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Technical Report for Department of Trade & Industry

COASTAL SHELLFISH RESOURCES AND FISHERIES IN SEA7

Prepared by:

Colin J. Chapman
Bloomfield
Milltimber
Aberdeenshire
AB13 0EQ

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EXECUTIVE SUMMARY

This report deals with the shellfish resources and their commercial fisheries within the Strategic Environmental Assessment area SEA7, which comprises a large zone off the West coast of Scotland, extending from the coast to deep water west of Rockall. Exploited species of shellfish are found in the SEA7 zone occupying all types of habitat and distributed over a considerable range of depths, from the littoral zone down to 1000m. These species provide important fisheries and make vital contributions to the economy of remote communities on the west coast of Scotland.

The main species reviewed in this report are:

Norway lobster
European Lobster
Crawfish
Edible crab
Velvet swimming crab
Shore crab
Red crabs

Giant scallop
Queen scallop
Cockle
Common mussel
Razor shells

Whelks
Periwinkle

Most of these species inhabit relatively shallow water from the inter-tidal zone down to 100m or so. Within the SEA7 zone, the Norway lobster extends to much deeper water, around 600m and three species of red crab are found in very deep water down to 1000m or more. Exploitation of shellfish within the SEA7 zone involves use of a diverse range of harvesting methods; varying from mobile gears, such as trawls and dredges; static gears, such as creels, tangle and gill nets; hand gathering, including SCUBA diving. Choice of fishing method, and possible effects on the environment, are now important issues. There is a requirement to ensure integration of environmental considerations into fishery management. This topic is touched on briefly throughout this review.

Information on the distribution and importance of the fisheries for each shellfish species in this report is based mainly on the recorded landings by UK vessels into Scottish ports, and to a lesser extent, on landings into Ireland and Northern Ireland. Landings information in Scotland was provided by the Scottish Executive database, the Fisheries Information Network. Landings data from these sources is recorded with reference to the International Council for the Exploration of the Sea (ICES) grid of statistical rectangles. Each rectangle is defined by 0.5^{o} of latitude and 1.0^{o} of longitude and covers an area of approximately 30 x 30 nautical miles. Because the ICES grid does not provide a precise fit to the SEA7 zone boundary, the choice for collating fishery data involves a degree of compromise. The outer western boundary

of the ICES fishery statistics area chosen for this review is the 11°W longitude coordinate. Little shellfish are caught in the SEA7 zone outside this coordinate; in 2004, only 31 tonnes (of which 21t. were squid) were landed in Scotland from the SEA7 zone, west of 11°W, compared to 17,000t of shellfish landed from grounds east of this longitude.

A word of caution is required regarding the accuracy of the reported landings data. For some of the species dealt with in this report, there is anecdotal evidence of under-reporting by fishermen. This is a particular problem in the case of the Norway lobster where the European Union (EU) attempts to manage the fisheries by Total Allowable Catch (TAC).

Landings of shellfish from the SEA7 coastal zone by UK vessels in Scotland totalled 17,002–21,475 tonnes in the most recent three years for which data are available, exceeding in each year the landings weight of demersal fish. As a proportion of total landings, the contribution of shellfish amounted to between 26 and 30% by weight but a much higher proportion of total value, 58–65%. The value of all shellfish landings from the SEA7 coastal zone in 2002–2004 was around £37–41 million, representing 36–44% of the value of all shellfish landed in the whole of Scotland (£91.6–101.5 million).

Biological information concerning distribution, habitat, life-cycle and reproduction for most species were dealt with in a previous review for SEA5*. Biological details are only given here for species that were not covered by the earlier review.

The Norway lobster, *Nephrops norvegicus* (L.) is the most valuable shellfish species exploited by the Scottish fishing industry. The species is found on a range of soft sediments consisting of varying mixtures of mud and sand particles. The main areas of exploitation are in the North Minch, South Minch and the Sound of Jura. In addition, Norway lobsters are found in many of the sea lochs on the Scottish mainland and on the east coast of the Outer Hebrides, and at the other extreme, they are also found in deeper water (600m or more), on the continental shelf and slope west of the Outer Hebrides. The total landings from the SEA7 coastal zone ranged from 6,720 to 8,755 tonnes over the reference period from 1995-2004. Most of the landings are made by various types of trawl but the creel fishery now accounts for about 20% of the landings. The value of all Norway lobster landings taken within the SEA7 zone in 2004 was about £21 million, representing 57% of the total value of all shellfish from the zone.

With concerns about the reliability of official landings and fishing effort data, more weight is now given to assessments based on fishery-independent stock surveys using towed TV camera sledges. Counts of Norway lobster burrows can be made and related to observed area of sea bed to provide burrow density estimates. These are then raised to the total ground area to provide estimates of stock abundance and biomass. These surveys have been conducted for several years in some areas to provide useful indicators of stock condition. For the main N. and S. Minch grounds, the surveys have shown that estimates of burrow density and abundance have increased noticeably since 2001. On this basis, ICES recommended a large increase in the TAC for the Scottish West coast stocks. New regulations affecting the Norway lobster trawl fisheries in SEA7 have been introduced by the EU as part of a cod recovery plan. This regulation limits vessels targeting Norway lobsters with 70-99 mm mesh cod-ends to 25 fishing days per month. Nets also have to be fitted with square mesh and headline panels to permit fish to escape.

The Norway lobster creel fishery, along with similar static gear fisheries for other species, is affected by the terms of the Inshore Fishing Order 1989 which controls the use of mobile gear (trawls, dredges) and creels within Scottish inshore waters. In Loch Torridon, the Norway lobster creel fishery is being managed by the local fishermen. This experiment in local management led to the fishery being awarded certification by the Marine Stewardship Council in 2003.

The European lobster is common around the coasts within SEA7, occurring on rocky shores, reefs and boulder fields from low water down to 60m. Lobsters are exploited by small inshore vessels using baited creels, which may also catch edible crab, velvet swimming crab and shore crab. The largest reported landings come from around the islands of the Inner and Outer Hebrides. Annual landings from the zone were in the range 280-320 tonnes up to 1998 but have since fallen below 180 tonnes due to diversion of effort to other species. The value of the fishery in the SEA7 zone was about £1.6 million in 2004. The lobster fisheries are controlled by a suite of technical measures, including a Minimum Legal Size (MLS), an upper size limit for females and a ban on the landing of 'V'-notched lobsters. The latter two measures are designed to protect large, mature, highly fecund females in order to boost egg production and subsequent recruitment of juveniles.

Artificial reefs are being considered as a means of enhancing lobster stocks and such a reef has been constructed off the island of Lismore in Loch Linnhe. The reef extends to an area of about 1 km^2 and is one of the largest in Europe. Colonisation of the reef by fauna and flora, including European lobsters and fish, is being closely monitored by scientists of the Scottish Association for Marine Science.

The crawfish, or European spiny lobster, is found within the SEA7 coastal zone mainly inhabiting rocky reefs at depths of 20-70 m. The fishery is relatively small with most landings coming from the Outer and Inner Hebrides. Crawfish are caught in baited creels and in the bottom-set tangle net fishery for monkfish. Virtually all the landings of crawfish by UK vessels in Scotland come from the SEA7 zone. The fishery is currently too small to warrant assessment in Scotland, where the species is probably at the northern limit of its distribution. With climate change, it is conceivable that crawfish may become more common in Scottish waters in the future. The only legislation applying to crawfish is an EU imposed MLS.

Within the inshore waters of the SEA7 zone, a baited creel fishery exploits three species of crab, the edible crab, the velvet swimming crab and the shore crab. The largest landings of edible crab come from waters around the Outer Hebrides and around Skye, Mull and Islay. Landings have averaged around 3,500 tonnes in the last 10 years. In 2004, the edible crab fishery within the SEA7 zone was estimated to be worth £3.1 million to UK fishermen. The Irish crab fishery in ICES area VI is one of the largest and commercially important fisheries in Europe. Annual landings in 2001-2003 were in the range 6,000-7,500 tonnes. Based on records of fishing effort from fishermen's logbooks, it is estimated that about 50% of these landings were derived from the SEA7 coastal zone. Thus, this fishery is on a par with that in Scotland.

Creel fishing for edible crab within the SEA7 coastal zone is controlled by technical measures; a MLS, a ban on landing berried females, a ban on landing ‘soft’ recently moulted crabs and a limit on the landing of crab claws.

Velvet crabs form an important component in the mixed creel fishery with European lobster, edible crab and, to a lesser extent shore crab. The crabs are landed and transported live to continental markets, particularly Spain. The largest landings are taken around Islay, Mull and in parts of the Outer Hebrides. Landings from the SEA7 zone have varied from around 900 to 2,900 tonnes in the period 1995-2004. There has been a gradual decline in landings due to the partial switching of effort by inshore vessels towards Norway lobsters. In 2004, the value of this fishery was estimated to be £1.6 million. The fishery for velvet crab within the SEA7 zone is unregulated apart from a national MLS regulation.

The shore crab is very common in the littoral zone and also occurs in deeper water down to 200m. The species occurs throughout the SEA7 coastal zone where it forms the basis of a small fishery. The species is mainly landed as a by-catch in the creel fishery for velvet crabs. Since 1998, landings from the SEA7 zone have fallen sharply to around 30-50 tonnes with an estimated value in 2004 of only £18,800. Shore crabs are only lightly exploited as a by-catch species and there are no management controls in place.

The deep water red crab recorded in Scottish landings data, could be a mixture of three species but the larger *Chaceon affinis* is likely to account for most of the landings. Within the SEA7 zone, red crabs occur from around 300 to 1000m on Hatton, Rosemary and Rockall Banks, on the Wyville-Thomson Ridge and west of St Kilda. There are conflicting reports concerning the habitat of red crab; they have been found on rocky and stony sediments at the Rockall and Rosemary Banks but they are also known to occur on fine mud sediments and it has been suggested that they may excavate burrows. The fisheries for red crab within the SEA7 zone are poorly documented, and it is clear that landing statistics are under-reported by national fleets. Red crab are landed as a main target species using tangle nets and baited ‘inkwell’ pots, and also as a by-catch from bottom set gill-net fisheries for angler fish, sharks and other deep-water fish. Many of the vessels, although nominally registered in the UK, are Spanish owned and most of their landings are made at La Coruna in Spain. Although the number of vessels is modest, their fishing effort using gill-nets can be very large.

There were no landings of red crab reported before 2000 but in 2003, 192 tonnes were landed in Scotland from the whole SEA7 zone. No assessments have been carried out for red crab stocks within the SEA7 zone, an omission which really needs to be addressed. Since the species grows and matures relatively slowly, and little is known about recruitment patterns, it is regarded as being particularly vulnerable to over fishing. It would seem that underwater TV camera surveys would be a suitable method for conducting surveys. The fishery for red crab is unregulated. A major problem with the deep sea fisheries is loss of gear and dumping of damaged gill-nets, which continue to ‘ghost fish’. In 2005, the EU Council of Ministers introduced a temporary ban on gill netting, in depths below 200m for waters to the west of Scotland and Ireland. There is an area in the SW corner of Rockall Bank, known as the ‘haddock box’, closed to all fishing methods, other than long-lining, in order to protect juvenile haddock and there are proposals to close other areas on Rockall and Hatton Banks in order to protect vulnerable cold-water corals.

The giant scallop is widely distributed on the west coast of Scotland and supports two major fisheries within the SEA7 coastal zone. The main areas of exploitation are the North and South Minch, around the Outer Hebrides, Skye, Mull, Islay and Jura. The main method of fishing is by 'gangs' of toothed dredges deployed on either side of the vessel. This method of fishing is potentially damaging to the environment and to underwater installations. In the period, 1995-2004, total landings from the SEA7 zone varied from around 2,200 to 5,600 tonnes, with dredge gear accounting for 84-96% of the landings, the remainder being taken by SCUBA divers. The value of the giant scallop fishery in the SEA7 coastal zone in 2004 was estimated to have been £6.7 million.

Present controls on scallop dredging involve licensing of vessels, restrictions on dredge numbers depending in fishing zones, a MLS regulation and the Inshore Fishing Order provisions on use of mobile gear. New legislation has been introduced to control certain technical specifications of scallop dredges, namely their width, number of teeth and size of 'belly' chain rings. This legislation is not being enforced in the meantime, pending further consideration in relation to the EU Technical Standards Directive. It is well known that the toothed dredges employed in the fishery have significant environmental impacts.

The queen scallop is widely distributed on the west coast of Scotland, though within the SEA7 zone, exploitation is limited to one main area in the south of the zone close to the N. Ireland coast near Rathlin Island. Vessels from Scotland and N. Ireland are engaged in this fishery, though all the landings go to Scottish ports. Relatively high landings have been reported since 2000 with a peak in 2002 of 3,500 tonnes. No assessments have been undertaken for queen scallop stocks within the SEA7 zone and the fishery is unregulated.

The cockle is fairly common on suitable inter-tidal habitat within the SEA7 coastal zone but there are relatively few large areas where cockles are sufficiently dense to support viable fisheries. The only fisheries within the SEA7 coastal zone are located on several beaches in the Outer Hebrides, principally on Barra, and to a lesser extent on N. Uist, and S. Uist. The only fishing method now permitted is hand raking and gathering. Since 1995, when 380 tonnes were landed from the SEA7 zone, the exploitation of cockles has declined to a low level, averaging only 20 tonnes in the last five years. It is likely that all of these landings have come from the Traigh Mhor strand on the Island of Barra. This fishery was over-exploited in 1994-995, with the introduction of a tractor-drawn dredge. This represented a major increase in fishing effort. The high landings in 1995 were partly the result of this controversial development. Surveys at that time showed the stock biomass of cockles had been reduced by about 75%. As a result of this, and to prevent similar situations arising elsewhere in Scotland, the Scottish Office introduced a national ban on tractor dredging in 1995, under the Inshore Fishing Order.

The common mussel occurs all round the Scottish coast, generally on rocky shores or gravel beaches, attached to the substrate by means of byssus threads. Mussel farming is based on the settlement of spat on ropes deployed for the purpose. There are small mussel beds within the SEA7 coastal zone but very little information about their precise location. Small landings of mussels have been reported in some years from the Outer Hebrides, but details concerning the ownership of the beds, is unknown. There is no public right to fish for mussels or oysters, since these rights usually belong to the Crown.

There are three species of razor shell on the west coast of Scotland and a small fishery has developed for two of them in recent years, *Ensis siliqua* and *E. arcuatus*. The main harvesting method is by SCUBA diving, with some taken by hydraulic suction dredges. Annual landings from the SEA7 zone have varied from 10 to 62 tonnes. The fishery is virtually unregulated apart from a MLS which is well below the size acceptable to Far East and European markets. While the SCUBA diver based fishery has little or no environmental impact, the same cannot be said for dredging methods which need to excavate a deep trench in the sea bed to catch razor shells. Suction dredge and water jet fishing methods are banned in certain sensitive areas under the Inshore Fishing Order.

Three species of gastropod mollusc are exploited in the SEA7 zone, though the fisheries are relatively small. These are the common whelk, red whelk and periwinkle. Landings of the latter species, which are made by hand gathering, are seriously under-reported. Landings of the two whelk species are sometimes mixed together. Since 2001, landings of whelks from the SEA7 zone have stabilised around 120-180 tonnes, contributing 11-19% of Scottish landings.

The wild fisheries for giant scallop, queen scallop and common mussel are augmented by production from a small but thriving farming industry. In addition, the native oyster and the Pacific oyster are also farmed. Within the SEA7 coastal zone, there are large numbers of shellfish farm sites leased from the Crown Estates, including nine Several Order (SO) sites. West coast farms produced 2,380 tonnes of shellfish in 2004, of which mussels accounted for 85% and Pacific oysters a further 12%. The total value of shellfish farm production in 2004 was estimated to be £2.63 million, of which mussels contributed £2.14 million. Production of giant scallops by culture methods is still very small, despite the granting of SO status to nine sites within the SEA7 coastal zone. It is possible that, in the future, scallop culture methods will be used to enhance the wild fisheries by reseeding.

There has recently been some interest in the exploitation of echinoderms such as sea urchins, either from wild stocks or, more likely, by culturing them, possibly in cages alongside salmon. There is a ready overseas market for sea urchin roe, particularly in Japan.

During the preparation of this review, some doubts have emerged concerning the reliability of official landings statistics used. This is particularly true in the case of the Norway lobster, red crab and periwinkle data. This unsatisfactory situation could change in the future, however, with the introduction in 2006 of a compulsory registration scheme for buyers and sellers of first sale fish and shellfish.

Under the revised Common Fisheries Policy, member states are required to introduce fisheries management measures to protect the marine environment. Most problems have arisen in relation to mobile gears. Scallop dredging is a particular problem for beds of coralline-algae (maerl) which are easily broken up by the gear. Maerl beds are widespread throughout the SEA7 coastal zone. In the future, it is likely that more use will be made of closed areas to protect certain vulnerable habitats, such as maerl beds, from damage by fishing gear.

Most of the fisheries within the SEA7 zone are virtually unregulated. It is likely that shellfish fisheries will only be properly controlled when they come under local area management. This could be achieved by using Regulated Fishery Orders, though other methods are also being considered, aimed at giving stakeholders a greater say in the management of offshore and inshore fisheries. As part of a review of the CFP, the EU has created seven Regional Advisory Councils to cover different areas or fisheries; that most relevant to the SEA7 zone is the North Western Waters Regional Advisory Council which came into being in 2005.

The Scottish Executive has also introduced new initiatives to involve stakeholders in the management of inshore fisheries within Scotland's territorial seas. In 1999, the Scottish Inshore Fisheries Advisory Group (SIFAG) was sent up. SIFAG produced a strategy document for inshore fisheries in Scotland, a key recommendation being the establishment of 12 Inshore Fisheries Groups covering different regions of the Scottish coast. The task of these groups will be to develop local objectives and management plans for inshore fisheries. As well as these initiatives, the UK Government set up the Scottish Coastal Forum, with a wider brief than just fisheries, to bring together representatives of all major stakeholders with an interest in integrated management of the coast.

The shellfish species included in this review are all relatively sedentary, living within or on the seabed. Although local movements can occur, most species do not undertake significant migrations. This limited mobility means that shellfish species are extremely vulnerable to environmental disturbance and pollution. Bivalve molluscs, such as mussels, razor shells and scallops, are filter feeders that take in food with an inhalant current of sea water. In this way they can accumulate algal toxins, faecal bacteria and contaminants.

Bivalve molluscs such as mussels and scallops are subject to the EU Shellfish Hygiene Directive and associated national legislation. This calls upon competent authorities (The Food Standards Agency Scotland {FSAS}) to classify shellfish production areas by testing flesh for contamination by faecal bacteria There are four categories of classification but only category A (<230 *E. coli*/100g flesh) allow shellfish to go directly for human consumption. There are now 104 areas that meet the category A standard, mostly on the west coast of Scotland and in the Northern Isles. The Scottish Environment Protection Agency (SEPA) is responsible for monitoring designated shellfish growing areas to ensure their water quality meets the requirements of the EU Shellfish Waters Directive. Regular tests include general physio-chemical parameters, metals, hydrocarbons, organohalogens, as well as faecal bacteria.

Another requirement of the EU Shellfish hygiene regulations is that the FSAS monitors shellfish for the presence of marine biotoxins and the designated waters for the phytoplankton species which cause the toxicity. Offshore scallop stocks are also included in the monitoring programme. Three main types of algal toxins can occur in

Scottish shellfish, Paralytic Shellfish Poisons, Amnesic Shellfish Poisons (ASP) and Diarrhetic Shellfish Poisons. The presence of these toxins above prescribed threshold levels results either in Voluntary Closure Agreements for short periods of time, or a closure under the Food and Environmental Protection Act, 1985. Probably, the most serious effect on fisheries has been the number and extent of closures of offshore giant scallop grounds because of ASP. In 2004-2005, ASP was detected on all major scallop fishing grounds.

Tributyltin (TBT) is the active ingredient of some anti-fouling paints used on ships. It was also widely used on the west coast of Scotland to treat salmon farm cages. It gradually leaches out into the water and can also contaminate sediments. TBT affects the sex hormonal balance in gastropod molluscs, such as the dog whelk, *Nucella lapillus* (L.), causing females to develop a penis, a phenomenon referred to as 'imposex'. TBT can also affect shell shape and the reproductive capacity of native and Pacific oysters. In 1987, TBT based paints were banned from being used on vessels less than 25m in length. This action was certainly effective up to a point but the problem has not been eradicated. 'Imposex' monitoring is now part of the Oslo and Paris Commission (OSPAR) Coordinated Environmental Monitoring Programme and the UK National Marine Monitoring Programme (NMMP). A UK-wide survey of 'imposex' prevalence still reveals some 'hot-spots', most notably around harbours frequented by large vessels which may still be coated with TBT based paint, for example Ullapool, Portree and Mallaig within the SEA7 coastal zone. The International Maritime Organisation has agreed that TBT based paints should be phased out over the next five years.

Farmed salmon are vulnerable to infestation by sea lice ecto-parasites that cause stress and damage to the skin. Various chemical treatments are available which are licensed for veterinary use in salmon. The use of these products is controlled by SEPA to ensure minimal effects on the environment. A recent study found no major changes in the ecology of sea lochs where sea lice treatments were being used.

There are several monitoring schemes which taken together may provide a reasonably broad picture of water quality within SEA7 coastal waters. SEPA operates several classification schemes which cover coastal waters out to 3nm. These schemes include (i) Estuarine waters, (ii) Coastal waters, (iii) Bathing waters, (iv) Shellfish growing waters. In the late 1980s, the NMMP was initiated to coordinate the monitoring of marine coastal waters throughout the UK. A network of 87 monitoring stations was established comprising estuarine, inshore and offshore areas, of which 19 sites are located around the Scottish coast, mainly concentrated in the Firths of the Clyde, Forth and Tay. Extensive monitoring is also initiated by the FSAS in relation to food safety. Since 1999, the NMMP programme has been replaced by the Clean Seas Environment Monitoring Programme. It appears that there is a good body of contaminant data being collected to meet specific monitoring programmes in inshore waters but there is a need to extend the coverage to deeper waters in relation to future oil and gas exploration within SEA7.

Topics identified during the SEA7 review, where more research is needed include; studies of the ecology of early stages in the life-cycle of edible crab and scallops; monitoring of landings of each species and fishing effort in the deep water red crab fisheries, and stock surveys in relation to habitat; surveys of deep water shrimp resources and continuing base-line monitoring of contaminants.

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*Chapman, C.J. (2004a): Northern North Sea shellfish and fisheries. Strategic Environmental Assessment – SEA5, Technical Report for the DTI, pp. 1-69.

1. Introduction

This report deals with the shellfish resources and their commercial fisheries within the Strategic Environmental Assessment area SEA7, which comprises a large zone off the West coast of Scotland, extending from the coast to deep water west of Rockall (Fig. 1). The main species dealt with in the report are listed in Table 1, which includes information concerning their preferred habitat, depth range and the commercial fishing methods used to exploit them. Exploited species of shellfish are found in the SEA7 zone occupying all types of habitat and distributed over a considerable range of depths, from the littoral zone down to 1000m. The species listed in Table 1 support existing fisheries and make vital contributions to the economy of, often remote, communities on the west coast of Scotland. Although most shellfish are found in coastal waters, some are more widely distributed, such as the Norway lobster, various species of squid (dealt with in a separate report by Hastie *et al*., 2006), and the red crab, which inhabits deep water throughout the SEA7 zone.

