

## APPENDIX 4 - FISH AND SHELLFISH ECOLOGY

### Introduction

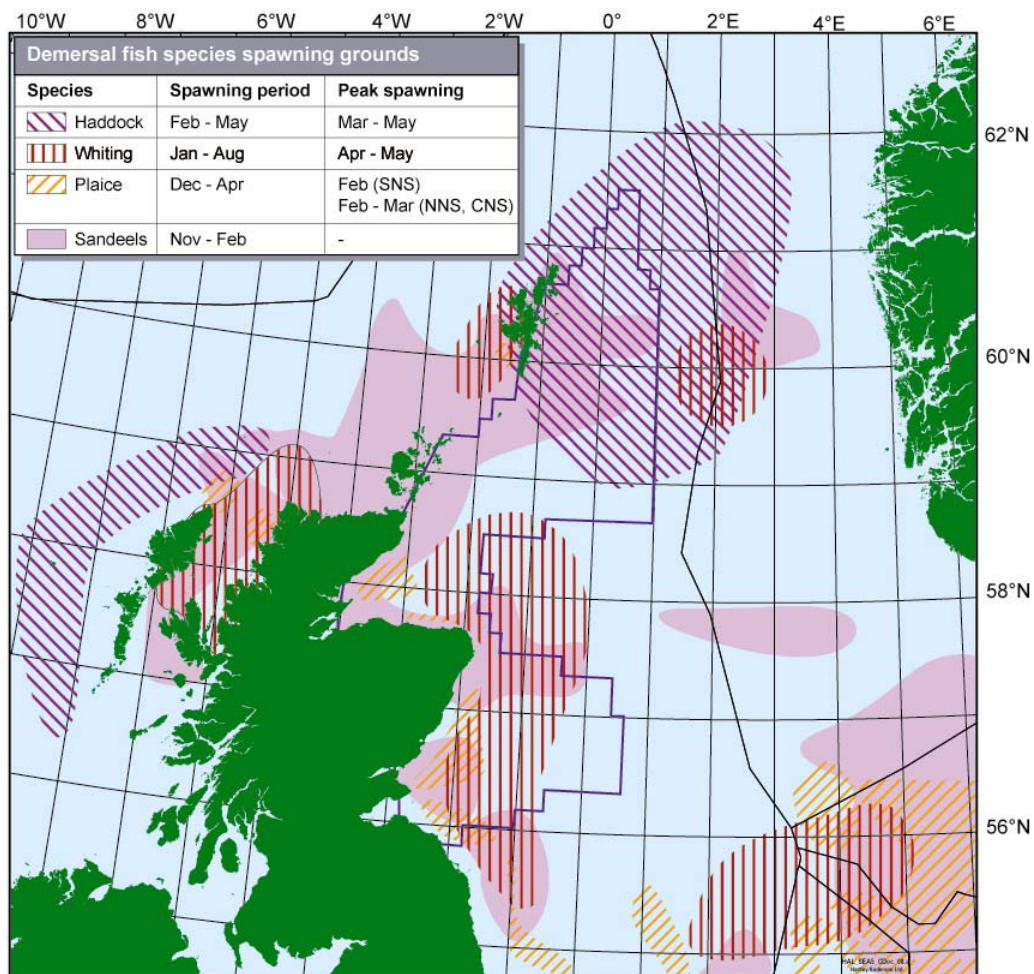
This section provides further ecological information relating to the main fish and shellfish species which are commercially exploited in the SEA 5 area. Much of the information comes from the CEFAS (2001) report for SEA 2.

Spawning and nursery areas for most fish species are dynamic features and are rarely fixed in one location from year to year. Thus, while some species have similar patterns of distribution from one season to the next, others show greater variability. General spawning areas (Coull *et al.* 1998) for the main demersal, pelagic and shellfish species in SEA 5 are highlighted below.

### Demersal fish species

Figures A4.1 and A4.2 provide information on the spawning grounds and timing of spawning of the main demersal fish species in the SEA 5 area including haddock, whiting, plaice, sandeel, saithe, Norway pout, cod and lemon sole. Further information regarding the ecology of these species is presented below.

Figure A4.1 – Spawning grounds of demersal fish species in the SEA 5 area



Source: Coull *et al.* (1998)

## Haddock

Haddock occur throughout the northern North Sea, although they can occasionally be caught south of the Dogger Bank during the summer. Haddock are generally regarded as benthic fish but they can also be found in midwater, and this is confirmed by their adult diet, which includes sandeel, Norway pout, long rough dab, gobies, sprat and herring (Cranmer 1986).

