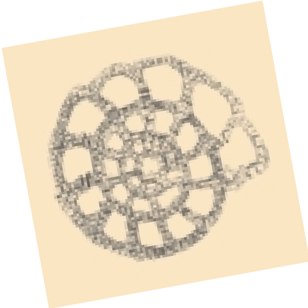
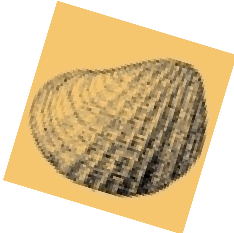
Marine Sample Collections

their value, use and future

Prepared for IACMST
by Dr R G Rothwell

IACMST





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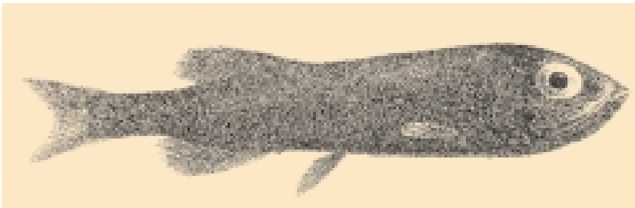

Preface

As part of its commitment to consult on, and promote marine science and technology, the IACMST publishes a series of Information Documents which review topical issues. Oceanographic physical object collections (biological specimens, rock and sediment samples, photographs etc.) are important raw data resources of long-standing value to the scientific community. In April 2000, the IACMST sponsored a meeting of the oceanographic community to review modern and potential usage of biological and geological marine collections; and discuss common problems relating to provision of wider access and adequate funding of these important data resources.

This meeting, held at the Natural History Museum, London, as part of its Millennium Science Festival, attracted marine scientists and collection management specialists from all over the United Kingdom and also from Europe. This volume presents articles derived from talks given at the meeting and the conclusions and recommendations of the workshop. The articles cover overviews of important marine sample collections within the United Kingdom and presentation of modern, often cutting-edge, research that has relied extensively on pre-existing marine sample collections.

Collecting marine samples has been, and is, extremely costly. Proper curation and data management can extend the value of marine samples considerably, providing a greater return on the cost of collecting the samples in the first place. The United Kingdom is fortunate in that its institutions host marine collections of global importance. This Information Document provides an overview of the United Kingdomís marine sample holdings, their continued value in modern research and the problems faced by collection facilities. It is hoped that it will play a role both in informing and stimulating debate.

Ms Jo Durning
Office of Science and Technology
Chair of IACMST

July 2001

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Executive Summary

The following articles derive from presentations given at a workshop on '**Marine sample collections – their value, use and future'** held at the Natural History Museum, London on 3rd April 2000. This meeting aimed at bringing together marine researchers and collection management specialists to discuss issues of common interest, particularly the role that sample collections can play in modern research, and mechanisms that would promote greater access to sample collections and secure funding. The articles provide overviews of marine sample collections within the United Kingdom, illustrate their value in modern research and present a series of recommendations for securing the future of these important raw data resources.

Phil Rainbow *(Natural History Museum)* reviews the immense sample holdings of the Natural History Museum, London, and their vital role in identification, description and taxonomy and hence for studies of phylogentics, biogeography, biodiversity and conservation. He highlights the increasing importance of new disciplines such as molecular biology in systematics and phylogentic studies and the techniques being developed to extract DNA from the museum collections associated with such research. A historic marine sample collection recently acquired by the museum is the 'Discovery' collections, previously kept at the Institute of Oceanographic Sciences, Wormley, that provides a unique record of Antarctic Ocean biota and dates from the early decades of the 20th Century. These samples, some as yet unstudied, provide potential benchmarks for models of community change over time, as well as including unique taxonomic material rarely encountered. Making this rich legacy available to the world requires immense electronic databasing – something which will be a slow process, without the introduction of unaffordable human resources. However, the opening of the Museum's new Darwin Centre will allow increased and informed public access to the museum's collections and science.

Guy Rothwell and David Gunn *(Southampton Oceanography Centre)* describe the British Ocean Sediment Core Repository *(BOSCOR)*, the United Kingdom's national core repository located at Southampton Oceanography Centre. They illustrate the value of cores in a wide variety of marine research and the need to keep them under specialised conditions for optimum preservation. Properly conserved cores can remain in a pristine condition for decades, and major developments in our understanding of recent environmental change have come from material stored effectively in long-term core repositories. BOSCOR operates a comprehensive suite of state-of-the-art, non-destructive core logging equipment for community use, maximising the data that can be obtained from these sediment records. These data are integrated into the BOSCOR database which is available to users online. As we enter the third millennium, pressing environmental concerns such as global warming (which could severely impact Britain through disruption of the Gulf Stream) require that we understand more fully oceanic circulation and how it can change and on what timescales. To see how climate may change in the future we need to see how it has changed in the past. Models of past climate changes can only be validated by examining the past record preserved in marine sediment and ice cores. Material stored in core repositories will be of vital importance in answering our questions about the past and future world.

Colin Graham *(British Geological Survey)* describes the British Geological Surveys marine core collection - a huge collection of seabed samples taken mainly from the United Kingdom's continental shelf and adjacent deep water areas. These data have been used to produce seabed sediment classification maps around the UK. This archive and associated analytical data provides an invaluable source of information for scientific research and commercial activities, reducing the need for expensive field-work, or providing time-based comparisons with newly acquired core. The archive has been intensively used by universities and research organisations both in the UK and abroad. The main commercial users of the archive are the civil engineering, hydrocarbon and mineral resources sectors. The BGS core collection has played an invaluable role in research examining geological processes and development of the NW European continental margin.

Susan Chambers (*National Museums of Scotland*) describes how commercial surveys, such as those conducted by the Atlantic Frontier Environmental Network, can enhance museum collections by providing additional material. These surveys obtained a wealth of biological material, some new to science, from a previously biologically poorly known area of the Atlantic margin to the north and west of the Shetland Islands. More than 2,000 species were recorded in the samples collected and these have been incorporated into the collections of the National Museums of Scotland, where work continues on the new species found within the recovered fauna. The AFEN surveys provide an excellent model of how industry and museums can co-operate in adding to the knowledge base by depositing samples collected as part of industrial activities in public institutions where they can be preserved for future research.

Ivor Rees *(University of Wales, Bangor)* highlights the lack of curation of underwater photographs and video nationally. This is an area where there is prospect that important data could be lost. Like sediment and biological samples, seabed images beyond diving depths are relatively expensive to obtain and can have many uses beyond the reason for which they were taken. They may even have uses as records of long-term change. He describes a pilot study for a restricted area of the Irish Sea, funded by the DETR and undertaken by the University of Wales, Bangor, which may serve as a model for what should be done in other areas. A CD-ROM was produced giving representative coverage of as much of the Irish Sea as possible. Video and still images are valuable for putting the seabed environment into context. However, until now images have fallen into a gap somewhere between the numerical archives of oceanographic data centres and museum collections with actual samples. This is an area where much work needs to be done.

Andrew Mackie *(National Museum of Wales)* describes the marine invertebrate collections in the National Museum of Wales and their rapid expansion during the last two decades. These collections have also benefited from large donations of samples collected during environmental survey work such as that carried out by the oil and gas industry. Such specimens represent invaluable taxonomic and historical resources and must be conserved although acceptance of such material, of course, may have major curatorial implications for museums. A proposal made to the UK Offshore Operators Association *(UKOOA)*, and subsequently accepted by them, to allow contractors to deposit their specimens in recognised national collections for safe-keeping, cataloguing and for making them available for scientific study is also presented.

John Wilson *(Royal Holloway, University of London)* and Mike Thurston *(Southampton Oceanography Centre)* review the role of existing sample collections in a wide range of research. They describe good practise regarding curation and storage, emphasising the importance of good documentation and assess the vulnerability of different types of collection to disruption and disposal. Collections in research institutes may be under serious threat after a project is terminated and the staff assigned to other work, or the site is closed or relocated to a new site. They then describe a number of case histories that highlight the problems that can arise when collections are dispersed or relocated. Great care and vigilance is required when collections are relocated from one location to another.

Ian Tittley *(Natural History Museum)* describes the Natural History Museum's important algal collections, assembled over 350 years, and the role they can play in assessing environmental change. The collections contribute to recognising changes in spatial or temporal occurrence and changes in species richness, factors related to changes in environment. In addition the morphological structure and reproductive state of algal specimens often relate to environmental factors, such as sea temperature, salinity and wave exposure, in which the plant originally grew. Further algae are also known bio-accumulators, which record in their tissues, indications of the chemical environment in which they occurred. He describes a number of case studies around the UK, where museum algal collections, obtained at known times from specific localities can be compared with occurrences today. Such studies demonstrate changes in water quality over time and the effect of pollution. Algal collections will be important in predicting change due to global warming – the spread of warm water species over time may indicate rises in sea temperature.

Guy Rothwell describes the EU-SEASED project – an important European Union funded initiative for accessing the European marine sediment sample archive. Marine sediment cores and other seafloor samples are a raw data resource of immense scientific value and many tens of thousands of bottom samples have been collected by European institutions and are stored at locations dispersed throughout Europe. Previously there has been no way of knowing what samples were available and where they were stored. EU-SEASED is a new internet-based database of seafloor samples held by European institutions. Users can search for cores and samples in areas of interest using text-based query options or through a map-based graphical interface. The database lists metadata only and access to the samples and any associated accessory datasets is for negotiation between the requestor and the institution holding the samples. EU-SEASED is a good example of how European institutions should collaborate to provide online catalogues of their data, thereby providing greater data access and promoting greater secondary usage of raw data resources. Many other seafloor data types could be databased in this way.

The next two papers discuss recent innovative research using pre-existing collections. Lawrence Hawkins *(Southampton Oceanography Centre)* and co-authors show how the determination of glycogen in preserved material can be used as a retrospective indicator of environmental stress. For this study, it would not have been possible for a single research cruise to be mounted so as to be able to assemble such a comprehensive set of samples in which to investigate this phenomenon. Alex Rogers *(Southampton Oceanography Centre)* discusses the use of preserved material in museum collections in marine biodiversity research using molecular methods, particularly DNA extraction. He demonstrates the power of this new innovative technique to discern cryptic species, fundamental aspects of population structure and valuable new information on the evolution of marine systems. Specimen collections held in museums and other institutions around the world represent a vast and largely untapped resource for studies of molecular phylogenetics, biodiversity and historical changes in populations. Although DNA is degraded in various ways according to the preservational process, DNA has been extracted from a variety of terrestrial mammals up to 100,000 years old. Although, as yet, there are no examples of DNA extraction from marine organisms of comparable age, important data relating to temporal genetic variation in marine populations has been obtained from DNA samples from museum specimens. This clearly demonstrates that museums contain vast resources for genetic studies by taxonomists, ecologists and fisheries managers.

In the last article, Gordon Paterson *(Natural History Museum)* summarises the conclusions and recommendations of the workshop. He summarises the results of a discussion session, open to the floor, held after the presentations. Raising the profile of collections to ensure their continued use in contemporary research is clearly necessary. This can be done by securing greater representation for institutions that curate marine samples on national advisory groups and international bodies, and by highlighting activities that demonstrate the value and use of collections to funding and scientific organisations. Funding organisations need to pay regard to proper curation of samples collected during research projects and ensure funds are allocated for this when they dispense grants. Better liaison between research groups collecting samples and collection storage facilities must be encouraged, in order to foster better long-term curation of important collections. However, there must also be concerted effort to increase access to marine sample collections. Institutions need to establish on-line catalogues of their holdings, and funds need to be secured to allow this. When collections are relocated to other institutions, this can place an extra burden on the new host institution, and resources need to be allocated for this. Agreements that allow samples collected as part of commercial surveys to be deposited in recognised collection facilities must be encouraged. New types of collections often face problems similar to more traditional types of collection. It is evident that seafloor photographs and video are not being curated well at a national level and awareness of what is available, and access to it, is poor. This is an area where new initiatives are necessary to prevent loss of data and to provide accessible indexes of such data for community use.

Introduction

Marine sample collections (sediment cores, dredged material, grabs and biological specimens) are important raw data resources that, if properly curated and preserved, can have long-term value to researchers long after the samples were originally collected. Collecting marine samples can be expensive involving ship-time and specialised equipment and personnel. Preservation of samples for secondary use by other researchers, therefore, offers the potential for considerable savings in time and money, maximising the return on the cost of collecting the material in the first place. Major advances in our understanding of recent environmental changes have come from material stored in long-term repositories. For example, the North Atlantic 'Heinrich layers', indicating six major collapses of the North American Ice Sheet during the last 60,000 years are a prime example of the usage of stored material to firstly identify, and then to investigate, in detail an important global change phenomenon. As new analytical techniques are developed, preserved specimens can reveal new data and add to the knowledge base. Further, some marine collections form unique time series from an era before widespread human impact and hence form essential baselines to measure human influence on the marine environment. Despite their long-term value, the funding of marine sample collections is, and may always be, difficult. The best way to ensure long-term support for sample-based physical object collections is their continued use in research that addresses contemporary issues.

On 3rd April 2000, 41 researchers and collection management specialists, from as far a field as Greece, Madeira and Tasmania, met at the Natural History Museum, South Kensington, London, to discuss current issues associated with collections of oceanographic samples and their associated data. The meeting originated from a suggestion by the Marine Environmental Data Advisory Group of the UK's Inter Agency Committee for Marine Science and Technology (IACMST) that it would be timely to organise a meeting of the oceanographic community to review modern and potential usage of marine biological and geological collections. One of the aims of the meeting was to provide a forum for discussion of common problems of securing adequate funding of these important data resources, and provision of wider community access.

A series of presentations were also made giving informative up-to-date overviews concerning:

- **modern trends in the research use of collections**
- **use of new technology in extracting more information from sample archives**
- **new initiatives to increase accessibility to sample collections**
- **modern trends in curatorial practise**

The meeting was sponsored by the IACMST, the Natural History Museum and Southampton Oceanography Centre. It was convened by Drs. Gordon Paterson *(Natural History Museum)* and Guy Rothwell *(Southampton Oceanography Centre).*

This report provides an account of the presentations, a summary of the discussion, and a list of recommendations resulting from this. The presentations provide an overview of key marine sample collections in the United Kingdom and their continuing use in high-level research. It is hoped that this report will contribute to the case for ensuring adequate funding for the curation of long-term marine sample collections; and the recognition that collections are more than just assemblages of physical items – they are valuable resources for modern research.

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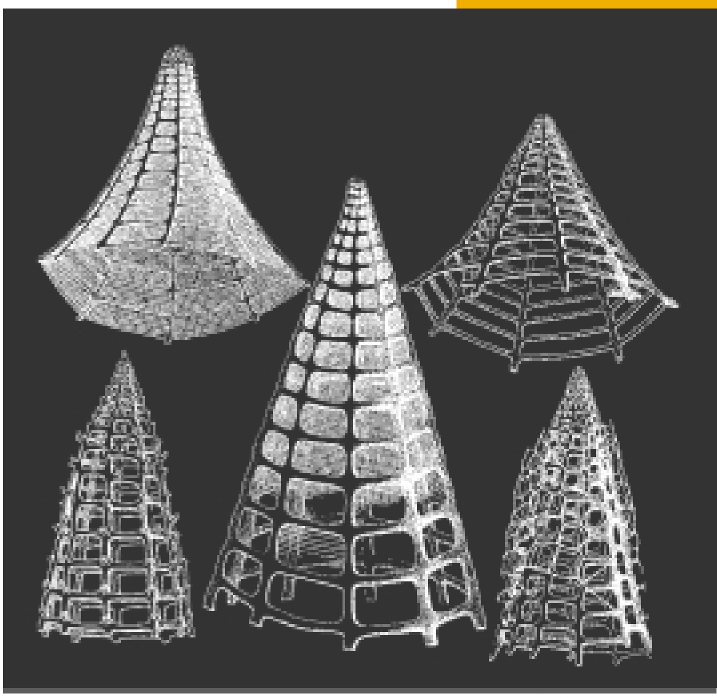

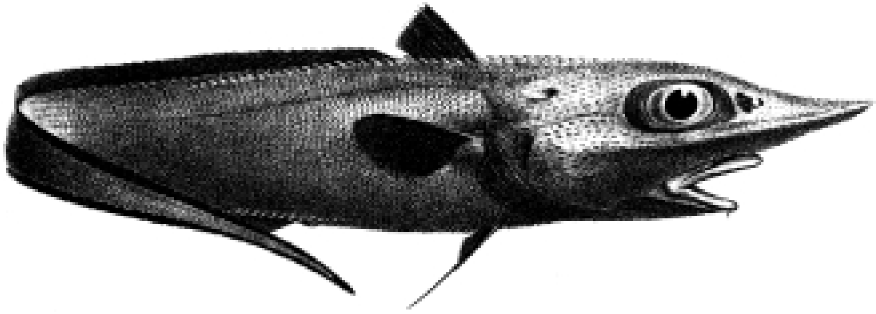

Collections: Past, Present and Future

Phil Rainbow
Keeper of Zoology, The Natural History Museum, London SW7 5BD

The Natural History Museum has long fulfilled the classic role of holding, maintaining and developing biological collections, primarily for the purpose of systematic research. Thus the Museum holds more than 70 million specimens in the custodianship of five scientific research departments – Botany (5 million), Entomology (28 million), Zoology (27 million plus), Palaeontology (10 million) and Mineralogy (375,000). Simply counting the specimens in all their different shapes and forms is an awesome task, and the numbers given can only be approximate. Collections of specific interest to marine scientists are spread across the departments of Mineralogy (sediments), Palaeontology (marine fossils), Botany (macrophytic seaweeds and protistans such as diatoms) and Zoology (marine invertebrates and vertebrates).

The Department of Zoology, for example, holds specimens ranging in size from whales to flagellate protistans. The specimens themselves may be dry (e.g. skeletons, taxidermy), pickled (in alcohol or formalin), deep-frozen or mounted on slides. For historical reasons this department also houses microbiologists investigating the biodiversity and phylogeny of prokaryotes and basal unicellular eukaryotes, with appropriate collections of cultures. Table 1 gives an approximate breakdown of our holdings before the recent addition (see later) of the 'Discovery' Collections from the Institute of Oceanographic Sciences, now incorporated into the Southampton Oceanography Centre.

In holding these collections and making them available to scientists throughout the world, the Natural History Museum plays an absolutely vital role, crucial for identification, description and taxonomy, and thence for studies of phylogenetics, biogeography, biodiversity and conservation. Particularly important is the curation of type specimens and the Department of Zoology alone holds more than 375,000 types (Table 2). On the other hand, there is also immense value in the holding of large numbers of what may be replicates of the same species. Such collections allow studies of sympatric morphometric and genetic variation of populations, or the investigation of biogeographic variation and ultimately the recognition of taxonomic distinction at various levels including subspecies and species (e.g. Clark *et al*., in press).

As molecular biology has been added as a tool in systematics and phylogeny, we are stockpiling deep-frozen and ethanol-fixed material specifically for the application of molecular biological tools. Techniques are also being developed to extract DNA from our existing collections, primarily dry material but increasingly also 'wet' preserved material (e.g. Herniou *et al*., 1998). The application of molecular biology to museum collections can be used, for example, for identification (e.g. species identification of whale tissue), phylogenetic analysis, population genetics (variation in space and time) or the recognition of species differences integral to conservation management (e.g. Carranza *et al*., 1999).

