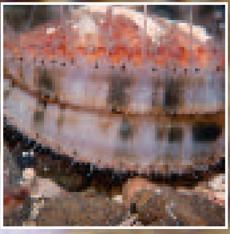
SCOTTISH NATURAL HERITAGE

Natural Heritage Trends

The Seas Around Scotland

2004



Working with Scotland's people to care for our natural heritage

Natural Heritage Trends

The Seas Around Scotland 2004

Graham Saunders

Scottish Natural Heritage

Battleby, Perth

2004

Acknowledgements

This report was supervised and edited by Ed Mackey and John Baxter.

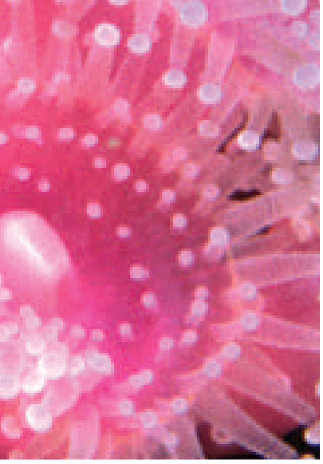
Grateful thanks are due to Ed Mackey, Phil Shaw, Catriona Burns, Beth Mouat, Katie Gillham, Sandy Downie and John Baxter for their major contributions to the text of this publication.

Thanks also to Colin Galbraith and George Lees for further editorial comment and suggestions.

Thanks for contributions, use of data, thoughts and comments should also go to David Donnan, John Gordon, Anton Edwards, Judy Dobson, Bob Reid, Calum Duncan, the Marine Conservation Society, the Sea Mammal Research Unit, the Scottish Environment Protection Agency and the Scottish Executive.

Finally, many thanks are due to Bill Forbes, Betty Common and Jim Jeffrey for assisting in the design and production.

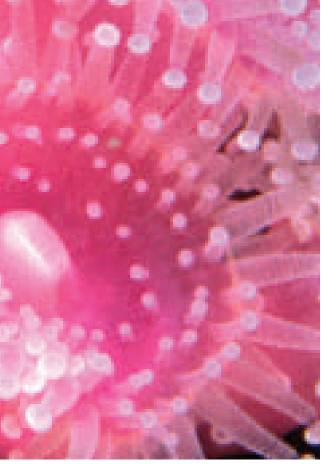
Front cover: Jewel anemones (*Corynactis viridis*), G. Saunders
Inserts: Andi Robertson/SNH, MCNR/SNH, G. Saunders/SNH.



Contents

Abbreviations

ACFM	Advisory Committee on Fishery Management
ASCOBANS	Agreement on Small Cetaceans of the Baltic and North Seas
ASP	amnesic shellfish poisoning
BGS	British Geological Survey
BOD	biological oxygen demand
BODC	British Oceanographic Data Centre
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CFP	Common Fisheries Policy
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CONSLEX	Continental Slope Experiment
CPUE	catch per unit effort
cSAC	candidate Special Area of Conservation
CTD	conductivity, temperature and depth
DDT	dichlorodiphenyltrichloroethane
DEFRA	Department for Environment, Food and Rural Affairs
DML	Dunstaffnage Marine Laboratory
DSP	diarrhetic shellfish poisoning
EC	European Commission
EQS	environmental quality standards
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FRS	Fisheries Research Services
GIS	geographical information systems
ha	hectare
IACMST	Inter-Agency Committee on Marine Science and Technology
ICES	International Council for the Exploration of the Sea
IOS	Institute of Oceanographic Sciences
ISA	infectious salmon anaemia
IUCN	International Union for Conservation of Nature and Natural Resources (or World Conservation Union)
IWC	International Whaling Commission
JCD	Joint Cetacean Database
JONSDAP	Joint North Sea Data Acquisition Project
JNCC	Joint Nature Conservation Committee
JRC	James Rennell Centre for Ocean Circulation
m	metre
MAFF	Ministry of Agriculture, Fisheries and Food
MARPOL	International Convention for the Prevention of Pollution from Ships
MBA	Marine Biological Association of the United Kingdom
MCS	Marine Conservation Society
MLURI	Macaulay Land Use Research Institute
MNCR	Marine Nature Conservation Review
NANSEN	North Atlantic Norwegian Sea Exchange
NERC	Natural Environment Research Council
NERPB	North East River Purification Board
NHM	Natural History Museum
NORSWAM	North Sea wave model
OSPAR	Oslo and Paris Conventions for the Prevention of Marine Pollution
OWS	ocean weather ship
PCBs	polychlorinated biphenyls
PDV	phocine distemper virus
PML	Plymouth Marine Laboratory
POL	Proudman Oceanographic Laboratory
PS	particle size analysis
pSAC	possible Special Area of Conservation
PSP	paralytic shellfish poisoning
ROSCOP	Report of Observations/Samples Collected by Oceanographic Programmes
RPB	River Purification Board
SAC	Special Area of Conservation
SAHFOS	Sir Alister Hardy Foundation for Ocean Science
SAMS	Scottish Association for Marine Science
SCOS	Special Committee on Seals
SEPA	Scottish Environment Protection Agency
SMRU	Sea Mammal Research Unit
SNH	Scottish Natural Heritage
SOAFD	Scottish Office Agriculture and Fisheries Department
SPA	Special Protection Area
SRD	sewage-related debris
SRPB	Solway River Purification Board
SSSI	Site of Special Scientific Interest
STD	salinity, temperature, depth
TBT	tributyltin
TERC	Tay Estuary Research Centre
TRPB	Tay River Purification Board
UKCIP02	UK Climate Impacts Programme 2002
UKOOA	UK Offshore Operators Association
UNESCO	United Nations Education, Scientific and Cultural Organisation
UOR	undulating oceanographic recorder
WFD	Water Framework Directive
WOCE	World Ocean Circulation Experiment



Foreword

In presenting this analysis of the seas around Scotland, three questions might come to mind: why have we done it?; how does it relate to our policies and plans?; and how can the outputs be used to take forward the work of Scottish Natural Heritage (SNH)? I shall address them in turn.

In our Natural Heritage Futures policy statement on Scotland's coasts and seas, which we published in 2002, we point out that comparatively little is known about the marine environment. Nevertheless, the wealth of information that does exist, from many and disparate sources, is not readily known or accessible to the non-specialist. Our task has been, quite simply, to bring together the best information available on natural heritage trends in the marine environment. Inevitably, we have had to put bounds on this. Our focus here is on life within the seas. While no less relevant, matters relating to the land/sea margin, landscape and recreation are largely beyond the scope of our present study. Trends across recent decades have been documented up to the start of 2004.

The SNH Natural Heritage Futures programme sets out challenging, but achievable, natural heritage objectives within a 25-year time horizon. Eight key objectives are defined for coasts and seas, including, for example, improving understanding of marine ecosystems; safeguarding and enhancing maritime biodiversity; ensuring that fishing is sustainable; and improving the water quality of estuaries and seas. This report provides evidence to back up our policies, and we address that specifically in the conclusions. While this report is of value to SNH, it is for the widest possible readership.

In relation to the third of my questions, the information contained within this report is already being put to use. We are working with the Scottish Executive and others on a Scottish Sustainable Marine Environment Initiative, on the preparation of a Marine Implementation Plan for the forthcoming Scottish Biodiversity Strategy and on the specification of biodiversity indicators for Scotland. Summary trend notes are being made publicly accessible through the SNH web site.

Many hands have been involved in bringing this report into print, the latest in our Natural Heritage Trends series. We expect that natural heritage trends will appeal to a broad range of interests in Scotland and beyond; within the public, private and voluntary sectors; for use in education; and to guide and evaluate policy and action. We welcome your thoughts and views, and have included a feedback form at the end of this report that can be copied and returned to us, or completed electronically.

Let me close on a quote from the report itself: 'Scotland's seas, positioned between subpolar and subtropical influences, are among the most biologically productive in the world. They support a fascinating and diverse assemblage of marine habitats and species, provide a wealth of important natural resources, and offer abundant opportunities for enjoyment'. We have a magnificent marine natural heritage. I hope you will continue to enjoy it, prosper from it and come to appreciate and respect it more through this new account of the seas around Scotland.

John Markland

Chairman, Scottish Natural Heritage

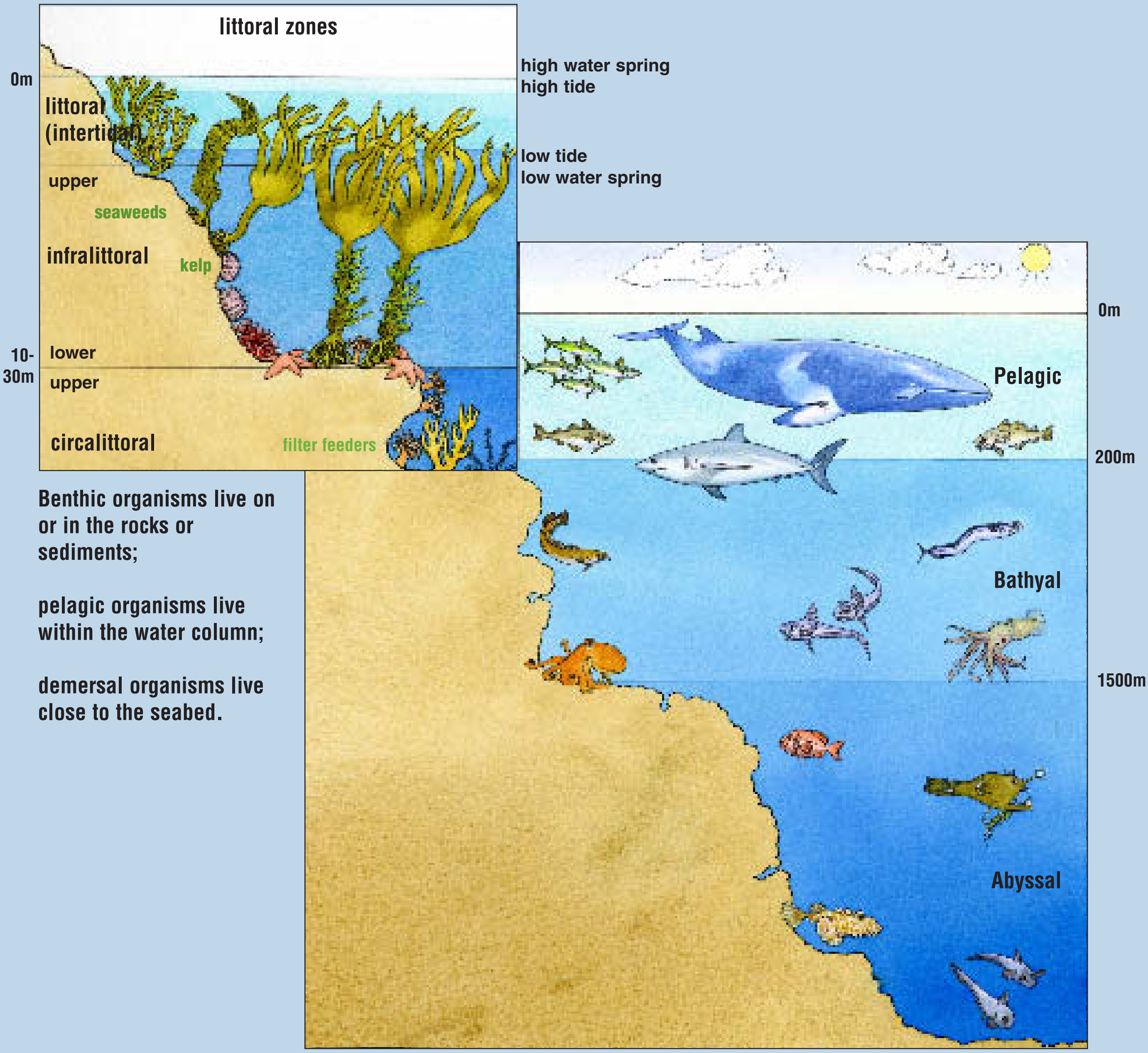
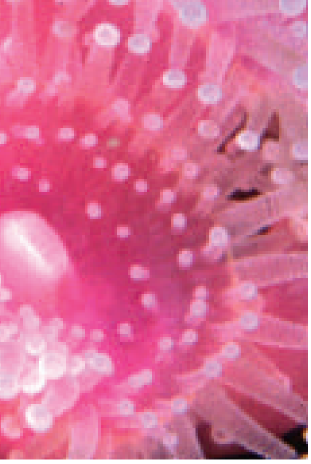


Figure 1.
Profile of Scottish seas.
Illustration by Claire Hewitt



Introduction

Scotland's seas, positioned between subpolar and subtropical influences are among the most biologically productive in the world. They support a fascinating and diverse assemblage of marine habitats and species, provide a wealth of important natural resources and offer abundant opportunities for enjoyment.

The sea surrounding Scotland is integral to its character, influencing the geography of the coastline by wave action and tidal flows, controlling climate with a complicated convergence of offshore water masses and providing a rich medium in which a vast array of animal and plant forms, many of international importance, flourish. The Scottish coastline is remarkably intricate and variable. To the west, the Atlantic coast is characterised by a highly indented fjordic and fjardic landscape with exposed islands, high sea cliffs and rocky skerries. To the east, the North Sea coast is predominantly low lying, often supporting sedimentary shores with only intermittent stretches of cliff. This part of the coastline is also less convoluted but is deeply penetrated by five large inlets or firths. The outer isles form three major archipelagos of Shetland, Orkney and the Western Isles, each with a range of distinctive coastal habitats.

Owing to the complexity of the boundary between the land and the sea, the length of the Scottish coastline is difficult to determine, but it is often stated to be about 11,800 km, representing over 8% of the entire coastline of Europe (Doody, 1999). However, coastal length is scale-dependent. Advances in computer mapping technology have allowed improved estimates to be made. Calculations based on a 1:25,000 scale suggest a revised Scottish coastline length of some 16,491 km (MLURI, 1993). Moreover, calculation of the area of sea enclosed within the 12-mile territorial limit returned a figure of 88,597 km^2, suggesting that some 53% of Scotland's administrative territory is essentially marine in nature (Scottish Office GIS Unit, personal communication).

Human influence on the marine environment is of growing concern throughout the world and, despite a relatively low population density, evidence of human impact is commonly observed around Scotland's coasts. Since the time of the earliest human settlers, the sea has been of supreme importance: as a provider of food, as an effective means of transport, as an important resource for commerce and as a receiver of domestic and industrial wastes.

This audit was undertaken with the purpose of bringing together the best information available relating to marine natural heritage trends. The report has been prepared to meet an identified need for an assessment of the state of Scotland's marine environment in order to inform and guide policy development and advice requirements. During the preparation of the report it was recognised that, in ecological terms, international boundaries are largely meaningless when drawn across a continuous body of water. Hence, in examining some of the problems associated with Scotland's seas some of the information was necessarily drawn from sources with European or even wider perspectives.

It is envisaged that this account of the seas around Scotland and their wildlife will be of interest to a wider audience, within government, in environmental organisations, in research and in education. The geographical focus is Scotland, but with an international readership in mind. Information has been presented with scientific rigour, but in ways that are hopefully interesting and understandable to a non-specialist readership.

Trend data are few and far between for the marine environment, and so this is necessarily an incomplete account. Nevertheless, the chapters of this report bring together a wealth of new information from a wide range of sources that would not otherwise be readily accessible. An example from each chapter is as follows:

1 Spectacular recent discoveries include the submarine structures of St Kilda and coldwater coral.

2 Biodiversity Action Plans have been prepared for 13 marine habitats and 17 marine species, or groups of species, occurring in Scottish waters.

3 The basking shark (*Cetorhinus maximus*), which is globally vulnerable and regarded as commercially extinct in British territorial waters, has been protected by law under the Wildlife and Countryside Act since 1998. Also vulnerable to commercial exploitation, the angel shark (*Squatina squatina*), common skate (*Dipturus batis*) and long-nosed skate (*Dipturus oxyrhinchus*) were recommended for similar protection in 2002.

4 According to the OSPAR Commission (Oslo and Paris Conventions for the Prevention of Marine Pollution), most species of large whale are showing signs of recovery in European waters.

5 Harbour seal numbers have rapidly returned to, or exceed, pre-1988 epidemic (phocine distemper virus) levels; however, a new outbreak of PDV occurred in 2002.

6 Between 1969–1970 and 1985–1987, 11 out of 18 seabird species showed a marked increase in their breeding populations (i.e. by at least 10%), and four showed a marked decline.

7 Commercial salmon farming began in Scotland in 1969. In 2002, over 145,000 tonnes of farmed Atlantic salmon (*Salmo salar*) was produced.

8 Of the 16 commercially exploited sea fish species for which Scottish data are available, seven were considered by the International Council for the Exploration of the Sea (ICES) to be outside safe biological limits in 2002/03.

9 Among 12 commercially exploited deep-water species, five were considered by the ICES to be harvested outside safe biological limits in 2000 and the status of others is largely unknown.

10 Upper Clyde estuary sediments, dominated in the 1970s by a few pollution-tolerant species, now have a more diverse invertebrate community and rising numbers of fish species.

11 Seabirds and their chicks are susceptible to ingesting litter. Plastic bags can cause gut blockage and death by starvation among turtles, which mistake them for their jellyfish prey.

12 Of 24 non-native marine species found in Scottish waters, ten have potentially harmful effects on the environment and/or on commercial interests.

13 Perhaps in response to changing sea temperature, a shifting distribution of fish species is evident in the northerly retreat of eelpout (*Zoarces viviparus*) and advance of fatherlasher (*Myoxocephalus scorpius*) in the lower Forth estuary.

Technical terms are kept to a minimum and explained as fully as possible where they occur. Some commonly encountered terms are illustrated in Figure 1.

References

Doody, J. P. (1999). The Scottish coast in a European perspective. In: *Scotland's Living Coastline*. Baxter, J. M., Duncan, K., Atkins S. and Lees, G. (eds), pp. 15–29.The Stationery Office, London.

Hiscock, K. Southward, A., Tittley, I., Adam, J. and Hawkins, S. (2001). *The Impact of Climate Change on Subtidal and Intertidal Benthic Species in Scotland.* Report to Scottish Natural Heritage from the Marine Biological Association of the UK. Phase 1: Introduction and species researched. Research Survey and Monitoring Report, No. 182. Scottish Natural Heritage, Edinburgh.

MLURI. (1993). *The Land Cover of Scotland 1988.* Final report. Macaulay Land Use Research Institute, Aberdeen.

Part 1
Knowledge of the marine environment

1 Knowledge and enjoyment

Introduction

Scotland's territorial seas constitute an area greater than that of the seas around the rest of the UK. They are as visually spectacular and varied as the Scottish terrestrial environment, and provide opportunities for the development of tourism (Box 1.1).

Previous page: SNH Surveyor, Shetland.
G.Saunders

Children playing at rockpool.
L. Gill/SNH

Mostly, however, the sea remains hidden from sight and comparatively little-studied. Because of the cost and technical challenges of working in the sea, knowledge of species, habitats and communities, particularly those found below the low-tide line, is still at an early stage.

Trends

Davison (1996) and Davison and Baxter (1997) estimated the total number of Scottish marine species to be more than 40,000 (Table 1.1). Among these, there are thought to be of the order of 800 benthic algae and about 4,500 benthic faunal species (excluding viruses and protozoans).

Scottish marine survey work, as in the rest of the UK, has not been uniformly distributed, often being concentrated around favoured sites or close to research or educational establishments. A major expansion of survey activity occurred in the late 1970s and early 1980s (Figure 1.1) and was further accelerated by the Marine Nature Conservation Review (MNCR) in 1987. The increased survey effort was sustained into the 1990s, partly because of the additional information required to support the

Box 1.1 Tourism

The ruggedness and relatively unspoilt nature of the Scottish coastline is a major tourist attraction that contributes significantly to both national and local economies. Excursions to view wildlife in natural surroundings are increasingly popular. Marine wildlife tourism in Scotland generated revenues of some £57 million and provided around 2,670 full-time jobs in 1996 (Masters, 1998). Whale-watching may account for up to 12% of local tourism revenue (Hebridean Whale and Dolphin Trust, 2001). Education and raising public awareness can be added benefits.
Nevertheless, wildlife tourism remains, for the most part, underdeveloped. A future programme of coordinated and sustainable tourism development, with due regard to the balance between access and conservation, could provide important socio-economic benefits for coastal communities. This might, for example, be achieved by integrating a strategy for the development of marine wildlife tourism with the management of Special Areas of Conservation (SAC) and Special Protected Areas (SPAs).

Seal watching on the west coast.
L. Gill/SNH

Table 1.1 The number of marine species occurring in Scottish waters
(source: Davison, 1996; Davison and Baxter, 1997)

Phylum	Common name	Great Britain and Ireland	Scotland
Protista = Protozoa		25,000–30,000	25,000–30,000
Mesozoa	Microscopic parasites	2	Unknown
Porifera	Sponges	353 (360)	250–300
Cnidaria	Jellyfish, hydroids, anemones, corals	375 (390)	250–350
Ctenophores	Comb jellies	3	3
Platyhelminthes	Flatworms and meiofaunal worms	355–375 (377)	300–350
Nemertea	Ribbon worm	67 (85)	60–70
Rotifera	'Wheel animalcules'	10–15	10–15
Gastrotricha	Meiofaunal roundworms	85 (140)	80–90
Kinorhyncha	Microscopic worms	15 (16)	6–10
Nematoda	Round worms	408 (410)	350–400
Acanthocephala	Spiny-headed worms	10–20	10–20
Priapulida	Worm-like animals	1	1
Entoprocta	Similar to sea mats	35 (45)	35–40
Chaetognatha	Arrow worms	22	20
Pogonophora	'Beard' worms	2 (10)	2–10
Sipuncula	Worm-like animals	12 (21)	12–15
Echiura	'Spoon' worms	7	3
Annelida	Bristle and sludge worms, leaches	940 (995)	800–900
Chelicerata	Sea spiders and marine mites	91	60–70
Crustacea	Branchiopods, barnacles, copepods, ostracods, stomatopods, shrimps, crabs, lobsters, etc.	2,465 (2,665)	2,000–2,460
Uniramia	Marine arthropods	3–4	3–4
Tradigradia	'Water bears'	16	16
Mollusca	Chitons, limpets, sea snails, sea slugs, tusk shells, bivalves octopus, etc.	1,395 (1,465)	650–700
Brachiopoda	Lamp shells	18	11
Bryozoa	Sea mats	270 (290)	120–150
Phoronida	Tube worms	3 (5)	2
Echinodermata	Feather stars, sea stars, brittlestars, sea urchins, sea cucumbers, etc.	145	100–130
Hemichordata	Acorn worms and planktonic larvae	12+ (?)	11+ (?)
Tunicata*	Sea squirts and salps	120 (125)	100
Pisces	Fish	300 (332)	250
Reptilia	Sea turtles	5	4
Mammalia	Sea mammals	28 (35)	28–35
Archaebacteria and other Eubacteria	Bacteria	1,500–2,000	1,500–2,000
Cyanobacteria = Cyanophyta	Blue–green algae	41 (120)	41 (70)
Rhodophyta	Red algae	350 (450)	250
Heterokontophyta	Golden etc. algae, diatoms, phytoflagellates	1,241 (1,341)+?	1,201–1,321+?
Haptophyta = Prymnesiophyta	Phytoflagellates	117	115
Cryptophyta	Phytoflagellates	78	78
Dinophyta	Dinoflagellates	440 (460)	250–450
Euglenophyta	Euglenoids	5–10	5–10
Chlophyta	Green algae	160 (220)	100–150
Non-lichenous fungi	Non-lichenous fungi	120 (150)	120–150
Viruses	Viruses	2,000–2,500	2,000–2,500
Grand total	Excluding Protista = Protozoa	13,625–14,666 (15,573)	11,207–13,605 (13,634)
	Including Protista = Protozoa	38,625–44,666 (45,573)	36,207–43,605 (43,634)

*Subphylum. Numbers in brackets indicate a 'potential maximum', i.e. numbers of those that could potentially occur plus those that have been recorded from British waters.

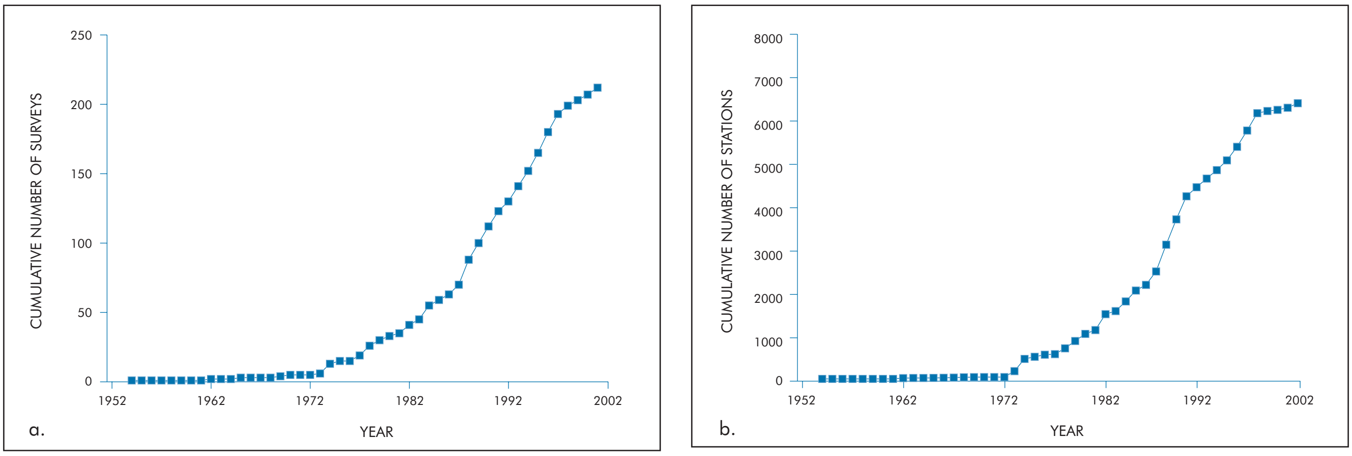


Figure 1.1
Cumulative Scottish marine survey effort represented by entries into the MNCR database. (a) Surveys. (b) Individual survey stations.
Source: MNCR database

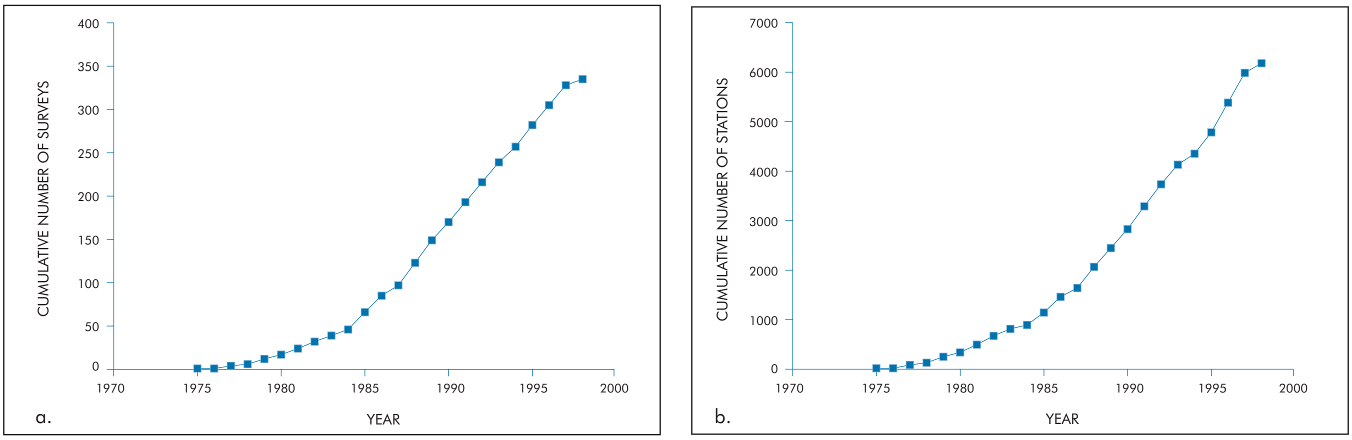


Figure 1.2
Cumulative offshore oil and gas industry survey effort. (a) Surveys. (b) Individual survey stations.
Source: UKbenthos database

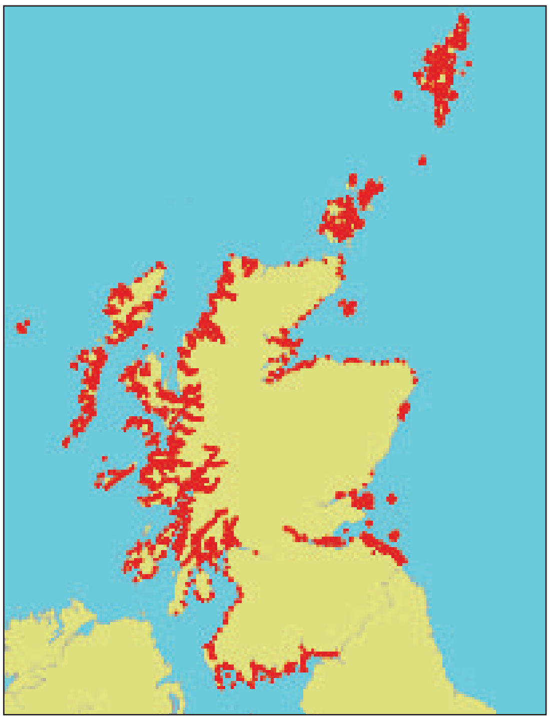


Figure 1.3
Location of Scottish survey stations held in the MNCR database.
Source: MNCR database

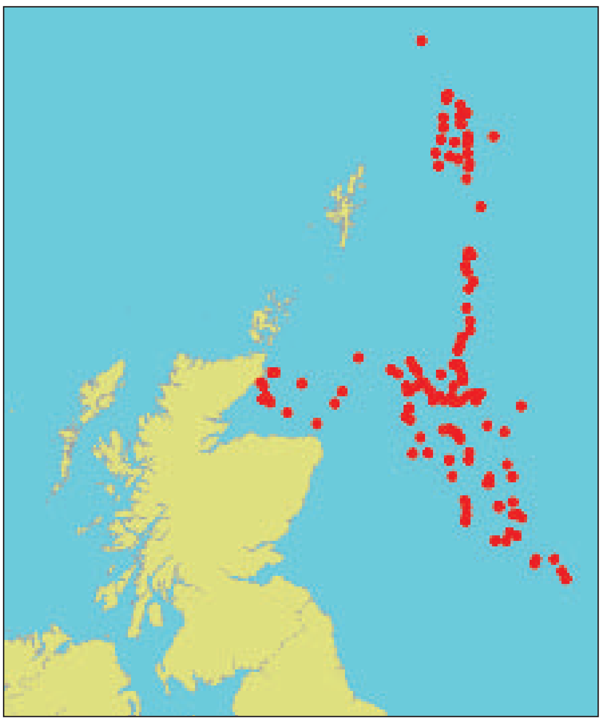


Figure 1.4
Location of oil and gas industry survey stations.
Source: UKbenthos database

implementation of the European Union (EU) Habitats Directive in the UK. Moreover, the early 1980s was a time of increased oil and gas industry activity, with environmental monitoring and sampling, largely of sediments, accompanying all major exploratory and development projects (Figure 1.2). Knowledge of the extent and distribution of marine habitats and species comes from a large number of sources. Even so, the coverage is widely dispersed and patchy, with substantial sections of the north and east coast remaining poorly surveyed (Figure 1.3), reflecting either operational considerations or selection of what might be considered 'interesting' areas of coastline.

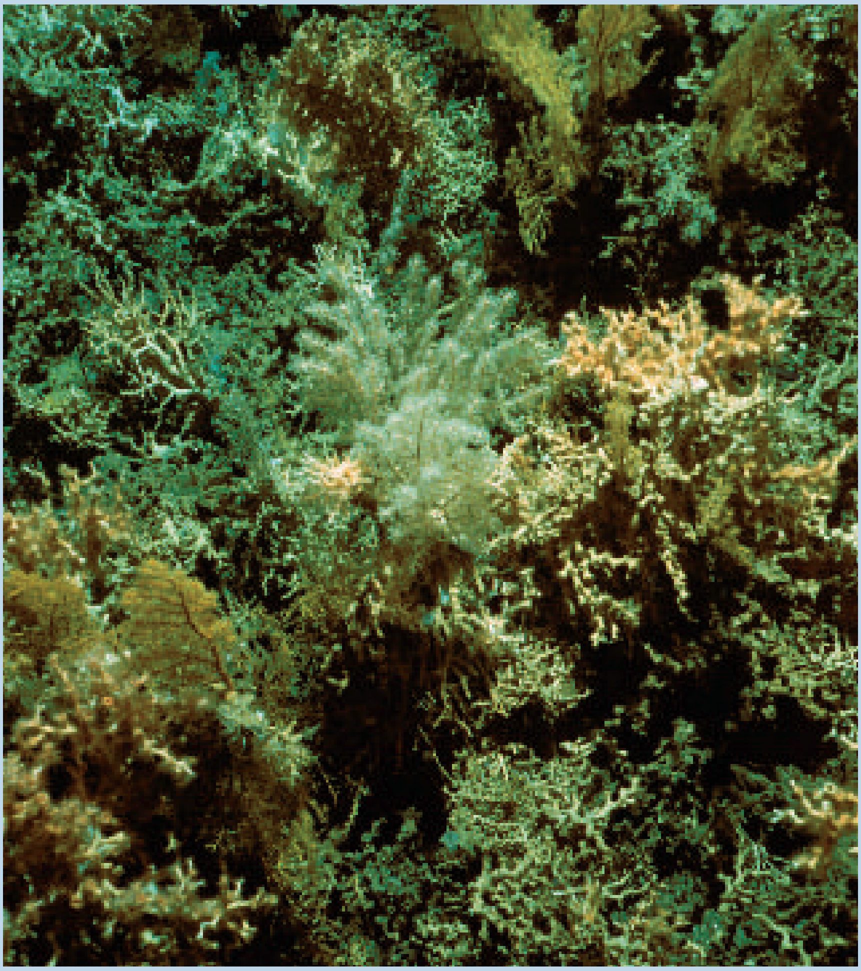
Scotland's eastern and north-eastern shores define the north-western boundary of the North Sea, one of the most biologically productive areas in the world, and probably among the most exploited. Offshore areas have undergone intensive extraction of oil and gas, an industry that has dominated the economy of the North Sea basin for almost three decades. Oil industry survey effort has been mainly concentrated in the North Sea (Figure 1.4).

Issues and implications

The collation of these data, however incomplete, has revealed a rich and spectacular assemblage of marine communities and habitats. Survey records from the MNCR exist for almost 2,300 plant, invertebrate and fish species in Scottish waters. Many are common and widely distributed. Others are clearly restricted in their distribution because of their dependence on particular conditions, such as those provided by the sheltered west-coast sea lochs.

Incomplete as the knowledge base is, new technology is making it possible to explore the marine environment more fully. Spectacular recent discoveries have included cold-water corals (Box 1.2) and near-pristine conditions among the submarine structures of St Kilda (see Box 2.2).

Such information is invaluable in the establishment of baselines against which assessments of change, disturbance and the effectiveness of marine environment protection may be achieved.



Box 1.2 Cold-water coral

Reef structures dominated by *Lophelia pertusa* and incorporating a number of other coral species have been discovered in the Norwegian waters of the north-eastern North Sea. They support a rich associated fauna, with over 850 species living on or within the reefs, and provide an especially rich habitat for target and non-target fish species. Vessels in pursuit of high fish densities on these reefs have caused damage, but in Norway many of the known reefs are now protected from further fishing-related damage.
A survey in 2003 investigated historical records of *Lophelia pertusa* in Scottish waters, in particular to the east of Mingulay, off Rum, and to the north-west of Skye. Results will help to inform conservation measures which may be required to protect reef structures around Scotland.

Cold-water coral (*Lophelia pertusa*).
B.Bett/Southampton Oceanographic Centre

Sources of data

The MNCR database is the primary repository of marine survey data collected by all of the UK conservation agencies. It does, however, also contain data from a range of other sources. The MNCR database is currently in the process of being transferred to a new software platform. The new format will be referred to as Marine Recorder. The MNCR also maintains Mermaid, a web-based version with reduced search capabilities.

The UKbenthos database contains all of the biological and chemical information obtained during oil and gas industry surveys and was compiled and made available to the public in 2000 by the UK Offshore Operators Association (UKOOA).

References

Davison, A. and Baxter, J. M. (1997). The number of marine species that occur in Scottish coastal waters. In: *Biodiversity in Scotland: Status, Trends and Initiatives*. Fleming, L. V., Newton, A. C., Vickery, J. A. and Usher, M. B. (eds), pp. 57–62. The Stationery Office, Edinburgh.

Davison, D. M. (1996). *An Estimation of the Total Number of Marine Species that occur in Scottish Coastal Waters*. Scottish Natural Heritage Review Report, No. 63. Scottish Natural Heritage, Edinburgh.

Hebridean Whale and Dolphin Trust. (2001). *Whale-watching in West Scotland*. Report for the Department for Environment, Food and Rural Affairs. Department for Environment, Food and Rural Affairs, London.

Masters, D. (1998). *Marine Wildlife Tourism: Developing a Quality Approach in the Highlands and Islands*. Unpublished report. Tourism and Environment Initiative and Scottish Natural Heritage.

2 Marine conservation

Introduction

The conservation of Scotland's coasts and seas is considered by many to be of the highest priority, and a wide range of campaigns, management initiatives and conservation designations are currently being employed to this end. A pivotal point in the creation of a framework for statutory nature conservation in Britain was reached with the establishment of the first Sites of Special Scientific Interest (SSSI) under the National Parks and Access to the Countryside Act 1949. The application of this Act has facilitated the development of a network of scientifically evaluated sites which are notable for the quality, extent and/or rarity of the species, habitats or geological formations found within them.

Underwater rock wall, St Abbs.
G. Saunders

Sites of Special Scientific Interest have subsequently been identified under the Wildlife and Countryside Act 1981, which created a requirement for the owner or occupiers to be involved directly in the notification process. In Scotland, it is incumbent on Scottish Natural Heritage (SNH) to identify activities that may damage or destroy the feature of interest. Owner and occupiers must then consult SNH prior to carrying out such operations.

Since their inception, SSSI have excluded the area below the mean low-water spring tide, thus placing a key component of Scotland's maritime natural heritage outside conservation management legislation. Although provision for the establishment of statutory Marine Nature Reserves, comprising both littoral and sublittoral elements, was included in the 1981 Wildlife and Countryside Act, only a small number – all outside Scotland – have been established so far.

In 1992, the European Community formally adopted the Habitats Directive (Box 2.1) with the aim of establishing a Europe-wide network of high-quality conservation sites, termed Special Areas of Conservation (SAC). These complement Special Protection Areas (SPAs), created under the Birds Directive (Council Directive 79/409/EEC). The introduction of SAC has resulted in statutory site-based conservation extending across both the littoral and sublittoral for the first time in Scotland.

Figure 2.1 Scotland's Special Areas of Conservation, January 2004. pSAC indicates possible SAC, other sites are candidate SACs. Produced by Scottish Natural Heritage Geographic Information Group based on the Ordinance Survey 1:25,000 map. © Scottish Natural Heritage. Licence Number GD315 G0005. © Crown Copyright.

Top: Lochs Duich, Long and Alsh cSAC.
J.Baxter

Centre: Faray & Holm of Faray cSAC.
J.Baxter

Left: Papa Stour cSAC.
J.Baxter

Box 2.1 The Habitats Directive

(sources:
http://europa.eu.int/comm/environment/nature/habdir.htm;
http://www.jncc.gov.uk/marine/offnat/sac_offshore_waters.htm;
http://www.marlin.ac.uk/glossaries/legislation.htm)

In May 1992, the member states of the European Union adopted Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, also known as the Habitats Directive. The aim of the Directive is to conserve biodiversity throughout the European Union. A prominent component of this is the establishment of a pan-European protected areas network, known as Special Areas of Conservation. As at 31 March 2003, a total of 230 sites in Scotland, covering an area of 874,808 ha, had been submitted by the UK government to the European Commission as candidate Special Areas of Conservation (cSAC). Of these, 24 were put forward on the basis of their European importance for marine features, and a further nine for their mix of marine and non-marine elements (SNH, 2003). The locations of sites are shown in Figure 2.1.

The requirements of the Habitats Directive were transposed into UK legislation through the Conservation (Natural Habitats etc.) Regulations 1994. In the marine environment they apply to waters only within the 12 nautical mile (nm) limit of territorial seas. However, the subsequent Offshore Marine Conservation (Natural Habitats, etc.) Regulations 2003 apply the Habitats Directive to waters of the UK continental shelf and as far as the 200-nm limit over which the UK exercises sovereignty (DEFRA, 2003).

The UK government is currently considering designating an area known as the Darwin Mounds, covering approximately 10,000 ha, as the first offshore cSAC. The Darwin Mounds are a unique collection of sand and coldwater coral mounds located in the Rockall Trough at a depth of around 1,000 m, some 185 km north-west of Shetland. Marine elements of cSAC currently extend to an area of around 35,000 ha, equivalent to about 0.4% of the sea area within the 12-nm limit.

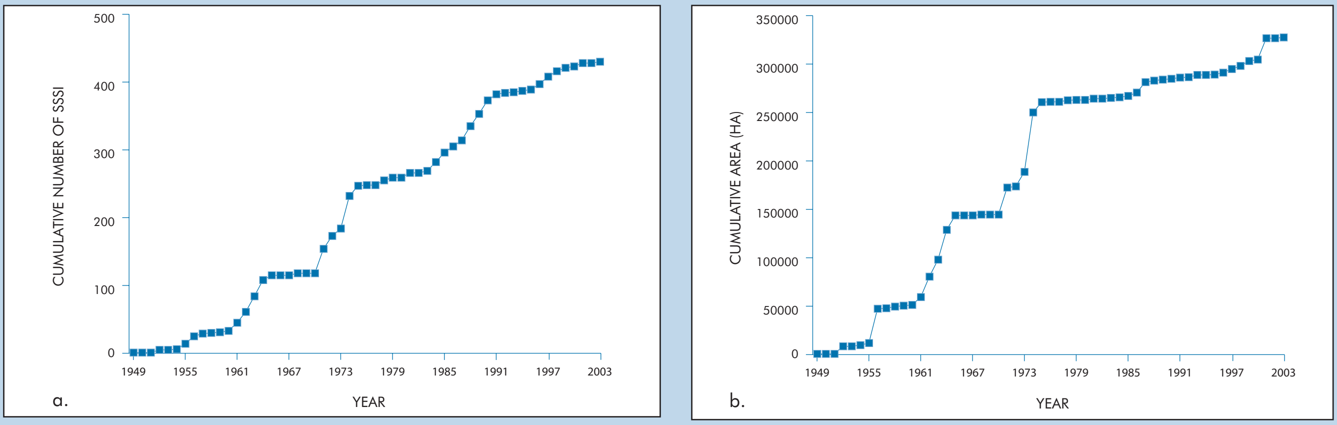


Figure 2.2
Scotland's Sites of Special Scientific Interest with a coastal element.
(a) Cumulative number of SSSI.
(b) Cumulative SSSI area.

Trends

The significance of the maritime natural heritage was reflected in the selection early on of a number of coastal SSSI. Since 1949, the number of Scottish SSSI with a coastal element has increased steadily, reaching 430 in 2003 (Figure 2.2a). The area covered by these sites increased rather less steadily (Figure 2.2b), with a tendency, after around 1975, towards the confinement of coastal SSSI boundaries to smaller areas. By 2003, SSSI with a coastal element covered some 327,504 ha of coastal land, although some sites included only a small length of shoreline.

The Habitats Directive requires sites to be designated SACs if they support typical, rare or vulnerable natural habitats and species of

Table 2.1
Habitats Directive Annex 1 marine and coastal habitat types

Habitat	Examples in Scotland
Marine	
Estuaries	✔
Large shallow inlets and bays	✔
Lagoons	✔
Mudflats and sandflats not covered by seawater at low tide	✔
Reefs	✔
Sand banks which are slightly covered by seawater at all times	✔
Posidonia beds	✘
Submerged or partly submerged sea caves	✔
Marine 'columns' in shallow water made by leaking gases	✘
Coastal	
Atlantic salt meadows (*Glauco–Puccinellietalia*)	✔
Decalcified fixed dunes with *Empetrum nigrum*	✔
Coastal dunes with *Juniperus* spp.	✔
Dunes with *Salix repens* subsp. *argentea* (*Salicion arenariae*)	✔
Embryonic shifting dunes	✔
Atlantic decalcified fixed dunes (*Calluno–Ulicetea*)	✔
Dunes with *Hippophae rhamnoides*	✘
Fixed dunes with herbaceous vegetation (grey dunes)	✔
Humid dune slacks	✔
Machair	✔
Annual vegetation of drift lines	✔
Perennial vegetation of stony banks	✔
Salicornia and other annuals colonising mud and sand	✔
Spartina swards (*Spartinion maritimae*)	✘
Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)	✔
Vegetated sea cliffs of the Atlantic and Baltic coasts	✔
Mediterranean and thermo-Atlantic halophilic scrubs (*Sarcocornetea fruticosi*)	✘

✔ yes; ✘, no.

Far left: Brittlestar bed (*Ophiothrix fragilis*), Loch Duich. *G. Saunders*

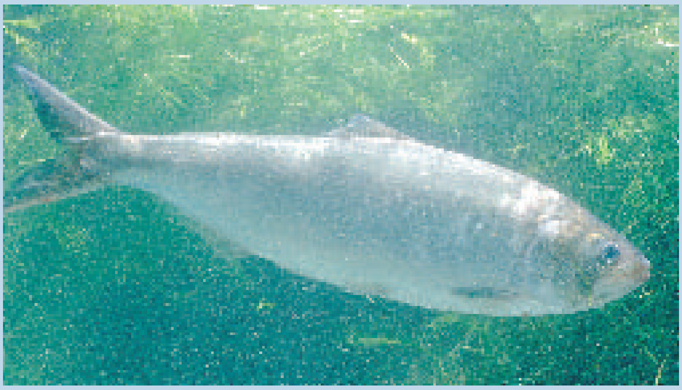
Left: The Vadills, Shetland. *G. Saunders* plants or animals as set out in Annex I and Annex II of the Directive. Scotland's territorial waters support seven of the nine marine and all but three of the coastal Annex I habitats (Table 2.1), together with nine of the ten marine Annex II species (Table 2.2).

A proposal has been submitted to the United Nations Education, Scientific and Cultural Organisation (UNESCO) to extend the St Kilda World Heritage Site to encompass the surrounding sea and sea bed (Box 2.2).

Table 2.2
Habitats Directive Annex II marine, estuarine and coastal species

Species	Present in Scotland
Fishes	
Sea lamprey (*Petromyzon marinus*)	✔
River lamprey (*Lampetra fluviatilis*)	✔
Allis shad (*Alosa alosa*)	✔
Twaite shad (*Alosa fallax*)	✔
Mammals	
Bottlenose dolphin (*Tursiops truncatus*)	✔
Harbour porpoise (*Phocoena phocoena*)	✔
Otter (*Lutra lutra*)	✔
Grey seal (*Halichoerus grypus*)	✔
Harbour or common seal (*Phoca vitulina*)	✔
Plants	
Shore dock (*Rumex rupestris*)	✘

✔ yes; ✘, no.



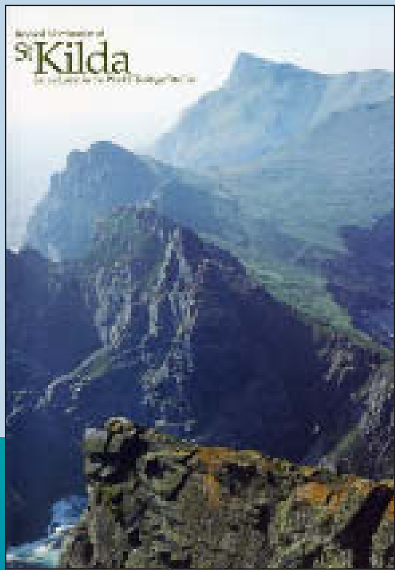
Allis Shad.
NHPA

Bottlenose dolphins.
D.Whitaker

Box 2.2 St Kilda World Heritage Site

The St Kilda archipelago represents the remnants of a long extinct ring volcano rising from a seabed plateau approximately 40 m below sea level (Scottish Executive, 2003). It is a World Heritage Site in view of its outstanding terrestrial natural heritage and globally important seabird colonies. The present site boundary encompasses the purely terrestrial components, somewhat less than 1,000 ha in extent.

The submarine elements remained undiscovered until recent surveys revealed a remarkable assemblage of features, more or less devoid of human impact. Changing sea levels during the Quaternary are apparent as submerged coasts. The influence of the north-east Atlantic Drift means that a number of northern species reach the southern extreme of their range there and vice versa. In view of the global importance of the marine elements, a proposal has been put forward to extend World Heritage Site status to around 24,000 ha overall.



Far left: Stac Lee, St Kilda. J.Baxter

Left: Revised Nomination of St Kilda for inclusion in the World Heritage Site List.

Below: Underwater – St Kilda. *R.Holt/MNCR/SNH*

Bass Rock, Forth Islands SPA.
P. & A. Macdonald /SNH

Issues and implications

A comparison of North Sea coastal development in 1988 with that of 1999 revealed little change, other than an increase in the relative importance of leisure and recreational uses (Ritchie and McLean, 1988; Ritchie, 1999).

The benefits of the use of SSSI and other types of designations in conservation management are becoming evident. Ritchie (1999) observed that over the last 30 years there has been a cultural change towards conserving and enhancing the environment. With direct conservation management applied to large areas of the eastern Scottish coastline, he observed that '… the coastline is cleaner, more scenic, better managed and aesthetically conserved.'

SSSI, however, carry a major constraint that limits their effectiveness within the marine zone. Since their inception they have explicitly excluded the area below the mean low-water spring tides (Scottish Office, 1998), thus excluding a key component of Scotland's maritime natural heritage from conservation management legislation.

In November 1999, as a result of a case initiated by the environmental pressure group Greenpeace, the UK High Court ruled that the Habitats Directive applied to 'the UK continental shelf and superadjacent waters up to a limit of 200 nautical miles'. Prior to this, designations under the Habitats Directive were limited to sites within the 12-mile limit of UK territorial waters. This action was stimulated by concern over the latest in a series of rounds in which the UK government was considering granting licences allowing seismic surveying and exploratory drilling for the presence of oil and gas deposits. The area under greatest scrutiny lies to the north and west of the Hebrides, Shetland and Orkney Isles. This is considered to be a region of major importance for large cetaceans, a group particularly vulnerable to seismic surveys but not included in Annex II of the Habitats Directive. The deep waters off the continental shelf break, although not well studied, are known to support a wide range of habitats ranging from mudplains and undulating sandbanks to reefs dominated by coldwater corals. Such rocky reef habitats are a qualifying feature under Annex I of the Habitats Directive.

The perceived threat posed by deep-sea oil and gas exploration is small when compared with a more immediate problem of deep-water fishing, an activity that currently lies outside the jurisdiction of the United Kingdom's application of the Habitats Directive.

In 1994, as a direct response to the 1992 United Nations Convention on Biological Diversity, the UK government convened a Biodiversity Steering Group and published *Biodiversity: The UK Action Plan*. Subsequently, specific Action Plans were prepared for a range of UK species and habitats that are considered to be representative, rare or at risk (Box 2.3). The marine environment is well represented, with around 25% of the identified priority habitats (Mackey *et al.*, 2001). Overall, 81 marine, estuarine or brackish-water species are incorporated within Action Plans, and about 74 of these species are found around Scottish coasts (UK Biodiversity Group, 1999).

Box 2.3 Biodiversity Action Plan

Action plans have been prepared for 13 marine habitats and for 17 marine species or groups of species occurring in Scottish waters (UK Biodiversity Group, 1999).

The 13 marine habitats are *Lophelia pertusa* reefs, maerl beds, *Modiolus modiolus* beds, mud habitats in deep water, mudflats, *Sabellaria alveolata* reefs, *Sabellaria spinulosa* reefs, saline lagoons, seagrass beds, *Serpulid* reefs, sheltered muddy gravels, sublittoral sands and gravels, and tidal rapids.

