Beatrice Offshore Windfarm Limited (BOWL)

Scottish and Southern Electricity (SSE) Renewables & SeaEnergy Renewables

Fish and Shellfish Ecology Technical Report

Brown & May Marine Ltd
Progress Way
Mid Suffolk Business Park
Eye
Suffolk
IP23 7HU
Tel: 01379 870181
Fax: 01379 870673
Email: sja@brownmay.com

Reference	Issue Date	Issue Type	Checked	Approved
BEANFR-04	08/12/2011	FINAL	JW/SX /JH	SJA

Contents

Figures

Tables

1.0 Introduction

The following report details the current Fish and Shellfish Ecology baseline assessment for the Beatrice Offshore Wind Farm development.

For the purposes of this report the fish and shellfish species have been separated into four main categories:

- Species of commercial interest.
- Species potentially using the development area as a spawning or nursery ground.
- Key prey species.
- Species of conservation importance, including migratory species.

It should be noted that certain species are relevant within more than one of the categories given above. As a result, some overlap is to be expected.

Given the socio-economic and conservation importance of salmon and sea trout in Scotland, their ecology and fisheries have been separately assessed in a standalone document (Salmon and Sea Trout Ecology and Fisheries Technical Report), and are therefore not covered in this document.

2.0 Methodology

2.1 Guidance

The following documents have provided guidance for the undertaking of the Natural Fish Resource baseline assessment:

- Strategic Environmental Assessment (SEA) of Draft Plan for Offshore Wind Energy in Scottish Territorial Waters: Volume I: Environmental Report (Marine Scotland, 2010).
- Habitats Regulations Appraisal of Draft Plan for Offshore Wind Energy in Scottish Territorial Waters. Appropriate Assessment Information Review (Marine Scotland, 2011).
- Cefas Guidance Note for Environmental Impact Assessment in Respect of the FEPA and CPA Requirements (Cefas 2004).
- Marine Scotland Science (MSS) Scoping Opinion.
- Scottish Natural Heritage (SNH) and Joint Nature Conservation Committee (JNCC) Scoping Advice (14.05.2010).

2.2 Sources of Data and Information

Establishing a Natural Fish Resource baseline requires an approach that incorporates a number of different data and information sources. The principal sources of information used were as follows:

- Marine Scotland Science (MSS) publications.
- International Council for the Exploration of the Sea (ICES) publications.
- Marine Management Organisation (MMO) Landings Data by ICES rectangle (2000-2009).
- Centre for Environment, Fisheries and Aquaculture (Cefas) publications.
- Fisheries Sensitivity Maps in British Waters (Coull *et al* 1998).
- Mapping spawning and nursery areas of species to be considered in Marine Protected Areas (Marine Conservation Zones). Report No 1 (Ellis *et al* 2010a).
- Results of Benthic Surveys carried out in the site (CMACS 2011)
- Other relevant research publications.

2.3 Data sensitivities, Gaps and Limitations

2.3.1 MMO Landings Data

ICES statistical rectangles are the smallest spatial unit used for the collation of fisheries statistics by the European Commission (EC) and Member States. The boundaries of ICES rectangles align to 1° of longitude and 30' of latitude, being large in relation to the area of the Beatrice Offshore Wind Farm. In addition, fishing activity is rarely evenly distributed throughout the area of a rectangle. The analysis of the fisheries statistics provided below should therefore be taken in the context of the spatial limitations of the data set.

Furthermore, whilst landings data provide a good indication of the commercial species present by ICES rectangle, in some cases their relative abundance and importance may be misrepresented as a result of factors, such as, low quota allocations, fisheries closures, changes in demand, etc. In addition, the presence and distribution of fish and shellfish species are dependent on a number of biological and environmental factors, related to each other in direct and indirect ways, and are subject to seasonal and annual variations.

2.3.2 Spawning and Nursery Grounds

The assessment of the potential for the area of the wind farm to be used as a spawning and nursery ground has primarily been undertaken using the charts provided in Coull *et al* (1998) and Ellis *et al* (2010a). Whilst these are useful sources to identify spawning and nursery grounds, the broad areas defined in these publications do not allow for the identification of exact grounds, especially in relation to discrete areas such as that of the Beatrice Offshore Wind Farm. Where available, alternative publications have been used to help define the extent of the grounds on a site specific basis.

2.3.3 Gaps in Current Knowledge

It is recognised that there are gaps in the understanding of the distribution, behaviour and ecology of certain species. This is particularly evident for a number of migratory species and species of conservation importance (e.g. sea lamprey, European eel) for which little is known in relation to migration routes and the use they may make of coastal areas.

2.4 Study Area

The Beatrice site is located off the north east coast of Scotland (ICES Division IVa) on the north western point of the Smith Bank in depths of 30 to 70m, 18km south-east of Wick, Caithness.

The local study area has been defined as ICES rectangle 45E7, the rectangle within which the wind farm is located. The regional study area comprises rectangle 45E7 and all adjacent rectangles. The local and regional study areas together with the boundary of ICES Division IVa are shown in Figure 2.1 below.

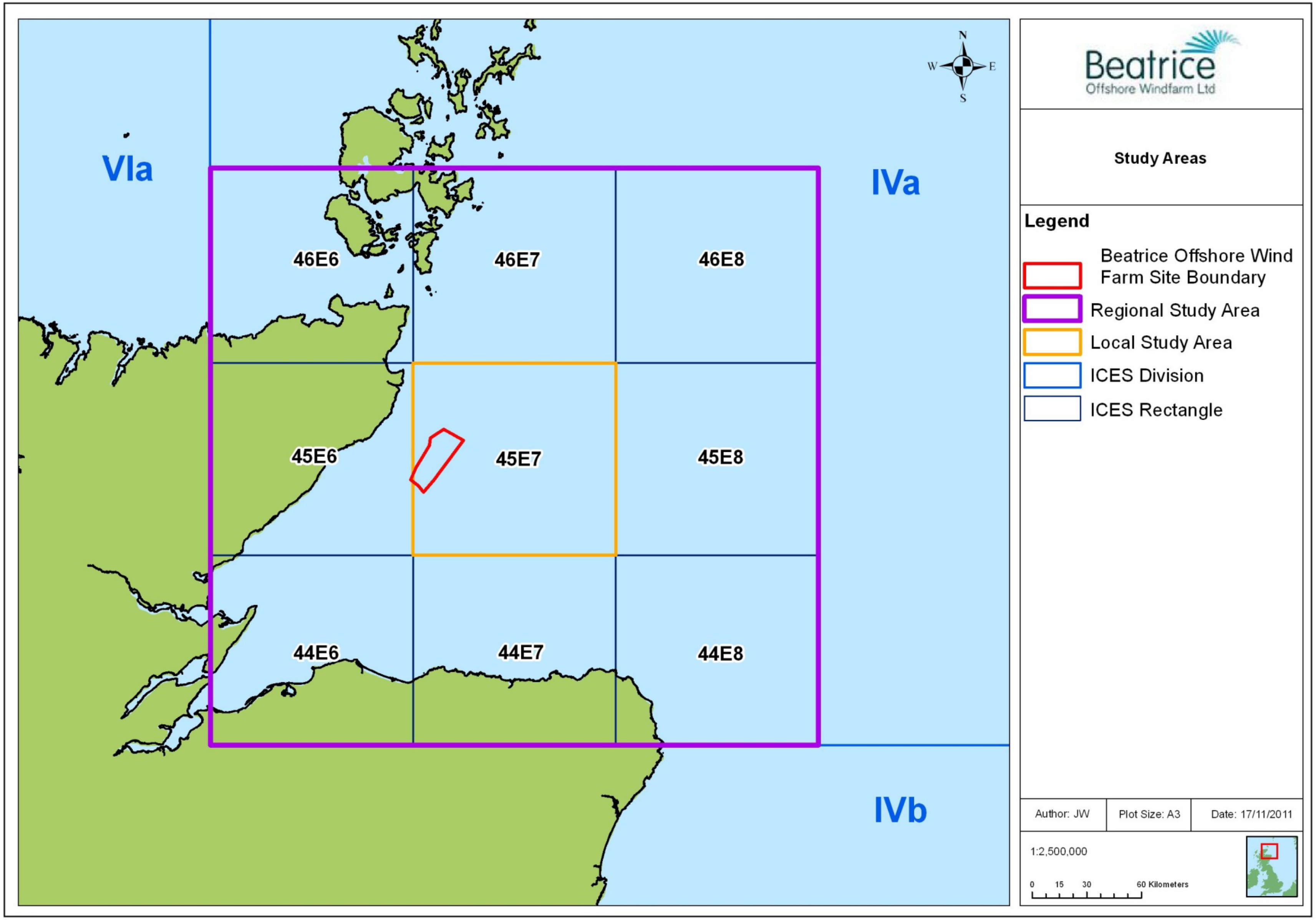

Figure 2.1 Study areas

3.0 Baseline Assessment

3.1 Introduction

In ICES Divisions IVa and IVb (northern and central North Sea), fish populations are dominated by haddock, whiting, herring, dab and plaice in shallower waters (50-100 m depth), whilst at greater depths, species such as Norway pout dominate. The fish assemblages of these Divisions differ from those of areas further south principally as a result of changes in water depth and temperature (ICES, 2011c).

In Division IVa shellfish species are also widely distributed, being more prevalent in coastal areas, where they support commercial fisheries of importance (e.g. nephrops, scallops, crabs, squid) (Commercial Fisheries Report BMM 2011).

In addition to depth and temperature, sediment type affects the distribution of some species. Seabed sediment types in the Moray Firth are given in Figure 3.1. It can be seen that muddy substrates dominate in the inner and southern area, whilst sand and gravelly sands are prevalent in the northern and central areas of the Firth including the area of the Beatrice Offshore Wind Farm. Site specific surveys carried out in the wind farm defined the Beatrice site, based on interpretation of sidescan sonar reflectivity data, as being composed of the following main ground types: "predominantly sand", "sandy gravels", "mosaic of sand and sandy gravels" and "till outcrops/coarser ground" (CMACS Benthic Report 2011).

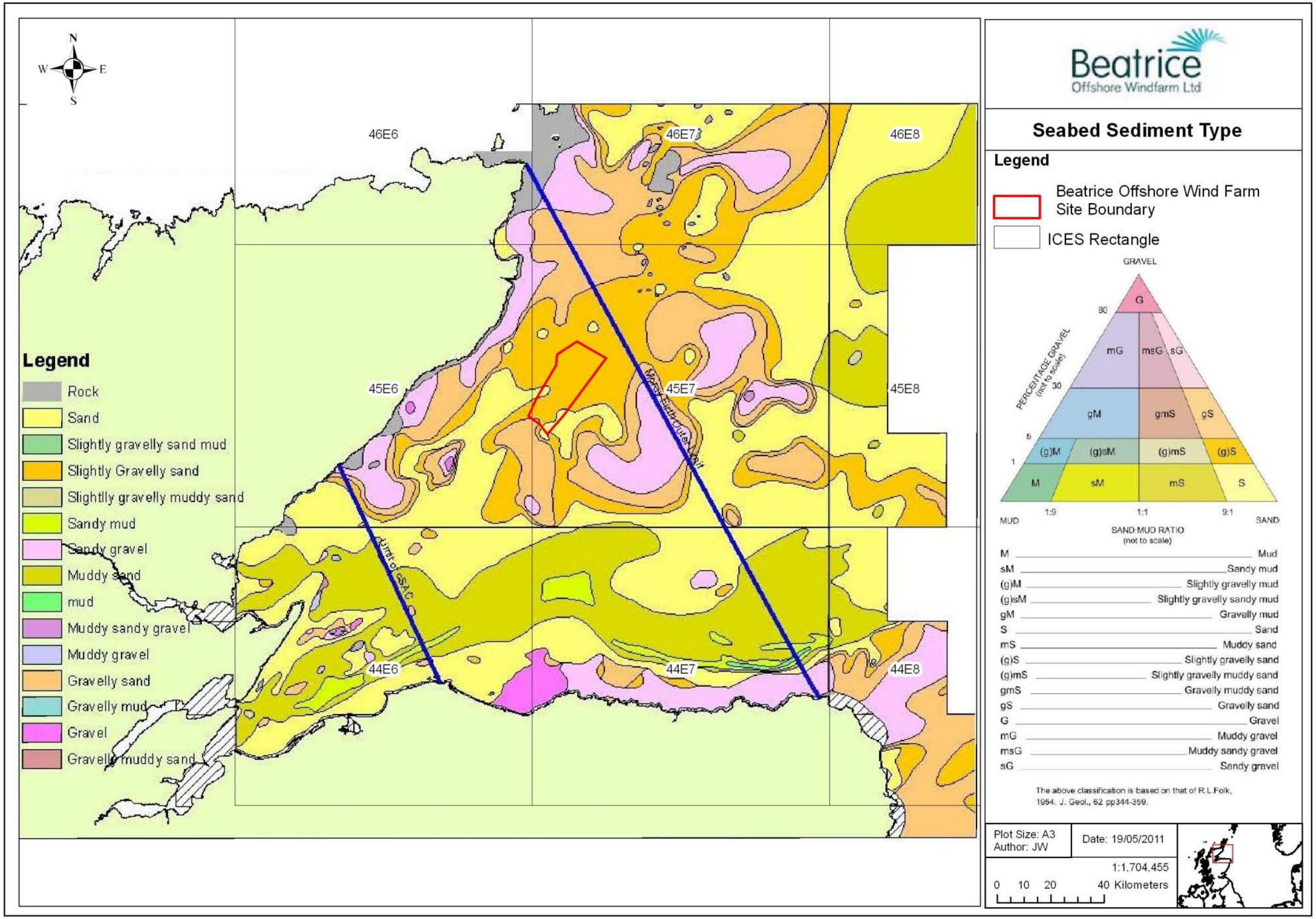

Figure 3.1 BGS (British Geological Survey) seabed sediment chart with ground type

3.2 Commercial Species

The principal commercial species present in the regional study area are given in Figure 3.2, based on annual average (2000-2009) landings weights by species and ICES rectangle (MMO 2010).

Scallops, nephrops, edible crab and squid are the principal shellfish species landed. Haddock, herring, monks and whiting account for the majority of the fish landings. The relative importance of each species to the total landings weights varies depending on the ICES rectangle under consideration. Nephrops for example, are of greatest importance in the southern (44E6, 44E7 and 44E8) and eastern (46E8, 45E8) rectangles. Haddock accounts for a relatively high percentage of the total landings in the majority of rectangles, although the highest landings by weight for this species are recorded in the eastern rectangles of the regional study area. In the case of scallops, landings values by weight are particularly high in the local study area (45E7) and in adjacent rectangles 46E7, 45E6 and 44E6.

It should be noted that sharks and rays (elasmobranchs) constitute a very small percentage of the total landings both in the regional and in the local area, being included (together with other fish species) under the category "Other" in the chart below.

An indication of species presence/absence by ICES rectangle within the regional study area, based on MMO landings data for the period 2000-2009 (MMO 2010), is given in Table 3.1 and Table 3.2 for fish and shellfish species respectively. Species presence in the local study area is highlighted in yellow.

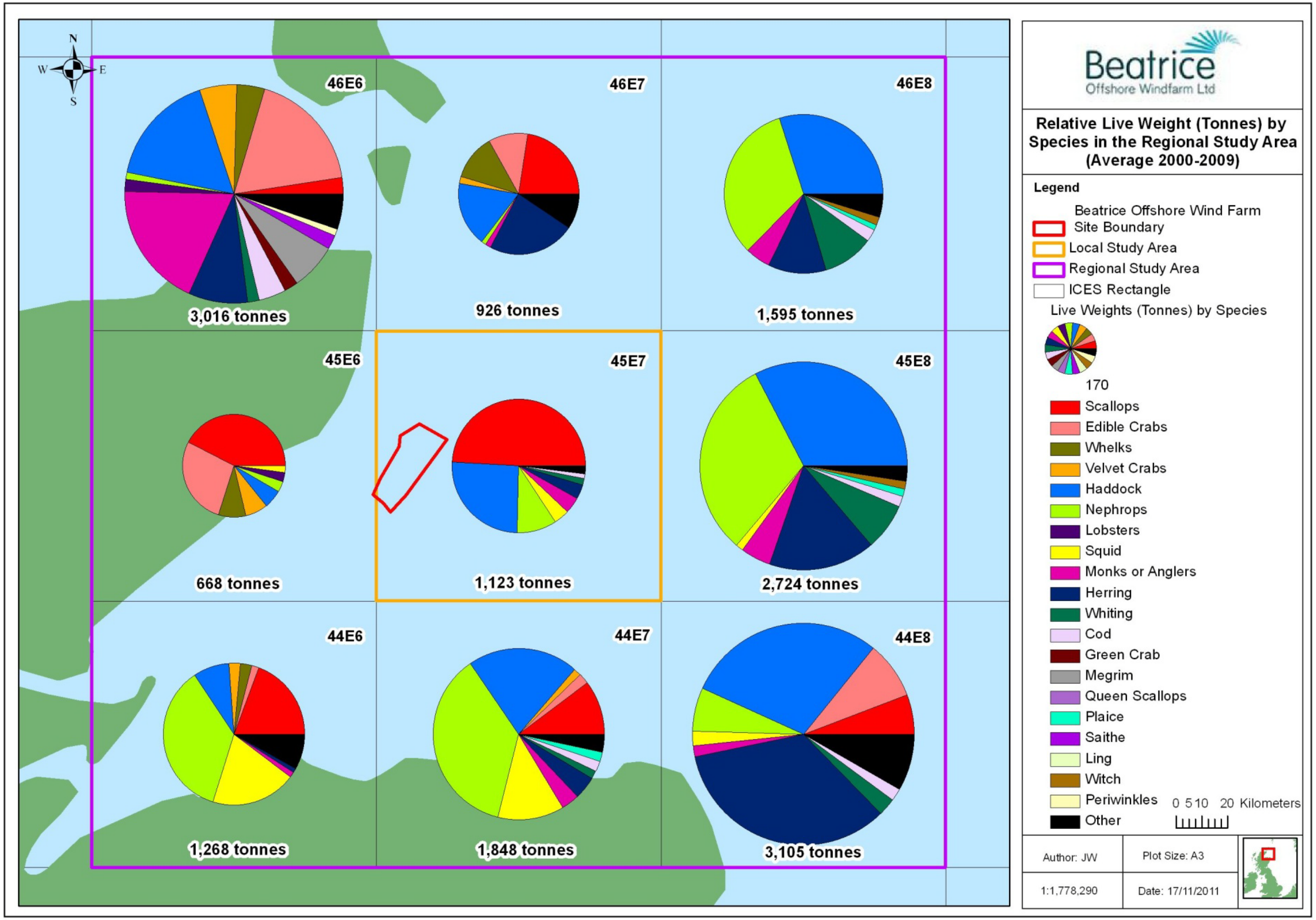

Figure 3.2 Live weight (tonnes) by species in the regional and local study area (MMO landings data)

Table 3.1 List of fish species in the local (light yellow) and regional study area (MMO landings data)

Species		Presence (✓) within ICES Rectangles								
Common Name	Scientific Name	44E6	44E7	44E8	45E6	45E7	45E8	46E6	46E7	46E8
Teleosts										
Albacore	*Thunnus alalunga*	-	-	-	-	-	-	-	✓	-
Bass	*Dicentrarchus labrax*	-	✓	✓	-	-	-	✓	-	-
Black Scabbardfish	*Aphanopus carbo*	-	-	-	✓	✓	-	✓	✓	-
Blue Ling	*Molva dipterygia*	✓	✓	✓	✓	-	-	✓	✓	-
Blue Mouth Redfish	*Helicolenus dactylopterus*	-	-	-	-	-	-	✓	-	-
Ray's bream	*Brama brama*	-	-	✓	-	-	-	-	-	-
Brill	*Scophthalmus rhombus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Catfish	*Anarhichas spp.*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cod	*Gadus morhua*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Common Mora	*Mora moro*	-	-	-	-	-	-	✓	-	-
Conger Eels	*Conger conger*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dabs	*Limanda limanda*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Eels	*Anguilliformes spp.*	-	-	✓	-	-	-	✓	-	-
Four-Spotted Megrim	*Lepidorhombus boscii*	-	✓	✓	-	-	✓	-	-	-
Greater Forked Beard	*Phycis blennoides*	✓	-	✓	✓	-	-	✓	✓	-
Greater Silver Smelt	*Argentina silus*	✓	-	-	-	✓	-	✓	-	-
Gurnards - Grey	*Eutriglia gurnardus*	-	✓	✓	-	✓	✓	✓	✓	✓
Gurnards - Red	*Aspitrigla cuculus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Haddock	*Melanogrammus aeglefinus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hake	*Merluccius merluccius*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Halibut - Atlantic	*Hippoglossus hippoglossus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Halibut - Greenland	*Reinhardtius hippoglossoides*	✓	-	✓	✓	✓	-	✓	-	-
Herring	*Clupea harengus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Horse Mackerel	*Trachurus trachurus*	-	-	-	-	✓	✓	✓	✓	✓
John Dory	*Zeus faber*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lemon Sole	*Microstomus kitt*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ling	*Molva molva*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Long Rough Dabs	*Hippoglossoides platessoides*	-	-	-	-	✓	-	-	-	-
Mackerel	*Scromber scrombus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Megrim	*Lepidorhombus whiffiagonis*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Monks or Anglers	*Lophius piscatorius*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Plaice	*Pleuronectes platessa*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pollock	*Pollachius pollachius*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Rabbit Fish (Rattail)	*Macrouridae spp.*	-	-	✓	✓	-	-	✓	✓	-
Red Mullet	*Mullus surmeletus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Redfish	*Sebastes marinus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Roughead Grenadier	*Macrourus berglax*	-	-	-	-	-	-	✓	-	-
Roundnose Grenadier	*Coryphaenoides rupestris*	-	✓	✓	✓	-	✓	✓	✓	✓
Saithe	*Pollachius virens*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sole	*Solea solea*	✓	✓	✓	✓	-	✓	✓	-	-
Torsk (Tusk)	*Brosme brosme*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Turbot	*Psetta maxima*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Whiting	*Merlangius merlangus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Witch	*Glyptocephalus cynoglossus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Elasmobranchs (Sharks and Rays)										
Birdbeak Dogfish	*Deania calcea*	-	-	-	-	-	-	✓	-	-
Common Skate	*Dipturus batis*	-	-	-	-	-	-	✓	-	-
Gulper Shark	*Centrophorus granulosus*	-	-	-	-	-	-	✓	-	-
Leafscale Gulper Shark	*Centrophorus squamosus*	✓	✓	-	-	-	-	-	-	-
Long-nosed Skate	*Dipturus oxyrinchus*	-	-	-	-	-	-	✓	-	✓
Portuguese Dogfish (Shark)	*Centroscymnus coelolepis*	✓	✓	-	✓	-	-	✓	✓	-
Sailfin Roughshark	*Oxynotus paradoxus*	-	-	-	-	-	-	✓	-	-
Sharks	-	✓	✓	✓	✓	✓	✓	✓	✓	✓
Skates and Rays	-	✓	✓	✓	✓	✓	✓	✓	✓	✓
Spurdog	*Squalus sp.*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Thornback Ray	*Raja clavata*	-	-	-	-	-	-	✓	-	-
Tope	*Galeorhinus galeus*	-	-	-	-	-	-	-	-	✓
Unidentified Dogfish	*Squalidae spp.*	-	-	-	✓	✓	✓	✓	✓	-
White Skate	*Rostroraja alba*	-	-	-	-	-	-	✓	-	-

Table 3.2 List of shellfish species in the local (light yellow) and regional study area (MMO landings data)

Species		Presence (✓) within ICES Rectangles								
Common Name	Scientific Name	44E6	44E7	44E8	45E6	45E7	45E8	46E6	46E7	46E8
Crustaceans										
Brown Shrimp	*Crangon crangon*	✓	✓	✓	-	-	-	-	-	-
Velvet Crab	*Necora puber*	✓	✓	✓	✓	✓	-	✓	✓	✓
Edible Crab	*Cancer pagurus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Crawfish	*Palinurus spp.*	-	-	✓	-	-	-	✓	-	-
Green Crab	*Carcinus maenas*	✓	✓	✓	✓	✓	-	✓	✓	-
Squat Lobster	*Galatheoidea sp.*	✓	--	✓	✓	-	-	✓	✓	-
Lobsters	*Homarus gammarus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Nephrops	*Nephrops norvegicus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pink Shrimp	*Pandalus montagui*	-	-	-	-	✓	✓	-	-	-
Spider Crabs	*Majidae spp.*	-	-	-	-	-	✓	-	-	-
Molluscs										
Bivalves										
Cockles	*Cardiidae spp.*	✓	-	-	✓	-	-	✓	✓	-
Oysters	*Ostreidae spp.*	✓	-	✓	-	-	-	-	-	-
Queen Scallops	*Aequipecten opercularis*	✓	✓	✓	✓	✓	✓	✓	✓	-
Razor Clam	*Ensis arcuatus*	✓	✓	-	✓	-	-	✓	✓	-
King Scallops	*Pecten maximus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Surf Clams	*Spisula solida*	✓	-	-	-	-	-	✓	-	-
Cephalopods										
Cuttlefish	*Sepiida spp.*	-	-	-	-	-	-	-	✓	✓
Octopus	*Octopoda sp.*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Squid	*Teuthida spp.*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gastropods										
Periwinkles	*Littorina littorea*	✓	-	✓	✓	✓	-	✓	✓	-
Whelks	*Buccinum undatum*	✓	✓	✓	✓	✓	✓	✓	✓	✓

3.2.1 Shellfish

King scallops are the main shellfish species landed by weight from the local study area, accounting for 78.1 % of total shellfish landings (average 2000-2009). Nephrops and squid account for 15.5 % and 5.8 % of the total shellfish landings weights respectively. It should be noted that these species account for a large percentage of the total landings (including fish) from the local study area (61.1 %).

In rectangles adjacent to the local study area, landings by weight for other shellfish species such as crabs (principally edible crab) and, to a lesser extent, whelks and lobster are of relative importance (Figure 3.2).

Table 3.3 Percentage distribution of the catch of shellfish species in the local area (45E7) (MMO landings data)

Species	Average (2000-2009) Landings Weight (t)	Percentage of Total Shellfish Landings Weight in the Local Study Area (45E7)	Percentage of Total Landings Weight (Fish and Shellfish Species combined) in the Local Study Area (45E7)
King Scallops	539.0	78.1%	48.0%
Nephrops	106.7	15.5%	9.5%
Squid	40.2	5.8%	3.6%
Edible Crab	2.5	0.4%	0.2%
Queen Scallops	1.2	0.2%	0.1%
Velvet Crab	0.3	<0.1%	<0.1%
Octopus	0.1	<0.1%	<0.1%
Whelks	< 0.1	<0.1%	<0.1%
Green Crab	< 0.1	<0.1%	<0.1%
Lobsters	< 0.1	<0.1%	<0.01%
Mixed Crabs	< 0.1	<0.01%	<0.01%
Periwinkles	< 0.1	<0.01%	<0.01%
Pink Shrimp	< 0.01	<0.01%	<0.01%

3.2.1.1 Scallops

The king scallop (*Pecten maximus*) is the main species of scallop in Scottish waters (Howell *et al* 2006). They can be found on a variety of substrate types, from rocks and stones to fine silty mud, although they are most abundant in areas with rocky outcrops or boulders on silty sand mixed with shell substrates and at depths of 15-75 m (Pawson 1995, Franklin *et al* 1980). Queen scallops (*Aequipecten opercularis*) also occur in much the same areas as king scallops, but usually in somewhat deeper water, down to as much as 200 m or more. They are also landed from the local study area, although to a lesser extent than king scallops.

The highest scallop landings in the regional study area are recorded in ICES rectangle 45E7, within which the Beatrice Offshore Wind Farm is located. In this rectangle king scallops account for 57 % of the total landings values and for 48 % of the total landings weights (Commercial Fisheries Report BMM 2011). Both species were found in beam trawl samples during benthic surveys undertaken in the site (CMACS 2011) with a total of 2 king scallops and 81 queen scallops being caught.

Scallops have an aggregated distribution within their geographical range. Where the population is sufficiently abundant to support a commercial fishery, such areas are referred to as « grounds » and are usually widely separated by areas that are environmentally unsuitable for the species. The absolute size of grounds may vary substantially from a few km² to a few thousand km² (Brand 2006). Scallop grounds are located in areas of the Moray Firth, including the Smith Bank, the southern and western coastlines and in eastern, offshore areas (Commercial Fisheries Report BMM 2011). Scallop grounds appear to be absent from areas characterized by muddy sand substrates, where nephrops are more prevalent (Figure 3.1, Figure 3.5).

Within each ground there are usually a number of areas of several km², where scallop abundance is higher than elsewhere, these are referred to as « beds ». Beds may be permanent aggregations, precise in their location and separated by areas that are unsuitable for scallops, or they may be temporary aggregations that vary in their location from year to year, resulting from uneven settlement or early survival. In addition, within each bed the distribution of scallops may be aggregated into « patches », the scale of which is generally measured in terms of tens or hundreds of m² (Brand 2006).

The scallop fishery is cyclical and is often left to recover from intensive fishing periods while the fleet targets grounds elsewhere (Figure 3.5, pers. comm. scallop fisherman, December 2010). In the Moray Firth scallop stock levels are considered to be currently stable (Commercial Fisheries Report BMM 2011).

Scallops spawn in Scottish waters for the first time in the autumn of their second year, and subsequently spawn each year in the spring or autumn (Keltz & Bailey 2010). Following external fertilisation eggs remain on or near the sea bed for a number of days and then develop into free-swimming larvae (called veliger larvae) that migrate towards the sea surface, and spend three weeks or more in the water column (Keltz & Bailey 2010, Pawson 1995). Pelagic veliger larvae eventually descend towards the seabed where they develop into pediveliger larvae (Pawson 1995, Franklin *et al* 1980). It is at this stage of the larval cycle that substrate preference will determine the settlement of the young larvae. During this stage, larvae alternatively swim and crawl over the seabed testing surfaces upon which to settle (Franklin *et al* 1980). When a suitable settling surface such as algae, hydroids or bryozoans is found the scallop anchors itself by means of sticky threads (called byssus threads) from a gland at the base of the foot (Franklin *et al* 1980). The larvae then undergo a complete metamorphosis of internal anatomy and become what is termed “spat”. It then feeds until the shell is strong and thick enough for the scallop to inhabit sand and gravel on the sea bed (Franklin *et al* 1980).

Spat settlement and/or survival appear to be extremely irregular, with certain age classes often entirely absent from a population. It has been suggested that a minimum of spawning adults is necessary to ensure good recruitment of spat (juvenile scallops), and productive spawning areas may therefore be more restricted than the overall distribution of the species would indicate (Pawson 1995).