In the North Sea, haddock spawn between February and May, with peak spawning activity between mid-March and early April. The main spawning area is in the northern North Sea between the Shetland Islands and the Norwegian Deep, and southwards towards the Fladen Ground (Figure A4.1). After spawning, adult haddock disperse and migrate westward toward the Orkney and Shetland Islands and into the central North Sea to feed. The eggs and larvae are pelagic and mainly distributed in surface waters to a depth of approximately 40m (Bjorke & Saetre 1994). At about seven months of age and at a length of about 5cm, the young fish leave their pelagic phase, and enter a bottom-dwelling phase. Haddock larvae feed on immature copepods (Russell 1976), while decapod larvae, copepods and fish are food items for juvenile haddock (Robb & Hislop 1980). During the late summer the juveniles are at their highest density off the northeast coast of Scotland (Albert 1991).

## Whiting

Whiting is one of the most numerous and widespread species found in the North Sea. The whiting diet includes juvenile fish, crabs and shrimps and it is one of the main predators of other commercially important fish species with Norway pout, sprats, sandeel, young herring, cod, haddock and even whiting themselves frequently eaten (Knijn *et al.* 1993).

Whiting on average attain sexual maturity at 2 years of age (Knijn *et al.* 1993). The spawning season for an individual female lasts at least 10 weeks, during which time she releases many batches of eggs. The main spawning areas for whiting are in the central North Sea north of the Dogger Bank and off the east coast of Scotland (Figure A4.1). The spawning season is long and extends from January in the south through to late August, or early September, in the north, but the majority of spawning takes place in April-May. Hatching typically takes 8 to 12 days depending on the water temperature. The spatial distribution of 0-group whiting in the pelagic phase is extensive and during summer juveniles can be found throughout much of the North Sea, but particularly to the northeast and east of Scotland and off northeastern England (Gordon 1977).

## Plaice

Plaice are typically a coastal species, and can be found at highest abundance in the southern part of the North Sea, along the east coast of the UK, and in the eastern Channel, Skagerrak and Kattegat. Plaice are flatfish which live on mixed substrates at depths of between a few metres to around 200m, with older individuals generally occurring in deeper water.

Plaice spawn throughout the shallower parts of the southern North Sea and off the eastern coast of Britain, from Flamborough Head to the Moray Firth, with peak spawning in the SEA 5 area between February and March (Figure A4.1). Shallow, sandy bays and estuaries on the North Sea coasts of England and continental Europe act as important nursery areas for plaice, and juveniles gradually disperse further offshore away from these nursery areas as they get older (Rijnsdorp 1989). Polychaete worms are often the most important prey items for plaice but crustacean species such as amphipods, mysids, bivalve molluscs and brittle stars are also important (De Clerck & Buseyne 1989).

