COMMISSION OF THE EUROPEAN COMMUNITIES

COST 647 - COASTAL BENTHIC ECOLOGY

REPORT ON THE PERIOD 1985 - 1987

The cerianthid anemone *Pachycerianthus multiplicatus* Carlgren
from the west coast of Ireland.

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COMMISSION OF THE EUROPEAN COMMUNITIES
ENVIRONMENT RESEARCH PROGRAMME
DIRECTORATE GENERAL FOR SCIENCE, RESEARCH AND DEVELOPMENT

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COASTAL BENTHIC ECOLOGY

COST 647

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The COST 647 Project on Coastal Benthic Ecology

- Activity Report for the Period 1985 - 1987.

Introduction

COST (abbreviation for "Coopération europénne dans la domaine de la Recherche Scientifique et Technique") forms a framework and forum for European research co-operation which includes, and extends beyond the frontiers of, the European Community .

Project 647 dates from 1979 and derives from a series of meetings where scientists from different countries met to consider the then status of benthic ecology and the problems of accurately evaluating biological changes in the marine environment. They recognised that :

a) benthic ecological studies in general were short-term, un-coordinated and often non-comparable in their methods;

b) a few extended studies had greatly expanded awareness of how local physical and biological factors, and especially key species, influenced spatial and temporal variation;

c) the general inability to set data in a geographical context could often make it unclear whether or not changes ascribed to local conditions (either natural or man-made) were in reality part of a broadscale, natural pattern;

d) the dynamic character of communities rendered useless the old narrow concept of "baselines" and necessitated its replacement by an awareness of the ranges of temporal variation that are entirely natural in different types of communities;

e) while toxicological studies were revealing the extreme sensitivity of larval stages to pollutants, the wide natural fluctuations in annual recruitment to benthic populations suggested that larvae, or other phases in the overall reproduction / repopulation process were also very sensitive to natural variables. The latter appeared to be climatic / hydrographic, but little was known about their operation.

In view of the foregoing, it was agreed that new approaches were urgently required in coastal ecology , and these emerged as the specific objectives of COST 647. The overall intent was to replace the existing "baseline" concept with a much broader range of knowledge and understanding, covering the following:

1. the spatial and temporal scales of natural variability over as long a time frame as possible, to give reasonable assurance that a wide range of climatic/hydrographic events had been observed.

2. sufficient understanding of community dynamics to allow prediction of the consequences to the whole community of dramatic changes in the abundance of individual species as a result of natural factors or selective pollutants. To this end, intensive study of natural variability, and experimental manipulation of community composition, would reveal the identity of the "key species" (if they existed in a particular community) and the extent to which community composition was controlled by biological interactions or resulted from chance physical events.

3. sufficient understanding of the specific causes of biological change to permit prediction about the consequences of natural events with some degree of certainty. Special emphasis was to be placed upon the population dynamics of the key species, and particularly upon the extent to which variations in their reproductive cycles, recruitment and mortality could be related to changes in natural physical conditions.

While elements 2 and 3 could be dealt with at a local level, and were to varying degrees incorporated in much current work, they would certainly benefit from a co-ordinated, harmonised approach. Element 1 became the hallmark of COST 647. Simultaneous studies of selected communities were proposed, using the same or intercalibrated methods, in a network of recording stations, across the geographical range of each community.

From the many benthic habitats and communities around the Atlantic coasts of Europe, four types were selected for collaborative study. Among the criteria used in their selection were: wide geographical distribution around Europe ; wide availability in currently non-polluted waters, or relative freedom from frequent physical destruction ; and a good data base resulting from current studies in one or more countries. Their selection acknowledges the fundamental division of benthic habitats according to substratum type (rocky or sedimentary) and that they exist both subtidally and intertidally.

These four communities were proposed as separate programmes within the overall project and four co-ordinators were nominated to harmonise methods and data analysis in each programme, and to facilitate interprogramme discussions (Table A). The methods appropriate to each programme would be markedly different but the biological data sought would be similar, i.e. community composition and dynamics ; the identification of the most important interactions and of key species (if they exist) ; the population dynamics and lifespans of key or major species, with special emphasis upon natural variation in their reproduction and recruitment.

Table A.

Habitat	**Community**	**Co-ordinator**
i) Subtidal rock	Ascidiacea	T.Lundalv (Sweden)
ii) Intertidal rock	Patellidae / Trochidae / Cirripedia	J. Lewis (United Kingdom)
iii) Subtidal sediment	*Amphiura* / *Abra*	L.Cabioch (France)
iv) Intertidal sediment	*Macoma* / Polychaeta	J. Beukema (The Netherlands)

The rationale behind the Project was incorporated into a 'Memorandum of Understanding' which was signed by Belgium, Denmark, France, the Federal Republic of Germany, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden and the United Kingdom. Italy and Greece have since joined COST 647. The continuing development of the constituent programmes is overseen by a Concertation Committe, which comprises representatives from each participating country (see Appendix 1).

For its first five-year phase, the Project had 'Category III' status within the COST framework, i.e. where each country funded its own research activity, with the Commission of the European Communities providing a co-ordinating secretariat, but no financial support. Since 1984, COST 647 has enjoyed "Category II" status which means that some money can be provided by the Commission for symposia, workshops, and co-ordination meetings. National participation to the end of 1987 was as outlined in Table B.

Taking advantage of this new status, a symposium ("Long-term changes in coastal benthic communities") was held in Brussels, in December 1985, to mark the first five year phase of COST 647. The proceedings were subsequently published in the international journal , "Hydrobiologia", and were later issued in a separate, commemorative volume.

Over the intervening period, each 'habitat' has had its own co-ordinating workshop: Subtidal Rock (Galway, Ireland; September / October, 1986) ; Subtidal Sediment (La Coruna, Spain ; October, 1986) ; Intertidal Sediment (St. Valery-Sur-Somme, France ; December, 1986) and, Intertidal Rock (San Sebastian, Spain ; August , 1987). The proceedings of these workshops are presented chronologically hereunder and form the main body of this Activity Report.

A proposed extension of COST 647 to the Mediterranean was considered at a specially convened meeting in Ferrara (Italy) in June 1985. Presentations were made on recent and current benthic research programmes in some French, Italian and Greek institutes and universities. It was patent that some of the Mediterranean work could give direct, geographic extension (in a faunistic sense) to the subtidal sediment and subtidal rock programmes of COST 647. Further, there was general agreement that an entirely new element , focusing on the *Posidonia* community, could be added to COST 647. A proposal to the latter effect was tabled at the February 1987 meeting of the COST 647 Concertation Committee meeting. It was agreed that the aims, research schedule and geographical spread of the proposal were completely in harmony with the COST 647 rationale and the meeting unanimously endorsed the incorporation of the *Posidonia* project into 647. The meeting ratified the selection of C. F. Boudouresque (France) as specific project co-ordinator. The *Posidonia* proposal is reproduced in full below , following on the reports of the 1986 - 1987 workshops.

Invited rapporteurs to the 1985 Brussels' Symposium i) applauded the growing corpus of well-focused ecological data being generated within the COST 647 project at large, ii) drew attention to the varying capacities within the participating institutes to exploit this data, iii) criticised the generally low level of biostatistical expertise within the project, and iv) emphasised the need for greater cross-comparison between data sets from different geographical areas and for enhanced intercalibration and standardisation in methods and techniques. Responding to these remarks, it was decided (and agreed at the 1987 Concertation Committee meeting) that the next composite workshop would, in large measure,

TABLE B: National participation in each programme to 1987

	Subtidal rock	Intertidal rock	Subtidal Sediment	Intertidal Sediment
Norway	C	**I**	**X**	n/a
Sweden	**C**	n/a	C	n/a
Denmark	n/a	n/a	C	**C**
Germany	**I**	n/a	**C**	**C**
Netherlands	**I**	**I**	C	**C**
Belgium	n/a	n/a	C	**X**
U.K.	**I**	**C**	C	**C**
Ireland	**C**	**X**	**C**	C
France	**I**	**I**	**C**	C
Spain	**X**	C	C	I
Portugal	**X**	**C**	**X**	**X**

<u>Key to symbols</u>

C Pre-existing studies which have become the core of that habitat programme or new studies developed specially for COST purposes. In some cases, there was specific financial support which variously allowed employment ranging from one part-time technical assistant up to 4 full-time scientists.

C No specific COST funding. Independent research or studies funded for other purposes, but which have been adapted to varying extents to provide data relevant to COST 647. Most data are obtained on a part-time basis.

I Expressions of interest.

X The habitat is available, but there is no activity under COST 647.

n/a The habitat and community are not readily available.

address the perceived shortfall in COST 647 data analysis. This is scheduled to take place in Crete over the period September 20 to 24th., 1988, and has the central theme : "Space and time series data in coastal benthic ecology".

The workshop will allow the presentation, by each co-ordinator, of a critical review of the four habitats studied to-date. These reviews will be set in context of the rationale and aspirations of the overall programme and should not only allow some appreciation of the progress (or lack of same) but equally serve as bases for charting the future course of COST 647. Each co-ordinator has available to him the services of a consultant data-analyst in preparing his review. The analysts will be present at the workshop and will respond to the review papers with critical / contrasting interpretations, suggestions on alternative methodologies and advice on future programme planning. Further, a researcher of post-doctoral grade has been appointed to liaise between the project co-ordinators, the consultant analysts and individual researchers, particularly those responsible for longterm data sets. It is intended to publish the proceedings of the Crete workshop, which will also include a number of invited papers from recognised experts in the field.

Brendan F. Keegan.
Chairman,
COST 647 Concertation Committee.

Acknowledgements : The assistance of Dr. Patricia Dinneeen , Dr. Pauline King, and of Ms. Sandy Lawson in the preparation of this report is gratefully acknowledged.

HABITAT REPORT 1. SUBTIDAL ROCK WORKSHOP.
GALWAY, IRELAND - SEPTEMBER 30TH. TO OCTOBER 3RD., 1986

CHAIRMAN: T. Lundalv (SWEDEN)

PARTICIPANTS : J. Costelloe, B.F. Keegan (IRELAND), B. Picton (NTH. IRELAND), B. Gulliksen, H. Christie (NORWAY), I. Wallentinus, C. Larsson (SWEDEN), B.Bullimore (UNITED KINGDOM).

HOST ORGANISATION/ ORGANISER: University College, Galway / B.F.Keegan.

PROCEEDINGS:

1. Delegates presented reports on the status of their individual programmes. It was agreed that the overall programme was in danger of collapse if the "ear-marked" funding was not forthcoming from some source.

2. After lengthy discussion, the Core Programme was revamped, notably to de-emphasise the ascidian element in the communities, to include benthic macroalgae, to highlight the interest in the intercalibration of methodologies, and to promote the development of computer-aided image analysis and remote sampling techniques.The revamped programme is outlined in Annex 1.1

3. Consideration was given to possible common ground for joint reports/publications. It was concluded that satisfactory material existed for the ascidian, *Ciona intestinalis* in North and South Norway, Sweden and Ireland. Data on long-term variation, population dynamics and gonadal cycles is to be submitted to T. Lundalv for preliminary synthesis and evaluation. The role of echinoderm predation /grazing as a structuring element in rocky subtidal communities was foreseen as a future subject for joint efforts.

4.There was a discussion of possible ways and means to enhance and expand the project overall, particularly within the context of E.E.C. R & D programmes. It was queried if the Environmental Programme might be a suitable vehicle to carry the central facility alluded to in element 'D' of the Expanded Core Programme ? Further, could "EUROMAR" be incorporated into, or otherwise linked to the COST Subtidal Rock programme ? These matters were to be put to the Brussels' Secretariat at the next meeting of the Concertation Committee. In an attempt to promote greater cohesion within the programme, it was mooted that the question of having jointly supervised Ph. D. programmes shouLd be examined; students of such programmes might be able to work between different (i.e. transnational) geographical sites.

5. It was decided that the revamped Core Programme should be looked at again at the upcoming Crete Workshop. The need to prepare a "Layman's Exposition and Promotion" of COST was again emphasised. As one step in this direction, T. Lundalv undertook to prepare a 'preamble'

which would cite the pertinency of epibenthic organisms in pure and applied research contexts: this preamble forms Annex 1.2 of this report.

6. Delegates aired their views on the likely contribution of the Subtidal Rock Group to the Crete workshop on time and space series data analysis. B. Keegan expressed the view that there was likely to be a common, formatted appproach for all the habitat groups and that this would be discussed at the next meeting of the COST Concertation Committee.

ANNEX 1.1

CORE PROGRAMME - SUBTIDAL ROCK HABITAT

1. The Programme focuses on the epibenthic communities (including algae) of hard substrates.

2. Permanent test areas (minimum 1 m^2 each) should be set up at different depths (e.g. 5, 15 and 25m below extreme low water spring) at each site. Where possible or practical, it is recommended that the test areas be located on vertical or near vertical surfaces.

3. Test areas should be monitored, in non-destructive fashion, on a seasonal (four times per year) basis. Stereophotography is the preferred (**but not the exclusive**) sampling method.

4. Test areas should be subjected to quantitative analysis, at least with respect to density and/or percentage cover of species of quantitative or presumed ecological importance. Further data collecting/processing methods should be intercalibrated.

5. Supporting physical and chemical data (at least temperature and salinity) should be collected as often as possible.

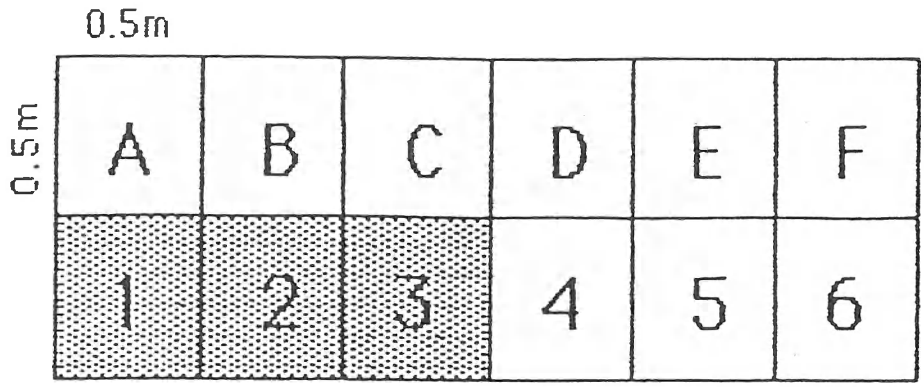
6. The Programme seeks to promote the research and development of new techniques (e.g. computer-aided image analysis, remote sampling) for collecting and processing relevant data.

Expanded Core Programme

A. Comparative recolonization experiments

Aims:
To establish the sequence and rate of recruitment within experimentally denuded test areas.
To account for and compare characteristics of succession and community development between
1) different geographical regions
2) different environments within a region, and
3) adjacent natural and experimentally denuded substrates.

Methods:
Test areas (minimum $3m^2$) should be marked at three different depth levels for at least one site.
The experimental areas should be stereophtographed and then treated as follows:



Compartments A to F would function as controls, while those numbered 1 to 3 would be mechanically denuded prior to, and 4 to 6 following upon , the major settlement period. The development within the test areas should then be recorded non-destructively four times per year. Alternatively, recruitment panels can be used to the same end.

A comparative measure of resilience could be provided by cluster analysis (based on % cover and an index of similarity or distance) of data from the denuded substrates and adjacent natural communities.

B. Recruitment

Aims:
To determine seasonal and annual variability in recruitment and, if possible, to correlate this with climatic/hydrographic factors.
To estimate the effects of competition for space and predation on recruitment.

Methods:
Artificial settlement panels (preferably non-glazed and approx. $0.1m^2$) should be suspended adjacent to permanently-marked test areas in a way that prevents benthic predation. One set of panels should be exchanged monthly, one set each time the test areas are photographed (four times per year) and one set once a year. Recruitment and community development should be analyzed on the different sets of panels and be compared to corresponding data from the permanent test areas.

C. Biological interactions

Aims:
To identify possible "key" species in the community and to quantify their functional roles with regard to community structure and dynamics.

Methods:
Appropriate methods can only be specified in relation to the functional characteristics and biology of

a particular species or species group. Echinoderm predation/grazing is recommended as the first target for such interaction studies.

General approaches:

1) Predation: Effects on the community of predator exclusion/inclusion experiments by means of selective removal, cages or settling panels that are protected from benthic predators.

2) Competition for space: Effects on the community of selective removal of one or several species within experimental test areas. Studies on fecundity and reproductive strategies should also be incorporated.

3) Energy flow: Production estimates for selected species or entire communities.

D. Methodology

The value of stereophotographic sampling in ecological studies is increasingly appreciated. Whilst it facilitates the collection of large amounts of data, with minimum disturbance to the environment, ready and full utilization of this technique is curtailed by the time-consuming manual analysis of the images. However, computer-aided capacity in this regard is now being developed. COST participants need to communicate their particular requirements to the developers and assist, where necessary, in adapting such capacity to marine ecological research. Early access to what is likely, at first, to be expensive technology, may necessitate the creation of a central facility, on a multi-institutional basis. This, of itself, would impose standards and calibrational codes at both intra- and international levels.

ANNEX 1.2

COST 647 SUBTIDAL ROCK PROGRAMME

General Background

Subtidal hard substrates constitute a major part of the coastal marine ecosystems along much of the European coastline. Rocky coasts are important or dominating in countries like Finland, Sweden, Norway, U.K., Ireland, France, Spain, Italy, Yugoslavia and Greece. Further, in areas where natural rocks or boulders are less prominent, substantial areas of hard substrates are usually present in the form of man-made structures, including ships.

Many organisms linked to hard substrates are of economic importance. Among the commercially interesting species may be mentioned lobsters, crabs, oysters, mussels, abalone, sea urchins and several species of benthic macroalgae. There is reason to believe that rocky subtidal communities are important in providing shelter and feeding grounds for several fish species of commercial importance. Furthermore, rocky subtidal organisms create problems and financial loss due to fouling of various man-made structures. Toxic coatings used to prevent fouling, in turn, create new problems in the coastal environment. Consequently, there is need for more biologically sound measures of fouling-prevention; these can only be based on a better understanding of natural control mechanisms in biological communities.

It is known that rocky subtidal communities are often highly productive, although little hard-core data is as yet available. The few investigations made in this field seem to indicate that rocky subtidal communities are typically 10 - 100 times more productive than comparable sediment communities. This could mean that the quantitative role of rocky subtidal communities in the circulation of energy and matter in coastal ecosystems has been widely underestimated in many geographical areas.

In spite of the interesting basic features stated above, very little ecological research has been directed towards rocky subtidal communities in the past. Even today, only a handful of researchers are active in this field on the European scene. There can be no doubt that the reason for this lack of activity is closely linked to methodological difficulties in studying rocky subtidal communities in the past. Unlike other major components of the marine ecosystem (sediment infauna, plankton, neuston), there were no quantitative sampling methods for the rocky subtidal that could be operated remotely from a ship. Quantitative work on natural communities has been totally dependent on diving, which introduces a major restriction in itself. Furthermore, the conventional manual sampling techniques used in the past were highly time-consuming and cumbersome and, at the same time , largely unsuitable for the study of the dynamic properties of the communities.

The introduction of stereophotographic sampling techniques, upon which the COST 647 Rocky Subtidal Programme is based, has opened totally new possibilities. This technique permits rapid, non-destructive and fully quantitative sampling of well-defined communities, populations or even single individuals, at chosen intervals, over any period of time. Important properties in the studied communities, such as individual size, growth and spatial distribution can be measured accurately in 3 dimensions. Detailed and accurate studies of population-dynamic features can be undertaken. The technique can also be used to monitor the results of various manipulative field experiments *in situ*.. Photographic sampling permits convenient and compact long-term storage of vast amounts of primary data which can be examined or up-dated in the light of new findings. Available results, especially from long-term studies in Sweden (16 years) and Norway (7 years), clearly indicate that the technique provides a sound basis for highly sensitive detection of biological change (short- or long-term) in the coastal zone.

In addition to the unique possibilities stated above, rocky subtidal communities exhibit a number of features that are ideal for biological monitoring purposes: (1) The communities are dominated by sessile organisms, which are unable to avoid possibly unfavourable conditions in the surrounding water mass; (2) Rocky subtidal communities include both primary and secondary producers (several trophic levels) with species exhibiting a wide range of life strategies and ecological requirements. Various components in these communities could therefore be expected to react to a very wide range of changes in environmental factors. Benthic macroalgae provide a much more conservative representation of primary production than planktonic algae, upon which the bulk of research has been focussed; (3) Detailed representation of various water depth strata can easily be obtained in a single locality; (4) Unlike the rocky intertidal, where similar studies can be undertaken, the rocky subtidal constitutes a fully marine and relatively stable environment, where short-term influences of climatic extremes are less likely to create "noise", complicating the interpretation of observed data.

The facts and ideas stated above offer justification for intensified studies on rocky subtidal communities, both as a means of obtaining more sensitive detection of possible change in the marine environment and of filling large gaps in our basic knowledge about a hitherto largely neglected, but probably highly important part of the coastal ecosystem. However, the methods currently used in the COST Rocky Subtidal Programme still have limitations preventing full utilization of the possibilities. One of these limitations is the dependence on diving. This dependence restricts the number of students and researchers who are willing to commit themselves to rocky subtidal studies, both because of the physical requirements and the risk that studies can be interrupted by minor health problems, etc. Stricter safety regulations in many research organizations also tend to complicate the utilization of diving. Another limitation in the present programme lies in the analysis of the primary stereophotographic material. The manual analytical techniques hitherto used are highly time-consuming and require much training on the part of the personnel before they become fully reliable.

There is no doubt that the limitations mentioned can largely be overcome by utilization of technical advances combined with new specific adaptations. One example is that recent and foreseeable developments within the field of computer-aided image analysis open possibilities to automate much of the picture analysis work. Diving in connection with underwater photographic recording could also be substituted for by "R.O.V's" (Remotely Operated Vehicles) equipped to carry the camera equipment to specific sites on the bottom. The remaining problem is that this is still an expensive and complicated technique and there is need for additional technical developments which could facilitate and lower the cost of research applications.

It thus seems clear that important rocky subtidal research could be promoted by technical development and adaptation. The high-tech and high-cost nature of such applications call for co-operation both within the research community and with industry. COST seems to offer an ideal background for such co-operation, and a new emphasis on technical development has been incorporated into the Rocky Subtidal Programme.

T. LUNDALV

HABITAT REPORT 2. SUBTIDAL SEDIMENT WORKSHOP. LA CORUNA , SPAIN - OCTOBER 28TH. TO 31ST., 1986

CHAIRMAN: L.Cabioch (FRANCE)

PARTCIPANTS: J. Dorjes, A. Kunitzer, H. Rumohr (FED. REP.GERMANY); C. Heip, P. Herman (BELGIUM); K. Jensen (DENMARK); C.F.Boudouresque, F. De Bovee, J.M. Dewarumez, R. Plante, C. Retiere (FRANCE); A. Nicolaidou (GREECE); P.Dinneen, B.F. Keegan, B. O'Connor (IRELAND); G. Colombo (ITALY); A.C. Smaal (THE NETHERLANDS); M. Conneely, T. Pearson, E.I.S. Rees (UNITED KINGDOM); F. Aguirrezabalaga, N. Anadon, M. Ibanez, E. Lopez-Jamar, C. San Vincente, C. Sola , A. Romero (SPAIN).

HOST ORGANISATION / ORGANISER: Instituto Espanol de Oceanographica / E. Lopez-Jamar

PROCEEDINGS:

1. The principal items on the agenda were: **a**) progress reports from delegates on developments since the 1985 Brussels' Symposium and on their national situations with respect to participation in COST 647; **b**) a reevaluation of the core programme; **c**) a presentation on the objectives and progress of the "ICES North Sea Benthos Ecology Working Group" ; **d**) preliminary consideration of the likely format and content of the proposed Crete Workshop on Data Analysis, and **e**) a discussion of possible, trans-national research applications (within the broad COST framework) in context of the E.E.C. Environmental Research Programme.

2. The individual, delegate reports have been reproduced, in whole or in abstract, and (excluding those by Boudouresque and de Bovee) form Appendix 2 to this Activity Report. Some of these are of a more general nature than actual updates of recent results; they are presented in the following sequence:

N. ANADON:

"Subtidal baseline survey off the North Coast of Spain".

C.F. BOUDOURESQUE:

"Problemes d'echantillonnage dans les herbiers de *Posidonia* ".

F. de BOVEE:

"Standardisation et calibration de methodes d'echantillonnage. Aspects meiobenthiques".

L. CABIOCH, P. CONTI, S. FRONTIER, F. GENTIL, Y. LAGADEUC & C. RETIERE:

"Variabilite macrobenthique et phenomenes physiques. Etude du determinisme du recrutement en Baie de Seine orientale: Hypotheses de travail, strategies d'echantillonnage et resultats preliminaires".

G. COLOMBO, C. CORAZZA & V.U. CECCHERELLI:

"Partial observations on macrobenthos and meiobenthos of a bay in the Po River Delta (Sacca di Goro). Consideration of a plan for pluriannual investigations".

M.E. CONNEELY:

"Investigations on the sublittoral macrobenthic communities of Swansea Bay (Northern Bristol Channel)".

J. M. DEWARUMEZ, D. DAVOULT, J. PRYGIEL, R. GLACON & A. RICHARD:

"Macrozoobenthic assemblages in the southern part of the North Sea".

P. DINNEEN:

" Longterm benthic investigations on the south coast of Ireland"

P. HERMAN & C. HEIP:

"Spatial and temporal variability of benthic communities : consequences for monitoring.

K. JENSEN:

"Sampling macrozoobenthos : maximum returns for minimum effort".

A . KUNITZER:

"An *Amphiura filiformis* association northeast of the Doggerbank - species composition, abundance, biomass and population dynamics".

E. LOPEZ-JAMAR:

"Ecology, growth and production of *Thyasira flexuosa* (Montagu) (Bivalvia, Lucinacea) from Ria de La Coruna, North-West Spain".

E. LOPEZ- JAMAR, B. O'CONNOR & G. GONZALEZ:

" Demography and gametogenic cycle of *Paradoneis armata* Glemarec (Polychaeta, Paraonidae) in Ria de La Coruna, North-West Spain"

A. NICOLAIDOU & M. KOSTAKI-APOSTOLOPOULOU:

"Life cycle of *Abra ovata* in a brackish water lagoon in Greece".

B. O' CONNOR:

"The *Amphiura filiformis* community in Galway Bay".

T. H. PEARSON, G. DUNCAN & J. NUTALL :

"Long-term surveillance studies in Loch Linnhe and the Firth of Lorne,West Coast of Scotland".

E.I.S. REES & A.J.M. WALKER:

"Long term variation in benthic populations in Liverpool Bay".

E.I.S. REES & N.A.HOLME:

"A local, enriched macrobenthos association in the Irish Sea."

J.P. REYS, R. PLANTE & M.R. PLANTE - CUNY:

"Sampling problems in the quantitative estimation of microphytobenthos".

H. RUMOHR:

"Synoptic sampling with grab, diver-taken cores, photographs, video and side - scan sonar".

C. SAN VINCENTE, C. SOLA, A. ROMERO, M. IBANEZ & F. AGUIRREZABALAGA :

"Subtidal sediment research on the Basque Coast".

A.C. SMAAL:

"Macrozoobenthos in an ebb-tidal delta complex in the south-west of the Netherlands (the Voordelta)".

3. The core programme was considerered in some detail and minor amendments are included in the agreed version which is outlined in Annex 2. Three sub-programmes on prominent and widely distributed species are presented in the succeeding Annexes 2.1 to 2.3. It was agreed that a further sub-programme on the bivalve, *Tellina fabula* , would be planned, and circularised for comment, by Drs. Dinneen (Ireland) and Lopez-Jamar (Spain) before the Crete Workshop.

4. C. Heip (BELGIUM) informed the meeting of the aspirations of the ICES North Sea Working Group and undertook to elaborate further on the Group's plans at the next meeting of the Concertation Committee.

5. It was recalled that the 1985 Brussels' Symposium on "Long term Changes in Coastal Benthic Communities", the rapporteurs a) applauded the growing corpus of well focused ecological data being generated within the COST 647 Project at large, b) drew attention to the varying capacities within the participating institutes to exploit this data, c) criticised the generally low level of biostatistical expertise within the project, and d) emphasised the need for greater cross-comparison between data sets from different geographical areas and for enhanced intercalibration and standardisation in methods and techniques. It was agreed that the next composite workshop (to be held in Crete) should address the perceived shortfall in COST 647 data analysis . B. Keegan (Chairman, COST 647) undertook to present a resume of suggestions on the possible format of the workshop to the 1987 meeting of the COST 647 Concertation Committee meeting.

6. L. Cabioch introduced the item relating to posible trans-national applications on COST 647 -related research topics within the E.E.C. Environmental Research Programme. Possible logistical problems were discussed, as were the questions of central co-ordination and accountability. While the overall mood of the Workshop was very positive, it was felt that the imminency of the closing date for applications would not permit the necessary inter-institutional preparations. France would be making a unilateral application on COST 647 related studies and might also make a trans-national submission with Belgium and, perhaps also, The Netherlands. It was agreed that the

matter should be considered anew if there is to be a second call for tenders within the overall programme.

ANNEX 2

Core Programme

Sampling Area and Times

An area of $0.5m^2$ should be sampled on four occasions in each year , i.e., 1. during the period when community numbers are at a minimum (early spring in most areas); 2. during the period when community numbers are at a maximum (late autumn in most areas) and two other times spaced more or less equally between the two primary sampling points.

Sampling Gear

Left to the discretion of the individual operator. A minimum of five individual samples corresponding to an area of $0.5m^2$ should be taken on each sampling occasion. A species /sample area curve should be constructed for each sampling area, together with an estimate of the depth of penetration of the sampling gear.

Treatment of samples

Sieve on a 1mm sieve. Preserve in formalin. Sort by eye or using a binocular microscope; staining with Rose Bengal dye recommended.

Data

Identify to species level the four major groups : Molluscs, Echinoderms, Polychaetes, Crustacea. Specific identification of other groups optional but presence should be noted.

Records

No. of species, abundance and biomass. Biomass to be formalised wet weight, after not less than 3 month's storage. Living Mollusc shells to be included. Polychaete tubes removed (if difficult, e.g. *Myriochele* , then inclusion as part of biomass estimate should be noted).

Abiotic Measurements
Granulometry of sampling area to be analyzed initially. Temperature and salinity to be recorded on each sampling occasion. Other environmental measurements optional.

ANNEX 2.1

Abra alba and ***Abra nitida***

Co-ordinators: Eike Rachor (A), Heye Rumor (B) and Alf Josefson (C)

A: Institut for Polar and Marine Research, Postfach 120161, Columbusstrasse, D-2850 Bremerhaven, F.R.Germany.

B: Institut fur Meeresekunde an der Universitat Kiel, Dusternbroocker Weg 20, D-2300 Kiel, F.R.Germany.

C: Kristineberg Marine Biological Station, S-45034, Fiskebackskil, Sweden.

Sampling Methods and Sample Treatment

A minimum of 5 x 0.1 m^2 grab samples to be taken on each sampling occasion. Samples to be sieved on a 1mm sieve. In order to get a proper estimate of the time and density of recruitment subsamples should be sieved through a 0.25mm mesh. Three subsamples may be taken from a grab, adding up to at least 20 cm^2 ; subsamples from the same sample may be combined. Use of the Barnett fluidised bath is optional. Sorting by eye for 1mm fraction and under stereomicroscope for 0.25mm fraction. Samples should be taken at least four times a year with special attention being paid to the time of expected minimum abundance, spat fall and occurrence of a major part of recruits in 1mm mesh.

Recruitment, Growth and Mortality

These are to be estimated from length frequency histograms. Maximum shell length to be read to at least 0.25mm using an ocular-micrometer.

Reproductive Cycle

From the size groups >3mm, five specimens from each class are opened and the gonad stage is assessed, i.e. immature, developing, full, partially spent, fully spent. Oocyte diameter to be measured for a sufficient number of eggs and their mean recorded.

Biomass (Optional)

Wet weight per m^2. Relationship between shell length and ash-free dry weight (afd) in each sample is needed for at least the first year of study. Total afd per m^2 can then be calculated.

Any Other Information

Parasitism, predation, etc.

ANNEX 2.2

Amphiura filiformis, A. chiajei and ***Acrocnida brachiata***

Co-ordinators: Brendan O'Connor (1), Tim Bowmer (1), Franck Gentil (2), Yvon Corouge (2)

1. Department of Zoology, University College, Galway Ireland
2. Station Biologique, 29211 Roscoff, France

Sampling Methods and Sample Treatment

A minimum of 5 x 0.1 m^2 grab samples to be taken on each occasion. Samples to be sieved on an 0.5mm sieve. This can be split later into a 0.5mm and 1.0mm fraction and the 0.5mm residue can be sorted independently. Should the fraction greater than 0.5mm prove so large as to greatly increase sorting time, a 1.0mm sieve can be used. In order to properly estimate recruitment, subsamples (taken either from extra grab samples, mouse trap sampler or diver taken surface skims or cores) should be sieved through a 250μm sieve. Use of the Barnett fluidized sandbath is optional. Sorting under a stereomicroscope. Fixation and preservation in 4% neutral buffered formalin. Samples should be taken four times a year, i.e. winter, spring, pre and post spawning.

Recruitment, Growth and Mortality

These are to be determined from disc diameter and oral width size frequency histogrammes. Disc diameter is measured on the aboral surface from the outer edge of one set of radial plates to the edge of the disc in the opposite interradius. Oral width is measured as the distance from the distal edge of the buccal shield in one interradius to the outer edge of the 1st ventral arm plate in the opposite interradius (the madreporite bearing interradius is never used). Both measurements to be made with an ocular micrometer, the disc (at x 10 magnification) read to the nearest 0.25mm and the oral width (at x 20) read to the nearest 0.1mm.

Reproductive Cycle

To determine the reproductive condition of *Amphiura* , thirty individuals per sampling session should be examined in squashed, stained preparations to measure oocyte diameter (ca. 200 oocytes) and stage the gonad. The recommended method for assessment of ophiuroid maturity based on the "stages" of the gonads, is adopted from Fuji (1960), Tyler and Gage (1979) and Bowmer (1982).

Squash Technique

1. Remove gonad, place on a slide with a drop of water; cut it open to liberate oocytes and add 1 drop of albumen. Cover with slip. Dry for twenty four hours then place preparation in a mixture of 3/4 alcohol - 1/4 formaldehyde for one hour.

2. Stain for nuclear material.

3. Count and measure oocytes; it is recommended to do so for all oocytes in two gonad sacs per individual. Should it be possible, a histological technique is outlined below as it is preferable to squashes.

Histology

1. Decalcification in Bouin's fluid for four days with one change of fluid.

2. Dehydration, clearing and blocking out by standard histological procedure. (56-58 degrees centigrade MP wax is recommended).
3. Sectioning at 7mm and staining in Ehrlich's Haemotoxylin and eosin.

In counting oocytes, gonads should be picked at random and all those sectioned through the nucleus should be measured to ensure a representative count. If possible, several gonads from around the body should be examined (this is facilitated by horizontal histological sections). Where the staging of maturity is concerned, it should be remembered that, in the males, each stage represents a different phase of the germ cell development, i.e. spermatogonia, spermatocytes, etc. In the females, however, only primary oocytes are ever found except some hours before spawning when the later development occurs.

Biomass (optional)

Wet weight per m^2. For a more accurate measurement, gently sieve through a 2mm screen and individually preserve specimens. Determine relationship between wet weight and oral width.

Any other information

Number of arms, number of arms regenerating, predation.

References

Bowmer, C.T. 1982. Reproduction in *Amphiura filiformis* (O.F.Muller) (Ophiuroidea, Echinodermata) : Seasonality in gonad development. *Mar. Biol.* 69 : 281 - 290.

Fuji, A. 1960. Studies on the biology of the sea urchin. *Bull. Fac. Fish. Hokkaido Univ.* 11(2): 49 - 57.

Tyler, P. & Gage, J. 1979. Reproductive Biology Of Deep Sea Ophiuroids from the Rockall Trough. In " *Cyclic Phenomena in Marine Plants and Animals*". Proc. 11th. Mar. Biol. Symp. Eds.: E. Naylor & R. Hartnoll, Pergamon Press, Oxford. 466 pp.

ANNEX 2.3

Melinna palmata

Organisers: M. Guillou (1) and T. Pearson (2)

1. Laboratoire d'Oceanographie Biologique, 6 Rue le Gorgeu, 29283 Brest Cedex, France.
2. Dunstaffnage Marine Research Laboratory, P.O. Box No. 3, Oban, Argyll, Scotland.

Sampling

A minimum of 5 x 0.1 m^2 grab samples to be taken to obtain a mean of 200 individuals on each sampling occasion (if less than 100 obtained from five grabs then more grabs to be taken to obtain this minimum). Samples to be sieved on a 1mm sieve. In order to get a proper estimate of the time and density of recruitment, a 0.5mm sieve to be used after the presumed spawning period. The sampling to be repeated every two months during the first year (if monthly sampling can't be done). For the following years, four times per year (i.e. winter, spring, pre and post spawning) should be enough.

Recruitment, Growth and Mortality

These to be estimated from length frequency histograms. Length measurement of live specimens (preferable). Place worms in a solution of 0.2% MS 222 (Sandos Products Ltd.) in sea water for 5 - 10 minutes. Suspend from a pair of light forceps and measure to the nearest mm (Hutchings, 1973).

Length measurement of preserved specimens (only if live material cannot be obtained), on formalin preserved specimens measure width of the 10th setiger (Guillou et Hily, 1982). In both cases a minimum of 100 specimens per month should be measured.

Reproductive Cycle

10 male and 10 female specimens to be examined each month.

a) Female

Puncture body wall. Withdraw a small drop of coelomic fluid and place in a drop of sea water on a mocroscope slide. Measure the diameter of 50 - 60 oocytes per specimen using a micrometer eye piece. Put into 0.25mm size classes ranging from 0-4.25mm, giving 17 classes in all.

b) Male

Using the above technique examine the fluid and classify the sperm cells into the relative proportions present in each of the following categories (Hutchings, 1973; Guillou et Hily, 1982):

a) Single spermatogonia (2-8 cells, 5µm diameter)
b) Small rosettes (8-32 cells, 10µm diameter)
c) Large rosettes (32-256 cells)
d) Sperm morule (composed of spermatozoa with flagellum)

Biomass (optional)

Wet weight per m^2

Any Other Information

References

Guillou, M. & Hily, Ch. 1983. Dynamics and biological cycle of a *Melinna palmata* population (Ampharetidae) during the recolonisation of a dredged area in the vicinity of the Harbour of Brest (France). *Mar. Biol.* 73, 43-50.

Hutchings, P.A. 1973 (a). Age structure and spawnings of a Northumberland population of *Melinna cristata* (Polychaetae: Ampharetidae). *Mar. Biol.* 12, 128-227.

Hutchings, P.A. 1973(b). Gametogenesis in a Northumberland population of the polychaete *Melinna cristata* . *Mar. Biol.* 18, 199-211.

HABITAT REPORT 3. INTERTIDAL SEDIMENT WORKSHOP.
ST. VALERY-SUR-SOMME, FRANCE - DECEMBER 7TH. TO 10TH.,1986.

CHAIRMAN: J.J.Beukema (THE NETHERLANDS).

PARTICIPANTS: P.Brinch Madsen (DENMARK); J. Coosen, R. Dekker, K.Essink, H. L. Kleef (THE NETHERLANDS); G.Bachelet, M. Desprez, J.-P. Ducrotoy, B. Elkalm, B. Sylvand (FRANCE); S. Flothmann, A. Haase (FED. REP. GERMANY); M.F. Dyer, D. S. McLusky (UNITED KINGDOM); J.G. Wilson (IRELAND).

HOST ORGANIZATION:GEMEL (Groupe d'Etude des Milieux Estuariens et Littoraux), Station d'Etude en Baie de Somme, 80230 St. Valery/Somme.

PROCEEDINGS:

1. Reports on ongoing work

Reports were presented on work on intertidal macrozoobenthos in Denmark, FRG, the Netherlands, Britain and France. Except for two German groups (Michaelis-Rhode and Dorjes), all participants in the Programme were present and reported on their progress.

Long-term data series on the abundance of macrofauna species are now available from Denmark (several transects on tidal flats in the Wadden Sea), FRG (several sampling stations on a tidal flat and in shallow subtidal water near Norderney) and the Netherlands (several stations and transects in the eastern and western part of the Dutch Wadden Sea). Outside of the Wadden Sea area, the data series are generally short, or are limited to highly disturbed locations. Consistent sampling along the lines outlined for the COST 647 programme (Annex 3.1) has frequently been difficult, e.g. the standardized methods could not be applied (because the data were gathered primarily for a different purpose) or the sampling stations were disturbed and had to be changed (as a consequence of heavy sedimentation or erosion).

Thus, so far, it is only within the Wadden Sea area that some data series can be compared to assess common trends in the fluctuation patterns of benthic species. More or less synchronous fluctuations are indeed taking place in the population size of several species living at different places in the Wadden Sea. Such parallel fluctuations appear to be governed mainly by winter temperatures. Eutrophication may be another environmental factor acting over extensive areas.

2. Discussion of Core Programme

At a former workshop (viz. at Roscoff in 1982), general agreement was reached on common methods, selected species and emphasis on numerical changes in these species (see Annex 3.1). Some problems encountered in the meantime were discussed. Perceived major problems are: inadequate sampling depth (can be easily remedied); incomplete sorting (live sorting is not feasible in all areas, and since some workers reject formalised material, uniformity cannot easily be achieved), and man-induced or natural disturbance of sampling stations (drastically changing the environmental conditions at the station). As regards the last point, it was recommended that sampling be carried out along transects perpendicular to the "shifting zonation". Such a procedure was strongly preferred to changing the exact location of the sampling station.

The emphasis on numerical changes is to be maintained, but several subsidiary projects have started and these fit in very well with the core programme, e.g. studies on recruitment patterns and growth rates in key species.

3. Intercomparison exercise

During a field trip to the tidal flats in the northern part of the Baie de Somme, 6 groups of participants each took a series of samples using their own equipment. The corers employed proved to be widely different in size and depth of penetration.

All samples were taken within a limited (about 1000 m^2) , and at first sight , homogeneous area where sieving was easy. Unfortunately, high numbers of *Pygospio* were present, making sorting a laborious and time-consuming effort.

Comparisons of the numbers of living animals observed per sample, and of the calculated estimates of numerical densities, led to the following conclusions:

1. For most specieS, a high variation was found even within the series of individual participants. Variances often exceeded the means by an order of magnitude. In homogeneous sampling areas, these values tend to be roughly equal. Thus, the area sampled was in fact far from homogeneous. This seriously hampered further comparisons.

2. The mean numbers of several species obtained with corers which penetrated only about 10cm into the sediment were significantly lower than those obtained with corers penetrating some 20cm or deeper.

3. Further differences between the various data series were sometimes considerable but lacked statistical significance as a consequence of the high intra-series variability.

Thus, the results of the sampling exercise were rather meagre and not really worth the time spent in sorting all the samples. Sorting took so much time that the period left for discussion on the statistical evaluation was too short. Further, the discussion on recommendations for a common methodology was unsatisfactory, which is regrettable as common methods are indispensable if results from different areas are to be made intercomparable. Several participants, however, use methods which are well adapted to their own environment and particular aims. It is quite understandable that these people should be less than willing to change their methods, since it would either involve more labour or would violate comparisons with earlier data. Thus, the initial (1982) agreement on common methods has proven to be unrealistic. Unfortunately, lack of time prevented the workshop from achieving agreement on possible changes in the 1982 agreements. These still stand, but appear to be resticted in consistent usage to the Wadden Sea area.

Generally, the workshop proved very useful in facilitating the interchange of views and in exposing the real status of the programme, including shortfalls in the methods employed.

ANNEX 3.1

Core Programme - Intertidal Sediment (*Macoma* community)

This study is planned to identify events and their causes which have large geographical scales. The geographic limits of the study area are those of the well developed *Macoma* community along the West European coasts, from the Arctic in the North to the French-Spanish boundary in the South.

In the first place, it was decided to study dominant species from this community, in global order of importance and ease of sampling: *Macoma balthica, Arenicola marina, Cardium (Cerastoderma) edule, Nephthys hombergii, Lanice conchilega, Littorina littorea, Nereis diversicolor, Mya arenaria, Tellina tenuis, Scrobicularia plana* and *Mytilus edulis*. Records of other species should also be retained, but sampling effort will be directed primarily to those high in the above list, viz. by a proper choice of sampling stations and by sampling a sufficiently large area in such a way (sampling depth, spacing of samples) that representative, reliable and precise data can be collected on the top species.

The chosen stations will be sampled over a period of years , at least twice per year, viz. at the time of lowest abundances and weights (March - April) and after the completion of summer recruitment (August - September).

Samples will be taken from fixed sampling stations (marked by, for example, iron poles). Such stations may be either squares (wherein samples are taken at random points) or transects (with samples taken at regular distances). Sufficient samples (of a fixed size and preferably taken with a corer) should be taken to ensure that at least several tens of each of the main species are collected on each occasion. Generally 0.5 to 1.0 m^2 should suffice. A high number of well-spaced small samples is preferred to a few large samples, particularly for species with a clumped distribution pattern, but to speed up sorting and further working up, a number of small samples may be lumped. A lmm sieve should be used. Sorting should be done by naked eye, either immediately with live animals or subsequently for fixed material.

Emphasis will be on numbers rather than on weights and biomass. Numerical densities (No./m^2) will be the main parameter for each species, which as far as possible should be split up into age groups, allowing separate estimates for annual recruitment and survival. Weights are expressed preferably in ash-free dry weights of soft parts and weight of dry shell material. Growth can be expressed either in weight changes when the time of sampling is appropriate (i.e., at the start and end of the growing season of the species concerned), or in changes of lengths of hard parts like shells and jaws.

The sampling area should be described in detail. As far as feasible, the following abiotic parameters should be measured regularly : level in the intertidal zone, daily time of water coverage, temperature, annual time of ice cover, sediment composition (grain size distribution, organic matter content), sediment load of overlying water, irradiance, wind force and wind direction. Nearby meterological stations can supply some of these data, but careful checks will be needed to judge whether their data really reflect conditions at the sampling stations.

Experiments in the sampling areas are encouraged, e.g. to study recruitment on bare places, species interactions, etc.

Existing series of recorded data should be worked through and reviewed to answer questions like: "Are there any long-term trends in the abundance of macrobenthic intertidal soft-sediment species ? Are these trends synchronized for different geographical areas and species ? Is there any parallel trend in an abiotic parameter of the environment ?"

HABITAT REPORT 4. INTERTIDAL ROCK WORKSHOP.
SAN SEBASTIAN, SPAIN - AUGUST 14TH TO 16TH., 1987

CHAIRMAN: J. Lewis (UNITED KINGDOM)

PARTICIPANTS: R.S. Bowman, M.Kendal (UNITED KINGDOM); M. Ibanez[1], J. Pena[1], A. Borja[1], J.M. Urrestavazu[1], M.J. Ruiz[1], A. Martinez[1], C. San Vicente[1], A. Arino[2], J.M.Ruiz[3], M.Bosch[4] (SPAIN); M.J. Gaudencio , M. Guerra (PORTUGAL); O. Ravera (C.E.C.).
(1: San Sebastian ; 2 : Pamplona ; 3 : Bilbao ; 4 : Mallorca)

HOST ORGANISATION/ORGANISER: This workshop, unavoidably postponed from Autumn 1986, was held in San Sebastian, Spain, April 14 - 16, 1987. Local organisation was provided by M. Ibanez and other members of INSUB (Sociedad Cultural de Investigacion Submarina), meetings being held in the Society's new laboratories in the Museo de Quendo.

Probably because of the relatively short notice, attendance was not as high as had been hoped, particularly among those who might have been persuaded to join the programme and give it a wider national and/or geographical coverage.

PROCEEDINGS:

The principal aims were essentially practical:
1) to ensure comparability of methods and interpretation among existing participants,
and
2) to demonstrate these to potential newcomers.

This need to check methods arose because they were based on early U.K. experience, and there were uncertainties about their exact suitability in S.W. Europe. A workshop in Spain therefore afforded opportunity for joint "on the spot" consideration.

Two major field sessions were therefore held, after preliminary lectures, to look for and to try to identify the 1 - 3mm stages of limpets and trochids. In the case of the limpets, no serious identification problems arose. The shell shapes and markings were as expected and as distinct as in the British Isles, and it was felt that with a little more experience newcomers would have no difficulties in applying the available key.

The choice of recruitment monitoring sites poses some problems because the conditions most suitable for juveniles often lie in innaccessible clefts between steeply sloping strata. Nevertheless, good situations can be found and with spat of at least two *Patella* spp. being very abundant, the

San Sebastian team confidently hope to add recruitment to their existing gonadal studies.

The trochid programme of COST 647 involves (at present) one species each of *Monodonta* and *Gibbula*. Around Spain and Portugal two *Monodonta* and three *Gibbula* spp. occur in the littoral. Distinction between the juveniles of the two *Monodonta* spp. proved to be easy and a short guide will be prepared. By contrast, separation of the 3 *Gibbula* spp. at the 1-3mm stages has been causing increasing concern to the Portuguese team. After detailed study of Basque specimens, it was agreed that both there and in Portugal the high percentage of "indeterminate" specimens in many samples prevents accurate recruitment monitoring in S.W. Europe for the present. Resumption necessitates a prior basic study of the external characters of spat and juveniles (as was the case several years ago for *Patella* spp.).

Contrasting with the above difficulties, it was therefore ironic that the sites favourable for trochid spat and juveniles ("nurseries") proved similar to those in Britain and were easily identifiable. Thus for *Monodonta* spp., there is now no practical obstacle to accurate studies on recruitment and population dynamics. Fullest appreciation of early shore life involves, however, spat smaller than those visible in the field. To include these in a study necessitates the use of settlement plates (limpets) or plastic mesh "collectors" (trochids). Examples of both were shown and their use discussed.

The second area of uncertainty where possible misinterpretations could arise involves gonad cycles. The work of all participants (as presented at the Brussels symposium and since) leaves no doubt that the duration of the period of gonad activity increases towards the south of species ranges, and in some cases appears to involve most of the year. In these latter cases, it is not clear whether gonads are releasing and redeveloping frequently over many months, or remain large with mature eggs awaiting a synchronising environmental stimulus to spawn. It was reported to the workshop that an allied species (*Gibbula cineraria*), not in the COST 647 programme, has a breeding season as long as that which *G. umbilicalis* appears to have in S.W. Europe but still has a short, discrete period of larval settlement. Various qualitative and quantitative methods of assessing gonad development, degree of spawning etc., were described, and both fresh and prepared materials and photographs were examined. These discussions, often involving microscope usage, took place in small groups, even on a one-to-one basis. Only time can show whether these sessions will lead to confirmation or modification of existing views on the gonad cycles in S.W. Europe.

M. Kendall reported on the recent addition of *Nucella (Thais) lapillus* to the U.K. programme as a result of the very serious adverse effects of anti-fouling paint containing tri-butyl tin which are now coming to light. This study differs obviously from the main COST 647 remit as it seeks to expand information on the mode of operation and its effect on populations. If prevention of reproduction is as widespread as feared, the loss of this, the principal littoral predator of mussels and barnacles, will have a dramatic effect upon community dynamics. If and when the effects are reduced, the recovery of populations will be greatly hindered by the lack of a dispersive larval stage in *Nucella* .

Future Outlook

Among existing participants continued support is assured in Portugal although personnel are having to give more of their time to other work. Members of INSUB are confident that even without official national recognition COST 647 studies will expand in the San Sebastian region. The UK situation is currently under official revue. The COST 647 project is arousing much interest in Spain, and the practicality of extending *Patella* studies into the Mediterranean is now being seriously examined by M. Bosch of Mallorca. Other personnel on the south coast of Spain not able to attend the workshop hope to provide a geographical link between Atlantic and Mediterranean locations.

The north coast of Spain from Galicia to San Sebastian presents (in one country) greater gradients of temperature and biological distribution than over much larger north/south extents of the western European coastline. In the hope of exploiting this natural situation, Prof. Jordano of Pamplona (who visited the workshop for a half-day) will consult with others along the entire coast about the possibility of formulating a collaborative programme.

Members of INSUB are also studying sedimentary communities, both littoral and sublittoral, and co-ordinators of these programmes in COST 647 might wish to contact M. Ibanez (Museo de Oquendo, Apartado de Correos 3031, San Sebastian).

In discussion about future work it was acknowledged that financial supporters might be more interested in the relatively simple "monitoring data" (i.e. description of adult population levels or changes) than in the much more time-consuming science-in-depth which aims to provide explanations for such changes. It was agreed that judicious blends of both types of work might be needed to satisfy individual situations and yet still achieve worth-while science.

As acknowledged by the Chairman,visiting participants were most impressed by the efforts of the INSUB members to make the workshop a success, both scientifically and socially.

EXTENSION DU PROGRAMME COST 647 A LA MEDITERRANEE

RAPPORT DU GROUPE DE TRAVAIL POUR L'ELABORATION D'UN PROGRAMME DE RECHERCHES SUR LES HERBIERS DE POSIDONIES

Sous l'égide de la Commission des Communautés Européennes, le Groupe de travail "Posidonies" s'est réuni à Luminy (Marseille, France) du 19 au 21 Mars 1986. Le groupe se composait de Charles F. BOUDOURESQUE, Eugenio FRESI, Mireille HARMELIN-VIVIEN, Carlo HEIP, Michel JANGOUX, Alain JEUDY DE GRISSAC, Lucia MAZZELLA, Panayotis PANAYOTIDIS, Alfonso RAMOS, Oscar RAVERA (adresses en annexe).

Charles F. BOUDOURESQUE a été élu Coordonnateur du groupe.

Le groupe a élaboré une proposition de programme de recherche se conformant à la philosophie générale du COST 647. Cette proposition, ainsi que le contexte dans lequel elle s'insère, sont détaillés ci-dessous.

Exposé des motifs

Par l'importance de sa production primaire, la richesse exceptionnelle de sa faune et de sa flore, l'exportation d'une grande partie de sa production primaire vers de nombreux autres écosystèmes, son rôle dans le contrôle des flux sédimentaires et du profil d'équilibre des lignes de rivage, l'herbier à *Posidonia oceanica* (Phanérogame marine) est considéré aujourd'hui comme l'un des écosystèmes benthiques les plus importants de Méditerranée (BLANC & JEUDY DE GRISSAC, 1978; BOUDOURESQUE & MEINESZ, 1982; JEUDY DE GRISSAC & TINE, 1980; LIBES, 1984; OTT, 1980; PANAYOTIDIS, 1980; ROMERO-MARTINENGO, 1984; TEMPLADO, 1984).

Les herbiers à Posidonia oceanica sont présents à peu près partout en Méditerranée, du Nord au Sud et de Gibraltar à l'Egypte, entre la surface et 30-40 m de profondeur : à l'exception des embouchures des grands fleuves (Rhône, Pô, Nil). Ils constituent une ceinture pratiquement continue le long des côtes, ce qu'illustrent quelques cartes en annexe (JEUDY DE GRISSAC, 1975; GIRAUD, 1980; COLANTONI et al., 1982). En outre, dans certaines régions où le plateau continental est large, les herbiers de Posidonies prennent une extension considérable : Baie d'Hyères (France), côtes orientales de Corse, Sardaigne, Sicile, Golfe de Gabès (Tunisie). Au total, ils couvrent en Méditerranée des surfaces considérables (peut-être plus de 2% de la surface totale de la Méditerranée selon BETHOUX, comm. verb.).

La régression actuelle de ces herbiers, bien documentée au voisinage des grands centres urbains et portuaires, constitue une préoccupation majeure pour les pays riverains. Les causes de cette régression apparaissent comme complexes : agressions chimiques, mais aussi mécaniques, et surtout déséquilibres sédimentologiques et dysfonctionnement de l'écosystème. La préservation des herbiers de Posidonies implique donc impérativement la compréhension des mécanisme du fonctionnement de cet écosystème.

Des séquences pluriannuelles existent déjà en plusieurs secteurs; en outre, une découverte récente, la lépidochronologie, offre la possibilité remarquable de permettre la reconstitution, sur au moins 50 années, de paléo-séquences.

Dans le cadre de l'extension du programme COST à la Méditerranée, l'herbier de Posidonie constitue donc un choix obligé. Ecosystème très important, présent partout, couvrant de vastes surfaces, s'intégrant bien à la problématique COST, il offre en outre l'avantage de constituer le lieu géométrique des préoccupations de nombreux laboratoires des pays riverains (Espagne, France, Italie, Grèce) et de Belgique, de telle sorte qu'une coordination de leurs efforts serait immédiatement opérationnelle et particulièrement féconde.

