Biological Oceanography Committee ICES CM 1996/L:5

REPORT OF THE BENTHOS ECOLOGY WORKING GROUP

Aberdeen, Scotland

1–4 May 1996

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International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1 OPENING OF THE MEETING

The Benthos Ecology Working Group met in Aberdeen at the Marine Laboratory of the Scottish Office of the Agriculture, Environment and Fisheries Department, under the chairmanship of Paul Kingston. Les Watling was elected rapporteur. A list of participants is given in Annex 1.

1.1 Terms of Reference

a) Report on co-operative benthic surveys throughout the ICES area.

b) Consider recent studies on the effect of sea bed disturbance on benthic communities.

c) Finalise plans for a second North Sea Benthos Survey.

d) Report on progress in the use of computer aided taxonomy systems for the identification of benthos.

e) Report on studies of the small-scale spatial relationships of benthos.

f) Review methods for the study of community structure of the benthos of hard substrata.

2 ACTIVITIES OF INTEREST TO ICES AND OTHER ORGANISATIONS

2.1 Advisory Committee on the Marine Environment (ACME)

A report on meeting of the meeting of ACME was received from Jan-Rene Larsen. There were no specific requests from ACME for this meeting of the Working Group.

2.2 OSPAR Commission (OSPARCOM) inc ASMO & JAMP

A. Kunitzer informed the group that OSPARCOM has established, among others, two different working groups, one is SIME and the other is IMPACT, the latter being concerned with fisheries. The first deals with monitoring of biological effects in relation to contaminants and nutrients, including macroinfauna and epifauna components of the communities. There was no clear indication whether this monitoring will be mandatory. Some guidelines have been developed, for soft bottom macrobenthos and epilithic benthos, (phytobenthos, and hard bottom phyto- and zoo-benthos). Also discussed was quality assurance, the establishment of a Steering Group on QA, and development of guidelines. Some working groups in ICES already deal with quality assurance, but some details need to be sorted out. Note from J. Larsen suggests that BEWG should organise themselves to develop such guidelines for QA.

Recent experience in the UK concerning the development of QA procedures for benthos data arising from the 'National Monitoring Plan' was noted; further details are provided in Annex 2.

Such QA guidelines are currently being developed in the Baltic. T. Pearson reports from Norwegian oil field studies that there are written guidelines for those aspects of benthic sampling where there was too much latitude. BEWG could endorse guidelines that already exist, or review documents developed by others.

K. Essink reported that there is development of guidelines and QA for monitoring for the Wadden Sea (trilateral programme of Denmark, Germany, and the Netherlands).

A need for taxonomic QA workshops was also expressed. However, different objectives might mean that taxonomy may not be relatively important (that is, it may be that the need is only to recognise distinct taxa, but their identities are not critical), but if names are going to be put into reports they should be correct. There is also a need to emphasise the importance of correct identifications if names are to be used for other science purposes.

BEWG recommends that all benthic studies include funds for taxonomic QA.

A communication from J Larsen suggested that the working group established a joint OSPARCOM BEWG group for QA. A. Kunitzer suggested that we should look at OSPAR guidelines on benthos monitoring since these will be finalised in November of this year.

2.3 Baltic Affairs

H. Rumohr reported on a recent meeting of the ICES/HELCOM WG on QA of benthic parameters in the Baltic. The QA group had four meetings and regional intercalibration workshops and have validated the results. They will edit a new set of guidelines for Baltic benthos based on ICES Tech. Pap. 8 (1990). Their applicability will include concerns problems in the North Sea and the wider North Atlantic.

Other news relayed by H. Rumohr: There will be a conference in Bornholm, Denmark to focus on updates on Baltic Marine Science, 22-26 October 1996. He also noted that 31st EMBS will be held in St. Petersburg, 9-13 September 1996, where themes will be adaptation strategies of marine organisms, interactions of marine organisms in communities, and *Obelia* as a dominant in epibiontic communities. A symposium on New Challenges for North Sea Research will be held 21-23 October 1996 in Hamburg to examine the benthic-pelagic coupling of processes in the North Sea.

2.4 US National Science Foundation (NSF)

P. Taylor was unable to attend but sent an extensive account of NSF activities and planning which are given in Annex 3.

2.5 Westerschelde

J. Craeymeersch reports that a data report of the 1994 surveys has now been produced. Work is ongoing.

2.6 Mediterranean

C. Smith informed the group about marine science projects in the Mediterranean. The equivalent organisations of CIESM and the GFCM are not as well organised nor funded as is ICES. He noted that marine science policy is driven by what funds are available from external funding sources, i.e. the EC supported Mediterranean Targeted Project, which involves both Mediterranean and northern European institutes. This project is just starting a second run of 3 years., and principally concerns studies on fluxes. There is not much funding for biodiversity and benthic projects are not well supported. This year's work mostly involves plankton and nutrients. There are some attempts to work with southern Mediterranean countries, especially Tunisia and Morocco because of fisheries problems. Difficulties of working with Israel and Arab countries were explained.

2.7 Arctic Monitoring Assessment Program.

A. Kunitzer noted that the final report is nearly finished. Continuation of this programme will essentially be a political decision. Canada, Russia and cooperating countries and Scandinavian countries were very active in this project, but there was little involvement from the US.

2.8 Pomeranian Bay and Gulf of Gdansk

J. Warzocha informed the group about a recent project in the Polish part of the Baltic. The aim of the project is to study the impact of the Oder River on the Pomeranian Bay ecosystem. The project is a continuation of a joint German - Polish study started in 1993, and will last for three years (1996-1998). The sampling and measurements will be done during 8 cruises with the participation of two ships R/V "Baltica" from Sea Fisheries Institute and R/V "Oceania" from the Polish Academy of Sciences. The Sea Fisheries Institute is the coordinator of the project which is split into three sub-projects dealing with:

- abiotic factors, including Oder River derived matter load
- ecosystem functioning
- pollution

The Foundation of Polish-German Cooperation has undertaken the role of supplementary financing of the project.
The long term studies in the Gulf of Gdansk started in 1978. The results were used in the Third Periodical Assessment of the State of the Baltic Sea (HELCOM) which is already finished.

2.9 Atlas of the North Sea Benthos

J. Craeymeersch reported that the atlas of the benthos of the ICES North Sea Benthos Survey (1986) is finished, but publication has been delayed.

K. Essink told about a one-day symposium held in The Hague, 23 April 1996, on the occasion of the publication of an Atlas of the benthos (macro- and meio-) of the Dutch Continental Shelf. Copies of this atlas is being mailed to BEWG members.

2.10 Marine Habitat Monitoring.

K. Hiscock reported that the marine benthic work of the UK nature conservation agencies was becoming greatly driven by the site management requirements of the EC Habitats Directive. The agencies would be responsible for monitoring the maintenance of the conservation status of the Special Areas of Conservation (SACs). Monitoring guidelines are to be produced and work will be commissioned to prepare guidelines and QA requirements for SAC monitoring. These SAC's do not exclude fisheries activities, but only activities that are deemed to not be sustainable, that is, those that are likely to cause disturbance or deterioration outside the limits of acceptable change.

2.11 Norwegian Studies

T. Brattegard noted that there are no marine conservation areas in Norway, so the government commissioned some studies of marine benthos distributions in order to plan for possible establishment of such regions. For this study, the coast of Norway was divided into 26 sectors extending from the Swedish to Russian borders. Faunal distributions were mapped over this regions, with species being characterised as either northern, southern, extensive, or rare. With quality control for taxonomic names, a total 5600 species were mapped. Because not all species are known from all sectors within their known ranges, some occurrences are interpolated. Using 2500 species, the Norwegian coast can be divided into the Skagerrak, West-Norwegian, and Finmark subprovinces. The West-Norwegian subprovince extends further north than previously recognised, now extending to Loppharet, north of Tromsö. He also reported that the vertical convection of the deep Greenland Sea has stopped and temperature at 2000 m depth at Weathership Stn M of the Norwegian Sea is rising, and current flowing from Greenland Sea to Norwegian Sea has reversed. This might mean a cooling of the waters in the North Sea, which should consequently see a change in its fauna. In response to a question T. Brattegard said that so far the Norwegian government has not identified nationally rare or scarce species, as has been done in Britain.

Jan Helga Fossa informed the group about Norwegian studies of kelp beds and noted the use of the kelp beds by a variety of benthic animals and algae. Each year about 150,000 tonnes of kelp is harvested About 50% of the kelp beds is grazed down in northern Norway, depending on the fluctuations of urchins.

2.12 Long term studies in northern Spain (La Coruña harbour)

E. López-Jamar reported on the long-term variation of benthic infauna which has been studied in two stations in La Coruña Bay, NW Spain, during a 14-year period (1982 to 1995). One of the stations is located in muddy, hypoxic sediments of the harbour area, where harbour dredging was carried out in 1982. Following a relatively quick recovery after dredging operations, the infaunal community did not vary much with time, in spite of frequent sediment disturbances. The bivalve *Thyasira flexuosa* and opportunistic polychaetes are the dominant organisms. The high stability of this community is related to the dominance of opportunists having short life-cycles, and thus well adapted to environmental disturbances. The other station is located in a relatively clean fine sand area of the bay, and the community is dominated by species having longer life-cycles, such as *Tellina fabula* and *Paradoneis armata*. This community shows a wider temporal variation, both seasonally and interannually. The effects of the *Aegean* oil spill on this temporal pattern is also reported (see Annex 4).

2.13 Belgian activities

H. Hillewaert gave a report about the southern North Sea sampling programme, which included both macrobenthos (infauna and epifauna) and fishes. Macrobenthos samples were stored for years, and are only now being sorted and identified. For epibenthos the net gear used was changed in 1985, so reliable data is available only since that time. Monitoring sites were established for sand extraction areas and for places where dredged material is being deposited. There are also a series of reference stations.

For epibenthos a 8 m beam trawl was used with a shrimp net with 36 mm mesh size. The trawl dragged for 30 minutes at 3-4 knots. Abundance and biomass of epibenthos and fishes were extrapolated to 100,000 m^2. Macrobenthos was sampled with a modified Van Veen grab with $0.1m^2$ surface. These were sieved at the laboratory over a 1 mm sieve after fixation in formalin on board ship. Stations in western zone showed a decreasing number of species in time whereas the eastern zone showed an increase in species. There is also an increase in grain size on the banks where sand is extracted (western zone), which correlates with decreasing species number.

Macrobenthos results for 1992 don't seem to be reliable. For the 1993 macrobenthos samples data are more comparable to studies by J. Craeymeersch and others. Cluster analysis gives four clusters: sand banks, onshore, offshore and one small cluster representing muddier stations.

2.14 Evaluation of the SIME Monitoring Programme

A. Kunitzer noted that this monitoring programme was already presented to OSPAR. This monitoring programme was previously based only on chemicals, and now it will include the effects of the chemicals on the organisms. The priorities for the monitoring programme need to be established, which can then be used to determine where funds for sampling will be spent. At present, the outline of the possible SIME-Monitoring Programme within the Joint Assessment and Monitoring Programme (JAMP) has been nearly completed according to the attached matrix, agreed to by OSPAR. Each cell in the matrix will be assigned a value (promising/not promising) according to applicability, feasibility, type of monitoring, etc. All techniques, etc., will be judged according to the criteria established in the matrix. The matrix was presented to the group for comment on the benthic components (see Annex 5). There was discussion about whether some of the categories in column A could be modified so that all items would be listed as "effects." There was also the suggestion that the scores assigned to each parameter be considered as categorical data, and that, therefore, they not be summed, but rather, the numbers of each category determined for each parameter. H. Rumohr noted that the minimum, rather the maximum, time for trend monitoring should be rated. L. Watling suggested that the scheme as presented treated the scores as additive values, rather than categorical values. This cannot be done since the techniques are not equivalent. Using the values as categories, one would then list of the numbers of high, medium, and low ratings for each parameter, and would use some judgement then as to which parameters to measure.

R. Stagg informed the group about Biological Effects Sub-Committee request to the BEWG to provide information on the response of benthic communities to contaminants, in terms of both methodology and QA, with a view to re-writing guidelines for a general monitoring handbook.

2.15 Introduced Species into European Estuaries

K. Essink reported on the further establishment of the North American polychaete, *Marenzellaria viridis* in Dutch coastal waters. This worm has dramatically increased in biomass in the Dollard in the three years since its first appearance. The worm has increased the overall biomass of the benthic system and has not pushed out historical inhabitants, so it is likely that the overall food availability of the system has been increased. Certain predatory species, e.g., juvenile flatfish, are feeding on the parts of this worm so it is contributing to the trophic system. Has this species invaded an open niche in the Dollard? Susan Smith reports that the species is moving slowly northward along the Swedish east coast. J. Craeymeersch reports that the species also has been found now in the south of the Netherlands.

2.16 Great Britain Marine Nature Conservation Review

Now that marine nature conservation work in Great Britain is being largely driven by the requirements for management of sites under the EC Habitats Directive, new approaches to survey and management are being developed. The descriptive survey of inshore benthic habitats around Great Britain by the Marine Nature Conservation Review (MNCR) has a timetable to March 1998 to complete survey and reporting on those areas of the coast of GB which have been surveyed (about two thirds of the coastline). There would be a series of publications starting with the MNCR Rationale & Methods volume to be published in July and including the benthic biotopes classification for the British Isles. It was planned that survey work undertaken from the Joint Nature Conservation Committee would be switched to support survey and monitoring requirements within SACs.

3 REPORT OF CO-OPERATIVE STUDIES

3.1 BIOFAR and BIOICE.

In the absence of A. Nørrevang, T. Brattegard reported that sampling will continue until 1998, with the emphasis now on completing intertidal to shallow water stations. Also established is the BIOICE program working around Iceland, with a new field station established near the Reykjavik airport. Planning is now underway for a BIOGREEN programme, working with new equipment in some of the previously sampled fjords.

3.2 Dutch Coastal Nourishment Studies

K. Essink informed the group about the Risk Analysis of Coastal Nourishment Techniques (RIACON) project to study the effects of sediment addition on macrofauna. Sediments are being supplemented along the foreshore to counteract the erosion of the beach. In RIACON (MAST II) the benthos was investigated by scientists in Denmark, Germany, The Netherlands, Belgium, and Spain. The last surveys were done in the autumn of last year. A decrease in macrofaunal abundance followed by recovery was observed but the data are still being analysed. K. Essink also reported that the sand being used for the nourishment was a little coarser than local sediment and was seen to stay in place for longer than expected.

K. Essink reported on a new, still experimental, practice in the Netherlands. For local beach nourishment a temporal borrow-pit is made in the foreshore that is filled with sand extracted in deeper water (> 20 m) or originating from maintenance dredging of navigational channels. This practice will be acceptable only if effects on local benthos and near shore sediment transport are acceptably small.

3.3 The Baltic Intercalibration Study

H. Rumohr informed the group about a QA study designed to intercalibrate benthic sampling methods. The study was conducted in the Baltic in order to minimize differences due to taxonomic problems. However, the importance of regular taxonomic workshops was also noted. The results were tabled at a workshop held in Helsinki, at which time it was also decided to prepare a video which shows dramatically the action of the various sampling gear.

4 EFFECTS OF DISTURBANCE ON THE SEA FLOOR

4.1 Impact II

4.1.1 Scottish Studies

As part of the AIR IMPACT II programme, the Marine Laboratory in Aberdeen is carrying out an experimental trawling study in The Gareloch, Scotland, an unfished sealoch. Fishing in the loch has been banned for 25 years due to the presence of a naval base in the loch. Ian Tuck reported on progress and told the working group that The Gareloch was surveyed in November 1993, using sidescan and Roxann sonar, towed underwater TV and epifaunal sampling techniques. No evidence of physical disturbance was noted, and infaunal communities were not different between t he areas chosen for study. An experimental trawling programme commenced in January 1994 on a one day per month basis, and continued until April 1995. The disturbed area was compared to a reference area within the loch on 6 monthly research cruises, commencing in May 1994, which will continue until October 1996. Sidescan and Roxann data showed considerable physical disturbance in the trawled area, which had reduced in magnitude following 6 months recovery. Analysis of infaunal data showed that following 10 months of disturbance, the communities in the two areas had both changed, and were significantly different from each other. These changes are interpreted as both seasonal and disturbance effects, and analysis of samples from other disturbance and recovery surveys should clarify this.

4.1.2 German Studies

H. Rumohr noted that under IMPACT II, historical changes in biota as well as direct impact of fishing on the sediments is being investigated. REMOTS was used in a high energy tidal habitat where the average penetration depth of the camera prism was proposed as a measure of sediment compaction and surface roughness of the sediment. Fished areas were subjected to 12 m beam trawl activity. There was always a difference in penetration depth with the fished area being about 1 cm less than unfished areas. Surface roughness was also about 1 cm higher in unfished areas vs. fished areas. Trawling seems to remove surface ripples and re-suspend the finer particles. Penetration of the prism is governed by the compaction of the lower layers, so lower penetration also indicates loss of upper 1 cm.

4.1.3 Dutch Studies

J. Craeymeersch reported on studies looking at direct effects of different fishing gear. Several different areas, including both sandy and muddy bottoms were investigated. Areas were sampled immediately before fishing using triple-D (deep digging dredge) after which they were hauled with either a 12 m beam trawl, a 4 m beam trawl, a 4 m beam trawl equipped with a chain matrix, or an otter trawl. Mortality of caught animals was estimated. The triple-D was used again afterwards. All species evaluated were larger infauna and low mobile epifauna. Several species suffer high mortalities. *Echinocardium cordatum* e.g. suffers about 90% mortality in muddy areas and about 75% in sandy areas. The otter trawl caused lower levels of mortality of this species. For all species, the 4 m beam trawl affected the most species and otter trawl the fewest.

4.2 Effects of scallop dredging in coastal Maine.

L. Watling reported on a small study examining the impact of scallop dragging on a muddy sand community in mid-coastal Maine. After a single day of dragging, some components of the benthos, for example, the photid and phoxocephalid amphipods, as well as the cumaceans, avoided the drag track until about 5 months after the drag event. It is thought that this avoidance is due to the fact that the surface loose material, with high water and food content, was blown away by the dredge. This material is not replaced rapidly due to the low sedimentation rate in this embayment. See Annex 6.

4.3 Effects of Gravel Extraction off the English Coast

H. Rees presented a summary of current findings regarding the macrofauna inhabiting marine gravels from several locations around the coast of the UK. The primary objective of the study is to characterise the benthic community of these sites, and try to link gradients in the benthos to particles size and hydrographic influences such as water motion. Such information will be used to whether some sites are more vulnerable to gravel extraction than others. In high current regimes where there is a lot of sand mixed with the gravel there is more sediment mobility and reduced fauna. (Annex 7 by Kenny et al)

4.4 Biotope mapping of gravels

H. Hillewaert gave a report from the Sand and Gravel Extraction Working Group. The principal focus of previous reports was on effects of commercial fishing, but now there needs to be more emphasis on growth and production of non-commercial species. They also need to add criteria for habitat mapping which includes micro-scale parameters, etc., that are strictly geological but could be critical for habitat mapping. Acoustic mapping is becoming far more refined and is being used to locate sampling stations in relation to bedforms, etc. There is also a need to develop suitable sampling strategies for sand and gravel biotopes. BEWG will be asked to review methods for sampling in these areas.

4.5 Effects of traps and other fishing gear on the seafloor

K. Hiscock noted that a study has taken place under EU funding to examine the effect of traps on certain benthic species. The results are being written up currently and will be available in the near future, after they have been delivered to the EU. A study of the general effects of scallop dredging on bottom habitats is presented by MacDonald (1993).

5 INDICATOR SPECIES SENSITIVE TO DISTURBANCE

The Working Group considered the problem of indicator species, but felt that more natural history information was needed before certain species could be designated. Last year the group established a series of criteria which could be used to designate likely sensitive species. It was concluded that a project should be funded to examine the list of sensitive species for the North Sea area in light of these criteria. An example of such a study is the list provided by MacDonald et al, see Annex 8.

6 COMPUTER-AIDED TAXONOMY

6.1 ETI

M. de Kluijver gave a demonstration of an ETI CD-ROM which will be developed during the next two years. The CD-ROM will contain three different keys, diagnoses, and images of ca. 1000 macrobenthic organisms (> 1 mm in length) occurring in the southern North Sea down to depths of about 100 m. In addition, standard protocols for sampling, identifying, and mapping benthic communities will be developed by combining existing methodologies. References to existing guidelines of OSPARCOM, HELCOM, and ICES will be given.

6.2 HTML

H. Hillewaert demonstrated a technique for using existing identification keys on an Internet website. Pictures and text are scanned and the text is subsequently converted with Optical Character Recognition. HTML (hypertext mark-up language) code is added to provide links between several parts of the key and the pictures.

This technique is fairly easy and could be use to produce new keys quickly or to provide easily accessible updates to existing keys.

6.3 DELTA

J. Craeymeersch) demonstrated INTKEY4, which is part of a number of programs using descriptions encoded in the DELTA-format (Descriptive Language for TAxonomy), a format adopted by the International Taxonomic Databases Working Group as a standard for data exchange. Information about the specimen being identified is entered via menus. One has to choose from characters in a list which is displayed (the 'best' character at the top). Illustrations of the character states are displayed. At each step, taxa which do not match the specimen are eliminated, and the number of taxa remaining is reduced.

The group also received a demonstration version of MATHER (demo to mayfly families). The system is written in visual basic and uses fuzzy logic.

7 ICES BENTHOS DATA BASE

The BEWG is asked to give advice regarding database establishment and, in particular, to discuss the use of species codes. H. Rumohr noted that species codes were invented in times when data storage was limited. This is no longer necessary. However, H. Rees noted that the UK has adopted the NODC coding system for archiving benthos data from the National Monitoring Plan. The interchangeablitiy of codes is no real problem as long as they are all based on standard taxonomic nomenclature. We recommend that ICES adopt the NODC code which is an already well-established international system.

Derek Moore of the Aberdeen lab gave a brief presentation on the NODC system (see Annex 9). He reported that the UK species list in the Marine Conservation Society's Species Directory, which is shortly to be published as a second edition, will be fully coded very shortly. It is intended that this will be made available in electronic format, alongside the MCS codes. It was also noted, however, that NODC is planning to serialise its code. It is not clear whether NODC will then phase out the hierarchical 12-digit code it currently uses.

H.. Rumohr enquired as to whether there were any coding systems for sediment based on grain size. A. Kunitzer noted that OSPARCOM has a code for sediment contaminants, which may include grain size.

L. Watling gave a demonstration on the use of fuzzy clustering, emphasizing the particular usefulness of applying the technique in situations where species are distributed along an environmental gradient.

8 MNCR BIOMAR BIOTOPES BENTHIC CLASSIFICATION

Keith Hiscock described progress with the development of the MNCR-BioMar biotopes benthic classification. The report of the European workshop held in Cambridge in November 1994 had been published and a further European workshop held in Dublin in September 1995. The aim of these workshops was to involve European marine biologists in the development of a classification especially the framework for the classification. Also during 1995, an intertidal biotopes manual had been published. In relation to the North Sea, the Declaration from the June 1995 Ministerial meeting had invited the European Commission and the European Environment Agency to develop a biotopes classification for the North Sea. Although the MNCR classification is for the British Isles, it could clearly be used as a basis for the development of that invitation particularly as the framework had been thoroughly discussed with European marine biologists. For the moment, further development would be for the British Isles and, by the time of the next BEWG meeting, there would be a completed classification.
The meeting endorsed the development of the classification as a practical management tool.

9 METHODS FOR STUDYING HARD BOTTOM SUBSTRATA

A sub-group was set up to consider and report on sampling methods for hard bottom substrata sampling methods. Hard bottoms were extended to include kelp forests and coarse aggregate substrates. Their report is appended as Annex 10.

10 NORTH SEA BENTHOS SURVEY

A sub-group was set up to finalize the plans for a new North Sea benthos survey. It was a agreed to attempt to submit a proposal in response to the EC programme for data gathering and study projects within the framework of the Common Fisheries Policy, the deadline for which was the end of May. It was felt that the proposed survey could be fitted into the section "Gathering environmental data", in particular Item A.6 - monitoring the development of populations and marine environments affected by fishing. If this not was not possible within the time-scale, the proposal would be submitted as part of the MAST programme, the deadline for which was October.

Members of the group were able to identify up to four institutions that may contribute ship time to the project (Netherlands, Germany, U.K. and Belgium). If shiptime can be supported some other way, then the research funds (approximately 2-300,000 ECU) will go primarily to support taxonomic efforts and meetings. Sampling will be concentrated in areas of borders of water masses and in the vicinity of fronts. Approx. 100 stations are proposed. There was a general call for information regarding taxonomists who might be willing to help.

11 MICRO-SPATIAL DISTRIBUTIONS

L. Watling presented a comparison of spatial data analysis methods, utilizing quadrate variance and time series methods over very long transects. It was suggested that quadrate-variance methods were generally unsatisfactory at representing the structure of large scale patches where there were no clear gaps between the patches. The group decided to have a more detailed discussion of micro-spatial distributions at the next BEWG meeting.

12 ELECTION OF NEW CHAIRMAN

Dr Kingston retired as Chairman of the Working Group having served five years. Dr Karel Essink was unanimously elected as the new Chairman of the Benthos Ecology Working Group.

13 ANY OTHER BUSINESS

The Working Group was asked to consider a MAST proposal on biodiversity of sand and gravel deposits by Professor Carlo Heip and Dr Bas de Groot of the Working Group on the Effects of Extraction of Marine Sediments on Fisheries. The BEWG decided that it was not in the position to offer support to any individual proposal, but it would offer general support to the Biological Coordinator of such a project, with the additional suggestion that the Coordinator also be a member of BEWG.

14 RECOMMENDATIONS

The Benthos Ecology Working Group recommends that Dr Karel Essnink should be appointed as the new chairman of the BEWG and it should meet on 23-26 April in Gydnia, Poland to:

1. Review cooperative studies throughout the ICES area.

2. Report on progress of the North Sea Benthos Survey.

3. Assess the results of the IMPACT II project on the effects of fishing on benthos.

4. Review studies on the small scale

5. Review computer aids to benthic studies.

6. Review methods to increase the efficiency and quality of identification aids in benthos studies.

15 ACTION LIST

1. Karel Essink to report on the effects of shellfisheries activity on seabirds.
2. D Basford, J Craeymeersch and H Rumohr to report on the results of the IMPACT II project.
3. Keith Hiscock to report on progress on the BIOMAR project.
4. Johann Craeymeersch to update progress on the production of interactive computer taxonomic aids.
5. J-M Dewarumez to report on studies on an *Abra* community in the southern North Sea and English Channel.
6. J-M Dewarumez to report on progress on the GLOBEC project in the English Channel.
7. J-M Dewarumez to report on studies on meroplankton distribution in the southern North sea.
8. Gerard Duineveld to report on bioturbation studies.
9. Gerard Duineveld to report on the use of DNA/RNA to study sediment quality and growth status of organisms.
10. Karel Essink to report on Dutch coastal nourishment studies.
11. Karel Essink to report on the Dutch Monitoring Programme and other projects of the Rijkswaterstat.
12. Hans Hillweit to update progress on the monitoring the impact of sand and gravel extraction off the Belgian coast.
13. Paul Kingston and Eduardo Lopez-Jamar to report on comparitve studies on the effects of the *Braer* and *Aegean Sea* oil spill
14. Ingrid Kronke to report on long-term benthic studies off Nordeney.
15. Ingrid Kronke to report on studies in the Wadden Sea.
16. Anita Kunitzer to report on Arctic studies.
17. Anita Kunitzer to report on studies of the distribution of macroalgae in the shallow areas of the Baltic Sea.
18. Anita Kunitzer to report on progress on the Joint Assessment Monitoring Programme.
19. Anita Kunitzer to report on imposex in snails.
20. Jan-Rene Larsen to report on the ICES Science Meeting in Reykjavik.
21. Jan-Rene Larsen to report on the meeting of ACME.
22. Hubert Rees to report on an epifaunal survey of the UK coast.
23. Jan Warzocha and Martin Powillet to report on further results of benthic studies in the Pommeranian Bight and Gulf of Gdansk.

24. Les Watling to report on the workshop on PEET (electonic means of disseminating taxonomic aids.

25. Les Watling to report on methods for spatial analysis of benthos.

26. Johann Craeymeersch to report on the results of studies on small scale benthic distribution.

27. Eike Rachor to report on ENTAS and Arctic projects.

28. Jan Fossa Helga to report on ecological impact of the utilization of kelp.

29. Tom Pearson to report on developing Norwegian Arctic projects.

30. Tom Pearson to report on progress in regionalization of oil pollution monitoring in Norway.

31. Heye Rumohr to report on the outcome of the Baltic Science Conference to be held in Denmark.

32. Torliev Brattegard to report on studies on the zoogeography of Norway.

33. Torliev Brattegard to report on grab sampling studies in Norwegian waters.

34. Chris Smith to report on eastern Mediterranean cooperative projects.

35. Mario de Kluijver to report on progress in computer based taxonomic studies.

ANNEX 1

PARTICIPANTS OF THE BENTHOS ECOLOGY WORKING GROUP MEETING (Aberdeen 1-4 May 1996)

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ANNEX 2

National Marine Biology Analytical Quality Control Scheme

It has been increasingly recognised by biologists working in coastal waters that there is a pressing need to standardise methods of analysis and move towards developing and managing a control system ensuring uniformly high quality data. Reliance on benthic infaunal data in terms of its ability to describe in quantitative terms, the quality of the ecosystem and sedimentary environment and any impact thereon has been increasing and the development of Environmental Quality Standards based on biological determinands has further reinforced this need.

