Technical Report TR_003

Technical report produced for

Strategic Environmental Assessment – SEA2

NORTH SEA FISH AND FISHERIES

Written by CEFAS

Data supplied by FRS

August 2001

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EXECUTIVE SUMMARY

The DTI intends to complete a series of sectoral Strategic Environmental Assessments (SEA) to assess the potential impact of the offshore oil and gas licensing rounds, and to promote the environmentally sound development of Britain's hydrocarbon resources. The first of such SEAs was of the area to the north and west of Shetland known as the 'White Zone'. This report is a contribution to SEA2, which includes the mature oil and gas fields of the Southern, Central and Northern North Sea, and describes issues related to fish and fisheries. The information provided as part of this process will be used to describe environmental sensitivities in the region, and may be used to impose conditions on some licences.

The recent OSPAR Quality Status Report of the North Sea identified several priority human activities which have greatest impact on the marine environment, and these included the direct and indirect effects of fishing, the input of oil and PAHs by the offshore oil and gas industry, and the input of nutrients and trace organic contaminants from land. This report has focussed on the implications for fish and fisheries of continued exploration and production of oil and gas. Of course, there are several other human activities in the North Sea which also impact fish and fisheries, and foremost amongst these is the effect of commercial exploitation itself. This report has restricted discussion of the impact on fish populations to these two industries.

The report describes the fish resources of the region (i.e. spawning grounds, nursery areas), and also the intensity and distribution of commercial fishing activity. It describes those fisheries management measures which recommend seasonal closures of parts of the North Sea to protect spawning or juvenile fish, and regions where these may have consequences for oil and gas exploration and production. The report also summarises the most important consequences of oil and gas exploration for fish populations and commercial fisheries, such as the use of seismic surveys and the placement of structures on the sea bed.

Most of the commercially important fish species spawn in the spring, between January and June, although sandeel and herring are exceptions which spawn outside this period. Shrimp, edible crab and lobster tend to be winter spawners, but the period of egg brooding is protracted. Spawning areas and nursery grounds for most fish species are dynamic features of life history and are rarely fixed in one location from year to year. Thus, while some species have similar patterns of distribution from one year to the next, others show greater variability. The combined distribution of spring-spawning fish species showed that much of the northern SEA2 region supports spawning activity of three or more of these species, while in the central region spawning activity is more sporadic, and some areas have low sensitivity (Fig. 3.3.3). In the southern SEA2 region the greatest spawning activity occurs in coastal waters and in the most easterly part.

There are several fish species of conservation importance in the North Sea, however relatively few are found in the offshore waters of the North Sea, and may thus be considered vulnerable to human activity in this region. The European sturgeon is rare and at its northerly limit in the North Sea. The basking shark, tope and porbeagle are likely to occur in small numbers throughout the North Sea, and the common skate occurs at low density throughout the northern North Sea, but is very rare in the southern North Sea.

Descriptions of major North Sea fisheries were prepared from official landing statistics, anecdotal information from local ports, and over-flight surveillance data. Official landing statistics of the major species by ICES rectangle are available for UK fleets, but only for cod and sandeel are international landings by rectangle available.

The North Sea is one of the world's most important fishing grounds. Major UK and international fishing fleets operate in the southern, central and northern North Sea and target both pelagic and demersal fish stocks. One of the most important fisheries in the North Sea is the mixed demersal fishery that targets cod, haddock and whiting in the central and northern parts of the region. Otter trawl and seine net vessels catch cod as part of a mixed fishery in which haddock and whiting form an important component of the catch. Otter trawling accounted for most of the fishing effort in the northern North Sea, where beam trawls are rarely used, but in central and southern SEA2 regions otter trawls are less common. Most effort was confined to the northeast coast of the UK, northeast of Scotland and east of the Shetland Islands. Parts of the Norwegian Deep and the central North Sea were relatively lightly fished. Recent overflight data shows that most otter trawl effort was concentrated to the north and west of the Orkney and Shetland Islands throughout the year, near the Fladen Ground and the northeast coast of England in the 1^{st} and 4^{th} quarters of the year, and during the spring and summer months further offshore near the Dogger Bank and the Silver Pit.

North Sea plaice and sole are taken in a mixed flatfish fishery by mainly Dutch and UK registered beam trawlers in the southern and southeastern North Sea. There are also directed fisheries for plaice carried out with seine and gill nets and by beam trawlers in the central North Sea. The distribution of the international beam trawl fleet indicates that most trawling activity is concentrated in the Southern Bight of the North Sea, particularly along the Continental coast from Denmark to the Straits of Dover, and is high in the offshore part of the southern SEA2 region. Inshore fleets are heavily dependent on sole, especially during the second half of the year.

