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Biological Oceanography Committee

REPORT OF THE BENTHOS ECOLOGY WORKING GROUP,

Yerseke, The Netherlands, 9-13 May 1994

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1 OPENING OF THE MEETING

The Benthos Ecology Working Group met at Yerseke, The Netherlands under the chairmanship of Dr P Kingston. Dr M Kaiser was appointed rapporteur. The Chairman welcomed Professor A Eleftheriou (former Chairman of BEWG) and Dr Yannis Karakissis of the Institute of Marine Biology of Crete as observers. A list of participants is given in Annex 1.

1.1 Terms of Reference

The Benthos Ecology Working Group is to:

a) prepare information on and, if possible, compile an initial list of indicator species, particularly with reference to species sensitive to physical disturbance of the seabed, and report to ACME;

b) prepare for ACME, guidelines on quality assurance procedures for benthos studies;

c) review and report to ACME on how benthic communities are affected by physical disturbance of the sea floor;

d) review co-operative benthic studies conducted throughout the ICES area;

e) further review existing benthos data bases and their compatibility to benthic scientists, and investigate the establishment of an ICES North Sea benthos database;

f) review current techniques for sampling the benthos of hard bottom substrata;

g) review the feasibility of conducting an analysis of all available North Sea benthos data and explore the desirability of a follow-up North Sea benthos survey in 1996;

h) organize the production of ICES identification sheets on marine benthos and explore the possibility of producing a computer-aided 'expert' system.

2 ACTIVITIES OF INTEREST IN ICES AND OTHER ORGANISATIONS

2.1 BMB (Baltic Marine Biologists)

Dr Rumohr reported on the activities of the BMB. The last symposium was held in Riga, Latvia, and the next symposium will be in 1995 will be in Pærnu, Estonia. The working groups are the active bodies of this informal organisation. Discussions are in progress to change the status of the BMB and combine it with other bodies or research organisations involved in the Baltic region.

2.2 LOICZ (Land Ocean Interactions in the Coastal Zone)

LOICZ is part of the International Geosphere Biosphere Programme and deals with systems going from river basins to the shelf break and the continental slope. The LOICZ Science Plan has been accepted in 1993 and the Core Project Office has been established at the NIOZ on Texel in the Netherlands. It is becoming fully operational. LOICZ is presently generating a very large research effort in many countries. The goals of LOICZ are:

1) to determine a) fluxes of materials between land, sea and atmosphere through the coastal zone; b) the capacity of coastal systems to transform and store particulate and dissolved matter and c) the effects of changes in external forcing conditions on the structure and functioning of coastal ecosystems;

2) to determine how changes in land use, climate, sea level and human activities alter the fluxes and retention of particulate matter in the coastal zone and affect coastal morphodynamics;

3) to determine how changes in coastal systems will affect the global carbon cycle and the trace gas composition of the atmosphere;

4) to assess how the response of coastal systems to global change will affect the habitation and usage by humans of coastal environments and to develop further the scientific and socio-economic bases for the integrated management of the coastal environment.

2.3 ELOISE (European Land Ocean Interactions, Socioeconomics and Ecology)

Professor Heip reported on the ELOISE programme which is presently being developed as the European contribution to LOICZ. The ELOISE programme should be funded within the Fourth Framework Programme, more specifically the MAST and ENVIRONMENT programmes of the European Union. ELOISE will deal with the role of coastal systems in global change, the human impact on coastal systems, the coupling of socio-economics and ecology and the technological requirements for coastal research.

2.4 MARS (Marine Research Stations)

Professor Heip reported on MARS which is a formal network of marine research stations. One of the first aims is to examine the state of European biodiversity. The organisation has 40 members from both Atlantic and Mediterranean nations.

2.5 ESF (European Science Foundation)

The European Science Foundation initiated the European Coastline Study which was originally intended to study the biology of the coastline as a sensitive indicator of change. In a meeting in Galway in May 1992 the EUCO-study was defined and subsequently accepted by the ESF for follow-up. The present status is that the original science plan of EUCO has been split into the biogeochemical aspects that will be part of ELOISE and the biodiversity aspects that will be further explored by a joint ESF/CEC effort for which funds have already been allocated. The coastal marine biodiversity programme could be part of the Diversitas programme of IUBS.

2.6 JGOFS (Joint Global Ocean Flux Studies)

Dr Taylor reported on JGOFS. Initially the programme concentrated on studies in the Northern Atlantic, but has since expanded to areas such as the Arabian Sea, with particular reference to the effects of monsoon disturbance to the upper layers of the ocean and its effects on the benthic communities. The southern oceans around the Antarctic will be a future area of research. Benthic studies tend to be neglected in these research programmes and concentrate more on the physical oceanography.

2.7 Land Margin Ecosystems Research Programme (LMER)

Dr Taylor reported on the general nature of the programme and then gave details on a single project focusing on Waquoit Bay, Massachusetts, led by Dr Ivan Valiela. This regional programme is trying to assess how different rates of ground water nutrient loading alter the structure and function of coastal estuarine ecosystems. He discussed the hypothetical direct and indirect effects of eutrophication on benthic portions of the ecosystem.

2.8 Coastal Ocean Processes Programme (CoOP)

Dr Taylor reported on the project entitled 'Coupled Biological, Physical, Geological Processes Affecting Larval Transport on the Inner Shelf' headed by Dr C Butman. This project focuses on the utilisation of physical aspects of the water column by larvae of benthic invertebrates. The project has involved the development of new technology of new time series, sampling of larvae and quantification of physical aspects of the environment and seeks to understand vertical cross shelf and along shelf components of the physical environment that are important for recruitment to populations.

2.9 HELCOM (Helsinki Commission)

Dr Rumohr reported on Helcom which is responsible for Baltic Sea monitoring. This group is about to produce its third assessment on the state of the Baltic marine environment. The Baltic has been divided into five study regions to examine different parameters such as benthic ecology, pelagic biology and trace elements. Guidelines for the quality assurance of the sampling programme have been drawn up. Dr Andersen reported on the 15th HELCOM conference where it was proposed to assign marine protected areas. It was proposed to formulate management plans for different areas of the Baltic Sea. It is also proposed to draw up a list of important species and biotopes. The Joint Action Research programme has been set up to restore marine areas that have been heavily polluted. In addition it is proposed to instigate management strategies of coastal lagoon areas.

2.10 Westerschelde

Dr de Jong reported on monitoring in the Westerschelde, Netherlands. The River Schelde is about to be dredged to allow the access of large ships to Antwerp. A monitoring programme has been set up to examine changes in the benthic macrofaunal communities, and fish and bird communities in the marsh areas. Studies of the relationship between sedimentation patterns will be related to changes in the benthic communities. The programme is a co-operative venture between The Netherlands and Belgium. This is an important programme as dredging will be recurrent.

2.11 Benthic Atlas of Dutch Marine Waters

Dr Asjes reported on a study to map the benthic communities of the Dutch estuarine and subtidal areas which will be completed by 1995. This atlas will contain the distribution and ecology of 75-90 macrofaunal benthic species and 16 meiofaunal taxa.

2.12 BIOMAR (North Eastern Atlantic)

Dr Hiscock reported on BIOMAR which is a programme of marine coastal zone management through the identification, description and mapping of biotopes. The CORINE biotope classification system is at present inadequate for benthic communities, hence improvements are sought to ensure that the eventual system adopted is acceptable to benthic ecologists. The aims and framework of the programme is outlined in Annex 2.

2.13 JMAP (Joint Monitoring and Assessment Programme)

Dr Künitzer reported on a new monitoring programme called JMAP which will involve five regions, Arctic, Greater North Sea, Irish Sea, Bay of Biscay and the wider Atlantic regions. This will lead to a quality status report (QSR) in the year 2000. The nations most closely associated with these regions will be responsible for the monitoring of their area. The QSR will be similar to the North Sea QSR which is already in existence.

2.14 AMAP (Arctic Monitoring and Assessment Programme)

This programme has already been running for two years, involving the countries that border the Arctic. Apart from marine data, both freshwater and terrestrial data are included in the programme.

2.15 ASMO (Assessment and Monitoring Committee of the 1992 Paris Convention on the Protection of the Marine Environment of the NE Atlantic)

Dr Hiscock reported that ASMO had determined that there would be five regional Quality Status Reports for the NE Atlantic, for one of the areas (west of the British Isles) this was to be completed by 1998. This clearly requires input of data on marine benthic communities and will undoubtedly involve members of this working group in the future.

2.16 Long-term Changes in the Macrofauna of the Gulf of Gdansk

Dr Warzocha reported on a long-term programme to study changes in the macrofaunal benthic community in the Gulf of Gdansk. Within the bay there are deep basins that suffer from anoxia in the summer months. The first quantitative studies were conducted in 1925. Despite differences in sampling techniques it is still possible to see obvious differences in the communities within the Bay. Below 80 m the bottom was devoid of macrofauna. Since 1951 the abundance of molluscs, such as *Astarte* decreased continually, whereas the abundance of deposit feeding polychaetes *Scoloplos* increased. A new national project has been proposed (National Coastal Monitoring programme), which will be a coastal monitoring programme, and it has been suggested that the study area be made a conservation area.

3 REVIEW OF CO-OPERATIVE STUDIES

3.1 BIOFAR (Benthic Invertebrates of Faroes Waters)

Dr Nørrevang reported on the Faroe project BIOFAR. A detailed report is given in Annex 3. Many new species continue to be found from different groups of animals. The programme has enlisted the aid of expert taxonomists from different nations. The Faroe Islands have a wide diversity of fauna, however, studying such a range of benthic communities and new species requires a large number of well trained taxonomists.

One of the more interesting finds of the Faroe study is the occurrence of large coral reefs, up to 20 m high, which support a wide diversity of fauna and act as a nursery area for some species of fish. However, fishermen had been attempting to destroy some of these reefs as they were snagging their gear. Fortunately it appears that education through news articles has stopped this destructive activity.

3.2 BIOICE (Benthic Invertebrates of Icelandic Waters)

Dr Nørrevang reported on the Faroe project BIOICE. Icelandic waters are one of the world's most productive marine areas and the foundation of the nation's economy. As more of the marine resources are becoming fully exploited, the more important it becomes to increase our knowledge of the marine biota on which to base management decisions.

Knowledge of species composition and distribution in Icelandic waters is mainly based on samples collected during the Danish Ingolf expedition in 1895/96. The results were published in the series *The Danish Ingolf Expedition* and in the periodical *The Zoology of Iceland.*

To improve the knowledge of benthic animals in Icelandic waters the BIOICE programme started formally in 1992, and is estimated to end in 1998. The research area covers 758,000 km^2 and extends to 3000 m deep. The waters around Iceland connect the North Atlantic Ocean and the Arctic Ocean. Possible future climate changes will presumably have profound effects in this area.

3.3 Arctic Studies

Dr Kröncke reported on the results of the Arctic expedition, ARK8/3. At 30 stations along a transect from northern Svalbard towards the Makarov Basin macrofaunal samples were taken. Depths ranged between 1018 and 4478 m. Species numbers, abundances and biomasses were extremely low with 0 to 11/0.02m^2, 0 to 950 ind/m^2 and 0 to 82.65 g/m^2 wet weight. A total of 42 species was found. The most common species was the amphipod *Jassa marmorata.*

At 13 stations with water depths of between 258 and 4427 m samples were taken to determine bacterial communities and biomass. Bacterial abundance dropped along the transect from 3.03 to 0.63 x10^8 cells/cm^3, and correspondingly bacterial biomass decreased from 17.35 to 3.43 µg C/cm^3 sediment. Positive correlations were only found between TOC concentrations of surface sediment layers and biomasses of small coccoid cells and small rods.

Depth dependent changes in abundance and biomass distribution of macro and meiofauna, foraminifera and bacteria are shown and discussed in connection with geochemistry and food availability.

3.4 Coastal Nourishment of Terschelling

Dr Essink reported on the environmental effects of this project which is designed to protect the coastline by adding sand to the foreshore. The main aims are to study the dynamics of the sediment and consequently the effects on the benthic fauna. A working document can be found in Annex 4. A pre-deposition (nourishment) survey was carried out in 1993, both at the deposition site and at a reference site. The results of this study will be compared with results from similar projects elsewhere, such as Spain.

3.5 Wadden Sea and Other Dutch Coastal Areas

Dr Essink reported that the benthic monitoring programme in the Wadden Sea is continuing in conjunction with NIOZ, Texel; he also gave an account of other studies in the Ems estuary and SW-Netherlands (Annex 5).

3.6 Thematic Mapping and Sensitivity of the Wadden Sea (WATIS)

Dr Künitzer reported on another study in the Wadden Sea. This study spanned 1987-1993 to examine biological sensitivity to oil. The whole area has been mapped for fish, macro, microinfauna, sediment structure, marshes and bird populations. This data has been installed on a data bank plus a compilation of all the other Wadden Sea studies. Colour coded maps have been produced which show the distribution of these different factors. This plan has been instigated to provide a baseline survey in the event of an oil-spill.

3.7 Additional Projects in the Wadden Sea

With the establishment of national parks for the Wadden Sea in Germany, an ecosystem research scheme was inaugurated in the late 1980s. The scheme is composed of two corresponding parts which are carried out in Schleswig-Holstein and Lower Saxony, each composed of two branches: one focusing on applied and one on basic sciences. Projects are well under way in Schleswig-Holstein and for the applied section in Lower Saxony. Here, after completing a pilot phase for the basic branch in March 1993, work can now continue on key questions of the ecology of this ecosystem.

To analyse the resilience of the Wadden Sea, the projects investigate temporal and spatial patterns on every heirarchy level of the ecosystem and record their variations following simulated disturbances. Ultimately, this research will identify key components and processes which require prime conservation status.

3.8 Dogger Bank

Dr Kröncke reported on a new proposal which has been put forward to examine pelago-benthic coupling, benthic productivity and benthic fluxes on the Dogger Bank. However, this study has not yet received any funding.

3.9 Pomeranian Studies

Dr Powilliet and Dr Warzocha reported on studies in the Pomeranian Bay. The Pomeranian Bay Study aims to examine the impact of river borne materials on the marine ecosystem. This is an interdisciplinary project of the Institut for Baltic Sea Research (IOW) started in February 1994 together with chemists, oceanographers and biologists.

In a pilot study a benthic survey was undertaken in April 1993 that covered the whole Pomeranian Bay. These results will be compared to data collected in the 1960s. Results indicate that there have been major changes in the distribution of some benthic animals such as (*Cerastoderma lamarcki*). The circulation, mixing and transport of material from the River Odra were investigated on another research cruise in 1993. Polish benthic samples are currently being analysed. The project will identify community changes along pollution gradients and will examine benthic productivity, sediment characteristics and community metabolism.

Studies of bioturbatory activity have been performed in the laboratory by studying the diffusion rate of a tracer, bromide, through the sediment. The rate of diffusion depends on the organisms present, ie whether bivalves or polychaetes. A more detailed report is found in Annex 6.

3.10 Danish Monitoring Programme

Dr Andersen reported that there is a Danish Benthic monitoring programme to study long-term changes in communities. However, the report is currently in Danish, but it is hoped that the data will be available on a database in the future.

4 EFFECTS OF PHYSICAL DISTURBANCE OF SEA FLOOR ON BENTHOS

4.1 Canadian Experiments on the Effects of Trawling on the Seabed

T Rowell reported on Canadian experiments to examine the effects of otter trawling on the seabed communities. The study began in 1991, with preliminary investigations on the Western and Grand Banks. The biomass and species number was highest on the Grand Bank site, and hence this was the site chosen for experimental studies. This was enhanced by a moratorium on mobile gear fishing on the Grand Bank. Experimental trawling is undertaken along three 13 km long waylines which are arranged in triangular pattern. Adjacent to each trawled corridor is a control corridor, which remains unfished. Each corridor was trawled 12 times in succession. Details of some of the sampling equipment used in this study are given in Annex 7. Side-scan sonar revealed that the experimental area had been successfully trawled and had not affected the untrawled area.

4.2 German Studies on the Impact of Fishing

Dr Rumohr showed a video which described the German studies on the impact of fishing. Otter trawl tracks were videod using an ROV. The tracks were rapidly filled with drifting algae.

4.3 The Effects of Fishing on *Arctica islandica*

R Witbaard reported that this project was initiated to investigate the possibility of using *Arctica* as an indicator species of fisheries activities. This has been achieved by examining externally visible scars on the shell which have arisen as the result of fishing gears hitting the shell. Most (80%) of the observed scars were observed in the posterior part of the shell where the scars are located. The high percentage to this particular region of the shell is attributed to the mode of action of beam trawls. Using the growth lines in the shell it was possible to determine the date on which the any observed damage occurred. Occasionally sand grains are incorporated into the shell matrix as a result of the damage. It appears that the occurrence of damage to this species has increased over the last two decades, coinciding with the development of beam trawl fleets. The first signs of major fishing disturbance begin in 1974. Dr Lopez-Jamar asked whether these scars could be attributed to the effects of predation by crabs or lobsters, however, it was argued that a predator would continue to eat an *Arctica* once the shell was cracked.

4.4 Impact of Fishing Gears in Greece

Professor Eleftheriou (Crete) reported that studies had begun off the coast of Greece to investigate the effects of trawling on seabed communities. Samples will be compared from an area which is heavily fished for 6 months of the year with samples from an unfished area.

4.5 4 m Beam Trawling in the Irish Sea

Dr Kaiser reported on the results of experiments to study the effects of 4 m beam trawling in the Irish Sea. Results to date indicate that immediately after trawling an area of the seabed, the number and biomass of certain species, such as *Alcyonium digitatum* and hydroids, decreases. However the number of mobile scavenging species, such as *Liocarcinus depurator* and *Asterias rubens*, either remain the same or increased. Although the number of infauna polychaetes, molluscs and crustaceans tended to decrease immediately after fishing, this was not a statistically significant change. Survival experiments using animals retained in the codend revealed the mortality of many of the animals was <15% (*Eledone cirrhosa, Eupagurus prideauxi, Buccinum undatum, Aequipecten opercularis, Crossaster papposus*). However the tow duration was only 30 min, which is shorter than standard commercial tows, hence longer tows (1 and 2 h) will be used in future.

In April 1994, an experiment to examine the movement of scavengers onto recently trawled areas revealed that the number of highly mobile species, such as swimming crabs and dabs increased significantly 1 h after trawling. The number of less mobile species such as starfish had increased significantly after 24 h. 48 h after trawling the number of crabs on the trawled area had reduced to pre-trawling levels, however the number of starfish and dabs persisted. Diver observations of the trawled area, using a video camera, showed hermit crabs feeding on damaged *Corystes cassivelaunus* and *Ophiura ophiura* immediately after fishing. 24 h later starfish were observed feeding on the broken remains of *Echinocardium cordatum* and *Arctica islandica*. The seabed at this site was typically composed of medium compacted sand with small (height 3 cm) sand ripples. The trawled area was characterised by a smooth substrate with a large proportion of shell fragments on the surface. Signs of reforming sand ripples were observed after 48 h.

4.6 An Analysis of Fishing Effects in a Previously Unfished Area

D Basford reported on a project currently underway in Gareloch, Scotland, that will investigate the effects of fishing in an area that has been closed to fishing for three years. The objective of this project is to follow changes in the benthos in an inshore habitat that has had only restricted access for fishing since September 1967 and no fishing since 1990. It is proposed to:

1 document the community that has developed after three years protection from fishing;

2 study any changes in the fauna and sediment composition due to the increase of fishing activity.

The initial survey of the whole loch took place in November 1993 and experimental trawling started in January 1994. The experimental work will be undertaken in May and October until 1996 to study the effects of the trawling and any recovery. The survey work will involve a RoxAnn and side-scan sonar survey, a TV survey and sampling of both the epi- and infauna. In many respects, the scientific programme will employ standard sampling and analytical techniques, but it is the uniqueness of the situation rather than the scientific methodology which gives this study its power.

4.7 Voordelta Closed Fishing Area

J Craeymeersch reported on the closure of an area to shellfish fisheries in the Voordelta (The Netherlands). As the Voordelta is characterised by a large diversity of habitats, the effects of shellfish fisheries cannot simply be analysed by comparing the benthos within trawled areas and areas closed for fisheries (expected to be established this year). Therefore, a corridor will be chosen covering both the closed and open area. Fisheries will be allowed in the corridor within the closed area, and banned in the corridor within the open area.

4.8 Bivalve Fishery Closure in the Wadden Sea

Dr Essink reported that, several years ago, 15% of the Wadden Sea was closed to cockle and mussel fisheries to examine whether this will enhance recruitment to these populations The benefits of this exercise will be assessed later in 1994.

4.9 Species Sensitive to Physical Disturbance of the Sea Bed

The BEWG considered the production of a list of indicator species with reference to physical disturbance of the sea bed and, in accordance with the request from ACME, produced a preliminary report which is given in Annex 8.

5 IDENTIFICATION SHEETS AND COMPUTER-AIDED TAXONOMY

The working group considered the feasibility of producing ICES identification sheets for benthos and concluded that a traditional approach would be too expensive and that emerging computer-aided techniques might provide a practicable alternative.

Dr Sluys of the Centre of Expertise for Taxonomic Identification was invited to give a presentation on the use of computers in taxonomy identification and demonstrated a system they had developed. The system attempts to fill two gaps a) information related to biodiversity and b) the lack of taxonomists which are essential requirement for studies of biodiversity. One approach to filling this gap is to create taxonomic databases which are user-friendly and multi-media. Experts contribute to the database by entering their data into a standard software shell. The database allows non-experts to identify material from several perspectives which moves away from the limitations of dichotomous keys. Dichotomous keys become limited when essential features have been lost or are misidentified. A presentation was given to show the system in operation, however, to date there are only limited databases available, eg flatworms and lobsters. There is no current general database for northern European benthic animals, but this is clearly desirable.

The working group generally agreed that the approach described by Dr Sluys had considerable potential. An attractive feature of the software was the inclusion of an authoring program that would enable taxonomists to produce identification programs without the need for trained computer programmers. Dr Kingston proposed that working group members carried out an evaluation of the system both as an identification aid and a means of producing identification aids.

6 SAMPLING TECHNIQUES

6.1 General Review

Dr Rumohr reviewed current benthic sampling technology. He presented examples of various dredges in use as well as a wide variety of grabs, corers and air-lifts. In a video he showed the current state of video and camera applications used in Kiel, comprising observation of the seafloor of sediment profile (REMOTS). He introduced a new version of diver held and operated sediment profiling camera which is designed for special use under fish cages and in areas where ships cannot operate. Further he showed the use of video in controlling the performance of sampling gear and in the observation of the fishing process of shrimp trawls in the German Wadden Sea. He could show the relatively small impact of this gear on the seabed and the benthic community and the rapid subsequent invasion by swimming crabs, scavenging on the animals exposed or damaged by the trawl. T Rowell described a dredge developed in Canada that is used in conjunction with a video and has an automatically released door to prevent entry of material at the end of a sampling run. This attempts to eliminate the problems associated with hauling errors. In summary, there is a wide range of grab and corer devices which vary in their efficiency, hence in comparable studies there is a great need to standardise sampling devices and to conduct inter-comparability exercises. The Dutch (NIOZ) have developed a deep digging dredge that penetrates to a depth of 15 cm and collects animals which tend to be missed by grabs or corers. Results indicate that this obtains quantitative samples in soft sand sediments.

6.2 Sampling of Hard Substrata

In his review of sampling techniques, Dr Rumohr described a wide range of heavy anchor dredges and towed dredges which are used depending on the substrate to be sampled. The only device that resembled a grab type system was the Hammon grab which takes quantitative samples from gravel substrates. A detailed comparison of the efficiency of the Hammon grab and an anchor dredge operating in gravel substrates is given in a paper provided by Dr Rees in Annex 9. Dr Rumohr also described a freshwater device to collect gravel bed fauna. This involved a net basket filled with gravels allowing animals to settle over a time period. Photographic methods seemed to be some of the best quantitative methods for measuring communities attached to rocky surfaces. Dr Hiscock is a particular specialist in this area and offered to give a review of techniques at the next meeting.

7 QA FOR BENTHOS STUDIES

The BEWG was asked to prepare guidelines on quality assurance procedures in benthic studies by the ACME. Much of this work had already been covered in an ICES/HELCOM workshop held to draw up similar guidelines for Baltic work and which had extended its remit to cover the North Sea. Nevertheless, the BEWG considered their findings and produced a set of guidelines as a supplement to those of the ICES/HELCOM meeting. The guidelines are given in Annex 10.

8 BENTHIC DATABASES

J Craeymeersch reported on the database BEDMAN (Benthic Data Management). The database includes data from the North Sea benthos survey (1986), various North Sea monitoring programmes and data from Norway and Sweden (see Annex 11). The majority of the data is concentrated around the Dutch coastline, but the data extends from the southern North Sea to north of the Shetland Islands. The database is run under the Paradox system, however there is a user interface that can be interrogated by those unfamiliar with Paradox. One the most pertinent points that arose was the ownership of data that was entered on large databases, especially when data is unpublished. Scientists or nations could be wary of either plagiarism or of other nations accessing politically sensitive data.

The Working Group welcomed the news that ICES was to consider integrating the North Sea Database into the ICES Environmental Database. Dr Larsen presented a working paper that he had prepared for BEWG approval before forwarding to ACME. The document raises various problems such as standardising the methods and details recorded on individual's databases. The BEWG endorsed the paper, a copy of which is given in Annex 12.

9 NORTH SEA BENTHOS SURVEY

It was generally agreed that it would be extremely valuable to repeat the 1986 North Sea Benthos Survey to determine whether there have been any changes in the benthic community over the last 10 years. This information is necessary to determine the effects of eutrophication, anthropogenic disturbance to the seabed etc. The main reservation raised was the problem of funding from the various governments or the European Union. It was felt that if ICES gave its support for this survey governments would be more willing to fund this research. In addition it was suggested that a similar, parallel survey in the Irish Sea would be desirable, especially in view of the impending Irish Sea Quality Status Report.

The original North Sea Benthos Survey provided important information that enabled synoptic mapping of the distribution of benthos, from which overall trends in biodiversity and biomass could be related to wide scale geographical factors. Such information is important in not only permitting a fuller understanding of the benthic regime in the North Sea to scientists, but also providing the background for important decisions in the resource management of the North Sea.

There is increasing concern for the state of the North Sea Environment, stemming from the increasing impact of fishing activities, pollution and the wider effects of climatic changes. The Working Group proposes a new survey ten years after the first since it is believed that this period of time should be adequate to reveal changes of a long-term nature. Such a study would be of great importance both in terms of scientific and technical development as well as in management and environmental control.

The study will aim to detect long-term changes in the benthos at population, community and biotope levels, and will enable greater understanding of:

a) species distribution
b) biodiversity changes

c) biomass changes
d) changes in size spectra
e) changes in predominant life history strategies
f) productivity

Information of such a survey will also be important in management decisions concerning:

a) regulation of fisheries
b) closed areas
c) nutrient inputs
d) oil and gas explorations
e) marine conservation areas

This study will also encourage the development and application of new and improved technologies, for sampling, sediment measurements, positioning and imaging systems and taxonomy.

10 OIL SPILLS

10.1 *Aegean Sea* Oil Spill

Dr Lopez-Jamar reported on the *Aegean Sea* oil spill. In December 1992 the oil-tanker *Aegean Sea* was wrecked in the vicinity of La Coruña, NW Spain, releasing about 60000 t of light crude oil. Benthic studies were undertaken to estimate the effect of the spill on the subtidal infauna of the area. The paper in Annex 13 presents the results of the first year of study on the Ría de La Coruña, Ría de Ferrol, and adjacent continental shelf.

As data on temporal evolution of benthic infauna from Ría de La Coruña were available, an estimation of the changes caused by the spill could be made. In sandy areas, a reduction of species number and a high mortality of certain taxa were recorded, as well as a dramatic increase in the abundance of opportunistic polychaetes. The community in the harbour area is well adapted to chronic spills and frequent sediment disturbances, and thus the effects of the spill have been less important. Only a few species decreased their abundance, while many other did not show any effect or even increased their number.

Previous data on benthic dynamics were not available for the Ría de Ferrol and adjacent continental shelf. The evolution of the communities since the oil spill suggests that there have been some effects attributed to the oil spill, although, to date, the scarcity of samples does not permit definite conclusions.

Professor Heip asked whether intertidal areas were being studied, but Dr Lopez-Jamar did not have the information to hand. Apparently dispersants were not used on this occasion, oil was either sucked up or directed to specific of parts of beaches.

10.2 The *Braer* Oil Spill

Dr Kingston gave a report on the results of the benthos studies of the sea bed affected by the wreck of the oil tanker *Braer* which went aground off sheltered in January 1993, spilling 84,000 tonnes of oil into the sea.

Although almost all of the oil was dispersed into the water column surveys carried out a few weeks after the spill showed that there were local areas of seabed to the west of Shetland and southeast of Fair Isle that had elevated levels of hydrocarbon in the sediments. In some places there exceeded 20,000 ppm.

A benthic survey was carried out in which transects were run from areas of low to high oil contamination and the community composition and structure analysed to assess the impact of the oil.

Univariate and multivariate analysis of the data which was obtained from 5 0.1 m^2 grab samples at each of 23 sites failed to reveal any faunal distribution trends that could be related to the presence of oil. However, certain species known to be sensitive to oil were absent from the contaminated areas, most notable being all members of the Amphipoda. In addition, species known to be associated with oil contaminated conditions were present at the most heavily impacted sites (eg *Capitella* spp, *Thyasira* spp and *Chaetozone setosa*).

Meiofaunal studies were also carried out at selected sites and again, regardless of the high levels of oil contamination at the most contaminated sites, no trends in distribution were revealed by univariate and multivariate statistical approaches. However, the copepod family Ectinostomatidae was completely absent from heavily oiled sediments.

Comparison of the response of the diversity index H_s with respect to sediment oil concentration between offshore studies associated with oil well drilling activities and the *Braer* spill showed surprising differences. Whilst at sediment oil concentration as high as 10,000 ppm, the benthos off Shetland showed no fall in diversity, the diversity of benthos around the offshore platforms falls dramatically at sediment oil levels of only 100 ppm. This is a surprising result and may either indicate that the offshore benthos is responding to some other factor or that the offshore response is to chronic pollution (in most cases several years). In the *Braer* spill, it may be that the surveys were carried out too soon after the accident (1-5 months) to evaluate the effects of chronic exposure to be manifested.

11 BIOTOPES CLASSIFICATION

D Connor of the Joint Nature Conservation Committee (UK) gave a presentation on the proposal to develop a new standard Biotope Classification system for the north-east Atlantic. The main problem highlighted was the diversity of classification systems currently in use and the lack of intercomparability and the lack of a single comprehensive system covering all rock and sediment habitats. The system has been developed to cover marine, estuarine and brackish water systems, rock and sediment, the upper-shore to the continental shelf (200 m). Although the system will be based on data from the British Isles it should be expandable to the north-east Atlantic. A more detailed report is given in Annex 14. The classification is being developed as part of the BioMar programme and will substantially develop the existing marine elements of the European CORINE classification.

Dr Asjes asked whether there was any software developed to accompany this classification system. Dr Connor said that this was a desirable area for development. Dr Rumohr asked what whether this type of system was really useful in view of its lack of dynamics by delimiting the biological aspects of communities. D Connor replied that they would take into account the effects of variation caused by pollution or natural temporal change and also argued that the system was based on the observation that repeated surveys had shown that certain biotopes remained consistent. However, Dr Rumohr argued that this takes no account of the continuing development of biological systems. D Connor emphasised that in the hierarchical classification the broad features at the top of the system accounted for biotope dynamics whilst finer detail at the lower end of the classification related more directly to field observations. Dr Nørrevang advocated the idea of the scheme, especially to enhance politicians' understanding of marine communities as long as the system was not enforced on scientists as the system is too inflexible to accommodate the subtle differences encountered.

12 INTRODUCED SPECIES

Spatfalls of the Non-native Oyster, *Crassostrea gigas*

Dr Kaiser reported on the occurrence of a spatfall of Pacific oysters in the Menai Strait and the River Exe. Pacific oysters one of the most important cultivated bivalve species in England and Wales. However, concern has been expressed about the possibility that this species may spawn in UK waters and develop a sustainable population. Annex 14 attached to this report gives a detailed account of observations of naturally settled spat at two sites. Settlement date was estimated from the size and weight of the animals and from growth lines in the shell matrix, results indicated that these animals settled in 1989 or 1990. This settlement is attributed to the unusually warm summers that occurred in both years. However, the number of spat is too low (<1000) to support a self sustaining population.

13 ALGAL BLOOMS

Dr Kaiser reported on the after-effects of a *Phaeocystis* bloom on benthic fauna in the Menai Strait, North Wales. The benthic infauna at the study site has been investigated triannually since 1991 as part of a study of the impact of intertidal clam cultivation. In May and June 1992 an unusually dense *Phaeocystis* bloom occurred along the North Wales coastline. Once the bloom crashed, the large amount of decomposing material on the seabed caused the expected anoxic conditions. However, oxygen levels were so low that common shore crabs came ashore, and large numbers of fish were killed. There was a severe reduction in the abundance and biomass of the benthic infauna at our study site, when compared with the benthic community documented 12 months previously. Under normal circumstances the community was dominated by *Pygospio elegans* ($158/m^2$), *Scrobicularia plana* ($134/m^2$) and *Cirratulus* spp ($37/m^2$). However, two weeks after the onset of anoxic conditions, the community was dominated by *Crangon crangon* ($45/m^2$) and the density of all other species was $<3/m^2$. The community had also become more heterogeneous, as would be expected after a major disturbance event. Further analysis of samples taken after July 1992 will reveal how quickly the site has been recolonised.

14 RECOMMENDATIONS

The Benthos Ecology Working Group recommends that the Benthos Ecology Working Group meet at Kaldbak, Faroe Islands on 3-6 May 1995 to :

1 Plan a repeat of the 1986 North Sea benthic survey in 1996.

2 Evaluate the use of computer aided taxonomy systems for identification of benthic species.

3 Review co-operative benthic studies throughout the ICES area .

4 Review methods for studying hard bottom substrata and intertidal communities.

5 Review studies on the effects of fishing disturbance on benthic communities.

6 Define indicator species which are sensitive to the effects of physical disturbance.

15 ACTION LIST

1 Dr Hiscock to report on the development of a north-east Atlantic classification of marine benthic biotopes.

2 J Craeymeersch/Dr Kaiser to report on the EC IMPACT II project.

3. J Craeymeersch to report on the benthic by-catch of beam trawls.

4 Dr Asjes to report on the Dutch Benthic Atlas.

5 Dr Essink, Dr Kingston, Dr Krönke, Dr Kunitzer, Dr Lopez-Jamar, Dr Neiland, Dr Nørrevang, M Poweillet, Dr Rowell, Dr Rumohr to evaluate the use of computer based taxonomy systems. Professor Heip/J Craeymeersch to co-ordinate.

6 Dr Andersen, D Basford, Dr Brattegard, Dr Duineveld/Dr de Wilde, Dr Essink, Professor Heip, Dr Kaiser, Dr Kingston, Dr Krönke, Dr Rumohr to report on the progress in planning the North Sea Benthos survey for 1996.

7 Dr Norrevang to report on the taxonomic techniques used in BIOICE.

8 T Rowell/ Dr Schwinghamer to report on results from the Canadian experiments on the impact of otter trawls.

9 Dr Schwinghamer to report on the progress developing acoustic methods for identifying benthic animals *in situ*.

10 Dr Kaiser to report on the effects of intertidal clam cultivation on benthic communities.

11 Dr Kingston to report on the final results of the *Braer* oil spill.

12 Dr Lopez-Jamar to report on further results from the *Aegean Sea* oil spill.

13 Dr Künitzer to report on the progress of the Joint Monitoring programme, the Arctic monitoring programme and the Baltic monitoring programme.

14 Dr Warzocha to report on the results of benthic studies in the Pomeranian Bay.

15 Dr Warzocha to report on results of long-term monitoring studies.

16 Dr Hiscock to report on the results of inshore surveys.

17 Dr Hiscock to report on techniques for studying fauna on hard substrata.

18 Dr Duineweld to report on monitoring studies in The Netherlands.

19 Dr Duineweld to report on bioturbation and sediment phytopigments.

20 Dr Kröncke to report on the latest results from the analysis of the Nordeney long-term data series.

21 Dr Kröncke to report on progress on German Arctic studies.

22 S Dahle to report on Norwegian/Russian co-operative studies in the Barents Sea.

23 Dr Andersen to report on the meeting of the Nordic Council to examine the need for comprehensive literature on the identification of invertebrates in Nordic countries.

24 Dr de Jong to report on the effects on benthos of deepening the shipping channel in the Westerschelde.

25 Dr Kaiser will co-ordinate the production of a list of species which are vulnerable to the effects of physical disturbance to the seabed with input from all working group members.

ANNEX 1

List of Participants

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(Yerseke May 10-13)

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AN INTRODUCTION TO BIOMAR
'MARINE COASTAL ZONE MANAGEMENT: IDENTIFICATION, DESCRIPTION AND MAPPING OF BIOTOPES'

The management of coastal ecosystems requires a structured knowledge of the types of habitats and communities (biotopes) present. BioMar is a partly EC-supported (through the LIFE Fund) Irish-led, four-year project which began in 1992. Its main aims are to:

i. produce a classification of benthic marine biotopes applicable to the cold-temperate north-east Atlantic and

ii. develop computer software for the storage, retrieval, analysis and presentation of information on coastal biotopes using computer mapping systems (Geographical Information Systems).

The study will include both littoral (intertidal) and sublittoral biotopes.

In conjunction with this, an ecological survey of the coast of the Republic of Ireland will be conducted. Marine areas will be surveyed by Trinity College Dublin with assistance from University College Galway and Aquafact International. Maritime areas will be reviewed, and a list of candidate sites for inclusion in NATURA 2000 (protected areas under EC Habitats Directive) will be selected by the National Wildlife and Parks Service in Dublin. A demonstration project by the University of Newcastle, UK, will examine the feasibility of remote and rapid survey techniques (e.g. sonar, video) in the identification of marine biotopes. Results will be linked with those from:

i. current surveys in Britain by the Marine Nature Conservation Review team of the Joint Nature Conservation Committee, and

ii. previous studies in Northern Ireland (by the Ulster Museum and Heriot-Watt University)

to develop the biotopes classification and data handling and presentation systems.

Additionally, the location and the status of marine protected areas in Europe and relevant legislation in different countries will be reviewed by AIDEnvironment, Netherlands.

The final product of the Irish part of the BioMar project will be a compilation of information pertaining to coastal biotopes (e.g. biotope descriptions and locations, bibliography, cartographic data) in a database with maps and analytical facilities. The information will be easily accessible for non-specialists involved in coastal management in Ireland. In a European context, the results will form a pilot study for developing a marine biotope classification and data handling system for at least the cold-temperate north-east Atlantic. This will facilitate the EC CORINE (Co-ORdination of INformation on the Environment) classification managed by the European Environment Agency Taskforce.

BIOFAR

Investigations of the marine benthic fauna of the Faroe Islands

Programme description
and
activities

April 1994

Kaldbak Marine Biological Laboratory
við Skriðubakka, FR-180 Kaldbak, Faroe Islands

Faroe Islands and the surrounding seas

The Faroe Islands

The Faroe Islands are an achipelago of 18 larger islands at 62°N and 7°W.

The Faroes themselves and their shelf area are the remnants of a volcanic area evolved about 45-25 million years ago. The Faroes constitute part of the ridge stretching from Scotland to Greenland which again constitutes the border between the colder Norwegian Sea and the warmer Central Atlantic.

The economic zone stretching to 200 nautical miles or the mid lines towards Iceland and the Shetland Islands comprises ab. 308.000 km².

Areas less than 200 m deep comprise ab. 21.000 km².

Water masses and currents are equally diversified. Three distinct water masses are recognized. In the deeper channels and north of the islands bottom temperatures are below zero, while the deep bottoms west of the islands are within the deep Atlantic regime.

The sea bottom is very varied from mud in fjords and sounds to bedrock, where strong currents prevail.

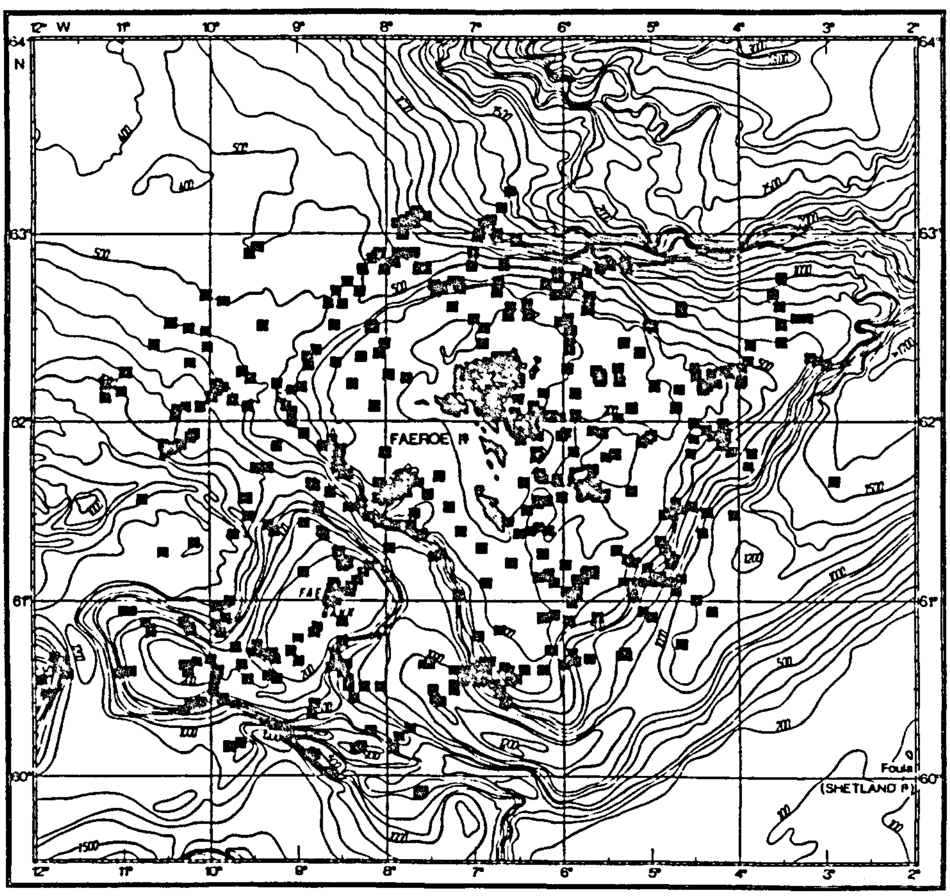
Bottom topography

The islands and their surrounding shelf constitute a mini-continent. The overall topography of the sea bottom, the extent of the continental shelf and the adjoining deep trenches and basins are illustrated by the map.

Bottom types

We have no accurate map of bottom types around the Faroes, although official maps give some clues. From the registrations in connection with sampling and from various new and old map sources, attempts are currently being made to map these bottoms.

This much can be said by now, that as would be expected, the deeper sediments are mud, clay or silt, while coarser sediments are found on the "continantal" slope and on the banks. Very rough bottom is found in several places, including stones, boulders and rock. No easy bottom to sample!



Map of Faroese seas with sampling stations

Water masses and currents

Oceanographers have studied water masses and currents around the Faroe Islands, especially Bogi Hansen from the Fisheries Laboratory of the Faroes.

Water masses from a branch of the Gulf Stream, called North Atlantic Water (NAW), run NNE between Iceland and the Shetlands, thus passing on both sides of the Faroes. This water mass is relatively warm - 5-11° C - is carried into the northern North Sea and the Norwegian Sea. It reaches down to about 500 meters depth.

Deep Norwegian Sea Water (DNSW) enters the Faroe-Shetland Channel from the NE, passes south of the Faroes turning NW through the Faroe Bank Channel and along the southern slope of the Faroe-Iceland-Ridge. The temperature lies just below -1°C and its upper limit lies at around 5-600 meters depth.

North of Iceland and along the northern slope of the Faroe-Iceland-Ridge water masses of about 2-4°C (East-Iceland-Water, EIW) pass SW under the NAW, bends S east of the Faroes into a bend, that turns NE once again, but the bend is very variable in extent. Some of this water intermittantly spills over the Faroe-Iceland-Ridge into the Atlantic.

This complicated pattern leads to great differences in bottom temperatures, and a special study by dr. Håkan Westerberg is accompanied by maps.

On the Faroe Bank an anticyclonic gyre makes the water over the bank more or less stagnate for up to five summer months, but recent investigations show a complicated current pattern. A similar, but less pronounced gyre circumvents the island group itself.

Tidal currents, standing waves and water mass movements combined have a pronounced effect on the bottom environment. Dr. Håkan Westerberg has modelled the bottom currents at the sampling stations, and these velocities are included in the BIOFAR station list. One published paper by Westerberg et.al. adresses the problems of currents and sedimentation along the boarders of the shelf and the banks.

Exploration history

Marine invertebrates have been described from the Faroes since the 17th century, but more thorough investigations did not start before the 19th century. The "Ingolf"-Expedition also sampled in Faroese waters. The Danish fisheries research vessel "Dana" has taken samples in later cruises. In the 1920's the Carlsberg Foundation sponsored a thorough investigation of "The Zoology of the Faroes" resulting in the 6 volume treatise of the same name, 1928-1971.

The BIOFAR-programme

Initiation of the BIOFAR-programme

The vast majority of the samples taken during the Zoology of the Faroes scheme were from shallow depths, obviously due to the lack of appropriate research vessels. Furthermore, since that time new types of sampling gear and new methods for treating the samples have been developed.

Danish and Norwegian marine scientist have for ages taken a keen interest in the North Atlantic and the Norwegian Sea, and many sampling expeditions have been to the deeper parts of these ocean parts.

The Fisheries Laboratory of the Faroes have initiated a programme for multiple species research including studies of stomach contents of the more valuable fish species.