Table 1: List of main shellfish species included in this review, with information on preferred habitat, depth range and fishing methods used in SEA7 zone.

Species common names (+)	Habitat	Usual depth range (m)*	Fishing methods
Norway lobster	Muddy sand – mud	10-600	Trawl; creel
European lobster	Reefs, rock, boulders	0–60	Creel
Edible crab	Reefs, sand, gravel	0-100	Creel
Velvet crab	Reefs, rock, boulders	0–15	Creel
Green crab	Rocky shores, sand	0-200	Creel
Crawfish	Offshore reefs	20-70	Creel; tangle net
Red crab	Offshore rock,stone,mud	300-1000	Creel; tangle, gill nets
Squat lobster	Sand, gravel, mud	15-600	Creel
Giant scallop	Sand	0–100	Dredge; diving
Queen scallop	Sand, mud	0–100	Dredge; otter trawl
Cockle	Sand – mud flats	Inter-tidal	By hand
Mussel	Rock, gravel beds	Inter-tidal	Dredge
Razor shell	Sand, muddy sand	Inter-tidal-10	Dredge; diving
Whelk	Sand, gravel	0-100	Trap; trawl
Periwinkle	Rocky shores	Inter-tidal	By hand

* 0 = LWST
(+) Scientific names given in text

Exploitation of shellfish within the SEA7 zone involves use of a diverse range of harvesting methods; varying from mobile gears, such as trawls and dredges; static gears, such as creels, tangle and gill nets; hand gathering, including SCUBA diving. Choice of fishing method, and possible effects on the environment, are now important issues. There is a requirement to ensure integration of environmental considerations into fishery management. The current process of reforming the Common Fisheries Policy (CFP) calls on member states to introduce fisheries management measures to protect the marine environment (Anon., 2002). These matters are touched on briefly throughout this review and elaborated in Section 3.2.

Acronyms and abbreviations used in the text are defined when first employed but are also listed in Appendix C. for convenience.

2. Shellfish resources

2.1 Fishery data

Information on the distribution and importance of the fisheries for each shellfish species in this report is based mainly on the recorded landings by UK vessels into Scottish ports, and to a lesser extent, on landings into Ireland and Northern Ireland. Although data on fishing effort is collected, it is not considered sufficiently reliable for most shellfish species, particularly where static gears are used. Information on fishing vessel activity is theoretically available from the observations of surveillance aircraft deployed on behalf of the Scottish Fisheries Protection Agency (SFPA) and also from satellite tracking technology via the Vessel Monitoring System (VMS). Unfortunately, at the present time, neither of these systems provides useful information on shellfish vessel activity. According to Mills & Eastwood (2005), over-flight surveillance coverage tends to underestimate inshore fishing activity by shellfish vessels. Under Commission Regulation (EC) No.2244/2003, VMS has been required to be fitted to >18m vessels since 2004, and >15m vessels since 2005. The vast majority of Scottish shellfish vessels are smaller than these categories, 81% being less than 10m, and are therefore not covered by this regulation. Indeed, at the present time, VMS data is not available for scientific purposes owing to an administrative error regarding data protection legislation. Some information on fishing activity by *Nephrops* trawlers, derived from surveillance aircraft observations, is given by Gordon (2006).

Landings information in Scotland was provided by the Scottish Executive database, the Fisheries Information Network (FIN), and from the Scottish Fisheries Statistics published annually, the most recent issue being for 2004 (Anon., 2005a). Information from N. Ireland was provided by Dr Richard Briggs. Landings data from these sources is recorded with reference to the International Council for the Exploration of the Sea (ICES) grid of statistical rectangles. Each rectangle is defined by 0.5^{o} of latitude and 1.0^{o} of longitude and covers an area of approximately 30 x 30 nautical miles. The portion of the ICES grid chosen for this review is shown in Fig. 1. Because the ICES grid does not provide a precise fit to the SEA7 zone boundary, the choice for collating fishery data involves a degree of compromise. As Fig. 1 shows, the outer western boundary of the ICES fishery statistics area chosen for this review is the 11^{o}W longitude coordinate. Very little shellfish are caught in the SEA7 zone outside this coordinate; in 2004, only 31 tonnes of shellfish (of which 21t. were squid) were landed in Scotland from the SEA7 zone, west of 11^{o}W, compared to 17,000t of shellfish landed from grounds east of this longitude (Table 2). For the purposes of this review the chosen area, depicted in Fig. 1, is referred to as the SEA7 coastal zone; the region west of 11^{o} W is referred to as the SEA7 outer zone. It should be noted that the SEA7 zone falls within parts of ICES Regions VIa, VIb and XII. Landings of shellfish at Scottish ports by foreign vessels is extremely small (< 0.5% of the total for Scotland as a whole) and can be ignored for the purpose of this review.

A word of caution is required regarding the accuracy of the reported landings data. For some of the species dealt with in this report, there is anecdotal evidence of under-reporting by fishermen. This is particularly likely to be the case in the Norway lobster where the European Union (EU) attempts to manage the fisheries by Total Allowable Catches (TACs) and national quotas (see Section 2.2.1 and Section 3.1).

The shellfish resources within the coastal region of SEA7 are extremely important to the remote communities of the Scottish west coast, and of the islands in the Inner and Outer Hebrides. This may be judged by reference to Table 2, which shows the landings weight and value of shellfish, in comparison with those for bottom living demersal fish ('white fish') and pelagic fish, taken from within the SEA7 coastal zone. Landings of shellfish by UK vessels in Scotland totalled 17,002–21,475 tonnes in the most recent three years for which data are available, exceeding in each year the landings weight of demersal fish. As a proportion of total landings, the contribution of shellfish amounted to between 26 and 30% by weight but a much higher proportion of total value, 58–65%. It can be seen from Table 2 that the value of shellfish landings from the SEA7 coastal zone in 2002–2004 was around £37–41 million, representing 36–44% of the value of all shellfish landed in the whole of Scotland (£91.6–101.5 million).

Table 2: Landings weight (tonnes) and value (£ million) of shellfish (including cephalopods) compared with demersal and pelagic fish species, in years 2002 – 2004 by UK vessels, and landed at Scottish ports from within the SEA7 coastal zone shown in Fig.1. Note that data in this and other Tables is taken from FIN database and/or Anon. (2005a), unless stated otherwise.

Units	Category	2002	2003	2004
Weight (tonnes)	Demersal fish	15,432	11,427	10,791
	Pelagic fish	33,827	39,426	34,693
	Shellfish	21,475	18,198	17,002
	Total	70,734	69,052	62,486
	% shellfish	**30.4**	**26.4**	**27.2**
Value (£ million)	Demersal fish	14.73	11.83	11.65
	Pelagic fish	10.41	16.79	8.03
	Shellfish	40.75	39.03	36.83
	Total	65.90	67.66	56.52
	% shellfish	**61.8**	**57.7**	**65.2**

In the following Sections, each shellfish species, listed in Table 1, is dealt with in turn. Landings of these species account for 98–99% of all shellfish taken from the SEA7 coastal zone, the remainder being largely accounted for by landings of squid. Biological information concerning distribution, habitat, life-cycle and reproduction are covered briefly here, more details of these aspects for most of the species in Table 1 having been provided in a previous review for SEA5 (Chapman, 2004a).

2.2 Crustacean species

2.2.1 Norway lobster

The Norway lobster, *Nephrops norvegicus* (L.) is the most valuable shellfish species exploited by the Scottish fishing industry. The species is found on a range of soft sediments consisting of varying mixtures of mud (silt & clay) and sand particles. Reasonably accurate information on distribution in a given area may be obtained from sea bed sediment charts published by the British Geological Survey (BGS, 1: 250,000 scale). Areas of muddy sand, sandy mud and mud provide suitable habitat in which Norway lobsters construct burrows. The main areas of distribution can be identified from Fig. 2, which shows the location of the landings within SEA7. The main areas of exploitation are; North Minch, extending from the Scottish mainland to Lewis and to the north-west and north-east of Skye; South Minch, extending from the west of Skye to Stanton Bank; the latter Bank, lying south of the Outer Hebrides; Sound of Jura lying between Islay/Jura and the Kintyre Peninsular. In addition, Norway lobsters are found in many of the sea lochs on the Scottish mainland and on the east coast of the Outer Hebrides, and at the other extreme, they are also found in deeper water (600m or more), on the continental shelf and slope west of the Outer Hebrides.

<u>Fisheries</u>

The main fisheries within the SEA7 coastal zone are found in the North and South Minch. The state of both these stocks is assessed regularly by ICES (see below; Fig. 2). The North Minch fishery is mainly exploited by trawlers using single-rig gear with a 70mm mesh, though some vessels use 100mm mesh. A few trawlers use twin-rig nets. About 135 trawlers are involved in this fishery. The main ports of landing are Ullapool, Gairloch and Stornoway. Unlike the North Sea fisheries (Chapman, 2004a), a significant proportion, around 20%, of landings in this fishery are obtained by small local vessels using baited creels. Landings from creel vessels come mainly from inshore grounds and sea lochs and may be made at numerous local piers.

The South Minch fishery is mainly exploited by trawlers, most of which (80%) use 70mm mesh nets. A few vessels use twin-rig gear. The main ports of landing are Oban and Mallaig. About 10% of landings are made by creel vessels fishing the inshore grounds and in sheltered sea lochs.

Norway lobsters from the creel fishery are usually of a larger size compared with trawl landings, and are landed live. They are then transported in this condition, generally by air freight, to continental markets, especially to Spain, where they can command a very high price.

<u>Landings</u>

Landings of Norway lobsters from the SEA7 coastal zone are shown in Table 3, with those from the two main Minch stocks shown separately. Fig. 2 shows the ICES statistical rectangles aggregated together for the assessment and management of each of the Minch stocks. The total landings from SEA7 coastal zone ranged from 6,720 to 8,755 tonnes over the reference period, while those from the N. Minch have varied from 2,441 to 3,656 tonnes and those from the S. Minch from 3,305 to 4,680 tonnes.

Table 3: Landings (tonnes) of Norway lobster by UK vessels from SEA7 coastal zone in 1995–2004, overall and by trawl and creel, together with the contributions from the two main fisheries, North & South Minch. The % creel caught in SEA7 shown in parentheses in final column.

Year	N. Minch	S. Minch	SEA7 total	SEA7 Trawl	SEA7 Creel (% creel)
1995	3656	4680	8755	7598	1157 (13.2)
1996	2871	3995	7325	6433	892 (12.2)
1997	3046	4345	7957	7015	942 (11.8)
1998	2441	3730	6720	5762	958 (14.3)
1999	3257	4051	7808	6838	970 (12.4)
2000	3246	3952	7601	6300	1301 (17.1)
2001	3259	3992	7679	6252	1427 (18.6)
2002	3440	3305	6991	5610	1381 (19.8)
2003	3268	3879	7387	5870	1517 (20.5)
2004	3082	3868	7111	5519	1592 (22.4)

These two areas combined have accounted for 92 -98% of the landings from SEA7 in recent years. Landings from Stanton Bank, to the west of the S. Minch averaged about 40 tonnes in recent years (Fig. 2). Landings from the Sound of Jura (identified in Fig. 2 as the half statistical rectangle in the SE corner) were around 500 tonnes in the early 1990s (Anon., 2005b) but have since declined, averaging only 20.6 tonnes in the last three years (Fig. 2). A low level of exploitation in deep water over a wide area of continental shelf, west of the Outer Hebrides is evident in Fig. 2. Landings of Norway lobsters from SEA7 into Northern Ireland ports are small, averaging less than 10 tonnes in the period 2003-2005 (R. Briggs, pers. com.).

Table 3 shows that the contribution from creel fishing has risen steadily since 1999, to reach over 22% by 2004. There has been an increase in creel fishing by numbers of the smaller inshore vessels (length, <10m) which are not prevented by their licence entitlements from joining in the Norway lobster fishery.

The value of all Norway lobster landings taken within the SEA7 zone in 2004 was about £21 million, representing 57% of the total value of all shellfish from the zone (Table 2).

A further breakdown of landings from SEA7 by gear type is given for the most recent years in Table 4. As pointed out in an earlier review (Chapman, 2004a), the assigning of Norway lobster landings to different trawl gears is somewhat arbitrary in that it depends, retrospectively, on the relative weights of the crustacean and the total quantity of fish landed. Where Norway lobsters form 30% or more of the weight of landings, it is assumed that they are the main target species and a vessel would be classed as a *Nephrops* trawler. Vessels not meeting this criterion are assumed to have targeted demersal fish with Norway lobster as a by-catch; the gear classification for these vessels in Table 4 is given as 'other' trawl. The gear used by most *Nephrops* trawlers comprises a single net, but some of the larger vessels use twin-rig or multi-rig gears consisting of two or more nets linked together. These gears have a much larger spread, cover more ground per unit time and consequently have much greater fishing power than single-rig trawls. Because of this, the use of this type of gear is subject to additional technical restrictions (see below).

Table 4: Landings of Norway lobster (tonnes) from SEA7 coastal zone in 2002–2004 by UK vessels using different types of gear.

Year	*Nephrops* trawl-single	*Nephrops* trawl – twin/multi	'Other' trawl	Creel	Total
2002	5000	117	494	1381	6991
2003	5419	119	333	1517	7387
2004	5049	301	170	1592	7111
Mean	5156	179	332	1497	7163
%	72.0	2.5	4.6	20.9	100

Table 4 shows that 72% of Norway lobster landings from SEA7 are made by vessels using single-rig gear and that the use of twin-rig and multi-rig gears is comparatively small. The creel fishery has accounted for over 20% of landings in recent years (see also Table 3).

The seasonal patterns of trawl and creel landings from SEA7 are compared in Fig. 3. Landings are made throughout the year but are generally higher in the spring and summer months. The seasonality of landings is particularly marked in the trawl data, less so in the case of creels. The main reason for this is related to sex differences in burrowing and feeding behaviour, and in burrow emergence rhythms (Chapman, 1980;1987). The fall in landings during the winter months is due mainly to the reduced availability to capture of mature egg-bearing females that tend to remain within their burrows for most of the time. During this period the females tend not to emerge from their burrows to feed but rather rely upon stored food reserves and prey occurring within the burrow system. The decline in landings of females, and hence overall landings, is particularly marked in the trawl fishery (Fig. 3a). In the creel fishery, the presence of bait within the creels provides a strong stimulus for emergence, such that egg-bearing females are relatively more common in this fishery than in the trawl fishery, hence the less obvious contrast between winter and summer landings (Fig. 3b).

An additional reason for the decline in winter landings in the trawl fishery, particularly in the S. Minch, is that effort may be diverted to a seasonal sprat fishery which often takes place in Nov.–Dec.

<u>Stock assessments</u>

In the past, the state of the main Norway lobster stocks was assessed by the ICES *Nephrops* Working Group (Anon., 2003) but in 2005 responsibility for this task was transferred to the ICES Working group for the assessment of Northern Shelf Demersal fish Stocks (WGNSDS) (Anon., 2005b). The justification for this change was that in most management areas the exploitation of Norway lobsters was mainly by trawl gear in which there was a significant by-catch of demersal fish and, because of the smaller mesh size used, a large amount of discarding of under-sized fish. Because of this interaction it was considered desirable to combine fish and Norway lobster assessments rather than to treat them separately.

With the change in ICES working group, there has been a change in the approach to stock assessment. With concerns about the reliability of official landings and fishing effort data, and on the appropriateness of catch–at–age analysis (VPA) for the species, more weight is now given to fishery-independent stock surveys using towed TV camera sledges (Chapman, 1985; Chapman and Bailey, 1987; Bailey *et al*., 1993; Marrs *et al*., 1996; Tuck *et al*., 1997). Counts of burrows can be made and related to observed area of sea bed to provide burrow density estimates. These are then raised to the total ground area to provide estimates of stock abundance and biomass. A random stratified sampling design is used based on the BGS sea bed sediment strata. Survey variance in the abundance is estimated by summation of variance across strata, to provide 95% confidence limits of the estimate. These surveys have been conducted for several years in some areas to provide useful indicators of stock condition.

The results of these surveys for some of the grounds within SEA7 are summarised in Table 5. Fuller details of this work and the methodology are given in Bailey *et al* (1993), Tuck and Bailey (2004), Tuck *et al* (2004) and Anon. (2005b).

For both N. and S. Minch grounds, Table 5 shows that estimates of burrow density and abundance have increased noticeably since 2001. There are some uncertainties as to whether the surveys truly reflect the full distribution of the stock and fishery; for example, no surveys have been carried out in all the sea lochs which are included within the management areas (with the exception of Loch Torridon - see below). Nevertheless, for 2005, ICES recommended an increase in the TAC for the Scottish West coast stocks (which also includes the Firth of Clyde, in SEA6) from 11,300 to 12,700 tonnes, and an even larger increase for 2006, to 17,675 tonnes. As noted previously (Chapman, 2004a), the aggregation of a TAC over several stocks is unsatisfactory because of the difficulty of achieving a balanced exploitation between stocks requiring different management strategies.

Table 5: Time series of Norway lobster burrow density (burrows/m^2) and abundance (millions) estimates on grounds within SEA7, from TV surveys conducted by the FRS Marine Laboratory, Aberdeen (Anon., 2005b). Ground areas given in km^2.

Year	N. Minch		S. Minch		Sound of Jura		Stanton Bank	
	Ground area =1775		5071		474		288	
	density	abundance	density	abundance	density	abundance	density	abundance
1994	0.38	665	No Survey					
1995	No survey		0.30	1520	0.50	190	0.22	64
1996	0.25	439	0.38	1945	0.53	204		
1997	No survey		0.28	1434	No survey		0.28	80
1998	0.41	728	0.38	1916			No survey	
1999	0.32	565	0.23	1146				
2000	0.41	725	0.37	1851				
2001	0.39	691	0.44	2228	0.85	324	0.24	68
2002	0.49	876	0.42	2114	1.24	474	0.27	78
2003	0.64	1131	0.42	2121	0.81	309	0.31	90
2004	0.62	1107	0.50	2543	No Survey		No Survey	

Limited surveys have also been carried out on the shelf edge grounds west of the Hebrides in 2000, 2002 and 2004. Successful TV camera deployments have been achieved at a small number of stations, down to depths exceeding 700 m. Burrow density estimates were very low, mean 0.04/m^2, though the Norway lobster occupants appeared to be larger on average than found on inshore grounds. It should be noted that three species of red crab occur in the same habitat and there is a possibility that they constructs burrows, creating the possibility of confusion in burrow counts (see Section 2.2.7).

Management controls and legislation

New regulations affecting the Norway lobster trawl fisheries in SEA7 have been introduced by the EU as part of a cod recovery plan (EC 2056/2001). This regulation limits trawlers targeting Norway lobsters with 70-99mm mesh size to 25 fishing days per month. Nets also have to be fitted with square mesh and headline panels to permit fish to escape. The headline panel is made from 140mm diamond mesh netting and is fitted on the upper surface of the trawl behind the headline. The effectiveness of this panel is still being evaluated following a series of sea trials by N. Ireland fishing vessels jointly coordinated by the Anglo-North Irish Fish Producers Organisation (ANIFPO), Department of Agriculture and Rural Development (DARD) and the Sea Fish Industry Authority (SEAFISH) (R. Briggs, pers. com.). In addition, Scottish legislation has been introduced (SSI No. 2000/226) for vessels using twin-rig trawls north of 56^{o}N; a mesh size of 100mm or above must be used, without an outer lifting bag and with not more than 100 meshes round the circumference of the cod-end; the latter being made from up to 5mm double twine. Vessels using a single trawl may use 70–99mm mesh, with a lifting bag and 120 meshes round the cod-end, made from 4mm single twine.

The Minimum Legal Size (MLS) for Norway lobsters on the west coast of Scotland, and in the Irish Sea, is 20mm carapace length (with equivalents in terms of total and tail length, 70 & 37mm respectively); this is smaller than in the North Sea, reflecting a slower growth rate and a smaller average size of the lobster in some areas.

The Norway lobster creel fishery, along with similar static gear fisheries for other species, is affected by the terms of the Inshore Fishing Order 1989 (Appendices A & B) which control the use of mobile gear (trawls, dredges) and creels within Scottish inshore waters (6nm from baselines). In some areas, in which there was only a six month prohibition on the use of mobile gear, a degree of conflict ensued between trawl and creel fishermen during the ‘open’ season, with many of the latter suffering damage to, or loss, of creels. This situation was particularly acrimonious in the Loch Torridon area. In 2001, the Scottish Executive agreed that the seasonal prohibition on mobile gear in L. Torridon should be extended to the whole year, initially for a period of five years (SSI No. 2001/174). At the same time, the Norway lobster creel fishermen agreed a management plan for the area which led to the fishery being awarded certification by the Marine Stewardship Council (MSC) in 2003. The management plan is voluntary and includes restrictions on fishing effort, such as limits on numbers of creels and days fishing per year; requires creels to be fitted with escape gaps; requires egg-bearing females to be returned to the sea; requires daily recording of landings and effort data in logbooks; and sets an annual TAC of 100-150 tonnes (Mason *et al*, 2002; Hough, 2004; 2005). As well as reliance on voluntary compliance, another potential weakness in the management plan is that it does not limit the entry of new vessels into the Torridon fishery. This experiment in local management is being monitored by Scottish Natural Heritage (SNH) and FRS. An assessment of the state of the Norway lobster stock in L. Torridon was carried out prior to implementing the new legislation (Tuck and Bailey, 2000) and a further assessment is due in 2006.

Implicit in the award of MSC certification is that the Torridon creel fishery meets certain criteria, namely, that the fishery is managed in a sustainable way and it maintains habitat and species diversity. In general, Norway lobster creel fishing is highly selective, in that very few undersized lobsters are caught, and those that are taken are undamaged, and should survive on being returned to the sea. In addition, the by-catch of non-target species is very small so that the fishery has minimal effect on species diversity. The Norway lobster creels themselves have been shown to have little physical impact on the environment (Kinnear *et al*., 1996). Further work on this, and other related topics is being undertaken in L. Torridon by a PhD student, Jonathan Adey (2006).

The benign nature of the creel fishery, in terms of environmental effects, is in stark contrast to the Norway lobster trawl fishery, where the small mesh trawls used take a large by-catch of undersized demersal fish, unwanted invertebrates and large numbers of undersized target species ((Bergmann and Moore, 2001; Bergmann *et al*., 2002). These discards have a low probability of survival and there is pressure to tackle this problem by means of technical measures, such as the square mesh and headline panels mentioned above. Other methods of reducing the fish by-catch, such as separator trawls and use of rigid sorting grids were discussed previously (Chapman, 2004a), but so far these methods have not found favour with the fishing industry. Trawling disturbance can also have long-term effects on the topography of the sea bed and the benthic fauna (Tuck, *et al*., 1998: Hall, 1999).

2.2.2 European lobster

The European, or common lobster, *Homarus gammarus* (L.), is common around the coasts within SEA7, occurring on rocky shores, reefs and boulder fields from low water down to 60m (Table 1). Details of lobster general biology were given in an earlier review (Chapman, 2004a). A detailed comparative investigation on European lobster populations in the Outer Hebrides and off the Fife coast was carried out by Lizárraga-Cubedo (2004).

