JOINT NATURE CONSERVATION COMMITTEE

Marine Nature Conservation Review: Rationale and methods

edited by

Keith Hiscock

Joint Nature Conservation Committee

Monkstone House, City Road

Peterborough PE1 1JY

UK

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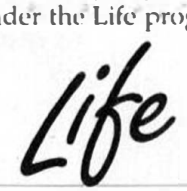


Contents

Foreword

The British are an island people. Our land is surrounded by the sea and our lives are full of maritime associations. Famous voyages of discovery have set sail from our shores and great seaports have developed to service our trade with the world. The seaside holiday has been an important part of our culture for over a hundred years. Recent politics have been much concerned with the survival of traditional maritime industries - shipbuilding, fishing, the merchant navy - and the development of new ones such as the oil and gas industry, fish and shellfish farming.

We make enormous demands on the sea. It provides us with food, fertilisers and a means of transport. We extract sand and gravel from the floor of the sea and pump oil and gas from its basement. We dump our waste into it. But the sea around us is also a wonderful natural environment. It is biologically very rich. Beneath our seas and along our coasts are plant and animal communities which are as fascinating as tropical rainforests; indeed, there are great kelp forests just offshore; along with sea-grass beds, reefs and flat plains of mud or sand teeming with buried life. There are brightly coloured sea slugs and cup corals, delicate sponges and sea fans and groups of fragile sea pens which stand over a metre tall. This beautiful environment is just as much in need of care and conservation as our terrestrial woodlands or grasslands.

Nature conservation in Great Britain (published by the NCC in 1984) defined nature conservation as "the regulation of human use of the global ecosystem to sustain its diversity of content indefinitely." Safeguarding any natural resource requires information on its nature, extent, quality and vulnerability. The marine environment around our coast is similar in scale and complexity to its terrestrial counterpart - but we know very much less about it.

The Marine Nature Conservation Review (MNCR) began in 1987. Its aim is to provide information describing the marine habitats, communities and species around Great Britain. This has been collected in such a way as to underpin the development of management systems for marine nature conservation and to support the identification of marine protected areas.

This volume provides an appraisal of marine nature conservation needs in Great Britain, lays out the rationale for the MNCR and describes the methods used for descriptive survey and assessment in the marine environment. It provides a touchstone for all those concerned with the marine environment, whether in terms of education, research or conservation; but I hope it will be of absorbing interest to readers far beyond the 'nature conservation community'.

Magnus Magnusson KBE,
Chairman, Scottish Natural Heritage
and Chairman of the MNCR Project Management Board
April 1996.

Marine Nature Conservation Review: rationale and methods - Summary

Introduction

The variety of marine habitats in Britain is tremendous - the greatest of any European state with an Atlantic coast - from the rugged wave-beaten Atlantic shores of northern Scotland to the still muddy backwaters of southern estuaries. The range of coastal topography includes rocky islands, extensive sandy coasts, tide-swept sounds, steep-sided sealochs and isolated brackish lagoons. The waters around Britain are crystal-clear in offshore areas but are described as being like liquid mud in some tide-swept estuaries. The temperature of shallow waters range from those described as warm temperate to those of cold temperate conditions. This great range of environmental features is reflected in a wide variety of plant and animal life forming different communities according to the combination of geographical position and local environmental features. Conserving the consequent high biodiversity requires information on which to base decisions on environmental protection and management, including the best locations for marine protected areas. Acknowledging these requirements, the Marine Nature Conservation Review (MNCR) was commenced in 1987 by the Nature Conservancy Council with the objectives of:

- extending our knowledge of benthic marine habitats, communities and species in Great Britain, particularly through description of their characteristics, distribution and extent;
- identifying sites and species of nature conservation importance.

The data collected also provide information to support more general measures required to minimise adverse effects of development and pollution, particularly on sites and for species of nature conservation importance.

Subsequent to the Environmental Protection Act 1990, the MNCR has been undertaken by the Joint Nature Conservation Committee (JNCC) on behalf of the Countryside Council for Wales (CCW), English Nature (EN) and Scottish Natural Heritage (SNH). Country agency staff contribute to the development of MNCR methods for survey, assessment and reporting and take forward the results of MNCR work to identify the marine natural heritage importance of sites including in relation to potentially damaging activities.

Scope of the MNCR

The geographical area within the statutory remit of the country nature conservation agencies and JNCC is England, Scotland and Wales. It excludes Northern Ireland and the British Crown Dependencies of the Isle of Man and the Channel Islands.

In order to obtain the most pertinent information from the the vast area holding marine habitats and species within British jurisdiction, it has been important to ensure that the MNCR programme is clearly focused to meet the immediate priorities for conservation. This has meant identifying those areas, both widescale and more localised, where survey is most required to support wildlife conservation and identifying the habitats and species which should be surveyed. The type of information collected has also been influenced by practical aspects of working in the marine environment, including constraints of environmental conditions, equipment capabilities and cost, as well as by the techniques and expertise available.

Taking these various considerations into account, the focus of MNCR work is therefore on benthic habitats and their associated communities, which together are described as 'biotopes', in inshore areas.

The extent of this inshore coastal zone varies but is generally taken to reach about 3 miles or 5 km offshore. The coastal zone includes both sediment and rock habitats and is particularly affected by wave action on the seabed, by the presence of turbid water and by the acceleration of tidal currents by coastal features. Plumes of turbid, low salinity water from large estuaries such as the Humber or offshore emergent features such as the Sarns in Cardigan Bay may effectively extend habitat features of the coastal zone and consequently require survey effort further offshore. The 50 m depth contour is also important as it is approximately where offshore areas of low-turbidity, seasonally-stratified waters meet those inshore which are generally of higher turbidity and are well-mixed throughout the year. It is also the depth below which wave action is unlikely to have a substantial effect on the seabed on the open coast.

Even restricting to the coastal zone the area on which the MNCR primarily focuses, there remain many tens of thousands of square kilometres of shore and seabed to consider. The task of review and survey has, however, been made more manageable by dividing the coast into fifteen physiographically or biogeographically distinct areas, the MNCR 'coastal sectors'.

The MNCR database

All aspects of the MNCR are supported by a powerful database which enables rapid access, manipulation and dissemination of data. The database is also held by each of the country nature conservation agency marine teams. Information can be exported from the database for display using UKDMAP (United Kingdom Digital Marine Atlas Project) software. Information on sites surveyed and reported in the literature are available on commercial copies of UKDMAP.

Main elements of the programme

The MNCR programme has seven main elements.

1. Collation and assessment of existing information

Three main types of existing information are used by the MNCR.

i. **Information which contributes to marine conservation issues** Where information is relevant to the work of the MNCR it is reviewed and incorporated into the literature review module of the MNCR database. Each paper, book, report or other item of information receives a reference, keywords, an abstract and, where relevant, an indication of its geographical coverage.

ii. **Site-specific survey information** Site-specific details of marine biological surveys are incorporated into a literature sites module of the MNCR database. Here the source reference, the types of survey undertaken and the specific location of each site are recorded. Through display on mapping facilities within the database, this module provides a rapid indication of where surveys have been undertaken and is particularly useful in responding to site-specific issues of marine conservation management.

iii. **Survey information which enables full description and/or conservation assessment of the site** Where survey information has been collected to similar standards and aims as that of MNCR field surveys, and therefore can contribute to the detailed description of habitats and their component species or to the assessment of marine natural heritage value, it is incorporated into the field survey module of the MNCR database.

2. Undertaking new field surveys to fill gaps in knowledge

Before the start of the MNCR, large stretches of coast were poorly surveyed or lacked studies where data were collected for nature conservation aims. The surveys undertaken by the MNCR aim to give a broad but comprehensive overview of the range of habitats present, from which locations of high marine natural heritage importance are identified. For practical and economic reasons the surveys do not attempt to map in detail the distribution of habitats present in each sector although recent techniques such as acoustic mapping can provide such information.

The MNCR uses reconnaissance, inventory and mapping surveys as a first step in determining the locations of sites for the more detailed surveys which provide the information needed for site comparison and assessment. Survey work undertaken by the MNCR requires the use of a variety of techniques depending on substratum type and environmental conditions. Hard substrata are surveyed directly by recording the abundance of the conspicuous species present. For sublittoral areas, this requires diving and, for depths below 50 m, video photography. Sediments are described directly and samples are taken usually by coring in situ or remotely by grab sampling. Records of habitats and flora and fauna are supported by photographs and specimens.

3. Setting standards for data collection, storage and interpretation

The MNCR establishes and promotes common standards for field survey methods, data storage through the MNCR database, data interpretation and conservation evaluation both nationally and internationally.

4. Classifying marine biotopes

The MNCR is developing a marine classification system to underpin interpretation of data, assessment of conservation importance and management of marine areas.

5. Comparing and evaluating locations

Comprehensive data sets enable objective assessment and comparison of locations to be carried out based on their scientific merits. Computer-aided analysis facilitates this evaluation.

6. Identifying locations and species of marine natural heritage importance

Following broad-scale survey, undertaken by standard methods, the MNCR identifies locations of high natural heritage value within each coastal sector through a standard assessment protocol. The protocol can also be used to assess the marine natural heritage importance of sites proposed for development or where potentially damaging activities might be undertaken. Records held on the MNCR database can be used to assess species distribution and rarity.

7. Publishing results

The results of MNCR field surveys are disseminated for use by conservation organisations. Until 1994, dissemination was through reports of each separate field survey. The MNCR now produces a variety of publications to suit regional and national requirements for information on marine management, nature conservation and marine ecology. A report series provides information for each of the 15 coastal sectors and includes:

- **A biotope classification** A classification for the MNCR coastal sector or major physiographic type of coast. The classification contributes to the national MNCR classification.
- **Area summaries** An account of each physiographically similar stretch of open coast, marine inlet or lagoon within the sector.
- **Conservation assessment** A comparative assessment of the marine natural heritage quality of each stretch of open coast, marine inlet or lagoon within the MNCR coastal sector.
- **Overview** An account of the major physical and biological features of the entire MNCR coastal sector or major physiographic type of coast incorporating or taking account of non-MNCR work.

Reports and papers are also published describing the development of MNCR work and methods. MNCR information is incorporated into publications such as the Coastal Directories series being undertaken by JNCC and disseminated through the electronic publication UKDMAP. Further publications, both on paper and through electronic media, are planned.

1 Historical perspective

1.1 Early concerns

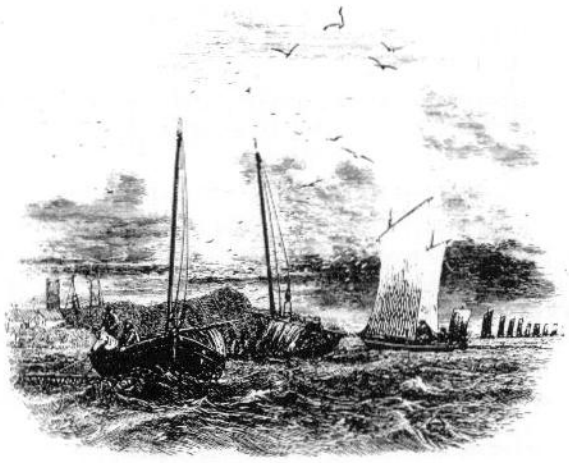
Roger Mitchell and Keith Hiscock

Though not having the antiquity of forest clearances on land, significant human impact on marine habitats and wildlife populations extends back several centuries. Concern about the adverse effects of fishing dates back to the 14th century in Britain when it was noted in a petition presented to Parliament in the year 1376–7 (quoted in Hore & Jex (1880)) that:

"The hard and long iron of the said "wondyrchoun", [an oyster dredge]...destroys spawn and brood of the fish beneath the said water, and also destroys the spat of oysters, muscles [sic], and other fish by which large fish are accustomed to live and be supported."

Degradation of estuarine and coastal water quality most likely became significant for marine life during the Industrial Revolution whilst the development of ports, land-claim for agriculture and many other human activities have all had effects on habitats and species. Recreational impact was occurring even in the 19th century. Edmund Gosse, writing in 1906, commented on the beauty of marine life observed while accompanying his father onto the shore:

"All this is long over and done with. The ring of living beauty drawn about our shores was a very thin and fragile one. It had existed all those centuries solely in consequence of the indifference, the blissful ignorance of man. These rock-basins ..... thronged with beautiful sensitive forms of life - they exist no more, they are all profaned, and emptied and vulgarised. An army of 'collectors' has passed over them and ravaged every corner of them. The fairy paradise has been crushed under the rough paw of well-meaning, idle-minded curiosity."



Changes to the seabed by fishing extend back several centuries: oyster dredging at Cockenzie, Firth of Forth (Bertram 1865).

Seashore amusements: the Victorian passion for collecting may have depleted seashore habitats (Courtesy of the Ilfracombe Museum).

1.2 The development of general nature conservation measures

The nature conservation movement began at the end of the 19th century but gained particular strength following the Second World War with the Government report *Conservation of nature in England and Wales* (Command 7122, 1947) and the subsequent National Parks and Access to the Countryside Act 1949. Those who had most influence in developing nature conservation in Great Britain were terrestrial naturalists and ornithologists. The lack of consideration of the marine environment was exacerbated by most of it being out of sight and poorly known - so much so that *A Nature Conservation Review* (Ratcliffe 1977) did not consider marine habitats on rocky shores or below low water mark. The *Review* included

intertidal sediment flats, but almost entirely for their ornithological interest. *A Nature Conservation Review* provided the basis for identifying an extensive network of Sites of Special Scientific Interest (SSSIs). These were sites with statutory protection and could include intertidal areas. However, very few were to be established because of their marine biological interest. There was conservation effort in the marine environment but this was directed at sustaining fisheries, and only the closure of areas to fisheries or restrictions on the use of mobile gear were measures likely to help wildlife conservation, albeit incidentally. The Geological Conservation Review, now being published, also identified locations to be notified as SSSIs at coastal and intertidal locations.

Box 1.1. Human activities affecting marine ecosystems

Exploitation of natural living resources

Marine mammal stranding and culling
Fishing
Sea angling
Spear-fishing
Shell fisheries
Bait collecting
Collecting
Experimental manipulation of organisms or environmental conditions for educational or scientific purposes

Cultivation of living resources

Fin-fish farming
Molluscan shellfish farming
Algal farming
Introduction of non-native species
Control of predators at fish and shellfish farms

Exploitation of non-living resources

Aggregate dredging including sand and gravel offshore and onshore maerl, gravel and shell-sand dredging
Oil and gas industry activity including exploration and production
Alternative energy including generation of power by wave energy or establishment of wind farms
Coastal superquarries
Marine archaeology and salvage

Use of coastal land and water space

Land-take/claim
Land run-off
Coastal industrialisation and urbanisation
Recreation
Military activities
Docks and marinas
Barrages and causeways
Artificial reef construction
Shipping and navigation

Waste disposal

Sewage
Refuse and resultant beach litter
Industrial wastes
Inorganic mine wastes
Spoil dumping
Thermal discharge
Radioactive waste

Coastal defence and flood protection

Coastal defences
Accretion enhancement

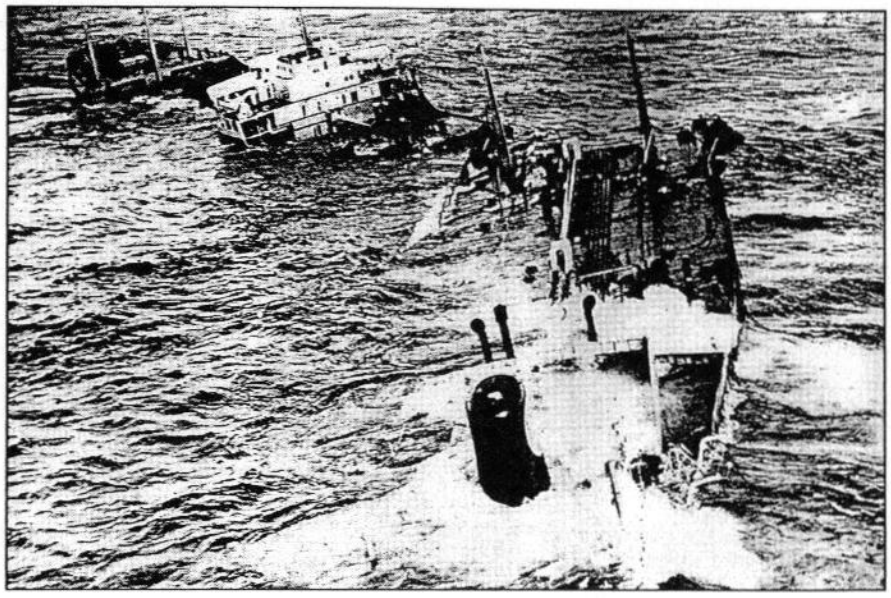
Activities which might adversely affect the nature conservation interest of a site. The list is based on that in the Marine Conservation Handbook (Eno 1991).

1.3 The development of marine conservation up to the start of the MNCR

Our current approach to marine wildlife conservation can be traced back to 1965 when a group of marine biologists and scientific divers wrote to the Natural Environment Research Council (NERC) which, at the time, included the Nature Conservancy (a predecessor of the current statutory nature conservation agencies). They drew attention to the expansion of SCUBA diving as a sport in Britain and the potential threat this posed to marine life through the over-collection of organisms for food or as curios. They recommended that certain areas below the low water mark should be set aside for photography and biological study and protected from over-exploitation. From their collective experience, they suggested three possible sites for 'underwater reserves': Skomer Island in south-west Wales, St Anthony Head near Falmouth, and the Farne Islands and Holy Island in north-east England. Certain of these scientists continued to lobby NERC to give more priority to the conservation of marine wildlife in the British seas.

The wreck of the *Torrey Canyon* with subsequent oil pollution and related environmental damage in 1967 drew attention to the threat which marine life faced as a result of human activities (Smith 1970). This event, and subsequent oil spills, have particularly contributed to greater public and political interest in the conservation of marine wildlife.

In the late 1960s there was a great deal of activity world-wide in establishing marine parks and reserves. Inevitably, questions were asked about the possibility of such areas being established in Britain. The first indication of the consideration of a formal policy for marine nature conservation in Great Britain was in 1969, when a meeting was held between NERC's nature conservation and marine science staff to discuss the need for better communication and liaison in relation to the conservation of intertidal areas. As a result of this meeting the Nature Conservancy prepared a paper entitled *Conservation policy in the shallow seas* which recommended that a scientific committee should



Oil pollution drew attention to and concern about human effects on the marine environment. Wreck of the Torrey Canyon oil tanker on the Seven Stones reef, 1967 (Hulton-Deutsch collection).

be established to:

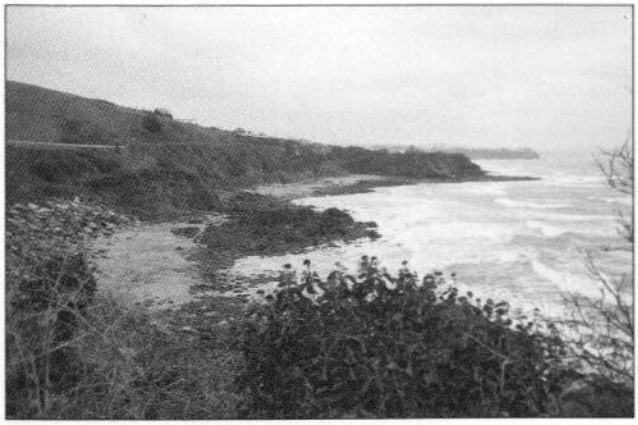
- review the state of knowledge of intertidal Britain;
- recommend measures for safeguarding as nature reserves areas of key importance as representative samples of major shore types or as research and educational sites; and,
- consider whether conservation measures were desirable for areas below the low water mark.

Although the proposal for setting up this committee received a positive response from those to whom it was circulated, NERC's Oceanography and Fisheries Committee advised that in the absence of strong evidence that a marine conservation problem existed due to controllable factors, the proposal should not be pursued at that time. Meanwhile, by 1971, the island authorities at Lundy in the Bristol Channel had accepted the proposal for Britain's first voluntary marine nature reserve to be established around the island (Hiscock *et al.* 1972). At about the same time, discussions were underway to establish a local nature reserve at Saltern Cove in South Devon with a boundary which extended to 2 m below chart datum level in order to protect its marine biological interest. Torbay Borough Council notified the reserve under section 21 of the National Parks and Access to the Countryside Act 1949 in August 1973.

During the 1970s, a very few intertidal areas were notified under the National Parks and Access to the Countryside Act 1949 as Sites of Special Scientific Interest (SSSIs) with marine biology of cited importance. SSSIs were then essentially a means of notifying planning authorities and owners and occupiers of land of their scientific importance. The significance of SSSI notification increased after the passing of the Wildlife and Countryside Act 1981 where provisions for safeguard were increased but intertidal marine life continued to figure little in cited importance of sites.

In 1971, there were further Parliamentary Questions and enquiries from the Department of Education and Science and the Council for Nature regarding the establishment of marine parks and reserves below the low water mark. In view of this renewed pressure, the Nature Conservancy's Scientific Policy Committee recommended that NERC should establish a Working Party to consider the need to protect marine life around the United Kingdom. This was agreed and, in 1971, NERC established a Working Party on Marine Wildlife Conservation to make a preliminary assessment of evidence and advise whether there was a case for additional conservation measures in the marine environment.

The specific terms of reference for this Working Party were to advise NERC, on the basis of existing knowledge of marine ecosystems, on the case for establishing marine



Saltern Cove, Torbay. A local nature reserve established to protect its marine biology in 1973 (Keith Hiscock).

Lundy. Britain's first voluntary (1971) and first statutory (1986) marine nature reserve (Dan Laffoley / English Nature).

nature reserves or other conservation measures, giving consideration to:

- the definition and identification of areas or species of special interest;
- the problem of measuring changes, distinguishing between natural and artificial factors, the extent of the pressure on marine habitats;
- the investigation necessary to quantify measures; and
- the need, if any, for protective measures.

After considering both written and oral evidence the Working Party prepared a report *Marine wildlife conservation: an assessment of evidence of a threat to marine wildlife and the need for conservation measures* (Natural Environment Research Council 1973) making a number of cautious recommendations which, *inter alia*, emphasised the need for:

- data collection schemes to be examined and made compatible;
- establishing new coastal/intertidal National Nature Reserves (NNRs) specifically for research;
- exploring the legal procedures for establishing sublittoral NNRs, and
- taking advantage of the marine biological knowledge and experience within NERC, the Fisheries Departments and the universities.

Among the papers considered by the NERC Working Party was the report *Nature conservation at the coast* prepared by the Nature Conservancy (1970). This reviewed the research and educational importance of coastal areas and their value as wildlife habitats. Using eight site assessment criteria, 371 sites in England and Wales were evaluated and classified into four main categories:

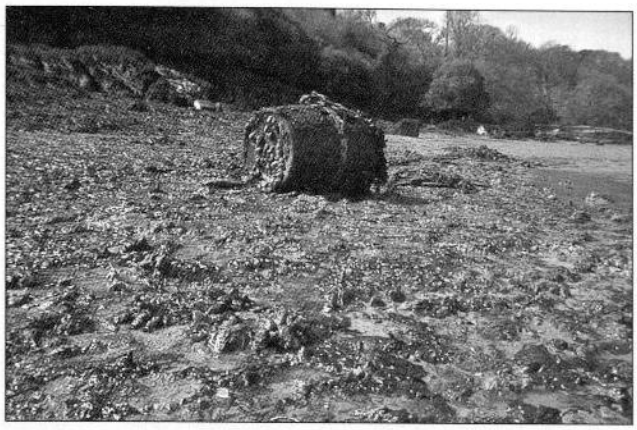
a. areas of outstanding scientific importance
b. areas of special scientific importance
c. areas of conservation value
d. degraded and intensively developed areas of negligible scientific importance.

Although all of these sites included intertidal habitats, in only nine cases was the marine biological interest (other than birds) specifically mentioned. The report was able to draw on information being collected about coastal areas and an initial selection of important sites by Nature Conservancy staff and others for the projected *Nature Conservation Review* (Ratcliffe 1977). However, this was in many respects a foundation report on coastal information and a far-sighted document in respect of its proposals and recommendations, the key elements of which prescribed what is now known as 'Coastal Zone Management and Planning'.

Neither the 1970 Nature Conservancy nor the 1973 NERC reports prompted much immediate action in advancing marine nature conservation. However, with the transfer of NERC's responsibilities for nature conservation to the Nature Conservancy Council (NCC) in 1973 through the Nature Conservancy Council Act 1973, the recommendation from the NERC report (Natural Environment Research Council 1973) for another expert Working Party to review scientific information and general developments pertinent to the conservation of marine wildlife was implemented jointly by NCC and NERC. The NCC/NERC Joint Working Party on Marine Wildlife

Table 1.2 Key dates in marine conservation in Great Britain.

1949:	Nature Conservancy (NC) established by Royal Charter
1949:	National Parks and Access to the Countryside Act
1965:	Nature Conservancy becomes part of Natural Environment Research Council (NERC)
1967:	Wreck of Torrey Canyon
1969:	Nature Conservancy Paper: Conservation policy in the shallow seas
1969/71:	Need for Marine Nature Reserves (MNRs) raised in Parliament
1971:	NERC Working Party on Marine Wildlife Conservation established
1971:	Lundy proposed as Britain's first Voluntary Marine Nature Reserve
1973:	NERC Working Party reported
1973:	Nature Conservancy Council (NCC) Act - NC split into NCC and Institute of Terrestrial Ecology (ITE)
1973:	Management plan for Lundy Voluntary Marine Nature Reserve prepared
1975:	Joint NCC/NERC Working Party on Marine Wildlife Conservation established
1977:	Underwater Conservation Year
1979:	Joint NCC/NERC Working Party reported
1979:	Underwater Conservation Society (UCS) formed
1981:	DoE consultation paper on MNRs
1981:	Wildlife and Countryside Act - Marine Nature Reserve provisions
1983:	UCS becomes the Marine Conservation Society (MCS)
1986:	Lundy becomes Britain's first statutory Marine Nature Reserve
1987:	Marine Nature Conservation Review of Great Britain initiated
1990:	Environmental Protection Act separates NCC (in 1991) into three country agencies with a Joint Nature Conservation Committee
1991:	Skomer established as statutory Marine Nature Reserve
1992:	British Government signs EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (the 'Habitats Directive') which includes provisions for the protection of examples of marine habitats and species of maerl, cetacean, seal, marine turtle, and some migratory fish.
1992:	United Nations Conference on Environment and Development - UK signs Biodiversity Convention and announces Darwin Initiative
1993:	House of Commons Select Committee on the Environment report on Coastal Zone Protection and Planning published - identifies need for further consideration of legislative requirements in marine conservation and recommends a Coastal Zone Management approach
1994:	UK Government launches its Biodiversity Action Plan which includes target to "complete the MNCR under the aegis of the JNCC" "The Conservation (Natural Habitats, &c.) Regulations" come into force on 30 October with special provisions for the establishment of "European marine sites"
1995:	UK government lists 37 possible Special Areas of Conservation for marine habitats under the provisions of the EC Habitats Directive. UK government publishes Biodiversity: the UK Steering Group Report which includes costed action plans for five marine species and for two marine habitats.



Salcombe to Kingsbridge Estuary is one of the few Sites of Special Scientific Interest established for the importance of marine biological features: a rich muddy gravel shore in Salcombe Harbour (Keith Hiscock/JNCC).

Active conservation policies for vertebrate species spending a part of their life ashore existed in the early 1970s. Seals at Blakeney Point, Norfolk (Keith Hiscock).

Conservation first met in 1975 and its terms of reference were interpreted to relate primarily to the littoral and sublittoral areas of the coastal zone, since active conservation policies already existed for maritime flora and fauna, seals and seabirds. In addition, consideration of commercial fish stocks were specifically excluded since these were the statutory responsibility of the Fisheries Departments.

In 1977, *A Nature Conservation Review* (NCR) was published (Ratcliffe 1977). This seminal work reported the results of the review, initiated in 1965, to describe and analyse the range of variation of the natural and semi-natural vegetation of Britain, together with its characteristic communities of plants and animals, in order to identify the most important sites which should be conserved. The *Review* did not include marine habitats except intertidal areas as a habitat for birds and their food and some saline lagoons. However, the general philosophy and strategies developed for the NCR greatly influenced those which were later adopted for the MNCR.

Following ten meetings of the NCC/NERC Working Party, during which many written papers and oral reports were considered, their report to both Councils, *Nature conservation in the marine environment*, was published (Nature Conservancy Council & Natural Environment Research Council 1979). The recommendations are summarised in Appendix 2. This report recommended that NCC should develop a formal marine conservation policy and consider obtaining legislation for the establishment of marine reserves. Further recommendations covered the number, size and type of reserves required and the additional studies needed to improve the description and classification of marine communities. Particular emphasis was placed on the need to promote an informed conservation-oriented viewpoint among users of the coastal zone and the general public. The Working Party recognised that, before it would be possible to select with confidence the most appropriate sites for designation, there was a need for more consultation and supplementary survey work. The key recommendation covering MNCR-type work was:

"We recommend further consultation and discussion and, where necessary, provision of support for additional studies related to improving description and classification of the lesser known plant and animal communities; high priority should, in particular, be given to sublittoral rocky communities."

Progress has been made on all the recommendations and, in some cases, this has been substantial.

Meanwhile, a number of scientific and recreational divers with a common interest in marine conservation in British waters had promoted 1977 as Underwater Conservation Year during which a number of professionally-led amateur projects were started. These projects were continued as the Underwater Conservation Programme in 1978 and 1979, stimulating sufficient interest to prompt the formation of the Underwater Conservation Society (UCS) in 1979. UCS became the Marine Conservation Society (MCS) in 1983. From the outset, the Society recognised the need for the development of a sound scientific basis for marine conservation and actively lobbied for new legislation to allow adequate conservation below the low water mark, which was then the limit for statutory conservation sites.

Partly in response to the recommendations from the NCC/NERC Working Party, the Department of the Environment (DoE) set up an inter-departmental working party on marine nature reserves in 1979. The purpose of this was to consider the legal and administrative aspects of the proposals to establish statutory marine reserves below the low water mark. At the conclusion of discussions in 1981 the DoE issued a consultation paper, *The establishment of marine nature reserves*. While this was still open for comment, the opportunity arose to insert appropriate provisions for the establishment of statutory marine nature reserves in the Wildlife and Countryside Bill. Due to sustained pressure from NCC and the voluntary conservation organisations combined with particularly strong support in the House of Lords, appropriate provisions were included in the Wildlife and Countryside Act 1981. A detailed description of legislative provisions for marine nature reserves is given by Gibson (1984).

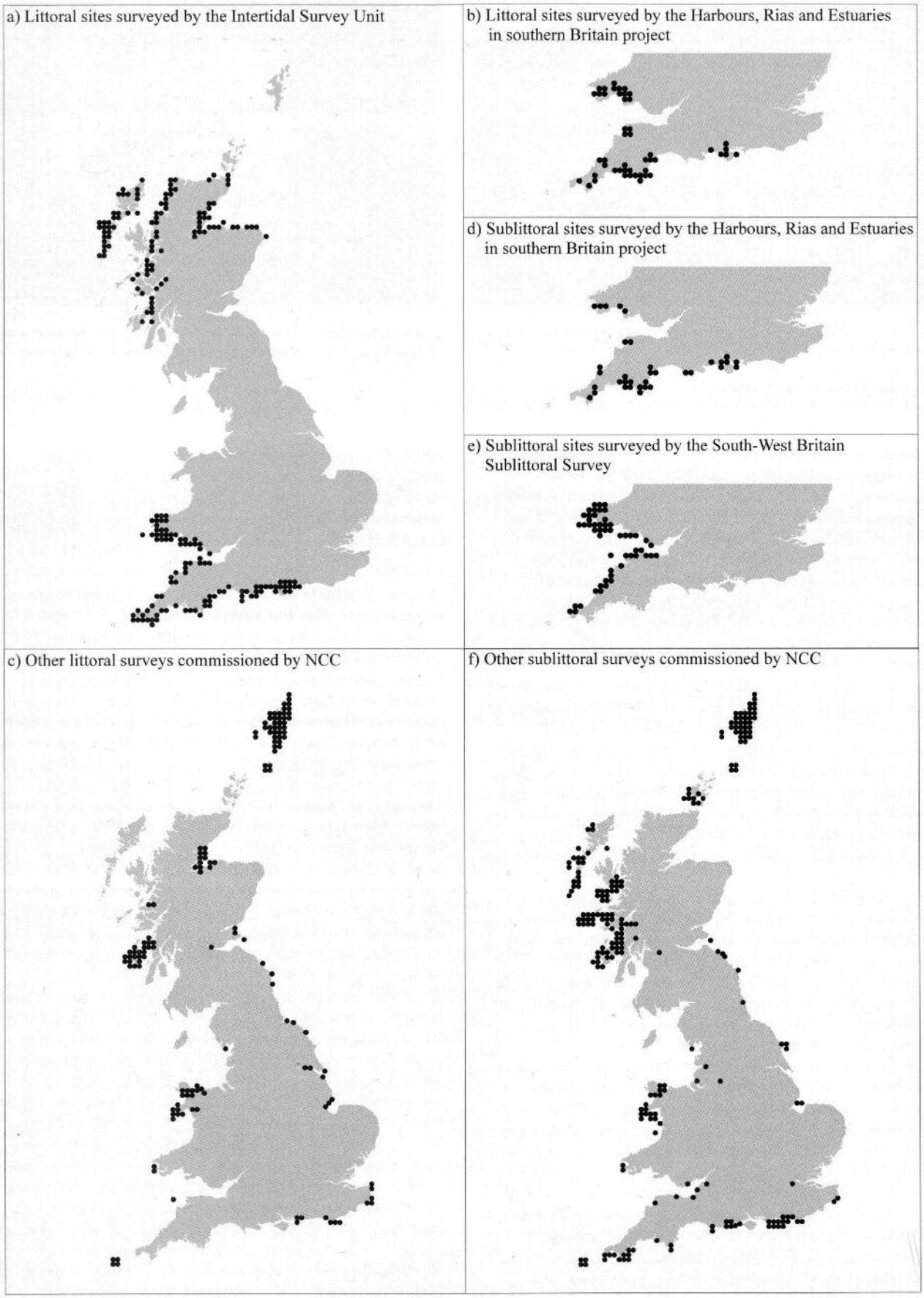
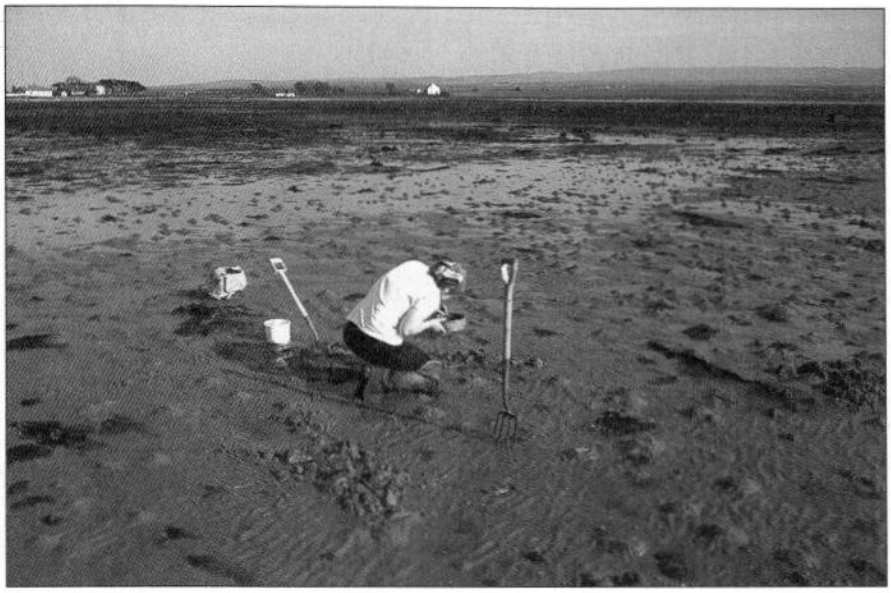


Figure 1.1 Location of marine biological surveys for the NCC prior to the start of the MNCR. Locations are plotted for each 10 km x 10 km Ordnance Survey grid square and may represent several sites and more than one survey.



