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International Council for the Exploration of the Sea

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Biological Oceanography Committee

# REPORT OF THE BENTHOS ECOLOGY WORKING GROUP

Kiel, Germany, 3-8 May 1993

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## 1 OPENING OF THE MEETING

The Benthos Ecology Working Group met at the Institut für Meereskünde, University of Kiel, Germany under the chairmanship of Dr P. Kingston. Dr M. Kaiser was appointed rapporteur. A list of participants is given in Annex 1.

### 1.1 Terms of Reference

The Benthos Ecology Working Group is to;

a) review and report on how benthic communities are affected by disturbance of the sea floor;

b) review cooperative benthic studies area throughout the ICES area;

c) review and report on existing benthos data bases and their compatibility and availability to benthic scientists, and investigate how they are related to initiatives in Europe and North America;

d) produce an initial list of marine benthic indicator species within the ICES area potentially vulnerable to physical disturbances of the seabed;

e) review the benthic implication of global climate change including their relation to fish stocks;

f) if possible, prepare material for use by the Working Group on Ecosystem Effects of Fishing Activities at its next meeting in 1994.

## 2 ACTIVITIES OF INTEREST TO ICES AND OTHER ORGANISATIONS

### 2.1 Advisory Committee on the Marine Environment (ACME) (formerly ACMP)

ACMP was disbanded and the Advisory Committee on the Marine Environment set up in its place on 1 November 1992. Members of the new committee comprise the Chairmen of relevant ICES standing Committees and new members nominated by ICES member countries. Dr K. Richardson has been appointed Chairman of the ACME. The first meeting is to be held in June 1993. Under the new system the environmental working groups will have a more prominent role in the provision of advice to ICES member countries and the various commissions. The precise role of each group will not emerge until after the first meeting.

### 2.2 North Sea Task Force (NSTF)

Dr A. Künitzer reported that the NSTF is currently preparing a quality status report which is due to be presented in December 1993. There is now a move to make benthos monitoring an integral part of the monitoring programme of the northeast Atlantic (Joint Monitoring Programme). J. Craeymeersch reported that the data from the North Sea Monitoring Master Plan have been installed on a central database, but that the data set is incomplete. Data input has been particularly time consuming, which has left no time for detailed analysis. However, the data are available for individuals to undertake their own analyses. Some institutes, eg., MAFF, have collected samples, but do not have the resources to analyse the data, which is partly due to the current programme being superseded by national monitoring plans. It was proposed that money should be sought from the NSTF to fund analysis of the database, especially in view of the usefulness of the data to future surveys. H. Rees recommended that the stations should be treated as individual entities as the temporal data gained by continuing the survey would be invaluable regardless of the spatial considerations. Further discussion on this topic can be found under Section 5.

### 2.3 Atlantic Canadian Continental Shelf Studies

Dr P. Schwinghamer reported on a similar programme for long-term zoogeographic monitoring in Canada. The programme involves groundfish surveys combined with grab sampling at trawl haul stations to examine macrofauna associated with particular bottom characteristics and fish communities.

T. Rowell reported that rapid species identification manuals for the more easily identified megabenthos are being developed for the use of observers onboard commercial fishing vessels for recording megafaunal bycatch in trawl catches. A similar, but more detailed, system will be used during groundfish surveys.

### 2.4 Coastal Benthic Ecology (COST 647)

Dr K. Essink reported on COST 647. In the CEC concerted action on Coastal Benthic Ecology (COST 647), co-ordination and stimulation of long-term benthic research has been carried out since ca. 1981 in four (western European) coastal habitats (Annex 2).

In the last phase of COST 647, which came to an end in 1992, special attention was paid to numerical data analysis. These analyses were supervised and carried out by Dr F. Ibanez of the Zoological Station at Vellefranche.

For various CEC reasons, the COST 647 programme could not be continued. At present a follow-up programme 'Change in Coastal Ecosystems' (CICE) is being launched under the CEC. Environment Programme.

## 2.5 Baltic Marine Biologists (BMB)

a) Dr H. Rumohr reported on the progress of the BMB group, which holds scientific biannual meetings. The 13th Baltic Marine Biologists Biannual Symposium is to be held in Riga, Latvia, on September 1-5, 1993. The BMB sponsors several working groups which promote cooperative work, covering topics such as: shallow water fish ecology, identification keys of Baltic macroflora, historical benthos data (chaired by H. Rumohr), fish diseases and parasites, diatom species identification, artificial substrate communities and zooplankton.

The historic database in Kiel now includes 1,600 (unpublished) Polish benthic stations from the Baltic Sea and the Kattegat in addition to other data from 1902-1912, 1925-1932 and 1949-1979. This database has revealed that long-term trends in benthic communities in the Baltic are only apparent when a time scale of 5-10 years is examined.

## 2.6 Gulf of Riga Project

Dr H. Cederwall gave a synopsis of the Gulf of Riga project. The aims of this project are primarily to establish a budget of nutrients and organic contaminants and, secondarily, to construct an integrated model of the Gulf. The project will last for 3 years with a possible extension to 5 years, starting in 1993, and is financed by the Nordic Council of Ministers and national funds. A steering group leads the project, which is split into five sub-projects dealing with:

1) Meteorology, runoff and sediment load
2) Hydrography and nutrients
3) Pelagic ecology
4) Sediments
5) Organic contaminants and metals

The sub-project on sediments will study sedimentation of C, N and P; sediment chemistry (fractions of C, N, P and Si); macrofauna (production, lipid concentration, excretion); meiofauna (annual dynamics, production).

In July 1993 a survey will map the fauna and sediments in the Gulf. Based on the results obtained, two stations will be chosen for intensive study, 10 times/year, during 1994 and 1995.

## 2.7 Joint Ocean Global Flux Study (JGOFS)

Dr N. Silverberg reported on progress in eastern Canada. The Canadian government is supporting a pair of studies on the presently very poorly known carbon cycle in the Gulf of St. Lawrence. The pelagic group (with a strong phytoplankton component but with some interest in all size classes of zooplankton and microbial activity) is oriented towards the understanding of food chain dynamics on a seasonal basis. Several surveys were carried out in 1992, and a surprisingly well-developed bloom was observed in mid-December. Five stations were visited last year. The stations varied in their productivity and physical attributes. The benthic group, dominated by geochemists but with some benthic ecology, is attempting initially to determine the style of early diagenesis in relation to the carbon cycle on a once-a-year basis. There has been some degree of collaboration in the selection of sites to be visited, and the use of short-term drifting and long-term moored sediment trap collections as a link between the two groups. Sedimentation rates are expected to be low in the Gulf compared to the estuary. Further work will examine how much carbon generated by phytoplankton may be available to the benthic community.

## 2.8 Land/Ocean Interactions in the Coastal Zone (LOICZ)

Dr H. Rumohr reported on developments in LOICZ. A planning meeting took place in Germany in 1992, and this has been established as a new core project. In IGBP (International Global Biological Programme), the topics of future research will include: transport processes from the land to the sea, temporal changes of coastal morphology, ecological processes in a wide variety of marine habitats, and scientific techniques. This group is presently undergoing development.

## 2.9 European Science Foundation (ESF)

Dr A. Nørrevang reported that a basic science programme, under the auspices of the European Science Foundation, has been set up to study the zoogeographical limits of certain benthic species along the Norwegian coast, and possibly will be extended to the whole European area. However, this programme is currently in the preliminary stages of development.

## 2.10 Studies in the United States

Dr Taylor reviewed some of the active, developing and planned programs sponsored in the U.S. by the U.S. National Science Foundation, Oceans Sciences, that are of interest to the BEWG. The Land Margin Ecosystem Research (LMER) program comprises ecological research at regions of the land-sea interface. It is a component of the U.S. Global Change Program and a likely major U.S. contribution to the IGBP-LOICZ project. Individual projects are of 5-year-duration, focusing on estuarine systems and upstream/land influences and fluxes. Emphasis in the projects includes nutrient cycling, system variation related to nutrient loading, sediment denitrification, benthic/water column interactions and periodic sediment loading. The projects include seasonal monitoring and processoriented studies.

There are currently five projects, three of which are along the Atlantic Coast of the U.S. These are:

i. the Chesapeake Bay System, a large, enclosed embayment with large population and agricultural influences and anoxia problems ;

ii. Plum Island Sound, Massachusetts;

iii. Waquoit Bay, Massachusetts, a very small, enclosed bay with significant ground water nutrient inputs and an ecosystem that has seen a major macrophyte shift from seagrass to macroalgal dominance.

The funding of the overall program is about $3 million (U.S.) per year; projects are of 5 years duration and renewable.

The U.S. JGOFS (Joint Global Ocean Flux Studies) program is part of the IGBP-JGOFS core project directed toward understanding carbon-cycling in the world's oceans. The U.S. JGOFS activities have, to date, a decidedly deep ocean emphasis, with biological and geochemical studies dominating. In the initial North Atlantic project, benthic studies were virtually absent in the U.S. program, being completed primarily by the U.K. and Germany. In the Equatorial Pacific and upcoming Arabian Sea projects, benthic microbiological, bioturbation and geochemical studies are included, integrating with the surface and deep water column studies. The NSF support of U.S. JGOFS is about $15 million (U.S.) per annum with additional support from NASA (National Aeronautics and Space Administration) and NOAA (National Oceanic and Atmospheric Administration). Integrated shelf/coastal carbon-cycling studies are supported primarily by the Department of Energy.

The U.S. GLOBEC (Global Ocean Ecosystems Dynamics) programme is part of the developing International GLOBEC (IOC, SCOR, ICES, PICES) programme. The scientific programme focuses on the population dynamics of marine animals, zooplankton (incl. mesoplankton and ichthyoplankton) and the physical influences (micro- to basin scale) on these dynamics. The current program involves sampling technology development (acoustic and biochemical), coupled physical-biological modelling studies and a single major field program in the Northwest Atlantic (Georges Banks, Gulf of Maine and vicinity). This NW Atlantic programme involves U.S./Canadian cooperation and is viewed as part of the nascent ICES Cod and Climate Change program. To date, studies of the larval ecology of benthic species are not included in the NW Atlantic project. Currently GLOBEC is supported by NSF, NOAA and the Office of Naval Research at about $6 million (U.S.) per annum. Planned projects in the California Current (Eastern Boundary and upwelling system) are to include research on cross-shelf and long-shore transport processes and animal population dynamics, including benthic taxa. Benthic systems will be an important component of the planned Antarctic project as well.

The RIDGE (Ridge Interdisciplinary Global Experiments) programme is aimed at understanding the geology, geophysics, biology, ecology and geochemistry of the mid-ocean ridge system. The biological/ecological aspects are a minor component of the overall program. These emphasise:

i. the physiological ecology of animal/bacterial chemoautotrophic symbioses;

ii. ecological succession in fauna and microbes;

iii. larval dispersal ecology and population genetics;

iv. microbial ecology;

v. biological aspects of black-body radiation.

Several of these foci are being pursued in the context of the French/U.S. (FARA) studies on the Mid-Atlantic Ridge. RIDGE is part of the international INTER-RIDGE program. Current support from NSF is about $1 million (U.S.)/year for biological/ecological research.

The last established programme that involves benthic ecological studies is the COOP (Coastal Ocean Processes) program for interdisciplinary coastal oceanography. The one active research project furthers research looking at transport processes (small scale to cross-shelf), sediment geophysics, and the ecology of settlement and dispersal in infaunal organisms of the inner shelf. The 4-year program is situated along the North Carolina coast and is supported at over $1 million (U.S.) per annum. Other programs are planned.

There are two new initiatives being developed within NSF-Ocean Sciences. The first nascent, basic science, initiative deals with Harmful Algal Blooms (HAB). Like the international discussions on HAB (IOC/SCOR), initial discussions on research planning in the U.S. have emphasized planktonic algae almost to the exclusion of attention to benthic (macroalgal and microalgal) bloom problems. This problem will be alleviated in the initiative. HAB will focus on the general topics of:

i. understanding biological rate processes related to bloom dynamics;

ii. development/refinement of coupled physical/biological models relevant to proper time and space scales for blooms;

iii. field and experimental studies to look at successional processes and biotic interactions implicated with bloom formation (allelopathy, competition for nutrients, grazing), and the influences of nutrient dynamics;

iv. physiology and physiological ecology related to toxin production and interspecies effects (allelopathy, toxic effects);

v. probe development for ecological studies and basic assays;

vi. ecological (community, ecosystem) effects of blooms.

The other initiative currently being planned is BIOMAR (Biological Diversity in Marine Systems). Again, much of U.S. and international discussion over the past 5 years has been occurring but with a general lack of attention to marine systems (coastal, pelagic or deep sea). This initiative will concern the basic science issues related to a broad definition of biological diversity and will involve benthic and pelagic systems. It should provide a substantial scientific basis for policy/management decisions on the conservation of marine biological diversity, a foundation which is currently lacking. The programme will have four main foci:

i. processes that control or change diversity in an ecosystem at the species and genetic levels;

ii. the role and importance of species and diversity in population, community and ecosystem processes (e.g., food web dynamics, nutrient cycling, successional patterns);

iii. the impact of introduced species;

iv. the maintenance and/or improvement of taxonomic understanding necessary to support the overall program.

## 2.11 Network Marine Biodiversity Steering Group (MARS)

J. Craeymeersch reported that at a recent meeting of the MARS Network Marine Biodiversity Steering Group, set up to coordinate the submission of proposals to the EC (DG XII), two projects were put forward:

a) Ecosystem function of biodiversity

The overall objective of this outline proposal is to determine the relationship between the rates and efficiencies of defined marine ecosystem processes and the biodiversity of the organisms which are responsible for or mediate these processes (Contact person: Dr R. Warwick).

b) Inventory and monitoring of biodiversity

The programme will be designed to provide information on species richness and faunal/floral composition at particular sites and also the spatial relationship among habitat types along gradients. Careful consideration will be given to the standardisation of the collection and processing of data to ensure strict comparability between laboratories. Intensive monitoring over time of a few key reference sites, chosen on the basis of the results of the extensive study, will also be undertaken. Here the scope of the inventory will be expanded, both in terms of habitats studied and taxonomic breadth. (Contact person: Prof. C. Heip).

## 2.12 European Regional Seas Environmental Model (ERSEM)

D. Basford reported that there was currently a group modelling areas of the North Sea which intends to study the Fair Isle inflow area. The model will include benthic data input from five stations sampled across the inflow area over several years in both the spring and autumn.

## 2.13 Ecosystem Projects in the Wadden Sea

Dr K. Essink reported on long-term benthic data for the Wadden Sea. Data on abundance and biomass of intertidal macrozoobenthos have been collected since 1969 in the Balgzand area by Dr J.J. Beukema (NIOZ, Texel) and in the eastern Dutch Wadden Sea by Dr K. Essink. Further details of the resulting publications can be found in Annex 2.

## 2.14 Quality Assurance of Benthic Data from the Baltic Sea

Dr A. Künitzer reported on a steering group that will give advice on the quality control of Baltic biological data. The aims are to provide critical analysis of the Baltic Monitoring Programme (BMP) data and to produce guidelines for quality assurance between each laboratory with regard to the techniques used. As the expertise does not exist within the steering group, representatives from various Working Groups have been asked to consider these problems at the BMB symposium in Riga, in Autumn 1993 (see Section 2.5 above), and to give advice on the procedures that should be adopted. Hopefully there will be two workshops, one on benthos and the other devoted to plankton, which will set the standards for quality control. It will be mandatory for each laboratory participating in the BMP to participate in these workshops. The BEWG has been approached to comment on quality assurance procedures for benthic monitoring. Dr H. Rumohr emphasized the need for continuity in the staff employed on these programmes which aids standardization of procedures such as sorting and identification, thus making results intercomparable.

The necessary guidelines on methodology already exist in the literature (Rees & Heip, 1990; Rumohr, 1990). Unfortunately there were too few representatives of the BMP to produce a set of guidelines on quality assurance at this meeting.

# 3 REVIEW OF COOPERATIVE STUDIES

## 3.1 Cooperation with Baltic Nations

Dr H. Rumohr pointed out that cooperation with eastern European nations is impeded by the fact that presently they have no money available for equipment or travel expenses. Hence, the basic requirement for exchange to occur is for western European countries to provide travel money. Officials responsible for the issuance of visas must ensure that these are expedited as efficiently as possible. A list of addresses of known benthic experts from Lithuania, Latvia, Estonia and Russia is given in Annex 3.

## 3.2 Institut für Ostseeforschung, Warnemünde

Dr M. Powilleit related that after the political changes in Germany, the Institut für Ostseeforschung, Warnemünde, was officially opened in February 1992. Biological oceanography is one of four scientific sections and supports ca. 20 scientists. The research activities of the institute are focused on exchange processes between shallow lagoons (Bodden), the coastal waters and the open Baltic Sea, and centre on a multi-disciplinary research programme. Cooperation with other Baltic countries is another important aim.

No benthic research has been performed in Warnemünde for the last two decades, so it has been necessary to construct new laboratories and acquire new benthic sampling equipment. A major project is planned in the Pomeranian Bay, in cooperation with Polish institutes, to study the effects of the input of River Odra material into the Bay and subsequent transport and modification of this material in the sediment by benthic organisms. Benthos studies will include: i) distribution of macrozoobenthic communities along a gradient of organic enrichment and/or pollution from the estuary to the bay; ii) population dynamics; iii) bioturbative activities of dominant species; iv) content of chlorinated hydrocarbons in these species; v) sediment characteristics.

Another project deals with the introduced polychaete species, *Marenzelleria viridis*, in European coastal areas, especially in the Baltic Sea. This is a joint project together with other institutes including the University of Rostock. Investigations are being made into the ecophysiology (oxygen, salinity and temperature stress adaptation) and the bioturbative activity of this species.

## 3.3 Biological Survey of the Faroe Islands (BIOFAR)

Dr A. Nørrevang presented some more results from the BIOFAR programme which was funded by the Nordic Council of Ministers. A model now exists for the bottom temperature regimes in the area around the Faroe Islands. A cold water mass separates the warm water of the Faroes Bank from the Island coastal shelf. The large number of new benthic species encountered has required the taxonomic expertise of 65 specialists located around the world. This information is stored on a database that also incorporates bottom temperature and current velocity. On the slope of the Faroese Banks there is an area of critical slope where stagnant water occurs, causing increased local sedimentation. This is correlated with the occurrence of coral and sponge communities. The Faroes have a more diverse fauna than other European areas, e.g., 190 species of bryozoans have been found so far, 25 are new to science. Muddy sediments are relatively uncontaminated, PCB concentrations were 0.25 of the levels typically found in the North Sea. The Faroes Bank has a range of bottom types, mostly shell sand interspersed with rocky outcrops, with some inexplicable faunal associations. Southern species have recently been found in samples, eg *Cancer pagurus* and *Echinus esculentus*, the reason for their appearance is unknown. Trawling is destroying slow-growing (2 cm/year) coral banks, but an appeal has been made to the fishermen to avoid these areas as they are important nursery areas for fishes.

## 3.4 Biological Survey of Iceland (BIOICE)

The BIOICE programme aims to map the fauna of Icelandic waters. Three scientists and five technicians work at a newly created laboratory in Sandgerdi, west of Reykjavik. An inter-Nordic scientific advisory group has been established. In cooperation with the BIOFAR, and possibly, BIOGREEN (Greenlandic programme), programmes, it is intended to map the benthic zoogeography of the fringe area between the Norwegian Sea and the Atlantic. This might be important for studies of possible global climate change. Three vessels from Iceland, Norway and the Faroes will combine their efforts to sample on five consecutive years between 1992 to 1996.

## 3.5 Helsinki Commission (HELCOM)

Dr H. Rumohr reported on the latest developments in the HELCOM monitoring programme (the Baltic Monitoring Programme (BMP)). Under the HELCOM Environment Committee a new approach has been implemented to consider nature conservation issues in the HELCOM activities as well as closer cooperation with national coastal monitoring programmes. At present a revision of the monitoring guidelines is being undertaken.

### 3.6 Coupling between Physical Processes and Biogeochemistry (COUPPB)

Dr N. Silverberg reported on studies in eastern Canada on sediment water column interactions. The programme on Coupling between Physical Processes and Biogeochemistry is now at the writing stage, with an overall synthesis still in the future. The large size of the Lower St. Lawrence Estuary (LSLE) permits complex hydrodynamic motions more characteristic of open coastal waters. The 1989 water column data revealed that rapid (a week or less) changes in the horizontal structure can have as much influence on primary production as changes in the vertical structure involving the photic zone. Empirical orthogonal function (EOF) analysis of the T, S, Chl and $NO_3$ profiles collected during the June-July phytoplankton bloom was used to reduce the mass of data. The first three "modes" accounted for only 55% of the variability, the major interpretation being a shift from a longitudinal separation across the estuary to a radial pattern. Improved modelling of mesoscale (10-100 km, days-weeks) physical dynamics is essential for a true understanding of short-term variations in the phytoplankton regime.

The data also show that simple algorithms for determining the f-ratio (the proportion of primary production derived from nitrate assimilation as opposed to that of regenerated ammonia) may not be applicable in the coastal zone. The f-ratio correlates poorly with the nitrate distributions. At the 50% light level it is not linearly correlated but can be predicted from the horizontal concentration field. At lower light levels it can be related to the vertical stratification of nitrate using EOF analysis, but the relationships are not as expected, i.e., higher f-ratios are found at the 25% light level, rather than next to the "nitracline".

ETS activity profiles (using filtered material from Niskin bottles in 1990) showed a very strong dominance of $CO_2$ production within the photic zone. In the aphotic zone there was little relation to changes in primary production and much remains to be understood to balance the carbon budget in the water column.

Preliminary data are now available from sediment traps moored at three sites along the axis of the LSLE. They reveal that sedimentation is maintained throughout the winter months at levels which may be higher than during the ice-free season. These continuous weekly to monthly settling matter data are consistent with the inverse relationship between carbon content and total sedimentation rate, a pattern observed at both shorter and longer time scales. Thus, the carbon flux to the benthos is somewhat equalized throughout the year. The quality of the organic matter is likely to be important, however. Results from a recent study of the organic geochemistry of the settling material indicates that the terrigenous component makes up roughly 50% of the total C flux, and that more labile marine components increase in a seaward direction and, as expected, during the summer phytoplankton production.

### 3.7 Dogger Bank

Dr I. Kröncke reported on further results from the Dogger Bank study. There are high concentrations of heavy metals and organic contaminants in the sediment and in the livers of dab, *Limanda limanda*. There is a large riverine input into the area resulting in phytoplankton production throughout the year, and a high settlement of organic matter into the area. There has been a decrease in the number of long-lived macrobenthic species and an increase in the number of opportunistic species. There are two seasonal peaks in biomass and abundance of animals which occur in the spring and summer. The distribution of food found in the stomach of dab also followed this pattern, the interpretation is that dab may be partly responsible for the drastic seasonal decrease in benthic biomass.

### 3.8 Arctic Studies

a) Arctic Monitoring and Assessment Programme (AMAP)

S. Dahle reported on cooperative research with Russian scientists. There are few biological or contaminant data from the Barents Sea area, although there are large oil and gas resources in this area and dumping of radioactive materials has been frequent.

An Arctic Monitoring and Assessment Programme (AMAP) has been started. This involves the 8 arctic nations which are studying areas north of the Arctic Circle. In 1996 a report will be produced that lists the geographical distribution of benthic species and maps the levels of contaminants (metals, organochlorines, radionuclides). Included in AMAP are efforts to standardize methods and analyses, and to implement specific quality assurance procedures. As part of the AMAP studies, Akvaplan-Niva carried out three different cruises in the Barents Sea in 1992. The aims of the studies were i) to map geographical distributions of different benthic species and to characterize the species composition; ii) to map the level of different contaminants in sediment and biota; the contaminants determined were metals, organochlorines (PCBs, pesticides, etc.), PAHs and radionuclides, as defined by AMAP; iii) intercomparison of Russian and Western methodology and results.

All the cruises were carried out in cooperation with scientists from the Murmansk Marine Biological Institute of the Russian Academy of Science. On the cruises to

Franz Josef Land and to the Pechova/Novaya Zemlya, Russian research vessels were used.

Van Veen grabs and gravity corers were used for the benthic studies, whilst the Russians used Okean grabs. Organisms for studies of contaminants were collected by sledge, trawl and angling. Sediment analyses involve cooperative studies with the Norwegian Institute of Water Research (NIVA) and the Bedford Institute of Oceanography, Canada. The cooperative studies with the Russians have been so far been very fruitful and have scope for further development. The Russians have been working in Arctic areas for decades; they have many data and results which, to a great extent, are unknown to western science.

Based on the success in 1992 a cruise has been proposed to the eastern Kara Sea and the estuaries of the major Siberian rivers, Ob and Seneki. This cruise will take place in September on the same ship and with the same organisations.

Other Norwegian benthos studies in the area are carried out by the Norwegian research institute. During 1991/92 they have carried out several cruises where sampling to meet the AMAP requirements has been included.

b) Alfred-Wegener Institut (AWI) Arctic Programme

Dr E. Rachor reported on a research cruise in the Barents Sea and planned work in the eastern Arctic. The latter will concentrate on the sensitivity of the Arctic ecosystems to global climate changes, and how the ecosystem is affected by the impinging water masses. The intent is to study the main ecological processes, biogeography and natural variability of marine populations and communities.

In 1991 a transect from the Nansen Basin to the Central Barents Sea was surveyed. Benthic biomass dropped from 50-250 g/m$^2$ on the upper shelf (200 m) to 3 g/m$^2$ on the floor of the basin. Oxygen uptake of the micro- and macrofauna revealed that 48% of the oxygen was respired by the micro-organisms, 41% by the macro-epifauna and 11% by the infaunal animals. This is probably the first time an oxygen budget has been calculated for this benthic community.

Ecological research by the Alfred-Wegener Institute in the Arctic Ocean is aimed at a better understanding of the interrelationships of the deep basins and the eastern shelf seas (which have enormous riverine runoff) as well as the relative importance of the Atlantic influx in terms of whole global climatic changes and, moreover, playing a key role in triggering such changes. The understanding of ecological processes as well as biogeographical distribution patterns and community fluctuations are prerequisites for the prediction of possible future changes in the biotic conditions of the Arctic Ocean.

Russian scientists have an in-depth knowledge of the Eastern Arctic ecosystems, but due to the pack-ice coverage, the very important transition zone between the well-investigated shelf seas and the poorly explored deep Arctic basins and the continental slope zone still needs extensive work. We are very interested in understanding the ecological processes in these slope areas and comparing Siberian shelf seas and their slopes (Laptew) with the shelves subjected to strong Atlantic influx (e.g., Barents Sea).

Plans for the intended 1993 cruise of the R/V *Polarstern* and cooperating Russian vessels are, therefore, to be considered a first west to east comparison of the water circulation and the different life conditions, distribution patterns and ecological processes along the shelf slopes. The main focus of biology will be on processes related to the pelago-benthic coupling (production, vertical flux of organic matter and incorporation in benthic communities) and to the advection of plankton and organic matter from productive waters to sedimentary habitats down and along the slopes. In the Laptew Sea, stratification and modification of water masses due to the river runoff during summer are expected to be a main factor controlling the whole pelagic productivity. Therefore, information from the relevant shallow shelf areas and the Lena Estuary is necessary to understand processes and life conditions in the deeper shelf slope environments.

### 3.9 Geographic Information Systems (GIS) in Marine Research

P. Hempel reported on ODER (Oder Discharge-Environmental Response) which is an EC-funded research programme centred in the Pomeranian Bay to study discharges from the River Oder. The programme examines biogeocycling in the marine ecosystem, in particular, sediment transport from the River Oder into the marine environment. The project is split into: radiochemistry; sediment transport and organic geochemistry; benthic ecology; heavy metal geochemistry. Techniques will include ROV, the use of carbon isotopes and remote sensing, and the data produced are fed into a GIS (Geographic Information System) database. This is a powerful tool for combining a vast array of different data types which can be overlaid to give an informative visual presentation of results. The potential to combine normally incompatible data such as side-scan sonar survey results and benthic community data should aid the analysis and interpretation of studies centred on factors affecting benthic communities.

## 4 USE OF MESOCOSMS IN BENTHIC RESEARCH

### 4.1 The Institut Maurice-Lamontagne (Canada) Benthocosm

Dr N. Silverberg reported on the progress of the project, including the results of his colleague, J-M. Gagnon. The latest (Series IV) of the three 1m x 1m benthic mesocosms containing blocks ("self-annealed") of sediment box cores from a depth of 350 m in the Laurentian Trough, eastern Canada, have now been maintained in a relatively healthy condition for at least 12 months. Recent improvements include isolation of the seawater reservoirs for each basin and the use of Instant Ocean-augmented readily available sea water from 17 m depth to renew one-third of the reservoir after every two weeks to suppress the build-up of nutrients. Ammonia levels, which can be high due to the release of reduced pore waters during the set-up of the basins, can now be controlled at near *in situ* levels (2 M). Oxygen uptake measurements can now be performed routinely using a YSI Endeco pulsed oxygen electrode system. Whole-sediment respiration rates consistently fall around 0.4 moles.cm$^{-2}$.d$^{-1}$.

More details of the macrofauna abundances after the benthocosms were terminated are now available. They reveal that the densities of the dominant taxa are close to those observed in freshly obtained box cores. The four most dominant species represented an average of 72% in the benthocosms compared to 65% *in situ*. In general, rank order varied both in individual benthocosm basins and in field samples. A number of small species actually appeared to show preferential enhancement in the laboratory (e.g., *Thyasira* c.f. *equalis*, *Aricidea albatrossae*, *Tharyx acuta*). Some of the megafauna were less resistant and showed gradual disappearance or sensitivity to temperature fluctuations or unknown contaminants or pathogens (e.g., *Ophiura sarsi*, *Brissaster fragilis*, *Pennatula acuta*). Small crustaceans were also affected, perhaps because of their swimming ability (lost through the overflow, trapped at the air-water interface, eaten by anenomes). Many of these differences were apparent as well for Series III, which was screened after only 50 days, suggesting that the origins for the changes begin early on, reflecting stresses associated with the initial installation procedures.

During Series II it was demonstrated that the bacterial numbers and activity remained close to that of freshly collected material. Similarly, during Series III, the counts of meiofauna (exclusively nematodes apparently) was also shown to be indistinguishable between the benthocosm and fresh field subsamples.

Time-lapse video imaging has permitted the elucidation of behavioural traits otherwise unattainable *in situ* (e.g., periodic ventilation of oxygen depleted burrow water by *Calocaris templemanni*, and the progression of *Brissaster fragilis* below the surface by passing sediment backwards using its dorsal spines). Multiple video observations of burrows have permitted the quantification of their mean rate of sediment displacement for several species: the head-down feeding *Maldanidae* sp. displaces anoxic sediment from 2 cm depth towards the surface in the form of fecal pellets at rates of 0.3 L.m$^{-2}$.y$^{-1}$; *Ampharete arctica* collects surface material radially around its tube and redistributes it as pellets at 2.4 L.m$^{-2}$.y$^{-1}$; the mudstar *Ctenodiscus crispatus* accounts for both horizontal and vertical mud displacement of 89 L.m$^{-2}$.y$^{-1}$, while the heart urchin *Brissaster fragilis* displaces a conservative estimate of 16 L.m$^{-2}$.y$^{-1}$.

### 4.2 NIOZ Mesocosm Studies

Dr G. Duineveld reported on research activities at Dutch institutes concerning mesocosms. The mesocosms study southern North Sea subtidal communities. Mesocosms were stocked with 6 *Nephtys* spp, 6 *Echinocardium* spp. and 6 *Telina fabula*, which made a biomass of 14.5 g AFDW.m$^{-2}$. This community was housed in a plastic container 40 cm high x 30 cm wide. The mesocosm was fed pulses of dried *Phaeocystis* spp. A single pulse feed was given (22.5 gC.m$^{-2}$) to one set of mesocosms, to another weekly pulses were given (145 gC.m$^{-2}$). The effect of food on macro- and meiofauna, bacteria and protists was assessed. The macrofauna did not survive well, only *Echinocardium* spp. showed an increase in weight. However, growth curves did not increase exponentially, possibly because the animals spawned during the experiment. Experiments with meiofauna have not been successful so far. An experiment to examine the effects of macrofauna on the mesocosm showed that with macrofauna present, detrital and bacterial carbon increased, whereas nanoflagellate carbon decreased. Oxygen uptake was not affected by the presence of macrofauna; these animals only account for about 10% of the total respiration in the system. Bacterial respiration was higher in the presence of macrofauna. The bioturbatory activity of *Echinocardium* spp. increased the amount of inputed carbon accounted for in measurements of respiration.

## 5 MONITORING PROGRAMMES

### 5.1 Coordination of North Sea Benthic Monitoring

The Monitoring Master Plan of the North Sea Task Force (NSTF) required, as a minimum, sampling at specified stations for a wide range of determinands in the North Sea (including the Skagerrak and the English Channel) by bordering countries. Sampling of the benthic macrofauna was included as a voluntary requirement. The BEWG provided basic advice and procedures to be followed in their 1990 report. In the event, most were sampled, and in some regions, eg. the Netherlands, stations additional to those specified were included. However, only a proportion have been worked up and the data submitted to the Delta Institute for analysis and archiving on behalf of ICES (see Figure 1). Further, only a preliminary analysis of the available data has been conducted owing to a lack of resources and, while only providing partial coverage, **the BEWG strongly recommends completion of this task.** Remaining stations should also be worked up and added to the database, since only by this means can the validity of the station selection for benthos be assessed. It seems likely that there will be a future requirement for comparable North Sea-wide assessments of "ecosystem health". A lack of effort directed at an assessment of the suitability of the existing NSTF "baseline" will therefore simply become a problem deferred.

For the purpose of the Quality Status Report (QSR) boundaries in time were set governing the suitability of historical data for inclusion, and the ICES North Sea Benthos Survey conducted in 1986 was acceptable on this basis. As a result, much reliance has (rightly) been placed on the results from this spatial survey. Among other things, this work identified natural regional-scale differences in the types of benthic assemblages. These differences will need to be taken into account in future comparative work aimed at "quality assessments". As far as possible, comparisons should be made between similar assemblage types; the benefits of assessing the status of one particular assemblage type by reference to all others across the North Sea are less clear.

As a follow up to (or in parallel with) NSTF work, "Master Plans" have been developed or revised on a national scale, generally incorporating original NSTF positions to meet the future needs of both domestic and international assessments. The rationale is explained elsewhere but generally includes the sampling of "estuarine", "intermediate" and "offshore" stations by the appropriate national agencies.

The international dimension to such national monitoring plans raises a number of issues regarding the study of benthic communities:

i. the importance of a long-term time series of data; while the degree of spatial intercomparison between samples taken from different areas may be useful, the main focus of attention should be long-term changes with time at individual stations treated as separate entities;

ii. the "representative" nature of stations; agencies must satisfy themselves that the location and sampling practices are realistic. Moreover, a periodic review of the continued validity of these stations will be required, probably entailing a more extensive grid-type survey of the general area at infrequent intervals;

iii. the "internal" consistency of the data; important aspects include continuity in personnel and the adoption of standard procedures;

iv. intercomparability of data between institutions, both on a national and international level; in order to achieve this, there will be a similar requirement for the adoption of standard procedures for sampling and analysis and also a significant commitment of effort e.g., "intercalibration" exercises. Guidelines for the former can be found in the 1990 BEWG report and subsequent BEWG documents published in the *ICES Techniques in Marine Environmental Sciences* series;

v. frequency of sampling. For the monitoring of long-term trends, this should be at least once per year (in February to May).

In conclusion, the BEWG considers that it has an important role to play in the provision of advice at the national and international level concerning the coordination of benthic monitoring programmes, the application of standard methodology for sampling and analysis, and other aspects relevant to "quality control". However, since at this stage the degree of emphasis to be placed on the outcome of benthos sampling as part of the new Joint Monitoring Programme is not clarified, at least for some countries, then the scope for providing detailed advice is presently considered to be somewhat limited. The BEWG nevertheless strongly supports the incorporation of a benthos component in future national/international monitoring plans, because of its unique advantage as an integrator of environmental effects over time. For example, many benthic species do not migrate and, therefore, patterns of distribution do not alter over short time scales; the characteristics of most benthic assemblages therefore, clearly reflect local environmental conditions.

## 5.2 Monitoring of Geomorphology in Relation to Benthos and Bird Populations

J. Craeymeersch reported that a programme has been started to monitor the effects of a land reclamation scheme, which is designed to extend Rotterdam harbour, and has been recommended to last for 30 years. So far there have been few changes in community distribution. However changes in biomass did occur. In the shallowest areas, there was a decrease in the biomass of the subtidal community from 1983 to 1990 due to fishing for cockles. In deeper areas, *Spisula subtruncata* showed periodic massive spatfalls but these were washed out during the winter. *Spiophanes bombyx* disappeared from this area between 1983 and 1990. On the tidal flats there was a 85% decline in the density of *Corophium volutator* from 1983 to 1990.

### 5.3 Rijkswaterstaat Monitoring Programme

Dr K. Essink reported on the monitoring programme undertaken by the Dutch research organisations subcontracted by the Rijkswaterstaat. The areas covered are: i) North Sea, Dutch sector; ii) southwest Netherlands; east and west Scheldt; iii) Wadden Sea (see Annex 4).

Some of the macrofauna have increased from 1970 to 1990, e.g., *Nereis* spp. and *Heteromastus* spp.; this is possibly linked to increased eutrophication of the Wadden Sea from riverine input and discharge from Lake IJssel. However, similar results in the German Wadden Sea, where there is no riverine input, question this conclusion. The seasonal temperature fluxes in the Wadden Sea have an important effect on the winter survival of macroinfaunal populations. Primary production increased from 1960 to the mid-1980s, which was highly correlated with inputs of phosphates from Lake IJssel. Measures of increasing biomass divided by the increase in density of animals towards 1990 indicated that the mean weight of individual animals is decreasing with time. This suggests that benthic populations are currently composed of smaller individuals, on average, compared with the previous 20 years. *Marenzelleria viridis* was recorded for the first time in the Dollard Estuary in 1983 and continued to increase in density up to 1990. This increase has coincided with a decrease in the density of *Nereis* spp.; this may be as a result of interspecific competition. Enclosure experiments have revealed that *M. viridis* is at least partly responsible for the decline of juvenile *Nereis* spp. However, the species has become a component of the diet of some fishes.

J. Craeymeersch reported on the progress of monitoring meiobenthos on the Dutch coastal shelf. R. Huys is examining the abundance and biomass of nematodes and harpacticoid copepods. The stations examined so far fall into three of the North Sea community types and are perceived to be useful for long-term monitoring to detect natural or anthropogenic changes in the community.

Dr G. Duineveld reported on monitoring of the macrobenthos of the Dutch coastal shelf. Studies have so far been carried out in 1991 and 1992. The aim was to investigate whether there had been a shift in the community. Most of the stations were very closely associated in the multivariate analysis, which showed that there was little change between 1991 and 1992. Changes that were observed were explained by the periodic settlement of transient species such as *Abra alba*. Only in the coastal regions were there clusters of stations that showed synchronous changes in the abundance of certain infaunal species. H. Rees suggested that annual variations in the timing of recruitment might have a bearing on the results.

### 5.4 Monitoring in the Baltic Sea

Dr H. Rumohr gave an overview of present monitoring activities in the Baltic Sea. Stations are sampled from the Kattegat to the inner Baltic Sea. Each of the Baltic countries share the responsibility for the representative sampling stations in all parts of the Baltic Sea. The main river discharges into the Baltic are from Poland, Sweden and Russia. These organic inputs are built up in the deep basins of the Baltic and contribute to the decrease in dissolved oxygen and the formation of $H_2S$ in the deep waters. This is a key problem in the Baltic as the occurrence of water exchange is infrequent, although such an event occurred in January 1993, and changes in the fauna following this event will be monitored. There is no clear trend in these water exchange events. Assessment of environmental status is speculative because of limited temporal coverage. The status quo can only be judged when you know the history of these events. The long-term fluctuations mean that short-term studies, for trend assessments, are irrelevant. Broadening of the data basis with historical data, i.e., retrospective monitoring and the retrieval of additional environmentally important data from contaminated structures, will enhance scientific judgements on the status of the Baltic Sea. Access to previously unpublished quantitative historical data from as far back as the 1920s has revealed major changes in the benthic community.

### 5.5 U.K. National Monitoring Programme and Other Activities

H. Rees described MAFF activities to monitor former NSTF sites, which have now become national monitoring sites. In May and December 1992, two cruises were carried out. Samples were taken with grabs and a 2-m beam trawl. There was a higher number of epifaunal species in the English Channel than in the North Sea. Grab samples have not yet been worked up.

MAFF has been monitoring a dredgings disposal site off the mouth of the River Mersey. This has generated a time series of data for infaunal animals. Despite daily disposal of dredged material at this site, populations of some animals such as *Pectinaria* spp. were high nearby, and remained so over several years. Guidelines for sea disposal of wastes in UK waters have been laid down on the basis of simple concepts, such as the Pearson and Rosenberg (1978) model. A steering group is attempting to define guidelines for acceptable levels of alteration to the benthic community as a result of dumping activities. Action points have been defined/suggested, which compare the number of taxa, their abundance and biomass at a reference site with those found at the disposal site. If, for example, disposal:reference site ratios exceed a certain level, then some preventative action should be instigated.

