Trends - The Sea

Front cover main photograph: Loch Lomond, looking northwards.
Scotland's first proposed National Park.

14 The marine environment

Scotland's marine natural heritage is as visually spectacular and varied as the Scottish terrestrial environment, but remains largely hidden from sight and comparatively little studied. Because of the cost and technical difficulties of working in the marine environment our knowledge of many of the species, habitats and communities, particularly those found below the low tide line, can still be considered to be at an early stage of development. Aspects of the marine environment for which trend data are available are summarised in Table 14.6.

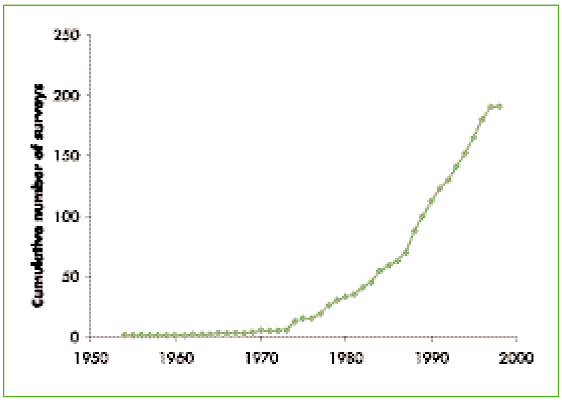
An estimate of the number of Scottish marine species was made by Davison (1996) and Davison & Baxter (1997), arriving at a total figure of over 40,000 if protozoa, bacteria and viruses were included, but of the order of 8,000 species of plant, invertebrate and fish (Box 14.1).

Marine survey around Scotland, as with 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 (Figures 14.1 & 14.2) and was further accelerated by the establishment of the Marine Nature Conservation Review (MNCR) in 1987. The increasing survey effort was sustained into the 1990s partly due to the additional information required for supporting initiatives under the EU Habitats Directive. Additionally, the late 1970s were also a time of increased oil and gas industry activity, with environmental monitoring and sampling, largely from sedimentary environments, accompanying all major exploratory and development projects (Figure 14.3)

The diversity of Scotland's coasts and seas is still less well recorded and understood than that of the terrestrial environment. Tolsa, Isle of Lewis.

Figure 14.1 Cumulative Scottish survey effort represented by entries into the MNCR Database

a) Surveys



b) Individual survey stations

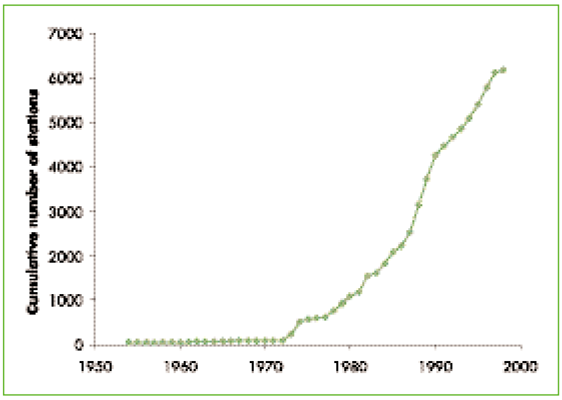
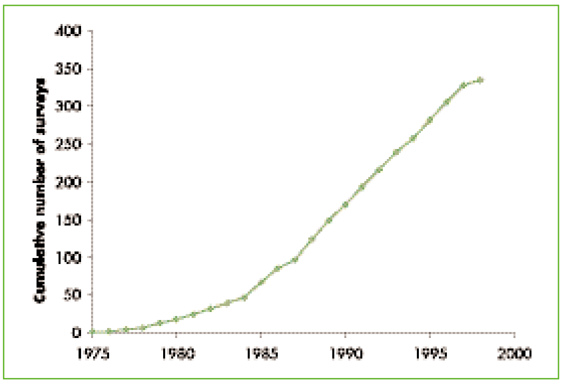


Figure 14.2 Location of Scottish survey stations held in the MNCR Database (1954-1998)

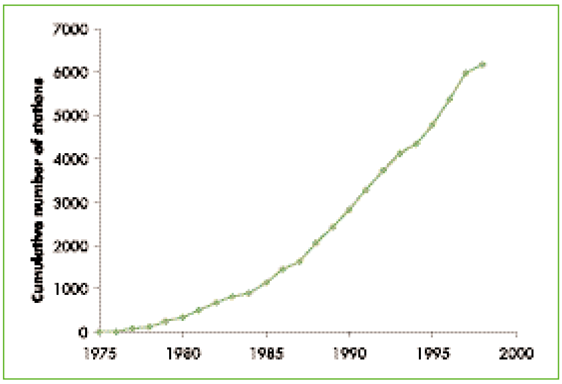
Source: MNCR Database

Figure 14.3 Oil and gas industry survey effort

a) Surveys



b) Individual survey stations



Source: UKbenthos Database

It is largely from these sources that the character, distribution and extent of many of the species and habitats identified as UK conservation priorities have been determined. Some of these habitats, although not unique to Scotland are particularly well-developed around the Scottish coast, such as the beds of maerl and horse mussel (Figure 14.4)

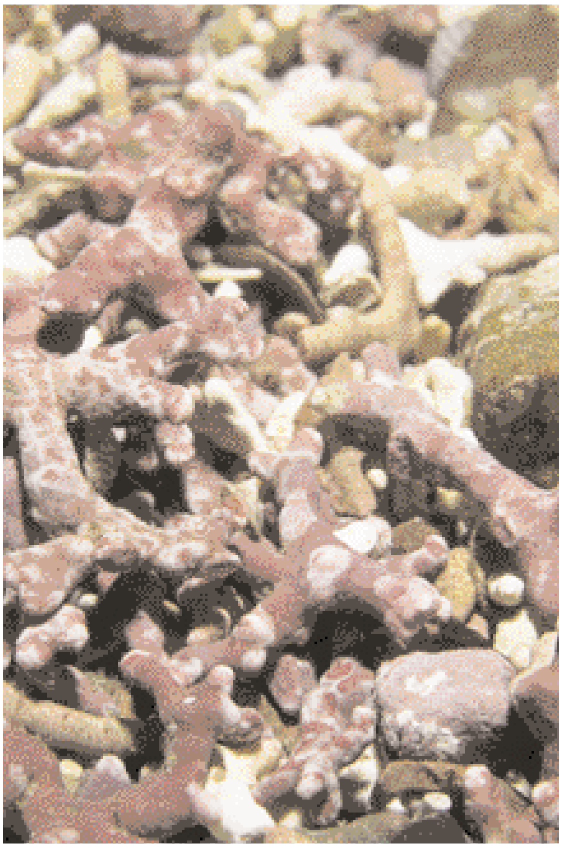
Scotland is also host to a range of larger marine animals such as the basking shark (Box 14.2), seals (Box 14.4) and cetaceans.

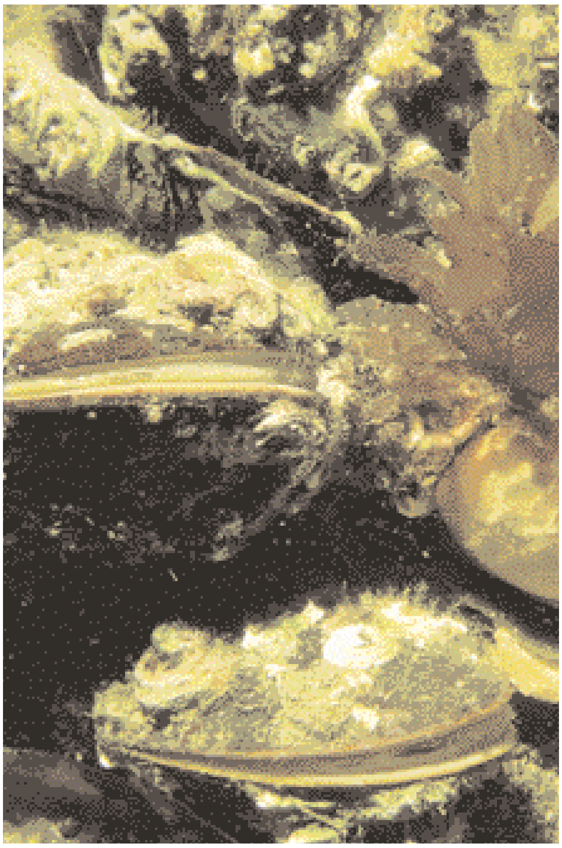
Figure 14.4 Distribution of Scottish maerl beds and horse mussel beds at a resolution of 10x10 km

a) Maerl beds

b) Horse mussel beds

Source: MNCR Database





Maerl is a collective term for several species of calcareous red seaweed of which at least two species, *Lithothamnion glaciale* and *Phymatolithon calcareum*, are known to form extensive beds in Scottish waters. Maerl beds may cover substantial areas of the seabed and constitute an important habitat for a wide variety of marine animals and plants. Scallop dredging constitutes the greatest threat to maerl beds in the Clyde.

The **horse mussel** can form beds on a variety of seabed types, but the denser aggregations are usually to be found on muddy sediments. The live mussels, together with shells, sediment and other debris, are bound together by secreted byssus threads, providing an important stabilising effect on the seabed. Horse mussel beds support an extremely rich associated fauna. The use of trawls and dredges causes widespread and long-lasting damage to these beds.

Cetaceans

Twenty-five species of cetacean have been recorded in British and Irish waters within the last 100 years and 23 within the last 20 years (Evans, 1992). Of these, 21 species have been sighted alive and reported more than once around Scotland. Accurate assessments of the distribution and population status of almost all cetacean species occurring in European waters are not currently available. However, an overview of all of the Scottish resident or migrant species, combining information from several sources, is given in Table 14.1.

The **harbour porpoise** is Britain's most abundant and widely distributed cetacean. It is particularly common around the Shetland Islands and the northern coast of Scotland. Marked declines in porpoise numbers were recorded in these areas during the 1980s.

A Scottish-based, Norwegian-owned commercial whaling operation was established in Loch Tarbert, Harris around 1903 and 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 14.2. A moratorium on commercial whaling was imposed in 1986, but 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 549 has been set for 2001.

Apart from direct exploitation, cetaceans are under threat from the following sources:

- **Fisheries** – The scale and nature of commercial fishing operations is such that entanglement in fishing gear and subsequent damage or drowning is a significant threat to cetaceans. Studies of incidental catches are few, but indicate that porpoises and dolphins are at greatest risk. 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). The total annual bycatch for the North Sea Danish gill net fishery in 1993 was estimated at approximately 7,000 harbour porpoises (Lowry & Teilmann, 1994; Vinther, 1995) out of a total population of around 300,000 (Hammond *et al*., 1995)
- **Pollution** – Anthropogenic inputs to the marine environment have greatly increased in the last 100 years. Organochlorines such as DDT, 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 animals 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 twenty years, but careless disposal, leakage from storage sites and a 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 & Parsons, 1999). Trace metal levels in resident Scottish cetacea have been determined to be well within the range observed for marine mammals world-wide.
- **Acoustic disturbance** – Noise from marine traffic, military activity, coastal industry and oil exploration and production is thought to cause varying levels of disruption to normal 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, designed to reduce the impacts of such activity, was recently introduced by the UK Government.
- **Overfishing of prey** –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).

Cetaceans have also been affected by ingestion of, or entanglement in marine debris and collision with marine vessels.