Our collections, therefore, offer extractable information on change over time - variation in morphometrics, molecular genetics, species composition for example, and it is this aspect that is particularly relevant to the recently required role of the Department of Zoology as a depository of the Institute of Oceanographic Sciences' 'Discovery' collections. These represent a hard won, unique record, including for example unstudied Antarctic Ocean plankton samples from the 1920s, providing a potential benchmark for models of community change over time, as well as including unique taxonomic material rarely encountered. Table 3 lists more than 50,000 specimen jars from the Discovery collections incorporated into the museum collection by one of the two invertebrate divisions of the Department. These probably represent between 5 and 10 million actual specimens, to which can be added 14,000 molluscs, more than 4,000 sponges and bryozoans, 3,000 fish and 1,000 plus cetacean samples.

The Natural History Museum has a continuing role to play in preserving this rich legacy on behalf of the international scientific community, and in providing a mechanism to make such collections available to the world. The electronic databasing of the Zoology collections is clearly desirable, but the electronic listing of more than 27 million samples simply boggles the imagination. Without the introduction of unaffordable human resources, this task of databasing can only be approached incrementally. The database of the Department of Zoology stands now at more than 250,000 specimens and coverage across the taxa is inevitably patchy. In the last year, the Department has hosted 5,693 scientific visitor days, dealt with 16,577 enquiries and loaned out 6,565 specimens to scientists worldwide. In the first half of 2001, the Department of Zoology will be transferring its spirit collections (15 to 20 million specimens) into a new purpose-built facility which will also house many of its staff and visitors in modern offices and laboratories. This Zoology building is Phase 1 of the Museum's new Darwin Centre, which has the additional aim of allowing increased and informed public access to the Department's collections and science. The collections of the Natural History Museum are a resource to serve the scientists of the world, including the many types of marine scientists in their varied disciplines.

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Table 1
Approximate numbers of specimens of different taxa held in the collections of the Department of Zoology, Natural History Museum (1999 data)

Mammals	360,000
Birds	2,500,000
Reptiles/Amphibians	200,000
Fish	2,500,000
Molluscs	8,000,000
Crustaceans	3,500,000
Parasitic Worms	500,000
Annelids	290,000
Sponges	250,000
Bryozoans	105,000
Nematodes	104,000
Other Invertebrates	80,000
TOTAL	**>27,000,000**

Table 2
Approximate numbers of type specimens of different taxa held in the collections of the Department of Zoology, Natural History Museum

Mammals	8,000
Birds	9,000
Reptiles/Amphibians	8,500
Fish	15,000
Molluscs	80,000
Crustaceans	25,000
Parasitic Worms	22,000
Annelids	4,500
Sponges	140,000
Bryozoans	50,000
Nematodes	10,500
Other Invertebrates	5,000
TOTAL	**>375,000**

Table 3
Numbers of specimen jars containing particular invertebrate taxa incorporated from the 'Discovery' collections into the collections of the Department of Zoology, Natural History Museum

Cnidarians	2,932
Ctenophores	470
Ostracods	623
Calanoids	1,800
Euphausiids	5,570
Other crustaceans	8,273
Polychaetes	876
Other worms	63
Chaetognathes	2,304
Echinoderms	560
Salps	1,158
PLANKTON	**26,452**
TOTAL	**>51,000**

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BOSCOR –
The United Kingdom's national core repository

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Sediment cores stored under proper conditions can remain in pristine condition for several decades. BOSCOR ensures that cores will be preserved for the use of future researchers.

Introduction

Sediment cores and seabed samples have a wide range of applications and are the fundamental data source for information on seabed character and recent sedimentation. The sediments of the deep-sea floor commonly contain continuous records of recent environmental changes that have affected the Earth. Research into global climate change, slope stability, oil exploration, pollution assessment and control, surveying for laying telecommunication cables and offshore pipelines, coastal development and the siting of seafloor structures by government and commercial concerns all rely on data obtained from marine sediment samples (Table 1). Important oceanographic and earth science disciplines such as palaeoceanography rely on core material to elucidate past changes in ocean circulation and associated climatic changes.

Table 1:
End-users of core and seafloor sample data

Scientific research	Industry-related research	Training
• research into environmental change	• seafloor mapping and surveys (ground truth)	• undergraduate, postgraduate and professional training
• palaeoceanographic research	• hydrocarbon exploration	
• studies of slope stability	• national resource assessment	
• geochemical studies	• pollution assessment and control	
• geochronological studies		
• studies of sedimentary processes and dynamics	• environmental protection and monitoring	
• benthic surveys	• surveying for laying submarine cables and pipelines	
• productivity studies		
	• studies of acoustic response and defence applications	

Britain has had a long tradition of seafloor sampling dating back even before the beginning of submarine cable-laying in the mid-nineteenth century. Sir James Ross made one of the first successful attempts at recovering a substantial sample from the deep sea floor when he recovered several pounds of greenish mud from a depth of 1920m in Baffin's Bay, offshore Canada, in 1818. More deep-sea samples were recovered in subsequent years, but it was not until the voyage of HMS *Challenger* (1872-76) that enough samples were recovered to produce the first global seafloor sediment map. The voyage of HMS *Challenger*, led by Professor Charles Wyville Thompson of Edinburgh University, was the first large-scale expedition devoted to oceanography. It recovered a wealth of sample material from the seafloor (seafloor samples were recovered from 362 observing stations, spaced at uniform intervals along the 128,000 km track traversed during the voyage). John Murray, who edited the Challenger Reports, following the death of Wyville Thompson in 1882, oversaw the initial analysis of the recovered samples, which culminated in the publication of the milestone Challenger Report on 'Deep-Sea Deposits' (Murray and Renard, 1891), the first comprehensive volume on the sediments of the deep seafloor. Following Murray's death in 1914, the Challenger sediment samples were donated to the Natural History Museum, London, by his family in 1921, where they continue to form an important part of the museum's Ocean Bottom Deposits Collection.

Cores and bottom samples continued to be collected by British researchers investigating the seafloor but it was not until 1997 that a national core repository was set up to store deep-sea cores collected by the UK research community. Although, many other countries had recognised the scientific need and cost-effectiveness of storing deep-sea sediment cores for future secondary use much earlier. France and Portugal established national core repositories in 1975 and the Scripps Institution of Oceanography, San Diego, California, established a deep-sea core repository in 1955, although "systematic storage of cores" at Scripps began earlier (P. Worstell, pers. comm., 2001).

Why store marine sediment cores ?

- Marine sediment cores and sediment samples are very expensive to collect and can degrade rapidly if not stored under optimum conditions.

  A typical three-week coring cruise, which might collect 20 deep-sea cores, costs around £ 150,000.

  Cores dry out and fracture within months unless stored in airtight containers at 4°C.

  Cores stored in proper conditions can remain in pristine condition for several decades.

- Cores do not always demonstrate their full value within the first few years after collection.

  As new measurement techniques become available and new concepts evolve, existing cores can be re-sampled to add to the knowledge base.

- Major developments in our understanding of recent environmental change have come from material stored effectively in long-term core repositories.

  The North Atlantic 'Heinrich Layers' indicating six major collapses of the North American ice sheet during the last 60,000 years, are a prime example of the usage of stored material to, first, identify and later, to investigate in detail, a key global change phenomenon.

The British Ocean Sediment Core Repository (BOSCOR)

In response to the recognition of a strategic need to preserve cores and sediment samples collected by research ships and NERC-funded researchers, the Natural Environment Research Council (NERC) set up a national core repository at the Southampton Oceanography Centre in 1997. The core collection was based on the cores collected by the Institute of Oceanographic Sciences (Wormley) prior to its relocation to Southampton Oceanography Centre in 1995. These cores totalled 356 in number in March 1997, but the collection has now grown to 710 cores (March 2001), although the BOSCOR database contains exclusive data on 1178 sample stations (these include cores now longer extant, but which the repository holds some data on).

BOSCOR has a clearly defined purpose and user community:

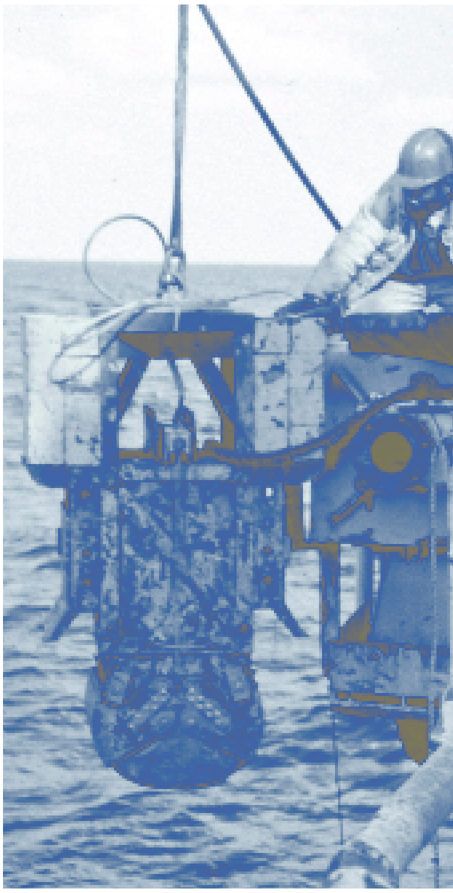
- to provide long-term storage of NERC's marine sediment cores
- to carry out non-destructive multi-sensor physical property logging of cores entering the repository, thereby maximising the data obtained from the cores
- to maintain a database of sediment cores and samples and their photographs, together with all data collected on those cores
- to promote secondary usage of its cores in scientific research
- to develop and utilise new innovative logging techniques and sensors
- to hold reference collections of comparative material (smear slides) for users to consult
- to allow UK scientists to sample at other core repositories worldwide through reciprocal arrangements

BOSCOR's user community:

Researchers, both in the UK and abroad, who are investigating Earth history and processes recorded in the sediments of the ocean floor and postgraduates undertaking training in the area encompassed by the NERC Mission.

Although BOSCOR, as a national facility, has only been in existence since April 1997, there are few UK University geoscience departments with a marine interest that have not been BOSCOR users. Indeed, many departments have been multiple users. About one quarter to a third of sample requests are from overseas researchers, mainly from the countries of the European Union, demonstrating the international importance of the BOSCOR core collection. Access to the cores is governed by certain rules, the most significant of which is that sample requests received within 5 years of core collection are passed to the principal scientist who originally collected the core, so he can assess whether the request is in conflict with his/her own research interest. If there is no conflict the request is granted. In this way the integrity of the principal investigators research, and that of any co-researchers, or associated Ph.D. studentships reliant on the core material, is protected. Sample requests made 5 or more years after core collection are honoured where possible, providing there is material available. Exceptions may be made if the size and number of samples is so large as to seriously deplete the core. In these cases, the BOSCOR management committee, which has both academic and NERC Centre/Survey representation, decides on the merits of the request.

Besides offering specialised facilities for long-term storage of sediment cores, BOSCOR also operates a suite of advanced state-of-the-art core logging equipment for community use. The main piece of equipment is a multi-sensor logging track which can provide continuous downcore physical property logs. BOSCOR was the first repository in the world to operate a split core logger which provides much higher resolution measurements that whole-core loggers (Gunn and Best, 1998). The BOSCOR split core logger can measure compressional (P) wave velocity, bulk density (using gamma-ray attenuation) and magnetic susceptibility downcore at user-defined intervals of typically 1-4 cm. P-wave velocity data can be used to create synthetic seismograms for comparison with seismic profiles, and magnetic susceptibility data may be used to identify palaeoclimatic events that might not be directly visible in the core (e.g. Robinson, 1990; Chi and Mienert, 1996). In short, multi-sensor core logging provides a rapid, effective, non-destructive method of gaining high-resolution quantitative information for a wide range of geological and environmental studies.



Sediment cores and seabed samples have a wide range of applications and are the fundamental data source for information on seabed character and recent sedimentation. They also contain records of environmental change.

Recently, a Minolta spectrophotometer has been integrated with the core logger to allow collection of high-resolution colour measurements. Sediment colour has become a increasingly recognised diagnostic property of marine sediments in recent years, and has been shown to relate to a variety of important parameters such as calcium carbonate and organic carbon content. Indeed, core colour changes have been shown to reflect climatic changes in remarkable detail (e.g. Thurrow *et al*., 1996; Chapman and Shackleton, 1998). BOSCOR is the first core repository in the world to have a spectrophotometer integrated with its multi-sensor core logger. Cores entering the BOSCOR repository are routinely logged using the multi-sensor logger and the data obtained made available to users.

BOSCOR operates a comprehensive website on the World Wide Web (www.boscor.org) and users can search the BOSCOR database online. This gives information (principally metadata) on the repository holdings. Further information on the cores, including core photographs, graphic logs, multi-sensor track (MST) data and related cruise reports are available on CD-ROM. The BOSCOR website also contains extensive public understanding of science and educational outreach pages. Specific attention has been given to describing the role that cores can play in understanding some of the environmental problems that face us today, for example, climate change and tsunamis caused by submarine slope instability.

BOSCOR staff represent NERC at meetings of the curatorial community at an international level. For several years, curators of repositories submitting metadata to the 'Index of Marine Geological Samples' database at World Data Centre A, National Geophysical Data Centre, Boulder, Colorado, USA, have met periodically to discuss curatorial issues and share knowledge on new techniques and procedures. BOSCOR staff have regularly attended these meetings and have taken a lead role in some initiatives arising from these workshops, for example, in the production of training aids for new core describers. BOSCOR has also taken a leading role in sample-based data management initiatives funded by the European Union. BOSCOR co-ordinates the EUROCORE project, funded under the Marine Science and Technology (MAST) programme of the European Union, which has set up a searchable internet database of seafloor samples held by European institutions (see Rothwell, this volume), promoting access to what was once an underexploited raw data resource.

The Future

The BOSCOR refrigerated core store at Southampton Oceanography Centre originally had a capacity to store 3,500 m of core. This capacity has now been reached. The growth of the BOSCOR core collection has been especially rapid in recent years due to the development of long, wide-diameter, piston coring systems and most new core entering the repository is now of this type. Although BOSCOR's remit is to store core collected by NERC ships and NERC-funded researchers, offers of core collected by private companies, as part of environmental surveys, are sometimes made. Acceptance of such cores, of course, increases pressure on storage space, but can provide additional material for scientific research, at no, or little, cost. Providing the offered cores have accurate locational data and are not degraded through prior inappropriate storage, BOSCOR has accepted such cores and integrated them into its collection.

Funding has been acquired to extend the BOSCOR refrigerated store and sampling laboratory. The extended store will increase the storage area four-fold and double the present laboratory space where visitors can lay out, describe and sample cores. In addition, funds have been acquired to purchase a digital X-radiography system for community use, and the extension will also contain a purpose-built x-ray laboratory. Half of the funding for the extension has been provided by the NERC and half by Southampton Oceanography Centre. Work will begin on building the extension in 2001 and it should be completed in the same year. The extended facility will have the capacity to store 14,000 m of core and current projections suggest that the capacity of the new store will be met sometime between the years 2010 and 2040. Further extension may be difficult due to limitations on available space and once the extended core store is full, if further extension is not possible, then consideration may need to be given to core disposal to make space for new acquisitions. This is a difficult problem as it is impossible to determine which cores may add to the knowledge base in future years.

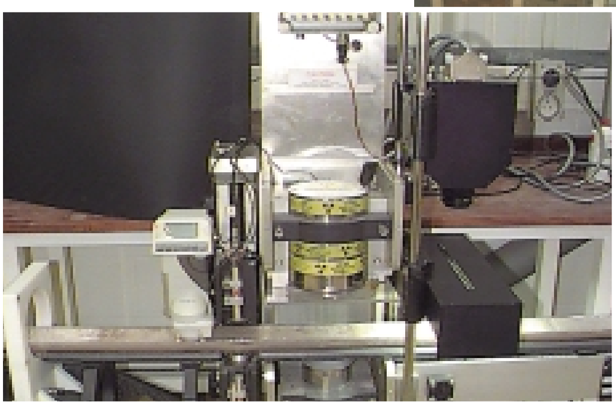
Like all NERC Services and Facilities, BOSCOR is funded in multi-year blocks (five in the case of BOSCOR) and subject to review prior to renewal. While periodic review of the need, use and quality of service of BOSCOR is right and proper, funding by five-year blocks, does mean that renewal is subject to the vagaries of government funding and the mood-of-the-moment concerning funding priorities. However, BOSCOR is a unique, strategic facility within the UK, it contributes to NERC's strategic aims and its mission complies with NERC's data management policy which recognises data as resources in their own right, which if properly managed and preserved can be used and reused by future researchers.
Such further uses often never envisaged in the first instance, commonly makes additional contributions to NERC's objectives (NERC Data Strategy Group, 1998).

Britain was late compared to other nations running marine geoscience programmes in setting up a national core repository. Core storage facilities offered by universities are very limited and prior to the establishment of BOSCOR, expensively-acquired core material was often thrown away following work-up of the primary data requirement, or kept in ambient temperature conditions, so that the cores eventually desiccated and became useless for further research. Marine sediment cores are ultimately the only true record of ocean history and the uses to which they can be put are constantly changing as new technologies develop. BOSCOR ensures that cores will be preserved for the use of future researchers and the development of new techniques that will extract more detailed information on recent earth history.

And we will really need this information – for as we enter a new millennium, we are faced with pressing environmental challenges, some of which may impact on Britain and Northern Europe directly. To take one example: will global warming affect Britain's climate through disrupting the North Atlantic circulation ? Broecker (1997) was among the first to recognise that changes in ocean circulation will have profound climatic impacts and that man-made global warming could trigger such changes. Britain's and Northern Europe's present pleasantly mild climate is dependent on the Gulf Stream transferring warmth from the tropics. Increased discharge of freshwater, derived from melting glaciers and ice sheets, into the North Atlantic could affect the density of surface water and so disrupt ocean currents. If ocean circulation patterns change, and the Gulf Stream significantly weakens or deflects further to the south, then Britain and Northern Europe would become 2-5° colder and precipitation would increase dramatically (Taylor, 1999). Effects on fauna, flora, agriculture and the quality of life could be profound. Recent research based on both ice and marine sediment cores suggests that ocean circulation, and resultant climatic, changes can be abrupt and occur over a few decades. Indeed, disruption of the Gulf Stream has occurred in the recent past, due to increased meltwater runoff from continents into the North Atlantic following the end of the last ice age around 12,000 years ago (see Manabe and Stouffer, 1995). Computer models suggest that green-house induced changes could have a similar effect (Stocker and Schmittner, 1997).
To understand Britain's future climate prospects, we need to more fully understand oceanic circulation and how it can change and on what timescales. To see how climate may change in the future we need to see how it has changed in the past. Models of past climate changes can only be validated by examining the past record preserved in marine sediment cores and ice cores. National core storage facilities, such as BOSCOR, will more than prove their worth in the coming years in helping to understand the past, and predict the future, world.

The British Ocean Sediment Core Repository houses over 700 deep-sea cores and exclusive data on 1200 within its databank. Cores do not always demonstrate their full value within the first few years after collection. As new measurement techniques become available and new concepts evolve, existing cores can be re-sampled to add to the knowledge base.

BOSCOR operates a suite of innovative state-of-the-art core logging equipment for community use. This equipment provides a rapid, effective, non-destructive method of gaining high-resolution quantitative information for a wide range of geological and environmental studies.