## 6 EFFECTS OF PHYSICAL DISTURBANCE OF THE SEA FLOOR ON THE BENTHOS

### 6.1 Manganese Nodule Mining in the South Pacific Ocean

Dr G. Schriever reported on the disturbance created by manganese nodule mining in the south Pacific Ocean. The project is centred 400 miles south of the Galapagos Islands. The first cruise in 1989 was divided into seven phases. A suitable area was sought that had a density of manganese nodules suitable for commercial extraction. The experimental survey area had a diameter of 2 nmiles and was divided into 10 experimental areas. Multiple corer, box core and video surveys were conducted prior to the removal of manganese nodules in the area. After removal of the nodules, side-scan sonar revealed that about 25% of the area had been impacted. A large sediment plume was produced by the removal activity, which was transported away and blanketed the remaining 75% of the experimental area. Animals living in the area were collected using baited traps. After 28 months the tracks made by the nodule removing device were still visible. Studies have also concentrated on the effects of the sediment plume on the near-bottom and surface plankton. In addition, a close bottom side-scan sonar has been used to collect accurate information on the distribution of the impacted areas. Meiofauna densities decreased after nodule removal. Nematodes and harpacticoid copepods further decreased 6 months later, but after 3 years had exceeded initial densities. Foraminifera increased, and attained initial densities approximately 3 years later. Megafauna densities fell from 1500 animals/1000m$^2$ to <500 animals/1000m$^2$. The majority of these animals were holothurians. Mobile animals such as crustaceans had left the area after nodule removal, however after several years the density of animals in the impacted area far exceeded the initial densities. It appeared that the impacted area was now more attractive to some macrofauna, possibly because the depressions in the sediment collected phytoplankton bloom detritus and consequently increased bacteria growth.

### 6.2 The Effects of Aggregate Extraction on Benthic Communities

H. Rees reported on work by MAFF on the effects of aggregate extraction on benthic communities. Aggregate extraction is a contentious issue in view of its potential conflict with commercial fisheries and conservation interests. The project has two main aims: 1) to compare spatially distributed gravel areas around the UK coastline, 2) to study the recolonization of an experimentally dredged area in comparison to undredged areas. Future work will hopefully determine how long the sediment and benthos will take to "recover", and what possibilities exist for generalizing the effects to other areas. A copy of the report is given in Annex 5.

T. Rowell described a project, being initiated in 1993 by the Geological Survey of Canada, to assess the potential for the extraction of aggregates around the coast of Nova Scotia. The project will include a biological sampling program by the Department of Fisheries and Oceans to evaluate likely impacts to marine habitats and benthos.

### 6.3 The Effects of Dumping Dredge Spoil on Benthic Communities

Dr K. Essink reported on the effects that dredge spoil dumping have on benthic communities of the north coast of the Netherlands. Benthic surveys were undertaken before and after dumping the spoil. In the first instance, 544,000 tonnes and, in the second instance, ca. 900,000 tonnes of spoil were dumped. There was a significant reduction in the number of species from 10 to 5 after the dumping event. Species affected included: *Nephtys hombergi* which reduced from ca. 60 to ca. 15 animals/m$^2$. The greater the thickness of spoil deposited, the greater the percent reduction in number of individuals and species. The density of some benthic infauna attained normal levels after one year. At every dumping event there is a negative effect on the infauna, but the community "recovers" after approximately one year.

### 6.4 The Impact of Beam Trawling on Benthic Communities in the North Sea

J. Craeymeersch reported on a project which has examined historical benthic by-catch data collected by Dutch scientists since the 1970s. These data will be analysed for temporal trends and correlated with the possible influence of fishing activity.

An investigation of the direct effects of 4-m beam trawling on the Flemish Banks has been funded under the EC IMPACT I project (see Annex 6). Survival experiments have been undertaken which indicate that many of the invertebrates survive the trawling experience much better than flatfish. The mortality of animals collected in a covering net was also examined; the sole which escaped the commercial net had a higher survival rate than those retained in the commercial net. The density of infaunal animals was so variable that it has been difficult to make any statistical conclusions about the effects of fishing on the infauna.

S. Kühne reported on German input into the EC IMPACT I project. A wreck has been used to quantify the change in degree of fishing disturbance in terms of changes in benthic communities. The assumption is that the presence of the wreck will prevent fishing activity due to the risk of fouling gear. Changes in the sediment composition also occur as samples move further away from the wreck. It is still to be determined whether the changes in the benthic community are explained by the presence of the wreck or by fishing activity.

### 6.5 The Impact of 4-m Beam Trawling in the Irish Sea

Dr M. Kaiser reported on a MAFF study that is investigating the short- and long-term effects of 4-m beam trawling on a benthic community in the Irish Sea (see Annexes 7 and 8). After an experimental box had been fished 10 times with a 4-m commercial beam trawl, the density of sessile animals such as *Alcyonium digitatum* and hydroids decreased by ca. 50%. The density of more mobile animals, such as fishes, crabs and *Palaemon* spp., remained constant or increased. An assessment of the survival of animals caught in the codend indicated large variation between species. Echinoderms with flexible tests, e.g., *A. rubens*, showed low mortality, whereas those with brittle tests, e.g., *Psammechinus miliaris*, were readily damaged leading to high mortality. Mortality in fishes seemed to be related to the amount of epidermal armour, such as scales, spines, boney plates and slime. *Callionymus* spp. suffered 68 - 97% mortality, whereas between 34 - 38% of *Pleuronectes platessa* and *Raja naevus* died respectively. Those animals which are able to survive the trauma of being caught in the codend and handled on deck (e.g., *A. rubens*) may be able to capitalize on dead animals and discards and hence benefit from the effects of trawling in the long-term.

Dr M. Kaiser also reported that a joint proposal had been submitted to the EC to fund a two-year project to study the effects of "ghost fishing" set nets on a subtidal community in the Irish Sea. This would be a collaborative venture with English Nature (EN) and the Countryside Council for Wales (CCW). It is proposed that set nets be fished in the voluntary marine reserve at Skomer Island. The main perceived problem is the potential damage to fragile hard-substrate species that are chafed by the nets. There is little known about the longevity or "ghost fishing" capabilities of lost set nets.

### 6.6 The Effects of the Size and Frequency of Experimental Disturbance on Benthic Communities

D. Basford reported on a SOAFD project which is examining the effect of a disturbance gear (20-m long rake) on an inshore benthic community. The experimental area is off Stonehaven on the east coast of Scotland. A baseline survey examined benthic communities and sediment structure prior to the beginning of experimental disturbance. The experiment has been set up to examine the effects of different sizes of disturbed area and the frequency of disturbance. Problems with weather and the development of the disturbance gear have delayed the start of the experimental part of the programme.

### 6.7 Impacts of Fishing Gear in Canada

T. Rowell reported on progress made in various projects, both completed and currently undertaken (Annex 9). They have concentrated on mobile gears, in particular otter trawls, and the physical and biological impacts these have. Three potential study sites were evaluated in 1992, two within a large closed area on Western Bank and another on a closed area of the Grand Banks. The Western Bank area has been closed to otter trawling since 1988, which made it a potentially useful area for the study of trawling effects. Unfortunately, the area is not closed to scallop dredgers and the security of any experimental sites could not be assured. The Grand Banks site appears more secure in view of the complete ban, at least until 1994, due to the complete moratorium on fishing put in place in response to the northern cod problem. Additionally, the Grand Banks site has a much richer fauna, higher biomass, and more homogeneous conditions than the Western Bank sites. On average, 61 species were found in each grab sample. It is planned to conduct three cruises in 1993; one to establish corridor studies in the closed area, followed by two others to determine changes after 1 month and again after 3 to 4 months. In another aspect of the study, carried out in collaboration with geologists from the Geological Survey of Canada, an open trawl will be towed over a distance of 60 km in depths extending from 140 m to 70 m. This will provide information on the effects of otter trawling over different energy levels and substrate types.

Videos and descriptions of the three principal sampling gears to be used in the studies were also provided. These were a Bottom Referencing Underwater Instrumented Vehicle (BRUTIV), a video-equipped epibenthic sled, and a newly designed video equipped 0.5 $m^2$ grab which is hydraulically closed and can be reopened while still on the seabed should closure not have been satisfactory.

A video was also shown of a long-term bottom sampler (RALPH) that has been developed by the Geological Survey of Canada. This can be deployed from the surf zone to the continental shelf edge. A time-lapse stills camera records changes in the seabed. Other parameters measured include: wave height, sediment load, seabed profile, wave power, wave current. This would be a useful instrument for measuring long-term changes in seabed morphology which could be related to environmental conditions.

Dr P. Schwinghamer reported on the use of observer data collected from onboard commercial fishing vessels in the Grand Banks area. This data set covers the past 10 years, and will be fed into a GIS system to plot the bottom area swept by trawls in 7-km diameter sampling areas. This will give an overview of the micro-distribution of trawling disturbance. A study is currently being undertaken to relate morphological variation in bivalves to trawling intensity, which will also be tied in with the observer data.

In addition, the use of high-resolution acoustic techniques to identify benthic infauna and biogenic structures is described in Annex 10.

### 6.8 Impact of Shrimp Trawling in the Wadden Sea

Dr H. Rumohr reported on the impact of shrimp trawling on the benthic community in the German Wadden Sea, which is a part of the EC IMPACT I project. Observations were made by attaching a SIT camera to the beam shoes to observe the behaviour of shrimps in relation to the gear. Divers were used to survey the trawl tracks 10 minutes after fishing. A standard shrimp beam trawl, 10 m wide, was used in the study. The video record revealed that the rollers used on the gear do not roll over the ground, but tend to slide across the surface of the sediment. The disturbance generated by the rollers caused the shrimps to initiate an escape response, which led to them jumping into the net. After trawling, diving observations revealed a large immigration of *Carcinus maenas* into the trawl tracks.

## 7 EFFECTS OF GLOBAL WARMING

### 7.1 Norwegian Studies

An overview of global warming studies in the northern and Arctic regions was given by S. Dahle and Dr A. Nørrevang. Diving stations have been operated since 1976 from the University of Tromsø (Bjørn Gulliksen), which have been regularly surveyed for their communities and could provide useful long-term data. S. Dahle reported on work by Dr T. Brattegard and T. Holthe, who have been looking at coastal species collected from Norwegian museums and published literature. This collection is composed of 3988 coastal species (benthic macrofauna and flora), which were divided into 4 distinct groups based on the limits of their latitudinal distribution; one of the groups included only endemic Norwegian species. They studied 17 areas along the Norwegian coast, and arrived at a classification into 3 regions: one Arctic, one western area south of the latter, and one southern region. One of the main problems associated with these studies is the overwhelming requirement for taxonomic expertise, as nearly 3,000 species in the BIOFAR study alone have been encountered so far.

The plan of BIOICE, BIOFAR and possibly BIOGREEN is to monitor shelf areas between the land masses bordering the Norwegian Sea from the Atlantic. Changes in the water masses passing over caused by global warming might be reflected in the distribution of long-lived benthic species.

### 7.2 German Arctic Studies

Dr I. Kröncke described research undertaken by the AWI in the Arctic region. A transect was studied across the polar region. In general, the abundance of animals found was low, with a large variance of the mean. The majority of the biomass was composed of amphipods. There was a decrease of meiofaunal species towards the pole; this may be a response to the move away from areas of riverine input. Dr P. Schwinghamer expressed the view that the amphipods in the area may remain dormant until a food source arrives on the bottom, when they become activated to take advantage of this food source.

### 7.3 Land/Ocean Interactions in the Coastal Zone (LOICZ)

Dr H. Rumohr reported on a LOICZ workshop in 1992 where the aims of this project were better defined; details are given elsewhere in this report (see Section 2.8). Mesocosm, long-term monitoring and remote techniques to study the sea floor were recommended to examine the effects of global change. This will ultimately be the group that directs European scientific research programmes directed at marine research into global warming effects. The use of historical evidence to examine changes in marine ecosystems has been undertaken. Research in the Limfjord in Denmark has used sediment cores to examine historical events preserved in the sediment column. A sand layer that is a well-recorded historical event gives these cores an accurate time scale. Hot periods seven years long are well recorded in the historical literature, from sources as diverse as the Bible and monastic records. Although this is anecdotal evidence, it could be correlated with findings in cores. A comparison of species found in more southerly regions (with a mean sea temperature 2°C higher than that of the Baltic Sea) with Baltic species, could be used to model the effects of prolonged periods of higher than average temperatures.

### 7.4 Use of Long-lived Species in Assessing Environmental Change

Dr G. Duineveld gave a presentation, on behalf of Dr R. Witbaard, that centred on studies of *Arctica islandica*. He is currently growing these bivalves on trays in the North Sea, while monitoring plankton availability. The growth bands of the shell incorporate particles, such as sand grains, into the matrix of the shell. This results from damage to the edge of the shell, possibly resulted resulting from fishing activities. The occurrence of the enclosure of the particles in the shell acts as a historical record, that could be used to catalogue the intensity of fishing activity and other long-term changes. The frequency of these enclosures has increased from 1967 to 1991, with the highest frequency occurring around 1985-1987. This correlates with the increase in fishing activity and also with the development of gears, such as the use of heavier chains, larger beam trawls and boats with more powerful engines. Dr H. Rumohr pointed out that *Arctica* from the shallow areas of the Baltic Sea are impossible to age because the growth rings show no defined pattern, possibly because of frequent storms that resuspend phytoplankton causing spasmodic feeding, and the periodic anoxic conditions that occur in these shallow areas. There has also been a long-term change in the strength of the shell of these Baltic animals; they have become so fragile that they can be broken by hand, whereas 20 years ago they could only be broken with a hammer.

### 7.5 Use of Historical Data Sets in Long-term Benthic Studies

Dr H. Rumohr reviewed the use of historical data sets in long-term benthic studies (Annex 11).

## 8 ENDANGERED SPECIES

Dr E. Rachor reported that there had been little progress in compiling an endangered species list, but he was about to participate in a meeting in Germany to discuss endangered species lists for benthos. He will report on the outcome at the next Working Group meeting. General discussion amongst the group revealed some concern over the use of the word "endangered", and the ability to accurately identify such species, other than perhaps locally. There was also a risk that such a list might be wrongly taken to imply that changes in other species or even whole communities were of little importance. Dr A. Nørrevang proposed that species were certainly vulnerable on local scales (1 m to 1000 m) to complete extinction, particularly where high levels of anthropogenic activity impinge on the environment. Dr E. Rachor and H. Rees made the point that the marine environment is an open system that allows recruitment from distant populations. However, Dr P. Taylor informed the group that the trend in the USA is to consider the vulnerability of populations and standing stocks rather than individual species. Without good data on the population dynamics of the benthic species considered to be endangered, it will be difficult to truly assess their vulnerability to fishing and other activities.

## 9 EFFECTS OF AQUACULTURE ON BENTHOS

### 9.1 Impact of Manila Clam Cultivation

Dr M. Kaiser reported on a MAFF study to examine the potential impact of Manila clam (*Tapes philippinarum*) cultivation on the intertidal zone. The presence of the clams and/or the presence of the plastic netting used to protect them from predation could cause changes in the infaunal benthic community. Baseline studies of the benthic communities at two sites, one in the River Exe, Devon, England, and the other in the Menai Strait, North Wales, were carried out in 1991-1992. In April 1992 Manila clams were seeded on experimental plots at a density of 500/m$^2$. Six months after the clams had been laid the species composition and biomass (increased) under the experimental plots with netting and with netting and clams differed significantly from adjacent control plots. These changes are possibly caused by i) the increase in the organic content of the sediment due to the output of faeces and pseudofaeces of the clams; ii) the changes in topography associated with the presence of the netting; iii) the exclusion of predators such as fish, crabs and wading birds from the plots covered with netting. The study will continue to monitor changes before, and several years after, harvesting of the clams. Details of the study are given in Annex 12.

### 9.2 Studies under Fish Cages in Israel

Dr H. Rumohr described a study undertaken by P. Krost (Kiel), D. Angel and D. Zuber (Eilat) in Eilat, Israel that has examined the effects of caged fish farming on the environment. The fish farm was set up in late 1992. Transects from under the fish cages to the surrounding area were surveyed with a diver-operated REMOTS sediment profile camera and video camera. Only a few months after the farm was set up, the fall out from the fish cage (fish food and faeces) caused a build up of mats of *Beggiatoa* spp. At the site of a decommisioned farm, the surface sediment was highly bioturbated by burrowing shrimps (*Charybdis longicollis*).

## 10 OIL SPILL IMPACT STUDIES

### 10.1 Aegean Sea Oil Spill

Dr E. López-Jamar described the progress in the study of the effects of this oil spill. About 80,000 tonnes of crude oil were released near La Coruña, although a large proportion of this oil evaporated or was burnt by the resulting fire. The spill progressed in a northeasterly direction affecting mainly the Ria de Ferrol, Ria de Ares and Ria de la Coruña. The dispersion of the oil was rapid because of severe weather conditions. Benthic samples are being collected monthly in the Rias and the nearby coastal shelf. Preliminary results indicate that immediately after the accident the species richness decreased dramatically (30% lower than normal) at a station in La Coruña Bay. There is an indication that some increase in richness occurred three months after the spill, but again some species were found to be more sensitive than others. A more detailed account of this project is given in Annex 13.

### 10.2 *Braer* Oil Spill

Dr P. Kingston reported on the current state of affairs regarding the *Braer* oil spill. The ship went aground off the southern coast of Shetland and released 80,000 tonnes of Gullfaks light crude oil into the environment. The severe weather conditions at the time resulted in the total dispersion of the oil into the sea and atmosphere. The efficient dispersion of the oil into the sea resulted in exceptionally high concentrations of hydrocarbons in the water column. However, monitoring studies carried out by SOAFD Marine Laboratory show that this quickly dropped to background levels within a relatively short period. The acute toxic effects on the shore fauna appeared to be limited to the area in the immediate vicinity of the wreck. However, substantial numbers of sublittoral rocky shore species were seen on the strand line of shores over a wider area. Diver observations have not shown gross changes in the sublittoral rocky fauna, although widespread mortality of *Ensis* spp. was observed on sandy bottoms.

Hydrocarbon residue analyses of sediments carried out by SOAFD have indicated accumulations of hydrocarbons in areas of fine sediment deposition. One "hot spot" was identified approximately 5 km west of the south Shetland mainland and one southwest of the Fair Isle. Samples for study of the benthos have been taken from transects running across the affected areas and the results should be available for reporting at the next BEWG meeting.

## 11 GROWTH AND PRODUCTION OF *ABRA ALBA* AND *ABRA NITIDA*

Dr E. Lopez-Jamar reported on growth and production of *Abra alba* and *Abra nitida* off the coast of northern Spain. He discussed the recruitment, growth rate and population dynamics of these species. Results of this study are given in Annex 14.

## 12 BENTHIC DATABASES

Dr H. Rumohr stated that a database had been set up for the Institut für Meereskunde and had been programmed in-house. It is a relational database and would require transfer to a commercial package for wider use. It contains data from the 1950s to the present. It also contains data from Poland from the late 1940s, however this data is the property of BMB.

Dr A. Künitzer reported that the Bundesamt für Seeschiffahrt und Hydrographie (BSH) marine environmental databank (MUDAB) contains information from the Baltic and North Sea. Dr A. Künitzer is responsible for the databank which is installed on a mainframe computer but contains no biological data. However, such data are readily available on diskette. BSH has a second databank, the German Oceanographic Data Centre (DOD). There is also a databank for the Wadden Sea (WATIS) which contains biological information from research projects.

Dr H. Rumohr stated that HELCOM held a database at the Finnish Environmental Data Centre which stores all BMP monitoring data and uses the RUBIN code for species identification.

H. Rees said that the UK Joint Nature Conservancy Committee (JNCC) had established a large database using information from their current Marine Nature Conservation Review (MNCR) which surveyed intertidal and subtidal marine fauna and flora around the UK. UK government pollution agencies have decided to use the NODC system for coding species.

J. Craeymeersch reported that the North Sea database is being used as a model for the proposed Rijkwaterstaat database which is to include chemical as well as biological parameters.

Dr P. Schwinghamer stated that Canada has plans to put data into a GIS that includes a fully relational database. T. Rowell also reported that there were plans for a GIS for the Scotia Fundy region which will include benthic and fishery data.

Dr N. Silverberg said that the Canada Green Plan intended setting up a database for coastal biological information which would involve environmental agency and academic study data.

Dr P. Kingston put forward the view that a central database, with open access to relevant individuals, and logged benthic data in the ICES area, would be highly desirable and informative. However, this would require permanent staff to run such an undertaking. Dr A. Kunitzer expressed the view that the BEWG should recommend that ICES set up a benthic database, using the database currently operating in Yerseke. H. Rees pointed out that ICES already has databases for chemical and physical data. However, these databases exist because of the mandatory requirement for monitoring. Dr H. Rumohr expressed concern that unpublished data included in a database would be vulnerable to preemption by workers outside the control of those generating the data.

The general consensus of the BEWG was that it should recommend that ICES should develop a database for benthic data using the Yerseke database as a start, and if necessary restricting initial input to data currently in the public domain.

## 13 THE NORTH SEA BENTHOS SURVEY

Prof. C. Heip suggested by letter that the NSBS survey should be repeated in 1996. U. Daam concurred that to examine the effects of global warming a resolution of 10 years would be correct. J. Craeymeersch emphasised that this would be invaluable to reinforce statutory monitoring studies. If the BEWG is to recommend a repeat of the 1986 survey, a decision by politicians would be needed rapidly to allow organisation of sea time and personnel in time for the survey. H. Rees expressed the opinion that the NSTF sampling stations may well suffice for long-term data, especially as these samples have been taken on a regular basis. Dr M. Kaiser cautioned that any differences detected in 1996 may only be due to natural fluctuations rather than other effects, however Dr P. Kingston and Dr H. Rumohr were convinced that the scale of the study and additional interim data would overcome this problem. Dr H. Rumohr recommended that the study be repeated, but that the magnitude of the survey and the possible use of current sampling programmes be reviewed, and that political support is essential.

## 14 TAXONOMY AND SYSTEMATICS

Dr A. Nørrevang commented that there is a crucial need for a firm basis of taxonomy before credible studies of ecology can be undertaken. There is a lack of knowledge about the natural history of many species. There is a Norwegian scheme in which the relevant references and other essential biological data for each species is collated. However, this database is quite unique and similar systems are required for other areas. Dr H. Rumohr had the view that taxonomy does not attract enough funding, because it is a subject vulnerable to swings of fashion. The group was in general agreement that an official compilation of benthic taxonomic identification sheets should be undertaken. Although this is a mammoth undertaking, it will be indispensable for future benthic biologists. Such identification sheets for fish and plankton have already been published by ICES.

## 15 SAMPLING TECHNIQUES

During the meeting, the group was shown the sampling devices now adopted by the Institut fur Meereskunde, which include the use of REMOTS and grabs and dredges fitted with cameras for quality control. This led to the suggestion that the group should consider gear developments at the next meeting. Photographic techniques used to sample hard bottom communities should be explored by inviting relevant scientists to the next meeting.

## 16 RECOMMENDATIONS

The Benthos Ecology Working Group will meet in Yerseke, Netherlands, 2-6 May, 1994 to:

a) review cooperative benthic studies throughout the ICES area;

b) review and report on how benthic communities are affected by disturbance of the sea floor;

c) further review existing benthos databases and their compatibility and availability to benthic scientists, and investigate the establishment of an ICES North Sea benthos database;

d) produce an initial list of marine benthic indicator species within the ICES area potentially vulnerable to physical disturbance of the sea bed;

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

f) 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;

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

## 17 ACTION LIST

1. Dr G. Duineveld will report on monitoring results from NIOZ studies in the Netherlands.

2. Dr G. Duineveld will report on recent developments in NIOZ benthic samplers.

3. Dr G. Duineveld to report on work on sediment phytopigments and bioturbation.

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

5. Dr E. Rachor and Dr I. Kröncke to report on progress on German Arctic studies.

6. Dr I. Kröncke to report on benthic studies in the Wadden Sea area.

7. Dr E. Rachor will report on progress in establishing a list of threatened benthic species.

8. S. Dahle will report on Norwegian/Russian cooperative studies in the Barents Sea.

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

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

11. Dr M. Powilleit will report on the first results of the Pomeranian benthos project.

12. Dr P. Schwinghamer to report on progress on Canadian studies of trawling impacts on benthos.

13. Dr P. Schwinghamer to report on progress on experiments with acoustic imaging systems.

14. Dr L. Loo to produce a list of experts in the taxonomy of benthic organisms.

15. Drs P. Kingston, H. Rumohr and T. Rowell to review current benthic sampler technology.

16. Dr E. López-Jamar to report on studies of the impact of the *Aegean Sea* oil spill on the benthos.

17. Dr P. Kingston to report on studies of the offshore benthos impacted by the *Braer* oil spill.

18. D. Basford will report of the effects of the *Braer* oil spill on inshore benthos.

19. Dr A. Nørrevang to report on further progress on the BIOICE project.

20. H. Rees to report on surveys of epibenthos in U.K.waters.

21. H. Rees to report on benthic responses to chemical contamination.

22. Dr N. Silverberg will report on sediment/water interactive studies in the Gulf of St Lawrence region.

23. Dr A. Künitzer to report on the new Joint Monitoring Programme.

24. Dr A. Künitzer to report on the final results of the Wadden Sea macroalgae research project.

25. Dr A. Künitzer to report on the current status of the Arctic Monitoring and assessment Programme.

26. J. Craeymeersch to report on the analysis of beam trawl by-catches for monitoring long-term environmental change.

27. J. Craeymeersch to report on progress in the Dutch national monitoring programme.

28. J. Craeymeersch to report on progress on the ICES benthic mapping scheme.

29. D. Basford to report on Aberdeen benthic disturbance experiments.

30. Dr M. Kaiser to report further on the results of 4-m beam trawling on a benthic community in the Irish Sea.

31. Dr M. Kaiser to report on the recent spat falls of *Crassostrea gigas* in the UK.

32. Dr M. Kaiser to report on the impact of a *Phaeocystis* spp. on an intertidal benthic community.

33. Dr M. Kaiser to report on a possible EC funded study which will examine the effects of "ghost fishing" set nets on a subtidal community.

34. J. Craeymeersch to review computer aided expert systems for use in identification.

35. T. Brattegard to report on the Norwegian phytoplankton computer aided expert system.

36. T. Rowell to report on benthos studies on aggregate extraction impacts in Nova Scotian waters.

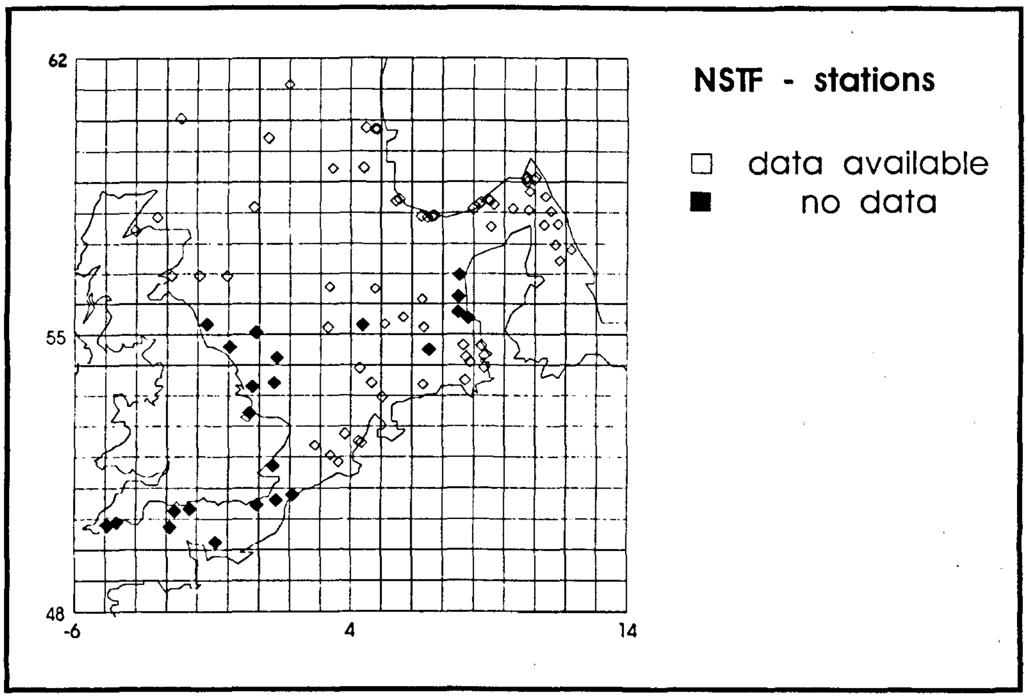
37. H. Rees to report on sampling techniques for coarse substrata.

38. Dr J. Warzocha to report on Polish contributions to benthic studies in the Pomeranian Bay.

39. Dr J. Warzocha to report on long-term changes in macrofauna in the Gulf of Gdansk.

40. Dr L-O. Loo to report on progress on the Skagerrak project.

Figure 1



# ANNEX 1

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3-8, May,1993


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Dienst Getijdewateren

Aan
ICES Benthic Ecology Working Group
Kiel, FRG, 3-7 May 1991.

Van
Dr. K. Essink

Datum
1 mei 1993

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## 1. INTRODUCTION

At the meeting of the ICES Benthic Ecology Working Group at Bergen (N), 4-8 May 1992, the following actions were listed:

11. Dr. Smaal/Essink to report on long-term benthic data for the Wadden Sea

12. Dr. Smaal/Essink te review work carried out in western Europe under COST 647.

## 2. LONG-TERM BENTHIC DATA FOR THE WADDEN SEA

Data on abundance and biomass of intertidal macrozoobenthos are being collected since 1969 in the Balgzand area by Dr. J.J. Beukema (NIOZ, Texel) and in the eastern Dutch Wadden Sea ('Groninger Wad') by Dr. K. Essink. Shorter data series exist for other areas (Table 1).Sampling is usually carried out in early-spring and late-summer.

Similar data series are available for parts of the German (Norderney; Dr. H. Michaelis) and the Danish Wadden Sea (P.B. Madsen; T. Knudsen).

Analysis of long-term data sets has been carried out in the framework of the C.E.C. Action COST 647 on Coastal Benthic Ecology. This has resulted in several publications (see below), showing both synchronous fluctuations patterns (e.g. in species sensitive to low temperatures) and differential population development in different western European areas.

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Table 1. Data series on macrozoobenthos in the Dutch Wadden Sea and Ems estuary.

| AREA | | PERIOD |
|---|---|---|
| intertidal: | Balgzand | 1969 - present |
| | Groninger Wad | 1969 - present |
| | Ballastplaat | 1977 - 1987 |
| | Piet Scheveplaat | 1977 - present |
| | Heringsplaat (Ems est.) | 1977 - present |
| subtidal: | western Wadden Sea | 1989 - present |
| | Bocht van Watum (Ems est.) | 1977 - present |

## 3. WORK UNDER COST 647

In the C.E.C. Concerted Action on Coastal Benthic Ecology (COST 647) co-ordination and stimulation of long-term benthic reseach was achieved since ca. 1981 in four (western European) coastal habitats (Table 2).
In the last phase of COST 647, which came to an end in 1992, special attention was paid to numerical data analysis. These analyses were supervised and carried out by Dr. F. Ibanez of the Zoological Station at Villefranche (F).

For various C.E.C. reasons the COST 647 programme could not be continued. At present a follow-up programme 'Change in Coastal Ecosystems' (CICE) is being launched under the C.E.C. Environment Programme.

Table 2. Review of COST 647 organisation and habitat groups

| | | | |
|---|---|---|---|
| C.E.C. official: | Dr. A. Sors/Dr. C. Nolan | | |
| Chairman COST 647: | Dr. B.F. Keegan | | |
| Habitat groups: | Rocky shore/subtidal | coordin.: | Dr. T. Lundalv |
| | Rocky shore/intertidal | coordin.: | Dr. J.E. Lewis |
| | Subtidal Sediments | coordin.: | Dr. L. Gabioch |
| | Intertidal Sediments | coordin.: | Dr. J.J. Beukema/ Dr. K. Essink |

## 4. RECENT PUBLICATIONS (a selection)

BEUKEMA, J.J., 1991. Changes in composition of bottom fauna of a tidal-flat area during a period of eutrophication. Mar. Biol. 111: 292-301.

BEUKEMA, J.J., 1991a. The abundance of shore crabs Carcinus maenas (L.) on a tidal flat in the Wadden Sea after cold and mild winters. J. Exp. Mar. Biol. Ecol. 153: 97-113.

BEUKEMA, J.J., 1992. Expected changes in the Wadden Sea benthos in a warmer world: lessons from periods with mild winters. Neth. J. Sea Res. 30: 73-79.

BEUKEMA, J.J., K. ESSINK, H. MICHAELIS & L. ZWARTS (in prep.) Year-to-year variability in food supply for wader birds on tidal flats of the Wadden Sea.

DESPREZ, M., G. BACHELET, J.J. BEUKEMA, J.P. DUCROTOY, K. ESSINK, J. MARCHAND, B. ROBINEAU & J.G. WILSON, 1991. Dynamique des populations de Macoma balthica (L) dans les estuaires de Nord-Ouest de l'Europe: Première synthèse. In: Elliott, M. & J.P. Ducrotoy (eds), Estuaries and Coasts: Spatial and Temporal Intercomparisons. Proceed. ECSA 19 Symposium, pp. 159-166. Olsen & Olsen, Fredensborg, Denmark.

DUCROTOY, J.P., H. RYBARCZYK, J. SOUPRAYEN, G. BACHELET, J.J. BEUKEMA, M. DESPREZ, J. DORJES, K. ESSINK, J. GUILLOU, H. MICHAELIS, B. SYLVAND, B. ELKAIM, J.G. WILSON & F. IBANEZ, 1991. A comparison of the population dynamics of the cockle (Cerastoderma edule) in North-Western Europe. In: Elliott, M. & J.P. Ducrotoy (eds), Estuaries and Coasts: Spatial and Temporal Intercomparisons. Proceed. ECSA 19 Symposium, pp. 173-184. Olsen & Olsen, Fredensborg, Denmark.

ESSINK, K., J.J. BEUKEMA, J. COOSEN, J.A. CRAEYMEERSCH, J.P. DUCROTOY, H. MICHAELIS & B. ROBINEAU, 1991. Population dynamics of the bivalve mollusc Scrobicularia plana: comparisons in time and space. In: Elliott, M. & J.P. Ducrotoy (eds), Estuaries and Coasts: Spatial and Temporal Intercomparisons. Proceed. ECSA 19 Symposium, pp. 167-172. Olsen & Olsen, Fredensborg, Denmark.

ESSINK, K. & H.L. KLEEF, 1993. Distribution and lifecycle of the North American polychaete Marenzelleria viridis (Verrill, 1873) in the Ems Estuary. In: Proceed. ECSA-21 Symp., 9-13 Sept. 1991, Gent, Belgium, Netherl. J. Aquat Ecol. 27 (in press)

JONGE, V.N. DE & K. ESSINK, 1991. Long-term changes in nutrient loads and primary and secondary producers in the Dutch Wadden Sea. In: Elliott, M. & J.P. Ducrotoy (eds), Estuaries and Coasts: Spatial and Temporal Intercomparisons. Proc. ECSA 19 Symposium, pp. 307-316. Olsen & Olsen, Fredensborg, Denmark.

KEEGAN, B.F. (Ed.), 1991. Space and Time Series Data Analysis in Coastal Benthic Ecology. An analytical exercise organised within the framework of the COST 647 project on Coastal Benthic Ecology. Commission of the European Communities, Brussels.

KEEGAN, B.F. (Ed.), 1992. Commission of the European Communities, Directorate-General XII for Science Research and Development, Environment Research Programme. COST 647 Coastal Benthic Ecology, Activity Report 1988-1991.

# ANNEX 3

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# ANNEX 4

## OVERVIEW OF ZOOBENTHIC WORK CARRIED OUT BY RIJKSWATERSTAAT, TIDAL WATERS DIVISION, THE NETHERLANDS

by

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Report to the

BENTHOS ECOLOGY WORKING GROUP

of the

INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA

Kiel, Germany, 3-7 May 1993.

OVERVIEW OF ZOOBENTHIC WORK CARRIED OUT BY RIJKSWATERSTAAT, TIDAL WATERS DIVISION, THE NETHERLANDS

by

KAREL ESSINK

## 1. INTRODUCTION

In 1992/93 the Tidal Waters Division has been involved in a variety of studies focussing at the benthos of the North Sea, the coastal zone, Wadden Sea and estuaries. A short overview of a selection of these studies will be given.

## 2. BIOLOGICAL MONITORING

### 2.1. RIJKSWATERSTAAT PROGRAMME

Monitoring of macrozoobenthos and meiobenthos was continued. The larger part of this work was carried out under contract by the Netherlands Institute for Sea Research, Texel (macrozoobenthos in North Sea, Wadden Sea and Ems estuary), and by NIOO-CEMO, Yerseke (meiobenthos North Sea; macrozoobenthos SW-Netherlands).
Data were made available in reports by Duineveld (1992) and Dekker (1993).

At November 18, 1992, a symposium on biological monitoring in the aquatic environment was held in Amsterdam (Colijn & Marteijn, 1992). The purpose of this symposium was to present and discuss the Rijkswaterstaat biological monitoring programme (in fresh as well as marine waters) in an audience of scientists and administrators.
Contributions at this symposium relevant to ICES BEWG were:

* Sample variance and sampling strategy
  (by J. van der Meer)
* Long-term changes in the macrobenthos of the Wadden Sea
  (by K. Essink & J.J. Beukema

### 2.2. INTEGRATED WADDEN SEA PROGRAMME

In accordance with par. 33 of the Ministerial Declaration of the Sixth Trilateral Governmental Conference on the Protection of the Wadden Sea, Esbjerg, 13 November 1991 (Anonymous, 1992), a Trilateral Monitoring Expert Group (TMEG) was installed to report on:

1. The concept for a procedure for an ecological survey, evaluation, assessment and presentation of data which will enable a continuous evaluation of the ecological state of the Wadden Sea as a whole;
2. A plan for implementation and execution of a first phase of the Joint Monitoring Programme, which should include at least the basic parameters of an ecological survey.

Scientists of the Tidal Waters Division took part in the work of the TMEG. In November 1992, a report was published on the Integrated Monitoring Programme of the Wadden Sea Ecosystem (TMEG, 1992).

## 3. INTRODUCED SPECIES

### 3.1. *ENSIS DIRECTUS*

The first record of juveniles of the North American jack-knife clam *Ensis directus* in North Sea waters off the French coast in 1991 were confirmed, and consequently published (Luczak et al., 1993).

### 3.2. *MARENZELLERIA VIRIDIS*

The North American spionid polychaete *Marenzelleria viridis* has established a stable population in the Dollard, i.e. a brackish embayment in the Ems estuary. High muddy intertidal flats serve as nursery (up to 1 million juveniles per $m^2$) from where animals disperse over larger parts of the estuary (Essink et al., 1993.

Comparative research is currently in progress at the University of Rostock/Institute of Baltic Research/Warnemünde in eastern Germany focussing on reproduction biology, physiology and genetics of populations from North Sea estuaries (Ems and Weser) and Baltic coastal waters (Saaler Bodden, Greifswalder Bodden). Preliminary observations showed differences in timing of reproduction and genetic structure between Dollard and Saaler populations. Further observations and test are in progress to confirm this.

## 4. MAST/JEEP 92

The Tidal Waters Division took part in the MAST/JEEP 92 project 'Major Biological Processes in European Tidal Estuaries'. The project was co-ordinated by NIOO-CEMO, Yerseke (NL), and focussed on 'Ecological structure' and 'Major Biological Processes'. Comparative observations were made in the estuaries of the Elbe, Ems, Scheldt, Somme, Gironde, Tagus and Shannon.
In 1992, sampling programme on microphytobenthos, meiobenthos, macrozoobenthos, hyperbenthos and zooplankton was carried out in the Ems estuary as well as in the Scheldt estuary.
Preliminary results have been published in a Report of a Workshop (Herman, 1992). Further results will be published in the Report of a Workshop held in Febr. 1993 in Faro. Final results will be published in a volume of the journal Hydrobiologia

## 5. RESTORATION OF ECOSYSTEMS

Due to a long-term sanitation scheme the load of degradable organic pollutants discharged on the Dollard (Ems estuary) has decreased considerably in 1983/84. In comparative studies the effects of this improvement of environmental conditions on populations of microphytobenthos, meio- and macrozoobenthos was documented (Esselink et al., 1989; Essink & Romeyn, 1993; Peletier, 1992.)

In 1992, a further reduction of the organic waste load to the Dollard was realized. In 1993 further observations are carried carried out to document the response of the Dollard benthic system.

## 6. FEEDING ECOLOGY OF BIVALVES

In the Eastern Scheldt, SW Netherlands, studies on the effect of food quality on carbon and nitrogen budgets and on growth and condition of bivalves (*Ceras-*

*toderma edule, Mytilus edulis*) (cf. Prins & Smaal, 1989; Smaal & Van Stralen, 1990) are being continued. Measurements are carried out under natural conditions at intertidal populations, with help of plexiglass tunnels in the field (cf. Dame et al., 1991), as well as in mesocosms.

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# PRELIMINARY RESULTS ON THE EFFECTS OF MARINE GRAVEL EXTRACTION ON BENTHOS: POST-DREDGING RECOLONISATION

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## INTRODUCTION

### *Background*

During the 1980's the demand for aggregates in the UK steadily increased, primarily as a result of the boom in the construction industries which required the basic raw materials for "ballast" and concrete. In addition, there was a need for high quality aggregates which could be supplied from the marine environment. The recent advances in marine mining technologies, the short supply of land-based sources and favourable market economics have paved the way for increased production of aggregates from marine resources. However, during the 1970's, concern was growing over the environmental impact of marine aggregate extraction, and in particular the potential threat to benthic communities and their dependent fisheries (Lart, 1991). Initial research was undertaken by the Ministry of Agriculture, Fisheries and Food (MAFF) but the impacts on the benthos and the rates of recolonisation were not fully quantified. Accordingly, in October 1990 a three-year research programme was initiated by the Crown Estate Commission (CEC) and MAFF to determine: i. the initial impacts of dredging on the benthos and sediments; ii. the processes of recolonisation post dredging; iii. the natural faunistic differences between gravels on a wide-scale; and iv. coarse sediment quantitative sampling methods.

