Hamon Grab samples (BW and GS)

station number	sample number core	depth range	% vol. fraction > 8 mm	% vol. fraction 1 - 8 mm
A1	88A503	0 - 5 cm	52	22
		5 - 10 cm	41	30
		10 - 15 cm	48	28
		15 - 20 cm	38	34
A2	88A512	0 - 5 cm	52	24
		5 - 10 cm	38	19
		10 - 15 cm	41	22
		15 - 20 cm	39	17
A3	88A506	0 - 5 cm	40	51
		5 - 10 cm	31	44
		10 - 15 cm	31	35
		15 - 20 cm	26	40
A4	88A509	0 - 5 cm	14	16
		5 - 10 cm	8	29
		10 - 15 cm	20	24
		15 - 20 cm	14	22
A5	88A515	0 - 5 cm	39	21
		5 - 10 cm	27	14
		10 - 15 cm	29	17
		15 - 20cm	35	19
A6	88A518	0 - 5 cm	54	38
		5 - 10 cm	54	38
		10 - 15 cm	54	38
		15 - 20 cm	54	38
A7	88A524	0 - 5 cm	21	64
		5 - 10 cm	31	32
		10 - 15 cm	19	40
		15 - 20cm	28	43
A8	88A521	0 - 5 cm	44	64
		5 - 10 cm	22	43
		10 - 15 cm	10	24
		15 - 20 cm	25	35
A9	88A527	0 - 5 cm	30	38
		5 - 10 cm	35	37
		10 - 15 cm	16	40
		15 - 20 cm	22	35
A10	88A530	0 - 5 cm	53	54
		5 - 10 cm	26	35
		10 - 15 cm	30	49
		15 - 20 cm	27	28
B1	88A533	0 - 5 cm	33	39
		5 - 10 cm	30	44
		10 - 15 cm	42	45
		15 - 20 cm	33	38
B2	88A536	0 - 5 cm	37	33
		5 - 10 cm	40	32
		10 - 15 cm	38	26
		15 - 20 cm	44	29
B3	88A542	0 - 5 cm	2	5
		5 - 10 cm	9	16
		10 - 15 cm	26	19
		15 - 20 cm	25	22
B4	88A539	0 - 5 cm	45	42
		5 - 10 cm	27	36
		10 - 15 cm	37	48
		15 - 20 cm	41	32

Appendix 2 (1): gravel percentages of core samples

station number	sample number core	depth range	% vol. fraction > 8 mm	% vol. fraction 1 - 8 mm
B5	88A545	0 - 5 cm	27	44
		5 - 10 cm	16	52
		10 - 15 cm	34	38
		15 - 20 cm	37	45
B6	88A548	0 - 5 cm	32	23
		5 - 10 cm	24	21
		10 - 15 cm	25	29
		15 - 20 cm	32	35
B7	88A551	0 - 5 cm	61	22
		5 - 10 cm	58	30
		10 - 15 cm	39	48
		15 - 20 cm	32	40
B8	88A554	0 - 5 cm	36	49
		5 - 10 cm	35	55
		10 - 15 cm	47	46
		15 - 20 cm	54	31
B9	88A560	0 - 5 cm	67	43
		5 - 10 cm	42	26
		10 - 15 cm	52	22
		15 - 20 cm	21	37
B10	88A557	0 - 5 cm	63	24
		5 - 10 cm	43	24
		10 - 15 cm	22	30
		15 - 20 cm	16	27
C1	88A563	0 - 5 cm	37	24
		5 - 10 cm	27	38
		10 - 15 cm	8	21
		15 - 20 cm	8	3
C2	88A566	0 - 5 cm	7	3
		5 - 10 cm	13	19
		10 - 15 cm	14	12
		15 - 20 cm	?	?
C3	88A570	0 - 5 cm	51	10
		5 - 10 cm	38	15
		10 - 15 cm	18	27
		15 - 20 cm	16	21
C4	88A569	0 - 5 cm	17	5
		5 - 10 cm	63	18
		10 - 15 cm	25	23
		15 - 20 cm	6	7
C5	88A575	0 - 5 cm	18	12
		5 - 10 cm	25	15
		10 - 15 cm	41	20
		15 - 20 cm	15	20
C6	88A578	0 - 5 cm	28	7
		5 - 10 cm	1	2
		10 - 15 cm	9	4
		15 - 20 cm	0	0
C8	88A581	0 - 5 cm	67	14
		5 - 10 cm	29	8
		10 - 15 cm	7	4
		15 - 20 cm	?	?

Appendix 2 (2): gravel percentages of core samples

Track A (line 108): start: 54-06-23.2 N end: 54-09-17.8 N
03-12-44.1 E 03-14-15.7 E

Sediment:

Relatively uniform gravel deposits interspersed with few sand patches (± 10 - 20 m. across). Empty shells (mainly *Dosinia*, *Arctica* and *Ensis*) lay scattered around or have been accumulated in small ridges.
The gravel beds show large wave-marks (0.8 - 1.5 m. across) running in east-west direction. Generally, the gravel is sandy on the lower parts of the ripples. At the top gravel is more or less concentrated and sorted, occasionly with the interstitial spaces left open by the smaller fractions.

Epifauna:

All species visible at the sediment surface were found in only small densities, on average never exceeding a coverage percentage of 1 %.
Most conspicious in this track are the yellow and white 'death men's fingers' (*Alcyonium digitatum*) attached to small stones or, more often, loosely gliding over the surface as free-living colonies. *Tealia felina* and a few *Metridium senile* are scarcely distributed in the more sandy and respectively gravelly areas. Some surface dwelling snails (*Buccinum* and *Natica*) have been identified on flat sandy patches.
Close-ups of gravel showed the presence of sea-urchins (Psammechinus miliaris) and Ophiuridae. The coarsest gravel fraction was coveraged with serpulide and, probably, amphipode tubes.

	A(start) *A(end)*	*A1*	*A3*	*A5*	*A7*	*A9*
	O-------- O	>--------	>--------	>--------	>--------	>--------
substratum	G	G	G/S	G	G (L)	G/S
Alcyonium digitatum	+++	++	+++	++	+++	+++
Metridium senile					+	++
Tealia felina	+++	++	++	+++	++	++
Psammechinus miliaris			P	P		P*
Asterias rubens				P		P
Ophiuroidea						
Aequipecten opercularis						
Aporrhais pes-pelecani						
Mya truncata						
Buccinum spec.		+		+		+
Natica spec.	++	+			+	+
Colus gracilis					P*	
Tunicata (Ascidiella)						
Hydroids				P	P	P
Decapoda (hermit crabs)						P*
Flatfishes		P		P		P
Gadidae	P			P		
Callionymus spec.						

GG = > 80% gravel beds; < 20 % sand patches
G = 60 - 80 % gravel beds
G/S = 40 - 60 % gravel beds
S = 60 - 80 % sand patches
SS = > 80 % sand patches; < 20 % gravel beds
*** = close up**
(L) = large rocks

P = present
+ = 1- 3 specimens
++ = 3-10 specimens
+++ = > 10 specimens

Appendix 3 (1): sediment type and species identified on the video recordings

Track B (line 208): **start: 54-09-11.8 N end: 54-07-21.7 N**
03-12-33.7 E 03-13-14.1 E

Sediment:

The gravel beds are more homogeneous in structure than at trajectory A, with less sandy patches and less accidented ridges and dips (at least at the first part of trajectory B). The wave-marks run in east west direction, as in trajectory A. Heterogeneity increases towards the end of the trajectory, i.e. more sand and less sorted gravel, occasionally with huge stones.

Epifauna:

Colonies of *Alcyonium digitatum* (typically for trajectory A) and the sea-anemone *Tealia felina* almost disappeared. The coverageof stones by sessile species increases with their dimensions. Relative big rocks (up to 1 meter) are almost completely fouled by hydroids, tunicates(*Ascidiella)* and sponges.
Three times the mollusc *Aequipecten opercularis* was seen swimming away in fear for the camera. Furthermore, a rare close up was made of a crawling Pelicans-foot (*Aporrhais pes-pelecani*).

B(start) B2 B4 B6 B8 B10
B(end)
O-------- >--------- >--------- >-------- >--------->--------O

substratum	G	GG	G	G/S	G/S (L)	S (L)
Alcyonium digitatum				++	+	
Metridium senile	++					
Tealia felina	++	+		++		+
Psammechinus miliaris					P	P*
Asterias rubens				+		
Ophiuroidea		P*				
Aequipecten opercularis		+	+			
Mya truncata	P					
Aporrhais pes-pelecani				+		
Buccinum spec.		P(eggs)				
Natica spec.						
Colus gracilis						
Tunicata (Ascidiella)					++*	++
Hydroids					+++*	+++
Decapoda (hermit crabs)					P	
	P					
Flatfishes						
Gadidae	P			P		
Callionymus spec.			P			

GG = > 80% gravel beds; < 20 % sand patches
G = 60 - 80 % gravel beds
G/S = 40 - 60 % gravel beds
S = 60 - 80 % sand patches
SS = > 80 % sand patches; < 20 % gravel beds
*** = in close up**
(L) = large rocks

P = present
+ = 1- 3 specimens
++ = 3-10 specimens
+++ = > 10 specimens

Appendix 3 (2): sediment type and species identified on the video recordings

<u>Track C (line 308):</u> start: 53-59-58.9N end:
53-59-58.8 N
03-05-45.4 E 03-07-15.4 E

<u>sediment:</u> The area is very patchy, compared with trajectories A and B. Irregular gravel deposits are interspersed by large sandy fields of several hundreds of meters length. Now and then chunks of the deeper boulder-clay layer (till) pirce through the surface sediments.

<u>epifauna:</u> The sea-anemone *Metridium senile* is found in large densities, as well as the echinoderm *Psammechinus miliaris.* Close-ups of larger stones yielded the same sessile species as at trajectory B (tunicates and hydroids). Other close-ups yielded a view of tiny tubes, probably containing amphipods.

	C(start) *C(end)*	*C2*	*C4*	*C6*	*C8*	*C10*
	O-------- O	>--------	>--------	>--------	>--------	>--------
substratum	G/S	G/S	S(L)	G/S(L)	SS	S(L)
Alcyonium digitatum					+	
Metridium senile	+++	++	+	++	+++	++
Psammechinus miliaris	++	+++	++	+++	++	++
Asterias rubens	+			+	+	+
Ophiuroidea						
Aequipecten opercularis						
Mya truncata						
Aporrhais pes-pelecani						
Buccinum spec.				+		
Natica spec.	+		+	+		+
Colus gracilis		+(?)				
Tunicata (Ascidiella)			P	P		
Hydroids	P	P	P		P	
Decapoda (hermit crabs)				P	P	P
Flatfishes						
Gadidae				P		
Callionymus spec.						

GG = > 80% gravel beds; < 20 % sand patches
G = 60 - 80 % gravel beds
G/S = 40 - 60 % gravel beds
S = 60 - 80 % sand patches
SS = > 80 % sand patches; < 20 % gravel beds
*** = in close up**
(L) = large rocks

X = present
+ = 1- 3 specimens
++ = 3-10 specimens
+++ = > 10 specimens

Appendix 3 (3): sediment type and species identified on the video recordings

		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
	station number	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
	sample number	GH501	GH508	GH511	GH505	GH514	GH517	GH523	GH520	GH526	GH529
	volume (liters)	11	18	19	19	10	15	21	23	28	17
	surface (m2)	0,18	0,21	0,21	0,21	0,18	0,20	0,22	0,23	0,24	0,21
Echinodermata	number/sample										
	Amphiura spec.										
	Asterias rubens										
	Echinocardium cordatum										
	Echinocyamus pusillus	16	4	12	30	8	8	44	18	36	20
	Leptosynapta inhaerens										
	Ophiura albida	3	2	4	12	1	18	12	21	8	17
	Psammechinus miliaris						2			1	
	Spatangus purpureus		1								
	Thyone fusus		1								
Mollusca	number/sample										
	Acropagia crassa						1	2	4		
	Aporrhais pespelecani					1					
	Arctica islandica										
	Dentalium spec.										
	Dosinia exoleta	3		4	2	1	6	13	2	9	2
	Ensis arcuatis	1						1	3		
	Gari fervensis										
	Gibbula spec.										
	Natica spec.						12	4			
	Nucula spec.								1		
	Panomya spec.										
	Polinices polianus										
	Spisula elliptica	2	3	1							1
	Thracia phaseolina	1	5		1				2		1
	Venus ovata										
Polychaeta	number/sample										
	Aglaophamus rutella						4				
	Anaitides lineata										
	Aonides paucibranchiata	8	2	8							
	Aphrodita aculeata										
	Chaetopterus (tube)				1					1	1
	Chone duneri	15			9	18	36		8	12	24
	Gattyana cirrosa			4					4		
	Glycera alba	1		32	8	9	6	24		32	12
	Glycera capitata					1				4	
	Glycinde nordmanni										
	Goniada maculata					1				4	
	Kefersteinia cirrata										
	Laonice cirrata										
	Lumbrineris latreilli			4				12		4	19
	Magelona papillicornis										
	Nephtys caeca				1						
	Nephtys cirrosa					2		4	1		
	Nereis spec.										
	Notomastus latericeus	5		8	4	4		24	25	22	17
	Ophelia limacina	4	3	8		1		16		8	4
	Owenia fusiformis	1	5		8						
	Pectinaria spec.										
	Pisione remota										
	Poecilochaetus serpens	4			4						
	Polycirrus medusa					12					
	Prionospio malmgreni					3				4	
	[illegible]orvillea keferstelni							4			
	Scalibregma inflatum										
	Spiophanes bombyx										
	Sthenelais limicola										
Other taxa	number/sample										
	Upogebia spec.										1
	Crustacea (amphipods)	+	+	+	+	+	+	+	+	+	+
	Cerebratula spec.										
	Sipunculida			4				1			
	Ammodytes spec.										
	Branchiostama lanceolatum	1		1	8		5		2		

Appendix 4 (1): volume, surface and specimen number of the Hamon Grab samples (BW)

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
	station number	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
	sample number	GH532	GH535	GH541	GH537	GH544	GH547	GH550	GH553	GH559	GH556
	volume (liters)	17	19	17	18	16	16	24	13	19	12
	surface (m2)	0,21	0,21	0,21	0,21	0.20	0,20	0,23	0.19	0,21	0,19
Echinodermata	number/sample										
	Amphiura spec.										
	Asterias rubens		4		4						
	Echinocardium cordatum										
	Echinocyamus pusillus	29	12	29	32	4	32	12	13	39	29
	Leptosynapta inhaerens										
	Ophiura albida	16	17	4	5	8		20	5	3	12
	Psammechinus miliaris								1	4	
	Spatangus purpureus										
	Thyone fusus										
Mollusca	number/sample										
	Acropagia crassa										
	Aporrhais pespelecani									1	
	Arctica islandica						1	1			
	Dentalium spec.										
	Dosinia exoleta	2	2	1	1	5	6			4	3
	Ensis arcuatis										
	Gari fervensis										
	Gibbula spec.								1		
	Natica spec.				4						
	Nucula spec.										
	Panomya spec.		1								
	Polinices polianus		2								
	Spisula elliptica										
	Thracia phaseolina	2		4	1		1	4			
	Venus ovata		4		1						
Polychaeta	number/sample										
	Aglaophamus rutella										
	Anaitides lineata							4			
	Aonides paucibranchiata						9		2		
	Aphrodita aculeata										
	Chaetopterus (tube)				1						
	Chone duneri	46		37		20	8		7	35	
	Gattyana cirrosa										
	Glycera alba	15	26	24	16	16		8	13	16	21
	Glycera capitata		12		4		4		1		
	Glycinde nordmanni										
	Goniada maculata						4				4
	Kefersteinia cirrata									4	
	Laonice cirrata							4			
	Lumbrineris latreilli	8		12	1		4		6		4
	Magelona papillicornis						12				
	Nephtys caeca	4	1	1	1						
	Nephtys cirrosa				4	16					
	Nereis spec.								1		
	Notomastus latericeus	10	20	16	26	36	16	24	11	20	16
	Ophelia limacina			8	8			8		4	
	Owenia fusiformis					4					
	Pectinaria spec.										
	Pisione remota					8					
	Poecilochaetus serpens				4				1	8	
	Polycirrus medusa							4			
	Prionospio malmgreni	4	8								
	Protodorvillea kefersteini					4					
	Scalibregma inflatum				2						
	Spiophanes bombyx										
	Sthenelais limicola					4					
Other taxa	number/sample										
	Upogebia spec.					1					
	Crustacea (amphipods)	+	+	+	+	+	+	+	+	+	+
	Cerebratula spec.										
	Sipunculida	1								5	
	Ammodytes spec.						1				
	Branchiostoma lanceolatum				2	1				3	4