Following the establishment of the National Marine AQC scheme in 1992 it became clear that the biological components of the National Monitoring Plan (NMP) would not be covered by the scope of the original scheme. The National Marine Biology AQC scheme (NMBAQC) was therefore established at the request of the UK Marine Pollution Monitoring Management Group (MPMMG) and is designed to assess the performance of those laboratories submitting benthic biological and associated data to the NMP.

The scheme is the overall responsibility of a Co-ordinating Committee under the chairmanship of Dr Matthew Service, of the Department of Agriculture, Northern Ireland (DANI). Dr Steve Hull of SEPA (East) acts as Secretary. This committee clearly sets out the nature of the material to be circulated and the conditions for collection of the samples. The day-to-day running of the scheme is managed by Anne Henderson of SEPA (West) and the contractors to the scheme, supplying the materials and reporting back to the Co-ordinating Committee, are UnicoMarine.

During the first year of operation 25 laboratories participated in the scheme which consisted of three components; analysis of two macrobenthic samples, particle size analysis of four sediment samples and identification of four sets of twenty animal specimens. The results of this exercise were presented in the form of a report to MPMMG in which the various laboratories remained anonymous.

The scheme has successfully completed its second year and is now entering its third.

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ANNEX 3

REPORT FROM THE NATIONAL SCIENCE FOUNDATION

1 Ridge Inter-Disciplinary Global Experiments - RIDGE

see: http://ridge.unh.edu/

In the US, the National Science Foundation continues to support the development of the RIDGE (Ridge Inter-Disciplinary Global Experiments) Initiative.

- RIDGE is designed to integrate exploration, experimentation and theoretical modelling into a major research effort to understand the geophysical, geochemical and geobiological causes and consequences of the energy transfer within the global rift system through time.

- Its long-term strategy is to obtain a sufficiently detailed spatial and temporal definition of the global mid-ocean ridge system to construct quantitative, testable models of how the system works, including the complex interactions among the magmatic, tectonic, hydrothermal and biological processes associated with crustal formation.

- The RIDGE Program components are therefore intrinsically interdisciplinary, and are intended to complement existing ridge crest research by emphasizing an integrated, investigative approach that can be accomplished only with high levels of coordination. Funding is divided between the Marine Geology and Geophysics and Biological Oceanography programs within the Division of Ocean Sciences, NSF. Assuming the present funding profile is maintained, approximately $45 million may be available over the next five years for RIDGE-related research.

- International activities through InterRidge will serve to increase substantially the effectiveness and the accomplishments of such a coordinated strategy for investigations of ridge crest processes.

2 The Larvae At Ridge VEnts Project (LARVE)

This is a component of the RIDGE (Ridge Inter-Disciplinary Global Experiments) Initiative.

-- The goal of the LARVE Project is to investigate larval dispersal and gene flow in benthic populations in vent environments and evaluate the potential role of these processes in generating and maintaining biogeographic patterns along mid-ocean ridges and across ocean basins. These experiments are coordinated within RIDGE to foster interdisciplinary studies of reproduction, larval ecology and physiology, physical transport processes, recruitment and population genetics in deep-sea hydrothermal vent habitats. The LARVE Project is a series of inter-related experiments and observations that address the persistent questions of how vent species maintain their populations in ephemeral vent environments, how they colonise new vents, and what controls their distributions over regional and global scales. These processes can be fully understood only through coordinated investigation of a series of events: reproduction, larval dispersal, recruitment, gene flow, and, ultimately, speciation.

The specific objectives of the project are to obtain critical measurements and observations in four different stages of the process leading to dispersal and gene flow between vent habitats:

1. **Reproduction.** This component includes observations of gametogenic patterns and gamete production as evidence of spawning periodicity and synchrony, studies of environmental cues for spawning, and quantitative measurements of reproductive output (age at first reproduction and variations in reproductive effort over time and relative to environment). These measurements will be coupled with models to characterise reproductive output at the community level.

2. **Larval dispersal and retention.** An understanding of mechanisms controlling the fate of larvae in the water column requires a multidisciplinary approach, including a characterization of the flow patterns in hydrothermal plumes and benthic boundary layer that influence larval transport, corresponding measurements of

the three- dimensional larval distributions in the water column near vents to reveal how currents facilitate larval dispersal or retention, and laboratory studies (conducted at pressure, if necessary) of larval growth, development, physiology and swimming and sinking behaviours. Species-level identification of larvae will be critical for some aspects of these field studies.

3. **Recruitment**. To understand what controls recruitment success in vent larvae and post-larvae, it is necessary to know whether specific cues are involved in the settlement process, and to document settlement episodicity and early post-settlement mortality. Studies of early post- settlement processes will address the importance of species interactions during recruitment.

4. **Gene flow and biogeography**. To measure levels of successful exchanges among populations that result from dispersal, genetic surveys will be conducted on target species. Biogeographic (phylogeographic) surveys on ridge-segment and multi-segment scales, coupled with geological surveys will be conducted to locate and explain gaps between genetic populations. These studies will lead to modelling of metapopulation dynamics in collaboration with geological studies.

Location. The region between 9o10'N on the East Pacific Rise (EPR) will be the primary location for coordinated studies on larval biology, retention, and recruitment; larger-scale gene-flow studies will expand to regional ridge segments. Active vent sites with diverse biological communities are concentrated in the area near 9o50'N.

Target Species. To focus the studies of the different components of the project, and ensure that they mesh into a cohesive whole, the following are recommended as target species (based on abundance, ecological importance, and to represent a range of reproductive and developmental modes):

Riftia pachyptila (vestimentiferan tube worm)
Tevnia jerichonana (vestimentiferan tube worm)
Bythograea thermydron (crab)
Munidopsis subsquamosa (galatheid crab)
Bathymodiolus thermophilus (mussel)
Calyptogena magnifica (clam)
Cyathermia naticoides (trochoid archaeogastropod)
Lepetodrilus elevatus or *L. pustulosus* (limpets)
Phymorhynchus sp. (egg-capsule producing turrid gastropod)

Proposed Project Time Line

Fall 1996 Development of hyperbaric chambers for larval culture, physiology and behaviour; Preparation for physical oceanographic studies

Spring 1997 Laboratory and field teams meet to coordinate initial field experiments

Fall 1997 *Four-week submersible cruise to initiate reproductive and demographic sampling, laboratory and field experiments on spawning cues, larval physiology and behaviour studies in hyperbaric chambers (incl. symbiont acquisition), studies of larval dispersal and retention near vents (including identification and quantification of larvae of vent species), studies of intensity and timing of settlement, intraspecific genetic surveys, biogeographic (phylogeographic) survey across ecological and geological gaps; One-week cruise to implement segment-scale physical oceanographic study

Winter 1997 Field teams meet to evaluate preliminary data and coordinate 1998 field studies

Spring 1998 Three-week submersible cruise to continue previous studies (particularly those on reproduction and settlement that require frequent visits), and initiate laboratory and field experiments on settlement cues, flow field characterization on vent scale, metapopulation dynamics modelling

Fall 1998 Three-week submersible cruise to continue field studies and/or initiate projects mentioned above

Fall 1999 Three-week submersible cruise to continue field studies and/or initiate projects with later starts

Fall 2000 Three-week submersible cruise to complete remaining field studies

* Initial cruises are open to any of these "high-priority" studies, but it is anticipated that some will be initiated later in the project. "Submersible cruise" requires an underwater vehicle with advanced manipulative and collection capabilities; a remotely operated vehicle (ROV) is a possible alternative for these cruises.

SHIP REQUIREMENTS

The ideal schedule for the LARVE project as outlined in the project description includes six cruises over a four-year period. Five of these cruises require submersible (or ROV) operations; the other cruise requires a moderate-sized conventional ship for deployment of moorings anticipated to be a component of the large-scale physical oceanographic studies. Some of the submersible cruises may require a moderate-sized conventional ship in addition to the submersible support vessel to provide for personnel, equipment (e.g., high-pressure larval culture systems), and transportation to a US port. Requests for this additional ship will be proposal dependent. Aside from the initial mooring deployments, physical oceanographic studies are expected to be conducted from the submersible support vessel.

NON-U.S. PARTICIPATION

The LARVE project is not a formal InterRidge program, but non-US participation is encouraged.

3 LMER Update

The Land Margin Ecosystems Research Program (LMER) is to help answer the scientific and societal questions about the present functions and future changes of coastal environments. The goals of LMER are to increase the understanding of the organisation and function of land-margin ecosystems, the linkages between these systems and adjacent terrestrial and marine ecosystems, and the impacts of major natural environmental perturbations in these regions. This is a US component of the IGBP LIOCZ program.

Several major changes have occurred in LMER in the recent past with the completion and additions of projects/sites.
see http://www.mbl.edu/html/ECOSYSTEMS/lmer/lmer.html

A. Trophic Interactions in Estuarine Systems (TIES)

The Chesapeake Bay LMER project, Trophic Interactions in Estuarine Systems (TIES), uses Chesapeake Bay to investigate mechanisms by which production at higher trophic levels is influenced by inputs from adjacent watershed, ocean and atmosphere. This project has changed dramatically over the original project with the focus now on the production of animal populations of the Bay. Research examines:

How fine-scale distributions (as well as regionally integrated values) of physical and biological properties and processes respond to interannual variations in inputs from terrestrial and oceanic margins;

How physical structures and biological patches influence production and trophic structure of the estuarine ecosystem.

B. Columbia River Estuarine Turbidity Maxima (CRETM)

The Columbia River Estuarine Turbidity Maxima (CRETM) project studies the importance of estuarine turbidity maxima (ETM) to river estuaries and coastal ecosystems. Since particles are the primary currency of organic matter transfer from watershed to estuary, the research focuses on:

- Particle aggregation/disaggregation as a key linkage between ETM physics, geochemistry and ecology;
- Biogeochemical and ecological processes affected by ETM dynamics;
- Modelling of these processes to quantify mass, constituent and energy fluxes, and chemical transformations, and to investigate selected scenarios of watershed and global change;
- Interactions of ETM with surrounding estuarine habitats, watershed and the coastal ocean; and
- Selected comparisons with other estuaries, particularly LMER sites.

C. Georgia Rivers LMER studies the transport and transformation of inorganic and organic materials carried from the land into the sea by the five major coastal rivers of Georgia, offering an unusual opportunity for the comparative ecological study of the impact of the land, via rivers, on the nearshore ocean and of the ocean, via tidal flooding, on the riparian and coastal wetlands. The activities set out for the research are:

- To measure the hydrodynamic characteristics of the rivers and estuaries that are necessary for understanding and quantifying the flux of materials, to measure chemical and physical changes in concentrations and bioactivity of constituents as they pass through distinct communities within the land sea margin, and to conduct a series of laboratory and field experiments to further extend knowledge f the interaction of land, river, sea and riparian and coastal wetlands;

- To utilise models to guide the selection of sampling sites and to integrate the flux study work.

D. Plum Island Sound Comparative Ecosystems Study (PISCES)

The Plum Island Sound Comparative Ecosystem Study investigates the importance to estuarine ecosystems of organic carbon and organic nitrogen inputs from watersheds with various land covers and uses. It also asks whether the interaction of inorganic nutrients with the quantity and quality of organic carbon and organic nitrogen play an important role in determining the trophic structure, production and trophic efficiency in estuaries. To answer these questions, the scientists:

- Measure the quantity of dissolved and particulate organic carbon and organic nitrogen entering coastal waters from lands;

- Conduct experiments to determine the effects of various nutrient and organic matter inputs and interactions on the flow and recycling of C and N through pelagic and benthic food webs including higher trophic levels;

- Model food chain transformations and the effects of changes in land use and land cover.

E. Waquoit Bay LMER (WBLMER)

This project has been reported on previously and is being phased out currently.

The Waquoit Bay LMER studies the coupling between the land and sea by comparing watershed-estuarine systems in which different land use leads to different nitrogen loading. Process and ecosystem research is designed to understand sources, fates and ecological consequences of nutrient loading in the water column, in the benthos, in sediments, and on watersheds.

- Water column process and ecosystem studies examine the coupling of loading to hydrographic and ecological processes;

- Sediment process studies examine the contribution of sediments to regenerated nutrients in the water column;

- Watershed ecosystem studies are designed to better understand sources of N, and the evaluate mechanisms governing nutrient transport below watershed surfaces, and

- Long-term studies also involve the detection of secular changes to responses to continuing urbanization of watersheds, and resulting increases in nutrient loading.

F. Tomales Bay LMER: Biogeochemical Reactions in Estuaries (BRIE)

This project has been reported on previously and has now been completed.

Research on Biogeochemical Reactions in Estuaries (BRIE) used Tomales Bay to study the biogeochemical processes and geochemical coupling at the land-sea interface. Questions asked were:

- What are the causes of interannual variability in the geochemical performance of the system?
- How do terrestrial processes influence net system geochemistry?
- What controls the gross processes that determine net system behaviour?

4 US GLOBEC (GLOBal ocean ECosystems dynamics)

This is a research program organized by oceanographers and fisheries scientists to address the question of how global climate change may affect the abundance and production of animals in the sea. Zooplankton (small drifting animals) are a focus because they are the key link in the food chain between phytoplankton and higher trophic levels. Early life stages of most marine animals are planktonic (they drift wherever ocean currents take them). Recruitment of many fishes (such as cod and sardines) and benthic invertebrates (oysters, scallops, sea urchins) depends upon survival of planktonic larvae and subsequent transport of larvae to nursery areas. Ocean circulation and other aspects of the physical environment are major factors controlling patterns of marine animal abundance. see:
http://www.usglobec.berkeley.edu/usglobec/globec.homepage.html

A. Northwest Atlantic Project Description and Rationale:

The Georges Bank region was selected by the US GLOBEC Program because (1) ecosystems in and around Georges Bank are thought to be highly sensitive to climatic variability as the Bank is situated in a faunal, climatic and oceanic boundary region; (2) physical transport processes in the Georges Bank region are predicted to be more heavily impacted by climatic variation than other areas in the North Atlantic Ocean; (3) primary and secondary production on Georges Bank has supported a commercially valuable fishery; and (4) Georges Bank is of sufficient size, with a physical circulation pattern enabling distinct, and trackable populations to develop and persist for long periods, making them amenable for time-series studies.

The Georges Bank ecosystem has recently undergone significant perturbations. Many of the traditional fisheries have collapsed, with a shift in biomass and production to other fish species. There have been changes in fish predator-prey interactions as well. Management plans have been initiated to limit fishing and to rebuild the groundfish stocks. Knowledge of the physical and biological processes acting at the present time will contribute to a better understanding of changes in the fish stocks during recovery. On-going monitoring, process research, modelling and retrospective analyses of past conditions will contribute to an assessment of when commercially-important stocks will recover. Information produced by these studies will lead to more effective advice to fishery management councils to help guide the recovery process.

B. Northwest Atlantic Project Phase II. (Benthos will continue to be largely absent from the study)

US GLOBEC research will continue to focus on target species chosen to represent key elements of the planktonic assemblages on Georges Bank and surrounding regions. These are the pelagic eggs, larvae and juvenile stages of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) and the copepods, *Calanus finmarchicus* and *Pseudocalanus* spp.

Observational evidence suggests that five physical processes are of greatest importance to biological activities on the Bank: advection, turbulent mixing, stratification, frontal exchange, and bottom boundary layer phenomena. In testing the hypotheses related to Phase Two of this program (i.e., source, retention, and loss of water and animals to/from the Bank), four activities and objectives will be addressed:

- quantification of the abundances of target species in time and space on Georges Bank over the winter/spring period;
- measurement of the vital rates of target species as they relate to population dynamics;
- quantification of rates of physical exchanges of water and biota across the boundaries of the Bank; and determination of how physical exchange processes and vertical migration behaviour influence retention/loss of planktonic animals on the Bank.

5 US - JGOFS

A. Overall Program

The resulting synthesis of US-JGOFS data and process studies' interpretations should advance us towards our stated operational goal:

To assess more accurately, and understand better the processes controlling, regional to global and seasonal to interannual fluxes of carbon between the atmosphere and ocean interior, and their sensitivity to climate changes

Within this broad framework US-JGOFS has five specific objectives:

- To characterise the present geographical distribution of key biogeochemical properties and rate processes pertinent to the oceanic carbon system, as a necessary prerequisite to predicting change in the system.
- To identify and quantify the biogeochemical mechanisms, including trophodynamic and physico-chemical processes, that control the forms in which carbon moves with and through the water, via ocean currents, mixing, diffusion, and particle sinking, and the rates of processes transforming carbon among dissolved and particulate, living and non living, organic and inorganic forms.
- To determine the response of the ocean carbon system to physical and chemical forcing from sub-seasonal events to decadal changes.
- To develop coupled physical and biogeochemical models of the ocean for the purposes of testing our understanding and improving our ability to predict future climate-related change.
- To improve observational constraints on the passive uptake of anthropogenic CO2 by the oceans, and to improve our understanding of the potential for changes in ocean circulation and biology to modify the oceanic uptake.

B. US - JGOFS Field Program Activities

B.1 Arabian Sea (just completed) Rationale:

It is unclear whether the northwestern Indian Ocean (Arabian Sea) is a sink for atmospheric carbon dioxide via its high rates of primary productivity and large concentrations of sedimentary carbon, or a source via outgassing of carbon dioxide brought to the surface during upwelling. The unique properties of the Arabian Sea can be used to expand our general understanding of the carbon cycle, productivity, and vertical flux of particulate material and biogeochemical transformations in the sea. Its principal unique feature is the regular oscillation of high rates of primary production and generally oligotrophic conditions under relatively constant levels of illumination. The oscillations in productivity and biomass that in high latitudes are forced by temporal variations in solar irradiation are here of a similar magnitude, but are forced by monsoonal atmospheric conditions which, via surface pressure fields and baroclinic adjustments, affect mixed-layer development and nutrient supply. The Arabian Sea experiences extremes in atmospheric forcing that lead to the greatest seasonal variability observed in any ocean basin. The wide range of climatic variability in the Arabian Sea makes it an excellent place in the present-day ocean to look clearly t past climates and possible future climates.

Arabian Sea: Objectives

- Primary Productivity and Carbon/Nitrogen Cycling: Does the regularity of monsoon reversals and strength of monsoon forcing create conditions in which the response of the region in terms of carbon fixation (primary production) is immediate and massive and in which balances between carbon and nitrogen exchanges between the euphotic zone and the atmosphere and the euphotic zone and depth are predictably time-varying signals of large magnitude?

- Heterotrophic Processes: Does the combination of high rates of carbon fixation, predictable in space and regularly oscillating seasonally, and widespread suboxic conditions below the euphotic zone restrict carbon cycling by metazoans primarily to regions above 150 m or below 1,500 m and intensify carbon cycling by unicellular organisms in intermediate layers with the result that carbon concentrations at depth (e.g., in the form of zooplankton biomass and possibly detrital material) are elevated?

- Water Column Geochemistry: Does the massive, pulsed vertical input of organic matter from high rates of carbon fixation occurring during monsoon periods, particularly during the southwest monsoon, lead to a strong oxygen demand at the sea floor, as well as in the water column, which, in turn, provides a major control on water column geochemistry through lateral transport from continental margins to the central basin of the Arabian Sea?

- Benthic Fluxes and Paleoceanography: Does the large, seasonally forced input of organic material to the seabed result not only in large burial as well as recycling of organic carbon, carbonate, and organic nitrogen, but also in large depositions of organisms that act as paleoceanographic indicators of temporal and spatial scales of productivity? Can these be correlated with known climate change of the past and used to understand responses of this ocean basin to climate change in the future?

B.2 Southern Ocean (just about to start, late 1996) Rationale:

The Southern Ocean, defined for the purposes of this study as the region south of, and including, the Subtropical Convergence, covers nearly 20% of the global ocean area. The Antarctic Circumpolar Current (ACC) has the largest volume flux of any major ocean current (130 Sverdrups). It is the only continuous circumglobal current, without beginning or end, and it is responsible for mixing of the deep waters of the other major oceans. Most of the ventilation of deep-sea water masses takes place in the Southern Ocean; in other words, deep water masses exchange gaseous components, including CO_2 with the atmosphere. Furthermore, most deep waters derive their physical, chemical, and biological characteristics in the regions of the Southern Ocean where isopycnals outcrop at the sea surface and where mixing, cooling, and sea ice formation produce new water masses which sink into the ocean interior and renew the intermediate and deep waters of the world's oceans.

A unique feature of the Southern Ocean is the extensive regular seasonal advance and retreat of sea ice, oscillating between a maximum coverage of 20 106 km2 and a minimum of 4 106 km2. This surface feature, too, can be thought of as a frontal system, one that migrates north and south many hundreds of km annually. Biological productivity of surface waters is strongly influenced by the presence, and melting, of sea ice. Ice-edge productivity supports an abundance of life at higher trophic levels including mammals and birds as well as zooplankton and fish. Fluxes of carbon in the Southern Ocean are large and play an important role in the global carbon cycle, yet the magnitudes of these fluxes remain poorly constrained.

Global warming is likely to perturb circulation, ventilation, and biogeochemical processes in the Southern Ocean and these, in turn, represent potentially significant feedbacks into the nature of global change. At present, we know too little to predict the role of the Southern Ocean in global change, or the response of biogeochemical cycles in the Southern Ocean to anticipated warming. By successfully conducting process studies in the Southern Ocean, and then incorporating the results into ongoing efforts to construct coupled physical-biogeochemical models, we can better determine the present role of the Southern Ocean in the global carbon cycle, and improve our capability to predict the likely response of the region to anticipated global change.

Southern Ocean, Objectives:

- To better constrain the fluxes of carbon, both organic and inorganic, in the Southern Ocean and to place these fluxes into the context of the contemporary global carbon cycle,
- To identify the ecological and biogeochemical factors and processes which regulate the magnitude and variability of primary productivity, as well as the fate of biogenic materials,
- To determine how the Southern Ocean has responded ecologically and geochemically in the past to naturally-occurring climate changes, and
- To develop quantitative coupled physical-biogeochemical models of the Southern Ocean that reproduce past and present carbon fluxes with sufficient accuracy as to lend credibility to the predicted response to anticipated global warming.

B.4 Other Activities - New Initiatives

-all of these have been curtailed with the present budget woes and uncertainty in Washington-yet we continue to work to enhance scientific efforts along these lines using scientific agenda developed by the community

Integrated Reef System Science - part of the International Coral Reef Initiative
Ecology and Oceanography of Harmful Algal Blooms
Biological Diversity in Marine Systems

6 Ecology and Oceanography of Harmful Algal Blooms (ECOHAB)

The Problem:

Over the last several decades, the United States, as other countries, has experienced an escalating and worrisome trend in the incidence of problems associated with harmful and toxic algae - both in the planktonic and benthic systems of our coasts. The impacts of these phenomena include mass mortalities of wild and farmed fish and shellfish, human illness and death from contaminated shellfish or fish, death of marine mammals, seabirds, and other animals, and alteration of marine habitats or trophic structure through shading, overgrowth, or adverse effects on life history stages of fish and other marine organisms. Where formerly a few regions were affected by harmful algal blooms (HABs) in scattered locations, now virtually every coastal state is threatened, in many cases over large geographic areas and by more than one harmful or toxic species. It is still a matter of debate as to the causes behind this expansion, with possible explanations ranging from natural mechanisms of species dispersal to a host of human-related phenomena such as nutrient enrichment, climatic shifts, or transport of algal species via ship ballast water. Whatever the reasons, virtually all coastal regions of the US are now subject to an unprecedented variety and frequency of events.

ECOHAB --- Rationale and Benefits

The significant economic, public health and ecosystem impacts of HAB outbreaks are strong, practical motivations for a research program such as ECOHAB, made all the more pressing by the apparently escalating trend in their incidence. The direct benefits to society from a research program of this kind are many, and include management issues such as bloom detection and prediction, control or mitigation strategies, site selection criteria for aquaculture, and assessment of impacts from altered nutrient loading, dredging or other coastal zone activities. There are indirect benefits as well. For example, many of the mechanisms underlying bloom formation by harmful algal species are the same as those responsible for blooms of other phytoplankton in the ocean. Support of multidisciplinary field HAB programs can address a specific problem while providing new techniques and basic scientific information relevant to plankton ecology and oceanography in general.

ECOHAB --- Program Needs:

To develop an understanding of the population dynamics and trophic impacts of harmful algal species, and to use this information to minimize the adverse effects of HABs on the economy, public health, and ecosystem ecology.

ECOHAB --- Program Implementation:

No single study site can be identified that would permit all of the major biological and physical features that underly HAB phenomena to be investigated. Given this diversity, the proposed ECOHAB initiative will rely on multi-disciplinary regional programs as well as projects by individual investigators or small groups. The initiative will require at least three types of research.

Laboratory or Mesocosm Studies. Studies of HAB species and their food chain interactions under controlled conditions are needed, focusing on genetic, biochemical, behavioural and life history processes. These experimental studies will extend from the organismal to the ecosystem level.

Field Investigations. Multi-disciplinary field studies of major HAB species are needed to document the distribution and dynamics of key elements of HAB ecosystems, emphasizing the complex interactions between biotic and physical or chemical factors. Since no single field program could possibly address the wide array of HAB phenomena, a series of regional field studies is envisioned, in the expectation that this comparative approach will reveal differences and commonalties between regimes and ecosystems.

Theoretical Studies. Existing models will be applied, and new approaches developed, which incorporate field and laboratory measurements into realistic and testable simulations of HAB dynamics in different oceanographic systems.

7 Integrated Reef Systems Science

Coral reefs are ecologically and economically important systems of tropical/subtropical coastal regions with extremely high biological diversity. Living in ocean margins, reef organisms may be among the first to suffer from changing climate. In many regions anthropogenic perturbations are already taking a major toll. Important perturbations come via atmospheric (T, UV, visible light), hydrographic (storms/waves) and hydrologic (sediments, nutrients, FW) pathways.

An integrated reef system science program needs to incorporate ecology, geology, paleontology, climatology. Research approaches need to include elements of long-term observation systems, retrospective analysis of climate/reef system history, coral and reef ecosystem response processes. Many of the sciences issues need to be confronted on spatial scales from local to regional (e.g. within region of W. Pac., Caribbean), to basin-scale (pan Pacific), to global (Pacific-Caribbean comparison). Expanded time scales will derive from observation, experimentation and retrospective studies.

Integrated Reef Systems Science: Scientific elements:

- Document integrated climate/reef system ecological history via coral and reef coring to evaluate ecosystem responses to climate, sea level rise and alternative drivers. Trace element geochemistry, isotope fractionation studies and species composition will document extent and timing of historic climate and responses.
- Establish integrated, long-term observation system for environmental parameters to allow detection and understanding of reef changes, and provide the context for field experimentation. This activity is currently being planned as an element of the coastal module of GOOS.
- Experimental evaluation (microcosm/field) of coral species responses to effects of radiation (UV, visible), temperature, and elevated CO2, as well as synergisms with anthropogenic perturbations (e.g., land use changes, nutrients). Physiological and cell biological experimentation to determine causes and responses to stressors (e.g., thermal stress yielding bleaching vs. protective heat-stress proteins). Studies on regulation of symbiont populations in coral-zooxanthellae (and other symbioses, e.g. foraminfera) and whether other stressors amplify such responses.
-
- Hermatypic corals are one obvious element responding to stressors (e.g., bleaching), but complex, indirect responses must be examined to predict full reef system responses. Need to develop physical/biological model simulations of reefs. Focused, interdisciplinary themes include: How do stressors impact organism interactions (mutualisms, predator-prey) that naturally sustain reefs as ecosystems as high productivity, high diversity systems? Do post-stress reefs suffer disproportionately from natural disturbances of the physical environment (e.g., storms/waves) compromising coastal protection? How is recruitment, erosion and accretion impacted by stressors? Can widespread, climate induced perturbation result in alternative stable ecosystem states with reduced economic/ecological value as can be the case with other perturbations?

This proposed coral reef research program will represent the NSF contribution to the US Coral Reef Initiative (CRI) that is being developed by DOS, NSF, NOAA, DOI, USAID, and EPA. The CRI is now the US implementation of the International Coral Reef Initiative.

8 Biological Diversity in Marine Systems

The oceans house a large fraction of the earth's biosphere; a diversity of flora and fauna that is fundamental to the biogeochemical cycles and ecosystem processes of the entire earth system and that serve as the basis for the resources (food, pharmaceuticals, other chemicals) we take from the sea.

The oceans contain the vast majority of phyla of plants, animals and microbes, many which are in fact endemic to the seas. Yet we have a very poor understanding of the contribution individual species and assemblages of species make to the way in which our coastal and marine systems function. In many systems -- the interior of the deep oceans, the ocean floor, tropical coastal areas -- our most basic understanding of species richness is rudimentary.

The unique attributes - genetics, physiologies and biochemistries - of marine life have not been adequately explored yet human impacts on the marine species is increasing rapidly. With over harvesting, unintentional transport and introduction of exotics and the genetic perturbations from cultivated stocks, native populations are suffering threat world-wide.

With this background in mind, marine biological diversity is one of the major priorities for ocean scientists to be addressing in the decade ahead.