Cores are ultimately the only true record of ocean history. They contain records of climate change. To predict how climate may change in the future, we need to know how it has changed in the past. Models of past climate changes can only be validated by examining the past record preserved in marine sediment cores and ice cores.

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The British Geological Survey marine core collection

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Fig. 1
Distribution of sample stations around the British Isles held in the British Geological Survey's marine core archive

The British Geological Survey (BGS) is part of the Natural Environment Research Council, and is the Earth Science Data Centre for the UK. It has a long history of core acquisition and archiving going back to 1835. The current onshore collection amounts to 82 km of curated core, 650,000 samples of cuttings and over 1.5 million subsamples of analysed material, as well as the associated analogue and digital data. Further information on BGS and its data holdings is available at www.bgs.ac.uk.

BGS began to collect marine core and seabed samples in the mid-1960's (Fannin, 1989). Since then, there has been a continuous programme of core collection around the UK and adjacent deep-water areas, followed by analysis, interpretation and curation. BGS obtains marine core through its own survey programmes, by the donation of material from a variety of commercial and public sector organisations, and involvement in a very wide range of commissioned and scientific research projects. These projects include geological mapping, geological processes, geophysical and engineering properties, geochemistry and pollution, geohazards, environmental studies, sea-level and climate change, economic geology and data management.

BGS now has core and/or sea-bed samples from approximately 32,000 offshore sample sites from its survey programmes around the UK (see Figure 1), as well as the splits and subsamples retained after analysis. This amounts to almost 25,000 sea-bed samples, 21,000 shallow cores and 570 boreholes, which represents an average sample density of between about 5 and 10 km over the entire UK continental shelf. The shallow cores are up to 6 m in length and the maximum borehole length is 274 m. The core material occupies about 15,000 x 1 metre-length boxes.

Geological descriptions are available for all of the BGS seabed samples and cores. For most of the seabed samples, particle size analysis has been performed at least to the level of gravel, sand and mud content. These data have been used to produce Folk classification maps of the seabed sediments around the UK (for example, Stevenson, 1999). Phi or half-phi data for the sand fraction are also available for many samples. In addition, the carbonate content of the gravel, sand and mud fractions has been measured. Concentrations of up to 38 chemical elements have been measured in many of the samples (Stevenson *et al*., 1995). For the shallow cores and boreholes, various types of analyses have been performed depending on the nature of the material, the specific requirements of individual research projects and the resources available. Information for any one core varies greatly, but can include particle size analysis, geotechnical measurements, magnetic polarity, micropalaeontology and age dating. Indexes, metadata and many of the results of analysis are held digitally. There are also large volumes of descriptions, core logs, reports and associated descriptive data in paper format.

Almost all of the BGS core material is available for inspection or sub-sampling, subject to some restrictions. In general, fees are not charged for academic use, although copying, handling and transport charges may be applied if the work involved is significant. In return for access to the data, BGS generally requires

that any results of subsequent analysis and interpretation be provided to the archive for future use. Such 'new' data can be held as commercial-in-confidence for an agreed period of time. Unused subsample material should also be returned to the archive as some cores have been subject to intensive sub-sampling, testing and analysis over the years.

In addition to sample and core material owned by BGS, organisations and companies donate data to the archive, or BGS stores data on their behalf. This amounts to some 30,000 samples, with associated data held in 4,000 reports. These samples and cores may be available for inspection or subsampling, subject to obtaining permission from the owners of the data. BGS will consider storing and archiving any marine core material that is no longer required or that is not being actively managed. Such data can be held as commercial-in-confidence for an agreed period of time.

The archive provides a source of information for scientific research and commercial activities, reducing the need for expensive field-work, or providing time-based comparisons with newly acquired core. Projects include crustal structure, hydrocarbon prospectivity, basin analysis and modelling, geochemistry of seabed sediments, pollution, geological processes, glacial processes, sediment transport, slope stability, biological habitats and sea-level/climate change. The archive is used by universities and research organisations both in the UK and abroad. The main commercial users of the archive are the civil engineering, hydrocarbon and mineral resources sectors.

An example of how a core can be used by a number of research groups is BGS Borehole 88/7. This borehole, on the upper slope north-west of the Outer Hebrides in a water depth of 565 m was drilled to a total depth of 104 m below the sea bed. A sequence of Quaternary and late Tertiary sediments were recovered. The core material has been analysed by researchers from several universities and provides a record of climate change, oceanographic conditions and sedimentological build up of the outer shelf and slope. Another example is the use of core material collected during the LOIS project to examine sea-level and climate changes along the east coast of England.

Current projects that make use of existing BGS core material include multinational projects examining geological processes and development of the north-west European continental margin, PhD research into glacial processes on the north-west slope, regional assessments of slope stability, sediment transport and geohazards, pipeline and cable route studies, equipment installation, hydrocarbon prospectivity and sea-bed process modelling.

BGS is a participant in the EC-funded EUMARSIN (EUropean MARine Sediment Information Network) project, which, along with the EUROCORE project, is developing a European meta-database of marine samples and cores. The two projects have joined to create a single Internet database called EU-SEASED, and a GIS-based enquiry system is under development. The database is currently being populated. All holders of marine core or sample material are encouraged to submit information to the EU-SEASED database. BGS has already supplied information on over 30,000 of its sample locations for the UK and is preparing to deliver another 20,000 in the near future.

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The Atlantic Frontier Environmental Network surveys – A good example of how to develop sample collections

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Introduction

The National Museums of Scotland have recently acquired approximately 10,000 zoological specimens from the deep waters off Scotland. These specimens were collected in 1996 and 1998 as part of the largest and most comprehensive environmental research programme ever funded by UK industry (through the Atlantic Frontier Environmental Network – AFEN – consortium). The survey was the first large-scale environmental programme to take place in the deep waters of the Atlantic margin in the area to the north and west of the Shetland Islands.

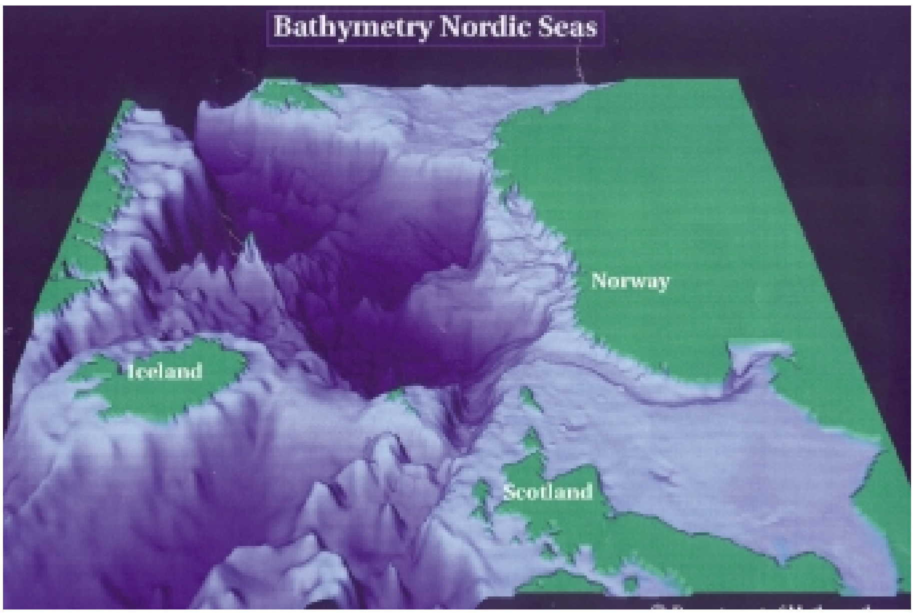
The Atlantic Frontier Environmental Network (AFEN)

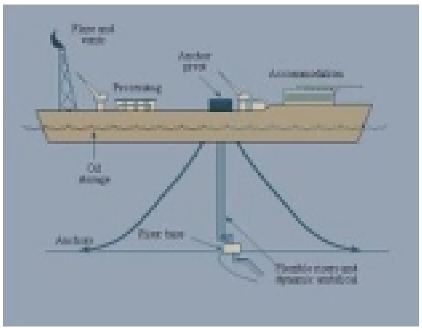
AFEN is an industry consortium that manages the environmental programme for oil exploration and production in the Atlantic margin on behalf of the oil and gas industry. It is compised of representatives from all the operating companies, the Department of Trade and Industry, the Scottish Executive and the Joint Nature Conservation Committee with administrative support from the Centre for Marine and Petroleum Technology (for more information about AFEN please visit their website: www.ukooa.co.uk/issues/Afen/index.htm).

Surveying the sea bed of the Atlantic frontier

Environmental data are essential in assessing whether operations in an area can be carried out with the minimum impact to the marine environment. The logistical problems of surveying an area of 30,000 square kilometres (larger than the area of Wales) coupled with deep water and strong currents made existing shallow water sampling methods almost impossible to follow. New approaches were required to gain detailed information over a wide area.

Perspective bathymetric map of the northern European continental shelf (Atlantic Margin) showing the Faroe Shetland channel, Wyville Thompson Ridge and the deep Norwegian Basins. The AFEN survey areas were to the west of Shetland and west of the Hebrides on the Atlantic Margin)





Floating production storage and offloading vessel. A deep sea drilling platform for exploration and extraction

Day grab sampling equipment used to sample the seafloor during the AFEN surveys

The WASP camera system (Wide Angle Survey Photography) which gives a 'bird's eye' view of the sea bed

right: Benthic sampling sledge used to collect bottom-dwelling organisms

Pcynogonid (sea spider) recovered during the AFEN surveys

Lophelia deep water coral

Working in the laboratory at the National Museums of Scotland

To obtain a wide picture of seafloor types and benthic communities present, a range of very specialised instruments and techniques were required. These included acoustic, visual and biological sampling techniques, specifically TOBI (Towed Ocean Bottom Instrument), which produces sidescan sonar images of the seabed on a similar scale to satellite photography, and the WASP survey camera system (Wide Angle Survey Photography), which gives a narrower 'birds-eye' view of the seabed. In addition, three types of sampling equipment were used: Day grabs, box corers and 'mega' corers.

The data obtained from the AFEN seabed surveys were analysed by Southampton Oceanography Centre and the benthic samples were identified by an environmental consultancy, CORDAH, now based in Scotland. The resulting report records more than 2,000 species (including the pcynogonid), many of which are new to science.

New discoveries

There were many new discoveries about this area of the ocean resulting from the AFEN surveys, including the presence of 'Darwin Mounds' the structure of which is unknown. The mounds deposit a plume of material which has an interesting associated fauna including huge protozoans measuring 500 mm in diameter (most protozoans are less than 0.1mm in diameter) and the cold water coral *Lophelia pertusa.* This major survey of the UK's northern continental margin took 2 years but it has provided an invaluable starting point for further research on colonies of *L. pertusa.*

AFEN and the National Museums of Scotland

The biological specimens recovered during the AFEN surveys are currently being incorporated into the collections of the National Museums of Scotland, where further work continues on describing new species found within the recovered fauna. The deep-sea animals from the AFEN seabed surveys will greatly contribute to the Museum's collections and facilitate further deep-sea research and eventually our understanding of this largely unknown environment.

The AFEN surveys provide a excellent model of how industry and museums can co-operate. In adding to the knowledge base by depositing samples collected as part of industrial activities in public institutions they can be preserved for future research. As the west of Shetland Atlantic margin is a relatively unexplored region, many of the species will be unknown and the community assemblages are of great interest. In order to facilitate a greater understanding of this deep-sea environment AFEN have established a bursary award scheme to promote further research (for further information please search the UKOOA website www.oilandgas.org.uk). Researchers with an interest in systematics and ecology of the area may apply for funding. The museums role is to co-ordinate the loan and return of samples so that they are available to the wider scientific community.

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Archiving seafloor photographs and video

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Introduction

Remotely operated photographic and video equipment of various types have been used to obtain images of the seabed for over 50 years. Usually the images were obtained for specific projects so the resulting films or video tapes remained in the files of the scientists who ran the projects. Even in many government research institutes, let alone the university marine laboratories, there seems to have been little attempt to archive such material. With time, those responsible for such material moved to other jobs, retired and in some cases have died. Inevitably material that might be of value has been lost or remained inaccessible to those who might have found other uses for it. Images of the seafloor beyond diving depths are relatively expensive to obtain and can have many uses beyond those for which they were originally obtained. They may even have uses as records of long-term change.

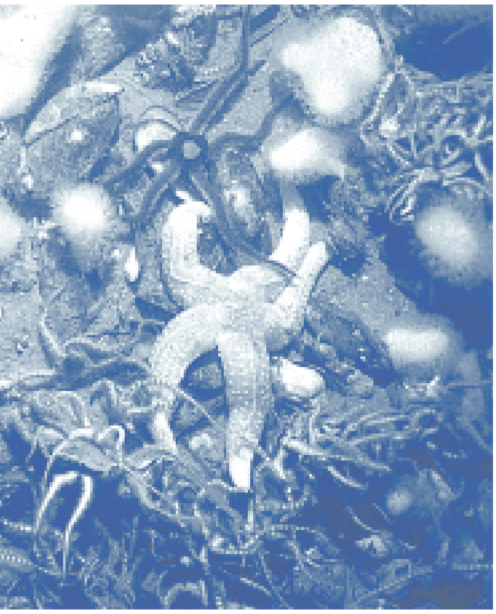
The Irish Sea Seabed Image Archive

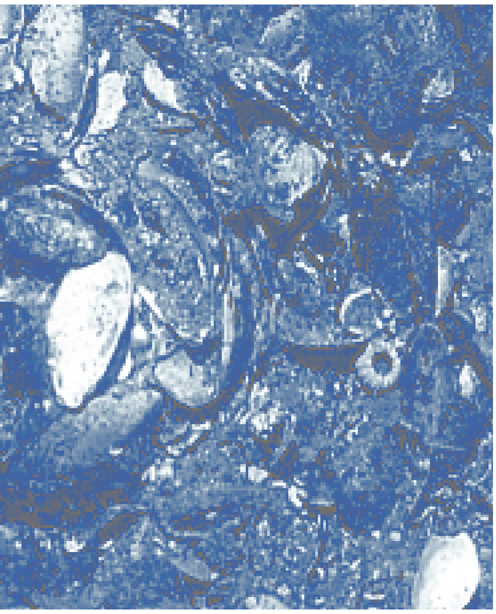
For the restricted area of the Irish Sea (ICES Area VIIa) and limited to remotely taken still photographs, a DETR funded project was undertaken by UW Bangor to assess how much material exists, who holds it, what condition it is in, what geo-reference data exists to go with it and how it might be brought together in a database archive. A report titled Irish Sea Seabed Image Archive (ISSIA): A Directory of Seabed Camera Studies in the Irish Sea was completed at the end of 1999 by P.L. Allen & E.I.S. Rees. This report did not deal with video tape records or photographs obtained by divers. The later were omitted because it was felt that the Marine Nature Conservation Review had an adequate collection on the inshore biotope photographs covered by that survey. Eight research institutes provided material for the Irish Sea archive, in some cases several different research groups within a single institute site had material. Most of the photographs were taken with cameras mounted on sledges, records being located of 329 camera sledge tows in the Irish Sea. A reference directory was produced of these tows.

A representative selection of over 300 stills were scanned to produce a digital archive. We aimed to get representative coverage of as much of the Irish Sea as possible. We also tried to digitise representative material from each of the contributing research groups. The images were converted into a digital JPEG file format for the database. The ISSIA database on a CD-ROM runs under Microsoft Access 97. In addition an interactive presentation was produced to allow a wider audience to appreciate the range of seabed types found in the Irish Sea.

The Irish Sea has a particularly good sequence of shelf seabed types within a relatively small area. These include epifauna encrusted lag boulders and gravel, left after shorelines advanced following the last glaciation and which are swept by strong tidal currents. Biogenic reefs formed by beds of the horse mussel *Modiolus modiolus* overly the lag in places and photographs provide a particularly appropriate means of recording the state of these. At the other end of the scale of dynamic stress bioturbation of the cohesive muds by numerous megafaunal burrows is well illustrated by photographs.

Video and still images are valuable for putting the seabed environment into context. However, until now images have fallen into a gap somewhere between the numerical archives of oceanographic data centres and museum collections with actual samples.





The Irish Sea Seabed Image Archive should be seen as a pilot project providing experience as to what, it may be possible and worthwhile to retain in digital format. Inevitably, in a rather turbid sea such as the Irish Sea, a proportion of the photographs just usable for their original purposes are hardly worth keeping. Equally, with remotely operated equipment, the gear is not always fully on the ground or there may have been some malfunction so a measure of selectivity is required. Choice of the sharpest images obtained under good clear water conditions during summer neap tides, has to be balanced by the retention of images that were representative of the range of benthic biotopes.

In digital format the photographic records should last better than film, be easier to store and be more accessible. In digital form the images can be post-processed if the illumination was uneven, as it often is from sledge mounted systems. Problems of film deterioration through the growth of fungus are avoided and ease of copying means that the best images are less likely to be dispersed into lecture slide sets.

The need to archive photographic images

A case can be made for replicating what was done for the Irish Sea for other parts of the sea which have been worked by several different organisations. The Irish Sea project was just a pilot undertaken through a university. Still to be considered is which of the several UK agencies with responsibilities for marine data, would be best placed to take this forward. Copyright issues have also still to be resolved in many cases.

For many years, video cameras have been run for similar purposes as the sledge mounted still cameras. Various different analogue video formats were used so that there are tapes now in store that it is difficult to find machines to play them on. In some laboratories tapes were re-used once analysed for the original purpose, even though such tapes were very cheap by comparison with the ship-time used in making the recordings. Whether VHS or SVHS recorders were used, in general rather poor freeze frame still images could be obtained from the analogue systems. Though they were excellent for putting the seabed environment into context. Often in shallower water the sledges were seen to move as a series of rushes so that although in theory views were obtained of continuous transects, in practice the best views were obtained when the sledge intermittently stopped.

Fairly recently digital video cameras intended for the top end of the hobby market have become available. These produce near broadcast quality at a price far below the cameras used by broadcasters and of a size that will fit in underwater housings. Experience off the Welsh coast during SAC monitoring demonstration trials under the EU LIFE-Nature programme have allowed protocols to be developed for the use of these. The digital camcorders have within them mini-tapes of about 1 hour's running time. The cameras and housings also have output ports allowing transmission of the signal to the ship. Though there is some loss of definition when the umbilical is over 60 m long such camcorder-based systems have been used with 300 m umbilicals. Primarily the image obtained at the surface, while the gear is down, is used to check it is working and the correct speed over the ground is maintained. Analysis and tape editing is done with the better quality signals from the mini-tape in the camera. In shelf seas 1 hour tapes give enough records for each station deployment. Software to enable digital video to be edited or freeze frames captured is now readily available for PC and Mac desktop computers.

The basic practicalities of archiving seabed photographs have been established. The need now is for wider considerations of where responsibilities should lie and how best to bring video and particularly digital video under a similar framework.

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Marine Invertebrate Collections in the National Museum of Wales

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Collections are fundamental to our National Museums. They are our *raison d'être*, underpinning all other functions of research, interpretation, education and display. On a wider scale, these collections are also historical representations of species and environments (e.g., Brooke, 2000a) – capable of yielding information at a number of different levels, including previously unforeseen insights through the application of new analytical techniques (e.g., Rosenbaum *et al*., 2000). In the marine context, benthic invertebrates are important because our taxonomic and ecological knowledge of many groups, and most species, is so very poor. These animals are, however, significant in marine food webs and have great potential for signalling short- and long-term environmental change (whether due to natural fluctuation, pollution, climate change, species invasion or whatever). Despite a widely acknowledged shortage in taxonomic expertise (e.g., Scheltema, 1996; Lee, 2000), it is vital that specimens and benthic samples – often collected at much effort and financial cost – are conserved, maintained and made available for research. All such materials are unique, representing situations at a particular time and place, and thus irreplaceable.