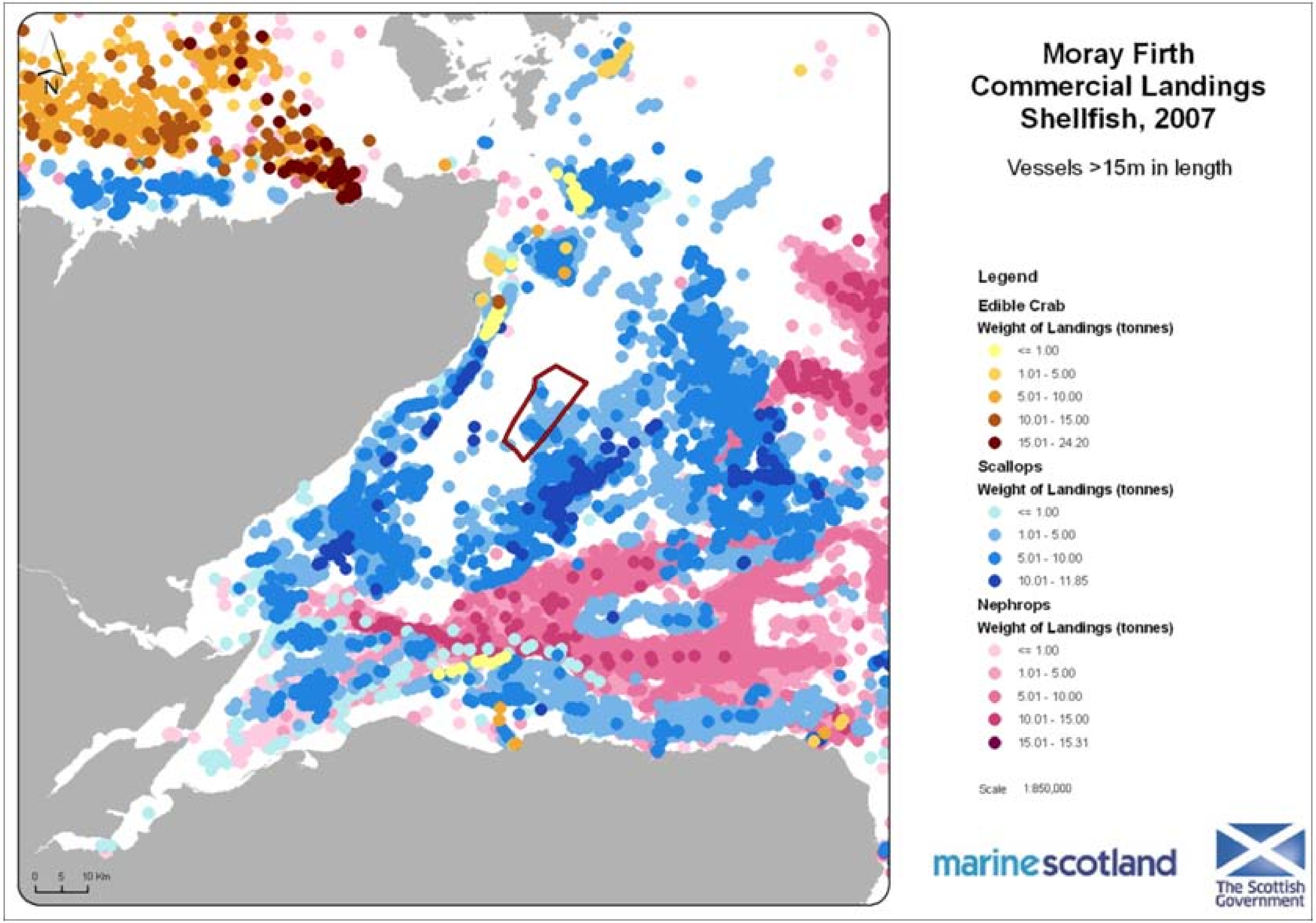

Figure 3.3 Commercial landings of shellfish (edible crab, scallops and nephrops) for over-15 metre vessels in the Moray Firth, 2007 (Source: Marine Scotland)

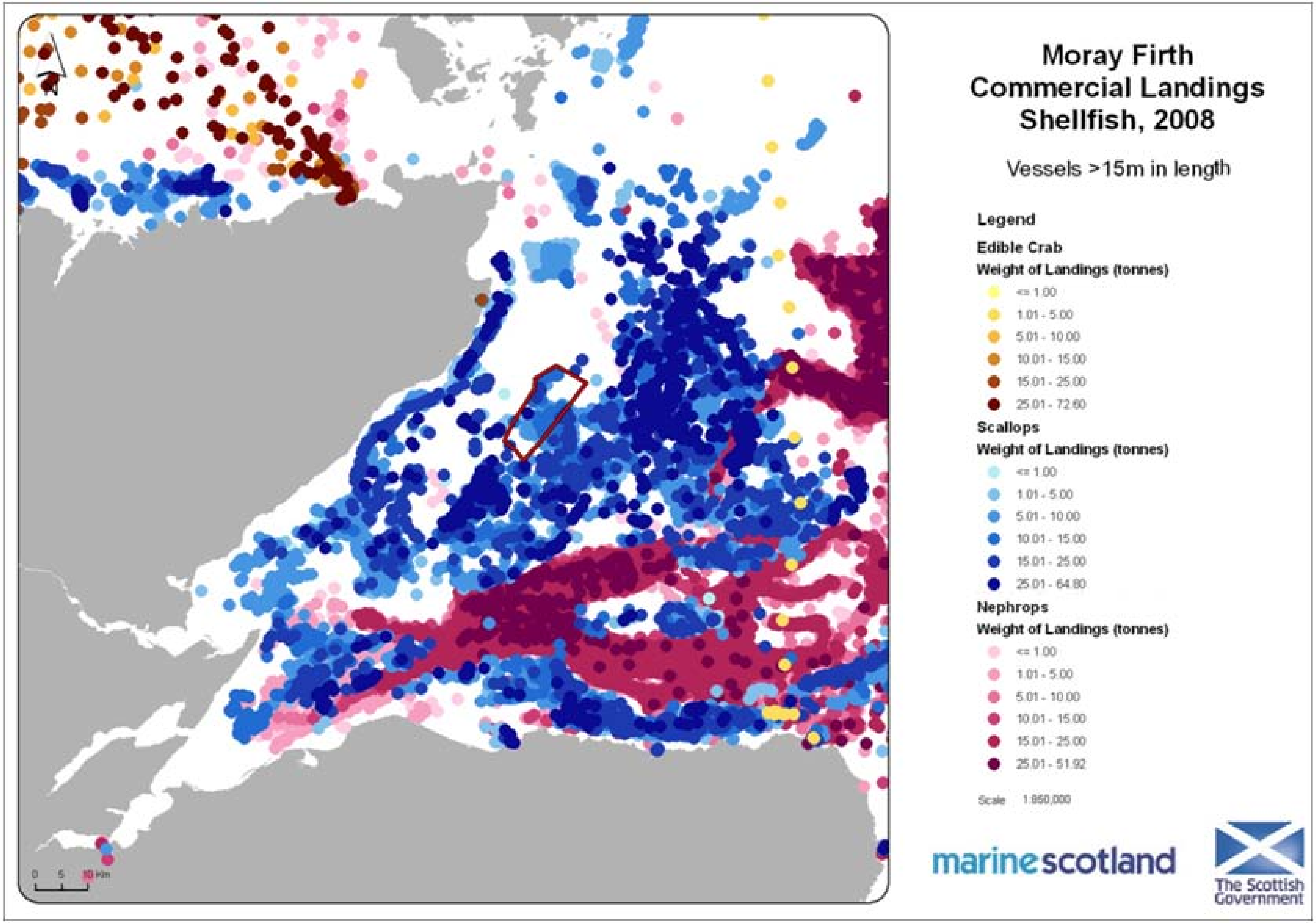

Figure 3.4 Commercial landings of shellfish (edible crab, scallops and nephrops) for over-15 metre vessels in the Moray Firth, 2008 (Source: Marine Scotland)

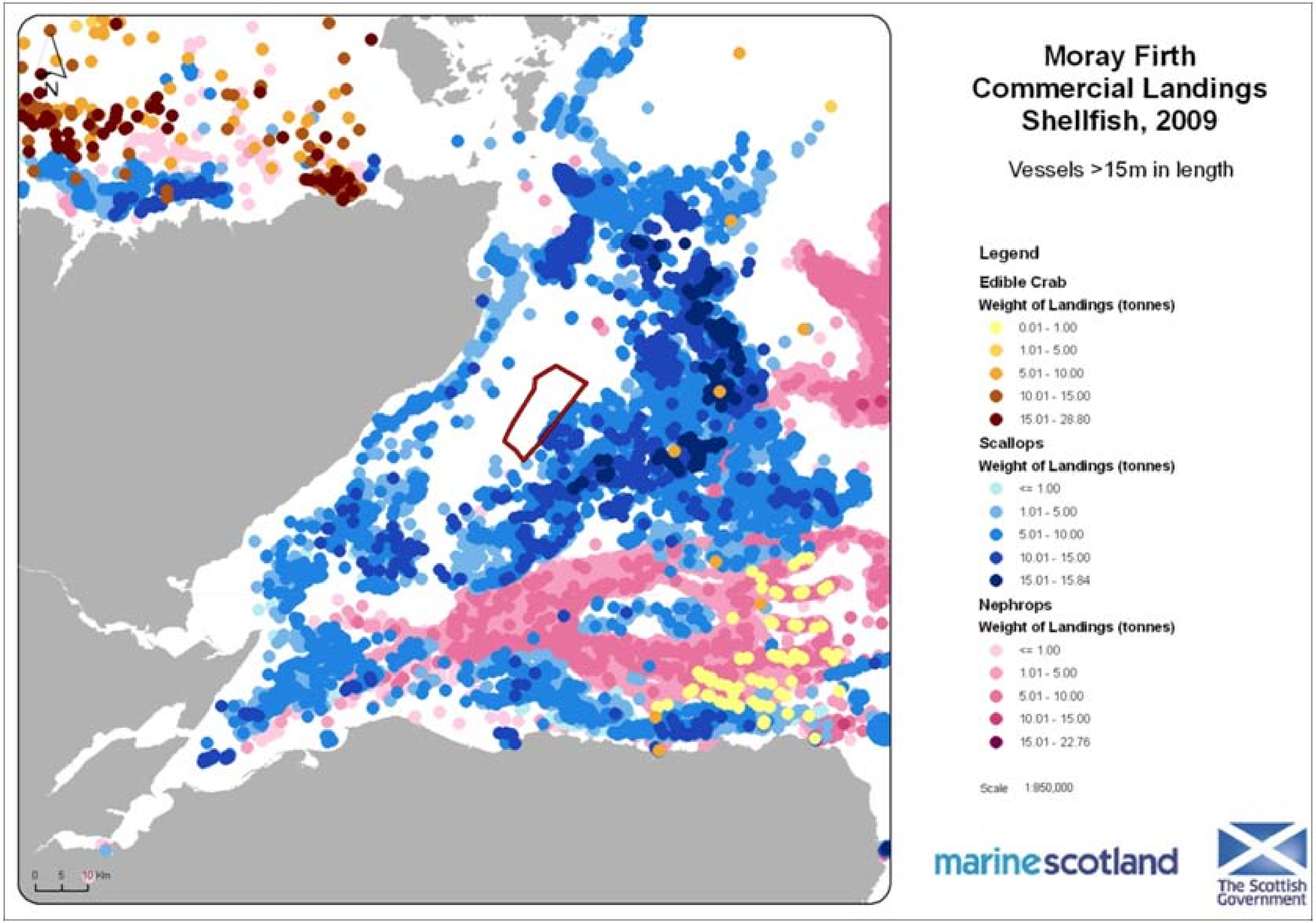

Figure 3.5 Commercial landings of shellfish (edible crab, scallops and nephrops) for over-15 metre vessels in the Moray Firth, 2009 (Source: Marine Scotland

3.2.1.2 Nephrops

Nephrops (*Nephrops norvegicus*), also commonly referred to as Norway lobster and Dublin Bay prawn, are found at depths ranging from 15 m to more than 800 m. They are more commonly found in Scottish waters at a depth between 40 and 200 m (Howard 1989).

Nephrops distribution is dependent upon the availability of a seabed composed of fine cohesive mud in which they can construct burrows, although the precise nature of the sediment can vary markedly. Sediment type also appears to affect the structure of nephrops populations, with areas of fine sediment being characterised by the presence of large nephrops and low population densities, and areas of coarser sediment showing higher population densities and nephrops smaller in size (Howard 1989).

Although an important fishery to the local area in terms of landings, the Moray Firth nephrops fishery is on a much smaller scale compared to fisheries in the Minches and the Fladen Grounds (Southhall & Hambrey 2005). Nephrops in the Moray Firth, as suggested by landings statistics, are principally distributed in the southern area and eastern rectangles in muddy sand areas and not within the Beatrice wind farm site (Figure 3.1, Figure 3.2, Figure 3.3).

3.2.1.3 Squid

A substantial proportion of Scottish squid landings (*Loligo forbesi*) come from the Moray Firth (Young *et al* 2006). The species is typically found on the continental shelf and offshore banks. Although spawning grounds have not yet been documented, it is very likely that the Moray Firth includes spawning grounds for this species (Young *et al* 2006). Fishermen have reported finding squid eggs off Burghead and Buckie in May and June in waters 5 to 6 m deep. Eggs have also been encountered on lobster creels shot on hard ground in the Moray Firth (Young *et al* 2006).

In Scottish waters spawning occurs over an extended period from December to June, with peak spawning having been reported from December to March (Lum-Kong *et al* 1992, Pierce *et al* 1994, Boyle 1995, Collins *et al* 1997). The winter breeding cohort appears to spawn in inshore waters and some evidence suggests that the spawning grounds of the summer breeders are also inshore (Viana *et al* 2009). All individuals are semelparous and die after spawning (Rocha *et al* 2001). Recruitment of juvenile squid to the adult population has been reported to peak in spring (April) and in autumn (July to October) (Boyle 1995, Viana *et al* 2009, Pierce *et al* 1994), the latter being the main recruitment period (Viana *et al* 2009).

The main Scottish fishery for *L. forbesi* occurs in coastal waters and usually exhibits a marked seasonal peak around October and November, corresponding to the occurrence of pre-breeding squid. In the Moray Firth, a directed fishery for squid has developed in late summer and autumn in coastal waters between Troup Head and Spey Bay in the south of the Moray Firth, with additional activity recorded on parts of the Smith Bank and along the north coast (pers. comm. squid fisherman, December 2010, Young *et al* 2006, Campbell & McLay 2007).

At the beginning of the season, catches are best in shallow water over hard (even rocky) ground close inshore, in depths of around 10 m. As the season progresses, the fishery gradually moves further offshore to a sandy/muddy bottom in waters of around 55 m depth (Young *et al* 2006).

It is noted that the squid fishery records highly variable annual fluctuations in landings weights (i.e. 4.9 tonnes in 2006 and 265.7 tonnes in 2009). Furthermore, the fishing may also vary seasonally, depending upon the arrival of the species in the Moray Firth. Anecdotal evidence suggests that in

2011 the fishery commenced in late May, several months in advance of previous years (Commercial Fisheries Report BMM 2011).

3.2.1.4 Crab

In the Moray Firth, crabs are mainly targeted in coastal waters located to the south and west of the site. Landings weights for edible crab and velvet crab are particularly high in inshore ICES rectangle 45E6 adjacent to the site, representing 26.3 % and 6.8 % of the landings. In the local study area (45E7) landings weights for these species are comparatively low, with edible crabs representing 0.2 % and velvet crabs less than 0.1 % of the total.

Edible crabs (*Cancer pagurus*) are found around the Scottish coast on the lower shore and shallow sub-littoral areas and in offshore waters at depths of up to 200 m (Mill *et al* 2009, Pawson 1995). They are often associated with rocky reefs but also inhabit mixed coarse grounds and soft sediments (muddy sand) particularly offshore (Hall 1993). Adult female crabs undertake seasonal inshore and offshore migrations of 20 to 70 km (Ungfors *et al* 2007, Jones *et al* 2010). One edible crab was found during the benthic survey (CMACS, 2011).

Velvet crabs (*Necora puber*) are fast moving, swimming species which inhabit grounds from the intertidal areas down to about 80 m, but are most commonly found at depths of about 25 m (Norman & Jones 1992). They are typically found in areas of hard substratum where rocky reef and boulders provide crevices for shelter (Jessop *et al* 2007). Females are thought to move offshore during the winter (Norman & Jones 1993), however, long distance migrations as those observed in edible crabs, have not been recorded for this species (Kinnear & Mason 1987).

3.2.1.5 Lobster

Lobster (*Homarus gammarus*) is found on rocky grounds from the intertidal zone to depths up to 200 m, although most commonly in waters less than 30 m (Pawson 1995, Mill *et al* 2009, Howard & Nunny 1983). Unlike edible crabs, lobsters are not thought to undertake extensive migrations and will only move a few miles along the shore (Pawson 1995, Smith *et al* 2001, Thomas 1955, Keltz & Balley 2010). Recent studies of the north east coast of England have however indicated seasonal offshore movements of berried females (Keltz & Balley 2010).

Lobsters are mainly targeted in coastal waters of the Moray Firth (Commercial Fisheries Report BMM 2011). Landings weights represent 2.9 % of the total in ICES rectangle 45E6, and less than 0.1% in the local study area (45E7).

3.2.1.6 Whelk

Whelk (*Buccinum undatum*) is found throughout the littoral zone. Landings weights within the regional study area are relatively high in ICES rectangle 45E6, representing 8.3 % of total landings weights, and comparatively low in the local study area (45E7), accounting for less than 0.1 % of total landings weights in this rectangle. Whelks were found at three stations in beam trawl samples during the benthic survey (9 individuals) (CMACS, 2011).

3.2.2 Fish

The percentage distribution of fish landings weights by species is given in Table 3.4 (percentage distribution, all species combined, is also shown).

Table 3.4 Percentage distribution of the catch of fish species in the local area (45E7) (MMO landings data)

Species	Average (2000-2009) Landings Weight (t)	Percentage of Total Fish Landings Weight in the Local Study Area (45E7)	Percentage of Total Landings Weight (Fish and Shellfish Species combined) in the Local Study Area (45E7)
Haddock	280.6	65.2%	25.0%
Monks or Anglers	43.1	10.0%	3.8%
Herring	39.1	9.1%	3.5%
Whiting	16.4	3.8%	1.5%
Cod	12.4	2.9%	1.1%
Horse Mackerel	8.2	1.9%	0.7%
Megrim	7.3	1.7%	0.6%
Plaice	6.7	1.6%	0.6%
Witch	2.8	0.7%	0.3%
Spurdog	2.3	0.5%	0.2%
Hake	2.0	0.5%	0.2%
Skates and Rays	1.8	0.4%	0.2%
Ling	1.8	0.4%	0.2%
Lemon Sole	1.6	0.4%	0.1%
Saithe	1.4	0.3%	0.1%
Other	3.2	0.8%	0.3%

Haddock accounts for the majority of fish landings by weight in the local study area (65.2 %) followed by monks (10 %), herring (9.1 %) and whiting (3.8 %) with cod, horse mackerel, megrim and plaice being landed to a lesser extent. The remaining 31 species account together for only 4.7 % of the total average fish weight landings in ICES rectangle 45E7.

Spurdog is the most prevalent elasmobranch species accounting for 0.5 % of total fish landings weights from the local study area, followed by skates and rays (0.4 %). Dogfish and sharks are relatively scarce in the landings weights and have therefore been included in the category “other”.

3.2.2.1 Demersal Species

Haddock

Immature and adult haddock (*Melanogrammus aeglefinus*) are found in northerly areas of the North Sea (Hedger *et al* 2004). Shoals are typically found in colder waters at depths from 40-300 m, over rock, sand, gravel or shells (ICES 2011b, FAO 2011). Haddock shoals show a preference for depths between 75 and 125 m, bottom temperatures greater than 6° C and salinities greater than 35.5 ppt (Hedger *et al* 2004).

This species is the second most important species landed by weight in ICES rectangle 45E7, accounting for 65.2 % of total fish landings weights and 25.0 % of the total in this rectangle (Table 3.4). Haddock landings are recorded at relatively low levels in the south of the Moray Firth in an area which broadly corresponds to nephrops fishing grounds. This species is targeted by a local whitefish fishery that operates on grounds at depths greater than 45 m to the north of the Beatrice site (Commercial Fisheries Report BMM 2011). One individual was caught in beam trawl samples in the benthic survey (CMACS, 2011).

Monks

Monkfish (*Lophius piscatorius, Lophius budegassa*), also called anglerfish, occur in shallow waters to depths of approximately 1000 m on muddy/gravelly bottoms of the continental shelf (Cefas 2011). *L. piscatorious* is usually caught at depths between 20 and 150 m, whereas *L. budegassa* occurs mostly in depths greater than 100 m. Spawning appears to occur largely in deep waters, from February to August, off the edge of the continental shelf and recruitment occurs in relatively inshore areas such as the Moray Firth and along the Norwegian coast in northern North Sea (ICES 2009c, Pawson 1995).

This species constitutes 3.8 % of total landings by weight in ICES rectangle 45E7 (value 6.7 %) (Table 3.4, Commercial Fisheries Report BMM 2011).

Whiting

Whiting (*Merlangius merlangus*) is widely distributed throughout the North Sea, Skagerrak and Kattegat (ICES 2011b). The species is typically found near the seafloor in waters from 10 to 200 m, but may move into midwater in the pursuit of prey (ICES 2011b).

In the Moray Firth landings weights for this species are comparatively low. This species constitutes 3.8 % of total fish landings weights and 1.5 % of the total in ICES rectangle 45E7 (Table 3.4).

Cod

Cod (*Gadus morhua*) is found from shallow coastal waters to the shelf edge (200 m depth) and beyond with catches reported from 600 m depths (ICES 2011b, Hedger *et al* 2004). Hedger *et al* (2004) found the greatest abundances of mature cod in depths less than 50 m or greater than 150 m (along the Norwegian Trench) over the entire temperature and salinity range of the North Sea. Cod in the Moray Firth is believed to be a sedentary residential population that provides year round site fidelity (Wright *et al* 2007).

Cod was historically commercially targeted in the Moray Firth. A series of quota reductions in the 1980's restricted the fishermen's ability to legally land cod, rendering the fishery presently unviable in the Moray Firth (Commercial Fisheries Report BMM 2011). Landings weights for this species are therefore relatively low within the Moray Firth, representing 2.9 % of total fish landings weights and 1.1 % of the total within ICES rectangle 45E7.

Megrim

Megrim (*Lepidorhombus whiffiagonis*) are found mainly in muddy seabed habitats at around 100-300 m depths, but can occur at depths ranging from 50 to 800 m. Megrim show a gradual expansion in bathymetric distribution throughout their lifetimes. Mature males and juveniles tend to occupy deep waters, while mature females are found in shallower waters outside the spawning season (Cefas 2009).

Megrim accounts for 1.7 % of total fish landings and for 0.7 % of the total landings weights in ICES rectangle 45E7. One individual was caught in beam trawl samples in the benthic survey (CMACS Benthic Report 2011).

Plaice

Plaice (*Pleuronectes platessa*) are generally found in shallow waters less than 50 m. Juveniles are found in shallow coastal waters and outer estuaries. As they grow older they gradually move into deeper water (ICES 2011b).

The results of a tagging study in the Central North Sea conducted by Hunter *et al* (2003) showed directed seasonal migrations of plaice from winter spawning grounds to summer feeding grounds

250 km to the north. The timing of the migration was considered to be synchronous and characterized by a 100 % spawning site fidelity.

Plaice accounts for 1.6 % of total fish landings and for 0.6 % of the total landings weights in ICES rectangle 45E7. This species was caught in beam trawl samples at seven stations in the benthic survey (12 individuals) (CMACS Benthic Technical Report, 2011).

3.2.2.2 Pelagic Species

Herring

In ICES rectangle 45E7 herring (*Clupea harengus*) account for 9.1 % of total fish landings weights and for 3.5 % of the total. Herring is a migratory species targeted by a seasonal fishery. Adult herring migrate considerable distances in large shoals to feeding and spawning grounds (Munro *et al* 1998). Juvenile fish remain generally up to two years in nursery areas before joining adult fish on their migration.

Herring's migration is divided into three phases: The Over-wintering phase (O), the Feeding phase (F) and the Reproduction/Spawning phase (R). The distribution of different migration phases of North Sea herring is shown in Figure 3.6. They spawn off the Scottish and English east coast, migrate east to the Skagerrak and Kattegat where they overwinter and then move to the feeding grounds in the Fladen Grounds and Viking Bank before returning to the spawning grounds.

In the Moray Firth juveniles are present throughout the year, whilst adults are more prevalent during the spawning season. Herring's spawning behavior and distribution and nursery areas, as well as its role in the North Sea food-web are further discussed in the subsequent sections of this report.

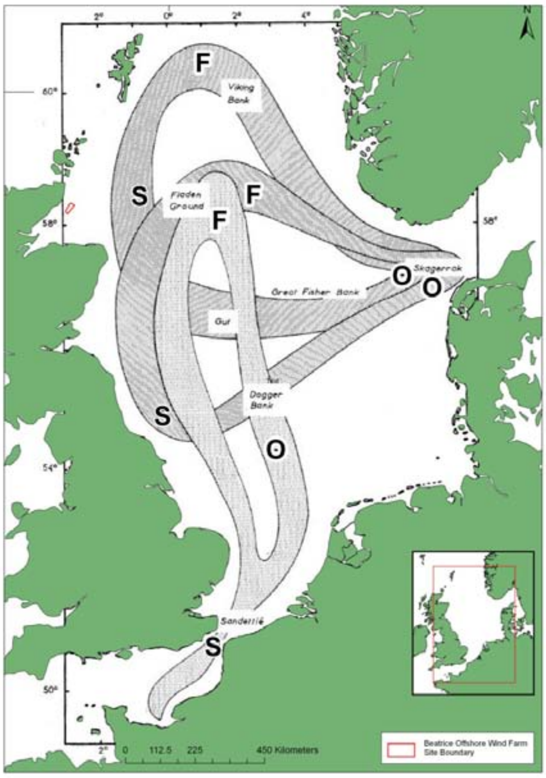

Figure 3.6 Herring migration routes in the North Sea, between (S) Spawning, (O) Over-Wintering and (F) Feeding grounds (Modified from Cushing & Bridger 1966, Maucorps 1969)

Horse Mackerel

Horse Mackerel (*Trachurus trachurus*) account for 1.9 % of total fish landings weights and for 0.7 % of the total in the ICES rectangle 45E7.

Adult horse mackerel are widespread in the North Sea, whilst juvenile fish are absent from the northern part of the North Sea (Teal *et al* 2009). Horse mackerel form large shoals that remain close to the bottom during the day. During the night they rise a few metres off the seabed and then gradually disperse laterally to merge with neighbouring shoals to form a continuous layer (Lockwood & Johnson 1977). The species typically occupies continental shelf areas, and has been reported in depths between 180-250 m (Lockwood & Johnson 1977).

In autumn, as temperatures fall below ca. 10°C, fish retreat from feeding areas in the North Sea and migrate to over-wintering areas further south in the English Channel and along the continental slope in the Bay of Biscay and Celtic Sea. In spring, spawning commences and the shoals begin to disperse and migrate northward again with increasing water temperature (Lockwood & Johnson 1977).

Sprat

Sprat (*Sprattus sprattus*) does not appear in the MMO landings data from the regional area (Table 3.1). This is likely due to the closure of its fishery in the inner waters of the Moray Firth west of longitude 3°00' W, which was implemented in order to protect juvenile herring from exploitation. This restriction has been active since 1998 (ref EC 850/98).

Sprat is widely distributed in the North Sea being most abundant in the Dogger Bank and the Kattegat (ICES 2011b). They largely stay within the 50 m depth contour and are also common in inshore waters (ICES 2011b). Fish migrate inshore during the winter months in the North Sea and secondary concentrations are found in the Firth of Forth and in the Moray Firth (Wright & Begg 1997, ICES 2011b).

3.2.2.3 Sharks and Rays (Elasmobranchs)

The principal elasmobranch species present in the local area, based on records from landings data (2000-2009), are listed in Table 3.5 below.

Spurdog is the principal elasmobranch species landed, followed by skates and rays, unidentified dogfish and sharks. These species account for a very small percentage of the total catch in the Moray Firth, and are generally landed as by-catch.

Table 3.5 Percentage distribution of the catch of elasmobranch species in the local area (45E7) (MMO landings data)

Species	Average (2000-2009) Landings Weight (t)	Percentage of Total Elasmobranch Landings Weight in the Local Study Area (45E7)	Percentage of Total Landings Weight (Fish and Shellfish species combined) in the Local Study Area (45E7)
Spurdog	2.3%	54.6%	0.2%
Skates and Rays	1.8%	42.5%	0.2%
Unidentified Dogfish	0.1%	2.2%	< 0.1%
Sharks	< 0.1%	0.6%	< 0.1%

It should be noted that the majority of elasmobranch species are of concern from a conservation point of view as stocks have been severely depleted. The conservation status and state of the stocks of the principal shark and ray species potentially present in areas relevant to the site is further discussed in Section 6.0.

3.2.2.4 Other Species

Further to the above, a number of other commercial species are likely to be present in the local study area as identified by MMO landings data (Table 3.1, Table 3.2). Demersal species include brill, catfish, conger eel, dab, long rough dab, gurnards, hake, halibut, Greenland halibut, megrim, pollak, red mullet, redfish, saithe, tusk, turbot and witch. Pelagic species include mackerel, greater silver smelt and black scabbardfish. Mackerel, saithe, ling and hake are known to use the general area of the Beatrice Offshore Wind Farm a nursery ground (see Section 8.0).

In addition, a number of other commercial and non-commercial fish and shellfish species were recorded in beam trawl samples during the benthic survey. These are detailed in the Benthic Ecology Technical Report.

4.0 Species with Spawning and Nursery Grounds

The Beatrice site falls within, and is in close proximity to, the spawning and nursery grounds of a number of species (Coull *et al* 1998, Ellis *et al* 2010a). These are listed in Table 4.1 below together with their spawning times and intensity of spawning (where it has been defined). The spawning times are given as provided in Coull *et al* (1998) and the spawning/nursery intensity as described in Ellis *et al* (2010a).

Sandeel, nephrops, cod, plaice, lemon sole, sprat and whiting spawning grounds have all been defined within the area of the wind farm. In the case of herring, the wind farm does not fall within the spawning grounds but in their vicinity (to a distance of approx. 1.4 km at the closest point).

Nursery grounds have also been identified in the area of the wind farm for the species mentioned above and a number of other species (Table 4.1). These are provided in Section 8.0.

Table 4.1 Species with spawning and nursery areas within the Beatrice Offshore Wind Farm and its vicinity (Coull *et al* 1998, Ellis *et al* 2010a) and spawning times and intensity. Colour key: (red) = high intensity spawning/nursery ground, (yellow) = low intensity spawning/nursery ground, (green) = unknown spawning/nursery intensity, (*) = peak spawning

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Nursery
Sandeel	(red)	(red)									(red)	(red)	(yellow)
Nephrops	(green)	(green)	(green)	(green) *	(green) *	(green) *	(green)	(green)	(green)	(green)	(green)	(green)	(green)
Herring								(green)	(green)				(red)
Cod	(yellow)	(yellow) *	(yellow) *	(yellow)									(red)
Plaice	(yellow) *	(yellow) *	(yellow)									(yellow)	(yellow)
Lemon Sole				(green)	(green)	(green)	(green)	(green)	(green)				(green)
Sprat					(green) *	(green) *	(green)	(green)					(green)
Whiting		(yellow)	(yellow)	(yellow)	(yellow)	(yellow)							(red)
Spurdog	n/a												(yellow)
Thornback Ray	n/a												(yellow)
Spotted Ray	n/a												(yellow)
Blue Whiting	n/a												(yellow)
Ling	n/a												(yellow)
Hake	n/a												(yellow)
Anglerfish	n/a												(red)
Mackerel	n/a												(yellow)
Haddock	n/a												(green)
Saithe	n/a												(green)

A review of spawning activity by species with known spawning grounds in the general area of the site is given below. Where alternative grounds to those provided in Coull *et al* 1998 and Ellis *et al* 2010a and/or additional information in relation to spawning in the Moray Firth has been published, this has also been included.

