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Deep-sea Fishes Literature Review

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Summary

Information available on eleven species of fish regarded as potential features of designation interest for a proposed large-scale deep-sea marine protected area offshore to the west of Scotland waters is reviewed. The distribution and status of each species are reviewed together with accounts of the life cycle and fisheries exploitation.

Three species, the gulper shark, Atlantic halibut and orange roughy are very rarely encountered in surveys. The gulper shark is of uncertain status. This is the southern limit of the Greenland halibut which probably only occurs in the Faroe-Shetland channel and further north. Fisheries for the sharks, porbeagle, spurdog, leafscale gulper and Portuguese dogfish are all prohibited. The round-nose grenadier, blue ling, anglerfish and Greenland halibut are fished commercially within total allowable catch limits. For the roundnose grenadier, blue ling, anglerfish and orange roughy the study area provides important areas for spawning and may be of critical importance as a source of juveniles within the area and for surrounding seas. The study area contains distinctive habitat for endangered species of deep-sea sharks, the gulper sharks and Portuguese dogfish.

Protection across the study area could eliminate some bycatch of species for which there is already a zero Total Allowable Catch (TAC) and protect important spawning areas and spawning aggregations which are vulnerable to targeted fishing.

Contents

1 Introduction

The specified aim of the project is:

A detailed literature review aimed to collate available information and evidence to support the presence of deep-sea features of interest in offshore Scottish waters.

The list of features is drawn from the following sources:

- Scottish Priority Marine Features (PMFs)[1]
- Scottish Biodiversity list[2]
- OSPAR Threatened and/or Declining (T&D) species and habitats[3]

And comprises the species listed in Table 1

Table 1. List of Features in the assessment for evidence investigation

Feature name	Scientific name	Scottish PMF	Scottish Biodiversity list	OSPAR T&D
Porbeagle	*Lamna nasus*	Y	Y	Y
NE Atlantic spurdog	*Squalus acanthias*	Y	Y	Y
Gulper shark	*Centrophorus granulosus*	N	N	Y
Leafscale gulper shark	*Centrophorus squamosus*	Y	Y	Y
Portuguese dogfish	*Centroscymnus coelolepis*	Y	Y	Y
Round-nose grenadier	*Coryphaenoides rupestris*	Y	Y	N
Blue Ling	*Molva dypterygia*	Y	Y	N
Monkfish/Anglerfish	*Lophius piscatorius*	Y	Y	N
Orange roughy	*Hoplostethus atlanticus*	Y	Y	Y
Atlantic halibut	*Hippoglossus hippoglossus*	Y	Y	N
Greenland Halibut	*Reinhardtius hippoglossoides*	Y	Y	N

In this report the literature is reviewed on the status of these species within an area of search for a proposed deep-sea national marine reserve to be established in offshore Scottish waters referred to in this report as the “study area” (Figure 1).

The focus in the literature review has been on information relevant to the study area. For example, for species with a global distribution (e.g. orange roughy) the extensive literature from the Southern Hemisphere has not been reviewed except where it provides vital information. Where possible, data from within the study area have been used to write the species accounts or from the nearest available areas.

1.1 The study area

The study area comprises the deep water to the west and north of Scotland from the 800m depth contour on the continental slope to the outer limit of the Scottish Exclusive Economic Zone (EEZ) (Figure 1) including the entire water column from the surface down to the sea floor within those boundaries. Offshore areas with depths less than 800m on Rockall Bank, Anton Dohrn Seamount, Rosemary Bank, Rockall Rise, and slopes of Outer Bailey, Bailey’s Bank and the Wyville Thomson Ridge are also included in the study. The study area comprises two distinct biogeographic areas, the Rockall Trough south of the Wyville Thomson Ridge (ca. 60°N) and the Faroe-Shetland Channel to the north. The Wyville

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[1] https://www.snh.scot/professional-advice/safeguarding-protected-areas-and-species/priority-marine-features-scotlands-seas

[2] http://www.biodiversityscotland.gov.uk/advice-and-resources/scottish-biodiversity-list/

[3] https://www.ospar.org/work-areas/bdc/species-habitats/list-of-threatened-declining-species-habitats

Thomson Ridge at about 500m depth acts as a boundary between cold Arctic bottom waters to the north and the warmer Atlantic waters to the south. The Rockall Trough is a tongue of the North Atlantic basin that extends northwards to the west of Scotland with depths down to over 2000m between the Scottish continental shelf and Rockall Bank, punctuated by shallows over the Hebrides Terrace Seamount, Anton Dohrn Seamount, Rosemary Bank Seamount and the Rockall Rise (Figure 2). Along the edge of the continental shelf edge there is a slope current at 400-500m depth with relatively warm but dense water (some originating from the Mediterranean Sea) flowing northwards. This provides continuity with slope habitats around Ireland and the Bay of Biscay that lie upstream. The surface flow is dominated by the North Atlantic current, a branch of the Gulf Stream that carries warm water north eastwards across the area towards Norway. Cold deep Arctic water spills southwards over the ridges between Scotland and Iceland acting as one of the main sources of cold bottom water in the world's oceans, part of the great ocean conveyor (Broeker 1991). The Rockall Trough was the site of some of the earliest investigations of life in the deep sea and has been termed by Gordon (2003) as the *Cradle of Deep-Sea Biological Oceanography*.

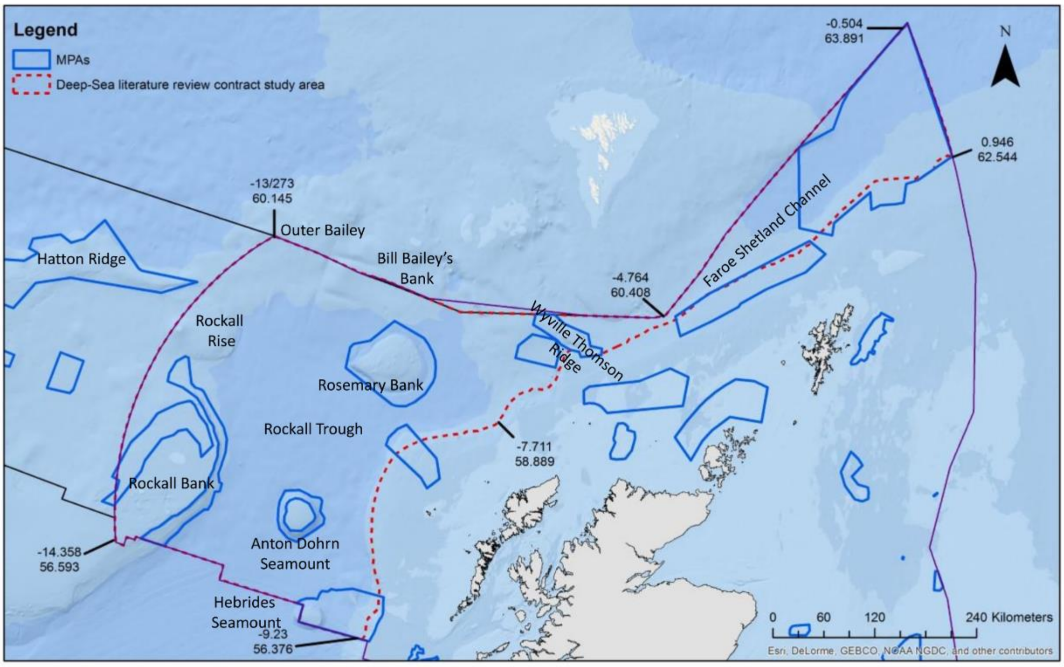

Figure 1. The existing offshore Marine Protected Area (MPA) network (blue lines) in Scottish waters and the study area for identification of a deep-sea marine reserve (red dashed line). The black line indicates the boundary of the extended Scottish continental shelf beyond the 200 nautical mile fisheries limit. [4]

The Faroe-Shetland channel slopes from 800m depth, north of the Wyville Thomson Ridge to over 2000m where it joins the Norwegian Deep. The study area covers the eastern slopes of the channel to the west of Shetland. The surface waters are dominated by warm water >6°C from the Atlantic, at middle depths 600-800m there are Nordic intermediate waters and the greatest depths are filled with cold <0°C bottom water (Bullough *et al* 1998). These waters are in constant motion including internal waves creating very complex environmental conditions for the animals that live there.

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[4] © JNCC 2018. Contains OD data © Crown copyright and database right 2016 and contain public sector information from multiple sources, licensed under the Open Government Licence v2.0, from the United Kingdom Hydrographic Office. Contains derived data from Ordnance Survey © Crown Copyright. 100001974 (20154). World Vector Shore © US Defense Mapping Agency. Not to be used for navigation. Map Projection: Europe Albers Equal Area Conic.

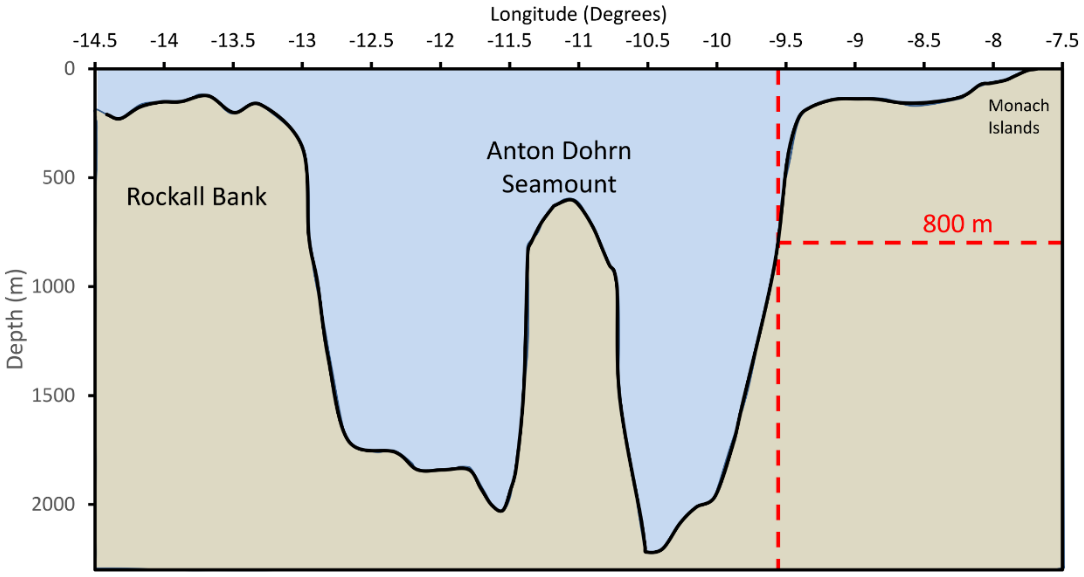

Figure 2. Section through the study area. From the Monach Islands (57.532°N 7.720°W) along a bearing of 269° across the Anton Dohrn Seamount to the Rockall Bank. Original diagram based on bathymetry from GEBCO (General Bathymetric Chart of the Oceans) extracted with the aid of Google Earth Pro. The red dashed lines denote the inshore boundary of the study area at 800m depth.

For the purposes of fishery statistics and management, ICES (International Council for Exploration of the Seas) divides the NE Atlantic into areas and Subareas (Figure 3). The Rockall Trough part of the study area is within ICES Subarea 6[5] which is divided into Subarea 6a from inshore to the middle of the Rockall Trough and 6b further offshore. Approximately half of Subarea 6b is within the EEZ and the western half is in international waters. The Faroe-Shetland Channel part of the study area straddles ICES Subareas 5b (Faroes), 4a (northern North Sea) and 2a (Norwegian Sea). This makes it very difficult to identify the catches from the Faroe-Shetland Channel part of the study area.

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[5] ICES in the past used Roman numerals for the Subareas.

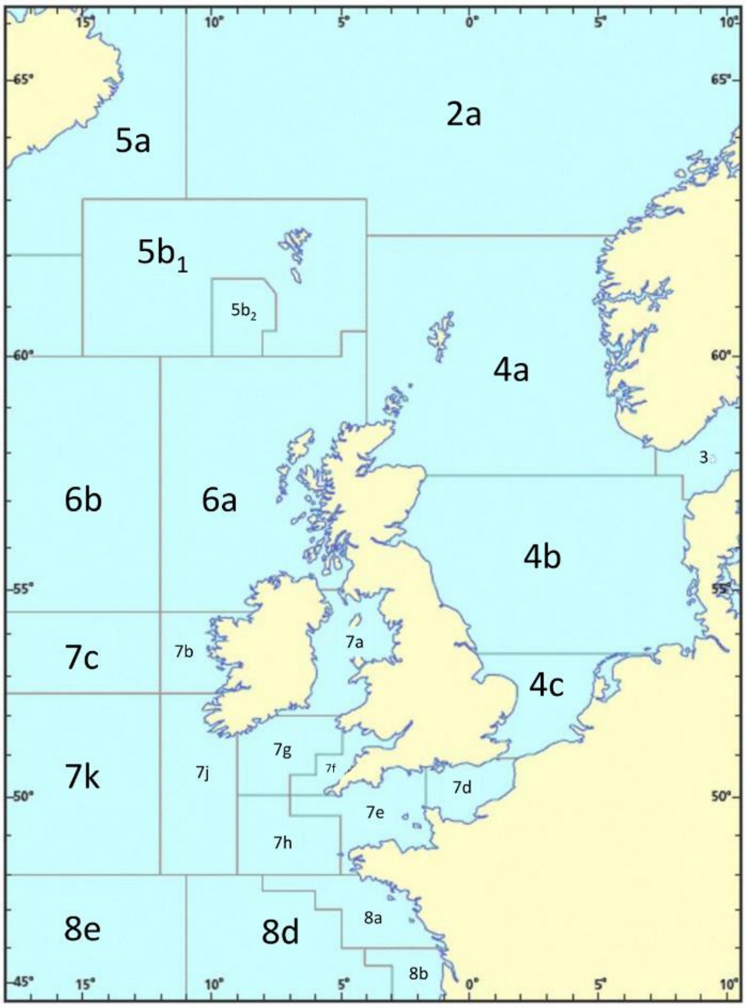

Figure 3. ICES areas. (after Sea Fisheries Protection Authority, Ireland[6])

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[6] http://www.sfpa.ie/Portals/0/Sea-Fisheries%20Conservation/ICES%202%20for%20website.gif

2 The deep-sea features of interest

The deep-sea features of interest considered in this report are all fishes.

The porbeagle (*Lamna nasus*), spiny dogfish (*Squalus acanthias*), gulper shark (*Centrophorus granulosus*), leafscale gulper shark (*Centrophorus squamosus*) and Portuguese dogfish (*Centroscymnus coelolepis*) are sharks belonging to the subclass Elasmobranchii, (Nelson 2006). The porbeagle is a member of the order Laminiformes: large fast-swimming sharks that have occupied the surface layers of the oceans for about 160 million years since the mid-Jurassic period (Sorenson *et al* 2014). The other sharks all belong to the order Squaliformes that originated over 200 Million years ago in the Triassic but colonised the deep sea and survived through the end-Cretaceous (K-Pg) mass extinction event (notable for the loss of the dinosaurs) 66 million years ago by virtue of their deep-water refuge (Kriwet & Benton 2004).

The round-nose grenadier (*Coryphaenoides rupestris*) and blue ling (*Molva dypterygia*) are bony fishes of the order Gadiformes (cods) that originated in the deep sea (Howes 1991) about 80 million years ago in the late Cretaceous (Near *et al* 2012), survived the K-Pg mass extinction after which some species (e.g. cod and haddock) have reinvaded shallow waters. The monkfish or anglerfish (*Lophius piscatorius*) is a relatively shallow-living member of the order Lophiformes that originated in the mid Cretaceous, about 120 million years ago and includes numerous bizarre anglerfishes peculiarly adapted to conditions in the abyss (Miya *et al* 2010).The orange roughy (*Hoplostethus atlanticus*) is a member of the very diverse order of spiny bony fishes the Beryciformes that originated in the early Cretaceous 140 million years ago but expanded greatly after the K-Pg mass extinction (Near *et al* 2013). The Atlantic halibut (*Hippoglossus hippoglossus*) and Greenland halibut (*Reinhardtius hippoglossoides*) are both flatfishes of the order Pleuronectiformes that emerged in the last 50-70 million years from Cretaceous ancestors and live mostly in shallow waters (Campbell *et al* 2013).

2.1 Porbeagle *Lamna nasus* (Bonnaterre 1788)

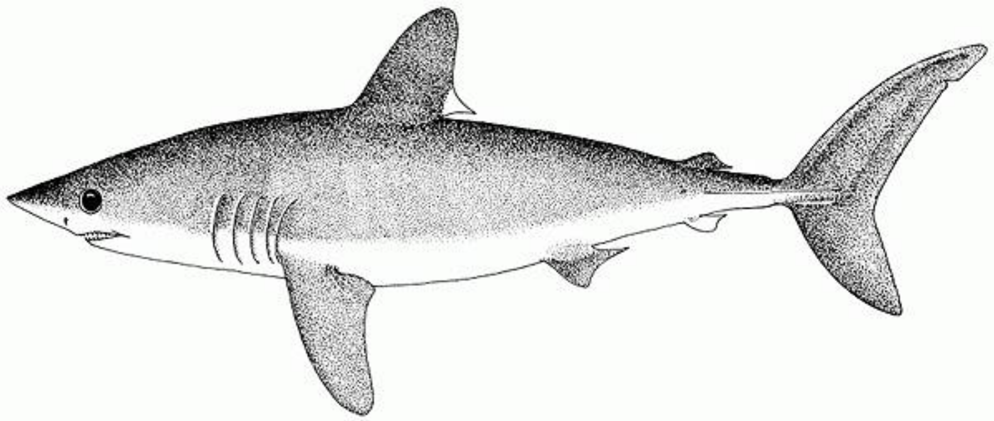

Figure 4. Porbeagle *Lamna nasus* (FAO image Compagno 1984)

The porbeagle shark belongs to the family of oceanic sharks known as the Lamnidae or mackerel sharks that includes the great white shark and the mako sharks (Nelson 2006). The Lamnidae are mobile top predators throughout the tropical to cool-temperate regions of the world's oceans. The porbeagle and its North Pacific cousin the salmon shark (*Lamna ditropis*) are the most cold-tolerant species in the family and are found mostly in temperate to subpolar waters. The porbeagle may have the widest temperature tolerance of any shark having been caught at sea surface temperatures of 2-23°C (Campana & Joyce 2004). They possess counter-current heat exchangers (retia mirabile) in the blood system that maintain temperatures in the muscles, brain, eyes, liver and other vital organs up to 16°C higher than that of the surrounding seawater according to data from the salmon shark (Anderson & Goldman 2001). The porbeagle grows to a maximum length of 350cm, the length range in Scottish waters being 81-288cm (median 185cm, mean 206cm) for males and 91-317cm (median 199cm, mean 214cm) for females (Gauld 1989). The diet generally comprises small and medium-sized pelagic schooling fishes, other sharks, squid and demersal fishes. In Scottish samples, the most common food items in rank order are cephalopods, herring, gadoid fishes and mackerel with some benthic invertebrates and one report of a seabird found in a stomach (Gauld 1989). In the absence of landings there are no more recent data on diet in Scottish waters.

2.1.1 Distribution and status in the study area

Porbeagles occur both in the Northern and Southern Hemispheres, circumglobally in the Southern Hemisphere but are confined to the North Atlantic and the Mediterranean Sea in the Northern Hemisphere. The study area is at the centre of the range of the species in the NE Atlantic (Figure 5).

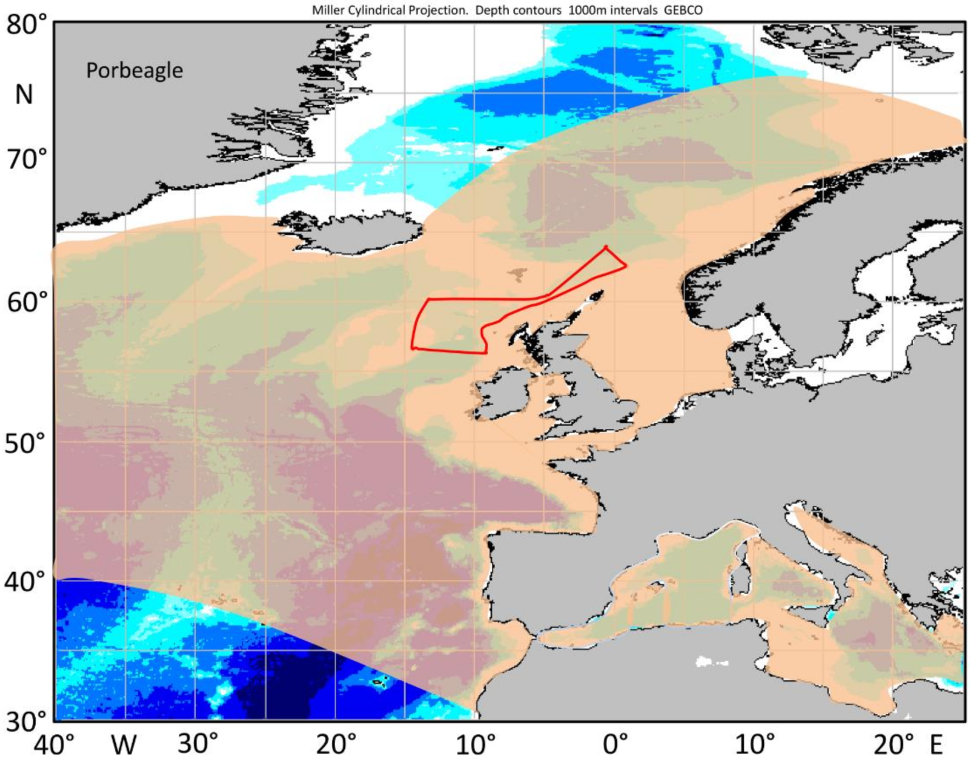

Figure 5. Range of the porbeagle (*Lamna nasus*) in the NE Atlantic and Mediterranean (orange shading). Red outline is the study area. The blue shading denotes 1000m depth increments, i.e, 1000, 2000, 3000, 4000 and >5000m. After Froese & Pauly (2017) and other sources.

Pioneering tagging work by Stevens (1976) showed that porbeagles tagged off SW England can make extensive migrations as far as Denmark in the north and to the coast of Spain in the south. However, using satellite tags Pade *et al* (2009) showed that during the summer months in the Celtic Sea area porbeagles occupy relatively localised areas of 8,000 to 90,000km^2 on the continental shelf between South West England, South Wales and Ireland but in the autumn move offshore into deeper water. Pade *et al* (2009) conclude that porbeagles in the NE Atlantic show fidelity to particular areas such as the Celtic Sea and English Channel but with long distance, possibly seasonal, movements away from such areas. Saunders *et al* (2011) found that in winter, porbeagles tagged off the North of Ireland made extensive migrations into deep water down to depths of 700m with one individual swimming as far as Morocco, 2400km to the south, which suggests that they exploit concentrations of pelagic fishes such as mackerel that tend to occur along the shelf edge. Biais *et al* (2017) found that individuals tagged in the Bay of Biscay in June and July could migrate to the Mid-Atlantic Ridge, Madeira and the Arctic Circle but showed a strong tendency to return the following spring to areas close to the starting point. Four of the nine individuals tagged in the Bay of Biscay passed through the study area off the west of Scotland during a northward migration in the Autumn. Gauld (1989) suggested there is an annual influx of migrating sharks into the North Sea during the second half of the year possibly pursuing shoals of herring or other prey. It is clear that the porbeagle is a widely distributed migratory species and individuals do transit through the study area but in the absence of any Scottish tagging studies there is no evidence that this might be a preferred area. The overall average speed in the study by Saunders *et al* (2011) was 28km per day which would predict a transit time through the study area of the order of one week. Porbeagles were found to exploit the water column, predominantly the mesopelagic >200m depth from autumn to spring and the epipelagic < 200m in the summer. Although one porbeagle reached a depth of 1600m, they rarely venture deeper than 700m (Froese & Pauly 2017) and therefore are unlikely to interact with the deeper areas of sea floor in the study area. Ellis and McCully Phillips (2015) state that porbeagles may forage near the sea floor but few are caught in bottom trawls, being recorded at 72-680m depth around the British Isles. Campana and Joyce (2004) found that porbeagles in the NW Atlantic have a preferred temperature range of 5-10°C (mean 7.4°C) regardless of the time of the year. Biais *et al* (2017) suggest that the return migration pattern they observed may represent homing behaviour towards breeding grounds in the Biscay area but captures of gravid females with large embryos east of Scotland and around Shetland (Gauld 1989) suggest that there may also be breeding grounds in Scottish waters. Genetic studies (ICES WGEF, Working Group on Elasmobranchs, 2017) show no differentiation between populations in the eastern and western North Atlantic although transatlantic migration is rare. The Southern Hemisphere porbeagles are genetically quite distinct from those in the North Atlantic.

2.1.2 Life history

Porbeagles are ovoviviparous producing one-five live young, usually four, per litter at a size of 60-80cm total length. The embryos develop inside the mother, ingesting successive batches of eggs released into the uterus. In Scottish waters Gauld (1989) observed that two embryos are commonly present in each of the two horns of the uterus explaining the usual fecundity of four in fully grown females. It is generally assumed that gestation lasts eight-nine months with mating in late summer and pups born the following spring (Froese & Pauly 2017); however, Gauld (1989) points to evidence that gestation could last up to two years. It is assumed that mating and pupping occur along the continental shelf edge at depths of just over 200m. A study by Natanson *et al* (2001) in the NW Atlantic shows that following birth, the young porbeagles grow to 1.49m length at five years, 1.88m at 10 years and 2.37m at 20 years. They estimated that life span or longevity could be up to 46 years in an unfished population. Males become sexually mature at eight years (1.74m length) and females at 13 years (2.18m). Since growth slows down at maturity, males tend to be slightly smaller than females as noted by Gauld (1989) in Scottish catches where the sex ratio was 1.3 females for every male. It is suggested that there is a nursery ground at the southern end of the Irish Sea in St Georges Channel and a pupping area along the western Celtic Sea shelf edge (ICES WGEF 2017), implying the new-born sharks move inshore onto the continental shelf to grow and it is the adults that migrate offshore. There may be other pupping and nursery areas within the species range in the NE Atlantic. Other than transit by tracked adult individuals and catch records, there is no direct evidence of utilisation of the study area by different life history stages. Gauld (1989) shows a hotspot of historic catches in the Rockall area.

2.1.3 Exploitation and management

The meat of the porbeagle is of high quality creating significant market demand in addition to the generic shark products, fins, liver oil, leather and fish meal. Targeted fishing in Scottish waters was first carried out by Norwegian vessels, followed by Denmark and France (Gauld, 1989). Landings by Scottish fishermen were largely incidental catches taken in a variety of fishing gears which included trawls, seine nets, gill nets and long lines along with some taken by sports fishermen. Of 2399 tonnes of Scottish landings reported to the Marine Laboratory, Aberdeen, from 1954 to 1987, 62% were from the North Sea and 37% from the west coast ICES areas 5 and 6, corresponding to the study area. Total annual landings of porbeagle from the NE Atlantic peaked at over 6000 tonnes in 1948 followed by a decline to less than 1000 tonnes by 1980; a zero TAC (total allowable catch) was implemented by the EU in 2010. Incidental landings since then have been estimated at 34 tonnes per annum (ICES WGEF 2017). This is interpreted as a classic case of a boom-and-bust elasmobranch fishery; however, the decline is partly explained by shifts in fishing effort to other species and other areas. In addition to targeted fishing, porbeagles are vulnerable to capture by long-lines set for pelagic species including swordfish (*Xiphius gladius*), yellowfin tuna (*Thunnus albacares*), and bigeye tuna (*Thunnus obesus*). In the NW Atlantic, Gallagher *et al* (2014) show that porbeagles have a relatively high chance (78%) of surviving if released after capture by long-line.