Needs:

- to investigate the ecological patterns, processes and consequences of changing marine biological diversity by focusing on critical environmental issues (eutrophication, over harvesting of resources, introduction of exotic species) and their threshold effects, and to address these effects at spatial scales from local to regional and at appropriate temporal scales.
- to understand the linkages between the marine ecological and oceanographic sciences by investigating the connectivity of local, smaller-scale biodiversity patterns and the regional, larger-scale oceanographic patterns and processes that may directly impact local phenomena.
- to use the new understanding of the ecological patterns, processes and consequences of marine biological diversity derived from regional-scale research approaches to improve predictions of the impacts of human activities on the marine environment.

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- to use the new understanding of the ecological patterns, processes and consequences of marine biological diversity derived from regional-scale research approaches to improve predictions of the impacts of human activities on the marine environment.

NSF focus on understanding:

1. Ecological, evolutionary and historical processes responsible for maintaining or changing diversity in a system, both at the level species (including symbioses) and the gene pool.
2. The functional role of diversity in ecosystems (species) and populations (genetic) and the importance of species/gene redundancy.
3. The impact of introduced species on natural ecosystems.
4. Basic research on restoration ecology.
5. Developing advanced procedures for resolving taxa in traditionally recalcitrant groups (e.g., microbes, algae, planktonic invertebrates).
6. Characterization of diversity in marine systems, including coastal, open ocean, sea ice, and deep-sea systems.
7. Biogeography related to dispersal processes.

ICES Benthos Ecology Working Group
Aberdeen, Scotland (UK), May 1996

Working document

ANNEX 4

Long-term changes (1982 - 1995) of the infaunal benthos of La Coruña Bay (NW Spain)

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SUMMARY

Long-term variation of benthic infauna has been studied in two stations in La Coruña Bay, NW Spain, during a 14-year period (1982 to 1995). One of the stations is located in muddy, hypoxic sediments of the harbour area, where harbour dredging was carried out in 1982. Following a relatively quick recovery after dredging operations, the infaunal community did not vary much with time, in spite of frequent sediment disturbances. The bivalve *Thyasira flexuosa* and opportunistic polychaetes are the dominant organisms. The high stability of this community is related to the dominance of opportunists having short life-cycles, and thus well adapted to environmental disturbances. The other station is located in a relatively clean fine sand area of the bay, and the community is dominated by species having longer life-cycles, such as *Tellina fabula* and *Paradoneis armata*. This community shows a wider temporal variation, both seasonally and interanually.

Species composition remained very stable through time in both stations, although the relative dominance of the main species may change. The *Aegean Sea* oil-spill (3 December 1992) has affected the communities during the last phase of the study, causing a decrease of amphipods and some bivalves and a dramatic increase of opportunistic polychaetes. However, three years after the spill, the benthic communities seem to be recovered.

INTRODUCTION

During the last decades the marine ecosystem is being affected by important disturbances caused by human activities. Resource exploitation, both living and non-living, and chronic or episodic inputs of a wide range of substances into the sea causes in many cases important effects on the marine environment, especially in the coastal areas. The benthic habitat is generally the most affected by these disturbances, and thus it has been the object of many studies aimed to determine the effect of human activities. Therefore a knowledge of its natural variability, both spatially and temporally, is needed to adequately ascertain the benthos response to these alterations and its eventual recovery if the disturbance ceases or it is greatly reduced.

Although there are many studies on the spatial and seasonal variation of benthic communities, long-term studies are scarce. Available benthic studies carried out in Spain were not long enough to discern long-term changes of infaunal communities.

In a relatively short period La Coruña Bay has been the scenario of several wrecks causing important consequences on the marine ecosystem. In 1976 the *Monte Urquiola* spilled about 100 000 t of crude oil, and most recently (December 1992) the *Aegean Sea* wrecked in the vicinity of La Coruña, releasing approximately 60 000 t of light crude oil. Moreover, some areas of La Coruña Bay are subject to pollution from urban sewage and to small, chronic spills from the harbour activities. The harbour constructions, dredgings, etc., also cause important disturbances on the benthic system.

Spatial distribution of the benthic communities of La Coruña Bay and benthic recovery after harbour dredging were described by López-Jamar and Mejuto (1985, 1988). The main objective of this study is to identify the patterns of long-term variation of infaunal benthos of La Coruña Bay, in order to evaluate the changes that may take place in the future, caused either by human activities or by natural variations.

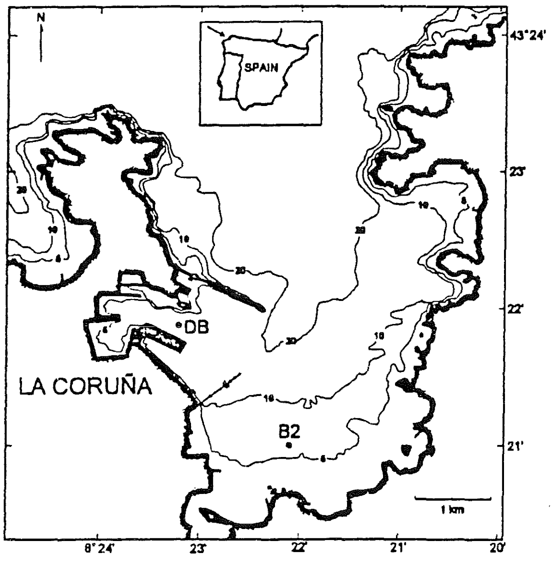

Fig. 1. Situation of the stations in La Coruña Bay. Depth lines in m.

MATERIAL AND METHODS

Benthic samples were collected with a modified Bouma box corer (0.0175 m^2 surface area and 10 to 20 cm sediment depth). At least 5 samples (= 0.0875 m^2) were taken at each of two stations in La Coruña Bay (Fig. 1), although occasionally 10 samples were collected to study the dynamics of selected species. The study started in July 1982 and it is currently undertaken. Sampling was carried out usually every 1 to 3 months, although in some cases the frequency was lower. In Station B2 only two samples could be taken from July 1982 to September 1983, and thus this period was not included in the analyses corresponding to this station. During the period 1986–1987 only one sample was taken in both stations, and this period was not incorporated to the analyses.

Macroinfauna samples were sieved on board through a 0.5 mm sieve, anaesthetized with a $MgCl_2$ solution and then preserved with 5 % buffered formaldehyde containing Rose Bengal solution. Organisms were sorted out in the laboratory and identified to species level whenever possible. Correlations of wet weight (WW) to ash-free dry weight (AFDW) were calculated to estimate biomass of each individual species (López-Jamar, unpublished data).

Particle size analysis was performed by a combination of dry sieving and sedimentation techniques (Buchanan, 1984). Organic matter content of the sediment was estimated as weight loss of dried (100 °C, 24 h) samples after combustion (500 °C, 24 h). Organic matter content of the sediment was estimated as weight loss of dried (100 °C, 24 h) samples after combustion (500 °C, 24 h).

As the time interval between two consecutive samples was not constant, a time-regularization of the sampling interval was performed by means of the exponential smoothing technique, giving a smoothed series with a 1-month interval between observations. All the graphs related to the temporal variation of sediment or community variables, as well as of individual species abundance, have been elaborated from these smoothed series.

Clustering classification and multi-dimensional scaling (MDS) ordination techniques were used to obtain a general representation of the temporal changes of the communities in both stations. Input data for these analyses were the root-root transformed values of the smoothed series, and the Manhattan measure of disimmilarity was utilised. A group of species were removed from the analysis attending to their low frequency.

RESULTS

General description of the communities

Station DB (43° 21.8' N, 8° 23.3' W, 16 m deep) is located in the main ship-loading area of La Coruña harbour, where the sediment is frequently disturbed by the navigation of big ships and by episodic dumping of diverse material. Sediment is composed predominantly of mud with a variable proportion of shell debris and a high organic content (Table 1). Although the relative proportion of the dominant species varies temporally, the most abundant species usually are the bivalve *Thyasira flexuosa*, the oligochaete *Tubificoides* sp., and the polychaetes *Chaetozone gibber* and *Capitella capitata*. The bivalves *Abra alba* and *Abra nitida* are relatively abundant as well (Table 2).

Table 1. Mean values and range of some community and environmental variables of Stations DB and B2 in La Coruña Bay.

	Station DB			Station B2		
	Mean	Max	Min	Mean	Max	Min
Abundance (ind·m^{-2})	11321	27535	1093	14377	44200	5623
Biomass (g·m^{-2} AFDW)	11.94	24.52	0.72	19.30	44.07	8.98
Species number	33	51	13	47	62	30
Diversity (H')	2.87	4.13	1.23	3.40	4.40	1.67
Evenness (J')	0.57	0.79	0.28	0.61	0.76	0.31
% Organic matter	12.06	17.76	5.19	2.89	4.53	1.44
Mean particle size (μm)	39	129	17	93	154	69
Surface water temperature (° C)	15.09	19.0	11.6	15.25	20.6	11.4

Table 2. List of the most abundant taxa in Stations B2 and DB in La Coruña Bay in the period 1982-1995. Abundances in ind·m^{-2}.

	Station B2			Station DB	
	Mean	Max		Mean	Max
Paradoneis armata	4000	8618	*Thyasira flexuosa*	4985	22071
Spio decoratus	3056	30712	*Tubificoides* sp.	1396	6527
Tellina fabula	1007	3909	*Chaetozone gibber*	1083	6218
Capitella capitata	731	4218	*Capitella capitata*	612	4298
Pseudopolydora cf. *paucibranchiata*	676	23752	*Ophryotrocha hartmanni*	544	6549
Magelona spp.	614	4743	*Pseudopolydora* cf. *paucibrnachiata*	462	10788
Spiophanes bombyx	577	2012	*Abra alba*	392	2938
Mediomastus fragilis	444	1749	*Spio decoratus*	245	4583
Amphipoda indet.	352	1074	*Notomastus latericeus*	234	834
Nemertea indet.	298	857	*Ophiodromus flexuosus*	208	743
Cumacea indet.	269	2457	*Abra nitida*	201	1429
Diopatra neapolitana	219	1737	*Armandia polyophthalma*	172	2595
Pseudopolydora pulchra	206	7658	*Mediomastus fragilis*	159	1063
Ostracoda indet.	188	629	*Ampharete finmarchica*	109	834
Notomastus latericeus	136	446	*Cerianthus* sp.	98	286
Glycera rouxii	133	697	*Prionospio* cf. *fallax*	97	720
Prionospio cf. *fallax*	131	1017	*Pseudopolydora pulchra*	85	1074
Diplocirrus glaucus	118	1553	*Diplocirrus glaucus*	72	617
Chaetozone gibber	106	766	*Lumbrineris gracilis*	68	606
Venus striatula	100	1349	*Nephtys hombergi*	58	331
Tubificoides sp.	86	720			
Galathowenia oculata	63	411			
Anaitides lineata	63	766			
Thracia phaseolina	52	342			
Lumbrineris gracilis	49	149			
Schistomeringos caeca	49	240			
Hyalinoecia bilineata	46	1212			

Harbour dredging was carried out in 1982 at station DB, originating an almost total defaunation of the sediment. Dredging ended in November 1982. Total macroinfauna abundance during the study period (including the final phase of the harbour dredging) ranged from 1093 to 27535 (mean = 11321) ind·m^{-2}, whereas total biomass ranged from 0.72 to 24.52 (mean = 11.94) g·m^{-2} AFDW (Table 1). The benthic recolonization after dredging operations is described by López-Jamar *et al.* (1986) and López-Jamar and Mejuto (1988).

Station B2 (43° 21.0' N, 8 22.2' W, 9 m deep) is located outside the harbour, in a relatively undisturbed area. Sediment is composed of well sorted, fine sand with low to moderate organic content (Table 1). The dominant species are the polychaetes *Paradoneis armata* and *Spio decoratus*, and the bivalve *Tellina fabula*. Other abundant species are the polychaetes *Magelona* spp, *Pseudopolydora* cf. *paucibranchiata* and *Capitella capitata*. Table 2 shows the abundance of the most important taxa. Total abundance ranges from 5623 to 44200 (mean = 14377) ind·m^{-2}, and total biomass from 8.98 to 44.07 (mean = 19.30) g·m^{-2} AFDW (Table 1).

Temporal variation of the communities

In Station DB, which was affected at the beginning of the study by harbour dredging, sediment characteristics are quite variable through time. After dredging concluded, the sediment became progressively finer and the organic matter content increased; several months later both grain size and organic matter content displayed temporal oscillations with no clear pattern. There is some similarity between the temporal variation of grain size and organic content; in general, finer sediments correspond to higher values of organic matter (Fig. 2).

Temporal variation of sediment grain size at Station B2 has neither a regular pattern. Organic content tends to decrease from the beginning of the study until 1989, but from that year on the trend is the opposite, and organic matter gradually increased until 1993, when it started do decrease (Fig. 2).

In Station DB the number of species during the dredging period was very low, but increased thereafter and remained relatively stable during the whole study period, with a slight increasing trend. Diversity increased initially at the beginning of the postdredging period, but then decreased sharply due to the high dominance of some species, mainly *Thyasira flexuosa*. As the community reaches a certain degree of equilibrium, diversity oscillations become smaller. However, diversity shows a general increasing trend, caused mainly by the gradual decrease of the dominance of *Thyasira flexuosa* (Fig. 3).

Total abundance in Station DB displays wide oscillations during the first part of the study. Initially (1982 to 1984) a rapid increase was evident during the recovery after dredging. Since 1984 the community became more stable, and relative annual maxima ussually occurred in spring/summer. During the first half of 1993 abundance in this station showed an important increase owing to the

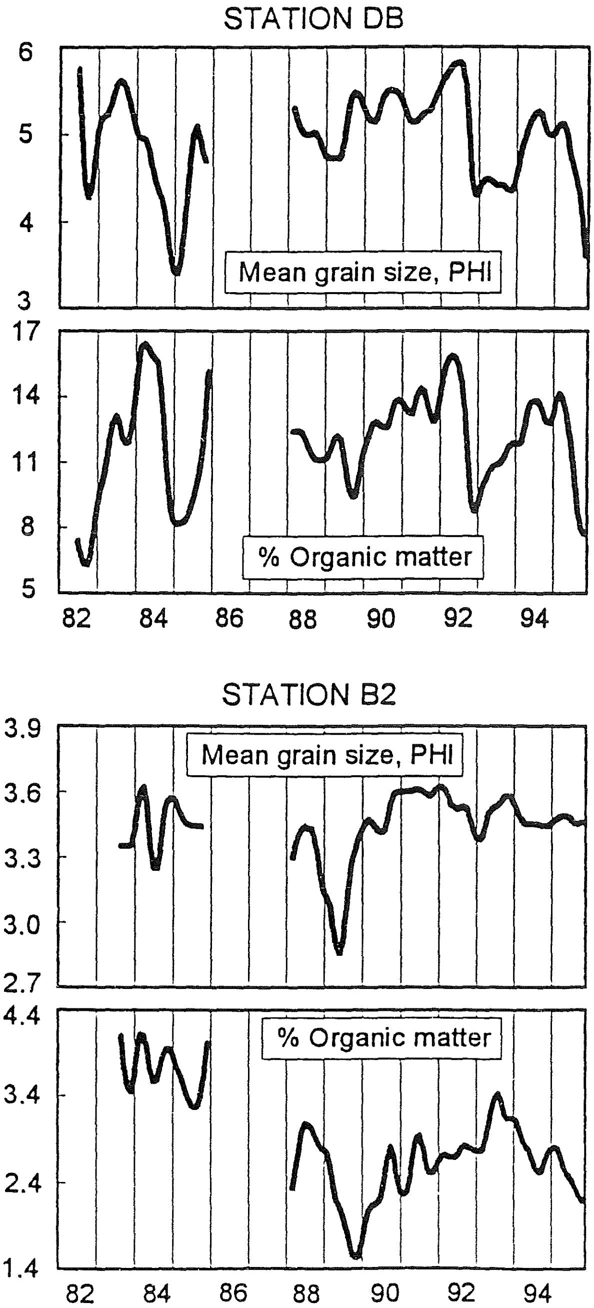

Fig. 2. Temporal variation of mean particle size and organic content of sediment in Stations DB and B2.

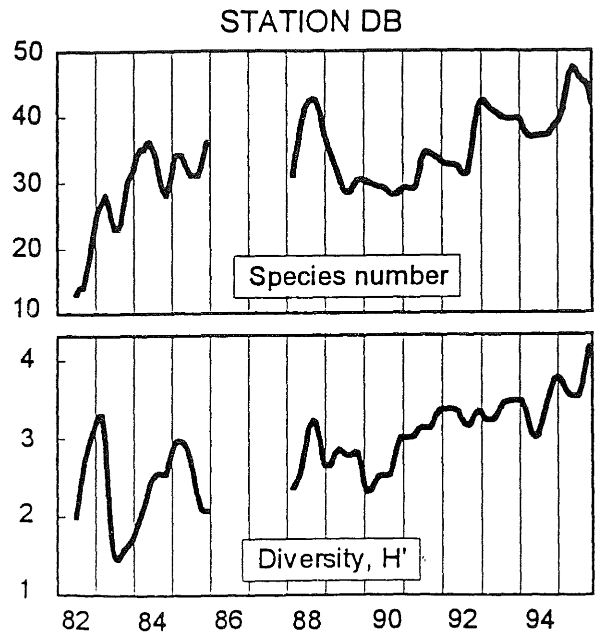

Fig. 3. Temporal variation of species number and diversity in Station DB.

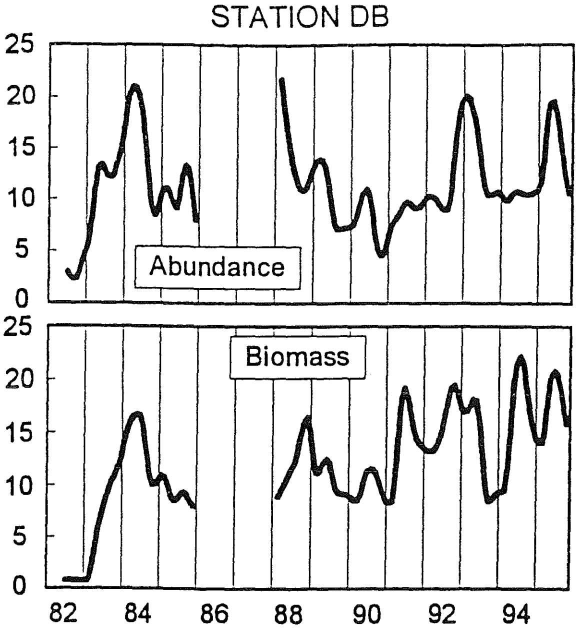

Fig. 4. Temporal variation of abundance ($10^3 \cdot ind \cdot m^{-2}$) and biomass ($g \cdot m^{-2}$ AFDW) in Station DB.

proliferation of some opportunists after the *Aegean Sea* oil–spill in December 1992 (Fig. 4). A similar increase ocurred in spring 1995 due to higher numbers of some species, mainly *Armandia polyophthalma* and *Ophryotrocha hartmanni*. Biomass displays a similar temporal pattern, with a sharp increase from 1982 to 1984, followed by a relative stabilization thereafter. Biomass decreased after the oil–spill owing to the mortality of relatively large–sized species such as *Abra alba* and *Abra nitida* (Fig. 4). However, high biomass values were present again from 1994 onwards. Relative annual maxima of biomass are usually more clear than those of abundance.

The general variation of the infaunal community at Station DB is expressed by the ordination of the samples obtained by MDS. In order to simplify the interpretation of this analysis, trimestral average values were used. Owing to the scarcity of samples during 1986–1987, the analysis was carried out separately in two phases: 1) from July 1982 to December 1985; and 2) from March 1988 to December 1995. In the first period (1982–1985), samples were distributed in three groups revealed by complementary cluster analysis (Fig. 5). Group 1 corresponds to the dredging and postdredging period (July 1982 to March 1983), when the community changed rapidly after dredging ended; these changes became slower as the community reached a certain level of stabilization. This period is characterized by the dominance of opportunistic species, mainly *Capitella capitata, Malacoceros fuliginosus* and *Pseudopolydora* cf. *paucibranchiata*. Group 2 (April 1983 to September 1984) shows a certain degree of stabilization, with a decrease in the proportion of opportunists.

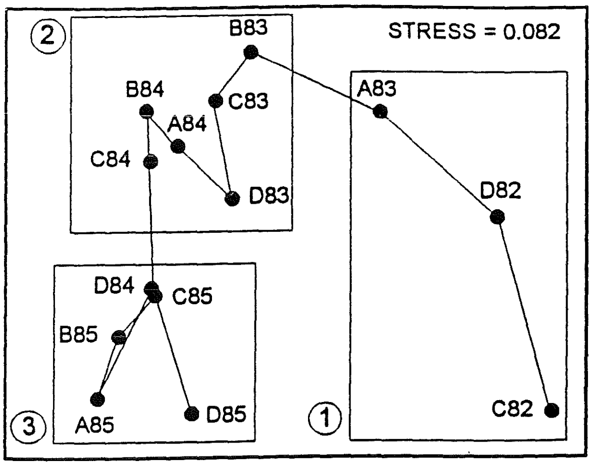

Fig. 5. Ordination of observations (1982 – 1985) in Station DB using MDS. Explanation in the text.

Thyasira flexuosa and *Chaetozone gibber* became dominant, and other abundant species were *C. capitata, O. hartmanni, Ophiodromus flexuosus* and *Abra alba*. Group 3 (October 1984 to December 1985) is characterized by a higher stability of the community; although the dominant species are the same as in the former period, the variations are less marked. This higher stability and the values of abundance and biomass indicate that the community has already recovered from harbour dredging.

The second phase of the analysis shows three main groups (Fig. 6). The change from Group 1 (April 1988 to December 1988) to Group 2 (January 1989 to September 1992) is characterised mainly by the decrease of the abundance of *Abra alba, Diplocirrus glaucus* and *Spio decoratus*, whereas *Chaetozone* gibber, *Abra nitida* and *O. hartmanni* increased. Group 2 and Group 3 (October 1992 to December 1995) are differentiated by the decrease of *A. alba* and *T. flexuosa*, and the increase of *Tubificoides* sp., *Armandia polyophthalma*, *C. capitata* and *P.* cf. *paucibranchiata*. Samples from Group 3 (except sample D92) were affected by the oil pollution caused by the *Aegean Sea* oil spill, and three subgroups can be distinguished: Subgroup 3a (October 1992 to June 1993), characterised by an important decrease of several species (*Ch. gibber*, *A. nitida*, *A. alba* and *T. flexuosa*) and by a high increase of the opportunists *C. capitata* and *P.* cf. *paucibranchiata*; in Subgroup 3b (July 1993 to March 1995) the abundance of opportunists decreased to almost normal levels, whereas species that were affected by the oil spill started to increase their numbers; in Subgroup 3c (April to December 1995), the community had recovered a similar structure to that before the spill.

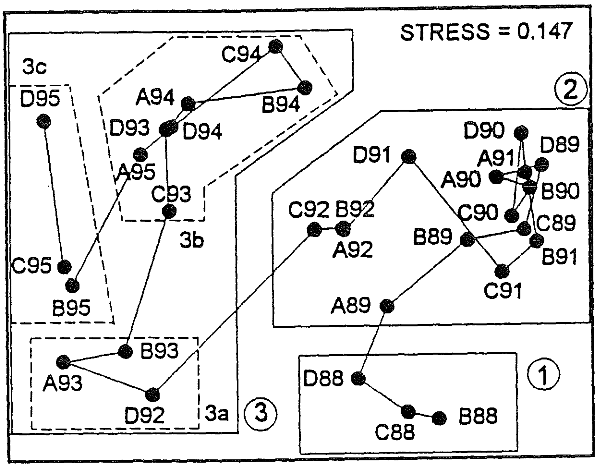

Fig. 6. Ordination of observations (1988–1995) in Station DB using MDS. Explanation in the text.

Station B2, located outside the harbour area, has not been affected by any major disturbance during these years, excluding the *Aegean Sea* oil-spill at the end of 1992. The temporal variation of the species number shows irregular oscillations, but relative annual maxima in summer can be distinguished (Fig. 7). Number of species decreased in 1993 and 1994 as a consequence of the oil-spill, but in 1995 it increased again. Diversity displays relatively clear annual peaks (Fig. 7), although in autumn 1994 a very low diversity was recorded due to excepcionally high numbers of *Spio decoratus*, which reached more than 30 000 ind·m^{-2} in November.

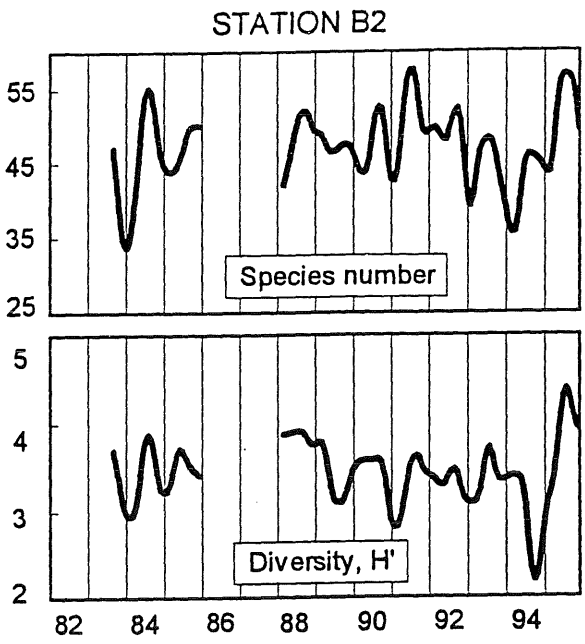

Fig. 7. Temporal variation of species number and diversity in Station B2.

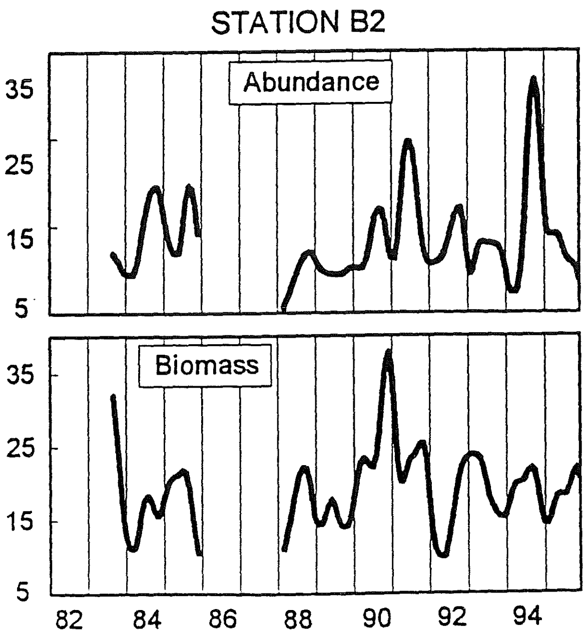

Fig. 8. Temporal variation of total abundance (10^3·ind·m^{-2}) and biomass (g·m^{-2} AFDW) in Station B2.

Total abundance shows a similar variation pattern, with relatively wide oscillations but generally having annual peaks in summer. Biomass presents a similar variation through time, although the oscillations are more irregular (Fig. 8).

The ordination of the samples by MDS in Station B2 in the first period (October 1983 to December 1985) shows three distinct groups (Fig. 9). Although the main dominant species are the same throughout this period, the shift from one group to the next is characterised by increases or decreases of several species. Group 2 (April to December 1984) is differentiated from Group 1 (October 1983 to March 1984) by a decrease of the abundance of *Magelona* spp., *Chaetozone gibber* and *Spio decoratus* and by an important increase of *Pseudopolydora* cf. *paucibranchiata*. The change from Group 2 to Group 3 (January to December 1985) is mainly caused by the decrease of *P.* cf. *paucibranchiata* and *Capitella capitata*, whereas *Venus striatula*, *S. decoratus* and *Spiophanes bombyx* increased.

The second period (April 1988 to December 1995) also shows three groups (Fig. 10). Group 1 (April 1988 to December 1989) and Group 2 (January 1990 to March 1993) are differenciated by a decrease of *Hyalinoecia bilineata*, *Mediomastus fragilis* and *Spio decoratus* and by an important increase of *Pseudopolydora pulchra*, *Magelona* spp. and, to a lesser extent, *Diopatra neapolitana*. The change from Group 2 to Group 3 (April 1993 to December 1995) is characterised by a decrease of *Magelona* spp., *P. pulchra*, *Paradoneis armata* and *Prionospio* cf. *fallax*, while *Pseudopolydora* cf. *paucibranchiata*, *S. decoratus* and *Tellina fabula* increase their abundance. Group 3 corresponds roughly to the observations after the *Aegean Sea* oil–spill, and the increase of opportunists and the mortality of amphipods are evident, especially in the first samples of this group.

Temporal variation of the dominant species

In both stations the temporal variations of the macroinfauna communities are mainly due to changes in the relative abundance of the dominant species. The species composition usually remained quite stable during the study period. We only have considered those species whose frequency and abundance in the samples permits the interpretation of the time series; rare species or taxa with low abundance were not included.