Oceanographers have been studying currents and water masses around the Faroes and Iceland in order to model the exchange of water masses between the Norwegian Sea/Polar Sea and the main body of the Atlantic Ocean.

These were the premises for a discussion, when, by chance, three colleagues of marine biology met in Torshavn in June 1986. They started a preliminary planning for a programme for investigation of the benthic fauna in Faroe waters from about 100 metres downwards, and to have graduate/postgraduate scholarships attached to the scheme, so that highly needed educational aspects could be included in the programme..

In January 1987, the NOS-N - Joint Committee of the Nordic Natural Science Research Council - funded a meeting in the Nordic House in Torshavn where 17 marine biologists from the Scandinavian countries and UK, discussed the feasibility of a large scale programme.

The enthusiasm of the participants warranted a search for funding, and the Fisheries Laboratory of the Faroes provided the research vessel "Magnus Heinason" for a 12-day pilot cruise. The results of this early initiative were very promising. 128 samples were taken on many different bottom types, and preliminary identifications of some groups showed the presence of many species, not previously found in Faroese waters. Subsequently, different funding institutions were approached, and by the end of the year funding had been secured for a three-year programme to be called BIOFAR.

Objectives

The objectives of the programme were laid down by the January 1987 meeting like this:

1. to provide local knowledge of the marine benthic fauna, establish possibilities for further local studies and create Nordic contacts for such studies.

2. to provide knowledge of the benthic fauna in Faroese waters, which is interesting bio-geographically, as a natural basis for local fisheries and as a reference area for pollution studies.

3. to use this inter-Nordic project to coordinate Nordic taxonomic expertise, for the benefit of further marine research projects.

Accordingly, two main sub-programmes were set up, see appendix

In view of the previous investigations in shallower waters, the depth limits were set to 100-1000 metres, but it has become clear that the programme has to be widened, including all depths, in order to obtain a comtemporary, overall view of the marine benthic fauna.

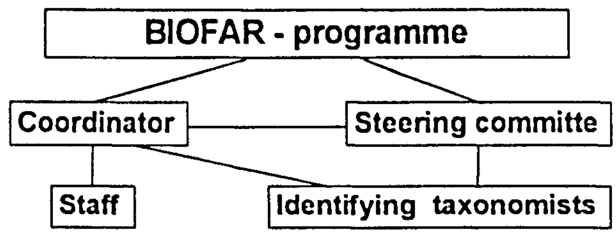
The BIOFAR-programme was scheduled to study macrofauna, i.e. by the use of 1 mm sieves. However, meiofauna was studied by some guests scientist - especially in connection with tha "Valdivia"-cruise.

While running the programme several special studies, designed by the participants, demanded special samples to be taken.

Organization

BIOFAR was run under the auspices of NKMB (Nordic Council for Marine Biology) in close cooperation with the NKFO (Nordic Council for Physical Oceanography) which are both commissions under the Nordic Council of Ministers.

A steering committe (board) was elected, see list of members, appendix . The board decides upon overall finances, larger investments,cruise plans, guests, attached projects, colloquia and workshops, while the coordinator was in charge of running the programme and directing the laboratory.



Dr. Arne Norrevang was appointed coordinator of the programme and director of the Kaldbak Laboratory.

At present the labotatory is run by the Faroese Government, with Arne Norrevang as director, and the former board continues its activities.

Finances

The main part of the programme - three years of intensive sampling, costing 215.000 US$/year - was funded by the Nordic Council of Ministers (Nordisk Ministerråd), the Carlsberg Foundation, the Faroe Government and Faroese financial institutions. For financing special purposes various funds were approached.

The continuation of the programme from 1991 onwards is financed by the Faroese government with additional funds from Faroese banks and the Faroe Seafood Ltd.

Financial sources 1988-1993 for the BIOFAR-programme (DDK)

	Government	Nord.Coun.Min.	Carlsbergfondet	Banks etc.	Total
1988	865.000	750.000	250.000	160.000	2.025.000
1989	264.500	750.000	250.000	160.000	1.424.500
1990	289.000	750.000	250.000	160.000	1.449.000
1991	490.000	0	150.000	125.000	765.000
1992	544.000	0	50.000	125.000	719.000
1993	503.000	0	0	125.000	628.000
Symposium sept. 1991				344.000	344.000
Total 1988-93	2.955.500	2.250.000	950.000	1.199.000	7.354.500

Facilities

The requirements of running the programme were such that a marine laboratory had to be established in the Faroe Islands.

In the village of Kaldbak, about 18 kilometres north of Torshavn, we found an old building originally used partly as a general store and partly as storage for salted fish, later as a plant for glassfibre boats and finally for processing *Mytilus*.

The building contained only floors and little else, so laboratories, dormitory and storage rooms were erected inside the existing framework, funded by the Faroe government. Furniture and some equipment was provided through Faroese firms and the Faroe government. On May 2nd the laboratory was officially opened in the presence of the Minister of Education and representatives for the Coast Guard, the Fisheries Laboratory, the University and many others.

Most of the laboratory equipment was purchased by an initial extra grant from the Faroese Gocernment.

Staff

The programmme and the Kaldbak-Laboratory is directed by dr. Arne Norrevang from his position as curator at the Museum of Natural History, Torshavn. The technical staff at present (July 1993) consists of one janitor, one sorting assistant on half time and one sorting assistant/clerk on full time. During the main sampling programme an additional sorting assistent was employed.

Library

Funds for the library are limited, and although we have established good relations with the Landsbókasavn (Faroese National Library) and institutional libraries, eg. at the Fisheries Laboratory, we have limited acces to relevant literature.

A quite good collection of identification books is kept in the laboratory.

Also, we try to build up a collection of reprints covering the subjects of identification, faunistics and distribution of all marine groups for the Northern and especially Northeastern Atlantic.

From the Zoological Museum, Copenhagen, The University Library, Bergen, and the Kristineberg Marine Biological Station we received duplicates. Prof. emer. Hans Brattström, Bergen, donated a large part of his reprint collection, built up during his long term as professor of marine biology.

At present the collection of book and reprints is being catalogued in a library database.

From the taxonomic specialists we hope to obtain relevant reprints and lists of identification papers for each animal group, and we intend to complete the collection with photocopies of papers no more available from the authors.

Reference collection

The specialists, identifying the BIOFAR material are asked to select representative specimens of each taxon to be kept as a reference collection at the Kaldbak Laboratory. This collection will be of great help for any eologist, physiologist a.o., who in the future may visit the laboratory to study communities or species, as they will have an opportunity to check their identifications at the laboratory.

Database

A database programme was designed specifically for the needs of the BIOFAR programme. It is possible to print lists for stations, for species and species groups and to plot maps from a menu system, while more complicated operations can be designed according to wishes from the individual specialists.
d specifically for the needs of the BIOFAR programme. It is possible to print lists for stations, for species and species groups and to plot maps from a menu system, while more complicated operations can be designed according to wishes from the individual specialists.

SAMPLING PROGRAMME

Sampling strategies

The pilot cruise gave a certain basis for the planning of later cruises, and sampling strategy was currently revised during the three main sampling years.

Both infauna and epifauna as well as hyperbenthic fauna should be sampled on as many positions as possible.

Two vessels participated for all three years of the main sampling programme, "Magnus Heinason" from the Fisheries Laboratory of the Faroes and "Håkon Mosby" from the University of Bergen. It was found inexpedient to use all types of gear on each individual cruise so that "Håkon Mosby" mostly sampled soft bottom and hyperbenthic fauna, while "Magnus Heinason" sampled hard and rough bottoms.

The sampling scheme was designed to cover most of the area within the Faroese 200 mile zone between 100 and 1000 meters depth and preferably with all types of gear. The !988 and 1989 cruises covered most of the scheme, and in 1990 additional sampling were made at positions that were found to be of special interest.

Sampling cruises

For the initial three sampling years of the programme - 1988-90 - the "Magnus Heinason" of the Fisheries Laboratory of the Faroes and the "Håkon Mosby" of the University of Bergen were available for a two-week cruise each.

As the programme progressed the "Valdivia" of the University of Hamburg joined the BIOFAR for research on meiofauna (interstitial fauna) for 18 days in May 1990, when more than 50 samples were taken, using a score of different gear. Also, the "Challenger" joined during one week for research of benthic fish in relation to food items present in the benthic fauna.

The Faroese Coast Guard has provided vessels for sampling for special purposes, e.g. coral- and sponge-asssociated faunas, in total more than 780 samples.

Furthermore, the BIOFAR station list, which will be provided upon request, contains the information on samples taken for other special purposes by smaller vessels - some of them inside the fiord systems.

Gear

A number of different gear types were used routinely, while more specialized gear was used for special purposes, e.g. for meiofauna.

Some of the sampling gear was specially designed for the rough bottoms around the Faroes.

Thus, the dimensions of steel and nets was increased as compared to gear used in other programmes.

Triangular dredge

The triangular was made of old truck springs. The frame measured 80 cm on each side. The net of the bag was fastened to round iron welded onto the inside of the triangular frame. Finer netting can be fitted as an inner bag to the last section of main bag. The arms from the corners of triangle were made of round iron with eyes in both ends (arms can be exchanged). One, which is slightly longer and with a larger upper eye than the other two, is shackled to the wire through a swivel. The upper eyes of the two shorter arms are fastened to the eye of the first one with a binding of twine or nylon cord. An "apron", made of strengthened rubber conveyor belt is applied to the outside of the bag on the side with the two shorter arms. A floater is attached to the corner with the longer arm.

Thus, the triangle will always touch the bottom with the apron, and if the gear fastens on rough bottom the twine will be severed, and the pull will continue through the upper arm.

Sneli-dredge (detritus sledge)

is a modification of conventional detritus sledges (modified by Jon-Arne Sneli, Trondheim). It is made of stronger material than the original modification. It is fastened to the wire with bindings of twine or nylon cord and a strong safety wire shackled to the towing wire is fastened to the hind end of the sledge. If the twine binding breaks the sledge will turn round and, hopefully, be brought on deck hind end first.

RP-sledge (hyperbenthic sledge)

is a modification of the original Rothlisberry-Pierce-sledge (modified by Torleiv Brattegard, University of Bergen) It war recently described in a scientific paper

McIntyre grab

This gear was modified by Alf Josefson, Copenhagen. It is not operated by springs, but rather by divergings arms as in the vanVeen grab. It can be loaded with extra weights at the corners of the frame - lead slabs of 5 kg each.

Treatment on board

Smaller amounts of sampled material was emptied into 90 l buckets. A special stool has been made for unloading the McIntyre-grab, so that the contents could be emptied into a container (plastic basin, 25 l).

Larger amounts of material was poured directly onto the deck and sorted by hand and - partly or in full - sifted through sieves. As a standard hole sieves with 3 (or 5) and 1 mm holes, 40 cm in diameter, were used, see drawing. They were placed in a sieving stool allowing for consecutive sieving from 3 mm to 1 mm. Many samples - mostly decanting from the RP-samples - were sieved down to 0,5 mm.

A sorting table was made with an outlet leading to the sieving stool.

Soft sediment samples were washed in a special washing tank, which could be inclined to about 90°, part of the opening of the tank at the outlet was covered. The outlet was a spout, 15 cm outer diameter. A flexible hose with spiral wire (standard for kitchen exhausts) was attached to the outlet. The sieving stool could be placed well under the rack.,i.e. the foot of the rack is open under the nozzle side of the tank.

The contents of the RP sledge was poured into buckets and decanted through hand-held sieves down to 500 micron mesh.

Conservation on board

The sampled animals were contained in standard, square-bottomed plastic vials of 1, 0.5, 0.25 litres. Except for samples meant for special purposes, all samples were preserved in ab. 4 % formalin with a surmount of borax. A small tablespoon of powdered borax was added for each litre. One hand writtened label (with pencil on plastic paper) was placed in each vial with station number, depth, gear, and sorting method, and in addition a label made by DYMO label marker on red plastic tape containing station number. On the screw lid was placed a pencil written label containing station number and sorting method.

Large and bulky samples were stored in self sealing plastic bags or bags closed with plastic strips, and placed in 30 litre drums with conservation or preserving fluid. Plastic bags were made onboard to different sized with a plastic welding apparatus (and some bags were also closed with this apparatus).

Station list

All stations were positioned with reference to the ship's log. The station list form was preprinted and contained spaces for various information, e.g. sorting method, number of vials and bags, sediment type, faunal composition etc.

Sorting of samples

When the preserved samples arrived at the laboratory from cruises, all of them were washed in tap water (which is almost destilled in the Faroes) and transferred to 70-80 % alcohol. Labels and plastic markers and the number of vials and bags were always checked against the station list.

The animals were sorted under binocular stereoscopes on the 45 or so different groups indicated in the preprinted sorting list form. Later, some groups, i.e. Isopoda, Amfipoda and Polychaeta, were sorted to lower groups by specialists or by specially trained sorters.

Some groups have not been assigned to specialists because of difficulty in identifying fixed material, e.g. Turbellaria and Nemertea.

Identification of collected material.

The main object of the whole programme is to provide an annotated species list of the benthic fauna around the Faroes.

About 65 taxonomist from all over the world have joined the BIOFAR-programme to identify material belonging to their respective groups.

The specialists were asked to fill in preprinted identification lists, according to an instruction aimed at standardizing the entries into the BIOFAR database.

BIOFAR - database

The main database is programmed as an interrelational database in dBaseIV - especially for the BIOFAR-programme - comprising 3 files:

1. station list with all relevant data, including hydrographic parameters (see below);
2. species list with codes for group down to family level, species code, species name and auctor;
3. all identified species referring to each station number.

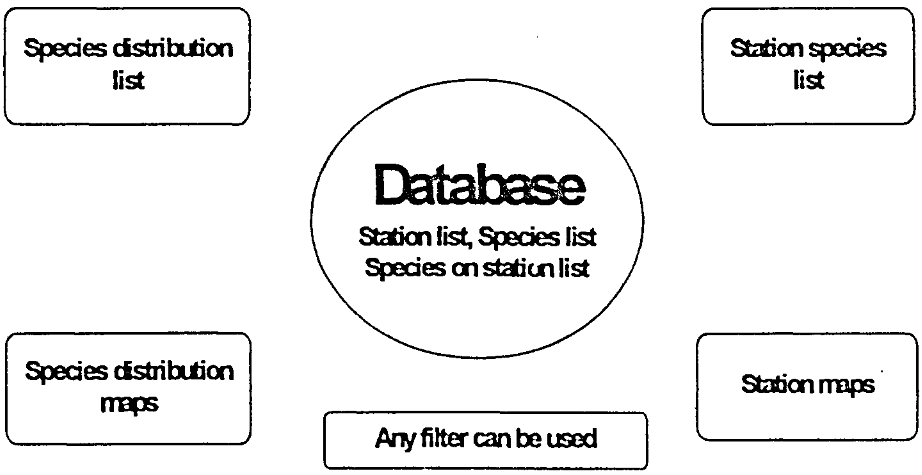
An elaborate menu system manages coding of results, editing and reporting (on station, on species, filter setting etc.) and for plotting on preprinted maps. More complicated operations, e.g. various couplings of files and special wishes for report managing can be designed according to wishes from the individual specalists. The programme is copyrighted, but will be made available to international cooperative projects.

The Nordic Council for Physical Oceanography has provided a separate database, which is linked to the main database station list. It comprises hydrological parameters (measured or interpolated from about 11.000 records), eg. temperature, salinity water masses, and bottom current velocity, covering nearly all stations.

All routine applications are controlled by a menu system. The different possibilities for plotting, listing and making corrections are indicated on the following page.

As there are more than 800 sampling station and each station may yield more that 100 different species, we will end up with a BIOFAR collection

Overview of the BIOFAR database



consisting of more than 100.000 vials. In order to keep track of all vials, they will be entered into the database as a separate collection file, referring to shelves and racks in the storage rooms.

New species

Our policy is that type specimens should be kept at one of the larger museums with special facilities for storage of such unique material. Therefore, all type specimens from the BIOFAR material must be deposited at the Zoological Museum, University of Copenhagen.

Some paratypes may be kept at the instituion of the individual specialist.

The BIOFAR specimen collection

All material remains property of the Museum of Natural History, Thorshavn.

When the identified material has been returned to the Kaldbak Marine Biological Laboratory, it will be stored and curated as normally in a museum collection. Until the identification of all groups has been completed, the material will remain at the Kaldbak Laboratory, and only after that will it be transferred to the Natural History Museum of the Faroes.

At the Kaldbak-Laboratory a reference collection will be set up, consisting of selected specimens of all species identified.

A substantial reference collection will be deposited at the Zoological Museum, University of Copenhagen

Also, the identifying specialists may keep a minor reference collection at his/her home institution on a deposit basis.

A database programme will be used to registrate the whole collection, including all specimens deposited elsewhere.

The collections will open to use for specialists as is normal for museum collections. Applications should be sent to the relevant curator and to the Kaldbak Marine Biological Laboratory, so that any use of the BIOFAR material can be tracked.

Publication policy

As mentioned, the results will ultimately result in an annotated fauna list, for which the specialists are asked to provide the manuscripts according to a defined layout. Otherwise, they may publish any results, taxonomic, faunistic or other, according to their wishes. It must be mentioned in the papers, that they present results of the BIOFAR-programme, preferably as "Contribution from the BIOFAR-programme" under the title or as a footnote.

Although the identifications will be entered into the BIOFAR-database, they will not be available to other scientist, without the permission of the specialist in question.

OTHER ACTIVITIES

Scholarships

During the initial phases of the project the Nordic Council for Marine Biology (NKMB) allocated scolarships to the BIOFAR-programme. Up to six months could be allocated to each student, and normally half of the time was spent at the Kaldbak Laboratory, while the other half might be spent at other Nordic institutions.

Graduate courses

In cooperation with the NKMB two graduate course were held:

8.-19. august 1988 at the Department of Marine Biology, Universitety of Bergen, on the topic: "Identification of Polychaeta, Crustacea and Mollusca". There were 9 participants from the Faroes (2), Norway (2), Sweden (1), Finland (1) and Denmark (3). Teachers worked: dr. J. H. Fosså, Bergen, dr.T. Brattegard , Bergen, dr. E. Oug, Grimstad, dr. J-A. Sneli, Trondheim and others. Mainly BIOFAR material was used and 81 taxa of Polychaeta, 141 of Crustacea og 99 of Mollusca were identified.

7.-19. august 1989 at Sletvik Field Station, Universitety of Trondheim, with the topic: "Polychaeta og Mollusca - identification, nomenclature og systematics". There were 10 participants from Iceland (1), Norway (2), Sweden (2), Finland (1) and Denmark (4). Teachers were: dr. T. Holthe, Trondkeim (polychaetes), dr. E. Oug, Grimstad (polychaetes), dr. A. Warén, Stockholm (molluscs), dr. P. B. Wikander, Grimstad (molluscs) and dr. J.-A. Sneli, Trondheim (molluscs). Samples from the BIOFAR-project were used as material, and 49 taxa of polychaetes and more than 200 taxa of molluscs were registrered.

Workshops.

In cooperation with the NKMB four workshops were held:

1.-8. October 1989 at the Kaldbak Laboratory on the topic: "Identification of Crustacea Isopoda". Five scientists and two postgraduate students participated. 67 species were identified, 36 were new to the Faroe region, and the number of identified species for the area now amounted to 91.

20.-26. august 1990 a workshop was held at the Kaldbak Laboratory on the topic: "Faunal analysis and zoogeografi - data analyses". Five scientists and four postgraduate students participated. A number of correlation and correspondance analyses were conducted applying to faunistics and zoogeography of material from the BIOFAR programme.

16.-23. september 1990 a workshop was held at the Marinbiological Field Laboratory, Frederikshavn on "Identification of Polychaeta". Nine scientists and one postgraduate students participated. A total of 101 taxa were identified, 63 of them being new to the Faroe area. Probably, at least five species were new to science.

A further workshop on "Mollusc taxonomy" was held in Frederikshavn 26. april - 4. may 1991. 8 malacologists joined efforts in identifying BIOFAR molluscs, and practically all material was identified (except for Scaphopoda).

4.-12.121993 13 Polychaete specialist met for a workshop in Frederikshavn, dividing the BIOFAR-material between them for identification, and for discussion of taxonomic problems with the research area.

Symposium

In 1990 it was decided to bring together as many experts as possible for a symposium to be held in the Faroes in 1991.

Cooperation with NKFO (Nordic Council for Physical Oceanography) had been very rewarding, so it was found desirable that oceanographers joined the symposium.

The purpose was multiple: that the biologists would be informed of the work and methods of their oceanography colleagues; to discuss further procedure in the programme - especially the intended fauna list; and last but not least to coordinate oceanography and faunistics as far as possible.

The symposium was financed by grants from NOS-N (Joint Committee of the Nordic Natural Science Research Councils), the Nordic House in the Faroes, Westnordic Cooperation, Búagrunnur Føroya, Føroyagrunnurin frá 1971, NKMB, NKFO and Atlantic Airways. The Faroese Government hosted the symposium dinner. Facilities for the meeting were provided by the Nordic House.

74 participating scientists presented 46 lectures and 26 posters on oceanography and benthic fauna of the Faroe Islands.

The abstracts from the symposium were published in the Yearbook of the Nordic House 1991-92, and separates are presented to authors and marine institutions. The abstract titles are listed separately under the heading "Publications".

Guest scientists

In connection with the sampling cruises, many of the participants stayed for shorter or longer periods at the Kaldbak Laboratory to work with identification of their specific groups. Dr. O. Tendal, Copenhagen studied Porifera, dr. T. Brattegard, Bergen, Mysidacea and Decapoda, dr. J. Svavarsson, Reykjavik, Isopoda and dr. A. Josefson, Copenhagen worked on community structure of soft bottoms.

Meiofauna has been studied relatively independant of the main BIOFAR programme. Lic. scient. R. Møbjerg Kristensen, Copenhagen, with dr. A. Nørrevang, Kaldbak, made preliminary studies of meiofauna in preparation for the "Valdivia" (University of Hamburg) cruise in April 1990.

In connection with the "Valdivia" cruise, prof. O. Giere, Hamburg, worked on Oligochaeta, prof. R. P. Higgins, Washington, on Kinorhyncha, lic. scient. R. Møbjerg Kristensen, Copenhagen, on Tardigrada and Loricifera, stud. scient. M. Jørgensen, Copenhagen, on Tardigrada and fil. lic. T. Cedhagen, Gøteborg, on Foraminifera.

Lic. scient. M. Berggren, Kristinebergs Marinbiologiska Station, investigated the occurrence of shrimps in the sublittoral.

Fil. dr. F. Pleijel, Stockholm, studied

polychaets, especially from shallow waters.

Dr.scient. T. Holthe, Trondheim, identified terebellomorph polychaetes.

Dr. M. Køie, Helsingør: fish parasites and their invertebrate vector hosts.

Dr. C. Clausen, Bergen: Gastrotricha, in particular from the Faroe Bank.

Dr. G. Guðmundson, Reykjavik: Foraminifera.

Fil.kand. Christoffer Schander, Göteborg: pyramidellid molluscs.

Prof. Peter Ax, Göttingen: euryhaline Turbellaria.

Stud. scient. Grete Dinesen, Kobenhavn: biology of *Modiolus* and associated fauna.

Drs. Åke Granmo and Kerstin Magnusson, Kristineberg: pollution studies on *Mytilus*.

Cand. scient. Peter Funch Andersen, Kobenhavn: Mesoprocta - new class - on mouth parts of *Nephrops*.

Stud.scient. Anne Cathrine Sorlie, Oslo: algae, genus *Ceramium*.

Stud.scient. Annette Grongaard, Kobenhavn: Tardigrada.

Stud.scient. Lis Lindahl Jorgensen, Bergen: fiord bottom fauna.

Drs. Phyllis and Wyn Knight-Jones, Swansea: sabellid, sabellariid and serpuloid polychaetes.

Stud.scient. Jouni Vainio, Helsinki: gammarid amphipods.

Cand.fil. Susanne Eriksson, Goteborg: physiology of *Nephrops norvegicus*.

FUTURE ACTIVITIES

+ 5 meters to — 100 meters

As mentioned the BIOFAR-programme was designed to sample at depths exceeding 100 meters, because intensive sampling - including marine benthic fauna - was made in the late 1920, resulting in the 6-volume treatise: "The Zoology of the Faroes" (1928-71). During the sampling cruises the reseach vessels sometimes had to go to lesser depths due to weather conditions. As samples taken at depths less than 100 metres were analyzed it turned out that up to 30 % of the species identified were new to the Faroes. It seems that new sampling techniques brought up more species, so that the treatise may be regarded as not uptodate.

Thus, it has been decided to apply for funds for a new benthic programme, which will be designed so as to cover all habitats from the upper splash zone down to 100 meters, includings fiords and sounds. Also, it will be attempted to cover all energy regimes from quiet lagoons and estuaries to hyper-exposed coasts. Botanists will join the programme with a special sub-programme on benthic algae and their distribution.

As working conditions in the upper sublittoral are different from those of a deep project, graduate student, divers and experts will be invited to join in sample collection and sorting, and special subprogrammes will be set up in order to cover as many aspects as possible. Accordingly, different sampling techniques will be used according to wishes from the taxaonomists joining the programme.

Faroe Bank project

In connection with a partial collapse of the cod stock of the Faroe Bank the Fisheries Laboratory has initiated a programme covering all aspects of the Faroe Bank ecosytem. Aseminar with invited participants was held at the Faroese Fisheries Laboratory and reported in the publication " Seminar om Færobanken, Torshavn, 12.-13. november 1992" The Kaldbak Marine Biological Laboratory has joined the project, covering the benthic fauna, and it is intended to initiate - hopefully in 1995 - a larger project with funds from the EU and in cooperation with institutions and universities in several countries.

During the "Valdivia" cruise and later sampling with vessels from the Coast Guard many samples of meiofauna were taken. The results turned out to be extremely interesting. The sediment is mostly fine to coarse shell sand and the meiofauna composition was unexpectedly rich. Out of 22 species of Tardigrada one third had previously been found in coral sand, one third in the deep sea and one third were new to science. !6 species of Loricifera were found, 12 of them new to science, the rest were previously identified from coral sand.

Guests at Kaldbak

After the completion of the BIOFAR programme the Kaldbak Marine Biological Laboratory offers facilities for visiting scientist studying any aspect of marine biology.Likewise, it is intended to open up the laboratory in Kaldbak for scientists who want to studv special species or faunas or make experiments in the aquarium system.

Most of the animals encountered during the BIOFAR-programme can be procured, but at present there is no cooling system to accomodate animals from the deep, sub-zero water mass regime. In most cases the Faroese Coast Guard will help sampling, but for some collections is may be necessary to hire a smaller vessel.

Kaldbak Marine Biological Laboratory

The laboratory building includes about 600 m², but all space has not been taken into use.

Main laboratory	65 m²
Laboratory for 2 scientists	12 m²
Laboratory for 1 scientist	6 m²
Workshop	6 m²
Storage rooms	135 m²
Aquaria room	10 m²
Sorting room (wet room)	15 m²
Dormitory	100 m²

Laboratory equipment comes to the standard of a small marine laboratory, including freezers, refrigerators, incubators, laboratory scale (1 mg) with computer connection, 7 stereo microscopes, 2 microscopes (one is interference-phase-contrast), Computers with print out facilities on P LaserJet printer and HP Plotter, overhead projector, extensive workshop facilities.

The aquaria facilities include has 4 wet benches, aquaria are made to measure for different purposes, and sea water is pumped directly from about 6 m depth.

The dormitory includes one double and 3 single rooms, large kitchen with cooking facilities for up to 10 persons, bathroom and sitting room, that also serves as library. TV and radio.

Pollution research and monitoring in the Faroes

The geographical situation of the Faroes- in the middle of the North Atlantic - makes it ideal for comparative pollution research.

The North Sea Task Force uses one sampling station of the BIOFAR-project as a reference for pollution monitoring in the North Sea.

This station W of the Faroes at appr. 250 meters shows sediment pollution values well below values obtained e.g.in N Kattegat. Concentration of heavy metals is very low. Organically bound Cl is less than ¼ and Br less than ½ of North Sea values. The same applies to insecticide traces.

Organic pollution is low, too. Some threshold fiords are monitored, but only in two of them is oxygen content a minor problem..

Faroese fish is monitored by the Faroese Hygienic Institute and it is a fact that PAH contents are among the lowest in the NE Atlantic

Some scientific results

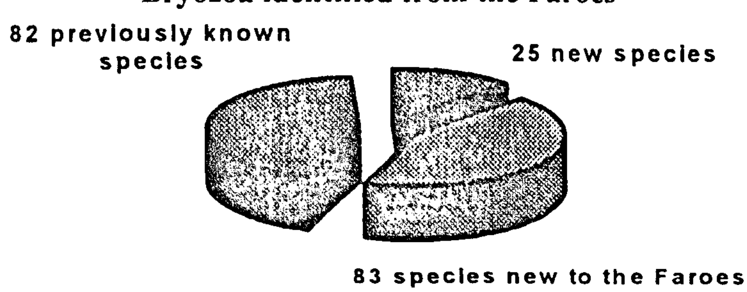
The original objective of the programme was to collect all macrobenthic organisms within the set limits of sampling.

The identification lists are now being returned from the taxonomic specialists, and a preliminary estimate of the number of species is 2 to 3 times the number of benthic organisms hitherto described from Faroese waters and will probably end up around 2500 different species.

Bryozoa and Mysidacea

The number of species of Bryozoa in the material isabout 190 and contains species not previously described - they are new to science. There are 23 Mysidacea, against previously known 2. There seem to be 2 species new to science

Bryozoa identified from the Faroes



The Faroe Bank

The meiofauna on the Faroe Bank contains many species, new to science. The newly descrubed phylum Loricifera are representended by 16 species and no less 12 species are new to science.

Similar conditions prevail for the phylum Tardigrada

SYMPOSIUM
Marine Biology and Oceanography of the Faroe Islands

(published in Nordens Hus Årbok 1991-92: 68-100)

Lecture abstracts

Water masses in Faroe waters in June 1986
Sv. A. Malmberg

Some investigations of the Deep-water through the Faroe-Bank Channel during the 1980's
P. Lundberg

Depth variations of Norwegian Sea Deep Water along the slope
J. Blindheim

On the hydrography and currents north and east of the Faroes
A. Herlevi

Some results of the nordic NANSEN activity during the period 1986-90
S. Østerhus.

Inflow of Atlantic Water to the Nordic Sea - a Bistable System
G. Walin

Reduced gravity modelling of the Northwest Approaches
L. P. Röed, B. Hackett and T. B. Irmann-Jacobsen

A note on wind mixing in a turbulent surface layer in the presence of a horizontal density gradient.
J. Rodhe

Some results from an ADCP and CTD survey in the Greenland Sea in 1988
U. Cederlöf, P. Lundberg and S. Østerhus

Nordic WOCE
E. Buch

Chimneys in the Greenland Sea
P. M. Haugan

Freons in the Denmark Strait: Measurements of ventilation and entrainment
E. Fogelkvist

Estimate of the CO_2-flux from the athmosphere to the Nordic Sea
G. Walin

Water Masses in the Region of the Iceland-Faroe Front
J.F. Read & R.T. Pollard

Water masses and circulation of the upper layers of Faroese waters
B. Hansen

Daylight heating, water transparency and UV-B daylight penetration in the Norwegian Sea and adjacent waters.
N. K. Hojerslev and E. Aas

Phyto- and zooplankton relation to nutrients and hydrography in Faroese waters during spring-summer 1990
E. Gaard and B. Hansen

The availability of suspended food particles in the benthic boundary layer
H. Westerberg

The influence of hydrography on postspawning blue whiting migration past the Faroes
S.H. í Jákupsstovu and B. Hansen

Internal tidal mixing and the distribution of large suspension feeders in the Faroe area
H. Westerberg

Faunal groups related to distribution of water masses in Faroese waters
J. H. Fosså, T. Brattegard and H. Westerberg

Distribution of opossum shrimps (Mysidacea) in Faroese waters
T. Brattegard & J. H. Fosså

Comparing species richness in constant and fluctating environments: A study of some bathyal soft-sediment communities on the Faroe-Iceland rise
L. Engnell

The Stylasteridae (Cnidaria, Hydrozoa) of the BIOFAR project
H. Zibrowius amd M. S. Thorsen

The Scleractinia (Cnidaria, Anthozoa) of the BIOFAR project
H. Zibrowius

The Fauna associated with the coral *Lophelia pertusa* around the Faroes.
R. Frederiksen

Provisional review of the Cirratulidae from the Faroes, with comments on some other groups (Annelida: Polychaeta)
M. E. Petersen

Nephtyid Polychaetes from the Faroe Islands
S.F. Rainer

Sabelliform tube worms of the Faroes and some associated animals
Ph. and W. Knight-Jones

Revision and review of some Ampharetidae (Annelida Polychaeta).
T. Holthe

Photographic observations of the mega-benthos at the Faroes. Demonstration and outlook for ecological analysis.
J. Gutt

Zoogeographical relationships of Cumacea of the Faroes
L. Watling

Distribution and habitat choice of littoral shrimps (Crustacea, Decapoda) at the Faroe Islands
M. Berggren

The Tanaidacea (Crustacea) of the Faroes region.
G. J. Bird

Amphipods of the Faroes: Patterns of distributionrelated to depth and water masses
R. Palerud

Marine bivalves as zoogeographical indicators in relation to their biology
K.W.Ockelmann

The bivalve genus Thyasira in North Eastern Atlantic waters, identification and distribution
O. Stokland

Foraminifera in palaeo-ecology
K. L. Knudsen

Benthic and planktic foraminiferal stratigraphy in cores from the Faeroe Bank Channel and the Faeroe-Shetland Channel
K. B. Christensen

Benthic macrofaunal structure - A comparison between the Faroe shelf and some North Sea areas
A. B. Josefson

The Meiobenthic Fauna of Faroe Bank
R. M. Kristensen

Macrodasyid Gastrotricha from the Faroe Bank
C. Clausen

The Ophiuroidea (Echinodermata) collected by BIOFAR
P.A.Tyler and R.H.Emson

The relationship between the benthic invertebrate fauna and the parasite-fauna of teleost fishes at the Faroes.
M. Koie

Poster abstracts

The Tanaidacea of the deep Norwegian Sea - a comparison with the Faroes and Rockall Trough
G.J. Bird

The use of Foraminifera in stratigraphy and ecology
K. B. Christensen, K. L. Knudsen, G. V. Laursen, S. H. Nielsen and M.-S. Seidenkrantz.

Faroe Bank gastrotrichs
C. Clausen

Pterobranchs of the Faroe Islands
P.N. Dilly

The Phyllodocidae, Lacydoniidae, Tomopteridae, and Pisionidae (Polychaeta) of the Faroe Islands: A preliminary report
D. Eibye-Jacobsen

The benthic fishes of the Faroe Islands
J. D.M. Gordon

The distribution of meiofauna along a depth transect in the Faeroe-Shetland Channel
O. Groß and Hj. Thiel

Faroe Island Bryozoa
P J. Hayward

Some rare species of nudibranch molluscs redescribed from the Faroe Islands
K. R. Jensen

Gnathia abyssorum (G.O. Sars, 1872) (Crustacea, Isopoda) associated with sponges.
A. B. Klitgaard

Dense aggregations of Demospongiae along the shelf of the Faroes, and possible causes
A. B. Klitgaard, O. S. Tendal and H. Westerberg

Some coat-of-mail shells (chitons) of the North Atlantic
A. B. Klitgaard and J. Knudsen

Sabellariidae and Sabellidae of the Faroes including some forgotten species
Ph. Knight-Jones

BIOFAR Serpuloidea and associated fauna
W. Knight-Jones

Parasites of cod, Gadus morhua, from Faroese waters.
M. Koie

Pedunculate barnacles from the BIOFAR survey
J. Moyse and R. Williams

Studies on the mollusc fauna of Faroe waters
Ch. Munksgaard

Overview of Norwegian Sea Amphipods, with special reference to the amphipods of Faroes waters.
W. Vader and R. Palerud

Well known cosmopolitan polychaete species: A closer look at some Faroese representatives
M. E. Petersen

Distribution of Decapoda Natantia (shrimps and prawns) in the Faroe area.
E. I. Romer

Electrophoretic studies of the European species of *Astarte* (Mollusca, Bivalvia) and some observations on the Faroese fauna.
Chr. Schander

The tectibranch gastropods of the Faroe Islands and their relations to temperature and depth
T. Schiøtte

Depth variation in shell shape in *Colus gracilis* (Bivalvia,Buccinidae)
J.-A. Sneli and A. Warén

The Hydroids of the Faroes
M. S. Thorsen

Xyloredo Turner, 1972, (Bivalvia, Pholadidae, Xylophaginae) in the Faroe Islands and the North Atlantic
P. Bie Wikander

Estimates of bottom roughness from underwater photography
H. Westerberg and J. Gutt

Publications
from the
BIOFAR-programme

The following list includes publications whether considering solely BIOFAR material, or based in part on samples from the BIOFAR programme.

Major publications:

Berggren,M.,1990: Occurrence of the *fascigera* forms of shrimp *Hippolyte varians* (Leach.) in Gullmarsfjorden, Sweden, with comparisons from the Faroe Islands. - Cah.Biol.Mar. 31:147-157

Westerberg,H., 1990: Benthic temperature in the Faroe area. -Dept. Oceanogr, Gothenburg, report no. 51: 15 pp.

Klitgaard, A., 1991: *Gnathia abyssorum* (G.O.Sars,1872) Crustacea, Isopoda) associated with sponges. - Sarsia 76: 33-39.

Warén, A,. 1991: New and little known Mollusca from Iceland and Scandinavia. - Sarsia 76: 53-124.

Warén, A. & A. Klitgaard, 1991: *Hanleya nagelfar*, a sponge-feeding ecotype of *H.hanleya* or a distinct species of chiton?. - Ophelia 34: 51-70

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Working document

Ministry of Transport, Public Works and Water Management
Directorate-General of Public Works and Water Management
National Institute for Coastal and Marine Management/RIKZ

To:
ICES Benthic Ecology Working Group
Yerseke, The Netherlands
10-13 May 1994

From:
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Telephone:
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Date:
3 mei 1994

Appendix/ces:
-

Number: Project
RIKZ/OS-94.610x
-

Subject:
Coastal Nourishment

COASTAL NOURISHMENT OFF TERSCHELLING (THE NETHERLANDS)

1. INTRODUCTION

At the Meeting of the ICES Benthic Ecology Working Group at Kiel, Germany, 3-7 May 1993, the following action was listed:

> 10. Dr. K. Essink to report on the effects of sand barrier construction on benthos off Terschelling (The Netherlands).

2. COASTAL NOURISHMENT

Several strectches of coast suffer regular erosion of beach and even dunes. In The Netherlands the dunes are important as a sea defence. Beach nourishments have been applied since the 1970's to counteract beach and dune erosion (VAN HEUVEL & HILLEN, 1991).
Recently, a new nourishment technique is used not on the beach but replenishing the foreshore. The principle of this new approach is to create a buffer of sand on the foreshore, from which compensation is expected to be given for future beach erosion during ca. 5 years.

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Coastal nourishment of the foreshore is subject of a MAST study (project name: NOURTEC = Innovative Coastal Nourishment Techniques), presently being carried out in The Netherlands (off the island Terschelling), Germany (at the island Norderney) and in Denmark (off Torsminde Tange). In the case of Terschelling a body of $2*10^6$ m^3 of sand, borrowed at 20 m depth in the adjacent North Sea, has been deposited in Spring 1993 on the foreshore between two breaker banks (Fig. 1).

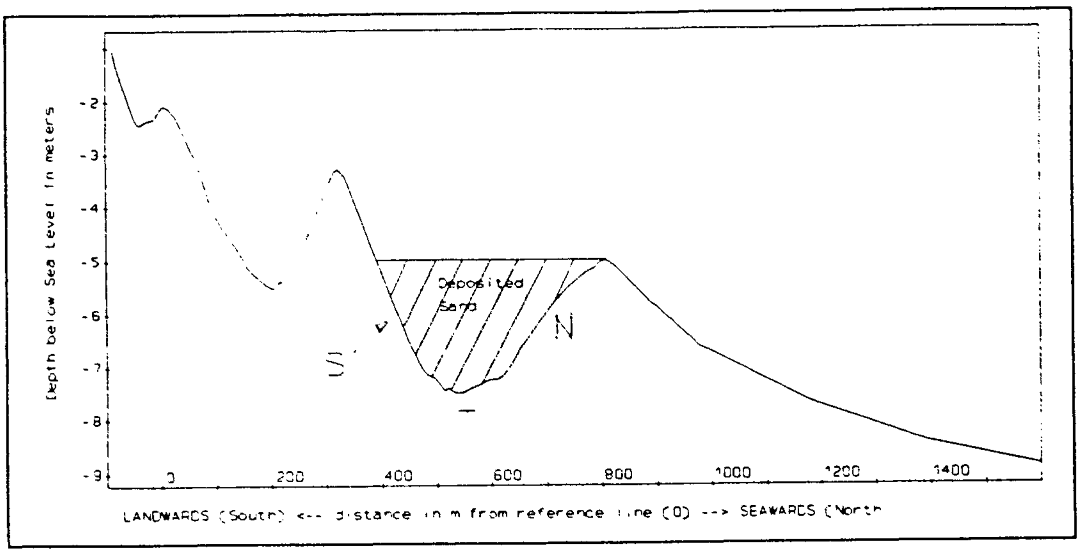

Figure 1. Profile of beach and foreshore at Terschelling, showing breaker banks and body of sand nourished in Spring 1993. N=North slope, S=South slope, T=Trough.

3. RIACON PROJECT

Sand nourishment of the foreshore will have an impact on the benthos due to burial by a body of sand. To study the direct effects of sand deposition, and the process of recovery of the benthic community a project proposal was formulated and submitted to the MAST programme of the Commission for the European Communities in December 1993 (ANONYMOUS, 1993). The project aims at analysing the risk of coastal benthic communities due to nourishment techniques o beach and foreshore, taking into account the direct negative effect on the benthos and the process of recovery. From this, the consequences for consumers of benthos (*e.g.* fish) will be deduced.

3.1. European extension

The RIACON project contracts are expected to be signed this month. Participating in RIACON are (see also Fig. 2):

* Denmark Torsminde Tange (= NOURTEC site)
* Germany Norderney (= NOURTEC site)
* The Netherlands Terschelling (= NOURTEC site)
* Belgium De Haan
* Spain Costa Daurada

The National Institute for Coastal and Marine Management (Dr. K. Essink) will act as overall coordinator of the RIACON project.

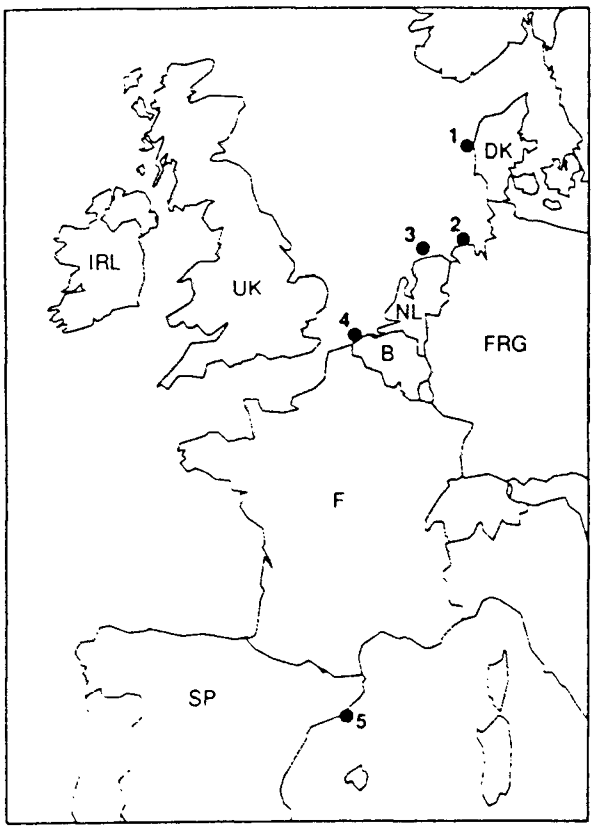

Figure 2. European sites involved in the RIACON project. 1) Torsminde Tange, 2) Norderney, 3) Terschelling, 4) De Haan, 5) Costa Daurada.

3.2. Terschelling Study

The Riacon study at the nourishment site off Terschelling involves:

1. Sampling of the nourishment site as well as a reference site (see Fig. 3) prior to the actual nourishment. This sampling was done in March 1993, according to a stratified ramdom sampling of the geomor-

phological strata North slope (N), trough (T), and South slope (S) (see Fig. 1).
2. Sampling of the nourishment site as well as a reference site in both spring and autumn in 1994 and 1995.
3. Sampling of the borrow site prior to sand extraction, in March 1993.
4. Sampling of the borrow site in the early autumn of 1994 and 1995.

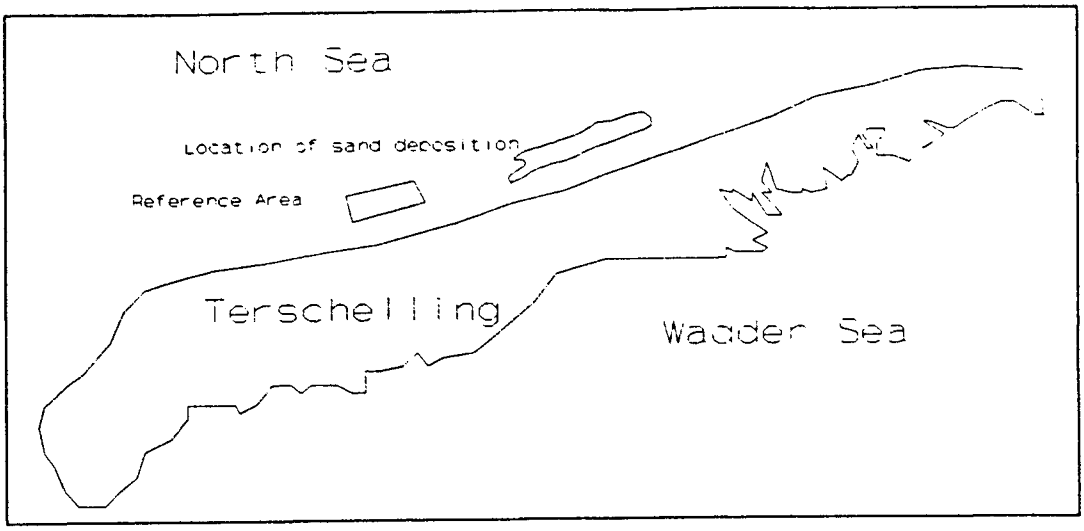

Figure 3. Location of nourishment site (sand deposition) and reference site off the island of Terschelling.