The NCC commissioned some extensive marine biological surveys before the start of the MNCR: sampling intertidal sediments during the Intertidal Survey of Great Britain (Intertidal Survey of Great Britain/JNCC).

A few months after it became possible to give statutory protection to sublittoral marine areas around Great Britain, the Council of Europe's European Committee for the Conservation of Nature and Natural Resources called for a group of experts to be assembled to prepare *A strategy for safeguarding the marine benthic biocenoses of the North Sea and Baltic by means of a network of marine parks*. The group met in 1982 and 1983 and prepared papers pertinent to their countries in 1984, reporting in 1987 (Mitchell 1987). The methods described in this document for the survey, classification and assessment of marine sites became the basis of the approach adopted by the MNCR.

With provisions for statutory Marine Nature Reserves (MNRs) in place, marine nature conservation assumed a higher priority in NCC, becoming a separate theme in the Corporate Plan for several years with a modest increase in resources. However, there was still a considerable shortfall in the effort required to make real advances in marine conservation. Recognising this, the Marine and Coastal Sector Review Group, responding to the World Conservation Strategy in 1983 in their report *Conservation and development of marine and coastal resources*, recommended that "The NCC should be given the resources needed to increase its level of expertise in the marine and coastal environment to take proper account of its greater responsibility in this area". Echoing this in its own contribution to the World Conservation Strategy, the NCC stated that "Marine ecosystems are the Cinderella of nature conservation in Britain" and drew attention to the lack of effective legislation for protecting important marine sites and the high requirement for littoral and sublittoral resource surveys (Nature Conservancy Council 1984). Their report, *Nature Conservation in Great Britain*, recommended that a Marine Nature Conservation Review should be launched immediately to identify prospective Marine Nature Reserves and other sites of regional importance, and that negotiations should be vigorously pursued for establishing the first statutory MNR.

single, major, co-ordinated programme for the inventory and assessment of marine habitats and wildlife resources, a series of projects had proceeded to acquire this information. Nine projects resulted in the collection of littoral and sublittoral information from sites in various parts of Great Britain. In addition, two volunteer projects were initiated to collect basic habitat information: Coastwatch in 1985 for littoral and fringing habitats, and Seasearch in 1986 for sublittoral habitats. With the co-operation of the NCC, MCS reviewed much of the information which listed and described the sites identified as important in NCC surveys conducted between 1974 and 1985 and produced the *A coastal directory for marine nature conservation* (Gubbay 1988) .

Meanwhile, the first seven potential marine nature reserves had been selected using a combination of available information and expert views. The same approach was also used in selecting the first tranche of non-statutory Marine Consultation Areas in Scotland in 1986 and the later additions in 1990 (the latter resulting from recommendations derived from MNCR surveys) (Nature Conservancy Council 1990).

The key recommendations for marine conservation in *Nature conservation in Great Britain* (Nature Conservancy Council 1984) were realised in November 1986 with Lundy being declared Britain's first statutory Marine Nature Reserve and in 1987 with the initiation of the Marine Nature Conservation Review programme.

2 The rationale and setting for the Review

Keith Hiscock and David Connor

2.1 Needs and objectives for a marine nature conservation review

We rely greatly on the sea especially for food and transport. In addition, we gather minerals from the seabed, we dump waste in the sea and we use it for a host of leisure activities. As a result, marine ecosystems are not the pristine wilderness that many once considered them to be. In places, they have been substantially degraded by human activities and that degradation continues. Inevitably there are therefore conflicts between the multiple uses of the marine environment and the conservation of wildlife.

There is a growing concern for the well-being of the sea and a desire to move towards its use in a more environmentally sensitive and sustainable manner. In particular, there is a growing demand for marine nature conservation interests to be considered more strongly, both in general sea-use management and in specific site protection measures. This is manifested at various levels, ranging from global initiatives such as the Biodiversity Convention (which was established at the United Nations Conference on Environment and Development in 1992) through European legislation, such as the EC Habitats Directive (Council of the European Communities 1992), to the setting up of local voluntary conservation areas.

Whilst marine conservation, compared with its terrestrial counterpart, is still in its infancy, its future success depends on the power of persuasion and the co-operation of all interested parties. Its most potent resource in this is a sound information base for the development of conservation policy.

The Marine Nature Conservation Review was initiated to provide just such a comprehensive baseline of information on marine habitats and species to aid coastal zone and sea-use management and to contribute to the identification of areas of high marine natural heritage importance throughout Great Britain. The MNCR was commenced in 1987 by the Nature Conservancy Council with the objectives of:

- extending our knowledge of benthic marine habitats, communities and species in Great Britain, particularly through description of their characteristics, distribution and extent;
- identifying sites and species of nature conservation importance.

The data collected also provide information to support more general measures required to minimise adverse effects of development and pollution, particularly on sites and species of nature conservation importance.

The MNCR is the third major resource survey to be initiated by Britain's statutory nature conservation agencies. The MNCR began in 1987 within the Nature Conservancy Council and follows the Nature Conservation Review (Ratcliffe 1977) and the Geological Conservation Review (Ellis *et al.* 1996). Subsequent to the Environmental Protection Act 1990, the MNCR has been undertaken by the Joint Nature Conservation Committee (JNCC) on behalf of the Countryside Council for Wales (CCW), English Nature (EN) and Scottish Natural Heritage (SNH). The statutory functions of these bodies are described in Appendix 3. The MNCR is included as a major initiative within *Biodiversity. The UK Action Plan*, the UK Government's response to the Biodiversity Convention (Anon. 1994).

2.2 Information requirements for nature conservation in the marine environment

Developing a strategy for marine conservation requires an approach which takes account of our experience of conservation on the land but which addresses the particular features of the marine environment. These features include very different environmental conditions, species and communities to those which prevail on the land. Furthermore, in relation to management of marine resources, many marine habitats remain in a near-natural state or would restore themselves to a natural condition if left undisturbed by human activities. Marine habitats do not usually need to be intentionally manipulated, as on the land, to retain or regain their scientific interest. There are also serious threats which are particularly important in the sea including the transport of dissolved pollutants in sea

water, the over-exploitation of living resources, the physical alteration of habitats by construction, fishing and mineral extraction and by shipping accidents which result in spillage of dangerous materials. It is also important to take account of the legal regime at sea where common rights abound and sovereignty extends only within territorial seas making effective legal measures for protection difficult to achieve.

Successful management of the sea, with nature conservation as a key consideration, requires information on the following main topics (those being incorporated into or developed by the MNCR are emboldened).

- **The type and distribution of habitats and their associated communities of species (biotopes)** This is the central part of MNCR work and includes obtaining data and information from a wide range of sources, including specially commissioned field surveys.
- **The distribution of species** Information is available from a variety of floras and faunas (usually compiled by marine laboratories), from a limited number of species recording schemes, from taxonomic and other published literature, from taxonomic experts and museums and from the increasing number of environmental impact studies required for major developments. Through the collation of literature and field survey information, the MNCR has become a substantial source of information on species distribution. The MNCR's prime focus, however, is on recording habitat associated species data; it has not attempted to undertake a comprehensive species recording programme for all field and literature records.
- **The relative quality of sites for their marine biotopes and species** Through a comprehensive survey and assessment procedure the MNCR provides an objective, scientifically-based evaluation of site quality.
- **The key non-biological features which determine species and biotope distribution** This is taken by the MNCR from charts, geological survey information and through direct observation during field surveys. The principal factors recorded are substratum, height or depth, wave exposure, tidal currents, salinity, geology, land form and turbidity. Specialised measurements of physical or chemical conditions and seasonal fluctuation in temperature, turbidity and salinity are, however, beyond the scope of the MNCR.
- The natural fluctuations in species composition within communities. This is required to set one-off ecological surveys into the context of longer term trends in community structure. The information has to be obtained from research and monitoring outwith the MNCR or from available literature.
- The functional and reproductive biology, physiology and natural population dynamics, including longevity, of species. This information is used to aid management, including contributing to environmental statements and impact assessment, and is work outwith the MNCR programme.
- The effects or potential effects of human activities on benthic marine habitats, communities and species Indicating the sensitivity of marine habitats, communities and species to the various human activities is of key importance in coastal zone and sea-use management. Although the MNCR does not undertake studies of the effects of human activities, the MNCR will provide a basis for indicating likely sensitivity of areas of seabed, by attaching sensitivity indices to each biotope within the classification being prepared (Section 7.2). Further research in this area is, however, required.
- **The location and extent of human activities and whether they are affecting the natural heritage interest of sites** Relevant information is collected by the MNCR during field surveys, although the MNCR does not undertake systematic surveys of human activities.
- **The location, distribution and status of existing protected sites** The MNCR has assessed features of marine biological interest within designated coastal and intertidal Sites of Special Scientific Interest (Davies *et al.* 1990, Davies & Mills 1990 a & b). Work to indicate the location and status of protected sites continues through the Protected Sites Database and the Coastal Directories project within JNCC, to which the MNCR contributes (for the *Directory of the North Sea coastal margin*, Doody, Johnston & Smith 1993; for the Coastal Directories series, see for instance Barne *et al.* 1995).
- **The location and status of protected species** Information on benthic marine species is held by the MNCR and contributes to ongoing assessment of their status through the quinquennial review of schedules within the Wildlife and Countryside Act 1981.

Table 2.1 Marine species protected under schedules 5 and 8 of the Wildlife and Countryside Act 1981:

All cetaceans
Odobenus rosmarus (walrus)
Lutra lutra (otter)
All marine turtles (Dermochelyidae and Cheloniidae)
Alosa alosa (allis shad)
Acipenser sturio (sturgeon)
Gammarus insensibilis (lagoon sand shrimp)
Victorella pavida (trembling sea mat)
Caecum armoricum (De Folin's lagoon snail)
Paludinella littorina (lagoon snail)
Tenellia adspersa (lagoon sea slug)
Thyasira gouldi (northern hatchet-shell)
Alkmaria romijni (tentacled lagoon worm)
Armandia cirrhosa (lagoon sand worm)
Edwardsia ivelli (Ivell's sea anemone)
Eunicella verrucosa (pink sea fan)
Nematostella vectensis (starlet sea anemone)
Lamprothamnium papulosum (foxtail stonewort)

2.3 Current measures for marine nature conservation in Great Britain

The information provided by the MNCR is used within a framework of various statutes, directives and conventions (listed in Appendix 4) as well as broader non-statutory coastal zone and sea-use management. Although subject to change, it is felt useful to indicate the framework within which MNCR currently (1995) provides information.

For statutory protection, the 1981 Wildlife and Countryside Act provides for the establishment of Marine Nature Reserves (MNRs) by the relevant Secretary of State. MNRs can be established within the 3-mile limit of territorial seas or, by Order in Council, out to the 12-mile limit of territorial seas. There are currently two MNRs in Great Britain: the islands of Lundy and Skomer. Sites of Special Scientific Interest (SSSI) can be established to Mean Low Water Mark (in England and Wales) or Mean Low Water of Ordinary Spring Tides (in Scotland). At the end of 1994, there were 744 coastal and intertidal SSSIs in Great Britain of which 84 included marine biology in their citations. The identification of intertidal SSSIs is supported by the general *Guidelines for selection of biological SSSIs* (Nature Conservancy Council 1989) with supplementary guidelines for intertidal habitats and saline lagoons (Joint Nature Conservation Committee 1996).

Statutory provisions specifically for nature conservation include only a limited basis for site-based nature conservation in the marine environment. They are strengthened by Regulations which came into force in October 1994 relating to the management of Special Areas of Conservation (SACs) under the European Commission Directive (Council Directive 92/43/EEC of 21 May 1992) on *The Conservation of Natural Habitats and of Wild Flora and Fauna* (Council of the European Communities 1992) - the 'Habitats Directive'. Those Regulations refer to proposed SACs in the marine environment as "European marine sites". The Regulations require that all authorities and public bodies with jurisdiction over the marine environment have a general duty to "have regard to the requirements of the Directive". Schemes of management will be developed for each site based on advice from the country nature conservation agencies and Government departments. Furthermore, to underpin the application of the Directive, the Environment Act 1995 makes provision for existing legislation to be applied for "marine environmental matters/purposes" (including the conservation of flora or fauna) (see Appendix 4). A list of possible SACs which included 37 areas for their marine habitats and species was published for consultation by the UK Government in 1995.

In some cases, statutes designed for a purpose other than nature conservation may be used to effect marine conservation. Most notably, the Sea Fisheries (Wildlife Conservation) Act 1992 requires appropriate Ministers and relevant bodies to have regard in the discharge of their functions under the Sea Fisheries Acts to the conservation of flora and fauna .

Several non-statutory initiatives are important. Relating to England and Wales, the House of Commons Select Committee on the Environment recommended in its report of April 1992 on *Coastal Zone Protection and Planning* that, "in its review of marine conservation legislation, the Government addresses the issue of how to link conservation of land and sea areas, how to protect sites of marine conservation importance, and consider as an option extending SSSI-type mechanisms below the low water mark." That House of Commons Select Committee report was followed by two consultation papers: *Managing the coast* and *Development below low water mark* issued in October 1993. In July 1994, the Government indicated (in a written reply to a Parliamentary Question) that it considered existing statutory systems are the most effective means of regulating development in the coastal zone and that no change was required to town and county planning legislation to extend it below low water mark. The Government at the same time took initiatives to establish policy guidelines for coastal planning (published in December 1994), to establish a standing forum on coastal zone management and to review powers for making bye-laws relating to coastal management.

The international *Convention on Biodiversity* was signed by the UK in June 1992 and ratified in 1994. *Biodiversity. The UK Action Plan*, published by the UK Government in January 1994 (Anon. 1994), provides a strong focus for work in the UK over the next few years. The 59 action points in the plan include 15 particularly relevant to marine ecosystems. Paragraph 4.107 of the plan summarises action in the marine environment under the plan:

- complete the Marine Nature Conservation Review;
- continue to implement new approaches to coastal flood defence and coast protection which manipulate and work with natural processes;
- continue to devise arrangements to prevent uncontrolled introductions of non-native marine species;
- promote active management of bay marine wildlife areas including management plans to secure the integrated management of vulnerable areas;
- review the intertidal SSSI network to ensure it covers the important marine wildlife habitats and species;
- utilise voluntary and statutory marine reserves and other relevant initiatives as mechanisms to involve individuals and communities in practical marine conservation work;
- designate sufficient marine Special Areas of Conservation and Special Protection Areas and ensure that mechanisms are in place for their effective conservation under the Habitats and Birds Directives.

The action points also stress the need to establish priorities for Red Data Books for the main taxonomic groups without them and to continue to have regard to the need to conserve marine fauna and flora in carrying out the Government's duty to regulate fisheries.

In *Biodiversity. The UK Action Plan*, a Steering Group was proposed, with members drawn from different sectors. The Steering Group was created to generate the collective views

of individuals with expertise and good potential for contribution, not just the views of government departments and their agencies. A further biodiversity report *Biodiversity: the UK Steering Group Report* was published in December 1995 (Anon. 1995) proposing costed species and habitat action plans. These costed action plans were for 116 species and 14 habitats in the UK. Costed plans were produced for the starlet sea anemone (*Nematostella vectensis*), Ivell's sea anemone (*Edwardsia ivelli*), the allis shad (*Alosa alosa*), the twaite shad (*Alosa fallax*), and the harbour porpoise (*Phocoena phocoena*) and for saline lagoons and for sea grass beds. A further five marine habitats were proposed for action plans to be produced over the following two to three years. Statements for eight broad marine habitats to encompass the full range for the continental shelf were made in the report. Just over one hundred marine or brackish-water species (excluding birds) were listed in the Report (8% of the total species listed).

Environmental protection measures relating to seabed wildlife are being incorporated more and more into international agreements, policies and directives. Those which may particularly draw on information collected by the MNCR include those concerned specifically with seabed species and habitats. Various of these measures were brought into focus at the Fourth International Conference on the Protection of the North Sea held in June 1995. The Ministerial Declaration from that Conference requires several actions which can be supported by the work of the MNCR including "to further develop and agree on a classification system for marine biotopes in the North Sea" and to "develop an integrated view on the specific conservation measures necessary for ecologically important or key biodiversity indicator species and their habitats which are, or may become, threatened or vulnerable in the North Sea, including coastal and offshore areas".

The protection of features of natural heritage importance is a consideration in a wide range of developments and activities at the coast and offshore. Nature conservation will be a consideration in the licensing of pipeline construction, oil and gas developments, mariculture and port developments as well as determining navigation routes. The degree of consideration varies greatly and cannot be based solely on the location of marine protected areas as these are so poorly developed.

Voluntary mechanisms are also important for nature conservation, not least because of the extent of local involvement which they often entail. Voluntary marine nature reserves or conservation areas have existed in Great Britain for many years. The first was established in the early 1970s at Lundy Island in the Bristol Channel and there were 13 at the end of 1995. Marine Consultation Areas, notified to relevant statutory and non-statutory bodies, were established in Scotland mainly in response to the development of fish farms: twenty-nine locations were identified (Nature Conservancy Council 1990). Although Marine Consultation Areas are unlikely to be extended to England and Wales, English Nature has identified 27 Important Marine Areas (now termed Sensitive Marine Areas) around the coast of England (English Nature Marine Task Force 1993). Coastal areas owned or leased by organisations concerned with nature conservation, such as the Royal Society for the Protection of Birds, county wildlife trusts and the National Trust, also provide protection to marine sites, particularly intertidal areas.

There is a growing number of local fora, such as those developing estuary management plans and strategies in England and Scotland, which help to integrate management of the coast and can consider the nature conservation interests alongside the other uses of the coast.

In Scotland, aspects of the philosophy underpinning many of the non-statutory mechanisms, such as Marine Consultation Areas and the estuary fora (the Firths Initiative), have been incorporated in a new and complementary statutory designation called a Natural Heritage Area. These are intended to provide special protection for extensive areas of outstanding natural heritage value. Integrated management strategies will be developed in a participatory manner and, if appropriate, subsequent designation by the Secretary of State for Scotland will help ensure these frameworks do indeed steer and guide all future activities which influence the natural heritage in the marine, coastal or terrestrial environment.

MNCR work aims to underpin wildlife conservation in all these different areas and in the wider marine environment.

2.4 The MNCR and the country nature conservation agencies

The MNCR is undertaken on behalf of the statutory country nature conservation agencies in Great Britain (The Countryside Council for Wales, English Nature and Scottish Natural Heritage). It fulfils the statutory (Environmental Protection Act 1990) functions of the agencies designated as 'special' functions in that they are directed at maintaining and establishing common standards for research, survey and monitoring and for the analysis of the resulting information and undertaking work which relates to Great Britain as a whole. MNCR staff also provide advice and information in support of national requirements and initiatives (for instance, the development of guidelines for intertidal and lagoon SSSIs, the EC Habitats Directive and *Biodiversity. The UK Action Plan*). The MNCR is thus viewed by the separate agencies as a project which has coherence across Great Britain and which should therefore be managed centrally. Country agency staff contribute to the development of MNCR methods for survey, assessment and reporting. They work with the MNCR team to ensure that the results of survey and assessment will provide the information needed to identify sites of marine natural heritage importance and assess the likely impact of potentially damaging activities at those sites. Marine specialists are mainly located in the headquarters of country agencies but, particularly with the growing

importance of coastal zone management initiatives and the requirements for the management of sites identified under the EC Habitats Directive, more responsibility for marine conservation is being taken by local, area or regional staff to which the MNCR will respond as required.

The MNCR Project Management Board established in 1993 has been particularly important in ensuring that approaches adopted by the MNCR produce the most useful information for the country agencies. Local, area or regional staff make use of the information from the MNCR through the reports of field surveys and can also use the UKDMAP volume (Barne *et al.* 1994) to locate literature describing the marine biology of sites. An area report series has been developed through the Project Management Board to meet the requirements of the country agencies. Area reports summarise survey information in a standard format and provide a conservation assessment for discrete areas of coast (for instance, a particular marine inlet or a length of open coast between major topographical features). This format replaces that of reports of each field survey which were produced until 1994.

The computer database (Chapter 6) is of central importance to the dissemination of information and its analysis. Copies of the database are held in each of the country agency headquarters and are used by marine specialist staff to answer questions about particular locations or topics. Information is also added to the database within the country agencies for literature they hold and for surveys they undertake. This information is combined with all other data on the central database. Thus, advice to local staff in the country agencies can be provided from their headquarters marine specialists.

3 Britain's marine habitats and species

Keith Hiscock

3.1 Introduction

The term 'habitat' refers to the physical and chemical environment prevailing at a site; a habitat can also be biological such as, for instance, a bed of horse mussels. The species present at a particular habitat constitute the 'community'. The combined habitat and community together are referred to as the 'biotope'.

The variety of marine habitats in Britain is tremendous - the greatest of any European state with an Atlantic border - from the rugged wave-beaten Atlantic coasts of northern Scotland to the still muddy backwaters of southern estuaries. In between these extremes there are rocky shores, boulder shores, sandy shores, underwater rocky and offshore sediment areas, tide-swept sounds, quiet sealochs, brackish lagoons, crystal-clear waters, and water sometimes described as like liquid mud. This great range of habitats is reflected in a wide variety of plant and animal life forming different communities according to the combination of geographical position and local environmental conditions.

This section provides only an introduction to the major habitats and the types of species found there.

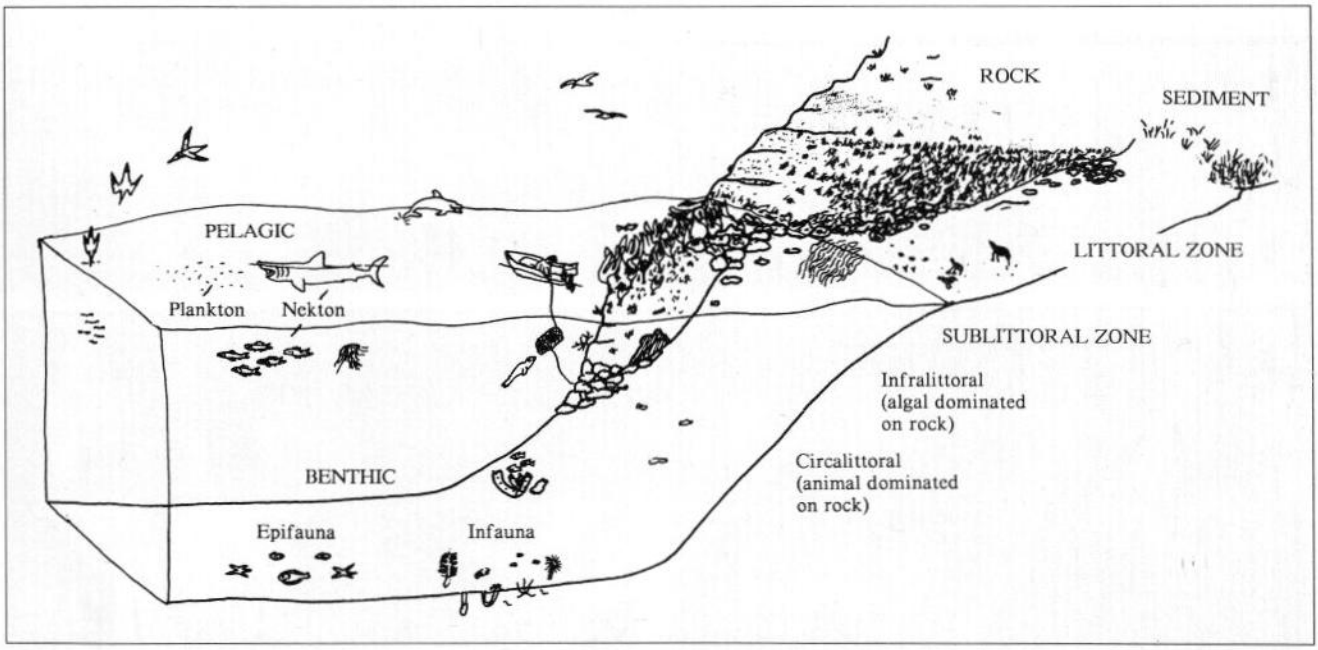
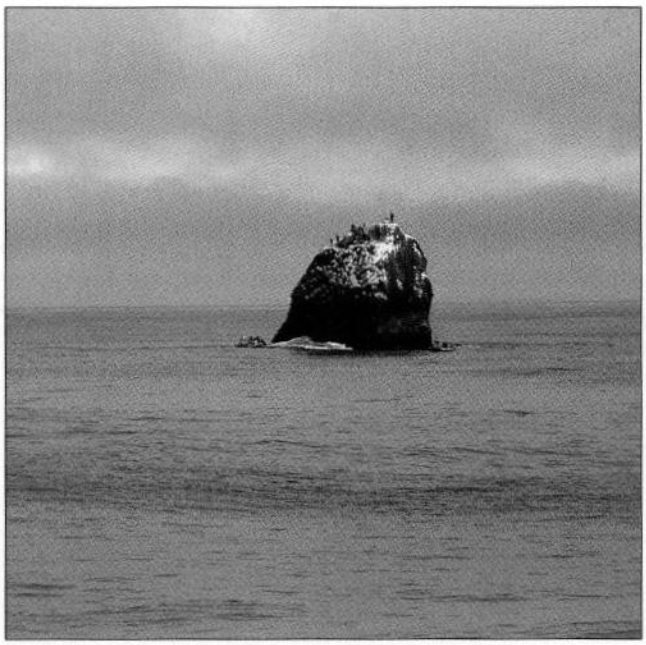


Figure 3.1 Marine ecosystems. Drawing by Keith Hiscock.

Marine habitats and their associated communities of species in Britain range from those characteristic of wave-sheltered rocky and sedimentary coasts to those of coasts extremely exposed to wave action. In the Isles of Scilly, this range of conditions is encapsulated within a small archipelago: view across Tresco towards Round Island (Roger Mitchell/JNCC).



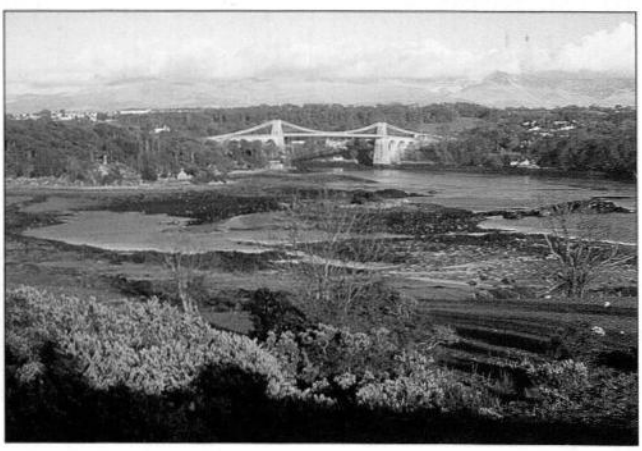
Rockall, 370 km west of the Outer Hebrides: the most exposed and most remote island in waters under British jurisdiction. Photographed during the MNCR survey of the area in 1988 (Iain Dixon/JNCC).

(right) Cliffs near Duncansby Head, Caithness: much of the coast of Britain is of high steep cliffs inaccessible except from the sea and exposed to strong wave action and with rock extending into deep water (Keith Hiscock).

Extensive areas of intertidal sediments which continue into the subtidal occur on many coasts, particularly in the northern Irish Sea and south-east England: sandy beach at Black Rock Sands, North Wales (Keith Hiscock/JNCC).

There are approximately 150 estuaries in Britain constituting a significant proportion of this habitat in Europe. Estuaries typically include extensive mudflats, which are important feeding areas for migratory and resident birds, saltmarshes and have often been modified by port developments and coastal protection measures: eastern Mersea to Brightlingsea Creek, Sussex/Essex (David Mills/JNCC).

Chalk rock attracts particular species and communities but is rare in Europe; England has approximately 75% of the European chalk coast: chalk cliffs and platform at Handfast Point, Dorset (David George/JNCC).

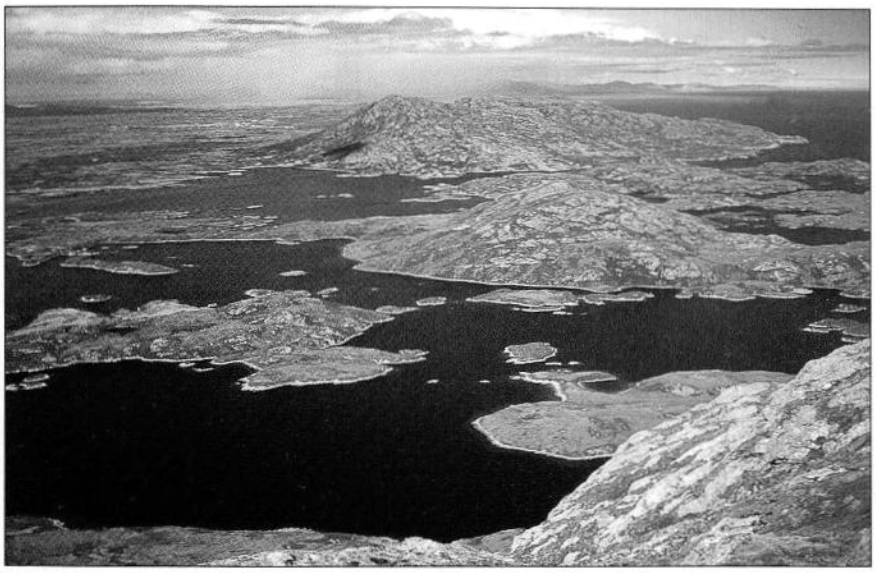


The strong tidal streams and shelter from wave action in tidal sounds creates rocky habitats characterised by species or growth forms not generally seen elsewhere: Menai Strait, North Wales (Keith Hiscock).

Shetland voes are mostly flooded river valleys with steeply sloping sides and no sill at the entrance. They contain rich sediment communities: Weisdale Voe (Keith Hiscock).

Fjordic sealochs with steep rocky sides often extending into deep water and partly separated from the open coast by sills include highly distinctive sediment and rock communities: Loch Leven (Keith Hiscock).

Lagoonal habitats in southern England predominantly form behind shingle banks and often contain rare or scarce species as well as a distinctive flora and fauna determined mainly by salinity: Plumpudding Island, Kent (Martin Sheader/JNCC).



Lagoonal habitats in Scotland occur in flooded glacial landscapes particularly in the Outer Hebrides where marine communities occur in rock-bound ponds many kilometres from the open sea and connected only by narrow channels: Loch Obisary, North Uist (Frances Dipper/JNCC).

Some of the coastline of Britain has been greatly altered by development, coastal protection and by disposal of wastes; sometimes creating habitats and assemblages of species not found on nearby natural coasts but often destroying irreplacible natural features: Sunderland Harbour and sea outfall, Tyne & Wear (Rohan Holt/JNCC).

3.2 The British marine fauna and flora

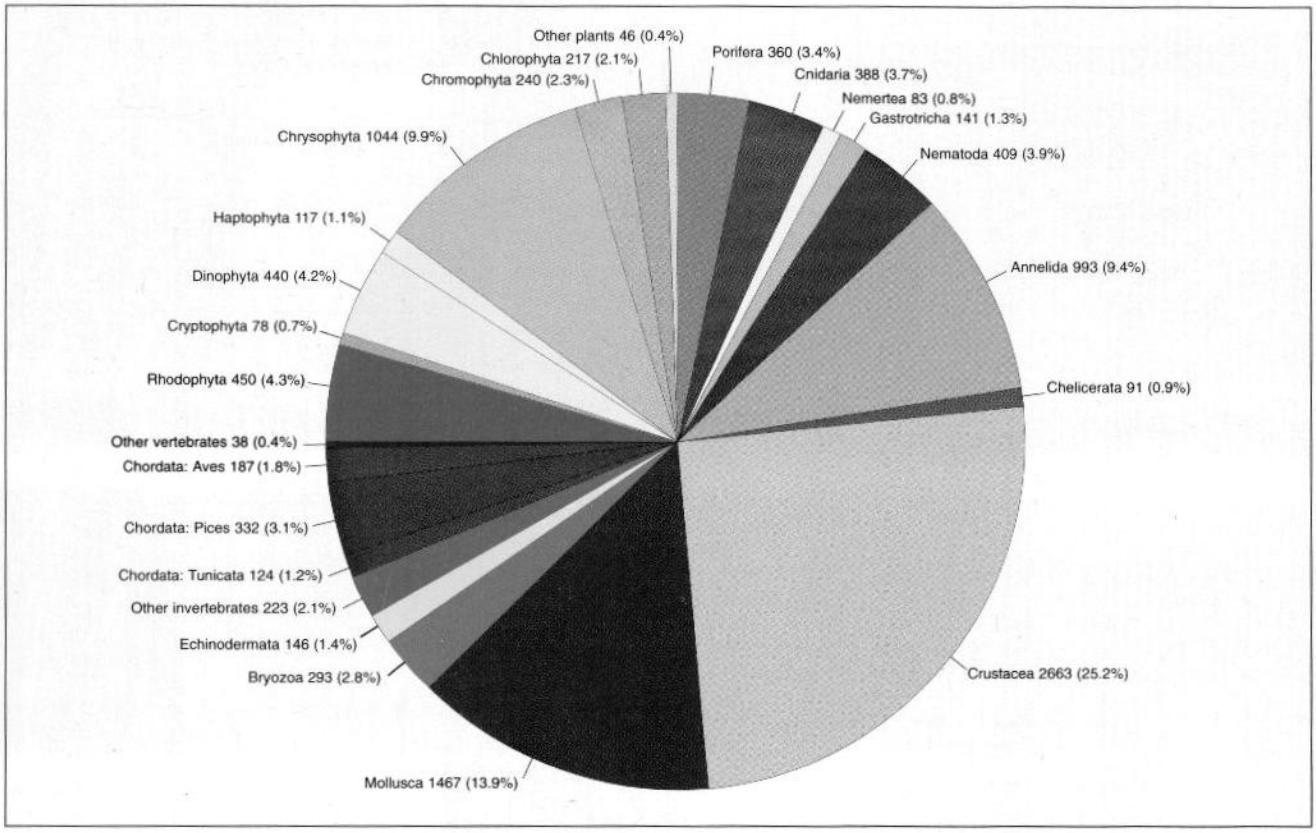


Figure 3.2 Marine species known for the continental seas of the British Isles (excluding Protozoa and Rotifera). Phyla containing less than 0.5 % of the total of 10,570 species have been grouped as 'Other invertebrates', 'Other vertebrates' and 'Other plants' whereas all fishes have been grouped as 'Chordata: Pisces'. 'Other invertebrates' includes the following groups (number of species is in parentheses): Ctenophora (3), Platyhelminthes (52), Kinorhyncha (16), Priapulida (2), Entoprocta (38), Chaetognatha (23), Pogonophora (10), Sipuncula (21), Echiura (7), Tardigrada (16), Brachiopoda (18), Phoronida (5) and Hemichordata (12). 'Other vertebrates' includes: Reptilia (5) and Mammalia (33). 'Other plants' includes Cyanophyta (41) and Angiospermae (5). 'Chordata: Pisces' includes Agnatha (3), Chondrichthes (50) and Osteichthes (279). It should be noted that the definition of a 'seabird' and therefore inclusion here follows Picton *et al.* (in prep.). Bacillariophycea (932 species) are included under Chrysophyta. Data from: Dodge (1982); Hartley (1986); Hendy (1974); Parke & Dixon (1976) and Picton *et al.* (in prep.). Data collated by Bill Sanderson and Robin Clark.