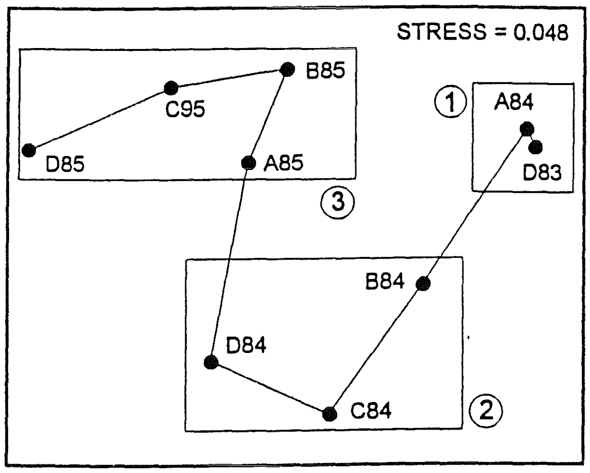

Fig. 9. Ordination of observations (1983-1985) in Station B2 using MDS. Explanation in the text.

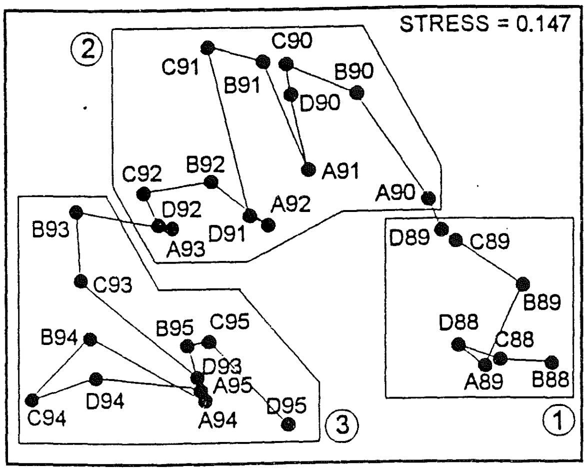

Fig. 10. Ordenation of observations (1988-1995) in Station B2 using MDS. Explanation in the text.

Thyasira flexuosa is the most abundant species in Station DB and it occurs in Station B2 as well. In Station DB the abundance of this species increased quickly several months after the completion of the harbour dredging owing to the coincidence of a strong recruitment with very favourable conditions because of low competition (López-Jamar and Mejuto, 1987). Highest abundance (22 000 ind·m^{-2}) occurred in May 1984 (Fig. 11), but it decreased thereafter. Since 1988 a steady decrease is evident, reaching a minimum of less than 1000 ind·m^{-2} by the end of 1993. In Station B2 *Thyasira flexuosa* was moderately abundant during 1984 and 1985, but it occurred much less frequently since then. Although the temporal variation of this species did not reveal distict annual maxima, López-Jamar and Mejuto (1987) indicated that *Thyasira flexuosa* in La Coruña Bay has an annual recruitment with a peak in spring.

The polychaete *Chaetozone gibber* is one of the most abundant species in Station DB and it is also relatively fre- quent in Station B2. Its temporal variation

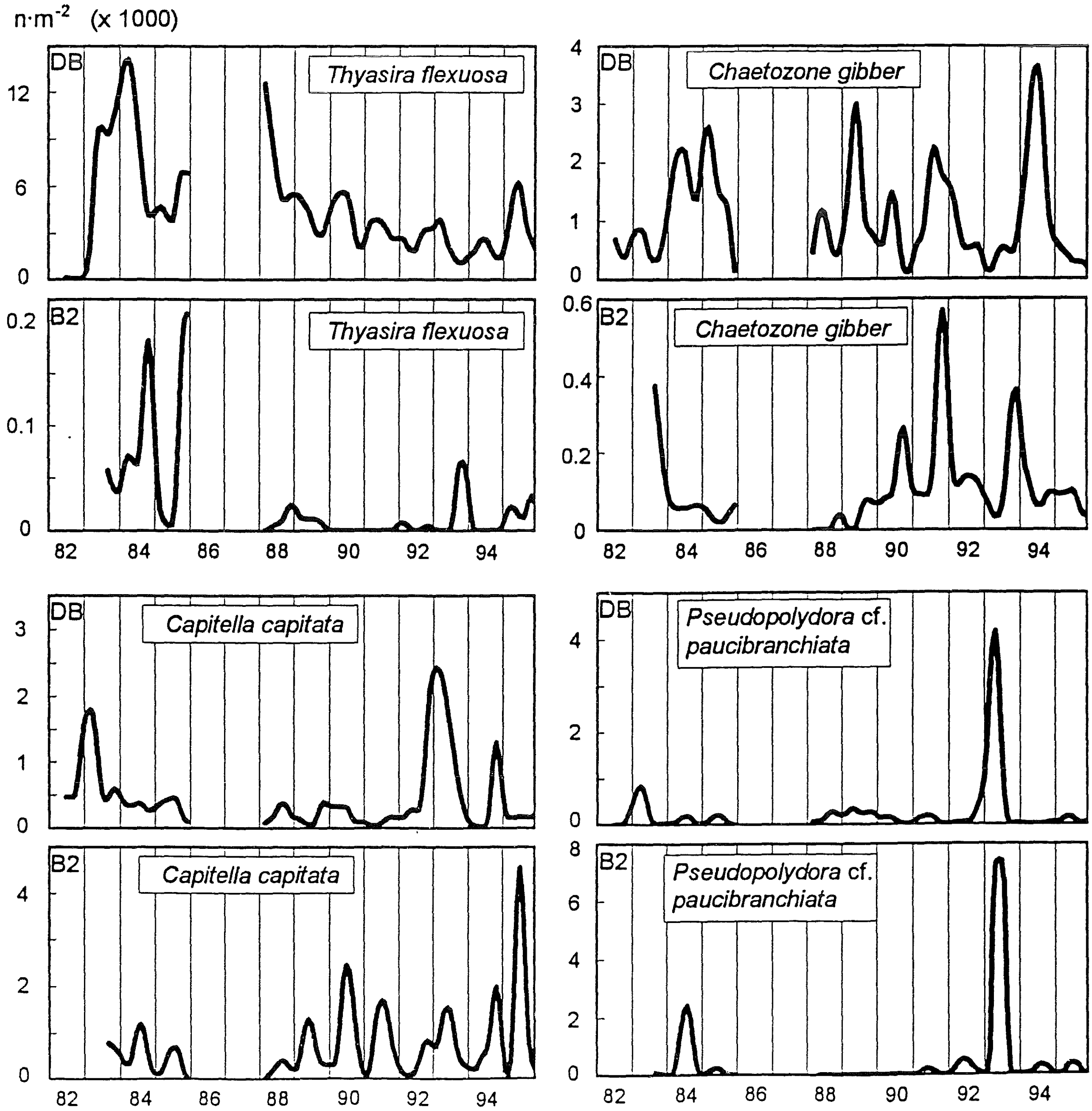

Fig. 11. Temporal variation of *Thyasira flexuosa*, *Capitella capitata*, *Chaetozone gibber* and *Pseudopolydora* cf. *paucibranchiata* in Stations DB and B2.

showed relatively clear annual peaks until 1993, but its variation since then is more erratic, which could be related to the effect of the oil-spill (Fig. 11). In Station DB this species has been little affected by harbour dredging, which suggests that its life-cycle is short. Therefore the annual peaks probably are not caused by annual recruitment but are related to an increase of the population number due to seasonal favourable conditions.

Capitella capitata is relatively abundant in both stations (Fig. 11). In Station DB its number increased quickly after harbour dredging ended, which agrees with its opportunist behaviour. In 1993 and 1994 its abundance increased much probably as a consequence of the *Aegean Sea* oil-spill. In Station B2 this species has much wider oscillations than in Station DB. Usually there are strong peaks of abundance in summer-autumn, with much lower numbers during the rest of the year. This annual peak is not related to an annual recruitment, as the life-cycle of this species is very short (Grassle and Grassle, 1974; Chesney and Tenore, 1985), but is probably caused by hypoxic conditions in the sediment during summer. High abundances of *Capitella capitata* have been frequently related to urban pollution (Pearson and Rosenberg, 1978; Sanders *et al.*, 1980; Tsutsumi, 1987; Reish *et al.*, 1989; Méndez, 1994).

The polychaete *Pseudopolydora* cf. *paucibranchiata* also shows a typically opportunistic behaviour, with quick population blooms interspersed with periods of low abundance (Fig. 11). This species has summer annual peaks in both stations. In some years this peak can be very high (1984 in Station B2 and 1993 in both stations). The overwhelming increase of this species in 1993 in both stations (up to ca. 24 000 ind·m^{-2} in June 1993 in Station B2) is undoubtedly caused by the conditions originated by the oil-spill. *Pseudopolydora pulchra* displays a similar temporal pattern, although annual peaks are less marked (Fig. 12). On the other hand, this latter species has not experienced an increase after the oil-spill. Several species of the genus *Pseudopolydora* have been reported as characteristic of polluted sediments (Sanders *et al.*, 1980; Reish *et al.*, 1989).

The polychaete *Malacoceros fuliginosus* also has a typically opportunistic behaviour. In Station DB its abundance increased very quickly after harbour dredging concluded, and decreased to very low densities thereafter. The abundance of this species did not increased immediately after the oil-spill, but one and a half year later (1994) it had an clear peak (Fig. 12). The opportunistic behaviour of *Malacoceros fuliginosus* has been indicated by several authors (Pearson and Rosenberg, 1978, among others).

The polychaete *Paradoneis armata* is the most abundant species in Station B2 practically during the whole period, whereas its occurrence in Station DB is occasional. Its temporal variation does not show a clear pattern (Fig. 12). Maximum abundances occurred in 1991, but a decreasing trend is evident since then. Population dynamics of this species has been studied by López-Jamar *et al.* (1987). Although spawning occurs probably once a year, the recruitment period of this species could not be clearly determined. *Paradoneis armata* densities remained high after the *Aegean Sea* oil-spill, which agrees with the findings of Dauvin and Ibanez (1986) in the coasts of Brittany after the *Amoco Cadiz* oil-spill.

The polychaete *Spio decoratus* is one of the dominant species in Station B2, although its abundance displays strong temporal oscillations (Fig. 12). A dramatic increase of its abundance (up to 30 000 ind·m^{-2}) ocurred by the end of 1994. This species is much less important in Station DB, though its abundance can occasionally increase. *Spio decoratus* usually has a very clear annual peak, generally in autumn-winter.

The oligochaete *Tubificoides* sp. is very abundant in Station DB, where it has experienced an important increase since 1988. It is much less abundant in Station B2. In both stations this species has a very irregular temporal pattern (Fig. 12).

Tellina fabula is the most abundant bivalve and one of the dominant species in Station B2, whereas in Station DB it occurs only occasionally (Fig. 13). Its temporal evolution generally shows annual peaks in autumn. During the period 1983–1986 its abundance was relatively high, but it decreased in 1988 and 1989, and increased steadily until the first half of 1995, decreasing again afterwards.

Two species of the genus *Magelona* are present in Station B2, but we have had difficulties in their identification, and thus they were treated together. From 1982 to 1989 their abundance was moderate, but increased remarkably during 1990 and 1991, decreasing again from 1992 on. Annual peaks are evident in most years, mainly in summer (Fig. 13).

The bivalve *Abra alba* is one of the

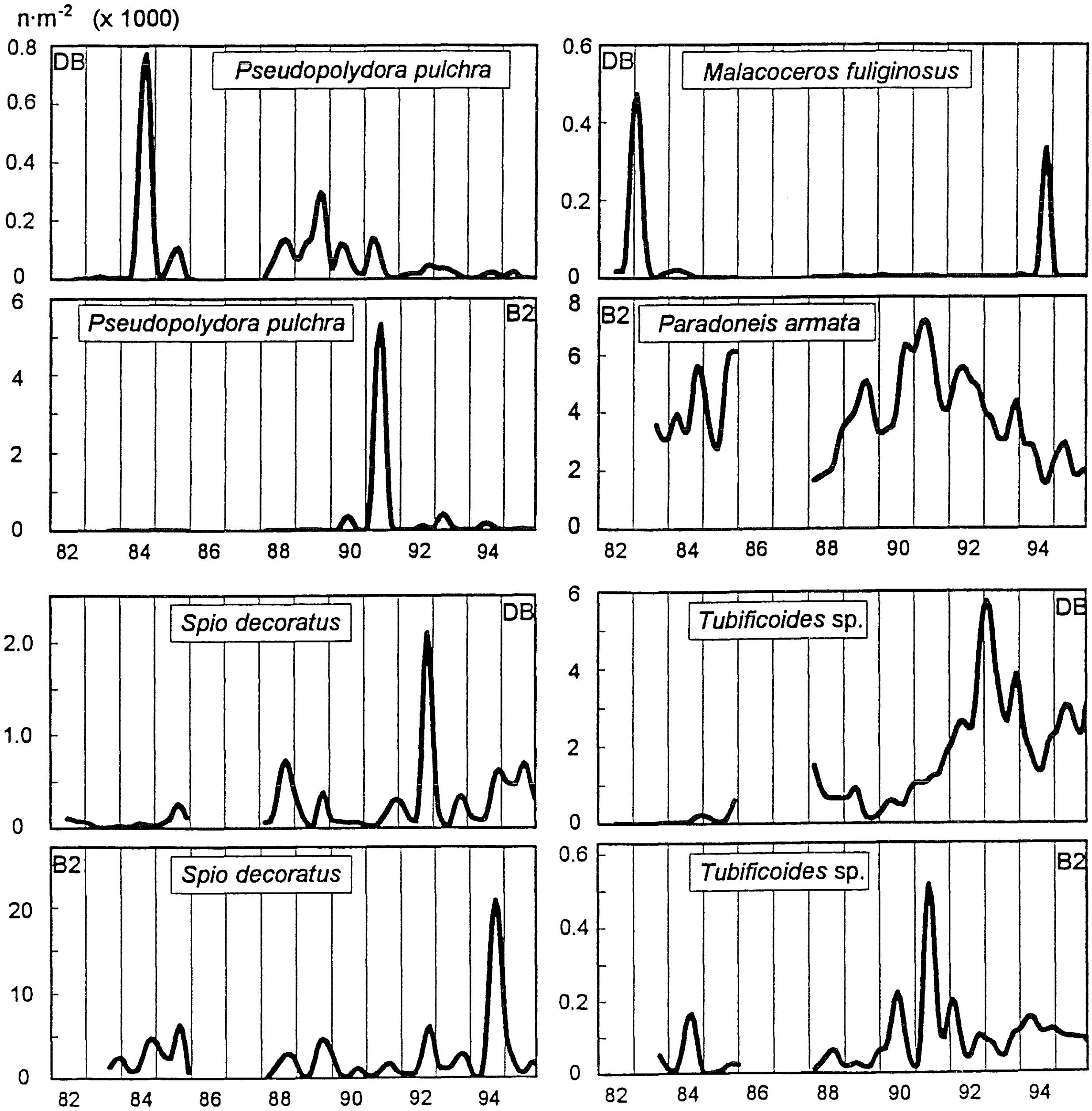

Fig. 12. Temporal variation of *Pseudopolydora pulchra*, *Spio decoratus* and *Tubificoides* sp. in Stations DB y B2, *Malacoceros fuliginosus* in Station DB, and *Paradoneis armata* in Station B2.

dominant species in Station DB, where it may account for an important proportion of total biomass. It is present in Station B2 as well, although in much lower numbers. In both stations annual peaks are relatively clear in spring-summer (Fig. 13), corresponding to the annual peak of recruitment in La Coruña Bay (Francesch and López-Jamar, 1991). Abundance of *Abra alba* in Station DB decreased since 1993 due to the effect of the *Aegean Sea* oil-spill.

Abra nitida is relatively abundant in Station DB, but only occasional in Station B2. Similarly to *Abra alba*, this species shows relative annual peaks in spring-summer, where recruitment is at its maximum (Francesch and López-Jamar, 1991). The abundance of *Abra nitida* shows an increasing tendency with time, although the oil-spill caused a decrease of its numbers since 1993 (Fig. 13).

Ophryotrocha hartmanni is a small polychaete with a very short life-cycle. It is relatively abundant in Station DB even

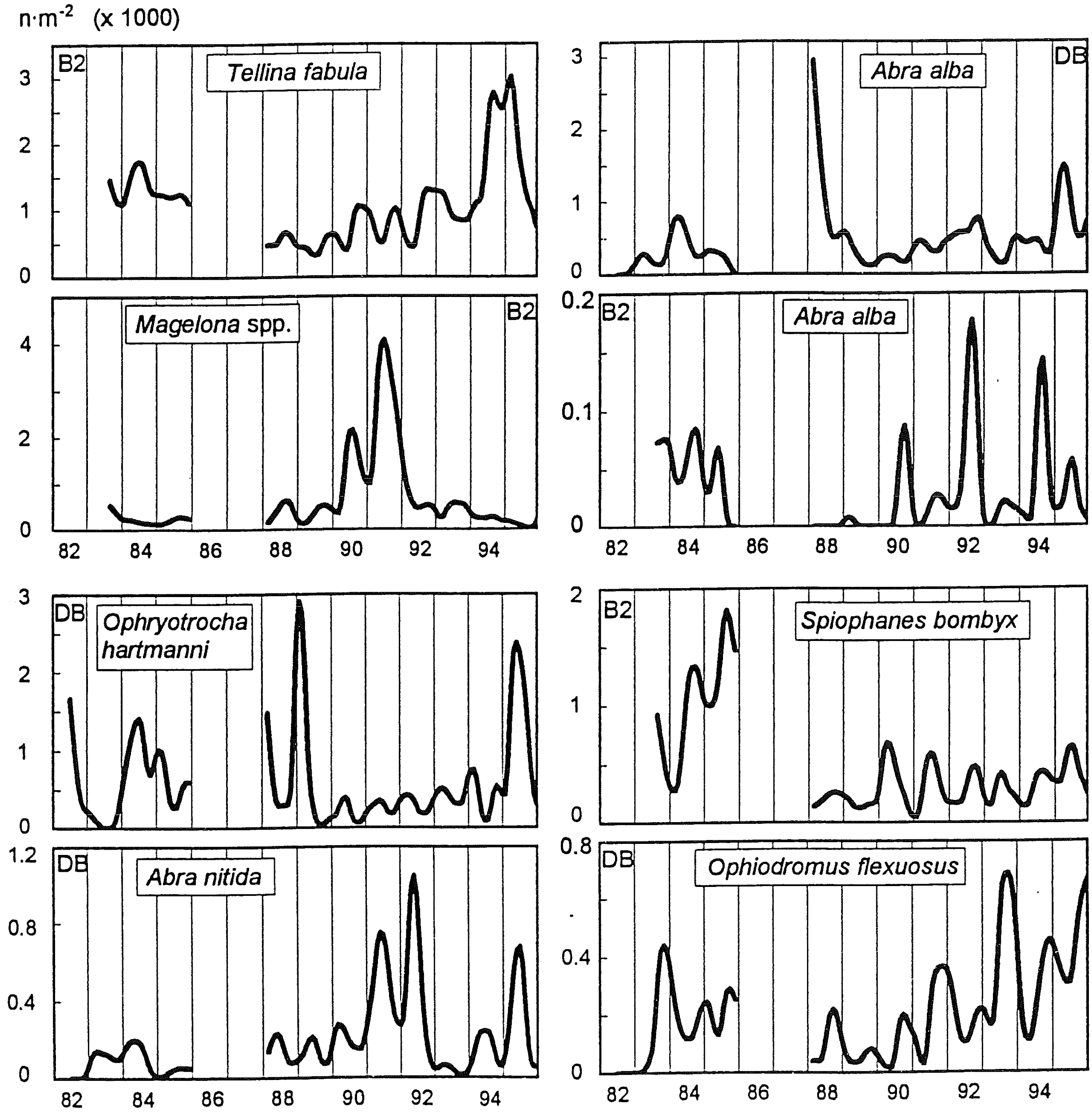

Fig. 13. Temporal variation of *Tellina fabula*, *Magelona* spp. and *Spiophanes bombyx* in Station B2, *Ophryotrocha hartmanni*, *Abra nitida* and *Ophiodromus flexuosus* in Station DB, and *Abra alba* in Stations DB and B2.

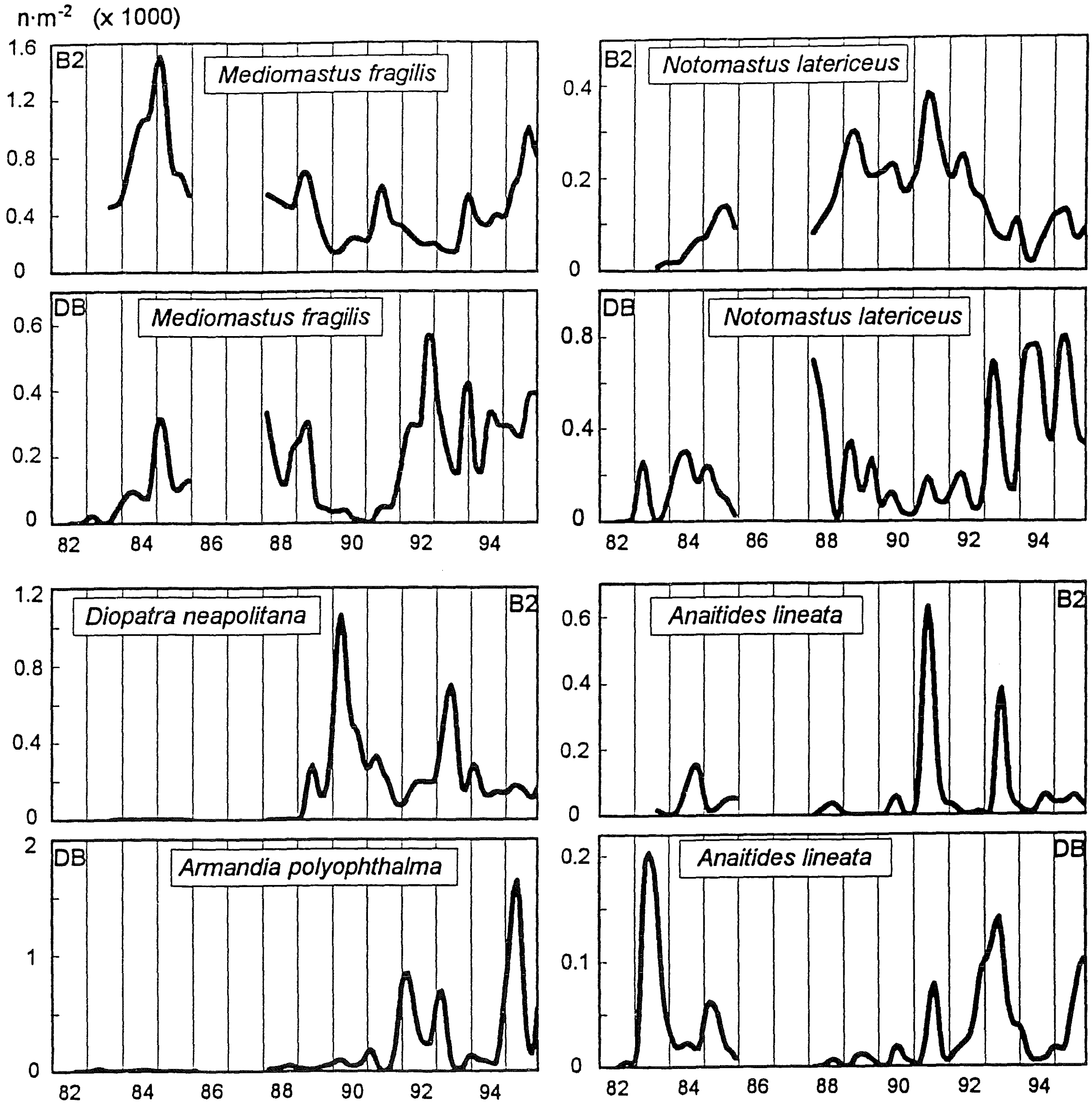

Fig. 14. Temporal variation of *Mediomastus fragilis*, *Notomastus latericeus* and *Anaitides lineata* in Stations B2 and DB, *Diopatra neapolitana* in Station B2, and *Armandia polyophthalma* in Station DB.

during the harbour dredging period. Annual peaks are quite evident in spring, but it may have intense proliferations occasionally, such as in 1984, 1989 and 1995 (Fig.13). Temporal changes of this species must be taken with caution: abundance may be underestimated owing to its small size, as an unknown proportion of individuals can pass through the 0.5 mm sieve.

The polychaete *Spiophanes bombyx* is a characteristic species of the *Tellina fabula* community in shallow bottoms of fine, hard-packed sand. From 1982 to 1986 it was a dominant species in Station B2, but its abundance decreased markedly since 1988. *Spiophanes bombyx* presents very clear annual peaks in summer (Fig. 13).

The polychaete *Ophiodromus flexuosus* is a relatively abundant species in Station DB. Relative annual maxima in autumn-winter can be observed. The abundance of this species increased notably 8 months after the harbour dredging concluded (López-Jamar and Mejuto, 1988) and also after the *Aegean Sea* oil-spill in December 1992 (Fig. 13). *Ophiodromus flexuosus* has been related with hypoxic conditions (Bagge, 1969; Evans, 1981).

The capitellid polychaete *Mediomastus fragilis* is relatively abundant in both stations. Its time-series did not reveal clear annual peaks, although relative maxima every 2 to 3 years were observed in Station B2. The temporal trend was opposite in both stations: in Station B2 it shows a decreasing trend, whereas in Station DB the temporal trend is increasing (Fig. 14).

The polychaete *Notomastus latericeus* is quite frequent in both stations, and it may constitute an important fraction of total biomass. Its temporal variation is quite irregular although a relative annual peak is usually evident. The variation of this species after the *Aegean Sea* oil-spill is different in both stations: in Station B2 its abundance decreased, whereas in Station DB increased, although its abundance displays wide oscillations (Fig. 14).

The polychaete *Diopatra neapolitana* was absent in Station B2 until 1989, but soon reached relatively high numbers. Its temporal variation during these years does not show any clear pattern; relative maxima appeared in 1990 and 1993 (Fig. 14). *Armandia polyophthalma* follows a similar temporal variation than that of *Diopatra neapolitana*; in Station DB this species occurred occasionally from 1982 to 1986, but since 1988 it appeared regularly in the samples, reaching relatively high densities in 1992, 1993 and 1995. Its temporal variation suggests winter annual peaks (Fig. 14).

The polychaete *Anaitides lineata* occurred in both stations in moderate numbers (Fig. 14). Its temporal variation generally shows relative annual peaks, although a bi-annual maxima sometimes occurred. This species experienced an important increase in Station DB in 1983, after the completion of the harbour dredging. Similarly, its abundance increased in 1993 in both stations, which probably is related to the *Aegean Sea* oil-spill. This suggests that this species has an opportunistic behaviour.

DISCUSSION

The study of long-term variation of subtidal macroinfauna communities usually reveals both general trends and the effect of local disturbances (storms, extremely cold winters, human induced alterations, etc.; Souprayen *et al.*, 1991). Severe winters may be important in more northern areas (Glémarec, 1979) and mainly in the intertidal habitat, although some important effects of cold winters have been reported in subtidal communities as well, such as in the *Amphiura filiformis* community in the North Sea (Gerdes, 1977). However, these climatic anomalies, that may be important in higher latitudes, usually do not affect the benthic communities of the southern European coasts. Surface water temperature was routinely recorded since 1988, and the minimum values were 11.6 and 11.4 °C at Stations DB and B2, respectively (Fig. 15).

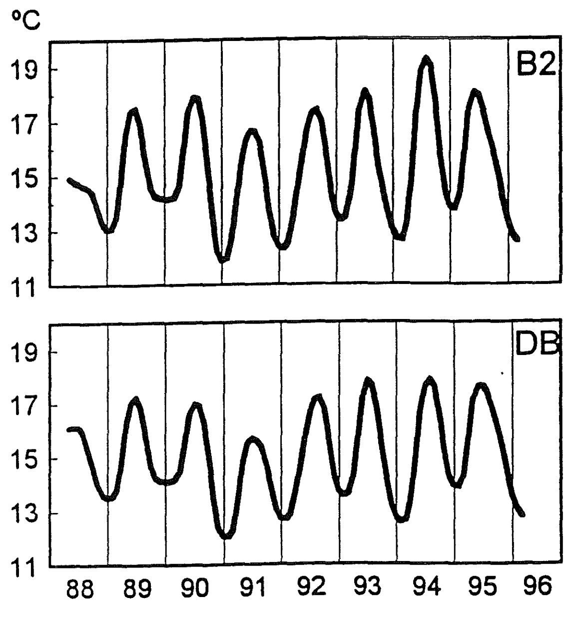

Fig. 15. Temporal variation of water surface temperature at Stations B2 and DB.

Storms can induce catastrophic effects on the benthos even in the subtidal habitat (Glémarec, 1979). Nevertheless, although storms are relatively frequent in the Galician coasts, no effect could be detected on the macroinfauna of La Coruña Bay during the study period, probably because of the weakening of the wave action as it enters in the bay.

In areas where the effect of severe winters and of storms is not very important, the long-term changes generally are due to longer period phenomena, such as fluctuations of the sea water temperature, or to the effect of human activities. In the coast of Sweden long-term changes of the benthos have been related with a general organic enrichment of the sediment (Rosenberg and Möller, 1979; Josefson, 1987) or with periodic oxygen deficiencies (Josefson and Rosenberg, 1988). In La Coruña Bay we could not detect an increasing trend of the organic content of sediment. Moreover, although the occasional sulphide smell in one of the stations (DB) suggests sporadic hypoxia, mortalities of benthic organisms due to this factor were not recorded.