ICES WGEF (2017) which provides advice on management, updates its work every four years, with the next assessment due in 2019. The porbeagle is considered a “widely distributed and migratory stock”. ICCAT (International Commission for the Conservation of Atlantic Tunas) also has an interest in the porbeagle and proposes a joint assessment with ICES in 2019. The porbeagle remains a prohibited species under EU fisheries regulations in all waters. Norway banned all direct fisheries for porbeagle from 2007; since 2011 live bycatch must be released but dead specimens can be landed. In the absence of regular catches there is a paucity of reliable information on the status of NE Atlantic porbeagle. The Working Group considers that targeted fishing should not be restarted without a means of monitoring stock abundance and means of avoiding bycatch and improving survival of discards should be addressed. The porbeagle in the North-East Atlantic is the subject of Multilateral Environmental Agreements with OSPAR, CMS and CITES.

2.1.4 Data and knowledge deficiencies

Other than evidence that porbeagles do transit through the area there is very little information on how they utilise the study area and no information on whether there are any pupping or nursery grounds. For the future, in the absence of fishery information, new research methods, e.g. tracking, are necessary to understand the biology of porbeagle off the west of Scotland

2.1.5 Conclusions

Porbeagle sharks are likely to be present in the surface waters throughout the study area, either feeding or during the course of migrations. Feeding may be focussed on prey fish concentrations along the outer edge of the continental shelf along the eastern boundary of the study area or around the Rockall bank. Most of the sea floor in the area is too deep for porbeagle to use for pupping or as nursery ground.

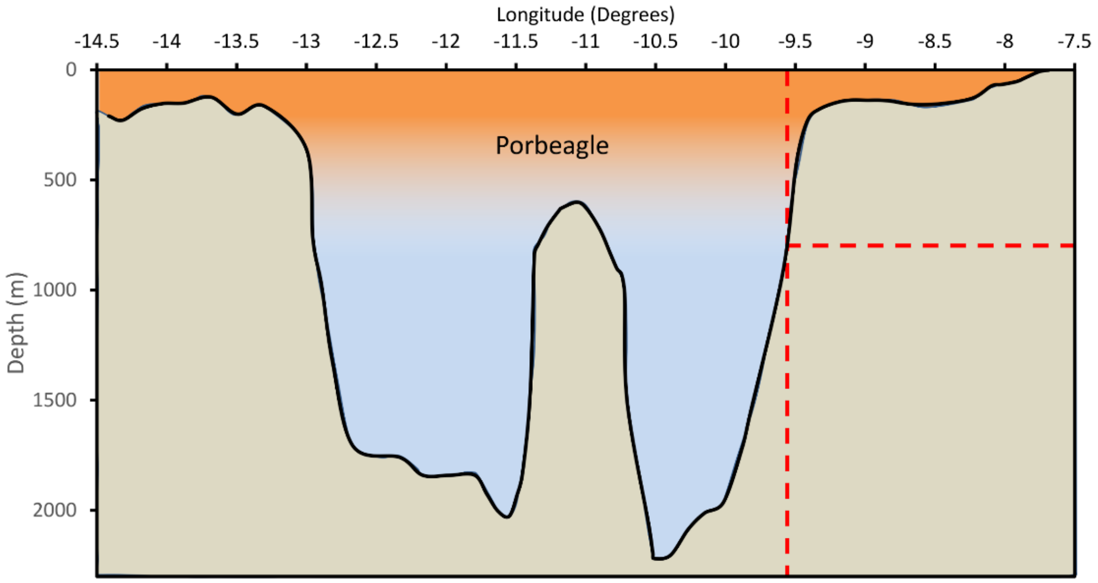

Figure 6. Section of the study area with intensity of orange shading showing the probable depth distribution of Porbeagle shark based on information from the relevant literature cited in the text.

The benefits of any marine reserve need to be evaluated in the context of the wide range of the stock in the North Atlantic with reference to ICCAT and other international bodies.

2.2 North East Atlantic spurdog / spiny dogfish *Squalus acanthias* (Linnaeus 1758)

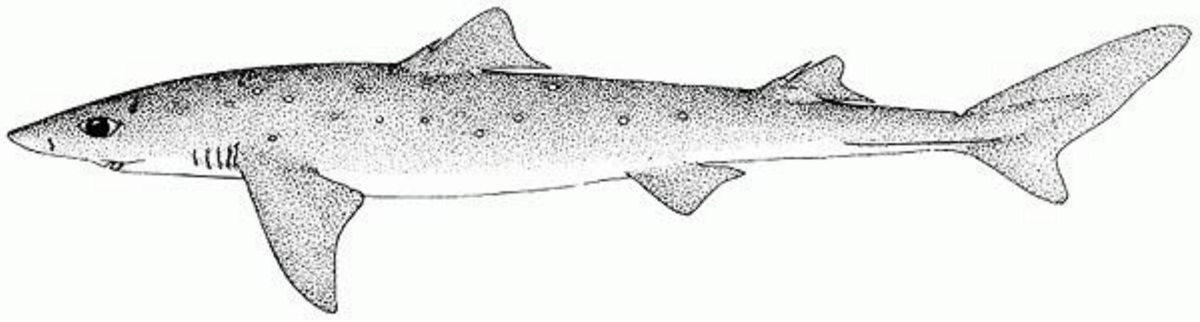

Figure 7. NE Atlantic Spurdog, *Squalus acanthias.* FAO name: Picked dogfish. (FAO Image Compagno 1984).

The spurdog is a member of the family Squalidae which comprises about 30 species mostly of small sharks, known as dogfish, found from inshore to 1400m depth (Priede 2017). The NE Atlantic spurdog has a spine on the leading edge of each of its two fins and grows to a maximum reported length of 160cm, though in the NE Atlantic adults are commonly 80-100cm long (Jones & Ugland 2001). Its behaviour is versatile, feeding on the seafloor, in midwater and near the surface. In Scottish waters the main components of the diet are small pelagic fishes, herring, sandeels and mackerel as well as the bentho-pelagic species whiting (*Merlangius merlangus*) and Norway pout (*Trisopterus esmarkii*). Pelagic invertebrates, euphausiids, cephalopods, ctenophores, coelenterates and salps are also important (Rae 1967). Unidentifiable material in the stomachs suggests that gelatinous prey, which is difficult to identify, may make up a significant proportion of food intake. Hanchet (1991) reports that in New Zealand waters smaller individuals mainly feed on planktonic invertebrates, switching to fish and more benthic prey as they increase in size. Cannibalism has been observed off New Zealand where adults eating young hatchlings may play a role in population regulation, but this has not been noted in Scottish waters. Dunn *et al* (2013) characterised the diet of *S. acanthias* off New Zealand as benthic to pelagic fishes, but adaptive including scavenging. Off Scotland there was concern that consumption of herring by spurdog might deplete or influence the migrations of herring stocks but Holden (1966) concluded there was no evidence for these assertions.

2.2.1 Distribution and status in the study area

The spurdog *Squalus acanthias* is a cosmopolitan species occurring in both the Northern and Southern Hemispheres, in the Atlantic Ocean from the Barents Sea and Greenland in the north to Argentina and South Africa in the south. It is also found in the Southern Indian Ocean, around Australia and New Zealand and across the South Pacific and it has been suggested that it may be the most abundant living shark. The Pacific spiny dogfish in the North Pacific is now recognised as a separate species (*Squalus suckleyi*) and there have been suggestions that *Squalus acanthias* should be split into a number of species or sub-species (Ebert *et al* 2010). Molecular genetic studies by Veríssimo *et al* (2010) support the differentiation between the North and South Pacific Oceans but show negligible difference between the NW and NE Atlantic, probably reflecting a small degree of transatlantic migration. The North Atlantic and Southern Hemisphere populations form a closely related group. The spurdog is primarily a temperate to subpolar species (Figure 8) in brackish inshore waters to a maximum reported depth of 1460m though usually between 10-200m depth.

It is evident that the study area is at the centre of distribution of *Squalus acanthias* in the NE Atlantic Ocean. In a series of tagging studies Aasen (1958, 1960, 1961) found that spurdogs move extensively between the west of Scotland, Shetland, the Faroes and the coast of Norway, suggesting that there is a distinct Scottish-Norwegian stock with limited interaction with a putative southern stock centred on the English Channel (Ellis 2015). Nevertheless, ICES WGEF (2017) consider that this is a mobile species and that there is a single stock present throughout the ICES area of the NE Atlantic from the Barents Sea to the Bay of Biscay. Satellite tracking of spiny dogfish in the NW Atlantic (Carlson *et al* 2014) indicates that northern groups (tagged at 43°N) move over a temperature range of 2.8- 19.2°C and southern (tagged at 36°N) over 5.5-22.1°C but with a strong preference for intermediate temperatures around 8.8-13.8°C with seasonal and latitudinal variations. These fish showed relatively localised seasonal migrations. The mean depth occupied by the sharks was 27m in the north and 93m in the south indicating that they spend most of their time above the sea floor foraging in mid-water thus confirming the diet observations of Rae (1967) for Scottish waters, i.e. that this is primarily a pelagic feeder. Neat and Campbell (2011) reported that spurdog are caught by demersal trawls both on the west coast continental shelf of Scotland and on the Rockall plateau confirming that the species distribution spans the study area as observed by Ellis (2015) who noted a peak of catches at 125m depth west of the British Isles.

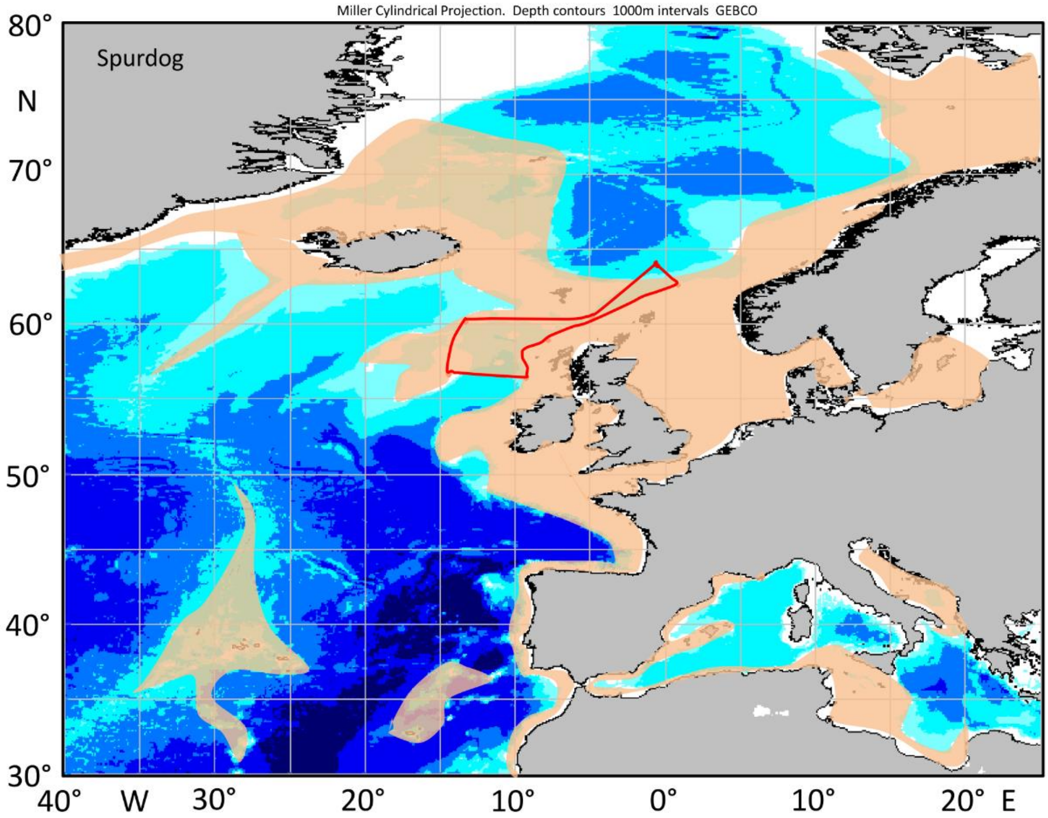

Figure 8. The range of the spurdog, spiny dogfish or picked dogfish (*Squalus acanthias*) in the NE Atlantic and Mediterranean (orange shading). Red outline is the study area. The blue shading denotes 1000m depth increments, i.e, 1000, 2000, 3000, 4000 and >5000m. After Froese and Pauly (2017) and other sources.

2.2.2 Life history

The reproductive cycle in the spurdog begins with ovulation in December to January according to samples from Scottish waters (Holden & Meadows 1964). The eggs are fertilized during mating, passing through the shell gland where they are enclosed in a protective capsule known as the candle (Jones & Ugland 2001). The egg inside its candle then comes to rest inside the uterus where it remains for the next 12 months. From November to January the embryos hatch at a length of about 10cm but remain inside the uterus, continuing to feed off the yolk sac. In samples from Oslo Fjord, growth rate accelerated from June onwards, reaching over 22cm by November to December. In Scottish waters live young are born from November to January with a length of 25-30cm, approximately two years after the ovulation and fertilisation of the egg (Holden & Meadows 1962). However, Gauld (1979) reports that births are slightly earlier limiting gestation to a maximum of 23 months. Fecundity is related to the size of the female, varying between two and fifteen pups per female in samples from the NE Atlantic with an average of three in 75cm long females and ten in 105cm long females. Prior to giving birth females migrate inshore to pupping grounds. Hickling (1930) found newly-born pups with a modal length of 33cm in Galway Bay at depths of 38 to 100m together with large adults which were almost all females. Sulikowski *et al* (2013) encountered approximately 47,000 neonate pups at 38 - 41m depth in the NW Atlantic in a small area off Rhode Island with an average length of 27.24cm. They were located in an area of clay silt-sand whereas adults were found nearby on gravel-sand substrates. In the Eastern Atlantic Ellis and Keable (2008) encountered a large aggregation of gravid mature females at 56m depth in the Irish Sea and found that fecundity varied from three to 21 pups per female and increased with total length of the female. Ellis and Keable (2008) show that these fecundities are somewhat higher previous values reported for the NE Atlantic population, 1-11 in the 1920s, 2-15 (Holden & Meadows 1964), 4-13 (Gauld 1979) and they suggest there may be a density dependent increase in fecundity following the depletion of stocks by fisheries. In Scottish samples, spurdogs reached a length of 73.2 and 81.0cm after 10 years in males and females respectively based on counts of growth bands in the spines (Holden & Meadows 1962). Nevertheless, more recent analyses (ICES WGEF 2017) indicate a slower growth rate in the NE Atlantic (71cm and 75cm after 10 years and 81 and 105cm after 30 years). Holden and Meadows (1962) suggested that females become mature at 9-13 years (75-95cm length) and earlier in males. Jones and Ugland (2001) found most females matured between 12 and 26 years and 50% maturity was at 17-18 years. Caillet *et al* (2001) cite longevity as 50 to 75 years. Ellis (2015) cites the example of one tagged specimen that was recaptured after 40 years confirming that the spurdog is one of the longer-living fish species. Young spurdogs gradually move into deeper water as they grow, males forming the greater proportion at 240m depth whereas at greater depths females become dominant; at 380m Hickling (1930) observed over 90% females. Over very deep water > 500m deep in the Faroe-Shetland Channel, Hickling found shoals of almost exclusively mature males, presumed to be feeding pelagically. In recent trawl surveys around the British Isles the largest, mostly female, fish occur at depths less than 100m (Ellis 2015). Hickling states that in the Faroe-Shetland Channel and off the west of Scotland *Squalus acanthias* are found at all depths from to 160 to 950m. The deep areas of the study area are likely to be utilised only by adult spurdogs during the growth phase of their life cycle.

2.2.3 Exploitation and management

ICES WGEF (2107) provides biennial updates to its advice on management and the next assessment is due in 2019. There is a long history of exploitation of spurdog and the West of Scotland ICES Subarea 6a has been one of the main fishing areas accounting for up to 30% of the total reported catch from the NE Atlantic. UK fishermen have been one of the major exploiters of this species with Scotland taking more than England and Wales combined. The reported landings increased to a peak in 1985 followed by a steady decline until in 2006 (Figure 9) it was determined that the stock (in the NE Atlantic as a whole) was endangered and in danger of collapse.

From 2010 there has been a zero total allowable catch across all ICES areas (1-8) and 300 to 400 tonnes of landings are reported as bycatch. Under Council Regulation (EU) 2016/1252, of 28 July 2016, bycatch landings permits are issued to vessels engaged in a bycatch avoidance programme which "*may land not more than 2 tonnes per month of picked dogfish that is dead at the moment recorded when the fishing gear is hauled on board*". In area 6, five tonnes were landed in 2016 (ICES WGEF 2017). In the absence of data from fishing trends, the main current information on spurdog abundance is from scientific trawl surveys. The spurdog is observed regularly from French commercial vessels operating in Area 6 but no trend of increase or decrease in abundance is apparent. The population is being modelled by ICES and it is considered that there should continue to be no targeted fisheries on spurdog. In Scottish surveys there has been a continuing trend of decline in abundance, but there are recent signs that the stock decline may have been arrested.

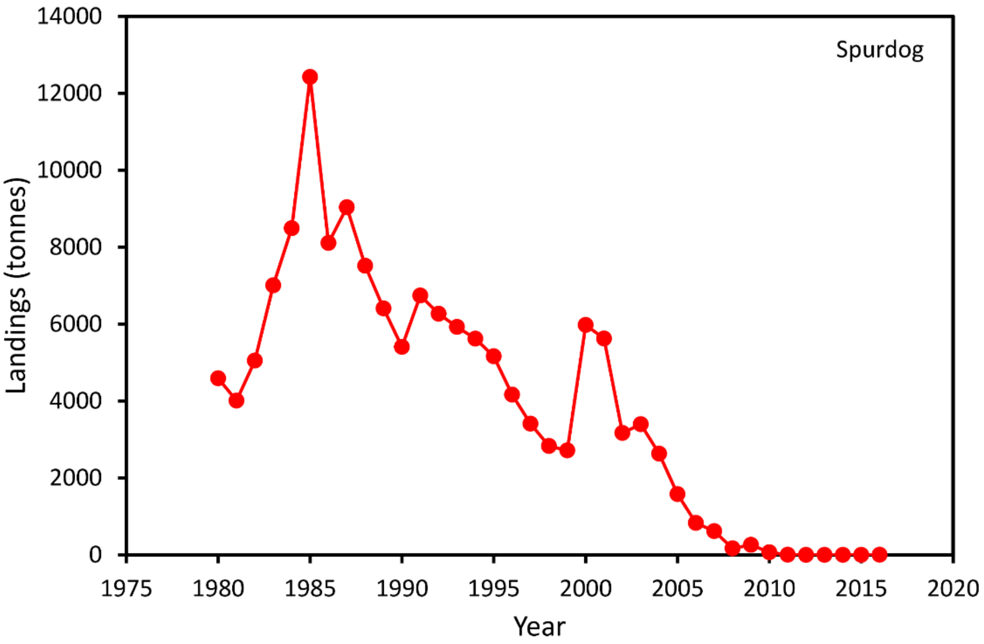

Figure 9. Reported landings of spurdog from ICES Subarea 6 West of Scotland. Data from ICES WGEF (2017).

The latest models indicate that the stock is at about 13% of the biomass in 1920 (ICES WGEF 2017) but it is recovering at a very slow rate and remains below reference levels. The stock is being monitored through the international bottom trawl survey and there is active management in place for recovery. The spurdog in the North-East Atlantic is the subject of Multilateral Environmental Agreements with OSPAR and CMS.

2.2.4 Data and knowledge deficiencies

In view of the zero TAC there are very limited new data on the state of the stock. Information on how spurdog utilise space in the study area is very sparse.

2.2.5 Conclusions

The spurdog is a shallow water species that has very little interaction with the sea floor of the study area except on the Rockall Bank and other offshore shallow areas (Figure 10). The area is too deep for females to give birth and for early stage juveniles. The spurdog are likely to forage in the surface layers on shallow areas of sea floor as well transit through the study area during migrations.

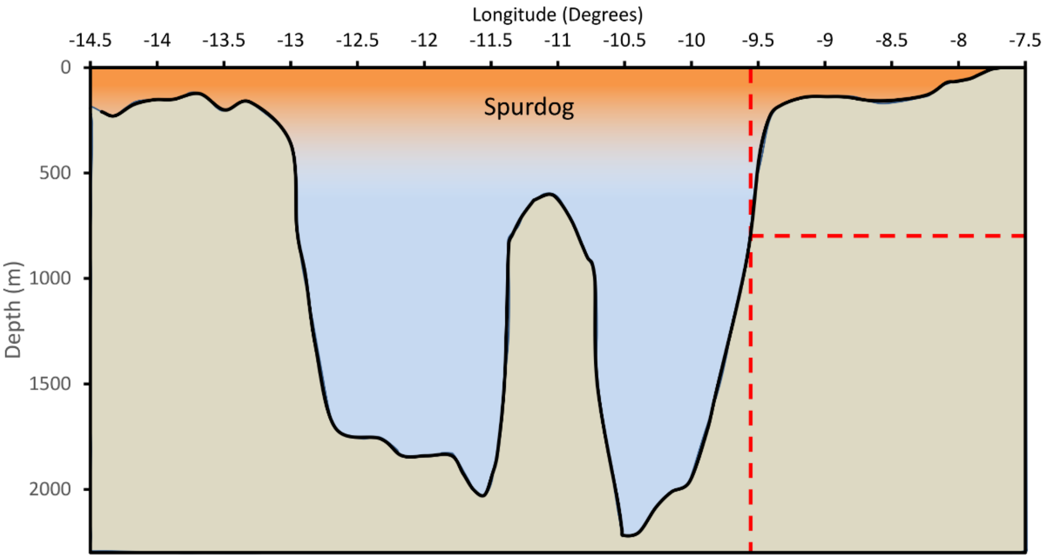

Figure 10. Section of the study area with intensity of orange shading showing the probable depth distribution of spurdog based on information from the relevant literature cited in the text.

2.3 Gulper shark *Centrophorus granulosus* (Bloch & Schneider 1801)

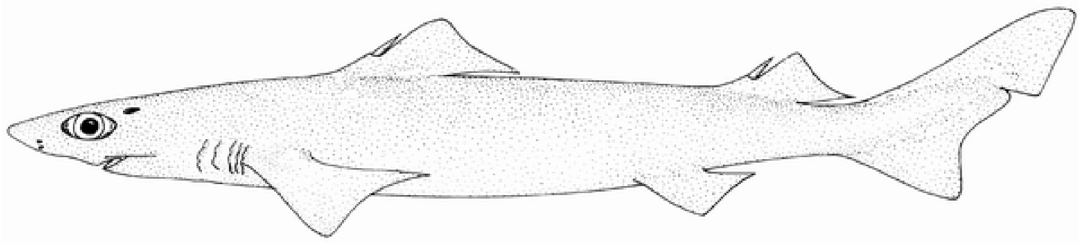

Figure 11. Gulper shark. *Centrophorus granulosus.* (FAO Image Compagno 1984).

The gulper shark is the archetypal species of the family Centrophoridae which contains about 20 species of bottom-living deep-water sharks distributed world-wide on the continental slopes down to 2400m depth. There are some difficulties in interpreting the status of the gulper shark because it is often confused with other species. Professional fishermen may not identify deep-water sharks or dogfish to species, landing them under the collective name “siki” or the livers and fins are removed at sea and landed in bulk with no species identification. Even for specialist scientists distinguishing different species of deep-water squaliformes can be problematic. A major difficulty has been that the species *Centrophorus granulosus* is easily confused with other members of *Centrophorus* including the leafscale gulper shark. This is partly because the original description of the species is not very precise and the type or reference specimen has been lost. Bañón *et al* (2008) reviewed the biological information available *on Centrophorus granulosus* in European waters and concluded that the differences between studies were so great that there must be more than one species present. White *et al* (2013) addressed this problem and concluded that the larger specimens of *Centrophorus granulosus*, that reach a maximum length of up to 1.7m, found in the NE Atlantic are the true *Centrophorus granulosus*. Furthermore, *Centrophorus acus* and *Centrophorus niaukang* are not separate species but should be recognised as *Centrophorus granulosus*. They propose that the smaller variety of *Centrophorus granulosus* which reaches a maximum size of 1.1m should be redesignated as *Centrophorus uyato* (little gulper shark). In the NE Atlantic the little gulper shark seems to have a more southerly distribution than the gulper shark, occurring in the Mediterranean and Portugal and to the south although Wienerroither *et al* (2015) describe a northernmost specimen taken off the coast of Norway. White *et al* (2013) provide updated descriptions of *Centrophorus granulosus*, with details of how features change during growth. The gulper shark can be distinguished from the leafscale gulper shark, *Centrophorus squamosus,* by the relatively smooth skin, (the dermal denticles are not on pedicels), pectoral fins with elongated rear tips, and the second dorsal fin spine is straight not curved. Veríssimo *et al* (2014) provide further descriptions stating that the tear-drop shaped dermal denticles give the skin a granular feel. The new descriptions have clarified many ambiguities but still leave a major problem as to how to deal with past records in which we cannot be certain as to the validity of the identification. Since the sharks are large they are rarely preserved so it is not often possible to return to old collections and check identifications. It is therefore prudent to use biological information from the fishery around Galicia where the species caught is definitely *Centrophorus granulosus* (Bañón *et al* 2008), and information given in White *et al* (2013). *C. granulosus* has been recorded at depths from 98 to 1700m so occupies a narrow strip around the ocean margins extending over what Haedrich and Merrett (1988) term the upper to mid slope. Froese and Pauly (2018) report that the diet is mainly fish, including hake, epigonids (deep-water cardinal fishes), myctophids (lantern fish), herring, smelts, cods, rattails and some squids and crustaceans, but in view of problems concerning species identification we cannot be certain about the accuracy of these data.

2.3.1 Distribution and status in the study area

Major reference sources including Froese and Pauly (2018) and Campagno (1984) state that in the NE Atlantic gulper sharks occur only south of 51°N and hence are absent from the study area. ICES WGEF (2017) states that very small landings of gulper sharks have been reported from Subareas 6 and 7 to the west of the British Isles, but that those from UK vessels should be considered to be misidentified. In scientific trawl surveys of the slopes of the Rockall Trough, Neat *et al* (2015) do not list the gulper shark as present, although Burns (2018) states there is one record of *Centrophorus granulosus* from the year 2000 at 640m on the slope just west of St Kilda. Furthermore, White *et al* (2013) cite a specimen of a juvenile male (457mm total length) in the Hamburg Zoological Museum which was taken at 57°40’N, 9°35’W off the west coast of Scotland. Gordon and Swan (1997) state that the C*entrophorus* species tend to be under-represented or absent from scientific deep-water trawls because their large size enables them to swim fast and actively avoid the nets. They report that in early surveys to the west of the British Isles during the 1970s most C*entrophorus* were identified as *Centrophorus squamosus* but a few were tentatively identified as *Centrophorus granulosus*. There is therefore evidence that the species *Centrophorus granulosus* is probably present in the study area as indicated on the map (Figure 12) but in view of its cryptic nature and lack of up-to-date identification keys (as explained above) it is likely to have been underreported. The study area is one of 17 localities world-wide in which the species has been found (White *et al* 2013).