The groups of organisms represented in the sea are generally very different from those on the land. Figure 3.2 illustrates the numbers of species recorded from each of the major taxonomic groups (except Protozoa and Rotifera) from the continental shelf around the British Isles (Picton *et al.* in prep.). Although only five species of flowering plant exist in British seas, the total marine algal flora is over 840 species compared with a terrestrial flora of about 2,223 vascular plants and perhaps 40,000 lower plants (including about 15,000 to 20,000 algae and about 15,000 fungi) (Kent 1992, Palmer 1995). In the sea, about 7,300 animal species are recorded from the seabed whilst, on the land and in freshwater, about 30,000 animal species are recorded (including about 20,000 insects, 5,000 nematodes and 3,000 arachnids) (Picton *et al.* in prep., Key 1994). The marine fauna living on and in the seabed includes taxonomic groups which are almost entirely restricted to marine habitats: sponges, hydroids (sea-firs), sea-anemones, bryozoans (sea-mats), echinoderms (starfish, sea-urchins and their relatives) and ascidians (sea-squirts). Other important groups with large numbers of marine species include the polychaetes (segmented worms), nematodes (unsegmented worms), crustaceans and molluscs. Of fish species, there are 329 species recorded from the seas around Britain and 55 recorded in freshwater habitats. Mammals and birds are, in numbers of species, only a small part of the total marine fauna but their ecological importance and/or intrinsic appeal leads to their achieving a particular conservation focus. Otters (around the Scottish coast) and seals are important species in areas adjacent to the shore. Cetaceans are creatures of the open seas but may occasionally venture near to the shore. Seabirds are marine species in virtually all respects except production of young. Waders and wildfowl play an important role in marine systems as intertidal predators and grazers near the top of the food-web.

3.3 Major benthic habitats and their biological characteristics

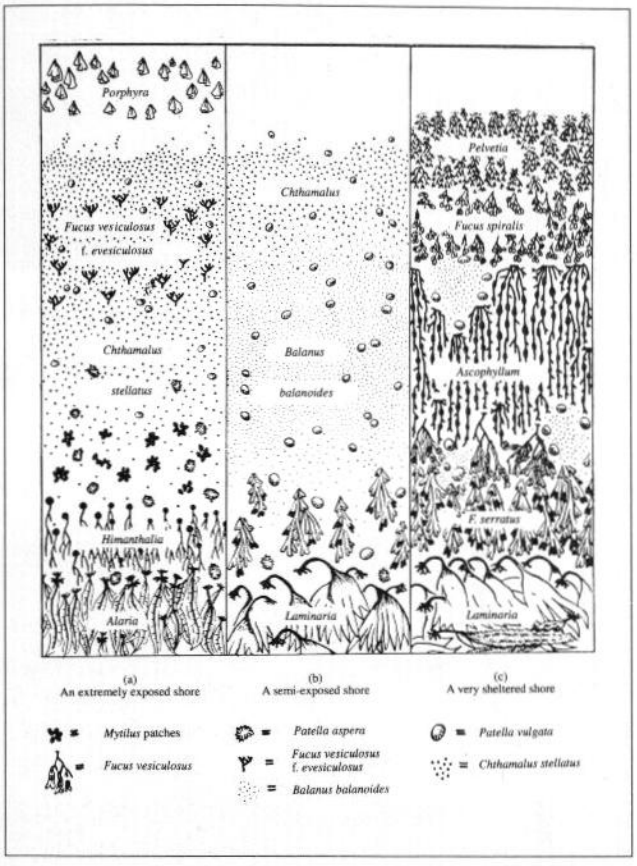


Figure 3.3 Diagramatic representation of communities present on 'extremely exposed', 'semi-exposed', and 'very sheltered' rocky shores in Pembrokeshire (from Ballantine 1961).

3.3.1 Littoral rock

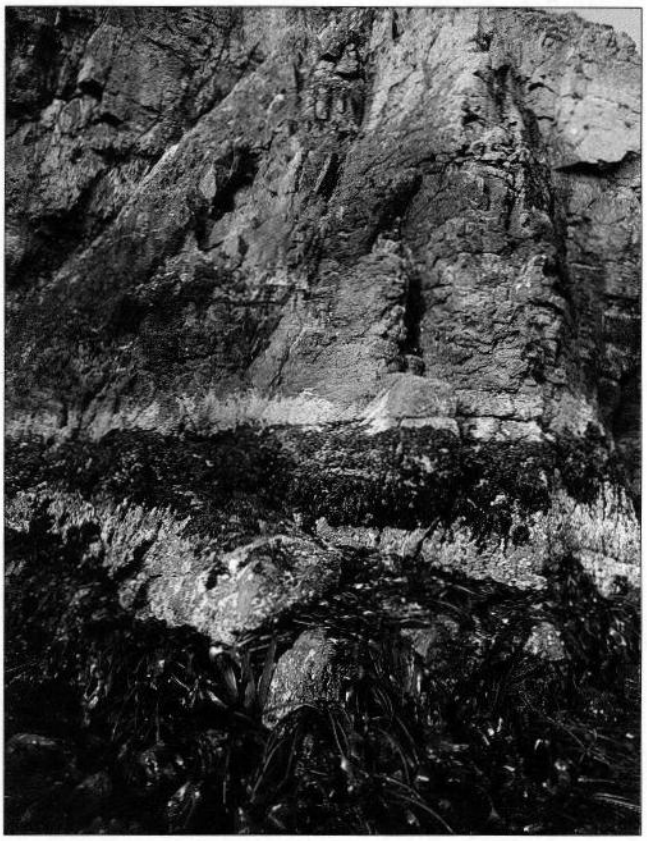
Rocky shores are dominated by species of plant and animal which are adapted to the rigours of a life of alternating immersion in seawater and exposure to the air. The composition of shore communities is determined mainly by the ability of species to survive the desiccating effects of exposure to air and various degrees of wave action, ranging from the constant pounding of Atlantic waves on western headlands to the stillness of backwaters where even a force 10 gale scarcely ruffles the surface. The 'architecture' of rocky shores is also very important with some rock structures creating platforms, cliffs, overhangs, caves, pools, boulder fields and other features which encourage high species diversity. Tidal rise and fall is a major factor determining one of the most striking features of rocky shores - the horizontal banding, or zonation, of species brought about by direct physical effects of tidal immersion and emersion and by biological interactions, especially competition for space, predation and grazing. The lowest part of the shore is a transition between the rigorous habitat which is exposed by every tide and the continuously submerged area beyond the lowest tides. Here, large brown algae, the kelps, overgrow the rock and, through their sweeping action and the shade they create, allow the survival of few species except encrusting red algae and animals in fissures and crevices or under overhangs.

On exposed coasts, limpets, barnacles and mussels characterise the shore together with small gastropod molluscs found living in crevices sometimes many metres above the high water mark. In contrast, sheltered shores are dominated by brown seaweeds which provide shade, creating a damp understorey habitat where a more diverse fauna, especially of gastropods and crustaceans, thrives. Mussels are a feature of many rocky shores with small individuals occurring on exposed coasts and clumps of large mussels in more sheltered conditions. Unstable hard substrata, ranging from large boulders on exposed shores to cobbles and pebbles on sheltered shores, may only support communities of ephemeral algae which grow in periods of calm weather, and mobile animals, especially small prosobranchs and crustaceans. Scour from mobilised sand or pebbles adjacent to the rock can also determine the type of community present. Rocky shore communities indistinguishable from those of bedrock can develop even on shingle and cobbles in the extreme shelter of sealochs and estuaries where these hard substrata are not disturbed by wave action. The variety of life on open surfaces of rocky shores above mean low water mark is generally small, but with up to about 60 species of macroalgae and 55 species of conspicuous animal on a rich shore surveyed within about six zonal habitats.

The desiccating effects found on the open shore are ameliorated in rockpools, under overhangs, in caves, under boulders and below dense algae: here, richer communities can develop. Under boulders, this can amount to as many as about 50 animal species for a half hour search. Rock type is also important and rich algal communities may occur if the rock retains water or is soft enough to allow penetration of holdfasts. Rocks which are soft enough to allow animals to bore into them provide security from predators and, when the inhabitant dies, a habitat for nestling species. Other rock types are creviced and, within the crevices, a distinctive fauna can develop.

Where rocky substrata occur in the low or variable salinity zones of estuaries, they are generally characterised by a low number of species which also occur in full salinity. However, some species are characteristic of rocky substrata in estuaries and particular communities develop where they are dominant. These species include a range of highly characteristic green and other filamentous algae, the brown alga *Fucus ceranoides*, the hydrozoan *Cordylophora caspia*, the barnacle *Balanus improvisus* and sphaeromid isopods.

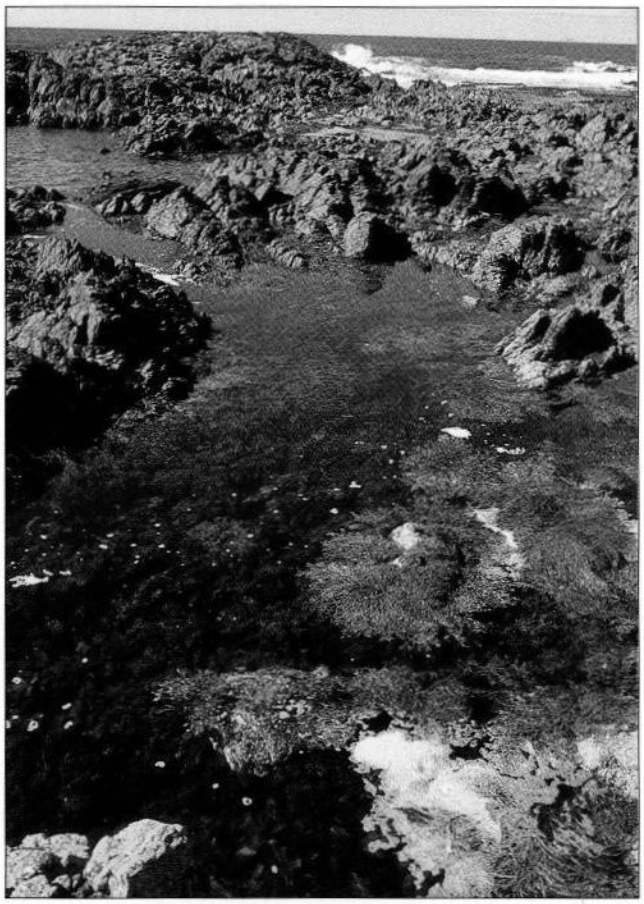
Rocky shores comprise about 35% of the coastline of Great Britain (Coastal Resources Database, unpublished) but are mainly a feature of the open coast and are rare in estuaries. Natural rocky shores are rare in the east basin of the Irish Sea between Colwyn Bay and Morecambe Bay and on the east coast of England between Flamborough Head and the Thames. Characteristic 'rocky' shore communities do, however, develop on structures such as breakwaters and piers.



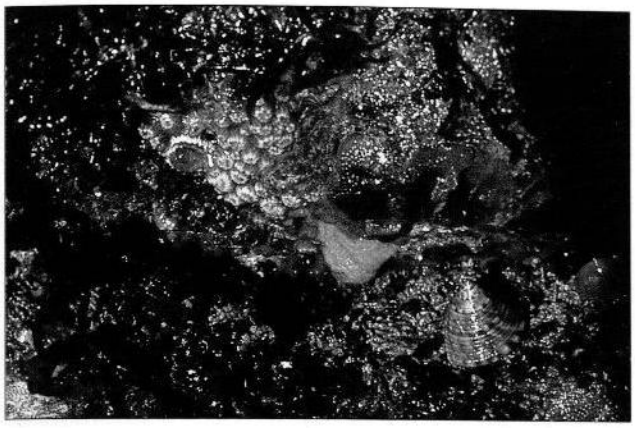
Rocky shores exhibit a distinctive zonation of species determined by tidal rise-and-fall and wave splash. A band of yellow and grey lichens is followed by bare rock or rock covered by black lichen with small gastropod molluscs; then barnacles with, in shelter, fucoid algae; limpets and barnacles with mussels. In sheltered conditions, the midshore rocks are dominated by brown algae. The lower shore is general dominated by red foliose algae with thong weed, then coralline algae and kelp near to low water level: Brei Holm, Papa Stour, Shetland (Keith Hiscock/JNCC).

Sheltered rocky shores are dominated by fucoid algae and littoral communities extend over a much shorter vertical range than nearby exposed locations: Voxter Voe, Shetland (Keith Hiscock).

An exposed shore in the extreme south-west where rocks have very few foliose algae but pink coralline encrusting and turf-form algae are extensive: Round Island, Isles of Scilly (Roger Mitchell/JNCC).



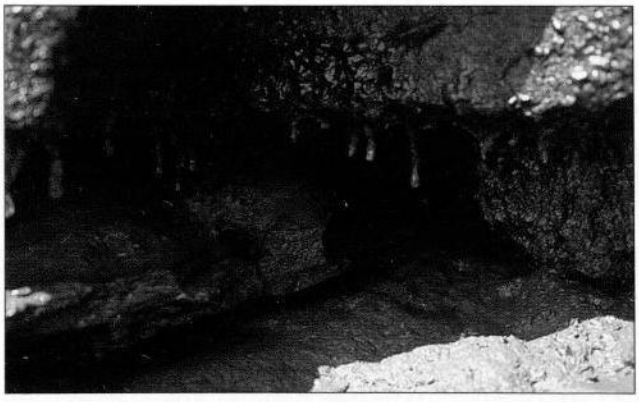
Rockpools provide fully immersed conditions especially for a variety of algae, crustaceans and fish only otherwise found on the lower shore or in the sublittoral: Tail of Uran, Fair Isle (Keith Hiscock/JNCC).



Intertidal overhangs and caves provide damp and shade and often are colonised by species usually found only in the sublittoral. Here, the ascidian *Sidnyum turbinatum* occurs with the encrusting bryozoan *Umbonula littoralis* and the topshell *Calliostoma zizyphinum*: Cellar Beach, River Yealm, South Devon. (Keith Hiscock/JNCC).

Strong tidal flow in the intertidal channels connecting shallow basins to each other or the sea encourage the growth of rich sponge and ascidian communities. Here, the sponge *Leucosolenia botryoides* occurs with the ascidians *Clavellina lepadiformis* and *Ascidia mentula*, Oban Uaine, Sound of Fladday, Benbecula (Frank Fortune/JNCC).

The undersurfaces of boulders provide shade, damp conditions and protection from predators for a characteristic community of species including sponges, crustaceans, bryozoans, echinoderms and ascidians: Wembury, South Devon (Keith Hiscock/JNCC).



Rocky shores in the low salinity zones of estuaries are rare and often man-made but are characterised by species not found in normal salinity: *Cordylophora caspia* at Cothele Quay, Tamar estuary, South Devon (Keith Hiscock).

3.3.2 Sublittoral rock

The fringe of rock extending downwards from the shore may be very shallow, especially in marine inlets, or deep where the seabed is steeply sloping and/or exposed to strong wave action or tidal streams. The shallow well-lit infralittoral zone of the rocky seabed is generally dominated by forests of kelp, mainly species of *Laminaria*, together with foliose red and brown algae. Green algae are absent from this zone because of their need for the red component of daylight, this part of the spectrum being filtered out by even shallow depths of water. Only where intensive grazing occurs, mainly by sea-urchins, is the rock clear of foliose algae leaving only a crust of calcareous red algae. The kelp forest is absent in very turbid waters but may extend as deep as about 25 m in the clearest conditions, for example, in the Isles of Scilly. Deeper than the kelp forest, scattered kelp plants (the kelp 'park') with dense foliose algae (except, as above, where urchins graze) form a narrow band in terms of depth, below which is the circalittoral zone dominated by animal species. Here, sponges, hydroids (sea-firs), anthozoans (sea-anemones, cup-corals, sea-fans and sea-fingers), tube-building polychaetes, decapod crustaceans

(crabs, lobsters), erect and encrusting bryozoans (sea-mats), echinoderms (brittlestars, feather-stars, starfish, sea-cucumbers and sea-urchins) and ascidians (sea-squirts) are the most conspicuous groups found. In many areas, erect bryozoans and hydrozoans form a turf occupied by a wide variety of polychaetes, amphipods, small decapods and bivalve and gastropod molluscs; up to 200 macrofaunal species per square metre are found in some of the richer habitats. Species of fish living on the rock include sea-scorpions, butterfish, ling and conger, while swimming over the rock or amongst the kelp are wrasse, pollack and gobies.

Kelp forest (the upper infralittoral subzone), ballan wrasse and foliose algae on an exposed coast: Montagu Bay, Lundy, 6 m depth (Keith Hiscock).

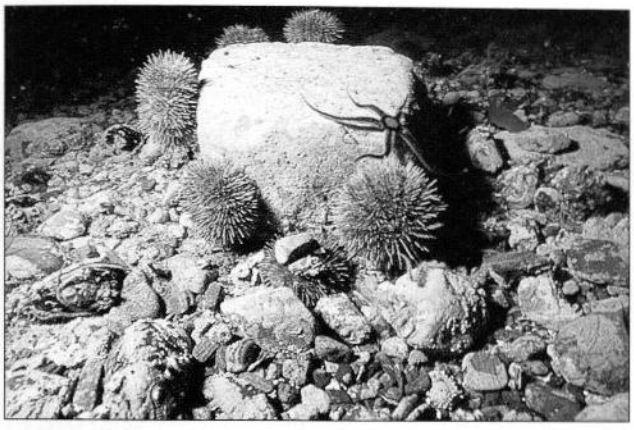
The vertical zonation of species on underwater rocks is determined mainly by the attenuation of light with increasing depth. Dense forests of kelp (mainly *Laminaria hyperborea*) in shallow depths extend to kelp park and rocks dominated by foliose algae (except where grazing by sea urchins and molluscs is heavy) then to rocks dominated by animals. Wherever grazing or sand scour are high, the crustose algae which cover the rock are the most obvious cover. Farne Islands, Northumberland (Sue Scott/JNCC).

Extremely exposed rock in deep water characterised by the usually sublittoral fringe species *Alaria esculenta* and by encrusting sponges and anemones: Rockall, 32 m depth (Sue Scott/JNCC).

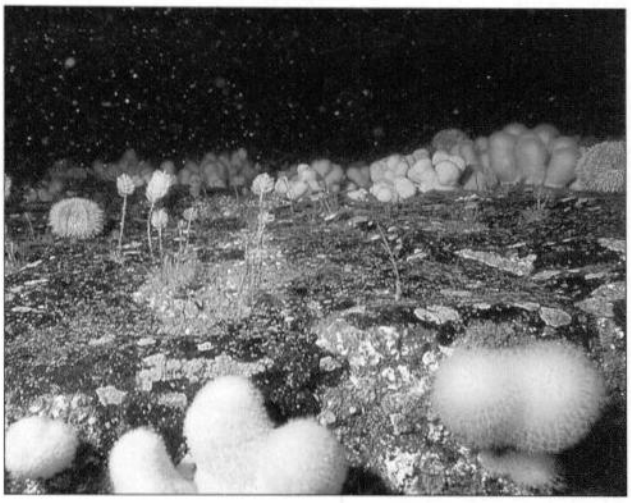
A mosaic of sponges, ascidians, jewel anemones and the anemone *Phellia gausapata*, characteristic of wave exposed rock: Rockall, 33 m depth (Sue Scott/JNCC).

Offshore circalittoral reef with dead mens fingers (*Alcyonium digitatum*) and abundant brown crabs (*Cancer pagurus*): The Smalls, Pembrokeshire, 22 m depth (Paul Brazier/JNCC).

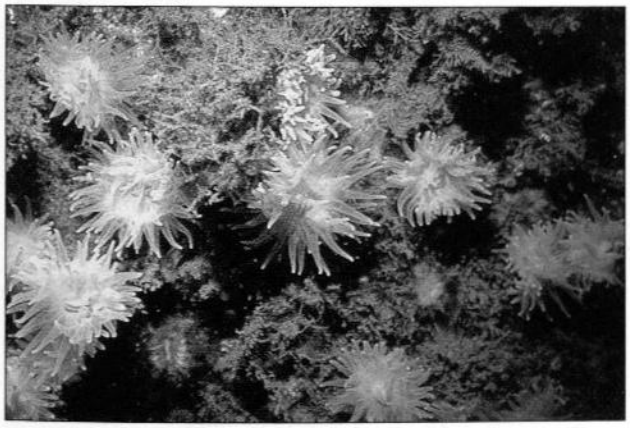
Circalittoral community dominated by branching and cushion sponges: Cuckoo wrasse *Labrus mixtus*, Penninis Head, Isles of Scilly, 21 m depth (Keith Hiscock).



Shetland is the only location in the British Isles where the northern sea urchin *Strongylocentrotus droebachiensis* occurs in significant numbers: The Skerries, Shetland, 20 m depth (Sue Scott/JNCC).



North Sea coast circalittoral rock characterised by grazed rock with crustose algae, the northern hydroid *Thuiaria thuja* and dead mens fingers *Alcyonium digitatum*: Knivestones, Farne Islands, Northumberland, 20 m depth (Sue Scott/JNCC).



The Southern cup coral *Leptopsammia pruvoti* is found at only a few locations in south-west England. Overhang on the sheltered east coast of Lundy at 15 m depth (Keith Hiscock/JNCC).

Circalittoral rock on the open coast of south-west England with the southern sea fan, *Eunicella verrucosa*, with red sea fingers, *Alcyonium glomeratum*: Plymouth Sound, 32 m depth (Keith Hiscock/JNCC).

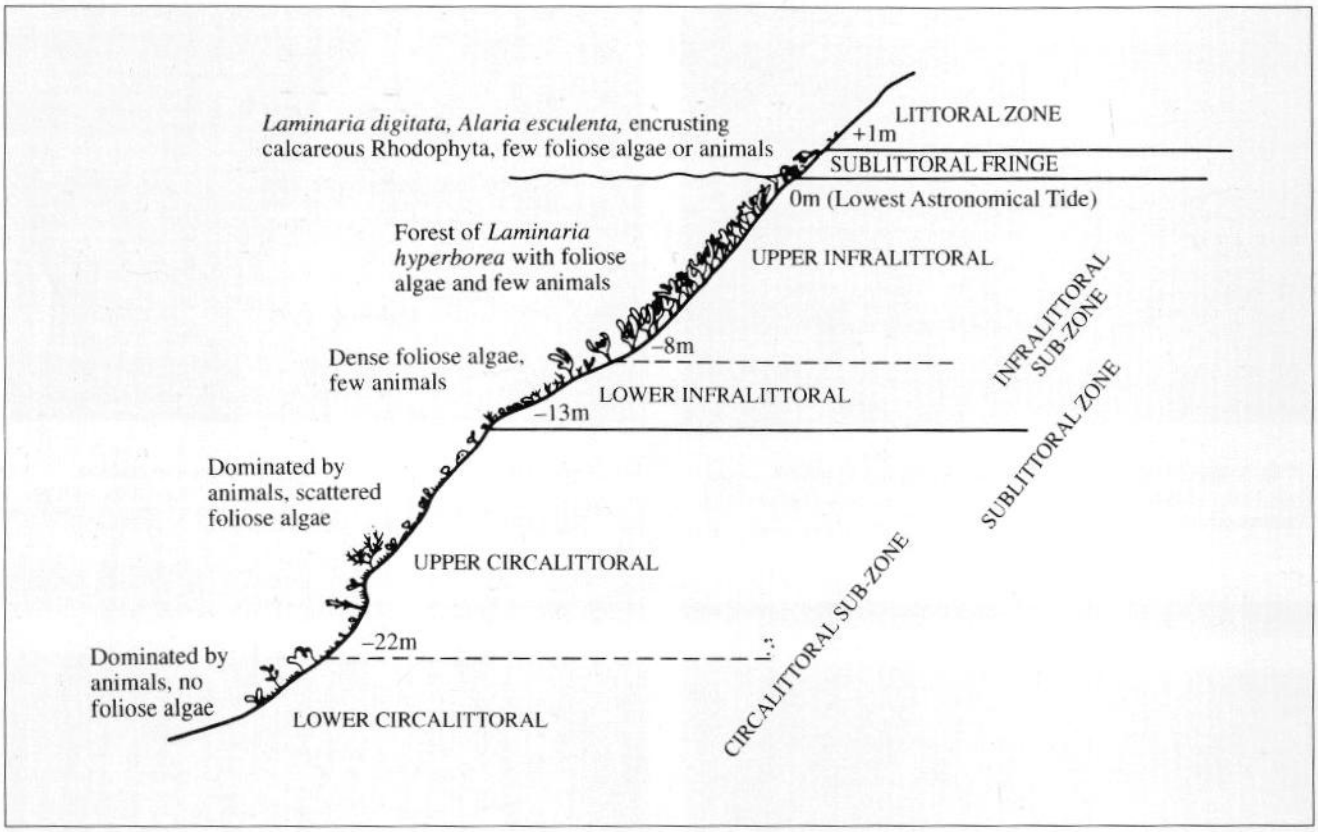
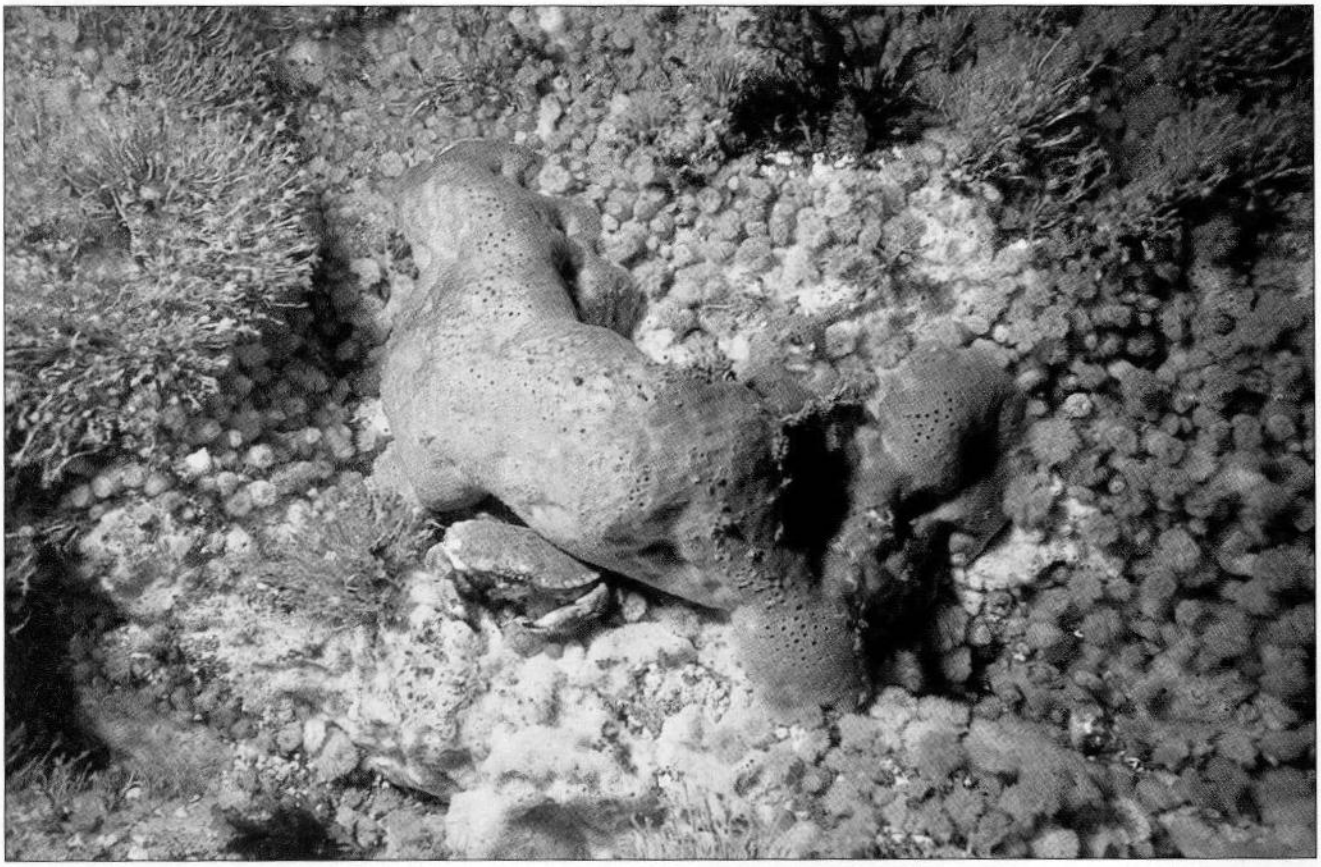
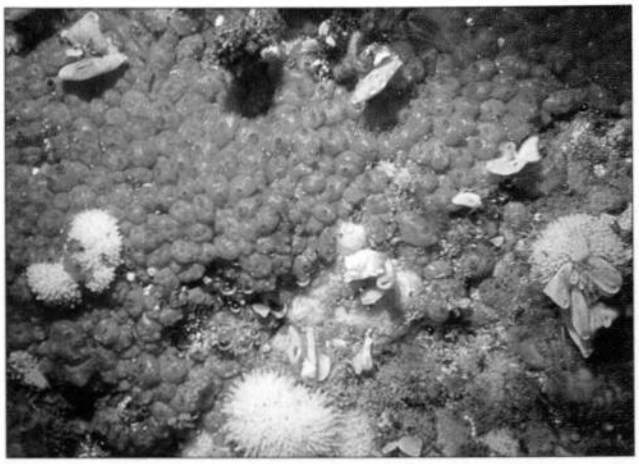


Figure 3.4 Zonation in the rocky sublittoral. Depths are for Lundy (from Hiscock 1985).



Tide-swept circalittoral community characterised by the hydroid *Tubularia indivisa*, encrusting sponges, the elephant-hide sponge *Pachymatisma johnstonia* and small plumose anemones, *Metridium senile*: Kyle Rhea, Ross & Cromarty, 15 m depth (Sue Scott/JNCC).

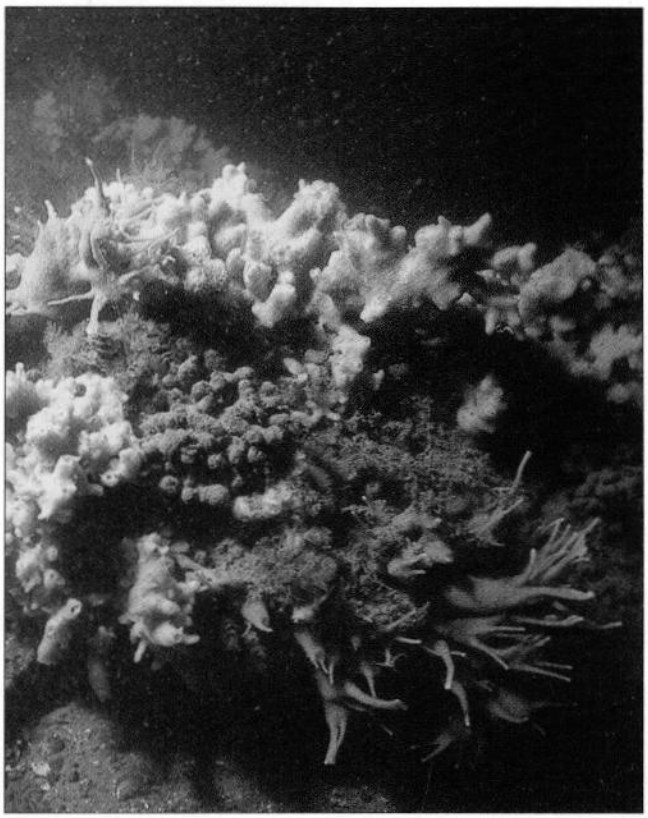
Underwater caves and tunnels are mainly features of exposed coasts and include a variety of communities characteristic of wave surge and scour: seal in Levinish Tunnel, St Kilda (Bernard Picton/JNCC).



Surge gulley community found in wave-exposed caves and gullies from the north to the south of Great Britain. Typically, the community is characterised by the ascidian *Dendrodoa grossularia* and the sponge *Clathrina coriacea*. Another componant here is the purse sponge *Grantia compressa*: Islay (Keith Hiscock).

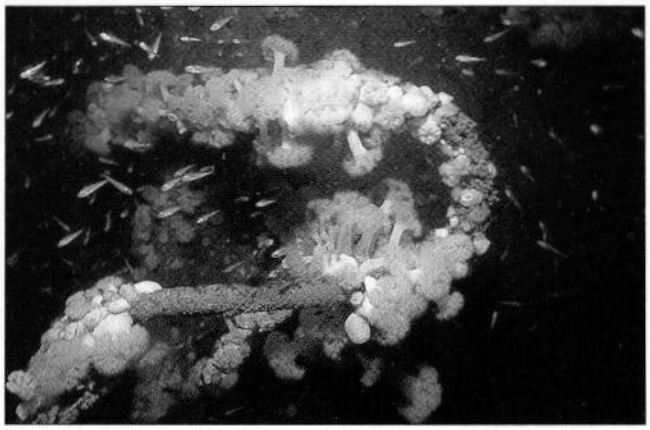
Biological reefs, for instance of horse mussels *Modiolus modiolus*, provide a hard substratum and many crevices for nestling species. Here, a small group of horse mussels provides a substratum for hydroids, the sealoch anemone *Protanthea simplex*, the tube worm *Serpula vermicularis*, brittle stars *Ophiothrix fragilis* and the colonial ascidian *Diazonia violacea:* Loch Duich, Skye and Lochalsh, 15 m depth (Sue Scott/JNCC).

The sea anemone *Protanthea simplex* and brachiopod *Neocrania anomala* together with feather worm *Sabella pavonina* and brittle stars, *Ophiothrix fragilis*, characteristic of circalittoral rock in Scottish sealochs: Loch Duich, Wester Ross, 18 m depth (Sue Scott/JNCC).



Sponge growths characteristic of sheltered rocks exposed to strong tidal streams and variable salinity especially in rias: Burton Cliff, Daucleddau Estuary, Dyfed 10 m depth (Keith Hiscock/JNCC).

Piddocks in limestone cleaned of its silt covering. The anemone *Cereus pedunculatus* also occupies an old piddock hole: Grove Point, Portland, Dorset, 23 m depth (Keith Hiscock/JNCC).



Artificial structures built or lost in the sea provide habitats often colonised by communities not otherwise present in the area. Deck rail dominated by the plumose anemone *Metridium senile* on the wreck of the MV Robert, Lundy, 17 m depth (Chris Lumb/JNCC).

Hard rock communities also develop on stable boulders and cobbles fringing the coast and particular communities occur on extensive plains of stable tide-swept cobbles offshore. Some hard substrata are mobile and only ephemeral communities develop during periods of calm. These mobile hard substrata may be boulders in shallow wave-exposed locations or cobbles and pebbles in deeper areas. Here, the division between hard substratum and sediment often become difficult to define. Scour by sand, pebbles, cobbles and boulders on rock habitats also restricts the range and type of species which develop and often produces a clear zonation from bare rock adjacent to the source of scour to rich communities with some long-lived species well above the scour zones.

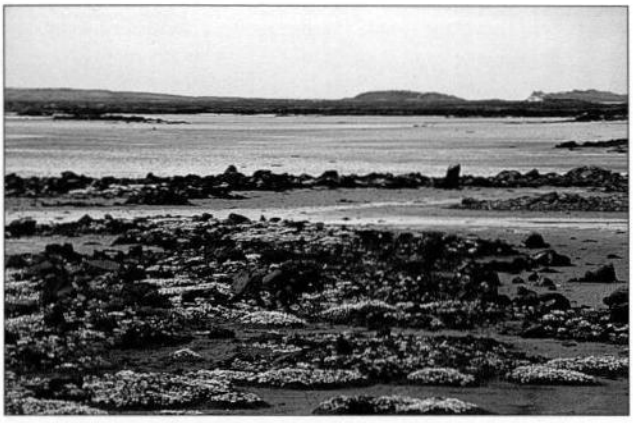
A sheltered sandy beach with rich infaunal communities: Amsterdam Point, Falmouth Harbour (Intertidal Survey Unit/JNCC).

3.3.3 Littoral sediment

Sediment shores range from being almost devoid of life, as in shingle and mobile sand on surf beaches, to being species-rich with up to about 40 macrofaunal species sampled by digging and sieving over about $1m^2$ on a sheltered muddy gravel shore. Some characteristically littoral species occur on sediment shores but the richest assemblages are the lower shore margins of much more extensive shallow sublittoral communities. Macrofaunal organisms which typically colonise sediments include polychaete worms, amphipod crustaceans, bivalve molluscs and (in the sublittoral fringe) burrowing sea-urchins. Particle size, the mixture of sediment grades and the stability of the sediment have the greatest importance in

Infauna from Amsterdam Point, Falmouth lower shore sand with the burrowing sea urchin *Echinocardium cordatum*, tubes of the worm *Lanice conchilega* and the gelatinous tube of *Myxicola infundibulum* (Keith Hiscock/JNCC).

