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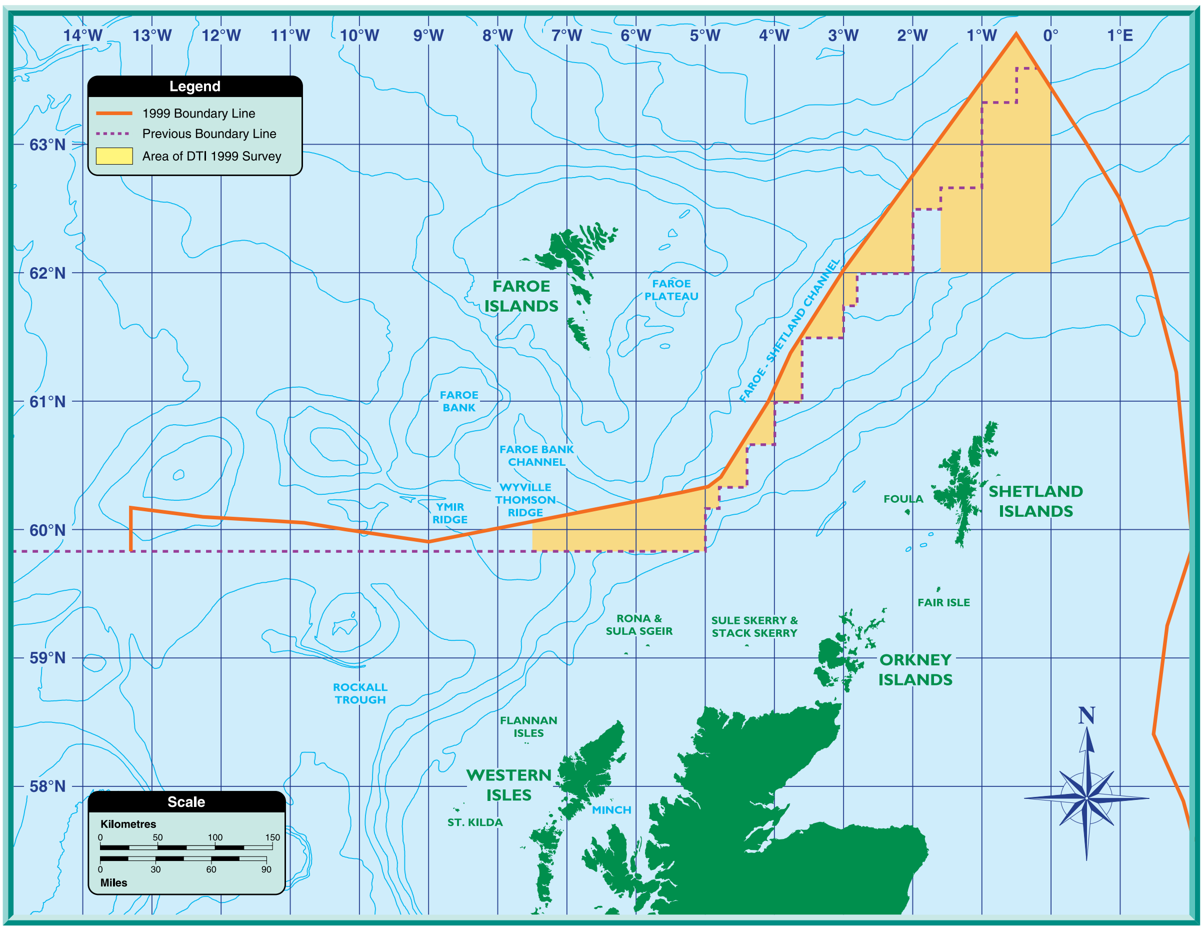
1 INTRODUCTION

The former White Zone comprises the area located along the median line between the UK and Faroese continental shelves. Following lengthy negotiations concerning the geographical definition of the median line, agreement was reached between the UK and Faroese Governments on 18 May 1999, enabling both countries to proceed with hydrocarbon licensing in respective territorial waters.

This document provides a Synthesis of Environmental Information, in support of a Strategic Environmental Assessment of the UK sector of the former White Zone. The Synthesis contains a comprehensive review of available information concerning the physical, chemical, biological and socio-economic environment of the former White Zone and adjacent coastal waters and coastlines. The Synthesis also provides sources and references for available data, and identifies significant gaps in data coverage.

The geographical area covered by the Synthesis includes the former White Zone (defined as the area between existing licensed acreage on the UKCS and the median line), including parts of the Faroe Shetland Channel, Faroe Bank Channel, Wyville Thomson Ridge and northern Rockall Trough (Figure 1) together with the coastal waters and coastlines of the Faroe, Shetland, Orkney and Western Isles and mainland of northern Scotland.

Figure 1 – Former White Zone



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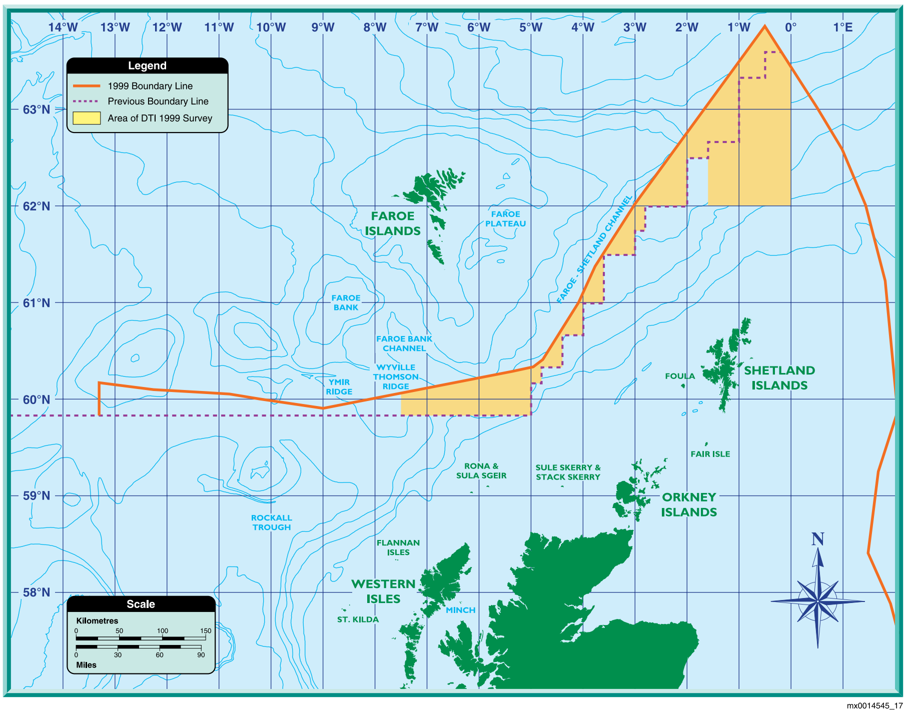
Report to the Department of Trade and Industry

Strategic Environmental Assessment of the Former White Zone

Volume 2 – Synthesis of Environmental Information



Consultation Document

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2 PHYSICAL AND CHEMICAL ENVIRONMENT

2.1 Meteorology

The former White Zone has a generally mild, maritime climate resulting from prevailing south-westerly winds and the warming influence of the Atlantic Continental Slope Current. The weather is strongly influenced by two semi-permanent weather systems, a low pressure region over Iceland and a high pressure area over the Azores. When these are in place, a stream of secondary depressions pass between the two in a general east or north-east direction. These depressions occur with a similar frequency throughout the year; however, they are most intense in winter months when gales are more common. The area has characteristically changeable weather patterns caused by the variability in positions of warm and cold fronts and development of anticyclones and depressions. Polar depressions from the Norwegian Sea are characterised by a relatively small circulation of intense, squally showers (of snow in winter). The area experiences frequent low cloud with periods of extensive rain and drizzle. Sea fog is more common in the summer and relatively uncommon during the winter months.

Winds in this area of the north Atlantic can occur from any direction, but predominant winds tend to be from the south-south-west, west-south-west and west. Less predominant, but displaying a more uniform distribution are winds from the east-north-east and east. During spring (April to June), the area is characterised by a uniform wind distribution, with east-south-east, north-north-west, north and north-north-east winds being predominant. During the rest of the year (from July to March) south-south-west, west-south-west and north winds occur with a percentage frequency of 32%. Marshall (1997) provides wind roses which summarise wind direction and speed data for the UK and Faroes.

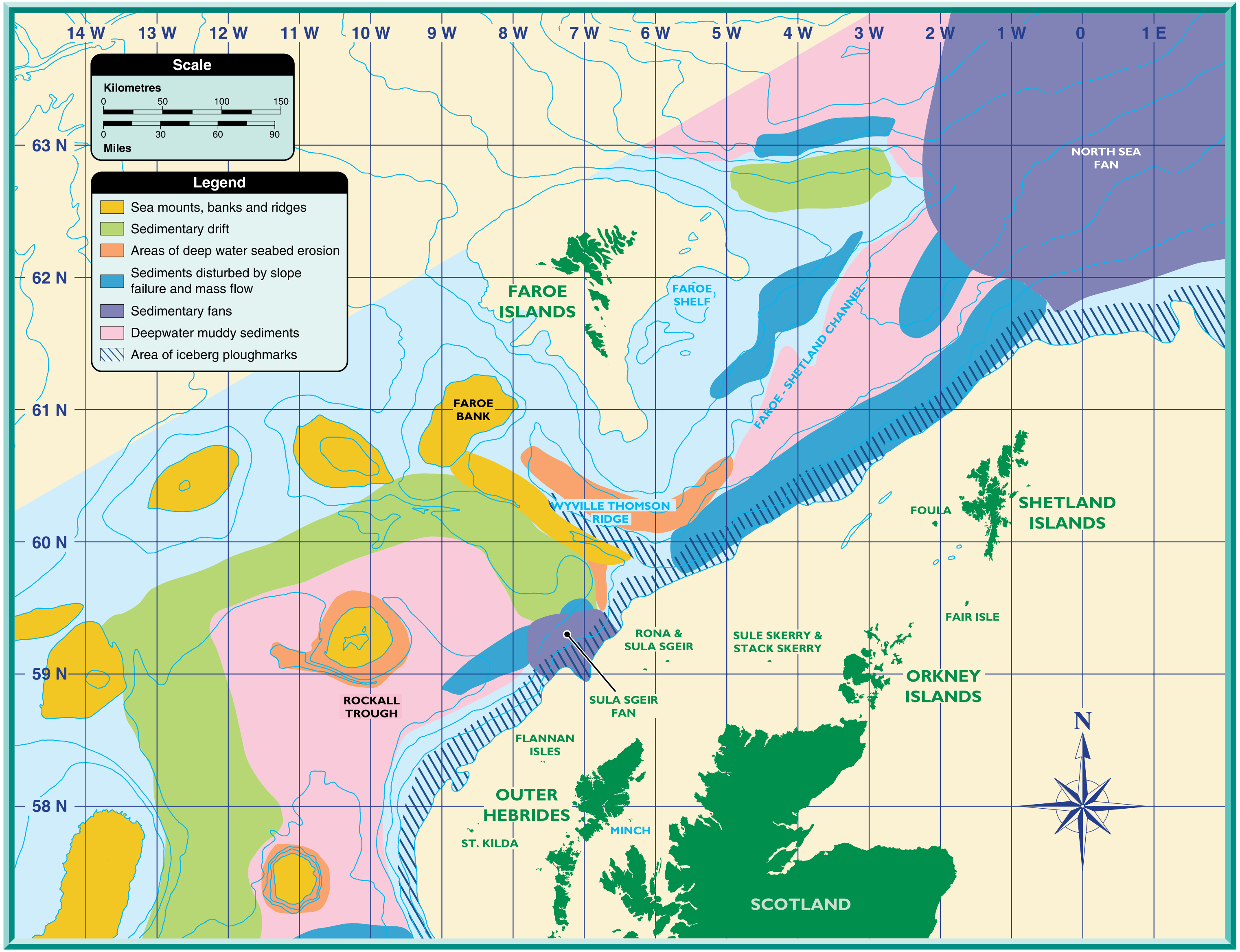
There is a significant seasonal variation in wind speed. Annual mean wind speeds tabulated by Marshall (1997) for Lerwick and Tórshavn are between 11 and 15 knots (moderate breeze). In winter (November to March), monthly mean wind speeds are between 12 and 17 knots but are generally less in the summer months ranging from 8 to 13 knots. Gales are common in winter, occurring on 8 days per month in January and December, and calm conditions are rare throughout the year.

2.2 Bathymetry and Topography

The former White Zone area is variable in bathymetry and topography (see Figures 1 and 2 and Stoker *et al.* 1993 and Britsurvey 2000) with, from the north, the primary features of the area being the North Sea Fan, the Faroe Shetland Channel, the Faroe Bank Channel and the Wyville Thomson Ridge.

In the broad part of the area to the north of 62°N, the gently sloping North Sea Fan is adjacent to the Norwegian Sea abyssal plain. Water depths are greatest in the north of this area with a maximum of around 2400m, decreasing to around 900m in the south-east of the surveyed area. The UK-Faroes boundary crosses the lower flank of the Fugloy Ridge, the east facing extension of the Faroes shelf, after which it traverses the Faroe Shetland Channel to approximately its southern extremity. Water depths through the Faroe Shetland Channel are in excess of 1000m. The boundary then turns westward and crosses just south

Figure 2 – Seabed features



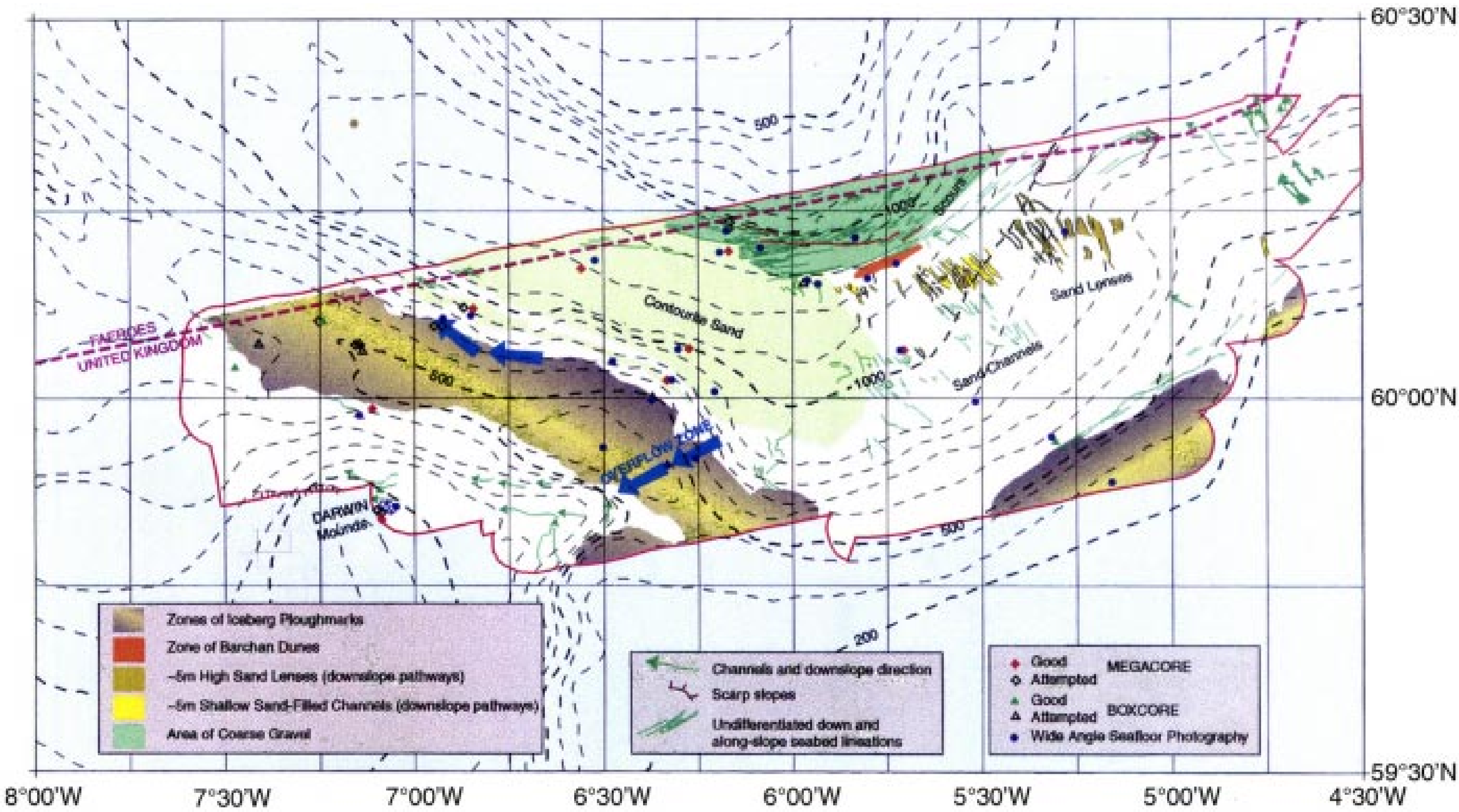
of the Munkagrunnur Ridge (the southern extension of the Faroes shelf) into the Faroe Bank Channel, a deep water channel perpendicular and intimately connected to the Faroe Shetland Channel. Water depths through this region are around 1000m with a maximum of 1200m in the centre of the Faroe Bank Channel. The median line then crosses the Wyville Thomson Ridge which divides the Faroe Bank Channel from the Rockall Trough to the south. The former White Zone includes a broad area to the west of 4° 30'W which covers the Wyville Thomson Ridge and its northerly and southerly flanks with water depths of between 400m at the ridge crest and 1200m in the Faroe Bank Channel; and eastern area in water depths as shallow as 200m which impinges on the UK continental shelf break.

In addition to the broad scale topography summarised above, the former White Zone includes numerous small scale features resulting from past volcanic and glacial activity and subsequent sedimentary processes including slope failure, sediment dewatering and erosion. Some of these small scale features were previously known, while others have only recently been discovered during AFEN and DTI seabed surveys (Bett 1997, Bett 1999, Jacobs and Masson 2000, Masson, in press). Iceberg ploughmarks occur all along the continental shelf edge to the west of the Hebrides, and the Orkney and Shetland Isles (Belderson *et al.* 1973) and were reported on the Wyville Thomson Ridge by Stoker *et al.* (1993). The 1999 DTI survey showed that iceberg ploughmarks occur in an extensive area between 200-500m water depth on the north flank of the Wyville Thomson Ridge (Jacobs and Masson 2000).

Kenyon (1987) described a range of mass wasting features along the continental slope to the west of north-eastern Europe, including at 60° 50'N on the east side of the Faroe Shetland Channel, a group of eight parallel sided, down-slope channels. These channels occurred between the 600m and 1000m depth contours and were about 10-15m deep, 200m wide and were interpreted as the result of small mass failures with possible depositional fans at the base. While the majority of the eastern and western flanks of the Faroe Shetland Channel represent glacigenic debris flows (Stoker *et al.* 1993, and Britsurvey 2000), large, recent slope failures have not previously been recorded in or adjacent to the former White Zone area (Kenyon 1987, Masson, in press and Bett 1997, 1999). A small failure (the AFEN slide) was discovered at 61° 20'N 02° 30'W during the AFEN 1996 survey (Masson, in press). The Miller slide at 61° 50'N 01° 00'W is regarded as a translational slide about 200,000 years old (Graham *et al.* 1996). Jacobs and Masson (2000) found significant evidence of slope failure at 62° 42'N 02° 00'W on the lower slopes of the Fugloy Ridge, with variably "blocky" seabed downslope of a series of headwall scarps from several hundred metres to 30km long and usually 10-30m (but up to 50m) in height. The area does not appear to be active at present, with the smaller scarps and blocky seabed being covered by undisturbed younger sediments. Small, linear bathymetric deeps of uncertain origin have been reported in the southern Faroe Shetland Channel (BGS 1990) some of which appear to coincide with scarp slopes interpreted from TOBI images from the 1999 DTI survey (Jacobs and Masson 2000).

Other small surface features of the Faroe Bank Channel and Wyville Thomson Ridge revealed by the DTI survey are indicated in Figure 3. The downslope channels are believed to represent earlier periglacial erosion while the barchan sand dunes, erosional scours and presence of coarse sediments around the base of the Munkagrunnur Ridge are the result of recent erosion and sediment transport by strong water currents. Rock and gravel outcrops were shown in this area (Jacobs and Masson 2000) and Stoker *et al.* (1993) record that igneous rock outcrops probably occur on the flanks of the Wyville Thomson Ridge. In the north of the former White Zone, during the 1999 DTI survey several large mud diapirs (in this case, eruptions of underlying material through the surface sediments) were found on the mid to lower slope of the North Sea Fan. These diapirs are around 6km across, very steep

Figure 3 – TOBI interpretation



sided and up to 100m high. The diapirs are composed of indurated sedimentary material with occasional concentrations of boulders and pebbles and are apparently not covered by recent sediments suggesting either recent origin or removal of sedimenting material through winnowing by water currents. Diapirs are not unique to this area and have been reported in adjacent regions including the Vøring Plateau (Hjelstuen *et al.* 1997). Smaller structures, possibly diapirs, were also found in the area of sediment failure off the Fugloy Ridge (see above). The North Sea Fan is characterised by abundant, simple downslope lineations indicative of some downslope sediment mobility.

Numerous small carbonate mounds (the Darwin Mounds) were discovered in a discrete area during the 1998 AFEN survey and a further area of these features were found during the DTI 1999 survey (Figures 4, 5 and 6). The nature of these mounds is described further in Section 2.7.3.4.

A large mound feature, possibly a rock outcrop was shown by TOBI imaging on the Wyville Thomson Ridge. Echo-sounding and seabed photography showed the feature to be a south facing scarp in an area of gravel, cobbles and boulders.

2.3 Hydrography

2.3.1 Data Sources

2.3.1.1 Measurement Programmes

There have been a number of specific research programmes focused on the oceanography of this area of the North Atlantic.

Since the pioneering *Porcupine* and *Lightning* studies of 1868-1870 (Wyville Thomson, 1874), the Faroe Shetland Channel environs have been one of the most studied oceanic regions of the world and two hydrographic sections across the Channel have been surveyed by the Aberdeen Marine Laboratory for over a century (Turrell *et al.* 1999a, 1999b). The Faroe Bank Channel (the continuation of the Faroe Shetland Channel to the south east) is less well studied, although since the late 1980's and the realisation of the importance of this area for the overflow of cold deep water south, a standard section has been studied regularly by the Faroese Fisheries Laboratory (Hansen and Østerhus 2000).

Since the 1960's there have been a number of large international oceanographic experiments in the North Atlantic, including the ICES sponsored Overflow '60 (Tait *et al.* 1967, cited in Van Aken and Eisma 1987), Overflow '73 (Ellett and Edwards 1978 and Müller *et al.* 1979, cited in Van Aken and Eisma 1987) and the Tyro 1983 (Van Aken and Eisma 1987, Van Aken 1988). These research programmes improved the understanding of the forces and processes which drive water mass exchange in the north east Atlantic.

During the 1980s the ICES Hydrography Committee encouraged scientists to focus on the wider aspects of water mass exchange in the area and a series of research cruises conducted by different nations and laboratories in the north Atlantic combined to form the North Atlantic-Norwegian Sea Exchanges (NANSEN) project (Van Aken and Becker 1996).

The work undertaken as part of the NANSEN project was continued through the Nordic WOCE programme which undertook current measurements throughout the North Atlantic

Figure 4 - Location of the Darwin Mounds and other records of the coral* Lophelia pertusa *within the former White Zone

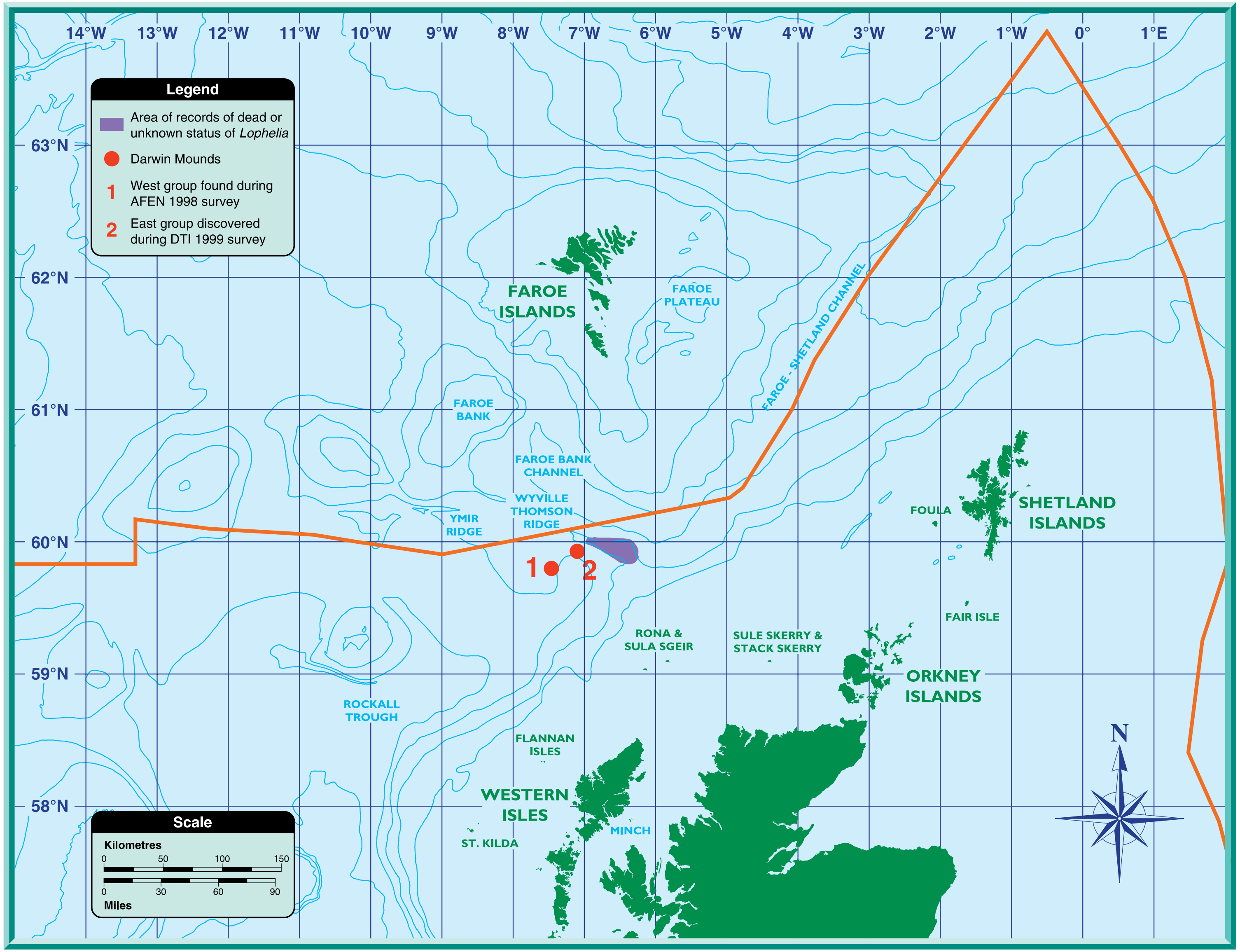


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Figure 5 – Distribution of Darwin Mounds East as interpreted from side scan sonar and photographs

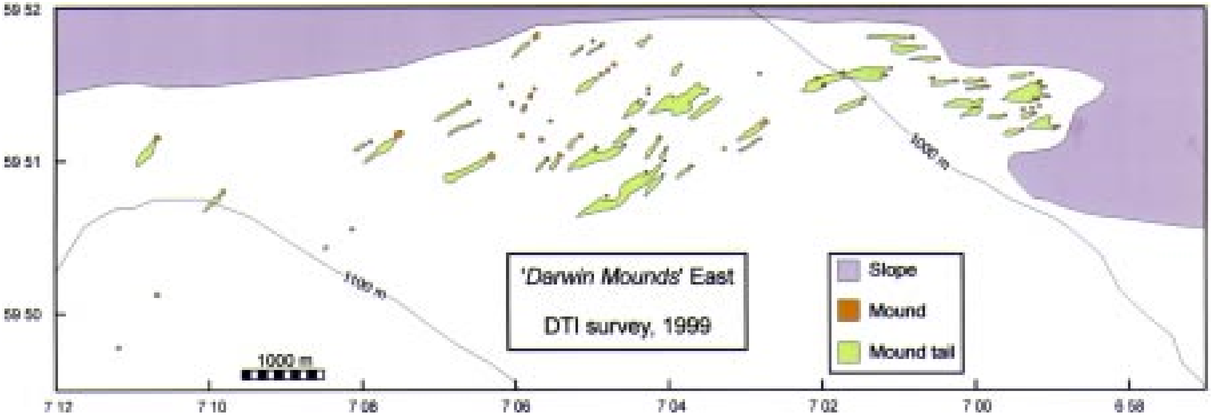
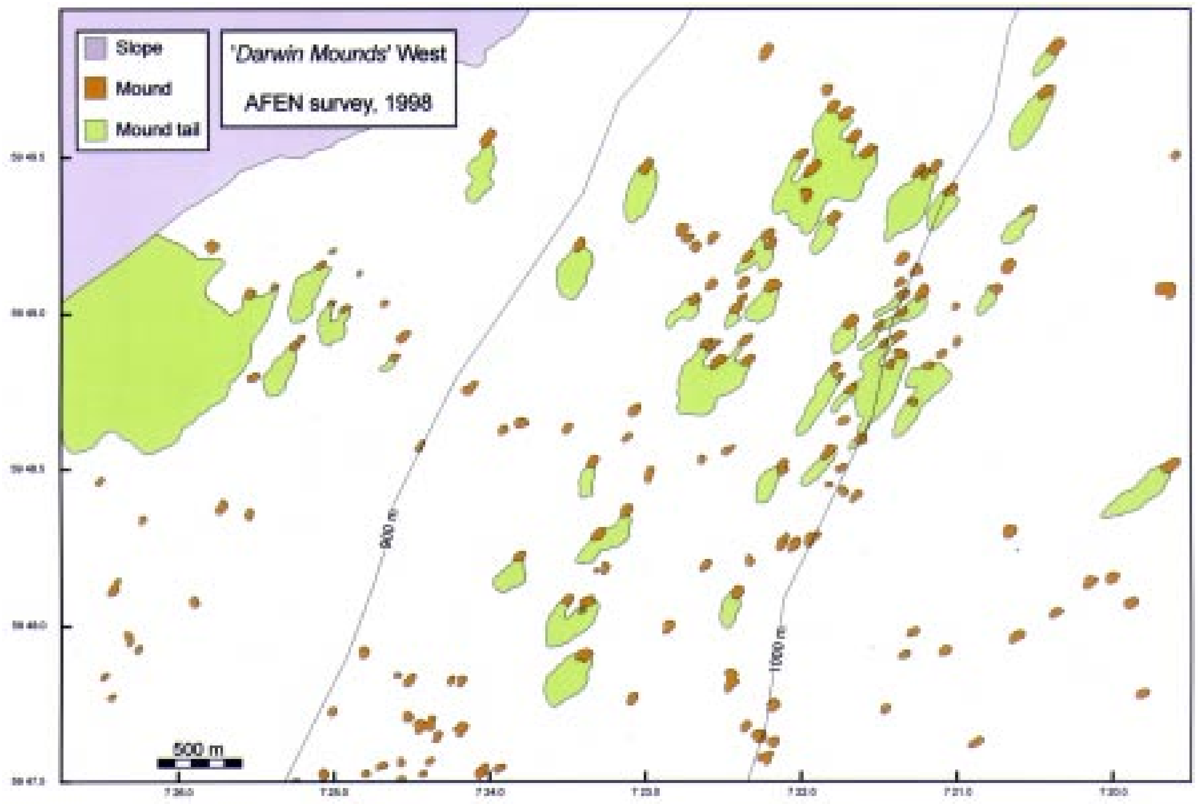


Figure 6 – Distribution of Darwin Mounds West as interpreted from side scan sonar and photographs



between 1993 and 1998. The results of the Nordic WOCE work have been discussed in a number of publications, e.g. Hansen *et al.* 1998, Turrell *et al.* 1999b, Østerhus *et al.* 1996a and b, Østerhus *et al.* 1999 and Orvik *et al.* 1999.

The observation system established during the Nordic WOCE programme has been continued with the EU-MAST VEINS (Variability of Exchanges in the Northern Sea) programme (Hansen and Østerhus 2000).

Recordings of hydrographic data in the Norwegian Sea have been undertaken since 1948 from Ocean Weather Station Mike (OWS M) located in the eastern margin of the Norwegian Sea at 66ºN, 2ºE (Østerhus *et al.* 1996b). This series of measurements represents the longest homogeneous time series from the deep ocean and is operated by the Norwegian Meteorological Institute.

The Svinøy section monitoring programme, consisting of a section running NW from approximately 62ºN on the Norwegian coast, was initiated in 1995 and funded by the Norwegian Research Council (Orvik *et al.* 1999). Since 1997 it has been run as part of the above mentioned VEINS programme. Other previous oceanographic studies along this section are recorded in Blindheim and Loeng (1981).

Cruises specific to the Norwegian Sea have also taken oceanography measurements. The Hudson cruise (1982), the Håkon Mosby cruise (1994) and the Magnus Hanson cruise (1996) took measurements in the Norwegian Basin. Also a section along 63ºN in the Norwegian Sea has been surveyed during Russian surveys in June/July every year since 1959 (Borovkov and Krysov 1995, cited in Blindheim *et al.* 1996).

The above detailed series of research programmes and cruises have allowed for the study of the long-term monitoring of water exchange between the Atlantic and Nordic seas.

In addition to the above mentioned research programmes there have been several current measurements programmes undertaken by individual oil and gas operators. However these measurements have tended to be conducted at specific locations for only a short duration. Grant *et al.* (1995) summarises work undertaken by BP and Shell in the development of a metocean design basis for the deep water harsh environment off the NW shelf of Europe. Metocean measurements have also been undertaken by amongst others Mobil, Amoco and Texaco.

2.3.1.2 Circulation Models of the North Atlantic

Several circulation models have been developed for the North Atlantic.

Some of the most recent modelling work has been completed as part of the ICOS research programme investigating migrations of the copepod *Calanus finmarchicus* between oceanic and shelf areas off north west Europe (Hainbucher and Backhaus 1999, Harms *et al.* 1999). Originally developed in 1985 (Backhaus 1985) this three dimensional model was applied to simulate water flow around Iceland, the Faroe Islands and the north west European continental shelf and slope, including the northern North Sea.

An oil industry consortium (The Northwest Approaches Group – NWAG) sponsored a project to develop a high resolution 3D computer model of the currents of the West of Shetland shelf and slope. This project was completed by HydroQual Inc. and involved the use of metocean data collected by oil companies in this area of the North Atlantic (Turrell *et al.* 1999b).

The North European Storm Study (NESS) was another oil industry and government agency sponsored research programme which modelled wind, wave and current conditions on the North European Continental Shelf, including northern North Sea and Norwegian waters (Peters *et al.* 1993).

2.3.2 Hydrographic Overview

Circulation patterns and water mass characteristics within the north-east Atlantic have been extensively studied and are of major interest in relation to both world ocean circulation and climatic studies and as a result are well documented. The current regime in the area can be described as complex, see Figures 7 and 8. This complexity arises from a number of factors which include bathymetry variations throughout the area and the influence of a number of water masses.

Long term data measurements in the area indicate irregular variability in water mass characteristics and water flow patterns in the north Atlantic. While a broad spectrum of timescales, ranging from seasonal and inter-annual to inter decadal is observed, the time series are also suggestive of more long-term fluctuations (Blindheim *et al.* 1996). The North Atlantic Oscillation (NAO) is the dominant recurrent mode of atmospheric behaviour in the North Atlantic Ocean and one of the most robust on Earth. Over the period of the instrumental record (since 1865), the NAO has exhibited considerable long-term variability which appears to be amplifying with time. Thus the 1960's experienced the most extreme and protracted negative phase of the NAO index and the late 1980's / early 1990's experienced its most prolonged and extreme positive phase.

The NAO index described the changing pattern of Atlantic heat exchange and resulting changes in sea surface temperature, and is reflected by significant variability in the track, number and intensity of winter storms and thus on the winter wave climate. Direct and indirect effects on ocean currents may operate on an oceanic scale, where the main Atlantic gyre circulation appears to have strengthened by 30% in parallel with the NAO, and at a regional scale where transport through the Faroe Shetland Channel has also increase. However, amplification of decadal variability in the NAO is unlikely to be associated with anthropogenic causes, as a recently-derived long-term proxy of winter NAO variability suggests that similar long period shifts in the NAO have been a regular if rare feature of the Atlantic climate over the past 500-600 years.

The UK sector of the former White Zone, comprises three distinct topographic areas:

- The Wyville Thomson Ridge
- The Faroe Shetland Channel and Faroe Bank Channel
- The northern North Sea/southern Norwegian Sea (the North Sea Fan).

2.3.2.1 Wyville Thomson Ridge

The Wyville Thomson Ridge forms the northern most limit of the Rockall Trough and is thought to limit the deep outflow from the Faroe Shetland Channel towards the Rockall Channel. Knowledge of the Wyville Thomson Ridge overflow was first documented in 1972 (Ellett and Roberts 1973) and is to a large extent the results of work undertaken by Ellett and co-workers (Ellett 1988, Ellett and Martin 1973, Ellett and Edwards 1978, Ellett *et al.* 1983, Ellett *et al.* 1986 and Ellett 1998).

Figure 7 - Deepwater currents

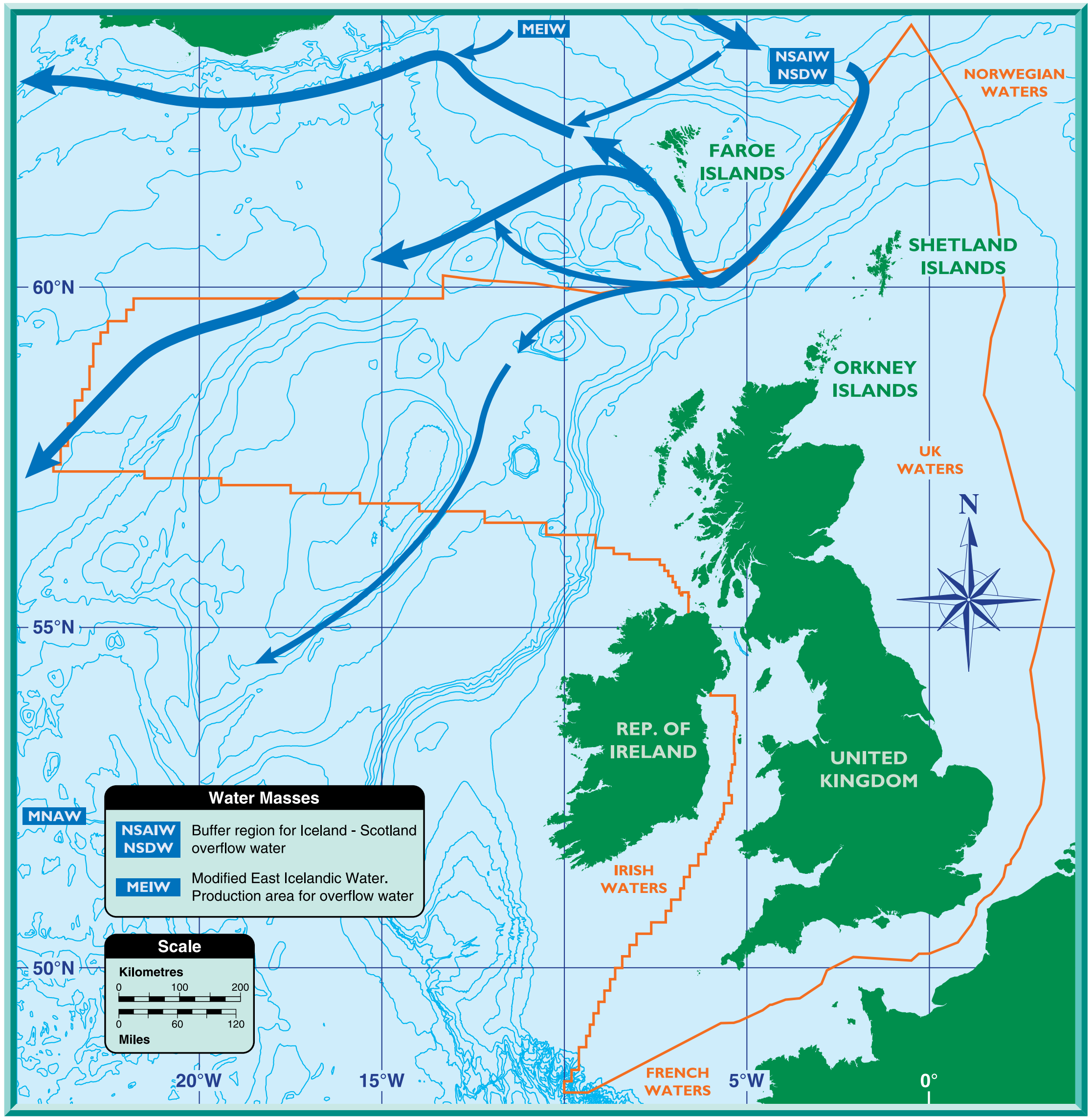


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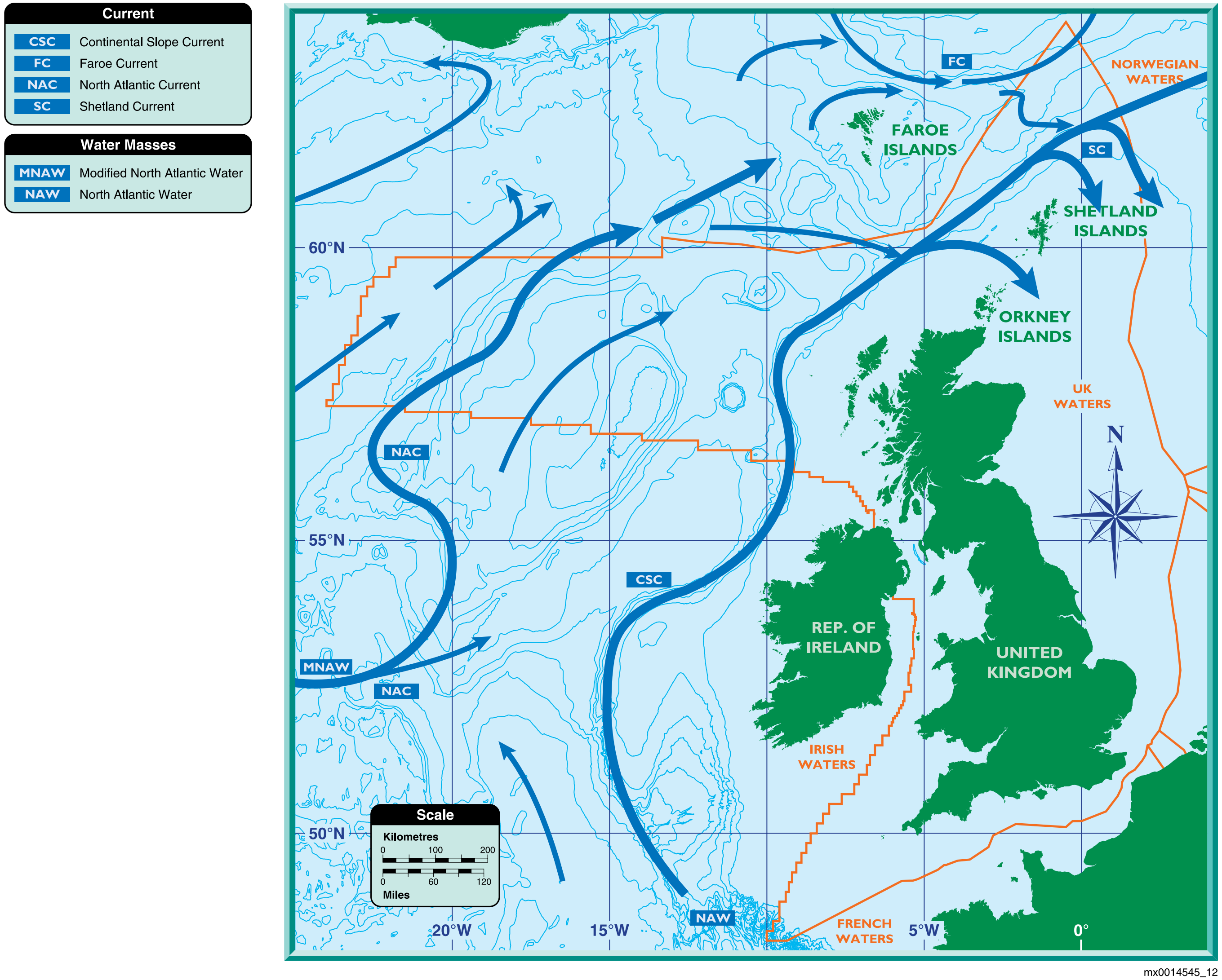
Figure 8 – Surface currents



The ridge is fairly flat with water depths mostly between 500-600 m along its total extent from the Faroe Bank to the Hebridean Slope, except for a depression in the middle (where the maximum sill depth of 600 m is encountered) (Ellett 1998).

