Marine Habitat Committee **ICES CM 2000/E:08**
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REPORT OF THE

BENTHOS ECOLOGY WORKING GROUP

Walpole, Maine, USA

25–29 April 2000

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1 OPENING OF THE MEETING

The Benthos Ecology Working Group met at the Darling Marine Centre, Walpole, Maine, USA, under the Chairship of Karel Essink. A number of BEWG members sent messages saying that they were unable to attend because of seagoing field work or other urgent obligations.

The meeting began with a tribute to Peter Schwinghamer, presented by Don Gordon. Peter Schwinghamer was an early participant in BEWG, who died from a brain tumour at the age of 52 in May 1999.

A list of participants is appended as Annex 1.

2 APPOINTMENT OF RAPPORTEUR

In keeping with recent tradition, and as local host, Les Watling was elected rapporteur.

3 TERMS OF REFERENCE

ICES C.Res. 1999/2:E:08

The terms of reference for the 2000 meeting of the Benthos Ecology Working Group were to:

a) report on progress in the North Sea Benthos Project;

b) evaluate possible secondary effects on benthos in the Baltic Sea from the dumping of fish offal and fish discards, based on information provided by SGDIB [HELCOM 2000/5]; this will include:

   i) a compilation of available information on benthos community structure and biomass by ICES Sub-area,
   ii) estimates of total consumption rates, and likely fraction of offal/discards in total consumption, by benthos, by ICES Subarea,
   iii) a compilation and mapping of the areas subject to permanent and/or temporary oxygen depletion in the entire Baltic Sea area;

c) report on further developments in computer aids in benthic studies (taxonomic and operational), and discuss problems in the field of quality assurance of taxonomic expertise as related to benthic studies;

d) further provide guidance to ACME on Quality Assurance procedures for benthic studies [OSPAR 2000/1.1] through:

   i) agreeing on a final draft of general guidelines for QA for biological monitoring,
   ii) finalising an extended review of standard operating procedures in use in ICES Member Countries,
   iii) further reviewing QA schemes for benthic studies;

e) continue the preparation of guidelines for sampling and objective description of epibiota (of soft sediments and hard bottom substrates), including QA matters;

f) continue an analysis of the impact of the North Atlantic Oscillations (NAO) and other climatic phenomena on long-term variations of benthic population parameters in different parts of the ICES area;

g) discuss data banking and related QA matters, including data exchange, with the ICES Environmental Data Scientist; this should include final review and approval of the Biological Data Reporting Format and data entry program.

BEWG will report to the ACME before its June 2000 meeting and to the Marine Habitat Committee at the 2000 Annual Science Conference.

4 ADOPTION OF AGENDA

After some small amount of discussion and with the addition of requests from other ICES groups (*viz*. SGMHM, WGFTFB) being addressed, the agenda for the meeting as adopted (see Annex 2).

5 REPORT ON THE 1999 ICES ANNUAL SCIENCE CONFERENCE IN STOCKHOLM, SWEDEN

K. Essink briefly summarised the items of interest to BEWG, and noted that the report was posted on the ICES website (www.ices.dk). H. Rumohr noted that there was little contribution by benthic ecologists to the 1999 ASC.

6 REPORT ON ACME MEETING AND OTHER MEETINGS OF INTEREST

6.1 Advisory Committee on the Marine Environment (ACME)

K. Essink referred to an extract of the ACME report from 1999, and noted that the attention given to benthos was small, but included items that BEWG should consider.

6.2 Report on Workshop on Ecological Quality Objectives

H. Rees reported on a Workshop on Ecological Quality Objectives (EcoQOs) held 1–3 September, 1999 in Scheveningen, the Netherlands, and organised within the framework of the North Sea Conference and the Convention for the Protection of the Marine Environment of the North-east Atlantic (OSPAR). An outcome of the Workshop was the identification of 10 issues relating to ecosystem structure or function appropriate for the development of EcoQOs. These were "reference points for commercial fish species", "threatened or declining species", "sea mammals", "sea birds", "fish communities", "benthic communities", "plankton communities", "habitats", "nutrient budgets and production", and "oxygen consumption". A major feature is the development of an ICES Study Group on Ecosystem Assessment and Monitoring (SGEAM) which will work on ecosystem issues and will have some benthic interests. SGEAM will meet in May 2000.

6.3 Report of the Working Group on Ecosystem Effects of Fishing Activities (WGECO) Meeting

D. Gordon summarised the WGECO meeting at which the IMPACT II report was reviewed. It was suggested that this report would be of strong interest to the BEWG. A peer review of the IMPACT II report, entitled "Effects of different types of fisheries on North Sea and Irish Sea Benthic Ecosystems", has been issued by the Advisory Committee on the Marine Environment to the European Commission.

6.4 Report on Marine Habitat Committee (MHC)

K. Essink and H. Rumohr reported on the MHC meeting held in Stockholm in September 1999. The meeting centred around the justification of the MHC activities in the frame of the ICES Strategic Five-Year Plan and stressed the fact that the scientific basis for the MHC work and ICES advice remains in the Working Groups and should be properly maintained.

6.5 Report on the Study Group on Marine Habitat Mapping (SGMHM)

The SGMHM meeting was held in The Hague, Netherlands, 10–13 April 2000. K. Essink and H. Rumohr reported on the results. One of the SGMHM's Terms of Reference was to:

> "(e) Assess whether and how BEWG should be involved in validating the biotopes already proposed."

For this reason K. Essink joined the meeting of SGMHM for two days. BEWG members H. Rumohr and J.-H. Fosså also attended the SGMHM meeting.

At the meeting, the latest update of the EUNIS habitat classification system was presented by C. Davies from the European Environment Agency (EEA). This system is now fully developed to Level 3, and partially to Level 4. Before going further, EEA wants to have, in the coming 12-month period, as much feedback as possible as to the applicability of the classification. As part of this work, testing in the OSPAR area is envisaged where possible. For feedback purposes the EUNIS classification can be inspected at http://mrw.wallonie.be/dgrn/sibw/EUNIS/home.html.

The SGMHM requested BEWG at its 2000 meeting to give, a first validation of the EUNIS classification in terms of:

1) a check on the proposed classification by comparison based on personal experience with habitats and communities,
2) is the hierarchy logical? Does it make sense?
3) do the criteria used to discriminate between classes make sense?

H. Rumohr noted that he had some problems with the system because it seems to reflect somewhat the old Petersen level-bottom communities. In particular, the temporal variability of the community is not accounted for, and, also, the Baltic benthic communities are not well covered. This is especially true for bottoms with temporary and permanent anoxia.

Another question is whether the classification can deal with anthropogenic alterations to the benthos. There was also much discussion about using typically geological tools, such as multi-beam surveys, to help with biological surveys. Nevertheless, the concern of many present is that most habitat mapping is merely surficial geology with the biological overlay added as an after-thought.

In sum, several comments and concerns about the EUNIS Classification System were compiled and are listed in Annex 3. BEWG agreed that it is reasonable to start the classification with a description of the physical substrate and add the biology at lower levels.

In addition, B. Ball noted the problem with scales of heterogeneity and that large areas of mundane, bland, muddy bottom are missed because they might be assumed to be homogeneous throughout.

Similarly, H. Rees suggested that there is an issue with using biologists only to "ground-truth" what was deemed to be certain habitat types as a result of the geological mapping. He noted that not all gravel bottoms have the same faunal assemblage, and that surficial geology is not necessarily a good predictor of the resident biota. Again, true habitat heterogeneity is not being dealt with, especially at the level of involving biologists early in the work.

S. Smith noted that, as an example of how technology has taken over habitat monitoring, Sweden has now adopted the SPI (sediment profile imaging) camera as its primary monitoring tool for the Swedish west coast. In the Baltic Proper, former stations at coastal habitats have been withdrawn from the national monitoring programme. Thus Sweden will no longer be able to report on any changes in its levels of biodiversity. There was discussion about this issue at last year's meeting, but apparently whatever concerns the BEWG expressed have not been heeded.

H. Rees gave an overview of a study dealing with biotope mapping (by CEFAS) in the eastern English Channel area. Emphasis was placed on the heterogeneity of fauna in "gravel" areas. A summary of this work to date is given in Annex 4.

The ICES Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT) also gave their reaction to the EUNIS system. K. Essink summarised their response. In sum, they suggested leaving biota out of the system until Level 4, and concluded that the basic system conforms to the Wentworth scale.

Finally, the members of the BEWG as well as other researchers are requested to test the applicability of the proposed EUNIS classification in the process of analysing own data sets from field surveys. Individual comments are welcomed by Cynthia Davies of the EEA (E-mail: cd@ceh.ac.uk).

6.6 Working Group on Fishing Technology and Fish Behaviour (WGFTFB)

The Working Group on Fishing Technology and Fish Behaviour (WGFTFB) met in Haarlem, the Netherlands, from 10–14 April 2000. K. Essink took part in this meeting for one day, when the topic of discussion was "Reduction of unintended effects on the seabed and associated communities of fishing operations and gear, including ghost fishing". Part of the work presented focused on seeking adaptations of gear with the aim of minimising physical contact of the net, with the sea floor, apparently without too much attention for the effects of this physical impact on the benthic fauna and flora. Other work was devoted to special provisions of the net, enabling caught infauna and epifauna to return to the seabed without delay. Generally, the greater the efficiency of these "drop out" provisions, the smaller the catch of the target species. Preliminary results with electric beam trawling were promising: higher catches of sole combined with lower by-catch of benthos. Unknown, however, are the possible detrimental effects of the applied electrical field on the benthos. Possibly, there is an imbalance in current research. Much research effort seems to be directed at the reduction of benthos by-catch, whereas in some instances numbers of damaged benthos in trawl tracks outnumber (by factor 5) the benthos caught in the net.

At the Haarlem meeting, a need was felt for further involvement of ecological expertise such as that present in WGECO and BEWG. This might be achieved by organising (1) a joint session of WGFTFB, WGECO, and BEWG, (2) a theme session at the ICES 2001 ASC, or (3) an intersessional workshop with specific tasks to be set. After discussion, it was decided that a proposal will be made to ICES for a theme session at the 2001 ASC having a broad coverage of the subject. The theme session could provisionally be described as "What information does management need from ecologists and gear technologists to assess the effects of fishing and to implement policies?" The conveners for this theme session have to be recruited from WGFTFB, WGECO, and BEWG. K. Essink informed BEWG that he will offer to serve as co-convener on behalf of the BEWG.

B. Ball, who is coordinating the EU REDUCE project, indicated that by 2001 results will be available for presentation. D. Gordon informed the meeting of the Canadian Responsible Fishing programme which, in collaboration with industry, is trying to develop "more environmental friendly" fishing gear. So, contributions to the proposed theme session can be expected.

The BEWG agreed with the general proposal for a theme session at the ICES 2001 Annual Science Conference (Oslo, Norway).

B. Ball gave a short account of the project REDUCE (Reduction of adverse impact of demersal trawls on the benthos) funded by EU FAIR 1998–2000. The project involves attempts to modify beam trawls and other trawls to reduce bottom contact and impacts on the benthos by means of alternative methods of stimulation and changes in gear design, for example, looking at a series of weighted rollers on the foot rope of the otter trawls and drop out panels. Beam trawls, electrical stimulation, water jets, and alternative chain arrangements and drop out panels in the nets are being investigated. The study uses a 4-part approach: (1) literature survey; (2) new gear designs and flume tank studies; (3) sea trials for gear effectiveness in catching fish; and (4) sea trials for effectiveness in reducing benthic by-catch and bottom impact. A number of gears show real promise. Ongoing work with roller gear suggests that there were some changes that could be made to minimise the by-catch of benthos. Between 5 % and 10 % of the total catch was benthic invertebrates and about 40 % was by-catch. The data will be made available soon in a report entitled "Quantitative and qualitative investigation of the benthic invertebrate discarding by Irish Demersal Otter Board Fleet" (report number IR97.MR.007). The study was jointly funded by the EU and the Irish Marine Institute.

D. Gordon made note of a recent report on trawling technology in Canada. K. Gilkinson gave a short report on a fishing industry workshop in St. John's in October 1999 dealing with gear technology (Summary report: "Minimising Sea Bottom Impacts of Trawling Gear"). He made the point that many fishermen are not aware of the problems that gear might cause and that because the seabed is sand and gravel there is not much living there anyway. Demonstrations of trawl gear alterations in a flume tank were also used to show how the impact on the seabed can be lessened. A report was circulated entitled "An assessment of trawling technology in Canada" Both reports are available from Andrew Duthie, Chief Responsible Fishing Operations, Fisheries and Ocean Canada, 200 Kent St., Ottawa, ON K1A 0E6, Canada.

6.7 Proposed ICES Study Group on Biodiversity

Both the Chair and H. Rumohr mentioned the possible existence of an ICES Study Group on Marine Biodiversity, without any concrete further information being available.

After some discussion, the BEWG concluded that it does not see the need for such a group but would rather see a statement of support for increasing taxonomic expertise. Biodiversity is an integral part of BEWG activities and those of other ICES Working/Study Groups.

7 REPORT OF COOPERATIVE STUDIES AND OTHER STUDIES RELEVANT TO ICES

7.1 Methodology

M. Zettler gave a presentation on a study of the application of underwater video for assessment of macrozoobenthic colonisation and habitat structure that was carried out at the Baltic Sea Research Institute in Warnemünde from 1998 to 2000. About 78 sites were visited once or twice, with special emphasis on the Mecklenburg Bight and the Arkona Basin. The presentation included information about the macrozoobenthic monitoring methods that were used, the explanation and application of the video system, as well as some examples of macrozoobenthic species by video. Altogether about 200 species were detected. The results demonstrated the different success of the different methods (van Veen grab, dredge, video) in the determination of macrozoobenthic species. It was recommended that different methods be used in combination for the assessment of macrozoobenthic colonisation. (See Annex 5.)

7.2 Long-Term Benthic Studies

J. Warzocha reported on the results of the long-term data analysis in the southern Baltic Sea. In the shallow zone, the observed changes of macrozoobenthos abundance and biomass were caused mainly by *Marenzelleria* cf. *viridis*. This species has become dominant in some regions (e.g., Pomeranian Bay and Gulf of Gdansk), now occurring in densities of 2000 ind. m^{-2} and biomasses exceeding 150 g m^{-2}.

7.3 Monitoring Programmes

S. Smith gave an overview of a regional monitoring programme in the Baltic Proper. Results from the subprogramme on macrozoobenthos in the county of Kalmar for 1999 were reviewed as follows: (1) a species list containing 54 taxa (a sum of 72 during 1995–1999), (2) abundance, and (3) biomass for all 65 sampling stations.

Long-term changes in the biomass of the dominant *Macoma balthica* showed an increase from 1989–1999 in the southern part and a decrease in the middle part. In the northern part the means of the biomass of this species increased again after a decrease from 1991–1996. In the middle part of the county, where a pulp mill is located, the declining biomasses in later years (from 1996 onwards) seemed to be linked to a recruitment failure. In 8 out of 10 stations in the vicinity of the pulp mill the reduction was 50 % or more. In two cases the whole population was wiped out. This could possibly be attributed to drifting algal mats as abundances also dropped dramatically. According to long-term oxygen measurements, though, low concentrations never occurred on these transport bottoms with a minerogenic sediment. Generally, the number of juveniles (1–4 mm) decreased 1–2 years before the crash in abundance and biomass of *Macoma* and the demography changed quickly to only big, old specimens i.e., a high mean weight per individual. This was correlated to low numbers of juveniles, but in some cases high juvenile numbers were observed at the time of the crash.

Only in localities below 20 m did the abundance of *Monoporeia affinis* peak in a cyclic manner every seventh year, as has been demonstrated by Andersin *et al*. Stable and high populations were found in connection with salmon farms. The oligochaetes and chironomids reacted with enormous numbers to a maximum in land run-off in 1998. The neozoon *Marenzelleria* cf. *viridis* was first observed in this county in 1994 and has since advanced north and had established itself in the northernmost locality in 1998.

7.4 Coral Reefs and Epifauna

L. Watling gave a short summary of a study examining the differences in the epibiota of boulders in an area of the Gulf of Maine subject to rock-hopper gear relative to an area that does not seem to have ever been fished. There was a clear reduction, by up to 50 % of the number of species, in the epibiota in the trawled area.