4.1 Sandeels

The North Sea sandeel stock has been divided into seven sub populations which are reproductively isolated from each other (ICES 2009). The sandeel population of the Moray Firth is part of the Central Western North Sea sandeel stock (ICES 2009).

Sandeels spend most of the year buried in the sea bed and only emerge into the water column briefly in winter for spawning and for an extended feeding period in spring and summer (Van der Kooij *et al* 2008). Spawning principally takes place in December and January (Gauld & Hutcheon 1990, Bergstad *et al* 2001, Winslade 1974b). Females lay demersal eggs and after several weeks planktonic larvae hatch, usually in February-March (Macer 1965, Langham 1971, Wright & Bailey 1996). After spawning the fish remain buried in sand until April (Winslade 1974b).

The area of the Beatrice site has been identified as a high intensity spawning ground and a low intensity nursery ground for sandeels (Ellis *et al* 2010a, Section 8.2). Spawning grounds are shown in Figure 4.1 together with the results of recent egg and larval surveys, as presented in Ellis *et al* 2010a.

As previously mentioned, sandeels require a suitable substrate in which to bury. It is therefore expected that sandeels' distribution and spawning grounds will occupy discrete patchy areas rather than be continuous throughout the Moray Firth and the Beatrice site. This is further discussed in Section 5.1.

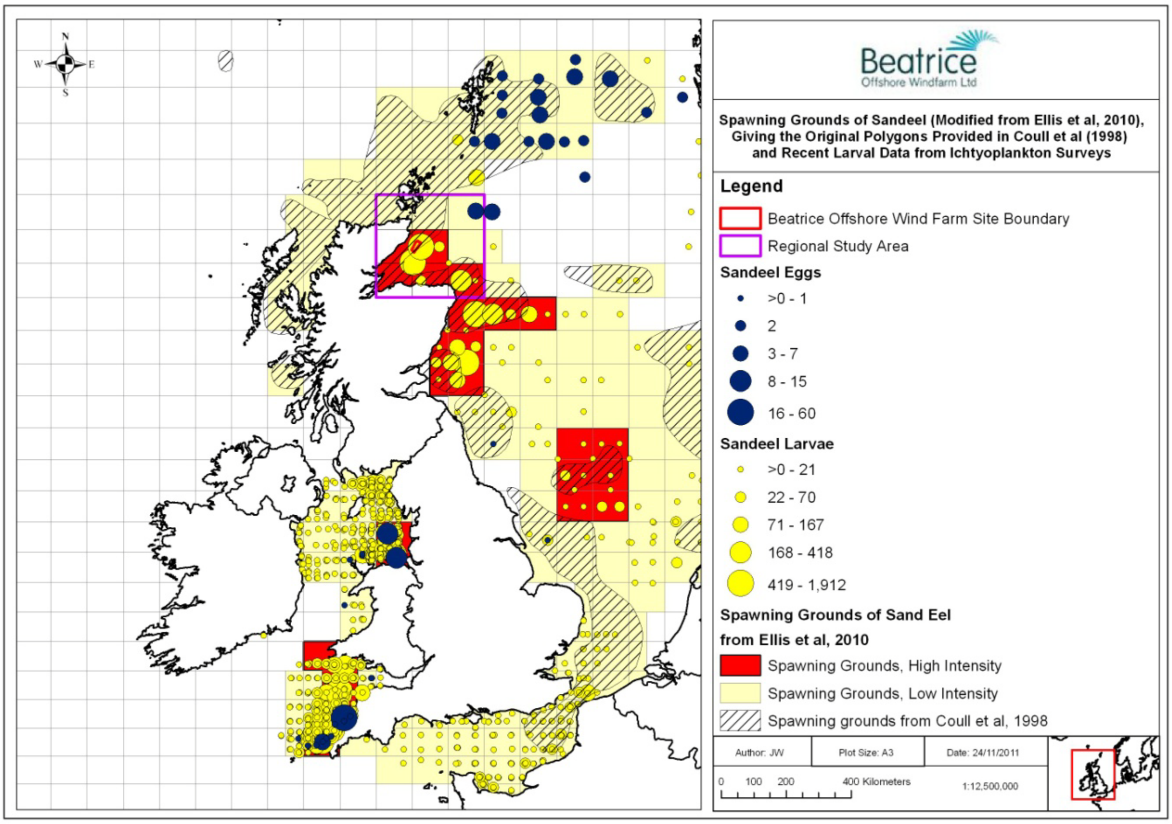

Figure 4.1 Sandeel spawning grounds (Modified from Ellis et al 2010a)

4.2 Nephrops

Nephrops spend most of their time in burrows, only coming out to feed and look for a mate (Keltz & Bailey 2010). In Scottish waters, spawning occurs from August to November (Keltz & Bailey 2010, Howard 1989).

Females carry eggs under their tails (described as being "berried") until they hatch from late April to August (Howard 1989). The egg-berried females stay in their burrows during egg incubation (Howard 1989). Larvae develop in the plankton before settling to the seabed six to eight weeks later as juveniles (Keltz & Bailey 2010). The juveniles enter the burrows of adults and remain there for approximately one year (Howard 1989).

The Beatrice site falls within the nephrops spawning and nursery grounds defined by Coull *et al* (1998) (Figure 4.2 and Section 8.1). However, given the substrate requirements of this species, it is unlikely that spawning will occur throughout the area defined. As previously mentioned in Section 3.1, areas of muddy sand and sandy mud are located to the south, and to a lesser extent to the east, of the site. It is therefore likely that there will not be significant nephrops spawning within the development area.

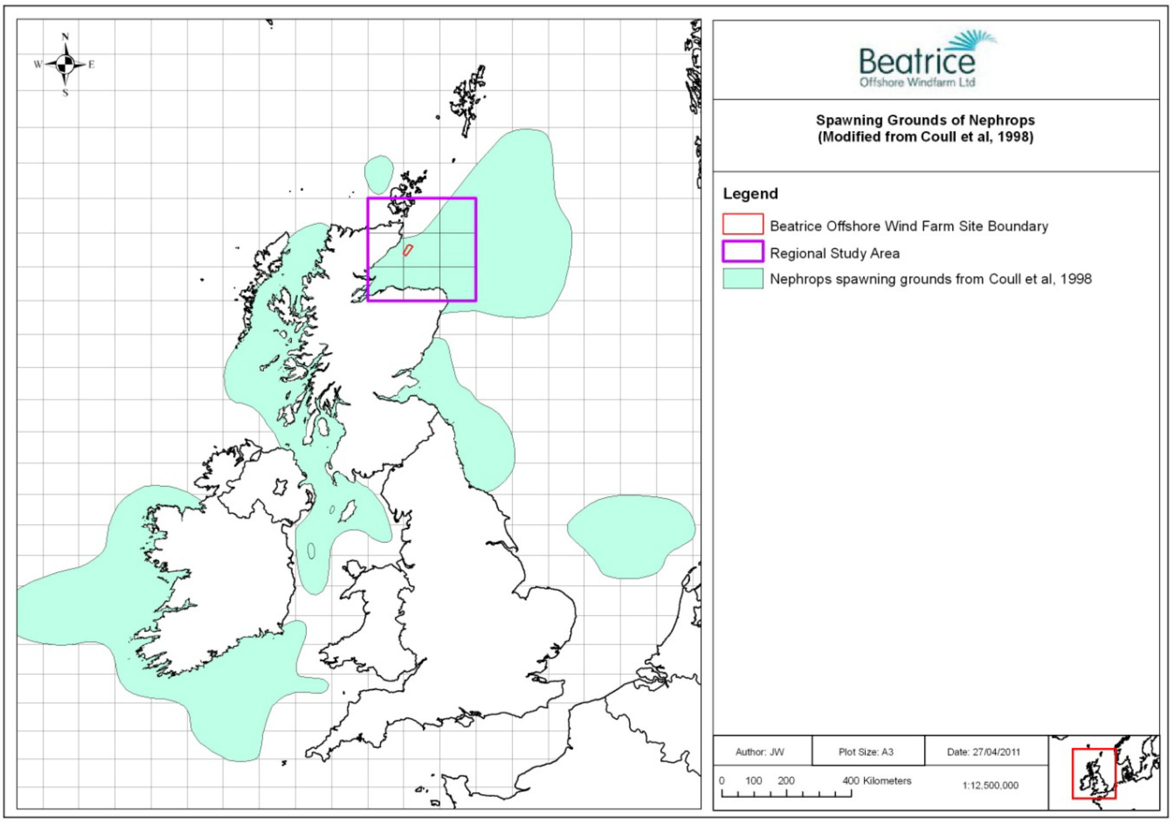

Figure 4.2 *Nephrops* spawning grounds (Modified from Coull *et al* 1998)

4.3 Herring

North Sea herring is divided into four sub-stocks on the basis of areas used for spawning. The spatial limits of these sub-stocks are shown in Figure 4.3. The sub-stock relevant to the Beatrice Offshore Wind Farm is the Orkney/Shetland stock which spawns off the Scottish east coast and in Shetland/Orkney waters.

Herring are demersal spawners and show a high preference for coarse grounds and high energy environments when selecting spawning grounds (Keltz & Bailey 2010, de Groot 1980, Maucorps 1969, Munro *et al* 1998, Parrish *et al* 1959, Blaxter 1985). Females deposit sticky eggs in single batches directly on to the seabed on a substrate of coarse sand, gravel, small stones or rocks (Keltz & Bailey 2010, Munro *et al* 1998, Hodgson 1957).

Spawning of the Shetland-Orkney sub-stock occurs between August and September (Coull *et al* 1998) and shoals of herring arrive at traditional spawning grounds in a series of waves, where they congregate (Lambert 1987). It has been suggested that herring are able to discriminate sources of sound emitted by various sediment types, each being characterized by its own specific noise spectrum. Herring would in this way be able to use the sound characteristics of the seabed as a clue to recognize their spawning sites in addition to homing (Enger 1967).

Herring larvae hatch in approximately three weeks, depending on sea temperature (Keltz & Bailey 2010, Maucorps 1969, Munro *et al* 1998, Hodgson 1957). Hatched larvae measure between 6 and 10 mm and depend on their yolk-sac until first feeding (Hodgson 1957). Once this has been absorbed larvae become pelagic and feed on plankton. They are then passively carried by prevailing currents before arriving at the nursery grounds (Keltz & Bailey 2010, Maucorps 1969, Munro *et al* 1998, Hodgson 1957).

Herring larvae from the Orkney/Shetland stock drift south into nursery grounds in the Moray Firth and east to nursery grounds in the Skagerrak and Kattegat. Herring larvae of the Buchan stock drift south into nursery grounds in the Firth of Forth and east to Skagerrak and Kattegat nursery grounds. Heath *et al* (1989) found that herring larvae from a spawning site at Clythness in the Moray Firth drifted from the spawning grounds at a rate of 1-2 km/day.

4.3.1 Spawning Grounds and Larval Distribution

Herring spawning grounds as presented in Ellis *et al* (2010a), including larval densities recorded in the 2008 International Herring Larval Survey (IHLS), and the grounds as defined in Coull *et al* (1998) are given in Figure 4.3.

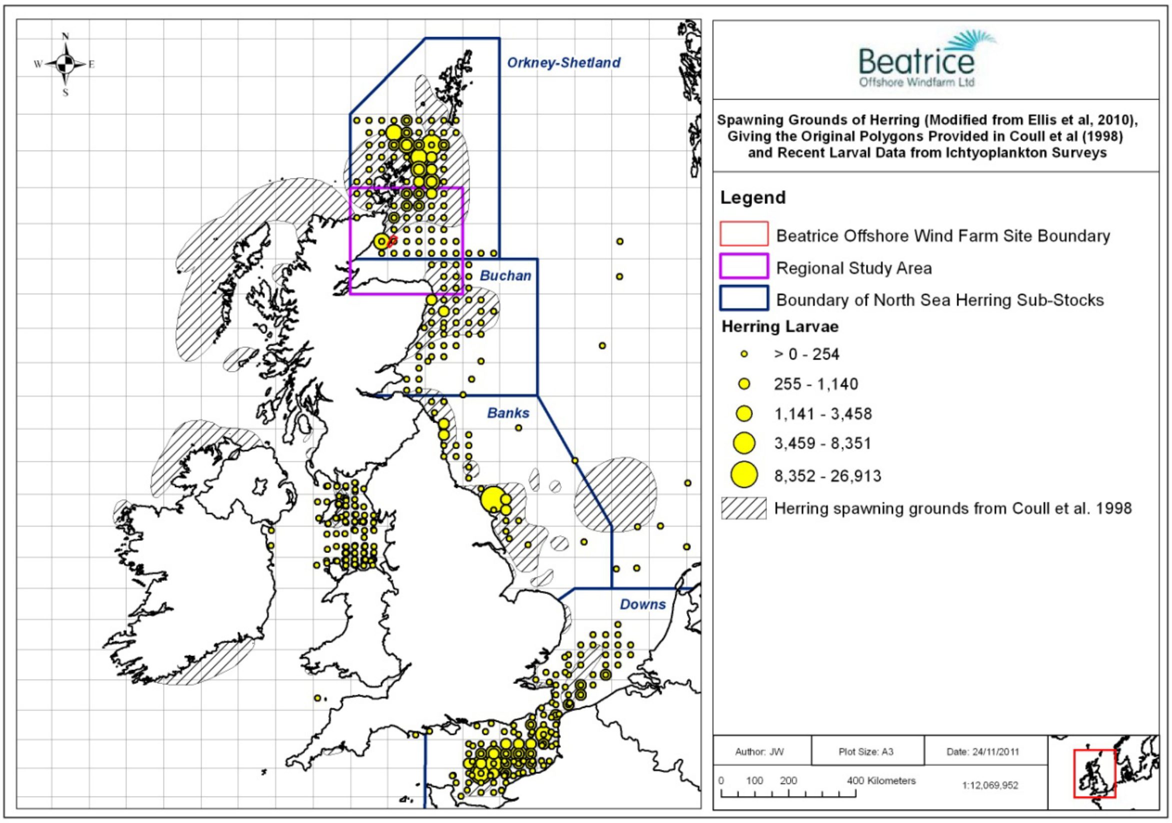

Figure 4.3 Herring spawning grounds (Modified from Ellis et al 2010a)

Herring spawning grounds as defined by Coull *et al* (1998) are located at approx. 1.4 km from the Beatrice site. Alternative publications however suggest that the development site falls within defined herring spawning grounds (e.g. Payne 2010). In addition, the development site falls within high intensity nursery grounds as defined by Ellis *et al* (2010a) (Section 8.3). It should be noted that given the substrate requirements of spawning herring it is very unlikely that the whole area defined in Coull *et al* (1998) will be used for spawning.

The definition of herring spawning grounds is principally based on the results of the International Herring Larval Survey (IHLS) which has been undertaken since 1972. A time series of the larval densities of the Orkney-Shetland stock based on data from the IHLS (MSS 2011a) is provided Figure 4.4 and Figure 4.5. These show newly hatched larvae (< 10 mm) densities from 1973-1994 (1-15 September) and from 1973 to 2004 (16-30 September), respectively. The distribution of larval densities in recent years (2005, 2006, 2008, 2009) is illustrated in Figure 4.6, as provided in Rohlf & Gröger (2006, 2009, 2010) and Schmidt *et al* (2007, 2008).

Spawning intensity in areas relevant to the site and in the wider area varies considerably depending on the year under consideration. From the time series provided below it appears that spawning activity in the vicinity of the Beatrice Offshore Wind Farm tends to be concentrated in coastal areas off Caithness. Spawning activity in this area is however comparatively lower than that recorded between the Orkney and Shetlands, where the bulk of spawning appears to take place in most years.

It should be noted that not all stations are sampled each year during the IHLS survey and therefore the lack of larvae in some locations for a particular year does not necessarily imply that spawning did not occur.

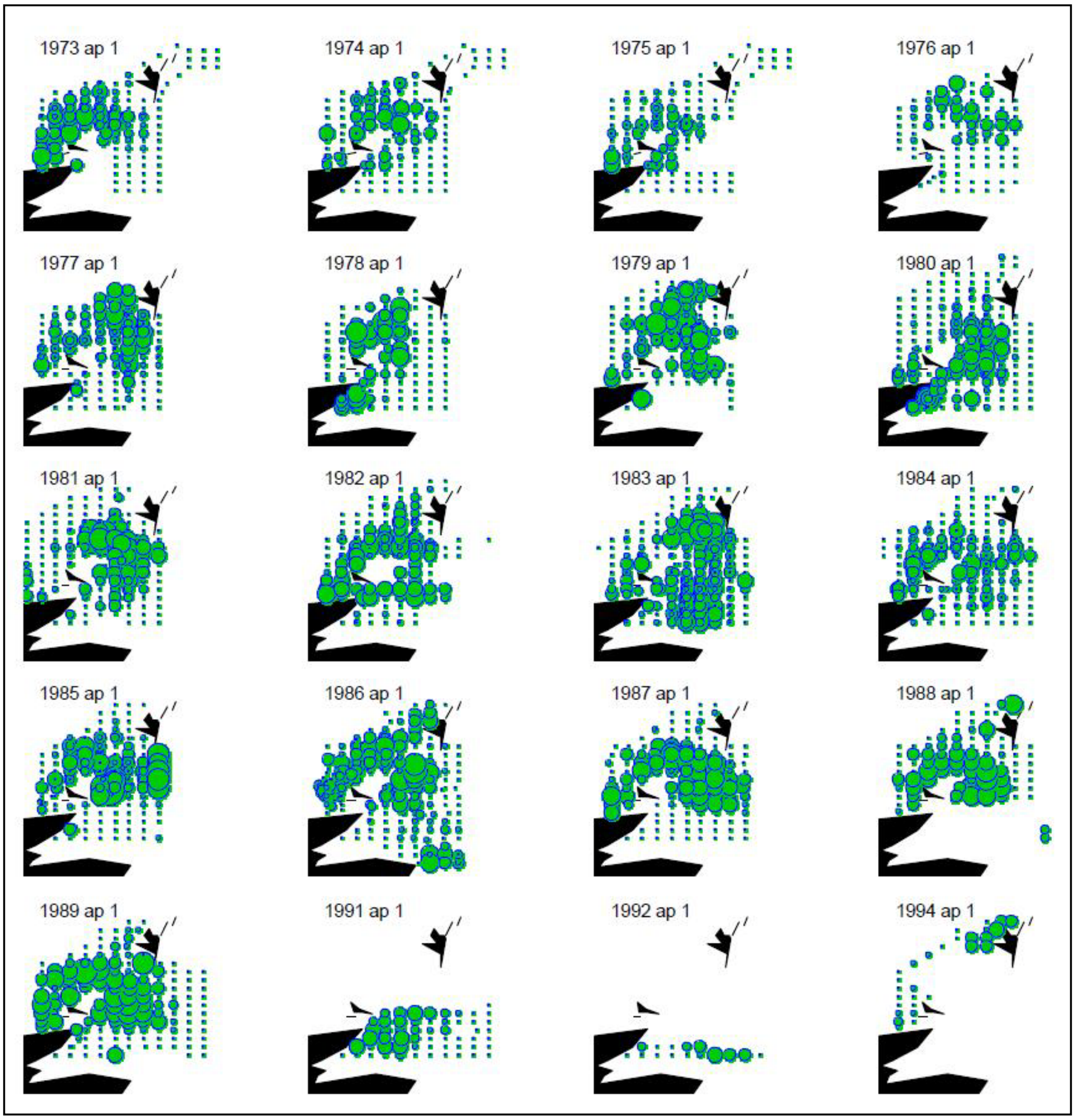

Figure 4.4 International herring larval surveys charts (1973-1994) of the Orkney/Shetland stock for the period 1 (1-15 September) (Source: MSS 2011a)

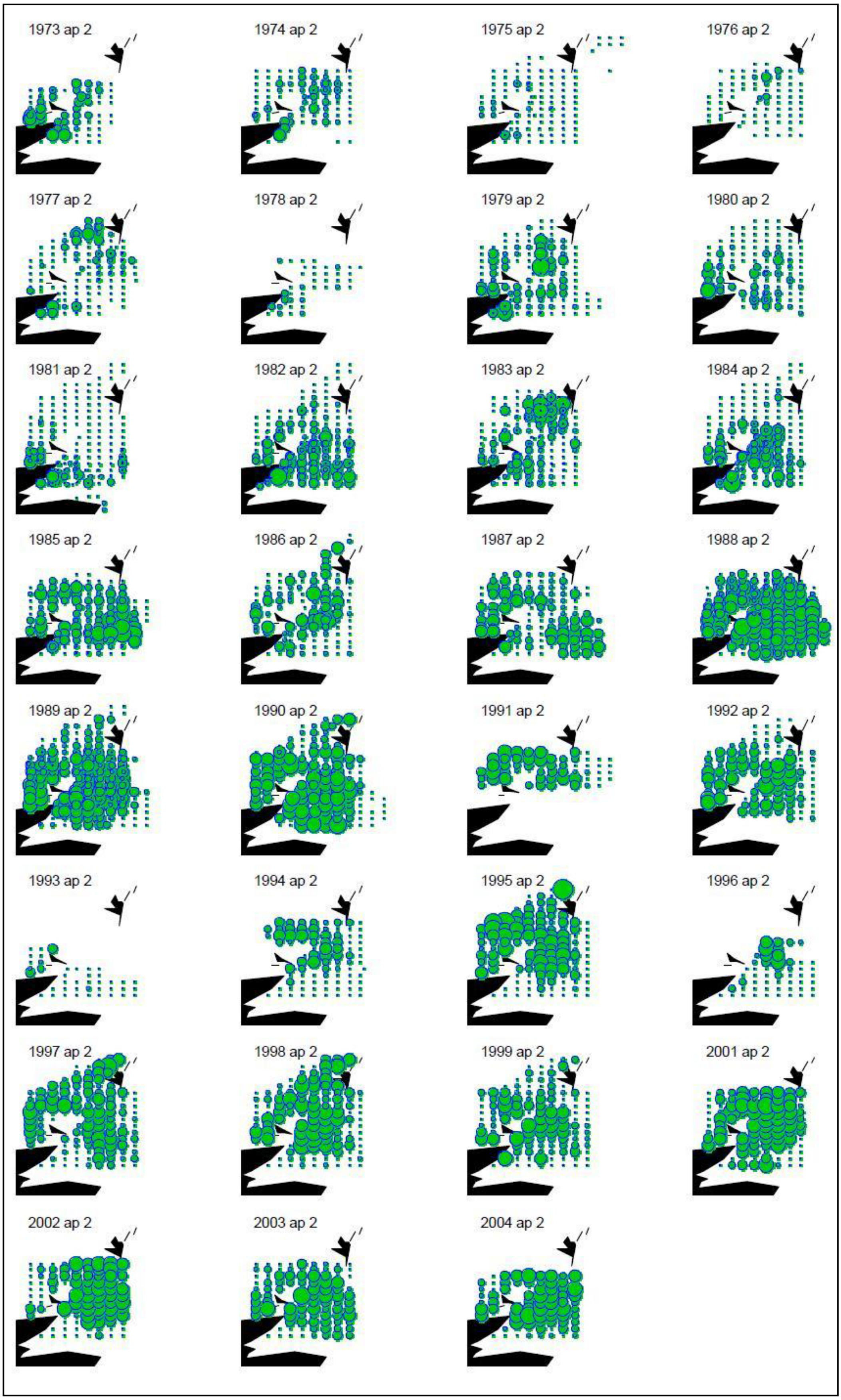

Figure 4.5 International herring larval surveys charts (1973-2004) of the Orkney/Shetland stock for the period 2 (16-30 September) (Source: MSS 2011a)

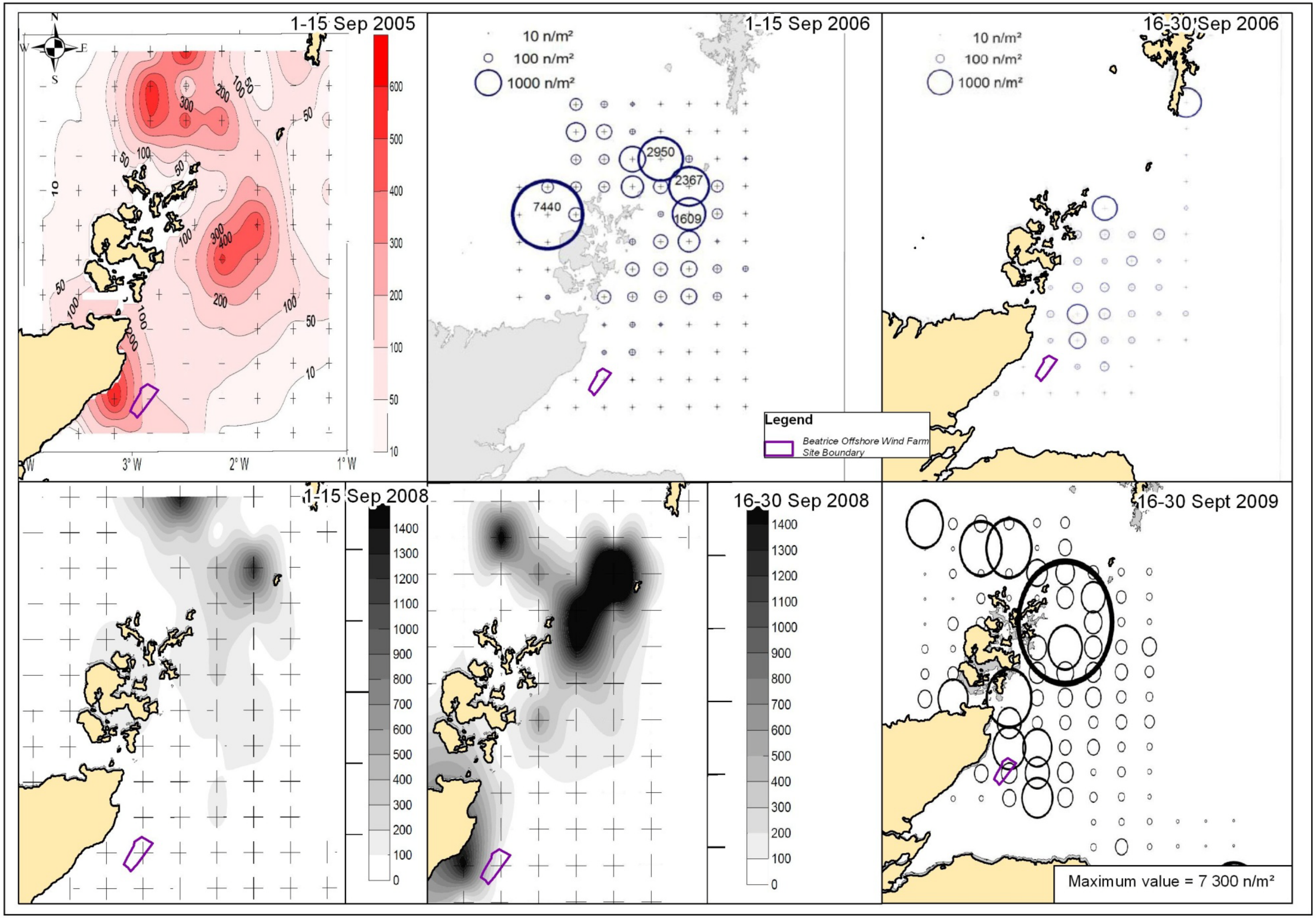

Figure 4.6 International herring larval surveys charts (2005, 2006, 2008, 2009) of the Orkney/Shetland stock (Rohlf & Gröger 2006, 2009, 2010; Schmidt *et al* 2007, 2008)

4.3.2 Spawning Substrate Suitability

An indication of the suitability of the Beatrice Offshore wind farm site as a spawning ground for herring, based on the distribution of sediment classes from grab samples (CMACS, 2010), is given in Figure 4.7 below.

As previously mentioned herring show a high preference for coarse grounds when selecting spawning grounds. Areas characterized by a high proportion of coarse sands and gravels are therefore more likely to constitute a suitable herring spawning ground than those with a high proportion of silts and fine sands. Areas of preferred sediment for herring spawning are mainly located in the southern and the middle-eastern sections of the site.

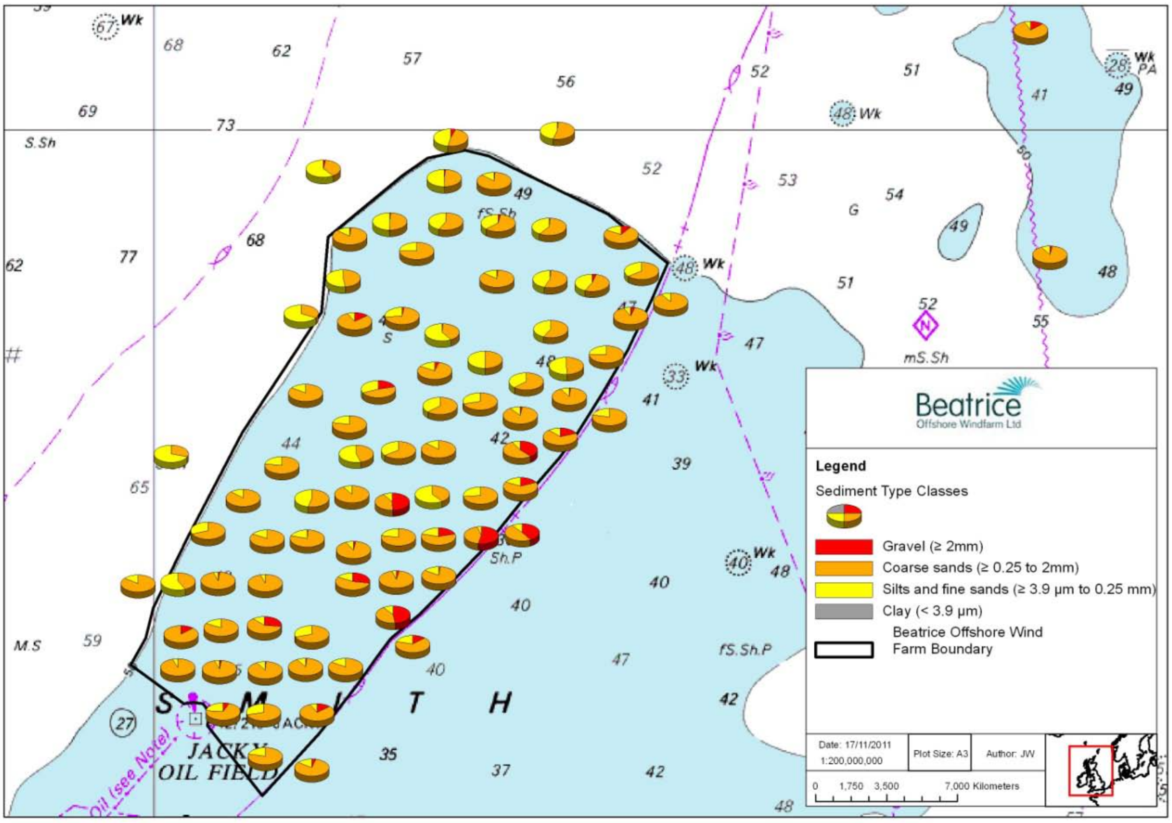

Figure 4.7 Sediment type distribution within the Beatrice Offshore Wind Farm derived from grab samples (CMACS, 2010)

4.4 Cod

The cod population of the Moray Firth has been found to be genetically distinct from other North Sea populations (Hutchinson *et al*, 2001). Cod spawn between January and April, with peak spawning taking place from February to March mainly in the evening and during the night (ICES 2005a, Coull *et al* 1998). Eggs are pelagic and hatch over a period of two to three weeks, depending on water temperature (Wright *et al* 2003). Male cod are known to produce a drumming sound during the spawning season (Nordeide & Kjellsby 1999, Fudge and Rose 2009) and it has been suggested that the sounds are used to defend territories and attract females during spawning (Brawn 1961).