The surface waters over the Wyville Thomson Ridge are dominated by North Atlantic water, which flows to the northeast into the Faroe Shetland Channel. This water predominantly comprises the Continental Slope Current, which follows the continental slope and originates off the European Continental shelf, south of the Rockall Trough. The upper 500-550m of the Slope Current can cross the Ridge, however water below this level is diverted westwards (Ellett 1998). Ellett *et al.* (1983) and Hansen and Østerhus (2000) also suggest that the surface waters over the Wyville Thomson Ridge are mixed with Modified North Atlantic water which branches off the main current stream to the east of the Faroe Bank. This was confirmed by Ellett (1998) who observed a persistent eastwards flow from the Rockall Plateau over the Wyville Thomson Ridge.

This surface water exhibits temperatures of over 8ºC and a salinity of over $35.30^{0}/_{00}$, and is generally warmer and more saline than other surface water masses present in this area of the North Atlantic. This is attributed to its southern origin (Turrell *et al.* 1999a).

Mid water currents (at the interface of the surface Atlantic waters and deep cold waters) are more variable. The currents appear to change from weak easterly currents in autumn and early winter to episodes of strong westerlies in late winter and spring. Ellett (1998) suggests that it is the relaxation during spring of the predominating winter south westerly wind which accounts for the outbreaks of westerly flow seen during this season.

The deeper waters are dominated by cooler and less saline waters which flow south westwards from the Faroe Shetland Channel. The majority of the Faroe Shetland Channel Bottom Water exits the Channel through the Faroe Bank Channel and mixes with the waters of Atlantic origin to form a component of the Iceland Scotland Overflow Water, which enters the North Atlantic through the Iceland Basin (Turrell *et al.* 1999a). However there is also a fairly steady southerly flow (although of less magnitude) through the central depression and over the north west part of the ridge crest (Ellett 1998 and Hansen and Østerhus 2000).

Current meter observations from a meter located 15m above the seabed, immediately to the south west of the Ridge recorded average current velocities in the order of 25-50 cm/s, with occasional direction reversals. Temperatures between 5-7ºC have been recorded which indicate a cold water component from the north east of the Ridge, but also indicate that there is a large component of Atlantic water present (Hansen and Østerhus 2000). Ellett (1998) suggests that this is a deep water branch of the Continental Slope Current which is turned westwards by the Wyville Thomson Ridge.

Ellett (1998) and others (Ellett and Edwards 1978, Saunders 1990 and Zenk 1980) have found evidence that the Wyville Thomson Ridge overflow can be intermittent both spatially and temporally (Hansen 1985 and Hansen and Østerhus 2000). In addition to the steady flow over the Ridge there is evidence of more distinct overflow events which can last for a number of days. During these events currents have been observed to be stronger than normal and temperatures lower (below 3ºC), which represents a greater influence of cold water from the Faroe Shetland Channel Bottom Water.

2.3.2.2 Faroe Shetland Channel

Five water masses, characterised by their salinity and temperature characteristics, are known to be present in the Faroe Shetland Channel and studies have shown there to be distinct differences in the distribution of these between the east and west slopes of the Channel (Dooley and Meincke 1981, Hansen 1985, Saunders 1990, Turrell 1997 and Turrell 1999a).

- North Atlantic Water
- Modified North Atlantic Water
- Arctic Intermediate/North Icelandic Water
- Norwegian Sea Intermediate Water
- Faroe Shetland Channel Bottom Water

The surface waters of the Faroe Shetland Channel are characterised by two distinct water masses; North Atlantic and Modified North Atlantic waters. North Atlantic water enters the Faroe Shetland Channel over the Wyville Thomson Ridge and is concentrated along the eastern side of the Channel, as a slope current close to the edge of the West of Shetland Shelf. It is most intense over the 400m contour (Turrell *et al.* 1999a). This water originates from the Rockall Trough. The Modified North Atlantic Water dominates the surface flow in the centre and along the western slope of the Channel and represents the northern branch of the North Atlantic Current. As this water flows towards the Faroe Islands from the west it splits and flows into the Faroe Bank and Faroe Bank Channel areas and northwards around the Faroe Plateau in clockwise direction entering the Faroe Shetland Channel from the north-east (Hansen 1985, Saunders 1990). The net flow of these two water masses is to the northeast (Turrell *et al.* 1999a).

Below the Modified North Atlantic Water, Arctic Intermediate/North Icelandic Water originating from north of the Iceland Faroe Ridge occupies water depths of 400-600m on the Faroese side of the Channel (Blindheim 1990). At the Scottish side of the Channel the area occupied by this water is narrow and in slightly shallower depths. A second intermediate water mass is present on the Faroese side of the Channel in the form of Norwegian Sea Intermediate Water which occupies water depths of 600-800m. This water becomes shallower and occupies a reduced depth range towards the Scottish slope and occasionally does not extend as far as the slope. The net flow of this water mass in the Channel is to the southwest (Turrell *et al.* 1999a).

Below these intermediate waters, at depths of greater than 800m the Channel is filled by cold water originating from the Norwegian Sea, known as Faroe Shetland Channel Bottom Water. It is believed that most of the transport within this water leaves the Channel through the Faroe Bank Channel and to a lesser extent over the Wyville Thomson Ridge (see above), although some may be recirculated back into the Norwegian Sea (Turrell *et al.* 1999a).

The temperature and salinity characteristics of each of the above identified water masses are defined below in Table 2.1 (Heath and Jónasdóttir 1999):

Table 2.1 – Water Mass Salinity and Temperature

Water mass	Temperature (ºC)	Salinity ($^0/_{00}$)
North Atlantic Water	> 7.5	> 35.3
Modified North Atlantic Water	6.0 - 7.5	35.12 - 35.18
Arctic Intermediate/North Icelandic Water	3.0 - 4.5	34.95 - 35.00
Norwegian Sea Intermediate Water	0.25 - 0.75	< 34.92
Faroe Shetland Channel Bottom Water	< 0.5	-

The mean velocity of the Scottish shelf edge current is approximately 40cm/s towards the northeast, and in the lower water mass 15cm/s towards the southwest (Saunders 1990). The shelf edge current exhibits a seasonal maximum transport in December/January and a minimum in June/July (Gould *et al.* 1985). Measured near-bottom current velocities indicate peak currents over 75cm/s on the upper continental slope west of Shetland (Graham 1990a, Graham 1990b, Strachan and Stevenson 1990). Sediment bedforms observed on the upper slope, such as small barchan-type sand waves, longitudinal sand patches and comet marks (Werner *et al.* 1980), confirm currents in the range 40 to >75 cm/s (Kenyon 1986). Periodic and episodic peak currents are driven by semi-diurnal tides, internal waves (Sherwin 1991), storm surges (Turrell and Henderson 1990), gyres and eddies (Dooley and Meinke 1981).

Internal waves form on the interface between the overlying Atlantic and underlying Norwegian Sea Deep waters, at approximately 500m below the surface. This can result in incursions of cold water from time to time at the seabed, accompanied by relatively strong currents (seabed surges) (Grant *et al.* 1995).

A phenomenon known as the *Nolter Maelstrom*, was observed by US Navy submersible operators working at around 500m on the West Shetland Slope close to the Wyville Thomson Ridge and is reported by Sherwin (1991). This consisted of a regular (tidal) occurrence of sand/mud swirls at the seabed followed by a rapid increase in current speeds to 2.5 knots (130cm/s) and a sharp drop in water temperature.

Westerberg (1990) has mapped temperature data from Conductivity Temperature Depth deployments throughout much of the Faroe Shetland Channel, indicating the 0°C isotherm ranging from 400-800m and the 7°C isotherm ranging from 300-500m, in close agreement with data from TOBI (Towed Ocean Bottom Instrument) deployments during AFEN surveys (AFEN 2000).

Research has shown that there is seasonal variability in the intensity of the flow of the water masses through the Faroe Shetland Channel (Harms *et al.* 1999). This variability is apparent in both the surface and underlying water layers, but most apparent at intermediate depths of 400-600m. Current velocities in the north-east flowing waters show a maximum in the winter and currents close to the bottom of the Channel show a maximum in summer.

The wave climate, due to the exposed nature of the Atlantic, is more severe than that found in the Northern North Sea. The wave conditions are similar throughout the Atlantic area with estimated 50 year wave heights of approximately 32m and wave periods of greater than 20 seconds (Grant *et al.* 1995).

2.3.2.3 Northern North Sea/Southern Norwegian Sea

The oceanographic measurements taken at Ocean Weather Station Mike located at 66ºN, 2ºE since 1948, represent the longest homogeneous time series of data from the deep ocean and have proved to be strategic both for studying the Atlantic inflow and the Norwegian Sea Deep Water (Østerhus *et al.* 1996a and b and Gammelsrød *et al.* 1992).

The waters of the northern North Sea / southern Norwegian Sea are influenced by three main water masses.

- Norwegian Atlantic Water
- Norwegian Sea Arctic Intermediate Water
- Norwegian Sea Deep Water

The upper few hundred metres are dominated by the warm, saline water of the Norwegian Atlantic Current. The deeper water depths are influenced by the bottom waters formed in the adjacent Arctic and Greenland Seas (Gammelsrød *et al.* 1992 and Østerhus *et al.* 1996b).

Atlantic water flows into the Norwegian Sea and occupies the upper few hundred metres (Gammelsrød *et al.* 1992) in the form of two main surface current streams, a northern and southern branch of Atlantic water.

The southern branch follows the continental slope and includes water from the Continental Slope Current, which flows north through the Faroe Shetland Channel and is recirculated water from the Iceland Faroe Gap. In the southern Norwegian Sea this current appears to be topographically locked to the main slope of the Norwegian shelf, following the 1,000m depth contour. This branch is present in the northernmost part of the former White Zone. The northern branch flows eastwards from the eastern tip of the Faroe Plateau (approximately 63ºN) and tends to follow what may be a secondary slope above bottom depths of 1,500 – 2,000m (Hansen and Østerhus 2000) in the north of the present are of interest. These water masses appear to occupy the top 400-500m of water in the southern Norwegian Sea (Orvik *et al.* 1999) The top 75m of these surface water masses can also be influenced by the less saline Norwegian Coastal Current (Helland 1963).

Norwegian Sea Arctic Intermediate Water is present below the surface waters from depths of 500 m (Blindheim 1990). This intermediate water is most likely created at the surface in the Arctic domain of the Iceland and Greenland Seas, north of the Arctic front. It flows south and is then subducted between the more saline surface waters of Atlantic origin and the Norwegian Sea Deep Water below (Blindheim 1990). The boundary between the Norwegian Sea Deep Water and Norwegian Sea Arctic Intermediate Water is usually defined to be where the temperature is -0.5ºC (Müller *et al.* 1979) which is found around (although usually above) the 1,000m contour and appears to be the depth from which the densest overflow into the Faroe Shetland Channel is drawn (Hansen and Østerhus 2000).

The temperature characteristics of each of the above identified water masses are defined below in Table 2.2 (Gammelsrød *et al*. 1992):

Table 2.2 – Water Mass Temperature

Water mass	Temperature (ºC)
Norwegian Atlantic Water	4.5 - 8.5
Norwegian Sea Arctic Intermediate Water	-0.5 – 4.5
Norwegian Sea Deep Water	< - 0.5

Current speeds in the surface water masses (at the 200m depth) vary between the two identified branch currents. The southern current has been recorded to have an annual mean current speed of 30 cm/s and a maximum of 117 cm/s, towards the north east (Orvik *et al.* 1999). The northern branch exhibits an average current speed of 20 cm/s (Hansen *et al.* 1998) and a weaker maximum current velocity of 80 cm/s, again to the north east (Orvik *et al.* 1999).

2.4 Solid Geology

The complex solid geology of the area is summarised in Stoker *et al*. (1993) who note that information on subsurface rock types is derived from British Geological Survey shallow boreholes and oil industry wells both of which commenced in the area in 1972.

Continental crust underlies the area but under the major rift axis of the Rockall Trough and Faroe Shetland Basin the crust may be thinner than in the surrounding shelf areas. Basement rocks at or near outcrop are pre-Devonian, Lewisian of the Foreland and Orthotectonic Caledonide Provinces, and Devonian and younger rocks. In the west of the area and in particular, the former White Zone, these younger rocks include Tertiary basalts believed to result from the 3 major extrusive events from the Faroes. While the solid geology outcrops to surface in places, over much of the area the rocks are overlain by varying thicknesses of unconsolidated sediments (particularly glaciomarine deposits).

2.5 Sediments

Prime sources of information on the seabed sediments of the former White Zone and adjacent areas are the continuing work of the British Geological Survey (eg Stoker *et al*. 1993 and BGS, 1990), the BIOFAR programme (Nørrevang *et al*. 1994), the 1996 and 1998 AFEN surveys (Masson *et al*. 2000) and the 1999 DTI survey of the area (Jacobs & Masson, 2000).

Unconsolidated sediments at the seabed surface are very variable over the area ranging from boulders to mud and the distribution of sediment types is often patchy within a limited area. However, the following broad patterns can be discerned; sediments in the deeper areas are usually mud or muddy sand, with the proportion of mud decreasing upslope to the continental shelf break where the sediments are clean sands usually with admixtures of gravel. In waters shallower than 200m (continental shelf), the surface sediments are usually a thin veneer of sand and/or gravel overlying Quaternary age clays and mixed sediments (for example, of the Otter Bank or Morrison sequences). The depths of these underlying unconsolidated sediments vary widely across the former White Zone, from more than 400m at the North Sea Fan and the Sula Sgeir Fan, 200-300m in two areas around the shelf break on the eastern flank of the Faroe Shetland Channel to less than 50m in the base of the

Faroe Shetland Channel and zero where rock outcrops occur. Ice rafted boulders and stones are widely reported and abundant across the entire area, and Stoker *et al*. (1993) note a lateral moraine from Scandinavian ice at 62°N 1°E although no such features were identified in the 1999 DTI survey of the area (Jacobs & Masson, 2000).

Sediment distributions in the area of iceberg ploughmarks are complex, with the edges of the ploughmark characterised by the accumulation of cobble and boulders, and the centre of the gouge by finer sediments (sands) believed to be the result of infilling by material transported by water currents. In addition, glacial boulder clays may be exposed in places at the edges of iceberg ploughmarks.

Local variations to the general pattern of sediment distribution are introduced by particular hydrodynamic and other conditions. In the Faroe Bank Channel, strong water currents around the southern extremity of the Munkagrunnur Ridge have resulted in an eroding seabed with the surface sediments consisting of gravel with occasional cobbles and boulders extending to a water depth of 1200m. The floor of the deeper part of the Faroe Bank Channel is composed of contourite coarse silt to very fine sand with a mud content of 23-38% (ERT, 2000b). This contrasts with the deeper parts of the Faroe Shetland Channel (and in particular the northern area) where mud contents are above 50% and in places more than 90% (Stoker *et al.* 1993). The sediment types associated with smaller scale seabed features such as barchan sand dunes are summarised in Section 2.2 and fauna/sediment type associations are noted in Section 3.2.2.

Kenyon (1986) reported a range of bedforms on the upper continental slope of the Faroe Shetland Channel indicative of sediment transport driven by the north east flowing North Atlantic Water current. The 1999 DTI survey of the former White Zone also showed a range of features (e.g. lineations, barchan dunes) suggesting active sediment transport but in this case driven by the south westerly flowing Faroe Shetland Channel Bottom Water. Sites of deposition of the transported sediments are believed to be the deeper parts of the south-eastern and south-western Norwegian Sea and the Rockall Trough.

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3 BIOLOGICAL ENVIRONMENT

3.1 Plankton

3.1.1 Primary Production

The main source of spatial and temporal data on plankton distribution in the North Sea and North Atlantic comes from the Continuous Plankton Recorder (CPR) (Reid *et al.* 1990 and Warner and Hays 1994) which has been deployed in the area since 1931. Apart from a break during the Second World War, CPRs have been deployed to the present day on a monthly basis. CPRs are towed by merchant ships on their normal routes of passage at a depth of approximately 10m (SAHFOS 1997). Methods of analysis and data processing and maps showing survey routes taken are provided by Warner and Hays 1994. Data from the SAHFOS database is available for extraction for user-defined areas and seasons (SAHFOS 1998).

Another source of data is the satellite imagery Coastal Zone Colour Scanner (CZCS) that collected synoptic images of near-surface concentrations of phytoplankton pigments between 1979 and 1986 (e.g. Reid *et al.* 1990, Campbell and Reilly 1988 and Holligan *et al.* 1983).

Rates of primary production will vary through the year and are dependent on a number of factors including the presence of nutrient salts and light availability, in turn influenced by physical mixing processes (Robinson 1970). Breakdown of the thermocline in winter months and strong winds allows nutrients in deep colder water to be redistributed into surface layers. This coupled with increased light in early spring leads to a bloom of phytoplankton (Zeitzchel 1986). As the thermocline becomes fully re-established in summer months and wind-induced mixing of the water layers is reduced, phytoplankton growth depletes the levels of available nutrients in the surface-layer. Phytoplankton growth is therefore quickly inhibited following the initial spring bloom. Therefore, during summer months high standing stocks of phytoplankton tend to persist only in regions where physical mixing processes maintain a relatively high upward flux of nutrients (Eppley and Peterson 1979 and Holligan and Groom 1986). Zooplankton grazing is also a limiting factor in phytoplankton blooms (Colebrook 1982).

Huthnance (1986) notes that phytoplankton distributions will vary between areas due to effects of slope topography on the propagation of oceanic eddies and internal waves, differences in shelf edge tidal currents and slope currents, and seasonal and latitudinal variations in the degree of stratification across the shelf edge. However, a broadly similar pattern of phytoplankton blooming is reported for the Northwest European shelf edge and adjacent Atlantic from the Rockall Trough through the Faroe Shetland Channel to the northern North Sea (Holligan and Groom 1986). Colebrook (1984) divides the plankton into two groups of species, one group involved in the spring bloom which are all diatoms and a second group which show a seasonal peak in abundance later in the year which are mainly *Ceratium* species but also include a few diatoms. Coccolithophores also bloom in summer, although with large annual differences in productivity as well as species dominance (Holligan and Groom 1986).

In deep oceanic waters north of 60°N, phytoplankton abundance is lower and length of productive season shorter than seen in the central and southern North Sea and coastal waters (Robinson 1970). However, enhanced primary production is a reported feature of shelf-break areas (Holligan and Groom 1986) and exceptional blooms have been recorded in these areas (Pingree and Mardell 1981, Holligan *et al.* 1983 and Reid *et al.* 1987). This enhanced productivity is likely to be explained by slope induced internal waves increasing the vertical nutrient flux to surface layers along the continental slope (Sandstrom and Eliot 1984, Pingree and Mardell 1981 and Klitgaard *et al.* 1997). Similarly, large blooms of diatoms are also reported on the southern edges of the Norwegian Deeps (Reid *et al.* 1987).

The size and timing of phytoplankton blooms in the Rockall Trough, Faroe Shetland Channel and entrance to the Norwegian Sea will vary from year to year depending on local weather and oceanographic conditions. In the North Atlantic, the spring bloom generally peaks in May with a sharp decline in June followed by a steady increase and fairly consistent standing crop until September after which there is a sudden decrease to the winter minimum (Robinson 1970, Colebrook 1982 and Colebrook 1984). Low levels of over wintering stocks of phytoplankton are reported in the literature (Colebrook 1984) particularly in oceanic waters.

Seasonal deposition of aggregated phytodetrital material is now recognised as a significant mechanism of vertical carbon flux in the deep sea (e.g. Billett *et al.* 1983, Rice *et al.* 1986, Bett 2000c). The timing and chemical composition of phytodetrital deposits, together with the species composition of recognisable detrital remains, suggests that sinking rates are relatively rapid (>100m/day) and that horizontal advection of phytodetritus is limited. Although direct observation of phytodetrital deposition is limited to south of the Wyville Thomson Ridge (Bett 2000), it is highly probable that similar deposition occurs in the Faroe Shetland and Faroe Bank Channels, mainly in late May and June following the spring diatom bloom.

3.1.2 Zooplankton

Until recently available knowledge on the distribution of zooplankton in the North Atlantic area was largely limited to data from surface (10m) trawls of the Continuous Plankton Recorder and a number of authors have reported on these data interpreting spatial and temporal variations in distribution (e.g. Rees 1957 cited in Fransz *et al.* 1991, Oceanographic Laboratory Edinburgh 1973, Colebrook 1982, Lindley 1982, Hays *et al.* 1996). Other work has also looked at the vertical distribution and migration of zooplankton using a variety of methods including trawls and Doppler current profilers (e.g. Russell 1927, Williams and Lindley 1982, Pipe and Coombs 1980 and Heywood 1996).

Recent work has revolved around an interdisciplinary investigation of copepod *Calanus finmarchicus* migrations between oceanic and shelf areas off north-west Europe (the ICOS Project) (e.g. Heath and Jónasdóttir 1999, Richardson *et al.* 1999, Madden *et al.* 1999, Gallego *et al.* 1999 and Heath 1999). Samples were collected for this programme in the Faroe Shetland Channel, southern Norwegian Sea and northern North Sea between 1993 and 1995. The overall aim of the recent ICOS programme was to understand the inter-annual and long-term variation in *C. finmarchicus* given the potential importance of this species in the food web of the North Sea. This work has been followed by the TASC project, which continued investigations into *Calanus* as well as other plankton communities. No data from this programme are yet published (Gallego, pers comm).

The zooplankton of the Faroe Shetland Channel is dominated by the oceanic calanoid copepods in particular *Calanus finmarchicus* (e.g. Pipe and Coombs 1980, Backhaus *et al.* 1994, Madden *et al.* 1999), as well as *Calanus helgolandicus, Metridia lucens, Pseudocalanus elongatus, Scolecithricella* spp. and *Acartia clausi* (Oceanographic

Laboratory, Edinburgh 1973). Other abundant taxa recorded include cyclopoid copepods in particular *Oithona* spp., the euphausiids (krill), in particular *Thysanoessa longicaudata*, and the chaetognaths in particular *Eukrohnia hamata*. (Oceanographic Laboratory Edinburgh 1973 and Pipe and Coombs 1980). Many larval species are also represented including crustacean (in particular decapods) larvae and fish larvae. Gelatinous zooplankton (e.g. medusoid hydrozoans and scyphozoans, ctenophores and salps) may also be extremely abundant. Most plankton communities show north-south and oceanic-neritic variations in species composition.

Zooplankton biomass in the Faroe Shetland Channel and northern North Sea may exceed 10 g (dry weight) / m^2 (Krause and Martens 1990). Zooplankton also shows seasonal cycles in abundance and these follow closely to the spring increases and winter decreases of phytoplankton (i.e. food availability). (Colebrook 1982). Zooplankton also show seasonal and diel vertical migrations (e.g. Heywood 1996 and Heath 1999) and seasonal geographical abundance is linked to both over-wintering stocks and food availability (Colebrook 1984).

The herbivorous copepod *Calanus finmarchicus* can represent up to 75% of zooplankton populations in the North Atlantic by number and more by weight (e.g. Pipe and Coombs 1980, Krause and Martens 1990, Gaard 1996 and Heath 1999). *Calanus finmarchicus* is of particular importance to the ecosystem of the North Atlantic and North Sea, as it represents an important food source for many fish species and is therefore an important element in the recruitment of fish stocks over the continental slope and shelf (Cushing 1984, Richardson *et al.* 1999 and Brander 1995)

Calanus finmarchicus overwinters in dense aggregations in cold water (< 0.5° C) at depths of 600 m off the edge of the continental shelf below the North Atlantic Current (Backhaus *et al.* 1994, Hirche 1996, Gaard 1996, Beare *et al*. 1998, Heath 1999) and the Faroe Shetland Channel is recognised is being an important over-wintering area with the winter population estimated to be 4.5 x 10^{14} individuals (Heath and Jónasdóttir 1999). *C. finmarchicus* migrate to surface waters in early spring with spawning females reaching the surface in March (Heath 1999 and Madden *et al.* 1999) and are transported into the North Sea primarily by the Norwegian Trench Atlantic Inflow and to a lesser extent the East Shetland Atlantic Inflow, the latter is seen to be more important for the later migration of *C. helgolandicus* (Madden *et al.* 1999). Overwintering stocks in the Faroe Shetland Channel originate from the Norwegian Sea or north of the Faroe Islands and are transported in by south flowing cold Norwegian Deep Sea water (Heath and Jónasdóttir 1999).

The Wyville Thomson Ridge forms a barrier to the southern distribution of Arctic waters and the abundance of overwintering *C. finmarchicus* is 25 times lower to the south of the ridge than to the north (Heath and Jónasdóttir 1999). Comparable high numbers of *C. finmarchicus* are found in the southern Norwegian Sea as in the Faroe Shetland Channel (Krause and Radach 1989, Heath and Jónasdóttir 1999 and Kaartvedt 1996). The Fair Isle Channel (and Faroe Shetland Channel) is at the southern extensions of the range of *C. finmarchicus* (Beare *et al.* 1998) and further south in the Rockall Trough area, the warmer water species *Calanus helgolandicus* has a greater abundance (Colebrook 1986). However a clear north-south split between these two species is not seen and their occurrence overlaps. Studies have suggested that *C. finmarchicus* and *C. helgolandicus* have slightly different behaviour patterns that allow these co-generic species to co-exist in the area (Williams *et al.* 1994 and Madden *et al.* 1999).

The geographical differentiation of water masses according to their plankton communities is well documented with distinctions between oceanic and neritic communities and a south to north progressive succession of plankton species (Oceanographic Laboratory, Edinburgh 1973 and Colebrook 1986). Much of this is based on CPR data, which is limited to single depth sampling. Vertical distribution of plankton within the water column has received less attention. However, work undertaken by Pipe and Coombs (1980) on the north face of the Wyville Thomson Ridge evaluated the distribution of species based on water depth and hydrography. Five groups of plankton by water mass were identified:

- Group I: Norwegian Sea Deep water plankton with peak abundance between 530-580m. Characterised by eight copepods and two chaetognaths. Numerical abundance by the copepods *Spinocalanus abyssalis* and *Oncaea conifera*. The euphausiid *Meganyctiphanes norvegica* was also present.
- Group II: Intermediate water plankton with peak abundance between 430-510m. Numerical abundance by copepod *Metridia longa* that has an overall depth range of 150-580m, *Calanus hyperboreus* and *Pleuromamma robusta*. The euphausiid (krill) *Thysanoessa longicaudata* was also characteristic of this group.
- Group III: Plankton found through the entire water column with no clear association with any water mass. Species present showed wide environmental tolerances. Numerical dominance by the copepods *Calanus finmarchicus, Metridia lucens* and *Scolecithricella minor.* This distribution was typical of spring sampling time and coincides with start of seasonal migration to surface by *Calanus finmarchicus*.
- Group IV: North Atlantic Oceanic water plankton confined to the upper 420m of water in temperatures of between 8-8.7°C. Two dominant species characterised this group: the copepod *Pseudocalanus elongatus* and *Munida* sp.
- Group V: Surface water plankton of North Atlantic and Norwegian Sea between 0-160m with a peak at 10m. Dominated by three species, most abundant of which is the copepod *Acartia clausi*.

From work undertaken on vertical distribution of zooplankton north of the Wyville Thomson Ridge, species diversity is shown to increase with depth with a peak below 530m in cold Norwegian Sea Deep water (Pipe and Coombs 1980). Biomass was also recorded to be greatest at this depth with other concentrations in warmer North Atlantic Ocean surface waters and between 220-400m (Pipe and Coombs 1980). No data are available for vertical distribution of plankton in the Rockall Trough area.

The macrozooplankton of the Faroe Shetland Channel is much less understood. However, some work has been undertaken on the *Euphausiids* (krill) (e.g. Lindley 1978, Williams and Lindley 1982 and Lindley 1982). *Thysanoessa longicaudata* is the numerically dominant euphausiid in the near-surface waters of the oceanic waters of the North Atlantic (Lindley 1978 and Williams and Lindley 1982) and Norwegian Sea (Lindley 1982). It is an important component of the plankton ecosystem, providing an important source of food for redfish and other pelagic carnivores. Work on the vertical distribution of this species shows it to be mainly confined to the upper 100m of the water column (Williams and Lindley 1982) although its distribution in the water column is related to water temperature. Swarms of *T longicaudata* have been frequently reported in oceanic waters but have also been recorded in the inshore waters around Shetland (Forsyth and Jones 1966). In the Faroe Shetland Channel and Rockall Trough, other krill species present in high numbers include *T. inermis* and *Meganyctiphanes norvegica* (Lindley 1982). *Euphausiid* biomass was highest in the colder waters of the Norwegian Sea where *M. norvegica* accounted for over 80% of the total biomass. Other macrozooplankton will include the larvae of a range of benthic species.

3.2 Benthos

3.2.1 Data Sources

3.2.1.1 Historic and Oilfield Surveys

The sampling locations of previous investigations in and around the former White Zone area are shown in Figure 9.

The first scientific samples collected from the seabed north-west of Britain were collected from HMS *Lightning* in 1868, and more successfully from HMS *Porcupine* in her third cruise of 1869, under the direction of Dr Carpenter. This survey employed a modified Ball's dredge to collect sediment, usually with "hempen tangles" attached which caught surface living animals particularly echinoderms. The resulting volume (Wyville Thomson, 1874) is a classic biogeographical text and established the vertical zonation of many species in relation to temperature. In 1880, the *Knight Errant* expedition carried out some dredging on the West Shetland Shelf (Tizard and Murray 1882) and further work was carried out by HMS *Triton* in 1882.

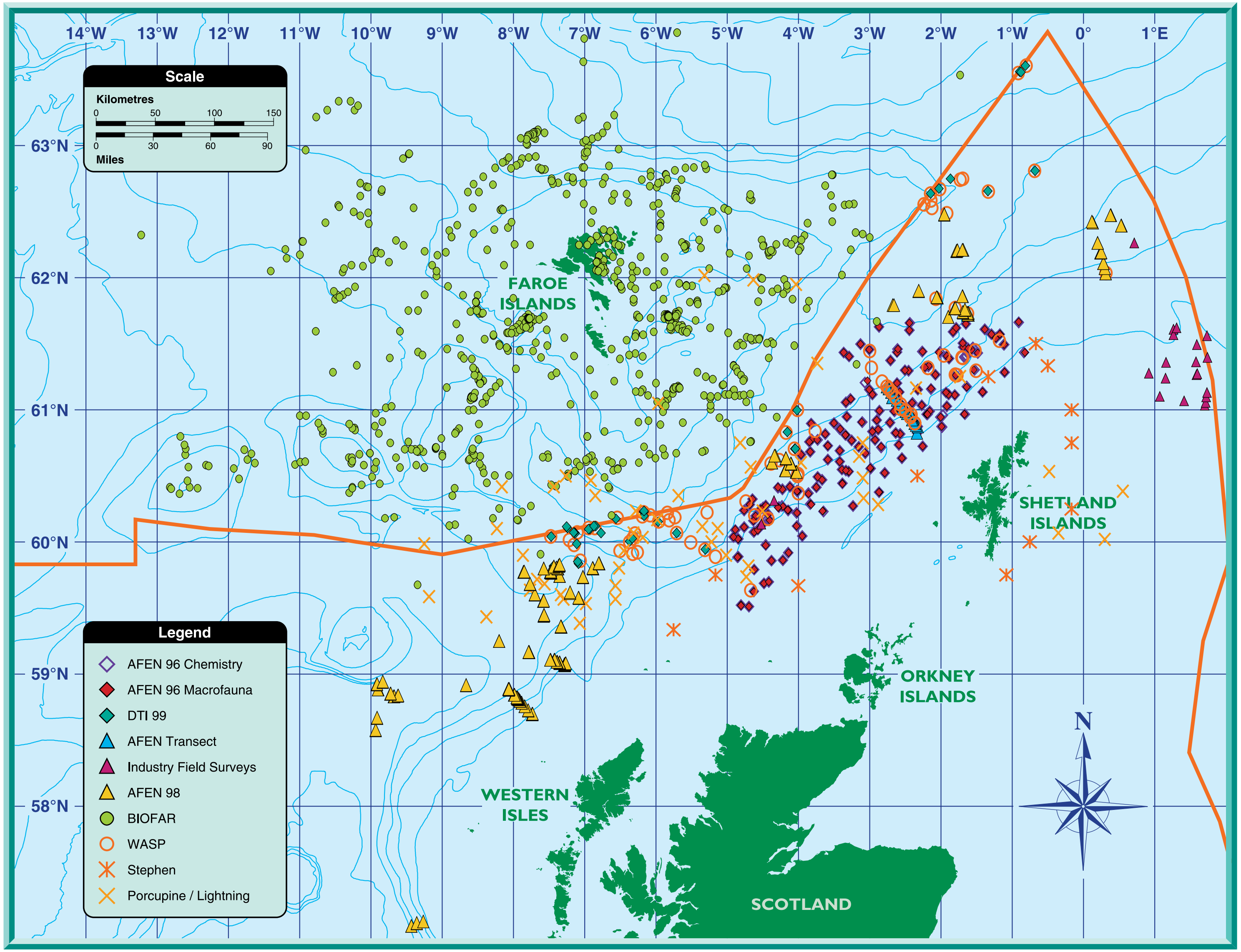
A history of investigations of the seabed around the Faroe Islands is provided by Tendal and Bruntse (2000). Early work included cruises by the Norwegian vessels *Vøringen* (1876), *Michael Sars* (1900 and 1902), *Armauer Hansen* (1914), the French vessel *Pourquois pas* (1913 and 1930), and numerous Danish naval and fishery inspection vessels. More recent work, to the north and west of the Faroes, was carried out from the German fisheries research ships *Anton Dohrn* (1966) and *Walter Herwig* (1981) and the French oceanographic research vessel *Jean Charcot* (1975).

In the 1970's the Scottish Marine Biological Association conducted exploratory sampling around the Wyville Thomson Ridge and Faroe Shetland Channel (Gage 1992). Data obtained from the MAFF demersal fish surveys, including trawled benthos and headline camera photography from sites west of Shetland, were reported by Dyer *et al.* (1982, 1983), Cranmer *et al.* (1984) and Cranmer (1985).

To the north and north-east of the former White Zone, oilfield-specific and regional surveys have also been conducted on the Norwegian continental shelf and adjacent waters, for example a recent baseline survey of the deep water Vøring area (DNV 1999) included three stations south of the Storegga Slide, at 63º 15-45'N, 2º 20'E.

In the northern North Sea, east of the White Zone, numerous seabed environmental surveys have been carried out in the UK (UKOOA 1999) and Norwegian sectors. In combination, these surveys provide a regional context of baseline sediment chemistry and biology, and of the effects of production facilities in the northern North Sea. A review and interpretation of the biological data acquired through UK North Sea oilfield surveys is currently being undertaken by Heriot Watt University on behalf of UKOOA. A similar study of Norwegian oilfield data has been undertaken by Dr T Pearson (pers. comm.). Baseline and monitoring studies around exploration wells and producing fields to the west of Shetland have recently been conducted (e.g. ERT 2000a).

Figure 9 – Benthic sampling stations in and around the former White Zone



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Other relevant studies include regional-scale surveys of the North Sea, for example early work by Stephen (1923) which included several sites on the continental shelf to the west of Shetland. More recently, work in the northern North Sea was carried out as part of integrated North Sea studies and is reported by Eleftheriou and Basford (1989), Basford *et al.* (1989, 1990). The latter studies were limited to the area south of 61°N and east of 7°30' E.

3.2.1.2 Regional Surveys

Three major regional surveys in the area of the former White Zone have been carried out on the last fifteen years; AFEN 1996, AFEN 1998 and BIOFAR. In addition, a survey commissioned by the DTI in 1999 was targeted specifically at the former White Zone. A further DTI initiated survey of the former White Zone is scheduled for summer 2000, with a focus on seabed sampling and photography although some additional seabed mapping will be undertaken.

The AFEN 1996 survey (RRS *Charles Darwin* Cruise 101C Legs 1 and 2; reported in Bett 1997, Cordah 1998 and AFEN 2000) achieved excellent coverage in the UK areas of the West Shetland shelf, slope and Faroe Shetland Channel, licensed for oil and gas exploration in the 16th and earlier licensing rounds. The survey design selected was a combination of seabed mapping using sidescan sonar imaging followed by sampling the seabed sediments using a range of equipment to suit the sediment types identified. In particular, use of a comparatively large sample area multicorer ("megacorer") provided samples of high quality. These two principal tools, of mapping and sampling, were supplemented by seabed photography to help 'ground truth' the sonar image data and provide a broader view than that derived from the sample points. The intent was for the sample locations to be finalised based on the information, particularly on sediment fabrics, obtained from the sidescan imaging. Locations sampled for sediment chemistry, biology and photographed are shown in Figure 9.

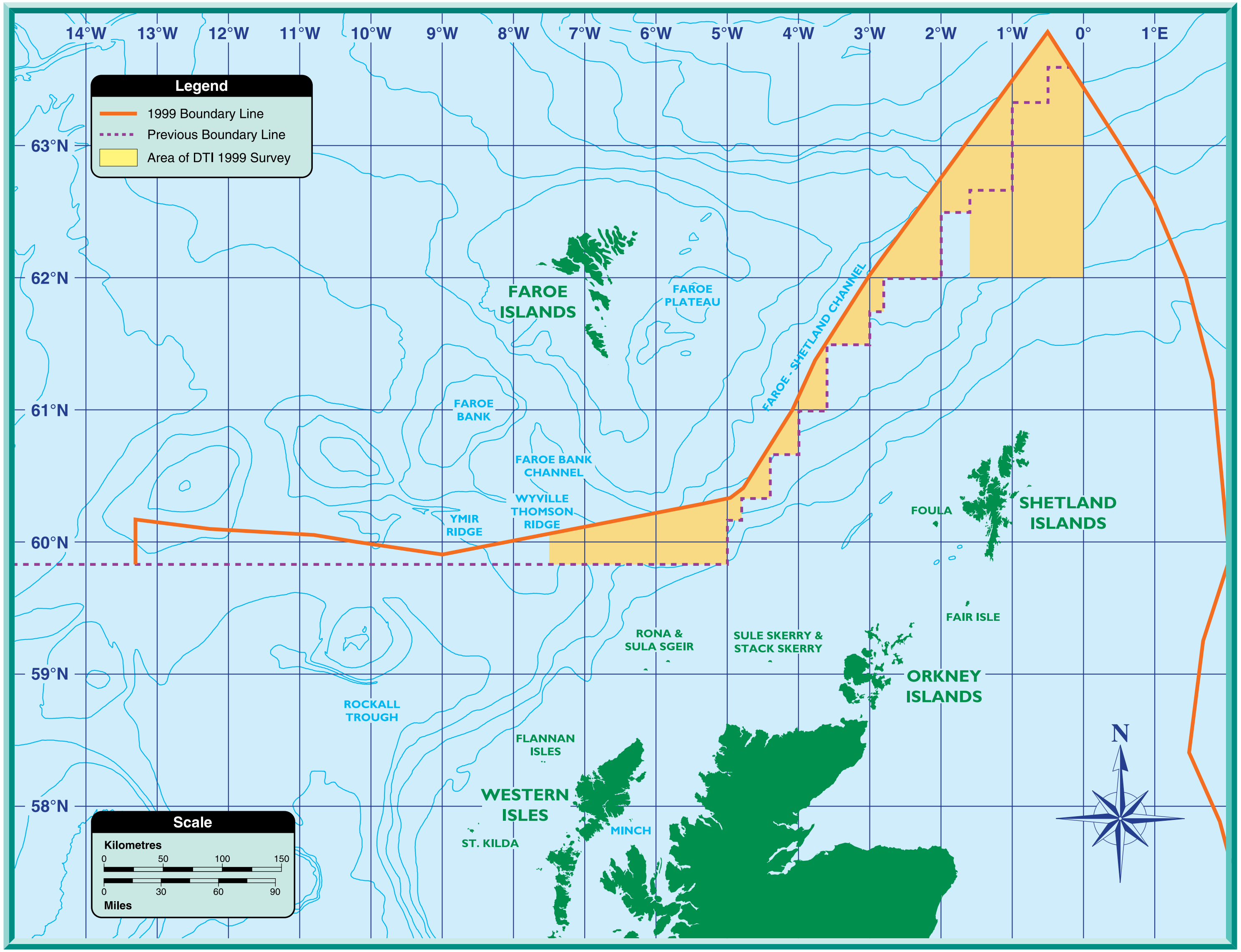
A similar approach was adopted by AFEN 1998 (RRS *Charles Darwin* Cruise 112C and RV *Colonel Templer* Cruises 1/98 and 2/98; reported in Bett 1999). This survey covered areas licensed in the 17th UKCS round, in the northern Faroe Shetland Channel and south of the Wyville Thomson Ridge.

Between the two AFEN sampling cruises, a total of 909 deployments of megacorer, box corer and Day grab were made, resulting in sediment samples being obtained at over 300 seabed stations. These cores were sub-sampled for biological, chemical and geological analyses onshore. Forty-six deployments of the WASP (Wide Angle Seabed Photography) system with video and still-photographic cameras were made. Other equipment, including fish traps and the epibenthic sledge, were deployed to a much lesser extent.

The DTI 1999 former White Zone survey (RRS *Charles Darwin* Cruise 119C Legs 1 and 2 reported by Masson 2000, Bett and Jacobs 2000, Jacobs and Masson 2000 and Bett 2000a) followed a similar approach to the previous AFEN surveys. The survey coverage included unlicensed areas of the northern Rockall Trough, Wyville Thomson Ridge, Faroe Bank Channel, Faroe Shetland Channel and North Sea Fan see Figure 10. Nineteen samples have been analysed for a range of physical and chemical parameters (ERT 2000b).

The internordic BIOFAR programme 1987-90 has allowed intensive sampling of benthic communities around the Faroe Islands (Nørrevang *et al.* 1994), see Figure 9. A total of 785 sites have been samples using a variety of methods. The majority of sampling locations

Figure 10 – 1999 DTI survey of the former White Zone – Coverage



were in Faroese shelf and inshore areas, although the overall sampling depth range is from about 100m to 1200m. Biological communities around the Faroes have been described, on the basis of BIOFAR samples, by studies sponsored by GEM (Bruntse and Tendal (eds) 2000).

3.2.2 Benthic Communities

Most of the former White Zone is located on the Wyville Thomson Ridge (and adjacent continental shelf), and in the Faroe Bank and Faroe Shetland Channels. However, the southern and northern extremities of the former White Zone are located over (or immediately adjacent to) the northern Rockall Trough and North Sea Fan respectively. Each of these areas is described individually in the following sections.

3.2.2.1 Northern Rockall Trough

Although a number of samples were taken by the *Porcupine* cruise (1869), the northern Rockall Trough and southern flank of the Wyville Thomson ridge were more recently investigated by the AFEN 1998 survey (area 1BA), from which the following description is derived. The latter cruise also identified an area of carbonate mounds, since named the Darwin Mounds. The DTI 1999 survey discovered a further area of similar mounds (the eastern Darwin Mound field). It is noted that additional research and contract cruises will visit the area during 2000, particularly with regard to the Darwin Mounds.