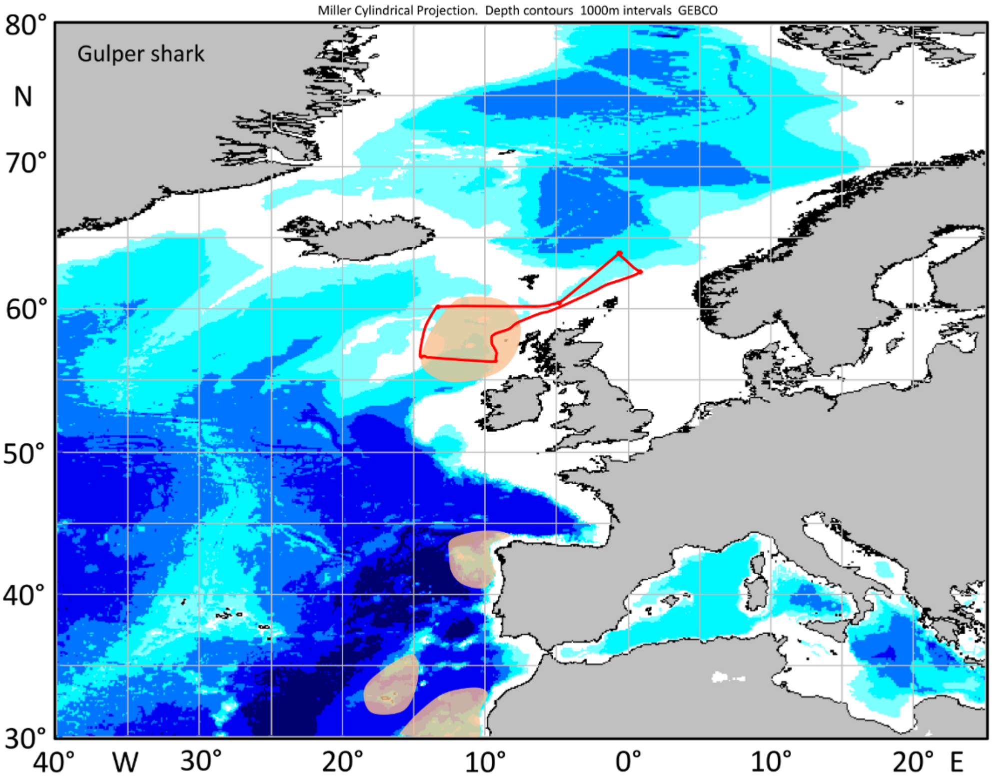

Figure 12. Distribution of *Centrophorus granulosus* in the NE Atlantic (orange shading) after White *et al* (2013). Red outline is the study area. Red outline is the study area. The blue shading denotes 1000m depth increments, i.e, 1000, 2000, 3000, 4000 and >5000m.

2.3.2 Life history

The gulper shark is ovoviviparous, retaining developing embryos in the uterus and producing 1-16 live young with a total length of 35-47cm at birth (Bañón *et al* 2008). Females caught off Galicia, NW Spain at depths of 741-1211m, range in size from 40 to 166cm, and size at 50% maturity is 147cm. The males are smaller, 73 to 127cm with a marked disparity in the sex ratio, over 21 females for every male in this area. Cotton *et al* (2015) in their analysis of samples from the Western Atlantic and the Mid-Atlantic Ridge found the size of 50% maturity to be 143cm for females and 110cm for males. Pregnant females seem to segregate from the rest of the population along the outer edge of the continental shelf and in canyons although these are not necessarily pupping grounds. There is no information on where birth occurs. Litter sizes of three to eight seem to be most common (White *et al* 2013). Cotton *et al* (2015) shows there is no maternal contribution of organic nutrition during development although the female does provide water and inorganic material. Cotton *et al* (2015) show that reproduction is a seasonal with all stages of oocyte and embryo development present throughout the year and presumably pups are produced throughout the year. This is commonly observed amongst sharks in the relatively constant environment of the deep sea and means that reproductive aggregations are unlikely. There is no reliable information on age, growth and migrations of this species. A study by Guallart and Vicent (2001) on reproduction in gulper shark was based on samples from the Mediterranean Sea which are no longer considered to be *Centrophorus granulosus* (White *et al* 2013).

2.3.3 Exploitation and management

For the purposes of European fishery management, the gulper shark is included in the deep-sea shark category (Council regulation (EC) No 1182/2013) for which since 2007 no directed fisheries have been permitted in ICES Subareas 6-9, albeit with some small bycatch dispensations. The NEAFC recommendation 7: (2013) requires prohibition of directed fishing for deep-water sharks including *Centrophorus granulosus* (ICES WGEF 2017). The gulper shark is almost certainly landed in unknown quantities either grouped together with other species as 'siki' sharks, sharks 'nei' (not elsewhere identified), dogfish 'nei', or misnamed as leafscale gulper shark or Portuguese dogfish. ICES WGEF (2017) gives the landings of "*mixed deep-water sharks, believed to be mainly Portuguese dogfish and leafscale gulper shark but* ***possibly also containing a small component of other species***" which for Subarea 6 are reproduced here in Figure 17. The gulper shark is likely to be part of the "small component of other species". In the absence of reliable data from fisheries or significant numbers caught in surveys there is no species-specific management regime in place, other than the general prohibition on fishing for deep-water sharks.

2.3.4 Data and knowledge deficiencies

Owing to problems of misidentifications it is not possible to confirm with certainty if the gulper shark exists in the study area. It is possible that an unknown proportion of leafscale gulper shark catches are actually gulper shark. This needs to be carefully checked by experts and verified by collecting whole specimens or samples for analysis of scales and DNA. Even a small percentage of the leafscale gulper data could indicate the presence of a significant population. At present, there is no evidence of a viable population of gulper shark in the study area.

2.3.5 Conclusions

The gulper shark is a deep-water shark and the study area encompasses a large area of potentially suitable habitat possibly including all life history stages (Figure 13).

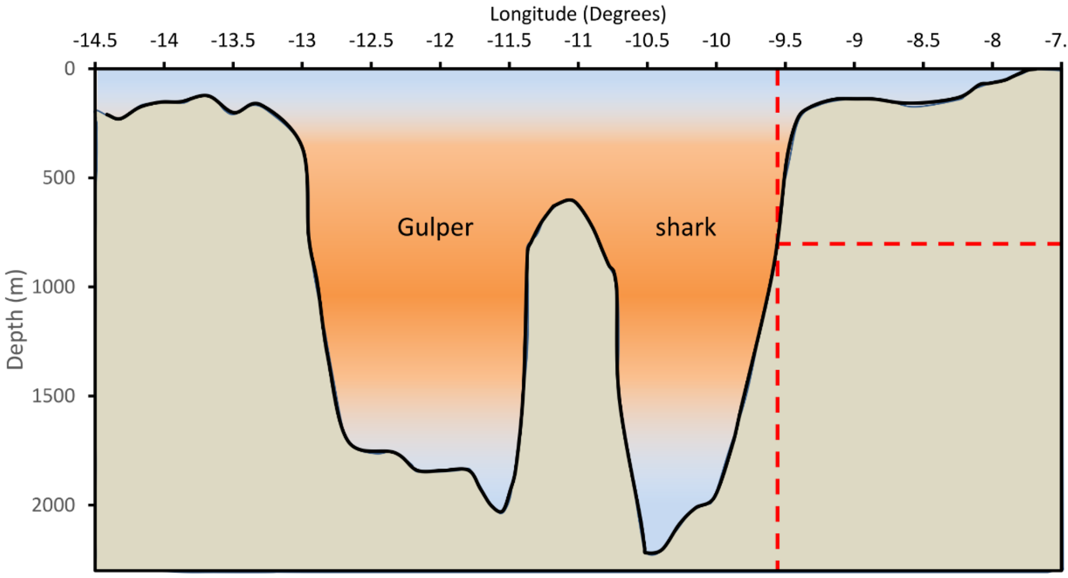

Figure 13. Section of the study area with intensity of orange shading showing the probable depth distribution of gulper shark based on information from the relevant literature cited in the text.

Until the redescription of the species by White *et al* (2013) and publication of a new "*Centrophorus* species key for the North Atlantic" by Veríssimo *et al* (2014) it was not possible to assert unequivocally whether or not the species is present owing to a lack of reliable identification criteria. On the basis of the review by White *et al* (2013), it seems certain the species is present in the study area and one of the few locations in the NE

Atlantic in which it occurs, however there is very limited evidence regarding extent and abundance. Known specimens have been caught on slopes west of Scotland to the east of the main study area. The species is vulnerable to capture as bycatch in deep-water trawl fisheries for roundnose grenadier.

2.4. Leafscale gulper shark *Centrophorus squamosus*[7] (Bonnaterre 1788)

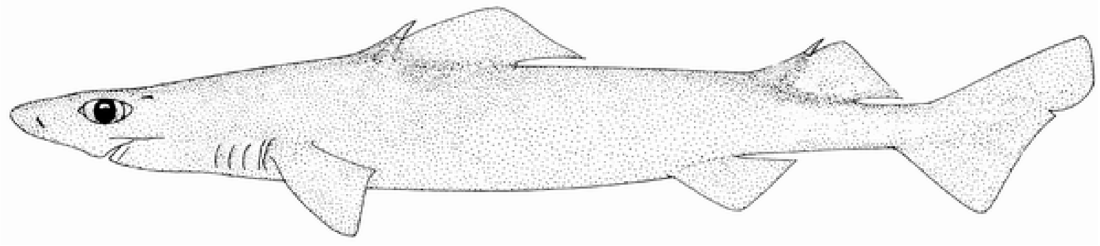

Figure 14. The leafscale gulper shark, *Centrophorus squamosus* (Image FAO, Compango 1984).

The leafscale gulper shark is a member of the family Centrophoridae which contains about 20 species of bottom-living deep-water sharks distributed world-wide on the continental slopes down to 2400m depth. Despite difficulties with the correct identification of different species of *Centrophorus* species, Veríssimo *et al* (2014) state: "*Centrophorus squamosus* has large, overlapping, leaf-shaped dermal denticles that are unique amongst *Centrophorus* which make this species easily distinguishable from all other gulper sharks regardless of size". Occupying a very wide depth range, from 145 to 2400m, it grows to maximum length of at least 164cm. It is the best-studied of any of the gulper sharks. It occurs in more trawl hauls than any other Elasmobranch species in the study area but in relatively low abundances (Neat *et al* 2015). The stomachs of leafscale gulper sharks sampled from the west of Scotland at depths from 415-2045m were found to contain predominantly fish fragments, including blue whiting (*Micromesistius poutassou*), other gadoids, Alecopocephalids (slick heads), chimaera, roundnose grenadier as well as squid (Mauchline & Gordon 1983). Dunn *et al* (2013) categorise the diet of those taken off New Zealand as mainly demersal and bentho-pelagic fishes with some scavenging.

2.4.1 Distribution and status in the study area

The leafscale gulper shark occurs in the North and South Atlantic (69°N - 54°S) in the Western and Eastern Indian Ocean, the North-Western Pacific, and the South-Eastern Pacific around Australia and New Zealand (Froese & Pauly 2016). In the NE Atlantic the range extends all around the British Isles to Iceland and the Barents Sea in the north and to the coast of NW Africa (Figure 15). The study area covers the centre of the species distribution. Neat *et al* (2015) found leafscale gulper shark to be distributed throughout the study area with peak abundance at 800m depth (Figure 16). The sex ratio was 0.54:1 (female:male) and most individuals were mature. Though Clarke *et al* (2002) found a more equal sex ratio, they also commented on the lack of juveniles west of the British Isles which could not be attributed to bias in the fishing gears used. The species is assumed to be highly migratory (ICES WGEF 2017). Rodríguez-Cabello *et al* (2014) found that individuals tagged with satellite tags off northern Spain travelled at depths of 575 to 1848m at mean speeds of 2.3 to 6.1 knots, in one case arriving at the Porcupine Bank west of Ireland after a period of three months. Rodríguez-Cabello *et al* (2016) confirmed that leafscale gulper sharks can travel in midwater, thousands of metres above abyssal plains (i.e. >4000m below the surface).

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[7] In some publications it is known by the name *Lepidorhinus squamosus.*

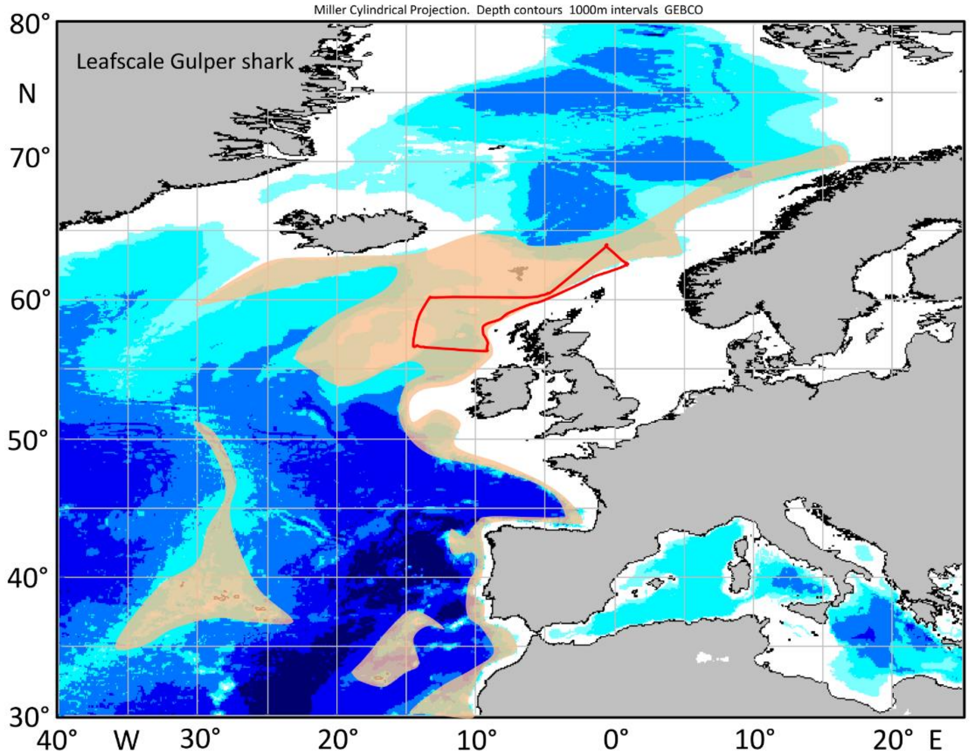

Figure 15. Distribution of *Centrophorus squamosus,* the leafscale gulper shark in the NE Atlantic (orange shading), after Froese and Pauly (2017) and other sources cited in the text. Red outline is the study area. The blue shading denotes 1000m depth increments, i.e, 1000, 2000, 3000, 4000 and >5000m.

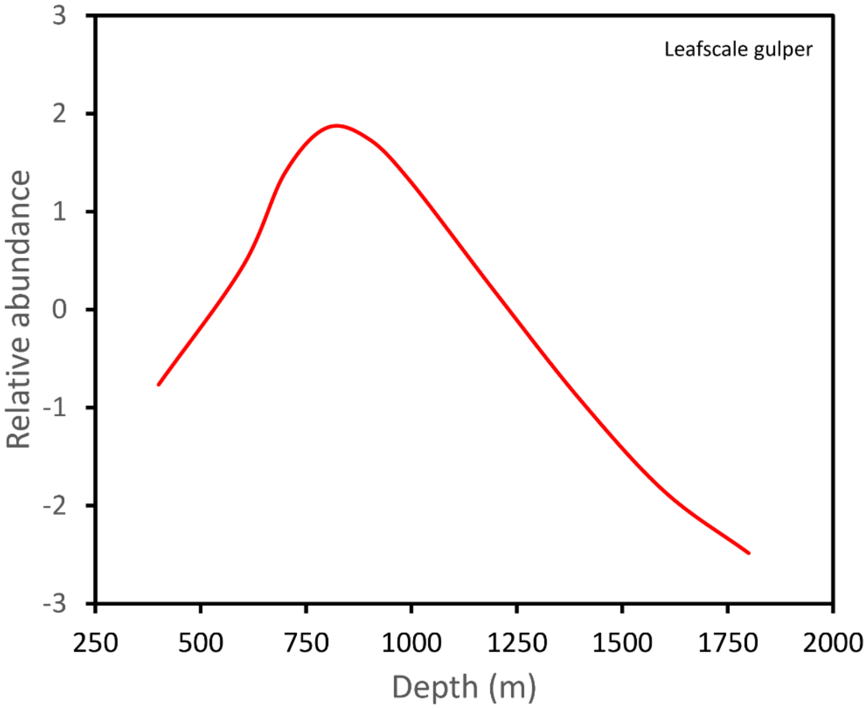

Figure 16. Depth distribution of leafscale gulper shark in the study area. Note the peak of relative abundance around 800m (after Neat *et al* 2015).

2.4.2 Life history

The female leafscale gulper shark becomes sexually mature on reaching a mean total length of 120cm (50% maturity), with a range of 105-135cm in samples taken from west of the British Isles (Girard & Du Buit 1999). Clarke *et al* (2002) found that 50% maturity occurred at 128cm in females and 102cm in males. There is no evidence of a seasonal reproductive cycle in males or females (Girard *et al* 2000). The females produce live young from eggs retained in the uterus with no intra-uterine maternal nutrition. Counting of ova indicates that fecundity does not vary significantly with female size and is between seven and eleven potential pups per female in the NE Atlantic (Girard & Du Buit 1999) or six and eleven according to Clarke *et al* (2001) although no late stage pregnant females were available for examination. Clarke *et al* (2002) cite unpublished reports of a fecundity of four to five for gravid specimens caught of Portugal. Samples from the Southern Hemisphere indicate size at birth of 35-43cm with a litter of five to eight pups (Froese & Pauly 2016). Late-stage pregnant females seem to segregate from the general population; in the NE Atlantic it was assumed that parturition took place in the south around Madeira until a more extensive analysis by Moura *et al* (2014) showed that pupping might also occur off Iceland, Portugal, Galicia and West Africa with no evidence, either positive or negative for Scottish waters. Interpretation of the life cycle in the NE Atlantic is hampered by the absence of juveniles and pregnant females from most samples. Clarke *et al* (2002) made an estimate of the ages of leafscale gulper sharks from sections of the dorsal spines and found that females of 84 to 145cm total length were 20 to 70 years old, reaching sexual maturity at 35 years. For males the length range in samples was 83-122cm and the age range 20 to 52 years reaching sexual maturity at 30 years. The leafscale gulper shark thus shows a very slow growth rate during adolescence in unknown parts of the NE Atlantic, migrating to the continental slopes at ages of 20-30 years. Clarke *et al* (2001) found a predominance of males at shallow depths <800m, approximately equal sex ratios at mid-depths and more females at depths >1100m. They suggest that mating may take place at the intermediate depths. Mature females are most abundant at mid-depths with none deeper than 1300m.

2.4.3 Exploitation and management

For management under ICES, the leafscale gulper shark is grouped together with the Portuguese dogfish as the two deep-water shark species of greatest economic importance, which had been exploited on a small scale since time immemorial by Portuguese long-line fishermen. Exploitation spread to the west of Scotland with the development of deep-water trawl fisheries during the 1990s as a bycatch in the fishery for roundnose grenadier and orange roughy. Off the west of Scotland reported catches of the two shark species combined peaked at almost 600 tonnes (Figure 17). From 2010, ICES WGEF began to separate the data for leafscale gulper and Portuguese dogfish and for 2010 the recorded landings for the two species were 21 and 22 tonnes respectively, along with other deep-water shark species.

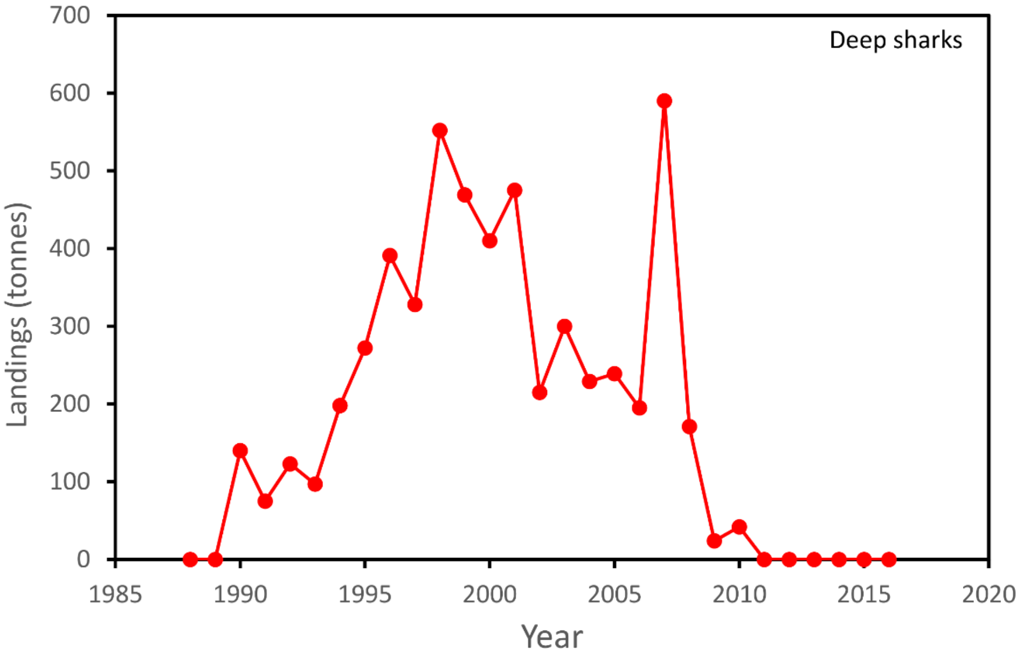

Figure 17. Reported landings of mixed deep-water sharks, believed to be mainly Portuguese dogfish and leafscale gulper shark but possibly also containing a small component of other species from ICES Subarea 6. Data from ICES WGEF (2017).

A zero total allowable catch has been in force since 2010. Current advice from ICES is that no targeted fisheries should be permitted from 2016 to 2019. Some bycatch occurs in Subarea 6 from French trawlers targeting roundnose grenadier, black scabbardfish and blue ling. Leafscale gulper shark are caught in 15% of trawl hauls. Scottish survey data indicate no significant change in the abundance of leafscale gulper shark since 2004. Any recovery of the stock is likely to be very slow.

2.4.4 Data and knowledge deficiencies

In view of the data from the Scottish Deepwater Trawl Survey, the information available on the leafscale gulper shark is relatively good for a deep-sea species. However, there is a weakness in that the time series began when the stock was already depleted. Absence of catches from an active fishery limits the information that can be obtained. The historic grouping of this species together with the Portuguese dogfish makes calculation of population trends difficult. ICES have separated the statistics for the two species, so over the coming decades it is expected that the information will improve.

2.4.5 Conclusions

The leafscale gulper shark is potentially resident throughout the deep waters of the study area (Figure 18). A particular problem is that the maximum abundance of the species occurs at 800m depth, so an important part of the population occurs on the sea floor at shallower depths which in the east on the slopes west of Scotland is outside the study area. The species remains vulnerable to capture as bycatch in deep-water trawl fisheries for roundnose grenadier.

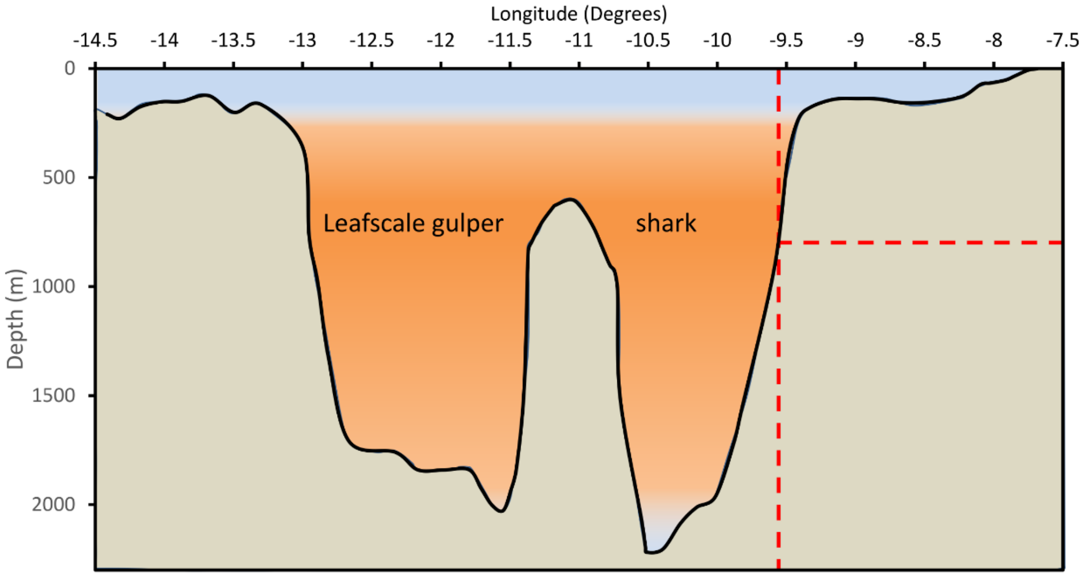

Figure 18. Section of the study area with intensity of orange shading showing the probable depth distribution of leafscale gulper shark based on information from the relevant literature cited in the text.

2.5. Portuguese dogfish *Centroscymnus coelolepis* (Barbosa du Bocage & de Brito Capello 1864)

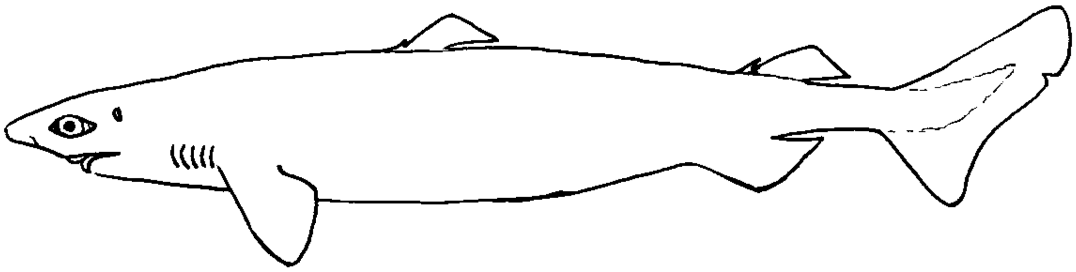

Figure 19. Portuguese dogfish *Centroscymnus coelolepis* (Image © Priede).

The Portuguese dogfish is a member of the family Somniosidae (Sleeper sharks), large deep-living sharks including the Greenland shark (*Somniosus microcephalus*) which may be the longest-lived vertebrate on the planet, with one individual estimated at 392 (+/- 120) years old (Nielsen *et al* 2016). These and other deep-water sharks were being exploited by Portuguese fishermen off Setubal long before the scientific community became aware of the existence of life in the deep sea (Wright 1870; Vaillant 1888). The Portuguese dogfish is the world’s deepest-living shark, with one specimen captured at 3700m by Foster (1973) on a baited long-line in the Bay of Biscay beyond the normal maximum depth limit of 3000m for sharks (Priede *et al* 2006). In deep water west of Scotland the size range is 22-132cm and it occurs down to the maximum available of depth of over 2000m in the Rockall Trough (Neat *et al* 2015). Mauchline and Gordon (1983) classified the Portuguese dogfish in this area as a bentho-pelagic feeder finding predominantly fish and squid in the stomachs including deep-water species such as roundnose grenadier and Alepocephalids (slickheads). They also found the flesh and blubber of whales that they assumed to be the result of scavenging. In the Western Mediterranean, Carrassón *et al* (1992) also found a high percentage (41%) of empty stomachs, with six different species of squid comprising the most important part of the diet, but they also consumed shrimps and deep-sea fishes. They found a switch in diet during growth; only the smaller fish (19-39cm long) consumed shrimps, and larger fish (40-75cm) did not consume shrimp but took cetacean blubber. The occurrence of blubber in the diet in widely disparate locations suggests that either opportunities for scavenging on cetacean carcasses are common or that the Portuguese dogfish is able to attack living cetaceans as does the cookie cutter shark (*Isistius brasiliensis*). Bagley *et al* (1994) showed that Portuguese dogfish are readily attracted to and rapidly consume baits placed on the sea floor at 1717-1650m depth. The ability to capture squid implies active pelagic foraging.