<u>Fisheries</u>
Lobsters are exclusively exploited by small inshore vessels using baited creels, which may also catch edible crab, velvet swimming crab and shore crab (Sections 2.2.4, 2.2.5 & 2.2.6). The main areas of fishing are shown in Fig. 4 in terms of the distribution of commercial landings. The largest reported landings come from the islands of the Inner and Outer Hebrides, with relatively smaller contributions from the Scottish mainland coast. Lobsters may be landed at many locations around the coast and they are usually loaded onto special ‘vivier’ trucks for transport alive to continental markets. Lobsters may also be air-freighted to more distant markets.

<u>Landings</u>
Table 6 shows the reported annual landings of European lobsters from SEA7 during the 10 year reference period. Landings from the zone were in the range 280-320 tonnes up to 1998 but have since fallen below 180 tonnes. The likely reason for this decline is that some vessels have switched effort towards other target species such as

edible crab and Norway lobster (see Section 2.2.1). This is certainly the case in the Hebrides, where recent landings of lobsters have declined sharply as vessels have switched from seasonal lobster fishing off the exposed west coast to Norway lobster fishing all year round in the relatively more sheltered waters off the east coast. The relative importance of the landings from SEA7 as a proportion of the Scottish total has varied from around 50% in some years to as low as 26% in 2000. The value of the fishery in SEA7 was about £1.6 million in 2004.

Table 6: Landings of European lobster by UK vessels from the SEA7 coastal zone, compared to the total for Scotland, 1995-2004.

Year	Landings (tonnes)		SEA7 Zone as % of Total
	SEA7 Zone	Scotland Total	
1995	281	567	49.6
1996	322	605	49.5
1997	320	652	49.1
1998	288	638	45.1
1999	167	527	31.7
2000	106	408	26.0
2001	106	301	35.2
2002	136	328	41.5
2003	147	288	51.0
2004	170	413	41.2

Landings of European lobster from the SEA7 zone at Northern Ireland ports are small, averaging about nine tonnes in the period 2003-2005 (R. Briggs, pers. com.). Most of these landings were taken off the coast of N. Ireland.

Fig. 5 shows that the highest landings are taken in the summer months, peaking in Aug.-Sept. In terms of the availability of the lobsters to capture, the Dec. peak in landings is an artefact caused by the widespread storage of lobsters, in shore ponds or in sea cages, to meet the high Christmas demand (associated with higher prices).

Stock assessment

EU member states are responsible for assessment of lobster stocks and for taking management action. The FRS Marine Laboratory carries out stock assessments on an irregular basis, the most recent review being in 2001 (J. Kinnear, pers. com.). The area within SEA7 was divided into several management units, Outer Hebrides, South Minch, Northwest mainland, and the area around Mallaig. The assessments concentrated on the first two of these units (Fig. 4); for the others, basic information was considered inadequate for detailed analysis. Although the assessments assume that each stock is homogeneous and in equilibrium, this is unlikely to be the case because of the discontinuous nature of lobster distribution within each area and the likelihood of varying environmental influence on biological parameters.

The main approaches to the assessments were Length Cohort Analysis (LCA) and, to a lesser extent, analyses of catch per unit effort (CPUE) data derived from logbooks supplied by volunteer fishermen. The length-based LCA method (Jones, 1974) is widely used for crustaceans which are difficult to age accurately. The method uses average length distributions from samples of the population, together with growth and natural mortality parameters to generate estimates of fishing mortality, abundance and biomass. This information can then be used to assess the state of stocks and to predict the likely effects of changes in fishing effort or MLS on long-term yield and stock biomass. Because of differences in growth and length/weight relationships, male and female lobsters were assessed separately.

Outputs from the LCA model for Hebrides lobsters suggested that current fishing effort was well above optimum in males but was about optimum in females. For males, a 50% reduction in effort should generate a 10% increase in long term yield at the same MLS (currently 87mm); however, this would result in a large reduction in the long-term yield of females. In both sexes, an effort reduction could lead to a large long-term increase in stock biomass. The analysis for the S. Minch stock produced essentially similar results. The main conclusion for both stocks was that an effort reduction would not generate additional long-term yield because the predicted gains from males would be balanced by losses from the females, but there would be a potential saving for fishermen in terms of a large reduction in fishing costs, such as fuel and gear. In other words, fishermen could obtain the same yield as now but at a greatly reduced cost, and therefore with higher profits. The main biological benefit would be a large increase in stock biomass with a possibility of enhanced recruitment. This scenario may well come about since, as we have seen from the landings data (Table 6), there has been a substantial fall in effort recently.

The other approach to assessment was to look at a time series of catch and effort data from records in a limited number of fishermen's logbooks. This information was used to estimate a time-series of CPUE, which is assumed to be proportional to stock abundance or biomass. These data were analysed using a Generalised Additive Model (GAM) (Lizárraga-Cubedo, 2004). The results for both Hebrides and S. Minch stocks indicated a steady decline in CPUE from the 1970s to the present. In both stocks, there was a strong seasonal trend in CPUE, similar to that for the landings (Fig. 5), with high values in the summer months, peaking in Aug.

Management controls and legislation

As we have seen in the case of Norway lobsters, creeling for European lobsters and various crab species, as well as the deployments of other forms of static gear (lines, fixed nets) are protected in some SEA7 areas from disturbance by mobile gear under the terms of the Inshore Fishing Order (Appendix A). In addition there are certain areas where creeling is prohibited at certain times of the year as a conservation measure (Appendix B).

Other regulations applying to lobster fishing in the SEA7 zone are; a MLS of 87mm carapace length (CL), an upper CL limit of 155mm in females, a ban on the landing of 'V'-notched lobsters and a 60mm minimum mesh size in parlour creels (Chapman, 2004a). The maximum size limit for females and V-notching experiments are designed to protect large, mature, highly fecund females in order to boost egg production and subsequent recruitment of juveniles. Whether these measures are effective is unclear. For example, many V-notching experiments have been carried out in UK waters and elsewhere, but in some cases without any thought as to how to monitor them and judge their success or failure. A recent V-notching experiment in the Outer Hebrides provides a good example of this. In 2000-2001, 7,367 female lobsters were V-notched and released at different locations off the west coast of the Outer Hebrides, from Lewis to Barra. The purchase of lobsters for the experiment, at full market price, was funded by the EU. To monitor the experiment fully over a five year period, the fishermen were required to keep logbooks in which daily lobster catch and effort were recorded, including the numbers of V-notched females taken and re-released. These data were to be sent to FRS for analysis. Unfortunately, the amount of logbook information received by FRS proved to be totally inadequate and as a result this experiment cannot be evaluated.

The idea of constructing artificial reefs to increase the availability of shelter for lobsters and to aggregate fish shoals was discussed in the previous review (Chapman, 2004a). Such a reef has been constructed off the island of Lismore in Loch Linnhe, near Oban. The reef consists of 24 modules, each consisting of 4,000 concrete blocks made from waste materials from a nearby quarry, Yeoman (Morvern) Ltd., a partner in the project. The reef extends to an area of about $1km^2$ and is one of the largest in Europe. Construction started in 2001 and colonisation of the reef by fauna and flora, including European lobsters and fish, is being closely monitored by scientists of the Scottish Association for Marine Science (SAMS), Dunstaffnage Marine Laboratory, Oban (Anon., 2004a). The idea of designing offshore wind farms to act as artificial reefs for lobsters and other species was considered earlier (Chapman, 2004a).

As in the case of Norway lobster creel fishing, the creels used in the European lobster fishery are not thought to have any long-lasting environmental impacts (Eno *et al*., 2001). Similar conclusions apply to other crustacean creel fisheries, for crawfish, edible crab, velvet crab and shore crab (Sections 2.2.3-2.2.6).

2.2.3 Crawfish

The common crawfish, *Palinurus elephas* (Fabricius), also known as the red or European spiny lobster is widely distributed in the Mediterranean Sea and in the NE Atlantic, from the Azores to Norway. It is common off the south and west coasts of the British Isles where it inhabits mainly rocky reefs at depths of 20-70m (Hayward and Ryland, 1995). It occurs off the west coast of Scotland, though it is not thought to be particularly abundant (Ansell and Robb, 1977).

<u>Biology</u>

Very little is known about the biology of crawfish in Scottish waters, so that information about them has to be inferred from studies elsewhere. In UK waters, females moult from Jul.-Sept. and males moult during the winter. Males grow to a larger asymptotic size than females but, for a given CL, have a smaller total length than females (Hunter, 1999). Crawfish feed mainly on a mixed diet of molluscs, crustaceans, echinoderms and fish (Hunter, 1999; Goñi *et al*., 2001).

Ovigerous (berried) females are found from Sept. onwards and the eggs are carried beneath the abdomen for about nine months in Atlantic waters. In the Mediterranean, female fecundity was reported to range from 23,000 to 202,000 eggs, depending on female size (Goñi *et al*., 2003); this is much lower than for many other spiny lobster species (Hunter, 1999). Hatching of the 3mm leaf-like phyllosoma larvae occurs in the early summer. There are 10 phyllosoma stages before metamorphosis to the puerulus stage, which has a total length of 21mm. After three more moults a postpuerulus or first juvenile stage is reached, having the visual appearance of the adult. This leaves the pelagic environment to adopt the bottom-living habits of the adult. The larval phase lasts several months during which the larvae may be dispersed over large distances. It is postulated that the occurrence of non-breeding crawfish in Norwegian waters results from the drift of larvae from the west coast of Scotland, or more probably Ireland, and not from adults breeding locally (Phillips and McWilliam, 1986).

Adult crawfish are known to migrate, although to what extent is unclear. From published information on closely related species (eg. Herrnkind, 1980), and from the seasonal pattern of the fishery (see below), crawfish in Scottish waters almost certainly migrate between shallow and deep water, and vice-versa, probably as part of their reproductive strategy. In early summer the lobsters move into shallow water to moult, mate and spawn. At this time, they become available to capture by fishing gear. After spawning in the autumn, it is likely that there is an offshore migration to over-winter in deeper water. It is unclear as to whether the return of females to inshore waters takes place before or after the eggs hatch. The fact that Ansell and Robb (1977) found females inshore with eggs about to hatch in the spring, and females with newly spawned eggs in the autumn suggests that the migration inshore occurs before hatching of the larvae. After hatching, the larvae will be dispersed by wind-driven and ocean currents. There is good evidence from other closely related species, that the dispersal of larvae by water currents is not a random process and that, through vertical migration behaviour, the larvae can select ocean currents, which after metamorphosis to the puerulus stage, return them to suitable adult habitat (Phillips and Mc William, 1986).

As a group the spiny lobsters are characterised by some interesting aspects of social behaviour, including sound production (the crawfish is know to do this) (Phillips *et al*., 1980), single-file queuing behaviour on migration (Herrnkind, 1980) and communal aggregation, sometimes in reef shelters or ‘dens’ (Atema and Cobb, 1980). These aspects have not been fully investigated in crawfish. According to Mercer (1977), a female that has recently moulted and is ready to mate, will emit a specific sound by rubbing the antennae against the rostrum, in order to attract a mate.

<u>Fisheries</u>

The fishery is relatively small with most landings coming from the Outer and Inner Hebrides. Crawfish are caught as a by-catch in the European lobster creel fishery (Section 2.2.2), in the bottom-set tangle net fishery for monkfish or in a targeted fishery using a type of creel known as an ‘inkwell’ pot by virtue of its shape, with a single top entrance. Some crawfish are taken by SCUBA diving.

<u>Landings</u>

Virtually all the landings of crawfish by UK vessels in Scotland come from the SEA7 zone. Table 7 shows that landings of 34-54 tonnes were made up to 1997 but they have since declined to a very low level. Most landings are made in the summer months, from May-Sept. No landings of crawfish from the SEA7 zone have been reported in N. Ireland (R. Briggs, pers. com.).

Table 7: Landings (tonnes) by UK vessels of three minor crustacean species, crawfish, red crab and squat lobster, from the SEA7 coastal zone, 1995-2004.

Year	Landings (tonnes)		
	Crawfish	Red crab	Squat lobster
1995	54.3		2.4
1996	38.1		3.1
1997	34.0		1.6
1998	11.5		11.0
1999	4.7		5.5
2000	3.7	3.0	4.2
2001	4.9		8.1
2002	3.2	78.4	2.3
2003	5.1	141.9	1.2
2004	3.8	35.3	0.4

Stock assessment, management and legislation

In 1980, FRS undertook two surveys for crawfish using tangle nets operated from commercial fishing vessels (Strange, 1980). Reasonable catches of crawfish were taken during Aug.-Sept. in coastal waters west of the Hebrides and around the Flannan Isles; none were caught at St Kilda. An unfortunate feature of the surveys was a large unwanted by-catch of seals, so these trials were never repeated. The fishery is currently too small to warrant assessment in Scotland, where the species is probably at the northern limit of its distribution. Although the species is found in Norway, no berried females have been reported there, suggesting that the specimens found may have arrived via larval drift. With climate change, it is conceivable that crawfish may become more common in Scottish waters in the future. The only legislation applying to crawfish is an EU MLS of 110mm CL.

2.2.4 Edible crab

The edible or brown crab, *Cancer pagurus* (L.), is found in similar inshore habitat to the European lobster, but also occurs on other sea bed sediments such as gravel, sand and mud down to a depth of around 100m (Table 1). It occurs throughout the SEA7 coastal zone and a reasonable appreciation of its distribution can be seen in Fig. 6, which shows the geographical location of the landings. Details of the general biology of edible crabs may be found in a previous review (Chapman, 2004a) and in Edwards (1978).

Fisheries

The edible crab is generally fished by inshore vessels that also target European lobster (Section 2.2.2) and velvet crab (Section 2.2.5). The main ports for SEA7 landings are Ullapool, Stornoway, Kinlochbervie and Portree. Most crabs are landed alive and exported live to continental markets; some are sent for processing at plants on the Scottish mainland. Some larger 'vivier' (these have facilities for keeping crabs alive on longer than normal voyages) vessels registered in England and the Channel Islands also occasionally fish for edible crab within the SEA7 zone, though most of their landings come from outside the zone in an area N. of Sule Skerry, NW of Orkney. These vessels mainly land their catches at Ullapool or Scrabster. The main method of fishing is by baited creels. To some extent, fishermen can vary the target species between lobster and edible crab by positioning of the gear and by the choice of bait; fresh, not salted, fish bait is used for edible crab whereas either type of bait is suitable for lobsters.

Table 8: Landings (tonnes) of edible crab by UK vessels from the SEA7 coastal zone, compared with the total for Scotland, 1995-2004.

Year	Landings (tonnes)		SEA7 zone as a % of total
	SEA7 zone	Scotland total	
1995	3663	6568	55.8
1996	3569	7243	49.3
1997	3826	7675	49.9
1998	3829	8014	47.8
1999	3279	7722	42.5
2000	3710	9615	38.6
2001	3787	8558	44.2
2002	3487	7693	45.3
2003	3281	7257	45.2
2004	2929	6937	42.2

Landings

The spatial distribution of edible crab landings from the SEA7 zone is shown in Fig. 6. The largest landings come from inshore waters around the Outer Hebrides and around Skye, Mull and Islay. Table 8 shows the trend in recent landings from the SEA7 zone. Landings have averaged around 3,500 tonnes in the last 10 years for which data are available but there has been a slight fall in the last two years of the series. There has also been a gradual fall in the relative contribution from SEA7 to the overall total for Scotland as a whole. This decline is likely to have resulted from the switch to Norway lobster creel fishing by some vessels, as mentioned in Section 2.2.1. Landings of edible crab from the SEA7 zone into N. Ireland ports averaged 34 tonnes in the period 2003-2005, most of which were caught locally (R. Briggs, pers. com.). In 2004, the edible crab fishery within the SEA7 zone was estimated to be worth £3.1 million to UK fishermen. The monthly variation in landings is shown in Fig. 7. Fishing takes place throughout the year, with higher landings in the last six months.

Some information is available on landings of edible crab in the Irish Republic from the Report of the ICES Study Group on the biology and life history of crabs (SGCRAB) (Anon., 2005d). The Irish crab fishery in ICES area VI is one of the largest and commercially important fisheries in Europe. This species was one of the top five most valuable in terms of landings into northwest Irish ports in 2001-2003. Annual landings in 2001-2003 were in the range 6,000-7,500 tonnes. Based on records of fishing effort from fishermen's logbooks, it is estimated that about 50% of these landings were derived from the SEA7 coastal zone. Thus, this fishery is on a par with that in Scotland (Table 8).

Stock assessments

As for European lobsters (Section 2.2.2), responsibility for assessing the state of edible crab stocks, and for taking management action, lies with EU member states. FRS carries out assessment of stocks from time to time, the most recent analysis being in 2001 (J. Kinnear, pers. com.). Within the SEA7 zone, the management areas chosen for review are the same as for lobsters, namely Hebrides and South Minch (see Fig. 4). The approaches adopted for assessment of edible crab were the same as for

European lobsters, namely use of LCA, with sexes analysed separately, and a time series of CPUE data from fishermen's logbooks.

The LCA results were essentially similar for both stocks in showing very flat-topped yield/recruit curves in both sexes, and suggesting that current fishing effort was close to the optimum level. The analysis showed that a reduction in effort would not increase long-term yields but there should be a substantial saving in terms of operating costs, resulting in a more economic fishery. An effort reduction should also bring about a substantial increase in stock biomass. The analysis of CPUE data from the logbooks of some fishermen using the GAM approach showed that in each area CPUE had increased in the most recent years, due mainly to specific targeting of edible crab and improved quality of the crabs. At the beginning of the fishery off the Hebrides in the 1970s, the quality of the crab was poor, the stocks being dominated by old diseased animals; once these were removed, the productivity of the fishery increased.

Information concerning the state of the edible crab stock in ICES region VI (part of SEA7 zone is within this region) is also available from Irish studies (Anon., 2005d). Landings per unit of fishing effort (LPUE, kg/creel) data were extracted from a small number of fishermen's logbooks. This showed that LPUE, assumed to be a function of stock biomass, declined between 1990 and 1994 as the offshore fishery developed and older diseased crabs were removed. LPUE was more stable up to 2000 but has since declined further.

Management controls and legislation

Creel fishing for edible crab within the SEA7 coastal zone is governed in a similar way to lobsters (Sections 2.2.1 & 2.2.2) by the terms of the Inshore Fishing Order (Appendices A & B). Other controls relevant to edible crabs are; a MLS of 140mm carapace width (CW), a ban on landing berried females, a ban on landing 'soft' recently moulted crabs and a limit on the landing of crab claws. The problem posed by the landing of crab claws (Tallack, 2002; Chapman, 2004a) appears to have receded (J. Kinnear, pers. com.).

2.2.5 Velvet crab

The velvet swimming crab, *Necora puber* (L.) is found in the same type of habitat as the European lobster, on inshore reefs and kelp beds. The species is found throughout the SEA7 coastal zone and an indication of its distribution is given by Fig. 8. Some details of the general biology of velvet crab were provided previously (Chapman, 2004a). The species has also been investigated in the Firth of Clyde and elsewhere (Skye, N. Uist and the Summer Isles), as part of a PhD studentship (Combes, 2002).

Fisheries

Velvet crabs are caught in creels baited with fresh fish and form an important component in the mixed creel fishery with European lobster, edible crab and, to a lesser extent shore crab. Velvet crabs are either fished with standard lobster creels, or using specialised creels which are smaller and lighter in weight than lobster creels. The crabs are landed and transported live to continental markets, particularly to Spain.

Table 9: Landings (tonnes) of velvet crab by UK vessels from the SEA7 coastal zone, compared with the total for Scotland, 1995-2004.

Year	Landings (tonnes)		SEA7 as a % of total
	SEA7 zone	Scotland total	
1995	2877	3713	77.5
1996	1984	2788	71.2
1997	1901	2816	67.5
1998	1542	2436	63.3
1999	1098	1882	58.3
2000	1272	2425	52.5
2001	1078	2243	48.1
2002	1127	1986	56.7
2003	924	1517	60.9
2004	1185	2298	51.6

Landings

The distribution of the recorded landings within the SEA7 coastal zone is shown in Fig. 8. The largest landings are taken around Islay, Mull and in parts of the Outer Hebrides. The recent landings are given in Table 9 and compared with landings from the whole of Scotland. Landings from SEA7 have varied from 924 to 2,877 tonnes in the period 1995-2004. There has been a gradual decline in landings due to the partial switching of effort by inshore vessels towards Norway lobsters (Section 2.2.1). In most years, the SEA7 zone accounts for over half of all Scottish landings. In 2004, the value of this fishery was estimated to be £1.6 million. In 2003-2005, there were no reported landings of velvet crabs from SEA7 into N. Ireland ports (R. Briggs, pers. com.). The seasonal pattern of landings is shown in Fig. 9. Velvet crabs are caught throughout the year, with higher landings being made in the last six months of the year.

Stock assessments

The most recent assessment report on creel-caught crustaceans by FRS includes velvet crab for the first time. The approaches adopted were similar to those employed for European lobster and edible crab, namely LCA using size composition data and analysis of a time series of CPUE data from fishermen's logbooks (J. Kinnear, pers. com.). Assessments were carried for the Hebrides and S. Minch management areas, with both sexes being analysed separately. The LCA outputs were used to generate yield per recruit curves (Y/R) as a means of predicting the long-term effects on yield and stock biomass of changes in the level of fishing effort.

For the Hebrides stock, the curves were very flat-topped in both sexes, particularly so in males, and indicted that current effort was above the optimum level. A 50% reduction in effort would be expected to generate a 5% increase in long-term yield but there should be substantial saving in the costs of fishing and a significant rise in profits. Such an effort decrease should result in a substantial increase in stock biomass. The analysis for the S. Minch stock arrived at essentially similar results and conclusions. Analysis of a time series of CPUE information from both stocks showed an increase in values during the 1990s, as velvet crab became a target species rather than a by-catch species in the European lobster fishery, and specialised creels for velvet crab were introduced. The analysis also shows a marked seasonal variation in CPUE with a notable peak in values during the winter and very low values during

June, following the main moulting season, when many crabs are 'soft' and in poor condition. These observations in the past prompted the idea that there should be a closed season for velvet crab fishing in the summer months. So far, the Shetland stocks are the only ones to receive this protection, from May to Sept., through a local by-law introduced, within the framework of a Regulated Fishery Order (RFO) by the Shetland Shellfish Management Organisation (SSMO).

Management controls and legislation

The fishery for velvet crab within the SEA7 zone is unregulated apart from a national MLS of 65mm CW.

2.2.6 Shore crab

Fisheries

The shore crab, or green crab, *Carcinus maenus* (L.), is very common in the littoral zone and also occurs in deeper water down to 200m. The species occurs throughout the SEA7 coastal zone where it forms the basis of a small fishery. The species is mainly landed as a by-catch in the creel fishery for velvet crabs (Section 2.2.5). The largest shore crabs are retained and used to supplement consignments of velvet crabs sent by vivier lorry to continental markets. Shore crabs that are about to moult are also used as bait by anglers though the extent of this exploitation is not known (Fowler, 1992).

Landings

Table 10 shows recent landings by UK vessels from the SEA7 zone, compared to the totals for the whole of Scotland. At the beginning of the time series, landings ranged from 170 to 270 tonnes and the SEA7 zone contributed a relatively high proportion of Scottish landings. Since 1998 however, landings from the SEA7 zone have fallen sharply to around 30-50 tonnes, representing only 11-17% of Scottish landings, and the estimated value of this fishery in 2004 was only £18,800. There are no reported landings of shore crabs from the SEA7 zone into N. Ireland ports (R. Briggs, pers. com.).