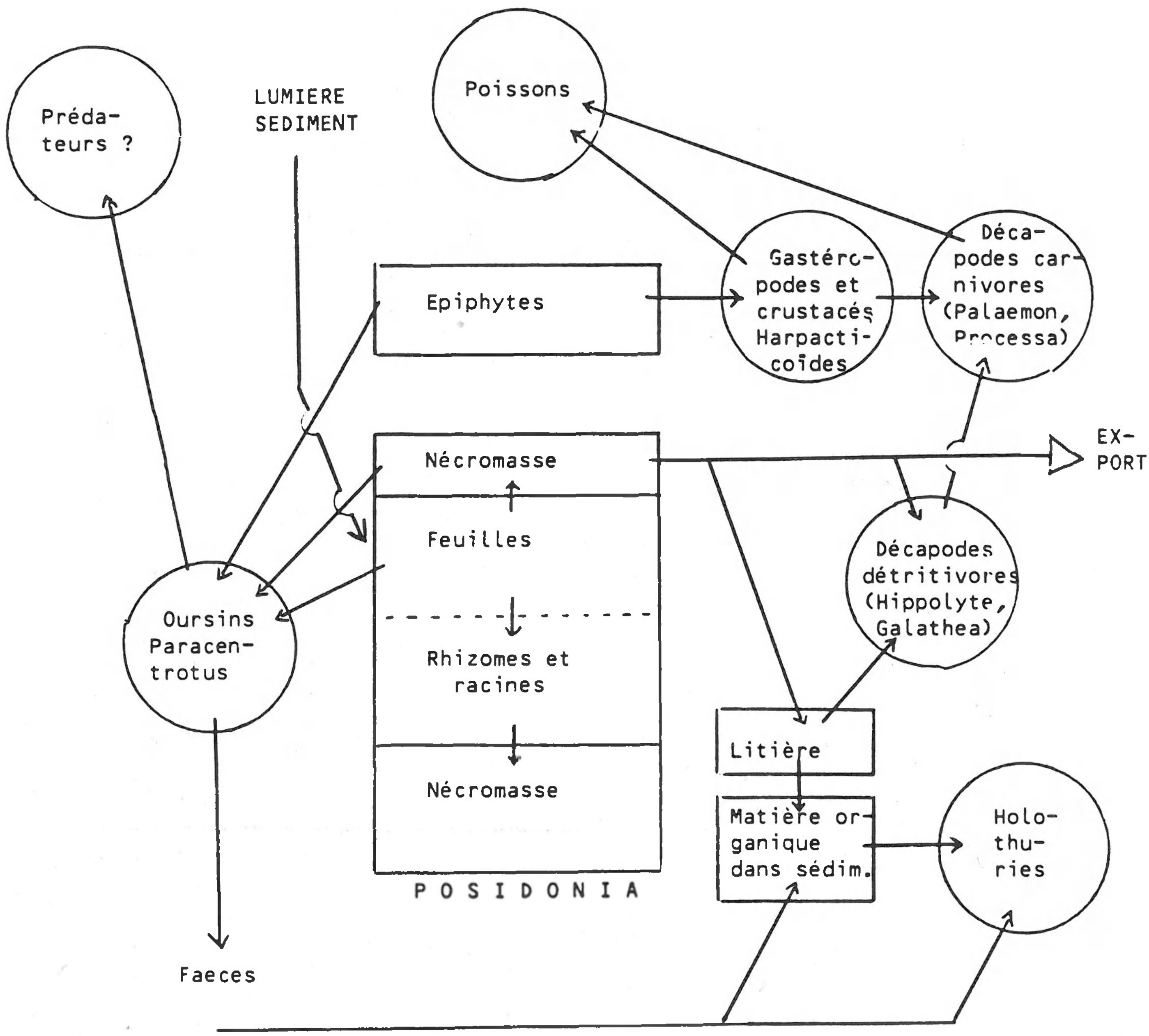
La présence, en Europe du Nord et de l'Ouest, d'herbiers à Zostera marina (Phanérogame marine) et de champs de Laminaria (macro-algues) y rend possible une approche similaire à celle proposée pour l'herbier de Posidonies en Méditerranée, approche qui permettrait de valablement comparer des écosystèmes qui, tous, s'organisent autour d'une espèce végétale édificatrice.

Objectifs généraux

Parce que les grands centres océanographiques méditerranéens sont le plus souvent implantés dans des zones urbanisées, et donc plus ou moins perturbées, la majeure partie des connaissances sur les herbiers concerne de tels secteurs. Les phénomènes observés dans ces secteurs (dysfonctionnement de l'écosystème, formation d'intermattes érosives, extension des mattes mortes, régression de l'herbier), sont en fait difficiles à interpréter objectivement, dans la mesure où les fluctuations naturelles sont mal connues.

La Méditerranée offre l'opportunité d'étudier des zones où les perturbations induites par l'homme peuvent être considérées comme faibles, et cela dans chacun des pays riverains. L'étude des fluctuations naturelles, en divers points d'une aire très vaste, permet alors de faire la part des phénomènes locaux et de dégager les grands mécanismes qui déterminent ces fluctuations.

Les connaissances acquises sur l'herbier de Posidonies permettent d'établir un pré-modèle simplifié de son fonctionnement (Fig. ci dessous). Dans ce pré-modèle, nous ne faisons apparaître que les compartiments majeurs, i.e. les espèces, ou les groupes d'espèces,



dont le poids écologique est considérable : édificateurs (la Posidonie elle-même), producteurs primaires, groupes-clef dont la biomasse est importante, et/ou dont la place dans le réseau trophique est telle que les fluctuations de leurs populations sont susceptibles de réguler ou de déréguler le système.

L'étude comparative, à long terme et en milieu non perturbé, de la structure, de la dynamique et de l'évolution de l'écosystème herbier de Posidonies dans diverses stations de Méditerranée s'articule autour d'un core-program, qui sera réalisé dans toutes les stations, selon une méthodologie rigoureusement harmonisée.

Autour de l'armature représentée par le core-program, les participants envisagent de réaliser des programmes complémentaires qui seront conduits seulement dans un, ou dans quelques uns, des sites sélectionnés.

Core-program

Le core-program débutera en 1987 pour une durée de 10 ans. Il réunira des opérations qui seront effectuées dans tous les sites choisis, i.e. la réserve de l'Île de Nuend-Tabarca, près d'Alicante (Espagne), le Parc National de Port-Cros (Var, France), Lacco-Ameno (Ischia, Italie) et la presqu'île de Methana (Grèce). Deux sites supplémentaires possibles sont également envisagés : Calvi-Scandola (Corse) et les îles Medas (Catalogne, Espagne). Ces différents sites ont été choisis pour la raison qu'ils présentent des herbiers peu perturbés, facilement accessibles, couvrant d'importantes surfaces, et qui tous ont déjà été approchés d'un point de vue scientifique.

Les opérations à réaliser sont les suivantes :

Structure du sédiment (granulométrie et nature des particules) : ce paramètre constitue un bon témoin de l'hydrodynamisme local.

Balisage de la limite inférieure de l'herbier : il s'agit d'étudier les fluctuations naturelles de cette limite.

Balisage d'intermattes symétriques et déferlantes : il s'agit de mesurer la vitesse d'évolution de ces structures érosives.

Carrés permanents : de petite taille, limités par des balises, ils servent à un suivi micro-cartographique de l'herbier (étude de sa dynamique), et de points de repères précis pour les études en suivi : densité des faisceaux, biomasse et nécromasse des feuilles, biomasse des rhizomes et des racines, biomasse des épiphytes des feuilles.

Lépidochronologie : il s'agit de l'analyse des fluctuations cycliques d'un certain nombre de paramètres morphologiques et anatomiques des écailles (pétioles des feuilles, persistant le long des rhizomes après la chute des limbes); les cycles élémentaires, correspondant à une année, permettent de les distinguer; on recherchera des séquences pluri-annuelles le long de la période étudiée (10 à 40 ans en arrière).

Floraison, fructification : la floraison semble irrégulière, localisée, plus ou moins synchronisée à l'échelle de la Méditerranée. La base des pédoncules d'inflorescences étant conservée entre les écailles, les floraisons anciennes peuvent être retrouvées et datées (lépidochronologie). Les nouvelles floraisons, et la fructification éventuelle, seront suivies avec précision.

Densité et structure des populations d'échinodermes (*Paracentrotus lividus*, *Holothuria polii* et *H. tubulosa*) : dénombrements et mesures du diamètre seront effectués *in situ*. La biomasse sera déduite de ces données.

Biomasse de la macrofaune vagile épigée : la macrofaune sera collectée au moyen d'une suceuse; la biomasse sera mesurée au niveau des principaux taxa.

Nombre et périodicité des opérations, répartition en fonction de la profondeur :

Opérations	Nombre d'observations par an	Périodicité (en années)	Profondeurs étudiées (en m)
Structure sédiment	1	5	gradient
Balisage limite inférieure	1	1	> 30
Balisage d'intermattes	1	1	5, 10-15
Carrés permanents	1	1	5
Densité faisceaux	1	5	5
Lépidochronologie	1*°	-	5, 15, 30
Floraison, fructification	x	1	5, 15, 30
Bio- et nécromasse feuilles	6	1	5, 30
Biomasse rhizomes racines	1*	-	5, 30
Biomasse épiphytes feuilles	6	1	5, 30
Populations échinodermes	6	1	5
Biomasse macrofaune épigée	4	1	5

* Ne doit être effectué qu'une fois. ° Renseigne sur une longue séquence d'années antérieures. x Le nombre d'observations dépendra de la durée de la floraison et de la fructification éventuelles.

Outils complémentaires : relevés stations météo locales (température, fréquence direction et intensité vent, nébulosité). Relevés température (minima-maxima) *in situ*; calcul (disque de Secchi), pour chaque station, du coefficient de correction des données générales d'éclairement, en fonction de la turbidité locale; pluviométrie dans les bassins versants. Certains paramètres seront déduits par simulation à partir des données mentionnées.

Les méthodes seront rigoureusement harmonisées entre les laboratoires participants; des réunions de travail, destinées à vérifier et éventuellement à améliorer l'intercalibration des méthodes seront organisées.

Programmes complémentaires

Les programmes complémentaires (à financement propre) ne font pas partie du core-program proposé, mais en constituent le prolongement naturel. Ils font appel à des compétences particulières, ou nécessiteront des opérations trop lourdes pour être dupliquées. Leurs résultats seront toutefois transposables et utilisables dans la majeure partie des sites retenus

Ces programmes s'articuleront autour de trois thèmes :

- Facteurs de contrôle,

Floraison : recherche, en culture (aquariums) du déterminisme de la floraison.

Phénologie et lépidochronologie : Suivi phénologique de *P. oceanica* (nombre de feuilles, longueur et largeur des feuilles, longueur des bases, rythme de renouvellement et de chute des feuilles) et rétrocontrôle lépidochronologique; interprétation lépidochronologique des années antérieures (10-40 ans). La biomasse sera déduite de ces données.

Photosynthèse : relations entre photosynthèse et intensité lumineuse, en particulier dans les herbiers profonds (laboratoire et contrôle *in situ*).

Bilan sédimentaire : alimentation par les bassins versants (fraction terrigène du sédiment de l'herbier); pièges à sédiment.

- Facteurs de répartition,

Meiofaune : biomasse et densité des copépodes de la phyllosphère dans tous les sites.

Poissons : Biogéographie du peuplement ichthyologique. Biomasse et évolution saisonnière du peuplement de poissons. Variations nycthémérales.

- Facteurs de régulation du système,

Meiofaune : Dans un ou deux sites, dynamique des populations de copépodes et interactions avec leurs prédateurs (poissons, juvéniles en particulier; contenus digestifs, expériences d'exclusion).

Poissons : structure des populations; essai de quantification des relations trophiques (plus particulièrement Labridae et Scorpaenidae).

Crustacés et Gastropodes : Dynamique des populations et biologie de la nutrition (en particulier analyse des contenus digestifs) de quelques groupes d'espèces (Hippolytidae, Galathea, Processa, Palaemon, Rissoa, Gibbula).

Echinodermes : recrutement, vitesse de croissance, taux de maturité sexuelle (taille maturité sexuelle), taux de fécondité, sex ratio, efficacité de l'alimentation (consommation feuilles avec ou sans épiphytes, biomasse et nécromasse), nature de la microflore du tube digestif et son effet sur l'assimilation, rythmes d'alimentation (nycthéméral, saisonnier), temps de transit, preferanda alimentaires, digestion des algues et des phanérogames. Espèces concernées : l'oursin Paracentrotus lividus (éventuellement Psammechinus microtuberculatus et Sphaerechinus granularis) et les holothuries Holothuria polii et H. tubulosa.

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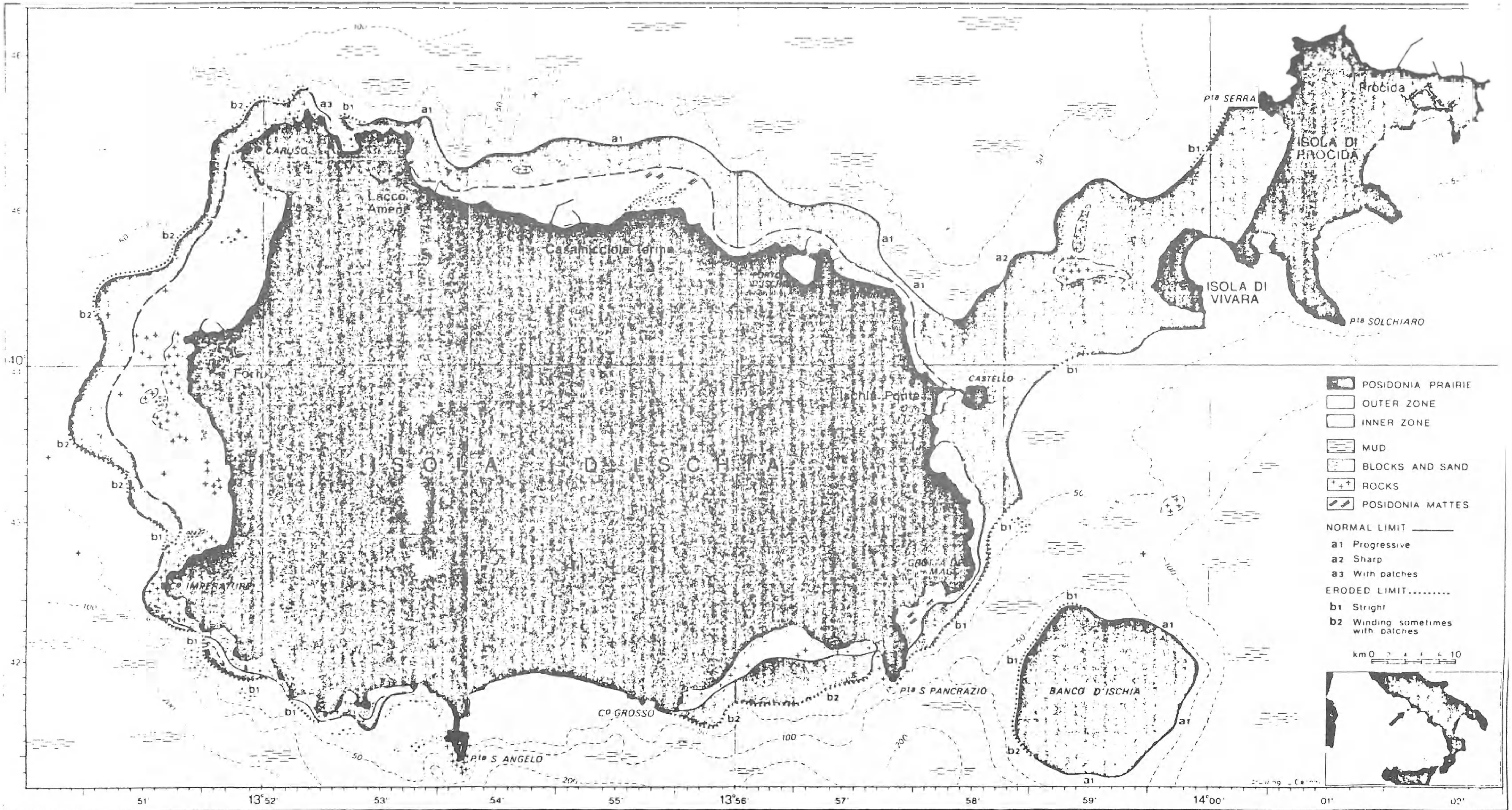
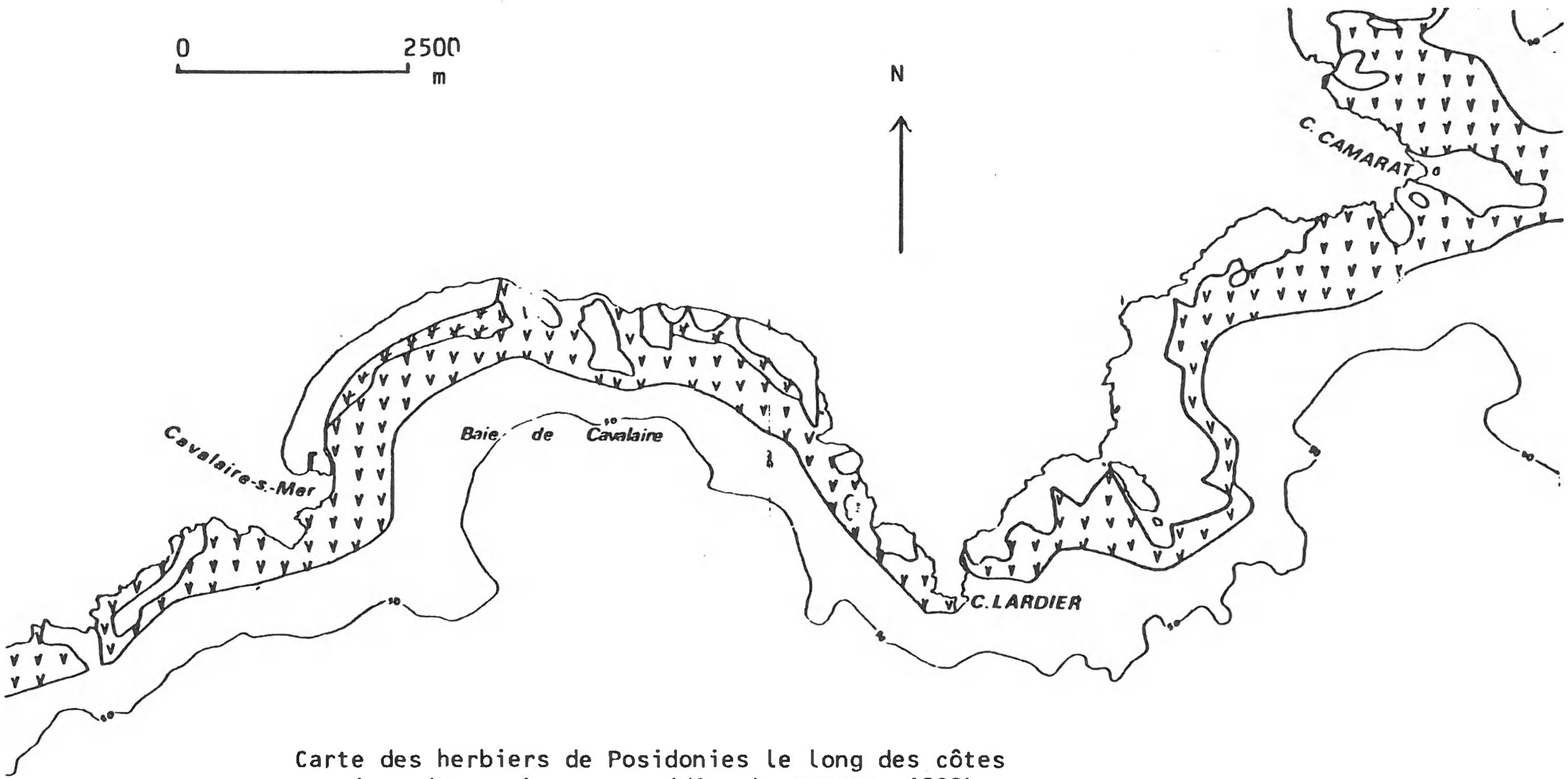
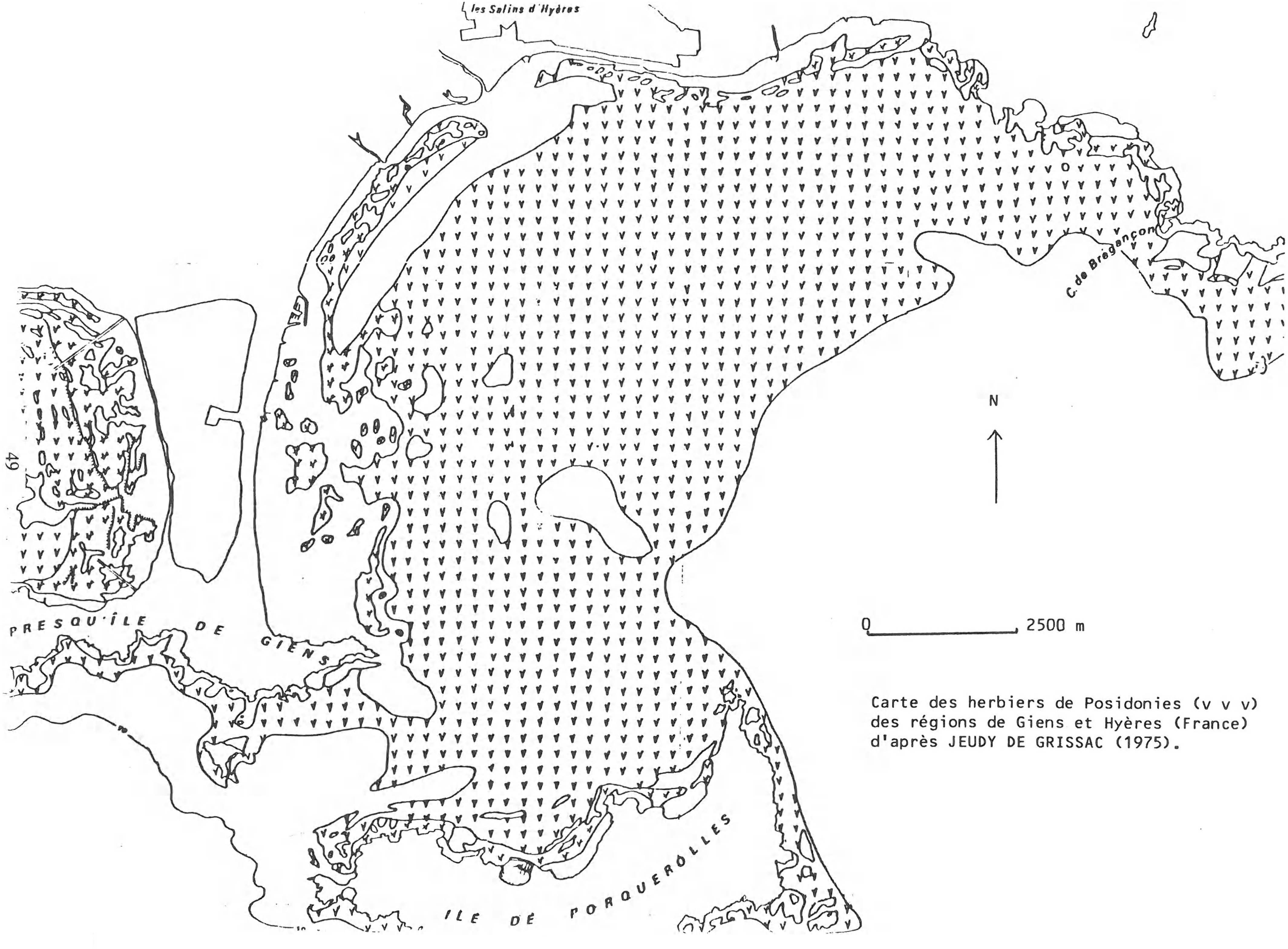


Carte des herbiers de Posidonies (en gris clair), autour de l'île d'Ischia (Golfe de Naples, Italie) (d'après COLANTONI et al., 1982).



Carte des herbiers de Posidonies le long des côtes varoises (France) : v v v (d'après GIRAUD, 1980).



Carte des herbiers de Posidonies (v v v) des régions de Giens et Hyères (France) d'après JEUDY DE GRISSAC (1975).

APPENDIX 1

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APPENDIX 2

PAPERS PRESENTED AT THE SUBTIDAL SEDIMENT WORKSHOP (SPAIN , OCTOBER 1986).

For each paper, the tables and figures follow, respectively and sequentially, after the references

Subtidal baseline survey off the north coast of Sain.

Nuria Anadon

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The University of Oviedo (North of Spain) is associated with the Instituto de Investigaciones Pesqueras of Vigo in carrying out this baseline survey of an area where it is planned to dump the coal slags from a power station.

Benthic samples are to be collected monthly, over a period of 12 months, along a line of transect ,with three stations at 40 m and 1200 m in depth. The bottom communities will be mapped on the findimgs of a 35 station cruise. Samples will be taken at each station with three different devices: Reineck Box corer, epibenthic sledge and anchor-dredge.

The main objectives are to study benthic community distribution and structure, annual biomass cycle, annual density cycle and the production of the principal species.

Currently (Oct. - 86), materials are being prepared prior to commencing the study. The study area lies off the coastline from Cabo Vidio to Gijón, and the work is funded by an electric power company.

**VARIABILITE MACROBENTHIQUE ET PHENOMENES PHYSIQUES.
ETUDE DU DETERMINISME DU RECRUTEMENT EN BAIE DE SEINE ORIENTALE : HYPOTHESES DE TRAVAIL, STRATEGIES D'ECHANTILLONNAGE ET RESULTATS PRELIMINAIRES.**

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INTRODUCTION, HYPOTHESES DE TRAVAIL :

Les peuplements benthiques, de par leur sédentarité, sont les indicateurs les plus accessibles des effets des fluctuations et des perturbations de l'environnement marin sur le milieu vivant; la connaissance de leur variabilité naturelle est donc essentielle pour l'identification des perturbations. La structure des communautés des mers côtières et leur cycle annuel ont fait l'objet de nombreux travaux. Par contre, l'analyse de leur évolution à long terme et de ses relations avec les conditions hydrologiques générales, dans une perspective prédictive, est un domaine bien moins exploré. Cela a motivé en 1979 le lancement de l'action concertée COST 647, avec comme objectif l'acquisition de longues séries de données sur un vaste espace géographique, pour en extraire la part de la variabilité temporelle induite par les phénomènes climatiques . Parmi les premiers résultats, l'analyse des observations effectuées en des points distribués du Danemark à l'Espagne dans les systèmes les plus étendus (communautés subtidales des fonds sédimentaires) révèle cependant un fort couplage entre la cinétique des peuplements et des facteurs locaux prédominants. La clarification des effets à grande échelle spatiale passe donc par l'étude de ces couplages à petite et moyenne échelle. Parmi eux, les phénomènes de transport advectif et dispersif des larves pélagiques d'espèces benthiques et leurs effets positifs (colonisation à distance) ou négatifs (déperdition sur des fonds inappropriés) sont parmi les plus universels. Ils concernent en outre la partie du cycle biologique qui a le poids le plus fort dans la génération de la variabilité interannuelle : le recrutement.

Dans la diversité des mers côtières, les régimes "mégatidaux", tel que celui de la Manche, offrent l'un des cas les plus intéressants dans l'étude de ces phénomènes : outre la grande amplitude des dénivellations de la surface libre, l'intensité de la circulation alternante de marée y crée en effet des conditions particulières, qui influent considérablement sur le fonctionnement du système marin dans toutes ses composantes et à diverses échelles.

En premier lieu, aux gradients généraux de vitesse sur l'ensemble du bassin sont associées des séquences biosédimentaires qui font prédominer les étendues de sédiments grossiers et leurs peuplements et confinent les dépôts fins à Abra alba à des isolats, dans les zones de faibles courants des baies et des estuaires (LARSONNEUR, BOUYSSE et AUFFRET, 1982 ; CABIOCH et GENTIL, 1975 ; CABIOCH et GLACON, 1977). Cette distribution en taches séparées parfois par de grandes distances est favorable à l'étude du rôle de l'hydrodynamisme dans le recrutement d'espèces benthiques à larves pélagiques (connaissance des sources larvaires, dispersion dans les masses d'eau, recrutement post-larvaire ou déperdition).

Deuxièmement, l'intensité des gradients de vitesse aux petites échelles des couches limites amplifie considérablement la dispersion. C'est le cas en couche limite de fond, où les effets additionnels des cisaillements, du décalage angulaire vertical des vecteurs vitesse et de leurs variations à la période de la marée créent une dispersion multidirectionnelle extrêmement active. De même, en couche limite latérale, le gradient de vitesse en régime alternant amplifie la dispersion longitudinale (CHABERT D'HIERES, 1986) et peut étirer rapidement le long de la côte les émissions larvaires issues des fonds qui en sont proches. Cela aboutit, dans ce dernier cas, à une exacerbation côtière de l'anisotropie générale de la dispersion en régime mégatidal, les mélanges longitudinaux, selon les courants de marée, étant de l'ordre de 10 fois plus intense que les mélanges transversaux (PINGREE, PENNYCUICK et BATTIN, 1975). On doit ainsi s'attendre, dans ce régime, à une dispersion très active, mais ordonnée dans l'espace, les possibilités de déperdition vers le large de larves issues des zones proches du littoral étant beaucoup plus faibles que leur dissémination parallèlement à la côte, vers des fonds favorables ou non.

On sait aussi que, dans de telles mers, les courants résiduels issus de la circulation de marée sont la composante prédominante des dérives générales qui se superpose aux courants dûs aux vents moyens (DJENIDI, NIHOUL, RONDAY et GARNIER, 1986). Leur action émerge des composantes plus aléatoires (vents variables, etc...), pour peu que la durée du phénomène dépendant soit suffisamment longue, de l'ordre du mois par exemple dans le cas du transport pélagique de nombreuses larves d'Invertébrés benthiques. Ainsi, le régime mégatidal contribue à assurer une certaine régularisation des transports advectifs à ces échelles de temps.

Pour une étude de couplage entre les processus biologiques et les phénomènes physiques en mer mégatidale, la Baie de Seine présente les avantages d'une régularité morphologique favorable à la modélisation et d'une remarquable simplicité dans l'ordonnancement de ses gradients biosédimentaires. En outre, on bénéficie au départ sur ce site d'un potentiel des connaissances dans toutes les disciplines de l'océanographie acquis notamment au cours du programme "Baie de Seine" du groupe de recherches coordonnées "Manche" du C.N.R.S. et dont la synthèse vient d'être réalisée (GRECO MANCHE, 1986).

Le peuplement à Abra alba de la Baie de Seine orientale :

Bordant la côte sur une largeur de 3 à 10 milles entre le secteur de l'Orne et le Cap d'Antifer (fig. 1), les sédiments fins plus ou moins hétérogènes et envasés hébergent en Baie de Seine orientale le plus vaste des isolats côtiers de la communauté à Abra alba le long des côtes françaises de la Manche. Ses caractéristiques quantitatives et cinétiques ont été décrites par GENTIL, IRLINGER, ELKAIM et PRONIEWSKI (1986). Elles se résument comme suit :

- Le peuplement présente des densités macrobenthiques (26.000 individus/m^2) parmi les plus élevées à l'échelle mondiale, de l'ordre de 7 fois la moyenne annuelle admise pour ce type de communauté, sans que cette richesse quantitative soit associée à une réduction notable de la richesse spécifique, comme c'est le cas aux débouchés du Rhin et de la Meuse, par exemple. La variabilité écologique, induite par la proximité de l'estuaire, ne se traduit guère que par l'existence de dominantes opportunistes, parmi les Polychètes et Mollusques de petite taille (Tharyx, Magelona, Chaetozone, Mysella, ...).

- Le cycle annuel des structures numériques (plus de 2 ans de suivi) et l'ensemble des observations ponctuelles effectuées depuis 1971 révèlent la permanence globale du peuplement et la bonne reproductibilité interannuelle de ses fluctuations saisonnières.

- La biologie des populations des espèces principales montre que la plupart d'entre elles ont un cycle bentho-pélagique à vie larvaire planctonique longue (de l'ordre du mois et plus) ; l'essentiel des recrutements a lieu à la fin du printemps et en été.

On est donc en présence d'un double paradoxe apparent :

+ un peuplement marin quasi-normal dans sa structure et son fonctionnement à proximité immédiate d'un estuaire à fortes pulsions perturbantes (crues, pollutions) ;

+ une reproductibilité relativement régulière du cycle annuel, donc probablement du recrutement malgré la longueur de la phase pélagique des larves (de l'ordre du mois), chez la plupart des dominantes et le fait qu'elles sont émises par des adultes en position d'insularité, dans le régime fortement dispersif d'une mer mégatidale.

L'apport pluridisciplinaire :

Les faits majeurs mis en évidence par les autres disciplines au cours du programme "Baie de Seine" et intervenant dans la cinétique du peuplement à Abra alba sont les suivants :

+ les mesures in situ et la modélisation montrent en Baie de Seine orientale l'existence d'une circulation résiduelle de fond de l'ordre de 5 cm/s, convergeant vers l'estuaire, alors que les eaux estuariennes s'évacuent en surface en sens opposé (Fig. 2). Cette circulation fait prédominer les apports marins sur le peuplement à Abra alba en conditions de faible débit (printemps et été).

+ le gros des apports particulaires annuels fluviaux et estuariens, avec leur charge polluante, est expulsé en mer, en peu de temps lors de la première crue hivernale, sans grande possibilité de dépôt massif à long terme en raison de leur remise en suspension et de leur dispersion lors des tempêtes.

L'interprétation écohydrodynamique : hypothèses de travail pour les recherches sur le déterminisme du recrutement :

- La phase de croissance du peuplement (recrutements benthiques printaniers et estivaux) a lieu en régime d'apports marins dominants, par le jeu de la circulation résiduelle de fond convergeant vers l'estuaire. Les fonds jouxtant l'estuaire sont donc susceptibles d'être approvisionnés en larves provenant de zones plus externes (ou d'autres isolats éloignés de même nature) et renouvelant le peuplement, quelles que soient les perturbations subies par les populations adultes locales.

- Les perturbations du peuplement par les crues et les pollutions prédominent en saison hivernale et ne font que participer au déclin usuel de ce type de peuplement en toutes circonstantes à cette saison (fin des recrutements, mortalités).

Il semble donc que cette discordance de phase entre la période d'établissement du peuplement et les perturbations majeures, jointe à la prédominance des apports marins en période de recrutement expliquent à la fois la permanence d'un peuplement marin si près de l'estuaire et la régularité interannuelle de sa cinétique.

Ces interprétations forment les hypothèses de travail à la base des recherches entreprises depuis fin 1985 en matière de déterminisme du recrutement sur le peuplement à Abra alba de la Baie de Seine orientale.

Parmi les composantes à distribution "insulaire" du peuplement à Abra alba on a retenu des espèces à période de ponte brève et à vie larvaire pélagique longue. Pectinaria koreni et Owenia fusiformis, dont les stades larvaires sont aisément identifiables, répondent à ces critères avec l'avantage supplémentaire de former des populations adultes très denses. Enfin, on savait que le recrutement benthique de ces deux espèces s'étendait sur une période de l'ordre de trois mois à partir de mai.

TECHNIQUES ET STRATEGIES D'ECHANTILLONNAGE :

Les observations planctoniques et benthiques ont été réalisées à intervalle de 10 jours, à titre d'essai, pour la première année d'étude.

Echantillonnage planctonique :

L'objectif de l'étude en phase pélagique est de suivre la dispersion des larves dans le système hydrodynamique de la Baie de Seine depuis le moment de l'émission jusqu'à celui du recrutement benthique et de définir son éventuelle influence sur la variabilité du macrobenthos.

Pour cela, on tente d'obtenir :

- des images de l'extension géographique et de la géométrie du panache. Ces images seront comparées à la circulation des eaux et aux effets de dispersion, calculés par les modèles mathématiques, durant la période de présence larvaire.

- une image de la répartition verticale des larves (migration verticale périodique, ontogénique, ou liée aux caractéristiques écologiques de la colonne d'eau). Celle-ci peut influencer la dissémination compte-tenu de la variation des courants sur la verticale.

- une estimation de la croissance et de la mortalité larvaires.

Deux échelles d'observation ont été adoptées : une grande échelle afin de reconnaître l'extension du panache larvaire et une petite échelle, adaptée à une meilleure observation des gradients d'abondance (fig. 3 et 4).

Deux techniques de prélèvement ont été utilisées : le pompage et des traits verticaux au filet. A l'une et l'autre des échelles d'observation, une condition importante de la représentativité de l'échantillonnage de l'ensemble des zones est sa réalisation en un minimum de temps. Cela a amené non seulement à mettre en oeuvre deux navires opérant simultanément l'un à la petite échelle, l'autre à la grande échelle, mais aussi à limiter à la petite échelle la technique du pompage en continu, plus précise mais plus lente que l'échantillonnage vertical au filet. L'échantillonnage à la pompe a été réalisé en faisant parcourir à l'extrémité libre du tuyau d'aspiration des allers et retours entre la surface et le fond, le navire avançant à une vitesse comprise entre 5 et 6 noeuds. Le prélèvement "continu" nécessite cependant une discrétisation : la base d'un aller-retour entre le fond et la surface a été choisie. Les vitesses de remontée et de descente du tuyau sont maintenues constantes pendant le prélèvement et ajustées de telle sorte que l'aller-retour dure environ 5 minutes, cela correspondant à un trajet horizontal d'environ 1/2 mille. La réalisation du parcours total nécessite 12 heures de travail, pour une collecte d'environ 150 échantillons.

Les prélèvements au filet sont effectués selon une verticale fond-surface à l'aide d'un WP2 à maille de 80 µm, choisie en raison de la taille des larves. Le volume filtré est contrôlé par un débitmètre TSK.

Enfin, la répartition verticale des larves est étudiée à point fixe (station A), toutes les heures, pendant la durée d'un cycle de marée, par immersion progressive du tuyau de pompage, par pas de 2 m, avec un prélèvement de 5 mm à chaque palier.

Echantillonnage benthique :

L'étude en phase benthique répond à un double objectif :

- repérer, à travers la localisation des populations de géniteurs les zones d'injection des larves dans le système hydrodynamique de la Baie de Seine ;

- rechercher un (ou des) stade(s) critique(s) (ontogénique(s) ou liés aux conditions écologiques) suceptible(s) d'influer sur la variabilité du macrobenthos mais aussi estimer le niveau de recrutement en fonction de la nature des fonds et de la densité des populations larvaires prêtes à les coloniser.

Dans ce but on cherche à :

- obtenir une image de la distribution quantitative, au sein du peuplement des sédiments fins vaseux, des individus adultes de Pectinaria koreni et Owenia fusiformis dont on analyse la cinétique de ponte (durée et fréquence) ;

- suivre les fluctuations de densité des populations de post-larves par un échantillonnage temporel plus ou moins serré réalisé le long de séquences édaphiques correspondant à des gradients d'abondance allant jusqu'à des fonds dépourvus d'adultes.

Pour localiser les noyaux à forte densité de géniteurs un réseau d'échantillonnage à grande échelle comprenant 40 stations espacées de 1,5 mille a été adopté (fig. 6). Les prélèvements ont été effectués à la benne Hamon (1/4 de mètre carré), au mois de février, à l'amorce la gamétogénèse. Compte-tenu de la taille atteinte par les individus à cette époque de l'année les deux échantillons recueillis à chaque station ont été tamisés sur une toile métallique de 2 mm de vide de maille.

Les populations post-larvaires ont été suivies de mai à juillet :

- selon un pas de temps de 10 jours en trois stations (E, A et B ; fig. 7) représentatives de trois faciès du peuplement à Abra alba (GENTIL et al. 1985);

- à plus large intervalle de temps (1 mois) sur une radiale (fig. 7) étendue à l'ensemble des sédiments fins, depuis des zones internes à forte efficacité de recrutement jusqu'aux sables à Ophelia borealis où son résultat est à peu près nul pour les espèces considérées.

Deux échantillonneurs ont été utilisés : le carottier Reineck (171 cm^2) et le carottier Rouvillois (21.2 cm^2). Dans les deux cas on a concervé pour analyse la couche superficielle (3 à 4 cm d'épaisseur) et l'eau surnageante. A partir d'une étude préliminaire on a fixé le nombre des échantillons par station à 6 dans le cas du carottier Reineck et à 10 dans celui du Rouvillois. Au moment du tri on choisit l'une ou l'autre des séries d'échantillons en fonction des densités rencontrées.

RESULTATS PRELIMINAIRES

Seuls sont présentés à titre d'exemple les résultats relatifs à l'espèce Pectinaria koreni.

Les populations de géniteurs

Les populations denses n'occupent que très partiellement les fonds de sables fins vaseux où elles se distribuent en trois noyaux bien individualisés (fig. 8) : l'un à l'ouest du secteur prospecté, l'autre à proximité de la côte plus à l'est et enfin le dernier en limite interne du peuplement face au débouché de l'estuaire. Les abondances variables d'un noyau à l'autre mais également au sein d'une même tache peuvent dépasser la valeur de 400 individus/m^2 au mois de février.

La période de ponte de la population de la station A délimitée grâce aux suivis conjoints de la taille des ovocytes et de l'indice de maturité défini par GENTIL et al. (1986) semble se situer, compte-tenu du pas d'observation retenu, vers la fin mai ; en effet au début de ce mois la moitié seulement des individus sont matures alors qu'aux premiers jours de juin une faction très importante de la population a déjà pondu (80 %).

La phase larvaire pélagique

La larve trochophore à durée de vie brève évolue en métatrochochore se transformant elle même rapidement en aulophore planctotrophe caractérisée par la présence d'un tube muqueux (THORSON, 1946 ; CAZAUX, 1981).

En raison du pas d'échantillonnage les observations réalisées au printemps de 1986 n'autorisent qu'une approximation grossière des durées de vie et de présence larvaire dans les eaux de la Baie de Seine ; toutefois la première peut être estimée à 10-15 jours la seconde n'excédant pas 15-20 jours.

Bien qu'elle demande à être répétée l'analyse de l'image de la répartition de l'abondance larvaire correspondant à une série d'observations à grande échelle réalisées les 12 et 13 juin apporte, dès à présent, deux enseignements majeurs (fig. 9) :

- la densité des larves est maximale à proximité des populations les plus denses de géniteurs ;

- la distribution des larves se manifeste par l'étirement des lignes de forte isodensité parallèlement à la côte en direction du N-NE, c'est-à-dire dans le sens de l'advection et de la dispersion anisotrope.

Une première étude de la distribution verticale des larves montre qu'à aucun stade elles n'effectuent de migrations nycthémérales. Mais alors que les larves métatrochophores se maintiennent dans les 7 premiers mètres d'eau (fig. 10) et se trouvent ainsi dans les conditions leur assurant une dispersion maximale, les larves aulophores se localisent au voisinage du fond, là où une circulation résiduelle convergeant vers l'estuaire peut favoriser leur retour vers les substrats favorables.

La phase post-larvaire benthique

Selon VOVELLE (1973) le premier stade benthique se caractèrise morphologiquement par la présence de deux bourgeons tentaculaires et l'existence d'un tube muqueux portant une rangée de grains de sables attestant des relations développées avec le substrat. Deux étapes intermédiaires qui se différencient respectivement par l'acquisition du nombre définitif de métamères, l'accroissement du nombre de bourgeons tentaculaires et branchiaux et l'élaboration d'un tube de plus en plus arénacé, conduisent au stade juvénile.

Le suivi de la densité des populations de post-larves révèle que les premières recrues observées le 11 juin, comprenaient à la fois des aulophores déposées sur le fond, de très jeunes stades benthiques, voire même quelques juvéniles ; la métamorphose n'est donc pas synchrone à l'échelle de la population. Cependant on peut raisonnablement penser que ces recrues ne restent guère plus de 3 à 4 semaines à l'état de post-larves, période au terme de laquelle 80 % des individus présentent déjà tous les caractères des jeunes vers.

La densité maximale observée le 23 juin sur un fond propice au développement des adultes (station A) est voisine de 100.000 recrues/m². Avant la ponte l'abondance de <u>Pectinaria koreni</u> est seulement de quelques centaines d'individus/m². Ces premières valeurs donnent un ordre de grandeur de la mortalité entre le stade recrue et le stade géniteur. Il reste a affiner les étapes de cette réduction de densité en les reliant aux stades de développement.

Le dénombrement des post-larves contenues dans les échantillons prélevés le 11 juin (début de recrutement) le long de la radiale R1-R8 révèle que leur abondance n'est pas significativement différente sur les sables fins vaseux favorables aux populations de Pectinaires adultes et sur les sables fins à moyens propres à Ophelia borealis qui en sont dépourvus.

CONCLUSION

Malgré leur caractère préliminaire, les résultats acquis laissent entrevoir les axes dans lesquels devront être engagées à plus ou moins long terme les recherches qui permettront de mieux juger du poids des processus hydrodynamiques sur le recrutement d'espèces à cycle bentho-pélagique, à distribution insulaire au débouché d'un grand estuaire, dans une mer à régime mégatidal.

Si la faisabilité technique de l'échantillonnage des phases majeures du cycle de vie de l'espèce étudiée Pectinaria koreni, à l'échelle spatiale appropriée est clairement démontrée au terme de la première année d'étude, il s'avère qu'une seconde saison d'observations, au pas d'échantillonnage bien adapté à la vitesse de déroulement des évènements biologiques, est nécessaire pour cerner avec précision des phases aussi capitales que l'apparition de la première ponte ou celle des tout premiers stades larvaires pélagiques.

De même les ordres de grandeurs numériques des densités des phases macrobenthique, pélagique et méiobenthique qui constituent dès à présent avec ceux relatifs à leurs durées de présence respectives dans la masse d'eau et sur le fond, des champs de valeurs plausibles pour les modèles de dynamique de population, devront être affinés au cours de la seconde année. Ainsi par exemple, il importe dès maintenant de passer de l'évaluation de la fécondité potentielle individuelle rendue possible grâce à la mise au point de la technique de dénombrement ovocytaire, à une approche quantitative de la ponte à l'échelle des populations de la Baie de Seine qui tienne compte de leur structure dimentionnelle en s'efforçant de définir la relation unissant la taille et la fécondité des individus.

Dans le même ordre d'idées, bien qu'une bonne concordance apparaisse déjà entre les images de distribution horizontale et verticale des larves pélagiques et les hypothèses de travail basées sur l'état actuel des données sur l'hydrodynamique de la Baie de Seine une délimitation plus complète de l'extension du panache est nécessaire, une meilleure connaissance de sa constitution ontogénique (à travers l'identification et l'âgeage des différents stades) contribuant à vérifier les hypothèses de stratification et d'absence de migration mycthémérale.

Les premiers résultats concernant la colonisation des fonds par les post-larves sont également d'importance et, de ce fait, demandent à être vérifiés ; il semble en effet qu'au cours du printemps de 1986 le recrutement s'est réalisé en densité du même ordre sur un large spectre édaphique que ce recrutement aboutisse ou non au développement de populations d'adultes. Pourtant parmi les incertitudes qui demeurent quant au déroulement de cette phase capitale du cycle de vie, certaines devront absolumment être levées ; ainsi il est essentiel de savoir si la présence simultanée de larves "âgées" (stades aulophoriens) dans la colonne d'eau et sur le fond correspond réellement à un décalage entre métamorphose et sédentarisation, cette dernière pouvant s'effectuer, plus ou moins lentement, à travers des remises en suspension activées par la dynamique mégatidale. Ce dernier point démontre bien toute l'urgence d'entreprendre l'étude des processus dynamiques en couche limite de fond.

Si la poursuite du programme nécessite l'affinement des données de terrain actuellement recueillies, une approche théorique par modélisation du comportement des particules en suspension dans ces eaux en circulation est à mettre en oeuvre simultanément. La conjonction de ce modèle et du modèle courantologique devrait permettre par comparaison avec la répartition observée des larves de déduire des informations en terme de déplacements, de mortalité etc...

Mais si l'on veut espèrer tendre vers une analyse causale des phénomènes encore convient-il d'intégrer aux modèles des paramètres biologiques où le comportement des larves trouvera sa place. L'expérimentation en laboratoire sur le comportement, en particulier moteur, doit être impérativement engagée pour commencer à combler l'immense lacune qui existe en ce domaine dans nos connaissances sur la biologie larvaire. L'exprérimentation constitue donc aux côtés de l'observation de terrain et de l'approche modélisatrice le troisième volet des recherches à promouvoir.

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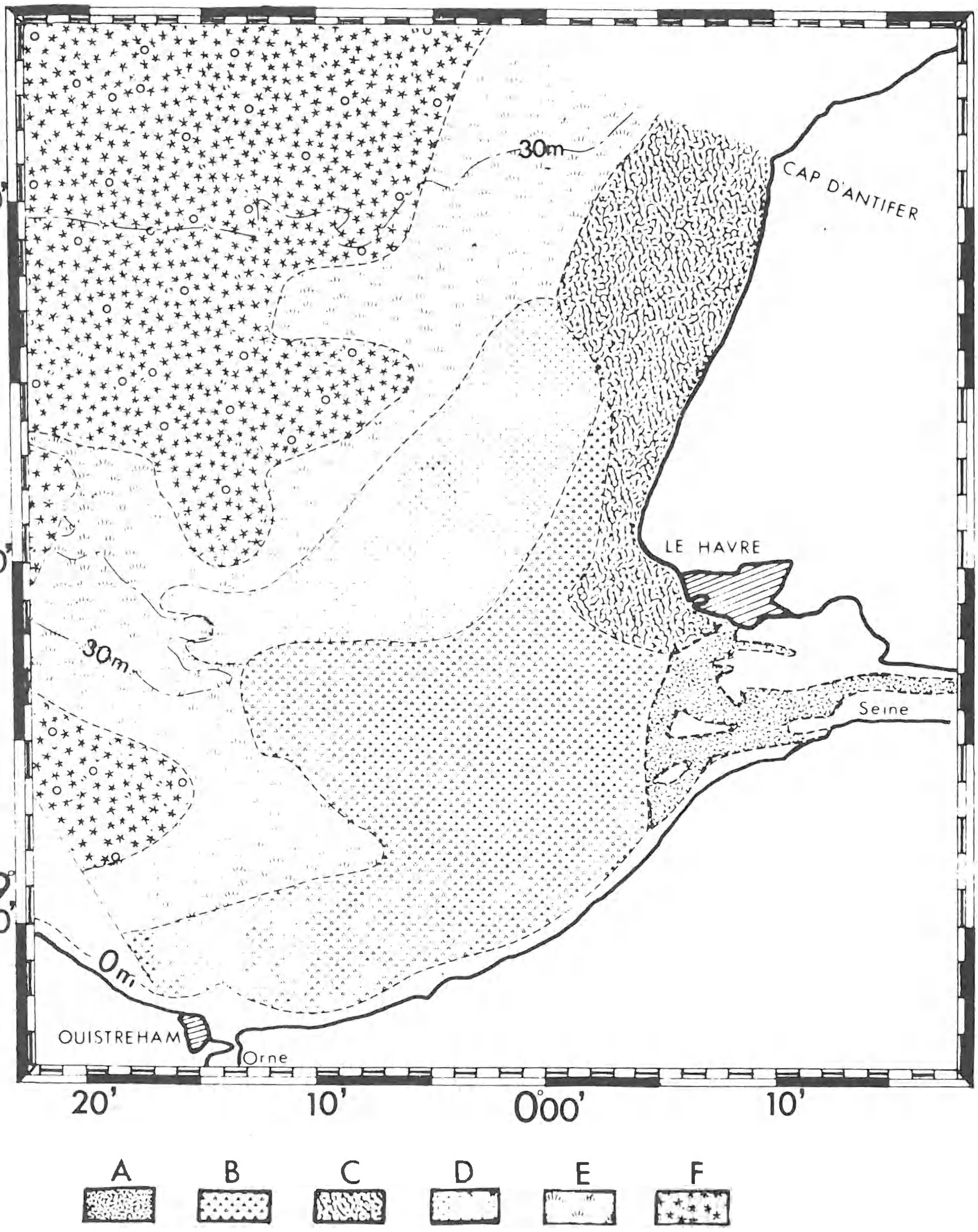

Fig. 1 : Peuplements benthiques de la Baie de Seine. A : Sédiments vaseux, communauté pauvre oligospécifique à Macoma balthica. B-C : Sables fins plus ou moins vaseux à Abra alba - Pectinaria koreni (B : faciès type ; C : faciès hétérogène envasé à Pista cristata). D : Sables fins à moyens propres à Ophelia borealis. E-F : Peuplement des graviers plus ou moins sableux à épibiose sessile (E : faciès type ; F : faciès à Ophiothrix fragilis). (D'après CABIOCH et GENTIL, 1975).

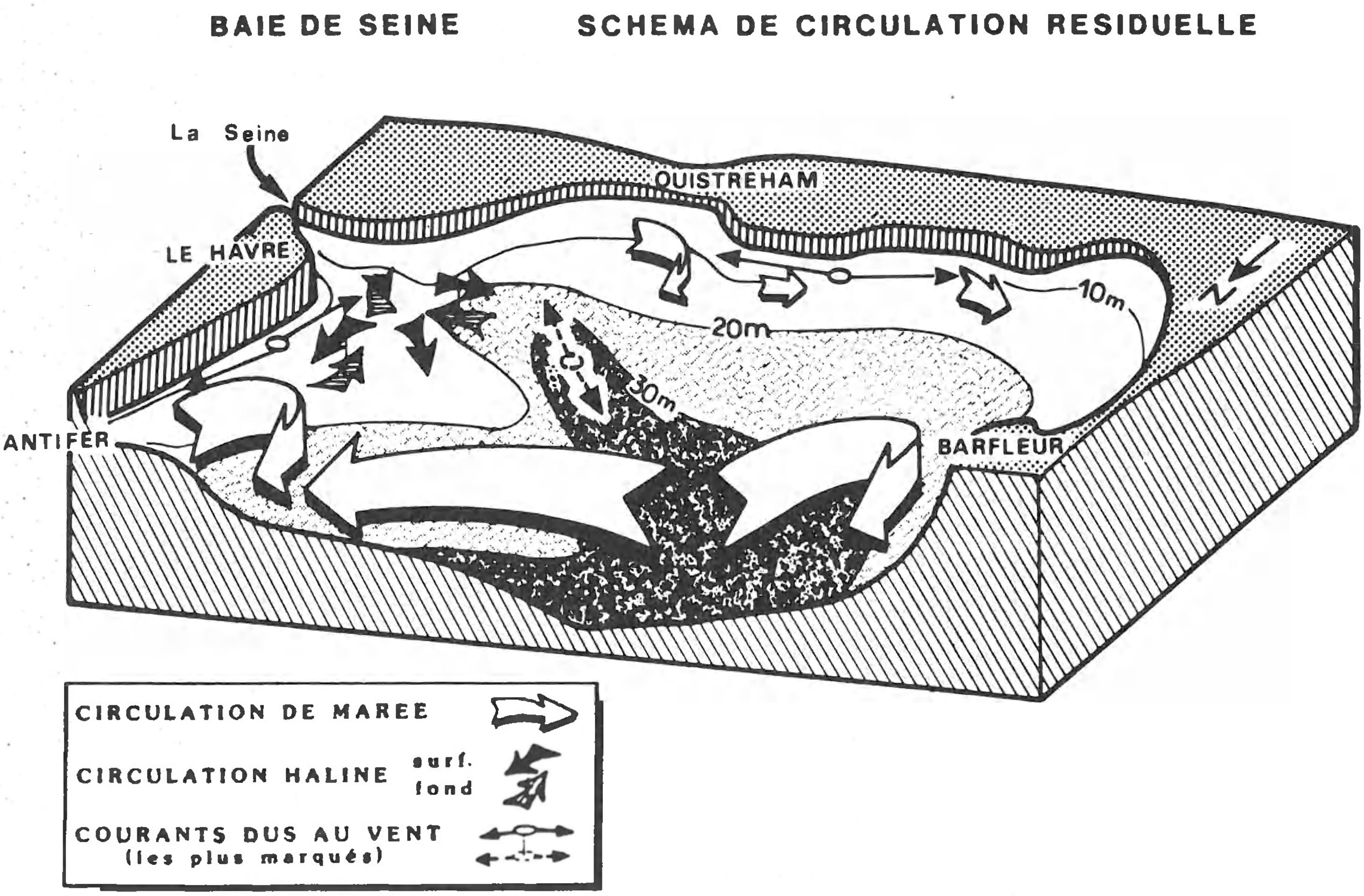

Fig. 2 : Schéma global de la circulation résiduelle moyenne en Baie de Seine (d'après LE HIR, SALOMON, LE PROVOST, CHABERT D'HIERES et MAUVAIS, 1986).