Excluding the extensive and well-established molluscan collections (including the important Melvill-Tomlin collection), the National Museum of Wales had relatively small holdings of marine invertebrates prior to the early 1980s. Since then there has been a rapid expansion associated with the development of a marine biological section, with particular emphasis on the Polychaeta.

The holdings can be broadly categorised under two headings:

- Material collected directly by Museum staff.
- Material donated by external workers or institutions.

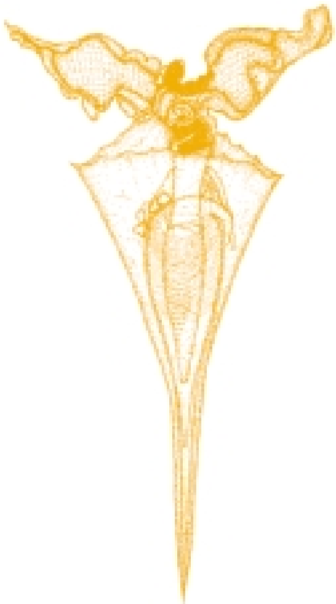
The first range from small collections carried out for taxonomic research purposes to large scale benthic investigations such as those in the Irish Sea (Mackie *et al*., 1995; Mackie *et al*., 2000; Wilson *et al*., 2001a-c) and, more recently, in the Seychelles (see the main BioSyB web site http://www.nmgw.ac.uk/biosyb).

The second can also be subdivided into smaller collections donated for research purposes (e.g., type or voucher specimens associated with taxonomic papers) and the (often) larger donations derived from environmental survey work such as carried out for the oil and gas industry. The latter are significant because of problems associated with their ownership, scale, value (monetary and scientific), storage, maintenance, accessibility, and subsequent use.

In relation to the oil industry, contractors were often unclear about their specimen responsibility or ownership following completion of their contracts. Most retained the specimens for a period (e.g., 5 years) after contract completion however, after this, the situation was often unclear. Due to space restrictions and maintenance problems, identified specimens could be re-amalgamated into containers by sampling station (e.g., as occurred with the AFEN material; see Chambers, this volume) or survey, or even disposed of! The ownership ambiguity and a consequent understandable reluctance to deposit the material in museums have largely been overcome. In 1998, a proposal (see Mackie, this volume) was made to the UK Offshore Operators Association (UKOOA) and they agreed that UK Oil Companies would allow their contractors (if they so desired) to deposit their specimens in, for example, National Museums that could guarantee their safe-keeping, cataloguing and availability for scientific study.

Fig. 1
Benthic samples in 5 litre buckets
Photograph: Michelle Forty

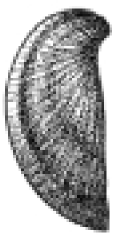
Fig. 2
Registered museum specimens in modern mobile storage units
Photograph: Teresa Darbyshire

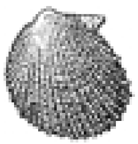


At the National Museum of Wales we have thus acquired much oil and gas related survey material from companies such as Environment & Resource Technology, Edinburgh (ERT), and the Oil Pollution Research Unit, Pembrokeshire (OPRU; now Cordah, Edinburgh). These specimens, and their associated collection/locality information (see Burgman *et al*., 1995; Snow & Keating, 1999), represent invaluable taxonomic and historical resources that must be conserved, but they also have major curatorial implications for the Museum. Apart from the simple storage space required, there are curatorial costs from the need to retube, relabel and catalogue the material. These financial and staff time costs can be considerable (see also Graves, 2000; Brooke, 2000b), particularly when quantitative samples have to be moved from bulk (Fig.1) through to fully registered individual species in modern storage systems (Fig.2). Hence, prioritisation in the curation process is an absolute necessity. In general terms the decreasing order of priority is:

- type/cited/voucher specimens
- backlog specimen curation (i.e., getting existing collections on to electronic databases)
- identified survey material (with associated locality information)
- sorted or previously identified, but now amalgamated, specimens
- bulk unsorted benthic samples.

Finally, museums are increasingly making improved access to collections a priority and, in an age of rapid electronic communication, this includes making collection data available on the Internet. Over the last five years, we have introduced net access to the basic fields in our Filemaker Pro™ databases of curated Mollusca, and marine Annelida, Arthropoda and 'Other Phyla'(http://zoology.nmgw.ac.uk).
For the last three groups, emphasis has been placed on making information available – whatever the possible accuracy of species identification (see also Scoble, 2000; Wirtz, 2000; Brooke, 2000b). However, a capability for upgrading both identification accuracy and species synonymy has been built into each of the three databases. For reasons relating to species rarity/vulnerability, collector/donator privacy, intellectual property rights etc. (see also Graves, 2000) access to all of the fields in each of the four databases can only be by application to the appropriate curator.





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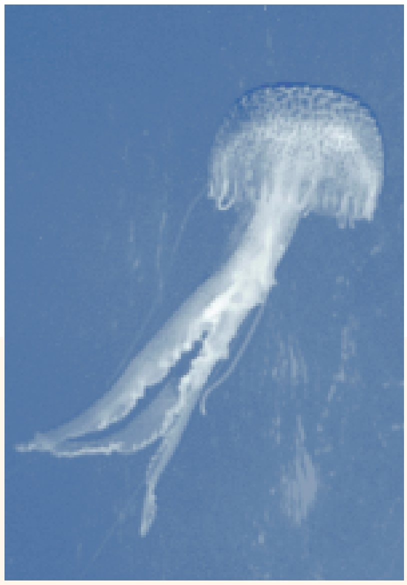
back

A proposal for the safe-keeping of marine invertebrate specimens collected during environmental survey programmes



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Preface

The proposal detailed below was first sent to members of the United Kingdom Offshore Operators Association (UKOOA) in September 1998. It was accepted, and UKOOA informed all its major contractors of this in January 1999. In 1998 UKOOA also commissioned Heriot-Watt University and Environment & Resource Technology (ERT) to collate all the data from UK offshore oil and gas surveys. This was published as UKOOA (1999) *Inventory of U.K. Offshore Oil & Gas Environmental Surveys* 1975-1999. 278 pp. A CD-ROM version is also planned.

Summary

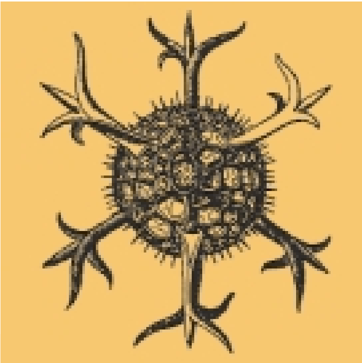
This proposal sets out the case for the voluntary placement (for safe-keeping and for taxonomic study) of marine benthic invertebrate specimens from environmental surveys in suitable institutions. These specimens form the basis for all subsequent data analyses (ecological, taxonomic, geographical) but, at present, are rarely stored and maintained in adequate conditions and are not readily available for pure scientific study. With an upsurge of interest in marine biodiversity *per se* and the launching of species recording schemes such as the *Marine Life Information Network* (MarLIN) this is an absolute necessity. Current offshore developments in new, previously uninvestigated, areas such as west of Shetland highlight the importance of making specimens (many undescribed) available to taxonomic experts. The United Kingdom Offshore Operators Association (UKOOA) can help change this situation by encouraging the UK Oil Companies to allow their contractors to deposit their specimens in, for example, National Museums that guarantee their safe-keeping, cataloguing and availability for scientific study.

Introduction

The expansion of offshore oil developments in UK waters since the mid 1960s has produced a wealth of information about benthic invertebrate assemblages; their species compositions, abundance, distributions, etc. Surprisingly, however, relatively little of this information has been widely published. There are some studies concerning specific oilfields (e.g., Addy *et al*., 1984; Hartley, 1984; Hartley & Bishop; 1986) and some concerning the taxonomy of selected species (e.g., Mackie, 1984, 1991; Petersen & George, 1991). Much less has been produced using collated data (e.g., Kingston, 1987), though the recent commissioning of a collation of data from offshore oilfields by UKOOA will undoubtedly rectify this (see preface).

One of the reasons why, for example, relatively little taxonomic work has arisen from the oil industry work is simply that the specimens are not readily available to specialist taxonomists. Indeed, they may not be aware of their existence. Environmental consultancy biologists are well aware of the numerous taxonomic problems they encounter, but the links with specialists who may be able to help them are sporadic. As the oil industry moves into deeper, and previously unstudied, areas the taxonomic problems encountered will escalate.

Following on from the UK Government's *Biodiversity: The UK Action Plan,* launched in 1994, two years after the landmark Earth Summit in Rio, programmes such as the *Marine Life Information Network* (MarLIN) – which is affiliated in turn to the *National Biodiversity Network* (NBN) – have been launched.
The success of MarLIN is dependent upon species data sets and the quality of these ultimately rests upon the accurate identification of the specimens.



The specimens

The importance of maintaining the specimens collected in these surveys in suitable storage would therefore seem self evident, however, this has received little attention. In fact, Environmental Consultancy groups are often uncertain of their position concerning the specimens. Most will maintain their own selected reference collections for each survey and will also undertake to store the bulk of the specimens for a certain time (e.g., 5 years) after completion of a contract. The situation thereafter is unclear and specimens may dry out (mostly becoming scientifically useless) or be actively discarded for space reasons.

Further, these consultancy groups are contracted to carry out very specific pieces of work and the maintenance of specimen collections will not be budgeted for. Increasingly, after identification and enumeration, specimens of species are not kept in individual vials; rather, each set of species from a station is returned to a single container. As well as being a retrograde step (wasting all the identification effort) this reduces the availability of individual specimens or species. To make the material fully available it would have to be reidentified!

At the National Museum of Wales we have been working towards securing such collections for posterity and, in some cases, have even supplied museum vials and pre-printed labels to prevent the amalgamation of previously separated species on the understanding that the material be ultimately lodged in our collections.

Once received by us, the specimens are catalogued using a relational computer database, double tubed in 80% alcohol/2% propylene glycol for long-term storage and integrated (in systematic order) with our other collections in an easy access mobile racking system. We will also conserve bulk samples, though making the individual species available from these is more highly dependent on manpower.

The Proposal

I would like to propose that The United Kingdom Offshore Operators Association (UKOOA) help promote the safe-keeping of these important benthic collections by encouraging the UK Oil Companies to allow their contractors to deposit their specimens in, for example, National Museums that guarantee their safe-keeping, cataloguing and availability for scientific study.

In this way everyone will benefit:

- The Oil Companies for being acknowledged as contributing to our knowledge of offshore benthic biodiversity and enabling taxonomists to tackle and solve problems of species identity.
- The contractor will likewise be acknowledged and will gain from the resolution of taxonomic problems by specialist taxonomists.
- The specialist taxonomist will benefit from the more ready availability of a wider range of specimens and will be better placed to identify and resolve problems at different taxonomic levels.
- Ultimately science in general and species recording schemes benefit from more accurate identifications.

The safe-keeping of the actual specimens is a logical extension to UKOOA's own collation of oilfield data and to species recording schemes such as MarLIN.

Conditions and Safeguards

Clearly if Oil Companies and their contractors are to agree to this proposal there have to be some conditions and safeguards for both of them and any institution agreeing to take the specimens.

I foresee the following as being of most importance, but am open to others that may arise:

1. The Oil Company and contractor must be acknowledged in any cataloguing, labelling of specimens and ultimately in any scientific publication citing the said specimens. If the information on original identifier is made available this can also be acknowledged as appropriate.

2. All donations of specimens should be voluntary or as directed to the contractor by the Oil Company. Here, an Oil Company may wish to consider whether the eventual location of the specimens could usefully be inserted as a clause in any future contracts. This would streamline the whole process and make everyone involved aware of the situation from the beginning.

However, I have no wish to proscribe absolutely in any manner that may conflict with, for example, a contractor's own taxonomic plans for particular specimens. It is important to realise that any material voluntarily donated would be available for study and any donor that indicated a specific requirement would naturally have first call on the taxonomic use of these specified specimens.

3. No use of the specimens would be undertaken that might pre-empt any publication by the Oil Company, contractor, or those working with or for them.

4. As well as the specimens themselves, the institution of safe-keeping, also requires some basic associated data (i.e., at least a general latitude-longitude position, approximate depth, general sediment type, and date of collection). Without these a specimen is of limited value; its identity being the only one. As a component representative of a benthic assemblage at a particular place and time the other information is necessary for future comparison and interpretation.

It is important to stress that in making this proposal I have no desire for confidential or sensitive information. If actual reports or other environmental information were made available, so much the better, but the basic information listed above in brackets will be adequate. Nevertheless, I understand that technically a lot of the reports are already in the public domain and much of the associated environmental information will be available in the future as part of UKOOA's own commissioned collation of data from offshore oilfields.

5. The institution of safe-keeping must be able to maintain the specimens in proper storage containers with suitable preserving fluid and labelling in an ordered manner such that their location can be rapidly determined and particular lots retrieved. The specimens should also be adequately catalogued and ideally their presence determined simply by consulting an institutional database.

6. No commercial gain would be obtained by the institution of safe-keeping from loaning donated specimens or disseminating information specifically associated with the specimens.

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Suitable institutions for conserving the specimens

It is likely that, in most cases, the most suitable institutions to take the specimens would be one of the main National Museums. Aside from my own museum, the National Museum of Wales in Cardiff, the main ones would be the National Museums of Scotland in Edinburgh, the Ulster Museum in Belfast and the Natural History Museum in London.

There may be other suitable institutions, but even some of the large National Museums may not have the necessary manpower, storage space or facilities to cope with such voluminous material as oilfield survey specimens.

At the National Museum of Wales, I currently have 2 assistants who spend a large part of their time curating both donated and in-house collected material. Our collections are international in nature and have numerous type specimens. In the last year we have placed over 12,000 species lots (i.e., vials) of polychaetes alone on an electronic database. It is hoped that this will be available for Internet consultation in the near future, following evaluation of a pilot scheme concerning some of our molluscan holdings. We can take all Marine Invertebrates, though because of our expertise in polychaete worms and molluscs these groups would be our priority.

I cannot speak directly for other institutions, but know that Susan Chambers of the National Museums of Scotland is interested also and would welcome the acceptance of my proposal.

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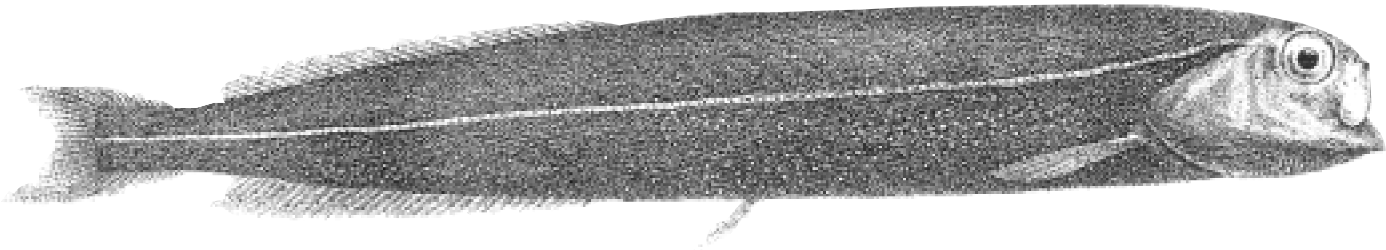

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The role of extensive existing sample collections in geobiological, ecological and sedimentological research

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Jars containing material in the Discovery Collections stored at Southampton Oceanography Centre

Introduction

Extensive collections of marine sediment and faunal samples are accumulated in the course of major scientific investigations. These programmes may go on for several years and many thousands of samples may be collected during the lifetime of such projects. During the 19th and early 20th century, many classic marine sediment and faunal collections were amassed. Some of these collections are stored and curated in major museums but others are dispersed and are less well curated. In many cases, due to changes in the financing of science which are based largely on the political mood of the moment, the on-going long-term programmes of work to study these samples and to publish the results are terminated prematurely and the samples remain with much of the research on them either not completed or never initiated.

In the case of collections which have been worked up in terms of the original research project or the survey for which they were collected, they can nevertheless be used for further investigations which were not envisaged at the time the samples were collected.

Marine samples are by their very nature expensive – and sometimes very expensive – to collect. Not only are there the costs of running the research vessel with all the overhead costs that entails, there are the costs of each of the scientists and the support staff required for the successful completion of the project both at sea and thereafter. Imponderables such as weather conditions, failures of the sampling equipment and occasionally systems on the ship make the collection of these samples anything but a routine operation.

These costs of collection are considerable but in many instances they are rarely if ever consciously considered when any decisions are made regarding the subsequent storage and proper curation of the samples. This can be explained in that budgets are allocated and spent over fixed periods and once spent during the accounting period, the account is closed in financial terms at least.

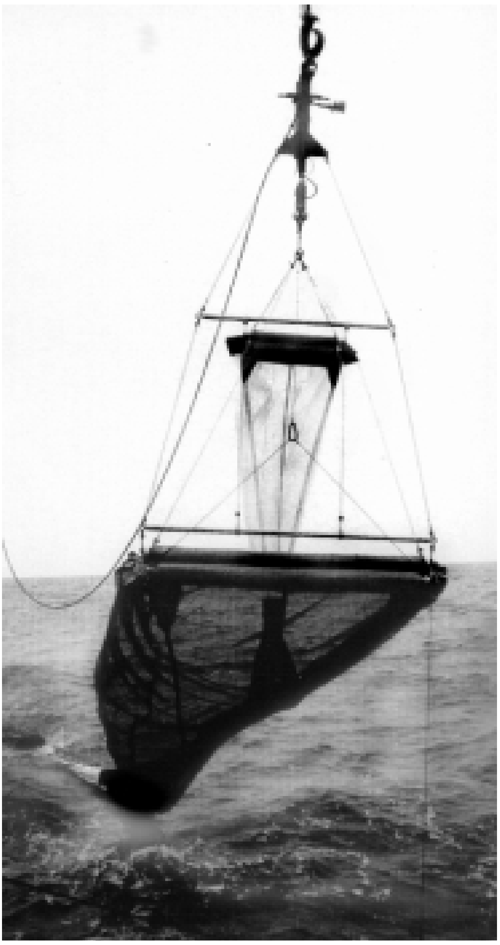
In any assessment of the value of collections, the cost of replacing the sample or specimen should be a major consideration in the estimation of its value. Indeed, in many cases regarding marine specimens and samples, replacement would not be practicable or even possible.

Curation and storage

Provided these sample collections are adequately curated at all stages and the records pertaining to the methods of collection and any subsequent treatment the samples received are well documented, they can be effectively used by later workers. It is often very relevant to later workers if the reasons for the samples having been collected in the first place are adequately recorded. Any initial observations made at the time of collection are also invaluable. If much or all of this additional information is available, then the collections have great value to science.

In many cases the samples were collected over a fixed period and therefore represent an invaluable asset in terms of the assessment of subsequent changes in the faunas or the sediments with time.