Species	Occurrence	Abundance estimate	Evidence for population increase/decline
Harbour porpoise	Common	Approx. 300,000 in North Sea (1994)	Decline (North Sea)
Bottlenose dolphin	Common	130 in the Moray Firth	Decline
Risso's dolphin	Uncommon	142 individuals identified in the Minch	Unknown
White-beaked dolphin	Common	Approx. 8,000 in North Sea & English Channel (1994)	Unknown
False killer whale	Rare	None	Unknown
Atlantic white-sided dolphin	Uncommon	None	Unknown
Common dolphin	Common	None	Unknown
Striped dolphin	Uncommon	None	Unknown
Northern bottlenose whale	Uncommon	None	Unknown
Cuvier's beaked whale	Uncommon	None	Unknown
Sowerby's beaked whale	Rare	None	Unknown
True's beaked whale	Rare	None	Unknown
Killer whale	Common	3,500-12,000 in eastern North Atlantic	Unknown
Long-finned pilot whale	Common	Estimated at over 700,000 in North Atlantic (late 1980s)	Unknown
Sperm whale	Uncommon	None	Unknown
Blue whale	Rare	None	Recovery (central-north Atlantic)
Fin whale	Uncommon	Over 14,000 (North Atlantic)	Unknown
Sei whale	Rare	None	Unknown
Minke whale	Common	Approx. 8,400 in North Sea (1994) 110,000 in eastern North Atlantic (1995)	Unknown
Humpback whale	Uncommon	10,000-15,000 in North Atlantic in 1992/93	Recovery
Northern right whale	Very rare	300 - extremely rare or possibly extinct in eastern North Atlantic	Decline

Sources: Evans *et al.*, (1986), Evans (1992), Hammond *et al.*, (1995), Shrimpton & Parsons (1999)

Table 14.1 (above) Status of cetacean species occurring in Scottish waters

Table 14.2 Scottish whaling catch records 1903-1951

Sources: Brown (1976), Evans (1992), Thompson (1928)

	Scottish catch records			
Species	Shetland (1903-1928)	Outer Hebrides (1903-1928)	Outer Hebrides (1950-51)	Population reduction by whaling
Northern bottlenose whale	25	1	0	Uncertain
Sperm whale	19	76	1	Reduced
Blue whale	85	310	6	Greatly reduced
Fin whale	4,536	1,492	46	Greatly reduced
Sei whale	1,839	375	3	Reduced
Minke whale[1]	-	-	-	Uncertain
Humpback whale	51	19	0	Greatly reduced
Northern right whale	6	94	0	Greatly reduced

[1]Not targeted by Scottish fishery but taken by Norwegian vessels around the Northern Isles

Marine Environment Quality

Some 6,900 km of coastline and 810 km^2 of estuarine catchment is examined annually for environmental quality by the Scottish Environment Protection Agency (SEPA). Assessment of each is by separate classification schemes applied to discrete stretches of coast or estuary and incorporates data on water quality, seabed invertebrate quality, status of fish populations and observations of aesthetic modifications. The current classification scheme is a revision of an earlier, less sensitive scheme and has been in use since 1995/96. Grading is on the basis of four classes; excellent, good, unsatisfactory and seriously polluted.

The overall quality of coastal waters was predominantly excellent or good between 1996 and 1999, with little more than 260 km, about 3%, of the coastline classified as unsatisfactory or seriously polluted at any time (Figure 14.5). In general, the areas rated as polluted were localised contaminated sites, either around long sea outfalls, inappropriately sited fish farms or sludge and spoil dumping sites. Some areas of the Solway coastline, notably Loch Ryan, had elevated levels of tributyltin, a chemical antifoulant monitored through its masculinisation effect on female dogwhelks. It is possible that this contamination originated from a breakers yard dismantling large naval vessels.

The majority of Scottish estuarine areas also maintained a favourable overall rating between 1996 and 1999. About 35 km^2 was classed as unsatisfactory or seriously polluted, but this declined to 32.5 km^2 in 1999 (Figure 14.6). The small, mostly localised areas classified as seriously polluted in1996 were further reduced by 40% in the same period.

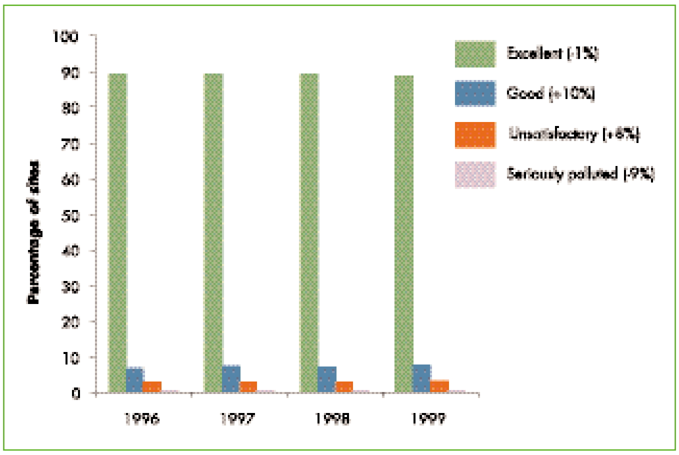


Figure 14.5 Coastal classification as a percentage of sites surveyed in 1996-99 (percentage change between 1996 and 1999 shown in brackets)
Source: SEPA

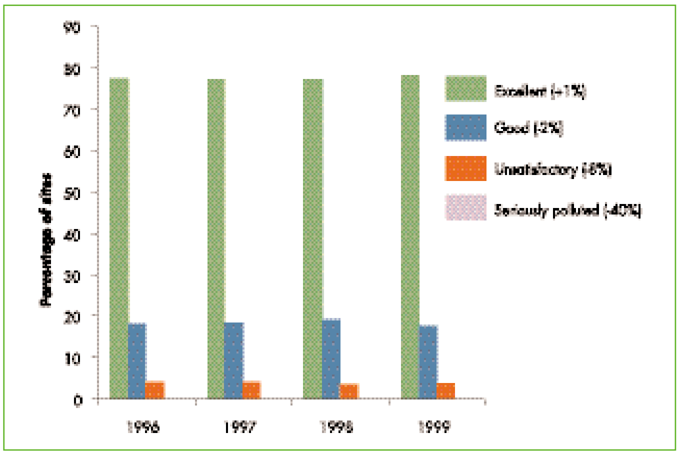
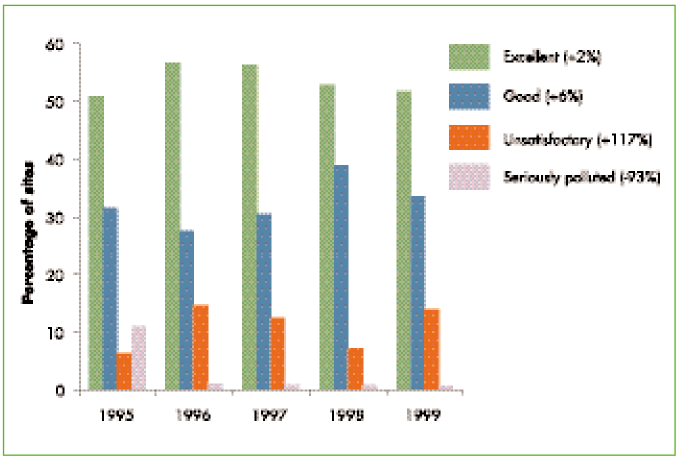


Figure 14.6 Estuarine classification as a percentage of sites surveyed in 1996-99 (percentage change between 1996 and 1999 shown in brackets)
Source: SEPA

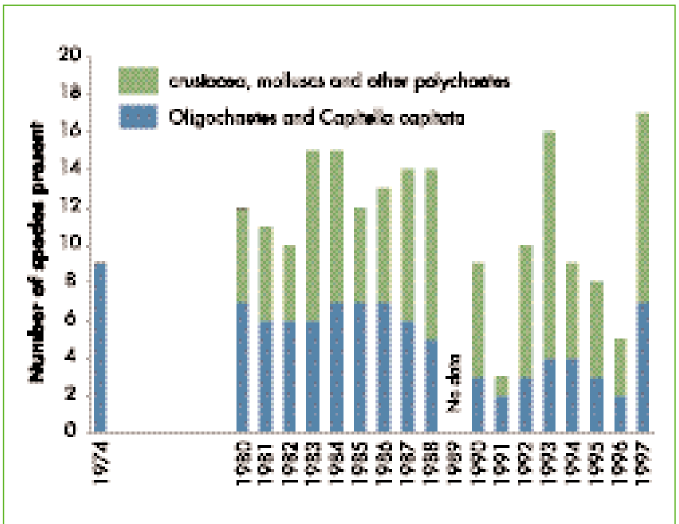
The Clyde Estuary receives domestic and industrial waste generated by half of Scotland's population. Since the 1970s discharge reductions and greater care in the treatment of waste has seen major improvements in the environmental quality of this and other estuaries.

Figure 14.7 Clyde estuarine classification as a percentage of sites surveyed in 1995-99 (percentage change between 1995 and 1999 shown in brackets)



Source: SEPA

Figure 14.8 The composition of benthic fauna at the Clyde/Cart confluence



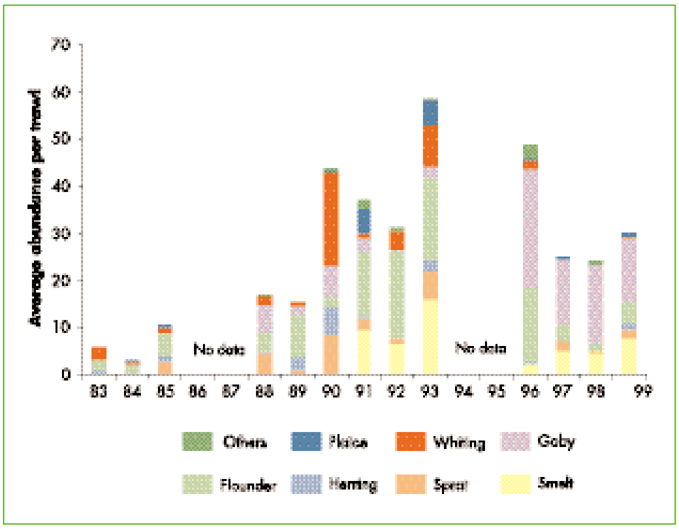
Source: SEPA

As the historical foci of Scotland's population and industry, the larger estuaries, such as the Forth and the Clyde have a long history of contamination. However, statutory controls on discharges have resulted in a steady improvement in water quality. In the Clyde, a major reduction in seriously polluted areas was achieved between 1995 and 1999 (Figure 14.7). In the 1970s the upper Clyde estuary sediments were dominated by a few pollution-tolerant species. In the 1980s, with improving water quality the faunal composition began to change in favour of a more diverse invertebrate community (Figure 14.8) and rising numbers of fish species (Figure 14.9). The establishment of resident populations of flounder was a further indication of improving water quality. Similarly, in the Forth, increasing dissolved oxygen and declining organic and metallic waste levels have been linked to returning fish populations, notably the smelt, a species known to be particularly sensitive to low oxygen levels (Figure 14.10).

Figure 14.9 Number of fish species recorded in the Clyde Estuary 1978-99

Source: SEPA

Figure 14.10 Fish species recorded in the Forth Estuary 1983-1999



Source: SEPA

Mariculture

The relatively clean waters and the widespread availability of wave-sheltered locations around the Scottish coast (notably the sea lochs of the west coast of Scotland, the Western Isles, and the Orkney and Shetland Isles) have proved highly suitable for mariculture.