The results of this study indicate that species composition of the macroinfauna communities was very stable during the study period, although the relative proportion of the dominant species may change temporally due to several factors. With the exception of the initial period, characterized by the recovery of the infaunal community after harbour dredging, temporal variations in Station DB were in general smaller than in Station B2. Station DB is located in an area where ship traffic, chronic spills, etc. cause frequent disturbances in the sediment. Consequently, the macroinfaunal community is dominated by opportunistic species having high reproduction rates and short life-cycles. These populations are able to respond quickly to environmental changes and can colonize in a short time disturbed habitats (Dauer, 1984). This better adaptation to frequent sediment disruptions determines that temporal variations of these communities are in general less marked than those in areas little affected by human activities. An important fraction of the dominant species of Station DB has several recruitments per year or a practically continuous recruitment, and therefore seasonal variation is generally small. Opposingly, other species have longer life-cycles and only one recruitment per year (i.e., *Abra alba* and *Abra nitida*) and thus relative annual peaks are usual. These species generally show wider interanual variations.

At Station B2 the macroinfaunal community has a higher proportion of species with longer life-cycles (*Tellina fabula, Spio decoratus, Paradoneis armata, Diopatra neapolitana,* etc.). These species usually have only one recruitment per year, and they are less adapted to changes in the environment. Consequently, seasonal oscillations are generally wider and interanual variations may be relatively important as a consequence of possible recruitment failures of some species. Opportunists (*Capitella capitata, Pseudopolydora* cf. *paucibranchiata*, etc.) are also present, but usually its abundance is much lower than in Station DB. However, occasionally these species have important population blooms caused by environmental changes, which also contributes to a wider variabiity, both seasonal and interanual. For instance, the abundance of *Pseudopolydora* cf. *paucibranchiata* and *Pseudopolydora pulchra* increased dramatically in summer during certain years, and *Capitella capitata* has summer blooms almost every year. These quick proliferations of opportunists probably are favoured by the setting of hypoxic conditions in summer because of the high temperatures and macroalgae accumulation in the sediment in Station B2. The *Aegean Sea* oil-spill in December 1992 also has originated a spectacular increase of the numbers of some opportunists. Therefore, temporal changes in Station B2, both seasonal and interanual, are in general more important than those of Station DB, whose macroinfaunal community is better adapted to environmental changes or sediment disturbances.

This study revealed the existence of annual cycles in many species, and in some cases, trends or tendencies of longer period are suggested. However, the confirmation of multianual cycles and trends needs more extended study periods.

The knowledge of the long-term variation of the benthic communities in La Coruña Bay has been very useful to adequately interpretate the changes caused in the benthos by the *Aegean Sea* oil-spill in December 1992. Sampling and analysis of the time-series is currently undertaken, and our intention is to continue the study during the next years.

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ANNEX 5

Evaluation of the SIME-Monitoring Programme

presented by Germany

Introduction

At present, the outline of the possible SIME-Monitoring programme within the Joint Assessment and Monitoring Programme (JAMP) has been nearly completed according to the agreed OSPARCOM-matrix. This possible monitoring programme needs to be reviewed under the aspects of applicability and feasibility of the methods, the specifity of techniques, the state of elaboration of methods (guidelines, routine, research methods), the involved costs of measurements and suitability for the intended type of monitoring (spatial, time trend or local/effluent monitoring at discharge places).

At SIME 96 a previous version of this paper (SIME 96/2/2) has been presented. SIME 96 had agreed, that an overall assessment of the various ongoing monitoring programmes and the new monitoring activities developed with regard to the JAMP would be useful and that Germany should present a final version of the evaluation scheme to SIME 97 taking into account:

a) comments on SIME 96/2/2 by 1 April 1996,

b) comments on an accordingly revised and distributed version of SIME 96/2/2 by 1 November 1996.

Hierarchy of the monitoring structure

The monitoring is, in particular, focussed on substances which are toxic, persistent, and bioaccumulative and on their effects, and also on nutrients and their effects. Monitoring includes screening/fingerprinting for the relevant contaminants, initial spatial surveys (base-line-studies) of these contaminants and their effects and is followed by time trend monitoring and/or repetition of spatial surveys and/or trend monitoring for fluxes of contaminants through the food chain. These monitoring activities should be applied according to the following hierarchy:

1. step:	screening/fingerprinting		
	↓		
2. step:	base-line-study (spatial monitoring)		
	↙	↓	↘
3. step:	food chain investigations	time-trend (x times a year for 30-35 years)	repetition of spatial survey (every10 years)

Aim of the evaluation scheme

An evaluation scheme is hereby submitted to SIME by which the above mentioned review and assessment might be facilitated.
It should help to:

1. perform an objective and holistic analysis of the currently discussed methods and their contribution to resolving the requirements of the assessment matrix,

2. to evaluate the consistency of the whole programme (missing parameters, unnecessary parameters, costs, means of interpretation),

3. to identify gaps in the completeness of all parts of the intended monitoring programme and assessment,

4. to set priorities for the implementation of the programme.

Review and evaluation criteria

The evaluation of the parameters and techniques of the SIME-monitoring programme was carried out according to the following criteria:

Method related criteria (table 1)

1. *Applicability*: where and how to be applied in the convention area, sensitivity for e.g. low concentrations of contaminants;
2. *Availability*: how many laboratories are able to apply the methods and perform subsequent assessments;
3. Specification: do the techniques applied give results that are specific for a contaminant or a group of contaminants;
4. *Efforts of sampling and determination*: time consumption, sophistication of the technique, experience required, analytical requirements;
5. *Costs of sampling and determination*: costs in man-months or per determination;
6. *Standard/ routine/ research*: is the method qualified for standard application, routine application or only as a research application, and what is the intercomparison status of the method;

Assessment and implementation related criteria (table 2)

1. *Assessment/interpretation of results*:
   - which interpretation/ conclusions can be drawn from the results of investigations with respect to monitoring needs, risk potentials and measures/ regulations/control;
   - are assessment criteria (background, ecotoxicological, others) and statistical assessment methods available?
2. *Feasibility*: is the technique suitable for a certain type of monitoring (e.g. spatial/time trend)? Does it provide proper results within the given deadlines?
3. *Type of monitoring*:
   - *local (e.g. effluent)*: where/how should the monitoring be applied;
   - *spatial baseline studies*: one-off survey or repetition after a certain period of time;

- *trend monitoring*: what is the sampling frequency required to pinpoint a certain change, what should the maximum duration for the trend monitoring be (e.g. 30-35 years).

For each criterion a number between

1 = not promising

2 = mean

3 = promising

was given to each parameter listed in the tables.

The following tables give an overview of this evaluation scheme which was applied to the three main parts of the monitoring:

- the chemical contaminant monitoring,
- the biological effect monitoring and
- the eutrophication monitoring.

The evaluation scheme has been developed for the methods (always table 1) and for the assessment and implementation (always table 2).

An example of the application of the evaluation scheme is enclosed. This should be understood as a provisional and tentative application.

Working hypotheses

ASMO is asked to consider the following working hypotheses for inclusion into the JAMP, which were derived from a prelimenary evaluation of the decision process tables.

a) Chemical monitoring and biological effect monitoring for contaminants must be undertaken at the same specimen (fish or benthos organism) to increase the quality of interpretaion.

b) Contaminant monitoring should preferably be carried out in all relevant matrices at the same location to increase the quality of interpretation.

c) Where applicable, different matrices should be monitored because bioaccumulation is measured in biota, persistence is measured in sediments and toxicity of hydrophilic contaminants is measured in seawater.

d) In order to free resources for other monitoring activities such as screening for hazardous PCB-substitutes, PCB monitoring should be restricted to areas where they are likely to cause problems.

e) A TBT-imposex baseline study should include chemical monitoring of TBT in biota (snails) for reference purposes.

f) Where EROD monitoring is performed, PAH-metabolites should be measured in fish bile for reference purposes.

Action required

ASMO is invited to consider the proposed evaluation scheme. It is proposed that it should be developed and worked out further by all Contracting Parties according to the procedure agreed by SIME 96, before final decisions on the implementation of the mandatory part of the JAMP are to be taken.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	PARAMETER	MATRIX	APPLICABILITY	SCOR	AVAILABILITY	SCOR	SPECIFITY	SCOR	EFFORTS	EFFORTS	SCOR	COSTS	COSTS	SCOR	STANDARD	ROUTINE
2				C		E		G	SAMPL.	DETERM.	IJ	SAMPL.	DETERM.	LM	FACTOR=1	FACTOR=0,66
3			SMALL SCALE=1		1 COUNTRY=1		LOW=1		HIGH=1	HIGH=1		HIGH=1	HIGH=1		ICES GUIDEL.=1	NO I.C.TESTING=1
4			REGIONAL SC.=2		> 3 COUNTR.=2		MEDIUM=2		MEDIUM=	MEDIUM=2		MEDIUM=	MEDIUM=2		OSPAR GUIDL.=	I.C.TESTING NEG.=2
5			CONVENTION SC.=3		CONVENTION SC.=3		HIGH=3		LOW=3	LOW=3		LOW=3	LOW=3		OECD STAND.=3	I.C.TESTING POS.=3
6	IMPOSEX/INTERSEX	NUCELLA	3		2		3		3	3		3	3		1-(2)	1
7		LITTORINA	3		2		3		3	3		3	3		(2)	1
8		BUCCINUM	3		2		3		1	3		1	3		(2)	1
9																
10	EROD	FISH	3		3		1		1			1			1	2-3
11																
12	DNA-ADDUCTS	FISH														
13																
14	LIVER-HISTOPATHOLOGY	FISH LIVER														
15																
16	LIVER NODULES	FISH LIVER														
17																
18	METALLOTHIONEINE	FISH LIVER														
19																
20	ALA-D INHIBITION	FISH BLOOD														
21																
22	ANTIOXIDATIVE ENZYMES	FIH LIVER														
23		MUSSEL														
24																
25	FISH DISEASE	FISH														
26																
27	EPIFAUNA COMMUNITY	BENTHOS														
28																
29	INFAUNA COMMUNITY	BENTHOS														
30																
31	LYSOSOMAL STABILITY	FISH														
32																
33	SEDIMENT BIOASSAY	BENTHOS														
34																
35	WATER BIOASSAY	BENTHOS														
36																
37	FISH REPRODUCTION	EELPOUT														

1=UNFAVOURABLE
2=MEDIUM
3=FAVOURABLE

INTERCOMPISON TESTING(ICT)
GOOD=ST.DEV.>....
BAD=ST.DEV.>....

	Q	R	S	T
1	RESEARCH	SCOR	TOTAL SCORE	
2	FACTOR=0,33	OPQ	METHOD	
3	1LAB./PUBL.=1			
4	>3LAB./1CP=2			
5	>3LAB./3CPs=3			
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7	3			
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1=UNFAVOURABLE
2=MEDIUM
3=FAVOURABLE

INTERCOMPISON TESTING(ICT)
GOOD=ST.DEV.>....
BAD=ST.DEV.>....

CONCEPTUAL FRAME FOR
THE DECISION PROCESS
AND IMPLEMENTATION OF
OSPAR MONITORING

TABLE 2

ASSESSMENT RELATED CRITERIA AND TOTAL RESULT

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	PARAMETER	MATRIX	SUMMARY	INTERPRETATIO	SCORE D	FEASIBILITY	SCORE F	MONITORING	SCORE H	COSTS	MONITORING	SCORE M	COSTS	MONITORING	SCORE P	COSTS	SCORE	TOTAL
2			METHODS					LOCAL/			BASELINE			TREND			ASSESS.	SCORE
3			SCORES					EFFLUENT										
4				LOW=1		LOW=1		LOW=1		HIGH=1	LOW=1		HIGH=1	LOW=1		HIGH=1		
5				MEDIUM=2		MEDIUM=2		MEDIUM=2		MEDIUM=2	MEDIUM=2		MEDIUM=2	MEDIUM=2		MEDIUM=2		
6				HIGH=3		HIGH=3		HIGH=3		LOW=3	HIGH=3		LOW=3	HIGH=3		LOW=3		
7	IMPOSEX/INTERSEX	NUCELLA		3		3		3			3			3				
8		LITTORINA		3		3		3			3			3				
9		BUCCINUM		3		3		—			3			3				
10																		
11	EROD	FISH		1-3		3		1			3			2				
12																		
13	DNA-ADDUCTS	FISH																
14																		
15	LIVER-HISTOPATHOLOGY	FISH LIVER																
16																		
17	LIVER NODULES	FISH LIVER																
18																		
19	METALLOTHIONEINE	FISH LIVER																
20																		
21	ALA-D INHIBITION	FISH BLOOD																
22																		
23	ANTIOXIDATIVE ENZYMES	FIH LIVER																
24		MUSSEL																
25																		
26	EXTERNAL FISH DISEASES	FISH																
27																		
28	EPIFAUNA COMMUNITY	BENTHOS																
29																		
30	INFAUNA COMMUNITY	BENTHOS																
31																		
32	LYSOSOMAL STABILITY	FISH																
33																		
34	SEDIMENT BIOASSAY	BENTHOS																
35																		
36	WATER BIOASSAY	BENTHOS																
37																		
38	FISH REPRODUCTION	EELPOUT																

1=UNFAVOURABLE
2=MEDIUM

INTERCOMPISON TESTING(ICT)
GOOD=ST DEV. >

CONCEPTUAL FRAME FOR THE DECISION PROCESS AND IMPLEMENTATION OF OSPAR MONITORING TABLE 1 METHOD RELATED CRITERIA

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	PARAMETE	MATRIX	APPLICABILITY	SCORE	AVAILABILITY	SCORE	SPECIFITY	SCORE	EFFORTS	EFFORTS	SCORE	COSTS	COSTS	SCOR	STANDARD	ROUTINE
2				C		E		G	SAMPL.	DETERM.	IJ	SAMPL.	DETERM.	LM	FACTOR=1	FACTOR=0,66
3			SMALL SCALE=1		1 COUNTRY=1		LOW=1		HIGH=1	HIGH=1		HIGH=1	HIGH=1		ICES GUIDEL.=1	NO I.C.TESTING=1
4			REGIONAL SC.=2		> 3 COUNTR.=2		MEDIUM=2		MEDIUM=2	MEDIUM=2		MEDIUM=2	MEDIUM=2		OSPAR GUIDL=	I.C.TESTING NEG.=2
5			CONVENTION SC.=3		CONVENTION SC.=3		HIGH=3		LOW=3	LOW=3		LOW=3	LOW=3		OECD STAND=3	I.C.TESTING POS.=3
6	CADMIUM	MAR.WATER														
7		SEDIMENT														
8		FISH LIVER														
9		MUSSEL														
10	MERCURY	MAR.WATER														
11		SEDIMENT														
12		MUSSEL														
13		FISH LIVER														
14	LEAD	MAR.WATER														
15		SEDIMENT														
16		MUSSEL														
17		FISH LIVER														
18	COPPER	MAR.WATER														
19		SEDIMENT														
20		MUSSEL														
21		FISH LIVER														
22	TBT	SEDIMENT														
23		SNAIL														
24	PCBs	SEDIMENT														
25		MUSSEL														
26		FISH LIVER														
27		SEA BIRD EGGS														
28	PAHs	SEDIMENT														
29		MUSSEL														
30	PAH-METAB	FISH LIVER														
31																
32	SUBSTITUTE/ADD:PRIORITY															
33	CHEMICALS e.g.DEHP,chloro-,															
34	nitro-AROMATES															

1=UNFAVOURABLE
2=MEDIUM
3=FAVOURABLE

INTERCOMPISON TESTING(ICT)
GOOD=ST.DEV.>....
BAD=ST.DEV.>....

	Q	R	S
1	RESEARCH	SCORE	TOTAL SCORE
2	FACTOR=0,33	OPQ	METHOD
3	1LAB./PUBL.=1		
4	>3LAB./1CP=2		
5	>3LAB./3CPs=3		
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INTERCOMPISON TESTING(ICT)
GOOD=ST.DEV.>....
BAD=ST.DEV.>....

CONCEPTUAL FRAME FOR THE DECISION PROCESS AND IMPLEMENTATION OF OSPAR MONITORING

TABLE 2

ASSESSMENT RELATED CRITERIA AND TOTAL RESULT

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	PARAMETER	MATRIX	SUMMARY	INTERPRETA	SCORE	FEASIBILITY	SCORE	MONITORING	SCOR	COSTS	MONITORING	SCORE	COSTS	MONITORING	SCORE	COSTS	SCORE	TOTAL
2			METHODS		D		F	LOCAL/	H		BASELINE	M		TREND	N		ASSESS.	SCORE
3			SCORES					EFFLUENT										
4				LOW=1		LOW=1		LOW=1		HIGH=1	LOW=1		HIGH=1	LOW=1		HIGH=1		
5				MEDIUM=2		MEDIUM=2		MEDIUM=2		MEDIUM=2	MEDIUM=2		MEDIUM=2	MEDIUM=2		MEDIUM=2		
6				HIGH=3		HIGH=3		HIGH=3		LOW=3	HIGH=3		LOW=3	HIGH=3		LOW=3		
7	CADMIUM	MAR.WATER																
8		SEDIMENT																
9		FISH LIVER																
10	MERCURY	MAR.WATER																
11		SEDIMENT																
12		MUSSEL																
13		FISH LIVER																
14	LEAD	MAR.WATER																
15		SEDIMENT																
16		MUSSEL																
17		FISH LIVER																
18	COPPER	MAR.WATER																
19		SEDIMENT																
20		MUSSEL																
21		FISH LIVER																
22	TBT	SEDIMENT																
23		SNAIL																
24	PCBs	SEDIMENT																
25		MUSSEL																
26		FISH LIVER																
27		SEA BIRD EGGS																
28	PAHs	SEDIMENT																
29		MUSSEL																
30	PAH-METABO	FISH LIVER																
31																		
32	SUBSTITUTE/ADD: PRIORITY																	
33	CHEMICALS e.g. DEHP,chloro-,																	
34	nitro-AROMATES																	

1=UNFAVOURABLE
2=MEDIUM
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INTERCOMPISON TESTING(ICT)
GOOD=ST.DEV. >.....
BAD=ST.DEV. >......

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	PARAMETER	MATRIX	APPLICABILITY	SCOR	AVAILABILITY	SCORE	SPECIFITY	SCORE	EFFORTS	EFFORTS	SCOR	COSTS	COSTS	SCOR	STANDARD	ROUTINE
2				C		E		G	SAMPL.	DETERM.	IJ	SAMPL.	DETERM.	LM	FACTOR=1	FACTOR=0,66
3			SMALL SCALE=1		1 COUNTRY=1		LOW=1		HIGH=1	HIGH=1		HIGH=1	HIGH=1		ICES GUIDEL.=1	NO I.C.TESTING=1
4			REGIONAL SC.=2		> 3 COUNTR.=2		MEDIUM=2		MEDIUM=	MEDIUM=2		MEDIUM=2	MEDIUM=2		OSPAR GUIDEL=2	I.C.TESTING NEG.=
5			CONVENTION SC.=3		CONVENTION SC.=3		HIGH=3		LOW=3	LOW=3		LOW=3	LOW=3		OECD STAND=3	I.C.TESTING POS.=
6	NH4-N	MAR.WATER														
7																
8	NO2-N	MAR.WATER														
9																
10	NO3-N	MAR.WATER														
11																
12	N total dissolv.	MAR.WATER														
13																
14	N TOTAL	MAR.WATER														
15																
16	N particulate	MAR.WATER														
17																
18	PO4-P	MAR.WATER														
19																
20	P total dissolv.	MAR.WATER														
21																
22	P TOTAL	MAR.WATER														
23																
24	P-particulate	MAR.WATER														
25																
26	SIO4-SI diss.	MAR.WATER														
27																
28	SALINITY	MAR.WATER														
29																
30	TEMPERATURE	MAR.WATER														
31																
32	O2/H2S	MAR.WATER														
33																
34	ADD ON PROPOSED BY DPEUT:															
35	DOC(DISS.ORG.CARB.)	MAR.WATER														
36	POC(PARTIC.OC)	MAR.WATER														
37	TOC(TOTAL OC)	MAR.WATER														
38	PORE WATER	MAR.WATER														
39	RATE OF SEDIMENTATIO	MAR.WATER														
40																
41	CHLOROPHYLL A	MAR.WATER														
42																
43	PHYTOPLANKTON	MAR.WATER														
44	KEY SPECIES, CELL NO															
45	TOTAL NO OF SPECIES															
46	BLOOMS															
47																
48	MACROZOOBENTHOS	SOFT BOTTOM AND HARD BOTTOM														
49	BIOMASS															
50	TOTAL NO OF SPECIES															
51																
52	MACROPHYTOBENTHOS	SUBLITORAL AND EULITTORAL														
53	DEGREE OF COVERAGE															
54	BIOMASS															
55	TOTAL NO OF SPECIES															

1=UNFAVOURABLE
2=MEDIUM

INTERCOMPISON TESTING(ICT)
GOOD=ST.DEV.>....

	Q	R	S	T
1	RESEARCH	SCORE	TOTAL SCORE	
2	FACTOR=0,33	OPQ	METHOD	
3	1LAB./PUBL.=1			
4	>3LAB./1CP=2			
5	>3LAB./3CPs=3			
6				
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INTERCOMPISON TESTING(ICT)
GOOD=ST.DEV.>....

CONCEPTUAL FRAME FOR THE DECISION PROCESS AND IMPLEMENTATION OF OSPAR MONITORING

TABLE 2

ASSESSMENT RELATED CRITERIA AND TOTAL RESULT

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	PARAMETER	MATRIX	SUMMAR	INTERPRETATIO	SCORE D	FEASIBILIT	SCORE	MONITO	SCORE H	COSTS	MONITORIN	SCORE K	COSTS	MONITORIN	SCORE N	COSTS	SCORE	TOTAL
2			METHODS					LOCAL/			BASELINE			TREND			ASSESS	SCORE
3			SCORES					EFFLUENT										
4				LOW=1		LOW=1		LOW=1		HIGH=1	LOW=1		HIGH=1	LOW=1		HIGH=1		
5				MEDIUM=2		MEDIUM=2		MEDIUM=2		MEDIUM=2	MEDIUM=2		MEDIUM=	MEDIUM=2		MEDIUM=2		
6				HIGH=3		HIGH=3		HIGH=3		LOW=3	HIGH=3		LOW=3	HIGH=3		LOW=3		
7	NH4-N	MAR.WATER																
8																		
9	NO2-N	MAR.WATER																
10																		
11	NO3-N	MAR.WATER																
12																		
13	N total dissolv.	MAR.WATER																
14																		
15	N TOTAL	MAR.WATER																
16																		
17	N particulate	MAR.WATER																
18																		
19	PO4-P	MAR.WATER																
20																		
21	P total dissolv.	MAR.WATER																
22																		
23	P TOTAL	MAR.WATER																
24																		
25	P-particulate	MAR.WATER																
26																		
27	SIO4-SI diss.	MAR.WATER																
28																		
29	SALINITY	MAR.WATER																
30																		
31	TEMPERATURE	MAR.WATER																
32																		
33	O2/H2S	MAR.WATER																
34																		
35	ADD ON PROPOSED BY DPEUT:																	
36	DOC(DISS.ORG.CARB.)	MAR.WATER																
37	POC(PARTIC.OC)	MAR.WATER																
38	TOC(TOTAL OC)	MAR.WATER																
39	PORE WATER	MAR.WATER																
40	RATE OF SEDIMENTATION	MAR.WATER																
41																		
42	CHLOROPHYLL A	MAR.WATER																
43																		
44	PHYTOPLANKTON	MAR.WATER																
45	KEY SPECIES, CELL NO																	
46	TOTAL NO OF SPECIES																	
47	BLOOMS																	
48																		
49	MACROZOOBENTHOS	SOFT BOTTOM AND HARD BOTTOM																
50	BIOMASS																	
51	TOTAL NO OF SPECIES																	
52																		
53	MACROPHYTOBENTHOS	SUBLITORAL AND EULITTORAL																
54	DEGREE OF COVERAGE																	
55	BIOMASS																	
56	TOTAL NO OF SPECIES																	

1=UNFAVOURABLE
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INTERCOMPISON TESTING(ICT)
GOOD=ST.DEV. >.....
BAD=ST.DEV. >.....

ANNEX 6

Impact of Scallop Dragging on a Shallow Subtidal Marine Benthic Community

by

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[3] Maine Department of Marine Resources, West Boothbay Harbor, ME 04575

Introduction

Over much of the world's continental shelves benthic-dwelling fish and shellfish are removed by trawls and dredges which are hauled along the bottom (de Groot 1984, Hutchings 1990). A wide variety of gear types are used over nearly all substrate types, including the recently developed "rock-hopper" gear for trawling in areas with large (~1m and greater diameter) boulders. Examples of gear types range from otter and beam trawls, which are basically nets with rollers or chains in contact with the bottom, to dredges or drags, which have large teeth or bars that dig into the bottom. The potential impact of this bottom-dragging activity on the functioning of benthic communities has recently begun to be seen as important by fisheries managers. Reviews of the impacts observed thus far suggest that the degree of disturbance is dependent on the gear type used and the composition of the sediment (Eleftheriou and Robertson 1992).

In the Gulf of Maine region of the United States many shallow marine embayments house commercially exploitable populations of the scallop, *Placopecten magellanicus*. These animals are harvested by means of a dredge equipped with a horizontal metal bar which plows through the surface sediments and a chain-link bag to retain the scallops. This type of scallop dredge differs from those used in Europe and further to the south in the United States by not being armed with long (12 cm) teeth on the bottom front bar. Nevertheless, the action of the dredge on the bottom is most likely similar to the toothed scallop dredges, that is, the bottom is "plowed" by the dredge.

While studies documenting the potential impacts of scallop dredging have been conducted with some frequency in European waters, few such studies exist for the United States. The extent to which the benthic environment is altered, or the resident fauna disturbed, seems to be clearly a function of the sediment composition. In general, sandy bottoms, which see periodic natural disturbances, usually due to large waves, seem not to be unduly affected by chain dredges (e.g., Butcher et al 1981, Eleftheriou and Robertson 1992), but in gravelly areas, large boulders might be pushed along the bottom or turned and rolled, crushing the epifauna (Caddy 1973). Sites that are muddier are much less studied, but have shown effects such as loss from the surface and burial to depth of organic matter (Mayer et al 1991), while in muddy sands decreased survivorship of scallop spat (Bull 1986), and reduced densities of small crustaceans, polychaetes, and molluscs (Thrush et al 1995) have been documented.

The purpose of the present study was to determine the extent to which a muddy sand community was altered by the action of a scallop dredge. Because the study site is located in shallow waters, and has not been disturbed by scallop draggers in the past, the project could also be used to to gain some insight into the mode of recovery of this benthic community.

Methods and Materials

This study was conducted in the Damariscotta River estuary, located in mid-coastal Maine, U.S.A. The marine section of this estuary has a small, commercially exploitable, population of *Placopecten magellanicus*. A small area of bottom, adjacent to (within 50 m) one of the scallop populations, was chosen for the dragging experiment. Not having a high density of scallops it was not disturbed by the commercial draggers.

The experimental site is characterised by sandy mud sediments located at a depth of 15 m below mean low water. The area was marked by buoys into an ambient section, which would not be dragged over, and a section that would be disturbed by the scallop drag during the scallop fishing season (March). In order to replicate as closely as possible the degree of disturbance likely under normal scallop fishing conditions, a New Bedford style scallop drag was pulled repeatedly over the marked area of bottom.

Bottom samples for sedment chemistry and fauna were collected by divers using push cores. Six replicate faunal cores (arranged in a line covering a distance of 0.5 m) and 3 replicate chemistry cores (arranged parallel to the faunal cores) were taken. The ambient and drag areas were sampled in November and December, 1994, and March, 1995, before the dragging event. On March 8, 1995, the drag area was fished with a commercial scallop drag in a manner approximating the commercial level of effort. The drag site was then sampled by divers on March 9, 1995, and both ambient and drag sites were sampled again in July and September, 1995.

On return to the lab the faunal cores were washed over a 500 μm sieve, fixed in 10% formalin, then washed again and stored in 70% ethanol. Following Warwick (1988) and Somerfield and Clarke (1995), all individuals were identified and enumerated at the taxonomic level of family.

Cores for sediment chemistry were sectioned in the lab, with the layers 0-1, 4-5, 9-10, and 14-15 cm below the sediment surface being analyzed. Sediment grain size was approximated using the one-point BET method of measuring sediment grain surface area (Mayer 1994), with the modification that organic matter was not removed prior to analysis. Sediment porosity was measured by weighing the sediment before and after oven-drying. Organic carbon and nitrogen were measured after vapor-phase acidification with HCl fumes (to remove calcium carbonate), using a Perkin-Elmer 2400 CHN analyser. Food value of the sediment was estimated by measuring the total microbial biomass, enzymatically hydrolyzable amino acids (EHAA), chlorophyll a, and total phaeopigment concentrations. Total microbial biomass was determined using the phospholipid phosphate technique of Findlay et al (1989) and EHAA were measured on frozen samples using the one-point (6 hour) method described in Mayer et al (1995). Chlorophyll and phaeopigments were measured by the method of Whitney and Darley (1979).