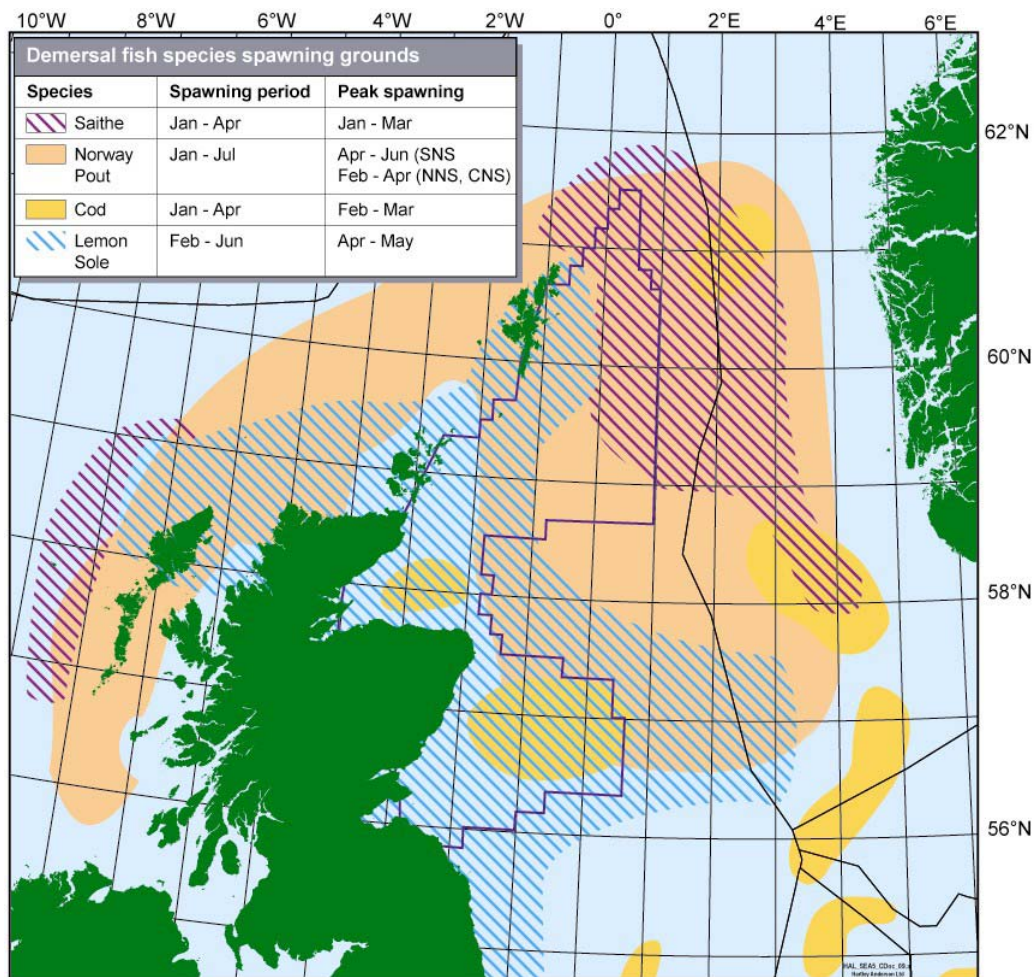
## Sandeel

There are five species of sandeel in the North Sea, though the majority of commercial landings are of *Ammodytes marinus*.

Sandeels are a shoaling species which lie buried in the sand during the night, and hunt for prey in mid-water during daylight hours. They feed mainly on planktonic prey such as copepods and crustacean larvae, but also consume polychaete worms, amphipods, and small fish, including other sandeels.

Spawning of *A. marinus* usually takes place between November and February with spawning activity occurring throughout much of the southern and central North Sea, but especially near sandy sediments off the coasts of Denmark, northeastern England, eastern Scotland, and the Orkney Islands (Figure A4.1). Sandeel eggs are demersal, and are laid in sticky clumps on sandy substrates. On hatching, the larvae are planktonic before adopting a demersal habit after 2-5 months. Tagging experiments have shown that there is little movement between spawning and feeding grounds, indicating that fishing and spawning grounds may coincide (Kunzlik *et al.* 1986). Sandeels are an important food item for mackerel, whiting, cod, salmon, other economically important fish species, seabirds and marine mammals.

Figure A4.2 – Spawning grounds of demersal fish species in the SEA 5 area



Source: Coull *et al.* (1998)

## Saithe

Saithe is a northern species and is widely dispersed in northern European waters. Adults are generally found in continental shelf and slope waters at depths of 80-450m (Jakobsen & Olsen 1987). Adult saithe feed on a range of demersal prey, including crustaceans and fish species such as sandeel, Norway pout, and haddock (Gislason 1983).

The main spawning areas for saithe are in the northern North Sea east of the Shetland Islands, and along the edge of the Norwegian Deep (Figure A4.2). There is a regular pattern of spawning migration from the Norwegian coast to spawning grounds in the northern North Sea and elsewhere in the Norwegian Sea. Spawning takes place mainly over the period January to March. After a short pelagic phase, the young fish migrate into inshore and coastal waters. By winter most of the juvenile stages are concentrated in the coastal waters of Norway, Scotland, Iceland and the Faroe Islands. Juvenile saithe have a similar diet to adults, and are known to consume a wide range of fish species such as herring, cod, and sandeel, as well as benthic invertebrates. Young saithe remain in these nursery areas up to the age of 3 or 4 before slowly migrating into deeper water. Tagging experiments have shown that young saithe leave their Scottish coastal nurseries during the spring and recruit to the stocks in the northern North Sea (Newton 1984).

## Norway pout

Norway pout are generally found in waters of 80-200m over sandy and muddy substrates, but also occur in waters of up to 450m depth in the Norwegian Deep (Bergstad 1990). They are typically found in the northern and central areas of the North Sea and in the Skagerrak and Kattegat, with the centre of distribution lying midway between the Shetland Islands and the Norwegian coast (Knijn *et al.* 1993). They are a gregarious species, often found in large schools. Norway pout is a benthic predator feeding on small crustaceans, amphipods, shrimps and small fish (Mattson 1981).