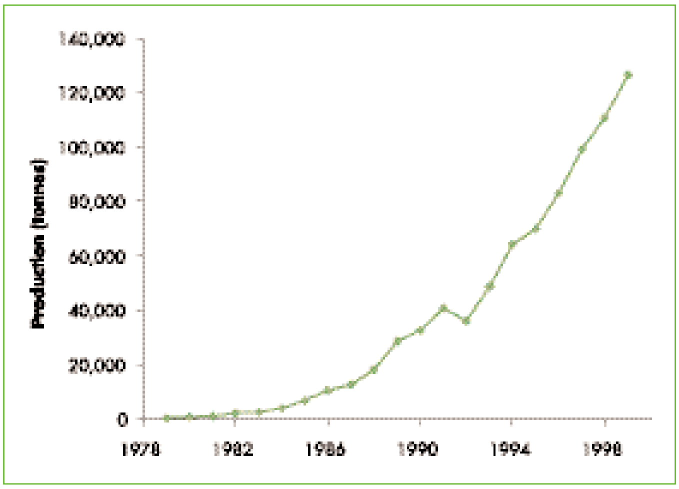
Mariculture, notably salmon farming, is a particularly important industry for Scottish coastal communities.

Commercial salmon farming began in Scotland in 1969 with the establishment of the first farms near Aberdeen and at Loch Ailort, Inverness-shire. At that time the availability of fresh salmon was limited and it was considered a high value species. In 1979 perhaps just over a thousand tonnes of wild salmon was available for market, but only 510 tonnes of farmed fish were produced (Anon., 2000a). Growth in production was slow until the mid-1980s, when financial incentives stimulated a major expansion of the industry (Figures 14.11a & b). In 1999 over 126,000 tonnes of farmed salmon was produced from 351 marine farm sites around Scotland.

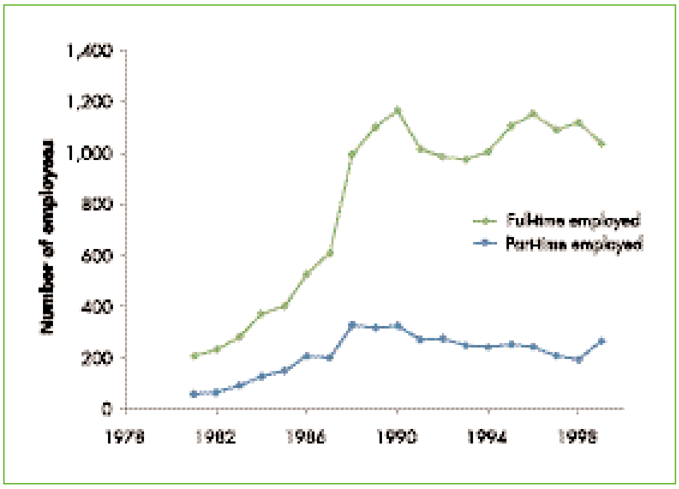
The number of salmon farm-related businesses peaked in 1989, but employment and the number of production sites have remained largely stable since then (Figure 14.11c). Advances in production methods and the use of modern technology in the design and manufacture of holding cages has led to greater yields and higher productivity (Figure 14.11d).

Figure 14.11 Trends in Scottish Fish Farming

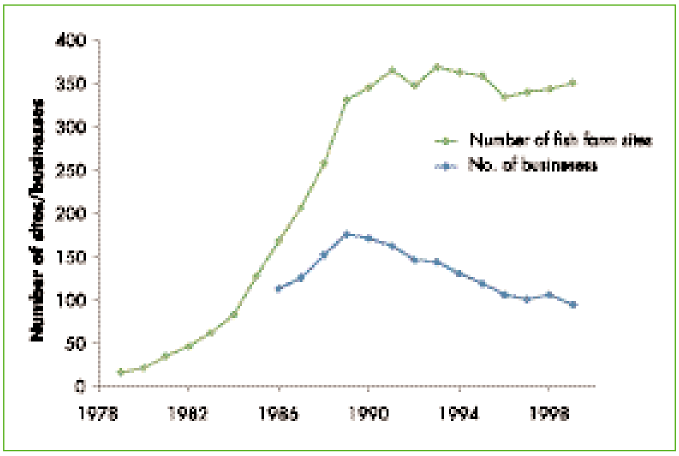
a) Total annual Scottish production of farmed salmon



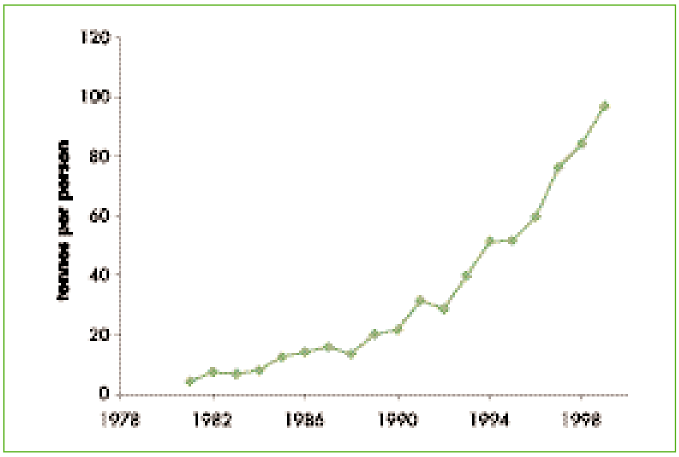
b) Number of people employed in the salmon farm industry



c) Number of fish farm production sites and businesses



d) Productivity



Source: Fisheries Research Services, Aberdeen

High stocking densities have increased susceptibility to disease outbreaks. Heavy losses of salmon occurred in 1990-91 due to sea lice and the bacterial disease furunculosis. A programme of slaughter and site fallowing was initiated following a 1998 outbreak of Infectious Salmon Anaemia (ISA) along the west coast of Scotland.

Experimental farming of other fish species, such as cod, turbot, sea trout and Arctic char is currently underway.

Shellfish farming has also undergone a rapid expansion since the 1980s. Five species; the scallop, the queen scallop, the mussel, the native oyster and the Pacific oyster were farmed at some 237 Scottish sites in 1999 (Figures 14.12a & b).

The transfer of disease and interactions with escaped fish are potential threats to wild salmon.

The seabed directly beneath salmon cages receives high levels of organic input from uneaten food and faecal material, often supplemented with pharmaceuticals and pesticides. In addition, copper, used as an antifoulant may also be introduced to nearby sediments. Evidence suggests that these areas of contamination and organic enrichment are localised and can be minimised if careful consideration is given to local factors such as the water depth below cages and current flow.

Shellfish farming is considered to be less environmentally damaging, but both activities may present an unfavourable visual impact. Careful siting to reduce effects on landscape attractiveness is considered an important factor in the planning of mariculture installations.

Climate and Sea Level Changes

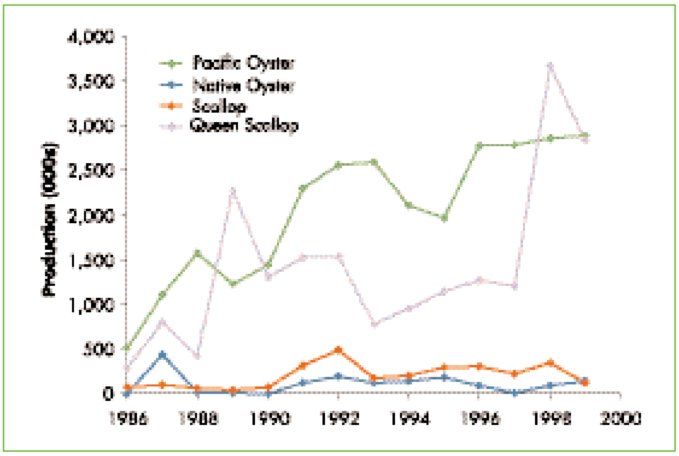
The issues of global warming and sea level rise continue to be the focus of much international debate. The interactions between weather, ocean currents and sea temperature are complex on both global and local scales. Although some Scottish records for wind speed, tidal height, sea and air temperature extend back over a hundred 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 Dawson *et al.*, (2001) and Fisheries Research Services (2000b).

Sea level change – All Scottish mainland tide gauges have recorded a sea level rise over the long term. The longest time-series from a gauge installed at Aberdeen indicates a rise 0.6 mm per year since 1862. In contrast, a tide gauge in Lerwick, Shetland has recorded a fall in sea level since 1957. This aside, the overall consensus is that relative sea levels are rising in all of the other areas where recording instruments are installed.

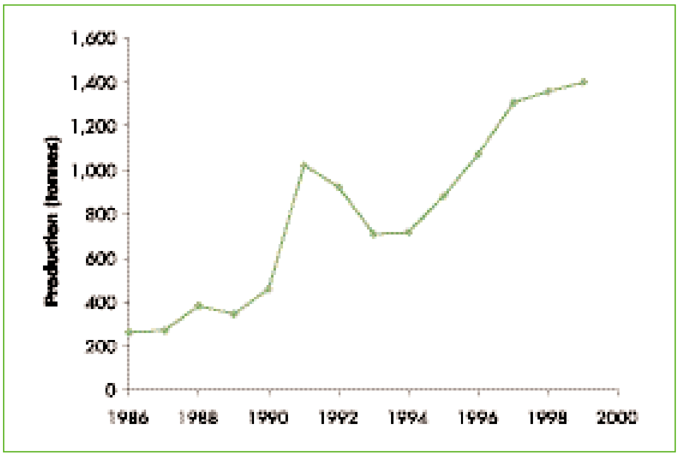
However, estimates of sea level change are modified by the simultaneous rise in the Scottish land mass which is still undergoing a rebounding process following the melting of the overlaying ice sheet some 10,000 years ago at the end of the last ice age. The rate of rebound is greatest in mainland areas where the ice layer was thickest, while 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. Estimates of current and future sea level change for Scotland, adjusted to take account of uplift movements, are shown in Figures 14.13 and 14.14.

Figure 14.12 Trends in Scottish shellfish production

a) Pacific oyster, native oyster, scallop, and queen scallop



b) Mussel



Source: Fisheries Research Services (2000a)

Increased storminess, higher sea temperatures and rises in relative sea level are predicted for Scottish coastal areas. Some marine species at their southern distribution limit may disappear, but an influx of southern species could increase overall diversity.

Storminess – There has been an increase in storminess in the NE Atlantic over the last 30 years, with an associated increase in wave height of 2.5-7.0 mm per year.

Sea temperature change – Fisheries Research Services (2000b) report 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, but argued that when placed in context with records from the past hundred years there is no clear trend.

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 would be restricted to a small number of northern species currently at their southern limit and that warming may increase diversity of Scottish seabed communities. A summary of proposed modified species distributions is shown in Table 14.3. Some communities that are particularly well-developed in Scotland could be affected over the longer term, such as those associated with maerl and horse mussel beds. Enclosed areas of seabed, such as sea lochs may experience greater seasonal impacts from deoxygenisation caused by increased thermal stratification.

Figure 14.13 Present rates of relative sea level change in Scotland

Source: Dawson *et al* (2001)

Figure 14.14 Best estimate of sea level rise for 2050 AD

Table 14.3 Species with currently restricted distributions in or near Scotland and predicted effects of sea temperature rise

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*	*Strongylocentortus 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*	

Source: Hiscock *et al* (2001)

Box 14.1 **The number of marine species occurring in Scottish waters**

Phyla	Common Name	Great Britain & Ireland	Scotland
Protista	Protozoa	25,000 – 30,000	25,000 – 30,000
Mesozoa	(Micoscopic parasites)	2 (10)	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 worms, sludge worms and 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**	**13,625 – 14,666 (15,573)**	**11,207 – 13,605 (13,634)**
	Including Protista	**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.