Herring is one of the most important species landed by the UK pelagic fleet. During the 1970s there was a decrease in their spawning stock biomass, largely caused by over-exploitation and poor recruitment. In 1977, the North Sea herring fishery was closed, and did not reopen until 1983. Fishing for herring is mainly undertaken with purse seines and trawls offshore and to a smaller extent by fixed nets in coastal waters. While North Sea stocks are fished throughout the year, landings are greatest in the third quarter of the year, predominantly from the Orkney/Shetland area, Buchan, northwest of the Dogger Bank and in coastal waters of eastern England.

The other major North Sea pelagic fishery is for mackerel, which supports an extensive, directed fishery by pelagic trawlers in the northern North Sea, taking advantage of the migration of the western stock to this feeding area. This is a very important species for the Scottish fleet, and by weight it is one of the most abundant pelagic species landed. Fishing in the North Sea occurs throughout the year with peak landings in July to September, and moderate levels of fishing activity take place between the Faeroe Islands and the Norwegian coast during the first half of the year.

Crustacean fisheries are generally of high value and target specific grounds at different times of the year. A range of gears, such as bottom trawls, prawn trawls, seines, pots and dredges are used in these fisheries. Norway lobster are landed from the north and west of the Dogger Bank, along the northeast coast of England, the eastern coast of Scotland, and on the Fladen ground in the central SEA2 region. The pink shrimp fishery is also concentrated in the deep muddy areas of the Fladen Ground. The edible crab fishery is an important source of income to UK shellfishers, and the fishery is now prosecuted throughout the year by many fishermen, supplying both the live continental market and the home processing market. Unlike Norway lobster and pink shrimp, crabs are captured in traps, called pots or creels, which are baited with fresh fish, and larger vessels will work up to 1000 traps. Crab fisheries occur on coarse grounds in coastal UK waters, and in the south these can extend eastwards into the gas fields of the southern SEA2 region. Finally, important scallop fisheries occur on suitable sand and gravel sediment around Shetland and Orkney, and along the east coast of Scotland, exploited by vessels using heavy, wide toothed dredges. Most landings are taken from inshore areas, but some grounds are over 60 miles offshore, and can extend into the oil fields in the northern North Sea.

The effects of these fish and shellfish fisheries are widespread and ecologically important, and the depletion of some target species impacts the whole North Sea ecosystem. There is concern about the stocks of herring, cod, haddock, whiting, saithe, plaice and sole which are close to or outside Safe Biological Limits. Catch levels for many fish stocks are almost certainly not sustainable.

To ensure the sustainability and recovery of these fisheries, a range of fisheries management measures have been implemented by the European Commission. This report describes only technical measures (area and seasonal closures) that restrict access to specific fleets in order to offer protection to juveniles and spawning adults and encourage stock recovery. For example, during spring 2001, a large closed area was implemented in the North Sea which restricted access to cod fisheries. The closure covered the main spawning area and season for mature cod. Similarly, in the southern North Sea a permanently protected area (the plaice box) was established to reduce the mortality of juvenile plaice in the beam trawl fishery (Fig. 4.2.1.1). Sandeel fisheries at Shetland and off the east coast of Scotland are also closed seasonally. Both the cod closure and plaice box have caused the displacement of fishing activity away from traditional grounds and towards the oil and gas fields of the North Sea. For the otter trawl fleet this represents an increase in existing levels of local effort in regions where the two industries already co-exist. There is some evidence of a slight increase in beam trawl activity in the Central and Northern SEA2 regions, since the gear was first used in the southern North Sea during the 1960s. This may have implications for the safety of both the fishing vessels and underwater structures associated with the hydrocarbon industry when they come into contact. Some form of spatial exclusion during the spawning season is likely to be retained for cod.

The offshore oil and gas industry has become a major economic activity in the North Sea since the late 1960s, and during the 1990s oil production almost doubled. There are now almost 500 platforms and 10,000 kilometres of rigid and flexible oil and gas pipelines running between offshore production wells and terminals on land. There are a number of ways in which offshore oil and gas exploration and production may impact fish populations and restrict the commercial exploitation of fish stocks. These can include the potential effects of seismic surveys on fish populations during the spawning season, the impact on the seabed of drill cuttings at well sites, and the exclusion of fishing vessels from subsea wellheads, the area adjacent to the platform, and associated structures which require protection.