Intertidal seagrass, *Zostera noltii* in this picture, occurs on muddy sand and mud and provides an important source of food for wildfowl: Lympstone, Hampshire (Teresa Bennett/JNCC).



Extensive intertidal sediments in extreme shelter in the Outer Hebrides. Here, species typical of saltmarsh, sheltered rock and sediments occur together: Oitir Mhór, North Uist (Keith Hiscock).

The low salinity upper reaches of estuaries will have a low diversity intertidal mud community: Swalwell, Tyne Estuary, Tyne & Wear (Clare Eno/JNCC).

Characteristic species of low or variable salinity intertidal muddy substrata: the bivalves *Scrobicularia plana* and *Mya arenaria* and the worm *Hediste diversicolor*: Llyn Bâch, Porthmadog, North Wales (Keith Hiscock/JNCC).

Muddy sediments now dominated by the non-native slipper limpet *Crepidula fornicata:* Black water estuary, Essex (Roger Covey/JNCC).

determining the types and number of species which colonise a particular sediment. Different sediments will have very different assemblages of species ranging from those characteristic of coarse muddy gravel to those of fine mud with a range of distinctive communities in-between. Different communities occur at different heights on the shore with about three zones merging into each other. This zonation is caused by differential water retention during low tides, which in turn is affected by sediment grade; finer sediments retaining water to a greater degree than coarse, well drained gravels. However, the zonation is less apparent in estuaries, where fine-grained water-retentive sediment flats show less variation in faunistic composition with height than on coarser well-drained beaches.

Muddy sediments occur along estuarine gradients and are characterised by particular species not present, or not present in high abundance, in full salinity. These species include the polychaete worm *Hediste diversicolor* and the bivalve mollusc *Scrobicularia plana*.

Sediment shores comprise about 52% of the coastline of Great Britain, representing a total area of over 235,000 ha, with their greatest extent in semi-enclosed or enclosed areas such as bays and estuaries but with some extensive areas of sand on the open coast of the North Sea and Irish Sea (Coastal Resources Database, unpublished). Extensive areas of intertidal sediment also occur on offshore drying banks.

3.3.4 Sublittoral sediment

In the sublittoral environment, sedimentary habitats and their associated communities are very extensive. Away from the coastal fringe where the seabed levels off or becomes a gradual slope, sediments rather than hard substrata predominate. Sediment composition varies according to the strength of wave action, tidal streams and the supply of sediment. Thus, although strong tidal streams generally lead to a coarse sediment, in the Severn estuary the suspended sediment load is so high that silt settles out and the seabed is muddy despite the very strong tidal streams. The most common macrofaunal species living in sediments are polychaete worms, crustaceans, bivalve molluscs and burrowing brittlestars and sea-urchins. Anthozoans (sea-pens and sea-anemones) are less common but often more conspicuous because of their presence at the surface. Fish which live on and in sediment may be important commercial species and include skate, plaice, sole, cod, halibut, gurnard and sand-eels. The most species-rich sediments are those which are stable over time and have a heterogeneous mixture of coarse and fine sediment grades. This is particularly the case where there are glacial lag deposits or abundant large shells. A rich sediment community may contain over 200 macrofaunal species in a square metre. Surface-living mobile species are important and include crustaceans, gastropods and echinoderms in particular. Particular communities

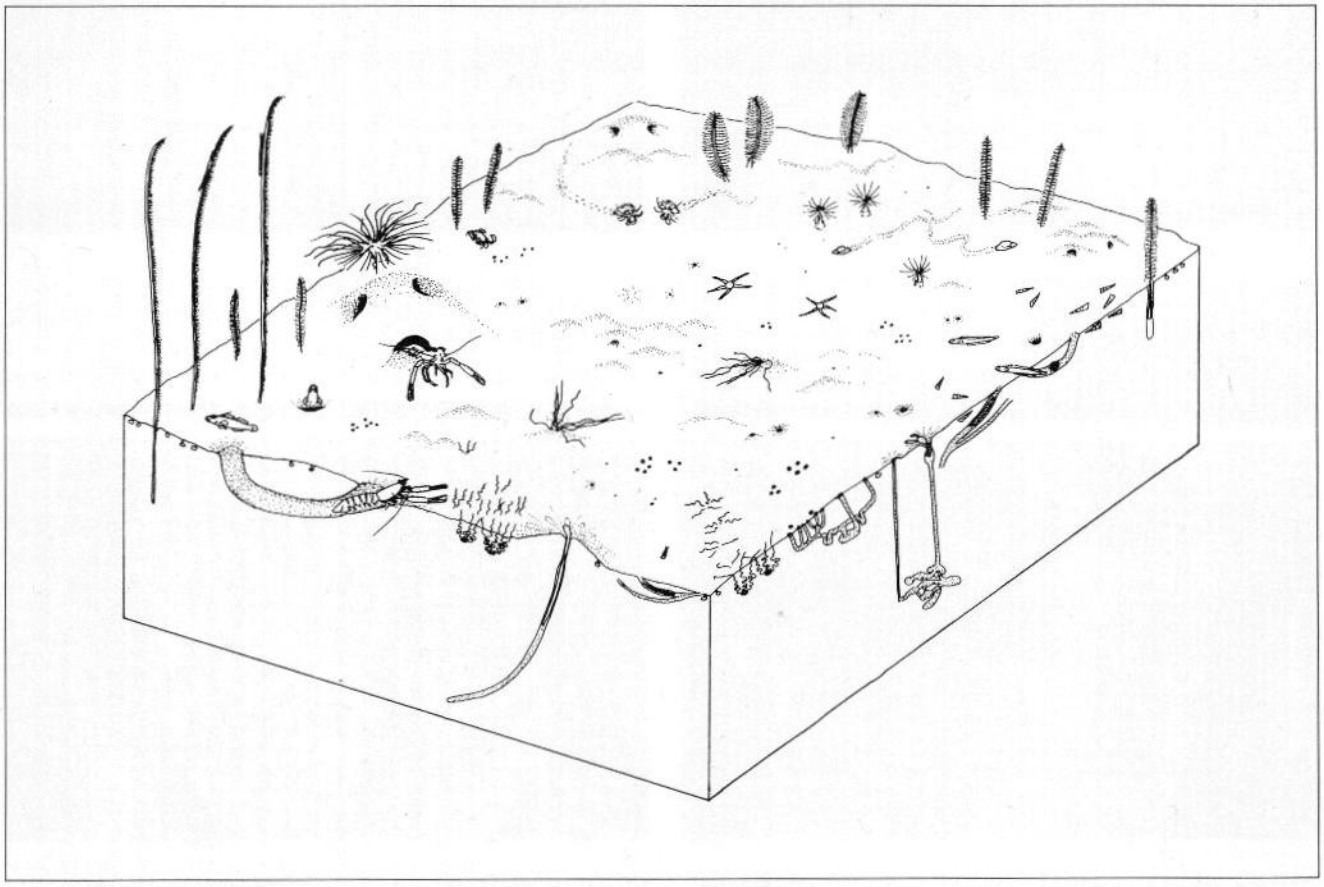
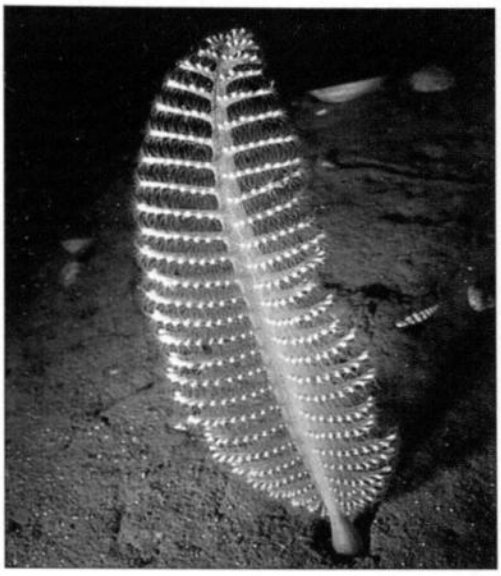


Figure 3.5 Cross section of sediment with infauna (from Howson, Connor & Holt 1994). The diagram shows burrows of the crustaceans *Callionassa subterranea*, *Calocaris macandreae* and *Nethrops norvegicus* and the fish *Lesueurigobius friesii*, the arms of *Amphiura* spp., terebellid worm tentacles, the sea-pens *Virgularia mirabilis*, *Pennatula phosphorea* and *Funiculina quadrangularis* and the anemones *Cerianthus lloydii* and *Pachycerianthus multiplicatus*. Width of illustrated area is about 2 m. Drawing by Sue Scott.

Rich shallow mud sediments in the shelter of a voe. Mounds of the lugworm *Arenicola marina*, arms of the burrowing brittlestar *Amphiura filiformis* and the hermit crab *Pagurus bernhardus:* Whiteness Voe, Shetland, 6 m depth (Keith Hiscock/JNCC).



The sea pen *Pennatula phosphora* in mud characteristic of wave-sheltered areas: Ard-an-Eoin, Loch Duich, Skye and Lochalsh, 20 m depth (Keith Hiscock/JNCC).

The burrowing sea cucumber *Thyonidium commune* and the anemone *Cerianthus lloydii*: two of the small number of species conspicuous at the surface of rich muddy gravel sediments: Lower Loch Linnhe, Highland (Bernard Picton/JNCC).

Part of a deep muddy shell gravel community sampled by dredge and including the starfish *Astropecten irregularis* and *Asterias rubens*, the bivalve *Phaxas pellucidus*, the tubes of the polychaete *Pectinaria koreni*, the crab *Liocarcinus depurator* and the seapen *Virgularia mirabilis*: Vaila Sound, Shetland, 40 m depth (Keith Hiscock/JNCC).

Course sediment waves in shallow depths: algae grow on larger particles during periods of reduced wave disturbance in summer: Toll Point, Helford, South Cornwall, 6 m depth (Sue Scott/JNCC).

Sand colonised by beds of seagrass *Zostera marina* in shallow depths: English Island, Isles of Scilly, 2 m depth (Keith Hiscock/JNCC).

Close-up photograph of a maerl (*Lithothamnion corallioides*) bed with horse mussels *Modiolus modiolus* and the brittle star *Ophiopholis aculeata*. Loch Carron, Ross-shire, 12 m depth (Keith Hiscock).

Mixed substrata including course sediments, pebbles and cobbles provide a temporary habitat for species tolerant of disturbance by storms and for development of ephemeral biota on the larger substrata during the period of summer calm weather: The Skerry, Fair Isle, 32 m depth (Sue Scott/JNCC).

develop on and in dense maerl (species of free-living calcareous algae) which forms beds of mobile coarse 'gravel' in tide-swept semi-enclosed coasts or of stable gravel and nodular maerl structures in enclosed wave-sheltered areas. Clumps or beds of horse mussels *Modiolus modiolus* establish on sediments and provide a hard substratum for a wide variety of associated species.

The type of infaunal community which develops is closely linked to sediment type and, to a lesser extent, to seasonal temperature cycles. The distribution of mobile species in offshore sediments is more closely bound to water temperature than sediment type and different communities are present above and below the seasonal thermocline between 50 m and 80 m depth. Ephemeral algae may attach to coarse sediments in shallow water during the summer. In sealochs, voes and some other sheltered situations, unattached algae can form a blanket cover over sediments or attach to stones and shells. Shallow subtidal sediments also support beds of the seagrass *Zostera marina*.

3.3.5 Brackish standing-water habitats

Lagoonal habitats are bodies of salt water, usually brackish, partially separated from the adjacent sea by barriers of sand, shingle or rock. Five major forms are currently recognised by the MNCR: isolated saline lagoons, percolation saline lagoons, sluiced or culverted saline lagoons, silled saline lagoons (including fjardic systems) and saline lagoon inlets (described in Joint Nature Conservation Committee 1996). Lagoonal habitats may be natural, artificial or semi-natural features (modified natural systems). Those associated with sedimentary coasts are often transient features subject to normal coastal processes and successional change. A great many are now 'controlled' by sluices or restriction of inlets and some have been substantially degraded by infilling, waste disposal or adjacent agricultural land-use. Saline lagoons often have a low diversity of habitats and associated communities, with many lagoons characterised by single communities. By far the most widespread habitat type is

Box 3.1 Specialist saline lagoonal species (i.e. species distinctly more characteristic of saline lagoon-like habitats than of freshwater, estuarine brackish waters or of the sea) recorded in Britain (after Barnes 1989a and Bamber *et al.* 1992 but excluding species widely found in brackish ditches or other non-lagoon habitats).

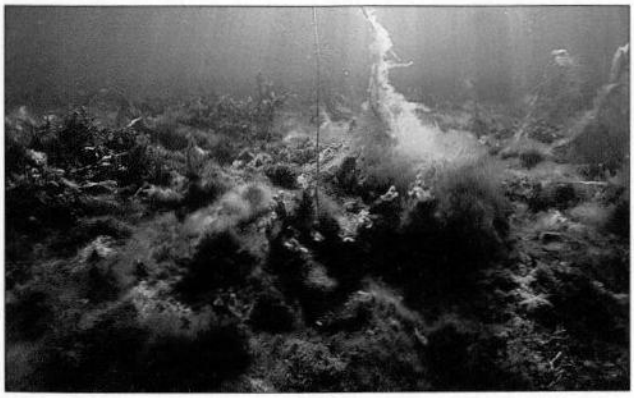
Cnidaria	*Gonothyraea loveni*
	*Edwardsia ivelli****(a, b)*
	*Nematostella vectensis***
Polychaeta	*Armandia cirrhosa****(a)*
	*Alkmaria romijni***
Crustacea	*Idotea chelipes*
	Sphaeroma hookeri
	*Gammarus insensibilis****(a)*
	Gammarus chevreuxi
	Corophium insidiosum
Mollusca	*Onoba aculeus (b)*
	Littorina tenebrosa
	*Tenellia adspersa***
	Cerastoderma glaucum (a)
	Hydrobia ventrosa (a)
	Hydrobia neglecta (a)
Bryozoa	*Conopeum seurati*
	*Victorella pavida****(a, c)*
Insecta	*Paracymus aeneus***
Flora	*Chaetomorpha linum*
	Chara baltica
	Chara connivens
	*Lamprothamnium papulosum***
	Tolypella n. nidifica
	Ruppia maritima
	Ruppia cirrhosa

** Protected by the Wildlife and Countryside Act 1981.
(a) In Britain known only from saline lagoon-like habitats.
(b) Known only from Widewater; now possibly extinct.
(c) Known only from Swanpool.

The Fleet situated behind the shingle ridge of Chesil Bank is the largest single lagoon in England at 480 ha in extent: The Fleet and Portland Harbour, Dorset (Nick Davidson).

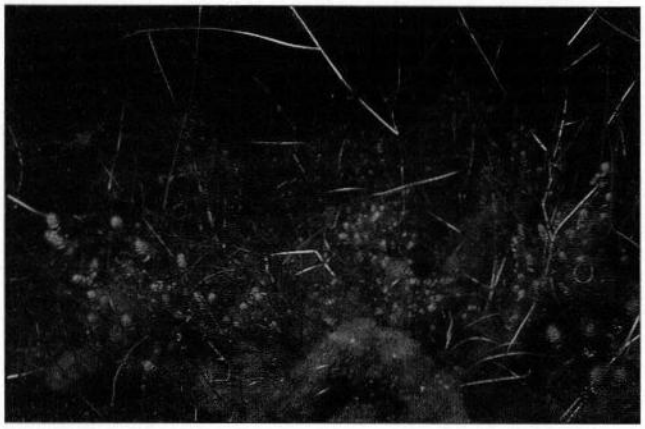
sediment, particularly mud and some fine sand. The community associated with this sediment will vary according to prevailing conditions but is generally one of loose-lying algae with an infauna of polychaete worms and bivalve molluscs living in the sediment and amongst the algae. Particularly noteworthy sediment communities occur at sites with beds of tassel weed *Ruppia* spp. or eelgrass *Zostera* spp.

Ruppia communities are often present in stable low salinity lagoons, whilst *Zostera* communities may be present in higher salinity lagoons which have a large water volume and stable conditions. Where present these communities may cover large areas of particular lagoons, but *Zostera* in particular is not a common constituent of saline lagoons although it occurs commonly in marine inlets and on the open coast.



Shallow sediments in lagoonal habitats are typically covered in a mat of loose-lying algae or algae attached to small stones and shells including fucoids, filamentous red and green algae and with cord weed, *Chorda filum*, often present: An-T-ob, Kyleakin, Skye, 1 m depth (Sue Scott/JNCC).

Rock surfaces within a lagoon habitat colonised by the seasquirt *Ciona intestinalis*: The Vadills, Shetland, 0 m depth (Keith Hiscock/JNCC).

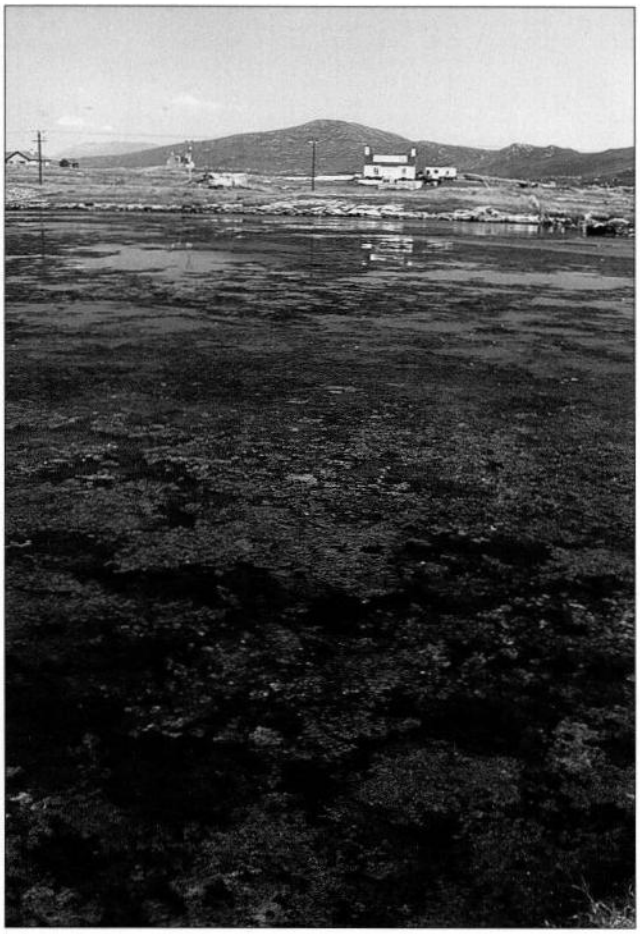


Beds of the lagoon foxtail stonewort *Lamprothamnium papulosum* amongst widgeon grass *Ruppia spiralis* in the peaty low salinity water of one of the Loch Maddy, North Uist lagoonal habitats, 1 m depth (Sue Scott/JNCC).

Also associated with the sediment habitat may be stoneworts such as *Chara aspera* or *Lamprothamnion papulosum*.

Barnes (1989) and Bamber *et al.* (1992) list lagoonal species. Lagoons may support salt-tolerant freshwater species, stenohaline marine lagoonal specialists, euryhaline marine species, and estuarine species which may be pre-adapted to lagoonal conditions. Lagoons are an uncommon and patchy habitat and the species restricted to them have limited opportunities for dispersal and colonisation. Lagoon species therefore figure highly in lists of 'rare' and 'threatened' marine organisms. Ten of the species are protected by the Wildlife and Countryside Act 1981.

Docks sometimes have features characteristic of lagoons and some may offer opportunities for education, recreation and scientific study, including *ex situ* conservation of threatened lagoonal species.



On the west coast of Scotland and especially the Outer Hebrides, lagoonal habitats are mainly rock-bound basins connected by narrow channels to, but often a considerable distance from, the sea. The stagnant state of this lagoon is indicated by the pink bacterial crust: North Loch Boisdale, South Uist (Sue Scott/JNCC).

3.4 Major pelagic habitats

This is the domain of species tied to the characteristics of the water column rather than the seabed. The distribution of both phytoplankton and zooplankton, reflects the salinity, nutrient composition, temperature and biological history of the water. Some species are characteristic of inshore areas, for instance the arrow-worm *Sagitta setosa*, whilst some are typical of more oceanic conditions, such as *Sagitta elegans*. There is a major change in plankton communities across the shelf break to the west of the British Isles. In frontal systems where seasonally stratified and well-mixed waters meet, plankton productivity is high and this often attracts large numbers of other species feeding on the plankton and, in turn, being fed-upon by larger species such as fish, birds and cetaceans. Such frontal systems occur particularly strongly and persistently off Flamborough Head and in St George's Channel at the southern entrance to the Irish Sea. The number of species found in the plankton is much lower in coastal waters compared to the open ocean although many species are very sparsely distributed in the oceans. Some plankton (the holoplankton) spend their whole lives in open water whilst others (the meroplankton) are temporary residents in the plankton and are usually the larvae of benthic species. The numbers of species and biomass of plankton rise and fall with the seasons, with blooms of phytoplankton in spring and late summer followed by increases in zooplankton populations. Phytoplankton are responsible for all but a small fraction of primary production in the world's oceans and, through the zooplankton which feed on them, are an essential base to the food chain which supports all pelagic, and the great majority of demersal, fish stocks. Planktonic species in particular may be affected by eutrophication causing a great increase in abundance with subsequent demands for oxygen outstripping supply, resulting in mass mortality both of plankton and, subsequently, benthos. The larger plankton include jellyfish which drift with the currents. Birds, seals, cetaceans and turtles which swim actively in pursuit of food are included with fish in the nekton.

3.5 Biogeography

Great Britain lies at the meeting of two major biogeographical provinces: the Lusitanian to the south and the boreal, which is centred on the British Isles. To the north and east, elements of a boreal-arctic fauna and flora occur particularly in Shetland but also on our North Sea coasts, where winter temperatures fall much lower than at similar latitudes in the open Atlantic. There is a decreasing trend in the number of species from the south-west to the north-east, with many species restricted in their distribution to south and west coasts, and a smaller number found only on north and north-east coasts. There are some species which are most probably relics of former colder or warmer times. There are probably no truly endemic marine species although there are species only recorded from Great Britain because of their global rarity. A review of papers describing biogeographical areas is given in Hiscock (in prep).

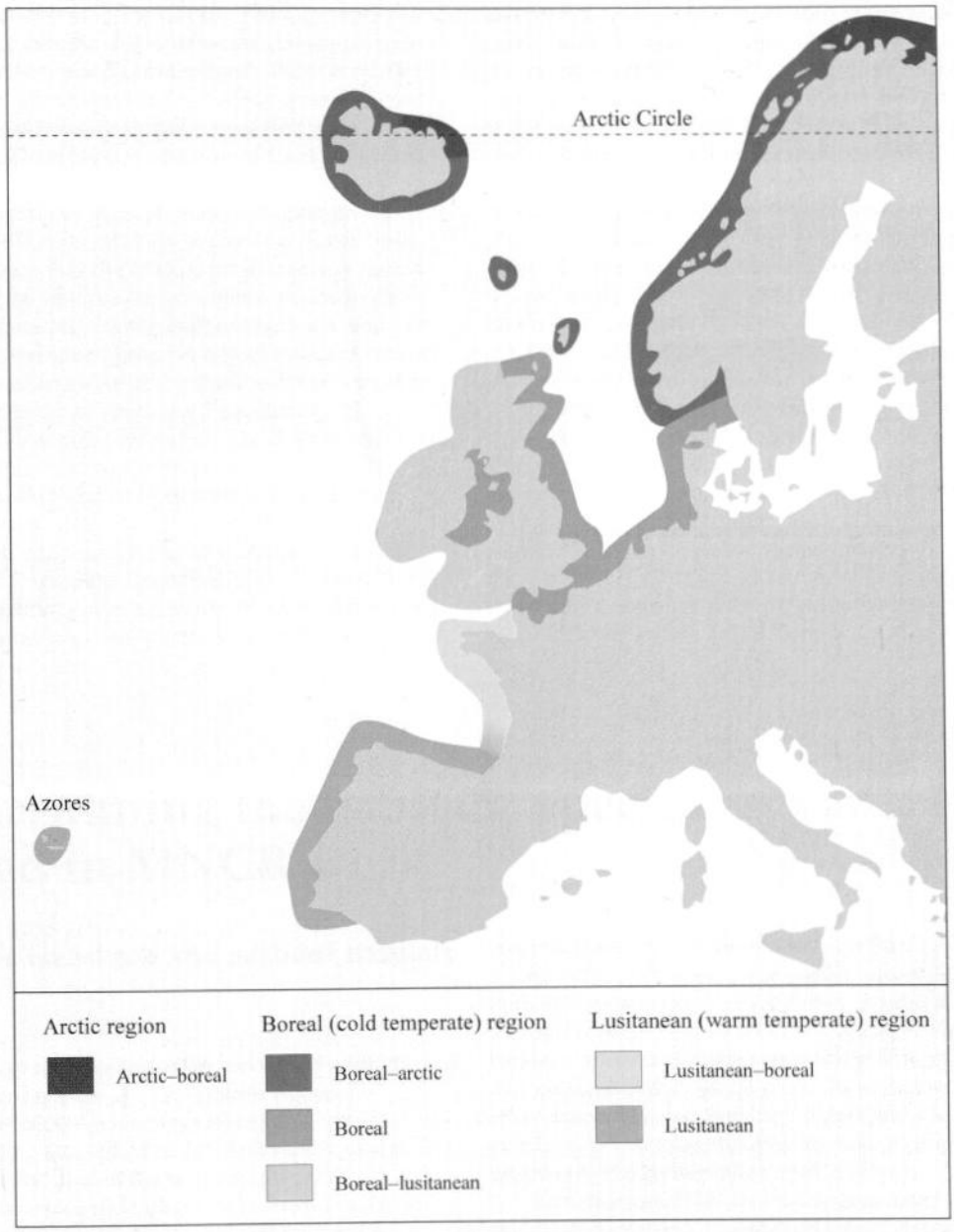


Figure 3.6 Biogeographical regions for inshore areas of the north-east Atlantic (based on Ekman 1953 and Briggs 1974 but with further original interpretation by the author and advice from Dr Torleiv Brattegard and Professor Michel Glémarec).

4 Scope and structure of the Marine Nature Conservation Review

Keith Hiscock and David Connor

4.1 Introduction

The marine environment of the UK shelf seas is similar in terms of scale and complexity to its terrestrial counterpart but is, in comparison, poorly understood. There is much still to be learned about species and habitat distributions, population and community dynamics, as well as the effects of human activities on habitats, communities and species.

With a lack of such basic information, and the potentially vast territory of marine habitats and diversity of species within British jurisdiction to consider, it has been important to ensure that the MNCR programme is clearly focused to meet the immediate priorities for conservation. The collection of scientific information which will support conservation requirements has also had to take account of the practicalities of working in the marine environment as well as the availability of specialised equipment, of expertise and of financial constraints. The development of priorities has required consideration of both the species and habitats to be studied and the extent of the area to be included in surveys.

The approach adopted for the MNCR has had to be different from that used for terrestrial sites. On land, the broad types of habitat present, the distribution of species and, to a considerable extent, the location of the best examples was already well known at the time that A *Nature Conservation Review* (Ratcliffe 1977) was being prepared and sites were identified on the basis of that knowledge. For marine habitats, knowledge was geographically incomplete at the start of the MNCR. Furthermore, in order to underpin site description and comparative assessment in a systematic and objective manner, a classification system for marine biotopes needed to be developed as survey progressed. This is an advance on terrestrial site assessment where the National Vegetation Classification (NVC) was developed after the great majority of sites for conservation had been identified.

The MNCR, whilst developing a systematic approach to nature conservation assessment for seabed habitats, followed a long history of marine biological study mainly associated with fisheries research or undertaken near to marine research stations. Work to describe and assess the marine natural heritage importance of some areas had also been commissioned by the Nature Conservancy Council since the mid-1970s. This knowledge allowed the identification before the start of the MNCR of some marine biological SSSIs and the initial list of potential Marine Nature Reserves suggested for establishment under the Wildlife and Countryside Act 1981.

4.2 Determining the habitats, species and area to be included in MNCR work

4.2.1 Benthic (seashore and seabed) habitats and species

Benthic species are fixed to, or closely associated with, the seabed and occur together as communities whose characteristics reflect the wide range of environmental conditions affecting the seabed at any particular location. The macrobenthos is that part of the benthos which is conspicuous or in which individuals or individual colonies are larger than 1 mm in size. Many of the macrobenthic species are attractive and of general, as well as scientific, interest whilst the communities they create are often aesthetically important features of areas. Macrobenthos can be readily observed or, in sediments, sampled to characterise communities. Meiobenthos is smaller than 1 mm whilst microbenthos includes species smaller than 0.1 mm in size; both include taxonomically difficult groups. Because their location is fixed, benthic communities are vulnerable to localised sources of disturbance and pollution which are concentrated in the coastal zone. These factors combine to make information on benthic habitats and species, particularly macrobenthic species, of high importance in addressing the conservation of biodiversity.

Some demersal fish are closely associated with specific benthic habitats and consequently are important to study as part of the benthic habitat. However, fish are highly mobile and some difficult to observe *in situ*. Identification of these species and their nature conservation requirements were the subject of a study undertaken in 1990 (Potts & Swaby 1991).

Commercial demersal fish are the subject of separate fisheries research and conservation measures.

4.2.2 Pelagic habitats and species (plankton and nekton)

Plankton are those species, usually less than about 20 mm in size, which drift with currents in the water column. They include not only permanently planktonic species but also the larvae or spores of benthic species. The role of plankton in marine conservation is perhaps most important in considering the sustainability of communities within protected sites (with regard to recruitment to the benthos from pelagic larvae or spores and sources of food). The conservation of plankton communities, through site-specific protection measures, is less practical than for benthos as planktonic species are highly mobile, especially in the open sea. However, more restricted water bodies, such as estuaries and lagoons, may have characteristic pelagic species or communities which need to be conserved for their own sake and because of their essential role in the ecosystem of the site.

The larger pelagic species, the nekton, are predominantly fish but also include cetaceans, seals, cephalopods and turtles able to swim actively and to move independently of water currents. Jelly fish are also part of the nekton but have very limited powers of movement. Conservation of fish, because many are commercial species, is predominantly a role for the fisheries regulatory authorities. However, fish as wildlife species - particularly rarely-encountered fish - are also important from the point of view of nature conservation assessment. These fish may have restricted habitats or be species which naturally occur in comparatively small numbers.

The gathering of information on seals is a statutory duty of the Natural Environment Research Council (NERC) through their Sea Mammal Research Unit. Information on cetaceans is gathered by several active groups including JNCC's Seabirds and Cetaceans Branch and the Sea Mammal Research Unit. Otters have been intensively studied, particularly by the NERC Institute of Terrestrial Ecology and the former Nature Conservancy Council. The three country conservation agencies and the JNCC currently have mammal specialists who have responsibility for work on otters. Populations of seals, cetaceans and otters are therefore not considered by the MNCR.

The information base on seabird populations, including distribution, abundance, fluctuations in abundance and international importance, is very good. The information has been collected through major surveys such as the Wetland Bird Survey and the Seabirds at Sea surveys. Responsibility for survey and monitoring of seabird populations lies currently with Seabirds and Cetaceans Branch in JNCC and is therefore not considered by the MNCR.

4.2.3 Geographical limits of MNCR work

The coastline of Great Britain is more than 19,000 km in length (Coastal Resources Database, unpublished), and the area of seabed within British territorial seas (12-mile limit) is about 180,000 km^2 or equivalent to about 78% of the land surface of Great Britain. Within the three-mile limit, the area of seabed is over 68,000 km^2, equivalent to about 34% of the land surface of Great Britain (original calculations). These are very extensive areas to be considered for their scientific interest and nature conservation importance and, to compound the problem posed by the extent of the resource, most of it is out of sight in an environment hostile to man.

The geographical area within the statutory remit of the country conservation agencies and JNCC is England, Scotland and Wales. It excludes Northern Ireland and the British Crown Dependancies of the Isle of Man and the Channel Islands. Furthermore, the offshore remit of the country agencies is taken as extending to the 12-mile limit of territorial seas. Outside these limits, within the Exclusive Economic Zone and internationally, advice related to nature conservation is provided by JNCC.

Although the core work of the MNCR is restricted to England, Scotland and Wales, relevant information is gathered from the north-east Atlantic region to ensure that the results can be set in a wider context. Information from Ireland is particularly important because of biogeographical similarity and because Northern Ireland is a part of the United Kingdom. Marine biological surveys with the same broad objectives as those being pursued by the MNCR were undertaken in Northern Ireland in the 1980s (Wilkinson *et al.* 1988; Erwin *et al.* 1990). A parallel programme to the MNCR for the Republic of Ireland began in 1992 under the BioMar project (Costello & Mills 1993). BioMar is part-funded by the EC LIFE programme in which JNCC is a partner. Irish partners are undertaking marine surveys using MNCR methods and use the MNCR database to the mutual benefit of both countries.

A Nature Conservation Review (Ratcliffe 1977) and other major habitat-based conservation assessment programmes have included saltmarsh vegetation, sand dunes and sea cliffs. The MNCR therefore focuses on habitats dominated by marine and brackish-water species. These include estuaries inland to the limits of saline influence and isolated saline water habitats (lagoons). On rocky shores, the upper limit is the splash or lichen zone below terrestrial flowering plants. On sediment shores, the upper limit is below the strandline or saltmarsh vegetation where present.

In order to provide advice to Government and the country nature conservation agencies, it is necessary to gather information about all British territorial seas. Additionally, it is important to establish access to information on the continental shelf and from within the territorial seas of European states with an Atlantic border where that information assists in interpreting the international significance of species or biotopes in Great Britain. The three-mile, or exceptionally the 12-mile (nautical miles), limit of territorial seas is the maximum distance to which areas might be considered for site-specific protection under current legislation. However, the 12-mile limit encompasses an area far too extensive for a focused and comprehensive review of benthic habitats and species within it and even the 3-mile limit can include extensive offshore areas such as the Sea of the Hebrides. Whilst information gathered for MNCR studies is not

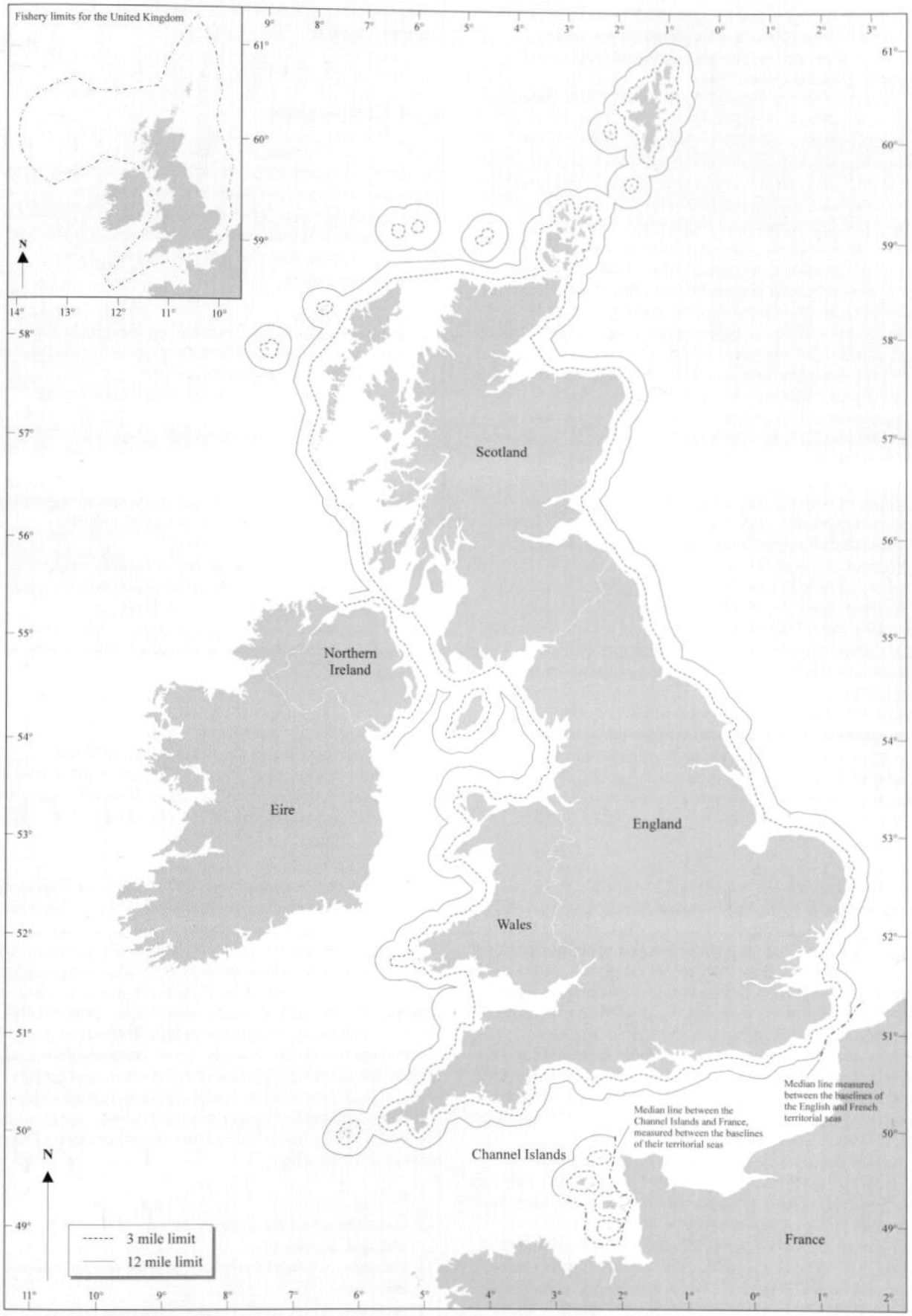


Figure 4.1 United Kingdom three and 12-mile limits and (inset) UK fisheries limits. Reproduced from Admiralty charts CB(W)15 and Q6353 by permission of the Controller of HMSO and the UK Hydrographic Office.

limited in offshore extent by territorial boundaries, field survey has to be restricted for practical reasons to nearshore areas but within an ecological framework which defines the coastal zone.