Although rich in ‘features’ shown by TOBI side scan sonar, the background sediment and associated fauna throughout area 1BA appears to be fairly consistent. At the scale of cores, the sediment surface was essentially featureless with little obvious fauna beyond occasional worm tubes. An exception to this is the relatively common occurrence of giant protozoan xenophyophores. This observation was supported by seafloor photography, which indicates that xenophyophores are probably the dominant surface dwelling animal throughout the area. Another feature of general note was the widespread occurrence of phytodetritus (see further below). At two sites, 1BA5 and 1BA12, a ‘fishy’ odour was noticeable on processing the samples; at the latter site, gas bubbles were also noted and bubble voids were present in the upper part of the sediment column. The WASP deployments that traversed seabed mounds recorded groups of *Lophelia* coral colonies on the mounds features. Coral was also noted at two other locations: a single isolated, small colony was observed during WASP run ‘BIOTARG’, and small fragments of dead coral were recovered from the 5-10 cm sediment horizon of a core at site 1BA9. The sledge run in the area of pockmarks recorded numerous furrow like features. It is possible that some of these might be associated with the pockmarks; however, the majority may simply be trawl marks.

3.2.2.2 Wyville Thomson Ridge

Following the discovery of the Wyville Thomson Ridge, with water depths of less than 500m, by the HMS *Lightning* cruise (1868), samples were taken from the ridge by the HMS *Porcupine* cruise of 1869. More recently, the BIOFAR programme included sample sites on the ridge (along with the Faroe, Bill Bailey’s and Lousy Banks to the west). Following sidescan sonar imaging, stations on the Wyville Thomson Ridge were sampled during the DTI 1999 cruise. The southern flank of the Wyville Thomson Ridge is characterised by an almost uniform area of medium-high backscatter, confirmed by photography and sampling as gravely sands with dropstones. Iceberg ploughmarking of an acoustically reflective substrate was evident over the northern flank of the ridge, similar to that found throughout the shallower slope areas on the eastern flank of the Faroe Shetland Channel.

The following description is based mainly on WASP images from the DTI 1999 cruise (Bett 2000a). Sites near the apex of the ridge (Stations W and V) had a limited encrusting fauna on gravely sand with rocks and boulders. The mobile epifauna was dominated by holothurians and cidarids, with spatangoids, asteroids and galatheids also observed.

Below the iceberg ploughmark zone, there is a transition to more open sediment habitats with the contourite band on the lower north slope of the Wyville Thomson Ridge, dominated by stalked sponges and sabellid polychaetes.

3.2.2.3 Faroe Bank Channel

Sedimentary habitats in the deeper Faroe Bank Channel (>1000m) are characterised by low-reflectivity sonar returns, interpreted as sands and sandy muds with occasional gravel lenses. The sediment and seabed features such as scours are indicative of strong bottom currents, where the southward flow of Norwegian Sea water is constrained by bathymetry. Most of the deepest part of the Faroe Bank Channel is muddy sand, with dense populations of stalked sponges.

Two distinct areas on the northern slope of the Faroe Bank Channel have been interpreted as sand with channels, lenses and barchan dunes, and gravel with lineations, both at depths of 800-1100m. Both areas are indicative of high current velocities, 75 cm/s and 100 cm/s respectively, which will have a major influence on benthos. WASP images from sites within or abutting the sand-related features area were heterogeneous with regard to seabed type, but showed little obvious fauna. The barchan dune area was dominated by small anemones, apparently on the lee side of the sand ripples. In contrast, the lineated gravel area was comparatively homogenous, with abundant sponges and featherstars.

3.2.2.4 Faroe Shetland Channel

Sidescan sonar interpretation indicates that the lower slope and bottom of the Faroe Shetland Channel is similar to the Faroe Bank Channel, largely consisting of sands and sandy muds with occasional gravel lenses (Jacobs and Masson 2000). The four central Faroe Shetland Channel sites sampled by the DTI 1999 survey were relatively heterogeneous, but with coarser sediments than suggested above, with gravely sand and cobbles indicative of appreciable current flow. The three lower slope sites were typically dominated by a mix of featherstars, octocorals and sponges; whereas the fauna of the channel floor site showed dominance by ophiuroids and cerianthids. This differentiation between lower slope and channel floor settings is consistent with the observations made during the AFEN 1996 survey (AFEN 2000). Stations in the northern part of the Faroe Shetland Channel, sampled by DTI 1999, are regarded by Bett (2000a) as being located on the Faroe Plateau slope. The shallower sites (ca. 1000m) are dominated by brisingid asteroid echinoderms. The deeper sites are dominated by ophiuroids in open sediment areas and sponges and octocorals where hard substrates are available. Sediments, however, are heterogeneous ranging from muddy sand to boulders, with a corresponding variability in burrowing and encrusting fauna.

Gage (1992) indicated that at depth, the fauna of the channel is essentially a southern extension of the deep sea fauna characteristic of the Norwegian Sea/Arctic deep basins.

3.2.2.5 North Sea Fan

The northernmost part of the former White Zone is variously regarded as North Sea Fan and Norwegian Basin. Although there is a considerable bathymetric range, sediments are uniformly muddy. Three large, discrete, mud diapirs were mapped by the DTI 1999 survey, characterised by significant area (6km or greater in area) and relief (up to 100m above surrounding seafloor). WASP video data indicate that the diapirs are composed of indurated sedimentary material and are largely free of recent sediment.

The obvious visible fauna in this area is somewhat limited, with large open burrows and feeding traces of asteroids as the main observations. The diapiric structures do not appear to support a distinct fauna, although the presence of 'scree slopes' and 'rock filled gullies' introduce a hard substratum potentially suitable for colonisation by epifauna.

The sedimentary setting and fauna of the Norwegian Basin area appears to be distinct from the contiguous area of the Faroe Shetland Channel floor (Bett 2000b, DNV 1999).

3.2.3 Discussion

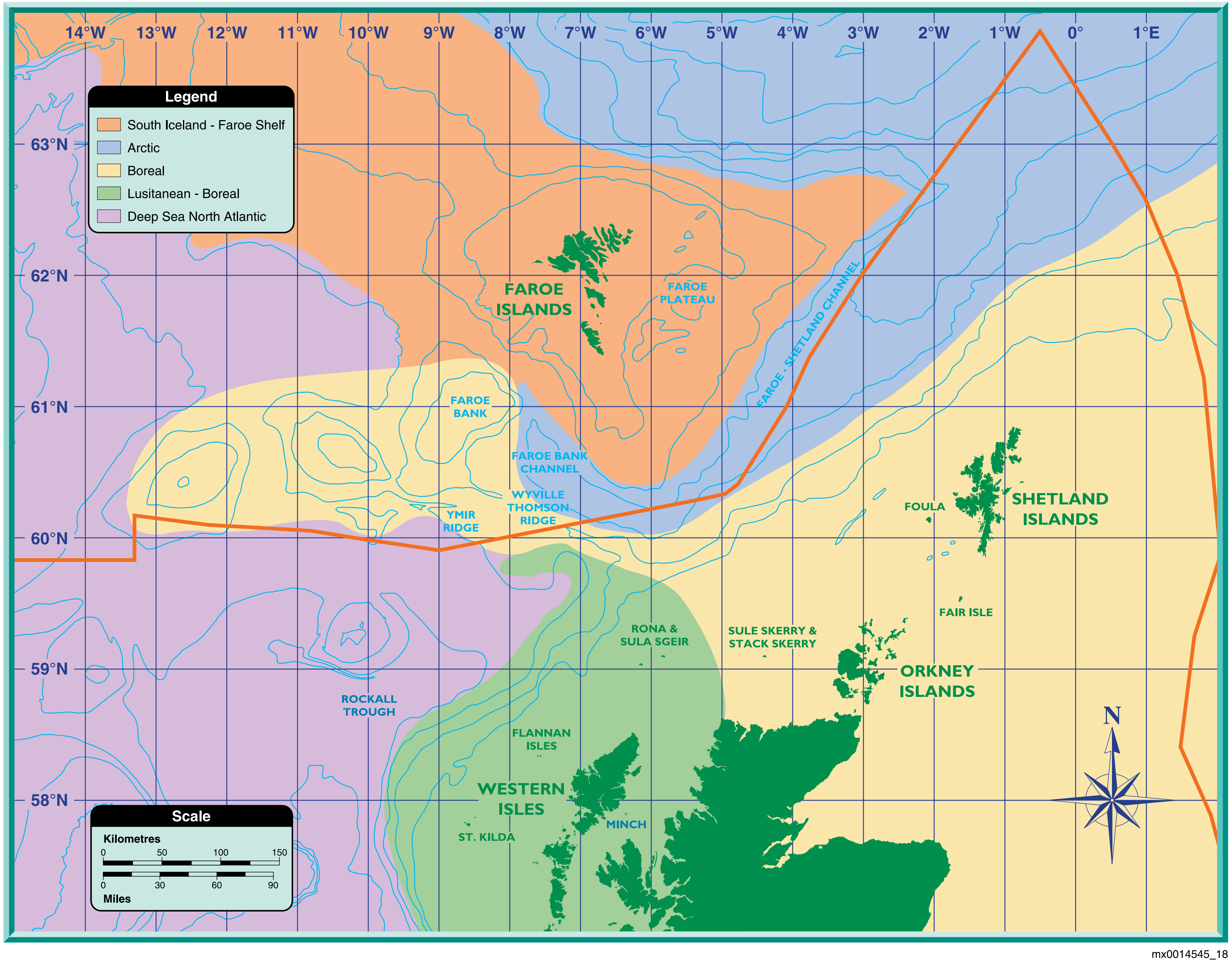
3.2.3.1 Macrofaunal Communities

The area lies at the interface of several biogeographic zones – see Figure 11. A comprehensive statistical analysis of macrofaunal composition and variation in the eastern slope of the Faroe Shetland Channel, based on AFEN 1996 data is provided by Bett (2000b). Temperature (absolute and variability), and to a lesser extent bathymetry were identified as the primary environmental influences on downslope distribution patterns in both community structure (i.e. abundance, biomass and diversity) and species composition. Macrofaunal abundance and biomass varied with depth in a complex fashion, having maxima at different depths (700m and 300-400m respectively). The observed pattern contrasts with the generally predicted simple monotonic relationship with depth (e.g. Gage and Tyler 1991). Diversity also showed an intermediate depth maximum, at 400m, although there appeared to be correlation ($p<0.002$) with habitat temperature range, rather than with measures of the ecological processes of competition and disturbance generally thought to control diversity patterns.

The downslope community distribution summarised above was interpreted in terms of an ecotone, at water depths of 300-700m, between warm and cold water communities. An ecotone is defined as an overlapped boundary between two communities, containing elements from both communities and potentially some specialist "edge species"; resulting in a local maximum in species turnover. As generally applied to the deep-sea setting, biological zonation is not intended to infer depth bands of homogeneous fauna with major changes only occurring at the boundary between zones. Instead, continuous variation with depth is expected, with regions of increased rates of change marking the position of zone boundaries (Carney *et al.* 1983).)

Detailed statistical analysis of alongslope variation in macrobenthic faunal composition within the Faroe Shetland Channel was also undertaken by Bett (2000b), quantifying variability within depth / habitat "zones" corresponding to the acoustic facies identified from TOBI data (and subsequently used to determine sampling strata). Three zones were analysed – the continental shelf, iceberg ploughmark zone (200-400m) and alongslope current zone (600-1000m), with subdivisions of the last. Variability within the data for all zones analysed at the local scale was always not significantly different from, or less than variability at larger scales (i.e. at the survey stratum or survey depth zone level). Although not obvious in the case of the shelf fauna, alongslope variations were detected within the iceberg ploughmark zone and the alongslope current zone. In both cases the alongslope variation appears to be related to sediment grain, possibly related to changes in channel

Figure 11 – Biogeographic zones



morphology, as well as to the presence of the contourite sand sheet at the base of the slope.

Statistical analysis of macrofaunal community composition at 22 sites located in the cold (sub-zero) Faeroe-Shetland Channel Bottom Water sampled by the AFEN 1998 survey, is presented by Bett (2000c). Cluster analysis of these deep sites alone indicates both clear bathymetric trends and apparent regional variations. The latter is indicated by the three discrete clusters formed by sites with depths less than 1,200 m from each of the three survey areas. The linkages between these clusters suggest a greater similarity between the two north of Shetland areas (3A and 3B) than between either of these areas and the west of Shetland area (2). The significance of this apparent regional variation is emphasised when the relative depth distributions of the sampling sites is considered. Despite the closer depth range match between areas 2 and 3B, there is nevertheless a greater faunal similarity between areas 3A and 3B. However, when this variation is assessed by ordination of the macrobenthos data, a rather different conclusion is reached.

Ordination of the deep northern sites again suggests differentiation of the three survey areas. When depth variation on the x-ordinate is considered, there appears to be a common depth trend among the Faeroe-Shetland Channel sites (i.e. areas 2 and 3A) that is not shared with the sites in the mouth of the Faeroe-Shetland Channel / Norwegian Basin (i.e. area 3B). This split between channel and basin sites, parallels that noted in the depth distribution of sediment mud content. When variation on the x-ordinate is considered with mud content, a single consistent trend is apparent among sites from all survey areas. Both depth and mud content are strongly correlated with the x-ordinate ($p<0.002$), but mud content offers a better fit than depth (r^2 linear = 0.803 and 0.637, r^2 curvi-linear = 0.875 and 0.646, respectively). Although there may be some regional variation in the faunas west and north of Shetland, it appears that depth-related factors, and in particular mud content, are most significant in determining the large-scale distribution of the macrobenthos in the deep waters of the Faeroe-Shetland Channel / Norwegian Basin. Latitudinal variation in sediment mud content appears to be significant in controlling the alongslope distribution of the fauna in this region. This effect was apparent in the AFEN 1998 survey, as outlined above, and in both upper and lower slope settings on the West Shetland Slope as determined in the 1996 survey. The latitudinal, or alongslope, variation in sediment mud content presumably results from the northward increase in the depth and width of the Faeroe-Shetland Channel and consequent decrease in near-bottom water flow rates.

Total numbers of species and individuals in the AFEN 1996 and 1998 samples were relatively high overall. Bett (2000c) presents “collectors curves” of the accumulation of species with sampling effort, that compare species richness recorded from the New Jersey / Delaware slope (Grassle and Maciolek 1992) and Norwegian continental shelf (Gray 1994). The “warm” and “intermediate” faunas of the Faroe Shetland Channel both encountered appreciably higher numbers of species. (It should be noted that this analysis is very dependent on taxonomic discrimination, which is difficult to standardise between surveys.)

The ecology of the West Shetland macrofaunal communities, for example in terms of individual species’ feeding and reproductive strategies, and of community trophic relationships, has not yet been systematically studied, although the AFEN 1996 data provides a basis for this (current study of the AFEN material is concentrated on macrobenthic taxonomy, and megafaunal distribution). Assessment of faunal community susceptibility to environmental effects of exploration and production is therefore difficult.

3.2.3.2 Phytodetritus

Phytodetritus, the degraded remains of surface ocean phytoplankton, has not been directly observed on the seabed of the Faroe Shetland Channel or West Shetland slope. However, in a detailed study of the organic constituents of sediments on the West Shetland slope (north of Foinaven), Russell *et al.* (1999) noted a high concentration of organic compounds characteristic of fresh phytoplankton derived organic matter, and the periodic occurrence of phytodetritus throughout the West Shetland slope is highly probable. Seasonal deposition of phytodetritus has now been documented in several oceanic areas around the world (Smith *et al.* 1996) and was observed in samples from the lower slope (>600m) of the Rockall Trough by the AFEN 1998 survey (Bett 2000c).

The ecological significance of phytodetritus relates to the periodic / seasonally enhanced supply of organic matter (Rice *et al.* 1994, Bett 2000c), resulting in short-lived population explosions in opportunistic species (mainly meiofauna and small macrofauna, e.g. foraminiferans; see Lambshead and Gooday 1990). Effects on larger, long-lived macrofauna and megabenthos (including *Lophelia*) may occur through modifications to feeding behaviour (e.g. Jumars *et al.* 1990) and reproductive strategies (e.g. Tyler *et al.* 1990).

3.2.3.3 Sponge Communities

Areas of seabed dominated by large sponges occur widely in the northeast Atlantic and have been recorded off the coasts of Greenland, Iceland, Faroe Islands, U.K. and Norway (Tendal 1992, Klitgaard *et al.* 1997, Klitgaard and Tendal 2000a and b). The Faroese sponges have been best studied and the following description is largely based on work of Tendal and Klitgaard from that area. A working definition of a sponge dominated area is where there is one large sponge per 10-50m^2 (based on dredge and photographic survey results), with sponges contributing around 90% of the benthic biomass. Numerous species of sponges occur in sponge dominated areas, although in terms of biomass *Geodia barretti*, *G. macandrewi*, *Isops phlegraei* and *Stryphnus ponderosus* predominate, with individual animals measuring up to 80cm across and weighing up to 25kg. The north Atlantic sponge dominated seabeds are characterised by large separate individuals and treated as distinct from the sponge bioherms recorded on the western Canadian continental shelf where hexactinellid sponges form sheets up to 15m thick and several kilometres wide (Conway *et al.* 1991).

Around the Faroe Islands, sponge dominated areas usually occur in Atlantic waters in depths of 250-500m in a narrow band (ca. 1-2km across) paralleling the shelf break and covering a water depth range of 100m. These areas are interpreted as current swept places where the continental slope is suitable for the propagation of internal waves, and where there is an enhanced supply of suspended food. Such areas are similar to those where the cold water coral *Lophelia pertusa* has been found in abundance in Faroese waters and although there is some overlap, the areas of occurrence are not entirely coincident. Large sponges occur on a variety of substrate types, primarily sand and gravel with stones and boulders, which are the main sediment facies on the continental shelf and upper slope.

Small areas of sponge domination have been reported on the western Wyville Thomson Ridge (Klitgaard and Tendal 2000a and b). The AFEN 1998 survey and the DTI 1999 survey covered parts of the Wyville Thomson Ridge and although sponges were sampled and seen in photographs, on the basis of size and density, the area would not be classed as sponge dominated. Discrete bands of sponge abundance have been recorded elsewhere e.g. in the Porcupine Seabight where the hexactinellid sponge *Pheronema carpenteri* is present in high densities in a band between 1000-1300m. On the northern flank of the Wyville Thomson Ridge below 700m is an area where stalked sponges (and sabellid polychaete worms) are very abundant (Bett 2000a).

The ecological importance of the sponge dominated areas is not clear. The high biomass of the areas may indicate high productivity, although almost nothing is known of the growth rates and energetics of the large sponges. Species richness is reported to be high although the majority of species found in association with the sponges are found in or on adjacent sediments, i.e. they are facultative rather than obligate associates. The areas may function as nurseries for some fish species and trawls in sponge dominated areas often recover large numbers of redfish, *Sebastes* spp. (Klitgaard and Tendal 2000b). On the death of the sponges, the structural silicaceous or calcareous spicules are either incorporated into the local sediment, in places creating a surface felt which can alter the benthic habitat (Bett and Rice 1992), or are spread widely by currents.

The main threat to large sponges is physical damage and disturbance, primarily from trawling. Trawling interactions can be incidental, when sponges are buried under sediment (Bett 1999) or caught in nets, or deliberate, as recorded by Klitgaard and Tendal (2000b), when fishermen trawl an area to crush the sponges in an attempt to improve the ground for fishing. Domination by sponges in a particular area has been reported to be variable over time (Klitgaard and Tendal 2000a and b), but whether this is an artefact of position fixing, natural variability or the effects of trawling is unclear. It is assumed that the large sponges are long lived (tens of years), slow growing and with infrequent recruitment (Klitgaard and Tendal 2000a and b), and consequently recovery of an area from physical damage is expected to be slow, probably over a period of decades.

Sponges in sedimentary areas are subject to natural sedimentation of an intensity and frequency varying with location. There is no information available on the tolerance of any of the relevant large species to sedimentation, but above critical loads or frequencies, morbidity and mortality will occur.

The recent recognition of the extent of sponge dominated areas, the assumed age of the large sponges and threats to them has lead to calls for protected areas (Klitgaard and Tendal 2000a and b, and see OSPAR 1999).

3.2.3.4 Darwin Mounds

The Darwin Mounds appear to be unique geological and biological features, which were discovered during the 1998 AFEN survey in a discrete area on the southern flank of the Wyville Thomson Ridge (Bett 1999). A second area of Darwin Mounds was found to the east during the DTI 1999 survey (see Figures 4, 5 and 6) (Bett 2000a). The Darwin Mounds were initially detected by TOBI side scan sonar which showed a series of small seabed mounds, most with a downcurrent tail. Subsequent photographic work and sampling indicated that, while visible to sonar, the tails appeared to have no physical expression at the seabed. Biologically however, the tails could be distinguished by the presence of dense populations of the xenophyophore protozoan *Syringammina fragilissima.* The central mound appears to consist of blocky rubble with the coral *Lophelia pertusa* usually present. The rubble may be carbonate cemented sediment, as found in areas of gas escape in the North Sea (Hovland and Sommerville 1985), the Kattegat (Jensen *et al.* 1992) and elsewhere (Aharon 1994) or a boulder(s) with carbonate debris from dead *Lophelia* coral. The reasons for the occurrence and form of the Darwin Mounds are unclear but suggested explanations include fluid or gas escape, in either the past or present. Similarly, the ecological significance of the mounds is unclear. Both *Lophelia* and xenophyophores are widely distributed elsewhere in the region and the *Lophelia* growth form is similar to thicket structures described by Wilson (1979) from the Rockall Bank rather than the massive reef like structures found elsewhere (see below). The abundance of xenophyophores in the mound tails may be linked to fluid escape or, more probably, to the physical effects of the topographic high provided by the mounds, which can influence food availability through enhanced particle deposition or residence time (Levin and Thomas 1988). The mounds will be investigated during a NERC funded, multidisciplinary research cruise in August 2000.

While much remains to be discovered about the formation and nature of the Darwin Mounds, the presence of *Lophelia* and large numbers of xenophyophores indicates they would be susceptible to physical damage and disturbance. Almost nothing is known of the susceptibility of these animals to sedimentation, and while some tolerance is expected given the current and sediment transport conditions in the areas of occurrence (Bett 2000c), smothering by sediment from natural events or human activities is likely to cause morbidity and mortality.

3.2.3.5 *Lophelia pertusa* and Other Cold Water Corals

The cold water coral *Lophelia pertusa* is widely distributed across the north Atlantic (Wilson 1979a, Rogers 1999), has been recorded in the Pacific and Indian oceans and may prove to have a global distribution. The species was first recorded from the area just south of the Wyville Thomson Ridge during the *Lightning* cruise of 1868 and subsequently by the 1869 *Porcupine* cruise when it was reported that in the warm, Atlantic water area it "forms stony copses covering the bottom for many miles" (Wyville Thomson, 1874). The distribution mapping work of Wilson (1979a) and Frederiksen *et al.* (1992) has recently been updated by Long *et al.*, (1999) who provide a map and listing of *Lophelia* records from UK, Faroese and Irish waters. Long *et al.* (1999) conclude that in the Faroe Shetland Channel, the depth distribution of *Lophelia* is significantly more restricted compared to other areas to the west of Britain, being only recorded from waters shallower than about 500m. This depth in the Faroe Shetland Channel corresponds to the boundary between the warm Atlantic water mass and the cooler waters below in particular the cold Norwegian Sea water. Long *et al.* (1999) suggest that *Lophelia* does not thrive in areas where the water temperatures are below 4°C, which accords with the distribution patterns found in Faroese waters by Frederiksen *et al.* (1992) and Bruntse and Tendal (2000). The known distribution of *Lophelia pertusa* within the former White Zone is shown in Figure 4.

Lophelia has been recorded in two main growth forms. The first form is small patches of 10-50m across with groups of individual colonies (Wilson 1979b), which appears to be the most common form of occurrence on the shelf and slope to the west of Scotland, including the offshore banks e.g. the Rockall Bank. The second growth form is of large to massive colonies such as found off the Celtic Sea (Le Danois 1948), Porcupine Seabight (Kenyon *et al.* 1998) and Norway (Mortensen *et al.* 1995, Freiwald *et al.* 1999). Such large colonies would be readily detected by the TOBI side scan sonar system used in the AFEN 1996, AFEN 1998 and DTI 1999 surveys, but none were seen in the areas surveyed. The reasons for the presence or absence of large *Lophelia* colonies are not clear. The occurrence of large colonies has been linked to hydrocarbon seepage (see for example Hovland *et al.* 1994, Hovland *et al.* 1998) although others have questioned the linkage (Freiwald 1998, Freiwald and Wilson 1998). Frederiksen *et al.* (1992) advanced the hypothesis that the distribution of *Lophelia* in Faroese waters was linked to areas where the bottom slope allowed the breaking of internal waves, resulting in enhanced suspended food availability. The EU has recently funded two research programmes on *Lophelia,* which can be expected to provide better insights into the ecology, palaeobiology and vulnerability of these corals.

Lophelia feeds either passively, on suspended organic material, zooplankton and phytodetritus or actively, on small prey including crustaceans and chaetognaths (Rapp *et al.* 1999, Bruntse and Tendal 2000, Roberts, unpublished). High food densities lead to high capture rates.

Estimates of the growth rate of *Lophelia* vary widely from about 4 to 8mm per year (Mortensen and Rapp 1998) up to 2.5cm per year (Mikkelsen *et al.* 1982) although the accuracy of the latter figure was questioned by Mortensen and Rapp, (1998). Even accepting the fastest reported growth rate it is clear that the very large colonies of *Lophelia* are ancient, i.e. many hundreds or thousands of years old. As large colonies grow, only the outer 1 to 2m remains alive and growing (Freiwald and Wilson 1998, Bruntse and Tendal 2000). The dead inner parts are bored by various small sponges and polychaete species and fine sediment accumulates in the interstices. The size and form of the coral colony results from an interplay between hydrographic conditions, coral growth rate and branch strength, degradation by boring animals, and physical damage.

Two distinct habitats are present within a coral colony, the outer living area and the dead coral with accumulated fine sediment. These habitats are colonised by a variety of epifaunal and infaunal species (see for example, Jensen and Frederiksen 1992 and Mortensen *et al.* 1995). Rogers (1999) provides a list of nearly 900 species which have been recorded from *Lophelia* colonies and describes the associated fauna as highly diverse. Comparative studies of the fauna of equivalent volumes of sediment and hard substrates from areas immediately adjacent to coral colonies have not been conducted, although there is extensive data on the sediment infauna of the Faroe Shetland Channel area (e.g. Cordah 1998). On the basis of the species composition and diversity index values reported by Jensen and Frederiksen, (1992) from living and dead coral blocks, and by Cordah, (1998), both coral and sediment appear to harbour a diverse fauna. Most, if not all *Lophelia* associated species reported to date are facultative rather than obligate species.

The ecological importance of *Lophelia* colonies has been shown by Freiwald and Wilson, (1998), and includes providing nursery areas for some commercial fish species. Large colonies also provide the opportunity for the investigation of past hydrographic and climatic conditions (Barnes and Lough 1996).

In addition to *Lophelia*, there are several other colonial coral species recorded from Faroese and Scottish waters, notably *Primnoa resedaeformis, Paragorgia arborea, Madrepora oculata* and *Solenosmilia variablis.* These corals are found in similar conditions to *Lophelia* and sometimes growing on *Lophelia* colonies. They do not form very large colonies (usually between 1 to 2.5m high and of limited lateral extent) but appear to be long lived, with Bruntse and Tendal (2000) citing an age of 1500 years for a large colony of *Primnoa resedaeformis*.

The main anthropogenic threats to large cold water corals are physical damage and disturbance, for example from trawling and anchoring. Rogers (1999) lists deep-sea fishing and oil exploration and production as having potentially serious consequences for the survival of *Lophelia pertusa*. In his consideration of the effects of the oil and gas industry on corals, Rogers (1999) cites the discharge of drill muds and cuttings as the most important factor although the discussion focuses on the effects of the routine discharge of oil based drill muds and cuttings. Such discharges in UK waters have reduced significantly in recent years and will cease by the end of 2000 following agreement between the DTI and the industry trade association (UKOOA) and the individual oil companies. The discharge of water based drill muds and cuttings is currently still permitted and effects of such discharges on corals will be a function of the particle loading at the seabed, any associated toxicity, coral tolerance to sedimentation, including to the particle size range of the material and clearance ability. The current regime at a point on the seabed will also influence the potential effects on corals, with stronger currents tending to assist coral clearance of sedimented material. The capacity of *Lophelia* to colonise hard surfaces has recently been shown by the recent discovery of colonies growing on northern North Sea oil installations (Bell and Smith 1999).

3.2.3.6 Gas Hydrates

The water temperatures and depths of the Faroe Shetland channel are such that methane hydrates are found widely in surficial sediments of the area (Long and Holmes 1998). Gas hydrates are ice-like crystalline structures formed by the combination of water and hydrocarbon gases under high pressure and low temperature conditions. When present near the sediment surface, methane hydrates can form mounds, and such mounds in the Gulf of Mexico have been found to harbour a novel species of worm in high densities (*Hesiocaeca methanicola*, Desbruyères and Toulmond 1998). The presence of similar (or other) features and species has not been recorded during any of the recent surveys of the Faroe Shetland Channel but cannot be discounted.

3.3 Fish

Spawning periods and an overview of the importance of the former White Zone and adjacent areas with regard to fish is given in Figure 12.

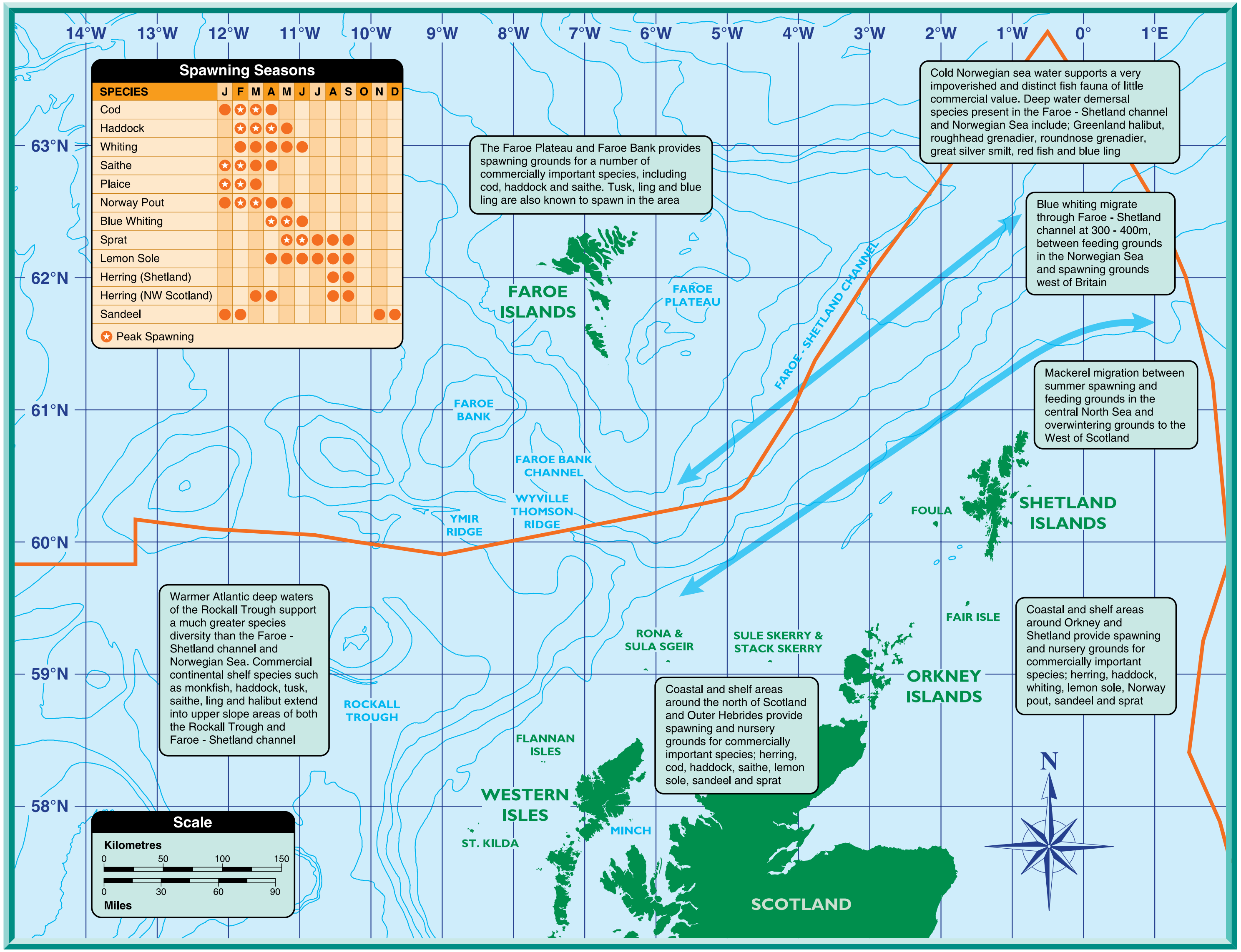
3.3.1 Pelagic Species

Data on fish spawning/nursery areas and major fishing areas for key commercial species have been collated by the Fisheries Research Services (FRS), Aberdeen and the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Lowestoft. These data have been published as fisheries sensitivity maps with the assistance of UKOOA and the Scottish Fishermen's Federation (Coull *et al.* 1998). The compiled data currently only extend to 62ºN. Fishery data have also been collated by the Proudman Oceanographic Laboratory (BODC 1998), but these data mainly consider key commercial species. Work is also ongoing by the Fisheries Laboratory of the Faroe Islands (Fiskirannsóknarstovan) on population biology of locally important commercial fish species (Jákupsstovu 1999).

The main pelagic species across the area are mackerel (*Scomber scombrus*), Norway pout (*Trisopterus esmarkii*) and blue whiting (*Micromesistius poutassou*). Herring (*Clupea harengus*) may also occur in the area (Coull *et al.* 1998). The greater silver smelt (*Argentinus silus*) is also present; this is considered to be a semi-pelagic deep-water species. Other than the greater silver smelt, commercial pelagic species are generally concentrated over the continental shelf and shelf break to the east of the White Zone. Information on non-traditional pelagic species is limited and the vertical distribution of deep-water species in the water column is still poorly understood because large midwater trawls have seldom been used in deep-water (Gordon *et al.* 1995).

Blue whiting migrate through the Faroe Shetland Channel at water depths between 300-400m from spawning grounds to the west of Britain to feeding grounds in the Norwegian Sea. Northerly migration occurs between May and July, with the return migration in December and January (Hansen and Jákupsstovu 1995, Jákupsstovu 1999). The blue whiting spawning ground extends across the south of the area as far north as 61°N and to 4°W. Spawning occurs between April and June each year (Bainbridge and Cooper 1973,

Figure 12 – Fish spawning and distribution



Spawning Seasons

SPECIES	J	F	M	A	M	J	J	A	S	O	N	D
Cod	●	★	★	●								
Haddock		★	★	★	●							
Whiting		●	●	●	●	●						
Saithe	★	★	●	●								
Plaice	★	★	●									
Norway Pout	●	★	★	●	●							
Blue Whiting				★	★	●						
Sprat					★	★	●	●	●			
Lemon Sole				●	●	●	●	●	●			
Herring (Shetland)								●	●			
Herring (NW Scotland)			●	●				●	●			
Sandeel	●	●									●	●

★ Peak Spawning

mx0014545_2

Coull *et al.* 1998) with the nursery area extending across the whole Faroe Shetland Channel area. Blue whiting eggs and larvae are pelagic and are carried north with the prevailing currents (Jákupsstovu 1999). Blue whiting eggs and larvae are found in increasing abundance from the surface to a maximum depth of 380-400m (Monstad *et al.* 1994).

Norway pout spawn around Faroe and to the west of Orkney and Shetland. Spawning occurs between March and May in deep waters and between January and April over the continental shelf (Coull *et al.* 1998). Norway pout forms an important part of the food chain for many commercial species such as cod and haddock.

Mackerel migrate north to summer feeding grounds in the Norwegian Sea and northern North Sea from spawning grounds to the south of Ireland during May and June, with the return migration in winter. Migration occurs along the UK continental shelf and shelf edge (Jákupsstovu 1999, Belikov *et al.* 1998). Mackerel migration routes and timing of migration have been seen to vary over time. The timing of the return migration has become later in the year over the last 20 years, with its peak shifting from August in the early 1980's to January in the mid 1990's. The mackerel nursery area extends into the southern areas of the White Zone (Coull *et al.* 1998) with the main spawning areas occurring further south.

Work has been undertaken by the Fishery Research Services (FRS) Aberdeen Marine Laboratory under the EU SEFOS (Shelf Edge Fisheries and Oceanography Study) Programme on the migration of mackerel through Scottish waters. Preliminary results indicate that the mackerel schools are restricted to water depths between 100 and 225m and certain water temperatures (8-8.75°C). This would limit mackerel migration routes to areas east of the White Zone (Walsh *et al.* 1995, Reid *et al.* 1997).

Work on herring distribution based on water temperature has shown that herring appear to prefer warmer (> 2°C) well-mixed waters (Maravelias and Reid 1997) and seem to concentrate at or near transitional layers between water masses, which are associated with higher productivity (Maravelias and Reid 1995 and Nøttestad *et al.* 1999). Herring spawn in waters to the east of the White Zone area, in waters around Orkney and Shetland during August and September (Coull *et al.* 1998). There is also some suggestion of a spring spawning of herring to the north and west of Shetland (Bowman 1923, Rankine 1986, Napier, pers comm.). These grounds have not been identified but evidence of their existence comes in the form of catches in this area of haddock and other fish species that have fed on herring spawn ("spawny haddock"). This spring spawning herring may be related to the more northerly Atlanto-Scandian herring stock found in the Norwegian Sea rather than the distinct North Sea herring stock (Napier, pers comm.).

The greater silver smelt is usually found in waters between 150 – 550m and is found in high concentrations on the continental shelf edge. The greater silver smelt spawns all year round with the maximum spawning in the second half of the year. When spawning, this species is known to form dense aggregations on the shelf edge (Gordon *et al.* undated).

3.3.2 Demersal Species

The former White Zone is predominantly a deep-water area with water depths greater than 500m. Demersal fish populations are characterised by deep-water fish species and the following section concentrates on these.

Comparatively little is known about the biology and distribution of deeper water fish populations. What is known is that in general terms, a higher species diversity is seen on the continental shelf than on the slope. The North Atlantic basin as a whole contains at least

1,094 species (Merrett 1994) and there are 120 known demersal species on the continental slopes to the west of the British Isles (Gordon *et al.* undated). Commercially exploited deep-sea species remain a small proportion of the total species richness. Dominance by one or a very few species is less apparent than seen on the continental shelf. Although species diversity is seen to increase with depth, numbers of individuals decrease (Gordon *et al.* 1995).

The food supply for these deep-water fish ultimately originates from surface primary production. "Food rain" from the surface and vertical/horizontal migrations of zooplankton and pelagic species will support fish biomass to depths of 1,000m or more. Nevertheless, the overall abundance of food is dependent on a thin and shallow productive surface layer with seasonal variations, and therefore biomass sustainability will ultimately decline by orders of magnitude with depth (Gordon *et al.* 1995 and Merrett and Haedrich 1997). Some deep-water fish species are thought to migrate to surface layers at night to feed. This behaviour therefore means a link between surface pollution and deep-water populations is feasible (Gordon *et al.* 1995).

Concerns about the sustainability of deep-water fisheries are based on these fish species having late sexual maturity, a long-life span, low fecundity and slow growth; all these factors are thought to be biological adaptations to low food availability (Atkinson 1994, Gordon *et al.* 1995 and Merrett and Haedrich 1997). Some larger deep-water fish species are known to exhibit semelparity (reproduce only once in a lifetime) (Gordon *et al.* 1995). Work on breeding biology of deep-water demersal species has been undertaken by Merrett (1994). This work was limited to commercially exploited species, which represented only 19% of the known demersal species in the North Atlantic Basin, and results from the study supported the generally held belief of late sexual maturity with only large adults spawning. All the species examined produced small (presumably pelagic) eggs. Such reproductive behaviour makes deep-sea fish populations especially vulnerable to exploitation and slow to recover from disturbances.

Some species can have very broad depth ranges of >1,000m, while others only occur over a few hundred metres. Juveniles tend to occupy shallower depths than adults.

The Wyville Thomson Ridge forms a major faunal barrier to deeper water fish and there is little similarity between the fish communities on either side of the ridge (Bergstad *et al.* 1999). Accordingly, in terms of deep-sea fish populations, the White Zone area can be divided into two main areas:

- A small area of the Rockall Trough south of the Wyville Thomson Ridge (Quadrants 164 and 165)
- The Faroe Shetland Channel and entrance into the Norwegian Sea

The two slope areas support different populations of deep-sea fish species. This difference is due to the very different hydrographic regimes in the two areas by separation by the Wyville Thomson Ridge. The Rockall Trough is characterised by warmer Atlantic water, while the deeper water (>500m) of the Faroe Shetland Channel is characterised by colder Norwegian Sea water. Temperature gradients in the Faroe Shetland Channel are very steep dropping rapidly from warm overflowing Atlantic water to the colder deep-water (<0ºC below 1,000m) (Gordon *et al.* 1995 and Gordon *et al.* undated). This steep temperature gradient is thought to be the major factor leading to the reduced species diversity in the Faroe Shetland Channel (Gordon 1992).

Cold Norwegian Sea water supports a very impoverished and distinct fish fauna of little commercial value (Gordon *et al.* undated, Bergstad *et al.* 1999). Very few of the Atlantic deep water species are found on the upper slopes of the Faroe Shetland Channel, and those species that are represented tend to be limited to those species with a limited depth span over their whole life cycle (i.e. limited to upper warmer layer of Atlantic water). Of note are those species that are found at the transition zone between cold Norwegian Sea water and upper layer of warm Atlantic water, species such as the Greenland halibut (*Reinhardtius hippoglossoides*), roughhead grenadier (*Macrourus berglax*) and the redfishes (*Sebastes* spp.). These species are only rarely found to the south and west of the Wyville Thomson Ridge (Gordon *et al.* undated).

In the Rockall Trough species diversity and biomass peak at between 1,000 and 1,500m whereas in the Faroe Shetland Channel and Norwegian Basin diversity, abundance and biomass decrease rapidly below about 500m. (Gordon *et al.* 1995). On the slope above 500m (above Wyville Thomson Ridge) fish species are similar to those found on the Rockall Trough slope.

3.3.2.1 Faroe Shetland Channel and Norwegian Sea

There is very little published information on the fish of the slopes of the Faroe Shetland Channel. Surveys have been undertaken by MAFF, the Institute fur Seefischerei (Hamburg) and a Norwegian laboratory in the 1970's, however only limited sampling was undertaken in the Faroe Shetland Channel (Gordon 1992). In 1990, the RRS Challenger undertook to investigate the fish fauna of the Faroe Shetland Channel slope. However, only a small number of samples were recovered due to bad weather conditions at the time.

Species recorded from trawls taken between 730m and 1,100m along the Faroe Shetland Channel include the Greenland halibut and the roughhead grenadier (Bridger 1978 cited in Gordon 1994). Analogous work undertaken in similar deep cold waters of the Norwegian Deeps record the presence of the roundnose grenadier (*Coryphaenoides rupestris*) and the greater silver smelt at depths of 400m and deeper (Bergstad 1990). Red fish (*Sebastes* spp) blue ling (*Molva dypterygia*) and eelpouts are also representative of the area (Gordon *et al.* undated).

3.3.2.2 Rockall Trough (500 – 1000m)

More work has been undertaken in the Rockall Trough area on deep-sea fish assemblages than in the Faroe Shetland Channel, with surveys being undertaken by MAFF (Bridger 1978), Institute fur Seefischerei, Hamburg (Ratz 1984 and Ehrich 1983) and the Dunstaffnage Marine Laboratory (Gordon and Duncan 1985, Gordon and Bergstad 1992, Coggan *et al.* 1998 and Gordon 1986).