Appendix 4 (2): volume, surface and specimen number of the Hamon Grab samples (BW)

		station number	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
		sample number	GH562	GH565	GH572	GH568	GH574	GH577	GH583	GH580	GH586	GH587
		volume (liters)	14	18	18	7	10	12	19	12	18	16
		surface (m2)	0,19	0,21	0,21	0,16	0,18	0,19	0,21	0,19	0,21	0,20
Echinodermata	*Amphiura spec.*	number/sample	1	1								
	Asterias rubens											
	Echinocardium cordatum						1					
	Echinocyamus pusillus		15	2	2	18	10	4	7	13	10	5
	Leptosynapta inhaerens				1							
	Ophiura albida		4	3	2	1	10	3	2	1	2	5
	Psammechinus miliaris			2			3					1
	Spatangus purpureus										1	
	Thyone fusus											
Mollusca	*Acropagia crassa*	number/sample										
	Aporrhais pespelecani					1						
	Arctica islandica							2				
	Dentalium spec.				3							1
	Dosinia exoleta		2	1			1	1	3	1		
	Ensis arcuatis			1					2	1	1	
	Gari fervensis			1	1			1		1		
	Gibbula spec.											
	Natica spec.											
	Nucula spec.											
	Panomya spec.											
	Polinices pollanus											
	Spisula elliptica										2	2
	Thracia phaseolina				2				3			
	Venus ovata											
Polychaeta	*Aglaophamus rubella*	number/sample										
	Anaitides lineata						1					
	Aonides paucibranchiata		1						1			
	Aphrodita aculeata			1								
	Chaetopterus (tube)											
	Chone duneri		2								4	2
	Gattyana cirrosa											
	Glycera alba				1	2		1	6		1	
	Glycera capitata		1		1							2
	Glycinde nordmanni									1		
	Goniada maculata											
	Kefersteinia cirrata											
	Laonice cirrata								1			1
	Lumbrineris latreilli		1								1	
	Magelona papillicornis							1				
	Nephtys caeca											
	Nephtys cirrosa			1			1					
	Nereis spec.											
	Notomastus latericeus		5		3		5		1	1	1	1
	Ophelia limacina		2	2	7	2		1	5	2	4	3
	Owenia fusiformis											
	Pectinaria spec.			3	1	1	3	1	3		2	1
	Pisione remota							1	1			
	Poecilochaetus serpens		1									
	Polycirrus medusa					1						1
	Prionospio malmgreni											
	Protodorvillea kefersteini											
	Scalibregma inflatum							1				
	Spiophanes bombyx			4			1					
	Sthenelais limicola								1			
Other taxa	*Upogebia spec.*	number/sample										
	Crustacea (amphipods)		+	+	+	+	+	+	+	+	+	+
	Cerebratula spec.						1	1			1	1
	Sipunculida		1		1	1				1		
	Ammodytes spec.											
	Branchiostama lanceolatum									1	1	

Appendix 4 (3): volume, surface and specimen number of the Hamon Grab samples (BW)

Group	Species	transect A	transect B	transect C
Echinodermal	*Amphiura spec.*	0	0	2
	Asterias rubens	0	8	0
	Echinocardium cordatum	0	0	1
	Echinocyamus pusillus	194	230	88
	Leptosynapta inhaerens	0	0	1
	Ophiura albida	98	90	33
	Psammechinus miliaris	3	5	6
	Spatangus purpureus	1	0	1
	Thyone fusus	1	0	0
Mollusca	*Acropagia crassa*	7	0	0
	Aporrhais pespelecani	1	1	1
	Arctica islandica	0	2	2
	Dentalium spec.	0	0	4
	Dosinia exoleta	42	24	9
	Ensis arcuatis	5	0	5
	Gari fervensis	0	0	4
	Gibbula spec.	0	1	0
	Natica spec.	16	4	0
	Nucula spec.	1	0	0
	Panomya spec.	0	1	0
	Polinices polianus	0	2	0
	Spisula elliptica	7	0	4
	Thracia phaseolina	10	12	5
	Venus ovata	0	5	0
Polychaeta	*Aglaophamus rutella*	4	0	0
	Anaïtides lineata	0	4	1
	Aonides paucibranchiata	18	11	2
	Aphrodita aculeata	0	0	1
	Chaetopterus (tube)	3	1	0
	Chone duneri	121	152	8
	Gattyana cirrosa	8	0	0
	Glycera alba	124	154	11
	Glycera capitata	5	21	4
	Glycinde nordmanni	0	0	1
	Goniada maculata	5	8	0
	Kefersteinia cirrata	0	4	0
	Laonice cirrata	0	4	2
	Lumbrineris latreilli	39	35	2
	Magelona papillicornis	0	12	1
	Nephtys caeca	1	7	0
	Nephtys cirrosa	7	20	2
	Nereis spec.	0	1	0
	Notomastus latericeus	109	195	17
	Ophelia limacina	44	28	28
	Owenia fusiformis	14	4	0
	Pectinaria spec.	0	0	15
	Pisione remota	0	8	2
	Poecilochaetus serpens	8	13	1
	Polycirrus medusa	12	4	2
	Prionospio malmgreni	7	12	0
	Protodorvillea kefersteini	4	4	0
	Scalibregma inflatum	0	2	1
	Spiophanes bombyx	0	0	5
	Sthenelais limicola	0	4	1
Other taxa	*Upogebia spec.*	1	1	0
	Ammodytes spec.	+	+	+
	Branchiostoma lanceolatum	0	0	4
	Crustacea (amphipods)	5	6	4
	Cerebratula spec.	0	1	0
	Sipunculida	17	10	2

Appendix 5: species collected at trajectory A, B and C (Hamon Grab samples; BW)

		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	(A) average		range
Echinodermata	*Amphiura spec.*	0	0	0	0	0	0	0	0	0	0			
	Asterias rubens	0	0	0	0	0	0	0	0	0	0			
	Echinocardium cordatum	0	0	0	0	0	0	0	0	0	0			
	Echinocyamus pusillus	89	19	56	141	46	40	200	71	151	97	91	+/-	57
	Leptosynapta inhaerens	0	0	0	0	0	0	0	0	0	0			
	Ophiura albida	17	10	19	56	6	91	55	89	33	83	46	+/-	33
	Psammechinus miliaris	0	0	0	0	0	10	0	0	4	0	1	+/-	3
	Spatangus purpureus	0	5	0	0	0	0	0	0	0	0	0	+/-	2
	Thyone fusus	0	5	0	0	0	0	0	0	0	0	0	+/-	2
Mollusca	*Acropagia crassa*	0	0	0	0	0	5	9	18	0	0	3	+/-	6
	Aporrhais pespelecani	0	0	0	0	6	0	0	0	0	0	1	+/-	2
	Arctica islandica	0	0	0	0	0	0	0	0	0	0			
	Dentalium spec.	0	0	0	0	0	0	0	0	0	0			
	Dosinia exoleta	17		19	9	6	30	59	9	38	10	20	+/-	18
	Ensis arcuatis	6	0	0	0	0	0	5	13	0	0	2	+/-	4
	Gari fervensis	0	0	0	0	0	0	0	0	0	0			
	Gibbula spec.	0	0	0	0	0	0	0	0	0	0			
	Natica spec.	0	0	0	0	0	61	18	0	0	0	8	+/-	19
	Nucula spec.	0	0	0	0	0	0	0	5	0	0	0	+/-	1
	Panomya spec.	0	0	0	0	0	0	0	0	0	0			
	Polinices pollanus	0	0	0	0	0	0	0	0	0	0			
	Spisula elliptica	11	14	5	0	0	0	0	0	0	5	4	+/-	5
	Thracia phaseolina	6	24		5	0	0	0	9	0	5	5	+/-	8
	Venus ovata	0	0	0	0	0	0	0	0	0	0			
Polychaeta	*Aglaophamus rutella*	0	0	0	0	0	20	0	0	0	0	2	+/-	6
	Anaitides lineata	0	0	0	0	0	0	0	0	0	0			
	Aonides paucibranchiata	44	10	38	0	0	0	0	0	0	0	9	+/-	17
	Aphrodita aculeata	0	0	0	0	0	0	0	0	0	0			
	Chaetopterus (tube)	0	0	0	5	0	0	0	0	4	5	1	+/-	2
	Chone duneri	83	0	0	42	91	181		36	50	116	60	+/-	58
	Gattyana cirrosa	0	0	19	0	0	0	0	18	0	0	4	+/-	8
	Glycera alba	6	0	150	38	51	30	109	0	134	58	58	+/-	55
	Glycera capitata	0	0	0	0	6	0	0	0	17	0	2	+/-	5
	Glycinde nordmanni	0	0	0	0	0	0	0	0	0	0			
	Goniada maculata	0	0	0	0	6	0	0	0	17	0	2	+/-	5
	Kefersteinia cirrata	0	0	0	0	0	0	0	0	0	0			
	Laonice cirrata		0	0	0	0	0	0	0	0	0			
	Lumbrineris latreilli	0	0	19	0	0	0	55	0	17	92	18	+/-	31
	Magelona papillicornis	0	0	0	0	0	0	0	0	0	0			
	Nephtys caeca	0	0	0	5	0	0	0	0	0	0	0	+/-	1
	Nephtys cirrosa	0	0	0	0	11	0	18	5	0	0	3	+/-	6
	Nereis spec.	0	0	0	0	0	0	0	0	0	0			
	Notomastus latericeus	28	0	38	19	23	0	109	107	92	83	50	+/-	43
	Ophelia limacina	22	14	38	0	6	0	73		33	19	21	+/-	23
	Owenia fusiformis	6	24	0	38	0	0	0	0	0	0	7	+/-	13
	Pectinaria spec.	0	0	0	0	0	0	0	0	0	0			
	Pisione remota	0	0	0	0	0	0	0	0	0	0			
	Poecilochaetus serpens	22			19	0	0	0	0	0	0	4	+/-	10
	Polycirrus medusa	0	0	0	0	69	0	0	0	0	0	7	+/-	22
	Prionospio malmgreni	0	0	0	0	17	0	0	0	17	0	3	+/-	7
	Protodorvillea kefersteini	0	0	0	0	0	0	18	0	0	0	2	+/-	6
	Scalibregma inflatum	0	0	0	0	0	0	0	0	0	0			
	Spiophanes bombyx	0	0	0	0	0	0	0	0	0	0			
	Sthenelais limicola	0	0	0	0	0	0	0	0	0	0			
	Upogebia spec.	0	0	0	0	0	0	0	0	0	5	0	+/-	2
Other taxa	*Cerebratula spec.*	0	0	0	0	0	0	0	0	0	0			
	Crustacea (amphipods)	+	+	+	+	+	+	+	+	+	+			
	Sipunculida	0	0	19	0	0	0	5	0	0	0	2	+/-	6
	Ammodytes spec.	0	0	0	0	0	0	0	0	0	0			
	Branchiostama lanceolatum	6	0	5	38	0	25	0	9	0	0	8	+/-	13

Appendix 6 (1): species densities (N/m2)

Group	Species	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	(B) average		range
Echinodermata	*Amphiura spec.*	0	0	0	0	0	0	0	0	0	0			
	Asterias rubens	0	19	0	19	0	0	0	0	0	0	4	+/-	8
	Echinocardium cordatum	0	0	5	0	0	0	0	0	0	0	0	+/-	2
	Echinocyamus pusillus	136	56	136	153	20	158	53	69	188	151	112	+/-	57
	Leptosynapta inhaerens	0	0	0	0	0	0	0	0	0	0			
	Ophiura albida	78	80	19	24	40	0	88	26	14	65	43	+/-	31
	Psammechinus miliaris	0	0	0	0	0	0	0	5	19	0	2	+/-	6
	Spatangus purpureus	0	0	0	0	0	0	0	0	0	0			
	Thyone fusus	0	0	0	0	0	0	0	0	0	0			
Mollusca	*Acropagia crassa*	0	0	0	0	0	0	0	0	0	0			
	Aporrhais pespelecani	0	0	0	0	0	0	0	0	4	0	0	+/-	1
	Arctica islandica	0	0	0	0	0	5	4	0	0	0	1	+/-	2
	Dentalium spec.	0	0	0	0	0	0	0	0	0	0			
	Dosinia exoleta	10	9	5	5	25	30	0	0	19	16	12	+/-	10
	Ensis arcuatis	0	0	0	0	0	0	0	0	0	0			
	Gari fervensis	0	0	0	0	0	0	0	0	0	0			
	Gibbula spec.	0	9	0	0	0	0	0	5	0	0	1	+/-	3
	Natica spec.	0	0	0	19	0	0	0	0	0	0	2	+/-	6
	Nucula spec.	0	0	0	0	0	0	0	0	0	0			
	Panomya spec.	0	5	0	0	0	0	0	0	0	0	0	+/-	1
	Polinices polianus	0	9	0	0	0	0	0	0	0	0	1	+/-	3
	Spisula elliptica	0	0	0	0	0	0	0	0	0	0			
	Thracia phaseolina	10	0	19	5	0	5	18	0	0	0	6	+/-	8
	Venus ovata	0	19	0	5	0	0	0	0	0	0	2	+/-	6
Polychaeta	*Aglaophamus rutella*	0	0	0	0	0	0	0	0	0	0			
	Anaitides lineata	0	0	0	0	0	0	18	0	0	0	2	+/-	6
	Aonides paucibranchiata	0	0	0	0	0	44	0	11	0	0	5	+/-	14
	Aphrodita aculeata	0	0	0	0	0	0	0	0	0	0			
	Chaetopterus (tube)	0	0	0	5	0	0	0	0	0	0	0	+/-	2
	Chone duneri	213	0	175		99	40	0	37	169	0	73	+/-	85
	Gattyana cirrosa	0	0	0	0	0	0	0	0	0	0			
	Glycera alba	73	122	116	76	79	0	35	69	75	108	75	+/-	37
	Glycera capitata	0	56	0	19	0	20	0	5	0	0	10	+/-	18
	Glycinde nordmanni	0	0	0	0	0	0	0	0	0	0			
	Goniada maculata	0	0	0	0	0	20	0	0	0	22	4	+/-	9
	Kefersteinia cirrata	0	0	0	0	0	0	0	0	19	0	2	+/-	6
	Laonice cirrata	0	0	0	0	0	0	18	0	0	0	2	+/-	6
	Lumbrineris latreilli	39	0	58	5	0	20	0	32	0	22	17	+/-	20
	Magelona papillicornis	0	0	0	0	0	59	0	0	0	0	6	+/-	19
	Nephtys caeca	19	5	5	5	0	0	0	0	0	0	3	+/-	6
	Nephtys cirrosa	0	0	0	19	79	0	0	0	0	0	10	+/-	25
	Nereis spec.	0	0	0	0	0	0	0	5	0	0	1	+/-	2
	Notomastus latericeus	49	94	78	124	178	79	105	58	94	86	94	+/-	36
	Ophelia limacina	0	0	39	38	0	0	35	0	19	0	13	+/-	18
	Owenia fusiformis	0	0	0	0	20	0	0	0	0	0	2	+/-	6
	Pectinaria spec.	0	0	0	0	0	0	0	0	0	0			
	Pisione remota	0	0	0	0	40	0	0	0	0	0	4	+/-	12
	Poecilochaetus serpens	0	0	0	19	0	0	0	5	38	0	6	+/-	13
	Polycirrus medusa	0	0	0	0	0	0	18	0	0	0	2	+/-	6
	Prionospio malmgreni	19	38	0	0	0	0	0	0	0	0	6	+/-	13
	Protodorvillea kefersteini	0	0	0	0	20	0	0	0	0	0	2	+/-	6
	Scalibregma inflatum	0	0	0	10	0	0	0	0	0	0	1	+/-	3
	Spiophanes bombyx	0	0	0	0	0	0	0	0	0	0			
	Sthenelais limicola	0	0	0	0	20	0	0	0	0	0	2	+/-	6
	Upogebia spec.	0	0	0	0	5	0	0	0	0	0	0	+/-	2
Other taxa	*Cerebratula spec.*	0	0	0	0	0	0	0	0	0	0			
	Crustacea (amphipods)	+	+	+	+	+	+	+	+	+	+			
	Sipunculida	5	0	0	0	0	0	0	0	24	0	3	+/-	7
	Ammodytes spec.	0	0	0	0	0	5	0	0	0	0	0	+/-	2
	Branchiostama lanceolatum	0	0	0	10	5	0	0	0	14	22	5	+/-	8