Trends and patterns in the data were determined by standard statistical techniques using Sokal and Rohlf (1995) and companion software, *Biomstat* v. 3.01. Multivariate analyses used the fuzzy *c*-means divisive clustering method (Bezdek et al 1984, Equhua 1990) as implemented in the software program, *Syntax V* (Podani, 1994). Rather than producing a dendrogram, as is the case for a hierarchical clustering method, fuzzy clustering results in a table of membership values relating each sample to each cluster. Because the method is divisive, the sample set can be partitioned into as many clusters as desired. In this study, clusters representing from two to five partitions were examined, but only the three partition case is reported.

Results and Discussion

The sediments at the study site is a muddy sand, with sediment specific surface area of 6-8 m^2 g^{-1}. The sediment porosities are somewhat low (0.55-0.75, as fraction of wet volume) in keeping with this sandy character. The bulk organic matter characteristics are normal for the Gulf of Maine coastal sediments (Mayer et al 1988), with organic carbon values of 8-15 mg g^{-1}, which are proportional to surface area, and C:N ratios of 8-10. There is little seasonal variation in these values, in keeping with the predominantly refractory character of the bulk organic carbon. Pigment values were minimal in the fall-early winter period. At the sediment-water interface there was a sharp increase in chlorophyll, and to a lesser extent, phaeopigments during the spring phytoplankton bloom period (March). The increase in pigments is gradually lost over the rest of the spring and summer, and appears to be reworked into deeper sediment horizons. The measure of labile organic matter (EHAA) shows a similar sequence as the plant pigments, in keeping with the predominantly algal origin of proteins in this area. A seasonal minimum in December is followed by an increase with the spring bloom. The decrease in pigments by the following September is not seen as strongly in either EHAA or total microbial biomass (as measured by total phospholipid) values, suggesting that the latter two measures represent a longer-lasting pool of material than do the pigments.

The sediments of the ambient and experimental sites did not differ from each other (as measured by total grain surface area) before the dragging event (March), although there was a slight coarsening of the sediment in December (Fig. 1). Dragging the site with a scallop drag resulted in the loss of the top few cm of the sediment surface (diver observations). Since the sediment grain surface area was substantially lower in the drag track as compared to the ambient site, it is clear that the sediment lost was the fine fraction of the upper sediment layers (Fig. 1). From the time of the dragging event until the study ended in September, the sediment of the dragged site did not recover the fine fraction.

Other sediment features, more related to the food value of the sediment, such as enyzmatically hydrolizable amino acids (EHAA) and total microbial biomass, also did not differ significantly between the ambient and experimental sites before the dragging event. Both were lowered substantially immediately followng the dragging event, but showed relatively rapid recoveries. EHAA, for example, were much reduced immediately following the drag event, but in July were just slightly lower than those at the ambient site and in September were indistinguishable from the ambient site values (Fig. 2). The same pattern was seen in the levels of total microbial biomass (Fig. 3). Neither the EHAA nor the total microbial biomass were strongly correlated with sediment grain size (Figs. 4 and 5) accounting for their apparent rcovery in the absence of additions of fine sediment grains.

The general faunal composition of the benthos at this site is comparable to that seen in similar sediments in the middle to lower reaches of the Damariscotta River (Watling, unpublished). Dominant taxa include the Cumacea, the polychaete families Nephtyidae and Spionidae, and the amphipod families Ampeliscidae, Photidae, and Phoxocephalidae. Seven polychaete families, four amphipod familes, and the Cumacea account for 97% of the individuals sampled over the course of the study (Table 1).

There was no significant difference in the overall composition of the benthos at the ambient and drag sites before the dragging event (Fig. 6). Following the dragging event, there was little discernible difference in the number of taxa present, but the numbers of individuals were strongly reduced through the July sampling period (Fig.

6b). By September, presumably following the summer larval production period, the drag site contained as many individuals as did the ambient site. Standard measures of diversity, such as H' and Hill's ratios, did not reflect these strong changes in the community compostion (Fig. 6c,d),

Patterns for the distribution of individual taxa (at the family level) were similar to that seen for the community indices, that is, little significant difference betwen the ambient and drag site following the dragging event, with two major exceptions. Abundances of nepthtyid polychaetes (Fig. 7c) and the crustaceans Cumacea (Fig. 8b) phoxocephalid amphipods, and photid amphipods (Fig. 9a,b) were much reduced in the drag track. While the nephtyids recovered by the July sampling date, the cumacean, phoxocephalid and photid abundances were not reduced in the drag track until September. Since cumaceans were the most abundant group in the benthos at this site, their absence strongly influences most of the community level analyses.

Fuzzy clustering techniques were used to examine the changes in the benthic community composition over all sampling periods. For this analysis, the samples were divided into two to seven groups. Results of the division into three groups is presented here (Table 2). Groups 1 and 2 comprise samples from both the ambient and drag sites prior to the dragging event, and from the drag site in September. Group 3 comprises samples taken in the drag track immediately following the dragging event and in July. So, at the community level, there is the integration of ambient and drag site samples by the September sampling period, paralleling changes seen in the sediment chemistry and faunal components of this study.

This study presents a short term view of a benthic community disturbance and recovery. The primary factor to consider is that the disturbance occurred only once. On most commercially exploited fishing grounds, of course, the bottom may be disturbed by dragging several to many times over a period of several months. Because of the long recovery time observed in this study (also occurring over the most favorable part of the year) it is likely that the cumaceans, phoxocephalids, and photids would be missing from a bottom that is dragged repeatedly.

We do not as yet know what it is about the dragged bottom that seems to cause the cumaceans and some of the amphipods to avoid the drag track. The surficial sediment grain size is consistently more coarse in the drag track than in the ambient area. Combined with the lower levels of available food (as measured by EHAA and microbial biomass) the surficial sediment habitat is unacceptable to the small crustaceans.

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Figure Legends:

Fig. 1. Changes in sediment surface area with sampling period. For this and following graphs the closed symbols represent the ambient site and the open symbols the site to be dragged. Samples are listed by month followed by AMB for ambient site, DR from the site to be dragged before dragging occurred, and PDR for the dragged site after the dragging event.

Fig. 2. Changes in sediment enzyme hydrolyzable amino acids with sampling period. Symbols and legends as for fig. 1.

Fig. 3. Changes in total microbial biomass with sampling period. Symbols and legends as for fig. 1.

Fig. 4. Relationship of enzyme hydrolyzable amino acids to sediment grain surface area. Filled symbols are ambient site samples; open symbols are drag site samples. Different symbol types represent the various sampling periods.

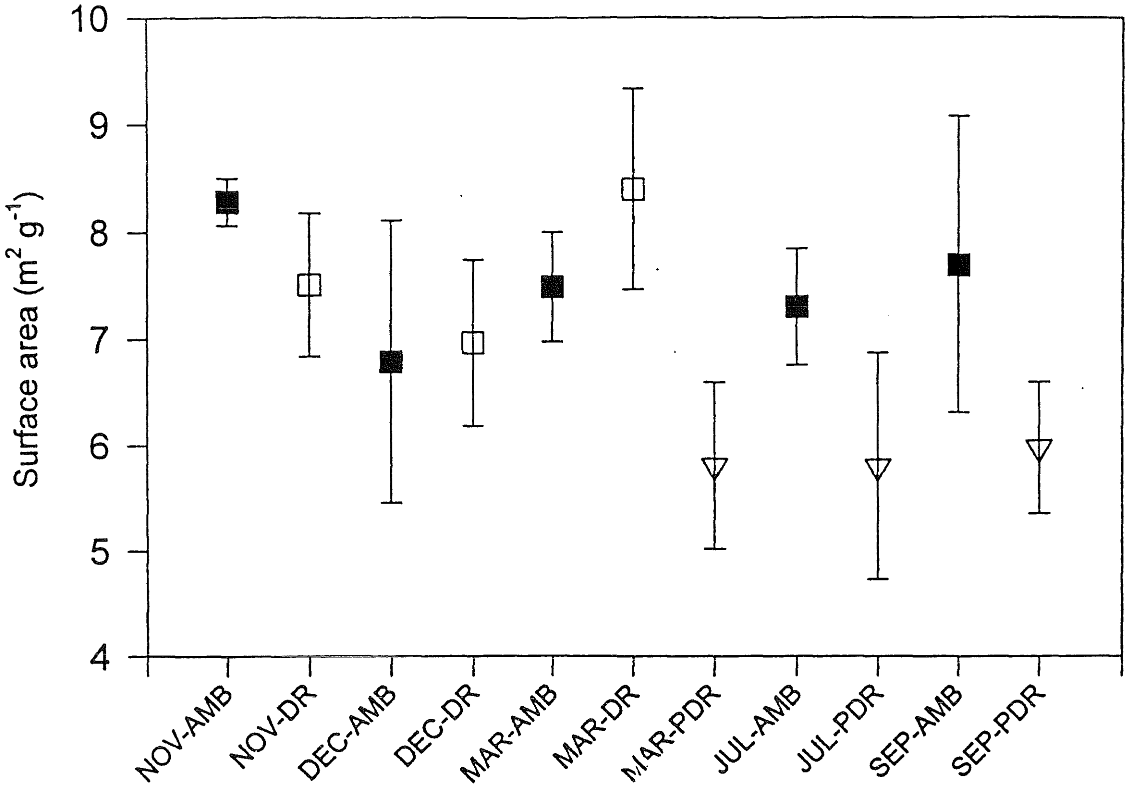
Fig. 5. Relationship of total microbial biomass to sediment grain surface area. Symbols as in fig. 4.

Fig. 6. Box and whisker plots (median, 75th and 95th percentiles) of changes in numbers of (a) families, (b) total individuals, (c) H'diversity, and (d) Hill's diversity measure with sampling period. Sample labels as in fig. 1.

Fig. 7. Box and whisker plots (median, 75th and 95th percentiles) of changes in abundances of (a) Spionidae, (b) Maldanidae, and (c) Nephtyidae with sampling period. Sample labels as in fig. 1.

Fig. 8. Box and whisker plots (median, 75th and 95th percentiles) of changes in abundances of (a) Ampeliscidae and (b) Cumacea with sampling period. Sample labels as in fig. 1.

Fig. 9. Box and whisker plots (median, 75th and 95th percentiles) of changes in abundances of (a) Phoxocephalidae and (b) Photidae with sampling period. Sample labels as in fig. 1.



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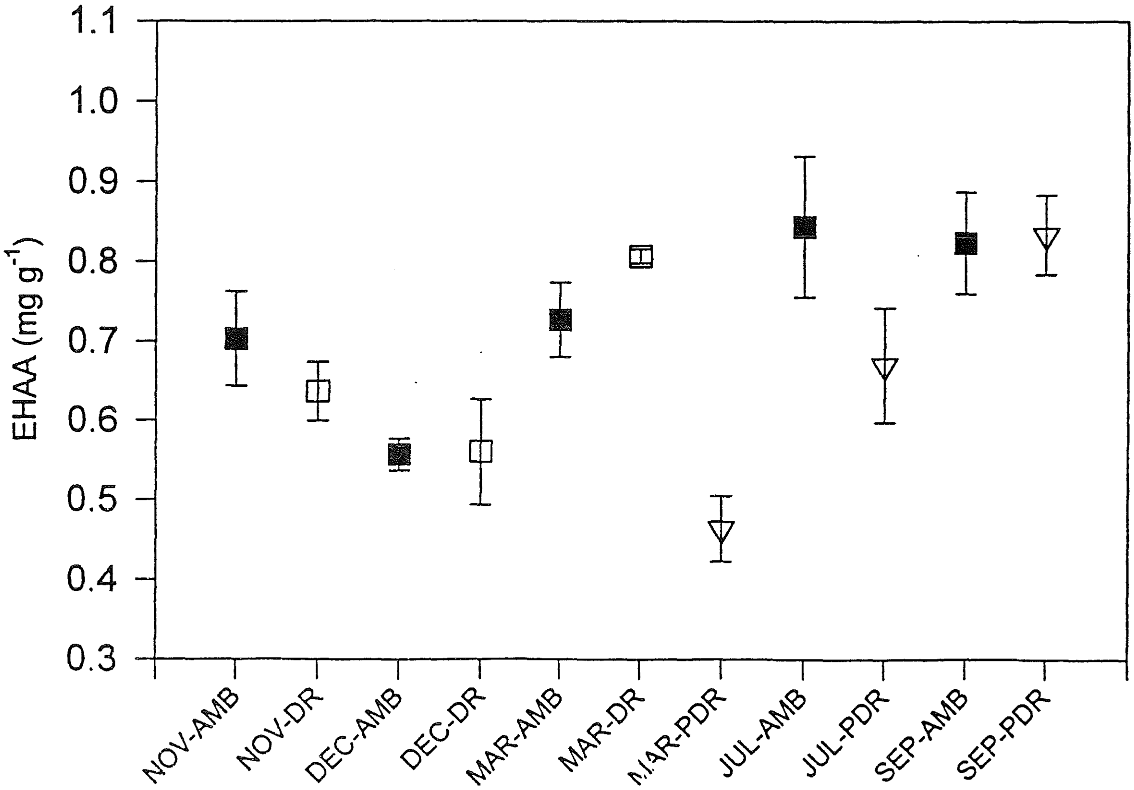


Fig. 2. Changes in sediment enzyme hydrolyzable amino acids with sampling period. Symbols and legends as for fig. 1.

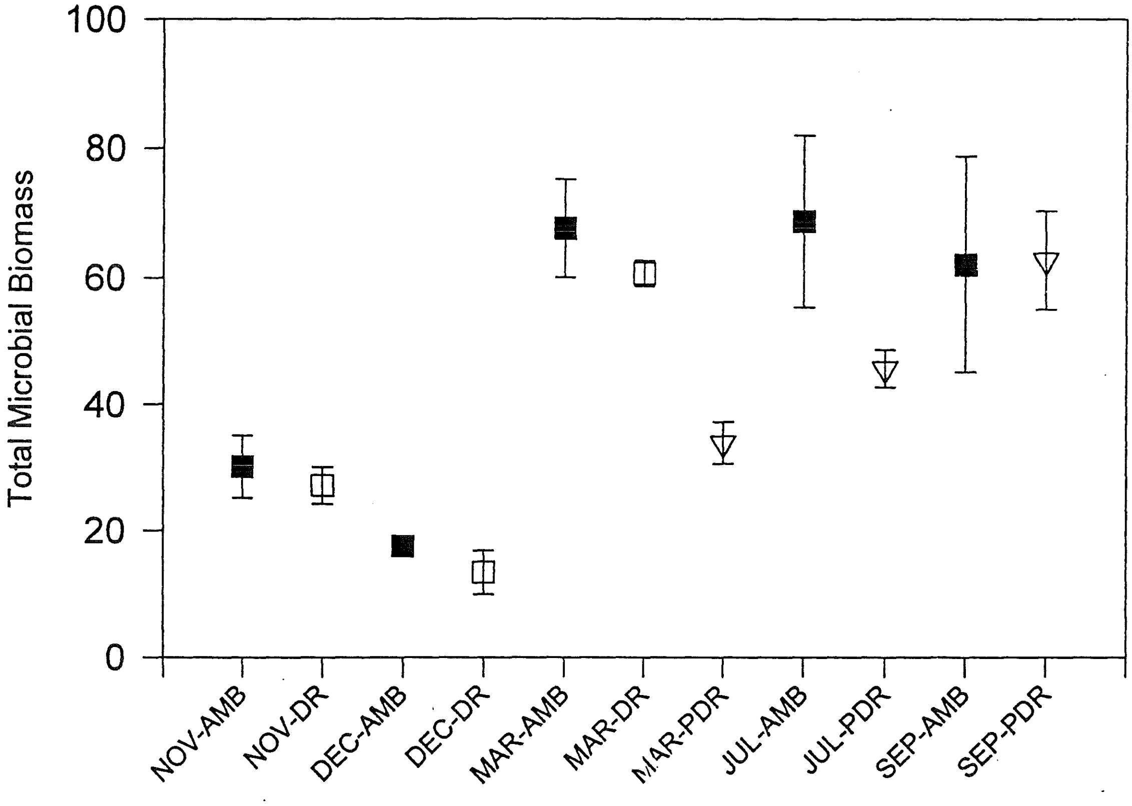


Fig. 3. Changes in total microbial biomass with sampling period. Symbols and legends as for fig. 1.

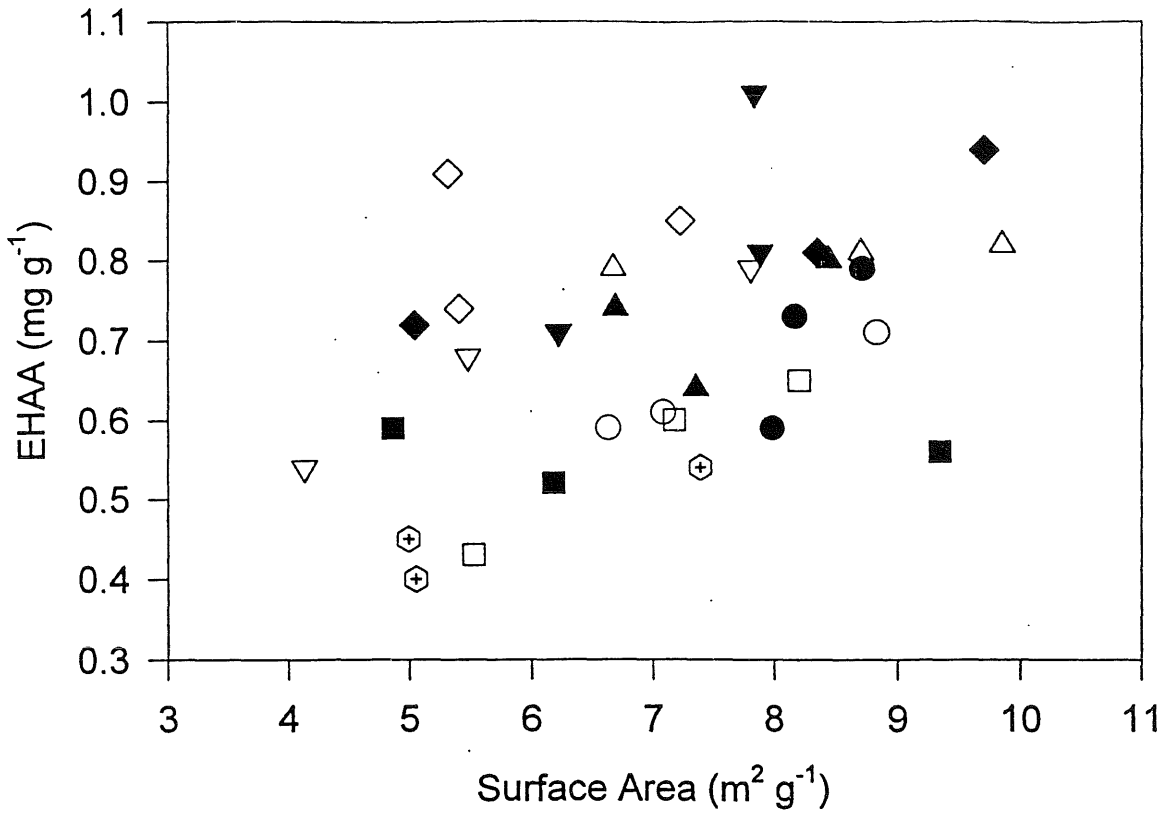


Fig. 4. Relationship of enzyme hydrolyzable amino acids to sediment grain surface area. Filled symbols are ambient site samples; open symbols are drag site samples. Different symbol types represent the various sampling periods.

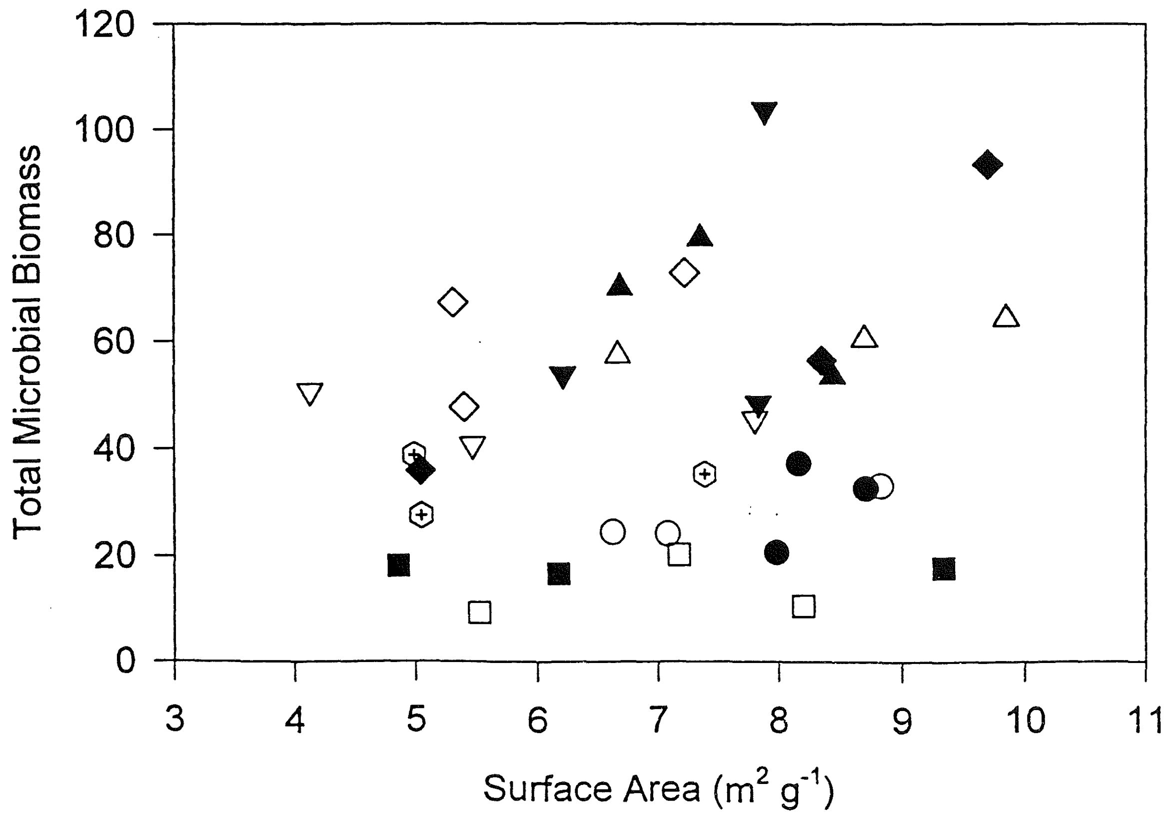
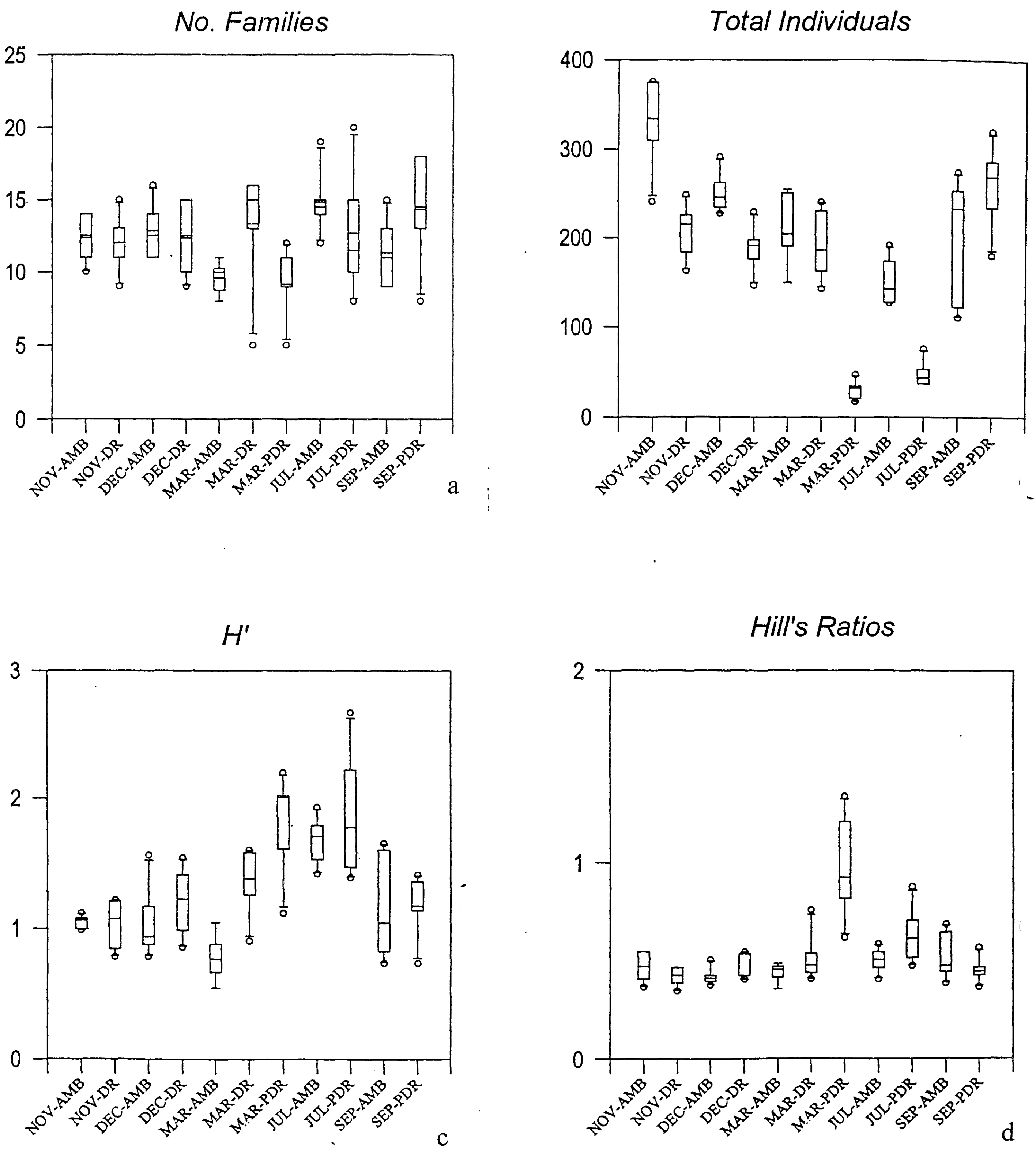


Fig. 5. Relationship of total microbial biomass to sediment grain surface area. Symbols as in fig. 4.