Sources: Davison (1996); Davison & Baxter (1997)

Box 14.2 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 around a few apparently favoured coasts where they are sometimes seen in relatively large numbers.

In Scottish coastal waters, basking sharks are seasonal visitors, and are observed mainly on the west coast in the summer months. Sightings peak around August with movements thought to be migratory and largely dictated by zooplankton abundance. However, long-distance tracking of individuals has never been carried out and 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 of moderately high levels of squaline in basking shark livers, 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 initiated a reporting scheme for public participation in 1987. These data (Figure 14.15) indicate a substantial UK and Scottish peak in sightings for 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 these data have been influenced by the timing and level of active promotion of the reporting scheme (Nicholson *et al.*, 2000). Increased media promotion occurred in 1988, 1989, 1990, 1991, 1995 and 1996.

The **basking shark** is the largest fish in UK waters. Its appearance in Scottish waters is seasonal and the numbers may be associated with zooplankton abundance. Basking shark fisheries have been characterised by large abundance fluctuations, often with stock reductions of at least 50% over very short time periods.

Exploitation of the basking shark has occurred over 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. In recent times there has been limited growth in its use in cosmetic and health supplement products, but 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.

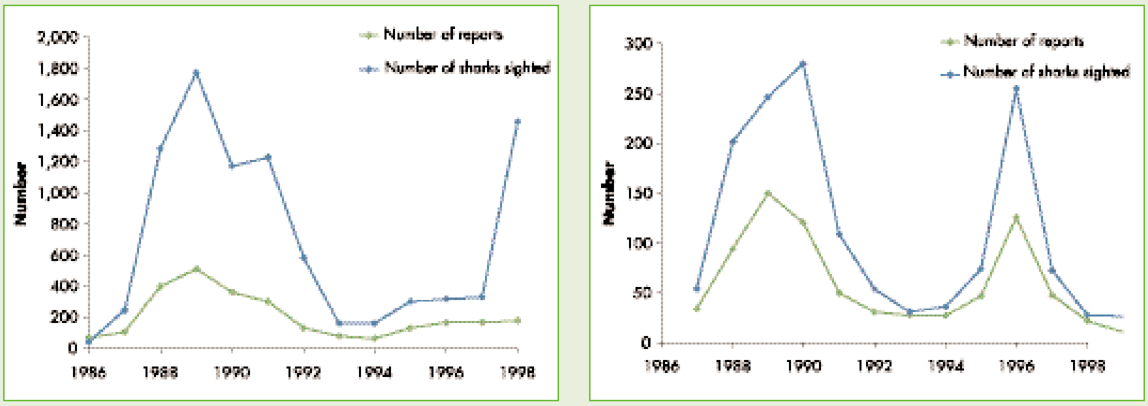
Throughout the North-east Atlantic, large numbers were caught between the mid-1940s and early 1980s (Figure 14.16), particularly by the Norwegian fleet. In the 1980s and 1990s catch levels were much reduced despite the high demand for shark fin. Several recent attempts to establish a Scottish fishery based in the Minch and Clyde areas failed due to marketing difficulties and widely fluctuating shark numbers (Kunzlik, 1988; Nicholson *et al.*, 2000) (Figure 14.16).

Although the influence of natural cyclical factors make assessments of population trends difficult, it is thought that their biology and location-faithfulness make basking sharks particularly vulnerable to overexploitation. Some directed fisheries have seen catch declines ranging between 50 to over 80%, often over periods of ten years or less (Table 14.4). There has been no subsequent population recovery, indicating that there is little or no migration of individuals from other areas.

Figure 14.15 Basking shark sightings reported to the Marine Conservation Society

a) Total UK sightings

b) Scottish sightings



Source: Marine Conservation Society

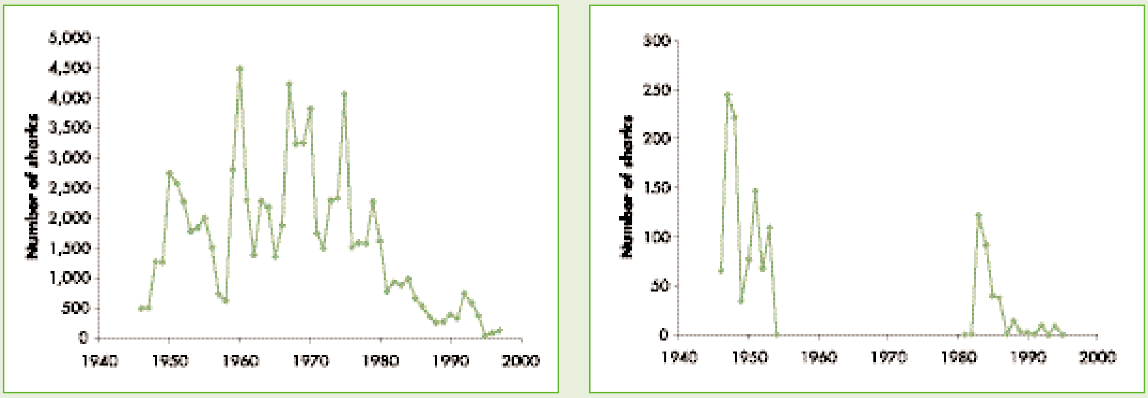
Globally, the status of the basking shark is assessed as vulnerable, but the Northeast Atlantic sub-population is currently considered to be endangered (2000 IUCN Red List of Threatened Species). Basking sharks have been protected within British territorial waters under the Wildlife and Countryside Act (1981) since 1998, and identified for conservation action through a Species Biodiversity Action Plan.

Key sources: Anon. (2000b); Fairfax (1998); ICES (1995).

Figure 14.16 Targeted basking shark landings

a) Northeast Atlantic

b) Scotland only



Source: ICES (1995), Anon (2000b)

Table 14.4 Trends in basking shark fisheries

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	1947-1950: 360 1951-1955: 1,475 1956-1960: 489 1961-1965: 107 1966-1970: 64 1971-1975: 50 1990s: rarely seen	>95% decline in 25 years
West coast of Scotland	1946-1953	121 throughout fishery 1946-1949: 142 1950-1953: 100	~30% in 7 years, but trend unclear
Firth of Clyde, Scotland	1982-1994	58.6 in first 5 years 4.8 in last 5 years.	>90% in 12 years
Norwegian catches	1946-1996	1946-1950: 837 1951-1955: 554 1956-1960: 1,541 1961-1965: 1,792 1966-1970: 3,213 1971-1975: 2,236 1976-1980: 1,706 1981-1985: 797 1986-1990: 343 1991-1995: 403	87% decline from peak landings in late 1960s to levels in the early 1990s
Northeast Atlantic (all catches combined)	1946-1996	1946-1950: 1,254 1951-1955: 2,094 1956-1960: 2,030 1961-1965: 1,899 1966-1970: 3,277 1971-1975: 2,385 1976-1980: 1,706 1981-1985: 848 1986-1990: 355 1991-1995: 407	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.

Source: Anon. (2000b)

Box 14.3 Cetacean strandings

Live strandings of cetaceans are thought to occur for a range of reasons, such as old age, poor health, injury, toxic chemical build-up and disorientation (Figure 14.17).

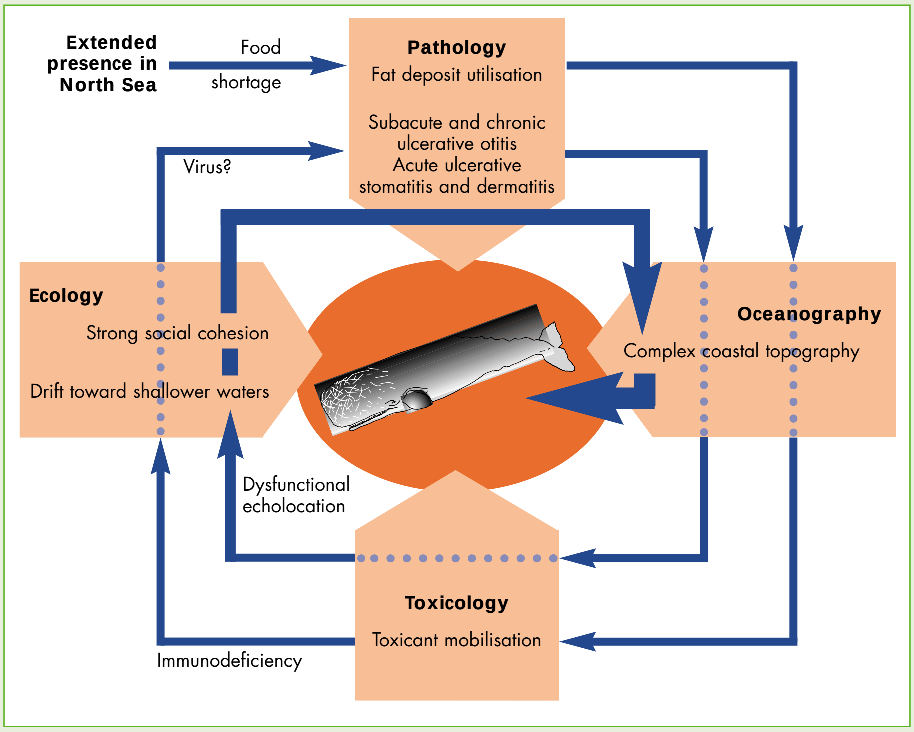
Between 1992 and 1995 Scottish strandings accounted for about 60% of the UK total. Of these, some 55% were associated with mass stranding events (Mayer, 1996). Records of strandings increased steadily around the UK and Ireland between the 1960s and 1980s and have continued to do so along continental North Sea coasts throughout the 1990s (OSPAR Commission, 2000).

Systematic records for Scottish standings have been compiled by the Scottish Agricultural College Veterinary Investigations Centre since 1992. Between 1992 and 2000 there was an average of 143 standings per year with relatively minor annual fluctuation (Figure 14.18). Harbour porpoise accounted for the greatest number of strandings each year and the annual proportion of the total for each species has been largely maintained throughout that period (Figure 14.19).

Key sources: Scottish Agricultural College Veterinary Investigations Centre; Mayer (1996); Weighell *et al.* (2000)

Cetacean strandings may occur for a variety of reasons. The number of strandings on Scottish shores has changed little since formal recording began in 1992.

Figure 14.17 Possible causes of sperm whale strandings in the North Sea



Source: OSPAR Commission (2000)

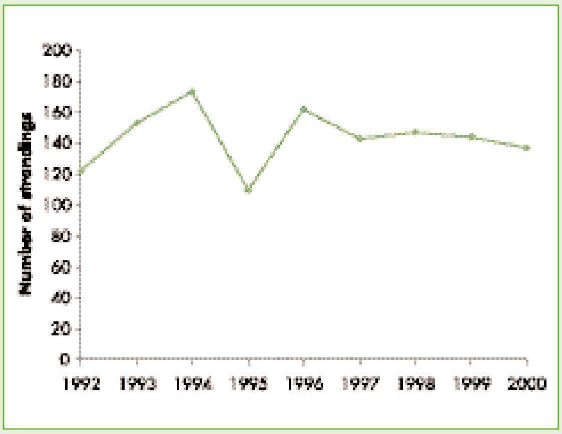


Figure 14.18 Total recorded Scottish cetacean strandings (1992-2000)

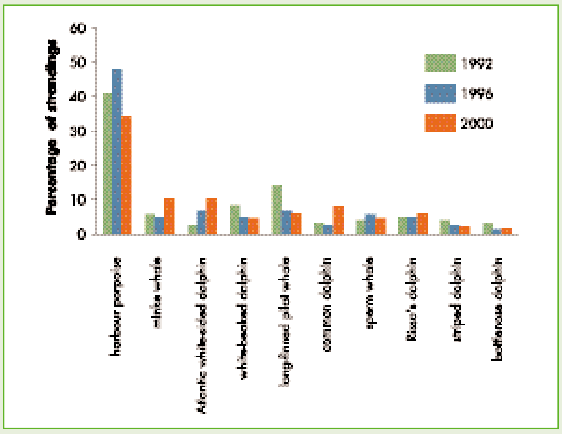


Figure 14.19 The ten species most commonly stranded on Scottish coasts represented as a percentage of all Scottish strandings for 1992, 1996 and 2000

Grey seal populations increased between 1984 and 1997 by an average of about 6% per year.