Appendix 6 (2): species densities (N/m2)

Group	Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	(C) average	(A,B,C) average range
Echinodermata	*Amphiura spec.*	5	5	0	0	0	0	0	0	0	0	1 +/- 2	
	Asterias rubens	0	0	0	0	0	0	0	0	0	0		
	Echinocardium cordatum	0	0	0	0	6	0	0	0	0	0	1 +/- 2	
	Echinocyamus pusillus	77	10	10	111	57	22	33	70	48	25	46 +/- 33	83,0 +/- 56,0
	Leptosynapta inhaerens	0	0	5	0	0	0	0	0	0	0	0 +/- 2	
	Ophiura albida	21	14	10	7	57	16	10	5	10	25	17 +/- 15	35,5 +/- 30,0
	Psammechinus millaris	0	10	0	0	17	0	0	0	0	5	3 +/- 6	2,3 +/- 5,1
	Spatangus purpureus	0	0	0	0	0	0	0	0	5	0	0 +/- 2	
	Thyone fusus	0	0	0	0	0	0	0	0	0	0		
Mollusca	*Acropagia crassa*	0	0	0	0	0	0	0	0	0	0		
	Aporrhais pespelecani	0	0	0	7	0	0	0	0	0	0	1 +/- 2	0,5 +/- 1,7
	Arctica islandica	0	0	0	0	0	11	0	0	0	0	1 +/- 3	
	Dentalium spec.	0	0	14	0	0		0	0	0	5	2 +/- 5	
	Dosinia exoleta	10	5	0	0	6	5	14	5	0	0	5 +/- 5	12,0 +/- 13,4
	Ensis arcuatis	0	5	0	0	0	0	10	5	5	0	2 +/- 3	
	Gari fervensis	0	5	5	0	0	5		5	0	0	2 +/- 3	
	Gibbula spec.	0	0	0	0	0	0	0	0	0	0		
	Natica spec.	0	0	0	0	0	0	0	0	0	0		
	Nucula spec.	0	0	0	0	0	0	0	0	0	0		
	Panomya spec.	0	0	0	0	0	0	0	0	0	0		
	Polinices polianus	0	0	0	0	0	0	0	0	0	0		
	Spisula elliptica	0	0	0	0	0	0	0	0	10	10	2 +/- 4	
	Thracia phaseolina	0	0	10	0	0	0	14	0	0	0	2 +/- 5	4,3 +/- 6,8
	Venus ovata	0	0	0	0	0	0	0	0	0	0		
Polychaeta	*Aglaophamus rutella*	0	0	0	0	0	0	0	0	0	0	+/- 0	
	Anaïtides lineata	0	0	0	0	6	0	0	0	0	0	1 +/- 2	
	Aonides paucibranchiata	5	0	0	0	0	0	5	0	0	0	1 +/- 2	5,2 +/- 12,8
	Aphrodita aculeata	0	5	0	0	0	0	0	0	0	0	0 +/- 2	
	Chaetopterus (tube)	0	0	0	0	0	0	0	0	0	0		
	Chone duneri	10	0	0	0	0	0	0	0	19	10	4 +/- 7	45,7 +/- 66,1
	Gattyana cirrosa	0	0	0	0	0	0	0	0	0	0		
	Glycera alba	0	0	5	13	0	5	28	0	5	0	6 +/- 9	46,2 +/- 48,0
	Glycera capitata	5	0	5	0	0	0	0	0	0	10	2 +/- 3	4,8 +/- 11,3
	Glycinde nordmanni	0	0	0	0	0	0	0	5	0	0	1 +/- 2	
	Goniada maculata	0	0	0	0	0	0	0	0	0	0		
	Kefersteinia cirrata	0	0	0	0	0	0	0	0	0	0		
	Laonice cirrata	0	0	0	0	0	0	5	0	0	5	1 +/- 2	
	Lumbrineris latreilli	5	0	0	0	0	0	0	0	5	0	1 +/- 2	12,2 +/- 22,3
	Magelona papillicornis	0	0	0	0	0	5	0	0	0	0	1 +/- 2	
	Nephtys caeca	0	0	0	0	0	0	0	0	0	0		
	Nephtys cirrosa	0	5	0	0	6	0	0	0	0	0	1 +/- 2	4,8 +/- 14,9
	Nereis spec.	0	0	0	0	0	0	0	0	0	0		
	Notomastus latericeus	28	0	14	0	29	0	5	5	5	5	9 +/- 11	51,0 +/- 47,9
	Ophelia limacina	10	10	33	13	0	5	24	11	19	15	14 +/- 9	15,9 +/- 17,3
	Owenia fusiformis	0	0	0	0	0	0	0	0	0	0		
	Pectinaria spec.	0	14	5	7	17	5	14	0	10	5	8 +/- 6	
	Pisione remota	0	0	0	0		5	5	0	0	0	1 +/- 2	
	Poecilochaetus serpens	5	0	0		0	0	0	0	0	0	1 +/- 2	3,6 +/- 9,3
	Polycirrus medusa	0	0		7	0	0	0	0	0	5	1 +/- 3	3,3 +/- 13,0
	Prionospio malmgreni	0	0	0	0	0	0	0	0	0	0		
	Protodorvillea kefersteini	0	0	0	0	0	0	0	0	0	0		
	Scalibregma inflatum	0	0	0	0	0	5	0	0	0	0	1 +/- 2	
	Spiophanes bombyx	0	19	0	0	6	0	0	0	0	0	2 +/- 6	
	Sthenelais limicola	0	0	0	0	0	0	5	0	0	0	0 +/- 1	
	Upogebia spec.	0	0	0	0	0	0	0	0	0	0		
Other	*Cerebratula spec.*	0	0	0	0	6	5	0	0	5	5	2 +/- 3	
	Crustacea (amphipods)	+	+	+	+	+	+	+	+	+	+		
	Sipunculida	5		5	7	0	0	0	5	0	0	2 +/- 3	2,5 +/- 5,6
	Ammodytes spec.	0	0	0	0	0	0	0	0	0	0		
	Branchiostama lanceolatum	0	0	0	0	0	0	0	5	5	0	1 +/- 2	4,7 +/- 9,0

Appendix 6 (3): species densities (N/m2)

		station number	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
Echinodermata	*Amphiura spec.*	ADW										
	Asterias rubens											
	Echinocardium cordatum											
	Echinocyamus pusillus		0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,01	0,00
	Leptosynapta inhaerens											
	Ophiura albida		0,03		0,03	0,22	0,01	0,31	0,11	0,14	0,14	0,15
	Psammechinus miliaris							0,10			0,07	
	Spatangus purpureus			1,03								
	Thyone fusus			0,38								
		ΣADW	0,03	1,41	0,04	0,22	0,01	0,41	0,12	0,14	0,21	0,15
		Σ Biomass	**0,18**	**6,74**	**0,17**	**1,05**	**0,06**	**2,05**	**0,53**	**0,62**	**0,89**	**0,73**
Mollusca	*Acropagia crassa*	ADW						0,86	1,02	2,84		
	Aporrhais pespelecani											
	Arctica islandica											
	Dentalium spec.											
	Dosinia exoleta		1,27		1,59	1,04	0,40	3,44	10,58	0,32	4,79	1,47
	Ensis arcuatis		0,85						1,39	4,33		
	Gari fervensis											
	Gibbula spec.											
	Natica spec.							1,41	0,19			
	Nucula spec.									0,01		
	Panomya spec.											
	Polinices pollanus											
	Spisula elliptica		0,13	0,74	0,26							0,06
	Thracia phaseolina		0,02	0,04		0,04				0,02		0,06
	Venus ovata											
		ΣADW	2,27	0,78	1,85	1,08	0,40	5,71	13,18	7,52	4,79	1,58
		Σ Biomass	**12,60**	**3,70**	**8,91**	**5,12**	**2,29**	**28,54**	**59,90**	**32,69**	**19,96**	**7,53**
Polychaeta	*Aglaophamus rutella*	ADW						0,01				
	Anaitides lineata											
	Aonides paucibranchiata		0,02	0,01	0,02							
	Aphrodita aculeata											
	Chaetopterus (tube)					0,24					0,17	0,34
	Chone duneri		0,01			0,01	0,01	0,03		0,01	0,01	0,02
	Gattyana cirrosa				0,03					0,03		
	Glycera alba				0,03	0,01	0,01	0,01	0,03		0,04	0,01
	Glycera capitata						0,02				0,08	
	Glycinde nordmanni											
	Goniada maculata						0,01				0,06	
	Kefersteinia cirrata											
	Laonice cirrata											
	Lumbrineris latreilli				0,17				0,22		0,11	0,41
	Magelona papillicornis											
	Nephtys caeca					2,09						
	Nephtys cirrosa						0,07		0,18	0,05		
	Nereis spec.											
	Notomastus latericeus		0,02		0,04	0,02	0,02		0,11	0,11	0,10	0,08
	Ophelia limacina		0,06	0,05	0,12		0,01		0,24		0,12	0,06
	Owenia fusiformis		0,01	0,04		0,06						
	Pectinaria spec.											
	Pisione remota											
	Poecilochaetus serpens		0,00			0,00						
	Polycirrus medusa						0,01					
	Prionospio malmgreni						0,01				0,01	
	Protodorvillea kefersteini								0,02			
	Scalibregma inflatum											
	Spiophanes bombyx											
	Sthenelais limicola											
		ΣADW	0,13	0,09	0,41	2,42	0,19	0,04	0,79	0,20	0,68	0,92
		Σ Biomass	**0,71**	**0,41**	**1,95**	**11,53**	**1,07**	**0,21**	**3,60**	**0,86**	**2,83**	**4,38**
Other taxa	*Upogebia spec.*	ADW										1,23
	Crustacea (amphipods)		0,01	0,03	0,00	0,00	0,00	0,00	0,00	0,02	0,00	0,01
	Cerebratula spec.											
	Sipunculida				0,00				0,00			
	Ammodytes spec.											
	Branchiostama lanceolatum		0,05		0,04	0,61		0,19		0,11		
		ΣADW	0,06	0,03	0,04	0,61	0,00	0,19	0,00	0,13	0,00	1,24
		Σ Biomass	**0,33**	**0,14**	**0,19**	**2,92**	**0,02**	**0,97**	**0,00**	**0,58**	**0,00**	**5,91**
		total ADW	2,49	2,31	2,34	4,33	0,60	6,35	14,09	7,99	5,68	3,89
		total Biomass	**13,82**	**10,99**	**11,12**	**20,62**	**3,45**	**31,76**	**64,03**	**34,76**	**23,68**	**18,55**

Appendix 7 (1): species ash-free dryweights (ADW) and biomass (ADW/m2)

Group	Species	station number	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Echinodermata	*Amphiura spec.*	ADW										
	Asterias rubens			0,26		0,17						
	Echinocardium cordatum											
	Echinocyamus pusillus		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Leptosynapta inhaerens											
	Ophiura albida		0,23	0,16	0,02	0,02	0,12		0,46	0,21	0,02	0,22
	Psammechinus miliaris									0,05	0,31	
	Spatangus purpureus											
	Thyone fusus											
		ΣADW	0,23	0,42	0,02	0,19	0,12	0,00	0,46	0,26	0,34	0,23
		Σ Biomass	**1,12**	**2,00**	**0,11**	**0,90**	**0,60**	**0,02**	**2,01**	**1,38**	**1,60**	**1,20**
Mollusca	*Acropagia crassa*	ADW										
	Aporrhais pespelecani										0,34	
	Arctica islandica							2,16	1,78			
	Dentalium spec.											
	Dosinia exoleta		1,35	0,57	1,24	1,01	4,82	2,70			2,96	3,56
	Ensis arcuatis											
	Gari fervensis											
	Gibbula spec.									0,05		
	Natica spec.					1,58						
	Nucula spec.											
	Panomya spec.									0,01	0,17	
	Polinices polianus					0,02				0,01	0,01	
	Spisula elliptica											
	Thracia phaseolina		0,06		0,05	0,03		0,02	0,12			
	Venus ovata			0,36		0,15						
		ΣADW	1,41	0,93	1,29	2,79	4,82	4,88	1,90	0,07	3,48	3,56
		Σ Biomass	**6,71**	**4,43**	**6,12**	**13,30**	**24,10**	**24,38**	**8,26**	**0,38**	**16,57**	**18,74**
Polychaeta	*Aglaophamus rutella*	ADW										
	Anaitides lineata								0,05			
	Aonides paucibranchiata							0,03		0,01		
	Aphrodita aculeata											
	Chaetopterus (tube)					0,22						
	Chone duneri		0,04				0,02	0,01		0,01	0,03	
	Gattyana cirrosa											
	Glycera alba		0,02	0,37	0,03	0,02	0,02		0,01	0,01	0,02	0,02
	Glycera capitata			0,37		0,08		0,07		0,02		
	Glycinde nordmanni											
	Goniada maculata							0,06				0,06
	Kefersteinia cirrata										0,08	
	Laonice cirrata								0,06			
	Lumbrineris latreilli		0,10		0,37	0,01		0,14		0,09		0,10
	Magelona papillicornis							0,08				
	Nephtys caeca		4,12	0,39	1,20	0,91						
	Nephtys cirrosa					0,01	0,04					
	Nereis spec.									0,01		
	Notomastus latericeus		0,05	0,09	0,07	0,12	0,16	0,07	0,11	0,05	0,09	0,08
	Ophelia limacina				0,12	0,12			0,12		0,06	
	Owenia fusiformis						0,03					
	Pectinaria spec.			0,01								
	Pisione remota						0,00					
	Poecilochaetus serpens					0,03				0,00	0,01	
	Polycirrus medusa								0,01			
	Prionospio malmgreni		0,04	0,07								
	Protodorvillea kefersteini						0,01					
	Scalibregma inflatum					0,04						
	Spiophanes bombyx											
	Sthenelais limicola						0,01					
		ΣADW	4,36	1,29	1,79	1,55	0,28	0,46	0,35	0,20	0,28	0,25
		Σ Biomass	**20,75**	**6,15**	**8,53**	**7,36**	**1,40**	**2,29**	**1,53**	**1,03**	**1,34**	**1,33**
Other taxa	*Upogebia spec.*	ADW					0,77					
	Crustacea (amphipods)		0,00	0,00	0,01	0,00	0,00	0,01	0,00	0,01	0,00	0,00
	Cerebratula spec.											
	Sipunculida		0,00								0,01	
	Ammodytes spec.							3,33				
	Branchiostama lanceolatum					0,23	0,07				0,05	0,11
		ΣADW	0,00	0,00	0,01	0,23	0,84	3,34	0,00	0,01	0,06	0,11
		Σ Biomass	**0,02**	**0,00**	**0,02**	**1,10**	**4,19**	**16,72**	**0,00**	**0,03**	**0,27**	**0,59**
		ΣADW	6,00	2,64	3,10	4,76	6,06	8,68	2,71	0,54	4,15	4,15
		Σ Biomass	28,60	12,59	14,78	22,66	30,29	43,42	11,80	2,83	19,77	21,86