The 17 priority marine species or species groups comprise vertebrates (9), invertebrates (7) and non-vascular plants (1). The vertebrates are baleen whales (grouped plan), basking shark (*Cetorhinus maximus*), deep-water fish (grouped plan), marine turtles (grouped plan), harbour porpoise (*Phocoena phocoena*), common skate (*Raja batis*), commercial marine fish (grouped plan), small dolphins (grouped plan), and toothed whales (grouped plan). The invertebrates are the sea-fan anemone (*Amphianthus dohrnii*), fan shell (*Atrina fragilis*), sea pen (*Funiculina quadrangularis*), native oyster (*Ostrea edulis*), sea squirt (*Styela gelatinosa*), lagoon sea slug (*Tenellia adspersa*) and northern hatchett shell (*Thyasira gouldi*). The non-vascular plant is the egg-wrack (*Ascophyllum nodosum* ecad *mackaii*).

Trends

An assessment of status was published in 2003 (http://www.ukbap.org.uk/asp/2002_main.asp). Trends were reported for five habitats and six species at the UK level; and for two habitats and four species at the Scottish level. Trends assessed are as follows:

Habitat/species	UK trend	Scottish trend
Lophelia pertusa reefs	Declining (continuing/accelerating)	No information
Maerl beds	Stable	Stable
Mud habitats in deep water	Unknown	Declining (slowing)
Sabellaria alveolata reefs	Fluctuating/no clear trend	No information
Sheltered muddy gravels	Declining (slowing)	Unknown
Tidal rapids	Declining (slowing)	No information
Basking shark (*Cetorhinus maximus*)	Fluctuating/No clear trend	Fluctuating/no clear trend
Commercial marine fish	Declining (continuing/accelerating)	No information
Common skate (*Raja batis*)	Declining (continuing/accelerating)	No information
Fan shell (*Atrina fragilis*)	Declining (slowing)	Declining (slowing)
Native oyster (*Ostrea edulis*)	Unknown	Declining (slowing)
Northern hatchett shell (*Thyasira gouldi*)	Declining (continuing/accelerating)	Declining (continuing/accelerating)
Sea-fan anemone (*Amphianthus dohrnii*)	Fluctuating/no clear trend	No information

Sources of data

A database of SSSI extents, feature(s) of interest and status is maintained by SNH.

References

DEFRA. (2003). *The Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2003: A Consultation Document*. Department for Environment, Food and Rural Affairs, London.

Mackey, E. C., Shaw, P., Holbrook, J., Shewry, M. C., Saunders, G., Hall, J. and Ellis, N. (2001). *Natural Heritage Trends: Scotland 2001*. Scottish Natural Heritage, Perth.

Ritchie, W. (1999). *The Environmental Impact of Changing Uses on the North Sea Littoral of Scotland. Denmark and Scotland: the Cultural and Environmental Resources of Small Nations.* Joint symposium of the Royal Society of Edinburgh and the Royal Danish Academy of Sciences and Letters, 15–18 September, 1999, Copenhagen.

Ritchie, W. and McLean, L. (1988). UK – Scotland. In: *Artificial Structures and Shorelines*. Walker, H. J. (ed.), pp. 127–135. Kluwer, Dordrecht.

Scottish Executive. (2003). *Revised Nomination of St Kilda for Inclusion in the World Heritage Site List.* Scottish Executive, Edinburgh.

SNH. (2003). *SNH Facts and Figures 2002/2003*. Scottish Natural Heritage, Battleby, Perth.

Scottish Office. (1998). People and nature. A new approach to SSSI designations in Scotland. The Scottish Office, Edinburgh.

UK Biodiversity Group. (1999). *Tranche 2 Action Plans*. Vol. V: *Maritime Species and Habitats.* English Nature, Peterborough.

Part 2
Marine Life

3 Sharks, skates and rays

Introduction

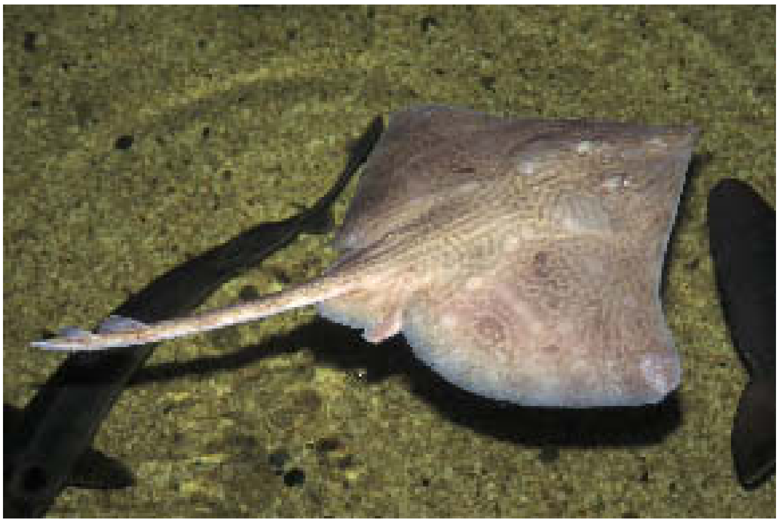
Sharks, skates and rays together make up the group of cartilaginous fish (jawed fish with a skeleton composed primarily of cartilage) known as the elasmobranchs. The number of species in British waters is uncertain, but recent listings suggest 30 sharks and 21 skates and rays.

Records for skates and rays include 11 species in Scottish coastal waters (Table 3.1).

At least 18 species of shark occur in Scottish waters (Table 3.2), varying in size from the small dogfish to the second largest fish in the world, the basking shark (the largest is the whale shark, *Rhincodon typus*, which occurs in tropical and warm temperate seas).

Table 3.1
Scottish skates and rays
Source: A. Hood, The Shark Trust, personal communication, 2003

Common name	Species name
Common skate	*Dipturus batis*
Long-nosed skate	*Dipturus oxyrhinchus*
Starry skate	*Amblyraja radiata*
Electric ray	*Torpedo nobiliana*
Blonde ray	*Raja brachyura*
Thornback ray	*Raja clavata*
Sandy ray	*Leucoraja circularis*
Shagreen ray	*Leucoraja fullonica*
Round ray	*Rajella fyllae*
Spotted ray	*Raja montagui*
Cuckoo ray	*Leucoraja naevus*



Previous page: Cuckoo wrasse (*Labrus mixtus*).
R. Holt

Above right: Common skate.
P. Kay

Right: Spotted ray.
R.Holt

Trends

Examination of the catch rates of rays from North Sea fishery survey data for 1929–1939 and 1991–1995 reveals a shift towards fewer species and smaller individuals (Walker, 1996). Major changes in the relative abundance of the eight ray species found in UK waters occurred over this period, possibly as a result of changes in size at maturity and thus vulnerability to capture. Due to its size, the common skate appears to be especially vulnerable (Box 3.1).

> **Box 3.1 Common skate**
>
> Brander (1981) and Walker (1996) noted a decline in catches of common skate (*Raja batis*) in the Irish Sea and North Sea respectively. Abundant in the past, the common skate was a commercially important component of the retained bycatch. The largest among UK skate and ray species, the common skate is now considered to be commercially extinct in most areas.

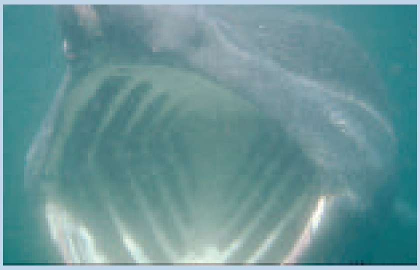
As part of the Fourth Quinquennial Review of Schedules 5 and 8 of the Wildlife and Countryside Act, 1981, in 2002 the Joint Nature Conservation Committee recommended that the angel shark and long-nosed and common skates should be granted full protection under Schedule 5. The black and the white skates, which have not been recorded in Scottish coastal waters, were also proposed. Statutory protection is needed for these species, which are all reported to be declining in British waters.

Globally, the status of the basking shark (Box 3.2) is assessed as vulnerable on the 1996 International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Animals. Basking sharks have been protected within British territorial waters under the Wildlife and Countryside Act (1981) since 1998, and identified for conservation action through a Species Biodiversity Action Plan. In 2000, a UK proposal to place basking shark on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was narrowly defeated, but a further attempt in 2002 was successful. In the interim, the UK has placed this species on Appendix III of CITES, banning other countries from importing basking shark products from the UK without a valid export licence.

Basking shark *P.Kay*

Table 3.2
Scottish sharks
Source: A. Hood, The Shark Trust, personal communication, 2003.

Common name	Species name
Frilled shark	*Chlamydoselachus anguineus*
Six-gilled shark	*Hexanchus griseus*
Bramble shark	*Echinorhinus brucus*
Darkie charlie	*Dalatias licha*
Greenland shark	*Somniosus microcephalus*
Spurdog	*Squalus acanthias*
Thresher shark	*Alopias vulpinus*
Basking shark	*Cetorhinus maximus*
Shortfin mako shark	*Isurus oxyrinchus*
Porbeagle shark	*Lamma nasus*
Black-mouthed dogfish	*Galeus melastomus*
Lesser spotted dogfish	*Scyliorhinus canicula*
Nurse hound	*Scyliorhinus stellaris*
Tope	*Galeorhinus galeus*
Smooth hound	*Mustelus mustelus*
Starry smooth hound	*Mustelus asterias*
Blue shark	*Prionance glauca*
Angel shark	*Squatina squatina*



Basking shark.
J. Leaver/Kelpie Design

Box 3.2 Basking shark

Basking sharks occur in the temperate waters of most seas and are present in both the northern and southern hemispheres. They are widely distributed but are infrequently recorded, except in a few coastal areas, where they are sometimes seen in relatively large numbers.

Basking sharks are seasonal visitors to Scottish coastal waters, observed mainly on the west coast in summer, with sightings peaking around August. Movements are thought to be migratory and in response to the sharks' zooplankton food source. Long-distance tracking of individuals has been achieved only very recently. While this has dispelled a long-held belief that basking sharks may hibernate in deeper water, questions remain about migration patterns. It is not currently known if there is a migration from deep to shallow water or from lower to higher latitudes, or both. The presence, in basking shark livers, of moderately high levels of squalene, a chemical characteristic of deep-water species, suggests that a part of their life history is spent in deep water.

Accurate and reliable quantitative data on basking shark populations in Scottish waters are not available. However, the Marine Conservation Society (MCS) initiated a reporting scheme for public participation in 1987. These data (Figure 3.1) indicate a substantial UK and Scottish peak in sightings in 1989 and 1990 respectively, with a subsequent large decline in sightings during the following 2–3 years. A second peak for Scottish sightings in 1996 was not reflected by overall UK observations. It is likely, though, that the data have been influenced by the timing and level of active promotion of the reporting scheme. Higher media promotion occurred in 1988, 1989, 1990, 1991, 1995 and 1996 (Nicholson *et al.*, 2000).

The basking shark has been exploited for several centuries, initially for the high oil content of the liver, which was used in the steel, medical, cosmetic and tanning industries as well as a fuel for lighting. While there has been limited growth in its use in cosmetic and health supplement products, it has been the demand and associated high prices paid for shark fin in Asian markets that has been the major driving force behind recent basking shark catches.

Throughout the north-east Atlantic, large numbers were caught between the mid-1940s and early 1980s (Figure 3.2), particularly by the Norwegian fleet. In the 1980s and 1990s catch levels were much reduced despite the high demand for shark fin (ICES, 1995; Anon., 2000). Several recent attempts to establish a Scottish fishery based in the Minch and Clyde areas failed because of marketing difficulties and widely fluctuating shark

Figure 3.1
Basking shark sightings reported to the Marine Conservation Society.
(a) Total UK sightings. (b) Scottish sightings.

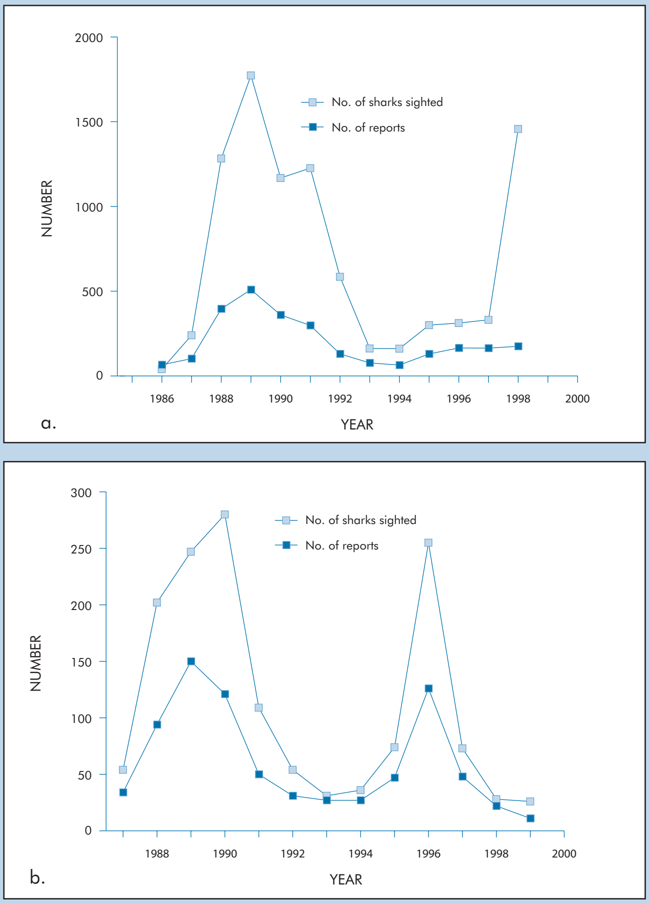
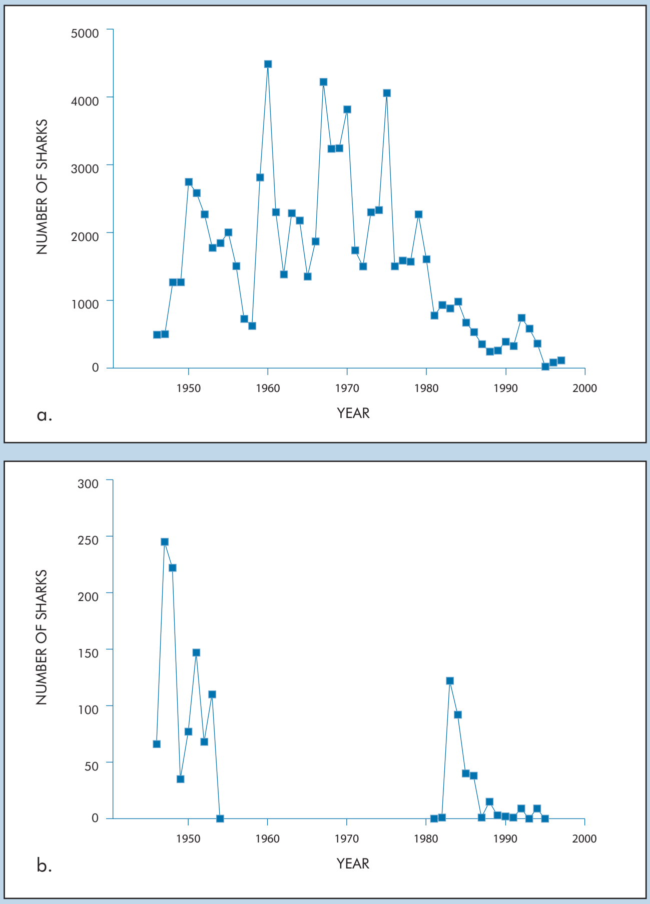


Figure 3.2
Targeted basking shark landings.
(a) North-east Atlantic. (b) Scotland only.



numbers (Fairfax, 1998; Kunzlik, 1998) (Table 3.3).

Although the influence of natural cyclical factors makes assessments of population trends difficult, it is thought that their biology and site-faithfulness make basking sharks particularly vulnerable to overexploitation. Some directed fisheries have seen catch declines of 50% to over 80% within a decade (Table 3.3). There has been no subsequent population recovery, indicating that there is little or no migration of individuals from other areas.

There are no regular, scientifically supported surveys of basking shark abundance in UK waters. Little is known of basking shark life history, feeding ecology and migration habits. Further study is essential to determine their present status in Scottish waters. In February 2001, a three-year project funded jointly by DEFRA, CEFAS and MBA was initiated to provide new information about the movements, distribution and population dynamics of basking sharks in European waters, combining data from archival satellite tags with sighting, stranding and fisheries records.

Table 3.3 Trends in basking shark fisheries
Sources: Fairfax, 1998; Kunzlik, 1998; Anon., 2000; Nicholson *et al.*, 2000).

Geographical area and description of records	Time scale	Average catches or sightings per year	Overall (decline) or increase in catches
Achill Island, Ireland, a targeted coastal basking shark fishery	1947–1975	360/year in 1947–1950 1,475/year in 1951–1955 489/year in 1956–1960 107/year in 1961–1965 64/year in 1966–1970 50/year in 1971–1975 Rarely seen in 1990s	>95% decline in 25 years
West coast of Scotland	1946–1953	121/year throughout fishery 142/year in 1946–1949 100/year in 1950–1953	~30% in 7 years, but trend unclear
Firth of Clyde, Scotland	1982–1994	58.6/year in first 5 years 4.8/year in last 5 years	>90% in 12 years
Norwegian catches	1946–1996	837/year in 1946–1950 554/year in 1951–1955 1,541/year in 1956–1960 1,792/year in 1961–1965 3,213/year in 1966–1970 2,236/year in 1971–1975 1,706/year in 1976–1980 797/year in 1981–1985 343/year in 1986–1990 403/year in 1991–1995	87% decline from peak landings in late 1960s to levels in the early 1990s
North-east Atlantic (all catches combined)	1946–1996	1,254/year in 1946–1950 2,094/year in 1951–1955 2,030/year in 1956–1960 1,899/year in 1961–1965 3,277/year in 1966–1970 2,385/year in 1971–1975 1,706/year in 1976–1980 848/year in 1981–1985 355/year in 1986–1990 407/year in 1991–1995	90% decline from the main period of peak landings in the late 1960s to landings in the late 1980s. This followed 20 years of fluctuating but rising catches

Issues and implications

Scottish coastal waters hold at least 18 species of shark, eight species of ray and three species of skate. Improved knowledge and conservation measures are required for their preservation. Vulnerable to commercial exploitation, several species have shown declines and four now merit statutory protection. The biggest among them – the common skate and the basking shark – have been pushed to commercial extinction.

Sources of data

Considerable reliance on catch data has provided an incomplete picture of the status and ecology of sharks, rays and skates in the seas around Scotland. Satellite tagging, combined with sighting, stranding and fisheries data, is leading to an improved understanding of the movements, distribution and population dynamics of basking shark in European waters.

References

Anon. (2000). *Proposal to Include the Basking Shark* (Cetorhinus maximus) *on Appendix II of the Convention on International Trade in Endangered Species* (CITES). UK submission to the 11th Meeting of the Conference of CITES parties (Cop 11), Kenya, 1999.

Brander, K. (1981). Disappearance of the common skate, *Raja batis*, from the Irish Sea. *Nature* **290**: 48–50.

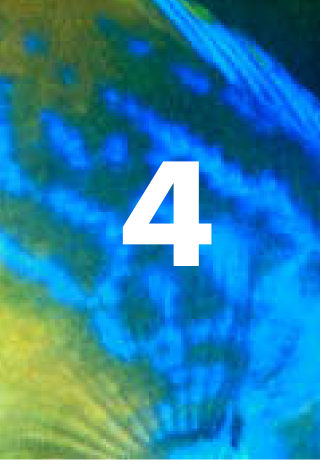
Fairfax, D. (1998). *The Basking Shark in Scotland. Natural History, Fishery and Conservation.* Tuckwell Press, East Linton, Scotland.

ICES. (1995). *Report of the Study Group on Elasmobranch Fishes.* CM 1995/G: 3. International Council for the Exploration of the Sea, Denmark.

Kunzlik, P. A. (1998). *The Basking Shark.* Scottish Information Pamphlet, No. 14. Department of Agriculture and Fisheries for Scotland, Aberdeen.

Nicholson, D., Harris, E. and Pollard, S. (2000). *The Location and Usage of Sites in Scotland by the Basking Shark* Cetorhinus maximus. Scottish Natural Heritage, commissioned report (unpublished), F99AA402. Scottish Natural Heritage, Edinburgh.

Walker, P. (1996). *Sensitive Skates or Resilient Rays? Spatial and Temporal Shifts in Ray Species Composition in the Central and Northwestern North Sea.* CM 1996/Mini: 4. International Council for the Exploration of the Sea, Denmark.



4 Dolphins, porpoises and whales

Introduction

Twenty-five species of cetacean (dolphins, porpoises and whales) have been recorded in British and Irish waters within the last 100 years, and 23 within the last 25 years (Evans, 1992). Of these, 22 species have been sighted alive and reported more than once around Scotland. Surveys carried out between 1979 and 1998 off the north and west of Scotland by the Joint Nature Conservation Committee (JNCC) Seabirds at Sea Team recorded 15 species (Weir *et al.*, 2001). An overview of species occurring within Scottish waters, combining information from several sources, is given in Table 4.1.

In the past, commercial whaling activities reduced populations of target species throughout the north-east Atlantic and northern North Sea. Although quantitative estimates of the scale of such reductions are not possible, anecdotal evidence combined with catch records suggest that sperm (*Physeter macrocephalus*) and sei (*Balaenoptera borealis*) whales sustained at least moderate population reductions, while blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaengliae*) and northern right whale (*Eubalaena glacialis*) populations were greatly reduced (Thompson, 1928; Brown, 1976; Evans, 1992).

Sperm whale (*Physeter macrocephalus*), Forth estuary. *E. Mackey*

White-beaked dolphin (*Lagenorhynchus albirostris*), Forth estuary. *E. Mackey*

Bottlenose dolphin (*Tursiops truncatus*). *D. Whitaker*

A Norwegian-owned commercial whaling operation, established in Loch Tarbert, Harris, around 1903, operated from 1904 to 1928 and briefly reopened between 1950 and 1951. Catch records and reported impacts of the wider industry are given in Table 4.2. A global moratorium on commercial whaling was imposed by the International Whaling Commission (IWC) in 1986. Norway lodged a formal objection and resumed exploitation of North Atlantic minke whale in 1993, taking 153 whales in the first year, increasing to 580 in 1997. A Norwegian national quota of 711 was set for 2003.

Cetaceans are currently protected throughout British waters under the Wildlife and Countryside Act (1981, reviewed 1986) and the Whaling Industry (Regulation) Act (1934, as amended 1981). The Nature Conservation (Scotland) Bill, which is expected to be enacted in 2004, will strengthen the existing legislation by including a provision for prosecuting those who cause harm or harassment through 'recklessness', whereas previously an intention had to be proven.

Trends

Few data are available for robust assessments of cetacean population trends. The OSPAR Commission (2000) reported that, following the moratorium on commercial whaling, most species of large whale are showing signs of recovery in European waters.

Table 4.1 Status of cetacean species occurring in Scottish waters
Sources: Evans *et al.*, 1986; Evans, 1992; Hammond *et al.*, 1995; Shrimpton and Parsons, 1999; Reid *et al.*, 2003.

Species	Occurrence	Abundance estimate	Evidence for population increase/decline
Harbour porpoise (*Phocoena phocoena*)	Common in both inshore and offshore shelf water	Approx. 150,000 in UK waters (1994)	Decline (North Sea)
Bottlenose dolphin (*Tursiops truncatus*)	Locally frequent in inshore waters	Approx. 130 in the Moray Firth (1999)	Decline, perhaps due partly to changing distribution
Risso's dolphin (*Grampus griseus*)	Locally frequent in inshore waters	42 individuals identified in the Minch (1999)	Unknown
White-beaked dolphin (*Lagenorhynchus albirostris*)	Frequent in both inshore and offshore shelf waters	Approx. 7,800 in North Sea and English Channel (1994)	Unknown
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	Common in offshore waters	Approx. 74,600 off north-west and west Scotland (1998)	Unknown
Common dolphin (*Delphinus delphis*)	Seasonally frequent in offshore waters, locally frequent in inshore waters	None	Unknown
Striped dolphin (*Stenella coeruleoalba*)	Rare	None	Unknown
Northern bottlenose whale (*Hyperdoon ampullatus*)	Uncommon in offshore waters	None	Unknown
Cuvier's beaked whale (*Ziphius cavirostris*)	Rare	None	Unknown
Sowerby's beaked whale (*Mesoplodon bidens*)	Rare	None	Unknown
True's beaked whale (*Mesoplodon mirus*)	Very rare	None	Unknown
Beluga or white whale (*Delphinapterus leucas*)	Very rare	None (only 14 live sightings)	Unknown
Killer whale (*Orcinus orca*)	Frequent in offshore waters, locally frequent in inshore waters	3,500–12,500 in eastern North Atlantic (1990)	Unknown
False killer whale (*Pseudorca crassidens*)	Very rare	None (only four live sightings)	Unknown
Long-finned pilot whale (*Globicephala melas*)	Common in offshore waters, occasional in inshore waters	Approx. 778,000 in North Atlantic (1987–1989)	Unknown
Sperm whale (*Physeter macrocephalus*)	Frequent in offshore waters	None	Unknown
Blue whale (*Balaenoptera musculus*)	Rare	None	Recovery (central North Atlantic)
Fin whale (*Balaenoptera physalus*)	Frequent in offshore waters	Approx. 47,300 in North Atlantic (1992)	Unknown
Sei whale (*Balaenoptera borealis*)	Occasional in offshore waters (NB: highly variable between years)	None	Unknown
Minke whale (*Balaenoptera acutorostrata*)	Frequent in both inshore and offshore shelf waters	Approx. 8,400 in North Sea, Celtic Sea and Skagerrak (1994), 112,000 in eastern North Atlantic (1995)	Unknown
Humpback whale (*Megaptera novaengliae*)	Rare	10,000–15,000 in North Atlantic in 1992–1993	Recovery
Northern right whale (*Eubalaena glacialis*)	Very rare	Extremely rare or possibly extinct in eastern North Atlantic	Decline

Risso's dolphins.
C. MacLeod/Seapics

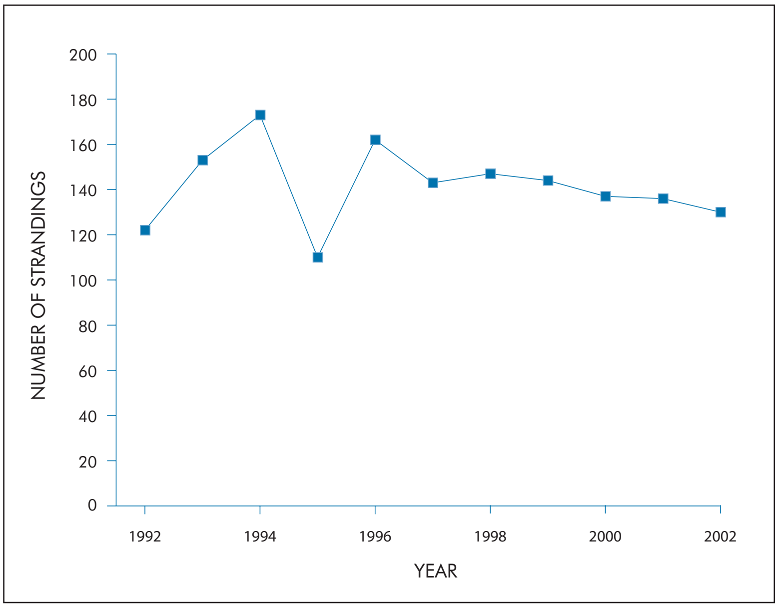
Far right: Humpback whale.
A. Rouse

Species	Scottish catch records			Population reduction by whaling
	Shetland (1903–1928)	Outer Hebrides (1903–1928)	Outer Hebrides (1950–1951)	
Northern bottlenose whale (*Hyperdoon ampullatus*)	25	1	0	Uncertain
Sperm whale (*Physeter macrocephalus*)	19	76	1	Reduced
Blue whale (*Balaenoptera musculus*)	85	310	6	Greatly reduced
Fin whale (*Balaenoptera physalus*)	4,536	1,492	46	Greatly reduced
Sei whale (*Balaenoptera borealis*)	1,839	375	3	Reduced
Minke whale* (*Balaenoptera acutorostrata*)	–	–	–	Uncertain
Humpback whale (*Megaptera novaengliae*)	51	19	0	Greatly reduced
Northern right whale (*Eubalaena glacialis*)	6	94	0	Greatly reduced

*Not targeted by Scottish fishery but taken by Norwegian vessels around the Northern Isles.

Table 4.2
Scottish whaling catch records 1903-1951.
Sources: Thompson, 1928; Brown, 1976; Evans, 1992.

Figure 4.1
Total recorded Scottish cetacean strandings (1992–2002)
Source: Scottish Agricultural College.



Recorded UK and Irish cetacean strandings increased steadily between the 1960s and 1980s, possibly reflecting increased population sizes. It should be noted that these are reported strandings, and some caution must be applied when relating these figures to the true number of total stranding events. Otherwise, there is very little direct evidence on which to base unequivocal statements of any population recovery. Formal recording of strandings around Scotland began in 1992. Between 1992 and 1995 Scottish strandings accounted for about 60% of the UK total (Mayer, 1996). In the period up to 2002, stranding events of both large and small cetacea showed little change (Figure 4.1). Similarly, there was little change in the proportion of species stranded (Figure 4.2), with the overall numbers broadly reflecting the prevalence of species around Scotland.

The Moray Firth is host to the world's most northerly population of bottlenose dolphin (*Tursiops truncatus*) and the only known 'resident' population of this species in the North Sea. Statistical studies suggest that this is an isolated, barely viable population, which may be in decline

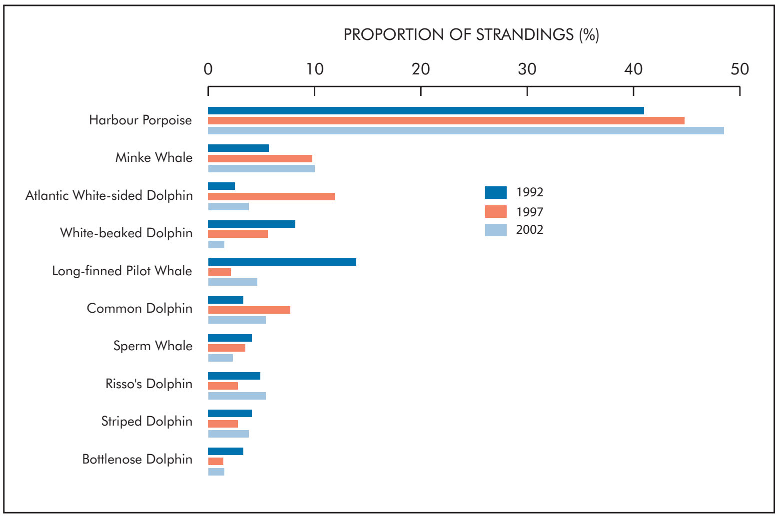


Figure 4.2
The 10 species most commonly stranded on Scottish coasts represented as a percentage of all Scottish strandings for 1992, 1997 and 2002.

(Sanders-Reed *et al.*, 1999). Part of the apparent decline may be accounted for by a change in the distribution of the population, having being sighted also in the Firths of Tay and Forth.

Issues and implications

Smaller whales, dolphins and porpoises have remained largely unaffected by direct commercial exploitation. They have nevertheless been faced with a range of threats from other sources, the greatest of which is entanglement in fishing gear. Studies of incidental catches are few but indicate that porpoises and dolphins are at greatest risk from bottom set nets and pelagic trawls respectively. Estimates for a range of north-eastern Atlantic pelagic trawl fisheries arrived at a catch rate of one dolphin for every 98 hours of towing (Morizur *et al.*, 1999).

Whaling harpoon, Leith docks, Edinburgh.
J. Baxter

Above: Dundee whaling fleet leaving port for a voyage to the Davis Straits about the turn of the 19th-20th century. *Dundee Museum*

Harbour porpoise (*Phocoena phocoena*) stranding.
P. Kay

Box 4.1 UK small cetacean bycatch response strategy

The strategy reviews fisheries interactions with small cetaceans in UK waters and the need to reduce bycatch of small cetaceans in general and harbour porpoises in particular. It recognises work that has been carried out with the support and cooperation of the fishing industry to identify where bycatch is a problem. It establishes bycatch reduction targets for specific fisheries over the next three years and makes recommendations as to mitigation techniques that should be employed by these fisheries. Key recommendations relate to compulsory use of acoustic pingers in certain fisheries, the need for an effective observer scheme, continued research into practical and cost-effective mitigation measures and the need to support further surveys to enable a better understanding of small cetacean abundance and distribution in UK waters.

The harbour porpoise (*Phocoena phocoena*) is the most abundant of the Scottish cetaceans, with the highest reported concentrations around the western and north-eastern coasts (Evans, 1992, 1997). A survey of North Sea harbour porpoise in 1994 estimated a population size of around 300,000 (Hammond *et al.*, 1995). Of these, some 7,000 per year are thought to have perished as a result of incidental capture in the Danish gillnet fishery alone (Lowry and Teilmann, 1994; Vinther, 1995). Overall, fishery-related mortality of harbour porpoise is believed annually to exceed 2% of the total North Sea population, a rate considered by the IWC to be unsustainable. As a first step towards a marine mammal conservation strategy, the Agreement on Small Cetaceans of the Baltic and North Seas (ASCOBANS) has recently pressed the EC to restrict incidental capture to less than 1.7% per year. Additional data on the rate of incidental capture specifically relating to Scottish fisheries are currently being gathered with the cooperation of a number of skippers of Scottish fishing vessels. The UK small cetacean bycatch response strategy (Box 4.1) sets out proposals to help tackle this issue (DEFRA, 2003).

Pollution of the marine environment has increased greatly in the last 100 years. Organochlorines such as dichlorodiphenyl-trichloroethane (DDT), polychlorinated biphenyls (PCBs) (and their metabolites and impurities) and other man-made chemicals are more soluble in fat than in water and so will accumulate to high levels in animals that rely on blubber as an energy store. At critical concentrations, an interaction with an animal's hormonal system may occur, resulting in reduced reproductive performance and disease resistance. The manufacture of many of these chemicals has been strictly controlled in Europe for over 20 years, but careless disposal, leakage from storage sites and persistence in marine sediments has resulted in a continued accumulation in marine mammals. Comparatively higher levels are found in coastal species that are at or close to the top of the food chain. Levels found in cetaceans from the west of Scotland are lower than those found in the North Sea (Shrimpton and Parsons, 1999). Trace metal levels measured in resident Scottish cetaceans are not considered high when compared with those observed for marine mammals world-wide.

Noise from marine traffic, military activity, coastal industry and oil exploration and production is thought to cause varying levels of disruption to cetacean activity. Shock waves and explosions may cause direct tissue damage and permanent auditory organ damage. An increase in background noise can interfere with acoustic communication, reducing the distance over which such communication can take place. Around Scotland, overall seismic activity associated with oil exploration has increased since 1994. A code of practice, *Guidelines for Minimising Acoustic Disturbance to Small Cetaceans from Seismic Surveys*, was introduced by the UK government in 1998.

The depletion of herring stocks may have resulted in the decline of UK harbour porpoise populations during the last 50 years (Evans, 1990; Hammond *et al.*, 1995). The recovery of herring stocks following a fishing ban in 1977 was followed by a slight increase in sightings of harbour porpoises. In the 1980s there was a decline in both seabird and harbour porpoise numbers in Shetland coastal waters, coinciding with successive years of poor recruitment of sandeels into the adult population (Evans, 1997).

In terms of interaction with man-made marine debris, entanglement, particularly in discarded or lost fishing gears, constitutes the greatest hazard (Laist, 1997; Gill *et al.*, 2000). Scars caused by rope or net abrasion are regularly seen, but evidence of incidents in which entanglement has resulted in death by drowning or suffocation is relatively rare, largely because the majority of these events occur below the sea surface. Ingestion of debris also occurs, but the available evidence suggests that this is not as common as entanglement and is far less likely to result in death (Laist, 1997)

Collision with marine vessels is known to occur, but the frequency of occurrence and the extent of injuries sustained are unknown. Codes of conduct to minimise the impacts from recreational sea users were introduced by the UK government in 1999: *Guidelines for Minimising Disturbance to Cetaceans from Recreation at Sea* and *Minimising Disturbance to Cetaceans from Whale Watching.*

Although knowledge of the distribution and ecology of the cetacea found in Scottish waters is improving, population trend data are few. The global debate on the resumption of commercial whaling continues to be dominated by disagreements on the size and stability of target whale populations.

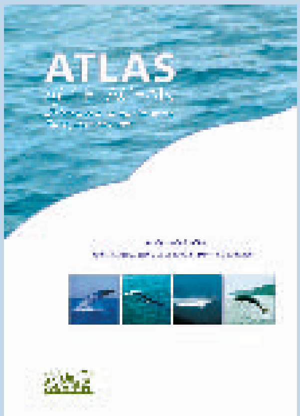
Sources of data

The precise population status of most cetacea occurring in Scottish waters, and indeed those around the whole of the UK, is largely unknown, with reliable scientific data restricted to observations on distribution rather than numerical abundance. The Joint Cetacean Database (JCD) is a repository of sightings data recently created by merging three databases previously held separately by the Sea Watch Foundation, the JNCC and the Sea Mammal Research Unit (SMRU). A product of this (Box 4.2) is the recently published *Atlas of Cetacean Distribution in North-West European Waters* (Reid *et al*., 2003).

Records for Scottish cetacean strandings are compiled annually by the Scottish Agricultural College Veterinary Investigations Centre. Systematic collation began in 1992.

Box 4.2 Atlas of Cetacean Distribution in North-West European Waters

The Atlas (Reid *et al*., 2003) provides a comprehensive account of the distribution of all species of cetacean known to have occurred in the waters off north-west Europe in the last 25 years. Individual species accounts include information on identification, behaviour and social organisation, diet and habitat preferences. Distribution maps for each species are based on data in the Joint Cetacean Database, with context information on global distribution and status in north-west Europe.



References

Brown, S. G. (1976). Modern whaling in Britain and the north-east Atlantic Ocean. *Mammal Review* **6**: 25–36.

DEFRA. (2003). UK S*mall Cetacean Bycatch response Strategy*. A consultation paper outlining the proposed strategy by the Department for Environment, Food and Rural Affairs, the Scottish Executive, the Welsh Assembly Government and the Department of Agriculture and Rural Development in Northern Ireland to reduce the incidental capture of small cetaceans in UK fisheries. Department for Environment, Food and Rural Affairs, London.

Evans, P. G. H. (1990). *Harbour Porpoise* (Phocoena phocoena) *in British and Irish Waters*. Paper submitted to the IWC Scientific Committee meeting, June 1990.

Evans, P. G. H. (1992). *Status Review of Cetaceans in British and Irish Waters*. Report to the UK Department of the Environment, London. Sea Watch Foundation, Oxford.

Evans, P. G. H. (1997). *Ecological Studies of the Harbour Porpoise in Shetland, North Scotland: Final Report*. Sea Watch Foundation, report for WWF-UK, Oxford.

Evans, P. G. H., Harding, S., Tyler, G. and Hall, S. (1986). *Analysis of Cetacean Sightings in the British Isles, 1958–1985*. CSD Report No. 892. Nature Conservancy Council, Peterborough.

Gill, A., Reid, R. J. and Fairbairns, B. R. (2000). Photographic and strandings data highlighting the problem of marine debris and creel rope entanglement to minke whales (*Balaenoptera acutorostrata*) and other marine life in Scottish waters. In: *Proceedings of Fourteenth Annual Conference of European Cetacean Society*, 3–6 April 2000, Cork, Ireland.

Hammond, P. S., Benke, H., Berggren, P., Borchers, D. L., Buckland, S. T., Collet, A., Heide-Jørgensen, M. P., Heimlich-Boran, S., Hiby, A. R., Leopold, M. F. and Øien, N. (1995). *Distribution and Abundance of the Harbour Porpoise and other Small Cetaceans in the North Sea and Adjacent Waters*. Final Report, October 1995. Life Project, LIFE 92–2/UK/027.

Laist, D. (1997). Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: *Marine Debris: Sources, Impacts and Solutions*. Coe J. and Rogers, D. B. (eds), pp. 99–119. Springer Verlag, New York.

Lowry, N. and Teilmann, J. (1994). Bycatch and bycatch reduction of the harbour porpoise (*Phocoena phocoena*) in Danish waters. In: *Report of the International Whaling Commission (Special Issue 15)*: 203–209.

Mayer, S. (1996). *A Review of Live Strandings of Cetaceans: Implications for Their Veterinary Care, Rescue and Rehabilitation in the UK*. Whale and Dolphin Conservation Society, Bath.

Morizur, Y., Berrow, S. D., Tregenza, N. J. C., Couperus, A. S. and Pouvreau, S. (1999). Incidental catches of marine-mammals in pelagic trawl fisheries of the northeast Atlantic. *Fisheries Research* **41**: 297– 307.

OSPAR Commission. (2000). *Quality Status Report 2000*. OSPAR Commission, London.

Reid, J. B., Evans, P.G. H. and Northridge, S.P. (2003). *Atlas of Cetacean Distribution in North-West European Waters*. Joint Nature Conservation Committee, Peterborough.

Sanders-Reed, C. A., Hammond, P. S., Grellier, K. and Thompson, P. M. (1999). *Development of a Population Model for Bottlenose Dolphins*. Scottish Natural Heritage Research Survey and Monitoring Report, No. 156. Scottish Natural Heritage, Battleby, Perth.

Shrimpton, J. H. and Parsons, E. C. M. (1999). *Cetacean Conservation in West Scotland*. Hebridean Whale and Dolphin Trust, Version 1.2.

Thompson, D. A. (1928). On whales landed at the Scottish whaling stations during the years 1908–1914 and 1920–1927. *Scientific Investigations Fishery Board of Scotland* **No. 3**: 1–40.

Vinther, M. (1995). Incidental catch of the harbour porpoise (*Phocoena phocoena*) in the Danish North Sea gill-net fisheries: preliminary results. *Proceedings of the Scientific Symposium on the North Sea Quality Status Report 1993, 1994*. Ebeltoft, Danish Environmental Protection Agency, Copenhagen.

Weir, C. R., Pollock, C., Cronin, C. and Taylor, S. (2001). Cetaceans of the Atlantic Frontier, north and west of Scotland. *Continental Shelf Research* **21**: 1047–1071.

5 Seals

Introduction

Two species, the grey seal (*Halichoerus grypus*) and harbour or common seal (*Phoca vitulina*), are present around the coast of Scotland in internationally important numbers. For thousands of years they were hunted for their pelts, oil and meat, but overexploitation by the early 1900s forced the establishment of a closed season for grey seals to prevent extinction (McGillivray, 1995). A UK-wide annual grey seal cull was maintained from 1962 until 1979, when it was abandoned in the face of sustained public protest. Harbour seals continued to be hunted for their skins until the early 1970s, when up to 90% of pups were taken annually. A ban on UK fur trading was established in 1973.

UK coastal waters support some 40% of the European harbour seal subspecies *Phoca vitulina vitulina* and 5% of the world population. About 90% of the UK harbour seal population is found in Scottish waters (SMRU, 2001). In 1988, a viral epidemic swept through the North Sea harbour seal population. Phocine distemper virus (PDV) was previously unknown but is related to canine distemper virus and the epidemic was probably a natural event, as similar epidemics are known to have occurred in the past. The disease reduced overall North Sea populations by over 40% and was most severe along the continental coasts (OSPAR Commission, 2000). In England, 50% of seals resident in The Wash were reported to have died, but Scottish populations were less affected. Mortality estimates for the Moray Firth populations vary between 10% and 20% (Thompson and Miller, 1992), with some west-coast populations sustaining slightly greater losses.

In 2002, the British grey seal population was estimated (to the nearest thousand) at 134,000 animals aged one year or older (SCOS, 2003). About 40% of the world's grey seals breed at well-established sites around Britain. Of these, over 90% – some 122,000 – are associated with Scottish coastal sites.

Trends

Throughout Europe and the UK, harbour seal numbers have rapidly returned to, or exceed, pre-1988 epidemic levels. Between 1996 and 2001, around 29,700 harbour seals were counted in Scotland (Table 5.1) out of a total of 33,700 in England and Scotland combined (SCOS, 2003). Periodic estimates at selected sites from the late 1980s to the present suggest that populations have remained largely stable, although regional counts show local fluctuations. Surveys carried

Below: Harbour seal.
L. Gill/SNH

Below right: Grey seal with satellite tag.
J. Baxter

Table 5.1 Sizes and status of European populations of harbour seals (numbers given pre-date the PDV epidemic of 2002)

Region	Population size[1]	Years when latest information was obtained	Population status
Outer Hebrides	2,400	1996–2000	Possibly increasing
Scottish west coast	12,800	1996–2000	Possibly increasing
Scottish east coast	1,800	1996–1997	Stable
Shetland	4,900	1996–2001	Possibly decreasing
Orkney	7,800	1996–2001	Possibly decreasing
Scotland	**29,700**		

Many of the population size estimates represent counts of seals. They should be considered as minimum estimates of total population size. Counts are rounded to the nearest 100 seals.

out by the University of Aberdeen suggest a decline in numbers in the Inner Moray Firth, while a 2001 population survey in Orkney and Shetland suggested a reduction in numbers of 9% and 18.5%, respectively, compared with the 1997 counts (Scottish Executive web site).

A new outbreak of PDV in 2002, originating in Denmark, again affected UK harbour seal populations. Populations in The Wash were again most badly affected. Sightings of dead, infected animals from around the coast of Scotland were recorded. At this time it is not possible to quantify the scale of the impact of this new epidemic (SCOS, 2003). A Scotland-wide Conservation Order for harbour seals was issued for an initial period of two years by the Scottish Executive on 3 September 2002. The order included grey seals within the Greater Moray Firth area only.

British grey seal populations increased steadily between 1984 and 1997, with an average rise of about 6% per year. This rate of increase was maintained at 5.6% between 1997 and 2001. Since the 1970s, pup production has increased greatly in the Orkney Isles and the Outer Hebrides, with a lesser expansion in the Inner Hebrides and North Sea (Figure 5.1). There is some evidence of a slow-down in the increase in pup production in recent years, with production at the main breeding sites showing an average increase of around 2.8% between 1997 and 2002 compared with 5.2% between 1992 and 1996 and 6.2% between 1987 and 1991.

Issues and implications

The status of both grey and harbour seal is currently considered to be good, although the effect of the 2002 PDV outbreak on Scottish harbour seal numbers cannot yet be predicted.

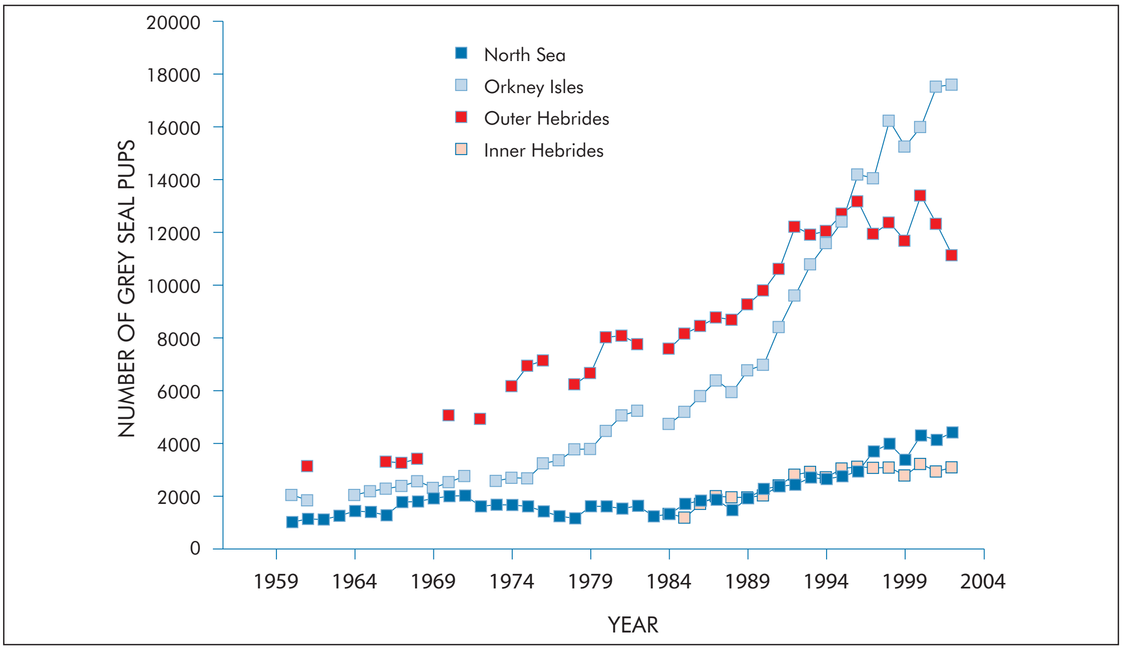


Figure 5.1
Grey seal pup production at main breeding sites
Source: Sea Mammal Research Unit

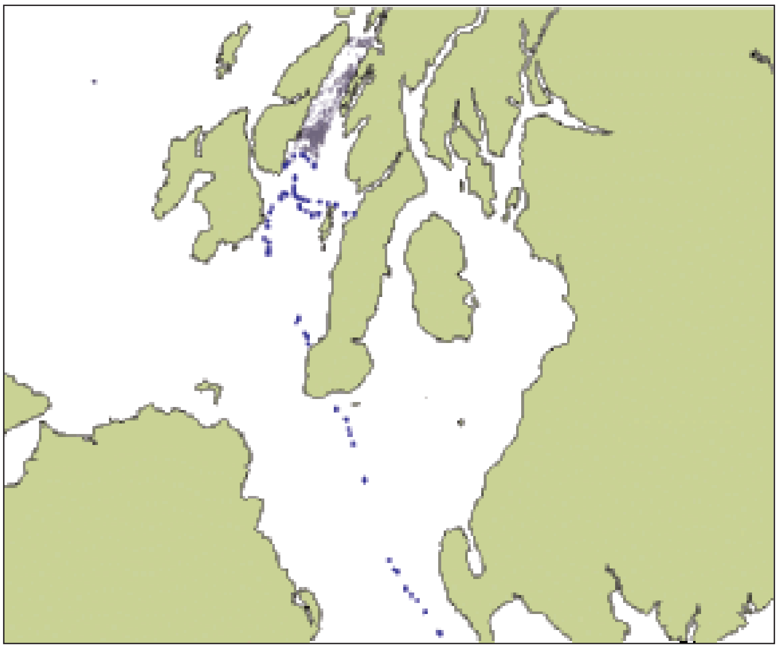


Figure 5.2
Track of harbour seal tagged on Jura, 2004.
Source: Louise Cunningham/SMRU

The reasons for the sustained growth in the grey seal population are not known, but the disproportionate rise in areas such as the Outer Hebrides suggests that the availability of sites free of human disturbance may be a factor in breeding success.

Both the fishing and fish farm industries have expressed concern with the increasing seal numbers, arguing that this has led to increased damage to farmed stocks and fish cages and has contributed to reductions in wild fish stocks. The fishing industry has called for the initiation of a culling programme. At present, there are no scientific data to indicate that depletion of north-eastern Atlantic commercial fish stocks is correlated with changes in seal numbers. Estimates of seal, harbour porpoise and seabird predation on North Sea fish suggest an annual consumption by each of 2–3% of the total fish biomass (Saunders *et al.*, 2002; see Figure 8.8). This compares with the removal of an estimated 25–30% by the fishing industry (Fifth International Conference on the Protection of the North Sea, 1997).

The debate surrounding grey seal population growth and the need for culling to preserve commercial fish stocks will continue. The interaction between seals and fisheries is complex, incorporating scientific, environmental, social, cultural and economic considerations, but the fundamental relationship between seal population dynamics and fisheries has yet to be established. A number of research projects directed towards providing such data are currently underway at the SMRU.

Sources of data

UK seal populations are monitored regularly by the SMRU on behalf of the Natural Environment Research Council (NERC). The NERC provides advice to the UK government on the size and status of the British seal population under the Conservation of Seals Act, 1970. This, together with the EC Habitats Directive, provides protection to seals when they come ashore to pup, breed and moult. Recent monitoring has been carried out largely by aerial survey and mainly at Scottish locations. As seals spend a large proportion of their time in the open sea, counting is carried out at times of greatest shore-based activity; during pupping season for grey seals and moulting for harbour seals. Total population estimates are derived from these data.

Recent data on seal populations are available on the Scottish Executive web site.

References

Fifth International Conference on the Protection of the North Sea. (1997). Assessment report on fisheries and fisheries related species and habitats issues. *Report from the Committee of North Sea Senior Officials to the Intermediate Ministerial Meeting on the Integration of Fisheries and Environmental Issues, 1997* (IMM 97), Bergen. Table 5.1 Sizes and status of European populations of harbour seals (numbers given pre-date the PDV epidemic of 2002).