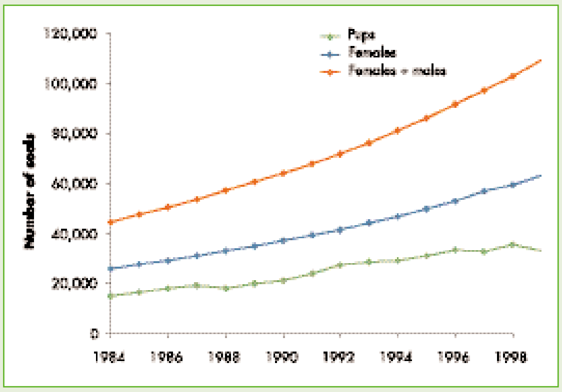


Figure 14.20 British grey seal populations at annually monitored sites

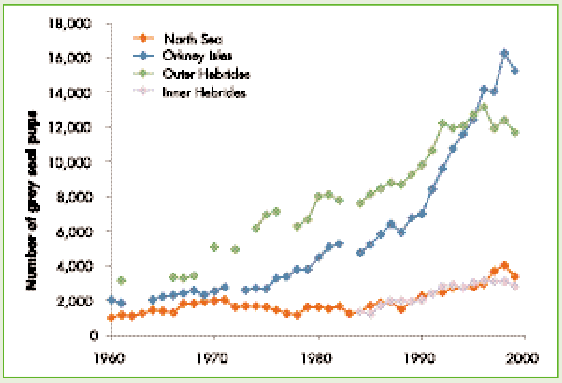


Figure 14.21 Grey seal pup production at main breeding sites

Key sources: Sea Mammal Research Unit; Sea Mammal Research Unit (2001).

Box 14.4 Seals

Two species, the grey seal and harbour or common seal, 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 over-exploitation 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 at some locations up to 90% of pups were taken annually. A ban on UK seal fur trading was established in 1973.

UK seal populations are monitored regularly by the Sea Mammal Research Unit (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 EU Habitats Directive, provides protection to seals when they come ashore to pup, breed and moult. Recent monitoring has largely been carried out by aerial survey and mainly at Scottish locations. Since seals spend a large proportion of their time in the open sea, counting is carried out at times of greatest shore-based activity; during the pupping season for grey seals and moulting for harbour seals. Total population estimates are derived from these data.

Table 14.5 Minimum harbour seal population estimates for selected SMRU-defined subregions

	Year of count							
Subregion	**1989**	**1991**	**1992**	**1993**	**1996**	**1997**	**2000**	**2001**
Shetland		4,797		6,227		5,991		4,900**
Orkney	7,137*			8,436		8,523		7,750**
Outer Hebrides			2,329		2,820		2,413	

*Visual helicopter count   **Provisional figures

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. In 1988, a viral epidemic swept through the North Sea harbour seal population. Phocine distemper virus was previously unknown but related to canine distemper virus, and was probably a natural event, since 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. Scottish populations were less affected, with mortality estimates for the Moray Firth population varying between 10-20% (Thompson & Miller, 1992). Throughout Europe and the UK, harbour seal numbers have rapidly returned to, or exceeded, pre-epidemic levels. In Scotland, 29,600 were recorded between 1996 and 1999. Periodic estimates for areas with the highest concentrations suggest that populations have largely remained stable (Table 14.5).

In 1999 the British grey seal population was estimated at 123,000 animals aged one year or older. About 40% of the world's grey seals breed at well-established sites around Britain. Of these, over 90% are associated with Scottish coasts. Overall, British grey seal populations increased steadily between 1984 and 1997 with an average rise of about 6% per year (Figure 14.20). 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 14.21).

Box 14.5 Breeding seabirds

Scotland's breeding seabird populations are internationally important, accounting for more than half of the world's great skuas and North Atlantic gannets, over one third of Europe's Manx shearwaters and at least 10% of the European breeding populations of ten other species[2] (Lloyd *et al*., 1991). Together, seabird numbers exceed four million birds, in hundreds of colonies around the coast.

There have been only two comprehensive seabird surveys in Britain; in 1969-70 and 1985-87. A third survey, 'Seabird 2000', is now underway, and is due to be completed in 2002. These are augmented by annual surveys within a sample of seabird colonies (Thompson *et al*., 1999).

Although the following figures describe changes in seabird abundance throughout Scotland, trends sometimes vary markedly between Scottish regions, for example between populations in the North Sea and Irish Sea/Atlantic Ocean.

Between 1969-70 and 1985-87, 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 (Figure 14.22). Note, however, that these figures apply to coastal populations only; two species, the black-headed and common gull, breed predominantly inland, where trends may have differed.

Several of those showing marked increases (great skua, Arctic tern and gannet) have especially large populations in Scotland.

The greatest proportional decline was that of the roseate tern, whose numbers in Scotland fell from 134 pairs in 1969-70 to nine in 1999.

Population increases have occurred despite occasional, local breeding failures in some species. These are usually attributed to a catastrophic decline in the food supply, in particular, the availability of sandeels. The breeding success of Arctic terns in Shetland fluctuated greatly during the 1980s-90s (Figure 14.23), with some 4,020 pairs fledging just 45 young in 1998 (Thompson *et al*., 1999).

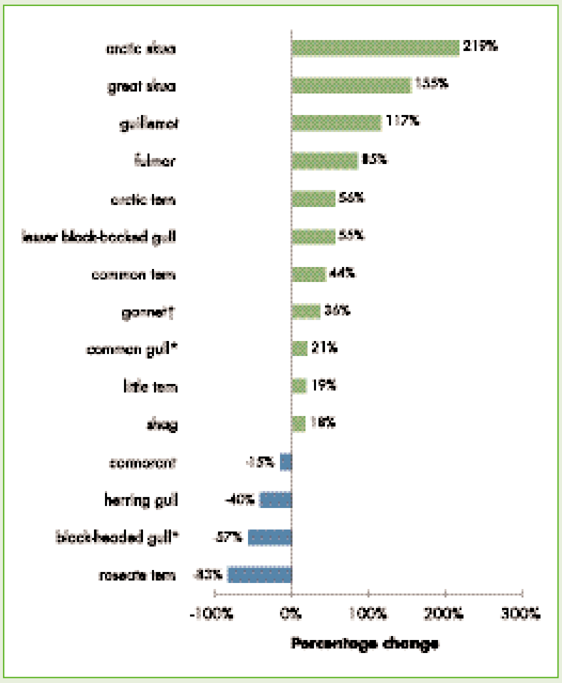
Most seabird species are relatively long-lived, however, and are therefore normally able to withstand occasional breeding failures.

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 increases in some species. Conversely, commercial fisheries, particularly for sandeels, can have a substantial, negative impact on food availability.
- ***Predation***. Rats, feral cats, ferrets and American mink can have a severe impact on breeding and, or adult survival.
- ***Drowning***. Nets, particularly monofilament drift nets, were considered the main cause of unnatural deaths among auks in the 1980s.

[2] Excluding the storm and Leach's petrel, for which adequate Scottish population estimates do not exist. Note, however, that 66-75% of the world's storm petrel population is thought to breed in Britain and Ireland, with sizeable colonies in Scotland.

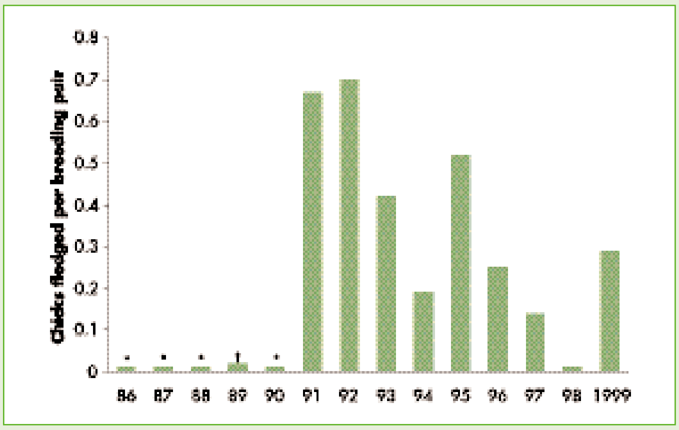
Figure 14.22 Seabird species showing changes of at least 10% in their Scottish breeding populations between 1969-70 and 1985-87.



† Percentage change between 1969-70 and 1984-85.
* Changes in coastal colonies only; the majority of the population of these species breeds inland.

Sources: Lloyd *et al*., (1991), Murray & Wanless (1997).

Figure 14.23 Variation in the mean number of Arctic tern chicks fledged per breeding pair, at a sample of colonies in Shetland.



* < 0.01, † < 0.02 chicks fledged per breeding pair

Source: Annual joint reports of JNCC, RSPB & Shetland Oil Terminal Environmental Advisory Group, on seabird numbers and breeding success in Britain and Ireland.

- ***Pollution***. Chronic oil pollution from illegal discharges have had a greater impact than occasional accidental spills. Pesticide residues and other toxic chemicals have been implicated in population crashes.
- ***Culling***. Egg collection, and the hunting for food, feathers and sport, has historically had a major impact on populations, but is now controlled through legislation.

Population trends are driven by a wide range of factors, and may differ markedly between colonies of the same species. Species trends for Scotland, from 1969-70 to 1985-87, were as follows.

Increases of greater than 50%

- Apparent increases in **Arctic skua** and **great skua** populations partly reflect a change in survey methodology, both species having been under-recorded in 1969-70.

The Scottish population of the **great skua** was reduced to two small colonies in Shetland in the 1890s, but now numbers about 7,900 breeding pairs; more than half of the world population.

- Increases in **Arctic tern** numbers partly reflect earlier census difficulties, and mask substantial local declines during the 1980s. In 1980 about 85% of the British and Irish population bred in Orkney and Shetland, where, by 1989, numbers 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.
- The **guillemot, fulmar** and **lesser black-backed gull** showed increases of greater than 50% between 1969-70 and 1985-87. East coast populations of guillemots continued to rise substantially during 1986-99 (Upton *et al.*, 2000).

Increases of 10-50%

- Apparent increases in **common tern** numbers partly reflect improved survey coverage during the 1980s.
- The **gannet** has shown a recovery from historical persecution. Between 1969-70 and 1984-85 its Scottish population increased by about 36%, and by a further 27% between 1984-85 and 1994-95 (Murray & Wanless, 1997).
- Although **common gull** numbers increased at coastal colonies, inland colonies, which hold the majority of the Scottish population, were not included in the two seabird surveys.
- **Shag** numbers increased by 10-50% during 1969-70 to 1985-87. However, in Shetland, which held about 20% of the Scottish population in 1985-87, numbers fell by more than 50% between 1986 and 1999. East coast populations also showed a dramatic drop in numbers following a winter 'wreck' in 1993/94.
- **Little tern** numbers increased by 19% between 1969-70 and 1985-87.