2.5.1 Distribution and status in the study area

The Portuguese dogfish is distributed around the North Atlantic Ocean the Western Mediterranean Sea, the South Atlantic, the Indian and Western Pacific Oceans including off New Zealand and Australia. The study area is within the species distribution in the North East Atlantic Ocean that extends from West Africa in the south to Eastern Greenland in the north (Figure 20).

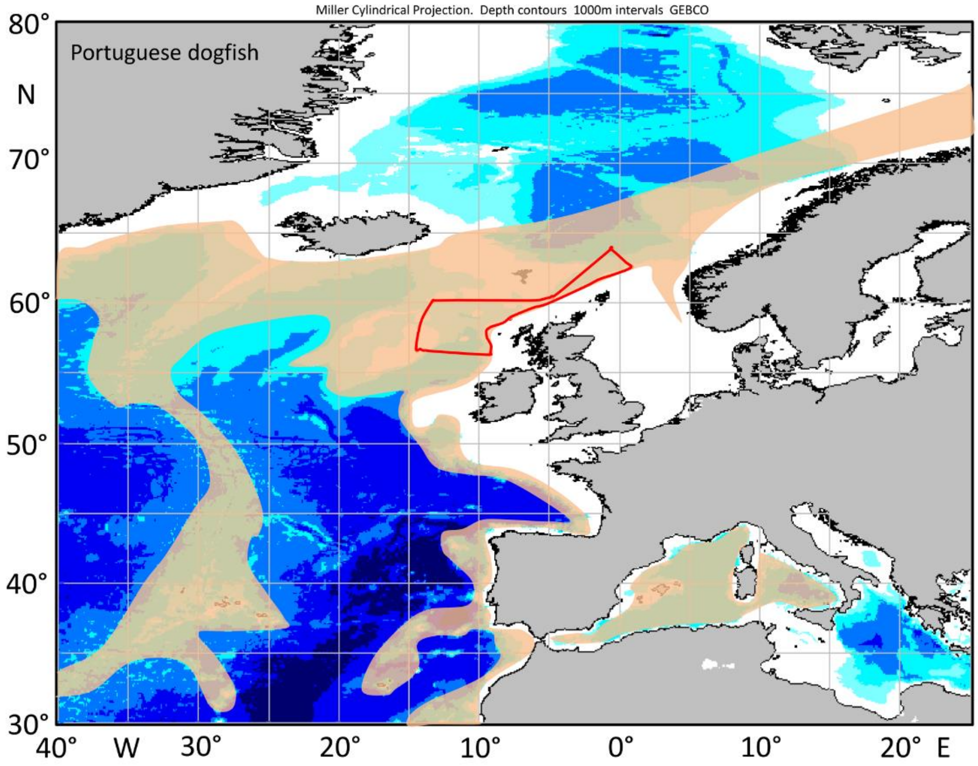

Figure 20. Distribution of *Centroscymnus coelolepis,* the Portuguese dogfish in the NE Atlantic (orange shading) after Froese and Pauly 2017 and other sources cited in the text. Red outline is the study area. The blue shading denotes 1000m depth increments, i.e, 1000, 2000, 3000, 4000 and >5000m.

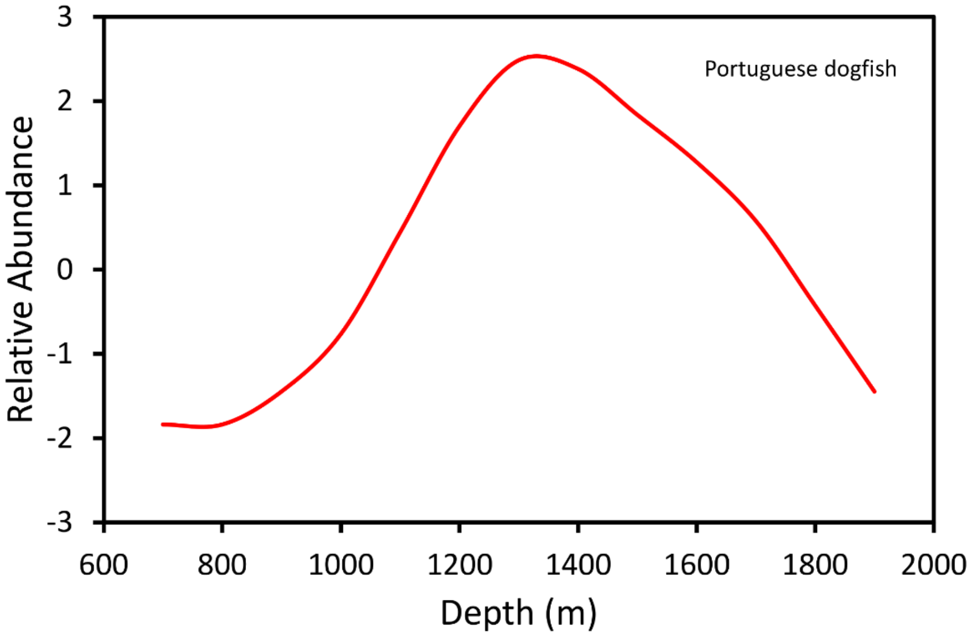

Figure 21. Depth distribution of Portuguese dogfish in the study area (after Neat *et al* 2015).

To the west of Scotland they are found at depths of 700 –1900m with a peak of abundance at 1300 to 1400m (Neat *et al* 2015) (Figure 21). Bagley *et al* (1994) tracked localised movements of Portuguese dogfish that had consumed ingestible acoustic transmitters at approximately 0.1m.s^{-1} across the sea floor but no tracking of more extensive movements has yet been carried out.

2.5.2 Life history

The Portuguese dogfish retains developing embryos in the uterus and gives birth to live young. West of the British Isles, Clarke *et al* (2001) counted the ovarian fecundity as ranging from 10 to 21 and the number of near-term embryos or uterine fecundity from 8 to 21. Girard and Du Buit (1999) estimate a litter size of 8 to 19 pups per female with a mean of 14; there is a slight increase in litter size with female total length. Further south, off Portugal, Veríssimo *et al* (2003) estimate the litter size as between 1 - 25 with a mean of 9.9. There is no evidence of an annual cycle of reproduction, as all developmental stages can be observed at any given time of the year. West of the British Isles females become sexually mature at 72 to 118cm; the length at 50% maturity is 102cm and 86cm for males (Girard & Du Buit 1999). According to Veríssimo *et al* (2011) the gestation period is two years with a pause in the ovarian cycle after parturition. Veríssimo *et al* (2011) found no evidence of genetic differentiation between samples taken from different parts of the species range in the NE Atlantic. They suggested that this was a result of large-scale migrations associated with the reproductive cycle; mating taking place on the Mid-Atlantic Ridge and west of the British Isles, and females moving south along the continental slope of Europe to give birth off Mauritania before returning to the more northern feeding areas.

In contrast, Catarino *et al* (2015) show that the species in the Mediterranean is genetically isolated from populations in the Atlantic Ocean. In a study of large-scale distribution of deep-water squaloid sharks, Moura *et al* (2014) found that female Portuguese dogfish generally outnumbered males in the NE Atlantic except in the Bay of Biscay. Numbers of juveniles were very low with only seven caught in the entire area. In the NW Atlantic juveniles are caught in trawls at 670 to 2624m depth but most (88%) are caught shallower than 1000m. Mature and pregnant females are caught regularly throughout the species range in the NE

Atlantic and Moura *et al* (2014) proposed that Portuguese dogfish can complete their life cycle within different regions without the long-distance migrations proposed by Veríssimo *et al* (2011). The small numbers of juveniles were caught at widespread locations also indicates multiple breeding areas; however there remains the possibility that there may be one or more as yet undiscovered pupping and nursery areas in the NE Atlantic. The asynchrony of the breeding cycle however means that it is unlikely that there are vast concentrations of neonates (as observed in the spurdog).

In the absence of means for determining the ages of the fish, the growth rate and longevity of this species remain unknown, although Catarino *et al* (2015) suggest a longevity of over 50 years by comparison with related species.

2.5.3 Exploitation and management

The Portuguese dogfish is grouped with the leafscale gulper shark as one of the two most abundant deep-water sharks on the slopes of the NE Atlantic. The combined landings data for the two species are given in Figure 17. Portuguese dogfish were traditionally targeted by artisanal fisheries off Portugal but the fishery to the west of Scotland is much more recent with most landings occurring as bycatch in the deep-water trawl fishery targeting roundnose grenadier, black scabbardfish and blue ling. Since 2010 targeted fishing for sharks has been prohibited. Nevertheless, on average Portuguese dogfish occurred as bycatch in 11% of deep-water trawls taken by French vessels operating to the west of the British Isles during 2005-2014 (Table 3.6 in ICES WGEF 2017) although the proportion is lower in more recent years. In the absence of commercial landings data, the stock is monitored by means of the Scottish Deepwater Trawl Survey (Neat *et al* 2010). The standardised abundance index shows a steady decline since 2000 with very low levels of abundance. The ICES continuing recommendation is to prohibit targeted fisheries for this species.

2.5.4 Data and knowledge deficiencies

In view of the data from the Scottish Deepwater Trawl Survey, the information available on the Portuguese dogfish is relatively good for a deep-sea species. However, there is a weakness, in that the time series began when the stock was already depleted. Absence of catches from an active fishery limits the information that can be obtained. The historic grouping of this species together with the leafscale gulper shark makes calculation of population trends difficult. Over coming decades as ICES has statistically separated the two species so the information should improve. Knowledge of the life cycle in the NE Atlantic remains limited.

2.5.5 Conclusions

The Portuguese dogfish is likely to be resident throughout the deep-water parts of the study area (Figure 22). This is part of widespread stock extending around the margins of the NE Atlantic Ocean with little genetic differentiation between areas.

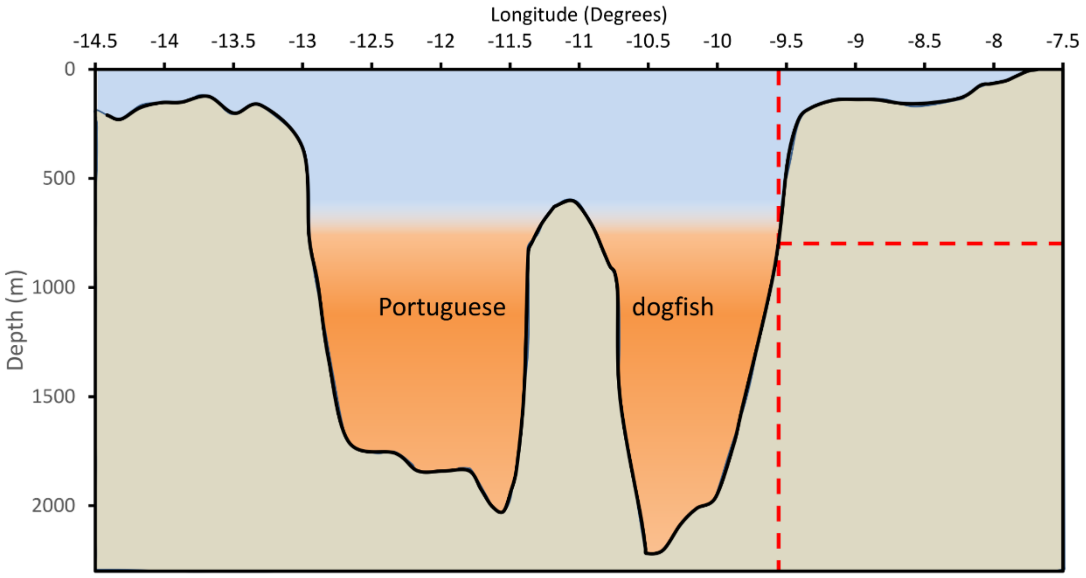

Figure 22. Section of the study area with intensity of orange shading showing the probable depth distribution of Portuguese dogfish based on information from the relevant literature cited in the text.

According to Veríssimo *et al* (2011) the study area could be an important adult mating area with pregnant females migrating south to give birth off West Africa, whereas Moura *et al* (2014) suggest the entire life cycle could occur in the study area, although samples of juveniles remain elusive. The species is vulnerable to capture as bycatch in deep-water trawl fisheries for roundnose grenadier.

2.6 Roundnose grenadier, *Coryphaenoides rupestris* (Gunnerus 1765)

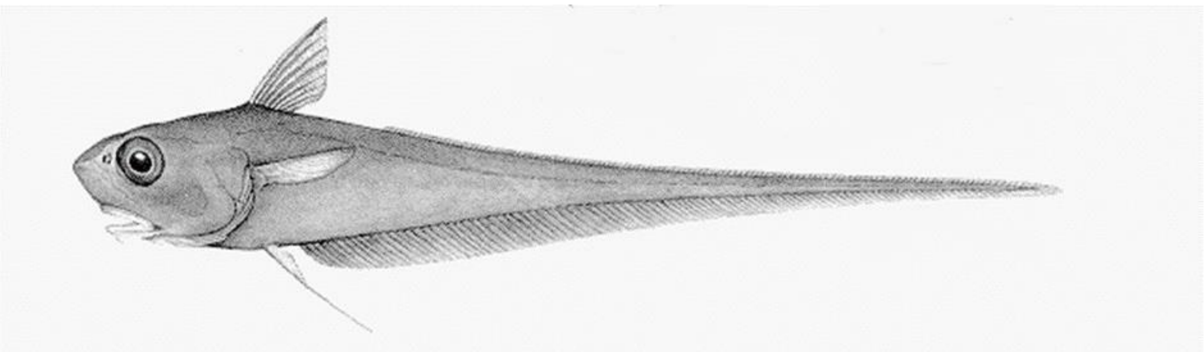

Figure 23. Roundnose grenadier *Coryphaenoides rupestris* (FAO Image. Cohen *et al* 1990).

The roundnose grenadier is a member of the family Macrouridae, variously known as grenadiers, rattails or whiptails, characterised by a long tapering tail usually with no distinct tail fin. There are almost 400 species of macrourids ranging in depth from the edges of continental shelves, down the slopes to the vast areas of the abyssal plains and the fringes of hadal trenches (Iwamoto 2008) where a sister species of the roundnose grenadier *Coryphaenoides yaquinae* has been found at just over 7000m depth (Linley *et al* 2017). They are typically bottom-living, demersal fishes although they are nonetheless capable of swimming above the sea floor to forage pelagically. The roundnose grenadier is one of the shallower-living species in its genus, found at 180-2600m depth and hence is confined to a narrow strip around the upper continental slopes. Compared with other species of grenadier the roundnose has very large eyes (Priede *et al* 1999). The brain has very well-developed optic lobes, but the other areas of the brain concerned with senses of smell, taste and touch are reduced (Wagner *et al* 2002). The roundnose grenadier is therefore a visual feeder, probably adapted to foraging in the twilight zone around 1000m depth where very faint sunlight still penetrates or the prey are bioluminescent. It is not attracted to the odour of baits, so cannot be caught on long lines or traps, only by trawl. In the Rockall Trough area the diet was found to consist predominantly of copepods, decapods and fish with some mysids, euphausids and cephalopod molluscs (Mauchline & Gordon 1984a). The diet changes as the fish grow, the smallest fish (4 -12.4cm long) feeding predominantly on calanoid and cyclopoid copepods. While calanoid copepods remain a significant dietary component important for larger individuals, amphipods, mysids, euphasids, decapods and fish figure more and more prominently in the diet, with fish particularly important for the largest size class, 63.5-105cm (Mauchline & Gordon 1984a). Further offshore on the Mid-Atlantic Ridge Bergstad *et al* (2010) also found that squids are a major part of the diet.

Mauchline and Gordon (1991) showed that the descent of pelagic prey organisms through the water column during their daytime diel vertical migration would be blocked by encounter with the sea floor on the continental slope at depths of 800 to 1550m in the Rockall Trough creating a rich concentration of food for species such as the roundnose grenadier, with no need for them to swim far above the sea floor to find their prey. Haedrich (1974) describes the capture of roundnose grenadier at depths between 1000-2000m and 270-1440m above the bottom, indicating that they are capable of actively pursuing pelagic prey. However, midwater observations are rare and despite considerable effort on the Mid-Atlantic Ridge Bergstad *et al* (2010) caught only 11 juveniles in pelagic nets. Mauchline and Gordon (1991) concluded that pelagic “excursions are rare or on a very short time scale”. Atkinson (1995) reviewed evidence for vertical migrations obtained by Russian workers which suggests that at night roundnose grenadier do not pursue their migratory prey towards the surface but remain on the sea bottom and ascend during the day to no more than a few hundreds of metres above the bottom to intercept the prey as it descends.

The roundnose grenadier is the most important commercially exploited species of macrourid in the world, having been first targeted by expanding deep-sea fishing fleets in the 1960s (Priede 2017).

2.6.1 Distribution and status in the study area

The roundnose grenadier is endemic to the North Atlantic Ocean at latitudes from 22° to 66°N, occurring in both the eastern and western Atlantic Ocean and around Iceland and the Mid-Atlantic Ridge (Figure 24).

In the Rockall Trough, Mauchline and Gordon (1984a) found it was the most abundant macrourid present amounting to 28% of the entire fish catch and occurring at all depths from 750m to 1750m. Further south, in the Porcupine Seabight, Priede *et al* (2010) found the depth range to be 706–1932m with peak abundance at around 1500m depth (Priede *et al* 2011). All size classes from 4cm to the maximum size over 100cm are present in the study area. The population is confined to its preferred depth zone on the continental slope and can be regarded as resident.

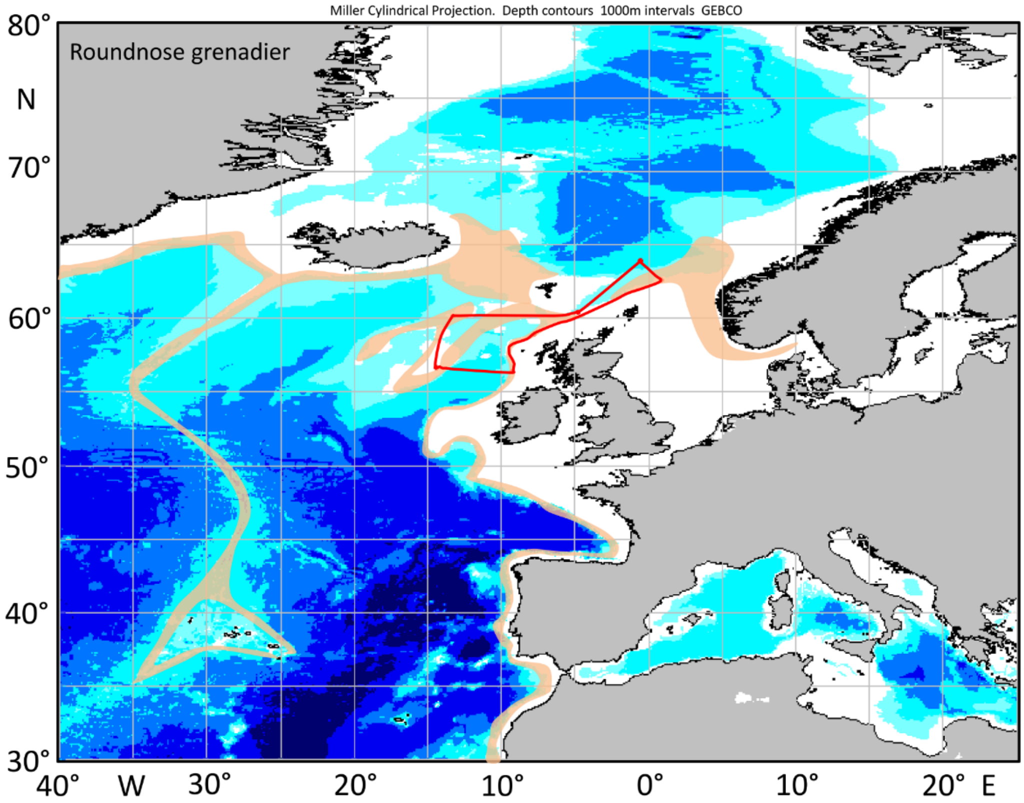

Figure 24. The geographic distribution of roundnose grenadier, *Coryphaenoides rupestris* in the NE Atlantic Ocean (orange shading). After Atkinson (1995). Red outline is the study area. The blue shading denotes 1000m depth increments, i.e, 1000, 2000, 3000, 4000 and >5000m.

ICES WGDEEP, Working Group on the Biology and Assessment of Deep-sea Fisheries Resources (2017) considers that the roundnose grenadier may be divided into separate populations with the Wyville Thomson Ridge acting as a barrier between a single population to the south of the Faroes, including the study area, and more northerly populations in the Norwegian Deep and the Skagerrak. Bullough *et al* (1998) point out that roundnose grenadiers are absent from the cold deep waters of the Faroe-Shetland Channel to the north of the Wyville Thomson Ridge where they are replaced by *Macrourus berglax*, the roughhead grenadier.

2.6.2 Life history

The roundnose grenadier grows to a maximum total length of 130cm or 29.5cm pre-anus length (Allain 2001). Because the long tapering tail is easily damaged, either in life or after trawling, the size of grenadiers is often measured as the length from the tip of the nose to the front edge of the anus: the pre-anal length. For roundnose grenadiers west of the British Isles, Kelly *et al* (1997) give a conversion equation:

$$L_T = 4.48\, L_{PA} + 0.76$$

Where L_T is the total length and L_{PA} is the pre-anus length. The lengths reported here will be total lengths which have been converted where necessary.

Kelly *et al* (1997), fishing in the Rockall Trough, captured fish between 9 and 108cm total length with a mode around 68cm total length. Early unpublished work by Gordon (cited in Kelly *et al* 1997) in the 1970s, before a fishery was established, found a similar size range, but with a mode of 90cm at depths < 700m, and 80cm at greater depths. There was also a mode of small fish around 15 to 20cm long which were most abundant at >700m. Bridger (1978) reported a mode around 80cm at all depths, though the small fish were absent. Kelly (1997) found that females grow larger than males to asymptotic lengths of 88cm and 70cm, corresponding to weights of 1573 and 922g respectively. The size of 50% sexual maturity is 46cm for males (age 8-10 years) and 55cm (ages 9-11) for females. Allain (2001) found that females matured at a slightly smaller size, 52cm at an estimated age of 14 years. There is some variation between authors in age estimations based on counting rings in the otoliths (ear stones). Kelly reported ages of 2 to 50 years for males and 2 to 60 years for females, with most falling between 10-38 years. Allain (2001) found the maximum age of females in her samples to be 38 years. Older fish tend to be missing from more recent samples; Drazen and Haedrich (2012) give the maximum longevity as 72 years. In the Skagerrak, Bergstad (1990) found that roundnose grenadiers mature at 8 years for males and 10 years for females (50% maturity), and commented that 90% of fish spawned for the first time at an age range of 7 to 8 years.

The roundnose grenadier is a typical teleost fish that spawn batches of eggs which are externally fertilised in the seawater. The eggs are ca. 2.4 – 2.6mm diameter which is relatively large for eggs of teleost fish (Bergstad & Gordon 1994). Kelly *et al* (1996) postulated that fecundity was determinate, i.e. the number of eggs to be spawned is fixed at the start of the spawning season. However, they note that all the eggs present at the start of the season are spawned and suggest that maturation might take longer than a year. Allain (2001) shows that west of the British Isles the spawning season extends from February to November, and that fecundity is indeterminate, with each female spawning an unknown number of batches of eggs during the course of the season. The spawning is at a maximum from May to October. The number of eggs in each batch was estimated at between 2500 and 70,000 per female (mean 23,000), and Allain (2001) gives equations relating fecundity to length, weight and age with larger and older females producing the most eggs. Information from the Skagerrak shows that eggs and larvae develop in the water column at depths from 150-550m (Bergstad & Gordon 1994), whereas Merrett (1978) captured larvae in the Atlantic Ocean at 20°W in midwater at depths of 350 to 850m. The best information on the life cycle comes from studies in the Skagerrak, where the larvae grow throughout the spring and summer (February to October) and then begin to settle down on the sea floor almost a full year after spawning, once they have grown to 8-10cm total length (Bergstad & Gordon 1994). These juveniles feed bentho-pelagically on small crustacea, mainly mysids (Mauchline *et al* 1994). Juveniles are generally found deeper than 800m.

Although the roundnose grenadier has an annual spawning cycle, the almost year-long pelagic life of the eggs and larvae is hazardous, so abundant settlement of juveniles every year is not necessarily guaranteed. Bergstad *et al* (2013) showed that in the Skagerrak, during almost three decades (1985 to 2012), there was only one major recruitment event in 1991 which rejuvenated the population and resulted in high catches over ten years later (2003-2005) when these fish had grown. In the Rockall Trough it is interesting to note that only samples taken by Gordon (unpublished) in the early 1970s show a distinct mode of juvenile fish (Kelly *et al* 1997), suggesting that here also recruitment may be a rare event occurring three or four times in a century. While there is still some uncertainty regarding the ageing of roundnose grenadier (Lorance *et al* 2003) there is substantial agreement between different studies as to the broad pattern of the life cycle and the longevity of the roundnose grenadier. There are important variations between different regions, for example off Iceland the species spawns continuously throughout the year, albeit with a peak in winter (Magnusson & Magnusson 1995).

2.6.3 Exploitation and management

The deep-sea fishery for roundnose grenadier in the North Atlantic was first opened up by the Soviet Union during the 1960s and 1970s (Sealy 1974). In the NW Atlantic the species was fished down to a point of being endangered (Devine *et al* 2006), but fishing continues in the NE Atlantic. In Subarea 6, the fishery is now operated mainly by French trawlers along the continental shelf edge and Spanish vessels offshore in the Hatton bank area (ICES WGDEEP 2017).

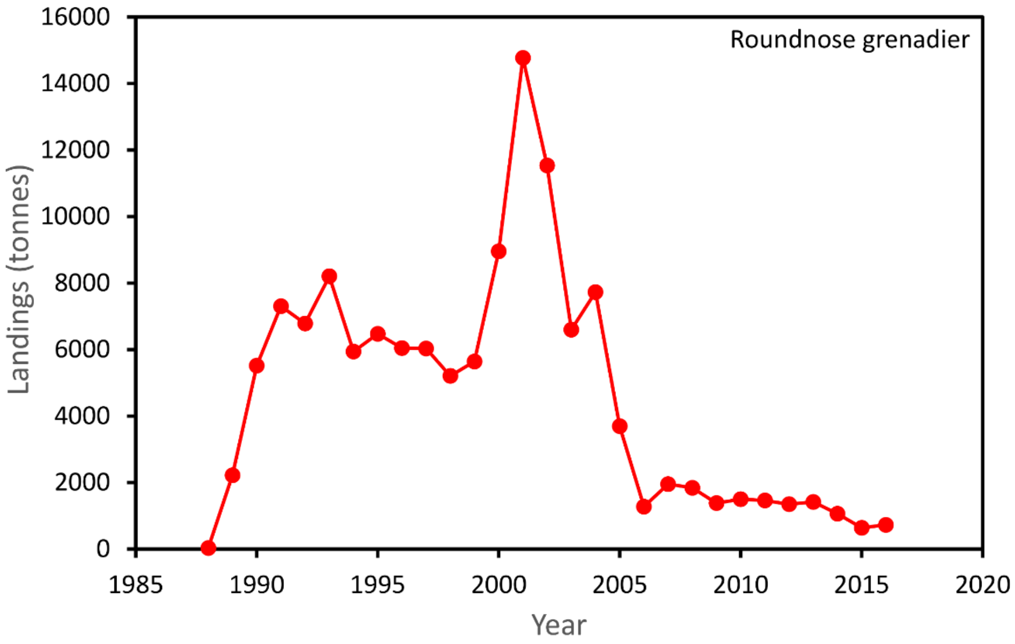

Figure 25. Landings of roundnose grenadier from ICES Subarea 6. Data from ICES WGDEEP (2017).