The extent of this 'coastal zone' varies but is generally taken to reach about three nautical miles (about 5.6 km) offshore of the mainland or of any emergent rocks or islands. The seabed within the 'coastal zone' is particularly affected by wave action on the seabed, the extent of rocky seabed offshore, the presence of turbid or reduced salinity water and the acceleration of tidal currents by coastal features. However, the offshore extent of such a 'coastal zone' so defined can vary greatly. For instance, the area of coastal character will extend further offshore where plumes of turbid reduced salinity water from large estuaries such as the Humber occur, or where slightly submerged offshore features influence surrounding areas in a similar way to that of the coast (for instance, the Sarns in Cardigan Bay) or where offshore islands provide shelter from wave action but may also, in the case of the Pentland Firth between Caithness and Orkney, cause acceleration of tidal currents.

The 50 m depth contour off the open coast is also important in defining a 'coastal zone' as it approximates to the depth of seabed separating areas of low-turbidity, seasonally-stratified waters from shallower waters which are generally of higher turbidity and are well-mixed throughout the year. It is also the depth below which wave action is unlikely to have a substantial effect on the seabed on the open coast. In the North Sea, 40 m is the depth separating the infralittoral (inshore) and coastal (offshore) *étages* defined by Glémarec (1973) although the separation of regions in the North Sea by subsequent authors (Dyer *et al.* (1983) and Frauenheim *et al.* (1989) for epibenthos and Adams (1987) for plankton) approximates to the 50 m depth contour. All four sources describe a further separation of zones at the 100 m depth contour. However, because of the greater strength of wave action on the open western coasts of Britain, the depth separating zones based on thermal stability is likely to be closer to 80 m in the south-western approaches and probably deeper still off western Scotland.

4.2.4 Conclusion

The MNCR has concentrated work on habitats dominated by marine and brackish-water macrobenthic species, including demersal fish closely associated with particular benthic habitats, within the coastal zone usually shallower, on the open coast, than 50 m depth because of the following key points:

- the biotopes and species have not been included in previous comprehensive reviews aimed at establishing natural heritage importance;
- it is the area of sea where the greatest variety of biotopes occurs;
- the area near the coast is highly affected by a wide variety of human activities;
- the area within the 3-mile and, to a lesser extent, the 12-mile limit of territorial seas is subject to legislation allowing for the creation of statutory wildlife conservation areas;
- extensive comparative survey of benthic habitats in the inshore zone can be carried out within the limits of finance and readily available technology;
- the coastal zone and its natural features is the area of most immediate interest or concern to the majority of people.

The MNCR does not undertake research into pelagic habitats, communities or species or into meio- and microbenthos but retains review information on coastal and marine habitats and species including those which are the responsibility of other groups.

4.3 MNCR coastal sectors

Even restricting the area on which the MNCR primarily focuses to the coastal zone, there remain many tens of thousands of square kilometres of shore and seabed to consider. The task of review and survey has, however, been made more manageable by dividing the coast into fifteen physiographically or biogeographically distinct zones, the MNCR 'coastal sectors' (Figure 4.2).

MNCR coastal sectors are based on those used by the Intertidal Survey Unit, a project funded by NCC from 1975 to 1980 (Bishop & Holme 1980; Harvey *et al.* 1980). In turn, those units were fitted, wherever appropriate, to the statistical rectangles of the International Council for the Exploration of the Sea (ICES) and the recording areas of the Conchological Society (Seaward 1990, 1993). Further oceanographic and other studies have reinforced the validity of many of these boundaries including, most recently, the identification of 'coastal cells' (areas within which localised coastal sediment processes are considered largely restricted) in England and Wales (Motyka & Brampton 1993). MNCR coastal sectors are not analogous with the 'Natural Areas' concept introduced by English Nature (English Nature 1994) although, in many cases, MNCR coastal sectors can be broken down into such areas based on landscape and geomorphology.

The 15 MNCR sector boundaries correspond with one or more of the following:

- locations where the geomorphology of the coast changes significantly;
- locations where the edge of range of several species coincide;
- locations where frontal systems separate different water bodies;
- locations where there is a marked change in coastal aspect.

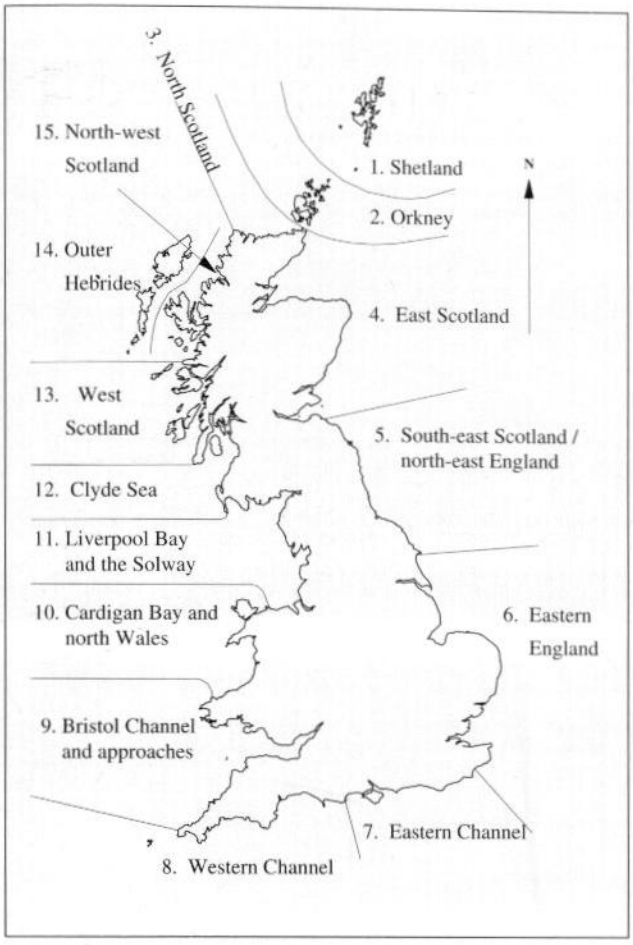


Figure 4.2 MNCR coastal sectors.

Quite often, these locations correspond to headlands where currents sweep offshore. Sector boundaries rarely correspond to administrative boundaries, which often extend down the middle of estuaries or terminate along part of a geomorphologically very similar coastline, making administrative boundaries unsuitable for the separation of units within which ecological comparisons are to be made.

4.4 Main elements of the programme

The objectives of the MNCR have remained broadly unchanged since the establishment of the programme in 1987. In 1991, an external science review group recommended slight changes to the original objectives to emphasise the essentially benthic nature of MNCR studies. The objectives are stated in Section 2.1.

The MNCR programme has seven main elements (Table 4.1), each of which is described in more detail in subsequent chapters.

All aspects of the MNCR are supported by a powerful relational database which enables rapid access, manipulation and dissemination of data (see Chapter 6).

The MNCR programme reports at both regional (MNCR coastal sector) and national (Great Britain) levels. For ease of data collection, interpretation and reporting, much of the work has been tackled on a sector by sector basis (or by survey of major habitat types such as sealochs within particular sectors). With the accumulation of information from many different parts of the coast, it has become increasingly possible to effectively assess the data at a national level (such as in the development of a national biotopes classification and the evaluation of sites of national and international importance for the EC Habitats Directive).

Table 4.1 Main elements of the MNCR programme

	Main elements	Key features
1	**Collection and utilisation of existing information**	Much information already exists which describes or provides data to describe the species, communities and habitats present in an area. Existing information on the physical characteristics of areas, survey methods and marine natural heritage importance are also particularly useful. Use of appropriate existing information is usually highly cost-effective compared with undertaking new surveys.
2	**Undertaking new field surveys to fill gaps in knowledge**	Large stretches of coast are poorly surveyed or lack comprehensive studies where data were collected with nature conservation aims. The surveys undertaken by the MNCR aim to give a broad but comprehensive overview of the range of habitats present, from which areas of highest importance can be identified. For practical and economic reasons the surveys do not attempt to map in detail the habitats present.
3	**Setting standards for data collection, storage and interpretation**	The MNCR establishes and promotes common standards for field survey methods, data storage through the MNCR database, data interpretation and conservation evaluation, both nationally and internationally.
4	**Classifying marine biotopes**	The MNCR is developing a marine classification system to underpin interpretation of data, assessment of marine natural heritage importance and management of the sea. The classification could have wide application throughout the north-east Atlantic and can be linked to part of the European CORINE classification (Commission of the European Communities 1991).
5	**Comparing and evaluating locations**	Comprehensive data sets enable objective assessment and comparison of locations based on their scientific merits. Computer-aided statistical analysis facilitates this evaluation.
6	**Identifying locations of marine natural heritage importance**	Through analysis of survey information undertaken by standard methods, the MNCR identifies locations of high marine natural heritage value within each coastal sector and nationally.
7	**Publishing results**	Through an ongoing publication programme, the results of MNCR studies are disseminated for use by conservation organisations, regulatory authorities and others. Publications are presented in a variety of forms to suit the requirements of different audiences.

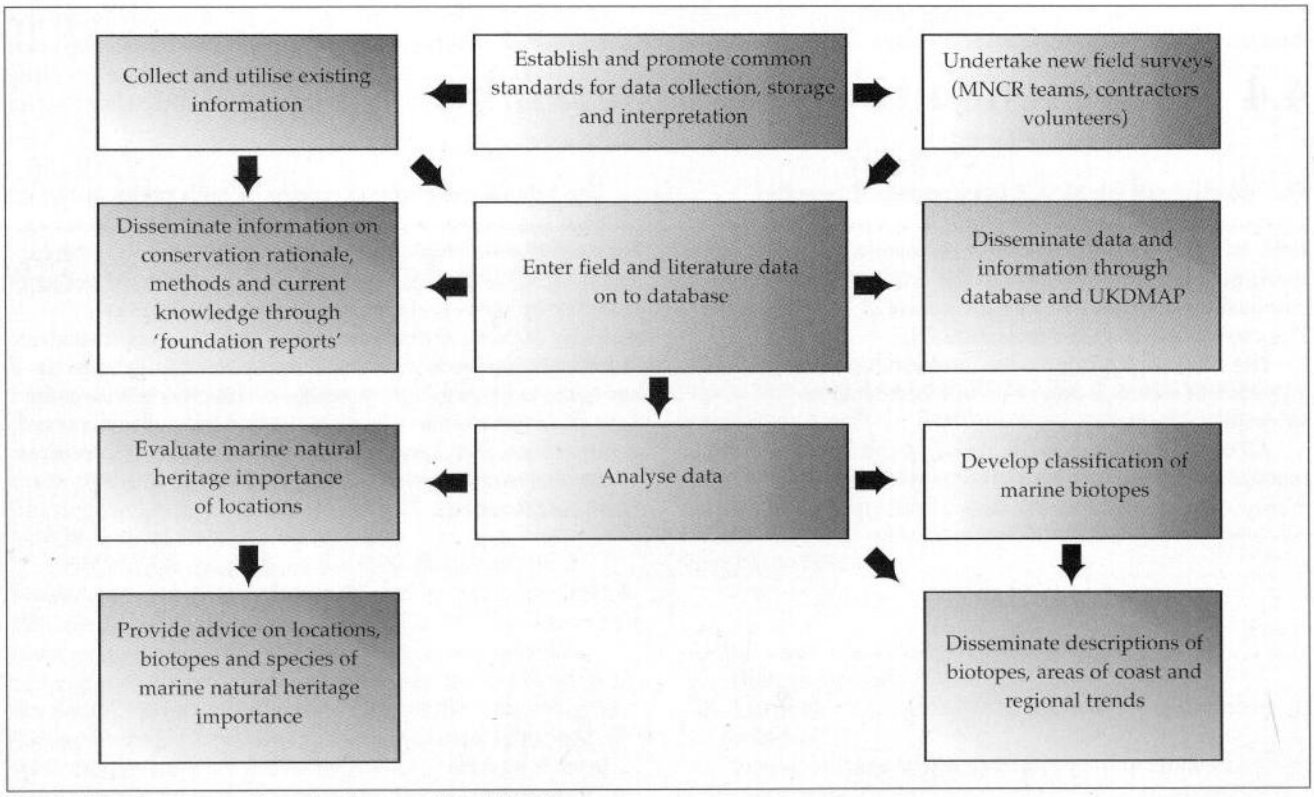


Figure 4.3 Links between the main elements of the MNCR programme.

5 Data collection methods

David Connor and Keith Hiscock

5.1 Collection and utilisation of existing information

5.1.1 Introduction

A great deal of information is available on the marine biology of locations all around Great Britain in literature that extends back over 150 years. The greatest volume of research has, however, been undertaken since the mid-1970s, and published in books, journals and commissioned research reports or held as unpublished data. Information has been, and continues to be, collected by universities, research institutes, conservation organisations, fisheries departments, regulatory authorities (such as the National Rivers Authority), industry (including oil, chemical and water companies), consultancies and individuals. The MNCR makes extensive use of this valuable resource.

5.1.2 The programme of literature collection

The collection and use of information, from external sources or collected by NCC before the commencement of the MNCR programme in 1987, has been undertaken using the following approaches.

1. Review of information

A major programme of identifying, collecting and reviewing literature was undertaken in the first two years of the MNCR. This included the review of existing NCC collections of reports and reprints and abstracts of information produced by the Intertidal Survey of Great Britain (Bishop & Holme 1980; Harvey *et al.* 1980) and the Survey of Harbours, Rias and Estuaries in southern Britain (Moore in prep.). Further material was added from the review of papers and reports held at research institutes and universities. The Marine Biological Association series, *Estuaries and coastal waters of the British Isles: a bibliography of recent scientific papers*, was particularly useful. A great deal of site-related information, in the form of less accessible 'grey' literature or the unpublished notes of marine biologists, was reviewed through visiting a large number of institutes, universities, fisheries laboratories and individuals.

Searching for and reviewing literature and other information required the development of a structured form that catered for the wide variety of different types of information likely to be encountered. The structure used is shown in an example of a completed information review sheet (Appendix 5). Appendix 6 gives a list of keywords used for this information review. Each paper, book, report or other item of information is assigned a reference code, keywords, names of any particular taxa included, an abstract and, where relevant, an indication of its geographical coverage. Information from these sources is incorporated into the *literature review* module of the MNCR database (Chapter 6). Search facilities in the database, using authors, keywords, taxa and geographical location, provide rapid access to the information. Much of the information is also held in a library which, in 1995, held over 5,000 reprints and 3,000 reports.

The initial review of marine biological information is being summarised in *Benthic marine ecosystems: a review of current knowledge for Great Britain and the North East Atlantic* (Hiscock in prep.).

2. Site-specific survey information

Where any of the information reviewed holds site-specific details of marine biological surveys, it is incorporated into a *literature sites* module of the MNCR database. Here the source reference, the types of survey undertaken and the specific location of each site or station are recorded. Through display on mapping facilities within the database, this module provides a rapid indication of where surveys have been undertaken, and is particularly useful in responding to site-specific issues of marine conservation management. This information is also widely available through the computer-based UKDMAP (United Kingdom Digital Marine Atlas Project) (Mills *et al.* 1993; Barne *et al.* 1994).

The data available in existing literature are highly variable in quality, particularly as they were often collected for reasons different to the aims of the MNCR. Thus only a proportion of the information identified here is used for the third type of literature assessment.

3. Survey information which enables full description and/or assessment of the site

Where survey information has been collected to similar standards to those of MNCR field surveys, and therefore can contribute to the detailed description of habitats and their component species or to the assessment of marine

natural heritage value, it is incorporated into the *field survey* module of the MNCR database (Chapter 6).

The use of appropriate existing field survey data published in reports or supplied as raw data has been greatly facilitated through two projects in which external data have been acquired and entered onto the MNCR database. The first of these, the Great Britain Nature Conservation Resource Survey, concentrated on the entry of data from surveys undertaken by the Nature Conservancy Council prior to the start of the MNCR (Downie & Davies 1991). Following this, each of the country conservation agencies initiated projects of data entry to further improve the base of field survey information on the MNCR database. A further major project, funded by the Department of the Environment, concentrated on the North Sea and English Channel coasts, and included the acquisition of a substantial volume of data from external sources, particularly universities, water companies and the National Rivers Authority (Hill *et al.* 1993; Mills *et al.* 1993). The result of these projects has been to build-up a substantial database of site-specific habitat and species data covering many parts of Great Britain.

5.1.3 Other information available to support the Review

In addition to the large volume of scientific literature and data used, other resources listed below also contribute to the work of the MNCR:

- the Marine Conservation Society's Species Directory (Howson 1987, Picton *et al.* in prep.);
- keys and guides for the identification of marine species (Appendix 7);
- a reference collection of specimens;
- a reference collection of photographs illustrating habitats, communities, species and coastal features;
- instructions to recorders (Appendix 8);
- site schedules for coastal and intertidal Sites of Special Scientific Interest;
- Admiralty charts, Ordnance Survey maps, British Geological Survey maps and coastal pilots, for navigation and for information on the physical nature of the coast and seabed.

5.2 The field survey programme

5.2.1 Introduction

While some survey information already existed prior to the start of the MNCR, the variety of methods used and the various levels of detail, meant that they were not always compatible with the standards required for the MNCR. The MNCR has consequently included a very substantial element of new field survey.

5.2.2 Origins of field survey methods

The establishment of the MNCR team in 1987 followed more than ten years of NCC-commissioned research projects directed at describing littoral and sublittoral habitats and communities. Major studies during this period included the (uncompleted) Intertidal Survey of Great Britain (Bishop & Holme 1980; Harvey *et al.* 1980), the South-West Britain Sublittoral Survey (Hiscock 1981) and the Survey of Harbours, Rias and Estuaries in southern Britain (Moore in prep.). In Northern Ireland similar studies had been undertaken of the littoral and sublittoral zones (Wilkinson *et al.* 1988, Erwin *et al.* 1990). All these studies required the development of survey techniques which would determine the natural heritage importance of marine sites. The techniques, described in several papers including Hiscock & Mitchell (1980), Knight & Mitchell (1980), Erwin *et al.* (1985) and Hiscock (1987), formed the foundation of present MNCR field methods. MNCR survey methods were initially described in Hiscock (1990).

Approaches to survey adopted for non-marine studies within the Nature Conservancy Council were also considered. Among these was the adoption of differing levels of detail (Phases 1, 2 and 3) according to the ultimate aims of the surveys undertaken. This is further described below (5.2.3).

The start of the MNCR was an opportunity to develop techniques further, particularly in relation to standardising recording to suit both its use for comparative assessment of sites and the storage of data on a customised computer database. Although techniques continue to be refined, particularly as new technology becomes available and evaluation techniques improve, the basic principles have remained close to those originally adopted to meet the objectives of the MNCR programme.

5.2.3 Levels of detail (survey phases 1, 2 and 3)

A phased approach to surveys, based on terrestrial survey techniques and outlined in Felton & Keymer (1993), incorporates various levels of detail to suit differing end requirements of surveys:

Phase 1 surveys are broad habitat surveys aimed at identifying the range of habitats in an area, and may give an indication of their extent and distribution. This information can also be used to target the selection of sites for more detailed Phase 2 surveys.

Phase 2 surveys describe the communities and their variation within habitats, thus providing information for assessing the natural heritage importance of sites.

Phase 3 surveys focus on individual species or groups of species within a site, providing detail on demographic

performance, abundance and distribution. This information provides details on population and community structure pertinent to site management.

Methods used for Phase 1 and 2 surveys are described in more detail later.

5.2.4 Factors governing survey strategy

The field survey techniques used for the MNCR take account of the factors noted below.

- **The need to assess the relative marine natural heritage quality of sites** This requires information on biotope and species richness, biotope and species rarity, representativeness and naturalness (see Chapter 7). Assessment will therefore require survey of sufficient sites representing the range of biotopes in an area to undertake comparative assessment.
- **The lack of a comprehensive marine biotope classification at the start of the MNCR** Without a comprehensive national classification, the MNCR has been hampered in its efforts to interpret data adequately at regional and national levels. A major component of the Review has therefore been the development of a suitable classification (see Chapter 7). This necessitates the collection of detailed species data from a wide range of habitats throughout the country as well as use of data from offshore. Development of the classification has had to run in parallel with survey for marine natural heritage assessment purposes.
- **The extent of the coastline to be included in the MNCR** With over 19,000 km of coastline to consider, the survey strategy has had to balance the requirement for detailed survey in often highly complex areas with the need to achieve an overview of large stretches of coast and seabed. The level of survey coverage is targeted to provide sufficient detail to allow meaningful assessment of relatively large sections of coast (e.g. for comparison of whole marine inlets or 20-30 km lengths of coast), but inevitably means that small features may be less well studied or overlooked. The aim has therefore been to provide a broad overview and to leave more detailed or intense study to others should this be required.
- **The nature of marine habitats and communities** The shore and nearshore marine environment is a place of often great change in environmental conditions over a few tens of metres or even over metres. The distribution and limits of extent of the communities present at any location is often highly complex and this complexity has an effect on sampling and assessment strategy. The sampling unit defined as a basis for survey, classification and assessment is an area of shore or seabed in which a group of species (the community) occur in a particular environment (the habitat) to create a biotope which is separable from other biotopes by means of ecological survey (see Hiscock & Connor 1991 for discussion of this definition). These areas may vary markedly in extent. For instance, on a level sediment seabed, the same biotope may occur over many hectares or square kilometres. In some cases, especially rocky shores, the biotopes constitute narrow bands stretching over extensive lengths of shore. Although biotopes are sampled from whatever area they occur in, those which regularly occur together (for instance the sequence of biotopes down a rocky shore of similar exposure) can be considered as single units for some purposes (e.g. mapping and management). Also distinct communities, e.g. epibiota on kelp plants, may develop within this defined sampling unit but are best considered as features within the habitat rather than separately. The characterisation of rocky habitats by their conspicuous epibiota and of sediment habitats by their infauna as well as epibiota has led to the need to sample the former by direct observation and the latter by additionally taking sediment samples. Direct observation in the sublittoral zone by SCUBA diving techniques provides data to the required level of detail for comparative quality assessment, but video cameras can be used to identify biotopes (see Section 5.2.6, Phase 1 surveys).
  For practical reasons, the main emphasis is placed on survey and assessment of conspicuous species (both epibiota and infauna), whilst recognising that meiofauna and meioflora also play an important role in marine ecosystems.
- **Methods developed before the start of the MNCR or used by others** The majority of previous survey work and ongoing research and survey by other institutes which provide data that contribute to the MNCR (see Sections 5.1.2 and 5.2.2) is oriented towards the provision of species and habitat data at specific sampling stations, often from stratified or regularly spaced stations. This type of data suits a variety of purposes, including assessment of marine natural heritage importance. Much less effort has been directed towards habitat mapping studies in previous or non-MNCR studies, although this is now receiving more prominence, particularly through the development of new techniques (see Section 5.2.6, Phase 1 surveys).
- **The nature of the marine environment and the constraints it places on survey techniques** The often hostile nature of the marine environment places severe constraints on the time available for survey. Time available is determined by such characteristics as the rising tides on shores, the effects of pressure in limiting time and depth for SCUBA diving and the restrictions imposed by weather (especially strong winds) on both diving and remote sampling. High turbidity underwater can limit the effectiveness of both divers and cameras. Access to the marine environment can be very expensive and this restricts the amount of survey which can be afforded.
- **The training and experience of personnel available to undertake the work** The main skills required are in taxonomic and field survey techniques. The number of suitably qualified personnel with this experience is fairly limited, in part due to low training opportunities at universities and a restricted requirement for these skills afterwards. Specific training is often therefore required, both for scientific purposes and in health and safety aspects of the work.

- **The equipment and other resources available** The resources available for marine nature conservation work, in comparison with other areas of marine research and some areas of nature conservation, have always been limited. This has necessitated a relatively modest approach to the programme in which the use of large boats and expensive seabed survey equipment has not been feasible. The emphasis is therefore on small teams working in inshore waters.
- **New developments and techniques** Opportunities continually arise, particularly in the electronics and computing fields, to develop and improve techniques. These are considered and adopted when they improve the efficiency of MNCR surveys without compromising the continuity of the programme.

Consideration of the above factors has led to a field survey programme of Phase 2 studies, following an initial Phase 1 stage usually restricted to reconnaissance (see Section 5.2.6). Emphasis has been placed on collection of data for assessment of marine natural heritage importance (as a key objective of the MNCR) and classification of biotopes (i.e. requiring detailed survey of a small number of representative sites) rather than orientation towards detailed habitat mapping studies. Mapping is, however, important before site designation and in dealing with casework and appropriate techniques and surveys are being developed elsewhere to meet this need. More specific Phase 3 studies may also be needed to assist conservation management of marine habitats, especially within designated areas.

5.2.5 Survey strategy and selection of sites for sampling

The approach adopted has been to achieve both a balanced geographical coverage and to sample the range of features present, at local, regional and national levels. Sampling thus takes account of geographical variation and the structure of the marine environment and its component habitats, which in turn are reflected in the structure of the biotope classification system (see Chapter 7 and Connor *et al.* 1995). This has led to the tiered sampling strategy described below.

Biogeographic variation

To ensure that full account is taken of biogeographic variation within Great Britain, separate survey programmes aimed at recording from the full range of habitats and communities in each of the 15 MNCR coastal sectors are undertaken.

Physiographic features

Within each coastal sector, sampling of each type of physiographic feature provides information on the full range of habitats present. Sampling therefore occurs on the open coast, around offshore islands, in straits, sounds, bays, rias, estuaries, sealochs and lagoons, and ensures coverage of a very wide range of habitats.

Site and habitat features

Within each distinct physiographic feature, selection of sites subject to the full range of environmental conditions present in the area ensures that a wide range of habitats and communities is sampled. Each combination of environmental factors can potentially give a different type of community and should therefore be sampled. The most important environmental factors considered in selecting locations for survey are shown in Table 5.1.

More details on these factors, including definitions, are given in Appendix 8.

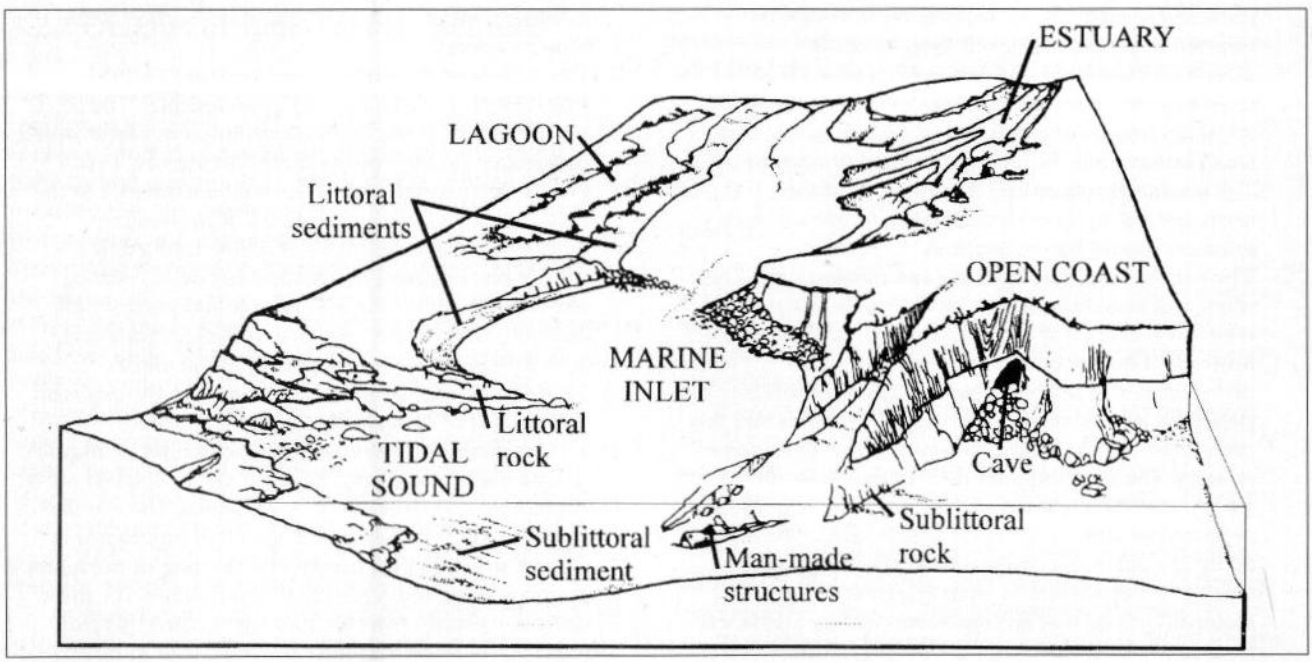


Figure 5.1 Major physiographic features of the coast. Drawing by Bob Foster-Smith.

Table 5.1 Site and habitat features used to determine survey locations

Factor	Range or variation to sample
Substratum	Bedrock and boulder, through unstable stony ground and mixed sediments, to coarse and fine sediments; biological reefs (e.g. mussels)
Zonation	Littoral and sublittoral zones, from the lichen and strandline communities and below (height or depth) saltmarshes to those in deep water (depths over 200 m may occur within 5 km of the coast)
Exposure to wave action	Extremely exposed to ultra-sheltered
Strength of tidal currents	Very strong (8 to 10 knots (4 to 5 m per sec.) or more) to negligible
Salinity	Fully marine, through variable salinities, to estuarine and brackish conditions
Geomorphology / inclination	Bedrock habitats ranging from horizontal rock surfaces to vertical walls and overhanging faces; gullies, tunnels and caves formed in some rock types; boulders of different size and shape creating microhabitats such as boulder holes
Geology	From hard igneous and metamorphic rocks, through sandstones to softer limestones, chalks and very soft clays: the type affects both the surface texture (e.g. very smooth, highly pitted) and the local topography (e.g. even rock platforms, highly fissured or folded)
Other modifiers	Features such as freshwater runoff, wave surge, pollution, sand scour, grazing, stratification and oxygenation may affect community composition

5.2.6 Phase 1 surveys and their role in the MNCR

As a precursor to MNCR Phase 2 surveys it is necessary to provide sufficient information to identify the potential range of habitats present in an area so that a balanced programme of detailed surveying can be undertaken. The main types of marine Phase 1 survey are described below.

Chart, map and literature surveys

Examination of Admiralty Charts, Ordnance Survey maps, British Geological Survey maps, coastal pilots and scientific and other literature can generally provide sufficient detail on the nature of the coastline, its substrata, wave exposure, strength of tidal currents, geology, salinity, topography and seabed inclination to allow identification of the likely range of habitats in an area. However, additional information, particularly on the distribution of sublittoral seabed types, is often desirable.

Reconnaissance surveys

For intertidal areas these range from aerial surveys, including photographic recording, to rapid surveys of the coast from a boat or cliff top or by walking along stretches of shore. In the subtidal, the use of towed, drop-down or remotely operated video cameras or divers towed on sledges can provide reconnaissance information. RoxAnn, an acoustic seabed discrimination system (Chivers, Emerson & Burns 1990), can also be used for reconnaissance (Foster-Smith & Davies 1994). Reconnaissance surveys describe the type and extent of habitats and permit the selection of representative sites for more detailed survey.

Aerial reconnaissance of intertidal areas helps to locate contrasting sites or special features for survey, for instance rocky substrata extending to extreme low water in otherwise muddy areas: the Ballast Pound, Tamar Estuary, Cornwall (Keith Hiscock/JNCC).

Inventory surveys

These surveys catalogue, without boundary mapping, the range of different habitats or biotopes in an area and allow the selection of sites for more detailed survey. Such surveys can catalogue according to coastal features (for instance, a particular beach or headland) or within units such as Ordnance Survey 1 km squares. Intertidal inventory methods are described by Hiscock (1993). In the sublittoral environment, the volunteer project Seasearch (Earll 1992, Foster-Smith 1995) provides inventory-type information.

Mapping surveys

These provide an indication of the area covered or the length of coast along which a particular habitat occurs. With increasing detail of survey, distinctive shore types,

formations and particular biotopes can be mapped.

In the intertidal, Coastwatch (Bennett, Mitchell & Earll 1987), covering Great Britain between 1986 and 1992, was a project which mapped major substratum types and features such as saltmarsh and sand dunes. A method which maps biotope groups (described as 'life forms') is being developed for intertidal areas by the Countryside Council for Wales (Richards, Bunker & Foster-Smith, 1996) and involves the use of aerial photographs, ground-truthing the photographic images and transposing the information to a geographical information system (GIS) to calculate areas for each biotope grouping. Such mapping can also use the more traditional method of shading different types using coloured pencils or pens on Ordnance Survey maps or acetate overlays of aerial photographs. 'Shore types' determined by the biotope groupings from different zones can also be mapped. Shore types are used as selection units in selection of SSSIs (Joint Nature Conservation Committee 1996). The most detailed Phase 1 survey includes mapping the extent of each habitat and its associated community (the biotope) thus providing information on the boundaries of features for use in site management. Surveying intertidal areas is undertaken *in situ* and requires accurate location according to topographical features, using differential GPS (Global Positioning System) or surveying equipment.

In the subtidal, towed video cameras or remotely operated vehicles (ROVs) with video are used to provides details of biotope types and their extent. Divers can also be used, either swimming transects or recording from a towed underwater sledge. RoxAnn, used in conjunction with a 'drop-down' video camera to provide 'ground-truth' information, is now extensively used for mapping (Foster-Smith & Davies 1994). RoxAnn data can also be incorporated into a GIS. Accurate location is again important.

In all the above surveys the level of definition of community types achieved depends on either the skill level of the surveyors (sometimes non-specialists) or the equipment used and can be limited to defining only broad habitat types and major cover organisms.

The MNCR has relied mostly on a combination of map-based and reconnaissance surveys to provide information for selecting sites for Phase 2 surveys. This has proved a cost-effective method for littoral survey, where larger scale indicative mapping of biotopes can be undertaken in conjunction with detailed recording with little additional effort. It is not so satisfactory in the subtidal where information available on Admiralty charts and geological maps may be of insufficient detail and where rapid reconnaissance is difficult due to limitations of underwater visibility and time constraints. Here the availability of more detailed Phase 1 information, through the volunteer project Seasearch or the newly developing techniques of acoustic and video survey, allows improved targeting of Phase 2 effort.

The MNCR launch *Swiftia* during a survey of Loch Duich, Skye and Lochalsh (Sue Scott/JNCC).