Seismic surveys use high energy sound sources to locate the geological structures that are associated with hydrocarbon deposits. When organisms are in close proximity to such an air gun array there is thought to be a high risk of injury or death, however, for fish populations, there is also concern for the non-lethal behavioural effects of the disturbance.

The disruptive effect of such surveys has been confirmed by recent studies which suggested that the use of air gun arrays could reduce catches of cod and haddock over a large area, and for several days after completion of the survey. Although the impacts of seismic activity outside the spawning season will be largely transient, and result merely in the temporary redistribution of fish, during the spawning season this effect could be more serious and may lead to the severe disruption of spawning activity. While there is no direct evidence of an adverse impact of seismic activity on the spawning success of fish, there is sufficient concern to suggest that a precautionary approach is applied to the use of this equipment. The Fisheries Departments currently apply licence conditions which prevent seismic surveys during specified periods of the year in certain blocks. These controls have been used effectively for the last decade, and are regularly reviewed. This suggests that the production of underwater noise by the offshore industry now has only a minor impact on fish populations.

Wells require lubrication by viscous drilling muds, and these have traditionally been discharged into the sea. Water based mud (WBM) released into the water column becomes separated from the cuttings and is diluted, and rock particles in the water column are unlikely to be distinguishable from natural suspended solids. In the relatively shallow and dispersive waters of the southern North Sea, it is generally considered that cuttings do not accumulate at the well site but are transported away from the platform and dispersed naturally. The most common effect of the WBM is an elevation of barium concentrations in the sediments, which may extend up to 1,000m from the drilling location along the predominant tidal axis. Barium persists in sediments, in the form of barium sulphate or carbonate, which are insoluble and therefore inert. Only in the deep waters of the northern North Sea have accumulated cuttings piles become the focus for more specific research. In these environments, physical changes attributable to drilling discharges can be long-lasting. Cuttings piles may still be clearly visible for some time, smothering the benthic fauna at the well site and resulting in reduced densities of benthic organisms nearby. While these cuttings piles remain within the 500 m safety zone they are considered to be relatively inert and to have a minimal impact on fish populations and trawling activity. It is increasingly common for operators to select environmentally acceptable drilling muds such as water-based muds or low toxicity oil based mud. The constituents of mud systems must also be identified in the Offshore Chemical Notification Scheme which categorises chemicals according to their toxicity, persistence and bioaccumulation potential. Many wells currently drilled in the North Sea retain muds for transfer to shore for processing and disposal, although WBM is generally left on site. Although some studies have investigated the site-specific impact of contaminants on benthic fauna, there are no data which describe the impact of cuttings on fish populations, or the secondary effects on populations through loss of feeding areas. The smothering of seabed fauna and sediments is a potential threat to species such as herring that require particular sediments on which to feed and spawn.

The preferred oil and gas industry option during decommissioning is to leave cuttings piles *in situ*, and this topic is currently the subject of an extensive UKOOA joint industry funded research project. It is possible that such piles may be rapidly dispersed by trawls, thereby increasing the potential for contamination. Concerns about the impact of over-trawling of such cuttings piles are currently the subject of research programmes.

The damage caused to the marine environment by an accidental release of oil, condensate or diesel depends on the size of the spill, the characteristics of the hydrocarbon, the prevailing weather conditions, and the proximity of sensitive populations. Diesel and condensate have low viscosity, and so when spilt at sea they spread rapidly and disperse. The accidental release of oil presents a greater risk, particularly in the event of an oil well blow-out in which the hydrocarbons cannot be contained. There have been no such incidents during drilling activity in the North Sea to date. All hydrocarbon spills can affect fish by tainting, caused by ingestion of hydrocarbon residues present in the water column and on the sea bed. In the event of a spill, Ministers can establish temporary fishing exclusion zones which prevent fishing for a fixed period of time to maintain public confidence in the standard of fish and shellfish as food. Recently, such fisheries exclusion zones were established after the Braer and Sea Empress oil spill incidents, which were related to the transport rather than to the exploration and production of hydrocarbons. The Braer spill had particularly severe effects on the fish farming industry in the Shetland Islands, while commercial fishing activities were only affected in a small area of the Burra Haaf. In 1997 an exclusion zone was established after a large spill at the Captain field in the outer Moray Firth. Monitoring studies conducted by FRS Marine Laboratory (SEERAD) showed a very localised area of shellfish taint that, after exhaustive chemical fingerprinting analysis, was shown not to have been derived from the spilt oil.