From 1990 to 2000 the catches were uniform at around 6000 tonnes per annum (Figure 25). During 2000 to 2005, other fleets from other countries (Lithuania, Poland, Spain and Scotland) reported high catches, resulting in a peak of almost 15,000 tonnes in 2001. An EU total allowable catch limit of 5253 tonnes was introduced from 2005 for the combined area to the west of the British Isles, Subareas 5b, 6 and 7. This was gradually reduced to 3324 tonnes in 2010 and then increased in 2015 to 4010 tonnes. A TAC of 3120 tonnes is provisionally proposed for 2018, but this also includes roughhead grenadier (*Macrourus berglax*).

By combining data from the fishery and abundance indices from the Scottish Deepwater Trawl Survey (Neat *et al* 2010), relatively well-founded estimates are being made of the trends in the stock size. Indications are that from 1988 the stock size in areas 5b, 6 and 7 was reduced from 140,000 tonnes to 40,000 tonnes in 2004. Since then according to ICES WGDEEP (2017) there is evidence of recovery but biomass remains below maximum sustainable yield. Discarding of small roundnose grenadier (ca 50% of number of individuals caught) remains an issue (ICES WGDEEP 2017) and for 2018 ICES recommended that the catch should be no more than 3399 tonnes, implying landings of no more than 3120 tonnes after discards in order to enable the stock to recover to maximum sustainable yield level.

2.6.4 Data and knowledge deficiencies

For a deep-water species the information on this stock is relatively good, there are reliable statistics from the French fishery supported by population assessment mainly carried out by IFREMER (Institut Français de Recherche pour L'Exploitation de la Mer). This is further enhanced by fishery independent data coming from the Scottish Deepwater Trawl Survey. A major uncertainty is the lack of direct information on recruitment from juvenile sampling, as in the Skagerrak (Bergstad *et al* 2013). Recruitment can be inferred from length and age frequency analysis.

2.6.5 Conclusions

The roundnose grenadier occurs on all the deep slopes of the study area and forages on midwater prey that impinges on the slopes during daytime. The stock is the target of an active fishery that is appropriately managed. The population in the study area is part of a more widespread stock extending along the European deep continental margin.

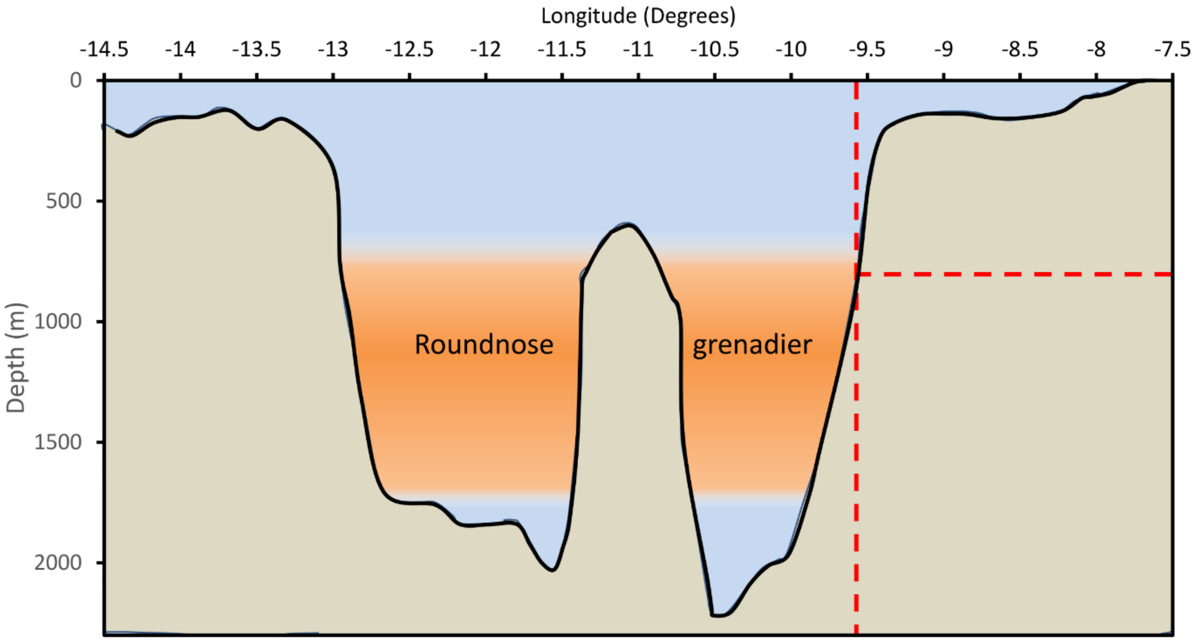

Figure 26. Section of the study area with intensity of orange shading showing the probable depth distribution of roundnose grenadier based on information from the relevant literature cited in the text.

2.7 Blue ling *Molva dypterygia* (Pennant 1784)

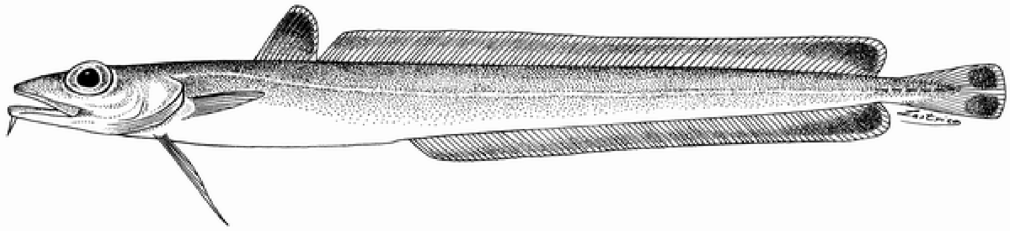

Figure 27. Blue ling, *Molva dypterygia* (FAO image Cohen *et al* 1990).

The blue ling is a member of the family Lotidae (cuskfishes, burbots, hakes) (Froese & Pauly 2016). However, it is often placed within the cod family (Gadidae) as a member of the sub-family Lotinae, together with the freshwater burbot and tusk (Rao-Varón 2009; Nelson 2006). There are three species of *Molva*, all endemic to the North Atlantic: ling *Molva molva*, usually found at depths of 100-400m depth, the deeper-living blue ling and the Spanish ling, *Molva macrophthalma* which is a more southerly species extending south to Morocco and into the Mediterranean Sea at depths down to 754m. Formerly the Spanish ling was considered a sub-species or a variety of blue ling and information on the two species is often mixed together in many information sources. The blue ling has large eyes and a long lower jaw that projects beyond the upper jaw, features that have allowed it to feed on large mobile prey, mostly fish (Bergstad & Hareide 1996). In the Rockall Trough, blue ling occur at 500 to 1250m depths, feeding on fish, squid and amphipods. Mauchline and Gordon (1984b) consider it to be primarily a fish eater that also feeds on epibenthic prey, including invertebrates. In an extensive trawl survey of the Norwegian Deep, during 1984 - 1987 at depths down to 600m, blue ling were found at depths from 200m and the diet comprised over 94% fish by weight, with crustacea being mostly consumed by small fish in the 60-69cm length category (Bergstad 1991a). Individuals caught at <300m depth were feeding mainly on blue whiting (*Micromesistius poutassou*) and Norway pout (*Trisopterus esmarki*) whereas at greater depths, greater argentine (*Argentina silus*) and roundnose grenadier (*Coryphaenoides rupestris*) became important. The length range on the fishing grounds in the Norwegian Deep was 45 to 140cm, whereas the maximum recorded size is 155cm total length and weight 30kg (Froese & Pauly 2016).

2.7.1 Distribution and status in the study area

The blue ling is distributed around the rim of the NE Atlantic from the SW Barents Sea to the west of the British Isles (Figure 28). It also occurs very rarely in the NW Atlantic. Reports of the species further south and in the Mediterranean arise from confusion with *Molva macrophthalma* which is now recognised as a separate species.

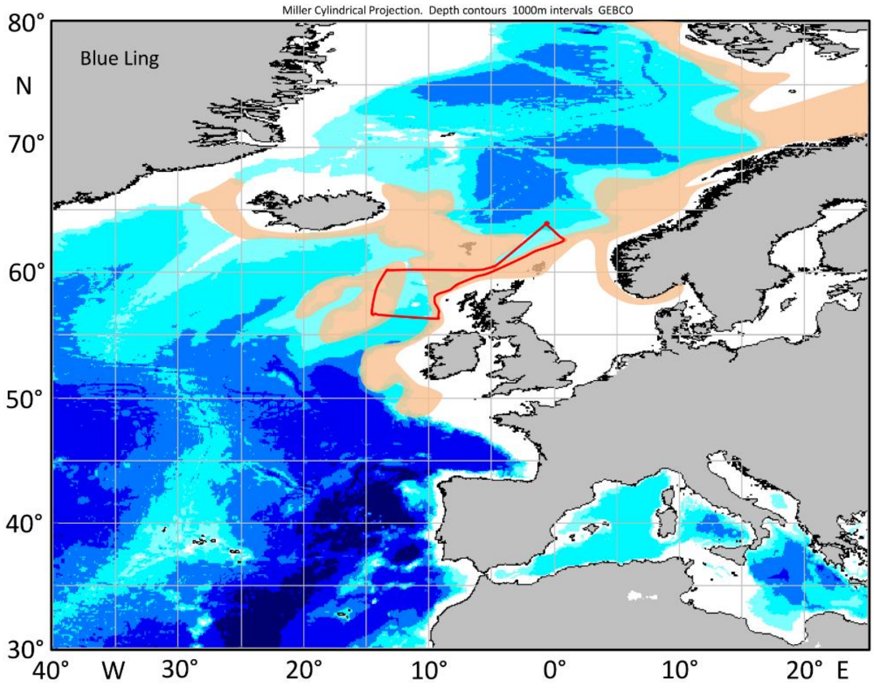

Figure 28. Species range of the blue ling *Molva dypterygia* (orange shading) after Fernades *et al* (2015) and Hislop *et al* (2015). Red outline is the study area. The blue shading denotes 1000m depth increments, i.e, 1000, 2000, 3000, 4000 and >5000m.

Blue ling are relatively non-migratory and there are considered to be two stocks, a northerly stock around Iceland and SE Greenland and a southern stock around the Faroes and to the west of Scotland. Large *et al* (2010) reported a depth range of 300 to 1500m for the southern stock off Scotland with peak abundance at 750 to 1000m depth. In their sampling, Mauchline and Gordon (1984b) listed blue ling as one of the “rare species” caught in small numbers; the subsequent development of fisheries has been based on exploiting the spawning aggregations west of Scotland.

2.7.2 Life history

Spawning occurs each year in five areas to the west of Scotland: (1) along the continental slope northwest of Scotland; (2) on, around, and northwest of Rosemary Bank; (3) on the southern and southwest margins of Lousy Bank; (4) on the northeast margins of Hatton Bank; (5) on the eastern and southern margins of Hatton Bank mainly at depths of 730 - 1100m (Large *et al* 2010) (see Figure 29). Large *et al* (2010) also suggest from tracking of Scottish fishing boats that there may be spawning aggregations on and around the Rockall Bank, on the NW margins of the Faroe Bank and on Bill Bailey's Bank. However, this is not corroborated by observations of fishers and thus remains speculative.

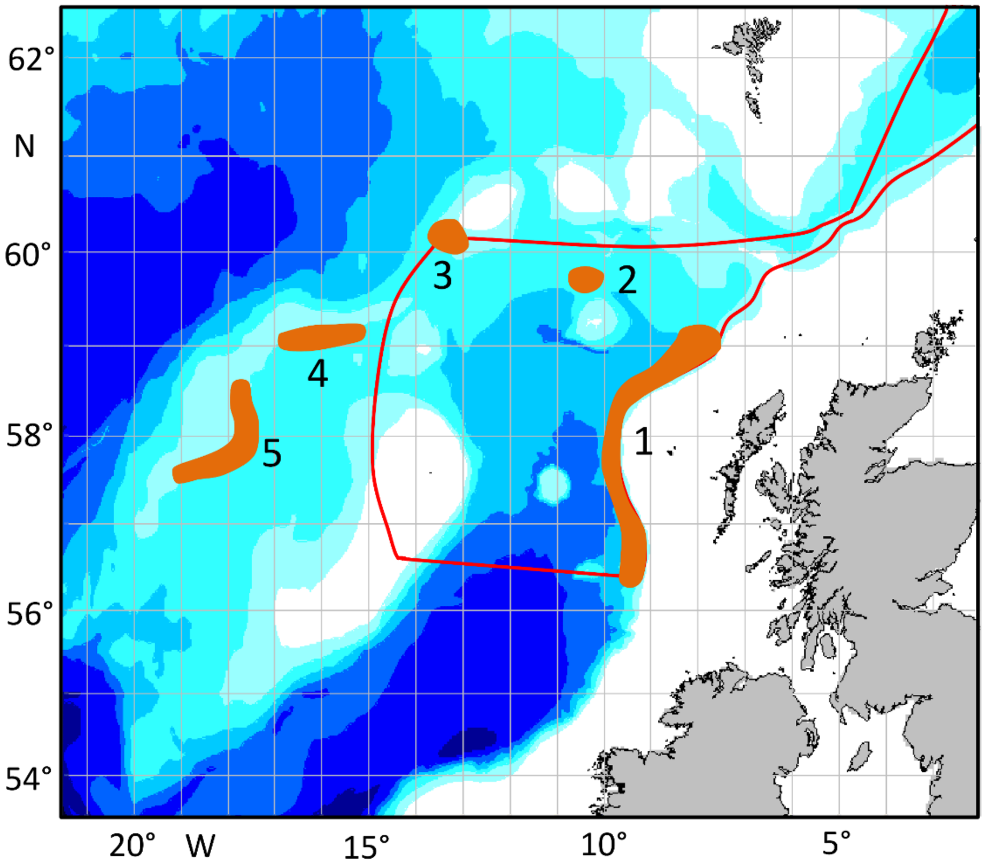

Figure 29. Spawning grounds of blue ling (after Large et al 2010) in orange: (1) Continental slope; (2) on Rosemary Bank; (3) Lousy Bank; (4) NE Hatton Bank; (5) SE Hatton Bank. The red outline is the study area.

The growth rate is relatively fast for a deep-sea fish species with a maximum age of probably 30 years. It is estimated that blue ling reach an average length of 91cm at 10 years and 132cm at 15 years. (ICES WKAMDEEP Workshop on Age Estimation Methods of Deep-water Species 2013). From seven years old, the growth rates of the sexes diverge, and though the females grow more slowly than the males, they attain a larger size. In the Faroe region blue ling become mature at an average length of 79cm, corresponding an age of 6.4 years for males and 8.1 years for females. Fecundity is very high, as is typical for gadoid fishes, estimated to be from 1 to 3.5 million eggs per female. Large *et al* (2010) show that west of Scotland spawning occurs from February to June, probably slightly later in the ICES Subarea 6a than further offshore in Subarea 6b, with peak spawning during March to May in Subarea 6a and in March to April further offshore. In the Norwegian Deep, spawning could be from March-April to August (Bergstad 1991a). There is an annual spawning cycle with spent and recovering fish in Autumn and maturing fish in Winter. Little is known about the eggs of blue ling. Schmidt (1909) reported post-larval stages from 6 to 80mm long in the NE Atlantic. Most of the early stages <3cm long were found over the 1000m isobath, the presumed site of adult spawning. Pelagic fry were found from the beginning of April, shortly after the start of spawning, to September with the greatest number in May and June. The greatest quantities of fry were found to the northwest and west of Scotland. In July, some of the early spawned larvae had grown to >5cm and were located inshore of the 200m isobath northwest and southwest of Shetland, presumed to have been carried by the prevailing current. By September some larvae had grown to 8cm long. No larvae were ever found in the North Sea. The nursery areas for early stage demersal juveniles are unknown. The smallest fish in the Norwegian Deep, 45-50cm long, are estimated to be 2-4 years old (Bergstad 1991a). Off Iceland in Autumn trawl surveys fish appear from 20cm and the abundance of those <40cm is taken as an index of recruitment (ICES WGDEEP 2017).

2.7.3 Exploitation and management

The blue ling has a very long history of exploitation with Norway reporting annual landings of 1000-2000 tonnes per annum during the 1950s. There is considered to be a single stock in ICES Subareas 5b (around the Faroes), 6 and 7 (west of the British Isles). The main fisheries are in area 5b by Faroese trawlers and 6a by French trawlers. The catches in area 7 are small.

Very high catches in the 1973 and 1974 (Figure 30) coincided with the first discovery of the spawning aggregations of blue ling in which they are very vulnerable to targeted trawling. Depletion of these spawning concentrations has resulted in a decline of the stock. Since the turn of the century blue ling in Subarea 6 have been mainly taken in the regular French continental slope fishery also targeting roundnose grenadier, black scabbardfish and deep-water sharks before the latter were prohibited. Management of the stock has been by biennial TACs until 2009, and annual TACs since 2009. Also from 2009, spawning aggregations of blue ling on the edge of the Scottish continental shelf and Rosemary Bank in Subarea 6a have been protected from March to May (EC Regulation No. 43/2009) (Large *et al* 2010; ICES WGDEEP 2017). The current ICES advice for 2019 is that for a maximum sustainable yield no more than 11,778 tonnes should be taken across the entire Subareas 6, 7 and 5b (Celtic Seas, English Channel and Faroes grounds). The spawning stock biomass has been slowly increasing since 2004 and recruitment of 9 year-olds into the population is stable. Fishing pressure is at a long-term low. The fishery is exploiting 9 to 19 year-old adults and with protection of the spawning aggregations the situation is stable (ICES 2018).

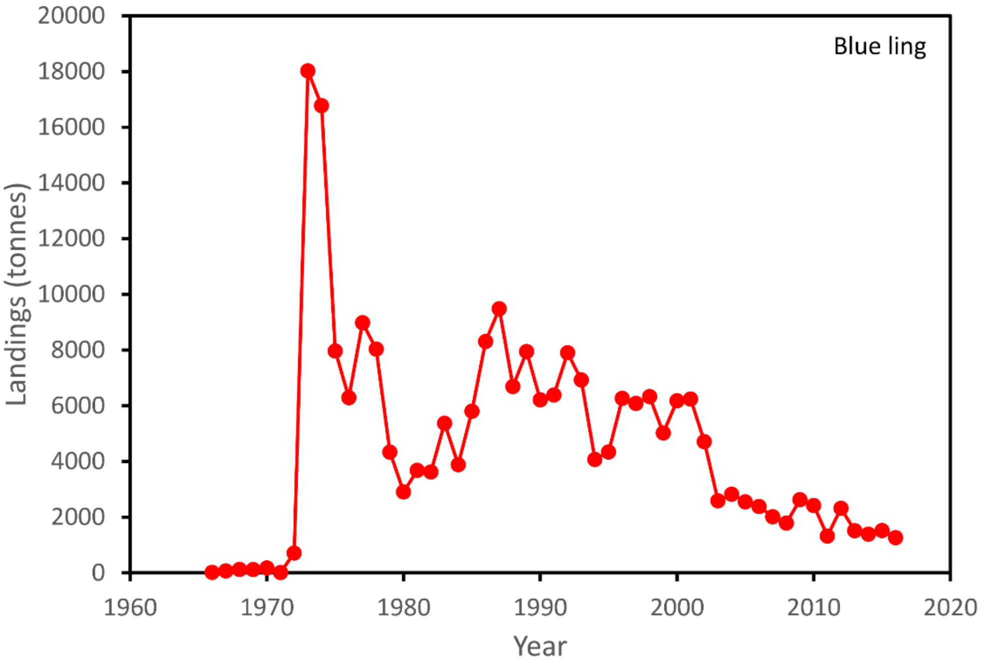

Figure 30. Landings of blue ling from Subarea 6a (West of Scotland), Data from ICES WGDEEP (2017).

2.7.4 Data and knowledge deficiencies

The information on this species is relatively good with landings data from a continuing active fishery and data from the Scottish Deepwater Trawl Survey and from ICES International Bottom Trawl Surveys (Hislop *et al* 2015). There remains the problem with interpretation of historic data in which *Molva macrophthalma,* the Spanish ling, was not necessarily recognised as a separate species. It is not certain that all the spawning aggregations that should be protected have been correctly identified. There may also be problems with correctly determining the ages of older fishes (Bergstad *et al* 1998). Almost nothing is known about where the larvae disperse and the locations where early stage juveniles develop.

2.7.5 Conclusions

This is a species with a long history of targeted exploitation which suffered severe depletion when the spawning aggregations were discovered in the 1970s within and around the study area. These proved vulnerable to new fishing technologies. Protection of these areas with seasonal exclusion rules appears to have been successful and stocks are recovering. There is the possibility of discovering additional spawning locations within the study area. The blue ling is endemic to deep slopes of the NE Atlantic and the study area encompasses a significant fraction of the species range including spawning areas.

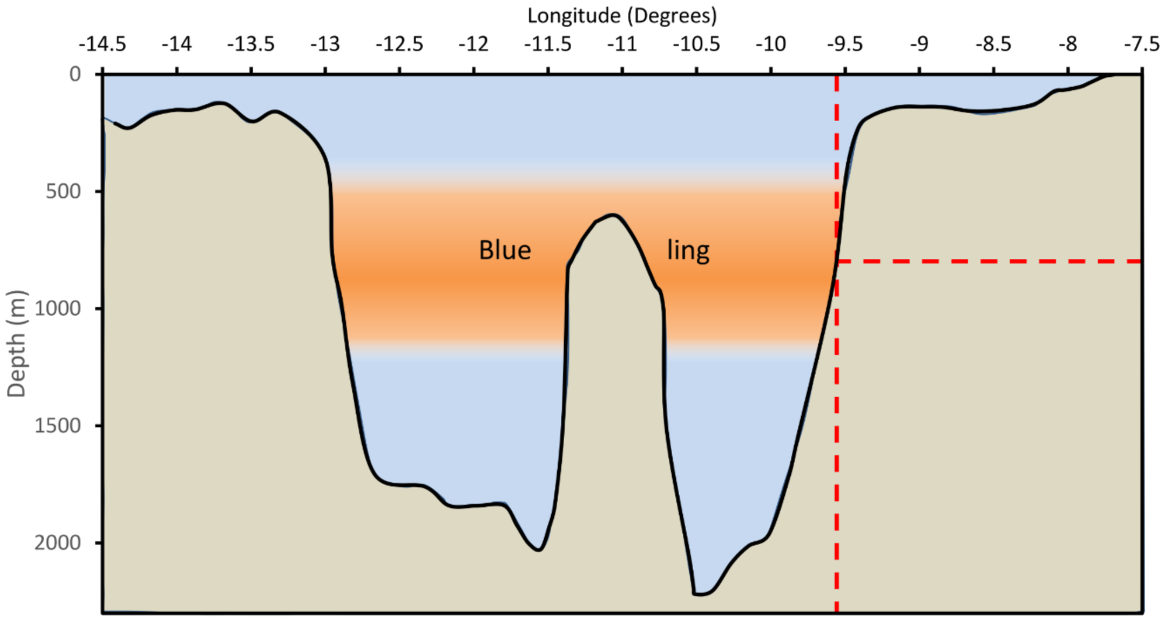

Figure 31. Section of the study area with intensity of orange shading showing the probable depth distribution of blue ling based on information from the relevant literature cited in the text.

2.8 Monkfish/anglerfish *Lophius piscatorius* (Linnaeus 1758)

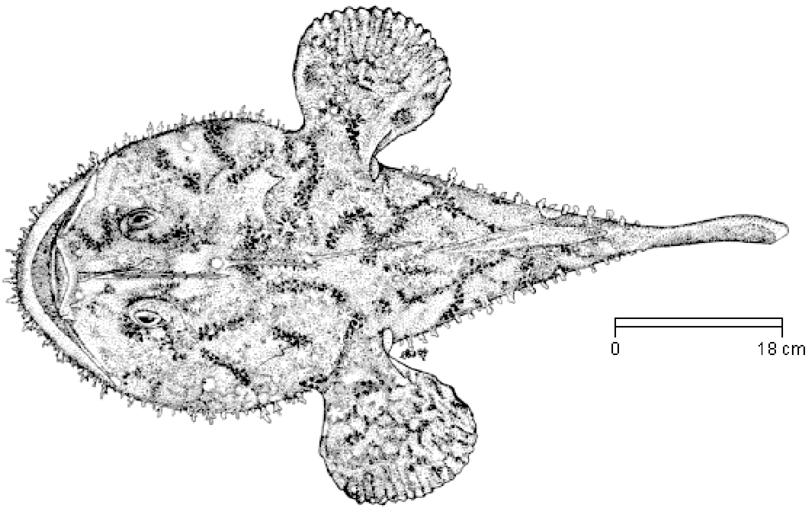

Figure 32. Monkfish/anglerfish *Lophius piscatorius* (FAO image Bauchot 1987).

There are three species of *Lophius* in the North Atlantic (Fariña *et al* 2008), the American angler or goosefish, *Lophius americanus* in the NW Atlantic and two in the NE Atlantic, the anglerfish *Lophius piscatorius* and the black-bellied angler *Lophius budegassa*. The two eastern Atlantic species have overlapping distributions, but *Lophius budegassa* has a more southern distribution; around the Shetland islands it comprises only 1% of the catch

(Laurenson *et al* 2005). The black-bellied angler is distinguished from the angler by its distinctive black peritoneum (internal lining of the belly) whereas the angler has a white peritoneum and is often known as the white anglerfish to avoid ambiguity, e.g. in Landa *et al* (2008). There are other minor differences between the two species. This report deals exclusively with *Lophius piscatorius,* but with the caveat that a small percentage of black-bellied anglers have also been caught in the study area.

Apart from the problems of distinguishing the different species of *Lophius*, the anglerfish is very easy to identify with its very large flattened head and wide jaws (Figure 32). It lives on the sea floor where it stalks its prey with the aid of a specially-adapted first ray of the dorsal fin (the illicium) tipped with an esca that functions as the eponymous angler’s lure. Using its pectoral and pelvic fins it can walk on the sea floor as well as excavate it. Excavations can attract prey species such as cod which feed on the released benthic invertebrates. The anglerfish then leaps forwards and can grab prey as large as a 60cm cod in its jaws (Laurenson *et al* 2004). While the maximum reported length of the anglerfish is 200cm and weight 58kg, most are less than 100cm long (Froese & Pauly 2017). Based on samples taken around Shetland, Laurenson and Priede (2005) found the diet to be over 95% fish with the two most important prey items being Norway pout (*Trisopterus esmarkii*) and the lesser sandeel (*Ammodytes marinus*). Twenty-six other fish species were identified, including cod (*Gadus morhua*), whiting (*Merlangius merlangus*), herring (*Clupea harengus*) and cannibalism on other anglerfish (Laurenson & Priede 2005). In many instances a single large prey item could account for a large percentage of the diet by weight. Despite being a demersal fish generally caught in bottom trawls, gill nets and long lines, Hislop *et al* (2000) report captures of anglerfish near the surface in pelagic trawls to the north and west of Scotland. These were post-juvenile fish from 24-103cm long and included one 62cm long individual captured in the Norwegian Sea, where the sea floor depth was 2600m. They suggest that those captured over shallow depths, on or near the continental shelf, are making migratory moves, possibly taking advantage of selective tidal transport, whereas those found over great depths (>1000m) may be strays.

2.8.1 Distribution and status in the study area

The geographical range of the anglerfish extends from the Barents Sea and Iceland in the north, to the Straits of Gibraltar, off Mauritania, the Mediterranean and Black Seas in the south (Figure 33). Over much of this range it overlaps with the black-bellied anglerfish, which is more abundant in the south, and for example can form large single-species aggregations in deep parts of the Adriatic (La Mesa & De Rossi 2008). The white anglerfish occurs over a depth range of 20-1000m (Froese & Pauly 2017). In the Rockall Trough, Gordon and Duncan (1985) found it in all depths zones down to 1000m, although never in great abundance, comprising a maximum of 2.23% by weight of fish catch at 750m depth. In extensive surveys during 2005 and 2006, Fernandes *et al* (2007) found the highest abundances of 200-400km^{-2} between the 200 and 500m depth contours in the Rockall area, and around 200m depth off the north and west of Scotland; it was very rare that no anglerfish were caught. Ellis and Vallesco (2015) record anglerfish in trawl surveys both on the continental shelf west of Scotland and around Rockall in consistent but modest quantities, with a peak in abundance at 200-300m depth.