Species recorded during these trawls between depths of 500 - 1,500m included: angler fish (*Lophius piscatorius*), tusk (*Brosme brosme*), greater silver smelt, blue ling (*Molva dypterygia*), roundnose grenadier (*Coryphaenoides rupestris*), smooth grenadier (*Nezumia aequalis*), hollowsnout grenadier (*Coelorinchus coelorhincus*), Murray's longnose grenadier (*Trachyrinchus murrayi), Lepidon eques, Halargyreus johnsonii,* the greater forkbeard (*Phycis blennoides*), black scabbard fish (*Aphanopus carbo*), cut-throat eel (*Synaphobranchus kaupi*), Baird's smoothhead (*Alepocephalus bairdii*), brotulid (*Cataetyx laticeps*) and rabbit fish (*Chimaera monstrosa*). Species numbers and presence varied with depth. An indication of the depth range of some deepwater species is given in Table 3.1 overleaf.

Table 3.1 – Species presence and depth range

0	250m	500m	750m	1000m	1500m	2000m
Rockall Trough species						
Tusk	■	■				
Monkfish	■	■	■	■	■	
Greater silver smelt (argentine)	▐	■	▌			
Blue ling	▐	■	■	■	■	■
Hollowsnout grenadier		■	■	■		
Greater forkbeard		■	■	■		
Big-eye rockling		▐	■	■	▌	
Roundnose grenadier			■	■	■	■
Smooth grenadier			■	■	■	
Rabbit fish			■	■	■	■
Cut-throat eel			■	■	■	■
Lepidon eques			■	■		
Halargyreus johnsonii			■	■		
Black scabbard fish			■	■		
Baird's smoothhead				■	■	▌
Murray's longnose grenadier				■	■	▌
Brotulid					▐	
Faroe Shetland Channel species						
Tusk	■	■				
Greater silver smelt (argentine)	▐	■	▌			
Blue ling	▐	■	■	■	■	■
Red fish		■	■			
Greenland halibut		■	■	■	■	
Roughhead grenadier			■	■	■	
Eelpout			■	■		
Arctic rockling			■	■	■	▌

Source: Gordon et al. undated, Haedrich and Merrett 1988.

Commercial continental-shelf species such as angler fish (monkfish), haddock, tusk, saithe, ling and halibut will also extend into upper slope areas of both the Rockall Trough and Faroe Shetland Channel. Banks to the north and west of Scotland and around Iceland and Faroe are important areas for ling and tusk spawning (Magnússon *et al*. 1997 and ICES 1998)

3.3.3 Demersal Shark and Ray Species

There are at least 16 demersal shark and dogfish species found in the north-eastern Atlantic. Again, species found in the warmer Atlantic waters of the Rockall Trough are distinct from those found in the cold deep waters of the Faroe Shetland Channel.

3.3.3.1 Rockall Trough

The Portuguese dogfish (*Centroscymnus coelolepis*) is the most important commercial shark species found. Other species include the leafscale gulper shark (*Centrophorus squamosus*), birdbeak dogfish (*Daenia calceus*), longnose velvet dogfish (*Centroscymnus crepidater*), black dogfish (*Centroscyllium fabricii*), greater lantern shark (*Etmopterus princeps*), and velvet belly (*Etmopterus spinax*). (Gordon *et al.* undated and Haedrich and Merrett 1988). In shallower waters (< 500m), species such as the blackmouth dogfish (*Galeus melastomus*) are seen.

Two species most likely to be encountered are the Norwegian skate (*Raja nidarosiensis*) and the round ray (*Raja fyllae*). Other ray species that may be seen include the deep-water ray (*Raja bathyphila*) (Gordon *et al.* undated and Haedrich and Merrett 1988).

3.3.3.2 Faroe Shetland Channel

In the colder waters of the Faroe Shetland Channel, the most abundant species are likely to be cold deep-water species such as the Arctic skate (*Raja hyperborea*) and Greenland shark (*Somniosus microcephalus*). Other species, which can occur above the cold-water interface (<500m), include the round ray (*Raja fyllae*), *Raja lintea, Raja radiata and Bathyraja spinicauda* (Gordon *et al.* undated).

Table 3.2 – Species presence and depth range

0	250	500	750	1000	1500	2000
Rockall Trough species						
Norwegian skate						
Round ray						
Leafscale gulper shark						
Velvet belly						
Greater lantern shark						
Portuguese dogfish						
Black dogfish						
Raja bathyphila						

Source: Gordon et al. undated, Haedrich and Merrett 1988.

3.3.4 Pelagic sharks

Pelagic sharks such as porbeagle (*Lamna nasus*), blue shark and basking sharks (*Cetorhinus maximus*) also occur over deep water.

Little is known about the spatio-temporal distribution of basking sharks around the Faroe Shetland Channel. However, Norwegian shark catchers first came to the Shetlands in some numbers in the late 1940s and continued to fish to the west of Shetland right through the 1950s and for some decades beyond that (Fairfax, 1998). Norwegian vessels are also reported to have engaged in line-fishing for porbeagle sharks as well as harpooning basking shark around Shetland and in the Minch. Twenty basking sharks were taken by a vessel operating from Scalloway, Shetland in the summer of 1953 (Fairfax, 1998).

Nothing is currently known as yet about migration routes taken by individual basking sharks, although satellite-tracking studies have recently commenced. It seems that in the NE Atlantic there is probably a general west-east (offshore-onshore) movement of most of the population in spring timed to take advantage of the high zooplankton abundance that occurs in coastal areas along tidal thermal fronts. Basking sharks appearing at the surface off southwest England do so between April and September, with greatest abundance from May to July. This also appears to be the case off the West Coast of Scotland. Clearly this implies a west-east (offshore-onshore) migration in spring rather than a south-north migration as seen with many whales (Simms, pers comm.).

The UK had submitted a proposal for inclusion of the basking shark on Appendix II of CITES, although this was not adopted.

3.4 Seabirds

3.4.1 Data Sources

In 1979 the Nature Conservancy Council (NCC) Seabirds at Sea Team began systematic survey work of the offshore distribution of seabirds in the North Sea, with later extensions of the this programme covering other parts of the North Atlantic. Pioneering work prior to this time (Nicholson 1928, Jespersen 1929 and Rankin and Duffey 1948) only covered a small proportion of the Atlantic Frontier area, as did later studies (e.g. Sage 1968). Further data on seabird distribution north and west of Scotland were collected as part of a project to survey waters west of Britain (Webb *et al.* 1990) and later research identified the concentrations of seabirds vulnerable to surface pollution south and west of Britain (Webb *et al.* 1995) and in the North Sea, but with some overlap into the Atlantic Frontier (Carter *et al.* 1993). Survey coverage remained inadequate in this area, however increasing interest from the oil and gas industry resulted in the commissioning of a two year study of the waters between the Shetland and Faroe Islands commencing in 1994 (Bloor *et al.* 1996). Since this publication further survey coverage has been obtained with the aim of improving both spatial and temporal distribution of coverage. Some of this later data have been made available through the JNCC/ESAS Seabird and Cetacean Distribution Atlas (Stone *et al.* 1994 and BODC 1998) and a final report summarising seabird and cetacean distribution in the Atlantic Frontier (JNCC 1999a and Pollock *et al.* 2000).

The above detailed studies provide data on seabird distribution and abundance for the area south of 62ºN including the area of the White Zone in the Faroe Shetland Channel south to the Wyville Thomson Ridge. However the JNCC SAST has not surveyed to any great extent the area to the North of Shetland (Cronin *et al.* 1998 and Pollock and Weir 1998) and the general distribution of seabirds in this area is poorly known. Weather conditions in the Atlantic Margin have often been unsuitable for conducting surveys on a number of planned cruises and for this reason surveys are still required in certain areas. Priority areas in the White Zone have been identified and will be the focus of surveys during 2000 (JNCC 1999a).

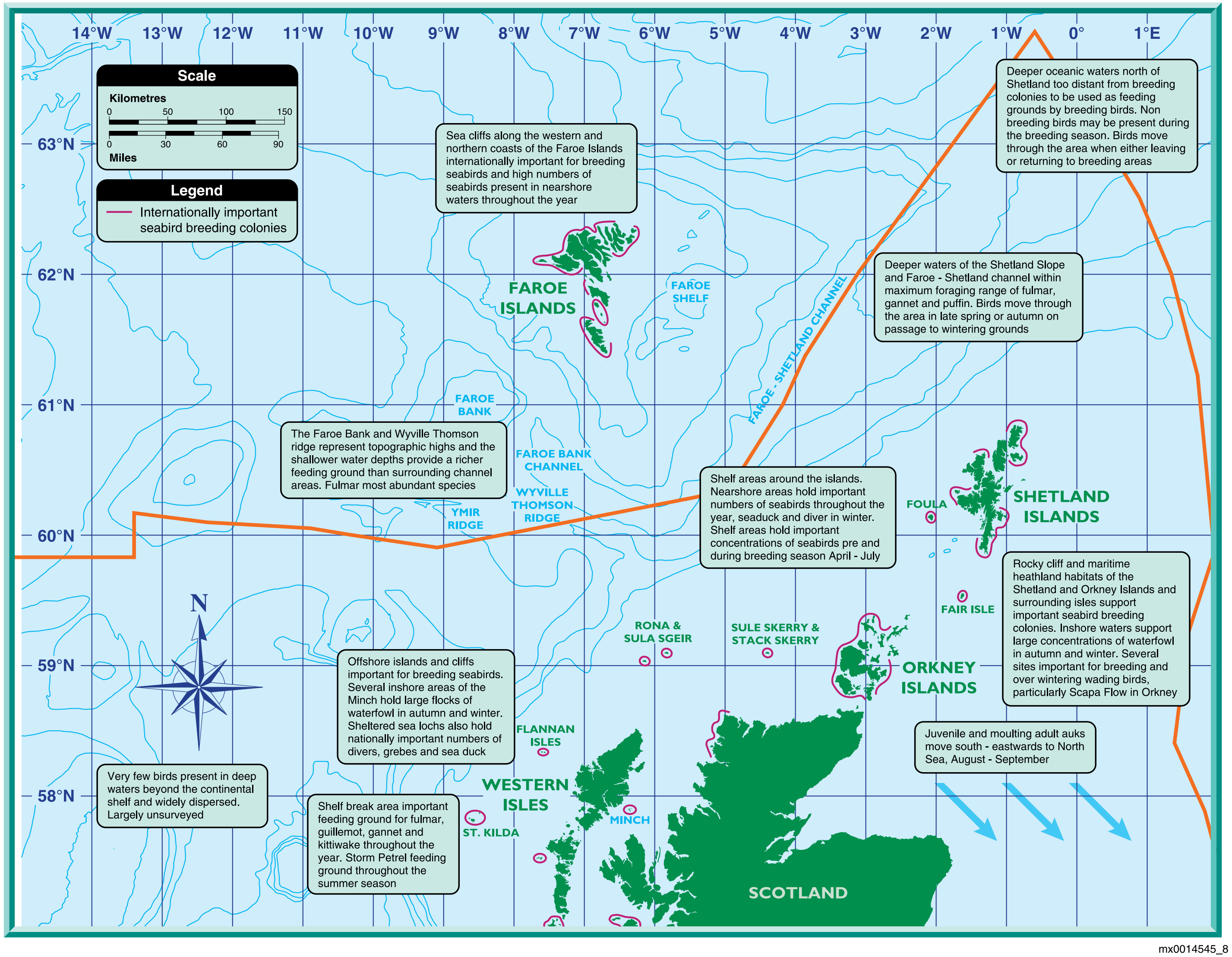
More widespread survey coverage of the North Atlantic was carried out during the North Atlantic Sighting Surveys (NASS), in 1987 and 1989 in the months July to August only. These surveys were undertaken from Faroese vessels with the aim of providing quantifiable information on seabird distribution for a vast sector of the North Atlantic. Survey coverage concentrated around the Faroe Islands, but also included some deeper offshore areas of the southern Norwegian Sea (Skov *et al.* 1995, Danielsen *et al.* 1990).

3.4.2 Distribution, Importance and Seasonal Variation

The seabirds found at sea over the Faroe Shetland Channel and to the North of Shetland are likely to originate mainly from major colonies in the Faroe, Shetland, and Orkney Islands and more northerly breeding areas such as Norway and Iceland. The areas are probably too far to visit during the breeding season for most species, and birds will generally move through the area in late summer and autumn on passage to winter breeding grounds, or in spring on route to breeding colonies, or over the winter months. See Figure 13.

Table 3.3 provides a generalised seasonal density of the principal seabird species present over the Wyville Thomson Ridge, in the Faroe Shetland Channel and north of Shetland.

Figure 13 – Seabirds



3.4.2.1 North of Shetland

These data show that in the area north of Shetland, fulmar is the most likely species to be present in greatest densities. Gannet, kittiwake and guillemot are also present, but in much lower densities. The greatest densities of birds in the area is between the months of March and September. During the main breeding season (May to July) birds present in the area are most likely to be non-breeding birds. Some breeding birds may be present, but most do not travel more than 30-50-km from their colonies. Fulmar, gannet and puffin have been found to travel greater distances (maximum 100-150km) away from Shetland colonies to obtain food, so the southern part of the area may be within the maximum limits of their feeding range. This area is likely to be mainly used by birds moving through the area, when either leaving or returning to breeding areas. After the breeding season birds disperse widely and this area can therefore be expected to be relatively unimportant for seabirds. Only fulmar and kittiwake are present in anything but low densities during the post-breeding season and during the winter months.

3.4.2.2 Faroe Shetland Channel

The area of the Faroe Shetland Channel is again probably too far to visit during the breeding season by most bird species, but is within the maximum foraging range of fulmar, gannet and puffin. Birds will therefore generally be moving through the area in late spring or autumn on passage to wintering grounds, or in spring returning to breeding colonies. Fulmar is the most abundant species, while storm petrel and kittiwake occur in moderate densities at certain times of the year, and low densities of gannet, guillemot and puffin may also be present (see Table 3.3).

3.4.2.3 Wyville Thomson Ridge

The Wyville Thomson Ridge is a topographic high on the seabed at the southern end of the Faroe Shetland Channel. The water depths are shallower than those of the Faroe Shetland Channel and this area will therefore potentially provide a richer feeding ground for those species which are known to forage large distances from their colonies. This is illustrated by the increased numbers of species found in moderate densities compared to the Faroe Shetland Channel. Fulmar is the most abundant species, while storm petrel, kittiwake, guillemot and puffin all occur in moderate densities at certain times of the year (see Table 3.3).

Seabird distribution is closely correlated to water depth, with more birds found over shallower continental shelves than the deeper oceanic waters (Stone *et al.* 1994). Therefore the Faroe Shetland Channel and north of Shetland Areas, and to a slightly lesser extent the Wyville Thomson Ridge, are less important for birds than the adjacent shelf areas. Birds present in the deeper slope and oceanic waters of the White Zone comprise mainly pelagic species such as fulmar, gannet, kittiwake and storm petrel.

3.4.3 Species Accounts

A total of 48 species of seabird were recorded in the AFEN study area by SAST/ESAS surveys (Pollock *et al.* 2000), with 40 species in slope and oceanic waters. Petrels (mainly fulmar) were the most abundant taxon, followed by auks and gulls. Eight species were present over the deep waters of the Atlantic Frontier throughout the year. In order of decreasing abundance they were: fulmar, gannet, kittiwake, puffin, great black-backed gull, guillemot, herring gull and razorbill. Apart from fulmar, all species were found in greater numbers over the shelf. Seven species were summer visitors: European storm-petrel, lesser black-backed gull, great skua, Leach's storm-petrel, Manx shearwater, Arctic tern and Arctic skua. Three species were winter visitors: Iceland gull, glaucous gull and little auk, and four were migrants: great shearwater, long-tailed skua, Pomarine skua and sooty shearwater.

Fulmar *Fulmarus glacialis*
The fulmar was the most abundant and most widespread species in the AFEN study area. From January to April, prior to the breeding season, highest densities of fulmars were concentrated along the continental slope south of 60ºN and around Shetland. Many fulmars along the continental slope were associated with fishing vessels. During the breeding season, from May to July, higher densities were recorded over the continental shelf with moderate to high densities of fulmars over the deep waters of the Norwegian Sea and following the shelf break north and west of Scotland. High densities of fulmars were recorded over the Wyville Thomson Ridge from August to October, with lower densities in November and December.

Great shearwater *Puffinus gravis*
This species breeds in the South Atlantic and is though to complete a clockwise migration circuit of the Atlantic Ocean. Scattered observations were made in the survey area between August to October, over the slope and Wyville Thomson and Ymir Ridges.

Sooty shearwater *Puffinus griseus*
Similar migration and distribution patterns to Great shearwater, with widespread records at low densities throughout the survey area. A small concentration was recorded in August over the Wyville Thomson Ridge.

Manx shearwater *Puffinus puffinus*
The main breeding colonies are south of the former White Zone, west of mainland Britain. Low densities were recorded between March and August over the Wyville Thomson Ridge and north-eastwards along the Faroe Shetland Channel. These may relate to immature non-breeding birds, which visit breeding grounds from their second summer onwards.

European storm-petrel *Hydrobates pelagicus*
Widespread in the survey area from June-August, with important colonies at Sule Skerry and Shetland, and high numbers of non-breeders in the area from the end of June. Highest densities over the shelf edge west and north-west of the Western Isles in June-July, and around the south of the Faroe Shetland Channel in August. Many birds from Shetland and more northern colonies are still breeding in September, before dispersing from the area.

Leach's storm-petrel *Oceanodroma leucorhoa*
Rarely observed north-east of the Ymir and Wyville Thomson Ridges, with moderate to high densities further south in May, June and July. More birds were recorded over the Ymir and Wyville Thomson Ridges, and along the Faroe Shetland Channel, in August, prior to departing to winter in the tropics.

Gannet *Morus bassanus*
Gannets are partial migrants, with some adults and most immature birds moving as far south as west Africa during the winter months. Adults return to the study area in March, followed by immature birds in May, with wide dispersion at low densities over most of the area regardless of water depths. Areas of high concentration are present between March and August near breeding colonies at Shetland, Sula Sgeir, North Rona, Mykines and Mykineshólmur, with an estimated maximum foraging range of 150km.

Pomarine skua *Stercorarius pomarinus*

Passage migrant, between wintering grounds off west Africa and breeding grounds in the high Arctic. High numbers in May and October, mainly along the shelf edge and Faroe Shetland Channel.

Arctic skua *Stercorarius parasiticus*
Mostly inshore distribution, close to breeding colonies from March to October. Low densities over deep water.

Long-tailed skua *Stercorarius longicaudus*
Passage migrant, with most sightings from the north end of the Faroe Shetland Channel in May, and August-September.

Great skua *Stercorarius skua*
Low densities of birds along the shelf break in April and May, with an area of higher concentration south-west of the Faroe Shetland Channel associated with fishing vessels. Widespread inshore, and at low densities in the Faroe Shetland Channel in June-July, and widely dispersed from August to October.

Herring gull *Larus argentatus*
Primarily coastal, especially during breeding and post-breeding periods. Migrants arrive during September and October, leaving in March and April with a favoured wintering area offshore west and north of Shetland.

Iceland gull *Larus glaucoides*
Scarce winter visitor, mainly over slope and inshore waters.

Glaucous gull *Larus hyperboreus*
Low densities between October and April, concentrated over the Faroe Shetland Channel and Rockall Trough.

Great black-backed gull *Larus marinus*
Widely dispersed in autumn and early winter (October-December) along the shelf break and in deeper waters. Higher numbers in late winter, January to April. During breeding and post-breeding season, May-September, widespread at low density within 50km of colonies.

Kittiwake *Rissa tridactyla*
The most abundant and widespread gull species in the study area. From January to April, widespread with highest densities along the continental slope, particularly along the Rockall Trough. From May to July, concentrated in coastal waters with low densities offshore, although moderate concentrations in the Faroe Shetland Channel were probably Faroese birds. Patchy distribution in August and September, with low densities offshore and lowest numbers offshore from October to December.

Common and **Arctic tern** *Sterna hirundo* and *S. paradisea*
Predominantly coastal, between May and October. Low densities of Arctic terns observed around the shelf break south of the Faroes in August, prior to migration.

Guillemot *Uria aalge*
Primarily a shelf species preferring waters less than 100m deep, but recorded along the shelf break in low densities throughout the year. Very high concentrations nearshore from May to July, with dispersion and moulting in large flocks in inshore waters during August and September. Most Shetland birds winter in the North Sea, although low densities were recorded over the Faroe Shetland Channel, Wyville Thomson and Ymir Ridges and south of the Faroe Bank throughout the autumn and winter.

Razorbill *Alca torda*
Primarily a shelf species, with few records in deep waters (>200m). Localised areas of low density were recorded beyond the shelf break during the breeding season (May to July) and post-moult in September to December.

Black guillemot *Cepphus grylle*
Almost entirely coastal, with localised ranges within 5km of nesting sites during breeding season, and 15-50km in winter.

Little auk *Alle alle*
Winter visitor from the islands of Arctic Europe, with low densities observed in the Faroe Shetland Channel from September to December. Higher numbers winter in the northern North Sea.

Puffin *Fratercula arctica*
More widespread than guillemots or razorbills, and common in deep water during the summer. During April and May, most puffin were over the shelf with low to moderate concentrations of probable non-breeders over the Faroe Shetland Channel. Foraging ranges during the breeding season are generally within 40km, although ranges increase during periods of low food availability. Puffins are most widespread in deep water during August and September, with moderate densities recorded south and west of the Faroes. Low to moderate densities were recorded over the Faroe Shetland Channel during winter.

Table 3.3 - Seasonal density of principal seabirds in the UK White Zone (adapted from Pollock et al. 2000, BODC 1998, Bloor et al. 1996, Hamer et al. 1993 and Danielsen et al. 1990,)

Table a – Seasonal density of principal seabirds North of Shetland

	Pre-breeding	Breeding season	Post breeding	Winter months
	Mar & Apr	May-Jul	Aug & Sept	Oct-Feb
Fulmar ***(Fulmarus glacialis)***	**Unsurveyed** *Although unsurveyed can be expected to be present north of Shetland during this time. During April undergo a pre-laying exodus from their colonies leading to higher densities over offshore areas*	**Low – high** *Do not breed until their 9th year, therefore as well as breeding birds feeding offshore, large numbers of non breeding birds will also be present*	**Low – high*** *Most birds begin to leave their breeding colonies during September and become widely dispersed throughout the North Atlantic*	**Very low – low*** *During the winter months disperse widely over the North Atlantic. Also known to be associated with areas of fishing activity*
Gannet ***(Morus bassanus)***	**Unsurveyed**	**Very low*** *Found widely at low densities in oceanic areas. Can feed up to 150km from breeding colonies*	**Very low*** *Become less widespread in September as they begin to migrate south*	**No birds*** *Migrate south over the winter months*
Kittiwake ***(Rissa tridactyla)***	**Very low*** *Widespread during early spring, but highest densities over shelf break rather than deep oceanic waters*	**Very low*** *Generally remain in the vicinity of breeding colonies and feed within 5 km of shore (but can feed up to 50km away in poor years). Not distributed over deeper waters*	**Very low*** *Disperse locally from breeding colonies in September, but distributed over deeper waters*	**Very low – low*** *Dispersed widely throughout North Atlantic during winter*
Guillemot ***(Uria aalge)***	**Unsurveyed** *Although unsurveyed not expected to be present. Highest densities around breeding colonies and in inshore waters*	**Very low*** *Highest densities around breeding colonies and over the continental shelves. Very few birds in deeper oceanic waters*	**Unsurveyed**	**No birds – very low*** *Birds dispersed to the North Sea and off the west coast of Norway*
Puffin ***(Fratercula arctica)***	**No birds*** *Highest densities found over shelf areas adjacent to breeding colonies. Generally absent from deeper oceanic waters*	**No birds – very low*** *Highest densities found over shelf areas and generally absent from deeper oceanic waters*	**Very low – low*** *Puffins breeding in Shetland and Orkney migrate to the North Sea*	**Unsurveyed**

Key

High 5.00 + birds/km^2
Moderate 2.00-4.99 birds/km^2
Low 1.00-1.99 birds/km^2
Very low 0.01-0.99 birds/km^2
***** Based on data available, however much of the area is unsurveyed

Table b - Seasonal density of principal seabirds in the Faroe Shetland Channel and over the Wyville Thomson Ridge

	Pre-breeding	Breeding season	Post breeding	Winter months
	Mar & Apr	May-Jul	Aug & Sept	Oct-Feb
Fulmar ***(Fulmarus glacialis)***	**FS Channel: Moderate** **WT Ridge: Unsurveyed** *During April undergo a pre-laying exodus from the their breeding colonies resulting in higher densities over the continental shelf edge*	**FS Channel: Low - moderate** **WT Ridge: Low - moderate** *Do not breed until their 9th year, therefore as well as breeding birds feeding offshore, large numbers of non breeding birds will also be present*	**FS Channel: Low - moderate** **WT Ridge: Moderate - high** *Most birds begin to leave their colonies during September. Highest densities in the south of the Faroe Shetland Channel and on the Wyville Thomson Ridge. Lower densities found further north in the Faroe Shetland Channel*	**FS Channel: Very low – moderate*** **WT Ridge: Unsurveyed** *During the winter months disperse widely over the North Atlantic, but moderate densities still recorded along the shelf edge. Also known to be associated with areas of fishing activity.*
Storm petrel ***(Hydrobates pelagicus)***	**FS Channel: No birds** **WT Ridge: No birds*** *Birds begin to return from southern wintering grounds in April.*	**FS Channel: Very low - moderate** **WT Ridge: No birds - moderate** *Birds at their greatest densities during July. In addition to breeding birds there is a large population of non-breeding birds. Deep water off the shelf edge is within feeding range of breeding adults*	**FS Channel: Very low - high** **WT Ridge: Low - high** *Population offshore generally widespread with highest numbers of birds found over the shelf break and deeper water areas*	**FS Channel: No birds** **WT Ridge: Unsurveyed** *Migrate south over the winter months so not expected to be present*
Gannet ***(Morus bassanus)***	**FS Channel: No birds - very low** **WT Ridge: Unsurveyed** *Densities in the Faroe Shetland Channel lower than those near the shelf edge and on shelf areas*	**FS Channel: Very low** **WT Ridge: Very low** *Found widely at low densities between Shetland and the Faroe Islands. Can feed up to 150 km from colonies*	**FS Channel: Very low** **WT Ridge: Very low** *Become less widespread in September as they begin to migrate south. Associated with fishing vessels along shelf break*	**FS Channel: Very low** **WT Ridge: No birds*** *Migrate south over the winter months*
Kittiwake ***(Rissa tridactyla)***	**FS Channel: Very low - moderate** **WT Ridge: Low** *Widespread during early spring. Highest densities recorded in the area over the shelf edge. Late spring begin to return to breeding colonies. Associated with fishing vessels at this time of the year*	**FS Channel: Very low** **WT Ridge: Very low – low** *Generally remain in vicinity of breeding colonies and feed within 5km. Not distributed over deeper waters. Occasional high densities in Faroe Shetland Channel associated with fishing vessels*	**FS Channel: Very low** **WT Ridge: Low – moderate** *Disperse from breeding colonies, but more common over Faroes Shelf and Wyville Thomson Ridge compared to the Faroe Shetland Channel*	**FS Channel: Very low** **WT Ridge: Unsurveyed** *Dispersed widely throughout North Atlantic*
Guillemot ***(Uria aalge)***	**FS Channel: No birds - very low** **WT Ridge: Unsurveyed** *Highest densities around breeding colonies and in inshore waters. Absent from the Faroe Shetland Channel*	**FS Channel: Very low** **WT Ridge: Low – moderate** *Highest densities around breeding colonies and over continental shelves. Very few birds in the Faroe Shetland Channel. After breeding adults and chicks move to the northern North Sea.*	**FS Channel: No birds - very low** **WT Ridge: No birds – low** *Dispersed from breeding colonies and present in low concentrations in the Faroe Shetland Channel on the Wyville Thomson Ridge*	**FS Channel: No birds - very low** **WT Ridge: Unsurveyed** *Birds generally absent from the Faroe Shetland Channel and shelf break areas. Birds dispersed to the North Sea and off the west coast of Norway*

(Continued overleaf)

Table b (cont) - Generalised seasonal density of seabirds in the Faroe Shetland Channel and over the Wyville Thomson Ridge

	Pre-breeding	Breeding season	Post breeding	Winter months
	Mar & Apr	May-Jul	Aug & Sept	Oct-Feb
Puffin *(Fratercula arctica)*	**FS Channel: No birds – very low** **WT Ridge: Very low – moderate** *Highest densities found over shelf areas adjacent to breeding colonies and Wyville Thomson Ridge. Generally absent from the Faroe Shetland Channel.*	**FS Channel: Very low** **WT Ridge: No birds – low** *Highest densities found over shelf areas and generally absent from the Faroe Shetland Channel and Wyville Thomson Ridge*	**FS Channel: Very low** **WT Ridge: No birds – low** *Puffins breeding in Shetland and Orkney migrate to the North Sea. Those breeding in the Faroes are found in greatest numbers on the Faroe Bank and Iceland Faroe Ridge. Generally absent from the Faroe Shetland Channel and Wyville Thomson Ridge*	**FS Channel: No birds - low** **WT Ridge: No birds*** *During October and November low to moderate densities recorded over the deeper waters of the Faroe Shetland Channel and Wyville Thomson Ridge. However for the majority of the winter months the birds are widely dispersed in the North Sea and into the Atlantic*

Key

High	5.00 + birds/km^2	**Low**	1.00-1.99 birds/km^2
Moderate	2.00-4.99 birds/km^2	**Very low**	0.01-0.99 birds/km^2

***** Based on data available, however much of the area is unsurveyed

3.4.4 Vulnerability to Oil Pollution

The vulnerability of bird species to oil pollution is dependant on a number of factors and varies considerably throughout the year. The JNCC Seabirds at Sea Team use an index to assess the vulnerability of bird species to surface pollution (including oil spills). The 'Offshore Vulnerability Index' (OVI) considers four factors:

- the amount of time spent on the water,
- total biogeographical population,
- reliance on the marine environment,
- potential rate of population recovery (Williams *et al.* 1994).

Vulnerability scores for offshore areas are determined by combining the density of each species of bird present with its vulnerability index score.

The latest vulnerability data for the UKCS were issued in 1999 (JNCC 1999b). Limited data are available for the area north of Shetland and generally no data are available for the areas of the Faroe Shetland Channel and Wyville Thomson Ridge, which were formally part of the White Zone. Data are however available for adjacent areas of the UKCS and these can be used to provide an indication of the times of year that seabirds will be most vulnerable to surface pollution, including oil.

3.4.4.1 North of Shetland

Between 62°N and 63°N data have been collated for most months of the year for some of the area. Although there is not complete coverage, the data available indicates that in the area just north of 62° some sea areas support bird concentrations that are moderately to highly vulnerable to surface pollution from May through to September. Further north, birds appear to be only moderately to highly vulnerable during the months of May and August (although data is lacking north of 63° for these months). Data is very sparse north of 63°30' and has only been collected for the month of July, when birds are expected to be highly – very highly vulnerable to surface pollution.

3.4.4.2 Faroe Shetland Channel

Although there has been no data collected in the White Zone area of the Faroe Shetland Channel, data on bird vulnerability is available for all months of the year for the Faroe Shetland Channel slope, adjacent to the White zone area. These data indicate that in the deepest waters in the north of the Faroe Shetland Channel, birds are generally moderately vulnerable to surface pollution from March through to August, although highly vulnerable populations of birds may be present in certain areas during September. Further south as water depths become less deep, bird populations are moderately vulnerable from March to October, and in some areas highly vulnerable to surface pollution during the post breeding season (May through to the end of July).

3.4.4.3 Wyville Thomson Ridge

Data is available for some of the White Zone area of the Wyville Thomson Ridge. These data indicate that this area supports bird concentrations that are highly and very highly vulnerable to surface pollution during the breeding and post breeding seasons. Birds are generally at greatest risk during the months of May and August when they are very highly vulnerable, while high vulnerability is experienced during April, July and in the extreme west of the area in October. This confirms that as suggested during the discussion of bird distribution and abundance the Wyville Thomson Ridge area of the White Zone is more important for seabirds than the Faroe Shetland Channel and North of Shetland areas.

3.4.4.4 Data Accuracy

It should be noted that the above assessment of bird vulnerability is only an indication of the likely seasons of greatest vulnerability to surface pollution and is based on extrapolation of existing data in adjacent areas or sparse data for the specific areas of interest. The JNCC intend to conduct surveys of the White Zone area during 2000. The results of these surveys will further clarify the data presented above.

3.5 Marine mammals

3.5.1 Data Sources

Exploitation of cetaceans and seals as a food, bone, oil, baleen and by-products resource has provided pre-historic and historic evidence on marine mammal distribution in the area, with the earliest data provided by seal remains in Mesolithic coastal shell middens in Argyll dated from c.8350 to c.4750 before present (Bonsall 1997). Comparable sites in Orkney and Shetland have not been found, probably because of coastal submergence (Turner 1998). Hunting statistics on the whaling in Faroese waters of long-finned pilot whale (*Globicephala melas*) and northern bottlenose whale (*Hyperoodon ampellatus*) are available for the period 1584 until present (Bloch 1996). Other small cetaceans, notably bottlenose dolphins and harbour porpoise, have been included in the Faroese catch (the intestine of the latter reportedly making excellent fishing bait). Baleen whaling around the Faroes was developed by Norwegian whalers and ran from 1894-1984 (e.g. Risting 1922, Bloch 1996). Whale landings at Scottish whaling stations in the Western Isles and Shetland between 1908-1914 and 1920-1927 were reported by Thompson (1928). An overview of cetacean exploitation in the eastern North Atlantic is given by Jonsgård (1974).

Long term cetacean strandings records have been collated for the British Isles by Sheldrick (1979) and for the Faroes by Bloch (1998). Recent marine mammals sightings and strandings in Shetland have been reported annually in Shetland Sea Mammal Reports (e.g. Harvey and Osborn 1998, Fisher 1999).

The North Atlantic Sightings Surveys in 1987, 1989 and 1995 (Buckland *et al*. 1993, Gunnlaugsson and Sigurjónsson, 1990, Sigurjónsson *et al*. 1989, 1991, Sigurjónsson 1995) were aimed at estimating the abundance and stock size of whales in Icelandic, Faroese and adjacent waters. A limited (17 recording days, 2157km) dedicated sightings survey was also carried out to the north and west of Shetland and the Western Isles in July-August 1998 by Greenpeace and the Whale and Dolphin Conservation Society (Hughes *et al*. 1998). Over the last ten years, inter-island and international ferries and fishery inspection vessels have recorded whale sightings in Faroese waters, providing a fairly systematic coverage and whale sightings scheme with records stored in the Faroese National Archive (Bloch 1998).

The west Shetland shelf and coastal waters around Orkney and Shetland received coverage by the SCANS survey in 1993, which focused on the distribution of harbour porpoise and other small cetaceans (Hammond *et al*. 1995).

Since 1979, offshore seabird surveys carried out by SAST/JNCC have opportunistically recorded cetacean and other marine mammal species. Following limited survey effort to the northwest of Scotland, a systematic two year seabird and cetacean survey was initiated in 1994 (Bloor *et al*. 1996), funded by BP and Shell, followed by further survey work funded by individual oil companies and the Atlantic Margin Group in 1997 and early 1998. The Atlantic Frontier Environmental Network (AFEN), funded surveys in Atlantic Frontier areas of the UKCS from March 1998, and surveys continued until March 1999 (Pollock *et al*. 2000). AFEN sightings surveys are continuing through 2000. Total SAST survey effort in Atlantic Frontier waters to March 1999 was 48,221 km^2, of which 33% was in deep water (>200m).

SAST coverage of Faroese waters, together with the White Zone and extension into the UKCS, was obtained between 1997 and 1999 with funding from GEM, including three dedicated vessel charters.

Watches for cetaceans have been carried out during seismic survey operations, by dedicated Marine Mammal Observers, in “sensitive” parts of the UKCS since 1996, under guidelines issued by Government (*Guidelines for minimising acoustic disturbance to small cetaceans* and subsequent revisions). Analyses of data for surveys in 1996, 1997 and 1998 are reported by Stone (1997, 1998, 2000). Clearly, this survey effort has focused on areas of hydrocarbon exploration interest, but has provided reasonable coverage of the Atlantic Frontier.

Cetacean sightings data from all the above SAST/JNCC surveys have been incorporated into the ESAS database (e.g. Stone *et al*. 1995, Bloor *et al*. 1996, Pollock *et al*. 2000).

Sightings records, predominantly from shorebased observers but including some offshore installations, vessels and weather ships, and SAST sightings, were collated for UK and Irish waters by the UK Mammal Society Cetacean Group (Evans 1992). This database contains records of ca. 20,000 sightings, with measures taken to verify identifications and standardised recording forms used from 1973. Both effort-related and opportunistic sightings records are included.

In addition to visual observations, cetaceans in the study area have also been monitored acoustically. From October 1996, vocalisations of fin, blue and humpback whales north and west of Britain and Ireland have been monitored using bottom-mounted passive hydrophone arrays (SOSUS arrays) operated by the US Navy. Six (later seven) large overlapping regions, from approximately 42º to 63ºN are monitored, with the White Zone area included in Region A which extends from the East Shetland Basin to approximately mid-way between the Faroes and Iceland. The first twelve months of study (October 1996 – September 1997) were reported by Clark and Charif (1998). Later results have been reported on a periodic basis to AFEN (Tasker, pers. comm.).

Field trials of acoustic monitoring of cetaceans during seismic surveys north west of Shetland were conducted during 1996, on behalf of Shell (Chappell 1996, Mansfield 1996).

BP Amoco has recently commissioned a study of local whale acoustic activity and levels of industrial noise in the vicinity of Foinaven and Schiehallion (Charif and Clark, in prep), using autonomous acoustic recording devices ("pop-ups"). Five pop-up units were deployed for approximately two months from late January 1999. Further deployments of pop-ups in the Foinaven area are planned for Q3/Q4 2000, funded by AFEN.

Available information on cetacean stocks and distributions in the study area has been compiled and reviewed by Moscrop (1996) and Pollock *et al*. (2000). Synopses of seal distribution and ecology in coastal waters are included in the relevant JNCC Coastal Directories (Barne *et al.* 1996 and 1997 a, b, c and d).

3.5.2 Species Accounts

Between June 1979 and March 1999, sightings surveys by SAST and other ESAS collaborators recorded a total of fifteen species (12,482 individuals) of cetaceans and three species of seals within the Atlantic Frontier, north and west of Scotland (extending south to the North Channel and Clyde). These were:

Fin whale *Balaenoptera physalus*

Sei whale *Balaenoptera borealis*

Minke whale *Balaenoptera acutorostrata*

Humpback whale *Megaptera novaeangliae*

Sperm whale *Physeter macrocephalus*

Northern bottlenose whale *Hyperoodon ampellatus*

Sowerby's beaked whale *Mesoplodon bidens*

Killer whale *Orcinus orca*

Long-finned pilot whale *Globicephala melas*

Atlantic white-sided dolphin *Lagenorhynchus acutus*

White-beaked dolphin *Lagenorhynchus albirostris*

Risso's dolphin *Grampus griseus*

Bottlenose dolphin *Tursiops truncatus*

Common dolphin *Delphinus delphis*

Harbour porpoise *Phocoena phocoena*

Common seal *Phoca vitulina*

Grey seal *Halichoerus grypus*

Hooded seal *Crystophora cristata*

SAST surveys have also recorded a significant number of unidentified beaked whales (probably *Mesoplodon* spp.) in deep water north and south of the Wyville Thomson Ridge. SOSUS acoustic monitoring has recorded blue whales throughout the Atlantic Frontier. In addition, striped dolphin (*Stenella coeruleolba*), beluga (*Delphinapterus leucas*) and Atlantic walrus (*Odobenus rosmarus*) have been recorded off the Shetland coast in recent years (Harvey and Osborn 1998, Fisher 1999).

Faroese sightings and strandings (Bloch 1998) include Northern Right Whale (*Eubalaena glacialis*, last recorded 1993), blue whale (*Balaenoptera musculus*, 1995), narwhal (*Monodon monoceros*, 1840), false killer whale (*Pseudorca crassidens*, 1978), bearded seal (*Erignathus barbartus*, 1998), harp seal (*Phoca groenlandica*, undated but relatively common), ringed seal (*Phoca hispida*, 1967) and Atlantic walrus (*Odobenus rosmarus*, 1998).

Distribution, seasonal patterns and population size of individual species, regularly recorded or of significant conservation value (northern right whale) in the former White Zone, are discussed below.

Northern Right Whale *Eubalaena glacialis*
Northern right whales have not been recorded by SAST / ESAS surveys or seismic surveys, and the only recent records are in the vicinity of Iceland in 1987 and 1989, and a single individual north-north east of the Faroes in September 1993 (Bloch 1998).

Formerly abundant between the Azores and Spitzbergen, right whales were the first species to be targeted by large-scale whaling and numbers in the northeast Atlantic are now so low that it is not possible to estimate population size from surveys (Evans 1992).

Fin whale *Balaenoptera physalus.*
The distribution of fin whales, recorded by SAST and seismic sightings, is centred north of 60ºN, and all sightings were near or beyond the 1000m contour. Sightings of fin whales (n=29) were recorded between May and October, with a peak in August, consistent with Faroese sightings records (n=334) which were highest in June-September. Hughes *et al*. (1998) recorded six definite and 14 possible fin whale sightings in 17 days effort between Shetland and the Faroes, including several in shallower water (200-1000m). It was previously considered (e.g. Evans 1987) that fin whales migrate between high latitude summer grounds and southern wintering grounds, with utilisation of the Atlantic west of Britain and Ireland throughout the summer. However, acoustic monitoring using SOSUS arrays detected at least some animals in all regions of the Atlantic Frontier in every month for which data were available, and with no consistent directional movement in any month. Pop-up deployments in the Foinaven area during January and February detected fin whales in 72.6% of the data examined from two sites. It therefore seems probable that at least some individuals are present throughout the year.

Fin whales are the most abundant large whales in the former White Zone area. SOSUS monitoring indicated minimum numbers of 6 to 20 vocalising individuals in Region A between October 1996 and April 1997, and SAST sightings recorded a peak number of 11 animals sighted during August.

The fin whale has a worldwide distribution in mainly temperate and polar seas of both hemispheres. In the North Atlantic, fin whales were heavily exploited, with at least 75,000 animals taken between the late 19th and mid 20th century (including 4,536 landed in Shetland, and 7,524 in the Faroes). Whaling from the Western Isles stations ceased in 1951, but continued until the mid-1980s in Faroese, Spanish waters. Recent sightings surveys indicate a total population numbering somewhere over 14,000 individuals, well below its former size (Evans 1992). Combined fin and sei whale abundance west of Shetland (Blocks B and C) was estimated as 1912 animals by Hughes *et al*. (1998), using density data uncorrected for detection efficiency.

Blue whale *Balaenoptera musculus*
Blue whale were not recorded by SAST / ESAS sightings surveys, although their spring migration route passes close to the Faroes, and recent sightings include one in April 1990 and two in July 1995 (Bloch 1998). Traditional knowledge of Faroese whalers indicated a consistent (geographical) migration, with blue whales reaching “the sound between Vágoy and Koltur” in spring time (Risting 1922).

Seismic surveys in the Faroe Shetland Channel recorded definite identifications of blue whales in 1996 (two individuals) and 1997 (three individuals), together with a larger number of indeterminate species identifications which may have included blues. The majority of definite blue whale sightings reported from seismic surveys throughout the UKCS were in the Faroe Shetland Channel, although effort was also distributed in deep water west of Scotland and Ireland.

SOSUS monitoring in 1996-97 showed pronounced seasonal variation throughout the Atlantic Frontier, with peak detection rates in November and December. Minimum numbers of vocalising individuals in Region A were one to nine, with comparable numbers (max 17) in other regions between August and April. Movement patterns of individual blue whales did not show any consistent pattern of directional movement. This data indicates that blue whales are present in, or close to, the former White Zone throughout autumn, winter and spring. No blue whales have been detected by pop-up deployments to date.