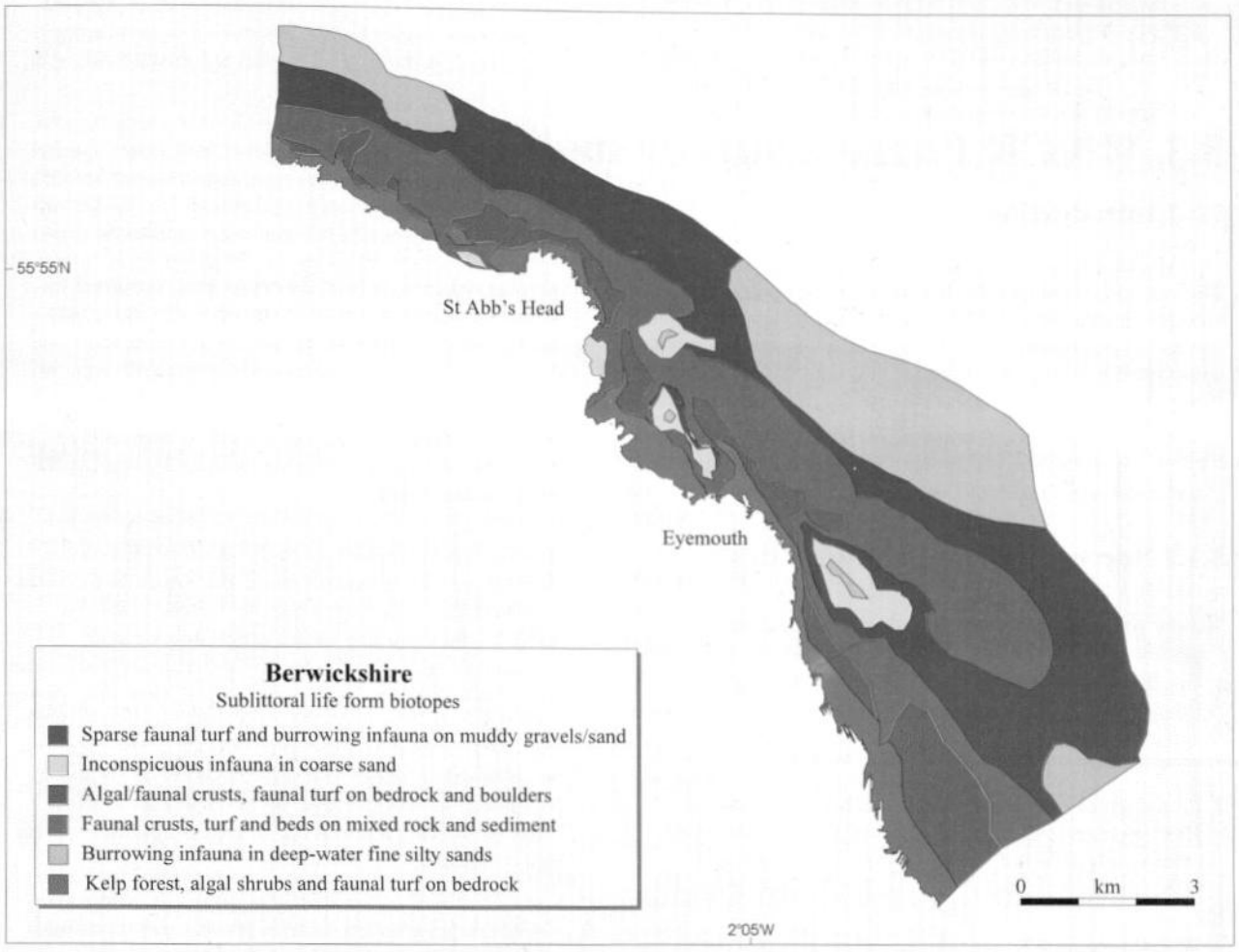


Figure 5.2 Phase 1 survey. Seabed biotope complexes mapped from acoustic survey, ground-truthed with video. From surveys undertaken by Dr R. Foster-Smith for Scottish Natural Heritage.

5.2.7 Prioritisation within the survey programme

Two main priorities have been prominent in the early stages of the MNCR:

- the requirement to get a broad overview of both the range of habitats and associated communities present and their geographical variation throughout the country, to aid interpretation of data within a national context;
- the requirements within the NCC, and since 1991 the country nature conservation agencies, for information to support current issues.

The latter tend to be in areas of greatest human pressure and resulted, in the 1980s, in programmes to survey the Scottish sealochs while fish-farming was undergoing great development, and surveys in estuaries in south-east England. Marine inlets in south-west Britain and Shetland, were the subject of ongoing surveys at the start of the

MNCR and were completed at an early stage in MNCR work. Survey programmes in MNCR Sectors 11 (Liverpool Bay and the Solway Firth) and 5 (south-east Scotland and north-east England) provided both improved geographical coverage and information where data were sparse. More recently the requirement for information to support site selection for the EC Habitats Directive has provided a further priority for surveys, most notably a survey of isolated saline water habitats ('lagoons') in Scotland.

The MNCR programme will continue to be modified to reflect changing priorities within the overall framework of completing survey and assessment within each coastal sector.

5.3 MNCR Phase 2 survey methods

5.3.1 Introduction

The methods used in MNCR surveys have remained broadly similar since 1987 (as described by Hiscock 1990) but have been modified in the light of experience to ensure compatibility of data collection in a wide variety of habitat types and following interpretation of large data-sets. The methods are outlined below, with more detailed instructions for surveyors given in Appendix 8.

5.3.2 Survey planning and logistics

Survey planning involves the activities listed below.

1. The review of current knowledge of the area to identifygaps in information, sites of known interest or sites which should be resurveyed to Phase 2 standards.

2. A search of maps and charts or other Phase 1 information to determine a survey strategy to record from each different habitat and to give a balanced geographical spread of sites within the area of survey.

3. Reconnaissance of the area to gather information on the distribution and extent of different intertidal habitats as well as access points for shore sites or to launch and recover boats.

4. Liaison with relevant local organisations and individuals to make them aware of the survey and to seek local advice relevant to the survey.

5. Resolving survey logistics, including personnel, equipment, transport, accommodation and timing.

5.3.3 General approach to survey

1. Within each project to describe and assess a coastal sector, a series of surveys are undertaken. The surveys are usually carried out between May and September when weather conditions are more clement compared with winter months. The survey teams stay in accommodation local to the area being surveyed for ready daily access tosites or occasionally, in remote areas, live on chartered boats.

2. The survey team operates as a self-contained unit during surveys, taking sufficient equipment to adequately undertake the survey or hiring facilities locally, e.g. day boats, as necessary.

3. The size and composition of the survey team varies according to local requirements, but typically includes between four and twelve people derived from the MNCR team, country conservation agency staff, contractors and other interested individuals. Each team includes ecologists experienced in the particular survey techniques to be employed, including familiarity with the identification of algae and animals in the field and in appropriate health and safety aspects of the work. The teams are further split up to survey individual sites, employing a minimum of two people per site for safety reasons.

4. Each survey comprises detailed recording at a series of sites. The sites are selected in accordance with the sampling strategy outlined in Section 5.2.5 and as informed by the Phase 1 survey (outlined in Section 5.2.6). A site may comprise a broad transect down a rocky slope (shore or underwater seabed) or be an area in a larger plain of sediment or other substrata. The site position is recorded as an Ordnance Survey grid reference on shores and latitude and longitude at sea (the different approaches reflect whether maps or charts are used but co-ordinates are interchangeable through the database). Shore topographical features are used where relevant to indicate position and, whilst both compass bearings and land-based electronic navigation aids have been used in the past, the satellite Global Positioning System (GPS) has been used since 1993.

5. Habitat and species details are recorded from each distinct habitat within the site, together with a description of the site as a whole. Site, habitat and species details are entered onto standard recording forms (see Section 5.3.4).

6. Habitats characterised by their epibiota (attached flora and fauna) are recorded by direct observation. Sediments characterised only or additionally by their infauna are sampled for species and granulometric analysis, both requiring later processing in the laboratory. Records of the epibiota, if present, on sediment are also made in order to associate the two elements of the community. Plant and animal communities are always recorded together and in association with the habitat in which they live.

7. Recording is undertaken over an extended area of the habitat, rather than being restricted to a quadrat or strictly defined transect, to ensure more widely spaced aspects of the habitat and its species are recorded. The area covered varies according to the method of survey and the type of habitat but is typically at least 10 m^2 in extent, except where the habitat is very restricted (e.g. rockpools) or samples are taken remotely by grab or dredge. Records are made from the main part of each habitat, i.e. avoiding the transition zones between habitats. This helps clarify the differences between habitats and is especially important in collecting data for the development of the biotopes classification (Chapter 7).

8. Taxa are recorded to species level whenever possible, except where taxonomic distinction is difficult. All conspicuous species are recorded during *in situ* surveys, whereas in sediment samples all those retained on a 0.5 mm mesh sieve are identified. During *in situ* surveys, recording continues until the habitat has been thoroughly searched and until the abundance of all conspicuous epibiota has been recorded. Completion of the survey within each habitat is thus standardised around the same degree of species recording intensity, to give data for comparative assessment of species richness, rather than within a specific time period. The time required to achieve this varies according to the type of habitat and its species richness, but typically may be only 5-10 minutes for upper shore habitats but more than 30-40 minutes for rich sublittoral rocky habitats.

9. Species *in situ* are recorded using a 'percentage cover' or 'density of individuals' abundance scale, which uses theSACFOR (Superabundant, Abundant, Common, Frequent, Occasional, Rare) notations (Appendix 9). The abundance scales used were developed specifically for the MNCR to cope with all species of animal and plant encountered and replace other scales used until 1990 (Hiscock 1990). The present scales take account of differing growth types and sizes of species, defining categories for 'crusts or meadows' and 'turfs or massive forms' for species which cover the substratum and four size groups (<1 cm, 1-3 cm, 3-15 cm and >15 cm) for species which occur as individuals. Species from sediment samples are counted per unit area of sample, and can be converted to the six-point SACFOR scale by the MNCR database for some types of analysis.

10. Specimens are collected where *in situ* identification is uncertain or not possible and to provide voucher material, particularly of less common species, for deposition in a museum (see 5.3.9).

11. Photographs are taken to record particular features of the site, its habitats, communities and species. The photographs are used to aid data interpretation, for illustration of survey reports, displays, leaflets and other publications and to act as a permanent record of the site. Illustration of the habitats and species in reports is considered particularly important, particularly regarding sublittoral areas which few people have the opportunity to see. Considerable attention is therefore paid to photographic recording during each survey.

Separate procedures specific to different major habitats are described below.

5.3.4 Recording forms

Central to all field surveying is a series of specifically designed recording forms onto which field data are transcribed in a standard format. The forms are described below.

Survey form

This is for general details about the entire survey, including the organisation and personnel involved, the dates and general location of the survey and the range of methods used.

Site form

This is for information on the main features of each site, including its name and position, the surveyors, the time and type of survey undertaken, general physical characteristics, uses and impacts.

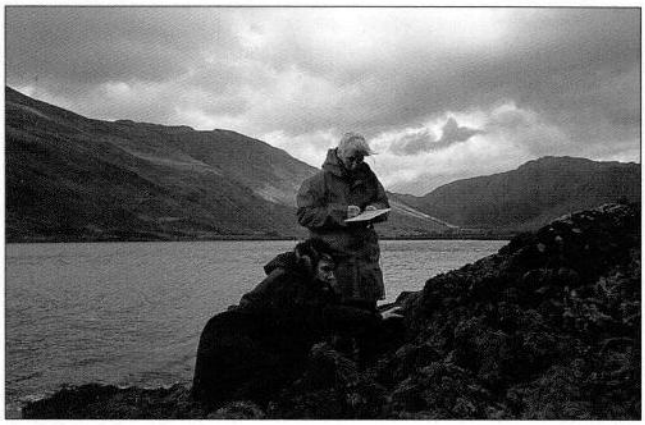
Habitat forms

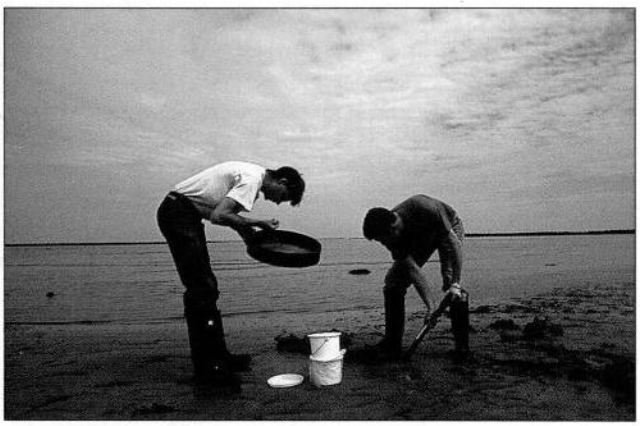
There are two habitat forms, one for littoral habitats and one for sublittoral habitats. They are for details of the physical and biological nature of the habitat and include a check list of species against which to record abundance.

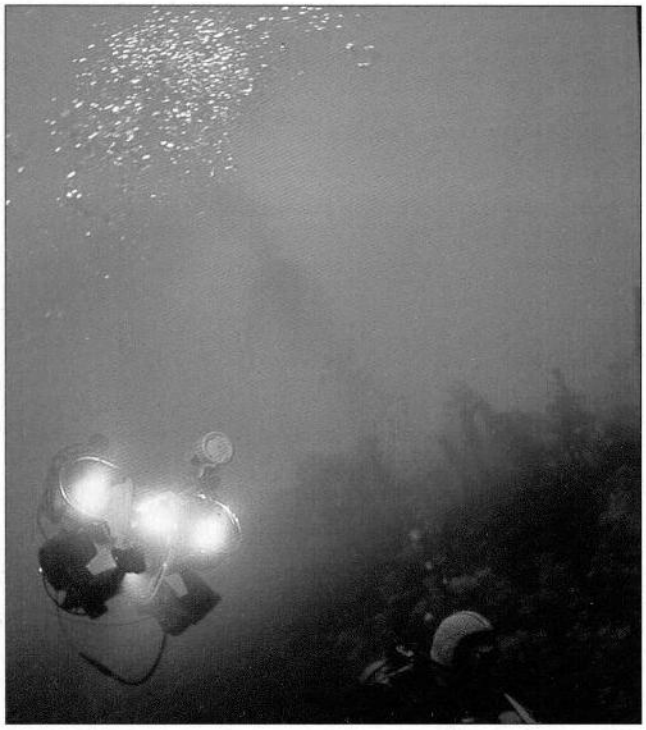
Infauna and granulometry form

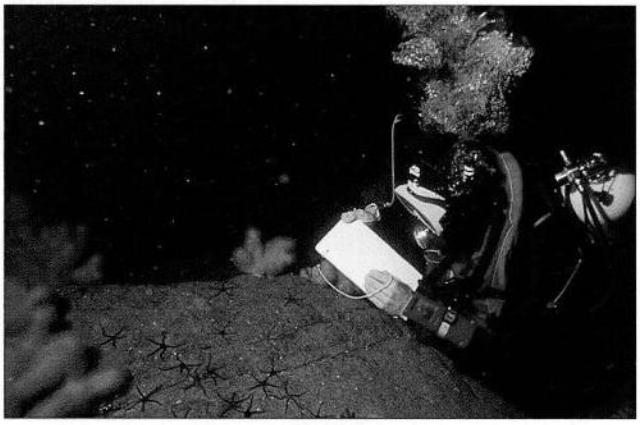
This is a worksheet for use in the laboratory during sample processing. It allows for recording the species present and their numbers in the samples together with the data on the sediment fractions from the granulometric analysis.

The structure of the forms is repeated in the data entry windows of the MNCR database used to store the field data (see Chapter 6). A list of the categories included in each form together with guidance notes for completion of recording forms are given in Appendix 8. Completed examples of each form are illustrated in Appendix 10.









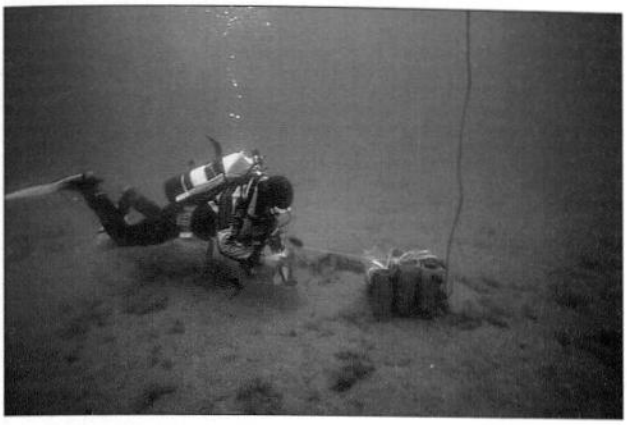
Surveys of rocky shores are carried out by recording the abundance of all conspicuous species within a habitat: Loch Beg, Loch Duich, Skye and Lochalsh (David Connor/JNCC). (Top left)

Littoral sediments are sampled by coring followed by sieving of samples and identification of all collected species. Digging-over the sediment identifies large widely-dispersed species: White Sands, Torness, Lothian (Eleanor Murray/JNCC). (Top right)

A Remotely Operated Vehicle (ROV) with video recording can be used to identify biotopes and to direct MNCR survey teams to particular features or representative sites; photographed during an exercise to compare video and diver recording: Ardnamurchan Point, Argyll (David Ainsley).(Middle left)

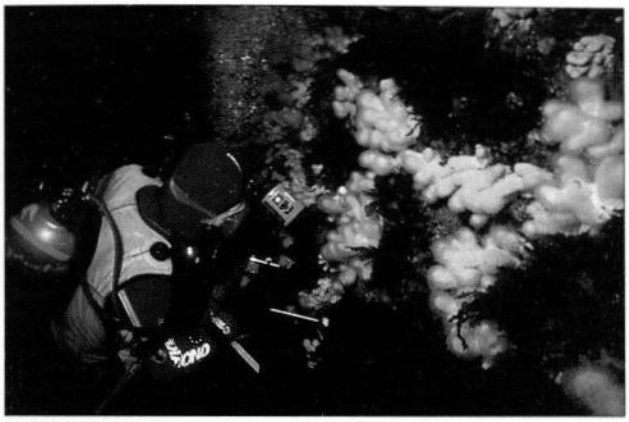
Diving is used to record the abundance of conspicuous species on sublittoral hard substrata: Holes of Burro, Shetland (Sue Scott/JNCC). (Middle right)

Remote sampling by grab is used to sample biotopes over extensive areas of sediment: Northumberland coast (Aquatic Environmental Services/JNCC). (Right)



During diving-based surveys or in areas where sediments are restricted in distribution, coring by divers, together with digging over the sediment for large widely-dispersed species is used to record from sublittoral sediment biotopes: Ceredigion coast (Paul Brazier/JNCC).

The MNCR launch *Swiftia* can be used to sample sediments using a dredge (Keith Hiscock/JNCC).



Photography is used as an illustrative tool and to assist the work of the report writer who will not have visited every site: Herma Ness, Unst, Shetland (Keith Hiscock/JNCC).

5.3.5 Littoral hard substrata

Rocky shores are surveyed on the best available spring tides to ensure adequate access to habitats on the lower shore. Although each site is surveyed at low water it is sometimes possible for a pair of surveyors to survey two shores on one tide, following the ebbing tide down one shore before transferring to a second shore to work up the shore with a rising tide. An initial inspection of the shore establishes the best area for surveying to include a representative range of habitats for that stretch of coast. It also establishes how best to split up the shore into distinct habitats, including the separate biological zones and any features such as rockpools and overhangs which may be present.

Surveying is undertaken from the lower limit of terrestrial flowering plants to the lowest level of the tide that day, i.e. from the supralittoral or lichen-dominated zone down to the sublittoral fringe or kelp zone. Recording, of the physical nature of the habitat and the abundance of all conspicuous species, is then undertaken within each selected habitat, working up or down the shore depending on the state of the tide. The shore is levelled with a cross-staff to enable the height of zones and other habitats to be recorded relative to sea level. These measurements are corrected, according to local tidal predictions obtained from Admiralty tide tables, to heights above chart datum (acd). Specimens are collected and photographs taken as outlined in Section 5.3.3.

The following is an example of the range of habitats which might be surveyed on one rocky shore.

Supralittoral rock at 7.5-5.5 m acd with yellow and grey lichens.

Littoral fringe rock at 5.5-4.5 m acd with *Pelvetia canaliculata* and *Verrucaria maura.*

Upper eulittoral rock at 4.5-4.0 m acd with *Fucus spiralis.*

Mid eulittoral rock at 4.0-2.0 m acd with patches of barnacles and *Fucus vesiculosus.*

Large deep pools at 3.0 m acd with *Corallina officinalis* and *Laminaria digitata.*

Lower eulittoral rock at 2.0-1.0 m acd with dense red algae and *Fucus serratus.*

Sublittoral fringe rock at 1.0-0.5 m acd with *Laminaria digitata.*

Lower shore overhangs at 1.0-0.5 m acd with colonial tunicates and erect Bryozoa.

5.3.6 Littoral sediment

The number of stations sampled varies according to the extent and nature of the sediment at a site, but typically includes sampling at least on the upper mid-shore, lower mid-shore and lower shore. Stations are selected to ensure sampling of obviously different sediment types, often distinguished by differing surface features or the degree of drying or firmness, and within different height zones on the shore.

At each station a description is made of the physical

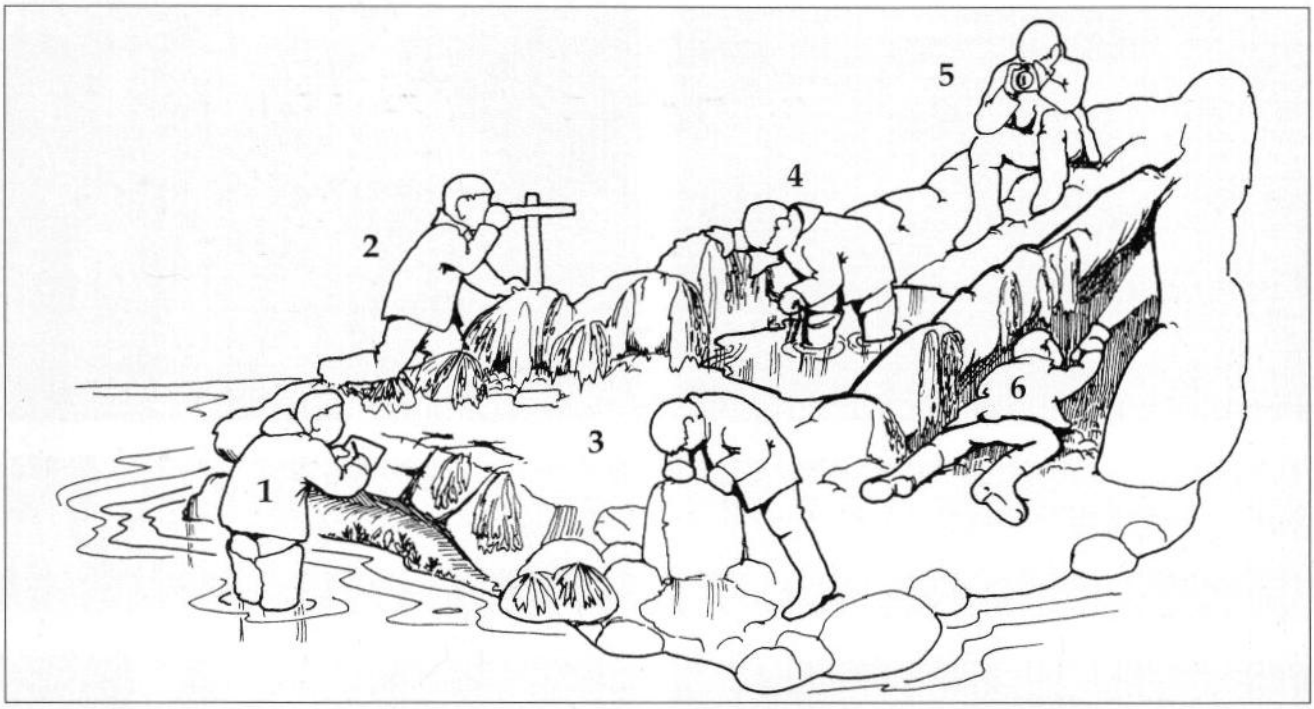


Figure 5.3 Recording and sampling on littoral hard substrata. 1. Recording habitat features and conspicuous species. 2. Establishing heights using a cross-staff. 3. Recording from localised habitats (underboulder). 4. Sampling a rockpool community. 5. Photographic recording (illustrative). 6. Recording from localised habitats (cave). Drawing by Bob Foster-Smith.

character of the habitat, including the type of sediment, together with a record of surface features such as ripples. The sediment is also investigated to describe subsurface features such as the depth below the sediment surface of the black anoxic layer or the presence of coarse material. The abundance of algae or animals found or indicated (for instance by casts or tubes) on the surface is recorded.

To sample large widely dispersed species such as

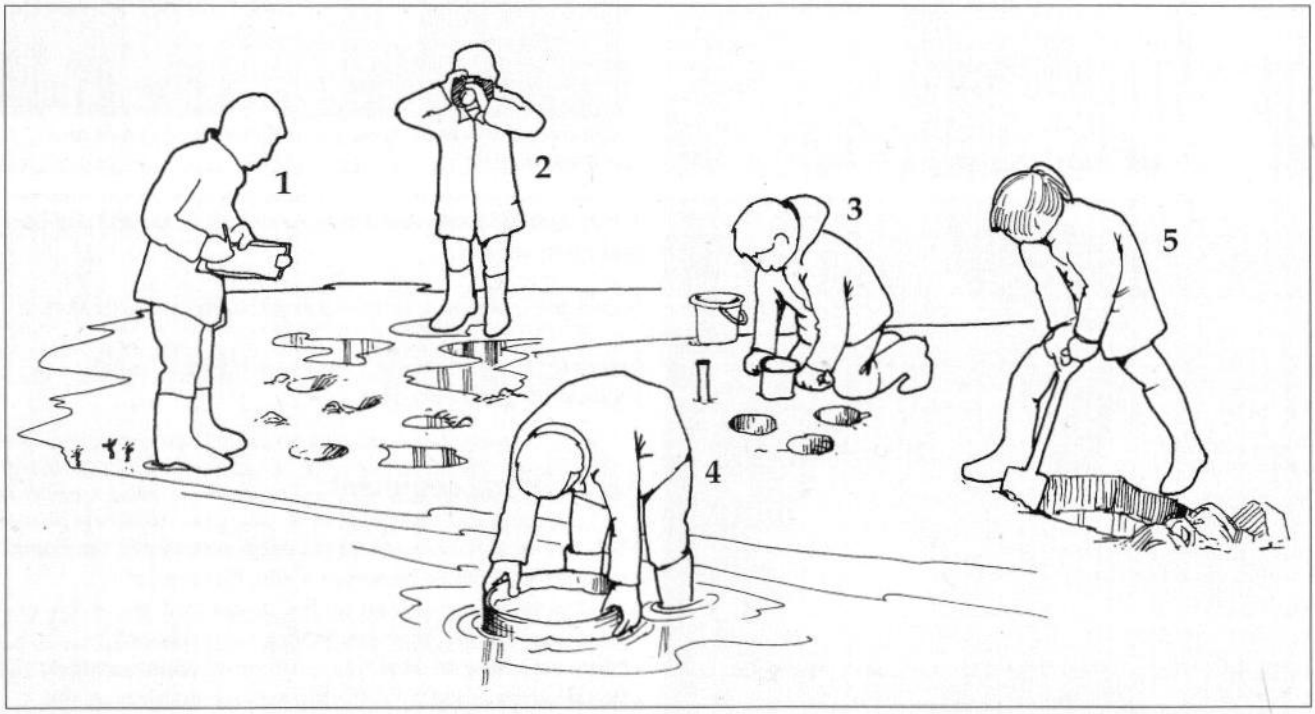


Figure 5.4 Recording and sampling from littoral sediments. 1. Recording habitat features and the abundance of epibiota. 2. Photographic recording (illustrative). 3. Core sampling for infaunal species plus a core for granulometric analysis. 4. Sieving sediment samples. 5. Digging over the sediment to reveal large burrowing species. Drawing by Bob Foster-Smith.

burrowing sea-urchins and some large bivalve molluscs, an area of about 1 m^2 is dug over to about 30 cm depth and the sediment separated to reveal any large individuals which can be counted to provide an estimate of abundance. The smaller fauna is sampled by collecting eight 10.3 cm diameter cores to a depth of about 20 cm at each station. (Prior to 1996, four 11 cm diameter cores were taken). The core samples are washed at the nearby water's edge over a 0.5 mm mesh sieve. Sieved samples are combined for the eight cores and preserved in 4% buffered formalin.

Sediment samples for granulometric analysis are taken using a 5 cm diameter core to a depth of about 15 cm. The core sample is retained for later analysis in the laboratory. Specimens are collected and photographs taken as outlined in Section 5.3.3.

5.3.7 Sublittoral hard substrata

Survey of rocky sublittoral areas follows a similar approach to that for rocky shores. However, selection of survey stations representing the range found in an area is often difficult because of the much poorer 'picture' of habitat range and location obtained from charts or remote sensing information prior to survey. The most effective way of surveying the range of habitats in an area is determined after taking account of factors such as depth, seabed topography, the strength of tidal currents and water turbidity. SCUBA diving is the most suitable and widely used technique in shallow rocky areas, enabling detailed recording, including of the smaller species present, specimen collection and high quality photography. However, the physiological limitations of using compressed air restricts diving to a maximum depth of 50 m with additional limitations on time available underwater. This, together with such problems as requiring slack water on some dives, limits the amount of work which can be undertaken. Cameras in remotely operated vehicles (ROVs) can be useful, particularly in deeper areas. They have limitations for species identification in MNCR Phase 2 studies but are very useful for Phase 1 surveys (see Section 5.2.6). The approach described below relates primarily to SCUBA techniques.

Where the seabed shelves steeply it is possible to survey a broad transect, as employed on rocky shores, surveying from the deepest extent of rock at the site (maximum 50 m using SCUBA) up to the sublittoral fringe. As such a transect can cover four or more habitats it may require several dives to complete, particularly when the habitats are very species-rich. In areas with more extensive gently sloping or horizontal habitats a series of dives is usually required to sample the range of habitats present. The process of surveying within each distinct habitat encountered is similar to that for rocky shores, involving description of the physical

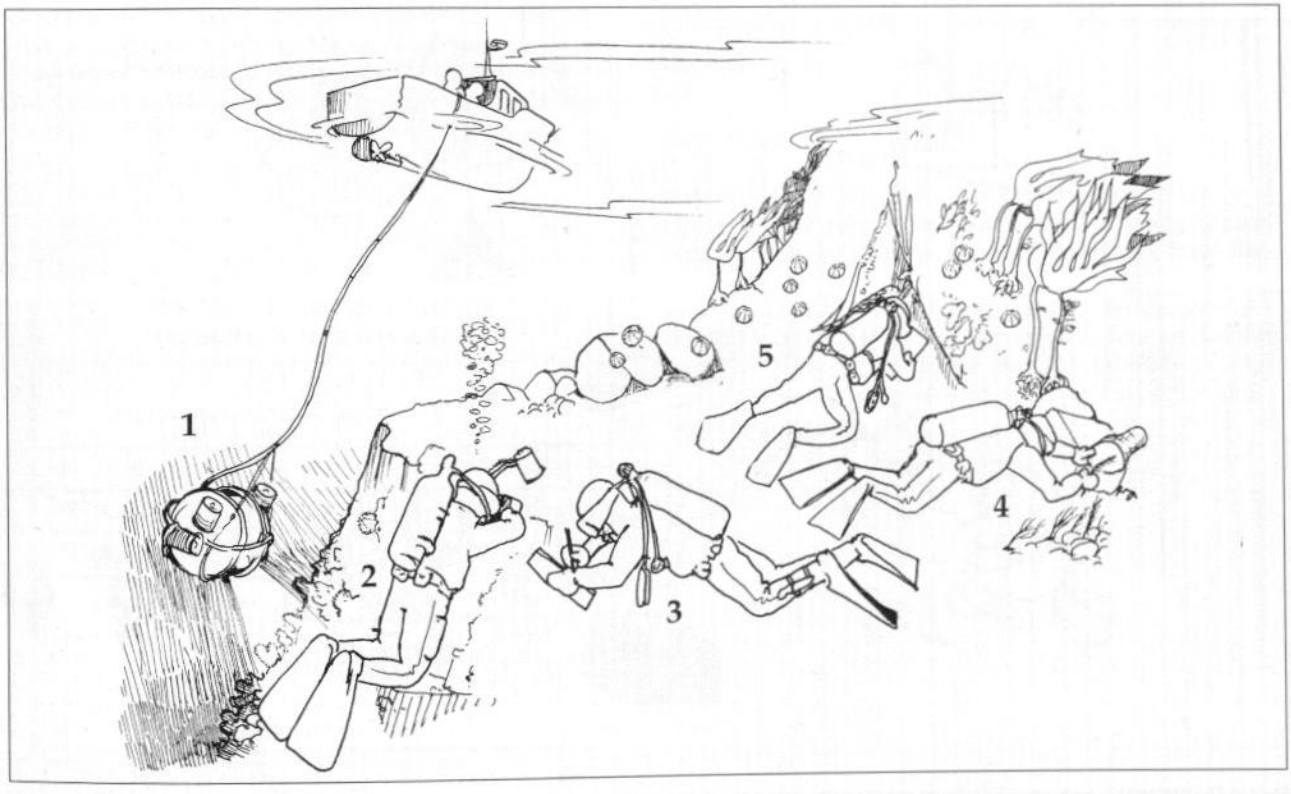


Figure 5.5 Recording and sampling on sublittoral hard substrata. 1. Recording from deep rocky habitats using an ROV. 2. Photographic recording (illustrative). 3. Recording habitat features and abundance of species from the main zones. 4. Sampling. 5. Recording from localised habitats (cave). Drawing by Bob Foster-Smith.

nature of the habitat and the spatial arrangement of the prominent taxa, recording the abundances of all conspicuous species, the collection of specimens where necessary and the taking of photographs to illustrate habitats and species. Depth limits for each habitat are recorded and corrected to depths below chart datum (bcd) according to tidal predictions for the area obtained from Admiralty tide tables.

The following is an example of the range of habitats which might be surveyed at one steeply sloping rocky site.

Sublittoral fringe bedrock at 1 m acd to 1 m bcd with dense *Laminaria digitata.*

Upper infralittoral bedrock at 1-12 m bcd with *Laminaria hyperborea* forest.

Lower infralittoral bedrock and boulders at 12-18 m bcd with *Laminaria hyperborea* and dense foliose algae.

Circalittoral vertical rock at 18-26 m bcd with hydroids, bryozoans, erect sponges and *Alcyonium digitatum.*

5.3.8 Sublittoral sediment

Sediment areas underwater are sampled remotely from a vessel or directly using SCUBA diving. Diving is used in shallow water when infaunal sampling can be undertaken in conjunction with direct observation and is useful in areas of coast with mixed rock and sediment habitats or when working from small boats. Remote sampling techniques can be used to sample from a much greater depth than is possible with diving techniques and are generally more appropriate for sampling extensive plains of sediment.

Remote sampling is undertaken using van Veen or Day grabs to collect 0.1 m^2 samples. One sample per station is taken, noting the volume and nature of sediment sampled and the general composition of the community. Each sample is washed over a 0.5 mm mesh sieve and preserved as for littoral samples. A sediment sample is retained for granulometric analysis.

Diver-operated sampling is undertaken by coring using the same techniques to littoral sampling for compatibility. The infaunal samples are pooled, sieved and preserved as for littoral samples. During the dive the sediment is also dug over to search for large sparsely-distributed infaunal species and the epibiota are surveyed in a manner similar to that for rocky habitats. Specimens are collected and photographs taken as outlined above. Sediment habitats are often encountered during surveys of rocky areas when standard records of the epibiotic species only are taken. Use of divers to observe and sample sediment fauna provides the ability to link the epibiotic community with the infauna. That link is of great importance in developing the biotope classification enabling, where possible, data from traditional remote sampling methods to be correlated with records from direct observation (by video and diver).