D. Gordon made reference to a Symposium on Deep-Water Corals to be held in Halifax this year (see Section 15.1).

7.5 Effects of Dumping and Aggregate Extraction

H. Rees presented a summary of an ongoing sampling project in an area of aggregate extraction along the southern English coast which, in 1999, sought to address the relationship between dredging intensity and the effects on benthic communities. This report is appended as Annex 6

M. de Kluijver reported on the effects of dumping activities on the macrobenthos at a dumpsite off the Dutch coast. During the last BEWG meeting in Sweden, it was reported that at borders of dumpsites off the Swedish and Belgium coasts, more species were found in larger abundances. During surveys in the years 1995–1999, it seemed that the same occurred at the Dutch dumpsite. Stations, outside the direct influence of dumping activities itself, showed higher silt contents in the bottom sediments, and more species and larger numbers per box-core, as compared to the reference stations.

7.6 Effects of Mobile Fishing Gear

D. Gordon gave a brief overview of the experiments being carried out by the Department of Fisheries and Oceans (DFO) on the effects of mobile fishing gear on benthic habitat and communities. These experiments have involved a large number of scientists, including numerous European colleagues. Data analysis of the three-year Grand Banks otter trawling experiment (1993–1995) is nearing completion. Papers describing the effects on habitat and epibenthic communities of this sandy bottom ecosystem have already been published. Effects on infauna as sampled by the DFO videograb appear to be minor. The major feature of this database is the significant natural variation in reference samples. Effects on molluscs also appear to be minor. These new results should be published in the near future.

A three-year otter trawling experiment (1997–1999) was recently completed on a gravel bottom ecosystem on the Western Bank. Experimental design and some preliminary results were presented. Visual signs of disturbance are quite limited but side-scan sonar indicates that door tracks are still discernible after one year. This database will be processed by E. Kenchington (Bedford Institute of Oceanography-BIO).

A three-year hydraulic clam dredging experiment (1998–2000) is currently being conducted on Banquereau in collaboration with industry. Experimental design and some preliminary results were presented. This database will be processed by K. Gilkinson.

Preliminary results were presented on the analysis of the spatial distribution of otter trawling effort off Newfoundland being conducted under the lead of D. Kulka (BIO). Effort is very patchy in distribution. Large areas of the seabed appear to be unaffected by trawling while other areas are heavily trawled year after year. Plans are under way to expand this spatial analysis of fishing effort in Canada to include other gear types and geographic regions.

K. Essink gave an overview of a broad ongoing study in the Dutch Wadden Sea investigating the effects of hydraulic dredging of cockles (*Cerastoderma edule*) and of fishing of young mussels (*Mytilus edulis*) for seeding sublittoral culture lots. This study is intended to enable the responsible minister to make decisions in 2003 regarding the extent and practice of the mechanical shellfish fisheries in relation to nature management purposes in the Dutch Wadden Sea (see Annex 7.

7.7 North Sea Benthos Studies

P. Kingston informed the meeting of a new benthic survey of the Firth of Forth in Scotland. The survey is supported by the Scottish Environmental Protection Agency, the National Museum of Scotland, East of Scotland Water Authority, and BP Amoco and exactly repeats a survey of the area carried out in 1976. The aim of the project is to relate long-term changes in the distribution and abundance of benthic species and communities with relation to changes in the use of the Firth of Forth over the 24 years and to provide information for the future management of marine resources in the area. 72 stations were sampled in February and March from the Forth Bridge to the Isle of May at similar positions and using similar methods to those used in 1976. The project is expected to be completed by the summer of 2002.

7.8 Benthos Studies in the North and Northwest Atlantic

D. Gordon gave a brief overview of recent benthic studies in eastern Canada, with emphasis on activities being carried by the Department of Fisheries and Oceans at the Bedford Institute of Oceanography. There has been a substantial reduction in overall scientific effort during the past five years because of financial cutbacks and many staff have taken early retirement. However, this period of downsizing seems to be over. There seems to be a much better appreciation of the importance of benthic processes in marine ecosystems and the need to expand our understanding of them. The new Canada Ocean Act provides the opportunity and responsibility for expanded ocean management, which will require new benthic information for successful implementation. Several new benthic initiatives are currently under way.

The expanding oil and gas industry off Atlantic Canada has led to research on the effects of particulate drilling wastes on benthic organisms, with emphasis on sea scallops. Extensive laboratory experiments have been carried out on the effects of different drilling muds (and their components) on the feeding, growth, and reproduction of adult sea scallops. These results have been used to interpret the output of numerical models, which predict the concentrations of drilling mud in the benthic boundary layer around potential exploration drilling sites on Georges Bank. Considerable effort is also being given to developing shellfish moorings (using sea scallop, Iceland scallop and mussels) which can be used to monitor the effects of wastes released from offshore exploration and production platforms. These are currently being tested at the Hibernia oil field off Newfoundland. Environmental effects monitoring programmes have been established at the four offshore development sites (CoPan, Sable Island gas, Hibernia, and Terra Nova). These are funded by industry and conducted by environmental consulting companies. Some, but not all, include monitoring of benthic communities. A workshop was recently held at BIO, which reviewed these monitoring programmes and the supporting research.

A long-term programme to map the benthic habitat within the entire Canadian Exclusive Economic Zone has been proposed (called SEAMAP). A concept paper has been prepared by Natural Resources Canada, the Department of Fisheries and Oceans and the Department of National Defense, and has been well received. Funding is in place to develop a more detailed proposal over the next few months for new funding from the federal government. The proposed multidisciplinary programme, to be conducted in collaboration with industry and university partners, will build upon existing Canadian technology and expertise and include multibeam, geological, and biological surveys. New methodology will be needed to classify and map benthic habitats on the basis of biological communities.

There is currently considerable interest in deep-sea corals in Atlantic Canada, as in other areas around the North Atlantic. Much of this interest is driven by environmental organisations and concern about the potential effects of oil and gas as well as fishing activities. As resources allow, video and photographic information is being collected on coral identification, abundance, and habitat preference in areas reported to support significant communities (i.e., the Gully and Northeast Channel). An international conference on deep-sea corals will be held in Halifax this summer from 30 July–2 August 2000 (http://home.istar.ca/~eac-hfx/symposium/).

A recent workshop was held at BIO to plan the Canadian contribution to the international LMR-GOOS programme. The need to carry out the proposed SEAMAP programme to map benthic habitat was stressed. In addition, a proposal was put forth to include a number of long-term benthic monitoring stations to measure natural temporal changes in benthic communities.

Complimentary copies of the new DFO CD-ROM virtual tour of the ecosystem of Sable Gully, a large submarine canyon southeast of Nova Scotia, were distributed. This includes photographs and video footings of benthic organisms.

7.9 Benthos Studies in Southern Europe

H. Rumohr reported on Cretan-German cooperation, which has included: (1) the transfer of SPI-related techniques to Crete; (2) application of a new ROV down to 2000 m depth; and (3) investigation of otter trawling on benthos at depths of about 170 m.

7.10 Alien Species

K. Essink noted that this topic was dealt with at the WGITMO and NEMOS meetings held 27–29 March 2000, at Parnu, Estonia, and that there will a Theme Session on this topic at the 2000 ASC in Bruges, Belgium.

8 NORTH SEA BENTHOS PROJECT

Owing to the lack of success in attracting direct funding for the North Sea Benthos Survey, it was decided to seek another route to achieve the objectives of the BEWG by taking advantage of national benthic monitoring programmes and other nationally funded benthos projects. Several such projects were identified that appeared to cover the geographical area of interest. These include:

- German Bight/Dogger Bank (Eike Rachor/ Ingrid Kröncke, 2000);
- CEFAS surveys—east coast of England (Hubert Rees, 2000);
- Dutch monitoring programme on Dutch Continental Shelf (Karel Essink, 2000/2001);
- Dutch Frisian Front survey (Gerard Duineveld, 1999);
- French sampling of eastern English Channel (Jean-Marie Dewarumez, 2000);
- UKOOA survey of central and northern North Sea (Paul Kingston, 2001).

A significant part of the North Sea will be covered by these planned and ongoing surveys. Although none of these individual surveys will give a complete overview of the distribution of North Sea benthos, coordination of the various surveys and collective analysis of the data will provide significant added value to the information. This should enable us to achieve the original objectives of the proposed ICES North Sea Benthos Survey without the advantage of direct funding.

To achieve these aims, it will be necessary to establish an effective means of liaising between the various institutions carrying out the work and to explore ways in which gaps in the coverage of the originally proposed sampling grid may be filled. The first step will be to call a meeting of participants to determine how the individual national sampling programmes can be integrated to form an approach that would be consistent with the objectives of the North Sea Benthos Survey. This will take place in Wilhelmshaven in May during the North Sea 2000 conference and will:

1) address how the individual sampling surveys may be integrated and standardised;
2) explore ways in which extra samples may be taken and analysed to fill any gaps in the 1986 grid;
3) determine how the individual data sets will be collated and analysed;
4) define the end product based on the resources identified;
5) decide whether or not this approach is feasible and whether the BEWG should proceed along these lines.

If it is decided to proceed, a second meeting will be convened in September 2000 to:

1) review progress of the national programmes;
2) identify remaining gaps, if any, in the sampling coverage and agree on how to approach the missing information;
3) allocate tasks and agree on a time scale regarding the treatment and analysis of data collected.

The timing of the third meeting will be dependent on the progress of the sampling programme and the time scale agreed upon, but will be targeted for the 2001 BEWG meeting in Wimereux. The purpose of this meeting will be to:

1) collate and carry out preliminary analysis of the data, provided that sufficient data are available;
2) make provisions for the collation and analysis of data obtained in 2001;
3) decide on how the data will be presented;
4) agree on a time scale for the production of the final report to ICES and publication of the results in the *ICES Journal of Marine Science*.

9 EFFECTS ON BENTHOS IN THE BALTIC SEA FROM DUMPING OF FISH DISCARDS AND FISH OFFAL

A subgroup discussed matters about possible impacts of discarded fish and offal on the benthic system of the Baltic Sea. The discussions were based on (1) the Report of the Study Group on Estimation of the Annual amount of Discards and Fish Offal in the Baltic Sea (SGDIB, February 2000), (2) an abstract provided by the Chair of BEWG, (3) the NIOZ Rapport 1993–8 on “Seabirds feeding on discards in winter in the North Sea”, and (4) HELCOM Baltic Sea Environment Proceedings No. 64B.

The subgroup came to the following conclusions:

a) with regard to the terms of reference, fishery Sub-divisions 21 and 23 can be disregarded since they belong rather to the fully marine Kattegat/Skagerrak area than to the benthos-impoverished Baltic Proper;
b) a compilation of available information on benthos community structure and biomass by ICES Sub-divisions can be done based on available data including seasonal and interannual variability; however, funding must be provided since this is beyond the scope of the BEWG;
c) estimates of total consumption rates and likely fraction of offal/discards in total consumption by benthos by ICES Sub-divisions should be divided according to various water depths such as 0–20 m, > 20 m, and anoxic basins because of the different benthic communities present. (Research needs have been identified that will be specified below);
d) a compilation and mapping of the areas subject to permanent and/or temporary oxygen depletion in the entire Baltic Sea area can rely on Finnish data and published products as well as HELCOM data and information from the World Wide Web. They need to be compiled by an outside contractor and be based on a comprehensive literature study (see b);
e) the whole complex of seabird predation and feeding on discarded fish and offal will be dealt with in a separate Working Group under the Chair of St. Garthe from Kiel University. Seabirds were regarded as most effective in the removal of discards and offal.

To answer the question in the ToR for the present BEWG meeting, the following topics need to be addressed:

a) since the Baltic is like an estuarine gradient, the problems have to be tackled on a regional scale following the ICES Sub-divisions;
b) which potential scavengers exist in each area and depth zone (Decapods, *Saduria*, *Asterias*, Polychaetes, gammarids, Isopods, fishes, sea mammals (?));
c) what is their depth distribution (e.g., *Carcinus*);
d) feeding guilds of benthic species (including consumption rates) need to be investigated;
e) aerobic and anaerobic decomposition processes (cost versus benefit for the ecosystem, O_2, and nutrient recycling);
f) video inspections for discarded material on frequently fishing grounds;
g) survival rates of discarded fish and benthos species (see also the IMPACT II report).

BEWG offers its expertise to evaluate reports by contracted experts and by the Baltic Seabird Working Group.

10 DEVELOPMENTS IN COMPUTER AIDS IN BENTHIC STUDIES AND QUALITY ASSURANCE OF TAXONOMIC EXPERTISE

Mario de Kluijver reported on the progress of the ETI CD-ROMs for the identification of macrobenthic species of the North Sea. This project was initiated by ETI and the Zoological Museum at the University of Amsterdam. It provides users with a complete and up-to-date catalogue of macrobenthic species, including reliable standardised identification guides. In a series of five CD-ROMs the biological diversity in shallow-water macrobenthos of the North Sea (down to 100 m) is documented. In two other CD-ROMs, the zooplankton and phytoplankton will be dealt with.

The CD-ROMs will have a hybrid format, so they can be used on both PC and a Macintosh.

Volume I of this series contains detailed information on 525 species of Mollusca and Brachiopoda, including fully illustrated computer-assisted picture keys, glossaries of terms used, and interactive distribution maps. This CD-ROM is in a final test phase and is expected to be released early this summer.

Volume II of this series contains information on 644 species of Polychaeta, Nemertina, Sipuncula, and Platyhelminthes. For the Polychaeta a “text key” and “Identify It” to the family level are provided, with links to the picture key that leads to species level.

Volume III will handle the Crustacea and Pycnogonida and is expected to be released at the end of this year.

Volumes IV (macroalgae) and V (Cnidaria, Ectoprocts, Phoronida, Echinodermata, Tunicata, Porifera, and miscellaneous groups) are scheduled for 2001.

K. Essink informed the meeting of the development of a computer-based identification aid for epibenthos at CEFAS, Swansea (Contact person: Ruth Zuehlke). This is aimed at inexperienced biologists, helping them to identify the major groups and taxa on-board ship. The preliminary version holds no more than 120 species, and still contains many mistakes in the text.

K. Essink also received information on operational computer aids for benthic field work and laboratory analysis of video images (non-taxonomic!) at CSIRO, Australia. (Contact person: Roland Pitcher).

11 ADVICE ON QUALITY ASSURANCE PROCEDURES FOR BENTHOS STUDIES

H. Rees gave a summary of the February 2000 report of the ICES/OSPAR Steering Group on Quality Assurance of Biological Measurements related to Eutrophication Effects (SGQAE). He drew BEWG’s attention to the General Guidelines on Quality Assurance for Biological Monitoring which was included as Annex 7 in the SGQAE report and stated that comments on these guidelines are welcome amd should be sent to him as soon as possible. It is expected that a final draft will be submitted to the BEWG for final review at its 2001 meeting. In discussion, emphasis was again placed on the importance of working to Standard Operating Procedures (SOPs) or comparable documentation, which involves written descriptions of field sampling and laboratory analytical routines followed by the individual laboratories. This provides an important means of ensuring consistency and continuity of approaches over time, thereby contributing to the production of data of sound quality, which is especially critical in the context of collaborative studies.

H. Rumohr reported on the progress of the EU BEQUALM project on Quality Assurance in Biological Effects Measurements. This project will run until 2001, and covers, inter alia, soft bottom benthos. Milestones in this project are:

i) a taxonomic workshop held in Hamburg in February 2000 with 20 participants—the workshop focused on various crustacean taxa, oligochaetes, Acari;

ii) a ring test with pre-sorted samples from the southern North Sea. The deadline for submission of the results is the end of April 2000.

It was stressed that the well-functioning quality control system of benthos analysis, *inter alia*, ring tests in the UK is of great value to Quality Assurance in benthic measurements. This example merits to be followed more widely!

12 GUIDELINES FOR SAMPLING AND DESCRIPTION OF EPIBIOTA, INCLUDING QA

A subgroup of BEWG members was formed to take forward this work (B. Ball, M. de Kluijver, K. Gilkinson, D. Gordon, H. Rumohr, and L. Watling with H. Rees undertaking the editorial role). It was agreed that the aim should be the production of a report, aimed at a wide readership, in the *ICES Techniques in Marine Environmental Sciences* (TIMES) series. It was also agreed that, in order to maintain continuity with earlier TIMES reports dealing with benthic sampling methods and to ensure that the output is of manageable size, the subject matter will be confined to the subtidal zone. Progress was made in further developing a structure for this account and in generating an initial text. The revised structure is given in Annex 8, together with the initials of subgroup members responsible for specific topics. Further work will be conducted intersessionally, including contact with possible contributors who were not in attendance at the 2000 BEWG meeting. A more complete draft will be submitted to the 2001 BEWG meeting for review.