The blue whale has a discontinuous worldwide distribution in tropical, temperate and polar seas of both hemispheres. Three subspecies are recognised (Carwardine 1995), representing distinct populations in the southern hemisphere, northern hemisphere and tropical southern hemisphere (pygmy blue whale). Isolation of North Atlantic and North Pacific populations seems likely, with only a few hundred individuals left in the North Atlantic (Klinowska 1991). Line transect and photo-ID studies indicate an overall North Atlantic population numbering in the low hundreds, mainly along the east coast of North America and in Icelandic waters (Evans 1992). Whaling catch records include 85 between 1903-28 from Shetland, 316 between 1903-28 and 1950-51 from the Western Isles, 125 from Ireland between 1908-1922 and at least 305 from the Faroe Islands in 1900-1950 (Atlantic Frontier total 831).

Sei whale *Balaenoptera borealis*

Sei whales had not been recorded in the ESAS database prior to the commencement of dedicated deep-water surveys, which recorded 42 animals, mainly in August (74%) in deep water to the south-east of the Faroes, although sightings were also recorded in the Rockall Trough.

A single sei whale was also sighted by one seismic survey in 1997, and six definite identifications were recorded by the Greenpeace/WDCS survey in July-August 1998. Faroese records include 17 observations of 35 sei whales between 1988-1997, all but one single individual south of the Faroes between February and September.

Sei whales are not particularly vocal (Chappell 1996) and acoustic detection is unlikely to be effective.

Sei whales have a worldwide, but primarily deep water, temperate distribution with northern and southern hemisphere populations showing some morphological differences. Whaling records suggest fluctuating numbers of sei whales in the north-east Atlantic, possibly as a result of annual variation in food availability, principally *Calanus finmarchicus* although euphausiids and small schooling fish are also taken (see Bloch 1998, Pollock *et al*. 2000). Nevertheless, whaling catches were considerable, with 2,140 taken from the Faroes between 1894-1979, 1,839 between 1903-28 from Shetland, 378 between 1903-28 and 1950-51 from the Western Isles, 91 from Ireland between 1908-1922 (Atlantic Frontier total 4,448). Sightings surveys indicate a current North Atlantic population numbering a few thousand individuals (Evans 1992).

Minke whale *Balaenoptera acutorostrata*
Minke whales are the most common baleen whale species in the area, with a total of 158 sightings recorded from the Atlantic Frontier area by SAST / ESAS. Most sightings occurred in water shallower than 200m, with the greatest concentration in the North Minch. There were relatively few sightings on the west Shetland shelf, north of the Wyville Thomson Ridge (11) or Faroes shelf (1). Minke whales were recorded only between May and October, with over 74% between June and August. The seasonal pattern is thought to reflect migration into British waters to feed during the summer months, before movement south to breed during the winter (Evans 1980).

Minke whales were sighted by seismic survey monitoring in 1996, 1997 and 1998, including a number of sightings in deep(>1000m) water in the Faroe Shetland Channel. From 1988-1997, 154 observations of 288 minke whales were made in Faroese waters. Minke whales are observed annually in July-September, inshore feeding between the Faroes Islands, with one observation in August 1997 of a group of 30-50 individuals (Bloch 1998). Minkes are also regularly sighted inshore around Shetland, e.g. 20 sightings in 1997, and 21 in 1998 (Harvey and Osborn 1998, Fisher 1999).

Minke whales are not detectable by SOSUS arrays, and operational problems prevented an assessment of short-range acoustic detectability during monitoring trials (Chappell 1996).

Commercial exploitation of minke whales started relatively late, in the 1940s. Landings to the Faroes have been limited, 99 individuals between 1966-1977, with no recorded landings in Scotland or Ireland although Norwegian vessels were taking minke whales in the region of the Northern Isles from the 1940s (Evans 1992).

Minke whales have a virtually worldwide distribution in tropical, temperate and polar waters. Three geographically isolated populations are recognised in the North Pacific, North Atlantic and southern hemisphere. In the eastern North Atlantic, recent sightings surveys have provided a wide range of population estimates from 37,000 to 125,000 individuals (Evans 1992).

Humpback whale *Megaptera novaeangliae*
The humpback whale is uncommon in the Atlantic Frontier, with only four sightings recorded by SAST / ESAS; two of which were in the Faroe Shetland Channel. Sightings occurred in summer months between May and September. Up to three humpback whales returned annually to inshore waters around the Shetland Isles between March and September from 1992 to 1997, although these individuals were not sighted around Shetland in 1998 (Fisher 1999). Individual humpbacks were also sighted in the Schiehallion area in June and July 1998 (Fisher 1999).

Three sightings from seismic vessels have been made in the Faroe Shetland Channel in 1996, 1997 and 1998. Twenty-four observations totalling 40 animals have been recorded in Faroese waters, between April and October, with an increase in sightings especially in the last few years. A single humpback whale drowned in a salmon farm cage at Haraldsund, Faroe Islands in April 1995.

Humpback whales were detected by SOSUS monitoring only between mid-November and late March, with groups of humpbacks tracked moving into and through Regions A, B, C and D (i.e. from the Faroe Shetland Channel to west of Ireland), travelling on generally south-westerly courses. No corresponding northward migration was detected. Minimum number of humpback whales in Region A peaked at ten individuals in December 1996 and January 1997.

Humpback whales are widely distributed in all oceans from polar regions to the tropics, and with at least ten geographically distinct sub-populations (Carwardine 1995). The northwest Atlantic population size is estimated through photo-ID studies as between 5,500 and 6,500 individuals, although the northeast Atlantic population is estimated (Klinowska 1991) as no more than a few hundred individuals, mainly around Iceland and the Barents Sea. Catches amounted to 51 between 1903-28 from Shetland, 19 between 1903-28 from the Western Isles, 6 from Ireland between 1908-1922 and 209 from the Faroe Islands in 1894-1964 (Atlantic Frontier total 285). Worldwide, more than 100,000 humpbacks were killed by whalers (Carwardine 1995). Sightings records suggest a potential return of some animals to the Atlantic Frontier region (Pollock *et al*. 2000).

Sperm whale *Physeter macrocephalus*
Sperm whales are the most frequently encountered species of large whale in the AFEN study area, with a total of 80 animals recorded in all months of the year except February and March (peak in June). Almost all sperm whale sightings occurred along the 1000m contour, particularly along the Ymir Ridge and in the Faroe Shetland Channel. Sperm whales feed particularly on mesopelagic cephalopods (Clark 1980) and their distribution is though to be related to food supply (Waring *et al*. 1993, Jaquet 1996). It is likely that most animals sighted were adult males (Pollock *et al*. 2000).

Sperm whales are also reported in Shetland coastal waters (e.g. a group of 12-14, accompanied by a mixed school of white-sided, white-beaked and Risso's dolphins, in the Fair Isle Channel in July 1998; Fisher 1999).

Sperm whales were recorded by seismic surveys in the Rockall Trough and Faroe Shetland Channel in 1996, 1997 and 1998. Most observations were of 1-4 individuals, consistent with the hypothesis that most sightings are of adult males. Forty-eight observations, totalling 187 individuals were made in Faroese waters of which only four were made inshore. Five definite identifications were recorded by the Greenpeace/WDCS survey in July-August 1998.

Sperm whale vocalisations were not assessed by the SOSUS methodology, although acoustic monitoring of sperm whales has been carried out in the northeast Rockall Trough (Lewis *et al*. 1998) and Faroe Shetland Channel (Chappell 1996), in addition to a substantial amount of work elsewhere in the world. Swift (1998) used acoustic monitoring techniques to determine the relative abundance and distribution of sperm whales in a survey block close to Rockall. Sperm whales were not completely excluded from the survey area and could be heard vocalising even when guns were firing, although their vocal behaviour was altered.

Sperm whales are widely distributed in deep waters worldwide, with a general poleward movement in summer and marked differences in distribution between sexes (into "bachelor schools", "breeding schools" and solitary or small groups of adult males). There are no population estimates for the North Atlantic population (Evans 1992) although the species is common in deep waters with breeding areas including the Caribbean and around the Azores. Between 1950 and 1986, more than 20,000 individuals were taken around Iceland, the Azores, Madeira and Spain. Catches amounted to 19 between 1903-28 from Shetland, 76 between 1903-28 from the Western Isles, 63 from Ireland between 1908-1922 and 702 from the Faroe Islands in 1894-1968 (Atlantic Frontier total 860).

Beaked whales *Mesoplodon* spp.
The distributions of beaked whales (*Mesoplodon, Ziphius* and *Hyperoodon* spp.) are poorly understood, worldwide. Beaked whales tend to be very difficult to identify, and to live in deep water far from land (Carwardine 1995) where their long dive duration and inconspicuous surfacing behaviour may explain the limited number of sightings. The diet of beaked whales is mostly squid and pelagic fish (Mead 1989), and distribution of many species is associated with ocean trenches and canyons. There are currently at least 20 known species, some of which are known only from sightings or from skulls, and have not been fully described.

SAST / ESAS surveys have recorded a total of 62 unidentified beaked whales from the AFEN area, thought to be *Mesoplodon* species, together with one positive identification of Sowerby's beaked whale (*M. bidens*) south of Rosemary Bank. Beaked whales were recorded throughout the year, except February-April and July, with a distinct peak in August. Beaked whale distribution in the study area is similar to that of sperm whale, with a greater proportion of sightings south of the Wyville Thomson Ridge. A total of seven beaked whale sightings (all unidentified) have been recorded in the former White Zone, all in the Faroe Bank and Faroe Shetland Channels (Pollock *et al*. 2000). Sightings throughout the AFEN area were most frequently of single animals, with a few observations of larger groups.

Other sightings of beaked whales west of Britain and Ireland are recorded by Evans (1992): Cuvier's beaked whale (*Ziphius cavirostris*) east of Orkney (1980), south of Ireland (1984 and 1987), off NW Ireland (1987) and off Skye (1988); Sowerby's beaked whale in the Minches (1977). Cuvier's, Sowerby's and True's (*Mesoplodon mirus*) beaked whales have also stranded in the region (Evans 1992).

There is no information regarding vocalisations or acoustic detectability of beaked whales in the study area. No landings from whaling are recorded and population status is unknown, although sightings and strandings evidence suggests that Cuvier's and Sowerby's beaked whales may be relatively common in the Atlantic Frontier.

Northern bottlenose whale *Hyperoodon ampellatus*
Unlike other beaked whales, northern bottlenose whales were heavily exploited by commercial whaling and the species' distribution and ecology are therefore better known.

SAST / ESAS surveys recorded seven sightings totalling 17 animals in the AFEN area, all over deep water reflecting the distribution of northern bottlenose whales in the North Atlantic (Reeves *et al*. 1993). Two sightings were recorded by seismic survey in the northern Faroe Shetland Channel in 1997. Northern bottlenose whales are thought to migrate northwards from low latitudes in the spring, returning south from polar waters in the autumn (Benjaminsen and Christensen 1979). However, catches of bottlenose whales in the Faroes occurred throughout the year (Bloch 1996) suggesting that some individuals are non-migratory. Bottlenose whales are frequently associated with pilot whales and other cetacean species.

Northern bottlenose whales are restricted to temperate, subpolar and polar areas of the North Atlantic, although a very similar species (*H. planifrons*) is found in the southern hemisphere. Population status of the northern bottlenose whale is uncertain, although the population size may be considerably less that estimated initial population prior to commercial exploitation (Evans 1992). A population estimate of 40,000 animals is given by Bloch (1998) for the eastern North Atlantic.

There have been two main periods of exploitation in the North Atlantic: about 50,000 were taken in the period 1882-1914 and 5,000 between 1955-72, mainly by Norwegian whalers. Small numbers were also taken in the Scottish whaling industry early last century, including 25 around Shetland between 1903 and 1928. From 1894 – 1935, 92 bottlenose whales were taken in offshore Faroese whaling, with a further 724 taken in the traditional pilot whale drive fishery from 1584 to 1998 (Bloch 1998). Bottlenose whales are taken for food, although only the meat is eaten as the blubber has a laxative effect.

Killer whale *Orcinus orca*
Killer whales were recorded by SAST / ESAS surveys on 52 occasions, over both the continental shelf and in deep offshore areas, and in every month of the year except February and September. Throughout May and June, sightings were distributed predominantly along the continental slope north of Shetland; during the rest of the year, sightings were widespread over the region. A similar distribution throughout the Faroe Shetland Channel and on the shelf north of Shetland was recorded by seismic surveys in 1996, 1997 and 1998.

Until recently, killer whales were fairly uncommon in inshore Shetland waters. However, from 1989-1998 there were 288 reported sightings of killer whales inshore around Shetland (Fisher *et al*. 1998), mostly around Sumburgh Head, Yell Sound and Bluemull Sound (probably due to regular ferry services in these areas providing observation platforms). Sightings have occurred in all months with most records in the summer months. The increase in sightings may reflect an expansion in the range of North Atlantic killer whales, relating to changes in prey distribution, climatic changes or behavioural habits. Records suggest that killer whales return to seal haul out sites in Shetland, with both common and grey seals taken in the water, often through co-operative herding behaviour, with none reported taken directly from rocks or beaches. Harbour porpoises are probably also taken on an opportunistic basis. Killer whales also feed on shoals of mackerel, occasionally close to line-fishing boats, and have been studied feeding on discards from Dutch mackerel freezer trawlers working northeast of Shetland (Couperus 1994). Other prey species include fin, minke and pilot whales, white-sided dolphins, eider, kittiwake, guillemot and puffin (Bloch and Lockyer 1988). Further extension of the prey species range within the Atlantic Frontier area is indicated by a report from 1680, when a killer whale overturned a fishing boat off west Lewis and killed three of the four crewmen; the fourth man being saved by another boat's crew who witnessed the attack (Martin 1695 cited in Murray 1973).

The resident killer whale pods off the Norwegian, Icelandic and Faroese coasts have been well documented with established photo-ID catalogues and studies on their movements and diet. A photo-ID programme has now been initiated in Shetland (Fisher and Brown 1998).

Killer whales are relatively easy to see and hear at most times, although acoustic detectability is variable. Detectable acoustic range for this species was about 1500m in preliminary trials during a seismic survey (Chappell 1996).

The killer whale has a worldwide distribution, with numbers in the North Atlantic greatest in subarctic and arctic waters. Population around Iceland and the Faroes is estimated as between 3,500 and 12,500 individuals (Gunnlaugsson and Sigurjónsson 1990). Commercial fisheries for killer whales existed between 1938 and 1981 when a total of 2,455 were taken primarily by Norway in coastal waters and offshore, including seas around northern Britain (Evans 1992). A small catch is also taken intermittently by the Faroese drive fishery, with a total of 65 individuals from 1960-1980 (Bloch 1998).

Long-finned pilot whale *Globicephala melas*
Long-finned pilot whale were the second most abundant cetacean species recorded by SAST / ESAS surveys, with 2,018 animals recorded. Distribution was concentrated along the 1,000m contour, with highest abundance in the Faroe Shetland Channel and Faroe Bank Channel. Within the study area, long-finned pilot whale feed principally on squid (Desportes and Mouritsen 1993) and their occurrence in deep water channels appears to be related to the distribution of squid (Bloch *et al*. 1993). Long-finned pilot whale are a gregarious species, with an average group size of 11.5 animals and a pod of 400 individuals recorded in the Faroe Bank Channel in August 1997. Associations were also recorded with white-sided dolphins, bottlenose dolphins, common dolphins and northern bottlenose whales.

Similar distribution patterns were observed from seismic surveys in 1996, 1997 and 1998, with abundance particularly high in the northern Faroe Shetland Channel and northern Rockall Trough.

Pilot whales are easy to identify visually and highly vocal in medium and possibly high frequency ranges. Chappell (1996) reports difficulty in separating pilot whale vocalisation from associated species, but estimates a detection range of around 1000m.

Long-finned pilot whales are distributed in temperate and subpolar seas in the North Atlantic and southern hemisphere, with a very similar species, short-finned pilot whale (*Globicephala macrorhynchus*) in tropical and subtropical regions. Northeastern and northwestern Atlantic populations have significant morphometric differences (Buckland *et al*. 1993, Borchers *et al*. 1996). Recent sightings surveys estimated the population in Faroese waters at around 7,000, and somewhere between 13,000 and 19,000 in Icelandic waters (Evans 1992). Organised pilot whale drives have taken place for at least eleven centuries in the Faroes, where they continue. Other drive fisheries previously operated in an opportunistic manner in Shetland, Orkney, the Outer Hebrides and Western Ireland (Evans 1992).

An international research programme under the auspices of IWC and UNEP was initiated in 1985 (Donovan *et al*. 1993) and an ICES study group in 1990 (Butterworth 1996). Whaling records indicate that approximately 250,000 long-finned pilot whale were caught in traditional drive fisheries between 1584 and 1998 (Bloch 1998).

Atlantic white-sided dolphin *Lagenorhynchus acutus*
This was the most abundant species observed in the AFEN study area, with a total of 4,925 animals recorded by SAST / ESAS surveys. The distribution was mainly in deep water along the shelf edge and in water deeper than 1000m, and the species was recorded in all months of the year. Atlantic white-sided dolphin were more widespread and abundant between June and November, when animals occurred in high abundance over the Faroe Shetland Channel and Faroe Bank Channel. The average group size of 14.4 indicates that white-sided dolphin was the most gregarious cetacean species recorded. Atlantic white-sided dolphin were regularly recorded in association with long-finned pilot whales and were also observed with fin and humpback whales, and bottlenose, white-beaked and common dolphins.

Similar distribution patterns were observed from seismic surveys in 1996, 1997 and 1998, with white-sided dolphin abundance particularly high in the Faroe Shetland Channel and, to a lesser extent, the northern Rockall Trough. Faroese records include 10,115 Atlantic white-sided dolphins, of which about half (5,579) were "harvested" in the period 1872-1997 and the other half observed (4,356) in the period 1988-1997.

Seventy-nine definite and 23 possible sightings were recorded by Hughes *et al*. (1988), who estimated a population of 27,000 animals within a survey area of 104,087km^2.

Chappell (1996) reports that "delphinids", likely to be predominantly Atlantic white-sided dolphin in view of the location, could be detected acoustically in a high frequency range at a range of 500 – 1000m, although reliable identification of individual species was not possible.

The overall distribution of Atlantic white-sided dolphin, on both sides of the North Atlantic, is reviewed by Northridge *et al*. (1997). As noted above, considerable numbers of white-sided dolphins have been taken by the Faroese drive fishery, although the species has not been targeted by the commercial whaling industry.

White-beaked dolphin *Lagenorhynchus albirostris*
The white-beaked dolphin (or squidhound) was the most commonly recorded species in shelf waters surveyed by SAST / ESAS north and west of Scotland, with distribution almost entirely confined to water depths <200m. The species was recorded in every month of the year, with increased numbers between May and October. In winter (November – April), white-beaked dolphins were distributed at low abundance in the Minch, south of Shetland and along slope waters; with a much more widespread pattern of distribution between May and October and higher concentration of animals in the northern Minch.

There are only a few Faroese records of white-beaked dolphin (Bloch 1998), and the species is reported to be found more commonly south of Iceland. Relatively few sightings, mainly north of Shetland, were made by seismic surveys; and a single sighting in the Faroe Shetland Channel by Hughes *et al*. (1998).

The white-beaked dolphin generally feeds on clupeids and gadids, and it has been suggested that seasonal distribution is related to concentrations of spawning herring. Northridge *et al*. (1997) report that white-sided dolphin are present all year north of Scotland and off the Yorkshire coast, and suggest that this is a local population, isolated to some extent from populations found in Norwegian and Icelandic waters. An apparent spring-time clustering into two groups around Britain is not immediately explainable. Around Iceland, Gunnlaugsson *et al*. (1988) reported that during an aerial survey of cetaceans in coastal waters during June and July of 1996, white-beaked dolphins were much more numerous than white-sided dolphins.

White-sided dolphin are often killed in the Faroese drive fishery when schools mix with pilot whales, and 79 animals were killed in six grinds between 1968 and 1992 (Bloch 1998).

White-sided dolphin have a discontinuous distribution throughout the temperate and subarctic North Atlantic (Northridge *et al*. 1997).

Risso's dolphin *Grampus griseus*
Risso's dolphin is less abundant than either of the two *Lagenorhynchus* spp in the region, but is widely distributed throughout the shelf waters of north Scotland, Orkney, Shetland and particularly the Western Isles (Pollock *et al*. 2000). Elsewhere in its range, this species is generally considered to be a deep water species (Kruse *et al*. 1999), although in Atlantic Frontier waters most sightings occurred in shelf waters shallower than 200m, with records along

the shelf edge between July and December. There is a particular peak in abundance around the Butt of Lewis in August and September. Studies have recognised individual dolphins in waters east of Lewis, with groups showing strong fidelity to particular coastal sites and individuals returning to the same locations over a period of at least twelve years (Evans 1992, Atkinson *et al*. 1997).

Risso's dolphin is not listed by Bloch (1998) as occurring in Faroese waters, although the species is regularly recorded in Shetland coastal waters. In 1997, most sightings were during the latter part of the year in the vicinity of Fetlar and north Yell (Harvey and Osborn 1998).

Risso's dolphin has a worldwide distribution in tropical and temperate seas in both hemispheres.

Bottlenose dolphin *Tursiops truncatus*
Bottlenose dolphins are generally uncommon in the Atlantic Frontier area, with a total of 21 sightings (131 animals) recorded by SAST / ESAS. Between April and August, bottlenose dolphins were recorded in coastal shelf waters in the north Minch and south of Shetland; between September and March, bottlenose dolphins were recorded offshore, with sightings concentrated along the Wyville Thomson and Ymir Ridges.

Although there is little doubt that they occur, bottlenose dolphins have not been positively recorded from Shetland coastal waters (see discussion of unidentified dolphins recorded at Unst; Pennington and Pennington 1999). Bloch (1998) records 2,411 sightings of bottlenose dolphin in Faroese waters, where they are also caught in the pilot whale drive fishery (943 animals).

It is likely, although not proven, that bottlenose dolphin in the Atlantic Frontier area are from an offshore population, in contrast to the resident and semi-resident populations in the Moray Firth and elsewhere around the UK.

Common dolphin *Delphinus delphis*
Common dolphin are at the northern extremity of their distribution in the region. There were only three records north of the Wyville Thomson Ridge in the ESAS database, with most sightings (98) west of the Western Isles, the majority in deep water >1000m.

Occasional strandings and sightings of common dolphin are reported from the Faroes and Shetland, e.g. two or three were present in Sullom Voe through July – September 1998 (Fisher 1999). No common dolphin were reported from the Faroe Shetland Channel by Hughes *et al*. (1998).

Common dolphin are gregarious, and average group size in the SAST / ESAS surveys was 12.0 animals. Associations with long-finned pilot whales and white-sided dolphins were also recorded.

Common dolphin have a worldwide distribution in tropical, subtropical and temperate seas in both hemispheres, although there appear to be many different populations and a high degree of morphological and colour variability (Carwardine 1995).

Harbour porpoise *Phocoena phocoena*
Harbour porpoise is the most abundant cetacean species in British and Irish waters (Evans 1992) and was the most frequently sighted species by SAST / ESAS surveys. Harbour porpoise are widely distributed in shelf waters, shallower than 200m, with smaller numbers in deeper waters, particularly within the Faroe Bank Channel. In winter (November – March), harbour porpoise were recorded in relatively high concentrations in two localised areas, northwest of Orkney and west of South Uist (both offshore but on the shelf). In summer, they were much more widely distributed, with moderate concentrations around Orkney and Shetland, and further south.

Harbour porpoise were recorded in deep water, in the Faroe Shetland Channel and close to the Hebrides seamount, by Hughes *et al*. (1998) in July and August 1998; Bloch (1998) reports 27 observations of harbour porpoise "far away from the coast" in water depths to 500m.

Harbour porpoise are recorded throughout the year in Shetland coastal waters (Evans 1992) except during mid-winter, probably due to survey bias. In 1997 and 1998, the largest aggregations were seen off Sumburgh Head in early May. The occurrence pattern appears to differ in the Faroes, with a less pronounced peak in late summer (Bloch 1998).

Acoustic monitoring has also shown the harbour porpoise to be more frequent in inshore waters (Lewis *et al*. 1998). Harbour porpoise have a distinctive high frequency acoustic signature, and were detected using an automated system in 72 groups during seismic survey operations over two months in the Faroe Shetland Channel (Chappell 1996). No visual sightings of harbour porpoise were made during the latter survey, and finding this species in such deep offshore waters was not expected. In view of the low visual detection efficiency for harbour porpoise, these observations suggest that harbour porpoise may be present in significant numbers in deep water.

The harbour porpoise harvest is relatively new in the Faroes (Bloch 1998), although it seems likely that some by-catch has been taken in drives over the preceding centuries. Recent recorded catches are relatively low, with a total of 44 animals recorded from 1987-1996 (Larsen 1995).

Common seal *Phoca vitulina*
The common seal is the most widespread of the northern pinnipeds, occurring throughout the temperate and subarctic waters of both the North Atlantic and North Pacific (Bigg 1981). The common seal is a resident breeder within the study region, and is distributed around all the coasts of northwest Scotland and the offshore islands. Following heavy hunting pressure, common seals do not breed in the Faroes and the last animal was taken in 1845 (Dánjalsson 1960). The UK population of common seals is estimated to be 28,980, 85% of these in Northern Ireland, the Western Isles, Orkney, Shetland and the northwest Scottish mainland (JNCC Coastal Directory Series 1997). The most recent estimate for the eastern Atlantic population is 72,000.

The SAST / ESAS surveys recorded common seals in inshore waters throughout the survey area, but rarely further offshore and only once in waters deeper than 200m, an animal on the edge of the Faroe Shetland Channel. During 1963-67, four common seals were shot in the Faroes (Bloch 1998), suggesting that occasional immigration takes place.

Grey seal *Halichoerus grypus*
Breeding populations of grey seal in Northern Ireland, the Western Isles, Orkney, Shetland and the northwest Scottish mainland are of international importance, comprising about 40% of the world population (Thompson 1992). The status of the Faroese population is unknown (Mikkelsen and Haug 1999).

Grey seals were recorded by SAST / ESAS during all months, with lowest numbers between October and December when animals are ashore to pup and mate. Grey seals were most frequently recorded in shelf waters, with rare observations in water deeper than 200m. Grey seals make long foraging trips from haul-out sites (Thompson *et al*. 1996), and are known to make trips from the UK to the Faroes (Boyd and Campbell 1971, McConnell *et al*. 1999).

Hooded seal *Crystophora cristata*
The nearest breeding population of hooded seals to the area is around Jan Mayen, 900km north of the Faroe Islands, where there is a population of ca. 250,000 animals (Reeves *et al*. 1992).

Two sightings of individual hooded seals were recorded by SAST / ESAS during May and June 1997 in deep water north of Shetland, followed by further sightings in all seasons. Hooded seals had been observed (and usually shot) previously in Faroese coastal waters and regularly observed in the salmon fishery ca. 300km north of the Faroes (Dánjalsson 1960, Reinart 1982). Satellite tagging in 1992 and 1993 has shown that hooded seals from Jan Mayen often frequent Faroese waters (Folkow *et al*. 1996), spending most of their time along the shelf break where they make repeated dives of greater than 1000m.

The number of hooded seals using the Faroe Shetland Channel is undoubtedly small (Pollock *et al*. 2000), although it seems probably that the area is used regularly by a small proportion of the hooded seal population, rather than by lost or vagrant individuals.

3.5.3 Discussion

Marine mammal distribution, and the importance of Atlantic Frontier deep water and shelf water north and west of Scotland for marine mammals, are discussed by Pollock e*t al*. (2000).

In general, observed cetacean distributions are thought to be related to prey distribution and abundance, rather than to a direct relationship between cetaceans and environmental characteristics (e.g. temperature, topography). Various mechanisms of habitat segregation, prey selection or foraging behaviour may allow different cetacean species to avoid direct competition for food.

In terms of distribution and feeding, marine mammals in the region can be broadly distinguished into nine groups:

Deep water baleen whales (blue, fin, sei and humpback) – recorded in deep water (>1000m), north and south of the Wyville Thomson Ridge. Not associated with the shelf edge. Pelagic feeders, with considerable specialisation in terms of prey selection and feeding method. Extensive migrations, although some individuals may utilise the region throughout the year.

Shelf baleen whales (minke) – summer visitor to shelf areas. Winter distribution unknown.

Deep water, squid-eating whales (sperm, beaked and pilot) – along the 1000m contour. Sperm and beaked whales concentrated on eastern flank of Rockall Trough, southern flank of Wyville Thomson Ridge and along eastern side of Faroe Shetland Channel. Northern bottlenose whale possibly more westerly distribution.

Deep water dolphins (Atlantic white-sided, common) – widely distributed in deep water, not associated with shelf break. Pelagic feeders, with differing species-specific geographical distributions (not directly related to water temperature).

Shelf dolphins (white-beaked, Risso's) – concentrated in shelf waters, with occasional records at shelf edge. White-beaked predominantly piscivorous, Risso's may also feed on cephalopods. Both species show localised distribution centres.

"**Generalist cetaceans**" (killer whale, bottlenose dolphin, harbour porpoise) – widely distributed over deep and shelf waters. Killer whales have a broad diet, probably mainly piscivorous offshore, with seals, small cetaceans and birds nearshore. Harbour porpoise probably present in higher densities in deep water, than visual sightings suggest.

Breeding seals – common and grey seals associated with defined haul-out and breeding locations, predominantly coastal foraging. Grey seals forage over considerable distances, although deep water sightings are rare.

Deep water seals – hooded seals utilise deep water in the Faroe Shetland Channel and north of the Faroes, throughout the year. Deep diving (1000m).

Vagrants - striped dolphin, beluga, narwhal, false killer whale, bearded seal, harp seal, ringed seal and Atlantic walrus are probably vagrants.

In terms of utilisation by marine mammals, four areas within and adjacent to the former White Zone can be distinguished:

Deep water channels (Faroe Bank and Faroe Shetland Channels, Rockall Trough) – used by deep water, pelagic baleen whales and dolphins (principally Atlantic white-sided, common dolphin more prevalent in Rockall Trough). Flanks used by sperm, beaked and pilot whales. Also used (pelagically) by killer whale and harbour porpoise.

North Sea Fan – as above, with hooded seals also present. Arctic vagrants (beluga, narwhal, bearded seal, harp seal, ringed seal) may be present.

Shelf break, Wyville Thomson and Ymir Ridge flanks – Main centre of distribution of sperm, beaked and pilot whales. Also used by pelagic baleen whales and dolphins and by killer whale (spring) and bottlenose dolphins (winter), and occasionally by grey seals.

Shelf areas – main centre of distribution for minke whale (summer), white-beaked and Risso's dolphin, harbour porpoise, common and grey seals. Other species as vagrants (blue, fin, sei, humpback, sperm and beaked whales) or regular visitors (killer and pilot whales, Atlantic white-sided, common and bottlenose dolphin).

Seasonal distribution patterns of individual species are shown in matrix form, below.

From 1979 to 1999, SAST / ESAS survey effort in the "Atlantic Frontier" study area has been considerable, with coverage of the deep water areas extended significantly from 1994. This study area extends to (approximately) the 1000m contour on the west side of the Faroe Shetland Channel and north side of the Faroe Bank Channel. Within this area, significant coverage gaps remain in autumn, winter and early spring (September – April), particularly in the Faroe Bank Channel, and the Faroese slope and northern Faroe Bank Channel.

Complementary survey work carried out on behalf of GEM and previous work reported by Danielsen *et al.* (1990) provides additional data for the Faroese Shelf and Faroes Bank, particularly in summer, although winter coverage of the former White Zone remains incomplete. Faroese sightings records, reviewed by Bloch (1988) provide an extensive dataset, although it is unclear how systematic the distribution of effort was. Variation within, and limitations of sightings survey data are discussed by Pollock *et al*. (2000), who note especially the observational difficulties presented by winter weather and short day length.

Blue, fin and humpback whales all typically produce long sequences of low frequency (ca. 20Hz) vocalisations that can be identified on SOSUS spectrograms by their distinctive signatures (Clark and Charif 1998). Other cetacean species in the north-east Atlantic vocalise in a "medium" frequency range (sperm, killer and pilot whales) and/or "high" frequency range (dolphins and porpoise) that can be detected over limited ranges, (Chappell 1996). Preliminary studies from a seismic support vessel, comparing acoustic detection and visual sightings, suggest that harbour porpoise can be detected acoustically (with no sightings to calibrate range), sperm whale to over 2 miles, killer whales to about 1500m, pilot whales to about 1000m and other delphinids to between 500 and 1000m.

Acoustic monitoring of cetaceans remains at a relatively early stage of development, with significant limitations imposed by species-specific vocalisation behaviour (or lack of – see Clark and Charif 1998), security restrictions (for SOSUS), range (particularly for medium and high frequency ranges) and various technical issues. Nevertheless, SOSUS and hydrophone monitoring during seismic surveys have dramatically increased knowledge of baleen whales and harbour porpoise distributions respectively, and have highlighted some inconsistencies with the interpretation of seasonal distribution from visual sightings data. Further work on automated detection systems, and on species which have received little attention in the study area (especially sperm and beaked whales), would seem to be particularly valuable.

Table 3.4 – Seasonal Occurrence of Cetaceans

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fin whale	*	*	*	*	D*	D*	D*	D*	D*	D*	*	*
Blue Whale	*	*	*	*				*	*	*	*	*
Sei whale							D	D	D			
Minke whale					S	S	S	S	S	S		
Humpback whale	*	*	*		D	D	D	D	D		*	*
Sperm whale	SB			SB	SB	SB	SB	SB	SB	SB	SB	SB
Northern bottlenose whale				SB	SB	SB	SB	SB	SB			
Beaked whales	SB				SB	SB	SB	SB	SB	SB	SB	SB
Killer whale	SB, S	S	SB,S	SB,S	SB(N),S	SB(N),S	SB,S	SB,S	S	SB,S	SB,S	SB,S
Long-finned pilot whale	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB
Atlantic white-sided dolphin	D, SB	D, SB	D, SB	D, SB	D, SB	D, SB	D, SB	D, SB	D, SB	D, SB	D, SB	D, SB
White-beaked dolphin	S	S	S	S	S	S	S	S	S	S	S	S
Risso's dolphin	S	S	S	S	S	S	S,SB	S,SB	S,SB	S,SB	S,SB	S,SB
Bottlenose dolphin	SB	SB	SB	S	S	S	S	S	SB	SB	SB	SB
Common dolphin	D	D	D	D	D	D	D	D	D	D	D	D
Harbour porpoise	S(O, SU)	S(O, SU)	S(O, SU)	S	S	S	S, D*	S, D*	S	S	S(O, SU)	S(O, SU)
Common seal	IS	IS	IS	IS	IS(B)	IS(B)	IS(B)	IS	IS	IS	IS	IS
Grey seal	IS,S	IS,S	IS,S	IS,S	IS,S	IS,S	IS,S	IS,S	IS,S(B)	IS,S(B)	IS,S(B)	IS,S
Hooded seal	D	D	D	D	D	D	D	D	D	D	D	D

* acoustic detection
D deep water (>1000m)
SB shelf break (1000m)
SB(N) shelf break north of Shetland
S (O, SU) shelf break, off Orkney and South Uist

S shelf waters
IS inshore waters
(B) breeding
■ Months with peak abundance

4 EXISTING ACTIVITIES

4.1 Fishing

The White Zone area lies across ICES Rectangles 48E2-E4, 49E2-E5, 50E5, 51E6, 52E6-E9, 53E7-E9, 54E8-E9, 55E8-E9 and 56E9 see Figure 14. Data on fishing effort and landings are available from a number of sources, in particular logbook returns made by fishermen to the relevant national authorities. These logbook data have not been sourced for this study. Other data are also available from fishery surveillance by the Scottish Fishery Protection Agency. However, the coverage of surveillance is limited north of 62°N and across the Faroe Shetland Channel (SFPA 1999). Another important source of information for fishing effort in the surrounding area is a report published by Coull *et al.* 1998. However the compiled data currently only extends to 62°N these data also do not consider deep-water species which are now being exploited (Coull, pers comm.)

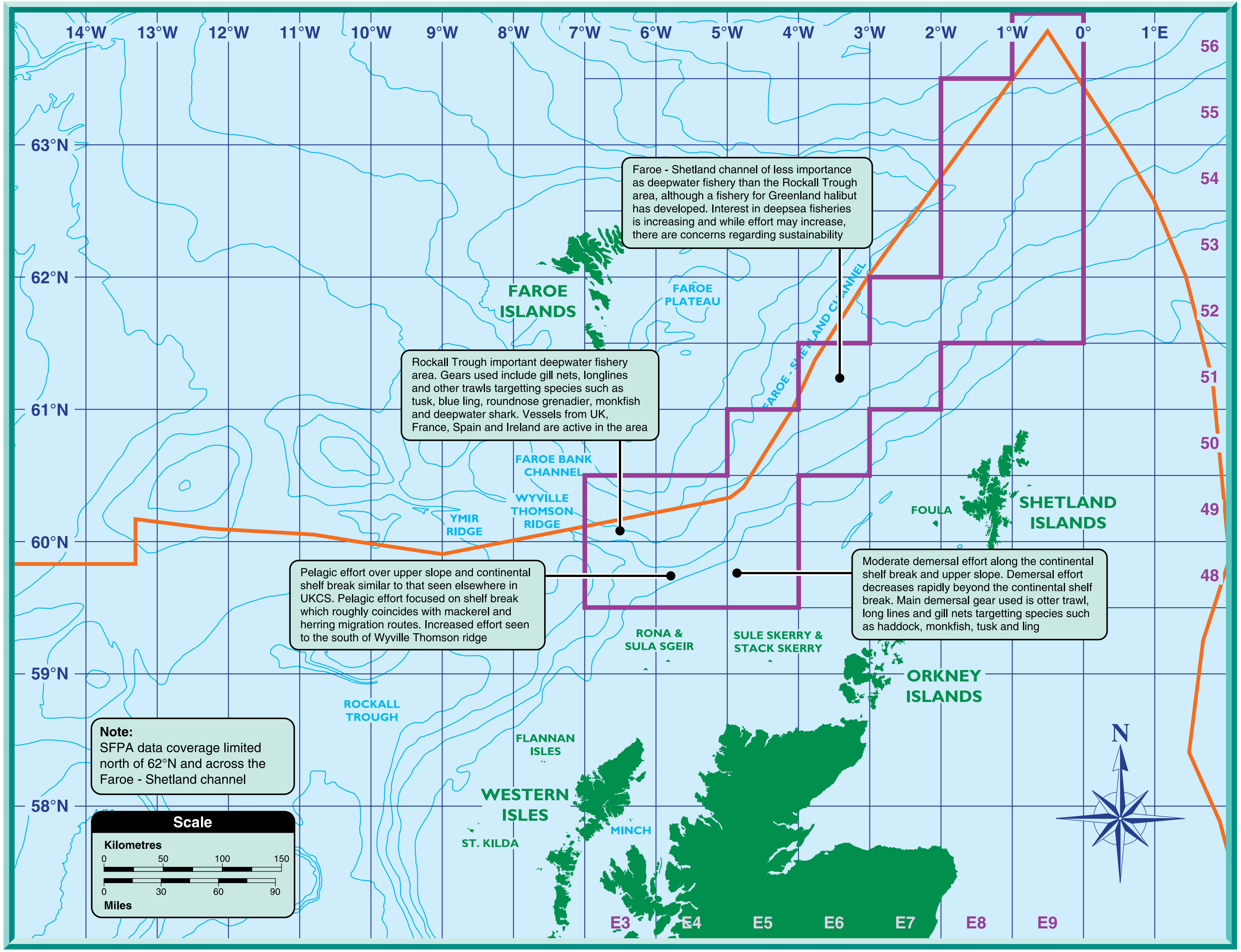
Deep-water vessels from Scotland, France, Spain and Norway dominate fishing in the area. Vessels from England, Faroe, Germany, Netherlands, Denmark, and Eire are also present in the area (SFPA 2000). The main demersal gears employed are otter trawls and long-lines, with some gill netting also being seen. Deep-water demersal trawlers are generally larger and more powerful than trawlers employed in shallower sea areas. Examples of Scandinavian vessels are described by Hareide (1995) and Gunnarsson (1995) (as cited in Merrett and Haedrich 1997) and Jákupsstovu (1999). These vessels are typically around 70m in length with a main engine of >1,000 HP. These vessels are capable of fishing in depths up to and greater than 1000m with two trawl winches of a capacity of 40 tonnes pull each. Long-lines and gill nets are generally deployed by smaller vessels because these gears are lighter and easier to deploy. Gill-netters in the Faroe Shetland Channel generally target species such as Greenland halibut and monkfish with longliners targeting ling and tusk (Jákupsstovu 1999).

Demersal fishing effort in the area is relatively low compared to other areas of the UKCS (Coull *et al.* 1998 and SFPA 2000) with greatest effort being seen over the area of the Wyville Thomson Ridge. Demersal effort along the continental shelf break and upper slope is classed as moderate by Coull *et al.* (1998) and effort decreases rapidly beyond the continental shelf break and upper slope (Coull *et al.* 1998 and SFPA 2000).

Demersal species being targeted in the Rockall Trough and Wyville Thomson Ridge area comprise commercial deep-water species such as tusk, blue ling, roundnose grenadier and monkfish. Deep-water sharks such as the Portuguese dogfish are also targeted. In the colder waters of the Faroe Shetland Channel, species such as the Arctic skate, Greenland halibut, roughhead grenadier, black scabbard fish and redfish will also be targeted. The Faroe Shetland Channel is however considered to be a less important deep-water fishery area than the Rockall Trough (Gordon *et al.*, undated), although a fishery for Greenland Halibut has recently been developed in the area (Gordon 1998).

Interest in deep-sea fisheries is increasing and effort in the area may increase. However, concerns remain over the sustainability of many of these deep-sea species (Gordon *et al.* 1995, Merrett and Haedrich 1997, Gordon 1998, Anon 1996, Greenpeace 1997, Haedrich *et al.* 1998). Indeed, the UK House of Lords stated that "ideally

Figure 14 – Fisheries distribution



mx0014545_3

we would recommend an interim suspension of all deep-sea fishing, but we recognise that it could not be enforced at present" (Anon 1996 and Gordon 1998). At the present time the management of deep-water species in the EU Atlantic sector is restricted to limit of effort rather than by landings. Enforcement is difficult (Gordon 1998).

Concerns on the sustainability of deep-water fish led to research on deep-water fish and fisheries being developed and funded by the EC FAIR Programme and this work is currently ongoing (Gordon 1998). In addition the International Council for the Exploration of the Seas (ICES) established a study group in 1993 to investigate and monitor deep-sea fisheries (ICES 1995).

Pelagic effort over the upper slope is at similar levels to that seen in other areas of the UKCS (Coull *et al.* 1998). An area of increased effort is seen in ICES Rectangles 48E5 and 49E5 to the south of the White Zone area. This is likely to coincide with mackerel migration routes through the area. Pelagic effort will be targeted at species such as mackerel, herring, blue whiting and greater silver smelt (argentines) which occur in greatest densities along the shelf break coinciding with an area of increased primary production. However, recent work has also suggested that the distribution and migration of fish species (in particular herring and mackerel) may also be controlled by water temperature (e.g. Reid *et al.* 1997 and Nøttestad *et al.* 1999)

4.2 Shipping

The waters of the former White Zone area are crossed by two comparatively minor shipping routes (although with no defined lanes or separation zones) with traffic primarily consisting of cargo vessels, tankers and fishing vessels. A limited number of seasonal ferries and cruise liners transit between Scotland, Norway, the Faroes and Iceland during in the summer months. Vessels associated with hydrocarbon exploration and production activities UK, Faroes or Norwegian waters may cross the area but at present the numbers are low and future trends will be dependant activity levels.

A review of shipwrecks was conducted as part of AFEN studies and indicated that there were few wrecks known in the former White Zone area. Of the wrecks greater than 60m in length and 1,000 gross tons, two were located on the Wyville Thomson Ridge and four around the 1000m bathymetric contour in the Faroe Shetland Channel. The majority of wrecks were first or Second World War casualties.