Table 10: Landings (tonnes) of shore crab by UK vessels from the SEA7 coastal zone, compared with the total landings for Scotland, 1995-2004.

Year	Landings (tonnes)		SEA7 zone as a % of total
	SEA7 zone	Scotland total	
1995	259	470	55.1
1996	277	354	78.2
1997	170	407	41.8
1998	177	462	38.3
1999	78	259	30.1
2000	50	304	16.4
2001	44	320	13.8
2002	52	362	14.4
2003	37	218	17.0
2004	30	258	11.6

The pattern of seasonal landings is shown in Fig. 10. Although shore crabs are landed throughout the year, the highest landings are made at the end of the year in

Nov.-Dec. Since the two fisheries are inter-linked, there is, not surprisingly, some similarity between the seasonal landings of shore crab and velvet crab (Figs. 9 & 10).

Stock assessments, management and legislation

Shore crabs are only lightly exploited as a by-catch species and there are no management controls in place. No stock assessments have been carried and there is a dearth of information about the population biology of this species.

2.2.7 Red crabs

The commonly used name, red crab, which forms the basis of a small deep water fishery in the SEA7 zone, is probably *Chaceon affinis* (Milne Edwards & Bouvier), formerly referred to in early literature as *Geryon affinis.* The distribution of this species, however, overlaps geographically with two other related species, *Chaceon gordonae* (Ingle, 1985) (formerly, *Geryon gordonae*) and *Geryon trispinosus* (Herbst) (formerly *Geryon tridens*). All three species have a widespread distribution in the eastern Atlantic Ocean (Clark, 1986) and are likely to occur together within the SEA7 zone. The main reason for thinking that *C. affinis* is the most likely candidate for exploitation is simply their larger size. The three species also overlap in recorded depth range, though *C. gordonae* appears to have a narrower depth range than the other two species and has not been found shallower than 1150m; the ranges are, for *G. trispinosus*, 40-2,220m; for *C. gorgonae*, 1,153-2,045m; for *C. affinis*, 339-2,047m.

Biology

The red crab, *C. affinis* inhabits oceanic seamounts in deep water, 300-1,000m, on the continental shelf and slope within the SEA7 zone. The species is found on Hatton, Rosemary and Rockall Banks, on the Wyville-Thomson Ridge and west of St Kilda. In these areas best creel catches were obtained over the depth range 550-650m, where catch rates averaged about one crab per creel (Shelton & Dooley, 1982). There are conflicting reports concerning the habitat of red crab; Shelton and Dooley (1982) found the species on rocky and stony sediments at the Rockall and Rosemary Banks, but also on smoother grounds on the Ymir Ridge; Anon. (2006a), Fernádez-Vergaz *et al*. (2000) and Pinho *et al*. (2001) suggested similarly varied habitat preferences. Red crabs are also known to occur on fine mud sediments and it has been suggested that they may excavate burrows. Underwater photographs taken on the Porcupine Bank show *G. trispinosus* in close proximity to large burrow entrances (Attrill *et al*., 1991) and these burrows were not thought to belong to Norway lobsters which certainly occur in adjacent areas.

Creel catches of *C. affinis* generally show a skewed sex ratio; Shelton and Dooley (1982) found more males than females in the ratio 2.3:1 and Stroud *et al*.(1979) reported a similar sex ratio of 2.1:1 in favour of males. Similar observations were reported for a population off the Azores (Pinho *et al*., 2001). This finding may be explained by an apparent sex difference in depth distribution, with females occurring in shallower depths than the males. Very little is known of the life-cycle of red crab within the SEA7 zone, though it is likely to follow the typical pattern of most brachyuran crabs, with mating following the female moult, egg carrying under the female abdomen, and a series of larval stages before juvenile settlement on the sea bed. There have been a number of investigations on *C. affinis* in other areas (Fernádez-Vergaz *et al*., 2000; Pinho *et al*., 2001), and on closely related species, which may offer some clues as to the life-cycle of *C. affinis* in the SEA7 zone (Hastie and Saunders, 1992; Hastie, 1995; Steimle *et al*., 2001).

Berried female *Chaceon quinquedens* are found in shallower water than the males (Steimle, 2001). The eggs are carried by the female for around nine months. There are four planktonic larval stages and the duration of this phase varies from 23 to 125 days depending on temperature. It seems that dispersal of the larvae may take them away from the coast so that by the time of metamorphosis, the megalopa or juvenile stage, settles on the sea bed in very much deeper water than the adults. The post-juveniles and adults gradually move up into shallower water, the females moving further up the slope than the males. As a consequence, there is usually an inverse relationship between red crab mean size in samples and depth (Pinho *et al*., 2001; Steimle, *et al*., 2001). Growth is thought to be very slow in *Chaceon affinis* and *C. quinquedens*, although both species ultimately attain a large size. Maximum sizes of male and female *C. affinis* caught on the Rockall and Rosemary Banks were 230 and 180mm CW respectively (Stroud *et al*., 1979; Shelton & Dooley, 1982). Older red crabs could moult as infrequently as once every five years and often show evidence of shell disease, such as lesions caused by chitinoclastic bacterial infections (Stroud *et al*., 1979; Steimle *et al*., 2001; Pinho *et al*., 2001).

The sexual maturation of *C. affinis* has been studied for a population around the Canary Isles (Fernádez-Vergaz *et al*., 2000). On average, male crabs attained sexual maturity at about 129mm CW; for females, estimates varied from 108mm CW based on ovary stage, to 113mm CW based on evidence of mating having taken place. It is likely that size at maturity will vary geographically, possibly in relation to growth rate.

Fisheries

The fisheries for red crab within the SEA7 zone are largely centred on Rockall, Hatton, George Bligh and Rosemary Banks. For the most part they are poorly documented, and it is clear that landing statistics are under-reported by national fleets. Red crab are landed as a main target species using tangle nets and baited 'inkwell' pots, and also as a by-catch from bottom set gill-net fisheries for angler fish, sharks and other deep-water fish. (Anon., undated; Hareide *et al*., 2005; Gordon, undated). Three UK registered vessels fish for red crab on Rosemary and George Bligh Banks, with angler fish and various shark species as the main by-catch. Most landings are made at Ullapool and Lochinver. In addition, there are over 25 UK and German registered gill-net vessels that fish primarily for deep sea fish but may land some red crab as a by-catch. Many of these vessels, although nominally registered in the UK, are Spanish owned and most of their landings are made at La Coruna in Spain. Although the number of vessels is modest, their fishing effort using gill-nets can be very large. The nets are made from monofilament netting, mesh size 280mm ('Rasco' type for angler fish) or 160mm ('Jata' type for sharks), each net panel measuring 50m in length. A typical vessel will shoot fleets consisting of 300-1,000 of these net panels giving an overall net length of 15-50km. Additional information concerning the deep water fisheries in SEA7 are given in a separate review by Gordon (2006).

Landings

Scottish landings of red crab by UK vessels are given in Table 7. There were no landings reported before 2000 but from 2002 to 2004, annual landings were in the range 35-142 tonnes. These landings refer to the SEA7 coastal zone defined by ICES statistical rectangles in Fig. 1 and were likely to have been made on grounds west of St Kilda and on Rosemary Bank In addition to these, there were some landings from within the SEA7 outer zone beyond 11^{o}W that are not included in Table 7. When the largest landings of 142 tonnes were made in 2003, an additional 51 tonnes were landed from the outer SEA7 zone giving an overall total of 192 tonnes from SEA7 zone as a whole. This represented about 60% of all red crab landings (314t) into Scotland in 2003. The landings of red crab from the SEA7 zone into Spanish ports are unknown. There are no landings of red crab at N. Ireland ports (R. Briggs, per. com.). In 2004, 74 tonnes of red crab were landed from the whole SEA7 zone, valued at £136,000.

<u>Stock assessments, management and legislation</u>
No assessments have been carried out for red crab stocks within the SEA7 zone, an omission which really needs to be addressed (see Section 5). Since the species grows and matures relatively slowly, and little is known about recruitment patterns, it is regarded as being particularly vulnerable to over fishing (Steimle *et al*., 2001). It would seem that underwater TV camera surveys would be a suitable method to accomplish this. TV cameras have been deployed by FRS at depths exceeding 700m (C. Shand, pers. com.) as part of a deep water Norway lobster survey (Section 2.2.1; Anon., 2005b). Work is also required on the composition of red crab resources in terms of species and their relative abundance. It also needs to be established whether all three species inhabit burrows.

The fishery for red crab is unregulated; indeed, there are few controls affecting the exploitation of deep sea fish (Anon., undated; Anon., 2005c; Hareide *et al*., 2005; Gordon, undated), and even those regulations which are in place have proven to be extremely difficult to enforce. In 2002, the EU passed several new regulations, including TACs, for several deep sea fish species. A major problem with the deep sea fisheries is loss of gear and dumping of damaged gill-nets, which continue to 'ghost fish' (Hareide *et al*., 2001; Sancho *et al*., 2003; Large *et al*., 2005). In 2005, the EU Council of Ministers introduced a ban on gill netting, in depths below 200m for waters to the west of Scotland and Ireland, initially for one year to give time for a proper management regime to be put in place (FRS, 2006). There is an area in the SW corner of Rockall Bank, known as the 'haddock box', closed to all fishing methods, other than long-lining, in order to protect juvenile haddock and there are proposals to close other areas on Rockall and Hatton Banks in order to protect vulnerable cold-water corals (Anon., 2005c).

2.2.8 Other crustacean species

<u>Squat lobsters</u>
There are two species of squat lobster occurring within the SEA7 coastal zone. These are *Munida rugosa* (Fabricius) and *M. sarsi* (Huus); the former is the more common species on the main fishing grounds and is likely to account for a higher proportion of the landings. Both species have a broad depth range but appear to differ in their depth preferences (Rice and Saint Laurent, 1986); for a given locality, *M. rugosa* tends to occur at shallower depths than *M. sarsi* (30-300m compared with 200-1,000m respectively). Both species generally occur on the edges of Norway lobster grounds and are mainly landed as a by-catch in the trawl and creel fisheries for the latter

species (Section 2.2.1). Squat lobsters inhabit burrows in the sediment, either disused Norway lobster burrows or their own excavations, often situated under stones (Howard, 1981). Further information concerning the fisheries biology of both *Munida* species may be found in a PhD student thesis (Combes, 2002).

Landings of squat lobsters by UK vessels from the SEA7 coastal zone are included in Table 7. Reported landings are small, averaging about four tonnes in recent years. In 2004, the landings were made off the N. Ireland coast and west of the Kintyre peninsular. No distinction can be made between the relative contributions of the two *Munida* species in the landings. It is likely that past landings of the species have been under-reported. Combes (2002) considered the future prospects for expanding the squat lobster fishery. At present the main processors seem reluctant to handle them due to smaller meat yields, compared to Norway lobster, and their greater proneness to damage and spoilage during capture and transport.

No assessments have been made of squat lobster population abundance or biomass, and there are no regulations governing the fishery other than those which apply to Norway lobster fishing gear (Section 2.2.1).

Shrimps

There are no significant fisheries within the SEA7 coastal zone for brown shrimp, *Crangon crangon* (L.), though the species is present on sandy beaches in many areas. The pink shrimp, *Pandalus borealis* Kroyer, which forms the basis of two fisheries in the North Sea (Chapman, 2004a), does not occur on the west coast of Scotland, but two related species, *Dichelopandalus bonnieri* Caullery and *Pandalus montagui* Leach are relatively common (Hayward and Ryland, 1995). These species are often taken in trawl hauls at depths down to around 250-300m. Between 1966 and 1978, the Department of Agriculture and Fisheries for Scotland (DAFS) Marine Laboratory, Aberdeen (now FRS) undertook a series of exploratory fishing surveys, using research ships, and in 1980-81, further surveys were conducted using chartered commercial fishing vessels. The latter trials were a collaborative exercise involving scientist observers from DAFS, the Ministry of Agriculture, Fisheries and Food (MAFF, now DEFRA) and the White Fish Authority (WFA, now SEAFISH). Many of the areas covered by the surveys were within the SEA7 zone but no commercially exploitable pink shrimp stocks were found (Anon., 1981). In 2004, reported landings of pink shrimp from the SEA7 coastal zone were trivial (<150kg).

There are a number of deep water shrimp species which could be marketed commercially and are probably landed in small quantities as a by-catch in the deep water trawl fishery. In 2001, the North Atlantic Fisheries College, Shetland (NAFC) undertook an exploratory trawl survey for deep water shrimp on grounds north and west of Scotland, including west of St Kilda within the SEA7 zone (Bullough *et al*., 2001). A 40mm mesh demersal shrimp trawl, fitted with a separator grid to reduce fish by-catch, was used but catches were disappointing. Nevertheless, several species of shrimp with marketable potential were caught, including *Pasiphaea tarda*, *Segestes robusta* and *Dichelopandalus bonnieri*. The results of this survey were affected by technical problems with the trawl gear and the authors of the NAFC report concluded that the trials would be worth repeating (see Section 5).

2.3 Bivalve molluscs

2.3.1 Giant scallop

The giant or king scallop, *Pecten maximus* (L.), is widely distributed on the west coast of Scotland and supports two major fisheries within the SEA7 coastal zone. The species is also farmed to a limited extend and the future prospects for this form of production are considered in Section 2.5. Details concerning the biology of giant scallops in relation to previous SEA reviews were given by Rogers and Stocks (2001) and Chapman (2004a). For a general account of the fisheries and biology of giant scallops, the book by Mason (1983) is recommended.

Fisheries

Giant scallops are found on sand, muddy sand and shell gravel sediments with a depth range extending from the sub-littoral zone to 100m. The distribution of the species within the SEA7 coastal zone is illustrated in terms of the landings in Fig. 11. The main areas of exploitation are the N. and S. Minch, around the Outer Hebrides, Skye, Mull, Islay and Jura. All of these grounds are within the SEA7 coastal zone.

For assessment and management purposes, FRS define two main areas, West Kintyre and North West based on the groupings of ICES statistical rectangles shown in Fig. 11. Most of the landings from the West Kintyre grounds are made at Port Ellen (Islay), Crinan, West Loch Tarbert and Campbeltown, and those from the North West grounds are made mainly at Mallaig, Gairloch, Ullapool and Stornoway. The main method of fishing, as in the N. Sea (Chapman, 2004a) is by ‘gangs’ of dredges attached to a pair of towing bars, deployed on either side of the vessel. The dredges are fitted with a spring-loaded bar on which a row of ‘teeth’ or tines are mounted. The scallops, which are recessed below the sediment, are dug out by the action of the toothed bar. This method of fishing is potentially damaging to the environment and to underwater installations. A proportion of the landings are taken by SCUBA diving (Table 11).

Landings

Table 11 shows a time series of reported giant scallop landings from the SEA7 coastal zone, in the period 1995-2004. Over this period, total landings from the zone have varied from 2161 to 5583 tonnes, with dredge gear accounting for 84-96% of the landings, the remainder being taken by SCUBA divers. The SEA7 coastal zone accounted for 95-97% of the combined landings taken in the two FRS management areas, North West and West Kintyre, as defined in Fig. 11. The SEA7 landings represent a varying proportion of the total landings for Scotland as a whole, ranging from 25% in 1999, to 61% in 2002. Fig. 12 shows the pattern of seasonal landings of giant scallops from the SEA7 coastal zone. Landings are reported throughout the year with little evidence for any marked seasonal trend. The value of the giant scallop fishery in the SEA7 coastal zone in 2004 was estimated to have been £6.7 million.

In 2003-2005, vessels landed 46 to 86 tonnes of giant scallops from the SEA7 coastal zone at N. Ireland ports. Nearly all of these landings were made in the south of the zone, close to Rathlin Island near the N. Ireland coast (R. Briggs, pers. com.).

Table 11: Landings (tonnes) of giant scallops by UK vessels from the SEA7 coastal zone, by method of fishing and overall, compared to the total landings for the whole of Scotland, 1995-2004.

Year	SEA7 coastal zone			Scotland total (T)	SEA7 zone as % of T
	Dredge	SCUBA diving	Total		
1995	2240	429	2669	9381	28.5
1996	3224	304	3528	9645	36.6
1997	3494	590	4084	9801	41.7
1998	4007	544	4551	9715	46.8
1999	1933	228	2161	8465	25.5
2000	4811	172	4983	8807	56.6
2001	5014	364	5378	9796	54.9
2002	5263	320	5583	9145	61.0
2003	4551	398	4949	10055	49.2
2004	3981	178	4159	11538	36.0

Stock assessments

The main Scottish scallop stocks are regularly assessed by FRS, the most recent assessments being in 2002 and 2005 (Howell *et al.*, 2003; 2006). The FRS assessments are carried out using landings and biological data for two management areas within the SEA7 zone, defined in Fig. 11. These are the areas referred to as North West and West Kintyre. As well as an analytical assessment using VPA, the scallop stocks are also monitored by an annual survey. The state of these stocks was also considered by Chapman (2004b).

Historical landings from West Kintyre show marked fluctuations; peak landings of over 2000 tonnes were recorded in 1969 but fell sharply during the early 1970s, only to increase again to around 1000-1700 tonnes in the period 1975-1985. After another fall in the late 1980s and early 1990s, landings again rose steadily after 1993 to around 1000-1600 tonnes. In 2003, landings from West Kintyre by all methods were 1469 tonnes. For the West Kintyre stock, the FRS report (Howell *et al.*, 2006) drew attention to a recent rise in fishing mortality (F) and to possible declines in spawning stock biomass (SSB) and recruitment. The VPA estimates for F were in line with estimates from survey data but the picture regarding SSB was somewhat at odds with the survey CPUE data, which suggested a rising trend in the abundance of commercial sized scallops. Although the VPA usually performs consistently for this stock, it is possible that it has not done so on this occasion; for example, output in terms of flesh weight yield seems to bear little relationship to the whole weight landings, or to F. A re-evaluation of the stock condition suggested that the fishery was operating in 2000-2001 above the optimum level of F, indicting that the stock could benefit in the long term from a modest reduction in fishing effort (Chapman 2004b).

The FRS North West management area is large and covers 23 ICES statistical rectangles (Fig. 11). The giant scallop grounds within the area have been subjected to periods of relatively heavy exploitation in 1969-1971, in 1981-1984 and from 1994 onwards. In 2002, total landings by all methods from the North West area were 4533 tonnes, the highest ever recorded. Effort transfer from the N. Sea following temporary closure of the latter grounds, due to Amnesic Shellfish Poisoning (ASP) algal toxicity, is the most likely cause of recent increases in landings. The SSB output from the VPA presented a reasonably stable picture and this was supported by survey CPUE data for commercial sizes scallops (Howell *et al*., 2006). The survey CPUE data for undersized scallops suggested a declining trend in recruitment.

In general, the west coast giant scallop stocks do not suffer to the same extent from the problem of highly variable recruitment that occurs in the N. Sea (Chapman, 2004a). The west coast populations usually comprise a broad range of year-classes (ages) indicating reasonably steady recruitment. There are some areas on the west coast where special spat collectors are used to obtain a reliable harvest of young scallops for farming and stock enhancement purposes (see Section 2.5).

<u>Management controls and legislation</u>
Present controls involve licensing of vessels, restrictions on dredge numbers depending in fishing zones, a MLS of 100mm in length and the Inshore Order provisions on use of mobile gear (Appendix A.). Details of these control measures were given in the previous review (Chapman, 2004a). More recently, new legislation has been introduced to control certain technical specifications of scallop dredges, namely their width, number of teeth and size of 'belly' chain rings. This legislation (The Regulation of Scallop Dredges (Scotland) Order, SSI 2005 No. 371) came into force on 21st Jul., 2005 but is not being enforced in the meantime, pending further consideration in relation to the EU Technical Standards Directive. It is too soon to determine whether the new legislation, controlling dredge numbers and their technical specifications, will have any significant impact on the state of scallop stocks.

It is well known that the toothed dredges that account for most giant scallop landings have significant environmental impacts. The harrowing action of dredge teeth can alter bottom topography and biodiversity, and cause mortality of benthic fauna (Eletheriou and Robertson, 1992; Jenkins *et al*., 2001; Lart *et al*., 2003).

2.3.2 Queen scallop

The queen scallop, *Aequipecten opercularis* (L.), is widely distributed on the west coast of Scotland, though within the SEA7 zone, exploitation is more or less limited to one main area. Like giant scallops, the smaller queen is also farmed to a limited extent (Section 2.5). Details concerning queen scallop biology were given in an earlier review (Chapman, 2004a) and are also dealt with by Mason (1983).

<u>Fisheries</u>
The main queen scallop fishery within the SEA7 coastal zone is located in the south of the zone close to the N. Ireland coast near Rathlin Island. Smaller fisheries are located near the Islands of Islay and Mull. The Rathlin Island fishery involves Scottish vessels from Troon, Islay and Tarbert and most of the landings are processed in Ayr or Kirkcudbright. In 2002-2003, about 90% of the landings were achieved using modified dredges, the remainder were caught by otter trawl; in 2004, the latter gear accounted for about half the landings. Vessels from N. Ireland also reported sizable queen scallop landings from the SEA7 coastal zone, especially from around Rathlin Island (R. Briggs, pers. com.). The N. Ireland vessels landed their catches at Scottish ports (A. Henning, pers.com.).

Table 12: Landings (tonnes) of queen scallops in Scotland by UK vessels fishing in the SEA7 coastal zone, compared with the totals for Scotland as a whole, 1995-2004. Also shown are recent landings from the zone by N. Ireland vessels, 2002-2005.

Year	Landings (tonnes)		SEA7 as a % of total	SEA7 landings by N. Ireland boats (tonnes)*
	SEA7 zone	Scotland total		
1995	681	1883	36.2	n/a
1996	83	1901	4.4	n/a
1997	31	5233	0.6	n/a
1998	40	6912	0.6	n/a
1999	285	4962	5.7	n/a
2000	841	4159	20.2	n/a
2001	827	5533	14.9	24
2002	3561	6766	52.6	1107
2003	825	4457	18.5	234
2004	862	2408	35.8	231
2005	n/a	n/a	n/a	87

n/a = not available
* The N. Ireland vessel landings are included in col. 2

<u>Landings</u>
Table 12 shows a time series of annual queen scallop landings from the SEA7 coastal zone. The Scottish landings show wide fluctuations, varying by two orders of magnitude from 31 to 3561 tonnes. The high landings since 2000 are mostly from the fishery near Rathlin Island. Both Scottish and N. Ireland vessels participated in this fishery and, since both fleets landed at Scottish ports, the landings for the two fleets are combined in the SEA7 zone figures in column 2 of Table 12. At its peak in 2002, the combined landings from the Rathlin Island area by Scottish and N. Ireland vessels were 3501 tonnes, representing 96% of all landings (3,561t) from the SEA7 coastal zone.

Fig. 13 shows that queen scallop fishery in the SEA7 coastal zone is markedly seasonal, with most Scottish landings being made in the period from Jul. to Oct. In 2004, the estimated value of the SEA7 fishery for Scottish and N. Irish vessels was £400 thousand.

<u>Stock assessment and management</u>
No assessments have been undertaken for queen scallop stocks within the SEA7 zone. Analytical assessments are difficult for queen scallops because of their short longevity, high natural mortality and variable recruitment. Surveys would offer a better option for assessment, together with catch and effort data from a fishing vessel logbook scheme (see Section 3.1). The Scottish fisheries for queen scallops are unregulated. There is a MLS regulation of 40mm in length, set by the EU, but this is below the size limit imposed by processing plants.