Spawning usually takes place between January and July, with the period of most intense activity in the central and northern North Sea between February and April. The precise location of spawning areas is not well understood but most spawning activity appears to be restricted to waters within the depth range of 50-200m (Figure A4.2). The majority of fish spawn for the first time when they are in their second year, but some may do so when they are one year old (Raitt & Mason 1968). During June and July, the pelagic 0-groups are thought to migrate vertically within the water column, spending most of the daylight hours close to the seabed and moving into midwater at night (Bailey 1975). Norway pout are not generally considered to have specific nursery grounds but pelagic 0-group fish remain widely dispersed in the northern North Sea close to spawning grounds. Juvenile and adult Norway pout are an important prey for haddock, whiting, cod and hake (Muus & Dahlstrom 1974).

## Cod

Cod occur throughout the central and northern North Sea. Recaptures of cod tagged in the North Sea indicate limited exchange of individuals between the North Sea and waters to the west of Scotland, but more exchange between the North Sea and the eastern Channel and the North Sea and the Skagerrak. Cod are a predatory species, and have a varied diet consisting of herring, capelin, haddock, codling, sandeels and other fish species. They also feed on *Nephrops*, shrimps, amphipods, polychaetes, and other benthic organisms.

Cod spawn all over the North Sea, although spawning is concentrated, particularly in the central and northern North Sea and around the Dogger Bank (Figure A4.2). There is also spawning activity in coastal waters off the east coast of Scotland and the northeast coast of

England. Spawning takes place mainly between January and April, peaking in February and March in the central North Sea. At that time, the eggs are found floating near the water surface over large areas (Daan 1978).

Cod eggs typically hatch at a length of about 4mm over a period of 2-3 weeks, depending on water temperature, and the young fish grow to between 20 and 80mm by June. Most cod larvae are distributed in the upper 30m of the water column, with their horizontal distribution determined by circulation and bottom topography (Brander 1994). Cod aged 1-2 years old can be found all over the North Sea but are concentrated in the shallow coastal waters of the eastern North Sea and the rocky coastal waters of the UK and Norwegian coast.

Since 1990, cod recruitment has been low with the removal of older fish from the stock by fishing thought to be a major contributory factor. There is evidence indicating that small young female fish: produce fewer eggs; produce eggs that are smaller and have a lower chance of survival; are inexperienced in spawning and are less effective in mating and producing healthy eggs; and, produce fewer batches of eggs over a shorter period of the spawning season, so that they are less likely to hit optimum conditions for survival of the eggs and larvae. High fishing mortality may, therefore, have resulted in a stock comprised of mainly small young fish that cannot generate the level of recruitment that older fish can achieve, thereby impeding stock recovery (RSE 2004).

Cod have been included on the OSPAR Initial List of Threatened and/or Declining Species and Habitats. The OSPAR justification for its inclusion highlighted overfishing in directed fisheries, as well as bycatch in mixed fisheries where juvenile cod in particular may be caught and then discarded as the greatest threat to cod stocks (OSPAR Commission 2004). In the North Sea, the combination of the very high exploitation rate and the relatively advanced age at which cod mature (3 to 6 years) means that less than 1% of the 1 year old fish in the North Sea are believed to survive to maturity (OSPAR Commission 2004).

## Lemon sole

Despite its name, the lemon sole does not belong to the sole family. The centre of distribution of mature lemon sole is in the coastal waters of northern Scotland and the Orkney and Shetland Islands, but they are also found off the northeastern coast of England and throughout the central and northern North Sea.

Lemon sole feed on a variety of benthic prey, including polychaete worms, crustaceans, molluscs and echinoderms. Spawning takes place over a wide area (Figure A4.2), and off the Scottish east coast extends from April to September. Nursery areas have a similar distribution to the spawning areas.