13 FURTHER ANALYSIS OF THE IMPACT OF THE NORTH ATLANTIC OSCILLATION (NAO) ON BENTHIC POPULATION PARAMETERS

Due to the unforeseen absence of A. Laine (Finland) and B. Tunberg (Sweden) there were no presentations on NAO-related studies in the Baltic Sea and Kattegat area. Attention was drawn by the Chair to a recent paper by Zorita and Laine (2000) on the dependence of salinity and oxygen conditions in the Baltic Sea on large-scale atmospheric circulation (Climate Research, 14: 25–41). M. Zettler stated that in the Baltic Sea the relationship between benthos and the NAO-phenomenon is generally weak due to (a) abiotic conditions often fluctuating on a shorter time scale, and (b) local conditions (e.g., anthropogenic influences) being of greater importance. S. Smith referred to recent findings by B. Tunberg, who recorded in 1999 the lowest benthic biomass ever along the Swedish west coast. This coincided with complaints of fishermen on low catches and poor condition of cod. This minimum in benthos fits into the relationship pattern reported earlier by Tunberg and Nelson (MEPS, 17 (1998): 85–94).

In her report on the benthos monitoring programme in the Swedish Kalmar area (see Section 7.3), S. Smith reported regionally different developments, e.g., poor recruitment of *Macoma balthica* in the mid-Kalmar area in 1996–1998. This suggests that local causal factors are at work rather than large-scale processes such as NAO. In the amphipod *Monoporeia,* a 7–8 year cycle in abundance was observed, however, only at some deeper monitoring stations. This possibly points towards hydrographic variation, which may be related to atmospheric circulation.

I. Kröncke and G. Wieking submitted a document giving an overview of long-term studies on benthos in the North Sea and the Wadden Sea (Annex 9). From data available it appears that population dynamics of benthic organisms in the North Sea and/or the Wadden Sea are regulated by a complex of factors. The role of NAO-related changes in the abiotic environment (e.g., cold winters) will be rather site-specific and dependent on the species composition of the benthic communities.

Finally, a general picture emerged that, going from more open and larger marine systems (North Atlantic, North Sea) towards more enclosed and less dynamic systems (e.g., Baltic Sea), there generally is a decreasing influence of NAO-related abiotic forcing and an increasing importance of local factors.

14 DATA BANKING, RELATED QA MATTERS, REVIEW OF BIOLOGICAL DATA REPORTING FORMAT AND DATA ENTRY PROGRAM

J. Nørrevang Jensen reported on the development of the ICES Environmental Database for biological community data. It was emphasised that, in principle, the distributed draft of the reporting format (see ICES CM 2000/E:08/Add.1) should be more or less final by the approval of the joint meeting of SGQAE and SGQAB in February this year. However, since BEWG, in fact, was prevented from commenting on this format until now, BEWG was asked to comment on the format during this meeting or by within the next week or so. The possibility of reporting data in a specific Excel format will be supported in future.

BEWG was asked to consider the development of relevant data products from the biological community database in future. It should be emphasised that the development and improvement of an operational database is dependent on continuous feedback from the respective users and experts, e.g., BEWG.

The experience gained within the coming year with the reporting format for biological community data will be reported and discussed at the 2001 meeting of BEWG in France.

P. Kingston updated BEWG on the three-phase project, funded by the United Kingdom Offshore Operators Association (UKOOA), to locate and catalogue, construct a database, and analyse the data from all the pre-operational and monitoring reports produced in connection with the UK offshore oil and gas exploration since operations started in the 1970s. Phase 1 of the project was completed last year. Phase 2, which was to produce a database of all chemical and biological data contained in the reports, is now complete and available on CD-ROM. The information is provided in a series of database tables (d-base 7 and d-base 5) which may be downloaded from the CD-ROM into Excel, Access, and other database systems. A simple search program (UK Benthos) is also provided on the disk to enable perusal of the database contents without the need for specialised software. Phase 3 of the project involves a detailed analysis of the data and is currently under way. The work should be completed by the end of July 2000 when the results will be published.

15 ANY OTHER BUSINESS

15.1 Future Meetings of Interest to BEWG and ICES

Forthcoming meetings of interest to members of BEWG are:

1) Baltic Sea Science Congress, Stockholm, 25–29 November 2000;
2) First International Symposium on Deep-Sea Corals, 30 July–2 August 2000, Halifax, Nova Scotia, Canada;
3) ICES 2000 Annual Science Conference, Bruges, Belgium, 27–30 September 2000.

It was anticipated that BEWG will be asked for advice by OSPAR regarding the topic of Ecological Quality Objectives (EcoQOs). BEWG is prepared to offer its expertise and is waiting requests through the usual ICES channels.

Some discussion was devoted to the factors determining poorer versus better participation in BEWG meetings. It was recognised that, for some benthic ecologists, sea-going work in spring may interfere with attendance at BEWG meetings. However, no serious problems were identified. It was concluded that potential participants must be informed about the dates of the next meeting well in advance, to be confirmed after the official fixing of dates must be by ICES in September.

L. Watling raised the question of the necessity of participation of geochemists in the BEWG. This expertise was judged valuable so as to be able to address questions on nutrient regeneration within the benthic system as such, and as influenced by various anthropogenic interferences, e.g., bottom trawling. It was agreed that K. Essink will inquire whether this subject is already covered by the Marine Chemistry Working Group (MCWG).

15.2 Participation in BEWG

K. Essink brought to the attention of BEWG that several colleagues had to cancel their intended participation due to fieldwork being scheduled in the same time period. He proposed that earlier dates for the 2001 BEWG meeting be considered to overcome this problem. Among the members of the BEWG, however, there was no agreement on having an earlier timing as being the solution to certain colleagues not showing up. An early announcement by the Chair to all potential participants in the BEWG, well in advance of the official resolutions by the ICES Council, was strongly advocated.

16 REPORT OF THE MEETING

16.1 Executive Summary

The Benthos Ecology Working Group (BEWG) met at Walpole, Maine, USA from 25–29 April 2000. There were 16 delegates, representing Canada, USA, Ireland, the UK, the Netherlands, Germany, Poland, Sweden, and ICES.

Marine Habitat Mapping

The major contribution from BEWG to the work of SGMHM was to comment on the structure and likely applicability of the proposed EUNIS habitat classification system, which is being developed at the request of the European Environment Agency. Comments related among others to inconsistencies in the hierarchy within the system, inconsistencies in the use of abiotic and biotic criteria as discriminators between habitat classes.

Effects of fishing gear on benthos

One of the major topics for the WGFTFB is the reduction of unintended effects on the seabed and associated communities of fishing operations and gear, including ghost fishing. Preliminary results from the EU project REDUCE and from related Canadian research projects indicate different options for reducing the impact on marine benthos. Members of the BEWG participated in the 2000 meeting of WGFTFB. Between the WGFTFB, BEWG, and WGECO agreement was reached on a proposal for co-organising a Theme Session on this subject at the 2001 Annual Science Conference, in which many results from the REDUCE project and the Canadian projects can be presented.

North Sea Benthos Survey

Although the BEWG has been unsuccessful in attracting direct funding for a renewed North Sea Benthos Survey, a similar, though limited approach, was agreed upon. This entails the integration of several independent national benthos surveys in the North Sea, ongoing and planned. These national surveys include the German Bight and Dogger Bank area, the Dutch Continental Shelf, the eastern English Channel and southernmost part of the North Sea, and English and Scottish waters. A series of meetings for participating institutes was planned, the first one being in May at Wilhelmshaven on the occasion of the North Sea 2000 Symposium. At this meeting, agreement was reached on tuning of the methods and on common goals. Progress will be reported at the 2001 meeting of the BEWG in Wimereux, France.

Effects on benthos in the Baltic Sea from dumping of fish offal and fish discards

At the request of HELCOM BEWG gave a first evaluation of the possible secondary effects on benthos in the Baltic Sea from the dumping of fish offal and fish discards, based on information on the amounts and geographical distribution of fish discards and offal in 1998 that was compiled by the Study Group on Estimation of the Annual Amount of Discards and Fish Offal in the Baltic Sea (SGDIB). BEWG came to the conclusion that additional information will be needed. This includes information on benthic community structure and biomass per *ICES fishery area*, estimates of fractions of offal and discards reaching the benthic system in various water depth strata (0–20 m, > 20 m, anoxic basins), and an estimate of sea surface and water column consumption of offal and discards by seabirds and fish. With respect to the fate and effect of discards and offal on the benthic system, BEWG indicated that potential consumers and scavengers (e.g., Decapods, Gammarids, Isopods, fish) need to be identified for each ICES Sub-division depth-zone, as well as feeding guilds and consumption rates of benthic species. Also aerobic and anaerobic decomposition processes need to be investigated. Additional insight can be obtained from video inspections for discarded material in frequently fished grounds, and survival rates of fish and benthos among the discards.

Computer aids in benthos studies

Significant progress was made by the Expert-centre for Taxonomic Identification (ETI, Amsterdam) in producing CD-ROMs (for PC and Macintosh) of the macrobenthos of the North Sea. Volume I (Mollusca, Brachiopoda) will be released in early summer 2000; Volumes II (Polychaeta, Nemertina, Sipuncula, Platyhelminthes) and III (Crustacea, Pycnogonida) will be ready later in 2000; Volumes IV (macro-algae) and V (Cnidaria, Ectoprocts, Phoronidae, Echinodermata, Tunicata, Porifera and miscellaneous groups) are scheduled for 2001.

For epibenthos of the North Sea, a computer-based identification aid is being developed at CEFAS, Swansea. This is aimed at inexperienced biologists, helping them to identify major groups and taxa on-board ship.

Quality assurance for benthos studies

In comparison with marine chemistry, development of quality assurance (QA) in marine benthos studies lies well behind. However, a well-functioning ring test procedure in the UK, and a first one held in Germany this year are great steps forward, as are taxonomic workshops like those organised in Copenhagen (1999) and Hamburg (2000). Members of the BEWG play a leading role in these activities.

BEWG has contributed to the formulation and documentation of "General Guidelines on Quality Assurance for Biological Monitoring". This was a request from the ICES/OSPAR Steering Group on Quality Assurance of Biological Measurements related to Eutrophication Effects (SGQAE).

Guidelines for sampling and description of epibenthos

The BEWG will produce a report for publication in the *ICES Techniques in Marine Environmental Sciences* (TIMES) series on sampling and community description of subtidal epibiota, including quality assurance. A revised report structure and allotment of tasks was agreed upon. During the BEWG meeting, an initial text was produced. This work will be continued intersessionally.

Impact of North Atlantic Oscillation (NAO) on benthic population parameters

There is continuing attention for climatic phenomena such as the NAO as the cause of long-term variability in pelagic as well as in benthic systems. From ongoing studies in the Baltic Sea, Kattegat, North Sea, and Wadden Sea, the general picture has emerged that, going from more open and larger marine systems (North Atlantic, North Sea) towards more enclosed and less dynamic systems (e.g., Baltic Sea), there generally is a decreasing influence of NAO-related abiotic forcing and an increasing importance of local factors.

Data banking

The draft reporting format for biological community data for the ICES Environmental Database was presented to the BEWG. Comments from BEWG members may lead to minor adjustments after which final approval will be asked from SGQAE and SGQAB.

An extensive catalogue and database has become available through the United Kingdom Offshore Operators Association (UKOOA) with data from all pre-operational and monitoring reports produced in connection with UK offshore oil and gas exploration since the 1970s.

16.2 Action List

1) Jan Helge Fosså to report on further results on deep-water *Lophelia* reefs in Norwegian waters.
2) Jan Helge Fosså to report on the development of an acoustical method for biomass estimation of kelp.
3) Gerard Duineveld to report on the effect of climate change on bivalve growth.
4) Gerard Duineveld and Brian Ball to report on the REDUCE project on selectivity of fishing gears in relation to their effects on benthos.
5) Sigmar Steingrimsson to report on further results from the BIOICE project.
6) Ingrid Kröncke to report on further results of benthos studies at the Dogger Bank.
7) Ingrid Kröncke to report on results of the epifauna biodiversity studies in the North Sea using bottom trawls.
8) Mario de Kluijver to report on progress regarding CD-ROM for the identification of macrobenthos of the North Sea.
9) Stefan Nehring to present first results of the new macrozoobenthos monitoring programme in German North Sea estuaries.

10) Stefan Nehring to present macrozoobenthos studies at dredge spoil dumpsites in German North Sea estuaries.
11) Sigmar Steingrimsson to report on results of experimental studies on the effects of otter trawling on benthos.
12) Johan Craeymeersch to report on shellfish surveys in coastal waters.
13) Heye Rumohr to report on results of the BEQUALM macrobenthos ring test.
14) Ashley Rowden to report on progress in studies on small-scale distributions of benthic invertebrates.
15) Doris Schiedek to report on progress in research on *Marenzelleria* spp.
16) Portuguese member(s) to report on new developments in Portuguese benthos research.
17) Spanish member to report on new developments in Spanish benthos research.
18) Hans Hillewaert to report on long-term effects of dredge spoil dumping on macrofauna.
19) Tasso Eleftheriou/Chris Smith to report on benthic studies in the Mediterranean Sea.
20) Hubert Rees to report on UK benthic studies at waste disposal and aggregate extraction sites.
21) Ann-Britt Andersin to report on the Finnish monitoring programme including the quality assurance system.
22) Ann-Britt Andersin/Ari Laine to report on the importance of NAO for the salinity and oxygen conditions in the Baltic Sea.
23) Brian Todd to report on further developments in non-traditional benthic habitat mapping.
24) Don Gordon to report on further results of mobile fishing gear experiments.
25) Heye Rumohr to report on first results regarding effects of *Spisula* dredging near Amrum.
26) Hubert Rees to present results of a review of UK SOPs.
27) Members to submit comments on draft guidelines for studying the benthos to Hubert Rees by December 2000.
28) Johan Craeymeersch to report on impact of shellfish fisheries on benthos.
29) Hans Kautsky to further report on the Swedish phytobenthos monitoring programme and related QA matters.
30) Jan Warzocha to report on further results of long-term data analysis in the southern Baltic.
31) Gerard Duineveld to report on OMEX-II studies at the Iberian continental margin.
32) David Connor to report on Internet database developments for MERMAID and MarLIN.
33) Jean-Marie Dewarumez to report on recruitment processes in the Southern Bight of the North Sea as an explanation of long-term variability of communities, e.g., *Abra alba* community.
34) Jean-Marie Dewarumez to report on the project “Rationaliser les connaissances pour préserver durablement le patrimoine naturel littoral (LITEAU)”.
35) Björn Tunberg to report on the long-term oscillations of the infaunal communities along the Swedish west coast.
36) Björn Tunberg to report on the project “Benthic community dynamics under various wetland management scenarios, Merritt Island National Wildlife Refuge, Florida”.

16.3 Recommendations

The Benthos Ecology Working Group (BEWG) recommended that it meet in Wimereux, France, from 18–21 April 2001 to:

a) finalize guidance to ACME on Quality Assurance procedures for benthic studies;
b) further evaluate possible secondary effects on benthos in the Baltic Sea from the dumping of fish offal and fish discards based on additional information to be provided by:
    i) the Working Group on Seabird Ecology (WGSE),
    ii) studies as recommended by BEWG from its 2000 meeting;
c) report on progress in the integration of national benthos surveys in the North Sea in relation to the ICES North Sea Benthos Survey;
d) review the benthic results of the EU REDUCE project;
e) review the significance of invertebrate discards in demersal fisheries over the ICES area;
f) produce guidelines for epibenthos sampling and community description for publication in the ICES TIMES series;
g) provide guidance to habitat mapping and habitat of benthic communities.

Justifications

a) This information is required by ACME to contribute to ICES/OSPAR and ICES/HELCOM working groups.
b) This item is required by HELCOM.
c) The BEWG is the forum for the organisation of the ICES North Sea Benthos Survey.
d) The expertise represented in the BEWG is most appropriate to evaluate the effectiveness of the REDUCE project with respect to the benthos.
e) Identify sources and extent of information on invertebrate discards for use in fishery management and ecosystem conservation.
f) These guidelines will form the basis of a new TIMES report to be published by ICES.
g) Requested by the Study Group on Marine Habitat Mapping (SGMHM).