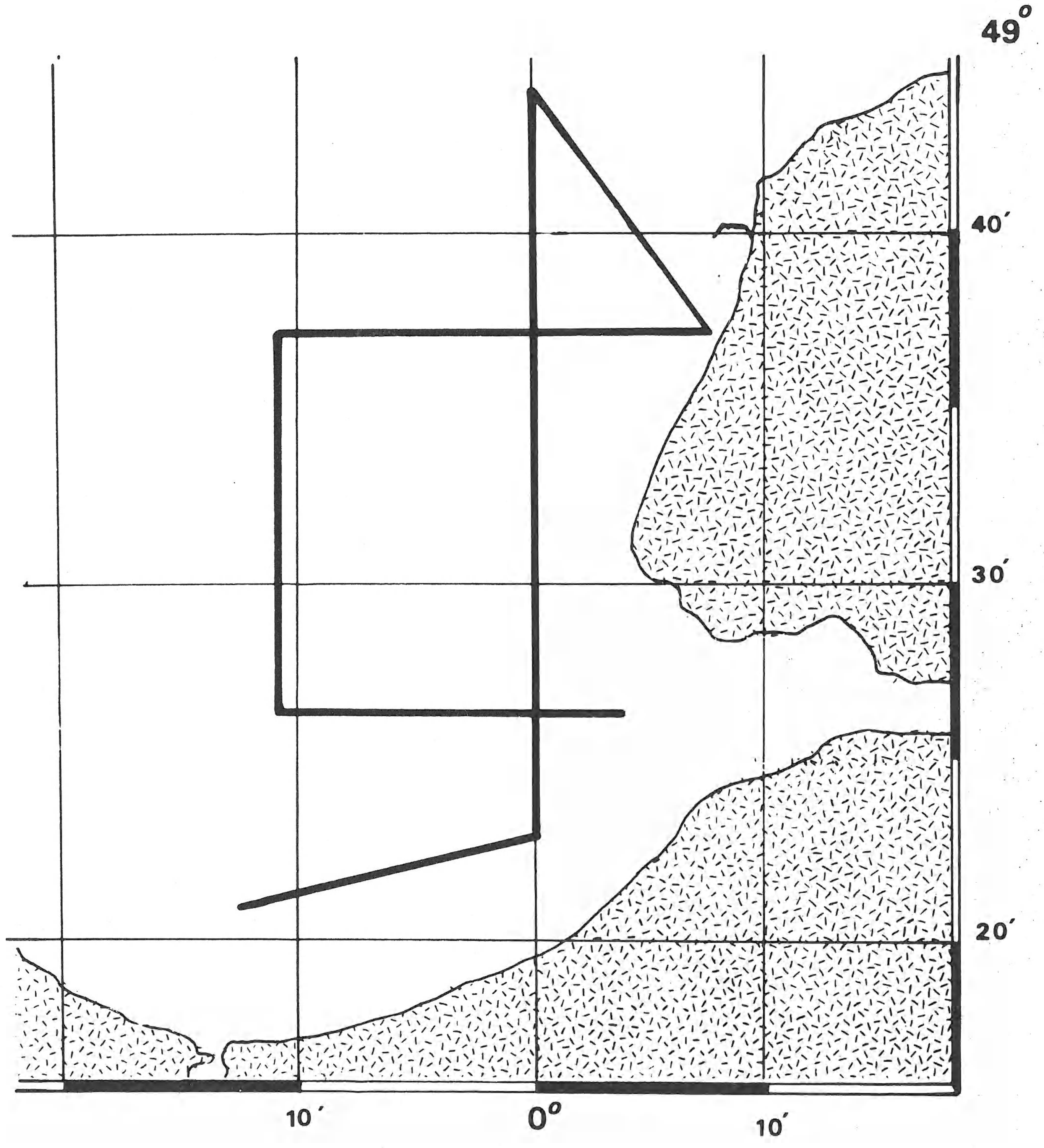

Fig. 3 : Observation à petite échelle. Prélèvements en continu à la pompe.

Trajet parcouru

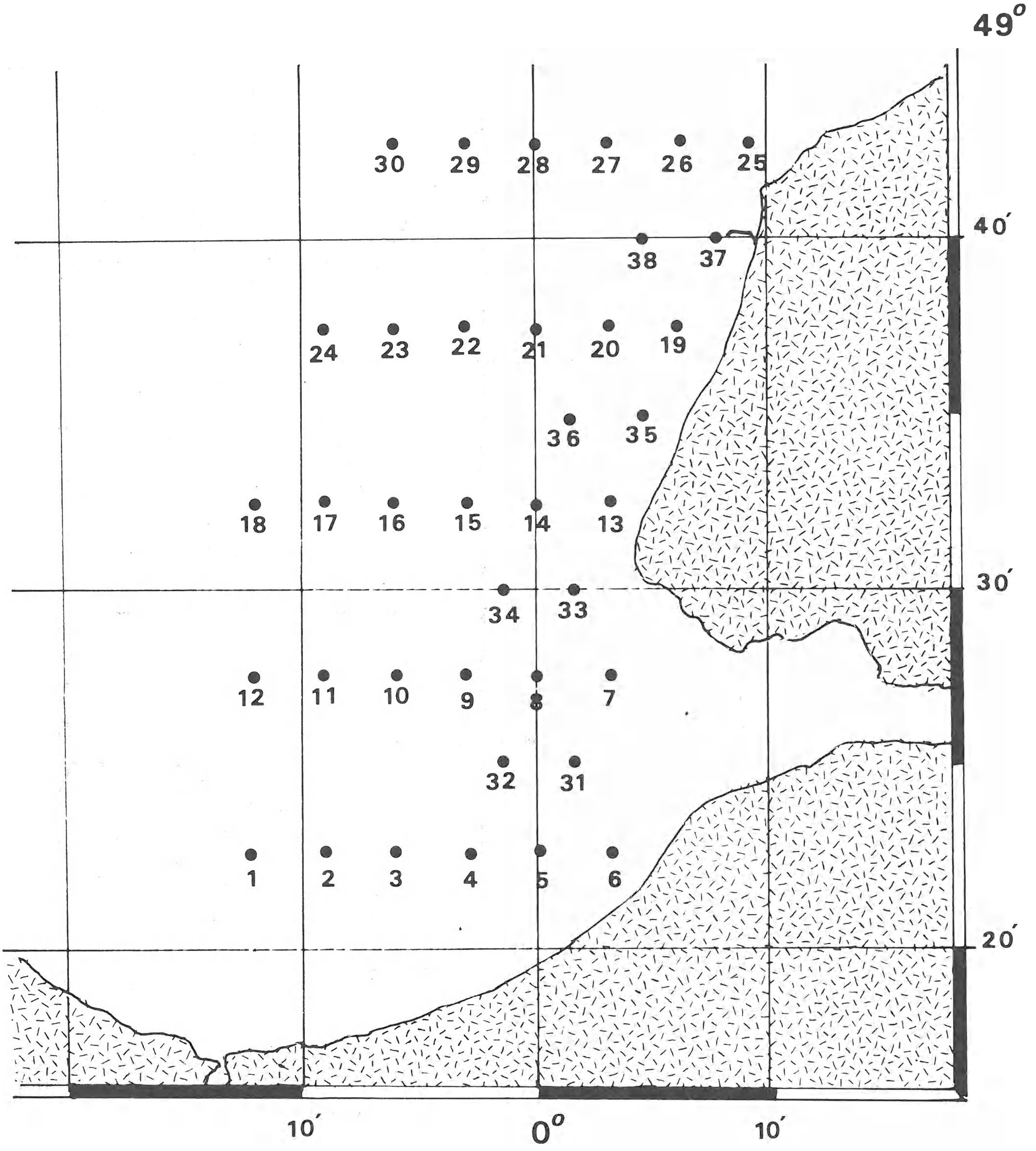

Fig. 4 : Observation à petite échelle. Stations de prélèvements au filet WP2 (80 µm).

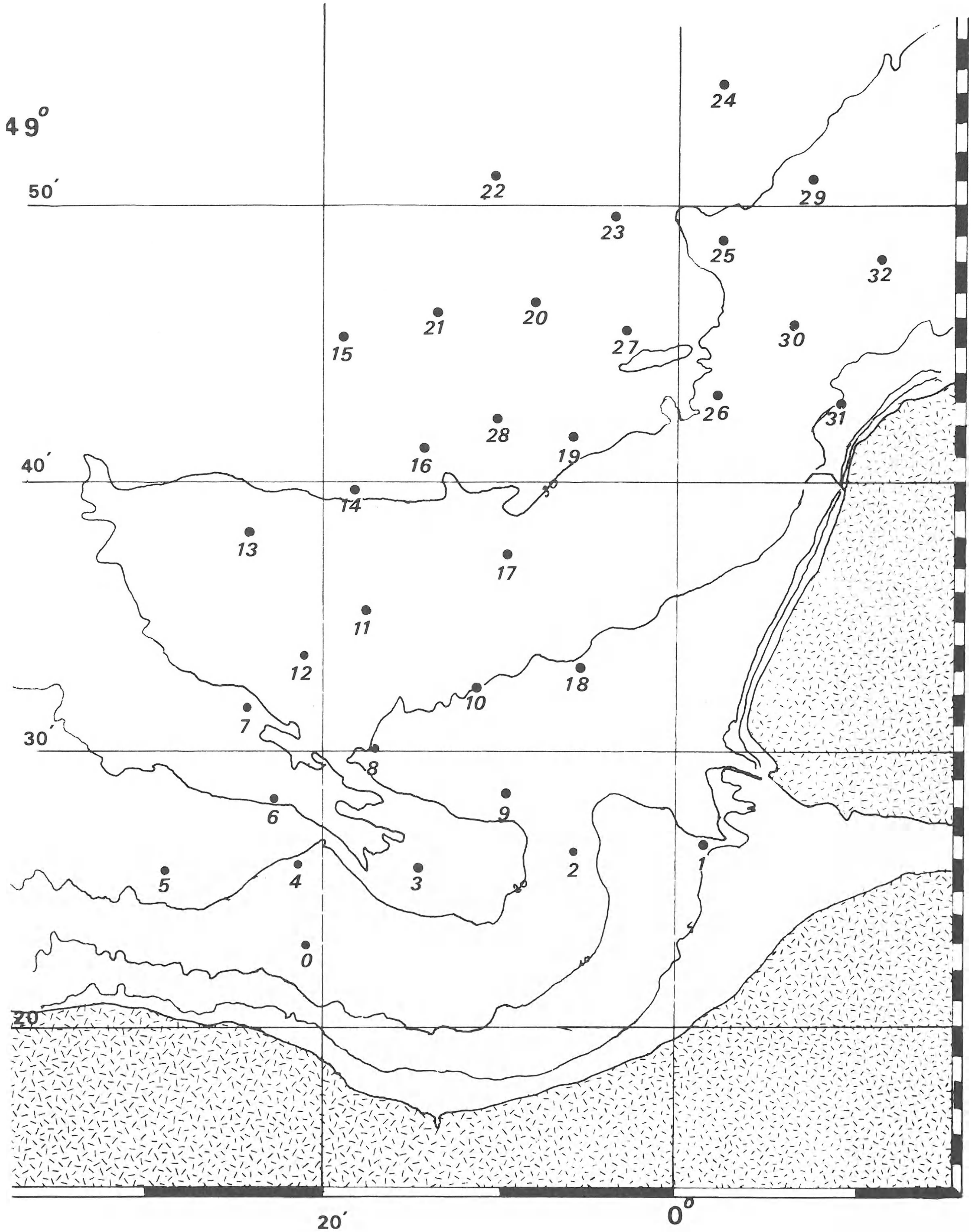

Fig. 5 : Observation à grande échelle. Stations de prélèvements au filet WP2 (80 µm).

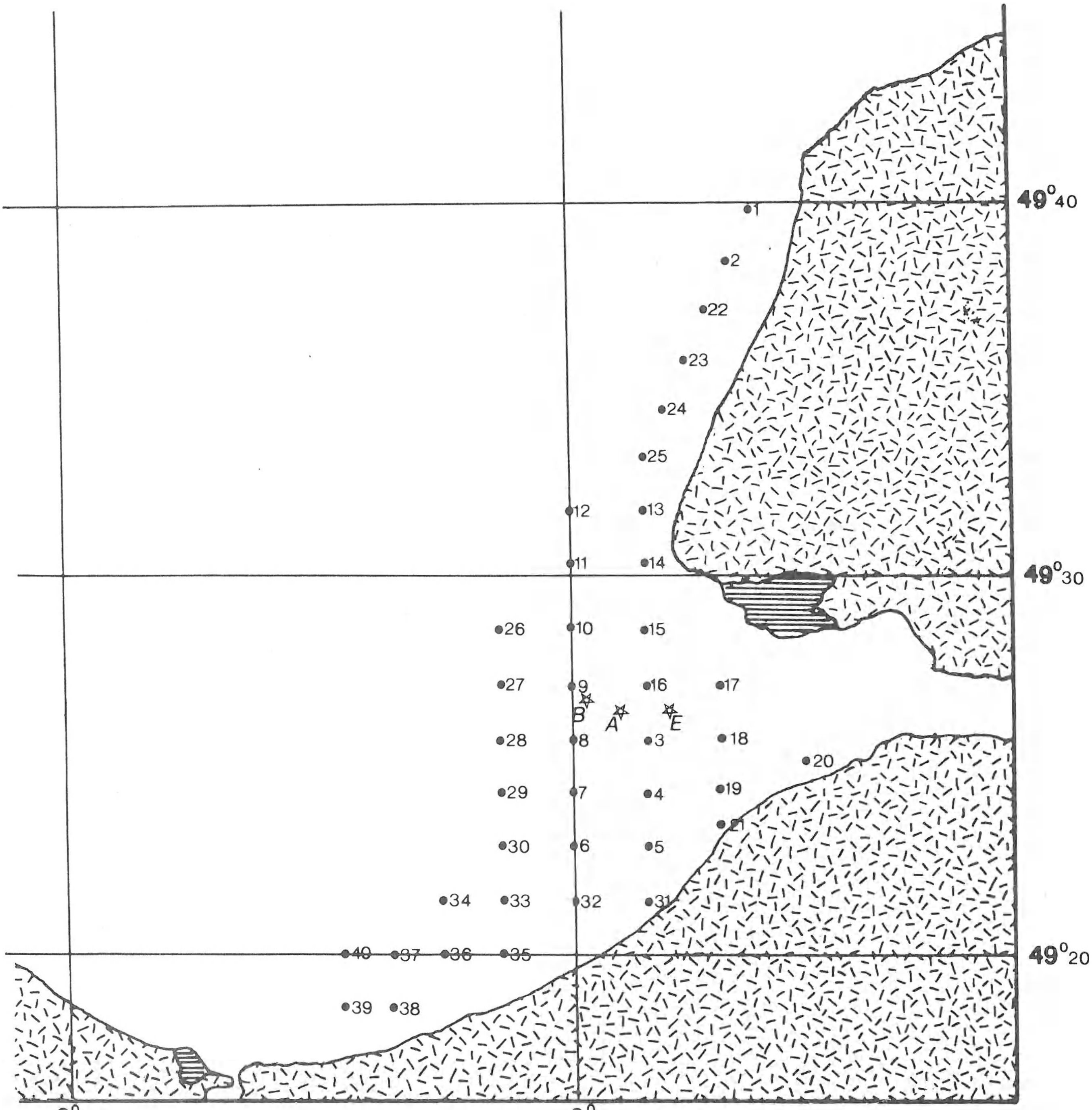

Fig. 6 : Stations d'échantillonnage des populations adultes en février 1986 ; stations 1 à 40 : prélèvements à la benne Hamon.

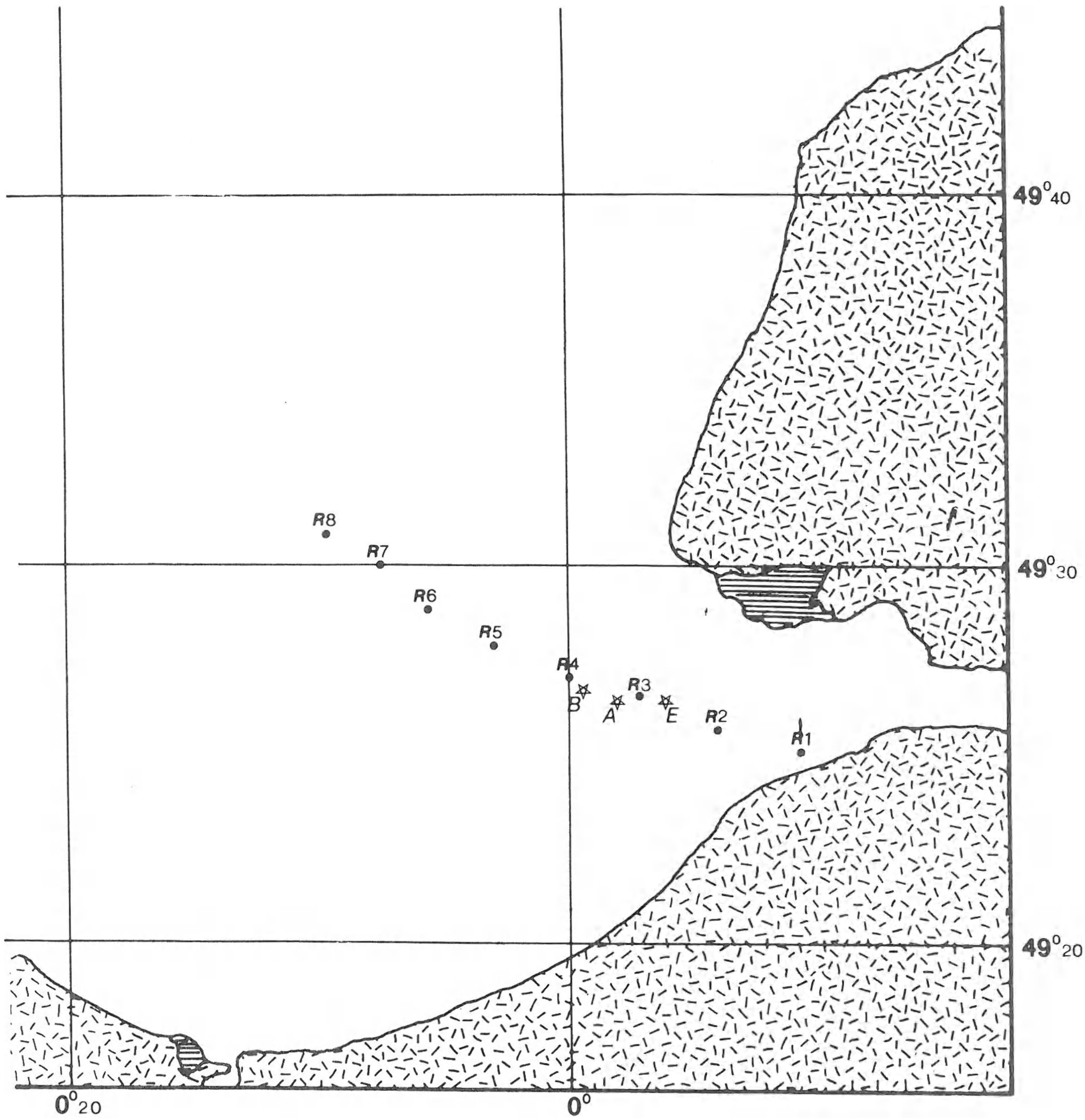

Fig. 7 : Stations d'échantillonnage des populations de post-larves ; stations R1 à R22 : prélèvements au carottier Reineck.

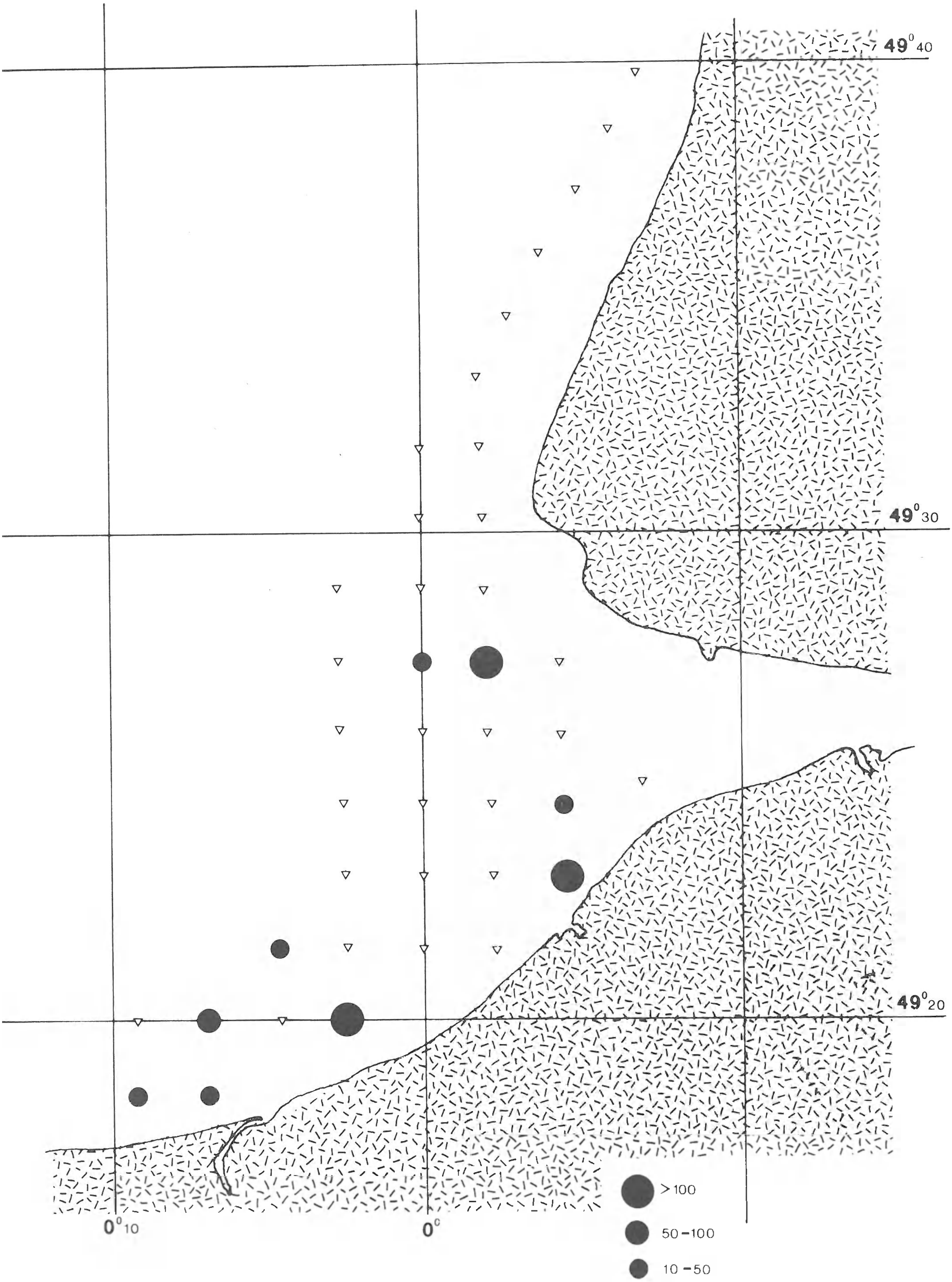

Fig. 8 : Densité de Pectinaria koreni adultes exprimée en nombre d'individus pour 0.5 m².

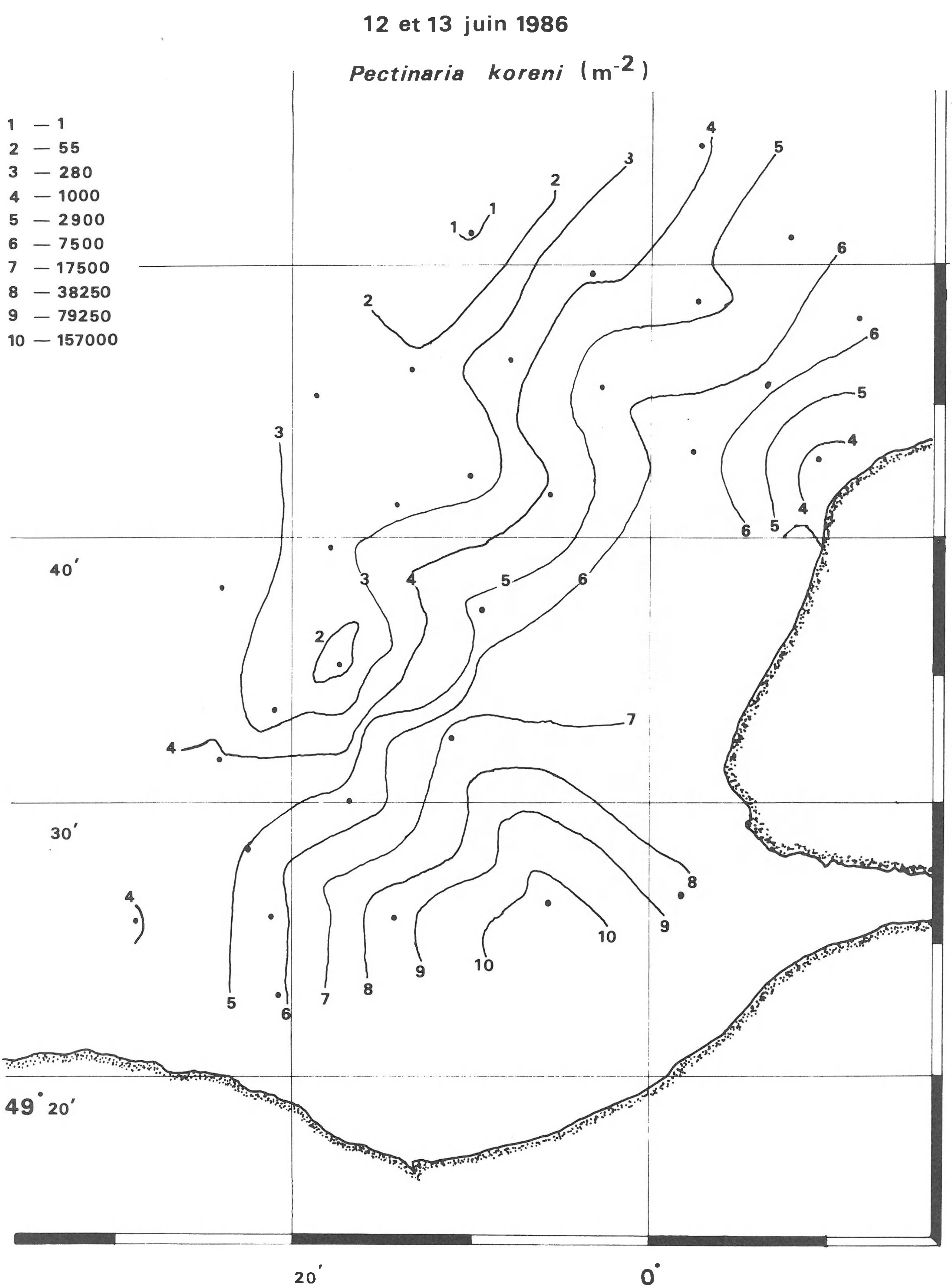

Fig. 9 : Distribution des lignes d'isodensité des larves de Pectinaria koreni les 12 et 13 juin 1986.

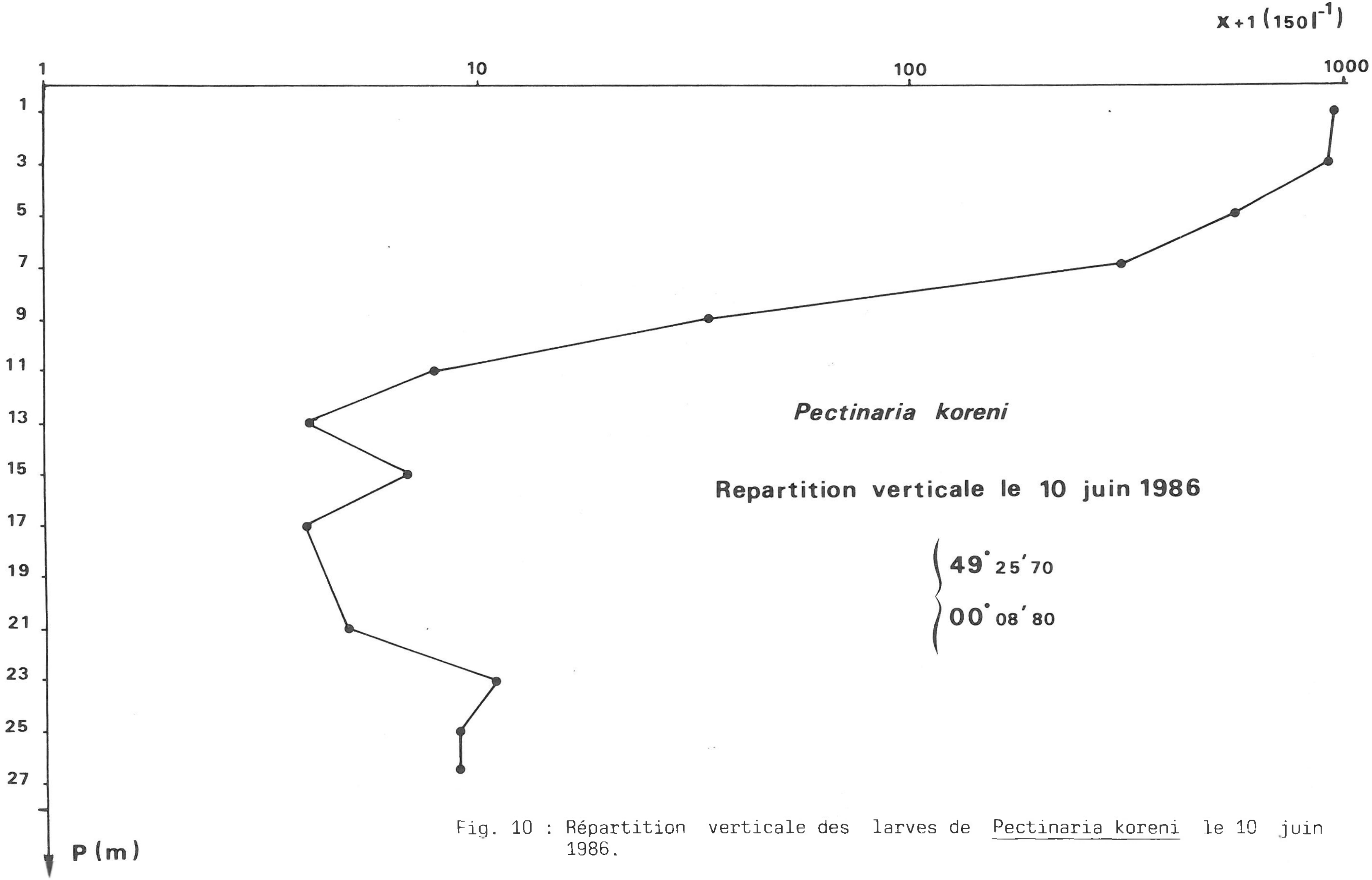

Fig. 10 : Répartition verticale des larves de Pectinaria koreni le 10 juin 1986.

Preliminary observations on the macrobenthos of a bay in the Po river delta. Consideration of a plan for pluriannual investigations.

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INTRODUCTION AND STUDY AREA

Deltaic embayments are characteristic environments of the Mediterranean Sea. They are almost always subtidal in spite of the shallow depth. Over the short period of a few decades, they undergo a more or less typical geological evolution changing to lagoons and then to dry land. However, new bays with the same characteristics are continually being formed; these, in turn , follow the same geological progression.

In many regions of the European Mediterranean countries, such as Northern Italy where the human population density has almost stabilized and intensive agriculture is highly developed, projects of land reclamation have halted. In these areas, the territorial policy has tended toward preserving the coastal acquatic ecosystems, mainly in estuaries and deltas. None the less, these ecosystems are still quite vulnerable to many interactive factors often leading to serious end effects. One of these is eutrophication. Because of the shallowness of the lagoons, benthic communities are the biotic component mainly affected by the impact of environmental perturbations and are, thus, worth monitoring.

On the other hand, deltaic bays are nursery grounds for the fry of many exploited fish species and benthic organisms are their most important prey items. Therefore, research on benthic community dynamics is also related to plans for rational exploitation of natural resources. This has a basic role in conservation programmes.

This report describes some results of studies performed on benthos in the Sacca di Goro, an embayment of the Po River Delta on the western Adriatic coast. These studies are preliminary to a long-term research project on that ecosystem. The reported observations may be of use in discussing the project itself and the methods to be used.

The Sacca di Goro is a small embayment on the southern part of the Po Delta (Fig. 1). All the land surrounding the bay has recently been reclaimed and the residual basin is now the object of conservation planning. This bay, as well as others in the same region, is exploited for specialized fisheries (mostly fish-fry) and shellfish culture. Therefore, the conservation efforts aim both to maintain the remaining wild areas and to improve exploitation of natural resources.

The bay was formed about one hundred years ago by the rearrangement of sediments discharged by the southern branch of the Po River. It is about 32 km^2, has an average depth of about 1m and quite a shallow seaward mouth, which is nearly 2.5km wide. A dredged underwater channel, 4m deep, crosses the bay, joining a fishing harbour to the sea. Tidal floods and storms are the main hydrodynamic factors affecting both current and sediment distribution patterns in the bay.

Minor freshwater inputs come through short and narrow channels, which cut the dyke of the adjacent river branch, and from reclamation pumping plants, which discharge the water from the surrounding land into the bay.

The bay is a brackish water environment with both wide seasonal and short-term irregular variations in salinity : a polyhaline environment.

Over a one-year period, the macrobenthos of the Sacca di Goro was studied at 4 stations, located at different distances and in different directions from the bay-mouth (Fig. 1). As mentioned above, the results are preliminary since samples from only 2 stations (St. 7 and St. 8) have thus far been analysed.

Some physical and chemical characteristics of both water and sediments at the two stations are summarized in Figs. 2 and 3 and Tables 1 and 2. Differences between the stations are quite obvious.

THE MACROBENTHOS

Sampling Methods

Macrobenthic organisms were sampled seasonally (5 dates) with a suction sampler using the counterflush technique (Van Arkel and Mulder, 1975) (Fig. 4) and collecting the animals retained by a 1mm mesh sieve. At each station, and on each date, sampling was performed by taking 16 cores along 4 transects distributed as shown in Fig. 5. The animals collected were fixed in buffered formalin, stained with rose of Bengal , sorted , classified to species level and counted. Weighing is still in progress.

The sampling method was tested in order to assess whether the number of replicates was sufficient to reliably estimate densities. ANOVA performed on density geometric averages between transects showed no significant F ratio at St. 7, which means that small scale variability (within transects) is not different from large scale variability (between transects). On certain sampling dates, some significant differences were found at St. 8, for total densities as well as for some species (Table 3).

By using the Elliott and Drake (1981) formula, the least number of samples required to obtain a reliable estimate of total density was calculated (Table 4). At times, 16 samples were not sufficient to give an acceptable density estimate at St. 8. However, on the whole, the reliability of the adopted sampling procedure was good enough. The same estimates were performed whenever possible on the density of each individual species and the resulting values were more or less the same as those shown in Table 4 for the ommonest, most abundant species. This was less satisfactory for the rarer species.

Since, the choice of a suitable sampling method is also related to other factors such as, for example, the labour input required to process and sort samples, it was judged that, all things considered, 16 samples per station, and per date, were an acceptable compromise for easy management of the investigation.

RESULTS

Taking all the samples into account (Table 5), 34 species were found at St. 7. They included polychaetes, bivalves, gastropods, crustaceans and chironomids, in addition to unidentified oligochaetes and turbellarians. Only 26 species of the above taxa were found at St. 8, in addition to unidentified oligochaetes and opistobranches. Based on the dominant species, two well differentiated communities seem to characterise the environments of the two sampling stations.

Macrobenthic density variation patterns as well as those of some single species were analysed. In Figs. 6 and 7, seasonal changes of total density averages in the communities at the two stations and the percentage species composition for each date are shown. St. 7 has higher density values in summer, whereas St. 8 shows them in winter. This is likewise true even when the high numbers of *Polydora ciliata* at St. 7, and those for *Hydrobia* sp., at St. 8, are respectively omitted from the totals.

Seasonal trends in the geometric average densities of some dominant species are shown in Figs. 8 to 14. Marked seasonal fluctuations differently affect the abundance of these species at the two stations. This is most likely due to the different ways in which the species populations, forming the two associations, respond to both seasonally recurrent and unpredictable environmental stress such as oxygen depletion, freshwater flushing, rough seas, etc.

CONCLUDING REMARKS

The structure and dynamics of the benthic communities of the Sacca di Goro, which are described here on the basis of a preliminary investigation, suggest some points for discussion.

The chosen sampling method had to be adapted to environmental characteristics. The suction sampler, with its relatively small corer diameter, appears to be very suitable in shallow lagoons because of its easy handling, digging performance and capture efficiency of both widely dispersed, large and highly dense, small animals.

However, the sampling strategy has to be tested because of the spatial variability in densities within the communities. In fact, the number of samples collected for the purposes of the present investigation turned out to be excessive in one of the surveyed stations (St. 7), and was barely sufficient in the other (St. 8). The benthic communities are clearly different at the two stations investigated to date. It seems likely that the communities at the two other stations yet to be examined will prove different in composition and structure as well.

No trend in any abiotic parameter considered separately appears adequate to explain the observed differences in community structure and dynamics at the two stations. The main factor determining the biotic structure of the different bay zones would seem to be the respective distance from the sea mouth, when considered from an hydrodynamic point of view. This also probably determines the kind and severity of seasonally recurrent environmental crises.

Benthos is the one biotic compartment of the lagoon environment which best retains traces of the environmental changes and which may characterise a community's response to environmental factor fluctuations. The research program planned for the Sacca di Goro will encompass both descriptive and experimental approaches to the investigation of macro- and meiobenthos, in order to define benthic population variability on a seasonal and multi-year time scale and test population responses to naturally recurrent or induced environmental disturbances. Species specific analysis will also include life history data and recruitment estimates.

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Taylor, L.R., 1961 - Aggregation, variance and the mean. *Nature*, London, 189, 732-635.

Van Arkel, M.A. & M. Mulder, 1975 - A device for quantitative sampling of benthic organisms in shallow water by means of a flushing technique. *Netherlands Journal of Sea Research*, 9, 365-370.

Table 1. Annual average values ± s.d. and ranges of main hydrological and trophic parameters at the two sampling stations.

		Station 7	Station 8
Temp ^{o}C	x ± s.d.	16.1 ± 6.6	16.5 ± 7.6
	range	4.2 - 27.0	4.3 - 29.0
Sal. %	x ± s.d.	22.8 ± 6.1	13.8 ± 5.2
	range	10.84 - 32.00	7.0 - 24.0
0_2 sat. %	x ± s.d.	95.25 ± 16.84	108.30± 15.79
	range	71.08 -126.55	76.10-136.45
Chl-a mg/m	x ± s.d.	16.2 ± 15.8	34.70± 38.7
	range	0.9 - 50.5	0.5 - 127.2
Seston mgC/l	x ± s.d.	2.31 ± 1.40	3.23± 2.15
	range	0.47 - 4.68	0.90 - 7.23

Table 2. Granulometric characteristics of the sediment at the two sampling stations.

	Station 7	Station 8
Depth (m)	0.70	0.80
Medium grain size: Md (mm)	0.207	0.007
First quartile deviation: Q_1 (mm)	0.250	0.045
Third quartile deviation: Q_3 (mm)	0.180	0.002
% silt clay	0.80	77.02
Grade classification	Fine-sand	Sandy-clayey-silt
Sorting (by Trask index)	VWS	VPS

Table 3. Results of a one-way ANOVA for comparing geometric mean densities (log(x+l)) between transects (d.f. of F = 3/12) performed at each date on the total macrobenthic specimens, on the overall bivalve taxon and on one of the most representative polychaete species (*Polydora ciliata*) respectively

		Mar '84	May '84	Sep '84	Nov '84	Mar '85
Tot.	St. 7	n.s.	n.s.	n.s.	n.s.	n.s.
	St. 8	p<0.001	n.s	n.s	p<0.05	n.s.
Bivalves	St. 7	n.s.	n.s.	n.s.	n.s.	n.s.
	St. 8	n.s.	n.s.	n.s.	-	-
Polydora ciliata	St.	n.s.	n.s.	n.s.	n.s.	n.s.
	St. 8	n.s.	p<0.01	n.s	n.s.	p<0.05

Table 4. Arithmetic mean densities per core ± s.d. 16 cores) of total macrobenthos for each date at St. 7 and St. 8 respectively. n = least number of sampling units required to estimate density with a 95% precision, D = 25% of the sample mean (x)(after Elliott & Drake, 1981).t = Student's t at P > 0.05 and 15 d.f. "a" and "b" are parameters (clumping indexes) obtained from the power-law relationships: $s^2 = ax^{-b}$ (Taylor, 1961) of the 5 seasonal estimates at each station

STATION 7

	x ± s.d.	$n = t^2 ax^{-b-2} D^{-2}$
Mar '84	139 ± 36	4.6
May '84	290 ± 64	5.9
Sep '84	413 ± 137	6.7
Nov '84	247 ± 85	5.6
Mar '85	205 ± 52	5.3

STATION 8

	x ± s.d.	$n = t^2 ax^{-b-2} D^{-2}$
Mar '84	366 ± 103	16.22
May '84	291 ± 284	19.40
Sep '84	493 ± 213	12.80
Nov '84	689 ± 474	9.90
Mar '85	510 ± 98	12.50

Table 5. Overall structure, by major taxa, of the macrobenthic communities atthe two stations: dominant species of each taxon are also indicated

	No of species	%	Dominant Species	%
STATION 7				
Polychaetes	10	82	*Polydora ciliata*	47.70
Bivalves	8	6	*Cerastoderma glaucum*	4.0
Gastropods	2	7	*Hydrobia* sp.	6.5
Crustaceans	13	4	*Balanus improvisus*	2.7
Chironomids	1	0.02	*Chironomus salinarius*	0.02
Others	?	0.98	Oligochaetes	0.75
STATION 8				
Polychaetes	6	20	*Streblospio shrubsolii*	9.18
Bivalves	3	0.51	*Cerastoderma glaucum*	0.49
Gastropods	2	51.55	*Hydrobia* sp.	51.53
Crustaceans	14	17	*Corophium orientale*	10.15
Chironomids	1	10.76	*Chironomus salinarius*	10.76
Others	?	0.18	Oligochaetes	0.14

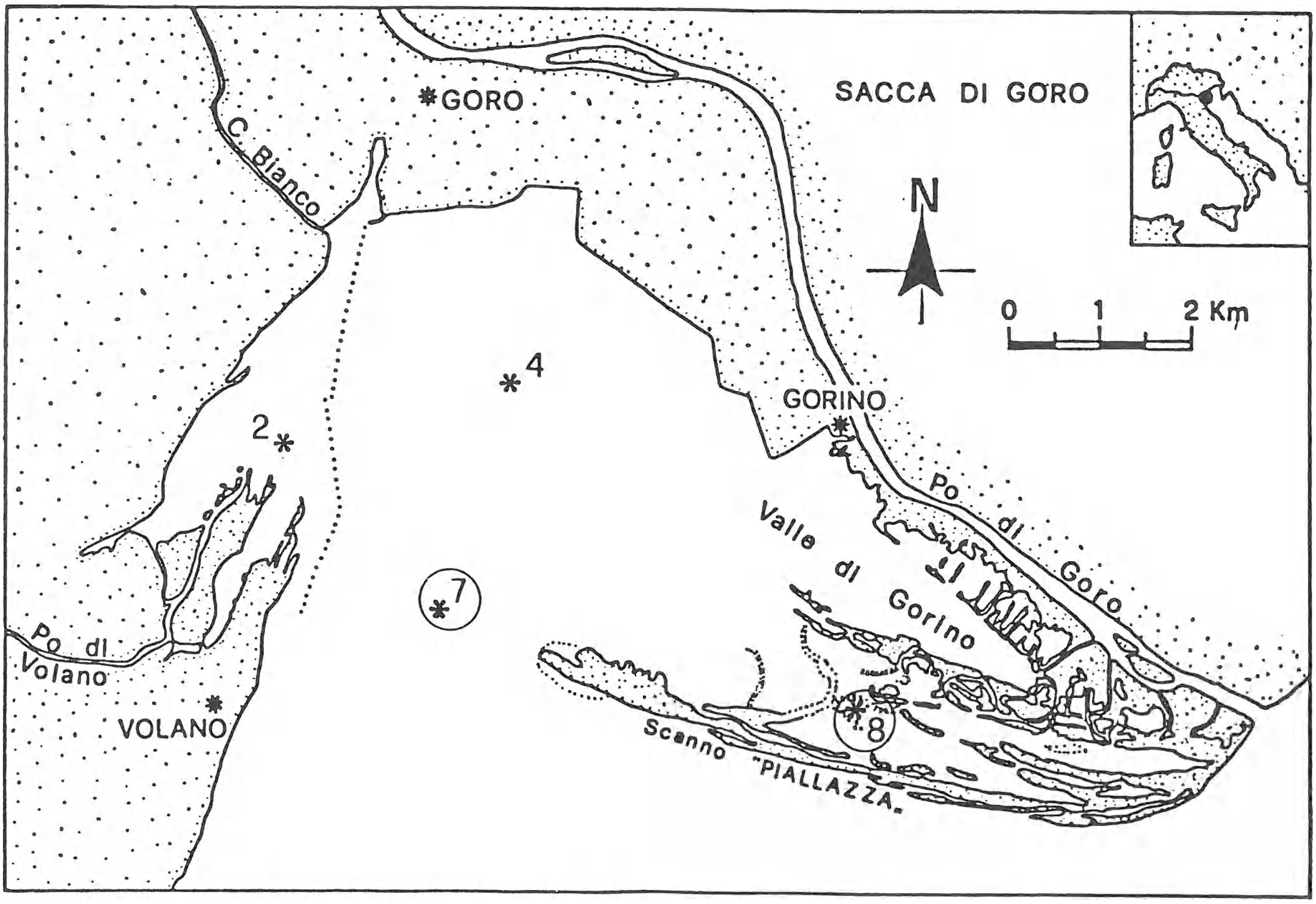


Fig. 1 Map of the Sacca di Goro and sampling stations.

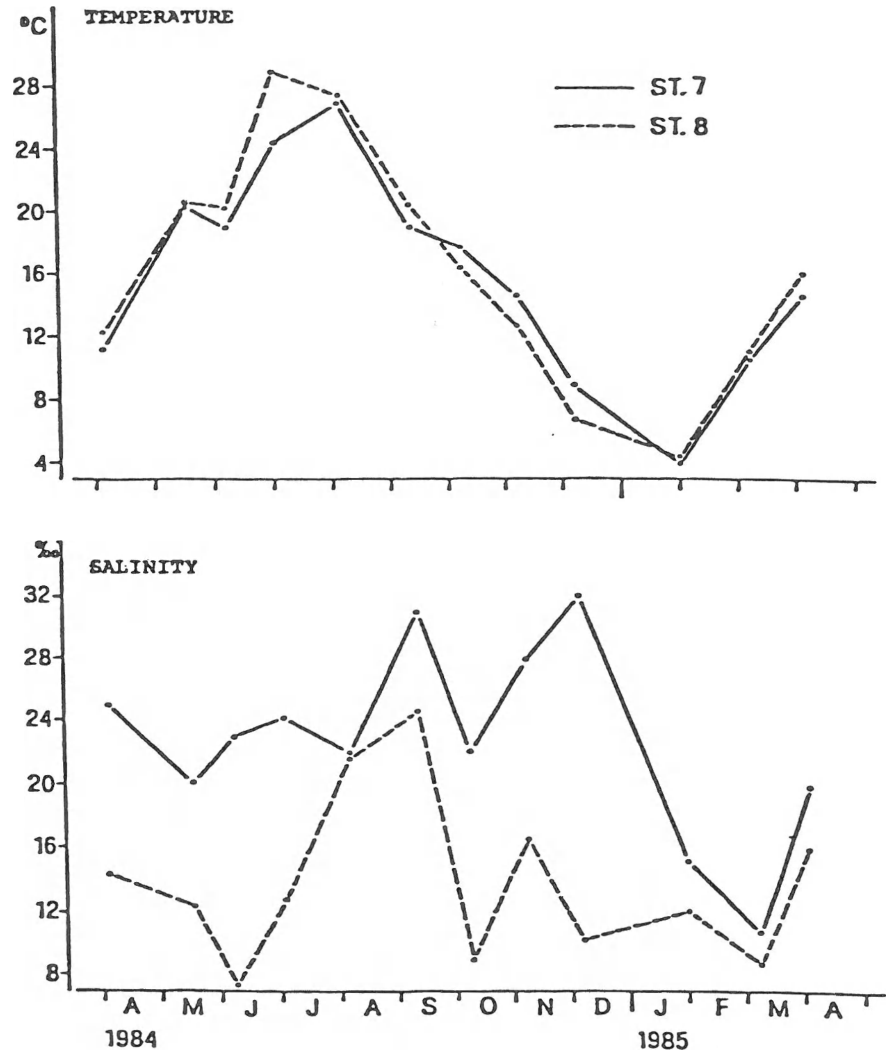


Fig. 2 Monthly trend of both temperature and salinity, recorded off bottom at the two sampling stations (7 and 8) from April 1984 to April 1985.

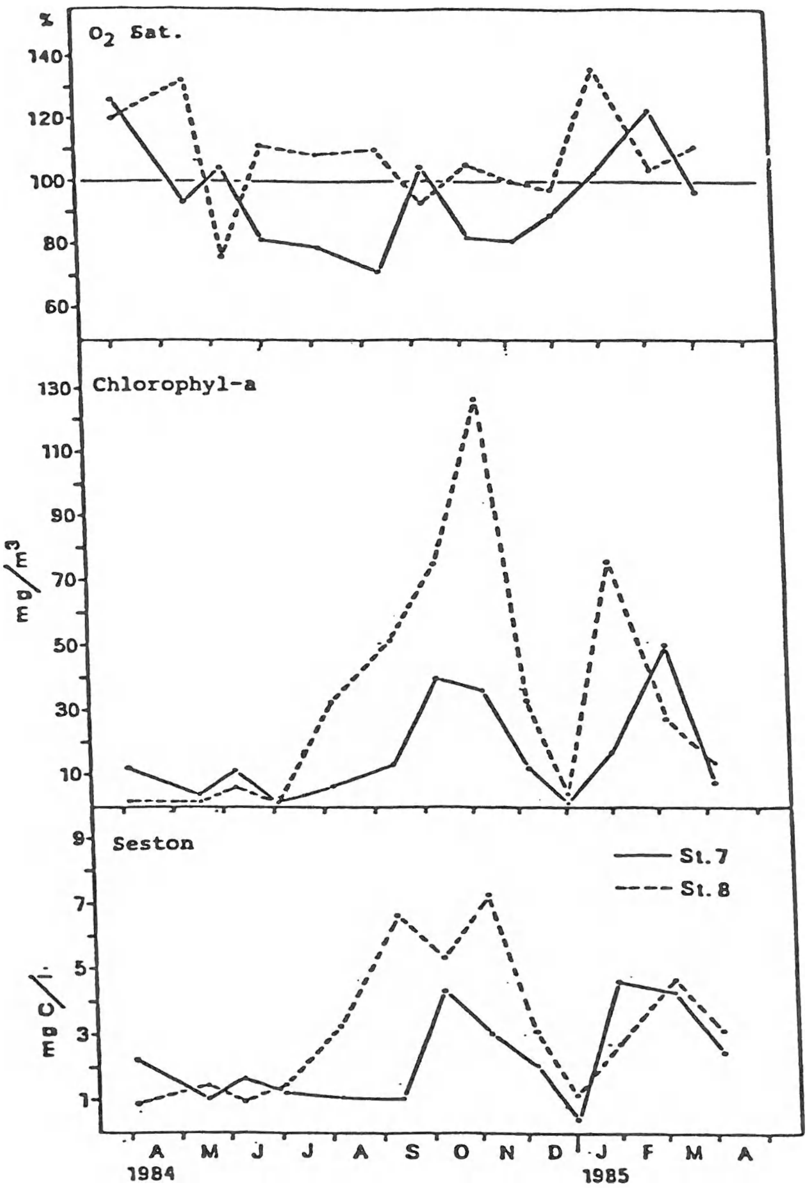


Fig. 3 Monthly trend of O_2 saturation, phytoplankton chlorophyl - a concentration and organic carbon content recorded in the near bottom layer of the two sampling stations (7 and 8) from April 1984 to April 1985.

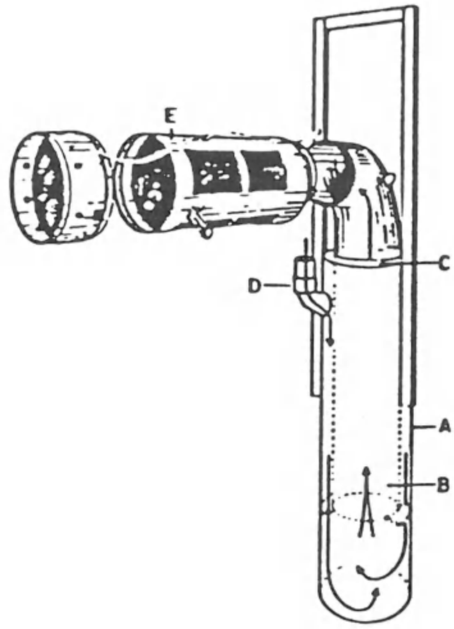
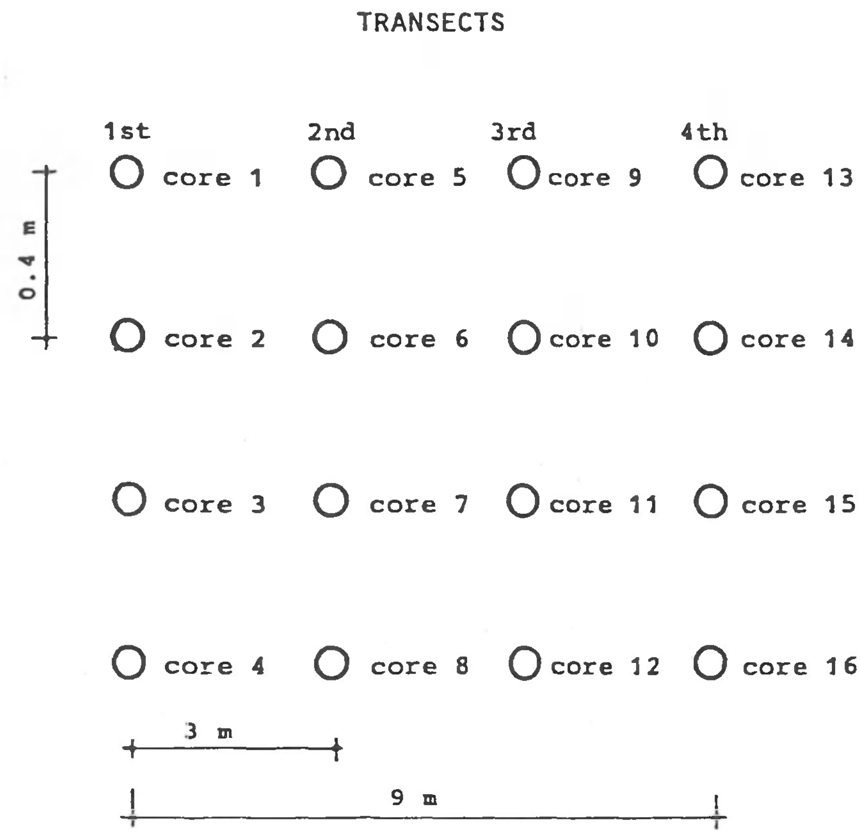


Fig. 4 Suction sampler of van Arkel & Mulder (1975).



Single core area = ~0.02 m^2 Single core height: 15 cm

Transect area (4 cores) = ~0.08 m^2

Total sampled area (16 cores) = ~0.32 m^2

16 cores x 5 dates x 2 stations = 160 samples

Sieve: 1 mm

Fig. 5 Sampling procedure at each station

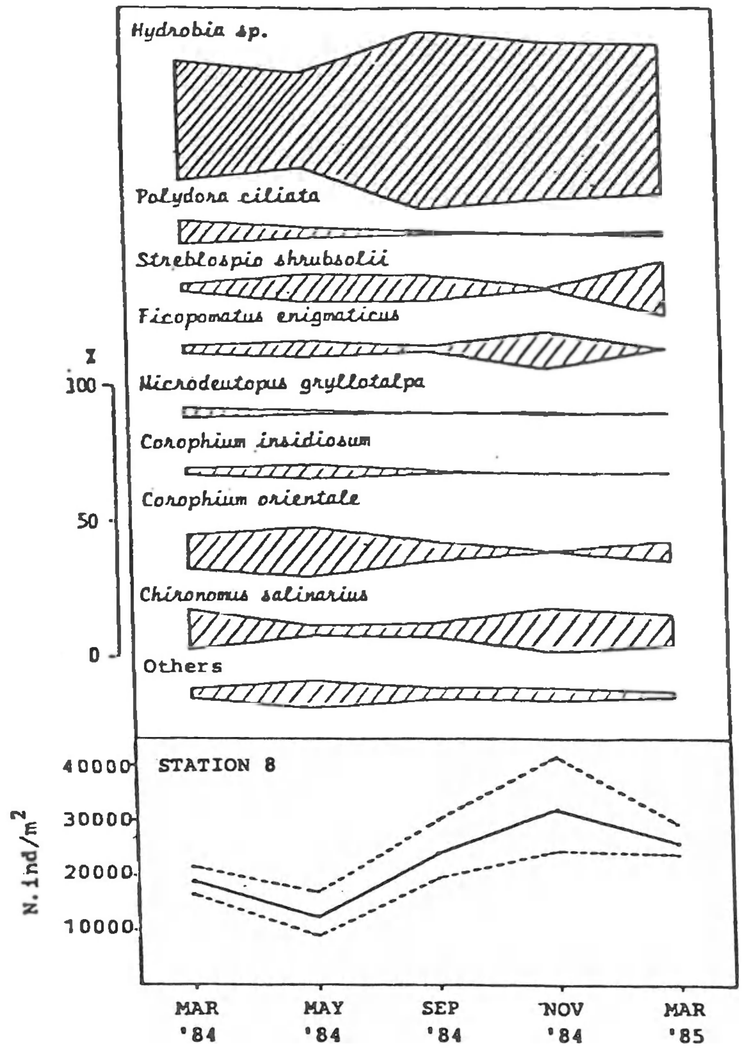


Fig. 6 Seasonal trend of total macrobenthic density geometric averages (± 95% C.L.) in St. 8 (below) and percent composition of the macrobenthic community on each sampling date.