## Monkfish

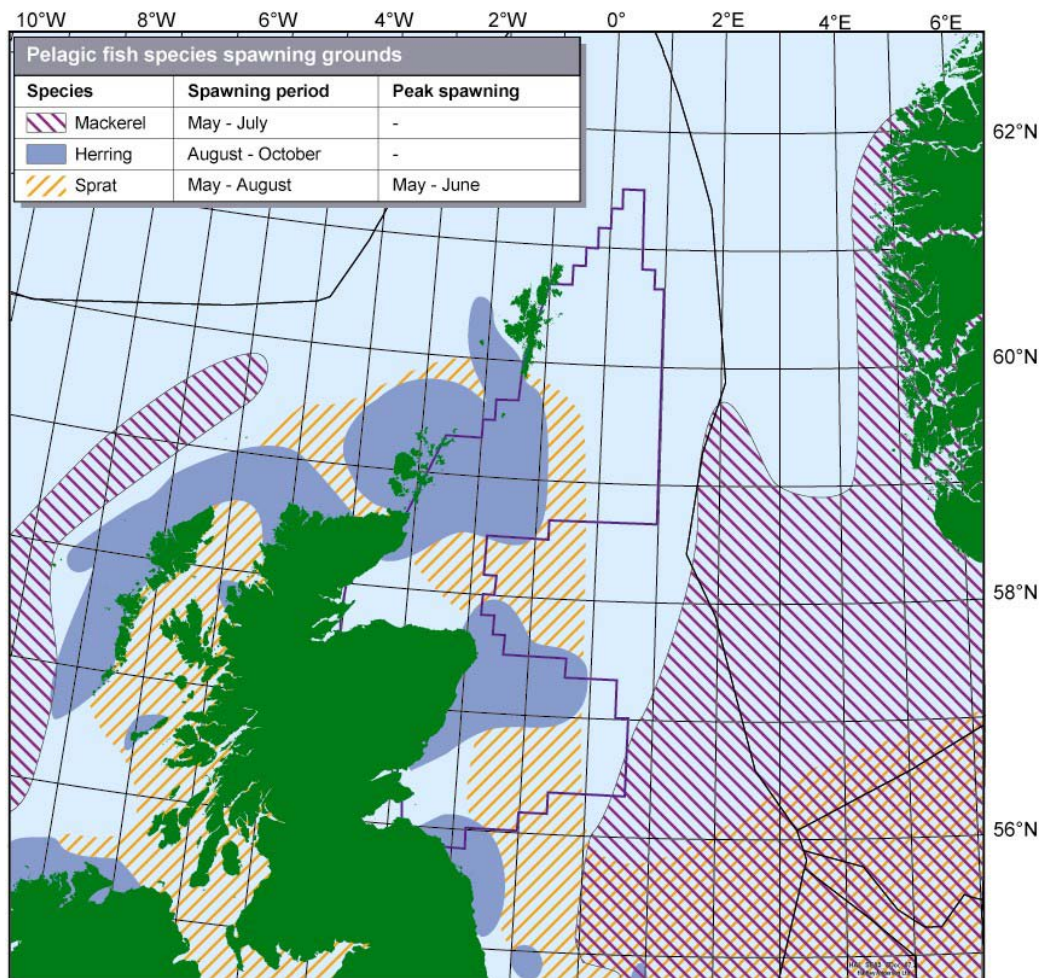
In UK waters there are two species of monkfish, the black bellied monkfish (*Lophius budegassa*) and the white monkfish (*Lophius piscatorius*). The latter predominates north of latitude 55°N in ICES Sub-area IV (North Sea) and Division VIa (West of Scotland) (Kunzlik *et al.* 1986). The basic biology of the two species is very similar, although in the waters surrounding the UK and Ireland, *L. budegassa* is found predominantly in the deeper waters of the continental shelf and slope. Monkfish are found in a wide range of depths, extending from the very shallow inshore waters down to around 1100m. Juvenile monkfish (mainly *L. piscatorius*) can be found over most of the northern North Sea to depths of about 150m, while spawning adults are found at all depths but are generally scarce in coastal waters.

Spawning takes place during January to June in relatively deep water, and although monkfish have a long spawning season, each female probably produces only one batch of eggs. Spawning female *L. piscatorius* have been found between November and May (Afonso-Dias & Hislop 1996) and spawning may extend into August. Females do not mature until they are at least seven years of age and many are caught before they have had the opportunity to spawn. After hatching, young fish spend three or four months in mid-water before they settle on the seabed (Hislop *et al.* 2001). Monkfish feed on a wide range of small fish which are enticed by a lure that extends from the top of the head.

### Pelagic fish species

Figure A4.3 provides information on the spawning grounds and timing of spawning of the main pelagic species in the SEA 5 area, including mackerel, herring and sprat. Further information regarding the ecology of these species is presented below.