17 DATE AND PLACE OF THE NEXT MEETING

The offer by J.-M. Duwaremez to host the 2001 meeting of the BEWG in Wimereux, France, was gladly accepted. The dates were set at 17–20 April 2000 (the week after Easter). This was confirmed by J.-M. Duwaremez after the meeting.

18 CLOSING OF THE MEETING

K. Essink formally closed the meeting on 28 April at 16.00 hours, and expressed his sincere thanks and appreciation to L. Watling and the staff of the Darling Marine Centre for the excellent local arrangements. The informal and extremely enjoyable closing of the meeting took place with a lobster bake at the bank of the Damariscotta River.

ANNEX 1: LIST OF PARTICIPANTS

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ANNEX 2: AGENDA

1) Opening and local organisation
2) Appointment of rapporteur
3) Terms of Reference
4) Adoption of Agenda
5) Report on ICES Annual Science Conference, Stockholm, Sweden
6) Report on meeting of ACME, and other meetings of interest
7) Report on cooperative studies and other studies relevant to ICES
   (including Action List of 1999 BEWG meeting)
8) North Sea Benthos Project [ToR: a]
9) Effects on benthos in the Baltic Sea from dumping of fish discards and fish offal
   [ToR: b]
10) Developments in computer aids in benthic studies and Quality Assurance of taxonomic expertise [ToR: c]
11) Advice on Quality Assurance procedures for benthos studies [ToR: d]
    - final draft of general guidelines for QA for biological monitoring
    - finalising of review of Standard Operating Procedures
12) Guidelines for sampling and description of epibiota, including QA [ToR: e]
13) Further analysis of the impact of North Atlantic Oscillations (NAO) on benthic population parameters [ToR: f]
14) Data banking, related QA matters, review of Biological Data Reporting Format and Data Entry Program [ToR: g]
15) Any other business
16) Report of the meeting
17) Date and place of next meeting
18) Closing of the meeting

ANNEX 3: COMMENTS AND CONCERNS ABOUT THE EUNIS CLASSIFICATION SYSTEM

In general, the BEWG was impressed with the amount of work that has been done to develop a classification system for marine habitats. Most members of the BEWG had little familiarity with the system, and after a short discussion, had the following concerns which they would like to pass along:

1) The system has, what appears to be, several internal consistencies in the top levels. There was considerable discussion about whether these inconsistencies were due to (a) the fact that the system seems not to be absolutely hierarchical, and (b) whether the system was designed on a pragmatic basis or whether there was any theoretical foundation on which the system is based. This may mean that the system would be useful to managers but would most likely be of unending frustration to the scientific community.

2) Some of the inconsistency seems also to be due to the fact that sediment and biota (chiefly in the form of angiosperms) are mixed. While it is understood that plants can significantly alter the character of the habitat, the BEWG felt that plants were not of the same level as abiotic aspects of the substrate.

3) The BEWG members were curious about the fact that the terrestrial ecosystems were relatively finely divided at Level 1 whereas the marine system was not. For example, the terrestrial system at Level 1 was subdivided into large-scale biotopes, such as fens and bogs. In the marine realm, the "biotope" aspect does not appear until Level 3.

4) How will the system deal with areas that are temporally variable, at least on the scale of a small number of years?

5) The term "gravel" is a catch-all term that does not reflect the substrate components that determine the nature of the biota. BEWG feels that large particle sizes, such as boulders, need to be accounted for as they will harbour a different assemblage of organisms than will be found on smaller particles included within the gravel designation.

6) With respect to adding the biota to the system, BEWG expressed concerns about the scale of the habitat classification system. Most of the techniques that might be used to map the substratum would almost surely operate at scales larger than the techniques that might be used to add the biotic information.

7) Depth, especially with respect to the categories of bathyal and abyss, is nearly useless in most North Atlantic areas. It was noted in the discussions of the BEWG that the biota can be seen to track with water mass (several projects from BIOFAR data show this, as do studies in the Baltic); so some water mass variables should be used in place of depth. A knowledge of North Atlantic oceanography could be used to devise categories with either temperature (for the shelf and slope) or salinity and oxygen (for the Baltic) as the key variables.

8) It was also noted that in some areas the sediment may be vertically stratified and that the biota might reflect the sediment type that is underlying a surface veneer of a different type. Can the classification system deal with this?

9) It was also noted that for hard substrata the orientation of the rock surface can be critical to the biota that might live there. In particular, the system needs to account for horizontal versus vertical surfaces.

10) In the Baltic Sea and fjords there are areas where the bottom oxygen levels are either temporally variable and other areas where the bottom waters are devoid of oxygen for several to many years. The system needs to have a low oxygen category.

11) The BEWG also felt that it should be stressed that marine systems are dynamic and any classification system is necessarily static. In some way the system needs to account for some of this dynamism. Once the system is established what will be the mechanism for amendment or addition?

ANNEX 4: DEVELOPMENT OF SUB-TIDAL BIOTOPE MAPPING TECHNIQUES IN UK WATERS,WITH EMPHASIS ON GRAVEL SUBSTRATES

C.J. Brown, K.M. Cooper, W. J. Meadows, D.S. Limpenny, and H.L. Rees
CEFAS, UK

An overview of progress in the habitat mapping project "**Mapping of gravel biotopes and an examination of the factors controlling the distribution, type and diversity of their biological communities (project A0908)**". A summary of the project aims and details of the presentation are provided below.

Date project commenced: April 1998.

Duration of project: 3 years.

Organisation(s) undertaking research project: The Centre for Environment, Fisheries and Aquaculture Science.

Funding bodies: MAFF

ABSTRACT OF RESEARCH

To establish the utility of seabed mapping techniques for surveying habitats which can then be applied in other areas to provide an essential underpinning to future site-specific environmental assessments of potential dredging areas. It will also describe the biological variation in areas dominated by the gravel biotope (i.e., habitat and associated communities) over different spatial scales and determine the major factors influencing this biotope in an area of the eastern English Channel. The biology and sedimentology of the seabed will be investigated and, with available information on the hydrodynamic regime, used to explain variability in the benthic ecosystem. Together with information on fish/shellfish stocks and the distribution of fishing effort, that will enable an assessment of the implications for resource exploitation.

The work is of direct relevance to the development of policy for extraction of the aggregate resource from the seabed ensuring sustainability of the associated ecosystems. Knowledge and techniques developed by this work will enable a more effective and structured approach to the assessment of the potential environmental impacts of applications for licences to extract aggregates from the seabed by aggregate companies and their consultants. This will both enhance the scientific basis for prediction of the effects of extraction activities and improve judgements of acceptability for licence applications.

PURPOSE OF RESEARCH

Much of the seabed surface around the England and Wales coastline is comprised of coarse material. Where these deposits are present in sufficient quantity, are of the right consistency, and are accessible to commercial dredgers, they may be exploited as a source of aggregate for the construction industry, to supplement land-based sources and as a source of material for beach nourishment.

It is likely that the demand for marine-won aggregate will further increase in the near future (especially to meet coastal defence needs), and construction companies are already prospecting on a much wider geographical scale for new sources of material. In timely anticipation of this demand, the present research programme seeks to establish the utility of seabed mapping techniques for surveying habitats and also to evaluate the fundamental role of superficial coarse deposits in the coastal marine ecosystem.

Research aims

- Establish the utility of seabed mapping techniques for surveying habitats to provide an essential underpinning to future site-specific environmental assessments of potential dredging areas.

- Fill fundamental gaps in knowledge by elucidating the major factors that operate over various scales (km^2 to m^2) and are responsible for determining the character of the gravel biotope. Such factors include substrate composition and bathymetry coupled with dynamic features of the water column. This will provide a greater understanding of the sources of ecological variation and supplement knowledge regarding the functional significance of the gravel biotope to fisheries and as an environmental resource.

A major challenge for the proposed work is to sample at relevant scales. This will be achieved by deployment of state-of-the-art seabed mapping tools, closely linked with physical and biological sampling, to derive descriptions of the nature and extent of the habitat. As an aid to interpretation of the output the data will be incorporated into a geographic information system (GIS) which will be of subsequent use in the provision of advice on specific licence applications within the areas surveyed. Appropriate measures will be identified to quantify the biological "sensitivity" of seabed types in the event of future exploitation. Site-specific findings will be used to derive generic hypotheses for change, thereby ensuring the wider application of the experienced gained.

Research Objectives

Summary Objective: to assess the utility of seabed mapping techniques for surveying habitats and examine the environmental influences affecting gravel biotope communities.

1) To characterise the seabed in an area of the eastern English Channel using various physical and geophysical techniques.

2) To incorporate biological, sedimentological and hydrographic information along with existing environmental and fisheries data into a geographic information system, in order to evaluate the functional role and importance of the gravel biotope relative to other substrate types, and for use in licensing procedures for the area surveyed.

3) To determine the causes of biological variation and of observed patchiness and to devise appropriate sampling strategies to allow for this variation. This work will take particular account of dynamic aspects of the environment within which the benthic communities have developed.

4) To establish the utility of seabed mapping techniques for surveying habitats.

5) To examine broad-scale fishery-independent beam trawl survey data from the eastern English Channel. Describe the range of assemblages sampled using dominance of commercially important fish and macro-epibenthic invertebrate by catch, and where possible explain the ecological rationale for observed patterns in species affinities.

6) To evaluate the susceptibility of gravel biotope benthic communities to anthropogenic disturbances in contrasting areas, particularly by dredging. This will involve the testing of established and novel methods for describing and quantifying biological status and sensitivity.

7) To report on the significance of the findings for the management of aggregate extraction activities.

Summary of the Project to Date

Work began in 1998 with a preliminary survey covering a small area of seabed (approximately. 4 km × 11 km) to the East of the Isle of Wight (Figure A4.1). Methodology was developed and trials of a number of acoustic techniques were conducted. Results from the preliminary mapping survey revealed a complex relationship between physical seabed type (derived from acoustic information) and the associated fauna (derived from grab samples), reflecting the small-scale variability of the sediments within this region. In order to widen the scope of the study, and further develop the biotope mapping methods that were applied in year 1, three locations exhibiting a wider range of physical and biological gradients were selected for study in year 2. An area of seabed in the English Channel off Shoreham (12 km × 28 km), with strong biological and physical gradients, displaying a high level of sediment homogeneity within discrete habitat boundaries, was selected as the main site for study. The other two areas (each 12 km x 4 km), one offshore from Hastings and the other to the east of Dungeness (Figure A4.1), were selected on the grounds that both contained similar sediment types to those encountered off Shoreham, but were widely separated geographically (forcing biological differences between areas) and displayed greater small-scale complexity in the arrangement of their sediment types.

The Shoreham and Dungeness areas were intensively surveyed in July 1999 using a combination of acoustic techniques (side-scan sonar and two seabed discrimination systems, RoxAnn and QTC View). A mosaic of the side-scan sonar traces from each area was produced to give a textural representation of the seabed, covering 100 % of each survey area. Using this output in conjunction with the other acoustic data, and treating each survey area separately, the seabed was divided into acoustically distinct regions (Figure A4.2 and A4.3). Early post-processing of these acoustic data sets revealed general agreement in the interpretation of sediment types between each of the acoustic techniques, although work is still ongoing to fully evaluate the utility of each acoustic system as a mapping tool.

Sediment interpretations of the acoustic outputs from each distinct region ranged from cobbles and gravel, through to various sand wave features and mud. These regions were sampled during the follow up "ground-truth" and biological survey in August 1999 using a suite of sampling techniques. The main sampling tool deployed was a $0.1m^2$ Hamon grab fitted with a video camera. During the preliminary survey of year 1 there were often discrepancies between the predicted sediment type, determined from the acoustic records, and the actual sediment type collected during the physical sampling programme. Fitting a camera to the grab allowed an image of the undisturbed seabed directly adjacent to the sampling bucket of the grab to be obtained. This revealed that thin surface deposits of one type of sediment can often "mask"the dominant sediment type below, and this approach to sampling proved to be an invaluable procedure when attempting to map biotopes, due to the additional visual information gained from the video footage regarding the physical habitat. The acoustically distinct regions were further ground-truthed using a Rallier du Baty dredge (a heavy-duty sampling tool suited for use on coarse substrates), and using underwater video and photography collected through deployment of a drop camera frame. Two microloggers in lobsterpots (equipped with instrumentation to collect data on current speeds, suspended load, temperature and pressure) were deployed in the north and south of the Shoreham area to record data on the hydrography of the region. An identical acoustic, biological and ground-truthing approach was carried out at the Hastings area during surveys in October and November 1999.

Biological samples collected using the Hamon grab from the Shoreham survey area have been worked up. Statistical analysis of data has revealed that there is a high degree of variation between replicate samples taken from each of the acoustically distinct regions, but, nonetheless, there is evidence of statistically distinct biological assemblages within most of these regions. Further analysis of acoustic and biological data, incorporating physical data sets such as particle size distributions of sediments, and the hydrographic data from the loggerpots, will assist in establishing the relationships between biological assemblage structure and physical habitat. Biological and sedimentological samples from the Hastings and Dungeness survey areas are presently being worked up.

Figure A4.1. Survey locations for Project A0908, eastern English Channel.

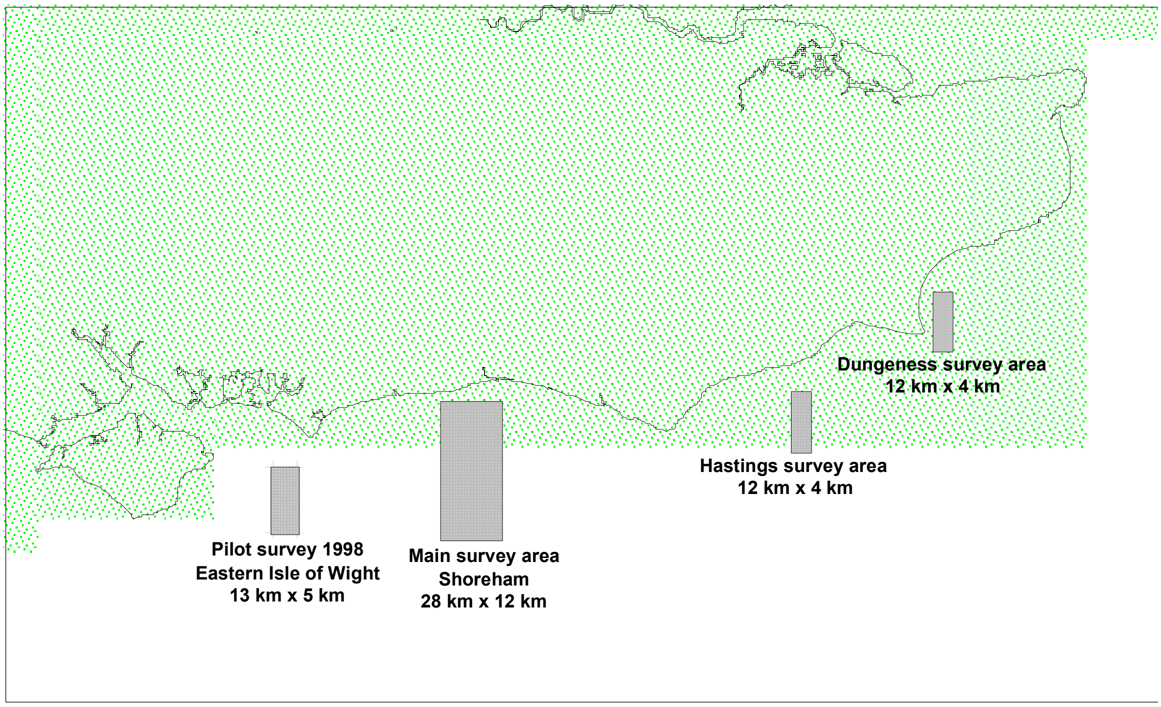


Figure A4.2. Representation of the Shoreham survey area showing delineation of the 7 acoustically distinct regions (determined from the side-scan data) and positions of the Hamon grab stations. Bathymetry interpolated from QTC data.