McGillivray, D. (1995). Seal conservation legislation in the UK – past, present, future. *The International Journal of Marine and Coastal Law* **10**: 19–51.

OSPAR Commission. (2000). *Quality Status Report 2000, Region II – Greater North Sea*. OSPAR Commission, London.

Saunders, G., Dobson, J. and Edwards, A. (2002). The state of Scotland's seas and estuaries. In: *The State of Scotland's Environment and Natural Heritage*. Usher, M. B., Mackey, E. C. and Curran, J. C. (eds). The Stationery Office, Edinburgh.

SCOS. (2003). *Scientific Advice on Matters Related to the Management of Seal Populations: 2003*. Natural Environment Research Council Special Committee on Seals.

SMRU. (2001). *Surveys of Harbour Seals on the West and East Coasts of Scotland.* Scottish Natural Heritage, Commissioned Report, F00AA417. Sea Mammal Research Unit, Edinburgh.

Thompson, P. M. and Miller, D. (1992). Phocine distemper virus outbreak in the Moray Firth common seal population: an estimate of mortality. *Science of the Total Environment* **115**: 57–65.

6 Seabirds

This chapter was prepared by P. Shaw (SNH).

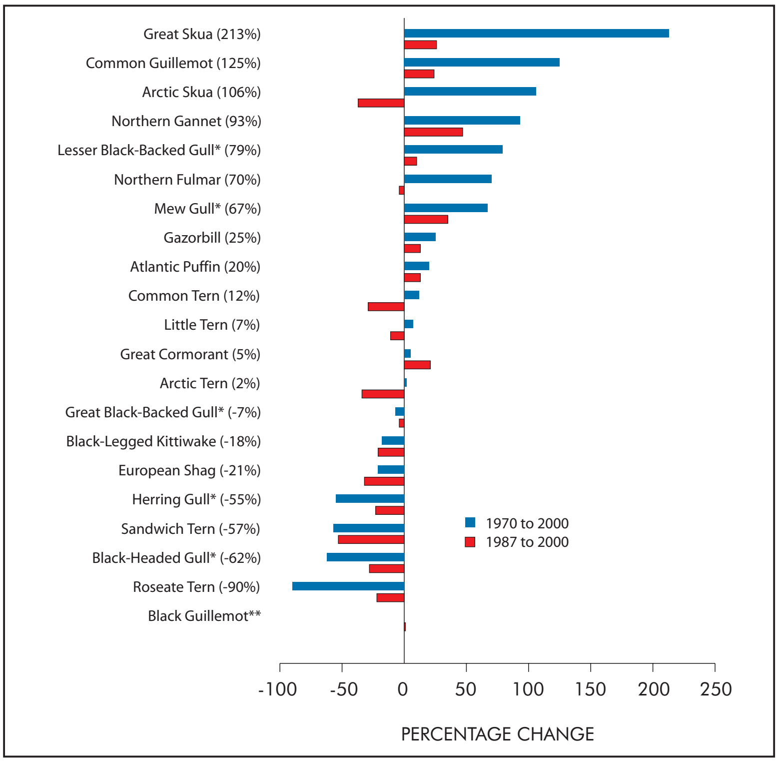
Atlantic puffin (*Fratercula arctica*).
L. Campbell

Introduction

The seas around Britain and Ireland are among the richest in the world for breeding seabirds, supporting almost 8 million birds of 25 species. Many of these have a high proportion of their breeding population in Scotland, which supports 60% of the world's great skuas (*Catharacta skua*), about half of the world's northern gannets (*Morus bassanus*) and about one third of the world's Manx shearwaters (*Puffinus puffinus*) (Mitchell *et al.,* 2004). Four species have more than 95% of their combined British and Irish population in Scotland, while 14 species have more than half of their population in Scottish breeding colonies. The latter include all four auk species, the northern fulmar (*Fulmarus glacialis*) and northern gannet, as well as great and Arctic skua (*Stercorarius parasiticus*). Most of those with less than half of their British population in Scotland are gull or tern species.

Trends

There have been three comprehensive seabird censuses in Britain spanning 30 years: 1969-70, 1985-88 and 1998-2002. These are referred to here as the '1970', '1987' and '2000' census, respectively. They provide comparable estimates for 20 seabird species between 1970 and 1987, and for 21 species in Scotland between 1987 and 2000. The most recent census, *Seabird 2000*, included some 3,200 colonies from 40,000 km of the coastline of Britain and Ireland (Mitchell *et al.* 2004). In Scotland, over 3.28 million seabirds were counted, comprising 76% of the UK total and 69% of the British and Irish total. *Seabird 2000* provided the first comprehensive counts of Manx shearwater, European storm-petrel (*Hydrobates pelagicus*) and Leach's storm-petrel (*Oceanodroma leucorhoa*). It included inland as well as coastal colonies of great cormorant (*Phalacrocorax carbo*), black-headed gull (*Larus ridibundus*), mew (common) gull (*L. canus*), lesser black-backed gull (*L. fuscus*) and common tern



* Change based on coastal colonies only.
**A comparable count of black guillemot (*Cepphus grylle*) was not undertaken during 1969-70, so no change estimate is available for this species during *c.* 1970-2000.

Figure 6.1
Percentage change in the number of seabirds counted in Scotland during c. 1970-2000 and c. 1987-2000. Figures in brackets show the percentage change during c. 1970-2000.
Source: Mitchell *et al.* (2004).

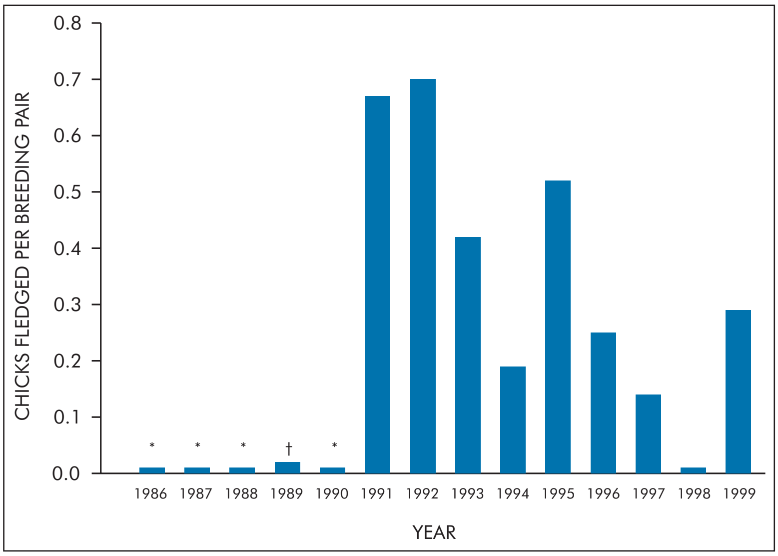


Figure 6.2
Variation in the mean number of Arctic tern chicks fledged per breeding pair, at a sample of colonies in Shetland.
Source: Annual joint reports of JNCC, RSPB and Shetland Oil Terminal Environmental Advisory Group, on seabird numbers and breeding success in Britain and Ireland).
*< 0.01.
†< 0.02.

(*Sterna hirundo*). Scottish counts from all three censuses are listed in Table 6.1. Although the following figures describe changes in seabird abundance throughout Scotland, it should be noted that trends sometimes vary markedly between Scottish regions, for example between populations in the North Sea and Irish Sea/Atlantic Ocean.

Between the 1970 and 2000 censuses, 10 out of 20 species (50%) showed a marked increase in their Scottish breeding population (i.e. by at least 10%), while six species (30%) showed a marked decline (Figure 6.1). The proportion of species showing gains or losses has changed considerably over the c. 30-year period, however. During the first half of the period (c. 1970-1987) 60% of species showed a marked increase, while 20% showed a marked decline. Equivalent figures for the same species during the second half of the period (c. 1987-2000) were 40% and 50%, respectively.

Over the 30-year period, the greatest increases shown were those of great skua, Arctic skua and common guillemot (*Uria aalge*), all of which more than doubled their Scottish populations. Conversely, populations of two gull and two tern species fell by more than half, the most extreme decline being that of roseate tern (*Sterna dougallii*) (-90%), a Biodiversity Action Plan priority species. While roseate tern numbers declined in both halves of the 30 year period (1970-87 and 1987-2000), some species have exhibited a reversal in their population trend. Of 12 species showing a marked population increase during the first half of the period, six have continued to increase, while five have shown a marked decline. In percentage terms, the greatest of these reversals was that of Arctic skua, whose population increased by 226% during 1970-87

Table 6.1
The number of seabirds counted in Scotland during each national census: *Operation Seafarer* (1969-70), *The Seabird Colony Register* (1985-88), and *Seabird 2000* (1998-2002) (from Mitchell *et al.*, 2004). Figures indicate the number of pairs, except where indicated.

Species		1969-70	1985-88	1998-2002	
northern fulmar	*Fulmarus glacialis*	285,067	504,640	485,852	
Manx shearwater	*Puffinus puffinus*	-	-	126,545	
European storm-petrel	*Hydrobates pelagicus*	-	-	21,370	
Leach's storm-petrel	*Oceanodroma leucorhoa*	-	-	48,047	
northern gannet[i]	*Morus bassanus*	96,860	127,867	187,363	
great cormorant	*Phalacrocorax carbo*	3,438	2,986	3,626	
European shag	*P. aristotelis*	27,077	31,560	21,487	
arctic skua	*Stercorarius parasiticus*	1,039	3,388	2,136	
great skua	*Catharacta skua*	3,079	7,645	9,634	
black-headed gull[ii]	*Larus ridibundus*	18,226	9,554	43,191	(6,888)
mew gull[ii]	*L. canus*	12,229	15,134	48,113	(20,467)
lesser black-backed gull[ii]	*L. fuscus*	12,031	19,524	25,057	(21,565)
herring gull[ii]	*L. argentatus*	159,237	92,950	72,130	(71,659)
great black-backed gull[ii]	*L. marinus*	15,950	15,315	14,776	(14,773)
black-legged kittiwake	*Rissa tridactyla*	346,097	359,425	282,213	
Sandwich tern	*Sterna sandvicensis*	2,465	2,286	1,068	
roseate tern	*S. dougallii*	134	18	14	
common tern	*S. hirundo*	4,285	6,784	4,784	
Arctic tern	*S. paradisaea*	46,385	71,178	47,306	
little tern	*S. albifrons*	308	373	331	
common guillemot[iii]	*Uria aalge*	519,461	943,098	1,167,841	
razorbill[iii]	*Alca torda*	111,038	123,586	139,186	
black guillemot[iii]	*Cepphus grylle*	-	37,172	37,505	
Atlantic puffin	*Fratercula arctica*	410,011	438,101	493,042	

[i] Not fully surveyed in 1998-2002. Extrapolated estimates for 1999.
[ii] Figures for these species in 1969-70 and 1985-88 were for coastal colonies only. In 1998-2002, inland as well as coastal colonies were counted, and are included in the totals for that census. For comparison, figures from coastal colonies are also given (in brackets) for the 1998-2002 census.
[iii] Figures refer to individuals, not pairs.

Source: JNCC

Far left: Northern gannet (*Morus bassanus*)
L. Campbell

Left: Roseate tern (*Sterna dougallii*)
C.Gomersall

but dropped by 37% in 1987-2000. Of four species showing a marked decline during the first half of the period, three (black-headed gull, herring gull (*L. argentatus*) and roseate tern) have continued to decline. Only the great cormorant has reversed this trend.

Breeding populations of great skua and Arctic skua in Britain and Ireland are virtually confined to northern Scotland, where each has more than doubled in size since 1970 (Figure 6.1). But while great skua numbers continued to rise during 1987-2000 (by 26%), the Arctic skua population declined (by 37%) due, in part, to increased predation and competition from great skuas. This may have arisen as a result of a reduction in the volume of fishing discards available to great skuas, which have increasingly turned to preying on Arctic skua chicks, and on other seabird species. The latter include black-legged kittiwakes (*Rissa tridactyla*), which Arctic skuas parasitise.

Common guillemot, by far the most abundant seabird species in Scotland, has shown a sustained rise between the three censuses, increasing by 82% during 1970-87, and by a further 24% during 1987-2000. Two other auk species, razorbill (*Alca torda*) and Atlantic puffin (*Fratercula arctica*), have shown more modest gains during each half of the period, resulting in increases of 25% and 20%, respectively, over 1970-2000. Counts of the least abundant auk species, the black guillemot, have changed little since a survey conducted in 1982-91 (+1%). Numbers in the Northern Isles, the core of its UK range, increased by 14%, despite heavy mortality caused by the *Braer* oil spill (see Box 10.1) in 1993 (Mitchell *et al.,* 2004).

The northern gannet has shown a strong recovery from historical persecution, population estimates having increased by 32% during 1970-87 and by 47% during 1987-2000, yielding an increase of 93% over the whole period. Northern fulmar numbers have also increased strongly over the 30-year period (+70%), despite a slight decline (-4%) during 1987-2000, particularly in the more densely populated areas in northern Scotland. No trend data are available for three other petrel species (Manx shearwater, European storm-petrel and Leach's storm-petrel), for which robust estimates were made for the first time in 1998-2002. Of around 48,000 pairs of Leach's storm-petrel counted in Britain and Ireland, 94% were found in just four small islands in the St Kilda archipelago (Mitchell *et al.*, 2004).

Two gull species, lesser black-backed gull and mew (common) gull, also showed strong increases within coastal colonies, of 79% and 67%, respectively. The bulk of the mew gull's Scottish population breeds inland, however, as does the black-headed gull, whose coastal population fell by 62% over the 30-year period. National counts of inland colonies of these species, undertaken for the first time during 1998-2002, will provide a more comprehensive baseline for future surveys.

Two other gull species have shown marked declines. The herring gull population in Scotland declined by over 50% during the 30-year period, coinciding with a general decline in commercial fishing, coupled with changes in fishing practices, both of which have contributed towards a reduction in the volume of discards. Black-legged kittiwake numbers have also shown a net decline during 1970-2000 (-18%), though relatively stable during the first half of this period. Although kittiwakes are still one of the most abundant seabirds, their breeding success in recent years

Box 6.1 Ground predators

Disturbance and predation by foxes (*Vulpes vulpes*), stoats (*Mustela erminea*) and American mink (*Mustela vison*) have caused marked, local declines in the breeding populations of some seabird species in the UK (Lloyd *et al.*, 1991). Other introduced species, including rats (*Rattus* sp.), feral cats (*Felis cattus*) and ferret (*Mustela furo*), also pose a threat to seabirds nesting on islands otherwise free from ground predators. Those at risk include hole-nesting species, such as Atlantic puffin (*Fratercula arctica*), Manx shearwater (*Puffinus puffinus*), European storm-petrel (*Hydrobates pelagicus*) and Leach's storm-petrel (*Oceanodroma leucorhoa*), as well as ground-nesting terns (*Sterna* spp.) and gulls (*Larus* spp.) and the black guillemot (*Cepphus grylle*), which nests in rock crevices.

Right: Manx shearwater (*Puffinus puffinus*). *L. Gill/SNH*

Manx shearwaters have a lengthy breeding season, making them particularly vulnerable to ground predators. Predation by rats has reduced the breeding success of Manx shearwaters on Canna, and has led to the abandonment of several colonies around the British coast (Lloyd *et al.*, 1991). Rats are also suspected or have been proved to have affected colonies of roseate tern (*Sterna dougallii*), black guillemot and Atlantic puffin (Lloyd *et al.*, 1991).

A study of American mink predation on seabirds on the west coast of Scotland found evidence of extensive predation at most gull and tern colonies (Craik, 1995). Although relatively few adults were killed by mink, no or very few fledged young were produced from colonies where mink were uncontrolled. The high impact of mink was attributed to their population density and propensity for surplus killing; in Iceland, one mink den was found to contain 200 guillemot chicks (T. Björnsson in Clode and MacDonald, 2002). The mink's impact is also due in part to its ability to swim to islands more than 2 km from the mainland (Craik, 1995) or, by 'island hopping', up to 10 km offshore (Clode and MacDonald, 2002). After one or more years of breeding failure, most of the areas colonised by mink on the west coast of Scotland held no birds, or only greatly reduced numbers (Craik, 1997). During 1989–1996, the impact of mink predation on breeding success and adult dispersal was thought to have been the main cause of a 52% decline in the breeding population of black-headed gull (*Larus ridibundus*) and a 30% decline in mew gull (*Larus canus*) numbers (Craik, 1997).

has been poor, as a result of low sandeel availability in the North Sea, particularly around Shetland. In contrast, great black-backed gull (*Larus marinus*) numbers have shown little change, declining by only 7% over the 30-year period, despite competing to some degree with the increasing great skua population (Mitchell *et al.*, 2004).

Three tern species have shown modest net changes, but contrasting trends, over the 30-year period. An initial 58% increase in common tern numbers during 1970-1987 was followed by a 29% decline, yielding a net increase of 12% over the whole period. Arctic tern (*Sterna paradisaea*) and little tern (*S. albifrons*) numbers showed similar, strong increases initially, of 53% and 21%, followed by declines of 34% and 11%. In 1980 about 85% of the British and Irish population of the Arctic tern bred in the Northern Isles, but by 1989 their numbers in Orkney and Shetland had fallen by 42% and 55% respectively (Avery *et al.,* 1993). In Shetland, these declines coincided with very low breeding success, associated with a lack of sandeel prey (Figure 6.2). Fluctuations in sandeel availability are occasionally associated with catastrophic breeding failures, as occurred there in 1998, when 4,020 pairs fledged just 45 young (Thompson *et al.,* 1999). Declines in the little tern population have been attributed, in part, to egg and chick losses to foxes (*Vulpes vulpes*), kestrels (*Falco tinnunculus*) and other predators (Mitchell *et al.*, 2004).

The Sandwich tern (*Sterna sandvicensis*) population in Scotland has shown a sustained decline amounting to 57% over the whole period. The causes of this decline are difficult to discern, but have been linked to persecution on the species' wintering grounds in NW Africa. Persecution is also thought to have contributed to the decline of the roseate tern which, having decreased by 67% in Britain and Ireland (by 90% in Scotland) during 1970-2000, is Britain's rarest breeding tern. The dramatic decline in the population in Scotland has been attributed to emigration (to Ireland), as well as to persecution in its wintering grounds. While the decline in its Scottish and UK population continued during 1997-2000, its combined British and Irish population has shown some signs of recovery, increasing by 44% (Mitchell *et al.*, 2004).

The great cormorant population declined by 13% during 1970-1987 but then increased by 21%, to give a net increase of 5% over the whole period. In contrast, European shag (*Phalacrocorax aristotelis*) numbers showed an initial increase (+17%; 1970-1987) followed by a decline (-32%; 1987-2000), resulting in a net reduction in numbers (-21%) over the whole period. In Shetland, which held about 20% of the Scottish population in 1985-88, numbers fell by more than 50% between 1986 and 1999. Populations on the east coast of Scotland also showed a dramatic drop in numbers following the winter of 1993/94.

Issues and implications

The main factors influencing population trends in Scotland's seabirds are as follows.

- *Food availability.* This has a major influence on breeding performance, and is in turn affected by commercial fisheries and climatic fluctuations. Two-thirds of seabirds in the North Sea in summer are thought to feed to some extent on fishery waste, and the abundance of commercial fishing discards has been linked to population change in some species. Commercial fisheries, particularly for sandeels, can also have a substantial, negative impact on food availability.

- *Predation.* Rats, feral cats, ferret (*Mustela furo)* and American mink (*M. vison)* can have a severe impact on breeding and adult survival (Box 6.1).

- *Drowning.* Nets, particular monofilament drift nets, were considered the main cause of unnatural deaths among auks in the 1980s.

- *Pollution.* Chronic oil pollution from illegal discharges has had a greater impact than occasional accidental spills. Pesticide residues and other toxic chemicals have been implicated in population crashes.

- *Culling.* Now controlled through legislation, egg collection, and the hunting for food, feathers and sport has historically had a major impact on populations.

Sources of data

Published data from the three national censuses, conducted in 1969-70, 1985-88 and 1998-2002, are augmented by annual surveys within a sample of seabird colonies (e.g. Mavor *et al.*, 2003), providing an indication of regional trends in population size and breeding success.

This chapter is based mainly on information presented in Lloyd *et al.* (1991) and Mitchell *et al.* (2004). The latter describes the most recent census, *Seabird 2000*, a collaborative project involving the Joint Nature Conservation Committee, the UK Government's conservation agencies, the Royal Society for the Protection of Birds, the Seabird Group, Shetland Oil Terminal Environmental Advisory Group (SOTEAG), BirdWatch Ireland and the National Parks and Wildlife Service (Dept. of Environment, Heritage and Local Government - Republic of Ireland).

References

Avery, M.I., Burges, D., Dymond, N.J., Mellor, M. and Ellis, P.M. (1993). The status of Arctic Terns *Sterna paradisaea* in Orkney and Shetland in 1989. *Seabird* **15**: 17-23.

Clode, D. and MacDonald, D.W. (2002). Invasive predators and the conservation of island birds: the case of American Mink *Mustela vison* and terns *Sterna* spp. in the Western Isles, Scotland. *Bird Study* **49**: 118-123.

Craik, C. (1995). Effects of North American mink on the breeding success of terns and smaller gulls in west Scotland. *Seabird* **17**: 3-11.

Craik, C. (1997). Long-term effects of North American Mink *Mustela vison* on seabirds in western Scotland. *Bird Study* **44**: 303-309.

Lloyd, C., Tasker, M.L. and Partridge, K. (1991). *The Status of Seabirds in Britain and Ireland.* T. & A.D. Poyser, London.

Mavor, R.A., Parsons, M., Heubeck, M., Pickerell G. and Schmitt, S. (2003). *Seabird Numbers and Breeding Success in Britain and Ireland, 2002.* Joint Nature Conservation Committee, Peterborough.

Mitchell, I.P., Newton, S.F., Ratcliffe, N. and Dunn, T.E. (2004). *Seabird populations of Britain and Ireland.* T. and A.D. Poyser, London.

Thompson, K.R., Pickerell, G. and Heubeck, M. (1999). *Seabird Numbers and Breeding Success in Britain and Ireland, 1998.* Joint Nature Conservation Committee, Peterborough.

Part 3
The use of the sea

7 Mariculture

Introduction

Clean waters and a widespread availability of wave-sheltered sites have made Scotland a particularly attractive location for the farming of both finfish and shellfish (mariculture). Commercial salmon farming began in Scotland in 1969 with the establishment of the first farms near Aberdeen on the east coast and at Loch Ailort, south of Mallaig, on the west coast. Modern shellfish culture became established around the mid-1980s. At the outset, the industry was hailed as environmentally sympathetic: potentially providing relief for the heavily exploited wild fish stocks while producing a healthy, high-value product raised within its natural environment. Few predicted the scale of success of the industry in Scotland and its eventual dominance of the economy of the western, north-western and island coastal communities.

Previous page: Creels.
D. Donnan

Right: Salmon farm, Shetland.
G. Saunders

Right: Mussel farm, Loch Striven.
C. Adams

Trends

In 1979, just over 1,000 tonnes of wild Atlantic salmon (*Salmo salar*) was available for market, but only 510 tonnes of farmed fish was produced (Anon., 2000). Growth in production was slow until the mid-1980s, when financial incentives stimulated a major expansion of the industry (Figure 7.1).

In 2002, over 145,000 tonnes of farmed salmon was produced by a total of 328 marine farm sites (Figure 7.2) around Scotland (Fisheries Research Services, 2003a).

A number of sites and companies are annually registered as non-producing. Although not yielding a harvest for market, they may be actively growing stock that will constitute the following years' product. A large drop in the number of producing sites between 1999 and 2000 reflects a programme of slaughter and site fallowing. This was largely initiated as part of the restrictions that followed the west-coast outbreak of the contagious viral disease infectious salmon anaemia (ISA) in 1998.

The number of salmon farm-related businesses peaked at 176 in 1989 and then declined, partly as a result of a series of mergers and buy-outs (Figure 7.2). The level of employment and the total number of production sites have, however, remained largely stable throughout the 1990s to the present (Figure 7.3). Advances in production methods and the use of modern technology in the design and manufacture of holding cages have led to improving yields and higher productivity (Figure 7.4).

Experimental farming of other fin fish species, such as cod (*Gadus morhua*), turbot (*Scophthalmus maximus*), sea trout (*Salmo trutta*) and Arctic char (*Salvelinus alpinus*), is currently under way.

Shellfish production is low in Scotland compared with other European countries and is considered to be less environmentally damaging. The main species are mussels (*Mytilus edulis*), Pacific oyster (*Crassostrea gigas*), scallop (*Pecten maximus*) and queen scallop (*Aequipecten opercularis*), with

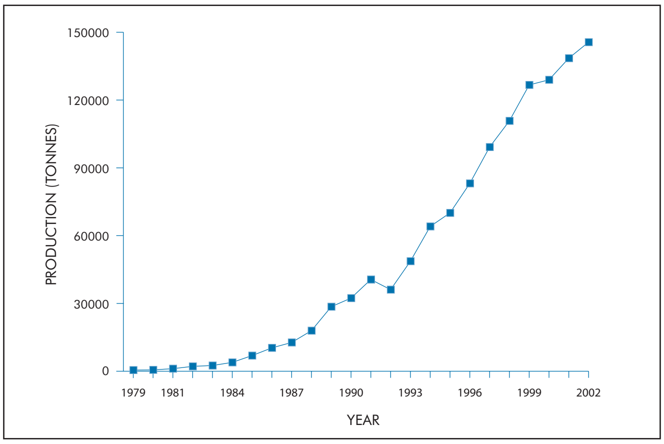


Figure 7.1 Total annual Scottish production of farmed salmon
Source: Fisheries Research Services, 2003a.

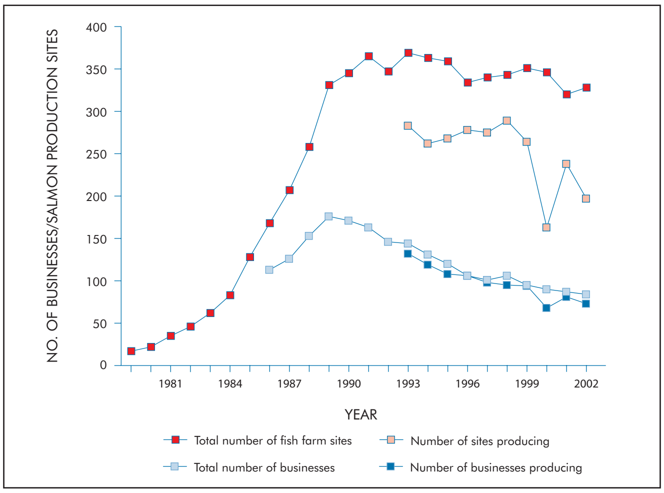


Figure 7.2 The number of Scottish marine salmon production sites and salmon production businesses operating in Scotland
Source: Fisheries Research Services, 2003a.

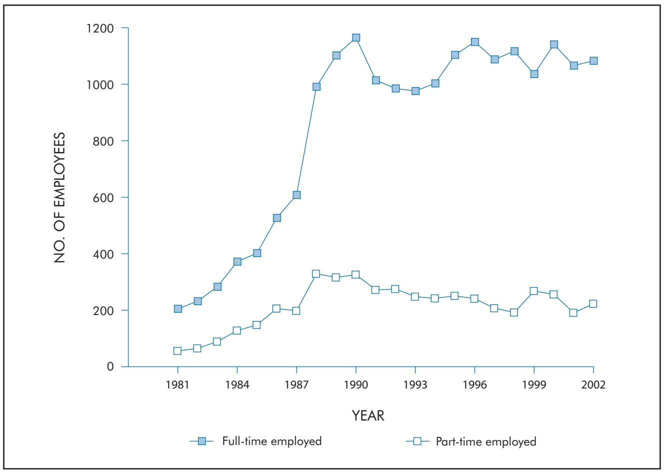


Figure 7.3 The number of people employed in the salmon farm industry
Source: Fisheries Research Services, 2003a.

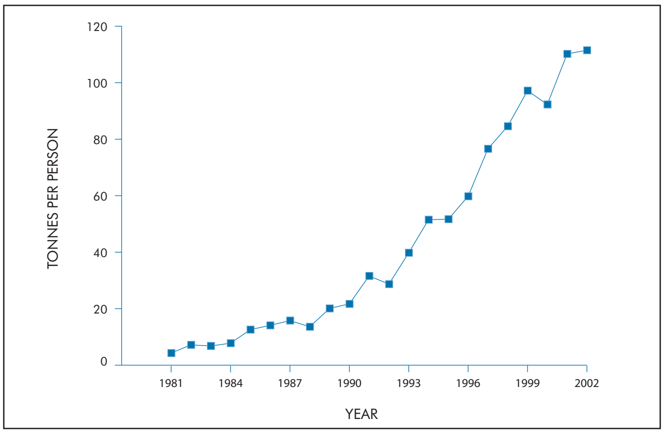


Figure 7.4 Scottish salmon farm productivity
Source: Fisheries Research Services, 2003a.

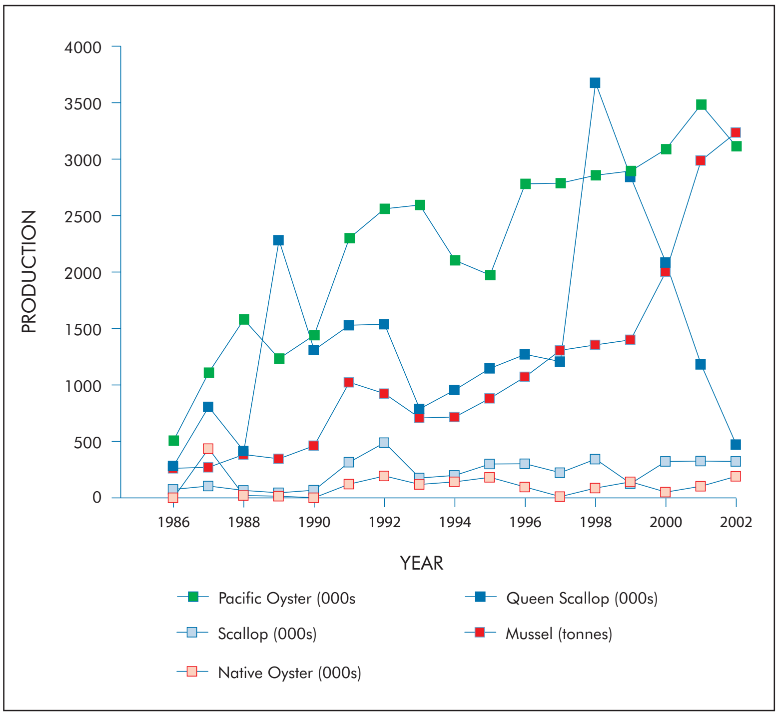


Figure 7.5 Scottish shellfish production for the table
Source: Fisheries Research Services, 2003b.

production concentrated on the west coast, particularly in Argyll. Production of shellfish has also grown, but on a much smaller scale, rising to 3,236 tonnes of mussels and 3,114,000 individual Pacific oysters (the main species) in 2002 (Figure 7.5).

Issues and implications

Currently, almost all sea lochs with conditions suitable for mariculture have at least one installation, prompting concerns about localised impacts on the sea bed, aesthetic degradation of the landscape, nutrient enrichment of coastal waters and interactions with wild populations. Salmon farming in particular has attracted criticism, with concerns over disease outbreaks and interactions with wild salmon populations (Baxter and Hutchinson, 2002).

High stocking densities have increased susceptibility to disease outbreaks. Heavy losses of salmon occurred in 1990–1991 due to sea lice and the bacterial disease furunculosis. Vaccines and therapeutic chemicals are now used routinely to keep stock losses to a minimum. In May 1998

Region	No. of confirmed cases
Shetland	2
Loch Nevis	3
Skye	1
Sound of Mull	5

Table 7.1
The number of confirmed cases of ISA by region.
Source: Scottish Parliament, 1999

an outbreak of ISA was confirmed in Scotland, and by August 1999 there had been 11 confirmed cases (Table 7.1), with a further 24 suspected (Fisheries Research Services, 2000). This disease, thought to be relatively benign in other species such as trout (*Salmo trutta*), was first recorded in Norway in 1984 and more recently in Canada in 1996. It is likely that ISA was introduced to Scotland through a slackening of hygiene and husbandry methods precipitated by the success of the furunculosis vaccine (Smith, 1999). Subsequent control measures and a maintained observance of improved working practices have prevented a recurrence.

In many cases, the sea bed beneath salmon cages is contaminated with uneaten food and faecal material, together with pharmaceuticals, pesticides and chemical antifoulants applied to the cage structure. Contamination may persist for as much as two years after the removal of cages (Pearson and Black, 2001). Good flushing regimes in site selection can help to disperse contaminants and so alleviate the problem of local accumulation.

The siting of new mariculture installations in Scotland is now the subject of consultation involving the Scottish Environment Protection Agency (SEPA) and SNH. The potential for damage to the environment is examined case by case, and advice is given using the best available information. Fish farms are granted discharge consents by SEPA, which may limit annual production and the quantities of chemicals that may be used. With vigilance encouraged by self-monitoring, together with revocation of consents if specified practices are not followed, recent improvements in benthic sediment quality around some marine cage fish farms have been documented.

Shellfish production relies on natural phytoplankton in the water as the food source.

Oyster farm, Loch Kishorn.
D.Donnan

Some of the planktonic species that constitute food for shellfish produce toxins that are subsequently concentrated within the shellfish. Consumption of shellfish containing these toxins may cause paralytic shellfish poisoning (PSP), amnesic shellfish poisoning (ASP) or diarrhetic shellfish poisoning (DSP), all of which are characterised by headaches, nausea, diarrhoea and respiratory paralysis.

Monitoring shellfish (both wild-caught and farmed) for the toxins responsible for PSP began after an outbreak in 1968 resulted in the hospitalisation of several people in north-east England and south-east Scotland. The programme was extended in 1999 to include ASP. Many of the shellfish production sites were closed during 2000 because of the presence of toxins. Concern has been expressed that nutrients released from salmon farms may be related to an increase in the frequency of toxic algal blooms. Further long-term monitoring is needed to establish if blooms of toxic algae are increasing in reality, or merely appear to be as a result of the greater intensity of monitoring. Other possible causes, such as climate change, natural variability and the effects of fisheries, pollution and global transfers of harmful species, may also be implicated and require further investigation.

Recent modelling data for dissolved inorganic nitrogen in Scottish lochs (Gillibrand and Turrell, 1997) suggest that a few fish farms may create minor localised enrichment relative to natural levels, but that mariculture-derived inputs remain comparatively low when viewed alongside other sources (Davies, 2001). A direct connection between mariculture and an increase in the occurrence of harmful algal blooms cannot therefore be reliably demonstrated, and such increases must be considered within the context of observed long-term natural changes in the Atlantic phytoplankton.

Sources of data

Detailed reports for both shellfish and finfish production are published annually by the Fisheries Research Services (the Marine Laboratory, Aberdeen).

References

Anon. (2000). Scottish fish farming: past and present. *Aquaculture Magazine* **26**, March/April 2000, 48–54.

Baxter, J. and Hutchinson, P. (2002). The Atlantic salmon: a case study of Scotland's environment and natural heritage. In: *The State of Scotland's Environment and Natural Heritage.* Usher, M. B., Mackey, E. C. and Curran, J. C. (eds), pp. 219–234. The Stationery Office, Edinburgh.

Davies, I. M. (2001). *Waste Production by Farmed Atlantic Salmon* (Salmo salar) *in Scotland.* International Council for the Exploration of the Sea, CM 2000/O :01 Sustainable Aquaculture Development.

Fisheries Research Services. (2000). *Final Report of the Joint Government/Industry Working Group on Infectious Salmon Anaemia (ISA).* Scottish Executive, Aberdeen.

Fisheries Research Services. (2003a). *Scottish Fish Farms. Annual Production Survey, 2002.* Scottish Executive Rural Affairs Department.

Fisheries Research Services. (2003b). *Scottish Shellfish Farm Production Survey, 2002.* Scottish Executive Rural Affairs Department.

Gillibrand, P. A. and Turrell, W. R. (1997). The use of simple models in the regulation of the impact of fish farms on water quality in Scottish sea lochs. *Aquaculture* **159**: 33–46.

Pearson, T. H. and Black, K. D. (2001). The environmental impacts of marine fish cage culture. In: *Environmental Impacts of Aquaculture.* Black, K. D. (ed.), pp. 1–31. Sheffield Academic Press, Sheffield.

Scottish Parliament. (1999). *Salmon Farming and the Impacts of ISA.* Scottish Parliament Research Note No. 99/20. Scottish Parliament, Edinburgh.

Smith, P. D. (1999). *Fish and Shellfish Cultivation and Health Review* for the Ministry of Agriculture, Fisheries and Food.

8

Continental shelf fisheries

Introduction

The scale of marine capture fisheries, both geographically and quantitatively, represents one of the greatest human-induced modifications of maritime ecosystems. It is estimated that globally over 80 million tonnes (including shellfish) was landed in 1999 (FAO, 2000). More than a quarter of world fish stocks are considered to be either overfished or in imminent danger of stock collapse.

Over 1,000 species of fish have been recorded in the north-eastern Atlantic and North Sea region. Of these, about 5% are considered to be commercially exploitable. Around 20 species constitute approximately 95% of total fish biomass.

In the North Sea, about a fifth of the estimated total of 10 million tonnes (mt) of fish are landed annually. This, of course, excludes discarded fish. The 2002 landings (ICES, 2003) of 2,125 mt comprised 337 mt of demersal species, 892 mt of pelagic fish and 896 mt from the industrial sandeel fishery.

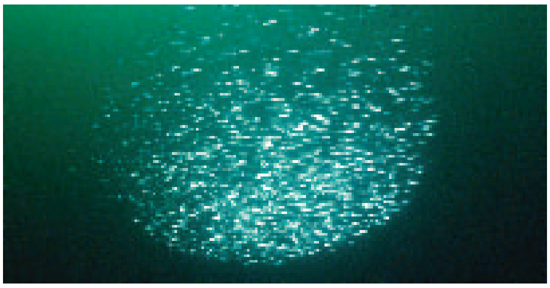
Finfish and shellfish have been harvested in Scottish coastal waters for many centuries. Early exploitation probably developed out of necessity, since the greater part of the country – especially the hill and mountain areas – is of limited productivity. Over several centuries the availability of this abundant and relatively reliable food source was a major factor in the settlement of the greater proportion of the population in coastal areas (Coull, 1996).

During medieval times the catching and processing of fish, notably herring (*Clupea harengus*), became an important feature of Scottish culture and trade (Cushing, 1988), and the commercial exploitation of fish and shellfish stocks remains a major contributor to Scotland's economy today. In 2001, total live weight landings of fish and shellfish by UK vessels into Scotland amounted to 307,700 tonnes valued at £247.1 million (Scottish Executive, 2002). Although England, Wales and Northern Ireland maintain a fishing fleet, Scotland remains at the centre of UK fishing activity, with 65% of all UK landings made in Scottish ports (Scottish Executive, 2002).

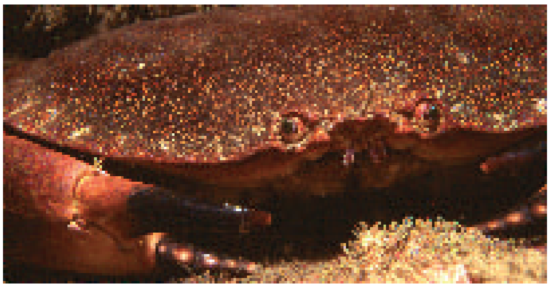
Pelagic trawler hauling nets.
C. Martin/SNH

Plaice (*Pleuronectes platessa*).
R.Holt

Herring shoal (*Clupea harengus*).
S. Scott



Edible crab (*Cancer pagurus*).
G.Saunders



The fishing industry comprises three main sectors:

- *Demersal* species such as cod, haddock, whiting and flatfishes mainly live close to the sea bed. They are caught principally with trawls, but static gill and tangle nets may also be used. Demersal fish have historically attracted a greater value per unit weight and have been preferentially harvested. Over-exploitation has resulted in a steady decline in demersal fish landings, with a decrease of greater than 10% for 16 of the 34 commercially important species between 1995 and 1999.

- *Pelagic* species such as herring or mackerel may range over considerable depths but are caught either close to the surface or in mid-water using seine nets or pelagic trawls. Catches of pelagic fish have generally increased since the 1960s, coincident with a decline in demersal populations.

- *Shellfish* traditionally includes species that have either a hard shell, such as scallops, cockles, mussels, winkles and buckies (whelks), or an exoskeleton, such as edible crabs, velvet crabs, crayfish, lobster and Norway lobster. Shellfish are caught using trawls, baited creels or pots and occasionally bottom-set nets.

Box 8.1 Stock assessment

In order to evaluate stock status four main characteristics of exploited populations are examined on an annual basis:

- *Landing:* the total annual reported tonnage of fish removed from the stock and landed by the fishing fleet.

- *Spawning stock levels:* measured as spawning stock biomass, which is the total estimated weight of fish that are mature enough to be able to spawn.

- *Fishing mortality:* an index of the total number of fish that are removed from a particular stock each year by fishing activities (a fishing mortality of 1.0 corresponds to a 60–70% reduction in stock over the course of one year).

- *Recruitment:* the number of young fish produced each year that survive to become adults and enter the fishery.

Trends

Stock assessment is based on landings, spawning stock, fishing mortality and recruitment (Box 8.1). Scottish data are available for 16 species, shown in Table 8.1.

In recent times, many marine capture fisheries throughout the world have entered a state of crisis, with many stocks severely depleted or exploited to the brink of collapse.

The number of people employed in the Scottish fishing industry declined by almost 30% between 1992 and 2002 (Scottish Executive, 2002), largely due to an inability to sustain catch levels and attempts to limit catches of stocks that had become dangerously depleted. In 2002, the Scottish fleet employed approximately 5,707 people working on a total of 2,513 vessels.

None of the species commercially exploited within Scottish waters is currently considered to be in danger of global biological extinction, as they often have a wide geographical range with established populations thousands of kilometres apart. However, many species maintain genetically discrete stocks, differentiated by the areas in which they spawn, develop and feed. Several individual stocks are considered to be either fully exploited or overexploited. Some have reached a point at which stock collapse is considered an imminent possibility. Conversely, stock recovery has been demonstrated through fisheries management (Box 8.2).

Table 8.1 Species trends for fisheries of greatest commercial importance (sources: ICES, 2001, 2002, 2003)

Species	Stock assessment	Stock health
Herring (*Clupea harengus*) (2003)	• Spawning stock level above the proposed precautionary stock biomass level • Fishing mortality for North Sea stocks below the proposed precautionary level and considered to be low for west of Scotland stocks • Recent recruitment has been strong in the North Sea and 2001 produced a strong year class to the west of Scotland	North Sea stocks are considered to be inside safe biological limits
Cod (*Gadus morhua*) (2003)	• Spawning stock levels below the proposed precautionary stock biomass level. Spawning stock has been declining since 1980 and the estimate for 2002 is the lowest ever • Fishing mortality is above the proposed precautionary level and the absolute value is difficult to determine owing to the suspected increased in unreported landings • Recruitment has been poor in the last five years and in the North Sea the 1997, 2000 and 2002 year classes are the poorest on record	Currently considered to be outside safe biological limits with a high risk of stock collapse
Haddock (*Melanogrammus aeglefinus*) (2003)	• Spawning stock levels above the proposed precautionary stock biomass level and boosted by the good recruitment of 1999 • Fishing mortality has been above the proposed precautionary level but fell below this in 2002 • Recruitment in 1999 was very strong, but since then in the North Sea has been considered well below average	Currently considered to be inside safe biological limits (except in the Irish Sea)
Whiting (*Merlangius merlangus*) (2003)	• Spawning stock level below the proposed precautionary stock biomass level • Fishing mortality is above the proposed precautionary level for west of Scotland stocks, but below it for the North Sea stocks • Recruitment in both North Sea and west of Scotland stocks has been low since the early 1990s. There are some indications that the North Sea stocks may have increased in recent years	Currently considered to be outside safe biological limits Data from the North Sea have produced conflicting trends for 2002, therefore the health of the stock in this area is unknown
Saithe (*Pollachius virens*) (2003)	• Spawning stock level close to or above the proposed precautionary stock biomass level • Fishing mortality is below the proposed precautionary level • Recruitment considered to be stable	Currently considered to be within safe biological limits
Norway pout (*Trisopterus esmarki*) (2003)	• Spawning stock level currently above the proposed precautionary stock biomass level but expected to decrease significantly • Fishing mortality considered to be low and is less than natural mortality • Recruitment is highly variable and is strongly influenced by spawning stock owing to the short lifespan of this species	North Sea stocks are considered to be within safe biological limits. The status of the west of Scotland stocks is uncertain
Sandeel (*Ammodytes marinus*) (2003)	• Spawning stock level is thought to have risen above the proposed precautionary level in 2003 • No indicators for fishing mortality have been set	The status of stocks in the North Sea is uncertain. The status of the west of Scotland stocks is unknown.

Year in brackets indicates the most recent assessment data available.
Stocks with are outside safe biological limits are indicated by blue shading.

Species	Stock assessment	Stock health
	• Recruitment in the 2001 year class is still strong although the 2002 year class was poor	
Monkfish (*Lophius piscatorius*) (2003)	• Spawning stock biomass has decreased although no biomass reference points have been identified for this stock. • Recent fishing mortality is well above the proposed precautionary level • No data available on recruitment, although the fishery is thought to be taking a proportion of juveniles, which are removed from the fishery several years before they become mature	Currently considered to be outside safe biological limits
Mackerel (*Scomber scombrus*) (2003)	• Spawning stock level above the proposed precautionary stock biomass level • Fishing mortality is above the proposed precautionary level • Recruitment appears stable	Currently considered to be outside safe biological limits. North Sea stock component considered to be severely depleted
Sprat (*Sprattus sprattus*) (2003)	• There are no data available for spawning stock level, fishing mortality or recruitment • Biomass appears to have increased in recent years; however, there is a relatively low abundance of older year classes. There are also indications of a strong recruitment in 2003	A high and stable catch biomass is thought to indicate a healthy North Sea stock level
Hake (*Merluccius merluccius*) (2003)	• Spawning stock level below the proposed precautionary stock biomass level Fishing mortality has remained above the proposed precautionary level since 1978 • Recruitment levels between 1997 and 2001 were the lowest recorded. There was, however, a slight increase in 2002	Currently considered to be outside safe biological limits
Megrim (*Lepidorhombus whiffiagonis*) (2003)	• Reliable estimates for spawning stock level, fishing mortality and recruitment are not available	There is not enough information available on the stocks to the west of Scotland to determine their status
Plaice (*Pleuronectes platessa*) (2003)	• Spawning stocks levels in the North Sea are close to the historical minimum. Stocks in the Irish Sea appear healthy • Fishing mortality is above the proposed precautionary level in the North Sea, but below it in the Irish Sea • Recruitment in the North Sea has been below average since a good year class in 1996	Currently considered to be outside safe biological limits in the North Sea and within safe biological limits in the Irish Sea
Sole (*Solea solea*) (2003)	• Spawning stock level is below the proposed precautionary stock biomass level • Fishing mortality is above the proposed precautionary level • Recent recruitment at or above average in the North Sea. The 2001 recruitment in the Irish Sea is the poorest on record.	Currently considered to be outside safe biological limits
Norway lobster (*Nephrops norvegicus*) (2003)	• Catch rates suggest that current levels of fishing are acceptable • Recruitment largely stable	Status of stocks variable, although most stocks are considered to be fully exploited.
Northern shrimp (*Pandalus borealis*) (2003)	• There are no data available for spawning stock level, fishing mortality or recruitment; total effort is thought to have been low since 1999	The current state of the North Sea stock is unknown

Year in brackets indicates the most recent assessment data available.
Stocks with are outside safe biological limits are indicated by blue shading.

- Of the 16 species for which Scottish data are available, seven are currently considered to be outside safe biological limits (Table 8.1). Cod have attracted particular concern (Box 8.3).

- In the 10-year period between 1992 and 2002, spawning stock biomass of some stocks of cod, whiting, plaice and sole declined substantially (Table 8.2). Conversely, the spawning stock biomass of herring, haddock, saithe and mackerel increased.

- Landings of the majority of species have declined (Table 8.2), either because of imposed catch restrictions or because of an inability to locate adequate supplies.

- Depletion of stocks of traditionally fished species has stimulated the targeting of previously unexploited species, such as monkfish and a number of species only found in the deeper, offshore grounds (Chapter 9).

The harvesting of shellfish has increased considerably in recent times. Between 1984 and 1997, the total UK shellfish catch more than doubled to over 142,000 tonnes. Landings of 5 of the 10 most commercially important species in Scotland increased by more than 10% between 1995 and 1999.

Box 8.2 Herring stocks

The Scottish herring fishery has a very long history, with records of trading extending back to at least the12th century. Today, herring continues to be an important catch for Scottish fishermen, with a value of over £6 million of landings to Scottish ports in 2002. By weight, herring is the second most abundant species, after mackerel, landed by the pelagic fleet, with the major fishing effort being concentrated around Shetland and to the north and west of Scotland. They are caught either by purse seine or by pelagic trawl.

North Sea stocks declined drastically between the early 1960s and 1976 (Figure 8.1), largely as a result of the combined effects of poor survival of young herring and overfishing of adults and immature fish on their nursery grounds. A ban on fishing for herring between 1977 and 1981 allowed stocks to recover (small landings during that time were probably due to bycatch from other fisheries and scientific survey). By 1996, however, exploitation levels in the North Sea had again increased to a such an extent that measures had to be reintroduced to reduce fishing mortality (ICES, 2001).

Currently, North Sea herring stocks are considered to be inside safe biological limits following a gradual recovery. Information has been insufficient to fully assess populations exploited to the west of Scotland, but reports suggest that stocks remain stable and fishing mortality may be decreasing, perhaps because of a poor market for herring compared with other pelagic fish.

Above: Herring (*Clupea harengus*). *C.Gomersall*

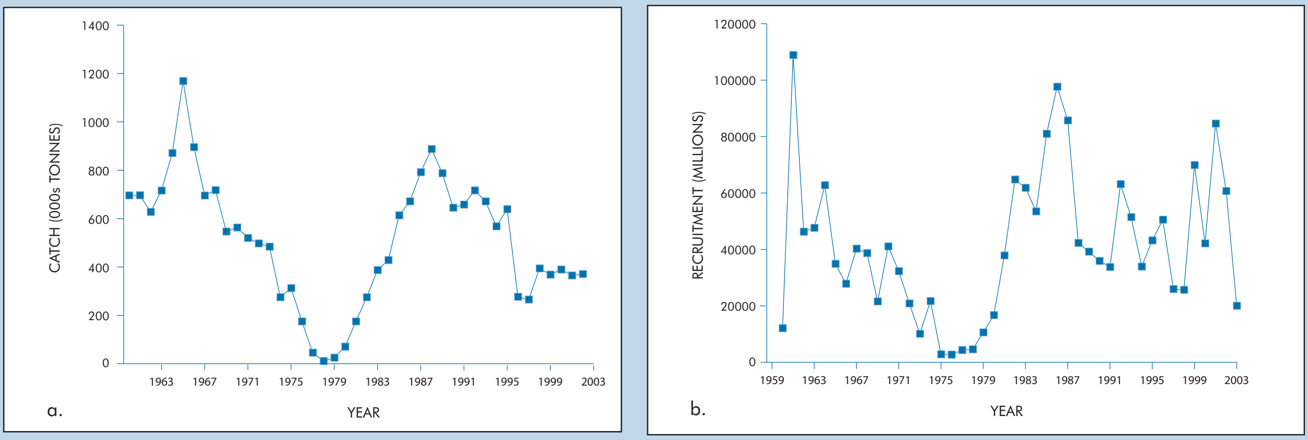
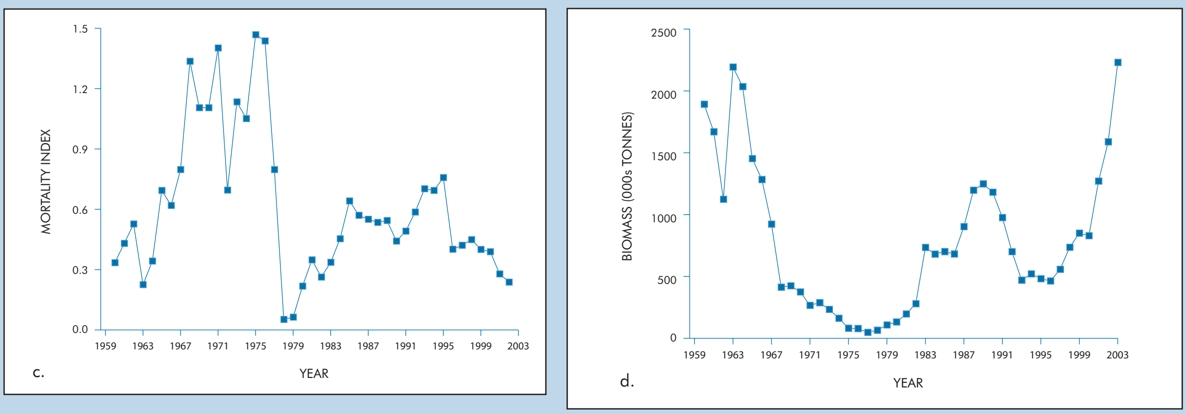


Figure 8.1
Changes in (a) catch, (b) recruitment (age 0), (c) fishing mortality (age 2–6) (d) spawning stock biomass for North Sea herring.