Appendix 7 (2): species ash-free dryweights (ADW) and biomass (ADW/m2)

		station number	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Echinodermata	*Amphiura spec.*	ADW										
	Asterias rubens											
	Echinocardium cordatum						0,08					
	Echinocyamus pusillus		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Leptosynapta inhaerens				0,01							
	Ophiura albida		0,10	0,01	0,01	0,01	0,19	0,08	0,02	0,03	0,01	0,07
	Psammechinus miliaris			0,09			0,09					0,09
	Spatangus purpureus										0,68	
	Thyone fusus											
		ΣADW	0,10	0,10	0,02	0,01	0,36	0,08	0,02	0,04	0,69	0,16
		Σ Biomass	**0,54**	**0,47**	**0,11**	**0,05**	**1,99**	**0,42**	**0,10**	**0,19**	**3,30**	**0,78**
Mollusca	*Acropagia crassa*	ADW										
	Aporrhais pespelecani					0,11						
	Arctica islandica							6,08				
	Dentalium spec.				0,02							0,01
	Dosinia exoleta		1,74	0,66			0,22	0,87	2,05	1,33		
	Ensis arcuatis			0,52					3,72	2,40	1,11	
	Gari fervensis			0,24	0,24			0,34		0,13		
	Gibbula spec.											
	Natica spec.											
	Nucula spec.											
	Panomya spec.			0,07			0,23					0,09
	Polinices pollanus		0,01									
	Spisula elliptica										0,25	0,17
	Thracia phaseolina				0,07				0,05			
	Venus ovata											
		ΣADW	1,75	1,49	0,33	0,11	0,45	7,29	5,82	3,86	1,36	0,27
		Σ Biomass	**9,20**	**7,10**	**1,59**	**0,69**	**2,50**	**38,37**	**27,71**	**20,32**	**6,48**	**1,34**
Polychaeta	*Aglaophamus rutella*	ADW										
	Anaitides lineata						0,02					
	Aonides paucibranchiata		0,00						0,00			
	Aphrodita aculeata			0,19								
	Chaetopterus (tube)											
	Chone duneri		0,00								0,00	0,00
	Gattyana cirrosa											
	Glycera alba				0,00	0,01		0,00	0,01			
	Glycera capitata		0,07		0,02							0,04
	Glycinde nordmanni									0,01		
	Gonieda maculata											
	Keferateinia cirrata											
	Laonice cirrata								0,01			0,01
	Lumbrineris latreilli		0,01								0,02	
	Magelona papillicornis							0,01				
	Nephtys caeca											
	Nephtys cirrosa			0,05								
	Nereis spec.											
	Notomastus latericeus		0,02		0,01		0,02		0,00	0,00	0,00	0,00
	Ophelia limacina		0,03	0,03	0,11	0,03		0,02	0,09	0,02	0,06	0,04
	Owenia fusiformis											
	Pectinaria spec.			0,02	0,01	0,03	0,02	0,01	0,02			
	Pisione remota							0,00	0,00		0,01	0,01
	Poecilochaetus serpens		0,00									
	Polycirrus medusa					0,01						0,00
	Prionospio malmgreni											
	Protodorvillea kefersteini											
	Scalibregma inflatum							0,01				
	Spiophanes bombyx			0,03			0,01					
	Sthenelais limicola								0,00			
		ΣADW	0,13	0,32	0,15	0,08	0,07	0,04	0,13	0,03	0,10	0,11
		Σ Biomass	**0,69**	**1,53**	**0,69**	**0,49**	**0,42**	**0,22**	**0,64**	**0,16**	**0,48**	**0,53**
Other taxa	*Upogebia spec.*	ADW										
	Crustacea (amphipods)		0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Cerebratula spec.						3,18	0,98			0,47	1,25
	Sipunculida		0,00		0,00	0,00				0,00		
	Ammodytes spec.											
	Branchiostama lanceolatum									0,06	0,13	
		ΣADW	0,00	0,01	0,00	0,00	3,18	0,98	0,00	0,06	0,60	1,25
		Σ Biomass	**0,00**	**0,06**	**0,00**	**0,00**	**17,68**	**5,16**	**0,00**	**0,29**	**2,86**	**6,25**
ΣADW			1,98	1,92	0,50	0,20	4,06	8,39	5,98	3,98	2,76	1,78
Σ Biomass			**10,44**	**9,15**	**2,39**	**1,23**	**22,58**	**44,17**	**28,46**	**20,95**	**13,12**	**8,89**

Appendix 7 (3): species ash-free dryweights (ADW) and biomass (ADW/m2)

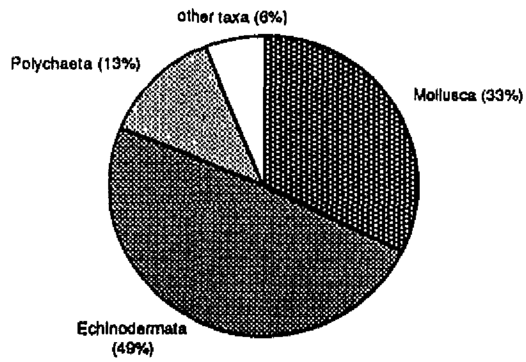
	gravel % > 1 mm		gravel % 1-8 mm		gravel % > 8 mm	
Mollusca						
Dosinia exoleta	+	P < 0,05	+	P < 0,01		
Acropagia crassa						
Gari fervensis	-	P < 0,01	-	P < 0,01		
Ensis arcuatis						
Thracia phaseolina						
Spisula elliptica						
Polychaeta						
Glycera alba	+	P < 0,01	+	P < 0,01		
Glycera capitata						
Notomastus latericeus	+	P < 0,01	+	P < 0,01		
Lumbrineris latreilli			+	P < 0,05		
Ophelia limacina						
Poecilochaetus serpens					+	P < 0,05
Pectinaria spec.	-	P < 0,01	-	P < 0,01	-	P < 0,05
Chone duneri						
Echinodermata						
Echinocyamus pusillus	+	P < 0,01	+	P < 0,01	+	P < 0,05
Ophiura albida			+	P < 0,01		
Psammechinus miliaris						
Chordata						
Branchiostoma lanceolatum	+	P < 0,05	+	P < 0,05		

Appendix 8: correlation of species densities and gravel percentages

station number	24	25	26	32	average
Echinodermata					
Acrocnida brachiata	48			3	12,8
Amphiura filiformis	54	6	869	594	380,8
Astropecten irregularis			3		0,8
Echinocardium cordat	20		17	14	12,8
Echinocardium flavescens		3			0,8
Echinocyamus pusillu	9	54			15,8
Ophiura albida	9	11	3	3	6,5
Mollusca					
Abra alba			3		0,8
Abra nitida		6			1,5
Abra prismatica	6	11		37	13,5
Aporrhais pespelecani			11		2,8
Chaetoderma spec			3		0,8
Cochlodesma praetenue		14			3,5
Cultellus pellucides	3		3	14	5,0
Cyclichna cylindracea	9	3	3	20	8,8
Cyprina islandica	11	9	6	3	7,3
Dosinia lupinus	20	28	42	17	26,8
Ensis ensis				3	0,8
Ensis siliqua	3				0,8
Gari fervensis	9				2,3
Montacuta ferruginos.	26		6	6	9,5
Mysella bidentata	79		207	614	225,0
Mysia undata	3	6	3		3,0
Natica alderi	37	9	14	40	25,0
Nucula tenuis		3	40	3	11,5
Nucula turgida	11		48	136	48,8
Sigalion mathildae	23			9	8,0
Tellina fabula	388			28	104,0
Tellina pygmaea		11		20	7,8
Thracia phaseolina	34	20	3	31	22,0
Thyasira flexuosa	11			133	36,0
Venus striatula	17		79	34	32,5
Vitreolina philippi			3		0,8
Polychaeta					
Anaitides groenlandica		3			0,8
Anaitides lineata		6			1,5
Anaitides subulifera	3			6	2,3
Aonides paucibranchiata		3	11		3,5
Aricidea minuta					0,0
Chaetopterus variopedatus			3		0,8
Chaetozone setosa	6	6	6		4,5
Cirratulidae indet.	3				0,8
Diplocirrus glaucus			3	20	5,8
Eumida sanguinea			3		0,8
Exogone hebes					0,0
Exogone naidina					0,0
Exogone verugera		3			0,8
Glycera alba		3	9	3	3,8
Glycera capitata		3			0,8
Glycera rouxii		3			0,8
Glycinde nordmanni	3	11	3	11	7,0
Goniada maculata	20		3	31	13,5
Gyptis capensis		3	3		1,5
Harmothoe longisetis			3		0,8
Hesionura angeneri					0,0
Magelona alleni	11				2,8
Magelona papillicornis	424	9	116	243	198,0

station number	24	25	26	32	average
Polychaeta (continued)					
Nephtys caeca		6	3		2,3
Nephtys cirrosa	99	14			28,3
Nephtys hombergi	96		34	85	53,8
Nephtys longosetosa	3	9			3,0
Notomastus latericeus	3		3	3	2,3
Ophelia borealis		57			14,3
Ophelina accuminata			3		0,8
Ophiodromus flexuosus			3		0,8
Orbinia sertulata		3			0,8
Owenia fusiformis	3			3	1,5
Paraonis fulgens					0,0
Pectinaria auricona	6		6	17	7,3
Pectinaria belgica				3	0,8
Pholoe minuta	11	9	71	198	72,3
Pisione remota					0,0
Pista cristata		3			0,8
Pista maculata		20			5,0
Poecilochaetus serpens	3		6	11	5,0
Polycirrus medusa		6			1,5
Scololepis bonnieri			3		0,8
Scoloplos armiger		57	40	14	27,8
Spio filicornis	74			48	30,5
Spiophanes bombyx	136	3	14	170	80,8
Spiophanes kroyeri			6	51	14,3
Stenelais limicola	6		11		4,3
Streptosyllis websteri					0,0
Synelmis klatti			17	9	6,5
Travisia forbesi		3			0,8

BIOMASS						
Mollusca	4,5	9,8	0,9	2,3	4,4	+/- 10,7
Echinodermat	7,4	0,0	11,7	7,3	6,6	+/- 5,8
Polychaeta	1,7	1,6	1,7	1,6	1,7	+/- 1,5
other taxa	0,0	0,2	2,3	0,5	0,8	+/- 2,5
Σ biomass	13,6	11,7	16,6	11,8	13,4	+/- 2,3



location		
station	N	E
24	54°15.74	2°29.47
25	54°00.28	3°00.22
26	54°14.67	3°31.84
32	54°30.52	3°01.07

Appendix 9: densities (N/m2) and the total biomass of echinoderms, molluscs and polychaetes at four stations around the Klaverbank. Each station was sampled five times with a boxcore sampler. The figure shows the relative share of the biomass of different taxa. (after data from the Synoptic Mapping Programme; de Wilde en Duineveld, 1988)

Figures

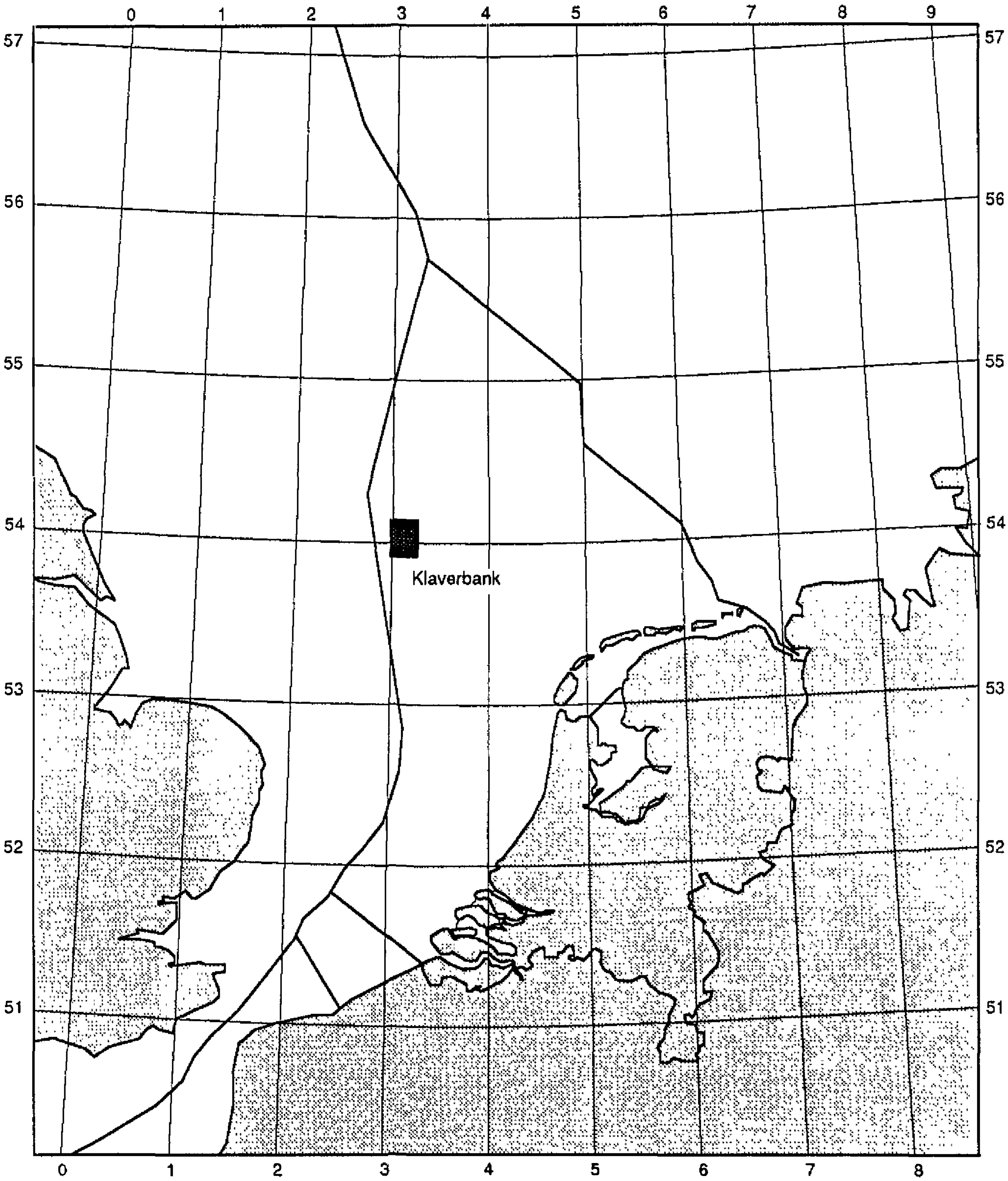


Figure 1a: geographic position of the Klaverbank (Fig. 1b)

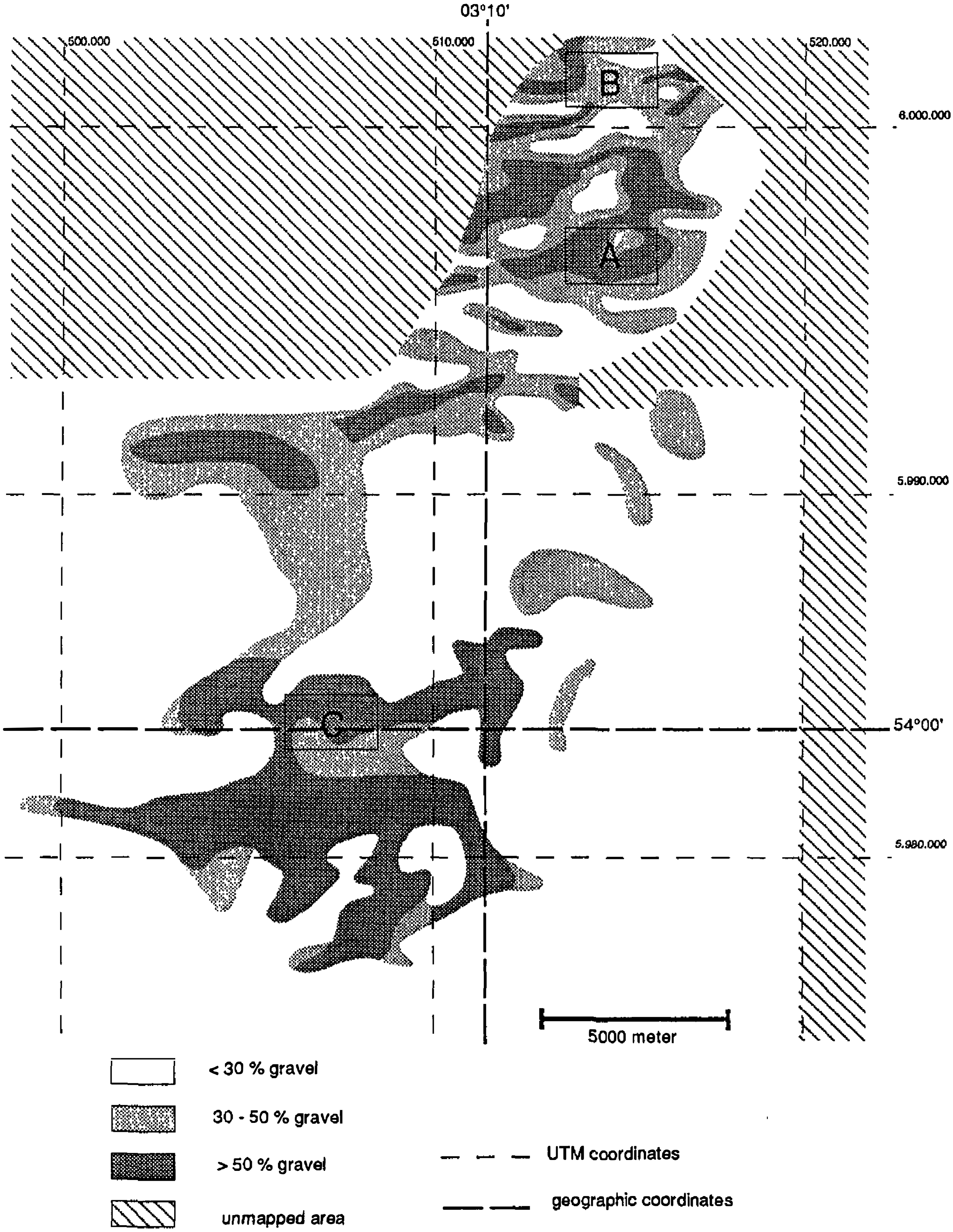


Figure 1b: geographic position of three sample sites at the gravel area of the Klaverbank (isoconcentration lines according to the Geological Survey of the Netherlands)