Original labels are of great importance and should remain with the samples together with any subsequent observations made by later workers. Care must be taken to use permanent inks or pencil for labels. Labels should be put both inside and outside the jar, tub or core and the labels must have permanent adhesives.



Standards of curation in accordance with the Museums Registration Scheme should be applied in all museums and repositories (Museums and Galleries Commission, 1995). This should be regarded as the best minimum standard to be achieved. These criteria include:

1. *the need for the museum to have a mission statement and forward plan;*
2. *access to a professional curator and professional museum management;*
3. *a properly constituted governing body such as a charitable trust, local authority or limited company;*
4. *an aquisitions and disposals policy agreed by the governing body;*
5. *have formal arrangements to manage collections;*
6. *the museum needs to be open to the public, sometimes by arrangement.*

Collections are not disposable assets. Museums must be based either on an Act of Parliament or Royal Charter or a Local Government Act or a formal decision of a University Council. This therefore excludes research institutes and university departmental museums.

All collections require curation and maintenance such as the provision of appropriate storage temperatures, humidity control and topping up when necessary in the case of collections preserved in spirit. These conditions are generally to be found in National Museums, Local Authority Museums and University Museums.

Collections are always subject to the vagaries of changes in curatorial policy, personnel and of course, financial stringencies. Some museums have a particular curatorial policy based on the mission statement which can sometimes clash with the best way to curate particular collections. For example, some systematic spirit collections are curated on purely taxonomic principles. This would mean that regional collections showing the range of faunal diversity and local variations which are best stored as assemblages might be split into component taxa. This might be good for the promulgation of taxonomic research but it would mean that regional faunal studies dependent on access to assemblages would be almost impossible to undertake especially if a study of faunal changes in a particular area through time is being undertaken.

The vulnerability of collections can be considered in terms of a possible hierarchy. Perhaps the most vulnerable are private collections, possibly made by an amateur naturalist, which are subject to the vagaries of disposal when the estate of the collector is dispersed.

Collections made by research students, post doctoral research assistants and other temporary members of university departments are frequently inadequately curated by the collector and are frequently disposed of following the departure of the original collector. Collections made by members of staff in university departments during their working lifetimes may be disposed of when they retire and there are subsequent pressures on storage following the recruitment of new younger staff. Such collections deposited in universities which have Registered Museum status are relatively safe. These collections must be in good order, however, before they are deposited in the museum. Some university departments do have a curator on the staff who is responsible for both the teaching and research collections held within the department.

Collections in research institutes are under serious threat after a project is terminated and the staff working on the project are dispersed to other unrelated activities. It is rare to find senior staff in research institutes who, when faced with short term crises, are prepared to take the longer term view of collections relating to a field of science in which they have little expertise or interest. Such collections are under their greatest threat when such research institutes and laboratories relocate to new sites, or worse still, close permanently. Skips filled with records and samples are all too familiar a sight at such events.

Great care and vigilance is required if collections are to be moved from one location to another. If possible, however, collections should be kept together to maximise their value to science. Documentation is under serious threat every time collections are reviewed or moved. Vital records can be destroyed in the mistaken belief that the notes are of no value. Many scientists are guilty of providing documentation which is adequate for their purposes at the time but which is largely indecipherable decades later.

The dangers to the safety and integrity of these collections increase as time passes. This is especially the case following the deaths of the original collectors and probably to an even greater extent following the deaths of the first generation of subsequent investigators.

CASE HISTORIES

1. *Institute of Oceanographic Sciences (IOS) Marine Sediment and Geobiology Collection*

The Marine Geobiology Collection was built up between 1970 and 1984 from the continental shelf and upper continental slope in the north-east Atlantic west and north-west of Scotland, Orkney and Shetland and in the western English Channel. The samples were collected as part of a major long-term project investigating the origins of biogenic carbonate shelly sediments and into the geobiology and taphonomy of particular key members of the shell-bearing invertebrate fauna. The project was run as part of the scientific programme of the Marine Geology Group. They were collected on a series of cruises when grab and dredge samples of the sediments, biogenic sediments and shell-bearing invertebrate faunas were obtained together with side-scan sonar and echo-sounder records. Underwater video tapes and photographs were also obtained as part of the project using a purpose built IOS towed television and camera sledge. The collection was originally stored in purpose built storage at IOS Wormley. The collection consists of some 11,000 jars, tubs and phials of unsorted dried sediments, sorted shell gravels and some faunal samples preserved in industrial spirit. Throughout the 1970's and early 1980's, research was undertaken on these samples and a number of papers were published on the results. During this period the samples were properly maintained and

Fig. 1
Part of former IOS Marine Geobiology Collection now stored on open shelving in the NHM store, Wandsworth

Fig. 2
Rows of hardwood cabinets housing the NHM Mineralogy Department marine sample collections

Fig . 3
Cabinet opened to show sliding shelves containing part of NHM sediment collection

Fig. 4
Part of Plymouth Marine Fauna Collection in original cabinet at Raglan Barracks, Devonport

Fig 5.
Jars containing part of Plymouth Marine Fauna spirit collection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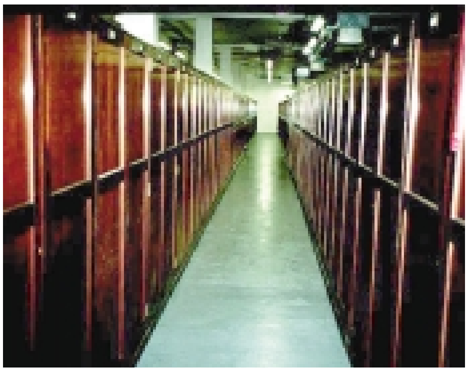
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curated. In 1984, following the disbandment of the Marine Geology Group at the Institute, research on these samples was terminated and the collection was no longer curated. During subsequent years the collection was consolidated due to anticipated pressure on storage and some of the larger bulk samples stored in plastic tubs were discarded. This was particularly unfortunate as the predicted pressure on storage did not happen.
When the IOS was moving to the Southampton Oceanography Centre (SOC), the question arose as to the future of the collection. As it was not envisaged that work on the samples would form any part of the SOC research programme and no provision had been made for the storage of the collection at the SOC, negotiations took place with the Natural History Museum (NHM) regarding the future of the collection. The collection was evaluated by the NHM and was considered to be of national importance and consequently it was moved in its entirety to the NHM store at Wandsworth where it is now housed *(Fig. 1)*. The video tapes are in the NHM store and the side-scan and echo sounder records are stored at the SOC. Research on the collection has recommenced and continues in the Geology Department, Royal Holloway University of London.

The collection is now administered by the Department of Mineralogy and is stored alongside the extensive NHM marine sediment collection which is stored in purpose built hardwood cabinets *(Fig. 2)*. These contain sliding shelves for the storage of the sample jars *(Fig. 3)*. These cabinets include some very important collections including material collected between 1872 and 1876 on the *Challenger* Expedition.

2. *Marine Biological Association, Plymouth Marine Fauna Collection*

The Plymouth Marine Fauna Collection is a reference collection of preserved marine animals which substantiate the Plymouth Marine Fauna published in 1904, 1931 and most recently in 1957 (Marine Biological Association, 1957). The collection had been stored in cabinets *(Fig. 4)* at Raglan Barracks in Devonport. The specimens are stored in jars in industrial spirit (approx. 90%) and formalin & others (10%) *(Fig. 5)*. As Natural Environment Research Council funding for the Marine Biological Association was reduced, the store was perforce vacated as a money saving exercise and therefore the collection comprising some 2800 jars had to be relocated. It was the wish of the Council of the Marine Biological Association that the collection should remain in the Plymouth area and should be accessible to Members of the MBA and to other accredited research workers. Negotiations took place with the Plymouth City Museum and Art Gallery in order that the collection could be curated as part of the Natural History Collections.

As part of the arrangements for the transfer of the collection to the museum, a conservation audit of the collection was undertaken. As the collection is in spirit, a programme of replacement of jars and seals will be undertaken and storage in compliance with current health and safety regulations will be provided by the museum. The costs incurred in the curation and storage of the collection will be carried by the museum and grants will be sought to assist with this. This insures the continued preservation of the collection as a regional reference collection.

Other items included in the transfer are Lebour plankton specimens, the Crawshay Porifera histology slide and spirit collection, a collection of Irish Sea hydroids with full collection data and a well-documented collection of Lusitanian and North Sea mollusc shells collected between 1800 and 1940.

3. *The Discovery Collections*

The idea for conducting research in the Southern Ocean was first mooted in 1908 when the British Government laid firm claim to the Dependencies of the Falkland Islands. One objective of this claim was regulation of the then shore-based whaling industry. In 1924 the Discovery Committee was set up by the Secretary of State for the Colonies to implement the recommendations made in a report by the Interdepartmental Committee on Research and Development in the Dependencies of the Falkland Islands (Anon., 1920). The work was financed by tax revenues from the whaling industry collected by the Government of the Falkland Islands (Mackintosh, 1950). Extensive studies of whale biology and the Southern Ocean ecosystem began in 1925 (Kemp *et al*., 1929) and continued without a break until 1939. Further sampling was undertaken in 1950-51. Although sampling in the Southern Ocean concentrated on krill and thus was mainly in mid-water, many benthic stations were worked. The collections so obtained, and the Discovery Investigations staff, were housed in the grounds of the Natural History Museum. The collections were worked on by staff and by international experts, and published in the Discovery Reports series (Institute of Oceanographic Sciences, 1981) and elsewhere. In accordance with agreements made by the Discovery Committee, most of the taxonomic material was deposited at the NHM.

In 1949 the staff, ships and assets of the Discovery Investigations were integrated into the newly formed National Institute of Oceanography (Mackintosh, 1950), later to become the Institute of Oceanographic Sciences. Some staff together with the whale and krill material remained at South Kensington, but most personnel and the extensive unworked collections moved to NIO, at Wormley in Surrey. Some of the whale material was incorporated into the NHM collections but the bulk was transferred to Cambridge when the NERC Sea Mammal Research Institute was formed in 1977. Following the major report on krill by Marr (1965) and subsequent work, much of the material was transferred to IOS.

Since 1952, biological work at IOS has been concentrated to a large extent in the eastern North Atlantic Ocean. Initially, research was conducted in the pelagic realm. Extensive vertical series and total water column studies were undertaken, and near-bottom sampling was carried out in depths down to 4000m (Baker and Chidgey, 1986). Some benthic sampling was undertaken in 1965, and a formal benthic group established in 1972. Major benthic collections were made along the north-west African margin, in the Porcupine Seabight off south-west of Ireland, and on the Porcupine and Madeiran Abyssal Plains (Rice *et al*., 1991, 1994).

Initially, the collections transferred to Wormley were accommodated in a single store. The advent of the benthic programme together with more intensive sampling on more frequent cruises resulted in an ever-increasing rate of accessions to the collections. By 1995, four dedicated storage areas were in use, including a very large basement area equipped with mobile racking. All material has been fixed in borax-buffered formaldehyde, and is held in glass jars or plastic tubs depending on volume. Early samples were kept in formaldehyde after fixation, but since 1972 industrial methylated spirits has been used increasingly as a preservative for benthic samples, and a propylene glycol/propylene phenoxetol solution for mid-water samples.

After a proposal for the inclusion of IOS into a new centre for oceanography at Southampton, plans were drawn up for sufficient storage space to accommodate the entire Discovery Collections. Following drastic cost-cutting exercises prior to construction, storage capacity provided at the Southampton Oceanography Centre was only one quarter of that planned originally. Despite dense packing, the storage facility could accommodate barely one third of the material held at Wormley. Material in the collections could be classified into three categories, current, secondary, and historic. A major part of the current material, samples required for on-going research programmes, was accommodated at SOC when IOS moved there in 1995. The historic part, consisting of the Discovery Investigations collections and ancillary material, and Atlantic material collected prior to 1963, was transferred to the NHM. The secondary category included all of the remaining material. Some of this, mainly mid-water samples, went to the NHM, but the bulk was placed in temporary storage at the Petersfield premises of Ocean Scientific International, as were larger benthic samples of current interest.

After plans for the new Spirit Building at the NHM were approved in 1997, additional material was moved from Petersfield to the NHM. In total an estimated 5-10 million specimens in about 51,000 containers were transferred to the NHM (P. Rainbow, pers. comm.). Provision of additional storage space at SOC in 1998 made room for all of the current collections, and the Petersfield store was vacated.

Much thought and effort had gone into handling, fixation, storage and documentation of samples from the earliest days of the Discovery Investigations (Kemp *et al*., 1929; Baker and Chidgey, 1986). As a result, the condition of all the material was remarkably good, and remains so despite all the moves and some exposure to less than optimal storage conditions.

The Discovery Investigations collections and the subsequent material amassed by IOS represent a huge resource of international importance. These collections provide a picture of the Southern Ocean prior to the catastrophic decline of whale populations, and a major documentation of mid-water and benthic environments in the eastern Atlantic Ocean over a 35 year time span.

Acknowledgements

Helen Fothergill and Nicola Moyle of the Plymouth City Museum are thanked for details of the transfer of the Plymouth Marine Fauna Collection to the Museum and for the use of the photographs reproduced in Figs. 4 and 5 and Andy Fleet of the Natural History Museum for permission to use the photographs reproduced in Figs. 1, 2 and 3.

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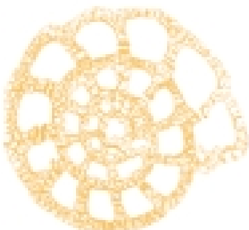

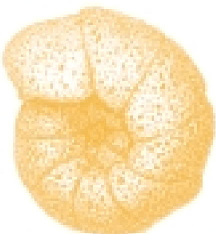

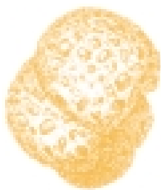

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EU-SEASED – A new initiative for accessing the European marine sediment sample archive

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Marine sediment cores and other seafloor samples are a raw data resource of immense scientific value and many tens of thousands of bottom samples have been collected by European research institutes, Geological Surveys, universities and exploration and survey companies. It has been a problem for potential users to know what is available and where they are stored.

Introduction

Marine sediment cores and other seafloor samples are a raw data resource of immense scientific value and many tens of thousands of bottom samples have been collected by European research institutes, Geological Surveys, universities and exploration and survey companies. Such data is vital to a large number of end-users in governments, industry and academia. Research into global climate change, slope stability, pollution control and assessment, hydrocarbon exploration, surveying for laying telecommunication cables and offshore pipelines, siting of offshore structures and coastal development all rely on data provided by marine sediment samples. After they have been analysed for the purpose for which they were taken, cores and bottom samples are normally stored under controlled conditions for further use. Consequently, samples are stored at a large number of locations dispersed throughout the countries of the European Union and provide a legacy of continuing scientific usefulness and importance. However, secondary usage of this important data resource has been seriously impeded by lack of knowledge of what cores are available and where they are stored.

The 'Index of Marine Geological Samples' – a US initiative to enable greater exploitation of seafloor samples

The problem of providing accessibility to large sediment sample archives has been long recognised in the USA. As early as 1977, several oceanographic research institutions got together in a collaborative effort to help researchers locate marine sediment and rock material for further analysis. Today, twenty oceanographic institutions make up this effort, submitting core data to the "Index of Marine Geological Samples" at the US National Geophysical Data Centre/World Data Centre A for Marine Geology and Geophysics, at Boulder, Colorado. Fifteen of the participating institutions are American, one is Canadian, two are German (the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, and the GEOMAR Research Centre for Marine Geosciences, Christian Albrechts University, Kiel) one is British (the British Ocean Sediment Core Repository, Southampton Oceanography Centre – see Rothwell and Gunn, this volume) and one is an

After they have been analysed for the purpose for which they were originally collected, cores and bottom samples are normally stored under controlled conditions for further use. Large numbers of samples are stored at locations dispersed throughout the countries of the European Union and provide a legacy of continuing scientific usefulness and importance. The EU-SEASED internet database provides access to this immense archive.

international programme (IMAGES – the International Marine Global Change Study). Of the major core repositories in Europe, of which there are at least thirty, only three participate. The "Index to Marine Geological Samples" database currently holds information for nearly 101,000 seafloor cores, grabs, dredges and drill samples and can be searched via the internet (http://www.ngdc.noaa.gov/mgg/curator/curator.html). The database is searchable by any parameter or combination of parameters. Inventories, data listings, data in digital form and plots by station/lithology/texture are available. Samples are normally available for further study, on request, from the participating institution. Participation in the database involves cost and several US institutions specifically receive funding from the US National Science Foundation to participate.

The value to marine scientists of the "Index of Marine Geological Samples" is immense. It is worldwide in coverage and provides a central access point for finding who has samples and where they are, although the number of institutions supplying data to the database is limited and very much American-dominated. As a result of the "Index" it is far easier to find out what cores, taken by American ships and stored in American Institutions, have been collected from European waters than it is to find out what cores have been taken by European ships and stored at European institutions.

Representatives from institutions that participate in submitting metadata to the "Index of Marine Geological Samples" meet about every two years to hear facility presentations, discuss common issues of interest, such as core-based research projects and facility information systems, and hold round table discussions on information needs and strategies for co-operation. The "Index" therefore also provides a valuable forum for the exchange of ideas and discussions, at which European curatorial institutions are under-represented and largely excluded.

The importance of the "Index of Marine Geological Samples" and the service it provides to the international marine science community was recognised by a resolution by the International Oceanographic Commission (IOC) Committee on International Data & Information Exchange (IODE), passed by the IOC in 1994, which states:

"The IOC Committee on International Oceanographic Data and Information Exchange, recognising the importance of analyses deriving from ocean sediment cores to studies of past climates and to palaeoceanography,

Being concerned with the diminishing amount of sample material and with the difficulty in locating material available for analysis, *Noting the need to identify, catalogue and curate all such remaining material so these materials can be fully utilised for analyses beyond those for which the samples were collected originally, ...*

.........Encourages member States to locate and catalogue marine sediment cores available for sampling and analysis and contribute information (metadata) about these cores to the Index of Marine Geological Samples database maintained by WDC-A-MGG;

Urges member States to establish procedures to provide access to these cores for sampling"[1]

EU-SEASED – making European-held seafloor samples more accessible to potential users

In the late 1990's there was increasing recognition within Europe that measures needed to be taken to increase access to European-held collections of seafloor samples. The advent of the Internet now provided the mechanism to do this. Two separate project proposals were submitted to the Marine Science and Technology (MAST) programme of Directorate General XII (Science, Research and Development) of the European Commission. One proposal, called EUROCORE, originated from a consortium of European deep-sea core repositories, the other, called EUMARSIN (European Marine Sediment Information Network), was proposed by a consortium of European Geological Surveys. Although separately conceived, both projects had similar aims – to set up a searchable Internet database of seafloor samples held at European institutions. However, EUROCORE planned to database metadata on deep-sea cores from anywhere in the world provided they were collected by, and stored at, a European institution; whilst EUMARSIN proposed databasing metadata on the marine sample holdings of the European Geological Surveys, and largely restrict their database to samples located on the continental shelves. Both proposals were therefore complimentary and were funded as Supporting Initiatives within the MAST programme by the European Commission.