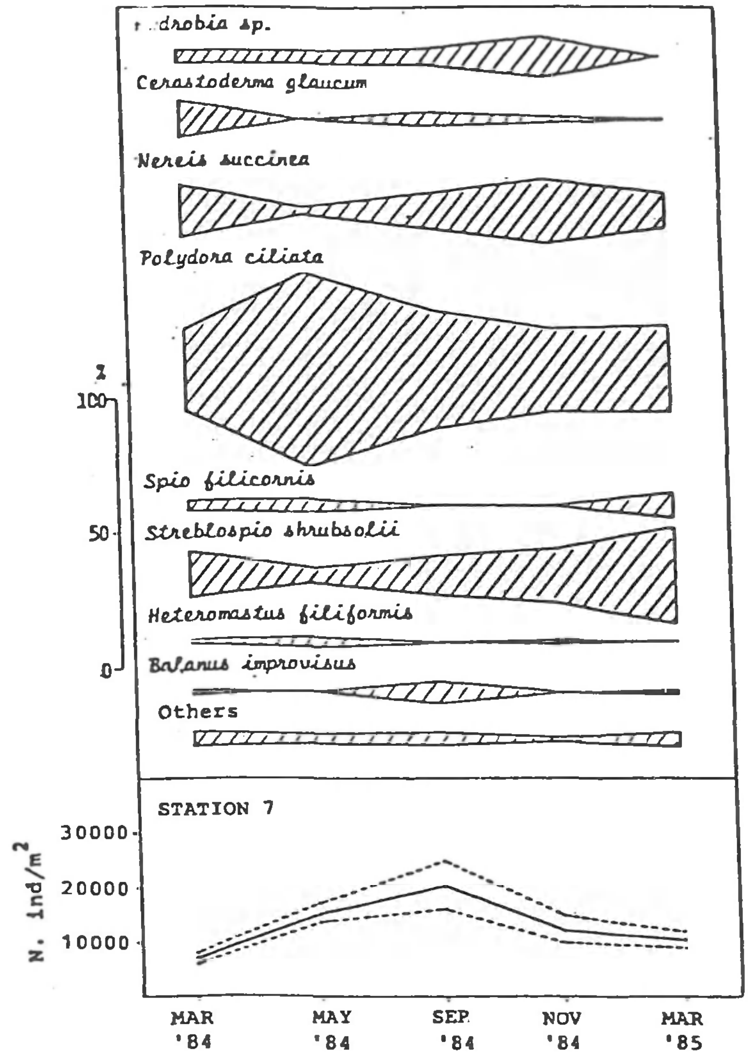


Fig. 7 Seasonal trend of total macrobenthic density geometric averages (± 95% C.L.) in St. 7 (below) and percent composition of the macrobenthic community on each sampling date.

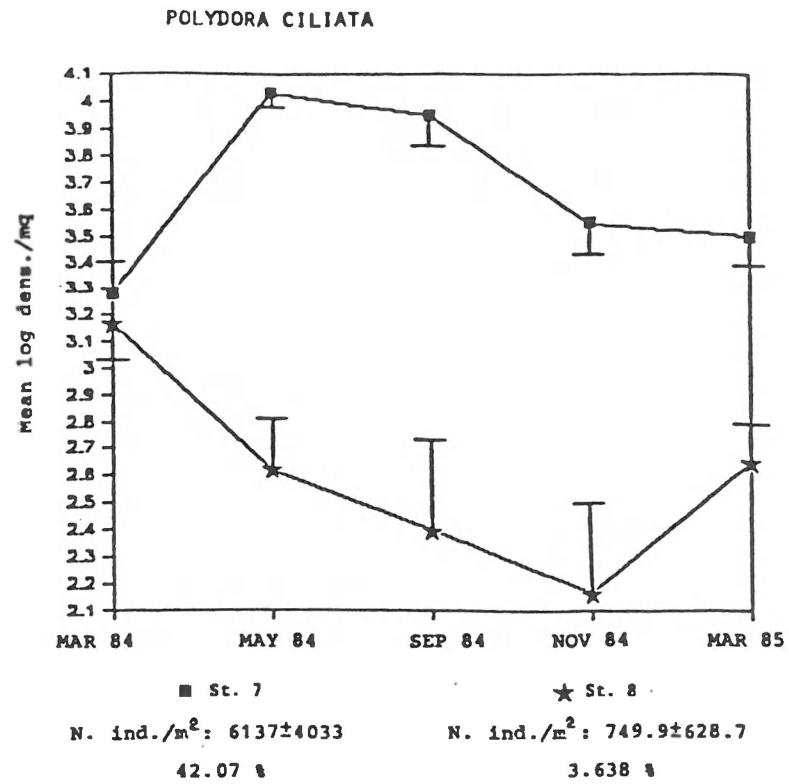


Fig. 8 – Trend of log-density averages (± S.D.) for the named species at the two sampling stations. Annual arithmetic average (± S.D.) and annual percent dominance at each station are shown.

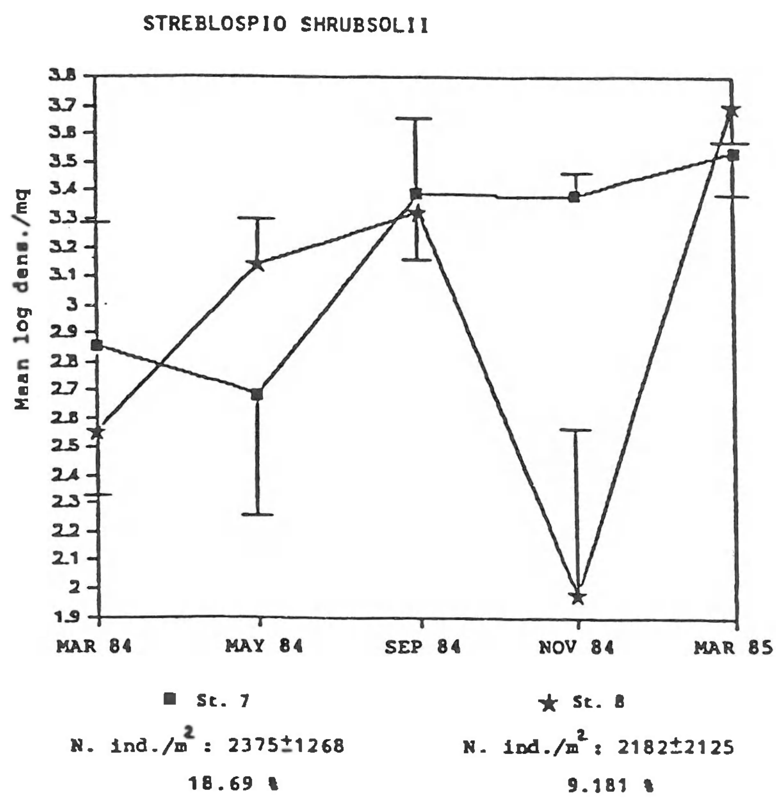


Fig. 9 – Trend of log-density averages (± S.D.) for the named species at the two sampling stations. Annual arithmetic average (± S.D.) and annual percent dominance at each station are shown.

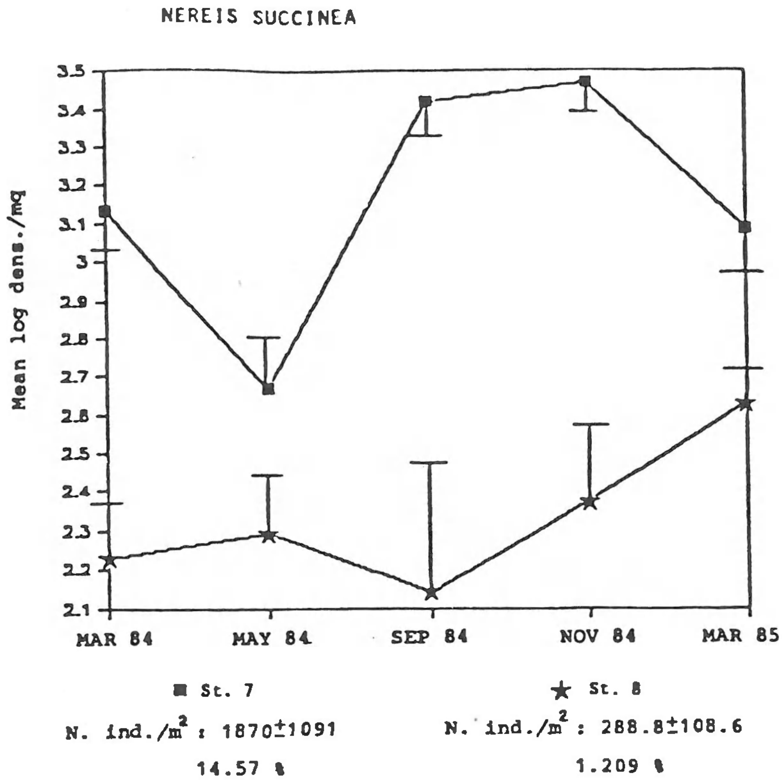


Fig. 10 - Trend of log-density averages (± S.D.) for the named species at the two sampling stations. Annual arithmetic average (± S.D.) and annual percent dominance at each station are shown.

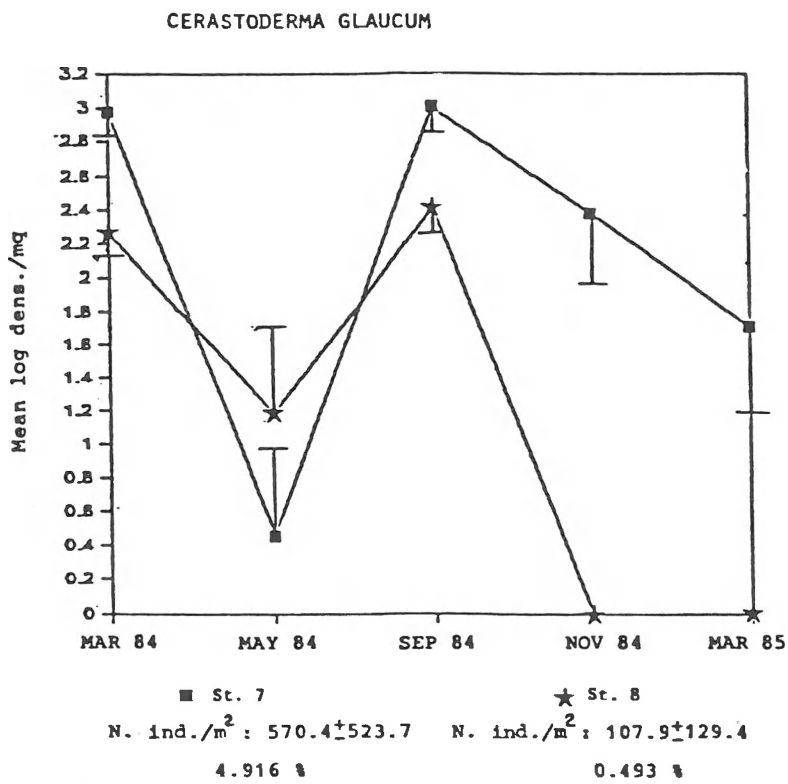


Fig. 11 - Trend of log-density averages (± S.D.) for the named species at the two sampling stations. Annual arithmetic average (± S.D.) and annual percent dominance at each station are shown.

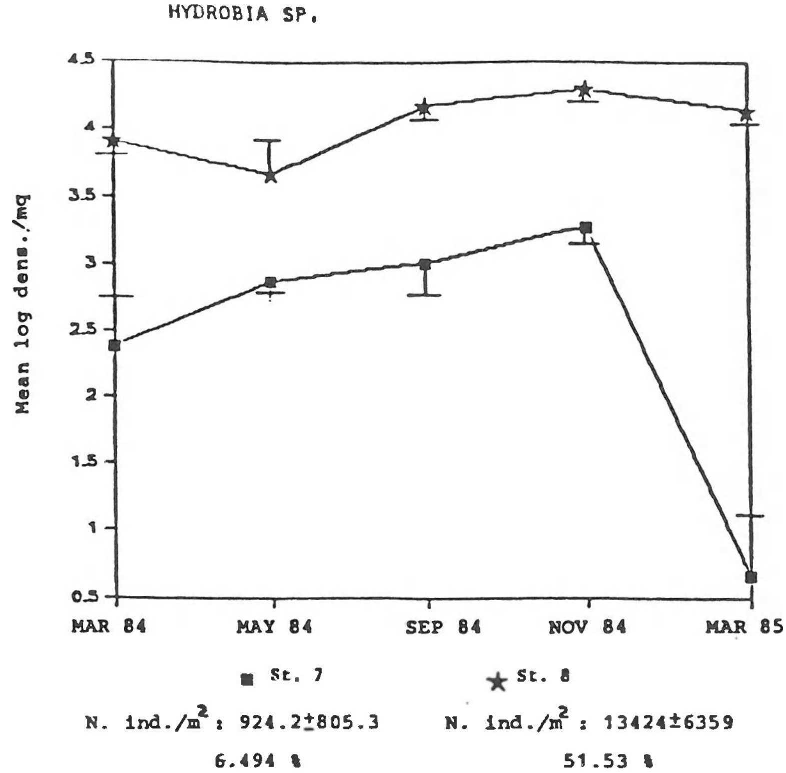


Fig. 12 - Trend of log-density averages (± S.D.) for the named species at the two sampling stations. Annual arithmetic average (± S.D.) and annual percent dominance at each station are shown.

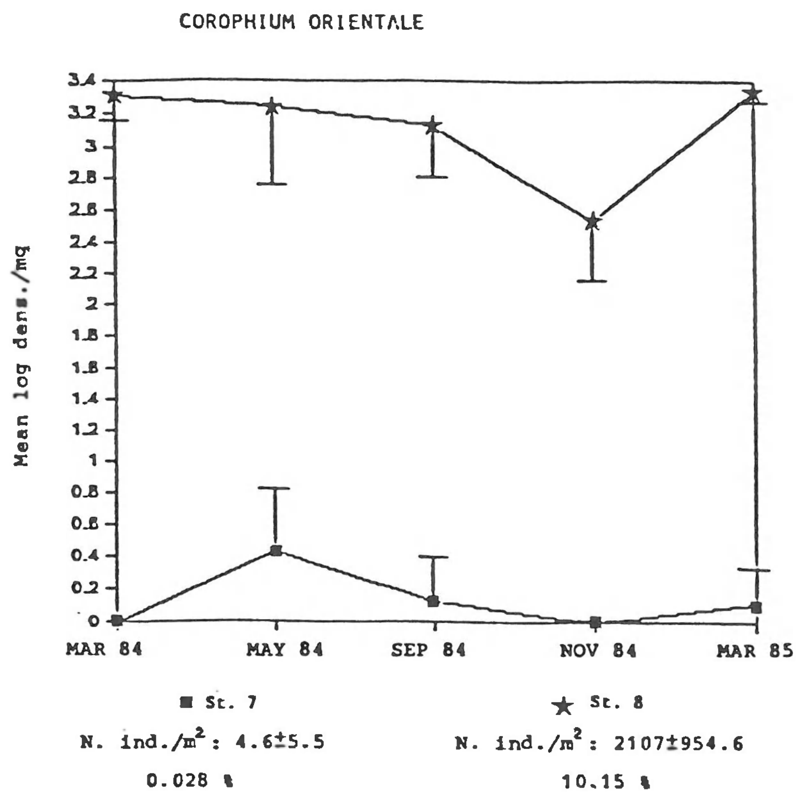


Fig. 13 - Trend of log-density averages (± S.D.) for the named species at the two sampling stations. Annual arithmetic average (± S.D.) and annual percent dominance at each station are shown.

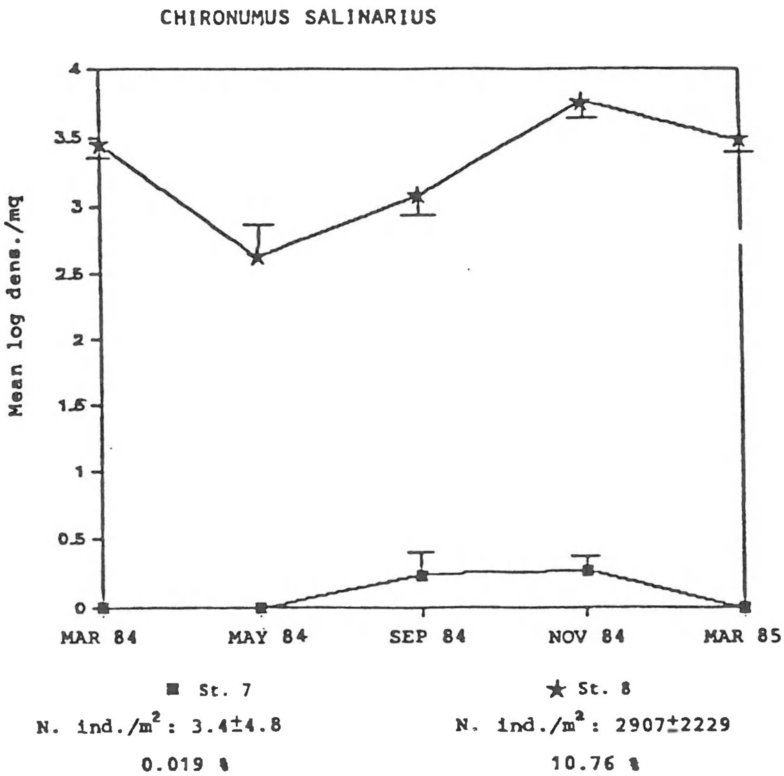


Fig. 14 – Trend of log-density averages (± S.D.) for the named species at the two sampling stations. Annual arithmetic average (± S.D.) and annual percent dominance at each station are shown.

Investigations on the sublittoral macrobenthic communities of Swansea Bay (Northern Bristol Channel)

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INTRODUCTION

It is generally recognised that Swansea Bay is heavily contaminated with pollutants from both historical and present day industrial activities. While these pollutants in themselves do not constitute a direct or immediate threat to human health, concern has been expressed about their effects on other components of the ecosystem and the ensuing consequences for other areas of public welfare. Such concern has prompted a number of investigations of various aspects of the environmental quality of the Bay by both the Welsh Water Authority and other organisations. Details of some of these investigations and further data on Swansea Bay can be found in the volume edited by Collins *et al.*, (1980). However, when a review of all existing information was undertaken in 1983 in at attempt to establish the extent to which the industrial and domestic discharges under Welsh Waters control contributed to any adverse conditions present, it became clear that there were still major gaps in the available data base. Of particular concern was the fragmentary and inconclusive nature of the information on the "status" of the macrobenthic fauna and sediments. A programme to acquire the necessary data was accordingly initiated in January 1984. The objectives of this programme were to:

i) Identify those areas where degradable and persistent pollutants are accumulating within the Bay and, where possible, establish whether or not they originate directly from discharges or other anthropogenic influences.

ii) Assess the status of the fauna in terms of the numbers and types of species present and their relationship to (i).

iii) Evaluate the implications of (ii) for the overall "health" of the biological regime particularly with respect to the fishery.

iv) Identify those areas of work where additional effort is still required to resolve (i) - (iii).

PHASE I - GENERAL SURVEY

Phase I of this programme consisted of a large scale survey of the Bay within the limits Port Eynon Point to Nash Point (an area of approximately 250 km^2). A 1 km^2 modular grid was adopted for sampling purposes, overlain by a series of finer grids (each unit = 0.5 km^2) around a number of the major outfalls within the Inner Bay (Mumbles Head to Sker Point). Sites were randomly selected with one site per unit giving a total of 272 sampling points (Figure l). A 0.lm^2 weighted Day-grab (courtesy of the University College of Swansea) was used throughout the survey. This grab was found to give adequate returns from muddy and sandy bottoms, but sampled gravel or rock substrates inefficiently or not at all.

Two replicates were normally obtained from each of those sites where it was possible to quantitatively sample. Subsamples of the surface sediment (approximately l cm deep) from the first grab were retained for subsequent analysis of particle size distribution and determination of organic carbon and nitrogen content and trace metal levels in the total sediment. The remaining material was washed on a l mm (square aperture) sieve and the residue retained for analysis of faunal content. The second grab provided an aliquot of sediment for analysis of trace metal levels in the less than 63 micron fraction of the sediment.

Details of sample treatment and the methods employed to analyse the data are not given here, but are available on request.

Faunal Assemblages

Only those sites from which quantitative samples were obtained (176) were included in the data analysis. A total of 153 species were identified with the major faunal groups being polychaetes (72), amphipods (29) and bivalves (19). On the basis of the distribution and abundances of these species four faunal assemblages were identified as being present within the area surveyed (Figure 2). These assemblages and their relationship to the physico-chemical factors are briefly commented on below.

Assemblage A - *Abra* community

The distribution of Assemblage A, the largest station group, reflects that of the muddier sediments in the Bay. *Nephtys hombergii, Nucula turgida, Diastylis rathkei* and *Spisula elliptica* were amongst the "characteristic or indicator" species for this group of stations (Table 1). An examination of the faunal composition of this assemblage - other species present in addition to the above being *Abra alba, Philine aperta* and *Spiophanes bombyx* - indicated that it was a continuation of the *Abra alba* community previously described by Warwick and Davies (1977) from the Bristol Channel. As this assemblage occupies the greater part of the Inner Bay where the majority of discharges occur, it was of interest to subject the data from these sites to a separate analysis. This analysis revealed the existence of a number of subgroups or "facies" within the greater community. Differences between the facies could be related to a reduction in species richness and diversity from that of a fairly typical *Abra* community as represented by Facies III to a more impoverished fauna, but with increasing dominance of a number of species such as *Nephtys hombergii, Diastylis rathkei* and *Spisula elliptica* in the other facies. While there are some differences in the silt-clay content of the sediments, the variations in faunal composition are not wholly explicable in terms of sediment texture. The north-eastern part of the Inner Bay in particular, where many of the outfalls are located, is a natural depositional zone where the highest trace metal levels and organic carbon and nitrogen content were found. In addition to the discharges present it has been suggested that dredging activities in this area may have an effect on the fauna (Shackley, 1982). The presence of *Spisula elliptica*, which is considered to be "atypical" of muddier sediments would also indicate that at least some of the area is subject to active sediment transport, particularly during stormy conditions (Shackley and Collins, 1984). It is difficult, therefore, with the current level of information to attribute the differences in faunal composition between the facies to any one or combination of these sources.

Assemblages B - *Modiolus* community

Assemblage B had the richest fauna, in terms of the numbers of species present, of the four assemblages identified. In relation to the prevailing hydrodynamic conditions, this area is somewhat of an anomaly with a heterogenous substrate of gravels inter-mixed with finer sands and silts. According to Collins *et al.* (1979) it is a region of balance between erosional forces and ephemeral deposition. The fauna present, in particular the polychaetes, consists of a curious mixture of errant and tube building species which may reflect the greater availability of micro niches in such an environment.

Assemblage C - *Venus* community

The third assemblage is associated with medium-fine sands, particularly along the coastline and over the sand banks in the south eastern part of the Bay. Only a limited number of species were found at these stations. However, those that are present, such as *Nephtys cirrosa*, *Urothoe* *brevicornis*, *Gastrosaccus spinifer* and *Bathyporiea pelagica* are indicative of a high energy physical environment (Tyler and Shackley, 1980). Again this assemblage would seem to be a continuation of the *Venus* community described by Warwick and Davies (1977) from the mid Bristol Channel.

Assemblage D - Coarse Sand community

Assemblage D consists of a small number of isolated sites with a number of species in common with the *Venus* community, but with *Ophelia borealis* as the only "indicator" species (see Table 1). The sediments contain a greater percentage of coarse and medium sands than those of the *Venus* community.

PHASE II - MONITORING PROGRAMME

Phase II of the programme was initiated as a result of the conclusions and questions raised by the findings of the general survey. Three sites "representative" of different facies of the *Abra* community were selected for an investigation of the temporal dynamics of the macrofauna over the period November 1985 - November 1986. Within the constraints imposed by weather, the sites have been visited on a monthly basis, with five replicate samples being obtained on each occasion. The samples are screened on a 0.5 mm sieve, but are subsequently separated into 1mm and 0.5mm fractions in the laboratory. Additional data for one of the sites is available for the period August 1985 - July 1986, when it was utilised as a trial site to obtain samples to test out different methods of biomass estimation. In addition to the routine faunal analysis an attempt has been made to examine the population structure and growth of certain of the dominant species. Only *Nephtys hombergii* and *Nucula turgida* occur in sufficient abundance at the three sites to allow comparisons to be made between them. *Spisula elliptica* had also been selected for a study of its population dynamics, but after the first year of sampling at the trial site, it became apparent that its presence was too sporadic and that it only occurred in high enough densities at this one site. Analysis of the data obtained from this programme is about to begin.

FUTURE INVESTIGATIONS

During the course of the present work it has become evident that there are still many lacunae in our knowledge of Swansea Bay. Interpretation of the faunal data in particular is hampered by lack of information on certain physical and chemical processes within the Bay. A more multi-disciplinary approach is, therefore, advocated for future work. In addition to the continuation and expansion of the monitoring programme to other communities, information is required on the movement of cohesive sediments, the relative lethal/sublethal toxicity of industrial and domestic discharges and dredge spoils and the relationship between demersal fish populations and the macrobenthic communities. Ultimately these studies would be integrated with the water quality model currently being developed to provide a predictive model of the processes within the Bay for management purposes.

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Table 1: The "Indicator" species of the four assemblages based on the results of the pseudo F-test (p < O.O1)

Species	F-Value (3,164 df)	Geometric mean no. per $0.1m^2$ for each assemblage A	B	C	D
Ophelia borealis	105.32	0.01	0.00	0.04	2.29
Nephtys hombergii	57.79	4.88	2.30	0.04	0.00
Lumbrinereis gracilis	56.16	0.04	1.28	0.00	0.00
Nephtys cirrosa	52.65	0.09	0.14	1.99	0.25
Pomatoceros lamarcki	48.03	0.00	1.54	0.02	0.00
Cirriformia tentaculata	35.85	0.03	2.24	0.10	0.00
Notomastus latericeus	27.75	0.04	0.96	0.00	0.00
Protodorvillea kefersteini	22.35	0.00	0.52	0.00	0.00
Paradoneis lyra	21.94	0.01	0.32	0.00	0.00
Nucula turgida	21.11	3.32	0.03	0.04	0.00
Polycirrus sp.	17.75	0.00	0.32	0.00	0.09
Anorothrus gracilis	17.43	0.00	0.49	0.00	0.00
Ampharete lindstroemi	20.60	0.08	1.83	0.05	0.00
Golfingia elongata	15.05	0.00	0.24	0.00	0.00
Amphicteis gunneri	15.14	0.00	0.31	0.00	0.00
Phoronis sp.	12.42	0.01	0.24	0.00	0.00
Eupagurus bernhardus	12.18	0.00	0.18	0.00	0.00
Unicola crenatipalma	12.11	0.00	0.25	0.00	0.00
Glycera tridactyla	11.94	0.10	0.90	0.12	0.00
Kefersteinia cirrata	11.58	0.00	0.23	0.00	0.00
Lagis koreni	9.26	0.01	0.16	0.00	0.00
Mytilus edulis	9.24	0.00	0.94	0.00	0.00
Leptonereis glauca	9.09	0.00	0.11	0.00	0.00
Mediomastus fragilis	9.04	0.02	0.23	0.00	0.00
Sthenelais boa	8.95	0.02	0.28	0.00	0.00
Lepidonotus squamata	8.37	0.00	0.18	0.00	0.00
Achelia echinata	8.05	0.00	0.20	0.00	0.00
Lepidopleurus asellus	7.91	0.00	0.36	0.00	0.00
Eumidia sanguinea	7.81	0.03	0.23	0.00	0.00
Sabellaria spinulosa	7.38	0.26	0.27	0.00	0.00
Melinna palmata	7.76	0.00	0.21	0.00	0.00
Diastylis rathkei	7.08	0.63	0.00	0.02	0.00
Aonides oxycephala	6.94	0.01	0.21	0.00	0.19
Gattyana cirrosa	5.70	0.00	0.07	0.00	0.00
Melita obtusata	5.56	0.00	0.18	0.04	0.00
Golfingia vulgaris	5.39	0.00	0.10	0.00	0.00
Anoplodactylus petiolatus	5.39	0.00	0.10	0.00	0.00
Urothoe brevicornis	5.24	0.00	0.00	0.17	0.00
Scoloplos armiger	5.40	0.06	0.36	0.02	0.00
Caulleriella alata	4.28	0.00	0.14	0.04	0.00
Gastrosaccus spinifer	4.26	0.02	0.00	0.15	0.09
Spisula elliptica	4.11	0.60	0.04	0.07	0.09

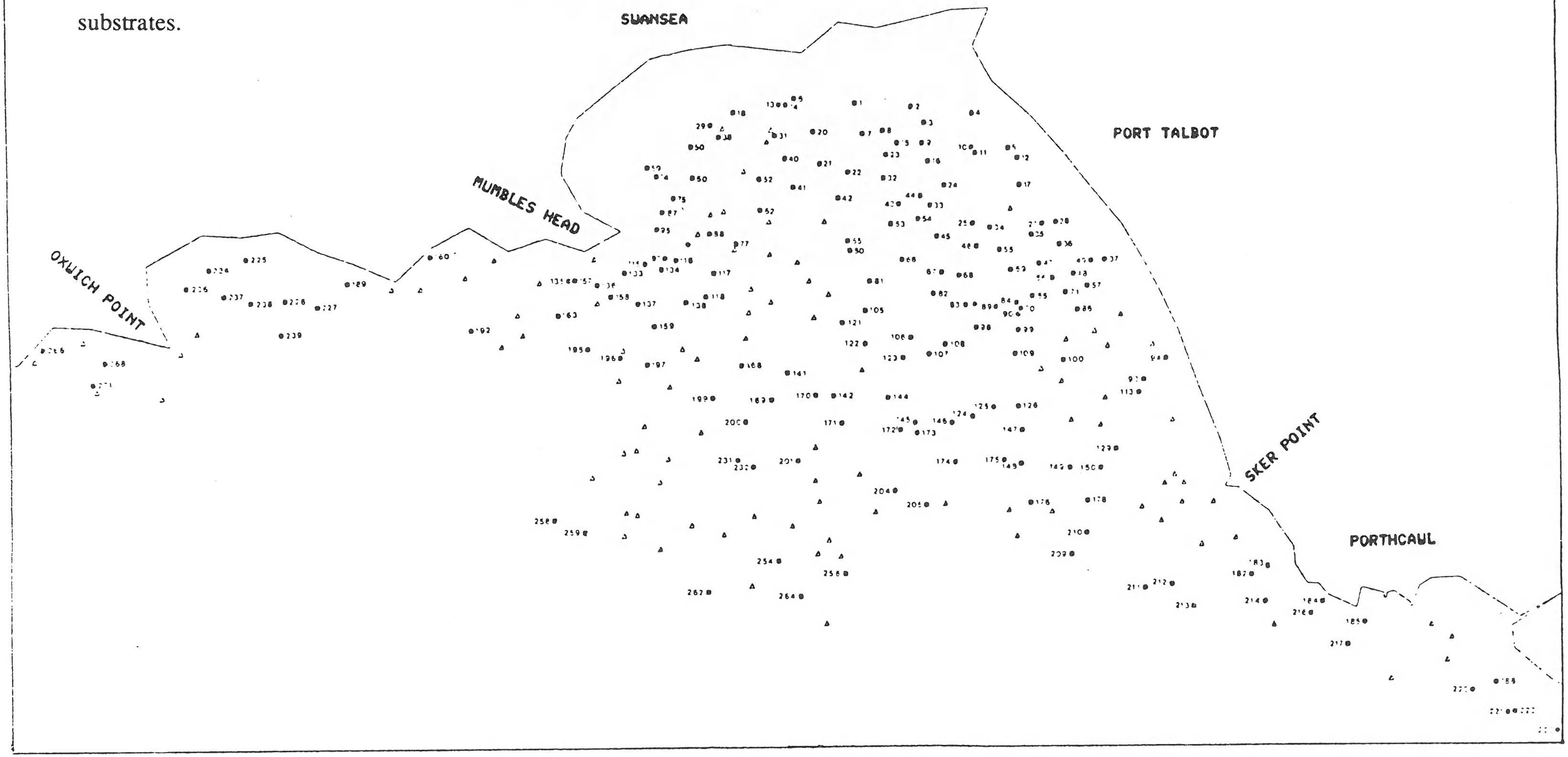
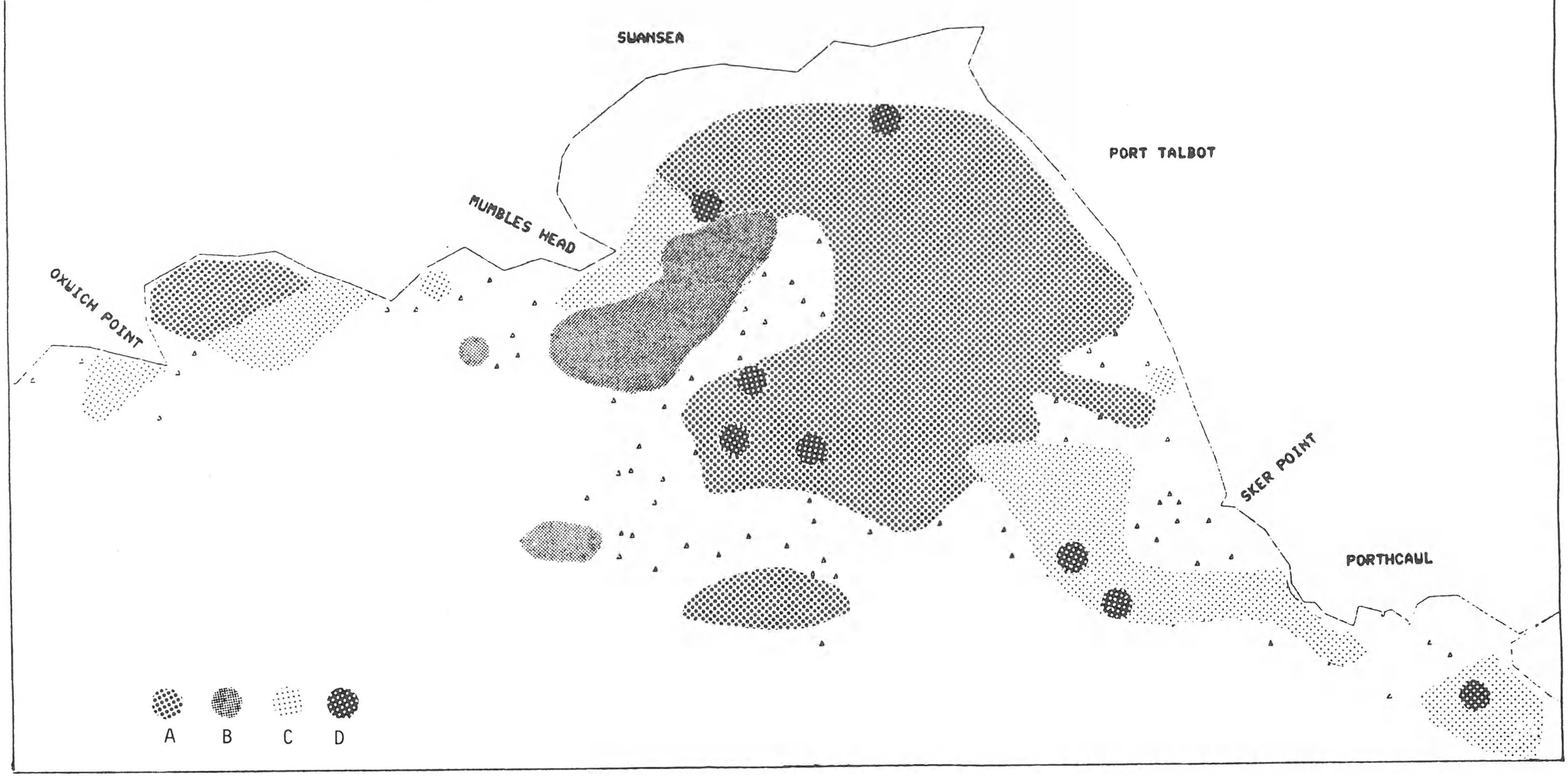


Figure l. Location of the sampling sites. Solid circles indicate those stations where quantitative samples were obtained. The remaining stations (triangles) were located on rock/gravel substrates.

Figure 2. The distribution of the four faunal assemblages. A - *Abra* community ; B - *Modiolus* community ; C - *Venus* community ; D - Coarse sand community.



Macrozoobenthic assemblages in the southern part of the North Sea (French Coast).

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The chart reproduced on the back cover of this Report follows on that published in 1980 by Souplet *et al.* From it, we can gain some appreciation of the stability of local benthic communities as well as adding to our knowledge of their offshore extension. 367 stations, together with 500 samples not included in the data processing and numerous diving observations, were used in compiling the chart.

The bionomical make-up of the southern part of the North Sea is without any doubt highly reflective of the tidal currents. The Strait of Dover, being funnel-shaped, serves to increase the speed of these currents. During spring tides, they reach 3 knots in the middle of the Strait , and slow down to 1.5 knots off Dunkirk. This decrease changes the sorting of sediments from pebbles and cobbles in the west to fine or medium sands in the east. Although the depth can reach 55 metres around the Strait of Dover, the area is broadly characterized by shallow waters. In the eastern part of the area, the bottom is disposed in permanent sandbanks, which run almost parallel to the coast.

Qualitative samples were taken with a "Rallier du Baty" dredge (a type of anchor dredge). From each, 30 litres of sediment was sieved on a circular mesh size of 1mm and the animals so retained preserved in formalin (4 percent). Both infaunal and epifaunal elements were identified to species level.

Similarity matrices (OCHIAI's index) were analysed using two analytical routines. The coastal part (286 stations) was analysed using principal component analysis, while the other stations were subjected to hierarchical analysis (the Lance and Williams algorithm). Intertidal communities were studied separately, involving several local investigations (see reference list). Their horizontal and vertical diversity did not allow them to be shown individually on the scale at which the chart was prepared; instead, they are collectively represented under the designation "Sediment Intertidal Communities."

Analysis of the subtidal macrozoobenthos lead to the identification of five communities:

I. Pebbles with sessile epifauna community

This community, characteristic of areas with strong currents, is localized to the vicinity of the Strait of Dover, where pebbles are dominant (70 to 80 percent of the weight of the sediment). Sessile epifauna is well represented. Mobile species are principally decapods (*Pisidia longicornis, Galathea intermedia, Pilumnus hirtellus, Hyas coarctatus, Macropodia rostrata*). Infauna is less important.

Where the currents are stronger (to the west), the sediment is made up of pebbles and cobbles which allow the occurrence of an important sessile epifauna where Cnidarians (*Abietinaria abietina, Alcyonium digitatum, Hydrallmania falcata, Sertularia cupressina, S. argentea* and *Urticina felina*) and Bryozoans (*Alcyonidium gelatinosum* and *Flustra foliacea*) are dominant. In the shallower part of this area, we find important ophiuroid beds (*Ophiothrix fragilis*). This species (80 percent of individual numbers) can wholly overlie the bottom, with the beds becoming less and less dense towards the open sea. Mussel beds (*Modiolus modiolus*) occur at a depth of 50 metres. From the west to the east of this community, the amount of finer sediment (as granule, gravel and coarse sand) increases. A more abundant and diversified infauna becomes established, so some polychaetes (*Lanice conchilega, Aonides oxycephala, Notomastus latericeus, Ophelia borealis, Glycera* spp., *Lumbrineris* spp.) and molluscs (*Spisula ovalis*) appear, while the number of decapods decreases.

In shallow waters, this evolution proceeds with a silting up of the sediment which permits the setting up of another community : the "Muddy heterogeneous sediment" community.

II. The Muddy Heterogeneous Sediment community

This community is localized to the dips between banks of sediment containing pebbles, sand and mud. The constituent species include a few hydrozoans and bryozoans, sparse decapods (*Pisidia longicornis, Galathea intermedia*) and some echinoderms (*Asterias rubens, Ophiura texturata, Psammechinus miliaris*). The remaining species are quite characteristic of this community : *Sagartia troglodytes, Sthenelais boa, Owenia fusiformis, Cerianthus lloydii, Sabella penicillus, Abra alba, Mya truncata, Golfingia elongata.* All these species favour muddy sediments.

III The *Amphioxus lanceolatus* community

This community is localized beyond the Sandettie Bank on clean gravel and coarse sand, although enclaves of it exist within the pebbles' community. These enclaves are seemingly long term phenomena, having been recorded in different studies. The number of component species is low, characterised by the presence of *Amphioxus lanceolatus* and*Spatangus purpureus*.. *Echinocyamus pusillus, Ampelisca spinipes, Spisula solida, S. elliptica, Ophelia borealis, Nucula nucleus,* and *N. hanleyi* are also prominent..

IV The *Ophelia borealis* community

This community is found on the banks in the eastern part of the study area. The associated sediment is a clean, fine or medium sand (80 percent of the weight of the sediment).

The community is characterised by the occurrence of *Ophelia borealis, Nephtys cirrosa, Nerine bonnieri, Bathyporeia elegans,* and *B. guillamsonniana. Spisula solida, S. elliptica, Gastrosaccus spinifer, Glycera gigantea* and *G. capitata* are also important.

V The *Abra alba* community

This community occurs on almost all the shallower subtidal bottoms (mean depth: 10 metres) of the study area. The sediment comprises fine sand (75 to 80 percent of weight) and clay (1 to 12 percent).

The most important species are *Abra alba, Tellina fabula, Lanice conchilega, Nephtys homergii* and *Lagis koreni*. Some other species are also important in the organization and the functioning of this community : *Ophiura texturata, Mysella bidentata, Spisula subtruncata, Phyllodoce mucosa, Spiophanes bombyx, Eumida sanguinea* and *Owenia fusiformis*. This community extends into the coastal zone of the North Sea.

CONCLUSION

The study of macrozoobenthic communities of the south part of the North Sea allows us to distinguish two different areas. To the west , coarse sediments are dominant while, in the east, the the deposits are much finer. This distribution pattern reflects the fall-off in the tidal streams from the Strait of Dover to the North Sea.

Some diving observations have confirmed that the transition between the Pebble community and the *Ophelia* community can take place without the necessary insertion of a community settled on intermediate sediments such as gravel (i.e. the *Amphioxus* community).

The offshore communities are very stable as regards both their geographical distribution and their bionomical structure. On the other hand, the coastal communities are rendered unstable by human activities (e.g.coastal engineering works, dredged spoil disposal and various pollutants). This instability affects the relative importance of the abundant species more than the overall structure of the community.

ACKNOWLEDGEMENTS

The authors particularly wish to thank Dominique Menu who drew the chart.

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Longterm Benthic Investigations on the South Coast of Ireland.

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INTRODUCTION

This report introduces a longterm investigation carried out by the Benthos Research Group of the Zoology Department, University College Galway on the south coast of Ireland. In 1978, the Group was contracted to initiate an ecological monitoring programme in a part of Kinsale Harbour (51°41'N 8°30'W) which was to receive effluent from a pharmaceutical plant (Fig. 1). The Harbour, covering 6 km^2, encompasses the euhaline zone of the Bandon estuary where depths range up to 25m. Entering the northwest portion of the Harbour, the Bandon river has a mean discharge of $15m^3s^{-1}$ and a flow rate which rarely exceeds $50m^3s^{-1}$. The area is a salt-wedge estuary where bottom salinities do not drop below S 27 and generally remain above S 30.

There has been a phased approach to this investigation.

Phase 1: Characterising Survey

Phase 1 involved a characterisation of the area in terms of substrate types and the nature and distributional extent of the animal communities of the shore and sublittoral sea-bed. This was carried out from 1978 to 1981.

Sublittoral deposite substrates, covering the inner harbour reaches, extending through the middle ground at the harbour mouth and across a central channel in the outer harbour area, are poorly sorted fine and/or silty sands (Fig. 1). More specifically:

- the inner harbour reaches are occupied by a sediment which is more heterogenous in structure and has a higher coarse sand and, in some areas, gravel content, relative to the remainder of the study area,
- a clean relatively compact fine sand, with a high medium sand content characterises the western flank of the middle ground,
- deposits in the outer harbour area form a homogenous silty fine sand with a silt clay content of 29 ± 13%.

The sediments are not enriched organically and indications are that such organic material as is deposited, rather than accumulating, is, for the most part, resuspended and dispersed throughout the area in general.

The distribution of the infaunal assemblages more or less coincides with the partitioning of the sedimentary environment as already outlined. Thus:

(i) the inner harbour is occupied by an admixture of *Abra alba* and *Tellina fabula* communites,with elements of the former being the more prominent. Elements of an *Amphiura filiformis* assemblage are also evident (see Table 1).

(ii) the sandy substrate of the middle ground is occupied by a *Tellina fabula* association, with the classical *Venus striatula* community occurring on the coarser deposits (Table 2),

(iii) the outer harbour is occupied by an *Amphiura filiformis* assemblage (Table 3).

The distribution of the assemblage-types is shown in Figure 2.

Phase 2: Base-line survey

In phase 2 of the investigation, three sites, located in the vicinity of the proposed effluent-outfall site, were monitored, on a monthly basis, for changes in sediment composition and in the abundance patterns of the infauna (Fig. 3). This second phase of the programme spanned May 1979 to July 1981; the actual pharmaceutical plant came into operation in March 1981.

On a temporal scale, findings indicate the operation of complex dynamic forces in the area. Cyclical changes in sediment granulometric composition were not detected at any of the three sites. However, periodic stratification of sediments in relation to (i) a blanketing of the area with a layer of fine material, (ii) a loosening of the top few centimeters of deposit in addition to changes in sediment compaction were observed. Sediments at the middle and outer monitoring sites were apparently homogenous and uniform in composition over time. This contrasted with the more variable composition of deposits, compounded further by their greater heterogeneity, at the more sheltered location in the inner harbour. It is proposed that the area in the outer harbour is subject to a hydrodynamic regime which turbates the bottom deposits either constantly or periodically. This turbation effects a uniform distribution of sediments on a broad temporal scale. In the case of the inner monitoring site, the findings are indicative of a dynamic substrate and the absence of a constant or equilibrating hydrodynamic regime.

In terms of the fauna, at the scale of sampling (i.e. material sorted on a 1mm mesh screen) there was an obvious constancy in assemblage structure (i.e. species dominance patterns) at each of the three sites over time. While there was a general lack of synchronisation in temporal distribution patterns, even for the same species, between the three sites, fluctuations in species abundances within each particular site seemed to have been remarkably synchronised. Thus, temporal changes reflected the involvement of most species in the assemblage.

A seasonal pattern of occurrence with summer peaks in abundance followed by winter/spring minima was typical of the sheltered inner site (cf. Figs. 4 to 6. Note: only those species identified as having a specific status within the COST 647 programme are presented here.) This was true for the majority of the fauna although some species did not show this temporal pattern (cf. Figs. 7 to 12). At the more exposed middle and outer sites, the weak seasonal pattern, shown by only a few species, was masked by aperiodic fluctuations in abundances (cf. Figs. 4 to 12). While poor faunal returns coincided at times with poor sampler performance, which, in turn, appeared to have been related to changes in sediment texture not detectable by straightforward granulometric analysis, this was not always the case. However, periods of faunal paucity were typically sampled after extreme conditions relating to river runoff and wind activity. It is considered that the physical turbation of the bottom deposits in this outer area causes any biologically-determined seasonal cycles to be largely masked. Occasionally, this also applies at the inner site, but this location, in its relatively sheltered position, is much less susceptible. However, the possibility that the summer periods of high faunal abundances, typical of this location, constitute periods of recolonisation/faunal establishment as disturbance is reduced, with some likely accumulation of fine material, cannot be excluded. The extent and magnitude of faunal depletion and/or its relocation or reestablishment in the study area is unknown. However, it is significant that, in general, those species which more or less maintained their numerical status, particularly in the outer area, were robust forms which, either as a result of their mobility and/or their being firmly anchored in tubes (e.g. *Lumbrineris gracilis* (cf. Fig. 9); *Owenia fusiformis* (cf. Fig. 11)), are more likely to be protected.

It is appreciated that, as material was processed on a 1mm mesh screen, early recruitment peaks are likely to have been missed as juvenile animals were probably not captured until they were approximately 1 year old. Against this, the population structure and reproductive cycles of both *Abra alba* and *Mysella bidentata* were studied in detail using a 0.5mm mesh screen (Crowe, 1985). Findings from this series of observations are in close agreement with the results outlined above (cf. Figs. 6 and 10).

Rainer (1981) points out that when environmental perturbations are severe it may be possible to relate changes in community structure to particular physical events, although stochastic factors may be important. On the other hand, if the perturbations are less severe, the ecological causality behind the stability or instability of a community may be unclear. Poore and Rainer (1979) rightly declare that, without experimental support it is fruitless to hypothesise on the relative roles of influential factors in explaining many of the observed irregular population fluctuations in the benthos.

Phase 3: Monitoring Survey

Phase 3 of this programme involves an evaluation of the stability of faunal assemblages by means of annual recharacterising surveys at a reduced, i.e. relative to the initial, number of sites. These surveys, carried out since 1981, involve taking triplicate faunal samples at some twenty sites distributed throughout Kinsale Harbour in the autumn months of each year (Fig. 3). The broadscale spatial pattern of the assemblages has essentially remained constant over the six year period, i.e. 1979 to 1984. However, some intra-group fluctuations in species abundancies have taken place. As these recharacterising surveys have been variously worked up by different personnel and as the findings have not yet been collated in full, it is not possible to expand further on the results at this stage. It is proposed, however, to process the findings arising from this longterm investigation within the context of results obtained elsewhere within the subtidal soft sediment COST 647 programme.

ACKNOWLEDGEMENTS

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COST I.D.	Species	% Occurrence	Mean No. $0.24m^{-2}$ ±S.D.
P 2	*Mysella bidentata*	100	185.4±92.3
P	*Spiophanes bombyx*	100	105.1±58.8
P T	*Amphiura filiformis*	100	46.4±58.8
1	*Owenia fusiformis*	100	29.6±14.0
2	*Euclymene oerstedii*	100	57.7±67.0
1	*Nucula* cf. *nitidosa*	100	22.6±18.6
	Myriochele cf. *oculata*	100	21.6±13.2
P 2	*Pholoe minuta*	100	24.0±17.7
2	*Lumbrineris gracilis*	100	15.8±10.7
	Magelona filiformis	95	34.4±56.8
2	*Spiophanes kroyeri*	85	11.2± 8.0
	Mediomastus fragilis	95	12.2± 8.0
P T	*Abra alba*	90	22.4±47.0
	Harpinia antennaria	90	10.0±10.2
	Pariambus typicus	90	11.6±14.7

Table 1: species dominating in Assemblage 1. ('P' refers to principal species within the *Abra alba* and/or *Amphiura filiformis* communities; T to target species; and 1 and 2 to category 1 and 2 species, respectively, as identified in the COST 47 Report for the period 1979-'84).

COST I.D.	Species	% occurrence	Mean No. $0.24m^{-2}$ ±S.D.
P	*Spiophanes bombyx*	100	135.1± 83.5
	Magelona mirabilis	100	140.5±129.0
	Magelona filiformis	100	84.2± 70.4
P 2	*Chaetozone* sp.	100	74.8± 87.8
P	*Spio filicornis*	100	31.3± 19.3
1	*Fabulina fabula*	100	32.8± 24.2
	Myriochele cf. *oculata*	58	28.6± 42.2
P 2	*Nephtys hombergi*	83	12.0± 8.9
1	*Owenia fusiformis*	100	16.7± 11.6
P T	*Abra alba*	100	9.8± 7.7
	Pariambus typicus	100	12.3± 12.2
	Pseudocuma longicornis	50	8.3± 18.4
1	*Phaxas pellucidus*	67	3.2± 5.4
	Aricidea minuta	83	10.8± 11.5
2	*Euclymene oestedii*	100	13.2± 25.1
P	*Eumida* cf. *sanguinea*	58	9.7± 27.4

Table 2: species dominating in Assemblage 2 (see Table 1 for legend)

COST I.D.	Species	% Occurrence	Mean No. $0.24m^{-2}$ ±S.D.
P 2	*Mysella bidentata*	100	185.4±92.3
P	*Spiophanes bombyx*	100	105.1±58.8
P T	*Amphiura filiformis*	100	46.4±58.8
1	*Owenia fusiformis*	100	29.6±14.0
2	*Euclymene oerstedii*	100	57.7±67.0
1	*Nucula* cf. *nitidosa*	100	22.6±18.6
	Myriochele cf. *oculata*	100	21.6±13.2
P 2	*Pholoe minuta*	100	24.0±17.7
2	*Lumbrineris gracilis*	100	15.8±10.7
	Magelona filiformis	95	34.4± 6.8
2	*Spiophanes kroyeri*	85	11.2± 8.0
	Mediomastus fragilis	95	12.2± 8.0
P T	*Abra alba*	90	22.2±47.0

Table 3: species dominating in Assemblage 3 (see Table 1 for legend)

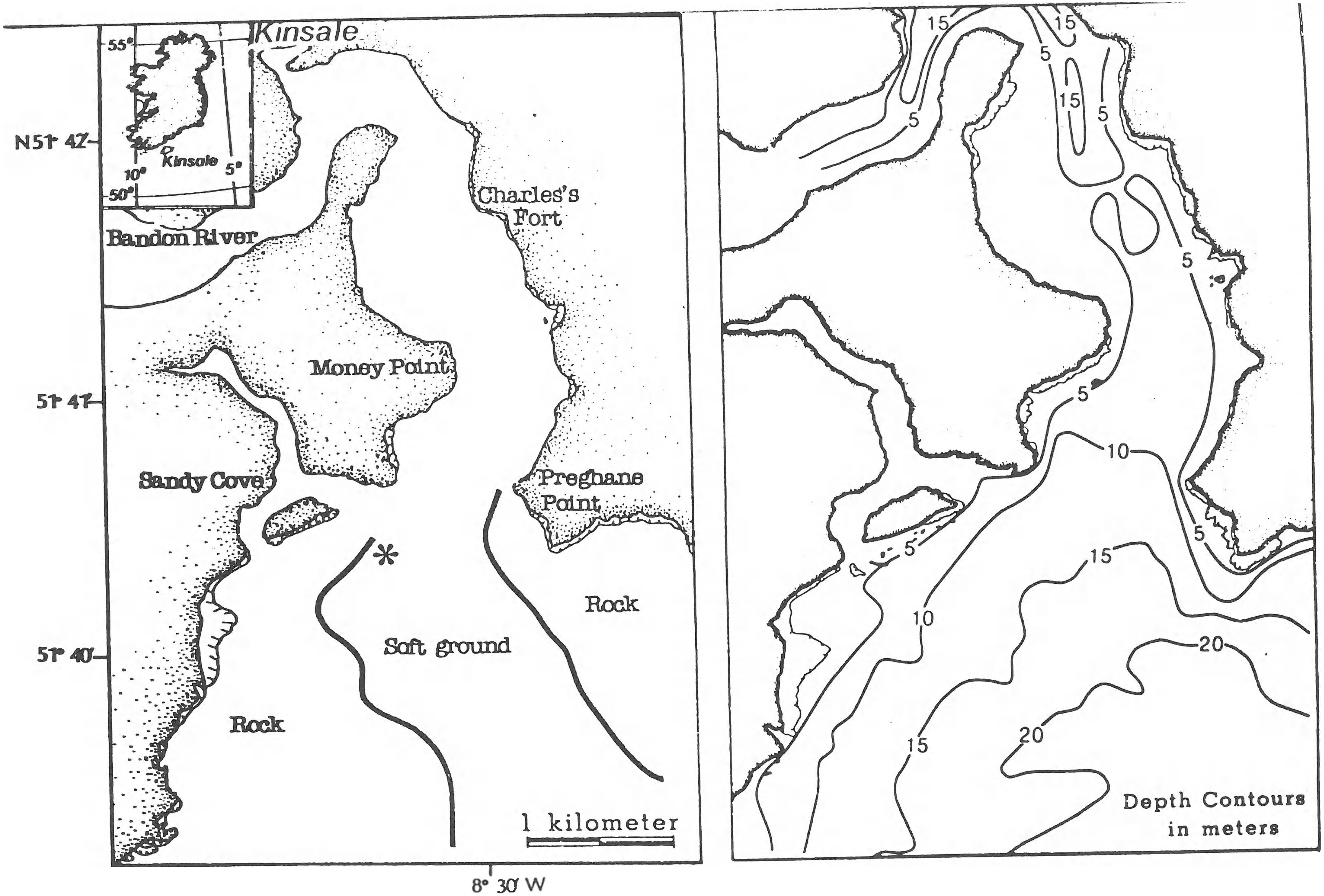

Figure 1. Study area location and bathymetry (based on British Admirality Chart 2053).