Changes of less than 10%

- Although the Scottish **kittiwake** population showed little change between 1969-70 and 1985-87, colonies in Shetland, which held about 14% of the Scottish population in 1985-87, showed a 50% decline during 1981-97. This was attributed to poor breeding success, due to low availability of sandeels, and to increased predation by great skuas (Heubeck *et al.*, 1999).
- **Great black-backed gull** and **Sandwich tern** numbers appeared to change by less than 10% between 1969-70 and 1995-97.

Declines of 10-50%

- The **cormorant** declined by 15% overall. Although the cause of this decline has not been established, disturbance and persecution are important factors in the control of its breeding numbers and output.
- **Herring gull** numbers on the Isle of May were substantially reduced by culling in the 1970-80s, but also declined around most of Scotland's coastline.

Declines of 50% or more

- **Black-headed gull** numbers declined by more than 50% at coastal colonies. However, like the common gull, the bulk of the black-headed gull population breeds inland, and was not covered by the two seabird surveys.
- The number of breeding **roseate terns** (a Biodiversity Action Plan priority species) fell by 83% between 1969-70 and 1985-87, and by 59% between 1987 and 1999. Its decline in Scotland has been attributed, in part, to emigration to Irish colonies, predation in its breeding colonies and to adult mortality associated with human persecution in its West African wintering grounds. However, its overall population in Britain and Ireland increased during the late 1990s.

In 1970 there were 134 breeding pairs of **roseate tern** in Scotland. This figure had dropped to nine breeding pairs by 1999.

Reliable national trend data for **Manx shearwater**, **storm petrel**, **Leach's petrel**, **razorbill**, **puffin** and **black guillemot** were not available. In the case of **razorbill** and **puffin** this was due to a change in the methods used during the two survey periods. Nonetheless, the figures suggest that there may have been an increase in the number of **razorbills**, and little change in the **puffin** population.

Key sources: this profile has been developed using Lloyd *et al.*, (1991), annual joint reports of JNCC, RSPB & Shetland Oil Terminal Environmental Advisory Group, on seabird numbers and breeding success in Britain and Ireland, and information provided by K.R. Thompson (JNCC), and M.A. Ogilvie.

Table 14.6 Summary of marine trends

Topic	Trends	Decreasing	Static	Increasing	Reliability of trend[3]
Marine exploration and survey	**1954-1998** The MNCR database of marine surveys began development in 1987. Data from a number of previous surveys have been entered. Between 1987 and 1998 the number of marine surveys around Scotland increased from 70 to 191 and the number of survey stations from 2,530 to 6,184.			⇧	**T**
	1975-1998 The oil and gas industry biological survey effort is held in the UKOOA database. Between 1975 and 1998 the number of surveys completed rose from four to 508 and the number of survey stations from 19 to 6,181.			⇧	**T**
Cetacea	**c.1986-2000** Of 21 species that have been recorded alive and more than once in the waters around Scotland the status of 16 is unknown. A decline has been reported for three species and a post-whaling recovery for two.	**3 Species** ⇩		2 Species ⇧	c
	1992-2000 Reported cetacean strandings increased from 122 to 137			**12%** ⇧	
Breeding seabirds	**1967-1987**: of 18 Scottish breeding seabird species for which trend data are available, 11 increased by more than 10% between 1969 and 1987, three varied by less than 10%, and four declined by more than 10% (from Lloyd *et al.*, 1991).	22% ⇩	17% ⇔	**61%** ⇧	**C**
Marine Environment Quality	**1996-1999** *Coastal environmental quality:* Overall quality has remained good or excellent with little more than 260 km, or 3% classified as unsatisfactory or seriously polluted in 1999. Overall quality improved slightly with the length classified as seriously polluted decreasing from 49.8 km to 45.3 km (-9%)			⇧	**C**
	1996-1999 *Estuarine environmental quality:* The majority of estuarine areas retained their favourable rating. Overall quality improved, with areas classified as unsatisfactory or worse declining from 35 km^2 to 32.5 km^2 in 1999. Seriously polluted areas declined by 40% during this period.			⇧	**C**
	1995-1999 *Clyde estuary environmental quality:* Overall quality improved with a major reduction in seriously polluted areas.			⇧	**C**
	1970s-1980s Changes in the quality of benthic and fish fauna in the Clyde: Improving water quality of the Clyde resulted in an increase in the diversity of invertebrate communities and increasing fish species, and a decrease in the once dominant pollution tolerant species.				
	Fish species increased from 25 in the late 1970s to 40 in the late 1990s.			**62.5%** ⇧	**C**

[1]Reliability of change or trend between the specified years: **T** = an increasing (or decreasing) trend established; **C** = change clearly established between first and last year, but no clear evidence for a trend; **c** = change probable but not fully-established; c = changed indicated but not well-established. A blank indicates that assessment of change was not appropriate. Statistical significance was tested where possible (at the 5% level).

Table 14.6 Summary of marine trends (continued)

Topic	Trends	Decreasing	Static	Increasing	Reliability of trend[3]
Mariculture	**1979-1999** Scottish production of farmed salmon increased from 1,789 tonnes to around 133,000 tonnes			⇧	T
	1979-1999 The total number of salmon farm sites increased from 17 to 351			⇧	T
	1986-1999 Production of farmed shellfish for the table increased, with 237 production sites reported in 1999. Mussel production increased from 262 tonnes in 1986 to 1400 tonnes in 1999			**43%** ⇧	T
Climate and sea level Change	**1862-1999** Tidal records from Aberdeen have recorded an overall sea level rise of 0.6 mm per year.			**0.6mm/yr** ⇧	C
	At 2001 the rate of relative sea level change for some southern mainland coasts is uncertain or unchanging but is estimated to be rising by 1mm per year for the Northern Isles and Outer Hebrides.		⇔ Greater central Scotland	⇧ North and eastern extremities	c
	1969-1999 There was an increase in storminess, indicated by an increase in wave height of 2.5-7.0 mm per year.			**2.5-7mm/yr** ⇧	T
	1980-1998 Average Summer sea temperature increased by 0.5°C every 10 years, while average winter temperatures increased by 1.0°C.			**0.5°C (Summer) 1.0°C (Winter)** ⇧	C
	Beyond 2001, 20 southern marine species may extend their range into Scottish coastal waters.			**20 species** ⇧	
	A further 72 southern species currently recorded in Scotland may extend their distribution or increase their abundance.			**72 species** ⇧	
	A decrease in abundance and extent, or complete disappearance has been predicted for 34 species.	**34 species** ⇩			
Basking Shark	**1946-1953** Scottish west coast fisheries recorded a reduction in catch of around 30%.	**30%** ⇩			C
	1982-1994 A Firth of Clyde fishery recorded a decline in catch of around 90% in 12 years.	**90%** ⇩			C
	1946-1996 The combined North Atlantic fishery recorded a decline in catch of around 90% in the period between the late 1960s and early 1980s.	**90%** ⇩			C
Seals	**1989-2000** Harbour or common seal populations remained stable at around 29,600.		⇔		
	1984-1997 Grey seal populations increased steadily at an average rise of 6% per year.			**6% per year** ⇧	T

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15 Scottish marine fisheries

The scale of marine capture fisheries, both geographically and quantitatively, represents one of the greatest human-induced modifications of maritime ecosystems. Globally, over 80 million tonnes (including shellfish) were estimated to have been 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.

In view of their ecological importance UK commercial fish species have been identified for conservation action through a Grouped Species Biodiversity Action Plan.

Over a thousand species of fish have been recorded in the NE 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, of an estimated 10 million tonnes of fish, approximately 2.5 million tonnes (excluding discarded fish) are landed annually (Box 15.1).

Marine fisheries have been extremely important to the economy and culture of Scotland.

Exploitation of marine species in Scottish waters has a long history, with a wide range of species being taken from intertidal, coastal and offshore habitats. The fishing industry continues to be of great importance to the economy and culture of Scotland. For example, in 1999:

- landings by Scottish-based vessels were valued at around £400 million or about 0.7% of Scotland's' GDP;
- Scottish vessels accounted for over 60% of the value of all landings by the UK fleet;
- 71% of all fish landings in the UK were made in Scotland;
- the Scottish fleet employed approximately 7,330 people working on a total of 2,585 vessels.

The number of people employed in the Scottish fishing industry declined by almost 13% between 1995 and 1999, largely due to an inability to sustain catch levels and attempts to limit catches of stocks that had become dangerously depleted.

The fishing industry comprises three main sectors:

Demersal - species that live mainly close to the seabed, such as cod, haddock, whiting and flatfishes. 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. Overexploitation 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 that may range over considerable depths, such as herring or mackerel, but are caught either close to the surface or in mid-water using seine nets or pelagic trawls. Catches of pelagic fish have increased steadily since the 1960s, partly due to the decline in demersal populations. Depleted herring stocks forced a six-year fishery closure in the latter part of the 1970s (Box 15.4), but overall pelagic species have continued to grow in importance. Landings of five of the nine most commercially important species increased by more than 10% between 1995 and 1999.

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. 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 five of the ten most commercially important species in Scotland increased by greater than 10% between 1995 and 1999.

Four main characteristics of exploited populations are currently examined on an annual basis (Box 15.2).

The effects of overfishing are compounded by the practice of discarding unmarketable fish. Fleets subject to EU regulations are obliged to discard undersized fish, but fish of commercially acceptable size may 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 do not survive.

In the North Sea demersal fishery the estimated average proportions of discarded cod and haddock 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 are discarded as bycatch.

Apart from effects on the target species, dredging or trawling is known to have a significant impact on seabed habitats and their associated biota. The functional design of most bottom trawls or dredges is such that both the seabed surface and the underlying sediment, perhaps to a depth of 25 cm, may be disrupted.

For over a century the North Sea has been one of the most intensively fished areas of the world. In general, trawling activities have been concentrated in a small proportion of the total area which are swept repeatedly over a short space of time. The long-term effects have recently been evaluated by combining data from a range of sources. The major conclusions were as follows:

- Parts of the North Sea have undergone a change in the species composition of the seabed community between the start of the 20th century and 1986, with an overall replacement of bivalve molluscs with scavenging crustaceans and seastars.
- There has been a fishing mortality-associated decline in large, long-lived species, but an overall increase in total benthic biomass resulting from an increase in abundance of opportunistic species.

Trends

None of the species commercially exploited within Scottish waters are currently considered to be in danger of global extinction, since 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 choose to spawn, develop and feed. Depletion of individual stocks has brought some to the point of collapse.

- Of the 12 species for which Scottish data are available, nine are currently considered to be outside safe biological limits (Table 15.1).
- In the ten-year period between 1989 and 1999 spawning stock biomass of some stocks of cod (Box 15.3), whiting and plaice declined substantially (Table 15.2).
- Landings of almost all species have declined (Table 15.2), either because of imposed catch restrictions or 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 (Box 15.5).

Trends in Scottish marine fisheries are summarised in Table 15.4.

Key sources: Food and Agriculture Organization of the United Nations; Frid *et al.* (2000); ICES (2000); OSPAR Commission (2000a); Rumohr & Kujawski (2000); FRS Marine Laboratory, Aberdeen; Scottish Executive (2000).