Both projects began in November 1998 and were integrated to populate a common database (called EU-SEASED), through a common data management partner, responsible for database construction and server maintenance. Project co-ordination was kept separate, with co-ordination of EUROCORE being done by Southampton Oceanography Centre, Southampton, UK; whilst the Institute of Geology and Mineral Exploration, Athens, Greece, co-ordinated EUMARSIN. The EU-SEASED database is accessible through the World Wide Web (http://www.eu-seased.net) and only lists sample metadata (i.e. data on data). Access to the actual samples and any related accessory datasets is for negotiation between the requestor and the repository where the sample is stored. The purpose of EU-SEASED is to provide the means by which scientists, engineers and other parties interested in the seafloor can quickly find out what seabed samples have been recovered and where they are stored; thereby promoting secondary usage of this previously under-exploited raw data resource.

Although EU-SEASED became an integrated project, a clear division of labour regarding population of the database was agreed at the onset. Partners within EUROCORE were charged with populating the database with metadata on cores and sediment samples collected

- by European universities, research institutes and marine stations
- from anywhere in the world providing the samples were collected by, and are held at, European institutions
- from areas seaward of the continental shelves (>200m water depth)

[1]International Oceanographic Commission (IOC) Committee on International Data & Information Exchange (IODE) Resolution IODE-XIV.2, 1994 (Published on the Internet at http://www.ngdc.noaa.gov/mgg/curator/ioc_resolution.HTML)

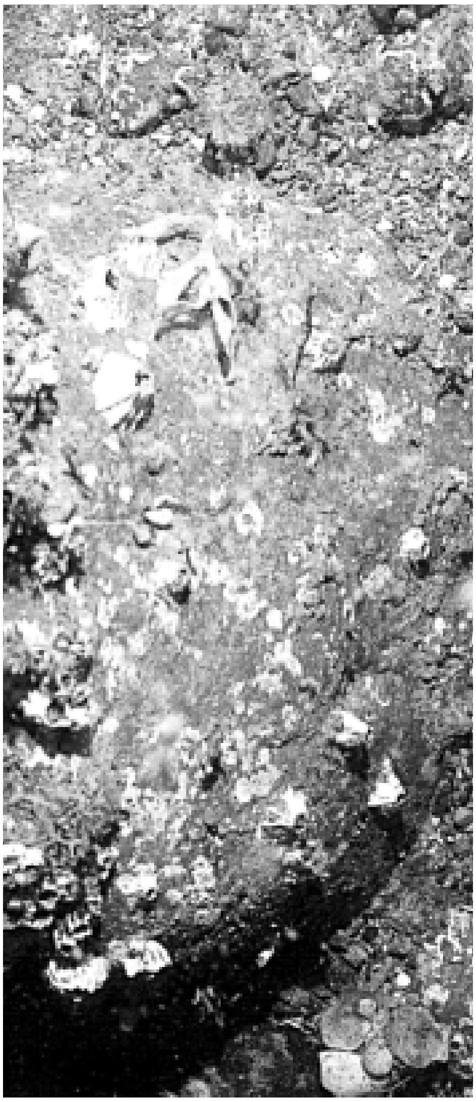
EUMARSIN partners are charged with populating the database with metadata on seafloor samples collected

- by the European Geological Surveys, commercial companies (if available) and hydrographic surveys
- only from the European seas
- in areas on the continental shelf (<200m water depth) but to include European Geological Survey data collected in deeper waters

Within the EU-SEASED partnership, it was recognised from the outset that the functional specification and the front-end options and capabilities of the database must be end-user driven. Hence there has been extensive consultation amongst partners, all themselves users of seabed data, concerning the best metadata format for data entry. This culminated in a workshop in the Netherlands in April 1999 and resulted in the production of an agreed standard form for metadata collection. Two types of metadata were identified: mandatory metadata fields and optional, but recommended if available, metadata fields (Table 1).

Table 1. EU-SEASED metadata fields for data collection

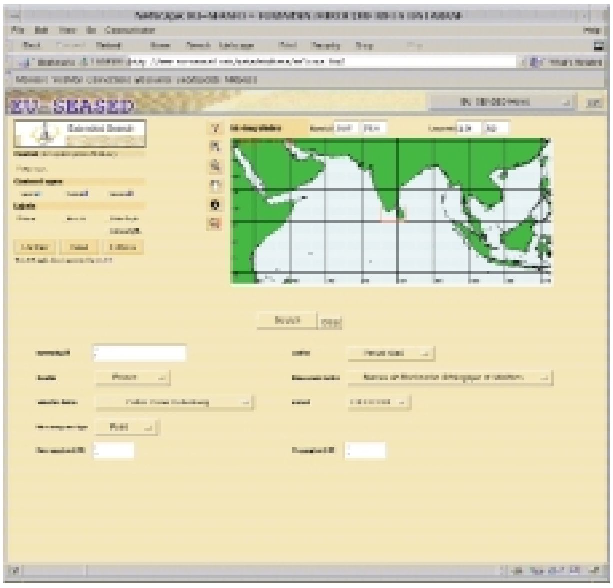
MANDATORY METADATA FIELDS
Record number, measuring ID, measuring area type, co-ordinates, sampling device, data source holder Mandatory only for EUROCORE samples: Sample state, sample storage condition
OPTIONAL, BUT RECOMMENDED, METADATA FIELDS
Internal reference number, objective of measurement, treatment/analysis, measured parameters, surface/subsurface sample, geographic area, monitoring site, physiographic province, navigation system, core/sample length, water depth (corrected/uncorrected/not known), core/sample penetration, core/sample diameter, date of collection, project/cruise name, research/survey vessel, project/cruise report, basal age or period, predominant sediment type, sample recovered (volume or weight of dredges or grabs), list of maps, references, comments



Agreement on the functional specification of the database and the boundary conditions on metadata format allowed the data collection phase to begin. At the time of writing (March 2001), the EU-SEASED database contains metadata on over 150,000 sample stations and metadata submission is continuing. The basis of the central database is a Windows NT server. Data searching can be done in two ways – either through text entry into defined metadata fields and searching on the entered parameters, or through a graphical map interface. On the map interface, user defined boxes may be drawn on a world map, which then zooms in to the defined area and plots the sample stations present within that area. Users can then highlight particular sample stations of interest and the metadata on the samples selected are automatically displayed. Over time, it is hoped to add GIS functionality, allowing enhanced search capabilities, such as identifying bottom samples within user-defined corridors, within certain distances from land or undersea features etc. In addition to the main database, a number of community-based pages have been established, in particular, an electronic newsletter on marine sedimentary themes called 'Seabed News'.

Partners within the EUROCORE project are contracted to not only provide metadata on their own repositories' holdings to the EU-SEASED database, but also to invite, and enable, participation in the project from other sample-holding institutions within their respective countries. These invitations have been positively met and EUROCORE takes a strongly pro-active approach to data-gathering, using questionnaires and data scouts to actively seek out metadata for the database. A proactive approach is important as many smaller sample-holding institutions may not have the resources to collate their data and EUROCORE provides the means by which this can be done.

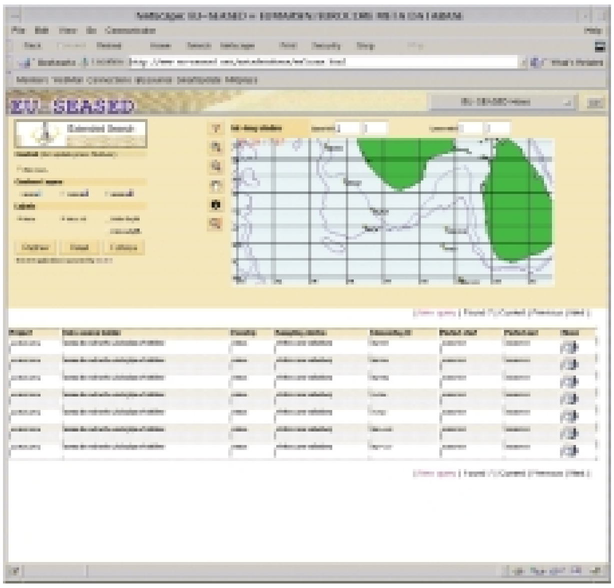
Fig.a



EU-SEASED users can search for seafloor samples in their area of interest using a graphical map interface. The area of interest can be selected by a user-defined click-and-drag box (Fig.a), the system will then zoom into the area of interest and display the cores available (Fig.b), a sample of interest can then be highlighted by the user and associated metadata will be displayed (Fig.c).

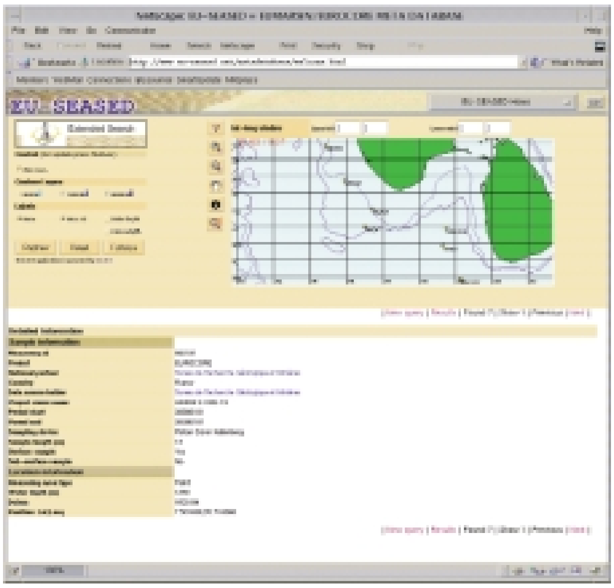
Although, EU-SEASED only lists metadata for the vast majority of the sample stations listed in the database, a demonstration model is planned as part of the EUROCORE project, whereby analytical datasets relating to particular cores, already published or otherwise in the public domain, can be accessed from the meta-directory level. This will be done through a direct download interface with data entered into the PANGAEA network for geological and environmental data operated by the Centre for Marine Environmental Research (MARUM), University of Bremen, and the Alfred Wegener Institute for Polar and Marine Research, Germany.

Fig.b



The EU-SEASED website was installed on the Internet in January 1999, and text-based searching and query options were available by the Summer of 1999. The search function using the graphical map interface was made available in July 2000. The website is now receiving between 40,000 and 60,000 'hits' a month (this is approximately a ten-fold increase since September 1999). But can we tell how many people are accessing the website and in particular using the database? Citations of the number of 'hits' can be misleading as this may relate to the number of files being accessed on a website. This will include picture files, so if a page contains four pictures, it will register as five total 'hits'. Therefore a more accurate figure for the number of visitors is the number of html pages accessed – each page will register as one 'hit'. During the last quarter of the year 2000, the EU-SEASED website received between 5,000 and 7,550 html 'hits' per month – a fourfold increase since the beginning of the year. However, perhaps a more important measure of the website's value to the scientific community, is the number of visitors to the database part of the site – this is registered as 'ASP hits'. Since October 2000, the number of 'ASP hits' has been far greater than the number of html 'hits' showing that visitors are actually more interested in the database than browsing other pages. The total number of pages accessed during the year 2000 (number of html 'hits' plus 'ASP hits') was 130,044. Of course, this does not mean that the site received 130,000 visitors during the year 2000, as in theory a few visitors could be accessing all those pages. However, the total number of clients/hosts (i.e. computers, servers) accessing the site for 2000 was 11,523.

Fig.c



One host must represent at least one individual visitor, so the real number of visitors to the site must be somewhere between 11,523 and 130,044.

Analysis of the country of origin for users accessing the EU-SEASED website during the year 2000, shows that there were users in few developed countries that did not access the website during the year. Indeed, users from several countries not normally associated with major marine research programmes, such as Austria, Macedonia, Switzerland and the Ukraine, regularly accessed the website. Clearly after only one year of operation (much of which has been a testing phase), the EU-SEASED database has established itself as one of the World's premier sites for searching for seafloor sample metadata.

The future

Funding for EU-SEASED has a finite life – 3 years in the case of the EUROCORE project and 2 years for EUMARSIN – the difference reflecting the more active data-gathering from institutions outside of the consortia in EUROCORE. However, by November 2001, EU funding for the population and development of the database will cease. However, cores and bottom samples will continue to be collected and if EU-SEASED is to continue to have value, then funds must be secured to allow updating of the database, finance continued hosting of the website (currently done by a private company), and ideally, develop the site, particularly the search capabilities, as Internet-GIS capabilities develop in the future.

One way of developing the database would be to incorporate accessory datasets relating to the cores, where published or otherwise in the public domain. The EUROCORE project will develop a demonstration model linking accessory analytical datasets to a small subset of cores for which this information is already in the public domain to show how this can be done. This work has potential to be expanded and would provide important extra information to users in determining what cores would be useful in their research.

All marine data, whether point (e.g. cores, dredges, photographs, heat flow stations), area (e.g. multi-swath bathymetric surveys, side-scan sonar surveys) or line (e.g. seismic, gravity and magnetic profiles) are very expensive to collect and have long term value to the scientific community long after they were originally collected. The long-standing tendency for such data to be closely held by institutions and individual investigators long after original collection and analysis has inhibited access to data. Inevitably important data has been lost, as investigators leave institutions, retire and die.

Hundreds of thousands of bottom samples, seafloor photographs and other seabed station data have been collected by national, international and EU-sponsored cruises within Europe. In addition, hundreds of thousands of kilometres of seismic lines and millions of square kilometres of side-scan sonar imagery and high-resolution swath bathymetry have been collected by European institutions. Like cores, these data represent a vast resource of continuing scientific usefulness and importance, at present stored at a large number of locations dispersed throughout the countries of the European Union. Secondary use of these data is currently seriously impeded by lack of knowledge of what is available and where the data is stored. EU-SEASED has demonstrated that successful collation and dissemination of metadata requires the formal establishment of an effective transnational data collecting infrastructure and universal rapid intuitive access and display. The project therefore provides a model that could be used to increase accessibility to other types of seafloor data, both station, profile and area-based. EU-SEASED has demonstrated the importance of the functional specification being end-user driven and the need for an intuitive graphical user-interface. Data acquisition needs a strongly proactive approach and the use of data scouts to actively solicit, and compile, third party metadata when necessary. For paper and photographic records, a specific effort is required to locate and digitise data (data archaeology) to allow preservation, recording and dissemination, and minimise future data loss. Considerable efforts have now been made through EU data management initiatives (e.g. EUROCORE, EU-SEASED, SEISCAN) to preserve and record non-digital marine data and make this more accessible to potential users. However, these efforts must continue, and expand to cover other types of marine data, if Europe is to capitalise on its considerable research investment and enable full exploitation of resources.

back

Museum algal collections and environmental change

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Introduction – Background to the collections

Floristic studies and research into problems in systematics and taxonomy have been the driving forces for the growth and development of the marine macro-algal (seaweed) collection at the Natural History Museum [BM]. Huxley & Bryant (1998) pointed out that one especially underrated value of museum collections is that they are verifiable records of an alga's existence in space and time. Collection data may therefore contribute to the recognition of change or stability in spatial and temporal occurrence, change in alpha diversity (species richness), and thus of environmental change.

Algal collections held in museums, marine laboratories and universities form a large information resource. It is not possible to quantify the global size of this resource but BM holds approximately 350000 specimens of world-wide origin. Most are herbarium specimens but there are also approximately 20000 microscope slides, 2000 formalin-preserved specimens, and 2500 specimens housed in boxes. The BM algal collection is not taxonomically or geographically complete; it has been assembled over the past 300–350 years with a peak of specimen acquisition in the nineteenth century.

The earliest records of algae were published in botanical 'herbals' (Gerard, 1597; Johnson & Gerard, 1633, held at BM); these are accounts which provide descriptions and illustrations of algal species and their medical uses, and also rudimentary ecological information. Such publications complement early plant collections notably those of the 'Sloane Herbarium'. Sloane volume HS 114, assembled by Buddle and dated 1757, contains algal specimens including *Padina pavonia* (L.) Thivy from Harwich, Essex (see also below). Volume HS 100, assembled by Plukenet and dated 1757, also contains identified and localised algal specimens from Britain. These collections provide the earliest basis for the comparison of verifiable floristic data in time.

The morphological structure and reproductive state of a specimen may also be helpful in indicating features of the environment (e.g. sea-temperature, salinity, wave-exposure) in which it originally grew. Algae are also known bio-accumulators, so tissue analysis of a specimen might provide an indication of the chemical environment in which it occurred.

Associated with most specimens are geographical, ecological, biological, temporal and historical data. A problem with many collections is that the accessibility of such information is not straightforward. To assist users, the systematic, geographical, and temporal extent of the BM marine macro-algal collections has been recorded. Data on type specimens can be provided (e.g. Tittley & Tyler, 1983), and more usefully from the environmental point of view, inventories of species holdings by country or more precise location (and vice versa) are complete (e.g. Tittley & Sutton, 1984). For the 120000 BM specimens from Britain and 650 species in the British flora, greater detail can be provided with specimen records mapped using 5 km squares of the National Grid (Anon., 2000); temporal data for all specimen records have been collated under three time-frames (pre-1900, 1900-69, 1970 to date). A component of the British algal collection (approximately 6000 specimens) is fully databased.

Fig. 1
Sporochnus pedunculatus shown by the Natural History Museum collections to have been present in the 19th century in the Orkneys, but now to have become locally extinct, probably due to coastal reconfiguration, land claim and urban development.

Collections as an aid to environmental studies

Environmental or monitoring surveys usually involve study of the marine flora at a particular location, often in relation to an impact or to conservation or planning requirements. Most environmental studies involving the marine vegetation have not attempted to create a historical profile for the vegetation at the site. In the few that have, museum collections data have proved useful in achieving this goal and have helped placing perceived change in vegetation in context. Collection data have also helped identify indicator species of change. Few recent environmental studies have provided supporting voucher specimens; where present they not only corroborate species data, but also contribute an important resource of species information for future studies. The use and value of herbarium collections and other early data in environmental studies is beginning to attract greater recognition (Cranbrook 1997; Gellini & Paoletti 1993; Huxley & Bryant 1998). The application of such data to some recent environmental and biodiversity studies is given below.

1. *Kent*

In east Kent the 'Thanet Coast marine candidate Special Area of Conservation (SAC)' is designated under the EC *Habitats Directive*. The foreshore reefs are noted by *English Nature* for "… the exceptional recorded history and continuity of marine research undertaken there …" (Anon. 1995). A recent survey of the SAC (Tittley *et al*., 1998) revealed 35 different intertidal biotopes most of which were characterised by algae. In one of Britain's earliest botanical publications (Johnson & Gerard, 1633) are records (also supported by early specimens) of *Fucus serratus* L., *F. vesiculosus* L, *Halidrys siliquosa* (L.) Lyngbye, *Laminaria digitata* (Hudson) Lamouroux, *L. saccharina* (L.) Lamouroux, *Corallina officinalis* L., *Palmaria palmata* (L.) Kuntze and *Ulva lactuca* L. These species today form the principal vegetational features on sea-shores in Thanet; comparison with data from the 18th, 19th, and 20th centuries (as specimens and literature citations) suggest long-term stability in these features of the marine vegetation.
One, *Halidrys siliquosa*, may now be locally threatened due to competition with the vigorous non-native *Sargassum muticum* (Yendo) Fensholt.