The Beatrice site falls within a cod spawning area as defined in Coull *et al* (1998). Spawning grounds are shown in Figure 4.8 together with larvae and eggs densities recorded in recent surveys (Ellis *et al* 2010a). In addition, the Moray Firth has been defined as a high intensity nursery ground for cod (Section 8.4).

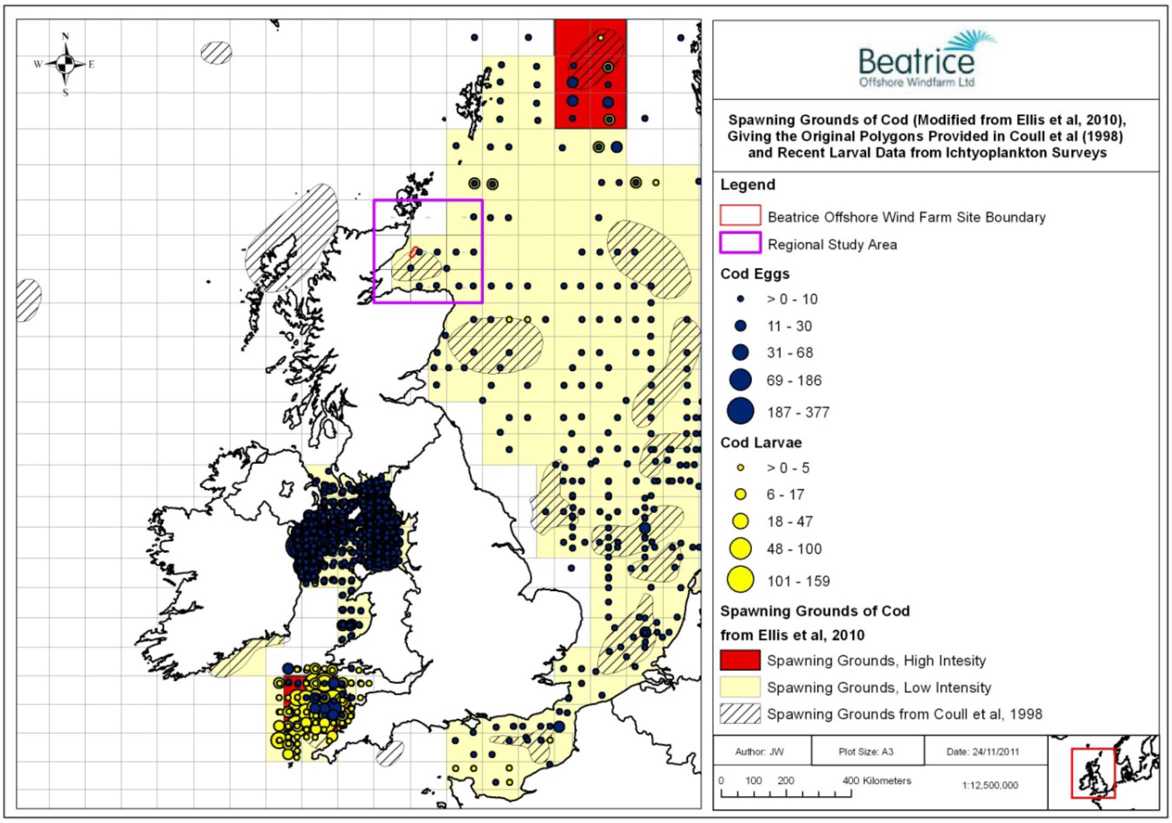

Figure 4.8 Spawning grounds of cod (Modified from Ellis et al 2010a)

In the North Sea Egg survey (2004) significant numbers of eggs were found off the Moray Firth and to the east of the Shetland Islands (Fox *et al* 2008). It has been suggested that passive transport of early life history stages could lead to a substantial advection of cod eggs and larvae from Shetland south to the Scottish east coast (Heath & Gallego 1997). Little cod spawning activity was observed in a spawning area survey carried out in March 2008 by the Fisheries Research Services (FRS) in the Moray Firth, during which relatively low numbers of running females were caught (Gibb *et al* 2008).

In 2002 the University of Aberdeen consulted 25 fishermen on the location and timing of cod spawning. Fishermen reported that significant aggregations of spawning fish were found to the east of Shetland. In addition, they identified the north east coast of Scotland between Fraserburgh and Banff (located within ICES rectangle 44E7) as a traditional cod spawning area, but one which is no longer used by the species. They commented that the stock in this area had been fished out in the early 1990s by seine netters and had not recovered since (Gibb *et al* 2008).

Gibb *et al* (2007) mapped the density distribution of 0-group cod in the North Sea and west coast of Scotland, in 2001 and 2002 to 2004. The combined survey data shows that, whilst 0-group cod occur over much of the studied region, the majority are confined to a few small coastal areas and overall densities are scarce, with median densities around 10 cod km^{-2}. Substantially elevated densities of more than 100 cod km^{-2} were only found within the Moray Firth, the Clyde and isolated sites off Mull in the Minch, west of Scotland, Shetland and St Andrews Bay, east of Scotland. In general terms sheltered areas (especially around Shetland) were found to have high juvenile abundance in comparison to exposed coastlines.

4.5 Plaice

The Beatrice site partly overlaps plaice spawning grounds in the south as defined by Coull *et al* (1998). The development site and its surroundings have been identified by Ellis *et al* (2010a) as a low intensity spawning and nursery ground (Figure 4.9, Section 8.5).

The distribution of spawning grounds is shown in Figure 4.9 together with larvae and egg densities including those recorded during the 2004 North Sea Egg survey, as provided in Ellis *et al* (2010a).

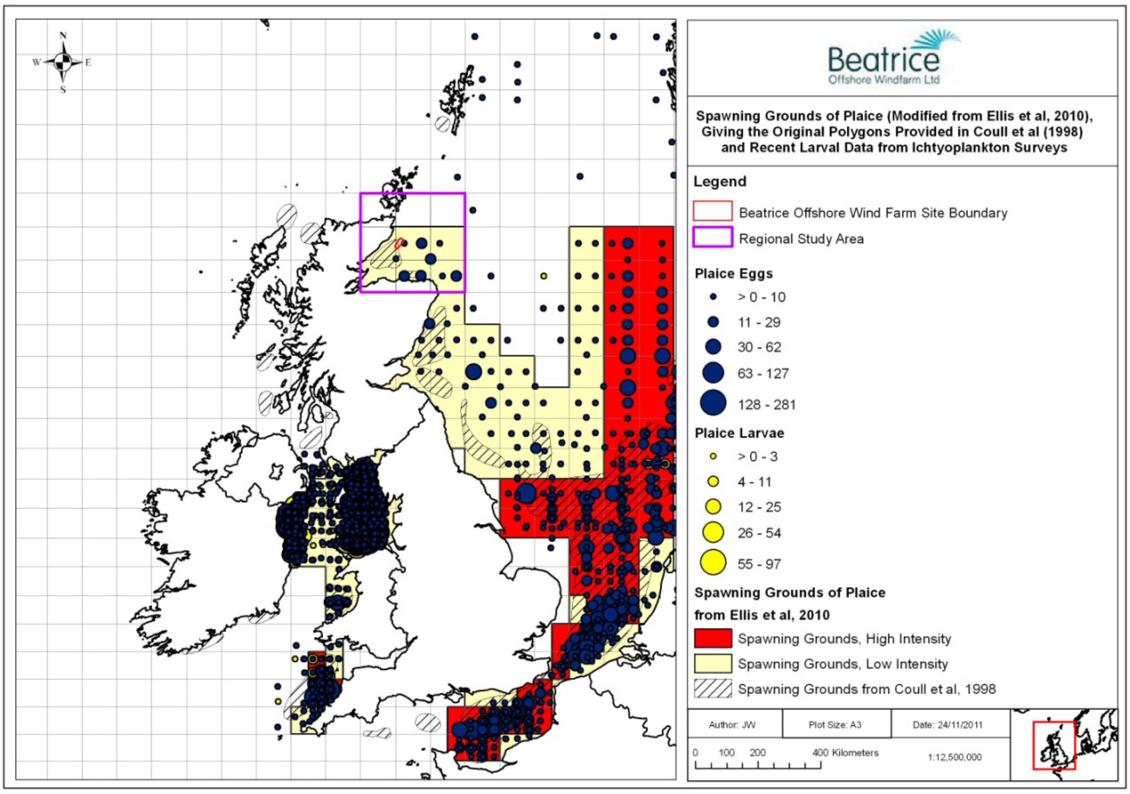

Figure 4.9 Plaice spawning grounds (Modified from Ellis et al 2010a)

Spawning takes place between December and March with peak spawning occurring in February/March (Rijnsdorp 1989, Simpson 1959, Harding *et al* 1978). During spawning pelagic eggs are released in batches (Rijnsdorp 1989, Armstrong *et al* 2001, Murua & Saborido-Rey 2003). Plaice rarely spawn beyond the 50 m depth contour (Harding *et al* 1978). Females spawn over a period of four to six weeks (Rijnsdorp 1989) and pelagic larvae hatch between seven to 21 days depending on temperature (Fox *et al* 2003).

The results of the North Sea Egg survey (2004) showed that plaice eggs north of the Dogger Bank were scarce except for isolated patches off Flamborough Head, off the Firth of Forth, the Moray Firth and to the east of the Shetland Isles (ICES 2005b). Concerns have however been raised, that the timing of the more northerly cruises may have been a little late to capture the peak of plaice egg production (ICES 2005b). Assuming spawning is relatively continuous, the centres of density of stage I eggs should be close to the sites of spawning although up to three days drift and dispersion may have occurred (ICES 2005b).

4.6 Lemon sole

The site lies within lemon sole (*Microstomus kitt*) spawning grounds defined by Coull *et al* (1998) (Figure 4.10.). As it can be seen in the figure, the spawning grounds cover large areas. Lemon sole are thought to spawn everywhere they are found (Rogers & Stocks 2001). Spawning occurs from April until September (Coull *et al* 1998). In addition to spawning grounds, nursery grounds have also been identified by Coull *et al* (1998) in the area of the wind farm (Section 8.6).

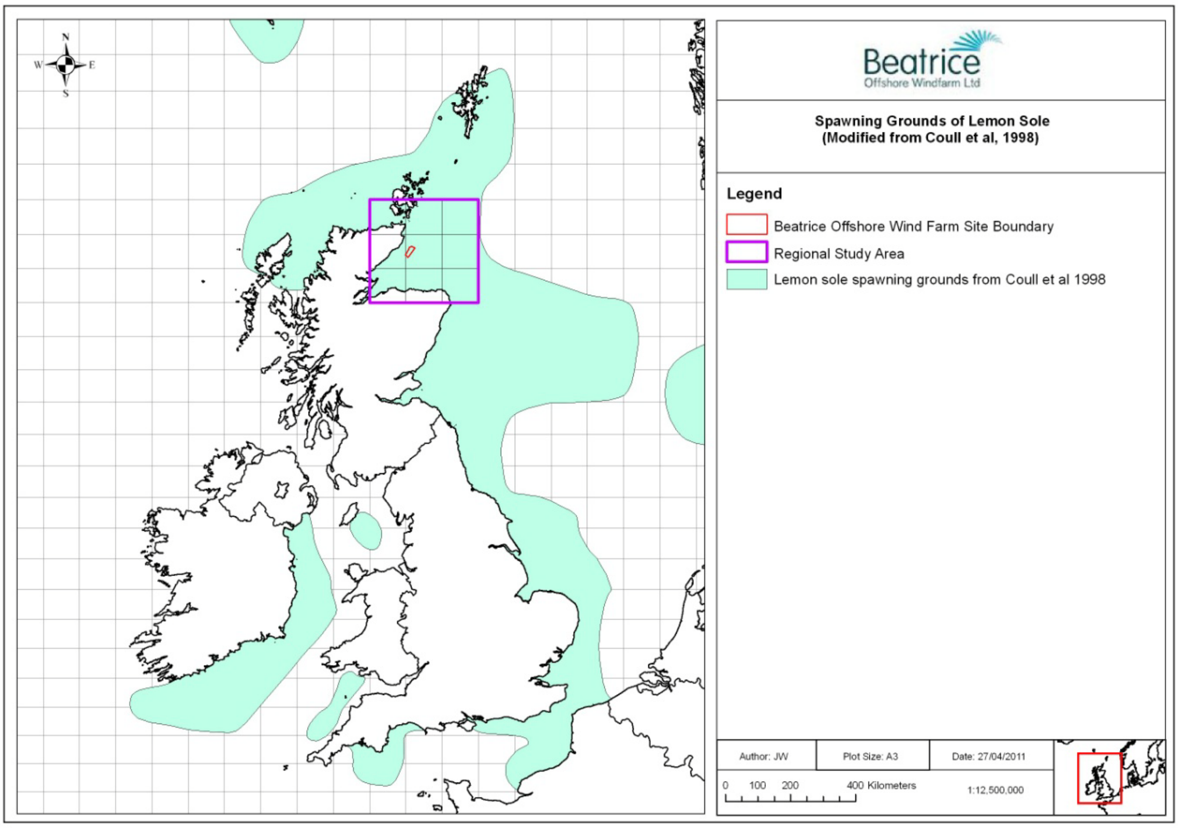

Figure 4.10 Lemon sole spawning grounds (Modified from Coull et al 1998)

4.7 Sprat

The Beatrice site falls within sprat spawning and nursery grounds defined by Coull *et al* (1998) (see Figure 4.11 and Section 8.7). As it can be seen sprat spawning grounds are widely distributed around the British Isles.

Spawning takes place from May to August (Coull *et al* 1998), with peak spawning observed from May to early July (Kraus & Köster 2001). Spawning occurs in both coastal and offshore waters, up to 100 km from the shore, in deep basins (Whitehead 1986, FAO, 2011, Nissling *et al* 2003).

Females spawn repeatedly in batches throughout the spawning season (Milligan 1986). Eggs and larvae of sprat are pelagic and so subject to larval drift, moving into coastal nursery areas, depending on the wind-driven currents (Hinrichsen *et al* 2005, Nissling *et al* 2003). Feeding larvae are mainly found in the upper part of the water column (Nissling *et al* 2003).

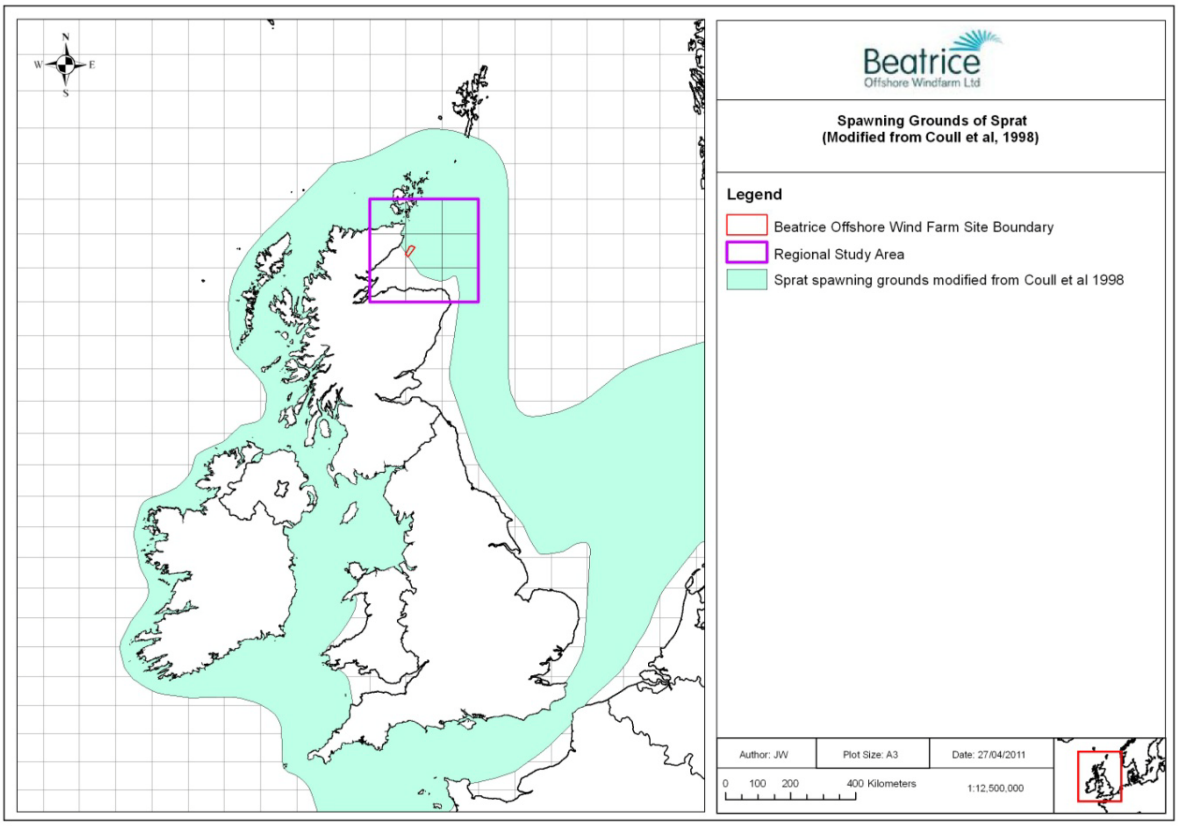

Figure 4.11 Sprat spawning grounds (Modified from Coull et al 1998)

4.8 Haddock

The site does not overlap with haddock spawning grounds as defined by Coull *et al* (1998), however, a recent publication of Marine Scotland Science (MSS) (Keltz & Bailey 2010) shows that spawning grounds are located in close proximity to the development (Figure 4.12 and Figure 4.13).

Results of international ichtyoplankton surveys carried out in 2004 found high concentrations of haddock stage I eggs in and off the Moray Firth (ICES 2005b). Similarly, significant spawning concentrations were noted historically to be located east of the Moray Firth (Gibb *et al* 2004).

Surveys conducted by the Fisheries Research Services (FRS) in 1999 found haddock spawning in both coastal and offshore areas (Gibb *et al* 2004). The highest densities of mature and spawning haddock were found in depths of around 100 m and most fish were associated with areas of mud or sand with few being caught in areas of harder substrate (Gibb *et al* 2004).

Spawning takes place between February and May (Coull *et al* 1998), at depths of 50 to 150 m (FAO 2011, Fillina *et al* 2009), with peak spawning occurring in March and April (Coull *et al* 1998, Fillina *et al* 2009). Haddock are serial spawners, releasing their eggs in batches over the spawning season (Gibb *et al* 2004, Fillina *et al* 2009). The eggs are laid at the bottom and after fertilisation rise into the water column where subsequent larval development occurs (Page & Frank 1989).

Haddock are capable of producing a wide range of sounds (Wahlberg & Westerberg 2005). Sounds produced by males during the spawning season are thought to serve to bring male and female fish together. In addition, it has been suggested that the sounds play a role in synchronising the reproductive behaviour of males and females (Hawkins & Amorim 2000).

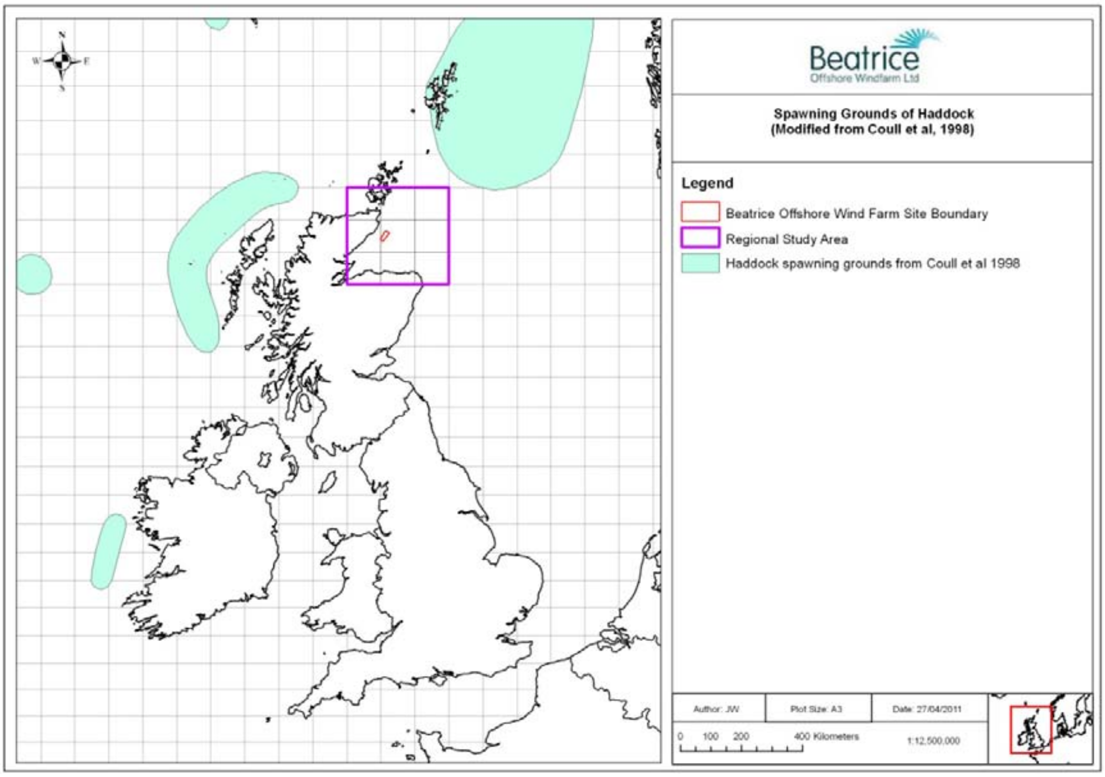

Figure 4.12 Haddock spawning grounds (Modified from Coull *et al* 1998)

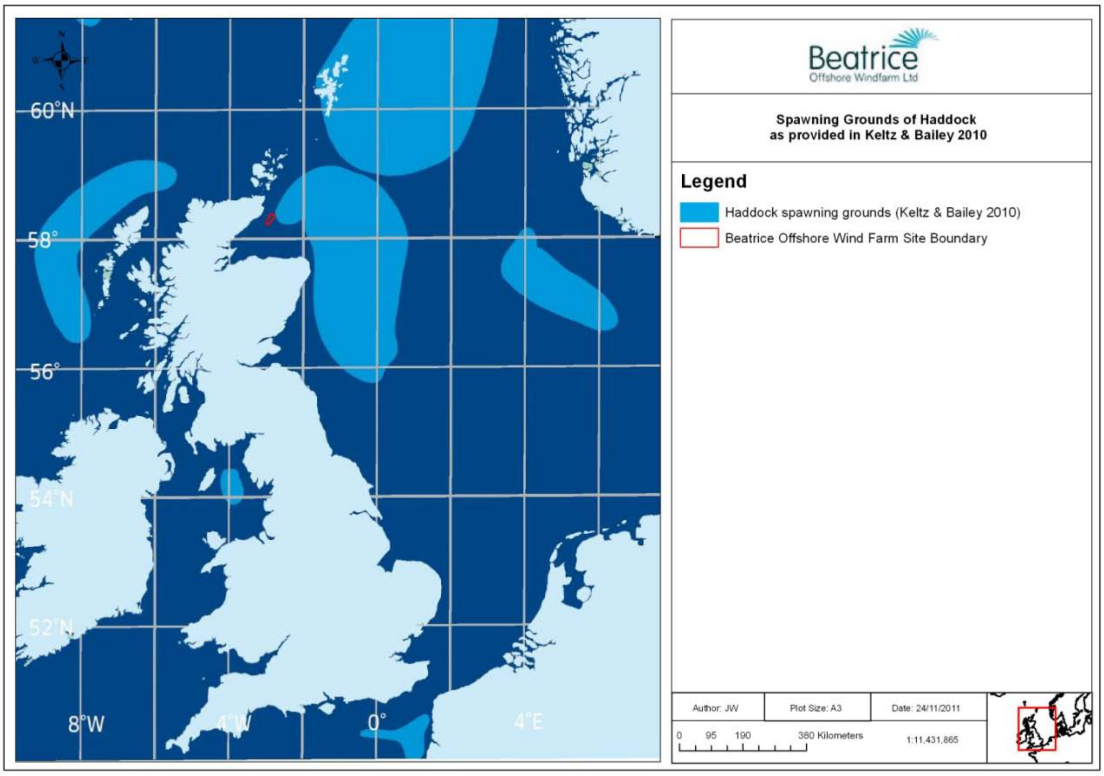

Figure 4.13 Haddock spawning grounds (Modified from Keltz & Bailey 2010)

4.9 Whiting

The Beatrice Offshore Wind Farm is located in the vicinity of spawning grounds defined by Coull *et al* (1998). Ellis *et al* (2010a) defined the area of the regional study area as low intensity spawning ground and high intensity nursery ground (Section 8.8). Coull *et al* (1998) and Ellis *et al* (2010a) spawning grounds are illustrated in Figure 4.14.

Spawning occurs between February and June. Females release their eggs in numerous batches over a period that may last up to fourteen weeks (Teal *et al* 2009). Eggs are pelagic and take about ten days to hatch (Russel 1976).

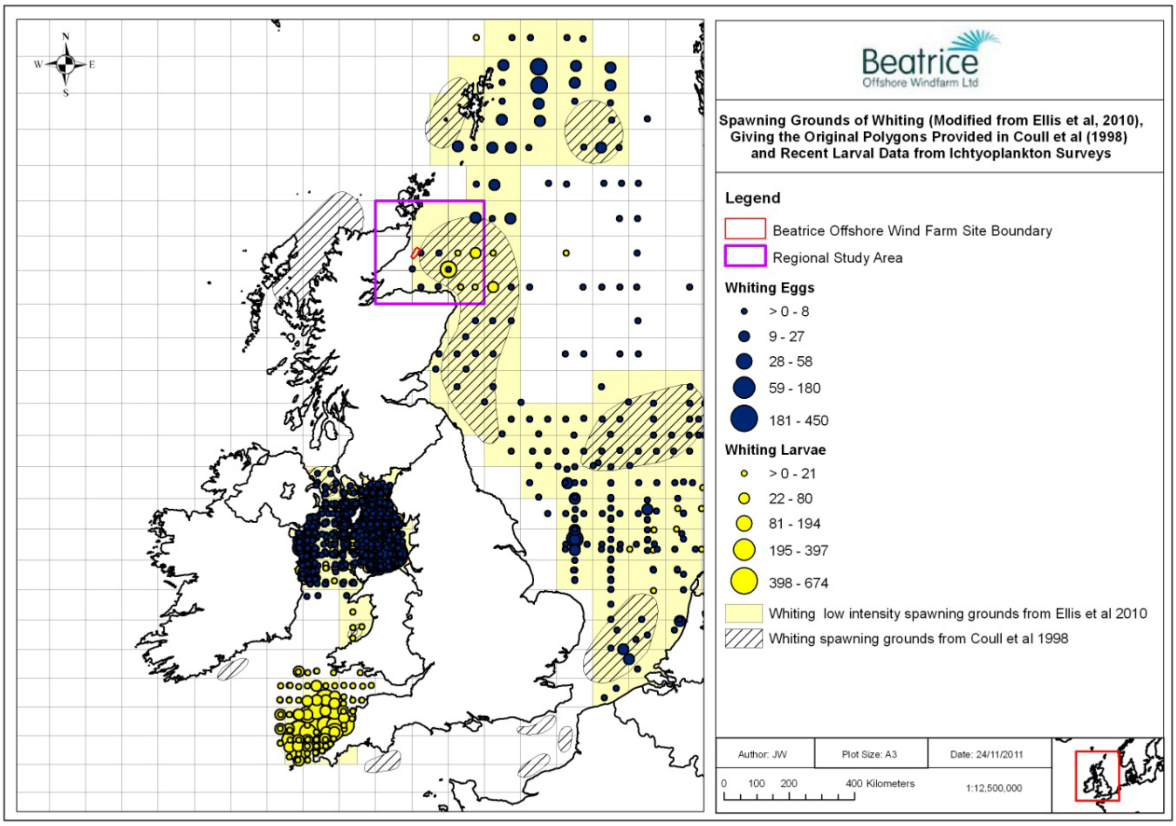

Figure 4.14 Whiting spawning grounds (Modified from Ellis et al 2010a)

5.0 Key Species in the Food-web

Herring, sprat and sandeel, among other species, play a key role in the North Sea's food-web, being situated in a mid-trophic position. They are major predators of zooplankton and the principal prey of many top predators such as birds, marine mammals and piscivorous fish. Prey preference is subject to seasonal variation as a result of changes in prey availability throughout the year. In addition, different prey age classes/size classes are preferred by different predators.

5.1 Sandeels

Three species of sandeels have been recorded in the Beatrice offshore wind farm site CMACS, 2010). These are *Ammodytes tobianus, Ammodytus marinus and Hyperoplus lanceolatus. A. tobianus* was present in the epibenthic trawls of five stations located in the middle of the Beatrice development site, in depths of 30 to 50 m and within areas characterized of sandy gravels and till outcrops/coarser ground. *H. lanceolatus* was recorded in the grabs of eight stations located in the eastern middle area and southern area of the development site in water depths of 30 to 45 m (CMACS, 2010).

A. marinus is relatively short lived (eight years), and spends most of the year buried in the seabed (Van der Kooij *et al* 2008). They prefer depths of 30 to 70 m, although they also occur between depths of 15 and 120 m (Wright *et al* 1998). They only emerge into the water column briefly in winter for spawning, from November until February, and for an extended feeding period in spring and summer (Van der Kooij *et al* 2008).

During the feeding period, occurring in spring and summer months, sandeel display a diurnal behavioural pattern: they emerge during the day to form large shoals feeding on a variety of zooplankton prey and bury themselves in the seabed at night (Van der Kooij *et al* 2008, Winslade 1974a, Kühlmann & Karst 1967, Arnott & Ruxton 2002). It is thought that the fish enter an overwintering stage between September and March, where they remain buried in the sand until the following spring (Wright & Bailey 1993, Winslade 1974b).

5.1.1 Sandeel sediment preference

Sandeels distribution is highly patchy and varies in relation to sediment type (Wright 1999a). Sandeels do not maintain permanent burrow openings and have to ventilate their gills with interstitial water. The presence of fine particles of silt rich sediments clogs gills and inhibits respiration. In addition, if the interstitial spaces between sand and gravel particles were occupied by silt particles the rate of exchange of interstitial water would be lower and oxygen supply inadequate (Holland *et al* 2005). Owing to their dependence on suitable sediment types, the distribution of post settled sandeels (late 0-group and older age classes) is therefore restricted and constant through time (Wright & Begg 1997).

Sandeels tend to occupy areas on the sloping edges of sandbanks (Greenstreet *et al* 2010). Holland *et al* (2005) analysed 2885 grab-samples to determine sandeel (*A. marinus*) sediment preference in terms of its particle size composition and defined eight particle size classes (see Table 2 in Holland *et al*, 2005). The results show that lesser sandeel require a very specific substratum, favouring seabed habitats containing a high proportion of medium and coarse sand (particle size ≥ 0.25 to < 2 mm) and low silt content (Holland *et al* 2005). Sandeels are rare in sediments where the silt content (particle size < 0.63 µm) is greater than around 4 % and absent where the silt content is greater than 10 % (Holland *et al* 2005, Wright *et al* 2000). Holland *et al* (2005) defined sediment characteristics for suitable and unsuitable habitats for sandeels. A habitat was defined as unsuitable for sandeels if all of the four sediment characteristics described below are present:

- >1% Medium Silt AND
- ≤55% Medium Sand AND
- >2% Coarse Silt AND
- ≤15% Coarse Sand

Suitable habitat was only broadly defined requiring one or more of the characteristics below:

- ≤1% Medium Silt OR
- >55% Medium Sand OR
- ≤2% Coarse Silt OR
- >15% Coarse Sand

5.1.1.1 Site Specific Benthic Surveys (CMACS, 2010)

Two species of sandeels were recorded in the beam trawls: *Hyperoplus lanceolatus* (nine stations) and to a lesser extent *Ammodytes tobianus* (five stations)*. H. Lanceolatus* was the sole sandeel species to be recorded in grab samples (14 stations)*.*

The distribution of trawl stations, in which sandeels were recorded, together with the total abundance of sandeels in each trawl, is illustrated in Figure 5.1.