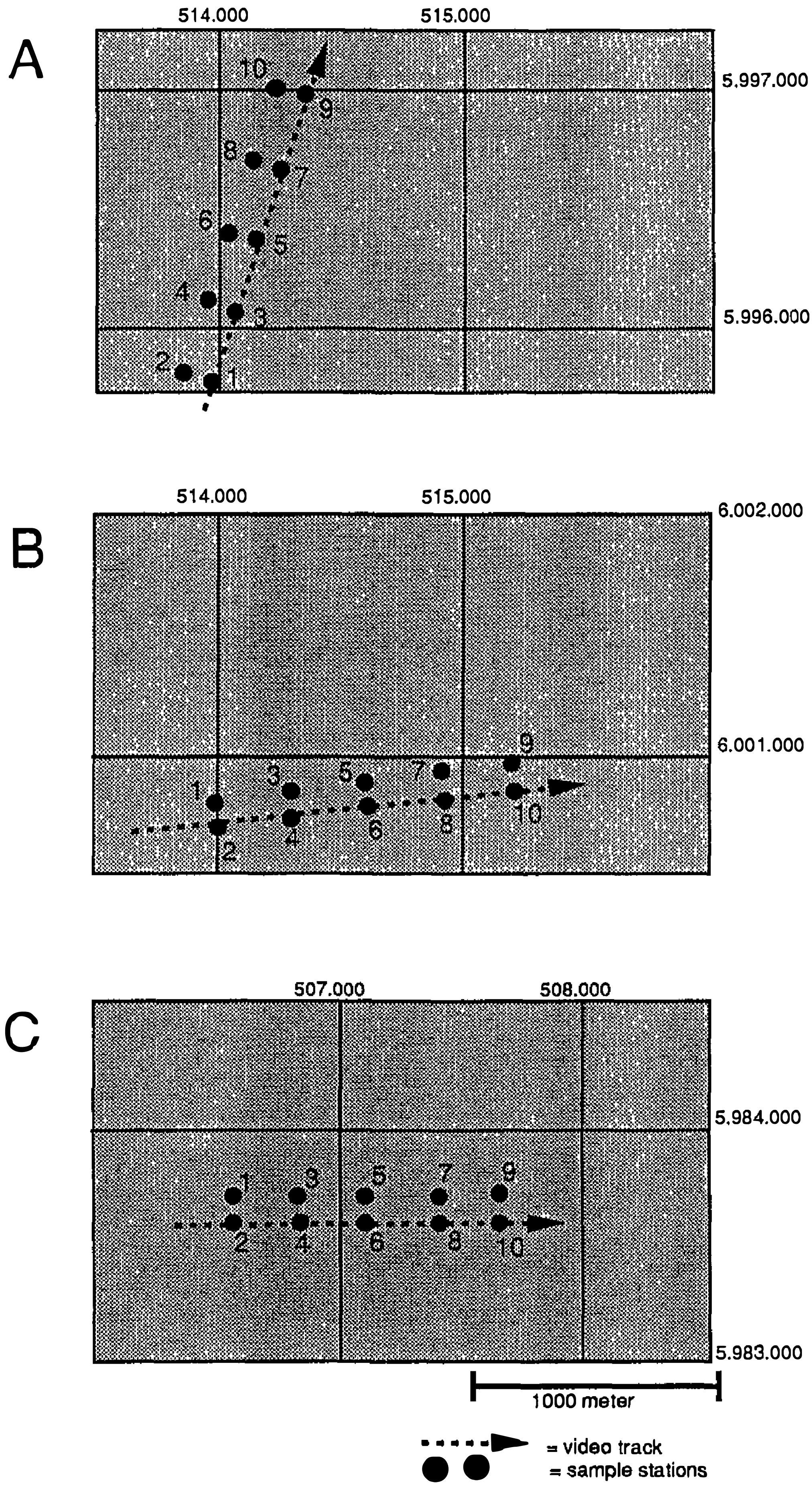


Figure 1c: geographic position of sample stations and video tracks at transect A, B and C

$$WR^2 \arcsin(S/2WR) - 0.5\, S \sqrt{(R^2 - 0.25\, S^2 / W^2)} - V = 0$$

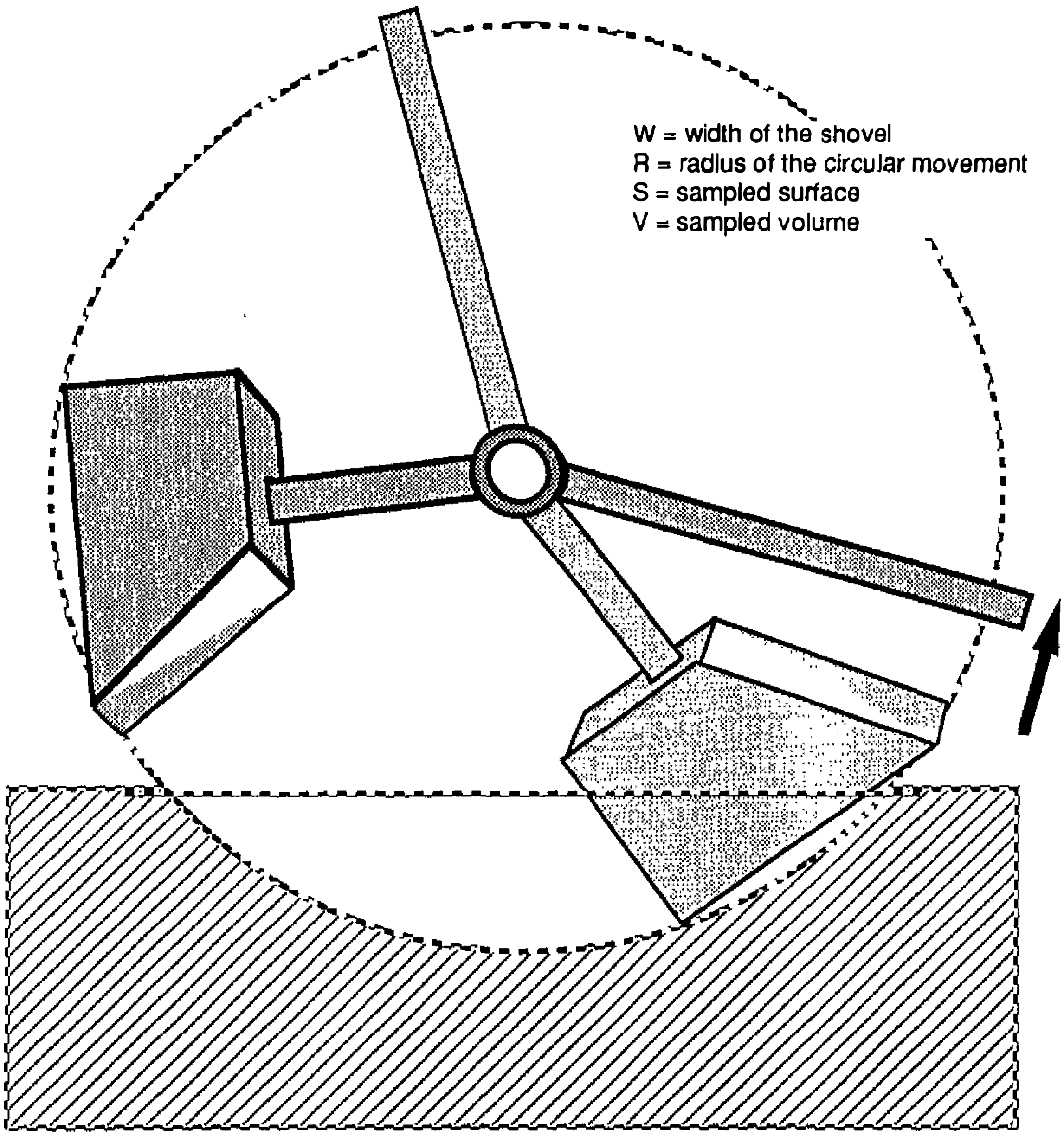


Figure 2: circle-segment calculation to convert Hamon Grab sampler volumes to surfaces

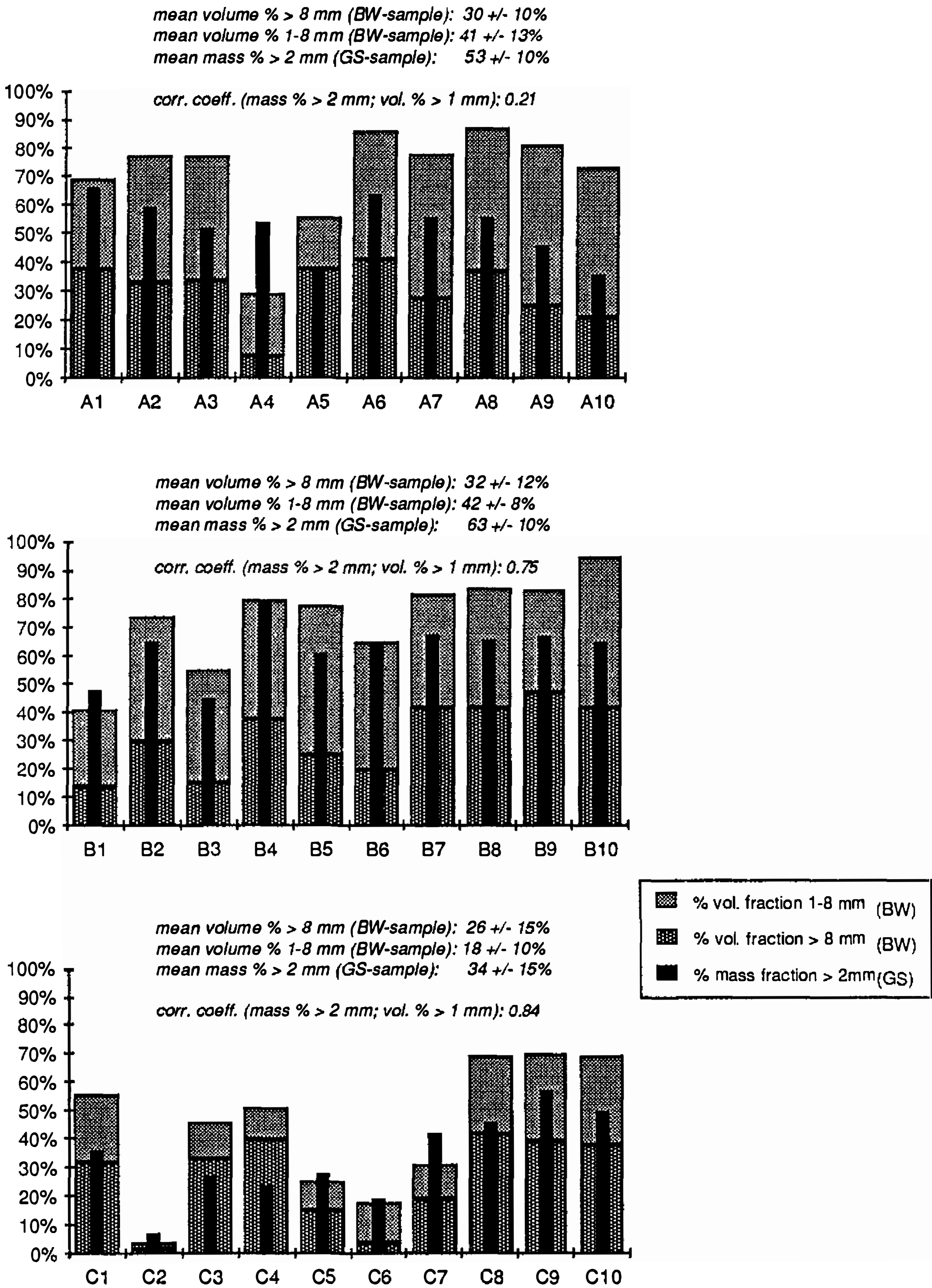


Figure 3: gravel percentages Hamon Grab samples (BW and GS)

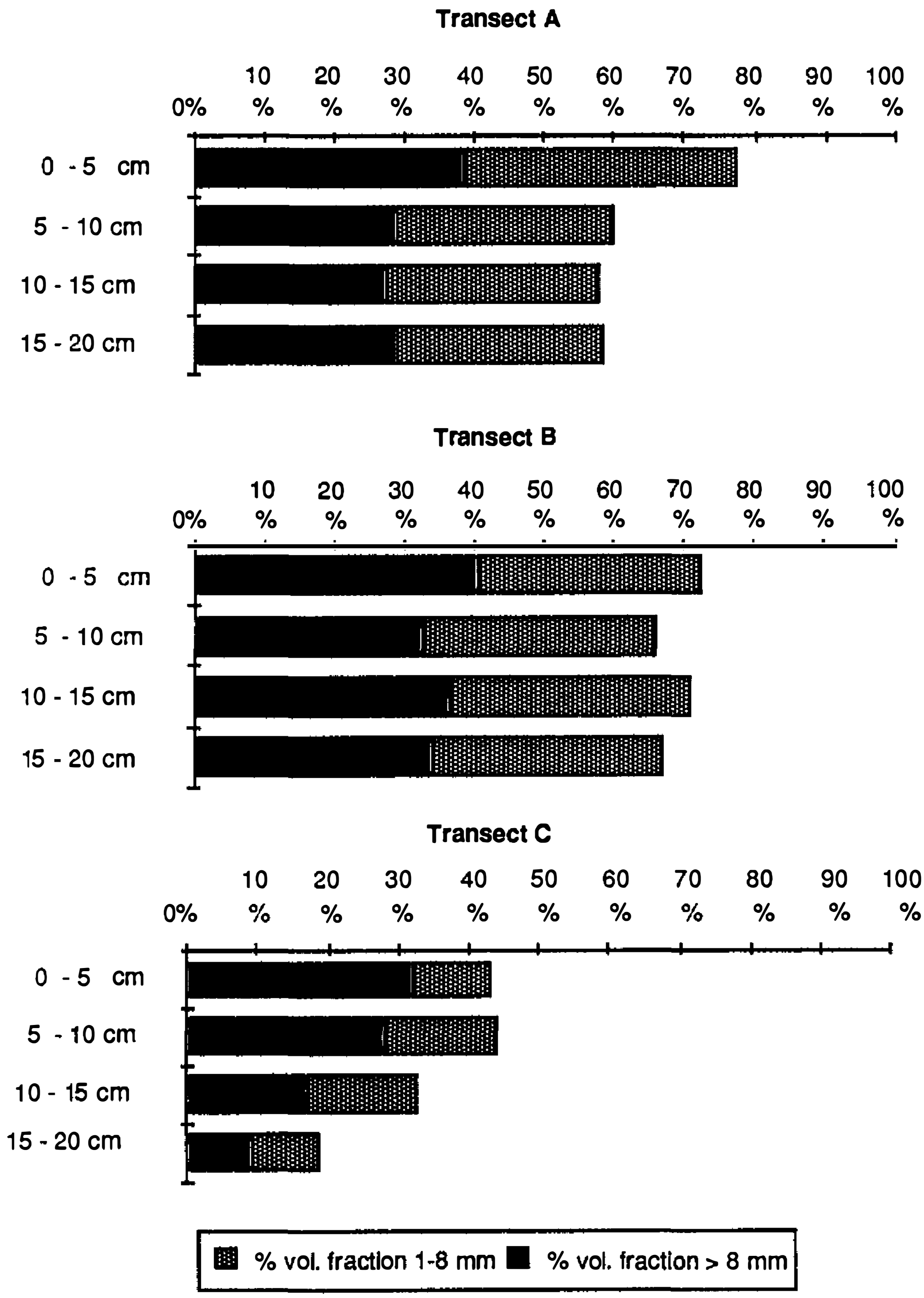


Figure 4: vertical distribution of gravel (core samples)