A wide variety of other sampling techniques, including biological or naturalist's dredges, Agassiz trawl, anchor dredges, pipe dredges, suction samplers

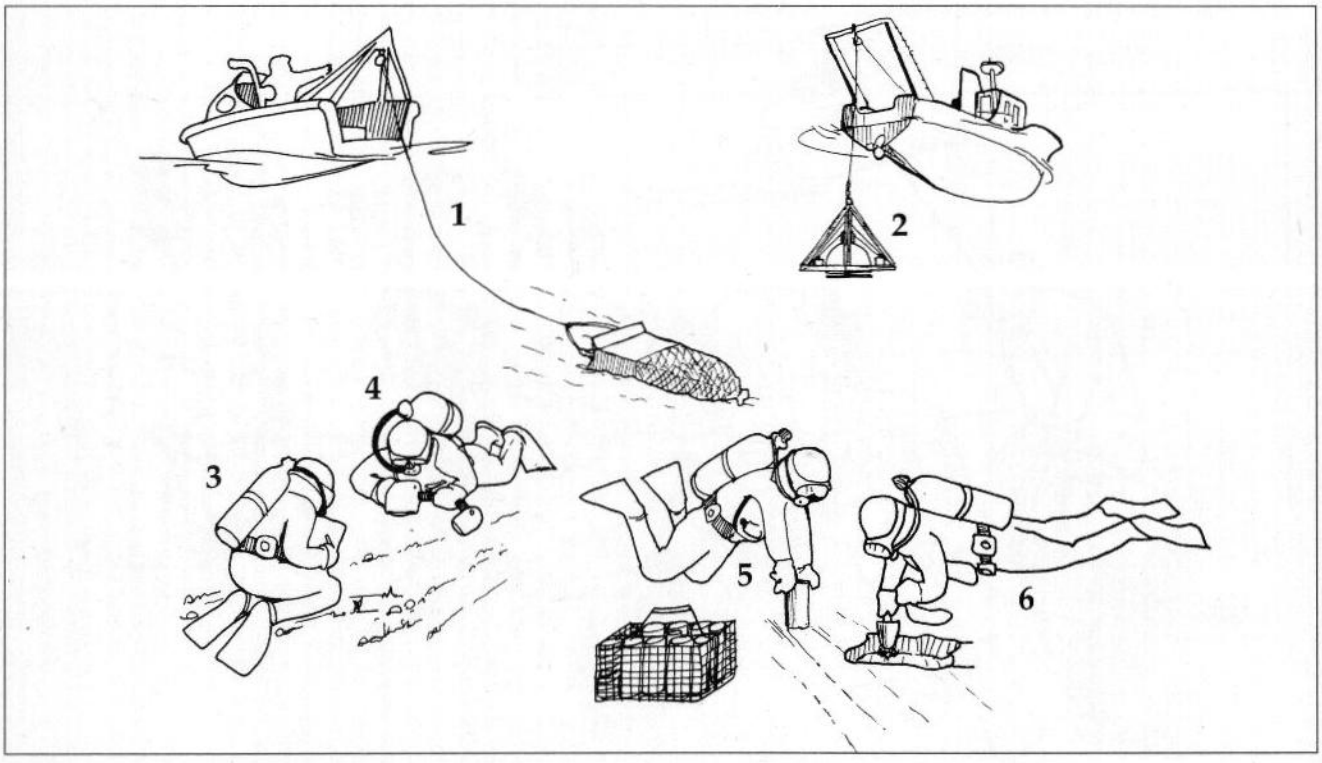


Figure 5.6 Recording and sampling from sublittoral sediments. 1. Biological dredge for remote qualitative sampling of infauna and epifauna. 2. Grab for remote quantitative sampling of infauna. 3. Recording habitat features and abundance of epibiota. 4. Photographic recording (illustrative). 5. Coring for quantitative sampling of infauna and for granulometry. 6. Digging-over the sediment to record large widely-dispersed species. Drawing by Bob Foster-Smith.

and Birge Ekman grabs, is available and all of this equipment has been used for surveys contributing to the MNCR. These techniques sample the sediment in different manners and consequently may lead to difficulties in interpreting results from different types of survey. To minimise these difficulties and to ensure consistency, the MNCR has restricted the number of techniques used as standard since about 1990 to those described in the previous paragraph.

Towed video cameras have been used to survey deep sediment plains as well as in Phase 1 mapping surveys where the video images help to define habitats for more detailed sampling.

5.3.9 Post-survey treatment of specimens, samples, photographs and data

Specimens

Accurate identification of species is an important part of the survey procedure and specimens are collected where their identity is uncertain or where a reference specimen might be necessary for unusual records. Analysis of samples from sediments also generates specimens. Identification is by the most recent taxonomic keys and guides available (see Appendix 7) but the nomenclature used is that of the Marine Conservation Society's *Species Directory* (Howson 1987; Picton *et al.* in prep.). Information recorded for each specimen is that listed on the sample label and an example is shown in Figure 5.7.

Collections from particular areas are lodged with museums which have agreed to maintain the collections. This is undertaken through the co-operation of the Royal Museum of Scotland in Edinburgh, the City Museum and Art Gallery in Glasgow, the National Museum of Wales in Cardiff, and several regional museums in England.

Joint Nature Conservation Committee Marine Nature Conservation Review	
Id. Garveia nutans	
Col. R. Covey	Date: 4-6-91
Det. C. Emblow	Date: 30-10-91
Habitat + Ht/Depth Lower circalittoral	
boulder slope at 1-18m bcd	Hab. No. 1
Site + Area Danger Patch, Lune Deep	
Lancashire	Site No. 288.15
OS Grid/Lat.Long. SD 280 520	

Figure 5.7 Information recorded for specimens

Infaunal samples

Each preserved sample is thoroughly sorted to extract all specimens from the sediment. The specimens are identified, to species level whenever possible, and counted to give the total number of each taxon within the sample. The identification is undertaken by experienced taxonomists, often externally contracted and accredited in the identification of benthic samples. A full voucher collection is made from each survey for deposition in a museum.

Granulometry sample

Each sample is processed to determine its particle size distribution in fractions from 8 mm (or greater) to 63 μm according to the Wentworth scale (Wentworth 1922); the silt and clay fraction below 63 μm is not further analysed. Once dried, the sediment is weighed, washed through a 63 μm mesh sieve to remove the silt and clay fraction, re-dried and passed through a standard Wentworth series of sieves to separate the remaining sample into different fractions. Each fraction is then weighed to assess the particle size distribution within the sample. Results from the granulometric analysis are used in interpretation of faunistic results.

Photographs

Photographs, mostly in 35 mm colour transparency format, are labelled with details of the site location, date taken, photographer and subject matter. These details are entered on the MNCR database (see Chapter 6) from which labels, including index numbers, are generated for each photograph.

Data sheets

Additional information gained from post-survey processing of specimens, samples and photographs is logged onto the appropriate field recording form for each site. The forms are checked for completeness and accuracy before entering the data on the MNCR database (see Chapter 6). The entered data are further checked for accuracy before use in data analysis. The raw data sheets are archived once data analysis and reporting are complete.

6 Data storage and analysis - the MNCR database

David S. MacDonald and David J.L. Mills

6.1 Introduction

When the MNCR commenced, the then Marine Science Branch of the NCC already possessed a library containing several thousand published papers and reports, and thousands of completed field recording forms and photographic transparencies from earlier marine biological surveys. This volume of data was expected to grow considerably during the lifetime of the MNCR. In order to facilitate access to, and analysis of, this information, it was essential to develop a computer database. This chapter describes the design of the MNCR's database, which underpins most MNCR work, and its use in the storage, retrieval and analysis of MNCR data.

6.2 Objectives of the MNCR database

The principal objective in developing a computer database for the MNCR was to provide MNCR staff with a system for the organisation, storage, rapid and easy retrieval, querying and analysis of the data gathered from both the information review and the field surveys. The database was intended to be used primarily as a repository for MNCR data and secondarily as a tool to assist MNCR scientific staff in the basic analysis and interpretation of their data and in the production of reports based on those data. Thus the objectives were fairly narrow, although recent user demands have pushed the database well beyond the original design brief.

6.3 Data held in the MNCR database

The data gathered by the MNCR are of two main types:

- data collated from existing sources of information (literature information);
- data derived from field surveys (field survey data).

The MNCR database was designed and developed to store the data collected by these two principal methods and allow retrieval, manipulation and analysis. The sources of information held in the database are described in Section 5.1.2.

6.4 Design considerations and development of the database

Development of the database commenced in the autumn of 1987 using the Revelation-G DataBase Management Software (DBMS), which was later succeeded by the Advanced Revelation DBMS (Revelation Technologies 1988, 1990).

Initially the database was developed and used on a single Personal Computer, then on three PCs. In 1990 it was installed on a small microcomputer network and later moved to JNCC's corporate network in 1993. Throughout much of this time it has also been distributed to a number

of external, off-site users who use it in multiple single user and network versions on different sites. During this period the database has become increasingly complex. The volume of data it stores (approximately 65 megabytes at the end of 1995) and the difficulty of the management tasks have grown considerably.

The development of the database took several years. Extra functionality has been gradually built in to the application, giving users greater power and flexibility in accessing the data and using it in analyses. Time has seen an increased number of customised interfaces allowing apparently invisible and direct communication with external packages, including statistical, mapping and plotting packages.

6.5 Database file structure

6.5.1 Information Review module

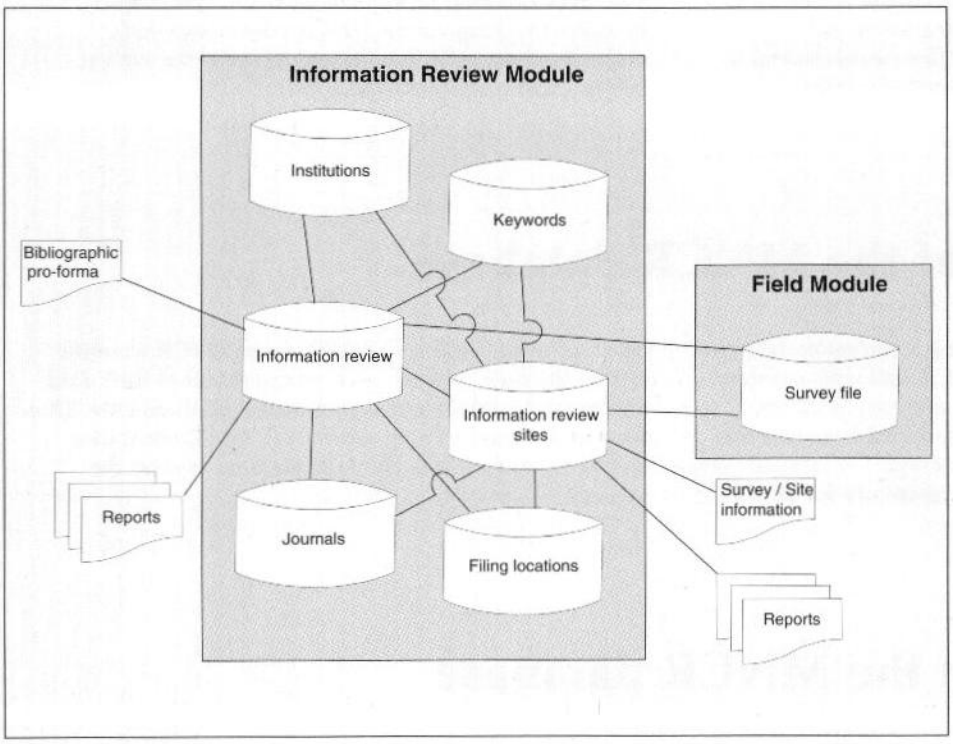


Figure 6.1 A summary of the relationships between the main files used in the Information Review module of the MNCR database and various associated inputs and outputs .

The Information Review module is designed to support the work of assessing and keeping track of information from non-MNCR sources. It consists of a number of files which, together, support the referencing of published information, whether it is in the form of an internal report, scientific journal or any other format. Apart from the files which store the data, there are other files which support data entry and act as dictionaries for standard items of information. The inputs to, outputs from and various relationships between the main files and dictionaries are summarised in Figure 6.2. They include the following:

- a standard list of journals and serial publications;
- a standard list of institutions awarding higher degrees;
- the various locations at which hard copies of publications are kept;
- a standard list of keywords (given in Appendix 6) describing the contents of information reviews.

6.5.2 Field Survey module

The Field Survey module is used to store the raw field data from surveys by the MNCR, contractors, and other surveys which have used broadly compatible methods. This includes the data from the Intertidal Survey Unit and Harbours, Rias and Estuaries databases, and other field survey data supplied by third parties.

The module contains four principal data files: survey, site, habitat and photographic records. Photographic records are included within the field database module because the majority of photographs held by the MNCR are illustrations of sites, habitats and species recorded during field surveys. These files are maintained together as a module within the MNCR database.

Recent developments to the Field Survey module have concentrated on the classification of biotopes. This provides a dictionary of biotopes and allows the storage of information

on characteristic species of the biotope and the physical conditions in which the biotope occurs. The MNCR biotope classification can also be cross-referenced to communities described in the literature, communities defined for other purposes (such as the estuarine communities used in the NCC Estuaries Review (Davidson *et al.* 1991)), and communities identified in the earlier MNCR reports.

There are several other files which specifically support the use of the Field Survey module, including a photographic keyword dictionary which is used to describe the subject matter of photographs, and files which store standard information such as MNCR coastal sectors, survey types (e.g. grab, littoral, etc.) used in entering data.

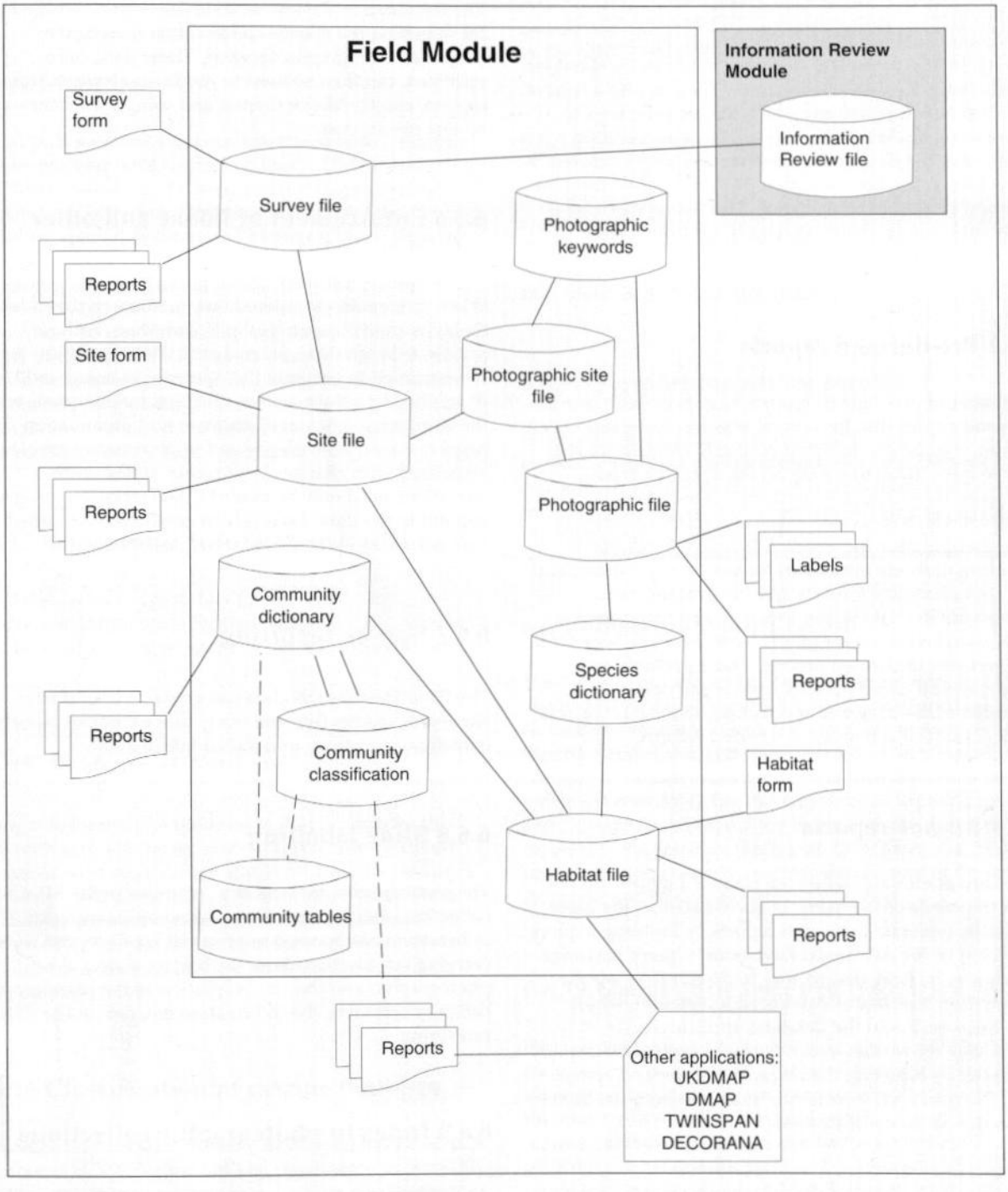


Figure 6.2 A diagrammatic summary of relationships between the main files used in the Field Survey module of the MNCR database and various associated inputs and outputs

6.6 Uses of the database

6.6.1 Entering data

Data entry processes are supported by a user guide. Data are validated before being entered onto the database. The pro-formas and recording forms provide the first, elementary means of data validation where the data must conform to the structure dictated by the forms. This also applies in the case of external contractors as they are required to conform to MNCR methods. Further validation is provided by the entry fields on the database which check the data during entry. There is also a field on the form and the database which the recorder uses to indicate the quality of the survey. These procedures ensure that the data in the database are fully validated. It should be noted, however, that this does not address the question of worker competence. This aspect can only be dealt with through training, where applicable, and selection of contractors with appropriate credentials.

6.6.2 Pre-defined reports

A number of pre-defined reports have been built into the database application for several reasons. Some reports are required frequently and so it is simply efficient for the user to have direct and easy access to such a report. However, there is also a number of cases where the kind of report which is needed requires a certain amount of data manipulation for which Advanced Revelation's reporting tools are not ideally suited. In such instances it has been necessary to write specific programs to manipulate the data in the required way before report generation and these programs have therefore been built into certain pre-defined reports. These pre-defined reports can be called directly from menu options provided in the database application, so long as the user has a current or active list of selected records.

6.6.3 *Ad-hoc* reports

There are often times when the standard reports do not meet the needs of the users. In such instances the users can easily generate their own reports by building a query statement in the Advanced Revelation's query language. Most users find the easiest way to do this is to use the 'Easywriter' features of Advanced Revelation, which have been built into the database application. As mentioned above, this aids the user in building the query statement by ensuring the correct structure and syntax. Once the query has been built, it can be saved to a library of queries for re-use if desired.

6.6.4 Index to bibliographic holdings

The Information Review module acts as an index to reprint and report collections held by the MNCR and, increasingly, by marine sections of the country agencies and can be used to generate catalogues.

6.6.5 Literature searches

The Information Review module provides a flexible tool for searching the marine conservation literature by subject and geographic location. These data, once retrieved, can then be used to produce reference lists for reports, subject bibliographies and completed information review pro-formas.

6.6.6 Enforcement of house and other reference styles

When references are entered they are broken down into their component parts (authors' surnames, authors' initials, title of article, journal etc.). These parts are then re-assembled to generate the reference in house style (or in another style such as that specified for a journal) with the correct sequence, capitalisation and punctuation. This helps to ensure consistency and minimises the problems associated with changes to reference styles, since alterations need only be made to the formatting program, and not to the data. Establishing correct titles is aided by a dictionary of journals and other periodical titles.

6.6.7 Survey reporting

The Field Database module can generate lists of sites surveyed, species lists and many other kinds of reports containing summary or detailed information.

6.6.8 Slide labelling

The photographic file acts as a catalogue of the MNCR's collection of slides and other photographic material. This information can be used to print out labels for the slides carrying information about the subject matter, the photographer and the site or location of the photograph, basically reflecting the information entered on the slide pro-forma.

6.6.9 Index to photographic collections

As the database acts as a catalogue to the MNCR's slide collections, it can be used to print out full catalogues of slides in the collection which conform to particular subjects connected with a matter or any other criteria which are relevant to the work of the MNCR.

6.6.10 *Ad hoc* queries

The field database is a powerful analytical tool which allows the user to query the data in many ways. For instance the user could pose a question such as "In which habitats was the sea-pen *Funiculina quadrangularis* recorded?" This could then be further refined to "In how many of these habitats, at greater than 30 m depth, did *Funiculina* co-occur with the Norway lobster *Nephrops norvegicus*?"

6.6.11 Mapping

The MNCR database has been interfaced with a number of map-plotting tools (including Plot 5, DMAP and UKDMAP) which can be used to display geographic distributions of certain attributes of MNCR data including species, habitats and biotopes. These plotting packages rely on the positional information gathered at the survey, site and habitat levels. Thus the positional information related to any given record (where it is known) can be used to display any data attribute of that record. Although there is often a complex data conversion and export process involved in getting the information into the mapping package, in most cases the process is invisible to the user who simply chooses the mapping options from the database application menu.

6.6.12 Geographic Information Systems

The database can export data for use in desktop Geographic Information System packages (GIS). GIS can then be used to analyse spatially various attributes of the data.

6.6.13 Analysis of field survey data

A major feature of the database is that it provides the user with access to many analytical functions through interfaces with multivariate statistical analysis packages, including TWINSPAN, DECORANA and Systat. These are used to perform classification and ordination of species data. The use of the database and the interfaced packages in carrying out these analyses are described fully by Mills (1994).

6.6.14 Classification of marine biotopes

A biotope classification is being developed by the MNCR (Connor *et al.* 1995). This has key importance in providing a structured framework in which to place survey results, and allowing comparative evaluation of similar communities and sites, and the database plays a central role in the development of the classification through data analysis and storage of biotope descriptions.

6.6.15 Site assessment

Once the described habitats are attributed to a particular category in the classification, a process of comparative assessment is carried out to indicate the key sites. Special data export routines assist in this process. The evaluation is undertaken using the site assessment protocol developed by the MNCR (outlined in Section 7.4).

6.6.16 Site inventory

A simple use of the database is the provision of site listings or site inventories for identifying areas which have been covered in the surveys. Reports can be compiled detailing desired information about the habitats present at these sites, along with distribution maps.

6.6.17 Support for advice service

When staff of the MNCR are contacted for advice on a particular aspect of marine conservation, the database provides an invaluable source of information which can be used in the formulation of a response and in the production of suitable outputs of information.

6.6.18 Electronic publication

The database can also export datasets for use with the UK Digital Marine Atlas Project (UKDMAP), developed by the Natural Environment Research Council. These datasets can then be mapped in conjunction with any of the physical, chemical or human impacts and other datasets contained within the atlas. Work has been undertaken to produce map-based computer displays of the location of sites surveyed and reported in the literature (Mills *et al.* 1993; Barne *et al.* 1994). Each site can be queried to provide descriptions of the source references and other site-related information.

6.6.19 Geographic index to field surveys

Because the survey details entered into the Field database include Ordnance Survey grid references and a variety of other geographic details such as the MNCR coastal sector, the country/district/county and so on, information about marine habitats and species can be tracked down according to geographic criteria. For example, if someone needs information about all MNCR survey work carried out in Sutherland in Scotland, this information can be accessed readily.

6.6.20 Survey planning and identification of gaps in survey coverage

Because the database holds data from all the marine surveys carried out under the auspices of the MNCR and others, it provides a comprehensive catalogue of areas which have been sampled. The database can thus be used in determining where survey work is required and the duplication of previous work can be avoided. It also allows the assessment of the quality of data gathered for a particular area and, on the basis of such assessments, decisions can be made as to whether it is necessary to survey a particular area again.

7 Interpretation of data

Keith Hiscock

7.1 Introduction

The information resulting from the literature review, field survey and data analysis is brought together and interpreted in a way which can be used in the assessment of marine natural heritage importance and the provision of advice on policies for or affecting nature conservation. This requires a structured and, where possible, quantified approach as well as the application of personal experience and judgement to produce information which can be used by those making decisions about environmental protection and management.

In order to structure and simplify large amounts of complex field survey data, a system of habitat and community classification is required. In order to interpret data from a single site visit or sample, a knowledge of the likely variability of species and biotopes with time is required. In order to assess marine natural heritage importance, a series of criteria and a protocol for their application is required. The approach the MNCR adopts to these three aspects of interpretation is described below.

7.2 Classifying marine biotopes

As part of the structured approach to interpreting data, a classification of benthic marine biotopes is being developed for the British Isles (Connor *et al.* 1995) with the following objectives:

- to provide a framework in which to place results from ecological surveys;
- to provide a common language for describing the biological character of the marine environment;
- to facilitate mapping of the distribution, frequency of occurrence and extent of biotopes at local, national and international levels;
- to allow the succinct description of the range of biotopes within a given area;
- to provide a basis for comparative assessment of species composition and richness in the same biotope occurring at a range of sites;
- to provide a basis for predicting the biological character of an area based on its physical environment;
- to underpin coastal zone and sea-use management by providing a better basis for assessment of scientific interest, natural heritage importance and sensitivity of areas to a range of different impacts, uses and developments, and
- to aid management of rare species by placing them in the context of their associated biotopes.

The classification will cover all inshore habitats subject to marine influence, including up to the splash zone on shores, to the limits of saline water within estuaries, and coastal lagoon systems. Whilst producing this classificatory structure to assist the interpretation of data, it is acknowledged that:

- MNCR surveys produce a 'snapshot' in time of a possibly variable community;
- marine communities are likely to be climax communities and very stable except where subject to physical or biological perturbation;
- 'communities' may be nodes along a continuum of change.

The principles of classification adopted by the MNCR for benthic marine biotopes are broadly the same as on land and are described by Hiscock & Connor (1991). On land, vegetation is the most conspicuous wildlife feature of the landscape and has therefore been extensively used to classify different communities. In Britain, the National Vegetation Classification (see, for instance, Rodwell 1991) is used as a descriptive and comparative tool in nature conservation and underpins the selection of biological SSSIs (Nature Conservancy Council 1989). However, vegetation alone cannot be used to classify communities in the marine environment as many communities, even in the intertidal, are dominated by animals. In the marine environment, the sedentary nature of benthic fauna makes them as useful as marine algae for classification. Although particular features of the marine environment are taken account of in the European Union CORINE (Co-ORdination of INformation on the Environment) classification (Commission of the European Communities 1991), the marine element currently in use is poorly structured and incomplete. The MNCR classification is being developed to expand the CORINE classification under BioMar (a project part-funded by the European Commission LIFE programme (Costello & Mills 1993)) and to provide a framework for classification of benthic marine biotopes throughout the north-eastern Atlantic.

By the end of 1995, a national classification had been developed for intertidal areas (Connor *et al.* 1995) and

work was in progress, drawing on regional classifications, on the national subtidal classification. Part of the intertidal classification is shown in Figure 7.1 and a page from the intertidal biotope manual (Connor *et al.* 1995) is shown in Figure 7.2. Figure 7.3. demonstrates the application of the classification to mapping.

Littoral (eulittoral) sediments (communities of amphipods, polychaetes and bivalves)

Shingle/gravel shores

LMXD.BAR Shingle or gravel shores with no apparent macrofauna

Clean sandy shores

LSND.BAR Very exposed coarse sand shores with no apparent macrofauna

LSND.AE Mobile coarse sand shores with burrowing amphipods and *Eurydice pulchra*

- LSND.AP Clean sand shores with burrowing amphipods and polychaetes
- LSND.AP.S Clean medium to fine sand shores with burrowing amphipods and *Scolelepis squamata*
- LSND.AP.AR Mid shore clean sand with burrowing amphipods, *Nephtys cirrosa* and *Arenicola marina*
- LSND.AP.ANG Lower shore clean stable sand with burrowing amphipods, *Nephtys cirrosa* and *Angulus tenuis*

Muddy sand shores

LMSND.ARB Mid to lower shore muddy sand with *Arenicola marina* and bivalves

LMSND.PC Lower shore slightly muddy sand with polychaetes and *Cerastoderma edule*

LMSND.LAN Tide-scoured lower shore sand with dense *Lanice conchilega*

Extreme lower shore communities see Shallow sublittoral sediments: LMSND.ECH and LMSND.ZOS

Muddy shores

LMUD.HM Sandy mud shores with *Hediste diversicolor* and *Macoma balthica*

- LMUD.HM.CER Mid to lower shore sandy mud with *Hediste diversicolor, Macoma balthica* and *Cerastoderma edule*
- LMUD.HM.MAN Reduced salinity mid shore sandy mud with *Hediste diversicolor, Macoma balthica* and *Manayunkia aestuarina*
- LMUD.HM.NEP Reduced salinity lower shore sandy mud with *Hediste diversicolor, Macoma balthica* and *Nephtys hombergii*

LMUD.AR Full salinity mid to lower shore mud with *Arenicola marina*

LMUD.HS Reduced salinity upper to mid shore mud with *Hediste diversicolor* and *Scrobicularia plana*

LMUD.HS.Z Upper to mid shore sandy mud or mud with *Zostera noltii* beds

LMUD.HO Low salinity mud with *Hediste diversicolor* and oligochaetes

Muddy gravel shores

LMGR.MYA Reduced salinity lower shore muddy gravel with *Mya arenaria* and polychaetes

LMGR.HED Low salinity muddy gravel shores with *Hediste diversicolor*

Figure 7.1. A section of the intertidal biotope classification (from Connor *et al.* 1995).

LRK.LDIG.LDIG: Moderately exposed sublittoral fringe rock with *Laminaria digitata*

Description

Moderately exposed to sublittoral fringe bedrock and boulders are dominated by a dense canopy of *Laminaria digitata* with a wide range of filamentous and foliose red algae beneath.

The rocky substratum is usually covered by encrusting red algae, on which occasional limpets *Patella vulgata* and topshells *Gibbula* spp. graze. A wide variety of fauna occurs, including the sponge *Halichondria panicea*, barnacles (*Balanus crenatus* and *Semibalanus balanoides*) and occasional small muscles *Mytilus edulis*. Kelp holdfasts provide a refuge for a varied assemblage of species including sponges (e.g. *Leucosolenia* spp.), anemones (*Urticina felina*), limpets (*Helcion pellucidium*), crustaceans, bryozoans and colonial ascidians. This biotope is usually found beneath the *Fucus serratus* zone (LRK.FSE) and above the truly sublittoral *Laminaria hyperborea* zone. Other canopy-forming algae such as *Alaria esculenta* and *Laminaria saccharina* may occur, although never at high abundance (compare with LRK.LDIG.AL and LRK.LDIG.LSAC respectively). In areas where tidal water movement is increased, a richer *L. digitata*-dominated biotope (LRK.LDIG.T) generally replaces the sheltered shore *Laminaria saccharina* (LRK.LSAC) biotope.

Very common

View of a well developed *Laminaria digitata* zone on a chalk platform (Newhaven, West Sussex; J.D. George)

Classification

Salinity:	Full
Wave exposure:	Moderately exposed-sheltered
Tidal streams:	Weak
Zone/range:	Sublittoral fringe
Substratum:	Bedrock and boulders
Other modifier:	

Encrusting coralline red algae beneath the kelp canopy (St Margarets Bay, Kent; J.D. George)

Figure 7.2 A biotope description from the intertidal biotope manual (from Connor *et al.* 1995)

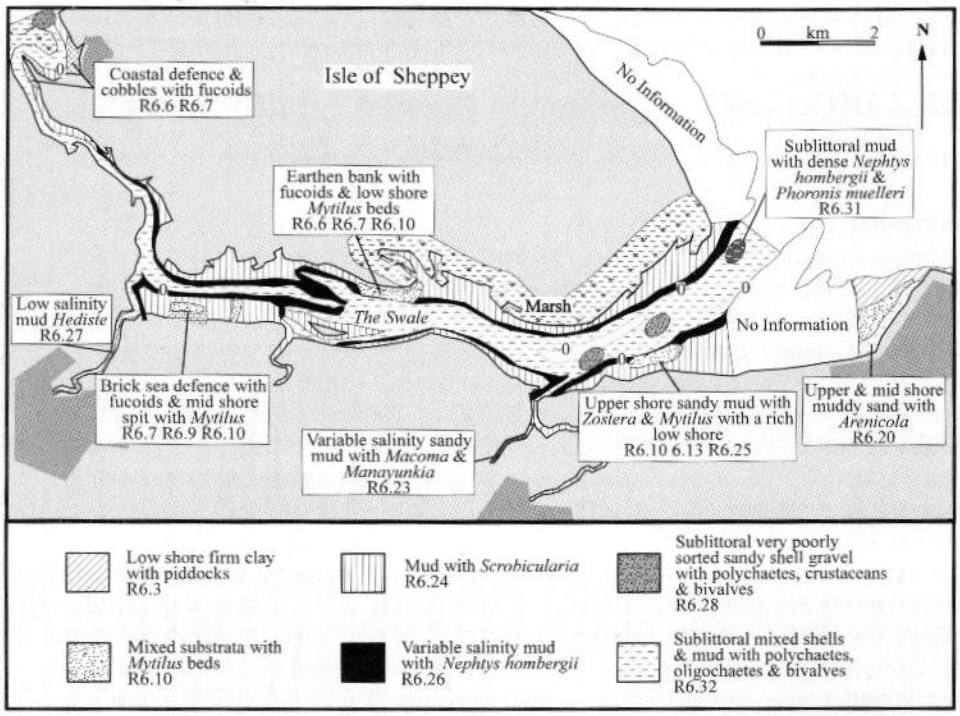


Figure 7.3 The distribution of biotopes in The Swale, Kent, extracted from one of the Area summaries (see Chapter 8)

7.3 Results of the MNCR in a changing ecosystem

7.3.1 Types of variability and change

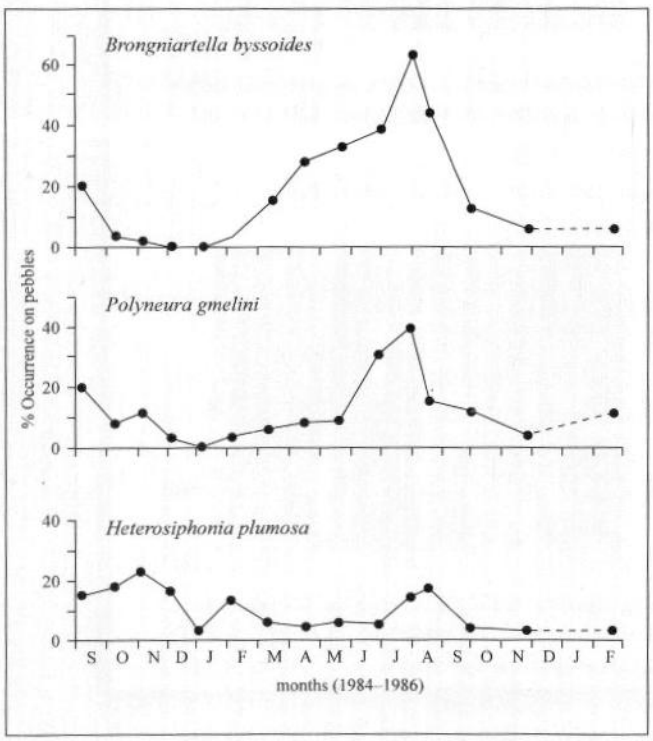


Figure 7.4 Seasonal change in the percentage occurrence of sublittoral algae on pebbles at Skomer, September 1984 - February 1986 (re-drawn from Hiscock 1986)

The overall impression of experienced marine ecologists returning to the same locations after or over many years is of the presence of the same habitats, communities and species as previously encountered. However, this constancy is so unremarkable, that there is very little published account of it whilst change and the causes of change, where it occurs, attract research. Several studies which provide the basis for establishing degree of change have to be interpreted with caution as they were undertaken in areas small enough for patchy change or apparent extinctions of small or rare species to dominate the picture. The considerable amount of work in the form of experimental manipulation studies only demonstrates that major switches in community type *can* occur if disturbance is severe enough (for instance, papers reviewed in Connell 1985).