Both species were not found in the northern area of the development. *A. tobianus* was mostly recorded in trawls undertaken in the middle of the development area, whilst *H. lanceolatus* was found more frequently in the southern and middle area of the development.

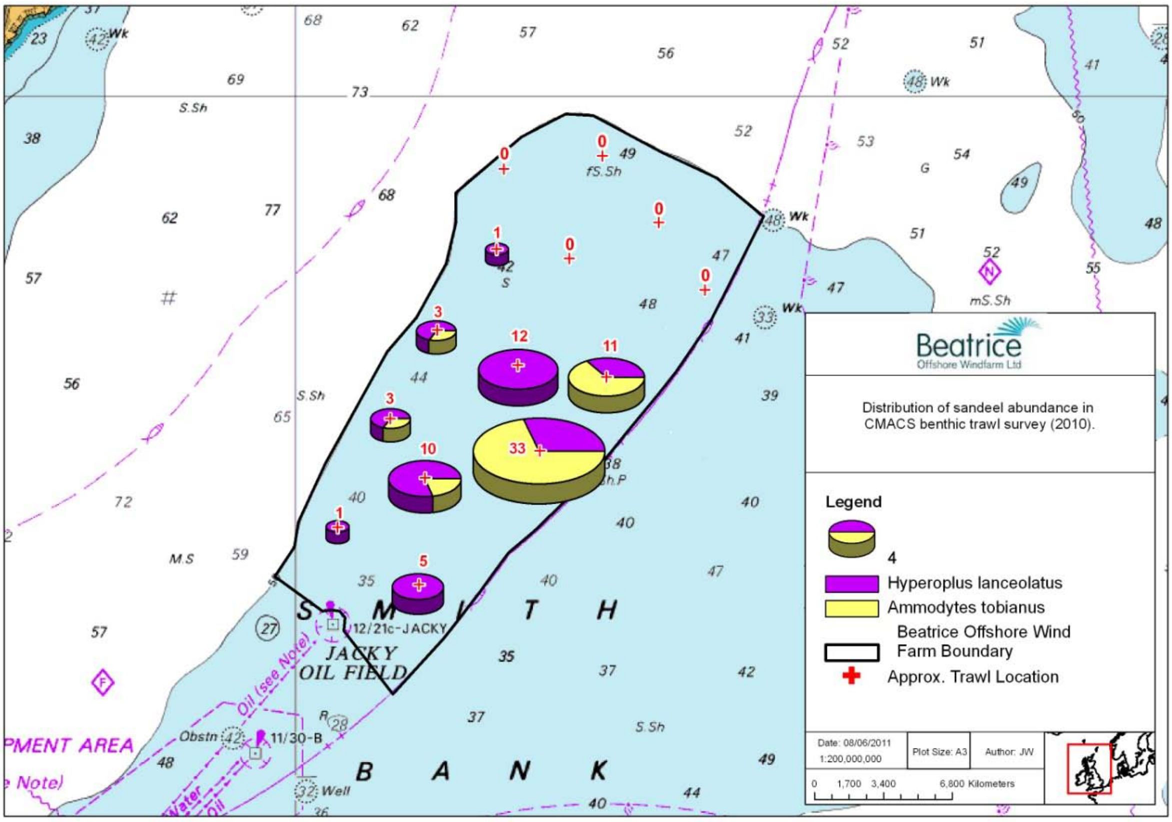

Figure 5.1 Distribution and abundance of sandeels in CMACS benthic trawls (2010)

Sandeels are thought to show increased preference for the habitat as the percentage of coarse and medium sands (particle size ≥ 0.25 to < 2 mm) increases (Holland *et al* 2005). In addition, research undertaken by Holland *et al* (2005) suggests they are rare in sediments where the silt content is greater than around 4 %.

An indication of the suitability of the wind farm site as a sandeel habitat based on the distribution of sediment classes from grab samples (CMACS, 2010) is given in Figure 5.2. In order to interpret the results of the analysis of the grab samples, two sediment categories were defined: coarse sands (particle size ≥ 0.25 to < 2 mm) and silts and fine sands (less than 0.25 mm) (Greenstreet *et al* 2010). Stations in which the proportion of "coarse sands" is high (larger pies Figure 5.2) are therefore more likely to constitute a suitable habitat for sandeels than those characterised by a high proportion of "silts and fine sands".

On the basis of the results of the PSA of grab samples it appears that the majority of the Beatrice Offshore Wind Farm site may potentially be suitable as a sandeel habitat. Silt contents higher than four percent, at which sandeels are considered to be rare, were not found at any of the stations sampled.

Given the relatively small sampling effort (e.g. distance between grab samples) and the general patchiness of sandeel distribution, sediment types, and therefore habitat suitability, should not be assumed continuous between stations.

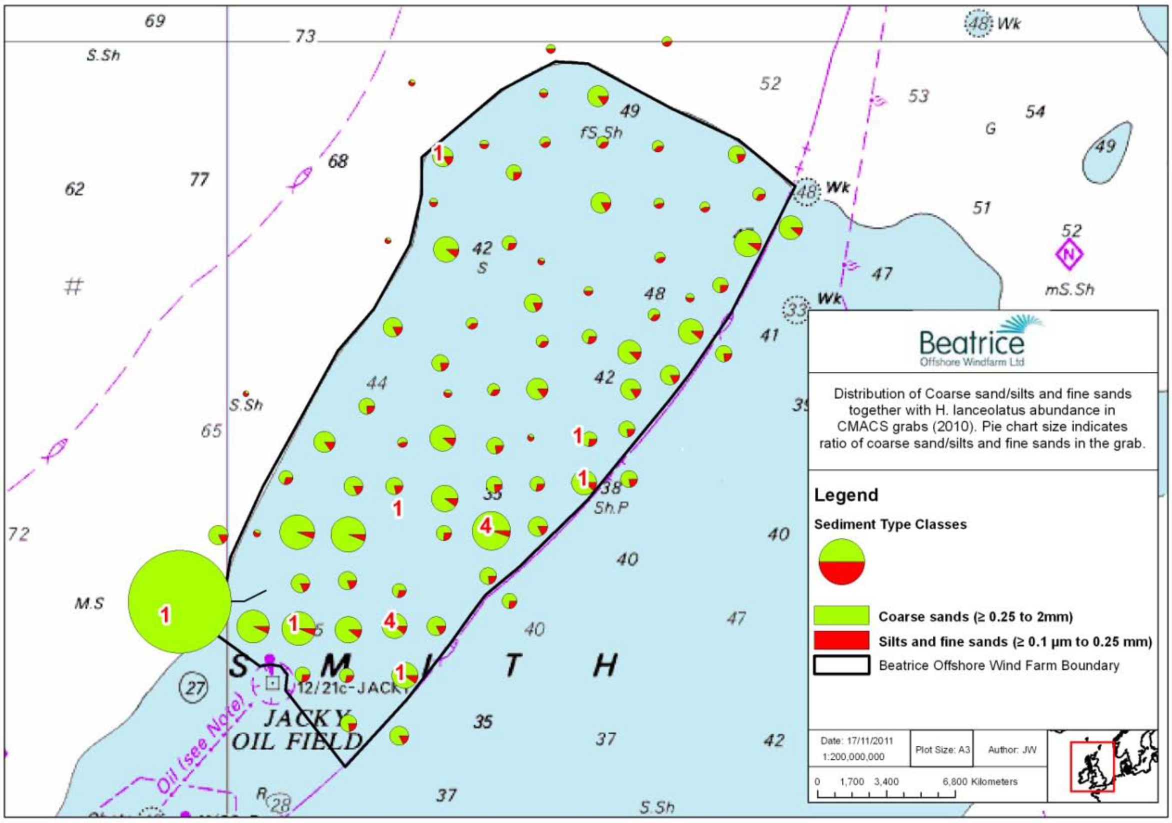

Figure 5.2 Distribution of CMACS grab stations together with coarse sands/ fine sands and silts proportion. Recordings of *H. lanceolatus* in the grabs are highlighted in red

The interpretation of the figures above should take account of the limitations of the data used. The number of sandeels caught in beam trawl samples and in grab samples are indicative of presence by species and are not to be used from a quantitative point of view, as sampling methods (e.g. beam trawl) and survey design (e.g. locations, sampling time, etc) were not selected taking account of the life cycle and catchability of sandeels.

5.1.2 Sandeel Predators

Sandeels are preyed upon in the sediment by a number of predators. They are however more commonly preyed upon when they are in transit to, or feeding in the water column (Van der Kooij *et al* 2008, Furness 2002, Hobson 1986), when they are more readily available. It is also during this period that they are targeted by pelagic trawls from the industrial fishery (Van der Kooij *et al* 2008).

Sandeels are a key component of the diet of many birds, such as kittiwakes, razorbills, puffins, common tern, arctic tern, European shag, great skuas and common guillemots, which are all known to rely on sandeel consumption during the breeding season (Wright & Bailey 1993, Furness 1999, ICES 2006b, Wanless *et al* 1998, Wanless *et al* 1999, Wanless 2005). In the Moray Firth, *Ammodytus marinus* is thought to support a large diversity and abundance of seabirds (Wrighjt & Begg 1997).
Sandeels also constitute an important prey species for a number of piscean predators such as herring, salmon, sea trout, cod, haddock, whiting, grey gurnard, saithe, mackerel, horse mackerel and starry ray as well as for squid (Wright & Kennedy 1999, ICES 2006, ICES 2005c, ICES 2008a, ICES 2010b, Walters 2010, ICES 2009b, Mills *et al* 2003, MSS 2010a, Walters 2011, Collins & Pierce 1996). Salmon post smolts are known to largely feed on small fish such as 0-group sandeels (Haugland *et al* 2006). Marine mammals such as common seals (ICES 2006, Thompson *et al* 2003), grey seals (McConnell *et al* 1999), harbour porpoises (Santos *et al* 2005, ICES 2005) and minke whales (Olsen & Holst 2001, Pierce *et al* 2004) also feed on sandeels.

Different sandeel age/size classes are preferred by different predators at different times of the year (ICES 2005). Studies conducted by Greenstreet *et al* (1998) in the Inner Moray Firth showed that sandeels were almost the only fish prey taken by whiting and haddock of all size classes in June, whilst from October to January (when relative sandeel abundances declined) the proportion of this species in the diet of both fish species was gradually replaced by sprat.

5.2 Herring

Herring is fed on by a number of fish species such as salmon, sea trout, whiting, cod, saithe, mackerel, horse mackerel and starry ray (ICES, 2008c, ICES, 2005c, ICES 2005b, Mills et al 2003, Walters 2011). Different age classes are preferred by different predators, with preference subject to seasonal changes. In the North Sea for instance, predation mortality of one year old herring is mainly due to predation by cod, whiting, saithe and sea birds, whilst herring that is younger than one year, 0-group herring, is largely preyed upon by horse mackerel (ICES, 2008c).

0-group herring is also a preferred prey species for salmon post-smolts in the Norwegian Sea and in the North East Atlantic. Herring's egg mats attract a number of predators such as spurdog, haddock, mackerel, lemon sole, and other herring (Haugland *et al* 2006, Mills *et al* 2003, de Groot 1980, Skaret *et al* 2002).

Marine mammals such as harbour porpoises and bottlenose dolphins, grey seals and common seals also feed on herring in the Inner Moray Firth (Santos *et al* 2005, ICES 2005, Thompson *et al* 1991).

5.3 Sprat

Sprat is fed upon by a number of fish species such as cod, grey gurnards, haddock, herring, sandeels, spurdog, horse mackerel, mackerel, saithe, salmon, sea trout and whiting (ICES 2005c, ICES 2009b, Mills *et al* 2003, MSS, 2010a). Horse mackerel, for instance, largely feeds on 0-group sprat and is responsible for approximately 69% of juvenile sprat predation mortality in the North Sea (ICES

2005c). Sprat older than one year is to a large extent preyed upon by cod and whiting, these two species are responsible for 12.7% and 81.5% respectively of this age group's predation mortality.

Studies carried out in the Inner Moray Firth by Greenstreet *et al* (1998) identified whiting and haddock as the main piscean predators. The species of fish prey taken varied considerably at different times of the year. Sprats were the preferred prey species for smaller whiting and haddock from October until January.

Sprat also represents a food source for marine mammals, such as harbour porpoises and common seals, and for squid (*L. forbesi*) (Thompson *et al* 1991, ICES 2005c, Collins & Pierce 1996).

6.0 Species of Conservation Importance

6.1 Diadromous Migratory Species

A number of diadromous[1] species could potentially use areas in the vicinity of the Beatrice site during certain times of their life cycle. These are listed in Table 6.1, together with their conservation status.

Table 6.1 Diadromous species of conservation importance in the Moray Firth

Common Name	Scientific Name	Conservation Status								
		OSPAR	IUCN Red List	Bern Convention	Habitats Directive	The Wildlife & Countryside Act 1981	The Conservation (Natural Habitats, &c.) Regulations 1994	UK BAP species	Scottish Priority Marine Feature (PMF)	The Nature Conservation (Scotland) Act 2004
European eel	*Anguilla anguilla*	✓	Critically endangered	-	-	-	-	✓	✓	-
Allis shad	*Alosa alosa*	✓	Least concern	✓	✓	✓	✓	✓	-	-
Twaite shad	*Alosa fallax*	-	Least concern	✓	✓	✓	✓	✓	-	-
Sea Lamprey	*Petromyzon marinus*	✓	Least concern	✓	✓	-	-	✓	✓	-
River Lamprey	*Lampetra fluviatilis*	-	Least concern	✓	✓	-	✓	✓	✓	-
Smelt	*Osmerus eperlanus*	-	Least concern	-	-	-	-	✓	✓*	-
Salmon	*Salmo salar*	✓	Lower Risk/least concern	✓	✓	-	✓	✓	✓	-
Sea Trout	*Salmo trutta*	-	Least concern	-	-	-	-	✓	✓	-
(*)= Due to be added to SNH PMF list (MS communication, 20/10/2011)										

The distribution and ecology of the diadromous species listed above is described in the following section. In the case of salmon and sea trout, their distribution and ecology are separately described in the Salmon and Sea Trout Ecology and Fisheries Technical Report.

6.1.1 River and Sea Lamprey

River and sea lampreys are parasitic anadromous[2] migratory species and have both been recorded in a number of rivers in the Moray Firth (Kelly & King 2001, JNCC 2011). Their distribution around the British Isles is given in Figure 6.1.

In the regional study area, sea lampreys (*Petromyzon marinus*) occur mainly in the River Spey, a designated Special Area of Conservation (SAC), but have also been recorded in the River Conon and Loch Ness (JNCC 2011, NBN Gateway 2011). Sea lamprey has been a primary reason for the SAC site selection in the river Spey (JNCC 2011). River lamprey (*Lampetra fluviatilis*) has only been recorded in the rivers Conon and Spey (JNCC 2011).

[1] Diadromous: Migratory fish which migrate between the sea and fresh water.

[2] Anadromous: Diadromous fish which spend most of their life in the sea and migrate to freshwater to spawn.

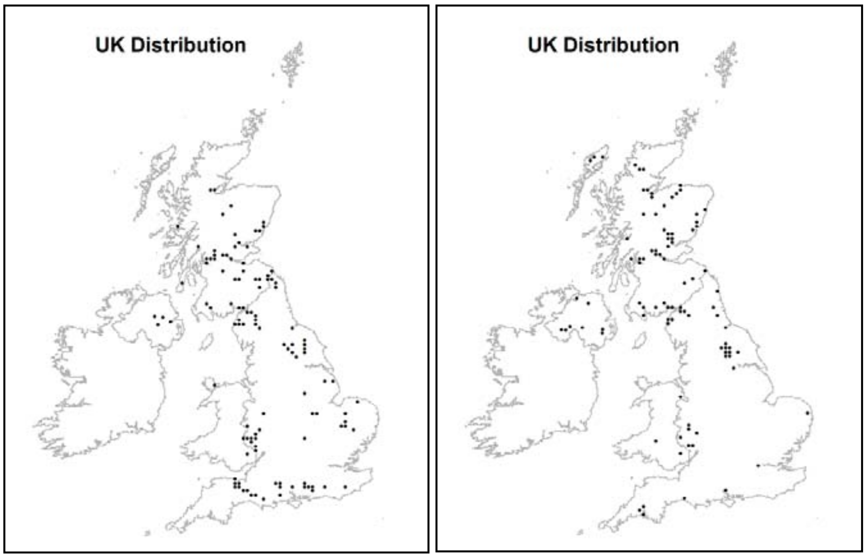

Figure 6.1 UK Distribution of river lamprey (left) and sea lamprey (right) (JNCC, 2011)

Both species spawn in fresh water in spring or early summer, followed by a larval phase (ammocoetes) spent in suitable silt beds in streams and rivers (Laughton & Burns 2003). In the Spey sea lampreys have been recorded returning to the river in early summer, and spawning in river in June/July (pers. comm. Bob Laughton May 2011). All individuals die after spawning (Mailtland 2003).

Ammocoetes can spend several years in these silt beds, feeding on organic detritus and eventually transforming into adults from late summer onwards (Laughton & Burns 2003). The transformation into the adult stage is characterised by the development of functional eyes and the mouth changes into a fully formed sucker (Maitland 2003). After transformation, river and sea lampreys migrate to sea, where they use their suckers to attach to other fish (Maitland 2003). In the Spey this was noted as occurring in late summer (pers. comm. Bob Laughton May 2011). After several years in the marine environment the adults return to fresh water to spawn (Laughton & Burns 2003).

The distribution of sea lamprey is largely dictated by their host (Waldman *et al* 2008). At sea, lamprey feed on a variety of marine mammals and fish, including shad, herring, pollock, salmon, cod, haddock, swordfish and basking sharks (Kelly & King, 2001, ter Hofstede *et al* 2008). Homing behaviour is not apparent in this species (Waldman *et al* 2008). Thus, unlike salmonids and shads, lampreys do not have specific river populations (ter Hofstede *et al* 2008). The rarity of capture in coastal and estuarine waters suggests that marine lampreys are solitary hunters and widely dispersed at sea (MSS, 2011). It is quite possible that they often feed in deeper offshore waters as they have been caught at considerable depths (as deep as 4100 m) (Moore *et al* 2003).

Unlike sea lamprey, river lampreys are generally found in coastal waters, estuaries and accessible rivers (Maitland 2003). In estuaries, they feed on a variety of fish, particularly on small fish such as young herring (*Clupea harengus)*, sprat (*Sprattus sprattus*) and flounder (*Platichthys flesus)* (Maitland 2003). After one to two years in estuaries, river lampreys stop feeding in the autumn and move upstream into medium to large rivers, usually migrating into fresh water between October and December (Maitland 2003).

6.1.2 European Eel

The European eel (*Anguilla anguilla*) stock has been assessed as being at a historical minimum and continuing to decline (ICES 2009). In 2007 an EU Regulation (EU 1100/2007) was established with the objective to protect and sustainably use the stock (ICES 2009). In the Moray Firth they are thought to be present in most rivers and streams.

European eel is a catadromous[3] migratory species which is thought to spawn in the Sargasso Sea. The newly hatched larvae use oceanic currents to cross the Atlantic Ocean towards the European continental shelf and once there, metamorphose into glass eels (Malcolm *et al* 2010). All juvenile eels found in the shallower waters off Scotland are therefore likely to be glass eels, with larval eels occurring only to the west of the continental shelf (Tesch 2003). Glass eels generally migrate into fresh water in their first year after arrival, although some may remain in coastal waters until they mature, while others may move back and forth between coastal, estuarine and freshwaters throughout their lives (Daverat *et al* 2006). After living and growing in these various environments for up to 60 years, adult eels (yellow eels) turn silver and start their migration back to the Sargasso Sea to spawn and, presumably, die (Malcolm *et al* 2010).

Glass eels entering coastal waters use selective tidal stream transport to migrate to the coast and into river systems. They are transported by the flood stream in higher water levels and dwell near the bottom during the ebb stream (Creutzberg 1985). To progress farther upstream, though, active migration into the river is required, swimming against the river flow (Bult & Dekker, 2007). The transition from selective tidal stream transport to active swimming has been related to a change in external factors (salinity or temperature; Creutzberg 1961), but also been described as an internally determined delay, allowing morphological and physiological adaptation (Deelder 1958; McCleave and Wippelhauser 1987).

Negative phototaxis[4] is pronounced in eels of all stages and they are rarely found within a few meters of the surface during daylight, or even bright moonlight, if deeper water is available (Malcolm *et al* 2010).

The migratory behaviour of eels in Scottish coastal waters is poorly understood and migration seasons for both adults and juveniles are probably quite protracted. Tesch (2003), notes that eels typically arrive off Shetland and the Western Isles in September, Orkney and Caithness in November, and areas off the rest of eastern mainland Scotland in December. The first eels may, however, arrive as early as August and continuous glass eel arrival is likely to occur for several months after the mid-winter peak and perhaps even through the whole year, although in lower numbers.

It has been suggested that glass eels destined for Scottish rivers remain in coastal regions until April or May before river temperatures rise sufficiently for them to enter fresh water. The bulk of the return of silver eel migration is thought to extend from September to January (Malcolm 2010).

6.1.3 Allis Shad and Twaite Shad

Allis shad and twaite shad are anadromous migratory species occurring mainly in shallow coastal waters and estuaries, with a preference for water 10-20 m deep (MSS 2011). Migration into fresh water occurs during late spring (April to June) along the coast to higher, middle watercourses of rivers to spawn from mid-May to mid-July (Maitland & Hatton-Ellis 2003, Acolas *et al* 2004, Patberg *et al* 2005). In contrast to twaite shad, the vast majority of allis shad only spawn once and then die (ter Hofstede *et al* 2008). There are no known spawning sites for allis shad in Britain, though both sub-adults and sexually mature adults are still regularly found around the British coast, including the Solway Firth (Maitland & Lyle 1995). Spawning populations of twaite shad are still found in a few rivers notably the Severn, Wye and Usk (Aprahamian & Aprahamian, 1990).

[3] Catadromous: Diadromous fish which spend most of their life in freshwater and migrate to sea to spawn.

[4] Phototaxis: Locomotory movement in response to the stimulus of light.

Allis shad and twaite shad are relatively scarce in the UK. The coastal distribution of allis shad and twaite shad is given in Figure 6.2. Allis shad has occasionally been recorded in the river Spey and estuarine and coastal areas of the Moray Firth (JNCC 2011, NBN Gateway 2011). No catches of twaite shad have been recorded in any rivers of the Moray Firth (JNCC 2011, NBN Gateway 2011), although this species has been recorded in coastal areas (Figure 6.2).

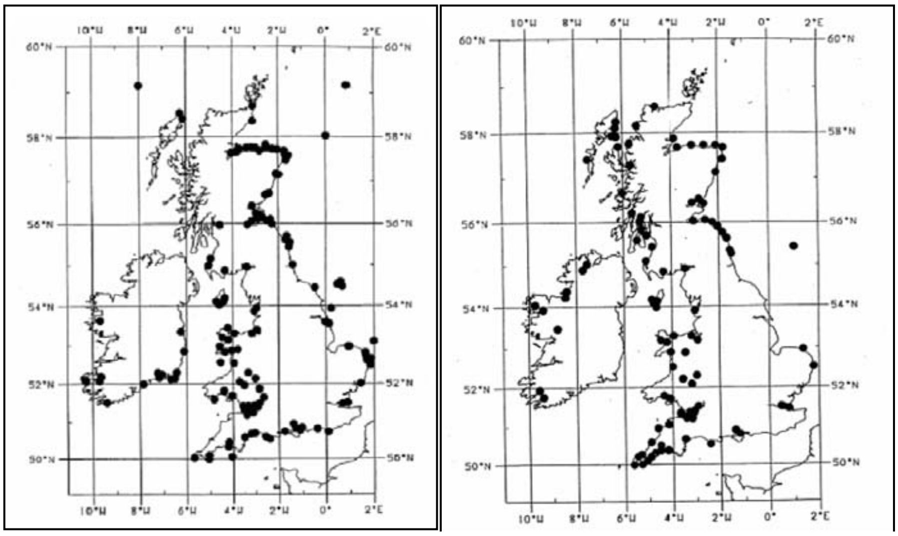

Figure 6.2 Coastal distribution of allis shad (left) and twaite shad (right) in the British Isles (date range unknown) from Potts and Swaby, 1993, as cited in Aprahamian et al, 1998 (JNCC, 2011)

6.1.4 European Smelt

Smelt (*Osmerus eperlanus*) are diadromous migratory species. Adults congregate in estuaries during the winter, entering rivers in early spring to spawn during March and April over a period of only a few days. After spawning the adults return to sea whilst the juveniles remain in the estuary for the remainder of the summer. Most adults die after spawning although some fish do return to sea, recover and spawn again in later years.

Smelt populations have declined in Great Britain and are no longer present in many rivers. In Scotland there are only three populations left (in the rivers Cree, Tay and Forth) from the fifteen or more previously recorded (Maitland & Lyle 1995, Dumfries and Galloway Council 2011).

6.2 Sharks and Rays (Elasmobranchs)

Sharks and rays have slow growth rates and low reproductive output compared to other species groups (Camhi *et al* 1998). This results in slow rates of stock increase (Smith *et al* 1998) and low resilience to fishing mortality (Holden 1974). Directed fisheries have caused stock collapse for many species (Musick 2005), although at present, mortality in mixed-species and by-catch fisheries seems to be a more important threat (Bonfil 1994).

6.2.1 Conservation Status

The principal species with conservation status and/or declining stocks, potentially transiting or inhabiting areas relevant to the Beatrice Offshore wind farm site are given in Table 6.2.

Table 6.2 Principal elasmobranch species with conservation status recorded in the Moray Firth

Common Name	Latin Name	MMO Landings Data	Recorded in the Moray Firth (Ellis *et al* 2005)	Conservation Status						
				OSPAR	IUCN Red List	The Wildlife & Countryside Act 1981	The Conservation (Natural Habitats, &c.) Regulations 1994	UK BAP species	Scottish Priority Marine Feature (PMF)	The Nature Conservation (Scotland) Act 2004
Sharks										
Basking shark	*Cetorhinus maximus*	-	-	✓	Vulnerable	✓	-	✓	✓	✓
Blue shark	*Prionace glauca*	-	-	-	Near threatened	-	-	✓	-	-
Gulper shark	*Centrophorus granulosus*	✓	-	✓	Vulnerable	-	-	✓	-	-
Leafscale gulper shark	*Centrophorus squamosus*	✓	-	✓	Vulnerable	-	-	✓	-	-
Porbeagle	*Lamna nasus*	-	-	✓	Vulnerable	-	-	✓	-	-
Portuguese dogfish	*Centroscymnus coelolepis*	✓	-	✓	Near threatened	-	-	✓	-	-
Sailfin Roughshark	*Oxynotus paradoxus*	✓	-	-	Data deficient	-	-	-	-	-
Spurdog	*Squalus acanthias*	✓	✓	✓	Vulnerable	-	-	✓	✓	-
Tope	*Galeorhinus galeus*	✓	-	-	Vulnerable	-	-	✓	-	-
Skates and Rays										
Common skate	*Dipturus batis*	✓	✓	✓	Critically endangered	-	-	✓	✓	-
Long-nosed skate	*Dipturus oxyrinchus*	✓	-	-	Near threatened	-	-	-	-	-
Sandy ray	*Leucoraja circularis*	-	-	-	Vulnerable	-	-	✓	-	-
Spotted ray	*Raja montagui*	-	✓	✓	Least concern	-	-	-	-	-
Thornback ray	*Raja clavata*	✓	✓	✓	Near Threatened	-	-	-	-	-
White skate	*Rostroraja alba*	✓	-	✓	Endangered	-	-	✓	-	-

6.2.2 Sharks

Spurdog (*Squalus acanthias*) are widely distributed around the British Isles and the Scottish coast (MSS 2011, Ellis *et al* 2005, ICES 2010c). They are commercially exploited, being principally caught as by-catch in mixed fisheries such as trawl fisheries, especially otter-trawl fisheries, and to a lesser extent gillnet and long line fisheries. In the local area (ICES rectangle 45E7) spurdog are the principal elasmobranch species landed by weight, although in relatively low levels. The wider Moray Firth area is considered to be a nursery ground for this species (Ellis *et al* 2010a) (Section 8.9).

Although formerly abundant, the stock is now considered to be depleted and in danger of collapse (ICES 2010c). Exploitation has been reduced substantially in recent years as a result of decreasing quota allocations, with the Total Allowable Catch (TAC) reduced by approx. 99.7 % between 2000 and 2009 (Ellis *et al* 2010b). In addition, in 2010, the TAC for spurdog was set to zero. Landings are still permitted under a by-catch TAC (equal to 10% of the 2009 quotas), provided certain conditions are met including a maximum landing length and by-catch ratio limits (ICES 2010c).

Other shark species potentially using the Moray Firth area are Portuguese dogfish (*Centroscymnus coelolepis*), porbeagle (*Lamna nasus*), tope (*Galeorhinus galeus)* and leafscale gulper shark

(*Centrophorus squamosus*). With the exception of porbeagle, all have been recorded in the landings data from the regional study area (2000-2009). It should be noted that the majority of these species are either rare or tend to be more prevalent in offshore waters and the west and north coast of Scotland, than in the Moray Firth. Portuguese dogfish, for example, are principally found off the far west and north coasts of Scotland. Similarly, tope tend to be rarer in the east coast and leafscale gulper sharks are primarily found off the far west and north-west coast of Scotland. Porbeagles are widely distributed around Scotland, although currently considered to be rare. In 2010 zero EU-wide TAC was introduced for this species (MSS 2011).

The blue shark (*Prionace glauca*), whilst not present in the landings data (2000-2009), is also known to make use of Scottish coastal waters as part of their migration. They are more commonly recorded off the west coast of Scotland during the summer months (MSS 2011).

In addition to the species mentioned above, another species of conservation importance which could potentially transit areas relevant to the Beatrice Offshore Wind Farm is the basking shark (*Cetorhinus maximus*). Basking sharks migrate from the western English Channel in spring to west Scottish waters, where they spend the summer and early autumn before moving offshore between November and March. Sightings for this species peak in the summer at a number of hot spots on the west coast. Sightings have also been recorded in the Moray Firth, however, to a much lesser extent. Increases in sea water temperatures are thought to be related to sightings being observed further north than in previous decades, with occasional records now around Shetland and Orkney north to the Norwegian coast and in the northern North Sea (Bloomfield & Solandt 2008, Solandt & Ricks 2009).

6.2.3 Skates and Rays

Thornback ray (*Raja clavata*) is considered to be the most important species of ray for commercial fisheries (ICES 2010c). The stock of this widely distributed species has steadily declined since the start of the 20th century resulting in a decreased distribution area, concentrated now in the southwest North Sea (from the Thames Estuary to the Wash) (ICES 2010c). The species is mostly found in shelf areas in depths of 10 to 60 m (Pawson 1995). They are considered to be one of the most abundant ray species through Scotland, being more common in the western and northern regions. The Moray Firth is considered a low intensity nursery area for this species (Ellis et al 2010a) (Section 8.10).