The offshore oil and gas industry also interacts with fishing fleets, as well as the fish resource. All surface installations and subsea structures, excluding pipelines, have a 500 m radius safety zone to exclude other sea users. Zones are normally patrolled by support vessels, and the proximity of fishing fleets can be monitored from the installations themselves. The loss of fishing area in the North Sea caused by these zones is less than 1%. The exclusion of fishing activity from these zones does not adversely affect fish catch rates, as fishing effort is simply diverted to other regions. The loss of area does not result in a proportional loss of catch, and the individual zones themselves are so small that they do not completely obscure any one fishing ground. It has been thought that these safety zones may act as closed areas, protecting populations and individuals from capture by fishing gears and thereby enhancing the stock. There is little evidence to support this assertion. Where possible, structures on the sea bed that could snag fishing gears are surrounded by a safety zone and provided with further protection. All sub-sea structures outside this zone are designed to be over-trawlable and have sloping sides to deflect trawls. Pipelines are protected by the addition of a protective coating or by burial.

A range of potentially toxic materials can be discharged with produced water, including heavy metals, PAHs and production chemicals. The quantities of discharged produce water by the offshore industry have recently been reduced using techniques which rely on the re-injection into the reservoir. The Offshore Chemical Notification Scheme has ensured that the discharge of oil and contaminants in produced water is now the subject of increased control.

There are now well established means of liaison between the fishing industry and offshore oil and gas industry, and claims for compensation and general safety issues are dealt with promptly. UKOOA and the fishing industry run a non-attributable compensation claims scheme, which considers claims for loss or damage to fishing gears, paid out of a central fund. There is also a joint Government and industry forum, the Fisheries and Offshore Operators Consultative Group (FOOCG), where representatives of the UK fishing industry, the oil and gas industry, seismic operators and key Government departments can raise and discuss industry concerns, and advise on best practice. There is, therefore, a relatively high level of communication and co-operation between the two industries.

1. INTRODUCTION

The DTI has recently completed a Strategic Environment Assessment (SEA) for an area to the north and west of Shetland known as the "White Zone" (DTI, 2000). It is the intention of Government to complete a series of further sectoral SEAs with the ultimate objective of assessing the entire UK continental shelf. The purpose of the SEA process is to assess the potential impact of the offshore oil and gas licensing rounds, and to promote environmentally sound development of Britain's hydrocarbon resources. Information provided as part of the SEA process will be used to inform the environmental sensitivity of the region, and as a result, blocks may be withdrawn or conditions imposed.

This report is a contribution to the second of these strategic assessments, SEA2, which covers the mature oil and gas fields of the Southern, Central and Northern North Sea (Fig. 1.1). The report deals with issues concerning fish resources such as spawning areas and nursery grounds, and the commercial exploitation of the main fishing stocks in the North Sea. In such a strategic assessment, it is clearly necessary to focus attention on the implications for fish and fisheries of continued exploration and production of oil and gas reserves. Of necessity this will deal with the North Sea on a broad scale rather than identify sensitivities in individual fields. There are, however, a number of other human activities in the North Sea which also impact fish and fisheries, and foremost amongst these is the effect of commercial exploitation itself. The recent Quality Status Report of the North Sea undertaken by OSPAR (OSPAR 2000), identified in the highest impact class several human activities such as the direct and indirect effects of fishing and the input of nutrients and trace organic contaminants from land. This report will deal only with the impact on fish and fisheries of the oil and gas industry and commercial fisheries. It will also discuss the interaction between these two industries and potential sources of conflict.

2. THE IMPACT OF HUMAN ACTIVITY ON NORTH SEA FISH AND FISHERIES

The report is divided into three main parts. Section 3 describes the fish resources of the North Sea with particular emphasis on the distribution of spawning grounds and nursery areas. The section deals with those fish and shellfish species of commercial importance and which have an offshore distribution, and for which spawning or nursery areas coincide with one of the three SEA2 areas. This information is used to identify the relative sensitivity of blocks within the SEA2 regions in terms of the spawning activity that they support, and in relation to the presence of other vulnerable locations such as herring spawning grounds. A brief description of species of conservation interest that occur in the North Sea is also provided.