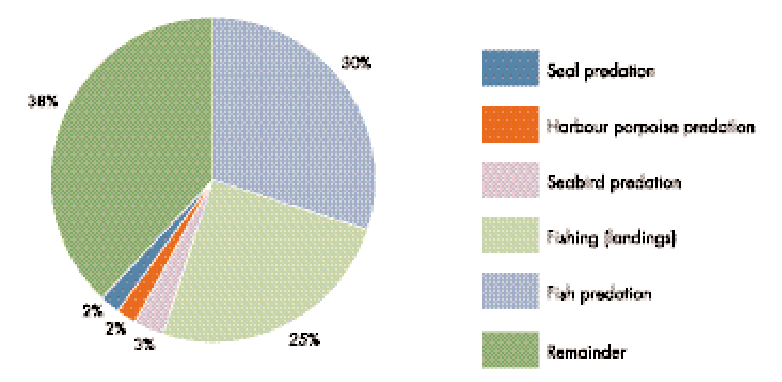
Box 15.1 The fate of fish in the North Sea

The removal of commercially exploited fish species from the North Sea has been variously reported as between 25 and 30% by weight. When compared against available estimates for removal by natural predation, fishing activities constitute a significant extraction of North Sea fish resources (Figure 15.1).

Estimates are based on:

- A total estimate of 10,000,000 tonnes of commercially exploited and non-target fish in the North Sea (Fifth International Conference on the Protection of the North Sea, 1997)
- Annual consumption by predatory fish of 3,000,000 tonnes per year (Anon., 1991)
- North Sea fish landings of 2,500,000 tonnes (excluding discards) per year (Fifth International Conference on the Protection of the North Sea, 1997)
- Annual seabird consumption of 250,000 tonnes per year (Camphuysen & Garthe, 2000)
- Approximately 300,000 harbour porpoises (Hammond *et al.*, 1995) consuming 2 kg of fish per day (Hislop, 1992)
- Approximately 36,000 harbour and 61,000 grey seals within the North Sea area (OSPAR Commission, 2000b) consuming 6 kg of fish per day (SMRU, pers. comm.).
- Remainder comprised of removal by other predators, natural mortality, fishery discards and survivors

Figure 15.1 Annual fate of fish in the North Sea



Box 15.2 Characteristics used to determine the state of commercially exploited fish stocks.

Landings	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	A measure of the total amount 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.

Source: FRS Marine Laboratory, Aberdeen

Table 15.1 The state of fisheries of greatest commercial importance

Species	Stock Assessment	Stock Health
Herring (P)	● Spawning stock level below the proposed precautionary stock biomass level (data available for North Sea only) ● Fishing mortality is close to or below the proposed precautionary level ● Recent recruitment has been above average	North Sea stocks are considered to be outside safe biological limits. The status of the west of Scotland stocks is uncertain.
Cod (D)	● 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 for the North Sea stocks ● Recent recruitment below average	Currently considered to be outside safe biological limits.
Haddock (D)	● Spawning stock level are below the proposed precautionary stock biomass level in the North Sea, but above for west of Scotland stocks ● Fishing mortality is above the proposed precautionary level ● Recent recruitment near to, or below average	Currently considered to be outside safe biological limits.
Whiting (D)	● 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 for the North Sea stocks ● Large fluctuations in recruitment, but a consistent decline has been observed for a number of years	Currently considered to be outside safe biological limits.
Saithe (D)	● Spawning stock level below the proposed precautionary stock biomass level ● Fishing mortality is above the proposed precautionary level ● Recruitment considered to be stable	Currently considered to be outside safe biological limits.
Norway pout (D)	● Spawning stock level currently low but expected to increase ● Fishing mortality considered to be low ● Large fluctuations in recruitment with no real trend	North Sea stocks are considered to be within safe biological limits. The status of the west of Scotland stocks is uncertain.
Sandeel (P)	● For the past 20 years spawning stock biomass, fishing mortality and recruitment has fluctuated without trend	North Sea stocks are considered to be within safe biological limits. The status of the west of Scotland stocks is unknown.
Monkfish (D)	● Current spawning stock levels uncertain ● Fishing mortality is above the proposed precautionary level ● No data available on recruitment	Currently considered to be outside safe biological limits.
Mackerel (P)	● Spawning stock level well above the proposed precautionary stock biomass level ● Fishing mortality is above the proposed precautionary level ● Recent recruitment has been above average	Currently considered to be outside safe biological limits.
Plaice (D)	● Spawning stock level below the proposed precautionary stock biomass level (data available for North Sea only) ● Fishing mortality is above the proposed precautionary level ● Recent recruitment at or above average	Currently considered to be outside safe biological limits.
Sole (D)	● Spawning stock level above the proposed precautionary stock biomass level ● Fishing mortality is above the proposed precautionary level ● Recent recruitment at or above average	Currently considered to be outside safe biological limits.
Norway Lobster	● Catch rates suggest current levels of fishing are acceptable ● Recruitment largely stable	Status of stocks variable, although most stocks are considered to be fully exploited.

Bracketed letters: (D) demersal species, (P) pelagic species

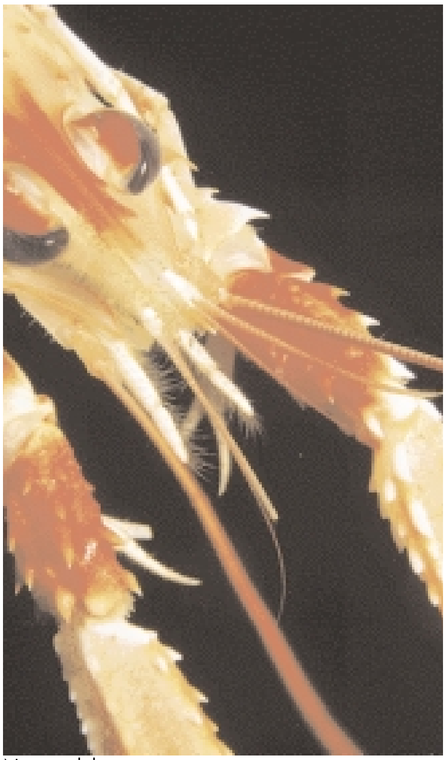
Source: ICES, 2000

Table 15.2 Characteristics of important commercially exploited fish stocks: ten-year trend (1989-1999)

Species	Area of Assessment	Landings	Fishing Mortality	Spawning Stock Biomass
Herring	North Sea	53% ⇩	37% ⇩	27% ⇩
Cod	North Sea	31% ⇩	4% ⇩	27% ⇩
Cod	West of Scotland	76% ⇩	11% ⇩	76% ⇩
Haddock	North Sea	3% ⇧	8% ⇩	3% ⇩
Haddock	West of Scotland	22% ⇩	22% ⇩	18% ⇩
Whiting	North Sea	52% ⇩	36% ⇩	46% ⇩
Whiting	West of Scotland	36% ⇩	5% ⇩	1% ⇩
Saithe	North Sea & west of Scotland	3% ⇩	34% ⇩	76% ⇧
Norway pout	North Sea	46% ⇩	22% ⇩	74% ⇧
Sandeel	North Sea	31% ⇩	28% ⇩	109% ⇧
Mackerel	North Sea	4% ⇧	2% ⇧	40% ⇧
Plaice	North Sea	52% ⇩	13% ⇩	47% ⇩
Sole	North Sea	19% ⇧	7% ⇧	48% ⇧

Source: ICES (2000)

Sandeels

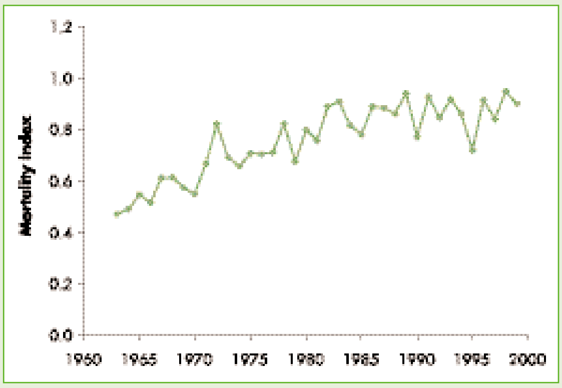


Norway lobster

Box 15.3 Cod stocks

Figure 15.2
Changes in cod fishing mortality

a) North Sea (ages 2-8)



b) West of Scotland (ages 2-5)

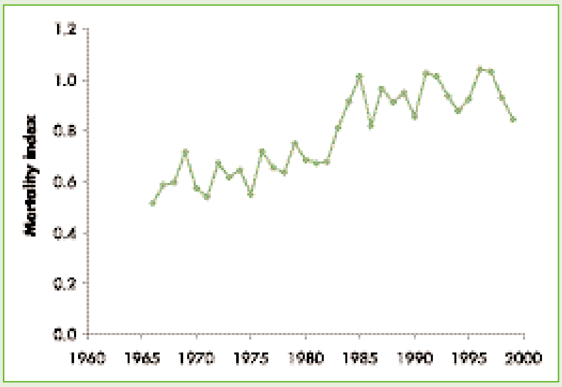
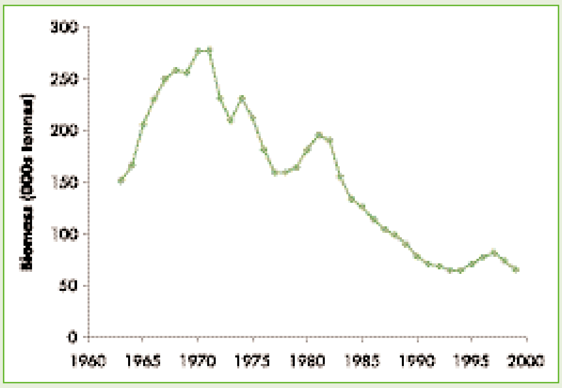
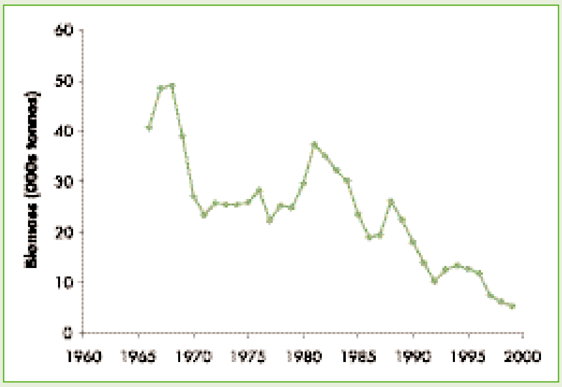


Figure 15.3
Changes in cod spawning stock biomass

a) North Sea



b) West of Scotland



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 15.2) with a notable increase for the west of Scotland stocks in the first half of the 1980s.

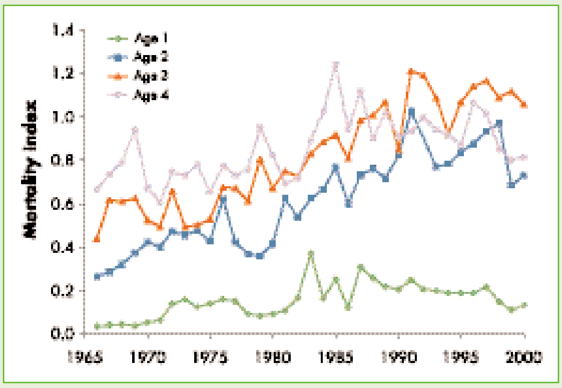
Spawning stock biomass of North Sea stocks had been declining since the early 1970s, and was followed by west of Scotland populations in the 1980s (Figure 15.3). Some stocks fell below estimated precautionary levels in 1984 and continued to decline thereafter. Recruitment, although variable, was consistently 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.

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 15.4).

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 over-exploitation.

Key sources: ICES (2000); FRS Marine Laboratory, Aberdeen.