Common skate (*Dipturus batis*) was historically one of the most abundant rays in the North-east Atlantic, being widely distributed around the British Isles. Current data indicates that they have disappeared from the English Channel and the southern and central North Sea, although they are regularly observed off northern and north-western Scotland, the Celtic Sea and along the edge of the continental shelf (Dulvy *et al* 2007).

Both the common skate and thornback ray have been recorded in the 2009 landings data in the regional study area together with the long-nosed skate (*Dipturus oxyrinchus*) and the white skate (*Rostroraja alba*).

Other species of conservation importance potentially present in the Moray Firth are sandy ray (*Leucoraja circularis*) and spotted ray (*Raja montagui*). Sandy ray are typically found on sandy or muddy seabeds of the north-west of Scotland although can occur elsewhere around the coast (MMS 2011). Spotted ray are widespread around the northern and western coasts of Scotland being rare in the North Sea (MSS 2011).

6.3 Other Species

In addition to the diadromous migratory species and elasmobranchs mentioned above, there are a number of other fish species with conservation status. The majority of these are commercially exploited in the Moray Firth having been recorded in landings data (2000-2009) within the regional study area. These are given in Table 6.3 below.

Table 6.3 Conservation status of fish species recorded in landings data (2000-2009) within the regional study area

Common Name	Latin Name	Scottish Priority Marine Feature (PMF)	UK BAP Species	OSPAR	IUCN Red List
Anglerfish	*Lophius piscatorius*	✓ (juveniles)	✓	-	-
Atlantic halibut	*Hippoglossus hippoglossus*	-	✓	-	Endangered
Atlantic mackerel	*Scomber scombrus*	✓	✓	-	-
Black scabbardfish	*Aphanopus carbo*	-	✓	-	-
Blue ling	*Molva dypterygia*	-	✓	-	-
Cod	*Gadus morhua*	✓	✓	✓	Vulnerable
Greenland halibut	*Reinhardtius hippoglossoides*	-	✓	-	-
Hake	*Merluccius merluccius*	-	✓	-	-
Herring	*Clupea harengus*	✓ (juveniles and spawning adults)	✓	-	Least concern
Horse mackerel	*Trachurus trachurus*	-	✓	-	-
Ling	*Molva molva*	✓	✓	-	-
Norway pout	*Trisopterus esmarkii*	✓	-	-	-
Plaice	*Peluronectes platessa*	-	✓	-	Least concern
Roundnoise Grenadier	*Coryphaenoides rupestris*	-	✓	-	-
Saithe	*Pollachius virens*	✓ (juveniles)	-	-	-
Sandeels	*Ammodytes marinus*	✓	✓	-	-
	Ammodytes tobianus	✓	-	-	-
Whiting	*Merlangius merlangus*	✓ (juveniles)	✓	-	-

7.0 References

Acolas, M. L., Be´gout Anras, M. L., Ve´ron, V., Jourdan, H., Sabatie´, M. R., and Baglinie`re, J. L., (2004) An assessment of the upstream migration and reproductive behaviour of allis shad (Alosa alosa L.) using acoustic tracking. e ICES Journal of Marine Science, 61: 1291e1304.

Aarestrup, K., Økland, F., Hansen, M.M., Righton, D., Gargan, P., Castonguay, M., Bernatchez, L., Howey, P., Sparholt, H., Pedersen, M.I. & McKinley, R.S., (2009) Oceanic spawning migration of the European eel (*Anguilla anguilla*). *Science*, 325, 1660.

Aprahamian, M. W. & Aprahamian, C. D., (1990) Status of the Genus Alosa in the British Isles: past and present. Journal of. Fish Biology 37A: 257–258. Status of the genus Alosa in the British Isles. Cited in Maitland & Lyle (1995).

Armstrong, M. J., Connolly, P., Nash, R. D. M., Pawson, M. G., Alesworth, E., Coulahan, P. J., Dickey-Collas, M., Milligan, S. P., O'Neill, M. F., Witthames, P. R., and Woolner, L., (2001) An application of the annual egg production method to estimate the spawning biomass of cod (*Gadus morhua* L.), plaice (*Pleuronectes platessa* L.) and sole (*Solea solea* L.) in the Irish Sea. ICES Journal of Marine Science, 58: 183–203.

Arnott S.A. and Ruxton G.D., (2002) Sandeel recruitment in the North Sea: demographic, climatic and trophic effects. Mar Ecol Prog Ser Vol. 238: 199–210.

Bellido, J. M., Pierce, G. J., Wang, J., (2001) Modelling intra-annual variation in abundance of squid *Loligo forbesi* in Scottish waters using generalized additive models. Fisheries Research 52, 23–39.

Bergstad, O. A., Hoines, A. S., and Kruger-Johnsen, E. M. 2001. Spawning time, age and size at maturity, and fecundity of sandeel, Ammodytes marinus, in the north-eastern North Sea and in unfished coastal waters off Norway. Aquatic Living Resources, 14: 293e301.

Bern Convention, (2011) Available online at http://conventions.coe.int/Treaty/EN/Treaties/Html/104.htm. Accessed on 25/04/2011.

BGS, (2011) Available online at http://www.bgs.ac.uk/products/digitalmaps/seabed.html. Accessed on 27/04/2010.

Blaxter, J.H.S., (1985) The herring: a successful species? Can.J.Fish. Aquat. Sci. 42 (Suppl.1):21-30.

Bloomfield, A. And Solandt, J.L., (2008) The Marine Conservation Society Basking Shark Watch 20-year report (1987-2006).

Bonfil, R., (1994). "Overview of world elasmobranch fisheries." FAO Fisheries Technical Paper No 341: 119pp.

Brand A. R., (2006) Scallop ecology: distribution and behaviour In: "Scallops: biology ecology and aquaculture". S.E. Shumway and G. J. Parsons (eds), Elsevier Press, 651-744. Accessible at http://books.google.co.uk. Accessed on 14/03/2011.

Brawn, V. M., (1961) Sound production by the cod (*Gadus callarias* L.). Behaviour, 18: 239–245. Cited in Nordeile & Kjellsby 1999.

Bult, T. P., and Dekker, W., (2007) Experimental field study on the migratory behaviour of glass eels (Anguilla anguilla) at the interface of fresh and salt water. – ICES Journal of Marine Science, 64: 1396–1401.

Boyle P.R., Pierce G.J., Hastie, L.C., (1995) Flexible reproductive strategies in the squid *Lologo forbesi. Marine Biology 121: 501-508.*

Camhi, M., Fowler, S., Musick, J., Brautigam A. And Fordham S., (1998) Sharks and their relatives: Ecology and Conservation. Occasional Paper of the IUCN Species Survival Commission Occas. Pap. No. 20.

Campbell, R. and McLay, A., (2007) The Moray Firth Squid Fishery 2006. Fisheries Research Services Internal Report No 15/07. RSE 2004. The Royal society of Edinburgh. Inquiry into the future of the Scottish Fishing Industry.

Cefas, (2004) Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA Requirements.

Cefas, (2009) Megrim in the south-west of the British isles. Available online at http://www.cefas.co.uk/media/311395/megrim.pdf. Accessed on 19/05/2011.

Cefas, (2011) ANGLERFISH in the South West of the British Isles (ICES Division VIIb-k and VIIIa,b) – 2009. Available online at http://www.cefas.co.uk/media/311369/anglerfish.pdf. Accessed on 12/04/2011.

CITES, (2011) Available online at http://www.cites.org. Accessed on 25/04/2011.

Collins, M. A. and Pierce, G. J., (1996) Size selectivity in the diet of “Loligo forbesi” (Cephalopoda: Loliginidae). Journal of the Marine Biological Association of the United Kingdom, 76, pp 1081-1090

Collins, M. A., Pierce, G. J., and Boyle, P. R., (1997) Population indices of reproduction and recruitment in *Loligo forbesi* (Cephalopoda: Loliginidae) in Scottish and Irish waters. Journal of Applied Ecology, 34: 778 – 786.

Coull, K.A., Johnstone, R., and Rogers, S.I., (1998) Fisheries Sensitivity Maps in British Waters. UKOOA Ltd.

Compagno, L.J.V., (1984) FAO species catalogue. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. FAO Fisheries Sypnosis Nº 125, Vol. 4 Part 2. 633pp. Cited in Rodríguez-Cabello, C., F. Sánchez, A. Fernández and I. Olaso, 2001. Is the lesser spotted dogfish (*Scyliorhinus canicula*) from the Cantabrian Sea. A unique stock? ICES CM 2001/O:06.

Cushing, D.H. and Bridger, J.P., (1966) The stock of herring in the North Sea and changes due to fishing. Fishery Invest. Lond. (2) 25 (1), i-vii, 1-123.

Creutzberg, F., (1958) Use of tidal streams by migrating elvers (Anguilla vulgaris Turt.). Nature, 181: 357– 358. Cited in Bult & Dekker 2007.

Creutzberg, F., (1961) On the orientation of migrating elvers (Anguilla vulgaris Turt.) in a tidal area. Netherlands Journal of Sea Research, 1: 257– 338. Cited in Bult & Dekker 2007.

Daverat, F., Limburg, K.E., Thibault, I., Shiao, J.-C., Dodson, J.J., Caron, F., Tzeng, W.-N., Iizuka, Y. & Wickström, H., (2006) Phenotypic plasticity of habitat use by three temperate eel species, *Anguilla anguilla, A. japonica* and *A. rostrata. Marine Ecology Progress Series*, 308, 231-241. Cited in Malcolm et al 2010.

De Groot, S. J., (1980) The consequences of marine gravel extraction on the spawning of herring, *Clupea harengus* Linné. Journal of Fish Biology, 16: 605 – 611.

Deelder, C. L., (1958) On the behaviour of elvers (Anguilla vulgaris Turt.) migrating from the sea into fresh water. Journal du Conseil Permanent International pour l'Exploration de la Mer, 24: 135– 146. Cited in Bult & Dekker 2007.

Dulvy, N.K., Notobartolo di Sciara, G., Serena, F., Tinti, F. & Ungaro, N., Mancusi, C. & Ellis, J., (2006) Dipturus batis. In: IUCN 2007. IUCN Red List of Threatened Species.

Dumfires and Galloway Council (2011) Dumfries and Galloway Local Species Action Plan. Available online at http://www.dumgal.gov.uk/CHttpHandler.ashx?id=584&p=0. Accessed on 15/08/2011.

Habitats Directive (92/43/EEC). Available online at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1992L0043:20070101:EN:PDF. Accessed on 02/11/2011.

Ellis, J. R., A. Cruz-Martínez, B. D. Rackham, and S. I. Rogers., (2005) The Distribution of Chondrichthyan Fishes Around the British Isles and Implications for Conservation. *J. Northw. Atl. Fish. Sci.*, 35: 195-213. doi:10.2960/J.v35.m485

Ellis, J.R., Milligan, S., Readdy, L., South, A., Taylor, N., and Brown, M., (2010a) Mapping spawning and nursery areas of species to be considered in Marine Protected Areas (Marine Conservation Zones).

Ellis, J., Doran, S., Dunlin, G., Hetherington, S., Keable, J. and Skea, N., (2010b) Programme 9: Spurdog in the Irish Sea. Final Report.

Enger, P.S., (1967) Hearing in herring. Comp. Biochem. Physiol. 22, 527-538. Cited in de Groot (1980).

FAO, (2011) Available online http://www.fao.org. Accessed on 15/04/2011.

Filina, E. A., V. N. Khlivnoy, and V. I. Vinnichenko., (2009) The reproductive biology of haddock (*Mellanogrammus aeglefinus*) at the Rockall Bank. *J. Northw. Atl. Fish. Sci*., 40: 59–73. doi:10.2960/J. v40.m639.

Foster-Smith, R., Sotheran, I., and Foster-Smith, D., (2009) Sublittoral Biotope Mapping of the Moray Firth SAC Scottish Natural Heritage Commissioned Report No.338

Fox, C. J., Geffen, A. J., Blyth R., and Nash, R. D. M., (2003) Temperature-dependent development rates of plaice (Pleuronectes platessa L.) eggs from the Irish Sea. Journal of Plankton Research. Volume 25/Number 11/Pages 1319-1329.

Fox, C.J., Taylor, M., Dickey-Collas, M., Fossum, P., Kraus, G., Rohlf, N., Munk, P., van Damme C.J., Bolle, L.J, Maxwell, D.L., and Wright, P.J., (2008) Mapping the spawning grounds of North Sea cod (Gadus morhua) by direct and indirect means. Proc Biol Sci. 2008 Jul 7; 275 (1642):1543-8.

Franklin A., Pickett G. D., Connor P. M., (1980) The Scallop and its fishery in England and Wales. Laboratory leaflet No. 51.

Fudge, S. B., and Rose, G. A., (2009) Passive- and active-acoustic properties of a spawning Atlantic cod (Gadus morhua) aggregation. – ICES Journal of Marine Science, 66: 1259–1263.

Furness R. W., (1999) Towards defining a sandeel biomass limit for successful breeding by seabirds. In P.J. Wright and F.M. Kennedy, 1999. Proceedings of a workshop held at FRS Marine Laboratory Aberedeen 22-24 February 1999. Fisheries Research Services Report No 12/99.

Furness, R.W., (2002) Management implications of interactions between fisheries and sandeel-dependent seabirds and seals in the North Sea.-ICES Journal of Marine Science, 59:261-269.

Gauld, J. A., and Hutcheon, J. R. 1990. Spawning and fecundity in the lesser sandeel, Ammodytes marinus Raitt, in the northwestern North Sea. Journal of Fish Biology, 36: 611e613.

Greenstreet, S. P. R., McMillan, J. A., and Armstrong, F., (1998) Seasonal variation in the importance of pelagic fish in the diet of piscivorous fish in the Moray Firth, NE Scotland: a response to variation in prey abundance? – ICES Journal of Marine Science, 55: 121–133.

Greenstreet, S. P. R., Holland, G. J., Guirey, E. J., Armstrong, E., Fraser, H. M., and Gibb, I. M., (2010) Combining hydroacoustic seabed survey and grab sampling techniques to assess “local” sandeel population abundance. – ICES Journal of Marine Science, 67: 971–984.

Gibb, F.M, Wright, P.J., Gibb, I.M. and O’Sullivar, M., (2004) Haddock and whiting spawning areas in the North Sea and Scottish West coast. Fisheries Research Services Internal Report No 11/04.

Gibb, F.M, Gibb, I.M and Wright, P.J., (2007) Isolation of Atlantic cod (*Gadus morhua*) nursery areas. Marine Biology: 1185-1194.

Gibb, I. M., Wright, P.J. and Campbell, R., (2008) Identifying Critical Spawning and Nursery Areas for North Sea Cod; Improving The Basis for Cod Management. Scottish Industry/Science Partnership (SISP) Report No 03/08.

Hall, S. J., (1993) Pit-digging by the crab *Cancer pagurus*: a test for long-term, large scale effects on infaunal community structure. Journal of Animal Ecology 62, 59-66. Cited in Mill *et al* 2009.

Harding, D., Nichols, J. H., and Tungarte, D. S., (1978) The spawning of plaice (*Pleuronectes platessa* L.) in the southern North Sea and North Sea plaice SSB using the annual egg production method 2009 Conseil International pour l’Exploration de la Mer, 172: 102–113. Cite in van Damme *et al* 2009.

Hawkins, A. D., and Amorim, M.C.P., (2000) Spawning sounds of the male haddock, *Melanogrammus aeglefinus*. Environmental biology of fishes. Volume 1 / 1976 - Volume 91 / 2011.

Haugland, M., Holst J.C., Holm, M. and Hansen, L.P., (2006) Feeding of Atlantic salmon *(Salmo salar L.*) post-smolts in the Northeast Atlantic. ICES J. Mar.Sci. 63(8):1488-1500.

Heath, M., Leaver, M., Matthews, A., and Nicoll, N., (1989) Dispersion and feeding of larval herring (Clupea harengus L.) in the Moray Firth during September 1985. Estuar. Coast. Shelf Sci. Vol. 28. 549-566.

Heath, M. and Gallego, A., (1997) From the biology of the individual to the dynamics of the population: bridging the gap in fish early life stages. J Fish Biol (Suppl. A):1–29. Cited in Gibb *et al* (2007).

Hedger, R., McKenzie, E., Heath, M., Wright, P., Scott, B., Gallego, A., and Andrews, J., (2004) Analysis of the spatial distributions of mature cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) abundance in the North Sea (1980-1999) using generalised additive models. Fisheries Research 70(1): 17-25.

Hinrichsen, H.H., Kraus, G., Voss, R., Stepputtis, D., and Baumann, H., (2005) The general distribution pattern and mixing probability of Baltic sprat juvenile populations. Journal of Marine Systems, 58: 52 - 66.

Hobson, E.S., (1986) Predation on the Pacific sand lance, A. hexapterus (Pisces: Ammodytidae) during the transition between day and night in southeastern Alaska. Copeia 1, 223–226.

Hodgson, W.C., (1957) The herring and its fishery. London, Routledge and Kegan Paul.

Ter Hofstede, R.H., Winter, H.V. and Bos, O.G., (2008) Distribution of fish species for the generic Appropriate Assessment for the construction of offshore wind farms. IMARES Report C050/08.

Holden, M.J., (1974). Problems in the rational exploitation of elasmobranch populations and some suggested solutions. Sea Fisheries Research (F. R. Harden Jones, ed). Elek: London 117-137.

Holland, G.J., Greenstreet, S.P.R., Gibb, I.M., Fraser, H.M., Robertson, M.R., (2005) Identifying sandeel Ammodytes marinus sediment habitat preferences in the marine environment. Mar. Ecol. Prog. Ser. 303, 269–282.

Howard, A. E. and Nunny, R. S., (1983) Effects of near-bed current speeds on the distribution and behaviour of the lobster, *Homarus gammarus* (L.). J. Cons. Int. Explor. Mer. 71, 27 - 42.

Howard, F.G., (1989) The Norway Lobster. Scottish Fisheries Information Pamphlet Number 7 1989 (Second Edition) ISSN 03099105.

Howell, T.R.W., Davis, S.E.B., Donald, J., Dobby, H., Tuck, I. And Bailey, N., (2006) Report of marine laboratory scallop stock assessments. Fisheries Research Services Internal Report No 08/06.

Hunter, E., Metcalfe, J.D. and Reynolds, J.D., (2003) *Migration route and spawning area fidelity by North Sea plaice.* Proceedings of the Royal Society of London B, 270. pp. 2097-2103.

Hutchinson, W.F., Carvalho, G.R. and Rogers, I., (2001) Marked genetic structuring in localised spawning populations of cod *Gadus morhua* in the North Sea and adjoining waters, as revealed by microsatellites. Mar Ecol Prog Ser. Vol. 223: 251–260, 2001.

ICES, (2005a) Spawning and life history information for North Atlantic cod stocks. ICES Cooperative Research Report, No. 274. 152 pp.

ICES, (2005b) Report of the Planning Group on North Sea Cod and Plaice Egg Surveys in the North Sea (PGEGGS), 10–12 May 2005, Lowestoft, UK. ICES CM 2005/G:11. 85 pp.

ICES, (2005c). Report of the Study Group on Multispecies Assessment in the North Sea (SGMSNS), 5–8 April 2005, ICES Headquarters. ICES CM 2005/D:06. 163 pp.

ICES, (2006) Report of the Study Group on Multispecies Assessments in the North Sea (SGMSNS), 20–25 February 2006, ICES Copenhagen. ICES CM 2006/RMC:02. 75 pp. For permission to reproduce material from this publication, please apply to the General Secretary.

ICES (2006b). Report of the Working Group on Ecosystem Effects of Fishing Activities (WGECO), 5 12 April 2006 , ICES Headquarters, Copenhagen. ACE:05. 174 pp.

ICES, (2007) Report of the Working Group Elasmobranch Fishes (WGEF), 22–28 June 2007, Galway, Ireland. ICES CM 2007/ACFM:27. 318 pp.

ICES, (2008a) Report of the Working Group on Multispecies Assessment Methods (WGSAM), 6–10 October 2008, ICES Headquarters, Copenhagen. ICES CM 2008/RMC:06. 113 pp.

ICES, (2009) Report of the ICES Advisory Committee 2009. ICES Advice, 2009. Book 6, 236 pp.

ICES (2009b) Report of the Working Group on Multispecies Assessment Methods (WGSAM), 5–9 October 2009, ICES Headquarters, Copenhagen. ICES CM 2009/RMC:10. 117 pp.

ICES, (2009c) Report of the ICES Advisory Committee 2009. ICES Advice, 2009. Book 5.

ICES, (2010) Report of the Working Group on Multispecies Assessment Methods (WGSAM), 4-8 October 2010, San Sebastian, Spain. ICES CM 2010/SSGSUE:05. 95 pp.

ICES, (2010c) Report of the Working Group on Elasmobranch Fishes (WGEF), 22–29 June 2010, Horta, Portugal. ICES CM 2010/ACOM:19. 558 pp.

ICES, (2010b). Report of the Herring Assessment Working Group for the Area South of 62n (HAWG), 15 - 23 March 2010, ICES Headquarters, Copenhagen, Denmark. 688 pp.

ICES, (2011b) ICES-Fishmap. Available online at http://www.ices.dk/marineworld/fishmap/ices/. Accessed on 12/04/2011.

ICES, (2011c) Available online at http://www.ices.dk/marineworld/fishmap/pdfs/fishcommunity.pdf. Accessed on 14/04/2011.

IUCN, (2011) Available online at http://www.iucnredlist.org/. Accessed on 02/11/2011.

Jensen, H., Wright, P. J., and Munk, P., (2003) Vertical distribution of pre-settled sandeel (Ammodytes marinus) in the North Sea in relation to size and environmental variables. E ICES Journal of Marine Science, 60: 1342e1351.

Jessop, R.W., Woo, J.R. and Torrice, L., (2007) Research report. Eastern Sea Fisheries Joint Committee.

JNCC, (2011). Available online at: http://www.jncc.gov.uk. Accessed on 23/04/2011.

Jones, G., Gibson, P., Dobby, H. and McLay, A., (2010) Brown Crab (*Cancer pagurus*) Migrations off the Northern Scottish Coast. Scottish Industry Science Partnership Report 02/10.
Kelly, F.L. and King, J.J., (2001) A review of the ecology and distribution of three lamprey species, *Lampetra fluviatilis* (L), *Lampetra planeri* (L.), and *Petromyzon marinus* (L.): a context for conservation and biodiversity considerations in Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy*. 101B(3):165-185.

Keltz, S., Bailey, N., (2010) Fish and Shellfish stocks 2010. Marine Scotland, the Scottish Government. ISSN 2044-0359.

Kinnear, J.A.M. and Mason, J., (1987) A preliminary study of an unfished population of the velvet swimming crab *Liocarcinus puber* (L.). *International Council for the Exploration of the Sea (CM Papers and Reports), (Shellfish and Benthos Committee)*, CM 1987/K:6, 10pp (Cited in in Jessop et al 2007).

Kraus, G. and Köster, F. W., (2001) Duration, frequency and timing of sprat spawning in the Central Baltic: An analysis based on gonadal maturity. ICES CM 2001/J:25.

Kühlmann, D.H.H., Karst, H., (1967) Freiwasserbeobachtungen zum Verhalten von Tobiasfischschwärmen (Ammodytidae) in der westlichen Ostsee. Z. Tierpsychol. 24, 282–297.

Lambert, T.C., (1987) Duration and intensity of spawning in herring *Clupea harengus* as related to the age structure of the mature population. Mar. Ecol. Prog. Ser. Vol. 39: 209-220. 1.

Langham, N. P. E., (1971) The distribution and abundance of larval sand-eels (Ammodytidae) in Scottish waters. Journal of the Marine Biological Association of the United Kingdom, 51: 697e707. Cited in Jensen et al 2003.

Laughton, R. and Burns, S., (2003) Assessment of sea lamprey distribution and abundance in the River Spey: Phase III. Scottish Natural Heritage Commissioned Report No. 043 (ROAME No. F02AC604).

Lockwood, S.J. and Johnson, P.O., (1977) Horse Mackerel (Trachurus trachurus). Ministry of Agriculture Fisheries and Food Directorate of Fisheries Research. Laboratory Leaflet No.38.

Lum-Kong, A., Pierce, G. J., and Yau, C., (1992) Timing of spawning and recruitment in *Loligo forbesi* Steenstrup (Cephalopoda: Loliginidae) in Scottish waters. Journal of the Marine Biological Association of the UK, 72: 301 – 311.

Macer, C. T., (1965) The distribution of larval sand eels (Ammodytidae) in the southern North Sea. Journal of the Marine Biological Association of the United Kingdom, 45: 187e207. Cited in Jensen et al 2003.

Mair, J.M., Moore, C.G., Kingston, P.F. and Harries, D.B., (2000) A review of the status, ecology and conservation of horse mussel *Modiouls* modiolus beds in Scotland. *Scottish Natural Heritage Commissioned Report F99PA08*.

Maitland, P.S., (2003) Ecology of the River, Brook and Sea Lamprey. Conserving Natura 2000 Rivers Ecology Series No. 5. English Nature, Peterborough.

Maitland, P.S. and Lyle, A.A., (1995) Shad and smelt in the Cree Estuary, SW Scotland. Report to Scottish Natural Heritage, Edinburgh.

Maitland, P.S., and Hatton-Ellis T.W., (2003) Ecology of the Allis and Twaite Shad. Conserving Natura 2000 Rivers Ecology Series No. 3. English Nature, Peterborough.

Maitland, P.S., (2003) The status of smelt *Osmerus eperlanus* in England. English nature research reports. Report number 516. ISSN 0967-876X.

Malcolm, I.A., Godfrey, J. And Youngson, A.F., (2010). Review of migratory routes and behaviour of Atlantic salmon, sea trout and European eel in Scotland's coastal environment: implications for the development of marine renewable. Scottish Marine and Freshwater Science Vol 1 No 14.

Maucorps, A., (1969) Biologie et peche du hareng en Mer du Nord, son exploitation rationelle. Science et Pêche, Bull. Insf. Pêches marif., no 186, Novembre 1969.

McConnell B., Hall A., Fedal M., (1999) Seal Foraging and Sandeel Distribution. In P.J., Wright and F.M., Kennedy., (1999) Proceedings of a workshop held at FRS Marine Laboratory Aberedeen 22-24 February 1999. Fisheries Research Services Report No 12/99.

McCleave, J. D., and Wippelhauser, G. S., (1987) Behavioural aspects on selective tidal stream transport in juvenile American eels. Transactions of the American Fisheries Society, 1: 138– 150. Cited in Bult & Dekker 2007.

Mill, A., Dobby, H., McLay, A. and Mesquita, C., (2009) Crab and lobster fisheries in Scotland: an overview and results of stock assessments, 2002-2005. Marine Scotland Science Internal Report 16/09.

Milligan, S. P., (1986) Recent studies on the spawning of sprat (*Sprattus sprattus* L.) in the English Channel. Fisheries Research Technical Report no. 83.

Mills, D.H., Hadoke, G.D.F., Shelton, R.G.J and Read, J.B.D., (2003) Atlantic Salmon Facts. Atlantic Salmon Trust Booklet. Prepared in 1986. Revised in 2003.

MMO, 2010. Marine Management Organisation.

Moore, J.A., Hartel, K.E. Craddock, J.E. and Galbraith, J.K., (2003) An annotated list of deepwater fi shes from off the New England region, with new area records. Northeastern Naturalist 10(2):159–248.

Munro, J., Gauthier, D. and Gagné, J. A., (1998) Description d'une frayère de hareng (Clupea harengus L.) à l'île aux Lièvres dans l'estuaire moyen du Saint-Laurent. Rapp. tech. can. sci. I halieut. aquat. 2239 : vi + 34 p.

Murua, H. and Saborido-Rey F., (2003) Female Reproductive Strategies of Marine Fish Species of the North Atlantic.

Musick, J.A., (2005) Management Techniques for elasmobranch fisheries. FAO Fisheries Technical paper 474.

MSS, 2010a. Sea trout. Marine Scotland Science online publications. Available online at: http://www.scotland.gov.uk/Topics/marine/marine-environment/species/fish/freshwater/seatrout. Accessed: 05/12/2010.

MSS, (2011) Scotland's Marine Atlas-Information for tyhe National marine Plan. Available online at http://www.scotland.gov.uk/Topics/marine/science/assessment/atlas. Accessed on 26/04/2011.

MSS, (2011a) Marine Scotland Science. Emma Hatfield personal communication.

NBN Gateway, (2011) Interactive Map of Allis shad. Avaliable online at: http://www.searchnbn.net/interactive/map.jsp?srchSp=113708. Accessed on 23/04/2011.

Nissling, A., Muller, A. and Hinrichsen, H.H., (2003) Specific gravity and vertical distribution of sprat (Sprattus sprattus) eggs in the Baltic Sea. Fish Biol. 63, 280–299.

Nordeide, J. T. and Kjellsby, E., (1999) Sound from spawning cod at their spawning grounds. – ICES Journal of Marine Science, 56: 326–332.

Norman, C.P. and Jones, M.B., (1993) Reproductive ecology of the velvet swimming crab, *Necora puber* (Brachyura: Portunidae), at Plymouth. *Journal of the Marine Biological Association of the United Kingdom*, 73, 379-389. Cited in Jessop, RW, Lowry, M, Graves KM, 2007. Eastern Sea Fisheries District Research Report 2004. Kings Lynn. Eastern Sea Fisheries Joint Committee.

Norman, C. P. and Jones, M. B., (1992) Influence of depth, season and moult stage on the diet of the velvet swimming crab *Necora puber* (Brachyura, Portunidae). Estuarine, Coastal and Shelf Science 34, 71-83.

Olsen, E. and Holst, J.C., (2001) A note on common minke whale (*Balaenoptera acutorostrata*) diets in the Norwegian Sea and the North Sea. *J. CETACEAN RES. MANAGE.* 3(2):179–183, 2001.

OSPAR, (2011) OSPAR's List of Threatened and/or Declining Species and Habitats. Available online at http://www.snh.gov.uk/docs/B469310.pdf. Accessed on 26/04/2011.

Page, F. H. and Frank, K. T., (1989) Spawning time and egg stage duration in northwest Atlantic haddock (Melanogrammus aeglefinus) stocks with emphasis on Georges and Browns Bank. Can. 1. Fish. Aquat. Sci. 46(Suppl, I): 68-81.

Payne, M. R., Hatfield, E. M. C., Dickey-Collas, M., Falkenhaug, T., Gallego, A., Gro¨ger, J., Licandro, P., Llope, M., Munk, P., Ro¨ckmann, C., Schmidt, J. O., and Nash, R. D. M., (2009) Recruitment in a changing environment: the 2000s North Sea herring recruitment failure. – ICES Journal of Marine Science, 66: 272–277.

Payne, M. R., (2010) Mind the gaps: a state-space model for analysing the dynamics of North Sea herring spawning components. – ICES Journal of Marine Science, 67: 1939–1947.

Parrish, B.B., Saville, A., Craig, R.E., Baxter, I.G. and Priestley, R., (1959) Observations on herring spawning and larval distribution in the Firth of Clyth in 1958. J.mar.biol. Ass. U.K. (1959) 38,445-453.

Patberg, W., de Leeuw, J.J., Winter, H.V., (2005) Verspreiding van rivierprik, zeeprik, fint en elft in Nederland na 1970. Nederlands Instituut voor Visserij Onderzoek (RIVO) BV. Rapport
Nummer: C004/05.