Sections 4.1 and 4.2 describe the main fishing fleets that exploit demersal and pelagic stocks in the North Sea, and the distribution of these fleets in relation to the SEA2 regions. The consequences for fish populations are also described, and recent fisheries management measures that have been applied to some of the stocks are presented. These are especially relevant in cases where seasonal closures of parts of the North Sea have been recommended to protect spawning or juvenile fish, and where these may have consequences for the exploration and production of further oil and gas reserves. Section 4.3 summarises the most important consequences of oil and gas exploration for fish populations and commercial fisheries. These focus on the use of seismic surveys during exploration, and the placement of structures such as well heads and pipelines on the sea bed, and the potential impact these may have on fish resources and fishing vessels.

The final part of the report, section 5, summarises the main sources of interaction between the two industries and identifies areas where future conflict may occur. The main threats to fish resources are also described, together with suggestions of ways in which they can be minimised.

The quality of this study depends to a large extent on the accuracy of the data that are used to describe the distribution of fish and fisheries. Despite several decades of monitoring in the marine environment, precise details of the life history of some species is still lacking. For example, although routine fisheries-independent surveys are a useful way of providing a snapshot of a species' distribution, they cannot be done in every month of the year, and sometimes not even in every year. These survey problems, together with the natural variability in fish distribution, indicate how difficult it is to precisely delimit the distribution of juvenile and adult fish. Where possible, the quality of the data used in each section of the report has been assessed.

Although there is no formal separation between the Central and Northern SEA2 regions, we have chosen the line of latitude 59°N as the nominal boundary.

3. FISH RESOURCES

The following section presents a summary of the important life history characteristics of commercially important fish and shellfish that occur within or close to the boundaries of the three SEA2 regions. The main focus is on timing and geographical distribution of spawning and juvenile phases. A brief description is also provided of non-target species that are of conservation importance, and which occur in the North Sea.

3.1 Sources of information and data quality

Descriptions of the seasonal distribution of commercially important fish and shellfish described in this report have been prepared using several sources of information. The most reliable of these are the routine research vessel surveys undertaken by European Research Laboratories. These annual surveys, often co-ordinated by the International Council for the Exploration of the Sea (ICES), target major commercial species but also record information on the distribution and abundance of the non-target components of the fish and shellfish catch. Much of the information available from these surveys has already been published in the scientific literature and, as a result of the peer review process, conforms to an acknowledged standard. Descriptions of the distribution and seasonal abundance of eggs, larvae, juvenile and adult fish from these sources are the most accurate available. Other data are available in unpublished leaflets and internal reports, but these documents have not undergone a peer review process and so some caution must be exercised when using them. Despite this, the 'grey' literature provides scientists with a useful means of making available information which may not be in a suitable format for formal publication, or for which the level of interest in the wider scientific community is low. It can often, therefore, describe good quality work.

It is important to realise that fisheries-independent survey data describe a snapshot of the distribution of a species in a region at a particular time. Spawning areas and nursery grounds are dynamic features of fish life history and are rarely fixed in one location from year to year. While some fish species exhibit the same broad patterns of distribution from one year or season to the next, others show a large degree of variability. These natural variations can be influenced by climatic effects, such as a particularly cold winter, or by the distribution of their prey items. The maps in this report describing the distribution of species, deliberately describe the broad scale distribution which is likely to be evident over a number of years. While higher resolution data from a single survey would be more accurate, there is a risk that it would not describe the distribution of that species in later years. The International Bottom Trawl Survey that currently takes place in the North Sea samples fish during August and September, and so is inappropriate to use in descriptions of spawning activity for the majority of spring-spawning fish species.

The distribution of fish and shellfish commercial landings from the North Sea has been described using the data obtained from local and regional fish markets by DEFRA (formerly MAFF) and SEERAD. Only for cod and sandeel fisheries were the total international landings by ICES rectangle available; for other species the UK landings have been used. The accuracy of the reported landings of commercial species is a source of considerable debate in the UK and Europe, and is governed by a number of complex and interrelated factors. For the purpose of this report, two issues are worth mentioning. Firstly, the catches of species that are controlled by quota management may be under-reported or mis-reported by area so that a fishery does not exceed its quota in a particular year. Secondly, those species which are not controlled by quotas may be under-reported because there is no legal requirement to record landings, or several species may be grouped together as historically there was little interest in collecting data by species.

3.2 Fish and shellfish populations of the North Sea

This section describes the biology of commercially important fish and shellfish that occur in the offshore waters of the North Sea. Recent research has suggested that there have been substantial changes in the fish communities of the North Sea during the 20th Century. These communities consist of species that have complex interactions with one another and the natural environment, either acting as predators at higher trophic levels, providing prey items for larger predators, or consuming a wide range of benthic invertebrates. Fish species in these communities will undergo natural variation in population size, largely as a result of variation in year to year success in recruitment. Broad scale patterns of climate change, and the impact of human exploitation, will also contribute to these population trends.