### *Previous Studies*

There are few original scientific investigations which describe the effects of marine aggregate extraction on benthos. Some of the early observations in the UK were made during the 1970's by Shelton and Rolfe (1972) and Dickson and Lee (1973) who examined the impacts of suction-anchor dredging on a shingle bank in the English Channel. Millner and Dickson (1977) examined the impacts of suction-trailer dredging off Southwold in the Southern North Sea. More recently, investigations have been undertaken off the Isle of Wight (Lees *et al,* 1990) and off Dieppe (Desprez *et al,* 1992) in the English Channel. In addition, a comprehensive study of the effects of suction-trailer dredging on the benthic communities and seabed topography has been made at an experimental site on the Klaverbank in the Dutch sector of the central Southern North Sea (Sips and Waardenburg, 1989; Von Moorsel and Waardenburg, 1990, 1991).

## METHODS

*Selection of an Experimental Dredging Site*

A wide-scale survey of gravel communities off the English Eastern and Southern coasts (Kenny *et al,* 1991) indicated potential sites for an offshore field experiment. These were located off North Norfolk, England (Figure 1). The gravel deposits off North Norfolk were found to support a relatively rich and stable epifaunal community, with the presence of long-lived sessile organisms such as the bryozoan *Flustra foliacea* ('horn wrack') and the hydroid *Nemertesia antennina*. This site was therefore considered to be well suited for experimental dredging. However, in order to determine the exact location of the 'treatment' and 'reference' sites, further sampling using a 3m vibrocore was undertaken to assess the thickness of the gravel deposits and to ensure that dredging would not expose an underlying stratum which was different in nature from the superficial substrate. The treatment site for the offshore dredging experiment was finally selected 17 miles North of Cromer, North Norfolk in September 1991 (Figure 1).

*Experimental Dredging*

During 5 days in April 1992, the MV "Sand Harrier", an "H" class commercial suction-trailer dredger, removed a total of 52,000 tonnes of mixed aggregate representing 11 hopper loads from an area measuring 500 by 270 metres.

The position and speed of the "Sand Harrier" was monitored using a Sea Information Systems "Microplot v3.1" installed on Compaq PC linked to a "RoxAnn" seabed sediment discriminator. Together they displayed a constant real-time image of the dredging operations. High navigational accuracy was achieved using a Sercel "NR53" differential Global Positioning System (GPS) which had been previously calibrated against a "range-range" differential GPS operated by BritSurvey. This gave an almost constant accuracy of $\pm$10m. Figure 2 shows the track output generated by "Microplot" for the entire operation, which represents a total of 200 tracks covering approximately 70% of the experimental area.

*Pre- and Post- Dredging Surveys*

An array of benthic sampling equipment was used to survey the treatment and reference sites pre- and post-dredging. Remote sampling of benthos was achieved using a Hamon grab (Figure 3). The Hamon grab was found to be ideally suited for quantitative sampling of coarse (or compacted) sediments. It operates by taking a scoop out of the sediment, and the sample bucket is then forced against a metal plate which prevents the sample from being washed away during retrieval.

In order to obtain an instant view of the seabed and provide detailed information on the occurrence, distribution and behaviour of benthic organisms, an underwater camera sledge was used. The sledge was towed for ~1 hour along a transect through the treatment and reference sites. In addition, an acoustic map of the dredged site was generated using a EG+G dual frequency (100kHz, 500kHz) side-scan sonar.

*Field Procedures*

Hamon grab stations were randomly located within the defined boundaries of the treatment and reference sites. Samples were washed over 5mm and 1mm square mesh sieves so as to remove excess sediment and obtain all the colonial and solitary benthos. The benthos was fixed in a 4-6% buffered formaldehyde solution (diluted with sea water) with "Rose Bengal" (a vital stain) and stored for laboratory identification and enumeration. In addition a 1 litre sub-sample was taken for particle size analysis.

The underwater camera sledge was fitted with a television camera linked via an umbilical to a TV monitor and U-matic video recorder present on the RV. A single lens Reflex (SLR) camera loaded with a 200 exposure colour 35mm film pre-set to take one exposure every 20 seconds was also attached.

*Laboratory Procedures*

Hamon grab samples were first washed with fresh water over a 1mm mesh sieve in a fume cupboard to remove excess formaldehyde solution. Samples were then sorted on plastic trays and specimens were placed into jars or petri dishes containing a preservative mixture of 70% methanol (GPR) , 10% glycerol and 20% tap-water. For each species a representative specimen was recorded, preserved and stored separately in a glass vial to establish a reference collection and provide a means for the verification of species identifications. Whenever possible specimens were identified to species level using the standard taxonomic keys.

Partial wet-weights for each species were determined by placing specimens on a plastic tray covered with white blotting paper for 12 hours before measuring their weights on a Sartorius 2004 MP five figure balance. Biomass estimates were then calculated from partial-wet weights using conversion factors given in Eleftheriou and Basford (1989).

Sediment sub-samples were analysed for their particle size distributions according to the Udden-Wentworth Phi Classification where Phi(0) = $-\log_2 d$ and d is the particle diameter in millimetres. Each sample was first wet sieved on a 63 micron mesh sieve to provide an estimate of the fines fraction (<63 microns). The remaining sample was then oven dried for approximately 12 hours at $100^{o}$ C and allowed to cool to room temperature before being sieved through a stack of geological test-sieves ranging from -6 phi (64mm) to +4 phi (0.0063mm). A weight for each size fraction was measured using a Sartorius top-pan balance to an accuracy of $\pm$0.01g.

## RESULTS

*Physical Observations*

Particle size data for 6 samples taken from the treatment site (Cruise COR 4/92) in March 1992, 4 weeks before dredging, were compared to 6 samples taken 2 weeks after dredging (Cruise COR 6/92) in May 1992. Results showed that the gravel content (>2mm) of the sediment increased from 36% to 56% (Figure 4).

Upon examination of the seabed using side-scan sonar and UW TV it was apparent that the dredge tracks have become infilled with sand, suggesting a redistribution of sediment has occurred. The action of the draghead on the seabed has agitated and vibrated the sediment to such an extent that gravel (>2mm) has consolidated to form ridges between furrows of sand. Inspection, by SCUBA divers, of the sand accumulations within the tracks showed that the deposits are superficial sand-ripple features, 1-2cm deep. In addition, the apparent increase in the gravel content at the treatment site may be caused by the preferential removal of sand by the suction action of the draghead.

*Biological Observations*

The total number of species recorded from 5 Hamon grab samples taken at the treatment and reference sites pre- and post-dredging are shown by major phyla in Figure 5. The total numbers of species 4 weeks before dredging (Cruise COR 4/92) at the treatment and reference sites were broadly similar at 70 and 62 species, respectively. However, 2 weeks after dredging (Cruise COR 6/92) the number of species at the treatment site had fallen to 30 (the polychaetes showed the most noticeable reduction from 35 to 16 species). At the reference site, the number of species has remained generally constant, having only increased slightly from May (64 species) to December (68 species). However, at the treatment site the number of species has increased from May (30 species) to December (53 species), which suggests that some readjustment or recolonisation has occurred.

The impact of dredging is more apparent when the abundance data are compared from each site, pre- and post-dredging. (Figure 6). The total abundance of animals recorded at the treatment and reference sites 4 weeks before dredging (Cruise COR 4/92) are broadly similar at $230/0.2m^2$. However, a dramatic reduction in the abundance has occurred at the treatment site post-dredging ($30/0.2m^2$), compared to the reference site ($209/0.2m^2$). The crustaceans and "others" phyla were numerically dominated by the barnacle *Balanus crenatus* and the sea-squirt *Dendrodoa grossularia.* Both showed an increase in abundance from May to December as a result of Summer recruitment. However, the increase at the reference site was greater than that at the treatment site (possible explanations are given below).

Biomass data for each site pre- and post-dredging (Figure 7) support the observations made on the abundance data (Figure 6). A large reduction in the biomass has occurred at the treatment site post-dredging: from $182g(AFDW)/m^2$ in March (Cruise COR 4/92) to $0.4g(AFDW)/m^2$ in May (Cruise COR 6/92). However, at the reference site the biomass figures remain high at

$80g(AFDW)/m^2$. At the treatment site in December, *B. crenatus* and *D. grossularia* contribute very little to the biomass, although they are present in relatively large numbers (Figure 6), suggesting they are new recruits. However, at the reference site the biomass figures for December are relatively large, reflecting the mixed populations of adults and juveniles of *B. crenatus* and *D. grossularia* present.

## DISCUSSION

Dredging at the experimental site in April 1992 preceded the natural Summer recruitment of benthos. The 'opportunists' *D. grossularia* and *B. crenatus*, which were numerically dominant before dredging, showed the greatest increase in abundance post-dredging. However, the increase was greatest at the reference site. This may be explained by a combination of the following: i. The treatment site is physically stressed compared to the reference site, due to deposits of mobile sand being present within the dredge tracks, thereby reducing the recruitment success of sessile epibenthos such as *Sabellaria spinulosa*, *D. grossularia* and *B. crenatus*; ii. there may be spatial differences in recruitment success between the reference and treatment sites such that a larger settlement has occurred at the reference site; iii. the loss of adult sessile epibenthic populations at the treatment site has reduced the recruitment potential of juveniles, since the "cues" to settle are no longer present. For example, *B. crenatus* may require the presence of adult populations in order to stimulate settlement, as has been observed for *B. balanoides* (Stubbings, 1975). In addition, as many adults have been removed by dredging the source of juveniles which recruit locally (within 100m) is reduced; for example, *D. grossularia* larvae are not transported in the plankton but settle within a few metres of their parents (Svane and Young, 1989).

The effects of seasonality should be borne in mind. The data cover a period of seven months post-dredging and mortalities will have occurred during the winter of 1992, thereby reducing the observed gains in abundance at the treatment site.

It remains to be seen whether the populations at the treatment site adjust to the newly-created physical regime by shifting from a relatively stable community to one characteristic of a more mobile sediment.

The results from future surveys, planned for 1993 and 1994, will help to further clarify the processes of recolonisation, and the resultant community structure, post-dredging.

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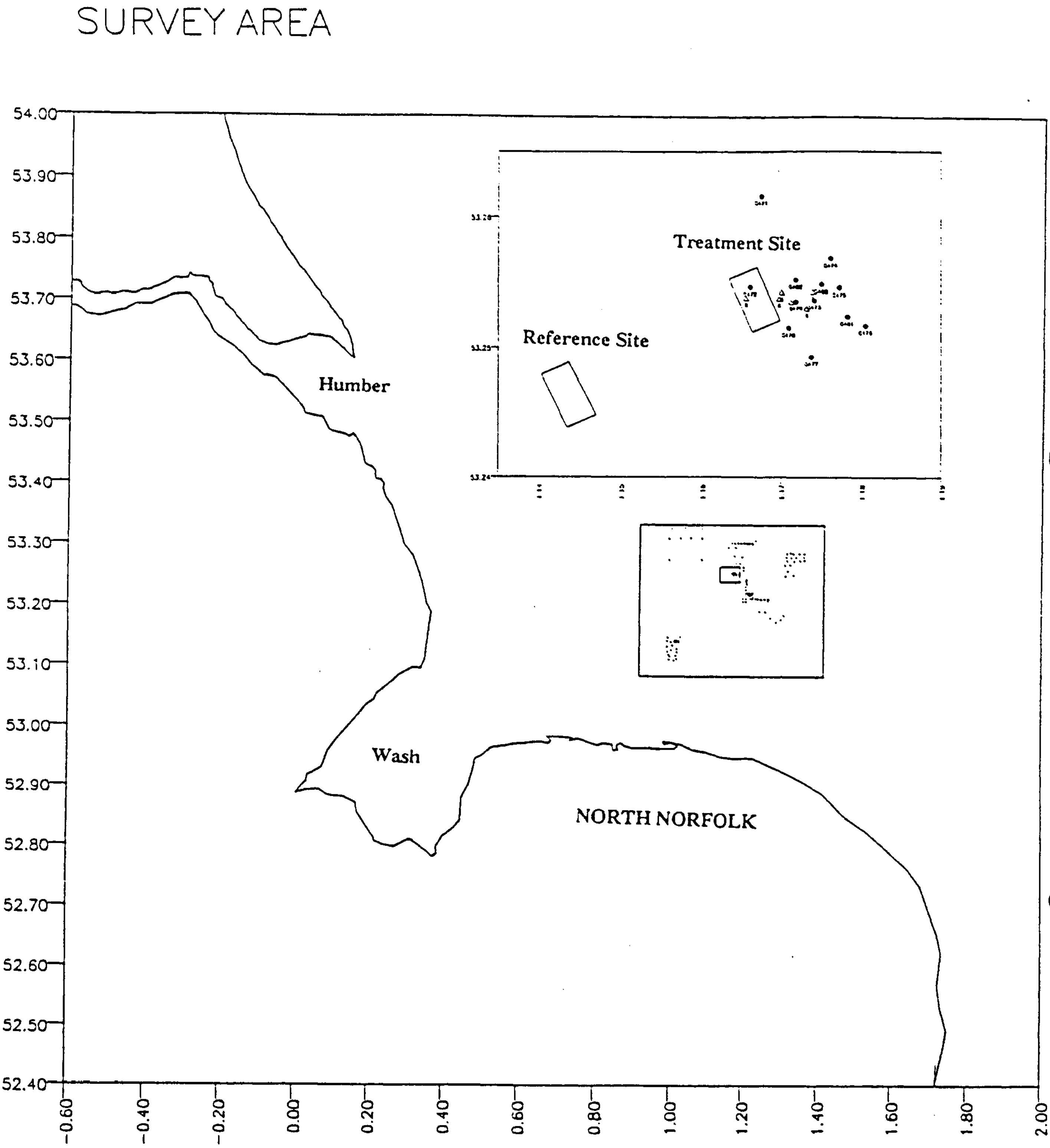



**Figure 1:** Benthic survey off North Norfolk (small box) in order to locate the experimental dredging and reference sites (large box).

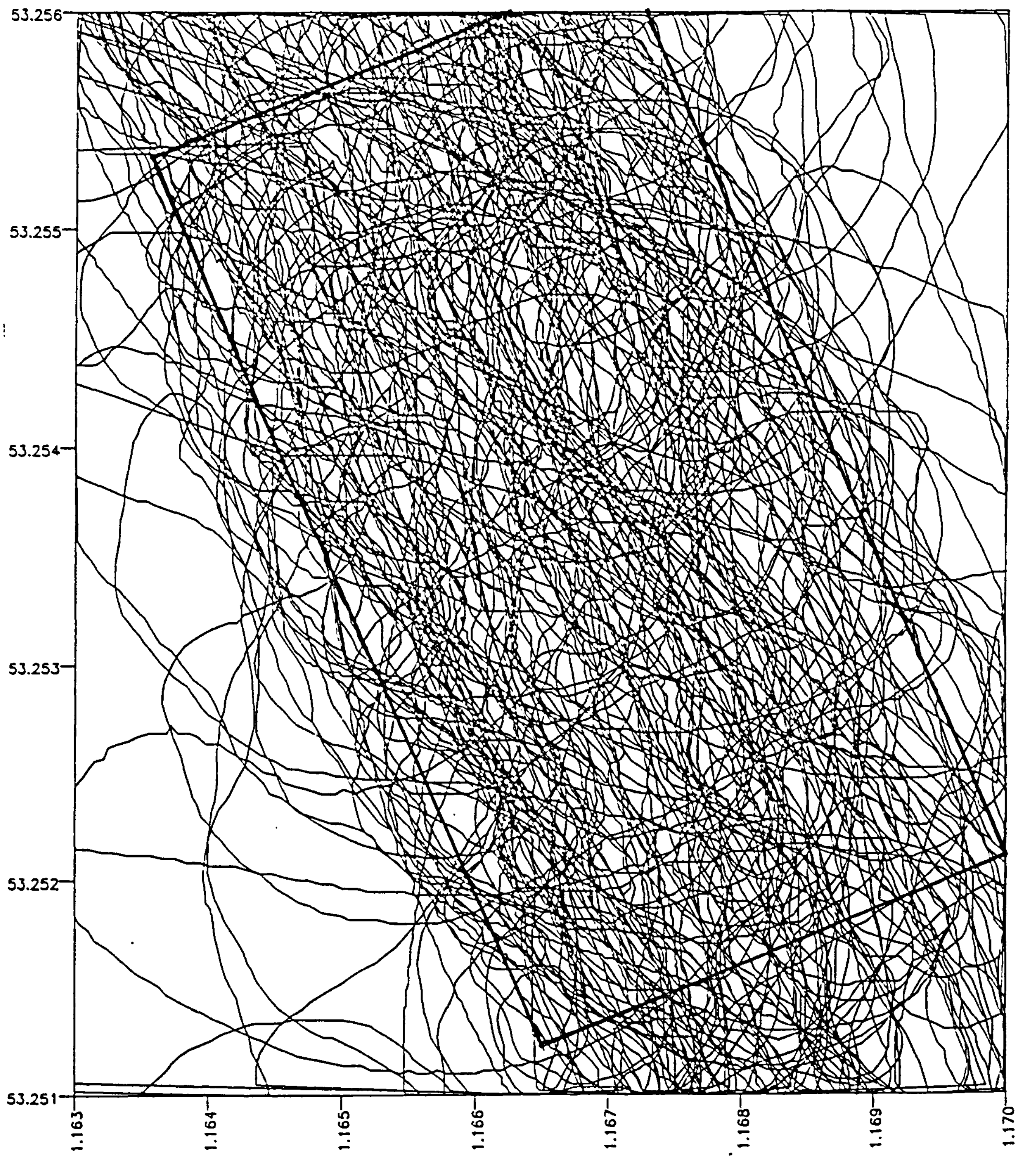



**Figure 2:** Tracks generated by the suction trailer dredger MV "Sand Harrier" at the experimental dredging site showing ~70% of the seabed area has been dredged.

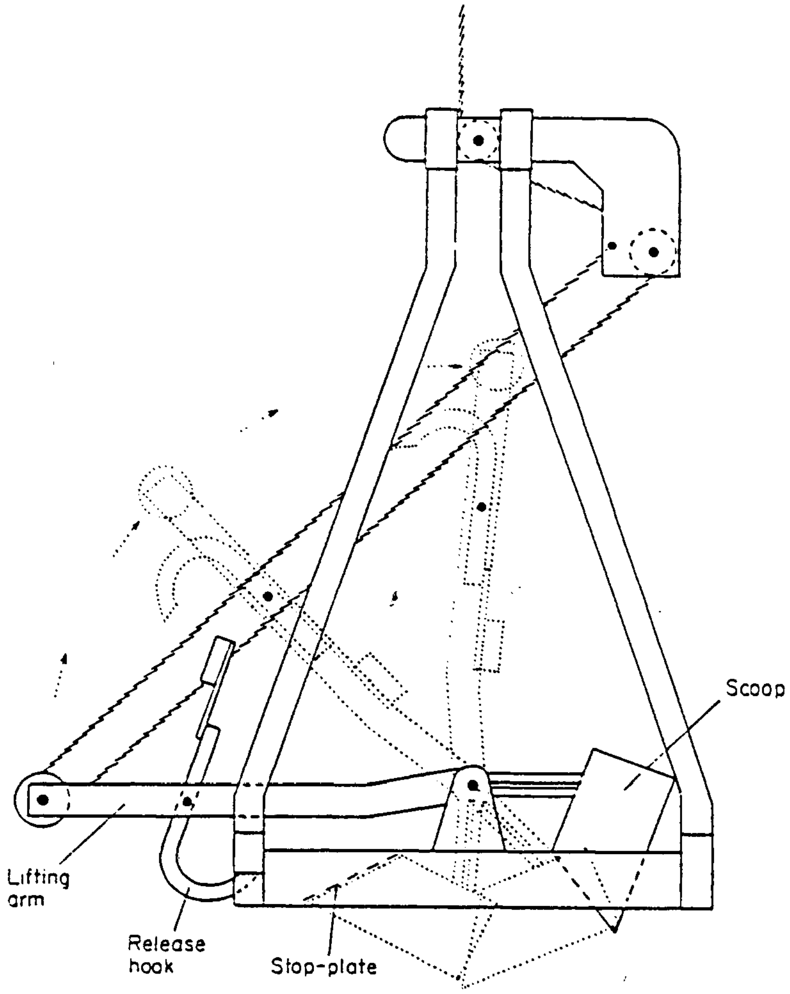



**Figure 3:** Schematic diagram of the Hamon grab (taken from Holme and McIntyre, 1984, after Oele, 1978).

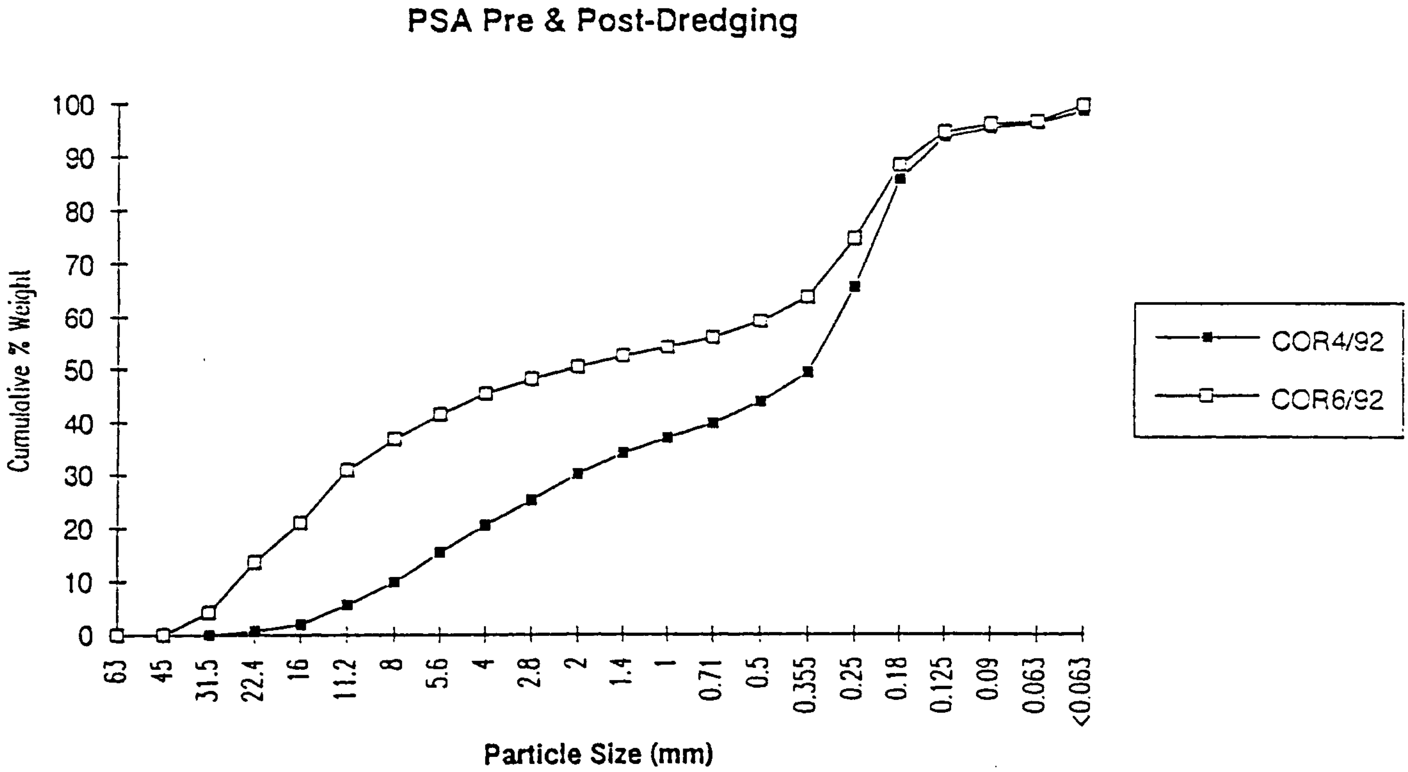
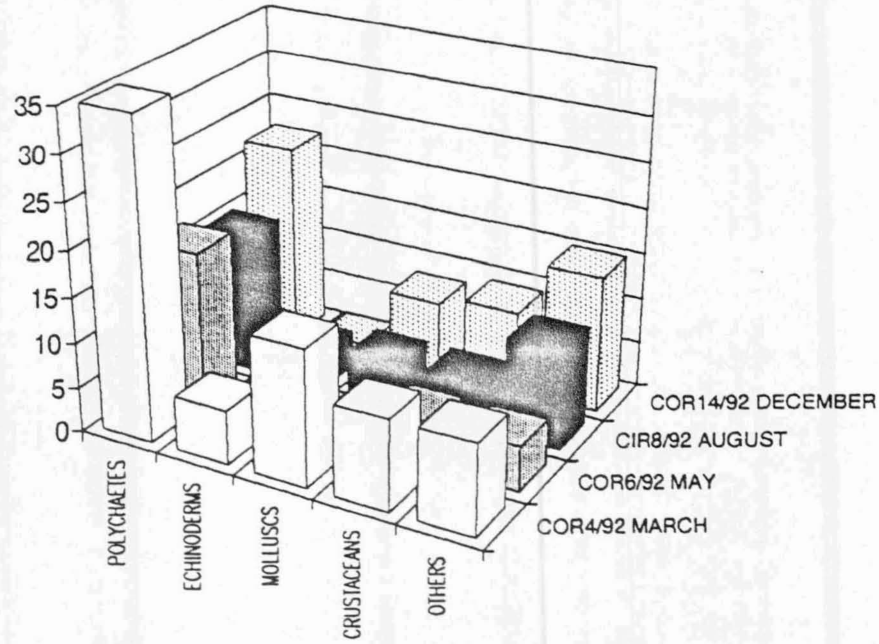



**Figure 4:** Average cumulative particle size distribution curves for samples taken before dredging (Cruise COR 4/92) and post-dredging (Cruise COR 6/92).

**TREATMENT SITE SPECIES NUMBERS/1.05m**

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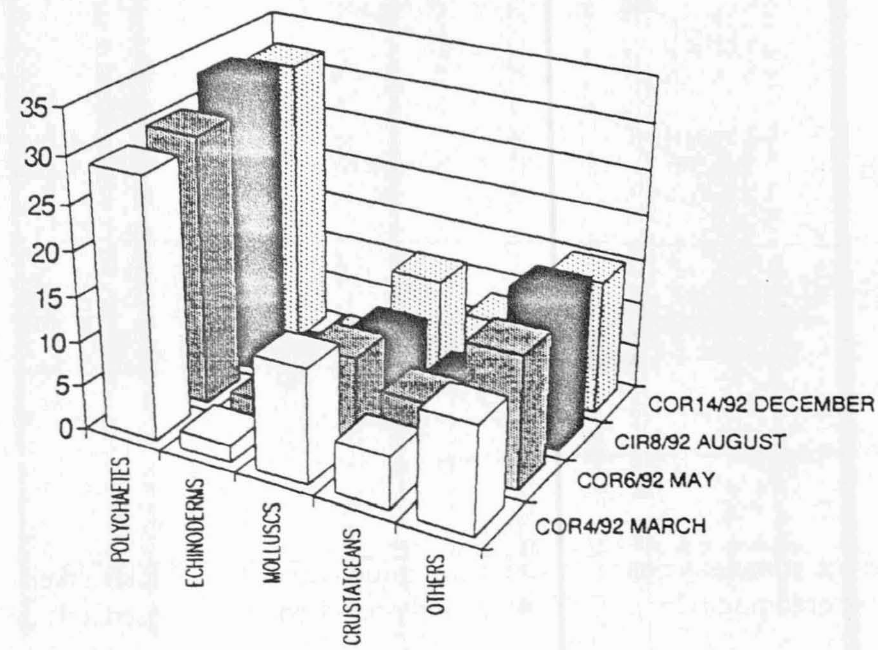
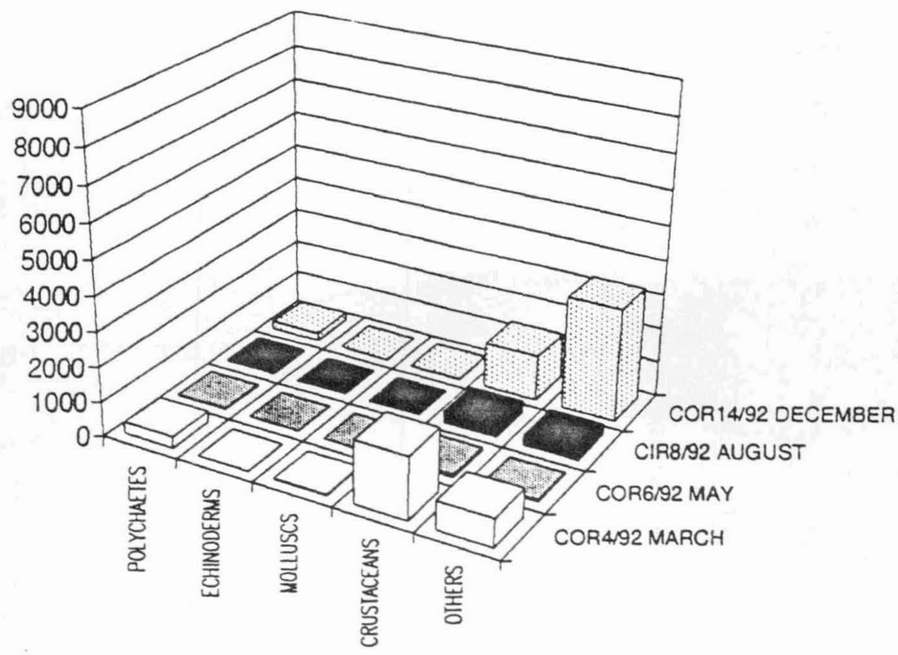



**Figure 5:** Number of species by major phyla for samples taken before dredging (Cruise COR 4/92) and post-dredging (Cruises COR 6/92, CIR 8/92 and COR 14/92) from the treatment and reference sites.

TREATMENT SITE ABUNDANCE 1.05/m




REFERENCE SITE ABUNDANCE/1.05m

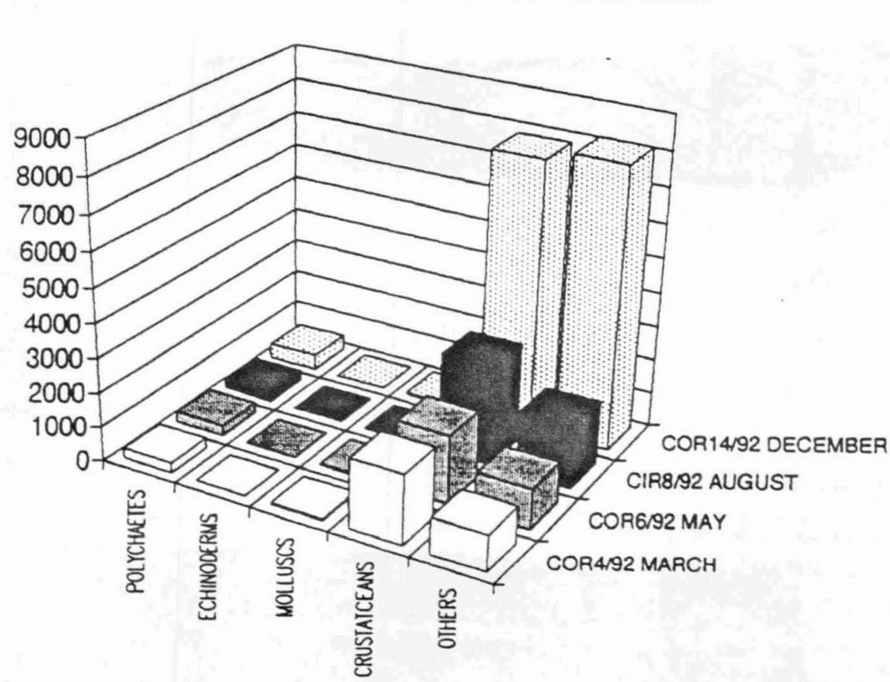



**Figure 6:** Abundance by major phyla for samples taken before dredging (Cruise COR 4/92) and post-dredging (Cruises COR 6/92, CIR 8/92 and COR 14/92) from the treatment and reference sites.

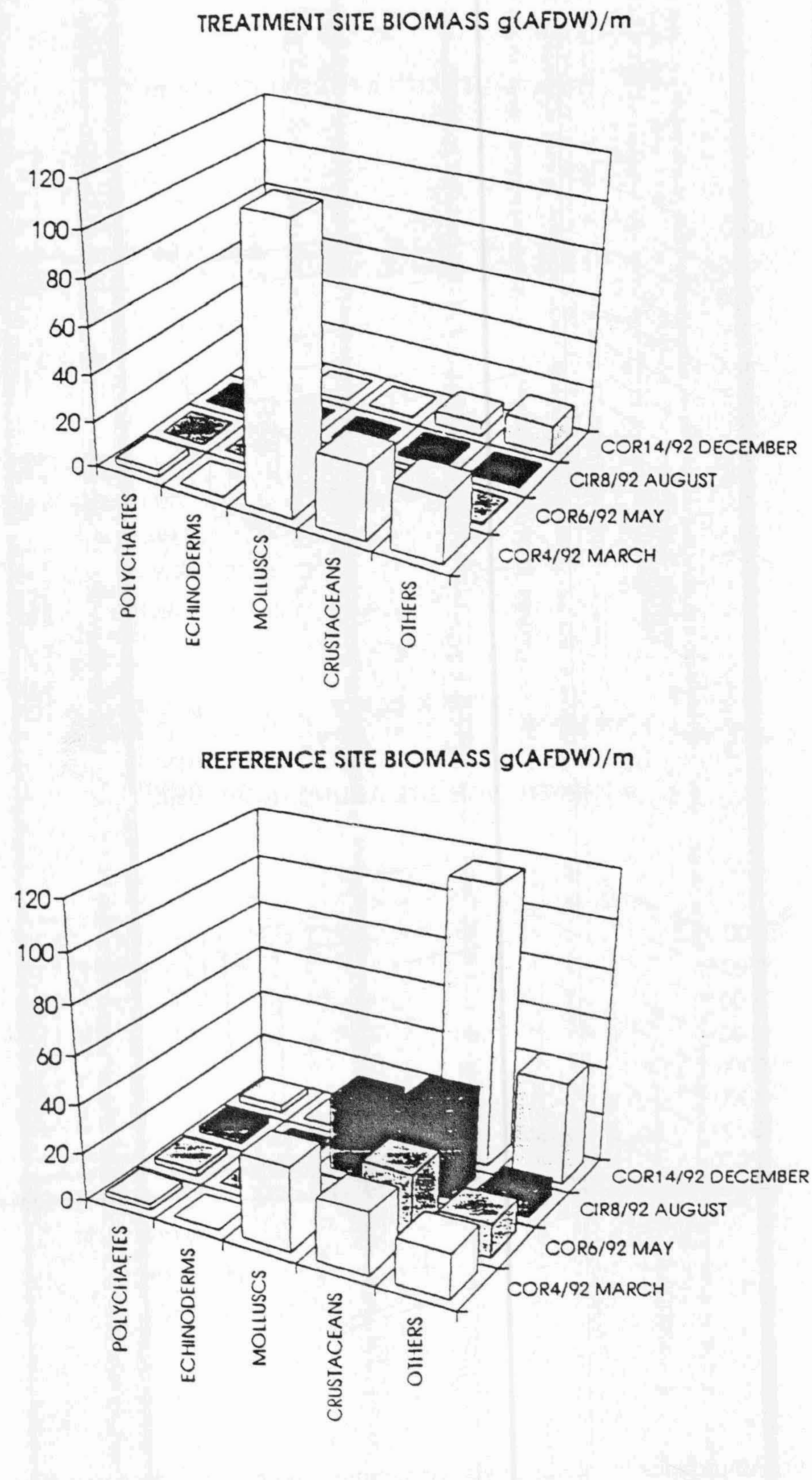



**Figure 7:** Biomass by major phyla for samples taken before dredging (Cruise COR 4/92) and post-dredging (Cruises COR 6/92, CIR 8/92 and COR 14/92) from the treatment and reference sites.

**FAR research project MA 2.549 "Environmental impact of bottom gears on benthic fauna in relation to natural resources management and protection of the North Sea".**

**First results of the surveys on the Flemish Banks**

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## Introduction

Within the framework of the EC-FAR IMPACT project, in 1992/1993 three trawling programs were carried out on the Flemish Banks. At all surveys, the R.V. BELGICA fished with a 4m beamtrawl equipped with chain mats, and a net with 8 cm meshes in the codend.

## Materials and methods

In April 1992 and March 1993 research has been done on a, mostly, hard sand bottom. In November 1992 the sediment ranged from muddy sand to mud.

The two main objectives were:

1. Sampling of macroinfauna before and after fishing (April 1992, November 1992);
   The macrobenthic infauna was sampled before and 24 hours after trawling by van Veen grabs (0.1 $m^2$).

2. Determination of survival rate of the organisms (April 1992, March 1993).
   In April 1992 and March 1993 survival experiments of epibenthic species and flatfish caught in the commercial net were performed. To estimate the survival of animals escaping through the nets, in March 1993 some short hauls were carried out with the cod-end of the commercial net covered with a narrow-meshed net. Live animals were placed in seawater tanks designed by the Fisheries Institute IJmuiden (described by van Beek et al., 1989; also used by BEON, 1990, 1991, 1992). Over a period of three days, survival was recorded and dead animals were removed every 24 hours.

## Results and discussion

### 1. Macrobenthic infauna

April 1992

Table 1 gives for $t_0$ the number of stations at which each species was found, the maximum number of species in one sample, and the mean number (and standard deviation) per sample. Densities were very low, with a maximum of 120 ind./m$^2$ for *Scoloplos armiger.*

Before sorting out the $t_1$-samples of the first survey, the probability of detecting a significant change in abundance if present (called the power of a procedure) was estimated, given the number of samples taken. The power is depending on several factors, including the precision of the estimates of abundance, the dependence of precision on changes in abundance, the nature and magnitude of the actual rate of change in abundance, the asymmetry between upward and downward trends, and the level ($\alpha$) of Type 1 error (the conclusion that the abundance changed, when in fact it did not) (Gerrodette, 1987). Power is defined as 1 - ß, where ß is the chance of making a Type 2 error (the conclusion that there was no change in abundance, when in fact abundance changed). An overview is given in following table (Peterman, 1990).

Four possible outcomes for a statistical test of some null hypothesis, depending on true state of nature. Probability for each outcome is given in parentheses.

| | Decision | |
|---|---|---|
| State of nature | Do not reject null hypothesis | Reject null hypothesis |
| Null hypothesis actually true | Correct (1 - $\alpha$) | Type 1 error ($\alpha$) |
| Null hypothesis actually false | Type 2 error (ß) | Correct (1 - ß) ( = power) |

All calculations were made on log-transformed data, using the formulae given by Gerrodette (1987) for a linear model of change, assuming that the coefficient of variation does not depend on abundance. The null hypotheses $H_0$: "the abundance has not decreased" and "the abundance has not increased" were tested against respectively "the abundance was decreased" and "the abundance was increased" (one-sided tests). The probability of detecting a change in abundance was calculated for the four dominant species, i.e. *Scoloplos armiger, Urothoe brevicornis, Spiophanes bombyx* and *Nepthys cirrosa.* Moreover, only these species have a standard deviation (of log-transformed data) smaller than the mean (and, thus, a coefficient of variation smaller than 1).

Figures 1 gives the power in function of the overall fractional change in abundance

(r) and the probability of concluding that the abundance changed when in fact it did not ($\alpha$). Calculations were made for both a decline ($r<0$) and an increase in numbers ($r>0$). Decreases are easier to detect than increases (curves for declining abundances lie above the curves for increasing abundances). The probability of detecting a change in abundance of *Urothoe brevicornis* is the highest, trends in *Spiophanes bombyx* are the most difficult to detect (e.g. for $\alpha=0.05$ and $|r|=0.5$, power is 0.51 for *Urothoe brevicornis*, 0.44 for *Nepthys cirrosa* and *Scoloplos armiger*, and 0.32 for *Spiophanes bombyx*).

If one wants to be as conservative about making a Type 2 as a Type 1 error, i.e. $\alpha=\beta$ and e.g a desired power = 0.95 for $\alpha$ = 0.05, the effect size (i.e. the magnitude of the true effect for which we are testing) that should have to exist to give a acceptably high power, has to be large. A power > 0.80 ($\alpha = \beta < 0.20$) is only reached when the (log-transformed!) abundances decrease by more than 70% (figure 2). A power of 0.95 will not be detected before the abundance of a species at $t_1$ becomes 0.

Given the higher abundance of benthos in November 1992, we further concentrate on the analysis of the second survey.

### 2. Survival experiments

The results of the survival experiments are presented in table 2 and 3. Total numbers of animals used, mortality after one, two and three days, and the % survival in the tests are given. Survival chances of the caught epibenthic species are almost 100%. Mortality of sole and dab in the commercial net is very high, but most of the sole that escape through the fishing net survive.