2.3.3 Cockle

The cockle, *Ceratoderma edule* (L.), occurs on sandy, muddy sand and fine gravel beaches, extending from mid-tide level to LWST. While fairly common on suitable habitat within the SEA7 coastal zone, there are relatively few large areas where cockles are sufficiently dense to support viable fisheries. Details on the biology of cockles were given in the previous review (Chapman, 2004a).

Fisheries

The only fisheries within the SEA7 coastal zone are located on several beaches in the Outer Hebrides, principally on Barra, and to a lesser extent on N. Uist, and S. Uist. The only fishing method now permitted is hand raking and gathering.

Landings

Landings of cockles from the SEA7 coastal zone are given in Table 13. Since 1995, when 380 tonnes were landed from the SEA7 zone, the exploitation of cockles has declined to a low level, averaging only 20 tonnes in the last five years of the data series. It is likely that all of these landings have come from the Traigh Mhor strand on the Island of Barra, where part of the cockle beach also serves as the local airport runway! Small landings are occasionally made at a few beaches elsewhere in the Outer Hebrides. In some years (1995, 1997 and 2004) the SEA7 zone accounted for a high proportion of total Scottish landings. Fig. 14 shows the monthly pattern of cockle fishing in the SEA7 coastal zone. The fishery is strongly seasonal, with most landings being made in the spring, from Feb. to May. After Apr.-May, cockles spawn, resulting in a lower meat yield. A seasonal closure during the summer months is normally beneficial to cockle fisheries.

The estimated value of the cockle fishery on Barra in 2004 was £28,000.

Table 13: Landings (tonnes) of cockles from the SEA7 coastal zone, compared to the reported total for Scotland, 1995-2004.

	Landings (tonnes)		SEA7 as a % of total
Year	SEA7 zone	Scotland total	
1995	380	449	84.6
1996	1	110	0.9
1997	37	72	51.4
1998	25	110	22.7
1999	46	120	38.3
2000	25	101	24.8
2001	21	103	20.4
2002	9	98	9.2
2003	22	75	29.3
2004	27	32	84.4

Stock assessments and management controls

The Traigh Mhor strand on Barra, which had sustained a small hand raking cockle fishery for decades came under severe pressure in 1994-1995 with the introduction of a tractor-drawn dredge. This represented a major increase in fishing effort and there were concerns over the sustainability of the resource. The high reported landings of 380 tonnes in 1995 (Table 13) were partly the result of this controversial development.

The Barra cockle stock had been investigated occasionally in earlier years (Mason, 1966; 1970; Farrow, 1974; Chapman *et al*., 1993) and after the introduction of tractor dredging, the Barra and Vatersay Council of Social Services and SNH commissioned a detailed survey in 1995 (McKay and Howell, 1995). This survey clearly showed that the introduction of mechanised harvesting had reduced the stock biomass of cockles from a historical average of around 1,100 tonnes to only 260 tonnes, roughly 25% of the former estimates. As a result of this, and to prevent similar situations arising elsewhere in Scotland, the Scottish Office introduced a national ban on tractor dredging in 1995, under the Inshore Fishing (Scotland) Order. A further survey of the Barra cockle stock was undertaken in 1999 (Chapman and Mckay, 1999). This survey showed a modest improvement in stock biomass, to 413 tonnes, emphasising that recovery of a cockle stock from the effects of over-fishing is often a rather slow process.

In addition to Traigh Mhor, Barra, some other beaches in the Outer Hebrides were surveyed in 1993 (Chapman *et al*., 1993). These were Bagh Mor, South Ford (both S. Uist); North Ford, Baleshare, Grenitote, Valley strand (all N. Uist). Although cockles were found on all of these beaches, their distribution was very patchy and cockle densities at that time were considered to be below the level required for viable fisheries.

2.3.4 Common mussel

The common mussel, *Mytilus edulus* (L.), occurs all round the Scottish coast, generally on rocky shores or gravel beaches, attached to the substrate by means of byssus threads. In sheltered areas, large 'rafts' of mussels may be attached to each other rather than to the substrate. Mussels are usually found from the upper shore level to the shallow sub-littoral zone but they will also settle in deeper water on man-made structures, including oil and gas production platforms, yacht moorings and navigation buoys. Mussel farming is based on the settlement of spat on ropes deployed for the purpose (Section 2.5). Details of the biology of mussels were given in a previous review (Chapman, 2004a).

<u>Fisheries</u>
There are small mussel beds within the SEA7 coastal zone but very little information about their precise location. Fishing is normally conducted using a mechanical dredge.

<u>Landings</u>
A time series of reported landings of mussels from the SEA7 coastal zone is given in Table 14. Sporadic landings were made in some early years in the time series but significant landings were only evident in 2001 and 2002, when 28 and 76 tonnes respectively were marketed. Most of the landings were from one ICES statistical rectangle (44E3) and were probably from a bed in the Outer Hebrides. There is no record of wild mussels from this area being tested under the UK food safety regulations (see Section 4.1) (D. Fraser, FRS, pers. com.).

Table 14: Landings (tonnes) of common mussels from SEA7 coastal zone, 1995-2004

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Landings (t)	0	0	1.3	0	2.0	0	27.7	76.0	1.2	8.7

Stock assessments and management controls

In an earlier review (Chapman, 2004a), it was pointed out that all mussel fisheries in Scotland were privately owned. There is no public right to fish for them, or oysters, since these rights have belonged to the Crown since the 19th Century. Mussel fishing rights are administered by the Crown Estate Commissioners, unless the Crown has ceded them to private landowners or communities. The owner of the rights is responsible for stock surveys and management of the resource. Ownership of the mussel bed in the Hebrides, from which the above landings were reported, is unknown.

2.3.5 Razor shells

There are three species of razor shell (sometimes called razorfish, razor clams or 'spouts') on the west coast of Scotland and a small fishery for them has developed in recent years. The species are the common razor shell, *Ensis ensis* (L.), pod razor shell, *Ensis siliqua* (L.) and curved razor shell, *Ensis arcuatus* (Jeffreys). The latter two species seem to be more prevalent in the landings than *E. ensis*.

Biology

All three species are relatively common. They have elongate narrow shells, shaped like an old-fashioned 'cut-throat' razor, hence their common name. They are usually found from the lower shore down to the shallow sub-littoral zone (Hayward and Ryland, 1995) in fine sand or muddy-sand sediments, in which they burrow. *E. arcuatus* lives on coarser sediments than the other two species. The burrows are vertical and deeper than the length of the occupant. When disturbed, razor shells withdraw rapidly into the burrow using their muscular 'foot' but they are normally found close to the sediment surface when suspension feeding on particulate matter taken in through the inhalent siphon. The three species have similar growth rates but grow to different maximum sizes, 130mm in *E. ensis*, 150mm in *E. arcuatus* and 200mm in *E. siliqua*. Both sexes grow at the same rate and mature at around 100mm, aged three years old. The longevity of razor shells is high; in *E. ensis*, >10 years; in *E. arcuatus*, up to 20 years and in *E. siliqua* up to 25 years. One of the main predators is the edible crab (Shelton *et al*., 1979; Hall *et al*., 1991). Some biological data on growth rate, size and age compositions, length-weight relationships and population density are given in Anon. (1998).

Breeding occurs during the summer. The larvae spend 1-2 months in the plankton before settling as juveniles. A potential problem for fisheries monitoring is that the juveniles of the three species are rather difficult to distinguish. Juvenile settlement tends to be very patchy but can lead to very dense adult beds capable of supporting viable fisheries.

Fisheries

Razor shells are widely distributed within the SEA7 coastal zone and support small scale fisheries in several localities on the Scottish mainland and in the Western Isles. The main harvesting method is by SCUBA diving, with some taken by hydraulic suction dredges. The main species exploited are *E. siliqua* and *E. arcuatus*, the former being the most sought after by virtue of its larger size. The relative contribution of these species to the fisheries varies from area to area (see below). The main markets are in the Far East and continental Europe.

Table 15: Landings (tonnes) of razor shells from SEA7 coastal zone, by method of capture, compared with the totals for the whole of Scotland, 1995-2004

Year	Landings from SEA7 zone			Scotland total (T)	SEA7 as % of T
	Diving	Dredge	Total		
1995	1	26	27	46	58.7
1996	31	0	31	67	46.3
1997	62	0	62	220	28.2
1998	42	19	61	115	53.0
1999	45	0	45	79	57.0
2000	46	0	46	87	52.9
2001	49	0	49	59	83.1
2002	18	0	18	37	48.1
2003	10	0	10	29	34.5
2004	10	3	13	102	12.7

Landings

Table 15 shows a time series of landings of razor shells from the SEA7 coastal zone by method of capture, compared with the overall totals for Scotland. SCUBA diving accounted for all the landings in most years with dredging only contributing significantly in 1995 and 1998. Annual landings from the zone have varied from 10 to 62 tonnes but in some years these have accounted for a large proportion of the total Scottish landings, notably in 1995 and 1998-2001. No landings of razor shells from the SEA7 zone were reported at N. Ireland ports (R. Briggs, pers. com.). Fig. 15 shows that most landings are made from late spring through to the autumn, a cycle largely reflecting weather conditions for diving activities. The estimated value of the fishery in 2004 was £38,000.

Stock assessments

Some assessments have been, or are being done on razor shell stocks within the SEA7 coastal zone. As part of an FRS investigation into the efficiency, selectivity and environmental impact of a novel water-jet based dredge, observations were also made on some aspects of razor shell biology (Anon., 1998). The biological work included assessment of species composition, size and age structure, length-weight relationships, growth and population densities. Also, a research project is currently underway at the University Marine Biology Station at Millport (Muir and Moore, 2002). In this study, populations of razor shells in the Firth of Clyde, the Highlands and the Western Isles are being studied to determine length and age structure, growth, mortality, reproduction and recruitment. Samples from the SCUBA diver based fisheries in these areas are being analysed to show species composition, size selectivity and proportions discarded.

The FRS study (Anon., 1998) was conducted at sites in the Western Isles, L. Carnan, Broad Bay, close to Grimsay and Berneray. *E. arcuatus* and *E. siliqua* were found in all these areas, though there were site differences in relative abundance; *E. siliqua* was the dominant species in catches from all areas apart from Grimsay. Estimates of razor shell density (both species combined) at Grimsay ranged from 2.2 to 14.6/m^2.

A survey of deep burrowing bivalve molluscs, including razor shells, was undertaken in 1989 using a specialised dredging vessel (McKay, 1992). Many areas were sampled within the SEA7 coastal zone, extending from around Islay and Gigha to Loch Eriboll, and including grounds in the Western Isles. The main razor shell species caught were *E. arcuatus* and *E. siliqua*, and in contrast to the later work (Anon., 1998), the former species was more abundant than the latter in most areas and overall (Table 16).

Table 16: Summary of dredge mean catch rates (no./hour fishing) of razor shell species in different parts of SEA7 coastal zone, and list of areas with the highest catch rates (>1000/hr for *E. arcuatus*; >50/hr for *E. siliqua*). Data from McKay (1992).

Area	No. hauls	Catch details	*E. arcuatus*	*E. siliqua*
North West	50	Mean catch/hour	330	7
		Main areas	L.Carron, Raasay & Skye	Gruinard Bay, L. Carron
Western Isles	33	Mean catch/hour	503	31
		Main areas	L.Maddy, Barra	L. Carnan, Eriskay Sound, Barra
South West	41	Mean catch/hour	114	11
		Main areas	L. Ailort	Morar Sound, Tiree & Coll

The results in Table 16 show abundance ratios, *E. arcuatus*:*E. siliqua* of 49:1 on North West grounds, 16:1 in the Western Isles and 10:1 on South West grounds. The highest catch rates of *E. arcuatus* (>1000 shells/hour tow) were obtained in L. Carron, around Raasay & Skye, in L. Maddy, around Barra and in L. Ailort. For *E. siliqua*, the largest catch rates (>50 shells/hour tow) were obtained in L. Carnan, Sound of Eriskay, around Barra, in Morar Sound and around Coll & Tiree. Detailed analysis of the samples of both razor shell species revealed broad length compositions in most areas suggesting that populations were reasonably stable in terms of juvenile recruitment.

One of the potential problems with any dredge based harvesting system for razor shells is the incidence of shell damage which can affect the viability of the fishery. During the 1989 survey (McKay, 1992), the proportions of damaged shells were 12.7% for *E. arcuatus* and 9.8% for *E. siliqua*. In the 1998 water-jet dredge study (Anon., 1998), the proportions of damaged shells varied with site, from 12.2 to 21.8% for *E. siliqua*, and from 5.3 to 14.3% for *E. arcuatus*.

<u>Management controls and legislation</u>
An EU statutory MLS of 100mm is the only technical measure in place but this is well below the size (170mm) acceptable to Far East and European markets. While the SCUBA diver based fishery has little or no environmental impact, the same cannot be said for dredging methods. To excavate the required depth of sediment to catch deep burrowing razor shells involves a dredge system that could incorporate water jets to fluidize the sediment, and suction pumps or an air lift to raise the catch to the surface. Such systems can have a severe immediate environmental impact, producing deep trenches in the sea bed, although depending on site exposure to water currents and wave action, recovery can be quite rapid (Hall *et al*., 1990; Anon., 1998). Suction dredge and water jet fishing methods are banned in certain sensitive areas under the

Inshore Fishing Order 1989 (Appendix A). Given the potential environmental impact of these methods, it would seem prudent to encourage the continuation of razor shell harvesting by SCUBA diving.

2.3.6 Other bivalve species

The native, common or flat oyster, *Ostrea edulis* (L.) is widely distributed in shallow water within the SEA7 coastal zone, where it occurs on hard ground to which it cements itself. Formerly an abundant species, the native oyster is now regarded as threatened by the activities of poachers (Anon., 2006b). The oyster is listed as a priority species in the UK Biodiversity Action Plan. Populations are also affected by competition and predation from introduced species, disease and anti-fouling paints (see Section 4.2). Almost all native oyster beds in Scotland are owned by the Crown Estate so that unauthorised fishing is illegal. Detailed knowledge of the location of wild oyster beds, and landings data, are not available. It seems likely that area closures will be used in the future to protect wild oyster beds (Section 3.4), and perhaps enhance them with cultured stock (Section 2.5).

In addition to razor shells, there are a large number of bivalve mollusc species that burrow deep down into sediments. The dredging survey by McKay (1992) referred to above (Section 2.3.5) identified 13 species, other than razor shells, for which markets could be developed. Palourdes, such as *Venerupis senegalensis* and *Paphia rhomboides*, and surf clams, such as *Spisula solida*, are already exploited to some extent (129t. of surf clams were landed from the N. Sea in 2004). Other potentially exploitable species are, *Glycymeris glycymerus*, *Lucinoma borealis*, *Lutraria angustior*, *L. lutraria*, *Arctica islandica*, *Circomphalus casina*, *Dosinia exoleta*, *D. lupinus*, *Chamelea gallina* and *Mya truncata* . All of these species were found at various locations within the SEA7 coastal zone. It must be stressed that any development of fisheries for these species would involve methods of extraction from the sea bed, potentially harmful to the environment.

2.4 Gastropod molluscs

2.4.1 Whelks

The common whelk, *Buccinum undatum* (L.) is found throughout the SEA7 coastal zone, on all types of sediment at depth from LWST to around 100m. The red whelk, *Neptunea antiqua* (L.) occurs in deeper water from 15-1200m, mainly on softer muddy-sand sediments. The two species are sometimes mixed together in the landings. The red whelk requires careful processing to remove the toxic salivary gland (Reid *et al*., 1988). Details of the biology of the common whelk were given in an earlier review (Chapman, 2004a).

<u>Fisheries</u>

The fishery for whelks in the SEA7 coastal zone is small compared to that in the N. Sea and Northern Isles (Chapman, 2004a). The main fishery occurs in the Sound of Jura, west of the Kintyre peninsula, from where landings averaged 100 tonnes in 2002-2004 (Fig. 16). Common whelks are mainly caught in baited pots whereas red whelks are taken as a trawl or dredge by-catch. Most whelks are exported to the Far East, particularly to Japan.

Table 17: Annual landings (tonnes) of whelks from the SEA7 coastal zone, compared with the total for Scotland as a whole, 2002-2004.

Year	Landings (tonnes)		SEA7 zone as a % of total
	SEA7 zone	Scotland total	
1995	14	1119	1.3
1996	884	3555	24.9
1997	312	1897	16.4
1998	40	1074	3.7
1999	24	1300	1.8
2000	85	2274	3.7
2001	184	1611	11.4
2002	119	856	13.9
2003	179	929	19.3
2004	166	1507	11.0

Landings

Table 17 shows a recent time series of reported landings from the SEA7 coastal zone, compared with the total landings for Scotland as a whole. Recent landings from the SEA7 zone have fluctuated widely, from a low of only 14 tonnes in 1995 to a high of 884 tonnes one year later. Since 2001, landings from the SEA7 zone have stabilised around 120-180 tonnes, contributing 11-19% of Scottish landings. Small landings of whelk from the SEA7 zone are occasionally made at N. Ireland ports by local vessels (R. Briggs, pers. com.). Landings at Scottish ports are made throughout the year, with above average values from Mar. to Jul. (Fig. 17). The estimated value of the fishery was £167,000 in 2004.

Stock assessments, management and legislation

No assessments have been conducted on whelk stocks within the SEA7 zone and the fishery is effectively unregulated. There is an EU MLS regulation set at 45mm shell length but this serves no useful purpose as it is below the size of maturity (50mm).

2.4.2 Periwinkle

The common winkle, *Littorina littorea* (L.) is widely distributed on all Scottish coasts inhabiting rocky, boulder and pebble shores. The species is most abundant from mid-tide level down to LWST but can also be found on kelp beds in deeper water. Some details on the biology of the species are given by McKay and Fowler (1996) and in an earlier review Chapman (2004a).

Fisheries

The fishery within the SEA7 zone is basically a ‘crofting’ activity operating in the ‘black economy’. Winkles are collected by hand from the shore at low water and stored in sacks for collection. Landings are mainly exported to continental Europe, particularly to Spain and France.

Landings

A time series of annual reported landings from the SEA7 coastal zone is shown in Table 18. These figures must be treated with caution, however, because of the unregulated nature of the fishery. It is likely that the official statistics in Table 18 are grossly under-reported.

Table 18: Annual landings (tonnes) of periwinkles from the SEA7 coastal zone, compared with the totals for Scotland as a whole, 1995-2004.

Year	Landings (tonnes)		SEA7 zone as % of total
	SEA7 zone	Scotland total	
1995	1650	2138	77.2
1996	1515	2032	74.6
1997	2147	2406	89.2
1998	1228	1675	73.3
1999	770	1002	76.8
2000	719	928	77.5
2001	477	603	79.1
2002	41	108	38.0
2003	0	57	0
2004	<1	56	0.5

Reported landings have declined sharply in recent years, both from the SEA7 zone and from all shores around the Scottish coast. In 2003-2004, there were virtually no reported landings of winkles from the SEA7 zone but before 2002 the zone accounted for 73-89% of all Scottish landings. The decline in landings is probably, in part, a reflection of improvements in the economy of local west coast communities through tourism, fish farming and other fishing opportunities, and also to the problem of lax reporting. Fig. 18 shows the pattern of monthly landings averaged over the 10 year period 1995-2004. Harvesting occurs throughout the year, with above average landings being made in the period May-Dec.

Stock assessments, management and legislation

No stock assessments have been carried out and the fishery is entirely unregulated. There are no reliable estimates of the numbers of people that have been involved in the fishery for any part of the Scottish coast.

2.5 Shellfish farming

The wild fisheries for giant scallop (Section 2.3.1), queen scallop (Section 2.3.2) and common mussel (Section 2.3.4) are augmented by production from a small but thriving farming industry. In addition, the native oyster, *Ostrea edulis* (L.) and the Pacific or Portugese oyster, *Crassostrea gigas* (Thunberg) are also farmed. Within the SEA7 coastal zone, there are large numbers of shellfish farm sites leased from the Crown Estates, including nine Several Order (SO) sites. Information about farms and their production is published annually by FRS, the most recent review available being that for 2004 (Pendrey and Fraser, 2005).

There are 202 registered active farm sites on the west coast of Scotland, of which just over half (105) were producing shellfish for the table or for on-growing at other sites. A regional breakdown of the sites, together with information about their production is given in Table 19. It should be noted that 14 sites within the Strathclyde region are in the Firth of Clyde, outside the SEA7 coastal zone but in the SEA6 zone. Eight of these sites are estimated to be actively producing shellfish and no correction for this has been made to the production figures and values given in Table 19.

Table 19: Numbers of active and producing shellfish farm sites on the west coast of Scotland in 2004, with estimates of their production (tonnes) and value (£) by species. Data from Pendrey & Fraser (2005).

		Highland	Western Isles	Strathclyde (*)	All regions
No. sites	Active	66	37	99	202
	Producing	37	14	54	105
Weight produced for table (tonnes)	Pacific oyster	58.88	0	226.24	285.12
	Native oyster	0.24	0	8.16	8.40
	Giant scallop	6.72	0	3.48	10.20
	Queen scallop	2.16	0	40.04	42.20
	Mussels	398	443	1,193	2,034
	TOTALS	**466**	**443**	**1,479.92**	**2,379.92**
Value (£)	Pacific oyster	73,600	0	282,800	356,400
	Native oyster	1,050	0	35,700	36,750
	Giant scallop	30,800	0	15,950	46,750
	Queen scallop	2,700	0	50,050	52,750
	Mussels	417,900	465,150	1,252,650	2,135,700
	TOTALS	**526,050**	**465,150**	**1,637,150**	**2,628,350**

(*) Includes 14 active sites (8 producing) outside SEA7 zone

Table 19 shows that west coast farms produced 2,380 tonnes of shellfish in 2004, of which mussels accounted for 85% (2,034 tonnes) and Pacific oysters a further 12% (285 tonnes). Production of native oysters and the two scallop species was comparatively small. The total value of shellfish farm production in 2004 was estimated to be £2.63 million, of which mussels contributed 81% (£2.14 million).

Production of giant scallops by culture methods is still very small, despite the granting of SO status to nine sites within the SEA7 coastal zone. An SO provides exclusive sea bed rights and is necessary to ensure security for young scallops relayed on the sea bed for the final production stage. Factors which may be holding back the culture of giant scallops in Scotland are the relatively slow rate of growth (four years to reach marketable size) and the uncertain supply of wild scallop spat for on-growing. It is possible that, in the future, scallop culture methods will be used to enhance the wild fisheries by reseeding (Brand *et al*., 1991).

2.6 Other resources

There has recently been some interest in the exploitation of echinoderms such as sea urchins, either from wild stocks or, more likely, by culturing them. There is a ready overseas market for sea urchin roe, particularly in Japan. NAFC carried out some feasibility trials in Shetland on wild populations of the common sea urchin, *Echinus esculentus* (L.) (Penfold *et al.*,1996). This study concluded that the quality of the species in Shetland was good but the roe colour was considered too pale and unattractive for the Japanese market. Feeding trials in aquaria using experimental diets failed to improve the roe colour. More recent work by SAMS has come to similar conclusions with regard to a wild fishery for *E. esculentus* but concluded that culturing them, and possibly other species, may represent better options (Kelly *et al*., 2001; Kelly, 2002). An interesting idea is to farm sea urchins in cages alongside salmon (Kelly, 2005; Kelly *et al*., 1998).