Anglerfish are also important in the northern North Sea with more than twice as much landed from ICES Subarea 4a than from the West of Scotland subarea 6a (ICES WGCSE 2017). Laurenson *et al* (2005) caught and tagged anglerfish close inshore around Shetland. Most tags were recaptured on nearby slopes at less than 500m depth but one tag was returned from SE Iceland after 1078 days and another off Faroe after 840 days. Anglerfish are regionally mobile and it is assumed for fishery management purposes that populations in the Skagerrak and Kattegat (Division 3a, 3b), the North Sea (Subarea 4) and the West of Scotland plus Rockall (Subarea 6) comprise a single stock (ICES WGCSE 2017).

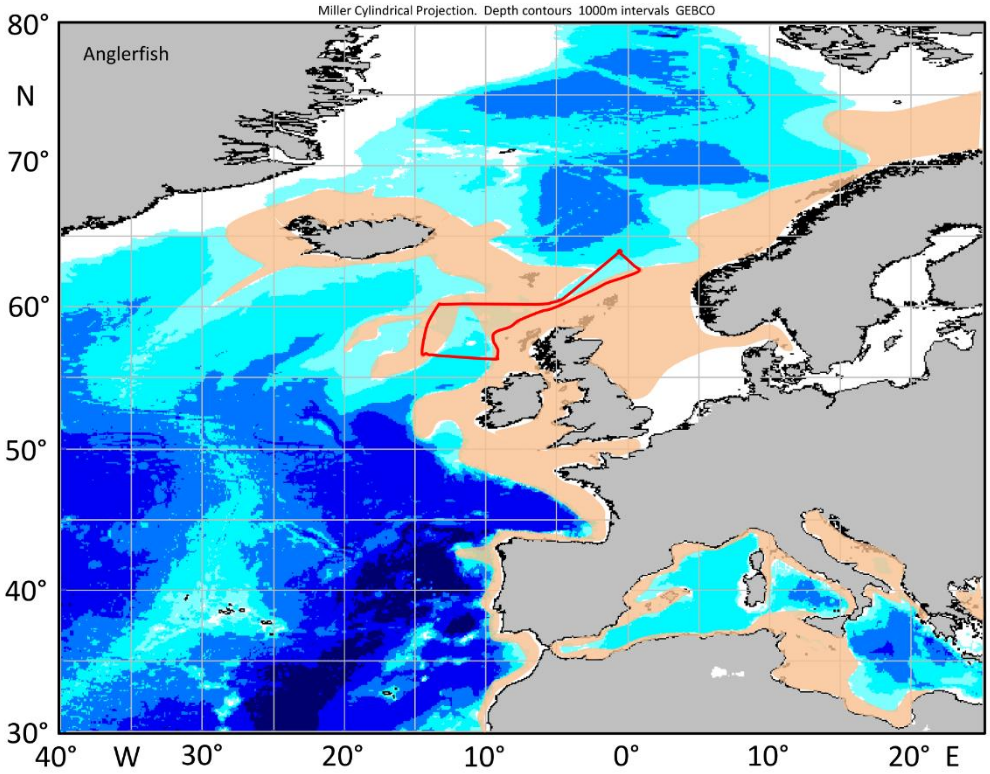

Figure 33. The distribution of white angler fish *(Lophius piscatorius*) in the NE Atlantic and associated seas (orange shading), after Froese and Pauly (2017) and Ellis and Velasco (2015). Red outline is the study area. The blue shading denotes 1000m depth increments, i.e, 1000, 2000, 3000, 4000 and >5000m.

2.8.2 Life history

Female anglerfish reach sexual maturity from a total length of 60cm upwards with 50% maturing at 73.5cm whereas for males 50% maturity occurs at 48.9cm. In their samples from the north and west of Scotland Afonso-Dias and Hislop (1996) observed females up to 120cm long, whereas the maximum size for males was 90cm. Spawning occurs from November to April to the west of Scotland at depths from 150 to 900m on the continental slopes to the west of the Hebrides and around Rockall (Hislop *et al* 2001). The eggs are enclosed in a buoyant gelatinous egg raft or egg veil, reminiscent of frog spawn, which swells with uptake of water to reach a size of over 10m long and 60cm wide. Information from *Lophius americanus* shows that eggs are produced in batches, each female producing several egg rafts per year containing 200,000 to 2.2 million eggs per batch depending on the size of the female (McBride *et al* 2017). This confirms previous speculations regarding the anglerfish in the NE Atlantic. Hislop *et al* (2001) estimated that off Scotland the eggs hatch in the surface layers from early February to late April, with the majority in March. The yolk sac stage lasts for about 20 days and then the larvae feed pelagically growing to a total length of 10cm by 120 days (post hatch), and 15cm by 160 days when they begin to descend to the seafloor. The prevailing currents carry larvae originating from the west of Scotland north and eastwards, mainly into the North Sea with some reaching Iceland. Those spawned in further offshore around the Rockall bank are mostly retained on the Rockall plateau. Evidence of large numbers of anglerfish <30cm long at less than 50m depth around Shetland suggests that juveniles begin their life on the sea floor at shallow depths on the continental shelf and gradually move into deeper water as they grow (Laurenson *et al* 2008), however Ellis and Velasco (2015) point out that such small individuals are also commonly found at depths beyond 200m. Anglerfish reach the size of first maturity (60cm) at six to eight years and the typical age of the largest fish *ca.* 130cm is 20 years (Wright *et al* 2002; Woodroffe *et al* 2003; Landa *et al* 2008).

2.8.3 Exploitation and management

Anglerfish are mostly captured demersal trawls that are targeting white fish. Off the west coast of Scotland (Subarea 6) Scottish vessels took 46%, French 29% and Irish 12% of the landings (ICES WGCSE 2017).

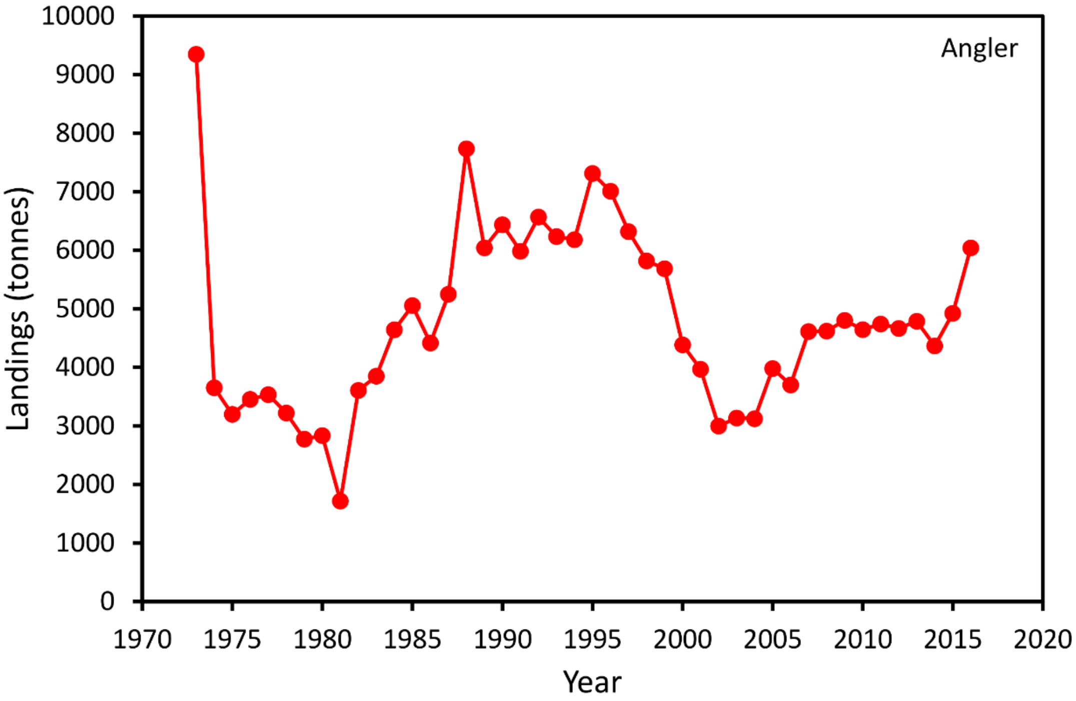

Figure 34. Anglerfish reported landings from Subarea 6 (ICES WGCSE 2017).

From the 1980s the landings rose to a peak around 1995 and then declined from 2000 when a 40% reduction TAC was advised (Figure 34) (ICES WGCSE 2017). The historic landings data are not considered reliable with widespread misreporting; ICES is very selective as to which parts of the time series it uses for assessment models of the stock. From 2000 continuing pressure was applied to avoid an increase in fishing effort and to decrease catches with lowering of the TAC in 2013 and 2014. Since 2015 there has been a precautionary increase in TAC to no more than 26408 tonnes in 2018 for the combined Subareas, 4, 6 and 3a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat. Ellis and Velasco (2015) show that in international bottom trawl surveys there is a long term upward trend in biomass, but with alternating periods of increasing and decreasing catches at a periodicity of about one decade. Recent data, for Subareas 4 and 6 combined, show a 70% increase in biomass (ICES WGCSE 2017) suggesting the stock is reaching a periodic peak. Nevertheless, owing to problems with data quality and difficulty of aging fishes ICES WGCSE (2017) has difficulty with successfully modelling the stock trends.

2.8.4 Data and knowledge deficiencies

It is assumed there is a single stock, covering Subareas 6 (West of Scotland and Rockall), 4 (North Sea) and 3a (Skagerrak). It is difficult to discern the state of the stock in the study area. ICES have difficulty modelling the stock because of poor data quality and lack of agreed methods for aging of fishes. There is little information on eggs, larvae and juvenile stages and the spawning grounds are not well identified although modelling indicates the study area is an important source of larvae.

2.8.5 Conclusions

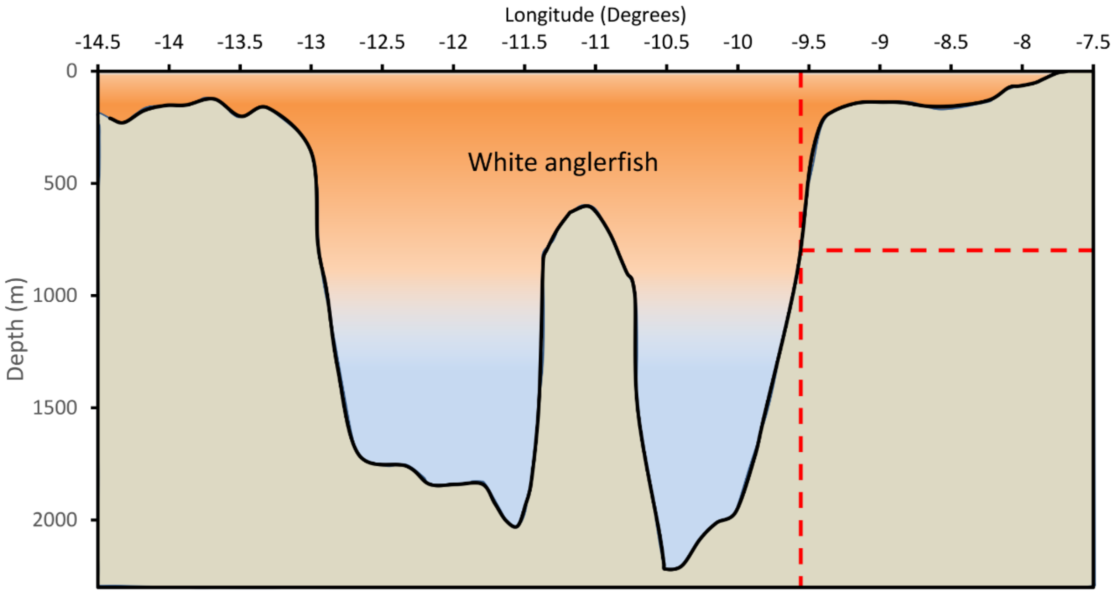

Figure 35. Section of the study area with intensity of orange shading showing the probable depth distribution of anglerfish/monkfish based on information from the relevant literature cited in the text.

The study area provides an important habitat for possibly all life history stages of this species. Spawning occurs in deep waters during the winter and larvae hatch from the egg masses in the surface layers during March. Whilst many larvae are carried by prevailing currents onto the continental shelf and into the North Sea a significant proportion or juveniles are contained around the Rockall Bank area and may pass their entire life span within the study area. The study area is an important source of larvae for the wider surrounding area and the northern North Sea. Large females are capable of making migrations (possibly to spawn) in midwater across deep areas (Ellis & Velasco 2015) such as occurs in the study area. The anglerfish is subject to continued fishery exploitation with signs that stock decline has been arrested by regional management measures (ICES WGCSE 2017) and there is evidence of a long term upward trend in the stock (Ellis & Velasco 2015).

2.9 Orange roughy *Hoplostethus atlanticus* (Collett 1889)

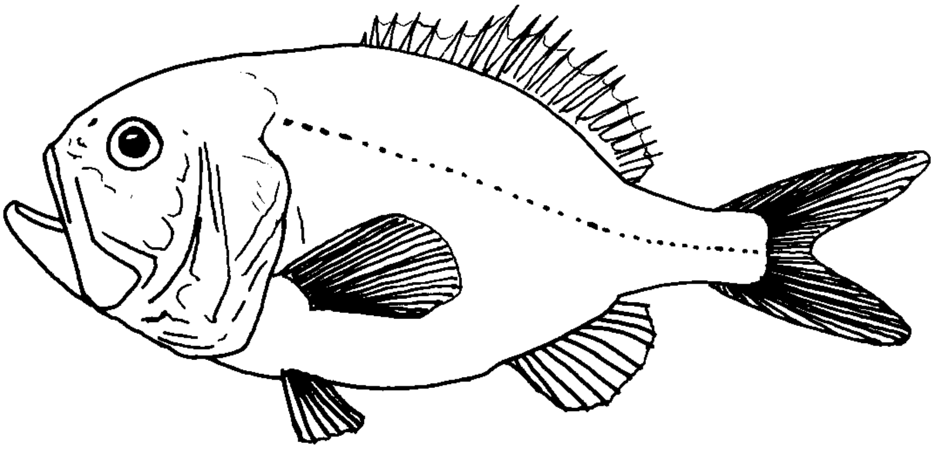

Figure 36. Orange roughy, *Hoplostethus atlanticus.* (Image © Priede).

The orange roughy is a member of the family Trachichthyidae which comprises about 50 species variously known as slimeheads, roughies and sawbellies amongst which the orange roughy is the largest and deepest-living species and the only one that is commercially exploited to a significant extent (Branch 2001). The depth range is 180-1800m and the maximum recorded length is 75cm. The species is best known for the great abundances captured off New Zealand during the 1980s: "*boats sinking under the weight of the roughy they'd hauled aboard, fish hanging off the sides when the decks were full, and the chance to earn millions if the catch was good*." (Ryan 2017). Early research during 1973-1981, in the Rockall Trough off the west coast of Scotland, found the orange roughy to be one of the most common species caught in the 1000 to 1250m depth zone (Gordon & Duncan 1987; Mauchline & Gordon 1984c), feeding on bentho-pelagic prey. Very little sediment was found in the stomachs confirming feeding off the bottom, with food items comprising mainly crustacea, including mysids, amphipods, decapods plus some cephalopods and fish including lantern fishes and deep-sea smelts (Gordon & Duncan 1987). The body of the orange roughy is relatively robust with strong bones, the density of which is offset by wax esters in the skull and vertebrae (20% by weight) as well as in the viscera, swim-bladder, skin and flesh so they are neutrally buoyant at depths of around 1000m. However, in warm surface waters the lipid melts and they become positively buoyant (Phleger & Grigor 1990).

2.9.1 Distribution and status in the study area

The orange roughy has a circumglobal distribution in the southern hemisphere off southern Chile, in the South Atlantic, the southern Indian Ocean, south Australia and New Zealand. In the North Atlantic it is mainly confined to the North East Atlantic in narrow bands of its preferred depth on the continental slopes, the Mid-Ocean Ridge and around offshore banks (Branch 2001) (Figure 37).

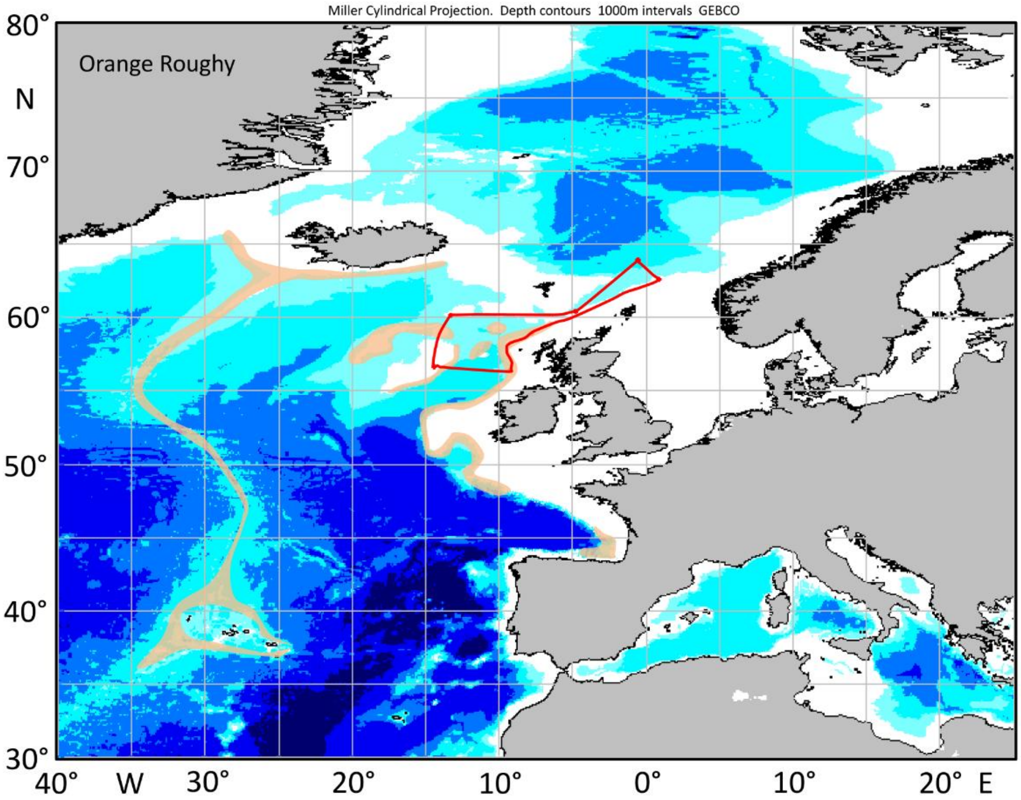

Figure 37. Distribution of orange roughy in the NE Atlantic (orange shading) (after Branch 2001). Red outline is the study area. The blue shading denotes 1000m depth increments, i.e, 1000, 2000, 3000, 4000 and >5000m.

Shephard and Rogan (2006) point out that this band is about 20 nautical miles wide and 360 miles long around the west and north of Ireland. Their preferred temperature range is 3-9°C. The study area therefore contains significant areas of orange roughy habitat. On the slopes of the Rockall Trough they were found at depths from 500 to 1750m (Gordon & Duncan 1985). Orange roughy tend to form concentrations around submarine features such as steep slopes, summits, rocky outcrops, canyons and carbonate mounds. Shephard and Rogan (2006) identified two distinct fisheries west of Ireland, a “flat fishery” and a “hill fishery”. On flat areas, punctuated by small-scale topographic features, the orange roughy are caught as part of a mixed fishery including roundnose grenadier, black scabbard and sharks. On hills, orange roughy form single-species congregations probably related to spawning, the bycatch being mainly cardinal fish (*Epigonus telescopus*).

2.9.2 Life history

Adult orange roughy form large spawning congregations around seabed features such as summits and steep slopes. On the Porcupine Bank west of Ireland, the spawning season is from January to April with peak spawning during February to March, according to Shephard and Rogan (2006), who also cite reports of spawning to the west of Scotland during March, and off the Faroes from January to early March. The size range of spawning fish off Ireland was 22-60cm with somewhat smaller spawners on the hills (50% spawning at 34.1cm) than on the flat ground (37.0cm). The flat grounds have a wider range of fish sizes (15-60cm) whereas the hills have a single size mode of large fish. It is suggested that fish start spawning on flat ground but when they reach maximum spawning they aggregate onto the hills away from the juveniles. Minto and Nolan (2006) estimated 50% maturity off Ireland to be at a length of 37.8cm and age of 27.5 years. The age range of spawning fish was 20 to

160 years with fecundity increasing with age up to 100 years and then some evidence of decrease associated with senescence in older fish.

The size of maturity of orange roughy is larger than in better-studied major stocks in the Southern Hemisphere off Australia and New Zealand where the range is 28-32cm. The fecundity ranged from 20,352 to 244,578 eggs per female equivalent to 9,701 to 64,493 per kg. These fecundities are much lower than the millions observed in gadoids and the anglerfish. The eggs of orange roughy are also much larger, 2.12 to 2.45mm in diameter (Jordan & Bruce 1993). Studies off Australia show that fecundity can vary with region and from year to year; for example, off Tasmania average fecundity increased by about 20% as the stock size was reduced by fishing by 50%, which suggests a density-dependent response by the population (Koslow *et al* 1995). Bulman and Koslow (1995) show that eggs hatch after 13 days at 7°C, and they float up through the water column from the spawning depth at 24m.h^{-1} which would mean they arrive at the surface within two days. Zeldis *et al* (1998) found that time to hatching was 11.5 days at 8°C and 6 days at 12°C. None would hatch at 6°C which suggests that ascent to warm surface waters seems to be essential for early larvae. However, Jordan and Bruce (1993) comment that it had not been possible to find orange roughy larvae off Australia or New Zealand despite extensive sampling, the smallest specimen ever captured being a 26mm long juvenile. They suggest that larvae occur further offshore or much deeper than is normally sampled. Analysis of stable isotopes from otoliths of orange roughy off Ireland show that post-larval growth is in the mesopelagic during active foraging at 700 to 800m depth, after which they adopt a benthic life style at 1200 to 1400m depth and on reaching around 10cm in length they gradually move up to the more typical adult depths as they grow (Shephard *et al* 2007). Despite this evidence, no larvae have been sampled from waters around the British Isles.

2.9.3 Exploitation and management

For the purposes of assessment by ICES WGDEEP (2017) the orange roughy in the NE Atlantic is divided into three units, Subarea 6, Subarea 7 and all other areas.

In Subarea 6, the fishery has been dominated by the French deep-water trawler fleet that discovered aggregations of orange roughy on the Hebrides Terrace Seamount to the west of Scotland (in the SE corner of the study area), catching 3502 tonnes in 1992 and 1422 tonnes in 1993, essentially removing this long-lived species from the area. After this time, small quantities of orange roughy were landed as part of the mix of species including roundnose grenadier, black scabbardfish and sharks in the deep-water trawl fishery on the continental slopes and adjacent summits. Ireland and Scotland took small quantities in 2001 and 2002, creating a temporary slight overall increase in landings (Figure 38). The Faroes have reported occasional landings including 700kg in 2016. The EU introduced a TAC of 88 tonnes in 2003 but landings continued to decline. The TAC was progressively reduced from 2007 and a zero TAC has been in force since 2010. There is a continuing risk of bycatch in fisheries for other species but the quantity is estimated to be low. Current advice from ICES WGDEEP (2017) is: "*it is not possible to manage a sustainable fishery for this species. ICES recommends no directed fisheries for this species*".

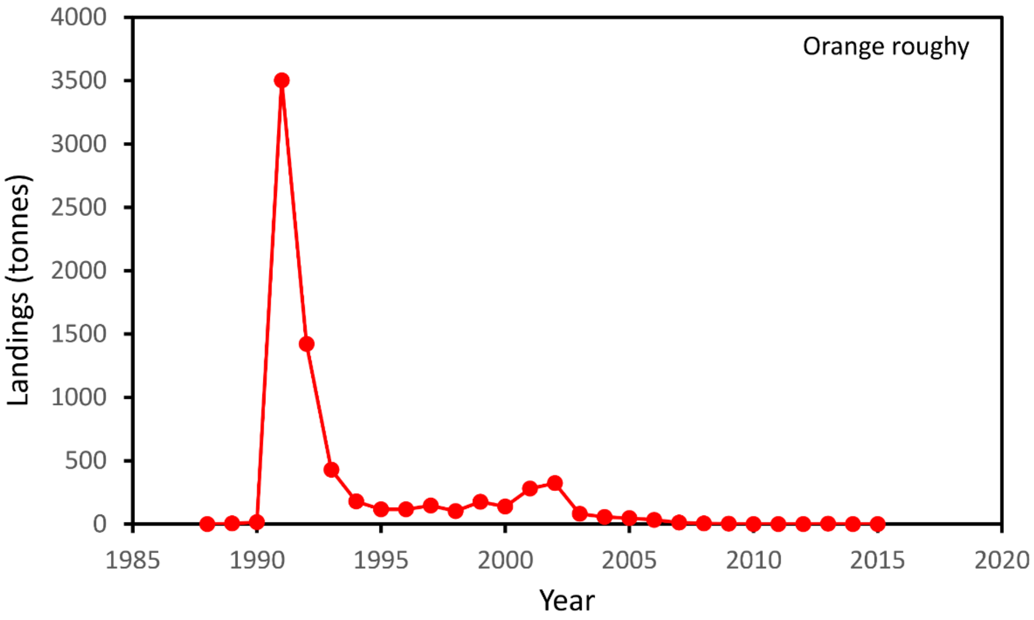

Figure 38. Orange roughy landings from ICES Subarea 6 West of Scotland. ICES WGDEEP (2017).

2.9.4 Data and knowledge deficiencies

The stock is severely depleted and there is little information that can be derived from fisheries. The Scottish Deepwater Trawl Survey acts as a monitor that should reveal any recovery that occurs. Little is known about the life cycle in the wild from eggs to recruitment. The most recent information on the biology of the species is from the west of Ireland, the population to the west of Scotland being too depleted for any meaningful studies.

2.9.5 Conclusions

The orange roughy is a valuable species that is commercially extinct in the study area. The study area is predominantly at the favoured depth distribution of the species and includes important spawning areas which straddle the eastern boundary on the continental shelf (Figure 39). The longevity with first maturity at ca. 28 years, means that even assuming the current zero TAC is effective any recovery of the stock is likely to be slow and the advice from ICES is that it is not possible to manage a sustainable fishery for this species.