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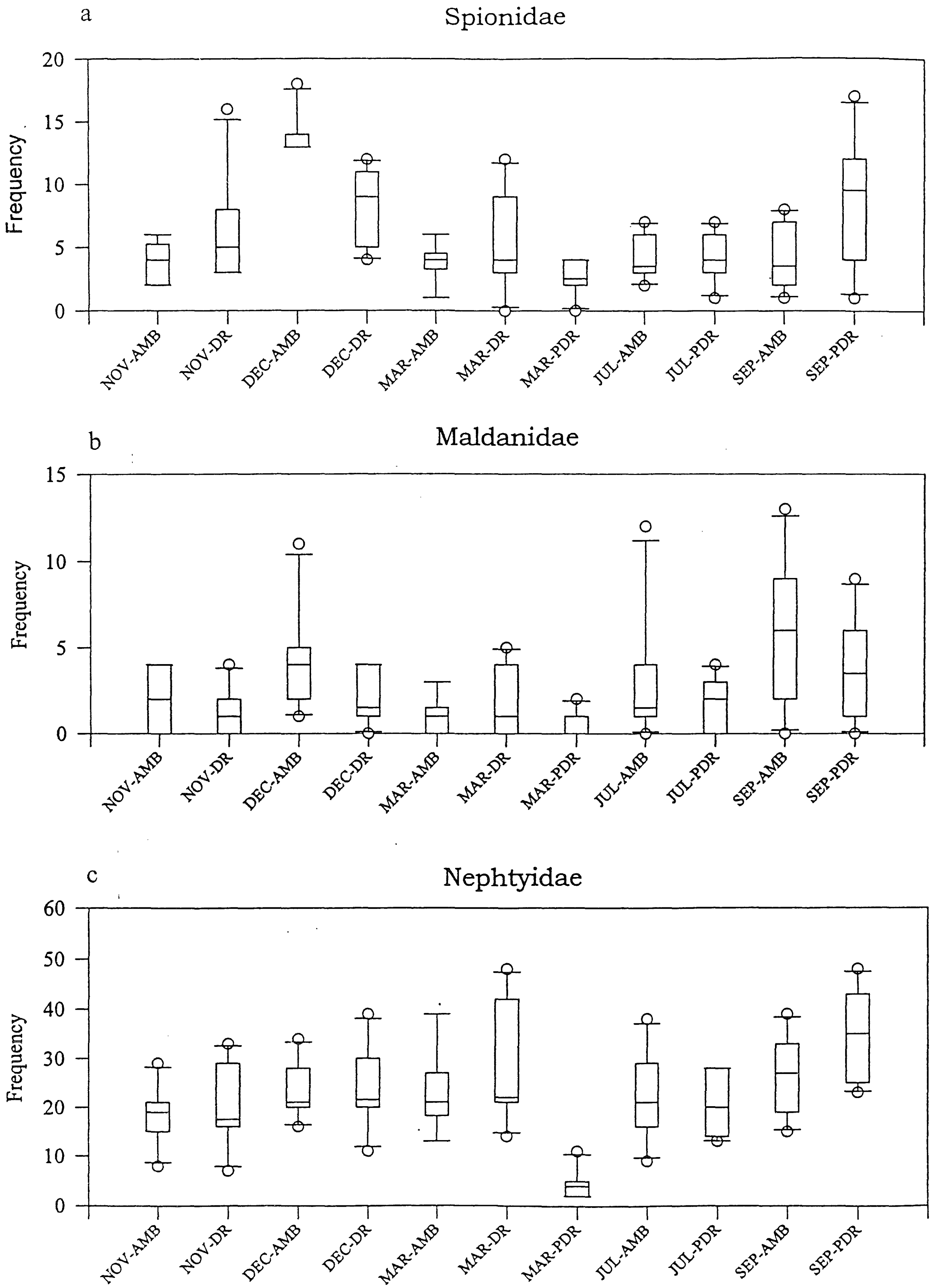

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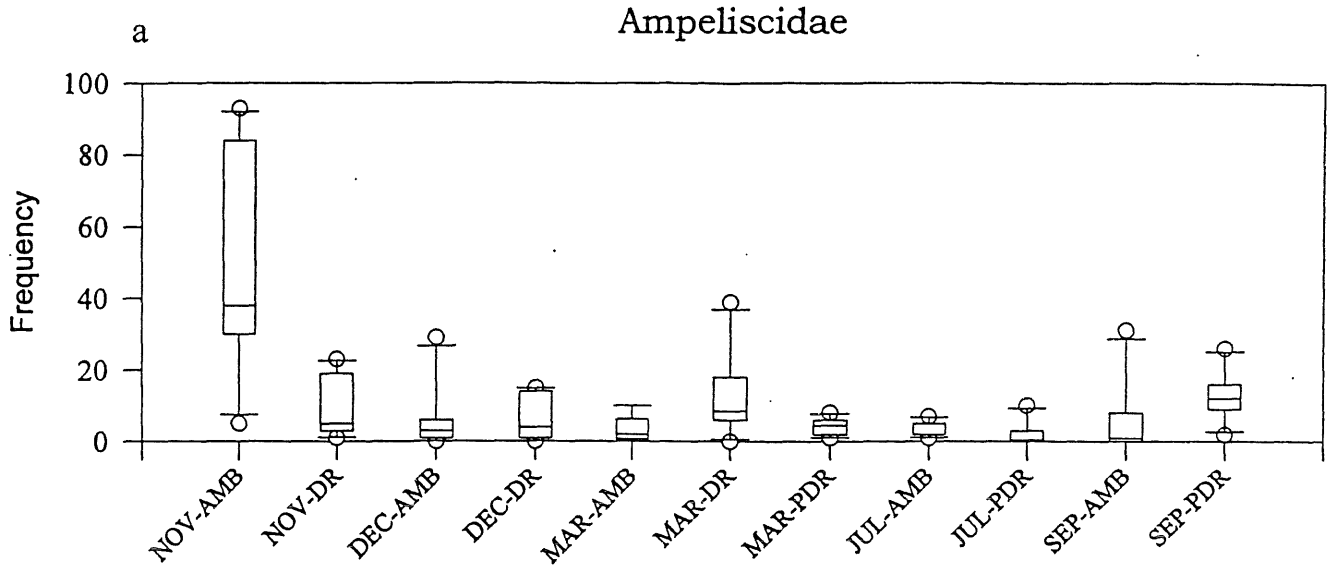

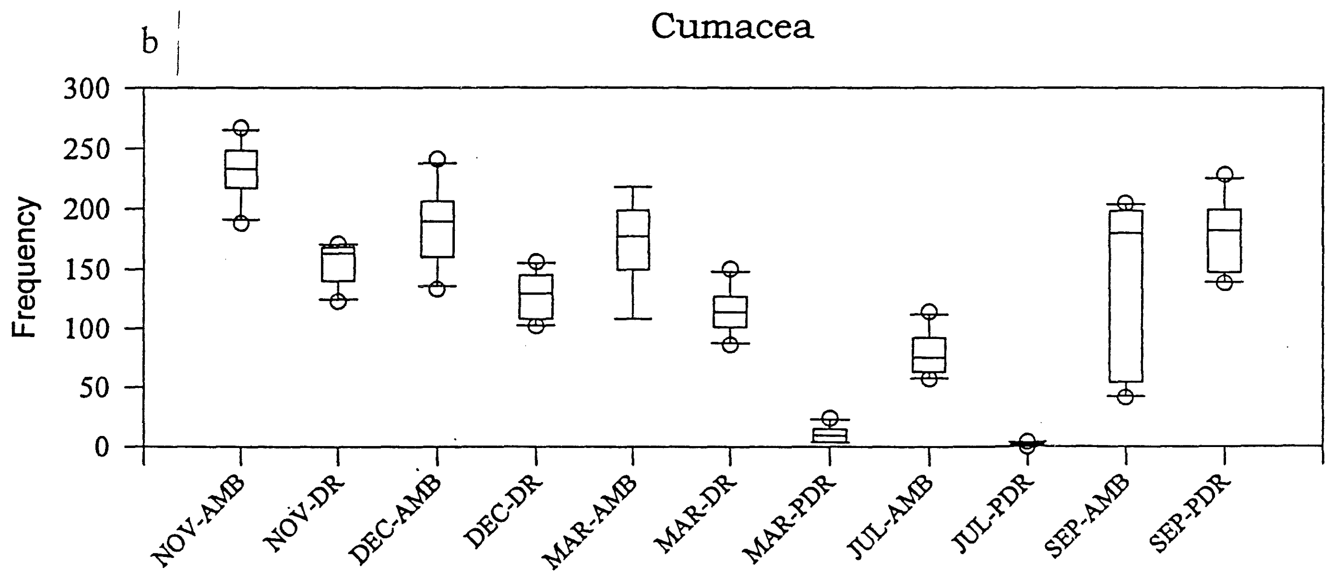

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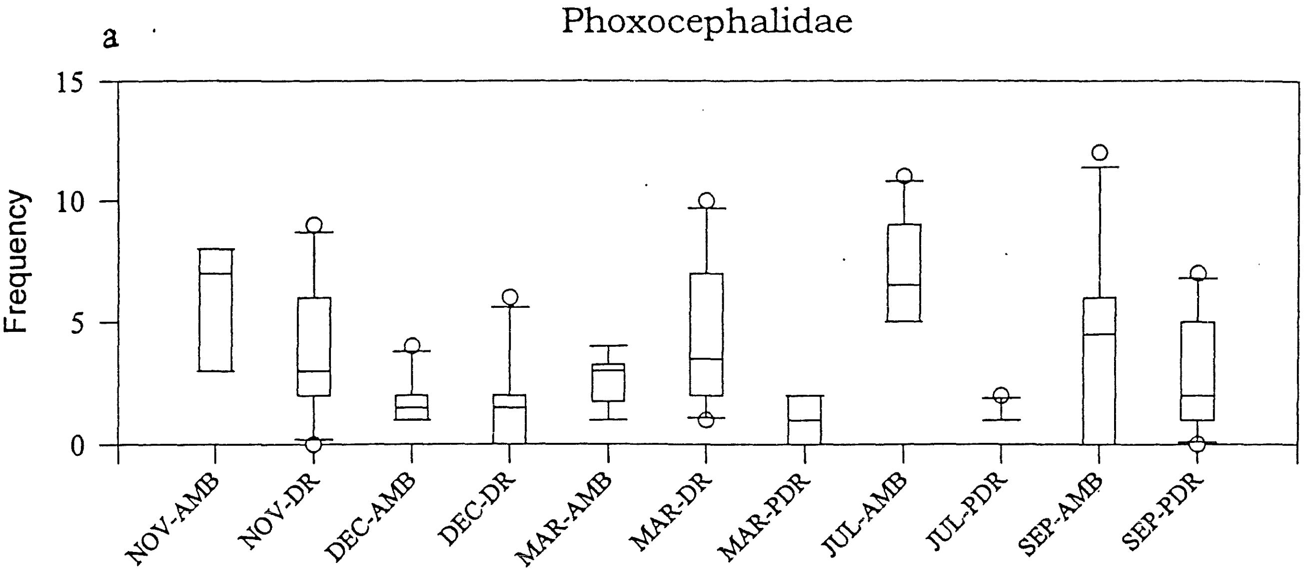

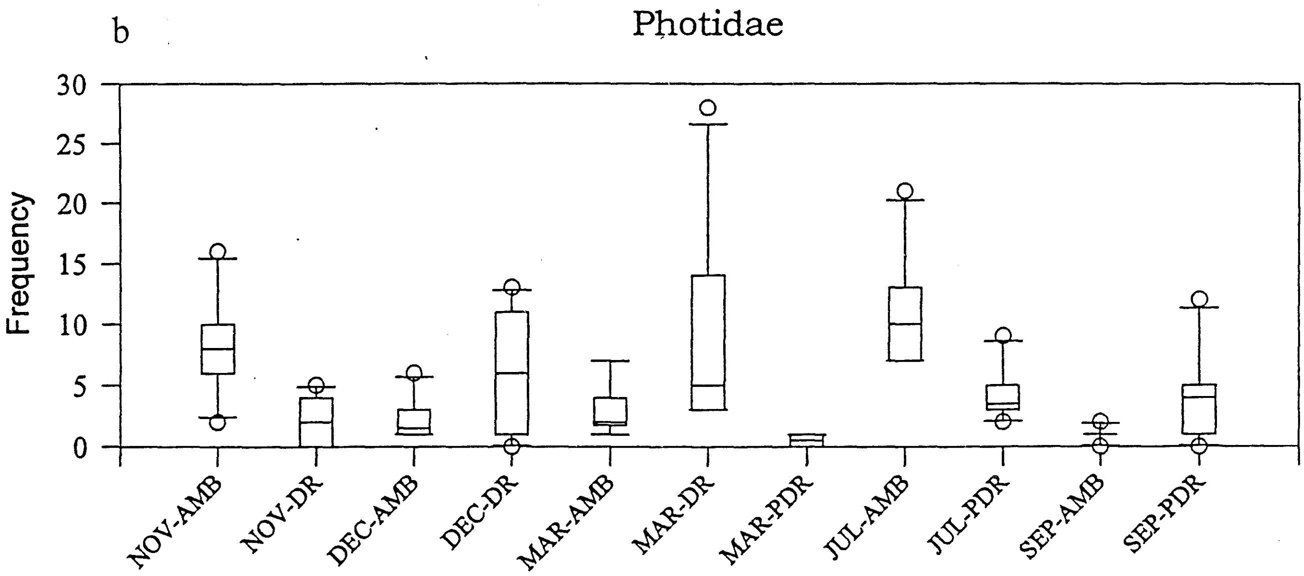

Fig. 9. Box and whisker plots (median, 75th and 95th percentiles) of changes in abundances of (a) Phoxocephalidae and (b) Photidae with sampling period. Sample labels as in fig. 1.

THE MACROFAUNA INHABITING MARINE GRAVELS OFF THE UK: SUMMARY OF CURRENT FINDINGS.

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INTRODUCTION

Several studies (see below) have shown that the benthos of marine gravels can vary widely in composition not only locally, but also on a regional scale, despite similarities in sediment granulometry. An assessment of the natural regional variation in gravel communities, in addition to examining the 'key' environmental factors which determine their structure, would be extremely valuable in appraising the biological consequences of future dredging activities and in assessing the processes which determine the biodiversity of coarse mixed sediments.

A great deal of the early work on gravel communities was undertaken in the English Channel. For example, Ford (1923), at the Plymouth Laboratory, described the fauna of shell-gravel deposits off the Eddystone rock which was followed by a rare quantitative survey undertaken by Holme (1953). More recently, wide-scale surveys of the western and central English channel have been carried out by Holme (1961, 1966) and in the eastern English Channel by Davoult *et al.* (1988), Davoult (1990) and Dewarumez *et al.* (1992). They identified a number of communities which were closely related to the physical environment. Similarly, the results from a wide-scale survey of the Bristol Channel (Warwick and Davies, 1977) allowed a definitive relationship to be established between the prevailing tidal conditions and the resultant sedimentary and community characteristics (Warwick and Uncles, 1980). On a more local scale, studies off the Isle of Wight (Lees *et al.*, 1990; Collins & Mallison, 1983, 1989), Hastings (Rees *et al.*, 1987), Southwold (Millner *et al.* 1977), North Norfolk coast (Hammond, 1963), Lowestoft (Kenny *et al.*, 1991) and central English Channel (Holme and Wilson, 1985) have provided descriptions of the biology of coarse aggregate deposits, either in their natural state or in relation to the impact of marine aggregate extraction.

The present study describes the macrofauna sampled from nine regions off England and Wales and measurements of the physical environment provide an explanation for the observed variation in regional assemblages.

PRELIMINARY RESULTS

An assessment of the natural biological and physical variation between non-dredged commercial gravel (mixed coarse aggregate) deposits was undertaken off England and Wales between 1990 and 1994. A total of 54 Anchor dredge samples, obtained from 9 coastal regions (Humber, Norfolk, Lowestoft, Thames, Hastings, Isle of Wight, Lyme Bay, Bristol Channel and Liverpool Bay) were analysed for their macrofauna (see Fig. 1). A total of 234 taxa for the >5 mm 'bulk' sample were identified and six species assemblages (communities) were identified using multivariate techniques.

The analysis of nearbed tidal current data in conjunction with sediment particle size information indicated a possible gradient of physical disturbance between the regional sample groups and hence provided a possible explanation for the observed faunistic variation (see Fig. 2). This modal is being further developed with the addition of quantitative benthic data, and will be reported upon more fully at a later date.

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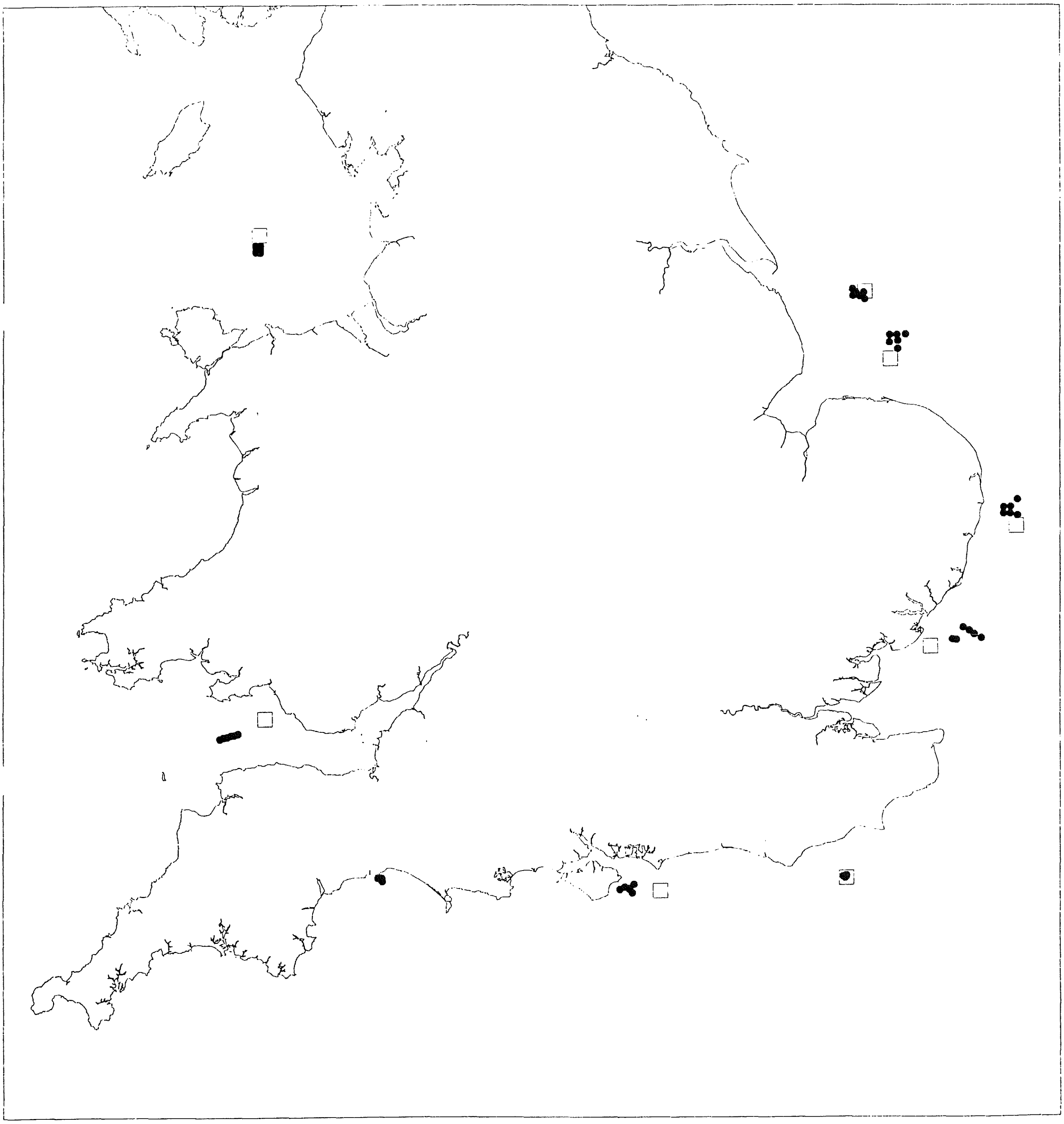
Location of regional sampling sites



□ **Near bed current meter**

• **Anchor dredge stations**

Lyme Bay and Humber Gravels		**Lowestoft and Thames Gravels**
high silt >2%, low sand <40%	**Relatively**	low silt <2%, high sand >40%
low current		high current
Increased diversity and abundance of epifauna and infauna		Reduced diversity and abundance of epifauna and infauna but potential increase in abundance of specialised infauna
Warwick and Davies (1977) Dewarumez *et al.* (1992)		Holme and Wilson (1985) Davoult (1990)

ANNEX 8

Towards assessing the sensitivity of benthic species and biotopes in relation to fishing activities

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Keywords: Sensitivity, vulnerability, impacts of fishing, disturbance, communities, biotopes, benthos, Critical Environmental Capital.

ABSTRACT

1. Preliminary estimates of the relative sensitivity of sea bed types and benthic species to physical disturbance, particularly fishing activity have been made, in order to identify areas where further studies are required and to help formulate management plans for sites of marine conservation importance.

2. Physical disturbance is considered in the context of a single encounter with fishing gear followed by a recovery period during which there is no fishing, but with a view to qualifying, in the future, the effect of multiple fishing events. Disturbance is considered in terms of the physical action of the gear on the sea bed and the unit area over which this action occurs.

3. The effects of a wide range of gear are considered. Static gears, which can be employed on a wide range of substrata, generally result in low level impacts for single fishing events and impacts are very localised compared with mobile gear. The effects of mobile gear can extend over considerable areas with each tow ranging from hundreds of metres to several kilometres in length.

4. The sensitivity of individual species is assessed on the basis of how well they cope with an encounter with fishing gear and on their likely recovery from destruction in terms of their reproductive strategies.

5. Species considered of key importance in the structuring of communities are suggested and examples of particularly sensitive species, which are therefore likely indicator species of physical disturbance, are listed.

6. Fragile, slow recruiting animals are regarded to be most susceptible to disturbance, while the least sensitive species are generally fast growing and have good recruitment.

INTRODUCTION

Pursuing fisheries will inevitably change marine ecosystems. Some of that change will be undesirable because it over-fishes stocks, removes non-target but ecologically or commercially important species, or degrades parts of the environment for their non-commercial values such as the conservation of biodiversity or maintenance of aesthetic values. In conserving biodiversity, it is particularly important that those parts of the natural environment which are irreplaceable are not damaged or destroyed. "Irreplacibility" is a key criterion in assessing nature conservation importance of sites and species. This is expanded in the concept of Critical Environmental Capital (CEC) currently being developed and tested by English Nature. CEC is formally defined as "those elements of the natural environment whose loss would be serious, or which would be irreplaceable, or which would be too difficult or expensive to replace in human time scales" (Masters and Gee, 1995). A challenge inherent in the practical application of the CEC concept in environmental management lies in determining those elements of the natural environment that qualify and those that do not. This depends on our ability to identify what can and cannot be replaced once lost. One of the characteristics established by Masters and Gee (1995) to assess CEC is the physical sensitivity of species.

Definition of terms

"Sensitivity" is sometimes synonymised with "vulnerability", but we prefer to maintain an important distinction. We define sensitivity "the intrinsic intolerance of a habitat, community or individual (or individual colony) of a species to physical damage or removal from an area due to an external factor beyond the range of environmental conditions normally experienced". We see the vulnerability of a habitat, community or individual (or individual colony) of a species as describing its "exposure to an external factor to which it is sensitive". Thus, a species may be sensitive to fishing disturbance but is only vulnerable to such disturbance if it occurs on the kinds of substrata where the disturbing fishing activity is or might take place. So, we might conclude that *Funiculina quadrangularis* (Pallas, 1766) is sensitive to bottom trawling, but is only vulnerable to bottom trawling in areas where its distribution coincides with trawled areas. Similarly, sensitive species that occur in fine sands are generally not very vulnerable to disturbance by crab potting because such pots are more usually set on rocky substrate.

Sensitivity must be assessed in relation to the anthropogenic activity that might impact on it. For example, a particular species may be very sensitive to damage from physical disturbance, but be tolerant of some particular form of localised pollution, such as nearby fish farm effluent. Being able to assess the sensitivity of species would therefore be an advantage when determining if a site should be given CEC status as this would feed into the management of activities in or near such sites. This in turn would implicitly require that the process also takes into account the vulnerability of species to the particular activity for which its sensitivity was being considered.

Types and effects of disturbance

There are many different forms of anthropogenic disturbance to which benthic species, habitats and communities are subjected (*e.g.* Probert, 1975, 1984; Conner and Simon, 1979; Jumars, 1981; McLusky *et al.*, 1983; Leidy and Fiedler, 1985). Fishing activities have long been regarded as particularly disturbing physically with protests dating back to the thirteenth century (Spurr, 1977, de Groot, 1984). However, much evidence of disturbance caused by fishing is anecdotal and there are few rigorous scientific studies on the impacts of fishing on benthos (but see, for instance, MacDonald, 1993; Kaiser and Spencer, 1993). Therefore, the present study, which focuses on fishing activities, is based on interpretations of available literature (*e.g.* de Groot and Apeldoorn, 1971; Margetts and Bridger, 1971; de Groot, 1984; Caddy, 1973; de Graaf and de Veen, 1973; Fonesca, 1984; Fowler, 1989; Eleftheriou & Robertson, 1992; MacDonald, 1993; Rees & Dare, 1993; ICES, 1994). This literature was combined with the authors' experience and communication with marine scientists in these fields.

Not all fishing activities will have detectable effects and the severity of the impact can depend on the frequency of the disturbance (MacDonald, 1993). Stable habitats with long lived species will generally take longer to recover following disturbance (Pickett and White, 1985). Such stable environments are often found in low energy systems such as sealochs, or deep water offshore, and may be substantially affected by even low frequency fishing disturbance (Dayton and Hessler, 1972; Grassle and Sanders, 1973). On the other hand, communities on mobile sands and gravel banks frequently disturbed by wave action might be expected to be more resilient to high frequencies of fishing disturbance because of the inherent instability of their habitats. In terms of species richness, the richest benthic communities often occur in stable sediments where long-lived species, which settle only occasionally, can survive and add cumulatively to the richness (the "biologically accommodated" community of the "stability-time hypothesis"; Sanders 1968).

Theoretical considerations of disturbance can be complex (*e.g.* Levin and Paine, 1974; Connell, 1978; Sousa, 1979a,b, 1980, 1984, 1985; Miller, 1982; Denslow, 1985) and disturbance due to fishing can be broken down into several components including intensity, frequency, size and shape (MacDonald, 1993). For the purposes of this study, however, disturbance refers only to the combination of the physical action of the gear on the sea bed and the area over which this action extends. The manifestations of disturbance may therefore range from only minimal physical damage to the benthic species through to major redistribution of substrata and very high mortality of benthos.

Development and application of sensitivity criteria

The present work sets out to develop criteria assessing the sensitivity of species and their habitats to physical disturbance from fishing activities, and apply those criteria within a framework to indicate particularly sensitive species and the levels of disturbance experienced for defined fishing practices. A good framework would help us to identify where field studies are required to improve our assessment of the extent and importance of sensitive species in an area, and therefore our ability to be more effective in applying concepts such as CEC and in formulating management plans for sites of marine conservation importance. In the context of this paper, sensitivity refers both to a species' susceptibility to physical damage caused by contact with fishing gear and to their ability to cope with such damage through repair, regeneration or recruitment.

METHODS

Rationale

In order to define an index for sensitivity, the components of sensitivity must be understood and taken into account. The sensitivity of a species to fishing disturbance has two main components:

1. the fragility of individuals of the species in physical contact with the fishing gear;
2. the ability of the species to recover to its former population or physical status within the disturbed area.

The first component of sensitivity (fragility) depends on the organism's physiology and/or structure including strength or flexibility. For example, a certain minimum force would be required to crush the test of an adult common urchin, *Echinus esculentus* Linnaeus, 1758. The susceptibility of the organism to physical damage will therefore depend on its inherent fragility and the intensity of the impact. For example, *Echinus esculentus* is very sensitive to scallop dredging where as many as 70% of tests can be smashed by the gear upon contact or by the material in the dredges (MacDonald, 1993), but we would expect this figure to be substantially lower for crab potting.

The second component of sensitivity (recovery) incorporates several concepts:

- the ability of damaged organisms to repair or regenerate lost or damaged parts;
- the ability of the organisms to continue occupying the disturbed habitat;
- the supply of larvae to the disturbed habitat and their settlement success;
- recruitment to the adult population from settled larvae.

The time taken for the species to recover to its former status can vary from a few months to decades, or, in some instances, full recovery may never be achieved (Bonsdorff, 1980, 1983, 1986; Reise, 1982; Reisen and Reise, 1982; Rosenberg, 1974, 1976, 1977; Guillou and Hily, 1983; Frid, 1989).

An index of sensitivity

All the above factors must be taken into account, we consider the recovery potential to be the most important and this should therefore be weighted. A meaningful index of sensitivity must therefore be based upon consistent assessment of these factors and this might be done using a formula. We therefore propose the following index of sensitivity (*S*):

$$S = (F \times I)\, e^{R}$$

where *R* is *recovery* (scored on a scale of 1 to 4, equivalent to short, moderate, long and very long recovery period or no recovery is likely); *F* is *fragility* (scored on an arbitrary scale of 1 to 3, equivalent to not very fragile, moderately fragile, and very fragile); and *I* is the *intensity of the impact* (was scored on an arbitrary scale of 1 to 3, equivalent to low, moderate and high intensity).

Recovery represents the time taken for a species to recover in the disturbed area. Where the organisms are largely unaffected by the passage of gear, *R* will be short. If the organisms are damaged or killed but migration into the disturbed area is rapid, then *R* may also be short. Where recovery depends on regeneration of damaged organisms or recruitment to the adult population from larval settlement and growth, recovery times will then depend on the recruitment and growth rates of the species. Slow growing, poorly recruiting species will have high *R* scores. With more information on the various life history and ecological parameters affecting recovery, it might be possible to further refine *R* by breaking it down in to constituent components such as immigration of mobile species and infilling types of growth by colonies, and recruitment of juveniles but including juvenile mobility or space occupancy where this is normal. However, without sufficient information available for all the species examined in this study, we opted to maintain the simpler approach. It is important to bear in mind that in considering recovery times, the context taken in this study was a single fishing event followed by a recovery period with no fishing. If there are multiple fishing events at the same site then recovery will take much longer or never be achieved.

Fragility represents the inability of an individual or colony of the species to physically withstand an impact with fishing gear. It is primarily related to the strength of body parts such as tests, shells and exoskeletons. Fragile organisms such as *Pentapora foliacea* (Ellis and Solander, 1786) and *Echinus esculentus* would have a relatively high fragility score. Tougher organisms such as *Buccinum undatum* Linnaeus, 1758, and hermit crabs in *Buccinum undatum* shells, would have a lower fragility score.

Intensity of impact depends on whether the gear is static or mobile and the degree of penetration into the substratum. Static gear will generally score low compared with mobile gear. Similarly, beam trawls would have a higher score than a long-line, which would have a low score.

Application of the index

Estimation of the relative sensitivities of different species to disturbance from fishing activities was carried out in the context of a single encounter with fishing gear followed by a recovery period during which there is no fishing. The initial approach was to think in terms of disturbance to sea bed types and species rather than biotopes. At a later stage assessments of disturbance to sea bed types and species could be combined to produce assessments of disturbance to biotopes. This reflects a currently restricted ability to identify definitive sublittoral biotopes, particularly sublittoral sediment biotopes, compared with the advanced stage of the Marine Nature Conservation Review littoral biotopes classification (Connor *et al.* 1995).

On obtaining the sensitivity scores for various species, these were then normalised by dividing each score into the maximum possible score using the following relationship;

$$S_{norm} = \frac{S_n}{S_{max}} \times 100$$

where S_{norm} is the normalised sensitivity score for any species n and S_{max} is the maximum possible sensitivity for the most disturbing fishing activity ($S_{max} = 491$).

RESULTS

The results of calculating sensitivity indices for a variety of species and different types of fishing activities are presented in tables 1 and 2. For example, for a scallop dredge encountering *Eunicella verrucosa* (Pallas, 1766), Fragility would be high ($F = 3$), the intensity of impact by a dredge would be high ($I = 3$) and the recovery time required by *Eunicella verrucosa* would be long ($R = 3$). This results in high sensitivity ($S = 18$, $S_{norm} = 37$). By contrast, the sensitivity of *Buccinum undatum* encountering a gill net would be much lower ($S = 4$, $S_{norm} = 2$) since it is not very fragile ($F = 1$), the intensity of the gear is low ($I = 1$), and the recovery would be moderate ($R = 2$).