Figure A4.3 – Spawning grounds of pelagic fish species in the SEA 5 area



Source: Coull *et al.* (1998)

### Mackerel

Mackerel are fast swimming pelagic fish that are widespread in north Atlantic shelf waters. Two main stocks occur in the northeast Atlantic, the western stock and the North Sea stock, and this separation is based on differences in the timing and the areas used for spawning.

Mackerel principally prey on small pelagic crustaceans but they also prey upon fish such as herring, sprat, sandeel and Norway pout.

The North Sea mackerel stock over-winters in the deepwater to the east and north of the Shetland Islands, and on the edge of the Norwegian Deep. In spring, they migrate south to spawn in the North Sea between May and August, but they may also spawn along the southern coast of Norway and in the Skagerrak (Figure A4.3). The pelagic eggs can be found in the central North Sea at depths to 60m below the surface, but the majority are found in the upper mixed layer. The North Sea stock has been at a very low level for many years due to high fishing pressure and poor recruitment.

The western mackerel stock is found on the shelf and near to the continental slope to the west of the British Isles, and occupies a very large area. These fish spawn between March and July, mainly to the southwest of the UK and Ireland, before migrating northwards to the feeding grounds north of Scotland and in the North Sea and Norwegian Sea. The return migration of the western stock forms the main target of the directed mackerel fishery.

The western stock currently over-winters in the northern North Sea, off northern Scotland and around the Shetland Isles, where they mix with the North Sea stock (ICES 1996). During the late 1960s and throughout the 1970s, most of the western stock over-wintered in the western English Channel. It is not understood why these changes took place, but it may have been a response to changes in the environment, possibly water temperature. In late winter and early spring, adult western mackerel move from the wintering grounds back towards their spawning areas (Eltink 1987).

## Herring

Atlantic herring are found throughout the shelf waters of northwestern Europe from the northern Bay of Biscay to Greenland, and east into the Barents Sea. During daytime, herring shoals remain close to the seabed or in deep water to a depth of 200m. At dusk they move towards the surface and disperse over a wide area. These diurnal vertical movements may be related to the availability of prey items or to the stage in their maturation cycle (Harden-Jones 1968). There are three major populations of herring in the North Sea which can be identified by differences in their spawning time and area. These 'races' are mixed for the majority of the year, but separate during the breeding season when each race migrates to its own spawning grounds (Daan *et al.* 1990). The races are:

- Buchan/Shetland herring, which spawns off the northeast Scottish coast and Shetland coasts during August to September (Figure A4.3).
- Banks or Dogger herring, which spawns in the central North Sea off the northeast English coast during August to October (Figure A4.3).
- Southern Bight/Downs herring, which spawns in the English Channel and Southern Bight of the North Sea during November to January.

Spawning normally takes place in relatively shallow water, at depths of approximately 15-40m. Herring deposit sticky eggs on coarse sand, gravel, shells and small stones, and shoals congregate on traditional spawning grounds where all members of the shoal spawn more or less simultaneously. Each female will produce a single batch of eggs every year, but there are pronounced differences in the number, sizes and weights of the eggs produced by each of the different spawning 'races'. Incubation of herring eggs takes one to three weeks depending on water temperature, and when the eggs hatch the pelagic larvae are transported by the prevailing water currents. Most autumn spawned herring larvae drift in an easterly direction from the western North Sea towards important nursery grounds in the eastern North Sea and to the Skagerrak and the Kattegat.

Larvae from the west of Scotland are thought to drift into the Moray Firth, and the Firth of Forth also provides a nursery area for herring of more uncertain origin. The pelagic larvae feed on copepods, euphausiids, juvenile sandeel and fish eggs (Last 1989). The dependency of herring on specific substrates makes the species particularly susceptible to impacts resulting from oil and gas exploration and production.