2. *Orkneys*

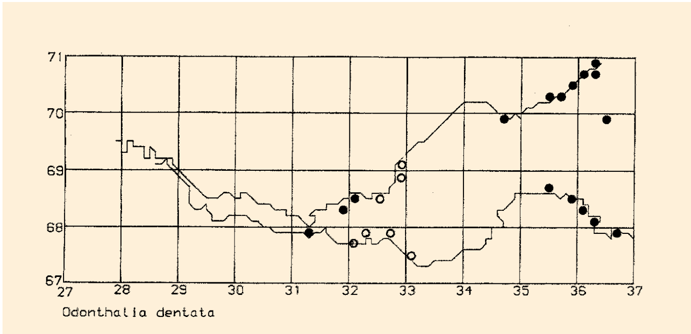
BM algal collections from the Orkney Isles made in the mid-nineteenth century are comprehensive (possibly due to interest in the marine flora because of the local 'kelp' industry). Comparison of past records with data from recent surveys at Skaill shows little change in alpha diversity (Wilkinson *et al*., 2000). The main difference is a greater number of recent microscopically small species records reflecting improved technology for algal study. At Kirkwall, by contrast, change in flora was detected. Species assemblages (e.g. *Arthrocladia villosa* (Hudson) Duby, *Asperococcus bullosus* Lamouroux, Desmarestia spp., *Isthmoplea sphaerophora* (Harvey) Kjellman, *Sporochnus pedunculatus* (Hudson) C.Agardh) shown by BM collections (Fig. 1) to have been present in the nineteenth century have become locally extinct. This has been ascribed to coastal reconfiguration, land-claim and urban development.

3. *Firth of Forth*

The Edinburgh coast, unlike Thanet and Skaill, has suffered a marked change in algal vegetation since the 19th century due to the deterioration in inshore water quality (Wilkinson *et al*., 1987). Sea-shores there formerly supported dense and diverse algal vegetation fully described in publications of the time and supported by excellent voucher specimens at BM and elsewhere. An example is *Odonthalia dentata* (L.) Lyngbye, (Fig. 2) which is no longer present at Edinburgh; present and past occurrence of *O. dentata* in the Firth of Forth is shown in Fig. 3. Mussels and barnacles with a qualitatively and quantitatively impoverished algal flora now characterise this area. In contrast, a comparable study at Elie on the north side of the Forth where inshore waters remained clean, showed little change in algal diversity and community structure (Wilkinson & Tittley, 1979).

Fig. 2
Odonthalia dentata, no longer present on the Edinburgh coast, although recorded in the past

Fig. 3
Distribution of *Odonthalia dentata* in the Firth of Forth showing present (closed circles) and past (herbarium) records (open circles)



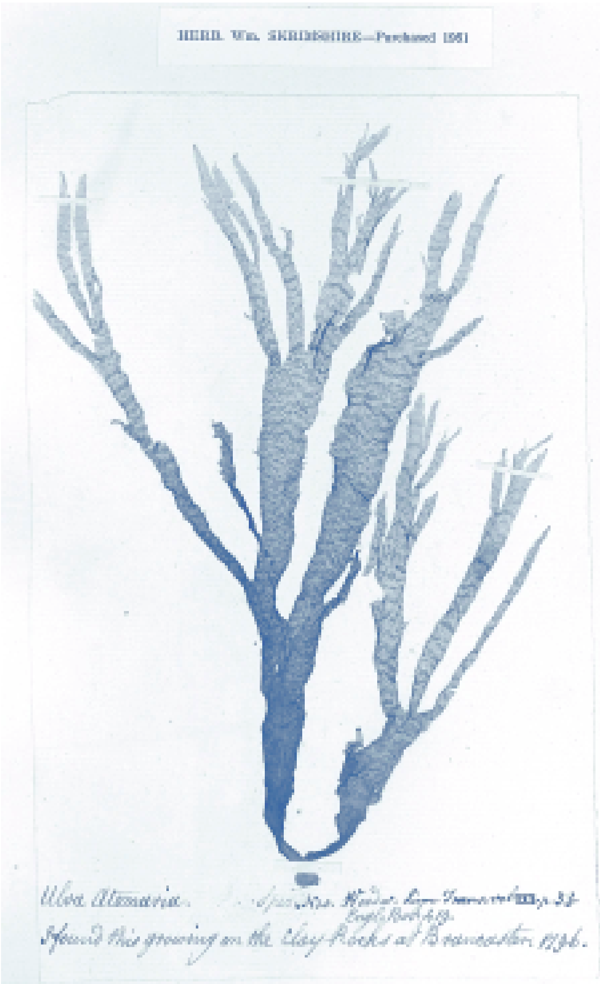


Fig. 4
Taonia atomaria which shows sporadic increases on the north Norfolk coast

Fig. 5
The Natural History Museum holds 18th century specimens of the saltmarsh red alga *Bostrychia scorpioides* from locations in Lincolnshire and Cambridgeshire, long since removed from marine influence

4. *Norfolk*

NHM has undertaken for *Anglian Water Plc* an assessment of marine communities near Cromer in north Norfolk that were potentially affected by the alteration of sewage discharge from inshore to offshore (Tittley, 1998). Monitoring over ten years has shown stability in species that characterise the intertidal algal assemblages, considerable year by year turnover in associated species, and sporadic increases (flushes) in some populations (e.g. of *Taonia atomaria* (Woodward) J.Agardh (Fig. 4) and *Scinaia furcellata* (Turner) J.Agardh). The site has a long history of algal study with representative collections at BM made in the 18th, 19th, and 20th centuries. Chapman (1937) presented an annotated inventory supported by voucher specimens (at BM), and a phytosociological classification of the marine vegetation. Comparison of recent data with those of Chapman suggests stability in the species characterising the algal communities. Differences were found in the associated flora of ephemeral annual species. Appraisal of 19th century specimen and literature data indicated the same dominant algal species, but revealed 50 species not found in the recent study. Whether the cause of this apparent loss is natural or anthropogenic is not clear. Museum records also show that populations of *T. atomaria* and *S. furcellata* have been present there for centuries but do not reflect the quantitative changes observed. The recent study also revealed a near-absence of *Laminaria* spp. despite their occurrence in similar habitats in Essex and Kent. The lack of herbarium specimens (given the cautions of Huxley & Bryant, 1998) and also literature records suggest the absence of *Laminaria* to be a persistent natural feature.

5. *Thames estuary*

The Thames estuary is another area where a drastic deterioration in water quality has had significant effects on the marine biota (Tinsley, 1998). Equally striking has been the recent amelioration and recovery of fauna and flora (Attrill, 1998). BM algal collections from the estuary are poor and exemplify the temporal and geographical patchiness of its holdings. A recent series of algal studies in the tidal Thames has led to the preparation of a representative collection. Even this reflects recent changes during the past two decades, notably the up-river migrations of *Fucus* spp. following an increase in salinity (Tittley & John, 1998). The few older specimen records are of green algae from ditches in the Woolwich and Greenwich reaches and are typical of the extensive marsh habitats present in the 18th century. Loss of wetland is a significant change to the coastal environment; BM holds 18th century specimens of the saltmarsh red alga *Bostrychia scorpioides* (Hudson) Kützing from locations in Lincolnshire and Cambridgeshire (Fig. 5), long since removed from marine influence (Price *et al*., 1977). Unfortunately, there are no specimens to indicate the occurrence of *B. scorpioides* in former Thames salt marshes, although it is present in the neighbouring Medway estuary (Tittley & John, 1998). The addition of new surfaces to the coastline, particularly sea wall and harbour structures, provide habitat for marine flora. Sea walls in the Thames estuary support *Ascophyllum nodosum* (L.) Le Jolis and floating jetties support *Bryopsis plumosa* (Hudson) C. Agardh at locations where formerly they would have been absent. The lack of museum records suggests these species to be new arrivals in the estuary (again, given Huxley & Bryant's (1998) cautions). Brodie (1998) proposed stability in the marine flora of the outer Thames estuary, citing specimens of red algae from the Isle of Sheppey recorded there over 200 years ago. Of note is *Porphyra umbilicalis* (L.) Kützing whose type specimen (Sherard Herbarium, Oxford) was collected from Sheerness on Sheppey between 1721 and 1724. The species occurs today on groynes.

Global climate change

Museum algal collections will be historically important in assessing and predicting change due to global warming (cf. Hiscock *et al*., 2000). At BM there are literature and specimen references to the warm-water alga *Padina pavonia* that date back 300 years (Price *et al*., 1979). These suggest a contraction in distributional range to the present boundary on the English south coast at the Isle of Wight. Specimens revealed the sporadic occurrence of *P. pavonia* in the 18th and 19th centuries in east Kent and Essex. Fig. 6 shows the distribution of *P. pavonia* in England based on specimens in BM. A future spread of *P. pavonia* and other south-western species beyond their present boundaries, or contraction in range of cold-water, northern species such as *Odonthalia dentata* (Fig. 3) and *Ptilota gunneri* P. Silva, Maggs & L.Irvine may be an indication of the predicted rise in sea temperature.

Fig. 6
Distribution of *Padina pavonia* along the English coast based on specimens in the Natural History Museum. A future spread of this, and other southwestern species beyond their present boundaries may indicate a rise in sea temperature

Conclusions

Huxley & Bryant (1998) noted that although museum specimens are verifiable records of an alga's existence in space and time, they provide only a punctuated series broken by factors that may not always reflect variations in distribution. Although BM holds many specimens of a species, the collection provides qualitative rather than the quantitative data often required in an environmental study, and thus are primarily helpful in assessing changes in local alpha-diversity or range distribution.

Hitherto, the acquisition of specimens depended on the abilities and interests of the collector. The BM collection of macro-marine algae has been eclectic in its development, reflecting the many floristic, taxonomic and other projects for which material was gathered. Sadly, very little voucher material has been obtained from the many recent marine surveys, the main exceptions being new or unusual species records, or those of conservation importance such as *Anotrichium barbatum* (C. Agardh) Nägeli the rarity of which was first recognised from museum specimens (Maggs, 2000).

The future

Although a random array of specimens will continue to arrive at BM, the recent assessment of the algal collection will enable a more focused approach to specimen acquisition, targeting taxonomic and geographical gaps.

In order to develop the historical context of especially the British collection (important as considerable changes are predicted for the coastal environment), regular temporal sampling should be undertaken at a small number of key reference sites. Although such algal collections would inevitably be qualitative, specimens taken could be accompanied by appropriate quantitative data.

Housing, preserving and maintaining access to collections is expensive. Collections managers and users need to agree that maintaining and developing such a resource makes a worthwhile contribution to environmental projects. If so, it is important that those responsible for commissioning environmental investigations are henceforth persuaded to include in their project costings a financial contribution towards the maintenance of voucher collections. In return they should perhaps have a greater say in collections development. The NHM is endeavouring to release as much information as possible on the macro-algal (seaweed) collections; although IT facilitates this considerably, gathering and organising the data inevitably proceeds slowly given present resources.

Acknowledgement

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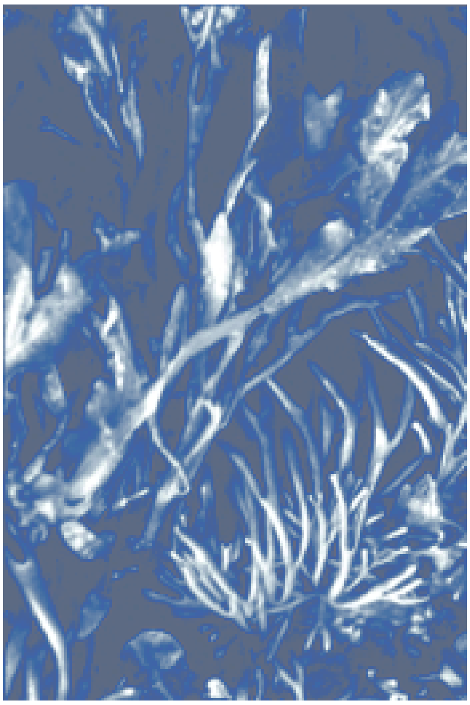
P.J Chimonides is thanked for his help with the production of algal distribution maps



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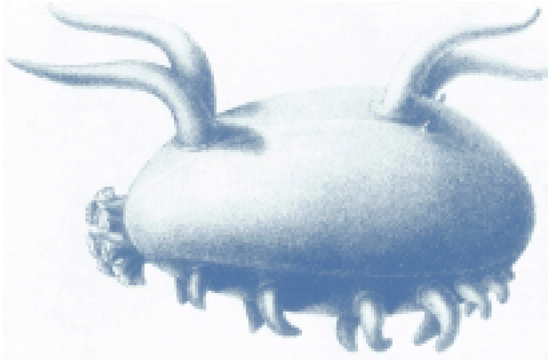

The determination of glycogen in preserved material as a retrospective indicator of environmental stress

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The physical entities that constitute museum and laboratory collections may be termed 'historical data'. Traditionally, this material has been primarily accumulated over many years for initial taxonomic study and subsequent reference; such material has been used more rarely as the basis of retrospective studies of population or community ecology. In the last few years however financial and other pressures have forced those responsible for such collections to assess their scientific value and, in some cases, to dispose of large amounts of material that is often unique in its temporal and or spatial coverage. Apart from the destruction of valuable information the loss of these collections also represents the loss of massive past investment of time and effort. This latter consideration is particularly true of collections of deep-sea material and so methods have been developed to obtain new information from preserved material, thereby enhancing its value and reinforcing the justification for its retention (see Hawkins *et al*.,1992).

The applications of this method to marine historical data sets are illustrated by the three examples described below:

1. *Investigation of the bathymetric zonation of deep-sea benthic megafauna*

By assembling a suite of samples from the 'Discovery' collections it was possible to examine the relationship between glycogen accumulation and bathymetric zonation in two species of holothurian. These samples were collected from the Porcupine Seabight and Porcupine Abyssal Plain by the Institute of Oceanographic Sciences, Wormley, between 1979 and 1983. It would not have been possible for a single research cruise to be mounted so as to be able to assemble such a comprehensive set of samples with which to investigate the metabolic processes underlying these zonations. Figure 1 shows that there were reductions in the mean glycogen contents of both species, with increasing depth. In *Laetmogone violacea* the correlation was significant at the $P < 0.001$ level and in *Oneirophanta mutabilis* the correlation was significant at the $P = 0.052$ level. The lowest glycogen levels found in *L. violacea* occurred at the maximum depth of occurrence. The sudden drop in glycogen in *O. mutabilis* between 4200 metres and 4400 metres coincided with a change in the abundance of this species.

Fig. 1

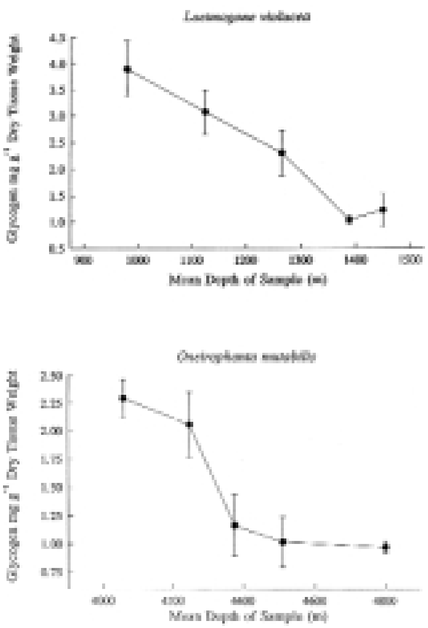

Figure 1 Relationship between glycogen accumulation and bathymetric zonation in two species of holothurian collected from the Porcupine Seabight and Porcupine Abyssal Plain (NE Atlantic) between 1979 and 1983. Note the reduction in the mean glycogen contents of both species with increasing depth. It would not be possible for a single research cruise to assemble such a comprehensive set of samples with which to investigate the metabolic processes underlying these zonations.

Fig. 2

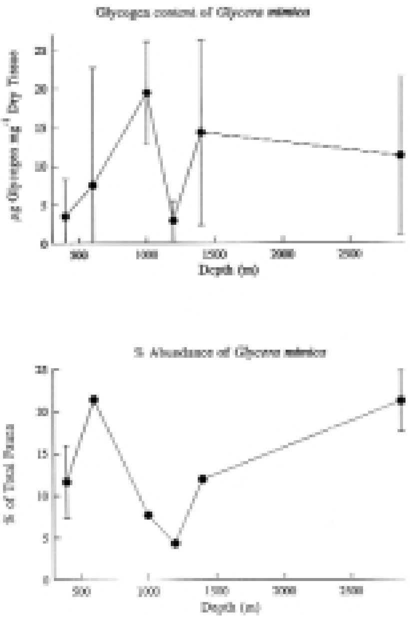

Figure 2 Variations in mean glycogen content and percentage abundance of *Glycera mimica*, a polychaete worm collected during sampling of a transect down Rockall Trough (NE Atlantic). The drop in glycogen content and percentage abundance at 1150 m is coincident with the peak abundances of other competitor species

2. *Detection of biotic disturbance effects on the abundance of* Glycera mimica

Glycera mimica was one of the dominant polychaete species found in samples accumulated from sampling of a transect down the Rockall Trough (54°N, 12°W) by the Scottish Association for Marine Science. **Figure 2** shows the variations in mean glycogen content and percentage abundance of *G. mimica* with depth. The drop in the glycogen content and percentage abundance at 1150 metres is coincident with the peak abundances of other competitor species, principally *Paraphinome pulchella,* indicating that there is a biotic interaction between *G. mimica* and *P. pulchella* in the form of competition for prey species. Whilst such a conclusion could have been drawn from the abundance data the additional information from the glycogen data provides independent supporting evidence.

Fig. 3

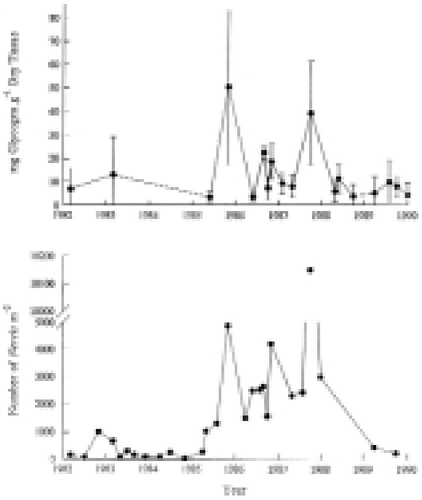

Figure 3: Temporal variability in glycogen and abundance of the polychaete *Nereis diversicolor*, a key macrofaunal species in the Somme Estuary (Northern France). These data show the correlation between glycogen and faunisitic changes from 1982 to 1990. This data illustrates the need to include periods of high resolution sampling when planning long-term studies

3. *The Somme Estuary long-term sampling data*

Access to the collection of benthic macrofauna collected from the lower Somme estuary by colleagues at the Group d'Etude de Milieu Esturiens et Littoraux (GEMEL) laboratory at St Valery-sur-Somme, France, made it possible to use the glycogen assay method to examine the temporal variability in the key macrofaunal species. In the example shown in **Figure 3** the long-term variability in the polychaete *Nereis diversicolor* was examined. This example illustrates the need to include periods of high resolution sampling when planning long-term studies. These data show the correlation between glycogen and faunistic changes and there are significant long-term cycles in the data of the order of 6-7 years. However, there was insufficient temporal resolution to have shown the depletion of glycogen that is known to presage the decline of populations of another dominant estuarine macrofaunal species *Cerastoderma edule*. There are often apparently anomalous results produced by this type of investigation and it is a truism that no single indexation method can completely describe animals' responses to their environment. These difficulties can be overcome to a greater or lesser extent by adoption of what may be termed a 'pluralist' approach. In the examples given above the glycogen measurements were always considered in conjunction with histological examinations of the gonads and digestive organs, as well as all the available information on the physico-chemical conditions at the time of sampling.