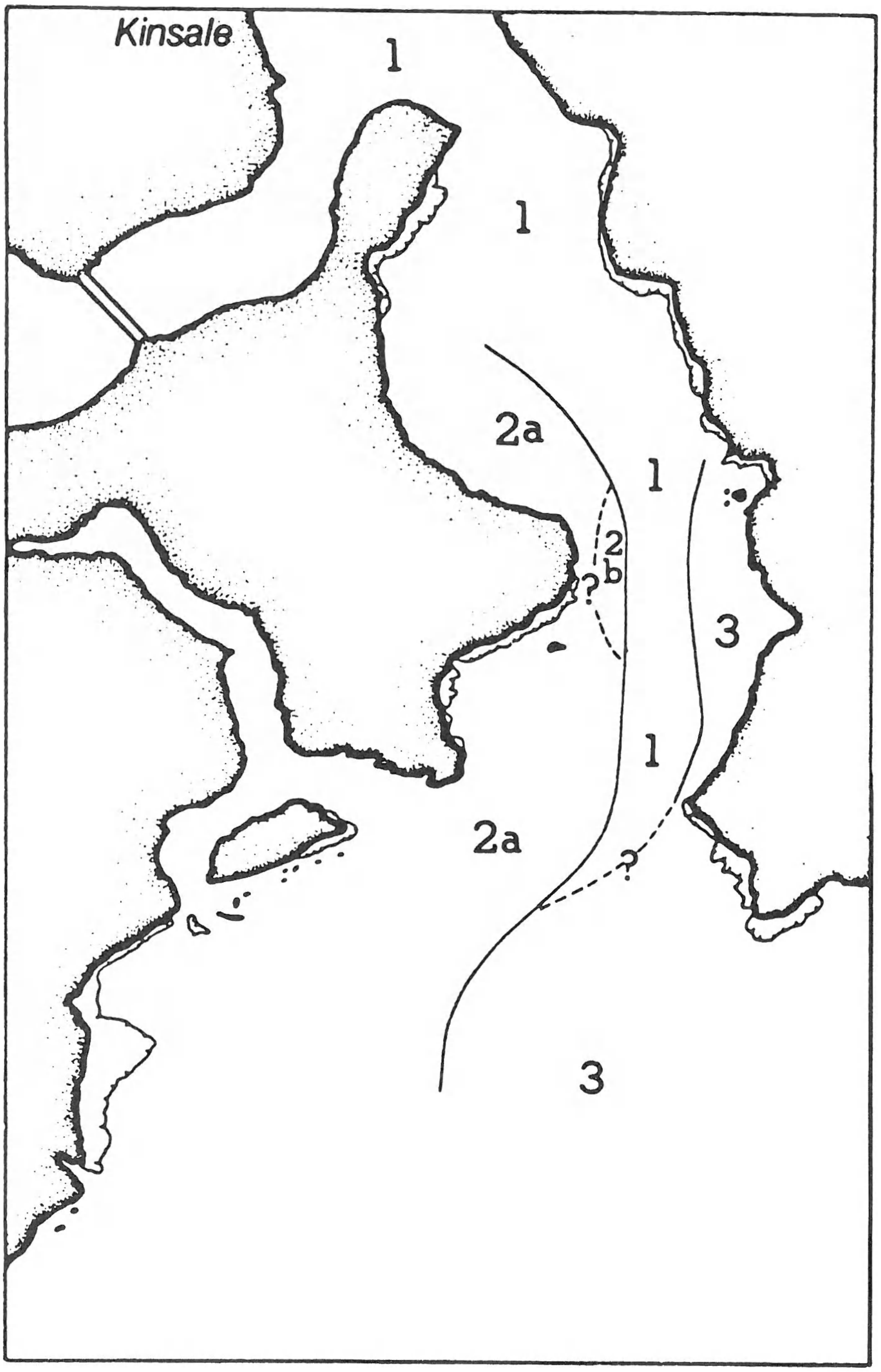

Figure 2. Distribution of the faunal assemblages identified for Kinsale Harbour.

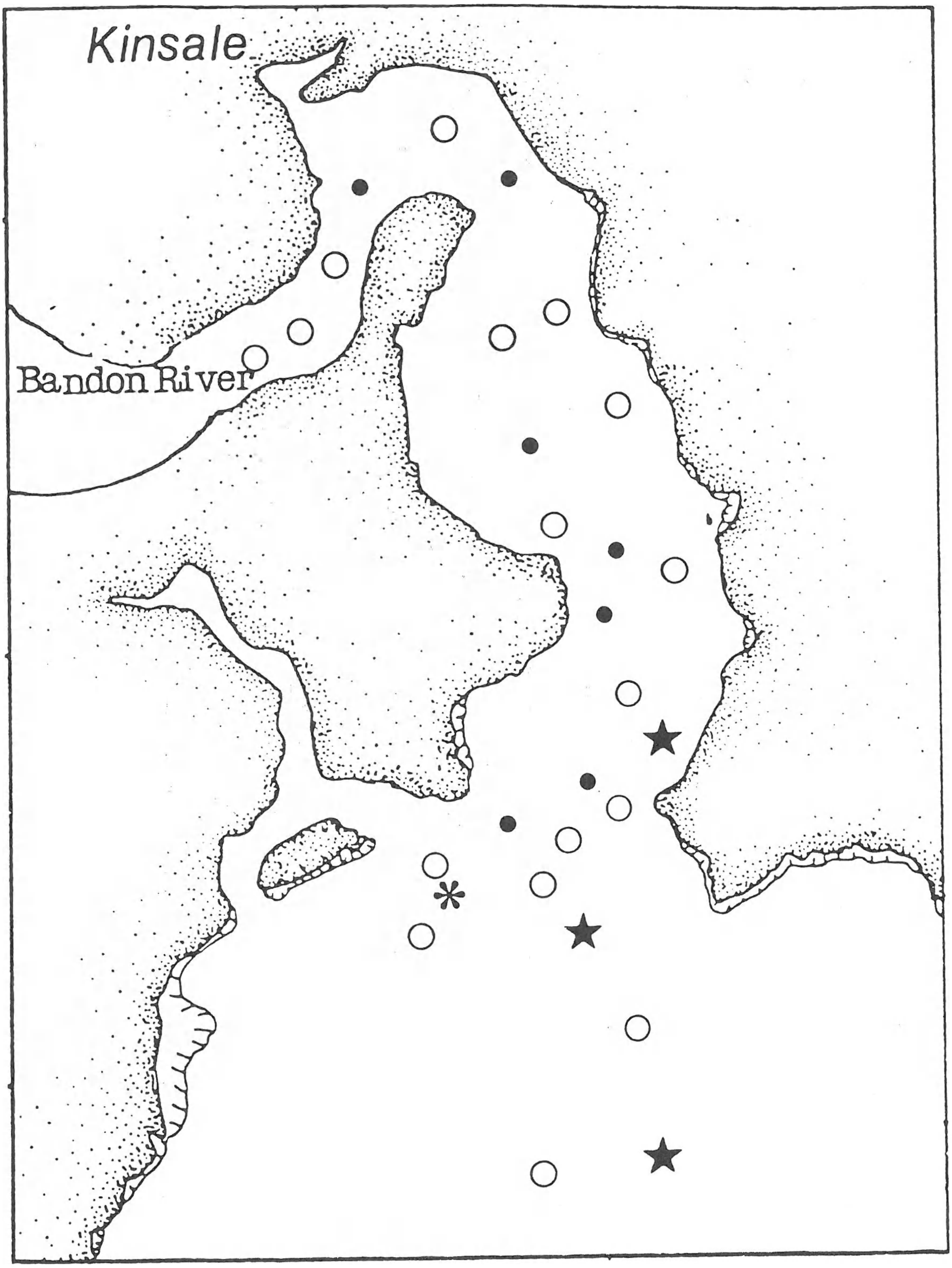

Figure 3. Sampling locations for temporal investigations:

= monthly monitoring sites,

= additional sites for annual recharacterising surveys,

= position of the pharmaceutical plant's effluent outfall site.

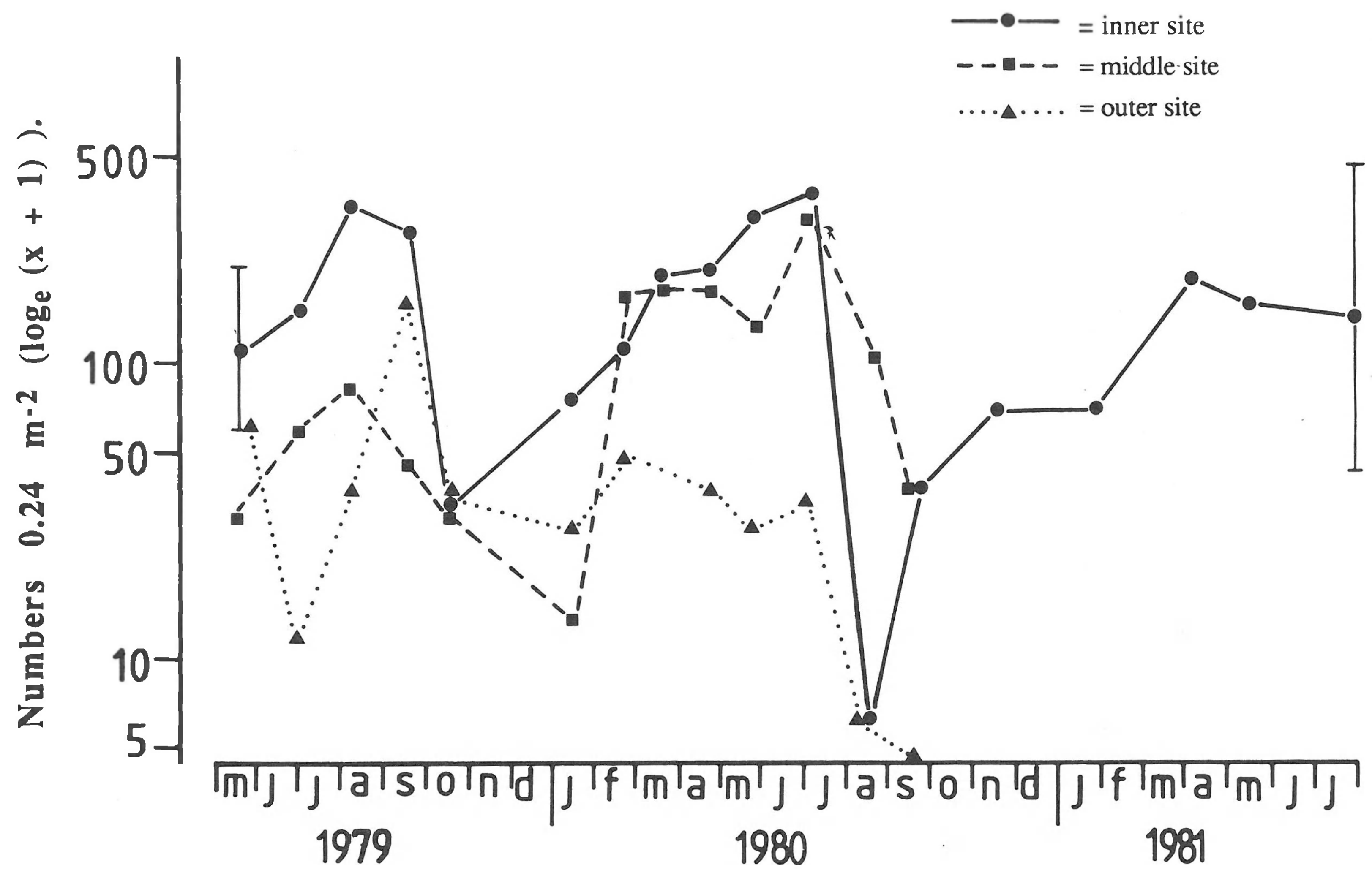

Figure 4. *Euclymene oerstedii:* : changes in abundances at three locations (see Fig. 3) for the period May 1979 to September 1980 and for an additional period, i.e. up to July 1981, at the inner monitoring site only.

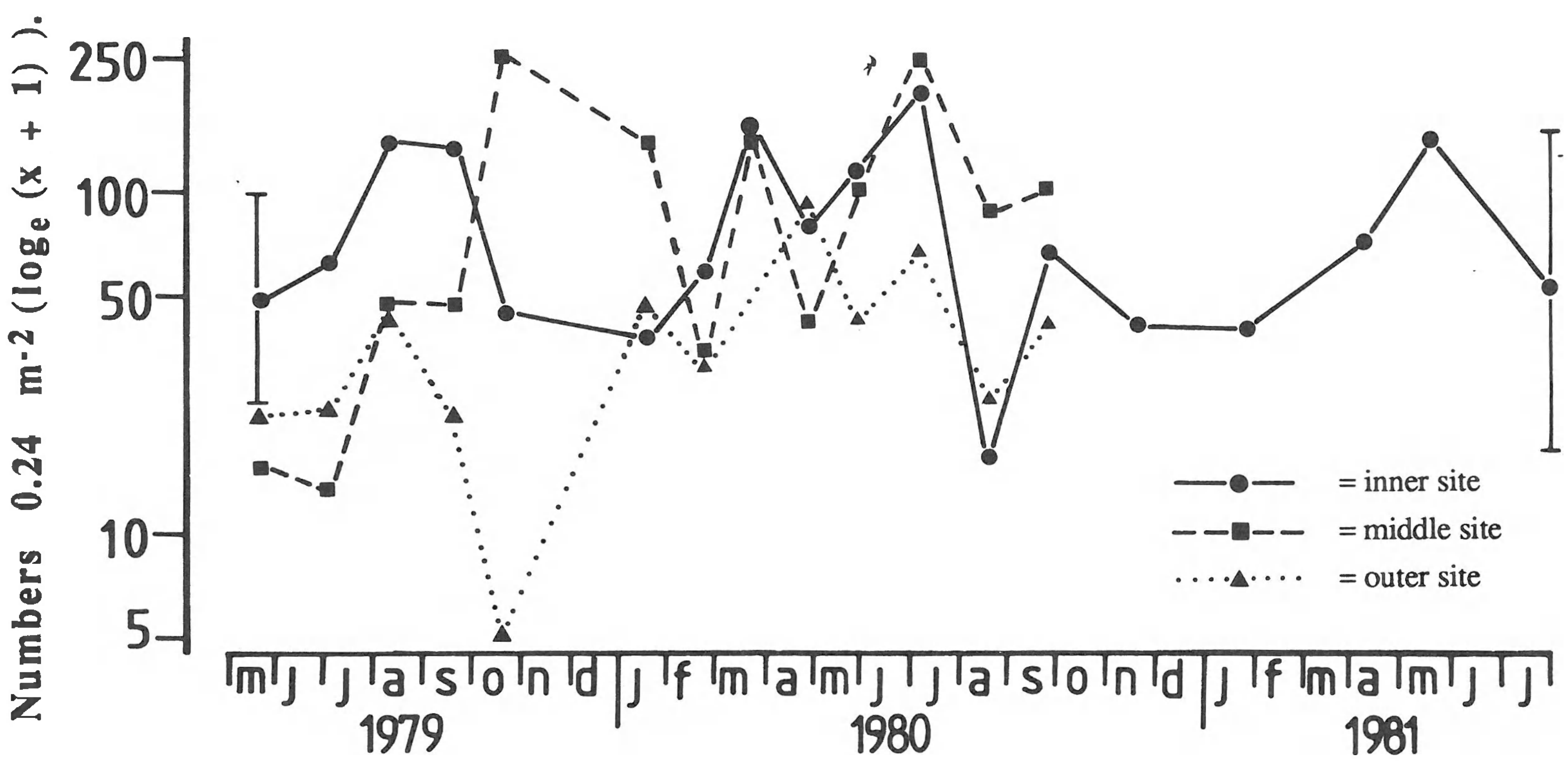

Figure 5. *Pholoe minuta* : changes in abundances at three locations (see Fig. 3) for the period May 1979 to September 1980 and for an additional period, i.e. up to July 1981, at the inner monitoring site only.

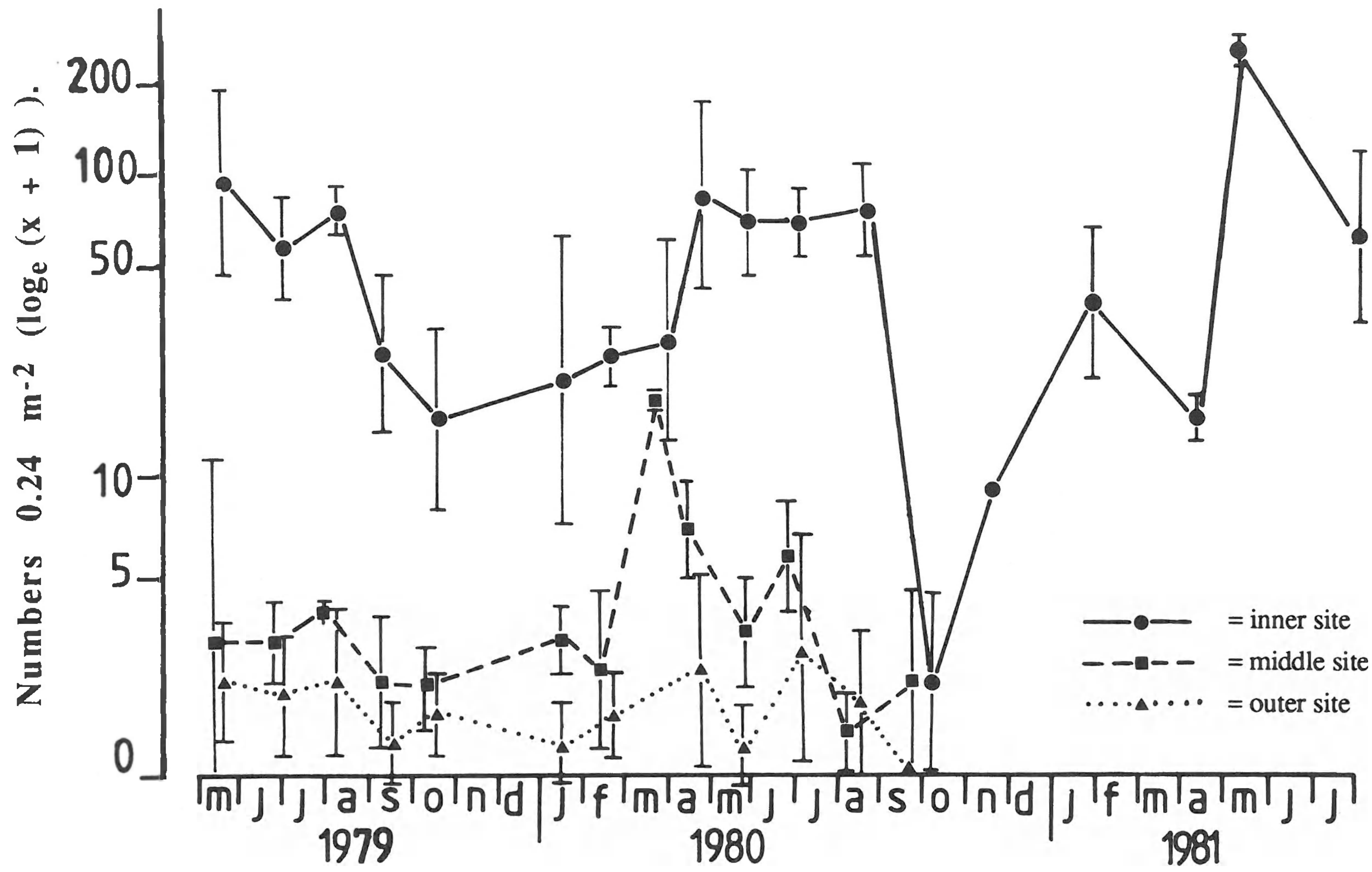

Figure 6. *Abra alba* : changes in abundances at three locations (see Fig. 3) for the period May 1979 to September 1980 and for an additional period, i.e. up to July 1981, at the inner monitoring site only.

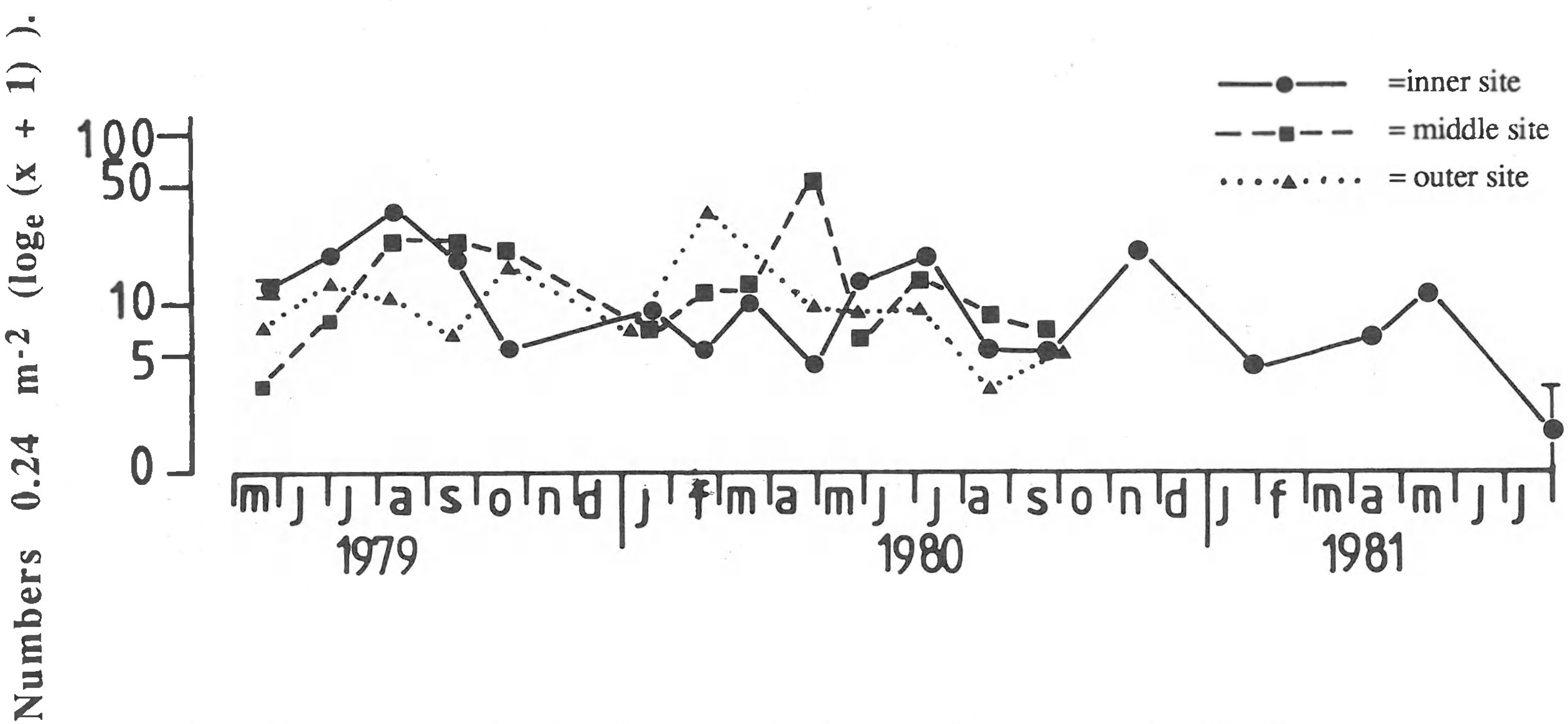

Figure 7. *Nephtys hombergi* : changes in abundances at three locations (see Fig. 3) for the period May 1979 to September 1980 and for an additional period, i.e. up to July 1981, at the inner monitoring site only.

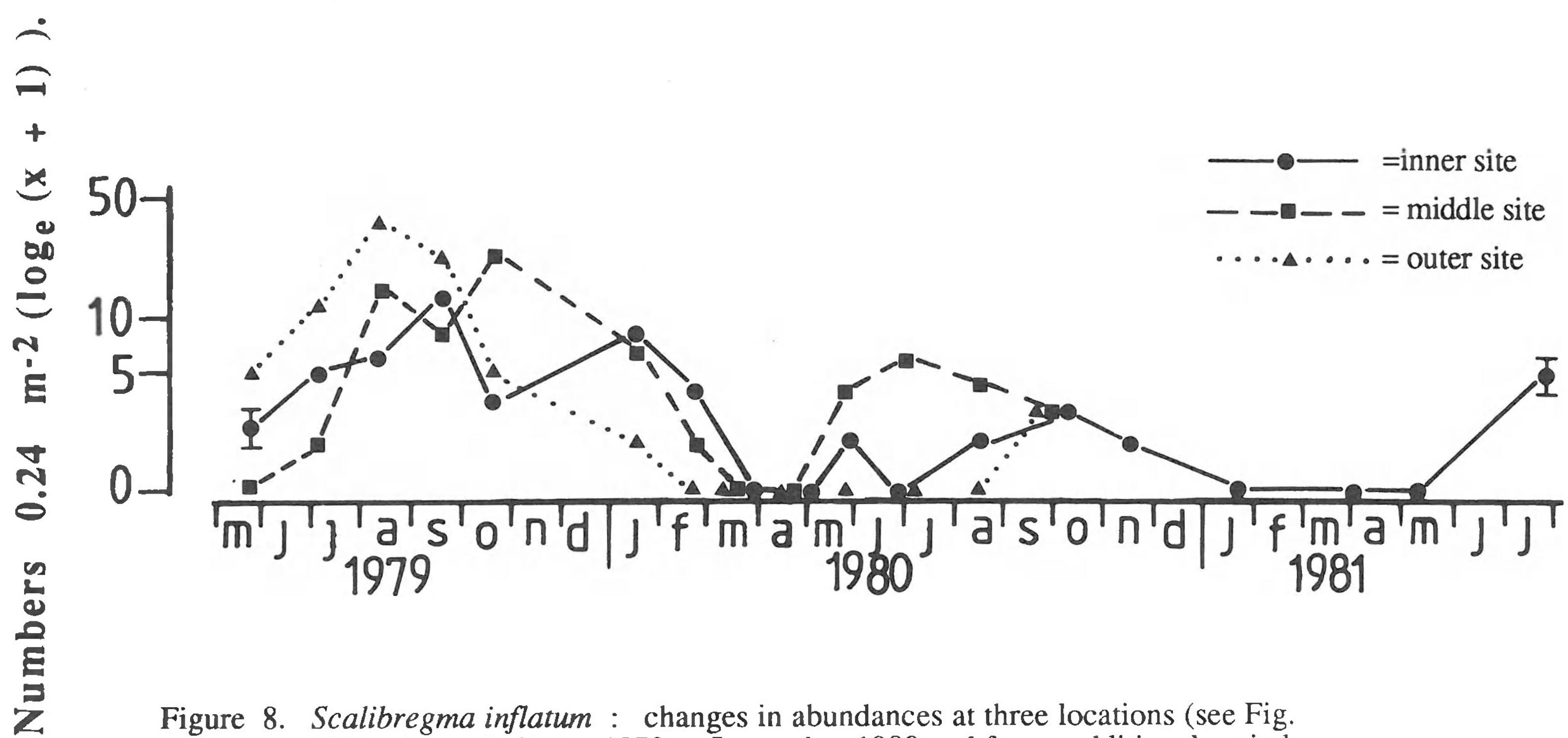

Figure 8. *Scalibregma inflatum* : changes in abundances at three locations (see Fig. 3) for the period May 1979 to September 1980 and for an additional period, i.e. up to July 1981, at the inner monitoring site only.

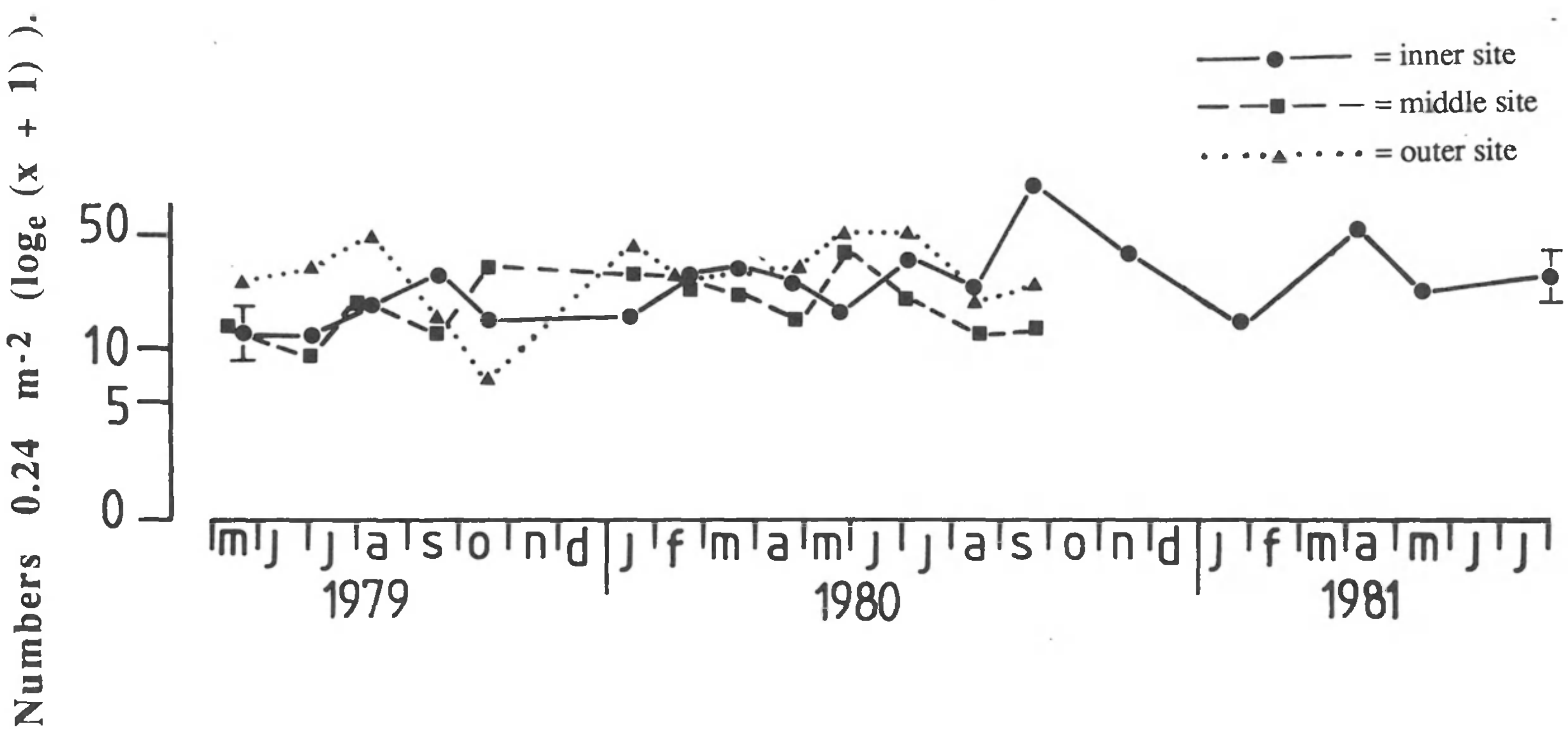

Figure 9. *Lumbrineris gracilis* : changes in abundances at three locations (see Fig. 3) for the period May 1979 to September 1980 and for an additional period, i.e. up to July 1981, at the inner monitoring site only.

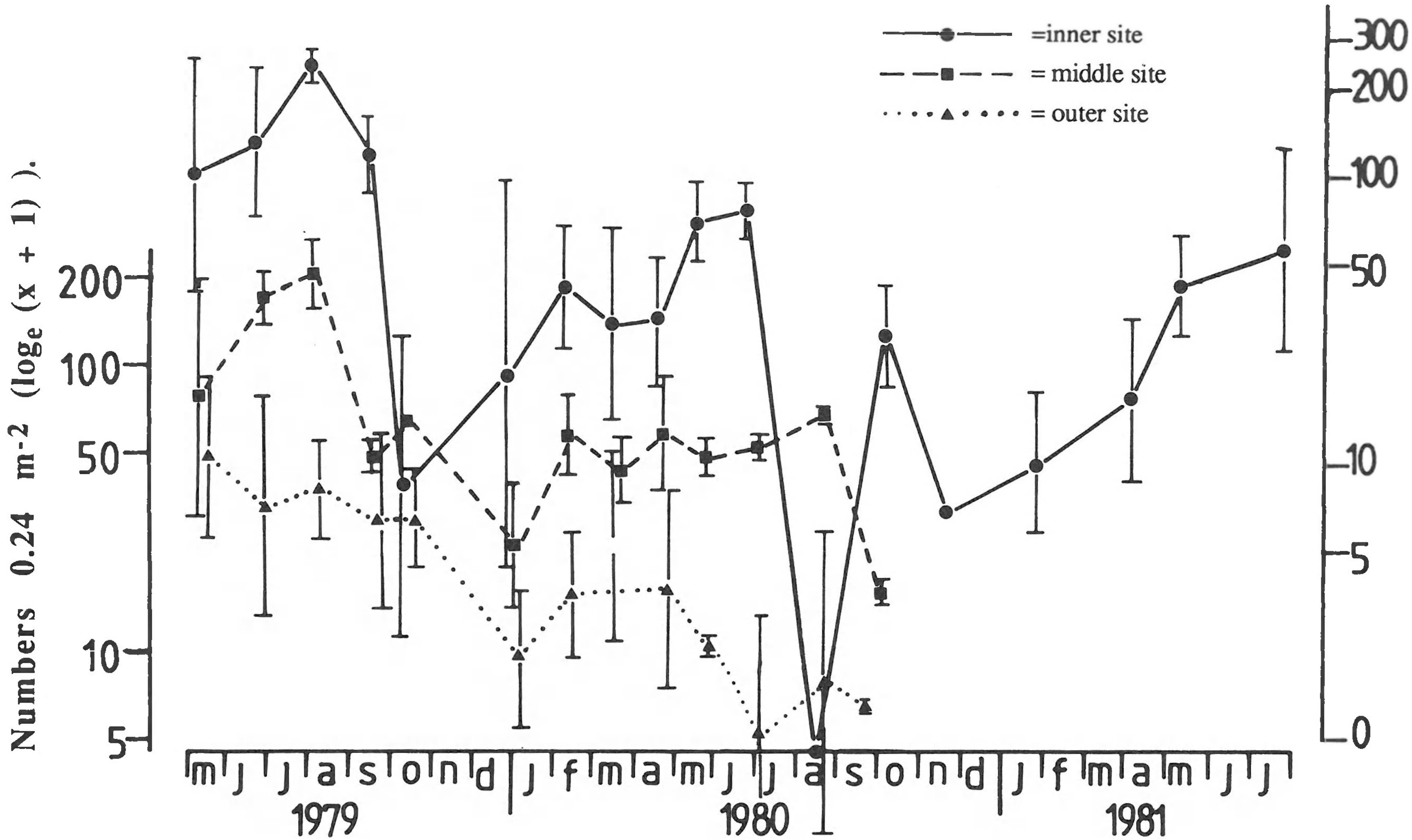

Figure 10. *Mysella bidentata* : changes in abundances at three locations (see Fig. 3) for the period May 1979 to September 1980 and for an additional period, i.e. up to July 1981, at the inner monitoring site only.

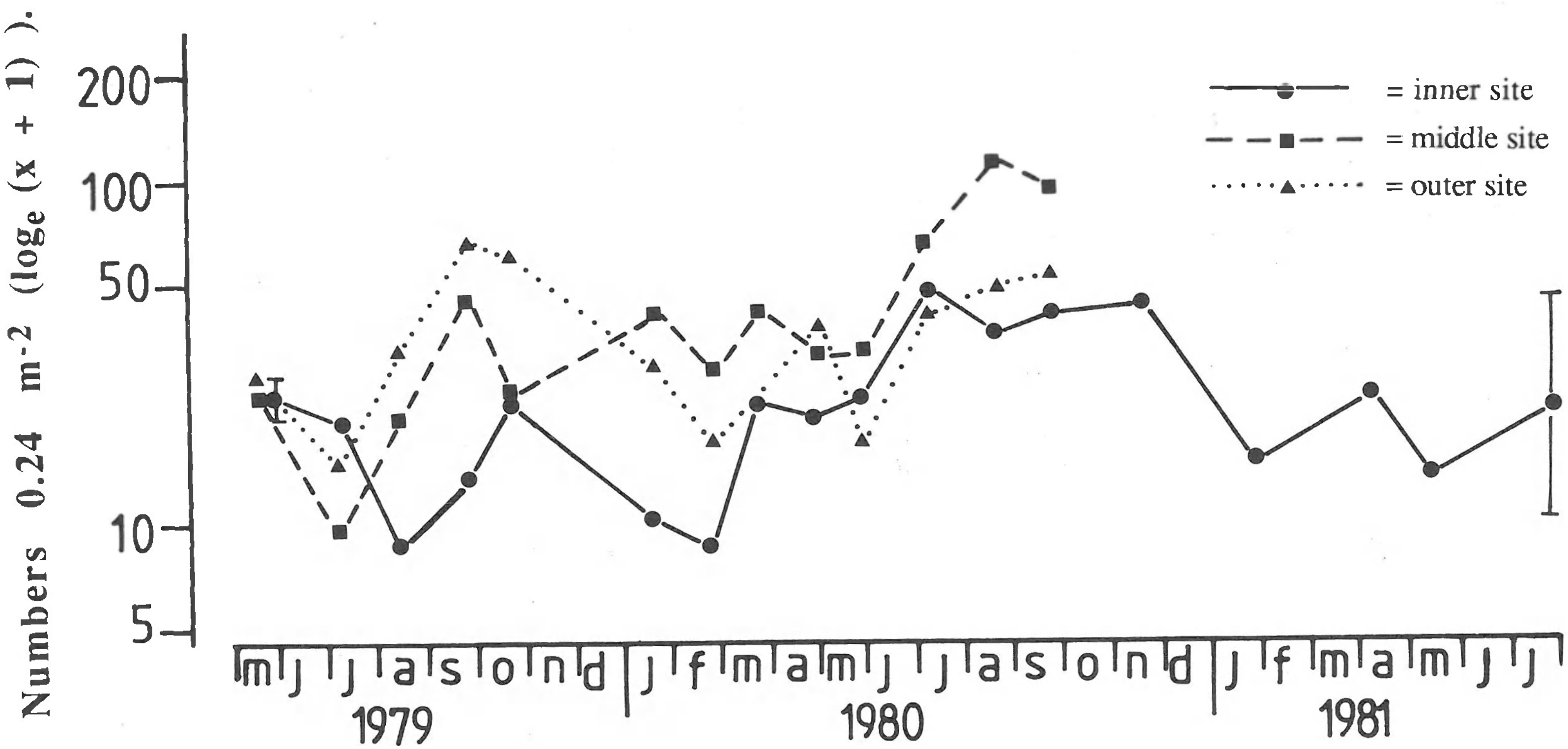

Figure 11. *Owenia fusiformis* : changes in abundances at three locations (see Fig. 3) for the period May 1979 to September 1980 and for an additional period, i.e. up to July 1981, at the inner monitoring site only.

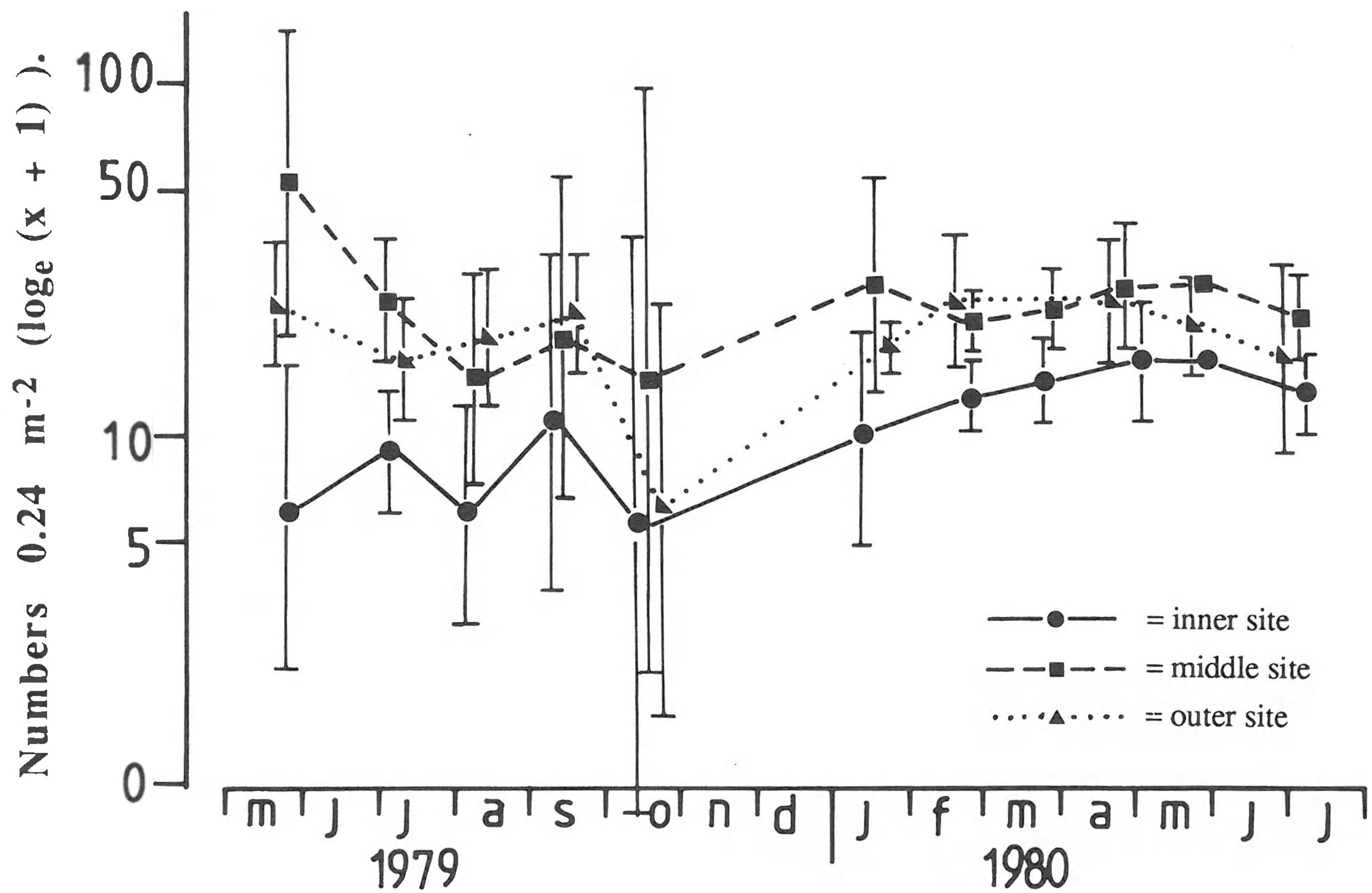

Figure 12. *Amphiura filiformis* : changes in abundances at three locations (see Fig. 3) for the period May 1979 to September 1980 and for an additional period, i.e. up to July 1981, at the inner monitoring site only.

Spatial and temporal variability of benthic communities: consequences for monitoring.

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ABSTRACT

It is clear that spatial variability of subtidal macrobenthic communities poses a serious problem, both for the study of the population dynamics of single species and for studies of community structure. We have investigated these effects from a community point of view.

We have produced a number of graphs based on the same reasoning as is used in time series analysis for the construction of autocorrelograms. An autocorrelogram expresses the correlation between values spaced k time units apart, as a function of the lag k. The autocorrelation value with lag 1 thus expresses the correlation between each value and the next; with lag 2, the correlation between all pairs of observations spaced 2 time units apart, etc.

The graph in Figure 1 shows time lags on the abscissa, while the ordinate expresses (Bray-Curtis) similarity indices between samples spaced k time units (months) apart. Replicate van Veen grab samples taken at station 10080, in the western part of the Belgian coastal zone are compared The similarity values plotted against lag 0 are the similarities obtained by comparing all possible pairs of replicate samples that can be formed. There are 10 sampling dates, with 3 replicates on each date, and it is possible to form 3 pairs on each date: (1,2), (1,3), (2,3). We thus have 30 points on the graph for a lag of 0 months. For a lag of 1 month there are more comparisons. The three replicates of January are compared with the three replicates of February, those of February with those of March, etc. With a strictly monthly sampling scheme (12 samples/year), there would have been 11 x 9 = 99 comparisons. As we missed the August and October months, we actually had 7 x 9 = 63 comparisons. In general, for A consecutive sample dates, B replicates on each sample date, and lag k, we have (A - k)B comparisons for k > 0, and A B (B-1)/2 for k = 0.

Each of the comparisons involves the calculation of the Bray-Curtis similarity index between the two samples.

It can be seen in Figure 1 that the similarity between "replicate" samples is not very high, and is variable. Two samples, taken on the same occasion, may easily differ more from one another than from a sample taken 7 months later! Temporal effects are weak compared with spatial variability.

Figure 2 gives the "autosimilarogram" for the station M50, close to the mouth of the Western

Scheldt in the Netherlands. This station was sampled monthly over 2 years. In Figure 2 the similarities for the second year (1984) are expressed as a function of the lag in days. Figure 3 is partially based on the same data (data for the years 1983-1984), but here the sample means were compared, instead of the replicates. Obviously, comparisons with lag 0 are not possible in this case. The sampling conditions for this campaign were nearly optimal. Five replicate samples were taken from an anchored boat, the position of which was determined to withing 10m. Nevertheless, the similarity between "replicate" samples is as variable as it was in station 10080 (Fig. 1). Seasonal effects are hardly discernible in Figure 3. Although a small hump is present around a lag of 12 months, the general feature of the similarogram is a downward trend. The main temporal effect is for the community to wander away from its present state.

The scale of the spatial variability can be evaluated on an analogous plot, where distance in space now replaces the lag, which was a distance in time. Figure 4 shows a "similarogram" against distance in space, for a sampling campaign off the western part of the Belgian coast. During this campaign three replicate van Veen grabs were taken from an anchored boat at twelve stations, which form an almost regular rectangular 3 x 4 grid (1.5 x 2 miles).

In this region two broad types of community occur. The two communities are intertwined, and there is no pattern in their spatial extent. This is reflected in the "similarogram". Similarities at a distance larger than 0 are in general either very low (indicating that the two stations belong to different strata) or relatively high, when they belong to the same community type. It is mainly this upper "layer" of points that is relevant. There is no change in the range of similarities with distance. Thus, we find two types of spatial pattern in these data. On the one hand, two drastically different communities are spatially separated by sharp boundaries. This spatial variability can be well described by our methods. On the other hand, the spatial variability , which creates the noise in our time series, is the patchiness within each stratum. This patchiness can be seen to occur entirely on a scale smaller than the resolution of our methods.

The situation is worse off the Belgian coast than in more stable habitats. Data from the GEEP workshop in Norwegian fjords show a better distinction between sample points. Still, there remains a considerable overlap. For the meiofauna, which has a much higher species diversity, no overlap between similarities within and between stations occurs. This, however, may be partially caused by the fact that the replicate cores for the meiofauna were taken close to one another in space.

Patchiness of the benthos may pose serious problems for the study of population dynamics. Increasing the number of samples is probably not a good solution. The mean densities, however well estimated, are probably not relevant for a population dynamics study, as the relevant interactions may be situated within the patches.

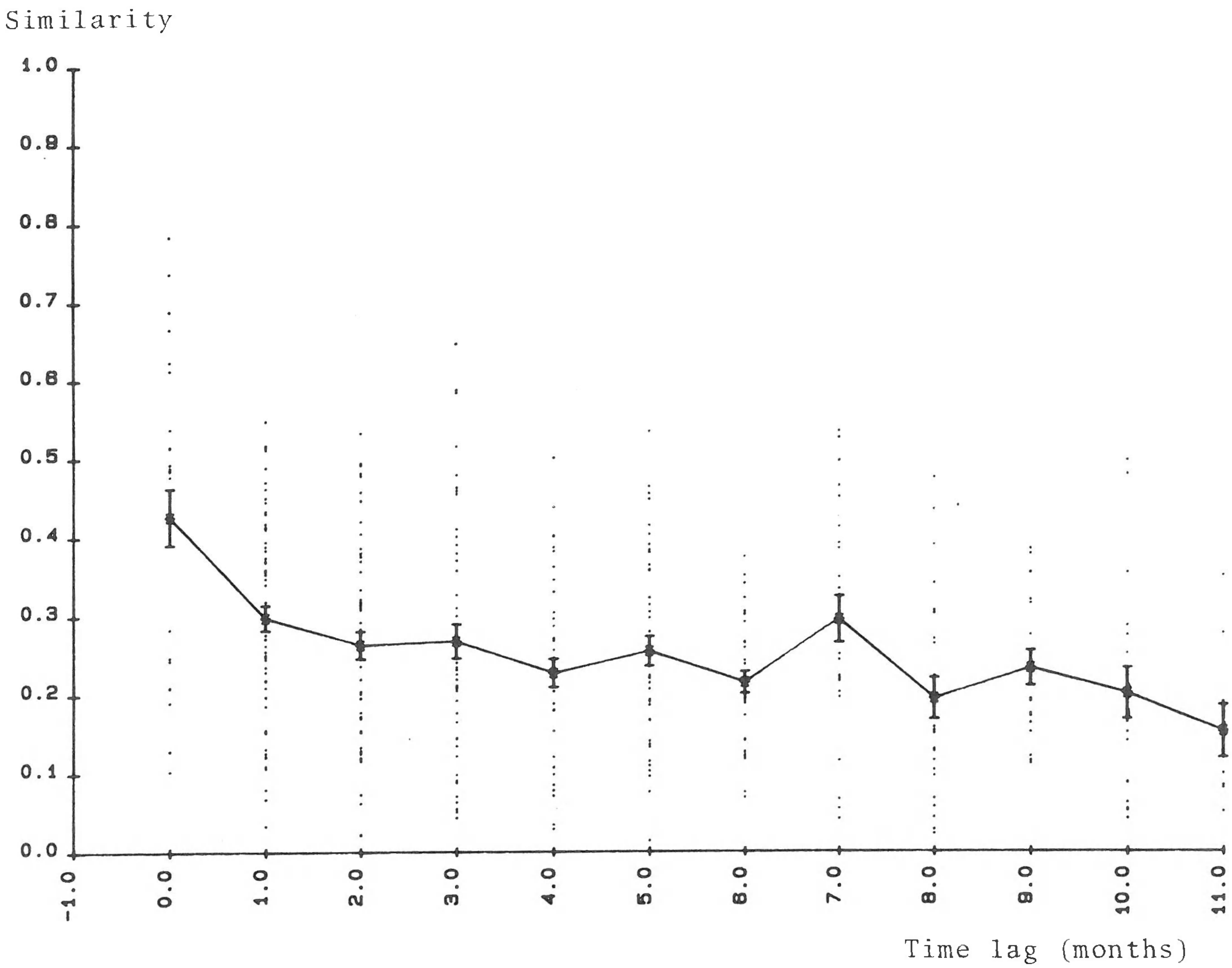

Figure 1. Station 10080 (Western part Belgian coastal zone) : autosimilarogram of a monthly sampling campaign. Bray-Curtis similarity between replicate van Veen samples is expressed as a function of the lag in months.

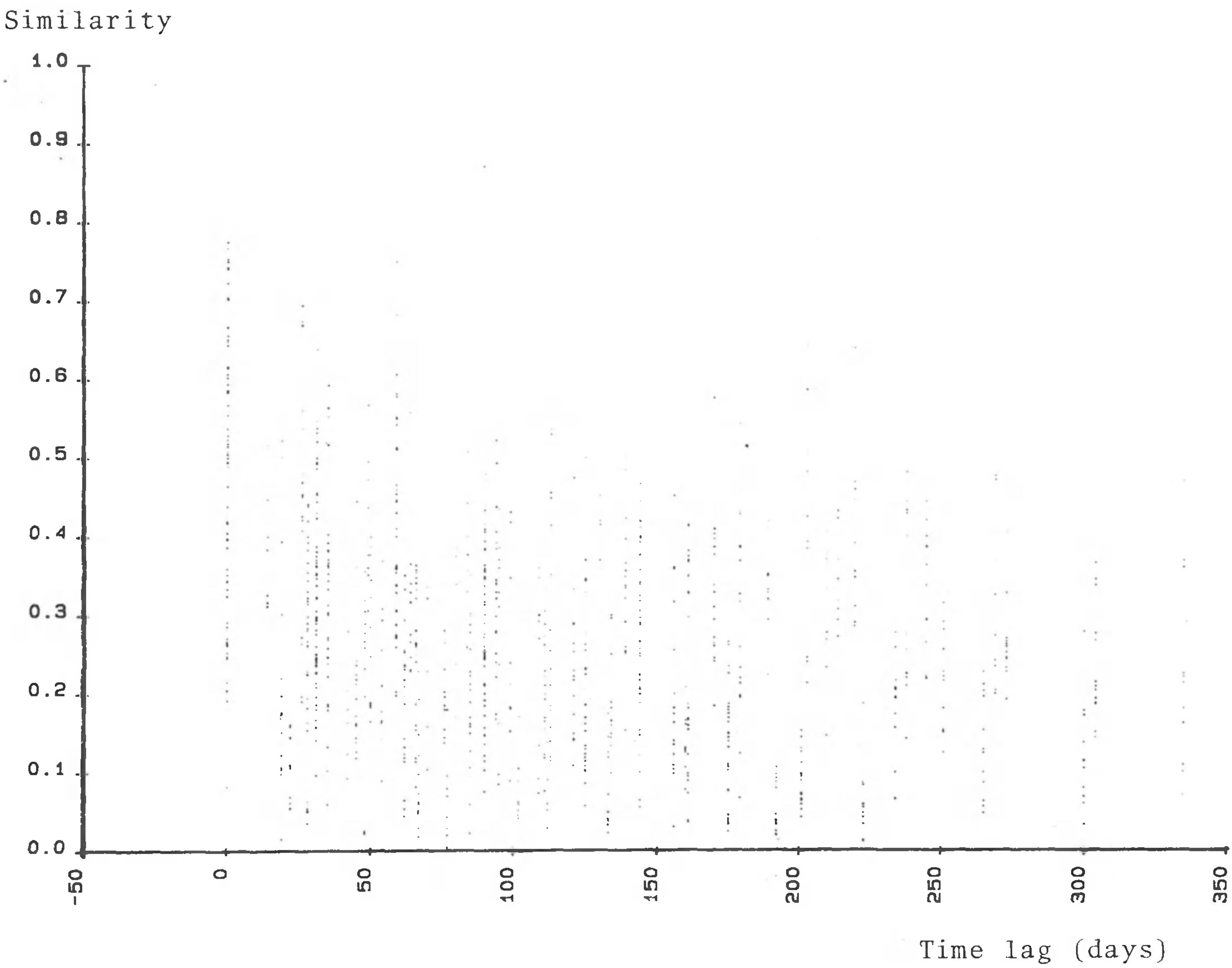

Figure 2. Station M50 (mouth of the Western Scheldt) : autosimilarogram of a monthly sampling campaign (1984).Bray-Curtis similarity between replicate van Veen samples is expressed as a function of the lag in days.

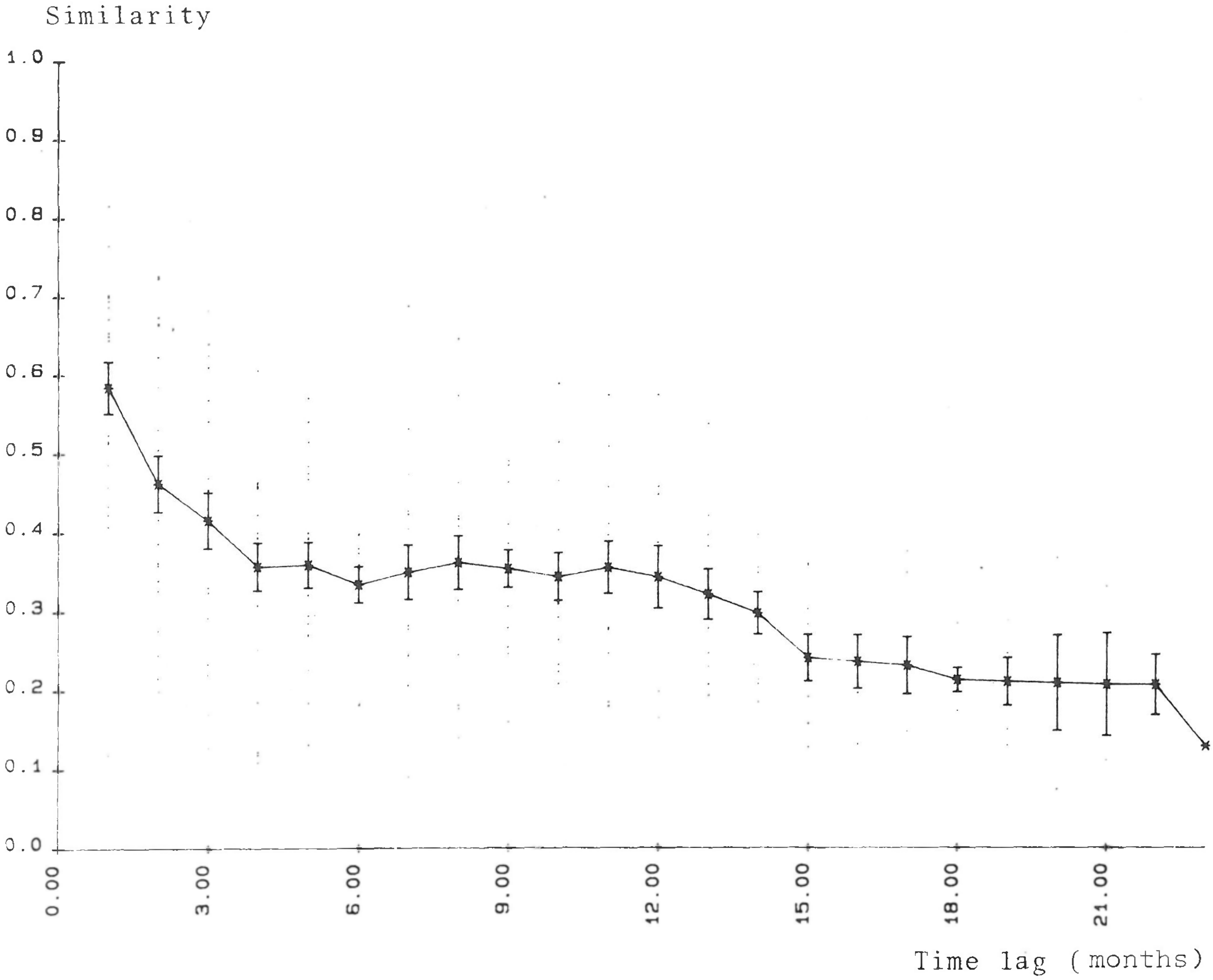

Figure 3. Station M50 : autosimilarogram of a monthly sampling campaign over two years (1983-1984). Bray-Curtis similarity between the monthly means is expressed as a function of the lag in months.