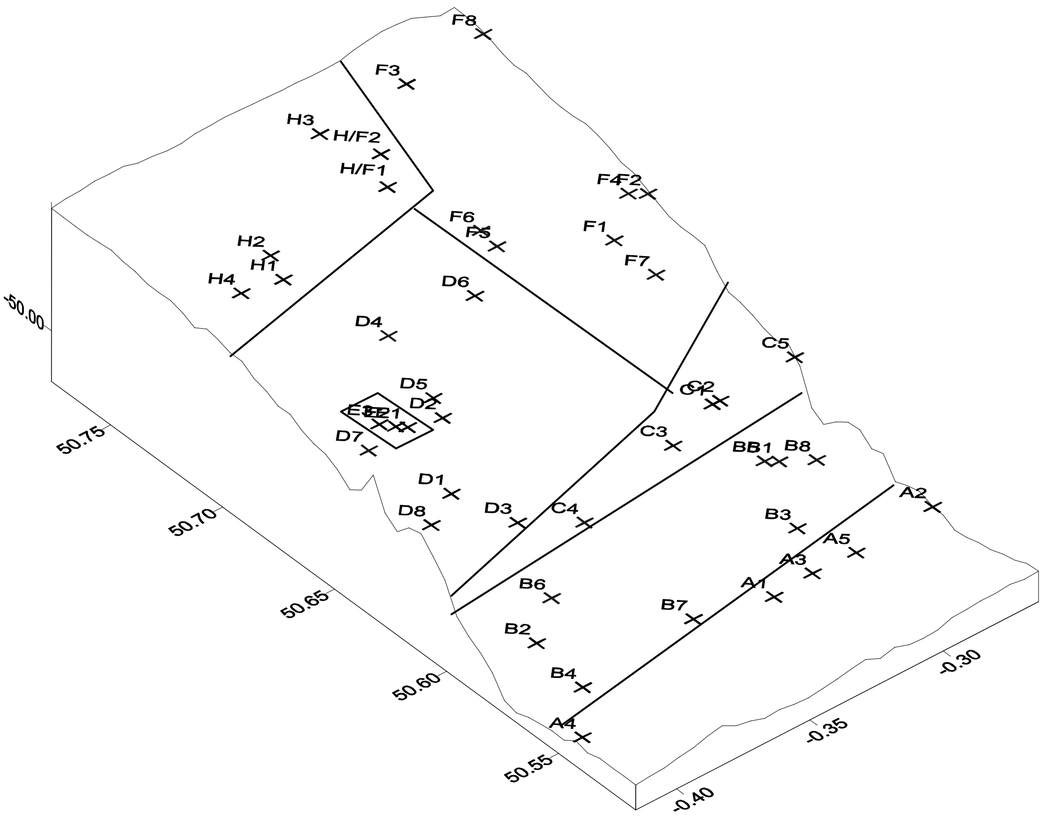
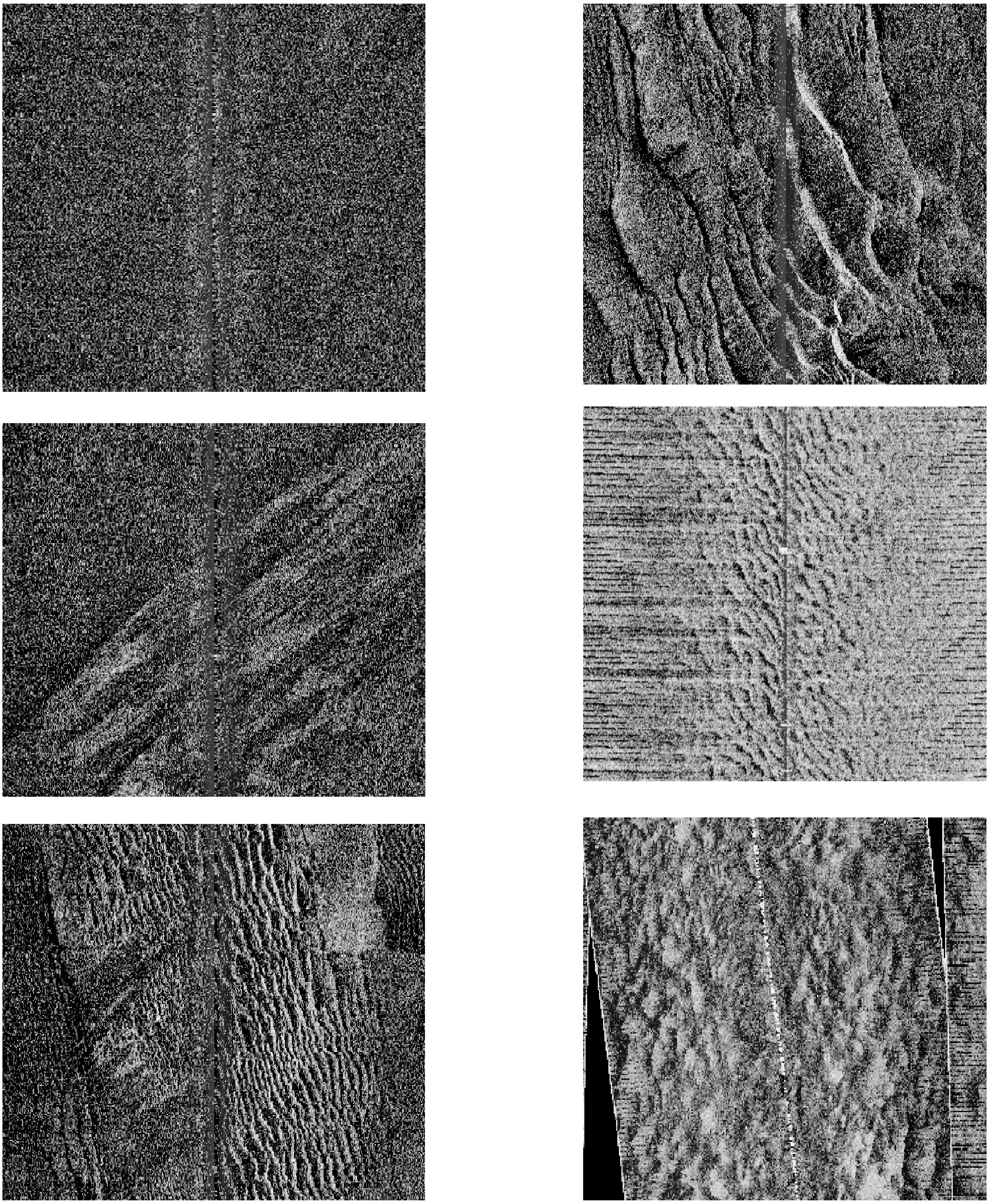


Figure A4.3. Examples of side-scan sonar images from acoustically distinct regions. (1) Area A=Offshore clean gravel; (2) Area B=Offshore gravel with thin sand veneer; (3) Area B=Offshore gravel with thick sand veneer; (4) Area C=Mega sand waves; (5) Area F=Inshore rippled sand; (6) Area E=Mixed heterogeneous sediment.



ANNEX 5: APPLICATION OF UNDERWATER VIDEO FOR ASSESSMENT OF MACROZOOBENTHIC COLONIZATION AND SEDIMENT STRUCTURE IN GERMAN BALTIC WATERS[1)]

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As known from several studies, the use of underwater cameras extends the range of possibilities offered by traditional benthos sampling (grab, corer, and dredge). The additional information obtained, e.g., on sediment structure, epibenthic fauna, and typical tracks of some endobenthic species will be helpful for the assessment of benthic communities and their changes. Therefore, two years ago a study was started aiming to develop an underwater video system for later application in a monitoring programme, e.g., within the frame of HELCOM. The underwater video system used consists of a security camera (Hitachi, VK-C78ES) protected by a water-resistant case and mounted on a sledge. The camera was installed on a pan and tilt head. Scaling was accomplished by four crossed laser beams projected into the screen. The sledge was towed over the bottom by a drifting vessel at lowest possible speed (< 1 knot). During the whole tow information on geographical position, water depth, date and time of video recording was visible on the screen, allowing the later assignment of the video material to the different areas investigated. During the study, about 78 sites were visited once or twice, with special emphasis on Mecklenburg Bight and Arkona Basin (Figure A5.1). During these cruises the underwater video system was used about 100 times in depths between 6 m and 90 m and over 20 hours of video material were recorded. For the later calibration of the video pictures, bottom samples were taken using van Veen grabs and dredges. In total, 194 macrozoobenthic species were found (Figure A5.2). We were able to determine approximately 16 % of these species with the video method. 7 % are exclusively detectable (qualitatively) when using the underwater video system. The quantifying of a small number of the latter group (adults of 7 species) was only possible by means of video technique. Some rare, epibenthic species (e.g., the seastar *Asterias rubens* or the brittle star *Ophiura albida*) belong to this group as well as endobenthic species with typical tracks such as the lugworm *Arenicola marina* or the boring bivalve *Barnea candida*. The knowledge of sediment structure allows estimation of the regularity or patchiness of habitats and their colonization by macrozoobenthic species. In conclusion we recommend the use of underwater video as an additional monitoring tool in order to follow and better understand the structure and changes within macrozoobenthic communities relative to environmental changes.

The study was supported by the Federal Ministries for the Environment (BMU) and for Education and Research (BMBF).

Figure A5.1. Investigation area with stations which were visited between 1998 and 2000. At each station three Van Veen grabs, one dredge, and one video survey were carried out.

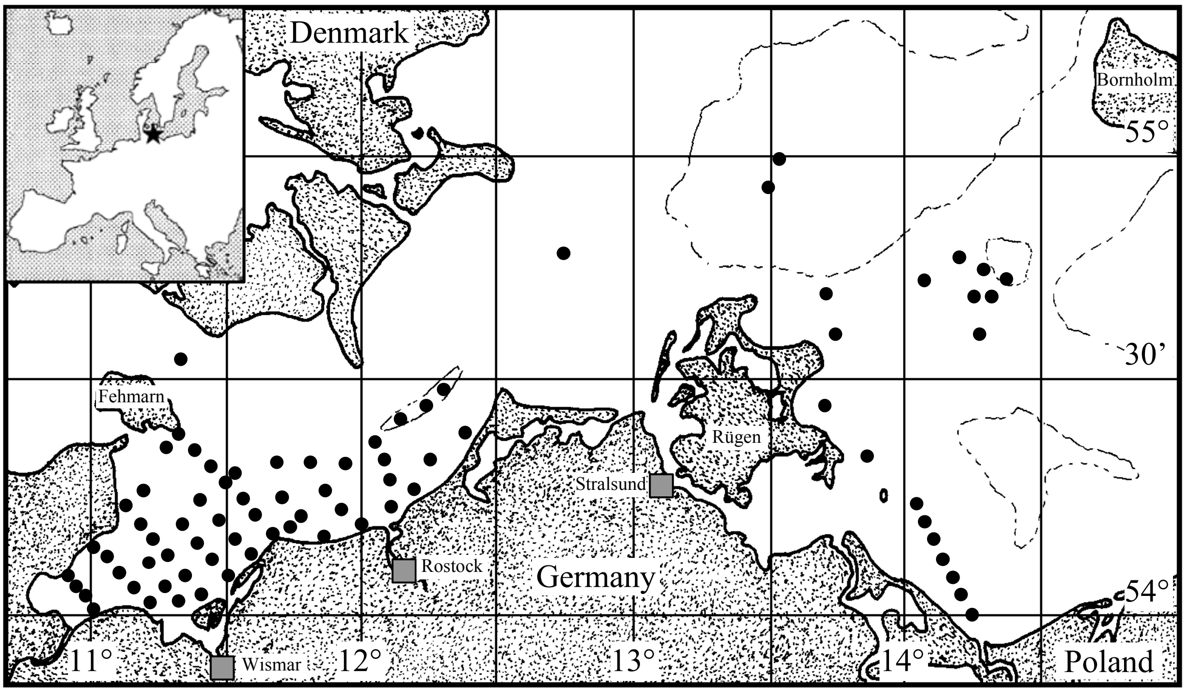
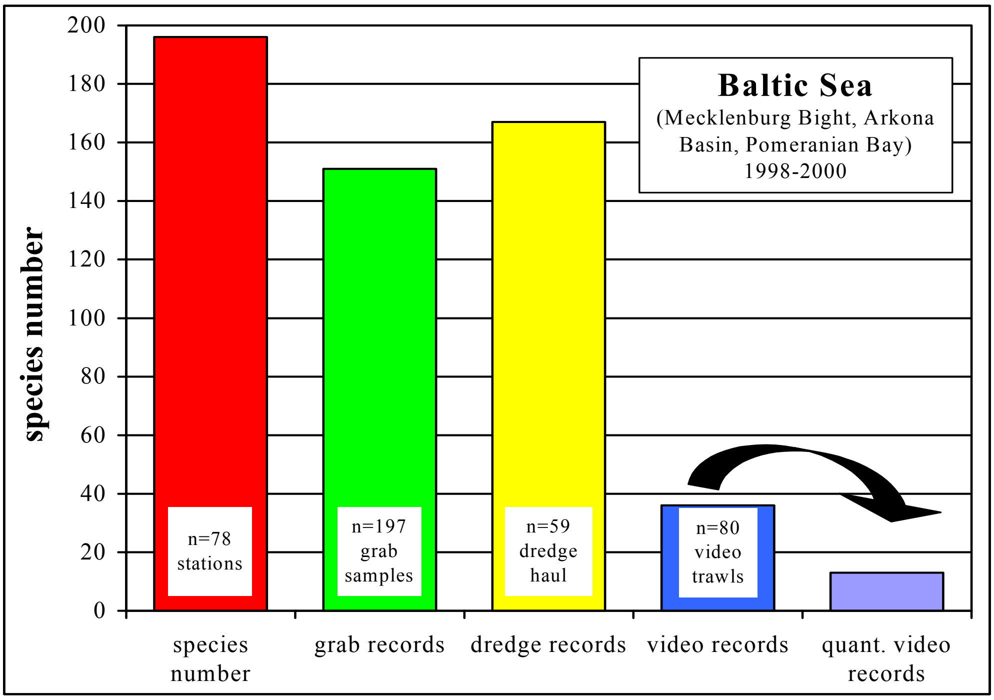


Figure A5.2. Comparison of species records determined by different methods.



ANNEX 6: THE EFFECTS OF DREDGING INTENSITY ON THE MACROBENTHOS IN COMMERCIAL AGGREGATE EXTRACTION SITES IN THE ENGLISH CHANNEL

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ABSTRACT

A survey was designed to examine the nature of impacts on the benthos arising from commercial aggregate extraction at sites east of the Isle of Wight in the English Channel. Samples of sediments and the associated macrofauna were collected from areas subjected to different levels of dredging intensity. Several of the sampled sediments collected from within areas of intensive dredging contained reduced quantities of gravel. However, changes in particle size were not sufficient to account for differences in assemblage structure between areas that had only limited exposure to the direct effects of dredging compared with undredged areas. Samples from intensively dredged sediments differed from undredged sites due to significant reductions ($p<0.05$) in numbers of species, biomass, species richness and diversity. Intermediate values of all calculated univariate measures were also observed in areas of reduced dredging intensity. Populations of the reef forming polychaete *Sabellaria spinulosa* were found to be particularly susceptible to dredging disturbance. This is in contrast to *Balanus* juveniles which were observed to be more numerous in intensively dredged sediments compared with elsewhere, suggesting that some settlement of this taxon occurs even during times of extraction.

The implications of these findings for assessing the potential for cumulative environmental impacts as a consequence of aggregate extraction are discussed.

INTRODUCTION

Historically in the UK, environmental impact assessments of the effects of aggregate extraction have concentrated on individual aggregate extraction licences to the exclusion of nearby dredging activity. However, impacts that may be viewed as insignificant as a result of dredging at an individual extraction licence could potentially accumulate in a region over time or combine with impacts from nearby dredging activity. Such impacts are termed ***cumulative***, and these are of concern as they may lead to the gradual degradation of a particular habitat or the loss of a key component of the ecosystem (Erikson, 1994). Cumulative impacts may occur as a result of dredging at a single locality but, more commonly, concerns are directed at the cumulative consequences of aggregations of licensed dredging activity (Jewell and Roberts, 1999). Consideration of this issue will also become increasingly important in the U.K., in view of the move towards statutory control of aggregate dredging activity through the introduction of Environmental Impact Assessment and Habitats (Extraction of Minerals by Marine Dredging) Regulations 2000.