Box 8.3 Cod stocks

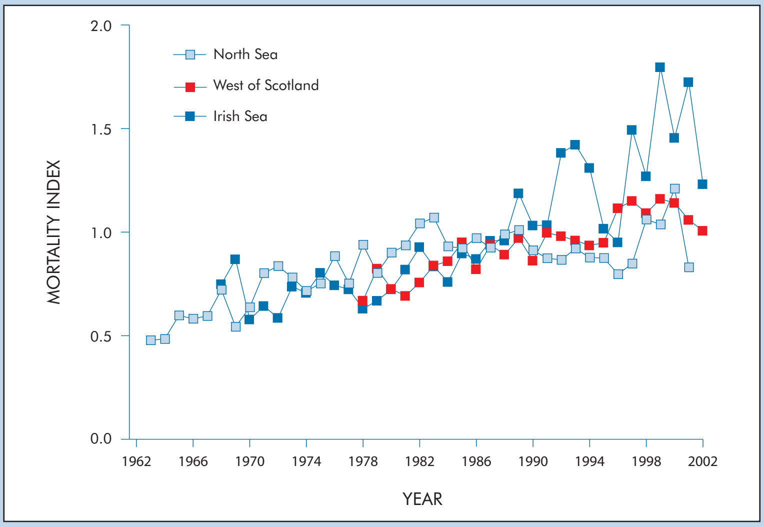


Figure 8.2 Changes in cod fishing mortality.

By 1999 the status of cod stocks from all UK sectors was giving cause for concern. Fishing mortality had increased steadily since the 1960s (Figure 8.2).

Cod (*Gadus morhua*).
S. Scott

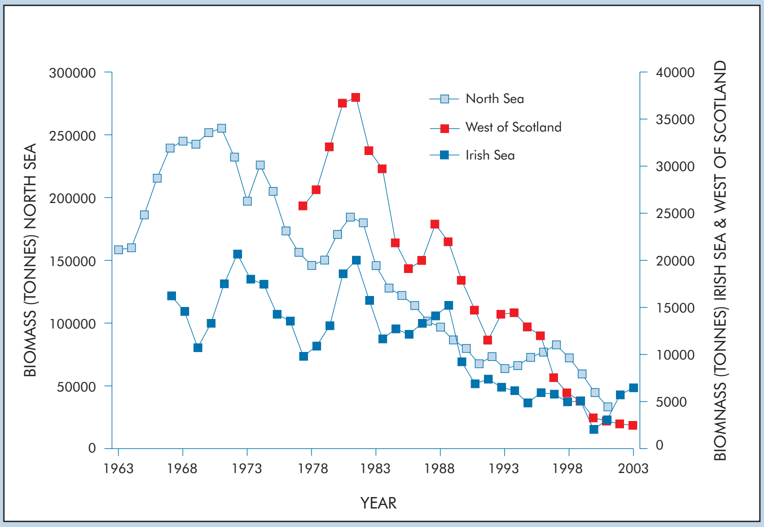


Figure 8.3 Changes in cod spawning stock biomass.

Spawning stock biomass of North Sea stocks had been declining since the early 1970s, and was followed by west of Scotland populations in the 1980s (Figure 8.3). Some stocks fell below estimated precautionary levels in 1984 and continued to decline thereafter. Recruitment, although variable, was consistently poor in the 1990s, with the 1997 North Sea year class being the poorest on record. By 1999, all cod stocks within UK waters were considered to be outside safe biological limits. Continued exploitation at current levels is thought likely to risk imminent stock collapse. Data from 2002 show an increase in the spawning stock biomass of cod in the North Sea. It is suspected that this is as a result of growth of individuals in the current population rather than an increase in numbers of fish present. The spawning stock biomass data for 2003 are considered uncertain.

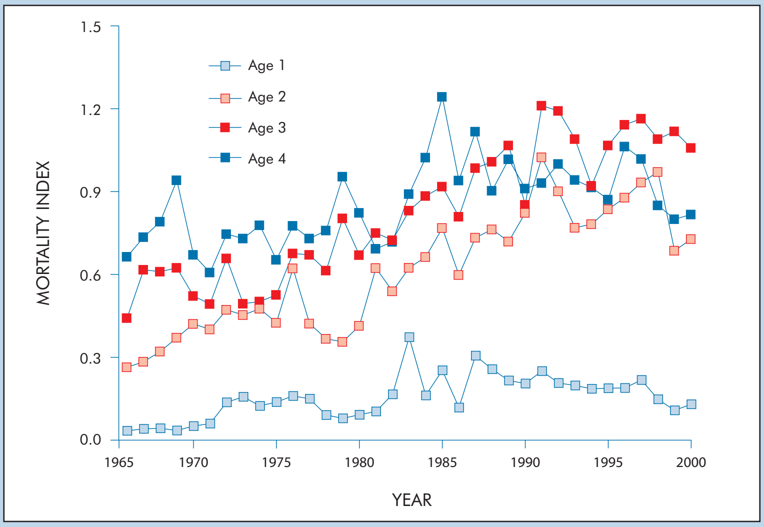


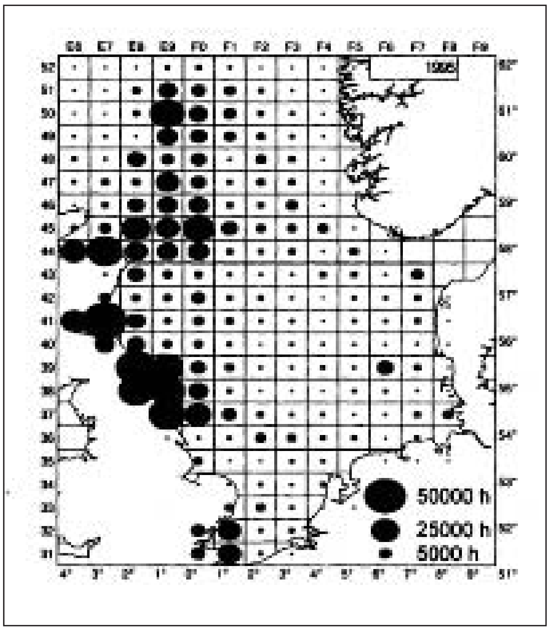
Figure 8.4 Trends in fishing mortality of different age groups of the west of Scotland cod stock.

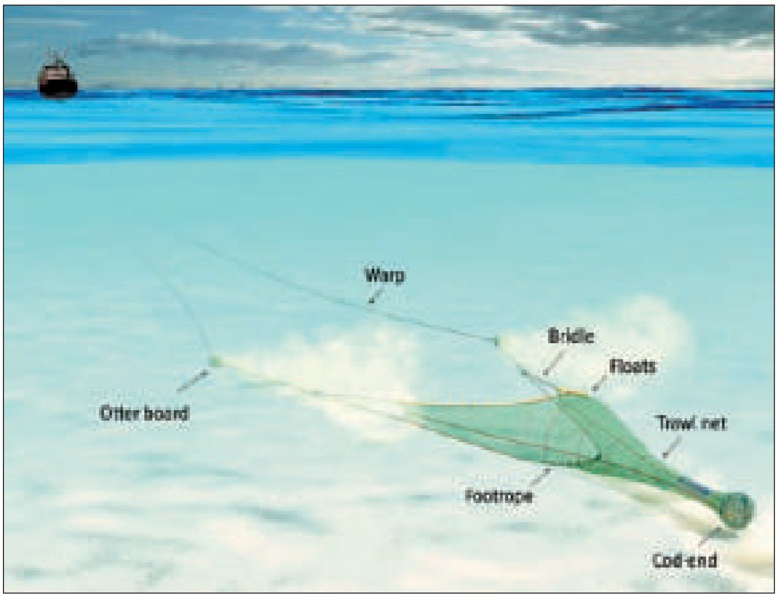
Increasing pressure has been exerted on cod populations by the removal of young fish. By the time they reach their second year, the still immature cod are fully exploited, and many will not reach maturity. As little as 0.05% of all one-year-old fish survive to reach their fourth year. Although fishing mortality has increased across all age groups, the two- and three-year age groups have been removed at disproportionately greater rates (Figure 8.4).

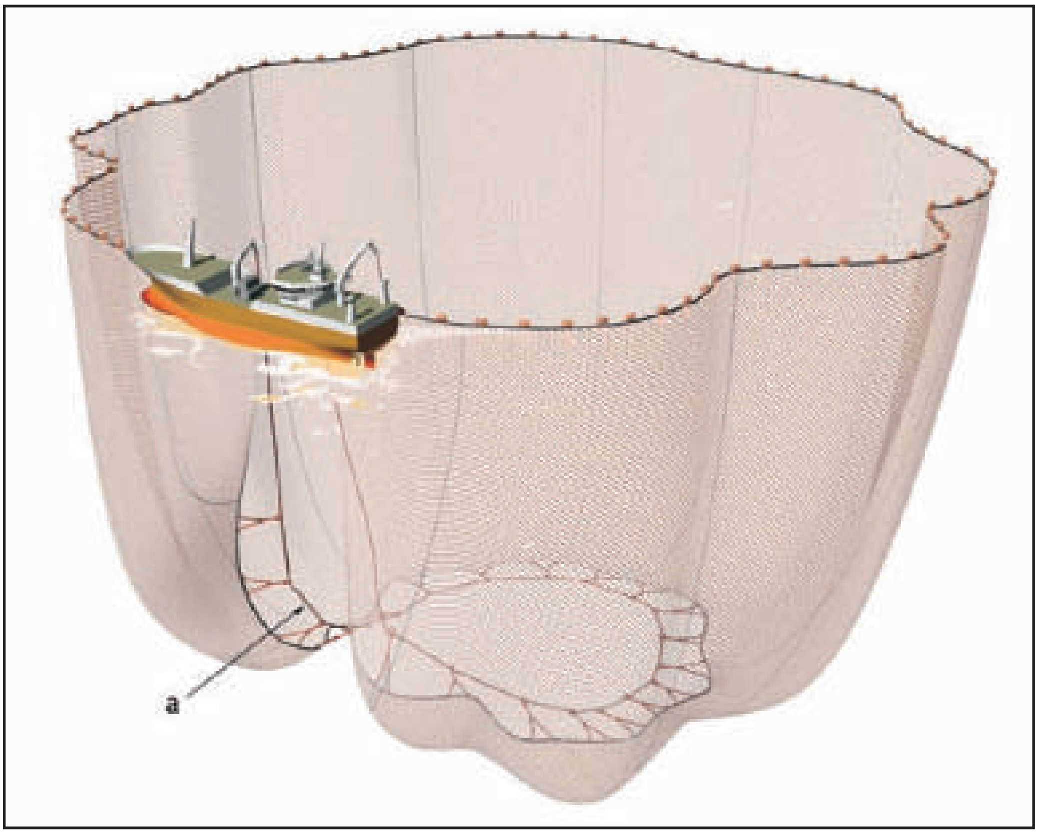
Moreover, the growth rate of North Sea cod has declined for reasons which are not clear. This, combined with high mortality of juvenile cod due to discarding, is likely to delay a future recovery of spawning stock biomass levels and leave stocks highly vulnerable to overexploitation.

Issues and implications

The seas around Scotland have traditionally been rich in commercially valuable species and have supported some of the most intensive fishing effort in the world. Detailed studies of UK and international fishing effort in the North Sea show that grounds presently subjected to the greatest intensity of otter trawling lie to the north-east of the UK (Figure 8.5), largely comprising areas off the east and north-east Scottish mainland and east of the Shetland Islands (Greenstreet *et al.*, 1999a; Jennings *et al.*, 1999, 2000). The nature of the fishery, as defined by the type of fishing gear, has changed within the last 30 years. The use of demersal gears, such as otter (Figure 8.6) and beam trawls, targeting species such as cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and plaice (*Pleuronectes platessa*), has increased steadily throughout the North Sea since the mid-1970s (Jennings *et al.*, 1999), while the pursuit of pelagic species, predominantly mackerel (*Scomber scombrus*) and herring, with seine nets (Figure 8.7) has decreased (Greenstreet *et al.*, 1999a).







Above:
Figure 8.5
Spatial distribution of international otter trawling effort (hours) in 1995.
Reproduced from Jennings *et al.* (1999).

Above right:
Figure 8.6
Typical otter trawl gear configuration
(Scottish Executive, Crown copyright).

Right:
Figure 8.7
Purse seine gear
(Scottish Executive, Crown copyright).

Table 8.2
Characteristics of important commercially exploited fish stocks: 10-year trend, 1992–2002 (except where indicated)
Sources: ICES, 2001, 2002.

Species	Area of stock assessment	Landings	Fishing mortality	Spawning stock biomass
Herring	North Sea	42.5% ⇩	46% ⇩	34% ⇧
Cod (1990–2000)	North Sea	44% ⇩	7% ⇧	31% ⇩
Cod	West of Scotland	77% ⇩	2.6% ⇧	81% ⇩
Haddock	North Sea	24% ⇧	65% ⇩	305% ⇧
Haddock	West of Scotland	41% ⇩	23% ⇩	47% ⇧
Whiting (1992–2000)	North Sea	62% ⇩	51% ⇩	17% ⇩
Whiting	West of Scotland	72% ⇩	13% ⇩	45% ⇩
Saithe	North Sea and west of Scotland	17% ⇧	66% ⇩	152% ⇧
Norway pout	North Sea	74% ⇩	43% ⇩	2% ⇩
Mackerel	North-east Atlantic and North Sea	7% ⇧	2% ⇧	56% ⇧
Plaice	North Sea	44% ⇩	1.4% ⇩	47% ⇩
Sole	North Sea	42% ⇩	12% ⇧	56% ⇩

Catch quotas were first implemented in the North Sea in the mid-1970s. Exploited stocks in European waters are now managed through the Common Fisheries Policy (Box 8.4), acting jointly with Norway in the case of shared stocks.

The ICES provides annual scientific advice on the status of all of the important commercial species. Catch levels are subsequently decided by the Council of Ministers, and catch quotas are duly allocated to member states. The primary objective is the maintenance of these resources at a level at which they can be harvested sustainably. The scale and ecological complexity of such an undertaking, combined with inevitable political pressures, have, however, proved to be major obstacles and the maintenance of stable population levels remains elusive.

Many demersal stocks, and notably cod (Box 8.3), have continued to decline despite successive reductions in catch quotas. This is probably a reflection of fundamental differences in the selectivity of pelagic and demersal fishing gears. Pelagic species are typically targeted as mid-water schools of high species uniformity and can be identified visually or by a characteristic acoustic signature. Avoidance of a particular species as a conservation measure is thus relatively easy and effective. Demersal trawling gears are far less selective and, although controls on the landing of a particular species may be in place, incidental capture of both adults and juveniles cannot be avoided without the closure of entire grounds (Hutchings, 2000).

Cod stocks from the North Sea, Irish Sea and west of Scotland are reported to be in danger of collapse (ICES, 2001, 2002). Recovery plans were initiated during 2000, incorporating limited area closures and modifications to gears to increase selectivity. Quotas were then cut by 45% in 2003 and remained the same in 2004. Then, effort reduction was introduced, limiting days at sea to 15 per month (increased from 10 days as a result of fleet reduction through decommissioning). A proposal was also announced to introduce multiannual management arrangements for cod stocks in the North Sea, west of Scotland, Irish Sea and eastern Channel. Along with this is a

Box 8.4 The Common Fisheries Policy

Fishing boats in Mallaig harbour.
D. Donnan

The European Common Fisheries Policy (CFP), which integrates the protection of the marine environment with fisheries management, was enacted in Council Regulation 3760/92 in 1992. This regulates the exploitation of commercial stocks through the specification of fishing quotas and, in some cases, the designation of marine areas within which fishing practices may be restricted. The CFP is enacted nationally through the Sea Fisheries (Wildlife Conservation) Act 1992 for the conservation of marine flora and fauna, requiring a balancing of duties between conservation and obligations under existing fisheries Acts. Several methods of reducing fishing effort have been made available under the Sea Fish (Conservation) Act 1992, including limits on fishing days at sea, restrictions on certain types of fishing gear and grant-aided decommissioning.

The recent review of the CFP (Council regulation 2371/2002) incorporated further environmental considerations, including application of the precautionary principle to stock management and the progressive implementation of an ecosystem-based approach to fisheries management.

Box 8.5 Ecological changes

Northern gannets (*Morus bassanus*) feeding on discarded fish.
L. Campbell

Estimates for the North Sea suggest that around a quarter of the total biomass of exploitable fish species is presently removed by commercial fishing every year (Figure 8.8), together with a considerable mass of non-exploited fish species. This is clearly a substantial quantity and is likely to constitute a significant modification of the North Sea ecosystem. By examining past records, Greenstreet *et al.* (1999b) demonstrated that selected areas off eastern and north-eastern Scotland that historically had supported prolonged fishing pressure had undergone changes in demersal fish community structure over a 72-year period. Where fishing was most intense, along the eastern Scottish seaboard, a consistent decrease in diversity coupled with the dominance of a few species was detected in non-target fish populations. Statistical analyses suggest that these changes may have occurred in the late 1970s or early 1980s, perhaps reflecting the increase in the use of demersal gears.
Similarly, Rogers and Ellis (2000) reported length–frequency distribution changes in both exploited and non-target species from the North Sea and Irish Sea over an 80-year period in favour of smaller individuals. There was also a coincident increase in the abundance of smaller, non-target species, and it has been suggested that a continuous removal of larger predatory fish, such as cod, may be implicated in the observed increases in stocks of juveniles and smaller fish.

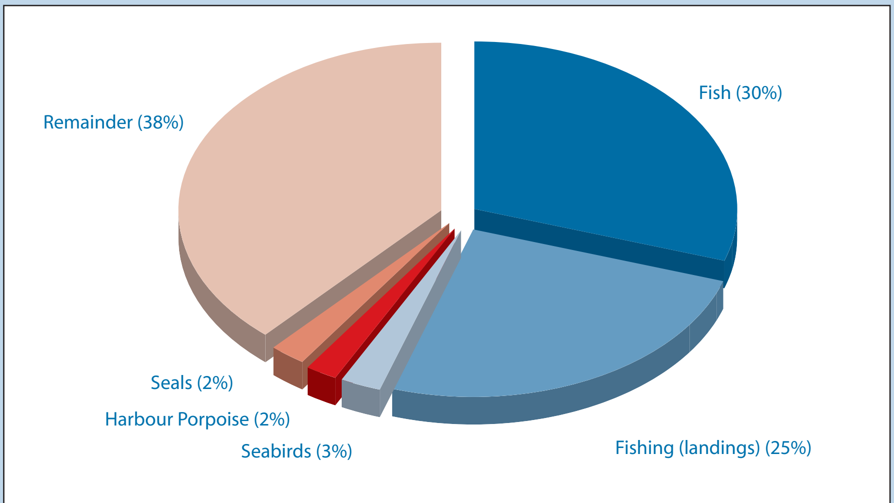


Figure 8.8
The fate of fish in the North Sea
Compiled from the following sources: ICES, 1991; Hislop, 1992; Fifth International Conference on the Protection of the North Sea, 1997; Camphuysen and Garthe, 2000; SMRU, personal communication.

Table 8.3
Effects of different types of fishing gear on seabed disturbance, some of the species affected and estimated area trawled in OSPAR regions II (greater North Sea) and III (Celtic Sea)
Sources: after Kaiser *et al.*, 1996; Fifth International Conference on the Protection of the North Sea, 1997; Gubbay and Knappman, 1999; OSPAR Commission, 2000)

Gear type	Penetration depth	Species affected	Estimated area trawled
Otter trawl (pair and twin)	Ground rope, bobbins chains:	Epifauna	
	<5 cm (soft bottom)	North Sea: Crustacea (*Corystes, Eupagurus*), Mollusca (*Abra alba, Arctica islandica, Donax vittatus, Spisula subtruncata, Placopecten*), Echinodermata (*Echinocardium, Psammechinus miliaris*), Cnidaria (*Alcyonium digitatum*)	Region II: 99,000 km^2 (entire North Sea)
	<2 cm (hard bottom)	Celtic Sea: Mollusca (*Arctica islandica*), Polychaeta (*Lanice conchilega, Spiophanes bombyx*), Echinodermata (*Echinocardium cordatum, Asterias rubens*)	Region III: 25% of Irish Sea
	Trawl door 6–20 cm (soft bottom		
Beam trawl	Chains:	Epifauna	
	4–8 cm (soft bottom)	North Sea: same as otter trawl, plus Polychaeta (*Pectinaria* spp., *Aphrodite aculeata*), Sipunculida and Ascidiacea, Mollusca (*Tellimya ferruginosa, Turritella communis, Chamelea gallina, Dosinia lupinus, Mactra corallina*)	Region II: 171,000 km^2 (area between Shetland Islands and Hardangerfjord, and the Straits of Dover)
	3–6 cm (hard bottom)	Celtic Sea: Same as otter trawl, plus Polychaeta (*Nephthys hombergii*), Mollusca (*Corbula gibba*) and Tanaid copepods	Region III: 22% of Irish Sea
	Trawl heads: 7–10 cm Combined effect of beam trawling in other areas: <10–20 cm deep tracks noted		
Demersal pair trawl	Ground rope 1–2 cm	Same as for otter trawl	Region II: 108,000 km^2 (entire North Sea)
Twin trawl	Same as for otter trawl but without door	Same as for otter trawl	
Seines and ring nets	Zero	Minimal effect on benthos	Region II: 245 km^2 (entire North Sea)
Pair seine	Zero	Minimal effect on benthos	
Dredges	Mussel dredge: 5–25 cm Cockle dredge: 5 cm Scallop dredge: 3–10 cm Hydraulic dredge: 25–60 cm	Same as for beam trawl Molluscs, surface-grazing gastropods (*Hydrobia ulvae*); long-term effects on large bivalves likely. Polychaeta: (*Pygospio elegans, Lanice conchilega*)	Region II: estuarine and coastal areas of North Sea Region III: 8% of Irish Sea
Shrimp beam trawl	Bobbins 2 cm	Benthos and juvenile fish	Region II: estuarine and coastal areas of North Sea
Prawn trawl	Bobbins 2 cm	Benthos and juvenile fish	Region II: northern North Sea
Industrial trawls	Same as for otter trawl	same as for otter trawl	Region II: 11,000 km^2 pair trawl (central North Sea), 127,000 km^2 single trawl (entire North Sea)

decoupling scheme (for species often caught with cod), which allows increases in the quota of other species, with substantial increases in the quota for haddock (+53%) and *Nephrops* (+30%).

Conservation concerns are founded, not least, on parallels between the present state of European cod stocks and that of the Canadian cod fishery just prior to its catastrophic collapse in the early 1990s (MacGarvin, 2001). The Canadian experience has shown that a failure to introduce rapid and appropriate action may leave stocks at a level from which recovery may not be possible in the foreseeable future.

In view of the potential ecological consequences of overexploitation (Box 8.5), commercially exploited fish species have been identified for conservation action through a UK Grouped Species Biodiversity Action Plan. This reaffirms the need to maintain all stocks inside ICES-defined precautionary reference points.

Fleets subject to EU regulations are obliged to discard undersized fish, but fish of commercially acceptable size must also be discarded if catches are in excess of quotas, or if the condition of a proportion of the catch threatens to affect grading and thus reduce economic returns. The great majority of the returned fish are already dead or do not survive.

In the North Sea demersal fishery the estimated average proportions of cod and haddock discarded are 22% and 36%, respectively, by weight, representing 51% and 49% by numbers. Only approximately half of the plaice caught by beam trawl may be retained, decreasing to 20% in shallower inshore grounds. For every tonne of Norway lobster landed from the Irish Sea trawl fishery just under half a tonne of whiting is discarded as bycatch.

The impact of fishing gear, particularly trawls and dredges, on seabed habitats and species is a further area of concern (Table 8.3). Jennings and Reynolds (2000) outlined the likely ways in which fishing may influence species diversity:

- by killing target and non-target species of fish or invertebrates;
- by modifying the ecological relationship between species;
- by changing habitat structure.

Examples of the first and, to some extent, the second point in relation to fish populations are discussed above, but direct evidence of lasting effects on the benthos has been difficult to demonstrate. This is primarily due to the lack of opportunities for study on areas entirely free of present and past fishing and the inability to disentangle the influence of other factors such as climate change and eutrophication (Jennings and Reynolds, 2000). Rumohr and Kujawski (2000) examined one of the few benthic data sets that allow comparisons between past (1902–1912) and contemporary (1986) North Sea communities. They concluded that there had been a decline in bivalve mollusc abundance, but scavenging or predatory crustaceans, gastropods and starfish had increased in abundance in response to the availability of fishery discards and animals killed or injured by the passage of fishing gear. These conclusions remain controversial and. although Frid *et al.* (2000), in a similar study, found some evidence for benthic community changes in three of five selected areas of the North Sea, they were unable to detect a decrease in bivalve abundance.

The state of commercially exploited fish populations and the ecological effects of the gear used to catch them are of serious concern. There is an overwhelming consensus of scientific opinion that fishing activity has, and continues to have, an impact on the entire north-eastern Atlantic region and may even be the main ecological structuring force on the benthos in areas of intense exploitation (Lindboom and de Groot, 1998).

The management of natural resources as economic commodities has brought some commercially exploited fish stocks close to collapse. A review of the CFP in 2002 accepted that the capacity of the European Community fishing fleet often far exceeds that required for sustainable harvesting. An ecosystem-based approach, based on an integrated fisheries management policy that takes account of ecological community structure, is imperative. For example, protection from fishing in ‘no-take zones’ can provide not only a refuge for exploited and other vulnerable species, but an environment in which the target species can grow larger and produce more offspring. This has been shown to enhance populations outside the protected areas (Roberts and Hawkins, 2000; Roberts *et al.*, 2001).

Sources of data

Information relating to the size of the Scottish fishing fleet, employment statistics and fish landings data are produced by the Scottish Executive and published yearly in a Scottish Fisheries Statistics document (also available at the web site http://www.scotland.gov.uk/stats/bulletins/sfs02-00.asp.

The biological data used to determine the status of fish stocks and the subsequent quotas for member EU states are collected by a range of organisations and institutions operating throughout European waters. These data are then used by ICES working groups to make stock assessments, which are then considered by the Advisory Committee on Fishery Management (ACFM). The ACFM advice, together with all of the supporting data, are published annually in the ICES Cooperative Research Report Series (also available at the web site http://www.ices.dk/committe/acfm/comwork/report/asp/acfmrep.asp).

The provision of data through ICES has changed in 2003, with more mixed fishery considerations and the inclusion of a wider range of species. The advice is being provided through a series of overviews for different areas and fisheries (although the advice is also still available on a species and area level).

References

Camphuysen, C. J. and Garthe, S. (2000). Seabirds and commercial fisheries: population trends of piscivorous seabirds explained? In: *Effects of Fishing on Non-target Species and Habitats.* Kaiser, M. J. and de Groot, S. J. (eds), pp. 163–184 Blackwell Science, Oxford.

Coull, J. R. (1996). *The Sea Fisheries of Scotland. A Historical Geography*. John Donald Publishers, Edinburgh.

Cushing, D. H. (1988). *The Provident Sea.* Cambridge University Press, Cambridge.

FAO. (2000). *The State of World Fisheries and Aquaculture 2000.* Food and Agriculture Organisation of the United Nations, Rome.

Fifth International Conference on the Protection of the North Sea. (1997). Assessment report on fisheries and fisheries related species and habitats issues. In: Svelle, M., Aarefjord, H., Heir, H. T. and Øverland, S. (eds) *Report from the Committee of North Sea Senior Officials to the Intermediate Ministerial Meeting on the Integration of Fisheries and Environmental Issues*, 1997 (IMM 97). Bergen.

Frid, C. L. J., Harwood, K. G., Hall, S. J. and Hall, J. A. (2000). Long-term changes in the benthic communities on North Sea fishing grounds. *ICES Journal of Marine Science* **57**: 1303–1309.

Greenstreet, S. P. R., Spence, F. B., Shanks, A. M. and McMillan, J. A. (1999a). Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. II. Trends in fishing effort in the North Sea by UK registered vessels landing in Scotland. *Fisheries Research* **40**: 107–124.

Greenstreet, S. P. R., Spence, F. E. and McMillan, J. A. (1999b). Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. V. Changes in structure of the North Sea groundfish species assemblage between 1925 and 1996. *Fisheries Research* **40**: 153–183.

Gubbay, S. and Knapman, P. A. (1999). A review of the effects of fishing within UK European marine sites (UK Marine SACs Project). English Nature, Peterborough.

Hislop, J. (1992). The North Sea fishery: a case study. In: *Proceedings of the 1992 Meeting of the European Cetacean Society*. European Cetacean Society San Remo, Italy.

Hutchings, J. A. (2000). Collapse and recovery of marine fishes. *Nature* **406**: 882–885.

ICES. (1991). *Report of the Multispecies Assessment Working Group*. ICES, CM 1991/Assess: 7.

ICES. (2001). *Report of the ICES Advisory Committee on Fishery Management, 2001. International Council for the Exploration of the Sea, ICES Cooperative Research* Report, No. 246. ICES, Copenhagen.

ICES. (2002). *Report of the ICES Advisory Committee on Fishery Management.* ICES, Copenhagen.

ICES. (2003). *Report of the ICES Advisory Committee on Fishery Management.* ICES, Copenhagen.

Jennings, S. and Reynolds, J. D. (2000). Impacts of fishing on diversity: from pattern to process. In: *The Effects of Fishing on Non-target Species and Habitats. Biological, Conservation and Socio-economic Issues.* Kaiser, M. J. and de Groot, S. J. (eds), pp. 235–250. Blackwell Science, London.

Jennings, S., Alvsvåg, J., Cotter, A. J., Ehrich, S., Greenstreet, S. P. R., Jarre-Teichmann, A., Mergardt, N., Rijnsdorp, A. D. and Smedstadt, O. (1999). Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. III. International fishing effort in the North Sea: an analysis of temporal and spatial trends. *Fisheries Research* **40**: 125–134.

Jennings, S., Warr, K. J., Greensreet, S. P. R. and Cotter, A. J. R. (2000). Spatial and temporal patterns in North Sea fishing effort. In: *The Effects of Fishing on Non-target Species and Habitats. Biological, Conservation and Socio-economic Issues.* Kaiser, M. J. and de Groot, S. J. (eds), pp. 3–14. Blackwell Science, London.

Kaiser, M. J., Hill, A. S., Ramsay, K., Spencer, B. E., Brand, A. R., Veale, L. O., Prudden, K., Rees, E. I. S., Munday, B. W., Ball, B. and Hawkins, S. J. (1996). Benthic disturbance by fishing gear in the Irish Sea: a comparison of beam trawling and scallop dredging. *Aquatic Conservation: Marine and Freshwater Ecosystems* **6**: 269–285.

Lindboom, H. J. and de Groot, S. J. (eds). (1998). *The Effects of Different Types of Fisheries on the North Sea and Irish Sea Benthic Ecosystems.* NOIZ-Rapport. 1998-1/RIVO-DLO Report C003/98.

MacGarvin, M. (2001). *Now or Never. The Cost of Canada's Cod Collapse and Disturbing Parallels with the UK.* WWF-UK, Godalming.

OSPAR Commission. (2000). *Quality Status Report 2000.* OSPAR Commission, London.

Roberts, C. M., Bohnsack, J. A., Gell, F., Hawkins, J. P. and Goodridge, R. (2001). Effects of marine reserves on adjacent waters. *Science* **294**: 1920–1923.

Roberts, C. M. and Hawkins, J. P. (2000). *Fully-Protected Marine Reserves: a Guide.* WWF, Washington, DC, and University of York, York.

Rogers, S. I. and Ellis, J. R. (2000). Changes in the demersal fish assemblages of British coastal waters during the 20th century. I*CES Journal of Marine Science* **57**: 866–881.

Rumohr, H. and Kujawski, T. (2000). The impact of trawl fishery on the epifauna of the southern North Sea. *ICES Journal of Marine Science* **57**: 1389–1394.

Scottish Executive. (2001, 2002). *Scottish Sea Fisheries Statistics 2000, 2001*. Scottish Executive, Edinburgh.

9 Deep-water fish and fisheries

Introduction

The decline of European continental shelf fisheries, increased catch unreliability and the introduction of fishing quotas have coincided with a growing interest in the exploitation of species that are considered largely outside the range of conventional fishing gear.

Despite often being portrayed as a dark and relatively lifeless environment, the zone below a depth of 400 m – defined as 'deep water' by the ICES – supports a diverse and abundant fish community. Towed fine-mesh nets deployed for research purposes in the Rockall Trough and along the continental slope have recovered over 130 species, with an abundance peak roughly corresponding to the 1,000-m depth contour. Of these, around 12 species are considered marketable (Table 9.1). Many of the target species have distinct but overlapping depth

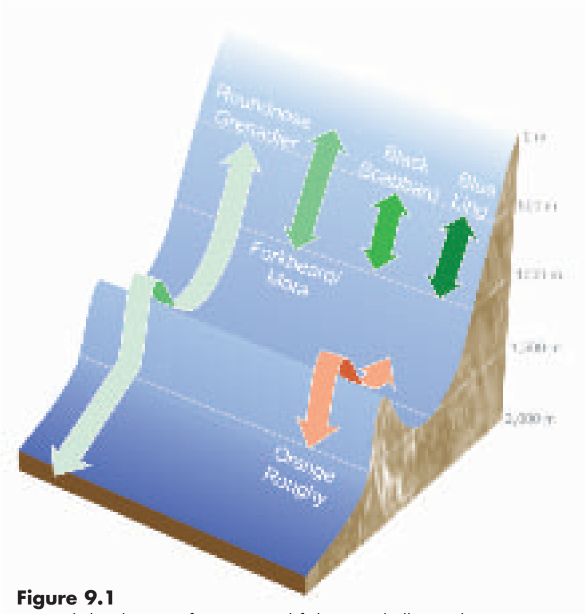
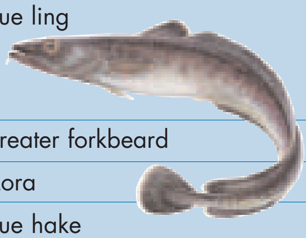
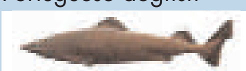


Figure 9.1
Vertical distribution of commercial fish in Rockall Trench
Crown copyright 2000. Reproduced with the permission of the FRS Marine Laboratory, Aberdeen.

Table 9.1 Commercially exploited deep-water fish species
Sources: FRS Marine Laboratory, Aberdeen; Gordon and Hunter, 1994; CES, 2000; Gordon, 2001a

Species	Common name	State of stock/fishery
Micromesistius poutassou	Blue whiting	Considered to be harvested outside safe biological limits
Molva dyptergia	Blue ling 	Total French landings peaked at 14,000 tonnes in 1985, but fell to only 3,000 tonnes in 1994 and have since remained stable. Currently considered to be harvested outside safe biological limits
Phycis blennoides	Greater forkbeard	Status of stock unknown
Mora moro	Mora	Status of stock unknown
Antimora rostrata	Blue hake	Owing to the technical problems of fishing at the depth of greatest density, commercial exploitation is currently not considered viable
Coryphaenoides rupestris	Roundnose grenadier	Status of stock uncertain or unknown
Aphanopus carbo	Black scabbardfish	Catches currently stable at around 6,000 tonnes but considered to be harvested outside safe biological limits
Hoplostethus atlanticus	Orange roughy 	Landings by French vessels in the Rockall Trough peaked at 3,500 tonnes in 1991 but then declined rapidly to less than 500 tonnes as concentrations became heavily depleted. Currently considered to be harvested outside safe biological limits
Argentina silus	Greater silver smelt or argentine	Status of stock unknown
Brosme brosme	Tusk	Considered to be harvested outside safe biological limits
Centroscymnus coelolepsis	Portuguese dogfish 	French landings of both shark species combined reached a maximum of approximately 3,000 tonnes in 1993, and have remained stable at this level
Centrophorus squamosus	Leafscale gulper shark	*Top:* Blue ling, *centre:* Orange roughy, *bottom:* Portuguese dogfish. *SAMS*

ranges (Figure 9.1), or may perform daily migrations to feed at or near the surface.

Some deep-water fisheries are historically well established, notably around oceanic islands with steep inshore slopes, such as Madeira and the Azores, but exploitation of the fishery to the north-west and west of Scotland is a relatively recent development.

Trends

Bottom trawling along the continental slopes of northern Europe began in the late 1960s, when the former Soviet Union and other eastern European countries began targeting roundnose grenadier (*Coryphaenoides rupestris*).

Among 12 commercially exploited deep-water species (Table 9.1), five are considered to be harvested outside safe biological limits and the status of others is largely unknown.

Rapidly increasing catches peaked in the 1970s, but the break-up of the Soviet Union, coupled with the introduction of 200-mile fishery limits around Europe and Iceland, contributed to a decline of the fishery. Attempts by other nations, notably Germany and the UK, to develop deep-water fisheries failed through lack of consumer interest. In the late 1970s, French trawlers, traditionally operating along the outer shelf, began moving into deeper water. A market was established initially for blue ling (*Molva dyptergia*), but by the late 1980s demand for other deep-water species formerly landed as bycatch began to grow. By 1992, larger French vessels had extended their fishing activities still deeper in pursuit of the valuable orange roughy (*Hoplostethus atlanticus*) stocks (Gordon, 2001b).

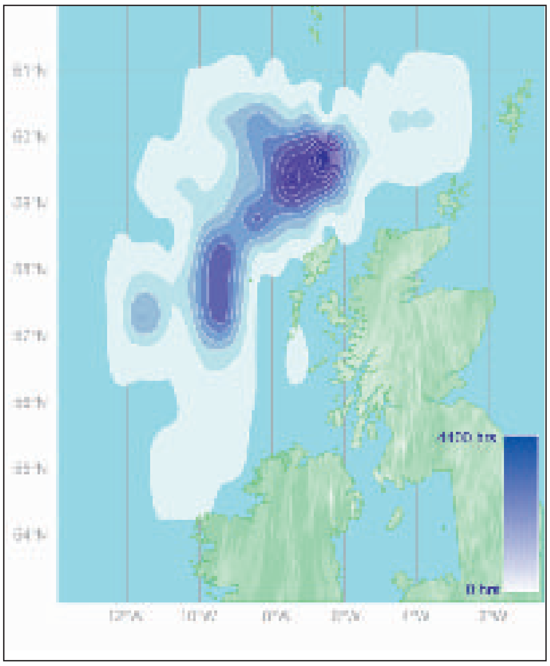


Figure 9.2
Hours fished by French Trawlers landing in Scotland in 1998
Source: FRS Marine Laboratory, Aberdeen.

The French fleet continues to be the most active along the continental slope, with the major effort concentrated around the Rockall Trough and Rosemary Bank (Figure 9.2). Markets have, however, developed in Spain and the United States, and increasing numbers of Norwegian, Icelandic and Faeroes vessels have begun trawling and longlining in the deep water. Both Ireland and the UK have commenced limited exploitation (Brennan and Gormley, 1999), but landings by Scottish vessels are largely of deep-water monkfish (*Lophius piscatorius*), with other species retained as bycatch. Irish fishing started around 1988, but a rapid decline in one of the target species, the greater argentine (*Argentina silus*), coupled with damage sustained to expensive gear, forced the fishery to close in 1990.

Deep-water fisheries have developed rapidly over the last 10 years, but landings of most species declined soon after commencement of exploitation (Figure 9.3). Although there was an apparent increase in the availability of orange roughy, it is thought that this simply reflects discovery and subsequent fishing of previously unexploited aggregations.

Catch per unit effort, a measure of how difficult a given species is to catch and thus an indication of how abundant it may be, has been calculated for a limited number of deep-water species (Figure 9.4). By that measure, black scabbardfish (*Aphanopus carbo*), roundnose grenadier and blue ling have all become scarcer.

Issues and implications

Deep-water fish largely conform to the life history adaptations of much of the deep-water biota, with slow growth rates, long natural lifespans and maturation at a high age. These characteristics render them particularly vulnerable to over-exploitation, and the rapid decline in landings has given rise to concerns that the current level of exploitation may be unsustainable. In addition, rapid pressure transition associated with recovery from such great depths and the delicate nature of much of the deep-water biota results in high bycatch mortality.

At present, deep-water fisheries are partially regulated, although for most species the status is

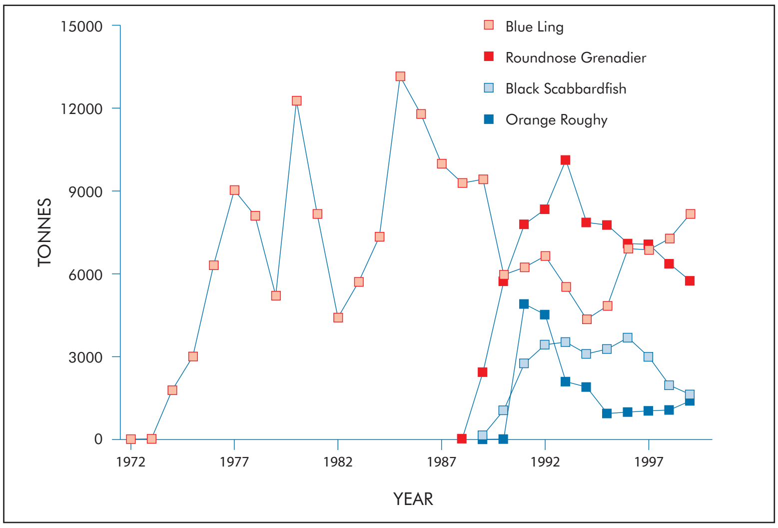


Figure 9. 3 Landings of deep-sea fish species from the west of Scotland
Sources: ICES; J. Gordon, DML.

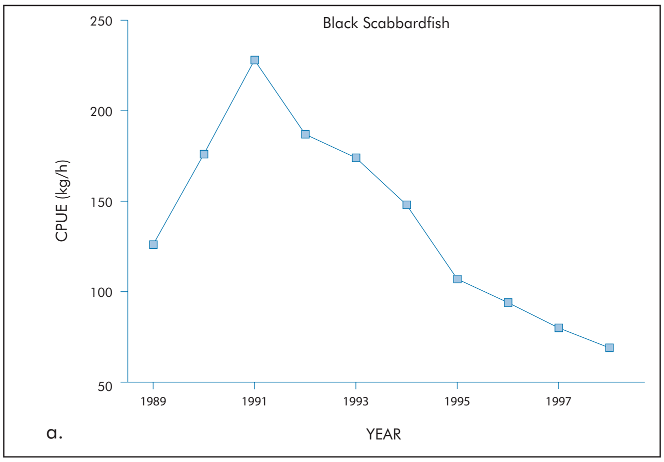
destructive influence on the often fragile habitats and species. Trawl marks on the sea bed between depths of 200 and 1,400 m have been observed all along the north-east Atlantic shelf break and may form continuous furrows for up to 4 km (Rogers, 1999; Fosså *et al.*, 2000; Roberts *et al.*, 2000; Hall-Spencer *et al.*, 2002). The impacts of such disturbance on sedimentary habitats are unknown, but the physical effects on harder substrates, particularly deep-water coral reefs, are perhaps easier to assess. Reef structures dominated largely by *Lophelia pertusa*, but incorporating a number of other coral species, are present throughout the North Atlantic, with large aggregations in Norwegian waters and smaller, scattered colonies widely distributed to the west of Shetland. These structures support a rich associated fauna, with over 850 species living on or within the reefs of the north-eastern Atlantic (Rogers, 1999). A single reef habitat may be host to some 200–300 species.

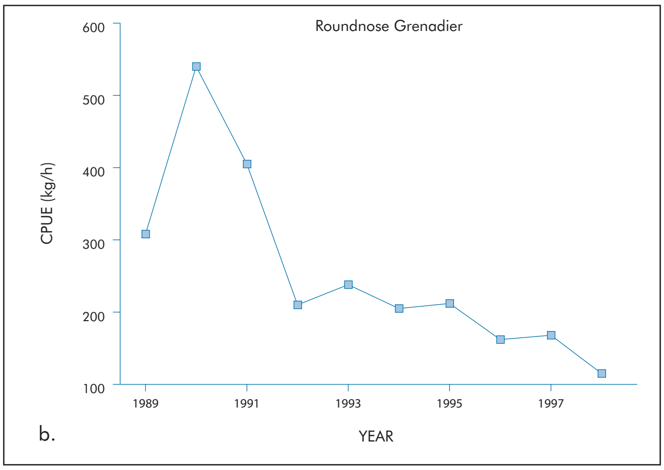
unknown or they are believed to be harvested outside safe biological limits. Recent advice to the EU recommends an immediate reduction in these fisheries unless they can be shown to be sustainable (ICES, 2001).

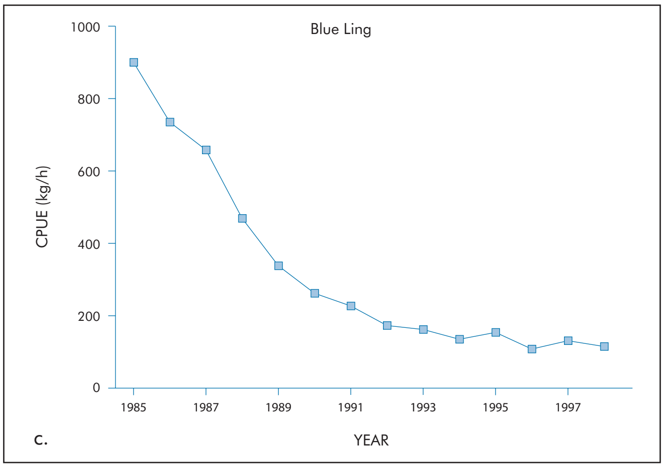
Deep-water fishing, although not of the intensity of the shallower fisheries, may still constitute a

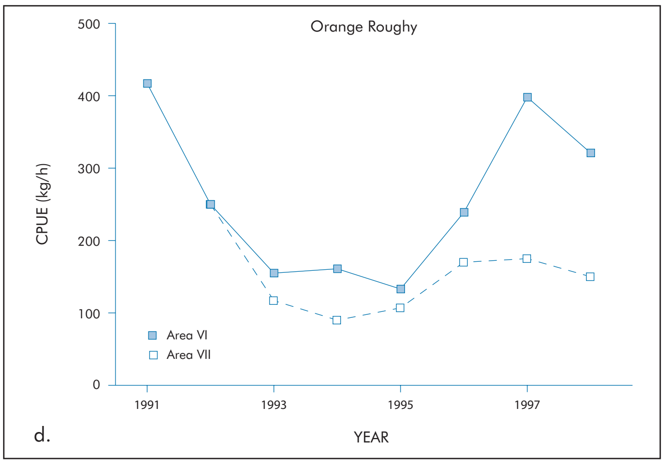
The complex topography of *Lophelia* reefs provides a particularly favoured habitat for non-target and target fish species, simultaneously supplying a refuge from predators and access to a high concentration of prey items. Consequently, fishing vessels in pursuit of the highest densities

Figure 9.4
Trends in catch per unit effort (CPUE) for four deep-water fish species. Data derived from a reference fleet of French deep-water trawlers operating in ICES areas VI (west of Scotland) and VII (west, south-west and south of Ireland).
Redrawn from ICES (2000).









of exploitable species often recover sections of reef after hauling in their trawling gear (Hall-Spencer *et al.*, 2002).

Prospects for deep-water habitats and the species that inhabit them are bleak unless internationally enforced conservation measures are put in place. In recognition of the further potential for unregulated overexploitation and a lack of detailed information on the biology of deep-water species, a UK Grouped Biodiversity Action Plan for deep-water fishes is being implemented (UK Biodiversity Group, 1999) with the objective of stabilising all stocks of commercially exploited species at or above safe biological limits by 2005.

Designation of SACs under the Habitats Directive is being considered for deep-water coral reefs, but such protection will apply only to features within precisely defined areas. While designation as a SAC under the Habitats Directive will require incorporation into UK legislation, fisheries are controlled at the European level. Protection of both corals and deep-water fish requires the EC to exercise control over fishing in these designated sites through amendments to the CFP. In 2002 the EC initiated a series of measures (Council Regulation (EC) No.2347/2002) designed to regulate and monitor deep-water fishing activity. These measures include the issuing of licences for landing deep-water species and the placing of independent scientific observers on board licensed vessels. In addition, fishing activities are closely monitored through a satellite tracking system fitted on each vessel. This management scheme will be reviewed and a report submitted to the European Commission before the 30th June 2005.

Sources of data

Population estimates of deep-water species found on the slopes of the Rockall Trough are derived from an intensive programme of study carried out by the Scottish Association for Marine Science (SAMS) since the mid-1970s.

Fishery landings data for some deep-water species are compiled and collated by the ICES Advisory Committee on Fishery Management (ACFM) and published in the *ICES Cooperative Research Report* Series (also available at the web site http://www.ices.dk/committe/acfm/comwork/report/asp/acfmrep.asp). Reported landings from the earlier exploration of the sea fishery for roundnose grenadier are considered to be inadequate, and the common practice of reporting landings of roundnose and roughhead grenadier as a single species continues to confound attempts at accurate stock assessment (Gordon, 2001a,b). In addition, deep-water species captured as bycatch are probably greatly under-reported. There are concerns that the UK adoption of the United Nation Convention on the Law of the Sea and the resulting removal of the UK 200-mile fishery limit around Rockall has led to a greater degree of uncontrolled exploitation. Although the enclosed area, which includes the Rockall Plateau and Hatton Banks, was not previously subject to any officially recognised regulation policy for deep-sea fishes, the number of vessels was restricted by nationality and reliable data on landings were collected. At present, landings are known to be incorrectly and erratically reported as a largely international fleet engages in a programme of exploration and exploitation.

References

Brennan, M. H. and Gormley, R. T. (1999). *The Quality of Under-utilised Deep-water Fish Species.* Irish Agriculture and Food Development Authority, Dublin.

Fosså, J. H., Mortensen, P. B. and Furevik, D. M. (2000). Lophelia-korallrev langs norskekysten forekomst og tilstand. *Fisken og Havet* **2**: 1–94.

Gordon, J. D. M. (2001a). *Deep Ocean Fisheries.* Joint Nature Conservation Committee, Peterborough.

Gordon, J. D. M. (2001b). Deep-water fish and fisheries: introduction. *Fisheries Research* **51**: 105–111.

Gordon, J. D. M. and Hunter, J. E. (1994). *Study of Deep-water Fish Stocks to the West of Scotland.* Vol. I. Final Report. Scottish Association for Marine Science, Oban.

Hall-Spencer, J., Allain, V. and Fosså, J. H. (2002). Trawling damage to NE Atlantic ancient coral reefs. *Proceedings of the Royal Society of London, Series B* **269**: 507–511.

ICES. (2000). Advisory Committee on Fishery Management. *Report 2000.* ICES, Copenhagen.

ICES. (2001). *Report of the ICES Advisory Committee on Fishery Management, 2001*. ICES Cooperative Research Report, No. 246. ICES, Copenhagen.

Roberts, J. M., Harvey, S. M., Lamont, P. A., Gage, J. D. and Humphery, J. D. (2000). Seabed photography, environmental assessment and evidence for deep-water trawling on the continental margin west of the Hebrides. *Hydrobiologia* **441**: 173–183.

Rogers, A. D. (1999). The biology of *Lophelia pertusa* (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. *Internationale Revue der gesamten Hydrobiologie* **84**: 315–406.

UK Biodiversity Group. (1999). *Tranche 2 Action plans.* Vol. V: *Maritime Species and Habitats.* English Nature, Peterborough.