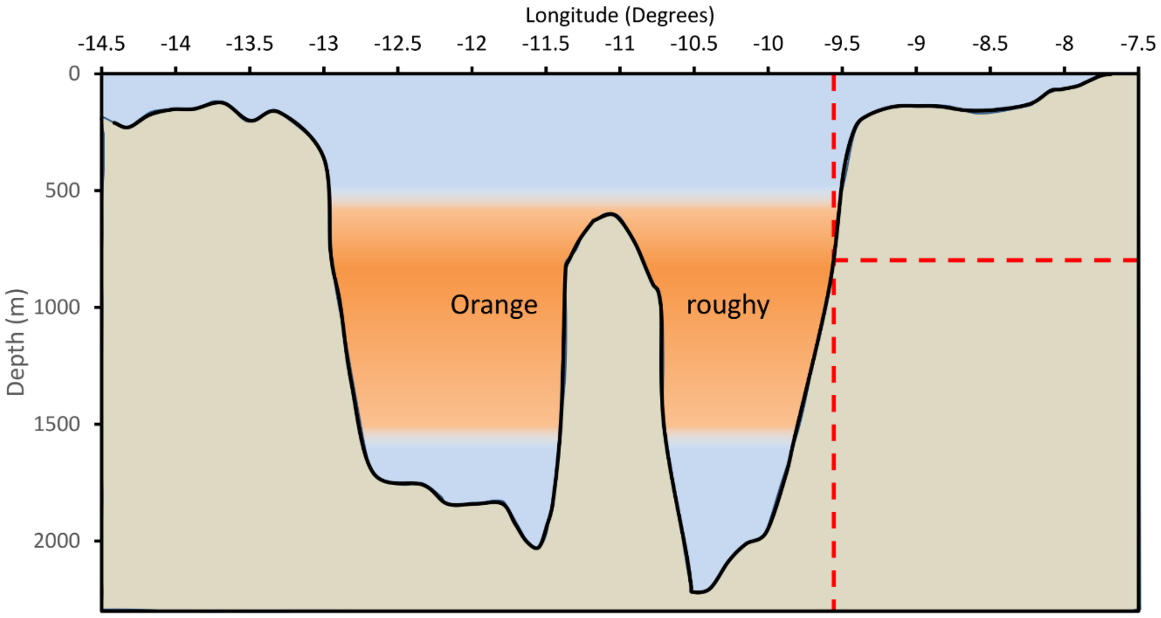

Figure 39. Section of the study area with intensity of orange shading showing the probable depth distribution of orange roughy based on information from the relevant literature cited in the text.

2.10 Atlantic halibut *Hippoglossus hippoglossus* (Linnaeus 1758)

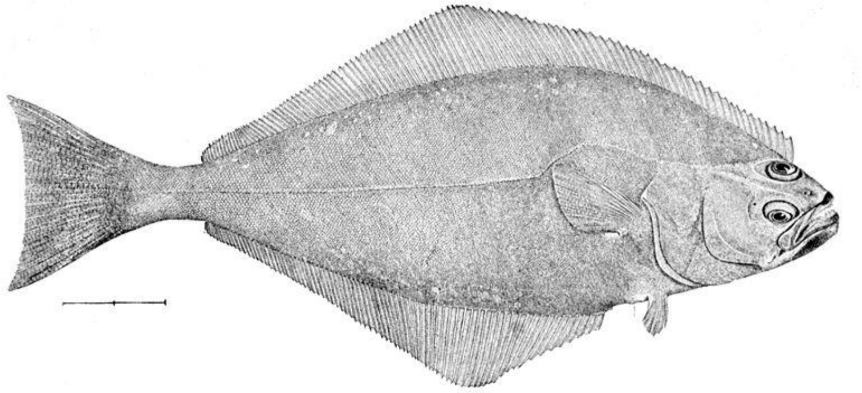

Figure 40. Atlantic halibut *Hippoglossus hippoglossus* (image Goode & Bean 1896).

The Atlantic halibut is an exceptionally large flatfish of the family Pleuronectidae, the righteye flounders, so-called because at metamorphosis the left eye migrates to the right side of the head and adults rest on the sea floor with the left (blind) side downwards. There are two species of *Hippoglossus*, the Pacific halibut (*Hippoglossus stenolepis*) and the Atlantic halibut (*Hippoglossus hippoglossus*) that together surround the Northern Polar seas and live at high latitudes in their respective oceans. It is thought that the Atlantic halibut originated from its Pacific sister species by invasion through the Bering Straits and across the Arctic about 4.5- 1.7 million years ago and became a distinct species (Haug 1990). The Atlantic halibut, the world's largest flatfish has a maximum recorded length of 470cm and maximum weight 320kg (Froese & Pauly 2016). It is usually white on its blind side although coloured variants are known. Unfortunately, in the NE Atlantic the halibut has suffered a catastrophic decline so that very few are ever caught in sampling programmes, e.g. only three individuals have been caught since 2000 in the Marine Scotland Science Deepwater Trawl Survey off the west of Scotland (Burns 2018). Therefore, the information here is largely drawn from historical data reviewed by Haug (1990).

Adult halibut which feed primarily on fish, are predators on the abundant pelagic species that live in different areas. In the early 1950s around Iceland, Scottish scientists found that the main prey was the redfish (*Sebastes marinus*) which comprised over 75% of the food by volume. Around the Faroes, redfish were less important but gadoids (cod family), clupeoids (herrings) and flatfish took their place according to data from before 1910. Around Rockall in the 1950s the diet included European hake (*Merluccius merluccius*), blue whiting (*Micromesistius poutassou*) and more southerly species such as black spot sea bream (*Pagellus bogaraveo*[8]). The diet varies during the course of the year and some authors suggest that females cease or reduce feeding during the spawning season. Juvenile halibut have a rather different diet; the smallest individuals <30cm feed almost entirely on crustacea, especially hermit crabs, prawns, small crabs and mysids. As they grow, so the proportion of fish in the diet increases; 30-60cm fish eat a mixture of fish and crustaceans, including haddock, sandeels, Norway pout and whiting in the spring, and with a bias towards more crustacea in the summer according to studies off the Faroe Islands.

2.10.1 Distribution and status in the study area

The Atlantic halibut is distributed in the NE Atlantic from SW Spitzbergen and Greenland to the west of Scotland and the northern North Sea with occasional reports as far south as the Celtic Sea and Bay of Biscay (Haug 1990; Goldsmith *et al* 2015) (Figure 41).

The study area is therefore within the southern limits of consistent occurrence of the species. Goldsmith *et al* (2015) and Neat and Campbell (2011) record catches in trawl surveys from both the west of Scotland slope and Rockall.

Immature halibut live in shallow nursery areas at 20-60m depth for the first four to six years of life, then switch to a more migratory habit with adults having been recorded down to a maximum depth of 2000m. The emigration from nursery areas appears to be random; tagged fish released off Lofoten moved to the north into the Barents Sea, to the south including into the North Sea, and some as far as Iceland (Godø & Haug 1988). Adult halibut show a homing behaviour returning to the same area for spawning in successive years but there is no evidence that they are homing to the spawning area of their parents. Genetic analysis shows little differentiation between putative populations in different parts of the NE Atlantic, implying that there is a wide dispersal phase early in life and that adults return to the spawning site they themselves have imprinted upon.

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[8] The fishery for black spot sea bream collapsed in the 1980s (Priede 2017).

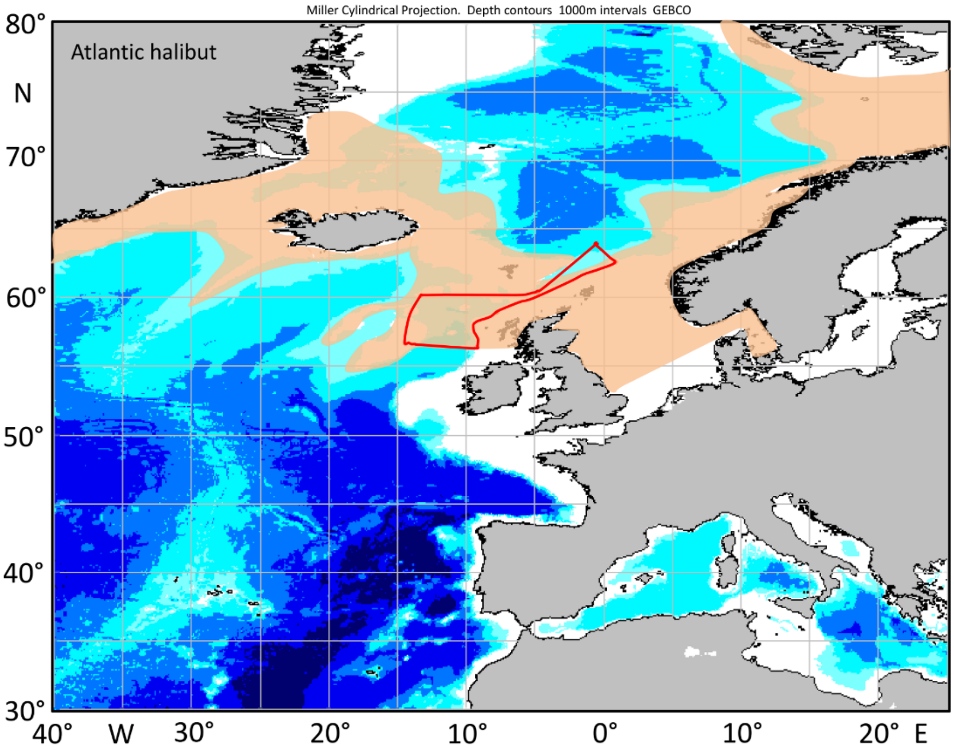

Figure 41. The distribution of Atlantic halibut, *Hippoglossus hippoglossus,* in the NE Atlantic (orange shading) After Haug (1990). Red outline is the study area. The blue shading denotes 1000m depth increments, i.e, 1000, 2000, 3000, 4000 and >5000m.

Around the Faroes, halibut spawn at depths of over 700m and catches have been taken of large adults at 800-1000m depth on the SW slope of Faroe bank (Jákupsstovu & Haug 1987) where the fish were possibly using cold deep-water currents as a cue. This spawning area is to the north of the Wyville Thompson Ridge approximately 60km beyond the boundary of the study area (Seitz *et al* 2014).

2.10.2 Life history

Halibut spawn in winter, the precise timing varying between regions, but SW of the Faroes spawning begins in January, intensifies in February and is presumed to peak in March and end in April (Jákupsstovu & Haug 1988). The youngest sexually mature males are four years old, the 50% maturity level occurs at 4.5 years and all are mature by ten years. The 50% maturity age for females is seven years. There is considerable sexual dimorphism in adult growth. At age of about the age of six halibut migrate from nursery grounds onto adult feeding areas and the female growth rate accelerates so that by eight years a typical female is 130cm long whereas the male is 80cm; at 20 years females reach 200cm and the males 130cm. In terms of weight the divergence is more important; at 20 years the female weighs 100 kg whereas the male is only 30kg (Jákupsstovu & Haug 1988). The growth rate off the Faroes is much faster than that observed further north in Norwegian waters (Karlson *et al* 2013). Longevity is up to over 50 years, but in Faroese waters spawning was dominated by fish less than twelve years old. The age of first maturity has decreased over time; possibly a density-dependent response to reduced population size. The fecundity of females varies with body size; Haug and Gulliksen (1988) made an estimation of 0.5 to 7 million eggs per spawning season produced in intermittent batches over an extended period of time. The released eggs are 3.06 to 3.49mm in diameter and float upwards to intermediate depths, 4.5-7.0°C off northern Norway and 7.5-8.1°C off the Faroes. Blaxter *et al* (1983) found that the time to hatching was 20 days at 4.7°C, 18 days at 5°C and 13 days at 7°C. McIntyre

(1957) captured halibut eggs with well-developed embryos over deep water SW of Iceland and suggested that these were drifting inshore from deep bottom spawning grounds far off the shelf in the Irminger Sea. Larvae are very rarely seen in the wild although there is now considerable knowledge of larval development derived from the rearing of fish for the aquaculture industry. Larvae hatch at a length of 6-7mm and they start feeding when the yolk is fully absorbed (47 days when reared at 6°C and having reached a length of 13mm). They feed on plankton in the water column and metamorphosis to the bottom-living life takes place between 34 and 40mm length, 75 to 90 days post-hatching. At this stage the left eye moves over to the right side of the head and the adult-like fins appear. These young fish then make their way onto the inshore nursery grounds where they remain for the first years of their life (Haug 1990). Van der Meeren *et al* (2013) describe the capture of halibut larvae in shallow plankton net tows at 3-5m depth in Skjerstadfjorden, ca. 67°N on the coast of Norway. They suggest that these would settle on inshore nursery grounds that are also used by cod for spawning. Tracking of adult halibut with pop-up tags shows that some individuals remain within Sognefjorden throughout the spawning season, leading Seitz *et al* (2014) to propose that they might have spawned in deep water within the fjord and there may be small groups of halibut reproductively segregated from other stocks that spawn in deep water offshore. This suggests that halibut may be diversifying their spawning locations following the massive decline in population.

Very little is known about halibut within the study area to the west of Scotland. Past Scottish investigations of halibut tended to be focussed on the main fishing grounds off the Faroes and Iceland where the fishermen from Aberdeen traditionally fished for halibut (McIntyre 1953,1957). It is possible that there may be spawning areas for halibut in the deep waters of the study area.

2.10.3 Exploitation and management

Atlantic halibut is now so depleted that ICES does not collect data nor issue advice. Small quantities are landed from fisheries around Iceland with Faroese vessels permitted to take 40 tonnes per annum (ICES WGDEEP 2017). There has been an increase in catches off Norway north of 62°N, but catches in the south of Norway are still very low (Karlsen *et al* 2012). The fishery off Norway is conducted by bottom set gill nets (55%) and long lines (30%) (Seafish 2018). The decline in the species can be attributed to the extreme vulnerability of spawning aggregations to targeted fishing (Karlsen *et al* 2012). Fishing for Atlantic halibut is now prohibited in Norwegian waters during the spawning season of 20 December to 31 March (IMR 2018). There is some evidence that halibut may exist in the study area to the west of Scotland since observer trips on Irish vessels fishing off Rockall during 1995-2001, mostly targeting haddock reported a catch of 179kg of halibut, representing 0.1% of the catch, all of which was landed (ICES 2004). There are also the few individuals taken in the Scottish Deepwater Trawl Survey. The IUCN (Munroe *et al* 2015) considers the species to be “vulnerable”.

McIntyre (1955b) describes how Scottish “great liners” from Aberdeen fished for halibut mostly off Iceland, Greenland, Faroe and in the North Sea, “*now and then making a trip to the west of Scotland and Rockall*”. Thus, when the fishery was active, the study area was not considered to be one of the richest areas for halibut.

2.10.4 Data and knowledge deficiencies

Atlantic halibut have become so rare that it is almost impossible to state anything meaningful about a potential population within the study area. There are no fisheries data, and only a few fish are caught in surveys.

2.10.5 Conclusions

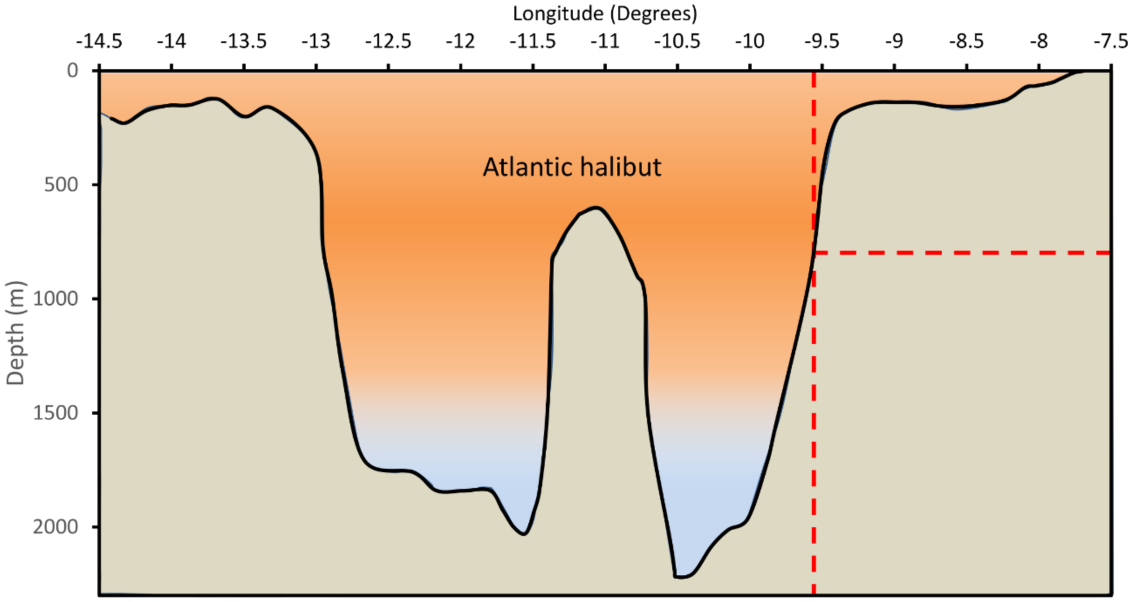

Figure 42. Section of the study area with intensity of orange shading showing the probable depth distribution of Atlantic halibut based on information from the relevant literature cited in the text.

The Atlantic halibut is a wide-ranging species that was fished to commercial extinction, but viable populations remain to the north and west of the study area. The potential depth distribution extends from the shelf areas across much of the study area, but on the continental slope the highest abundances are likely to occur in shallow areas to the east (Figure 42). The species is particularly vulnerable to exploitation of spawning aggregations which tend to be at depths of 700-1000m. Since it is a predominantly a cold-water fish, in the face of global warming there is a concern whether the environment to the south of the Wyville Thomson Ridge will remain suitable. The part of the study area to the NE of the ridge is in cold water near known spawning areas south of the Faroes.

2.11 Greenland halibut *Reinhardtius hippoglossoides* (Walbaum 1792)

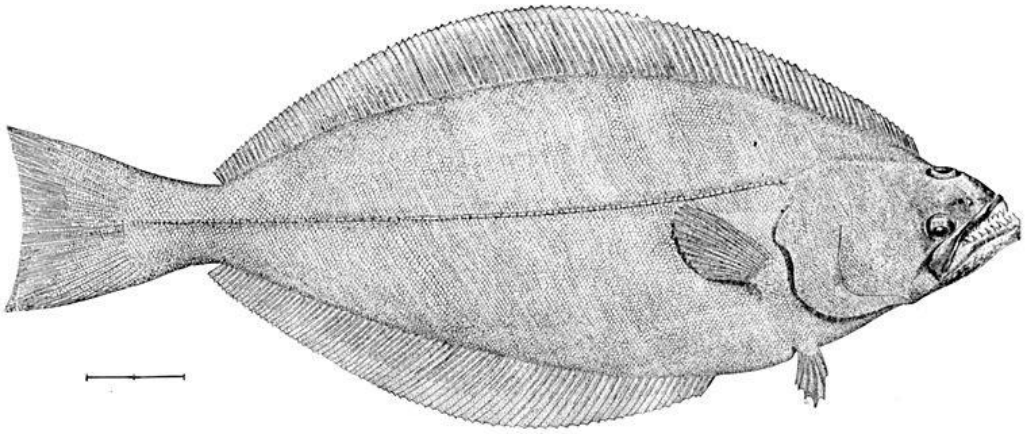

Figure 43. Greenland halibut *Reinhardtius hippoglossoides* (image Goode & Bean 1896).

Like the Atlantic halibut, the Greenland halibut is a member of the family Pleuronectidae but is the only species in its genus, *Reinhardtius*, with a more northerly distribution than the Atlantic halibut, occurring around the Arctic Ocean in both the North Pacific and the North Atlantic sectors. It is a right-eyed flatfish with the left or blind side usually pigmented. The left eye is not fully displaced to the right, giving a wider field of view than most flatfish and the shape is rather elongated compared with most flatfish (Jørgensen 1997). It can be regarded as a flatfish that is partly evolving back towards a round-fish pelagic life style. The Greenland halibut is an active top predator mainly feeding on fishes (Dwyer *et al* 2010); adults consume large species such as redfish, cod, Arctic cod, roughhead grenadier as well cannibalism on smaller Greenland halibut, whereas the smaller individuals consume forage-fish such as capelin, sandeels as well as myctophids. Greenland halibut under 25cm in length eat a variety of zooplankton. Despite the high pelagic content of the diet Jørgensen (1997) showed that it is only the one-year old fish that are abundant in the water column where they occur particularly at night, whereas older fish were rarely encountered pelagically. It is possible that adults are able to forage in very brief bouts of pelagic activity and spend the rest of their time digesting their meals on the sea floor. As the prey fish stocks in the NW Atlantic have become depleted, Greenland halibut have switched to more dependence on invertebrate prey such as *Pandulus* shrimp and *Gonatus* squid (Dwyer *et al* 2010). Greenland halibut are somewhat smaller than the Atlantic halibut, with the maximum reported length being 130cm (Froese & Pauly 2016). Off the north of Norway, the usual maximum length in surveys is slightly over 90cm (Hoines & Korsbrekke 2003).

2.11.1 Distribution and status in the study area

The Greenland halibut has a circum-global distribution in polar waters of the Northern Hemisphere (Figure 44). Reference sources commonly give the distribution in the NE Atlantic as from Spitzbergen to Ireland (Froese & Pauly 2106). There is evidence of individual specimens caught as far south as the English Channel, but Gødo and Haug (1989) in their review, state that the southern limit is at the Faroe Islands. Priede *et al* (2010) recorded no Greenland halibut in their surveys off the SW of Ireland. They were absent from samples taken in the Rockall Trough by Gordon and Duncan (1985), although Burns (2018) reports occasional captures just south of the ridge in Scottish Deepwater Trawl Surveys and comments that they look in poor condition having possibly become stranded on the "*wrong side of the ridge".* The Greenland halibut is primarily a cold-water fish and the study area is at the southern extreme of its distribution. Bullough *et al* (1998) found that Greenland halibut are captured by commercial fishermen from Scotland in the Faroe-Shetland Channel at temperatures between 1.2° and 6.3°C with the highest catches between 0.5° and 2.2°C. Norwegian fishermen also catch Greenland halibut in this area (ICES AFWG 2017). Tracking adult Greenland halibut with satellite pop-up tags in the Cumberland Sound shows that they swim in water temperatures of 1.3-2.7°C and at depths of 900-1400m in preferred localised deep areas during the ice-free summer season (Peklova *et al* 2012). The warmer deep waters to the south of the Wyville Thomson Ridge are not the normal habitat of Greenland halibut.

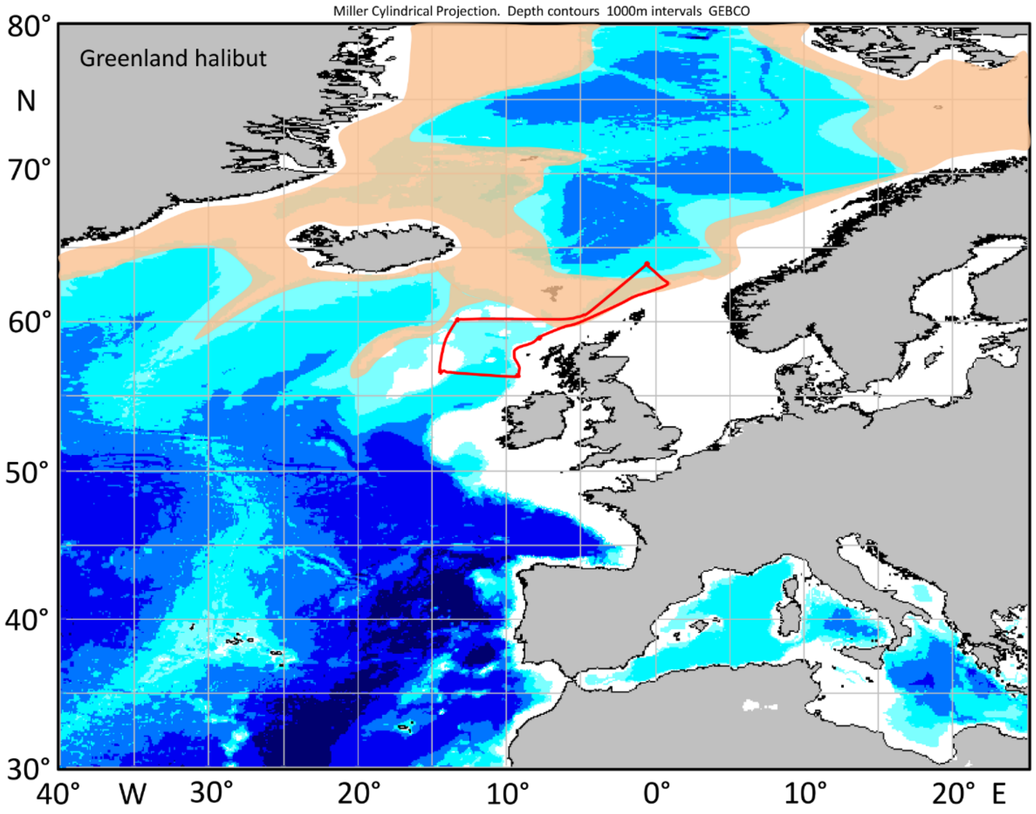

Figure 44. The distribution of Greenland halibut *Reinhardtius hippoglossoides* in the NE Atlantic (orange shading). After Froese and Pauly (2017) and Gødo and Haug (1989). Red outline is the study area. The blue shading denotes 1000m depth increments, i.e, 1000, 2000, 3000, 4000 and >5000m.

ICES NWWG (2017) states that formerly there was a continuous belt of fishing along the NE Atlantic continental slope at variable depths from 300 to 1500m from the Faroe Plateau to Iceland and south Greenland. There is also a small fishery on the Hatton Ridge to the west of the study area. Morgan *et al* (2003) state that in the NE Atlantic there are three main areas of concentrations of Greenland halibut: the eastern Greenland population, the Iceland and Faroe Islands (Nordic) population and the north-eastern Arctic population to the west and north of Norway. The study area can be considered to be on the southern fringes of the Nordic population.

2.11.2 Life history

Female Greenland halibut in the NE Atlantic become sexually mature at 57 to 64cm (Cooper *et al* 2007) corresponding to an age of around ten years (Albert *et al* 2003). As they mature during the Autumn the fish move from shallow nursery areas to spawning areas on slopes at 450 -1100m depth. North of Norway the main spawning season is from November to

January with a peak in December after which the fish leave the spawning areas (Albert *et al* 2001). Outside the defined spawning time and areas there is evidence of widespread erratic spawning throughout the year; for example, Albert *et al* (2001) found running females (releasing eggs) in late June at 300-400m depth off the coast of Norway. Off eastern Greenland spawning is in July to August, but around Iceland spawning occurs from January to March, with evidence of some spawning all year round (Morgan *et al* 2003). Dwyer *et al* (2016) suggest that a protracted spawning season is the reason for problems in identifying clear year-classes in some stocks of Greenland halibut. Each female produces from 20,000 to 230,000 eggs depending on size. Typically fish around 80cm long produce 40-100,000 eggs (Cooper *et al* 2007). According to Gundersen *et al* (1999) all the eggs are released in a single annual spawning event, i.e. there are no batches, whereas Stene *et al* (1999) state it is not known whether or not they are serial spawners. Newly-spawned eggs in the wild are 3.9 to 4.7mm in diameter, float at a depth of about 650m and larvae hatch after 53 days at 2°C at a length of 6mm (Stene *et al* 1999). The yolk sac is absorbed by 17mm length and metamorphosis is complete when the juvenile bottom-living stage is reached after 72mm (Duffy-Anderson *et al* 2013). The eggs and larvae are carried by currents from the spawning areas towards the continental slopes. Duffy-Anderson *et al* (2013) found no eggs over continental shelf areas, but by February to May (following spawning in the preceding winter months) larvae were present in the water column, and by September juveniles had settled on the sea floor of the middle and outer continental shelves of the Bering Sea. Similar studies of larval drift were carried out in the North Atlantic by Stenberg *et al* (2009) off West Greenland, where they found that larvae settle on banks where year one juveniles are found at 200 to 400m depth. The initially settling areas tended to be on fine-grain sediment whereas during subsequent growth the juveniles move onto coarser-grained sediments. This might not be a direct preference for different sediments but reflect responses to the bottom current regime with slower currents in the fine grain areas and stronger currents where the sediments are coarser. Juveniles aged two onwards were most abundant at 300 - 500m depth with a general pattern of movement to deeper areas as they grow. Using new methods to validate age estimates in the NW Atlantic, Dwyer *et al* (2016) show that males and females grow at similar rates up to eight to nine years, to a length of around 55cm. Then growth in females slows down, but continues to a much older age, reaching 106cm at 33 years, whereas growth in males ceases at 90cm and 19 years of age. They estimate that sexual maturation occurs at 70cm (10 years) for males and at 72cm (12-13 years) for females, somewhat older than estimates in NE Atlantic. Junquera *et al* (2003) show that adolescent females with developing ovaries appear from six years old in the NE Atlantic but spawning does not begin until 10 years old, a 4-year delay. They show a peak of female adolescents at 10 years old, followed by a peak of spawning at 14 years old. They suggest that the ovarian cycle in the Greenland halibut may be as long as four years and individual females may spawn only once every four years.