From a practical perspective, the assessment of any cumulative environmental impacts as a consequence of aggregate dredging requires an understanding of the effects of dredging and the definition of appropriate spatial and temporal boundaries (Preston and Bedford, 1988). In addition, the potential for cumulative environmental impacts of dredging will depend upon many factors including the intensity and duration of dredging within an area, the spatial extent of effects, and the rate of recovery of the community. Most studies on the effects of aggregate extraction have concentrated on establishing the rates and processes of macrobenthic recolonisation upon cessation of dredging (Van der Veer *et al*., 1985; Van Moorsel, 1994; Kenny and Rees, 1994, 1996). These studies indicate, typically, that dredging causes an initial reduction in the abundance, species diversity and biomass of the benthic community. However, Lees *et al*. (1990) working in an area east of the Isle of Wight in the English Channel, was unable to establish a causal link between the distribution of faunal assemblages and dredging intensity inferred from sonographs of the seabed and diver observations. In this area there are a number of extraction licences, within which the seabed has been subjected to the effects of dredging for the last 25 years or more. In recent years, approximately 2–3 Mt of sand and gravel has been removed from this region.

The work described here is part of an ongoing field assessment programme designed to investigate the potential for the cumulative environmental consequences of aggregate extraction within licences east of the Isle of Wight, and elsewhere. More specifically, the purpose of this survey was to further examine the nature of impacts arising from commercial aggregate extraction and to test the null hypothesis (H_o) that there is no significant difference between the effect of different levels of dredging intensity on macrofauna assemblages.

METHODS AND MATERIALS

Since 1993, every vessel dredging on a Crown Estate licence in the UK has been fitted with an Electronic Monitoring System (EMS). It consists of a PC electronically linked to a navigation system and one or more dredging status indicators. This automatically records the date, time and position of all dredging activity every 30 seconds to disk. Many of the dredgers operating in UK waters are fitted with Differential GPS navigation systems, which allows the EMS to operate with an accuracy of ±10m.

EMS information was interrogated in order to locate areas of the seabed within extraction licences to the east of the Isle of Wight, which had been subjected to different levels of dredging intensity. Six replicate stations were randomly selected from areas representing three different levels as follows: 1) >15 hours (15h) of dredging within a 100 m by 100 m block over 1998, 2) <1 hour (1h) of dredging within a 100 m by 100 m block over 1998 and 3) no dredging (0h) activity recorded within a 100 m by 100 m block over a period of 5 years (Figure A6.1). The dredging history of each sampling location is presented in Table A6.1.

With this design, the 15h treatment represents conditions following the repeated removal of commercial aggregate from most of the total surface area of a 100 m by 100 m block, many times over the course of 1 year. This is assumes that a dredger, typically a trailer suction hopper dredger, moves slowly over the seabed at a speed of 2kt and creates a dredge track of approximately 2.5 m wide. It also assumes that the dredger works systematically across an area. In practice, particular deposits will be more frequently targeted by the dredging industry and therefore, under the 15h treatment, some areas of the seabed may be dredged on a regular basis whereas other areas of the seabed may only be dredged once or twice in a year. In contrast, the 1h treatment represents conditions after the removal of up to about 90 % of the total surface area in a similar 100 m by 100 m block. However, some locations within this treatment may have only experienced limited exposure to the direct effects of extraction, allowing survival of some species and recolonisation by others. In addition, the 1h sampling points were all located close to centres of intense dredging activity. Therefore these sites were potentially subjected both to the direct effects of minimal dredging and any indirect effects (e.g., settlement of plume material) associated with the nearby more intensive dredging activity. This scenario is further complicated, as anchor hopper dredgers carry out dredging in some of the extraction sites in this area. In this case the dredger anchors over the deposit and mines it by forward suction through a pipe (ICES, 1992). This results in localised pits on the seafloor.

The 0h samples were located in areas that had not been subjected to dredging for the past 5 years (known from EMS records) and away from indirect effects of dredging activity. In these areas, dredging may never have taken place, as such areas usually contain sub-commercial deposits. However, this is difficult to verify as, prior to the inception of EMS, historical records on the location of dredging activity are more sporadic. All these samples were located in commercial extraction sites where dredging was still active, and in that sense this was not a controlled field experiment, rather this study is a more pragmatic attempt at assessing the effects of commercial dredging activity. In addition 4 replicate samples were collected from a nearby reference site located away from both indirect and direct effects of dredging. Samples were collected using a $0.1m^2$ Hamon grab on 25 and 26 May 1999 from within a 50-m range ring, using the SEXTANT hydrographic software package and DGPS position fixing (Figure A6.1). Following estimation of the total sample volume, a 500 ml sub-sample was removed for laboratory particle size analysis. The whole sample was then washed over 5 mm and 1 mm square mesh sieves to remove the fine sediment. The two resultant fractions (1-5 mm and >5 mm) were back-washed into separate containers and fixed in 4–6 % buffered Formaldehyde solution (diluted in sea water) with the addition of a vital stain "Rose Bengal".

Laboratory analysis

The 5-mm sample fraction was first washed with fresh water over a 1 mm mesh sieve in a fume cupboard, to remove excess Formaldehyde solution, then back-washed onto a plastic sorting tray. Specimens were removed and placed into labelled glass jars containing a preservative mixture of 70 % methanol, 10 % glycerol and 20 % distilled water. Specimens were identified, where possible, to species level. The 1–5mm fraction was first washed over a 1 mm sieve then back-washed into a 10 litre bucket. The bucket was filled with fresh water and the sample was then gently stirred in order to separate the animals from the sediment. nce the animals were in suspension, the sample was decanted over a 1 mm mesh sieve. This process was repeated until no more material was recovered. Specimens from this fraction were placed into labelled petri-dishes for identification and enumeration. The sediment was then placed on plastic trays and examined under an illuminated magnifier for any remaining animals such as bivalves not recovered in the decanting process, which were then added to the petri dishes. The blotted wet weight (in grams) for each species recorded from replicate samples was also recorded.

Sediment sub-samples for particle size analysis were initially wet sieved over a 63 mm mesh sieve to provide an estimate of the fine fraction. The remaining sample was then oven-dried and sieved through a stack of geological test sieves ranging from -6 phi (64 mm) to +4 phi (0.063 mm). The percentage distribution, by weight, of particles for each size fraction was then calculated.

Data analysis

The following univariate measures were calculated: total abundance (A), numbers of species both including (S) and excluding (T) colonial taxa, Shannon-Wiener diversity index H'$\log_2$ (Shannon-weaver, 1949), and Margalef's species richness (d). Ash-free dry weights were calculated using standard conversion factors (Rumohr *et al*., 1987; Ricciardi and Bourget, 1998).

Differences between each level of dredging intensity were determined through calculation of Least Significant Intervals (LSI's). This method assumes that where the means do not overlap there is a statistically significant difference at the 95% probability level (Andrews *et al*., 1980). The inter-relationships between the dredging history at each sample location over different years, sedimentary parameters and a range of univariate indices of biological structure were examined using Pearson product moment correlation coefficients.

Non-metric multi-dimensional ordinations of the inter-sample relationships (Kruskal and Wish, 1978) were produced to view the similarity of samples in terms of their species composition. The ordination was based on a lower triangular similarity matrix of log-transformed abundance data using the Bray-Curtis similarity co-efficient (Bray and Curtis, 1957). To test the null hypothesis H_o that there were no significant differences in community composition between samples collected from areas subjected to differing levels of dredging intensity, an analysis of similarities was undertaken employing the ANOSIM procedure (Clarke, 1993). As a basic aim of this study was to provide an empirical basis for describing the effects of aggregate extraction, it was important to establish the species contributing to any observed differences in the community composition of fauna. This was established by means of similarity percentage analyses (SIMPER) on the species sample matrices, which revealed any characteristic species contributing to the Bray-Curtis dissimilarity between sample groups (Clarke, 1993).

To examine which factors are important in accounting for the distribution of faunal assemblages, information on the dredging history and sediment variables were compared singly or in combination with the ranked dissimilarity matrix of faunal abundance data (see Clarke and Ainsworth, 1993). Sub-sets of environmental parameters that were found to best explain the biological variability were then identified by the highest correlation coefficients (p_w).

RESULTS

Dredging history of sites

The maximum number of hours of recorded dredging at each sample location for 1993-May 1999 inclusive are given in Table A6.1. In general, the level of dredging at each sampling position was relatively stable over time. Actual values of recorded dredging over 1998 for 15h replicates range from 9 to 59 hours of dredging. The lower than expected value of recorded dredging in 1998 at 15hF is due to errors associated with accurately collecting samples at sea from target areas.

Physical observations

In general, 0h sediments contained similar proportions of sand and gravel (Figure A6.2A), having a characteristic bimodal distribution. A distinctive mode was observed at about 16 mm (gravel) and a smaller secondary mode at about 250 μm (medium sand). A similar pattern was observed with 1h sediments, although there was a tendency for particles to be less well-sorted (Figure A6.2B). However, the particle size distributions of sediments from the 15h sample replicates were much more variable than both the 1h and 0h sediments, with several samples (15hC, E & F) containing a reduced quantity of gravel (Figure A6.2C). A silt-clay fraction was also more prominent in one of the 15h sample replicates (15hE) than other sampled sediments.

Biological observations

Overall, relatively few species were abundant and 69 of the 231 recorded taxa (including colonial taxa) were single occurrences. Variations in total numbers of individuals (non-colonial taxa only) are considerable. This has been noted previously in individual EIAs for aggregate extraction (Oakwood Environmental, 1999) and reflects both a highly diverse fauna and a patchy distribution of the populations in the region (see also Lees *et al*., 1990). Nevertheless, both the numbers of non-colonial species (S) and values of species richness (d) are significantly reduced ($p<0.05$) in the dredged sediments (1h and 15h) compared with the 0h sample group. For example, the average number of non-colonial species recorded from 6 Hamon grab samples from the 0h treatment group was 45 compared with an average number of 27 and 8 species from the 1h and 15h sample replicates, respectively. Indeed, excepting the numbers of individuals, all other univariate measures calculated reveal significantly lower values ($p<0.05$) in the 15h treatment compared with the 0h treatment (Table A6.2). Intermediate values of all measures were observed in the 1h treatments and these differences were significantly lower ($p<0.05$) than 0h sample replicates for species richness and numbers of non-colonial taxa. There were no significant differences ($p>0.05$) for any of the calculated univariate measures when comparing 0h and reference site samples. Trends in biomass for each treatment are in general agreement with those for numbers of species with intermediate values obtained for 1h sediments. The mean biomass for 0h sediments was 59.8g (ash free dry weight) m^{-2}; this was reduced in 1h sediments and 15h sediments with mean values of 9.82g and 0.73g m^{-2}, respectively. This reflects the removal of a range of macrofaunal species including the slipper limpet *Crepidula fornicata*, the reef forming polychaete *Sabellaria spinulosa*, the bivalve *Nucula nucleus* and a number of tunicates such as *Polycarpa pomaria*, *Dendrodoa grossularia*, and *Pyura microcosmos,* which were locally abundant in the 0h sample replicates.

The outcome of non-metric multi-dimensional scaling (MDS) indicates that the 15h samples are clearly separated from both the 1h and 0h sample replicates. Furthermore, the 15h replicate samples are widely separated on the MDS plot indicating that they are biologically dissimilar. Results of pair-wise analyses of similarities (ANOSIM) on log-transformed data confirm that differences between the 15h treatment and all other assemblages are significantly different (Table A6.3). Repeating this analysis with 4th root transformed data, a less severe transformation when used on low abundance data sets such as this, also confirms that the differences between all assemblages within extraction sites are significantly different ($p<0.05$) (Table A6.4). The disturbance from dredging within the 1h treatment also provoked less severe changes in the community composition compared with dredging disturbance in the 15h treatment (Table A6.4). These results imply that the null hypothesis (H_o) of no significant difference in community composition as a consequence of dredging intensity can be rejected. However, differences between the reference site and both the 1h and 0h treatments were not significant ($p<0.05$), but this appears to be largely a function of the lower numbers of replicate samples collected at the reference site which reduced the discriminatory power of the analysis. This also reflects the generally low and variable abundances of individual species, which masked any differences between assemblages observed at the 1h and 0h sites and the reference site.

The distribution of organisms that was influential in accounting for the distinctions between sample groups is presented in Table A6.5. The 15h samples differed from the both the 1h and 0h groups largely due to the elimination or reduced abundance of a range of macrofaunal taxa including the polychaete *Sabellaria spinulosa*, the tunicate *Dendrodoa grossularia* and the barnacle *Balanus crenatus*. Conversely, higher densities of newly recruited Balanidae juveniles within the 15h sample group also contribute to the observed dissimilarities, albeit at a lower level of similarity. This probably reflects a recent larval settlement of this species on the denuded sediments. Adults of the barnacle *Balanus crenatus* were also more abundant in the 1h samples than elsewhere. Higher densities of the r-selected species *Dendrodoa grossularia* in 1h and 0h samples also helped to distinguish these groups from the reference site samples.

There was also a discernible trend towards increasing abundance of *Sabellaria spinulosa* with decreasing levels of dredging disturbance, with the greatest cover of *Sabellaria* reef found at the reference site. A range of infaunal and epifaunal polychaete species such as *Typosysllis* spp., *Ehlersia ferrugina*, *Autolytus* sp., *Pomatoceros lamarcki*, *Polydora caeca* (agg.), *Perkinsiana rubra* and *Pseudopotamilla reniformis* were also more numerous at the reference site compared with extraction site samples, implying that these species live in association with the reef matrix.

Biotic and environmental relationships

A correlation matrix for a range of biological and sedimentary variables, and recorded dredging effort for each year is given in Table A6.6. In general, there is a relatively strong negative correlation between the numbers of taxa (both colonial and non-colonial) found in May 1999 and the maximum level of recorded dredging effort in each year. There are also strong negative correlations between species richness (d) and dredging effort for most years. The correlation analyses therefore confirm that there is an adverse effect on the numbers of species (both colonial and non-colonial) in sites exposed to dredging disturbance. There were no significant relationships between any of the biological measures and sediment characteristics. Overall, this suggests that the level of dredging disturbance is more influential in determining the structure of biological assemblages than sedimentary parameters.

Relationships between dredging effort and biological variation were also explored using the method of Clarke and Ainsworth (1993). The highest correlation ($pw = 0.715$) arose from a combination of 5 variables: dredging effort in

1993, 1996 and 1998, % medium sand and % silt/clay (Table A6.7). However, the level of recorded dredging effort in 1999 explains most of the variability in the biological data with a correlation coefficient of 0.661. Similarly, a relatively high correlation coefficient (pw = 0.637) was obtained with recorded dredging activity in 1998, suggesting that it is recent dredging events that are most critical for defining the biological community structure. Lower correlations were found with sedimentary parameters.

DISCUSSION

During 1999, when these sites were sampled, approximately 20 % of the area, licensed for sand and gravel extraction in this region was dredged (Crown Estates *pers. comm.*). Of this area, most of the dredging effort consisted of <1h of dredging recorded in 100 m by 100 m blocks over the course of the year. This level of dredging effort has been relatively stable over the last five years. Furthermore the location of active dredging (known from EMS records) has been similar between years for the same period. Therefore the findings from this study can be considered as representative of conditions at these extraction sites in recent years.