Part 4
Quality of the marine environment

10 Coastal and estuarine environment quality

Previous page: Knotted wrack (*Ascophyllum nodosum*). G. Saunders

Above: Coll. *L. Gill/SNH*

Introduction

In 1960, River Purification Boards (RPBs) were given responsibility for monitoring and improving the levels of new discharges to tidal waters. From 1965 they became responsible for all discharges; nevertheless, river water was considered a priority and domestic and industrial discharges to estuaries and coasts remained largely untreated (Saunders *et al.*, 2002). In the 1970s a programme of discharge controls was initiated and major improvements in estuarine and coastal water quality followed.

Two-thirds of Scotland's coastal traffic is of bulk liquid, primarily crude petroleum from North Sea terminals. Accidental spillage is an ever-present threat to marine habitats (Box 10.1).

To assist in the assessment of water quality the RPBs developed classification schemes in which biological and chemical sampling data were combined to provide a single index of water

Box 10.1 Shipping

Over 80% of the world's commodities are transported by shipping. Sea-borne freight traffic around Europe and the UK has continued to increase. In 2000, the Forth and Sullom Voe ports accounted for cargoes of 41.1 and 38.2 million tonnes respectively, making them the fourth and fifth largest ports by volume in the UK (DTLR, 2001).

Each year, many pollution incidents occur around Scotland, involving vessels from large bulk carriers to smaller coasters, ferries, fishing boats and recreational craft. Many, mainly those involving small spillages of oil, go unreported. Occasionally, as in January 1993 with the wreck of the oil tanker *MV Braer* on the southern coast of Shetland, a major pollution incident may arise. Such an occurrence can have a devastating and immediate impact on the local environment, wildlife and coastal amenity. Local economic and social interests can be similarly affected. In the longer term, however, oil contamination will eventually disappear through the action of natural processes.

On average, around 60 pollution incidents per year involving oil or chemical contamination are brought to the attention of SNH, which provides advice on natural heritage implications and appropriate mitigation measures. Referrals come from the Maritime Coastguard Agency, harbour authorities and local authorities.

The wreck of the *MV Braer,* Shetland.
G. Storey

quality. Annual assessments of this type were first applied in 1968, but no improvement in water quality was observed until after 1975. Separate schemes for coastal and estuarine classification were introduced in 1990, and improvements in water quality were reported between 1990 and 1995.

In 1995, SEPA was established under the Environment Act 1995 and assumed statutory responsibility for Scotland's tidal waters. The coastal and estuarine classification schemes continued to be applied by SEPA but were immediately subject to substantial revision to increase monitoring sensitivity. A further revision for coastal water quality assessment, incorporating additional island and other coastlines, was applied to data from 1999 onwards.

In 1999, annual monitoring was extended from 6,900 km to 11,800 km of coastline, together with 810 km^2 of estuarine catchment. Data are collected on water quality, seabed invertebrate quality, the status of fish populations and observations of aesthetic modifications. Grading is on the basis of four classes: excellent, good, unsatisfactory and seriously polluted (see Appendices 1 and 2 for an explanation of classification schemes).

The EC Bathing Water Directive (76/160/EEC) requires member states to identify bathing waters and improve or maintain them at a prescribed standard. The UK government set a definition of a bathing site based on the number of people using the area as a bathing destination. A total Scottish set of 23 was announced in 1987 by the Secretary of State for Scotland. A review by the Scottish Office resulted in the addition of a further 37 bathing waters in May 1998. The Bathing Waters (Classification) (Scotland) Regulations 1991 implements the 19 monitoring and interpretation parameters specified by the EC Bathing Water Directive. The Directive specifies two main water quality standards:

- mandatory – minimum standards which must be met by member states;
- guideline – stricter values that member states should endeavour to observe.

The microbiological requirements for each are given in Appendix 3.

Trends

The overall quality of Scottish coastal waters was predominantly excellent or good between 1996 and 2002, with little more than 260 km, about 3%, of the coastline classified as unsatisfactory or seriously polluted at any time (Figure 10.1). In general, the areas rated as polluted were localised contaminated sites, around long sea outfalls, inappropriately sited fish farms or sludge and spoil dumping sites.

The majority of Scottish estuarine areas also maintained a favourable overall rating between 1996 and 2002. About 35 km^2 was classed as unsatisfactory or seriously polluted, but this declined to 15.4 km^2 in 2002. The small areas classified as seriously polluted were highly localised and were reduced by 60% over the period (Figure 10.2).

Land-based industrial development and subsequent urbanisation has, in general, been restricted to the areas surrounding the major inlets or firths of the Central Belt. Of a total Scottish population of 5.2 million, about 1.8 million people live around the Clyde estuary catchment and a further 1 million around the Firths of Tay and Forth. The cumulative effects of prolonged domestic and industrial discharges from these areas into the nearby estuaries have been severe and persistent.

Below: Forth estuary. *P. & A. Macdonald /SNH*

Below right: Dog whelks (*Nucella lapillus*). *J.Baxter*

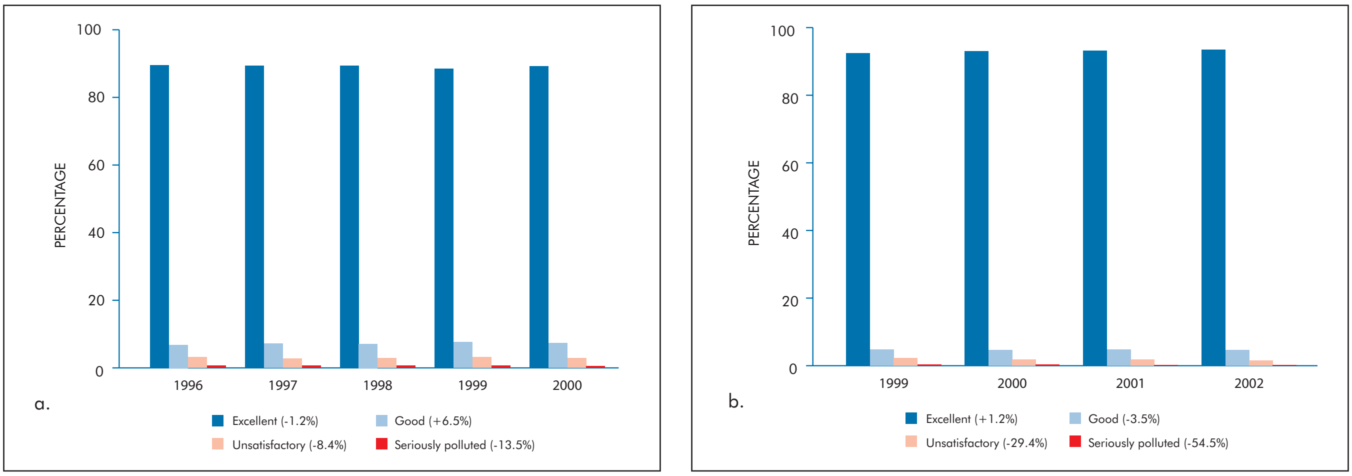


Figure 10.1
Coastal classification as a percentage of sites surveyed:
(a) 1996–2000,
(b) 1999–2002 (incorporating previously excluded costal areas). Percentage change between start and end of reporting periods are shown in brackets
Source: SEPA.

Statutory controls on discharges have, however, promoted a steady recovery since the 1970s, and an increasing number of species are returning and re-establishing at locations where past contamination levels excluded all but a few highly tolerant taxa.

In the Clyde, a major reduction in seriously polluted areas was achieved between 1995 and 1999 (Figure 10.3). In the 1970s, the upper Clyde estuary sediments were dominated by a few pollution-tolerant species mainly consisting of oligochaetes and the polychaete worm *Capitella capitata*. In the 1980s, with improving water quality, the faunal composition began to change in favour of a more diverse invertebrate community (Figure 10.4) and rising numbers of fish species (Figure 10.5). The establishment of resident populations of flounder was a further indication of improving water quality.

Similar improvements have occurred within the Forth estuary. Bacterial oxygen consumption is a natural process, at its greatest in the upper reaches of estuaries where suspended particulate matter is most concentrated. The addition of organic waste has historically stimulated microbial growth, measured as biological oxygen demand (BOD), in the Forth and depressed the level of oxygen available to other fauna and flora. As discharges have declined, the extent and duration of oxygen depression have diminished (Figure 10.6). The combination of increasing dissolved oxygen and declining organic and metallic waste levels has been linked to returning fish populations, notably the smelt (*Osmerus eperlanus*), a species known to be particularly sensitive to low oxygen levels (Figure 10.7).

Contrary trends of species recovery on formerly polluted mudflats (Box 10.2) and declining numbers of scaup (*Aythya marila*) in the Forth estuary (Box 10.3) are consistent with improving ecological status.

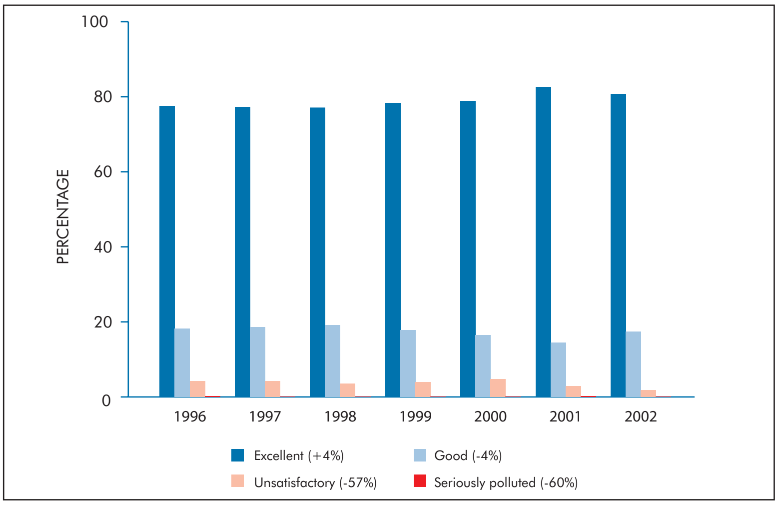


Figure 10.2 Estuarine classification as a percentage of sites surveyed in 1996–2002. Percentage change between 1996 and 2002 shown in brackets.
Source SEPA.

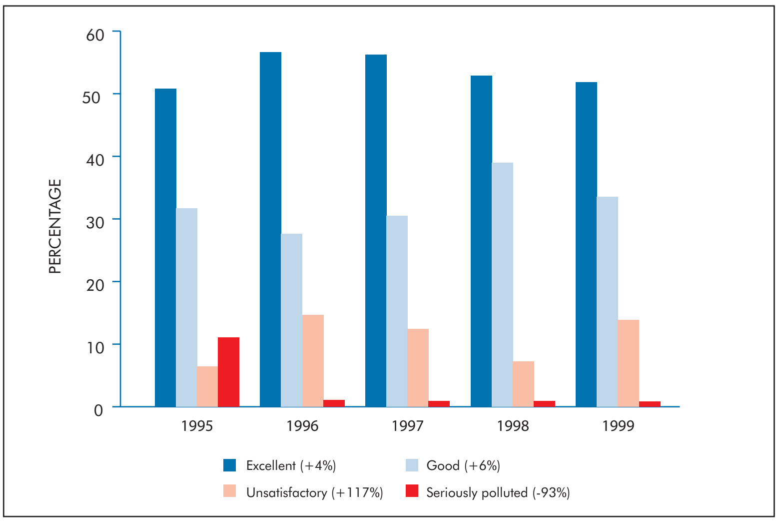


Figure 10.3 Clyde estuarine classification as a percentage of sites surveyed in 1995–1999. Percentage change between 1995 and 1999 shown in brackets
Source: SEPA

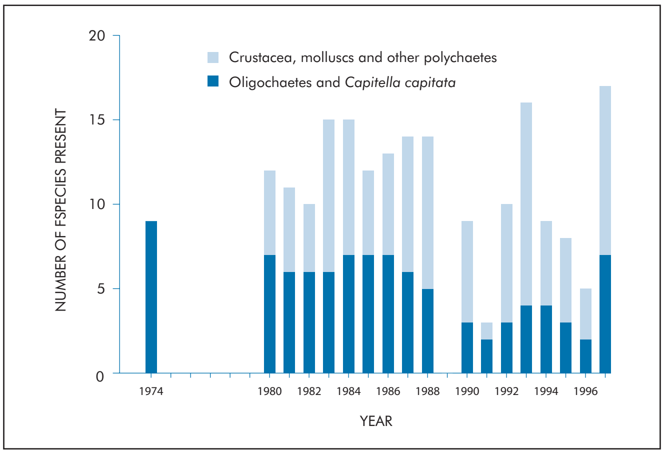


Figure 10.4
The composition of benthic fauna at the Clyde/Cart confluence
Source: SEPA

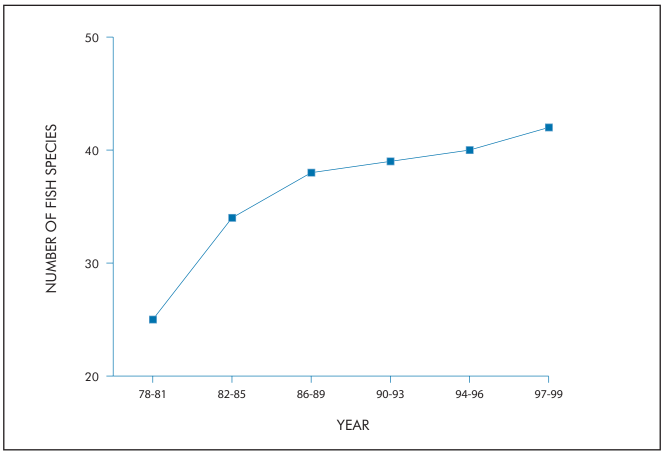


Figure 10.5
Number of fish species recorded in the Clyde Estuary 1978–1999
Source: SEPA

Figure 10.6
Trends in biological oxygen demand (BOD) originating from point source discharges in the Forth estuary.

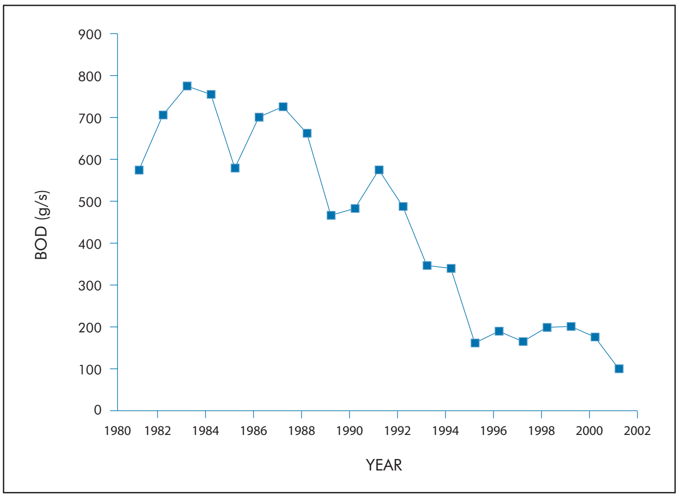
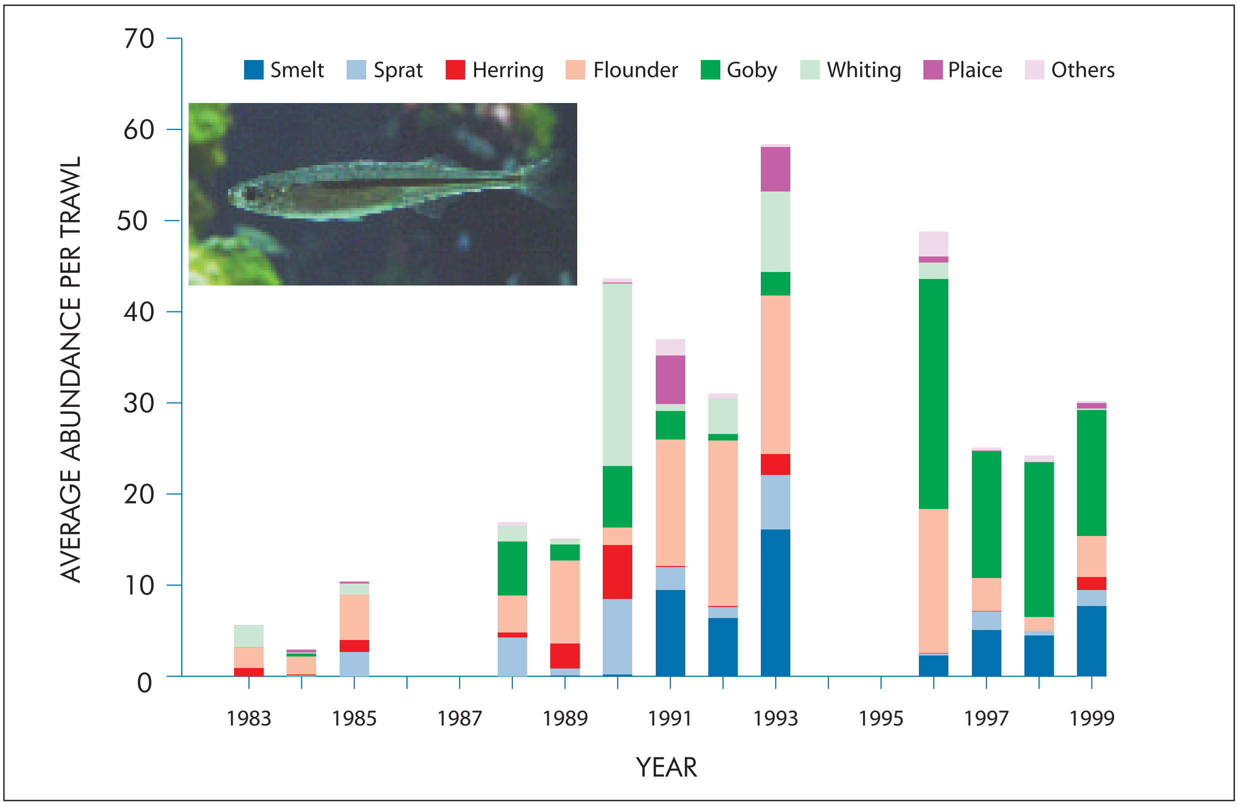


Figure 10.7
Fish species recorded in the Forth estuary,1983–1999
Source: SEPA.

Inset: Smelt *(Osmerus eperlanus)*.
G. Saunders



Box 10.2 Kinneil mudflats

A reduction in effluent discharges from an oil refinery adjacent to the Kinneil mudflats in the Firth of Forth promoted recolonisation of the formerly almost lifeless sediments (Figure 10.8) (McLusky and Martins, 1998).

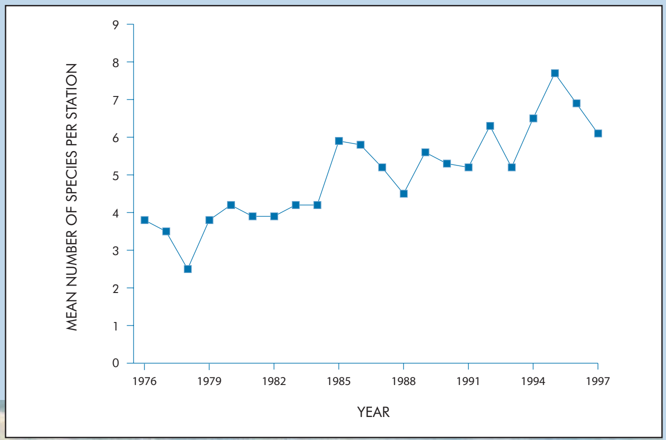


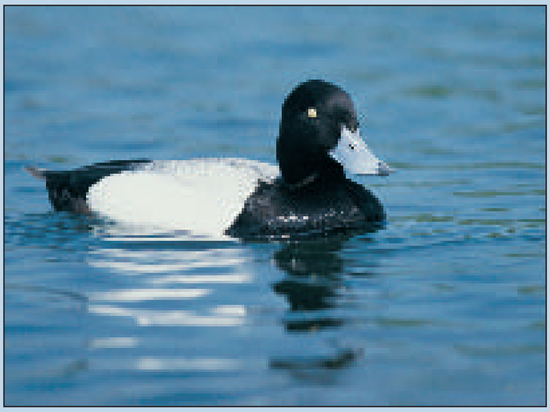
Figure 10.8
Mean number of species of benthic in fauna at Kinneil mudflats in the Forth estuary
After McLusky and Martins, 1998.

Kinneil mudflats.
J.Baxter

Box 10.3 Declining scaup (*Aythya marila*) numbers on the Forth

The scaup is a diving duck, occurring mainly as a winter visitor in the UK, from Iceland, the Baltic Sea and Russia (Thom, 1986). During 1995–1999, peak counts of scaup in Britain averaged around 5,500, of which about 60–98% occurred in Scotland (Musgrove *et al.*, 2001). The bulk of these were counted in the Solway, Lochs Ryan and Indaal, the Inner Moray Firth and the Forth estuary.

Much higher numbers of scaup were recorded in Scotland during the 1960s, particularly on the Forth, where their numbers appeared to be influenced by the discharge of waste grain and sewage. Grain discharge into the Forth increased progressively up to 1968, when over 30,000 scaup were counted between Leith and Levenhall (Figure 10.9). Declining scaup numbers in subsequent years reflected a reduction in grain discharge levels and, in 1975, the implementation of a sewage treatment programme at Seafield (Thom, 1986).



Scaup (*Aythya marila*).
E. Janes/RSPB

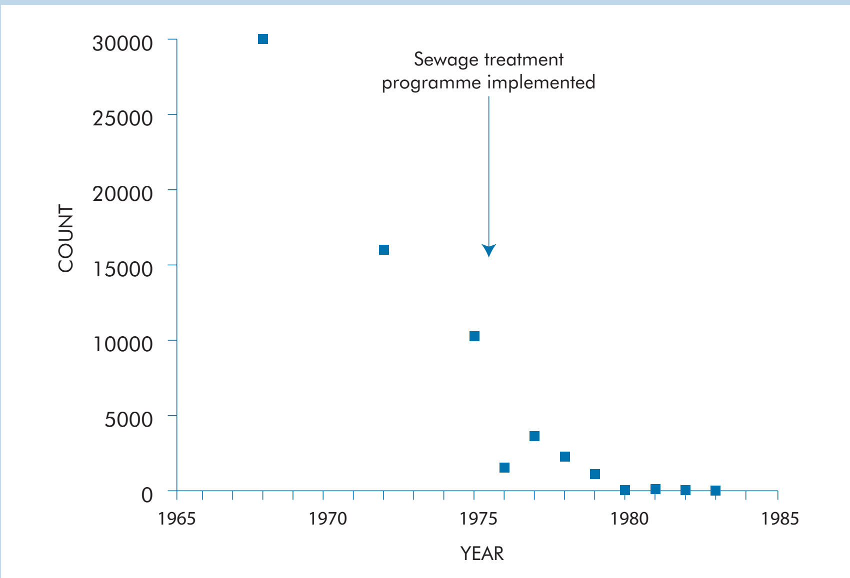


Figure 10.9
Peak counts of scaup wintering on the Forth between Leith and Levenhall during the 1960s to 1980s.
Source: Thom, 1986.

Populations of the dogwhelk (*Nucella lapillus*) declined substantially throughout the 1980s and early 1990s, becoming locally extinct at some regularly monitored locations around the UK. This was attributed to the widespread use of tributyltin (TBT), a chemical antifoulant commonly applied to the hulls of marine vessels. High concentrations of TBT were shown to be associated with a masculinisation effect on female dogwhelks and other mollusc species, thus reducing their reproductive capacity. The most severe effects were found in the littoral zone adjacent to areas of high vessel activity. In 1987, the UK imposed a ban on the use of TBT-based antifouling treatments for vessels below 25 m in length and this, together with the development of slow-releasing paints for larger vessels, has resulted in reduced TBT concentrations in estuarine and coastal waters. A study undertaken in 2001 indicated that dogwhelk populations had re-established at almost all of the sites from where they had disappeared as a result of high TBT levels (Birchenough *et al.*, 2002). Scottish sampling locations included the Isle of Cumbrae and Lerwick harbour, Shetland. However, some areas of the south-west coastline, notably Loch Ryan, continued to exhibit elevated levels of TBT up to 1999. A possible source of this contamination may be a breaker's yard dismantling large naval vessels (SEPA, 2000).

While peak counts for the estuary averaged 4,600 during 1976-1979, numbers continued to fall in the Leith-Levenhall section, reaching an average peak of only 50 birds in 1980-1983. During the 1990s, peak counts for the estuary varied widely (77-1,031) but were still well below the figures recorded in the 1960s (Musgrove *et al.*, 2001).

In 2001 only 85% of Scotland's identified bathing waters were able to meet the mandatory standard, of which only 40% were of a sufficient quality to attain the guideline standard. This represented no improvement on the previous year and a deterioration when compared with 1998 and 1999 (Figure 10.10). In 2002, however, there was a notable increase in the number reaching the mandatory standard, resulting in some 92% of Scotland's identified bathing waters attaining an acceptable standard or above. Over the longer term there has been a steady reduction in failure to comply with the minimum standard (Figure 10.11). Areas of persistent compliance failure have been identified in Ayrshire and Argyll, and in the majority of cases this has been attributable to sewage effluent (SEPA, 2001).

Sewage sludge dumping from Glasgow and Edinburgh was discontinued in 1998 (Box 10.4).

Figure 10.10
Quality assessments for Scotland's identified bathing waters, 1997–2002
Source: SEPA.

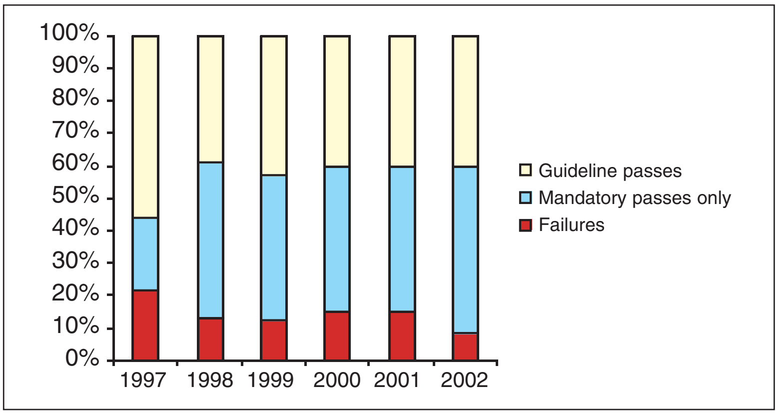
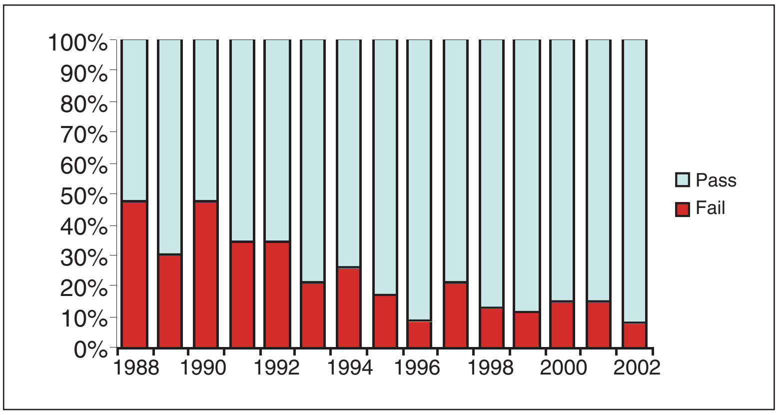


Figure 10.11
Trends in Scottish bathing water compliance failure, 1988–2002
Source: SEPA.



Box 10.4 Effects of sewage sludge dumping

Sewage sludge from Edinburgh and Glasgow was dumped at sea until 1998, when dumping was stopped in compliance with the EC Urban Waste Water Treatment Directive (91/271/EEC).

Frequent monitoring of the dumping grounds showed a greater impact at the Firth of Clyde Garroch Head (Glasgow) site, which was less dispersive than the two North Sea sites used by Edinburgh. The dumping ground at Garroch Head was contaminated by persistent organochlorine compounds (Kelly and Balls, 1995) and the benthos modified by the organic input. Recent studies have shown that the benthos has improved since dumping stopped. Sludge disposal off the Firth of Forth had no discernible ecological impact, presumably because of the biodegradability and low concentration of persistent contaminants in the dumped material (Saunders *et al.*, 2002).

Issues and implications

To date, national and European legislation directed towards regulating traditional point source discharges has successfully reduced the extent of polluted tidal waters. Where inputs of organic waste and persistent substances have been reduced, the environment has shown signs of recovery. Nevertheless, problems associated with more diffuse pollution remain. Of greatest concern is bacterial and nutrient contamination.

Diffuse inputs of faecal coliforms are under investigation as the probable cause of failures to meet the standards of the Bathing Waters Directive in places where point source discharges have been largely eliminated (Centre for Research into Environment and Health, 1999).

Monitoring results for the Firth of Forth have shown no trend in the concentrations of coastal nutrients or chlorophyll over the past 20 years (Dobson *et al.*, 2004), whereas a local problem has been recognised in the catchment and estuary of the River Ythan (Box 10.5). A recent and more general review of nitrogen inputs to tidal waters has shown rivers to be the major source,

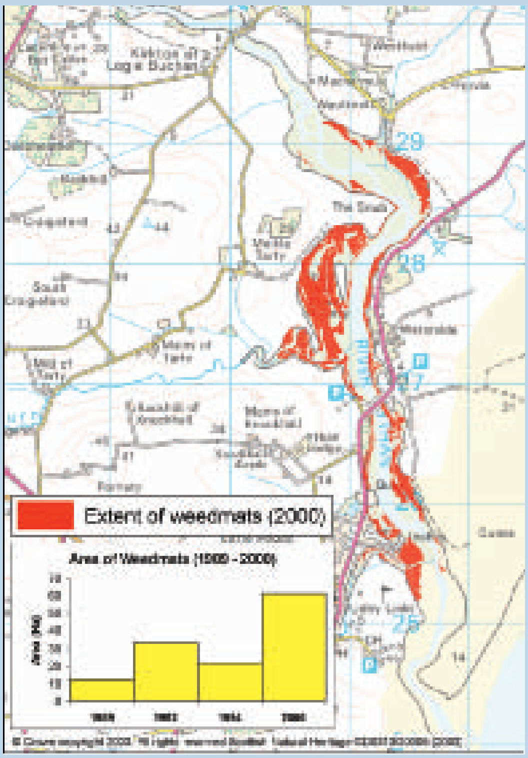
Box 10.5 Nutrient enrichment

Problems associated with diffuse pollution, notably from bacterial contamination and nutrient enrichment, remain in several estuaries and particularly on the east coast. Whereas nutrient and chlorophyll concentrations have remained largely unchanged in the Firth of Forth over the past 20 years, they have increased markedly in the arable catchment and estuary of the River Ythan.

In the future, the EC Water Framework Directive (WFD) will replace and complement many existing directives and will provide a framework in which good ecological status is actively sought for all waters other than those heavily modified for essential services. Present policies of tolerating no deterioration in classification status will continue, as will control of point sources. In contrast to past legislation, the WFD maintains a more explicit focus on diffuse inputs from agricultural and urban runoff, requiring some adjustments of emphasis relating to monitoring and control.

Assessing algal biomass, Ythan estuary.
SEPA

Extent of algal mats, Ythan estuary.
SEPA



with relatively minor inputs from point source discharges.

Sources of data

Data relating to estuarine and coastal water quality are collected annually by SEPA and are available electronically.

Bathing water is sampled at least once every two weeks for total and faecal coliforms, transparency, colour, mineral oil, surface-active substances reacting with methylene blue and phenols. A minimum of 12 samples are taken during the bathing season. The results are published annually in the *Scottish Bathing Waters* document (SEPA, 2001, 2002, 2003).

SEPA datasets relating to all of the above can be found at:
http://www.sepa.org.uk/data/index.htm.

References

Birchenough, A. C., Evans, S. M., Moss, C. and Welch, R. (2002). Re-colonisation and recovery of populations of dogwhelks *Nucella lapillus* (L.) on shores formerly subject to severe TBT contamination. *Marine Pollution Bulletin* **44**: 652–659.

Centre for Research into Environment and Health. (1999). *Faecal Indicator Organism Sources and Budgets for the Irvine and Girvan Catchments, Ayrshire.*, Vols 1 and 2. A report to WOSWA, SEPA and South Ayrshire Council.

Dobson, J., Edwards, A., Park, R. and Richardson, L. (2003). Decadal changes in the Forth Estuary and Firth of Forth in relation to the North Sea 1980–1999. In: Burning Issues of North Sea Ecology. The 14th International Senckenberg Conference, 'North Sea 2000', Wilhelmshaven, Germany, 8–12 May 2000. *Senckenbergiana maritima*, 31, (2). Kröncke, I., Türkay, M., Sündermann, J. (eds). E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

DTLR. (2001). *Maritime Statistics: United Kingdom: 2000*. The Stationery Office, London.

Kelly, A. G. and Balls, P. W. (1995). *Persistent organochlorine compounds in the Firth of Clyde. In: Coastal Zone Topics: Process Ecology and Management. 3. The Estuaries of Central Scotland.* McLusky, D. S (ed.), pp. 88–97. Joint Nature Conservation Committee, Peterborough.

McLusky, D. S. and Martins, T. (1998). Long-term study of an estuarine mudflat subjected to petro-chemical discharges. *Marine Pollution Bulletin* **36**: 791–798.

Musgrove, A., Pollitt, M., Hall, C., Hearn, R., Holloway, S., Marshall, P., Robinson, J. and Cranswick, P. (2001). *The Wetland Bird Survey 1999–2000: Wildfowl and Wader Counts.* BTO/WWT/RSPB/JNCC, Slimbridge.

Saunders, G., Dobson, J. and Edwards, A. (2002). The state of Scotland's seas and estuaries. In: *The State of Scotland's Environment and Natural Heritage*. Usher, M. B., Mackey, E. C. and Curran, J. C. (eds). The Stationery Office, Edinburgh.

SEPA. (2000). *West Region Water Quality Review.* Scottish Environment Protection Agency, Stirling.

SEPA. (2001, 2002, 2003). *Scottish Bathing Waters 2001 (2002, 2003*). SEPA, Stirling.

Thom, V. (1986). *Birds in Scotland.* T & A.D. Poyser, Calton.

11 Marine litter

Above: Beach litter. *C. Duncan/MCS*

Above right: Public participation in litter monitoring, MCS Beachwatch, Cramond. *C. Duncan/MCS*

Introduction

The accumulation of man-made debris is a considerable problem in the Scottish maritime environment, on and within the open sea, on the sea bed and on the shore. Discarded material may originate from either land or marine sources. Some 50-80% is estimated to be derived from land-based activities such as refuse disposal, sewage discharge or tourism. Marine sources are predominantly the shipping, fishing and mariculture industries. The offshore oil and gas industry was a significant contributor in the past, but controls and improvements in waste management practices have greatly reduced such inputs. The main impacts of marine litter are as follows:

- aesthetic degradation due to visual impact of litter;
- associated economic losses due to decrease in tourism;
- damage to boats and fishing gear;
- risk to human health from sewage-related debris or hazardous chemicals;
- hazards to wildlife, mainly from entanglement in discarded nets and ingested debris;
- introduction of non-native species from colonised floating debris transported by currents.

The nature of the materials themselves and wind, wave and tide action results in accumulation at, or above, the high-water mark, where the debris is visually intrusive. The problem is often increased at times of the highest spring tides and concurrent storms, commonly in early autumn and late winter. At these times winds may be particularly strong and dry litter can be lifted from the strandline and deposited considerable distances inland, where 'snagging' and accumulation of plastic bags and wrapping material on fencing, trees and hedges is common. In the absence of a clean-up policy, large amounts of litter can remain on beaches for extended periods of time, undergoing a continuous cycle of exposure and reburial by the action of wind and tide, with smaller items remaining buried for longer (Williams and Tudor, 2001).

In the sublittoral, the continental shelves and slopes have been subject to a continuous accumulation of debris, consistent with concentrations observed floating at the surface (Galgani *et al.*, 2000). The composition and abundance of material can be traced to proximity to major rivers in the case of sewage-related debris, shipping lanes in the case of vessel-derived litter and areas of greatest fishing intensity in the case of lost or discarded fishing nets and other fishing-associated debris (Williams *et al.*, 1993; Galgani *et al.*, 2000).

Trends

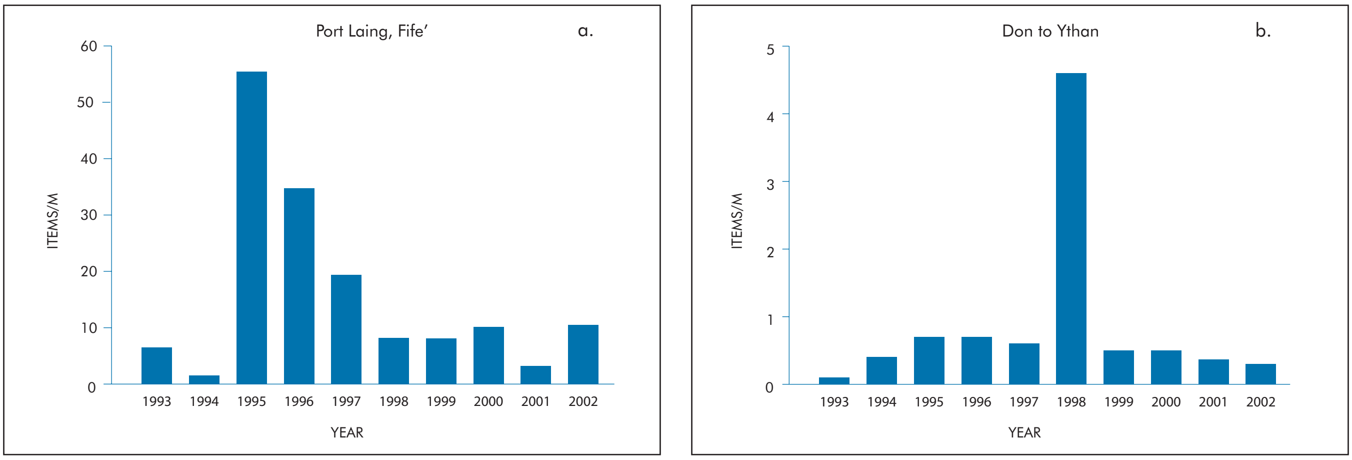
The inconsistent manner in which data have been collected and changes in reporting format make it difficult to interpret trends. Results from annual collections from two beaches on the east coast of Scotland show widely varying amounts between sites and years but no consistent pattern of change (Figure 11.1). Other reports have, however, suggested that beach litter has increased over the last 10 years (OSPAR Commission, 2000a). Velander and Mocogni (1998) noted that the quantity of the litter found on Cramond beach, Edinburgh, more than doubled between 1984 and 1994, rising from 0.35 to 0.8 pieces of litter per square metre.

Discarded material from tourist and recreational activities has been the greatest source of coastal litter (Figure 11.2), with commercial fishing and sewage-related debris the second and third largest sources respectively. There was a reduction in litter originating from discharges from shipping between 1997 and 2002.

The bulk disposal of waste material at sea as an alternative to landfill became particularly prevalent in the second half of the twentieth century. In the 1980s the greatest proportion of dumped material was derived from dredging activities, constituting some 80–90% of the total amount of discarded material. Other types of waste disposed of at sea included industrial effluent, sewage sludge, incineration products, mine tailings, redundant military ordinance (Box 11.1) and shipping waste.

The dumping of dredged material continues around the UK, but licensing now enforces greater controls over the dumping location, amount and chemical constituents of the dredged material. The dumping at sea of other material has been addressed at an international level. Resultant UK legislation has put an end to the marine disposal of most types of waste. Disposal of radioactive waste at sea stopped at the end of 1982, burning of waste at sea has not been permitted since 1990, dumping of industrial waste stopped at the end of 1992 and dumping of sewage sludge stopped at the end of 1998.

Figure 11.1
Total number of beach litter items collected between 1993 and 2002 from two beaches on the east coast of Scotland
Source: Marine Conservation Society. (a) Port Laing, Fife. (b) Don to Ythan.



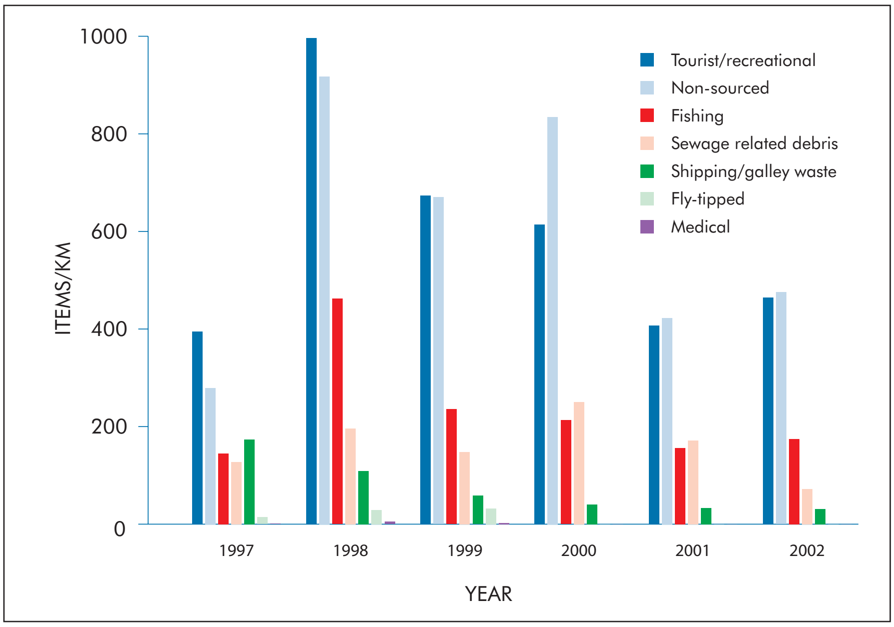


Figure 11.2
Sources of litter collected on Scottish beaches between 1997 and 2002
Source: Marine Conservation Society.

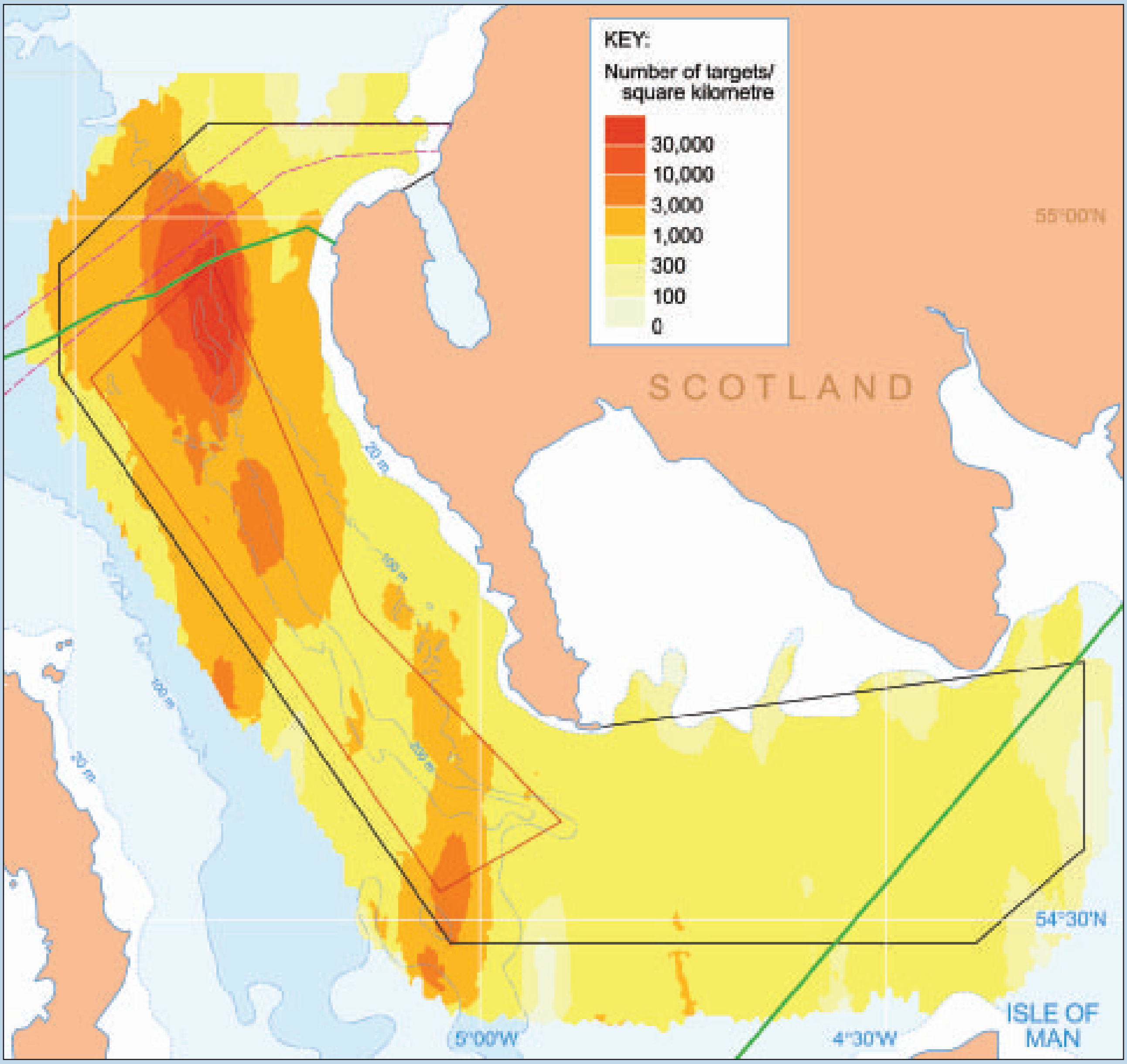


Figure 11.3
North Channel and northern Irish Sea, showing the distribution and densities of larger munitions, munitions-related materials and unidentified man-made debris, derived from combination of the sidescan sonar, underwater television and pulse induction data (number of targets/square kilometre)

Box 11.1 Munitions

Areas around the Scottish coast have been used as dumping grounds for waste munitions and more recently for disposal of chemical weapons. Of the order of a million tonnes of munitions was dumped in the Irish Sea in the years following the Second World War. In recent years, some of these materials, notably phosphorus flares, have been washed up on beaches or have been recovered in fishing nets. Underwater photography around submerged gas pipelines has revealed munitions (GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) and Advisory Committee on Protection of the Sea, 2001).

A survey carried out by the Fisheries Research Services showed that discarded munitions were distributed over a wide area and were commonly found outside the charted dump site (Figure 11.3). Examination of sediments and fish and shellfish tissue samples from the area revealed no trace of chemical warfare agents, or explosive or propellant residues. Metal levels were found to be within ranges found elsewhere in UK waters and it was concluded that, at that time, there was no measurable impact on the benthos.

Beach litter.
G. Saunders

Issues and implications

Over 10,000 tonnes of debris is removed annually from selected UK beaches at a considerable cost to local authorities. Out of a total UK coastal clean-up expenditure of around £2 million between 1997 and 1998, over £494,000 was spent on disposal of litter removed from some 300 km (less than 2%) of the Scottish coastline (Hall, 2000). In addition, floating debris represents a significant economic problem for the fishing, fish farming and shipping industries. Working vessels may sustain damage by propeller or driveshaft fouling or blockage of the coolant intake. Catches may be damaged or contaminated by coincident capture of debris, while the capacity of the net is reduced and time is spent on litter removal.

Horseman (1982) highlighted the large amount of waste disposed of at sea by merchant shipping in the early 1980s, pointing out that wrappings, cases, containers, packages, bottles and jars were eventually thrown into the sea, ignoring international regulations prohibiting such actions. More recently, the UK Merchant Shipping and Maritime Security Act 1997, an amendment of the Merchant Shipping Act 1995, provides powers to introduce regulations implementing provisions of international treaties (in particular MARPOL 73/78). In addition, the Act – made statutory by the Merchant Shipping (Port Waste Reception Facilities Regulations 1997) – places a responsibility on port and harbour authorities to provide adequate waste reception facilities and prepare waste management plans. The enforcement of these regulations may have contributed to observed reductions of sea-borne litter (Figure 11.2), but it remains difficult to obtain evidence of illegal disposal that is acceptable in a court of law, and prosecutions are rarely pursued.

Of all of the discarded materials that enter the marine environment it is plastic which attracts greatest global concern. Durable, versatile and cheap to produce, plastics have replaced many of the traditional manufacturing materials such as metal, glass and wood, with a world-wide demand in excess of 100 million tonnes per annum. Plastics are used to the exclusion of almost all other materials in the packaging, consumer and fishing industries, and it is largely through these routes that an estimated 10% of all global production finds its way into the sea. In the North Sea region non-degradable plastic may constitute 95% of discarded debris (OSPAR Commission, 2000b).

Plastics are notoriously resistant to degradation, and once thrown away may persist and accumulate in the environment for many years. The degradation process is slower in seawater than in air, but plastics do eventually break down into constituent fibres, which may become a major component of beach sediments (Marine Conservation Society, 2001).

Plastic objects are of relatively low density and will commonly float or drift in the water column, fouling fishing gear and presenting hazards to small craft and marine wildlife. Seabirds are known to be particularly susceptible to ingestion of litter and may pass items on to their chicks by regurgitation. Turtles are vulnerable also (Box 11.2).

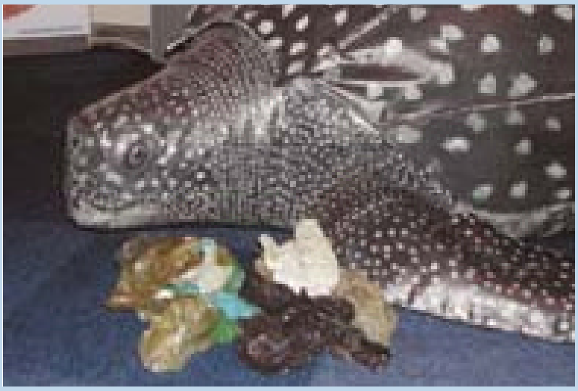
Floating plastic debris is now the most common man-made item found at sea. Wind and currents can transport these items considerable distances resulting in the coastal deposition of items from many different countries. A wide variety of animal species are able to colonise floating debris, increasing opportunities for the establishment of non-native species by as much three times in the temperate latitudes (Barnes, 2002).

Entanglement of marine mammals, birds, fish and shellfish in larger pieces is a frequent occurrence, with drowning or slow starvation common consequences (Laist, 1997). The overall incidences of entanglement are likely to be under-reported (Table 11.1).

Box 11.2 Turtles

The critically endangered leatherback turtle, (*Dermochelys coriacea*) is a regular, albeit uncommon, summer visitor. Of 86 turtle sightings in British and Irish waters in 2002, 60 were leatherbacks. Most Scottish sightings occur off the west and north coasts.

Entanglement in creel ropes of pot-based fisheries is a major cause of mortality in British and Irish waters, but autopsies on turtles which wash ashore dead have also revealed the insidious threat of marine litter. Plastic litter, ingested mistakenly for jellyfish which is their main prey, can cause gut blockage and death by starvation.



Plastic bags from the stomach of a leatherback turtle, with model for scale.
D. Donnan

Leatherback turtle off Shetland.
J.Tulloch

Dead leatherback turtle.
B.Reid/SAC Vet Services

Table 11.1
Factors complicating the analysis of marine entanglement records
Laist, 1997

Detection	Sampling and reporting biases
• Entanglements occur as isolated events scattered over wide areas	• Virtually no direct, systematic at-sea sampling has been done and there have been few long-term surveys
• Entangling debris is not easily seen on live animals at sea because animals may be only partially visible at great distances	• Sampling methodologies are inconsistent
• Dead animals are difficult to see because they float just beneath the surface and may be concealed within debris masses	• Stranding represents an unknown portion of total entanglements
• Dead entangled animals may disappear quickly because of sinking or predation	• Shore counts of live entangled animals are biased towards entanglement of survivors carrying small debris • Entangled animals spend less time ashore and more time foraging at sea • Some entanglements reflect interactions with active rather than derelict fishing gear • Many entanglement records may remain unpublished or are anecdotal and cannot be compared geographically or temporally • Few data are available prior to1990

Plastic polymers are commonly transported in the form of pellets, a few millimetres in diameter. Substantial quantities of these pellets enter the sea in industrial effluent, stormwater discharges or by loss or dumping from shipping. In 1992, plastic pellets were reported to account for 94% of all man-made debris in harbours along American coasts. To seabirds, fish and turtles the pellets resemble fish eggs and are readily ingested. In the North Sea, northern fulmars have been identified as being particularly at risk from ingestion of plastic, because plastic particles can accumulate in the gizzard of this species (North Sea Task Force, 1993). Plastic and rubber formed the greater part of ingested man-made items found in the stomachs of 42 out of 315 Atlantic puffins from the North Sea (Harris and Wanless, 1994).