The nourishment site measures ca. 3 x 1 km; the reference site ca. 1.5 x 0.8 km.
Sampling is carried out with a box corer of ca. 0.07 m^2. In the pre-nourishment sampling of March 1993, 50 samples were taken at the nourishment site, and 40 samples at the reference site.

In this way not only the recovery process at the nourishment site but also at the borrow site will be studied.
Information on sediment composition and dynamics off Terschelling is obtained from the NOURTEC project.

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Working document

Ministry of Transport, Public Works and Water Management
Directorate-General of Public Works and Water Management
National Institute for Coastal and Marine Management/RIKZ

To:
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Yerseke, The Netherlands
10-13 May 1994

From:
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3 mei 1994
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Subject:
Monitoring

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Appendix/ces:
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Project
-

ONGOING MONITORING STUDIES IN THE NETHERLANDS

1. INTRODUCTION

At the Meeting of the ICES Benthic Ecology Working Group at Kiel, Germany, 3-7 May 1993, the following action was listed:

9. Dr. K. Essink to report on ongoing monitoring studies in The Netherlands.

2. MONITORING BY RIJKSWATERSTAAT

Since long a chemical and physical monitoring programme is carried out by different Rijkswaterstaat departments. In 1989 a biological monitoring programme in coastal and marine waters of The Netherlands was started by the Tidal Waters Division (now: National Institute for Coastal and Marine Management/RIKZ) of the Rijkswaterstaat organisation within the Ministry of Transport, Public Works and Water Management.

2.1. Biological monitoring programme

The goals of the Rijkswaterstaat biological monitoring programme have

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been defined as:

*** to evaluate the effects of measures taken by the government,
*** to describe long-term trends in a specific, but limited set of target variables,
*** to discriminate between man induced changes and natural variability.

To this end a number of organism groups are monitored:

***	Phytoplankton:	Species compositions, with special attention for toxic or nuisance species.
***	Macrozoobenthos:	Abundance and biomass of sedimentary endobenthos, Structure of hard substrate benthos on selected dike foots in the Eastern Scheldt.
***	Meiozoobenthos:	Abundance of taxa in the Dutch Continental Shelf.
***	Coastal birds:	Numbers of breeding pairs (SW-Netherlands) Counts at high water roosts (SW-Netherlands)
***	Sea birds:	Abundance and distribution at the Dutch Continental Shelf (aerial counts)
***	Sea mammals:	Abundance and distribution at the Dutch Continental Shelf (aerial counts)

Monitoring of coastal birds in the Wadden Sea and Ems estuary is covered by non-Rijkswaterstaat institutes, mainly belonging to the Ministry of Agriculture, Nature Management and Fisheries. The same holds for the monitoring of seals (common seal, grey seal) in the Wadden Sea, Ems Estuary and SW-Netherlands.

Monitoring of fish stocks (fish egg surveys; young (flat)fish and shrimps surveys in coastal water; adult stock assessment in the North Sea) is a responsability of the Ministry of Agriculture, Nature Management and Fisheries, and is carried out in international cooperation by the Dutch Fishery Research Institute (RIVO-DLO) at IJmuiden.

2.2. Programme change in 1994.

In 1994 the programme summarized in paragraph 2.1. will be extended as follows:

***	Seagrasses:	Annual surveys of extent of *Zostera* beds in the Wadden Sea, Ems Estuary and SW-Netherlands.
***	Saltmarshes:	5-year surveys of area covered with saltmarsh vegetation, and vegetation records along permament transects (Wadden Sea, Ems Estuary and SW-Netherlands).

***	Microzooplankton:	A method is being developed; the aim is to provide a better linkage between phytoplankton and higher trophic levels in the ecosystem.
***	Macroalgae:	Methods are being developed to quantify occurrence (sometimes massive!) of the green algae *Enteromorpha* sp. and *Ulva* sp.

The Rijkswaterstaat biological monitoring programme is carried out mainly by specialized research institutions in the Netherlands by order of RIKZ.

2.3. Internal evaluation

Early 1994 an internal evaluation of the biological monitoring took place. Among the recommendations were improvement of internal organisation and communication, as well as improvement of effort for presenting results of monitoring to other departments, in and outside the Ministry of Transport, Public Works and Water Management, that are involved in water management and policy making.

3. RESULTS

Primary results are made available in what one could call 'data reports'. In these reports the data obtained during (mostly) a period of a year are presented, with a short explanation and comparison with data from (the) previous year(s). Recent reports on macrozoobenthos and meiobenthos are listed below.

Monitoring data play an important role in national and international policy making. In The Netherlands a Fourth Water Management Policy Document (1986) is being prepared, outlining developments and future policy for each of a great many water systems identified, coastal and marine as well as inland (fresh water). In international framework monitoring data have been used in producing Quality Status Reports for the Wadden Sea (DE JONG *et al.*, 1993) and the North Sea (ANONYMOUS, 1993).

4. OTHER STUDIES

Other mid- and long-term benthic studies by the National Institute for Coastal and Marine Management relate to:

*** Response of the Oosterschelde ecosystem to the construction of the strom-surg barrier in the seaward end of that sea arm. In integrated study, comprising ecophysiological aspects of macrozoobenthos, will be published in June, 1994 (NIENHUIS & SMAAL, 1994)

*** Development of biological criteria for the management of cultivated populations of bivalves, research in the framework of the European project TROPHEE (= TROPHic capacity of an Estuarine Ecosystem) (*e.g.* ZURBURG & SMAAL, 1993).

*** Long-term changes of the ecosystem of the Wadden Sea in relation to changes in man's activities (DE JONGE *et al.*, 1993)

*** Response of the benthic system (microphytobenthos, meio- and macrozoobenthos) of tidal flats in the brackish Dollard to reduction of organic waste input due to a sanitation scheme in the potato processing industries in the Province of Groningen (NE-Netherlands) (ESSINK & ROMEIJN, 1994)

*** Response of the benthic fauna to sand nourishment of the foreshore off the island of Terschelling. The sedimentological and physical aspects are being studied in the NOURTEC project under MAST. The benthic ecological aspects are dealt with in an other MAST project, *viz.* RIACON (= Risk Analysis of Coastal Nourishment Techniques) (ANONYMOUS, 1994). In RIACON also studies are carried out at nourishment sites in Denmark (Torsminde Tange), Germany (Norderney), Belgium (De Haan) and Spain (Catalunya). The MAST-contracts for RIACON are presently being prepared.

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First results of studies on the distribution and population dynamics and on bioturbative activity of macrozoobenthos in the Pomeranian Bight (Southern Baltic Sea).

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Seestrasse 15

The first cruise, in a study directed at evaluating the impact of input material from the River Odra on the distribution of the macrozoobenthos in the Pomeranian Bight, was performed in April 1993. A minimum of three bottom samples was taken at 22 locations using a box corer (0.0225 m^2) and a van-Veen grab (0.1 m^2). Samples were sieved with 0.5 and 1mm mesh size, respectively. Abundance and biomass of each species were analysed following the HELCOM-guidelines. The programme PREDABAN (Prena 1991) was used for data analysis. Further data were collected on the population structure of *Mya arenaria, Macoma balthica, Cerastoderma lamarcki, Nereis diversicolor* and *Marenzelleria viridis*, which are among the most dominant species in the study area.

The total number of benthic species is 29 (11-21 per sampling location). Density and biomass can be very high, especially near the river mouth (max 144 g AFDW/m^2).

Marenzelleria viridis was found at all stations.

A cluster analysis of the data suggests at least four different subareas of the Bight having different community structures:

- the south western coastal zone is strongly influenced by the outflow of River Odra and the Greifswalder Bodden;
- the shallow Oderbank region, including some stations in the eastern part of Pomeranian Bight;
- the deeper channel region in the north western part of the bight, which is the transition zone to the deeper Arkona-basin; and
- the station directly in the river mouth region.

For each of the first three subareas we choose a representative station for detailed macrofauna- sediment- and bioturbation analyses/measurements.

Station 165, which represents the south western coastal area, is dominated by large *Mya arenaria* (82g AFDW/m^2) and *Marenzelleria viridis* (8g AFDW/m^2).

Station 39 represents the shallow Odrabank region. This area is characterised by a high adundance of smaller bivalves (a result of a slow growth rate) and *Bathyporeia pilosa.*

Station 130, in the north western part, harbours a mixture of different communities (Arkona-Basin, Greifswalder Bodden, Oderbank). This station had the highest species diversity (21 species). *Mya arenaria* dominates the biomass.

Integrated values of the organic content of the upper 0-5cm sediment show highest values at Station 165 (about 1% of sediment dry weight).

The depth of the redoxcline in the sediment (redox potential values +100mV) is 6cm on Station 165 and 7cm on Station 130, whereas there are oxic conditions at Station 39 throughout the upper 10cm of the sediment.

Sediments at Station 165 also differ from the others, having ATP-biomasses three times higher in the upper sediment layers (up to 6000ng ATP/cm^3).

To determine the bioturbative exchange of dissolved substances at the sediment-water interface we performed tracer experiments with sediment cores in the laboratory. We used bromide as an inert tracer for dissolved substances. By means of a multi-box, non-steady state, diffusion model we simulated exchange coefficients on the basis of tracer concentrations in the water column (initial and final values), vertical profiles of tracer concentrations in the pore water, and the porosity of single sediment layers. Model calculations are based on Fick's first law of diffusion adapted to sediments. An 'effective diffusion coefficient' (D_{eff}) of the active benthic community was compared to an 'molecular diffusion coefficient' (D_{mol}) excluding all fauna. The ratio K_{bio} (D_{eff}/D_{mol}) was finally calculated to quantify the increase of the diffusive flux due to the benthic community. Values of K_{bio} were highest, ie 19, at Station 165 with the dominant species *Marenzelleria viridis* and *Corophium volutator* in the sediment cores. At Station 130, with the dominant species *Mya arenaria*, we calculated a K_{bio} of 15 and at Station 39 on the Odrabank a K_{bio} of 7 , with *Macoma balthica* and *Nereis diversicolor* being dominants.

Investigating the Impact of Otter Trawling on Benthic Communities of the Grand Bank

A report to the ICES Working Group on the Ecosystem Effects of Fishing Activities and the Benthos Ecology Working Group

by

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Introduction

The fishing industry in Atlantic Canada uses a variety of mobile gear types, the most common being otter trawls, scallop rakes and hydraulic clam dredges. Concern as to the possible effects that these harvesting methods may have on fish stocks and the habitat supporting them has increased dramatically in recent years (Haché 1989; Harris 1990). In 1990, these concerns resulted in the initiation by the Scotia-Fundy and Newfoundland Regions of the Department of Fisheries and Oceans (DFO) of a major research project to study fishing impacts.

Previous studies and reviews (BEON 1990; BEON 1991; Messieh et al. 1991; Jones 1992) and reports by ICES Working Groups (Anon. 1991; Anon. 1992a; Anon. 1992b; Anon. 1993a; Anon. 1993b) and others have identified or suggested the following possible effects of mobile gear types:

- direct mortality of those organisms harvested, those captured but discarded, and those left on the seafloor;
- indirect mortality of organisms which are exposed to predators or unable to escape predators due to injury;
- alteration of the physical properties of the seafloor;
- alteration of chemical fluxes between sediments and the water column; and
- alteration of benthic habitat and of its suitability for particular species.

An early decision was made to restrict our first studies to the impacts of otter trawls, this being the most widely used form of mobile gear in Atlantic Canada.

A review of existing Scotian Shelf side-scan sonar records for evidence of bottom disturbance from mobile fishing gear by Jenner et al. (1991) indicated that less than 2% of available records

contained any evidence of physical disturbance by such gear. Most of the observed disturbance was due to groundfish trawls and was restricted to areas of low sediment transport.
For the Grand Banks, less than 10% of the total length of record showed any evidence, even slight, of trawling disturbance. The south and eastern areas of the Banks were more intensively trawled than other areas, but even in these areas over 90% of the line segments with trawl tracks were in the <5% disturbance category. Less than 1% of the length of record showing disturbance was in the heaviest (>25%) disturbance category. These results provide no information on the effects of the physical disturbance observed.

A more detailed analysis of the spatial pattern of trawling on the Grand Banks and Labrador Shelf is available through analysis of commercial trawling effort data collected in the fisheries observer program over the period from 1980 to 1992. The area of bottom scoured by dragging has been calculated from duration of set, speed of vessel, and type of net used. Figure 1 shows that the most intense effort is directed toward the edges of the Banks and especially along the northeast Newfoundland continental shelf, where the major spawning concentration of northern cod was found. Areas of intense shrimp (Pandalus) trawling occur along the Labrador Shelf up to Cape Chidley. The general magnitude of the percent of bottom area trawled is in accord with the results of the side-scan analysis. Relatively small areas are intensely trawled, but even in these areas only about 10% of the bottom surface area is trawled annually.

Brylinsky et al. (1994) investigated the impacts of otter trawls on the intertidal sediments of the Minas Basin; with trawling carried out at high tide and observations of effects made at low tide when the trawled area was exposed. Impacts were judged to be relatively minor, especially since the intertidal sediments of this macrotidal area are already exposed to natural stresses imposed by storms and winter ice. The benthic communities found on offshore fishing areas have a much richer and more diverse assemblage of organisms, especially epibenthic forms which are much more susceptible to possible damage from mobile gear.

Experimental Design and Methodology

Design of Experiment

It was decided to restrict our first studies to the impacts of otter trawling, since otter trawls are the most widely used fishing gear towed in contact with the seabed in Atlantic Canada. In future, the impacts of scallop dredges will also be examined.

Cruises were conducted on the Scotian Shelf and on the Grand Bank in 1991 (C.S.S. *Dawson*) and 1992 (C.S.S. *Parizeau*) to locate suitable sites for experimental trawling. Selection criteria for study sites included:

- never trawled (or dredged), or not trawled in recent years, so that benthic communities are in a "natural" state
- protected from mobile gear disturbance for the duration of the project (at least five years)
- have sediment types and benthic communities representative of large areas of the shelf
- uniform conditions of depth, sediment type, etc. to reduce sampling error

In the course of the surveys and the early sample analyses, it became clear that another consideration in site selection should be species richness and biomass, since these factors greatly affected the possibility of recognizing any potential changes which might occur as a result of trawling.

Three possible sites were determined. Two of these were within the "Haddock" closure area of Western Bank on the Scotian Shelf (Fig. 2) and the third on an area of the Grand Bank approximately 60 km northeast of the proposed Hibernia oil production site (Fig. 3). The surveys revealed that the benthic community of the Scotian Shelf areas was generally impoverished and much lower in both species diversity and biomass than the Grand Bank site. This, coupled with the relatively small area and vulnerability to scalloping activities of the two Scotian Shelf sites, ruled against their use for the trawling impact experiment.

The Grand Banks site, 10 nautical miles square, is centred at 47° 10' N, 48° 17' W (about 60 km northeast of Hibernia) in an average depth of 137 m. The area has not been subjected to heavy trawling in the past decade, and it has been possible to close it to all mobile gear for an indefinite period for the purposes of this project. A side effect of the current moratorium on all demersal fisheries on the Grand Banks is that it ensures the continued protection of the experimental area from commercial trawling for the next couple of years. A mixed fishery, dominated by American plaice (*Hippoglossoides platessoides*), had previously been carried out in the area in the 100 to 150 m depth stratum. Side-scan sonar surveys in the area show no physical disturbance from fishing gear but iceberg furrows do cross the area. The sediment is a medium-fine sand which is very easy to process and, most importantly, there is an abundant and diverse community of benthic organisms, including a well-developed epibenthic assemblage.

The study was designed with two components:

One, which we have designated the "long-trawl", has as its objective the determination of trawl-track degradation rates in a number of energy and sediment regimes. The experimental design required the laying down of a continuous trawl track extending over a range of depths, and hence energy regimes, and sediment types, for subsequent observation of the rate of degradation over an extended period of time. This component is primarily of interest to the Geological Survey of Canada's Atlantic Geoscience Centre (AGC) as an analog for an iceberg scour, while DFO's interest relates to the ageing of trawl-tracks recorded on existing side-scan records for fishing areas.

The second and main component of the study is the trawling impact "corridor" experiment. This experiment has as its objective the determination of the immediate, short-term, intermediate-term, and long-term impacts of otter trawling on the seabed and the benthos. The experimental design called for the establishment of three corridors, all in relatively close proximity but having different headings, within which experimental trawl tracks could be layed down and sampled at intervals to determine immediate, short-term, intermediate-term, and long-term impacts to the seabed and the benthos. A control "corridor" was established parallel to each experimental "corridor".

It is planned to continue the study for a sufficient, but unfixed, number of years to determine the longer-term impacts and the rates of recovery of both the seabed and the benthos.

Two cruise series were mounted in 1993. The first, in which 11 days were spent on-site in July, was directed at establishing the experiment by doing a pre-trawl survey, carrying out the trawling, and then determining the immediate effects on the seabed and benthos. The second, in which 10 days were spent on-site in September, was directed at evaluating the short-term effects. In each case, approximately one day was required for the "long-trawl" study.

Methods

"Long-trawl" Experiment

The track for the "long-trawl" was selected to traverse a range of depths and sediment types in order to determine decay rates of a bottom disturbance in these substrates and energy regimes. During the establishment of the "long-trawl" the C.S.S. *Parizeau* accompanied the C.S.S.*Templeman* from 47° 04.00' N, 48° 11.00' W to 46° 45.46' N, 48° 46.27' W (Fig. 3). The *Templeman* towed the rock-hopper equiped Engel 145 trawl, with the codend open, between the above positions. This is the standard trawl of Canadian vessels fishing on the Grand Banks. Details of the trawl and trawl doors are shown in Fig. 4. The trawl was rigged similarly to standard commercial gear used in the Grand Banks fishery. The *Parizeau* followed immediately astern and to starboard of the *Templeman*, recording the position of the trawl with the Trackpoint acoustic positioning system, side-scanning (Simrad Mesotech 992) the trawl track being created and recording subsurface geological features with a Huntec high resolution deep towed seismic (DTS) profiling system in the boomer configuration. A second run was made along the "long-trawl" using the Huntec DTS system in the sparker configuration. Data from the side-scan and DTS were logged on a Ferranti SE 880 sonar enhancement system. Once side-scan and Huntec operations were completed, some limited sampling of surficial sediments was carried out at selected stations along the line near Hibernia using the video grab system described below.

"Corridor" Experiment

The "closed" experimental area selected for the main trawling impact study is centred on 47° 09' N, 48° 17' W of the Grand Bank (Fig.3). Within the "closed" area, three 7 nm (13 km) long by 200 m wide experimental corridors and their adjacent and parallel 50 m wide control corridors were established as in Fig. 5.

Each corridor was divided into 260 fifty metre long blocks, each block being given an individual identifier code (Fig.6). For each grab sample, one 50 m block was used and for each epibenthic sled sample five consecutive 50 m blocks were used. For epibenthic sled sampling stations, the identifier code for the central block in the string of five was used to designate the station and sample.

The principal biological sampling gear used in the study were a video-equipped 0.5 m^2 grab sampler, with hydraulically powered jaws, and a 1 m wide video-equipped epibenthic sled with a 0.34 m cutting blade and operational sampling width (Fig. 7). These samplers are described in detail by Rowell et al. (1994). Acoustic imaging of the bottom was carried out using side-scan sonar and optical imaging with a still and video-equipped bottom referencing underwater towed instrumented vehicle (BRUTIV) (Fig. 7)

The*Parizeau* was positioned using a Magnavox model 4200 dGPS receiver. Differential corrections were obtained from a monitoring station at Long Island, N.Y. via a Starfix II system. Survey and sampling equipment were positioned relative to the ship using an ORE Trackpoint acoustic positioning system. The accuracy of towed survey and sea floor sampler positions (Circular Error of Probability or CEP66) determined by this methodology is estimated to be +/-20 m. Real-time display and logging of all navigation data was accomplished with a custom hardware/software package developed at BIO.

The *Templeman* was equipped with a Furuno GPS navigation system, and Scanmar acoustic trawl instrumentation was used to monitor trawl door and wing spread and other net characteristics while fishing.

Establishment of the Experiment and Evaluation of Immediate Effects

On arrival at the study area, during the first cruise series in July, the *Parizeau* made an initial assessment was made of bottom characteristics within experimental corridors A and B and control corridors A and B using side-scan sonar (Fig. 8). One survey line was run along the centre of these 200 m wide experimental (to be subsequently trawled) corridors with the side-scan set at 200 m range (400 m swath); a further two lines were run along the outer edges of these experimental corridors with the side-scan set at 100 m range (200 m swath); and one line was run along the centre of the each 50 m wide control corridor with the side-scan set at the 100 m range (200 m swath). Pre-trawl sampling of these corridors was then carried out with the grab and epibenthic sled. Time did not permit pre-trawl side-scanning or sampling of corridor C. Stations were randomly selected from among the 260 sections along each corridor. Five grab samples each were taken from the control areas and from the experimental areas of corridors A and B. Two tows, of approximately 50 m, were made in each of the control and experimental corridors with the epibenthic sled. Pre-trawl samples from the experimental corridors were considered as control samples, since the areas were as yet undisturbed. As seen in Figure 6, adjacent blocks in the control and experimental corridors were numbered the same. In pre-trawl sampling, blocks sampled in the about to be trawled area were not matched with blocks sampled in the control corridors. In the subsequent post-trawl sampling, matching blocks of the experimental (trawled) and control corridors were sampled with the intent of reducing possible environmental variables related to distance between sampling stations. Pre-trawl sampling, with the exception of corridor C, was completed prior to the arrival of the *Templeman* and the commencement of its trawling operations.

On completion of pre-trawl sampling of corridors A and B by the *Parizeau*, the *Templeman* trawled experimental corridors A, B, and C with a rockhopper equipped Engel 145 trawl (Fig. 4). A Trackpoint transponder was fitted to the centre of the headrope for accurate recording of the trawl's position on the bottom throughout the trawling operations. During the trawling of corridors A and B, the *Parizeau* shadowed the *Templeman* and monitored the trawl's position from the Trackpoint system installed aboard the *Parizeau* (Figs. 9 & 10). Trawling operations in corridor C were not monitored with Trackpoint, since the *Parizeau* was occupied in the post-trawl side-scanning and sampling of corridors A and B. The *Templeman* made 12 trawling passes along the centre line of each corridor. During trawling operations, the catch was sorted at the end of each pass and numbers and biomass of fish and invertebrates recorded. Sub-samples of crabs were frozen for analysis of sex, age, and maturity. Stomachs and otoliths of all species of fish were retained from trawl passes at the beginning, middle, and end of the trawl series in each corridor. Unlike commercial gear, the trawl we used was equipped with a cod end liner of 3 cm mesh. This liner does not appreciably affect the hydrodynamic characteristics of the net but results in greater retention of benthic megafauna and small fish in the cod end. The catch is thus not strictly comparable to a commercial catch but may give a better indication of relative numbers of megafauna that are disturbed by trawling, independent of clogging of the cod end mesh by finfish catch. It was clear from the amount of broken crab, basket star, and other invertebrate parts on the mesh of the trawl belly and wings ahead of the liner that the megafauna retained in the cod end did not represent the major proportion of the invertebrates picked up by the trawl. Assuming that the invertebrates retained in the cod end were a consistent fraction of the total "catch" of invertebrates, an analysis of variance (randomized block design) was performed to determine if the number of times a corridor was trawled significantly affected the catch.

Once trawling operations were completed in experimental corridors A and B, the *Parizeau* conducted immediate post-trawl sampling using the grab and epibenthic sled for biological sampling, and BRUTIV and the grab's video system for visual imaging of both biological and physical changes, and side-scan sonar for mosaicing of physical disturbances. Within the trawled area, ten randomly selected stations were sampled with the grab and four tows, of approximately 50 m, were made with the epibenthic sled. One post-trawl video transect with BRUTIV was made along corridor A. In this transect, BRUTIV was flown approximately 2 metres above the bottom along the first and last thirds of the experimentally trawled corridor's length as well as along the centre one-third section of the parallel control corridor. Post-trawl side-scan surveys of experimental corridors A, B, and C were carried out, as described above, immediately after trawling. There was no post-trawl grab or sled sampling of the control and experimental corridors C due to time limitations.

<u>On-board treatment of samples</u>: On retrieval of each grab, and prior to dumping and sieving, duplicate 1 ml sediment samples, for bacterial analysis, were removed from the sediment surfacewith a 3 ml syringe. Five ml of 0.22 µm of filtered 2 % gluteraldehye was then added and the samples frozen. Duplicate 10 cm deep samples were also removed at this time, using a 140 ml syringe, and divided into sub-samples from depths of 0-2 cm, 2-5 cm, and 5-10 cm for meiofaunal analysis. Seven % $MgCl_2$ was added to relax the organisms and 2-24 hrs later, gluteraldehyde was added to a final concentration of 2 %. Duplicate 125 ml sediment samples were removed and frozen for grain size and CHNS analysis. The grab was then opened and the sample sieved through a 1 mm screen before being preserved in buffered formalin for later sorting and analysis. This analysis included, where possible, an assessment of damage to the macrobenthos. Epibenthic sled samples were sieved on the same screen and immediately sorted by species. Large and numerous species were counted and weighed on-board, while smaller and unidentitied specimens were seperated and frozen for later examination in the laboratory. Apparent damage, or lack thereof, was recorded during the sorting process for four megabenthic species; the sea urchins (*Strongylcentrotus drobachiensis* and *S. pallidus*), sand dollar (*Echinarachnius parma*), and the brittle star (*Ophiura sarsi*). Molluscs were separated into bivalves and gastropods, bagged, and frozen for laboratory analysis of shell damage caused by the trawl.

<u>Laboratory treatment of samples</u>: The preserved residue of the grab samples was brought into suspension, screened through a 1 mm-mesh, and sorted under a dissecting microscope. The retained sediment was examined under a magnification lense. Specimens were identified to species level when possible and additionally grouped into size classes. As in the sled samples, the damage of the two species of sea urchins was recorded; however, this was not possible in the brittle stars which additionally suffered through sieving and handling. Biomass was determined as formalin wet weight (molluscs with mantle cavity liquid and shells). Specimens were subsequently transferred into 70% ethanol.

Molluscan samples from the sled were analyzed for damage after careful thawing. This was to ensure that there would be no handling induced damage. The specimens were then sorted into four categories: 1) no damage; 2) minor damage (considered likely to survive); 3) moderate damage (might survive); and 4) major damage (considered unlikely to survive).

Frozen samples of whole sediment were thawed and subsampled for water content (wet weight minus dry weight after 24 h at 60°C), CHN analysis, and coulter counter analysis. The remaining sample (~100 mL) was wet sieved on a stack of circular brass sieves of 63, 125, 250, 500, 1000, 2000, and 4000 um mesh sizes. Wet sieving was used to retain the integrity of the biological structures, aggregates, etc. which would be disintegrated by preparation for dry sieving. The sieved fractions were placed in preweighed aluminum pans. They were then dried at 60°C for 24 h and weighed.

Particulate CHN was determined using a Perkin-Elmer 2400 Series II CHNS/CHN analyzer. Sediment was ground with an alumina mortar and pestle. One-half of the sample was acid treated to remove carbonates prior to analysis, while the other half was not.

Bacteria were counted using the acridine orange epiflourescence method detailed by Schwinghamer (1988a). A Zeiss ICM 405 inverted microscope equipped with a drawing tube and a 486 PC with a Java image analysis system were used to measure acterial sizes for biomass determination.

Meiofauna were extracted from the sediment using Ludox AM density gradient centrifugation (Schwinghamer 1988b). Meiofauna organisms will be counted and measured using a video-equipped Zeiss ICM 405 inverted microscope and a 486 PC with Mocha image analysis system.

There has not yet been any analysis samples of snow crabs, fish stomachs, and otoliths collected during the trawling operations.

Evaluation of Short-term Effects

The *Parizeau* revisited both the "long-trawl" and the experimental corridors in September to evaluate short-term (approx. 2 months) effects of the July trawling.

With the exception of BRUTIV, which was unavailable to this second cruise, all sampling gear, sampling proceedures, and navigational aids and positioning systems were as described for the initial July cruise.

The track of the "long-trawl" was run once and side-scan sonar imaging data acquired in order to evaluate short-term degradation of the trawl marks.

In the "corridor" study, a side-scan survey was also run within the three experimental corridors (A, B, and C) to assess changes in trawl mark characteristics two months after trawling. These surveys were carried out in the manner described above and illustrated in Fig. 8.

Biological sampling was again conducted, with the grab and epibenthic sled, at randomly selected stations in the control and experimental corridors A and B. As in the earlier cruise, there was no sampling of corridor C due to time limitations. Ten grab samples were taken from each of the control areas and experimental areas; 40 grabs in all being successfully completed. Nine 50 m (approx.) tows were made with the epibenthic sled; 7 and 2 being completed in the control and experimental corridors of A and B, respectively. Sampling and sample treatment were carried out in exactly the same manner as during the previous cruise.

The loss of several days to rough weather greatly reduced the level of sampling planned for the epibenthic sled and negated any opportunity to sample corridor C.

On-board and laboratory treatment of samples was essentially as described for the initial cruise series above.

Results

"Long-trawl" Experiment

Surficial sediments along the "long-trawl" are generally thin (typically less than 2 m) and dominated by the effects of a low sea level stand, modern sediment transport and iceberg scour processes. Five main depth-related sedimentary facies occur along the "long-trawl" (Barrie et al. 1984); they are, from northeast to southwest, Unit A -continuous sand, Unit B -gravel with sand ribbons, Unit C -boundary sand; Unit D -gravel; and Unit E -sand ridges over gravel. The sediments and their resident bedforms indicate increasing sediment dynamics with decreasing water depth. Ice scour features are most abundant and clearly defined in the Unit A, B, and C sediments which may indicate they are being modified and eroded in shallower water depths.

Modern sediment transport is inferred to occur to water depths of 120 metres on the Grand Banks (Amos and Judge 1991). Cobbles and pebble-sized materials can be moved in depths of less than 80 metres under storms of greater intensity than the storm of 1: year recurrence interval. More frequent seabed sediment transport under less intense storm conditions is indicated by the presence of megaripple fields, and wave-formed gravel ripples in water depths shallower than 110 m. Along the "long-trawl" the only bedforms that are clearly recent in origin are two patches of megaripples in the Unit D sands at about 80 m water depth.These must be continually reformed to overcome the degrading effects of benthic organisms such as sand dollars and bottomfish which would erase the megaripples in a matter of months (Barrie et al. 1984). Barrie et al. (1984) inferred that above 100 m unidirectional velocities in excess of 50 cm/sec must occur several times a year to rejuvenate the megaripples; the ripples imply more frequent reworking of small-scale bedforms on the seabed.

Unit A sediments (110 m below sea level to >135 m bsl) at the northeasterly deepwater end of the "long-trawl", in proximity to the "closed" area of the trawling experiment, are typically composed of moderately sorted, fine sand with minor silt. On side-scan they are characterized by uniform moderate reflectivity with dark-toned highly reflective patches and lineations which represent fresh and degraded iceberg scours and pits. There is no evidence of any bedforms suggestive of either modern or relict sediment transport on the side-scan sonograms.The trawl feature is very evident in Unit A sediments; both otter boards as well as internal trawl striations are identifiable. Ice scour features are quite clear in Unit A.

Unit B sediments (110 m bsl to ~100 m bsl) are defined by the presence of thin medium sand ribbons developed over a lag gravel. The ratio of gravel to sand increases to the west. Overall sediment thicknesses are typically less than 1 m thick. Sand waves are developed on the ribbons indicating a current direction from the north. Megaripples and wave-formed sand ripples were not identified on the side-scan records but are typically evident on bottom photos from this area. The trawl door marks are continuous on the sonograms but resolution and detail varies with the seafloor character. Areas of low to medium reflectivity (sands) tend to show internal striations within the trawl mark as compared to the higher reflectivity zones (gravels). Iceberg scours and pits are quite common and fairly distinct in Unit B sediments

Unit C (100 m bsl to 90 m bsl) represents more continuous thin (< 1 m) medium sand with isolated areas of gravel. Throughout this zone the trawl feature is clearly and continuously defined.

Unit D (< 80 bsl) is a highly reflective seabed composed of gravelly sand and sandy gravel. Lower reflectivity sand is observed to infill occasional iceberg pits and scours. Megaripples are clearly defined in zones over the coarser gravel material indicating transport in either a north or south direction. The trawl feature is continuously but poorly resolved on the side-scan sonograms;

in coarser gravel material, both otter doors can be identified

Unit E sediments, are evident on the southwesterly end of the "long-trawl", with large scale sand ridges (3 km wide, kilometres in length, and with a relief of 2-3 m) . They consist of medium to coarse, moderately sorted sands over a gravel lag surface. Superimposed on the sand ridges are cross-ridge sand-wave troughs trending ESE-WNW which can be incised up to 1 m in the sand ridge with coarser wave-formed ripples on their base. Trawl scours are vague to poor in the low reflectivity sands but become more apparent over the more reflective gravels.

"Corridor" Experiment

Experimental and Control Corridor Establishment

Trackpoint data (Fig. 10) and side-scan mosaics have confirmed that trawling activities were restricted, as planned, within the established 200 m wide experimental corridors. Equally importantly, side-scan mosaics of the control corridors show no evidence of any trawling activities such as might have resulted due to navigational error or other causes.

Grab Sample Data

Grab sample data for corridor A are essentially complete for each of the ten observations made prior to and immediately after to trawling during the first cruise series. In the 10 samples taken prior to trawling, an average of 69 species were encountered per sample and a total of 145 species overall (Tables 1 & 2). Extrapolation, by means of a species-area function, suggests that approximately 80% of the species present were collected and the occurrence of an additional 36 species. Thirty six species were common to at least 90% of the samples, 70 species were encountered in three or less samples. Figure 11 shows the number of species common to one, two, three. etc......up to the complete set of ten samples. Table 2 illustrates how the major phyla contribute to the numbers of species and specimens present, and to the biomass. Mean number of individuals m^{-2} was 2,476 and mean biomass 1,170.8 g (wet weight) m^{-2}. Ten species occurred on average with more than 50 m^{-2} specimens (seven species of polychaete and one species of mollusc, crustacean, and echinoderm). The total biomass per sample (station) ranged from 915-1437 g m^{-2} wet weight.

A Mann-Whitney test, F-test, ANOVA, and Behrens-Fisher test were performed to evaluate which species or groups appeared to be affected and the adequacy of the number of replicates in our sampling. Preliminary results indicate that some small-sized specimens increased in numbers subsequent to trawling. However, this observation was restricted to species which only occurred in smaller numbers and confirmation through further replicates is needed. These will be available once all samples have been sorted and the data analyzed. Mann-Whitney tests performed on subsets of observations suggest that the ten replicates taken per observation group are probably the minimum to give significant evidence of trawling effects.

Sled Sample Data

A total of 74 species were encountered in the 16 sled samples taken prior to and after experimental trawling during the first cruise series (Table 1). Most species occurred only in low numbers at a few stations. 19-31 species occurred at each station, approximately eight of them with sufficient regularity to be used for testing changes in their occurrence. However, the number of samples taken was too small to demonstrate an impact. Significant differences in the occurrence of some species could be detected, but results were not always consistent between the corridors. First analyses indicate that the similarity between the samples is, as a rule, not influenced by their distance apart. However, in one instance two sampling sites in close proximity were found to exhibit greater differences than generally observed, probably as a result of greatly differing sediments. This result suggests that proximity of sampling at sites may not necessarily reduce the variation in species occurence.

It was intended to evaluate the level of direct physical damage to the megabenthos as a result of trawling by comparison of damage levels seen in control samples to those seen in samples from the trawled areas; any higher level of damage observed in the trawled area samples being attributable as traw induced damage. In the three species of echinoderms studied, no significant difference in damage levels was apparent between the experimental and control samples. This suggests two possibilities; one is that there was no damage to these species by the trawl, and the other is that the level of damage caused by the sled and on deck sample handling was sufficiently high relative to that caused by the trawl that the trawl induced damage was masked. Overall, with all samples combined, the data indicate that approximately 34% of brittle stars (*Ophiura sarsi*) and 7.5% of sand dollars (*Echinarachnius parma*) were damaged, while sea urchins (*Strongylocentrotus spp.*)were very seldom damaged.

The very limited damage seen in sea urchins is surprising and raises some question as to the impact of the few days time delay which occured between the trawling activity itself and the post-trawl sampling of the corridors. It is plausible that urchins, if moderately damaged, are immediately preyed on and that any evidence of trawl induced mortality is lost even before the post-trawl sampling was begun. The low level of damage overall, i.e. including the control samples, may indicate that urchins are fairly robust to the type of damage likely to be caused by tumbling around in the box of the sampling sled. The questions raised may be answered in the 1994 studies by video and grab sampling immediately following trawling.

Preliminary results suggest molluscan species may be one of the better indicators of trawling impact. If one compares frequencies of no damage (Category 1) versus major damage (Category 4), there was significantly (χ^2) more damage in post-trawling versus pre-trawling among bivalves (all combined) and gastropods (all combined) in Corridor A. Bivalves and gastropods were anlayzed separately. In particular, there was significant trawling-induced acute damage in shallow-dwelling (upper 5 cm of sediment) molluscs. For the bivalves these results could be attributed largely to high levels of damage to the very shallow and slow burrowing *Astarte borealis*. Some deeper and faster burrowing species, such as the *Cyclocardia spp.*, sustained remarkably little or no damage while, amongst the gastropods, the trochids (*Margarites spp.*) also sustained little or no damage. In Corridor B, no significant level of damage to bivalves could be attributed to trawling, but there was some evidence of damage to gastropods (Buccinidae).

Time-lapse video records of reburrowing in the propellor clam *Cyrtodaria siliqua* after excavation, in addition to burrowing observations on other representative species, indicates that many of the infaunal bivalve species in the study area are slow to very slow burrowers. The most abundant, and seldom damaged, bivalve in the study area is the relatively deep and relatively fast burrower (*Macoma calcarea*).

Sediment Analysis Data (Corridor A only)

Grain Size

The sediment of the grand banks experimental site are homogeneous fine-medium sand with a uniform modal grain size of 194 μm in all samples, as determined by Coulter counter analysis.

Sieve analysis indicated the same pattern, with the 125 µm fraction dominating all samples. The sand is well sorted, with >80% dry weight in the range of 169-338 µm.

Although the gross aspect of the grain size distribution was remarkably invariant before and after trawling, and from July to September, the tails of the distribution in the silt clay size and coarse sand-gravel size were more variable. The variance in the larger size fractions (>0.5mm), which consists mainly of shell fragments and tube structures shows no discernable pattern. It is probably a result of the small sample size relative to the size of these particles. The fine silt and clay fraction (<32 µm) accounted for less than 1% of the total dry weight, but showed a coherent pattern of variation. In July, all values for this fraction were greater that 0.3% dry weight (0.32-0.78%) but in September, all of the values were less than 0.3% (0.07-0.29%). There was no overlap.

Water Content

The water content of the surface sediment ranged from 18% to 25% by weight, with no appreciable nor statistically significant differences among trawled, untrawled, July, or September samples.

Sediment Bacteria Data (Corridor A only)

Bacterial numbers were consistently low, in the range of 9×10^7 to 1.5×10^8 per ml of surface sediment. There were small but statistically significant increases in total bacterial numbers after trawling. Total bacteria increased from a mean of 9.98×10^7 per ml before trawling and in control areas to a mean of 1.28×10^8 per ml after trawling. Pseudomonads and especially filamentous bacteria accounted for most of the increase. Filamentous forms increased dramatically after trawling, from a mean of 64 per ml to 6.3×10^5 per ml. Pseudomonads increased from 3.97×10^7 per ml to 5.25×10^7 per ml. A biomass/size distribution of the bacteria indicates most of the biomass in the 1µm ESD class, with a lesser mode of pseudomonads in the 0.5um class.

Invertebrate Trawl Catch Data (Corridors A, B, and C)

The trawl catches were dominated by invertebrate epifauna, mainly snow crabs (*Chionoecetes opilio*), basket stars (*Gorgonocephalus arcticus*), and sea urchins (*Strongylocentrotus droebachiensis* and*s. pallidus*), American plaice (*Hippoglossoides platessoides*) and thorny skate (*Raja radiata*) dominated the vertebrate catch, with some Arctic cod (*Boreogadus saida*), capelin (*Mallotus villosus*) and a variety of incidental species. The fish catch was extremely small, being a maximum of 80 kg after a 2.5 hr tow (13+ km).

The invertebrate catch decreased significantly in all the corridors as the number of trawl passes increased. A randomized block ANOVA, using the corridors as replicates and the number of trawl passes as treatment, indicated that the treatment (repeated trawling) effect was significant at $p<0.05$, while the corridors (blocks) differed at $p<0.01$. In the first five trawls, the mean weight of invertebrates per trawl (over all corridors) was 25.8 kg (s.d.=7.34). In the final seven trawls, the mean weight of invertebrates per trawl was 11.3 kg (s.d.=0.98). A mean of 70% of the biomass removal was accomplished in the first five trawls over each corridor.

BRUTIV

During the BRUTIV survey of corridor A, it was immediately apparent from the black and white video that there was a significant difference between the appearances of the sea floor in the trawled and control areas. Within the trawled corridor, the bottom appeared to be a light colour with streaks of darker material and the white (shell hash?) and black (sand dollars?) objects were organized into linear features. Throughout the trawled area gouges or shallow troughs in the sea floor were seen. These were presumably caused by the trawl doors. In the nearby control area, the bottom was uniformly dark in appearance with the white (shell hash?) and black (sand dollars?) objects randomly distributed over it.

An effort has been made to quantify this qualitative observation. Figure 12 illustrates the grey scale histograms of ten video frames recorded approximately one second apart at a constant altitude of 2.1 m within the control area. The differences between individual histograms are caused by a combination of sea floor variability, electrical interference during the original data collection and degradation of video quality resulting from analyzing a copy rather than the original video tape. To facilitate comparisons with similar assemblages of histograms from other sections within both the trawled and control areas, an average histogram representing the ten has been employed. Figure 13 contrasts two such average histograms from two different sections within the trawled area of corridor A with the average histograms from two different sections within the nearby control area.

The decision to use an average of ten histograms obtained from video frames one second apart was purely arbitrary. Fortuitous as it may be, these parameters lead to a quantification of the video frames that clearly differentiates the trawled from the control areas. Further work is planned to explore whether or not these parameters can be optimized and to improve the quality of the video signal used for analysis. It will also be interesting to see whether or not one can quantify the difference in the video of the trawled area from year to year as the bottom returns to its former state.

Comments and Further Research Plans

The "long-trawl" will be regularly resurveyed by side-scan to monitor physical recovery rates of seabed features under the range of sedimentary and energy regimes existing along its length. The information gathered should provide a clearer understanding of trawl mark degradation rates and aid in interpretation of the extensive side-scan records existing for the continental shelf.

The "closed" area trawling impact studies reported here are intended to extend over several more years and to look at the impacts of both single and multiple trawling events. It is planned to resample the corridors in July, roughly one year after the experiment was put in place with the first trawling. Once sampling of the already trawled areas and controls is completed, it is planned to re-trawl one-half of each of the corridors and extend the length of the corridors to create newly trawled areas. These newly trawled ares will povide further replication of the "single event" trawling impact experiment, while the re-trawling of a part of the corridors already trawled one year previously will provide the basis for a "multiple event" trawling impact.