Pawson M.G., (1995) Biogeographical identification of English Channel fish and shellfish stocks. Fisheries Research technical report No 99.

Petitgas, P., (2010) Life cycle spatial patterns of small pelagic fish in the Northeast Atlantic. ICES Cooperative Research Report No. 306. 93 pp.

Pierce G. J., Boyle P.R., Hastie L.C. and Kye, L., (1994) The life history of *Loligo forbesi* (Cephalopoda: Loliginidae) in Scottish waters. Fisheries Research 21 (1994) 17-41.

Pierce, G.J., Santos, M.B., Reid, R.J., Patterson, I.A.P. and Ross, H.M., (2004) Diet of minke whales Balaenoptera acutorostrata in Scottish (UK) waters with notes on strandings of this species in Scotland 1992-2002. J. Mar. Biol. Ass. U.K. (2004), 84, 1241-1244.

Rijnsdorp, A. D., (1989) Maturation of male and female North Sea plaice *(Pleuronectes platessa* L). - J. Cons. int. Explor. Mer, 46: 35-51.

Rocha F., Guerra A., González A.F., (2001) A review of reproductive strategies in cephalopods. Biol Rev. 76, 291-304.

Rohlf, N. and Gröger, J., (2010) WD HAWG: Report of the herring larvae surveys in the North Sea in 2009/2010.

Rohlf, N. and Gröger, J., (2009) WD HAWG: Report of the herring larvae surveys in the North Sea in 2008/2009.

Rohlf, N. and Gröger, J., (2006) WD HAWG: Report of the herring larvae surveys in the North Sea in 2005/2006.

Russel, F.D., (1976) The eggs and planktonic stages of British marine fishes. Academic Press, London. 524 pp. In ICES, 2011b: ICES-Fishmap. Available online at http://www.ices.dk/marineworld/fishmap/ices/. Accessed on 12/04/2011.

Santos, M.B., Pierce,G.J., Ieno, E.N., Addink, M., Smeenk, C., Kinze, C.C. and Sacau, M., (2005) Harbour porpoise (*Phocoena phocoena*) feeding ecology in the eastern North Sea.

Schmidt, J., Rohlf, N. and Gröger, J., (2008) WD HAWG: Report of the herring larvae surveys in the North Sea in 2007/2008.

Schmidt, J., Rohlf, N. and Gröger, J., (2007) WD HAWG: Report of the herring larvae surveys in the North Sea in 2006/2007.

Sims, D.W., Southall, E.J., Merrett, D.A. and Sanders, J., (2003) Effects of zooplankton density and diel period on surface-swimming duration of basking sharks. J. Mar. Biol. Ass. UK (2003), 83, 4168/1-4.

Skaret, G., Axelsen, B. E., Nøttetstad, L., Fernö, A., and Johannessen, A., (2002) Herring as cannibals. Journal of Fish Biology, 61: 1050 – 1052.

Shark Trust, (2011) Available online at http://www.sharktrust.org/. Accessed on 24/05/2010.

Simmonds, E.J., (2009) Evaluation of the quality of the North Sea herring assessment.

Simpson, A. C., (1959) The spawning of the plaice (*Pleuronectes platessa*) in the North Sea. Fishery Investigations, London, Series II, 22(7). 111 pp. Cited in Van Damme et al (2009).

Smith, S.E., Au. D.W. and Show, C., (1998) Intrinsic rebound potentials of 26 species of Pacific sharks. Mar. Freshwater. Res., 41:663-678.

SNH, (2011) Priority Marine Features for Scottish territorial waters. Available at http://www.snh.gov.uk. Accessed on 02/11/2011.

Solandt, J.L. and Ricks, N., (2009) The Marine Conservation Society Basking Shark Watch 2009 annual report.

Southall, T.D. and Hambrey, J., (2005) Assessment of the Feasibility of Implementing the Moray Firth Fisheries Action Plan. *For the Moray Firth Partnership, on behalf of the Moray Firth Fisheries Action Group*

Teal, L.R., van Hal, R., van Damme, C.J.G., Bolle, L.J. and ter Hofstede, R., (2009) Review of the spatial and temporal distribution by life stage for 19 North Sea fish species. IMARES Wageningen UR. C126/09.

Tesch, F.W., (2003) The Eel (3rd edition, Thorpe, J.E. ed), Blackwell Science, Oxford, pp408. Cited in Malcolm *et al* 2010.

The Conservation (Natural Habitats, &c.) Regulations 1994. Available online at http://www.legislation.gov.uk/uksi/1994/2716/contents/made. Accessed on 02/11/2011.

The Nature Conservation (Scotland) Act 2004. Available online at http://www.legislation.gov.uk/asp/2004/6/pdfs/asp_20040006_en.pdf. Accessed on 02/11/2011.

The Wildlife and Countryside Act 1981. Available online at http://www.legislation.gov.uk/ukpga/1981/69. Accessed on 02/11/2011.

Thompson, P.M., Pierce, G.J., Hislop, J.R.G., Miller, D. and Diack, J.S.W., (1991) Winter foraging by common seals (*Phoca vitulina*) in relation to food availability in the Inner Moray Firth, N.E. Scotland.
UKBAP, (2011) Available online at http://www.ukbap.org.uk/newprioritylist.aspx. Accessed on 24/04/2011.

UKBAP, (2011) UK Biodiversity Action Plan Species List. Available online at www.ukbap.org.uk/. Accessed on 25/05/2011.

Ungfors, A., Hallback, H. And Nilson, Per G., (2007) Movement of adult edible crab (*Cancer pagurus* L.) at the Swedish West Coast by mark-recapture and acoustic tracking. Fisheries Research 84 (2007) 345–357.

Van Damme, C. J. G., Bolle, L. J., Fox, C. J., Fossum, P., Kraus, G., Munk, P., Rohlf, N., Witthames, P. R., and Dickey-Collas, M., (2009) A reanalysis of North Sea plaice spawning-stock biomass using the annual egg production method. – ICES Journal of Marine Science, 66: 1999–2011.

Van der Kooij J., Scott B.E. and Mackinson S., (2008) The effects of environmental factors on daytime sandeel distribution and abundance on the Dogger Bank. Journal of Sea Research 60 (2008) 201–209.

Viana, M., Pierce, G.J., Illian, J., MacLeod, C.D., Bailey, N., Wang, J. and Hastie L.C., (2009) Seasonal movements of veined squid *Loligo forbesi* in Scottish (UK) waters.

Wahlberg, M., and Westerberg, H., (2005) Hearing in fish and their reactions to sounds from offshore wind farms. Mar Ecol Prog Ser. Vol. 288: 295–309, 2005.

Walker, P. A., Howlett, G., and Millner, R., (1997) Distribution, movement and stock structure of three ray species in the North Sea and eastern English Channel. – ICES Journal of Marine Science, 54: 797–808.

Walters, M., (2010) Moray Firth Sea Trout Project. Progress report February 2010.

Walters, M., (2011) Moray Firth Sea Trout Project Final Report. A summary of the projects progress, findings and next steps.

Waldman, J., Grunwald, C. and Wirgin, I., (2008) Sea lamprey Petromyzon marinus: an exception to the rule of homing in anadromous fishes. Biol. Lett. (2008) 4, 659–662. doi:10.1098/rsbl.2008.0341.

Wanless, S., Harris, M. P., and Greenstreet, S. P. R., (1998) Summer sandeel consumption by seabirds breeding in the Firth of Forth, south-east Scotland. – ICES Journal of Marine Science, 55: 1141–1151.

Wanless S., Harris M. and Rothery P., (1999) Intra- and Inter- Seasonal Variation in Sandeel, Ammodytes Marinus Consumption by Kittiwakes, Rissa Tridactyla on the Isle of May and Long-term Changes in Numbers, Reproductive Output and Adult Survival. *In* Wright, P.J. and Kennedy, F.M., (1999) Proceedings of a workshop held at FRS Marine Laboratory Aberedeen 22-24 February 1999. Fisheries Research Services Report No 12/99.

Wanless, S., Wright, P.J., Harris, M.P. and Elston, D. A., (2005) Evidence for decrease in size of lesser sandeels *Ammodytes marinus* in a North Sea aggregation over a 30-yr period. Mar Ecol Prog Ser Vol. 279: 237–246.

Wheeler, A., (1969) The fishes of the British Isles and North-West Europe.Michigan State University Press. Great Britain 613 pp. *In* Rodríguez-Cabello, C., F. Sánchez, A. Fernández and I. Olaso, 2001. Is the lesser spotted dogfish (Scyliorhinus canicula) from the Cantabrian Sea, a unique stock? ICES CM 2001/O:06

Wheeler, A., (1978) Key to the fishes of northern Europe. Publ. Frederick Warne. Ltd. London. 350 pp. In Rodríguez-Cabello, C., F. Sánchez, A. Fernández and I. Olaso, 2001. Is the lesser spotted dogfish (Scyliorhinus canicula) from the Cantabrian Sea, a unique stock? ICES CM 2001/O:06

Whitehead, P.J.P., Bauchot, M.-L., Hureau, J.C., Neilsen, J., and Tortonese, E., (1986) Clupeidae. *In* Fishes of the North-eastern Atlantic and the Mediterranean Volume I. UNESCO, Paris, 268-281.

Winslade, P., (1974a) Behavioural studies on the lesser sandeel *Ammodytes marinus* (Raitt) I. The effect of food availability on activity and the role of olfaction in food detection. Journal of Fish Biology, 6: 565–576. doi: 10.1111/j.1095-8649.1974.tb05100.

Winslade, P., (1974b) Behavioural studies on the lesser sandeel *Ammodytes marinus* (Raitt) III. The effect of temperature on activity and the environmental control of the annual cycle of activity. Journal of Fish Biology, 6: 587–599. doi: 10.1111/j.1095-8649.1974.tb05102.x

Wright P. J. And Bailey M.C., (1993) Biology of Sandeels in the vicinity of Seabird colonies at Shetland. Fisheries Research Report No. 15/93.

Wright, P. J. and Begg, G. S., (1997) A spatial comparison of common guillemots and sandeels in Scottish waters. – ICES Journal of Marine Science, 54: 578–592

Wright, P. J., and Bailey, M. C., (1996) Timing of hatching in Ammodytes marinus from Shetland waters and its significance to early growth and survivorship. Marine Biology, 126: 143e152. Cited in Jensen et al (2003).

Wright P.J., (1998) Proposed stock structure for Ammodytes marinus. *In* Wright, P.J. and Kennedy, F.M., (1999) Proceedings of a workshop held at FRS Marine Laboratory Aberedeen 22-24 February 1999. Fisheries Research Services Report No 12/99.

Wright, P.J., Pedersen, S.S., Anderson, C., Lewy, P., Proctor, R., (1998) The influence of physical factors on the distribution of lesser sandeel, Ammodytes marinus and its relevance to fishing pressure in the North Sea. ICES ASC CM/ AA: 3.

Wright, P.J. and Kennedy, F.M., (1999) Proceedings of a workshop held at FRS Marine Laboratory Aberedeen 22-24 February 1999. Fisheries Research Services Report No 12/99.

Wright P.J., (1999a) Development of Survey Methods. *In* Wright, P.J. and Kennedy, F.M., (1999) Proceedings of a workshop held at FRS Marine Laboratory Aberedeen 22-24 February 1999. Fisheries Research Services Report No 12/99.

Wright, P.J., Jensen, H. and Tuck, I., (2000) The influence of sediment type on the distribution of the Lesser Sandeel, *Ammodytes marinus*. J Sea Res 44:243–256.

Wright, P.J., Gibb, F.M., Gibb, I.M., Heath, M. R. and McLay, H.A., (2003) North Sea cod spawning grounds. Fisheries Research Services Internal Report No 17/03.

Wright, P.J., Neat, F.C., Gibb, F.M., Gibb, I.M. and Gallego, A., (2007) Cod movements in relation to sub-stock structure in the North Sea and west of Scotland. Fisheries Research Services Internal.

Young, I.A.G., Pierce, G.J., Stowasser, G., Santos, M.B., Wang, J., Boyle, P.R., Shaw, P.W., Bailey, N., Tuck, I. And Collins, M.A., (2006) The Moray Firth directed squid fishery. Fisheries Research 78 (2006) 39–43.

8.0 Annex: Nursery Grounds

8.1 Nephrops nursery grounds

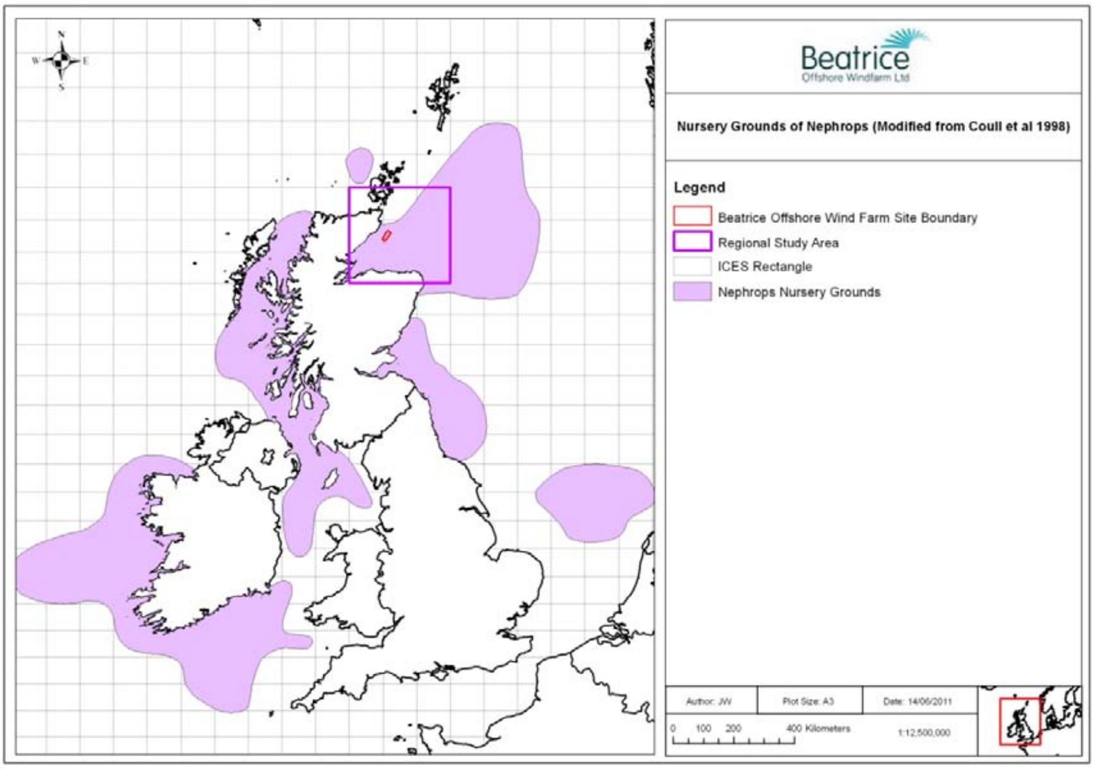

Figure 8a Nephrops nursery grounds (modified from Coull *et al* 1998)

8.2 Sandeels nursery grounds

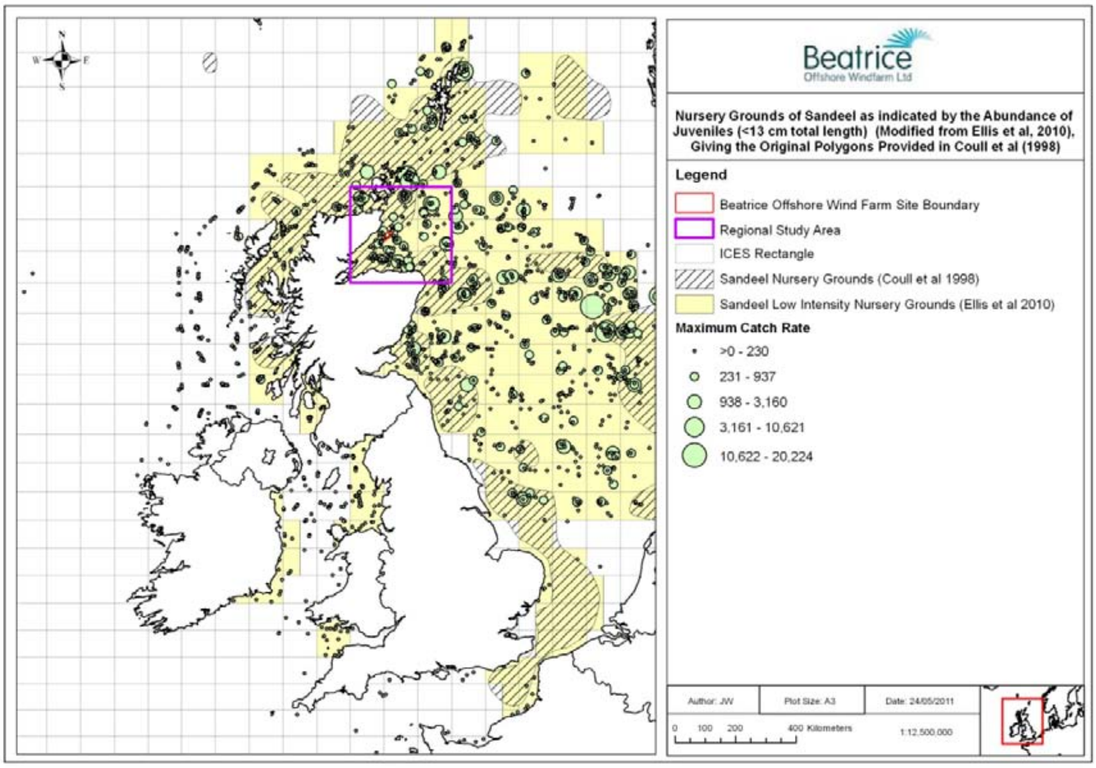

Figure 8b Sandeel nursery grounds (modified from Ellis *et al* 2010a)

8.3 Herring nursery grounds

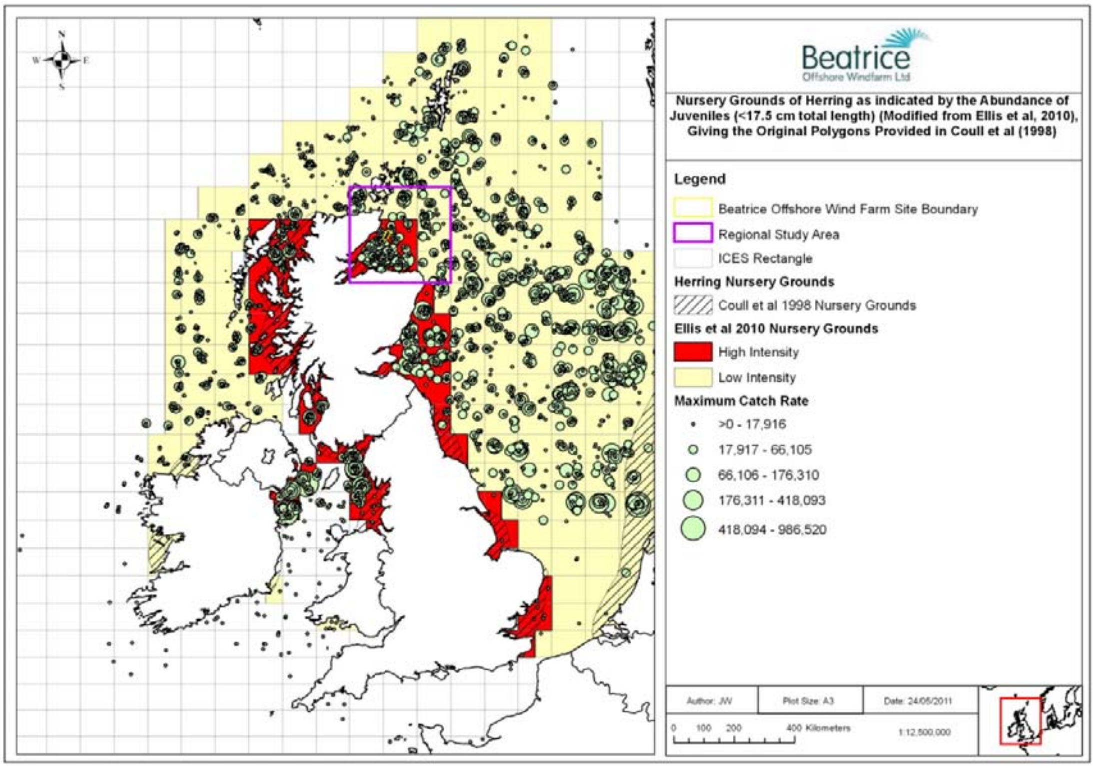

Figure 8c Herring nursery grounds (modified from Ellis *et al* 2010a)

8.4 Cod nursery grounds

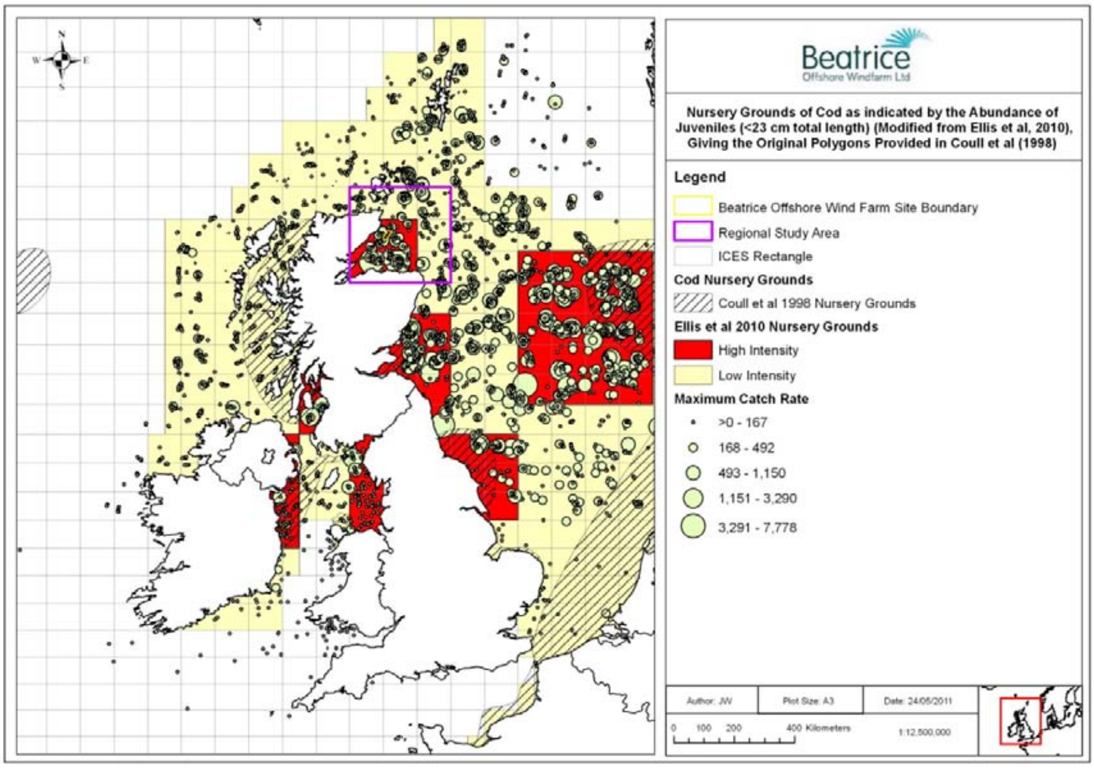

Figure 8d Cod nursery grounds (modified from Ellis *et al* 2010a)

8.5 Plaice nursery grounds

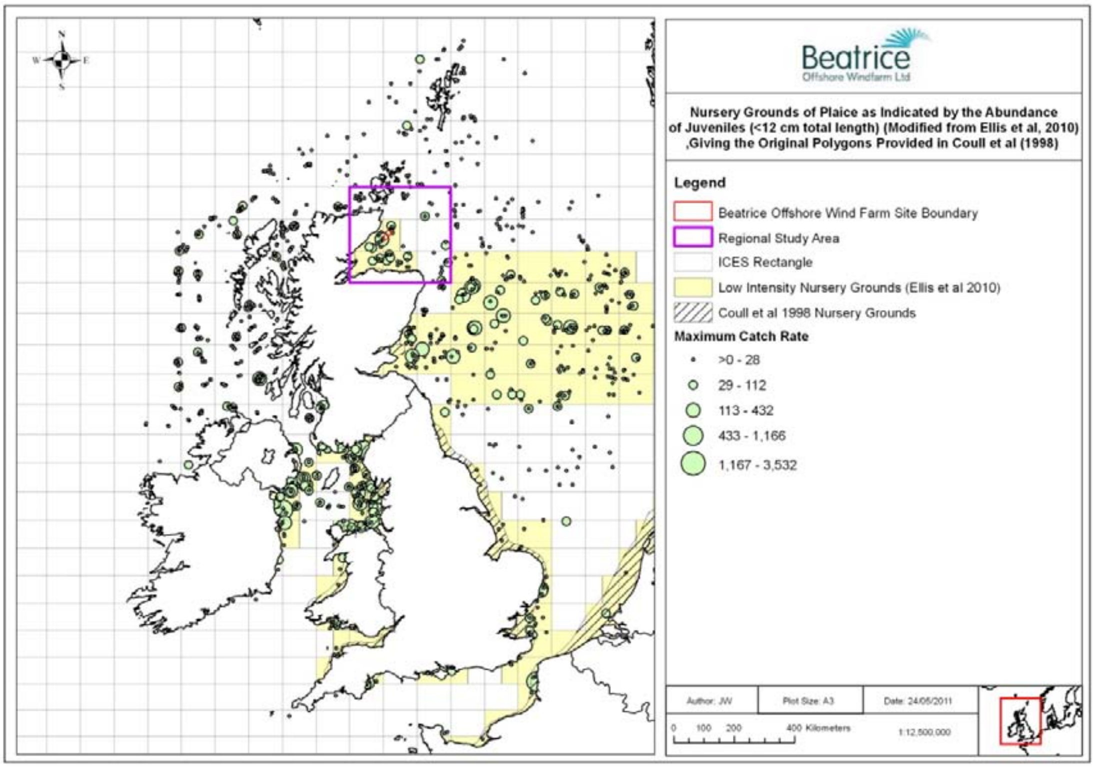

Figure 8e Plaice nursery grounds (modified from Ellis *et al* 2010a)

8.6 Lemon sole nursery grounds

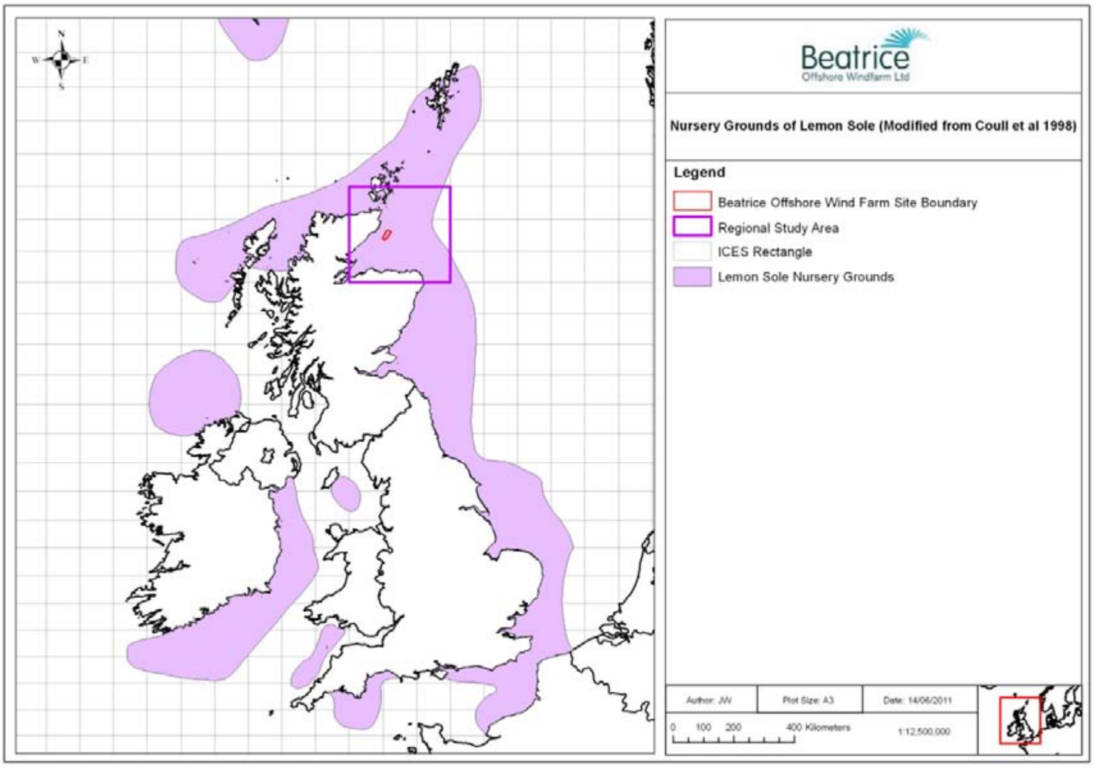

Figure 8f Lemon sole nursery grounds (modified from Coull *et al* 1998)

8.7 Sprat nursery grounds

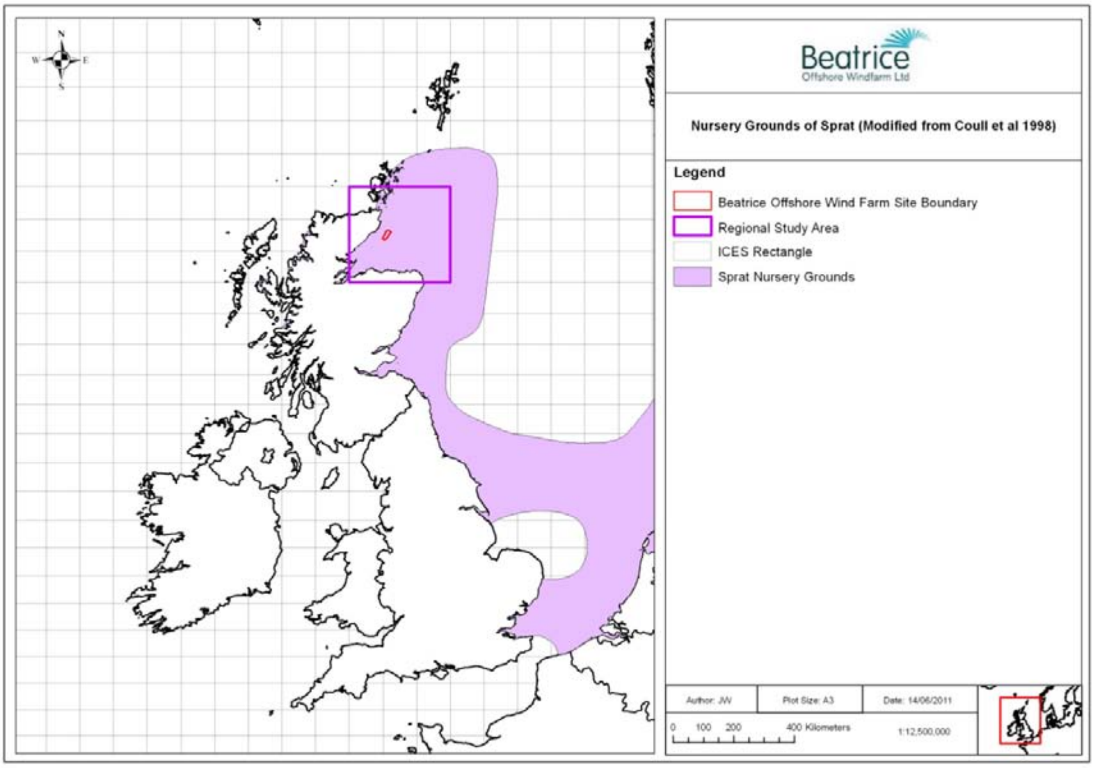

Figure 8g Sprat nursery grounds (modified from Coull *et al* 1998)