Recent research has suggested that these pellets (and probably larger plastic objects) may constitute a major source of chemical poisoning (Ananthaswamy, 2001; Mato *et al.*, 2001). Studies have shown that they can adsorb two types of toxic chemical, PCBs and DDE (a chemical closely related to DDT), in quantities of up to a million times greater than the surrounding seawater. Both of these chemicals are implicated in immunity and fertility damage to marine organisms. In addition, in Japan the pellets have been found to contain a hormone-disrupting chemical, nonylphenol, at 100 times the concentration of local sediments.

Sources of data

Information relating to marine litter is not widely available, with only two sources relevant to a Scottish perspective. The MCS Beachwatch initiative has organised an annual collection and recording of debris from a number of beaches around the UK since 1993. This event, mobilising a largely volunteer workforce, is timed to coincide with the International Coastal Clean-up scheme, which takes place in 75 countries world-wide. The results are published annually in the MCS Beachwatch Nationwide Beach Clean and Survey Report. Eight major categories of beach litter have been established according to material type (cloth, glass, metal, paper, plastics, polystyrene, rubber and wood), the majority of which are used as standard categories for world-wide annual litter surveys. An additional category, sewage-related debris (SRD), has been incorporated into British beach surveys, and items falling into this category may incorporate multiple materials, notably plastic, cloth and rubber. The annual MCS reports currently concentrate on the probable source of the litter items, with categories that include tourist/visitor, fishing,

Northern fulmar (*Fulmarus glacialis*).
L. Campbell

shipping, fly-tipping, SRD and non-sourced material.

Recently, a more localised appraisal of the litter problem in the west of Scotland was carried out by the Minch Project, a partnership consisting of Comhairle nan Eilean Siar, Highland Council, SNH, the Scottish Tourist Board and five local enterprise companies (Minch Project, 1997).

The present inability to draw robust conclusions regarding marine litter trends underlines the need for refinements to existing data collection strategies. The repeated surveying of specific beaches (widely distributed throughout Scotland) with consistent beach lengths (or area) and assessed at a standard tide level would go some way to increasing confidence and improving data clarity. Additional information regarding wind speed and direction prior to litter collection would also aid interpretation and comparisons of annual data.

References

Ananthaswamy, A. (2001). Junk food. A diet of plastic pellets plays havoc with animals' immunity. *New Scientist*, 20 January, p. 18.

Barnes, D. K. A. (2002). Invasions by marine life on plastic debris. *Nature* **416**: 808–809.

Galgani, F., Leaute, J. P., Moguedet, P., Souplet, A., Verin, Y., Carpentier, A., Goraguer, H., Latrouite, D., Andral, B., Cadiou, Y., Mahe, J. C., Poulard, J. C. and Nerisson, P. (2000). Litter on the sea floor along European coasts. *Marine Pollution Bulletin* **40**: 516–527.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) and Advisory Committee on Protection of the Sea. (2001). *Protecting the Oceans from Land-based Activities – Land-based Sources and Activities Affecting the Quality and Uses of the Marine, Coastal and Associated Freshwater Environment.* UNEP, Reports and Studies, GESAMP No. 71. GESAMP, The Hague.

Hall, K. (2000). *Impacts of Marine Debris and Oil. Economic and Social Costs to Coastal Communities.* KIMO, Lerwick, Shetland.

Harris, M. P. and Wanless, S. (1994). Ingested elastic and other artefacts found in puffins in Britain over a 24-year period. *Marine Pollution Bulletin* **28**: 54–55.

Laist, D. (1997). Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: *Marine Debris: Sources, Impacts and Solutions.* Coe, J. and Rogers, D. B. (eds), pp. 99–119. Springer Verlag, New York.

Horsman, P. V. (1982). The amount or garbage pollution from merchant ships. *Marine Pollution Bulletin* **13**: 167–169.

Marine Conservation Society. (2001). *Beachwatch 2000. Nationwide Beach Clean and Survey Report.* Marine Conservation Society, Ross-on Wye.

Mato, Y., Isobe, T., Takada, H., Ohtake, C. and Kaminuma, T. (2001). Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. *Environmental Science and Technology* **35**: 318–324.

Minch Project. (1997). *Marine Litter in the Minch.* A report produced for the Minch Project.

North Sea Task Force. (1993). *North Sea Quality Status Report 1993.* Oslo and Paris Commissions, London, and Olsen & Olsen, Fredensborg, Denmark.

OSPAR Commission. (2000a). *Quality Status Report 2000.* OSPAR Commission, London.

OSPAR Commission. (2000b). *Quality Status Report 2000, Region III – Celtic Seas.* OSPAR Commission, London.

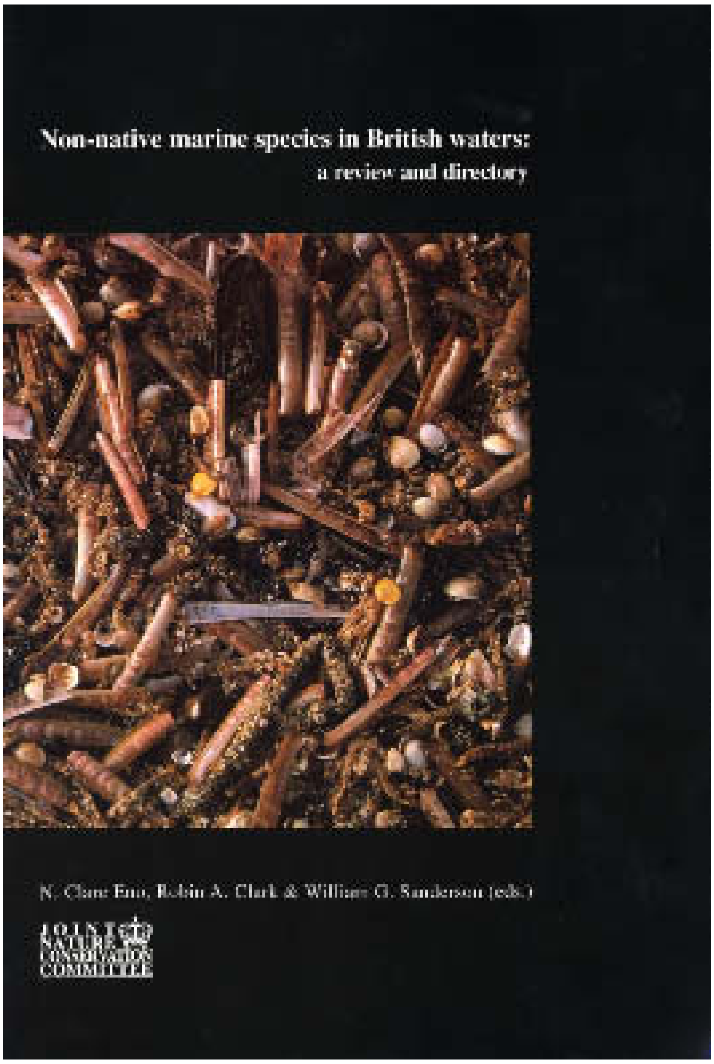
Velander, K. A. and Mocogni, M. (1998). Marine litter and sewage contamination at Cramond beach, Edinburgh – a comparative study. *Marine Pollution Bulletin* **36**: 385–389.

Williams, A. T. and Tudor, D. T. (2001). Litter burial and exhumation: spatial and temporal distribution on a cobble pocket beach. *Marine Pollution Bulletin* **42**: 1031–1039.

Williams, A. T., Simmons, S. L. and Fricker, A. (1993). Offshore sinks of marine litter: a new problem. *Marine Pollution Bulletin* **26**: 404–405.

12 Non-native species

This chapter was prepared with the assistance of Catriona Burns.



Introduction

The effects of introduced species on their host environment can include competition with native species for food and space, habitat alteration, changes in water quality, alteration of the gene pool through hybridisation, predation and the transmission of disease or parasites (Rosenthal, 1980; Kohler and Courtenay, 1986; Eno *et al.*, 1997). In general, detrimental effects tend to outweigh possible benefits and may bring about reduced species diversity. Over the past 400 years, more global extinctions have been attributed to introduced species than to any other single factor (World Conservation Monitoring Centre, 1992). Currently, nearly 20% of vertebrate species at risk of global extinction are threatened by introduced species (McNeely, 1995). While assessments have related predominantly to terrestrial and freshwater environments, the issues apply equally in the marine environment.

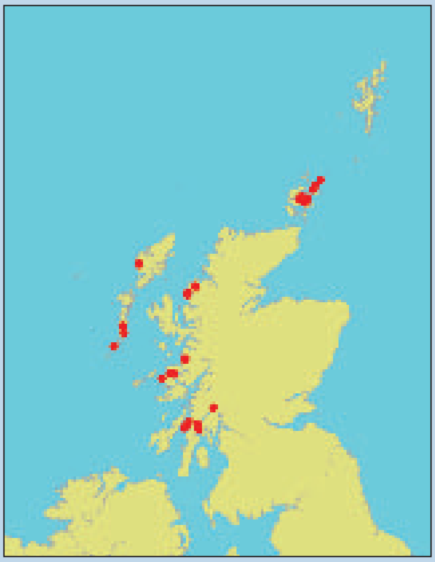
A review of non-native species in British waters identified 51 non-native species (Eno *et al.*, 1997). A non-native species was defined as a species which: a) has been introduced directly or indirectly (deliberately or otherwise) to an area where it has not occurred in historical times (within a 5000 year time-frame); b) is separate from and lies outside the area where natural range extension could be expected; c) has become established in the wild and has self-maintaining populations; and d) includes hybrid taxa derived from such introductions.

Trends

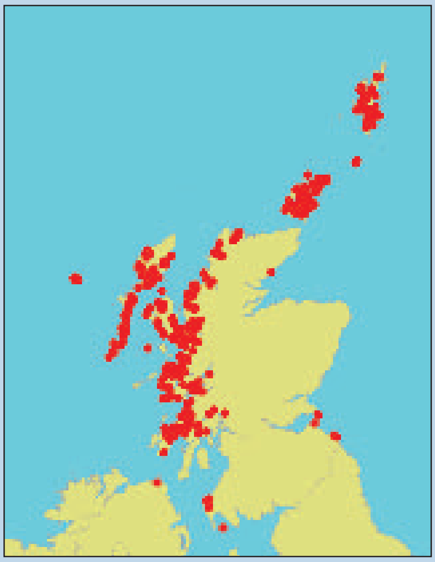
Of 24 non-native species which have been identified in Scottish waters, twelve are algae (three diatoms), one an anemone, one a polychaete worm, five are crustaceans (including two barnacles), four are molluscs and one is a sea squirt (Table 12.1). Many are reported to have spread rapidly in Scottish waters, some becoming established over large areas. Reported sightings, for 12 of them are available on the MNCR database, giving some indication of distribution. (Box 12.1).

Since the 1997 review (Eno *et al.*, 1997), a new introduction to the UK, the amphipod *Caprella mutica*, has been recorded at a salmon farm near Oban (Box 12.2). In February 2004, the Japanese seaweed *Sargassum muticum* was found in Loch Ryan (Table 12.1).

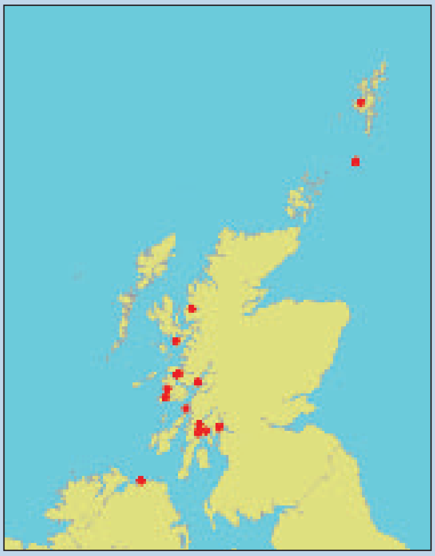
Box 12.1 Occurrence of 12 non-native marine species in Scotland
Source: MNCR Database



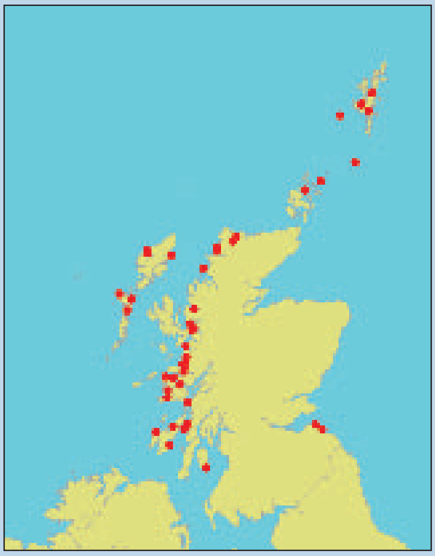
Asparagopsis armata, a red alga



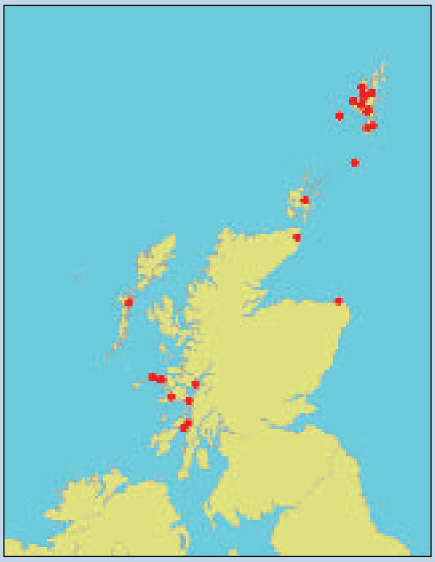
Bonnemaisonia hamifera, a red alga



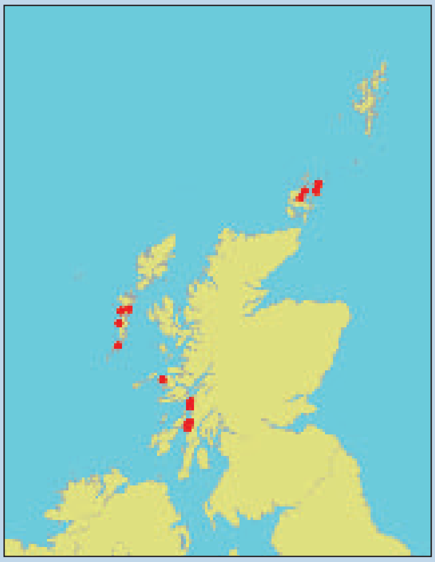
Antithamnionella spirographidis, a red alga



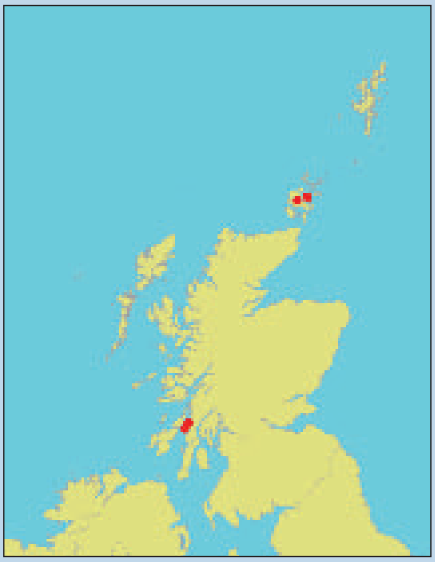
Colpomenia peregrina (oyster thief), a brown alga



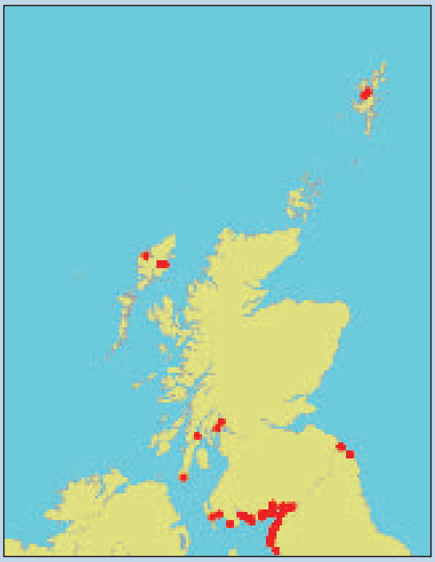
Codium fragile subsp. *atlanticum* (green sea fingers), a green alga



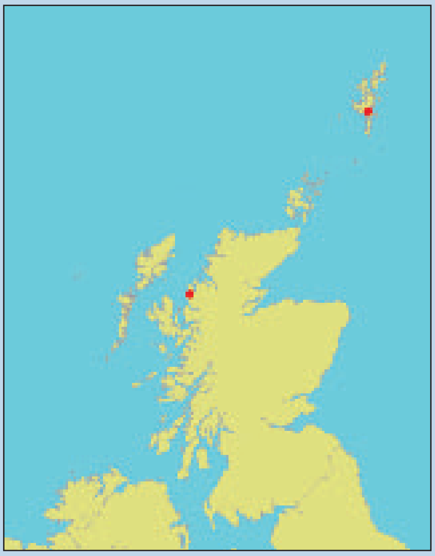
Codium fragile subsp. *tomentosoides* (green sea fingers), a green alga



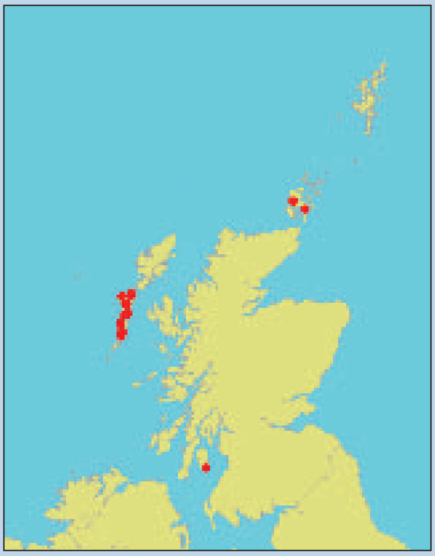
Haliplanella lineata (orange-striped sea anemone), a sea anemone



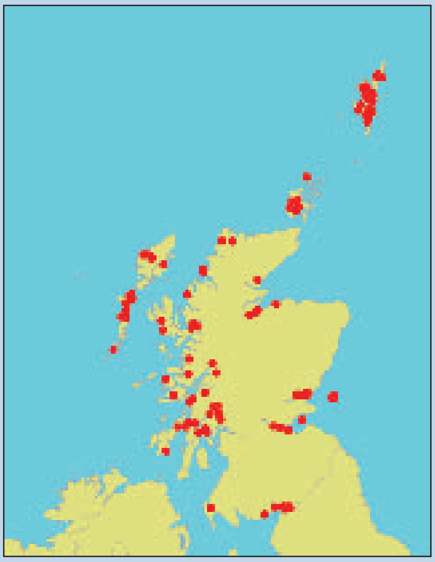
Elminius modestus, a barnacle (crustacean)



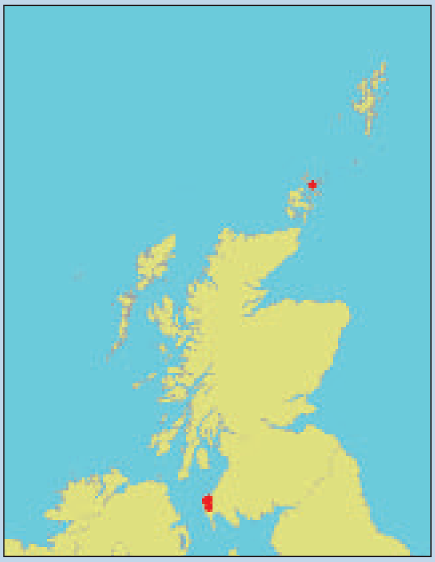
Corophium sextonae, an amphipod (crustacean)



Potamopyrgus antipodarum (Jenkins spire shell), a mollusc



Mya arenaria (soft-shelled clam), a mollusc



Styela clava (leathery sea squirt), an ascidian

Skeleton shrimp (*Caprella mutica*).
T. Nickell/SAMS

Box: 12.2
Caprella mutica

Caprella mutica, or skeleton shrimp, was recently identified off the west coast of Scotland (Cook *et al.*, 2003). Little is known about it, but related species are known to feed on a variety of microscopic marine animals. It has been reported from the Pacific coast of North America (Cohen and Carlton, 1995) to European coastal areas including the Netherlands (Platvoet *et al.*, 1995), Norway and southern England.

A project has been proposed by the Scottish Association for Marine Science (www.sams@ac.uk.dml.projects/coastal/caprellid) to investigate its biology and ecology, geographic origin and mode of invasion. The investigation of its likely impact on native species, its distribution and patterns of dispersal, would be a case study of the consequences of non-native species introduction.

Issues and Implications:

Large expanses of water provide a natural barrier to the spread of marine species between land masses. Temperature and substratum characteristics can limit the spread of benthic species. Barriers can, however, be breached. Unintentional introduction associated with mariculture as well as deliberate commercial introduction are known pathways, but it is the fouling of ships' hulls and, especially, ballast water which account for the greatest proportion of introductions (Carlton 1992 a & b). Whereas anti-fouling treatments limit the opportunities for species introductions from ship hulls, the historical use of solid ballast has been replaced by water. Upstream ports in which salinity levels are diluted by freshwater inflows have given way to large, deepwater ports on the coast. There, conditions are more favourable to the survival of non-native marine species in ballast water discharge.

Japanese seaweed (*Sargassum muticum*) in Loch Ryan.
G. Saunders

Of 24 non-native marine species found in Scottish waters (Table 12.1), ten have potentially harmful effects on the environment and/or on commercial interests (Eno *et al.*, 1997). They are *Polysiphonia harveyi, Colpomenia peregrina, Sargassum muticum, Codium fragile* subsp. *tomentosoides* and subsp *atlanticum, Marenzelleria viridis, Balanus amphitrite, Elminius modestus, Crassostrea gigas* and *Styela clava*. Their effects include the displacement of native species, competition with native species for food and space, disruption of commercial oyster beds and the fouling of ships, buoys and harbour structures.

The direct effects of non-native species on the marine environment in British waters has, in general, not been as detrimental as those reported from elsewhere in the world (Eno *et al.*, 1997). Control measures have been employed with varying success on a number of nuisance species, such as the leathery sea squirt (*Styela clava*) and slipper limpet (*Crepidula fornicata*), but none have been entirely eradicated. Many non-native species fail to become established and die out naturally. Site-related factors, such as the closure of a power station, have brought about local extinctions.

Table 12.1
Non-native species in Scottish Waters
Sources: Eno *et al.*, 1997; T. McCollin, Fisheries Research Services, Personal Communication

Species	Common Name and Group	Date of introduction and origin	Method of introduction	Rate of spread	Distribution
Thalassiosira punctigera (syn: Thalassiosira angstii)	None (diatom)	First detected in Plymouth, Devon in 1978. Origins unknown. Has been recorded in North Pacific and South Atlantic.	Unknown. Possibly ballast water or imported oysters.	English waters and Heligoland in 1978; Norway 1979; Netherlands 1981.	English Channel and North Sea.
Thalassiosira tealata	None (diatom)	First detected Blakeney, Gloucestershire in 1950. Origins unknown. Has been found in Japanese waters.	Unknown. Possibly ballast water or imported oysters.	English waters 1950; Norway 1968.	English Channel to Norway.
Odontella sinesis (syn: Biddulphia sinensis)	None (diatom)	Detected in European waters in 1889; first noted in British waters 1906. Recorded from China Sea but probably introduced from Red Sea or Indian Ocean.	Suspected ballast transport.	Has spread rapidly to become widely distributed in throughout European waters in less than 10 years.	Considered to be an important constituent of the winter and spring diatom flora around Britain.
Asparagopsis armata (syn: Falkenbergia rufolanosa – part of life cycle)	Harpoon weed (red alga)	First recorded on Lundy in 1949 as *Falkenbergia* phase. Asparagopsis phase first reported from Cornwall in 1950. Introduced from mainland Europe. Originates from Australia or New Zealand.	Possibly introduced to Europe with imported oysters, subsequently introduced to Britain by rafting and floating.	Ireland 1939; Lundy 1949; Plymouth 1950; Start Point, S. Devon 1953; Solent 1973; Shetland 1973.	Distributed throughout the British Isles, but uncommon on east coast.
Bonnemaisonia hamifera (syn: Trailliella intricata – part of life cycle)	None (red alga)	*Bonnemaisonia* first recorded Falmouth, Cornwall and Studland, Dorset in 1893. Trailliella phase first collected from Dorset in 1890. Originates from the Pacific and probably introduced from Japan.	Unknown, but considered to have been introduced unintentionally with shellfish.	Cornwall 1893; Orkney Islands 1929; Shetland 1949.	Distributed throughout British Isles, although uncommon on east coast.

Species	Common Name and Group	Date of introduction and origin	Method of introduction	Rate of spread	Distribution
Antithamnionella spirographidis (syn: Antithamnion spirographidis, Antithamnion tenuissimum)	None (red alga)	Introduced to Europe prior to 1911. First recorded from Plymouth docks in 1934. Introduced to Britain from the Mediterranean. Thought to have originated in the North Pacific.	Probably transported on hulls and mooring ropes of ships, although could also have been introduced with oysters.	Spread rapidly by shipping activities.	South coast of England. south and west coasts of Wales, Ireland and west coast of Scotland.
Antithamnionella ternifolia (syn: Antithamnionella sarniensis, Antithamnion sarniensis)	None (red alga)	First recorded in 1906 from Plymouth. Introduced from the southern hemisphere (possibly Australia).	Probably transported on hulls and mooring ropes of ships.	Spread rapidly around the coast of Britain, from Plymouth to western Ireland in 30 years, mainly by shipping activity.	South and west coasts of Britain as far north as Strathclyde in Scotland.
Polysiphonia harveyi (syn: Polysiphonia insidiosa)	None (red alga)	Introduced before 1908 onto the south coast of England, possibly from northern France. May have originated in the Pacific Ocean, being introduced from Japan.	Introduced unintentionally with oysters.	Rate of spread not known, although may have spread through drifting with larger weeds on which it is an epiphyte.	South and east coasts of England, and up the west coast to Scotland.
Colpomenia peregrina (syn: Colpomenia sinuosa var. peregrina)	Oyster thief (brown alga)	Introduced from France into Cornwall and Dorset in 1907. Occurs naturally in the Pacific Ocean and was introduced from the Pacific coast of North America.	Introduced with juvenile American oysters.	England 1907; Isle of Man 1923; Outer Hebrides 1936; Orkneys 1940.	Throughout Britain, with larger population on the west coast.
Sargassum muticum	Jap weed, wire weed, strangle weed	First attached plant recorded in the Isle of Wight in 1971 after arriving from France.	Introduced to France unintentionally with the commercial movement of oysters from Canada or Japan.	Spread rapidly along the English south coast at about 30 km/year, usually by drifting as fertile adults. Movement was slowed by conditions of exposed coasts of south-west England, but attached plants were found in Strangford Lough, Northern Ireland in 1995 and Pembrokeshire, Wales in 1997.	Isles of Scilly, entire English Channel coast, east coast north to Suffolk. Welsh coast and Strangford Lough. The first Scottish record of attached plants was reported from Loch Ryan in February 2004. Route of introduction as yet unknown.

Species	Common Name and Group	Date of introduction and origin	Method of introduction	Rate of spread	Distribution
Codium fragile subsp. *atlanticum*	Green sea fingers (green alga)	Recorded in south-west Ireland around 1808, from where it may have spread through rafting or floating. Found on the west coast of Scotland before 1840. Considered to have originated in the Pacific Ocean, possibly Japan.	Introduced to Ireland unintentionally with shellfish.	Spread the length of Britain , including Shetland, since 1840. Spread from Berwick-on-Tweed to St. Andrews between 1949 and 1955.	Found from Dorset up the west coast of Britain, Shetland and in east Scotland and Northumberland. More common in northern Britain.
Codium fragile subsp. *tomentosoides*	Green sea fingers (green alga)	Introduced from mainland Europe to Devon in 1939. Originated in the Pacific Ocean around Japan.	Spread either as an unintentional introduction attached to shellfish such as oysters; attached to ships' hulls or as spores in ballast tanks. Possibly also by rafting and floating.	Holland 1900; England 1939; Scotland subsequently.	Distributed throughout Britain, but particularly along the south coast of England and the west coast of Scotland.
Haliplanella lineata (syn: *Haliplanella luciae)*	Orange-striped sea anemone (anemone)	Probably introduced to the Atlantic from Japan towards the end of the 19th Century.	Probably carried on ships hulls and transported on oysters and other shellfish.	Rate of spread unknown.	Distributed around Britain, generally occurring in estuaries, ports and harbours on major shipping routes.
Marenzelleria viridis (syn: *Scolecolepsis viridis, Scolecolepides viridis)*	None (polychaete worm)	Recorded in the Firth of Forth in 1982 and the Firth of Tay in 1984. Occurs naturally on the east coast of North America.	Probably transported as larvae of adults in ballast water.	Rate of spread unknown.	Firth of Forth, Tay and Humber Estuary. Also found in estuaries on the European side of the North Sea and in the Baltic.
Elminius modestus	None (barnacle)	First recorded in Chichester Harbour, Hampshire in 1945 and is believed hove have arrived between 1940 and 1943. Naturally occurs in Australasia and was introduced from Australia of New Zealand.	Transported on ships hulls, or possibly flying boats and in ballast water.	Rapid spread; Chichester Harbour to Shetland in 38 years.	Distributed around the British mainland coast, but has also been reported from the Hebrides.

Species	Common Name and Group	Date of introduction and origin	Method of introduction	Rate of spread	Distribution
Balanus amphitrite	None (barnacle)	Recorded in Shoreham Harbour, Sussex in 1937. Considered to be native to the south-western Pacific and Indian Oceans.	Transported on ships hulls, or possibly as the larval form in ballast water.	Rate of spread unknown.	Has been found in southern England, southern Wales and has also been recorded from Shetland in 1988.
Acartia tonsa	None (calanoid copepod)	First recorded in Southampton water between 1916 and 1956. Previously known from western Atlantic and Indo-Pacific.	Possibly introduced by transport on ships hulls or in ballast waters.	Rate of spread unknown.	Has been found in Southampton water, Tamar Estuary, Exe Estuary and the Firth of Forth.
Corophium sextonae	None (amphipod)	Introduced into Plymouth, Devon in the 1930s from New Zealand, where it occurs naturally.	Route of introduction not known.	Rate of spread unknown.	Found in the southern and western British Isles north to Scotland.
Caprella mutica	None (caprellid amphipod)	First reported in 2003.	Introduced to a Scottish salmon farm. Known to be present at other sites owned by the same company. Originally described from Japanese waters.	Rate of spread unknown.	Recorded in 2003 from a salmon farm near Oban.
Potamopyrgus antipodarum (syn: *Hydrobia jenkinsi, Pomatopyrgus jenkinsi*)	Jenkins spire shell (mollusc)	Probably introduced as early as 1859 and was identified from the Thames Estuary. Originates from New Zealand, and was introduced to Australia.	Introduced in drinking-water barrels used by vessels from Australia. An ability to survive brackish water probably aided persistence in estuarine conditions.	Rate of spread moderate initially, but became more rapid after colonising freshwater habitats around 1904.	Found in saline lagoons and brackish water ditches around Britain. Distribution extends from Shetland to the Isles of Scilly. Generally confined to coastal areas in Scotland.
Aulacomya ater	Magellan mussel	First found in 1994 in the Moray Firth, north-east Scotland, where it was introduced from South America. This species originates on the coasts of Peru, Chile and the Falkland Islands and Argentina.	It is most likely to have been introduced on ship or barge hulls as a fouling organism.	Rate of spread unknown.	It has only been found in the Moray Firth in Scotland in 1994 and again in 1997; no other European populations are known.

Species	Common Name and Group	Date of introduction and origin	Method of introduction	Rate of spread	Distribution
Crassostrea gigas (syn: *Crassostrea angulata*)	Pacific oyster, Portuguese oyster (mollusc)	Introduced from Portugal into the River Blackwater in Essex in 1926. Occurs naturally in Japan and south-east Asia.	Deliberate commercial introduction.	Spread by placement of hatchery-produced seed, although there is some evidence to suggest the some conditions may allow the transfer of larvae over considerable distances.	Distributed throughout England Scotland and Wales.
Mya arenaria	Soft-shelled clam, soft clam, long-necked clam (mollusc)	Thought to have been introduced from the American coast during the 16th or 17th century.	May have been deliberately introduced for food or bait, or accidentally transported in the bilge of shipping.	Spread by natural dispersal of larvae.	Found on all British and Irish coasts.
Styela clava (syn: *Styela mammiculata*)	Leathery sea squirt (ascidian)	Probably introduced in 1952. Found in Plymouth, Devon in 1953. Introduced from the north-western pacific.	Transported on the hulls of warships following the end of the Korean war.	Spread rapidly. Plymouth 1953; Southampton Water 1959; south-west Wales and across the Channel to France by 1968. Ireland 1972. Found on oysters in Loch Ryan in in 1987.	South and west coast of England as far north as Cumbria. Present in Loch Ryan and other scattered Scottish localities.

References

Carlton, J.T. (1992a). Overview of issues concerning marine species introductions and transfers. In: *Proceedings of the conference and workshop on introductions and transfers of marine species: achieving a balance between economic development and resource protection*, Hilton Head Island, South Carolina October 30 - November 2, 1991. M.R. De Voe (ed.), pp. 65-67. South Carolina Sea Grant Consortium.

Carlton, J.T. (1992b). Marine species introductions by ships' ballast water: an overview. In: *Proceedings of the conference and workshop on introductions and transfers of marine species: achieving a balance between economic development and resource protection*, Hilton Head Island, South Carolina October 30 - November 2, 1991. M.R. De Voe (ed.), pp. 23-25. South Carolina Sea Grant Consortium.

Cohen, A.N. and Carlton, J.T. (1995). *Nonindigenous Aquatic Species in a United States Estuary: A Case Study of the Biological Invasions of the San Francisco Bay and Delta*. A Report for the United States Fish and Wildlife Service, Washington, D.C. and The National Sea Grant College Program Connecticut Sea Grant Program. 272 pp.

Cook, L., Willis, K., and Lozano, M. (2003). Alien Invasion: a new non-native invasive species on the west coast of Scotland. In: *Scottish Association of Marine Science Newsletter* **28**: 12.

Eno, N.C., Clark, R.A. and Sanderson, W.G. (eds). (1997). *Non-Native Marine Species in British Waters: a Review and Directory.* Joint Nature Conservation Committee, Peterborough.

Gibbs, P.E., Spencer, B.E., and Pascoe, P.L. (1991). The American oyster drill *Urosalpinx cinerea* (Gastropoda): evidence of decline in an imposex-affected population (R. Blackwater, Essex). *Journal of the Marine Biological Association of the United Kingdom* **71**: 827-838.

Kohler, C.C. and Courtenay, W.R. (1986). American Fisheries Society position on introductions of aquatic species. *Fisheries* **11**: 39-43.

McNeely, J.A., Gadgil, M., Leveque, C., Padoch, C. and Redford, K. (1995). Human influences on biodiversity. In *Global Biodiversity Assessment*, V.H. Heywood and R.T. Watson (eds). Cambridge: UNEP, pp. 711–821.

Platvoet, D., de Bruyne, R.H. and Gmelig Meyling, A.W. (1995). Description of a new *Caprella*-species from the Netherlands: *Caprella macho* nov. spec. (Crustacea, Amphipoda, Caprellidae). *Bulletin Zoölogisch Museum, Universiteit van Amsterdam* **15**: 1-4.

Rosenthal, H. (1980). Implications of transplantations to aquaculture and ecosystems. *Marine Fisheries Review* **42**: 1-14.

World Conservation Monitoring Centre. (1992). *Global Biodiversity: Status of the Earth's Living Resources*. London: Chapman & Hall.

Environmental change

Introduction

The issues of global warming and sea-level rise continue to be the focus of much international concern and debate. The interactions between climate, ocean currents and sea temperature are complex on both global and local scales. Although some Scottish records for wind speed, tidal height and sea and air temperature extend back over 100 years, they commonly exhibit a high degree of short- and long-term variability, making the evaluation of overall trends difficult and subject to regular revisions. The conclusions presented here are taken from Fisheries Research Services (2000), Dawson *et al.* (2001) and Hulme *et al.* (2002).

Wave-scoured coast.
L. Gill/SNH

Trends

Sea-level change

Global-average sea level rose by about 1.5 mm per year during the 20th century. This is believed to be due to a range of factors, including thermal expansion of warming ocean waters and the melting of land glaciers (Hulme *et al.*, 2002). The average rate of mean sea-level rise around the UK during the last century, based on long-term tide gauge records, has been approximately 1 mm per year (Woodworth *et al.*, 1999). All Scottish mainland tide gauges have recorded a sea-level rise over this period (Dawson *et al.*, 2001). The longest time-series from a gauge, installed at Aberdeen, indicates an average rise of 0.6 mm per year since 1862 (Figure 13.1). In contrast, a tide gauge in Lerwick, Shetland, has recorded a fall in sea level since 1957.

The position of sea level at any coast depends not only on changes taking place to the sea, but also on long-term changes taking place within the land mass (Box 13.1). Along most of Scotland's coast, measurements from tide gauges suggest that relative sea levels are rising.

Storminess

An increase in storminess has been detected in the north-east Atlantic over the last 30 years, with an associated increase in significant wave height of 2.5–7.0 mm per year (Figure 13.4).

Sea temperature change

Fisheries Research Services (2000) reports that Scottish coastal waters warmed between 1980 and 1998, with summer temperatures increasing at about 0.5°C every 10 years and winter temperatures by 1°C. Correspondingly, the average range of temperatures from summer to winter narrowed by about 0.5°C. In 1999, however, overall water temperatures were cooler than the previous year. Dawson *et al.* (2001) observed that between 1977 and 1997 there was a pattern of short-term temperature rise with a range between 0.05 and 0.12°C per year, but when placed in context with records from the past 100 years there is no clear trend.

Box 13.1 Rebound relative to rising sea levels

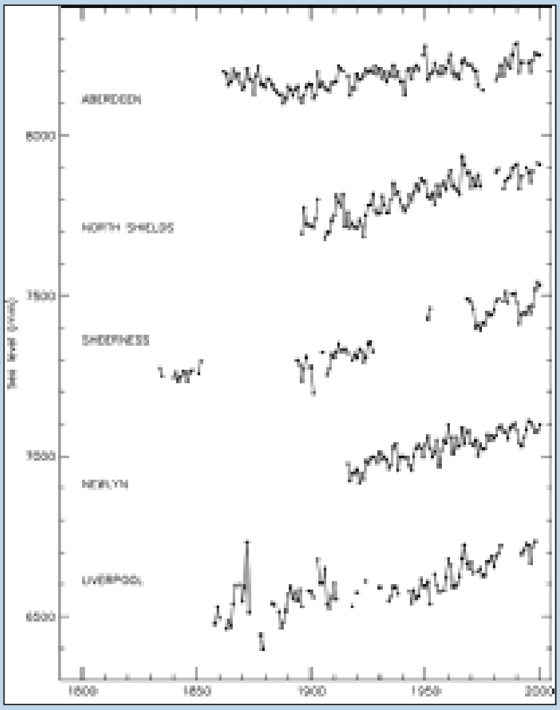


Figure 13.1
Changes in annual relative sea level (mm scale) recorded by tide gauges at five locations around the UK coastline. Data are unadjusted for natural land movements. The scale represents 100-mm graduations.
Reproduced from Hulme *et al.*, 2002, with permission from UKCIP.

Estimates of sea-level change are modified by a simultaneous rise in the Scottish land mass, which is still undergoing a rebounding process following the melting of the overlaying ice sheet some 10,000 years ago at the end of the last ice age.

The rate of rebound is greatest in mainland areas, where the ice layer was thickest. Offshore areas, such as the Northern Isles and the Outer Hebrides, were under thinner ice and so the extent of rise is correspondingly smaller and may even amount to a relative sinking (Shennan, 1989).

In areas where rebound is greatest, the rate of land uplift exceeds the rise in mean sea level, resulting in falling sea levels relative to the land. Estimates of current and future sea level change for Scotland, adjusted to take account of uplift movements, are shown in Figures 13.2 and 13.3.

Most of the tide gauges in Scotland lie outside the area of greatest uplift and record rising mean sea level.

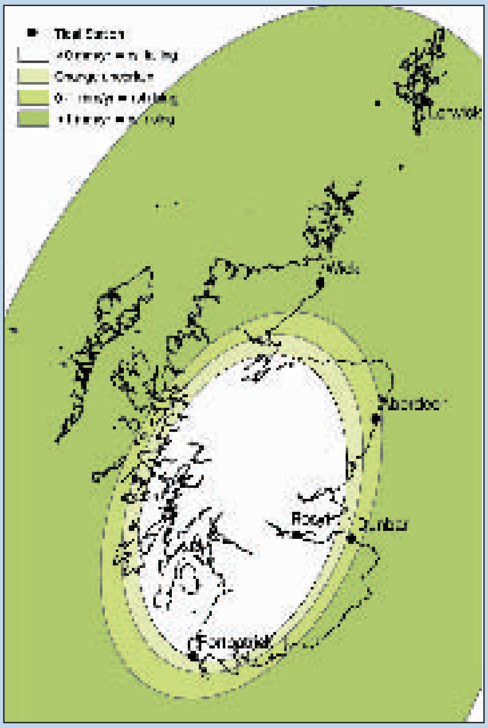


Figure 13.2
Present rates of relative sea-level change in Scotland
Source: Dawson *et al.*, 2001.

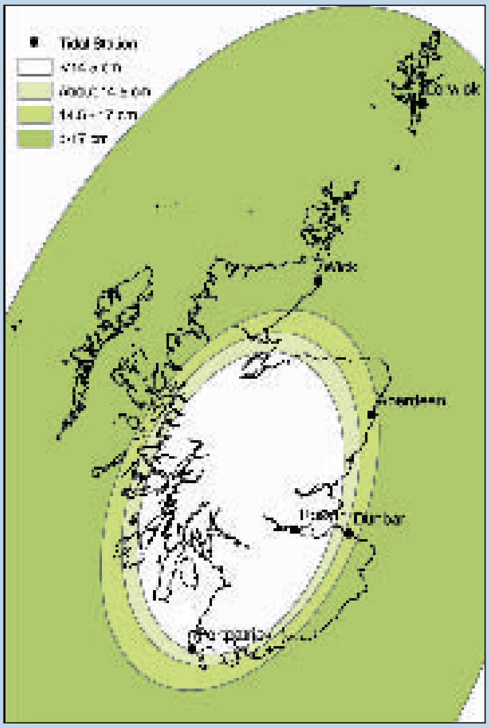
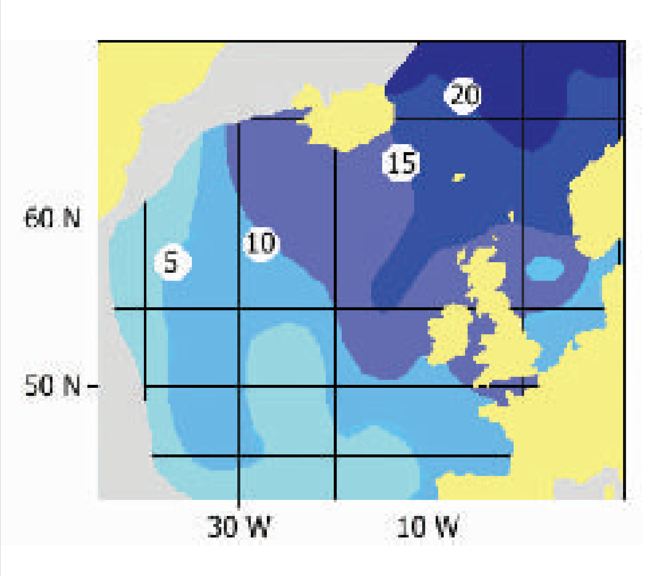


Figure 13.3
Best estimate of sea-level rise for 2050 AD.



Marine plankton has been proposed as a biological indicator of environmental change, being responsive to the combined effects of temperature and ocean currents (Box 13.2).

Figure 13.4
The percentage increase in the significant wave height (i.e. the average height of the highest third of the waves) in the North Atlantic in winter (December–February) between the periods 1985–1989 and 1991–1996. Note the short periods over which data are averaged
Source: JERICHO, (1999). Reproduced from Hulme *et al.*, 2002, with permission from UKCIP.

Box 13.2 Marine plankton – indicators of environmental change

Source: The Sir Alister Hardy Foundation for Ocean Science (www.sahfos.org))

Copepods, small shrimp-like crustaceans, form an important part of the diet of some fish and so provide an integrated measure of ocean biological production in waters around Scotland. Able to multiply rapidly, populations fluctuate readily in response to changing environmental conditions and modifications due to the management of the seas. According to the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) web site, they are ideally suited to monitoring environmental change.

Since the 1930s, marine plankton abundance has been measured in the North Atlantic and North Sea by towing a continuous plankton recorder behind commercial shipping on defined routes. From this record, two specific zooplankton indicators have been selected for reporting by SAHFOS:

Continuous plankton recorder.
SAHFOS

- the total annual abundance of copepods in the North Sea; and
- the abundance, in the northern North Sea, of a the cold–temperate water copepod species, *Calanus finmarchicus*, a dominant copepod in the sea and an important part of the food chain between phytoplankton- and zooplankton-eating fish.

Two key relationships have been identified:

- More copepods are present when the Gulf Stream follows a northerly path. The Gulf Stream Position Index, measured since 1966, is the position of the north wall of the Gulf Stream. Total annual abundance of copepods in the North Sea has varied greatly but peaks have tended to be associated with a more northerly Gulf Stream position and the timing of the onset of spring stratification – the formation of a warmer surface layer in the sea.

- In contrast, between 1958 and 1995, a marked decline in populations of *Calanus finmarchicus* in the North Sea has been associated with a trend towards stronger westerly air flows over the Atlantic in winter. The westerly air flow is linked to higher values of the North Atlantic Oscillation – the difference in atmospheric pressure between the south and north in the North Atlantic. The decline of *Calanus finmarchicus* may be the result of changes in overwintering habitat, food supply and/or warmer temperatures in the North Sea.

According to SAHFOS, a continued northward shift of the Gulf Stream could bring about increasing copepod numbers in the North Sea. However, the negative relationship between *Calanus finmarchicus* populations and the North Atlantic Oscillation suggests that not all species will benefit.

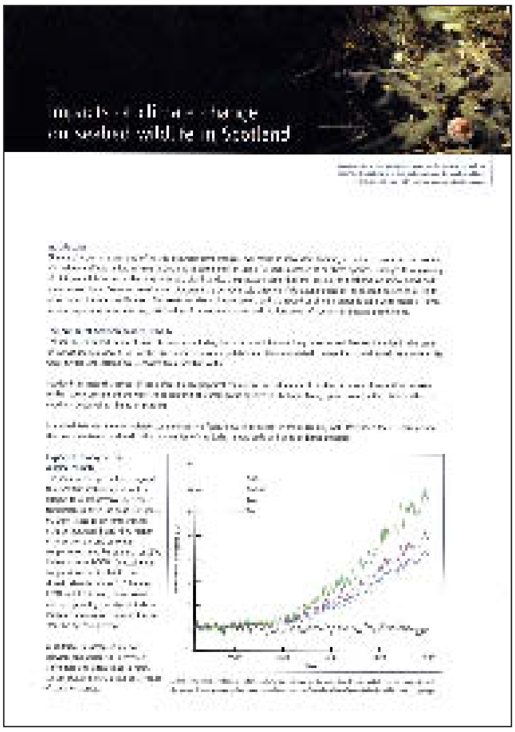
The long-term response of the Gulf Stream to global warming remains uncertain.

Issues and implications

The projected effects of climate change are subject to regular revisions as more data are included and modelling scenarios become ever more sophisticated. Predictions continue to be hampered, however, by uncertainties in both the underlying scientific theory and levels of greenhouse gas emissions.

A rise in sea level globally is considered to be very likely over the medium term, most probably at rates exceeding those of the twentieth century. Recent reports suggest that heating of the ocean surface caused by enhancement of the greenhouse effect will be transferred to the cooler deep waters, leading to a substantial volume expansion. This is predicted to initiate an average global sea-level rise of around 6–7 cm by 2020 (Hulme *et al.*, 2002). In Scotland, all coastal areas are likely to experience a relative sea-level rise in the 21st century, including those which have experienced a fall in relative sea levels to date.

Much of Scotland's coast is steep and rocky. The consequences of a rising sea level will be felt



MarClim: the impact of climate change on subtidal and intertidal benthic species in Scotland.

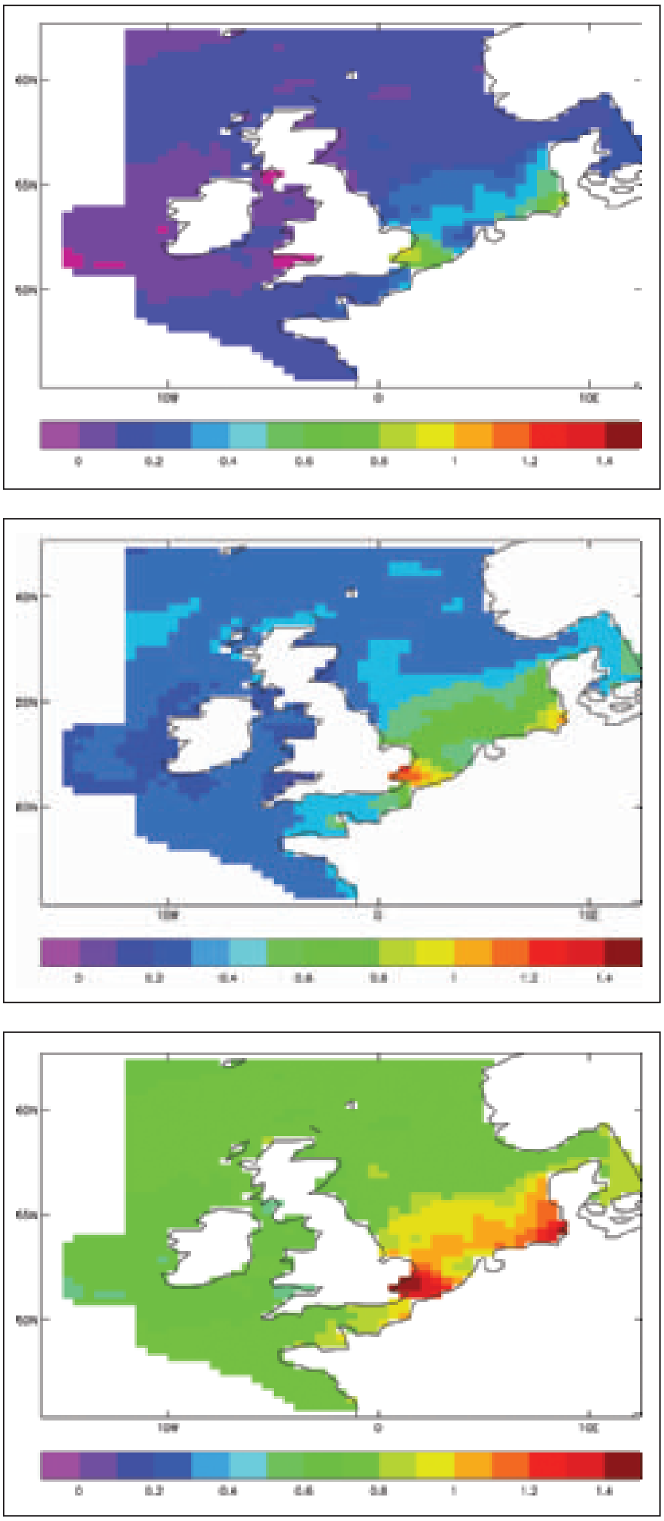


Figure 13.5
Change in 50-year return period surge height (metres) for the 2080s for three different scenarios. The combined effect of global-average sea-level rise, storminess changes and vertical land movements (from Shennan, 1989) are considered.
(a) **Low-emissions** scenario (low sea-level rise estimate: 9 cm).
(b) **Medium- to high-emissions** scenario (central estimate: 30 cm).
(c) **High-emissions** scenario (high estimate: 69 cm).
Reproduced from Hulme *et al.*, 2002, with permission from UKCIP.