While results of the experiment must await the full treatment of samples and analysis of the data, we are encouraged by the success of the basic experimental design and its field establishment. The other major success to date has been the development of new more quantitative sampling tools such as the video grab

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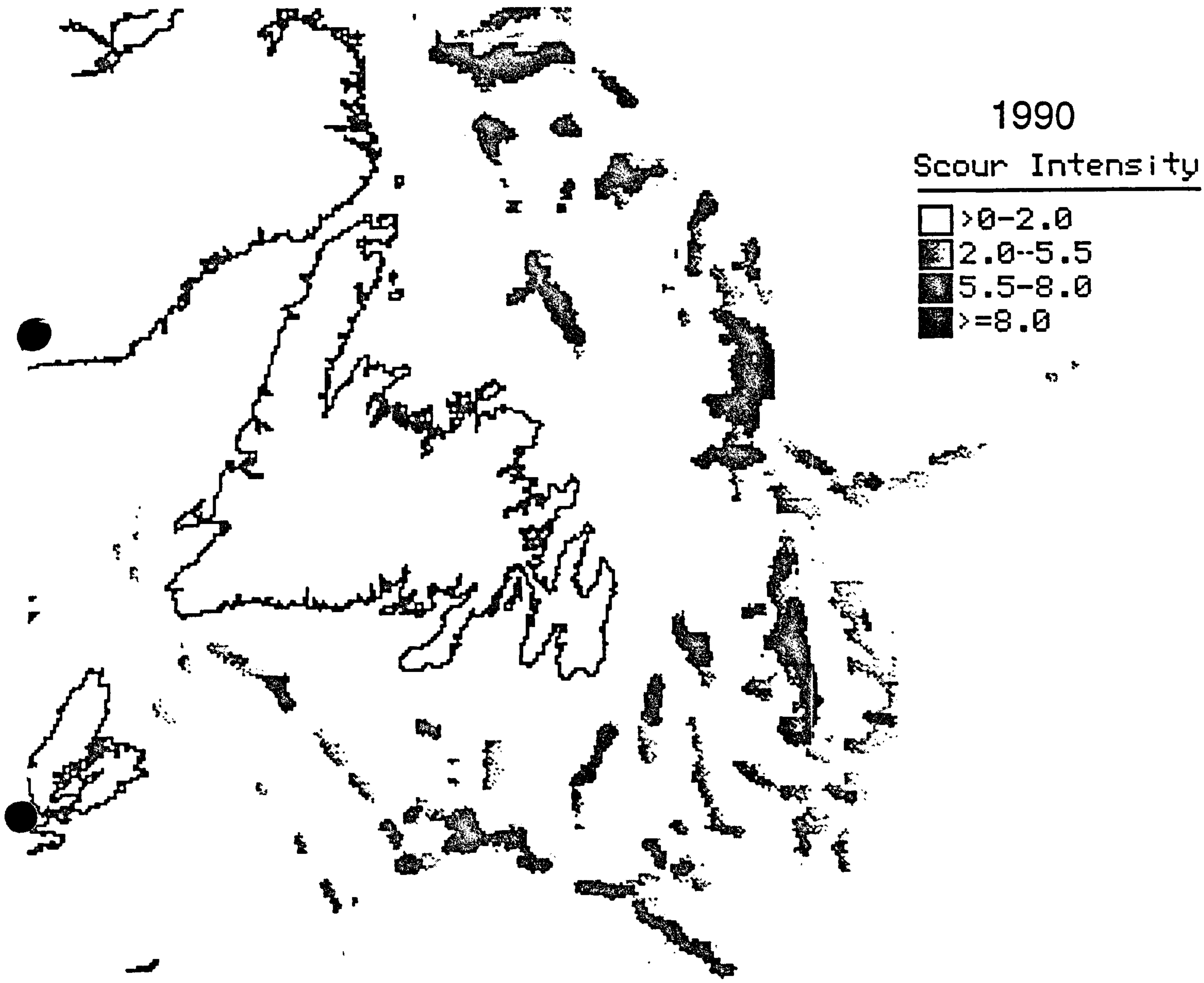

Fig. 1. Distribution and percent of seabed scouring by otter trawls on the Grand Banks as estimated from tow numbers, tow positions, mean length of tows, and sweep between doors (based on Newfoundland Region fisheries observer data). 16.7 km sampling circles.

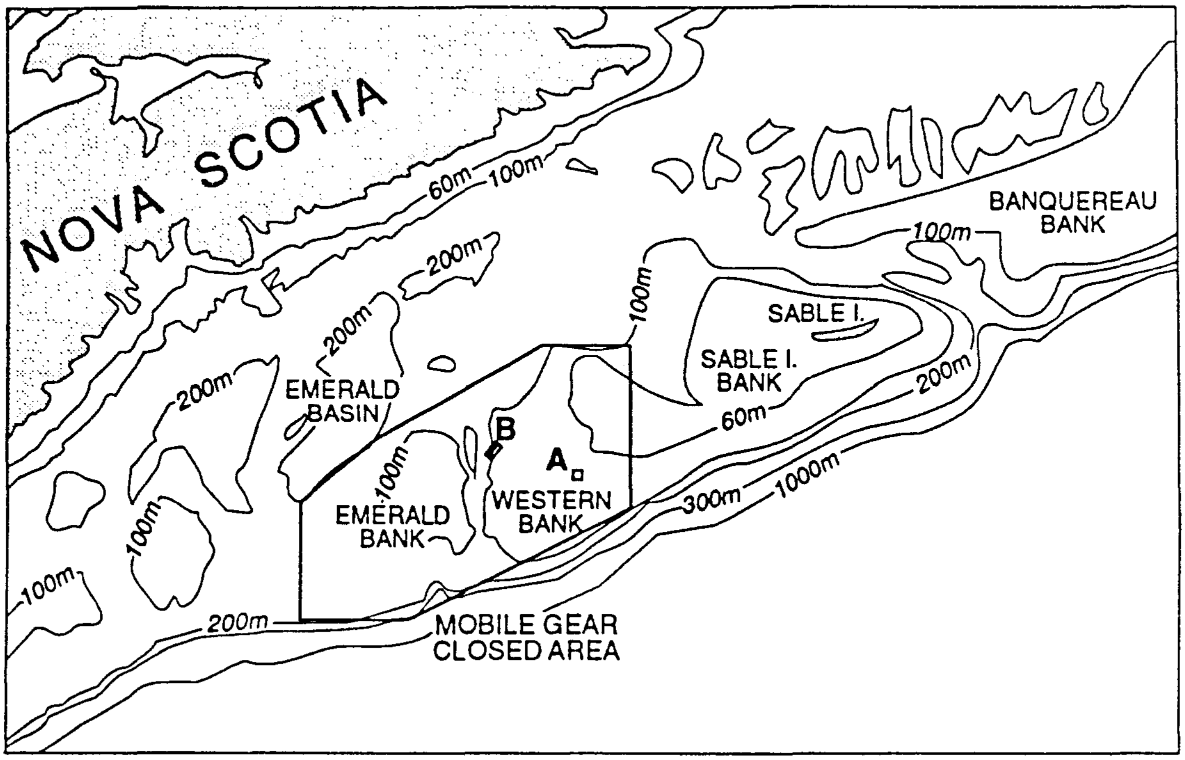

Fig. 2. The Scotian Shelf, showing the Western Bank area closed to mobile groundfish gear since 1987 ("Haddock" nursery area closure) and potential study areas A and B.

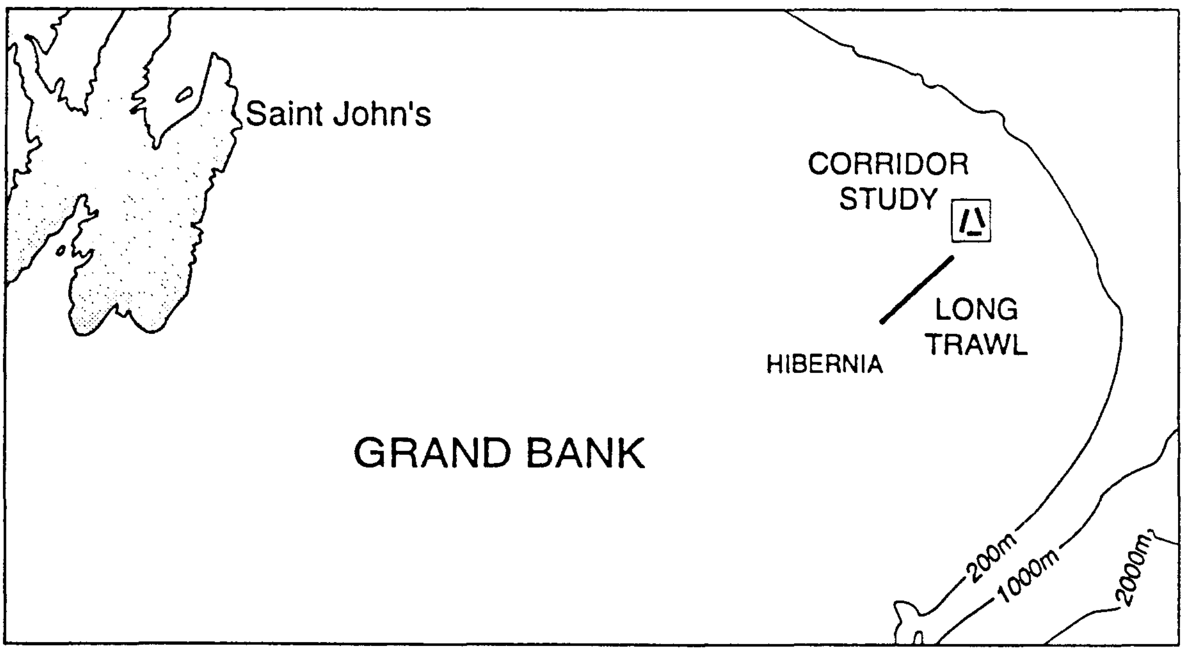

Fig. 3. The Grand Bank, showing east coast of Newfoundland, the site of the "closed" corridor study area and the track location of the "long-trawl".

Engel 145, High-Opening, Groundfish Survey Trawl -Isometric Assembly

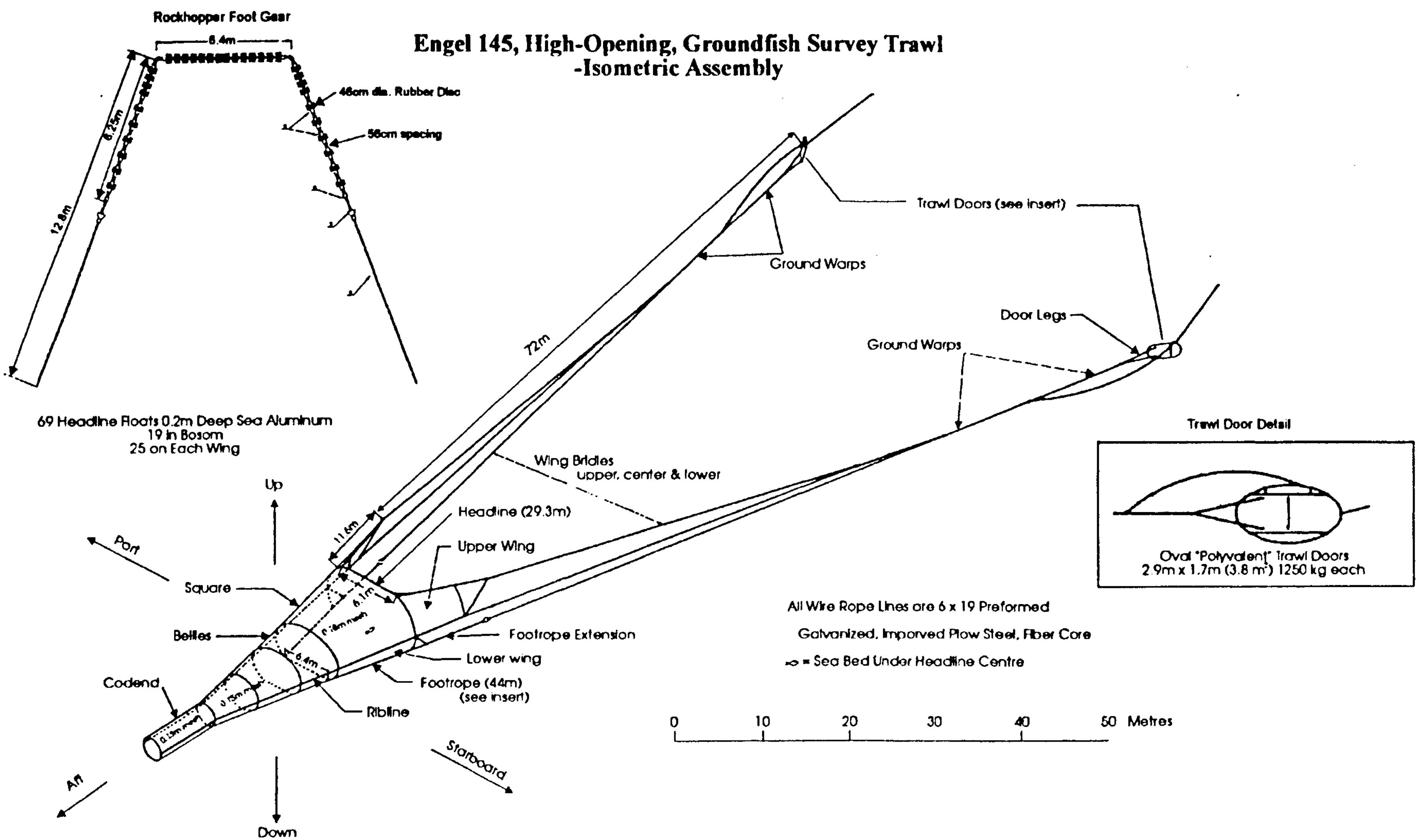

Fig. 4

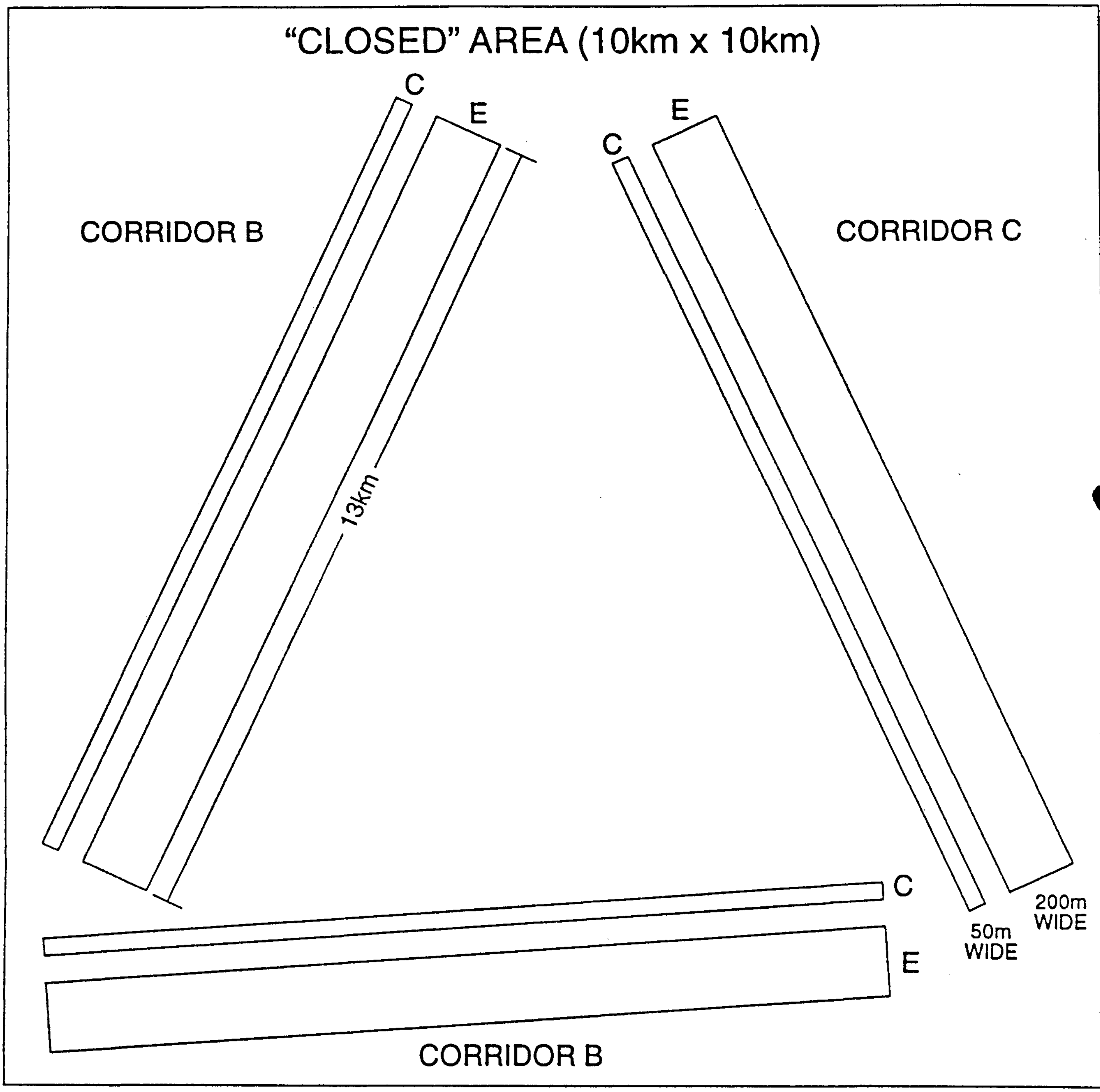

Fig. 5. The relative positioning and orientation of the Control and Experimental (trawled) Corridors A, B, and C within the "closed" area.

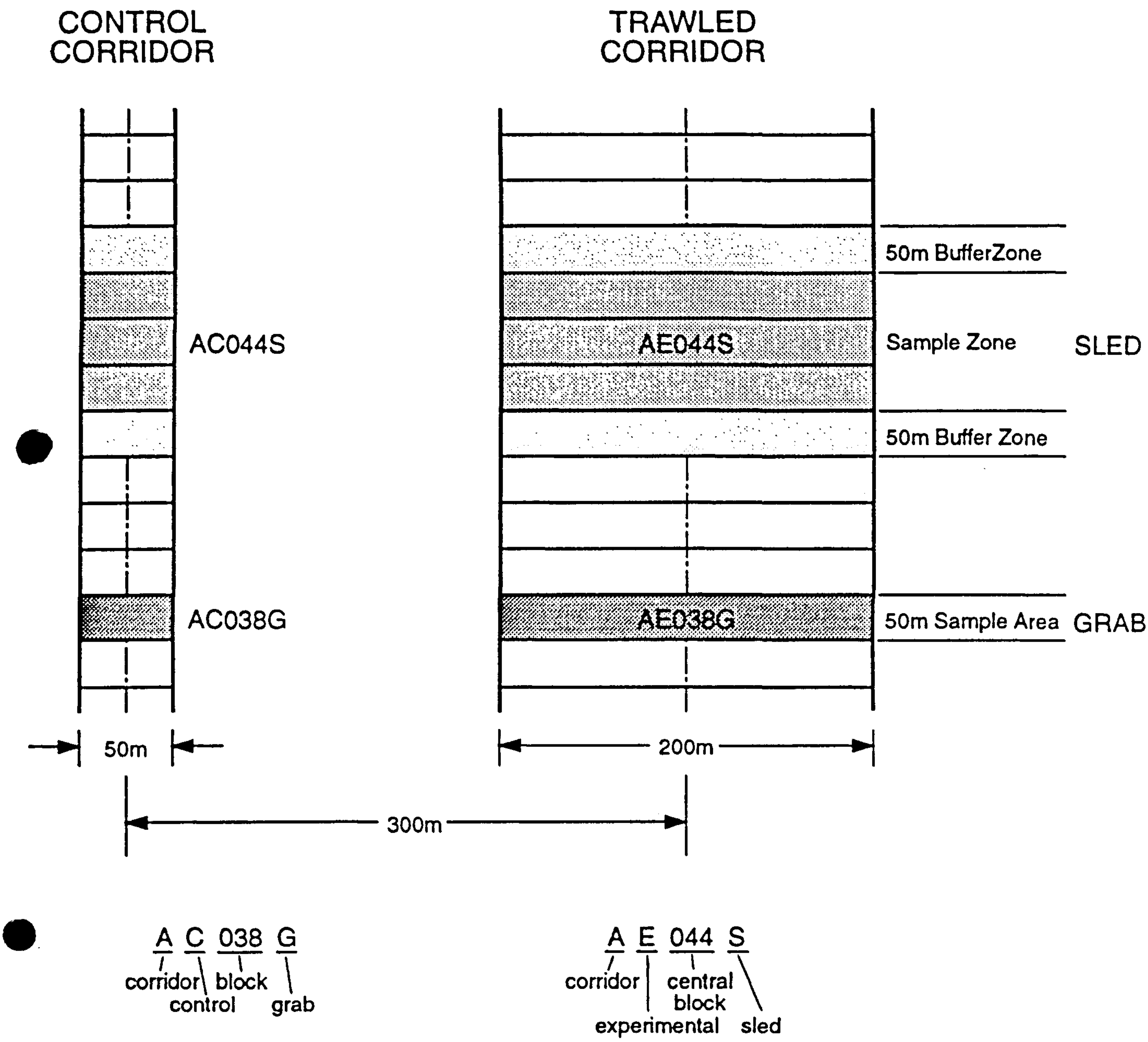

Fig. 6. A portion of a Control and an adjacent Experimental (trawled) Corridor, showing the 50 m blocks used individually for grab sampling and in combination for epibenthic sled sampling. Examples of station and sample coding is also given.

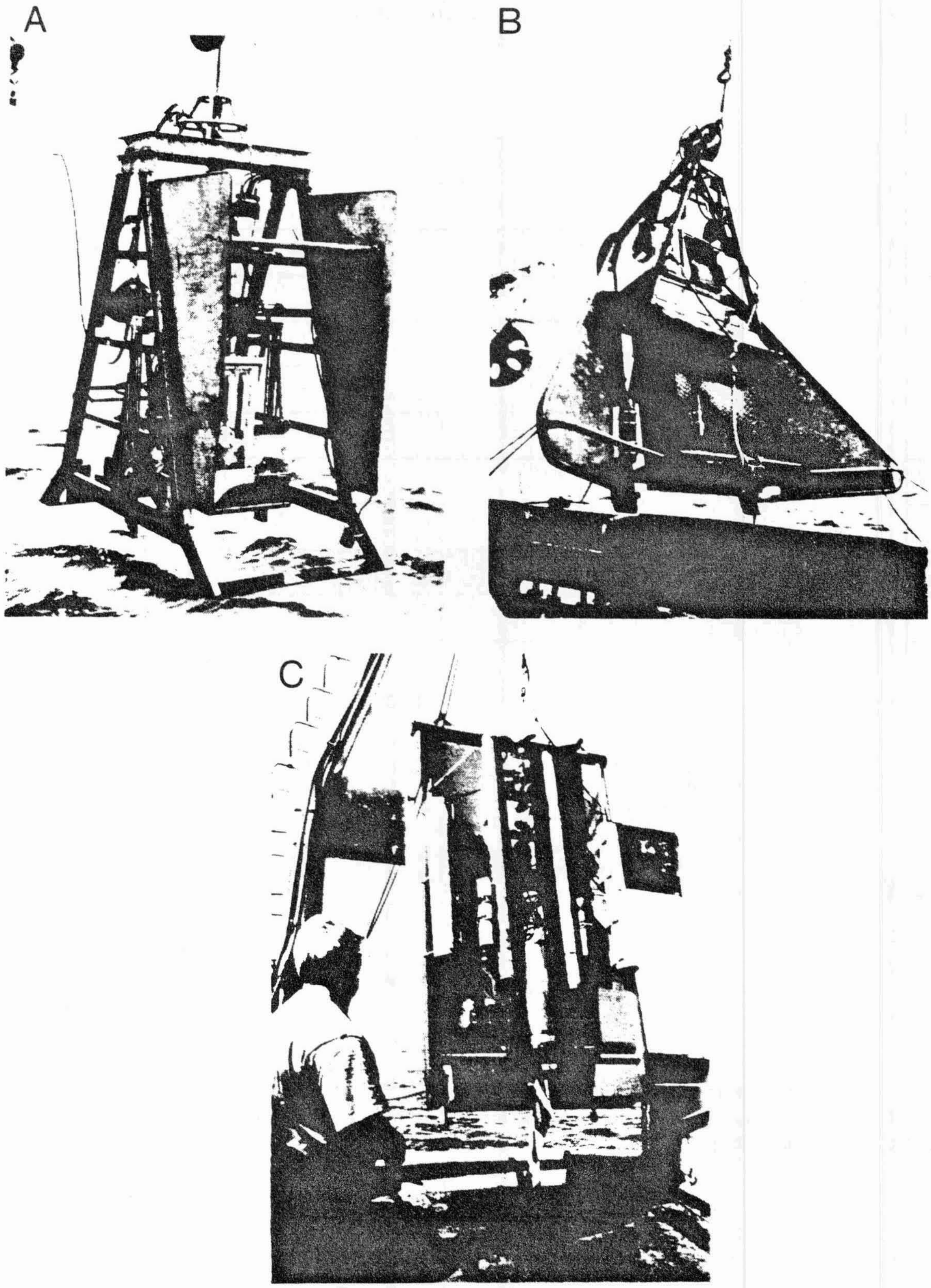

Fig. 7. The video grab (A), epibenthic sled (B), and Bottom Referencing Underwater Towed Instrumented Vehicle, BRUTIV, (C) being deployed from the C.S.S. Parizeau..

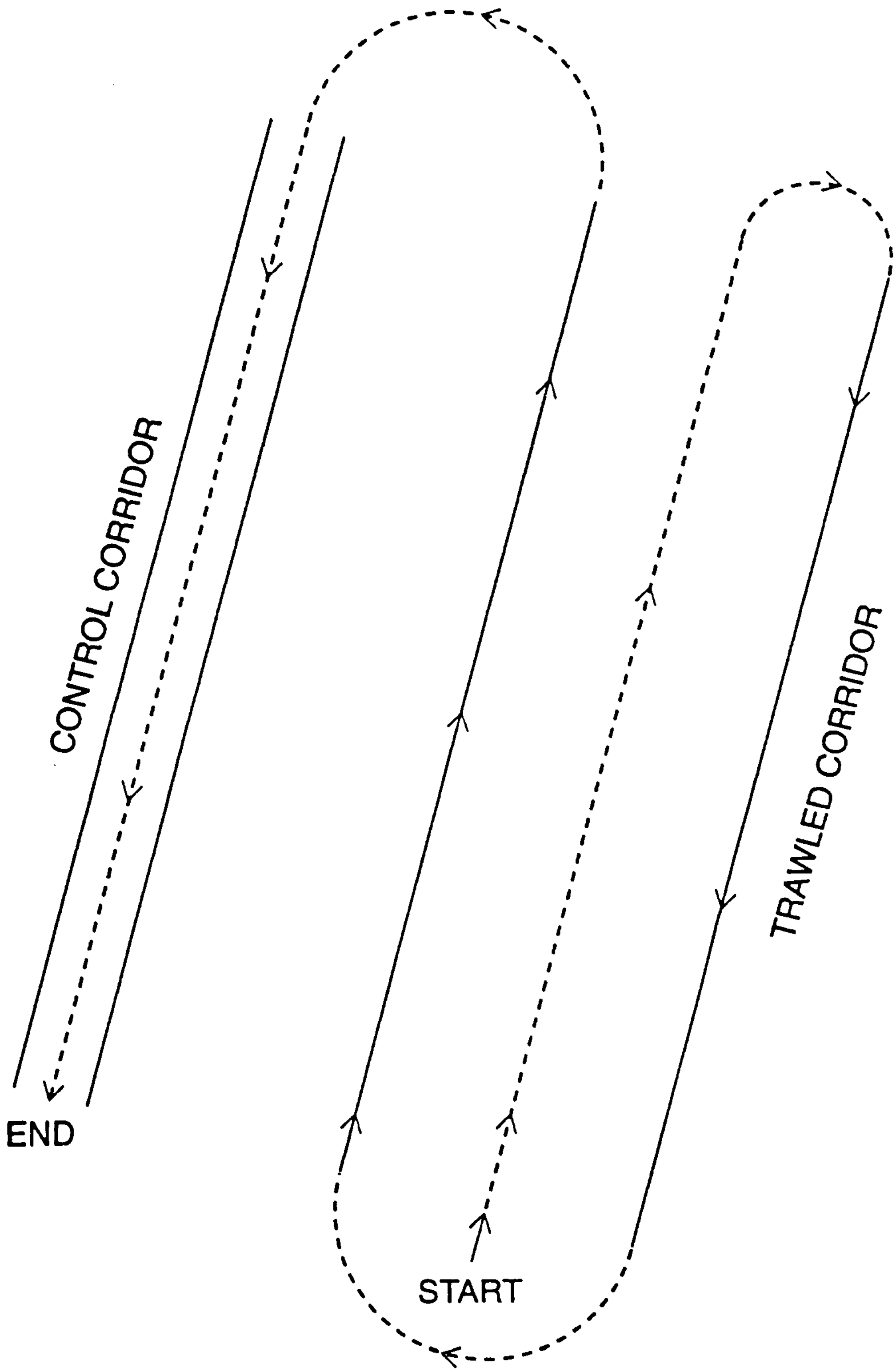

Fig. 8. Vessel track followed in side-scanning operations over on set of Experimental and Control Corridors. This track will provide complete coverage for mosaicing of the Experimental and Control Corridors and the area of seabed between them.

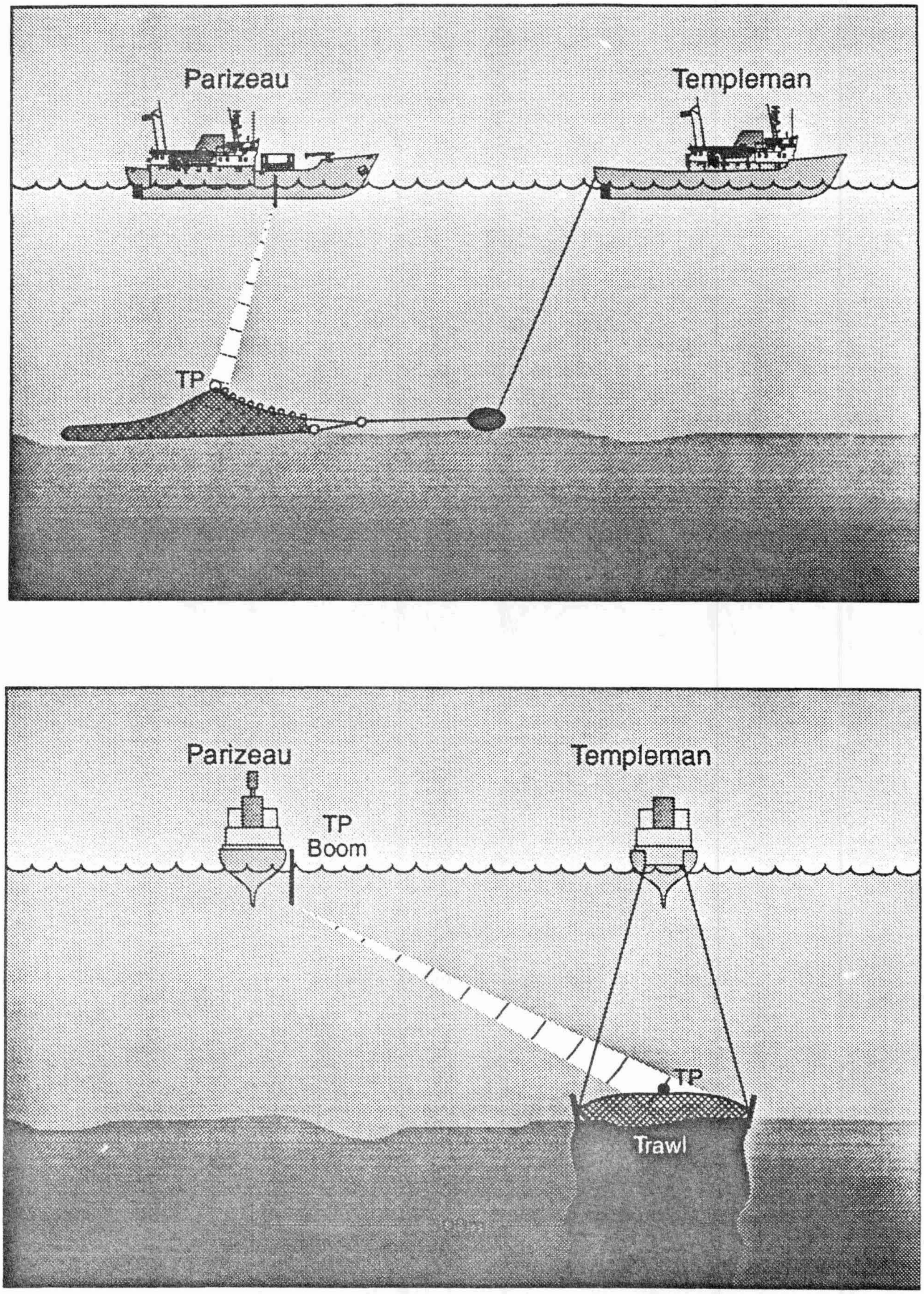

Fig. 9. Relative positioning of the C.S.S. Parizeau. and C.S.S. Templeman during Trackpoint (TP) monitoring of the trawl path in an Experimental Corridor.

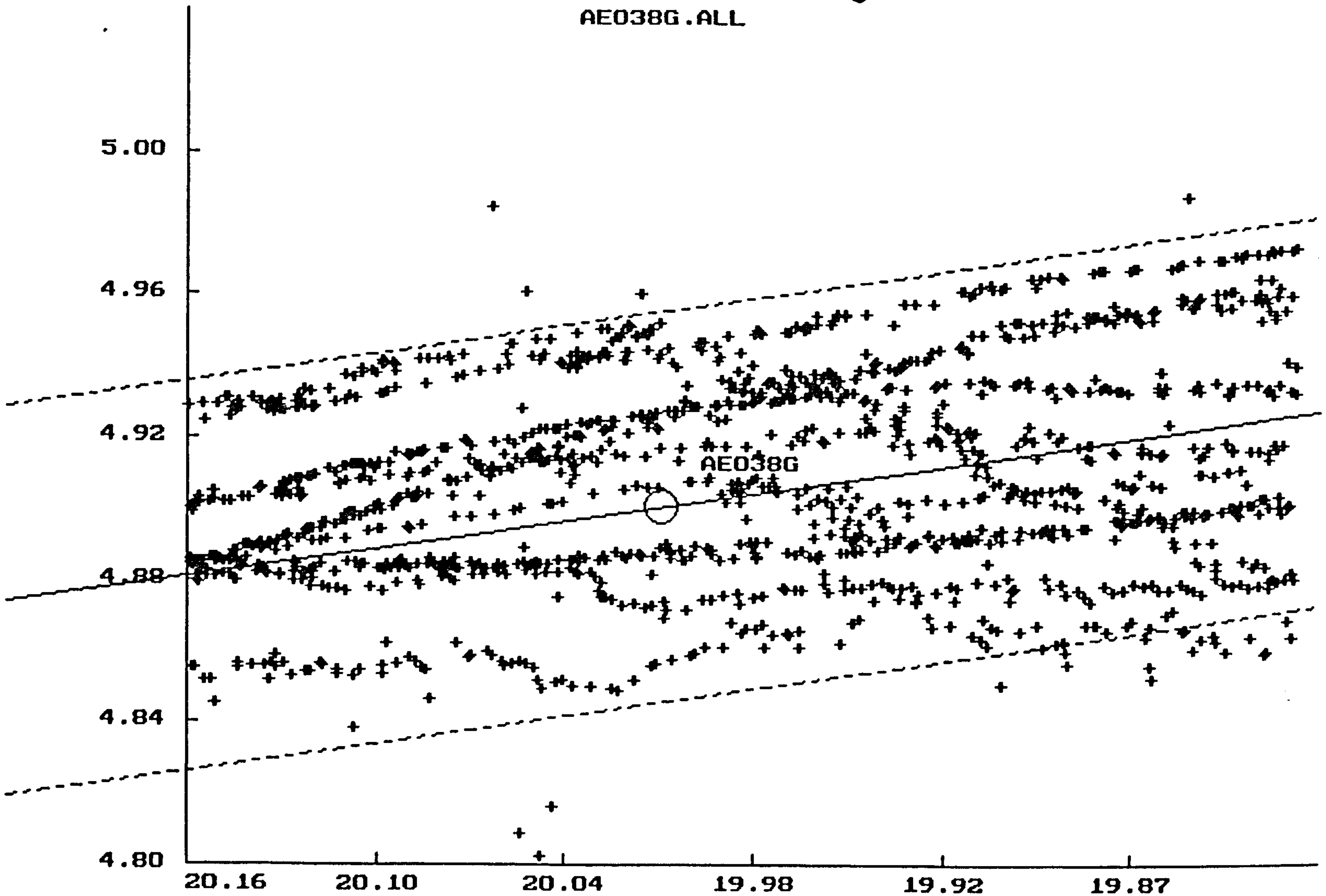

Fig. 10. Trackpoint indicated paths of trawls in relation to Grab Station No. 038 in Experimental Corridor A. The centre line and boundaries of the Corridor are also indicated.

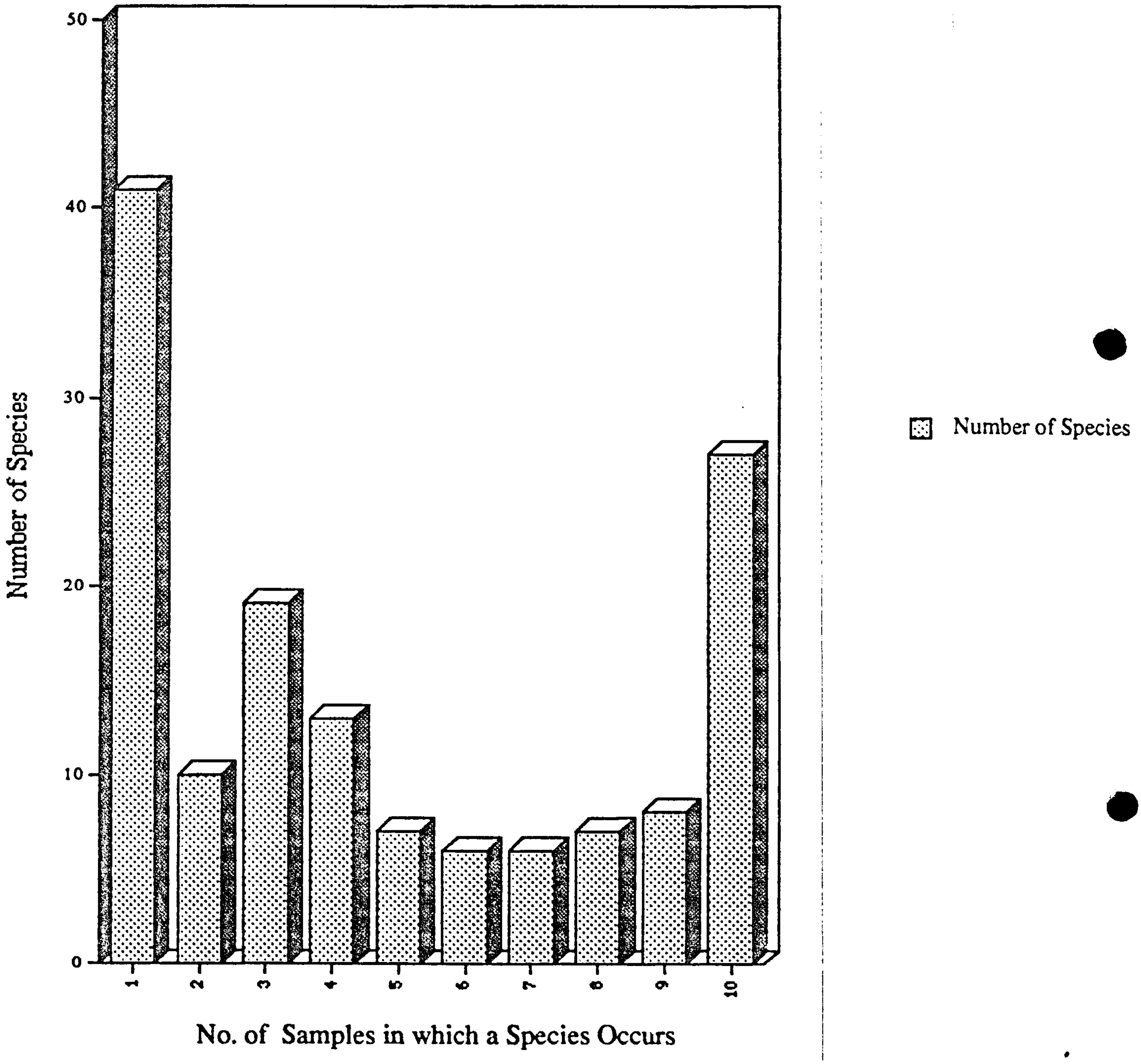

Fig. 11 Frequency of occurence of species in ten grab samples taken from control corridor A (5 samples) and the experimental area (pre-trawling) area of corridor A (5 samples) during Cruise 93-21.

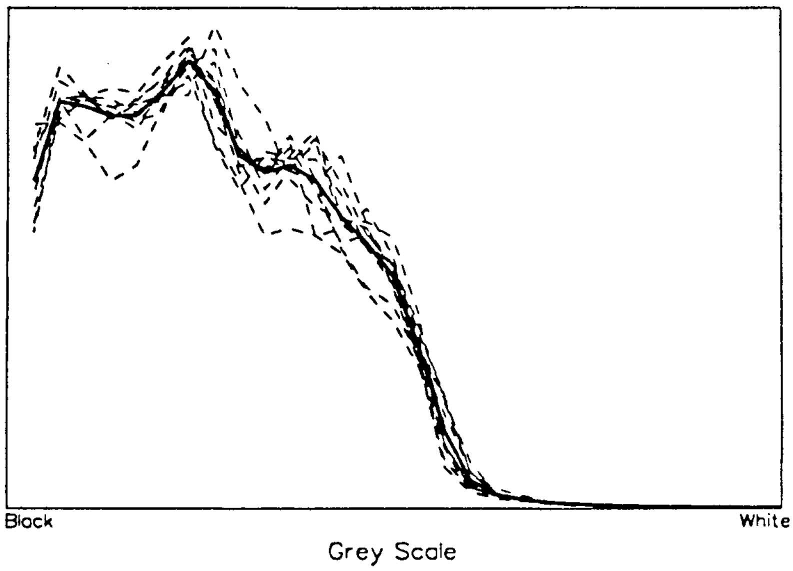

Figure 12. Composite of ten individual grey level histograms of sea floor video images of the control area sampled at approximately one second intervals. The heavy solid line is the average of the ten histograms.

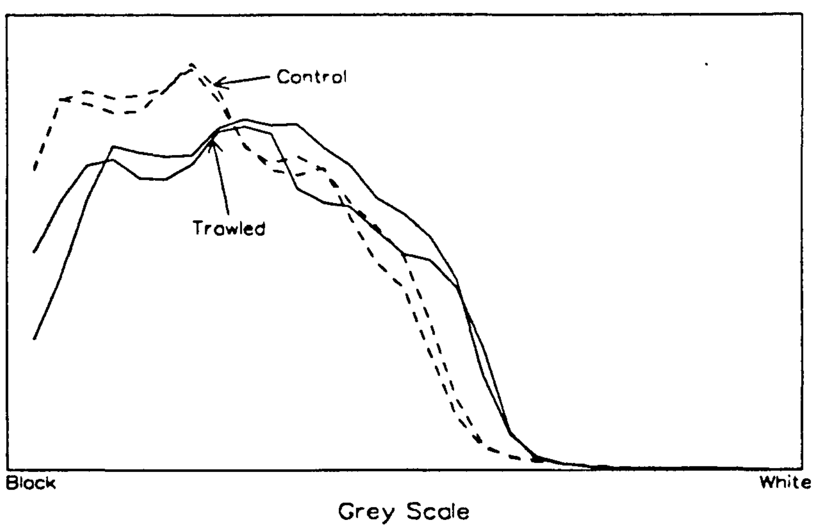

Figure 13. Averaged grey scale histograms from the trawled (one from each end of the corridor) and control (two widely seperated sections near mid-point) of corridor A.

Table 1. Summary of preliminary data on species richness, abundance, and distribution among stations sampled with the video grab and epibenthic sled.

GRAB SAMPLES[1]

- 145 species encountered
- 56-79 (species / sample (station))
  (Mean = 69)
- 27 species common to 100% of stations
- 36 species common to 90% of stations
- 41 species found only at one station

SLED SAMPLES[2]

- 74 species encountered
- 19-31 species / sample (station)
- 34 species common to approx. 20% of stations
- many species which occur only in low numbers at a few stations

[1] Corridor A only (total of 10 samples from untrawled areas only during cruise 93-21)

[2] Corridors A and B (total of 16 samples from both trawled and untrawled areas only during cruise 93- 21)

Table 2. Summary, by Phyla, of species numbers, density, and biomass for untrawled areas in corridor A during cruise 93-21.

Phylum	No. of Species	Individuals / m^2	g (wet) / m^2
Polychaeta	44	1561	54.3
Crustacea	34	202	7.5
Mollusca	51	575	640.2
Echinodermata	7	136	466.1
Other	9	2	2.7
Total	145	2476	1170.8

International Council for the Exploration of the Seas - Benthos Ecology Working Group meeting - Centre for Estuarine & Coastal Ecology (Yerseke), 10-13 May 1994

SENSITIVITY OF SPECIES TO PHYSICAL DISTURBANCE OF THE SEABED - PRELIMINARY REPORT

1 INTRODUCTION

The Working Group was asked by the Advisory Committee for the Marine Environment to:

> "prepare information on and, if possible, compile an initial list of indicator species, particularly with reference to species sensitive to physical disturbance of the seabed and report to ACME".

In addressing this request, the BEWG has reviewed new information as well as earlier reports (Anonymous 1990, 1993) and the draft report from the April 1994 meeting of the Working Group on the Ecosystem Effects of Fishing Activities.

The Working Group agreed that:

1. within the time available, and taking account of the information available at the meeting, the group did not feel it realistic to attempt to arrive at a definitive list of indicator (vulnerable) species or taxa. Rather, it was thought important to evaluate readily available summaries and develop a framework within which tasks could be assigned and carried out before the next meeting, allowing a proper evaluation of this item;

2. in considering "physical disturbance" it appeared that the request related specifically to disturbances of anthropogenic origin but that, in considering these disturbances, their scale and type of effect should be set against those of natural processes in the habitat in question;

3. "physical disturbance" was defined as:

   "Any discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment". (From Pickett & White 1985 quoted in Hall in press).

This definition does not include events such as anoxia and chemical pollution unless resulting directly from an anthropogenic activity such as dredging.

The WG considered what constituted an "indicator" species and was in general agreement with the WG on Ecosystem Effects of Fishing Activities comments on the issue. Throughout our report, we will use the term "vulnerable" rather than "indicator" species. "Vulnerable" species will include a wider range than the "indicator" species. "Vulnerability" takes account of both availability to the source of disturbance, life history, life style and species characteristics. "Vulnerability" is defined here as:

"the likelihood of the individual and/or population suffering some level of physical damage when exposed to physical disturbances".

It does not necessarily imply likelihood of local extinction.

Within this framework, we agreed two possible approaches to identifying potentially vulnerable species:

1 to examine the range in types of activity (for instance, mobile fishing, aggregate extraction) that would create a physical disturbance of the seabed and the character of disturbance as related (for instance) to fishing gear type;

2 to examine the characteristics of particular taxa which would lead to them being vulnerable to particular disturbance types.