DISCUSSION

Sensitivity in relation to intensity of fishing

Calculating the relative sensitivities of different species in the context of a single encounter with fishing gear followed by a recovery period during which there would be no fishing is clearly an unrealistic portrayal of what happens in many real fisheries where the same ground may be fished intensively until the catches no longer justify the effort involved in fishing. Multiple fishing events in exactly the same area will obviously cause greater disturbance. The quantification of the effect of multiple fishing events would be a logical progression from this work. This would allow further development of an index that could take into account the frequency of the disturbance event.

Although the index of sensitivity in relation to static gear for a single fishing event is considered to be low level when compared with that of mobile gear, this does not exclude the possibility of extensive damage to sensitive species by intensive use of static gear in small areas. Some pot fishermen deploy considerable numbers of pots and their repeated use in a small area could possibly affect fragile species such as *Eunicella verrucosa*. The impact of the weights of set nets or pots arriving on the sea bed may physically damage fragile organisms, and this is particularly the case on rocky ground where fragile species such as *Eunicella verrucosa* and *Pentapora foliacea* are found. The movement of set nets and pots on the sea bed during rough weather or during retrieval can further detach organisms from the surrounding rock surfaces. A study, involving the authors of this paper, is currently underway investigating the effects of deploying static gear in an intensive way.

Sensitivity in relation to gear type

It may be thought that epibiota on rocky substrata is unlikely to be affected by mobile gear because such areas are generally avoided to reduce the risk of damage to the gear and because of a reduction in efficiency of fishing. However, some types of gear are designed for rocky areas (the rockhopper type of otter trawl which is adapted and reinforced to operate on rocky ground, and the Newhaven type of scallop dredge which is used by some fishermen on rocky ground). Although other types of demersal trawl or dredge are designed principally to operate on sediments, they also come into contact with epilithic organisms on mixed grounds. They may also break-up biological reefs such as those formed by *Sabellaria spinulosa* Leuckart, 1848, and *Modiolus modiolus* (Linnaeus, 1758) (ICES, 1992) or friable rocky reefs such as shale reefs. Larger vessels generally have a greater capacity to fish mixed ground than the smaller inshore vessels because they are able to handle the more robust gear required. On grounds without erect epifauna the disturbance caused will depend on the size of the gear, its weight, and its degree of penetration into the sediment.

For mobile gears, the type of gear will also determine for each species the ratios of those individuals caught and taken aboard as by-catch, to those that are caught but pass through the gear, to those that are impacted *in situ* but not actually caught. However, there is not yet enough information available to allow to quantification of these ratios. Many species when taken aboard suffer increased stress from desiccation, trampling under crew member's feet and from suffocation, and mortality can often be very high (MacDonald, 1993; Kaiser and Spencer, in press). However, we do not yet know enough about these effects. When more is known about the effects of fishing methods on particular non-target species, and the different effects on by-catch and individuals remaining *in situ* can be determined, the assessment of species sensitivity could be further refined.

Applying sensitivity of species to sensitivity of biotopes

A biotope's sensitivity to an anthropogenic activity will be a function of the sensitivity of the different species making up the biotope's component community. This translates to a dependence on the community's sensitivity, based on the sensitivity of the component species. However, we face a problem in deciding how this assessment should be derived; should all the species be treated as equally important to the community, or should weight be given to particular species such as key species, rare species, particularly sensitive species, or species with high aesthetic value?

It may be possible to integrate the sensitivity of the component species to provide a sensitivity 'score' for the community in relation to particular impacts and activities. However, simply averaging sensitivity scores for all species present in a community tends to under-rate the sensitivity of the community. This reflects the high recruitment rates of many species which are therefore less sensitive to the occasional fishing event. However, if attention is focused on particularly sensitive species then unreasonably high sensitivity scores may be obtained for many communities that hold at least one very sensitive species.

Where many species are present in a community, a measure of community sensitivity will be difficult to arrive at. An alternative approach worth considering could be to focus on 'key' species (discussed below) in the community such as *Zostera marina* (Linnaeus 1758) in the case of a seagrass bed.

A more sophisticated method of assessing community or biotope sensitivity is not yet available. Until one is, a crude means of mapping biotope sensitivity in relation to specific impacts and activities could be provided: when the biotope classification being developed by the MNCR (Connor *et al.*, 1995) provides the basis for mapping biotope distributions based on analysis of survey data, those biotopes in which known sensitive species occur can be marked.

Sensitivity and 'key' species

Key species are effectively those species that structure the community. Masters and Gee (1995) identify criteria for identifying key species. The identification of key species is a cornerstone of the CEC concept: the loss of a key species within the community would seriously change the nature of the community and possibly its viability. Within the context of sensitivity assessment, this suggests that it is only necessary to assess the sensitivity of the key species rather than all the species present. The problem here is in identifying key species.

In the terrestrial environment, key species often correspond to dominant vegetation types present (*e.g.* oak trees in oak woodland). In the marine environment, the equivalent situation occurs where species form the substratum for other species (*e.g.* a bed of *Modiolus modiolus*), dominate by modified environmental conditions (*e.g.* shade and shelter from wave action under kelp forests) or by being major grazers or predators (*e.g.* limpets on a rocky shore), or structure the habitat through bioturbation. However, identifying key species may be difficult in many other cases, particularly with infaunal animals. The focus should therefore not just be on likely key species.

'Indicator' species are species that are particularly sensitive to fishing because the are fragile, slow growing and/or have poor recruitment prospects, are likely to be widespread and can be easily recognised. The abundance of such species might provide a guide to the level of fishing disturbance and therefore to whether the communities in an area are natural or altered by fishing. Indicator species are particularly useful as a measure of long-term fishing disturbance since they reflect the effects of multiple fishing events. An example might be the sea pen *Virgularia mirabilis* (Müller, 1776) which would be expected to be present on muddy sands in depths of 50 to 100 m but is very sensitive to mobile gear and only likely to be found where fishing is absent or low intensity. Although ICES (1994) consider that indicator species have little part to play in monitoring the long-term effects of fishing activities because directly monitoring is the simpler approach, we do not fully agree and suggest that (usually financially) restricted programmes of sampling could concentrate on certain likely indicator species. Table 3 presents some candidate indicator species for different seabed types where there are no obvious key species. Although we provide these examples, we recognise a problem where in many instances other potential indicator species may not be helpful since they may have already been fished out.

Effects of fishing on community composition.

Apart from the direct disturbance and mortality caused by the passage of fishing gear, changes in benthic community compositions after fishing events have been demonstrated (*e.g.* Eleftheriou and Robertson, 1992;

MacDonald, 1993). Increased levels of disturbance to benthos encourages a shift in species composition from long-lived and slow recruiting (sensitive) species, to more opportunistic species, which can quickly colonise disturbed areas through successful recruitment and rapid growth. Whether or not original communities will ever return following heavy disturbances is unpredictable since succession may not be unidirectional (see MacDonald, 1993, for a discussion).

It is important to bear in mind that the majority of the sea bed around the UK coast has been affected to various degrees by fishing and that many communities are a result of past and continued disturbance. It is also likely that sensitive species will not be present in such areas and will have become locally extinct.

Significance for nature conservation management

The aims of nature conservation in Great Britain are most eloquently given in Command 7122 (Ministry of Town and Country Planning 1947): "to preserve and maintain as a part of the nation's natural heritage places which can be regarded as reservoirs for the main types of community and kinds of wild plants and animals represented in this country, both common and rare, typical and unusual". To achieve such an objective in a scientific and defensible manner requires the development of concepts such as CEC supported by objective measures of sensitivity. In this paper, we have worked towards establishing a framework for assessing the 'real' sensitivity of species, biotopes and locations around our coasts to fishing activities. This is a substantial advance on previous equations of sensitivity with scientific interest. Certainly, sites that are valued because they include representative or rare features should be protected, but some will be more or less sensitive to different activities than others. Similarly, certain parts of marine protected areas will include species and features more sensitive to certain forms of fishing than others. Restrictions on fishing in those sensitive areas (but not in the other areas) might then be appropriate. Such considerations lead to the sorts of zoned management schemes described by Laffoley *et al.* (1994).

Further development of sensitivity assessment and information requirements

The sensitivity index, as currently scored, tends to place any species with a poor chance of recovery or re-establishment in the higher categories. A further category could be added for those species unlikely to re-establish because of their longevity and poor recruitment prospects. There are other possible ways in which the index could be variously refined, but these rely upon having further information available. For instance, the greatest difficulty in assessing sensitivity is that very rarely do we know enough about the longevity, growth rates and reproductive mechanisms of species to assign appropriate scores. Also, we do not have information about the effects of fishing on the vast majority of benthic species and, at best, we can only calculate sensitivity for a small percentage of the species present in certain communities. If sensitivity scores are to be widely used, this information needs to be compiled.

It is also clear from the literature that the effect of different fishing activities on benthos is largely unquantified. We therefore suggest that studies of trawl path mortalities, life history parameters, and "efficiency" of capture for different gears be undertaken for benthic species, particularly sensitive species, in order that the conservation risks associated with fishing may be better estimated. Furthermore, selected benthic communities should be monitored to assess the effects of fishing activity on resident communities and on the recruitment of other biota. This type of information is fundamental to our understanding of interactions between fishing gear and benthos.

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Table 1. Likely sensitivity of some species to disturbance caused by an encounter with fishing gear on rocky grounds. Fishing gears have been grouped according to the relative scale of disturbance they cause Low intensity gears include pots, gillnets and longlines. Medium intensity gears include otter trawls and Danish Seines. High intensity gears include dredges, rockhoppers and beam trawls. The values of F were derived from personal knowledge of the species structure and of R were derived from a review of literature on the life-histories of the species.

Species	*F*	*R*	*Low intensity gear (I = 1)*	*Medium intensity gear (I = 2)*	*High intensity gear (I = 3)*	S_{norm} $(I = 1)$	S_{norm} $(I = 2)$	S_{norm} $(I = 3)$
Leptopsammia pruvoti	3	4	16	20	24	33	67	100
Eunicella verrucosa	3	3	12	15	18	12	25	37
Caryophyllia smithii	2	3	9	12	15	8	16	25
Pentapora foliacea	3	2	8	10	12	5	9	14
Echinus esculentus	3	2	8	10	12	5	9	14
Flustra foliacea	2	2	6	8	10	3	6	9
Laminaria hyperborea (mature)	2	2	6	8	10	3	6	9
Cliona celata (massive)	2	2	6	8	10	3	6	9
Holothuria forskali	1	2	4	6	8	2	3	5
Crossaster papposus	1	2	4	6	8	2	3	5
Acmaea tessulata	1	2	4	6	8	2	3	5
Gibbula cineraria	1	2	4	6	8	2	3	5
Chitons	1	2	4	6	8	2	3	5
Alcyonium digitatum	1	2	4	6	8	2	3	5
Tubularia indivisa	3	1	4	5	6	2	3	5
Nemertesia antennina	2	1	3	4	5	1	2	3
Antedon bifida	2	1	3	4	5	1	2	3
Nitophyllum punctatum	2	1	3	4	5	1	2	3
Halichondria panicea	1	1	2	3	4	1	1	2
Pomatoceros triqueter	1	1	2	3	4	1	1	2
Encrusting algae	1	1	2	3	4	1	1	2

Table 2. Likely sensitivity of species to disturbance caused by an encounter with fishing gear on clean or mixed grounds. Fishing gears have been grouped according to the relative scale of disturbance they cause Low intensity gears include pots, gillnets and longlines. Medium intensity gears include otter trawls and Danish Seines. High intensity gears include dredges, rockhoppers and beam trawls. The values of F and R used in these examples were derived from a review of literature on the life-histories of the species.

Species	*F*	*R*	*Low intensity gear (I = 1)*	*Medium intensity gear (I = 2)*	*High intensity gear (I = 3)*	S_{norm} *(I = 1)*	S_{norm} *(I = 2)*	S_{norm} *(I = 3)*
Funiculina quadrangularis	3	4	16	20	24	33	67	100
Maerl	3	4	16	20	24	33	67	100
Modiolus modiolus	2	4	12	16	20	22	44	67
Virgularia mirabilis	3	3	12	15	18	12	25	37
Echinocardium cordatum	3	3	12	15	18	12	25	37
Arctica islandica	2	3	9	12	15	8	16	25
Ensis siliqua	2	3	9	12	15	8	16	25
Sabellaria alveolata/spinulosa reefs	3	2	8	10	12	5	9	14
Zostera marina	3	2	8	10	12	5	9	14
Ophiura texturata	3	2	8	10	12	5	9	14
Ophiocomina nigra	3	2	8	10	12	5	9	14
Ophiothrix fragilis	3	2	8	10	12	5	9	14
Corystes cassivelaunus	3	2	8	10	12	5	9	14
Aporrhais pespelecani	2	2	6	8	10	3	6	9
Pecten maximus	2	2	6	8	10	3	6	9
Aequipecten opercularis	2	2	6	8	10	3	6	9
Turritella communis	2	2	6	8	10	3	6	9
Maja squinado	2	2	6	8	10	3	6	9
Cancer pagurus	2	2	6	8	10	3	6	9
Urticina felina	2	2	6	8	10	3	6	9
Glycymeris glycymeris	2	2	6	8	10	3	6	9
Abra alba	2	2	6	8	10	3	6	9
Spisula spp.	2	2	6	8	10	3	6	9
Donax vittatus	2	2	6	8	10	3	6	9
Tellina fabula	2	2	6	8	10	3	6	9
Asterias rubens	2	2	6	8	10	3	6	9
Luidia spp.	2	2	6	8	10	2	3	5
Astropecten irregularis	2	2	6	8	10	2	3	5
Buccinum undatum	1	2	4	6	8	2	3	5
Eupagurus bernhardus	1	2	4	6	8	2	3	5
Portunus depurator	1	2	4	6	8	2	3	5
Lanice conchilega	3	1	4	5	6	2	3	5
Spiophanes bombyx	3	1	4	5	6	1	2	3
Pectinaria koreni	2	1	3	4	5	3	4	5

Table 3. Some candidate indicator species for different seabed types.

Sea bed type	*Candidate indicator species*
Sand	*Echinocardium cordatum*, *Ensis* spp., *Corystes cassivelaunus*
Muddy bottoms of sealochs	*Virgularia mirabilis*, *Funiculina quadrangularis*, *Pachycerianthus multiplicatus*
Bedrock and reefs	*Eunicella verrucosa*, *Pentapora foliacea*, axinellid sponges

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Extracted from NODC Taxonomic Code Version 7

INTRODUCTION

The Linnean system of biological nomenclature, which has been universally used by zoologists and botanists since 1756, provides an excellent method of arranging the Latin names of organisms or groups of organisms in ways that reflect their phylogenetic relationships. It is an extremely flexible system and has served the needs of the biological research community exceedingly well. In relatively recent times, however, it has become a source of considerable frustration to individuals who need to store and retrieve large amounts of biological data in a computerized environment.

During the past two decades, a number of coding systems have been developed in an effort to adapt the Linnean system to modern methods of data storage and retrieval. These systems, some based on simple abbreviations, some on discrete alphanumerical codes, and others on strictly numerical codes, have varied widely in their effectiveness and acceptance. The Taxonomic Code of the National Oceanographic Data Center (NODC), which now contains approximately 206,000 records, is the largest, most flexible, and most widely used of these various coding schemes.

HISTORY OF THE NODC TAXONOMIC CODE

In 1972 Richard Swartz, Marvin Wass, and Donald Boesch published "A Taxonomic Code for the Biota of Chesapeake Bay" at the Virginia Institute of Marine Science (VIMS Special Scientific Report No. 62). Their efforts were specifically oriented toward development of a universally acceptable coding system since, as they succinctly put it, they felt that "everyone [should] use the same code."

The VIMS codes contained a maximum of 10 digits, with each two digits representing a different level of the systematic hierarchy. The last six digits contained (exclusively) discrete taxonomic levels (families, genera, and species) while the first four digits variously represented phyla, classes, subclasses, and orders.

During the years 1974 and 1975, Dr. George Mueller of the University of Alaska developed a taxonomic code that enabled him and his colleagues to manage biological data for the Alaskan Outer Continental Shelf Environmental Assessment Program (OCSEAP). These codes, known as the "Alaska Species Codes," were based directly on the VIMS numeric concept but used a completely different numerical sequence.

In response to a request by the National Oceanographic Data Center for a taxonomic code into which virtually any existing taxon could be placed, Dr. Mueller developed the hierarchical structure on which the present NODC Taxonomic Code is based.

Personnel at the National Oceanographic Data Center, under the leadership of Dr. Elaine Collins and Mary Hollinger, began adding taxa to this basic framework, and in 1977, published the first edition of the NODC Taxonomic Code. In this edition, which contained approximately 16,000 records, two digits were added to the basic 1O-digit format in order to allow inclusion of subspecies or varieties.

A second edition containing approximately 18,000 records was published in 1978, and a third edition containing approximately 25,000 records was published in 1981. The last hard copy edition was published in 1984 and contained approximately 45,000 entries. Subsequent releases have been available only in digital format. The present release, version 7.0, contains approximately 206,000 records.

STRUCTURE AND CONTENT OF THE CODE NUMBERS

The NODC taxonomic codes contain a maximum of 12 digits, and each code number is partitioned into a series of 2-digit couplets. Each couplet represents one or more levels of the taxonomic hierarchy as follows (numbers in the example are fictitious):

93 (2 digits) Subkingdom, Phylum, Subphylum, Class, Superorder, Order

9301 (4 digits) Superclass, Class, Subclass, Superorder, Order, Suborder, Infraorder, Section, Superfamily

930101 (6 digits) Class, Order, Suborder, Family, Subfamily

93010101 (8 digits) Genus

9301010101 (10 digits) Species

930101010101 (12 digits) Subspecies

Taxonomic information is contained in the hierarchy of each code. For example, the species 9301010101 is part of the genus 93010101 in the above example.

Because the taxonomic code has expanded primarily in response to user requests for additional taxon numbers, the code does not reflect a single consistent taxonomy. In the study of taxonomy these classifications can change over time. There are plans to have the taxonomy inherent in the NODC Taxonomic Code peer reviewed by specialists during the next one to two years. NODC encourages and solicits user feedback on this product.

ANNEX 10

METHODS FOR THE STUDY OF THE COMMUNITY STRUCTURE OF THE BENTHOS OF HARD SUBSTRATA

Introduction

The text on this topic produced by David Connor in the 1995 BEWG report was endorsed by the sub-group, although an understandable bias towards shallow coastal and intertidal areas was noted.

It was decided to broaden the frame of reference to include gravely as well as rocky substrata. The term 'aggregate' provided a useful operational description of the former category, in that it is unusual to encounter deposits of pure gravel at the sea bed. Coarse substrata invariably consist of admixtures of coarse and fine material, typically pebbles, granules and sand but with significant quantities of finer (muddy) sediment in more quiescent areas, or near to estuaries.

A feature of rocky and coarse substrata is the potential for development of a rich and productive **epifauna.** There are several reasons why the epifauna are an important target for study :

On predominantly rocky substrata they may be the only significant component of the benthos. Such areas may support an exceptionally high diversity and biomass of species, e.g. associated with subtidal mussel beds.

Sedentary epibenthic species provide a direct route for carbon from the water-column to the seabed via filter-feeding; similarly, motile scavengers account for larger particles of settling detritus and other organic matter.

Irrespective of mode of feeding, they can have a significant role in the bio-accumulation and then transfer of contaminants through the food-chain.

Many species are preyed upon by fish. From the sampling standpoint, the significant difference between areas of rock and coarse 'aggregate' is of course that, with a few exceptions (e.g. boring bivalves), the former will be colonised exclusively by epifauna, while the latter will be colonised by a combination of epifauna and infauna, whose relative importance may vary between localities. Another important operational distinction is that areas of loose aggregate will generally present a flat profile, thus opening up wider possibilities for remote sampling.

The WG emphasise that approaches to the sampling of rocky and gravely substrata must be guided by a clear statement of the objectives of a study, which may range from local investigations of trends in relation to, e.g., a waste discharge, to wide-scale descriptive surveys of the biological diversity of hitherto unsampled sea areas. In the former case, sampling methods must be tailored to local circumstances, and hence may vary between study areas. In the latter case, especially where large areas are to be covered through international collaborative work, then there will be a need to standardise on the use of suitably robust and versatile sampling devices.

Further general guidance on approaches to sampling the fauna and flora of hard or coarse substrata may be found in Holme and McIntyre (1984) and Baker and Wolff (1987), while issues of sample processing and survey design, which are to a degree comparable with approaches to soft-sediment sampling, are also covered in ICES TIMES reports numbers 8 and 16.

Progress has been made on a classification scheme for benthic marine biotopes of the north-east Atlantic, under the BIOMAR-LIFE programme, and the proceedings of a Workshop has recently been published by the UK Joint Nature Conservation Committee.

Hard (rocky) substrata

The WG considered methods supplementary to Dr Connor's 1995 report. Members were unaware of any significant recent innovations, noting that the general paucity of quantitative data, especially for deeper-water substrata, could be largely accounted for by inherent difficulties in sampling. Diver-operated methods in shallow waters, and remote underwater photography in deeper areas, remained the most suitable options. The use of a heavy-duty rock dredge (see Holme and McIntyre, 1984) may also be suitable for remote qualitative or (at best) 'semi-quantitative' surveys at some locations.

Quantitative collection of samples had recently been carried out on sublittoral rock using suction samplers (see below) but there appeared to be little published information on minimum sample area required to collect the majority of species present or to collect sufficient samples to estimate mean densities of small species in the bryozoan turf typical of many circalittoral rock habitats. Earlier work addressing comparable issues was published by Weinberg (1978 : Mar. Biol., ***49***, 33-40).

Keith Hiscock reported on the results of quantitative sampling exercises undertaken on a level sublittoral hard substratum at Lundy (Hiscock & Rostron unpublished). 192 animal taxa were sampled from fourteen randomly located 0.1m² quadrats on the side of a wreck at 15 m below chart datum. 100 taxa had been recorded in the first two 0.1 m² samples taken on the wreck; about the number recorded in each 0.2 m² sample from natural substrata on transects elsewhere on the island. Extrapolation of the numbers of species using the method described by Hawkins & Hartnoll (1980) suggested that a further 13 species would have been recorded had 20 sample units been analysed and a further 19 had 25 sample units been analysed. Add to the records from samples the number of large widely dispersed species recorded by *in situ* survey alone and it is suggested that 250 is about the number of macrofaunal species present on rock in the circalittoral at a particular location (survey station) at a rich site in south-west England where rocks have a cover of erect Bryozoa and Hydrozoa encouraging the presence of cryptic species. The Lundy study suggests that about 15% of the macrofauna present at a site would be recorded by *in situ* observation by divers.

With regard to obtaining estimates of mean density of solitary species within a standard error of 20% of the mean, five $0.1m^2$ was adequate for the most common species such as *Pisidia longicornis* but about fifty samples would be required to obtain mean densities for the majority of the species recorded. Clearly, such precision will not be required for all surveys; this will depend very much on the objectives of the investigation.

For wider-scale synoptic mapping, mention was made of recent work using the ROXANN sea-bed discrimination system, e.g. off the Scottish west coast. Such surveys are not solely concerned with areas of hard ground, and do not offer scope for detailed mapping of community structure. Nevertheless, the methodology may have some use in the delineation of broad-scale spatial patterns, when accompanied by 'ground-truth' sampling of the sediments and biota.

In shallow rocky areas off the Norwegian coast, echo-sounder surveys have been successfully applied to the identification of kelp forest beds. The methodology can also identify areas affected by trawling, and work is currently in hand to relate the degree of backscatter to kelp forest biomass. Such methodology (and more sophisticated approaches such as multi-beam bathymetry) is more cost-effective than diving since large areas can be covered, but inevitably such an approach cannot discriminate between variation in community type or provide information on the details of kelp forest community structure.

Coarse substrata

A wider array of sampling methods are available for surveys of the benthos of coarse substrata. Experience suggests :

(i) that conventional soft-sediment samplers such as Van Veen or Day grabs will not perform reliably;
(ii) that areas supporting loose aggregates are inherently patchy in nature, and this is reflected in marked variations in the diversity and productivity of associated benthic assemblages, sometimes on scales of a few metres or less. This necessitates careful consideration of the appropriate size of the sampling unit, the distance to be covered in the case of towed gear, and the number of replicates required to adequately characterise a location.

The WG recognised the pressing need for more detailed guidance on sampling methods for coarse substrata. This was partly driven by the need to monitor the effects of commercial aggregate extraction, and it was noted that the UK intended to produce guidelines for sampling in such areas around their coastline in the coming year. It was also important in relation to proposed international collaborative surveys (e.g. under OSPARCOM auspices; ICES North Sea Benthos Survey) covering wide sea areas encompassing coarser as well as finer substrata. As with rocky subtidal areas, it can be argued that in historical terms the relative lack of knowledge of the benthos of coarse substrata is a direct consequence of inherent sampling difficulties.

As noted in the Introduction, our broad definition of coarse substrata implies the co-existence of both an infaunal and epifaunal component, whose relative importance may vary according to the proportion of coarser to finer material and, notably, according to the physical forces (wave action and tidal currents) acting upon them.

In shallow waters, quantitative surveys may be undertaken by divers using hand-held corers or suction-sampling devices for collection of material. Still and video imagery and *in situ* observations may be effective means for assessing the epifauna. Offshore, the Hamon grab (see, e.g., Holme and McIntyre, 1984), originally designed as a geological tool by the Dutch Geological Survey, has proved to be an effective quantitative sampler for the benthos of loose aggregate off the UK and French coasts. An example of recent application can be found in Annex 7. of the 1995 BEWG report (Rees and Kenny). Dr Kenny was currently evaluating a smaller version of the grab, which may prove to be more versatile, since it can be deployed from smaller vessels.

A significant factor to be considered in the collection of gravely samples is the handling of the large quantities of material that arrive on deck. This, along with a consideration of the appropriate mesh size to be used, will need to be addressed in the preparation of detailed guidelines.

Dr Rumohr drew attention to a large device for quantitative sampling of gravels designed by Russian scientists, although the WG had no practical experience of its use and hence was not able to assess its wider potential. Note was also made of the use of a large hydraulic 'clam shell' grab by the marine dredging industry for exploratory sampling of gravels, where there may be scope for sub-sampling, or conceivably construction of a smaller version specifically for benthos use. The problem of retaining gravel in hand-deployed (or even remotely-operated) corers has been addressed experimentally through the use of liquid nitrogen to freeze the enclosed material. **In general, the WG felt that there was significant scope for future innovation with respect to sampling methodology for coarse substrata, and the funding of appropriate research proposals should be encouraged.**

Most existing methods for remote destructive sampling of coarse substrata were qualitative or 'semi-quantitative' in nature. Of these, spot-sampling by means of an Anchor dredge (see Holme and McIntyre, 1984) had proved effective for pioneering surveys of the infauna and epifauna of the English Channel by N. Holme in the 1950s. The device has been used for more recent surveys of regional variation in UK gravel assemblages (see item .. of this WG report) and can still be recommended as a useful tool for exploratory surveys of new areas. French scientists (notably L Cabioch and co-workers) have extensive experience of working gravely substrata off the French coast and in the English Channel. For offshore surveys, towing of the larger, circular Rallier-du-Baty dredge has been used for wide-scale 'semi-quantitative' surveys on rough ground.

There are a number of other towed dredges which may be suitable for (or have the potential to be adapted to) surveys of coarse substrata. In most cases, the appropriate target will be the epifauna, rather than the infauna. Reinforced trawls, such as a 2 or 3-metre beam trawl, have also proved to be useful. Inevitably, a feature of such equipment will be its relative inefficiency and selectivity, and these aspects were the subject of much WG activity in its early years. Further comparative work of this nature, especially in relation to the development of new sampling gear, is to be encouraged.

It is most important that the limitations to the efficiency of towed sampling gear are considered at the outset of an investigation, and weighed up against the aims. For example, qualitative assessment of the biological diversity of offshore coarse substrata may be entirely acceptable using, say, a small trawl with tickler chains which can be relied upon to obtain a representative sample integrated over an appropriate distance. However, estimates of, say, community biomass or production from such samples will be precluded, or at least strongly biased, due to gear selectivity and design, unless a good deal of extra effort is put into calibrating efficiency. For some types of monitoring surveys, relatively low sampler efficiency may be deemed less important, provided that standard approaches to sampling are consistently followed over time. This will extend to standardisation of sampler design, including mesh size and agreement on these issues is required prior to the production of detailed guidelines.

Non-destructive sampling methods for offshore surveys include towed underwater camera sledges and ROVs. Images require skilled interpretation and will benefit from periodic 'ground-truthing' by means of trawl or dredge. Clearly, little insight can be gained into infaunal populations, and the main target will be the conspicuous epifauna. Photographic methods can provide important information on the patchiness of coarse deposits and the associated biota and, at least for certain species, is likely to be the most effective if accurate quantification is sought. Limitations to the routine use of such methodology include variation in water turbidity affecting the clarity of images, which could be a serious problem for regular monitoring programmes.