Table 13.1 Summary statements of the changes in sea level and marine climate for the UK Climate Impacts Programme (UKCIP02) climate change scenarios.
Source: Hulme *et al.*, 2002

Variable	UKCIP02 scenarios	Relative confidence level
Global-average sea level	• Will continue to rise for several centuries, and probably longer	H
	• The West Antarctic ice sheet will contribute relatively little to sea-level rise in the present century	H
	• Will increase by the 2080s by between 9 and 69 cm	M
UK sea-level change	• Continuation of historic trends in vertical land movements will introduce significant regional differences in relative sea-level rise around the UK	H
	• Will be similar to the global-average value	L
Extreme sea levels	• For some coastal locations and some scenarios storm surge return periods by the 2080s will reduce by an order of magnitude	M
	• Changes in storminess, sea level and land movement mean that storm surge heights will increase by the greatest amount off south-east England	L
Marine climate	• Sea surface temperatures will increase around all UK coasts	H

Relative confidence levels: H = high; M = medium; L = low.

most severely on low-lying coasts, and especially where prevailing winds tend to generate storm surges. Safeguarding property, infrastructure and production will be dominant concerns. The discussion here relates to natural heritage consequences.

In areas protected by flood defences, rising sea level is liable to result in the modification and loss of intertidal areas through ‘coastal squeeze’, whereby the low-water line migrates landward but the high-water line can only rise up the defensive wall. In low-lying unprotected areas, the coast will tend to be pushed inland. In both cases, it is extreme events such as storm surges and large waves that will cause most damage (Figure 13.5). A summary of the most recent predictions is given in Table 13.1.

Enclosed areas of sea bed, such as in sea lochs, may experience greater seasonal impacts from deoxygenation due to increased thermal stratification, or temperature layering. This inhibits the distribution of oxygen throughout the water column and thus depletes its availability at the sea bed.

Evidence to support temperature-mediated adjustments of species ranges has recently emerged from fish studies in the lower Forth estuary. Regular research trawls in the estuary routinely recover around 30 species of fish. Of these, the eelpout (*Zoarces viviparus*) was the most abundant between 1981 and 1987 (Elliott *et al.*, 1990), but by 2001 had declined to the seventh most abundant (Greenwood *et al.*, in preparation). A closely correlated pattern of eelpout abundance decline has also been observed in the Norwegian Kattegat area, and both, in turn, are very highly correlated with increases in the North Sea bottom temperature. The eelpout is close to the southern limit of its range in the Forth, and it is suggested that warmer weather has reduced reproductive success throughout the North Sea and caused a northward shift in eelpout distribution (Greenwood *et al.*, in preparation). On the basis of these trends it is speculated that eelpout may become extinct from the Forth in 20–40 years, in line with predictions for marine species and communities more generally (Box 13.3). Moreover, another species, the fatherlasher (*Myoxocephalus scorpius*), has shown significant abundance increases and may either be extending into the niche vacated by the eelpout or simply increasing in response to a northerly extension of its own range.

Box 13.3 Species impacts

An examination of the possible effects of currently predicted rises in sea and air temperature on the distribution of marine species and communities was undertaken by Hiscock *et al.* (2001). They concluded that species losses over the next 100 years would be restricted to a small number of northern species currently at their southern limit. Warming may increase the diversity of Scottish seabed communities owing to an influx of a greater number of southern species.

A summary of proposed modified species distributions is shown in Table 13.2. Some communities that are particularly well developed in Scotland could be affected over the longer term, such as those associated with maerl and *Modiolus* beds

Table 13.2
Species with currently restricted distributions in or near Scotland and predicted effects of a sea temperature rise of 1–2°C
Source: Hiscock *et al.*, 2001

Southern species not currently recorded in Scotland but which may spread to Scotland	Southern species currently recorded in Scotland whose extent of distribution or abundance might increase		Northern species which may either decrease in abundance and extent or disappear from Scotland
Ciocalypta penicillus	*Axinella dissimilis*	*Crassostrea virginica*	*Thuiaria thuja*
Haliclona angulata	*Hemimycale columella*	*Cerastoderma glaucum*	*Swiftia pallida*
Gymnangium montagui	*Phorbas fictitius*	*Gari depressa*	*Bolocera tuediae*
Eunicella verrucosa	*Haliclona cinerea*	*Pentapora fascialis*	*Phellia gausapata*
Aiptasia mutabilis	*Haliclona fistulosa*	*Asterina gibbosa*	*Lithodes maia*
Balanus perforatus	*Haliclona simulans*	*Paracentrotus lividus*	*Tonicella marmorea*
Maja squinado	*Alcyonium glomeratum*	*Holothuria forskali*	*Margarites helicinus*
Osilinus lineatus	*Anemonia viridis*	*Centrolabrus exoletus*	*Tectura testudinalis*
Patella depressa	*Aulactinia verrucosa*	*Crenilabrus melops*	*Onoba aculeus*
Crepidula fornicata	*Corynactis viridis*	*Ctenolabrus rupestris*	*Colus islandicus*
Tritonia nilsodheri	*Sabellaria alveolata*	*Labrus mixtus*	*Akera bullata*
Solen marginatus	*Chthamalus montagui*	*Thorogobius ephippiatus*	*Limaria hians*
Phallusia mammillata	*Chthamalus stellatus*	*Scinaia trigona*	*Anomia ephippium*
Scinaia furcellata	*Hippolyte huntii*	*Asparagopsis armata*	*Thyasira gouldii*
Chondracanthus acicularis	*Palinurus elephas*	*Bonnemaisonia hamifera*	*Leptometra celtica*
Stenogramme interrupta	*Polybius henslowi*	*Naccaria wiggii*	*Leptasterias muelleri*
Laminaria ochroleuca	*Ebalia tumefacta*	*Jania rubens*	*Semibalanus balanoides*
Bifurcaria bifurcata	*Corystes cassivelaunus*	*Lithothamnion corallioides*	*Lithodes maia*
Cystoseira baccata	*Liocarcinus arcuatus*	*Mesophyllum lichenoides*	*Strongylocentotus droebachiensis*
Cystoseira foeniculaceus	*Liocarcinus corrugatus*	*Calliblepharis ciliata*	*Cucumaria frondosa*
	Goneplax rhomboides	*Kallymenia reniformis*	*Styela gelatinosa*
	Pilumnus hirtellus	*Rhodymenia delicatula*	*Lumpenus lumpretaeformis*
	Xantho incisus	*Rhodymenia holmesii*	*Zoarces viviparus*
	Xantho pilipes	*Rhodymenia pseudopalmata*	*Lithothamnion glaciale*
	Tricolia pullus	*Halurus equisetifolius*	*Phymatolithon calcareum*
	Gibbula umbilicalis	*Sphondylothamnion multifidum*	*Callophyllis cristata*
	Patella ulyssiponensis	*Drachiella heterocarpa*	*Odonthalia dentata*
	Bittium reticulatum	*Drachiella spectabilis*	*Sphacelaria arctica*
	Cerithiopsis tubercularis	*Stilophora tenella*	*Sphacelaria mirabilis*
	Melaraphe neritoides	*Halopteris filicina*	*Sphacelaria plumosa*
	Calyptraea chinensis	*Dictyopteris membranacea*	*Chorda tomentosa*
	Clathrus clathrus	*Taonia atomaria*	*Ascophyllum nodosum mackaii*
	Ocenebra erinacea	*Carpomitra costata*	*Fucus distichus distichus*
	Acteon tornatilis	*Cystoseira tamariscifolia*	*Fucus evanescens*
	Pleurobranchus membranaceus	*Codium adhaerens*	
	Atrina fragilis	*Codium tomentosum*	

Sources of data

The Fisheries Research Services produce an irregular report, the *Ocean Climate Status Report*, outlining trends in the weather and the temperature of coastal, offshore and oceanic waters around Scotland. In addition, trends in the wider North Atlantic are examined in the *Annual ICES Ocean Climate Status Summary* published by ICES.

Other organisations that produce or analyse relevant data are:

- the Tyndall Centre for Climate Change Research;
- the Hadley Centre for Climate Prediction and Research;
- the UK Climate Impacts Programme;
- the MarClim Project – Marine Biological Assessment UK/SAMS.

References

Dawson, A., Smith, D. E. and Dawson, S. (2001). *The Potential Impacts of Climate Change on Sea Levels around Scotland.* Scottish Natural Heritage Research Survey and Monitoring Report, No. 178. Scottish Natural Heritage, Edinburgh.

Elliott, M., O'Reilly, M. G. and Taylor, C. J. L. (1990). The Forth estuary: a nursery and overwintering area for North Sea fishes. *Hydrobiologia* **195**: 89–103.

Fisheries Research Services. (2000). *Ocean Climate Status Report 1999*. Fisheries Research Services Report, 06/00. Fisheries Research Services, Aberdeen.

Greenwood, M. F. D., Hill, A. S. and McLusky, D. S. (in preparation). Trends in abundance of benthic demersal fish populations of the lower Forth Estuary, East Scotland, from 1982 to 2001.

Hiscock, K., Southward, A., Tittley, I., Adam, J. and Hawkins, S. (2001). *The Impact of Climate Change on Subtidal and Intertidal Benthic Species in Scotland*. Report to Scottish Natural Heritage from the Marine Biological Association of the UK. Phase 1: Introduction and species researched. Scottish Natural Heritage Research Survey and Monitoring Report, No. 182. SNH, Edinburgh.

Hulme, M., Jenkins, G. L., Lu, X., Turnpenny, J. R., Mitchell, T. D., G., Jones, R. G., Lowe, J., Murphy, J. M., Hassall, D., Boorman, P., McDonald, R. and Hill, S. (2002). *Climate Change Scenarios for the United Kingdom: the UKCIP02 scientific report.* Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich.

JERICHO. (1999). JERICHO: *Joint Evaluation of Remote Sensing Information for Coastal and Harbour Organisations*. Final report. BNSC Earth Observation LINK Programme, UK.

Shennan, I. (1989). Holocene crustal movements and sea level changes in Great Britain. *Journal of Quaternary Science* **4**: 77–89.

Woodworth, P. L., Tsimplis, M. N., Flather, R. A. and Shennan, I. (1999). A review of the trends observed in British Isles mean sea level data measured by tide gauges. *Geophysical Journal International* **136**: 651–670.

Additional source

ICES. (2001). *The Annual ICES Ocean Climate Status Summary 2000/2001*. ICES Working Group on Ocean Hydrography Report. Turrell, B. and Holliday, N. P. (eds). ICES, Copenhagen.

Part 5
Conclusions

14 Conclusions

Scotland's seas, positioned between subpolar and subtropical influences, are among the most biologically productive in the world. They support a fascinating and diverse assemblage of marine habitats and species, provide a wealth of important natural resources and offer abundant opportunities for recreation and enjoyment.

Nevertheless, the seas around Scotland have been subject to a multitude of pressures. Without improved knowledge, care and long-term commitment to their protection, they could be irreparably damaged. This audit has sought to identify and describe ways in which the marine environment is changing, and so help to inform policies and advice. We seek to share that knowledge so that it can be used by others who have an interest in the well-being of the seas around Scotland, and in marine environments more generally.

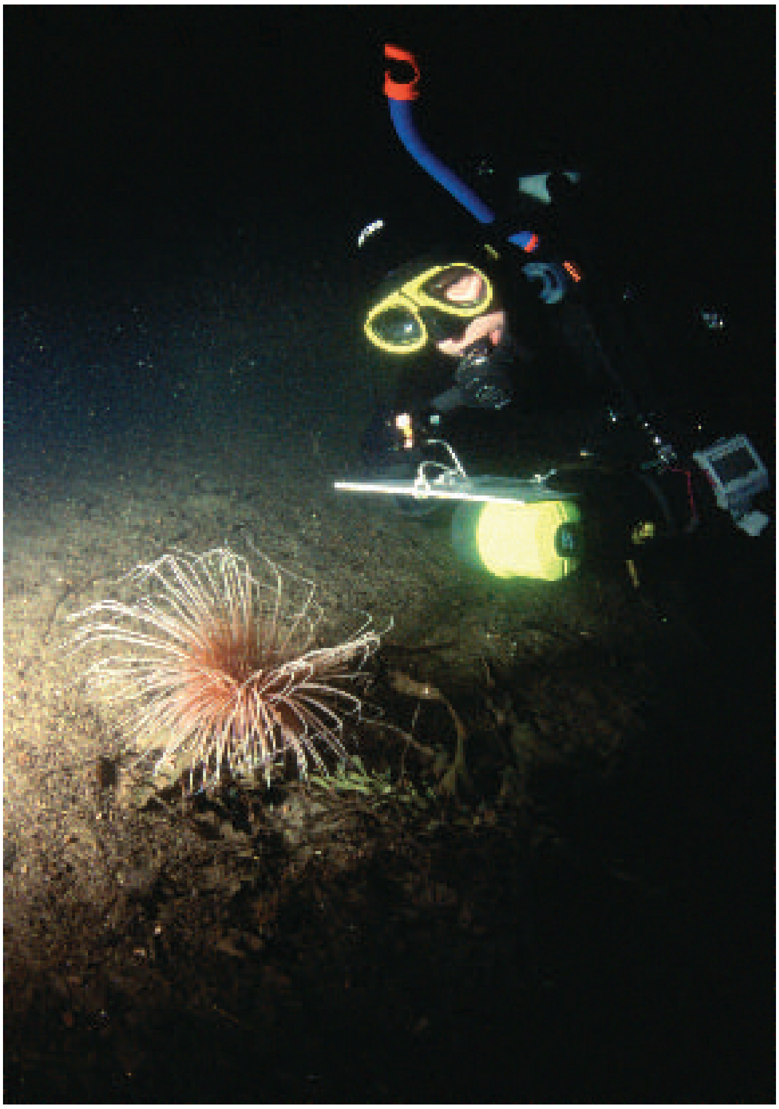
The SNH Natural Heritage Futures programme (Box 14.1) sets out natural heritage objectives for coasts and seas. They are examined here, in the light of audit findings. With a marine ecology focus, the audit of the seas around Scotland has more to say on some objectives than others. In particular, it did not attempt to address coastal issues, landscape or recreation. Coverage of those aspects of the maritime environment may be addressed more fully by future audits.

Previous page: Kelp forest (*Laminaria* hyperborea). *D. Donnan*

Above: Whale jawbone, North Berwick Law. J. Baxter

Box 14.1 Natural Heritage Futures

A suite of publications, called Natural Heritage Futures, has been prepared by Scottish Natural Heritage to guide the management of the natural heritage towards 2025. That on Coasts and Seas (SNH, 2002) examines maritime issues within the context of sustainable development. The Futures programme seeks to ensure that we take an integrated approach to our work across our whole remit and, at the same time, provide the basis for our engagement with other stakeholders.



Diver and fireworks anemone (*Pachycerianthus multiplicatus*).
G. Saunders

Natural Heritage Futures, Coasts and Seas, Objective 1: to improve management, stewardship, awareness and understanding of marine ecosystems

The total number of Scottish marine species is estimated to exceed 40,000 (Chapter 1). Knowledge of habitats and species comes from a variety of sources. Dispersed and incomplete as survey coverage is, it continues to reveal spectacular new discoveries, such as coldwater corals and the sublittoral St Kilda plateau tracing out the remnants of long extinct volcanic activity.

Biodiversity Action Plans have been specified for species and habitats that are considered to be representative, rare or at risk. Of the 81 marine, estuarine or brackish-water species incorporated within UK Action Plans, 74 are found around Scottish coasts (Chapter 2).

Two species of seal, the grey and the harbour (or common), are present around the coast of Scotland in internationally important numbers (Chapter 5). The status of both is currently considered to be good, although the full effect on harbour seal numbers of a phocine distemper virus (PDV) outbreak in 2002 remains to be seen. The fishing and fish farm industries have expressed concern over increasing seal numbers and research projects are under way at the Sea Mammal Research Unit (SMRU) to better understand seal population dynamics and diet.

A probable consequence of climate change (Chapter 13) is that a small number of northern species which are currently at the southern limit of their range may disappear from Scotland over the next 100 years. However, the effect of warming is that overall diversity is likely to increase as a greater number of southern species migrate into and become established in Scottish waters. There is already some evidence of shifting distributions among fish species which are at the limits of their northerly or southerly ranges in the lower Forth estuary. Some communities that are particularly well developed in Scotland could be adversely affected over the longer term, such as those associated with the calcareous seaweed, maerl and horse mussel beds (*Modiolus modiolus*), both of which are considered to be of international importance in Scottish waters.

Natural Heritage Futures, Coasts and Seas, Objective 2: to manage the coastline in sympathy with natural processes

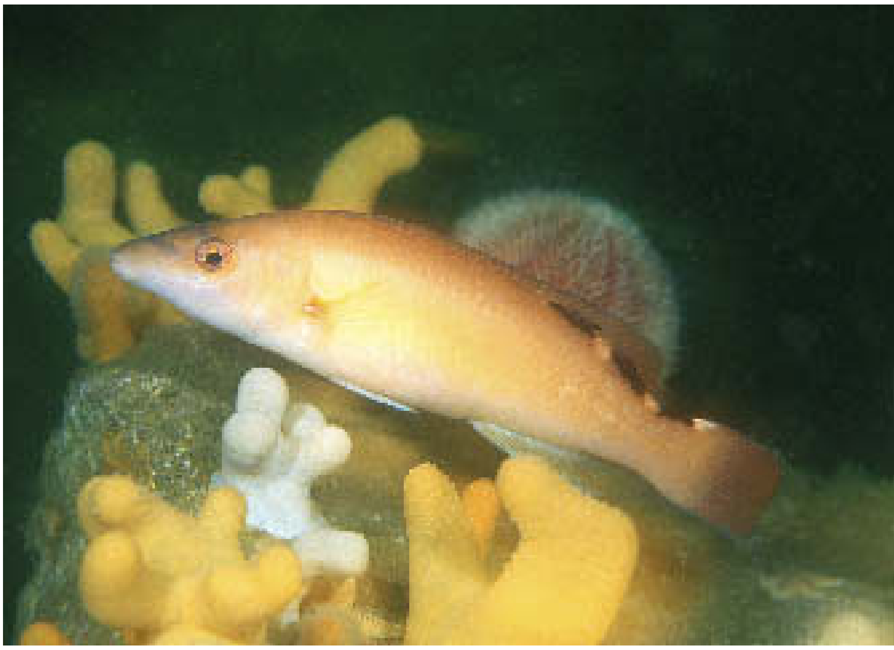
Studies of the Scotland's eastern coastline have concluded that it has become cleaner, more scenic and better managed over the last 30 years (Chapter 2). This has been attributed, in large part, to the effectiveness of direct conservation management. Throughout Scotland, SSSI coverage along the coast is well developed. However, similar regard to the protection of subtidal areas has occurred only with the application of the Habitats Directive in recent years.

Much of Scotland's coast is steep and rocky. The consequences of a rising sea level will be felt most severely on low-lying coasts, and especially where prevailing winds tend to generate storm surges (Chapter 13). On coasts protected by sea defences, the intertidal will be modified and reduced in extent. In low-lying unprotected areas, the coastline will tend to be pushed inland.

Natural Heritage Futures, Coasts and Seas, Objective 3: to safeguard and enhance maritime biodiversity and ecosystems

Few data are available on population trends for the 22 species of dolphin, porpoise and whale that occur in Scottish waters (Chapter 4). However, the OSPAR Commission (Oslo and Paris Convention for the Prevention of Marine Pollution) has reported that most species of large whale are showing signs of recovery in European waters following a moratorium by most countries on commercial whaling. No clear trends are evident for smaller whales, dolphins and porpoises. A steady increase in the number of strandings in UK and Irish waters was recorded between the 1960s and 1980s. No clear trends have been evident from Scottish strandings during the past decade; their occurrence seems simply to correspond with the general distribution of cetacean species around the coast.

Scotland's breeding seabird populations are internationally important (Chapter 6). Trends sometimes vary markedly between Scottish regions, for example between populations in the North Sea and Irish Sea/Atlantic Ocean. They



Kiloran Bay, Colonsay
L. Gill/SNH

Female cuckoo wrasse (*Labrus mixtus*).
R. Holt

are driven by a wide range of factors, and may differ between colonies of the same species. Between around 1970 and 1985, 11 out of 18 seabird species showed a marked increase in their breeding populations (i.e. by at least 10%), and four showed a marked decline.

Of 24 non-native marine species found in Scottish waters (Chapter 12), ten have potentially harmful effects on the environment and/or on commercial interests. Difficult or impossible to eradicate, the direct effects of non-native species on the marine environment (such as the displacement of native species, competition with native species for food and space, disruption of commercial oyster beds and the fouling of ships, buoys and harbour structures) have not yet proved to be as detrimental as those reported from elsewhere in the world. However, sea temperature rise may in the future give some non-native species an enhanced competitive advantage.

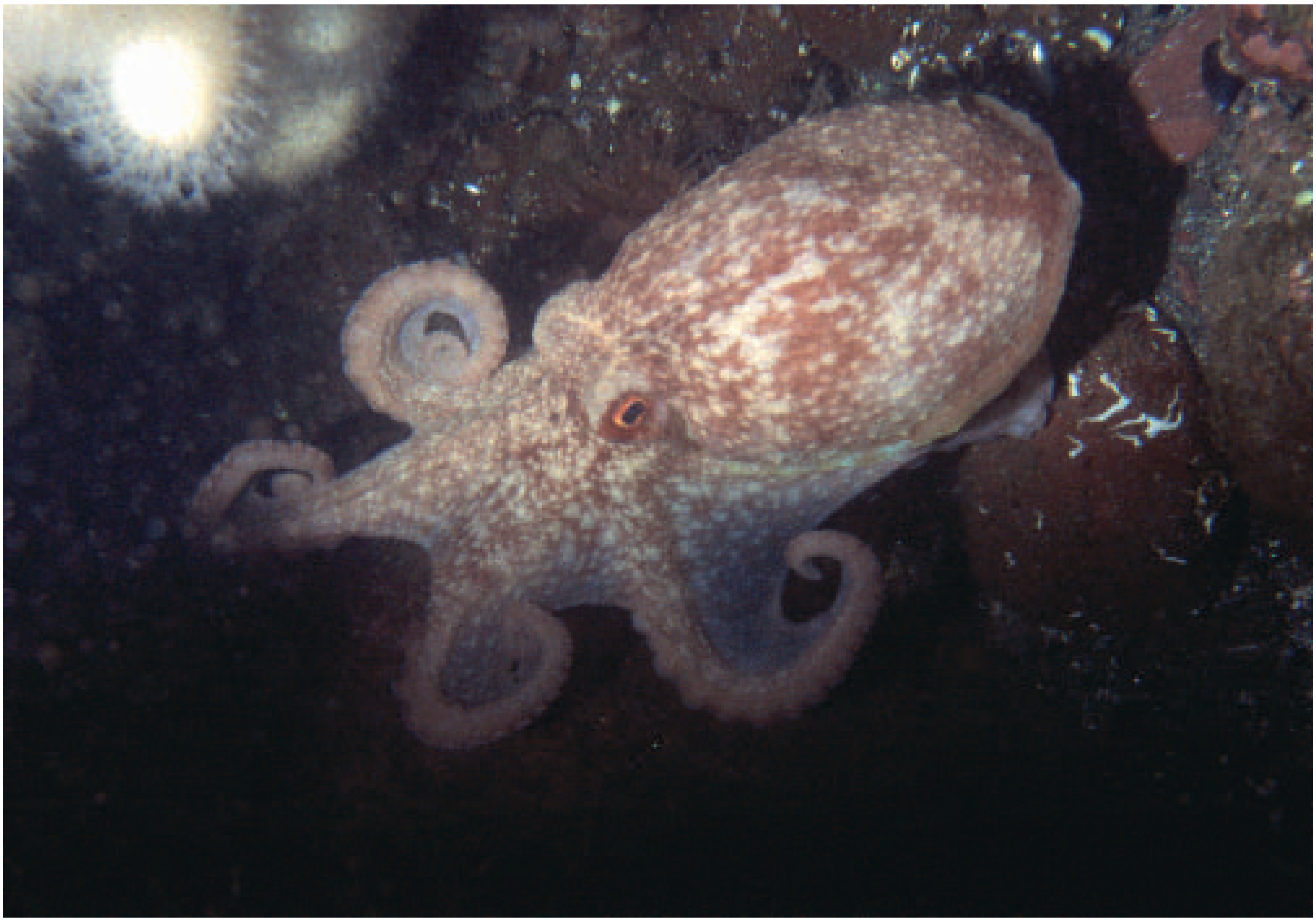
A further consequence of climate change may be that enclosed areas of sea bed, such as in sea lochs, may experience greater seasonal impacts from deoxygenation (Chapter 13).

Natural Heritage Futures, Coasts and Seas, Objective 4: to safeguard and enhance the fine scenery and diverse character of coastal seascapes and landscapes

A comparison of North Sea coastal development in 1988 with that of 1999 revealed little change, other than an increase in the relative importance of leisure and recreational uses (Chapter 2).

Right: Isle of Lewis.
L. Gill/SNH

Below: Curled octopus (*Eledone cirrhosa*).
G. Saunders



Natural Heritage Futures, Coasts and Seas, Objective 5: to enhance populations of overexploited commercial fish species and ensure that fishing is sustainable

The state of commercially exploited fish populations and damage to the sea bed from gear used to catch them raise ecological concerns (Chapter 8). Fishing activity has had an impact on the north-eastern Atlantic region and may be the main ecological structuring force on the benthos in areas of intense exploitation. An ecosystem-based management approach, based on an integrated fisheries management policy that takes account of ecological community structure and an appreciation of appropriate spatial and temporal scales, is imperative.

Scottish coastal waters hold at least 18 species of shark, eight species of ray and three species of skate (Chapter 3). Over-exploitation has been implicated in declines of various species. Four species are now in such a perilous state that they require statutory protection. The two biggest – the common skate and the basking shark – have been fished to commercial extinction.

Among 12 commercially exploited deep-water fish species, five are considered by ICES (International Council for the Exploration of the Sea) to be harvested outside safe biological limits and the status of others is largely unknown (Chapter 9). Deep-water trawling is a threat to habitats and species found along the European continental shelf break and slope.

Kirkwall harbour.
J.Baxter

Natural Heritage Futures Coasts and Seas, Objective 6: to ensure that salmon farming and other types of aquaculture are environmentally sustainable

Fish farming in Scotland has grown rapidly since the mid-1980s. It has become an important employer and revenue-generating industry among many of the remoter coastal communities (Chapter 7). Almost all sea lochs with conditions suitable for mariculture now have at least one installation. However, intensive farming practices, for salmon in particular, have raised ecological concerns about localised impacts on the sea bed, aesthetic degradation of the landscape, nutrient enrichment of coastal waters, predator control measures and interactions with wild Atlantic salmon populations.

Shellfish farming, reliant simply on naturally occurring phytoplankton in the water for food, must represent one of the most sustainable forms of production. However, some plankton species that constitute food for shellfish produce toxins which can build up in farmed and wild shellfish. This calls for a better understanding of the causes of toxic algal blooms, their frequency of occurrence and their implications for the marketability of shellfish.

Oyster farm.
J. Charity/SNH

Natural Heritage Futures, Coasts and Seas, Objective 7: to improve the water quality of estuaries and seas

Major improvements in water quality, brought about by pollution controls, have been reflected in signs of ecological recovery within the Clyde and Forth estuaries of central Scotland (Chapter 10). Problems associated with more diffuse pollution remain, such as in the catchment and estuary of the River Ythan. Elsewhere, dogwhelk populations that had suffered declines as a result of formerly high tributyltin (TBT) levels at monitored locations in the Shetland Isles, the Firth of Clyde and Loch Ryan had mainly re-established by 2001.

The accumulation of litter, on and within the open sea, upon the sea bed and on the shore, is a problem (Chapter 11). Unsightly degradation along the strandline is the most obvious consequence. More insidious effects tend to go unseen. Drowning and slow starvation are common consequences of entanglement in debris by marine mammals and birds. Plastic pellets, resembling fish eggs, cause chemical poisoning in birds, fish and turtles. Seabirds and their chicks are susceptible to ingesting litter. Plastic bags can cause gut blockage and death by starvation among turtles, which mistake them for their jellyfish prey.

Forth estuary.
J. Baxter

Natural Heritage Futures, Coasts and Seas, Objective 8: to promote access to the sea and coast for public enjoyment and recreation

Marine wildlife tourism in Scotland generated revenues of some £57 million and provided around 2,670 full-time jobs in 1996 (Chapter 1).

Angling on the Ythan estuary.
L.Gill/SNH

Deadman's fingers (*Alcyonium digitatum*) and the cushion star (*Porania pulvillus*)
S. Scott/SNH

Summing up

Looking across the eight objectives for coast and sea, many positive messages are present. Notable among them is the ability of nature, given time, to recover or re-establish where damage caused by pollution or other impacts is remedied. However, much still needs to be done to bring parts of Scotland's coastal waters back to a more favourable state – for health and enjoyment, and for the restoration of ecosystem functions.

The example of discarded litter around our shores should serve as an unsightly warning of unseen damage and distress caused to wildlife. It has economic impacts too. There is no reason why a cleaner environment cannot go hand in hand with a prosperous economy and enhance Scotland's attractiveness as a tourist destination and business location.

Several fish stocks of the continental shelf and in deep waters to the west are over-exploited. The biggest among our fish species have been reduced to commercial extinction. Trawl damage is now coming to light on the seabed, the last great frontier of exploration and discovery on our planet. We need to develop a better understanding of the characteristics and requirements of this functioning ecosystem.

The consequences of climate change in the marine environment are becoming evident. We need to become more responsive and adaptive to change.

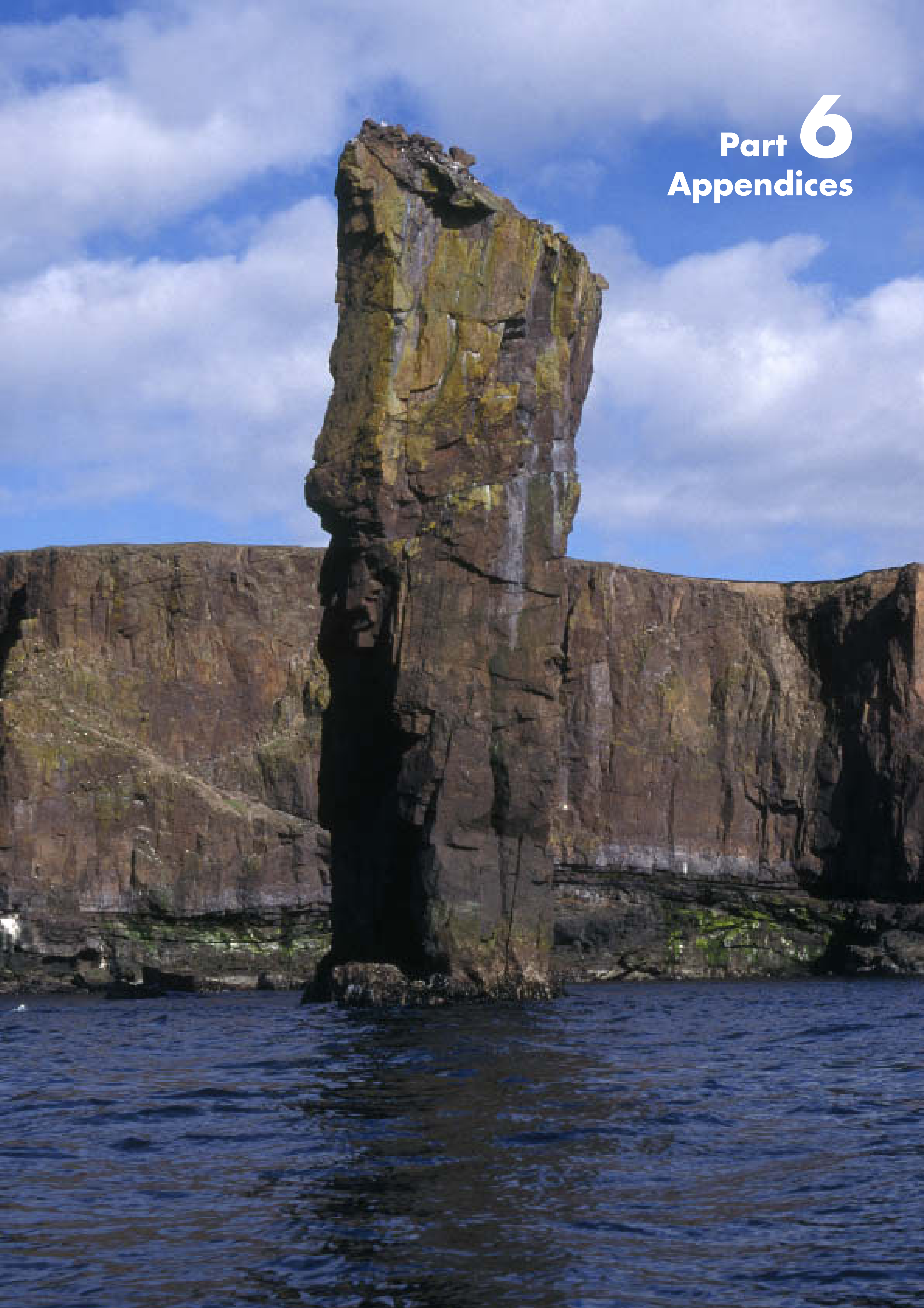
Opportunities exist to do something positive. A commitment to find solutions to these major issues is demonstrated by the Scottish Sustainable Marine Environment Initiative, led by the Scottish Executive. Similarly, a Marine Implementation Plan is being developed as part of the forthcoming Scottish Biodiversity Strategy.

Novel approaches to sustainable management are required. These must be in partnership, taking account of nature conservation priorities alongside socio-economic needs We need to arrive at a shared vision for the future, in which hard choices may be required to secure long-term gains.

What this report has shown is that we need to be prepared to learn, understand and re-examine the ways in which we interact with the seas around Scotland.

Reference

SNH. (2002). *Natural Heritage Futures: Coasts and Seas*. Scottish Natural Heritage, Battleby.



Part 6 Appendices

Appendix 1: SEPA coastal waters classification scheme

Class	Description	Use-related description	Aesthetic condition		Biological condition		Bacteriological condition		Chemical condition
A	Excellent	Fit for all defined uses	Near pristine, uncontaminated	and	Flora and fauna normal	and	Likely to meet quality standards no less stringent than the guideline standards for EC-designated shellfish and bathing waters		
B	Good	Fit for all defined uses	Unpolluted but may show signs of contamination	and	Flora and fauna normal	and	Likely to meet quality standards no less stringent than the mandatory standards for EC-designated shellfish and bathing water		
C	Unsatisfactory	Defined uses may be compromised by the occasional presence of sewage-derived material or by moderate organic enrichment	Occasional observations or substantiated complaints of sewage solids, smell nuisance or oil	or	Flora and/or fauna modified by effluent discharges	or	Likely to fail to meet quality standards no less stringent than the mandatory standards for EC-designated bathing waters	and	Likely to meet all quality standards applied as a consequence of the EC Dangerous Substances Directive
D	Seriously polluted	Defined uses compromised or prevented by the frequent presence of sewage-derived material or chemical pollutants	Frequent observations or substantiated complaints of sewage solids, smell nuisance or oil	or	Flora and/or fauna impoverished or absent	or	Likely to frequently fail to meet quality standards no less stringent than the mandatory standards for EC-designated bathing waters	or	Likely to fail any one or more of quality standards applied as a consequence of the EC Dangerous Substances Directive

Source: Saunders, G., Dobson, J. and Edwards, A. (2002). The state of Scotland's seas and estuaries. In: The State of Scotland's Environment and Natural Heritage. Usher, M. B., Mackey, E. C. and Curran, J. C. (eds). The Stationery Office, Edinburgh.

Previous page: Papa Stour cSAC, Shetland. *J.Baxter*

Appendix 2: SEPA estuarine waters classification scheme

Class	Description	Aesthetic conditions	Fish migration	Resident biota and/or bioassay	Resident fish	Persistent substances (biota)	Water chemistry	
							Dissolved oxygen (DO)	UK Red list and EC-designated dangerous substances
A	Excellent	Unpolluted	Water quality allows free passage	Normal	Resident fish community normal	Less than twice national background	Minimum DO > 6 mg/l	100% compliance of samples with environmental quality standards (EQS)
B	Good	May show signs of contamination	Water quality allows free passage	Normal	Resident fish community normal	More than or equal to twice national background but less than substantially elevated	Minimum DO £ 6 mg/l but > 4 mg/l	Annual compliance of samples with EQS
C	Unsatisfactory	Occasional observations or substantiated complaints of pollution	Water quality restricts passage	Modified	Resident fish community modified	Substantially elevated but not grossly elevated	Minimum DO £ 4 mg/l but > 2 mg/l	One or more List II substances fail to comply with EQS. List I and Red List all comply
D	Seriously polluted	Frequent observations or substantiated complaints of pollution	Water quality allows no passage	Impoverished or severely modified	Resident fish community impoverished	Grossly elevated	DO < 2 mg/l	One or more List I or Red List substances fail to comply with EQS

Source: Saunders, G., Dobson, J. and Edwards, A. (2002). The state of Scotland's seas and estuaries. In: *The State of Scotland's Environment and Natural Heritage*. Usher, M. B., Mackey, E. C. and Curran, J. C. (eds). The Stationery Office, Edinburgh.

Appendix 3: definition of microbiological requirements for guideline and mandatory passes of bathing waters based on the minimum number of samples (20) that are taken from each location

Level of pass	Interpretations	Total coliforms	Faecal coliforms	Faecal streptococci
Pass – guideline	Directive states	80% of samples should not exceed 500 total coliforms per 100 ml	80% of samples should not exceed 100 faecal coliforms per 100 ml	90% of samples should not exceed 100 faecal streptococci per 100 ml
	Based on 20 samples	At least 16 samples must contain 500 or fewer total coliforms per 100 ml	At least 16 samples must contain 100 or fewer faecal coliforms per 100 ml	At least 18 samples must contain 100 or fewer streptococci per 100 ml
Pass – mandatory	Directive states	95% of samples should not exceed 10,000 total coliforms per 100 ml	95% of samples should not exceed 2,000 faecal coliforms per 100 ml	The Directive contains no mandatory standard for faecal streptococci
	Based on 20 samples	Only one sample can contain more than 10,000 total coliforms per 100 ml	Only one sample can contain more than 2,000 faecal coliforms per 100 ml	The Directive contains no mandatory standard for faecal streptococci

Appendix 4: Scottish marine environment data sources

The following is a list organisations, institutions, laboratories and companies that hold information relating to the Scottish marine environment. Scottish data have been extracted from IACMST (1995) and separated into categories dependent on whether all or part of the information held is biological, biochemical/chemical or physical in content.

Source

IACMST. (1995). *Directory of Marine Environmental Datasets held by UK Laboratories.* Vols 1 and 2: *Academic Sector, Public Bodies, NERC-related Laboratories, Private Companies.* IACMST Information Document No. 4, Rickards, L. J. (ed.). British Oceanographic Data Centre on behalf of the Inter-Agency Committee on Marine Science and Technology,.

Note

a searchable database for all European data sets is now available at: http://www.bodc.ac.uk/frames/index4.html?../services/edmed/index.html&2.

Biological

Organisation	Geographic area	Data type	Time period	Data format	Comments
British Oceanographic Data Centre (BODC)	North-east Atlantic and continental shelf seas around the British Isles	Various parameters	1970 onwards	Electronic storage	The UK ROSCOP (Report of Observations/Samples Collected by Oceanographic Programmes) data set comprises over 4,000 forms completed by the principal scientists of research cruises undertaken since 1970. The forms are completed by scientists using research vessels belonging to the Natural Environment Research Council (NERC), the Ministry of Agriculture, Fisheries and Food (MAFF), the Scottish Office Agriculture and Fisheries Department (SOAFD) and the smaller research vessels belonging to university departments and marine biological associations
British Oceanographic Data Centre (BODC)	45° N to 65° N, 15° W to 15° E	UK Digital Marine Atlas (second edition): marine geology and geomorphology; marine and coastal parks, reserves and protected areas; marine and coastal conservation in Great Britain; seabirds; sea mammals; marine biology; currents, tides and surges; winds, waves and weather; seawater temperature, salinity and nutrients; chemical distributions; exploitation of the marine environment; fishing areas and fish spawning areas; data catalogues	Not specified	Electronic storage	
Culterty Field Station, University of Aberdeen	Ythan estuary, north-east coast of Scotland	Species (birds, fish, invertebrates), populations, nutrient concentrations, algal abundance, coastal ecology	Not specified	Hard copy	The long-term data sets maintained for the Ythan estuary are considered to be very valuable for increasing understanding of eutrophication processes
Cunninghame District Council	Area surrounding Great and Little Cumbrae Islands, Firth of Clyde	Marine and intertidal ecology (e.g. sites, habitats, species, communities, abundance, geology)	Not specified	Paper reports	At Kames Bay, populations of the thin tellin, *Angulus tenuis*, have been monitored for over 60 years, constituting one of the longest series of observations on an intertidal species in the UK

Organisation	Geographic area	Data type	Time period	Data format	Comments
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Firth of Lorne, associated sea lochs and adjacent sea areas	Fish larvae in Scottish sea lochs. Marine biology, fish, fisheries stocks, fish larvae	1970 –1976	Paper records	Seasonal sampling of fish larvae; used extensively by Sir Frederick Russell in his book Eggs and Larvae of British Fishes. His original identifications are held at SAMS. Some use made of material in other publications
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Firth of Lorne, associated sea lochs and adjacent sea areas	Inshore fish in Scottish sea lochs. Marine biology, fish, fisheries stocks, fish larvae	1969 –1980	Electronic storage, paper reports	Catch data for trawls in the Firth of Lorne, Loch Linnhe, Loch Etive, Loch Spelve, Loch Sunart, Sound of Mull and Tiree Passage
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Rockall Trough, Porcupine Seabight	Deep-sea fish from the Rockall Trough and Porcupine Seabight	1975 –1992	Electronic storage	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	48–61° N; 03–18° W, principally Rockall Trough, west of Ireland, including some samples from Porcupine Seabight	Deep-sea benthos of the Rockall Trough area	1973 onwards	Electronic storage, paper record, preserved specimens	The project has primarily aimed to sample the macro- and megabenthic community at two deep-sea permanent stations on a seasonal and interannual basis using epibenthic sled and Agassiz trawl respectively
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Tralee Bay, Ardmucknish Bay, near Oban, Argyll, Scotland	Abundance and species diversity of fish and crustaceans on a Scottish (west coast) sandy beach: number of individuals per 100 m^2, lengths and weights of fish species, salinity, temperature, wind values, number of species at sample date, fish biomass per 100 m^2	April 1986 to December 1989	Electronic storage, paper reports	

Organisation	Geographic area	Data type	Time period	Data format	Comments
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Loch Linnhe and Loch Eil, west coast of Scotland	West coast of Scotland Loch Linnhe/Loch Eil benthic ecology surveys: long-term changes in the benthic ecology of Loch Linnhe and Loch Eil; macrobenthic invertebrate abundances, species numbers and biomass quantified at c.10-week intervals; sedimentary carbon, nitrogen, redox potentials, acidity, temperatures, salinities and oxygen levels	1963 –1980	Published manuscripts/ paper reports	The survey was initiated to assess the impact on the sedimentary ecology of the area of the effluent from a pulp and paper mill discharging into the narrows between the two lochs. It was continued as a general study of organic enrichment of marine sediments and of fjordic benthic ecology
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Central Firth of Clyde, west coast of Scotland	Environmental monitoring survey of Garroch Head sewage sludge disposal grounds	1979 onwards	Published manuscripts/ paper reports	A monitoring survey to assess the comparative condition of the sediments and fauna in the area of the grounds where 1.5 ¥ 106 wet tonnes of sewage sludge is dumped annually
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Hunterston power station and surrounding areas (Clyde Sea area)	Hunterston power station, Clyde Sea area: sea biological populations time-series	1960 –1985	Electronic storage, biological samples	Biological core samples were taken to study densities of various species in the areas surrounding Hunterston power station and Kames Bay, Millport
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Hunterston power station and surrounding areas (Clyde Sea area)	Breeding behaviour of Assellopsis intermedia in the vicinity of Hunterston power station, Clyde Sea area	1960 –1975(?)	PhD thesis, paper notes	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	North-east Atlantic (Madeira –Faroes)	Meiobenthos studies at two sites west of Ireland and south-west Porcupine Seabight	1973 –1983	PhD theses, biological samples	Fortnightly samples were taken to study the breeding behaviour of the copepod *Asellopsis intermedia*

Organisation	Geographic area	Data type	Time period	Data format	Comments
Institute of Oceanographic Sciences (IOS) Deacon Laboratory/ James Rennell Centre for Ocean Circulation (JRC)	Eastern North Atlantic Ocean. Work areas centred on EEC station 48°50´ N, 16°30´ W; 31° N, 21o W; projected site at 20° N, 30° W	DEEPSEAS, abyssal benthic biology within the framework of IOS laboratory research project 4 (LRP4): abyssal biota, megafauna, macrofauna, meiofauna, foraminifera, bacteria, abundance, diversity, biomass, size spectra, life history strategies	1989 onwards	Electronic storage, biological samples, photographic images	The aim of DEEPSEAS is to study the responses of deep-sea benthic and benthopelagic communities to perturbation
Institute of Oceanographic Sciences (IOS) Deacon Laboratory/ James Rennell Centre for Ocean Circulation (JRC)	Eastern North Atlantic Ocean	IOS Deacon Laboratory biological database of the north-east Atlantic: macroplankton, micronekton	1969 onwards	Electronic storage	The IOS Deacon Laboratory has been engaged in a series of comprehensive mid-water sampling programmes in the North Atlantic between the equator and 60° N and from offshore Europe and Africa mainly to 33° W for many years
Institute of Oceanographic Sciences (IOS) Deacon Laboratory/ James Rennell Centre for Ocean Circulation (JRC)	North Atlantic (UK to Cape Farewell, Greenland)	World Ocean Circulation Experiment (WOCE), CONVEX. temperature, salinity, transmittance, dissolved oxygen, nitrate, silicate, oxygen-16/oxygen-18 ratio, chlorofluoro-carbons, plankton, meteorological measurements, current profiles, bathymetry	1991 onwards	Electronic storage	These data were collected to investigate the distribution of water masses and to derive full depth circulation
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Eastern Irish Sea	Benthic survey: taxonomic description of macrobenthos, sediment	1983 –1988	Paper files, published literature	Spatial distribution of the macrobenthos in the muddy sediments of the eastern Irish Sea. Redistribution of sediment bound artificial radionuclides originating from the Sellafield nuclear reprocessing plant
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	North Sea	MAFF Directorate of Fisheries Research International Young Fish Surve data set: length and quantitative estimate of catch; surface and bottom temperature and salinity	1965 –1990	Electronic storage, paper files	Initially designed to determine the distribution and abundance of adult and larval herring plus juvenile gadoids and to monitor environmental parameters as part of an ICES-coordinated programme
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	North Sea	North Sea Groundfish Survey data set: length and total weight for all finfish species, weight and numbers for benthic species; caesium-137 sampling from seawater and fish muscle tissue; ad hoc biological sampling	1977 –1991	Electronic storage	Surveys were primarily designed to determine the distribution and abundance of demersal fish species and to monitor environmental parameters

Organisation	Geographic area	Data type	Time period	Data format	Comments
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	North Sea	Length and total weight for all finfish species and the total weight of benthic species and anthropogenic debris; age/maturity	1992–1994 (August to September each year); 1991–1994 (October to November each year)	Electronic storage	ICES third- and fourth-quarter bottom trawl survey data sets
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Northern North Sea	Norway pout surveys in the northern North Sea. Length and total weight for cod, haddock, whiting, Norway pout, herring	1978–1983	Electronic storage, paper record	To determine the distribution and abundance of commercial gadoids in relation to the distribution of Norway pout in order to delimit an area where a ban on industrial fishing could be imposed as a conservation measure
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Mainly western Irish Sea	Irish Sea Nephrops larvae survey: plankton, nutrients, temperature, salinity	April to June 1982 and April to June 1985	Paper record	For estimation of the spawning stock biomass of the western Irish Sea Nephrops
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Irish Sea, Bristol Channel, western English Channel	Fish tagging data for cod, plaice, sole, spurdogs, rays, anglerfish	Ongoing	Electronic storage	
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Celtic Sea and English Channel	Gadoid survey: length and age/maturity; ad hoc biological and physical sampling	1990–1991	Electronic storage	Surveys to determine the distribution and abundance of groundfish, particularly cod
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Irish Sea	Irish Sea gadoid survey: length – all fish species and selected crustacea; maturity/age – cod, whiting, plaice and sole; ad hoc biological (e.g. weight, stomach contents, benthos) and physical (e.g. surface temperature and salinity) sampling	1979–1992	Electronic storage	Main objective was to determine the relative abundance of pre-recruit cod and whiting

Organisation	Geographic area	Data type	Time period	Data format	Comments
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Celtic Sea, Irish Sea	Near westerly groundfish surveys: length, weight, age/maturity of fish species and selected crustacea	1988 onwards (September each year, but including March from 1993)	Electronic storage	
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Western European Shelf between Shetland in the north to the southern part of the Bay of Biscay in the south	Western European shelf groundfish survey: fish distribution and abundance, size and age compositions, sea surface temperature, bottom temperature	1982 onwards	Electronic storage	Originally to investigate the distribution and abundance of juvenile mackerel, but extended to monitor the annual changes in distribution and abundance of length and age of all finfish species caught
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Various areas of the North Sea	Plankton, temperature, salinity	1962 onwards	Electronic storage, paper record	
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	UK	Inshore Waters Demersal Young Fish Survey: abundance and length distribution of small demersal fish, surface water salinity, temperature and substrate type	1970 –1975; 1979 onwards	Electronic storage, paper record	To provide abundance indices of group 0 and group 1 sole and plaice
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	North Sea and Irish Sea	Abundance and distribution of *Nephrops* larvae	1982, 1985 and 1987	Electronic storage	
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	UK; Mainly English Channel, Western Approaches, Bristol Channel and North Sea	Abundance and distribution of edible crab larvae	1981, 1989 and 1993	Electronic storage	
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Irish Sea	Irish sea *Nephrops* length samples: carapace length of market (landed) samples	1983 onwards	Electronic storage, paper record	

Organisation	Geographic area	Data type	Time period	Data format	Comments
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Eastern Irish Sea	Eastern Irish Sea *Nephrops* discard data: numbers at size of discarded and associated landed Nephrops by sex, and weights of samples	1991 onwards	Electronic storage (spread-sheet), paper copy	
MAFF Directorate of Fisheries Research, Fish Diseases Laboratory, Weymouth	Various areas of the North Sea, Southern Bight, English Channel, south-western approaches, Bristol Channel, Celtic Sea and Irish Sea	Marine fish disease surveys, including monitoring on dump sites	1992 onwards	Electronic storage, paper record, histopatho-logical samples	Monitoring trends for disease prevalences and investigations into the pathogenesis of new and emerging diseases
Marine Biological Association of the UK (MBA)	North-west Scotland	North-east England and north-west Scotland rocky shores species population dynamic	1967 onwards	Paper records	The data set comprises data on population dynamics of 'key' rocky shore species. There is an emphasis on recruitment
Marine Biological Association of the UK (MBA)	Western Argyll (Mull of Kintyre to Ardnamurchan Point), Outer Hebrides, north-west Scotland (Ardnamurchan Point to Cape Wrath), Moray Firth (Duncansby Head to Peterhead)	Intertidal survey unit database	1975 –1980	Electronic storage, paper reports	
Marine Conservation Branch of the Joint Nature Conservation Committee (JNCC)	UK	MNCR database: conservation, marine conservation, marine survey, sites, habitats, species, communities, abundance, granulometry, physiography, references, bibliography, community classification, biotope classification, life forms, photographs, littoral, sublittoral, infralittoral, circalittoral, substratum, position, grid reference, county, region, salinity, exposure, geology, stratification, designation	1987 onwards	Electronic storage	Currently holds data relating to around 212 surveys carried out in Scotland, incorporating over 6,400 survey stations. The data have recently been transferred to an updated system called Marine Recorder.