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**TABLE 1.** Number of stations (N) at which each species was found, the maximum number of individuals in one sample, the mean number (and standard deviation) per sample at $t_0$ (April survey) (untransformed data).

| Species | N | Max. | Mean | St.dev. |
|---|---|---|---|---|
| Actinaria indet. | 7 | 8 | 1.40 | 2.48 |
| Ampelisca brevicornis | 1 | 1 | .05 | .22 |
| Anaitides mucosa | 1 | 1 | .05 | .22 |
| Anaitides subulifera | 1 | 2 | .10 | .45 |
| Aonides paucibranchiata | 1 | 3 | .15 | .67 |
| Aricidiacea indet. | 1 | 1 | .05 | .22 |
| Ascidiae indet. | 1 | 4 | .20 | .89 |
| Atylus falcatus | 2 | 1 | .10 | .31 |
| Atylus swammerdami | 1 | 1 | .05 | .22 |
| Bathyporeia guilliamsoniana | 1 | 1 | .05 | .22 |
| Bathyporeia pelagica | 8 | 3 | .60 | .88 |
| Bathyporeia sarsi | 1 | 1 | .05 | .22 |
| Bathyporeia spec. | 1 | 1 | .05 | .22 |
| Bodotria pulchella | 1 | 1 | .05 | .22 |
| Capitella capitata | 1 | 1 | .05 | .22 |
| Callianassa tyrrhena | 1 | 1 | .05 | .22 |
| Chaetozone setosa | 2 | 3 | .20 | .70 |
| Crangon crangon | 1 | 1 | .05 | .22 |
| Diastylis bradyi | 2 | 1 | .10 | .31 |
| Echinocardium cordatum | 10 | 3 | .65 | .81 |
| Ensis spec. | 1 | 1 | .05 | .22 |
| Gastrosaccus spinifer | 2 | 1 | .10 | .31 |
| Harmothoe spec. | 1 | 1 | .05 | .22 |
| Heteromastus filiformis | 1 | 1 | .05 | .22 |
| Lanice conchilega | 3 | 1 | .15 | .37 |
| Magelona papillicornis | 1 | 1 | .05 | .22 |
| Megaluropus agilis | 1 | 1 | .05 | .22 |
| Montacuta ferruginosa | 3 | 3 | .25 | .72 |
| Natica spec. | 2 | 1 | .10 | .31 |
| Nephtys cirrosa | 18 | 14 | 6.70 | 3.73 |
| Nereis diversicolor | 1 | 1 | .05 | .22 |
| Nephtys hombergii | 5 | 2 | .30 | .57 |
| Nereis longissima | 2 | 1 | .10 | .31 |
| Nemertinae indet. | 16 | 5 | 1.45 | 1.32 |
| Nepthys spec. | 3 | 2 | .20 | .52 |
| Notomastus latericeus | 1 | 2 | .10 | .45 |
| Oligochaeta indet. | 3 | 2 | .25 | .64 |
| Ophiura albida | 3 | 1 | .15 | .37 |
| Ophiura spec. | 1 | 1 | .05 | .22 |
| Ophelia limacina | 5 | 3 | .35 | .75 |
| Owenia fusiformis | 1 | 1 | .05 | .22 |
| Pagurus bernhardus | 1 | 1 | .05 | .22 |
| Pectinaria koreni | 1 | 1 | .05 | .22 |
| Phyllodocidae indet. | 3 | 1 | .15 | .37 |
| Pontocrates altamarinus | 1 | 1 | .05 | .22 |
| Poecilochaetus serpens | 1 | 1 | .05 | .22 |
| Pseudocuma gilsoni | 1 | 2 | .10 | .45 |
| Pseudocuma spec. | 1 | 2 | .10 | .45 |
| Pygospio elegans | 1 | 1 | .05 | .22 |
| Scoloplos armiger | 19 | 38 | 12.00 | 9.53 |
| Scolelepis bonnieri | 1 | 1 | .05 | .22 |
| Scolelepis foliosa | 1 | 1 | .05 | .22 |
| Spiophanes bombyx | 20 | 52 | 9.45 | 12.40 |
| Spisula elliptica | 3 | 2 | .20 | .52 |
| Spisula spec. | 1 | 1 | .05 | .22 |
| Spisula subtruncata | 1 | 2 | .10 | .45 |
| Tellina fabula | 1 | 1 | .05 | .22 |
| Thia scutellata | 6 | 3 | .40 | .75 |
| Urothoe brevicornis | 20 | 17 | 8.05 | 5.52 |
| Urothoe spec. | 2 | 1 | .10 | .31 |
| Urothoe poseidonis | 4 | 2 | .30 | .66 |

**TABLE 2.** Results of survival experiments (April 1992)

| Species | Numbers alive at start | Numbers dead after day 1 | 2 | 3 | Total numbers alive | Total; survival % |
|---|---|---|---|---|---|---|
| Asterias rubens | 62 | 0 | 0 | 0 | 62 | 100 |
| Carcinus maenas | 1 | 0 | 0 | 0 | 0 | 100 |
| Limanda limanda | 14 | 5 | 8 | 11 | 3 | 21 |
| Liocarcinus holsatus | 27 | 1 | 1 | 1 | 26 | 96 |
| Liocarcinus puber | 1 | 0 | 0 | 0 | 1 | 100 |
| Ophiura sp. | 59 | 0 | 0 | 0 | 59 | 100 |
| Pagurus bernhardus | 23 | 0 | 0 | 0 | 23 | 100 |
| Patichthys flesus | 5 | 3 | 5 | 5 | 0 | 0 |
| Pleuronectes platessa | 22 | 0 | 1 | 7 | 15 | 68 |
| Solea solea | 29 | 16 | 22 | 24 | 5 | 17 |
| Liocarcinus pusillus | 4 | 0 | 0 | 0 | 4 | 100 |
| Aphrodite aculeata | 15 | 0 | 0 | 0 | 15 | 100 |

**TABLE 3.** Results of survival experiments (March 1993)
a: commercial net, b: covering net

| | Species | $N_d$ | $N_e$ | Numbers dead after day 1 | 2 | 3 | Total numbers alive | Total; survival % |
|---|---|---|---|---|---|---|---|---|
| b. | Liocarcinus depurator | - | 24 | 5 | 5 | 6 | 18 | 75 |
| | Liocarcinus holsatus | - | 110 | 8 | 11 | 16 | 94 | 85 |
| | Limanda limanda | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| | Lepidorhombus whiffiagonis | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| | Ophiura sp. | - | 80 | 1 | 1 | 2 | 78 | 98 |
| | Solea solea | 0 | 39 | 3 | 5 | 5 | 34 | 87 |
| a. | Liocarcinus depurator | - | 40 | 4 | 6 | 6 | 36 | 85 |
| | Platichthys flesus | 1 | 2 | 0 | 2 | 2 | 0 | 0 |
| | Liocarcinus puber | - | 1 | 0 | 0 | 0 | 1 | 100 |
| | Liocarcinus holsatus | - | 25 | 6 | 7 | 7 | 18 | 72 |
| | Gadus morhua | 1 | | | | | | |
| | Limanda limanda | 7 | 11 | 9 | 11 | 11 | 0 | 0 |
| | Pleuronectes platessa | 11 | 2 | 0 | 0 | 0 | 2 | 100 |
| | Trisopterus luscus | 4 | | | | | | |
| | Solea solea | 16 | 41 | 27 | 34 | 35 | 6 | 15 |
| | Merlangius merlangus | 3 | | | | | | |

$N_d$ = number of individuals dead in commercial net (covering net in b)
$N_e$ = number of individuals alive (fish) or used (epibenthos) at start of the experiment

Figure 2 Power of linear regression as a function of the fractional change r and Type 1 error α (r<0 solid lines, r>0 broken lines).

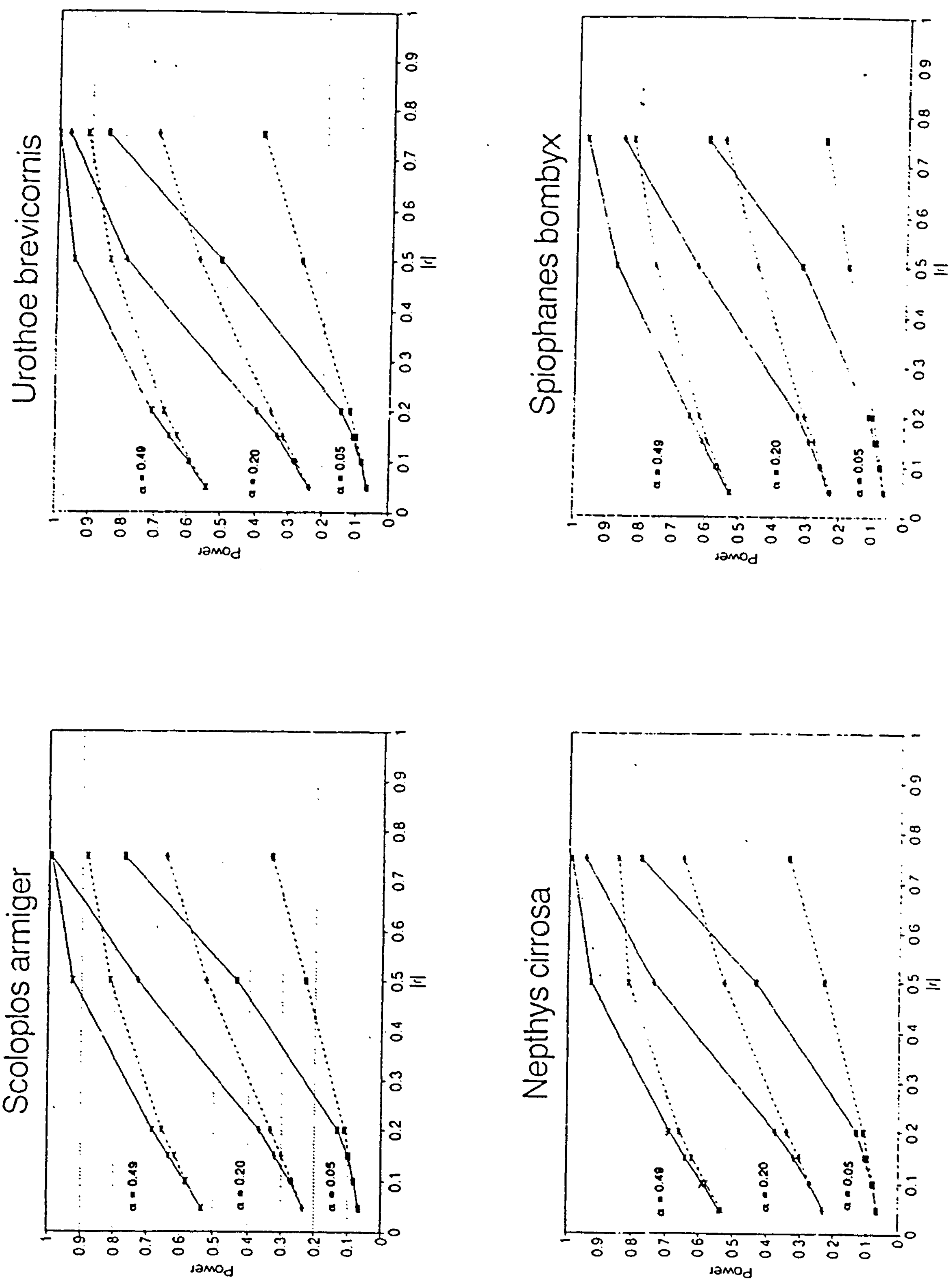
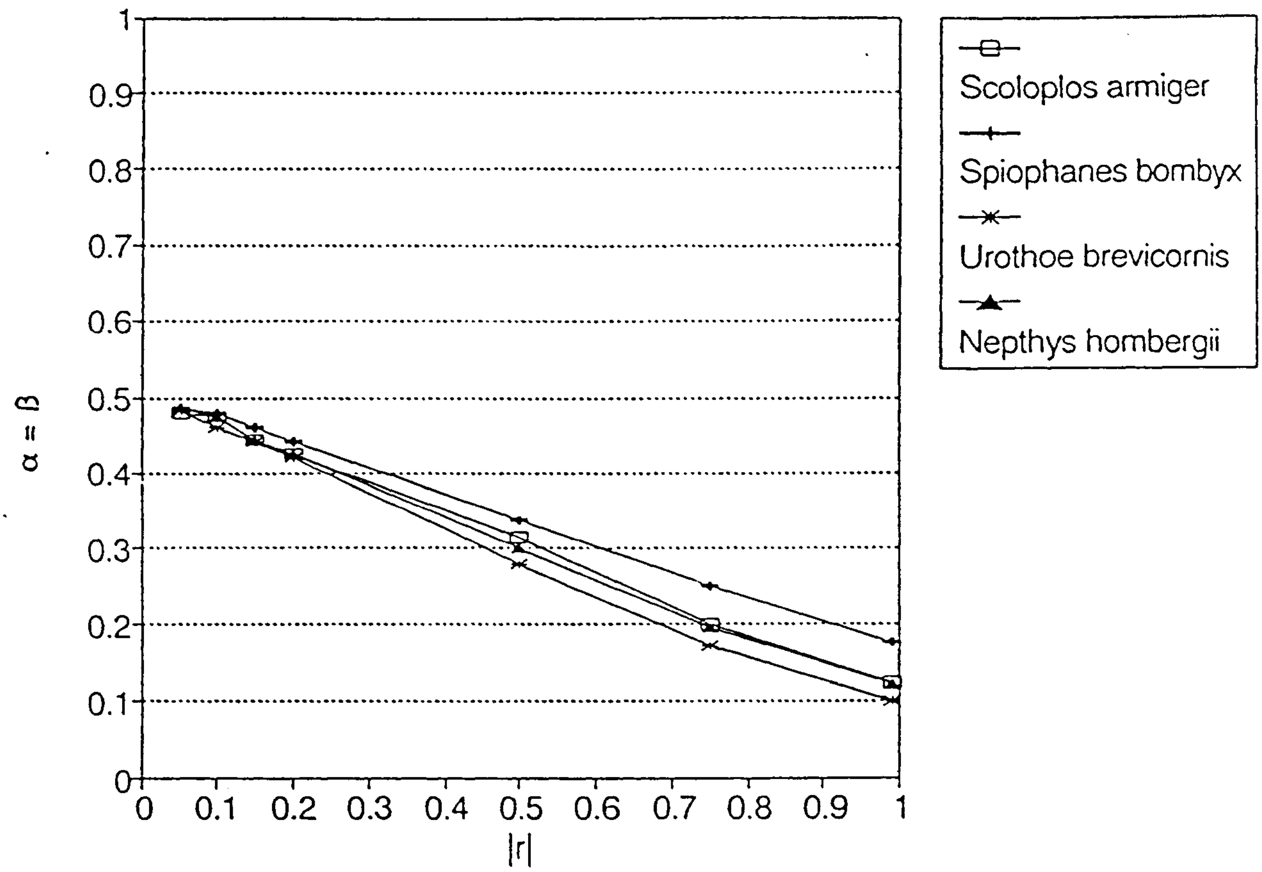


Figure 2 Power of linear regression as a function of r (r<0) and coefficient of variation (the coefficient of variation of *Scoloplos armiger* was 0.4329, the c.v. of *Nepthys cirrosa* 0.4261, the c.v. of *Urothoe brevicornis* 0.3837 and the c.v. of *Spiophanes bombyx* 0.5375).



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# A preliminary assessment of the immediate effect of beam trawling on a benthic community in the Irish Sea.

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## ABSTRACT

After an experimental box had been fished 10 times with a 4-m commercial beam trawl, the density of sessile animals such as *Alcyonium digitatum* and hydroids decreased by ca. 50%. The density of more mobile animals, such as fishes, crabs and *Palaemon* spp. remained constant or increased. Assessment of the survival of animals caught in the codend indicated large variation between species. Echinoderms with flexible tests, eg. *A. rubens*, showed low mortality, whereas those with brittle tests, eg. *Psammechinus miliaris*, were readily damaged leading to high mortality. Mortality in fish seemed to be related to the amount epidermal armour such as scales, spines, boney plates and slime. *Callionymus* spp. suffered 68 - 97% mortality whereas between 34 - 38% of *Pleuronectes platessa* and *Raja naevus* died respectively. Those animals which are able to survive the trauma of being caught in the codend and handled on deck may be able to capitalise on dead animals and discards (eg. *A. rubens*) and hence benefit from the effects of trawling in the long-term.

## INTRODUCTION

Beam trawls are an extremely effective fishing gear for catching flatfish (eg. Cruetzberg et al., 1987) and are used extensively in the North and Irish Sea. The increase in the size and engine power of modern trawlers has required modifications to the gear which increase its weight eg. longer beams and the addition of more chain mat or more tickler chains. Typically, a Dutch 12-m beam trawl weighs 7 to 8 t of which 1 t is made up of 19 tickler chains (BEON, 1991). These chains are designed to penetrate the sediment and disturb sole, *Solea solea*, that remain buried by day. The total depth to which these chains penetrate depends on both the vessel towing speed and substrate hardness, estimates varying from 3 cm on hard sand to 8 cm in soft mud (Bridger, 1972; BEON, 1991). However, while tickler chains increase catches of commercial flatfish they also increase the by-catch of non-commercial fish, epi- and infaunal invertebrates. Fragile animals such as sea urchins and some bivalve molluscs tend to be damaged and killed by trawling activity (Bergman & Hup, 1992; Rumohr & Krost, 1992). Conversely, other animals, such as starfish, survive in high numbers (BEON, 1991; present study) and may even benefit by scavenging the dead animals produced after the passage of the trawl. These effects, coupled with the intensity of the beam trawling effort in the North Sea, have led to suggestions that the latter is a possible cause of the long-term changes observed in the North Sea benthic community (Pearson et al., 1985; Lindeboom, 1990).

To date, most research has concentrated on large (6 to 12-m) beam trawls; no information exists on the effect of 4-m beam trawls on the benthic community. When fished in the Irish Sea, 4-m beam trawls tend to be fitted with chain mat, ie. tickler chains linked longitudenally to form a chain mat. This mat is designed to prevent rocks entering the net as well as to catch more flatfish. The Directorate of Fisheries Research, Conwy is investigating the short and long-term effects of this gear on a benthic community in the Irish Sea.

In March 1992 a preliminary investigation of an area between Point Lynas, Anglesey, and Great Ormes' Head, north Wales, was carried out to locate a suitable site for a short-term and long-term study of the effects of beam trawling on a benthic community. A suitable site with a conspicuous filter-feeding community, was found at approximately 4° 00' W, 53° 27' N. The presence of this community, that comprised long-lived species such as

*Alcyonium digitatum*, indicated that trawling activity in the area is relatively infrequent.

In August 1992 we returned to this site to carry out experimental fishing with a commercial 4-m beam trawl fitted with chain mat to examine the following effects:

1. The immediate effects on the benthic community.
2. The survival capabilities of animals caught in the cod-end.

Objective 1 will be discussed in terms of the epibenthic data as the infaunal samples are currently being processed.

## Effects on epibenthos

### Methods

An experimental box 40 m x 200 m, was marked on the ship's navigation plotter which was linked to a Sercel NR53 DGPS positioning system (accurate to ±2.5 m). Water depth varied between 32 to 34 m. All samples were taken from within this area. Prior to fishing with the commercial beam trawl, three 10 min tows (ship speed 0.4-0.9 kt) through the box with a 2-m young flatfish beam trawl (Rogers & Lockwood, 1989). The position at the start and end of each tow was recorded. The number of individuals and wet weight (±1 g) of each species was recorded from each catch. Catch data was standardised by expressing values as density (numbers/1000m$^2$) or biomass (g/1000m$^2$). Following this preliminary sampling, the box was fished 10 times with the 4-m beam trawl. This was followed by another three tows with the 2-m beam trawl and the catch quantified as before. Many of the animals occurred too infrequently to determine whether numbers had changed after fishing (eg. *Astropecten irregularis*). Therefore animals were grouped according to their mobility (Table I) on the assumption that mobile animals would recolonise or scavenge on animals killed or exposed by the beam trawl.

### Results

The dominant macrofauna (biomass) in the community were the anthozoan, *Alcyonium digitatum*, bryozoans, echinoderms (*Psammechinus miliaris, Ophiura texturata, Asterias rubens, Ophiothrix fragilis*) and crustaceans (*Macropodia tenuirostris, Eupagurus bernhardus, Pisa armata*) these were also the most abundant animals (Fig. 1). The density and biomass of many of the sessile or slow moving animals (molluscs, echinoderms, anthozoans) was much lower after experimental trawling (Table I). However, the density of mobile invertebrates such as *Eupagurus bernhardus, Liocarcinus holsatus, Palaemon* spp. and fish increased after trawling (Table I). After fishing with the commercial beam trawl the estimated density of sessile animals fell from 398 to 136/1000m$^2$, whereas the density of mobile animals increased from 89 to 159/1000m$^2$ ($x^2$=107.5, d.f.=1, P<0.0001). Similarly, the biomass of sessile animals decreased whereas that of mobile animals increased after fishing with the commercial trawl (sessile before, 3451 g/1000m$^2$, after, 689 g/1000m$^2$; mobile before, 613 g/1000m$^2$, after, 894 g/1000m$^2$. [$x^2$=917.0, d.f.=1, P<0.0001]).

## Assessment of Survival

### Methods

In March and August 1992 and April 1993, a 4-m beam trawl was towed for 30 min (n=3) on each occasion. After each haul, a sub-sample of the catch from the cod-end was placed immediately into a 50 l bin filled with sea water and then transferred to a survival system. The survival system consisted of six 4.0x0.5x0.3 m tanks, attached to a steel frame which was locked to the deck of the ship, each fitted with three evenly spaced removable partitions. Each partition had 20 1 cm diameter holes which allowed free circulation of water. The entire system was enclosed with a tarpaulin cover to eliminate light which may have increased animal's stress. The species selected for examination were maintained in separate compartments with sea water flowing to waste. An assessment was made of the initial mortality of each species collected in the subsample. Only live animals were placed in the survival system, their subsequent mortality was recorded at intervals of 24 h, although this varied from year to year depending on circumstances.

### Results

Echinoderms were, in general, highly resilient. The initial and delayed mortility (0 to 1%) of *Asterias rubens* and *Astropecten irregularis* was lower than other animals (Table II). *Ophiura ophiura* suffered low initial mortality, which increased to 14 - 19% after 120 h. Delayed mortality occurred in those animals which had badly damaged or crushed oral discs, which disintegrated with time. Amongst echinoderms, *Psammechinus miliaris* had the highest initial mortality (20%) and the greatest final mortality (51%). *Eupagurus bernhardus* showed low overall mortality (6%), the animals that died tended to be those which had abandoned their shells and had been crushed in the codend. However, *Eupagurus prideauxi* suffered slightly higher mortality (<14%). Despite their fragile appearance, *Macropodia tenuirostris* suffered relatively low total mortality (32%) after 72 h. In March 1992, swimming crabs suffered 45% initial mortality, this had only increased to 58% after 72 h, whereas in April 1993 overall mortality was much lower (<15%). Although *Callionymus* spp. had an initial mortality of 6 - 12% final mortality increased to between 68 and 97%. *Pleuronectes platessa* and *Raja naevus* showed delayed mortality increasing from an initial 6 and 0% to 38 and 34% final mortality respectively. Feeding polyps emerged from colonies of *Alcyonium digitatum* after 24 h and throughout the experiment. The colonies had taken up water after 24 h and retracted when exposed to light.

## DISCUSSION

These results show that the 4-m beam trawl lowered the density and biomass of the sessile animals in the experimental box. In particular, the biomass of *A. digitatum* and hydroids was reduced by approximately 50% after trawling (Table I). How quickly these animals will recolonize the area is unknown but could take months to years where natural recruitment is concerned. The density of some mobile species increased after trawling (Table I). Most of these species are scavengers or predators (eg. *E. bernhardus, Callionymus* spp. and *Palaemon* spp.) and are able to move rapidly (1-3 h) in response to chemical stimuli (Nickell & Moore, 1992) produced by damaged or killed animals which result from beam trawling activity. Other scavengers, such as *B. undatum* and *A. rubens*, may respond more slowly, arriving after 12 h (Sainte-Marie & Hargrave, 1987; Nickell & Moore, 1992). Other results also showed that dogfish, whiting and gurnards take advantage of this extra food source (Kaiser & Spencer, 1993), as do dabs, *Limanda limanda,* in the North Sea (M. Fonds, personal communication).

Animals that form the by-catch of a beam trawl can suffer injuries from a variety of sources. The beam shoes, chain mat and abrasion from the net can inflict wounds and injuries of different degrees of severity. On hauling the net, pressure from the weight of catch can inflict bruises and internal injuries which may lead to delayed mortality. Some animals survive this experience better than others (Table II). As in other studies (BEON, 1990, 1991) echinoderms, in particular asteroids, showed a high percentage survival which is not surprising considering their ability to regenerate limbs (Barnes, 1980). The susceptibility to damage seems to be related to the flexibility of the test, sea urchins have brittle tests, which are easily smashed and expose them to predation. Ophiuroids have flexible plates, which are more susceptible to damage than the more flexible test of asteroids. Although swimming crabs, *L. holsatus*, are able to regenerate limbs, they are killed when their carapaces are crushed. In another study (Kaiser & Rogers, unpublished data) tickler chains were identified as the part of the beam trawl that was mainly responsible for crushed carapaces. *Callionymus* spp. suffered high delayed mortality, which was contrary to our expectations as superficially they appeared undamaged. It is probable that a combination of stress and internal injuries contributed to their high mortality. Greater than 60% of *Pleuronectes platessa* and *Raja naevus*, were still alive after 120 h, which is probably attributable to their thick, armoured slimey skin. Those specimens which died showed signs of either severe (>30%) scale loss (*P. platessa*) and/or bruising (*R. naevus*).

Our results demonstrate that a 4-m commercial beam trawl fitted with chain mat reduces the biomass and density of, in particular, sessile invertebrates. However mobile animals quickly migrate into the trawl track and feed on some of the damaged and dead species. Not all the animals caught in the beam trawl are killed. Those which are able to survive the experience and utilise the additional food source produced after the passage of a trawl may benefit the most, eg. *A. rubens*. Whether this will lead to long-term changes in the community structure will be investigated in our long-term experiment.

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Table I. The change in density (numbers/1000m$^2$) and biomass (g/1000m$^2$) (mean of 3 samples) of selected dominant species sampled with a 2-m juvenile flatfish beam trawl before and after experimental fishing with a 4-m beam trawl. Motibity of animals is indicated by (S) sessile or (M) mobile.

| Species | Density | | Biomass | | Mobility |
|---|---|---|---|---|---|
| | Before | After | Before | After | |
| *Alcyonium digitatum* | — | — | 9570 | 4620 | S |
| *Bryozoan/hydroids* | — | — | 1055 | 670 | S |
| *Psammechinus miliaris* | 115 | 27 | 927 | 89 | S |
| *Asterias rubens* | 43 | 20 | 859 | 247 | S |
| *Ophiura ophiura* | 64 | 25 | 402 | 46 | S |
| *Palaemon* spp. | 17 | 27 | 2 | 3 | M |
| *Macropodia tenuirostris* | 128 | 47 | 67 | 12 | S |
| *Eupagurus bernhardus* | 34 | 47 | 313 | 513 | M |
| *Callionymus* spp. | 7 | 16 | 161 | 181 | M |
| *Pomatoschistus* spp. | 23 | 23 | 10 | 6 | M |

Table II Results of survival experiments carried out between March 1992 and April 1993. The cumulative % mortality for each species in 24 hourly intervals.

| Species | Date | Nos. | CUMULATIVE % MORTALITY | | | | | | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 24 | 48 | 72 | 96 | 120 | |
| *Aphrodite aculeata* | Mar. 92 | 46 | 0 | 5 | 7 | | | | No apparent reason for initial mortality. |
| | Apr. 93 | 65 | 0 | | 3.1 | 3.1 | 3.1 | 6.2 | Some intraspecific predation later. |
| *Ophiura ophiura* | Mar. 92 | 26 | 0 | 0 | 19 | | | | Mortality occurred in those individuals |
| | Apr. 93 | 34 | 5.9 | | 5.9 | 11.7 | 11.7 | 14.7 | with >50% damage to oral disc. |
| *Astropecten irregularis* | Mar. 92 | 17 | 0 | 0 | 0 | | | | No mortality, strong test, damage confined to arms. |
| *Asterias rubens* | Mar. 92 | 126 | 1 | 1 | 1 | | | | Mortality only occurred when whole animal crushed. |
| *Psammechinus miliaris* | Mar. 92 | 91 | 20 | 37 | 51 | | | | Delayed mortality indicated by loss of spines. |
| *Eupagurus bemhardus* | Mar. 92 | 39 | 6 | 6 | 6 | | | | Crabs well protected in shell. |
| | Apr. 93 | 15 | 0 | | 0 | 0 | 0 | 0 | |
| *Eupagurus prideauxi* | Apr. 93 | 29 | 13.7 | | 13.7 | 13.7 | 13.7 | 13.7 | Crabs not so well protected, only carrying piece of shell with attached anemone. Dead crabs severed at abdomen. |
| *Macropodia tenuirostris* | Aug. 92 | 22 | 8 | 22 | 25 | 25 | | | Crabs fold delicate legs under body and avoid damage. |
| *Liocarcinus depurator* | Mar. 92 | 45 | 29 | 29 | 40 | | | | Mortality tends to occur as a result of |
| | Apr. 93 | 34 | 8.8 | | 12.9 | 12.9 | 12.9 | 14.7 | intraspecific predation when individuals moult. |
| *Eledone cirrhosa* | Apr. 93 | 15 | 0 | | 0 | 0 | 0 | 13.3 | Nine animals escaped from the tanks. Two dead animals at the end of the experiment. |
| *Plueronectes platessa* | Apr. 93 | 50 | 4 | | 18 | 24 | 30 | 38 | Dead animals tended to have >30% scale loss and bruising. |
| *Agonus cataphractus* | Apr. 93 | 13 | 7.6 | | 25 | 25 | 25 | 25 | No obvious reason for death. |
| *Callionymus spp.* | Aug. 92 | 65 | 12 | 71 | 89 | 97 | | | Some fish showed signs of bruising. Mostly reason not obvious. |
| | Apr. 93 | 50 | 6 | | 24 | 46 | 68 | | |
| *Raja naevus* | Apr. 93 | 32 | 0 | | 0 | 12.5 | 34 | | Dead fish showed signs of bruising. |
| *Alcyonium digitatum* | Apr. 93 | 50 | 0 | | 0 | 0 | 0 | 0 | After 24 h the colonies appeared to have taken up water. All colonies had feeding polyps throughout the experiment. |

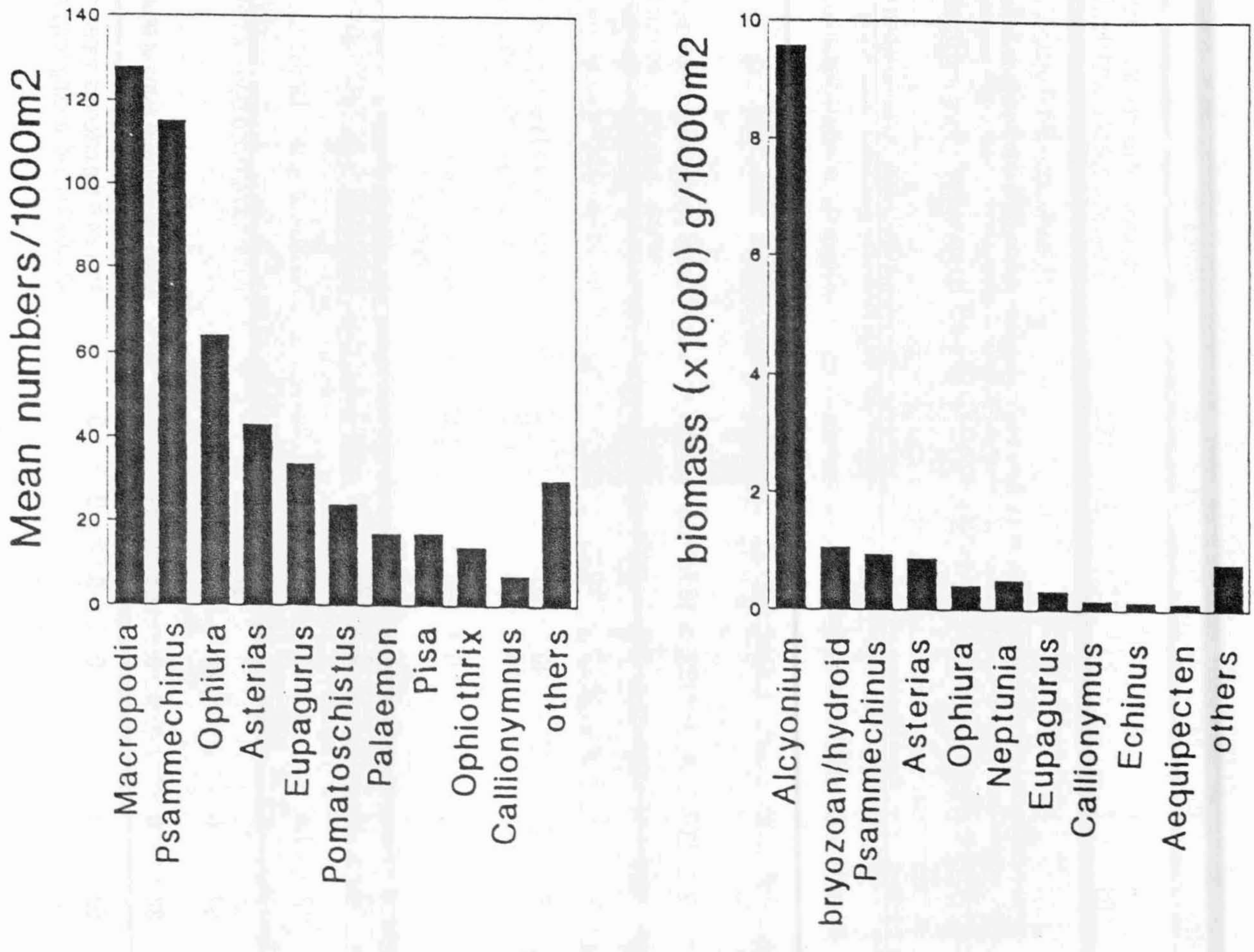


Fig. 1. The ten dominant species in the benthic community at the experimental site, based on density and biomass. NB. *A. digitatum* and bryozoans/hydroids have been omitted from the density analysis because of the difficulty of quantifying individuals or colonies.

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# OPPORTUNISTIC FEEDING ON BENTHOS BY FISHES AFTER THE PASSAGE OF A 4-m BEAM TRAWL

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## ABSTRACT

When a beam trawl passes over the seabed, benthic animals are either disturbed or killed by the action of the tickler chains and beam shoes. These animals are potentially available for scavenging/predation by fish that move into the trawl tracks after fishing. To test this hypothesis, two species of gurnard, *Eutrigla gurnardus* (L.) and *Aspatrigula cuculus* (L.), and lesser-spotted dogfish, *Scyliorhinus canicula* (L.), were collected before and 3 h after fishing the same track with a 4-m beam trawl three times. Stomach contents of the fish were collected, identified and weighed to determine if feeding had increased after fishing. The catch rate of dogfish was significantly lower 2 h after the previous fishing bout, whereas the catch rate of gurnards did not alter significantly. A comparison of the stomach contents of fish species at the beginning and after fishing indicated that fish were feeding selectively. Gurnards fed exclusively on crustaceans and fish, whereas dogfish fed on a mixed diet of crustaceans, fish, molluscs and polychaetes. Gurnard stomachs also contained significantly more shrimps and amphipods and dogfish stomachs contained significantly more amphipods after intensive fishing. It is deduced that predatory fish capitalise on animals killed or disturbed from their burrows, or other smaller predators that move into a recently trawled area. Furthermore, a side-scan sonar survey of beam trawl tracks 3 h after fishing showed that there were 3.8 times as many shoals of fish over the trawl tracks compared with the adjacent unfished area. Potential food generated by beam trawling could provide a significant component of the diets of certain opportunistic fish species in areas subject to intensive beam trawl activity.

## INTRODUCTION

Recent studies have indicated that beam and otter trawls damage fragile benthic species such as the heart urchin, *Echinocardium cordatum* and the bivalve, *Arctica islandica*, (BEON, 1991; Rumohr & Krost, 1991; Bergman & Hup, 1992). Presumably, animals killed by the passage of a beam trawl are scavenged by epibenthic predators. Although starfish, whelks and crabs are likely to be attracted by the scent of the dead animals, their response time varies from 1-48 h depending on their distance from the food source (Nickell & Moore, 1992). Conversely, fish are highly mobile and, therefore, able to respond rapidly, moving comparatively long distances. As yet, there is only anecdotal evidence to support the opportunistic use of this potential food source (Fonds pers. comm.). We present evidence that fishes are attracted by exposed, damaged and dead animals produced by the passage of a beam trawl.

## METHODS

The experiment was carried out in August 1992 and April 1993 at two different sites off the east coast of Anglesey (Fig. 1). The experimental protocol differed on each occasion (in April 1993 an oil tanker was anchored over the previous trawl track), hence a description of the differing elements is given. Ship's position was given by a Sercel NR53 DGPS navigation system which has an error of ±2.5 m. A track was recorded on the navigation plotter of the RV Corystes and trawled 6 times with a 4-m commercial beam trawl.

In August 1992 the duration for tows 1-6 was 30, 20, 10, 10, 20 and 30 min such that the mid point of each tow had the same coordinates. This configuration was fished for other experimental reasons. The beam trawl was fitted with chain matrix and a sole net (8 cm mesh cod-end) and a 2 cm mesh liner. The plotted track was initially fished three times between 09.16 h and 10.44 h. Inspection of the catch revealed that dogfish, *Scyliorhinus canicula*, and two species of gurnard, *Eutrigula gurnardus* and *Aspatrigula cuculus*, occurred frequently in the catches. It was assumed that these species were actively feeding in the area and for this reason 30 specimens each of dogfish and gurnards were collected at random from the three hauls. Three hours after the third haul the same track was trawled three more times. Similarly, 30 fish each of dogfish and gurnard were collected.

In April 1993, the duration of all tows was 30 min. The 4-m beam trawl was rigged as before but without the liner. Trawling was carried out between 1200 h and 1800 h. Whiting, *Merlangius merlangus*, were also included in the analyses, as they occurred frequently in these hauls. After the first and last three tows the trawl tracks were surveyed with side-scan sonar. Shoals of fish were observed as dark spots on the paper. The size of each shoal was estimated by measuring its maximum dimension on the record. The perpendicular distance of each shoal from the trawl tracks was also recorded.

Fish total length (to the nearest -1 cm) and mouth gape width (±0.1 cm) (across the articulation of the jaws of dogfish and between the upper and lower jaws of gurnards) were measured for each fish using a measuring board and vernier callipers respectively. Each fish was eviscerated and its entire stomach preserved in 4% formalin for later identification of contents to species level (when possible). In the laboratory, stomachs were scored (0=empty to 10=full) for fullness and the contents weighed wet after blotting on tissue paper. The widest cross-sectional dimension of each prey item was measured using an eyepiece graticule and binocular microscope.

The composition of the benthic community was surveyed with a Day grab (n=5) and 4-m commercial beam trawl (as above) in March 1992, and compared to the stomach contents of the fish to determine whether they fed selectively and/or altered their feeding preferences immediately after the passage of a beam trawl.

## RESULTS

The catch rate of dogfish decreased from 3.43/min to 2.00/min after three consecutive tows, and remained at a low level even after a further interval of 3 h (1.11-0.99/min). Conversely, although the catch rate of gurnards decreased from 0.63/min to 0.30/min after the first three tows, after an interval of 3 h, catch rate had increased to 0.5/min, but again decreased to 0.36/min after the sixth tow.

As there was no significant difference between the relationship of prey width to gape width for either gurnard species (ANCOVA, $F_{1,125}=2.45$, $P>0.10$), the results were pooled. There was a significant relationship between the minimum width of the prey eaten and the maximum dimensions for gurnards ($r^2=0.10$, n=141, $P<0.001$) and dogfish ($r^2=0.07$, n=104, $P<0.001$) (Fig. 2). However, the high degree of variability in these relationships tends to suggest opportunistic feeding. The variation could not be explained by inaccurate measuring techniques as the relationships between fish length and gape width were highly significant (Table I). Neither gurnards nor dogfish significantly altered the size of prey eaten after intensive fishing (ANCOVA, gurnards, $F_{1,125}=0.12$, $P>0.70$; dogfish, $F_{1,104}=0.72$, $P>0.40$).

Out of a total of 61 species identified to date in the benthic community (28 infauna, 35 epifauna), dogfish fed on ten whereas gurnards fed on only seven species (Table II). All the prey types found in the stomach contents were epifauna, except for *Nephtys hombergi* and *Upogebia deltaura* (dogfish) and *Ampelisca brevicornis* (dogfish and gurnards). Gurnard stomach contents were composed almost entirely of crustaceans and fish, although there were occasional *Natica alderi* present. Conversely, dogfish commonly ate *Buccinum undatum, Eupagurus bernhardus* and *Upogebia deltaura.* Both types of fish ate dragonets, *Callionomus* spp.

The numbers of some prey items/stomach increased significantly in both gurnard and dogfish stomach contents after the beam initial beam trawling (Friedman's ANOVA, df.=1, $P<0.002$) (Fig. 3). Gurnards significantly increased their intake of *A. brevicornis* and *Crangon crangon* after the passage of the beam trawl, whereas dogfish only increased their intake of *A. brevicornis* (Table III). *Palaemon* spp. were only found in gurnard stomachs after beam trawling. Mean ±SE stomach fullness or stomach contents weight did not vary significantly for either dogfish or gurnards before or after trawling (Table IV). Preliminary observations of the stomach contents of whiting from the last three hauls indicated that they had been feeding on the gonads of the purple heart urchin, *Spatangus purpureus.*

No evidence of fish shoals was observed on the side-scan records after the first three tows were completed. However, after the second three tows intense dark patches were observed most commonly over the area trawled (Fig. 4). These were seen also on the ship's echo sounder and are assumed to be shoals of fish (possibly whiting). Over a 480 m track 24 fish targets were recorded directly over the trawl tracks, 14 were observed within 25 m of the tracks and 10 were observed between 75 to 100 m away from the tracks (Table V, Fig. 4). The targets over the trawl tracks appear to be larger ( ie. more than one fish) than those over the unfished area (Table V).