2.11.3 Exploitation and management

The total catch for the Nordic stock of Greenland halibut in ICES Subareas 5, 6, 12 and 14 (Iceland, Faroes, West of Scotland and East Greenland) amounted to over 25,000 tonnes in 2016. Of this, only 400 tonnes were from Subarea 6 West of Scotland (Figure 45). Fisheries around the Faroes (Subarea 5b) reported 4685 tonnes (ICES NWWG 2017). The reported catches from Subarea 6 since 2001 are mainly from the Hatton Bank area by Spain, UK and France. Catches from the main part of the study area, south of the Wyville Thomson Ridge are probably zero or minimal.

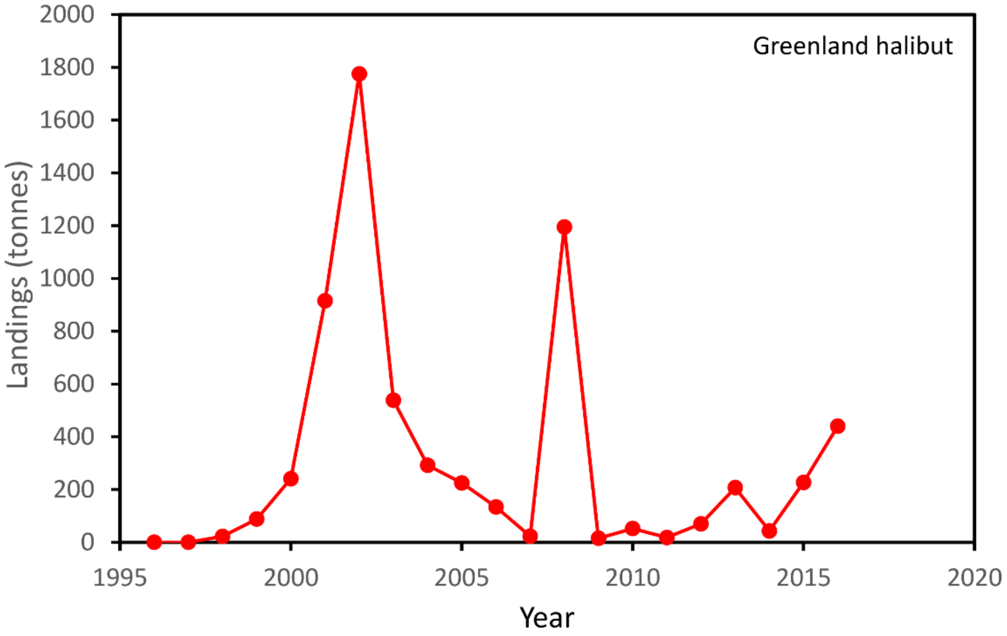

Figure 45. Landings of Greenland halibut from ICES Subarea 6 West of Scotland (ICES NWWG 2017).

For the overall Nordic stock, the peak catch of 80,000 tonnes in 1990 resulted in the decline of the stock biomass to below acceptable limits. Since then biomass has stabilised at about 70% of the maximum sustainable yield level. Catches of less than 30,000 tonnes per annum are necessary to allow the stock to grow. Current advice is to limit catches to 24,000 tonnes, but at this level it will take over ten years to rebuild to maximum sustainable yield level.

2.11.4 Data and knowledge deficiencies

The study area is at the southern limits of the distribution of Greenland halibut in the NE Atlantic Ocean. All the information available on biology, growth, spawning and fisheries is from further North and West. There are no data for the study area itself. The catches in Subarea 6 are small and probably entirely from the Hatton Bank to the west of the study area. There is considerable doubt as to whether Greenland halibut are native to the main body of the study area south of the Wyville Thomson Ridge.

Whilst stocks in different parts of the North Atlantic are managed separately there is strong evidence for interchange of fish between regions which could possibly invalidate these stock assessments.

2.11.5 Conclusions

The Greenland halibut is a circumpolar species and the study area is at the extreme southern limit of the species' distribution. Greenland halibut are caught in the Faroe-Shetland Channel to the northwest side of the Wyville Thomson Ridge and are certainly present in the northeast extension of the study area. This is a highly mobile species and any potential MPA must be viewed in the context of the overall distribution of the species in the NE Atlantic and Arctic Oceans where it is actively exploited.

3 General Conclusions

The species of fish considered here can be divided into two kinds: those for which there is a continuing fishery in accordance with ICES advice and those which are so depleted that the TAC is set for zero or there is no directed fishery (Table 2).

Table 2. IUCN Red list Assessments in Europe for the species considered

Species	Continued fishery	IUCN Assessment	Reference
Porbeagle	No	Critically Endangered	Ellis *et al* (2015b)
NE Atlantic spurdog	No	Endangered	Ellis *et al* (2015a)
Gulper shark	No	Critically Endangered	Guallart *et al* (2015a)
Leafscale gulper shark	No	Endangered	Guallart *et al* (2015b)
Portuguese dogfish	No	Endangered	Dureuil & Jung (2015)
Roundnose grenadier	Yes	Endangered	Cook *et al* (2015)
Blue Ling	Yes	Vulnerable	Fernandes *et al* (2015)
Monkfish/anglerfish	Yes	Least Concern	Fernandes *et al* (2015)
Orange roughy	No	Vulnerable	Collette *et al* (2015)
Atlantic halibut	No	Vulnerable	Munroe *et al* (2015a)
Greenland Halibut	Yes	Near Threatened	Munroe *et al* (2015b)

3.1 Continued fishery

The species still fished are: roundnose grenadier, blue ling, anglerfish and Greenland halibut and only the anglerfish is considered by the IUCN to of least concern.

The fishery for the roundnose grenadier in Skagerrak was closed in 2012 (Cook *et al* 2015) and globally the species is considered to be critically endangered following catastrophic depletion by fisheries in the NW Atlantic (Iwamoto *et al* 2015). Fisheries continue in the NE Atlantic in the vicinity of the study area managed under a precautionary approach which indicates annual landings of no more than *ca*. 3000 tonnes to attain a maximum sustainable yield. The study area encompasses a large area of important roundnose grenadier habitat.

The blue ling is endemic to the deep slopes of the NE Atlantic and seasonal protection of the large spawning aggregations that occur to the west of Scotland both within and outside the study area is considered as one of the success stories for European fisheries management, arresting the massive depletion of the stock that occurred from the 1970s. Any additional spatial measures introduced to reduce fishing pressure in the study area would be complementary to existing management measures for a stock still considered vulnerable.

The anglerfish is exploited both by fisheries on the continental shelf and in offshore deep waters. The study area provides habitats for all stages of the life cycle and is the source of juveniles for a wide area to the north and west of Scotland and for the Northern North Sea (Hislop *et al* 2001). Since the species does not form large spawning aggregations it does not show the same vulnerability to fisheries as those species that do. Fishery exploitation under present regimes seems to be sustainable.

The main part of the study area is south of the natural geographical range of the Greenland halibut. Significant catches are made in the Faroe-Shetland Channel north of the Wyville Thompson Ridge. The study area is of marginal significance to this circumpolar species.

The roundnose grenadier, blue ling and anglerfish are important components of the mix of species taken by deep-water trawlers operating on the slopes to the west of Scotland. The Rockall Bank and other shallow areas to the north and west of the study area support a wider range of fisheries. There is a distinct deep-water fishery in the Faroe-Shetland

Channel exploiting fishes including Greenland halibut and roughnose grenadier crowded into the transition zone at the boundary of cold Arctic waters (Bullough *et al* 1998).

3.2 Fishing prohibited or not monitored

All the sharks, porbeagle, spurdog, gulper, leafscale gulper and Portuguese dogfish are subject to a blanket ban on targeted fishing and are assessed by IUCN as endangered or critically endangered (Table 2).

The porbeagle is a fast-swimming wide-ranging species in the North Atlantic Ocean and the study area is a small part of the overall distribution of the stock with no evidence of it being of particular importance to the species except as a corridor for migration. The species is vulnerable to high seas fishing across the Atlantic Ocean.

The spurdog is primarily a shallow water species and it is the margins and surface waters of the study area that provide important habitats for the species. Ellis *et al* (2015) state that the original causes of the decline of the spurdog in the NE Atlantic have largely been removed through introduction of fisheries management measures but bycatch in substantial fisheries off NW Europe still remain a cause for concern.

The study area provides classic deep-sea habitats for the three deep-water sharks, gulper, leafscale gulper and Portuguese dogfish probably including all stages of the life cycle. There is concern that the gulper shark appears to be a rather rare species and the study area may be one of relatively few locations world-wide in which it occurs.

The orange roughy is a uniquely long-lived species with very late maturation which was rapidly depleted by fisheries in the study area off the west of Scotland. It is particularly vulnerable to fisheries when it forms spawning aggregations around summits and other underwater topographic features. The IUCN lists the orange roughy as vulnerable (Collette *et al* 2015) over the whole of the NE Atlantic but notes that in ICES Subarea 6 the fishery has been depleted and closed. Numbers are still caught as bycatch in the deep-water trawl fisheries to the west of Scotland.

The Atlantic halibut has become an enigmatic species with very low catches and no active management measures in place. It continues to be caught incidentally and landed as a valuable bycatch. The main remaining population reservoirs are to the North off Norway. In contrast to the rapid depletion of the orange roughy, North Atlantic halibut has declined in the face of continuous exploitation since the 1800s and according to Munroe *et al* (2015) “Stock levels are so low that the species is nowhere abundant and is uncommonly seen in fish markets”. Calculations for the stock in the NW Atlantic indicate a likely recovery time in excess of 25 years (Neubauer *et al* 2013).

The main concern with all these depleted species is that they remain vulnerable as bycatch for as long as fishing for other species continues.

3.3 Effects of a Marine Protected Area

The purpose of this section is to assess the effects of possible closure of the study area to fishing activity. The species under consideration have varying degrees of dependence on the study area according to their life history and behaviour.

For the porbeagle the study area represents a very small part of the species range that extends throughout the surface waters of the North Atlantic Ocean. However, a significant proportion of the NE Atlantic population that breeds in the Celtic Sea and Bay of Biscay moves through the study area during annual feeding migrations to and from Northern and Arctic waters. When porbeagle populations were much greater there was also an annual influx into the North Sea from the Atlantic Ocean during the autumn. The study area therefore is a migratory gateway for the species and removal of any interceptor fishery targeting other species would have a beneficial effect.

The study area encloses an important part of the area occupied by the Scottish Norwegian stock of spurdog and is probably of greatest importance as a feeding area for the species. Breeding tends to occur in shallower inshore waters. Spatial closure would eliminate bycatch of this species which remains a persistent problem for any recovery programme in view of the low fecundity and longevity of this species of up to 75 years.

The three deep-sea sharks, gulper shark, leafscale gulper shark and Portuguese dogfish are all globally widespread species that are resident in the deep waters of the study area. The leafscale gulper for example feeds on the rich shoals of blue whiting. Spatial closure would provide protection for a large part of the relatively long life-span; the leafscale gulper takes 35 years to reach sexual maturity. All three species probably migrate in an out of the study area visiting various putative breeding sites around the NE Atlantic, with some breeding possible within the study area. The gulper shark is particularly rare and the study area is one of few locations in the NE Atlantic where it has been positively identified.

The roundnose grenadier lives along a narrow band of continental slope at 700-2000m depth in the North Atlantic and the study area encloses a large area of this optimal habitat for feeding, growth and spawning. Formerly abundant stocks in the Rockall Trough with individuals aged up to over 60 years have been depleted by targeted fishing. Spatial closure would be additional to management measures already in place to restrict the fishing activity for this species.

The blue ling is a relatively non-migratory species and the study area encompasses part of the southern stock found around the Faroes and west of Scotland. From the 1970s, fisheries targeted newly discovered spawning aggregations which resulted in a fishing boom and massive depletion of the stock. Several of the key spawning sites at 730 to 1100m depth are within the study area. Annual seasonal closure of the spawning sites to fishing has been successful in arresting stock decline. Year-round spatial closure of a wider area would take in other hitherto unknown spawning areas and restrict fishery mortality.

The anglerfish is a widespread species occurring from the Mediterranean to the Barents Seas. Despite evidence of long distance migration, it is assumed there is relatively discrete stock in the West of Scotland, Rockall, northern North Sea and the Skagerrak. Spawning occurs in deep-water and it is likely that the study area is a main source of larvae and juveniles for this “Northern stock”. Spawning adults do not form spawning aggregations so they are relatively invulnerable to targeted fishing. Spatial closure would protect these largest spawning adults that live in deep- water.

The study area has large areas of slopes and summits at 500 to 1750m, the preferred depth range for orange roughy which in the 1970s it was one of the most common species caught at the middle of this depth range. Like the blue ling this species is very vulnerable to fisheries targeting aggregations of spawning adults. Between 1991 and 1994 the abundant stock in the area with many individuals over 100 years old was removed by fishing activity and has never recovered. The growth rate is much slower than for blue ling and with first maturity at 28 years, despite zero TAC in force since 2010, there has been no sign of recovery of the stock. Continuing bycatch by fisheries for other species continues to impact the stock. Spatial closure would reduce this continuing attrition but also allow sea bed features such as corals which are attractive to fish and have been damaged by bottom trawls to recover.

The Atlantic halibut is a widespread species on the shelves and slopes beneath temperate to cold waters of the NE Atlantic. Although historically fished commercially in the study area the main fishing grounds were further north around the Faroes, Norway and Iceland. The species is now severely depleted across its entire range. Although there is evidence that halibut exist in the study area occurrence in surveys is quite rare. It is doubtful if spatial closure could have much positive effect, the study area is a small marginal part of the species natural range.

The Greenland halibut is primarily a species of the Arctic Ocean and the study area lies at the extreme southern limit of its native distribution. Greenland halibut do occur cold deep-waters of the Faroe-Shetland channel extension of the study area north of the Wyville-Thompson Ridge. Any Greenland halibut found in the relatively warm waters of the main part of the study area are regarded as strays. For this species spatial closure of the study area would have no effect.

The proposed protected area is likely to be most beneficial to the deeper-living species, gulper shark, leafscale gulper shark, Portuguese dogfish, roundnose grenadier, blue ling, anglerfish and orange roughy that demonstrably utilise the deep-water habitat features in the study area for all or part of their life cycle. This has to measured against the likely immigration and emigration of individuals which at present cannot be known.

4 Summary table

Porbeagle, *Lamna nasus*		
Depth range	Minimum	Surface
	Maximum	700m
Distribution	In the study area	Oceanic shark that migrates widely throughout the temperate North Atlantic and Mediterranean including the study area.
	Seasonality	Transit through the area in the second half of the year.
	Migration	Homing to breeding grounds in the Irish Sea and Bay of Biscay.
Life History Characteristics	Sexual maturity *	Males 8 years, 1.74m total length. Females 13 years, 2.37m total length.
	Mating/pupping areas	Females give birth to usually 4 live young along the continental shelf edge (200m depth). There is circumstantial evidence for pupping west of Shetland to the east of the study area.
	Nursery areas	There are nursery areas in the southern Irish Sea but no information for the study area.
Habitat use in the study area		Adults feed mostly in the water column, migratory individuals pass through the area.
Threats		Porbeagles have been severely depleted by fisheries throughout the NE Atlantic. Since 2010, targeted fishing has been prohibited in EU waters. They remain vulnerable to capture in high seas fisheries for tunas and swordfish.
NE Atlantic spurdog, *Squalus acanthias*		
Depth range	Minimum	Surface
	Maximum	200m usually but 950m recorded in the study area.
Distribution	In the study area	In shallow and epipelagic waters of the study area on the continental slopes and around Rockall.
	Seasonality	Present throughout the year.
	Migration	Spurdog from the study area migrate to Faroe and southern Norway forming a distinctive Scottish-Norwegian stock.
Life History Characteristics	Sexual maturity *	Females 9-13 years, 75 - 95cm total length, males smaller.
	Mating/pupping areas	Spurdogs form large aggregations for pupping in inshore waters at around 50m depth; known sites are Galway Bay and the Irish Sea. Each female produces 2-21 pups. Most of the study area is too deep for pupping.
	Nursery areas	Mainly shallow areas near the pupping grounds, spurdog move deeper as they grow.
Habitat use in the study area		Spurdog feed in midwater, younger individuals targeting plankton and switching to fishes and benthic prey as they grow.
Threats		The study area was historically a rich fishery for spurdog but stocks are severely depleted with a zero TAC since 2010. The main threat is continued bycatch in long line and trawl fisheries, but there is evidence of very slow stock recovery.

Gulper shark, Centrophorus granulosus		
Depth range	Minimum	200m
	Maximum	2000m
Distribution	In the study area	The study area is the northernmost of 17 known locations around the world in which the species has been recorded.
	Seasonality	Present all the year round.
	Migration	No information, the nearest substantial population is off Galicia, NE Spain and migrations are plausible.
Life History Characteristics	Sexual maturity *	Females 147cm, Males 110cm. Age uncertain.
	Mating/pupping areas	Each female produces 3-8 live young. Reproduction is aseasonal with young produced all the year round. Location is unknown but possibly includes the study area.
	Nursery areas	No information
Habitat use in the study area		Demersal throughout the Rockall Trough within its depth range.
Threats		This species is a rare cryptic species that is not often identified but is captured in fisheries for "mixed deep-water sharks" which are depleted and zero catch recommended since 2010 by ICES.
Leafscale gulper shark, *Centrophorus squamosus*		
Depth range	Minimum	145m
	Maximum	2400m
Distribution	In the study area	Found throughout its depth range with peak abundance at 800 m depth.
	Seasonality	Present throughout the year.
	Migration	Extensive migrations in the NE Atlantic so the individuals in the study area form part of a wider population.
Life History Characteristics	Sexual maturity *	Females 35 years, 120cm total length, Males 30 years, 102cm total length.
	Mating/pupping areas	Each female produces 4 -10 pups. There is evidence of pupping off Iceland, the Iberian Peninsula, Madeira and west Africa, with no information for the study area.
	Nursery areas	No information.
Habitat use in the study area		Demersal fish that feeds on the bottom and on deep-water fishes including blue whiting.
Threats		Exploited together with the Portuguese dogfish as part of a mixed fishery. The stock is depleted and no targeted fishing is permitted but bycatch continues. No significant change in abundance has been detected since 2004.

Portuguese dogfish, *Centroscymnus coelolepis*		
Depth range	Minimum	700m
	Maximum	240 m in the study area but recorded as world's deepest shark at 3700m in the Bay of Biscay.
Distribution	In the study area	Peak abundance is at 1350m in the study area. Occurs on the Mid Atlantic Ridge and continental margins of the North Atlantic and other parts of the world.
	Seasonality	Present all the year round. No evidence of seasonality in reproduction.
	Migration	Capable of long distance migrations in the NE Atlantic.
Life History Characteristics	Sexual maturity *	Females 102cm total length, males 86cm ages unknown.
	Mating/pupping areas	Gravid females with 8-21 pups caught west of the British Isles. Pupping location(s) unknown but some authors suggest off NW Africa, but also evidence for localised pupping throughout the species range.
	Nursery areas	Few juveniles have been caught, most at less than 1000m depth. Nursery areas are unknown.
Habitat use in the study area		Bentho-pelagic feeder predominantly fish and squid in the stomachs.
Threats		Portuguese dogfish have a long history of exploitation but together with the leafscale gulper shark, stocks have become severely depleted and zero targeted catch since 2010. Bycatch continues in deep-water trawl fisheries in the study area and the Scottish Deepwater Trawl Survey shows continuing decline in abundance since 2000.
Round-nose grenadier, *Coryphaenoides rupestris*		
Depth range	Minimum	180m
	Maximum	2600m
Distribution	In the study area	On slopes around the Rockall Trough with a peak of abundance at around 1500m depth.
	Seasonality	Present all the year round.
	Migration	The species is endemic to the N Atlantic. Separate populations N and S of the Wyville Thompson Ridge.
Life History Characteristics	Sexual maturity *	Females 9-11 years, 55cm total length, Males 8-10 years 46cm total length.
	Mating/pupping areas	Spawning peaks during May to October and appears to occur all along the preferred depth range of the species. Egg and larvae disperse in mid water.
	Nursery areas	Larvae settle on the sea floor at 8-10cm total length. Nursery areas are not well defined.
Habitat use in the study area		Bentho-pelagic species that lives on the slopes and feeds on crustacea and fishes of the deep-scattering layers.
Threats		There is an active fishery for roundnose grenadier in the study area. The stock is depleted below maximum sustainable yield but with evidence of recovery. Evidence from other areas shows recruitment is sporadic and stocks are vulnerable. Recommended TAC is 3399 tonnes compared with peak catches of over 14000 tonnes in 2001.

Blue Ling, *Molva dypterygia*		
Depth range	Minimum	300m
	Maximum	1500m
Distribution	In the study area	Widely dispersed in the study area with peak abundance at 750-1000m. Species is endemic to the NE Atlantic and the study area is one of the most important areas of aggregation.
	Seasonality	Present all the year round but forming spawning aggregations mainly during March to May.
	Migration	Regional pattern of migration to the spawning areas.
Life History Characteristics	Sexual maturity *	Females 8.1 years, 79cm total length, Males 6.4 years 79cm total length.
	Mating/pupping areas	Spawning aggregations at depths of 730 -1100m. Each female produces 1 - 3.5 million eggs.
	Nursery areas	The nursery areas are unknown.
Habitat use in the study area		Demersal species that ventures into mid-water to prey on fish and squid. Seasonally forms spawning aggregations on slopes in preferred locations.
Threats		Very vulnerable to targeted fishing on spawning aggregations in and around the study area to the west of Scotland. Since 2009 these have been closed to fishing from March to May each year and a total allowable catch is imposed. Fishing pressure is considered to be at a long-term low and the stock is stable.
Monkfish/Anglerfish, *Lophius piscatorius*		
Depth range	Minimum	20m
	Maximum	1000m
Distribution	In the study area	Endemic to the shelves and slopes around NE Atlantic Ocean with highest abundances in the study area at 200 - 500m depth including around Rockall.
	Seasonality	Present all the year round.
	Migration	Adults make seasonal migrations to winter deep-water spawning grounds in the study area. Individuals can move between Shetland and Iceland and the study area.
Life History Characteristics	Sexual maturity *	Females 73.5cm total length, Males 48.9 m total length. 6-8 years old.
	Mating/pupping areas	Spawning occurs in the study area at depths of 150 - 900m during November to April, producing large eggs masses that float towards the surface and hatch during February to April.
	Nursery areas	From the study area juveniles mainly develop in the North Sea but those spawned around Rockall probably also grow there.
Habitat use in the study area		A demersal fish that preys mainly on other fish including Norway pout, sandeels, cod and whiting.
Threats		Anglerfish form an important component of the demersal whitefish fisheries. There was concern about decline in stock size, but ICES consider that since 2014 the stock is recovering. It is assumed there is a single stock covering Subareas 6 (West of Scotland), 4- (North Sea) and the 3a (Skagerrak).

Orange roughy, *Hoplostethus atlanticus*		
Depth range	Minimum	500m
	Maximum	175m
Distribution	In the study area	Circumglobal species found in the NE Atlantic along the Mid-Atlantic Ridge, continental slopes and around offshore banks. Occurs on slopes and summits of the study area.
	Seasonality	Present all the year round but forming spawning aggregations during January to April.
	Migration	The species is confined to narrow strips along the continental and mid ocean ridge slopes. No evidence of large scale migrations,
Life History Characteristics	Sexual maturity *	Females 27.5 years, 37.8cm total length (females continue spawning up to 160 years old).
	Mating/pupping areas	Dense spawning aggregations around seamounts and submarine hills but also spawn on flat ground. Each female produces 20,000 to 250,000 eggs. Little is known about the larvae. Post-larvae probably forage offshore in mid water at 700-800m depth.
	Nursery areas	Nursery areas are not known but studies from Ireland indicate that juveniles settle to a bottom life style at 1200 -1400m when about 10cm long and are presumed to gradually move shallower as they grow.
Habitat use in the study area		Bentho-pelagic fish that feeds off the bottom on crustacea, including mysids, amphipods, decapods plus some cephalopods and fish including lantern fishes and deep-sea smelts.
Threats		Growth rate is very slow and a significant part of the unexploited spawning population was over 100 years old. Spawning aggregations were discovered in the study area in the 1990s and were fished out within a few years. The stock is likely to take decades to recover. A zero TAC has been in force since 2010 but there is a continuing bycatch from fisheries for other species.

Atlantic halibut, *Hippoglossus hippoglossus*		
Depth range	Minimum	50m
	Maximum	2000m
Distribution	In the study area	The Atlantic halibut is endemic to shelf areas and continental slopes around the North Atlantic basin at depths of 50 to 2000m, ranging from the Barents Sea to the Bay of Biscay in the Eastern Atlantic with records from the study area on the continental slope west of Scotland, around Rockall and within the Faroe Shetland channel.
	Seasonality	Present all the year round with seasonal spawning aggregations.
	Migration	Wide dispersal during apparently random emigrations from nursery areas and capable of extensive migrations on the NE Atlantic slopes.
Life History Characteristics	Sexual maturity *	Female 7 years, Male 4.5 years. Longevity over 50 years
	Mating/pupping areas	Forms spawning aggregations at depths of 700 - 1000m during January to April. Spawning occurs S of Faroe very near to the boundary of the area. Each female produces 0.5 to 7 million eggs.
	Nursery areas	Juveniles live at depths of 20-60m during the first 4- 6 years and then gradually emigrate to deeper waters. Nursery areas in the study area are unknown.
Habitat use in the study area		Benthopelagic feeder consuming and increasing proportion of fish as they grow.
Threats		Atlantic halibut were historically the basis for a very valuable fishery including in the study area but from the 1950s stocks became so depleted that they are now rarely encountered. Discovery of spawning aggregations made the species particularly vulnerable. Stocks are so low that ICES collects no data and issues no advice. A small fishery continues off Faroe but in the study area the species is commercially extinct. Small remaining numbers are vulnerable as bycatch in demersal fisheries.

Greenland Halibut, Reinhardtius hippoglossoides		
Depth range	Minimum	300m
	Maximum	1500m
Distribution	In the study area	Circumpolar species endemic to cold waters of the northern hemisphere in both the Atlantic and Pacific Oceans. The study area is at the extreme southern boundary of the species native distribution. It is rarely caught south of the Wyville Thompson Ridge.
	Seasonality	Present all the year round in the Faroe-Shetland Channel.
	Migration	There is interchange of fish across the area occupied by the Nordic stock between Faroe and Iceland.
Life History Characteristics	Sexual maturity *	Female 57- 64cm long, *ca.* 10 years.
	Mating/pupping areas	Spawning occurs on continental slopes at 450 -1100m depth during November to January but with evidence all the year round spawning in some areas. Each female produces 20,000 to 230,000 eggs. There is no evidence of spawning in the study area.
	Nursery areas	Juveniles are found at 200- 500m depth but there is no evidence of their occurrence in the study area.
Habitat use in the study area		Pelagic top predator on fishes, but only North of the Wyville Thomson Ridge.
Threats		The study area is on the southern fringe of the Nordic stock of Greenland halibut. The species is caught in the Faroe-Shetland Channel but is essentially absent from the main part of the study area. The Nordic stock is considered by ICES to be below acceptable limits.

* where a single figure is given this is the age or length at which 50% of the population is sexually mature.

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