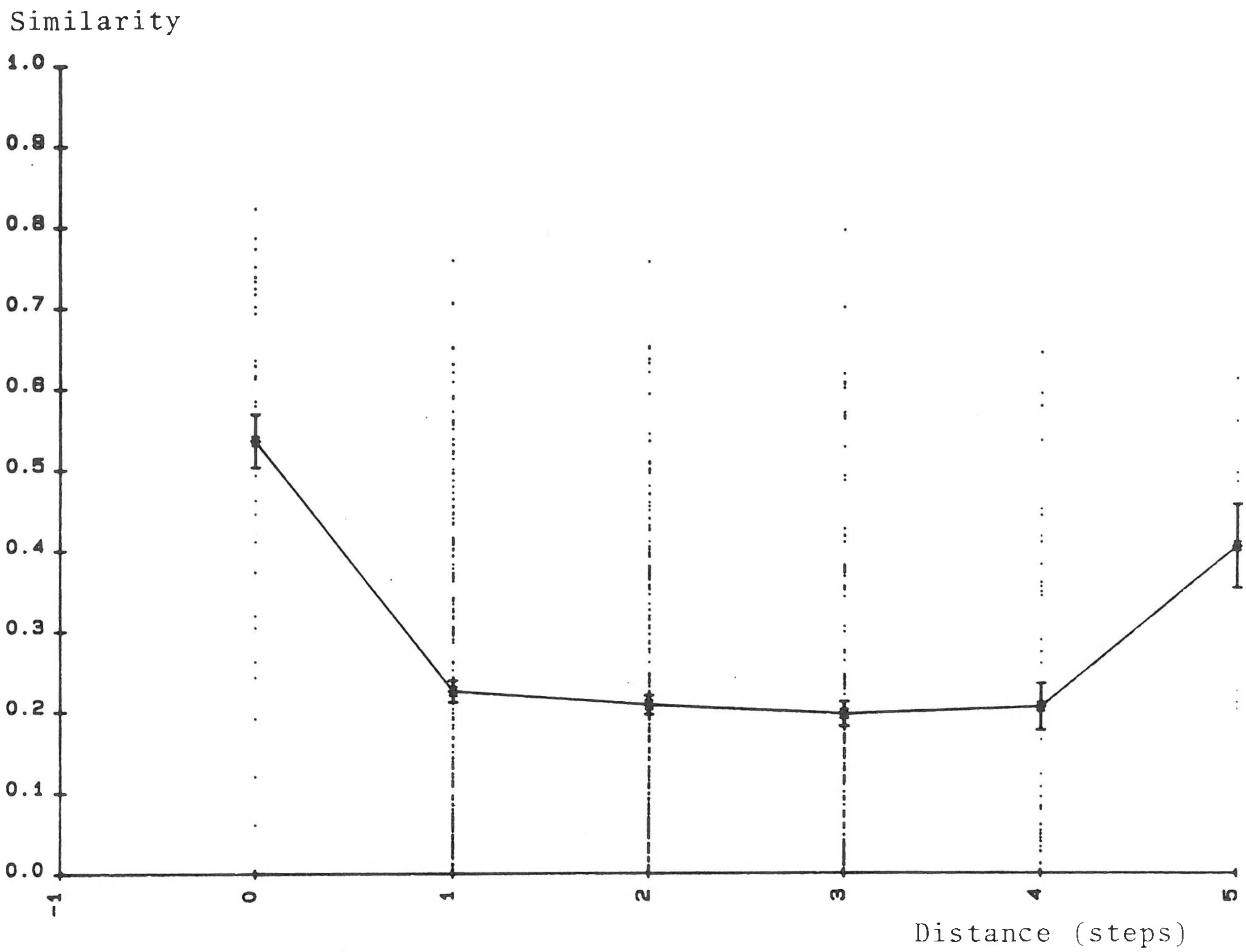

Figure 4. Western part of the Belgian coastal zone : Bray-Curtis similarity between replicate van Veen samples taken at twelve stations forming a rectangular grid expressed as a function of distance between the sampling points. Distance is coded as the minimum number of steps needed to go from one station to the other.

Sampling macrozoobenthos: maximum returns for minimum effort.

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Introduction

The non-diving biologist depends upon remotely operated sampling devices to sample subtidal macrozoobenthos. Since C.G.J. Petersen first introduced his quantitative approach to the study of the marine benthos, at the beginning of this century, many samplers have been developed to bring sediment samples from the sea bottom to the deck of the research vessel (see e.g. Holme & McIntyre, 1971).

The biologist requires a picture of that which can be considered as representing the actual occurrence of the compartment of the benthos under investigation. The perceived picture of the bottom fauna will naturally reflect the nature of the sampling device. In spite of this, the choice of bottom sampler will often have more to do with traditonal considerations, the ready availability of the device, or even a sort of "religious belief" in what is best for a particular study, than any objective appreciation of the study's aspirations. Clearly, the number of samples and the size of the sampler, should also be carefully considered before the start of a benthic investigation.This relates not only to the study objectives but also to the biologist's capacity to process the samples.

Sorting samples is time consuming. Some few biologists are in the happy position of being able to delegate this frequently boring chore to assistants. However, since most researchers have to do it themselves, there is good reason to try to obtain the desired results with as little sorting effort as possible. One thing is certain: the majority of benthic biologists can scarcely be condemned as lazy, given the enormous numbers of superfluous, excessively large, or often wrongly-taken bottom samples which have been processed over the years.

Quite a lot of studies have been published in which various types of bottom sampler are compared with each other. Such a comparison can be a useful way of initiating a study. However, in benthic investigations, a more reasonable approach would be, first, to consider the information required from the study and the degree of precision on which this will depend. The information is normally related to concepts such as species richness, density or diversity of taxonomic or ecological groups, or may focus on individuals within a certain size group of a single species. These considerations will all influence the choice of sampler.

The data presented hereunder derive from an investigation of a soft bottom, at 17m in the Sound, where a series of van Veen grab samples and HAPS (for construction see Kanneworff &

Nicolaisen 1973) core samples were analysed, and from a study of a sandy bottom (0.5 - 1.5m) in the Isefjord, where a series of samples taken with a simple handcorer were analysed.

Sampler type

The sampling of specimens of a single species hardly warrants any comment, since the biologist will use a device which gives the requisite number in a reasonable time. Towards this end, the dredge seems to be the preferred sampler.

However, density and, to some extent, also diversity (depending on the selected diversity index) are related to the area sampled. Thus, dredges cannot be called upon to describe the two cited parameters, since the area sampled is not well defined, even for dredges where the design intent is that they be able to take a well defined sample (Dickinson & Carey, 1975). So the choice lies between a core sampler and a grab.

Species richness is a parameter which is often determined for benthic sampling stations. The result depends on the area and the volume of the samples. The more sediment - and hence the more specimens sampled - the higher the species richness (Ursin, 1954). The concept makes no real sense unless it is defined as species richness relative to a specific area, be it the total area of the samples themselves, or a whole inlet for which species richness is estimated by extrapolation.

In the study of the Sound, the sorting time in the laboratory to find the one specimen of the last of 54 species was 6 hours. I think it is worth posing the question as to whether the exactness obtained by this effort (instead of estimating it by extrapolation) is really worth it. In most cases, there is a good chance that the last species to be found is extremely rare, takes a long time to identify, and is poorly known, biologicaly and ecologically.

Investigations have shown that core samplers record higher densities or abundances than grabs (Baker et al., 1977; Beukema, 1974, Jensen, 1981). This is due to the fact that a cylindrical sample normally represents a greater sediment volume per surface area, compared with the irregular biting profile of a grab (Ankar, 1977; Gallardo, 1965).

Similarly, my investigation in the Sound showed a higher abundance in the HAPS core samples than in the van Veen grabs (Figure 1). However, when the estimated densities of the individual species are compared, some species show significantly higher densities with the core sampler, while others do not (Table 1). The diversities as computed betwen the grab and core samplers do not differ much (Figure 2). It is not possible to distinguish between the effects of sampler type and of sample size on diversity. Under all circumstances, the biologist who is less than enamoured withthe sample sorting procedure will prefer to deal with core samples.

It has often been argued that core samplers do not function properly on sandy bottoms. However, the HAPS corer operates perfectly at 30-40 meters on sandy ground in the North Sea, and other types of core samplers such as the Reineck box corer (Reineck, 1963) can probably be modified to function even on very hard bottoms.

Sample size

The comparison of the van Veen grab and the HAPS core sampler shows that better results are obtained with the core sampler, and involves much less sorting effort. It is, however, difficult to distinguish how much of the difference relates to functional features and how much to sample size.

Holme & McIntyre (1971) state in their review of benthic sampling methods that "it is generally agreed that for macrofauna sampling an instrument covering at least $0.1m^2$ is required". This statement is absolutely unargued and unfounded. In contrast to most other fields of representative sampling, there are very few accounts on the the effect of sample size in marine benthic investigations. I submit that enormous amounts of resources could have been saved on sorting, identification, and counting in the laboratory, if the "blacksmith" had been told to produce a different size of sampler. Further, the advantages of larger numbers of smaller samples would be obvious to people - such as myself - with sparse knowledge of statistics, if only the appropriate analyses had been udertaken undertaken. Elliott (1977) emphasizes the advantages of small samples:

- more small units can be taken for the same amount of labour
- as many small units have more degrees of freedom than a sample comprised of a few large units, the statistical error is reduced, and
- since many small units cover a wider range of the habitat than a few large units, the catch of the small units is more representative.

The comparison between the $0.1m^2$ van Veen grab, and the 0.014 and $0.0026m^2$ HAPS corers (Table 2), shows that in most cases a great saving in resources may be achieved by reducing the sample size from that generally used to one approximately seven times smaller , and that this saving may be even greater on reducing to a sampler 40 times as small. (I should remark, of course, that one cannot exclude the possibility that cases exist where the sampler should be increased in size).

It may be contended that the analysis of sampling size seems to be a waste of time, and that the construction of many different sizes of sampler is too expensive. Firstly, it is common for biologists to work year after year, in the same locality and on the same community, so an investigation of sample size would be a good investment. Secondly, a sampler of the HAPS type is relatively easily converted to another size because the sediment sampling tube unit can be replaced separately.

Number of Samples

As already stated, the advantage of smaller sampling units is that the number of samples may be increased drastically while actually reducing effort in the laboratory. The actual numbers of samples which one must take will reflect the need for precision (see Table 2).

Elliott (1977) writes that because many species show contagious distribution, the published quantitative data are often unreliable because the total sampled area is too small.

It is not possible to do calculations on benthos data in the course of the actual sampling process. The most rational way, then, is to take a reasonably large number of samples and analyse the data while working up one sample at a time. Examples are shown in Figures 3 and 4 and Table 3. The decision to stop at a certain number of samples is of course a compromise between the need for precision and the available workforce. Figure 3 shows, however, that it is can be easy to save on working-up time while increasing the precision.

It may be contended that sampling time onboard a research vessel should be reduced as much as possible since shiptime is so expensive. It is true that taking more samples requires more time. However, smaller samples are handled faster than bigger ones. In my investigation, handling a van Veen grab took 15 minutes and the large and small HAPS, 4.2 and 3.7 minutes, respectively, on average. It may be a good idea to construct a multi-unit sampler to optimise on shiptime .

Conclusion

Comparisons between grab and core samplers have revealed that core samplers give better results with respect to density and diversity of macrozoobenthos, and that samples smaller than the commonly used 0.1m^2 will provide statistically better results and call on fewer resources. There is good reason to replace the van Veen or other grabs with a core sampler. The good news for the lazy biologist is that better results can be achieved using much less boring, sorting time in the laboratory.

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Table 1 : The densities of four species obtained with the three samplers in the sorting times indicated.

Sampler type	Van Veen	Large HAPS	Small HAPS
Sorting time (Hours)	67	19	6
Species(Density ind./m^2)			
Diastylis rathkei	738	971	1800
Rhodine gracilor	674	1071	1592
Pseudopolydora sp.	1434	1139	1073
Terebellides stroemi	528	748	627

Table 2 : The number of samples and the sorting time needed to obtain particular levels of precision (see Fig. 3) in the densities of the four most important species and total macrozoobenthos.

Density	Level of Precision %	Sampler type	Required number of Samples	Required sorting time/mins.
Total	20	VV	(<) 1 (0.39)	402
		LH	4	242
		SH	2	46
	10	VV	2	804
		LH	13	786
		SH	8	183
Diastylis rathkei	20	VV	1	402
		LH	15	907
		SH	15	344
	10	VV	5	2009
		LH	60	3626
		SH	61	1398
Rhodine gracilior	20	VV	5	2009
		LH	4	242
		SH	12	275
	10	VV	21	8438
		LH	16	967
		SH	50	1146
Pseudopolydora sp.	20	VV	1	402
		LH	8	484
		SH	11	252
	10	VV	2	804
		LH	33	1995
		SH	44	1008
Terebellides stroemi	20	VV	5	2009
		LH	6	363
		SH	7	160
	10	VV	20	8036
		LH	22	1330
		SH	26	596

Table 3 : Ten core samples of 85 cm^2, from 1.5m on fine sand, randomly pooled in different combinations. Effect of number of samples on mean abundance, mean diversity and standard deviations.

Number of pooled samples n = 10	Mean abundance 10^3ind./m^2 ± s.d.	Mean diversity H ± s.d.
1	26419 ± 6511	2.05 ± 0.28
2	25188 ± 2924	2.16 ± 0.22
3	26977 ± 3301	2.16 ± 0.20
4	25601 ± 2856	2.19 ± 0.17
5	26867 ± 1618	2.14 ± 0.09
6	26429 ± 1993	2.16 ± 0.10
7	25507 ± 1040	2.22 ± 0.06
8	26175 ± 909	2.17 ± 0.06
9	26419 ± 723	2.16 ± 0.06

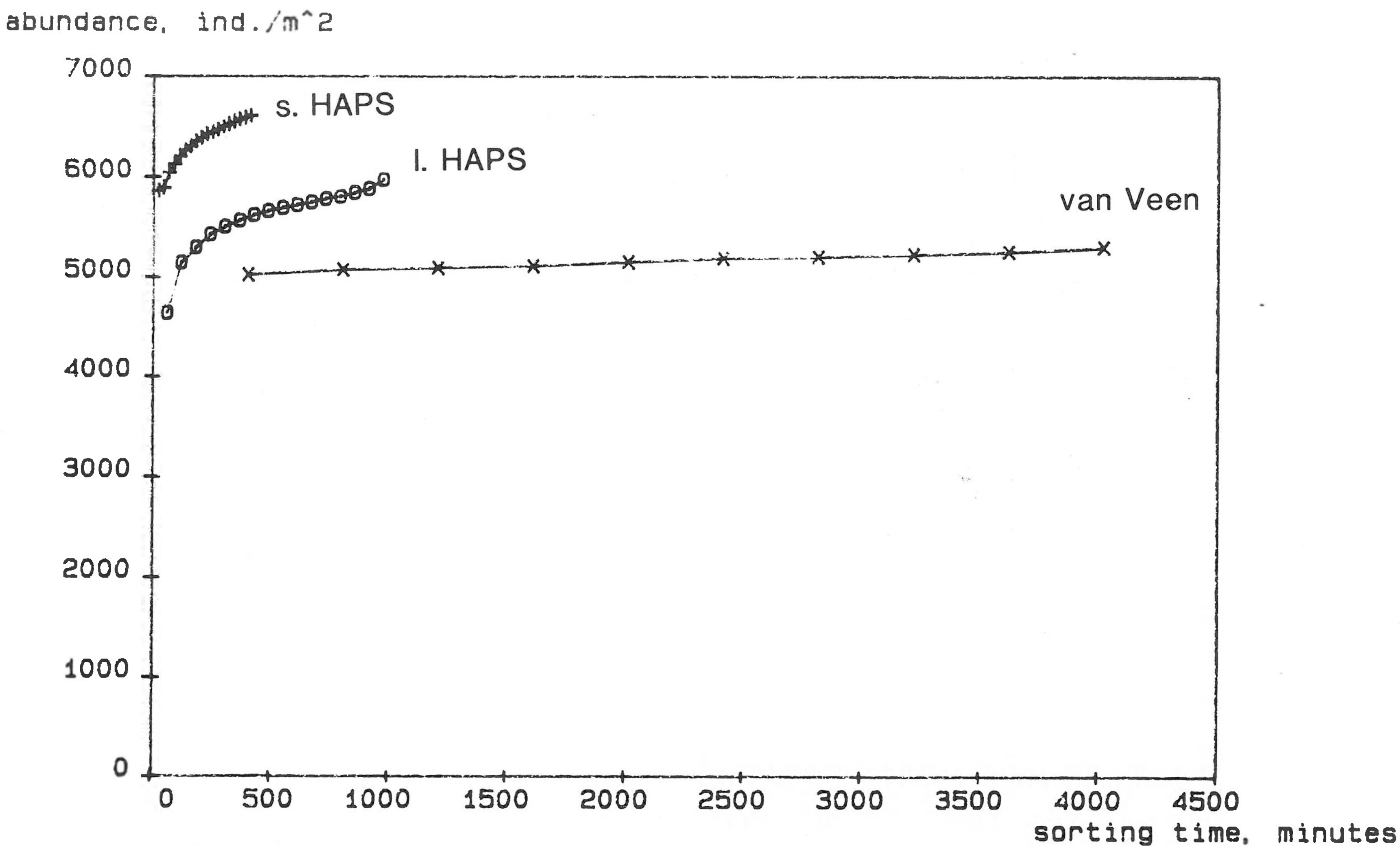

Figure 1: Abundance of macrozoobenthos at a 17m soft bottom station in the Sound, obtained with three samplers compared with the time spent in sorting samples in the laboratory. (x = van Veen grab $0.1m^2$, 0 = large HAPS core sampler $0.014m^2$, + = small HAPS core sampler $0.0026m^2$)

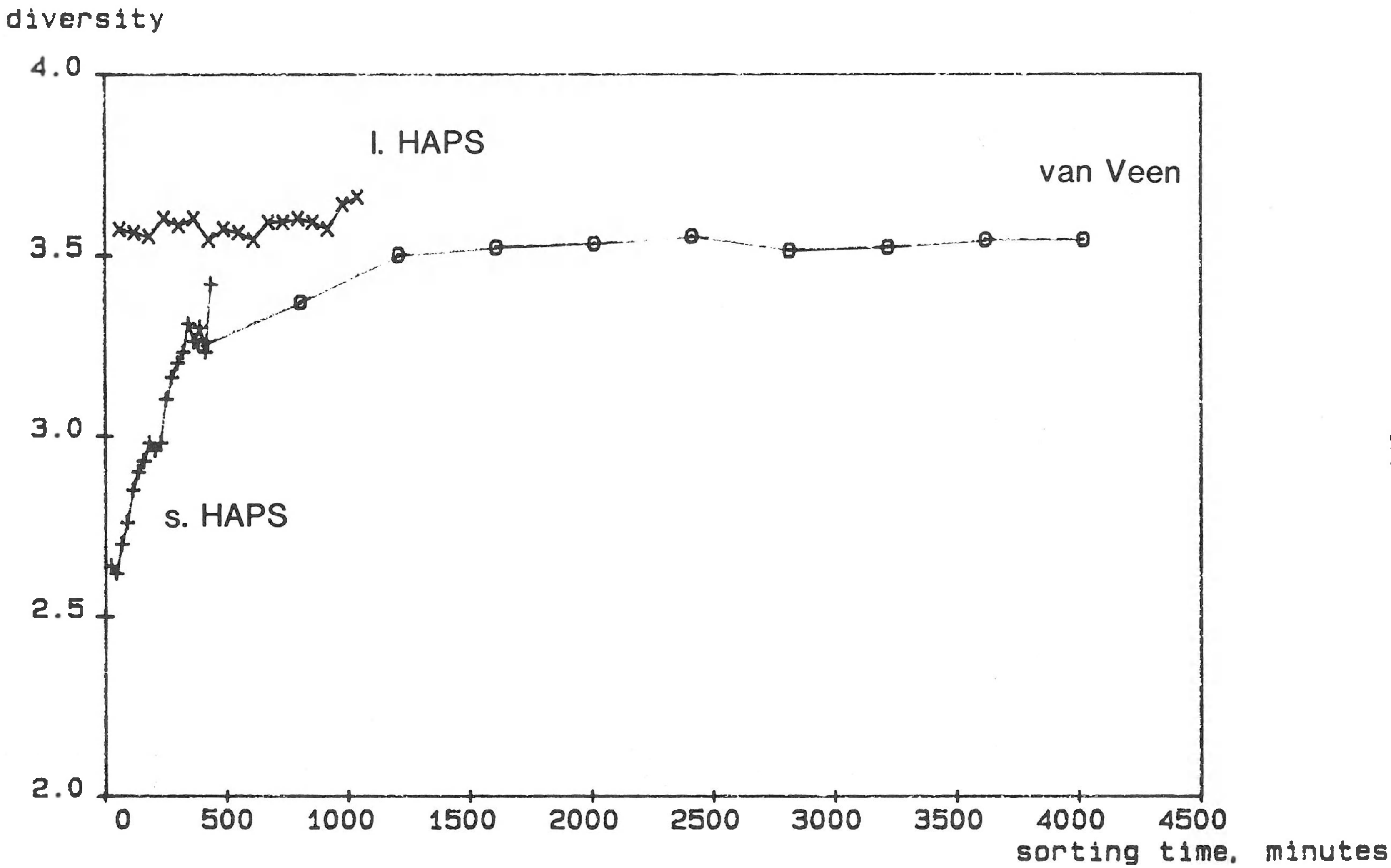

Figure 2 : Diversity (Shannon-Wiener index) of macrozoobenthos at a 17m soft bottom station in the Sound obtained with three samplers, compared with time spent at sorting samples in the laboratory.

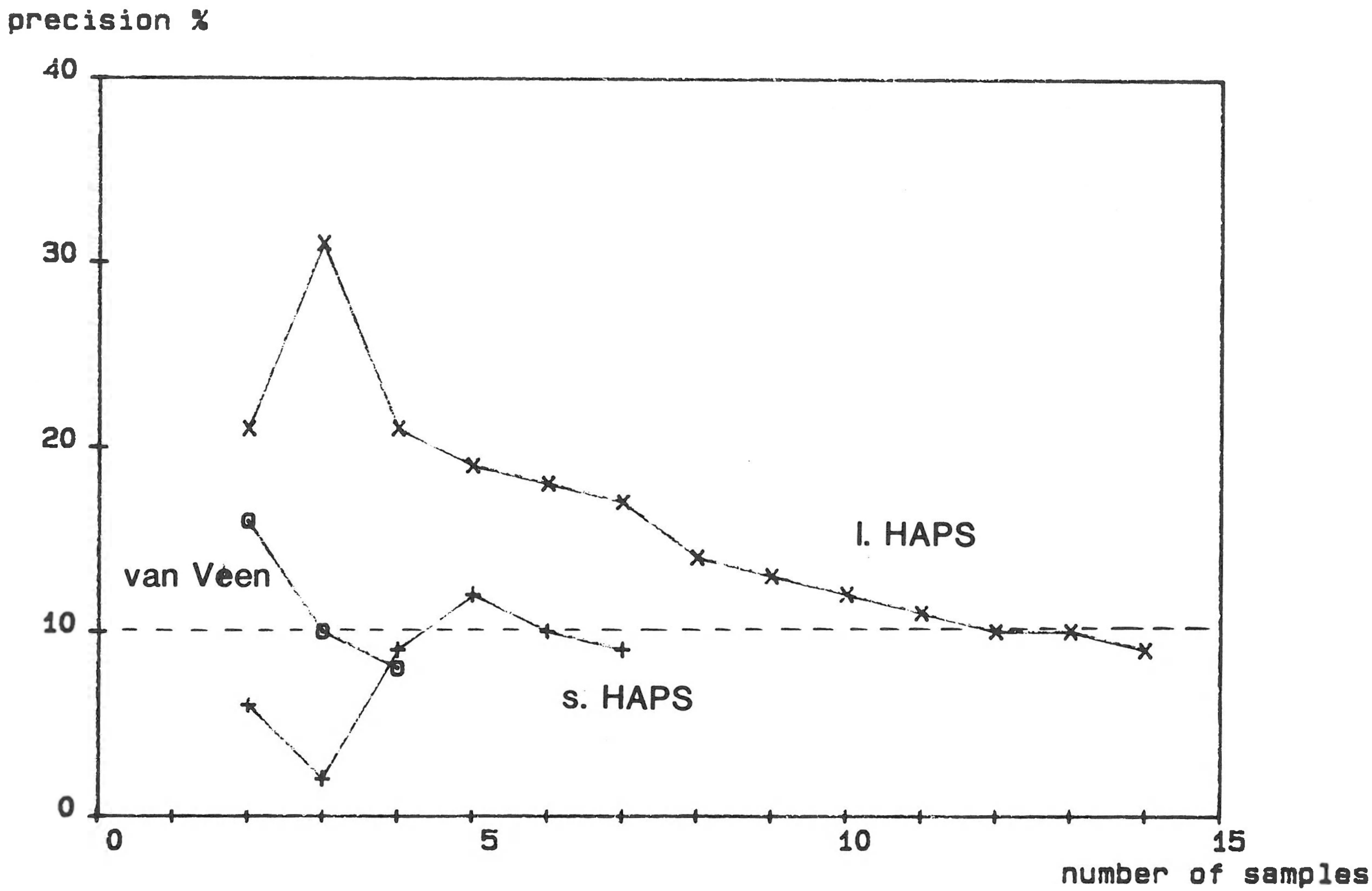

Figure 3 : Level of precision $\left(\frac{1}{x}\sqrt{\frac{s^2}{n}}\right.$ (Elliott, 1977)) on total density and number of samples with the three samplers.

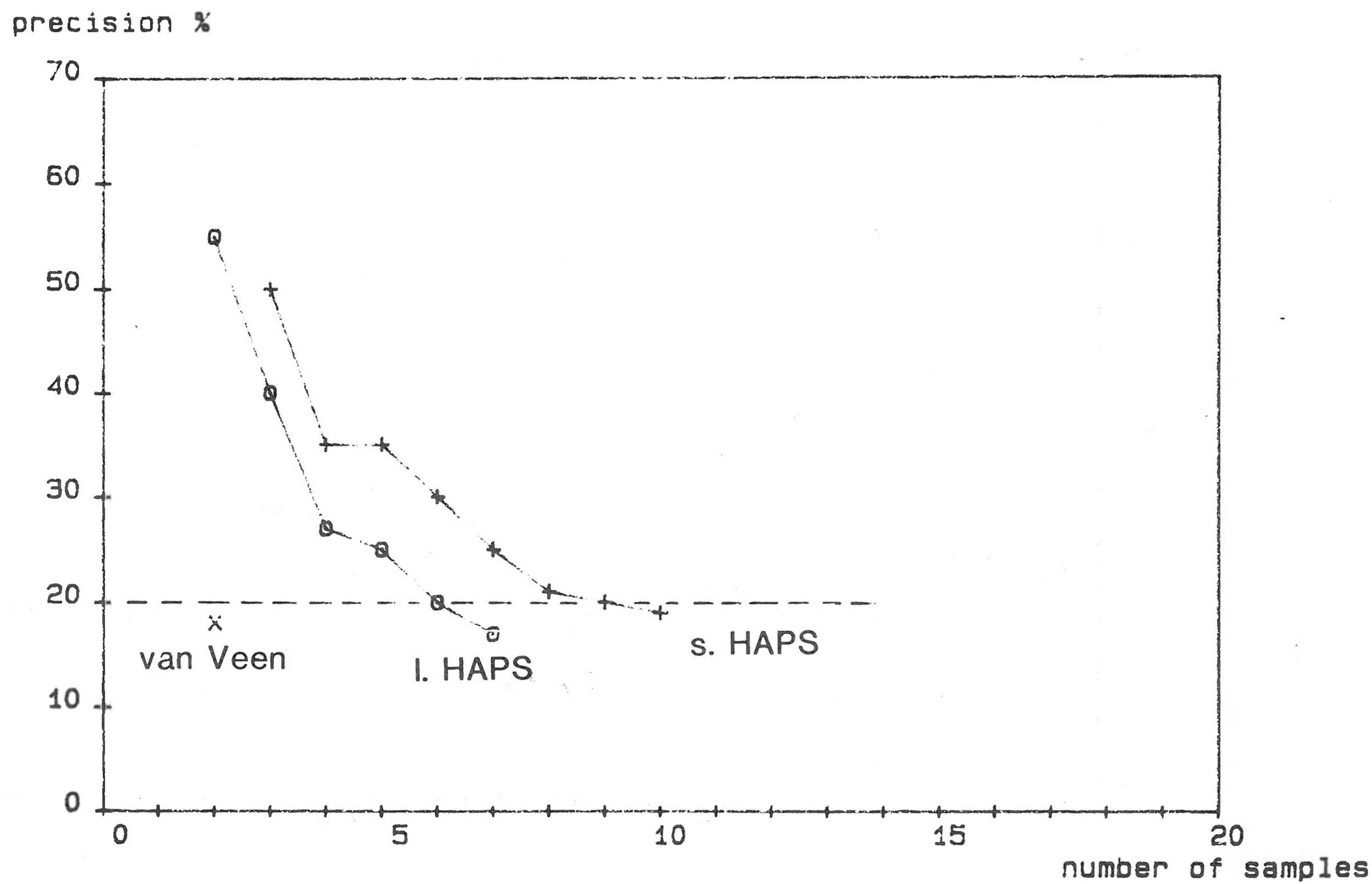

Figure 4 : Level of precision (see Fig. 3) on density of *Pseudopolydora* sp. and number of samples with three samplers.

An *Amphiura filiformis* association northeast of the Doggerbank - species composition, abundance, biomass and population dynamics.

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INTRODUCTION

The macrozoobenthos communities in the southern part of the North Sea are well investigated, but less is known about the communities of the central and northern part of the North Sea. The deeper areas of the southern North Sea are inhabited by an *Amphiura filiformis* association (Salzwedel et al., 1985; Cadee, 1984). This association is also present over large areas of the northern and central North Sea (Kingston & Rachor, 1982; own investigations). In the present study an area northeast of the Doggerbank at the margin of the central North Sea was investigated and the fauna was compared with that of the German Bight.

MATERIALS AND METHODS

The area northeast of the Doggerbank was investigated at two stations (Fig. 1): "NE Kaffeesuhle" (56°12'N; 05°34'E; 54m depth) and "NE Tailend" (55°55'N; 05°35'E; 51m depth). In 1983 samples were taken bi-monthly; in the following years only twice a year and according to COST 647 core programme guidelines.

RESULTS

At both stations the sediment is very fine sand with about 30% mud content (grain size < 63µm).

The water column is stratified during the whole summer, even in stormy months. Thus, the bottom water is cold in summer (7.5°C in August/September). The highest bottom temperatures were measured in autumn (11°C in November) after a breakdown of the stratification. The salinity of the bottom water was 34 to 35%.

The species composition in this area is that of an *Amphiura filiformis* association. Comparing this association with the *Amphiura filiformis* association of the German Bight (Table 1), the diversity (Shannon-Wiener Index) is higher, the number of species is nearly doubled, the number of individuals is nearly trebled and the biomass is twice as high.

Approximately the same species dominate at both the investigated stations (Table 2), but apart from *Amphiura filiformis*, *Mysella bidentata* and *Pholoe minuta*, additional species are dominant in the German Bight.

The growth and longevity of *Amphiura filiformis* and *Mysella bidentata* were studied more intensively. While the population of *Amphiura filiformis* is dominated by old individuals, there is a greater proportion of young individuals in the *Mysella bidentata* population. Growth seems to be slow with a seasonal maximum in autumn, when the bottom temperature is warmest. The life-span of both species is relatively long.

CONCLUSIONS

The investigated area northeast of the Doggerbank is situated at the "boundary" between the southern and northern North Sea. The Hydrographic conditions and species composition are those of the coastal etage which Glemarec (1973) described for water depths of 60 to 100m north of the Doggerbank. Against that, the high biomass values in the investigated area seem to be more typical for the southern North Sea (Rachor, 1982). De Wilde *et al.* (1984) found an area of high biomass south of the Doggerbank and according to the present study this area seems to extend to the northeast of the Doggerbank.

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TABLE 1: Comparison of the *Amphiura filiformis* association at two stations in the central North Sea with the *Amphiura filiformis* association in the German Bight. Values in brackets include large meiofauna retained on 0.5mm screens.
All values of the German Bight are from Salzwedel *et al*. (1985).
Mean values of the German Bight are means of eleven stations, those of the central North Sea stations are means over months.

	German Bight	NE Tailend	NE Kaffeesuhle
Depth (m)	34-45	51	54
Sediment	Muddy fine sand	Muddy fine sand	Muddy fine sand
Diversity	2.3	3.27	2.91
Evenness	0.6	0.64	0.60
Total number of Species	133	156 (165)	114 (120)
Mean number of Species	50	97 (103)	77 (81)
Mean number of Individuals	2184	5444 (6077)	5932 (7029)
Mean Biomass			
(g AFDW)	7.4	12.9	11.8
(g total wet weight)	108.2	201.5	181.7

Table 2: Dominating species (>1%) with their mean abundance (ind.m^{-2}) at the two stations in the central North Sea and in the German Bight.

GERMAN BIGHT		NE TAILEND		NE KAFFEESUHLE	
Amphiura filiformis	*297*	*Amphiura filiformis*	*898*	*Myriochele oculata*	*1250*
Venus striatula	*157*	*Myriochele oculata*	*876*	*Diastylis lucifera*	*960*
Pholoe minuta	*135*	*Mysella bidentata*	*672*	*Amphiura filiformis*	*901*
Mysella bidentata	*115*	*Eudorella emarginata*	*606*	*Mysella bidentata*	*584*
Echinocardium cordatum	*64*	*Diastylis lucifera*	*272*	*Eudorella emarginata*	*532*
Pectinaria auricoma	*63*	*Diastylis rathkei*	*180*	*Ophiura albida*	*363*
Edwardsia sp.	*55*	*Ophiura albida*	*128*	*Pholoe minuta*	*114*
Spiophanes bombyx	*40*	*Pholoe minuta*	*116*	*Rhodine gracilior*	*108*
Glycinde nordmanni	*40*	*Protomedeia fasciata*	*112*	*Eudorella truncatula*	*88*
Cultellus pellucidus	*36*	*Nucula tenuis*	*90*	*Owenia fusiformia*	*73*
Nucula nitidosa	*29*	*Harpinia antennaria*	*74*	*Diastylis rathkei*	*71*
Nephtys hombergii	*27*	*Microjaera anisopoda*	*66*		
Cylichna cylindracea	*26*	*Rhodine gracilior*	*62*		
Thyasira flexuosa	*23*	*Scoloplos armiger*	*59*		
Abra alba	*22*				
Lanice conchilega	*22*				
Phoronis sp.	*21*				

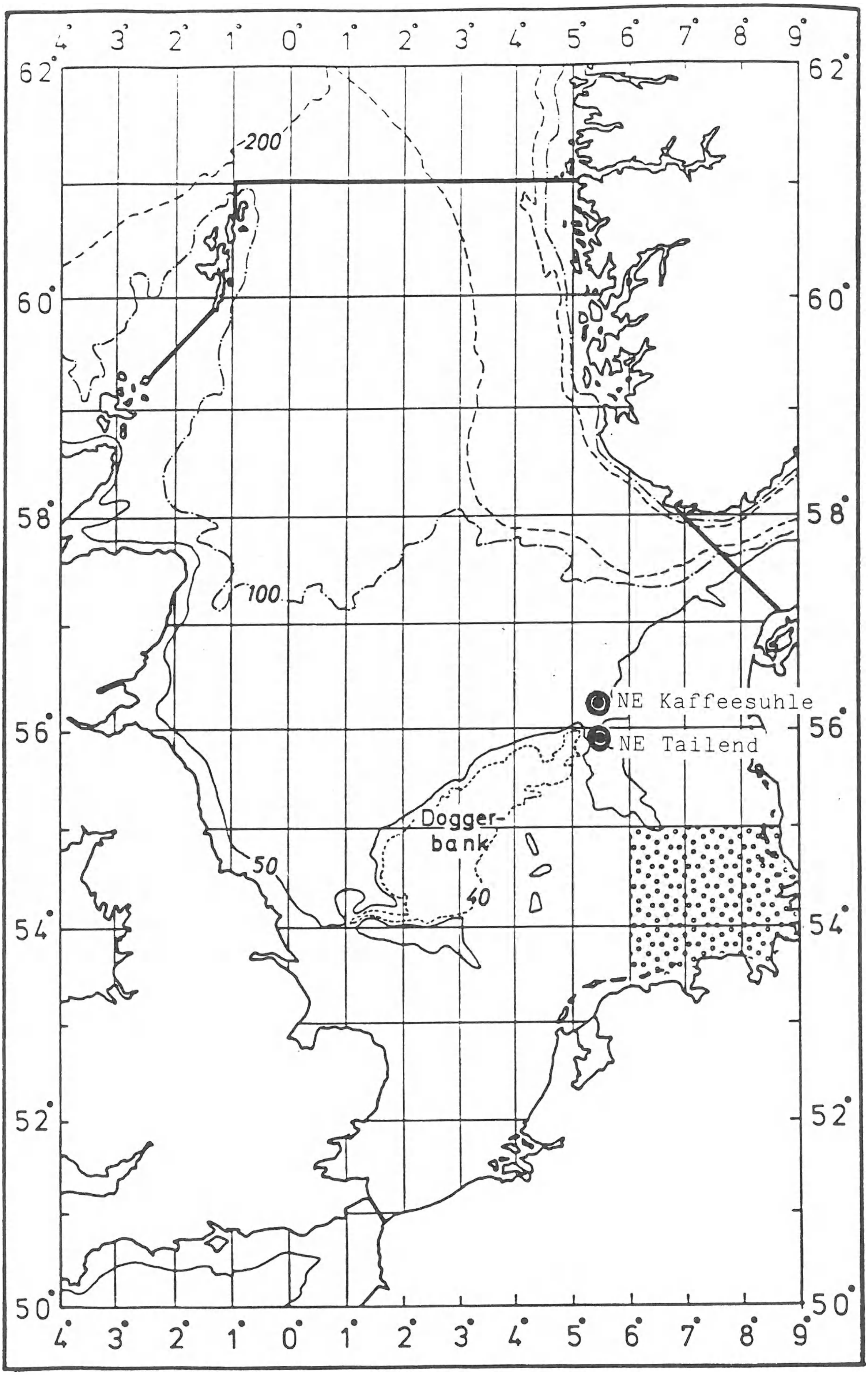

Fig. 1 Area of investigation (black points) and German Bight with adjacent areas (stippled).

Ecology, growth and production of *Thyasira flexuosa* (Montagu)(Bivalvia, Lucinacea) from Ria de la Coruna, North-West Spain

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ABSTRACT

Population dynamics, growth and production of *Thyasira flexuosa* have been studied from 3 yr observations in Ria de La Coruna. During the recolonization of sediment after harbour dredging operations, *T. flexuosa* was the macroinfaunal dominant, and three successive cohorts could be followed through time.

Densities were very high (up to 22000 individuals m^{-2}) during most of the study period. This species seems to be associated with high values of sediment organic matter, and it is tolerant of hydrocarbon pollution. Recruitment took place from January to late spring, with a marked peak in April-May. The intensity of recruitment did not vary much from one year to another.

Average size of individuals of *Thyasira flexuosa* was 3.2 and 4.8mm at the end of the first and second years of life, respectively, although individual growth showed large variations. Average production was 4.67g AFDW $m^{-2}yr^{-1}$, and mean P/B was 1.39. Variations of growth and production from year to year were mainly related to intraspecific competition due to the extremely high density. Values of growth and production are compared with other bivalve species, and general data on ecology are provided.

Subsequently published in : *Ophelia* 27: 111-126, 1987

Demography and Gametogenic Cycle of *Paradoneis armata* Glemarec (Polychaeta, Paraonidae) in Ria de La Coruna, North-West Spain

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ABSTRACT

A survey of the benthic macrofauna in Ria de La Coruna, North-west Spain, showed the infaunal paraonid polychaete *Paradoneis armata* Glemarec to be common at a number of stations. A monthly sampling programme was undertaken to collect samples at the station where this small polychaete was most abundant. This time series was analysed to give information on density, population structure and gametogenic cycle. Densities were high throughout the study period with a maximum of 8618 ind./m^{-2}. The population was characterized by a single mode with little evidence of recruitment. *P. armata* is dioecious and spawning occurred in June. Secondary sexual features, i.e. enlarged eyes and natatory chaeta, were noted.

Subsequently published in : *Ophelia* 27: 127-136, 1987

Growth of *Abra ovata* in a brakish water lagoon

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INTRODUCTION

Abra ovata (Philippi, 1836) is species similar to *A. alba* (W. Wood, 1802). Their most evident difference is the more triangular shape of *A. ovata,* its less shiny surface and its larger pallial sinus. It has a Mediterranean-lusitanian distribution (Glemarec, 1964). It extends from the Mediterranean and the Black Sea to the Atlantic coasts of Morocco and France. In the Mediterranean, *Abra ovata* is considered a characteristic species (Peres, 1967) of littoral lagoons which experience wide ranges of salinity and temperature. Thus, it is abundant in the lagoons of Prevost (Guelorget & Michel, 1974) and Berre (Stora, 1976) in France, in lagoons of the Northern Adriatic (Vatova, 1981) in Italy and the Messologhi (Bourgoutzani & Zenetos, 1983) and Mazoma (Nicolaidou *et al,* 1985) lagoons in Greece. In the Atlantic it is found at depths of up to 12-14m. In the gulf of Morbihan, in particular, *A. ovata* occured at high densities in shallow water sediments covered with *Zostera* (Dennis, 1981).

This paper examines the growth of *A. ovata* in the lagoon Mazoma of Amvrakikos Gulf on the west coast of Greece.

Description of Sampling Area

Mazoma is a brakish water lagoon in the Amvrakikos Gulf. It has a surface area of 3km^2. A thin strip of land separates it from the Amvrakikos with which it communicates through two narrow openings approximately 30m wide. The bottom is muddy covered in places by the eel grass *Zostera noltii* and the green alga *Chaetomorpha.* The depth ranges from 1.0m to 2.0m. During the period of study the salinity in the lagoon varied between 14% in January and 37% in July and September. The temperature ranged from 8^{o}C in January to 27^{o}C in June 1981. The dissolved oxygen was lowest in July (2.1 ml/l $^{-1}$) and highest in January (7.65ml/l $^{-1}$). There were no considerable differences in the values of the above parameters between different parts of the lagoon.

Methods

Sampling took place from June 1981 to June 1982 at approximately bimonthly intervals. An interval of three months exists between samples taken at the end of January and the beginning of May.

Ten stations were sampled and two samples were taken at each station with a Ponar grab sampling $0.05m^2$ of the bottom. The samples were sieved through a 0.5mm mesh sieve, preserved in 4% formalin in sea-water and dyed with Rose-Bengal.

The shell length (posterior to anterior end) was used as a measure of growth. Larger specimens were measured to the nearest 0.05mm with a pair of sliding callipers, while animals smaller than 3mm were measured under a microscope fitted with a graticule.

Size frequency distribution histograms were made using 1mm class intervals. The normal curves corresponding to the histograms were calculated according to the method described by Wonnacott & Wonnacott (1970).

RESULTS

The size frequency histogram in Figure 1 shows that in June 1981, at the beginning of sampling, a major recruitment took place (Cohort B). An older generation (A), probably from the previous year, was also present. In September a new cohort (C) appeaed and cohort A died away by November. Apart from those major settlements less extensive recruitment took place throughout the year as indicated by the continuous presence in the samples of very small individuals. As seen from the shift of the peaks, growth is a lot faster in the summer months. The growth of each cohort can be followed better in Figure 2, where the mean size of each cohort is shown at each sampling time. In June 1981 cohort A has an average length of 8.3mm and the newly settled cohort B only 1.4mm. Growth is very rapid in the summer months, and by September cohort A reaches its maximum size with mean length equal to 14.3mm. The settlement of C must have taken place between July and September and growth must have been very rapid: although C was not present in July it already has a mean length of 3mm in September. It can also be seen from these graphs that cohort A in June 1981 had a much smaller mean size than cohort B in June 1982 (8.3mm and 14.6mm, respectively) while it is comparable to the mean size (7.2mm) of cohort C in June 1982.

DISCUSSION

Abra ovata in Mazoma had a continuous recruitment with two maxima, one in June and the other in September. The cohort which settled at the beginning of the summer reached a mean length of 14.3mm by the following June. By that time the September settlement had reached half that size at 7.2mm. This is partly due to the fact that cohort B had a better chance to grow in the warm summer months and partly to the fact that the small numbers of the continuously arriving younger individuals are incorporated in cohort C.

The growth of cohort B, for which data are available for a whole year, can be compared with the growth of other *A. ovata* populations in France. In Table 1, the average monthly growth of *A. ovata* in the Bay of Morbihan, in the Atlantic, was estimated from the growth curve in Dennis (1981) for the equivalent period between June 1976 and June 1977. The average growth of the population in the lagoon of Prevost in the Mediterranean is taken from Guelorget and Mayere (1981). It can be seen that the growth of *A. ovata* in Mazoma is comparable to that of station 3 in Prevost. As pointed out by Guelorget and Mayere (1981) this station is situated at the innermost part of the lagoon, as opposed to station 16 which is close to the opening of the lagoon. Growth at the latter station is a lot slower and similar to that of the population in the Bay of Morbihan. From the available measurements of the environmental factors for the three areas, the salinity range seems to be the most important in controlling growth. However, definite conclusions cannot be drawn since the information is very limited and the studies were carried out in different years. The little evidence that exists supports the conclusion of Guelorget and Mayere (1981) that the growth of *A. ovata* is better in conditions typical of euryhaline and eurythermal lagoons.

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Area	Mean Monthly growth in mm	Sediment	Salinity S	Temperature °C
Morbihan	0.48	Mud	25-30/ 35-36	8-20
Prevost (St.16)	0.47	Muddy Sand	30-38	-
Prevost (St. 3)	1.09	Mud	17-40	3.5-24.5*
Mazoma	1.10	Mud	14-37	8-27

Table l. Comparison of the growth of *A. ovata* in three different areas.
*: Temperature data from the graph in Guelorget et Michel (1979)

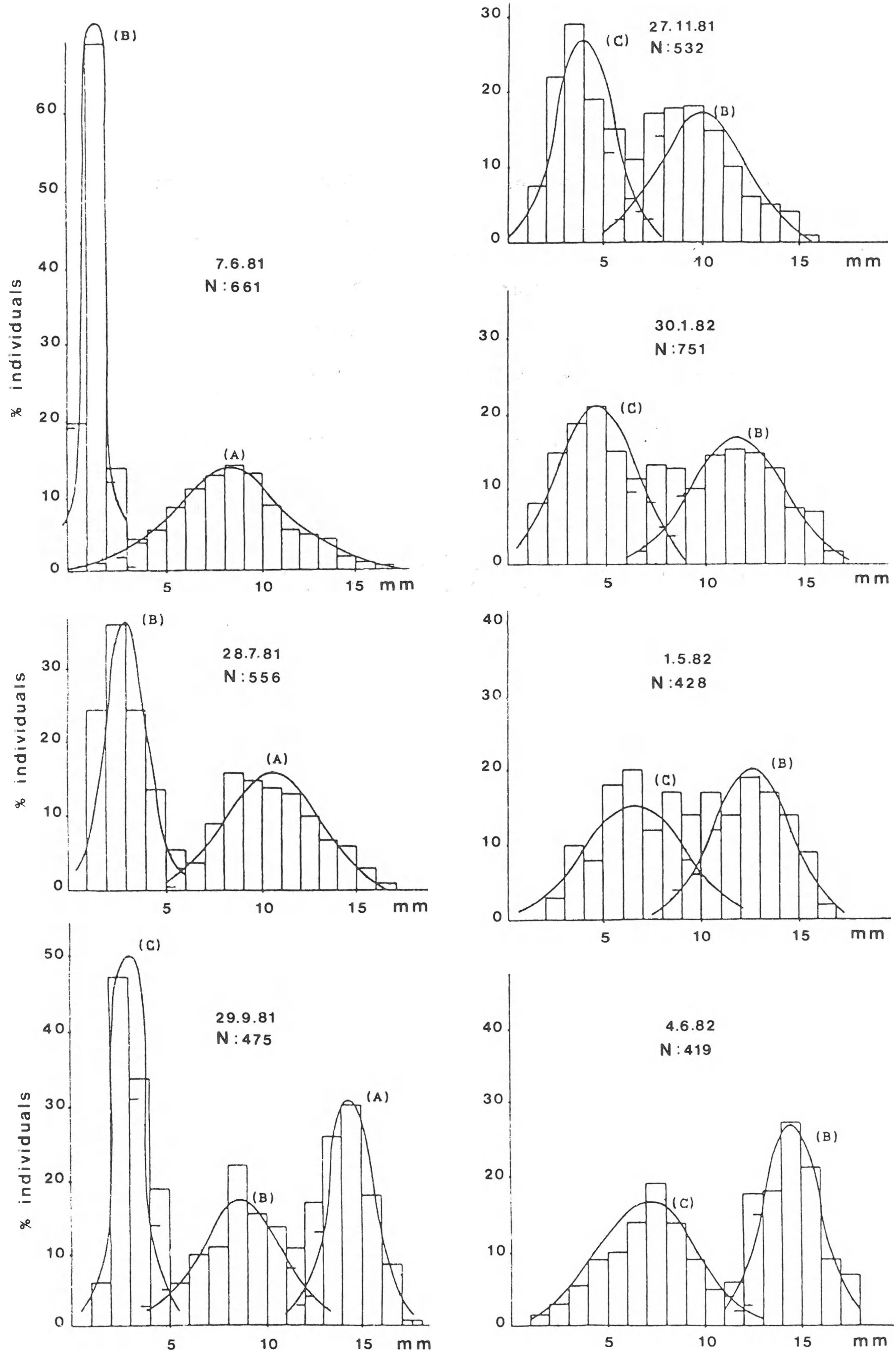

Fig. 1 Size frequency histograms and normal distribution curves of *A. ovata* for the period between June 1981 and June 1982.

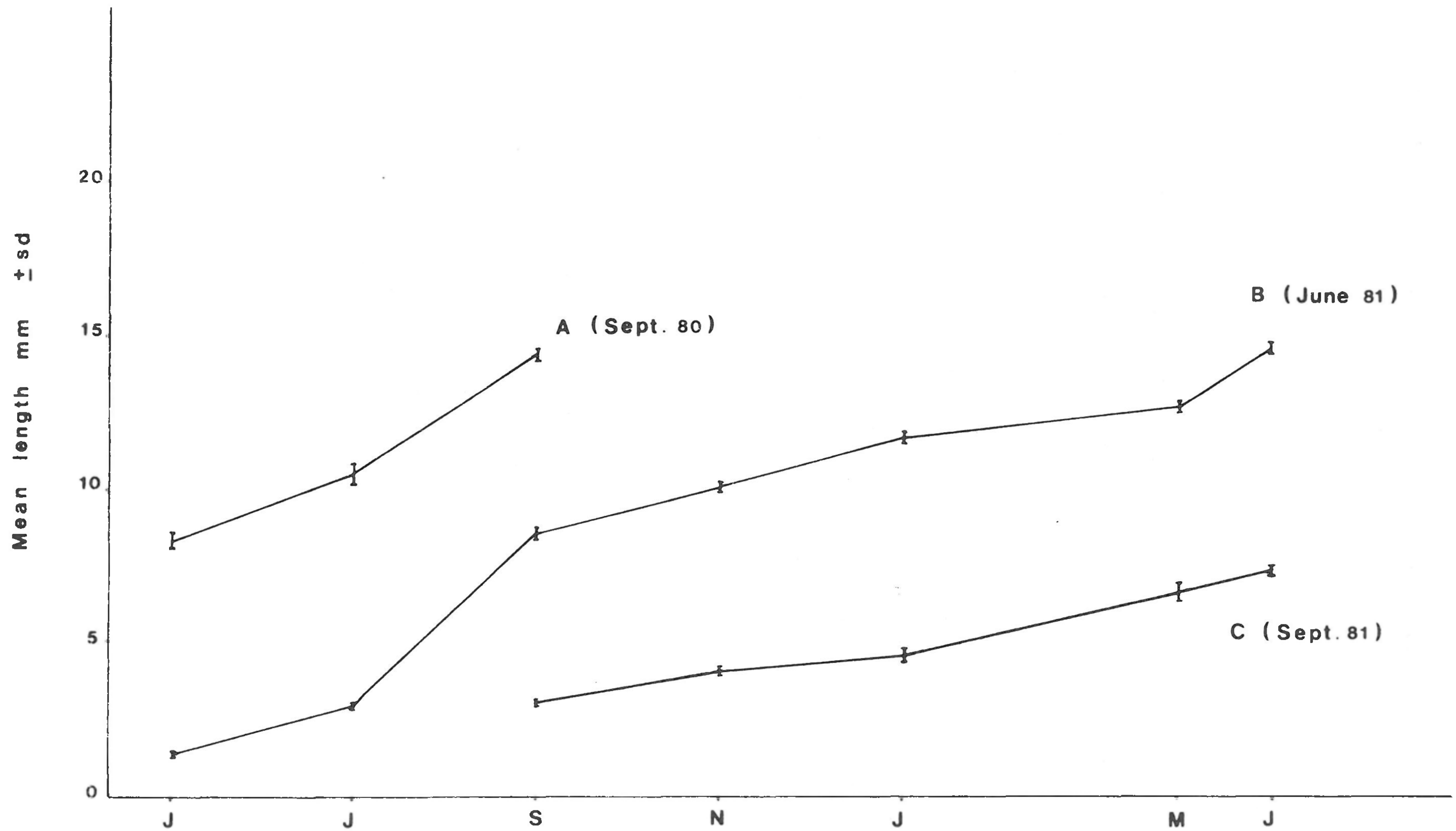

Fig. 2 Growth curves of the three cohorts of *A. ovata* as estimated from the normal distribution curves.

The *Amphiura filiformis* community in Galway Bay (West Coast of Ireland).

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Sampling has continued at the permanent monitoring station since the presentation of the report at the 1985 Bruxelles' Symposium. The frequency of sampling has been maintained at the level of four times per year for grabs and at monthly intervals for mouse trap and hydrographic samples (when weather permitted). Qualitative analyses of the grab samples show little in the way of change since December 1985, with large numbers of the dominant faunal constituent, *A. filiformis*, being clearly evident. In addition to the biological samples, material has been collected seasonally for sedimentological and organic carbon analyses. Proflies of salinity and temperature are recorded monthly.

The mouse trap samples are being collected over a long time-scale to examine fluctuations of the smaller macrofaunal elements, e.g. spionid polychaetes, in the assemblage. Such samples will also be examined for the earliest settling stages of the dominant species, i.e., *A. filiformis, Pholoe minuta* and *Mysella bidentata*. These data will be of particular interest in following the annual fluctuations of juvenile *A.filiformis* in the light of published data on the same species in different geographical locations.

Long-term surveillance studies in Loch Linnhe and the Firth of Lorne, West Coast of Scotland.

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ABSTRACT

Changes in the benthic infaunal populations of two areas on the Scottish west coast over a six year period have been related to a postulate linking environmental temperature fluctuations to benthic carbon supply. It is suggested that during predominantly cool periods a developing mismatch between peak zooplankton and phytoplankton productivity may increase the supply of pelagic carbon to the benthos. Such enhanced benthic food availability would influence macrofaunal populations in predictable ways. The data tend in general to support both the postulate and its subsidiary hypothesis.

INTRODUCTION

In a previous communication (Pearson *et al.*, 1986) based on an analysis of fluctuations in the macrobenthic populations of Lochs Linnhe and Eil on the west coast of Scotland over a 20 year period, it was suggested that the carrying capacity of sedimentary benthos is dependent on organic input, but that the species composition of the communities may be modified by climatic variability. This hypothesis will be further examined and extended here by reference to species population dynamics in the same area over the six year period 1980-'86, i.e.the period following the inception of the COST 647 programme.

STUDY AREA AND METHODS

Two sampling stations have been established for continuous surveillance under the COST 647 programme. These are station L53 in central Loch Linnhe and station LY1 in the Firth of Lorne (Fig. 1). The former is within the area of influence of the effluent discharched from a pulp and paper mill (Pearson, 1970, 1975). Pulp effluent discharge ceased in 1980 and thus organic enrichment of the sediments of the area has consistently decreased over the study period. Station LY1 is well beyond the areas influenced by effluent discharge and changes observed in benthic populations in that area are regarded as being attributable only to natural influences. Detailed sampling of the macrobenthic populations at these stations in accordance with the COST 647 protocols commenced in July 1980.

Full details of the study area and the methods used in data collection and analysis are given in Pearson (1970, 1975) and Pearson *et al.* (1982, 1986).

RESULTS

a) Temperature fluctuations

Deviations from the monthly mean sea temperatures (surface water at Millport, Firth of Clyde) for 1980-'85 are shown in Figure 2. These show that lower than normal temperatures prevailed from late 1980 to spring 1982 and from autumn 1982 to mid 1984. Higher than normal temperatures prevailed through much of 1980, the summer of 1982 and the latter part of 1984.

b) Changes in community population statistics at the two sampling stations.