## DISCUSSION

The relationship between mouth gape width and critical prey width indicates that dogfish and gurnards broaden their diets as they increase in size, but do not tend to specialise on a particular range of prey sizes. This suggests opportunistic feeding tendencies rather than highly selective feeding behaviour as in some other species (eg Kaiser et al., 1992). In studies of the spiny dogfish, *Squalus acanthias* (L.), as fish increased in size they tended to include more fish in their diet, concentrating on crustaceans when they were smaller (Jones & Geen, 1977; Tanasichuk et al., 1991). Evidence suggests that *S. canicula,* feed opportunistically like *S. acanthias* (Hanchet, 1991), as their diets tend to be unspecialised. Mean stomach fullness and stomach contents weight did not seem to increase after intensive beam trawling, suggesting that fish tended to feed on small prey immediately after trawling eg. the amphipod, *A. brevicornis*. Although *A. brevicornis* was common in the stomach contents of dogfish prior to intensive beam trawling, it was less common in those of gurnards. However, the stomach contents collected after intensive beam trawling were dominated by *A. brevicornis* for both dogfish and gurnard. *L. holsatus* and *C. crangon* both increased in the diets of gurnard after beam trawling. Swimming crabs and shrimps are mobile epibenthic scavengers (Hall et al., 1990; Hedqvist-Johnson & Andre, 1991), which may congregate around beam trawl tracks by responding to the scent of the damaged animals produced by trawling (Nickell & Moore, 1992). Conversely, these animals may themselves have been killed by the beam trawl and thence become available to other predators.

The increase of certain species in the stomach contents was assumed to be unaffected by diel variations in feeding activity as all the fishing was carried out between 09.00 h and 18.00 h. Moreover, we found no evidence in the published literature to suggest that either dogfish (Lyle, 1979), whiting (Dahl & Kirkegaard, 1986) or gurnards exhibit diurnal feeding patterns. The occurrence of shoals of fish detected by the side-scan sonar in the vicinity of the trawl tracks also coincided with dusk, which may be attributed to diurnal shoaling behaviour. The shoals of fish (presumed to be whiting) were viewed simultaneously on an echo sounder and were positioned within 1 m of the seabed. This observation, coupled with the large proportion of shoals directly over the trawl tracks, and the occurrence of sea urchin gonads, which would not ordinarily be available to fish, in the stomach contents strongly suggests that fish feed opportunistically in the wake of the trawl.

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**Table I.** The relationship between fish standard length (cm) and fish mouth gape width (cm) for both dogfish and gurnards.

| Species | n | Equation | $r^2$ | P |
|---|---|---|---|---|
| Dogfish | 60 | gape width = 0.037 fish length +1.74 | 0.48 | 0.0001 |
| Gurnards | 60 | gape width = 0.111 fish length -0.36 | 0.74 | 0.0001 |

**Table II.** A list of the groups of animals and some of the main species occurring in the benthic community and their occurrance in the stomach contents of gurnards (G) and dogfish (D).

| Epifauna | G | D |
|---|---|---|
| **Tunicates** | | |
| *Ascidia mentula* | | |
| **Bryozoans** | | |
| **Echinoderms** | | |
| *Asterias rubens* | | |
| *Astropecten irregularis* | | |
| *Henricia sanguinolenta* | | |
| *Crossaster papposus* | | |
| *Ophiura texturata* | | |
| *Ophiothrix fragilis* | | |
| *Echinus esculensis* | | |
| *Psammechinus miliaris* | | |
| *Spatangus purpureus* | | |
| *Paracucumaria hyndmani* | | |
| **Molluscs** | | |
| *Eledone cirrhosa* | | |
| *Sepia atlantica* | | |
| *Buccinum undatum* | | D |
| *Neptunia antiqua* | | |
| *Calliostoma zizyphenum* | | |
| *Aequipecten opercularis* | | |
| *Modiolus modiolus* | | |
| *Colus gracilis* | | |
| *Ensis ensis* | | |
| *Dosinia* sp. | | |
| **Crustaceans** | | |
| *Cancer pagurus* | | |
| *Liocarcinus puber* | | |
| *Liocarcinus holsatus* | G | D |
| *Corystes cassivelaunus* | | |
| *Hyas areneus* | | D |
| *Pilumnus hirtellus* | | |
| *Macropodia tenuirostris* | G | |
| *Eupagurus bernhardus* | | D |
| *Eupagurus prideauxi* | | |
| *Crangon crangon* | G | D |
| *Palaemon* spp. | G | D |
| *Upogebia deltaura* | | D |
| **Polychaete** | | |
| *Aphrodite aculeata* | | D |
| **Hydroids** | | |

| Infauna | G | D |
|---|---|---|
| **Crustaceans** | | |
| *Ampelisca brevicornis* | G | D |
| *Ampelisca macrocephela* | | |
| *Corophium crassicorne* | | |
| *Dexamine spinosa* | | |
| *Urothoe marina* | | |
| *Cirolana cranchil* | | |
| Mysid juveniles | | |
| **Polychaetes** | | |
| *Scoloplos armiger* | | |
| *Ampharete acutifrons* | | |
| *Pectinaria koreni* | | |
| *Lepidontes squaminifera* | | |
| *Eteone longa* | | |
| *Nephtys hombergi* | | D |
| Maldonidae | | |
| Spionidae | | |
| Syllidae | | |
| Orbinidae | | |
| Glyceridae | | |
| **Molluscs** | | |
| *Nucula nitidosa* | | |
| *Spisula* sp. | | |
| *Venerupis* sp. | | |
| *Doto* sp. | | |
| *Parvicardium scabrum* | | |
| *Dosinia* sp. | | |
| *Natica* sp. | G | |
| **Echinoderms** | | |
| *Ophiura fragilis* | | |
| *Psammechinus miliaris* | | |
| *Ophiura texturata* | | |
| **Oligochaetes** | | |
| **Nematodes** | | |
| **Anthozoans** | | |
| *Adamsia palliata* | | |
| *Alcyonium digitatum* | | |

**Table III.** The mean±SE number of prey/stomach (for the three most important prey in stomach contents) for dogfish and gurnards before and after fishing with a 4 m commercial beam trawl. Significant differences were determined with ANOVA on log (x+1) transformed data.

| Species | Before | After | F | P |
|---|---|---|---|---|
| **Dogfish** | | | | |
| *Ampelisca* | 0.53±0.18 | 1.81±0.39 | 10.5 | 0.002 |
| *Upogebia* | 0.50±0.13 | 0.55±0.16 | 0.06 | 0.800 |
| *Eupagurus* | 0.33±0.09 | 0.42±0.09 | 0.47 | 0.496 |
| **Gurnards** | | | | |
| *Ampelisca* | 0.15±0.01 | 2.00±0.92 | 5.10 | 0.030 |
| *Liocarcinus* | 0.52±0.30 | 0.90±0.31 | 0.76 | 0.390 |
| *Crangon* | 0.42±0.23 | 1.28±0.32 | 4.50 | 0.040 |

**Table IV.** The mean±SD stomach contents wet weigth (g) and fullness (scale of 0-10, empty-full) for dogfish and gurnards before and after intensive beam trawling (n=60).

| Species | mean±SE | F | P |
|---|---|---|---|
| **Fullness** | | | |
| Dogfish | before 4.23±2.80<br>after 4.63±3.21 | 0.28 | 0.50 |
| Gurnards | before 3.36±3.65<br>after 5.04±3.23 | 2.38 | 0.10 |
| **Contents weight** | | | |
| Dogfish | before 7.67±9.15<br>after 4.06±4.56 | 2.48 | 0.10 |
| Gurnards | before 0.98±2.57<br>after 1.10±1.20 | 0.04 | 0.80 |

**Table V.** The size distribution of shoals of fish observed over the trawl tracks (±25 m of the centre of the trawled area) and in unfished areas. Shoal size is measured on a scale of 1-5, taken directly from the side-scan record. The number of shoals directly over trawl tracks and in the adjacent areas for a 480 m length of side-scan record is also given.

| **Number of shoals** | **Shoal size** | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **>5** |
| Trawl tracks | 2 | 11 | 5 | 7 | 3 | 5 |
| Unfished area | 1 | 4 | 5 | 2 | 3 | 0 |

| | **Distance from trawl track** | | | | |
|---|---|---|---|---|---|
| | **0 m** | **25 m** | **50 m** | **75 m** | **100 m** |
| Number of shoals | 24 | 14 | 0 | 2 | 8 |

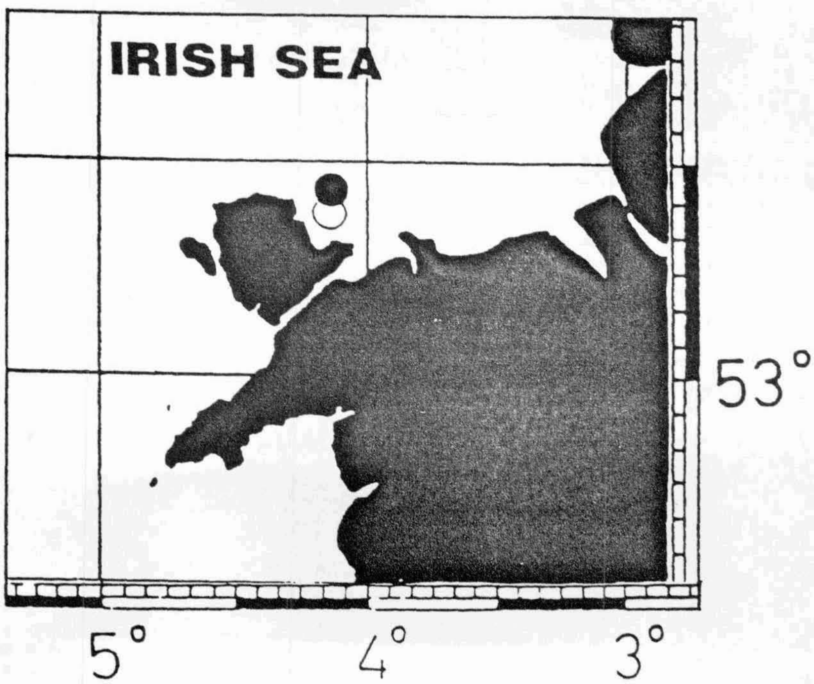


**Figure 1.** A map showing the location of the study area in the Irish Sea and the position of the 4-m beam trawl tows made in A) August 1992 (●) and B) April 1993 (○).

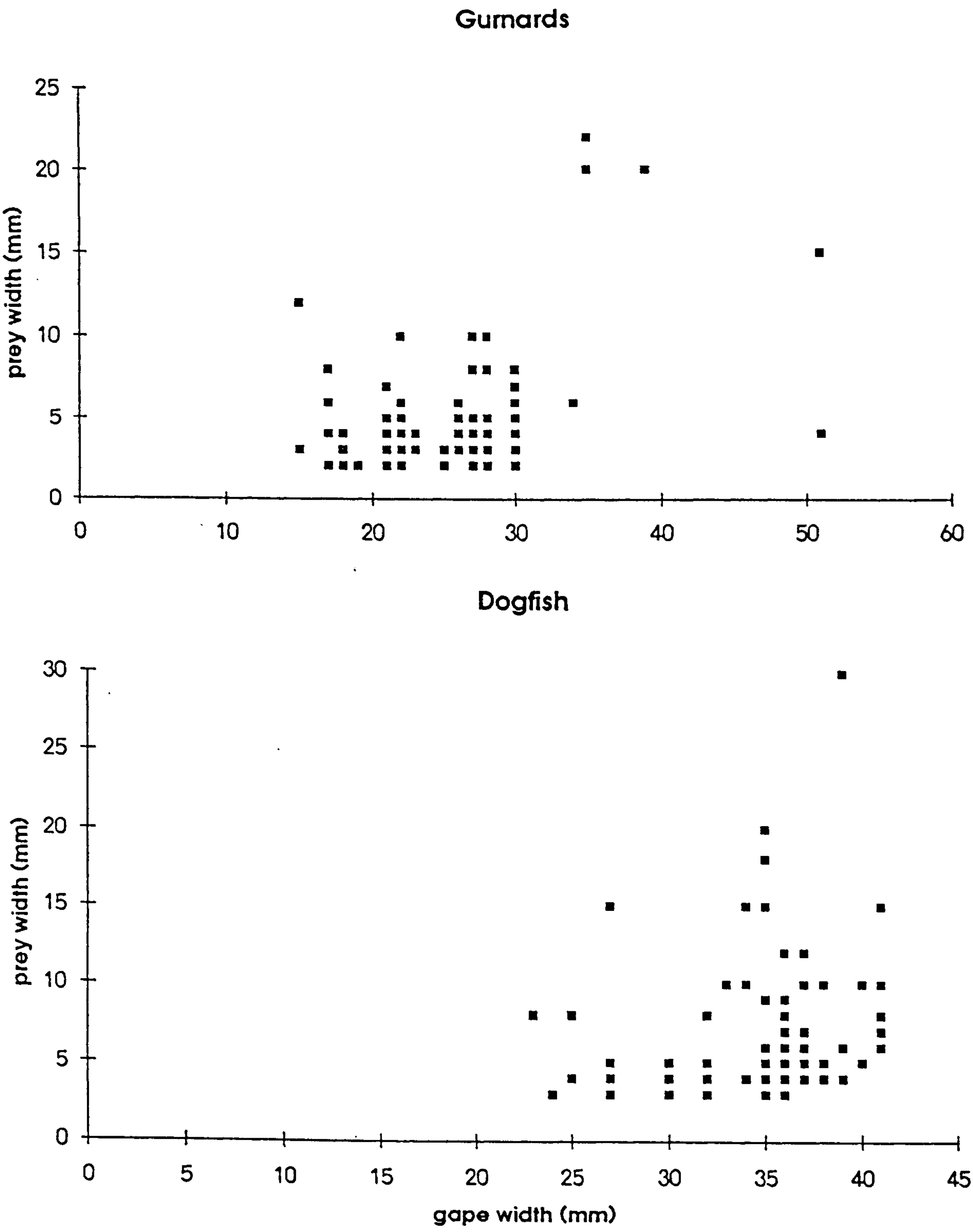


**Figure 2.** Relationship between fish gape width (mm) and prey width for both gurnards (pw=0.21gw-0.11) and dogfish (pw=0.25gw-2.33).

**KEY**
L.h=*Liocarcinus holsatus*
Cr=*Crangon crangon*
P.s=*Palaemon* spp.
Amp=*Ampelisca brevicornis*
Upo=*Upogebia deltaura*
Eu=*Eupagurus bernhardus*
Bu=*Buccinum undatum*
Po=Polychaetes
Mpd=*Macropodia* spp.
Na=*Natica alderi*
C.s=*Callionymus* spp.
o=others

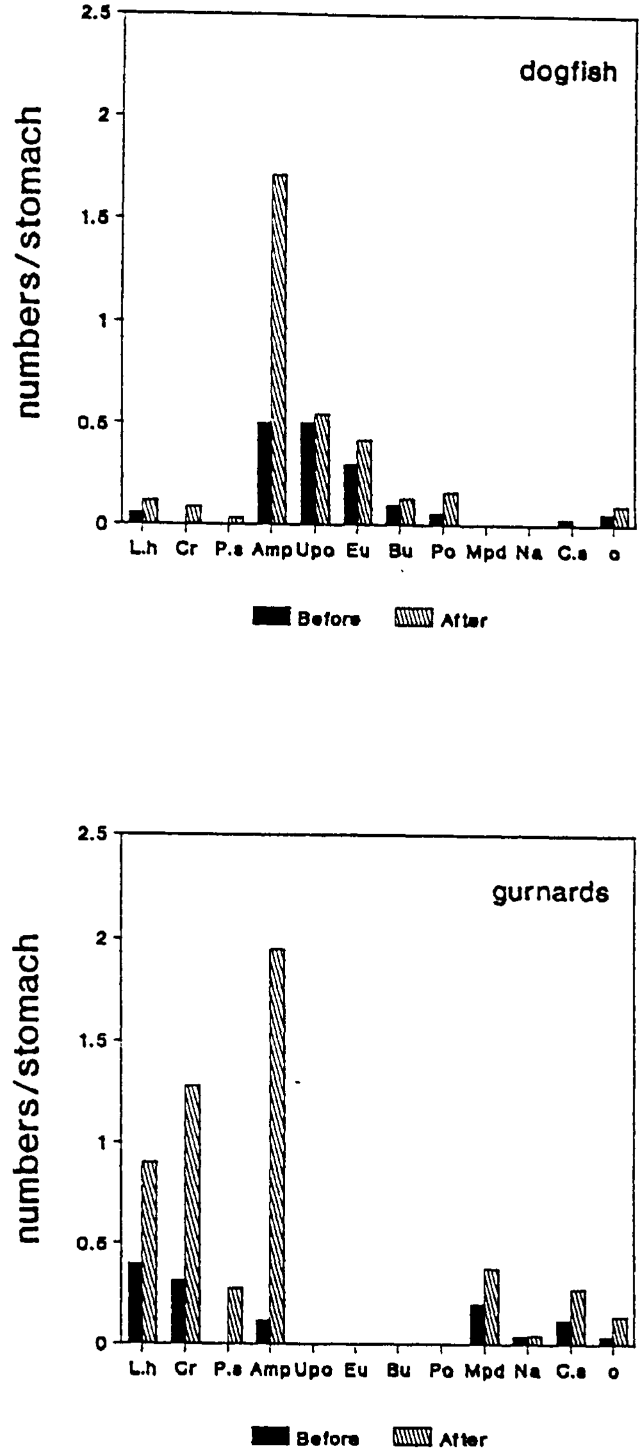


**Figure 3.** Mean number of prey/stomach for gurnards and dogfish before and after fishing with a 4-m commercial beam trawl.

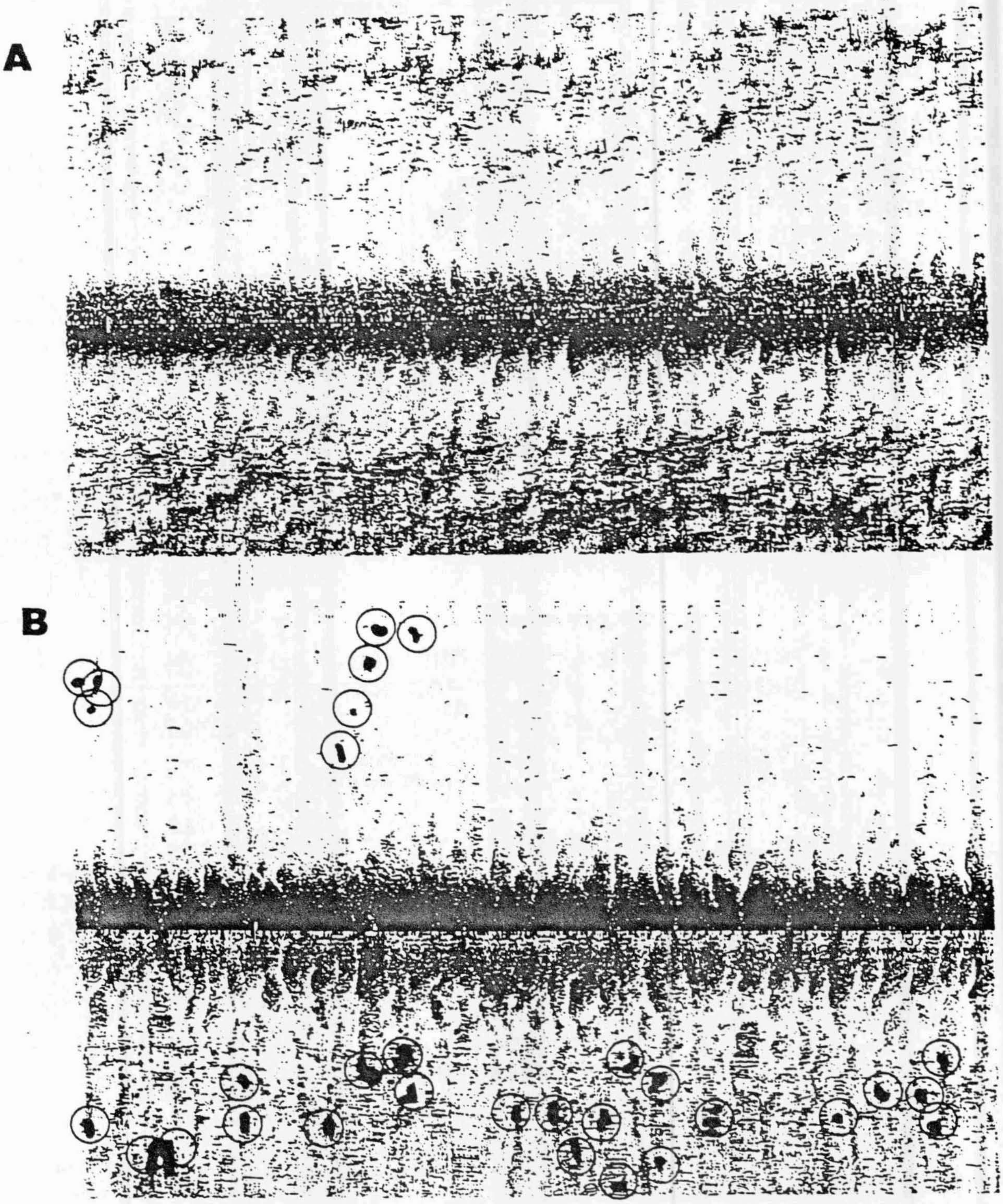


**Figure 4.** A) A side-scan record of 480 m of the trawl tracks after the first 3 tows recorded at 1500 h and B) the same area after 6 tows, the encircled dark areas are shoals of fish, which were observed simultaneously on an echo-sounder. Trawl tracks are visible in the lower half of each side-scan record.

# CANADIAN PROJECT TO EVALUATE THE IMPACTS OF MOBILE FISHING GEAR ON BENTHIC HABITAT

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

**by**

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## Introduction

The fishing industry in Atlantic Canada uses a variety of mobile gear types. The most common are otter trawls, scallop rakes and hydraulic clam dredges. While there has for a number of years been concern as to the possible effects that these harvesting methods may have on fish stocks and the habitat supporting them, it was not until recently that events in the Canadian east coast fishery resulted in the initition of an active research project to study fishing impacts.

Previous studies by others have already identified or suggested the following possible effects:

- direct mortality of organisms harvested, captured but discarded, or 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 its suitability for particular species.

Because of the complicated nature and scope of the issue, it will take many years of carefully directed research to fully evaluate all of these possible effects.

History and Accomplishments to Date

The project formally began in the summer of 1990 as a result of recommendations coming out of task forces established to review northern cod in the Newfoundland Region (Harris 1990) and groundfish in the Scotia-Fundy Region (Haché 1989). Funding for research on mobile gear impacts was established under the Northern Cod Science Program (Newfoundland Region) and Atlantic Fisheries Adjustment Program (Scotia-Fundy) and scientists were asked to design new projects. The benefits of collaboration between the two Regions were recognized from the very beginning, and scientists from the Northwest Atlantic Fisheries Centre and the Bedford Institute of Oceanography have worked closely together to develop this joint project. An early decision was made to restrict the first studies to the impacts of otter trawls, this being the most widely used form of mobile gear in both Regions.

A review of previous gear impact studies in Atlantic Canada was carried out as part of a broader evaluation of major anthropogenic impacts on the marine environment This resulted in a review paper on the impacts of trawling, dredging, and ocean dumping on the eastern Canadian continental shelf being prepared by Messieh et al. (1991).

More directed efforts have involved:

i. Analysis of all already available side-scan sonar records

Both Regions have funded contracts with Maritime Testing (1985) Ltd. to review existing side-scan sonar records for evidence of bottom disturbance from mobile fishing gear.

The results from the Scotia-Fundy study, funded and led by the Fisheries and Habitat Management Branch, indicate that less than 2% of the side-scan sonar records available (which were collected for other purposes) contained any evidence of physical disturbance from mobile fishing gear (Jenner et al. 1991). Most of the observed disturbance was due to groundfish trawls and was restricted to areas of low sediment transport.

About 15,000 km of side-scan sonar records from the Grand Banks were reviewed for evidence of tracks left by otter trawling. 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.

ii.Survey of fishing disturbance in the Bras D'Or Lakes

A contract, funded by the Industry Services and Native Fisheries Branch, was awarded to determine the distribution and physical characteristics of mobile fishing gear generated marks on the seabed in the Bras D'Or Lakes using side-scan sonar. The survey included: the establishment of a fresh Danish seine track to assist interpretation of the survey data; the seperate mapping of disturbances due to trawl, Danish seine, and inshore scallop gears; and the determination of seabed types affected by both interpretation of side-scan records and ground truthing by means of grab sampling.

Approximately 240 km of survey lines were covered using a high-resolution side-scan and a bottom profiler in the East Bay, Groves Point, and St. Andrews Channel areas. The data collected has provided information as to the nature and distribution of the various fishing gear disturbances and will serve as a baseline for any further studies in the area. Because of the close proximity of similar bottom types in fishable and non-fishable (due to geographic features) areas, and the shallow depths (e.g. 10 m) encountered, the Bras D'Or Lakes represent a unique opportunity for contolled gear impact studies in a protected inshore environment.

iii. Minas Basin experiments

With the collaboration of Acadia University, the Scotia-Fundy Region investigated the impacts of otter trawls on the intertidal sediments of the Minas Basin (11 m tidal range). Experimental trawl tracks were made at high tide and observations of effects were made at low tide when the intertidal area was exposed. Door furrows and roller marks remained visible for 2-7 months. No significant impacts were observed on either benthic diatoms or macrobenthos (dominated by polychaetes) while nematode numbers were initially depressed in the door furrows but did recover with time. Overall, the impacts are 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 damage from mobile gear. A manuscript has been submitted for publication in the Canadian Journal of Fisheries and Aquatic Science (Brylinsky et al. 1993).

iv. Equipment development

Research on the effects of mobile fishing gear on continental shelf benthic habitat requires equipment to sense and sample the seafloor. Side-scan sonar is available for detecting physical disturbance but additional equipment is necessary for determining biological effects. As part of this program, existing equipment has been improved and new equipment developed. Included are:

BRUTIV

The Metrology Division at BIO has refurbished and made improvements to BRUTIV which significantly enhance its usefulness as a towed camera and instrument platform. It is fitted with both video and still cameras to provide imagery information and will soon be adapted to carry both OBS and side-scan instruments. Its bottom referencing system now allows it to be towed dependably at 3-4 knots within a meter or less of the seafloor.

Epibenthic Sled

Modifications have been made to an existing video-equipped sled (French AQUAREVE III design) to improve its quantitativeness in sampling epibenthic organisms. These improvements include changes to the mouth and cutting blade, the mouth closuring door, dual odometers, wider runners, and improved camera positioning.

Video Grab

With financial support from both Regions, plus the Atlantic Geoscience Centre (AGC), and engineering support from the Engineering and Technical Services Division at BIO, a completely new video grab was designed, built, tested, and used in the 1992 cruise. A high resolution colour video system allows scientists to obtain excellent imagery information of the seafloor and to collect grab samples in microhabitats of particular interest (trawl mark, iceberg scour, undisturbed area, etc.). The grabbing operation can be watched through a monitor and poor samples discarded immediately without having to bring the equipment back on ship.

High Resolution Acoustics System

The Newfoundland Region is funding a contract with Guigné International Ltd. to develop high resolution acoustical imaging methods to detect organisms and biogenic structures in surficial sediments. The resolution of this new technology allows detection of structures on the order of millimetres in size to a depth of at least 0.5 m in sediments. The imaging is non-destructive, allowing time-course observations. Present development is focused on both hardware and artificial intelligence software. The acoustical head is being designed initially for mounting on the video grab where its use will allow combined video, acoustic and physical sampling of a single area of sediment. The primary use of this technology in the present project will be to follow the time course of re-establishment of biogenic structuring in sediments disturbed by trawling.

v. Field assessment of study sites (Western Bank and Grand Bank)

Cruises were conducted in 1991 (C.S.S. *Dawson*) and 1992 (C.S.S. *Parizeau*) to locate suitable sites for trawling impact experiments. 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

Two general areas have been investigated; Western Bank on the Scotian Shelf (Fig. 1) and a region northeast of the Hibernia site on the Grand Banks (Figs. 2 & 3).

Western Bank is in the 4TVW haddock nursery area (Management Area A) which has been closed year round to mobile groundfish gear for conservation purposes since 1987. However, it is open to scallop dredging, and physical disturbance from scallop dredges can be detected by side-scan sonar. Two specific areas have been surveyed as possible study sites; Area A is centred at 43° 28' N, 61° 41' W in an average depth of 74 m and Area B is centred at 43° 35' N, 61° 58' W in an average depth of 91 m. Area A was surrounded by recent scalloping activity in 1992 while Area B seems to be further removed from scalloping activity. Sediments at Area A are easier to sample than those at Area B. The fauna at both sites is similar.

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. This site was selected in consultation with industry. It has not been subjected to heavy trawling in the past decade, and steps are underway to close it for an indefinite period to all mobile gear for the purposes of this project. The predominantly mixed fishery in the area produces relatively small catches of cod (16-20%) compared to plaice and flounder, especially in the 100 to 150 m depth stratum, according to DFO research trawls. We hope to be able to discern whether competition or predation may be responsible for the apparently low cod biomass in this region since physical factors do not seem to be involved. Side-scan sonar surveys in the area show no physical disturbance from fishing gear but one iceberg furrow crosses the area. The sediment is a 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.

vi. International collaboration

Contacts have been developed with scientists from European countries who are conducting similar studies of trawling impacts. Magda Bergman from the Netherlands Institute for Sea Research participated in the 1992 cruise and further Canadian-Dutch collaboration is planned for the future. Dr. Jens Prena from Rostock, Germany joined the project in October 1992 for a two year period under German funding, and a graduate student, from the Agricultural University of Wageningen, the Netherlands, will join the project for 6 months commencing in mid-June 1993.

Immediate Plans

i. Equipment development

Work will continue on the development of an acoustical system for sensing benthic habitat. Field trials will begin in 1993. Further improvements to BRUTIV, the epi-benthic sled, and the video grab are being carried out and will be completed and tested prior to the 1993 cruises.

ii. Trawling experiment

Two controlled trawling experiments, conducted in collaboration with the AGC, are planned for the Grand Banks site beginning in 1993. Plans are still evolving and the final details, such as the frequency of follow-up sampling cruises, will depend upon resources available. Shiptime has been provided on both the research trawler *Wilfred Templeman* and the research vessel *Parizeau*. The *Wilfred Templeman* will perform the experimental trawling using a standard industry otter trawl equipped with rockhopper rollers. One experiment involves the laying down of a single 60 km long trawl mark that crosses a variety of bottom types (of prime interest to the geologists) while the other is based on the intensive trawling of three corridors, The corridors, each on the order of 200 m wide and 12 km long, will be randomly oriented within the "Closed Area". The *Parizeau* will conduct side-scan sonar, BRUTIV and biological sampling surveys just before the experimental trawling, immediately thereafter, at one and three months, and at one year. Sampling will also be conducted at nearby control sites. In the first year, all corridors will be trawled at the same level of intensity. In subsequent years, different levels of trawling intensity and frequency are being considered. There is a possibility that the manned submersible *Pisces* will be available for work at the experimental site in 1994. A more detailed outline of the planned experiments is attached as APPENDIX I

iii. Consultation

It is essential that the trawling experiments are designed to address as much as possible the questions faced by fisheries and habitat managers and that they produce unequivocal results that can be clearly communicated to industry. It is also important that they be conducted under realistic trawling conditions. Therefore, consultation is necessary not only with other scientists, but with fisheries and habitat managers and the fishing industry.

In the Scotia-Fundy Region, there has been continual consultation with the Industry Services and Native Fisheries Branch. A workshop was held at BIO on 19 October 1992 to review project progress and future plans. A briefing session for the Fisheries and Habitat Management Branch has been offered. It has been proposed that consultation with industry be handled through the Atlantic Groundfish Advisory Committee (AGAC) and a request to make a presentation has been made. As word of this project spreads, numerous fishermen have called directly to BIO for information and to offer advice.

In the Newfoundland Region, regular working consultation has been established with a fishing gear technologist in the Science Branch, and also with staff of the Industry Development Division. The project has been described to the Northern Cod Science Advisory Panel and to the Newfoundland Inshore Fisheries Association. Feedback from these groups has been useful. Industry liaison has been through the Fisheries and Habitat Management Branch.

iv. Communication of results

Because of the widespread interest in this project outside of DFO and the divergent viewpoints on the seriousness of trawling impacts, it is important that the research results be released in an organized format simultaneously to all interest groups. It has been proposed that DFO organize an annual meeting at which new results are presented to all interested parties. Perhaps such a meeting could be organized in cooperation with the Scientific Peer Review Committee. Communication of activities and results in the popular media are also planned as a useful adjunct to more formal communications such as publications and conferences.

## Long Term Plans

Assuming that significant effects are observed, the experiment planned for the Grand Banks in 1993 will continue for several years. It is proposed that, in addition to the planned re-trawling and sampling of the Grand Banks site in 1994, a second experiment might be started on Western Bank in 1994 using the same gear and experimental design. Further experiments could possibly consider other gear types and geographic locations.

## Contacts

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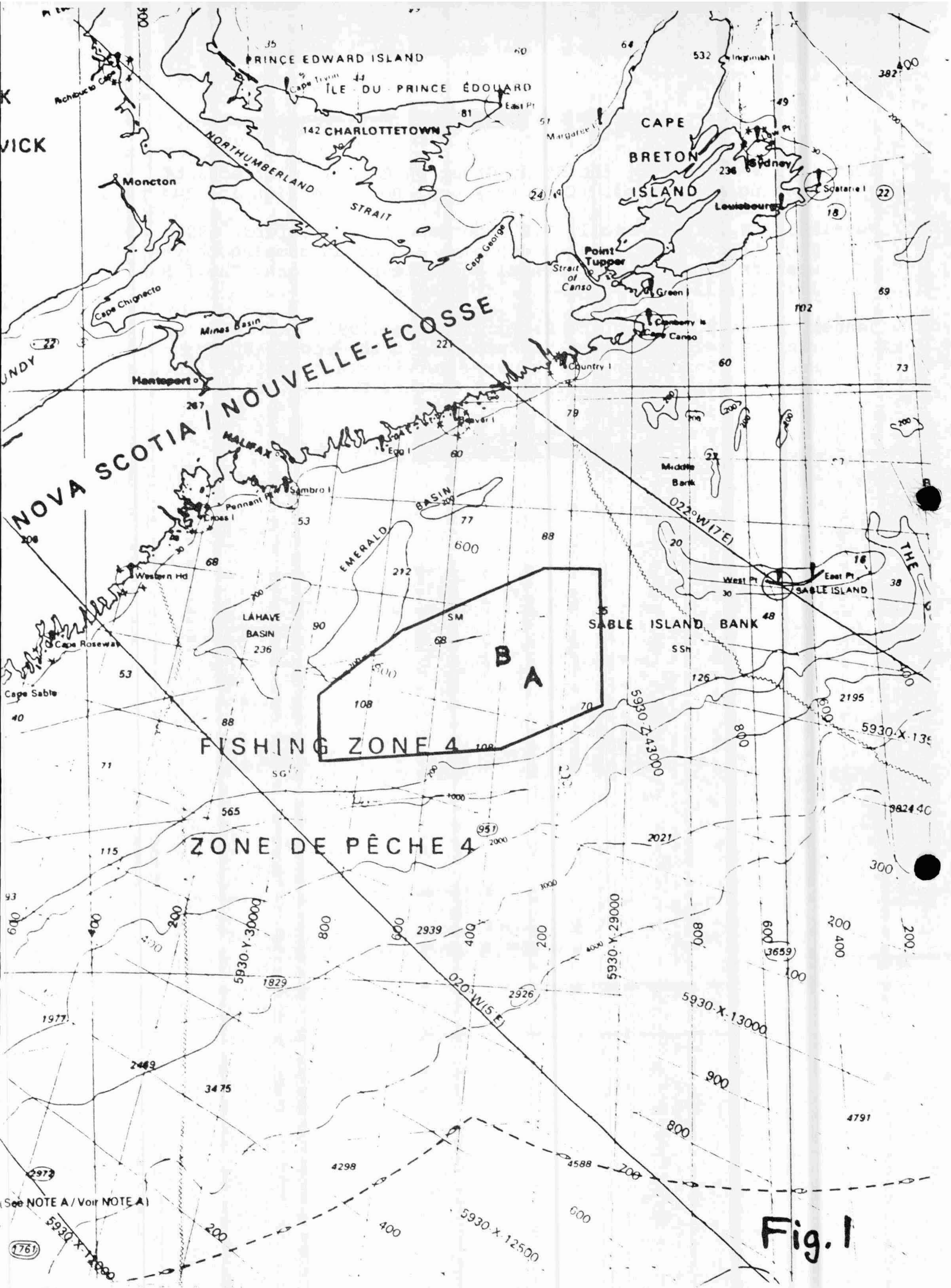
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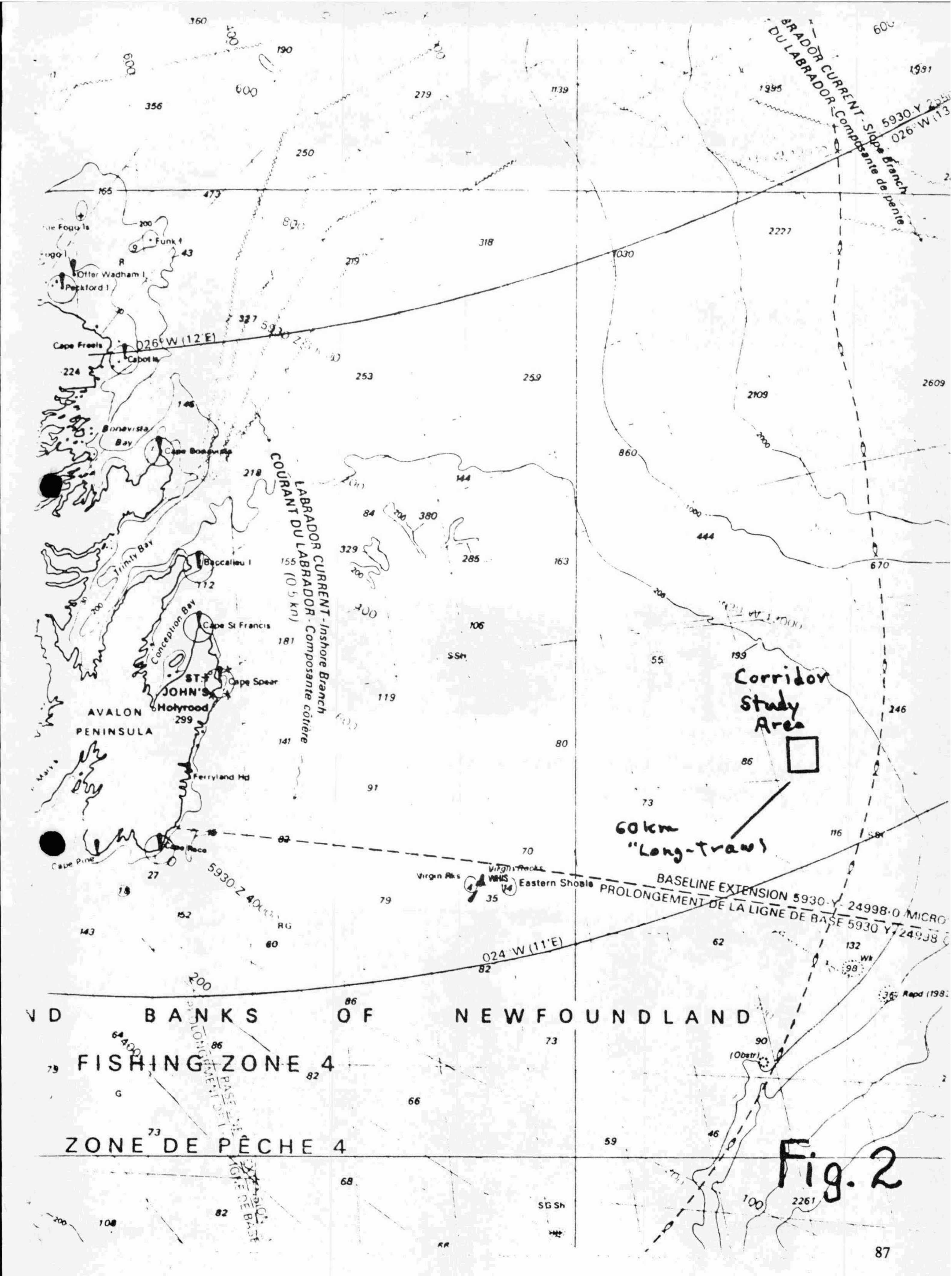
ÎLE DU PRINCE ÉDOUARD
CHARLOTTETOWN
NORTHUMBERLAND STRAIT
Moncton
Cape Chignecto
Minas Basin
Hantsport
NOVA SCOTIA / NOUVELLE-ÉCOSSE
HALIFAX
Sambro I
Pennant Pt
Western Hd
Cape Roseway
Cape Sable
CAPE BRETON ISLAND
Sydney
Louisbourg
Scatarie I
Point Tupper
Strait of Canso
Green I
Canso
Country I
Middle Bank
EMERALD BASIN
LAHAVE BASIN
SABLE ISLAND BANK
SABLE ISLAND
West Pt
East Pt
022°W(17'E)
020°W(5'E)
B
A
FISHING ZONE 4
ZONE DE PÊCHE 4
5930-Y-30000
5930-Y-29000
5930-Z-43000
5930-X-13000
5930-X-12500
(See NOTE A / Voir NOTE A)
Fig. 1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DU LABRADOR - Composante de pente
LABRADOR CURRENT - Inshore Branch
COURANT DU LABRADOR - Composante côtière
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Funk I
Offer Wadham I
Peckford I
Cape Freels
Cabot Is
Bonavista Bay
Cape Bonavista
Trinity Bay
Baccalieu I
Conception Bay
Cape St Francis
ST JOHN'S
Holyrood
Cape Spear
AVALON
PENINSULA
Ferryland Hd
Cape Race
Cape Pine
Virgin Rks
Virgin Rocks
Eastern Shoals
BASELINE EXTENSION 5930-Y-24998·0 MICRO
PROLONGEMENT DE LA LIGNE DE BASE 5930 Y
026 W (12 E)
024 W (11 E)
Corridor Study Area
60km "Long-trawl"
BANKS OF NEWFOUNDLAND
FISHING ZONE 4
ZONE DE PÊCHE 4

Fig. 2

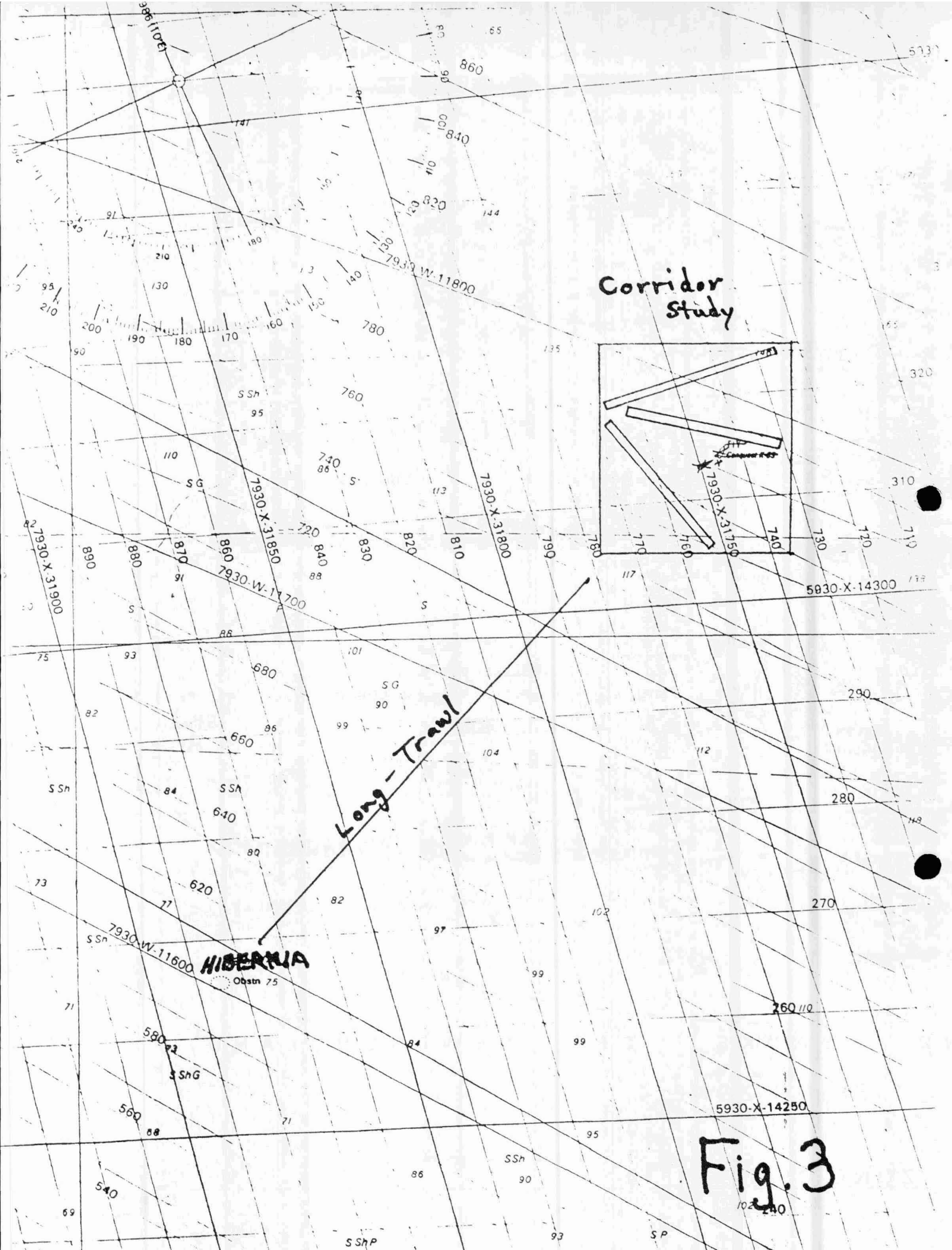
Corridor Study
Long-Trawl
HIBERNIA
Obstn 75
7930-W-11800
7930-W-11700
7930-W-11600
7930-X-31900
7930-X-31850
7930-X-31800
7930-X-31750
5930-X-14300
5930-X-14250

Fig. 3

**APPENDIX I**

# TRAWLING IMPACT STUDIES
# GRAND BANK

History of Project

A joint project of Scotia-Fundy and Newfoundland Regions.