3.0 Future shellfish fisheries management

3.1 Data quality

During the preparation of this review, some doubts have emerged concerning the reliability of official landings statistics used. This is particularly true in the case of the Norway lobster data, where there is anecdotal evidence of significant under-reporting of landings, possibly by as much as 30-50% (Section 2.2.1). This situation led to the ICES WGNSDS refusing to use official landings data to carry out assessments, and using instead TV survey data to determine TACs.

In all probability, there has recently been under-reporting of periwinkle landings. Table 18 shows a marked decline in reported landings since 1998 such that there were virtually no landings from the SEA7 coastal zone in 2003-2004. Information on landings is usually obtained from the buyers on a voluntary basis since, up to now there has been no statutory requirement to provide this data. The species of red crab represent another resource where fishery data are likely to be incomplete. While reported landings by UK vessels at Scottish ports (Table 7) may be considered reasonably representative, they under-estimate the true extent of the fishery within the SEA7 zone because no information is available for landings in Spain.

The above unsatisfactory situation could change in the future, however, with the introduction of a compulsory registration scheme for both buyers and sellers of first sale fish and shellfish (Registration of Buyers and Sellers of First Sale and Designation of Auction Sites Scheme {Scotland} 2005). This scheme becomes operational for shellfish in 2006. The registration requirement applies to all buyers, EU, UK and foreign. Information relating to the landing, marketing and sale of fish and shellfish in the EU must be submitted to the authorities in member states. These regulations are intended to improve the monitoring and control of fish and shellfish landed in the UK.

The above regulations do not cover the recording of fishing effort data and fishery regulatory authorities in Scotland need to address this problem in order to provide for better stock assessment and management of fisheries. Now that all fishing vessels have to be licensed, it should be a condition of the licence that daily records of landings, effort and fishing locations are entered into appropriate logbooks and that this information is submitted to the authorities on a regular basis. This logbook information, and the extension of the VMS scheme to all sizes of fishing vessel, would greatly improve the quality of information for monitoring fishing activity and providing better management advice (unfortunately, VMS information is not yet available for scientific analysis because of the data protection legislation).

3.2 Environmental effects of fishing

Until fairly recently, the emphasis in environmental research was in terms of the effects of the environment on fish and shellfish distribution, abundance and recruitment. Although this important work is still on-going, there is now as much research effort devoted to the inverse problem of the effects of fishing activities on the environment (Hall, 1999). As mentioned in the Introduction, a revised CFP requires member states to introduce fisheries management measures to protect the marine environment (Anon., 2002). These matters were touched on briefly throughout relevant parts of Section 2.

Most problems have arisen in relation to the mobile gears used for the harvesting of Norway lobsters (trawls), giant scallops (toothed dredges), cockles and razor shells (suction dredging/water jet methods). In the Norway lobster trawl fishery (Section 2.2.1), the main problem is the high by-catch taken by relatively small mesh nets, resulting in large catches of under-sized fish which are discarded with no chance of survival. The requirement that trawls are fitted with square mesh and headline panels is an attempt to address this problem, although the effectiveness of these measures is not clear cut (Gosden *et al*., 1995). These and other methods for reducing the fish by-catch in Norway lobster trawls were discussed in Chapman (2004a).

Giant scallop dredging is a particular problem for beds of coralline-algae (maerl) which are easily broken up by the gear (Hall-Spencer, 1995; 1998). Maerl beds form a fragile habitat in shallow sheltered areas and support a diverse fauna community. There is some evidence to suggest that the beds are important for the settlement of scallop spat. Maerl beds are widespread throughout the SEA7 coastal zone; indeed, there are probably more maerl beds within the zone than in any other part of the UK coastline (SNH, 2004). Maerl beds are a qualifying feature of several Special Areas of Conservation (SAC) nominated under the EU Habitats Directive, for example in the Sound of Arisaig.

While many static gear fishing methods are relatively benign in terms of the environment, such as baited creels (Section 2.2.1), others are not so, for example the bottom set gill nets used in the deep water fishery for monk fish and sharks, in which red crabs are taken as a by-catch (Section 2.2.7). The main problem seems to be that vessels are deploying more nets than can be easily recovered. This means that nets are left unattended for long periods of time, resulting in spoilage of the catch, high discard rates and loss of nets which nevertheless continue to 'ghost-fish' (Hareide *et al*., 2001; Sancho *et al*., 2003; Large *et al*., 2005).

3.3 Local management

In a previous review of shellfish fisheries for SEA5 (Chapman, 2004a), it was pointed out that most fisheries within that zone were virtually unregulated. The same is true for shellfish fisheries within the SEA7 zone. For the Norway lobster fisheries, the EU attempts to control effort indirectly by TAC but this is clearly unsuccessful when there is widespread under-reporting of the landings. For small inshore areas it is possible to use the Inshore Fishing Order (Appendix A), for example, to devolve the management of a Norway lobster creel fishery to local stakeholders, as in L. Torridon.

This experiment in local management is due for revue in 2006 and it will be interesting to see how successful it has been.

It is likely that shellfish fisheries will only be properly managed when they come under local area management. This could be achieved by using the Sea Fisheries (Shellfish) Act 1967 to grant RFOs. Since the last review (Chapman, 2004a), a RFO has been granted in the Solway Firth to provide local management of the cockle fishery there (The Solway Firth Regulated Fishery (Scotland) Order 2006 SSI 2006 No. 57). Another RFO, currently going through the planning enquiry stage, will if awarded, control most shellfish fisheries within the Highland Region, extending from L. Linnhe to Nairn and out to six nautical miles from the coast. At the same time that these developments have been taking place, there have been a number of other initiatives aimed at giving stakeholders a greater say in the management of offshore and inshore fisheries.

As part of a review of the CFP, the EU has created seven Regional Advisory Councils (RACs) to cover different areas or fisheries. The RAC most relevant to the SEA7 zone is that covering North Western Waters (NWWRAC) which came into being in 2005 (Commission Decision 2005/668/EC). An inaugural General Assembly was held in Dublin in Sep. 2005 to formerly establish the NWWRAC. Each RAC consists of a General Assembly and an Executive Committee, and the latter group can also establish working groups to discuss particular policies. Membership of the Executive Committee consists mainly of stakeholders from each member state, with scientists, environmentalists and administrators being invited to assist the work of the RAC.

The Scottish Executive has also introduced new initiatives to involve stakeholders in the management of inshore fisheries within Scotland's territorial seas. In 1999, the Scottish Inshore Fisheries Advisory Group (SIFAG) was sent up, as a joint venture by the Scottish Fishermen's Federation and SEERAD, to advise Ministers on the development and implementation of policy relating to inshore fishing. SIFAG produced a strategy document for inshore fisheries in Scotland (Anon., 2005e), a key recommendation being the establishment of Inshore Fisheries Groups (IFGs) covering the Scottish coast. The task of these groups will be to develop local objectives and management plans for inshore fisheries management. There will probably be 12 IFGs in total and the first of these, covering the Western Isles and the east coast from Eyemouth to Montrose, will be set up in early 2006. Others will follow; those relevant to the SEA7 zone are on the west coast from Cape Wrath to the Skye bridge, around the Small Isles and the south west coast.

As well as the above initiatives, the UK Government set up the Scottish Coastal Forum (SCF), with a wider brief than just fisheries, to bring together representatives of all major stakeholders with an interest in integrated management of the coast. One of the tasks of this forum is to help deliver the EU policy for the development of Integrated Coastal Zone Management (ICZM). In 2004, the SCF produced a major strategy document for the sustainable use of Scotland's coast and inshore waters (SCF, 2004). Through the working of a number of Task Groups, the SCF has also produced several position papers on fishing (SCF, 2002a), aquaculture (SCF, 2002b), oil and gas industry (SCF, 2003a), power generation (SCF, 2002c), water quality and pollution (SCF, 2003b) and nature conservation (SCF, 2003c).

3.4 Closed areas

The adoption of an ICZM approach to fisheries will inevitably lead to a greater use of closed areas, often referred to as 'marine protected areas' (MPAs) or 'no-take-zones'. Closed areas can be used to mitigate conflicts between different fishing methods, as in the Inshore Fishing Order (Appendix A) and to reconcile the needs of different stakeholders. It is inevitable that more use will be made of closed areas to protect certain vulnerable habitats from damage by fishing gear, for example, maerl and native oyster beds, and reefs of cold-water corals in deep water (Sections 2.2.7, 2.3.6 & 3.2). A report on the future of the UK fishing industry by the Prime Minister's Strategy Unit recommended the experimental adoption of marine protected areas to provide benefits to multiple stakeholders (Anon., 2004b).

Closed areas have often been used as technical measures in fisheries management, usually to protect fish spawning grounds or nursery areas at certain times of the year (see Appendix A). All too often, however, such measures have not been very successful. They have been set up without any clear idea of the objectives and the criteria for success. In a recent review of the benefits or otherwise of 52 restricted fishing areas, it was found that in 32 cases, stocks actually declined or had major fluctuations in abundance such that no change was detectable; in only 16 cases had stocks increased or were shown to have remained unchanged (Horwood, 2000). To some extent, the success of a closed area depends on the nature of the resource, and also on other management controls in place. In general, closed areas tend to be most effective in relatively small habitat-specific systems such as coral or rocky reefs where fish are residential (FSBI, 2001; Kaiser, 2005); small closed areas would be much less effective for conserving migratory fish such as the cod (Jennings, 1999; Horwood, 2000). It was shown by ICES that closure of 25% of the N. Sea would provide no detectable benefit to the cod stock (Jennings, 1999). Where TACs are used to control fisheries, closed areas are often ineffective since vessels simply transfer their effort elsewhere.

Because shellfish tend not to have discrete spawning and nursery grounds, closed areas have not generally found favour as management tools. Sometimes, the patchy settlement of bivalve molluscs, such as cockles and razor shells, leads to heavy colonisation by juveniles in localised areas and it makes sense to protect such areas by closing them to fishing for a limited period. Closed areas could also be used to protect over-wintering aggregations of berried female edible crabs (Howard, 1982; Chapman, 2004a). An interesting experiment in area closure has been undertaken on giant scallop grounds near the Isle of Man (Beukers-Stewart, *et al*., 2005). In 1989, a small area, less than 2km^2, was closed to fishing and has been intensively studied since then. Recent surveys have shown higher densities of scallops in the protected area, compared to fished areas outside. Juvenile scallops were also more abundant within the closed area, suggesting better settlement habitat and spat survival. There is also some evidence suggesting there has been a net export of larvae from the closed area to the grounds outside (Beukers-Stewart *et al*., 2004). This suggests that a mosaic of small MPAs could have long-term benefits in enhancing recruitment on scallop grounds and in smoothing out the large fluctuations in recruitment that occur in some areas. It is possible that fishery exclusion zones around wind turbines, and other installations, could act in the same way for a variety of species.

4. Environmental impacts on shellfish

The shellfish species include in this review are all relatively sedentary, living within or on the seabed. Although local movements can occur, most species do not undertake significant migrations, with the exception of female edible crab and crawfish. This limited mobility means that shellfish species are extremely vulnerable to environmental disturbance and pollution. Bivalve molluscs, such as mussels, razor shells and scallops, are filter feeders that take in food with an inhalant current of sea water. In this way they can accumulate algal toxins, faecal bacteria and contaminants. As a result, shellfish species and other invertebrates are used to monitor environmental conditions in relation to contaminant loads (Davies, 1980; Widdows *et al*., 1985; McIntosh *et al*, 2003) and they have to be carefully monitored as part of marketing hygiene regulations. The *Braer* oil tanker spill in Shetland demonstrated that contaminants can persist for many years after a pollution event (Chapman, 2004a).

4.1 Shellfish hygiene regulations

Bivalve molluscs such as mussels and scallops are subject to the EU Shellfish Hygiene Directive 91/492/EEC and associated national legislation, the Food Safety (Fishery products and Live Shellfish) (Hygiene) Regulations 1998 and 1999. This calls upon competent authorities (The Food Standards Agency Scotland {FSAS}) to classify shellfish production areas by testing flesh for contamination by faecal indicator bacteria (*Escherichia coli*). FRS is commissioned by FSAS to do this work. There are four categories of classification but only category A (<230 *E. coli*/100g flesh) allow shellfish to go directly for human consumption; categories B, C, require depuration and purification treatments prior to marketing. Uncategorised areas are so polluted that no shellfish production is possible. There are now 104 areas that meet the category A standard, mostly on the west coast of Scotland and in the Northern Isles. The Scottish Environment Protection Agency (SEPA) is responsible for monitoring designated shellfish growing areas to ensure their water quality meets the requirements of the EU Shellfish Waters Directive (79/923/EEC) (SCF, 2003b). Regular tests include general physio-chemical parameters, metals, hydrocarbons, organohalogens, as well as faecal bacteria. SEPA control all discharges into designated shellfish growing areas.

Another requirement of the EU Shellfish hygiene regulations is that the FSAS monitors shellfish for the presence of marine biotoxins and the designated waters for the phytoplankton species which cause the toxicity. This work is also undertaken by FRS (FRS, 1999; FRS, 2004a; Megginson and Bresnan, 2005). Scallop stocks offshore are also included in the monitoring programme. Three main types of algal toxins can occur in Scottish shellfish, Paralytic Shellfish Poison (PSP), Amnesic Shellfish Poison (ASP) and Diarrhetic Shellfish Poisons (DSP). The presence of these toxins above prescribed threshold levels results either in Voluntary Closure Agreements for short periods of time, or a closure under the Food and Environmental Protection Act, 1985 (FEPA).

Probably, the most serious effect on fisheries has been the number and extent of FEPA closures of offshore giant scallop grounds because of ASP. The toxin causing ASP is domoic acid and derivatives, and the causative organism is a species of the diatom genus *Pseudo-nitzchia*. In 2004-2005, ASP was detected on all major scallop fishing grounds (Megginson and Bresnan, 2005). This has resulted in ground closures under FEPA for a period, usually around 17 weeks but up to 35 weeks in one case. In some cases, where the toxin level in gonad tissue is below the action level, marketing has been permitted provided the scallops were processed first.

Marine biotoxins can also move up the food chain since they have been found in both edible crab and velvet swimming crab, usually concentrated in the hepatopancreas ('brown meat').

4.2 Tributyltin

Tributyltin (TBT) is the active ingredient of anti-fouling paints used on ships. It was also widely used on the west coast of Scotland to treat salmon farm cages. It gradually leaches out into the water and can also contaminate sediments. TBT affects the sex hormonal balance in gastropod molluscs, such as the dog whelk, *Nucella lapillus* (L.), causing females to develop a penis, a phenomenon referred to as 'imposex' (Bailey and Davies, 1989; SCF, 2003b). With severe exposure, female dog whelks can become sterile, leading to populations dying out. 'Imposex' has been reported in the commercially important common whelk and in many other gastropod species worldwide. TBT can also affect shell shape and the reproductive capacity of native and Pacific oysters (His and Robert, 1987). In 1987, TBT based paints were banned from being used on fish farm cages, and on vessels less than 25 m in length, on the basis that these vessels operating close inshore and in local harbours were the main cause of the problem. This action was certainly effective up to a point (Evans *et al*., 1996) but the problem has not been eradicated (FRS, 2005).

'Imposex' monitoring is now part of the Oslo and Paris Commission (OSPAR) Coordinated Environmental Monitoring Programme (CEMP) and the UK National Marine Monitoring Plan (NMMP). A UK-wide survey of 'imposex' prevalence still reveals some 'hot-spots', most notably around harbours frequented by large vessels which may still be coated with TBT based paint, for example Ullapool, Portree and Mallaig within the SEA7 coastal zone (FRS, 2005). There is an agreement with the International Maritime Organisation that the use of TBT based paints should be phased out over the next five years.

4.3 Fish farm - sea lice treatments

Farmed salmon are vulnerable to infestation by sea lice ecto-parasites that cause stress, and damage to the skin, which often leads to secondary infections (Revie *et al*., 2002; FRS, 2004b). There is concern that heavy sea lice infestations on farmed fish could be transferred to wild salmon and sea trout. Various chemical treatments are available which are licensed for veterinary use, including Cypermethrin, Emamectin benzoate and Hydrogen peroxide. The use of these products is controlled by SEPA to ensure minimal effects on the environment. A recent study found no major changes in the ecology of sea lochs where sea lice treatments were being used (SAMS, 2005).

4.4 Oil and gas developments

The impact of oil and gas exploration on ecosystems and fisheries has been well covered by earlier SEA reviews (Rogers & Stocks, 2001; Anon., 2001) and, in the case of contaminants, by Sheahan *et al*. (2001). This topic was also considered in relation to shellfish in an earlier review for SEA5 (Chapman, 2004a). All of these reviews are pertinent to any extension of oil and gas exploration into the SEA7 zone.

In the earlier review (Chapman, 2004a), the biological impact of seismic sound energy on shellfish were considered and it was concluded that serious affects were unlikely to occur. A more recent report has drawn similar conclusions. Parry and Gason (2006) examined CPUE data in the western Victoria (Australia) rock lobster fishery in relation to the level of seismic sound energy. There was no clear evidence that catch rates of rock lobsters were affected after seismic surveys had taken place.

There are several environmental monitoring schemes which taken together provide a reasonably comprehensive view of water quality throughout the inshore areas of the SEA7 coastal zone (SCF, 2003b) but there has been very little contaminant monitoring in the outer SEA7 zone. SEPA operates several classification schemes which cover coastal waters out to 3nm. These schemes include (i) Estuarine waters, (ii) Coastal waters, (iii) Bathing waters, (iv) Shellfish growing waters (Section 4.1). These classifications have different sampling requirements, but taken together they involve monitoring for dissolved oxygen, toxic contaminants, their biological accumulation and effects, chemical quality and bacteriology (Section 4.1). These various schemes indicate that nearly all coastal waters within the SEA7 zone would be classified as ‘excellent’ or ‘good’ in terms of water quality.

In the late 1980s, the NMMP was initiated to coordinate the monitoring of marine coastal waters throughout the UK. A network of 87 monitoring stations was established comprising estuarine, inshore and offshore areas (SCF, 2003b; FRS, 1999; FRS, 2005; MPMMG, 1998). There are 19 sites around the Scottish coast, mainly concentrated in the Firths of the Clyde, Forth and Tay. There was initially only one monitoring site within the SEA7 zone, located in the N. Minch, but more recently, sampling has been extended to several stations in the N. and S. Minches (R. Fryer, pers. com.). The NMMP surveys of contaminants in water include nutrients, such as nitrates, heavy metals and organochlorine pesticides. The programmes also include contaminants in sediments and biota, and their biological effects (eg. ‘imposex’ – Section 4.2). In Scotland, both SEPA and FRS collect data for the NMMP. FRS monitors six sites on an annual basis, including analyses for polycyclic aromatic hydrocarbons (PAH) which tend to persist in sediments. Surveys from 1999 to 2004 indicated that total PAH concentrations had not changed significantly at any of the sites over this time period (FRS, 2005).

Extensive monitoring is also initiated by the FSAS in relation to food safety. This monitoring includes faecal bacteria and biotoxins, as outlined in Section 4.1, and also trace metals, PAH, chlorobiphenyl and organochlorine pesticides, much of this work being undertaken by FRS (McIntosh, *et al*., 2002; 2003). The species monitored in these programmes were bivalve molluscs, common mussels, Pacific oysters and giant scallops.

Since 1999, the NMMP programme has been superseded by the Clean Seas Environment Monitoring Programme (CSEMP) which aims to integrate national and international monitoring programmes across UK agencies. Data collected for CSEMP is being stored in the MERMAN database (the Marine Environment Monitoring and Assessment National Database) which is managed by the British Oceanographic Data Centre (BODC). This database is currently in the user-acceptance testing phase and is not yet fully active (R. Fryer, pers. com).

It appears that there is a good body of contaminant data being collected to meet specific monitoring programmes in inshore waters but there seems to be a need to extend monitoring to deeper waters in relation to future oil and gas exploration within SEA7.

5. Suggestions for further research

In a previous review for SEA5 (Chapman, 2004a), it was concluded that the ecology of the early stages in the life-cycle of some shellfish species was poorly understood. This lack of understanding is also true for the SEA7 coastal zone. In the edible crab, it is unclear whether the presence of juveniles within the inter-tidal zone is indicative of a genuine inshore nursery area. Information is also required on the migrations of edible crabs, particularly the females, and on the distribution of over-wintering areas occupied by berried females. The behaviour of berried females is such that they do not feed and are therefore seldom captured in baited creels. A programme of research involving plankton surveys for the larvae and underwater TV surveys for the adults would help to address this gap in knowledge.

In the giant scallop, the production, distribution and settlement of spat, and their effects on recruitment variability warrants investigation within the SEA7 coastal zone. There is evidence that recruitment of juveniles is much less variable in some areas, than in others, and the reasons for this are unclear. The degree to which stocks within an area are self contained, or rely on recruitment from outside, needs to be examined. Comparative studies of adult distribution, larval and spat production, hydrographic conditions and DNA typing in different areas would help to address this topic. Part of this work could include the establishment of closed areas to replicate the investigations carried out in the Isle of Man fishery (Section 3.4).

It became apparent during the course of this review that the full extent of crustacean resources in deep water regions of SEA7 was not adequately known. The landings of red crab were under-reported, particularly by the Spanish gill netting fleet. Also, the abundance of each red crab species and their relative contributions to the landings were unknown. Confirmation of habitat preference, presence or absence of burrowing behaviour, were required in order to determine the best survey strategy. Use of underwater TV cameras is feasible in deep water and this seems to represent the most promising approach. There is a need for vessels, of all nationalities, engaged in the red crab fishery to provide accurate landings and fishing effort data by completing logbooks. Although the NAFC survey of deep water shrimp resources was inconclusive, it is possible that the gear used was not fishing optimally in relation to possible vertical migration behaviour of the target species. The NAFC trials would be worth repeating.

There is a need for additional contaminant data from deep water sites to provide a base-line summary prior to offshore oil and gas exploration within SEA7. Consideration should also be given to monitoring contaminant levels in shellfish species higher up the food chain than bivalve molluscs, for example, Norway lobsters and red crabs.

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Appendix A: Areas within the SEA7 coastal zone closed to mobile fishing gear under the terms of the Inshore Fishing (Prohibition of Fishing and Fishing Methods) (Scotland) Order 1989 and subsequent amendments. (Schedule 1)

Area (No.)*	Period of closure	Exemptions	Main aim of closure
Loch Torridon & north of Inner Sound (7)	All year	Dredging (**) in specified sub-area for scallops, Apr.-Sept	Fish nursery area, static gear reserve
South Inner Sound incl. Lochs Carron, Kishorn, Duich, Alsh, Hourn (7A)	a) Oct.-Mar. b) All year for trawlers >12m or when using trawls other than single		Fish nursery area, static gear reserve
Loch Gairloch (8)	All year		Fish nursery area. Static gear reserve
Little Loch Broom & Gruinard Bay (9)	Oct.-Mar.		Fish nursery area.
Enard Bay (10)	Oct.-Mar.		Fish nursery area
Eddrachilis Bay (11)	Oct.-Mar.		Fish nursery area
Loch Laxford (12)	Oct.-Mar.		Fish nursery area
Stuley Island to Barra Head and Gurney Point (13)	Mar.-Oct.	a) Sandeel fishing b) Dredging (**) for scallops, May-24th Oct.	Static gear reserve
Loch Maddy to Stuley Island (14)	Mar.-Oct.	Dredging (**) for scallops, May-24th Aug..	Static gear reserve
Sound of Harris (15)	Mar.-Sept.	Dredging (**) for scallops, Mar.-Sept.	Static gear reserve
Broad Bay (16)	All year		Fish nursery area. Static gear reserve
Loch Roag (17)	All year		Fish nursery area. Static gear reserve
Gallan Head to Aird Barvas (18)		(**)	Closed to suction dredging only

* For full definition of Area see No. given in the relevant paragraph of Schedule 1 of the 1989 Order and subsequent amendments.
** Not suction dredging; this method is prohibited all year round in all the areas in Schedule 1, including No. 18 in the schedule.