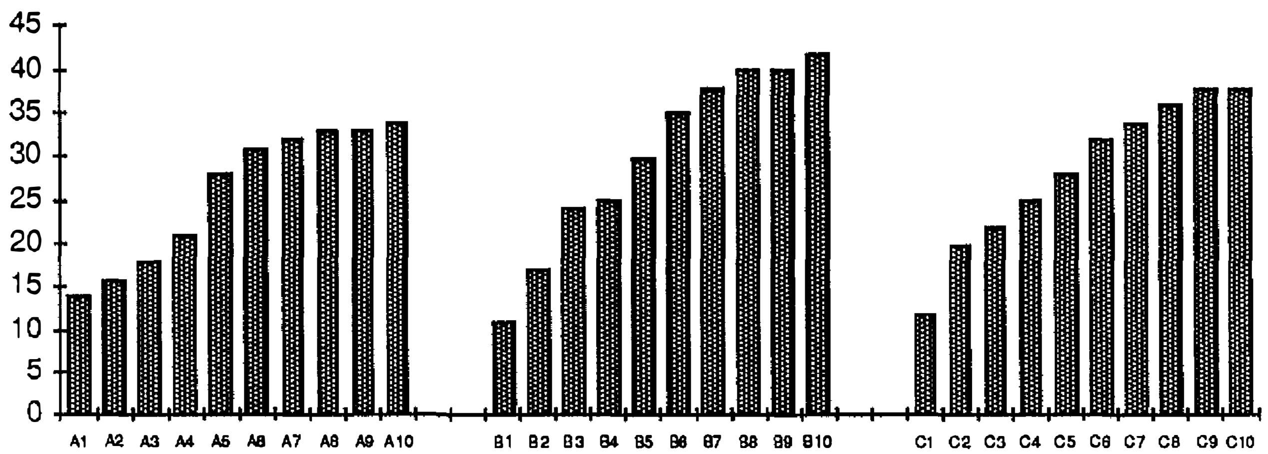
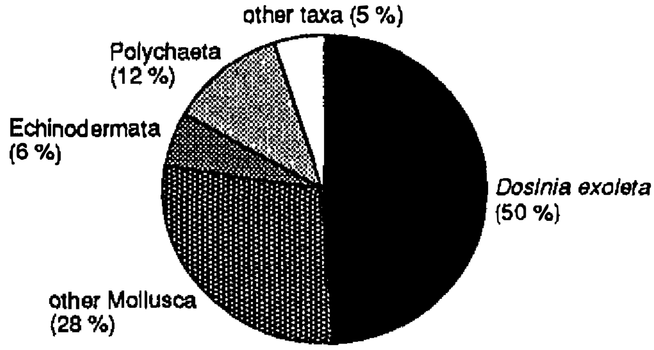
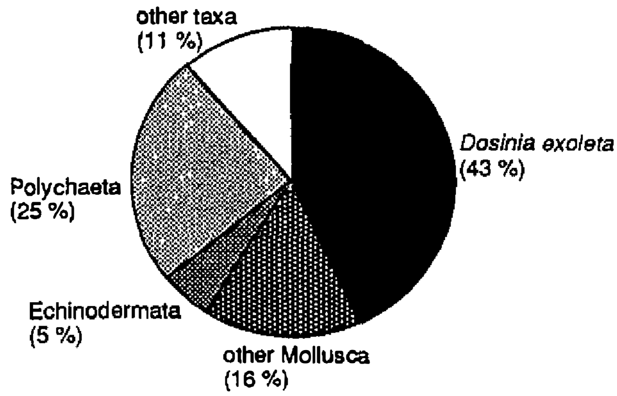


Figure 5: Cumulative increase of the number of species in subsequent grab samples of each transect

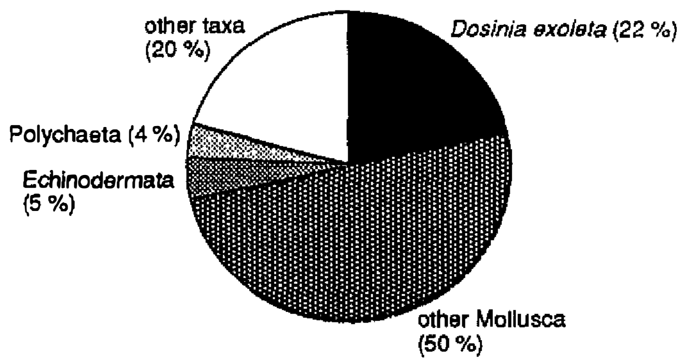
transect A



transect B

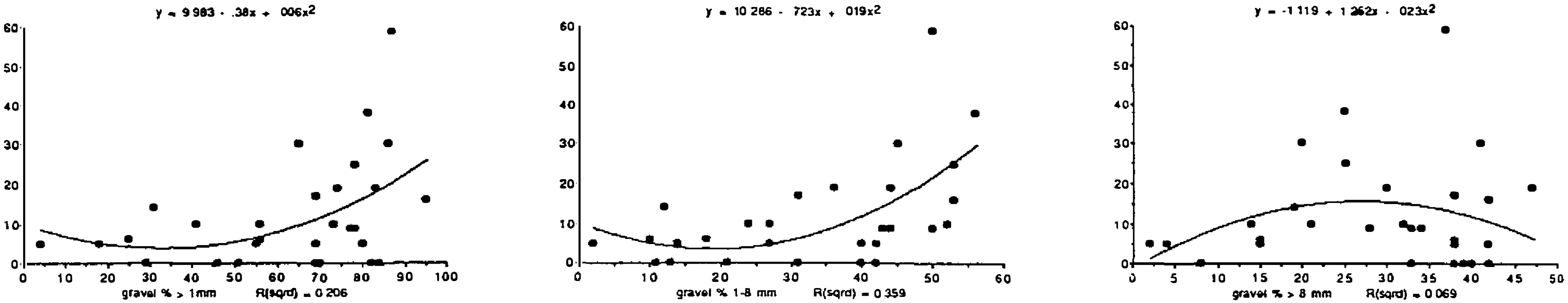


transect C

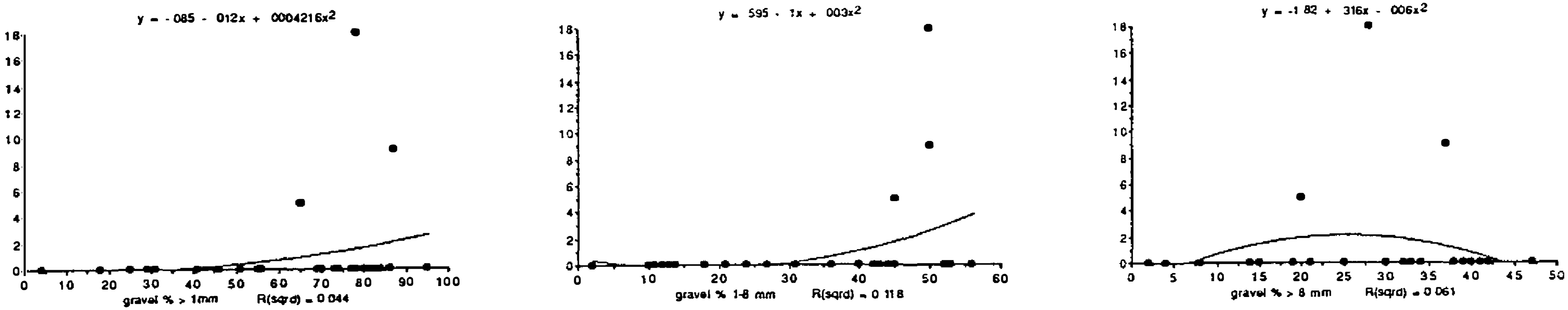


	transect A	transect B	transect C
Dosinia exoleta	11,55 +/- 14,38	9,03 +/- 8,19	3,49 +/- 3,93
other Mollusca	6,56 +/- 9,79	3,27 +/- 4,23	8,04 +/- 10,85
Echinodermata	1,30 +/- 1,99	1,09 +/- 0,70	0,80 +/- 1,05
Polychaeta	2,76 +/- 3,39	5,17 +/- 6,17	0,58 +/- 0,38
Other taxa	1,11 +/- 1,90	2,29 +/- 5,23	3,23 +/- 5,60
average Σ biomass	23,28 +/- 17,24	20,86 +/- 11,43	16,14 +/- 13,15

Figure 6: biomass (ADW/m2) of main groups at transect A, B and C.

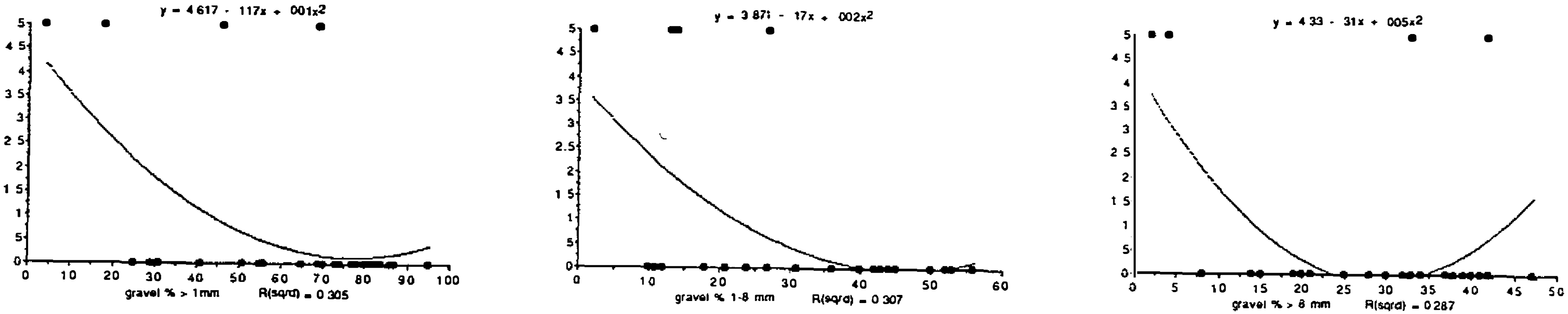


Dosinia exoleta

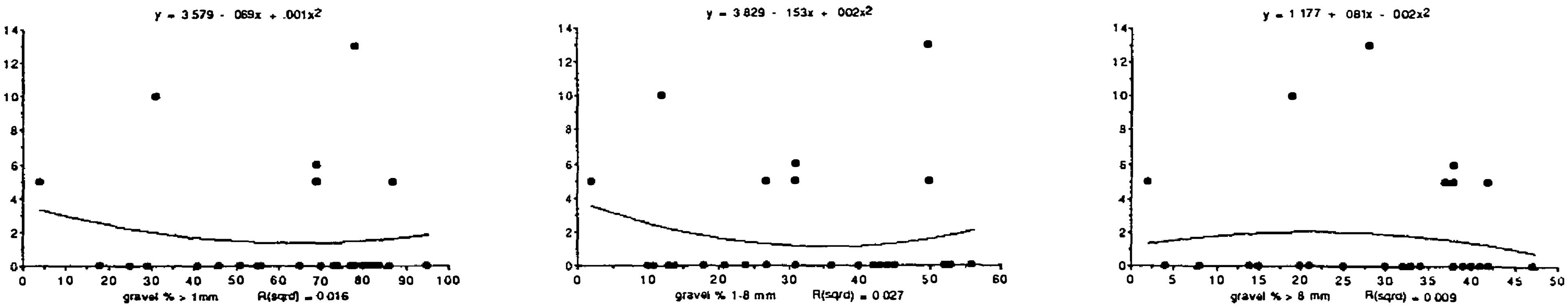


Acropagia crassa

Figure 7 (1): Species densities (n/m2) related with gravel contents (BW grab samples)

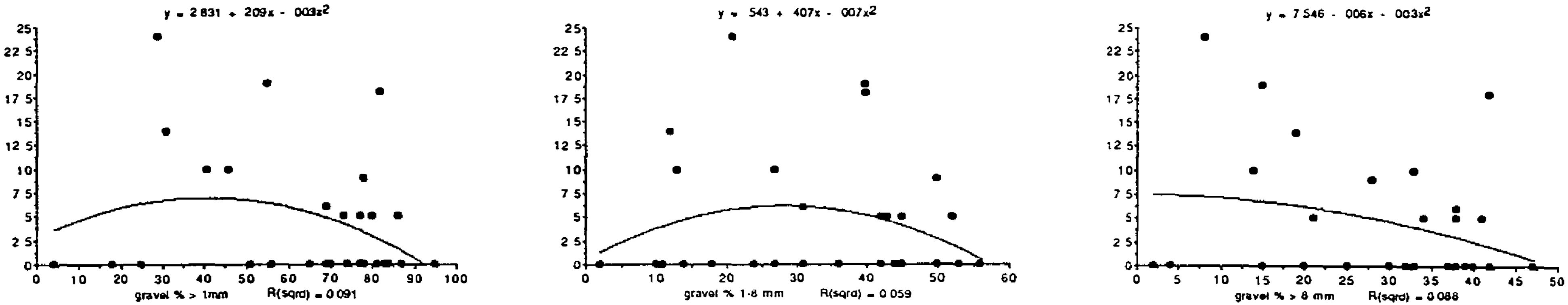


Gari fervensis

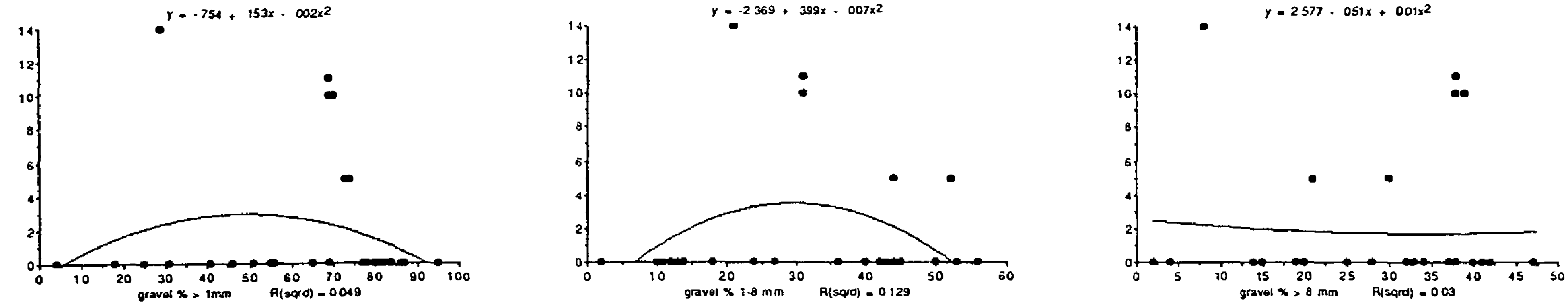


Ensis arcuatis

Figure 7 (2): Species densities (n/m2) related with gravel contents (BW grab samples)

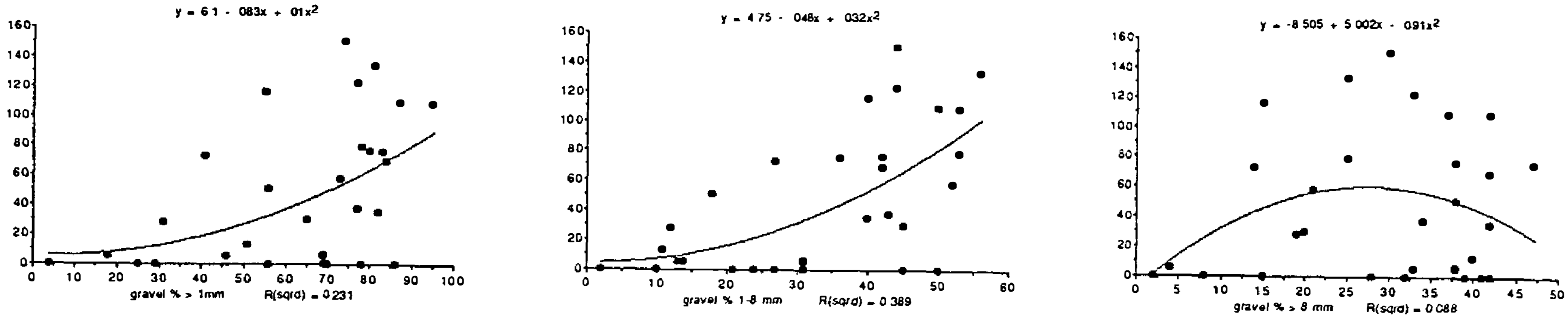


Thracia phaseolina

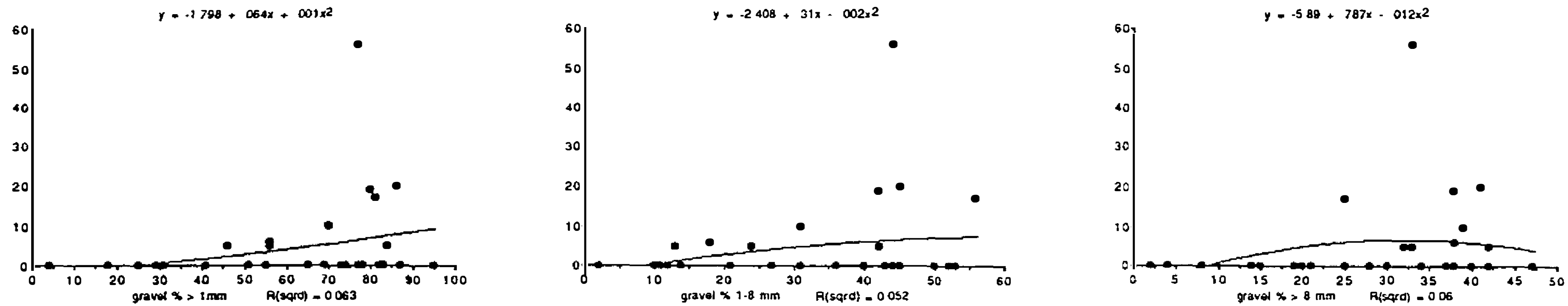


Spisula elliptica

Figure 7 (3): Species densities (n/m2) related with gravel contents (BW grab samples)