For the study we needed to:

- define the questions to be addressed.
    - does trawling significantly change the habitat in either the short term or the long-term?
    - if so, how does this habitat change in turn change the benthic communities?
    - do direct or indirect mortalities of the benthos ultimately change the benthic communities?
    - how do these changes in the benthos impact fish feeding, fish biomass, fish species composition (catch composition), and fish distribution?
    - how do habitat changes impact spawning, juvenile fish survival, etc., and ultimately fish biomass and species compositon?
- select the best site.
    - examined two possible "closed" areas (Western Bank, Grand Bank) and selected the latter.
- have the best possible sampling gear.
    - decided to build a new grab with very unusual capabilities (video, powered jaws, rearmable in situ)
    - decided to test, then modify, the epibenthhic sled to optimize its performance
    - decided to support the upgrading of BRUTIV
    - decided to support the design and development of a revolutionary new high-resolution acoustic, in situ, benthic imager with Guigné International
- have very accurate navigation and positioning capabilities for

the research vessels, the fishing gear, and the sampling gear. Must know exactly where the samples are from (i.e. area disturbed by a door vs. one disturbed by the footrope, belly, etc.).

- Through collaboration with the Atlantic Geoscience Centre (AGC), have use of:
  - AGCnav
  - Differential GPS
  - Trackpoint( on doors, body of trawl, and on sampling gear)

- have the optimal design for data and information capture.
  - consultations have taken place with scientists at ICES and at NIOZ and a chief scientist in the Netherlands' studies participated in the our '92 Trawling Impact Cruise.
  - design will be finalized only after reviewed by a reseach statistician.

Design of Studies

- two studies:
  - Corridor Study (main study to be carried out in the "closed" area on the Grand Bank)
  - Long-trawl Study ( 60 km long track over differing depths and energy regimes between the "closed" area and Hibernia).

i) Corridor Study

- "closed" area is a 10 nm x 10 nm box in 137 m of water approx. 60 km NW of Hibernia.
- seabed (medium-fine sand) and benthos are very homogeneous.
- three randomly oriented corridors, each approx. 12 km long x 200 m wide, will be established within the box.
- each corridor will be divided into three end-to-end sections approx. 4 km long.
- all sections within the corridors will be trawled at the same level of intensity in year one.

- sections of the corridors will be trawled at different levels of intensity in subsequent years:
    - two sections trawled a second time in year two
    - one section trawled a third time in year three
- the above regime will allow us to determine the differences in impact of single vs. repeated trawling.
- sampling will be carried out:
    - immediately prior to trawling
    - immediately after trawling
    - three to four weeks after trawling
    - two to three months after trawling
    - one, two, and three years after trawling
- during all sampling in year one, an attempt will be made to determine the impacts of particular parts of the trawl (doors, rollers, codend) with the video-grab.
- in year two and three, the video-grab will again be used in an attempt to determine the impacts of particular parts of the trawl, but only in the newly re-trawled sections.
- in the area(s) trawled only in the previous year(s), video-grab sampling will be divided between areas of apparent and non-apparent disturbance, if differentiable.
- because of the length of tow it requires, the epibenthic sled cannot selectively sample for the impacts of particular parts of the trawl, but will sample the general trawled area.
- sampling will be carried out on the:
    - epifauna
        - visual record of spatial distribution and density of surficial megabenthos using the video-grab and possibly BRUTIV
        - semi-quantitative estimates of density and biomass of megabenthos using the epibenthic sled
        - semi-quantitative estimates of damage and mortalities of megabenthos as a result of trawling using the epibenthic sled

- infauna - quantitative estimates of density and biomass of meiofauna, macrofauna, and megafauna using the video-grab

- sediments - seabed morphology using side-scan sonar, video-grab, and BRUTIV
  - changes in sediment structure, porosity, grain size, and CNS using the video-grab
  - changes in sediment structure and grain size using the video-grab and high-resolution acoustic imager
  - changes in biogenic structures, such as worm tubes and burrows, using the high-resolution acoustic imager

- fish - quantitative estimates of the species and their biomass in the experimental area using the "rockhopper" trawl
  - quantitative estimates of the biomass of all species in the fish diet using fish caught in the trawl

- benthic samples will be analyzed to determine both short and long-term changes, rates of recovery to pre-trawled conditions,etc.

- fish studies will provide information as to the important species components of the fishes' diet, which can then be evaluated relative to species and biomass changes brought about by trawling.

ii) Long-trawl Study

- a continuous, 60 km long, trawl track will be laid down over differing depths and energy regimes between the "closed" area and Hibernia.

- water depth along the track will range from 75-150 m, sediments from medium-fine sand to medium and coarse sands, and bedforms from degraded iceberg furrow through continuous sand, sand ribbon, and sand ridge provinces.

- the track will be laid down with a single continuous tow of the "rockhopper" trawl with the codend open.

- this track will allow evaluation of the degree of impact the trawl has in differing energy, sediment, bedform, and biotic regimes.

- for AGC geologists, the track will serve as an analog for an iceberg scour over these same regimes.

- while the trawling is being carried out by the Templeman, the Parizeau will follow immediately behind and to the side producing a side-scan record of the newly created track.
- on completion of trawling and side-scanning, the track will be retraced using BRUTIV to produce a visual record of the trawl track.
- subsequent to this, the track and areas to the side of it will be sampled using the video-grab.
- the track will be re-sampled two to three months after trawling, during the same cruise as the re-sampling of the corridors in the main study.

Vessel coordination

During the first cruise, when the two studies are being established, it is imperative that the reseach vessel and trawler operations be closely coordinated. Figure 1 (Annex) details the basic schedule of operations established for the two vessels.

Fig.1 (Annex 1) Coordination schedule for operations of the research vessels Parizeau and Templeman for the initial sampling and establishment of the trawling impact experiment. The date shown above each column is the starting date for the operations listed in that column. *Corridor C will not be sampled immediately following trawling due to time limitations. It will be sampled along with Corridors A and B during the August cruise.

**JULY**

| | 1 | 6 | 7.5 | 9 | 10.5 | 12 | 13 |
|---|---|---|---|---|---|---|---|
| **Parizeau** | **Pre-Trawl Sampling of Control Areas and Corridors A,B, C*** | **Shadow Templeman with Trackpoint** | **Post-Trawl Sampling of Corridor A** | **Shadow Templeman with Trackpoint** | **Post-Trawl Sampling of Corridor B** | **Shadow Templeman with Trackpoint and Side-Scan** | **Post-Trawl Sampling of Long-Trawl** |
| **Templeman** | | **Trawl Corridor A** | **Trawl Corridor C *** | **Trawl Corridor B** | **Trawl Door Impact on Molluscs** | **AGC Long-Trawl 60 km** | |

# HIGH RESOLUTION AND BROADBAND PROCESSING OF ACOUSTIC IMAGES OF THE MARINE BENTHOS

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## ABSTRACT

High resolution acoustic imaging can be used to study benthic fauna and biogenic structures in near surface marine sediments. Currently used physical sampling methods disrupt structure and displace organisms, preventing the study of fauna in their natural sub-seabed setting. In addition to being important food for demersal fishes, the benthos living on and in the seabed sediments is strategic to the regeneration of nutrients which are vital to planktonic primary production. The benthos is thus an integral part of the fisheries production system. Through careful design, broad bandwidth acoustic signals can be generated to produce precision acoustical snapshots, with millimetre scale resolution, of the benthic fauna and of their undisturbed habitat. Advances in digital signal processing techniques fully exploit the information captured in this wide frequency domain. Unique classification and sorting of indices are made possible based on discrete frequency dependent signatures of the benthos. This paper presents the physics for precision characterization of the near surface seabed. Actual data are used to illustrate how broad bandwidth signals are necessary for the development of acoustic classifiers which recognize benthic fauna and their associated structures in sediments.

## 1. INTRODUCTION

The physical structure of the marine sub-bottom benthic habitat is determined to a large extent by benthic infaunal activities which, in aggregate, are referred to as bioturbation. Information on the biogenic structure of marine sediments thus provides information about the activities of benthic organisms, and about how these activities may be affected by anthropogenic disturbances. The impact of human disturbance on the marine benthos by a host of activities is drawing increasing attention as some economically important fish stocks decline. Reasons for stock decline are beyond the realm of current fisheries population prediction models.

Study of the ecology of the marine soft-bottom benthos has been hampered by some limitations of conventional grab and core sampling techniques (Mills, 1975). An important limitation is that the structural integrity of the sediment habitat is disturbed and ecological information is lost in the

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14-16 April 1993, Bath University, Institute of Acoustics, Underwater Acoustics Group".

process of retrieving and processing sediments to obtain quantitative biological samples. Non-destructive sampling techniques such as side-scan sonar, camera, and video can only provide structural information on surface megafauna and sediment features but cannot produce images of subsurface sediment texture, fauna, and biogenic structures associated with bioturbation. Rhoads and Germano's Remots sediment profiling system (Rhoads and Germano, 1982) is capable of obtaining high resolution data from a vertical sediment face and has been useful in studies of infaunal succession. It is, however, restricted to the imaging of a vertical face cut into the sediment, with resulting displacement of features and restriction to a two-dimensional image. While x-radiography may be used to obtain images of sub-surface sediment structures, it requires a lengthy and destructive sampling process which substantially alters the *in situ* character of the sample in the process of data collection. In addition, the information provided has proven to be of limited use as it is visual and non-quantitative in character.

In an attempt to introduce non-destructive imaging techniques to overcome some of the above-mentioned problems, Orr and Rhoads (1982) used a 1.6 MHz acoustic backscattering system to image lamination and simulated benthic organisms within the upper 7 cm of a marine test sediment. The system could produce an image of sediment lamination within 3 cm of the surface and of worm tubes that are built above the sediment surface. It could not detect simulated organism structures in the sediment. Until now, further work on very high resolution acoustic imaging of surficial sediment features has not been reported in the literature. A need exists therefore for high resolution imaging of subsurface features of the soft-bottom benthos over relatively large spatial and depth scales, and with near-real-time data return. Studies on the effects of physical disturbance of the benthos and their recovery rates would greatly benefit from the ability to rapidly collect information on subsurface structures and fauna in a non-destructive manner.

Acoustic methods for benthic ecological studies are dictated by the resolution required to distinguish organisms and biogenic structures within the sediment with minimum interference and masking. It is desirable that the temporal resolution of a sound source be such as to prevent interference between thin sediment layers and "point" sources associated with benthic fauna. A short, broadband signal and narrow beam will reduce this interference. This would provide better signal-to-reverberation ratios when scattering is present in the medium. However, such pulse characteristics are rarely achievable using conventional seismic profilers. A tradeoff occurs between temporal resolution and depth of penetration, with the former requiring broadband, high acoustic frequencies and the latter requiring low frequencies (Guigné, 1986). Common acoustic sources such as those used for fisheries and plankton studies, and for geological studies of marine sediments, operate within the constraints of these tradeoffs. One approach which shows promise is to employ non-linear acoustical technology. The development of the parametric array allows for a broadband source to be realized in practice

(Berktay *et al.* 1979). Its broad bandwidth and narrow beamwidth characteristics appear well suited for biological seabed applications.

The use of very broadband acoustics for benthic studies offers several advantages over physical sampling techniques. The response from temporally and spatially precise and coherent acoustics can indicate unique sediment characteristics. Images of biogenic structures and physical features of taxonomic groups of fauna can also be produced. These characteristics would be useful for non-destructive imaging of these features, especially where precise taxonomic information is less critical than non-taxonomic features of community structure. There are many instances in benthic ecological studies where these conditions would apply. For instance it would be considered strategic for rapid, non-destructive estimates of benthic biomass in areas of known faunal composition, and for studies of long duration effects of anthropogenic stress on benthic communities. The acoustic responses could be combined with periodic physical sampling to obtain correlative information on taxonomic shifts associated with acoustically-imaged structural changes.

Our objective has been to obtain high resolution acoustic images of trawled and untrawled areas of seabed to provide data on the impact of trawling on benthic productivity over the continental shelf of eastern Canada. Our custom-designed high resolution broadband array is to be mounted on a large area (0.5 $m^2$) pneumatically operated grab sampler equipped with a high resolution video camera. Further development is underway to deploy and operate the acoustic array on a bottom-referencing towed instrument vehicle. This acoustic-trawling study is part of the Northern Cod Science Program, instituted by Canada's Department of Fisheries and Oceans to investigate the decline of the valuable northern cod fish stock.

## 2. METHODS

Laboratory experiments were carried out in the research laboratory of Guigné International Limited (GIL), Newfoundland, Canada, and in mesocosms at Institut Maurice Lamontagne (IML), Québec, Canada. The latter were kindly made available for our use by Dr. Norman Silverberg and Dr. Jean-Marc Gagnon, Department of Fisheries and Oceans, Québec, Canada.

### 2.1 Experimental Setup and Calibration at GIL

Initial calibrations were performed in GIL's test tank (see Figure 1), using preserved animals. The tank was constructed of plexiglas with dimensions 120 cm length x 50 cm width x 100 cm height. A sheet of styrofoam was firmly fixed to the tank bottom as a highly reflective base. A moveable aluminum rack located across the top of the tank held the acoustic sensors in accurate alignment. The transducer and hydrophone were mounted in vertical stainless steel tubes held in the rack and driven by a worm gear device.

A parametric array transducer designed by Guigné International Limited was placed in fresh water 760 mm above the highly reflective bottom. A Brüel and Kjær 8103 cylindrical hydrophone was placed below the transducer and 360 mm above the bottom. This geometry was fixed throughout the tests. The broad secondary spectra produced from the source exhibited a range from 10 kHz to over 200 kHz. The signals showed a high level of coherency over the base reflector.

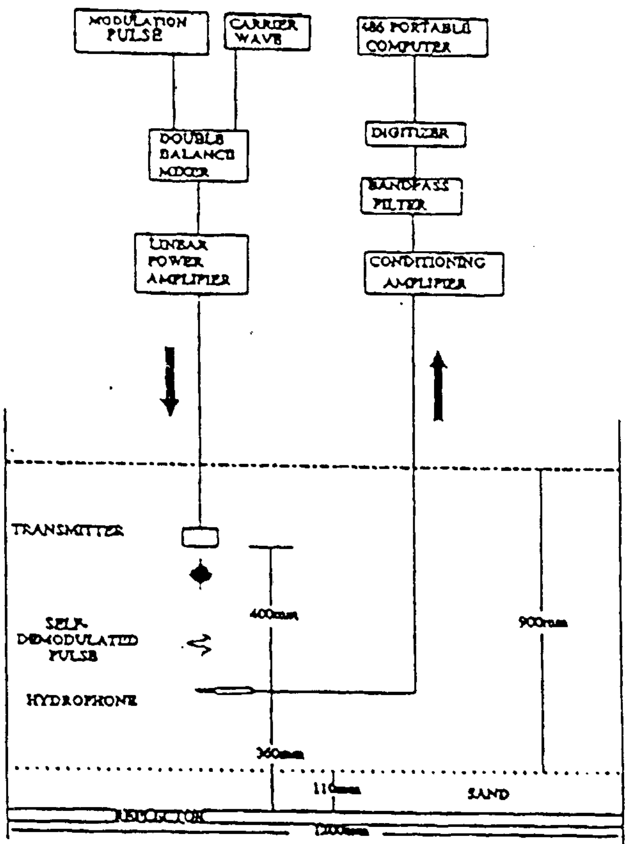


Figure 1. Schematic of Tank Setting in the Acoustic Laboratory of Guigné International Ltd.

Experiments were conducted on well sorted No. 0 Alwhite Silica Sand with a mean diameter of 0.45 mm and mean porosity of 46.1%. The sand was soaked and washed three times in hot water (65 °C) to release air bubbles. The sand was then allowed to cool to room temperature and was transferred to the water-filled tank and levelled at a height of 110 mm over the styrofoam base. Stable measurements were made after water temperature equilibrium in the tank was reached.

### 2.2 Acoustical Profiling

Preliminary profiles were obtained from the undisturbed, level sandbed and three benthic species common to the Grand Banks of Newfoundland: a sea-urchin (*Strongylocentrotus droebachiensis*), a juvenile yellowtail flounder (*Limanda ferruginea*) and a clam (*Macoma calcarea*). The alcohol-(70%) preserved specimens were placed on the sandbed and imaged acoustically. For the bivalve *Macoma calcarea* additional experiments were performed with the clam buried in the sand. The procedure for burying the clam involved first adding sand into the tank raising the sand thickness to a height of 8 cm. The clam was placed on the 8 cm high surface and more sand was added to a total height of 17 cm. The first acoustic measurement was performed two days after to allow the sand to stabilize.

### 2.3 Acoustic Testing in the Benthic Mesocosms at IML

The configuration of the acoustic device used in the GIL test tank was retained for the IML mesocosm experiments. The transmitting and receiving sensors were calibrated in GIL's Research Laboratory before they were used at IML.

Three mesocosm tanks, specifically designed for benthic process studies, were used for the experiments. The tanks were 71 cm deep, 109 cm x 109 cm top area, and 103 cm x 103 cm bottom area. Temperature-controlled seawater circulation systems maintained the tanks at 4°C. The tanks were covered with polyurethane foam lids. Temperatures remained stable for at least two hours without the covering lids while the acoustic measurements were performed.

Sediment was collected from a 350 m depth in the Gulf of St. Lawrence with a 0.25 $m^2$ box corer. The sediment cores were kept in temperature-controlled chambers and transferred into the three mesocosm tanks shortly after sampling. Each tank held four 0.25 $m^2$ cores. The thickness of the sediment blocks is about 35 cm.

### 2.4 Signal Processing

The acoustical data were processed with GIL's *SONIQUE*™ software to establish the key spectral signatures which could distinguish different species of macrobenthos. The effect of the reflective base or sediment matrix on the image of the test animal was investigated using impulse-response analysis such as that of echo reduction. The echo reduction (*ER*) of an organism may be defined in terms of the complex incident sound pressure and the complex reflected sound pressure. The following relationship expresses this:

$$ER = 20 \log_{10} \left| \frac{incident \;\; sound \;\; pressure \; p_i}{reflected \;\; sound \;\; pressure \; p_r} \right| \tag{1}$$

$$= 20 \log_{10} \left| \frac{1}{\hat{R}} \right|$$

where $\hat{R}$ is the complex reflection coefficient and the function $|\cdot|$ represents the modulus.

In order to accentuate the target echoes, the received signals were transformed into an envelope function which allow the data to be displayed in a similar manner to functions in the frequency domain. The Hilbert transform was used to create the complex analytic function. It is the resulting peak amplitudes of the magnitude envelope which make the curve maxima attractive as time markers. For more details on the application of the Hilbert transform to soundings refer to Guigné and Chin (1989) and Guigné *et al.* (1991).

Figure 2 shows the time history and Hilbert transform envelope series of a reflective pulse from the "azoic" sandbed. The instantaneous amplitudes of the envelope series represent pseudo-energy time curves. The peaks in the reflected energy histories are sharp and are easier to discern than the signals in Figure 2a. The echo reduction spectra in Figure 3 indicates the sandbed was fairly uniform and even.

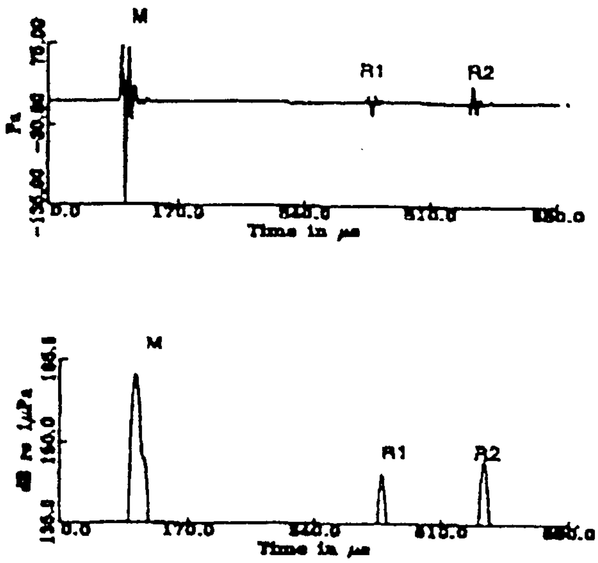


Figure 2. Time History and its Hilbert Transform Envelope Series

M is the first pulse received by hydrophone.
R1 is the reflective pulse from sand surface.
R2 is the reflective pulse off a styrofoam reflector.

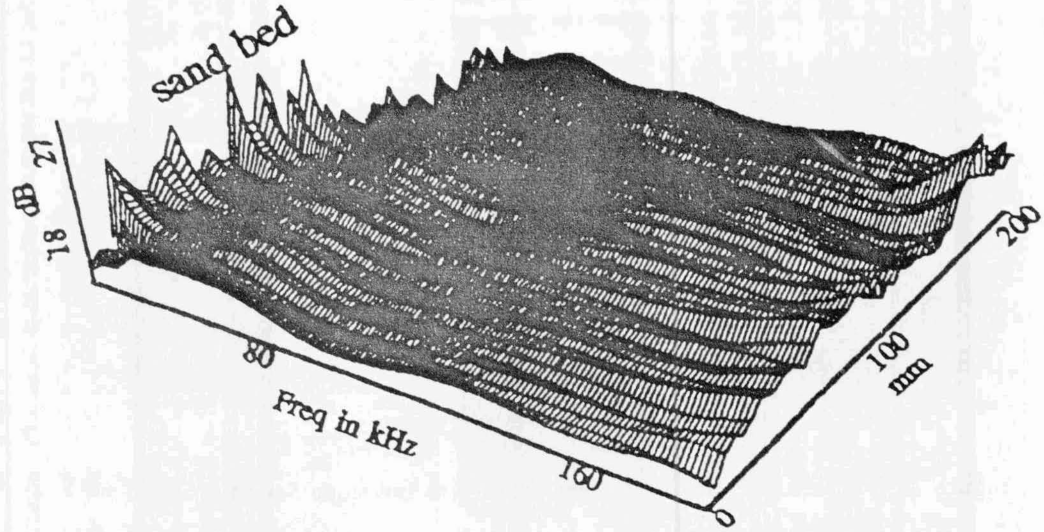


Figure 3. Echo Reduction of a Uniform Sand Bed

## 3. RESULTS AND DISCUSSION

### 3.1 GIL TEST TANK CALIBRATIONS

High resolution acoustic images of benthic macrofauna on and in the level sand base were obtained. The time histories of single cross-profile transects over the test animals demonstrate that GIL's transmitter had the resolving capability to obtain coherent images of the specimens without excessive scattering or noise (Figure 4). The shapes of the animals, in profile, and bottom contact with the sand are clearly definable. The Macoma clam buried in the sand was imaged with clarity equal to that of the clam on the sand surface. The coherent, high vertical resolution and lack of scatter cannot be attained using existing commercially available acoustic equipment.

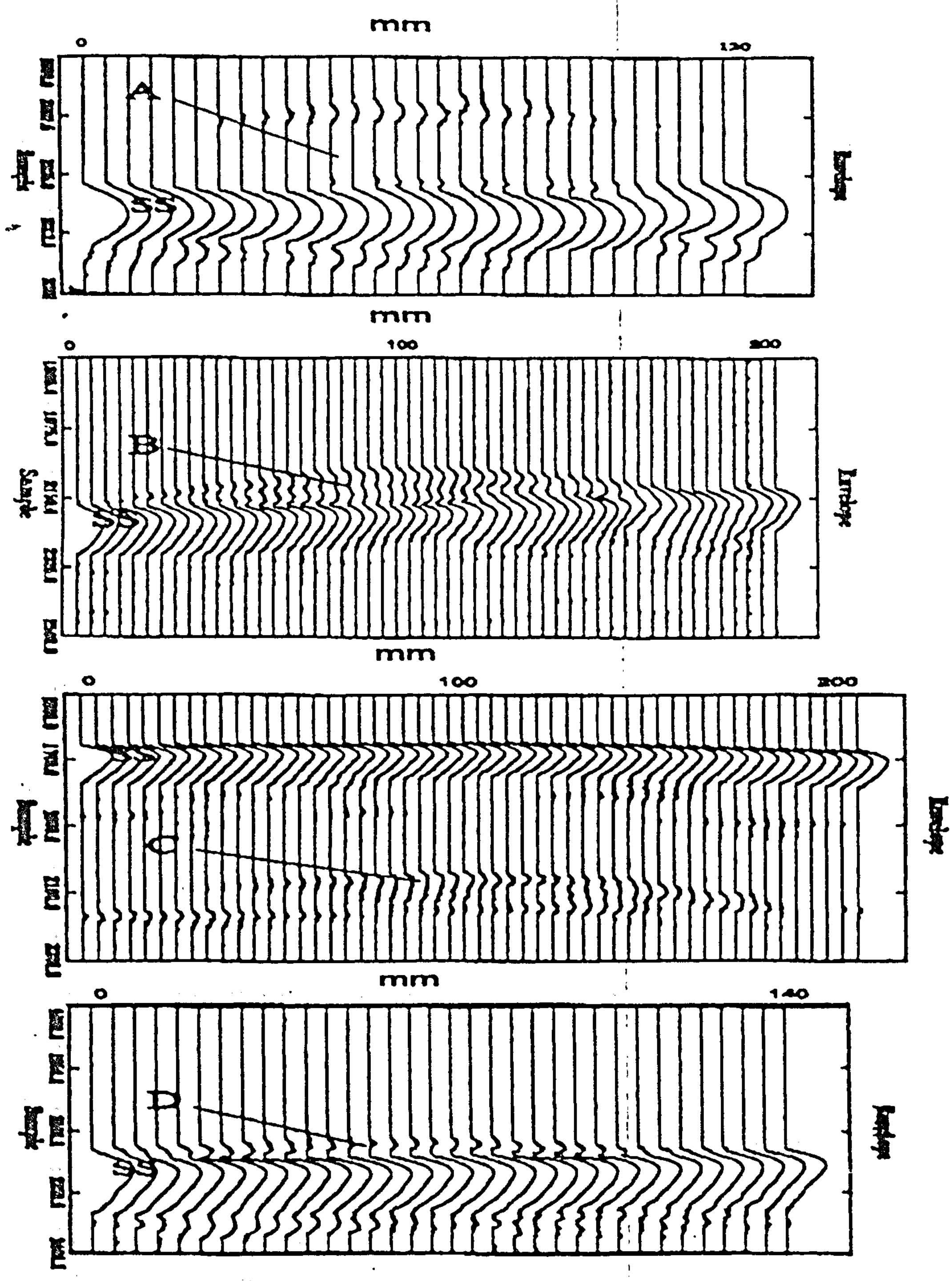


Figure 4. Hilbert Transform Envelop Series of Cross Profiles of Benthic Organisms Resting on Sandbed: Sea Urchin (A), Macoma Clam (B) and Yellowtail Flounder (D). (C) is the Macoma Clam buried in the Sand. SS indicates the Sediment Surfaces.

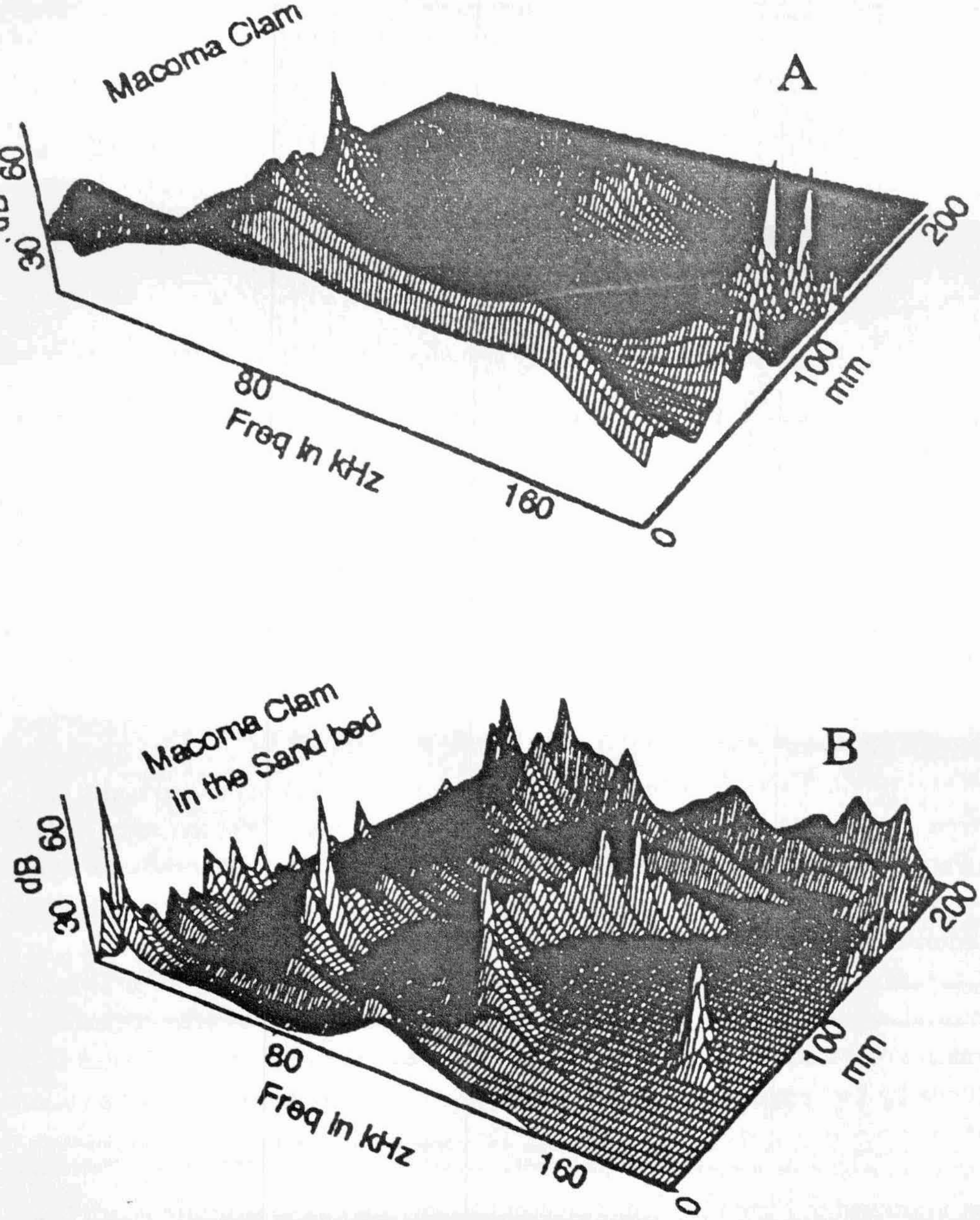


**Figure 6.** Echo Reduction Frequency Spectra from Line Profiles a Clam *Macoma calcarea* on a Sand Bed (A) and in a Sand Bed (B)

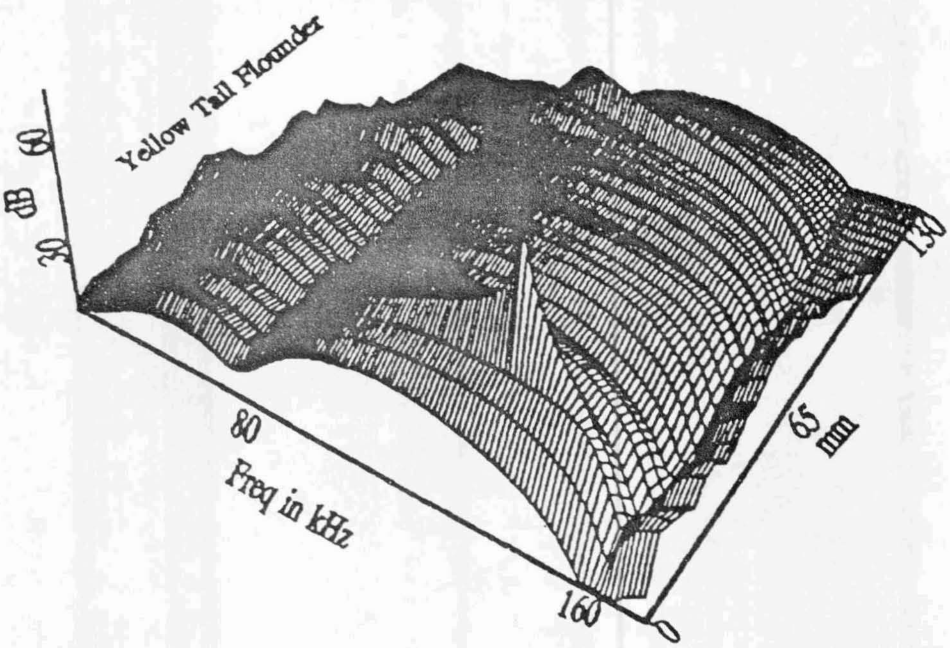


**Figure 7.** Echo Reduction Frequency Spectra from a Line Profile across a Yellowtail Flounder *Limanda ferruginea*

### 3.2 IML MESOCOSMS

Time history cross-profile transects through a mud urchin (*Brisaster fragilis*) buried under the sediment surface, and through an area of burrows made by mud shrimp (*Calocaris templemanii*) are illustrated in Figures 8a and 8b. The echo reduction profiles along the same transects are illustrated in Figures 9 and 10, respectively. The mud urchin appears as a coherent structure within a well-bioturbated sediment as indicated by the complex acoustic structure around it in Figure 8a. In the time domain, the nature of the coherent structure can be more clearly defined by its three-dimensional shape as reconstructed from adjacent transects. In the frequency domain, however, the echo reduction signature of the structure is distinguishable from the signature of the bioturbated sediment. In fact, the similarity between the mud urchin's acoustic signature and the sea urchin's signature in Figures 5 and 8a is obvious, giving some hints as to the origins of the signature in the structural composition and skeletal architecture of urchins. The mud shrimp burrows appear as a distinct zone in the transect illustrated in Figure 8b. The sediment has obviously more structure which is at a different scale than the adjacent area where little bioturbation was observed. Again, the echo reduction spectra in Figure 10 indicate strongly the two distinct zones of bioturbation along the transect. Unlike the mud urchin, however, the burrows appear in Figure 10 to be an intensification of a spectral pattern similar to the adjacent zone of light bioturbation; there is no dominant differentiable spectral quality.

## 4. CONCLUSIONS

The strength in the imagery centres on the broad frequency range inherent in the transmissions and on the narrow beam (devoid of significant side lobes) which maintains a high signal-to-reverberation ratio. Further calibration is underway to define the nature of structures revealed by the acoustic images with a view to understanding the determinants of the characteristic frequency domain signatures exhibited by different taxa of benthic fauna.

Using the echo reduction spectra then, it appears to be possible to determine the nature of sub-surface structures with some precision. Faunal taxa may be identifiable based on their composition and shape. They can be differentiated from sediment structures based on their echo reduction spectra. The rich information content of the echo reduction spectra is evident from Figures 9 and 10, keeping in mind that these illustrate only single line transects, and that the normal mode of data collection is to be over an area of sediment.