Figure 15.4 Trends in fishing mortality of different age groups of the west of Scotland cod stock



Box 15.4 Herring stocks

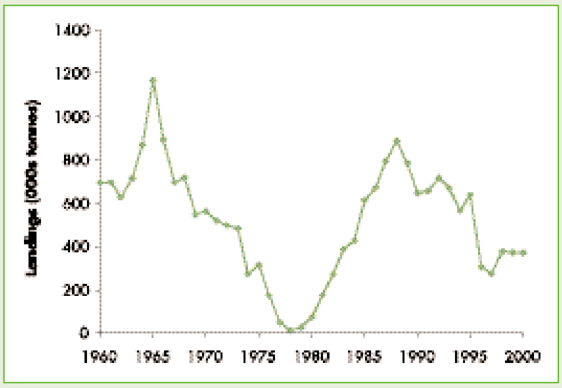
The Scottish herring fishery has a very long history, with records of significant trading extending back to at least the 12th Century. Today, herring continues to be an important catch for Scottish fishermen with a combined annual value of around £22 million for west of Scotland and North Sea landings. By weight, herring is the second most abundant species, after mackerel, landed by the pelagic fleet, with the major fishing effort concentrated around Shetland and to the north and west of Scotland. They are caught either by purse seine or pelagic trawl.

North Sea stocks declined drastically between the early 1960s and 1976 (Figure 15.5), 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 was initiated in 1977 to allow stocks to recover. This continued until 1983, by which time a recovery appeared to be in progress. By 1996, however, exploitation levels in the North Sea had increased to a level where measures had to be reintroduced to reduce fishing mortality.

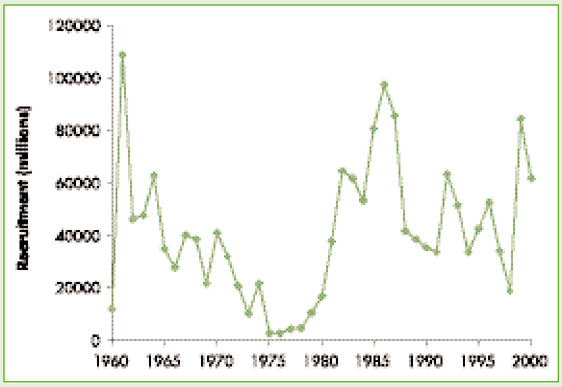
Currently, North Sea herring stocks are considered to be outside safe biological limits but a gradual recovery may be in progress. Information has been insufficient to fully assess populations exploited to the west of Scotland, but reports suggest that stocks remain stable and fishing mortality may be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

Source: ICES (2001); FRS Marine Laboratory, Aberdeen.

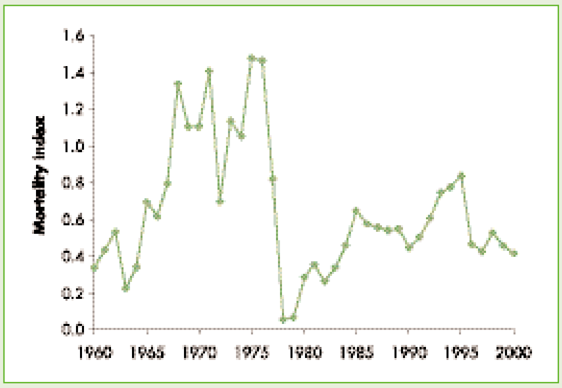
Figure 15.5
Changes in landings, recruitment, fishing mortality and spawning stock biomass for North Sea herring



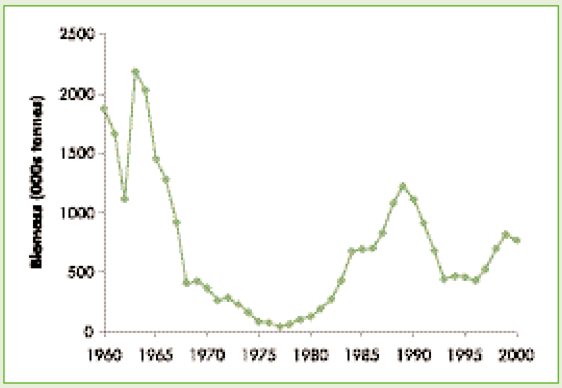
a) Landings



b) Recruitment (age 0)



c) Fishing mortality (ages 2-6)



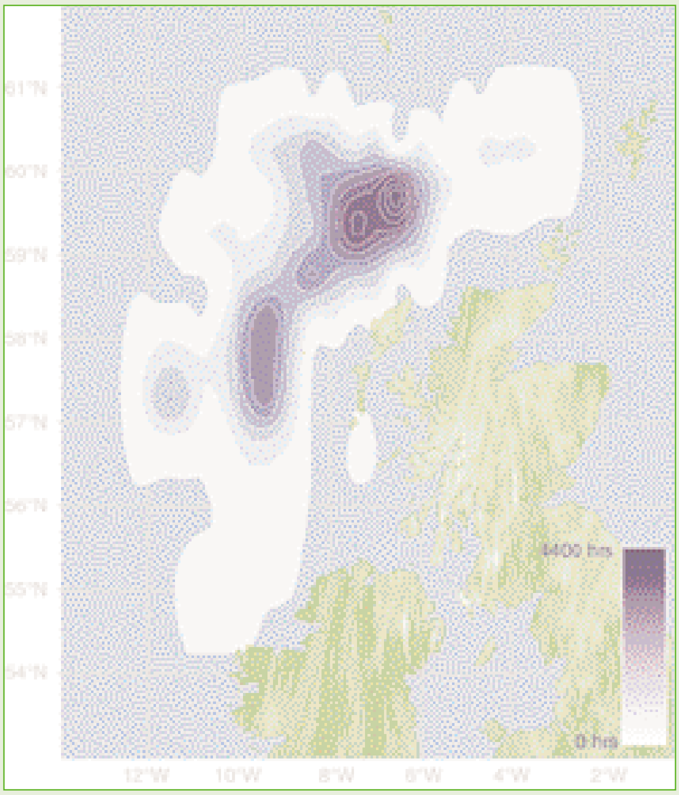
d) Spawning stock biomass

Box 15.5 Deep-water fisheries

As the traditional fisheries of the European continental shelf have declined, catch unreliability and the introduction of fishing quotas has stimulated 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 400 metres depth – defined as 'deep-water' by the International Council for the Exploration of the Seas – 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-metre depth contour. Of these, around 12 –15 species are of a sufficient individual size and abundance to be considered marketable (Table 15.3).

Some deep-water fisheries are historically well established, notably around oceanic islands with steep inshore slopes such as Madeira and the Azores, but the fishery to the north-west and west of Scotland represents a relatively recent development. 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 catching roundnose grenadier. 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. However, in the late 1970s French trawlers, traditionally operating along the outer shelf, had begun moving into deeper water, establishing a market for blue ling. By the late 1980s a fishery had developed for other deep-water species formerly landed as bycatch. By 1992 larger French vessels had extended their fishing activities still deeper, exploiting the valuable orange roughy stocks. This fishery has continued to the present and has remained an almost exclusively French enterprise, with the major effort concentrated around the Rockall Trough and Rosemary Bank (Figure 15.6). A number of Scottish vessels fish alongside the French but, in general, deep-water landings are largely derived from bycatch resulting from the targeting of monkfish.

Figure 15.6 Hours fished by French Trawlers landing in Scotland in 1998



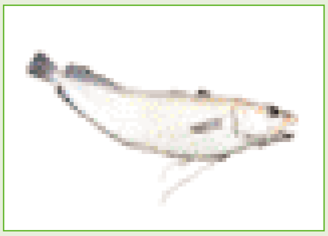
Source: FRS Marine Laboratory, Aberdeen.

Many deep-water organisms are long-lived, slow growing and only achieve maturity at a high age or large size. Consequently, there are concerns that the current level of exploitation may be unsustainable. In addition, the rapid pressure transition associated with recovery from such great depths and the delicate nature of much of the deep-water biota means that there is a high bycatch mortality. The passage of trawl gear may represent a major destructive event to species and habitats in an environment that rarely experiences change. Tracks left by trawling activity are thought to have become a common feature of deep-sea sediments. The damaging effects of fishing activity on the deep-water reef structures constructed by the coral *Lophelia pertusa* are of international concern. Such concerns are reflected in the development of UK Biodiversity Action Plans for both *Lophelia* reefs and deep-water fish. Furthermore, identification of Special Areas of Conservation under the EU Habitats Directive for the protection of these reefs is currently underway.

Key sources: FRS Marine Laboratory, Aberdeen; ICES (2000); Roberts *et al.* (in press); Gordon (2001); Gordon & Hunter (1994).

Box 15.5 Deep-water fisheries (continued)

Blue whiting

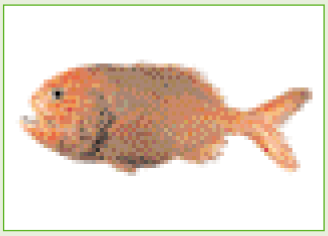


Greater forkbeard

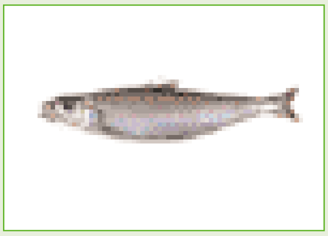
Blue hake

Roundnose grenadier

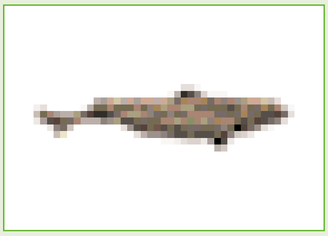
Black scabbardfish



Orange roughy



Greater silver smelt or **argentine**



Portuguese dogfish

Table 15.3 Commercially exploited deep-water fish species

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 in 1985 at 14,000 tonnes, 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	Due to the technical problems of fishing at the depth of greatest density, commercial exploitation is currently not considered viable.
Coryphaenoides rupestris	Roundnose grenadier	Considered to be harvested outside safe biological limits.
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	

Sources: FRS Marine Laboratory, Aberdeen; ICES (2000); Gordon (2001); Gordon & Hunter (1994)

Table 15.4 Summary of trends in fisheries

Topic	Trends	Decreasing	Static	Increasing	Reliability of trend[5]
Landings	**1989-99** Nine fish populations have shown a substantial decline (i.e. of at least 10%) in the annual reported tonnage landed, either because of imposed catch restrictions or an inability to locate adequate supplies. One population has shown a substantial increase, while three have shown relatively little change (Table 15.2).	**9 populations** ⇩	3 populations ⇔	2 populations ⇧	**C**
Fishing mortality	**1989-99** Eight fish populations have shown a substantial decrease in fishing-related mortality, while five have shown relatively little change (Table 15.2).	**8 populations** ⇩	5 populations ⇔	0 populations ⇧	**C**
Spawning stock biomass	**1989-99** Six fish populations have shown a substantial decline in the total estimated weight of individuals mature enough to be able to spawn. Five populations have shown a substantial increase, while two have shown relatively little change (Table 15.2).	**6 populations** ⇩	2 populations ⇔	5 populations ⇧	**C**
Stock health	**1999** Populations of nine of the 12 fish and shellfish species for which Scottish data are available are considered to be outside of safe biological limits (Table 15.3).				

[4] Reliability of change or trend between the specified years: **T** = an increasing (or decreasing) trend established; **C** = change clearly established between first and last year, but no clear evidence for a trend; **c** = change probable but not fully-established; **c** = changed indicated but not well-established. A blank indicates that assessment of change was not appropriate. Statistical significance was tested where possible (at the 5% level).

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