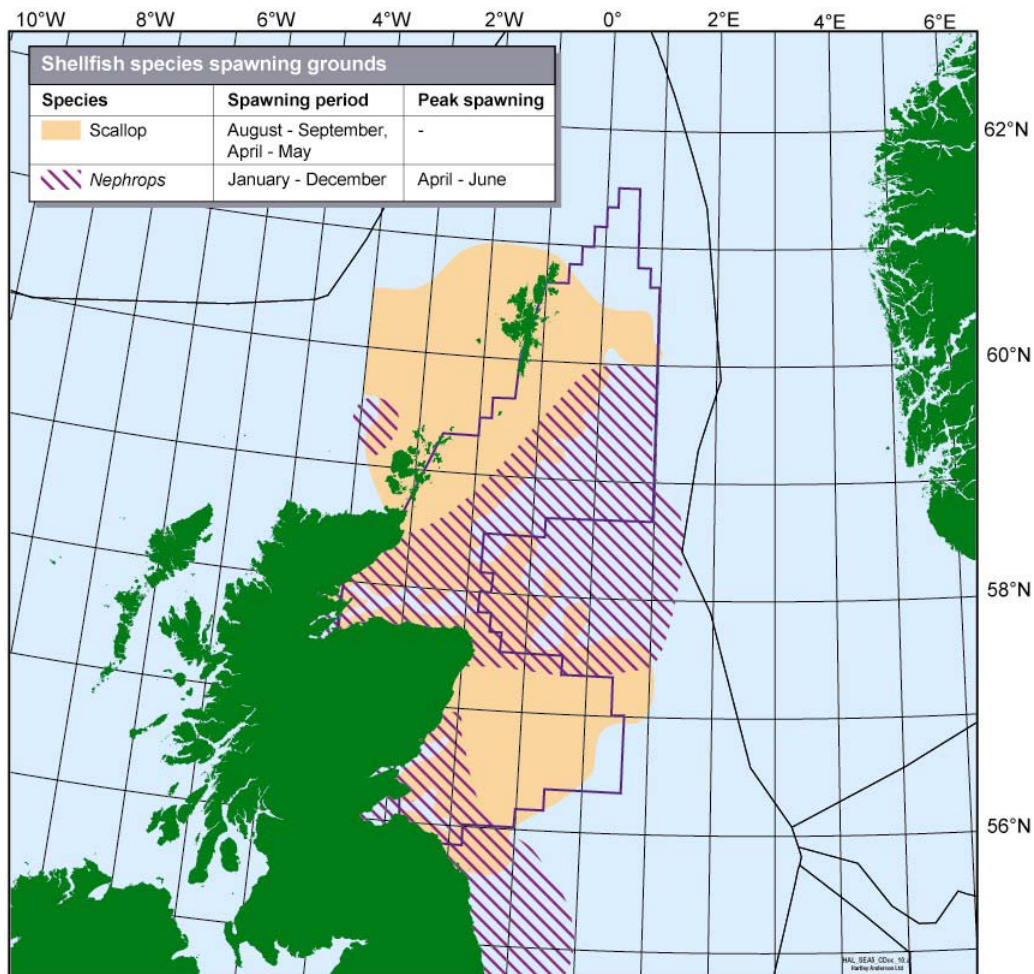
## Sprat

Sprat are most abundant in the relatively shallow waters of the southern North Sea and Skagerrak, and are found in UK coastal waters as far north as the Orkney Islands. Most sprat spawn for the first time at an age of about two years, and important spawning areas in the North Sea are centred on the inner German Bight, the area off the northwestern coast of Jutland, and the English east coast (Figure A4.3). Spawning occurs from May to August. Larval sprat feed in mid-water on copepods, bivalve larvae and mysids.

## Shellfish species

Figure A4.4 provides information on the spawning grounds and timing of spawning of the main commercially exploited shellfish species in the SEA 5 area including *Nephrops* and scallop. Further information regarding the ecology of these species is presented below.

Figure A4.4 – Spawning grounds of main shellfish species in the SEA 5 area



Source: Coull et al. (1998)



## Nephrops

*Nephrops* are mud-burrowing animals, and their distribution is determined by the extent of suitable sediments which range from sandy mud to very soft mud. They do not migrate, and spend their life in the area in which they settle as larvae. *Nephrops* spend most of their time in their burrows and emerge to feed on worms, crustacea, and other small invertebrates (Muus & Dahlstrom 1974). The timing of emergence varies with light level and tide.

The distribution of spawning grounds is shown on Figure A4.4. In all areas, females mature at about 3 years old and, from then on, carry eggs each year from September to April or May. There is a tendency for *Nephrops* located in more northerly waters to spawn later in the year (Farmer 1975). After hatching, the larval stage lasts 6 to 8 weeks, before settlement to the seabed. While carrying eggs, females come out of their burrows very infrequently, and are naturally protected from trawlers. Male *Nephrops* therefore dominate trawl catches for most of the year, and are more heavily exploited than females.