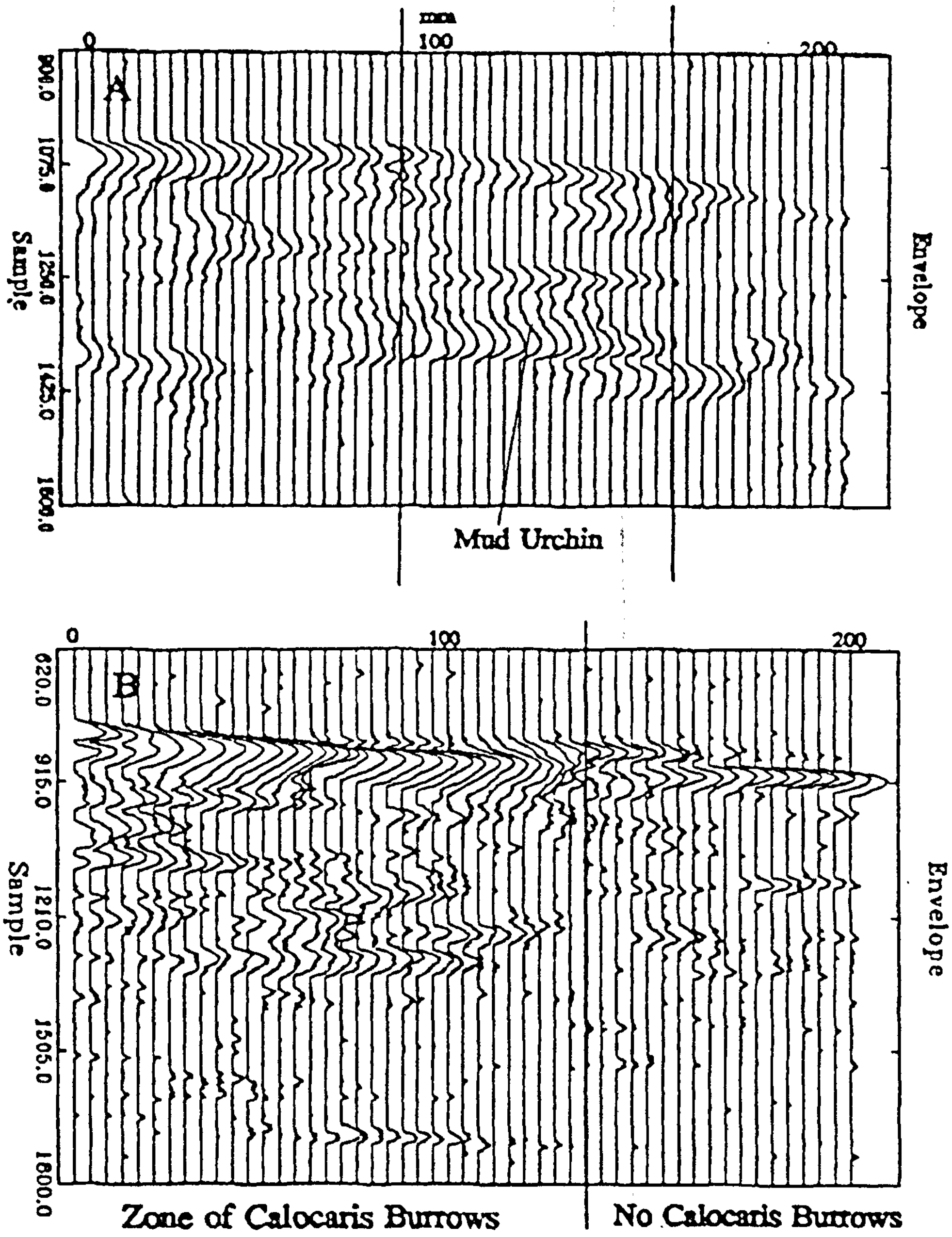


Figure 8. Hilbert Transform Envelop from Line Profiles across a Sediment Block with an Alive Mud Urchin *Brisaster fragilis* (A) and Burrows Made by Mud Shrimp *Calocaris templemanii* (B)

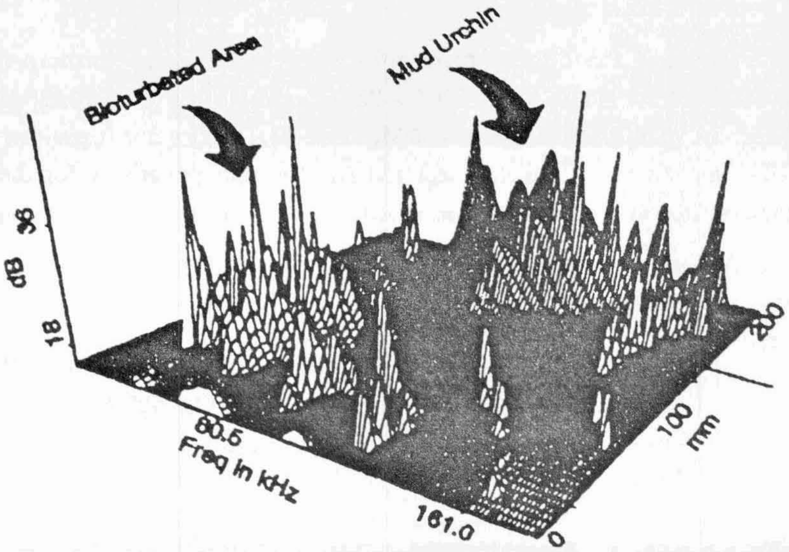


**Figure 9.** Echo Reduction Spectra from a Line Profile across an Undisturbed Sediment Block Containing a Buried Live Mud Urchin (Brisaster fragilis)

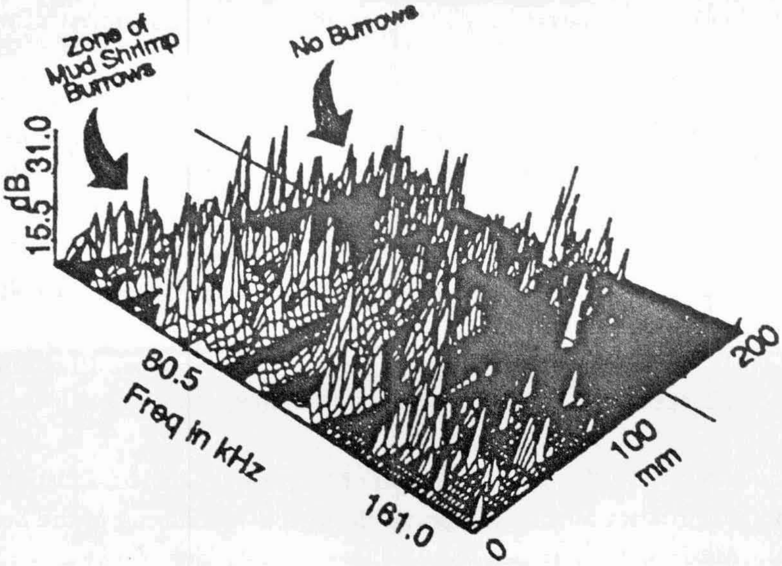


**Figure 10.** Echo Reduction Spectra from a Line Profile across an Area with and without Burrows Made by Mud Shrimp *Calocaris templemanii*

## 5. ACKNOWLEDGEMENTS

This research was supported by the Canada Department of Fisheries and Oceans Northern Cod Science Program under SSC Contract No. XAQ91-00042-(022) Serial No. FP0011 2042. Mr. Wali Li assisted in laboratory testing. Dr. J.-M. Gagnon and Mr. Luc Beaudin kindly provided advice and assistance for the IML mesocosms. We thank them and Dr. Norman Silverberg for their enthusiastic support of Quanshun Liu while he worked at IML.

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ICES BEWG, Kiel, 3.8.5.1993

# On the use of historical data sets in long-term benthic studies

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The assessment of the real status of an environment is often highly speculative because few data are usually available. Public media often announce the advent of "eco-catastrophes" ("Die Nordsee kippt um !") which lose their headline value when they are repeated too often. One reason for this can be found in a wide-spread paradigm that populations of marine organisms are inherently stable so that any changes in the system can only be caused by man´s activities and his effects on the marine environment. There is no doubt that man´s pollution of the ocean with all kinds of contaminants do have effects, despite i) the vast volume of the ocean; ii) the chemical and systemic buffering capacity and iii) the elasticity of food webs and community structures.

The problem in monitoring is to separate man´s effect on the marine environment from those induced by natural climatic changes in the physical environment. This problem was defined early in environmental research and various measures for its solution have been proposed in the last hundred years. One way out of this dilemma is to broaden our data base. This can be performed by taking measurements at more stations, or else by using any historical data to perform **retrospective monitoring.**

We have to realize that our scientific forebears knew much about the variability of the marine system and started early monitoring programmes ( Bonitierungen) which objected at understanding the productive forces of the sea and the sea bottom. When the Biologische Anstalt Helgoland was founded in 1892, Karl Möbius had already done his basic investigations on the fauna of the Baltic and the Wadden Sea Victor Hensen and the Preussische Commission had also initiated a 20 year series of synoptic coastal observations from widely dispersed stations, which reported hydrographical, meteorological and fishery data including daily reports of catches and fishing effort in order to assess the productive capacity ("Produktionskräfte") of the sea.

The coverage of the period 1902-1912, after the ICES has been founded and the new vessel RFD "POSEIDON"was in action, is impressive. Many sampling stations from routine cruisescovered the whole North Sea in this period. But the faunistic data have been only used by specialists for detailed studies of single species or groups. Recently we used labeled material in museum jars to reconstruct dredge protocols (Stein et al. 1990) that can be used as base-line material for historical comparisons.

In 1909, C.G.Joh. Petersen introduced the quantitative sampling of the benthos , after which grab sampling was increasingly used by other nations. The Germans took it over in 1924, in the person of Arthur Hagmeier (1886- 1957). He aimed at a comprehensive essay on the benthos (1932/1952) comparable to the "Nordisches Plankton" by Brandt and Apstein (1908) , but it was never published. All of Hagmeier´s data and tables were lost during the heavy bombardments of Helgoland in 1944. From a recovered manuscript, we were able to reconstruct further biomass values for the Baltic Sea. The history of this manuscript and a retyped version of his (Petersen-type) community approach to the benthos of the Baltic, together with the reconstructed biomass values can be found in Rumohr (1987).

Important steps towards the goal of setting up a **historical data bank** have been taken up in a working group of the Baltic Marine Biologists with the aim of compiling of all available historical data. These include, for example, nearly 1600 unpublished Polish benthos grab stations in the southern Baltic and the Kattegatt from the period of 1952 to 1979, which are now available for further comparative historical analysis. More historical data from sources in the Baltic states and Russia will be available in the near future.

This enables us, inter alia, to show different possibilities of interpretation with increasing length of the period of observation

There is an permanent problem in the use of historical data ,since old data are often only semi-quantitative and the quality may be different from our standards today. Nevertheless we must use thee data because we have no alternative. We must find levels of comparability to discover cyclic events or irregular (El Nino - type) events and show that change is the rule rather than the exception.

Additional data have to be retrieved from structural amazingly similar sources. These include both unpublished files (grey literature) and the interpretation of physical structures such as internal growth bands of long-lived bivalves and the laminated sediment structures in our sea floor as revealed by cores (Jonsson 1992) and REMOTS sediment profile photography (Rumohr 1990).

# ANNEX 12

An abstract submitted to the World Aquaculture Symposium, 1993.

## Impact of intertidal Manila clam (*Tapes philippinarum*) cultivation on infauna.

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Manila clams, *Tapes philippinarum*, are cultivated in sediments in the intertidal zone of temperate waters. Ground lays of clams are protected from predators by plastic net covers. Potentially the presence of the clams and the nets could alter the structure of the sediment and benthic community. Nets may increase sedimentation and also protect the non-cultivated infauna from predation. This, coupled with elevated organic output from the faeces/pseudofaeces of clams, could lead to changes in the benthic community.

An experiment, based on a Latin square design, was set up at the R.Exe, Devon, UK. Three treatments were investigated, net+clams (NC), net only (N) and no net or clams (control A). Samples from the surrounding mudflat were used as an additional control (B). Results 6 months after the clams were laid are presented. Samples from each treatment of the infauna (n=5), organic content (n=5), chlorophyll "a" and phaeopigment (n=9) and the sediment (n=3) were taken. Non-parametric Kruskal-Wallis ANOVA (H) was performed on the infauna data, whereas oneway ANOVA (F) was used to determine differences between treatments for the other variables. The similarity between benthic communities associated with each treatment was determined using cluster and multidimensional scaling (MDS) techniques.

Plot N contained the highest levels of photosynthetic pigments (8.2mg/m$^2$ chl. "a", 8.6mg/m$^2$ phaeo. $F_{1,34}$=43.3, P<0.001). Although plot NC had a lower level of chl. "a" (5.3mg/m$^2$), phaeo pigment levels were similar. Plots NC and N had significantly higher organic matter (2.4-3.6%) than plots A and B (1.8-2.9%) ($F_{1,14}$=10.3, P<0.01, after arcsine transformation). Plot B had a greater proportion of silt (30.3%) than the other plots (25.2%) ($F_{1,10}$=5.1, P<0.05). The benthic community differed greatly between treatments. Plot NC had significantly greater numbers of *Scrobicularia plana*, (H=5.4, P<0.02) and *Cirratulus* spp. (H=8.6, P<0.01) than the other treatments. Plots N and NC had higher numbers of *Ampharete acutifrons* (H=14.9, P<0.002) and *Polydora* spp. (H=4.0, P<0.05), but had lower numbers of *Scoloplos armiger* (H=9.1, P<0.003) than the other treatments. Numbers of *Nephtys hombergi* did not vary significantly between treatments (H=4.6, P>0.20).

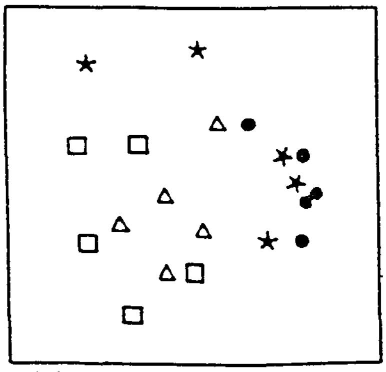

Figure 1. The first 2 axes of the MDS ordination. (●)=NC (★)=N, (□)=A and (Δ)=B.

Cluster analysis revealed that the treatments with and without netting (controls) formed two distinct groups. MDS (Fig. 1) revealed a much closer association between replicates in plots N and NC than was apparent for A and B.

Our results indicate that the use of netting with clam cultivation can have significant short term effects on the structure of the benthic community. Whether this is due to factors such as increased organic and photosynthetic pigment content of the sediment or the exclusion of certain predators will be discussed elsewhere.

ICES Benthic Ecology Working Group
Kiel, Germany, May 1993

Working document

# Preliminary results on the effects of the Aegean Sea oil spill on the infaunal benthos

by

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## INTRODUCTION

The *Aegen Sea* disaster took place at 5 AM of December 3, 1993 in the vicinity of La Coruña. The tanker had about 80.000 t of light oil. A wide oil spill, partially burning, began to spread in NE 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 Ría de Ares and Ría de Ferrol, although a smaller proportion entered in La Coruña Bay. The situation of the spill and the main direction of the oil is shown in fig. 1. The strong winds during and after the accident (30 to 50 knots) spread the oil quickly and contributed to its dispersion. As a whole, the general effect of the spill on the marine environment seems not to be as bad as expected, probably because of its quick evaporation, dispersion and burning.

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 was undertaken. In the present oil spill a coordinated reseach 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.

The spatial distribution of infaunal communities of La Coruña Bay is known (López-Jamar and Mejuto, 1985), as well as the long-term variation of the two main infaunal assemblages since 1982 (López-Jamar *et al.*, 1986). Benthic studies are also been carried out in Ría de Ares and Ría de Ferrol by the University of Santiago. The communities of the nearby continental shelf are also described (López-Jamar and González, 1987). This document presents a description of the studies in progress in the affected area and an account of the preliminary results in La Coruña Bay.

## Material and methods

Benthic samples are being collected at 22 stations (Fig. 2) in Ría de La Coruña, Ría de Ferrol and the nearby shelf (Ría de Ares is being studied by the University of Santiago) with a modified Bouma box corer (0.017 $m^2$ sampling area). Sediment is sieved through a 0.5 mm mesh. Of these 22 stations, 13 are being sampled monthly since the accident. Additional samples for sediment composition, organic matter and hydrocarbon content are also been collected. Bacterial abundance and C:N ratios at three sediment levels (0, 3 and 6 cm) are also been determined.

Priority has been given to stations C1 and C3, located in the Ría de La Coruña, because the composition and temporal variation of infaunal benthos was known in detail. At the moment of writing this document, three monthly samples of each of these stations are completey studied and have been compared with previous data to estimate the initial effects of the spill. Species richness, total abundance, biomass, diversity and abundance of the dominant species is compared to the corresponding average values of the previous year (since November 1991).

## Preliminary results

The infaunal assemblage of Station C3 is characteristic of fine (80 – 100 μm mean diameter) , hard-packed sands, and it is dominated by the polychaete *Paradoneis armata* and the bivalve *Tellina fabula*. Other infaunal dominants are the polychatetes *Magelona alleni, Capitella capitata* and *Spiophanes bombyx*, among others. After the accident, the number of species decreased about 30 % in relation to the average value of the preceeding year. The decrease of total abundance was even more important (20 to 60 %). However, biomass values do not seem to have changed significantly during the three months after the spill (Fig. 3). Organic matter content of sediment has increased slightly, although the figures do not show a clear tendency. Diversity values have decreased but the variation is within the normal variability along the year (Fig. 4).

Several of the dominant species show a decrease after the spill. This is clear in the case of *Paradoneis armata*, *Mediomastus fragilis*, amphipods and nemerteans. Other species, such as *Magelona alleni* and *Spiophanes bombyx*, display a decrease as well, but that lies within the normal range of temporal variation. *Tellina fabula* and *Capitella capitata* do not show a clear pattern and they seem not to be affected yet (Figs. 5, 6 and 7).

Station C1 is located in the harbour area, where the pollution level is expected to be much higher. Sediment is composed of black mud with a variable proportion of sand, and sulphide smell suggests that hypoxic conditions prevail. The infaunal community is largely dominated by the bivalve *Thyasira flexuosa*. Other important species are the oligochaete *Tubificoides* sp., and the polychaetes *Capitella capitata, Chaetozone* sp. and *Prionospio malmgreni.*

The effect of the spill in this station, if any, is not as clear as that of Station C3. Species richness increased slightly after the spill, but the increase of total abundance is more important (Fig. 8). This is due mainly to the increase of the abundance of *Thyasira flexuosa, Tubificoides* sp., *Capitella capitata* and *Prionospio malmgreni.* However, *Chaetozone* sp. shows a clear decrease (Figs.10 and 11). The increase of *Thyasira flexuosa* is due to the annual recruitment of this species starting in this period (López-Jamar and Mejuto, 1987).

Summarizing these preliminary results, in La Coruña Bay the oil spill is adversely affecting the infaunal benthos of fine sand sediments, but on the polluted harbour area, at least initially, the effect has been an increase of some opportunistic species. The data presented here correspond to a moderately affected area (La Coruña Bay), and it is too soon to draw any significant conclusion. The study of the samples from Ría de Ferrol, which has been much more affected by the spill, probably will reveal a more important adverse effect on the benthos.

Preliminary data from five stations in Ría de Ares (Mora. pers. comm.) show that highest mortality occurred in Amphipoda (mainly *Ampelisca* spp.) and echinoids such as *Echinocardium.* Results from Ría de Ferrol are not available yet, but the higher oil deposition in this ría probably will result in a more dramatic effect of the oil spill on the infaunal benthos.

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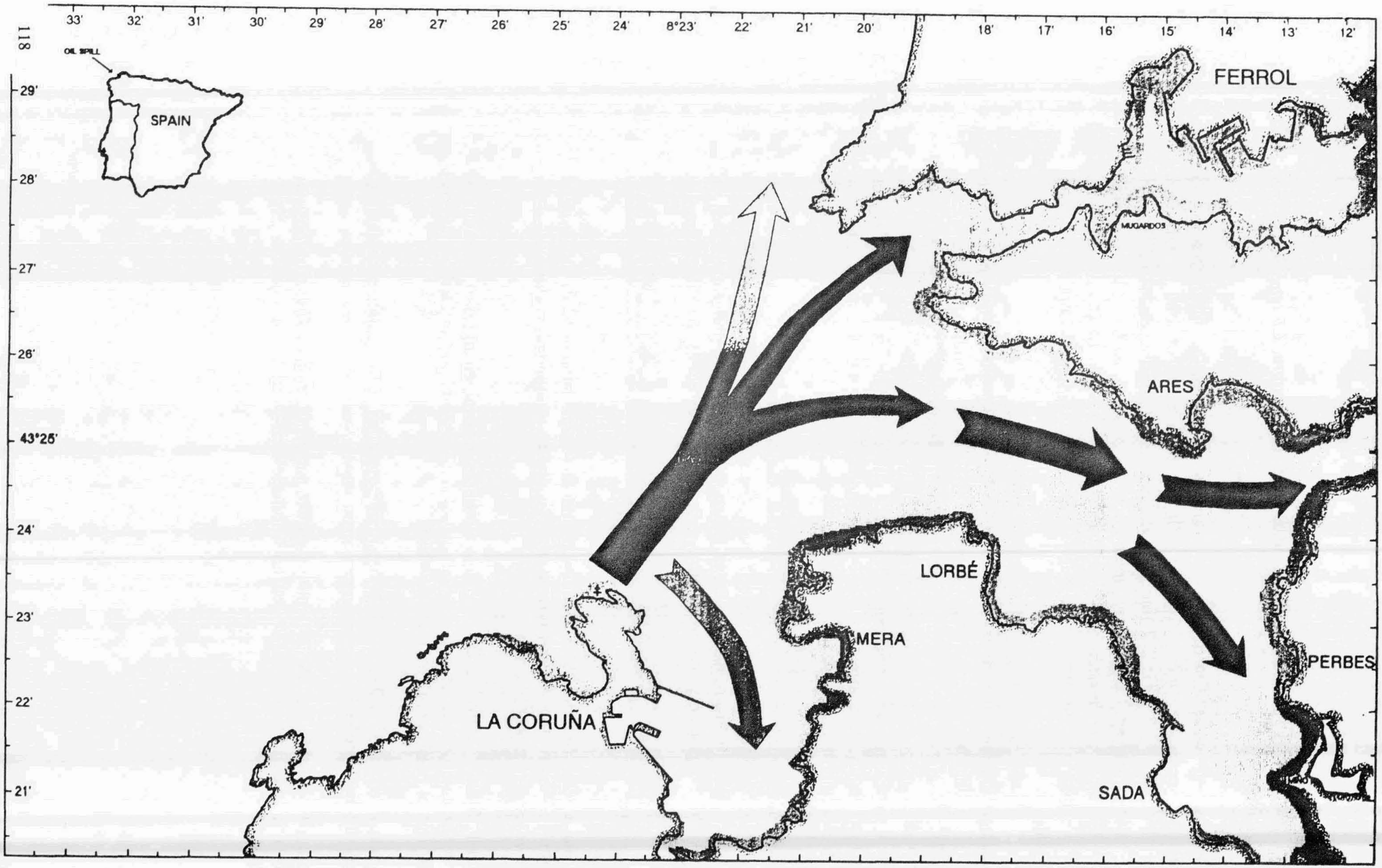


Fig. 1. Location and main directions of the oil spill. Shading corresponds approximately to the affected area. Darker shading means higher oil deposition. The extension of each area is estimated from visual observations, and it does not corresponds to actual measurements.

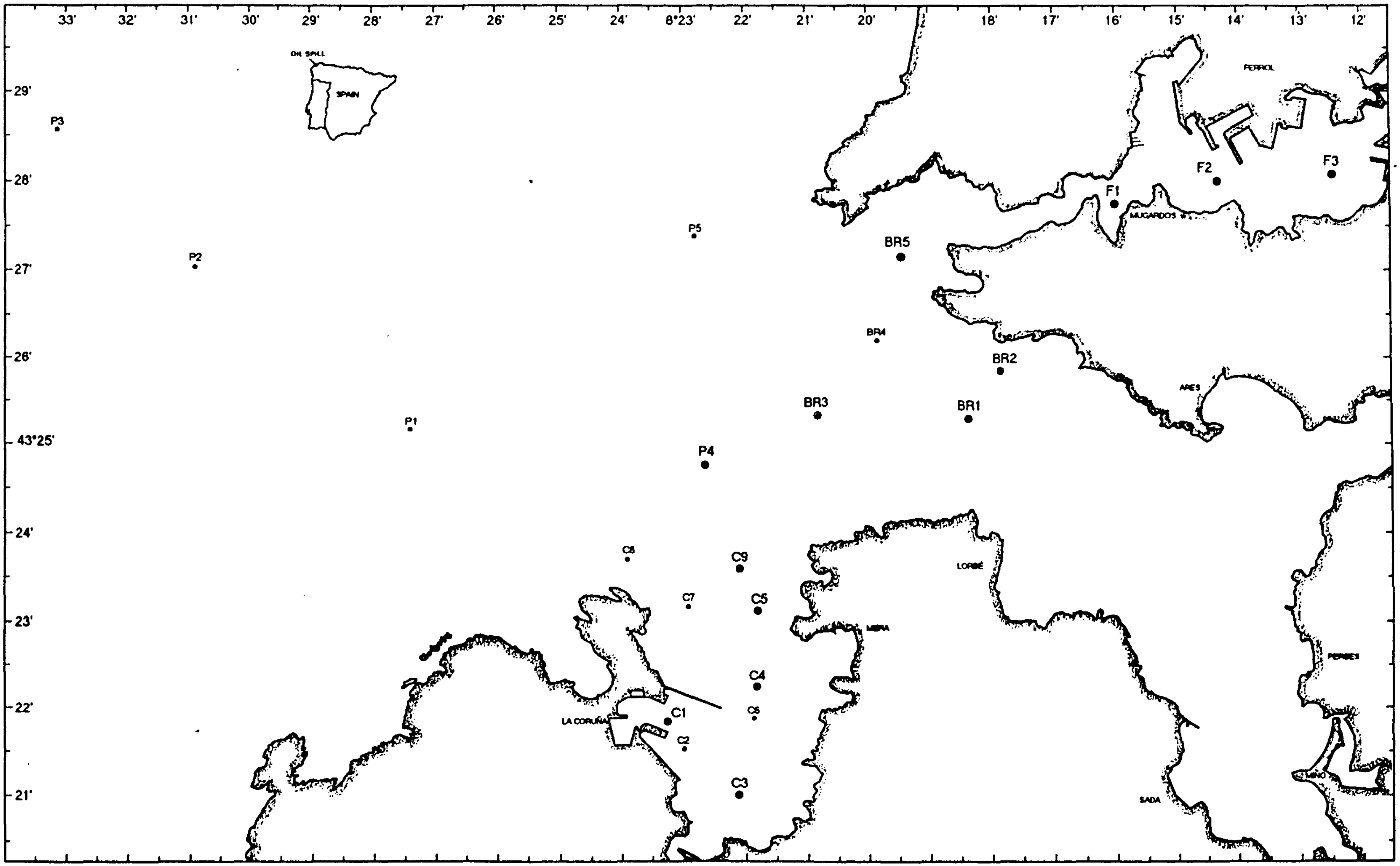


Fig. 2. Location of the sampling sites in La Coruña Bay, Ría de Ferrol and continental shelf. Circled points represent the stations being sampled monthly.

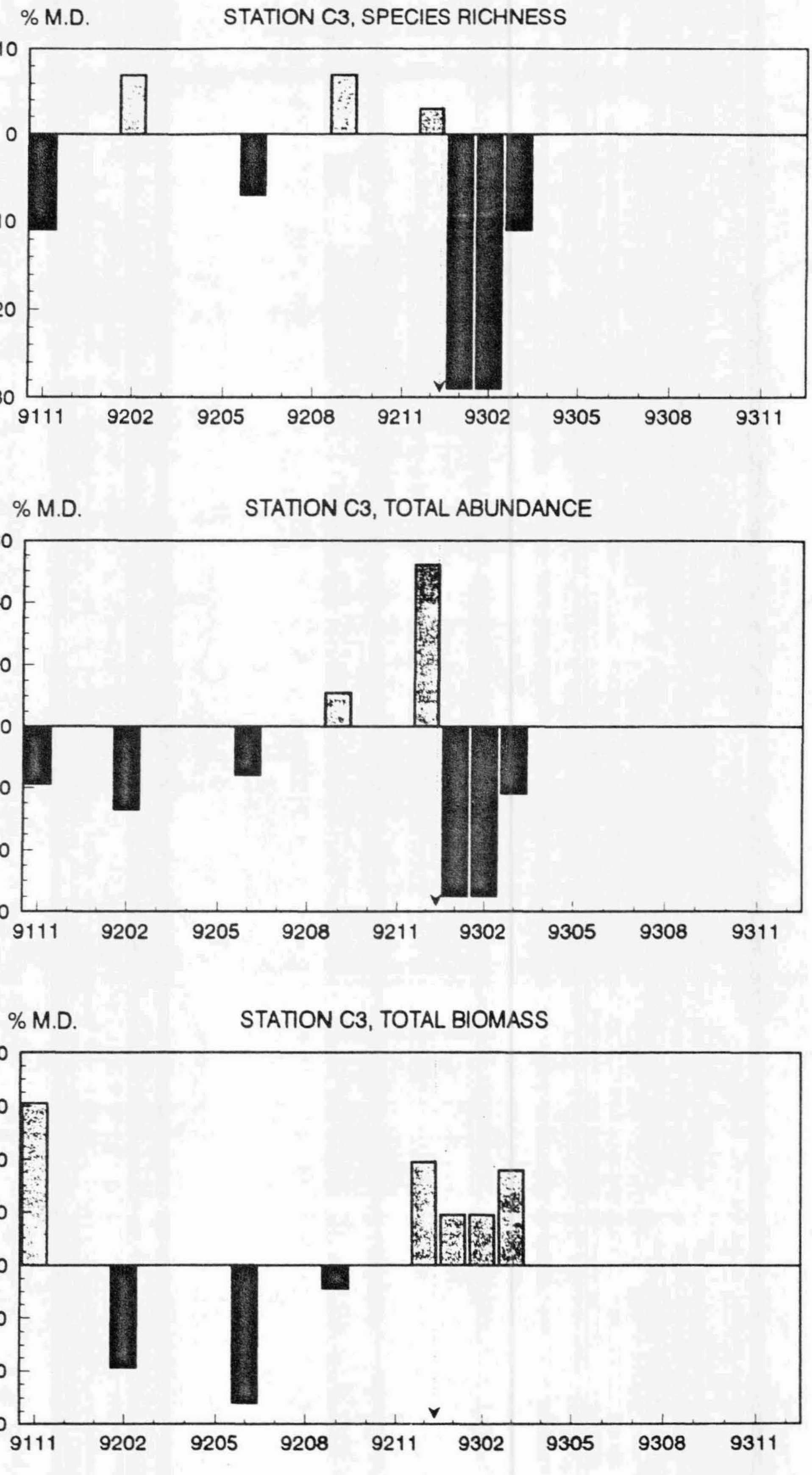


Fig. 3. Deviation from the mean value before oil spill (November 1991 – December 1992) of species richness, total abundance and total biomass at station C3 (La Coruña Bay). Arrow indicates the date of the accident.

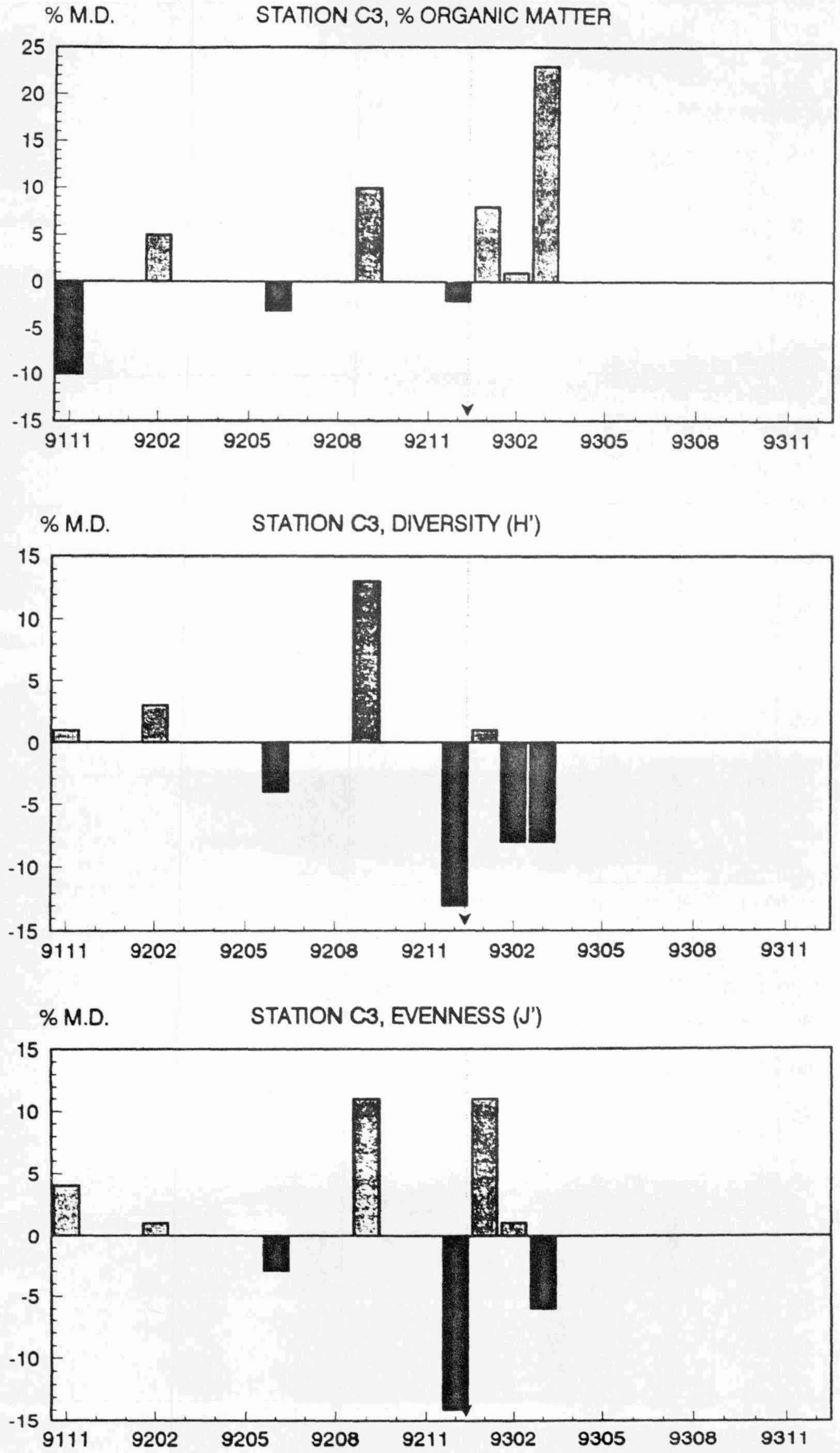


Fig. 4. Deviation from the mean value before oil spill (November 1991 – December 1992) of sediment organic matter, diversity abd evenness at station C3 (La Coruña Bay). Arrow indicates the date of the accident.

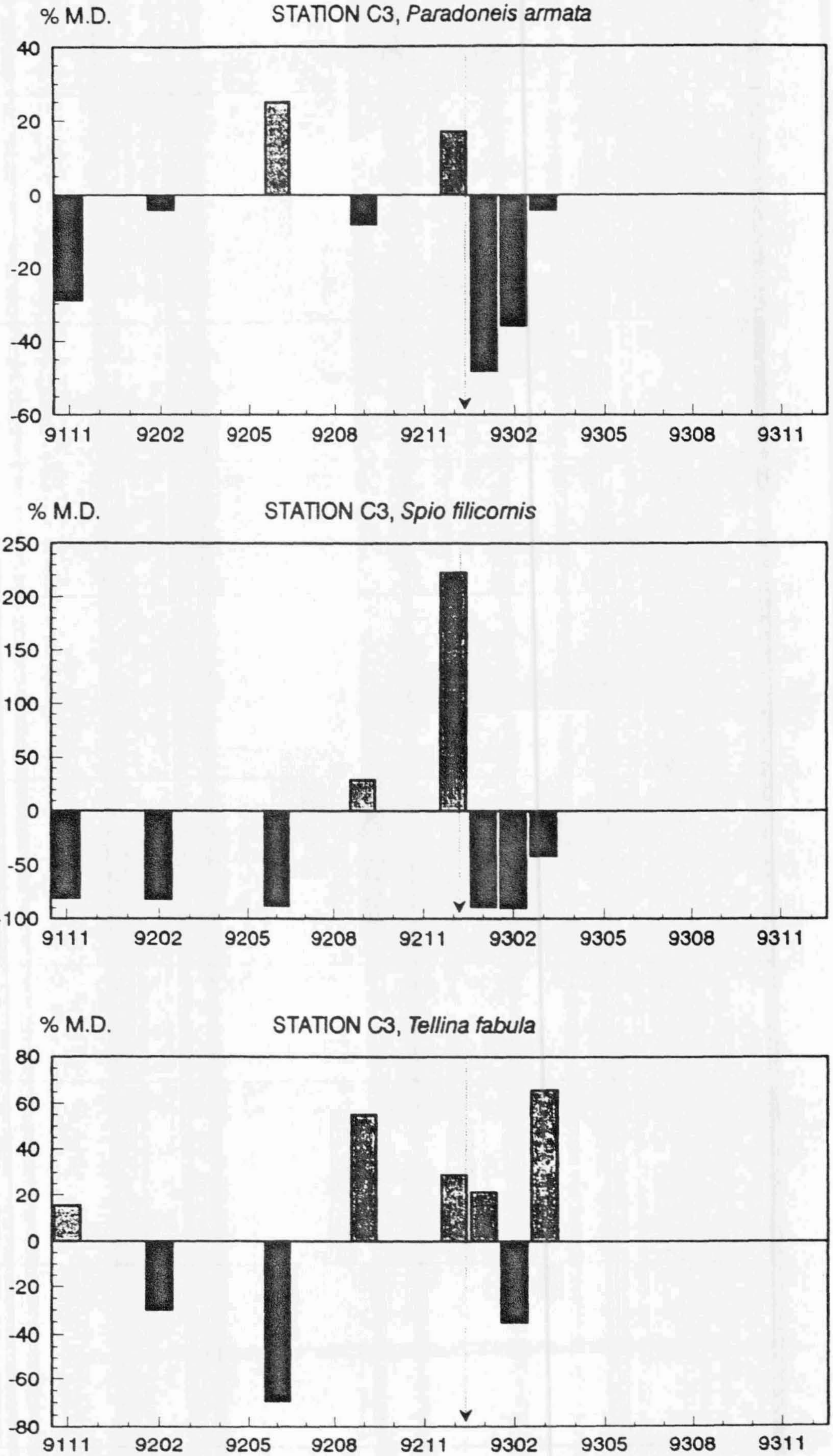


Fig. 5. Deviation from the mean value before oil spill (November 1991 – December 1992) of *Paradoneis armata, Spio filicornis and Tellina fabula* at station C3 (La Coruña Bay). Arrow indicates the date of the accident.

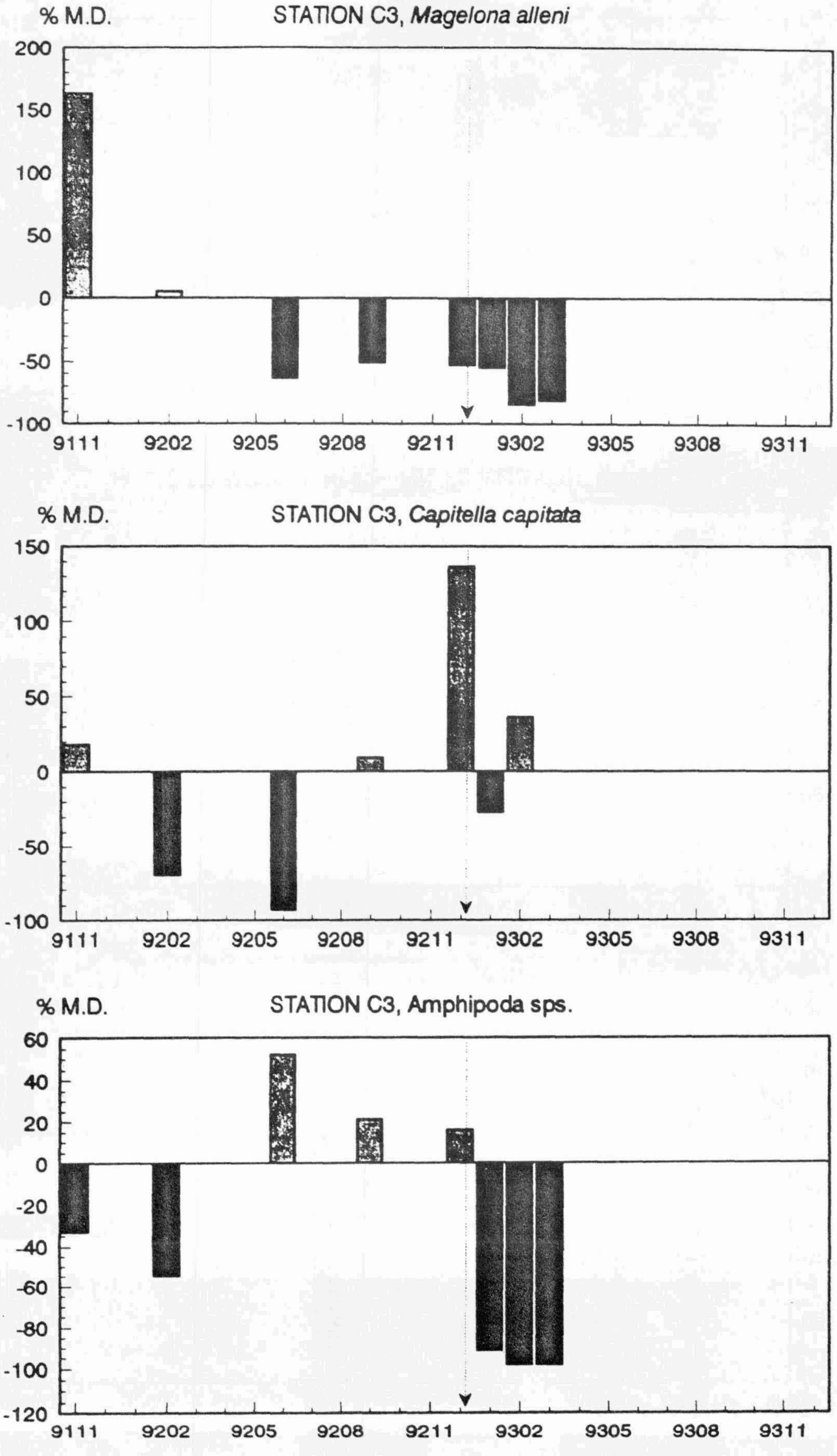


Fig. 6. Deviation from the mean value before oil spill (November 1991 - December 1992) of *Magelona alleni, Capitella capitata* and Amphipoda sps. at station C3 (La Coruña Bay). Arrow indicates the date of the accident.