An analysis of the overall population changes in the two areas has been made by comparing the size ratios and abundance ratios of the benthos over the survey period. The size ratio (B/A, the ratio of total biomass to total abundance in a sample) is a measure of the mean individual size of all species present. It thus provides an indication of the structure of the community. The abundance ratio (A/S, the ratio of total abundance to species richness in a sample), is a measure of the mean number of individuals per species in the sample. It gives an indication of the carrying capacity of the environment at the time of sampling (Pearson *et al.* 1982). Figure 3 shows the variation in these ratios, expressed as running means over three consecutive sampling occasions, over the six year survey period. It is immediately obvious that the relative values of the two ratios are reversed at the two stations. At L53 A/S was much higher than at LY1 throughout the survey period whereas B/A was much lower. Moreover, at L53 the A/S values were particularly high in 1980 -'81 but declined sharply through much of 1982. They increased again in the winter of 1982/'83 before dropping again to a level throughout 1984/'85 of about half that seen in 1980. The mean value of A/S at LY1 was less than half that of the lower levels seen at the Loch Linnhe station and fluctuations were far less. However there was also a decrease in values in 1982, and an increase in the winter of 1982/'83 followed by a further decrease, i.e. the pattern of change was similar in the two areas. Change in B/A showed a divergent pattern. At the Firth of Lorne station the values declined through 1980 and the summer of 1981, but increased in the winter of 1981/'82. They decreased again in summer 1982, but thereafter increased generally to a high point in 1985, interrupted by slight decreases during each winter period. In Loch Linnhe the values were generally lower. They declined through 1981/'82, recovered through the summer of 1983, declined in the winter of 1983/'84 and recovered again in 1984/'85.

c) Changes in the abundance of dominant species.

Changes in the abundance of some of the dominant species at the two sampling stations are illustrated in Figure 4. The species shown have been chosen on the basis of their contrasting ecologies and response to environmental change in each sampling area. Thus some of those species known to respond markedly to fluctuations in organic input have been included (e.g. *Myrtea spinifera, Thyasira flexuosa, Diplocirrus glaucus*) together with a further group whose fluctuations apparently coincide with temperature anomalies over the survey period (e.g. *Nucula sulcata, Rhodine loveni, Spiophanes kroyeri*). The data are presented as running means over three consecutive sampling periods. The comparative responses of each species to the contrasting environmental changes is discussed below.

DISCUSSION

The simplistic postulate rehearsed in the introduction may be extended to relate the interactive effects of environmental temperature fluctuations on carbon supply to the sediments and on benthic recruitment and productivity. Thus, it is suggested that during predominantly cool periods the mismatch between peak zooplankton and phytoplankton productivity, which is a well documented feature of fjordic systems, (Burrell, *in press*; Syvitzki *et al.* 1987) may be accentuated. This would result in an increased carbon input to the benthos perhaps reinforced by an increase in water column instability stemming from the reduced precipitation which often accompanies cool conditions on the Scottish west coast (Jones, 1979). Such enhanced benthic detrital inputs might be expected to increase the general biomass (B) and perhaps the species richness (S) of the benthic communities in previously unenriched areas, but not the overall abundance, at least initially, i.e. the additional available food would be absorbed by the existing *in situ* organisms and perhaps stimulate the settlement of additional post-larval individuals. Thus A/S would increase and B/A decrease under such circumstances. In areas already receiving high carbon inputs it might be expected that the additional planktonic carbon would increase all three community parameters. In that case A/S would increase and B/A decrease, i.e. the reverse of the expected trend in unenriched areas. Moreover, when considering the effect of such changes on individual species it is suggested that surface deposit feeding organisms would be initially favoured, with subsurface feeders benefiting later, and that species recruiting via benthic or lecithotrophic larvae would increase at the expense of those with planktonic larvae.

Some indication of the possible validity of these interlinked hypotheses may be obtained by reference to the data detailed above. Initially, the two sampling stations differed considerably in their comparative levels of benthic enrichment. In 1980 L53 in Loch Linnhe was enriched by cellulose effluent, an influence that ceased in that year, whereas LY1 in the Firth of Lorne was never enriched from extraneous sources. The overall effect of the Loch Linnhe enrichment is most obviously seen in the steady decline in the abundance ratio at L53 in 1981-'82 following the cessation of effluent input. It is notable that by 1985 although the ratio was then less than half its value in 1980, it was still consistently higher than that at the Firth of Lorne station, emphasising the continuing comparative enrichment of the Loch Linnhe area. This is further demonstrated by the consistently lower values of the size ratio at L53 indicating the continuing dominance of small organisms at that station throughout the survey period. At the Firth of Lorne station changes in the abundance ratio were relatively small but decreases in the abundance ratio occurred in the winter of 1980-'81 (a very cold period - Fig. 2) and again in 1983 -'84 (moderately cold). Much more obvious changes occurred in the size ratio which declined markedly during both cold periods at that station. At the Loch Linnhe station changes did not follow the predicted pattern quite so closely. The abundance ratio rose initially during both cold periods, but declined later, whereas the reverse happened with the size ratio. This reversal of the expected trend during the latter part of the colder periods may well be a seasonal effect since in both 1981 and 1983 it coincided with the onset of winter and the usual decline in the abundance of annual species. Such an effect would be more marked in those communities, such as that found at L53, dominated by smaller, more rapidly growing, annual organisms, *cf.* the declines in the *Spiophanes* and *Ancistrosyllis* populations during the winter periods at that station (Fig. 4). In general then, the observed changes in the population statistics give qualified support to the overall hypothesis.

The available evidence drawn from an examination of the changes in individual species abundances in support or in contradiction of the subsidiary hypotheses is more equivocal. Many of the dominant species at both stations are subsurface deposit feeders with benthic or lecithotrophic larvae. Thus whilst cold periods might favour their recruitment by decreasing the competition from planktonic settlement, the increased food availability might favour adult surface deposit feeders at the expense of settling juveniles. Moreover, some of the subsurface deposit feeders are known to feed at or below the redox discontinuity zone in the sediments in association with symbiotic sulphate reducing bacteria (Dando *et al.* 1983), e.g. the Lucinacian bivalves *Thyasira* and *Myrtea*.

Populations of such species are unlikely to respond rapidly to fluctuations in labile surface organics. Indeed, it was these species which predominated at the enriched station, that responded most markedly to the declining supply of pulp effluent and showed the least response to temperature anomalies (Fig. 4a) emphasising their reliance on the availability of recalcitrant carbon supplies. Despite such ambiguities and distinctions, however, the populations of some species do follow the predicted pattern. Thus the populations of *Pectenaria* and *Tauberia*, both of which have planktonic larvae, declined steeply at the beginning of each cold period, presumably through recruitment failure, but recovered later, possibly as a secondary response to increased food availability. A large surface deposite feeding polychaete with a lecithotrophic larvae, *Terebellides*, conformed to the predicted pattern in that its' populations increased at both stations during cool periods. Other sub-surface deposit feeding species which have lecithotrophic or benthic larvae recorded strong population increases during cold periods e.g. the polychaete *Rhodine* and the bivalve *Nucula*. The pattern was the same at both stations despite the differences in overall abundance of the two species in the two areas. Other species showed trends which conformed to the predicted patterns only partially. Amongst these, two surface deposit feeding polychaetes, *Spiophanes* and *Diplocirrus*, were of particular note. These species predominated in both areas but enjoyed much higher populations at the enriched station. The former has pelagic, and the latter benthic larvae. Thus populations of *Diplocirrus* might be expected to increase more readily during cool periods through more positive recruitment although both populations would be equally favoured by enhanced planktonic sedimentation. This pattern pertained at L53 initially but populations crashed there during the cool summer of 1983, whilst they increased at LY1. The greatest population fall in *Diplocirrus* occurred in late 1981 at L53 and was obviously associated with the cessation of effluent input.

Populations of *Spiophanes* tended to contradictory fluctuations at each station. In the cold period of 1981-'82 they increased at L53 but decreased at LY1; during 1982 and 1983 both areas followed the same seasonal pattern of summer increases and winter decreases but in 1984 there was a decrease at L53 and an increase at LY1, which was reversed again in 1985.

Despite the contradictory signals gleaned from such data enough of the population changes observed both in the dominant species at each station, and in the community statistics, tend to support the predictions arising from the initial hypotheses to suggest that the general postulate is worth pursuing. However, it must be stressed that such conclusions are at present both untested and tentative. Statistical tests of the significance of some of the trends described above are currently being carried out, and the continuation of the observations beyond the six year time series reported here is essential if the validity of the hypotheses is to be fully tested.

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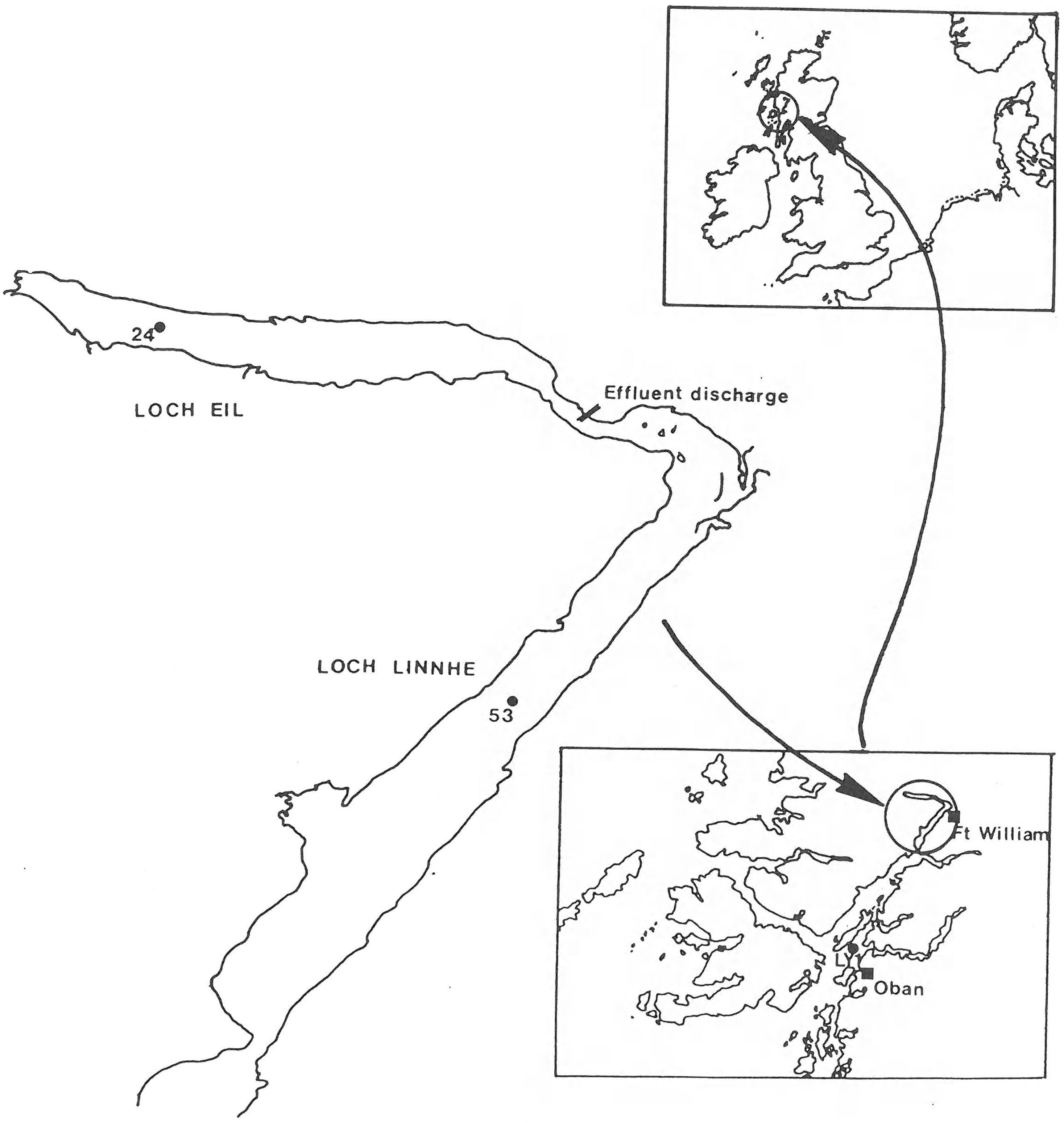
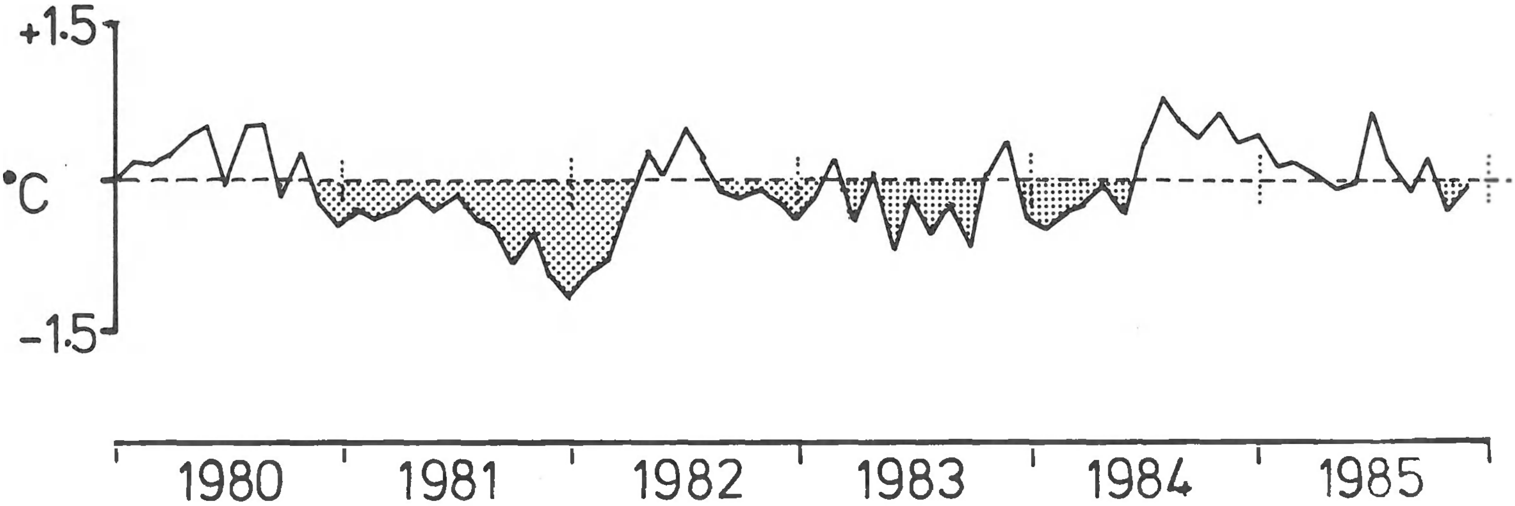


Fig. 1: Map of the area showing position of the sampling stations.

Fig. 2: Monthly sea-surface temperature anomalies (variation from 20yr. mean) for 1980-'85 at Millport, Firth of Clyde.



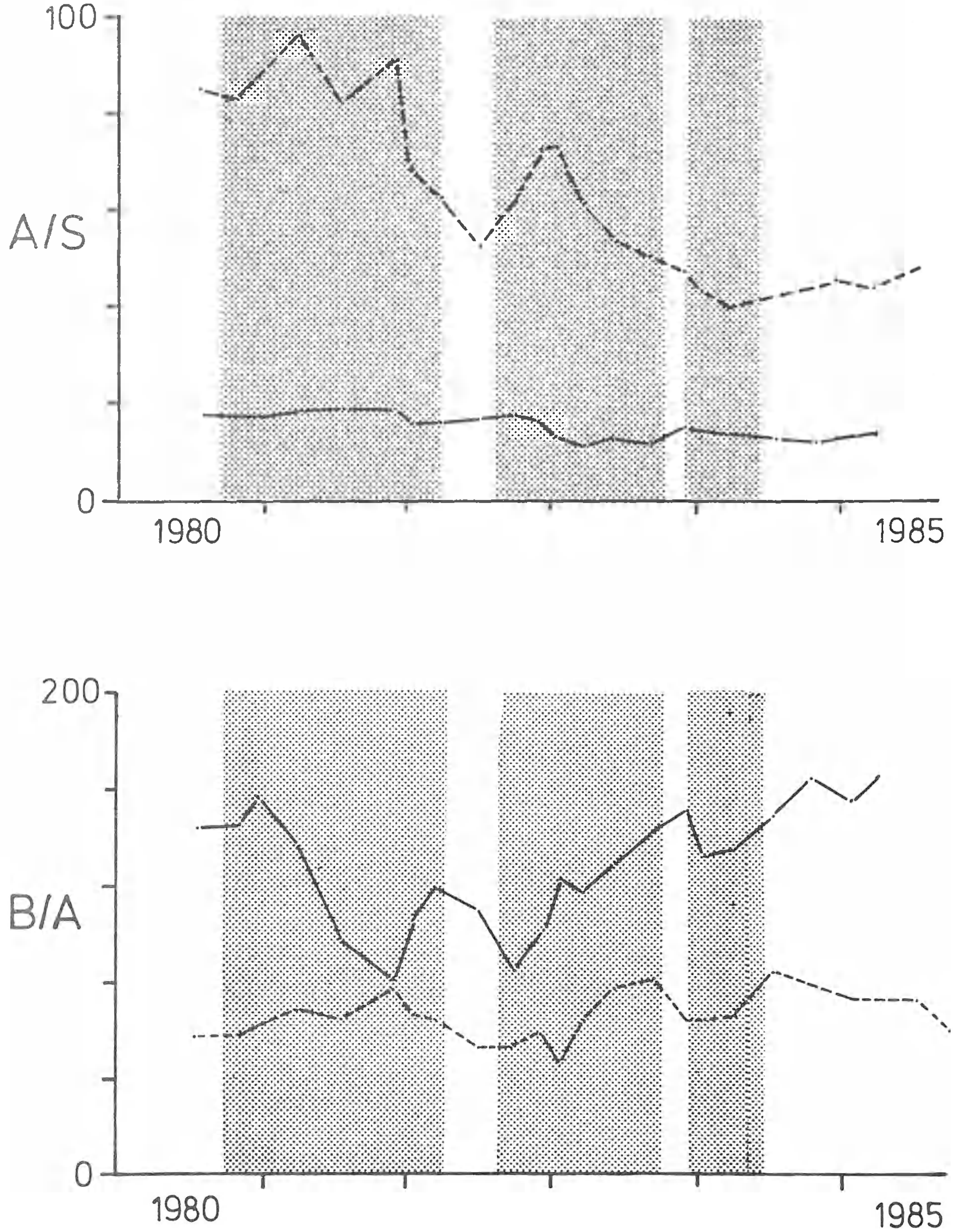


Fig. 3: Variations in the abundance ratio (A/S) and size ratio (B/A) for 1980-85 at the two sampling stations. Data are plotted as running means over three consecutive sampling occasions. A: Total abundance; B: total biomass; S: species richness. Broken lines: Station L53 in Loch Linnhe, an area enriched until 1980 by cellulose waste. Solid line: station LY1 in an unpolluted area of the Firth of Lorne. Periods of lower than average temperature are shaded.

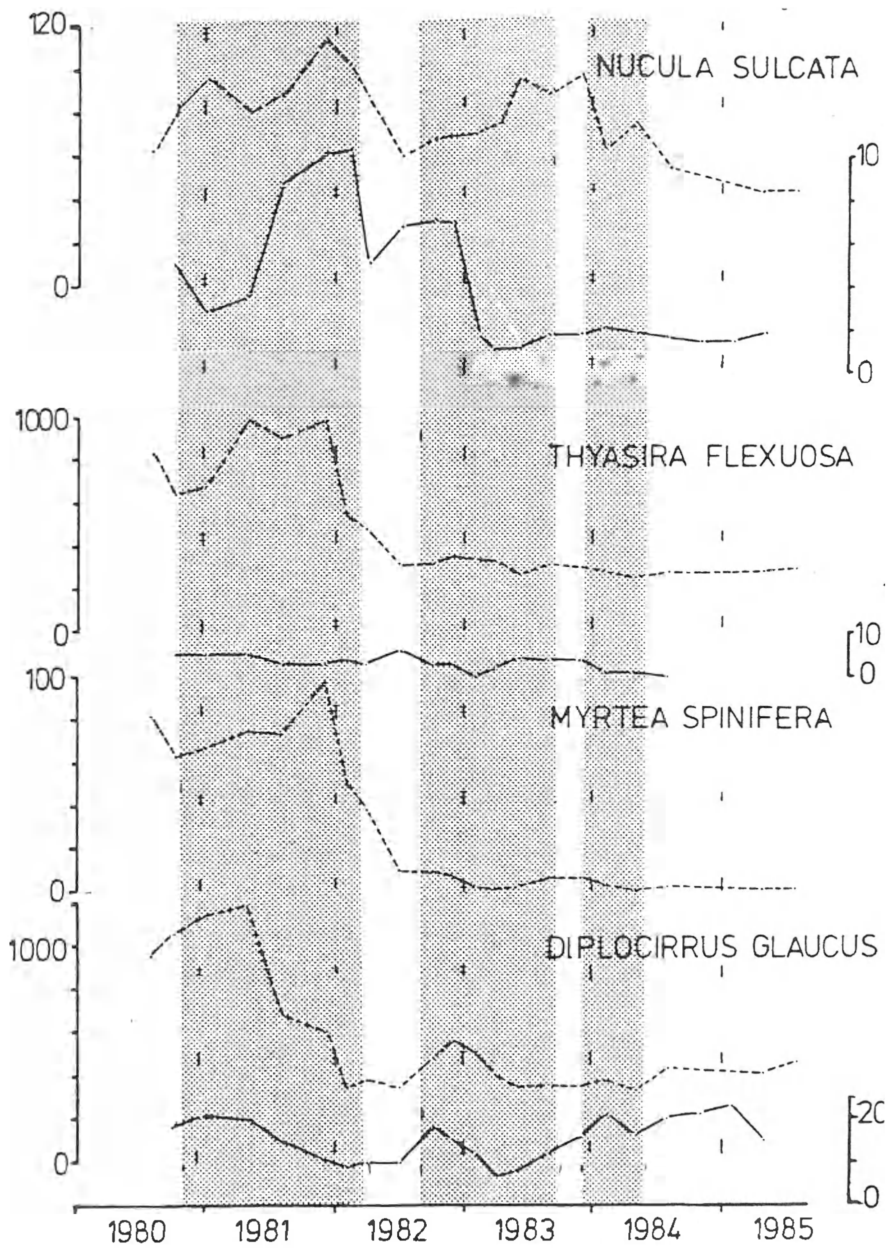


Fig. 4: Changes in the abundance (mean numbers m^{-2}) of some dominant species at the two sampling stations. Broken line: station L53 in Loch Linnhe. Solid line: station LY1 in the Firth of Lorne. Periods of lower than average temperatures are shaded.

(a) *Nucula sulcata*, a subsurface deposit feeding (DDF) bivalve with lecithotrophic larvae (L). *Thyasira flexuosa*, a DDF bivalve with benthic larvae (B). *Myrtea spinifera*, a DDF/L bivalve. *Diplocirrus glaucus*, a surface deposit feeding (SDF)/L polychaete.

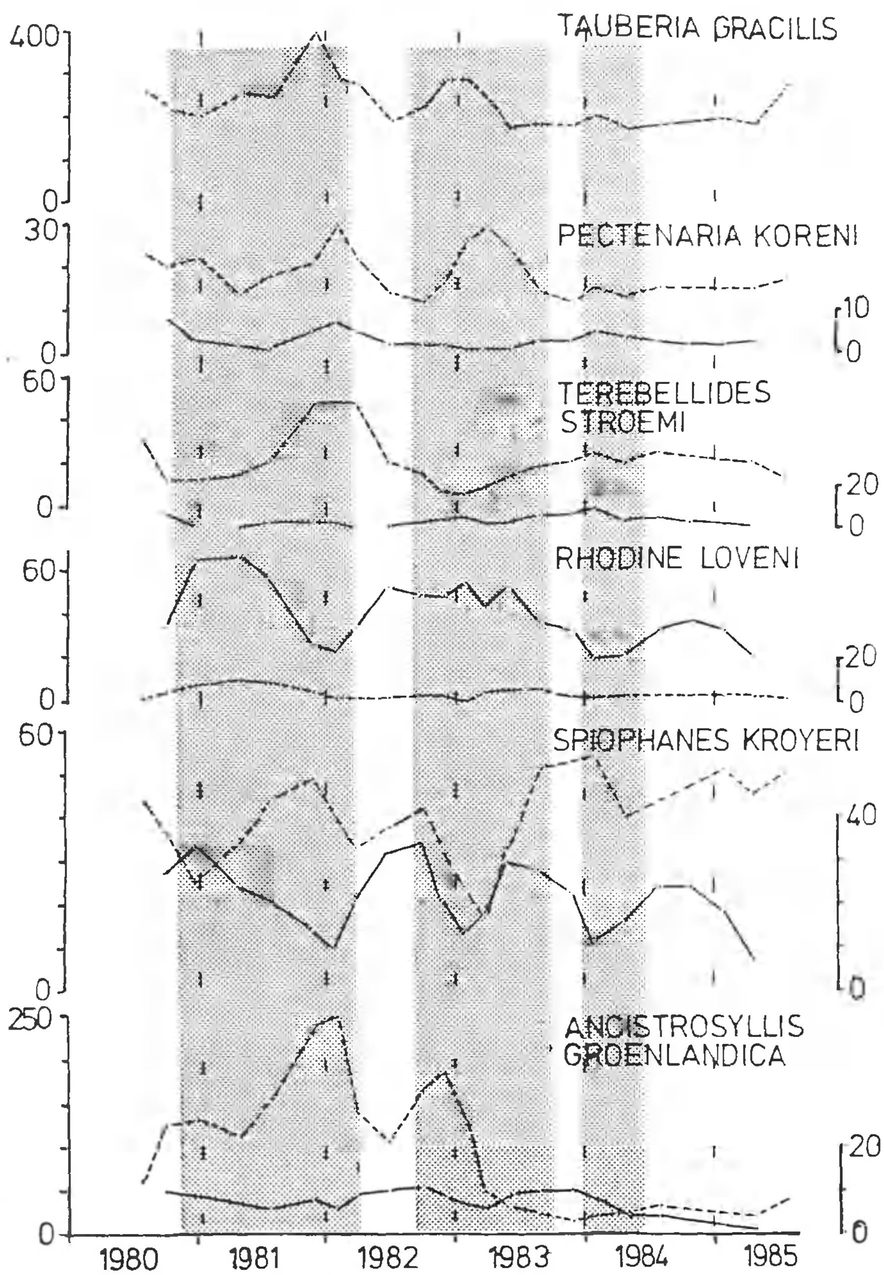


Fig. 4: Changes in the abundance (mean numbers m^{-2}) of some dominant species at the two sampling stations. Broken line: station L53 in Loch Linnhe. Solid line: station LY1 in the Firth of Lorne. Periods of lower than average temperatures are shaded.

(b) *Tauberia gracilis*, a DDF polychaete with planktonic larvae (P). *Pectenaria koreni*, a DDF/P polychaete. *Terebellides stroemi*, an SDF/L polychaete. *Rhodine loveni*, a DDF/B polychaete. *Spiophanes kroyeri*, an SDF/P polychaete. *Ancistrosyllis groenlandica*, a DDF polychaete.

Longterm variation in benthos populations in Liverpool Bay

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In 1970 when large increases in the rates of sewage sludge dumping were anticipated, a multi-disciplinary study was started in Liverpool Bay by the Department of the Environment. As part of this study, quantitative macrobenthos samples have been taken at a representative series of localities in the bay almost every year since then. Since the dumping site is "dispersive" for fine organic detritus, the sampling effort has had to be equally dispersed across a mosaic of differing sediment and community types. An area of about 600 square kilometres needed to be covered. The data series is therefore more suitable for indicating broad population changes in the bay as a whole, than for following the history of the benthos at particular stations within clearly defined communities. Even though the precise methodology of the COST 647 Core Programmes may not have been used, the 16 year time series data is directly relevant to the spirit of COST 647.

Throughout the study, sampling has been with $0.1m^2$ Smith McIntyre or Day grabs and 1mm mesh sieves. Sampling has always been in early autumn and generally two benthos samples have been collected at 25 - 30 stations each year. The total number of sorted samples that can be used for inter-year comparisons over the 1970-1985 period amounts to 826. In addition, enhanced sampling of localised patches was done in some years but has not been included here.

Changes can be inferred from a multi-year, multi-species data set in several different ways. At the simplest level the numbers of individuals encountered in an entire year's survey can be compared with the numbers encountered in other years, provided there is standardisation of the sampling effort (N per 100 grabs was used here) and a similar spectrum of ground types was sampled. This approach is viable even for species that regularly turn up less than five times per survey if they later fail to appear at all for a number of years.

For the more abundant species the frequency distributions of their occurrence in a series of abundance classes can be more informative than simple numbers. Geometric (x2) abundance classes give an appropriate series. This approach has been useful in demonstrating the way in which benthic species not only fluctuate in abundance in their prime habitat localities, but also sometimes spread out into sub-optimal habitats. A Geometric Abundance Frequency Index can be derived by multiplying the percent frequencies by the class notations and summing the results. Plots of Log_2 N/100 grabs against GAFI mostly fall on straight lines except for species that intermittently spread over adjacent sub-optimal habitats. Inferences about the unquantified colonial species such as sponges and hydroids can only be drawn from the frequencies of their occurrence.

In Liverpool Bay, very great differences occur in the total abundance of the fauna between different places. Pockets of muddy sand inshore and muddy gravelly sands offshore tend to be densely populated, but much of the rest of the bay is often only very sparsely inhabited. The mixed sediment offshore in the northwest part of the bay has been much more densely populated in recent years. The changes started about 8 years ago and have resulted in a numerical increase in the total abundance of the fauna of about 4x. Although the community type is rather different, the overall increase is somewhat similar in time and extent to that reported by Buchanan and Moore (1986) for muddy stations off the Northumberland coast.

For 180 of the species that have occurred in the Liverpool Bay grab samples, calculations have been made of their rates of occurrence each year in terms of numbers per 100 grabs. The medians of these annual values have been used to place the species in ranking order for their overall abundance in the bay as a whole over the entire 1970 - 1985 period (Table 1).

Rank	Species	Median N/100 Grabs
1	*Pectinaria koreni*	2517
2	*Abra alba*	1233
3	*Scalibregma inflatum*	1062
4	*Lumbrineris gracilis*	504
5	*Ampharete lindstroemi*	475
6	*Mysella bidentata*	336
7	*Lanice conchilega*	335
8	*Spiophanes bombyx*	248
9	*Owenia fusiformis*	214
10	*Nephtys hombergi*	171
11	*Pholoe minuta*	151
12	*Photis longicaudata*	144
13	*Mediomastus fragilis*	142
14	*Phoronis muelleri*	140
15	*Cerianthus lloydii*	131

Table l: The most abundant species in Liverpool Bay over the 1970 - 1985 period, based on the medians of their annual estimated numbers per 100 grabs. These values must be regarded as index values since all the habitat types in the bay have not been given coverage equivalent to their extent.

Over the 1970 - 1985 period most of the more abundant species have shown fluctuations in abundance rather than persistent population trends, whether considered in terms of their numbers per 100 grabs on in terms of their GAFI values. Several species including *Pectinaria koreni* and *Abra alba,* show signs of cyclical fluctuations that would fit a 6-year pattern. Three dramatic events have occured since 1970, (a) extensive but short-lived colonisation by spionids in 1972; (b) a pronounced offshore spread of the inshore muddy sand dominants such as *Pectinaria* in 1978 and 1979; (c) progressive increases in tube worms, particularly *Ampharete lindstroemi* and *Anobothrus gracilis* over the 1978 - 1985 period. These last two species apparently increased at compound interest rates of about 60 - 80% per annum.

With pooled data from 40 - 60 grabs per year it is possible to look for changes in the sparsely occurring species as well as the common ones. Indeed it is amongst these that there are the more obvious signs of environmentally relevant effects. The 180 species for which occurrence rates were calculated, could be allocated to seven different classes:- (a) normally stable species; (b) variable or erratic species showing no longterm trends; (c) species showing occasional extremes; (d) species that have declined or become absent since the early 1970's; (e) species that were not found in the early 1970's but are now regular and those that have increased since the early 1970's; (f) species with a U shaped abundance pattern, being commoner early and late; (g) species peaking in the middle years in the late 1970's.

It is the species that declined or disappeared in the middle years of the study that are of most interest, because their changes would have been coincident with the changes in dumping practices in the bay. Dumping rates increased from 40000 dry tonnes in 1969/70 to about 75000 dry tonnes in 1976/77. After peaking in the late 1970's, the dumping rate has fallen back to 52000 dry tonnes in 1984/85. A combination of tighter controls on industrial discharges and the economic recession means that the load of most metallic contaminants in the sludge have declined by three or four times since the late 1970's. It was mainly amongst the crustacea and the echinoderms, rather than among the dominant polychaetes, that species were found whose occurrence could be construed as mirroring the waste dumping. However there were signs, from the increased occurrence in the early 1980's of epifaunal species, that some parts of the bed of the bay had become physically more stable.

In an area like Liverpool Bay it is one thing to be able to observe changes in the populations of the benthos, it is quite another to separate out natural changes from anthropogenic influences deriving from dumping, dredging, the use of heavy fishing gear and the many other human activities.

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A local enriched macrobenthos association in the Irish Sea

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One way of economising on the great effort that has to be expended in soft bottom benthos grab surveys is to stratify the effort according to prior knowledge of the distribution of major sediment types. There are however, risks in doing this and the example quoted here highlights the case for caution if boundary zones between major sediment types are overlooked.

Over the past fifteen years a sledge with TV and photographic cameras has been developed at the Marine Biological Association Laboratories in Plymouth. During July 1985 the sledge was deployed from the UCNW research vessel Prince Madog on several transects in the area of the western Irish Sea front. That is, in the boundary zone between the muds of the deep western basin and the tide swept sands and gravels that are typical of much of the rest of the Irish Sea. At one location about 12 miles east of Lambay Island (53°30'N. 05°41'W) in depths of 70-75 metres and close to the margin of the mud area of the Western Basin an unusually dense bed of worm tubes was encountered. At first sight on the TV monitor the masses of fairly large tubes, waving gently in the current, resembled eelgrass. Small fish and shrimps could be seen moving amongst the tubes. There were open patches in the turf around the entrances to *Nephrops* burrows, and hermit crabs (*Eupagurus* sp.) were locally abundant. An Aggasiz trawl yielded large number of small *Pandalus montagui* and *Crangon allmani* with *Agonus cataphractus* and *Liparis liparis* being quite common.

A few grab samples taken later showed that the tubes were mainly those of *Ampharete falcata*. Large populations of bivalves, particularly *Parvicardium ovale* (>27000/m^2) together with *Abra nitida* and *Nucula tenuis* were also present. The occurrence also of both *Amphiura chiajei* and *Brissopsis lyrifera* suggests that the unnusually rich turf tube community was superimposed on a more typical deep water mud community. As several size cohorts of *Parvicardium* were present and since both this bivalve and *Ampharete* have direct development, the unusual community seems unlikely to have been an ephemeral feature.

This previously unrecorded and rich community seemed to be confined to quite a narrow zone in depth and distance, though there was not time to define the extent along the depth contours. As well as being at the western end of the front and on the edge of the Irish coastal current water, this turf community was situated where tidal velocity contours are closely spaced. The location is therefore one where there is a sharp depositional gradient combined with enhanced primary production. Elsewhere under the Irish Sea front an enriched *Abra* community has been found that parallels the enriched community reported by Creutzberg et al. (1984) in the southern North Sea. The *Ampharete* turf may be an even more pronounced example of localised benthic enrichment at the margin of a depositional area. Without the continuity provided by a TV transect across a boundary zone between sediment defined strata, there is a high probability that such an interesting but localised benthic community would be overlooked.

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Sampling Problems in the Quantitative Estimation of Microphytobenthos

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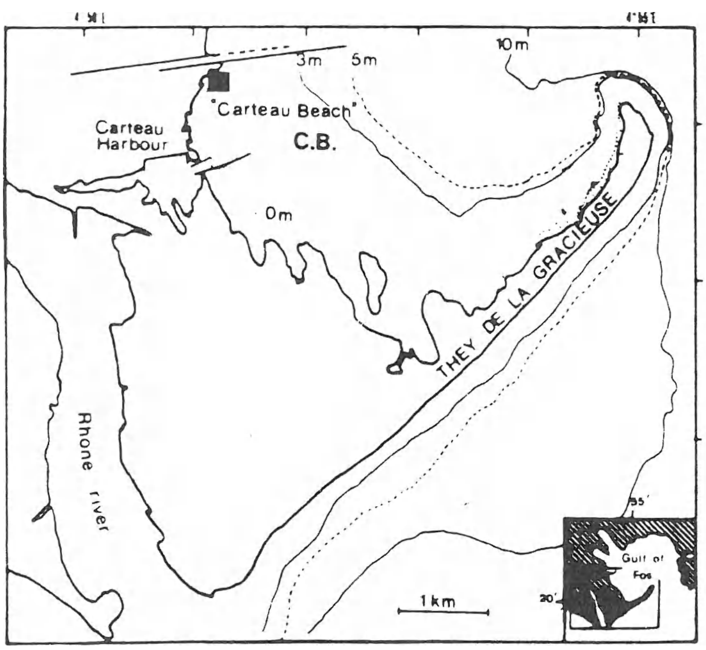
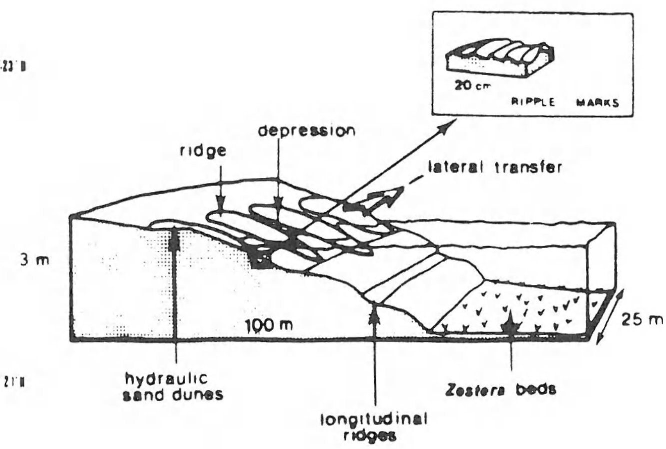
Introduction

Pigment concentration tends to be used as an index of the microphytic richness of the soft sea-floor. We have been evaluating the representativeness of chlorophyll a measurements in this regard. "Richness" is itself an ill-defined concept which may be interpreted either from a static viewpoint (i.e. as a "biomass" value) or from a dynamic one (i.e. as a measure of "production"), the latter being of major interest when dealing with trophic relationships in the benthic ecosystem.

We have studied the respective contributions of microphytobenthos and phytoplankton to the diet of infaunal molluscs.This study posed the general question:"how representative are the average values for pigment concentration?". This, in turn, leads one to query the dimensions of the "standard station" (i.e. size and number of samples).Further,we have to ask " if we can extrapolate results from one location to a whole site or to the whole set of similar sites in a given marine area, etc...?"

Sampling site





The littoral environment is certainly the most readily accessible location for a methodological study on benthic strategy. Our study was carried out on sublittoral sands colonised by dense populations of carpet-clam, *Ruditapes decussatus*. These sandy bottoms occur along the shore of the Gulf of Fos, 40 km west from Marseille and near the Rhone estuary. This shoreline is exposed to occasional eastern gales; these create longshore ridges, which fade close to the water's edge where they are broken up by orthogonal crescent-shaped dunes. Ordinary wave action generates small sized ripple-marks; these are well defined in the shallows and disappear with increasing depth.

Indicators

We used chlorophyll *a* and pheopigment measurements obtained from acetonic extracts on the upper cm of core samples. The pigment concentrations were expressed as µg of pigment per g of dry sediment or as mg per m^2. Variations of these values are supposed to be more or less proportional to the fluctuations of microphytic populations which suggests the use of logarithmic transformation. Even with this transformation, the variances are not always well stabilized and, so, statistical inferences cannot be made. This was not very important in our study, as we were primarily interested in knowing the structure of the population and its influence on the sampling strategy. None of the studied variables was studied per se but was used to produce comparative threshold values.

Furthermore, as we used continuous variables in dealing with questions of heterogeneity, we had to employ the coefficient of variation (Cassie, 1962), which, when calculated from logarithmic values, is:

$$CV = \left(\text{antilog} \frac{s^2}{0.4343} - 1\right)^{-2} \text{, from Bagenal (1955)}$$

with s^2 = variance of log x

Experimental variability

The first step consisted in establishing a threshold value for the experimental variability.We thoroughly combined several large diameter sand samples of 1cm and subsampled the necessary aliquots which allowed the calculation of coefficients of variation.

Variable	Dates:	4/3/83	7/6/83	2/9/83	20/10/83
Chlorophyll *a*	m	10,499	33,649	79,086	52,335
	s	0,814	3,241	6,312	6,692
	CV (%) on raw data	7,751	9,631	7,980	12,787
Pheopigments	m	0,551	6,067	23,026	21,589
	s	0,369	2,346	1,925	4,423
	CV (%) on raw data	66,980	38,661	8,361	20,490

The chlorophyll *a* values gave average coefficients around 10%, a value which is close to those obtained for parameters whose repeatability is only dependent upon the manipulating procedure: dry weight and the water content of the sediment. Conversely, the pheopigment values are much more variable, suggesting that the homogenization procedure may have been insufficient for the detrital fraction of the sediment. We think that this is probably due to the persistence of seagrass fragments in the mixed sediment. Accordingly, we adopted the 10% value as a threshold for the coefficient of variation of chlorophyll.

Sample size

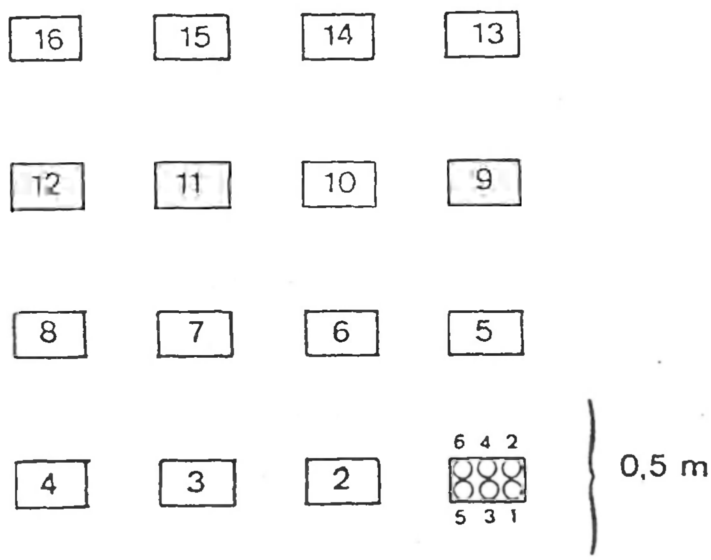
We decided from the outset to base our choice of core diameter on that producing the least variability of the chlorophyll *a* concentrations.Three tube diameters were tested, covering the wide range of the dimensions cited in the microbenthos literature: small (5,41 cm^2 section), medium (10,46 cm^2 section) and large (15,20 cm^2 section).It can be seen that the medium and large tubes are approximately 2 and 3 times larger than the small one.

	m	s^2	Cv on raw data	CV on log transformed data
Small Ø (2,625 cm)	15,2799	18,784	28,367	27,38
Medium Ø (3,65 cm)	14,974	26,960	34,676	37,80
Large Ø (4,40 cm)	14,048	17,646	29,903	35,89

There was no significant difference between the values obtained from the small diameter tube and the other ones. A significant difference appears only for a risk of 30%. The three diameters may then be considered as giving similar information on the chlorophyll content. We shall see later that variance analyses operated on grid experiments further supported the absence of a "corer-effect". When we took the actual cost of the samples also into account, we were content to employ the smallest tube diameter. We cannot of course say what would have occurred with an even smaller sized corer. With the selected core tube, the sample size is easy to split off. Further,the "edge-effect" is not important, whereas, in more narrow corers, the proportion of sand grains which are driven down by the corer wall may be significant.

Number of samples

The number of samples to be collected was investigated through variance analyses performed on several sets of data. These sets included grid-experiments, each grid representing a sampling station, and containing several blocks, each block being made of several sample units.The analyses led to general conclusions which may be summarized as follows: a) the "corer" factor is never significant, b) the variability is smaller between blocks than between sample units, and c) the number of samples to be collected could be calculated.



1o within a single station.

A sample value of pigment x is equivalent to the mean μ of the population corrected by the between blocks variability (B_i) and the between samples variability (Σ_{ik})

$$x_{ik} = \mu + B_i + \Sigma_{ik}$$

The variance of one measurement as related to μ may be estimated by

$$\sigma_x^2 = \sigma_B^2 + \sigma^2$$

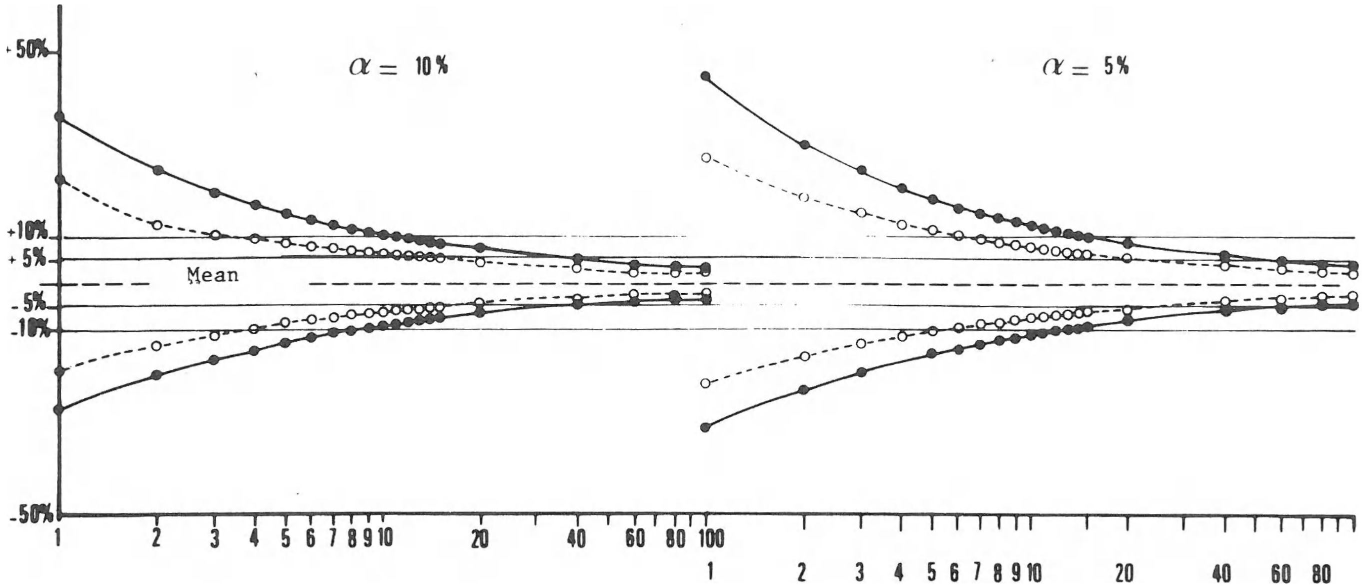
with σ_B^2 : variance between blocks, and σ^2 : residual variance,

and the variance of the average of measurements:

$$\sigma_{\bar{x}}^2 = \frac{\sigma_B^2}{a} + \frac{\sigma^2}{a.n}$$

with a = number of blocks and n = number of samples per block.

From this, it is possible to calculate the number of data whch have to be collected for a given level of precision. As we used log-transformed data, the upper and lower limits which contained the mean were not symmetrical. Nevertheless, when changing the values of a and n, we may follow both limits of the confidence interval of the mean.



We present here,the outcome of such a calculation for security coefficients of 95% and 90%. For example: with a risk coefficient of 5% (i.e. a security coefficient of 95%) and accepting a relative error on the mean of 10% we may choose:

- with 1 sample per block: 12 or 15 blocks depending on whether we give more importance to the lower or the upper limit of the interval, which means 12 or 15 cores per station (solid line).

- with 7 samples per block: 5 or 7 blocks which, for the same criteria, means a total of 35 to 49 cores (discontinuous line).

If the accept a larger risk coefficient (i.e.10%), these numbers become respectively:

for n = 1 , 9 to 10 cores

and, for n = 7, 4 blocks or 28 cores.

Conversely if we accept no more than a 5% relative error on the mean, the number of cores increases considerably:

= 5% for n = 1, 50 cores

and, for n = 7, 24 or 25 blocks (168 or 175 cores)

= 10% for n = 1, 38 or 40 blocks

and, for n = 7, 17 blocks (85 cores).

This example supports some axioms which are well known in statistics but seldom considered in benthic programs:

- for equal costs, and as long as the cost is related to the number of samples, one should opt to spread the samples over the station, with one sample per block.

- the greater precision given by multiplying the number samples per block does not increase proportionally.

2^{0} within a given site

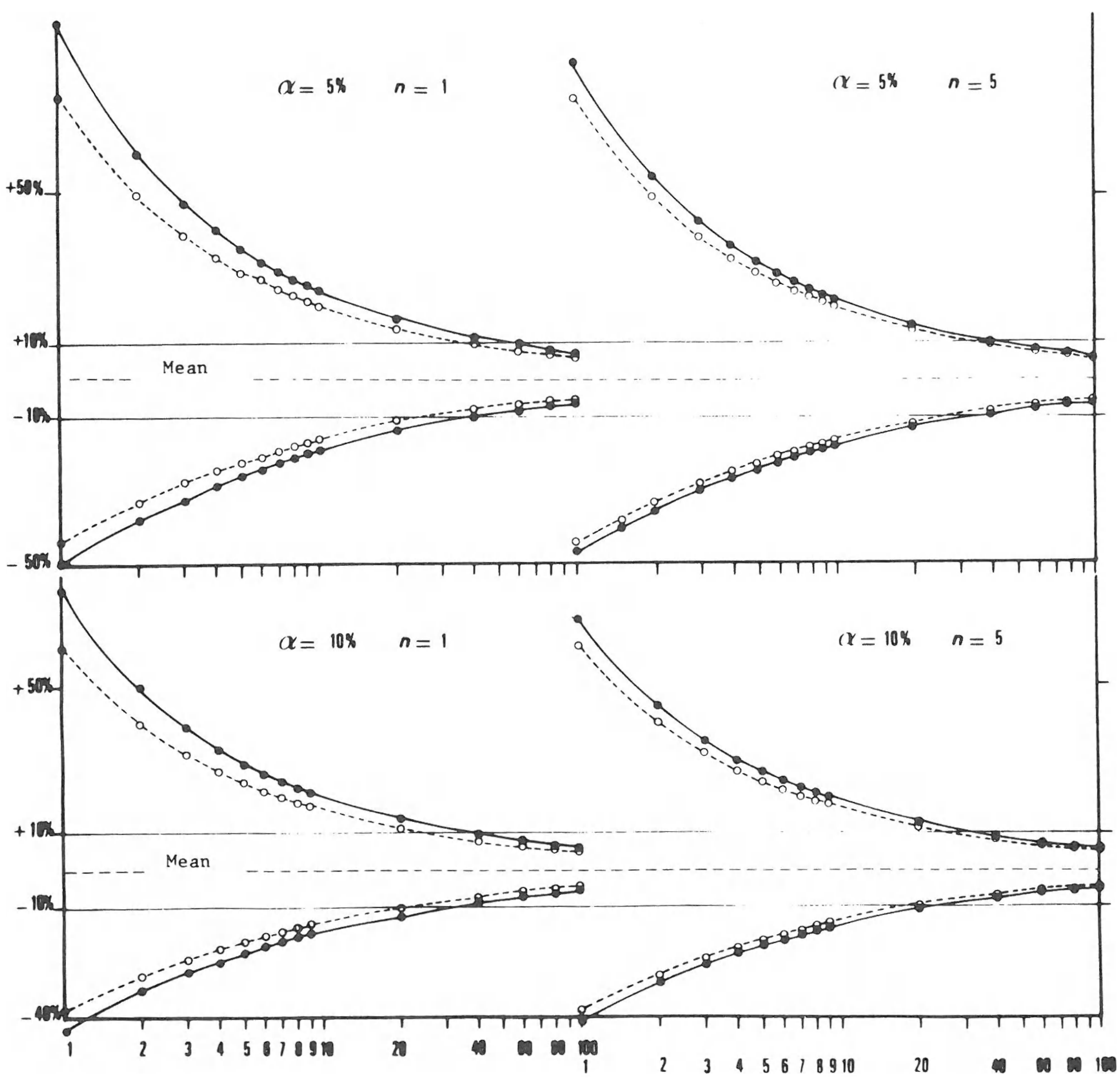
We then considered several stations. The sediment heterogeneity along the beach was related, as shown earlier, to the presence of sand dunes. Accordingly,we investigated, through variance analyses, the influence of this heterogeneity on the variability of sample values. We may conclude briefly that the "station" effect appears to be very strong, the difference between crests and furrows of the dune system being largely responsible of this variability.

Using a procedure similar to that outlined above, we can now apply a modified model where "station-variability" is also taken into account:

$$x_{ijk} = \mu + St_i + B_j + \Sigma_{ijk}$$

From this, we can plot sets of curves similar to the above, and present here some examples for a restricted number of values:

- two risk coefficients (5 to 10%)
- two numbers of blocks per station (n = 1 or 5)
- two numbers of samples per blocks (1: solid line;
  2: discontinuous line).



Once more, we may conclude that, for a given sampling effort, one should distribute the sampling stations widely over the studied site, with one block of one core per station. We may add that if one is not interested in the internal structure of the populations, a secondary subsampling routine may be employed after combining the samples, the number of which depends only upon the threshold value for the indicator in question. Of course, the number of samples calculated varies in relation to the site and type of sediment, which means that our figures only apply to the carpet-clam sands of the Carteau Beach. It remains to be established if similar studies on other sites would give similar figures.

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Synoptic sampling with grab, diver cores, photographs, video and side scan sonar.

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Introduction

The general aim of our sampling programme was to acquire a realistic picture both of the bottom dwelling fauna and, as far as possible, of the associated habitats.

We appreciate that each sampling method is biased and reveals only part of the picture, reflecting its particular design emphasis. We also recognise that we have to deal with different spatial scales in benthic distribution patterns, ranging from a few millimeters to 100m or more.

To cope with this problem, a variety of methods have been employed on a particular habitat in Kiel Bay, in an investigation lasting more than two years.

The area of investigation is a subtidal trench, perpendicular to the coastline, which extends from the beach (with sandy sediments), across boulder fields with coarse sand (10-15m), through muddy sand, sandy mud (17-20m), and down to a muddy environment at 25m. This trench was dredged 3m deep and 15m wide to accommodate a pipeline from an off-shore oil production rig to a land-based station. It was subsequently covered with clean sand from a shallow dredging area (Fig. 1).

The scientific aim of our work was to document the re-establishment of the habitat and the benthic fauna and to follow successional and seasonal events over a period of time.

To attain a realistic picture of the overall recovery process, a variety of different methods were employed; the results of these are partly presented here.

Materials and methods

The following methods were used in the investigation (Table 1).

Diver operated:

- small corers (ca. 20 cm^2) for temporary meiofauna
- diver operated cores (200 cm^2) for macrofauna
- underwater photography
- direct observation, documented after each dive

Shipboard methods:

- Van Veen grab samples ($0.1m^2$)
- Underwater video (OSPREY SIT-camera)
- echo-sounder (3.5 Khz)
- side-scan sonar (100 and 500 Khz ; EG + G)

Some remarks concerning UW-video applications

The video system employed was a silicon-intensified-target (SIT), low light level camera (OSPREY, Aberdeen), with a sensitivity of 5*10-4 lux, combined with a 300 W underwater lamp. This camera proved to be a very versatile surveying instrument and allowed us to take video profiles in 100m of water, without or with very little additional light. This has the advantage that plankton and detritus in the water column barely shows up on the monitor, giving a much clearer picture.

It must be stressed here that the use of single tube colour cameras for general surveys in our waters is not advisable since the information content of the picture is, in most cases, less than that of the more brilliant black and white recording (in fact, the SIT-technique will only produce a black/white picture). Normally, on the soft sea-floor, the resultant picture has very low contrast. This is even lower when the information is split into the three colours needed for a colour image. Should a colour image, such as those that we are used to from TV-films, be really necessary, one has to use a three tube (or solid state) video camera, which is much more expensive. Further, since the outcome of any video inspection depends on the performance of the poorest part of the whole system, one has to consider the capability of the recorder and the degradation of the colour video signal in the umbilical.

Another advantage of the SIT-camera is the focusing arrangement which allows the investigator togive his full attention to the subject matter. However, the video picture is built up of a limited number of pixels and the resolution is, in most cases, too poor, to permit species identification. Therefore, the use of still photography is obligatory in combination with all underwater video applications. The OSPREY TVP-camera system offers the opportunity to have both systems in one housing, andsharing the same viewing lens.

Results

The numerical results (not presented here in detail) revealed a very scattered and not easy to understand picture of the recovery process. As shown by side scan sonar (Fig. 2), and documented in detail by diver photography and video, the pipeline trench was not completely filled with sand, thus being partly a sediment and detritus trap and partly an area of erosion. Additionally, mats of decaying drift algae produced an unfavourable habitat for most of the fauna, thereby generating different modes in the recolonization and recovery process. In this particular case, we had the additional complication, that allochtonous material, together with the living fauna, was carried into the mud environment leading to an increasing gradient towards deeper water, i .e., between the pipeline trench and the surrounding area, which was to serve as a control.

Different sampling methods were also employed on a North Sea Cruise in May '86, when we took box cores, Van Veen and dredge samples, from 60 -100m depth, between 57^{o} and 58^{o}N on a transect between Jutland to Scotland. These samples were supplemented with additional underwater video-runs, of about 10 min each, to reveal the spatial heterogeneity of the habitat and record the occurrence of large epifauna. The examples presented here* are from the Danish coast where we see bed-ripple marks in coarse sand; these were still visible in the 0.1m^2 box core when documented by shipboard photography. The results show very different aspects of the same habitat under investigation and we have to face the problem of integrating the different methods and their returns.