Appendix B: Areas, under the Order 1989, within SEA7 coastal zone in which creel fishing is prohibited (Schedule 2).

Area (No.)+	Period of closure	Exemptions	Main aim of closure
Flannan Isles (1)	Dec.-Mar.		Conservation measure
Bragar to Dell (2)	Jul.-Sept.		Conservation measure
North Rona (3)	All year		Conservation measure
N. Barra, S. Uist, Benbecula, N. Uist, Harris (4)	Nov. –Mar.		Conservation measure

+ For full definition of Area see No. given in the relevant paragraph of Schedule 2 of the 1989 Order and subsequent amendments

Appendix C: Acronyms and abbreviations used in the text

	Definition
ANIFPO	Anglo-North Irish Fish Producers Organisation Ltd.
ASP	Amnesic Shellfish Poisons
BGS	British Geological Survey
BODC	British Oceanographic Data Centre
CEMP	(OSPAR) Coordinated Environmental Monitoring Programme
CFP	Common Fisheries Policy of the EU
CL	Carapace length (the preferred size measurement for lobsters, shrimps)
CPUE	Catch Per Unit Effort (used as a measure of stock abundance, biomass)
CSEMP	Clean Seas Environmental Monitoring Programme
CW	Carapace width (preferred size measurement for crabs)
DAFS	Department of Agriculture & Fisheries for Scotland (now SEERAD)
DARD	Department of Agriculture & Rural Development (N. Ireland)
DSP	Diarrhetic Shellfish Poisons
EU	European Union
F	Instantaneous rate of fishing mortality
FEPA	Food and Environment Protection Act
FIN	Fisheries Information Network (Scottish Executive statistics database)
FRS	Fisheries Research Services Marine Laboratory, Aberdeen
FSAS	Food Standards Agency Scotland
GAM	Generalised Additive Model
ICES	International Council for Exploration of the Sea
IFG	Inshore Fisheries Group
ICZM	Integrated Coastal Zone Management
LCA	Length Cohort Analysis
LPUE	Landings Per Unit Effort (measure of exploited stock abundance or biomass)
LWST	Low Water of Spring Tides
MERMAN	Marine Environment Monitoring and Assessment National Database
MLS	Minimum Legal Size
MPA	Marine Protected Area
MPMMG	Marine Pollution Monitoring Management Group
NAFC	North Atlantic Fisheries College, Shetland
NMMP	National Marine Monitoring Plan
NWWRAC	North Western Waters Regional Advisory Council
OSPAR	Oslo and Paris Commission
PAH	Polycyclic Aromatic Hydrocarbon
PSP	Paralytic Shellfish Poisons
RAC	Regional Advisory Council
RFO	Regulated Fishery Order
SAC	Special Area of Conservation (set up under the EU Habitats Directive)
SAMS	Scottish Association for Marine Science, Marine Laboratory, Oban
SCF	Scottish Coastal Forum
SCUBA	Self Contained Underwater Breathing Apparatus
SEAFISH	Sea Fish Industry Authority
SEERAD	Scottish Executive Environment and Rural Affairs Department

SEPA	Scottish Environment Protection Agency
SFPA	Scottish Fisheries Protection Agency
SGCRAB	ICES Study Group on the biology & life history of Crabs
SIFAG	Scottish Inshore Fisheries Advisory Group
SSB	Spawning Stock Biomass
SSMO	Shetland Shellfish Management Organisation
SNH	Scottish Natural Heritage
TAC	Total Allowable Catch
TBT	Tributyltin
UK-NMMP	UK National Marine Monitoring Programme
VMS	Vessel Monitoring System
VPA	Virtual Population Analysis
V-notch	Tagging of lobster by removal of V-shaped section of tail or uropod
WGNSDS	ICES Northern Shelf Demersal Stocks Working Group
Y/R	Yield per Recruit

Figures: Figures mentioned in the text.

Fig. 1: Chart of waters to the west of Scotland showing the SEA7 zone and the choice of ICES statistical rectangles forming the coastal zone used to review shellfish landings. Note that the Scottish Executive FIN database allows a division of one rectangle (ICES code 40E4) into two parts, thus separating the Firth of Clyde (which is in SEA6) from the Sound of Jura (in SEA7).

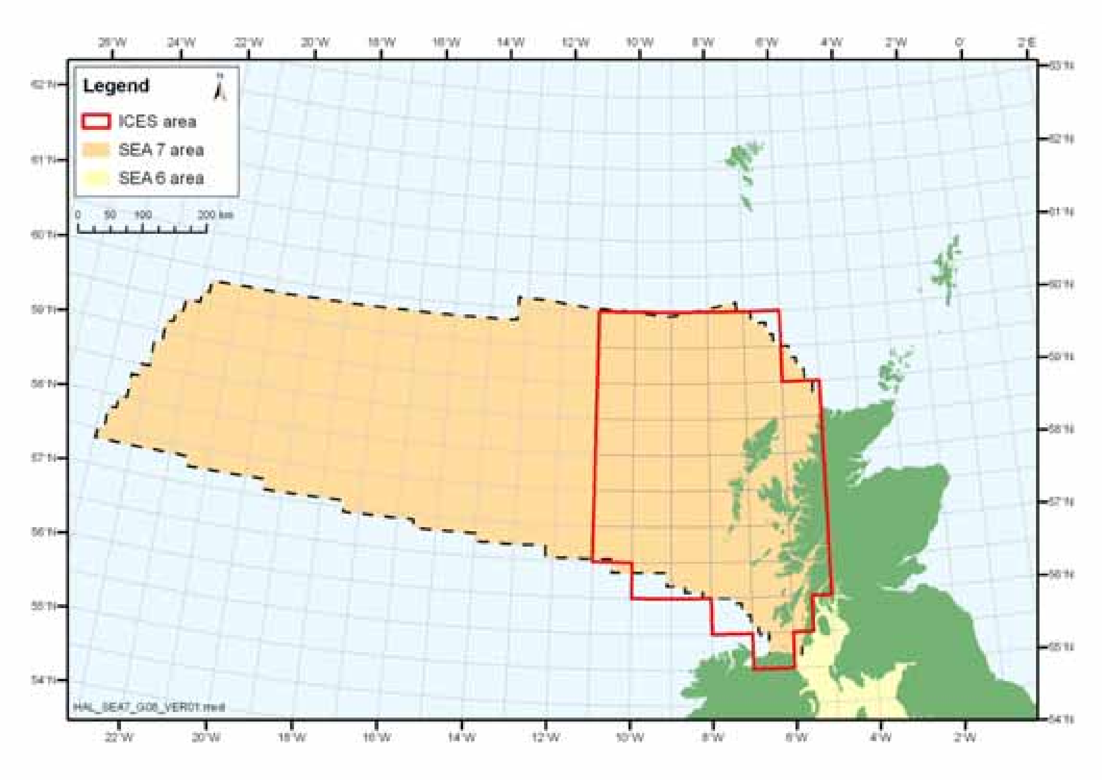


Fig. 2: Distribution of Norway lobster landed at Scottish ports by UK vessels fishing in the SEA7 coastal zone. Based on ICES statistical rectangles, and averaged over the three years, 2002–2004. Also shown are the groupings of rectangles forming the North and South Minch stocks (ICES Functional Units 11 & 12 for assessment and management purposes).

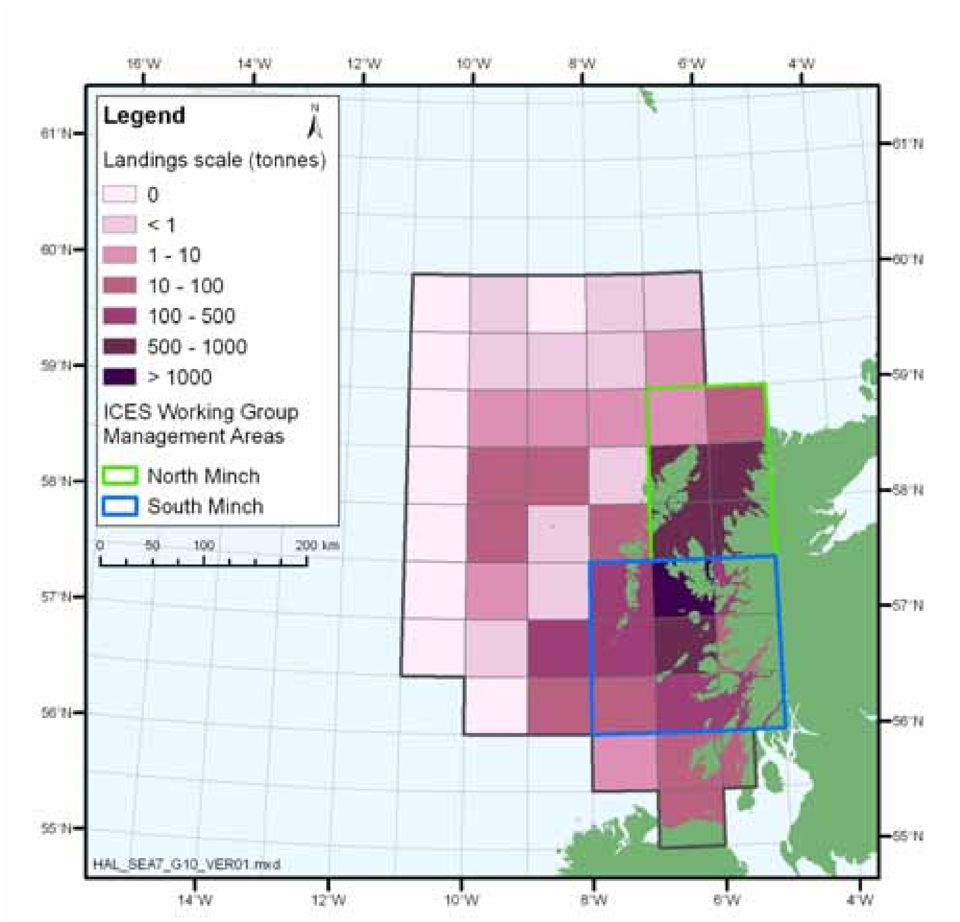
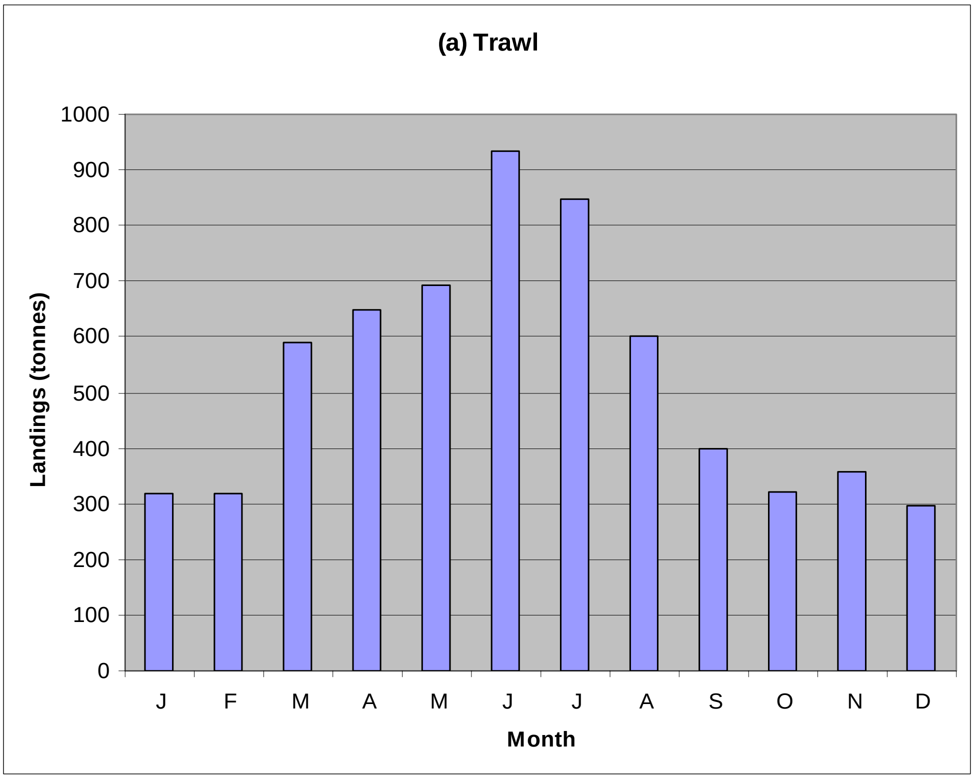


Fig. 3: Monthly landings of Norway lobster (tonnes) from SEA7 coastal zone by UK vessels fishing by (a) trawl and (b) creel, averaged over the period, 1995-2004.



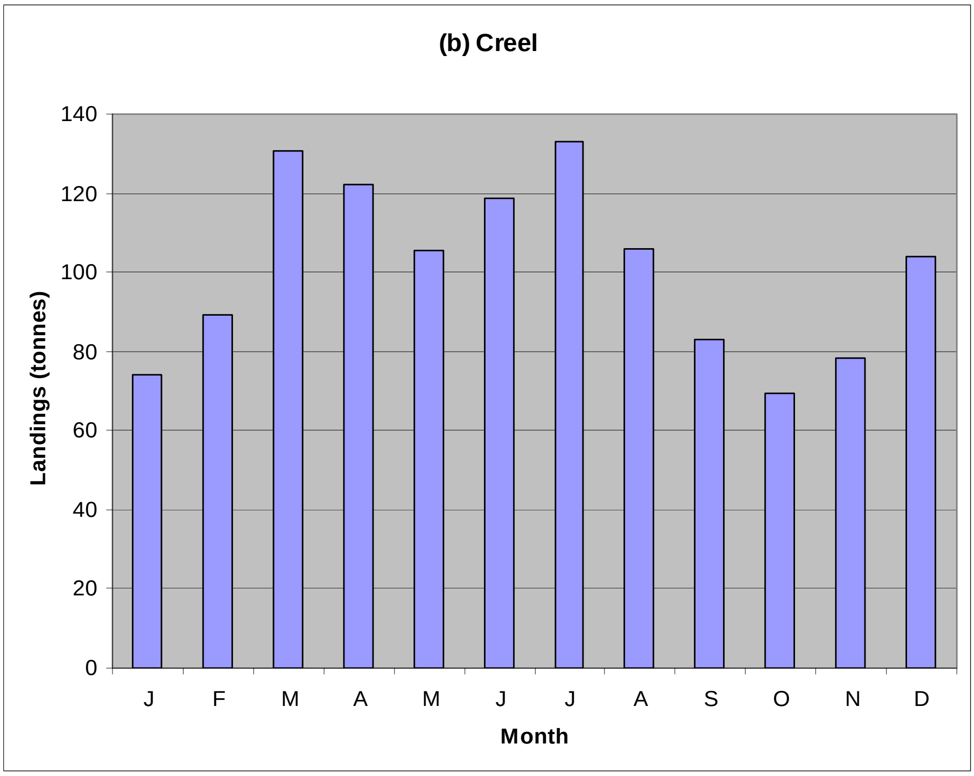


Fig. 4: Distribution of European lobster landed at Scottish ports by UK vessels fishing in the SEA7 coastal zone. Based on ICES statistical rectangles, and averaged over three years, 2002-2004. Also shown are the groupings of rectangles forming the FRS areas for lobster and crab stock assessment and management.

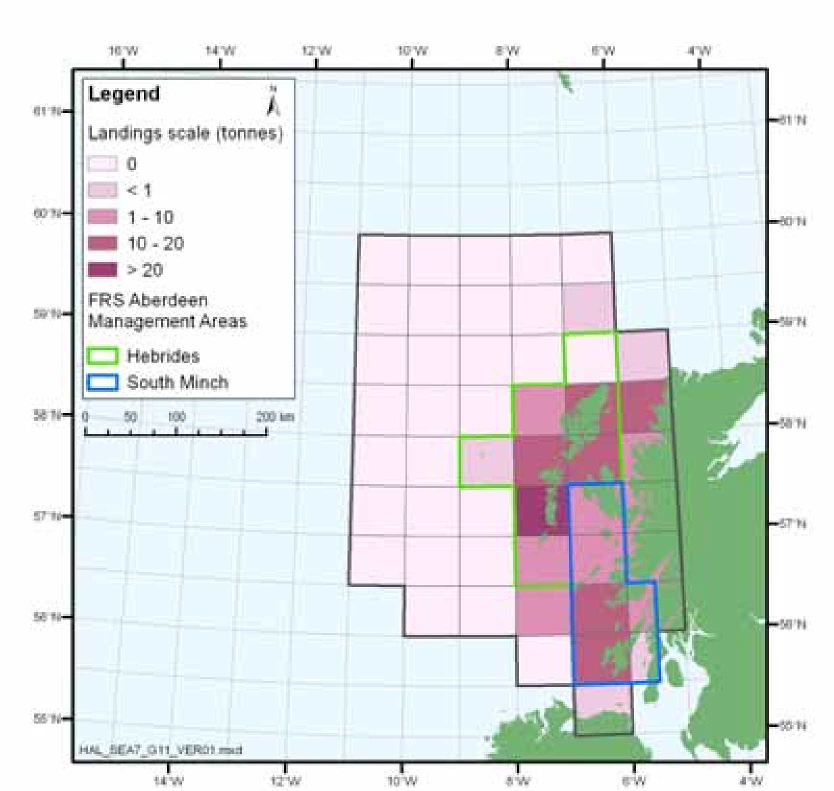


Fig. 5: Monthly landings of European lobster (tonnes) from SEA7 coastal zone by UK vessels, averaged over the period, 1995-2004.

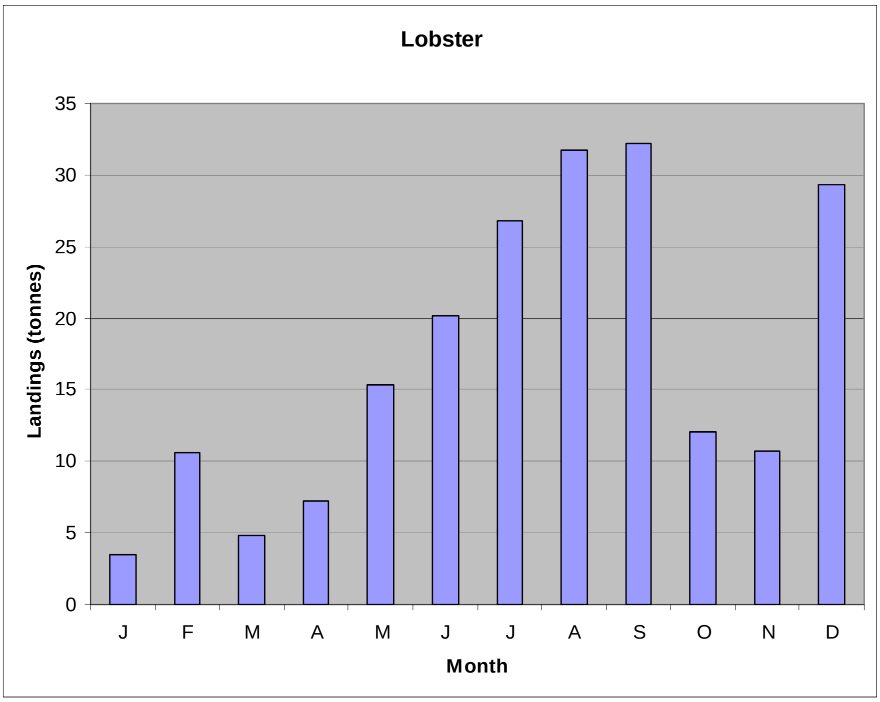


Fig. 6: Distribution of edible crab landed at Scottish ports by UK vessels fishing in the SEA7 coastal zone. Based on ICES statistical rectangles, and averaged over the three years, 2002-2004.

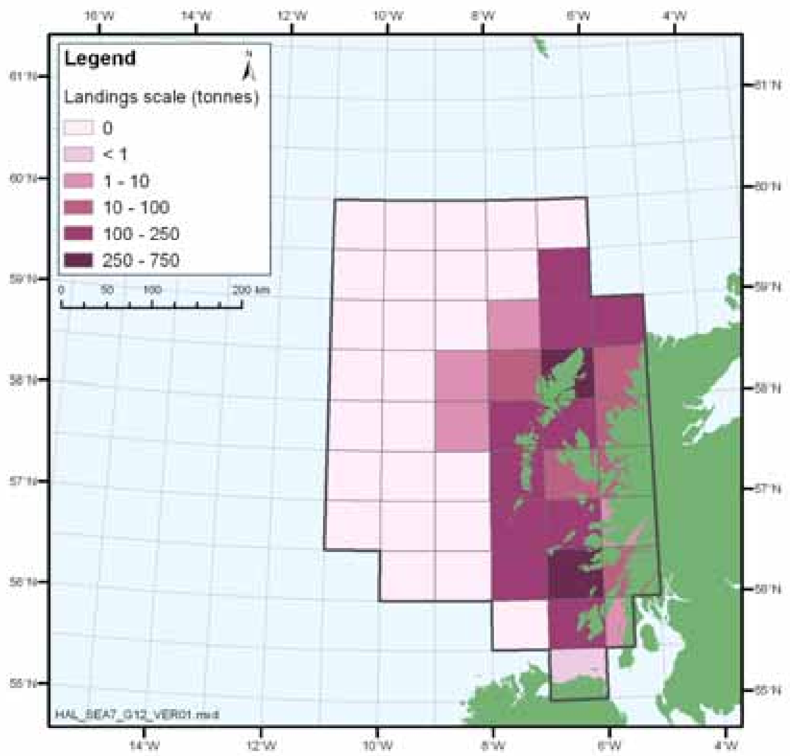


Fig. 7: Monthly landings of edible crab (tonnes) from SEA7 coastal zone by UK vessels, averaged over the period 1995-2004.