4.3 Oil and Gas

Areas to the west of Shetland were first offered for oil and gas exploration in the second UKCS offshore licensing round of 1965 (see DTI, 1999 for details of UKCS oil and gas activity). The first well was drilled in the area during 1972 and the first potentially commercial discovery in the area came with the Clair field in July 1977. A limited number of wells were drilled in the area in most years until there was a surge of interest and activity in the area following announcement of the discovery of the Foinaven field in October 1992 and the Schiehallion field in October 1993. Both the Foinaven and Schiehallion fields were developed using anchored Floating Production, Storage and Offloading vessels and started producing hydrocarbons in 1997 and 1998 respectively. Shuttle tankers are use to export produced oil and in the absence of an export route, natural gas surplus to requirements is disposed of by injection into rock strata. There have been a number of small discoveries in the vicinity of Foinaven and Schiehallion, of which the Loyal field is in production as a sub-sea tie-back to Schiehallion and a similar development has recently been proposed for the East Foinaven field (tied-back to Foinaven). No other oil or gas fields in the area are currently under development although the future development of the Clair field in possible.

Following agreement of the UK-Faroe boundary the Faroese Ministry of Petroleum announced a first Faroese licensing round in February 2000. The area offered is to the south and east of Faroe between 60° 17' and 62° 00'N and extending from the Faroe Shetland Channel onto the Faroe Plateau. The area offered covers some 14,000km^2 and applications had to be submitted by 17th May 2000 with block awards anticipated in September 2000. The nature and scale of any hydrocarbon accumulations and their exploitation in the Faroese area cannot be gauged until exploration wells have been drilled.

4.4 Telecomms

The former White Zone is crossed by two telecommunications cables one Torshavn to Shetland and one from Streymoy to Norderney (Germany). Both of these cables are disused.

4.5 Military

The former White Zone area does not contain any designated military exercise or training areas, although military use of the area does occasionally occur during NATO and other training exercises. Such exercises can involve aircraft and surface or submarine craft. Seabed mounted hydrophones (the SOSUS array operated by the US Navy) used for tracking submarines are present in the region although the precise location of the hydrophones and cables is confidential.

5 THE COASTAL ENVIRONMENT

5.1 Coastal Conservation Overview

5.1.1 Shetland

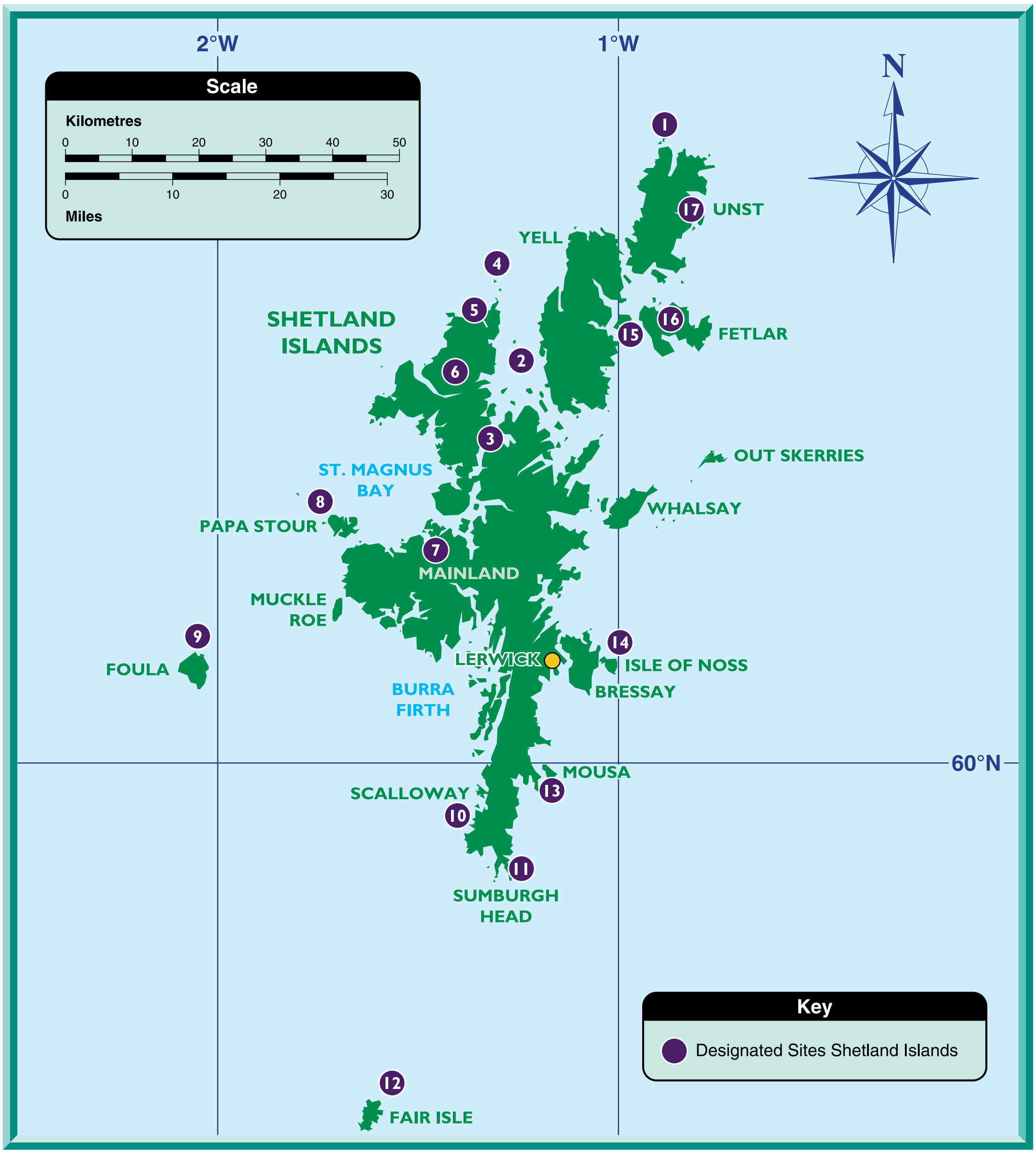
Shetland is the most northerly island group in the UK and is comprised of over 100 islands, including Foula and Fair Isle, of which only sixteen are inhabited. The coastline is highly indented and is 1,400km long representing 7.4% of the UK coastline. Shetland is very exposed and most of the land lies within 3km of the coast so the influence of the sea is important. The coastline is among the most wave-exposed in Britain, and these conditions have created a dramatic coastline ranging from high west-facing vertical cliffs to sheltered bays at heads of narrow inlets known as voes. Numerous rock stacks and islands lie offshore.

Much of the island group has been designated for the protection of its coastal habitats, indicating its importance on an international, European and national scale (see below). All of Shetland is designated an Environmentally Sensitive Area and approximately 10% of its coastline falls within nationally important Sites of Special Scientific Interest (SSSIs). Shetland is one of the few regions in Britain that currently lack Ramsar sites. Individual designated sites and their specific nature conservation importance are listed in Table 5.1 and shown in Figure 15.

Table 5.1 – Summary of International Sites

No	Site	Designation	Conservation interest
1	Herma Ness and Saxa Vord	SPA	Breeding seabirds
2	Yell Sound Coast	cSAC	Otters, common seals
3	Sullom Voe	cSAC	Marine habitats
4	Ramna Stacks and Gruney	SPA	Breeding seabirds, Leach's petrel
5	Tingon	SPA	Breeding moorland birds, blanket bog
6	Ronas Hill	SPA	Breeding moorland birds, flora, invertebrates
7	The Vadills	cSAC	Marine habitats, *Ascophyllum nodosum mackaii*
8	Papa Stour	cSAC	Breeding moorland birds and seabirds, flora, marine habitats
9	Foula	SPA	Breeding seabirds
10	Lochs of Spiggie and Brow	SPA	Wintering whooper swans, eutrophic loch
11	Sumburgh Head	SPA	Breeding seabirds
12	Fair Isle	SPA	Breeding seabirds, Fair Isle wren and field mouse
13	Mousa	SPA and cSAC	Breeding seabirds and seals
14	Noss	SPA	Breeding seabirds
15	Hascosay	cSAC	Blanket bog
16	Fetlar	SPA	Breeding seabirds and red-necked phalarope
17	Keen of Hamar	cSAC	Flora

Figure 15 – Internationally important designated coastal sites on Shetland



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The islands have a total cliff length of 483km, representing 12% of the UK cliffs. Tall vertical cliffs (reaching 370m at the Kame on Foula), steep non-vertical cliffs, headlands, caves, geos, blowholes, arches and stacks are all common and the scenic contribution is outstanding. In all but a few places, cliffs are exposed to Atlantic gales and storms which throw salt spray a considerable distance inland. As a consequence, Shetland has one of the largest maritime heath areas in Britain (Barne *et al.* 1997a).

Cliffs in the region are important for nesting seabirds and seven of the eleven SPAs in the area are designated for their internationally important seabird populations: Herma Ness and Saxa Vord, Ramna Stacks and Gruney, Foula, Fair Isle, Sumburgh Head, Mousa, Noss and Fetlar. Away from the cliffs, Shetland also has many boggy moorland areas, which support about half the British breeding population of red-throated diver and other moorland breeding bird species. There is some association between red-throated diver and coastal areas, as they feed in nearby coastal waters. Two areas have been designated as SPAs due to their importance for breeding moorland birds.

Shetland is nationally and internationally important for otters supporting approximately 700-900 animals which is a substantial proportion of the British population. The otters use shallow marine areas for foraging and are found in greatest numbers away from agricultural land and high cliff areas (Barne *et al.* 1997a). The Yell Sound Coast is identified as a candidate SAC for its otter population.

There is only limited development of sand dunes in Shetland, with most sites being small and located in sheltered bays. The dunes are predominantly bay dunes, although machair and climbing dunes are also present (Barne *et al.* 1997a).

Shetland has considerable lengths of shingle shoreline. Many of the shingle beaches in the region are exposed, high-energy environment and vegetation is sparse except where there is some shelter. The nationally scarce oysterplant (*Mertensia maritima*) grows on damp wrack-rich shingle shores and on sand dunes in Shetland. Scots lovage, *Ligusticum scoticum,* restricted in the UK to Scottish and Northern Irish cliffs and shingles, also occurs (Barne *et al.* 1997a).

The larger boulder/shingle beaches in Shetland are important breeding sites for arctic tern and ringed plover. On some of the smaller islands, e.g. Mousa, black guillemots and storm petrel often nest in crevices on boulder beaches.

Other coastline features include silled inlets and small saline pools at the heads of voes. These features are known as houbs (pools with a shingle ledge across the mouth) and vadills (bays with narrow rocky entrances) and many of these support “lagoonal” type flora and fauna and are classified as coastal lagoons (Barne *et al.* 1997a). Lagoons are a nationally rare habitat and a priority habitat type under Annex I of the EU Habitats Directive and one “lagoon” area in Shetland, the Vadills, is a candidate SAC.

Approximately 22% of the UK's common seal population occurs in Shetland making the area the second after Orkney in terms of UK importance for common seals. Common seals occur throughout the islands but their main haul out areas in August are Mousa and the southeast Mainland, Yell Sound, northwest Fetlar and Hascosay and the Ve Skerries in St Magnus Bay (Barne *et al.* 1997a). Grey seals are less abundant but may also be seen throughout the area. Both Mousa and Yell Sound are candidate SACs due to their common seal populations.

5.1.2 Orkney

The Orkney Islands comprise a large number of islands and skerries and consequently has a relatively long coastline, 881km, representing 7.5% of the Scottish and 4.7% of the UK coastline. The west coast of the island archipelago is characterised by dramatic cliff landscape compared to the more subdued, low lying Scapa Flow and east coast areas. Shores are predominately composed of bedrock or boulders, with sand in the bays. There are extensive shallow sublittoral areas and varied degrees of wave exposure around the islands.

Much of the island group has been designated for the protection of its coastal habitats, reflecting its importance on an international, European and national scale. Individual designated sites and their specific nature conservation importance are listed in Table 5.2 and shown in Figure 16.

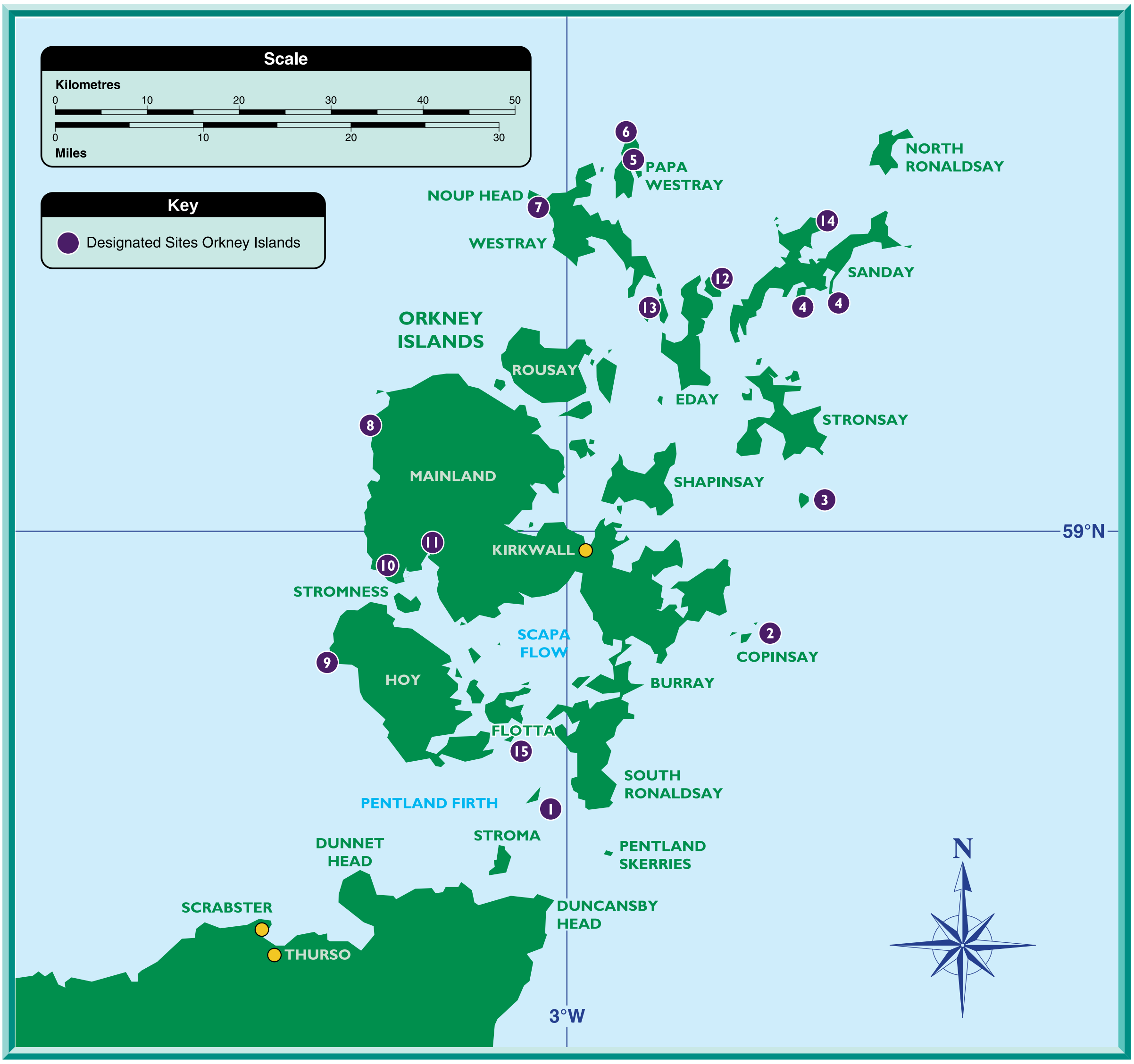
Table 5.2 – Summary of International Sites

No	Site	Designation	Conservation interest
1	Pentland Firth Islands	SPA	Arctic terns
2	Copinsay	SPA	Seabirds - kittiwake guillemot, great black backed gull
3	Auskerry	SPA	Seabirds – Arctic tern, storm petrel
4	East Sanday coast	SPA and RAMSAR	Wintering waders – purple sandpiper, turnstone, common seal
5	Holm of Papa Westray	SPA	Seabirds – black guillemot, Arctic tern
6	North Hill	SPA	Coastal heath, seabirds – Arctic tern, skua
7	West Westray	SPA	Breeding seabirds, flora
8	Marwick Head	SPA	Seabirds - kittiwake guillemot
9	Hoy	cSAC and pSPA	Geology, geomorphology, >20,000 seabirds, wet and montane heath, petrifying tufa springs, woodland, moorland birds, upland heath
10	Stromness Heaths and Coast	cSAC	Coastal heath, geology, geomorphology
11	Stenness Loch	cSAC and cRAMSAR	Freshwater plants, saline lagoon, wintering wildfowl
12	Calf of Eday	SPA	>20,000 breeding seabirds, cormorant
13	Faray and Holm of Faray	cSAC	Grey seal
14	Sanday	cSAC	Common seal
15	Switha	SPA	Roosting Barnacle geese

Cliffs dominate the west coasts of the island archipelago and the highest vertical cliffs reach over 330m on the island of Hoy. Orkney has many internationally important sites for breeding seabirds and over 20 colonies hold more than 1% of a species total in the European Union (EU). Seven sites in the region have been designated as SPAs for important seabird colonies namely: Copinsay, Auskerry, West Westray, Holm of Papa Westray, Sule Skerry, Sule Stack, Marwick Head and Calf of Eday.

The scenic contribution of the cliffs to the Orkney landscape is outstanding and tall vertical cliffs, steep non-vertical cliffs, headlands, caves, geos, blow holes, arches and stacks are all

Figure 16 – Internationally important designated coastal sites on Orkney



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common coastal features. The Hoy and West Mainland National Scenic Area (a national conservation designation), includes the most spectacular examples of cliffed coastline, including the Old Man of Hoy, one of the most famous sea stacks in Britain (Barne *et al.* 1997b). The northern area of Hoy is also a candidate SAC.

Coastal maritime heath supporting the nationally rare endemic Scottish primrose *Primula scotica* is associated with much of the cliffed coastline. One area of particular importance in this respect is Stromness Heaths and Coast which has been identified as a candidate SAC for its cliff vegetation (Barne *et al.* 1997b).

Shingle beaches are often bay head features and may be associated with stream outlets or be barriers to lochans. Shingle beaches are important for migrant and wintering waders, especially turnstone (Barne *et al.* 1997b). The shingle beach at Corn Holm on Copinsay forms part of a designated SPA. However, most of the shingle beaches in the islands do not have any conservation status.

The estuarine shores of Orkney add greatly to the coastal diversity of the islands, through the presence of sand and mud flats, and saltmarsh. Four areas within Orkney can be described as estuarine habitat, 3 on the shores of the Island of Sanday (a proposed SAC) and Deer Sound on the east coast of Mainland. These areas have a strong marine influence with freshwater input limited to small streams and ground water seepages. The inner tidal flats revealed at low tide are generally sand and shingle. Areas of mud are very small and restricted to the most sheltered parts of the shore, where there are small areas of fringing saltmarsh. Small areas of saltmarsh are also present at the heads of sheltered bays around the south west of Scapa Flow. Estuarine and sheltered shores support breeding and wintering wader and wildfowl populations, and small gull and tern breeding colonies (Barne *et al.* 1997b).

There are a number of coastal lagoons around the Orkney coastline, either wholly or partially separated from the sea, but with some influx of sea water. Lagoons in Orkney represent 24% of the UK total 'lagoonal' area. This type of shore is found along the north coast of Scapa Flow, north-east Mainland and around some of the north Isles. The area of most notable significance is the Loch of Stenness in the west Mainland, which is the largest area of lagoon habitat in Scotland (562ha), and has been proposed as a SAC (Barne *et al.* 1997b).

Most areas of Orkney sand dune are small and associated with open shores and bays, and as in other areas of northern and western Scotland are notable for the large extent of species rich grazed dune grassland. Some dune areas also include examples of distinctive wet dune vegetation and beaches, machair and sand hills in Orkney support a number of scarce terrestrial invertebrates. Orkney's sandy beaches are important for migrant and wintering wildfowl, particularly purple sandpiper, curlew and redshank. However, some sites have been damaged by beach sand and shingle extraction (Barne *et al.* 1997b).

Common seals are abundant along the coastline of Orkney, with the islands supporting up to 8,500 individuals, over 27% of the British population. They can be observed at all times of the year distributed throughout the islands, except on steep exposed shores. The island of Sanday and its surrounding waters has been identified as a candidate Marine SAC for its common seal population. Grey seals are also regularly observed throughout the islands. There are a number of colonies, some large, which together produce over 32% of the UK grey seal pups (second only to the western Isles) (Barne *et al.* 1997b). The islands of Faray and Faray Holm have been identified as a candidate Marine SAC for their grey seal populations.

In addition, parts of Orkney have been designated a World Heritage Site for archaeological reasons.

5.1.3 Western Isles

The total coastline of the Western Isles is 2,103km and comprises five main islands (Lewis/Harris, North Uist, Benbecula, South Uist and Barra) and a number of outlying islands including St Kilda. Steep rocky shores and sea cliffs characterise most of Harris, Lewis and the eastern coasts of the Uists. Sand dune systems and machair are also typical of western coasts in the area. Saltmarsh is also present in the region, but tends to be in small and isolated areas along the margins and at the heads of sea lochs.

The Western Isles has a large number of designated sites with coastal aspects, reflecting the varied nature of its coastline. In addition to sites designated under national statute, there are a large number of internationally designated areas and these are listed below. Some sites have a number of different international and national designations. St Kilda is the only World Heritage Site designated for nature conservation reasons in the United Kingdom. Individual designated sites and their specific nature conservation importance are listed in Table 5.3 and shown in Figure 17.

Table 5.3 – Summary of International Sites

No	Site	Designation	Conservation interest
1	Ness and Barvas	SPA	Corncrake
2	Lewis Peatlands	Potential SPA, proposed RAMSAR and cSAC	Red throated diver, black throated diver, golden eagle, merlin, dunlin, greenshank, blanket bog
	Loch Roag lagoons	cSAC	Lagoon
3	North Harris Mountains	SPA and cSAC	Golden eagle, heath
4	Shiant Islands	SPA	Seabirds – fulmar, shag, guillemot, razorbill, puffin, wintering barnacle geese
5	Loch an Duin	RAMSAR	Representative wetlands and waterfowl.
6	North Uist Machair and Islands	See below	Corncrake, wintering barnacle geese, ringed plover and turnstone, breeding ringed plover, dunlin, machair and diverse assemblage of breeding and over-wintering waterfowl.
	Phase I: Balranald Bog, Loch nam Feithean, Machairs Robach and Newton and Tigharry	SPA, RAMSAR and cSAC	See above
	Phase II: Baleshare, Kirkibost, Vallay, Pabbay, Berneray and Boreray	pSPA, proposed RAMSAR and cSAC	See above
7	Loch nam Madadh	cSAC	Shallow bays and inlets
8	Mointeach Scadabhaigh	SPA and cSAC	Red throated diver, black throated diver, blanket bog
9	Monach Islands	SPA and cSAC	Common tern, little tern, black guillemot, wintering barnacle geese, grey seal, machair, dunes
10	Obain Loch Euphoirt	cSAC	Lagoon
11	Aird and Borve	SPA and RAMSAR	Corncrake
12	South Uist Machair and Lochs	SPA, RAMSAR,	Breeding corncrake, little tern,

No	Site	Designation	Conservation interest
		Biosphere Reserve and cSAC	greylag geese, ringed plover, dunlin, wintering ringed plover, machair, shallow waters, lochs,
13	Kilpheder and Smerclate	SPA	Corncrake
14	Eoligarry	SPA	Corncrake
15	Mingulay and Berneray	SPA	Seabirds – fulmar, shag, kittiwake, guillemot, razorbill
16	St Kilda	SPA, cSAC, Biosphere Reserve and World Heritage Site	> 50,000 seabirds – fulmar, Manx shearwater, gannet, kittiwake, guillemot, razorbill, puffin, vegetated sea cliffs, reefs, sea caves
17	Flannan Islands	SPA	>20,000 seabirds – guillemot, razorbill, puffin, fulmar, gannet, shag, kittiwake
18	North Rona	cSAC	Grey seal, reefs, submerged sea caves, vegetated sea cliffs
19	Sule Skerry	SPA	Breeding seabirds - puffin, shag, storm petrel, Leach's petrel
20	Sule Stack	SPA	Breeding seabirds - gannet

Over 65% of the Western Isles coastline is comprised of cliffs and cliff-top habitats and these dominate the northwest and eastern coasts of the islands. St Kilda has the highest sea cliffs in Britain reaching over 420m (Barne *et al.* 1997c). The Western Isles sea cliffs support nationally and internationally important seabird populations and five cliff sites have been designated SPAs; St Kilda, Flannan Islands, Mingulay and Berneray, Monach Islands and Shiant Islands. Breeding seabirds are also found in large numbers in other cliff areas including North Rona, Sula Sgeir and Tolsta Head.

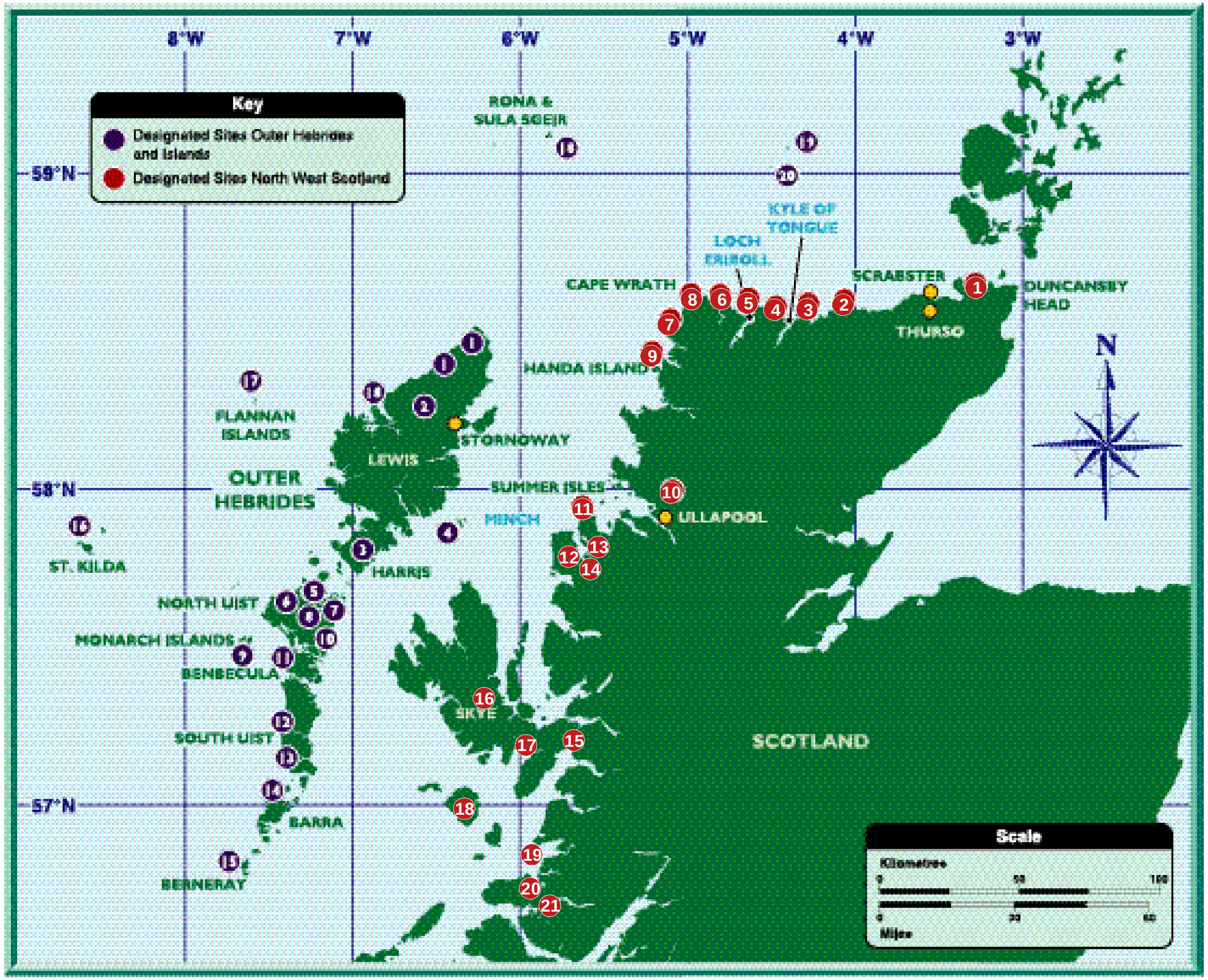
As well as cliffs, notable caves and sea stacks are present, including Stac an Armin on St Kilda, which rises to 191m, the highest rock stack in Britain. The scenic value of these remote cliff areas and offshore islands is high and they form an important element of the tourist industry in the area.

The open coast of the Western Isles is also characterised by the presence of large areas of sand dunes and machair. The Western Isles has 15% of the British sand dune resource (some 7,964 hectares). There are a number of very long stretches of which span some of the larger bay dune systems. The second longest sandy beach in the UK, occupies all of the western side of south Uist (Barne *et al.* 1997c).

Most of the sand dune systems in the area are hindshore types which develop above beaches with a good sand supply. The Western Isles is particularly known for its machair plains which are a hindshore variant with extensive inland dune plains and extend up to 2km inland. Machair is restricted worldwide to Scotland and western Ireland. Some of the best UK examples of machair are found in the Western Isles in particular around South Uist and North Uist.

Twenty-five of these sand dune/machair sites are Sites of Special Scientific Interest (SSSI), and three sites have international Conservation designations: the Monach Islands (SPA and cSAC), North Uist Machair and Islands (SPA and cSAC) and South Uist Machair and Lochs (SPA, Biosphere Reserve and cSAC). In addition the machair of the Uists, Benbecula,

Figure 17 – Internationally important designated coastal sites on the Western Isles and North Highland



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Barra and Vatersay have been designated an Environmentally Sensitive Area, to encourage environmentally sensitive farming practices.

The machair habitats of the Western Isles are considered internationally important breeding grounds for waders (in particular corncrakes (*Crex crex*)) and wildfowl. A number of nationally rare or scarce plants are found associated with machair including holygrass (*Hierochloë odorata*), oysterplant (*Mertensia maritima*), variegated horsetail (*Equisetum variegatum*) and Baltic rush (*Juncus balticus*).

Two coastal lagoons in the Western Isles are candidate SACs; Loch Roag and Loch Eport. Most lagoons in the area are species poor and support no notable species, although of interest for their physiography and low salinity. However, coastal lagoons in North Uist support dense beds of the rare foxtail stonewort *Lamphrothamnium papulosum* which is protected under the Wildlife and Countryside Act 1981. Most saltmarshes in the area are small (< 10ha) and are scattered throughout the larger islands with most on North Uist and Lewis.

Common seals are found in the sheltered eastern waters of the Western Isles and approximately 8% of the UK population present. Grey seals are common and widespread, particularly along the more exposed western coasts and the area supports a number of internationally important breeding sites which collectively produce nearly 40% of the grey seal pups born in the UK and 15% of pups born in the world (Barne *et al.* 1997c). Two sites have international conservation designations for their grey seal populations: North Rona (cSAC) and the Monach Islands (SPA and cSAC).

5.1.4 North Highland Coast

The coast of north and west Highland is some of the most rugged and exposed in Britain. Cliffs and steep rocky shores predominate along much of the coastline, and areas of intertidal sediment are limited to the upper reaches of sea lochs and isolated pocket beaches.

The western part of the coast is cut by three large inlets, Kyle of Durness, Kyle of Tongue and Loch Eriboll, which display contrasting features (Barne *et al.* 1997c). There is also a large break in cliffed coast at Dunnet Bay in the east. The west Highland sea cliffs, are more diverse in nature and more indented than the north Highland coast (Barne *et al.* 1996). Individual designated sites and their specific nature conservation importance are listed in Table 5.4 and shown in Figure 17.

Table 5.4 – Summary of International Sites

No	Site	Designation	Conservation importance
1	North Caithness Cliffs	SPA	Seabirds - fulmar, guillemot, razorbill, kittiwake
2	Strathy Point	cSAC	Machair, dune grassland, saltmarsh, maritime grassland, maritime heath, geology
3	Invernaver	cSAC	Blown sand, montane and maritime communities, juniper scrub
4	Ben Hutig	cSAC	Blanket bog, montane heath, geology
5	North Sutherland Coastal Islands	SPA	Wintering barnacle geese
6	Durness	cSAC	Dune grassland, limestone pavement, lochs, alpine grasslands
7	Oldshoremore and Sandwood	cSAC	Machair, dune grassland
8	Cape Wrath	SPA	Seabirds - guillemot, razorbill,

No	Site	Designation	Conservation importance
			kittiwake
9	Handa Island	SPA	Seabirds – guillemot, razorbill, kittiwake, arctic skua, great skua
10	Inverpolly	SPA	Black throated diver, blanket bog, heath, lochs, grasslands
11	Priest Island	SPA	>20,000 seabirds - storm petrel, wintering barnacle geese
12	River Kerry	cSAC	Various
13	Loch Maree Complex	SPA, RAMSAR and cSAC,	Black throated diver, golden eagle, pinewoods
14	Sheildaig Woods	cSAC	Various
15	Loch Duich, Long and Alsh reefs	cSAC	Reefs
16	Sligachan Peatlands	cSAC	Various
17	Strath	cSAC	Alpine calcareous grassland, limestone pavement, petrifying springs with tufa formations
18	Rum	Biosphere reserve, SPA and cSAC	The world's largest Manx shearwater colonies (62,000-100,000 pairs), golden eagle, merlin, peregrine, heath
19	Sound of Arisaig	cSAC	Sandbanks shallowly covered by sea water at all times
20	Claish Moss and Kentra Moss	cSAC	Blanket Bog
21	Loch Sunart Woodlands	cSAC	Otter *Lutra lutra*, old oak woods with holly and hard fern

The rocks which outcrop on the north coast of Highland include some of the oldest in Britain (from the pre-Cambrian era >590 million years old). There are also important coastal areas of limestone round Durness and down the west Highland coast. Old Red Sandstone (Devonian) dominates the cliffs in Caithness. The landscape of Skye and the Small Isles, including Rum, strongly reflects the properties of the Tertiary lavas and coarser intrusive igneous rocks of which they are largely formed (Barne *et al.* 1996 and 1997c). Raised beaches are characteristic of the west coast (Barne *et al.* 1997c).

Five sea cliff sites in the region support important numbers of seabirds and have been designated as SPAs; North Caithness cliffs, Cape Wrath, Handa Island, Priest Island and Rum. The island of Rum supports the world's largest breeding colony of Manx shearwater and Priest Islands holds the largest colony of storm petrel in Scotland (Barne *et al.* 1997c).

In many exposed places, particularly on the northwest Highland coast, salt spray is blown onto and over the cliff tops, creating some of the best and most extensive examples of maritime cliff vegetation in the UK. In a few extreme situations the extent of salt spray deposition is such that saltmarsh communities have formed high on the cliff top, particularly around the edge of geos (Barne *et al.* 1996 and 1997c).

The north coast of the region has some of the best examples or maritime heath vegetation in Britain. The endemic, nationally scarce Scottish primrose, *Primula scotic*a is present at a number of locations along the north west Highland coast, in particular Strathy Point (Barne *et al.* 1996c). Strathy Point, Ben Hutig and Inverpolly and Rum have all been identified as candidate SACs for their heath vegetation.

Sand dunes along the northwest Highland coast are generally small and scattered, with the exception of Dunnet Bay, and the climbing dunes at Oldshoremore and Sandwood, which are also of national importance for machair. Variegated horsetail (*Equisetum variegatum*), Baltic rush (*Juncus balticus*) and seaside centuary (*Centaurium littorale*) are nationally scarce species present with in these machair systems. Dunnet Bay is also recognised as important for machair lichens. Sandwood Bay is one of the most exposed beaches in the UK and exhibits a variety of foredune types and the presence of many large blowouts illustrates the instability of dunes under exposed conditions (Barne *et al.* 1997c). Smaller dune systems are present at Invernaver and Durness where sand has been blown over the cliff and resulted in the formation of climbing dunes. The climbing dune systems throughout the region support an Arctic-Alpine flora with montane avens *Dryas octopetala*, of significance in a European context as it occurs at a low altitude and is the core area for this vegetation type in Britain (Barne *et al.* 1996 and 1997c). Four areas along the north coast have been proposed as candidate SACs as a result of their dune and machair systems; Strathy Point, Invernaver, Durness, Oldshoremore and Sandwood.

On the very indented west Highland and Skye coasts there are numerous (almost 100) small sites of saltmarsh (very few sites exceeding 20ha) (Barne *et al.* 1997c). Along the north Highland coast there are five areas of small (<10ha) saltmarsh at loch heads and in bays and river mouths (Barne *et al.* 1996). Small areas of saltmarsh lack habitat and species diversity and generally only exhibit mid to upper marsh communities and therefore are not as important in nature conservation terms as other areas of the UK.

Shingle beaches are generally absent along the north and west Highland coast. Small areas of shingle are present in four bays on the north coast, to the east of the Kyle of Tongue (Barne *et al.* 1996). Areas of shingle are however slightly more common down the west Highland coast and 10 shingle beaches were identified by Barne *et al.* (1997c).

The only areas on the northwest coast of Highland which can be defined as estuarine in nature are the Kyle of Durness and Kyle of Tongue on the north coast of Highland. They are remote unspoilt sand filled glacial basins (fjards) with limited freshwater inflow and substantial sub tidal zones in their outer parts, (Barne *et al.* 1996). Saltmarsh has developed at the heads of these estuaries, but mud shores are absent. The narrow shores of these estuaries are composed of shingle or bedrock rather than soft sediments.

Coastal lagoons are defined as a nationally rare habitat and a ‘priority habitat type’ under the EU Habitats Directive. Loch Eriboll and Duart Lochan include lagoons (Barne *et al.* 1996 and 1997c) although neither is of international conservation importance.

The coastline of north Highland is not as important for seal populations as the nearby Orkney and Shetland Isles. Seals are not common on the north coast between Strathy Point and Duncansby Head, although Loch Eriboll is important for grey seal breeding and common seals haul out in Kyle of Tongue, Loch Eriboll and Kyle of Durness (Barne *et al.* 1996). The west Highland coast supports larger populations of common and grey seals.

5.1.5 The Faroes

The Faroes is an island archipelago of 18 islands situated in the heart of the North Atlantic, between Scotland and Iceland. The islands have over 1,100km of coastline and most of the land lies no more than 5km from the coast. The average height of land above sea level is 300m.

The islands form part of a thick basaltic plateau, which developed during volcanic periods in early Tertiary times. Erosion of the basalt by ice and other forces, have resulted in the Faroes landscape of today and the formation of distinctive coastal types.

In terms of overall morphology, open coasts account for much of the shoreline. The narrow sounds between islands and fjords provide more sheltered waters, but features such as bays, estuaries and lagoons are uncommon or absent. Some of the fjords have shallow sills, which extend across their entrances and reduce deepwater exchange with the adjacent coastal waters. Although the outer coasts are all exposed to similar wave attack, there are marked differences in morphology between the north and west coasts which tend to comprise the highest sea cliffs, and the lower, more subdued cliffs and, rocky boulder shores of the east coast.

The variety of coastal substrata which exist in the Faroes is also not great. Highly exposed cliff, rock and boulder shores dominate, with more sheltered rock and boulders characterising the inner sounds and fjords. There are isolated areas of sand, pebble and cobble beaches and small areas of saltmarsh habitat at the head of some fjords, however, muddy shores are generally absent. The only sand dune system is located at Sandur on the island of Sandoy.

The above features combine to create a relatively homogenous coastline with a comparatively low level of habitat diversity. Consequently, the fauna and flora of the Faroese coastline is likely to be restricted in terms of diversity in comparison with other analogous land-masses. Nevertheless, the position of the Faroe Islands at a boundary between colder Arctic water masses and the temperate Atlantic flow provides biogeographic variety to the biota of the area.

The sea cliffs around the Faroe Islands are of great interest from both a landscape and ornithological perspective. The high steep cliffs on the west coast of Streymoy and Sandoy include some of the most spectacular examples of cliffed coastline and important ‘bird cliffs’ (i.e. seabird colonies). The Faroe Islands are of international importance for a number of breeding seabird species and eighteen sites, concentrated along the open coastline, are considered important. Fifteen of these sites support one percent or over of the world’s population of seabird species and sixteen hold one percent of the European seabird population.

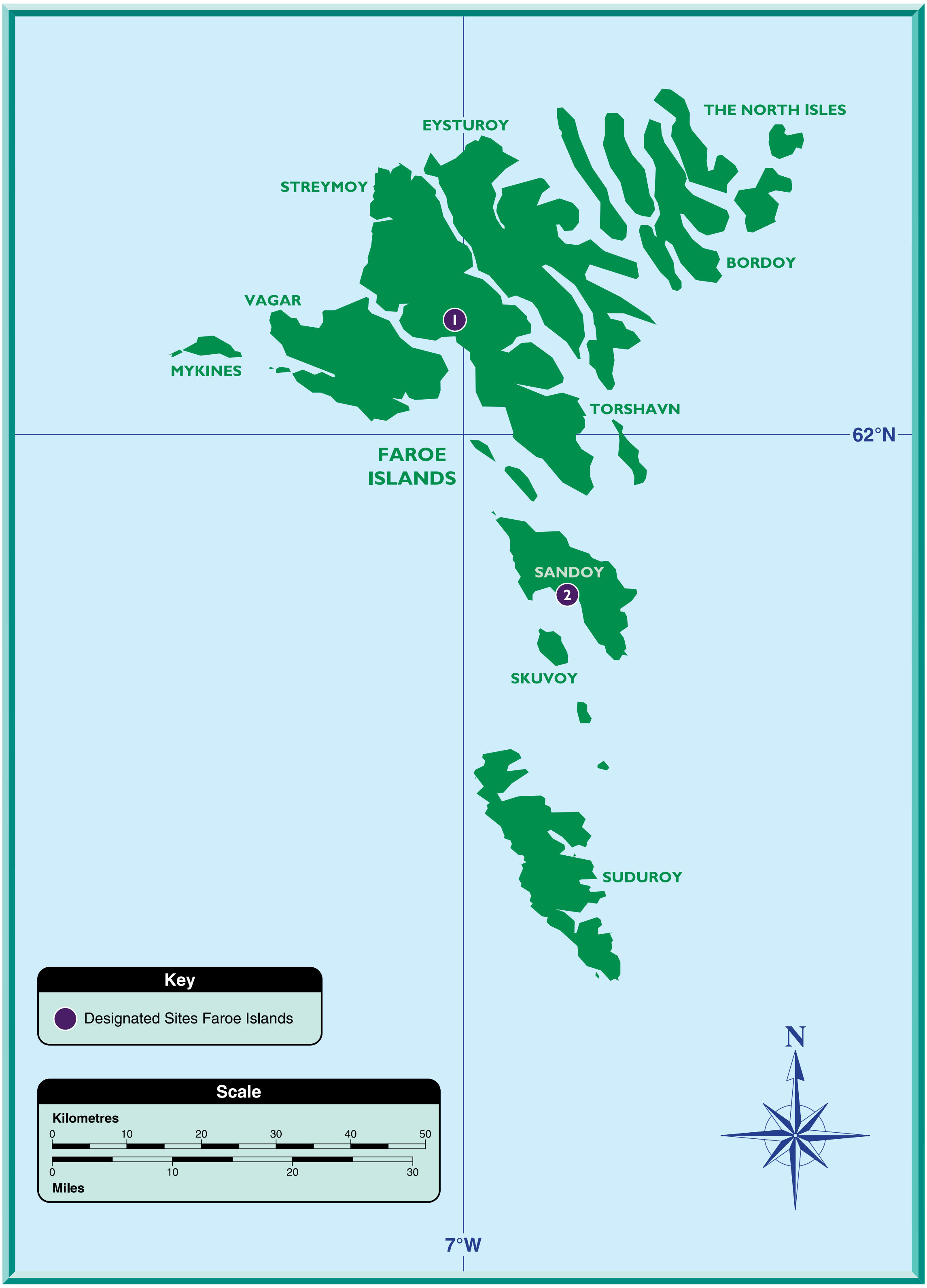
Despite the important numbers of birds present around the islands, there are no designated conservation areas. The Faroe Islands are a self-governing region of Denmark, and unlike mainland Denmark, the Islands are not party to the Berne Convention, World Heritage Convention, or the European Union (EU) Wild Birds or Habitats Directives. The Faroes as part of Denmark, are covered by the Bonn and Ramsar Conventions, but no Ramsar sites have been designated (Dam, pers comm). Individual designated sites and their specific nature conservation importance are listed in Table 5.5 and shown in Figure 18.