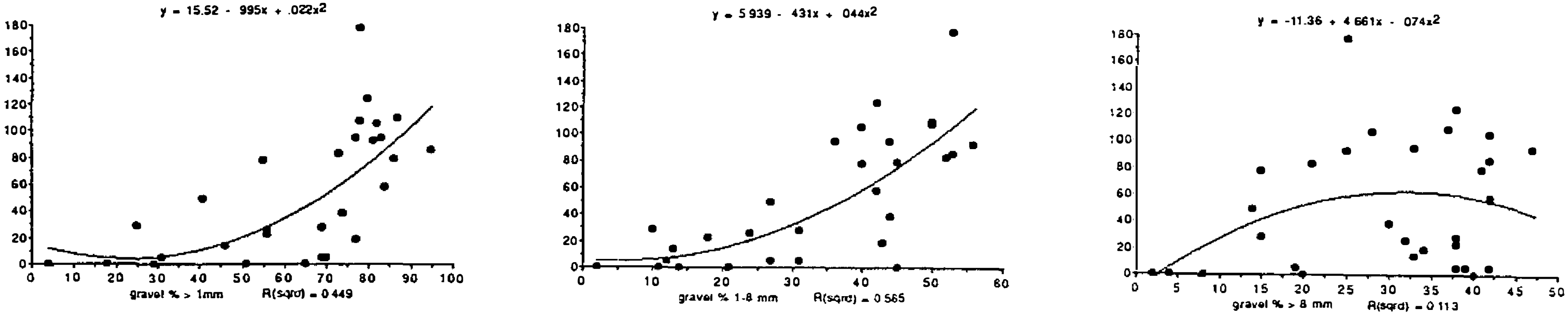


Glycera alba

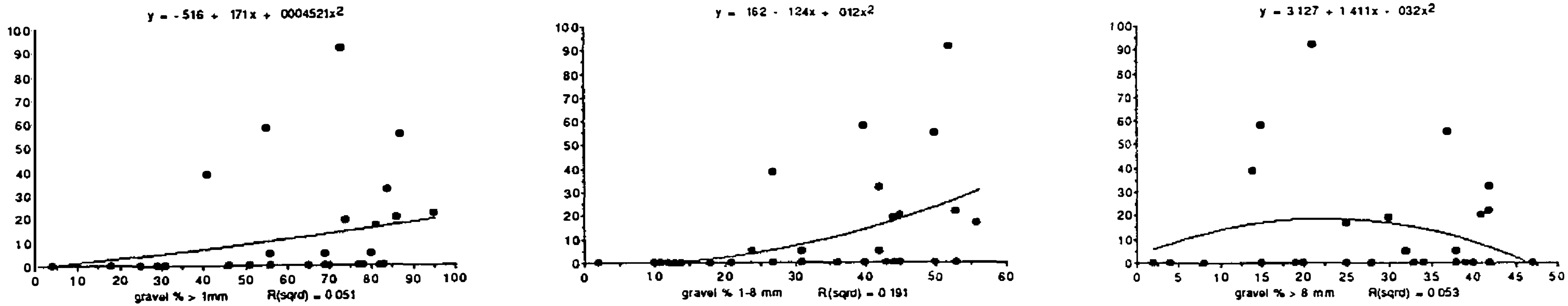


Glycera capitata

Figure 7 (4): Species densities (n/m2) related with gravel contents (BW grab samples)

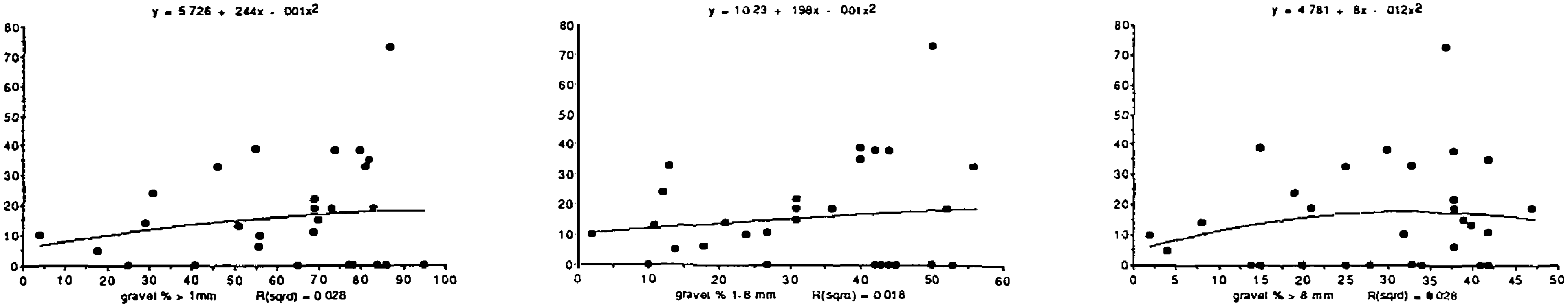


Notomastus latericeus

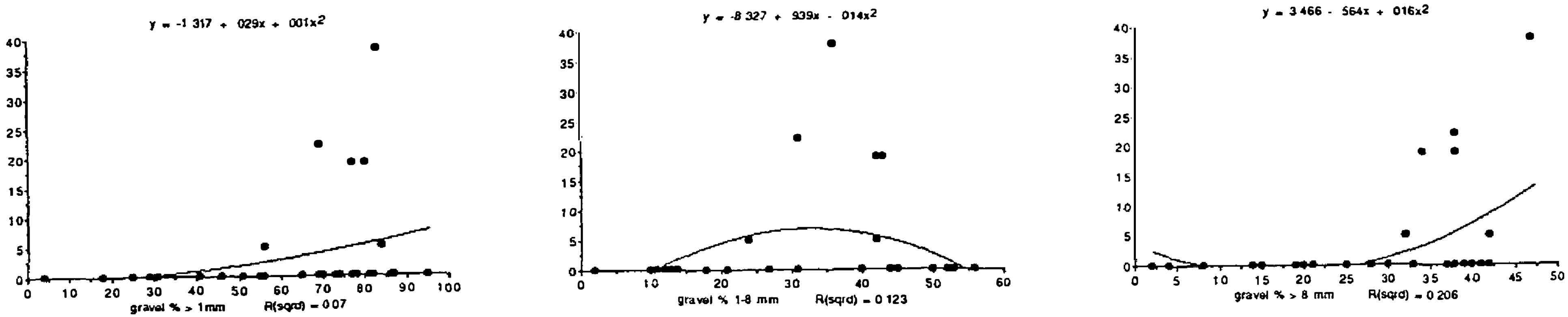


Lumbrineris latreilli

Figure 7 (5): Species densities (n/m2) related with gravel contents (BW grab samples)

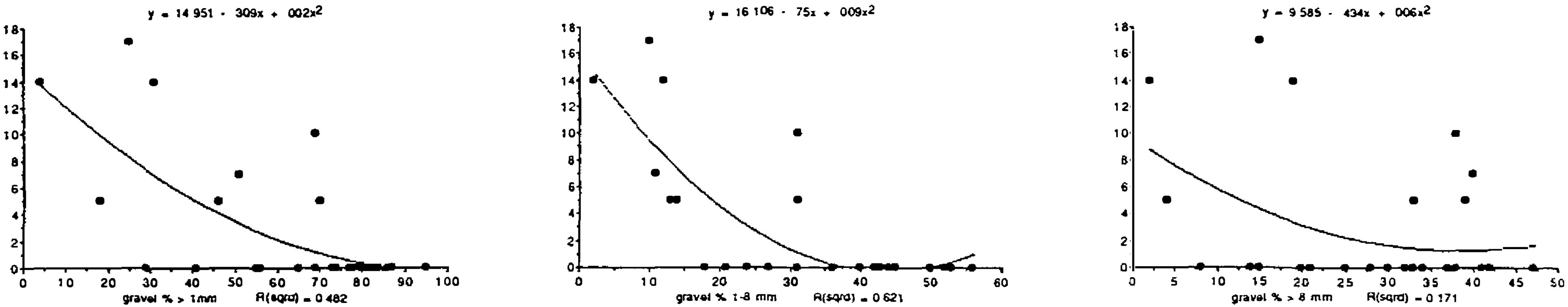


Ophelia limacina

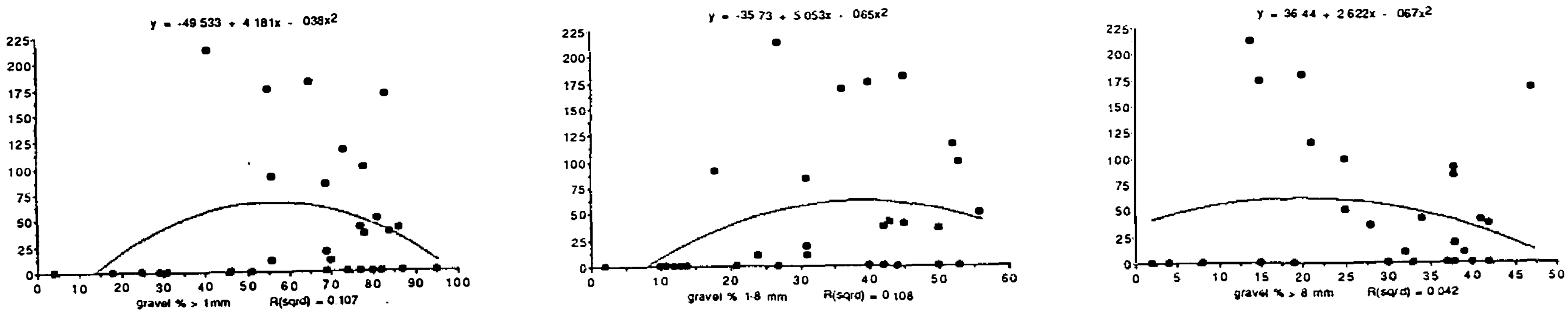


Poecilochaetus serpens

Figure 7 (6): Species densities (n/m2) related with gravel contents (BW grab samples)

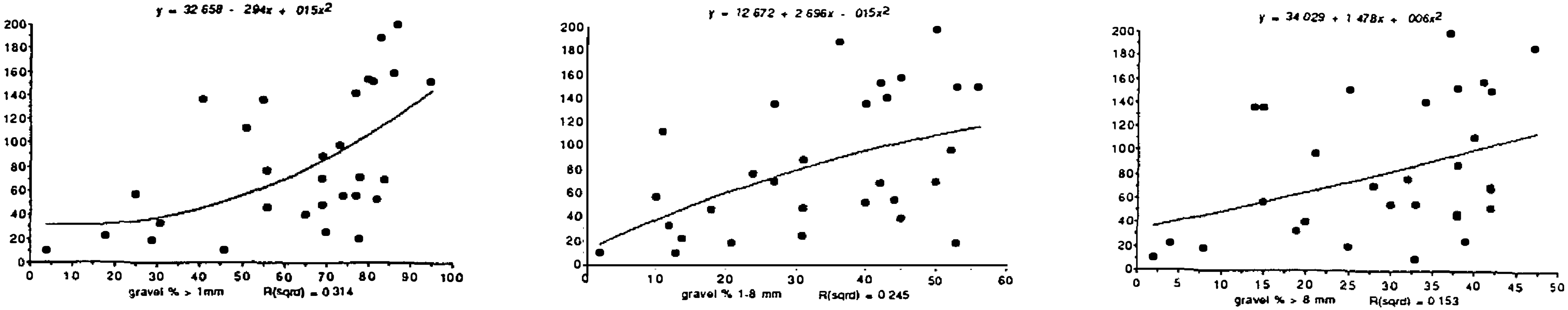


Pectinaria spec.

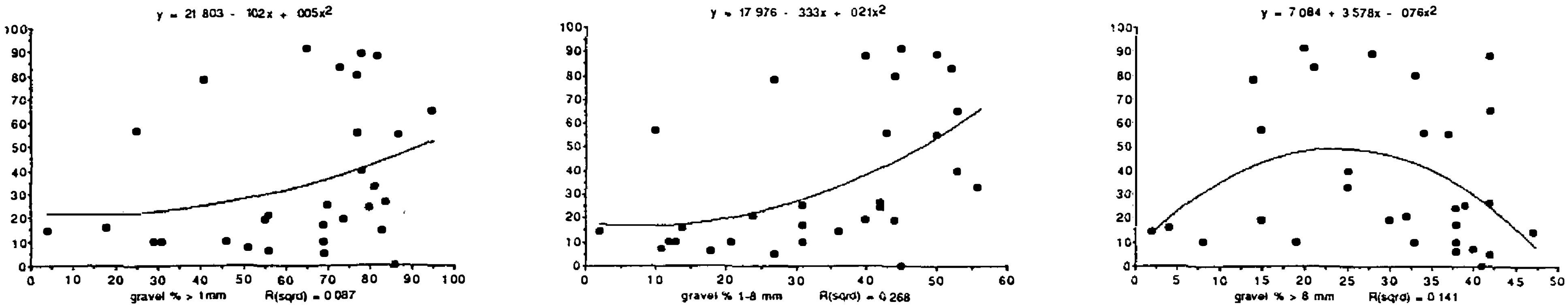


Chone duneri

Figure 7 (7): Species densities (n/m2) related with gravel contents (BW grab samples)

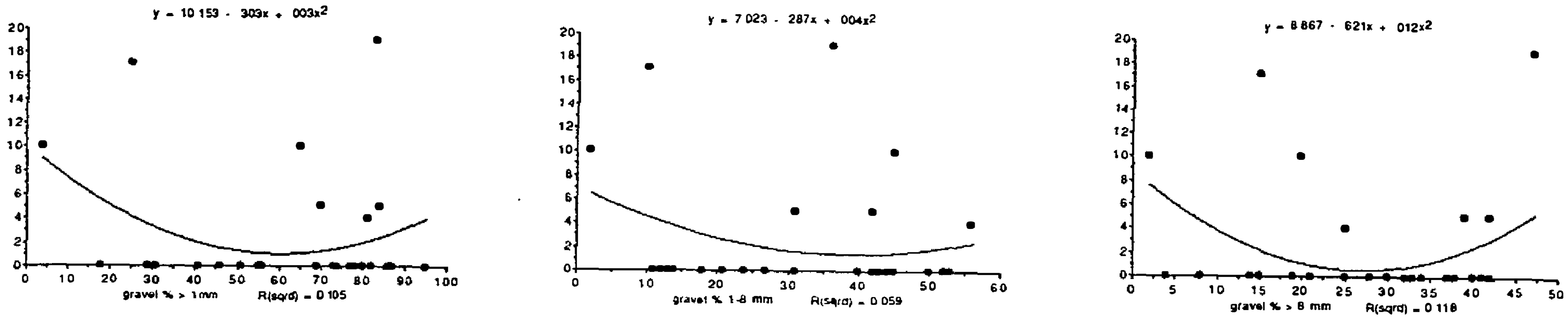


Echinocyamus pusillus

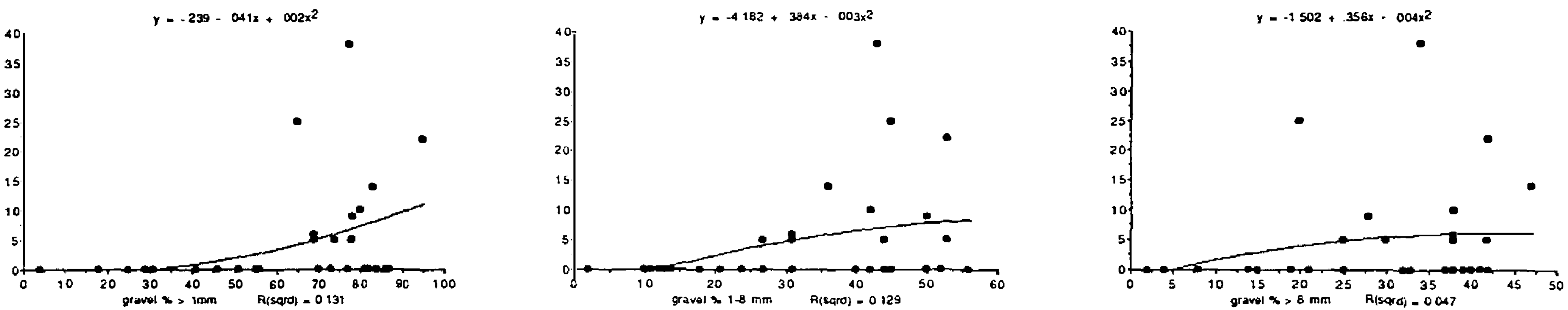


Ophiura albida

Figure 7 (8): Species densities (n/m2) related with gravel contents (BW grab samples)