Conclusions

My aim was to show the importance of using different benthic sampling and recording methods simultaneously; I want to emphasize the importance and usefulness of qualitative, non-destructive image-generating methods such as UW-video, photography, side-scan-sonar and ship-board photographic documentation. In addition, remotely controlled video gives a far better appreciation of gear behaviour and the quality of data returned. Until now, the tendency has been to deploy each of the described methods in single fashion. I advocate synoptic sampling with various methods, covering various spatial scales of the habitat. The intention is to create a sort of a "methodological-zoom", capable of registering more features of the benthic habitat and thus giving greater ecological insight.

*This paper was presented as a partial commentary on a series of U/W video recordings

Sampling	Resolution	Sample Size	Range	Disturbance of sample	Goal	Comments
Diver operated	~ cm	1-100cm2	-	± min	Infauna, undisturbed sediment cores	Diver Expensive
Box core	~ cm	0.001-0.25cm2	-	low	Infauna subsamples	-
Grab	~30cm	0.02 -0.2m2	-	Quite	Infauna quant. estimates	Normal procedure with well documented limitations
Dredge	~0.1km	100-1000m2	-	Completely	Epifauna/endof. qual. survey	Not quant. but important supplement to grab/core
UW photo/stills	mm	10cm2-10m2	cm - m	None	Spatial patterns "Lebensspuren"	Diver expensive needs experience
UW video	mm-cm	-	1m - 10m	None	Sed. surface "Lebensspuren"	Expensive Technology combination with stills obligatory
Side-scan	~0.15m	-	50 - 100m	None	Charting of seabed sed. structures	Needs skilled personnel Expensive technology. Ship needed
Echo Sounder	~0.5m	-	100-1000m	None	Contour + depth sea-bed, thickness of sediment layer	Ship needed

Table 1 Special features of the different methods applied

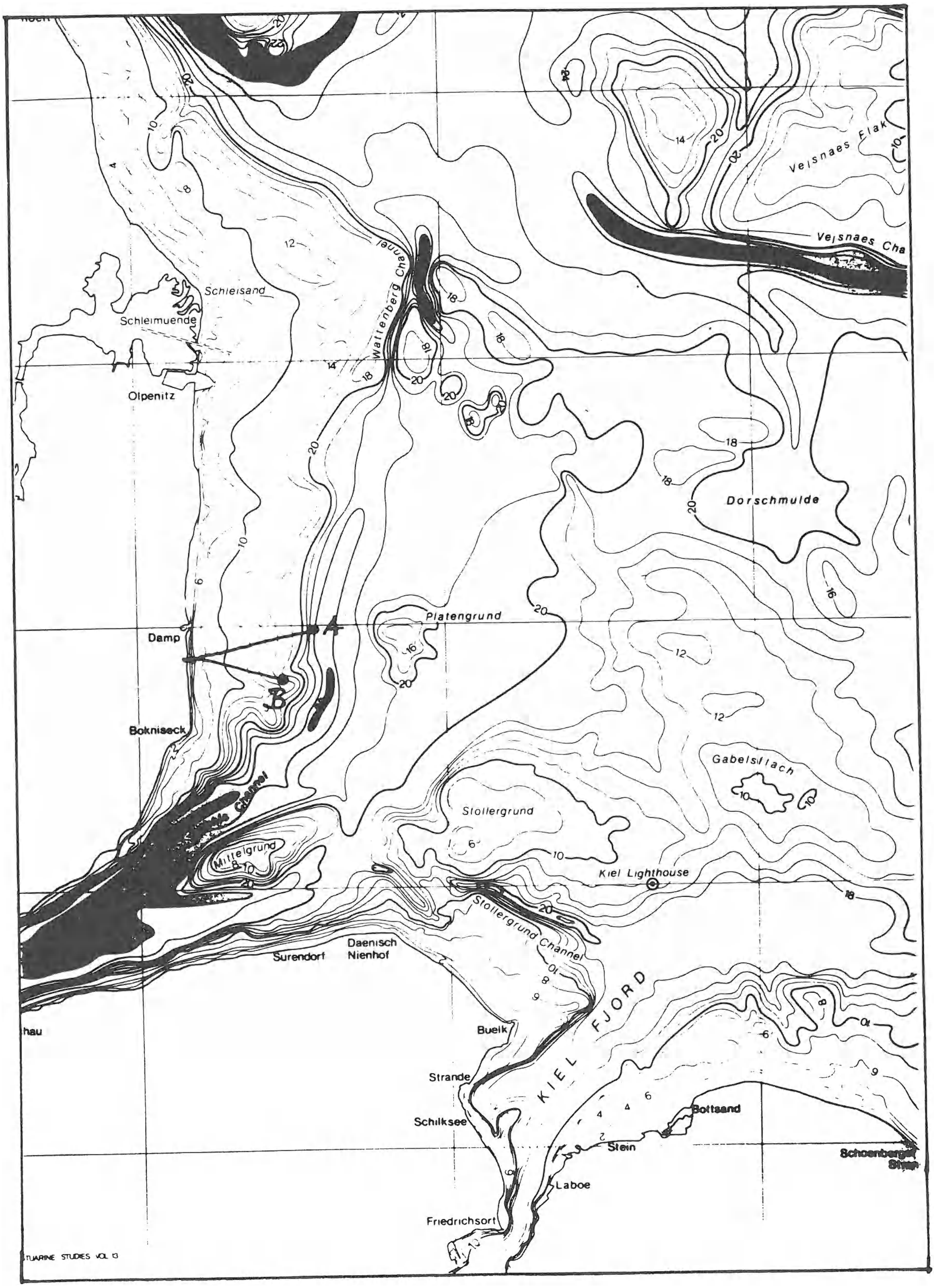

Fig. 1 Part of Kiel Bay bathymetric chart with position of pipelines to oil rigs ("A" + "B").

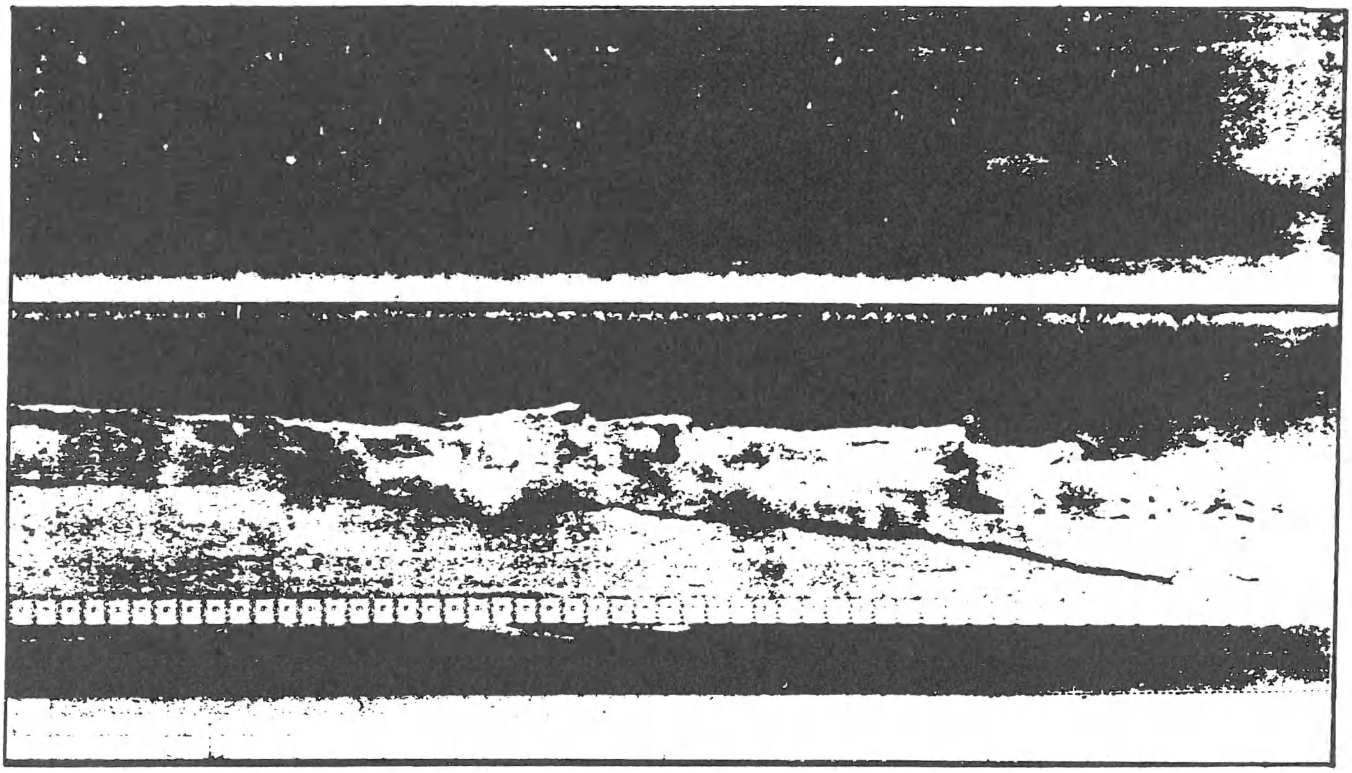

Fig. 2 Side-scan sonar (500 Khz) image of the incompletely refilled pipeline trench (width of the trench approx. 15m ; water depth 17m).

Research on subtidal sediments off the Basque coast.

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Comparatively little is known of the marine sediments off the Basque coast. In the seventies, the "Sociedad Cultural INSUB" initiated some qualitative and faunistic studies. Subsequently, and in the wake of some environmentally - linked research, marine sediment investigations were focused on the following:

1) Soft bottom estuarine communities of Guipúzcoa
2) Open littoral soft-bottom features of the Basque Coast.
3) Polychaete communities in the circalittoral zone of the Basque Coast.

Currently, the soft bottom studies are concentrated on features of the animal communities in the circalittoral zone of the Basque Coast , where samples have been taken at 25, 50, 75, 100 and 150 metres depth , out from the tidal self of Debasumaia (National Park of "Punta Mendata"). The estuarine community : "*Hediste diversicolor* - *Scrobicularia plana* " , in the soft bottom of the Bidasoa estuary, is also being investigated.

1) SOFT BOTTOM ESTUARINE COMMUNITIES OF GUIPUZCOA

The estuaries and estuarine communities of Guipúzcoa (fig. 1) can be characterised as follows :

a) High pollution levels in Pasajes Bay, with a population of *Malacoceros luliginosus* , in the more polluted area, which alternates with *Capitella capitata* and *Polydora ciliata* in the cleaner area.

b) Moderate organic pollution within the sheltered mouth of the Bidasoa estuary. The brackish worm, *Hediste diversicolor,* dominates in biomass, with *Streblospiao benedicti* being numerically dominant.

c) The polluted estuaries of Urola and Oria. The mouths of both are exposed. Diversity is very low in the mouths of the estuaries.

d) The channelled estuary of Urumea , with high organic pollution and an exposed mouth. This is faunistically poor, a feature which is related to sediment instability.

2) OPEN, LITTORAL SOFT-BOTTOM FEATURES OF THE BASQUE COAST

We have studied the macrobenthos of a typical sublittoral soft-bottom substrate on a highly surf - exposed area of the Basque Coast : the Bay of la Zurriola (San Sebastián).

The study was carried out from June to September of 1985, when 10 sublittoral stations, from 3 to 40 metres depth (fig. 2), were sampled with a van Veen grab. 1.73 sq. metres of sediment were returned from each station. The sediments are medium to fine sands.

Figure 3 presents the mean values, for the different depths, of the Shannon diversity index, species richness, biomass and densities.

From these results, we concluded that the qualitative and quantitative composition of the macrobenthic fauna is determined by exposure features (e.g. frequency and intensity of storms, wave action , etc.).

Sediment instability results from the action of three hydrodynamic mechanisms:

a) Permanent suspension above 5 metres depth, due to the action of the waves produced in the tidal cycle. This is a highly dynamic area and the macrobenthos is very poor, both qualitatively and quantitatively.

b) Temporary suspensions between 5 and about 20 metres depth, principally due to the autumnal storms. The macrobenthos becomes progressively more complex with increasing depth.

c) Exceptional suspensions at 40 metres depth, with occasional sediment instability, due to very strong storms. At this depth, we found a relatively stable community with high diversity, density and biomass of macrobenthic populations. *Echinocardium cordatum* and other species, which do not occur in more shallow water, are found here.

3. POLYCHAETE COMMUNITIES IN THE CIRCALITTORAL ZONE OF THE BASQUE COAST

One of the most important features of the Basque Continental shelf is the heterogeneity of the substrate. We have studied the two different locations (both at 100 metres depth) shown in figure 4. Seven (7) samples were taken in each area , using a van Veen grab. From each sample, 2 litres of sediment were washed through a 0.2mm screen.The samples were processed for species abundance, biomass and diversity ; inter-sample correlations were computed using the Kendal index and Spearman's rank correlation coefficients. Sediments were analysed granulometrically and are compared in figure 5. In figure 6, we can see the correlation between samples, based on their biological characteristics. It is obvious that the samples group similarly with respect to both their biological and granulometrical attributes.

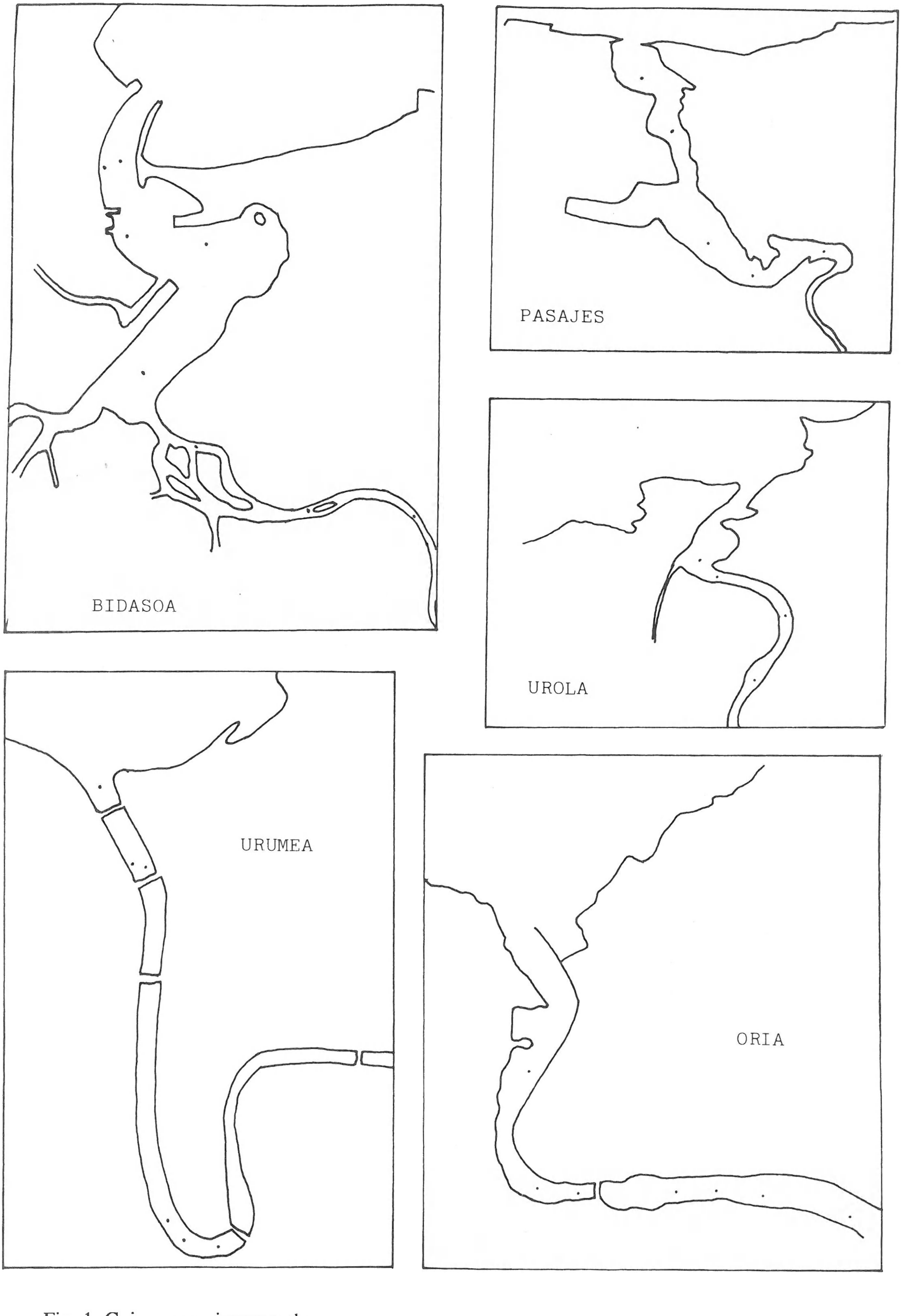


Fig. 1 Guipuzcoan river mouths.

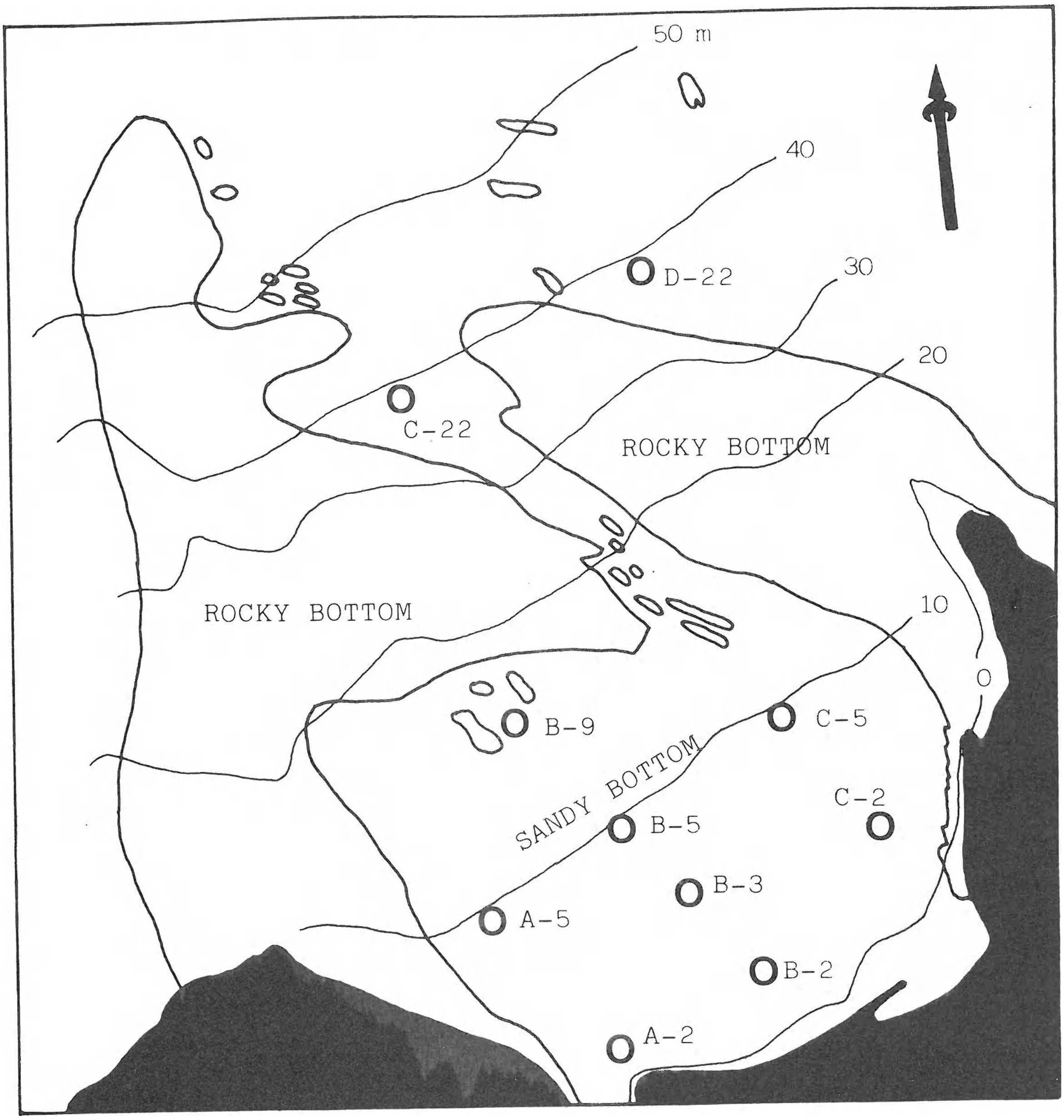
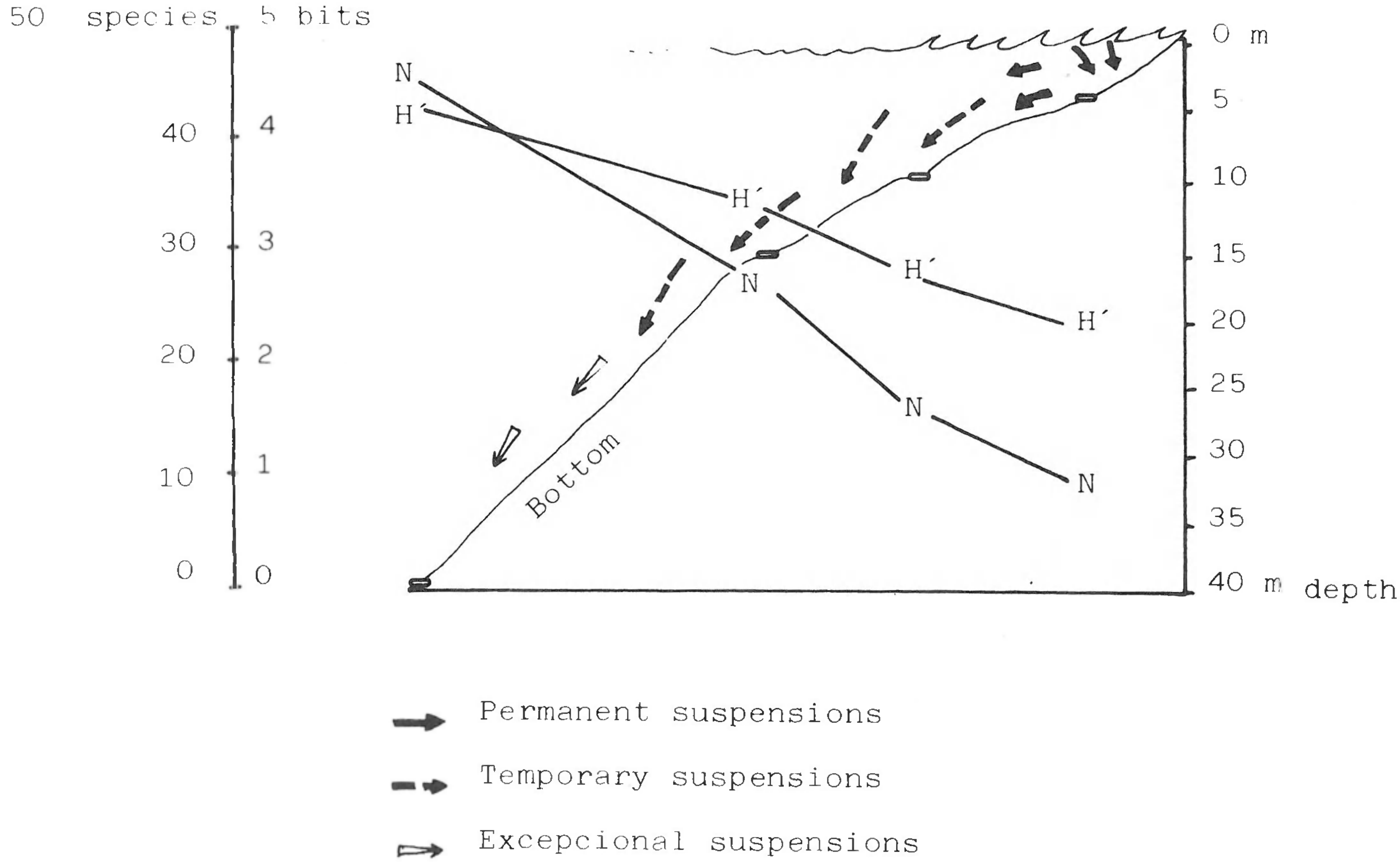


Fig. 2 Cartography and stations of the Bay of la Zurriola (San Sebastian, Spain).



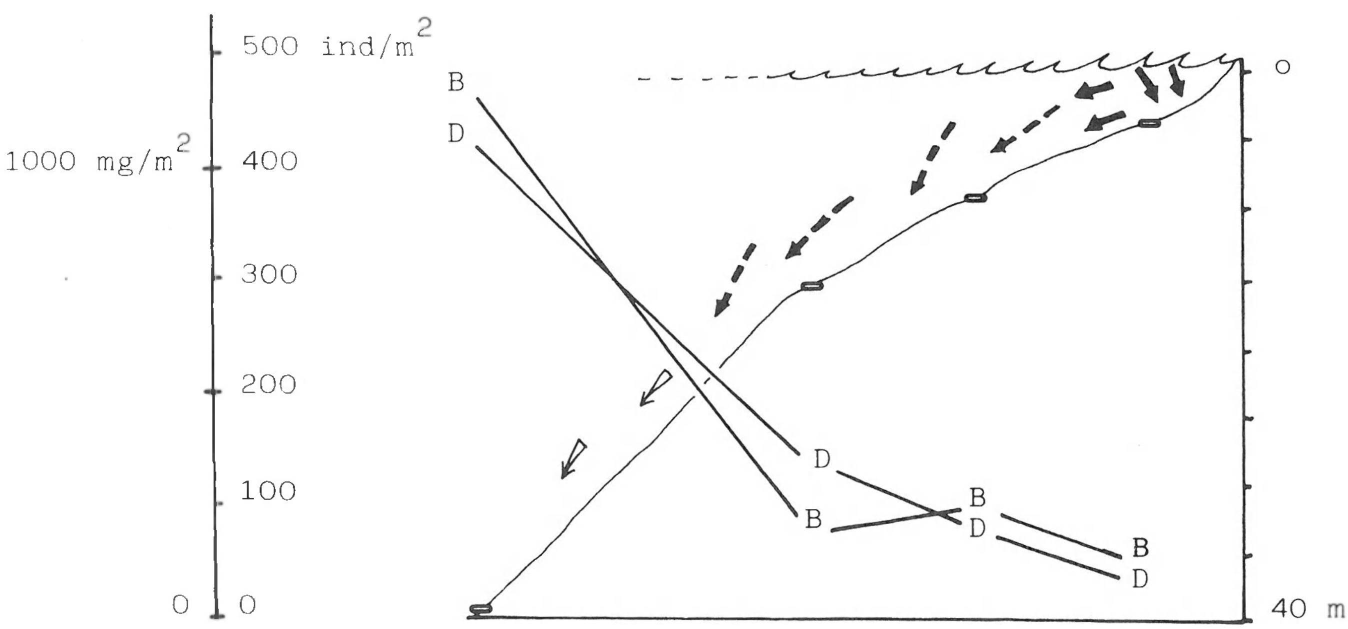


Fig. 3 Mean values, at different depths, of the Shannon index diversity (H'), specific richness (N), biomass (B) and densities (D).

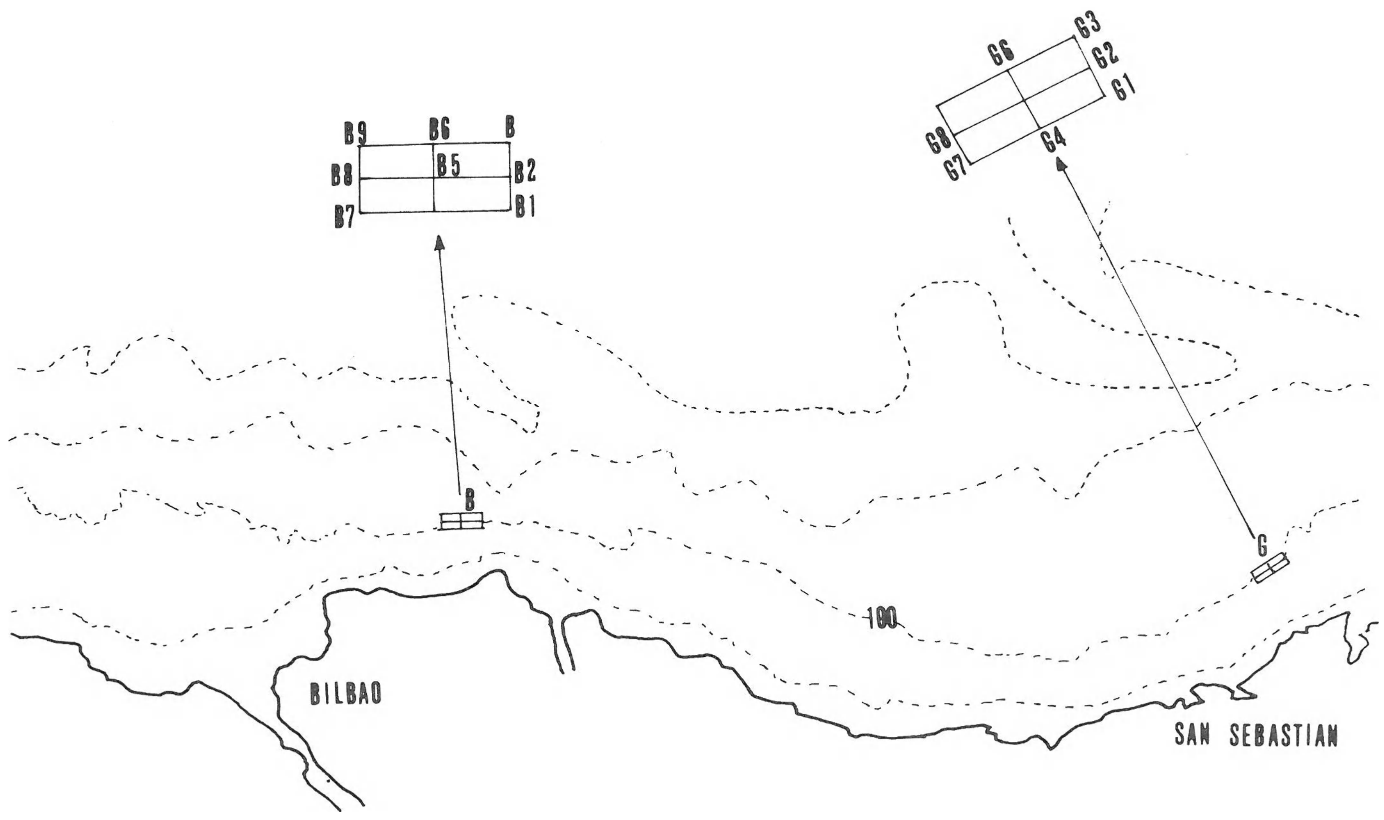


Fig. 4 Sampling stations.

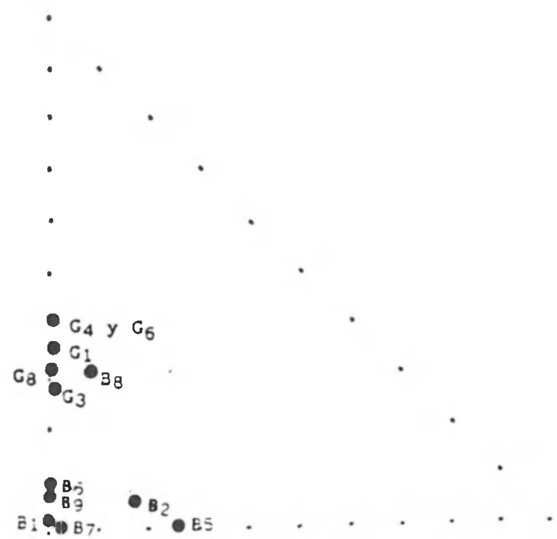
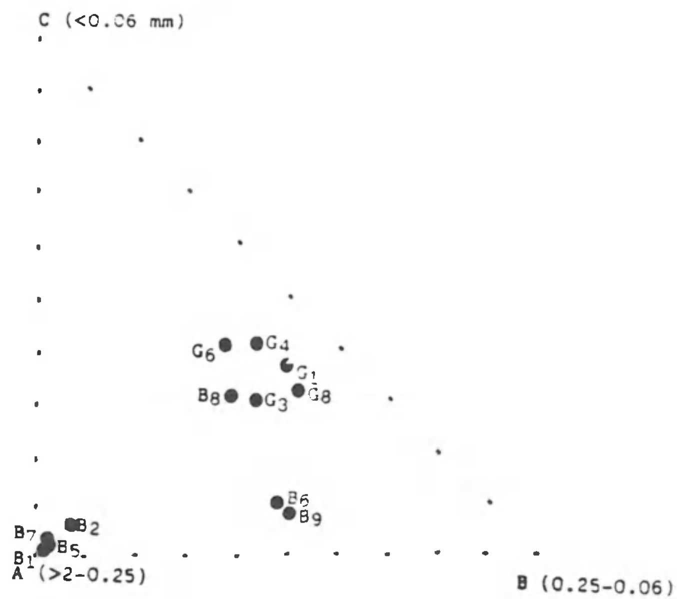


Fig. 5 Position of the samples in a granulometric diagram.



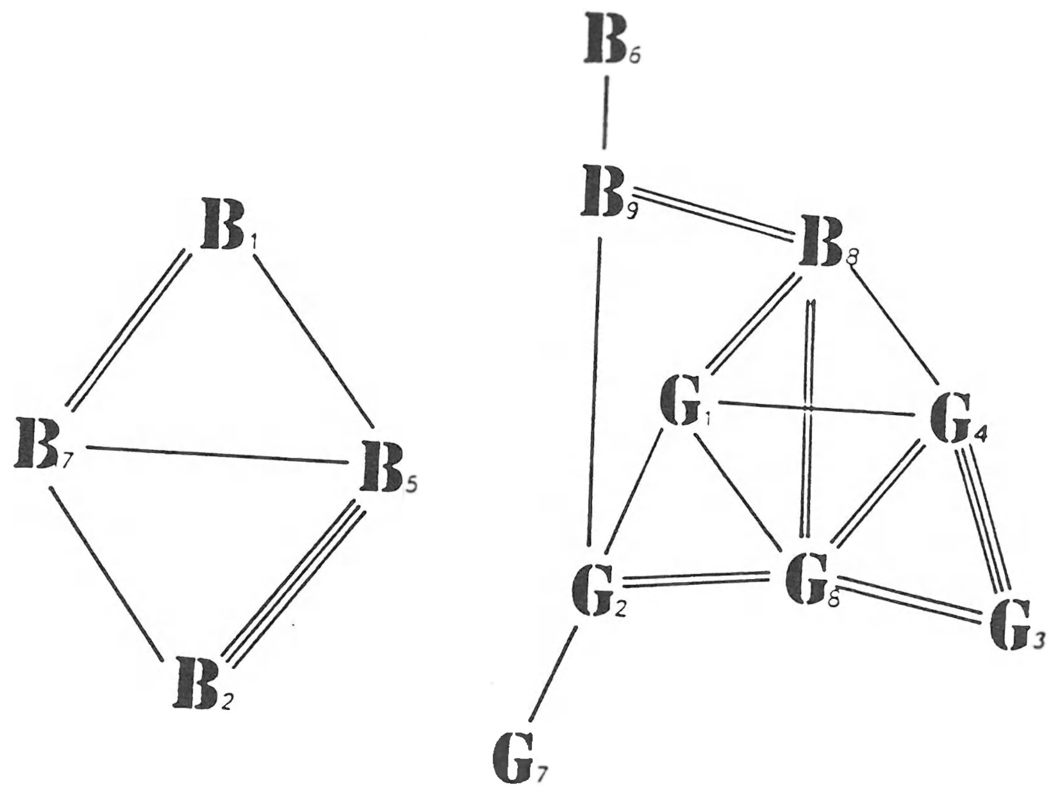


Fig. 6 Similarity between samples on the basis of the faunistic data.

Macrozoobenthos in an ebb-tidal delta complex in the south-west of the Netherlands (the Voordelta).

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INTRODUCTION

In the delta of the rivers Rhine, Meuse and Scheldt, coastal engineering projects have been carried out in the last decades resulting in the partial closure of estuaries (Fig. 1). The Haringvliet estuary was closed off from the sea in 1970 by locks which are used for controlling Rhine water discharge. Since 1971, a dam has turned the Grevelingen estuary into a saline lake, with very little water exchange between Lake Grevelingen and the North Sea. A storm surge barrier was completed in the mouth of the Oosterschelde, in 1986, and resulted in a 30% reduction in water exchange with the North Sea (Knoester *et al.*, 1983). No coastal engineering works have been undertaken in the Westerschelde, apart from maintenance dredging and sludge disposal.

As a consequence of the civil engineering projects, dramatic changes have been observed in coastal hydrodynamics and in the morphology of the subtidal areas. The ebb-tidal current from the estuaries so formed reach high velocities; as a consequence, gullies up to 60m deep, separated by subtidal sand banks, exist in the coastal delta. Sand transport in a coastal direction is now a dominant feature of this area, having been formerly prevented by the ebb-tidal currents from the estuaries. The marked reduction in the ebb-tidal currents, due to the waterworks, now results in the formation of intertidal sand flats, and mud deposition in the gullies.

The area is very heterogeneous in terms of morphology, sediment type and hydrodynamics. Salinity levels are also variable because of the influence of irregular river discharges. By far the most important fresh water inflow comes from the Rhine, but its influence is regulated by wind direction and velocity. The net tidal flow is to the north, so mean salinity levels are close to North Sea values (Table 1). Physico-chemical water quality is governed by estuarine water inflow. The Westerschelde and Haringvliet are considered as the main sources of pollution in the area.

Not much is known about the ecology of the area. Qualitative benthic surveys wrer carried out by Wolff over the period 1958 to 1969, i.e. before the closing of the estuaries (Wolff, 1973). The off-shore zone has been studied by Govaere (Govaere 1978). In the northern part, i.e. the Haringvliet coastal area, benthic distribution patterns are known from an extensive survey executed in 1983 (Seip, 1984). Epibenthos has been sampled twice a year since 1972 as part of a demersal fish survey by the Governmental Fishery Research Institute.

In 1984, a multidisciplinary research project was initiated to study the effects of the coastal engineering works, paying attention to water quantity and quality, substrate morphology, sediment characteristics, benthology and ornithology. The first phase, from 1984 to 1986, concentrated on producing a benthic inventory.

MATERIALS AND METHODS

Surveys

In September and October 1984, the first macrozoobenthic survey was carried out when 5 replicate samples were taken with a Reineck box core (RN: $0.068m^2$ surface; circular box of 30cmØ) at 65 stations. From one box core, three replicate meiofaunal samples were taken with plexiglas cores of 10cmØ. (The results of the meiofaunal analysis are presented elsewhere (Huys *et al.* , 1986)). Sediment samples were also taken from this core. In a considerable number of cases, a van Veen grab was used (VV: $0.18m^2$) because bad weather conditions did not allow the use of the 800kg Reineck device. This first survey served as a pilot study, especially with regard to the sampling strategy. In April and May 1985, a second survey was performed with the same equipment, but with quite a different sampling strategy. One RN core sample, or in some cases a single VV grab was taken at each of 175 stations.

The programme was continued in September 1985 and 1986 and will be reported upon separately.

Sampling Design

For the first survey, no actual information on sediment characteristics and other relevant abiotic or biotic factors was available for the area. Further, information on the variability of the benthos and possible explanatory factors had to be obtained by taking replicate samples at certain stations. For practical reasons, 5 replicates were taken at 65 stations, selected on the basis of general depth and togographical data. From this survey, it was concluded that at least 25 replicates should be taken to get a representative picture per station. Because information was needed on the whole area, a stratified random sampling approach was chosen for the following surveys. A TWINSPAN classification of the data from the first survey revealed station clusters which corresponded to more or less dinstinct areas, and the strata were distinguished in this way. This iterative approach was also adopted for the selection of sampling strata in the ongoing programme. This paper presents the results of the classificatory analysis carried out on the first and second surveys , with the strata identified on the basis of the first survey only.

Handling of the samples

Samples were taken from research vessels of the Public Works department. Sieving was carried out on board with a 1mm stainless steel sieve with circular meshes. Samples were fixed with 4% neutralized formol. In the laboratory, samples were washed, and individuals were counted per species. Biomass was estimated by drying for 48 hrs at 70^{o}C, and ashing for four hours at 520^{o}C.

Data analysis

For the first survey, the mean (with variance) species density was calculated per station. In the second survey, the data were log transformed and expressed per stratum as a geometric mean with 95% confidence limits.

Classification analysis based on densities per species per station was performed by using TWINSPAN (Hill, 1979a). Ordination analysis was performed by using DECORANA (Hill, 1979b).

Abiotic factors

Other disciplines participating in the project provided information on sediment types, depth, shear stress, water quality and salinity (Table 1). In this paper, only the sediment parameters are considered. For the 1985 survey, sediment parameters are based on samples taken at or close to the faunal stations (van der Weijden and Weijers, 1986). There is a strong positive correlation between mud, lutum, $CaC0_3$, and POC content; betwen median grain size and POC content; and betwen sorting, $CaC0_3$ content and depth. No correlation is observed between mud content, median grain size, sorting and depth (Table 2). The strata identified can be characterised on the basis of these parameters. In Figure 2, box and whisker plots (Tukey, 1977) of the sediment parameters are shown for the whole area and per stratum.

Rank correlations were also calculated between these sediment parameters and the DECORANA ordination axes.

RESULTS

Abundance and distribution

Table 3 gives a list of the 14 most dominant species found in both surveys out of a total of 124 species. In each survey, 98 species were recorded. Table 4 gives the complete list of species found in the surveys. Figure 3a shows the number of species per sampling point, ranging from 0 (at one station in the Westerschelde) to 19 species per core . Figure 3b shows the densities from the same survey with a maximum of 3588 specimens per m^2.

The densities of the 33 most dominant species found during the first survey (Autumn 1984) were used for classification analysis. The strata identified from this classification are shown in Figure 1. The boundaries of the strata are provisional, because the sampling network of the first survey was too open. Figure 1 also shows the distribution of the sampling points of the second survey, based on these strata. Figure 4 shows species numbers and densities for the six strata and for the area as a whole.

Correlation with sediment chracteristics

Table 5 shows the rank correlation for the 1985 data set between the DECORAMA axes and the sediment parameters. Significant correlations are observed for all sediment parameters with one or more of the axes. The correlation coefficient between mud and the first axis shows the highest value. So, species composition and abundance in this area, for Spring 1985, are most strongly correlated with mud content.

DISCUSSION

Species richness in time and space

The surveys of Autumn 1984 and Spring 1985 can be used as a first exposition of the benthic communities in the Voordelta. The 1984 survey served as a pilot study. Although many differences in methodology can be mentioned, a comparison of the results with those of Wolff

(1973), for roughly the same area from 1958 to 1969, can be made. Wolff distinguished several ecological classes, two of which are present in the Voordelt, i.e. coastal water and sediment with a median grain size between 2 and 3 phi, one well sorted (sorting <.45 phi) and the other less well sorted (sorting >.45 phi). From the data set of 1985, the frequency of occurrence in one of these classes was calculated for a number of species. So, the probability of occurrence of species from this survey can be compared with the results of Wolff. In this regard, many species with frequencies of occurrence of the same order of magnitude, show similarities in distribution over time. *Cerastoderma edule* and *Nephtys longosetosa* are exceptions to this finding. For *Cerastoderma,* this could be explained by the highly aggregated distribution for which a non-specific stratified random sampling design is not adequate. Lower levels of occurrence were recorded for 8 species, and higher values for 4 species. It is concluded that up to now no dramatic change in species richness has taken place as a result of the coastal engineering works performed in this area.

Distribution patterns and abiotic factors

A very strong correlation exists between species distribution and mud content (r = .8). Strong correlation is also shown with median grain size and depth (Table 5). These factors seem to vary in a mutually independant fashion. The role of other abiotic factors such as salinity, shear stress, etc., will be analysed in the near future.

The strata can be characterised by a combination of sediment variables. This corresponds with general distribution features: Strata 1 and VI are the extremes, where numbers of species and individuals are relatively low. Stratum 1 is a very muddy sedimentation area; stratum VI shows a rather large grain size (low phi values), indicating a relatively high shear stress. Stratum II and III are in the deeper parts with medium or high mud contents. Stratum IV and V are located in the shallow areas, and are probably exposed to wave attack.

From the 1984 and 1985 surveys, a general conclusion is drawn. The heterogeneity of the Voordelta area can be studied by reference to a number of strata with a defined degree of similarity in species composition and abundance. These can be characterised in terms of mud content, grain size, sorting and depth. Insofar as the area is still changing in hydrodynamics and, as a consequence, in topography and sediment characteristics, a changing pattern of strata and macrozoobenthos composition can be expected.

ACKNOWLEDGEMENTS

The authors would like to thank R. Brand for assistance with the sampling and species identification. The research was funded by the Public Works Department.

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TABLE 1 Abiotic characteristics of the Voordelta (Surface area: 1000km2)

		Min	Max	Average value
Temp	(^{o}C)	3	20	-
Current Vel	(m/s)	0	2	1
Rest current	(m/s)	0.01	0.11	0.05
Salinity	(gCl/l)	8	19	-
SPM	(mg/l)	5.8	63.1	26.4
Chlorophyll	(mg/m^3)	4.8	18.6	9.0
Depth	(m below MWL)	0	60	10
Med. grain size	(phi >50µm)	1	3.6	2.5
Sorting	(phi units)	0.23	0.95	0.43
Mud content	(% <50µm)	0	91.0	2.0
Silt content	(% < 2µm)	0	45.0	-

TABLE 2 Correlations of sediment parameters (data from the 1985 survey)

	n	mud	silt	med.grain size	sorting	$CaCO_3$	POC	Depth
Mud content	167	-						
Silt	167	.96	-					
Grain size	167	.39	.37	-				
Sorting	167	.36	.33	- .34	-			
$CaCO_3$ cont.	167	.77	.71	.21	.55	-		
POC	148	.81	.82	.43	.16	.61	-	
Depth	190	.18	.21	- .24	.47	.32	.10	-

TABLE 3 The most abundant species in the Voordelta in Autumn 1984 and Spring 1985. % = order of surface weighed frequency; N = occurrence on number of stations.

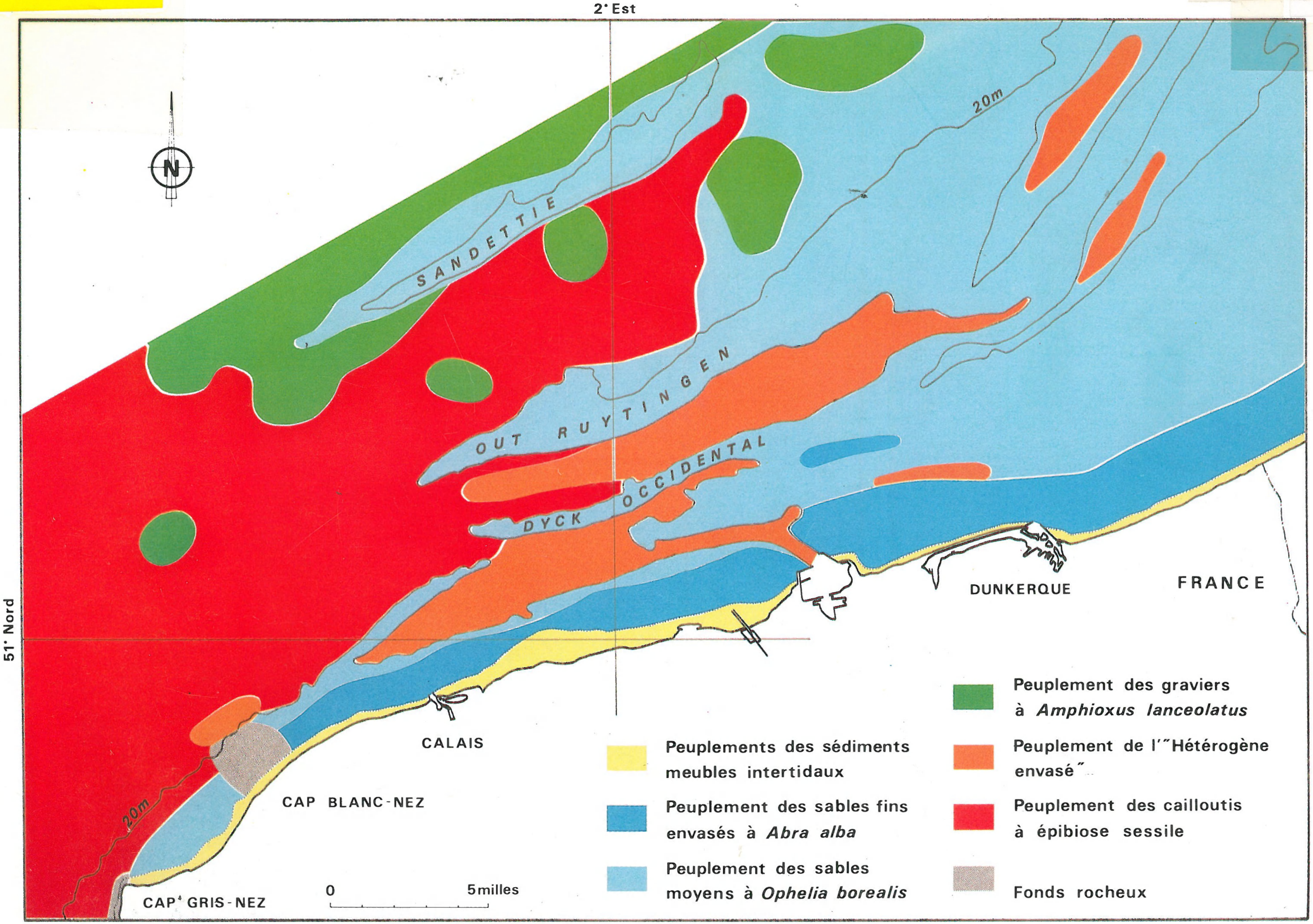
Species	1985 %	1985 N	1984 %	1984 N
Scoloplos armiger	1	119	2	45
Nephtys homergii	2	115	3	42
Bathyporeia elegans	3	80	4	40
Urothoe poseidonis	4	73	6	35
Nephtys cirrosa	5	59	1	52
Magelona papillicornis	6	62	8	33
Spiophanes bombyx	7	65	5	36
Spio filicornis	8	44	7	35
Spisula subtruncata	9	33		
Capitella capitata	10	35	9	33
Tellina fabula	11	45		
Nemertinea	12	31	12	30
Macoma balthica	13	30		
Ophiura texturata	14	45		
Atylus swammerdami			10	32
Anaitides mucosa			11	32
Echinocardium cordatum			13	27
Gastrosaccus spinifer			14	27

TABLE 4 List of species of the Voordelta with number of sampling points where the species were found in 1984 (I) and 1985 (II).

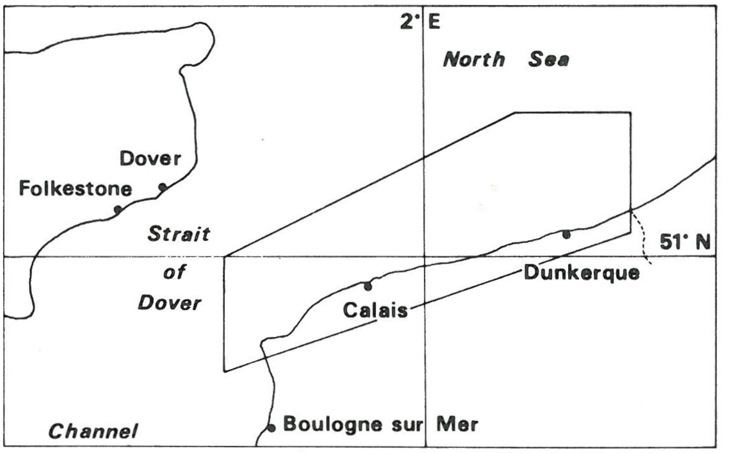
	I	*II*
Abra alba	13	18
Actiniaria (N.D.)	13	23
Ampelisca brevicornis	-	
Anaitides groenlandica	9	34
Anaitides mucosa	31	31
Arenicola subulifera	5	2
Arenicola marina	-	1
Asterias rubens	7	12
Atylus falcatus	21	13
Atylus swammerdami	32	27
Autolytus sp.	3	-
Balanus crenatus	2	-
Balanus improvisus	2	2
Barnea candida	-	
Bathyporeia elegans	40	87
Bathyporeia guilliamsoniana	11	24
Bathtporeia pilosa	1	1
Capitella capitata	33	50
Capitomastus minimus	2	-
Carcinus maenas	6	7
Cerastoderma edule	2	1
Chaetozone setosa	7	16
Corophium volutator	-	7
Corystes cassivelaunus	1	-
Crangon crangon	20	5
Cumacea (N.D.)	12	5
Diastylis bradyi	-	4
Diastylis lucifera	-	2
Diastylis rathkei	-	13
Diastylis rugosa	-	1
Donax vittatus	13	4
Echinocardium cordatum	27	36
Elasmopus rapax	1	-
Ensis arcuatus	-	1
Ensis minor	11	-
Ensis phaxoides	4	-
Ensis sp.	-	2
Eteone longa	13	13
Eumida bahusiensis	1	-
Eumida sanguinea	15	16
Gammarus locusta	5	-
Gammarus sp.	3	1
Gastrosaccus spinifer	27	9
Goniadella bobretzkii	-	2
Gyptis sp.	8	3
Harmothoe longisetis	-	1
Harmothoe lunulata	13	8
Haustorius arenarius	8	1
Hesionura augeneri	-	2
Heteromastus filiformis	15	31
Idotea linearis	4	1
Inachus dorsettensis	1	-
Lanice conchilega	16	24
Macoma balthica	21	42
Macropipus arcuatus	2	-
Macropipus holsatus	5	7
Mactra corallina	12	3
Magelona papillicornis	33	70
Melita obtusata	3	-
Mesopodopsis slabberi	5	-
Microphthalmus sp.	1	1
Montacuta ferruginosa	21	16
Mya arenaria	5	1
Mysella bidentata	15	22
Mytilus edulis	3	-
Natica alderi	21	41
Nemertinea (N.D.)	30	39
Nephtys caeca	3	9
Nephtys cirrosa	52	69
Nephtys homergii	42	125
Nephtys longosetosa	10	12
Nereis diversicolor	1	-
Nereis longissima	19	23
Nereis succinea	2	2
Oligochaeta (N.D.)	8	1
Ophelia limacina	8	9
Ophiura albida	-	1
Ophiura texturata	16	52
Orchomene humilis	1	-
Owenia fusiformis	7	8
Pagurus bernhardus	-	3
Paraonis fulgens	-	7
Pariambus typicus	4	1
Pectinaria koreni	10	19
Perioculodes longimanus	1	12
Petricola pholadiformis	5	3
Pisidia longicornis	1	-
Pholoe minuta	6	11
Plathyhelminthes (N.D.)	-	4
Poecilochaetus serpens	1	-
Polydora ciliata	1	-
Polydora ligni	1	2
Pontocratus altamarinus	1	2
Pontocratus arenarius	-	3
Portumnus latipes	2	-
Praunus inermis	1	-
Processa parva	1	-
Pseudocuma longicornis	-	4
Pseudopolydora pulchra	1	1
Pygospio elegans	5	15
Scalibregma inflatum	-	1
Schistomysis kervillei	12	15
Scolelepis bonnieri	10	23
Scolelepis foliosa	1	4
Scolelepis squamata	1	-
Scoloplos armiger	45	136
Scrobicularia plana	2	1
Sigalion mathildae	-	2
Spio filicornis	35	61
Spiophanes bombyx	36	78
Spisula solida	3	-
Spisula subtruncata	21	39
Stehenlais boa	6	-
Streblospio shrubsolii	-	2
Synchelidium haploch	-	6
Tellina (= Angulus) fabula	24	49
Tellina (= Angulus) tenuis	23	35
Terebellides stroemi	-	1
Tharyx marioni	8	14
Travisia forbesii	-	4
Urothoe brevicornis	15	15
Urothoe poseidonis	35	88
Venerupis pullastra	2	-
Venus striatula	-	3

TABLE 5 Spearman's rank correlations between 4 ordination axes and sediment variables, from the 1985 survey with 78 sepcies at 173 stations. Only significant correlation coefficients are given.
(xxx) at $p < 0.001$; xx at $p < .01$). The eigenvalues of DECORANA axes are also shown.

Axis	1	2	3	4
Eigenvalues	.487	.308	.193	.147
Med. Grain size	.47^{xxx}	--	--	.22^{xx}
Sorting	.28^{xxx}	.30^{xxx}	--	--
Mud content	.80^{xxx}	.46^{xxx}	.33^{xxx}	--
Depth	--	--	.22^{xx}	.44^{xxx}


2° Est
51° Nord
N
SANDETTIE
OUT RUYTINGEN
DYCK OCCIDENTAL
20m
20m
DUNKERQUE
FRANCE
CALAIS
CAP BLANC-NEZ
CAP GRIS-NEZ
0
5milles
Peuplements des sédiments meubles intertidaux
Peuplement des sables fins envasés à *Abra alba*
Peuplement des sables moyens à *Ophelia borealis*
Peuplement des graviers à *Amphioxus lanceolatus*
Peuplement de l'"Hétérogène envasé"
Peuplement des cailloutis à épibiose sessile
Fonds rocheux

A map of the benthic communities of the area indicated. The basis for this map is outlined in the Report by Dewarumez *et al.*



Geographical location