The reduced gravel component observed in several of the 15h sediments may, in part, be explained by screening activities carried out by the aggregate industry in order to meet specific sand/gravel requirements. Such requirements are met through the separation of different fractions of sediment whilst at sea, by passing the aggregate through a series of screens on board the dredger, one fraction being preferentially loaded and the unwanted material being discharged to sea via a reject chute. earnaley *et al.* (1996) estimated the material lost through spillways on board a dredger in comparison with material rejected and returned to the water column due to the screening process. These estimates were based on the analysis of measurements of a number of screened cargoes, and indicated that approximately 35 kg total dry solids per m^3 of material was discharged as overspill, 40 % of which consisted of silt/clay material. However, material returned overboard through screening activities was estimated to be an order of magnitude higher at around 500 kg total dry solids per m^3. Of this, approximately 1 % of the material consisted of silt/clay. When such estimates are scaled up, it has been calculated that, during the loading of a screened cargo, a total mass equivalent to about twice that of the total cargo is released back into the water column (Hitchcock and Dearnaley, 1995). Clearly estimates such as these are site specific, and will vary in relation to the grain size of seabed sediments, the grading required for the cargo and the efficiency of the dredger. However, estimates by Hitchcock and Drucker (1996) for a dredger working in our study area suggest that for a trailer suction hopper dredger of 4500 t capacity, 7223 t of material are rejected by screening. Furthermore in this area, the majority of the rejected material is likely to consist of sands and fine gravels (EEL, 1999). Video footage of dredging during routine loading of a cargo has also indicated that the greatest proportion of the discharged material is deposited beneath the dredger (Davies and Hitchcock, 1992). Over time, the progressive removal of the original sandy gravel and its replacement by sandier sediments may lead to a gradual fining of the sediment within the extraction licences. This accumulation of sandy material may not be considered to be significant when caused by dredging at a single extraction licence. However, when impacts of this type occur across a region, then they are potentially of greater concern and can be interpreted in the broadest sense as constituting a cumulative impact, i.e., when the sediments and impacts "accumulate" in a region over time (Cada and Hunsaker, 1990). Whether this quantity of rejected material significantly alters the composition of the sediment in the longer-term will depend upon how quickly the material is eroded away by tidal current and wave action. A change in the composition of sediment following aggregate extraction has also been observed in intensively dredged sediments off Dieppe (ICES 1992, 1993). However, at this site the fine material, which infilled the dredged furrows, resulted from a combination of plume settlement and from the transport and trapping of bedload sediments. In contrast, an experimental study off North Norfolk reported the coarsening of seabed sediments, as result of the exposure of deeper gravelly deposits following dredging (Kenny and Rees, 1996).

Although differences in the particle size distributions may account for contrasts in the fauna between areas of intense dredging (15h) and other sites, they are not considered sufficient to fully explain the differences in the fauna between sites exposed to limited dredging intensity (1h) and non-dredged sites within the extraction sites (0h). This suggests that the physical disturbance associated with extraction activity is also influential in determining the community composition. Gravel extraction can have a number of physical effects including the removal of the resident seabed fauna, the exposure of uncolonised sediments, increased turbidity and redistribution of fine sediments. Newell *et al.* (1999) have also recently claimed that fragmented benthos discharged with the outwash from working dredgers can contribute to an organic enrichment effect. However their measurements of the discharged organics were from unexploited deposits, whereas the extraction sites examined in this study have been worked over a number of years. Given that the biomass of benthic invertebrates was significantly reduced within the intensively dredged areas, it is unlikely that such an enrichment effect would be detectable in this area.

Lees *et al.* (1990) sampled part of the same area as the current study and, despite differences in sampling methodology, the faunal assemblages recorded are broadly similar. Nevertheless, they were unable to detect consistent differences in assemblage structure between stations unaffected by dredging disturbance and those that were inferred to be subjected to dredging activity, although they did observe a difference in the numbers of ascidians. The sampling conducted by Lees *et al*. during 1989 was conducted using a modified Forster anchor dredge (see Eleftheriou and Holme, 1984). This sampler is a non-quantitative device and hence it would limit the scope for accurately characterising the fauna. Advancements in the positioning capability of ships and the recording of EMS information have also undoubtedly improved the potential for accurately locating areas of seabed subjected to dredging activity.

Sabellaria spinulosa was found to be present at the reference site, reduced in abundance within areas exposed to limited dredging disturbance (0h and 1h), and absent from heavily exploited areas (15h). Connor *et al*. (1997) describe similar communities living in association with a *S. spinulosa* reef, to those recorded at the reference site, with an infauna consisting of polychaetes, as well as the bivalves *Abra alba* and *Nucula nitidosa* and an epifauna including attached *Polydora* tubes. Indeed populations of this reef-forming polychaete have been shown to promote short-term stability and permit diversification (see, e.g., George and Warwick, 1985; Holt *et al*., 1995; Rees *et al*., 1999). The elimination of this species in areas of intense dredging, and its reduced abundance elsewhere in the extraction sites, presumably as a result of its susceptibility to dredging disturbance, may also limit the scope for recolonisation by other species upon the cessation of dredging. Furthermore, the larvae of this species are considered to be stimulated to settle by the presence of adults, with settlement occurring more slowly in the absence of either dead or living cementation (Wilson, 1970; Holt *et al*., 1998). Thus it would appear that aggregate extraction has the potential to gradually reduce the spatial coverage of this important biotope. However, further research is needed to quantify the geographically extent of *Sabellaria* in the area, and to establish its rate of recovery following damage from extraction activities (Holt *et al*., 1998) before the significance of this “nibbling” effect (Preston and Bedford, 1988) can be fully assessed.

In contrast, the barnacle *Balanus crenatus* was found to be more numerous (as juveniles) in intensively dredged sites, and as adults in areas of more limited dredging compared with undredged sites. This suggests that recolonisation by this species proceeds relatively rapidly, with some settlement occurring even during times of extraction. This accords with observations by Kenny and Rees (1994, 1996) and Kenny *et al*. (1998) at an experimentally dredged site off North Norfolk where there was substantial recolonisation by *B. crenatus* within 12 months of the cessation of dredging. Furthermore, the r-selected species *Dendrodoa grossularia,* which was also found to have a fast colonising ability at the North Norfolk Experimental site, occurred in high densities within the east of the Isle of Wight extraction sites (0h and 1h), but was absent from the nearby reference site. This would suggest that this species is able to quickly colonise areas disturbed by dredging but may be competitively excluded in more stable areas.

Most of the seabed dredged in this region in recent years is likely to be similar in nature to the 1h treatment, although locally there are “hotspots” of more intensive dredging activity. Therefore, we can assume that large proportions of the dredged areas have a reduced abundance of *Sabellaria* and as a consequence a more limited number and diversity of reef-dwelling organisms. However, there is also likely to be an increase in the numbers of more opportunistic taxa such as *Balanus crenatus* and *Dendrodoa grossularia* which have taken advantage of the exposure of hitherto uncolonised sediments. At present, the significance of this change in the benthic fauna for other components of the ecosystem cannot be quantified. Therefore, further studies in this area, aimed at better identifying the nature of biological effects with a view to assessing the potential for cumulative impacts arising from aggregate extraction, are continuing.

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Table A6.1. Maximum number of hours of recorded dredging at each sample location over time (values for 1999 are for January to May 1999 inclusive).

Sample	1993	1994	1995	1996	1997	1998	1999
0hA	0	0	0	0	0	0	0
0hB	0	0	0	0	0	0	0
0hC	0	0	0	0	0	0	0
0hD	0	0	0	0	0	0	0
0hE	0	0	0	0	0	0	0
0hF	0	0	0	0	0	0	0
1hA	0	0	0	0	<1	<1	<1
1hB	0	0	<1	0	<1	<1	<1
1hC	0	<1	<1	<1	<1	<1	<1
1hD	0	0	0	0	0	<1	<1
1hE	<1	<1	<1	0	<1	<1	<1
1hF	0	<1	<1	<1	<1	<1	<1
15hA	0	<1	0	0	0	33.49	10.74
15hB	<1	18.24	12.49	9.99	14.99	16.49	3.24
15hC	<1	3.24	8.49	15.99	9.49	16.74	6.74
15hD	0	4.49	22.24	14.25	9.24	58.99	44.99
15hE	3.25	11.24	10.49	15.49	10.24	16.99	6.75
15hF	0	<1	<1	<1	1.49	8.74	2.99

Table A6.2. F ratios and significance levels (from $F_{3,18}$) from 1 way ANOVA tests for differences in various univariate measures of community structure between treatments.

Univariate measure	F	p
S (non-colonial taxa)	8.30	<0.01
A	1.21	0.34
H’	4.39	0.01
d	12.20	<0.01
T (all taxa)	9.47	<0.01
AFDW	2.33	0.10

Table A6.3. R-values from pairwise analyses of similarities to test significant differences between treatments based on log-transformed data

	Ref	0h	1h
Ref			
0h	0.187		
1h	0.246	0.161	
15h	0.310*	0.419*	0.374*

Asterisk (*) denotes significant difference at p<0.05

Table A6.4. R-values from pairwise analyses of similarities to test significant differences between treatments based on 4th root transformed data

	Ref	**0h**	**1h**
Ref			
0h	0.214		
1h	0.218	0.191*	
15h	0.325*	0.415*	0.361*

Asterisk (*) denotes significant difference at $p<0.05$

Table A6.5. The average abundance of the top 15 ranked species 0.1m^{-1} contributing to the dissimilarity between sample groups derived from SIMPER analyses of log-transformed data; species are ordered in decreasing contribution.

SPECIES	15h	0h
Sabellaria spinulosa	-	18.67
Clymenura sp.	-	3.67
Lumbrineris gracilis	0.67	7.00
Dendrodoa grossularia	-	86.83
Amphipholis squamata	0.33	6.83
Caulleriella zetlandica	0.17	1.83
Balanus crenatus	1.17	3.00
Praxillella affinis	-	2.83
Pomatoceros lamarcki	0.17	8.67
NEMERTEA	0.17	3.33
Crepidula fornicata juv.	-	18.00
Notomastus	1.00	4.50
Balanidae juv.	26.17	-
Harmothoe impar	-	2.83
Exogone verugera	-	0.83

SPECIES	1h	0h
Dendrodoa grossularia	13.33	86.83
Balanus crenatus	68.83	3.00
Sabellaria spinulosa	7.33	18.67
Lumbrineris gracilis	2.33	7.00
Leptocheirus hirsutimanus	4.00	0.33
Pomatoceros lamarcki	3.17	8.67
Crepidula fornicata juv.	0.33	18.00
Amphipholis squamata	0.50	6.83
Praxillella affinis	-	2.83
Notomastus sp.	1.33	4.50
Polydora caeca (agg.)	2.00	4.83
Nucula nucleus	0.33	10.00
Harmothoe impar	-	2.83
Polycirrus sp.	2.67	1.00
NEMERTEA	1.33	3.33

SPECIES	1h	15h
Balanus crenatus	68.83	1.17
Sabellaria spinulosa	7.33	-
Dendrodoa grossularia	13.33	-
Leptocheirus hirsutimanus	4.00	0.17
Clymenura sp.	2.50	-
Pomatoceros lamarcki	3.17	0.17
Lumbrineris gracilis	2.33	0.67
Polycirrus sp.	2.67	0.33
Balanidae juv.	-	26.17
Notomastus sp.	1.33	1.00
Pygospio elegans	2.67	-
Sphenia binghami	1.33	-
Thelepus setosus	1.17	-
NEMERTEA	1.33	0.17
Bathyporeia elegans	0.83	0.50

SPECIES	15h	Ref
Sabellaria spinulosa	-	69.75
Pomatoceros lamarcki	0.17	19.00
Crepidula fornicata juv.	-	10.25
Balanus crenatus	1.17	16.75
Typosyllis armillaris	-	12.75
Balanidae juv.	26.17	2.50
Autolytus sp.	-	4.25
Sphenia binghami	-	4.00
Polycirrus sp.	0.33	4.25
Typosysllis sp.	-	4.75
Crepidula fornicata	-	2.75
Lumbrineris gracilis	0.67	3.75
Ehlersia ferrugina	-	2.50
NEMERTEA	0.17	2.50
Perkinsiana rubra	-	2.50

SPECIES	Ref	1h
Balanus crenatus	16.75	68.83
Sabellaria spinulosa	69.75	7.33
Typosysllis armillaris	12.75	0.17
Dendrodoa grossularia	-	13.33
Crepidula fornicata juv.	10.25	0.33
Pomatoceros lamarcki	19.00	3.17
Leptocheirus hirsutimanus	0.50	4.00
Crepidula fornicata	2.75	-
Lumbrineris gracilis	3.75	2.33
Typosyllis variegata	4.75	1.00
Autolytus sp.	4.25	0.83
Ehlersia ferrugina	2.50	-
Polydora caeca (agg.)	2.25	2.00
Perkinsiana rubra	2.50	-
Pseudopotamilla reniformis	5.00	-

SPECIES	Ref	0h
Sabellaria spinulosa	69.75	18.67
Balanus crenatus	16.75	3.00
Typosyllis armillaris	12.75	1.83
Pomatoceros lamarcki	19.00	8.67
Crepidula fornicata juv.	10.25	18.00
Dendrodoa grossularia	-	86.83
Amphipholis squamata	0.75	6.83
Polycirrus sp.	4.25	1.00
Crepidula fornicata	2.75	2.33
Autolytus sp.	4.25	1.00
Polydora caeca (agg.)	2.25	4.83
Typosysllis variegata	4.75	2.83
Notomastus sp.	1.50	4.50
Praxillella affinis	-	2.83
Ehlersia ferrugina	2.50	-

Table A6.6. Pearson product moment correlation coefficients between biological and environmental variables at each sampling point (n=22). Significance levels:*0.05-0.01;**0.01-0.001;***<0.001.

	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**total**	**% gravel**	**% coarse sand**	**% medium sand**	**% fine sand**	**% silt/clay**
1993													
1994	0.67***												
1995	0.43*	0.69***											
1996	0.68***	0.70***	0.88***										
1997	0.65**	0.91***	0.87***	0.91***									
1998	n.s.	n.s.	0.82***	0.67***	0.59**								
1999	n.s.	n.s.	0.83***	0.60**	0.48*	0.93***							
total	n.s.	0.64**	0.96***	0.86***	0.82***	0.93***	0.88***						
% gravel	-0.71***	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.					
% coarse sand	0.68***	0.42*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-0.48*				
% medium sand	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-0.44*	n.s.			
% fine sand	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-0.59**	n.s.	n.s.		
% silt/clay	0.69***	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-0.76***	n.s.	n.s.	0.60**	
Nos. of species	n.s.	-0.43*	n.s.	-0.49*	-0.51*	-0.49*	n.s.	-0.50*	n.s.	n.s.	n.s.	n.s.	n.s.
Abundance	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
d	n.s.	-0.44*	n.s.	-0.48*	-0.51*	-0.48*	n.s.	-0.49*	n.s.	n.s.	n.s.	n.s.	n.s.
$H'log_2$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Nos. of taxa (incl. colonial)	n.s.	-0.47*	-0.46*	-0.52*	-0.54**	-0.53*	n.s.	-0.55**	n.s.	n.s.	n.s.	n.s.	n.s.
Biomass	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

1999:hours of recorded dredging in 1999 (Jan to May incl.); 1998:hours of recorded dredging in 1998 etc; total: total number of hours of recorded dredging from 1993-May 1999incl.

Table A6.7. Spearman rank correlations between macrofauna and environmental similarity matrices.

Numbers of variables	Best variable combination	Spearman rank correlation *(pw)*
1	1999	0.661
1	1998	0.637
1	total	0.606
2	1993,1998	0.687
2	1993,1999	0.664
2	1998,1999	0.657
3	1993,1998,%medS	0.682
3	1993,1998,1999	0.679
3	1993,1996,1998	0.675
4	1993,1998,%medS,%s/c	0.705
4	1996,1998,%medS,%s/c	0.704
4	1993,1996,1998,%medS	0.695
5	1993,1996,1998,%medS, %s/c	0.715
5	1993,1998,total,%medS, %s/c	0.711
5	1993,1997,1998,%medS,%s/c	0.709

1999:hours of recorded dredging in 1999 (Jan to May incl.); 1998:hours of recorded dredging in 1998; 1997: hours of recorded dredging in 1997 etc. total: total number of hours of recorded dredging from 1993-May 1999incl.; %medS: % medium sand; %s/c: % silt and clay.