This would produce a framework within which to indicate likely vulnerable species and habitats present in each area under consideration to be assessed rather than providing a definitive and universally applicable list.

In the following, we examine:

1 the sources of physical disturbance of the seabed, both anthropogenic and natural;
2 the effects of such disturbances, both physical and biological, and
3 those characteristics which we consider likely to make a species sensitive (vulnerable) to such disturbances.

We then present examples of species (or taxa) which are considered vulnerable. The examples represent three levels of confidence. In the first, we list those species for which we believe there is sufficient scientific evidence to demonstrate sensitivity or vulnerability. In the second, we list those species for which there is some evidence of sensitivity or vulnerability, but at a lower level of assurance than above. The third list is of species (or taxa) that the WG members felt likely to be vulnerable, based on their knowledge of the species, their habitats and potential impacts.

2 SOURCES AND NATURE OF DISTURBANCES

(Table 1 summarises sources of disturbance)

Physical disturbance of substratum can include*:

1 substratum removed to leave inhospitable habitat (eg sediment removed down to clay level, consolidated/stable substrata removed to mobile substrata including substrata likely to cause scouring);

2 hard substrata having fragile slow growing species may be broken-up, abraded or overturned;

3 reefs of slow growing species providing a biological substratum for other species (eg *Lophelia pertusa*, *Modiolus modiolus*) may be destroyed;

4 biological reefs or consolidated hard substrata overturned/destroyed but capable of rapid recolonisation after disturbance ceases (eg *Sabellaria spinulosa*);

5. (re)suspension of silt followed by sedimentation nearby or at a distance;

6 sediment compaction (below heavy gear);

7 substratum structure and composition changed producing a 'new' habitat (eg, topography changed, buried cobbles exposed, coarse shell material broken-up or exposed).

* Takes account of 1990 ICES Benthos Working Group report.

When considering the potential effect of physical disturbance on benthic fauna it is important to consider the scale, frequency and intensity of any disturbance event (reviewed by Hall, in press). Large-scale natural events such as periodic storms and anoxic events can affect extensive areas leading to mass mortalities of entire communities. Short-lived opportunistic species will rapidly colonise these areas, but the (re)colonisation by longer-lived, slow growing species will be slower, and clearly may never occur if large-scale events are frequent (annual ?). Many natural environments are subject to 'disturbance'. For instance, storms mobilise shallow sediments, and high river runoff carries silt which settles onto the seabed. Thus, although shallow subtidal benthic communities, such as those in the southern North Sea, are subject to disturbance by fishing gears, the communities present are frequently exposed to storm effects. Hence, where these circumstances occur, it may be thought less important to consider sediment disturbance caused by anthropogenic activities. However, fishing should still be considered in relation to effects of heavy gear damaging organisms. Also, high turbidity caused by storms will be associated with oxygenation whereas turbidity caused by fishing can occur in calm weather and may therefore result in smothering and deoxygenation. On communities that are rarely exposed to disturbance, such as in sheltered areas or at depths below the effective wave base, the effect of mobile gear may be more persistent, lasting several years. Hall (in press) cites Theil and Schriever's (1990) study of the effects of deep sea manganese nodule dredging at 4000 m depth. The furrows created by the dredge were still visible after two years and the epifauna were still absent from the site. This demonstrates how anthropogenic disturbance has a greater and more lasting effect in stable sites. Individual anthropogenic disturbances to the seabed tend to act on a local scale, for example the width of the area affected by a dredge or trawl will be less than 50 m, hence recolonisation by mobile fauna will tend to be rapid. However where these activities are intensive or chronic, the recolonisation time will increase. Repeated, frequent disturbances in the same area will hinder the recolonisation of those long-lived species which are killed by these activities.

Biogeochemical effects should also be taken into account, including alteration of sediment type, changes to contaminant and nutrient fluxes, biochemical reactions within microbial populations (from the 1990 report).

3 SPECIES CHARACTERISTICS WHICH MAKE THEM VULNERABLE

The vulnerability of a species is partly dependent on its structure, size, behaviour, life strategy etc and on the environment/habitat the animal lives in. The geographical distribution of species also has to be considered - species at the extreme edge of their distribution are likely to be more vulnerable.

Fragility of a species will, in the first instance, determine whether it is damaged or not. This fragility is determined by morphology (size and shape), whereas vulnerability is determined by the depth it lives in the sediment, (ie within or outside the reach of the physical disturbance) and (non)mobility . The nature of the sediment is also important, eg fishing gear may penetrate different sediments to different depths, and disturbance of large gravel or cobbles themselves will have a very different impact on species than, for instance, sand.

After being subjected to physical disturbance, the recovery process of an individual depends on the ability to regenerate, repair damage or to relocate itself. Low abilities of these attributes may make a species vulnerable to indirect effects of physical disturbance, in particular predation (Kaiser & Spencer, in press).

Sediment resuspension, interfering with filter-feeding and/or respiration may have a negative effect on growth and, ultimately, reproduction and recolonization.

Besides effects on the individual level, a long-term effect on population level may be present. Factors determining these are longevity of a species, growth rate, reproduction and settlement success. It should be realised that potential recruitment is thereby determined not only by standing stock of the parent population, but may also be affected by the changes in the physical characteristics of the habitat; for instance sediment grain size, as well as the absence/presence of a parent population. For some sessile organisms it has been shown that juveniles only settle in the vicinity of an older population releasing chemical stimuli, which promote settlement. Thus, to assess the vulnerability of a species, detailed knowledge of lifecycle, regeneration, growth etc is required.

The ICES working group on Ecosystems Effects of Fishing Activities based their assessment of vulnerability on life history characteristics and information derived from a wide variety of field studies relating fishing induced mortality to gear and sediment types. We considered the approach developed for the second meeting of that group (Anon. 1992), and now published in Rees & Dare (1993), to be a good model for assessing likely mortality of species.

4 VULNERABLE (SENSITIVE) SPECIES

4.1 DOCUMENTED VULNERABILITY

Currently, it is possible to document effects for two sources of disturbance; fisheries and aggregate dredging.

Impact of fisheries Effects on the benthic communities have been described by, eg Graham (1955), Bridger (1970), Houghton *et al* (1971), de Groot & Apeldoorn (1971), Margetts & Bridger (1971), de Groot (1973), Schafer (1972) and Bergman *et al* (1991). Damages, mortality and reduction in numbers has been reported for *Arctica islandica*, *Echinocardium*, *Lanice conchilega*, *Ophiura texturata*, *Astropecten irregularis*, *Pectinaria koreni*, *Liocarcinus holsatus*, *Cancer pagurus* and *Corystes cassivelaunus*, *Tellina* spp, *Hyas* spp and *Spiophanes bombyx*. The presence of infaunal benthos in beam trawls appears to confirm the extent of damage to other species such as *Tubularia*, *Pectinaria*, *Ensis* and *Solen*. On local scales the loss of target populations, such as oysters, and the destruction of physical structures such as *Sabellaria* reefs is well documented (eg Riesen & Reise, 1982). The disappearance of such species as *Ostrea edulis, Modiolus modiolus, Dosinia exoleta, Glycymeris glycymeris, Arctica islandica* and *Neptunea antiqua* has been suggested as having been caused by beam trawl fishery (Bergman *et al* 1991).

The WG draws attention to Section 3 of the draft report of the WG on Ecosystem Effects of Fishing Activities. Two tables are of particular relevance to the consideration of vulnerable species of the benthos. Table 3.3.1 provides estimates of 'equivalent potential jeopardy' for various fish and mollusc species from the North Sea. The table was derived using the formulae of MacDonald *et al* (1994) which links life-history parameters to potential jeopardy. It suggests that a number of molluscan species (eg *Arctica islandica* and *Modiolus modiolus*) may be in jeopardy even at low levels of fishing relative to more mobile species such as fish. In the same report, Table 3.3.2, the question of vulnerability to fishing gear and direct mortality of a range of benthic fauna is addressed. The mortality estimates presented are derived from a number of field studies on the effects of various gear types. A list of 'vulnerable species' might be derived from this table if one wished to establish some level of mortality at which the term is to apply (eg >25%). Even then, caution should be expressed since the level of mortality may be highly influenced by substratum type (eg *Placopecten magellanicus*; Shepart & Austen 1991).

Impact of gravel and/or sand extraction Local effects of gravel extraction on the Klaverbank are described by van Moorsel & Waardenburg, (1991). Densities of most species seem to have recovered within one year after aggregate extraction. This suggests that the species assemblage living at the Klaverbank is adapted to the dynamic nature of the seabed and hence capable of relatively rapid recovery. Species manage to survive either by rapid recolonisation or by adaptations which enable them to withstand aggregate redistribution. However, large bivalves (*Arctica islandica, Gari fervensis, Tellina crassa, Venerupis rhomboides, Dosinia exoleta, Ensis* spp), an important component of biomass, had not recovered from gravel extraction 15 months later.

4.2 APPARENTLY VULNERABLE SPECIES

Under this heading, we are considering species where sufficient information about their life history characteristics is available to allow a realistic evaluation of their potential vulnerability. The best example of how these life history characteristics can be used to evaluate vulnerability is given in a report by Rees and Dare (1993). They evaluate the risk of local extinction for nine species of invertebrates based on information as to:

"(i) species characteristics: life-style, habitat/distribution, densities, biomass/ production, life-cycle strategy, recruitment, longevity, annual mortality rate;

(ii) sources of mortality: burial/wash-out, temperature, predation, plankton blooms/eutrophication, trawl/dredge effects, pollution and 'other'."

Reference to their Table 2(a) and 2(b) and Figure 2 allow an evaluation of the relative level of risk (vulnerability) to local extinction from various natural and anthropogenic factors. The report suggests vulnerability to physical disturbance to be moderate to high, relative to other sources of risk for: *Pectinaria koreni, Sabellaria spinulosa, Abra alba, Arctica islandica* and *Echinocardium cordatum.*

4.3 CONSIDERED LIKELY TO BE VULNERABLE

The review of Jones (1992) provides examples of organisms exhibiting vulnerability. These included the scallop *Pecten novaezelandiae*, the coral *Lophelia* and bryozoans. Long-lived, slow-growing species may be nearly exterminated by a single impact, eg the passage of a trawl or other fishing gear. That applies to *Lophelia*-banks, large corals such as *Paragorgia* and large sponges such as *Geodia, Chondrocladia* a.o., sea pens such as *Virgularia mirabilis* and *Funiculina quadrangularis* and to reefs or mats of *Sabellaria* species. Most of the mentioned species are spatially restricted to concentrated assemblages, and may actually deserve being included in 'endangered species' lists ('red lists'). (This information from the Faeroes, unpublished)

Some fragile species may be fatally damaged, eg sea urchins and soft-shelled bivalves, while thick-shelled species may react with 'repair' as demonstrated for *Arctica islandica* (Klein & Witbaard 1993)

4.4 FURTHER APPROACHES

The potential vulnerability of species should be assessed on the basis of life history characteristics, physical fragility/robustness of the species, habitat and behavioural characteristics [epifaunal/infaunal/deep burrowing/rapid burrowing]. We felt that practical consideration required a classification into which certain species could be included. Features listed above were grouped in the following types:

- fragile long lived species with infrequent recruitment - unlikely to recover within a foreseeable future. Examples likely to include: *Paragorgia arborea, Funiculina quadrangularis, Lophelia pertusa,* large sponges (for instance *Axinella polypoides),*

- fragile long lived species with good prospects of recruitment/regrowth (but after several years). Examples likely to include: *Modiolus modiolus, Sabellaria* spp (thick reefs), *Pentapora foliacea,* large bivalve molluscs, eg *Dosinia exoleta,* some hydroids, eg *Eudendrium* spp, *Thuiaria thuja,*

- fragile but fast growing/recruiting species - likely to be damaged but recover rapidly. Examples likely to include: individuals or thin crusts of *Sabellaria spinulosa, Echinocardium cordatum,*

- robust or deep burrowing species species unlikely to be damaged: examples likely to include *Upogebia* species,

- species likely to thrive in disturbed situations (eg predators, opportunistic species). Examples likely to include: *Capitella capitata.*

One important means for establishing a list of vulnerable species will be the absence or substantial reduction in number of the species in question. That requires direct knowledge of the previous abundances of the species in the actual area. Alternatively, their former presence might be inferred from comparison with similar habitat in the vicinity which has not been subject to disturbance - however, such comparisons are dangerous!

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Theil & Schners

TABLE 1 Sources of disturbance from 1994 (and 1990) meetings of the ICES Benthos Ecology Working Group

ANTHROPOGENIC SOURCES

1	Mobile fishing/sampling gear:	dredges hydraulic or suction dredges trawls - beam - otter
2	Aggregate extraction (Industrial dredging): (includes maintenance dredging)	rock gravel sand mud maerl/calcareous sediments
3	Dumping (Dumping from ships/ discharge from pipelines)	dredged material mine tailings sewage sludge drill muds beach nourishment/coastal defence
4	Laying pipelines (Construction works)	pipelines (barrages) (harbours)
5	Shipping movements	propeller wash wake-wash
6	Bait digging	manual mechanical
7	Seaweed extraction	grabs dredges
8	Tangle/ghost nets and pots (creels)	

NATURAL SOURCES

1	Storm events (wave and tidal current action)	
2	Tidal current extremes	
3	Siltation	
4	Bioturbation	- burrowing - fish and mammal feeding - megafauna feeding
5	Ice	- ploughing - scouring

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QUANTITATIVE SAMPLING OF GRAVELS

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Introduction

Most of the previous work which has been undertaken to describe the benthos associated with marine gravels has relied on semi-quantitative dredges such as the Anchor dredge (Forster, 1953) used by Holme (1966), the Ralier du Baty dredge used by Davoult *et al.* (1988) and a modified Anchor dredge used by Kenny *et al.* (1991). The Anchor dredge is typically deployed with about 3 times the water depth of warp. This allows the dredge to settle on the bottom before the motion of the ship brings the warp taut causing the dredge to take a single bite out of the sediment before it is hauled. However, the dredge frequently gets dragged along the sea bed before being hauled, especially when deployed from a large vessel, which introduces possible variation between the area of sea bed sampled and the volume of the sediment retained. In addition, the risk of washing-out of some of the sample contents (especially motile epibenthic species) due to the open-ended nature of the sample bucket may reduce the sampling efficiency.

A recent investigation of the effects of marine aggregate extraction on the Klaverbank in the Dutch sector of the North Sea (Sips and Wardenburg, 1989) reported that the Hamon grab was an effective quantitative coarse sediment sampler. The Hamon grab (Figure 1) effectively takes a scoop out of the seabed with a relatively constant surface area, thereby reducing the sample variation as experienced with the Anchor dredge. A Hamon grab was constructed by MAFF and a preliminary assessment of its sampling efficiency was made during sea trials in 1992.

Methods

A comparison of the sampling efficiency of the Hamon grab and Anchor dredge was made at a gravelly site off the East coast of England in December 1992. 5 Hamon grab samples and 5 Anchor dredge samples were taken at the same location.

Both Hamon grab and Anchor dredge samples were analysed according to the procedures given in Kenny *et al.* (1991). However, prior to cluster analysis it was necessary to exclude the numerically dominant *Dendrodoa grossularia* and *Balanus crenatus* as well as the very rare species (i.e. those occurring in no more than 2 samples and whose total abundance was less than 2) in order to highlight the differences between the sampling efficiencies of the devices.

Results

The combined output from cluster analysis, on root-transformed abundance data (>1mm), at the reference site is shown in Figure 2. It can be seen that, in general, the complement of common species sampled by the Hamon grab is similar to that sampled by the Anchor dredge. In addition, both *D.grossularia* and *B.crenatus* were numerically dominant (Table 1). Out of a total of 49 common species sampled, 44 were present in both Hamon grab and Anchor dredge samples. Four of the remaining 5 species, *Spiophanes bombyx, Eusyllis blomstrandi, Adalaria loveni* and *Golfingia vulgaris* were sampled only by the Hamon grab whereas *Crossaster papposus* was sampled only by the Anchor dredge.

Table 1. Sample averages (x) and Standard Deviations (SD) of *D. grossularia* and *B. crenatus* for each device.

	Anchor Dredge		Hamon Grab	
n=5	x	SD	x	SD
D.grossularia	2300	1895	1626	575
B.crenatus	2243	2199	1485	624
Total Abundance	4694	4135	3305	1206

Both the standard deviations for *D. grossularia* and *B. crenatus* in Table 1, and the relative position of the Anchor dredge stations A2 and A4 in the dendrogram (Figure 2), suggest a higher variance between Anchor dredge samples compared to the Hamon grab. However, using the log (variance/mean) ratio as a means of assessing community patchiness (Elliott, 1977) both samplers provided very similar results, namely 1.75 and 1.97 for the Hamon grab and Anchor dredge, respectively. Although the two dominant taxa were more abundant in Anchor dredge samples (Table 1), a number of other species such as the polychaetes *Spio martinensis, Pholoe minuta* and *Syllis cornuta* and the amphipods were more abundant in Hamon grab samples.

Discussion

An earlier study which compared the sampling efficiency of the Hamon grab with the Anchor dredge (MAFF, unpublished data) indicated that the Anchor dredge captured significantly more epifauna (Figure 3). This was attributed to the dredge being towed a substantial distance (50-100m) over the seabed before being hauled. Two factors which contributed to this were the action of strong tides and wind on the research vessel at the time of sampling. However, this was not thought to be a problem during the present study and the results show that the densities and variety of epifaunal species were no greater in

Anchor dredge samples compared to the Hamon grab. Indeed the complement of species and densities sampled by the Anchor dredge and Hamon grab were very similar.

It would appear that the sampling efficiency of the Anchor dredge is dependent on a number of factors such as the size of the research vessel and the strength of the prevailing tide and winds. Forster (1953) points out that the Anchor dredge, in order to work efficiently, should bring the ship to a halt. Clearly, this is not feasible for larger ships and especially in rough conditions the behaviour of the dredge at the sea bed may be unpredictable. In support of this conclusion is the relatively low success rate for sample collection by the Anchor dredge (about 60%) compared to the Hamon grab (about 100%).

The present study indicates that under certain conditions the performance of the Anchor dredge compares favourably with the Hamon grab, and it retains a value for initial semi-quantitative assessments of the benthos of coarse substrates. However, for quantitative studies such as those concerned with monitoring the effects of gravel extraction on the benthos, the Hamon grab is the preferred sampler, largely because it can sample a relatively constant surface area with greater success than comparable devices used in surveys of soft sediments.

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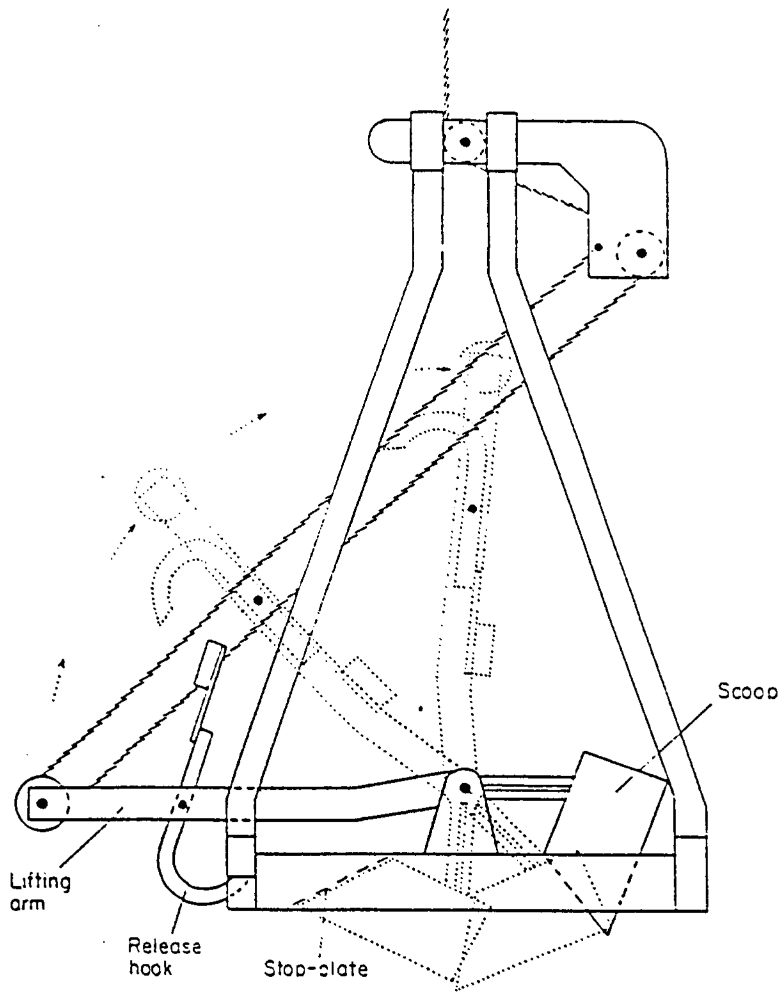
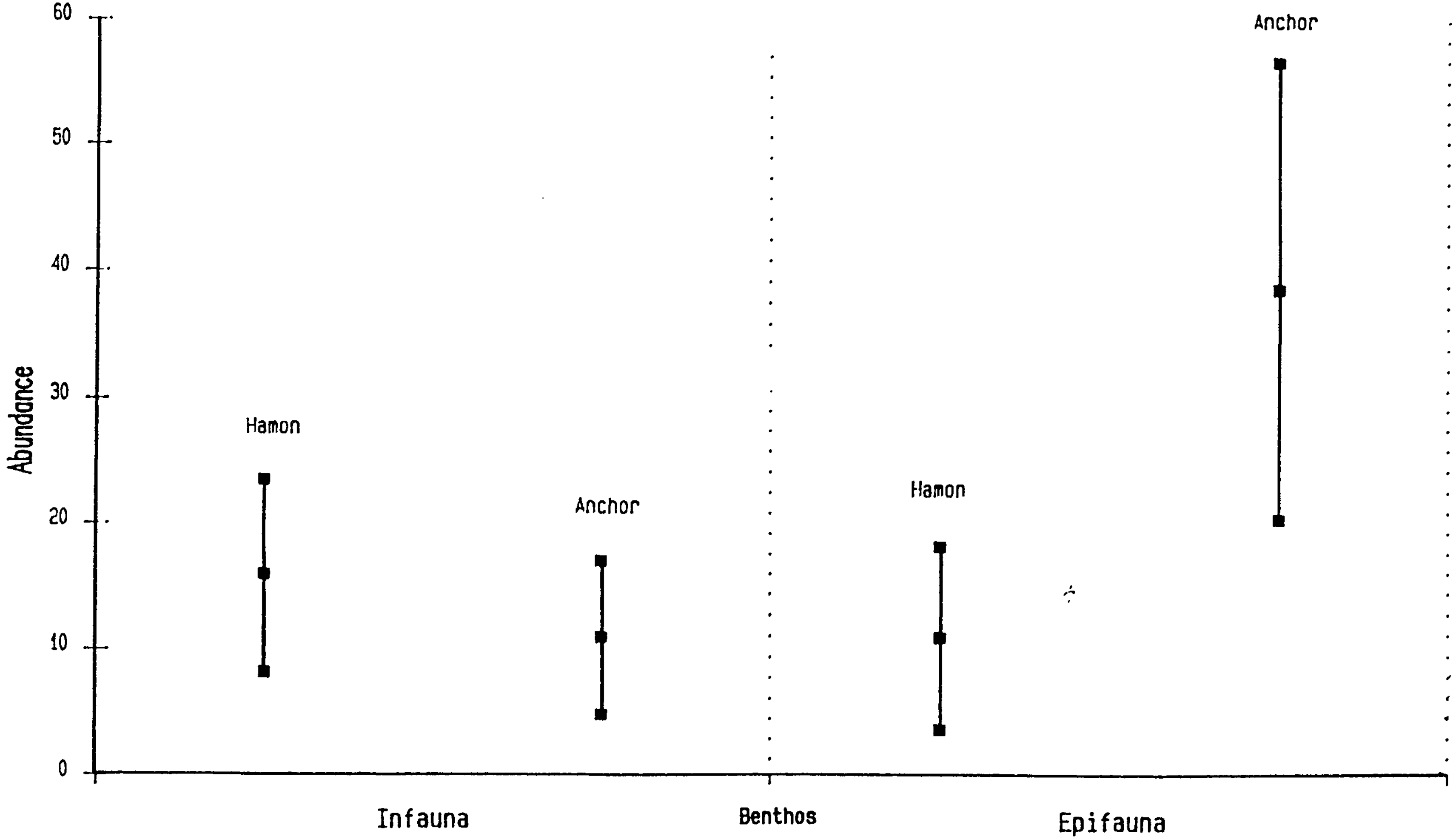


Figure 1. Schematic diagram of the Hamon grab taken from Holme and McIntyre (1984).

Figure 2. Cluster analysis by samples and species. A1-A5 are Anchor dredge samples. H1-H5 are Hamon grab samples. Circles represent root-transformed densities.

Figure 3. The average abundance of epifauna and infauna sampled by the Anchor dredge (5 samples) and Hamon grab (5 samples). Error bars are 95 % confidence intervals.



International Council for the Exploration of the Seas - Benthos Ecology Working Group Meeting - Centre for Estuarine & Coastal Ecology (Yerseke) 10-13 May 1994

QUALITY ASSURANCE GUIDELINES FOR BENTHOS STUDIES

This report by the BEWG on Quality Assurance Guidelines for benthos studies is a further step in improving the reliability and comparability of data from benthic samples in order to understand better benthic ecosystems and the changes that occur in them. The target ecosystems for these guidelines are those found primarily in subtidal sediment habitats. Nevertheless, some elements and recommendations of the report will be applicable to other benthos studies, eg taxonomy, laboratory procedures, and quality control routines. Future attention by the BEWG will be specifically directed towards quality assurance issues in the littoral soft benthos and hard substrate systems.

This report is mainly directed towards establishing guidelines for use in routine sampling and environmental surveys and monitoring programmes. Special research projects and experimental programmes may require different and/or additional guidelines.

This report of the BEWG is partly based on earlier quality assurance documents like the BMB recommendations (Dybern *et al* 1976), the HELCOM guidelines and the ICES recommendations for the collection and treatment of soft bottom samples (Rumohr, 1990). The main discussions were held in conjunction with the ICES/HELCOM workshop on quality assurance of benthos measurements in the Baltic Sea (23-25 March 1994, Kiel). This workshop's discussions anticipated the need to generalise recommendations and conclusions to regions beyond the Baltic Sea, specifically the North Sea. This report of the BEWG should be viewed in conjunction with the ICES/HELCOM report; it seeks to provide further recommendations for quality assurance particularly pertaining to taxonomic issues.

RECOMMENDATIONS

1 SAMPLING

Sampling approaches should be based on stations representing a defined region and replicates for obtaining adequate representation should be collected.

Track plotting and echo sounding information should be used to ensure accurate location of stations when sampling from ships.

The nature of variability of the habitat should be assessed using video, if possible, to help define optimal sampling strategies. Pilot (preliminary) sampling should be used to optimize sampling design. Both of these processes are needed to ensure that sample size/numbers are sufficient to provide the necessary statistical power.

Adaptive sampling is necessary to provide relevance to the type/size of fauna, the density of animals, the depth profile of the fauna within the sediments and the sediment nature. penetration depth of the sampling device should be recorded. Criteria should be established to identify and reject unsuitable samples based on such features as sample volume and the condition of the samples. For community structure studies, the sampling should achieve a depth that ensures that at least 95% of the fauna (biomass/numbers) is sampled.

The winching operations are crucial to sample integrity with van Veen and box corers. The final 5 m of descent should be at a rate less than 0.5 m/s to minimize bow wave disturbance. Weather conditions and wave heights should be documented and criteria established for conditions considered unsuitable to productive sampling.

All data and information should be recorded by hand in notebooks unless it is completely automated. This will allow quality checks later.

2 SAMPLE PROCESSING

When processing grab or core samples the maximum sieve pore diameter size should be 1 mm. In all cases, the sizes of sieves and pore diameter and shape (square or round) used in processing samples must be documented along with details about methods of processing.

Formalin fixation is mandatory and should be implemented as soon as possible following collection. Alcohol is an inadequate fixative. Procedures must be established to avoid human health problems during fixation and subsequent handling. Sieving should be accomplished always before fixation. Stains should be used with fixation. The recommended stain is Rose Bengal in 40% formaldehyde solution.

Sample fractionation is recommended to optimize sieving of gravel samples in order to minimize the destruction of specimens. Subsampling and lumping of replicate samples is specifically discouraged. When subsampling or lumping is used for special reasons, the nature of the procedures must be specified.

There should be established an explicit minimum standard for the percentage of samples to be checked by a second sorter to ensure proper and complete sample processing.

Procedures need to be established to optimize the complete processing of samples.

3 TAXONOMY

The keys and guides used for taxonomic identifications need to be documented. Additionally, the recommended resolution for taxonomic identification for all major groups should be documented.

Identifications must be made to 100% accuracy at the specified level of taxonomic resolution. In all studies there should be established procedures for taxonomic checking to ensure the accuracy of identifications.

Regional taxonomic workshops should be employed regularly to optimize consistency in taxonomic identification. These should be organized to ensure participation by taxonomic experts, research technicians directly involved in identification and private industry employees involved in monitoring.

Taxonomic reference materials (reference collections) must be maintained.

A system for certification of taxonomic competence needs to be established and must include specific guidelines for the testing procedures used for certification, such as that being established by the British Natural History Museum, London.

4 PROCEDURE FOR DOCUMENTATION AND CERTIFICATION

Existing established ICES guidelines are mandatory.

For all procedures, protocols should be established, standardised and documented. This should include sampling, sample processing, taxonomic determinations, etc. These should be established with a view to creating checklists that can be used to maximise accuracy and precision, and to achieve certification of all steps. Checklists should follow a sample from initial sampling to final taxonomic determination and quantification. Levels of acceptable variability have to be set for all measured parameters.

BEDMAN
BEnthic Data MANagement

J. Buijs, J.A. Craeymeersch & P.M.J. Herman

" Data has a tendency to grow over time. Therefore, it's important to be able to break data into small, easily managed tables. A database is an organized collection of this information. In a relational database (like Paradox), tables contain categories of data, repeated for each item in the table. For example, if you structure an address book as a table, you might put names in one column, addresses in another, phone numbers in another, and so on. A relational database lets you define a relationship (called a link) between different tables. This lets you extract or combine data from several tables and get the exact results you need."

- Borland International , inc.. Paradox for Windows. Getting Started, Introduction.

Introduction

During several surveys in the North Sea and adjacent waters accomplished over the last 10 years, the macro- and meiobenthic endofauna has been sampled. Part of the data of these, mostly inventory or monitoring, programs has been gathered in a database: BEDMAN.

The creation and management of the database was funded by the North Sea Directorate and the National Institute for Coastal and Marine Management of the dutch Ministry of Transport, Public Works and Water Management, ICES and the Netherlands Institute of Ecology. The database was developed using the PARADOX database management system on a personal computer. Other database management programs can probably read the primary files of the database.

Database

At the moment the data base contains data of following surveys (fig. 1 and 2).

1) the ICES North Sea Benthos Survey (1986)
2) stations in the northern North Sea lying on an extrapolated ICES grid (1980-1985)
3) surveys in the Voordelta (coastal region from the Belgian border to the Hoek van Holland in the north) (1984-1988)
4) an inventory of the spatial distribution of the zoobenthos on the Dutch Continental Shelf (MILZON) (1988-1993)
5) monitoring program of Rijkswaterstaat on the Dutch Continental Shelf (1991-1992) (EXP*BMN)
6) monitoring program of Rijkswaterstaat in the estuarine area of the rivers Rhine, Meuse and Scheldt (1991) (EXP*BMN)
7) monitoring program to evaluate the effects of a land reclamation scheme, designed to extend Rotterdam harbour (SLUFTER) (1988-1990)
8) Norwegian NSTF benthos data NIVA (1990-1991)
9) surveys for Norwegian oil fields (1981-1990)
10) German monitoring program (1987-1990)
11) NSTF benthos data of Scottisch coast and Shetland (1990)

Surveys of 5), 8), 10) and 11) include benthos data as contribution to the North Sea Task Force (NSTF) Monitoring Master Plan (MMP).

In the near future, data of following surveys will be included:

* monitoring program of Rijkswaterstaat on the Dutch Continental Shelf (1993) (EXP*BMN)
* monitoring program of Rijkswaterstaat in the estuarine area of the rivers Rhine, Meuse and Scheldt (1990-1993) (EXP*BMN)

Further, we did receive data of:

* Swedish west coast benthic program (including NSTF stations) (53 stations, 1985-1991) submitted by the Marine Research Station at Kristineberg (B.G. Tunberg)
* UK NSTF 1991 programme of the North Sea coast and offshore (11 stations) submitted by MAFF (H.L. Rees)
* Norwegian NSTF 1990-1991 programme submitted by the Institute of Marine Research, Bergen (P. Johannessen).

Most of the data included are macrobenthic infauna data: numbers, density, and biomass of the individual species. For surveys 1) and 2) only biomass data of the phyla are known.

For surveys 1), 3), 4) and 5) data on the taxon composition and density of the meiobenthos are included. Detailed information on the nematode and harpacticoid composition and density of part of the stations of surveys 1), 3) and 5) are included as well.

Besides benthos data, the database contains following information describing the sites sampled: site name, date of sampling, geographic position, depth and some sediment characteristics (% silt, % sand, median grainsize, sorting, sediment type) are included. It should be stressed, however, that not all of this information was available for each site.

This database consists of 9 files (tables). Each table contains data about some specific thing. For example, the BEDMAN2 table contains only the information on numbers, density and biomass. The information about the original station name is given in another table called BEDMAN6. Using different tables to keep track of different types of information offers several advantages: e.g. time saving when entering information, saving disk space, saving maintainance time.
The different tables are linked by common fields: identification numbers for samples, stations, cruises and species. This enables the user to ask questions of several tables in a single query.

Cruise	A collection of samples taken in a relatively short time, e.g. on one boat or other field trip.
Sample	Total of one to several replicate grabs, cores, or other basic entities. The sample is used to estimate the density and biomass of the benthos at a particular station at a particular moment in time.
Replicate	One grab, core, or other basic entity. One to several replicates are combined to form a sample.

A more detailed description of the contents of each table is given in the annex.

Some additional species information is included in four additional tables.
The table SYNONYM contains for several species one or more synonyms and the source that cited the names as synonyms. If the species is included in the main database, the species identification number is given as well. Species name and synonyms include both author and year of introduction.
The tables FEEDING and FEEDNEMA contains for several species information on their feeding strategy (resp. of the macrobenthic infauna and the nematodes). In a so-called memo field the original literature is quoted. In such memo fields text that is variable in length can be stored. The amount of data a memo field contains is limited only by the disk space available on your system. The entire memo is stored outside the table in a separate file.
All known species [at this moment at the institute] are stored in file SPEC_TOT. As BEDMAN5, the table contains for each species a species identification numer, the code used in the Marine Conservation Society Species Directory, and the RUBIN code. In the field 'Checked' it is indicated whether the species name has been

checked for synonymy or not.

In order to protect the database from access by unauthorized users, two types of passwords are established. A master password - only known by the database manager(s) - gives all the rights to any function of the table. An auxiliary password gives the user the right to view a table, but not to change it in any way.

Future developments

Updating

It is clear that a regular update of the database is necessary. Besides, periodically enhancements will have to be made to improve e.g. performance or add information that is presently not included.

Intellectual property and use by others

Principally the data in the database are the intellectual property of persons who made them available. Probably, a minor database has to be made excluding data not available (yet) to others.

Consulting the database

For experienced users of Paradox's 'Query by example' method, consultation of the database will not pose great difficulties. The highly flexible interface will generate all custom-made queries, forms and reports.
For less experienced users, however, predefined forms and programmes should be made to facilitate the basic searches. Such a user-interface has recently been build for the JEEP-92 database. PARADOX provides a runtime version that provide users access to all capabilities and operations that are built into the application. Unlimited copies of application programs can be distributed with no licensing fees.

Data entry

Analogously, predefined forms could be used to enter data into a database table. Validity checks can impose restrictions on a field to ensure that the data entered in the field meets certain requirements. For example, one can define a 'required field' validy check for a field so one can't move from the record until a value has been entered. Table lookup can help one to enter data in a field that exist in another table (e.g. check-list for correct species names).

Annex. Description of the files constituting the database.

Field types are given between brackets (A=Alphanumeric; N=Number; S=Short number; D=Date; M=Memo)

BEDMAN1.DB 7199 records

Sample id	number sample [S]
Replicate id	number replicate [S]
Cruise id	number cruise [S]
Station id	number station [S]
Date	date of sampling [D]
Macrobenthos	code macrobenthos-data available (1 if available) [S]
Meiobenthos	code meiobenthos-data available [S]
Nematoda	code nematoda-data available [S]
Sediment	code sediment-data available [S]
Depth	depth in meters below sealevel [N]
Lgrad	geografic position degrees longitude [S]
Lminute	geografic position minutes longitude [S]
Lsec	geografic position seconds longitude [S]
Bgrad	geografic position degrees latitude [S]
Bmin	geografic position minutes latitude [S]
Bsec	geografic position secondes latitude [S]
West/East	geografic position West or East of Greenwich [A1]

BEDMAN2.DB 129623 records

Sample id	keyfield [S]
Replicate id	keyfield [S]
Species id	number of species [S]
Number	number induviduals found [S]
Density	density species Macro (N/cm^2) Meio (N/10 cm^2) [N]
Biomass	only for macrobenthos gram AFDW/m^2 [N]

BEDMAN3.DB 3637 records

Sample id	keyfield [S]
Replicate id	keyfield [S]
Species id	number of Nematoda species [S]
Number	number induviduals found [S]

BEDMAN4.DB 2278 records

Sample id	keyfield [S]	
SEDTYP	sediment type [A2]	
	CS	= coarse sand [phi 0 - 1]
	MS	= medium sand [phi 1 - 2]
	FS	= fine sand [phi 2 - 3]
	VS	= very fine sand [phi 3 - 4]
	SI	= silt [phi > 4]
Silt%	percentage silt [N]	
Sand%	percentage sand [N]	
Median	median grainsize (phi) [N]	
Sorting	sorting grain (mu of phi) [N]	

BEDMAN5.DB 2860 records

Phylum	[A30]
Classis	[A20]
Subclassis	[A20]
Ordo	[A20]
Subordo	[A20]
Familia	[A25]
Genus	[A25]
Latin name	Latin name of species [A65]
Species id	keyfield [S]
MCSSD-NO	Marine Conservation Society Species Directory code [A8]
Rubin-code	Rubin code [A8]

BEDMAN6.DB 3145 records

Station id	keyfield [S]
Station name	original stationname [A8]
Description	description station name [A50]

BEDMAN7.DB 21 records

Name	keyfield [A25]
Address	address [M10]

The first 10 characters are stored in the table. The [illegible] is stored in the file BEDMAN7.MB

BEDMAN8.DB 50 records

Cruise id	keyfield [S[
Description cruise	cruise description [A50]]
Region	region of sampling [A75]
Number of stations	number of locations [S]
Vessel	name research vessel [A25]
First day of cruise	first sampling day of survey [D]
Last day of cruise	last sampling day of survey [D]
Resp. scientist	responsible scientist survey [A25]
Resp. data	responsible scientist data conservation [A25]
Publications	available publications [M20]

BEDMAN9.DB 301 records

Sample id	keyfield [S]
Cruise id	keyfield [S]
Poly	biomass polychaetes [N]
Moll	biomass mollusca [N]
Crust	biomass crustacea [N]
Echi	biomass echinodermates [N]
Rest	biomass others [N]
Sum	biomass total [N]

SYNONYM.DB 1081 records

Phylum	code for phylum as used in the MCSSD [A2]
Name	latin name [A100]
Synonym	synonym [M100]
Species id	species identification number [S]
Literature	reference [M25]

FEEDING.DB and **FEEDNEMA.DB**

Species id	[S]
Latin name	[A50]
Feeding	feeding strategy [A10]
Feeding info	literature [M20]

with dep = deposit feeder
sf = suspension feeder
df = subsurface deposit feeder
sd = surface deposit feeder
if = interface feeder (changing feeding strategy: sf and sd)
he = herbivore
op = omnivore/predator

and 1A = selective deposit feeder
1B = non-selective deposit feeder
2A = epistratum feeder
2B = carnivore/omnivore

SPEC_TOT.DB 11295 records

Species id	keyfield [S]
Latin name	Latin name of species [A65]
MCSSD-NO	Marine Conservation Society Species Directory code [A8]
Rubin-code	Rubin code [A8]
Checked	j=Yes; n=No [A1]

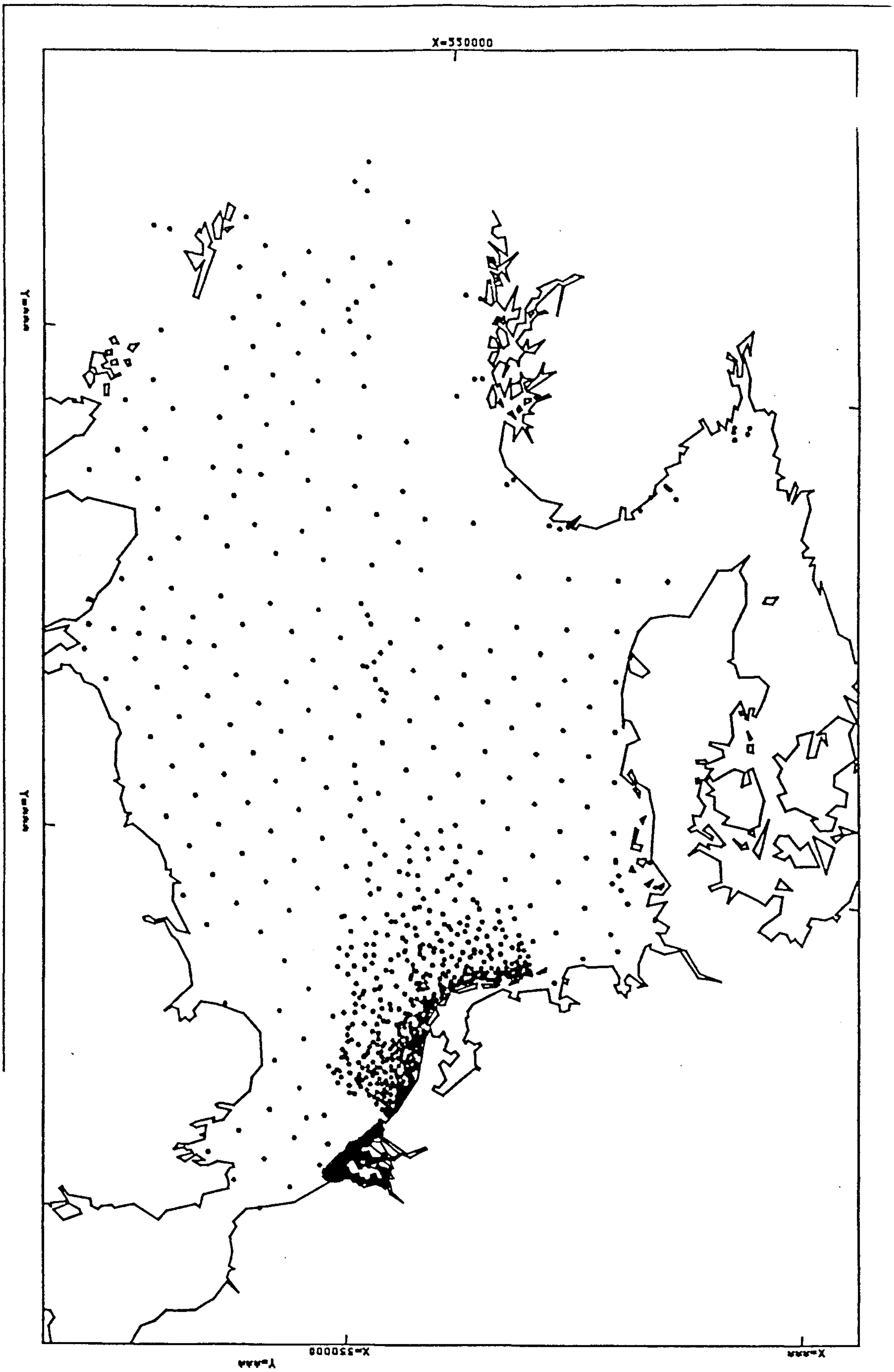


Fig . 1 Stations database BEDMAN

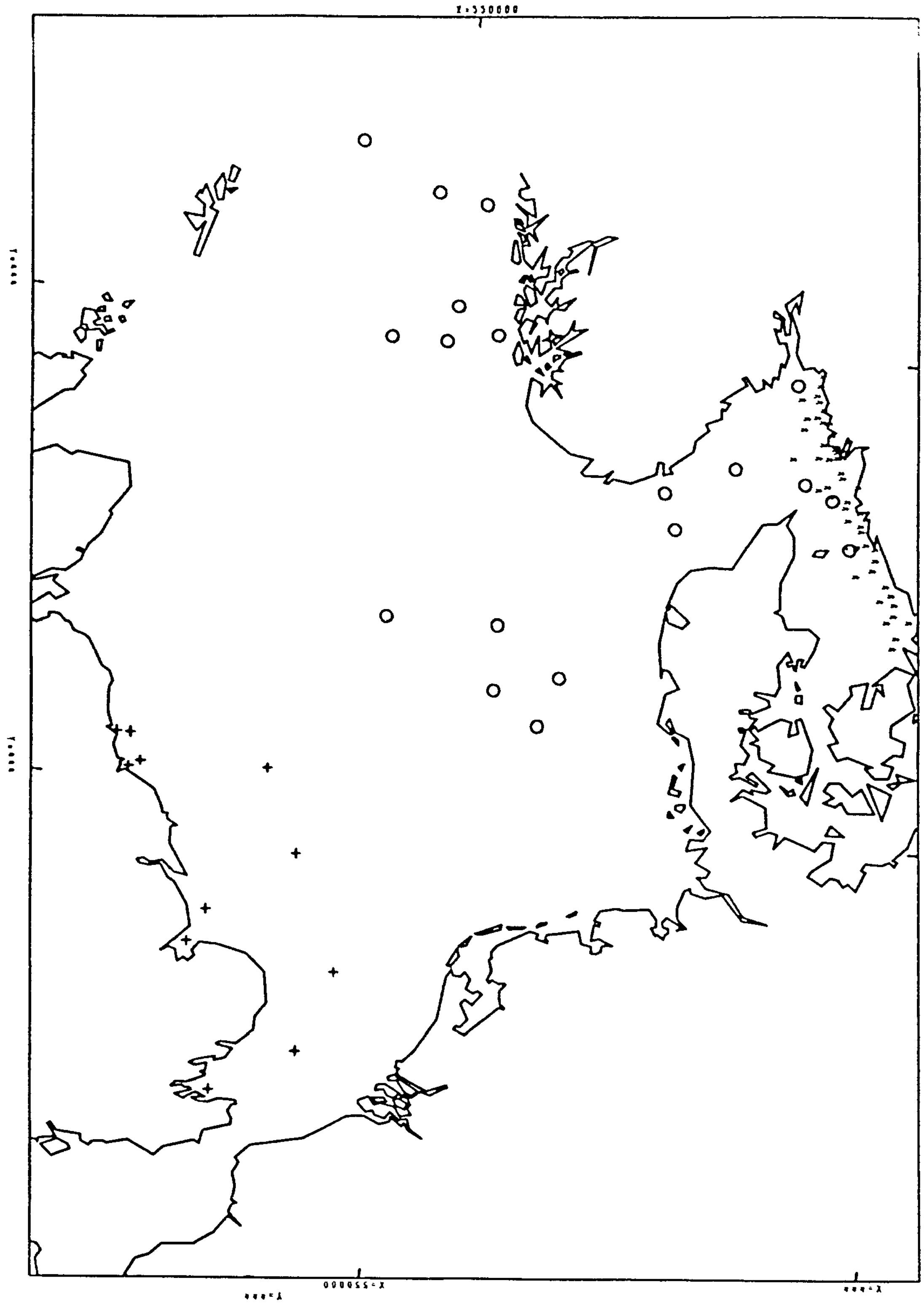


Fig. 2 Sations Swedish data [*], Norwegian data [o] and English data [+]

INTEGRATING THE NORTH SEA BENTHOS SURVEY INTO THE ICES ENVIRONMENTAL DATABASE

0. Introduction

The 18th meeting of the OSPARCOM Joint Monitoring Group decided to give ICES the task '...to calculate the costs of integrating the benthos data currently held in a data base in Yerseke (the Netherlands) in the ICES data base.' This report is the responds to this request. It should, however, also be seen in the light of the recommendation from the 1993 meeting of the ICES Benthos Ecology Working Group (BEWG) that ICES establishes a proper benthos data base (Anon., 1993).