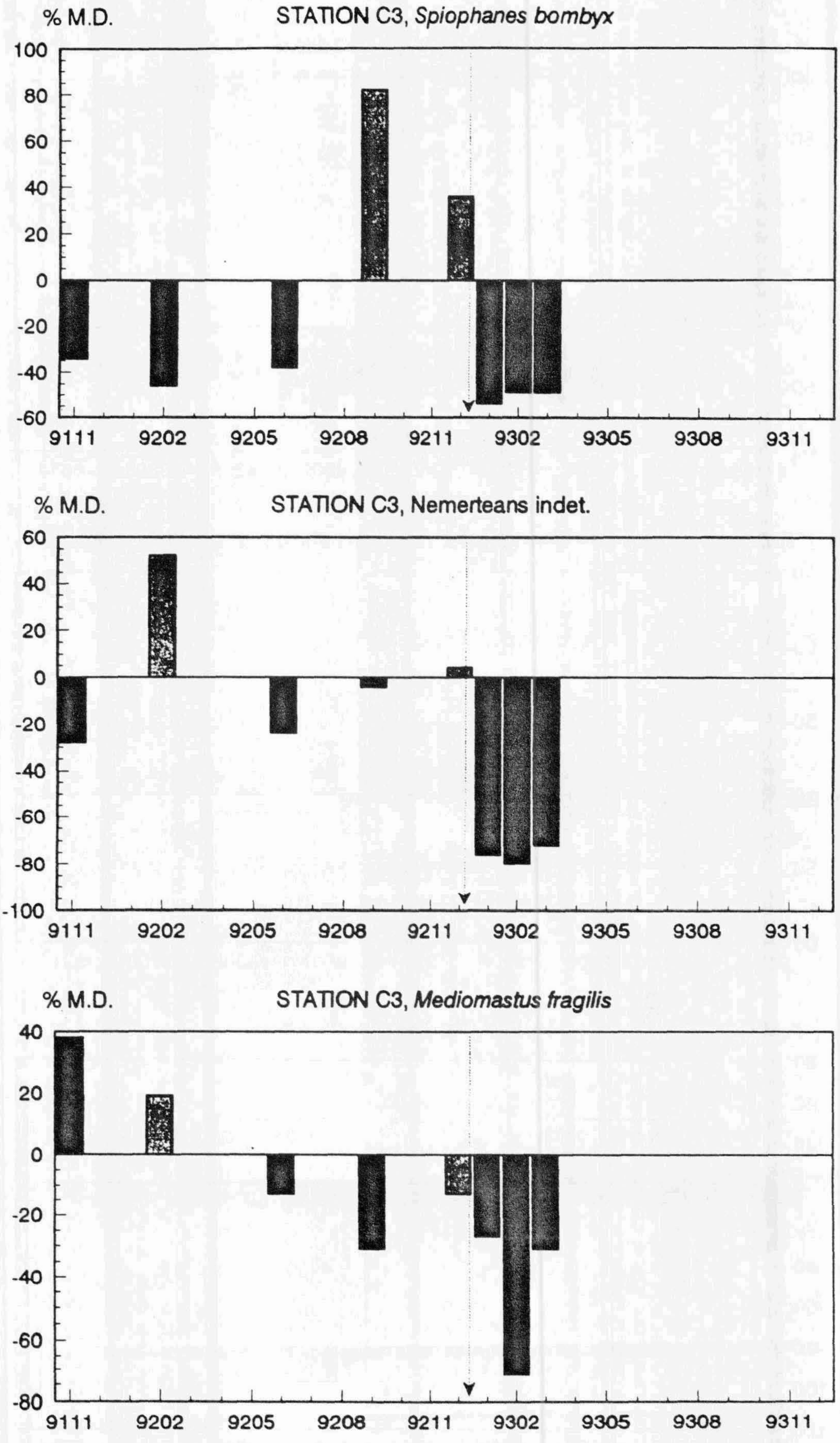


Fig. 7. Deviation from the mean value before oil spill (November 1991 – December 1992) of *Spiophanes bombyx*, Nemerteans indet. and *Mediomastus fragilis* at station C3 (La Coruña Bay). Arrow indicates the date of the accident.

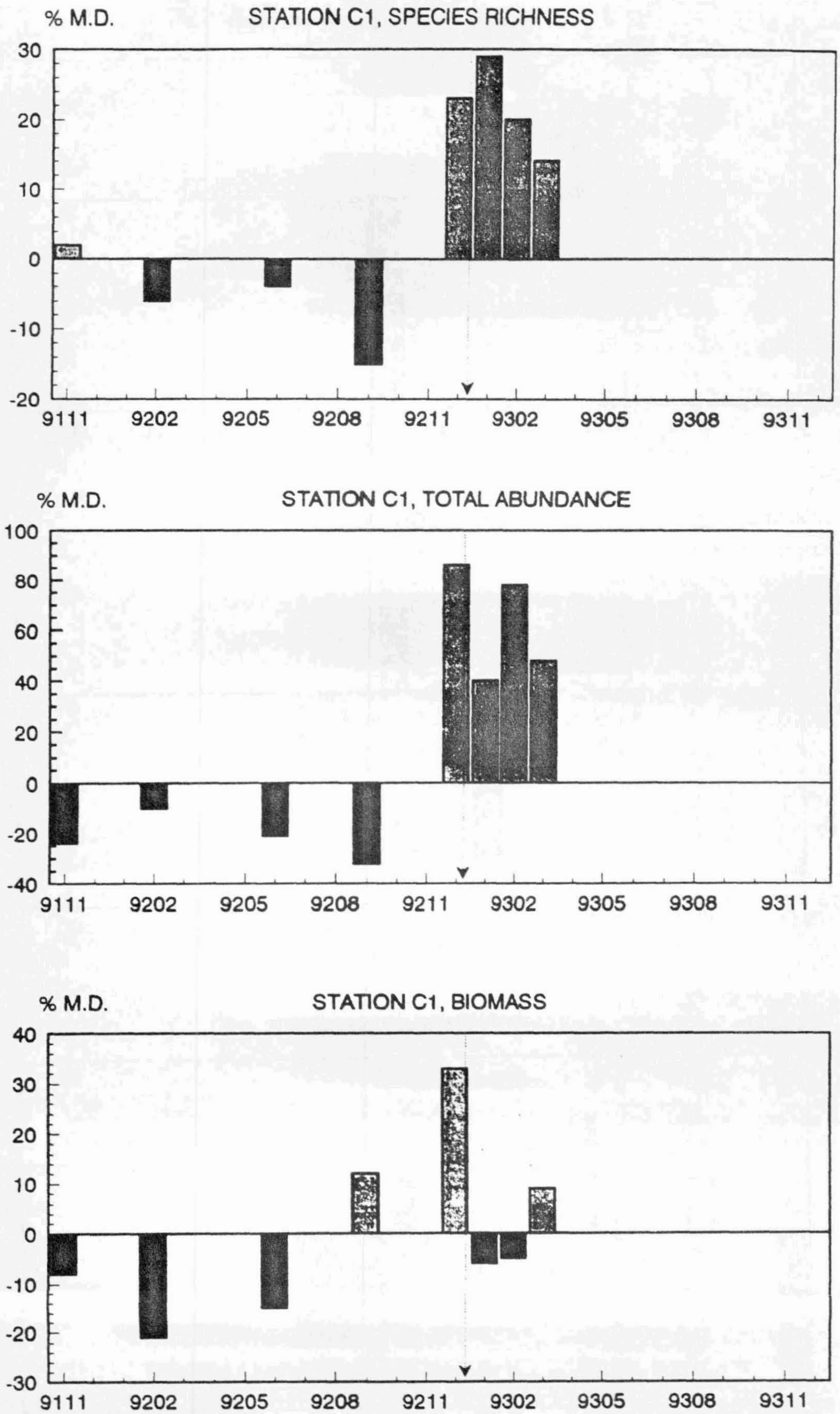


Fig. 8. Deviation from the mean value before oil spill (November 1991 - December 1992) of species richness, total abundance and total biomass at station C1 (La Coruña Bay). Arrow indicates the date of the accident.

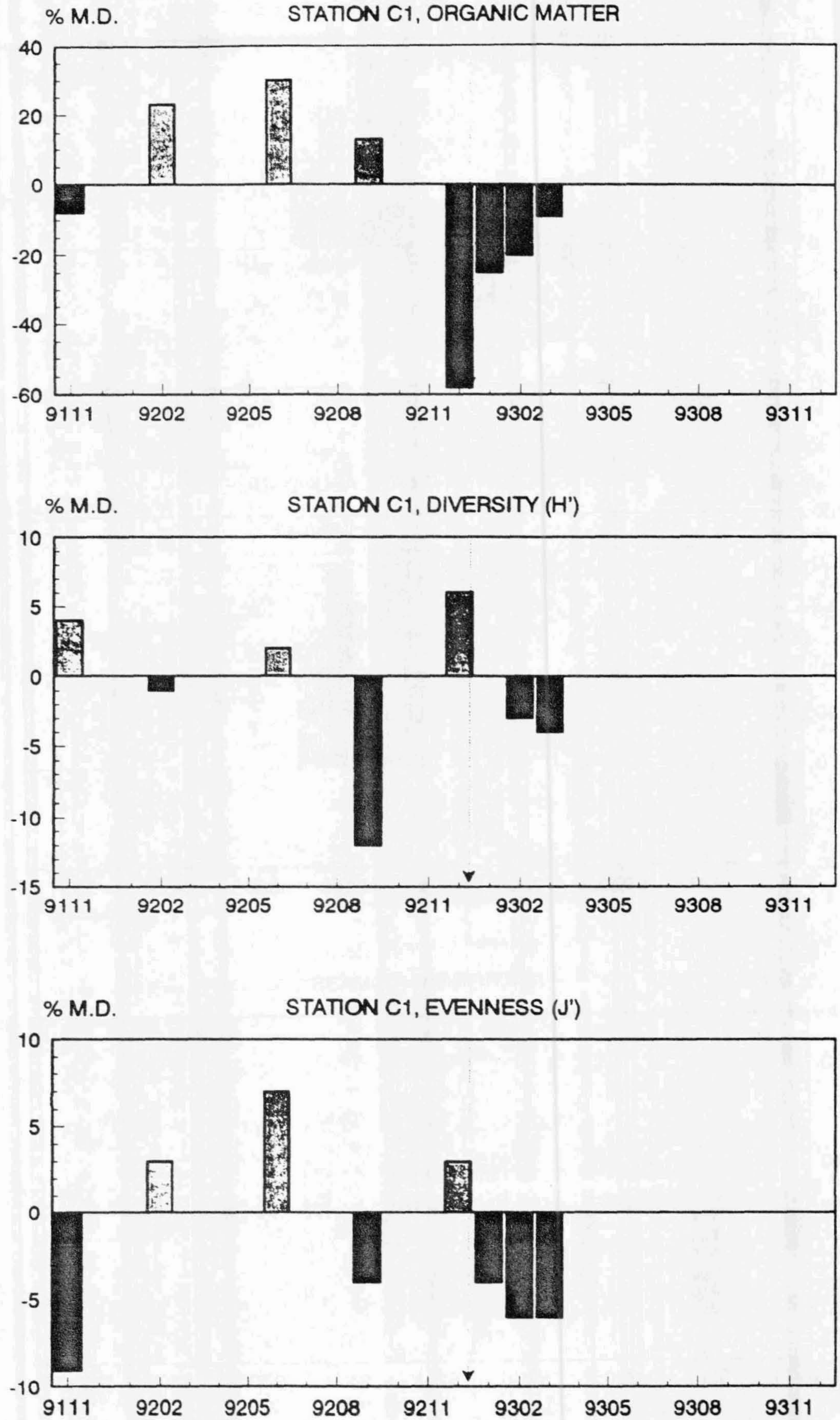


Fig. 9. Deviation from the mean value before oil spill (November 1991 – December 1992) of sediment organic matter, diversity and evenness at station C1 (La Coruña Bay). Arrow indicates the date of the accident.

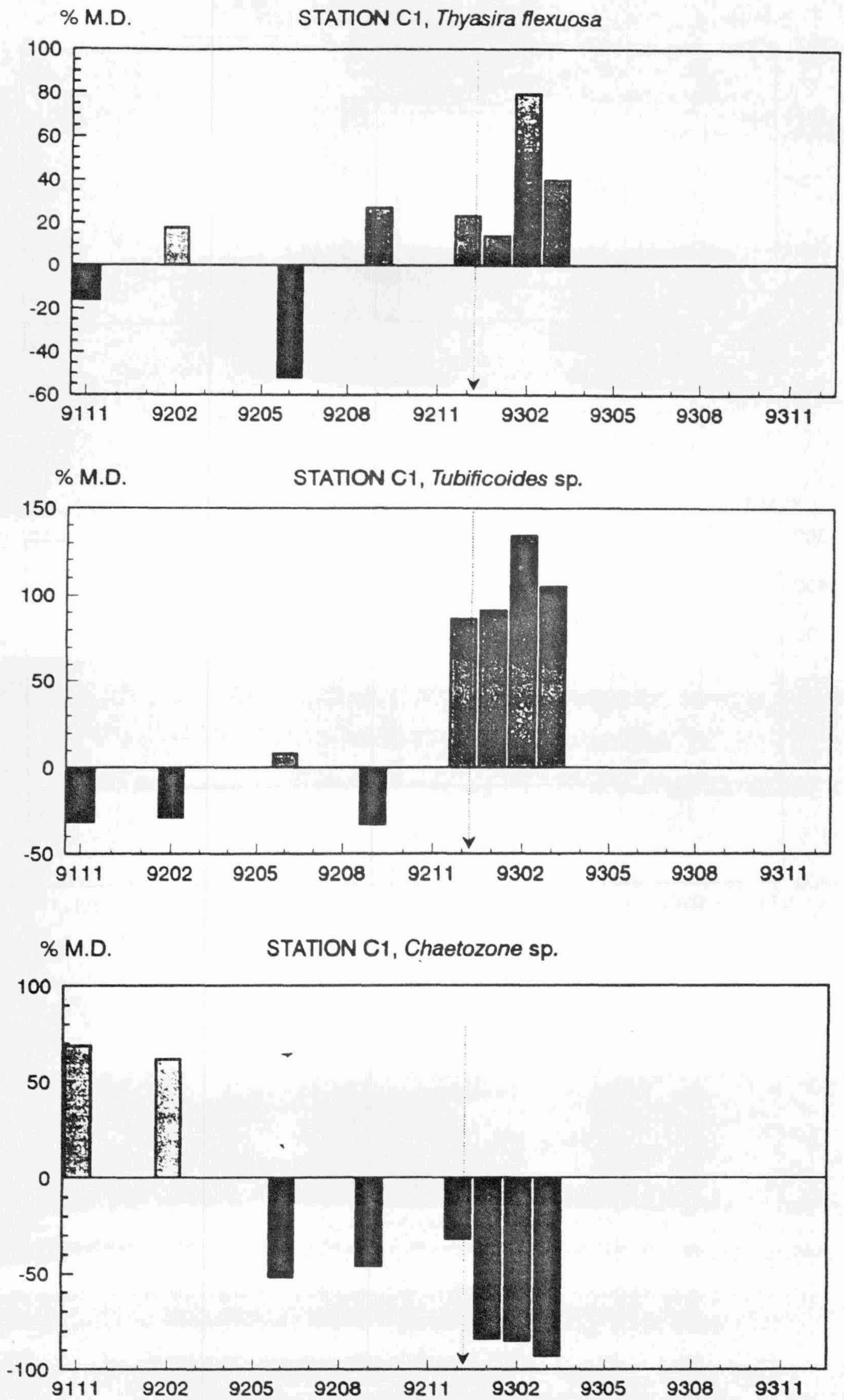


Fig. 10. Deviation from the mean value before oil spill (November 1991 – December 1992) of *Thyasira flexuosa, Tubificoides* sp. and *Chaetozone* sp. at station C1 (La Coruña Bay). Arrow indicates the date of the accident.

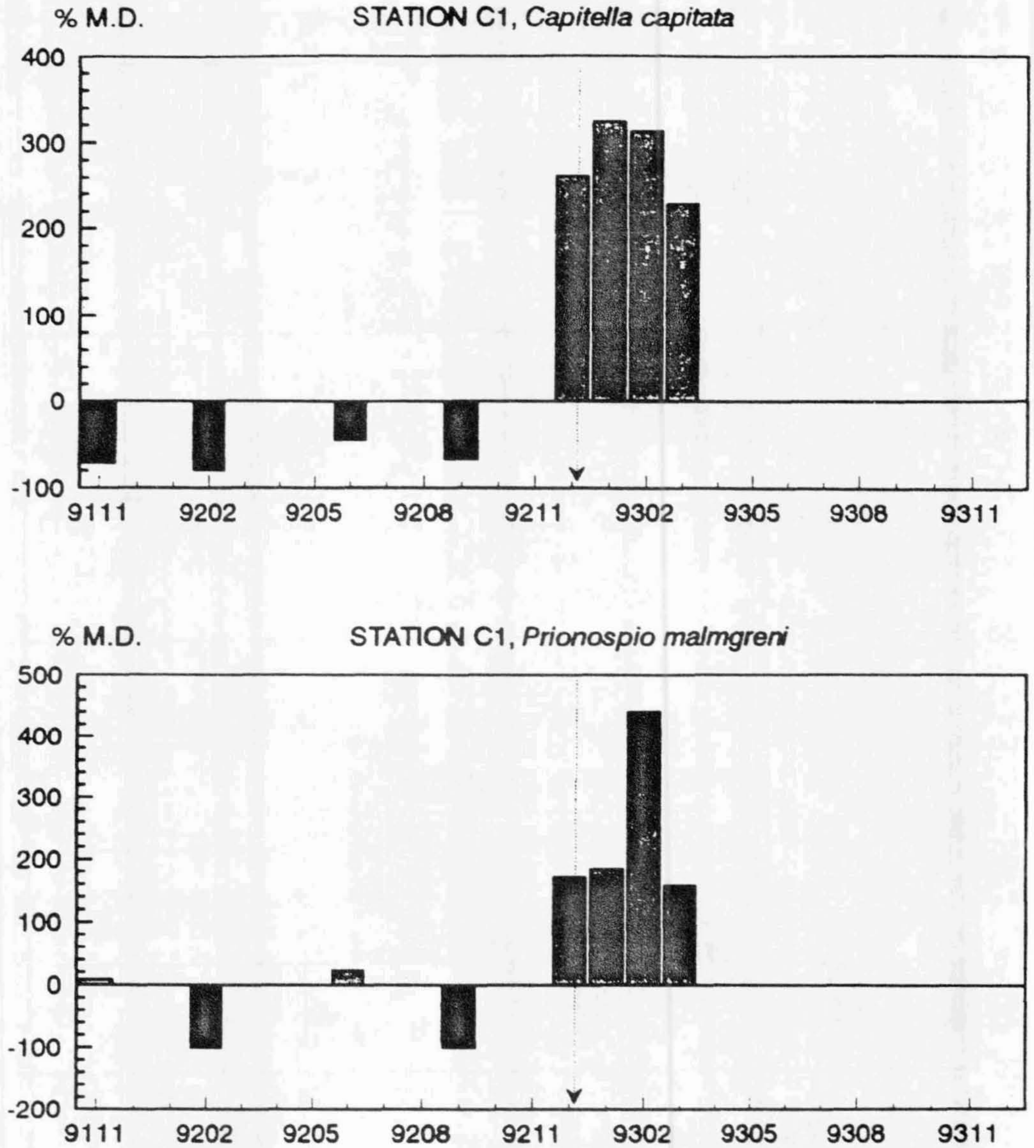


Fig. 11. Deviation from the mean value before oil spill (November 1991 – December 1992) of *Capitella capitata* and *Prionospio malmgreni* at station C3 (La Coruña Bay). Arrow indicates the date of the accident.

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# Dynamics, growth and production of Abra alba and Abra nitida in La Coruña Bay, NW Spain[1]

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## INTRODUCTION

This document presents the results of a three year study on the dynamics, growth and production of two species of *Abra (A. alba* and *A. nitida)* that occur in the same site, a muddy, hypoxic sediment bottom in the harbour area of La Coruña Bay. The benthic community of this area is dominated by *Thyasira flexuosa*.

## MATERIAL AND METHODS

Monthly samples were collected with a modified Bouma box-corer (0.017 $m^2$ sampling area x 10 corers = 0.17 $m^2$ total area sampled) at a fixed station (43° 21.85' N; 8° 23.25' W, 16 m deep)) in La Coruña Bay. Samples were sieved on board with a 0.5 mm mesh and preserved with 5 % buffered formaldehyde solution stained with Rose bengal. In the laboratory, samples were sorted by eye, and individuals were measured to the nearest 0.1 mm. Size/weight relationship was calculated by separating the individuals in 0.5 mm-interval size classes; biomass (AFDW, shell included) as the loss by ignition (500 °C, 24 h) of dried samples (90 °C, 24 h). Size/weight equations were utilized to estimate biomass of each cohort from the size-frequency distribution. A Normsep package (Tomlinson, 1971) was used to separate modes.

The progression of the modes was fitted to the model of Von Bertalanffy (Gulland, 1983) and to the Gompertz equation (Zweizel and Lasker, 1976). Production of each cohort was calculated as the sum of weight increments along time (Crisp, 1984).

[1]This document is a summary of a paper published in *Bol. Inst. Esp. Oceanogr.* 7(2): 101-113.

## RESULTS

### Population dynamics

During the sampling period (March 1988 to February 1991) *Abra alba* abundance varied from 97 to 2939 $ind \cdot m^{-2}$. After several years of low recruitment, in 1988 a very abundant year-class was established, whereas the following recruitments were moderate again. Maximum abundance occurs between January and March, matching the highest yearly recruitment (Fig.1).

The 1988 cohort is quite abundante from March 1988 to January 1989. From this date on its abundance is very low, overlapping with the 1989 cohort. The 1989 cohort is much less abundant, and it present in the samples since October 1988; however, recruitment is important only from February 1989. Although the abundance of this cohort is relatively low, it can be identified until April 1990. The 1990 cohort is present in the samples since September-October 1989 but highest recruitment takes place from Februay 1990 on. Abundance of this cohort is also low, and by February 1991 practically has disappeared. Finally, the 1991 cohort began to recruit at low densities by September 1990, but recruitment is important only since December 1990.

Abundance of *Abra nitida* is more constant throughout the study period, ranging from 46 to 480 $ind \cdot m^{-2}$. Highest abundance occurs in May, except in 1990 when numbers are relatively high from February to July (Fig. 2). The 1988 cohort can be detected in the samples until January 1989. The 1989 cohort begins to appear in October 1988, but recruitment is strong only from February 1989; this cohort can be followed until April 1990. The 1990 cohort starts a weak recruitment in October 1989, being strong since January 1990. This latter cohort practically disappeared by February 1991.

### Allometry and size-weight relationships

The height/length relationship of both species of *Abra* was calculated, and the equations obtained were:

*Abra alba:* $H = 0.702 \cdot L^{0.989}$ (r = 0.997)

*Abra nitida:* $H = 0.814 \cdot L^{0.932}$ (r = 0.998)

The length/weight relationships obtained were:

*Abra alba:* $AFDW\ (mg) = 0.00822 \cdot L^{2.894}\ (mm)$ (r = 0.989)

*Abra nitida:* $AFDW\ (mg) = 0.01215 \cdot L^{2.548}\ (mm)$ (r = 0.996)

## Growth and longevity

In both *Abra* species the Gompertz equation fits better than the Von Bertalanffy function, so we have used it to describe the growth of both species. Fig. 3 shows the theoretical growth curves for *Abra alba.* During 1988 samples were available only from March on, and thus the results of the growth of this cohort must be taken with caution. However, the growth curves are very similar for the three years considered. The values of the teorethical maximum length ($L_\infty$) ranged from 12.925 to 14.945 mm. These values are lower than the observed maximum lenght of this species in La Coruña Bay (17 mm). However, $L_\infty$ is a theoretical value without biological significance. Maximum longevity can be estimated as the intersectin value of the straight line $L = L_\infty$ with the growth curve. For *Abra alba,* the theoretical maximum longevity obtained is 2.9 years. In practice, it is very rare to get individuals older than 1.5 years.

In the three cohorts of *Abra alba* studied the growth pattern was very similar. If we express growth rate as the size increment by month, this is initially small, increasing rapidly thereafter to reach a maximum for t = 0.6 years (end on May). Maximum growth rate is similar for the three cohorts: from 2.2 to 2.7 $mm \cdot mo^{-1}$ (Fig. 5). Afterwards growth is much slower, specially for sizes over 12 mm.

For *Abra nitida* it was only possible to calculate growth for the 1989 and 1990 cohorts. $L_\infty$ of these two cohorts is 11.656 and 11.629 mm respectively, whereas the maximum observed length in La Coruña Bay was 14.3 mm. The theoretical maximum longevity for this species in the study area is 3.9 years, although individuals older than 1.5 years are rare in the samples. Growth curves for this species are shown in Fig. 4.

The two cohorts of *Abra nitida* studied had a quite different growth pattern. The 1989 cohort displays a relatively constant growth during a long period. Maximum growth rate (0.95 $mm \cdot mo^{-1}$) is reached for t = 0.6 years, but this maximum is not very marked. On the contrary, the 1990 cohort has a similar pattern than that of *Abra alba:* growth rate increases rapidly until a maximum of 1.85 $mm \cdot mo^{-1}$ for t = 0.52 years, decreasing relatively fast thereafter.

## Production

Net production of the three cohorts of *Abra alba* is shown in table 1. Most of the production of each cohort takes place during the year when the cohort is dominant, and thus the yearly net production is originated almost totally by only one cohort. In the first year (March 1988 – February 1989) the production is very high as compared to the following years. This is due to the great strength of the recuitment of the first cohort in relation to the 1989 and 1990 cohorts. P/B is also much higher in the first year.

Similarly to *Abra alba,* most of the yearly production of *Abra nitida* is caused by the dominant cohort of each year. Production figures for this species are quite lower as compared to *Abra alba.* P/B ratios for *Abra nitida* are similar than those of *Abra alba* for the same period.

Table 1. Net production (P), mean biomass (B) and P/B ratio of *Abra alba* and *Abra nitida* in La Coruña Bay. P expressed as g AFDW· $m^{-2}$· $yr^{-1}$. Biomass expressed as g AFDW· $m^{-2}$; *: production negligeable; –: no data available.

| | Year I | Year II | Year III |
|---|---|---|---|
| *Abra alba* | | | |
| P cohort 1988 | 14.71 | 0.21 | 0 |
| P cohort 1989 | * | 3.19 | 0.07 |
| P cohort 1990 | 0 | * | 2.82 |
| P total | 14.71 | 3.40 | 2.89 |
| B | 3.65 | 1.43 | 1.36 |
| P/B | 4.03 | 2.38 | 2.13 |
| *Abra nitida* | | | |
| P cohort 1989 | – | 0.75 | 0.04 |
| P cohort 1990 | – | 0.01 | 1.06 |
| P total | – | 0.76 | 1.10 |
| B | – | 0.27 | 0.45 |
| P/B | | 2.81 | 2.44 |

## Discussion

In the continental shelf off Gascony recruitment of *Abra alba* takes place from May to June (Bachelet and Cornet, 1981), which is much later than in La Coruña Bay. The most likely reason of this difference is the higher temperature in Galicia. In the North Sea recruitment is more extended, but presents a maximum by the end of spring (Dewarumez, 1979). Dauvin *et al.* (1986) indicated that this species has a recruitment maximum from March to June in the Bay of Morlaix, but it has three yearly recruitments in the English Channel. Growth rate of *Abra alba* in the North Sea if 2.5 mm·$mo^{-1}$ seven months after recruitment (Dewarumez, 1979), which is in agreement with the results of the present study.

Available data of *Abra nitida* are scarce. Josefson (1982) pointed out that recruitment and growth of this species in the Swedish coast are very variable both temporarily and spatially. Bachelet *et al.* (1986) suggest that this species could have a very extended spawning period in the continental shelf off Gascony. In La Coruña Bay recruitment stars in October, but maximum takes place in January–February, being almost negligeable from March on.

Literature data on production of both *Abra* species have a great variability. In general, P/B values for *Abra alba* in La Coruña Bay are higher than those other areas. The high variability of the production figures for this species has been pointed out by Cornet (1986).

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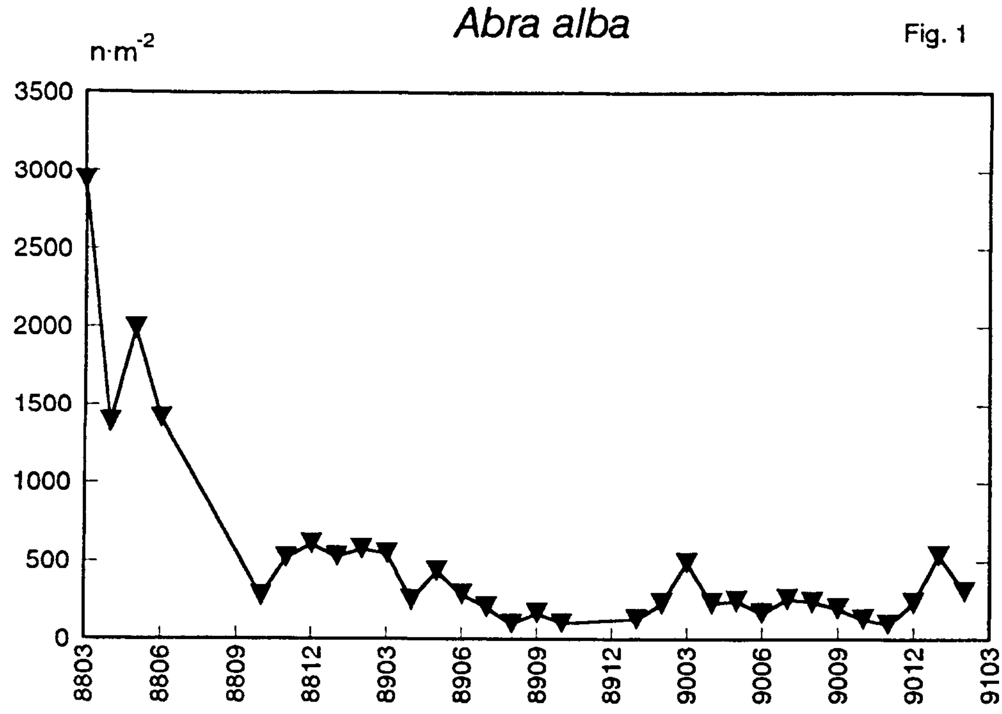


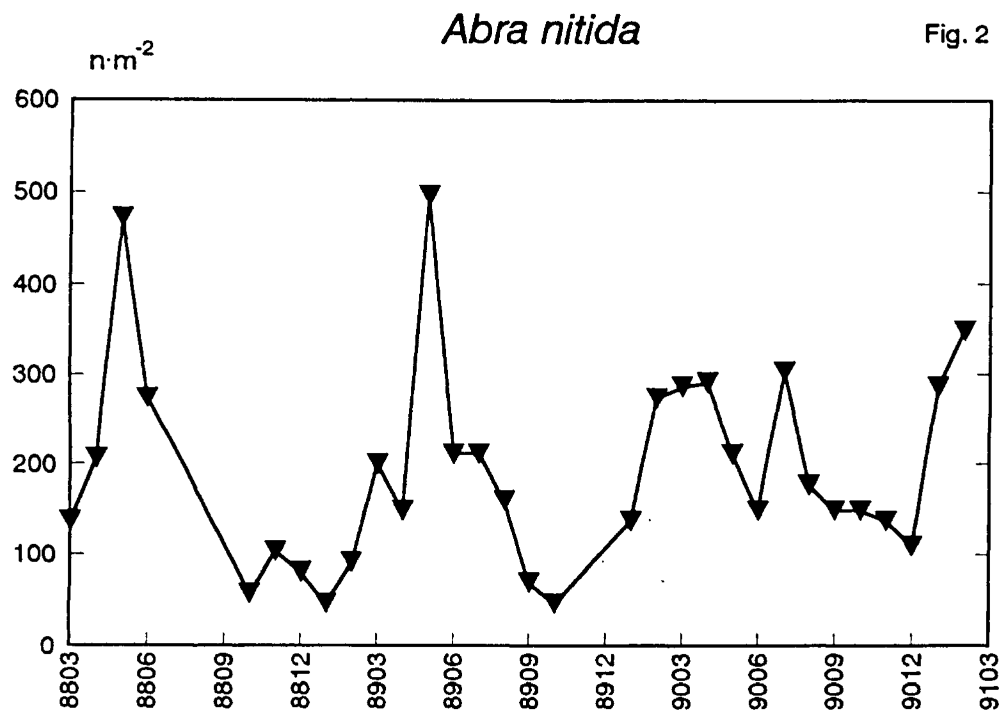
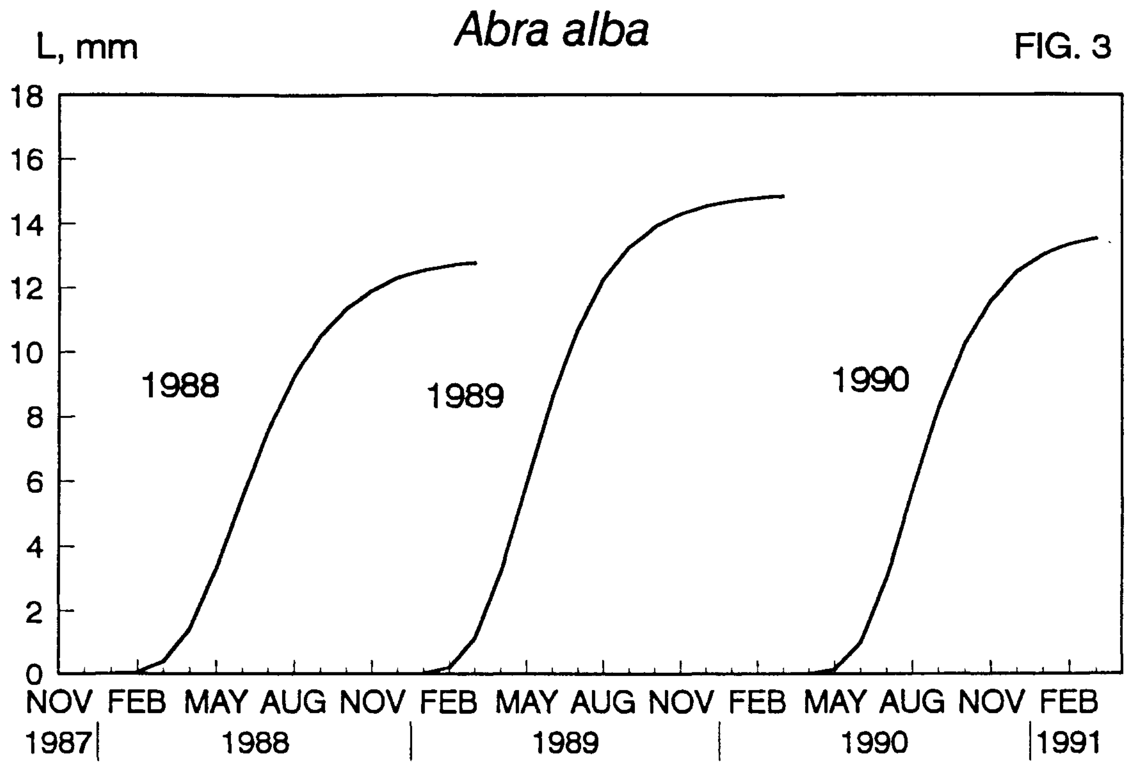




Fig. 1 . Temporal variation of abundance of *Abra alba* in La Coruña Bay.

Fig. 2. Temporal variation of abundance of *Abra nitida* in La Coruña Bay.



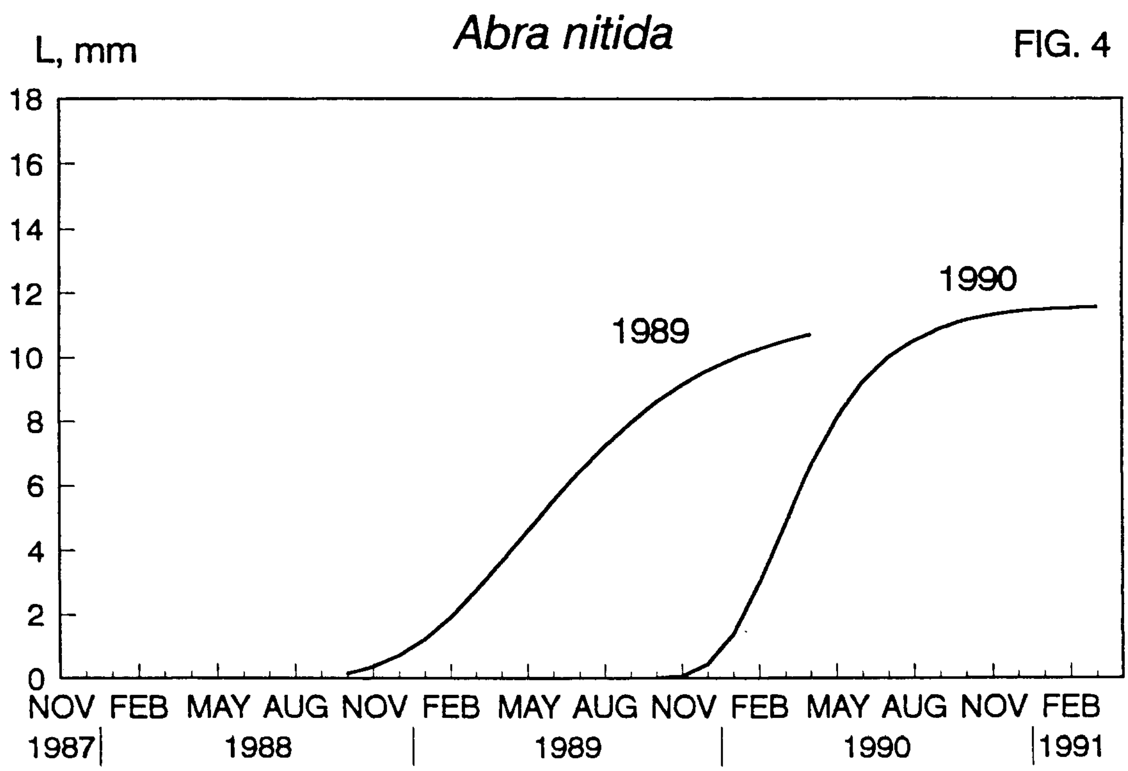
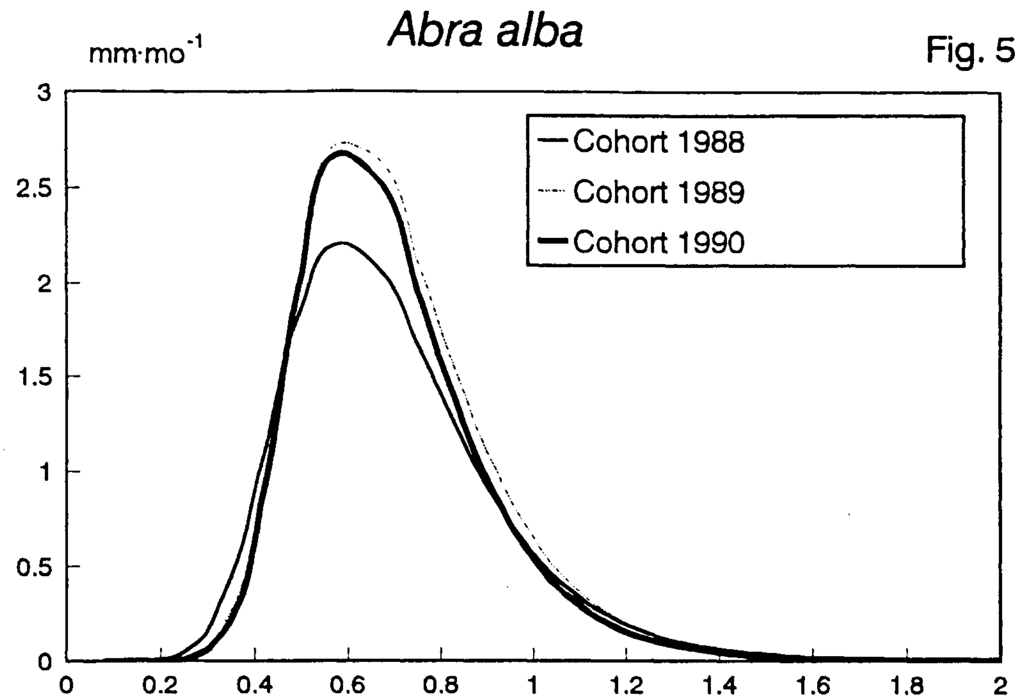




Fig. 3. Growth curves for *Abra alba* in La Coruña Bay in 1988 – 1990.

Fig. 4. Growth curves for *Abra nitida* in La Coruña Bay in 1989 – 1990.



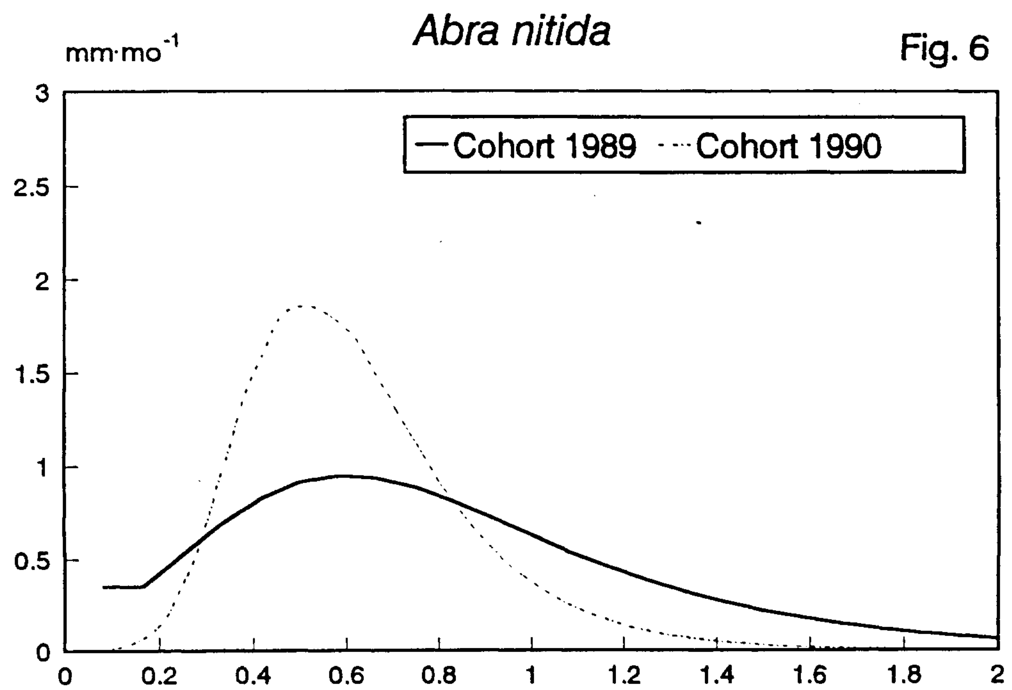




Fig. 5. Growth rate curves (mm/mo$^{-1}$) for *Abra alba* in La Coruña Bay in 1988–1990.

Fig. 6. Growth rate curves (mm/mo$^{-1}$) for *Abra nitida* in La Coruña Bay in 1989–1990.