Table 5.5 – Summary of Faroese Sites

No	Site	Designation	Conservation interest
1	Leynar	Local statute	Freshwater lake
2	Molheyggjarnir heima a Sandi	Local statute	Sand dunes

The grey seal is the only pinniped which currently breeds in the islands and records from when this species was still hunted (late 1960s) suggested the population to be in the order of 3,000 (Bloch 1998). Little research has been undertaken with regard to preferred locations for breeding and haul out sites, but grey seals are likely to be found breeding along exposed rocky shores.

Figure 18 –Important designated coastal sites on the Faroes



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5.2 Uses of the Coastal Zone

5.2.1 Sea Coastal Users – Shetland

See Figure 19 for overview.

5.2.1.1 Fishing

Fishing is one of the main industries in Shetland, with 14% of the total employed in Shetland being employed by the fishing and fish processing industry (Shetland Islands Council 1999). In 1998, fish landings and fish processing were worth £85 million to the Shetland economy equivalent to 27% of Shetland's total income (Shetland Islands Council 1999).

UK vessels landed just over 70,000 tonnes of fish in Shetland in 1998 with a total value of £24.7 million (Scottish Executive 1999). This represents about 21% by weight of total Scottish landings. The majority of landings in Shetland are of fish caught in waters around Shetland. However, some fish caught in Shetland waters are not landed there and so are not represented in the above figures. This includes catches by Shetland, other Scottish and foreign vessels who land elsewhere in the UK or on the continent. Fish caught in Shetland waters but landed elsewhere are mainly pelagic, many of which are landed in Scandinavian ports.

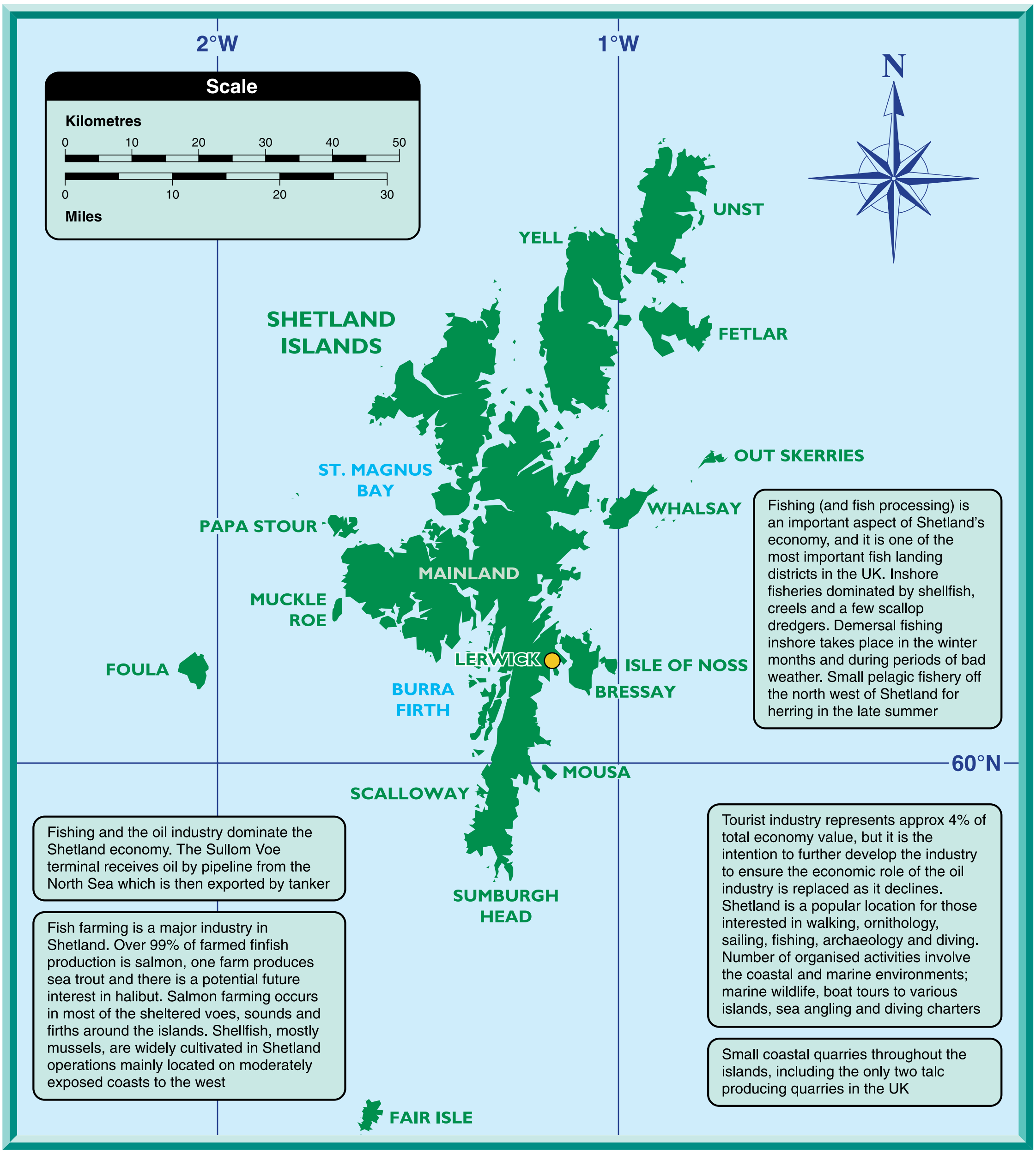
In Scotland, Shetland is second only to Peterhead in terms of quantity of fish landed, making it one of the most important fish landing districts in the UK. This importance is a direct reflection of the importance of the fishing grounds in the waters around Shetland. In fact, given that a significant proportion of the fish taken around Shetland is landed outwith the islands, these figures understate that importance.

At the end of 1998, 251 fishing vessels were officially recorded as being based in Shetland, although not all were registered there (Scottish Executive 1999 and Jamieson 1999). This fleet ranges in size from under five metres to almost 75 metres in registered length. The Shetland fleet uses five main types of fishing gear: the demersal trawl, seine net, scallop dredges, creels and the pelagic trawl. A small number of vessels also use other types of fishing gear including hand lines, long lines and set (gill) nets.

The majority (74%) of the Shetland fishing fleet is comprised of inshore fishing vessels of under 10 metres in length. Almost all of these vessels fish for shellfish, most (90%) with creels and a few with scallop dredges (Scottish Executive 1999). About 17% of the fleet falls in the 10 to 20 metre class size, with a fairly even split between those fishing for shellfish and those fishing for demersal fish. These medium sized vessels fish mainly offshore but will spend some of their time fishing in inshore waters in winter months and during periods of bad weather. All of the fishing vessels in the 20 to 50 metre class fish for demersal fish in offshore waters, while the largest size class (over 50 metres) are pelagic trawlers. These large pelagic trawlers mainly fish offshore with the exception of a late summer inshore herring fishery which exists close inshore off the north west of Shetland (Napier, pers comm). Fishing vessels not registered in Shetland may also fish close inshore.

Inshore fishing grounds occur all round the Shetland coast. Important demersal grounds include a seine net fishery and demersal otter trawl fishery (including sandeel grounds), which can occur close inshore and traditional fishing grounds include Burra Firth and St Magnus Bay (Barne *et al.* 1997a). Inshore pelagic fishing is limited, however, in addition to

Figure 19 – Uses of the Shetland coastal area



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the seasonal herring fishery mentioned above, a small hand line fishery for mackerel also exists.

Virtually all shellfish fishing takes place in inshore waters and scallop dredgers and creels are deployed all round the Shetland coast. Creels are principally used to target edible crab, lobsters and velvet crabs. The main season for edible crabs is from April to September and for lobster from April to December (Murison and Barne *et al.* 1997). Pots are set close inshore for lobsters, but fishing for edible crabs can occur further offshore. A growing fishery for whelks also exists. Scallops and queen scallops are exploited around Shetland by scallop dredgers either in multiple or single rigs (Barne *et al.* 1997). The scallop fishery has been affected in recent years by closures due to the presence of PSP (paralytic shellfish poisoning) and ASP (amnesic shellfish poisoning) (Fisheries Research Services 1998).

Under the Shetland Islands Regulated Fishery Order 1999, the Shetland Shellfish Management Organisation will be implementing a series of regulations with the aim of controlling shellfish fishing around Shetland. The principal management measure being introduced is a local licensing scheme for shellfish vessels. Other controls include gear limitations, minimum landing sizes, catch limits and closed seasons or areas.

Approximately 600 fishermen are employed in the Shetland fleet (Scottish Executive 1999) of which about 61% are full-time. The full-time employees are concentrated on the larger vessels, while many of the smaller shellfish fishing vessels are operated on a part-time basis. In addition, approximately 280 people are employed in ancillary services to the fishing industry (e.g. net manufacturers etc) (Shetland Islands Council 1999).

5.2.1.2 Fish Processing

In 1998 there were 22 fish processing factories in Shetland with a total of 34 processing lines for salmon, shellfish and demersal and pelagic fish (Shetland Islands Council 1999). The number of factories has increased since 1998. Approximately 785 people are employed in the fish processing industry with 614 (78%) being full-time and the remainder part-time (Shetland Islands Council 1999).

The fish-processing turnover increased from £49 million in 1995 to £59 million in 1998 (Shetland Islands Council 1999). Turnover (and employment) in the fish processing sector are likely to increase in the coming years as there is currently a strong drive to increase the quantity of processing, particularly high value “value added” processing, carried out in the islands. At present a high proportion of the fish landed or produced in Shetland is exported from the islands with no, or only primary processing (Napier, pers comm).

5.2.1.3 Salmon Farming

At present, the vast majority of Shetland’s farmed finfish production (>99%) is based on salmon. There are some moves towards the farming of other species in Shetland: one company is producing farmed sea trout and there is interest in the potential of halibut (Barne *et al.* 1997a and Napier, pers comm). Salmon is grown on in sea-cages in most of the sheltered voes, sounds and firths around Shetland. There are also land-based salmon hatchery and smolt units.

Salmon farming in Shetland currently employs 293 full-time and 93 part-time, with an additional 339 employed in the ancillary industry (including hatcheries). Figures for salmon processing are included in fish processing in the previous section.

Salmon production in Shetland has increased from 1,500 tonnes in 1986 to 33,304 tonnes in 1998 (Shetland Islands Council 1999), this is equivalent to 30% of total Scottish production in 1998 (Fisheries Research Service 1999a) and represents the greatest Scottish production in one area. The average tonnage per farm has also increased in this time from 56 tonnes in 1986 to 666 tonnes in 1998. There are 175 licensed sites for salmon farms around Shetland, operated by 50 companies (Crown Estate 2000a and Shetland Islands Council 1999). Many of these sites will be operated as single farm units and there are approximately 140 salmon farms around the Shetland coastline (Napier, pers comm). There is also a single sea trout farm in the Loch of Strom (Crown Estate 2000a).

Despite declines in the value of farmed salmon the total value of salmon production in Shetland has continued to increase from £6 million (£3,787 per tonne) in 1986 to £56 million (£1,680 per tonne) in 1998 (Shetland Islands Council 1999). In addition to salmon production, salmon processing also generates income for the Shetland economy. Figures for salmon processing are included in total fish processing turnover in the previous section.

Salmon production in Shetland was severely affected during 1999 by suspected and confirmed outbreaks of Infectious Salmon Anaemia (ISA) a viral disease of salmon. ISA is a class 1 disease under EU Regulations and statutory management measures include compulsory slaughter of all fish, compulsory fallowing periods for infected sites and those in close proximity (up to 7km away), and restrictions on movement of fish and equipment within infected areas.

The Shetland Islands Council is the licensing authority for all mariculture sites in Shetland waters. Seabed leases must also be sought from the Crown Estate in Edinburgh. The licensing of new sites is anticipated to be limited as most, if not all, suitable sites using existing sea-cage technology, are already occupied. Shetland Islands Council imposes minimum separation distances of 1,000 metres between adjacent salmon farms and 500 metres between salmon and shellfish farms. The Scottish Environment Protection Agency has imposed a production limit of 500 tonnes per site in an effort to control possible pollution from salmon farm sites and a Code of Practice is currently being developed for salmon farming in Shetland, which will recommend maximum stocking densities (Crown Estate 2000b)

5.2.1.4 Shellfish Farming

Shellfish, mostly mussels, are widely farmed in Shetland, in particular on moderately exposed coasts to the west of Shetland (Barne *et al.* 1997a). This industry is based on the on growing of naturally settled spat on ropes suspended from rafts or lines. There is no significant farming of other shellfish species in Shetland although there is some interest in both scallops and oysters.

After a number of years of fairly low production the mussel farming industry in Shetland is now expanding rapidly, production having increased from about 10-20 tonnes per annum in 1994-1996 to approximately 175 tonnes in 1998 (Fisheries Research Services 1999b) with a total value of £150,000. At present only a few sites are producing, but there are 42 sites with Crown Estate licences (Crown Estate 2000a, Napier, pers comm). In addition there are two scallop, two oyster and two mixed shellfish sites with Crown Estate leases (Crown Estate 2000a)

Shellfish farming is restricted to relatively sheltered areas and is subject to a minimum separation distance between sites of 500m. There is unlikely to be a significant increase in licensed sites, but the number of producing sites is on the increase. It is currently estimated that total production could reach about 800 tonnes per annum by 2002, but there is considerable uncertainty in this figure (Napier, pers comm).

Employment levels on mussel farms is currently low in Shetland, since mussel farming is non-labour intensive; in 1998 there were four full-time and eight part-time employees (Fisheries Research Services 1999b). These figures are likely to increase with expansion in production.

5.2.1.5 Tourism and Recreation

The tourist industry contributed £12.8 million to the value of the Island's economy in 1998. This represented approximately 4% of the total economy value and the same contribution as agriculture (Shetland Islands Council 1999). The number of tourists visiting Shetland during the main tourist season (June to September) in 1995 was approximately 18,300 (Shetland Islands Council 1999). The Shetland Islands Council intend to further develop and grow the Islands tourist industry, as it is important that as the role of the oil industry in the Islands declines that its value in economic terms is replaced. Employment in the Shetland tourist industry was estimated to be approximately 450 FTEs (full time equivalents) in 1997 (Shetland Islands Council 1999).

Shetland is a popular destination for those interested in walking, ornithology, sailing, fishing, archaeology and diving. There are a few sandy beaches around the Islands, however most are small and not heavily used by tourists.

Organised, although informal, nature walks encompassing spectacular cliff scenery and bird watching tours are available to tourists. Sites of particular importance for birds include the National Nature Reserve on the islands of Noss and Unst, the RSPB reserves at Fetlar, Lumbister and Sumburgh Head and the Fair Isle Bird Observatory (Harrop 1994).

Brown trout, sea trout and salmon fishing takes place in the lochs and at the head of voes throughout the Islands. The brown trout fishing season is between 15th March and 6th October and the sea trout season 24th February – 31st October (Shetland Islands Tourism 1998). The practice of fishing for sea trout in the sea takes place in both Orkney and Shetland, however is rare elsewhere in the UK. Sea angling is also popular and takes place from the shore and boats from May to October. The local Association of Sea Anglers organises competitions throughout the season (Shetland Islands Tourism 1998).

Sites of archaeology and historical interest are distributed throughout the Islands, many on the coast. One of the main archaeological attractions is the ancient settlement of *Jarlshof* located at the southern tip of Mainland (Barne *et al.* 1997a).

There are three active scuba diving clubs around Shetland who dive a number of scenic and wreck diving sites around the area. (Cuthbertson, pers comm.). A number of commercial dive charters also operate around Shetland, including Shetland based Selkie Divers as well as a number of dive charters who visit Shetland from Orkney and elsewhere in the UK. Wreck sites are located all around the coast of Shetland with concentrations around Lerwick, Unst and on the southwest coast of Shetland (Shetland Sub-Aqua Club 1989). Shetland has the highest density of discovered historic wrecks in Scotland. Notable wrecks include the Dutch East Indiaman, the *Kennemerland* on Stoura Stack and the Danish warship, *Wrangels Palais* on the Out Skerries, which are both designated under the Protection of Wrecks Act 1973 (Martin 1998).

Sailing is popular throughout the Islands and most districts hold local regattas. The increasing popularity of this sport in the Islands is demonstrated by the increase in the number of visiting yachts recorded in Lerwick and Scalloway harbours, 500 in 1995 compared to 100 in 1981 (Barne *et al.* 1997a). Marinas and small piers for local and visiting yachts are located all round Shetland in the numerous sheltered voes. As at the end of 1999 there were over 50 registered marinas and yacht anchorages (Shetland Islands Tourism, undated and Marshall 1997). There are also a number of active yacht clubs. Cruise liners are also regular visitors into Shetland, in particular Lerwick and Unst (Cruise Development Shetland, pers comm.). In 1998, 37 liners visited the Islands capital Lerwick (compared to 21 in 1991) (Shetland Islands Council 1999).

There are a number of organised activities available to tourists in the region, which involve the coastal and marine environments. These are summarised below:

- Marine wildlife and scenic tours to the islands of Bressay, Noss, Mousa and Muckle Flugga.
- Trips to the bird observatory on Fair Isle.
- Boat charters available from Lerwick harbour for sea angling (season May – October) and scuba diving trips.
- Boat trips around Lerwick harbour on a traditional Norse Longship during the summer months (Shetland Islands Tourism 1998 and Shetland Islands Tourist Board 2000).

5.2.1.6 Other Industry and Coastal Users

Shetland is relatively undeveloped and supports a population of just under 23,000 (1998 estimate, Shetland Islands Council 1999). Industry in the Islands is primarily situated in coastal locations, particularly around Lerwick, Scalloway and the oil terminal at Sullom Voe. In addition to the oil terminal and fisheries (see above) the main industries in the region are marine engineering and fish processing (Barne *et al.* 1997a).

The Sullom Voe oil terminal, which began operation in 1978, occupies an area of approximately 400 ha on the north coast of Mainland at Calback Ness. BP Amoco operates the terminal on behalf of the oil companies participating in the Brent and Ninian pipeline groups. The terminal currently has a throughput design capacity of 1.2 million barrels of crude oil per day (70 million tonnes per year) and reached a peak in 1984 with a total receipt of 439,434,656 barrels (58 million tonnes). At present throughput average is 600,000 barrels per day, but is in decline. The terminal had a throughput of almost 29 million tonnes of oil and 350,000 tonnes of gas (propane and butane), when 277 oil tankers and 29 gas tankers used the port. In 1998 the terminal and its associated operations (including sub contactors) employed 860 personnel, 82% of which were local islanders (Shetland Islands Council 1999).

There are three major ports in Shetland, Sullom Voe, Lerwick and Scalloway. Sullom Voe is the port servicing the oil terminal and Lerwick and Scalloway are natural harbours serving other shipping traffic to the Islands. Scalloway, originally the capital of the islands, has a relatively small harbour, which is now mainly used by fishing vessels. The main focus of shipping is now in the much larger harbour at Lerwick. There are oil service berths at Lerwick (sixteen), Sella Ness and Scalloway (one) harbours The main base for large fishing vessels in Shetland is the island of Whalsay and there are also fishing centres at Out Skerries and on the northern islands of Unst and Yell. There are numerous other smaller harbours throughout the islands, many of them with facilities for the inter island ferries (Barne *et al.* 1997a).

The isolated nature of the Shetland Islands makes them very dependent on ferry transport. There are inter-island ro-ro ferry links to Yell, Unst, Fetlar, Bressay and Whalsay, plus other seasonal passenger links to some of the smaller islands. The main external ferry routes to the Islands run into Lerwick. The P&O line provides links with the Orkney Islands and Aberdeen and runs a weekly service to Bergen in Norway, during the summer months (Shetland Islands Council 1999).

There are a number of small coastal quarries throughout the Islands, which produce igneous rock, sandstone, sand and gravel and talc. The two talc-producing quarries are the only two in the UK (Barne *et al.* 1997a). Navigational dredging is occasionally carried out to deepen channels and shipping berths etc, at Lerwick, Symbister, Fair Isle and Foula (Barne *et al.* 1997a).

5.2.2 Sea Coastal Users – Orkney

See Figure 20 for overview.

5.2.2.1 Fishing

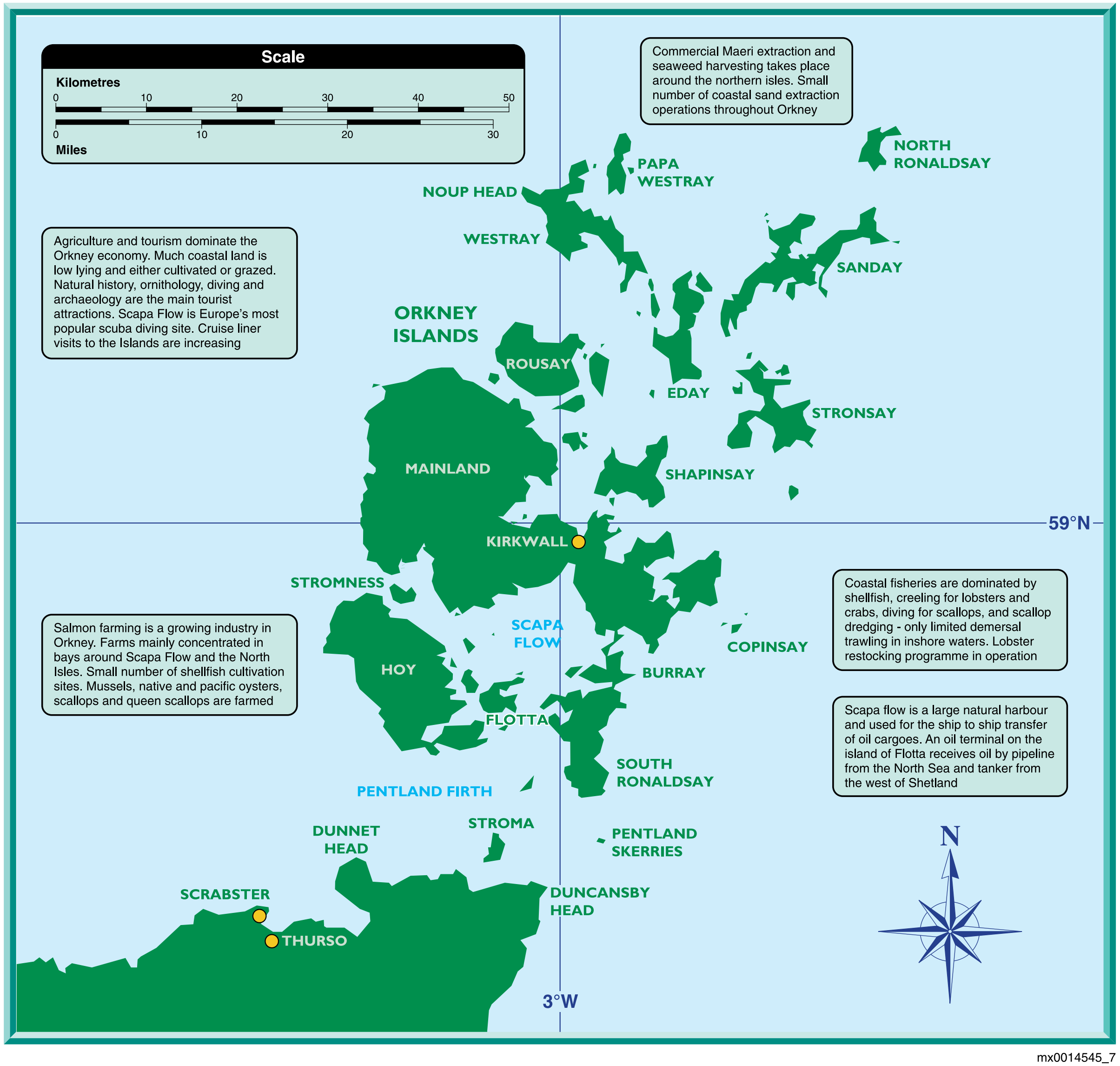
Figures for employment in the fishing industry in Orkney show 6% of the total workforce being employed in the industry in 1996. The total number employed decreased slightly in 1998 to 256 full-time and 109 part-time (Scottish Executive 1999). In 1998, fish landings were worth £5 million to the Orkney economy. (Scottish Executive 1999).

UK vessels landed 3,659 tonnes of fish in Orkney in 1998 with a total value of £5 million (Scottish Executive 1999). This represents only 1% by weight of total Scottish landings and is below the average for Scottish regions. Landings were dominated by shellfish landings with a weight of 3,286 tonnes and a value of £4.6 million and shellfish landings represent 6% by weight of total Scottish shellfish landings with significant landings of lobster and velvet crab. Very little whitefish is landed in Orkney with most whitefish being landed in Shetland, Aberdeen and Scrabster. Most shellfish landed in Orkney is taken in Orkney waters and 99% of total landings into Orkney by Scottish vessels are from Orkney based vessels.

At the end of 1998 195 fishing vessels were officially recorded as based in Orkney, although not all were registered there (Scottish Executive 1999). The Orkney fleet ranges in size from under 10m to a single large freezer trawler of just under 75m. The Orkney fleet is dominated by shellfish vessels (creels and scallops dredgers) with a small number of demersal trawlers. No pelagic trawlers are currently based in Orkney.

The majority of shellfish vessels in Orkney employ creels or pots to target lobster, crabs and whelks. Of these, approximately 72% are under 10 metres, and of these smaller creel boats up to 50% are only operated on a part-time basis (Bruce, pers comm). Many of these smaller vessels will not only target the creel fishery but also employ other methods such as small dredges or scallop diving, moving between fisheries depending on season, catch levels and market demand. Larger inshore creel vessels can use over 1,000 creels, per fishing trip (Barne *et al.* 1997b) compared to smaller boats that typically use between 50-100 creels.

Figure 20 – Uses of the Orkney coastal area



Creeling for lobster and crab species occurs around 85-90% of the Orkney coastline, with principal effort focused on Orkney's west coast (Coghill, pers comm). Lobsters are the most important species landed in terms of revenue with 97.2 tonnes landed in 1999 with a value of £1.2 million (Bruce, pers comm.); velvet crabs, edible crabs and scallops are also important in terms of revenue with 1999 landings worth £1.2 million, £897,000 and £679,000 respectively. Lobsters are taken all year round with the peak season between August and November. During the peak season, creels are also set out with Orkney coastal waters for example in the Pentland Firth (Barne *et al.* 1997b). The edible crab is caught all year round, with the peak season running from May to August, effort in summer months extends to waters to the west of Orkney. In winter months fishing effort is concentrated in the sheltered waters of Scapa Flow and other weather protected inshore areas of Orkney.

A number of larger shellfish vessels from other parts of the UK and the Continent also target the crab fishery in waters to the west of Orkney during summer months. Most of these catches are landed out with Orkney. There is also a growing fishery for whelks with pots being laid in sheltered waters around Orkney, in particular Scapa Flow.

There are approximately 20 vessels in Orkney active full-time or part-time as scallop dredgers (Scottish Executive 1999). Of these, approximately seven are over 12m in length and these are employed full-time targeting scallop grounds to the west and east of Orkney. Both scallops and queen scallops are taken. Visiting scallop dredgers also work local beds. A number of smaller dredgers are also active, some full-time and others switching between dredging and creels. Scallops are also collected in shallow inshore waters by divers. Scallops are taken all year round, however the scallop industry has been affected in recent years by prohibitions (mainly in summer months) on shellfish collection being in force due to high levels of toxic phytoplankton (*Alexandrium* spp *(*paralytic shellfish poisoning) and since 1997, *Pseudo-nitzchia* spp (amnesic shellfish poisoning) being found (Fishery Research Services 1998).

There is a seasonal closure on fishing for crustacea in Scapa Flow made under the Inshore Fishing (Prohibition of Fishing and Fishing Methods) (Scotland) Order 1989. The order bans all fishing for crustacea (lobster, crabs and prawns) in Scapa Flow between 1 June to 1 September each year. Minimum landing sizes are also applied.

In 1984, the Sea Fish Industry Association (SFIA) initiated trials to artificially enhance lobster stocks by releasing hatchery-reared juveniles into the surrounding waters. In 1988, the first recoveries of market size lobster occurred and recaptures have occurred since, alongside an ongoing re-stocking programme that is now managed by the Orkney Fisherman's Association (OFA). The OFA provides financial support via grant aid to North Isles Shellfish Ltd, who produce the juvenile lobsters for re-stocking, in several areas, mainly to the west of Scapa Flow (Coghill, pers comm.).

Demersal trawlers based in Orkney fish offshore and land to ports out with Orkney. Only limited demersal trawling effort is seen inshore, for example along the west coast of Hoy (Coghill, pers comm). Most of the demersal trawlers are based in Kirkwall or Westray.

There is a seasonal closure on the use of mobile fishing gear (trawl, seine net, dredge etc) made under the Inshore Fishing (Prohibition of Fishing and Fishing Methods) (Scotland) Order 1989 along the west coast of Orkney Mainland and Hoy. This bans the use of mobile gear in the designated area between May and September (inclusive) and was designed to protect recognised nurseries.

5.2.2.2 Fish Processing

Little or no whitefish processing takes place in Orkney, however the shellfish processing industry is of great importance to the Orkney economy with an approximate value of £3.5 million in 1999 (Crighton, pers comm.). In the past a large proportion of shellfish was shipped live to Spain for processing, however with the strength of the UK pound, more shellfish is now being processed locally and this is set to grow by 5-10% per annum (Crighton, pers comm.).

There are currently 95-100 full time equivalent employees in the shellfish processing industry in Orkney (Crighton, pers comm.), equivalent to 1.5% of total employment in Orkney.

5.2.2.3 Salmon Farming

The farming of Atlantic salmon is a growing industry in Orkney, although the industry is much smaller than that seen in Shetland. There is also interest in halibut on-growing with a number of trials currently being undertaken in Orkney most halibut is currently being grown in pump ashore tanks at Tankerness and Rousay although there is a single offshore site with a Crown Estate lease for halibut (Crown Estate 2000c) but this is not yet operational. Salmon is all on grown in sea-cages in a number of locations around Orkney. There are also land-based pump-ashore salmon hatchery and smolt units.

Salmon farming in Orkney currently employs 66 full-time and 15 part-time (Fishery Research Service 1999a). Figures are not available for those employed in support industries or in the salmon processing industry, although the number of employed in these areas have also increased in recent years.

Salmon production in Orkney has increased from 1,245 tonnes in 1993 to 4,485 tonnes in 1998 (Fishery Research Service 1999a) and this is equivalent to 4% of total Scottish farmed salmon production. The percentage contribution to total Scottish production has however increased from only 2% in 1993, and production for 1999 is forecast to be 6% of total Scottish production. Salmon farming is important to the Orkney economy and an estimated £7.5 million was brought into the local economy in 1998. Income will also be generated from salmon processing but no figures are available for this.

There are 42 licensed sites for salmon production around Orkney (Crown Estate 2000c); these are mainly concentrated in bays around Scapa Flow and the north isles of Orkney. Not all sites with Crown Estate leases are currently operational. Within harbour areas (including Scapa Flow), work licences from Orkney Islands Council are required as well as Crown Estate leases. There are currently 24 sites with work licences in Orkney waters (Orkney Islands Council 2000a). This represents about 50% of total operational salmon farm sites in Orkney waters. In general salmon farm sites in the more exposed sites in the north isles of Orkney are much larger than those seen in the sheltered waters of Scapa Flow.

As salmon farming is a growing industry in Orkney the demand for new sites is high. It is anticipated that all sites with Crown Estate leases will be fully operational within the next 2-3 years with further sites being added to this. However, a number of objections are being raised regarding this increase in the number of sea-cage sites in Orkney, particularly from sea-anglers and local residents. Whether these objections will have a limiting effect on the anticipated future growth is not known. There is currently a moratorium on new sites being licensed within Scapa Flow unless the sites are being developed for fallowing or rotational purposes (i.e. no overall increase in stocking biomass) (ICIT 2000). Improving sea-cage technology is however allowing salmon farm development in more exposed locations and this is reflected in the growing number of sites in the Orkney north isles. A number of salmon farms in Orkney (in particular the smaller sites) are converting to organic production (Orkney Islands Council 1999).

5.2.2.4 Shellfish Farming

There are only a small number of sites in Orkney where shellfish are cultivated. Species farmed include mussels, native and Pacific oysters, scallops and queen scallops (Barne *et al.* 1997b). Mussels are mainly grown using pastorally cultivated wild beds (Barne *et al.* 1997b) but some on growing of naturally settled spat on ropes suspended from rafts is also now seen. Scallops and queen scallops are grown on the lower shore from natural spat suspended in net bags or individually from holes drilled in the shells. Hatchery-reared 'spat' of Pacific and native oysters are grown to market size in net bags located on trestles on the lower shore (Barne *et al.* 1997b).

Production in Orkney is low compared to other areas, with 190 tonnes of shellfish produced in 1998; of this 182 tonnes were oysters (Pacific and native) and 8 tonnes of mussels (Fisheries Research Services 1999b). Production in Orkney is likely to remain at current levels (Orkney Seafayre, pers comm.). At the end of 1998 there were 2 full-time, 8 part-time and 3 casual workers employed by the shellfish farming industry in Orkney.

There are currently 15 shellfish farming sites in Orkney with Crown Estate leases (Crown Estate 2000c). Of these five are for scallops, one for mussels, one for oysters and eight mixed shellfish sites. The majority of these also have Orkney Islands Council work licences (Orkney Islands Council 2000a). With the exception of a large shellfish farm in the Bay of Firth to the west of Kirkwall, the majority of shellfish sites are run on a small scale and part-time basis.

The Bay of Firth to the north of the Orkney Mainland has been designated as a shellfish growing area under the Surface Waters (Shellfish) (Classification) (Scotland) Regulations 1997, no further information was available on this (Coghill, pers comm.).

5.2.2.5 Tourism and Recreation

The tourist industry is an important aspect of the economy of the Orkney Islands and during 1998 tourists are estimated to have spent approximately £17 million in the county (Orkney Tourist Board, pers comm). The number of estimated tourist visitors to Orkney in 1998 was estimated to be approximately 109,000, this was a 2% increase compared to the previous year (Orkney Islands Council 1999).

The tourist season in Orkney is from April through to October (Orkney Tourist Board, pers comm).

Natural history, ornithology, diving and archaeology are the major tourist attractions. The greatest concentration of tourist related infrastructure and the greatest intensity of touristy and leisure related activity is on the Mainland, Burray and the north west coast of South Ronaldsay.

The Islands' importance for bird life is demonstrated through the large number of protected sites designated for bird conservation. Sites of importance for birds include the RSPB reserve on North Hoy, St Johns Head (the highest sea cliffs in Britain), Yesnaby and Marwick Head on the west coast of Mainland, Noup Head and the west coast in Westray, Sule Skerry, the lochs of West Mainland and the bird observatory on North Ronaldsay (Tait 1997 and Barne *et al.* 1997b).

Scapa Flow is Europe's most popular scuba diving site. Wreck sites include; the remains of the German High Seas Fleet (scuppered in 1917); the blockships (also remains of the World Wars) lying in Burra Sound and around the Churchill Barriers (which link the islands Mainland, Burray and South Ronaldsay), and wrecks around the northern Isles. There are currently 14 dive boats operating in Scapa Flow and approximately 3,000 divers visit Orkney each year. Most diving is concentrated around the German wrecks, which lie around the Island of Cava in Scapa Flow (Cuthbertson, pers comm). Diving also takes place from the shore, particularly around the Blockships at the Churchill Barriers.

For non-divers interested in the shipwrecks around Orkney there is boat trip that operates in Scapa Flow and explores the wrecks by means of a remotely operated vehicle (ROV), which relays video pictures to the vessel deck (Tait 1997).

Orkney is also famous for its sites of archaeological and historical importance, and there are over 1,000 sites of historical interest dating from Mesolithic (10,000 years ago) times up to remains of the two world wars. Many of these places of interest are located around the Islands coastline. The best-known site is probably the pre-historic village of Skara Brae, which is situated at the south end of the Bay of Skaill on the west coast of Mainland (Tait 1997).

Other activities, which attract visitors to Orkney, include fishing, walking, sailing and climbing.

Fishing is very popular and there are six major lochs all of which are well stocked with brown trout, and four with sea trout. Sea trout are also fished for from bays and other coastal locations in Scapa Flow and around the Islands. The practice of fishing for sea trout in the sea takes place in both Orkney and Shetland, however is rare elsewhere in the UK. The brown trout fishing season is from 15th March - 6th October and the sea trout season from 26th February – 31st October. Sea angling is also popular and the best fishing areas found in the Pentland Firth, off the west coast of the Mainland and some of the North Isles and around Copinsay (Tait 1997).

Sailing is popular during the summer months and there are active sailing clubs in Kirkwall, Stromness and Holm and annual regattas are organised at Westray, Kirkwall, Stromness and Holm (Tait 1997 and Barne *et al.* 1997b). Marina facilities for visiting yachts are at present limited, but there are plans in place for facilities to be developed in Stromness and Kirkwall. Windsurfing is a popular pastime in Scapa Flow, with an active club that organises several annual competitions. The most popular area used is Scapa Bay, but windsurfers may also take place in Stromness Harbour, the Bays and Sounds to the west of the Churchill Barriers and Swanbister Bay in Scapa Flow. Water-skiing also takes place in Scapa Flow and surfing in the Bay of Skaill.

The famous sea stack the Old Man of Hoy on the west coast of the islands of Hoy is a popular site for rock climbing.

Cruise liner visits to the Islands have increased in recent years. In 1999, 59 cruise liners visited the Islands (Stromness and/or Kirkwall) and this will increase to 63 during 2000 (Orkney Tourist Board, pers comm).

5.2.2.6 Other Industry and Coastal Users

Orkney is relatively undeveloped and supports a population of just over 20,000 (1996 estimate, Orkney Islands Council 1999). Industry in the Islands is primarily located in coastal areas, particularly around Kirkwall and Stromness on the Mainland and at the oil terminal on the island of Flotta in Scapa Flow. Agriculture and tourism (see above) dominate the local economy, but fishing and fish farming (see above), the oil industry and the construction and service industries are also economically important.

Most of the coastal land in the Orkney islands is low-lying and relatively fertile with the exception of the islands of Hoy and Rousay and the west coast of Westray that is suitable for rough grazing only. Sheep in North Ronaldsay are confined to the coastal area where they feed on seaweed. The islands are relatively intensely farmed with livestock (beef and dairy) being very important. Some crops are also grown and barley is particularly important (Barne *et al.* 1997b).

The Flotta oil terminal was developed by the Occidental Consortium of oil companies following the discovery the Piper oil field in 1973. The first oil arrived at the terminal in 1976. The Elf consortium took over operatorship of the terminal in 1991 and it recently changed hands again in 2000 with the Canadian oil company Talisman Energy now operating the terminal. Flotta receives oil by pipeline from 10 North Sea oilfields (Orkney Islands Council 1999). The terminal has a throughput capacity of 500,000 barrels per day. Production of oil through the terminal fell by just over 1 million tonnes in 1997 to 9.5 million tonnes compared to the previous year. Production of gas (LPG and ethane) also fell in 1997 compared to the previous year, from 265,000 tonnes in 1996 to 200,000 tonnes in 1997. There was however a partial recovery in oil production in 1998 with the terminal producing 10 million tonnes of oil. Some of this increase was attributed to the terminal being awarded the contract to handle shuttle tankers from the BP Foinaven field west of Shetland. Gas production at the terminal fell again in 1998 to 126,000 tonnes (Orkney Islands Council 1999). Predictions for the future lifespan of the terminal vary, however the present owners Talisman are keen to extend by either increasing the reserves that can be produced from the older North Sea oil fields and by bringing more marginal fields into development which will produce through the Flotta pipeline system.

The main port developments in Orkney are Kirkwall, Stromness and at the Flotta oil terminal. Stromness has fish landing and roll on-roll off facilities, and Kirkwall handles shipments of livestock, grain and other cargoes. There are many small harbours and jetties located on the other islands that are primarily used as fishing harbours and for the inter islands ferry service which links the Mainland to the majority of the outer Isles. The huge natural harbour of Scapa Flow has long been an important deep water sheltered anchorage and now has its own port facilities at Scapa Bay, Kirkwall, as a result of the oil terminal development. Ship to ship transfer of crude oil has been undertaken on a sporadic basis in Scapa Flow since 1980 with a total number of 12 transfers between 1980 and the end of 1997. However the frequency of these operations has increased since 1998 to approximately 15 in 1999. The frequency of ship to ship transfers is market driven with more expected during periods of low oil price. Ship bunkering operations have also recently commenced in Scapa Flow due to the requirement for the Foinaven shuttle tankers and other tankers to re-fuel (Orkney Islands Council 2000b).

The main external ferry routes to the Islands run into Stromness. The P&O Line provides links with The Shetland Islands and with Aberdeen and Scrabster on the Scottish mainland.

There are a number of small coastal quarries extracting sand and gravel throughout the Islands. One operation at Bu Sands on the east coast of Burray extracts sand from the beach. There are 4 licensed sites for the disposal of dredged material in the Islands, Kirkwall, Scapa and 2 near Stromness (Barne *et al.* 1997b).

Kelp traditionally has been a major industry in Orkney, with laminarian fronds and stipes collected from beaches and burnt (Johnston 1985) to produce, kelp fertiliser, (rich in potash and soda). Only small-scale collection continues today. However, the feasibility of harvesting seaweed in Orkney waters has been investigated (Johnston 1985) and a new Company the 'Orkney Seaweed Company' has recently been established to harvest and process seaweed on the island of Westray.

Live maerl and maerl gravel are widely distributed in Orkney waters, for example large accumulations are seen in high energy sounds around Scapa Flow in the southern Isles and Rousay in the northern Isles (Murray *et al.* 1997). In July 1996 a favourable Government View (with conditions) was given to extract 20,000m^3 of maerl gravel over five years from Wyre Sound, Rousay.

5.2.3 Sea Coastal Users – Western Isles

See Figure 21 for overview.