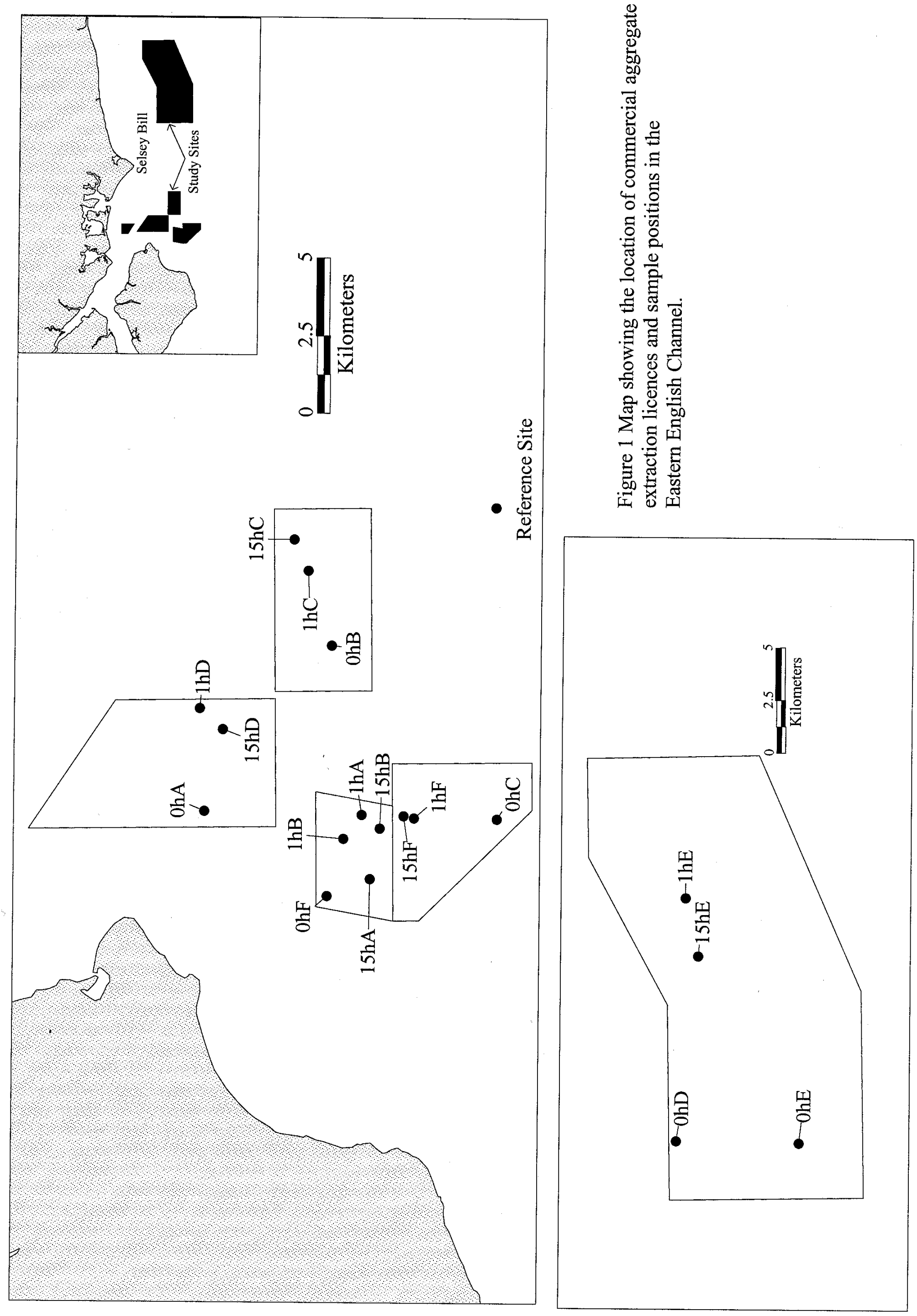
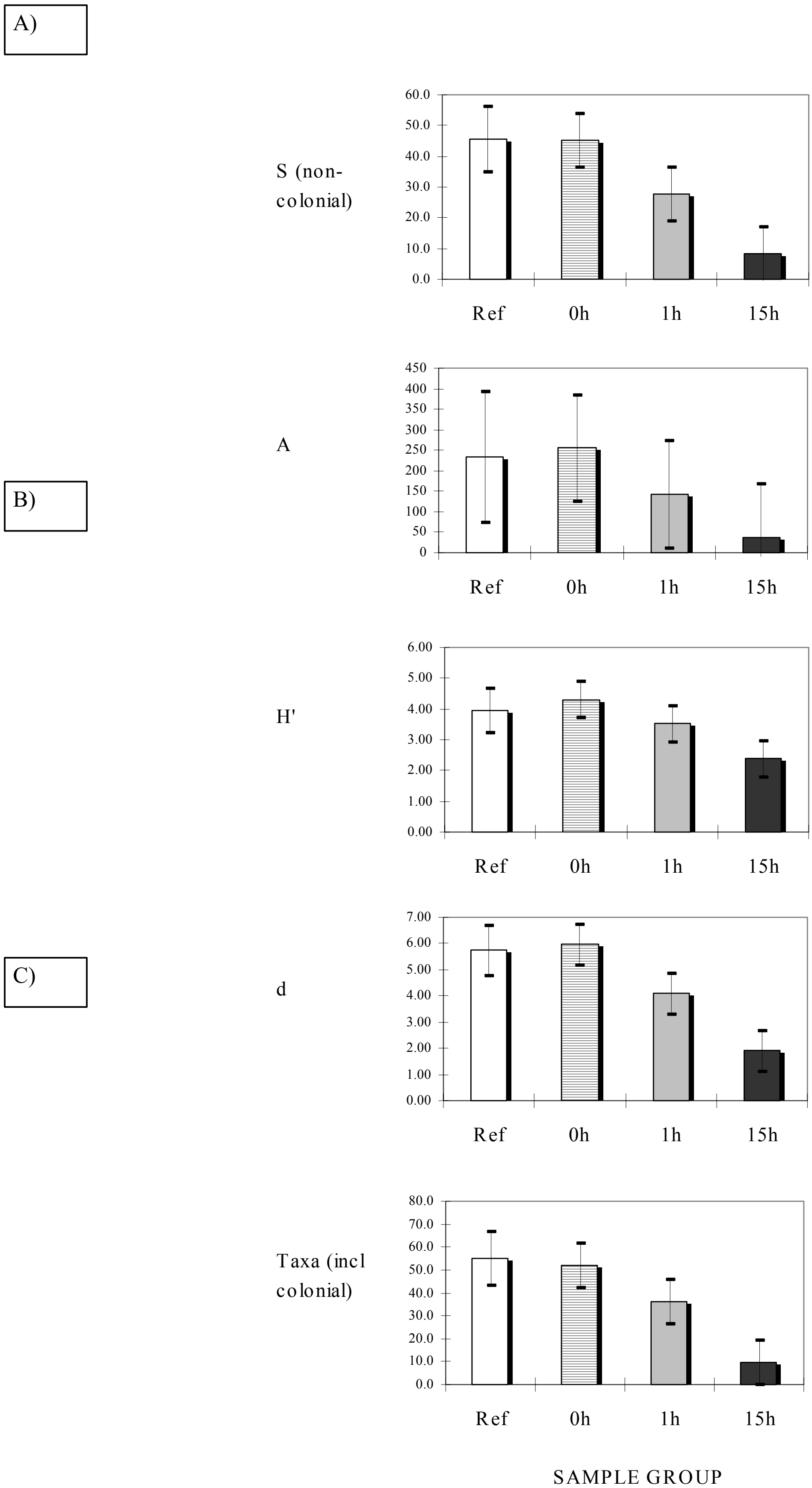


Figure 1 Map showing the location of commercial aggregate extraction licences and sample positions in the Eastern English Channel.

Figure A6.2. Particle size distributions determined from samples taken from each level of dredging intensity.



ANNEX 7: EFFECTS OF SHELLFISH FISHERIES IN THE DUTCH WADDEN SEA; RESEARCH PROGRAMME 1999–2003

To:

ICES Benthos Ecology Working Group
Walpole, Maine, USA

26-29 April, 2000

From:

Dr. Karel Essink

Date

20 april 2000

Subject

Effects of shellfish fisheries in the Dutch Wadden Sea

1 Introduction

Since 1993, four sub-areas of the Dutch Wadden Se, to a total of ca. 25 % of the intertidal flats, have been closed for fishery for seed mussels (*Mytilus edulis*) and mechanical fishery for cockles (*Cerastoderma edule*). Quotas have been set in such a way that at least 60 % of the food requirements of bivalve eating shorebirds is safeguarded. In years with bivalve stocks too low to provide for 60 % of the food requirements of these birds, shellfish fisheries are not allowed.

In 1999 the government decided that since the "closing of areas" measure, not enough data had been produced to base a proper decision on the future of the shellfish fisheries in the Wadden Sea. Therefore, an extension of an evaluation programme was decided. This programme has to enable the policy makers to take proper decisions in 2003 as to the acceptable extent of shellfish fisheries in the Wadden Sea.

2 Evaluation programme 1999–2003

By 2003, the Ministry of Agriculture, Nature Management and Fisheries expects an answer to the following questions:

1) What are the acceptable effects of shellfish fisheries on benthic biotopes (e.g., *Mytilus* beds, eelgrass beds), and bivalve-eating shorebirds?
2) Have the measures of closing sub-areas of the Wadden Sea been effective with respect to food reservation for birds?
3) Are the effects of shellfish fisheries and regulatory measures such as to meet the requirements of the Bird Directive and the Habitat Directive of the European Union?
4) If negative effects of shellfish fisheries will be demonstrated, what additional measures can be taken to minimise these effects?

The evaluation programme concentrates on a series of research questions, derived from the above four policy-related questions. Among these research questions are:

1) Development of numbers of oystercatchers (*Haematopus ostralegus*) in the Wadden Sea. To what extent is there a causal relationship between bird numbers and bivalve stocks, which in their turn maybe dependent both on natural conditions and exploitation by man. What is the prospect on the long run for the bird populations of the present, and of alternative regulatory measures? For the latter question ecological modelling will be applied;
2) Similar questions with respect to the Eider (*Somateria mollisima*) in the Wadden Sea;
3) To what extent did mechanical Cockle fishery influence the benthos communities of intertidal flats? Did a change towards a greater share of polychaetes occur? Can such an effect also be demonstrated by looking at the composition of the bird community in the Wadden Sea, especially when comparing sub-areas open or closed for Cockle fisheries?
4) Is there any indication of mechanical Cockle fishery impeding the natural development of eelgrass (*Zostera marina, Z. noltii*)? If so, this would make a case for closing also potential eelgrass habitat for fishery. At present fishing is not allowed in existing eelgrass beds;

5) What are the functional characteristics of “stable” mussel beds? What mechanisms are involved in their development and survival. What is the impact of seed-mussel fishery on these mechanisms as compared to that of natural disturbances (e.g. ice scour, storms)?
6) Has the sediment composition of the intertidal flats in the Wadden Sea changed (did the sediment get coarser; “muesli-effect”)? Did and does mechanical Cockle fishery contribute to this?
7) What are the characteristics of Cockle beds? What role do natural conditions vs. Cockle fishery play in the dynamics of Cockle population in the Wadden Sea? Derived from that, is there any effect of Cockle fishery on food availability for birds and on conditions for development of stable mussel beds?

Basic information will be supplied by the fisheries itself: where and when is fished, and how much is the catch and the fishing effort. Data from Black Boxes, installed at fishing vessels, will be made available.

4 Research institutes involved; coordinator

The overall project is commissioned by the Ministry of Agriculture, Nature Management and Fisheries to 1) the Dutch National Fishery Research Institute (RIVO-DLO), and 2) Alterra (= former Institute for Forest and Nature Research/IBN-DLO).

The Ministry of Transport, Public Works and Water Management, through the National Institute for Coastal and Marine Management/RIKZ, takes part in the projects on sediment composition (6) and eelgrass (4).

Co-ordinator of the entire evaluation research programme is Dr. Bruno Ens of Alterra, Texel (E-mail: B.J.Ens@Alterra.wag-ur.nl).

ANNEX 8: CONTENTS OF GUIDELINES FOR THE STUDY OF THE EPIBIOTA OF SUBTIDAL ENVIRONMENTS [DRAFT 28.4.2000]

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7 REFERENCES

ANNEX 9: BENTHOS AND NORTH ATLANTIC OSCILLATION (NAO)

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The North Atlantic Oscillation is the dominant signal of inter-annual variability in sea level pressure pattern over the North Atlantic region. It influences the position and strength of weather systems as they cross the North Atlantic which in turn determine precipitation (Hurrel, 1995), sea surface temperature (Planque and Taylor. 1998) the direction and flow of marine currents, the height of waves and the stability of the water column (Reid *et al*., 1998a).

Kröncke *et al*. (1998) showed that off the island of Norderney sublittoral macrofauna abundance, species number and biomass in the second quarter correlated with the North Atlantic Oscillation Index. The mediator between the NAO and benthos is probably the sea-surface temperature in late winter and early spring. Macrofaunal communities were severely affected by cold winters. Mild meteorological conditions connected with a rising NAOI resulted in an increase in abundance, species number and biomass since 1989.

These results are confirmed by several investigations in the Wadden Sea and coastal areas which indicated that cold and mild winters are important determinants of changes in macrofaunal communities. Beukema (1990, 1992), Beukema *et al*. (1996) and Reise (1992) emphasized the importance of cold winters for the structure of littoral benthic communities. Generally, highly successful recruitment after cold winters results in increased biomass (Beukema, 1990, 1992). After a period of warm winters, Beukema (1990, 1992) found an increase in species number, stable total biomass, but a decrease in individual biomass of bivalves.

Therefore, single cold winters appear to have minor long-term effects on the benthic communities of sublittoral coastal regions in the North Sea. Periods of low temperature are part of the natural variability in the habitat and may even stabilize the system (Beukema, 1990, 1992; Reise, 1993). In contrast, a period of mild winters leads to distinct long-term changes in the subtidal benthic communities. These patterns contradict the one claimed for the Wadden Sea by Beukema (1990, 1992) and Reise (1993), but indicate a general difference in the functioning of benthic communities in eulittoral and sublittoral coastal areas.

At a benthic station off Northumberland, Buchanan and Moore (1986) identified cold winters as an ephemeral destabilising factor only. Cold winters favoured the survival in the dominant species at the expense of the lesser ranked species due to reduced primary production. But changes in benthic biomass at the Northumberland Coast are correlated with the intensity of inflow of Atlantic water masses into that area (Austen *et al*., 1991; Buchanan, 1993). Strong connections between the inflow of North Atlantic water to the North Sea and the NAOI (Planque and Taylor, 1998) suggest a possible relationship to the Northumberland benthos.

Tunberg and Nelson (1998) proposed that climatological linkages affecting surface primary production result in bottom-up control of benthic population changes off the west coast of Sweden. The NAOI was positively correlated with Skagerrak deep-water temperature and negatively correlated with stream flow from western Sweden. Stream flow was correlated with benthic abundance and biomass at stations down to 100 m depth, but negatively correlated with bottom water oxygen content.

The detection of relationships between climatic and biological parameters of macrofauna communities is limited to small-scale studies in coastal areas. To investigate whether rising NAOI is connected with changes in offshore macrofauna communities, we revisited 28 Stations in the Dogger Bank area sampled by Kröncke in 1985–1987 (Kröncke, 1992). Stations were located on top of the bank and on the slopes and deeper parts around the bank.

The results of the long-term comparison between 1985–1987 and 1996–1998 can be summarized as follows (Wieking, 1997; Wieking and Kröncke, in prep.):

Multivariate analyses revealed that the most obvious changes between 1996–1998 and 1985–1997 occurred at the northern slope and at the northeastern part of the Dogger Bank. Along the northern slope of the Dogger Bank abundances of species which prefer coarser sediment (e.g., *Echinocyamus pusillus*) increased in the 1990s as well as those of the hyperbenthic predators *Cerianthus lloydii* and *Corymorpha nutans*, whereas abundances of *Ophelia limacina* and *Edwardsia* species decreased.

On top and at the southern slope of the Dogger Bank species with a warm temperate geographical distribution like *Acrocnida brachiata* and *Megaluropus agilis* showed higher abundances compared to the 1980s. In this area we also observed higher values in the sediment silt content.

The analysis of feeding types showed an increase of interface-feeding species on top of the Dogger Bank and along the southern slopes. At the northeastern stations interface feeder decreased and communities showed a higher diversity of feeding types compared to the 1980s.

We suppose that the observed changes are in relation to changes in the NAOI. The possible links between the atmospheric variations and the macrofauna of the Dogger Bank result from several factors. The increase in southern species as well as the decrease of northern species in the southern part might be influenced by increasing bottom temperatures. The increase in species preferring coarse sand indicates a change in sediment composition and food availability caused by resuspension of fine material due to increasing wind stress and stronger currents at the northern slope of the Dogger Bank. In addition, with a stronger inflow of North Atlantic water masses and possibly connected changes in larval supply and primary production, this results in a pronounced dissimilarity of northern and southern macrofauna communities on the Dogger Bank.

Since factors and processes connected to the NAOI in the North Sea are also often discussed in connection with benthos dynamics, we assume that there is a relationship between the NAO and macrofauna communities of the whole North Sea. Strength and time lags of these connections and which community parameter and species are affected will be site-specific and depend on the species composition of the communities in question.

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