8.8 Whiting nursery grounds

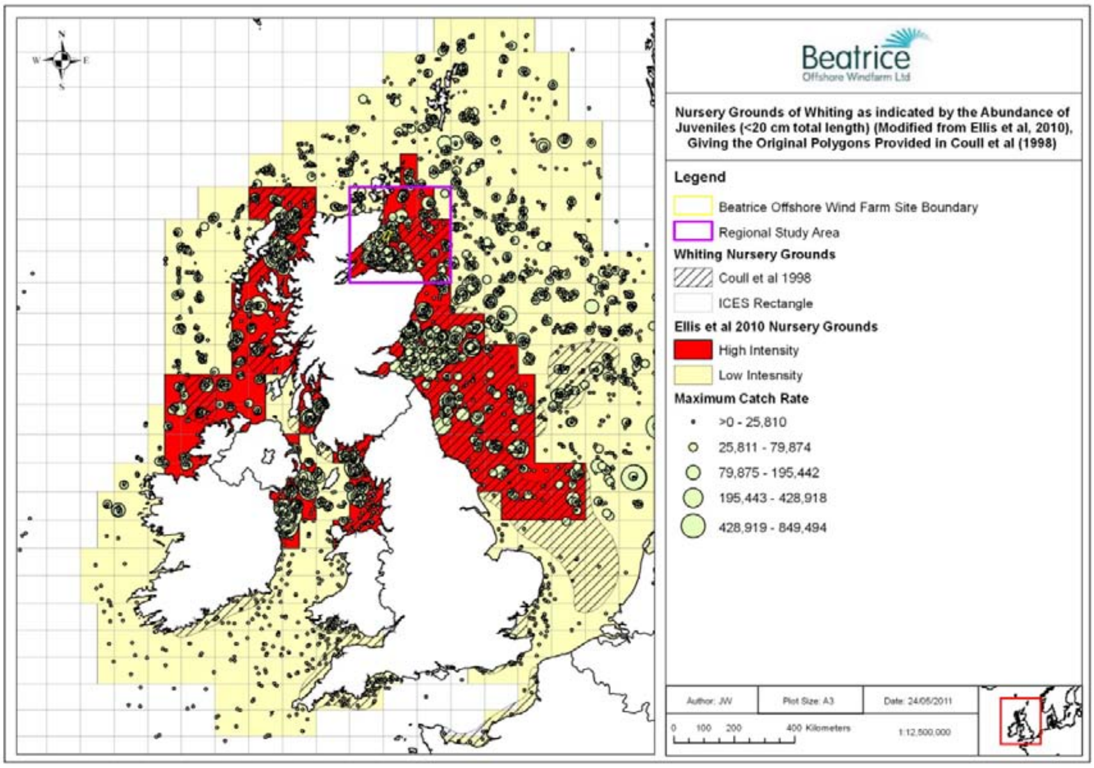

Figure 8h Whiting nursery grounds (modified from Ellis *et al* 2010a)

8.9 Spurdog nursery grounds

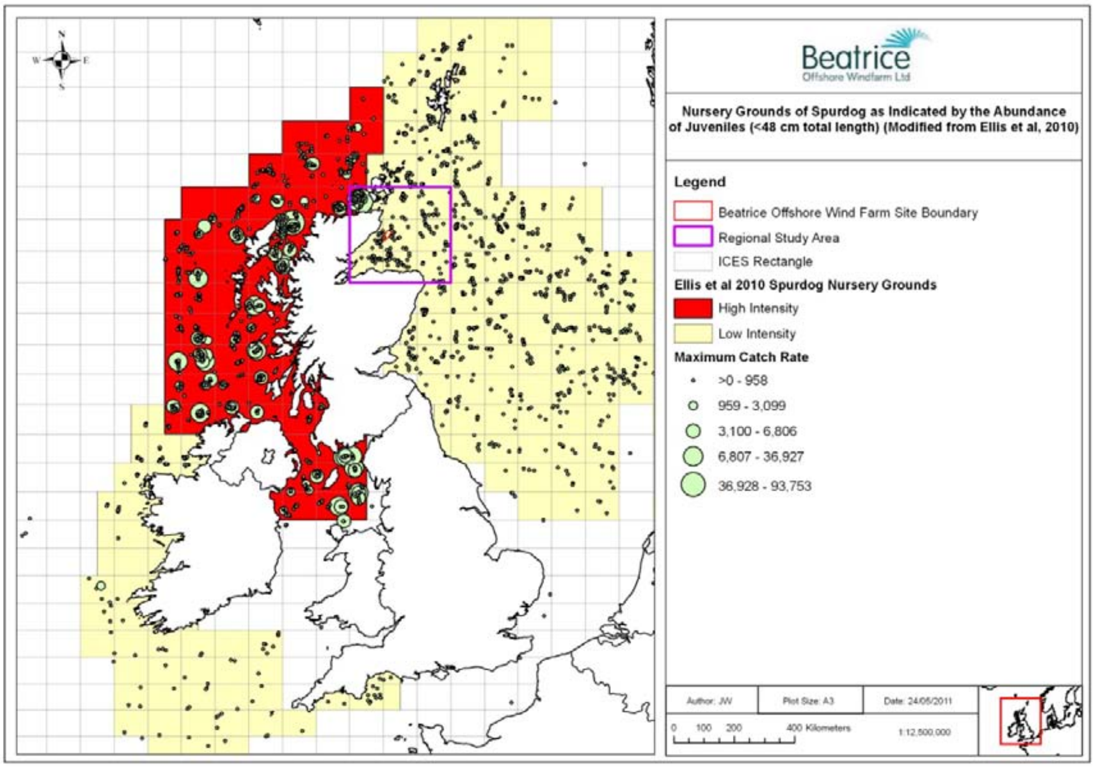

Figure 8i Spurdog nursery grounds (modified from Ellis *et al* 2010a)

8.10 Thornback ray nursery grounds

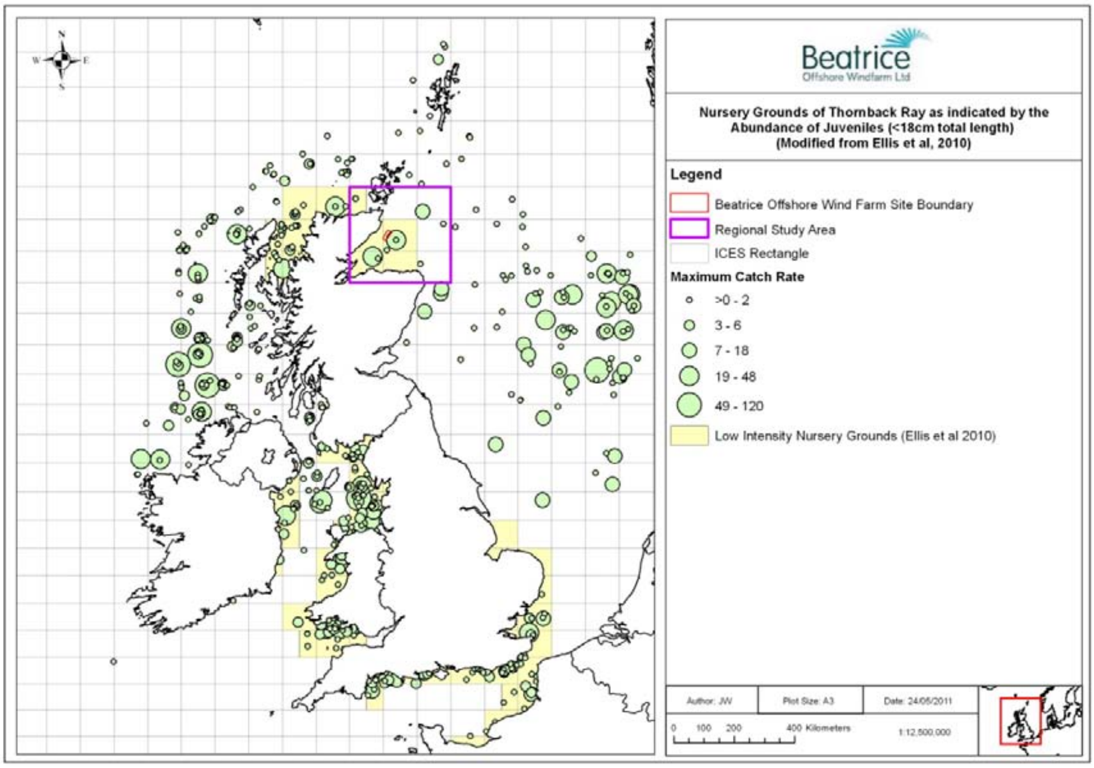

Figure 8j Thornback ray nursery grounds (modified from Ellis *et al* 2010a)

8.11 Spotted ray nursery grounds

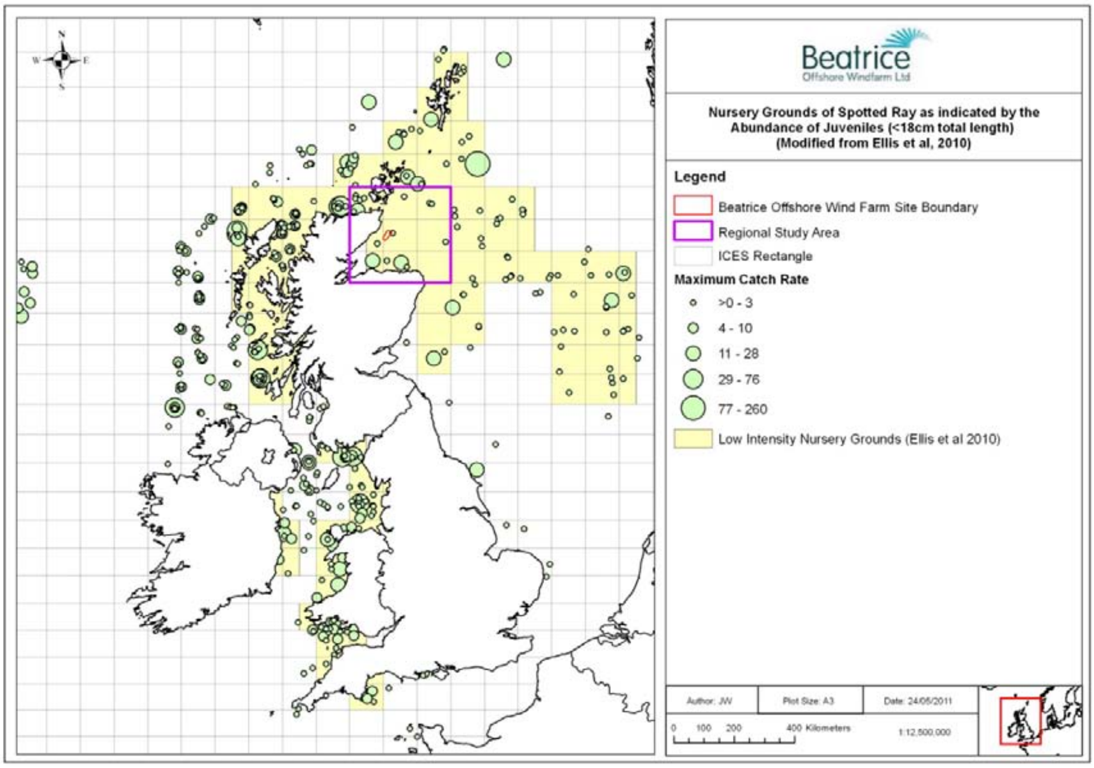

Figure 8k Spotted ray nursery grounds (modified from Ellis *et al* 2010a)

8.12 Blue whiting nursery grounds

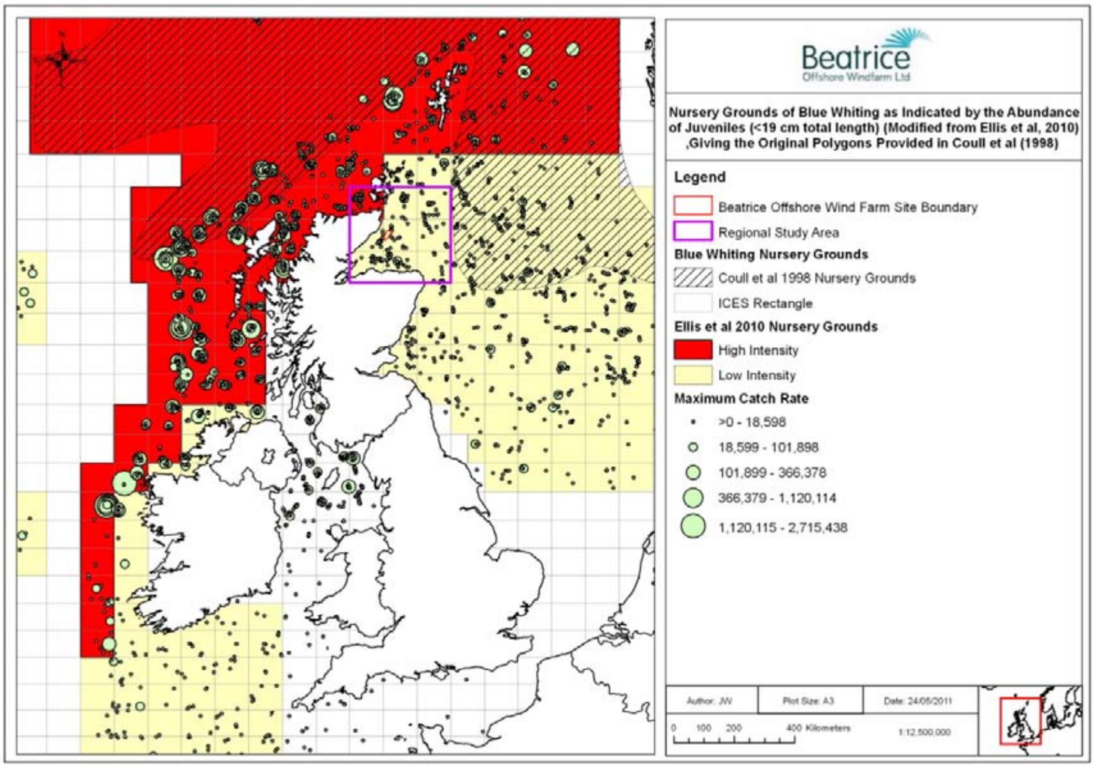

Figure 8l Blue whiting nursery grounds (modified from Ellis *et al* 2010a)

8.13 Ling nursery grounds

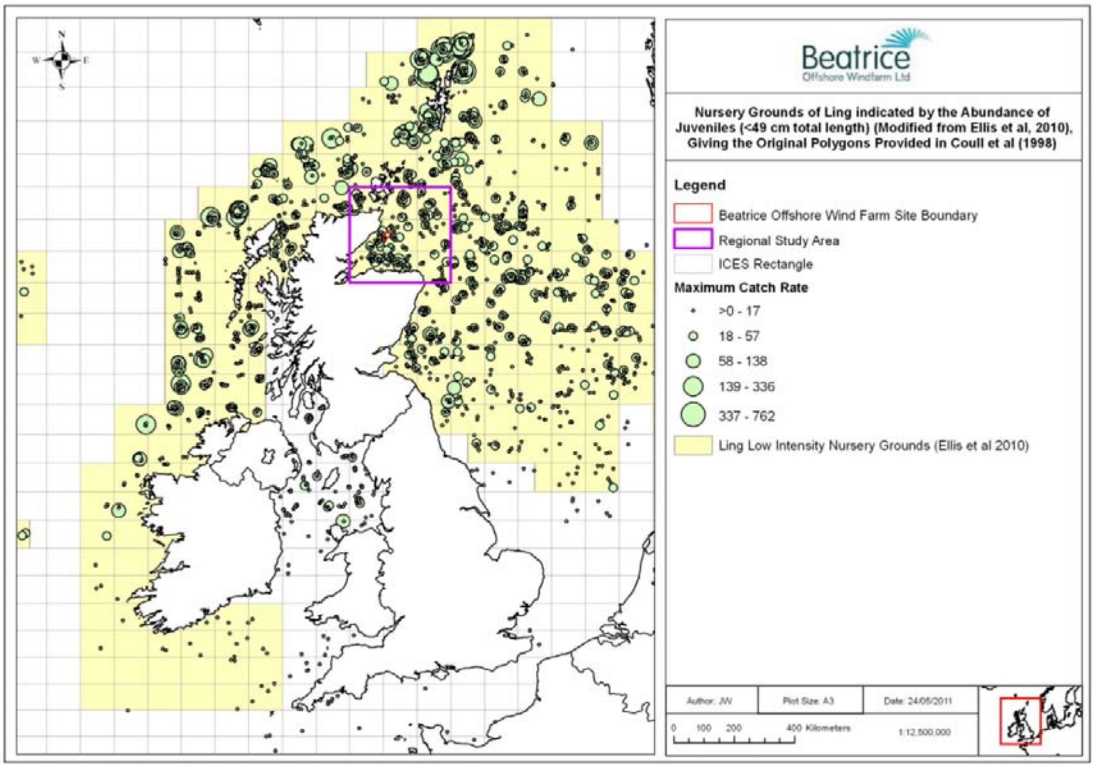

Figure 8m Ling nursery grounds (modified from Ellis *et al* 2010a)

8.14 Hake nursery grounds

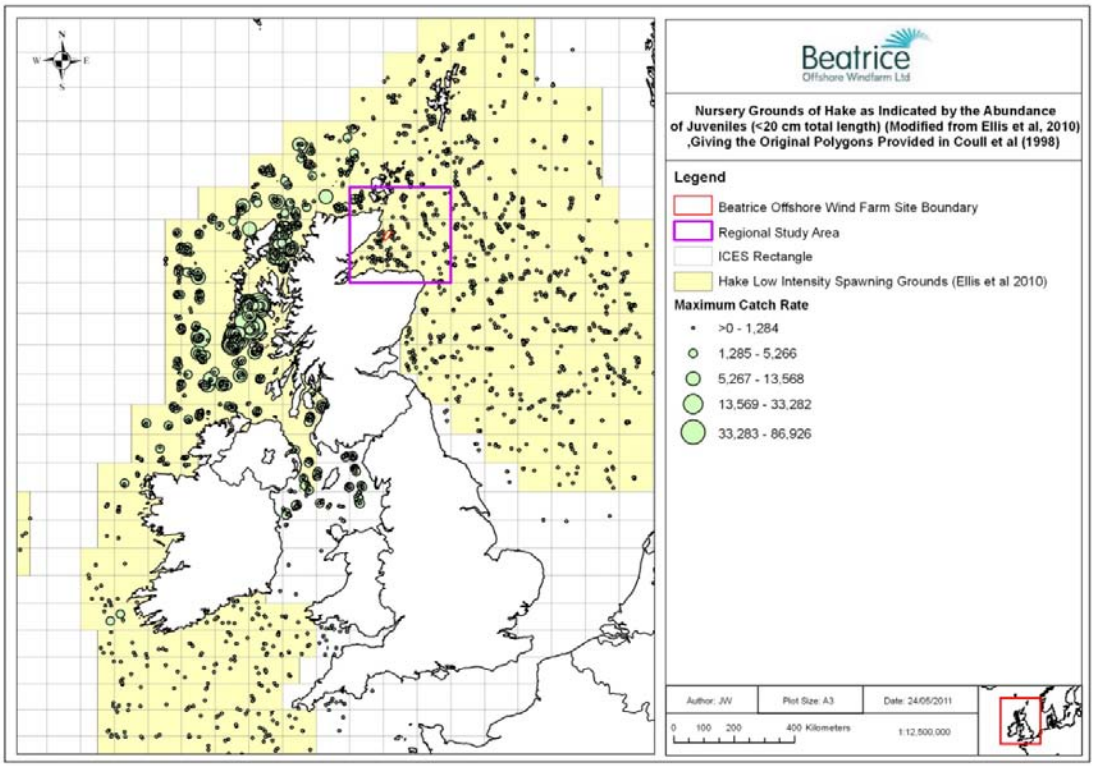

Figure 8n Hake nursery grounds (modified from Ellis *et al* 2010a)

8.15 Anglerfish nursery grounds

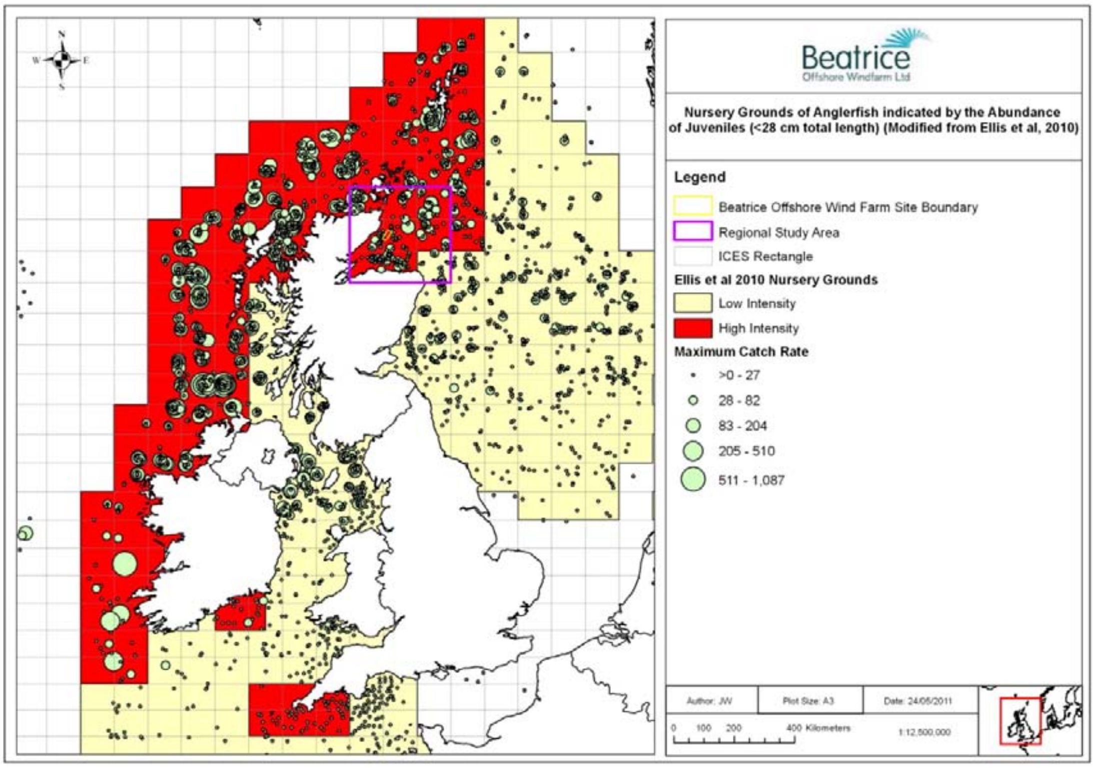

Figure 8o Anglerfish nursery grounds (modified from Ellis *et al* 2010a)

8.16 Mackerel nursery grounds

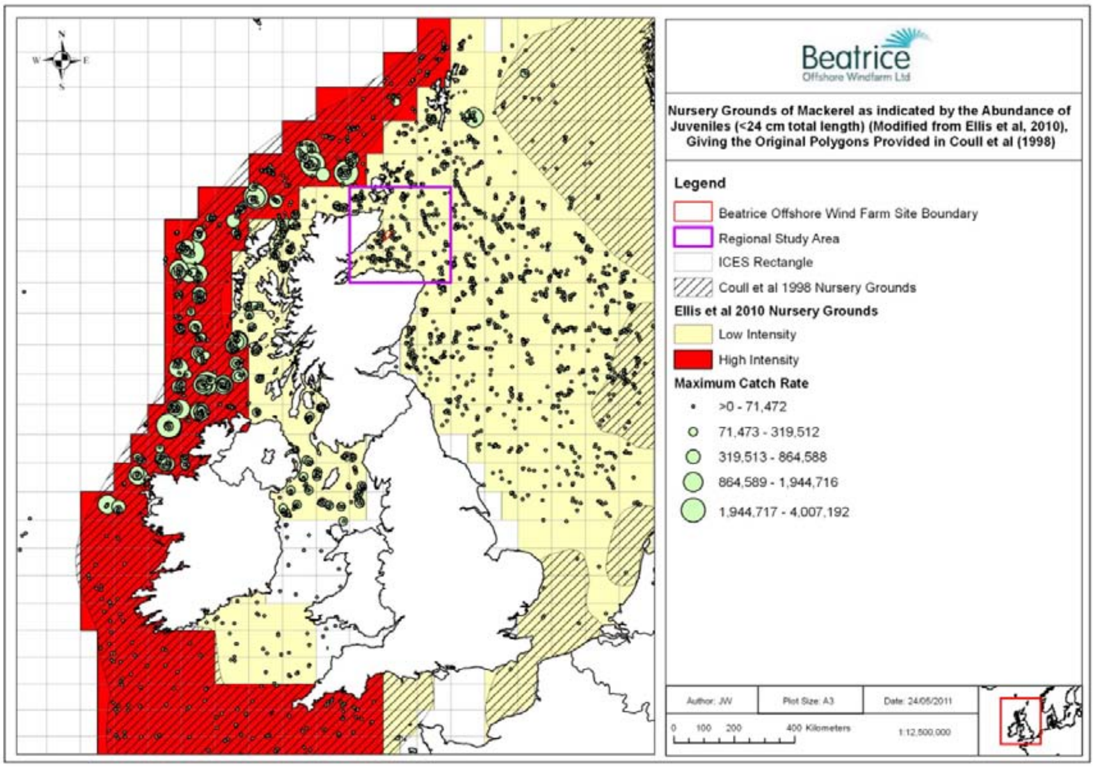

Figure 8p Mackerel nursery grounds (modified from Ellis *et al* 2010a)

8.17 Haddock nursery grounds

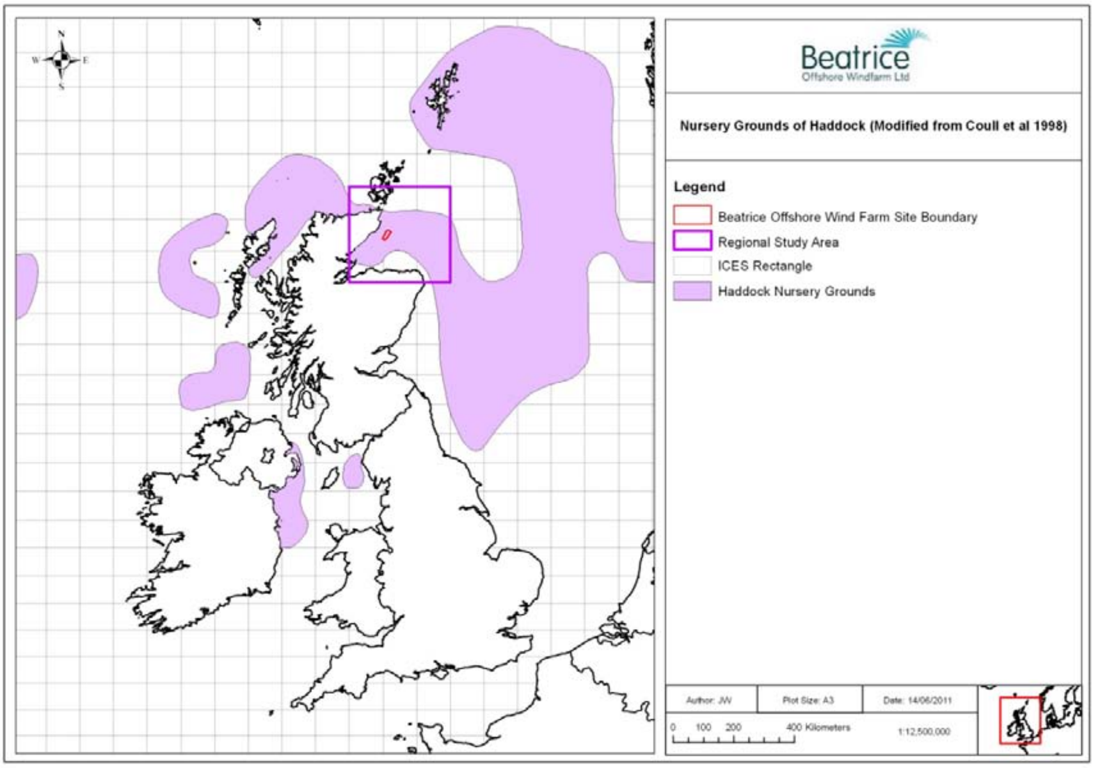

Figure 8q Haddock nursery grounds (modified from Coull *et al* 1998)

8.18 Saithe

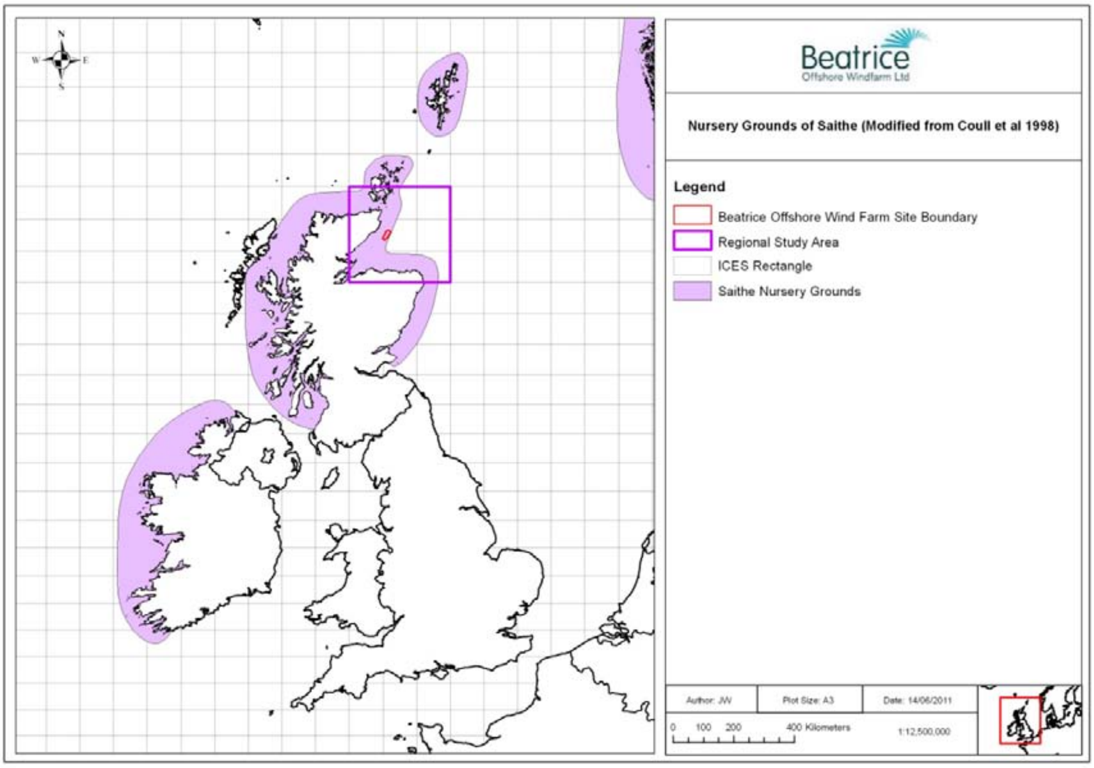

Figure 8r Saithe nursery grounds (modified from Coull *et al* 1998)