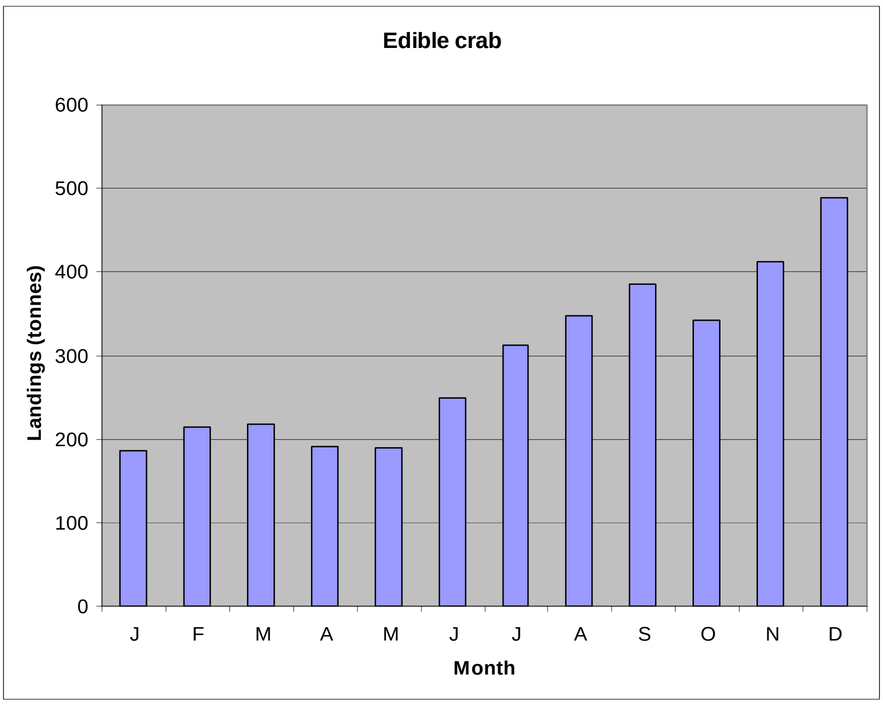


Fig. 8: Distribution of velvet crab landed at Scottish ports by UK vessels fishing in the SEA7 coastal zone. Based on ICES statistical rectangles, and averaged over the three years, 2002-2004.

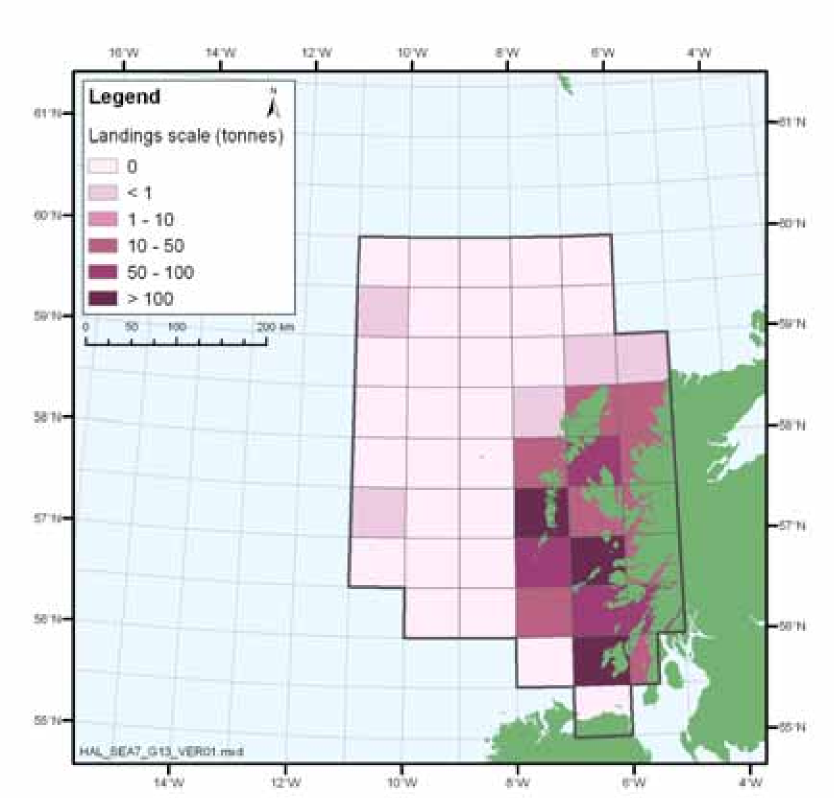


Fig. 9: Monthly landings of velvet crab (tonnes) from SEA7 coastal zone by UK vessels, averaged over the period 1995-2004.

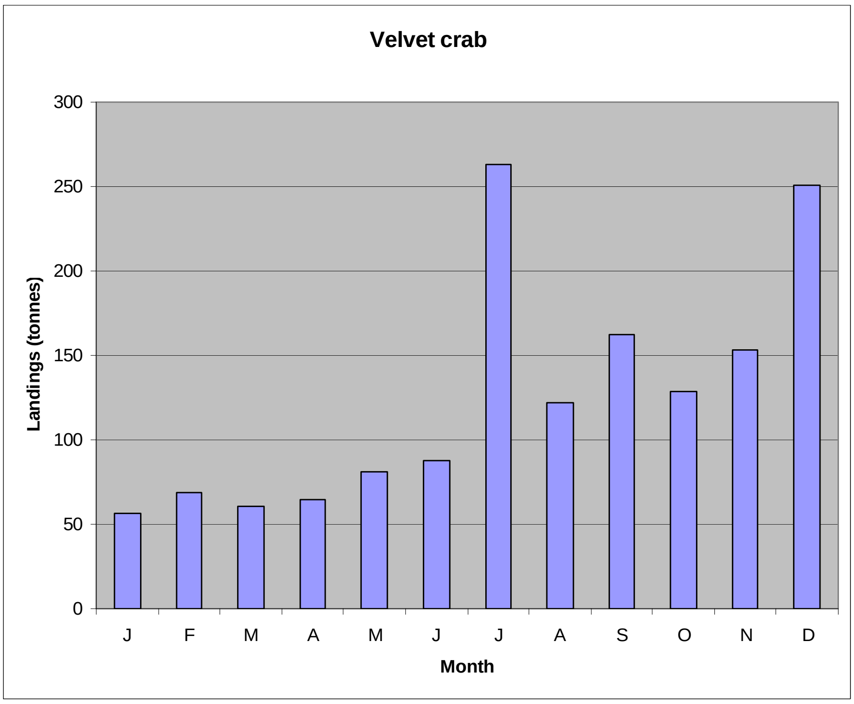


Fig. 10: Monthly landings of shore crab (tonnes) from SEA7 coastal zone by UK vessels, averaged over the period, 1995-2004.

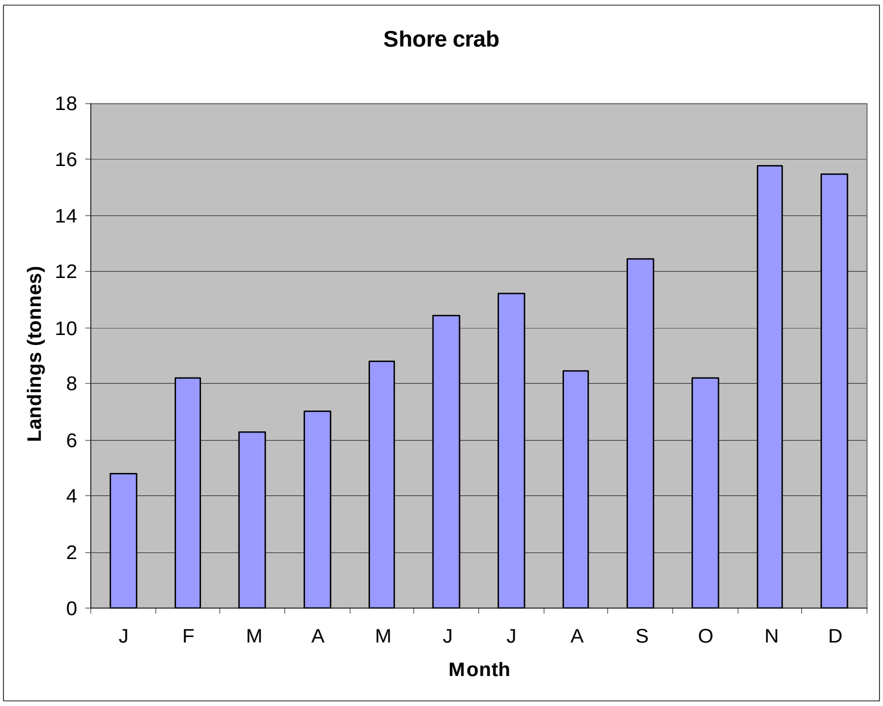


Fig. 11: Distribution of giant scallop landed at Scottish ports by UK vessels fishing within the SEA7 coastal zone. Based on ICES statistical rectangles, and averaged over the three years, 2002-2004. Also shown are the groupings of rectangles forming the FRS areas for stock assessment and management.

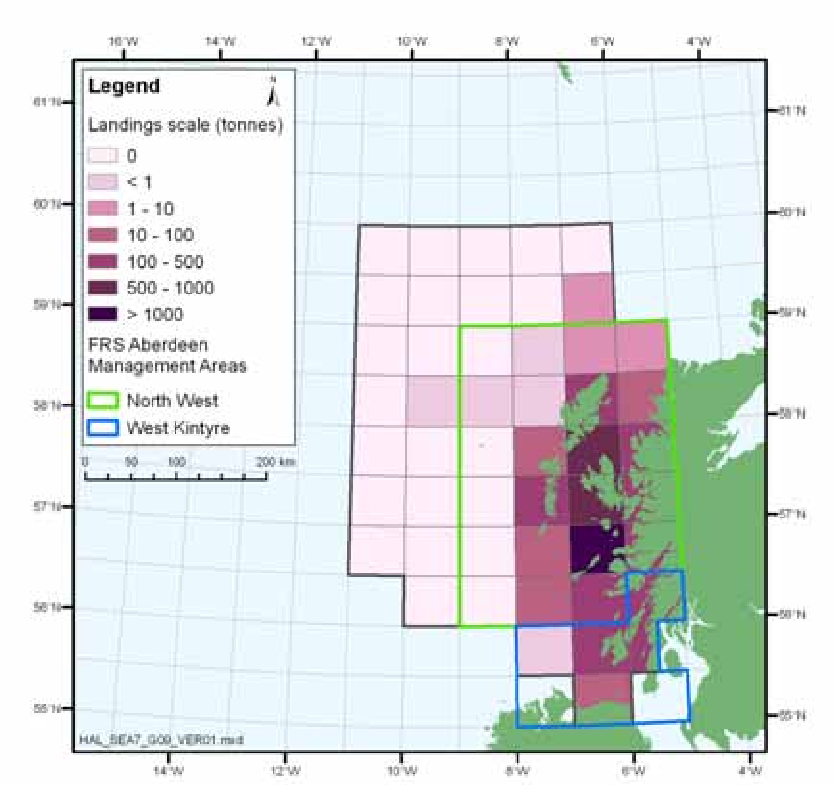


Fig. 12: Monthly landings by all fishing methods of giant scallop (tonnes) from SEA7 coastal zone by UK vessels, averaged over the period, 1995-2004.

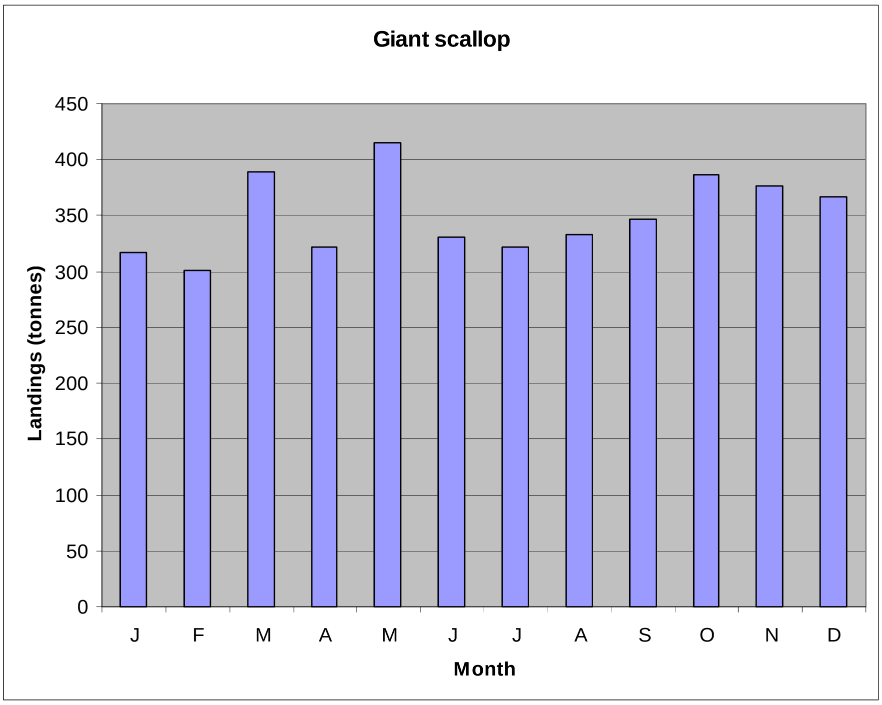


Fig. 13: Monthly landings of queen scallop (tonnes) from SEA7 coastal zone by UK vessels, averaged over the period 1995-2004.

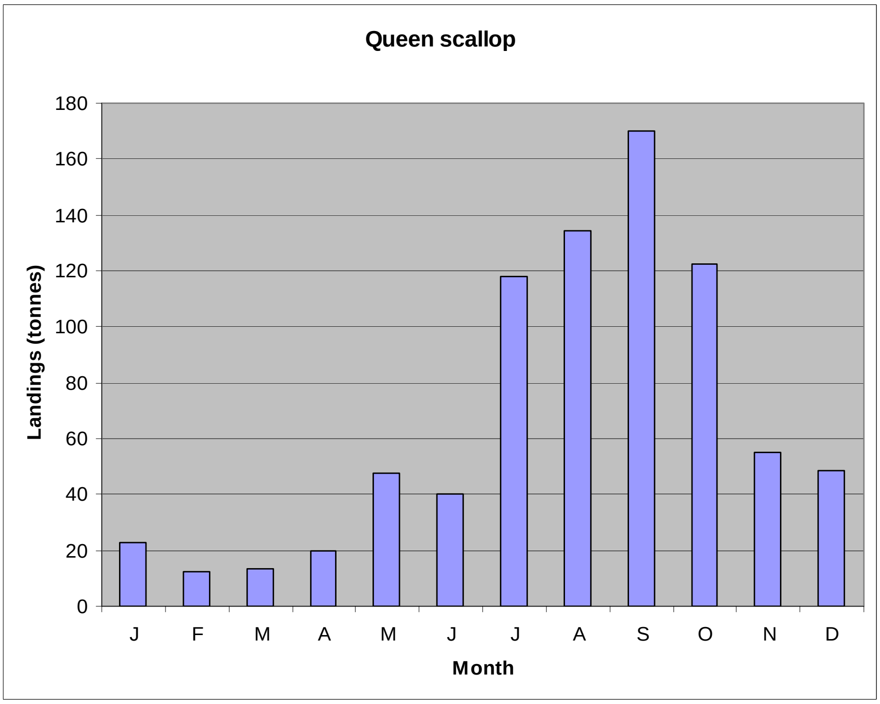


Fig. 14: Monthly landings of cockles (tonnes) from SEA7 coastal zone by hand gathering, averaged over the period, 1995-2004.

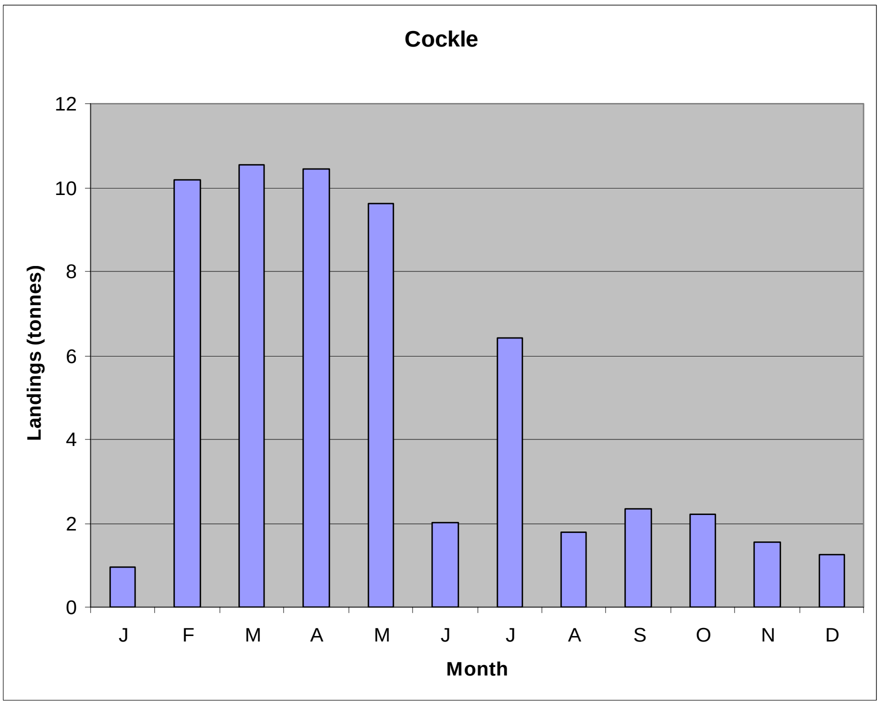


Fig. 15: Monthly landings of razor shells (tonnes) from SEA7 coastal zone by all methods, averaged over the period, 1995-2004.

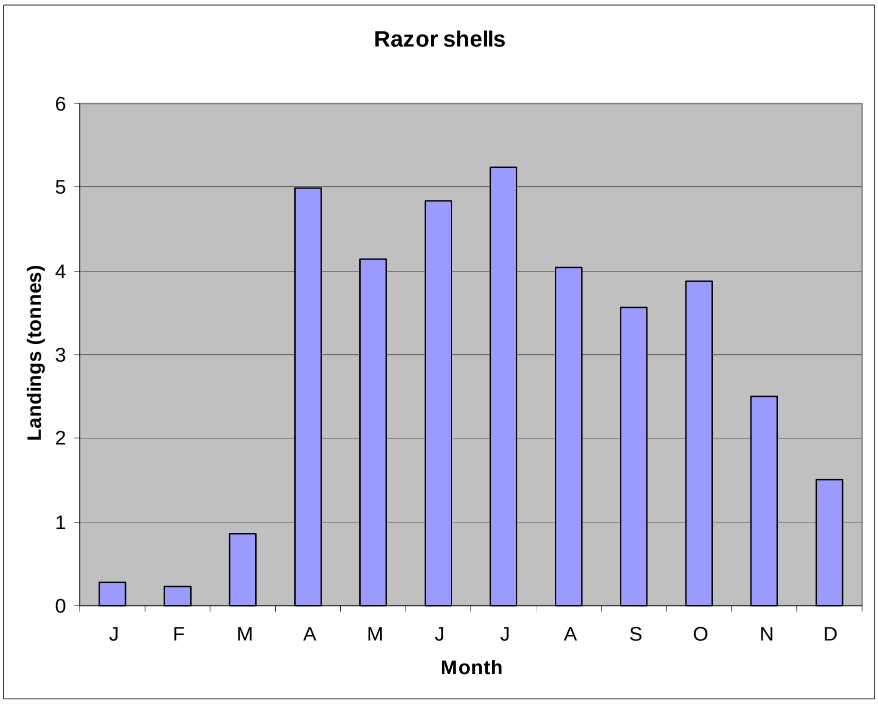


Fig. 16: Distribution of whelk landings at Scottish ports by UK vessels fishing within the SEA7 coastal zone. Based on ICES statistical rectangles, and averaged over the three years, 2002-2004.

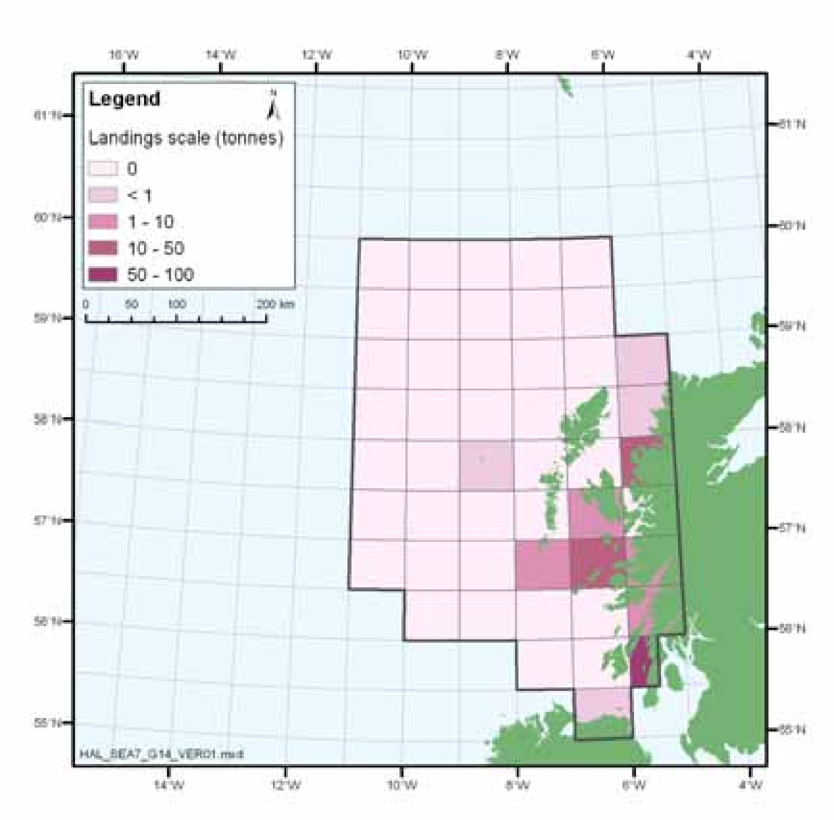


Fig. 17: Monthly landings (tonnes) of whelks from the SEA7 coastal zone, averaged over the period 1995-2004.

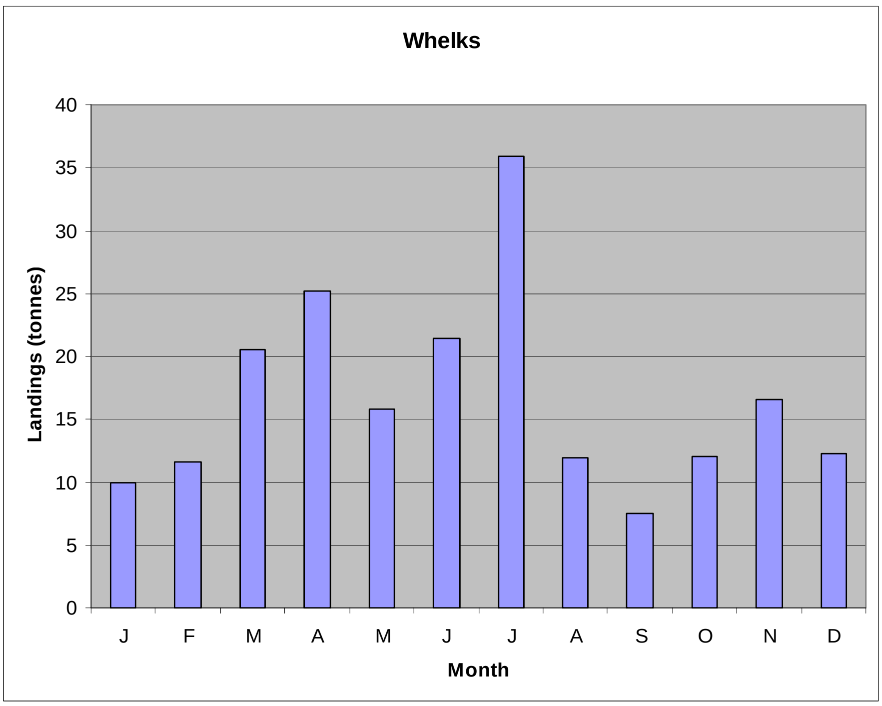


Fig. 18: Monthly landings (tonnes) of periwinkles from the SEA7 coastal zone, averaged over the period, 1995-2004.