The report consists of four main sections. Section one describes the ICES North Sea Benthos Survey. The survey was conducted in 1986, and the data obtained forms the core of the present North Sea Benthos Data Base. This data base is described in section two. Section three describes anticipated problems associated with the integration of the data into the ICES Environmental Data base. This section also calculates the costs associated with the integration. Section four gives references.

1. The North Sea Benthos Survey

The BEWG identified the need for a large-scale benthos survey in the North Sea (Anon., 1985). Basic knowledge on species composition and biomass distribution of benthos in the North Sea did not exist for large areas. The group stated that this type of information is essential in addressing questions like food composition of benthic fish species, effects of eutrophication, pathways of pollutants etc.

The BEWG proposed, planned and conducted the ICES North Sea Benthos Survey (NSBS). The sampling was done in April/May 1986 through the commitment of several marine institutes. The analysis of the samples comprised identification of organisms to a defined taxonomic level and analysis for associated geochemical parameters.

A list of the stations sampled is given in Anon., 1986.

1.1.1 Analysis of samples

The analysis of the NSBS samples was initiated in 1986. The main effort was put into the analysis of epifauna and macro infauna. Estimates of density and biomass was obtained by phyla and by species of molluscs, echinoderms and dominant species of other groups. Determination of the biomass of major taxonomic groups was completed in 1988, and agreement on a final integrated species list was reached in early 1990.

Two workshops were held in 1988 to deal with taxonomic problems arising from analysis of the macrofauna and meiofauna samples. Two further workshops were held in 1989 to agree on the final form of a combined species list for the macrofauna.

Samples were also analyzed for content of trace metals, organic matter, proteins, plant pigment and particle size distribution. This work was completed in 1987, and results presented at the 1987 ICES statutory meeting.

1.1.2 Analysis of data

The results of the analysis of the NSBS data was reported at a mini-symposium held in 1990. 6 papers were published in ICES Journal of Marine Science, Vol. 49 no. 1 and 2., 1992 (Authors: D. Basford, M. J. N. Berman, J. Craeymeersch, J. M. Dewarumez, J. Dorjes, G. G. A. Duineveld, A. Eleftheriou, C. Heip, P. Herman, M. Hup, R, Huys, P. Kingston, A. Kunitzer, M. A. Lambert, R. G. Lees, D. S. Limpenny, P. Niermann, U. Rachor, H. L. Rees, S. M. Rowlatt, H. Rumohr, P. K. Soetart, T. Soltwedel, and A. J. de Wilde).

Production estimates based on data from the NSBS was presented by Brey, 1989 (Anon, 1989)

2. The North Sea Benthos Data Base

The BEWG initiated the discussions about setting up a proper North Sea benthos data bank in 1985 (Anon, 1985). For NSBS, the BEWG adopted the HELCOM data reporting protocol, based on the GF3 system and used by the group of Baltic Marine Biologists. A preliminary format for storage and retrieval was outlined in Anon. 1985, and is found in Annex 1.

The present version of the data base is described in Annex 2. It comprises approximately 130000 records.

2.1 Surveys included (geographical coverage)

In addition to the data from the North Sea Benthos Survey, the present version of the data base contains data from several other surveys. Annex 2 gives a complete list of the data sets included.

The report of the 1993 meeting of the BEWG (Anon., 1993) contains a list of additional data sets which could be included in the data base.

2.2 Information included

Most of the data included are macrobenthic infauna data: numbers, density and biomass of individual species. For some surveys, data on composition and density of meiobenthos are included as well. Additionally, the data base contains information identifying and characterising the sampling location: Site name, date of sampling, geographical position, depth, and some sediment characteristics. This information is, however not complete for all sampling sites. A detailed description of the information included in the data base is given in Annex 2.

2.3 Species coding

In order to keep track of data on individual species in the data base, a unique species coding system is necessary. The topic has been discussed several times in the BEWG. Several possibilities have been considered, amongst these the GF3, NODE, MCSSD, and RUBIN code system.

GF3 was originally adopted. This applies a plain language abbreviation code for species consisting of 6 characters for genus and 6 for species. This was later changed so that an 8-character code was assigned to each species name (Anon., 1989). The present version of the data base applies a unique species identification number. For some species the and/or the MCSSD code is known as well. To develop and maintain a proper species coding system, is an important task for the data centre responsible for a benthos data base (See section 3.1.1).

2.4 Software

The integration of the data base and the development of a management system was funded by the North Sea Directorate and the National Institute for Coastal and Marine Management of the Dutch Ministry of Transport, Public Works and Water Management, ICES and the Netherlands Institute of Ecology, Centre for Estuarine and Coastal Ecology.

Staff at the Netherlands Institute of Ecology, Centre for Estuarine and Coastal Ecology have developed software for maintenance and handling of data. The data base is organised as a relation database, structured using the PC database program Paradox. The associated software allows the user to extract data on density and biomass based on a selection of either species, sample or position. Additional software allows presenting the data in the form of circles on maps, the area of the circles being proportional to the abundances of individual species.

3. Integrating the North Sea Benthos Data Base into the ICES Environmental Data Base. Establishing an ICES Benthos Data Base.

3.1 Anticipated problems associated with the incorporation

It is a general problem in the database that very little documentation of the data exists. In most cases, data has been submitted to the database as files with numbers, without any associated explanation on how these numbers should be interpreted. The managers of the present data base has put a large effort into 'detective' work to provide the necessary additional information.

3.1.1 Species coding/species information

In the present version of the database, each species is assigned a unique identification number. When available, the species are also assigned a code as defined by either the 'Marine Conservation Society Species Directory Code' (MCSSD) or by the 'RUBIN' code system. In the future, it is desirable that a single coding system is applied.

In the data reported to the database, the same species is sometimes reported under several different systematic names (synonyms). The problem is solved in the present version of the database by maintaining a list of possible synonyms for each species. This work is, however, not finalised and should be continued (See section 3.2.3).

For some species the present version of the database contains information on feeding strategy. This work is, however, not finalised and should be continued (See section 3.2.3).

3.1.2 Raw data vs. derived data

For some of the data stored in the present version of the data base there is some inconsistency as to the level of aggregation. This is mainly due to the lack of an agreed data reporting protocol.

As an example data are on some instances reported as density or biomass pr m2, while other data are reported as number of specimens or total weight of specimens found in the sample. The latter is the desired level, if the data base should be of scientific value. This level is necessary, if the user of the data wants to explore for instance between-sample variability or effects of sampling device.

In some instances only a fraction of a sample has been analyzed. Information on this should be retained in the data base as well.

3.1.3 Taxonomic level

The present data base contains some inconsistency in the reporting of data for various taxonomic levels.

In the analysis of samples, the general problem is that it is usually impossible to identify all specimens to a given taxonomic level (the species level, for instance). The solution usually applied is that the specimens are identified to the agreed taxonomic level whenever possible, the remaining specimens being 'lumped', i.e. identified to some higher level. When the results of the analysis is reported, the data originator would not always specify if results from the lower taxonomic level is included in the 'lumped' category.

Another problem concerns the definition of macro/meiofauna. For assessment purposed, it is desirable that each observation is referred to as being either macro- or meiofauna. The problem is that the definition differs among workers so that individual species is referred to one group or another depending on the worker/study/survey. An example from the present data base is the handling of Nematoda. Some workers apply the definition that specimens passing the sieve belong to meiofauna, those retained belong to macrofauna. Other workers applies the definition that all Nematoda species should be referred to the meiofauna group.

3.1.4 Quality assurance

To ensure comparability in results between laboratories/workers participating in international programmes, quality assurance should be an integral part of the programmes. In this respect, the present data base does not include any kind of qualification or evaluation of the data. A new data base should include options for such an evaluation.

3.2 Establishing an ICES Benthos Data Base. Cost calculations

The establishing of an ICES Benthos Data Base (IBDB) will require six different types of activities:

a) Transferring and integrating the present North Sea Benthos Data Base into the IBDB
b) Receiving and integrating other historic benthos data sets into the IBDB.
c) Defining a reporting protocol for the reporting of results of future studies into the IBDB. Implementing this protocol at the ICES headquarters.
d) Receiving and integrating data submitted according to the new protocol.
e) Maintaining the IBDB.
f) The production of outputs and software.

Two types of costs will be involved: Costs associated with the purchase of hardware and software and costs associated with manpower.

The costs associated with purchase of software and hardware will be DKR 5000 for a Paradox licence and DKR 25000 for a PC (including the necessary hardware and software necessary for linking the

PC to the network at the ICES headquarters)

The manpower requirements could be broken down into three categories: Professional (PR), technical assistance (TA), and programming assistance (PA). These requirements will be described in sections 3.2.1 - 3.2.6.

3.2.1 Transferring and integrating the present North Sea Benthos Data Base into the IBDB

As described, the present data base is organised as a PC-based Paradox data base. This is not a convenient basis for the organisation of the IBDB, mainly because PC-based systems have general capacity limitations when large amounts of data should be handled. Moreover, it would require all participants in international programmes to have access to PC-based systems with a Paradox licence. The experience from other international programmes is that data handling should not be based on the assumption of the data originators to have access to a particular computer system.

The main effort required to transfer the present data base is that the data in the data base should be converted to comply with a new data reporting protocol (section 3.2.3). The necessary software should be developed to do this.

It is anticipated that for some historical data sets, it will not be possible to do the conversion, because the data are too non-compatible with a new protocol. These data sets will have to be stored 'as is' and handled on an ad hoc basis (see section 3.2.2).

The development of the necessary conversion software will require 10 PR days, 10 TA days, and 20 PA days.

3.2.2 Receiving and integrating other historic benthos data sets into the IBDB.

The effort required to integrate historic benthos data sets not already included in the Benthos Data Base, will depend on the number of data sets to be included and the condition of the data.

An inventory project will have to be conducted in order to identify the historic data sets to be included. This work could be done by the BEWG.

For data sets already available in digitised form, experience shows that the processing of each data set requires between 1 and 6 weeks. On the average, it is anticipated that each data set will require 4 weeks, i.e. 10 TA days and 10 PA hours/data set.

The effort required to convert data sets available only as paper forms, will depend on the volume of the data set, and can not be estimated at this stage.

3.2.3 Defining and implementing a new data reporting protocol

To ensure a proper handling and processing of data, it is essential that a well defined data reporting protocol exists. For future submissions of benthos data, a new data reporting protocol should be developed, together with the necessary software to support the protocol.

The protocol should be developed in close corporation between the BEWG and the ICES staff. This will require 20 PR days and 10 TA days.

The software applied at the ICES headquarters to handle and check data submissions (the 'screening' and the 'pollfx' program) should be revised to support the new protocol. This will require 40 PA days.

Experience gained during the North Sea Benthos Survey shows that the best way to ensure that data are reported correctly is to let the data originator apply a designated data entry program. To develop this program will require 40 PA days.

The software developed at the Netherlands Institute of Ecology for management, extraction and mapping of data requires data to be available as computer files with a defined structure. The structure of the IBDB will not immediately support this software. If desired the necessary software could be developed. This will require 15 PA days.

An essential tool in the management of a benthos data base is a well defined species list. As mentioned in section 2.2, this work has been initiated at the Netherlands Institute of Ecology. To complete this task will require 40 PA days.

The costs associated with the establishment of the IBDB will finally include the participation of an ICES staff member in the annual meetings of the BEWG.

3.2.4 Receiving and integrating data submitted to the IBDB

When the IBDB is established and the necessary software developed, experience shows that the effort required to receive and integrate new data sets are approximately 1 TA day pr data set.

3.2.5 Maintenance

When established, maintenance of the data base will require approximately 10 PR days, 5 TA days, and 15 PA days pr year.

3.2.6 The production of output.

The costs associated with the production of output will depend on the task, and will have to be estimated from case to case. As a rule of thumb, the production of simple univariate statistics (tables, figures, maps) usually requires 1 PR day pr task.

4. References:

Anon., 1985: Fourth Report of the Benthos Methodics Working Group. Bremerhaven, 25-29 March 1985. CM 1985/L:33.

Anon., 1986: Fifth Report of the Benthos Ecology Working Group. Ostende, 12-15 May 1986. CM 1986/L:27.

Anon., 1989: Report of the Benthos Ecology Working Group. Vigo, Spain, 18-21 April 1989. CM 1989/L:89.

Anon., 1993: Report of the Benthos Ecology Working Group. Kiel, Germany, 3-8 May 1993. CM 1993/L:3.

ICES Journal of Marine Science, Vol. 49 no. 1 and 2., 1992 (Authors: D. Basford, M. J. N. Berman, J. Craeymeersch, J. M. Dewarumez, J. Dorjes, G. G. A. Duineveld, A. Eleftheriou, C. Heip, P. Herman, M. Hup, R, Huys, P. Kingston, A. Kunitzer, M. A. Lambert, R. G. Lees, D. S.

Limpenny, P. Niermann, U. Rachor, H. L. Rees, S. M. Rowlatt, H. Rumohr, P. K. Soetart, T. Soltwedel, and A. J. de Wilde).
IOC, 1987. GF3: A general formatting system for geo-referenced data.

Annex 1

Information reported under NSBS (Anon., 1985)

Biomaster record

Benthos type:

- Macrobenthic epifauna
- Macrobenthic infauna
- Meiobenthos
- Fish

Type master record

Sampling method (14)
Sampler type (16-17)
Preservative (51)
Other sampler details (52-55)
Sample volume (56-59)

Data cycle record

Species identifikation (24-36)
Biomass (62-66)
Ash free dry weight
Bottom environmental parameters (72-78)

Annex 2

Annex 2 to 'INTEGRATING THE NORTH SEA BENTHOS SURVEY INTO THE ICES ENVIRONMENTAL DATABASE' is included in this report as ANNEX 11.

ICES Benthos Ecology Working Group
Yerseke, The Netherlands, May 1994

Working document

The "Aegean Sea" oil-spill: effects on the subtidal benthic communities

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SUMMARY

In December 3 1992 the oil-tanker *Aegean Sea* wrecked in the vicinity of La Coruña, NW Spain, releasing about 60000 t of light crude oil. Benthic studies were undertaken to estimate the effect of the spill in the subtidal infauna of the area. This paper presents the results of the first year of study on the Ría de La Coruña, Ría de Ferrol, and adjacent continental shelf.

As data on temporal evolution of benthic infauna from Ría de La Coruña were available, an estimation of the changes originated by the spill in this Ría could be made. In the sandy area, a reduction of species number and a high mortality of certain taxa were recorded, as well as a dramatic increase of the abundance of opportunistic polychaetes. In the harbour area, the community is well adapted to cronic spills and frequent sediment disturbances, and thus the effect of the spill has been less important. Only a few species decreased their abundance, while many other did not show any effect or even increased their number.

In the Ría de Ferrol and adjacent continental shelf previous data on benthic dynamics were not available. The evolution of the communities since the oil spill suggests that they could be somewhat affected, although the scarcity of sampling so far does not permit a clear estimation of the consequences yet.

INTRODUCTION

During the past years oil–spills as consequence of wrecks have been unfortunately frequent in coastal areas, originating in many cases catastrophic effects on the marine ecosystem. The benthic habitat is usually the most affected and where the consequences last longer (Cabioch *et al.*, 1978). In the European area, the *Amoco Cadiz* oil–spill in the coasts of Brittany in 1978 has been the subject of many studies, whose results constitute a good reference for similar cases.

The *Aegen Sea* disaster took place at 5 AM of December 3, 1992 in the vicinity of La Coruña. The tanker had about 80000 t of light crude oil. A wide oil–spill, partially burning, began to spread in Northeast direction. Several hours later, the ship exploded and most of the remaining oil was spilled out. However, according to the experts, a large proportion of the oil (near 50 %) possibly evaporated due to its composition, and an important proportion was burned. The oil progressed towards the nearby Ares Bay and Ferrol Bay, although a smaller proportion entered in La Coruña Bay. The strong winds during and after the accident (30 to 50 knots) spread the oil quickly and contributed to its dispersion.

In 1975 a similar accident, the *Monte Urquiola,* happened in the same area. However, no studies on the effects of the spill on the benthos were undertaken. In the present oil–spill a coordinated research project has been prepared, including hydrocarbon pollution studies in the water column and the sediments, the effect on plankton and benthos, and the effects on the mussel aquaculture.

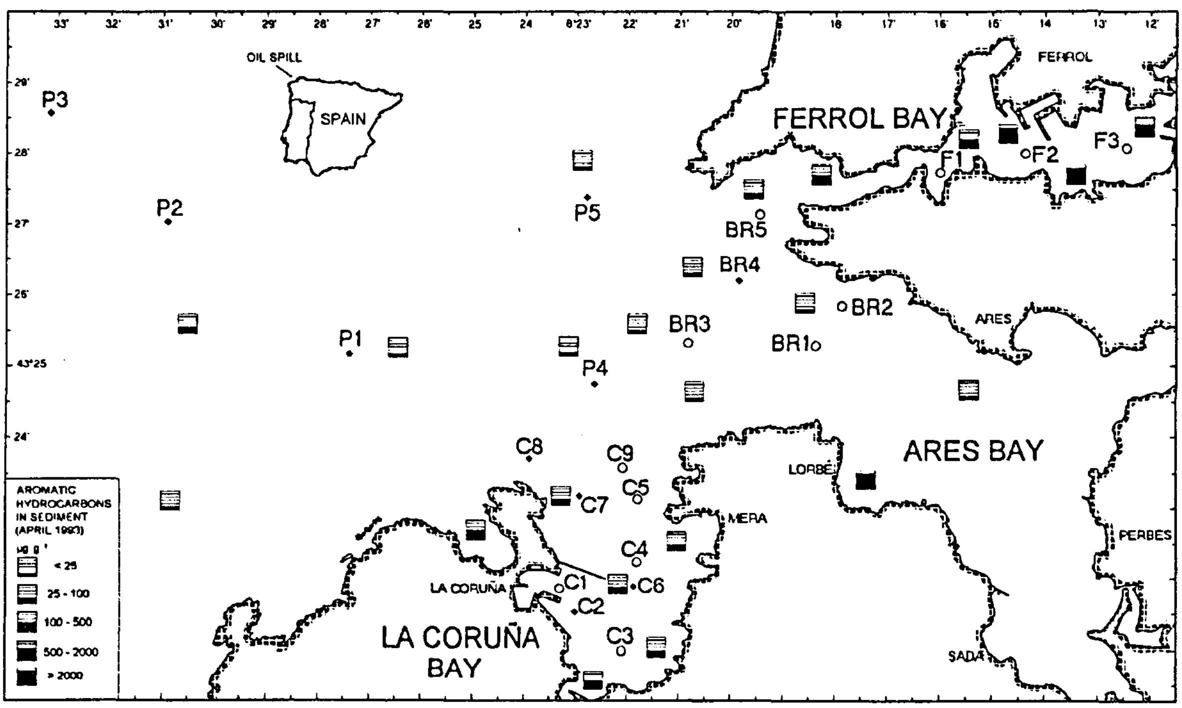

Fig. 1. Location of the sampling stations and hydrocarbon levels in the sediment in April 1993. Open dots: stations sampled monthly; solid dots: stations sampled only once.

This paper presents the results of the study of the short and mid-term effects of the oil-spill on the subtidal benthic communities from La Coruña Bay and from the continental shelf off Ares and Ferrol Bays. The evolution of the soft-bottom communities and of the dominant benthic species during the first year after the spill is described.

MATERIAL AND METHODS

Five benthic samples were collected monthly with a modified Bouma box corer (0.0175 m^{-2} surface area) in each of 22 stations located off Ares Bay (BR1 to BR5), in La Coruña Bay (C1 to C9) in Ferrol Bay (F1 to F3), and in the continental shelf (P1 to P5). 12 stations were selected for a monthly sampling programme (Fig. 1). Samples were sieved on board through a 0.5 mm sieve, anaesthetized with a $MgCl_2$ solution and then preserved in 5 % buffered formaldehyde containing Rose Bengal solution. After each cruise, the preserved samples were sorted, identified to species level whenever possible, counted, and wet weight of each taxa recorded. Correlations of wet weight to ash-free dry weight (AFDW) were used to estimate biomass. Particle size analysis was performed by a combination of dry sieving and sedimentation techniques (Buchanan, 1984). Organic matter content of the sediment was estimated as weight loss of dried (100 °C, 24 h) samples after combustion (500 °C, 24 h).

Data on temporal variation of the community prior to the oil-spill were available in Stations C1 and C3 from La Coruña Bay. This has permitted to compare the changes after the accident with the natural variation of the community at these sites. In this stations a principal component analysis (PCA) was used to obtain a temporal ordination of the successive observations according to their similarity. Raw data were previously smoothed by using the moving average technique, and log transformed before applying the PCA.

In these two stations, total abundance, species richness and abundance of the most important species were compared with the corresponding average values from the three year-period before the oil-spill (1990–1992), and changes were expressed as the percent of deviation from this mean.

RESULTS

General characteristics of the macroinfauna communities

Station C3, located in the inner area of La Coruña Bay, has a sediment composed of well sorted, fine sand (mean particle size, MD = 74 to 196 μm) with a relatively low organic matter content (1.55 to 3.61 % AFDW). The dominant species are the polychaetes *Paradoneis armata, Spio decoratus* and *Magellona alleni*, and the bivalve *Tellina fabula*. Station C1, located inside the harbour area of La Coruña Bay, has a poorly sorted sediment composed of silt with a variable proportion of shell debris (MD = 17 to 129 μm), with a high organic matter content (9.23 to 16.11 %). The dominant species in this station are the bivalve *Thyasira flexuosa*, the oligochaete *Tubificoides* sp., and the polychaetes *Chaetozone* sp. and *Capitella* *capitata*. The bivalves *Abra alba* and *Abra nitida* are relatively abundant as well, and they can form a significant proportion of total biomass. This two macroinfaunal communities are described in more detail by López-Jamar and Mejuto (1985).

Stations C4, C5 and C9, located in the middle and outer area of La Coruña Bay, have similar sediment features. Sediment is composed of well sorted, fine sand (MD = 74 to 159 μm) with a low organic matter content (1.53 to 2.82 %). The dominant species are the polychaetes *Paradoneis armata, Hyalinoecia bilineata, Spio decoratus* and *Spiophanes bombyx*, and the bivalve *Tellina fabula*. Species composition of these three stations is very similar to that of the *Tellina fabula* – *Paradoneis armata* assemblage described by López-Jamar and Mejuto (1985).

Stations BR1 and BR2 are located in the outer Ares Bay, Station BR5 in the outer Ferrol Bay, and Station BR3 in the continental shelf off the three bays (Fig. 1). These four stations have a sediment with similar characteristics, composed of fine to medium sand (MD = 102 to 379 μm). Organic matter content is usually very low, ranging from 0.49 to 2.91 %. Macroinfaunal dominants are the polychaetes *Paradoneis armata, Spio decoratus* and *Spiophanes bombyx*, and the bivalve *Venus casina*.

Station F1, located in the middle area of Ferrol Bay, has a sediment composed of silt with a high proportion of shell debris (MD = 190 to 518 μm). Organic matter content is from moderate to high, ranging from 4.96 to 11.84 %. The dominant species are the polychaetes *Paradoneis lyra, Mediomastus fragilis, Chaetozone* sp. and *Tharyx marioni*, and the bivalve *Abra alba*. Station F2, located in the middle bay, has a silty sediment (MD = 51 to 55 μm) with a high organic matter content (12.00 to 13.24 %). The dominant species are the polychaetes *Paradoneis lyra, Ampharete acutifrons* and *Chaetozone* sp., and the bivalves *Thyasira flexuosa* and *Abra alba*. Station F3 is located in the inner bay, and its sediment is composed of silt (MD = 19 to 21 μm) with a high organic matter content (11.41 to 11.84 %). The dominant species are the polychaetes *Paradoneis lyra, Chaetozone* sp. and *Prionospio malmgreni*, and the bivalves *Abra alba, Abra nitida* and *Thyasira flexuosa*.

Effects of the oil-spill

The distribution of hydrocarbon levels in the sediment four months after the oil spill is shown in Fig. 1. Relatively high values were recorded in the entire study area; the highest levels ocurred in Lorbé (not sampled por infauna) and in the inner Ferrol Bay.

In order to compare the natural variation with the changes induced by the oil-spill, we have considered first the effect on the macroinfauna of the stations where information on the temporal variation prior to the spill was available: Stations C1 and C3 in La Coruña Bay. For this comparison we have used data from a three year-period before the spill. Furthermore, this comparison helps to interpretate the changes occurred in the stations where no previous data were available.

In these two stations the effect of the oil-spill on the community has been estimated by means of a PCA on the succesive observations. Fig. 2 shows the result of this analysis in Station C3. Two periods can be distinguished: (1) February 1990 to

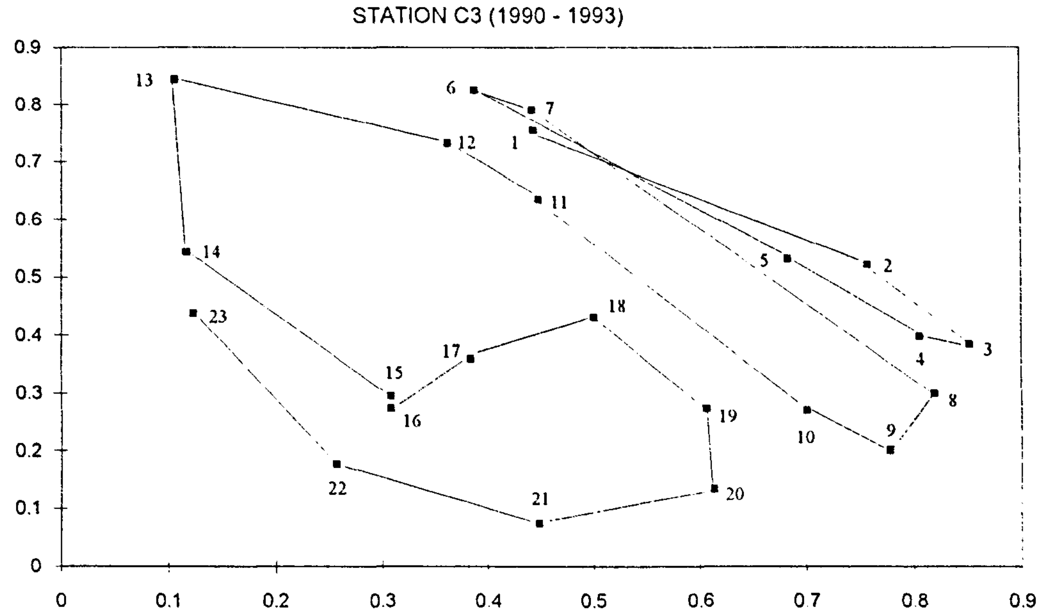

Fig. 2. Results of the PCA at Station C3 (La Coruña Bay).

October 1992 (points 1 to 17 from Fig. 2); and (2) December 1992 to December 1993 (points 18 to 23 from Fig. 2). The first period shows a marked seasonallity, which is revealed by clear diagonal displacements of the observations from spring–summer to autumn–winter. The species responsible for these seasonal changes are mainly opportunistic polychaetes (*Capitella capitata, Pseudopolydora kempi* and *Pseudopolydora pulchra*), whose abundance is very high in summer and usually very low the rest of the year. Temporal variation of *Capitella capitata* and *Pseudopolydora kempi* in the period 1990–1993 is shown in Figs. 3 and 4. The second period is characterized by an alteration

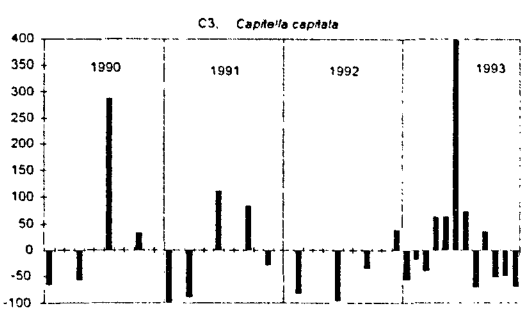

Fig. 3. Temporal variation of *Capitella capitata* in Station C3.

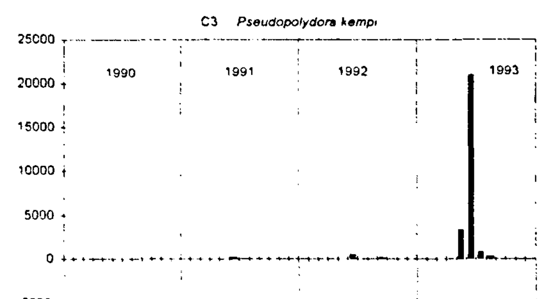

Fig. 4. Temporal variation of *Pseudopolydora kempi* in Station C3.

of the seasonal cycle: the "winter" observations do not move towards their usual zone, but remain close to the "summer" observations. The main reasons for this alteration of the seasonal cycle are mainly two: (1) the increase of the abundance of the opportunistic species occurred earlier in the year and it was much higher than in the former years, affecting the "winter" points owing to the method used (moving average); (2) the

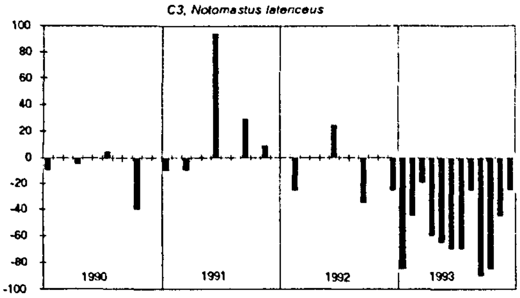

Fig. 5. Temporal variation of *Notomastus latericeus* in Station C3.

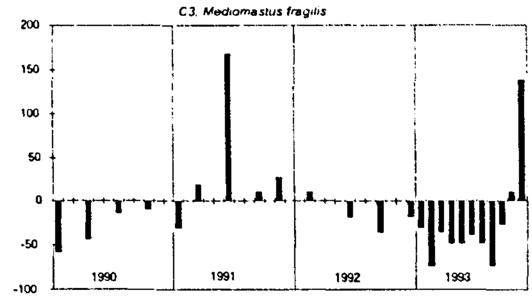

Fig. 6. Temporal variation of *Mediomastus fragilis* in Station C3.

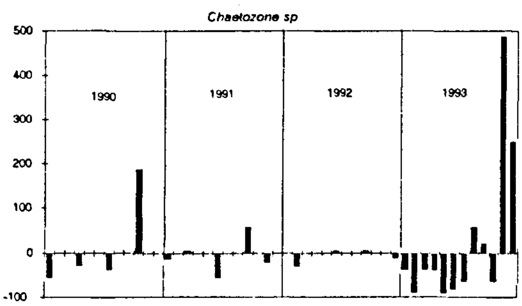

Fig. 7. Temporal variation of *Chaetozone* sp. in Station C3.

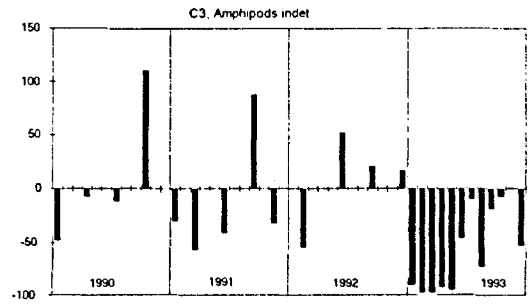

Fig. 8. Temporal variation of Amphipods indet. in Station C3.

abundance of several important species (*Notomastus latericeus, Mediomastus fragilis* and *Chaetozone* sp.) decreased during this period. Temporal variation of these three species is shown in Figs. 5, 6 and 7. A decline of the abundance of amphipods (Fig. 8), of total abundance (Fig. 9) and of species richness (Fig. 10) is also evident. These changes are very likely related to the effects of the *Aegean Sea* oil-spill. However, the last points of the temporal series show a tendency to recover the normal seasonal cycle. A similar

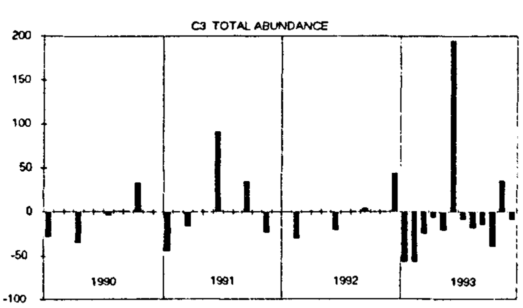

Fig. 9. Temporal variation of total abundance in Station C3.

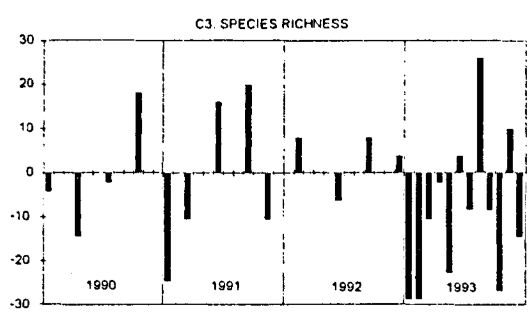

Fig. 10. Temporal variation of species richness in Station C3.

alteration of the seasonal cycle was described in the Bay of Morlaix after the *Amoco Cadiz* oil-spill by Dauvin (1982).

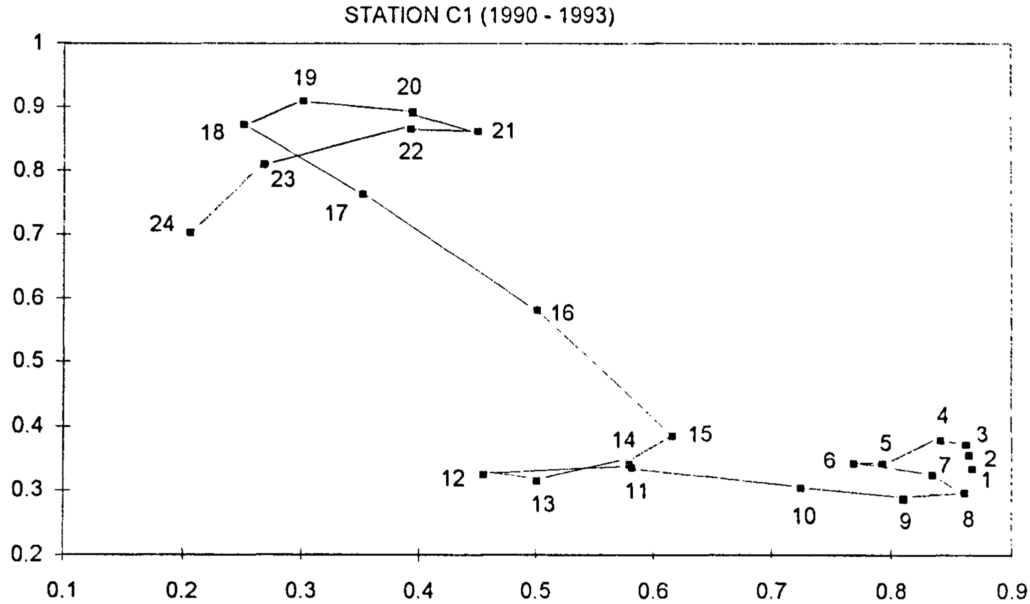

Fig. 11. Results of the PCA at Station C1 (La Coruña Bay).

The result of the PCA in Station C1 is indicated in Fig. 11. At this site the macroinfaunal community does not show a clear seasonal cycle. However, the points of the temporal series are distributed in two groups than approximately correspond to the periods before and after the spill. From February 1990 to June 1992 (points 1 to 15 from Fig. 11), the observations more or less grouped, but from August 1992 (point 16) on, the observations gradually shift and form another group (October 1992 to December 1993). The first group is formed by observations that are anterior to the oil–spill, and it is characterized by the dominance of *Thyasira flexuosa, Tubificoides* sp. and *Chaetozone* sp. Opportunists such as *Capitella capitata* and *Pseudopolydora kempi* have moderate abundances that do not vary much temporally. The second group is formed by the observations that are posterior to the spill, excluding October and December 1992, this latter being affected by the 1993 observations due to the moving average technique. In this period an important increase of species number (Fig. 12) and of total abundance (Fig. 13) ocurred. The increase of species number is difficult to interpretate, but this releatively high species number remained throughout 1993. On the other hand, this period

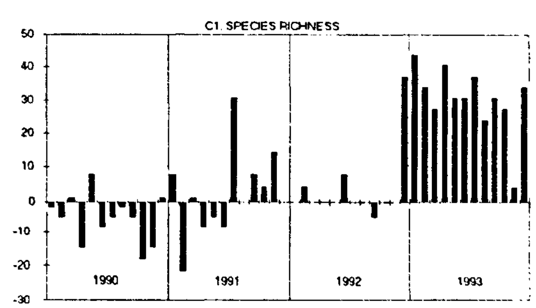

Fig. 12. Temporal variation of species richness in Station C1.

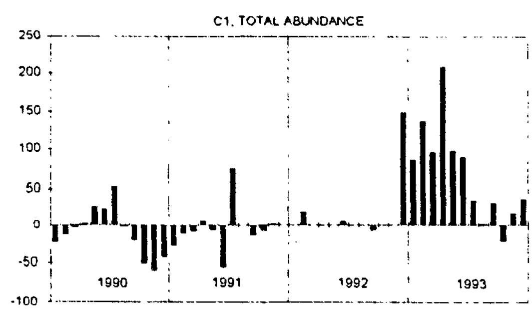

Fig. 13. Tempotal variation of total abundance in Station C1.

shows an important increase of the abundance of opportunists. *Capitella capitata* experienced a sudden increase, and its abundance remained high during most of 1993 (Fig. 14). The increase of *Pseudopolydora kempi* started much earlier than in Station C3, and the maximum abundance occurred in April (Fig. 15). Other species also showed an increment of their abundance after the spill: *Notomastus latericeus* (Fig. 16), *Tubificoides* sp., *Ophiodromus flexuosus* and *Mediomastus fragilis*. Opposingly, the abundance of some species experienced an important decrease, such as *Chaetozone* sp. (Fig. 18), *Abra alba, Abra nitida* and *Thyasira flexuosa*. It must be indicated that the sample taken in

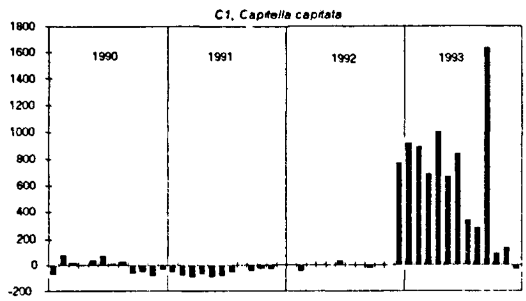

Fig. 14. Temporal variaton of *Caoitella capitata* in Station C1.

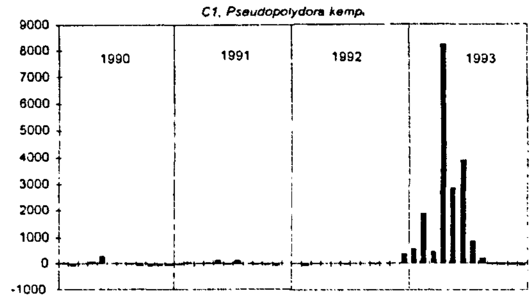

Fig. 15. Temporal variation of *Pseudopolydora kempi* in Station C1.

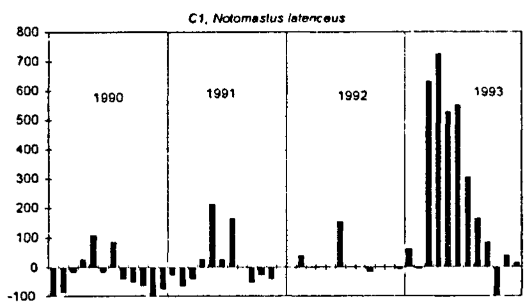

Fig. 16. Temporal variation of *Notomastus latericeus* in Station C1.

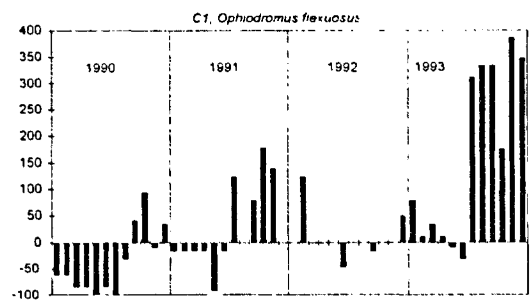

Fig. 17. Temporal variation of *Ophiodromus flexuosus* in Station C1.

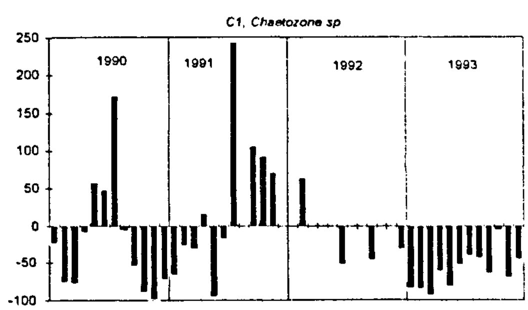

Fig. 18. Temporal variation of *Chaetozone* sp. in Station C1.

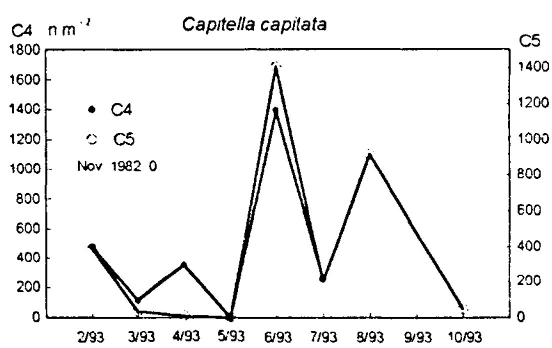

Fig. 19. Temporal variation of *Capitella capitata* in Stations C4 and C5 after the spill.

December 1992, just before the spill, had an unusually high abundance of opportunists, and its sediment was quite different than that of the rest of samples at this station. This suggests that data from this sample must be taken with caution, as it is very likely that these differences could be caused by a positioning error.

The effect of the oil spill was generally quite clear at Stations C1 and C3. The abundance of opportunist increased remarkably, whereas some species dissapeared or suffered a great mortality.

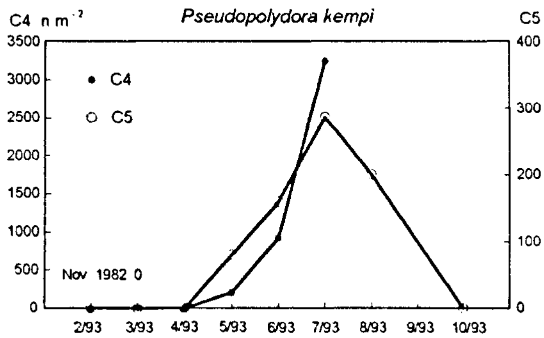

Fig. 20. Temporal variation of *Pseudopolydora kempi* in Stations C4 and C5.

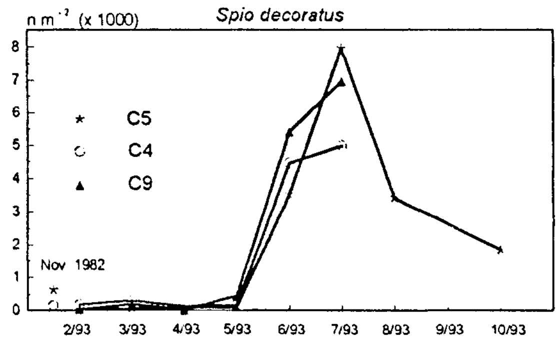

Fig. 21. Temporal variation of *Spio decoratus* in Stations C4, C5 and C9.