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Molecular methods for marine biodiversity research and the use of preserved materials from museum collections

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Introduction

The application of molecular methods to study biodiversity in marine systems (genetic and species diversity) has been very slow. Yet studies using biochemical- and, more lately, molecular-genetic methods have demonstrated the powers of these techniques to discern cryptic species, fundamental aspects of population structure and valuable new information on evolution in marine systems. Application of molecular methods to studies of systematics and ecology of marine organisms, especially in relation to biodiversity are illustrated using examples from studies on metazoans. In addition, the application of molecular methods to preserved DNA samples will be discussed, particularly with attention to potential pit-falls of such studies.

Specimen collections and their use in genetic studies

Specimen collections held in museums and other institutions around the globe represent a vast and largely untapped resource for studies of molecular phylogenetics, biodiversity and historical genetic changes in populations (the Natural History Museum, London, alone contains 63,000,000 specimens of animals and plants; Thomas, 1994). This is especially the case for marine organisms, where collections of specimens from intertidal to deep-sea habitats were taken on a series of global oceanographic expeditions in the 19th and 20th centuries. Many of these samples were taken prior to industrial exploitation of ocean resources and may contain valuable data on historical genetic variation of populations of commercial species and on the effects of global climate change. On economic grounds alone such widespread collection of specimens is unlikely to be repeated in the economic climate of today.

Specimens in museums have been preserved in a variety of ways. Skeletons, animal skins, scales and otoliths have been preserved by drying. In such cases specimens may have been dipped in ethanol or defleshed and boiled or defleshed and placed in dermestid beetle colonies, prior to drying (Thomas, 1994). In some cases animal skins were tanned or, as for many insects, the specimen was pinned and dried at room temperature (Thomas, 1994). Such specimens were often treated for protection against insects or fungi (Thomas, 1994). Many other animals, especially marine organisms, were fixed in formalin or other fixatives (e.g. mercuric chloride or arsenic or lead-based fixatives) and then transferred to ethanol for preservation (Thomas, 1994). Some groups of organisms (e.g. nemerteans) have been preserved as series of sections on slides.

DNA is degraded in various ways depending on the type of fixation and preservation used in a specimen. DNA in a dead organism will undergo hydrolysis, particularly through depurination, that leads to cleavage of DNA molecules into smaller fragments (Lindahl, 1993). Hydrolysis may also result in deamination of base residues, particularly cytosine. DNA is also damaged by the presence of oxygen in the form of reactive hydroxyl radicals (Lindahl, 1993). Other small reactive molecules may also cause significant damage to DNA. Over a period of thousands of years all DNA within a specimen will have degraded into small fragments. The presence of high ionic strength solutions, adsorption of DNA on to hydroxyapatite (bone), partial dehydration and an absence of oxygen may all slow down the process of degradation (Lindahl, 1993). Formalin and other fixatives cause the formation of covalent bonds between

nucleic acids. This can cause the fragmentation of DNA but more usually prevents DNA amplification by polymerase chain reaction (PCR) by interfering with the chemical structure of DNA and its associated proteins (Thomas, 1994).

PCR amplifiable DNA has been extracted from specimens of bones, teeth and coprolites of a variety of terrestrial mammals of up to 30,000 – 100,000 years old (e.g. Höss *et al*., 1996; Krings *et al*., 1997; Greenwood *et al*., 2001). Obtaining DNA from such old specimens is difficult and generally requires that specimens have been preserved in conditions particularly suitable for DNA preservation (e.g. Poinar *et al*., 1996). All of these studies have been based on mitochondrial DNA, because it is present in high copy numbers in eukaryotic cells. In the case of neandertal fossils, an extract of approximately 0.4g of bone has been found to contain 1,000 – 1,500 fragments of mitochondrial (mt) DNA molecules of approximately 100 base pairs (b.p.) in length (Krings *et al*., 1997). It is therefore unlikely that such specimens contain any DNA from single copy nuclear genes.

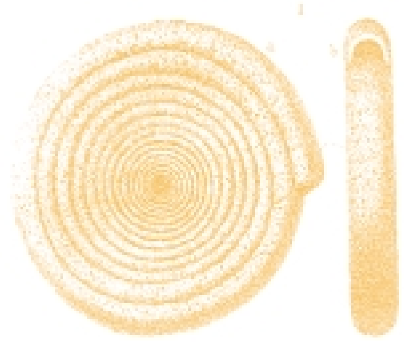
For marine animals there are no examples of DNA being extracted from material of comparable age to terrestrial studies. However, there have been several successful studies on molecular phylogenetics and population genetics using dried or formalin fixed material. Dried material, obtained from aquatic organisms, include scales and otoliths. Microsatellites are regions of repetitive DNA sequence (e.g. ….CACACACA…), that have a high rate of mutation. Within a species microsatellites therefore show length polymorphisms and they make excellent co dominant, and usually neutral, genetic markers. Nielsen *et al*. (1997) have analysed variation in four microsatellite loci in recent samples of Atlantic salmon and in scales preserved in paper bags since the 1930s from Danish rivers. Results indicated a possible decrease in the genetic variation of Danish salmon populations, possibly resulting from a bottleneck caused by over fishing. A similar study has also been carried out on the New Zealand snapper, *Pagrus auratus,* using analyses of both microsatellite loci and mtDNA (Adcock *et al*., 2000). As with the previous study, short stretches (approx. 200 b.p.) of DNA from over 90% of scales was amplifiable using PCR. A similar approach has also been used to amplify microsatellite loci from DNA extracted from dried otoliths of cod *(Gadus morhua)* stored in individual paper bags (Hutchinson *et al*., 1999).

Formalin-fixed material has yielded sufficient DNA for several studies of genetic variation in deep-sea crustaceans and molluscs. The amphipod, *Eurythenes gryllus* is a common deep-sea scavenger that was thought to have a global distribution in cold waters at depths between 184m – 6,500 m (Gage and Tyler, 1991). An investigation of variation in partial sequences of 16S mtDNA region has been carried out for freshly collected and formalin-fixed museum specimens of this species from around the world and from different depth zones (France and Kocher, 1996). It was found that below 3,200m depth *Eurythenes gryllus* showed little haplotype divergence, whilst specimens collected in shallower water showed marked divergence from deep-water specimens and a marked divergence amongst themselves, even within geographic regions. The results were consistent with the existence of a species complex within *Eurythenes gryllus.* Below 3,200m depth a single species probably exists that may have invaded the abyssal zone, around the world, relatively recently. Above 3,200m depth, results were consistent with the existence of several species occurring in different regions, sometimes within the same ocean (France and Kocher, 1996).

Similar studies on formalin-fixed bivalve and gastropod molluscs from the continental slope of the western North Atlantic have also revealed surprising levels of haplotype divergence between populations separated by depth (Chase *et al*., 1998a; Etter *et al*., 1999). As for *Eurythenes gryllus*, partial sequence analysis of 16S mtDNA region indicates that haplotype divergence between populations of a number of species located above and below 2,500m depth is indicative of the presence of cryptic species. The reasons for this are uncertain but may reflect speciation along the depth gradient driven by selection, a lack of gene flow between vertically separated populations or because of historical events (Chase *et al*., 1998a,b; Etter *et al*., 1999). Subsequent studies have obtained amplifiable

DNA from 8 species of protobranch bivalves and 7 species of gastropods (Chase *et al*., 1998b). Both mitochondrial (16S rDNA, cytochrome b) and nuclear DNA (28S rDNA) have been amplified from formalin fixed molluscs (Chase *et al*., 1998a).

All these studies have a number of important features in common. Almost all studies, especially of extremely ancient DNA samples, have to employ stringent procedures during DNA extraction to prevent contamination from modern sources (e.g. Krings *et al*., 1997; Nielsen *et al*., 1997). Generally, most studies have targeted very short stretches of mitochondrial DNA, though amplification of nuclear regions from formalin-fixed material is possible (e.g. Chase *et al*., 1998a). In some cases repetition of PCR amplifications and subsequent sequencing or screening of genotypes for microsatellites, was carried out for single individuals. When DNA is present in very low concentrations, misincorporations of nucleotides during the early cycles of amplification can lead to a large fraction of molecules in the final product. This maybe a particular problem in ancient material where extensive damage is present in DNA fragments (Krings *et al*., 1997). For microsatellites, low template concentration can lead to non-amplification of some alleles or the amplification of false alleles (Goosens *et al.*, 1998). Non-amplification of alleles may result from different amplification efficiency amongst alleles of different lengths. Amplification of false alleles is probably a result of slippages during initial cycles of PCR (Goosens *et al*., 1998).



The future of genetic studies of marine specimens in museum collections

There are relatively few genetic studies of marine specimens preserved in museum collections. However, the few studies that have been carried out have revealed temporal genetic variation in marine populations, previously unrecognised species diversity and new information on the evolution of the deep-water fauna. This clearly demonstrates that museums contain vast resources for genetic studies by taxonomists, ecologists, and fisheries managers and for studies of the effects of climate change (in the palaeo-oceanographic and recent sense). For studies that require temporal sampling of genotype or haplotype frequencies, museums and other collections may provide the only source of material.

The widespread occurrence of cryptic species in the marine environment has severely hampered the study of many groups, especially soft-bodied invertebrates. These have relatively few morphological characters and often show a high degree of intraspecific morphological variation. Molecular genetic methods provide a new suite of tools with which to study such taxa. Methods are now available for the extraction of PCR amplifiable DNA from formalin-fixed material for even very small animals such as nematodes (e.g. Thomas *et al*., 1997). In the case of soft-bodied organisms, such as meiofaunal Platyhelminthes, where conventional collection and preservation methods often destroy morphological features (through extreme contraction) molecular methods may provide the only reliable means of accurate species identification (e.g. Litviatis *et al*., 1994). Molecular methods may also provide a means to rapidly assess the species diversity of small invertebrates from environmental samples by using similar methods to those used for identification of microorganisms (e.g. Muyzer *et al*., 1993).

It is clear that the application of molecular genetic studies in concert with conventional morphological taxonomy and accurate metadata (specimen collection data) is opening up a new era of research on the evolution of marine populations, species and higher taxa. Use of formalin-fixed or other preserved material for genetic studies remains technically complex and the enhancement of old collections with newly collected material, preserved for both morphological and molecular studies are becoming more widespread practice. The potential of museum collections for molecular studies must be recognised by funding authorities around the world for full potential to be exploited. It will be up to scientists to come up with exciting questions that can be addressed using the material available in these collections.

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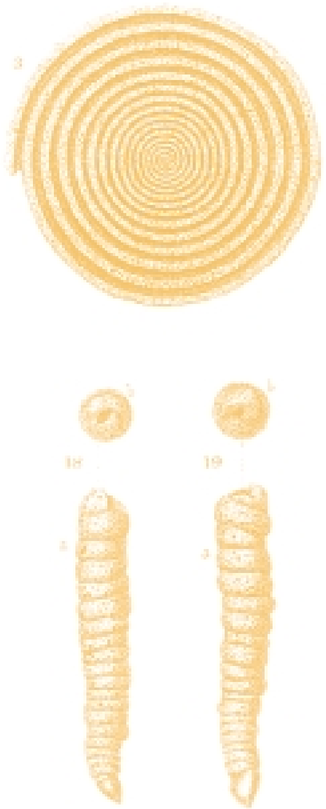

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Securing the future for marine sample collections – Conclusions and recommendations

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Introduction

The best way to ensure long-term support for sample-based physical object collections is their continued use in research that addresses contemporary issues. An active research community is the most effective way of achieving this. To effect this the sample collections community needs to overcome the perceived notion that physical object collections are old fashioned and curators need to raise the profile of such collections.

Raising the profile

Sample collections need to be recognised as data:

- Institutions that curate marine sample collections need greater recognition and representation on national advisory groups, for example, the Inter-Agency Committee on Marine Science and Technology (IACMST) and international bodies, such as the International Oceanographic Data and Information Exchange (IODE) and the International Council for the Exploration of the Sea (ICES).

- Increasing representation could be achieved through circulating reports on curatorial meetings, discussions with national representatives to ICES and the Intergovernmental Oceanographic Commission (IOC), and via national committees such as Marine Environmental Data Advisory Group (MEDAG) making representations to gain necessary recognition.

Activities that demonstrate the value and use of collections:

- Institutions that curate marine sample collections need to demonstrate the use and scientific value by using citation statistics, visitor numbers to collection facilities in reports to funding organisations. Many organisations such as museums already produce such statistics but usually such figures are supplied to the sponsoring Government department as part of the official yearly report. Such figures should also be targeted, via groups such as MEDAG, to funding and scientific organisations such as the Research Councils, IOC and ICES.

- Similarly such institutions need to demonstrate the value to society of collections by emphasising:

  1. the often unique nature of collections, i.e. time series from an era before global human impact, etc.

  2. collecting samples has been, and is, extremely costly for the tax-payer but many collections will have continued value long after the initial research has finished. So why are we throwing away such a resource ?

  3. better awareness of existing collections will enable scientists to identify research priorities and result in more efficient use of public funds.

- On an individual level, researchers should be encouraged to make more prominent acknowledgement of their use of collections and put an appropriate reference in the keywords of resulting papers.

Increasing recognition and use of marine sample collections:

- There is a need to get data management policies both at national and international levels to include the proper curation of physical samples in their recommendations. Such protocols need to become a feature of best practice in data management.
- Organisations which gather sample data, together with MEDAG and IACMST, should produce recommendations of best practice in management of sample data to guide funding bodies.
- Funding bodies such as the Research Councils need to include recommendations on proper curation as conditions of granting awards, for example, that researchers should deposit voucher collections, etc., in recognised collection storage facilities.
- Better liaison and collaboration between research groups collecting material and collection storage facilities must be encouraged, in order to foster better long-term curation of important collections.

Increasing the use of collections comes from making the scientific community aware of the resources available.

- Collection storage facilities need to establish on-line catalogues of their collections. A recent successful example of this is the European Union funded EU-SEASED project (see Rothwell, this volume) to set up a searchable Internet database of seafloor samples held by European institutions.
- Consortia of collection-holding facilities should be formed to develop proposals to fund such catalogues. Organisations such as the IOC and IODE should be approached to gain international support.
- Many institutions have been successful in attracting European Union Framework funding through the Large Scale Facilities Programme. Other organisations should investigate this opportunity to gain recognition.

Resources for the long term

Securing support for sample/ physical object collection facilities is, and always will be, difficult. In particular the recent spate of collection disposal by organisations, such as the Institution of Oceanographic Sciences (IOS), the Marine Biological Association (MBA), both sponsored by the Natural Environment Research Council (NERC) and the Environment Agency, may indicate a fundamental change in priority within these organisations. However, such disposals may not appear to give sufficient time, or resources, to ensure the long-term preservation of nationally and internationally valuable collections.

The first major task is to get a dialogue started about the future of collections in research institutes and universities, identifying centres of excellence such as the British Geological Survey or the British Ocean Sediment Core Repository at Southampton. In the UK the IACMST would appear to be the obvious organisation to initiate this.

The experiences of the disposal of collections such as the IOS and MBA indicate that there can be a considerable burden imposed on organisations taking on the storage of these important collections. Sudden acquisition of material requires access to resources such as storage space, access and databasing. Long-term storage, it could be argued, is the remit of collection storage facilities but the transfer of collections needs to be better managed. The sponsoring organisation of the institute, which is disposing of material, needs to make proper provision for the extra resources that will be needed to transfer collections. Such funding is not necessarily great but needs to be carefully planned.

Future research initiatives that will generate large numbers of physical samples should include some funding for the long-term preservation and curation of the collected samples; for example, proper documentation of the location and fate of samples, and ultimate transfer to recognised collection facilities.

Commercial collections

There are many collections made during the course of environmental impact assessments and monitoring programmes. Commercial companies make many of these collections either for governments or for other companies. Such collections can be important beyond the purpose for which they were originally taken. In areas such as the North Sea they represent a time series, monitoring anthropogenic impact since the beginning of oil exploration and extraction. Until recently there was no agreement as to what should happen to this material and inevitably some of it has been lost through disposal. However, A. Mackie (National Museum of Wales) has secured agreement that such collections should be deposited in recognised collection facilities (see A. Mackie, this volume).

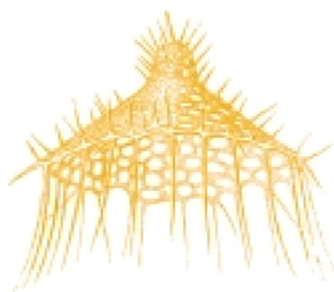
There is also a similar willingness to deposit geological material, but this is often *ad hoc* and done at short notice without any funding to support the transfer of collections. The Atlantic Frontiers Environmental Network initiative reported by S. Chambers (this volume) demonstrates that there can be very positive benefits both to the commercial company and to the collection facilities of a collaboration which properly funds the curation of commercial sample programmes.

- The collection facilities community should encourage the commercial sector to properly curate environmental collections that have long-term value and to enter into collaborative partnerships to achieve this. Within a share-holding environment, collection storage facilities could encourage this by showing the value-added aspects that such partnerships could bring to companies; for example, in terms of publicity for environmental awareness or contributions to biodiversity research.

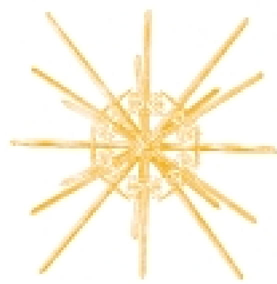
- Where the government is the client and sponsor of environmental impact assessment, it should stipulate that collections be properly curated and deposited in a recognised collection facility and make the necessary funding available for this to happen. Examples of this working successfully are the Mineral Management Services of the Department of the Interior of the United States which insisted that all collections from a major survey for oil off the eastern seaboard were deposited in the US National Museum. Again it may be up to the collection facilities to be better organised so that they can show government organisations the value of proper curation and long-term value of sample collections.

New types of collection

New types of physical object collections often face problems similar to those of more traditional collections. Two examples are the products from molecular biological studies and photographs and film/video of the ocean floor.



Molecular biology, by and large, has dealt with many of the data management issues associated with this discipline. However, long-term storage of molecular biology samples poses its own problems because such samples must be stored frozen. Unlike conventional samples, any problems associated with breakdown of freezers or power failure must be dealt with immediately before the tissues thaw and decompose. Such active curation also has resource implications and it is likely that many organisations will have to make decisions about long-term storage of tissue in much the same way that the IOS, etc. have had to make about traditional samples.



There must be hundreds of thousands of photographs and miles of film and video footage of the sea floor stored in institutes and universities around the world. While such collections are often well curated within an organisation, locating particular photographs is difficult. Often there is no catalogue of holdings. It appears that while we can photographically map the planets we have no way to collate what is already available for our own oceans !

- These new types of collections should be included in data management policy and plans.

- Consortia of institutions holding photographic collections should be formed to develop catalogues of holdings enabling the research community to gain access to this valuable resource. An example of how this might be achieved is given by I. Rees (this volume) who discusses a recent UK Department of Transport and the Regions project. This is a most important action as it would allow researchers access to what is available.

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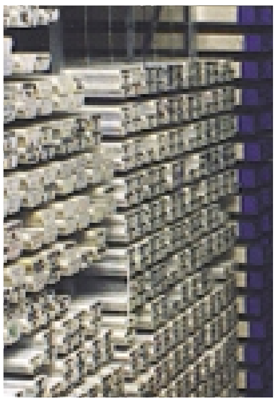

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