5.2.3.1 Fishing

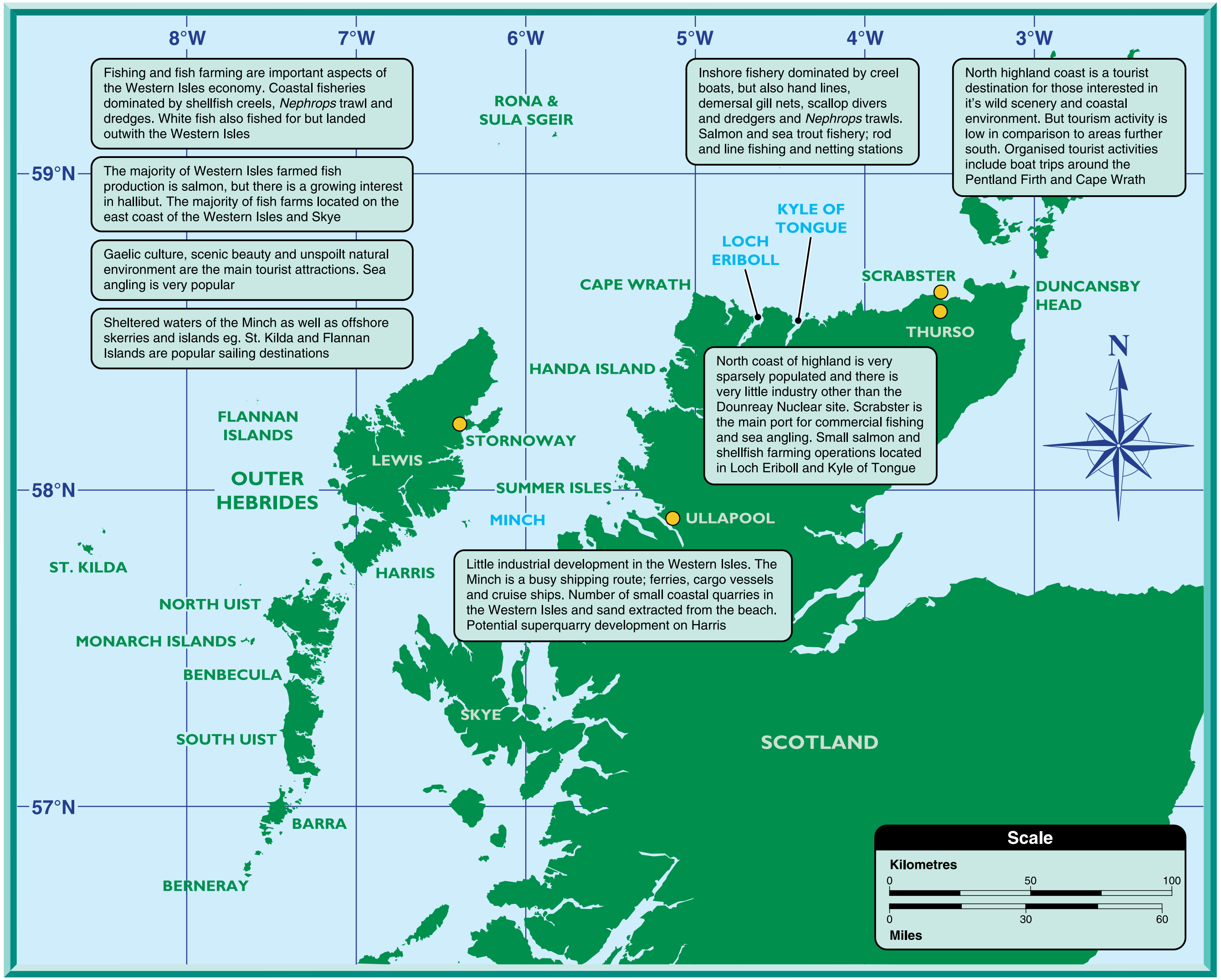
Fishing (and fish farming) is an important part of the economy of the Western Isles. In 1997, there were 681 directly employed in the fishing sector with an estimated 300 employed in ancillary services including 192 in fish processing and 100 in gear repair and manufacture (Western Isles Council 1999). This represents approximately 10% of total employment in the area. Numbers employed in this industry have remained steady in recent years despite economic pressures (Western Isles Council 1999).

UK vessels landing just over 6,029 tonnes of fish with a total value of £10 million into the Western Isles in 1998 (Scottish Executive 1999), this represents approximately 2% of total landings by weight and 3.5% by value of total landings into Scotland in 1998. Total value of landings has increased since 1990, but fallen slightly since a peak of nearly £15 million in 1995. Landings into the Western Isles are dominated by shellfish with 5,044 tonnes (83.6% of total landings) landed in 1998 with a value of £9.5 million (Scottish Executive 1999). A significant proportion of shellfish is exported and the reduced value of landings since 1996 is partly a reflection of the high value of sterling compared to previous years (Western Isles Council 1999). It should be noted that some fish caught in waters around the Western Isles will be landed elsewhere, in particular into ports on the west coast. This is particularly true of demersal and pelagic species. What white fish is landed is generally a by-catch of the local *Nephrops* fishery and is either sold locally or shipped to Aberdeen with little or no whitefish processing taking place on the islands (Perrett 1995). The dogfish fishery has been increasing in recent years with 237 tonnes landed in 1998 (Scottish Executive 1999) representing 7.5% of total landings into Scotland by UK vessels. Dogfish are taken using long lines and nets (Barne *et al.* 1997c).

The two main fishing ports in the Western Isles are Stornoway and Barra and the combined landings represent 57% of all landings by UK vessels into the Western Isles.

At the end of 1998, 341 vessels were based in the Western Isles. Of these over 80% were under 10m in length. The fleet ranges in size from under 10m to over 35m (Scottish Executive 1999). The Western Isles has the largest fleet of small vessels of any fishery

Figure 21 – Uses of the Western Isles and North Highland coastal area



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district in Scotland and is therefore well placed to develop the shellfish and non-quota stocks in inshore waters (Western Isles Council 1999).

Over 95% of fishing vessels under 10m based in the Western Isles use creels for shellfishing (Scottish Executive 1999). Other gears used by these inshore vessels include gill nets, *Nephrops* trawls and small demersal trawls. Creel caught shellfish comprise mainly *Nephrops*, lobsters, brown crabs and velvet crabs (Perrett 1995). Creels are laid all round the Western Isles, with key creel fleets based in Loch Roag, Stornoway, Scalpay, Kallin, South Uist, Barra and Berneray (Perrett 1995). The west side of Uist is generally only accessible to small local vessels during summer months (Perrett 1995). In addition to the <10m fleet, over 50% of the 10-15m vessels are creel boats (Scottish Executive 1999).

The larger vessels of over 10m are dominated by *Nephrops* trawls with vessels ranging in size from just over 10m to 20m overall length. Other gears used by the larger vessels include mechanical dredges, suction dredges, gill nets, and demersal trawls. There are also two large pelagic trawlers based in the Western Isles (Scottish Executive 1999). The most significant change in the composition of the Western Isles fleet in the last decade has been the decline in the number of boats in the 10-15m category. This trend reflects the changing economics of inshore fishing and is not unique to the Western Isles (Western Isles 1999). Decommissioning has encouraged 'trading down' to smaller vessels with lower running costs. Due to the high costs of boats and licences, new entrants to the industry are mainly in the under 10m sector.

The Western Isles, the Minch and areas to the south of Skye are important *Nephrops* fishery areas with over 34% of UK landings in 1992 coming from this area (Barne *et al.* 1997). The majority of the inshore shellfish fleet are reliant on this species and fishing is undertaken all year round. The larger prawn trawlers are generally based in Stornoway, Scalpay or Barra (Perrett 1995).

In 1998, landings of *Nephrops* into the Western Isles were of a value of £3.5 million representing nearly 10% of total *Nephrops* landings by UK vessels into Scotland (Scottish Executive 1999). Other shellfish species of high value being landed include edible crabs (£1.3 million), lobsters (£1.9 million), scallops (£1.3 million) and velvet crabs (£1.1 million) (Scottish Executive 1999). Some shellfish are also collected by hand in particular periwinkles that are collected from sheltered rocky shores all around the Western Isles; 213 tonnes of periwinkles were landed in the Western Isles in 1998 (Scottish Executive 1999).

There is very little whitefish processing in the Western Isles, however shellfish processing does occur with shellfish processors located at Loch Roag (crab), Stornoway (*Nephrops* and scallops), Benbecula (crab, *Nephrops* and scallops) and Barra (all species) (Perrett 1995). No figures are available for the value of shellfish processing to the Western Isles.

Salmon and sea trout are also caught in the waters around the Western Isles either by net or rod-and-line (Barne *et al.* 1997c). The area is not as important as the west Highland or east Highland coast as the area supports smaller populations than seen there. Salmon and sea trout catches for the five-year period 1989-1993 for the Western Isles were 1,959 tonnes and 2,122 tonnes respectively (Barne *et al.* 1997c).

Under the Inshore Fishing (Prohibition of Fishing and Fishing Methods) (Scotland) Order 1989 a number of closed seasons are in place around the Western Isles in order to preserve stocks. Closed areas around the Western Isles include (Barne *et al.* 1997c):

- Broad Bay – full-year prohibition on mobile fishing gear

- Loch Maddy to Stuley Island – prohibition on mobile fishing gear (March-October) and suction dredging (January-February and November-December)
- Stuley Island to Barra Head and Gurney Point – prohibition on mobile fishing gear (March-October) and on suction dredging (January-February and November-December)
- Sound of Harris – prohibition on mobile fishing gear (March-September) and prohibition on suction dredging (January-February and October-December)
- Loch Roag – full-year prohibition on mobile fishing gear
- Flannan Isles – prohibition on creel fishing January-March and December;
- Bragar to Dell – prohibition on creel fishing July-September

5.2.3.2 Fish Farming

Salmon farming is an important industry in the Western Isles. At present the vast majority of the Western Isles farmed fish production is salmon, but there is growing production of other species, in particular halibut (Crown Estate 2000b). Salmon and halibut are on-grown in sea-cages in most of the sheltered bay and sea lochs around the Western Isles. There are 111 licensed sites for salmon farms around the Western Isles and 7 sites licensed for halibut (Crown Estate 2000d). There are also land-based hatchery and smolt units.

Fish farming in the Western Isles currently employs 214 full-time and 27 part-time in marine sites (Fisheries Research Services 1999a). More recent estimates give employment in fish farming as 314 FTEs (full time equivalents in 1999) (Western Isles Council, pers comm), this figure includes employment in hatcheries and shellfish farming. No information is available on the number of people employed in salmon processing in the islands.

Salmon production in the Western Isles has increased from 6,834 tonnes in 1993 to 17,073 tonnes in 1998 (Fishery Research Services 1999a), which is equivalent to 15.4% of total Scottish salmon production in 1998. Salmon production in the Western Isles was affected in 1998/1999 by suspected and confirmed outbreaks of Infectious Salmon Anaemia (ISA) and production in 1998 was down compared to 1997.

The Crown Estates is currently the lead licensing authority for all mariculture sites in the Western Isles. The licensing regime has however been under review with concerns regarding the Crown Estate dual role in being landlord and “planning authority”. The licensing role is therefore to be passed to the local councils (Western Isles Council), although the timing of this changeover is still uncertain.

Halibut farming is relatively new in Scotland and to date little production has been seen. However a number of companies are planning to move into commercial production this year including Marine Harvest McConnell who plan to produce 45 tonnes of halibut mainly from their sites in the Western Isles (Crown Estate 2000b). Increases in fish farming sites in the Western Isles are likely to coincide with commercial production of this new species.

5.2.3.3 Shellfish Farming

There are 47 licensed sites around the Western Isles producing shellfish operated by 21 companies (Crown Estate 2000d), of these sites only 28 are currently operational (Fisheries Research Services 1999b). Mussel farming dominates the shellfish farming industry but other species including scallops and oysters are also farmed but at much lower production levels. In 1998, 128 tonnes of mussels were produced by farms in the Western Isles (Fisheries Research Services 1999b). Production of other species was all less than 1 tonne.

Shellfish farming in the Western Isles employed 7 full-time and 11 part-time as at the end of 1998. This low level of employment reflects the low-labour intensity of mussel farming.

The number of shellfish farms has decreased in the area since its peak in the 1990's. The current level of shellfish farming is thought to be stable with no major growth expected (Barne *et al.* 1997). A slight decline in mussel production was seen between 1997 and 1998 (Fisheries Research Services 1999b).

5.2.3.4 Tourism and Recreation

Tourism plays an important role in the Western Isles economy. The Western Isles Tourist Board estimate that the tourism sector generates around £13 million and supports around 1,000 FTEs (full time equivalents) (Western Isles Council 1999). The total number of tourist visitors to the Western Isles in 1997 was estimated to be approximately 93,250 (Western Isles Council 1999).

The Gaelic culture, scenic beauty and unspoilt natural environment make the Western Isles a unique tourist destination. Ornithology, archaeology and history are major tourist attractions.

The west coasts of North Uist, Benbecula and South Uist are characterised by long sandy beaches backed with sand dunes and machair. Reef Sands, Uig Sands, and the beaches at Traigh Mor and Port Geiraha on Lewis; and Huisinis Bay, Scarasta, Luskentyre and Northton on Harris are particularly renowned beautiful beaches (Western Isles Tourist Board 2000).

There are a number of specific areas in the Western Isles and the surrounding offshore areas, which are important for bird life and as such attract visitors. The areas most renowned are The Shiant Isles in the Minch, Loch Druidibeg agus a' Machair, South Uist, the Monach Isles off the west coast of North Uist, and the St Kilda and Flannan Isles offshore to the west. Increasing interests in bird watching and other wildlife can lead to disturbance, particularly during breeding seasons. A number of voluntary schemes and codes of practice have been developed (as part of the Minch Project) to protect vulnerable species from disturbance by leisure and tourism activities in the Western Isles and the Minch (Barne *et al.* 1997c).

On the west coast of South Uist there are four large sea lochs; Eynort, Carnan, Boisdale and Skipport which provide excellent natural harbours and are popular anchorages for visiting yachts. Other popular mooring locations include: Stornoway (Lewis), Rodel (Harris), Lochmaddy (north Uist), Kallin (Benbecula), Acairseid (Eriskay), Castlebay (Barra) and a number of locations on Skye (Barne *et al.* 1997c). Yacht charters are available from operators based on Lewis and Skye, in the Summer Isles and further south on the Scottish mainland.

North Harris is the most mountainous part of the Western Isles and offers excellent hill walking and climbing. Coastal walks are also popular on the other islands.

Water based activities such as water skiing, sea canoeing, windsurfing, surfing and dinghy sailing are also popular and centres of main activity are in Lochmaddy in North Uist and Bayble Bay on Lewis.

Sea angling is popular off the west coast of the Western Isles. There is a very active club in Stornoway which hosts national and international events. There are also active clubs on Harris and South Uist. Trout and salmon fishing are also popular.

The islands are rich in archaeological and historical sites. Well known sites include the Calanais Standing Stones and visitor centre on Lewis, Bosta Iron Age village on Great Bernera and the remains of the old whaling station at Bunavonesdar in Harris (Western Isles Tourist Board 2000).

There are a number of places in the Western Isles region which provide scenic locations for scuba diving. The west coast of Lewis, Scarp and Gasker as well as off the Flannan Isles and St Kilda are all popular diver destinations. Although there is not a large diving infrastructure, local boat charters are available, which can include diving excursions (Island Cruising 2000).

In September, Sula Sgeir (30 miles north of Lewis) is an important site for local hunters of 'guga' (gannet chicks). 'Guga' is considered a delicacy by local people (Western Isles Tourist Board 2000).

Cruises which include visits to the Scottish isles are becoming increasing popular and in recent years there has been an increase in the number of cruise liner passengers visiting the Western Isles.

There are a number of organised activities available to tourists in the Hebrides, which involve the coastal and marine environments. These are summarised below:

- Whale watching and wildlife cruises around the inner Hebrides, the Western Isles and offshore islands (including St Kilda) available from operators in Harris, Lewis, Skye and on the mainland.
- Yacht charters available from Skye and mainland based operators.
- Surfing holidays and other outdoor pursuits organised on Lewis.
- Sea angling charter trips.
- Guided walking holidays organised in the Hebrides (Western Isles Tourist Board 2000).

5.2.3.5 Other Industry and Coastal Users

The population of the Western Isles is just under 30,000 (Western isles Council 1999) and is one of the least populated areas of the UK. The Islands contain extensive undeveloped areas, particularly in Lewis, Harris and the east coasts of the Uists (Barne *et al.* 1997c).

There is very little industrial development in the archipelago. Stornoway on Lewis is the main centre of population, and industrial development in general concentrated in this area; marine engineering industry, small boating building and repair, salmon processing and the Harris Tweed company. There are a few small fish processing plants (see above) located elsewhere in the islands and there is a pharmaceuticals plant on East Loch Roag (Barne *et al.* 1997c).

Stornoway on Lewis is the most significant port in the Western Isles, important for fishing, ferries, cargo vessels and cruise liners. There are smaller harbours throughout the islands which are important for fishing and ferries. Ferry transport is of great importance and central to the economy of the region, particularly as many of the islands are dependent upon supplies from the mainland. The main ferry crossings are operated by Caledonian MacBrayne.

Large deposits of seaweed are washed ashore in Poll-na-Crann bay on Benbecula. It is gathered for both alginate production and fertilising machair areas (Perrett 1995).

There is a traffic separation scheme north of Skye and a voluntary loaded-tanker exclusion zone in the Minches. There is substantial shipping traffic along the western Scottish seaboard, including super-tankers destined for oil terminals on Shetland and Orkney. Traffic in the Minches includes ferries and cargo vessels within the Hebrides and between the Western Isles and mainland Scotland, as well as cruise ships and considerable volume of through traffic. Large oil tankers (over 10,000 tonnes) are recommended to keep to the deep water route to the west of the Western Isles, to minimise the danger of environmental damage in the event of an oil spill.

There are number of small coastal quarries in the Western Isles which produce sand and gravel and igneous rock and shell sand has long been extracted from the beaches of the Western Isles for constructional and agricultural purposes. Lingerabay on Harris is the subject of a potential super quarry development, however there has been considerable opposition and a lengthy public enquiry the final verdict of which is still outstanding (SNH, pers comm.).

5.2.4 Sea Coastal Users - North Highland Coast

See 21 for overview.

5.2.4.1 Fishing

The main Scottish Sea Fisheries Districts along the northwest coast of Scotland are Wick (Barne *et al.* 1997c), Kinlochbervie, Lochinver and Ullapool (Barne *et al.* 1997c).

Fishing is an important industry in the area, although the industry is not as large as that seen on the north-east coast or Shetland. The industry employs 382 full-time and 157 part-time in the districts Wick-Ullapool, with the greatest number being employed in the Wick District with 191 full-time and 141 part-time. Employment in the area as a whole represents 7% of total employment in the Scottish fishing industry (Scottish Executive 1999).

UK vessels landed 46,365 tonnes of fish with a total value of £53 million into the four districts in the region in 1998, this represents approximately 13.5% of total landings by UK vessels into Scotland for that year. Greatest landings by weight were made into Ullapool and Wick districts with 9,865 tonnes and 16,965 tonnes respectively (Scottish Executive 1999). Landings of 13,461 tonnes and 6,075 tonnes were made into Kinlochbervie and Lochinver. However, in terms of value, landings into Wick and Kinlochbervie were the most important, with landing values of £21.6 million and £15.3 million respectively. Landings into Lochinver and Ullapool were worth £8.8 million and £7.9 million respectively.

Ullapool is the fourth most important port in Scotland in terms of pelagic landings after Shetland, Peterhead, Fraserburgh and Aberdeen. However, pelagic landings of 5,133 tonnes represented only 10.5% of total pelagic landings into Shetland (Scottish Executive 1999). Ullapool has been affected by the reduction in the klondyker fleet in the area, with significant reductions in terms of volume and values of landing, with a value of pelagic landings in 1998 of just over £1 million compared to £10 million in the early 1990's (Highland Council 1999). Landings into Wick are dominated by shellfish (3,642 tonnes in 1998) and demersal species (13,263 tonnes in 1998) (Scottish Executive 1999). Landings into

Kinlochbervie and Lochinver are mainly demersal species (13,143 tonnes and 5,513 tonnes respectively in 1998).

As at the end of 1998, there were 250 fishing vessels based in the four districts Wick-Ullapool, although not all were registered there. Over 50% of these are based in the Wick district in Scrabster and Wick harbours. The majority of vessels (over 67%) are small inshore fishing vessels. Over 95% of these are creel boats with the remainder employing hand lines, demersal gill nets, scallop divers, scallop dredgers and *Nephrops* trawls (Scottish Executive 1999). Of vessels over 10m in length, a mixture of fishing gear is employed ranging from larger creel vessels, *Nephrops* trawls, mechanical scallop dredges, demersal trawl (single and multiple nets) and demersal seines. There are no pelagic trawlers based in the region (Scottish Executive 1999), however Ullapool is an important port in terms of pelagic landings, in particular mackerel, and many pelagic vessels will base themselves there during the mackerel season (Barne *et al.* 1997c).

The make-up of the fleets in each area reflects the type of fisheries exploited locally, for example, Wick's fleet of vessels >10m which predominantly work out of Scrabster is dominated by scallop dredgers and larger creel vessels which will target the productive shellfish grounds around Orkney. These larger creel vessels may lay up to 1,000-1,500 creels per fishing trip compared with smaller creel vessels which will on average lay 200-300 creels per trip (Barne *et al.* 1997c). In comparison, Ullapool's fleet of 10m+ vessels is dominated by *Nephrops* trawls (Scottish Executive 1999), which will target the productive *Nephrops* grounds in the southern areas of the Minch and to the south of Skye. *Nephrops* landings from the Minch area represent approximately 34% of total UK landings (Barne *et al.* 1997c). A large fleet of demersal trawlers, most >20m, work out of Lochinver (Scottish Executive 1999). However, the majority of the demersal trawlers fishing along the northwest and in the Minch are registered on the east coast of Scotland but based at west coast ports such as Kinlochbervie, Lochinver and Mallaig (Barne *et al.* 1997c).

A salmon and sea-trout fishery also exists on the north Highland coast. Salmon and sea trout support rod-and-line fisheries from rivers as well as netting stations. Net and rod-and-line fishing is permitted on the coast, in estuaries and rivers (Barne *et al.* 1997b). The area is not as important for salmon and sea trout catches as the east coast of Scotland as the local rivers support smaller populations of salmon and sea trout. Four Scottish Salmon Fishery Statistical Districts lie across the north coast of Scotland: Hope and Grudie, Naver and Kinloch, Halladale and Strathy and Thurso and Fosso. Five-year average catches for these areas combined between 1989-1993 for salmon and sea trout were 14,731 tonnes and 744 tonnes respectively. This represents approximately 6% and 0.5% of total Scottish landings for these species.

Under the Inshore Fishing (Prohibition of Fishing and Fishing Methods) (Scotland) Order 1989 a number of areas have seasonal or full year prohibitions on use of fishing gear. In the north and northwest Highlands a number of closure areas exist (Barne *et al.* 1997c), including:

- Thurso and Dunnet Bay - full year closure on mobile fishing gear;
- Loch Laxford, Eddrachillis Bay, Enard Bay, Little Loch Broom and Gruinard Bay - seasonal closure on mobile fishing gear (October-March) and suction dredging (April-September).

Under the Food Protection (Emergency Prohibitions) (Dounreay Nuclear Establishment) Order 1997 a prohibition on all fishing for demersal, pelagic and shellfish species exists in an area to the north of Dounreay. The designated area is defined as the area of sea at the

Pentland Firth off the North Coast of Sutherland enclosed by a 2km radius taken from the outlet pipe at Dounreay Nuclear establishment.

5.2.4.2 Salmon Farming

There are two salmon farms on the north coast of Scotland, both located in Loch Eriboll (Fisheries Research Service 1999a and Crown Estate 2000e). There are also two smolt production units at Loch Eriboll (Fisheries Research Service 1999a). Further south along the west coast of the North Highlands there are greater concentrations of salmon farms, for example at Loch Inchard, Loch Laxford, Loch Nedd, Enard Bay, Badentarbat Bay, Loch Canaird, Loch Broom and Loch Ewe. Further south and around the coast of Skye there are even greater concentrations of salmon farms with the sheltered sea lochs and bays in these areas being ideally suited to sea-cage operations (Barne *et al.* 1997c).

The Northwest Highlands as a whole is a major salmon producing area in Scotland with 32,213 tonnes being produced in 1998. This equates to 29% of total Scottish production in 1998 (Fisheries Research Service 1999a). The combined Northwest Highlands and Western Isles area produces nearly half of the total Scottish salmon production tonnage (Barne *et al.* 1997c and Fisheries Research Services 1999a).

Salmon production in the North West Highland area has increased from 20,279 tonnes in 1993 to a peak in 1997 of 35,218 tonnes. Production dropped between 1997 and 1998 and is expected to fall further (Fisheries Research Service 1999a). As in Shetland, salmon production has been affected by suspected and confirmed outbreaks of Infectious Salmon Anaemia (ISA). ISA is a class 1 disease under EU Regulations and statutory management measures include compulsory slaughter of all fish, compulsory fallowing periods for infected sites and those in close proximity (up to 7km away) and restrictions on movement of fish and equipment in infected areas.

Salmon farming in the Northwest Highlands region employs 396 full-time and 43 part-time (Fisheries Research Services 1999a). The number of people employed on the north coast at Loch Eriboll is expected to be a small percentage of this. No figures are available for employment in the salmon processing and other support industries in the area. The salmon farming industry generated approximately £5.5 million income to the Northwest Highland area in 1998 (Fisheries Research Services 1999a). This figure does not include income from salmon processing, although this is expected to be important to the local economy. Fish farming is considered to be the most significant commercial activity in the region.

The Crown Estates is currently the lead licensing authority for all mariculture sites in Northwest Highland waters. The licensing regime has however been under review with concerns regarding the Crown Estate dual role in being landlord and “planning authority”. The licensing role is therefore to be passed to the local councils (Highland Council), although the timing of this changeover is still uncertain. Development of new farm sites in the region is still ongoing, with the Highland Council being consulted for six applications for new or modified seabed leases for salmon farms in 1996-1997 (Highland Council 1999). This trend is expected to continue. There was also a single application for a cod farm (Highland Council 1999). There were also indications of fish farm companies considering more exposed and remote sites as a means of expansion.

5.2.4.3 Shellfish Farming

There are eight shellfish farm sites on the north coast of Scotland, most located at Loch Eriboll with a single site at Kyle of Tongue. Of these six are for mussels, one for oysters (Kyle of Tongue) and a single mixed site for Pacific oysters and scallops (Barne *et al.* 1997c and Crown Estate 2000e). Mussels are on grown on ropes suspended from rafts or lines from naturally settled spats (Barne *et al.* 1997c). There are also a number of shellfish farms further south along the west coast, in particular at Loch Inchard, Loch Laxford, Eddrachillis Bay, Loch Glencoul, Bay of Stoer, Enard Bay, Loch Broom and Loch Ewe (Barne *et al.* 1997c). These are a mixture of predominantly mussel and oyster farms with limited scallop on growing seen as well.

There are an estimated 72 companies, operating 104 shellfish farm sites in the Highland region as a whole (Fisheries Research Services 1999b). Over 95% of these are located along the west coast. The Scottish shellfish industry is dominated by small producers with only a handful of large companies which make a significant contribution to overall production (Fisheries Research Services 1999b). In the Highland region as a whole there are 37 full-time, 51 part-time and 25 casual employees in the shellfish farming industry. No breakdown figures are available for employment on the north coast only.

A total of 2,479 tonnes of shellfish were produced by farms in the Highland region in 1998 (Fisheries Research Services 1999b). Of this, 1,182 tonnes were Pacific oysters, 391 tonnes mussels, 676 tonnes of queen scallops and 204 tonnes of scallops (Fisheries Research Services 1999b).

5.2.4.4 Tourism and Recreation

Tourism is an important part of the Highland economy and in the Highland area as a whole the distribution, hotel and catering industry accounts for 29% of employment (Highland Council 1999). Expenditure from tourists in the region in 1996 was estimated to be almost £370 million (Highland Council 1999). Visitor numbers recorded from visits to Tourist Information Centres in Caithness and Sutherland show that visitor numbers peaked in 1996 and then have subsequently fallen back to the level of previous years. The total number of visitors to the highland area was estimated to be just under 2 million in 1998 (Highland Council 1999).

The north Highland coast is an important tourist destination for visitors interested in its wild scenery, unspoilt coastal environment and outdoor sports and the North west Sutherland coast is officially recognised as the West Highland Tourist Route. The main significance of the region for water sports and leisure is derived from the unspoilt coastal and marine environment. However the local population is sparse and tourism activity is low in comparison with areas further south (Barne *et al.* 1996).

Beach leisure uses are much more limited in extent along the Highland coast than along the more heavily populated and popular holiday coasts further south (Barne *et al.* 1996). Although there are some spectacular beaches around Durness and Cape Wrath in the north western corner of Sutherland eg Sandwood Bay, and Loch Eriboll on the north coasts of Sutherland is the deepest sea loch in Britain. The Old Man of Stoer is a famous sea stack on the west coast which is a popular destination for climbers (Highlands of Scotland Tourist Board 2000 and Virtual Hebrides 2000).

There are many coastal paths in the region and the Highland Regional Ranger Service organise guided walks (Barne *et al.* 1996). Bird watching also takes place at many coastal locations. Sea angling occurs out of Scrabster. Scuba diving is popular among rock coasts, including the Kyle of Durness at the western extreme of the north coast. A small amount of surfing occurs at the beaches around Thurso.

There are a number of organised activities available to tourists along the North Highland coast, which involve the coastal and marine environments. These are summarised below:

- Marine wildlife and scenic tours by jet drive rigid inflatable boat are organised out of John O'Groats. These trips visit the Island of Stroma in the Pentland Firth, the stacks of Duncansby Head and other caves and geos along the north coast of Caithness. The same company also organises white water adventures in the Pentland Firth.

- Boat tours to Smoo caves near Durness and to Cape Wrath (the most north westerly point on the British mainland).

- Tours to Handa Island off the west coast of Sutherland operate during the summer months. Handa Island has some of the most significant seabird breeding colonies in the UK, including Britain's largest breeding colony of guillemots. It is also an important ancient burial ground.

- Marine wildlife and scenic boat trips to the Summer Isles take place from Ullapool. (Highlands of Scotland Tourist Board 2000).

5.2.4.5 Other Industry

Caithness and Sutherland is one of the most sparsely populated large areas of Britain. The north coast has a scattering of small crofting and farming communities, with Thurso, located in the north-east being the main centre of population (Barne *et al.* 1996).

There is very little industry along the north Highland coast. The Dounreay Nuclear site near Thurso, operated by British Nuclear Fuel Ltd (BNFL) and UK Atomic Energy Authority (UKAEA) has operated experimental fast breeder reactors and associated fuel processing plants for over 30 years. The 200MW Dounreay Fast reactor ceased generation of electricity in 1994. Since this time the relevance of Dounreay for 'energy' has disappeared, however the establishment will continue to be an important strategic subject for Highland because of the economic and /or environmental significance of a number of issues including, decommissioning works to the various reactors now shut down, reprocessing of spent fuel, rectification of previous contamination incidents and the long term storage of low level radioactive waste (Highland Council 1999).

Scrabster near Thurso, is the main port on the north coast of Scotland for commercial fishing and sea angling, and the base for the P&O ferry which operates between the Orkney Islands and the Scottish mainland. There are several small harbours along the north Highland coast (concentrated mainly in the east) at Portskerra, Sandside, Ham, Harrow and the islands of Stroma and Keiss. Port Vasgo represents the only small harbour along the western sector of the north coast (Barne *et al.* 1996).

Small crofting communities are common on the North Highland Coast, although many villages were abandoned during the 19th Century Clearances. Highland Council has established a Consultative Committee on Crofting to promote initiatives for crofting, which is important for sustaining population in rural communities (Barne *et al.* 1996).

The north coast of Highland has been identified as a potential development area for future coastal superquarries. Consultants for the Regional Council in 1993-4 studied the potential for a large coastal quarry in the Durness/Eriboll area. The overall conclusion of the study was that the balance of arguments did not favour any superquarry development in this area. An appropriate policy regarding future possible large coastal quarries in Highland is likely to be addressed in the impending Structure Plan Review (Highland Council 1999).

5.2.5 Sea Coastal Users - Faroe Islands

See Figure 22 for overview.

5.2.5.1 Fishing

The economy of the Faroe Islands is dependent on fisheries, with fishing, fish farming and processing contributing to over 96% of exports in 1997 (Hagstova Føroya 1999).

The majority of fishing takes place in the offshore waters of the Faroe Plateau, Faroe Bank and the surrounding deeper water areas, however the more shallow inshore waters are also fished.

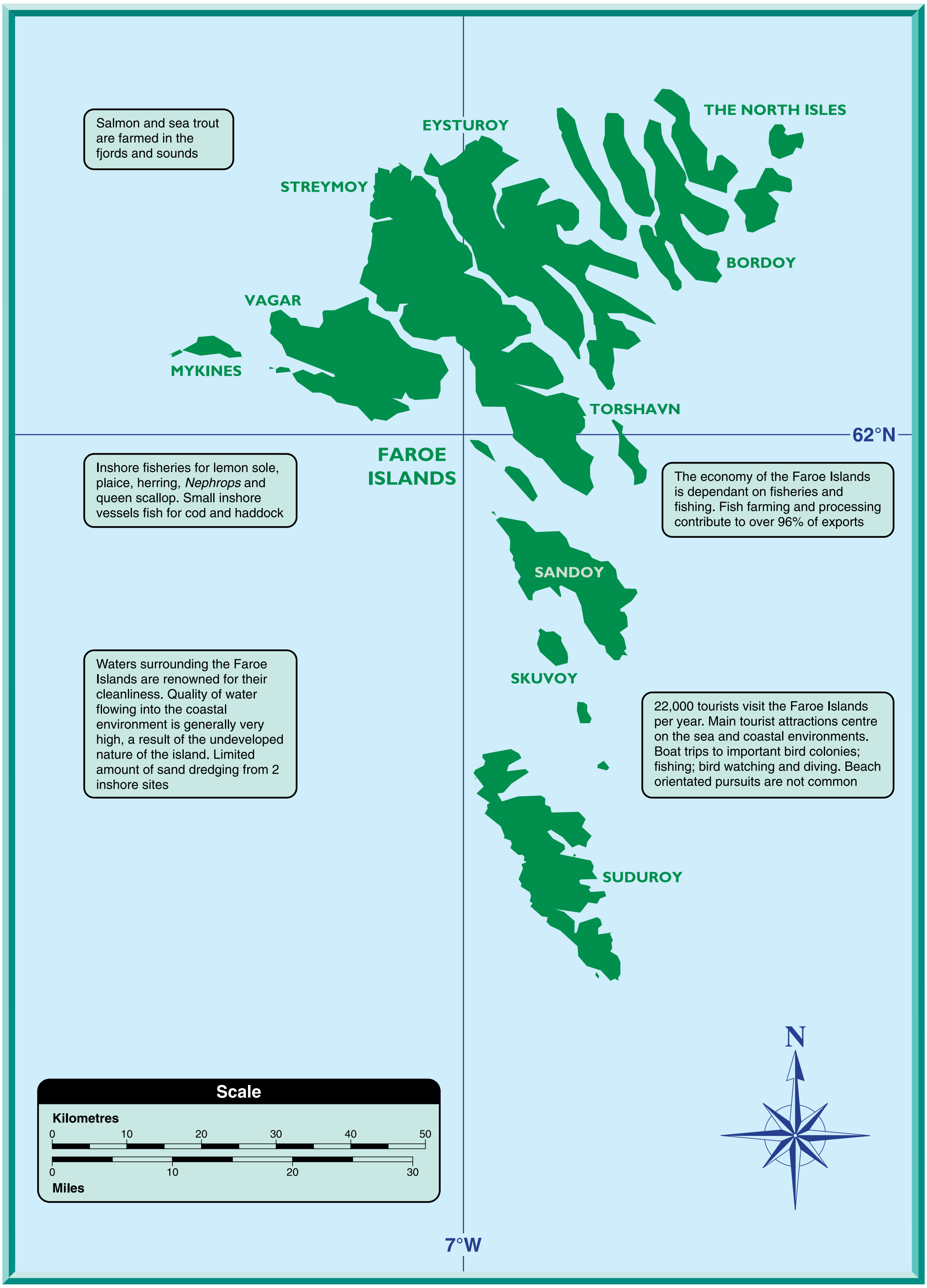
Small inshore vessels target species such as cod and haddock using small trawlers or hook and line and there is a small inshore gill-net fishery for herring (Jákupsstovu 1999). There is also an important inshore fishery (within 12 nautical mile territorial fishing limit) for plaice and lemon sole in water depths between 100 and 200 m.

A queen scallop fishery also exists in inshore waters particularly in grounds to the east of Faroe within 15 nautical miles. Queen scallops occur all around the islands, but two areas of particularly large concentrations are found on the Faroe Plateau, one to the north of the islands and one to the east (Bruntse 2000). The beds are found at 60-100 m on sandy, rocky or soft bottoms. The queen scallop ground to the east of Faroe is fished regularly, however no scallop dredging currently occurs in the northerly ground due to protests by long-line fishermen.

There is a Norway Lobster (*Nephrops*) fishery in the Faroese fjords. This species is caught in pots (not trawled for) and the fishing season extends from October through to February. However in recent years the season has been shorter as quota limits have been reached before February (Nicolajsen, per comm, cited in AMG 1997).

Whaling for pilot whales in coastal waters, is a traditional, non-commercial fishery, which has been carried out in the Faroe Islands (and other areas of the North Atlantic) for over 1,000 years. The pilot whale fishery is regulated by Faroese law that sets standards for the killing and usage of animals. The Faroe Islands are divided into nine whaling districts, with designated whaling bays (approximately 20). Each district is supervised by a sheriff and it is illegal for whales to be driven or beached anywhere other than in these authorised areas. Individual whaling bays or entire districts are closed for pilot whaling by governmental executive order when it is clear that further catches would create an over supply and this closure is common practice whenever the supply of meat and blubber is deemed sufficient by the district authorities (AMG 1997).

Figure 22 – Uses of the Faroese coastal area



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Schools are not often driven for more than 1 - 2 nautical miles and although drives can take place at any time of the year, the majority are during the summer months (July to September) when sea and weather conditions are better and there is a greater abundance of pilot whale prey. Statistics on the number of pilot whale drives per year and the number of whales caught indicate that on average there can be six drives per year with the average number of whales killed per drive in the region of 140 (Bloch 1998).

Under the 1986 regulations all whale species are fully protected, with the exception of the pilot whale and four other species: white-beaked dolphin, white-sided dolphin, bottlenose dolphin and harbour porpoise. Usually only very few of these species are caught each year and are most often taken when individual dolphins travel within a school of whales (Bloch 1998 and Sanderson 1994).

5.2.5.2 Aquaculture

Both salmon and trout are farmed around the Faroe Islands in the sheltered locations of the fjords and sounds. Some fjords are more suited to cultivation than others. Problems with sea lice and disease have seen a decline in the number of farms in production. This has been particularly true where too many farms were located in long narrow fjords where water exchange between the fjord and coastal water is not as good as that in more open and/or short fjords. During the 1980's there were over 60 farms in production but this has declined to less than 20 in 1999 (Dam, pers comm), although farms have increased in size. There appears to be a general move away from the more sheltered fjords to sea cage sites in better flushed areas. Most farms are located in the fjords and sounds around the islands of Eysturoy and Streymoy.

In 1997 approximately 16,000 tonnes of salmon and 1,250 tonnes of trout were exported, this represented 16% of the total Faroese export market (Hagstova Føroya 2000). As very little of the salmon produced in Faroe is consumed locally, this figure is representative of total production.

All salmon smolts and young rainbow trout are produced in land-based fresh water hatcheries. Traditionally, salmon smolts were put into sea-cages during the spring and trout in the autumn. Since 1993 with the introduction of new hatchery techniques, it has been possible to stock sea-cages with salmon smolts throughout the year. This has allowed the timing of salmon production to meet peak market demands, in particular Christmas and New Year (Reinert, pers comm cited in AMG 1997).

5.2.5.3 Tourism and Recreation

Tourism is the second largest industry contributing to the Islands' economy and the Islands' attract approximately 22,000 tourists per year (Faroese Tourist Board 2000). The long stretches of coastline are substantially undeveloped and boast an unspoilt natural landscape. Due to the islands geography, topography and dependence on the sea, all tourists visiting the islands gain a close appreciation of the coastline and the main tourist attractions concentrate on the sea and coastal environments.

A variety of boat trips operate throughout the islands. Trips are available to view seabird colonies including Vestmanna on the west side of Streymoy and Skúvoy off the west coast of Sandoy. Fishing trips take place from Suduroy and some of the northern islands, there are trips to 'Enniberg' the highest sheer headland in Europe and the restored sailing ship the Nordlysid operates daily trips out of Tórshavn. The Tourist Board also advertises deep-sea fishing charters and scuba diving excursions. Organised outdoor pursuits such as cliff top hiking, bird watching, cycling and horseriding are also available to tourists. The islands also have various sites of historical interest (Faroese Tourist Board 2000).

In addition to the marine and coastal tourist orientated attractions and activities, there are a limited number of recreational uses of the coast. Sea angling from the coast or boats for cod, haddock and saithe is common amongst islanders and tourists with the most popular months being August and September. Salmon and sea trout are important recreational fisheries. The main fishing season is July to September when fish are caught both along the coast and in lochs.

During the summer there are local festivals almost every weekend from early June to late August. Rowing competitions take place at each festival in traditional Faroese boats (AMG 1997).

Swimming, sunbathing and other beach orientated pursuits are not common. The number of sandy bays along the Islands' coasts are limited and even during the summer, the sea temperature is low. In the event that temperatures do rise enough to attract people to the coast, the beaches at Laynar and Gøtusandur are likely to be the most popular. However, they can only be expected to busy a few days each year (AMG 1997).

5.2.5.4 Other Industry and Coastal Users

The waters surrounding the Faroe Islands are renowned for their cleanliness and the quality of water flowing into the coastal environment is generally very high, a result of the undeveloped nature of the Islands. Although all centres of population are located along the coast, no areas of coastline can be described as heavily urbanised.

The economy of the Islands is dependent on fisheries, with fishing, fish farming and processing contributing to over 96% of exports in 1997 (Hagstova Føroya 1999). Other exports include ships (fishing and cargo vessels) and woollen products, (accounting for 4.3% of exports in 1997). Local industry is therefore largely related to the fishing industry (see above), or dependent upon products from fishing.

The Faroes had a strong economy for many years resulting from good fishing, high fish prices, and considerable private and public investment programmes due to a good access to the international finance market. However this reversed in the early 1990's when the country experienced severe economic decline. Drastically reduced fish catches, due to over fishing and changes in oceanic conditions, followed by a fall in fish prices resulted in a 30% drop in GDP over 4 years. This decline left the Islands with one of the world's heaviest per capita debts, (over 8,000 million DKK in 1990, which has subsequently reduced to approximately 4,000 million DKK in 1995). Thus the economy of the Faroes is vulnerable to change, in particular to fluctuations in fish catches, fish prices, exchange rates and the prices of import products.

Ferries form an important part of communication through the movement of local population and trade between islands within the Faroes. The frequency of ferry connections varies from two per week to ten per day, but some routes are served by passenger boats only. The most frequent sailings are between Vestmanna on Streymoy and Oyrargjógv on Vágar (the island on which the airport is situated) and between Leirvík on Eysturoy and Klaksvík on the northern Island of Bordoy (Anon 1996b).

External merchant shipping traffic in and out of the islands is dominated by international arrivals and departures of ferries, cargo vessels and cruise liners. International passenger and car ferries operate to and from Iceland, mainland Europe and the UK. The Smyril Line operates a weekly passenger and car ferry service during the summer (May to September) between the Faroe Islands, Denmark, Norway, Shetland Islands and Iceland, and during the winter there is a weekly ferry service between the Faroe Islands and Denmark (Faroese Tourist Board 2000). Cruise liner visits to the Islands have steadily increased over recent years and in 1995 totalled 25 throughout the summer season (AMG 1997). The Iceland based Eimskip and the Faroese based Faroe Line are the main cargo vessel operators to and from the Faroe Islands. They operate routes between Mainland Europe, UK, Iceland and Tórshavn.

As mentioned previously, a considerable part of the Islands internal traffic takes place by sea and a necessary part of the development of the Islands' modern society has been the construction of ports and harbours. The seven largest harbours in the Islands, based on levels of activity in 1996, were: Tórshavn and Kollafjørdur on Streymoy, Klaksvík in the north Isles, Fuglafjørdur and Runavík on Eysturoy, and Tvøroyri and Vágur on Suduroy (AMG 1997). The main harbours can accommodate vessels of 6 - 7m draught (deeper facilities may be available at some locations, but contact with the appropriate harbour is required prior to arrival) and 100 m in length. Most locations were originally designed as fishing harbours and for general cargo, although some container equipment is available at Tórshavn, Runavík, Klaksvík and Tvøroyri.

There are two main sites for commercial sand dredging in the Faroes, one located in the sound between the islands of Streymoy and Eysturoy and the other in a sound in the North Isles. Some 10,000-15,000 cubic metres of sand are extracted from each site per year. Three dredging vessels operate between the different sites (Poulsen, pers comm, cited in AMG 1997).

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