Stations C4 and C5 were sampled in November 1982, so the composition of the infaunal community was known (López-Jamar and Mejuto, 1985). This allowed a comparison of the community before and after the spill. Although the species composition in both periods did not change much, a proliferation of opportunistic polychaetes such as *Capitella capitata* and *Pseudopolydora kempi* several months after the accident is evident. (Figs. 19 and 20). The abundance of *Spio decoratus* increased notably in June, whereas its recruitment usually takes place in winter (Fig. 21). Furthermore, in Station C4 amphipods were absent from the samples after the spill, but they were moderately abundant in 1982. These results indicate that these two stations were moderately affected by the oil spill.

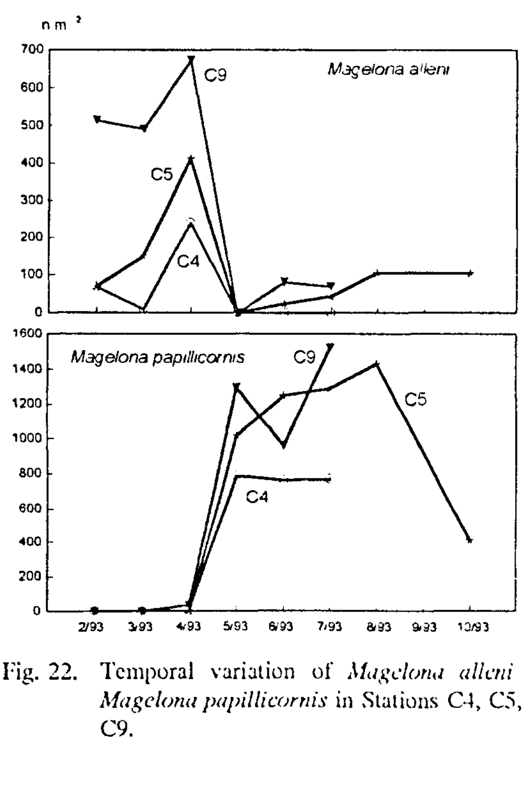

Fig. 22. Temporal variation of *Magelona alleni* and *Magelona papillicornis* in Stations C4, C5, and C9.

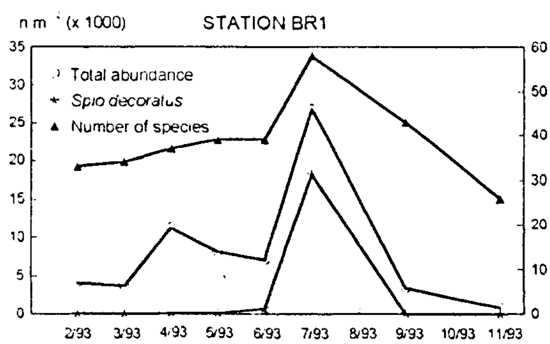

Fig. 23. Temporal variation of total abundance, number of species and abundance of *Spio decoratus* in Station BR1.

In the rest of stations no data prior to the accident were available, and therefore the interpretation of the temporal variation after the spill is more problematic. In Station C9 *Spio decoratus* increased in June, similarly to Stations C4 and C5 (Fig. 21). An interesting fact is the sustitution of *Magelona alleni* by *Magelona papillicornis* in Stations C4, C5 and C9 since april 1993 (Fig. 22). We do not know if this could be related to the effects of hydrocarbons in the sediment.

In Station BR1 number of species increased from 33 in February 1993 to 58 in July, but it decreased to only 26 species in November. Total abundance follows a similar pattern, increasing from February to July, but decreasing therafter. The dominant species in this station is *Spio decoratus*, wich accounted for most of the variation of total abundance (Fig 23). The opportunists *Capitella capitata* and *Pseudopolydora kempi* reached relatively high abundances several months after the spill. *Magelona alleni* and *Magelona papillicornis* display the same substitution pattern than in Stations C4, C5 and C9; *M. alleni* practically dissapeared in May, being replaced by *M. papillicornis*. The temporal variation in this station suggests that the effect of the spill was relatively high during the first months after the accident, but the community was recovering slowly its initial state. However, the strong storms that took place in September and October probably resuspended the sediment, releasing again the oil and thus originating a "re-pollution" of the superficial layer of the sediment. This could explain the low values of abundance and number of species recorded in September and in November.

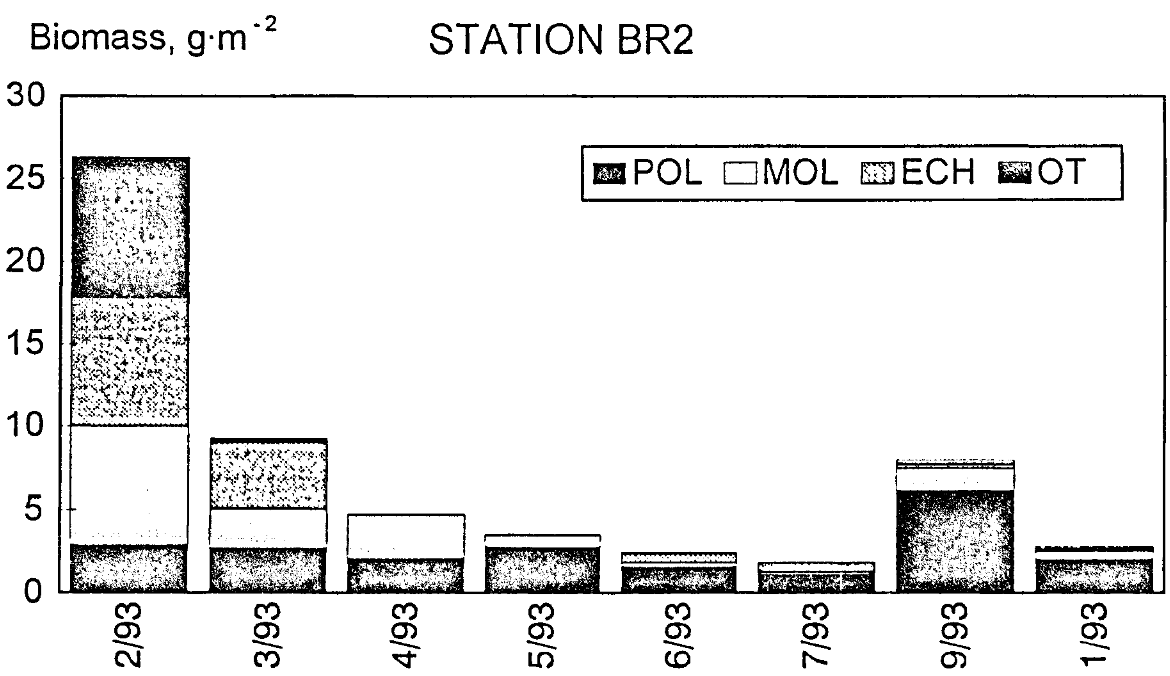

Fig. 24. Temporal variation of total biomass (AFSW) and proportion of taxonomic groups in Station BR2 after the oil spill.

In Station BR2 the accumulation of crude oil was the highest, at least visually. Total abundance decreased remarkably since April 1993, mainly the molluscs. *Mysella bidentata* and *Tellina fabula*, which were relatively abundant in February and March, practically dissapeared since April. A similar situation occurred with the echinoderms *Leptosynapta bergensis* and *Acrocnida brachiata*, which are absent from April on. Crustaceans in general, and mainly amphipods, are absent from the samples in February and March, but appeared again since April. Total biomass also has a strong decreasing pattern, ranging from 26.3 g m^{-2} AFDW in February to 2.4 g m^{-2} in June (Fig. 24). *Capitella capitata* ir relatively abundant in February and March, but practically dissapeared thereafter. These results indicate that the effect of the spill has been relatively important in this station.

In Station BR3, located in the continental shelf, no major changes were recorded that could be related to the oil spill. However, *Magelona alleni* and *Magelona papillicornis* showed the same substitution pattern explained before.

In Station BR5, located in the outer Ferrol Bay, abundances of *Pseudopolydora kempi* and *Pseudopolydora pulchra* were highest in May/June. *Spio decoratus* had moderate abundances from February to May, but increased dramatically since June, reaching > 25000 ind m^{-2} in September. The two species of *Magelona* display the same pattern again. Biomass has a decreasing trend, but mortality of the most sensitive species (i.e., amphipods) is not evident, which indicates that the effect of the oil spill on this station has been very low.

In Ferrol Bay (Stations F1, F2 and F3) sampling started in April 1993, and data are available only from April to September. Stations F1 and F2 have a very diverse infaunal community, and no effect of the spill could be detected on the fauna. Station F3, located in polluted sediments of the inner bay, has a relatively poor community, but no clear effect of the spill was evident. This is somewhat surprising because this bay had the highest levels of hydrocarbons in the sediment, and these levels remained relatively high during the whole year 1993.

DISCUSSION

The results presented in this paper generally agree well with those of similar studies in other areas. A high mortality of amphipods was recorded in several stations, which is a general feature of infaunal communities after an oil spill. These organisms are very sensitive to hydrocarbon pollution, as it has been indicated in the benthic studies on the effects of the *Amoco Cadiz* oil spill (Cabioch *et al.*, 1978; Gentil, 1982; Dauvin, 1982; Dauvin, 1986; Dauvin and Ibanez, 1986, etc.). Another typical effect of pollution after an oil spill is the increase of abundance of opportunists, mainly small polychaetes. The increase of *Capitella capitata*, which has been recorded in several stations, has been frequently cited as characteristic of such events (Pearson and Rosenberg, 1978; Sanders *et al.*, 1980; Glémarec and Hussenot, 1981). Some species of *Pseudopolydora* also have been related with hydrocarbon pollution (Pearson and Rosenberg, 1978; Sanders *et al.*, 1980). In our study, *Pseudopolydora kempi* experienced a dramatic increase in several stations after the oil spill.

In some affected stations the infaunal community is slowly recovering its original state prior to the spill: amphipods and other sensitive species reappeared, and the abundance of opportunists decreased to normal levels. This recuperation usually began 7 or 8 months after the spill, although this period is very variable. It must be pointed out that the time of recovery depends much on the type of the original community. Communities well adapted to a chronically polluted environment will recover its original state in a relatively short time; on the contrary, we may expect that communities from less polluted areas will last longer to recover.

The results from this study provide interesting information on the short- and mid-term changes on the infaunal communities after the *Aegean Sea* oil spill. Nevertheless, this research project will continue at least during 1994 to ascertain more precisely the consequences of the spill and the recovery of the communities.

Acknowledgements:

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Appendix 5.2b Paper presented at 28th European Marine Biology Symposium, Crete. Sept. 1993.

A CLASSIFICATION SYSTEM FOR BENTHIC MARINE BIOTOPES

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ABSTRACT

The north-east Atlantic region lacks a comprehensive classification of benthic marine biotopes, with existing classifications restricted either in their geographical range or in the variety of habitats considered. A classification system has been developed, based on data collected throughout Great Britain, which will encompass all marine and brackish-water habitats in both the littoral and sublittoral zones.

The classification is being developed to underpin management and conservation of coastal ecosystems. It provides a structure within which to place results from ecological survey and allows for the inventory and mapping of biotopes within discrete areas and for inter-site comparison of habitat and species diversity. The classification should encourage more objective scientifically based decisions on use and development within the coastal zone but recognises that, in dealing with highly complex ecosystems, such classifications also have their scientific limitations.

The classification integrates both biological and physical features. The physical factors of substratum and vertical zonation patterns, which appear to most strongly influence community composition and are most readily assessed in the field, are used to structure the upper end of a hierarchical system. Biological variations within similar habitats, due to factors such as recruitment, disturbance, predation and biogeographic variation, are recognised and accounted for. Biotopes are distinguished on the basis of their species composition and relative abundance, including the use of appropriate ordination and clustering techniques to assist with interpretation of large data sets.

KEYWORDS: Classification; benthic; marine; north-east Atlantic; British Isles; communities; biotopes.

INTRODUCTION

A major resource survey of the shores and near-shore benthic marine habitats of Great Britain (the Marine Nature Conservation Review) has highlighted the lack of a comprehensive and structured classification system for benthic marine habitats and communities for Great Britain and the north-east Atlantic (Hiscock and Connor 1991). Such classifications have been developed for terrestrial vegetation systems, including Great Britain's National Vegetation Classification (*e.g.*, Rodwell 1991) and the European CORINE classification (Commission of the European Community 1991). The lack of a suitable marine classification hampers the interpretation and application of benthic marine data for both scientific and coastal management purposes. At a European level this is reflected in difficulties in both interpretation and implementation of the recent European Community Directive on the conservation of natural habitats and of wild fauna and flora (the 'Habitats and Species Directive') because it was derived from the under developed and poorly structured marine section of the CORINE classification.

Augier's (1982) classification for the Mediterranean and the recently published classification for French coasts (Dauvin 1993) compliment that being developed here. The present system is being developed as part of 'BioMar', a four year project which is part funded by the European Community 'Life' programme and which includes field survey in Great Britain and Ireland. Development of the classification for Great Britain is well underway, although there remains much to do, both in stabilising the classification and in extending it's coverage to other parts of the north-east Atlantic. The final classification will substantially develop the present marine elements of the CORINE system. The principal uses of the classification and its basic structure are outlined here. A limited section of the system (from the sealochs of western Scotland) is presented here to illustrate the general structure adopted.

APPLICATIONS OF THE CLASSIFICATION

The classification is being developed to underpin management and conservation of coastal ecosystems within a scientific framework. In doing this it will:

1 provide a framework in which to place results from ecological survey;

2 help structure the future collection and interpretation of survey results (an important factor in helping to achieve standard approaches to environmental assessments and other types of ecological survey);

3 provide a common language for describing the biological character of the marine environment;

4 enable mapping of the distribution and extent of marine biotopes at local, national and international levels;

5 indicate the range and diversity of communities within a given area (areas with high biotope diversity are likely to have high species diversity, thereby identifying areas suitable to actively conserve biodiversity);

6 provide a basis for comparative assessment of species richness in the same biotope occurring at a range of sites;

7 provide a basis for predicting the biological character of an area based on its physical environment (although the degree of confidence will vary according to particular habitats);

8 provide a classification for habitat sensitivity to a range of different impacts, uses and developments;

9 provide a structure for coastal management, particularly through the mapping and assessment of biotopes;

10 aid the management of rare species by placing them in the context of their associated communities.

SCOPE OF THE CLASSIFICATION

The classification will encompass all benthic marine habitats, including those in estuarine and brackish-water habitats in connection with the sea, throughout the British Isles. It will include habitats from the upper shore (supralittoral and strandline zones) through to the continental shelf to 200 m depth. Although the classification is being developed using data from the British Isles it's structure and content will be widely applicable throughout the north-east Atlantic. Other existing classifications will be capable of synonymy or addition to the present system.

THE TERMS COMMUNITY AND BIOTOPE

A community, as defined by Mills (1969), is a group of organisms occurring in a particular environment (the habitat), presumably interacting with each other and with the environment, and separable by means of ecological survey from other groups. The direct association of habitat with a suite of species is considered highly important in the marine environment and is discussed further below; the concept is most usefully referred to by use of the term biotope.

Central to a classification system is the basis for the differentiation of types. Despite the complexity of the marine environment, and the many factors both physical and biological which contribute to community structure and composition, recurrent communities, in which species appear to have similar tolerances to a particular set of environmental conditions, are found to develop in widely separate geographical locations. The basis for separation of types has been discussed by many workers. Thorson (1957) provides amongst the most useful and comprehensive criteria and many of his ideas have been found to be workable and are adopted here. In particular the use of dominant species (*i.e.* those which provide high coverage of the seabed) and the use of life forms or functional groups provide important distinctions between the broadest divisions in a classification. Use of characteristic associations of species and the presence of highly preferential species, within discrete habitats, provide the basis for the lower divisions.

Boundaries between communities may be distinctive, particularly where the environmental gradients are sharp, such as the vertical zonation on rocky shores. In other situations however the gradients are more diffuse and the change from one 'community' or ecotone to another is much more gradual. In these cases practical considerations in where to place divisions between types must be adopted in order to achieve a workable classification.

STRUCTURE OF THE CLASSIFICATION

For a classification to be both widely applicable and widely acceptable it needs to accommodate:

- the variation in scale of physical and biological features;
- different levels of detail in available data;
- different skill levels of future surveyors;
- the variety of intended applications;

and to:

- be practical in format and operation;
- be presented within a logical structure.

A hierarchical approach enables features at a variety of scales to be encompassed, recognising that the scale of ecological process in the marine environment occurs at a range of different levels. For mapping at national level, for instance, the most appropriate scale would be rather different to that suitable for detailed study in an individual estuary. The marine element of the CORINE classification (Commission of the European Community 1991) recognises this by including both physiographic features (*e.g.* estuaries) and habitat and community features (*e.g.* sublittoral rocky seabeds;

mussel beds) within its structure and allowing cross referencing between the two. This approach can be further developed to include, for instance, different types of estuary (as defined in Davidson *et al.* 1991) and relating the suite of biotopes which occur within each type to the physical structure of the estuary.

A hierarchical approach is also essential to cope with data collected to different levels of detail and enables future surveys also to be conducted at levels suitable either to the skills of the surveyors or to the different purposes for which the classification may be used. Clear presentation of the classification is necessary to make it quick and easy to use, whilst a logical structure should ensure that similar biotopes are placed near to each other and at the appropriate hierarchical level within the classification. Whilst acknowledging that the marine environment is enormously complex the classification should not lose sight of its practical aims and become over detailed in its operation or level of detail.

In the marine environment there is a strong relationship between the physical nature of the habitat and the biological composition of the community. Most assemblages of species appear to occur within a recognisable suite of physical conditions, although some communities occur within a more tightly defined physical habitat than do others. Community structure is additionally modified by biological factors such as recruitment, predation and inter-species competition. Whilst the divisions of the classification are biologically led the dynamic nature of certain communities means it is essential to identify the habitat within which potentially a variety of communities may occur over time. Full use is also made of the physical habitat attributes to provide a structure which is both logical and easy to use. In this way much more significant use of the habitat is made than for terrestrial systems, where vegetation alone is usually the prime determinant of the classification's structure. The classification is presented in such a way as to allow access via either the physical habitat or the biological community.

Presentation through habitat features

The physical attributes which appear to most strongly influence community composition are substratum, the vertical gradients of exposure to air and desiccation on the shore and attenuation of light or change in temperature with depth in the sublittoral, wave exposure, tidal stream strength, salinity, temperature, and oxygenation (further discussed in Hiscock & Connor 1991). Each of these can be considered as an environmental gradient which form axes within a multi-dimensional matrix. Each community develops within a suite of physical conditions which lie within the multi-dimensional matrix. Although the degree of importance of each physical attribute varies for differing communities the first two, namely substratum and vertical gradient or zonation, appear to play a highly significant role in all communities. They are also the most easily and reliably recorded attributes in the field and are readily mapped. These factors combine to make the two attributes of substratum and zonation the most appropriate for structuring the upper end of the classification. Individual biotopes are placed within a primary matrix of substrata versus zonation (Figure 1; Appendix 1). The variety of communities found within the stable rock section of the primary matrix will invariably be high, and warrant a second matrix of wave exposure versus zonation to expand and clarify this part of the system (Figure 2; Appendix 2). In the examples given, from the sealochs of Scotland, habitat variety at the sheltered end of this second matrix is also high and additional matrices with axes for tidal stream strength or salinity would be useful to fully display the suite of communities present and their relationship to these physical attributes. Additional matrices can be set up along other gradients, for instance a salinity / sediment matrix for estuarine systems, to expand the classification as appropriate to display the communities being considered.

FIG. 1 here

FIG. 2 here

The divisions adopted on each of the physical gradients are those which, through the experience of survey work and data interpretation, appear to be most biologically meaningful (for instance, it is appropriate to distinguish cobbles on the shore which can be highly mobile from more stable boulders but not to distinguish small from large cobbles as the latter has little affect on the community composition but the former does). The divisions of each matrix are not restrictive; biotopes may appear in more than one box in the matrix or the boxes may be merged, as shown in Appendices 2, where, for instance, on rocky shores more biotopes are distinguished on the lower shore compared with the upper shore.

Placement of the biological entities within such a physical framework has a number of benefits. It helps to display the relationship of each biotope to other closely related types and to clarify the physical factors which contribute to its structure. These relationships are less clear in conventional listings of types (as in Appendix 3). It enables the identification of dissimilar communities within apparently similar physical environments. Here, although there may be subtle physical factors which drive such differences in biological composition, other factors such as seasonal change, chance recruitment, grazing pressures or pollution effects may account for the differences and allow such communities to be linked within the classification. It also provides a structure for undertaking new ecological survey, to ensure that the full range of habitats in an area is identified and sampled (although each area may have only a limited range of available habitats, such as a lack of subtidal rock in coastal plain estuaries).

Particular parts of the coast will provide data for the development of particular sections of the classification. For instance, sheltered rocky habitats are predominant in the sealochs of western Scotland and it is here that the more subtle variations in community composition related to changes in salinity regime or tidal stream strength within sheltered habitats have been elucidated. Conversely the open North Sea coast of England is predominantly moderately exposed to wave action and here the changes in structure due to differences in shore topography have been identified.

Presentation through biological features

The classification adopts a hierarchical approach to the differentiation of types, related to the ability to discriminate by various methods of remote and *in situ* sampling and to the ease of recognition by workers of differing skill levels. The two prime physical factors of substrata and zonation form the upper tiers in the hierarchy, as outlined above. Below this communities are distinguished at two levels. Level 1 'communities' are typically distinguished by different dominant species or life forms and are likely to be readily recognised by rapid survey or by less experienced workers. Level 2 'communities' are subdivisions of the level 1 type, typically based on less obvious differences in species composition (less conspicuous species), minor geographical variations or more subtle variations in the habitat and will often require greater expertise or survey effort to identify. Whilst such a philosophy of approach from broad scale easily recognisable types to finer detail less readily recognised types is advocated it is recognised that certain communities, particularly in sediments, will not conform with this approach. Appendix 3 shows examples of the classification to illustrate the approach adopted here.

The communities are listed in the classification following the sequence of substrata and zonation from the primary physical matrix. Subsequent divisions in the classification are based on the level 1 and 2 types, but these are further ordered according to the other important physical attributes of wave exposure (strong to weak), tidal stream strength (strong to weak) and salinity (full to low). (terms used for each of these attributes are given in Hiscock 1990). Thus within the infralittoral bedrock section *Laminaria hyperborea* communities, which occur in more wave exposed or tideswept habitats, are listed before *Laminaria saccharina* communities. Listing of communities in this way provides a logical sequence to the classification. However the relative importance of each attribute should not be inferred from such a sequence as each community derives its character from a complex of attributes, both physical and biological.

Single biotopes may cover many tens of square kilometres in the case of offshore uniform sediments or only a few square meters for distinctive features (e.g. rockpools) on rocky shores. For practical purposes there needs to be a lower limit on the scale of units described as biotopes so that the classification avoids being unwieldy. Consequently small features, such as crevices in rock or the biota on kelp stipes, are described as features of the main biotope rather than biotopes in their own right.

METHODS

The data used to develop the classification is derived from surveys undertaken in a wide range of habitats throughout the British Isles. These have been undertaken as part of the Marine Nature Conservation Review programme in Great Britain and the BioMar programme in Ireland. To this information is added the considerable volume of useful data already available in the literature. The data used to distinguish different types consists of semi-quantitative abundance data (using Rare, Occasional, Frequent, Common, Abundant and Superabundant notations based on Log_{10} and percentage cover scales) for epibenthos (rocky habitats)and quantitative data for infaunal communities (sediment habitats). Data collection methods are fully described in Hiscock (1990). The data are held on a customised relational database (Mills 1991) and are analysed using appropriate clustering and ordination techniques, including TWINSPAN, DECORANA and GENSTAT (Mills 1993). To avoid 'computer-generated' communities, resulting purely from the analytical methods, the end groupings generated from any analysis are always related to field descriptions and scrutinised by experienced field ecologists to ensure the end groups are valid ecological units. Testing of the classification in the field further ensures the practicality of the divisions adopted.

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LEGENDS

Figure 1 Matrix template of main divisions of substrata and vertical zones.

Figure 2 Matrix template of wave exposure gradient and vertical zones for rocky habitats.

Appendix 1 Example set of biotopes (from the sealochs of western Scotland) places within the primary habitat matrix of substrata and zonation. Main biotopes are in bold; variations are not emboldened and shown at the bottom of each box. Biotope titles and numbers given refer to those listed in Appendix 3.

Appendix 2 Subset of biotopes from the rock section of Appendix 1 showing relationship of biotopes to wave exposure and zonation. Main biotopes are in bold; variations are not emboldened and shown at the bottom of each box. Biotope titles and numbers given refer to those listed in Appendix 3.

Appendix 3 Example of the layout of the classification , using a classification of biotopes defined for Scottish sealochs

Appendix 1 Example set of biotopes (from the sealochs of western Scotland) places within the primary habitat matrix of substrata and zonation. Main biotopes are in bold; variations are not emboldened and shown at the bottom of each box. Biotope titles and numbers given refer to those listed in Appendix 3.

ZONE (Rock)	BEDROCK; STABLE BOULDER AND COBBLE	MIXED ROCK AND SEDIMENT	GRAVELS	SANDS	FINE SAND / MUDDY SAND	MUDS	ZONE (sediment)
SUPRALITTORAL	**Orange & grey lichens 1**						STRANDLINE / SALTMARSH
UPPER LITTORAL FRINGE	**Black lichen 2,3**						
LOWER LITTORAL FRINGE	***Chthamalus* spp. 4** ***Pelvetia* 5**						
UPPER EULITTORAL	**Barnacles 6** ***Fucus spiralis* 7**						UPPER SHORE
MID EULITTORAL	**Barnacles/fucoids 9, 8** ***Ascophyllum nodosum* 10** Tideswept 11 Salinity-reduced 13	**Fucoids 30**		**Bivalves (*Angulus tenuis*) 26**	**Polychaete / bivalves 28** ***Zostera noltii* 27**	**Polychaetes 29**	MID SHORE
LOWER EULITTORAL	**Barnacle/fucoids 14** ***Fucus serratus* 15** Tideswept 16 Salinity-reduced 17 Sand scour 23	Extreme shelter *A. nodosum mackaii* 25 Tideswept (bivalve/maerl) 32 Salinity reduced (*Mytilus* beds) 31 low (*Fucus ceranoides*) 12					LOWER SHORE
SUBLITTORAL FRINGE	**Kelps 18, 19, 35** Wave surge 34 Tideswept 21 Salinity 22 Sand scour 23	**Kelps 35** Tideswept 21 Salinity 22	**Kelp 72** **Maerl 71**	***Zostera marina* 73** ***Echinocardium cordatum* & *Arenicola marina* 74**	**Kelps 75, 76**	**Kelp 77** **Filamentous algae 78**	SHALLOW
INFRALITTORAL	**Kelps 37, 38, 39, 40, 41, 42, 43, 44** Vertical 36 Tideswept 58, 59, 60 Salinity 45, 65, 66	**Kelps 35, 43** Tide/salinity 70 Tideswept 69 Salinity 45				**Polychaetes & seapens 80, 79** Salinity low *Ruppia* 81	

CIRCALITTORAL	**Epifauna** 49, 50, 51, 52, 53, 54, 55 Vertical 48, 53p Tideswept 61, 62 Tide/salinity 63, 64 Salinity 67, 68	**Epifauna** 55p, 56, 57, 88, 89, 91, 92 Tideswept 82 Salinity 67	*Neopentadactyla* & *Ensis* spp. 84 *Limaria* 83	*Echinocardium cordatum* & *Amphiura filiformis* 85	*Virgularia*, *Ophiura* spp. & *Pecten* 86	**Seapens & burrowing megafauna** 90 Ascidians 93 Deoxygenation 87	DEEP

Appendix 2 Subset of biotopes from the rock section of Appendix 1 showing relationship of biotopes to wave exposure and zonation. Main biotopes are in bold; variations are not emboldened and shown at the bottom of each box. Biotope titles and numbers given refer to those listed in Appendix 3.

ZONE	EXPOSED	MODERATELY EXPOSED	SHELTERED	VERY SHELTERED
SUPRALITTORAL	**Yellow & grey lichens 1**			
UPPER LITTORAL FRINGE	***Verrucaria maura* & *Littorina neritoides* 2**		***Verrucaria maura* & *Littorina saxatilis* 3**	
LOWER LITTORAL FRINGE	***Chthamalus montagui* 4**		***Pelvetia canaliculata* 5**	
UPPER EULITTORAL	**Barnacles & *Patella vulgata* 6**		***Fucus spiralis* 7**	
MID EULITTORAL	**Barnacles/*Mytilus***	***Semibalanus/Fucus vesiculosus* mosaics 8** ***Semibalanus balanoides* & *Patella vulgata* 9** Sand scour (fucoids & green algae) 23	***Fucus vesiculosus***	***Ascophyllum nodosum* 10** Tideswept-*A. nodosum*, sponges & ascidians 11 Salinity reduced-*A. nodosum* & *Mytilus* 1[illegible] Salinity low-*Fucus ceranoides* 24
LOWER EULITTORAL	**Barnacle/*Fucus serratus* mosaics 14** Sand scour (fucoids & green algae) 23		***Fucus serratus* 15** Tideswept-*F. serratus*, sponges & ascidians 16 Salinity reduced-*F. serratus* with *Mytilus edulis* 17	
SUBLITTORAL FRINGE	***Alaria esculenta* 18** Wave surge (sponges & anemones) 34	***Laminaria digitata* 19** Tideswept (*L. digitata* with sponges & ascidians) 21		***Laminaria saccharina* & *Chorda filum* 35** Salinity reduced-*L. saccharina* & *Psammechinus miliaris* 45 Salinity low-*L. saccharina* & filamentous green algae 22
UPPER INFRALITTORAL		***Laminaria hyperborea* forest 37** Grazed kelp 40	***Laminaria hyperborea* mixed 39** ***L. saccharina* mixed 41**	***Laminaria saccharina* forest 42** Tideswept-*Laminaria* spp. 58; *L. hyperborea* 60 Salinity reduced-*L. saccharina / Psammechinus* 45 Salinity low-*L. saccharina* & filamentous green algae 65

LOWER INFRALITTORAL	Vertical (*Corynactis* & polyclinids) 36	***Laminaria hyperborea* park 38** Grazed kelp 40	Grazed *L. saccharina* 44	***Laminaria saccharina* park 43** Salinity low-*L. saccharina* & *Phyllophora* spp. 66
CIRCALITTORAL	Vertical (*Corynactis* & anemones) 48	***Swiftia* & *Porella* 49** ***Parasmittina* & *Porella* 50**	**Hydroids, brachiopods & solitary ascidians 51** **Solitary ascidians 52** **Hydroids & brachiopods 55** Grazed - *Ophiothrix*/*Ophiocomina* 54 Tideswept - *Alcyonium*/hydroids 61 Tide & salinity - Hydroids, bryozoans & barnacles 63, 64	***Neocrania* & *Protanthea* 53** Salinity reduced - *Neocrania* & ascidians 67 Salinity low-Ascidians (impoverished) 68

Appendix 3 Example of the layout of the classification, using a classification of biotopes defined for Scottish sealochs

No	SUBSTRATUM	ZONE	Biotope (level 1)	Biotope (level 2)
		LITTORAL		
1	Bedrock; stable boulder & cobble	Supralittoral & Littoral fringe	Orange & grey lichens	
			Verrucaria maura	
2				Exposed rock with *Verrucaria maura* & *Littorina neritoides*
3				Sheltered rock with *Verrucaria maura* & *Littorina saxatilis*
4			Exposed rock with *Chthamalus montagui*	
5			Sheltered rock with *Pelvetia canaliculata*	
6		Eulittoral-upper	Exposed rock with barnacles & *Patella vulgata*	
7			Sheltered rock with *Fucus spiralis*	
		Eulittoral-mid	Exposed rock with barnacles & *Mytilus edulis*	
			Moderately exposed rock with *Semibalanus balanoides*	
8				*Semibalanus / Fucus vesiculosus* mosaics
9				*Semibalanus balanoides* & *Patella vulgata*
			Sheltered rock with *Fucus vesiculosus*	
			Very sheltered rock with *Ascophyllum nodosum*	
10				Very sheltered rock with *Ascophyllum nodosum*
11				Tideswept rock with *Ascophyllum nodosum*, sponges & ascidians
13				Reduced salinity rock with fucoid algae & large *Mytilus edulis*
24			Low salinity rock with *Fucus ceranoides*	
		Eulittoral-lower	Rock with *Fucus serratus*	
14				Moderately exposed rock with barnacle / *Fucus serratus* mosaics
23				Sand scoured rock with fucoids & green algae
15				Rock with dense *Fucus serratus*
16				Tideswept rock with *Fucus serratus*, sponges & ascidians
17				Reduced salinity rock with *Fucus serratus* & *Mytilus edulis*
18		Sublittoral fringe	Exposed rock with *Alaria esculenta*	
34			Wave surged rock with sponges & anemones	
			Moderately exposed to sheltered rock with *Laminaria digitata*	

19				Moderately exposed to sheltered rock with *Laminaria digitata*
21				Tideswept rock with *Laminaria digitata*, sponges & ascidians
			Sheltered rock with *Laminaria saccharina*	
35				Rock & sediment with *Laminaria saccharina* & *Chorda filum*
45				Reduced salinity rock with *Laminaria saccharina* & *Psammechinus miliaris*
22				Low salinity rock with *Laminaria saccharina* & filamentous green algae
30	Mixed rock & sediment; gravels	Eulittoral	Sheltered mixed rock & sediment with fucoid algae	
32			Tideswept mixed sediments with bivalves & maerl	
31			Reduced salinity mixed sediments with *Mytilus edulis* beds	
12			Stony shores by freshwater runoff with *Fucus ceranoides*	
25			Extremely sheltered stone & sediment with *Ascophyllum nodusum* ecad *mackaii* beds	
35		Sublittoral fringe	Very sheltered mixed substrata with *Laminaria saccharina* & *Chorda filum*	
26	Sands	Littoral	Sandy shores with *Angulus tenuis*	
27			Fine sand & muddy sand with *Zostera noltii*	
28			Fine sand & muddy sand with *Arenicola marina* & *Cerastoderma edule*	
29	Muds	Littoral	Lower shore mud with *Arenicola marina*	
		SUBLITTORAL		
36	Bedrock; stable boulder & cobble	Infralittoral	Exposed cliffs with *Corynactis viridis* & polyclinid ascidians	
			Laminaria hyperborea in exposed or tideswept habitats	
37				*Laminaria hyperborea* forest
38				*Laminaria hyperborea* park
40				Moderately exposed rock with grazed *Laminaria hyperborea*
39				Sheltered rock with mixed kelp dominated by *Laminaria hyperborea*
58				Bedrock rapids with *Laminaria hyperborea* & *Laminaria saccharina*
60				Tideswept bedrock with *Laminaria hyperborea* forest

			Laminaria saccharina in sheltered habitats	
41				Sheltered rock with a mixed kelp dominated by *Laminaria saccharina*
44				Sheltered rock grazed by *Echinus esculentus* or brittlestars
42				Sheltered rock with *Laminaria saccharina* forest
43				Sheltered rock with *Laminaria saccharina* park
45				Reduced salinity rock with *Laminaria saccharina* & *Psammechinus miliaris*
65				Low salinity rock with *Laminaria saccharina* & filamentous green algae
66				Low salinity rock with *Laminaria saccharina* park & *Phyllophora* spp.
48	Bedrock; stable boulder & cobble	Circalittoral	Exposed bedrock cliffs with *Corynactis viridis*	
49			Moderately exposed rock with *Swiftia pallida*	
50			Moderately exposed rock with *Parasmittina trispinosa* & coralline crustose algae	
			Sheltered rock with fine hydroids, solitary ascidians & brachiopods	
51				Sheltered rock with slight tidal streams with hydroids & ascidians
52				Sheltered rock with solitary ascidians
55				Sheltered impoverished rock with ascidians
54			Grazed rock with *Ophiothrix fragilis* & *Ophiocomina nigra*	
61			Tideswept rock with *Alcyonium digitatum* & hydroids	
63				Tideswept rock in variable salinity with barnacles & hydroids
64				Tideswept rock in low salinity
53			Very sheltered bedrock with *Protanthea simplex* & *Neocrania anomala*	
67				Low salinity rock on muddy sediment with *Dendrodoa grossularia*
68				Very sheltered impoverished boulders in low salinity with ascidians
59	Mixed rock & sediment	Infralittoral	Cobble & boulder rapids with *Laminaria* spp.	
69			Tideswept rocks & gravel with ephemeral algae	
35			Very sheltered mixed substrata with *Laminaria saccharina* & *Chorda filum*	

70			Tideswept stones & gravel in variable salinity with *Lithothamnion glaciale*	
62		Circalittoral	Tideswept boulders & cobbles with a hydroid turf	
82			Tideswept stones & gravel with *Modiolus modiolus* beds	
56			Sheltered boulders on sediment with ascidians & brittlestars	
57			Sheltered rocks on mud with *Ascidiella aspersa*	
91			Rocks on muddy sediment with *Munida rugosa*, *Antedon* spp., solitary ascidians & *Modiolus modiolus*	
88				Rocks on muddy sediment with reefs of *Serpula vermicularis*
92			Stones on mud with holothurians & *Modiolus modiolus*	
71	Gravels	Infralittoral	Tideswept muddy gravel & wave exposed clean gravel & sand with maerl	
72			Muddy gravel with *Laminaria saccharina* & filamentous red algae	
84		Circalittoral / deep	Shell gravel & coarse sand with *Neopentadactyla mixta* & *Ensis arcuatus*	
83			Muddy gravel in weak tidal streams with *Limaria hians*	
73	Sands	Infralittoral / shallow	Very shallow sand with *Zostera marina*	
74			Clean rippled sand with *Echinocardium cordatum* & *Arenicola marina*	
75			Sheltered sand with *Laminaria saccharina*, *Chorda filum* & filamentous red algae	
76				Muddy fine sand with *Ostrea edulis*
85		Deep (>10-15 m)	Clean sand with *Echinocardium cordatum* & *Amphiura filiformis*	
86			Sandy & shelly mud with *Virgularia mirabilis*, *Ophiura* spp. & *Pecten maximus*	
77	Muds	Infralittoral / shallow	Very sheltered muddy sediment with *Laminaria saccharina*, *Chorda filum* & brown algae	
78			Muddy sediment covered by filamentous algae	
80			Very shallow fine mud with *Arenicola marina*	
79			Shallow fine mud with *Philine aperta* & *Virgularia mirabilis*	
89				Stones & shells on muddy sediment with dense *Ocnus planci*
81			Brackish mud in lochans with *Ruppia maritima*	
87		Deep (>10-15 m)	Impoverished & deoxygenated mud with *Beggiatoa* spp.	
90			Deep fine mud with burrowing megafauna & seapens	

93

Deep mud with *Styela gelatinosa*

Figure 1

	SUBSTRATA						
ZONE (Rock)	Bedrock; stable boulder and cobble	Unstable cobble and pebble	Mixed rock and sediment	Gravels	Sands	Muds	ZONE (Sediment)
Supralittoral							**Strandline / saltmarsh**
Littoral fringe							
Eulittoral Upper Mid Lower							**Upper shore** **Mid shore** **Lower shore**
Sublittoral fringe							
Infralittoral Upper Lower							**Shallow**
Circalittoral Upper Lower							**Deep**

Figure 2

ZONE (Rock)		WAVE EXPOSURE: Very exposed	Exposed	Moderately exposed	Sheltered	Very sheltered
Supralittoral						
Littoral fringe	Upper					
	Lower					
Eulittoral	Upper					
	Mid					
	Lower					
Sublittoral fringe						
Infralittoral	Upper					
	Lower					
Circalittoral	Upper					
	Lower					

SPATFALLS OF THE NON-NATIVE PACIFIC OYSTER, *CRASSOSTREA GIGAS*, IN BRITISH WATERS

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ABSTRACT

1. Light spatfalls of the Pacific oyster, *Crassostrea gigas*, have occurred in the Rivers Exe, Teign and Dart, Devon and in the Menai Strait, Gwynedd, near to sites of commercial cultivation of this species.
2. Comparisons of the sizes of the naturally settled oysters with hatchery oysters suggests that the spat from the R Teign and Menai Strait settled in 1989 and 1990. The springs and summers of these years were exceptionally warm with mean monthly air temperatures 0.8-1.3°C above the 1951-1980 average for the period April to August.
3. Although sitings of Pacific oyster spat were made in Loch Sween and Emsworth Harbour over 20 years ago, there is no evidence that self-sustaining populations have developed.
4. The spatfalls which occured in some coastal waters of Devon and Gwynedd in 1989and 1990 are unlikely to sustain natural fisheries and are likely to die out as did the Portuguese oysters which occassionally settled in the River Blackwater, Essex.

INTRODUCTION

The UK oyster industry traditionally relies upon natural spatfalls of the European flat oyster, *Ostrea edulis L.* to replenish the fisheries. The demands for oysters in the first half of this century, however, were sufficiently great to encourage the practice of importing large quantities of half-grown flat oysters from France and Holland which were relaid on British oyster beds for growing to market size (Utting and Spencer, 1992). The oyster industry also imported non-native species of oysters which were fattened and then sold during the summer when the flat oyster was breeding and unmarketable. The American oyster, *Crassostrea virginica* (Gmelin), was deposited on beds in Essex, Devon, Sussex, Humberside and Gwynedd, from about 1870 to 1940 and the Portuguese oyster, *Crassostrea angulata* (Lamarck), on the east coast of England from 1901 to 1962. There is no evidence that the American oyster reproduced successfully in British waters but spatfalls of the Portuguese oyster occurred occasionally in the River Blackwater, Essex, from which a minor trade in cocktail oysters arose. However, this local population of Portuguese oysters died out once the practice of importing oysters was discontinued.

The nature conservation and fisheries implications of depositing unquarantined non-native species of oysters from overseas were not taken into account with these earlier deposits. As a consequence, two species of American oyster pests became established in some areas where deposits were made. The American oyster drill, *Urosalpinx cinerea* (Say), a voracious gastropod predator of flat oyster spat, became established in Essex and Kent and caused considerable mortalities to natural spatfalls of flat oysters in the 1940's and 1950's (Cole, 1951; Hancock, 1954). The slipper limpet, *Crepidula fornicata* (L), another gastropod but a sub-tidal competitor for space and food of flat oysters, became more widely distributed around the coast (Walne, 1956). In some areas, it produced large quantities of unwanted mud from its filtration activities which added considerably to the costs of husbandry (Hancock, 1974).

Since 1960, the Directorate of Fisheries Research has introduced a number of new bivalve species of commercial interest to broaden the base of the shellfish industry at a time of diminishing landings of native oysters. These introductions were made through the quarantine facility at the Fisheries Laboratory, Conwy, to prevent the escape of unwanted pests or disease organisms during the period when the imported broodstock was being conditioned for breeding. First generation juveniles were also kept in quarantine for ca.15 months while histological tests confirmed their freedom from pests and diseases. Sea trials were then undertaken to verify that the species was suitable for release for commercial purposes. The quarantine procedure was later incorporated into a protocol adopted by ICES, 1973.

During the period 1962-1984, seven species of non-native bivalves were bred at the Conwy Laboratory, but only two, the Pacific oyster [*Crassostrea gigas* (Thunberg)] and the Manila clam [*Tapes philippinarum* (Adams and Reeve)], were given to the commercial hatcheries for cultivation. Both of these species were imported from the west coast of North America, the Pacific oyster from British Columbia, Canada, in 1964 and 1972, and the Manila clam from Washington State, USA, in 1980. Neither of these species are native to that Continent but have become naturalised there following the deposits of large quantities of Pacific oyster seed (which included some Manila clams) from Japan.

The Pacific oyster is cultivated in many estuaries and sheltered coastal waters of the British Isles. Production, compared with that of France (> 100 000 tonnes per annum), is quite small, estimated to be about 300 tonnes from 36 farms in England and Wales in 1992 with the largest quantities grown in Whitstable Bay, Kent; Morecambe Bay, Cumbria; River Blackwater; Essex, and Carew River, Dyfed (Figure 1).

The Pacific oyster requires a different annual temperature regime than normally occurs in the UK to produce regular natural spatfalls sufficient to sustain a viable fishery. The cultivation industry, therefore, is dependant on a regular supply of seed from the two British commercial hatcheries. Since its introduction into the UK there have been regular reports from the shellfish producers of Pacific oysters spawning during the summer, probably in response to elevated temperature and handling shocks when placed in depuration plants. However, reports of naturally occurring spat are sparse and refer usually to individual sitings of oysters. Small numbers of Pacific oyster spat were seen in Loch Sween, Strathclyde, Scotland in 1969 or 1970, but not in a survey in 1991 (Mitchell pers. comm., 1993), and two spat were collected from Emsworth Harbour, Hampshire in 1971 (Askew pers. comm., 1993) (Figure 1).

The first information of a spatfall in the River Teign (Devon) (Figure 1) was provided by Captain P. Gibbon (Offshore Farms Ltd.) who noticed small spat on cultivated Pacific oysters in plastic containers (poches) in the autumn, 1990. Two spat measuring 28 and 30 mm shell breadth (ca. 3 g live weight) suggested that the spatfall had occurred in the summer of 1989. Other reports then emerged of the occurrence of natural spatfalls of Pacific oysters in the Rivers Exe and Dart (Devon) and in the Menai Strait (Gwynedd) (Figure 1), areas where Pacific oysters are cultivated. This paper provides some details of the location, abundance and sizes of oysters and the estimated time of settlement/s.

MATERIALS AND METHODS

(i) Shore searches: visits were made to the following sites (Figure 1)

(a) R. Teign in October and November 1991 and November 1992.