Psammechinus miliaris



Branchiostoma lanceolatum

Figure 7 (9): Species densities (n/m2) related with gravel contents (BW grab samples)

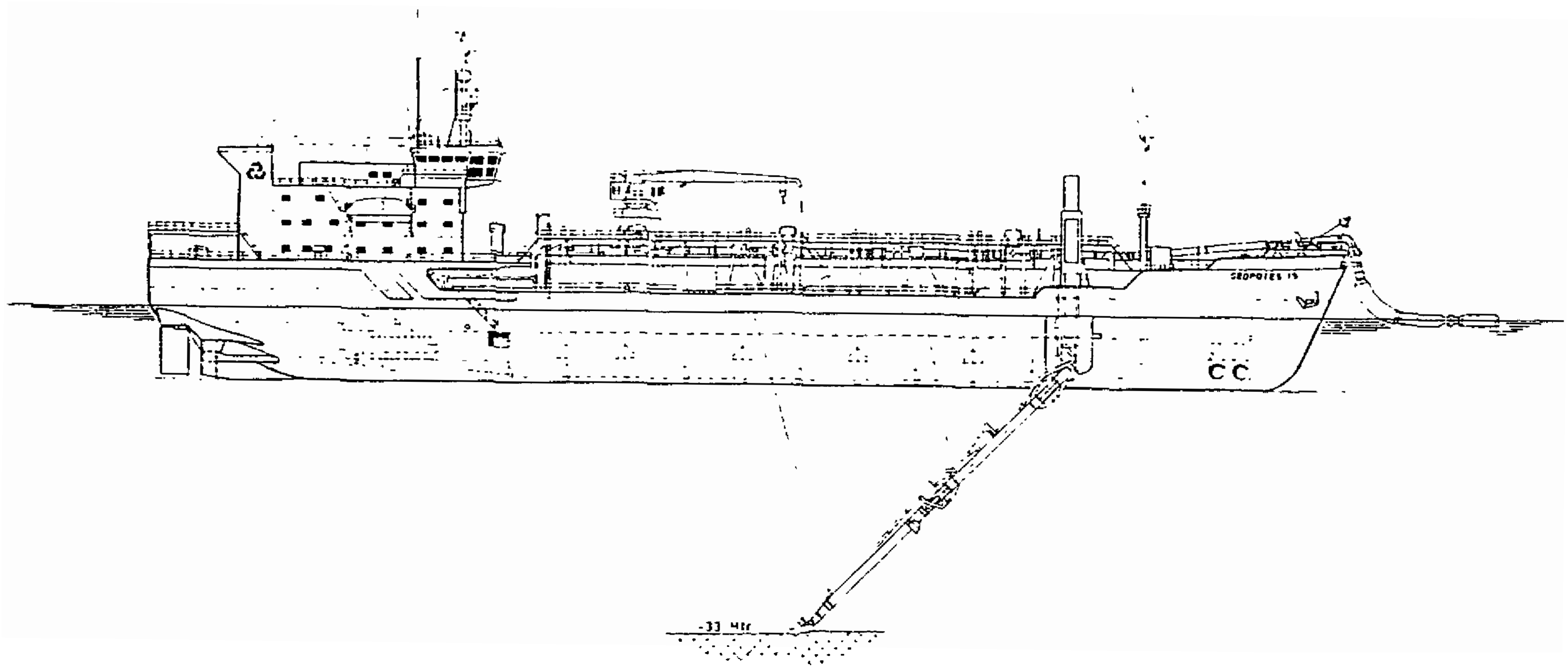


Figure 8: trailing hopper dredger (figure from North Sea Directorate
Volker Stevin

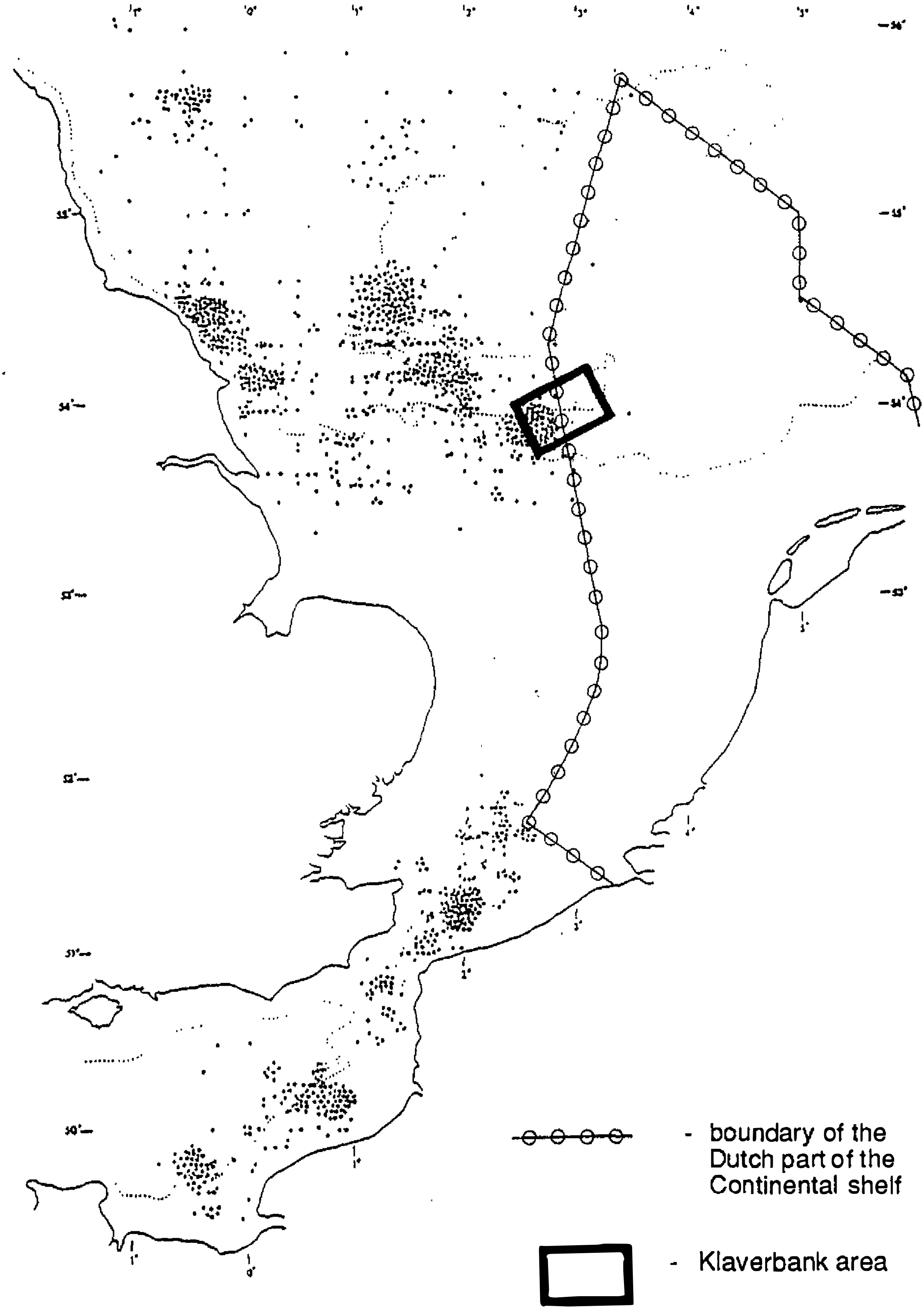


Figure 9: spawning grounds occupied by herring in the central and southern North Sea in the years 1955-1973 (from Postuma et al., 1975)

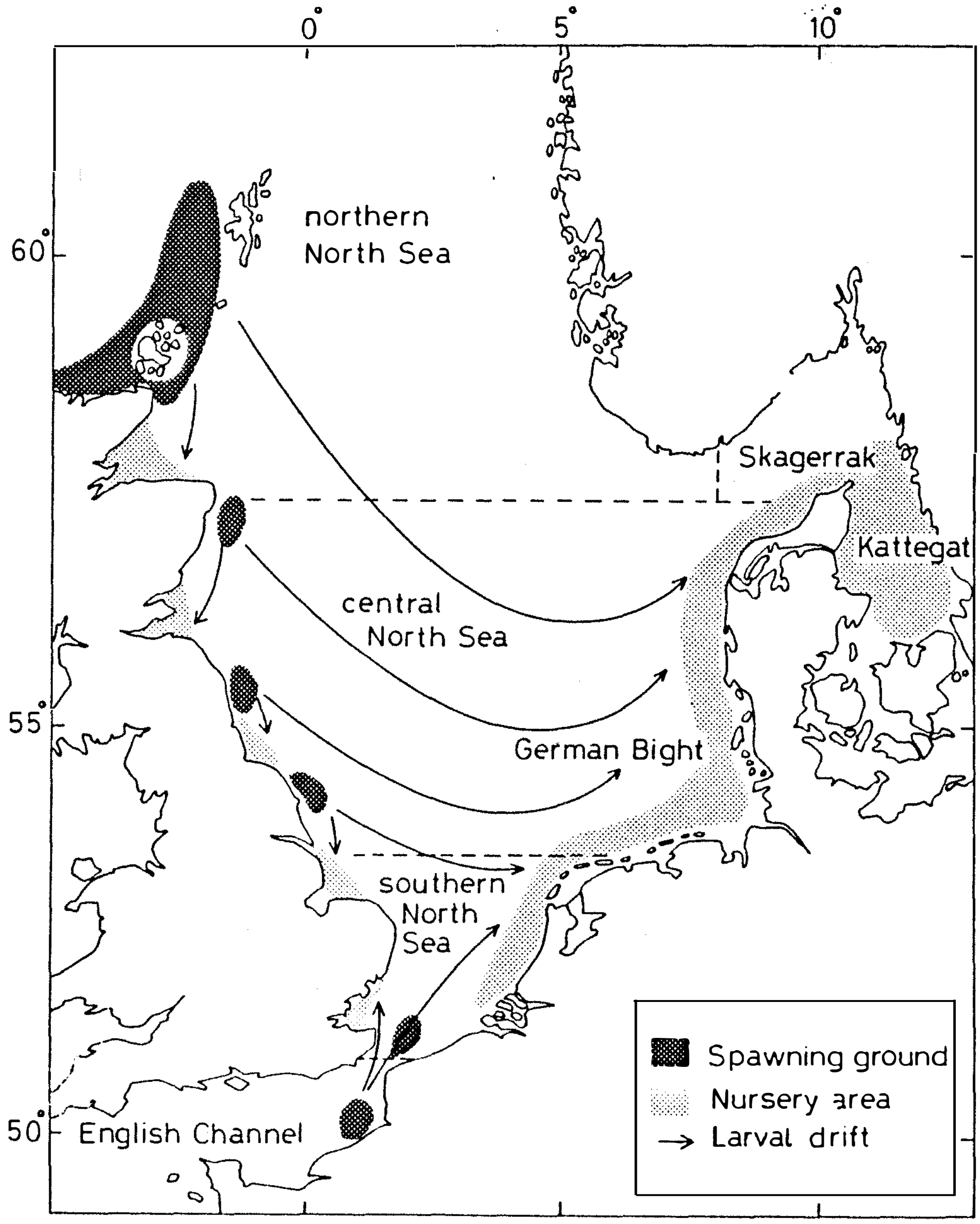


Figure 10: Herring spawning grounds, nursery areas, and drift routes after the decline of the stock in the 1960s and 1970s (from Corten, 1986).

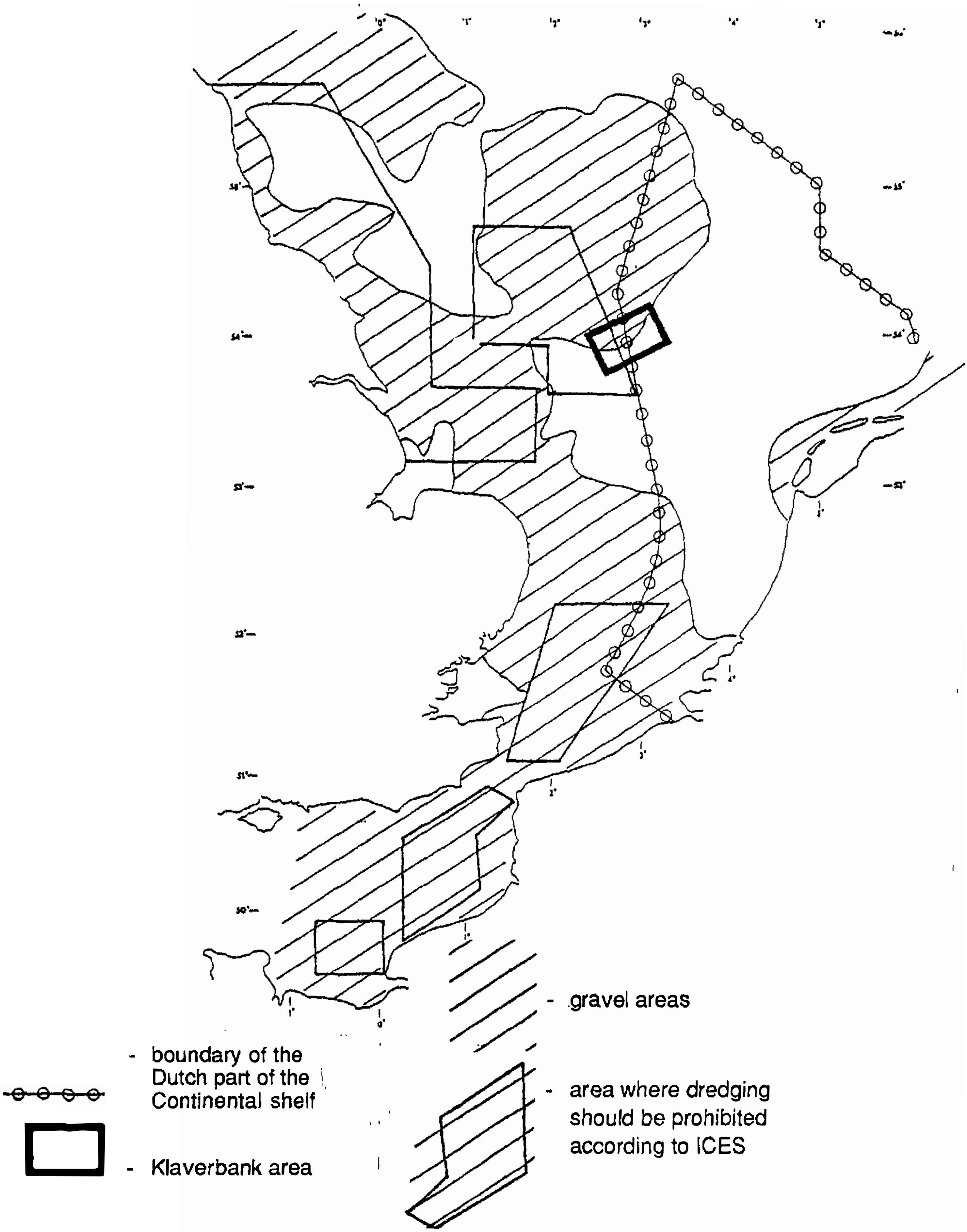


Figure 11: Map of the North Sea, showing gravel deposits and restricted areas (*after* de Groot, 1979)