3.2.1 Whiting

Whiting is one of the most numerous and widespread species found in the North Sea. The recaptures of tagged whiting, and the use of a number of fish parasites as markers, show that the populations to the north and south of the Dogger Bank form almost separate populations. It is also possible that the whiting in the northern North Sea may contain both inshore and offshore populations (Hislop & MacKenzie, 1976).

The diet of whiting varies with size of the fish and from season to season, however their major food items are juvenile fish, crabs and shrimps. In the North Sea, whiting is one of the main predators of other commercial important fish species. Norway pout, sprats, sandeel, young herring, cod, haddock and even whiting themselves are frequently eaten (Knijn *et al*, 1993). After the first year of life whiting grow relatively slowly and there is a great deal of individual variation in growth rate, for a 30 cm fish in February may range from

1 to 6 years old (Hislop, *et al*., 1991). 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. At four years old a single female of about 30 cm length may produce 400,000 ripe eggs during a spawning season (Hislop & Hall, 1974). The main spawning areas for whiting are in the Southern Bight, in the central North Sea north of the Dogger Bank, and off the east coast of Scotland (Fig. 3.2.1.1). The whiting stock in the Skagerak probably migrates into the northern North Sea to spawn (Knudsen, 1964). It is likely that other parts of the North Sea are also important but information on whiting spawning is rather limited. The spawning season is long, and extends from January in the Southern Bight 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 (3-5cm in length) is extensive, and during summer juveniles can be found throughout much of the North Sea, but particularly to the north-east and east of Scotland, off north-eastern England and in the German Bight (Fig. 3.2.1.2) (Gordon, 1977).

3.2.2 Cod

Cod occur throughout the northern and central areas of the North Sea. The recaptures of cod tagged in the North Sea show that there is limited exchange of individuals between the North Sea and waters to the West of Scotland, but that there is much more exchange between the North Sea and the Eastern Channel and the North Sea and the Skagerrak. These tagging studies also showed that the distance travelled from the release point was generally limited to about 200 miles, but that more extensive migrations were possible.

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 there are several areas where spawning is concentrated, particularly in the northern North Sea, the central North Sea around the Dogger Bank and in the southern North Sea and the German Bight (Fig. 3.2.2.1). There is also spawning activity in coastal waters of the east coast of Scotland and the northeast coast of England. Spawning mainly takes place 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). They typically hatch at a length of about 4 mm over a period of 2-3 weeks, depending on water temperature, and the young fish grow to between 20 and 80 mm by June. Most cod larvae are distributed in the upper 30m of the water column, with peak concentration between 10m and 20m. The horizontal distribution of the larvae is determined by circulation and bottom topography (Brander, 1994). Cod aged 1 and 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 (Fig. 3.2.1.2).

3.2.3 Haddock

Haddock occur throughout the northern North Sea, although in the Norwegian Deep adult haddock are not regularly encountered below 250 m and the highest catch rates occur between 80 m and 200 m (Albert, 1994). Although the haddock has a northerly distribution, 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 (Villemarque, 1985; 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 central northern North Sea between the Shetland Islands and the Norwegian Deep, and southwards towards the Fladen Ground (ICES, 2001; Knijn *et al*, 1993) (Fig. 3.2.3.1). After spawning, adult haddock disperse and migrate westward toward the Orkney and Shetland Islands and into the central part of the North Sea to feed. The eggs and larvae are pelagic and mainly distributed in surface waters to a depth of approximately 40 m (Bjorke & Saetre, 1994). At about seven months of age and at a length of about 5 cm, the young fish leave their pelagic phase, and enter a bottom-dwelling (demersal) 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) (Fig. 3.2.1.2).

3.2.4 Saithe

Saithe is a northern species, and is widely dispersed in northern European waters from the Celtic Sea to Greenland, Iceland and Spitzbergen. Adults are generally found in continental shelf and slope waters at depths of 80-450 m (Jakobsen & Olsen 1987; Anon, 1995). 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 (Fig. 3.2.4.1). 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 Faeroe Islands. Some fish, however, are carried northwards by the coastal current and may reach the southern Barents Sea. 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 and Norwegian coastal nurseries during the spring (Nedreaas, 1987) and recruit to the stocks in the northern North Sea (Newton, 1984).