(b) R. Exe in October 1991, November 1992 and June 1993.

(c) Portland Harbour and the Fleet (Dorset), R. Dart, Kingsbridge estuary and R. Avon (Devon) in November 1992.

(d) Menai Strait in March and May, 1993.

(ii) Site surveys: intertidal areas, from about low water of spring tides to mid-tide level, were searched. This was accomplished by one or more people walking along a section of the shore at about mid-tide level and returning at about low water. Since many of the shorelines were comprised mainly of mud which is unsuitable for spat settlement, searching was concentrated on areas with a hard substrate of shell and stone. In some estuaries (Exe, Teign, Dart and Kingsbridge), the upper and lower surfaces of tiles laid by soft-crab bait-fishermen were also examined.

In addition to the ground search, hatchery-reared Pacific oysters cultivated in poches on trestles at LWST in the R. Teign were examined in October 1991. Twenty poches each holding ca. 100 oysters were inspected. From these, 110 naturally settled spat, together with the cultivated oysters on which they had settled, were placed in two labelled poches for a further 12 months for measurement of growth and survival .

(iii) Observations on the oysters: shell breadth (longest axis from umbo to shell margin to the nearest mm below) and total live weight (to 0.1 g below) of samples of the naturally settled oysters were measured in the laboratory. Condition indices (CI) of ten pooled oysters collected in May 1993 from natural populations in the R. Teign, Menai Strait and from 1989 hatchery-reared oysters grown in trays in the Menai Strait were calculated from:

C I = dry meat weight (mg)/dry shell weight (g) (Walne and Mann ,1975).

(iv) Age determination: acetate peels of the sectioned umbo region of twelve oyster shells collected in April and May 1993 from natural populations, which had settled inter-tidally on the ground in the R. Teign, Menai Strait and from oysters, hatchery-reared in 1989 and grown in trays in the Menai Strait, were prepared by the method of Richardson et al., (1993b). Annual growth lines were examined and counted using a low power microscope. The size frequency distributions of oysters from the R Teign and Menai Strait were examined for the separation of size-classes by Bhattacharya's method (1967) using the software package ELEFAN (Gayanilo et al., 1989) which fits the best model to the data. The data were smoothed using continuous averaging over groups of three consecutive size-classes. The resulting model was tested for goodness of fit using a chi squared test and deemed to be satisfactory when not significantly different from the frequency distribution.

RESULTS

Location of spatfalls

River Teign

(i) Spatfall on the shore: the estuarine inter-tidal zone comprises mainly sand and mud areas with some cultivated and natural mussel beds which are exploited by local fishermen. Pacific oysters are cultivated , mostly in poches on trestles, in a few inter-tidal areas on both sides of the estuary. This fishery began about 10 years ago and its perpetuity depends on an annual supply of hatchery seed. Searches in October and November 1991 revealed a light spatfall of naturally set spat in two areas (Figure 2). Most spat were found on the south shore in the vicinity of the commercial oyster trays at Arch Brook on two small patches of shell-covered ground (approximately 100 x 50 m) located on a mud-flat midway between low water of spring tides (LWST) and high water of neap tides (HWNT). The oysters were attached mostly to mussel shell but also to cockle shell, stones and occasionally to winkles, *Littorina littorea* L. Several hundred oysters were seen and it transpired, in conversation with local growers, that some had been removed to their oyster lays. A small spatfall of 9 oyster spat was found after
5 man-hours of searching on the north shore on an area (approx. 200 x 20 m) of old mussel shell.

(ii) Spatfall in oyster poches: the numbers of spat attached to oysters from 20 poches (Table 1) averaged 1.5 spat per poche with most occurring as single spat but occasionally with two (on 6 oysters) or three spat (on one oyster) per oyster. They ranged in size from 15 to 50 mm (mean breadth = 28.9 mm) in October 1991 and 30 to 100 mm (mean breadth = 65.6 mm) in October 1992 (Figure 3). Survival of the naturally set oysters in the poches after one year was 96%.

River Exe

The inter-tidal shore of the estuary is comprised largely of sand and mud flats with occasional stone and shingle areas near to Exemouth. An extensive natural mussel bed (Bull Hill) is located in the central part of the estuary between Exemouth and Cockwood and a number of cultivated beds at LWST along the western shore between Starcross and Dawlish Warren. Pacific oysters are grown in poches on trestles at LWST near to Dawlish Warren. A shore crab bait fishery is also pursued by the placement, inter-tidally, of numerous crab shelters, comprising ceramic or asbestos, roofing tiles or similar refuges.

(i) Spatfall on the ground: in November 1991, 32 spat were found attached to the under-surface of 191 crab tiles at a site near to Dawlish Warren. These same tiles examined in June 1993, had 27 live oysters (mean shell breadth ± 95% confidence interval, 100.4 ± 6.7 mm) and the scars of 5 dead oysters (16% mortality) attached to them. Another group of 211 tiles near to Cockwood, examined in June 1993, had one large attached oyster.

(ii) Spatfall in oyster poches: in October 1991, an examination of 20 000 adult Pacific oysters in poches revealed no attached spat.

River Dart

In November, 1992 a search of the inter-tidal shore (a distance of ca. 1 km) of rocks/stones and crab-bait tiles in the vicinity of Pacific oyster poches near to Waddeton was made. Spatfalls of Pacific oysters on stones, rocks, shells and tiles was light over the area examined with densities occasionally 1-2 m^{-2}.

Kingsbridge estuary

No Pacific oyster cultivation is undertaken in this estuary. Approximately 3 km of shore-line, covering various stony/rocky areas and crab-bait tiles in mid-estuary, the rocky shore at the mouth of the estuary and a stone jetty in the harbour, was examined. No spat were seen.

River Avon

Approximately 2 km of inter-tidal shore, comprising shale and rocks in the vicinity of a small Pacific oyster fishery at Hexdown and the rocky shore at the mouth of the estuary, was examined. No spat were seen.

Portland Harbour

No Pacific oyster cultivation is undertaken in the harbour. Approximately 0.5 km of shore, comprising a rocky reef and disused sewer pipe on the north-west shore, was examined. No spat were seen.

The Fleet

Three sites were visited.

(i) Army Bridging Camp: approximately 1 km of the inter-tidal shore, comprising stones, shells and rocks, was examined. One *Ostrea edulis* (30-40 mm in size) was seen.
(ii) Ferry Bridge: the inter-tidal Pacific oyster storage area near to the Pacific oyster depuration plant was examined.
(iii) Pacific oyster depuration plant: about 500 cultivated Pacific oysters from the plant were examined.

No Pacific oyster spat were seen at any of these sites.

Menai Strait

A preliminary search in March 1993 along the shore of the Menai Strait at Beaumaris (Figure 4) revealed a light spatfall of Pacific oysters attached mostly to mussel shell at mid-tide level. Fifty oysters were collected by 3 people at a rate of 22 oysters per man-hour. Nine oysters were collected from the opposite shore near to the ancient Ogwen fish weir after 2 man-hours of searching.

A more detailed search was made in May 1993 to determine the extent and intensity of the spatfall throughout the Menai Strait (Figure 4). This search revealed a patchy distribution of spat mostly on the north shore with the greatest numbers occurring to the east and west of Beaumaris and at Gallows Point at the eastern end of the Menai Strait (Figure 4; Table 2). Up to 10 oysters m^{-2} were collected from one patch of stony ground near to Beaumaris pier. Some oysters were collected from the north-western end of the Menai Strait near to the commercial/experimental Pacific oyster growing areas at Tal-y-foel. Only one oyster was found on the south shore.

Condition Index

Oysters from the Menai Strait had a lower CI than those from the R. Teign (Table 3). The condition indices of the Menai Strait oysters, however, were similar irrespective of site or origin.

Age by shell sectioning

Difficulty was experienced in interpreting the growth lines in the umbo region of the shells of the three batches of Pacific oysters examined. This may have been due to the fact that this species of oyster frequently continues to grow slowly during the winter in the UK, resulting in a less conspicuous boundary between summer and winter shell deposition than occurs with other temperate species of bivalves. The estimated times of settlement of the groups of sectioned oysters from the three locations (Table 4) may, therefore, be less precise than assessments of age of other oyster species using the shell sectioning technique (Richardson et al., 1993a; Richardson et al.,1993b).

Separation of size classes by the method of Bhattacharya

The oysters from the Menai Strait showed a wide size distribution (Figure 5). The smaller oysters were thick shelled and stunted and probably of the same year class as some of the larger oysters. The breadth/weight relationship for the oysters was similar irrespective of area of settlement (Figure 6).

The small number of oysters collected from Beaumaris east, Ogwen, Gallows Point and Tal-y-Foel in the Menai Strait (Figure 5) prevented fitment of a model to their length-class distributions. The population at Beaumaris west and the combined data for the whole of the Menai Strait, however, fell into two length classes ($*^2 = 0.56$, *df.* = 1, $P > 0.05$; =X^2 and $*^2 = 1.7$, *df.* = 6, $P > 0.05$; Table 5).

The oysters from the R. Teign, settled on cultivated oysters in poches, were unimodal in length distribution in 1991 ($*^2 = 2.5$, *df.* = 4, $P > 0.05$), but showed three separate size classes in 1992 ($*^2 = 1.39$, *df.* = 2, $P > 0.05$; Table 5).

DISCUSSION

Evidence of natural spatfalls of the Pacific oyster since its introduction into the UK in 1964 is not well documented. In the early 1970's, a few naturally set oysters were seen in Loch Sween, Scotland and Poole Harbour (Mitchell, pers comm., 1993) and Emsworth Harbour (Askew, pers. comm., 1993). The observations of this study indicate that light spatfalls have occurred in several adjacent estuaries (Exe, Teign and Dart) in Devon and in the Menai Strait, Wales, where Pacific oysters are cultivated commercially. Although it is not known from which broodstock the spatfalls in the Devon estuaries were derived, it is unlikely that the small quantities of Pacific oysters in the R. Dart were responsible. Nor is it likely that oysters on the French coast were responsible for the spatfalls in Devon since the nearest stocks on the Cherbourg Peninsular are > 100 km away. Since Pacific oyster larvae are free-swimming, for a period of ca. several weeks, depending on water temperature and food availability (Utting and Spencer, 1991), before cementing themselves to suitable settlement surfaces, it is conceivable that embryos/larvae from the estuaries of the Exe and/or Teign, which largely empty at low water, could have been carried by prevailing currents to neighbouring estuaries, a maximum linear distance of ca. 30 km. Similarly the spatfalls seen at the eastern end of the Menai Strait are likely to be the result of larval transport from the areas of commercial cultivation some 20 km away.

The size distribution of the naturally set oysters on the cultivated Pacific oysters in trays in the R. Teign, measured in October 1991, (Figure 3), and of the Menai Strait oysters in 1993 (Figure 4) was similar to that of hatchery oysters grown in trays which are 1-2 year old and 3-4 year old, respectively, (Spencer et al., 1985 and 1992). This would indicate that spatfalls occurred in 1989 and/or 1990. The size distributions of R.Teign oysters in trays in 1992 and Beaumaris west oysters appear bimodal (Figures 3 and 5) and examination of length size distributions of both samples by Bhattacharya's (1967) method indicated the presence of several size classes (Table 5). Factors likely to influence the separation of the oysters into size groups in these circumstances, in addition to age, include tidal exposure and, in the case of oysters in poches, stocking density. The shell sectioning technique was not sufficiently accurate to age the oysters precisely. The evidence (Table 4) suggests that some oysters, 55-112 mm in size, settled in 1991; it is unlikely, however, that this size would have been reached within one growing season. The spring and summer temperatures of 1988 and 1991 were near to the average but those of 1989 and 1990 were above average. Mean monthly air temperatures at Valley (Anglesey) were 0.8 and 1.3°C and at Exmouth (Devon) 1.2 and 1.1°C above average for the period April to August inclusive (from The Meteorological Office Tables) for these years respectively. These warmer temperatures could have provided up to an extra 150 air day-degrees (D°; accumulated day-degrees of air temperature above 10°C) (Mann, 1979) to the average of 453 for Exemouth, and up to an extra 225 D° to the average of 534 for Valley during the period when active gonad ripening was taking place. Occasional daily sea water temperatures, available for the Menai Strait for 1989 and 1990 (National Rivers Authority), were also above the 7-year mean values (Figure 7) compiled from data supplied by the School of Ocean Sciences (University College of Wales, Bangor).

Rate of gametogenesis, fecundity and quantity of eggs in some bivalves is related to temperature and the quantity and quality of available food (Utting, 1993). Mann (1979) found that *C. gigas* became sexually mature after 595 day-degrees (accumulated day-degrees of the water temperature above 10°C) of conditioning at various temperatures in laboratory experiments. Although this information cannot be closely applied to field conditions because of the large differences in food availability, it provides an estimate of the onset of sexual maturity of Pacific oysters using known temperature regimes. Thus, in the Menai Strait (from Figure 7), Pacific oysters may mature by mid-September in years with average temperatures or early August when temperatures are about 1°C above average in April to August as occurred in 1989 and 1990.

The introduction of non-native species of animals and plants for commercial or aesthetic reasons is very much in evidence in many countries of the world. In many cases, a species, whether introduced intentionally or accidentally, may acclimate to its new environment and become established as a self-sustaining population eg *Mercenaria*

mercenaria (L.) in Southampton Water, England (Heppell, 1961; Mitchell, 1974; Utting and Spencer, 1992), Japweed, *Sargassum muticum,* in France and England (Gruet, 1976; Farnham et al., 1973). In fisheries, examples of naturalisation are seen with the Pacific oyster, a native of Japan and Korea, which has become resident in some areas of Canada, the USA, France, The Netherlands, New Zealand and Australia. In North America (Quayle 1964) and France (Grizel and Heral 1991), seed oysters shipped across from Japan in massive quantities were deposited for a number of years before their natural reproductive capacity overcame the need for continued importations. Nowadays, production from these fisheries has an increasingly high value with landings, for example, in France in excess of 100 000 tonnes per year.

Due to less stringent controls on introductions than apply in the UK, and inadequate ecological assessments, some countries have experienced ecological embarrassment with the introduction of new species. Pacific oysters introduced into the cooler southern waters of Australia have enabled a successful fishery, based on hatchery seed, to develop there. The species, however, has now spread by man-assisted movements into the warmer waters of Victoria and New South Wales where it has become established and is displacing the highly valuable, and preferred, native Sydney rock oyster [*Saccostrea commercialis* (Iredale and Roughley)] (Holliday and Nell, 1985). The Pacific oyster, also imported accidentally into New Zealand, has become established there and now constitutes an increasingly valuable fishery (Coleman, 1986).

The policy of introducing non-quarantined shellfish is fraught with problems which must be weighed against the economic benefits of the introduction. In the past, undesirable pests, disease, and also benign marine flora and fauna have become established which themselves may have an effect not only on the introduced species but on the natural ecology as well. In England and Wales, fisheries and environmental conservation measures were put into practice in 1974 with legislation [Molluscan Shellfish (Control and Deposit) Order, 1974] to control deposits of bivalves in order to reduce the risk of spreading existing pests (*Mytilicola intestinalis*, *Crepidula fornicata* and *Urosalpinx cinerea*) and to prevent the introduction of new pests and diseases from overseas (Spencer, 1990). A Variation Order was introduced in 1983 to control the flat oyster disease, *Bonamia ostreae*. In 1993, however, the Molluscan (Control of Deposit) Order, 1974, Variation Order, 1983, was superceded by a European Community Directive (91/67/EC) which allowed bivalves from approved zones in EC countries to be deposited in the UK as part of the "free market" agreement. Control of deposit of bivalves is now determined by the presence of *Bonamia ostreae* and with *M. intestinalis*, *C. fornicata* and *U. cinerea* now disregarded as pests. Meanwhile the enactment of the

Wildlife and Countryside Act, 1981, provided further protection against intentional release into the wild of non-native animal and plant species except under licence. Although Pacific oysters and Portuguese oysters are non-native species, their deposit is allowed under general licence and it is not necessary to apply for individual licences for their release.

The Canadian and French shellfish industries have benefited enormously, from an economical point of view, by introducing, albeit unquarantined, Pacific oysters. The UK industry, however, suffered substantial damage to the east coast flat oyster fisheries by the unintentional introduction of the American oyster drill. Nowadays, however, with the flat oyster industry in decline, the UK is fortunate to be able to sustain a bivalve cultivation industry by the successful development of commercial hatcheries capable of producing millions of Pacific oysters in an environment which does not support natural fisheries of this species. The spatfalls which have occurred in Devon and Gwynedd, probably in 1989 and 1990, in response to exceptionally warm summers, are unlikely to sustain natural fisheries and are likely to die out as did the Portuguese oysters which occasionally settled in the R. Blackwater.

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Table 1: Numbers of Pacific oyster spat attached to cultivated Pacific oysters in poches in the R Teign in October 1991

No. of spat per poche	No. of poches	Total spat
0	6	0
1	8	8
2	2	4
3	2	6
5	1	5
7	1	7
TOTAL	20	30

Table 2: Areas of the Menai Strait searched on 13 March (Areas A to C) and 5/6 May 1993 (Areas D to N) for naturally set Pacific oysters. Figure 4 shows locations of areas searched.

Area	Location	Substrate	Length of foreshore searched (km)	No of persons	Time (h)	No of oysters collected	Oysters per manhour	Oysters per km
A	Beaumaris east	stones/pebbles/mussel shell	2.8	3	0.75	50	22	18
B	Ogwen (ancient fish weir)	stones/mussel shell	1.0	1	0.50	8	16	8
C	Ogwen	stones mussel shell	0.8	1	0.50	1	2	1
D	Beaumaris west	stone/shell	1.2	2	2.00	55	14	46
E	Gallows Pt west	stone/mussel, *Ostrea edulis* and *Crassostrea virginica* shell	2.5	2	1.50	14	5	6
F	Menai Bridge east	stone/mud	1.5	4	1.00	1	<1	<1
G	Bangor	stones/mussel, *O. edulis* and *C. virginica* shell	1.2	2	0.75	0	0	0
H	Bangor west	stone/shale/mussel shell and mud	1.5	2	0.75	1	<1	<1
J	Llanidan	stones/mussel shell	2.0	3	0.75	0	0	0
K	Tal-y-Foel	stones/mussel shell	2.2	3	1.00	10	3	4
L	Port Dinorvic	stones/mussel shell	2.1	4	0.75	0	0	0
M	Griffiths Crossing	stones/mussel shell	2.5	2	0.75	0	0	0
N	Caernarfon	stones/mussel shell	1.6	3	0.75	0	0	0

Table 3: Mean dry meat and shell weights and condition indices of naturally set Pacific oysters from the R. Teign and the Menai Strait and hatchery-reared oysters from the Menai Strait.

	Meat weight (mg)	Shell weight (g)	C I
R. Teign	4265	52.4	81
Beaumaris (west)	3726	69.3	54
Gallows Point	6513	112.1	58
Tal-y-Foel (hatchery)	2559	45.6	56

Table 4: Year of settlement determined from shell sectioning and size range of three groups of Pacific oysters. Numbers of oysters examined are shown in parenthesis.

	Size range of oysters (mm)			
	1988	1989	1990	1991
R Teign		82- 85 (2)	71-104 (5)	81-95 (3)
Menai Strait	88 (1)	77-119 (4)	53-110 (3)	55-112 (2)
Hatchery oysters reared in 1989		107-114 (6)	91-106 (3)	

Table 5: Classification of length-class distributions of naturally set Pacific oysters from the Menai Strait and R. Teign using Bhattacharya's method (1967).

Site	Numbers of oysters	Mean length (mm) ± SD	*df*	χ^2	*P*
Beaumaris east	8	59.9 ± 8.5	assumptions not met		
	26	86.0 ± 10.6			
Beaumaris west	39	63.1 ± 7.9	1	0.56	ns
	6	88.6 ± 6.4			
Menai Strait	51	63.6 ± 8.4	6	1.70	ns
(all sites)	56	87.2 ± 12.7			
R. Teign (Oct. 91)	111	28.7 ± 10.0	4	2.50	ns
R. Teign (Oct. 92)	18	42.5 ± 8.0	2	1.39	ns
	62	64.3 ± 7.4			
	23	84.0 ± 10.0			

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	23	84.0 ± 10.0			

FIGURE LEGENDS

Figure 1. Map showing location of sites referred to in text.

Figure 2. R. Teign: location of naturally set ( ) and cultivated Pacific oysters (◯).

Figure 3. Size distribution, in October 1991 and 1992, of naturally set Pacific oysters attached to cultivated Pacific oysters in pouches in the R Teign.

Figure 4. Menai Strait: areas searched in March, ( ) and May 1993 ( ), for naturally set Pacific oysters.

Figure 5. Size distribution, in March and May 1993, of naturally set Pacific oysters from different areas of the Menai Strait.

Figure 6. Relationship between shell length and live weight of Pacific oysters from the Menai Strait.

Figure 7. Mean monthly sea temperatures of the Menai Strait for 1972-1978 (●) and incidental daily records averaged for six sites in 1989 (D) and 1990 (x) (NRA data).

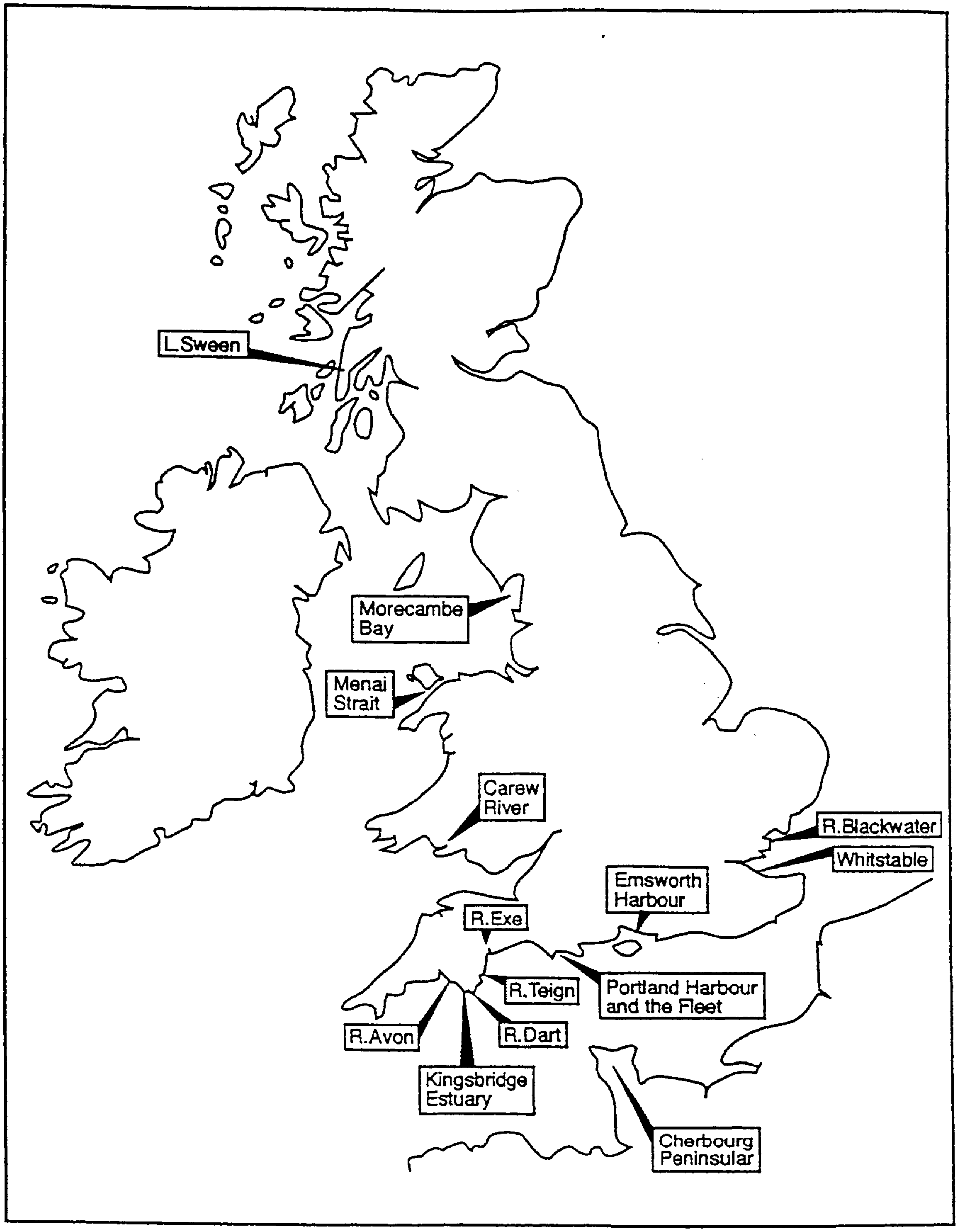

L.Sween
Morecambe Bay
Menai Strait
Carew River
R.Blackwater
Whitstable
Emsworth Harbour
R.Exe
R.Teign
Portland Harbour and the Fleet
R.Avon
R.Dart
Kingsbridge Estuary
Cherbourg Peninsular

FIGURE 1

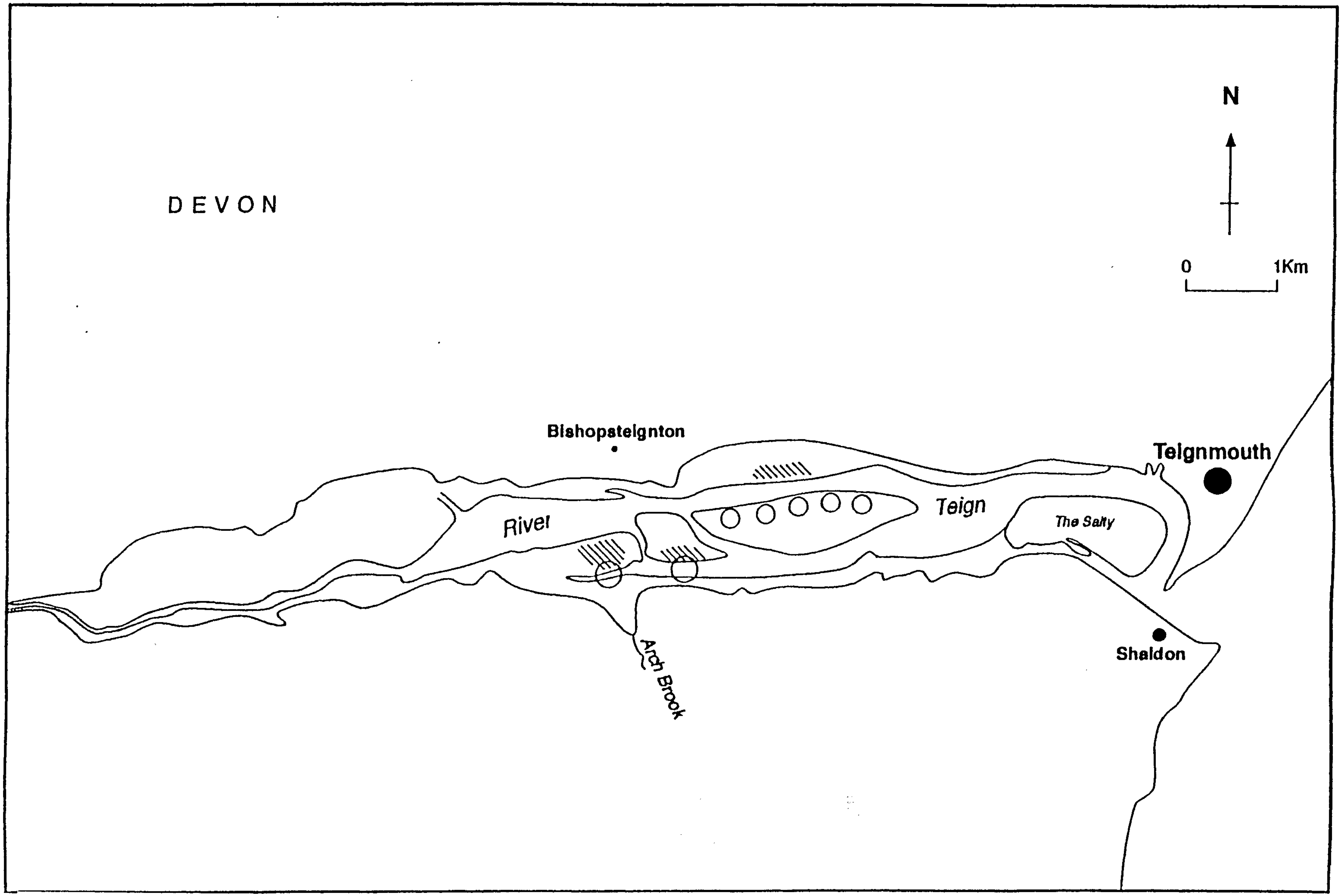

N
0
1Km
DEVON
Bishopsteignton
Teignmouth
River
Teign
The Salty
Arch Brook
Shaldon

FIGURE 2

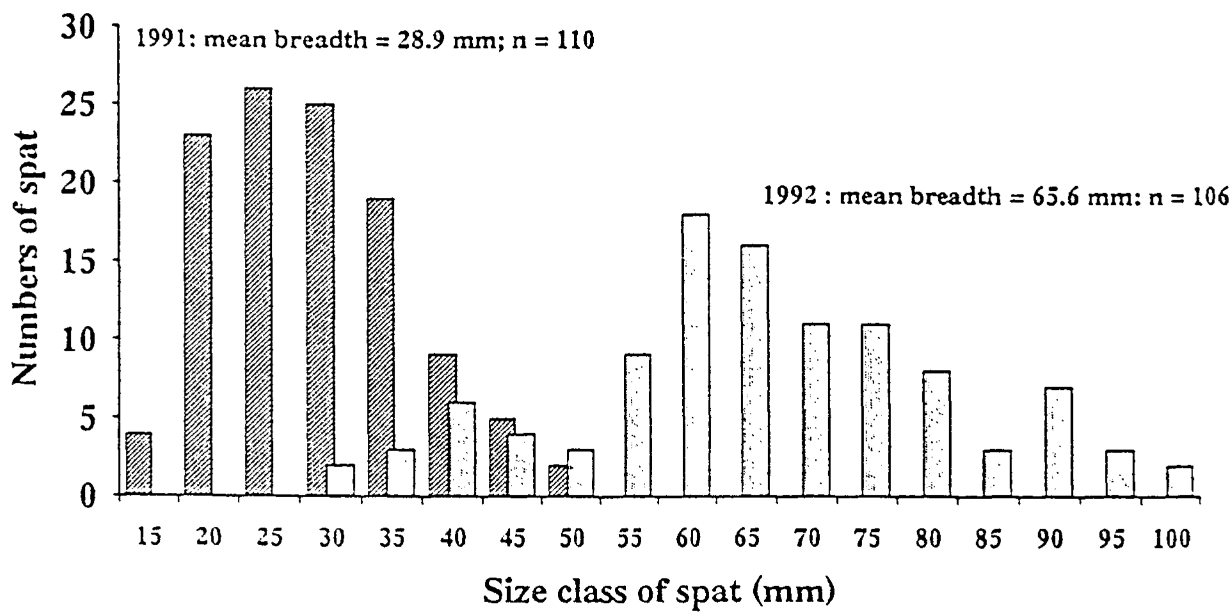
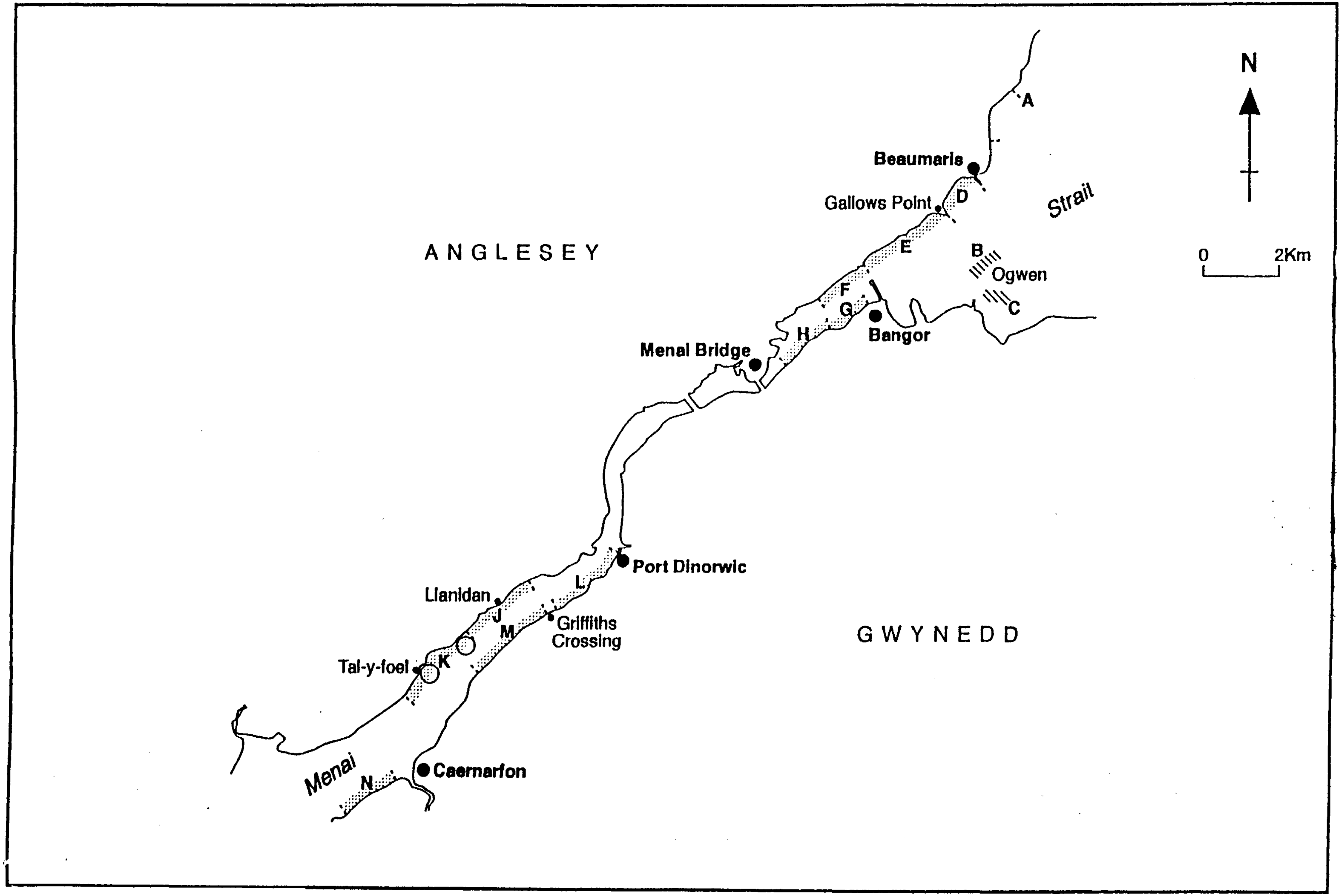

1991: mean breadth = 28.9 mm; n = 110
1992 : mean breadth = 65.6 mm: n = 106
Numbers of spat
0
5
10
15
20
25
30
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Size class of spat (mm)

FIGURE 3



N
0
2Km
A
Beaumaris
D
Gallows Point
Strait
ANGLESEY
E
B
Ogwen
F
G
C
Bangor
H
Menal Bridge
Port Dinorwic
L
Llanidan
J
Griffiths
Crossing
M
GWYNEDD
K
Tal-y-foel
Menai
N
Caernarfon

FIGURE 4

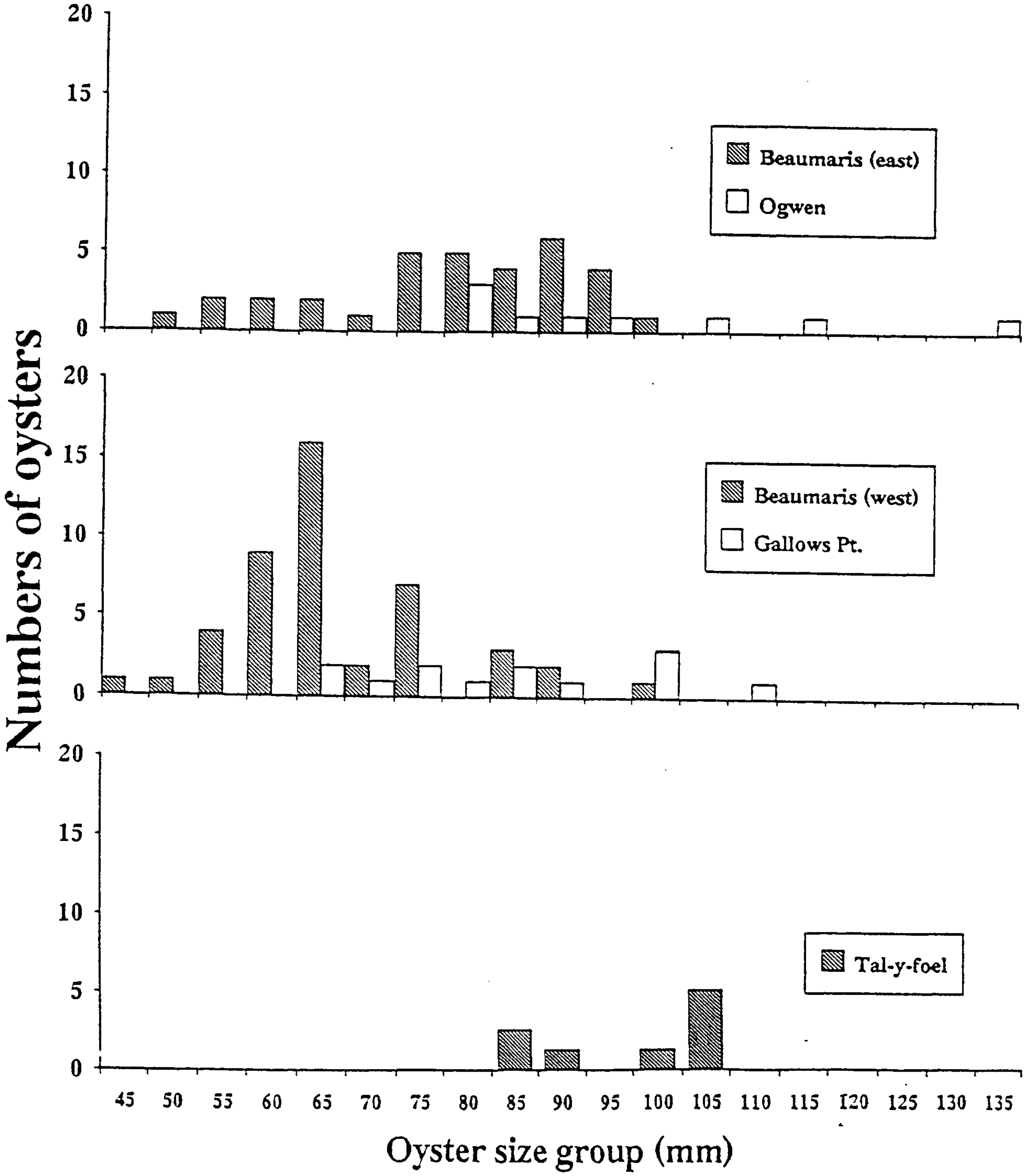
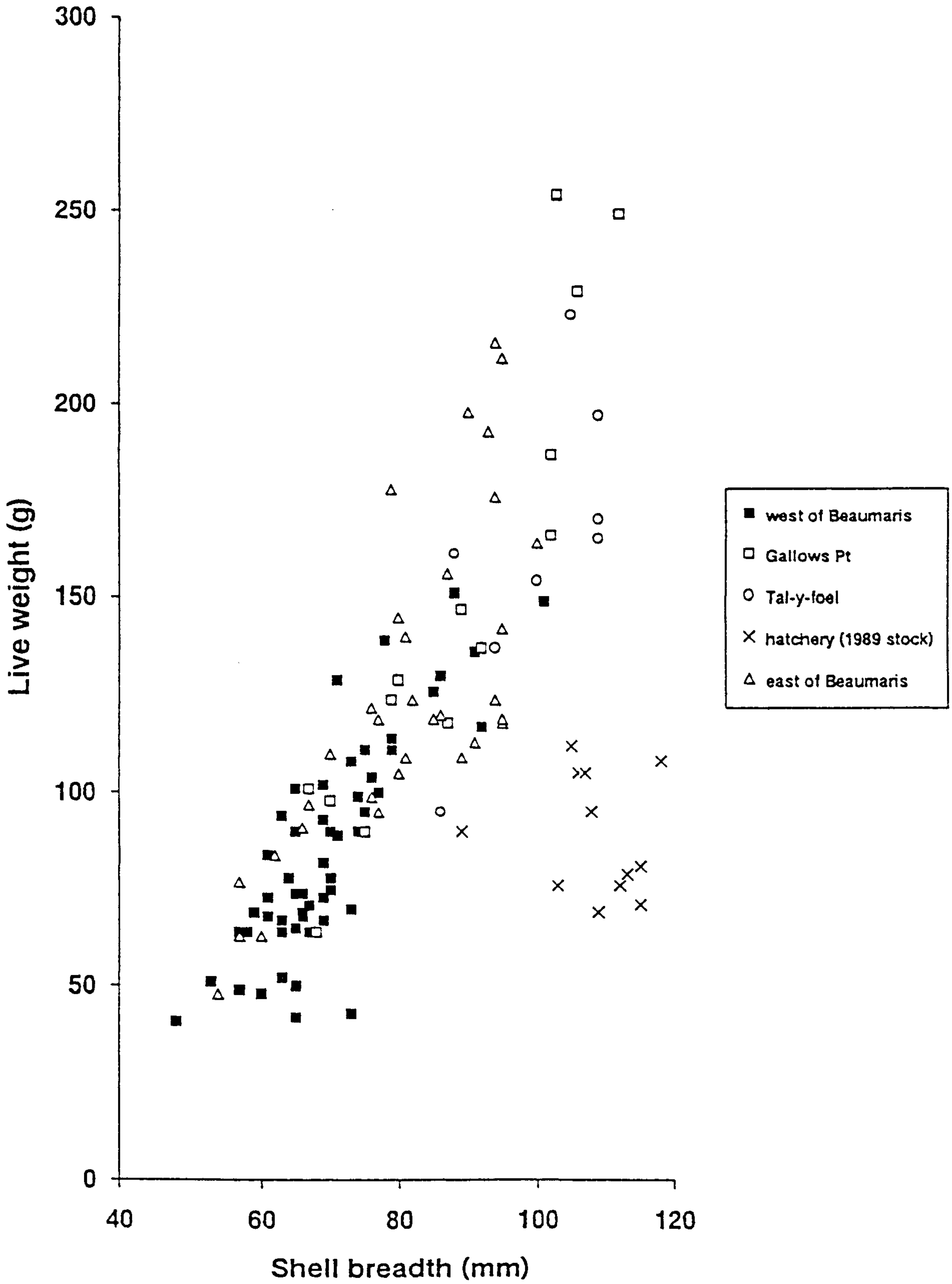

Numbers of oysters
20
15
10
5
0
Beaumaris (east)
Ogwen
Beaumaris (west)
Gallows Pt.
Tal-y-foel
45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135
Oyster size group (mm)

FIGURE 5



300
250
200
150
100
50
0
Live weight (g)
40
60
80
100
120
Shell breadth (mm)
west of Beaumaris
Gallows Pt
Tal-y-foel
hatchery (1989 stock)
east of Beaumaris

FIGURE 6

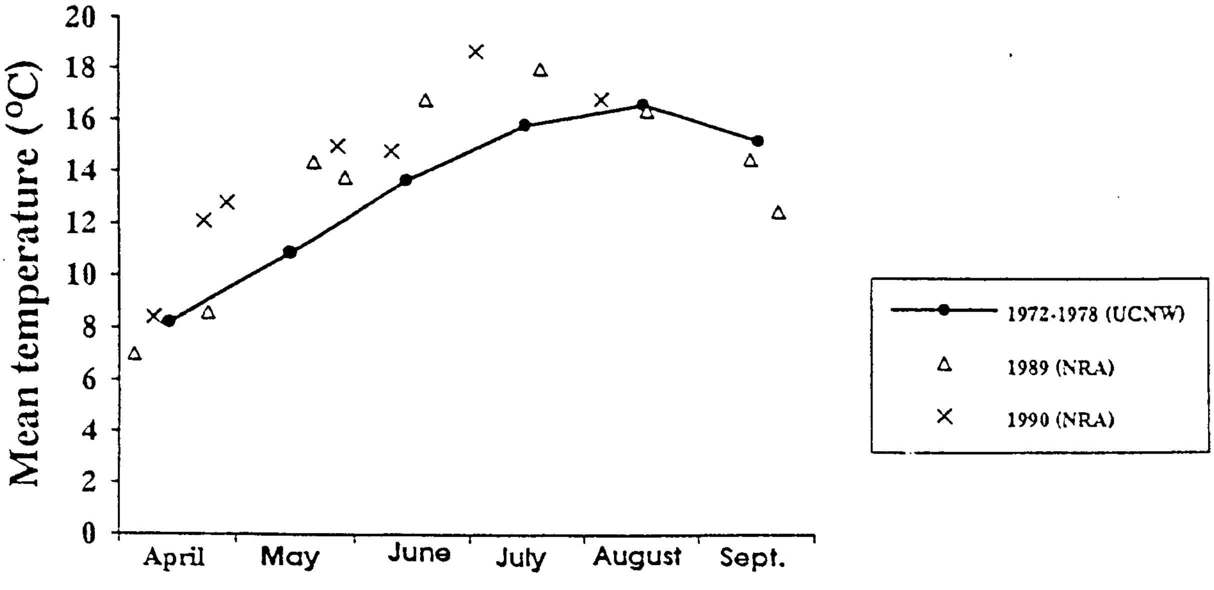

20
18
16
14
12
10
8
6
4
2
0
Mean temperature (°C)
April
May
June
July
August
Sept.
1972-1978 (UCNW)
1989 (NRA)
1990 (NRA)

FIGURE 7