## Scallop

The scallop is a mollusc that lives in discrete populations all around the British Isles on suitable sediments. It is a filter feeder that normally lives recessed into the sea bed with the flat valve uppermost and covered by a fine layer of sediment. It occupies sandy, gravelly mud sediments throughout the northern North Sea and is found from just below low water mark to depths of beyond 100m. The scallop is a hermaphrodite but avoids self-fertilisation by releasing the male gametes first. Scallops spawn on suitable sediments throughout the SEA 5 area (Figure A4.4) in the spring with a later spawning in the autumn. Larvae are free-swimming and spend about 3-4 weeks in the water column before settling onto the sea bed. They sometimes initially attach themselves by a threadlike bysus to weed or hydroids before eventually becoming detached and reaching the sea bed. Scallops can live for 20 or more years and grow in excess of 175mm in length.

## Other fish species

### Diadromous species

Sea trout share a similar life history to salmon. Both are anadromous species, migrating from the sea to breed in freshwater. Spawning takes place in shallow excavations called redds, found in shallow gravelly areas in clean rivers and streams. After a period of 1-6 years the young salmon migrate downstream to the sea as 'smolts'. Salmon have a homing instinct and spawn in the river of their birth after 1-3 years in the sea (JNCC website – <http://www.jncc.gov.uk/idt/>).

On leaving the rivers, the movements of post-smolts in the North Sea appear to be highly dependent on the speed and direction of surface currents (Holm *et al.* 2000). For the first few months at sea, post-smolts are passively transported northward (Jonsson *et al.* 1993, cited in Friedland *et al.* 2000) and their geographic distribution conforms well with the main surface current patterns, in particular with the slope currents west and north of Scotland (Holm *et al.* 2000).

Salmon on the return migration to spawn are believed to enter the North Sea from the north, to move south and then inshore, before swimming north along the English coast to their home rivers. Sea trout originating from these same rivers are thought to migrate southwards to feed in the southern North Sea and are also exploited as they migrate north to spawn (Pawson *et al.* 2002).

The European eel (*Anguilla anguilla*) is thought to spawn in spring in the Sargasso Sea between Bermuda and the Bahamas. Larvae drift from the Sargasso Sea in the Gulf Stream and North Atlantic Drift and on reaching the continental shelf, metamorphose into glass eels which, as they move closer inshore, become pigmented and are known as elvers. These enter freshwater during the spring, with the peak of the migration taking place on the increasing tides in April and May. Some eels remain in coastal waters where they feed and grow in the sea, while others may migrate to and from freshwater throughout their life (Environment Agency website - <http://www.environment-agency.gov.uk/>).

Eels live on or near the bottom of rivers and lakes, migrating slowly upstream. During this period they are commonly referred to as yellow or brown eels due to their colour. Eels feed mainly on invertebrates, although larger individuals may also eat other fish. Male eels stay in freshwater for between 7 and 12 years, maturing at a length of about 36cm. Females stay between 9 and 16 years, maturing at the slightly larger size of 46cm. As the fish mature, their skin takes on a silvery blue colour and these silver eels migrate seawards and once at sea, are assumed to migrate westwards at depth to the Sargasso Sea, where they spawn and die (Environment Agency website - <http://www.environment-agency.gov.uk/>).

### Non-commercial species

Although widely distributed in both hemispheres, basking sharks appear to be most regularly recorded in coastal areas of the UK with seasonally persistent tidal fronts (e.g. western Scotland, Clyde area, central Irish Sea and the western approaches to the English Channel). They are mainly recorded in surface waters from April to September, when mostly immature females are seen.

A satellite-tracking study, funded jointly by DEFRA, CEFAS, and the Marine Biological Association of the UK, is currently underway with the aim of providing more information on the life histories of basking sharks in European waters. Findings so far indicate that basking sharks tagged in UK waters in the summer remain on the European continental shelf throughout the winter and do not make transoceanic migrations; tagged fish move extensively within continental shelf waters, and there does not appear to be separate sub-populations off Scotland and southwest England (CEFAS website - <http://www.cefas.co.uk/sharks/default.htm>).

The porbeagle shark is distributed widely over the northern North Sea with the highest reported catches around the Shetland Islands. They are thought to be present all year round in deepwater off the Faroe Islands and to migrate into the North Sea during the second half of the year. Their diet consists mainly of cephalopods and fish. The porbeagle is viviparous and produces about 4 young with a length at birth of between 60 and 75cm (Gordon 2003).