3.2.5 Norway pout

Norway pout are generally found in waters of 80-200 m over sandy and muddy substrates, but also occur in waters of up to 450 m 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, usually found within a few metres of the seabed where it preys upon small crustaceans, amphipods, shrimps and small fish (Mattson, 1981).

Spawning usually takes place between January and April on the continental shelf, with the period of most intense activity during February and March. In deeper parts of the northern North Sea spawning occurs slightly later, between March and May, and may extend into early summer. 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 (Schmidt, 1909) (Fig. 3.2.5.1). The majority of the 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 source of prey for haddock, whiting, cod and hake (Muus & Dahlstrom, 1974).

3.2.6 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 200 m, with older individuals generally occurring in deeper water (Muus & Dahlstrom, 1974; Whitehead, *et al*., 1986).

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. Centres of high egg production occur in the Southern Bight, whilst egg production around the Dogger Bank and in the German Bight is more diffuse (Heessen & Rijnsdorp, 1989) (Fig. 3.2.6.1). Spawning begins in the spring at a water temperature of approximately 6^{o}C. Peak spawning occurs in early January in the eastern part of the English Channel, and during February in the Southern Bight, German Bight and off Flamborough Head (Muus & Dahlstrom, 1974; Fox *et al*., 2000). The duration of the planktonic developmental stages, two to three months, is long compared with that of many fish species. This prolonged period results in long exposure to residual currents, leading to the young plaice settling in nursery areas some distance from where they were spawned. Part of the North Sea plaice population spawns in the English Channel and returns to its feeding grounds in the North Sea after spawning. The offspring of this spawning population are thought to enter the North Sea by passive drift on the prevailing currents (Houghton & Harding, 1976).

Many shallow, sandy bays and estuaries on the North Sea coasts of England and continental Europe act as important nursery areas for plaice, especially the Dutch Wadden Sea (Kuipers, 1977). Such shallow coastal waters support the majority of 1 year old plaice, and juveniles gradually disperse further offshore away from these nursery areas as they get older (Rijnsdorp, 1989). Polychaete worms, especially the sessile *Pectinaria koreni*, are often the most important prey items for plaice, but crustacean species such as amphipods, mysids, bivalve molluscs and brittle stars are also important prey items (De Clerck & Buseyne, 1989).

3.2.7 Sole

The sole is a southern species that is close to the northern limits of its distribution in the North Sea. It is confined to those parts of the southern North Sea where winter temperatures do not fall below 5^{0}C for prolonged periods (Horwood, 1993), and seasonal movements are generally governed by the local temperature regime. During extremely cold winters, dense aggregations of sole occur in deeper and warmer waters of the North Sea such as the Silver Pit (ICES rectangles 35F0, and 36F0) (Fig. 1.1) (Woodhead, 1964).

Sole spawn in shallow inshore areas and close to sandbanks less than 30m deep during April and May. Spawning occurs earlier in the southern part of the North Sea and later in populations off the northeast coast of England and in the German Bight. Major southern North Sea spawning grounds include the Belgian coast, the Thames Estuary, the Norfolk Banks, the Wadden Sea, and the German Bight (Rijnsdorp *et al*., 1992) (Fig. 3.2.7.1). Whilst sole larvae are pelagic at first, during a period of approximately one month they metamorphose into the demersal phase. This relatively brief period in the water column prevents the offspring from moving large distances away from spawning grounds. It is therefore likely that local abundances of 0-group sole reflects the spawning success of local spawning aggregations (Beek *et al.,* 1989). Nursery grounds are situated in shallow waters along the English and continental European coasts at depths between 5 and 10 m. The relative importance of these nursery grounds to the whole North Sea sole stock varies from year to (Beek *et al.,* 1989). Juveniles feed mainly on amphipods, young opisthobranchs and polychaete worms such as *Arenicola marina* and *Lanice* spp. (Braber & De Groot, 1973). Bivalve molluscs and their siphons are also a common food item.

3.2.8 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. There do not appear to be seasonal differences in distribution, and the species as a whole probably does not undertake extensive migrations.

Lemon sole feed on a variety of benthic prey, including polychaete worms, crustaceans, molluscs and echinoderms. Little is known about the spawning habits of lemon sole, and it is thought to spawn everywhere it is found. The spawning season is long, and off the Scottish East coast extends from April to September.