Organisation	Geographic area	Data type	Time period	Data format	Comments
Marine Conservation Branch of the Joint Nature Conservation Committee (JNCC)	Coastal areas of Great Britain, including Northern Ireland for estuaries	JNCC integrated coastal database: vegetation communities, areas, human activities, site protection	1982 onwards	Electronic storage	A range of data sets are combined into a single module, including national inventories of sand dunes, saltmarshes, estuaries, cliffs, shingle sites; also a map-derived data set of the areas and lengths of 'coastal resources' by 10 km
Natural History Museum (NHM), London	North-east Atlantic	North-east Atlantic abyssal polychaetes and nematodes: abundances, diversity, species richness, equitability, trophic groups	August 1989 to August 1992	Electronic storage	
Natural History Museum (NHM), London	North-east Atlantic	North-east Atlantic deep demersal fish data set: catch identified, counted and weighed at sea; sex and stomach contents were noted	1973 onwards	Electronic storage	Multiple oceanic sites in the eastern North Atlantic
Natural History Museum (NHM), London	Oceans and seas adjoining Europe	Foraminifera collection; plankton and benthos	1850 onwards	Electronic storage, paper record, preserved specimens	
North East River Purification Board (NERPB), now part of the Scottish Environment Protection Agency (SEPA)	Grampian, east coast of Scotland	Bathing water bacteriological surveys: faecal coliforms per 100 ml, total coliforms per 100 ml, temperature, wind speed and direction, presence of oils	1987 onwards	Electronic storage, paper record	
North East River Purification Board (NERPB) now part of the Scottish Environment Protection Agency (SEPA)	Grampian, east coast of Scotland	TBT imposex data	February 1990 to February 1992	Paper reports	
Plymouth Marine Laboratory (PML)	Irish Sea	PML Irish Sea Project data set. Phytoplankton, zooplankton, fish larvae, fish eggs, primary production, particle characterisation, salinity, temperature, chlorophyll	1987 –1991	Electronic storage	The aim was to study the productivity of both phytoplankton and zooplankton, in relation to the survival of fish larvae, and to investigate how differences in ecosystem structure might influence the availability of food and successful recruitment of fish

Organisation	Geographic area	Data type	Time period	Data format	Comments
Plymouth Marine Laboratory (PML)	Celtic Sea	PML Celtic Sea Project data set: phytoplankton, zooplankton, fish larvae, fish eggs, primary production, particle characterisation, salinity, temperature, chlorophyll	1982 –1986	Electronic storage, paper record, published reports	The project was an investigation of the role of picoplankton in pelagic productivity of a shelf sea
Plymouth Marine Laboratory (PML)	River Eden estuary, Fife	Nitrogen cycling parameters, bacterial numbers	1976 –1979	PhD thesis, published reports	Nitrogen cycling parameters and bacterial numbers were collected to study the rates of sediment nitrification and denitrification in nutrient lenses in the sediments
Scottish Office Agriculture and Fisheries Department (SOAFD), Marine Laboratory, Aberdeen	North Sea	ICES Benthos Working Group North Sea Survey: benthic fauna, carbon, chlorophyll, heavy metals, proteins	1980 –1986	Electronic storage	
SOAFD, Marine Laboratory, Aberdeen	Scottish coastal waters	Metals in organisms, seawater, sediments and rainwater; trace metals, mercury	1989 onwards	Electronic storage	
SOAFD, Marine Laboratory, Aberdeen	Scottish coastal waters, central and northern North Sea, Rockall, north-east Atlantic	Zooplankton data: species composition, biomass concentration, dry weight, feeding and growth rates, length/weight data and other derived parameters	1986 onwards	Electronic storage, manuscript	From various internal projects, national and international programmes
Sea Mammal Research Unit (SMRU)	UK coast especially Scotland	Common seal distribution and numbers in August	1988 onwards	Electronic storage, paper record	Seal population data are collected in late July and early August during the common seal annual moult
Sea Mammal Research Unit (SMRU)	Inner Hebrides, Outer Hebrides, Orkney, Isle of May, Loch Eriboll (i.e. all the main grey seal breeding sites in the UK)	Grey seals: pup production and population size	1960 onwards	Photographs	Annual grey seal surveys are conducted during the breeding season, from late September through late November

Organisation	Geographic area	Data type	Time period	Data format	Comments
Sir Alister Hardy Foundation for Ocean Science (SAHFOS)	North Atlantic (35° N to 60° N, 71° W to 11° E)	North Atlantic continuous plankton recorder survey data set: phytoplankton, zooplankton	1931 onwards	Electronic storage	The continuous plankton recorder is a piece of apparatus towed by vessels for sampling plankton near the sea surface. Continuous plankton recorders are towed by ships of opportunity at a depth of 10 m and are deployed, as far as possible, at monthly intervals over a standard set of routes
Solway River Purification Board (SRPB)	Inner Solway Firth beaches	Intertidal invertebrate communities, particle size analysis (PSA), trace metals in sediments	1987 onwards	Paper reports	Twenty-four sampling stations on the intertidal zone of the Inner Solway Firth, between Dorknockbrow and Arbigland (54°53′ N, 03°11′ W to 54°54′ N, 03°34′ W)
Solway River Purification Board (SRPB), now part of the Scottish Environment Protection Agency (SEPA)	Beach and seabed around the Galloway Creamer outfall, Loch Ryan, south-west Scotland	Invertebrate communities, particle size analysis (PSA)	1987 onwards	Paper reports	Annual survey of 24 sampling points (16 subtidal, eight intertidal) at the head end of Loch Ryan.
Tay River Purification Board (TRPB), now part of the Scottish Environment Protection Agency (SEPA)	East coast of Scotland	Bathing water survey: total coliforms and faecal coliforms per 100 ml seawater	1988 to 1992 (summer periods)	Paper reports	
Tay River Purification Board (TRPB), now part of the Scottish Environment Protection Agency (SEPA)	East coast of Scotland	Shellfish contamination surveys: faecal coliforms per 100 g tissue and fluid	1988 to 1992	Paper reports	Samples taken four times per year at EC-designated sites using caged or native mussels from the intertidal region
Tay River Purification Board (TRPB), now part of the Scottish Environment Protection Agency (SEPA)	Tay estuary	Faecal coliforms per 100 ml water	1989 –1992	Paper reports	Offshore samples of surface water taken four times per year

Organisation	Geographic area	Data type	Time period	Data format	Comments
Tay River Purification Board (TRPB), now part of the Scottish Environment Protection Agency (SEPA)	Barnhill sewage outfall, Tay estuary	Fauna	1992	Paper reports	
Tay River Purification Board (TRPB), now part of the Scottish Environment Protection Agency (SEPA)	Tay estuary	Fauna and sediment chemistry	1991 –1992	Paper report	
Tay River Purification Board (TRPB), now part of the Scottish Environment Protection Agency (SEPA)	Inner Eden estuary, east coast of Scotland	Fauna and sediment organic content	1989 and 1992	Paper reports	
Tay River Purification Board (TRPB), now part of the Scottish Environment Protection Agency (SEPA)	Dundee foreshore between road bridge and Broughty Castle	Fauna, loss-on-ignition and particle size analysis	1989 and 1991	Paper reports	
University of Wales, Bangor, School of Ocean Sciences	Loch Creran, Argyll	Phytoplankton study: temperature, salinity, chlorophyll, nutrients, phytoplankton species composition	1971 –1982	Paper records, reports, theses and digital tapes	A study of the relationship between phytoplankton community composition and hydrography
University of Wales, Bangor, School of Ocean Sciences	Loch Striven, Argyll	Temperature, salinity, currents, optical measurements, nutrients, chlorophyll, zooplankton biomass, phytoplankton species composition	1980 –1994	Paper records, reports, theses and digital data	

Organisation	Geographic area	Data type	Time period	Data format	Comments
Biological and chemical					
British Geological Survey (BGS)	UK continental shelf and adjacent slopes	Grain size, weights of gravel, sand and mud fractions, and carbonate content of the fractions; whole and half phi analysis of the sand fraction	1966 onwards	Electronic storage	
British Geological Survey (BGS)	UK continental shelf and adjacent slopes – except the Irish Sea, Celtic Sea and English Channel	Marine geochemical data. Trace element geochemical concentrations of sea-bed samples.	1975 –1990	Electronic storage	Concentrations of up to 30 trace elements in approximately 11,000 seabed samples
British Oceanographic Data Centre (BODC)	North-east Atlantic and continental shelf seas around the British Isles	Various parameters	1970 onwards	Electronic storage	The UK ROSCOP data set comprises over 4,000 forms completed by the principal scientists of research cruises undertaken since 1970. The forms are completed by scientists using research vessels belonging to the Natural Environment Research Council (NERC), the Ministry of Agriculture, Fisheries and Food (MAFF), the Scottish Office Agriculture and Fisheries Department (SOAFD) and the smaller research vessels belonging to university departments and marine biological associations
British Oceanographic Data Centre (BODC)	Shelf seas around the UK, eastern North Atlantic	Temperature, salinity, nutrients, oxygen, pH, alkalinity, chlorophyll a	1893 onwards	Electronic storage	Data routinely collected by UK research and naval vessels since the beginning of the twentieth century. Compiled by the ICES Oceanographic Data Centre

Organisation	Geographic area	Data type	Time period	Data format	Comments
British Oceanographic Data Centre (BODC)	45–65° N, 15° W to 15° E	*UK Digital Marine Atlas* (second edition): marine geology and geomorphology; marine and coastal parks, reserves and protected areas; marine and coastal conservation in Great Britain; seabirds; sea mammals; marine biology; currents, tides and surges; winds, waves and weather; seawater temperature, salinity and nutrients; chemical distributions; exploitation of the marine environment; fishing areas and fish spawning areas; data catalogues	Not specified	Electronic storage	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Scottish continental shelf, North Channel, Sea of the Hebrides, Minches	Radiocaesium (caesium-134 and caesium-137) surveys upon the continental shelf west of Scotland	1976 –1988	Manuscript	Water samples for radiocaesium analysis were collected in association with conductivity, temperature and depth (CTD) sections upon the western Scottish shelf. The data have been used to obtain travel times within the coastal current system and budgets of ocean/shelf exchange
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Loch Linnhe and Loch Eil, west coast of Scotland	West coast of Scotland Loch Linnhe/Loch Eil benthic ecology surveys: long-term changes in the benthic ecology of Loch Linnhe and Loch Eil; macrobenthic invertebrate abundances, species numbers and biomass quantified at c.10-week intervals; sedimentary carbon, nitrogen, redox potentials, acidity, temperatures, salinities and oxygen levels	1963 –1980	Published manuscripts/ paper reports	The survey was initiated to assess the impact on the sedimentary ecology of the area of the effluent from a pulp and paper mill discharging into the narrows between the two lochs. It was continued as a general study of organic enrichment of marine sediments and of fjordic benthic ecology
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Central Firth of Clyde, west coast of Scotland	Environmental monitoring survey of Garroch Head sewage sludge disposal grounds	1979 onwards	Published manuscripts/ paper reports	A monitoring survey to assess the comparative condition of the sediments and fauna in the area of the grounds where 1.5 x10^6 wet tonnes of sewage sludge are dumped annually

Organisation	Geographic area	Data type	Time period	Data format	Comments
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Loch Eil and control station by Greag Island, west of Dunstaffnage	West coast of Scotland Loch Eil nutrient data. Temperature, salinity, phosphate, nitrate, nitrite, ammonium, dissolved organic phosphorus, dissolved organic nitrogen, chlorophyll, phaeopigment, acid ratio.	November 1975 to March 1977	Electronic storage, paper record	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Cat Firth, Garth's Voe, Gluss Vos and Sullom Voe, around the Shetland Islands, north of Scotland	Nutrient data set from around the Shetland Islands: temperature, salinity, phosphate, nitrate, nitrite, ammonium, dissolved organic phosphorus, dissolved organic nitrogen, chlorophyll, phaeopigment, acid ratio	June 1977 to September 1978	Electronic storage, paper record	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Upper and middle basins of Loch Etive, Argyll	Loch Etive nutrient data: temperature, salinity, dissolved oxygen, phosphate, nitrate and nitrite, silicate, dissolved organic phosphorus, chlorophyll, phaeopigment, acid ratio	June 1980 to November 1982	Electronic storage, PhD thesis	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	West coast of Scotland, Firth of Lorn, from the head of Loch Eil to Colonsay	West coast of Scotland, Firth of Lorn nutrient data: temperature, salinity, nitrate and nitrite, silicate, chlorophyll, phaeopigment, acid ratio	February 1979 to February 1983	Paper record	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Flooded quarry on Easdale Island, off Seil, Argyll, west coast of Scotland	Easdale quarry, Easdale Island, Firth of Lorn, west coast of Scotland, nutrient data: nitrite, nitrate and nitrite, dissolved silicon	March to November 1984	Paper record, paper reports	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	West coast of Scotland Loch Etive, Loch Goil, Loch Fyne	West coast of Scotland Loch Etive, Loch Goil and Loch Fyne nutrient data: nitrate and nitrite, phosphate, silicate, ammonium	1989	Electronic storage	

Organisation	Geographic area	Data type	Time period	Data format	Comments
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	West coast of Scotland Loch Linnhe, Argyll	West coast of Scotland Loch Linnhe nutrient data: nitrate and nitrite, phosphate, silicate, ammonium	February to June 1990	Electronic storage	
Institute of Oceanographic Sciences (IOS) Deacon Laboratory/ James Rennell Centre for Ocean Circulation (JRC)	North Atlantic (UK to Cape Farewell, Greenland)	World Ocean Circulation Experiment (WOCE), CONVEX: temperature, salinity, transmittance, dissolved oxygen, nitrate, silicate, oxygen-16/oxygen-18 ratio, chlorofluorocarbons, plankton, meteorological measurements, current profiles, bathymetry	1991 onwards	Electronic storage	These data were collected to investigate the distribution of water masses and to derive full depth circulation
Institute of Oceanographic Sciences (IOS) Deacon Laboratory/ James Rennell Centre for Ocean Circulation (JRC)	North-east Atlantic (Iceland –Scotland –Faroes region)	NANSEN (North Atlantic Norwegian Sea Exchange); World Ocean Circulation Experiment (WOCE): temperature, salinity, transmittance, dissolved oxygen, current speed and direction, silicate, surface meteorology, wave parameters, fluorescence	1986 onwards	Electronic storage	
Institute of Oceanographic Sciences (IOS) Deacon Laboratory/ James Rennell Centre for Ocean Circulation (JRC)	Eastern North Atlantic	IOS Deacon Laboratory marine chemistry data: nutrients, chemical analysis of sediments, solid-phase geochemistry, pore water chemistry	1975 onwards	Electronic storage, paper reports	
Kyle and Carrick District Council	Barassie Shore in the north of Kyle and Carrick district to Finnarts Bay in the extreme south of Kyle and Carrick district	Common radioactive pollutants	1985 onwards	Electronic storage	All radiation data are compiled on a calendar year basis and information is available to the present date
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	UK	Radionuclide measurements (Radbase): concentrations of radionuclides and beta- and gamma-ray dose rates	1959 onwards	Paper records and electronic format	Mostly shelf waters around the UK, but also some oceanic data for the north-east Atlantic and some UK surface water data

Organisation	Geographic area	Data type	Time period	Data format	Comments
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	North Sea, English Channel and Irish Sea	Nutrients: total oxidised nitrogen, nitrite, silicate, phosphate, ammonia; temperature and salinity	1960 onwards	Electronic storage	Samples collected from 156 MAFF cruises, and measurements for 11,000 samples
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Eastern Irish Sea	Benthic survey: taxonomic description of macrobenthos, sediment	1983 –1988	Paper files, published literature	Spatial distribution of the macrobenthos in the muddy sediments of the eastern Irish Sea. Redistribution of sediment-bound artificial radionuclides originating from the Sellafield nuclear reprocessing plant
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Irish Sea, including Solway Firth, Esk and Ribble estuaries	Artificial radionuclides (plutonium, americium, curium, caesium and other neutron activation and fission products); sediment type	1968 onwards	Electronic storage, paper files, published literature	Distribution and behaviour of sediment-bound artificial radionuclides released from the nuclear reprocessing plant at Sellafield
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Irish Sea, English Channel, Malin Shelf, North Sea, Norwegian Sea, Barents Sea	Artificial radionuclides (caesium, plutonium, americium, technetium, antimony), Kd values, suspended load, salinity	1972 onwards	Electronic storage, paper files, published reports	As part of a collaborative EC MAST project. The distribution of artificial radionuclides released into the marine environment as a result of fuel reprocessing (Sellafield, La Hague, Dounreay)
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Irish Sea, southern North Sea	Naturally occurring radionuclides (uranium, thorium, polonium, leas, radium), K_d values, suspended load, salinity	1983 onwards	Electronic storage, paper files, published reports	
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Mainly western Irish Sea	Irish Sea *Nephrops* larvae survey: plankton, nutrients, temperature, salinity	April to June 1982 and April to June 1985	Paper record	For estimation of the spawning stock biomass of the western Irish Sea *Nephrops*
North East River Purification Board (NERPB), now part of the Scottish Environment Protection Agency (SEPA)	Grampian, east coast of Scotland	Bathing water bacteriological surveys. Faecal coliforms per 100 ml, total coliforms per 100 ml, temperature, wind speed and direction, presence of oils	1987 onwards	Electronic storage, paper record	

Organisation	Geographic area	Data type	Time period	Data format	Comments
North East River Purification Board (NERPB) now part of the Scottish Environment Protection Agency (SEPA)	Grampian, east coast of Scotland	TBT imposex data	February 1990 to February 1992	Paper reports	
Plymouth Marine Laboratory (PML)	Irish Sea	PML Irish Sea Project data set: phytoplankton, zooplankton, fish larvae, fish eggs, primary production, particle characterisation, salinity, temperature, chlorophyll	1987 –1991	Electronic storage	The aim was to study the productivity of both phytoplankton and zooplankton, in relation to the survival of fish larvae, and to investigate how differences in ecosystem structure might influence the availability of food and successful recruitment of fish
Plymouth Marine Laboratory (PML)	North Sea	North Sea nutrients: nutrients, primary productivity, nitrogen assimilation	May 1986 to February 1992	Electronic storage, paper record	Nine cruises following a track covering the whole of the North Sea
Plymouth Marine Laboratory (PML)	River Eden estuary, Fife	Nitrogen cycling parameters, bacterial numbers	1976 –1979	PhD thesis, published reports	Nitrogen cycling parameters and bacterial numbers were collected to study the rates of sediment nitrification and denitrification in nutrient lenses in the sediments
Plymouth Marine Laboratory (PML)	North Sea (Dover Straits to Shetland)	Undulating oceanographic recorder (UOR) data: CTD, chlorophyll, photosynthetically active radiation (PAR)	1986 –1991	Electronic storage	
Plymouth Marine Laboratory (PML)	NE Atlantic	Undulating oceanographic recorder (UOR) data: CTD, chlorophyll, transmittance	1987 –1991	Electronic storage	
Proudman Oceanographic Laboratory (POL)	Continental shelf and slope areas around the British Isles (e.g. North Sea, Irish Sea, Celtic Sea)	POL databank of CTD/STD profiles: conductivity/salinity, temperature, depth/pressure, occasionally oxygen, transmittance	1974 onwards	Electronic storage	

Organisation	Geographic area	Data type	Time period	Data format	Comments
SOAFD, Marine Laboratory, Aberdeen	North Sea	ICES Benthos Working Group North Sea Survey: benthic fauna, carbon, chlorophyll, heavy metals, proteins	1980 –1986	Electronic storage	
SOAFD, Marine Laboratory, Aberdeen	Scottish coastal waters	Metals in organisms, seawater, sediments and rainwater; trace metals, mercury	1989 onwards	Electronic storage	
SOAFD, Marine Laboratory, Aberd	Scottish coastal waters	Organochlorines	1989 onwards	Electronic storage	
SOAFD, Marine Laboratory, Aberdeen	Scottish coastal waters, central and northern North Sea, Rockall, north east Atlantic	Hydrographic data: pressure (depth), temperature, salinity, (sigma-t), oxygen, phosphate, nitrate, silicate, ammonia, chlorophyll a, phaeopigments, particulate organic carbon and particulate organic nitrogen	1893 onwards	Electronic storage, manuscript	From various internal projects, national and international programmes
Solway River Purification Board (SRPB)	Inner Solway Firth beaches	Intertidal invertebrate communities, particle size analysis (PSA), trace metals in sediments	1987 onwards	Paper reports	Twenty-four sampling stations on the intertidal zone of the Inner Solway Firth, between Dorknockbrow and Arbigland (54°53´ N, 03°11´ W to 54°54´ N, 03°34´ W)
Tay Estuary Research Centre (TERC), Universities of Dundee and St Andrews	Tay estuary, east coast of Scotland	Data from physical and chemical measurements: tide height, current speed and direction, water temperature and salinity, suspended sediment concentration	June 1972 (neap and spring tides)	Hard copy	A major programme designed so that simultaneous changes in various physical and chemical parameters could be measured throughout the entire length of the Tay estuary
Tay River Purification Board (TRPB), now part of the Scottish Environment Protection Agency (SEPA)	Tay estuary	Fauna and sediment chemistry	1991 –1992	Paper report	
Tay River Purification Board (TRPB), now part of the Scottish Environment Protection Agency (SEPA)	Inner Eden estuary, east coast of Scotland	Fauna and sediment organic content	1989 and 1992	Paper reports	

Organisation	Geographic area	Data type	Time period	Data format	Comments
Tay River Purification Board (TRPB), now part of the Scottish Environment Protection Agency (SEPA)	Estuaries of the rivers South Esk, Tay and Eden and some coastal waters	Standard pollution parameters, metals	1980 –1992	Paper reports	A study of the relationship between phytoplankton community composition and hydrography
University of Wales, Bangor, School of Ocean Sciences	Loch Creran, Argyll	Phytoplankton study: temperature, salinity, chlorophyll, nutrients, phytoplankton species composition	1971 –1982	Paper records, reports, theses and digital tapes	
University of Wales, Bangor, School of Ocean Sciences	Loch Striven, Argyll	Temperature, salinity, currents, optical measurements, nutrients, chlorophyll, zooplankton biomass, phytoplankton species composition	1980 –1994	Paper records, reports, theses and digital data	

Organisation	Geographic area	Data type	Time period	Data format	Comments
Physical					
Amoco (UK) Exploration	North Sea	Wind, wave and water level data from *Leman, Indefatigable, Lomond* and *North Everest* platforms	1972 onwards	Electronic storage, paper record	
BP Exploration Operating Company Ltd	North Sea	BP current meter data from the North Sea and English Channel: current speed and direction	1971 –1992	Electronic storage	
British Gas plc	North Channel, Irish Sea, North Sea, west of Shetland	Current speed and direction, water levels	July 1980 to December 1984	Electronic storage	
British Geological Survey (BGS)	UK continental shelf and adjacent slopes	UK Offshore Regional Mapping Programme: index data, geological descriptions, samples, results of analyses (non-digital)	1966 onwards	Electronic storage, paper records	Collection of approximately 35,000 offshore samples, using grab samplers and shallow coring devices (to a maximum depth of 6 m below the seabed)
British Geological Survey (BGS)	UK continental shelf and adjacent slopes	Marine geotechnical data: shear and compressive strengths	1975 onwards	Electronic storage	
British Geological Survey (BGS)	UK continental shelf and adjacent slopes	Grain size, weights of gravel, sand and mud fractions and carbonate content of the fractions; whole and half phi analysis of the sand fraction	1966 onwards	Electronic storage	
British Geological Survey (BGS)	UK and north-west European continental shelf	BIRPS (British Institutions Reflection Profiling Syndicate) deep seismic data	1981 –1992	Electronic storage, paper records	
British Geological Survey (BGS)	UK continental shelf and adjacent slopes	Marine geophysical and seismic records: index data, analogue ship-borne gravity and magnetic records, seismic records, side-scan records, echo-sounder records	1966 –1991	Paper records, samples	
British Geological Survey (BGS)	UK continental shelf and adjacent slopes	Composite borehole logs, results of analyses, interpretations, reports and core material.	1969 onwards	Electronic storage	UK Offshore Regional Mapping Programme and consortium-funded projects; NERC Land Ocean Interaction Study (LOIS)

Organisation	Geographic area	Data type	Time period	Data format	Comments
British Geological Survey (BGS)	UK land and continental shelf, and adjacent marine areas	Digital marine line gravity (unadjusted and adjusted), digital land/seabed point gravity, gridded gravity, digital aeromagnetics, digital ship magnetics, digital water depths	c. 1950 onwards	Electronic storage	From UK Offshore Regional Mapping Programme, UK Onshore Gravity and Aeromagnetics Mapping Programmes, Marine Gravity Compilations and Adjustments
British Oceanographic Data Centre (BODC)	North-east Atlantic and continental shelf seas around the British Isles	Various parameters	1970 onwards	Electronic storage	The UK ROSCOP data set comprises over 4,000 forms completed by the principal scientists of research cruises undertaken since 1970. The forms are completed by scientists using research vessels belonging to the Natural Environment Research Council (NERC), the Ministry of Agriculture, Fisheries and Food (MAFF), the Scottish Office Agriculture and Fisheries Department (SOAFD) and the smaller research vessels belonging to university departments and marine biological associations
British Oceanographic Data Centre (BODC)	Continental shelf areas around the British Isles	Total pressure (seawater plus atmospheric), relative pressure	1970 –1983	Electronic storage	Time-series measurements from offshore pressure gauges mounted on the sea floor Time-series measurements from offshore pressure gauges mounted on the sea floor
British Oceanographic Data Centre (BODC)	North Atlantic Ocean	Total pressure (seawater plus atmospheric), relative pressure	1970 –1983	Electronic storage	
British Oceanographic Data Centre (BODC)	North-east Atlantic and continental shelf areas around the British Isles	UK national databank of moored current meter data: current speed, current direction; also temperature, pressure and conductivity	1967 onwards	Electronic storage	
British Oceanographic Data Centre (BODC)	North-west European Shelf (North Sea, Irish Sea, English Channel)	Moored current meter data: tidal constituents	1970 –1988	Electronic storage	

Organisation	Geographic area	Data type	Time period	Data format	Comments
British Oceanographic Data Centre (BODC)	North Atlantic and UK continental shelf	UK National Databank of CTD/salinity, temperature, depth (STD) profiles: conductivity/salinity, temperature, depth/pressure, occasionally oxygen, transmittance	1975 onwards	Electronic storage	
British Oceanographic Data Centre (BODC)	Shelf seas around the UK, eastern North Atlantic	Temperature, salinity, nutrients, oxygen, pH, alkalinity, chlorophyll a	1893 onwards	Electronic storage	Data routinely collected by UK research and naval vessels since the beginning of the twentieth century. Compiled by the ICES Oceanographic Data Centre
British Oceanographic Data Centre (BODC)	North Sea	Joint North Sea Data Acquisition Project (JONSDAP) data: current speed and direction, temperature	March to June 1976	Electronic storage	
British Oceanographic Data Centre (BODC)	Scottish continental slope (51–63° N, 0–15° W)	Continental Slope Experiment (CONSLEX) data set: current speed, current direction, temperature, pressure	August 1982 to March 1983	Electronic storage	Collaborative exercise between the Institute of Oceanographic Sciences Deacon Laboratory, Proudman Oceanographic Laboratory, Dunstaffnage Marine Laboratory, Scottish Office Agriculture and Fisheries Department and the Ministry for Agriculture, Fisheries and Food designed to study water movements across the Scottish continental slope
British Oceanographic Data Centre (BODC)	Continental shelf areas around the British Isles	UK National Databank of wave data: ship-borne wave recorders, moored waverider buoys, pressure recorders	1955 onwards	Electronic storage	
British Oceanographic Data Centre (BODC)	Continental shelf areas around the British Isles	One-dimensional wave spectra collected by UK laboratories: wave energy spectra computed from sea surface displacement/heave	1976 onwards	Electronic storage	
British Oceanographic Data Centre (BODC)	Offshore sites on the UK continental shelf	UK Offshore Operators Association (UKOOA) meteorological/ocean data set: wind, wave, current and surface meteorological parameters	1973 –1988	Electronic storage	
British Oceanographic Data Centre (BODC)	North-east Atlantic (47–64° N, 40° W to 6° E)	Digital version of IOS bathymetric chart of the north-east Atlantic (1:2.4 million): bathymetric depth contours	Not specified	Electronic storage	

Organisation	Geographic area	Data type	Time period	Data format	Comments
British Oceanographic Data Centre (BODC)	45–65° N, 15° W to 15° E	*UK Digital Marine Atlas* (second edition): marine geology and geomorphology; marine and coastal parks, reserves and protected areas; marine and coastal conservation in Great Britain; seabirds; sea mammals; marine biology; currents, tides and surges; winds, waves and weather; seawater temperature, salinity and nutrients; chemical distributions; exploitation of the marine environment; fishing areas and fish spawning areas; data catalogues	Not specified	Electronic storage	
British Oceanographic Data Centre (BODC)	North Sea	North Sea wave model (NORSWAM) input data set: wind and atmospheric pressure	1966 –1976	Electronic storage	Undertaken in order to supplement the limited number of measured wave data that were available in the northern North Sea on which to base design and certification criteria for offshore structures
British Oceanographic Data Centre (BODC)	North Sea, Irish Sea, English Channel, north-east Atlantic to 15° W	MAFF sea surface temperature and salinity data set (ship routes to and from the UK). sea surface temperature, surface salinity	1963 –1990	Electronic storage	
British Oceanographic Data Centre (BODC)	Between approximately 60° N and 60° S	GEOS-3 satellite wave height and wind speed data	April 1975 to November 1978	Electronic storage	
British Oceanographic Data Centre (BODC)	North Atlantic	North Atlantic ocean weather ship (OWS) surface meteorological data: wind direction, wind speed, air temperature, wet bulb/dew point temperature, air pressure, cloud type, height and coverage, visibility, sea surface temperature, wave height, period and direction	1945 –1983	Electronic storage	

Organisation	Geographic area	Data type	Time period	Data format	Comments
British Oceanographic Data Centre (BODC)	North Atlantic	North Atlantic ocean weather ship (OWS) temperature and salinity hydrocast data	1910 –1990	Electronic storage	
British Oceanographic Data Centre (BODC)	North Sea	Climatological atlas of salinity and temperature for the North Sea	1968 –1985	Electronic storage	The data set was compiled by the Institut fuer Meereskunde, Hamburg, Germany
BT (Marine) Ltd	Girvan, Scotland, to Larne, Northern Ireland; Irish Sea	Burial assessment survey, Scotland to Northern Ireland no. 2 cable route: bathymetry, seabed sediments, tension and penetration of burial assessment tool, pitch, roll and ship's speed	1992	Paper charts	
Chevron Petroleum UK Ltd	West of Shetlands	Current meter data to the west of Shetlands	April to September 1985	Electronic storage	
Cromarty Firth Port Authority (CFPA)	Invergordon, Cromarty Firth (east coast of Scotland) tidal records	Tide gauge measurement of sea level	1981 onwards	Paper graphs (weekly records)	
Defence Research Agency (DRA)	Rockall Trough, eastern North Atlantic	Internal wave climate (temperature) from thermistor chain measurements	From 28 May to 9 June 1983	Electronic storage	The data have been screened for format and data errors and corrected to produce a 'clean' data set
Defence Research Agency (DRA)	Rockall Trough, Jan Mayan front, marginal ice zone, eastern North Atlantic, Greenland Sea, Norwegian Sea	Temperature, conductivity, surface meteorology, surface parameters	2 May to 6 June 1988	Electronic storage	All data have been screened for format and data errors and corrected to produce a 'clean' data set
Defence Research Agency (DRA)	Iceland–Faeroes frontal zone, Denmark Strait and Faeroe–Shetland gap, North Atlantic	Acoustic data for NATO Military Oceanography (MILOC) Group	9 July to 17 August 1987 and from 15 April to 24 May 1988	Electronic storage	All data have been screened for format and data errors and corrected to produce a 'clean' data set
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	North-east Atlantic	Satellite-tracked drogue drifts over Faeroe Bank and the Faeroe–Iceland ridge	1986 –1989	Electronic storage	

Organisation	Geographic area	Data type	Time period	Data format	Comments
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	North-east Atlantic, northern Rockall Channel, Faeroe Bank	Norwegian Sea deep-water overflow across the Wyville–Thomson ridge: current speed and direction, CTD profiles	September 1987 to October 1988	Electronic storage	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Scottish continental shelf, North Channel, Sea of the Hebrides, Minches	Radiocaesium (caesium-134 and caesium-137) surveys upon the continental shelf west of Scotland	1976 –1988	Manuscript	Water samples for radiocaesium analysis were collected in association with CTD sections upon the western Scottish shelf. The data have been used to obtain travel times within the coastal current system and budgets of ocean/shelf exchange
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Scottish continental shelf, North Channel, Sea of the Hebrides, Minches, Outer Firth of Clyde	CTD sections upon the continental shelf west of Scotland: water column temperature and salinity	1975 onwards	Electronic storage	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	North-east Atlantic, Rockall Channel, 57–58° N	Rockall channel CTD section time series: water column temperature and salinity	1975 onwards	Electronic storage	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science	North-east Atlantic, Rockall Channel, 56–58° N	Rockall Channel surface temperature and salinity time-series	1948 onwards	Manuscript	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Loch Etive: 55°30´ N, 5o10´ W	West of Scotland Loch Etive CTD data: temperature and salinity	1970 –1973	Printed tables	Loch Etive is a Scottish fjord. Fifteen CTD stations in Loch Etive were surveyed every two weeks in 1970 to 1973. The aim of the experiment was to describe the aperiodic changes in the water masses of the loch resulting from fluctuating freshwater flows into the fjord system
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Scottish west coast	Catalogue of Scottish sea lochs: bathymetry and hypsography.	To 1986	Electronic storage, paper report	

Organisation	Geographic area	Data type	Time period	Data format	Comments
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Loch Linnhe: 55 o50´ N, 5o15´ W	West of Scotland Loch Linnhe CTD data: temperature and salinity	1990 –1992	Electronic storage	The aim of the experiment was to describe the aperiodic changes in the water masses of the loch resulting from fluctuating freshwater flows into the fjord system
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Sleat Sound: 57o08´ N 5o45´ W	West of Scotland Sound of Sleat CTD data: temperature and salinity	1990 –1992	Electronic storage	The aim of the experiment was to describe the aperiodic changes in the water masses of the sound
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Tralee Bay, Ardmucknnish Bay, near Oban, Argyll, Scotland	Abundance and species diversity of fish and crustaceans on a Scottish (west coast) sandy beach: number of individuals per 100 m^2, lengths and weights of fish species, salinity, temperature, wind values, number of species at sample date, fish biomass per 100 m^2	April 1986 to December 1989	Electronic storage, paper reports	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Loch Linnhe and Loch Eil, west coast of Scotland	West coast of Scotland Loch Linnhe/Loch Eil benthic ecology surveys: long-term changes in the benthic ecology of Loch Linnhe and Loch Eil; macrobenthic invertebrate abundances, species numbers and biomass quantified at c.10-week intervals; sedimentary carbon, nitrogen, redox potentials, acidity, temperatures, salinities and oxygen levels	1963 –1980	Published manuscripts/ paper reports	The survey was initiated to assess the impact on the sedimentary ecology of the area of the effluent from a pulp and paper mill discharging into the narrows between the two lochs. It was continued as a general study of organic enrichment of marine sediments and of fjordic benthic ecology
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	UK shelf seas including sea lochs and Rockall Channel	Current meter data collected mainly in UK shelf seas: current speed and direction and (usually) temperature	1975 onwards	Electronic storage	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Hunterston power station and surrounding areas (Clyde Sea Area)	Hunterston power station, Clyde Sea area sea temperature time-series	1960 –1985	Electronic storage, paper record	Temperature data logged to be used in conjunction with biological samples taken to monitor effects of warm water effluent from the nuclear power station at Hunterston

Organisation	Geographic area	Data type	Time period	Data format	Comments
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Northeast Atlantic	DML north-east Atlantic drifters: drift velocities, sea surface temperature	May 1983 to February 1985	Electronic storage	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Loch Eil and control station by Greag Island, west of Dunstaffnage	West coast of Scotland Loch Eil nutrient data: temperature, salinity, phosphate, nitrate, nitrite, ammonium, dissolved organic phosphorus, dissolved organic nitrogen, chlorophyll, phaeopigment, acid ratio	November 1975 to March 1977	Electronic storage, paper record	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	Upper and middle basins of Loch Etive, Argyll	Loch Etive nutrient data: temperature, salinity, dissolved oxygen, phosphate, nitrate and nitrite, silicate, dissolved organic phosphorus, chlorophyll, phaeopigment, acid ratio	June 1980 to November 1982	Electronic storage, PhD thesis	
Dunstaffnage Marine Laboratory (DML)/Scottish Association for Marine Science (SAMS)	West coast of Scotland, Firth of Lorn, from the head of Loch Eil to Colonsay	West coast of Scotland, Firth of Lorn nutrient data: temperature, salinity, nitrate and nitrite, silicate, chlorophyll, phaeopigment, acid ratio	February 1979 to February 1983	Paper record	
Institute of Oceanographic Sciences (IOS) Deacon Laboratory/ James Rennell Centre for Ocean Circulation (JRC)	North Atlantic (UK to Cape Farewell, Greenland)	World Ocean Circulation Experiment (WOCE), CONVEX: temperature, salinity, transmittance, dissolved oxygen, nitrate, silicate, oxygen-16/oxygen-18 ratio, chlorofluoro-carbons, plankton, meteorological measurements, current profiles, bathymetry	1991 onwards	Electronic storage	These data were collected to investigate the distribution of water masses and to derive full depth circulation
Institute of Oceanographic Sciences (IOS) Deacon Laboratory/ James Rennell Centre for Ocean Circulation (JRC)	Eastern North Atlantic	CTD, SEASOAR and current meter data from the eastern North Atlantic Ocean: temperature, salinity, dissolved oxygen, transmittance, fluorescence, current speed and direction	1967 –1990 onwards	Electronic storage	Moored current meter data have been collected since 1967, mainly in the eastern North Atlantic, concentrating on the areas to the north and west of Scotland, the west of Ireland and the Madeira abyssal plain, often in water depths of over 4,000 m

Organisation	Geographic area	Data type	Time period	Data format	Comments
Institute of Oceanographic Sciences (IOS) Deacon Laboratory/ James Rennell Centre for Ocean Circulation (JRC)	North-east Atlantic (Iceland –Scotland –Faroes region)	NANSEN (North Atlantic Norwegian Sea Exchange); World Ocean Circulation Experiment (WOCE): temperature, salinity, transmittance, dissolved oxygen, current speed and direction, silicate, surface meteorology, wave parameters, fluorescence	1986 onwards	Electronic storage	
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	North-east Atlantic, North Sea, Irish Sea, English Channel, Denmark Strait and south-west Indian Ocean	Current meter data set: current speed, current direction, also temperature, pressure and conductivity	1968 onwards	Electronic storage	Data holdings are approximately 1,400 data series. Data records contain current speed and direction. In addition, temperature is often measured and pressure and conductivity are occasionally measured.
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Primarily North Sea and Irish Sea, some North Atlantic	Temperature, salinity	1980 onwards	Electronic storage	CTD dataset collected on several cruises each year
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	North Sea, Irish Sea, English Channel	Temperature and salinity: water bottle data set	1930 –1960	Electronic storage	Collected mainly in the North and Irish Seas. Includes almost 7,000 stations
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	North Sea, English Channel and Irish Sea	Nutrients: total oxidised nitrogen, nitrite, silicate, phosphate, ammonia; temperature and salinity	1960 onwards	Electronic storage	Samples collected from 156 MAFF cruises, and measurements for 11,000 samples
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Eastern Irish Sea	Benthic survey: taxonomic description of macrobenthos, sediment	1983 –1988	Paper files, published literature	Spatial distribution of the macrobenthos in the muddy sediments of the eastern Irish Sea. Redistribution of sediment-bound artificial radionuclides originating from the Sellafield nuclear reprocessing plant

Organisation	Geographic area	Data type	Time period	Data format	Comments
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Irish Sea, including Solway Firth, Esk and Ribble estuaries	Artificial radionuclides (plutonium, americium, curium, caesium and other neutron activation and fission products); sediment type	1968 onwards	Electronic storage, paper files, published literature	Distribution and behaviour of sediment-bound artificial radionuclides released from the nuclear reprocessing plant at Sellafield
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Irish Sea, English Channel, Malin Shelf, North Sea, Norwegian Sea, Barents Sea	Artificial radionuclides (caesium, plutonium, americium, technetium, antimony), Kd values, suspended load, salinity	1972 onwards	Electronic storage, paper files, published reports	As part of a collaborative EC MAST project. The distribution of artificial radionuclides released into the marine environment as a result of fuel reprocessing (Sellafield, La Hague, Dounreay)
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Irish Sea, southern North Sea	Naturally occurring radionuclides (uranium, thorium, polonium, leas, radium), Kd values, suspended load, salinity	1983 onwards	Electronic storage, paper files, published reports	
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	North Sea	MAFF DFR International Young Fish Survey (IYFS) data set: length and quantitative estimate of catch; surface and bottom temperature and salinity	1965 –1990	Electronic storage, paper files	Initially designed to determine the distribution and abundance of adult and larval herring plus juvenile gadoids and to monitor environmental parameters as part of an ICES-coordinated programme
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	North Sea	North Sea Groundfish Survey (NSGFS) data set: length and total weight for all finfish species, weight and numbers for benthic species; caesium-137 sampling from seawater and fish muscle tissue; ad hoc biological sampling	1977 –1991	Electronic storage	Surveys were primarily designed to determine the distribution and abundance of demersal fish species and to monitor environmental parameters
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Mainly western Irish Sea	Irish Sea Nephrops larvae survey: plankton, nutrients, temperature, salinity	April to June 1982 and April to June 1985	Paper record	For estimation of the spawning stock biomass of the western Irish Sea Nephrops
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Celtic Sea and English Channel	Gadoid survey: length and age/maturity; ad hoc biological and physical sampling.	1990 –1991	Electronic storage	Surveys to determine the distribution and abundance of groundfish, particularly cod

Organisation	Geographic area	Data type	Time period	Data format	Comments
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Irish Sea	Irish Sea gadoid survey: length —all fish species and selected crustacea; maturity/age - cod, whiting, plaice and sole; ad hoc biological (e.g. weight, stomach contents, benthos) and physical (e.g. surface temperature and salinity) sampling	1979 –1992	Electronic storage	Main objective was to determine the relative abundance of pre-recruit cod and whiting
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Western European Shelf between Shetland in the north to the southern part of the Bay of Biscay in the south	Western European shelf groundfish survey: fish distribution and abundance, size and age compositions, sea surface temperature, bottom temperature	1982 onwards	Electronic storage	Originally to investigate the distribution and abundance of juvenile mackerel, but extended to monitor the annual changes in distribution and abundance of length and age of all finfish species caught
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	Various areas of the North Sea	Plankton, temperature, salinity	1962 onwards	Electronic storage, paper record	
MAFF Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft	UK	Inshore waters demersal young fish survey: abundance and length distribution of small demersal fish, surface water salinity, temperature and substrate type	1970 –1975; 1979 onwards	Electronic storage, paper record	To provide abundance indices of group 0 and group 1 sole and plaice
Marine Advisory Service (Commercial Services), Meteorological Office	Various fixed points on the North Atlantic and North Sea	Climatological Marine Data Bank: wind speed, wind direction, wave height, wave period, wave direction, air temperature, sea surface temperature, visibility, sea level atmospheric pressure, cloud	1945 onwards	Electronic storage	Meteorological observations made at fixed points (e.g. light vessels, ocean weather ships, offshore platforms)

Organisation	Geographic area	Data type	Time period	Data format	Comments
Marine Conservation Branch of the Joint Nature Conservation Committee (JNCC)	UK	MNCR Database: conservation, marine conservation, marine survey, sites, habitats, species, communities, abundance, granulometry, physiography, references, bibliography, community classification, biotope classification, life forms, photographs, littoral, sublittoral, infralittoral, circalittoral, substratum, position, grid reference, county, region, salinity, exposure, geology, stratification, designation	1987 onwards	Electronic storage	Currently around 450 surveys, 1,900 sites and 20,000 habitats
Marine Conservation Branch of the Joint Nature Conservation Committee (JNCC)	Coastal areas of Great Britain, including Northern Ireland for estuaries	JNCC Integrated Coastal Database: vegetation communities, areas, human activities, site protection	1982 onwards	Electronic storage	A range of data sets are combined into a single module, including national inventories of sand dunes, saltmarshes, estuaries, cliffs, shingle sites; also a map-derived data set of the areas and lengths of 'coastal resources' by 10 km^2
Plymouth Marine Laboratory (PML)	Irish Sea	PML Irish Sea Project data set: phytoplankton, zooplankton, fish larvae, fish eggs, primary production, particle characterisation, salinity, temperature, chlorophyll	1987 –1991	Electronic storage	The aim was to study the productivity of both phytoplankton and zooplankton, in relation to the survival of fish larvae, and to investigate how differences in ecosystem structure might influence the availability of food and successful recruitment of fish
Plymouth Marine Laboratory (PML)	Bay of Biscay and Celtic Sea	Physical oceanography – slope currents and surface transport. temperature, salinity, currents	1980 onwards	Electronic storage	
Plymouth Marine Laboratory (PML)	North Sea (Dover Straits to Shetland)	Undulating oceanographic recorder (UOR) data: CTD, chlorophyll, photosynthetically active radiation (PAR)	1986 –1991	Electronic storage	
Plymouth Marine Laboratory (PML)	North-east Atlantic	Undulating oceanographic recorder (UOR) data: CTD, chlorophyll, transmittance	1987 –1991	Electronic storage	

Organisation	Geographic area	Data type	Time period	Data format	Comments
Proudman Oceanographic Laboratory (POL)	Continental shelf and slope areas around the British Isles (e.g. North Sea, Irish Sea, Celtic Sea, continental slope off north west Scotland)	POL moored current meter databank: current speed, current direction, also temperature and pressure	1968 onwards	Electronic storage	
Proudman Oceanographic Laboratory (POL)	Continental shelf and slope areas around the British Isles (e.g. North Sea, Irish Sea, Celtic Sea)	POL databank of CTD/STD profiles: conductivity/salinity, temperature, depth/pressure, occasionally oxygen, transmittance	1974 onwards	Electronic storage	
Proudman Oceanographic Laboratory (POL)	North West European shelf (48°N–63°N, 12°W–13° E)	The POL operational storm surge model data archive: model output of tidal elevation, horizontal components of residual currents	1982 onwards	Electronic storage	A storm surge forecast scheme, based on a model developed and maintained by POL for the Ministry of Agriculture, Fisheries and Food (MAFF). The present scheme makes use of meteorological data from the limited area model (LAM), which runs operationally at the UK Meteorological Office for weather forecasting
North East River Purification Board (NERPB), now part of the Scottish Environment Protection Agency (SEPA)	Grampian, east coast of Scotland	Bathing water bacteriological surveys: faecal coliforms per 100 ml, total coliforms per 100 ml, temperature, wind speed and direction, presence of oils	1987 onwards	Electronic storage, paper record	
SOAFD, Marine Laboratory, Aberdeen	Scottish coastal waters	Metals in organisms, seawater, sediments and rainwater; trace metals, mercury	1989 onwards	Electronic storage	
SOAFD, Marine Laboratory, Aberdeen	Scottish coastal waters, central and northern North Sea, Rockall, north-east Atlantic	Thermosalinigraph data: temperature, salinity, fluorescence and occasionally soundings logged with date, time, and position	1970 onwards	Electronic storage, paper record	From various internal projects, national and international programmes

Organisation	Geographic area	Data type	Time period	Data format	Comments
SOAFD, Marine Laboratory, Aberdeen	Scottish coastal waters, central and northern North Sea, Rockall, north-east Atlantic	CTD data: pressure, temperature, conductivity, salinity	1985 onwards	Electronic storage	From various internal projects, national and international programmes
SOAFD, Marine Laboratory, Aberdeen	Scottish coastal waters, central and northern North Sea, Rockall, north-east Atlantic	Moored self-recording instrument data. Current speed and direction, temperature, conductivity (salinity), pressure	1967 onwards	Electronic storage, manuscript	From various internal projects, national and international programmes
SOAFD, Marine Laboratory, Aberdeen	Scottish coastal waters, central and northern North Sea, Rockall, north-east Atlantic	Hydrographic data: pressure (depth), temperature, salinity, (sigma-t), oxygen, phosphate, nitrate, silicate, ammonia, chlorophyll *a*, phaeopigments, particulate organic carbon and particulate organic nitrogen	1893 onwards	Electronic storage, manuscript	From various internal projects, national and international programmes
Solway River Purification Board (SRPB)	Inner Solway Firth beaches	Intertidal invertebrate communities, particle size analysis (PSA), trace metals in sediments	1987 onwards	Paper reports	Twenty-four sampling stations on the inter-tidal zone of the Inner Solway Firth, between Dorknockbrow and Arbigland (54°53´ N, 03°11´ W to 54°54´´ N, 03°34´ W)
Solway River Purification Board (SRPB), now part of the Scottish Environment Protection Agency (SEPA)	Beach and seabed around the Galloway Creamery outfall, Loch Ryan, south-west Scotland	Invertebrate communities, particle size analysis (PSA)	1987 onwards	Paper reports	Annual survey of 24 sampling points (16 subtidal, eight intertidal) at the head end of Loch Ryan
Tay Estuary Research Centre (TERC), Universities of Dundee and St Andrews	Tay estuary, east coast of Scotland	Data from physical and chemical measurements: tide height, current speed and direction, water temperature and salinity, suspended sediment concentration	June 1972 (neap and spring tides)	Hard copy	A major programme designed so that simultaneous changes in various physical and chemical parameters could be measured throughout the entire length of the Tay estuary. Data were collected from over 50 measuring stations as part of undergraduate, doctoral and post-doctoral research programmes

Organisation	Geographic area	Data type	Time period	Data format	Comments
Tay Estuary Research Centre (TERC), Universities of Dundee and St Andrews	Tay Estuary, east coast of Scotland	Data from tidal cycle measuring stations in the Tay estuary, east coast of Scotland: tide height, current speed and direction, water temperature, salinity, suspended sediment concentration, Secchi disc depths	1972 –1982	Hard copy	A major programme designed so that simultaneous changes in various physical and chemical parameters could be measured throughout the entire length of the Tay estuary. Data were collected from over 50 measuring stations as part of undergraduate, doctoral and post-doctoral research programmes
Tay River Purification Board (TRPB), now part of the Scottish Environment Protection Agency (SEPA)	Dundee foreshore between road bridge and Broughty Castle	Fauna, loss-on-ignition and particle size analysis	1989 and 1991	Paper reports	
University of Wales, Bangor, School of Ocean Sciences	West of Scotland	CTD and moored current meter data collected during the Scottish Coastal Current experiment: temperature, salinity, current speed and direction	July 1983, February 1985, October 1987, December 1987, February 1988	Electronic storage	827 CTD profiles of temperature and salinity collected on five cruises and a series of 71 moored current meter data readings The data from the 1987 and 1988 cruises were collected as part of the Scottish Coastal Current programme and the Autumnal Circulation Experiment (ACE)
University of Wales, Bangor, School of Ocean Sciences	Loch Creran, Argyll	Phytoplankton study: temperature, salinity, chlorophyll, nutrients, phytoplankton species composition	1971 –1982	Paper records, reports, theses and digital tapes	A study of the relationship between phytoplankton community composition and hydrography

Part 7
Have your say!

Natural Heritage Trends: The Seas Around Scotland

What do you think of the report?

Strengths
What do you like about the report?

Weaknesses
Is there anything you dislike about the report?

Uses
How would you make use of the report?

Improvements
How could the report be improved?

What changes to the natural heritage are of most concern to you (from direct experience or other knowledge)?

In this report
What issues in this report concern you most?

Elsewhere
What are your top (say, five or more) natural heritage concerns?

Please add details about yourself if you wish

Make a copy of the form and return it by post to:

FREEPOST Natural Heritage Trends (no stamp required)

or email comments to

trends@snh.gov.uk

Visit our web site

www.snh.org.uk/trends

Index

Working with Scotland's people to care for our natural heritage

Scottish Natural Heritage
is a government body responsible to the Scottish Executive and Scottish Parliament.

Our mission statement is:
Working with Scotland's people to care for our natural heritage.

Our aim is:
Scotland's natural heritage is a local, national and global asset. We promote its care and improvement, responsible enjoyment, greater understanding and appreciation, and sustainable use now and for future generations.

Our operating principles are:
We work in partnership, by co-operation, negotiation and consensus, where possible, with all relevant interests in Scotland: public, private and voluntary organisations, and individuals.

We operate in a devolved manner, delegating decision-making to the local level within the organisation to encourage and assist SNH to be accessible, sensitive and responsive to local needs and circumstances.

We operate in an open and accountable manner in all our activities.

Further information
further copies of this report
are available from
Scottish Natural Heritage
Publications Section
Battleby
Redgorton
Perth PH1 3EW
t: 01738 444177
t: 01738 458613
e: pubs@snh.gov.uk
w: www.snh.org.uk/trends

ISBN 1 85397 4048

NPO.5K0804

PRICE £10

SCOTTISH NATURAL HERITAGE

ISBN 1-853974-04-8
9 781853 974045