Despite a general expectance of constancy, several types of variability and change need to be taken into account in determining survey strategy and interpreting MNCR results.

1. Short-term variability

Variability over hours or days may occur in mobile species. For instance, small prosobranch molluscs will be feeding on the open shore in the damp of early morning or in the rain and will be recorded as of high abundance but, when it is sunny at mid-day, they will retreat into the depths of damp crevices where they cannot be seen and will apparently be of low abundance.

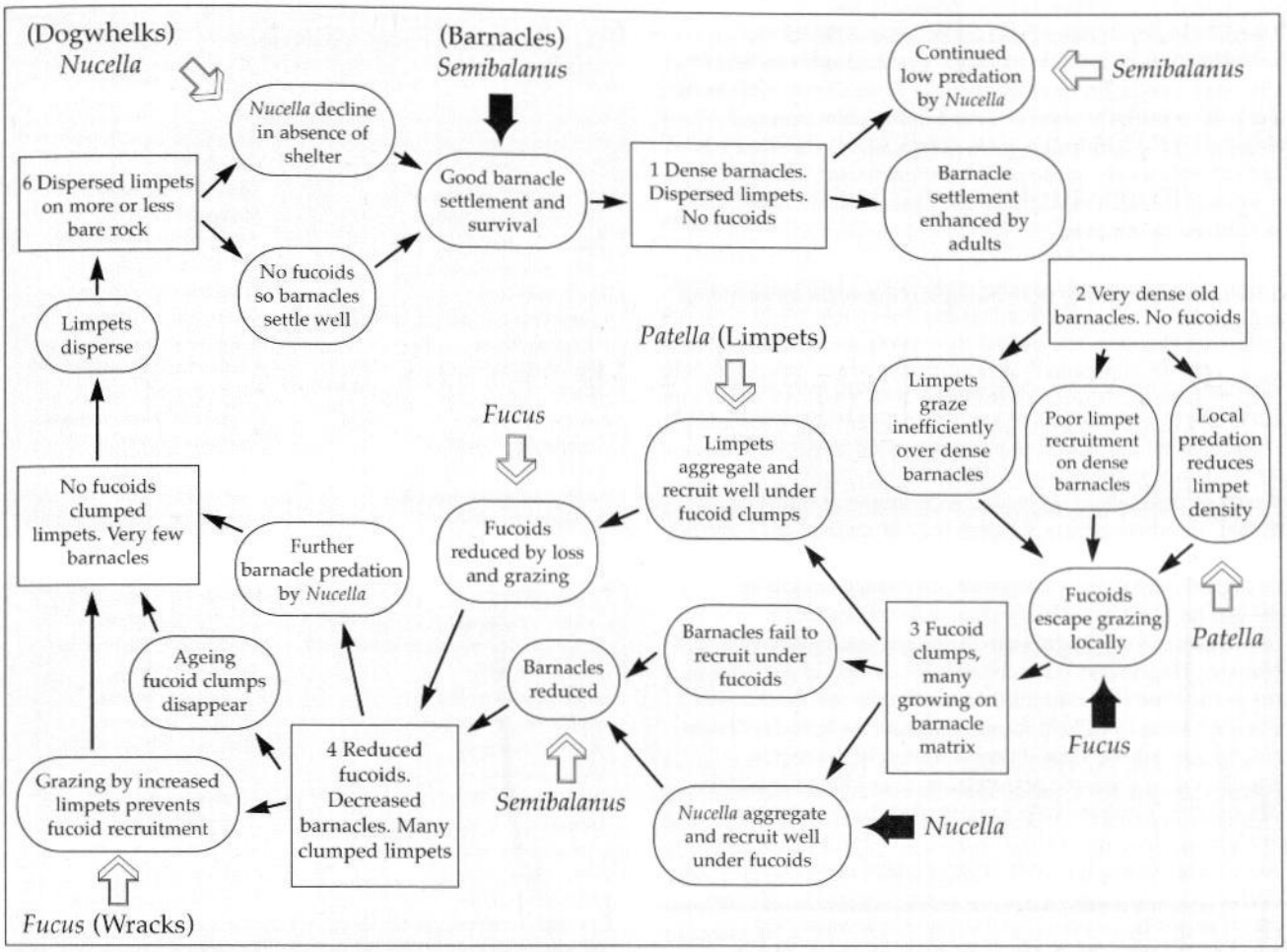


Figure 7.5 A simplified flow chart to represent the sequence of events over several years in the mid-tide level of a moderately exposed rocky shore on the Isle of Man (modified from Hawkins *et al.* 1994).

2. *Seasonal variability*

Seasonal variation is likely to occur especially in the growth of ephemeral algae (see, for instance, Figure 7.4) but also in some animals which have an inconspicuous overwintering stage and a conspicuous spring to autumn growth (for instance, the sea-squirt *Clavelina lepadiformis*). Migration might also be important. For instance, rockpool fish may migrate on and offshore between summer and winter.

3. *Variability resulting from physical events*

Habitats subject to physical disturbance (for instance, mobilization of sediments by storms, dredging, boulder-turning, trampling) can be characterised by different species depending on the time of year disturbance occurred, the severity of disturbance, the larvae or spores available to colonise when disturbance ceased and the length of time elapsed since disturbance. Some of those species may be able to survive disturbance and re-establish (for instance robust bivalve species typical of mobile sediments such as *Venus casina*) whilst some will be be typical of different successional stages in recovery (for instance, the flush of green algae which occurs on shores after winter scouring by mobile sand).

4. *Variability and change resulting from changes in water quality*

High rainfall can result in the lowering of salinity in shallow waters so that sensitive species are killed and may therefore be absent or of low abundance compared to records taken when such events have not occurred for some time. Similar mortalities of benthic species, with presumably subsequent recovery, may occur due to short-term de-oxygenation after eutrophication has resulted in plankton blooms which die and decompose on the seabed. Some effects of eutrophication are long-term and may invalidate older data from use in determining the likely communities present in an area (for instance, substantial changes since the beginning of this century in benthic communities at the entrance to the Baltic: Pearson, Josephson & Rosenberg (1985), a transition in sediment benthos community structure in the late 1970s at sites off the Northumberland coast: Austen *et al.* (1991) and upward trends in the biomass of several species in the Wadden Sea: Beukema (1992)). The effects of chemicals on benthic species are less easy to establish but it seems likely that some may have significantly reduced the species diversity of some benthic communities in enclosed

inlets through adverse effects on larvae and therefore recruitment (for instance, evidence of increased benthic species diversity in the estuary of the River Crouch following the ban on use of tributyl tin anti-fouling paint on small vessels; Dr P. Matthiessen, pers. comm.). Data collected whilst such chemicals are in use may therefore record a lower species richness than might be the case when contamination is reduced or removed.

5. Variability resulting from biological interactions including disease

Change can result from short-term biological interactions, particularly of predation or grazing or can be long-term, such as the gradual reduction in abundance of a species which recruits only sporadically and in which many years may therefore pass before successful recruitment and restoration of high numbers occurs. Change may be cyclical over several years reflecting, perhaps, long-term climate patterns or biological interactions. Some natural changes might be devastating and completely change the character of communities in a geographical area. For instance, in northern Norway, Hagen (1983) described how natural expansion of the population of sea-urchins *Strongylocentrotus droebachiensis* changed areas from kelp forest communities to rocks devoid of kelp and foliose algae. Later, infection of the urchin population by parasitic nematode worms killed the urchins (Hagen 1987) and the kelp communities have become re-established. In Britain, Hiscock & Mitchell (1980) report a switch from mussel to hydroid dominated communities after starfish predation on the Gower coast. The sort of changes which might occur on a rocky shore due to biological interactions and patterns of settlement are illustrated in Figure 7.5. However, such change may be patchy. For instance, following a study of circalittoral rock-wall communities in the Gulf of Maine, Sebens (1985) concluded that, although there was switching between alternative stable communities in the same environmental conditions, they were part of a mosaic of dominant species which, over an extensive area of the same habitat, remained the same. Understanding the scale of such natural fluctuations in space and time and the importance of patchiness is important in determining the size of the area from which records are collected and interpreting results of one-off surveys.

6. Variability and change due to climate

Severe winters are known to result in significant change to the abundance of some intertidal species at least in the short-term (for instance, Crisp 1964 catalogues the effects of the 1962-63 winter on species). Except for severe winters, changes are likely to be small in scale but possibly significant. For instance, the 20-year study by Beukema (1992) on 29 species in the Wadden Sea revealed a group of 12 species which showed low densities after cold winters. Effects of long-term climatic change (warming at present) are less easy to predict although changes are likely to be of increased abundance and spread northwards of southern species and reduced abundance and retreat northwards of northern species. The scale of change is likely to be small.

Box 7.1 Non-native marine species present in British waters, from Eno (in prep.)

Plants
Bacillariophyta
Thalassiosira tealata
Thalassiosira punctigera
Pleurosigma simonsenii
Odontella sinensis
Coscinodiscus wailesii
Rhodophycota
Grateloupia filicina var. *luxurians*
Pikea californica
Agardhiella subulata
Solieria tenera
Solieria chordalis
Grateloupia doryphora
Antithamnionella spirographidis
Antithamnionella ternifolia
Polysiphonia harveyi
Bonnemaisonia hamifera
Asparagopsis armata
Chlorophycota
Codium fragile subsp. *atlanticum*
Codium fragile subsp. *tomentosoides*
Chromophycota
Sargassum muticum
Colpomenia peregrina
Undaria pinnatifida
Angiospermae
Spartina anglica
Animals:
Cnidaria: Hexacorallia
Gonionemus vertens
Rhizogeton nudum
Clavopsella navis
Haliplanella lineata
Nematoda: Dracunculoidea
Anguillicola crassus
Annelida: Polychaeta
Gonidaella gracilis
Hydroides ezoensis
Hydroides dianthus
Ficopomatus enigmatica
Janua brasiliensis
Pileolaria berkeleyana
Clymenella torquata
Marenzelleria viridis
Chelicerata: Pycnogonida
Ammothea hilgendorfi
Crustacea: Maxillopoda
Elminius modestus
Balanus amphitrite
Acartia tonsa
Crustacea: Eumalacostraca
Eriocheir sinensis
Corophium sextonae
Crustacea: Ostracoda
Eusarsiella zostericola
Mollusca: Gastropoda
Rapana venosa
Crepidula fornicata
Urosalpinx cinerea
Mollusca: Pelecypoda
Crassostrea gigas
Tiostrea lutaria
Aulacomya ater
Mercenaria mercenaria
Ensis directus
Petricola pholadiformis
Mya arenaria
Tunicata: Ascidiacea
Styela clava

7. Effects of non-native species

A recent study of non-native species in British waters concluded that only in a small number of instances had non-native species replaced dominant native species (and therefore replaced the native community) (Eno in prep.). However, some non-natives such as the alga *Sargassum muticum* and the ascidian *Styela clava* are conspicuous and present in large amounts and are likely to characterise particular communities.

7.3.2 Importance of variability to the MNCR

Variability and change may affect the survey strategy and interpretation of MNCR results in the following ways.

1. Prediction of biotopes present

If variability in the communities present at a particular location is low, it might be expected that, based on assesment of the physical and chemical environmental factors at a site, it should be possible to predict the community which will occur there. This is generally the case in systems where one factor is

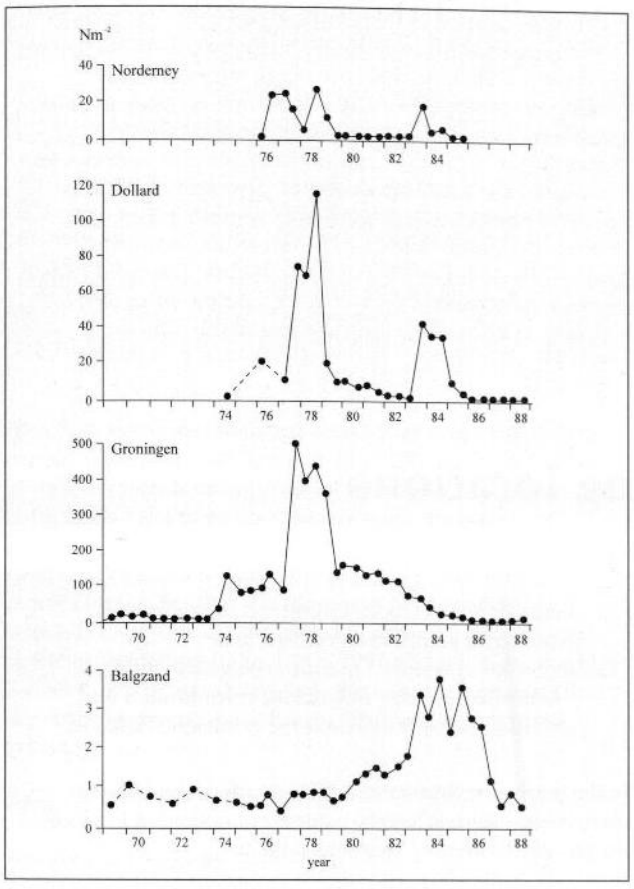


Figure 7.6 Average numerical density of the bivalve *Scrobicularia plana* at sites in the Wadden Sea (from Essink *et al.* 1991)

of over-riding importance - for example, very strong tidal currents on circalittoral rock, extreme shelter from wave action in fjordic environments, or degree of exposure to wave action of rocky shores. However, where conditions are less extreme, different communities may occur in apparently similar conditions at different locations. This is particularly the case in sublittoral rocky areas where the large variety of species available to colonise, and the range of communities which develop, are high. Here, the presence of different communities, stable with time, in apparently the same habitat reflects the likelyhood that habitat requirements and effects of localised conditions for each community are more subtle than can be detected by MNCR techniques.

2. Identification of biotopes

If one of the species which varies greatly overall is considered a characteristic of the community, definition of the biotope may be difficult. For instance, (Figure 7.6) the bivalve *Scrobicularia plana* (a key characterising species for the *Hediste-Scrobicularia* community) showed very large fluctuations at several locations in Europe over an 18-year period (Essink *et al.* 1991). By using the biotope approach, MNCR identifies the habitat and a range of the species that typically occur in that habitat so that absence of a characterising species should not prevent identification as that biotope. Such changes emphasise the importance of characterising sites and areas by the habitats present as well as species to ensure that potential sites for conservation are identified by habitat types in which particular communities and species are likely to occur and not solely on the basis of the species there at the time of a single survey.

3. Long-term relevance of results including conservation assessment

The (mostly unpublished) observations of constancy in the presence of the same biotopes and species at the same locations after many years suggest that the results of MNCR one-off survey can be relied upon to characterise an area unaffected by major developments or natural disasters. However, the quality of the biotopes may change and re-assessment may be necessary if several years have elapsed since survey, and especially in the case of locations identified as of marine natural heritage importance and where quality assessment is an important part of management.

7.3.3 Taking account of variability in the MNCR

Long-term constancy can be expected in most biotopes and therefore one-off surveys are valid to meet the specific needs of the MNCR in the majority of situations. However, change does occur in certain situations and circumstances and MNCR methods therefore aim to minimise difficulties resulting from changeability and patchiness by the following:

- small scale variability with time is allowed for in analysis of survey results by not rating small differences in the abundance of species between communities as of great importance;
- because there are likely to be changes in the mosaic features of communities, sampling areas are large enough to be representative of the range of mosaic features and to average out patchiness;
- species which are known to show large fluctuations in abundance from year to year (for example, most nudibranchs), or rare species, are, wherever possible, not used to characterise biotopes;
- characterisation of a biotope is based on a suite of species associated with a defined habitat, rather than one or two species which may vary considerably in their population size (the exception is where species themselves are the habitat, such as reefs of the horse mussel *Modiolus modiolus* or beds of maerl);
- ephemeral communities are identified as distinct biotopes;
- because some biotopes are subject to seasonal change, surveys are undertaken at the time of year (summer - May to September) when most macrobiota are conspicuous;
- although many biotopes are highly stable, this does not mean that their presence can be consistently predicted from physical characteristics of the habitat- although prediction is possible in 'extreme' habitats;
- where a biotope is dominated by a species which may be very variable in abundance, habitat

characteristics are as important as species in defining that biotope type.

The survey methods used and the differential skills of surveyors are also important factors to consider when minimising apparent variability. Using standard methods and analysing data to discount rare and/or inconspicuous species are both undertaken to minimise problems of the limitations of survey in relation to variability of communities with time and to worker variability. Sampling an adequate area to take account of patchiness in species distribution generally has to be left to the judgement of surveyors. Such judgement is usually successful where epibiota are being surveyed and patchiness can be observed. In sediments, more general guidelines have to be adopted. Some short-term variability is difficult to take into account in analysis but, because of the low importance of presence of any one species or presence in a particular abundance of one species, the identification of biotopes should not be greatly affected. For instance, the higher number of small prosobranchs visible on wet days, compared to dry, is unlikely to affect the identification of the biotope.

7.4 Comparing and evaluating locations

7.4.1 Introduction

The identification and protection of locations of natural heritage importance is a fundamental part of nature conservation. The aims of site protection are broadly those spelt out in Command 7122 (Ministry of Town and Country Planning 1947):

"to preserve and maintain as a part of the nation's natural heritage places which can be regarded as reservoirs for the main types of community and kinds of wild plants and animals represented in this country, both common and rare, typical and unusual."

It is important to note, however, that marine site protection is only one aspect of the marine conservation strategies being developed within the country agencies and internationally. Protected sites are likely to be established in areas of high marine natural heritage value where conservation measures are appropriate to the use and management of the area. However, the continued well-being of any location identified as of marine natural heritage importance relies very heavily on the maintenance of a favourable environment in the surrounding waters and the wider marine environment. This is particularly important in the sea as contaminants are widely distributed in sea water and larval recruitment or migration of species into an area may be from distant sources. Therefore, much conservation effort is directed at maintaining the general quality of the marine environment, while aiming for a network of protected sites to represent the marine biodiversity of our coasts.

The evaluation of information to identify the marine natural heritage importance of locations has to be undertaken as objectively as possible but taking account of the experience of marine biologists with a wide knowledge of British and north-east Atlantic marine ecosystems. Comparing and evaluating sites requires:

- a criteria for comparative site assessment;
- a protocol for applying the criteria;
- a dataset with sufficient information to allow meaningful comparison of sites, and
- access to experienced marine ecologists with a practical knowledge of habitats, communities and species in Great Britain and the north-east Atlantic.

In the marine environment, where much of the inshore marine ecosystem is largely natural but degraded in places, we are able to identify locations which:

- have biotopes with a rich variety of species;
- have a wide range of representative biotopes;
- have rare or scarce species;
- have particular species or biotopes which are representative of, or special to, the geographical area or type of coast;
- are degraded in some way and may benefit from positive management measures to restore the habitats and species to a more natural state.

The identification of locations representing the full range of natural biotopes, and their subsequent incorporation into a network of protected areas, provides a logical and practical method of maintaining biodiversity.

7.4.2 Site assessment criteria and protocol used by the MNCR

MNCR data must underpin nature conservation through the provision of advice on the marine environment in general and the identification of particular locations where the features of British marine ecosystems are best represented. The criteria and protocol used to indicate 'importance' must be robust and, within the limitations of sensible analysis, objective. The role of the MNCR is to undertake assessment to identify the most highly rated locations for nature conservation and for the relevant country agencies to take these forward to designation, or promote other management measures, as appropriate.

Using survey results to identify marine natural heritage importance requires the application of relevant criteria. For marine habitats, the criteria described by Mitchell (1987)

Box 7.2 Criteria for comparative evaluation of marine biocenoses in the site selection process used between about 1985 and 1995, from Mitchell (1987)

Ecological/scientific	**Practical/pragmatic**
1. Naturalness	7. Situation
2. Representativeness	8. Recorded history
3. Rarity	9. Research & educational potential
4. Diversity	10. Restoration potential
5. Fragility	11. Intrinsic appeal
6. Size	12. Vulnerability
	13. Urgency
	14. Feasibility

(Box 7.2) were used between about 1985 and 1995. In a further paper, Hiscock & Mitchell (1989) added definitions of different levels of importance for sites. Those criteria and definitions have been used in assessing the results of survey by the MNCR and, in the course of that use, both need and practicality have dictated alternatives or modifications. Further development of assessment and selection criteria were discussed at a nature conservation agencies workshop in February 1992 and taken forward by the MNCR in conjunction with the country agencies to develop the protocol used from 1995 and summarised below.

Aims

The protocol aims to:

- ❑ assess the natural heritage importance of marine biotopes within the context of the broader physiographic features of the open coast, marine inlets and lagoons, based on data available to the MNCR, and
- ❑ identify locations which encompass the highest quality examples of each physiographic feature and biotope and populations of the rarer species represented within each MNCR sector.

The protocol is not intended for the assessment of highly mobile species of fish, mammals and birds or of plankton.

The assessment is undertaken to a standard procedure, using a series of established scientific criteria, to provide a comparative assessment within a given MNCR sector. The assessment aims to make best use of information which is readily available to the MNCR and avoids the use of information which might be difficult to acquire or interpret. The protocol avoids a fully mechanistic approach which excludes expert judgement. The procedure must therefore be used by an experienced marine ecologist who is familiar with the data set being assessed and preferably has direct knowledge of the area being considered. Detailed aspects of the approach continue to be developed and so are not described here.

The philosophy and criteria used have strong parallels with the approaches for assessing terrestrial locations, for example biological SSSIs (Nature Conservancy Council 1989; Joint Nature Conservation Committee 1996). They have been adapted to ensure that they are applicable to the marine environment, the type of information available and the intensity of sampling currently achieved by the MNCR. The criteria used are similar to ecological criteria adopted for the identification of marine protected areas in other countries (Salm & Price 1995), and by the International Maritime Organisation (1991).

Scale of approach

Assessment is undertaken to various scales. The biotopes used for assessment are those being developed as part of the national MNCR classification. Assessment is undertaken within each of the 15 MNCR sectors.

Areas which contain a wide range of biotopes forming a recognisable biological system, such as an estuary, a sealoch or an island complex provide the main unit within which assessment is undertaken. These areas represent sensibly-sized units for nature conservation management and make best use of the data available.

Biotope complexes or site types can be identified mainly because of the importance of height on the shore or depth underwater in creating a series of different biotopes which regularly occur together and hence, are usefully considered as individual units. The biotopes in subhabitats such as rockpools and overhangs are also included in these groupings. This level of approach has been adopted for intertidal SSSI selection (Joint Nature Conservation Committee 1996).

Biotopes are recognised in the field as distinct ecological units (distinguished by their different habitat characteristics and associated species compositions) and are the basic unit of recording in the MNCR (equivalent to MNCR habitat records). A quality assessment of most biotopes is included as a part of the overall assessment of an area.

Populations of species are the finest level of distinction considered. Except for the conspicuous and macroinfaunal species recorded consistently by the MNCR, information on the distribution and abundance of species is generally poor and most attention in conservation management is therefore focused on habitat conservation. However, where there is confidence that available information is good, information on species, particularly the rarer ones, is important.

Assessing local to international importance

Marine natural heritage value has to be qualified in terms of local, regional, national or international importance. For instance, a stretch of rocky shore on an extensive sandy coastline may be highly valued locally because of the scarcity of this habitat in the area, but may not be of significance nationally. Conversely the tide-swept narrows in Scottish sealochs may seem quite common-place locally but their rich habitats are a rare feature in Europe and as such they are of international importance. As international data are generally limited, such judgements are necessarily based on expert opinion using the best available information rather than any specific quantifiable criteria. It will also be difficult to apply quantitative criteria at a national level until MNCR survey work is completed. A descriptive approach to describing importance is given below.

Locally important biotopes and locations Biotopes or locations which are among the best examples or the only examples within a particular physiographic feature or area of coast but occur widely elsewhere in the coastal sector.

Regionally important biotopes and areas Biotopes or areas which are among the best examples or the only example in the coastal sector under consideration.

Nationally important biotopes and areas Biotopes or areas which are highly rated in a coastal sector will be

Box 7.3 Criteria for assessment of nature conservation importance and for site selection

Scientific/ecological criteria used in the MNCR	Further scientific/ ecological criteria	Practical criteria
Species richness	Integrity (structure & function)	Situation
Biotope richness	Irreplaceability	Recorded history
Representativeness	Sensitivity	Research and educational potential
Naturalness	Risk of extinction	Restoration potential
Species rarity	Dependency	Intrinsic appeal
Biotope rarity (incorporating extent)	Productivity	Vulnerability
		Urgency
		Feasibility
		Socio-economic effects

described as of national importance if they are among the best examples or the only examples known in Great Britain.

Internationally important biotopes and areas Biotopes or areas which are highly rated in Great Britain will be considered of international importance if they are among the best examples or the only examples present in the north-east Atlantic (North Cape, Norway to Gibraltar).

Procedure

Assessment by the MNCR is undertaken in the six stages listed below.

1. Collate comprehensive data set for MNCR sector.
2. Analyse data to classify biotopes.
3. Divide coast into areas of discrete physiographic features or stretches of coast with similar substratum, aspect, exposure and topography for inter-comparison.
4. Assess biotope quality within each area.
5. Assess quality of each area as a whole.
6. Identify locations of highest quality.

The results of assessment are forwarded to country nature conservation agencies

Stages 1 to 3 are considered in Chapter 5 and in Section 7.2. Stages 4 to 6 are described below.

Stage 4. Assess biotope quality within each area

Assessment of biotope quality within each area is undertaken by comparison of records for each biotope recorded in the coastal sector using the following four criteria.

Species richness Records which have a large number of species are ranked higher than those with a few species. Data are assessed using a banded ranked relative richness (BRRR) method. In BRRR, each example of a particular biotope in an MNCR coastal sector is ranked by its species richness and the data set split into 5 equally sized bands. This part of the assessment is only suitable for biotopes which have a minimum of 15 examples within the MNCR sector.

Representativeness Records are assessed to determine how closely they represent the character of the biotope in the MNCR sector as a whole. The most highly rated examples will have a high proportion of the species which characterise the biotope or are highly preferential to it.

Naturalness Non-natural features, including artificial substrata, polluted or disturbed habitats and the presence of non-native species which affect community composition, may down-grade the record. A list of established non-native species in Britain is given by Eno (in prep.).

Biotope rarity (incorporating extent) Areas which contain rare or scarce biotopes are rated more highly. This is further weighted to take account of extensive examples. Biotope rarity is assessed at a regional level (the MNCR coastal sector) until data are available to assess adequately at a national level. The approach used is similar to that for the assessment of species rarity. Assessment is based on the number of 5 km x 5 km squares in which the biotope occurs as a proportion of the total number of 5 km x 5 km squares in the MNCR sector.

An overall quality rating for each biotope in each area of assessment is derived by integration of the ratings for the above four criteria. For some biotopes, however, it would be inappropriate to place emphasis on the species richness score since it may, by definition, be a species poor biotope (such as those found in low salinity systems). In such a case more emphasis would be placed on representativeness and naturalness.

Stage 5. Assess quality of each area as a whole

The quality of each area as a whole unit is assessed using the following four criteria.

Species richness (of whole area) This is assessed separately for littoral rock, littoral sediment, sublittoral rock and sublittoral sediment to provide a relative assessment within the MNCR sector. Areas with a large number of species are valued most highly, as these tend to include populations of rarer species.

Biotope richness Areas which have a large number of biotopes are ranked higher than those with a few. Biotope richness is assessed separately for littoral rock, littoral sediment, sublittoral rock and sublittoral sediment to provide a relative assessment within the MNCR sector.

Due consideration of the relative quality of the biotopes is required in the final considerations.

Species rarity Areas which contain nationally rare or scarce species are rated highly. The rarity of a species is based on the number of 10 km x 10 km squares in which the species is recorded in comparison to the total number containing sea within the Great Britain 3-mile territorial limit (Sanderson in prep.).The viability of a population is taken into account by favouring significant populations of a species rather than very small populations of a species which may not represent a population which can be actively conserved or will persist in the area. Species assessed are conspicuous and reliably identified when present. Moderation of results by experienced marine ecologists and taxonomists is required as information is limited and species may be more widespread offshore.

Naturalness Naturalness of the whole area is assessed by considering the proportion of natural substrata, the extent of modification by human activities (e.g. length of modified coast, changes to water flow and natural freshwater input), the degree of pollution and the level of disturbance to the natural communities present (from fishing, dredging and other uses). The more natural areas are most highly rated. It may be necessary to produce more than one rating for large areas (such as the upper, mid and lower reaches of an estuary).

Stage 6. Identify locations of highest quality

The assessments of quality for each area and of their component biotopes and populations of species resulting from stages 4 and 5 are considered together to identify a series of locations which represent the full range of natural features in the sector. These locations may equate to some of the biologically or physiographically distinct areas for which assessments were undertaken or may be much smaller locations within them or across them. For instance, an area of rock platforms with rich rockpool habitats may qualify as a location of importance within a much larger area where open rocky shore biotopes have been less highly ranked. Furthermore, an area of open coast plus an adjacent estuary might represent a large proportion of the good quality biotopes in a sector and therefore be rated highly as a location of marine natural heritage importance. Where viable populations of nationally rare or scarce species are not encompassed within any of the above locations, suitable additional locations should be identified.

This final stage will identify a series of locations of highest marine biological importance in the MNCR sector. Each will be considered of regional importance.

7.4.3 Further considerations

In addition to assessing the quality of locations using the approach described above, other factors will be taken into account in assessing marine natural heritage importance or in identifying sites for protection. This further assessment is not a requirement of MNCR work. The following considerations will require scientific information.

1. The **integrity** of a location in terms of structure, function and viability.

2. The **irreplaceability** of a feature. 'Irreplacability' reflects the fact that some locations will include habitat features, biotopes and species which, if destroyed in some way, will not be capable of replacement. This may be because the habitat cannot be restored or replaced or because species present have poor or local recruitment, are relict (and therefore have no nearby sources of larvae for recruitment) or, for some other reason, will not re-establish once lost.

3. The **sensitivity** of a species or habitat will be relevant. Sensitivity is here considered to include 'fragility' - the term used previously in conservation criteria. Species or habitats are likely to be sensitive if they:

   - ❑ are fragile (brittle);
   - ❑ are susceptible to pollution;
   - ❑ are long-lived;
   - ❑ are slow to reach maturity;
   - ❑ have poor recruitment;
   - ❑ have poor larval dispersal or no larval stage;
   - ❑ are unable to move away.

   In many cases the presence of sensitive species or sensitive habitats will make a location of otherwise poor rating important in management considerations.

4. **Risk of extinction** is the cornerstone of the IUCN Red List Categories (IUCN - The World Conservation Union 1994) and is applied to species. Almost all marine species would currently fall into the IUCN Red List "Data Deficient" category and assessing "risk of extinction"does not therefore seem to be a useful exercise with regard to many benthic and most pelagic species. However, it is possible that some species are at risk and may become functionally extinct, for instance serpulid worms as reefs harbouring distinctive communities.

5. The **dependency** of a species, community or ecological process on a particular location (for instance, a feeding, breeding, sheltering area or a migration corridor) or structure (for instance, a kelp forest, a sea grass bed, a maerl bed) makes that location important particularly if there are no (or very few) alternative locations for a species or community to survive.

6. The **productivity** of a location. Productive locations are favoured over less productive ones of similar character.

Identification of sites for conservation also involves use of practical criteria such as **situation, recorded history, research and educational potential, restoration potential, intrinsic appeal, vulnerability, urgency, feasibility** (see

Mitchell 1987 for an explanation of their application) and **socio-economic effects** (impacts on employment and local industry).

7.4.4 Limitations of MNCR work for assessment and selection of sites

Results of MNCR work do not, or are unlikely to, include:

- information on features important for determining stability of biotopes and species including temporal change in species abundance, species recruitment, growth rates and longevity;
- information on meio- or micro-biota;
- information on pelagic biota;
- information on fish or seabird populations;
- marine biological information for every statutory site (SSSIs which include the intertidal).

Although addressed in general terms, MNCR results do not generally comment directly or in detail on:

- vulnerability of species or locations;
- urgency of protection;
- feasibility of protection.

Although indicating the macrobiota and range of habitats and communities present in areas which have been studied, MNCR data will not necessarily be available for casework at a particular location. Extrapolation from information for nearby locations or a dedicated survey may be necessary.

The difficulty of undertaking comprehensive surveys in areas below low water mark which are hidden from view, and the universal problem of being unable to survey every likely important feature, mean that some special locations may not be identified by MNCR surveys and will only come to light in the future.

8 Dissemination and use of MNCR information

David Connor

8.1 Introduction

There are inevitably many uses for the information generated from a major resource survey programme, and the nature of end products can be equally varied. Results are published in a variety of forms from traditional easily accessible books and reports to new electronic forms capable of storing and displaying maps, images and other information in a variety of ways. Some of these publications are outlined below.

8.2 Publications

8.2.1 Limited circulation reports

These act as a forum for rapid dissemination of MNCR results and as a foundation for the production of more widely available published reports. The MNCR has produced two main series of limited-distribution reports:

- ❑ 'Survey reports' - these report on the results from survey of a length of coast covered in one or more field surveys;
- ❑ 'Occasional reports' - these are for topics other than field surveys, including information reviews and descriptions of methods.

Since 1994, survey reports have been replaced by the *Area summaries* described below.

Reports are circulated to the three statutory country nature conservation agencies, to the BioMar partners and the European Commission, to marine institutes, fisheries laboratories, major libraries, and to other bodies (for example, universities, water companies, NRA Regions, local authorities) and individual marine scientists local to the area or with a particular interest in the topic or area. Increasingly, they are also being used by other bodies, including non-governmental conservation organisations.

8.2.2 The MNCR report series

To meet the needs of a wide audience the work of the MNCR will be published in a series of volumes, comprising general or 'foundation' volumes and more localised reports including:

- ❑ *Rationale and methods* (the present volume);
- ❑ *Benthic marine ecosystems: a review of current knowledge for Great Britain and the north-east Atlantic* (Hiscock in prep.);
- ❑ a national classification of benthic marine biotopes;
- ❑ an overview of Britain's marine habitats and species (at the end of the MNCR);
- ❑ a regional report series related to each of the MNCR coastal sectors or to major habitat types (such as sealochs or lagoons) and comprising a detailed classification of biotopes for the sector or major habitat type, a set of *Area summaries* describing each physiographic feature (i.e. each estuary or sealoch or lagoon) or length of open coast, an assessment of marine natural heritage importance, and an overview of the sector or major habitat type.

An example of an area summary (for the River Blackwater) is included as Appendix 11. The regional overview reports include descriptions of the coast, an account of the information used and locations surveyed, a summary of the biotopes classification for the region, an account of the distribution of biotopes in the region including descriptions and illustrations of biotopes, an account of any trends in distribution of features, and a note of any features of high marine natural heritage importance.

8.2.3 Other publications

MNCR information contributes to a wide range of other publications, either from JNCC and country agency sources or elsewhere. These include the Estuaries Review (Davidson *et al.* 1991) and the Coastal Directories (Doody, Johnston & Smith 1993 and, for instance, Barne *et al.* 1995 and other publications in the series). MNCR work is also published through scientific literature (e.g. Laffoley & Hiscock 1993; Connor *et al.* 1995).

8.3 Other uses and output from the MNCR

8.3.1 The MNCR database

The MNCR database is held by the country nature conservation agencies to provide direct access to the information to support country agency marine work. The database software and data are regularly updated. The database is also held by BioMar partners and by contractors for specific projects. The database may be disseminated more widely in the future depending on the available resources.

8.3.2 Electronic publications

Several datasets have been distributed on the computer-based mapping facility UKDMAP (United Kingdom Digital Marine Atlas Project), including an atlas of marine biological studies around Great Britain (Mills *et al.* 1993; Barne *et al.* 1994). Electronic publication offers significant opportunities for disseminating a wide variety of information, particularly in map and image form, which is not feasible through traditional paper publication. It is likely, therefore, that, as technology improves, this area of dissemination will be expanded.

8.3.3 Advice

Advice is given on a wide range of MNCR-related topics, particularly to each of the country agencies, to other JNCC branches and to Government. The advice includes issues relating to common standards for collecting, storing and analysing data, to assessment of natural heritage importance and site selection, to the biology of specific locations, and to the management of habitats and species.

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