3.2.9 Monkfish

In UK waters there are two species of monkfish, also called anglerfish, the black bellied monkfish *Lophius budegassa*, and the white monkfish, *Lophius piscatorius* The latter predominates north of latitude 55^{o}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 an unusually wide range of depths, extending from the very shallow inshore waters down to around1100 metres. Juvenile monkfish (mainly *L. piscatorius*) can be found over most of the northern North Sea to depths of about 150 metres, 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 based on egg surveys spawning may extend into August (Fulton 1903; Bowman 1920; Tåning 1923). Females do not mature until they are at least seven years of age, and so 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 close to its mouth by delicate movements of a lure that extends from the top of the head.

3.2.10 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 sea bottom or in deep water to a depth of 200 m. 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). Although most fish species have a single spawning season in the North Sea, herring is an exception. Sub-populations of North Sea herring spawn at different times and localised groups of herring can be found spawning in almost any month. At present there are three major populations of herring in the North Sea, which can be identified by differences in their spawning time and area (Fig. 3.2.10.1). 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:

a) Buchan / Shetland herring, which spawns off the northeast Scottish coast and Shetland coasts during August to September.
b) Banks or Dogger herring, which spawns in the central North Sea off the northeast English coast during August to October.
c) 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 their 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. The result of such spawning activity is an ‘egg carpet’, which may be 4 to 9 layers thick and cover an area of one hectare (Blaxter & Hunter, 1982). Each female will produce a single batch of eggs every year, but there are pronounced differences the number, sizes and weights of the eggs produced by each of the different spawning ‘races’ in the North Sea. Incubation of herring eggs takes one to three weeks depending on water temperature, and when the eggs hatch the larvae become pelagic and are transported by the prevailing water currents (Dragesund *et al*., 1980). 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.

3.2.11 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 (Winslade, 1974). Sandeels feed mainly on planktonic prey such as copepods and crustacean larvae, but they can also consume polychaete worms, amphipods, and small fish including other sandeels. Sandeels have neither swim bladder, nor fins capable of compensatory movements, and in order to remain clear of the bottom they must swim continually.

Spawning of *A. marinus* usually takes place between November and February. Spawning activity occurs 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 (Fig. 3.2.11.1). Sandeel eggs are demersal, and are laid in sticky clumps on sandy substrates. On hatching, the larvae become planktonic, resulting in a potentially wide distribution, and the larvae of *A. marinus* are the most abundant of the sandeel larvae in the North Sea (Reay, 1970; Proctor, *et al*., 1998). Sandeels adopt a demersal habit by around 2-5 months after hatching (Wright and Bailey, 1996) and are believed to over-winter buried in the sand. 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, and sea birds.

3.2.12 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. The North Sea stock has been at a very low level for many years due to high fishing pressure and poor recruitment. Mackerel principally prey on small pelagic crustaceans, but they also prey upon fish such as herring, sprat, sandeel and Norway pout.

North Sea mackerel overwinter in the deep water to the east and north of the Shetland Islands, and on the edge of the Norwegian Deeps. In spring, they migrate south to spawn in the North Sea between May and July, but they may also spawn along the southern coast of Norway and in the Skagerrak (Lockwood, 1978; Dawson, 1991) (Fig. 3.2.12.1). The pelagic eggs can be found in the central North Sea at depths to 60 m below the surface, but the majority are found in the upper mixed layer above 26 m (Coombs *et al.,* 1981). The distribution of juvenile mackerel observed during first quarter surveys in the late 1990s (Fig 3.2.12.2) shows a concentration along the northern shelf break of western mackerel, and others in the central North Sea, probably of the North Sea stock. The Western mackerel stock is found on the shelf and near to the continental slope to the west of British Isles, and occupies a very large area. These fish spawn between March and July, mainly to the southwest of the UK and Ireland. After spawning, the western stock migrates northwards to the feeding grounds north of Scotland and in the North Sea and Norwegian Sea. 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 (Lockwood, 1988; Eltink, 1987).

3.2.13 Sprat

Sprat are most abundant in the relatively shallow waters of the southern North Sea and Skagerrak, and are found in the 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 north-western coast of Jutland, and the English East coast (Fig. 3.2.13.1). Spawning in the vicinity of the southern SEA2 region is from May to August and peaks during May and June. Larval sprat feed in mid-water on copepods, bivalve larvae and mysids.

3.2.14 Shrimp

Although there are a number of different shrimp species exploited commercially in the North Sea, the most important for SEA2 is *Pandalus borealis*, which is primarily an offshore species.

P. borealis occurs on relatively soft sediments in coastal waters of the northern North Sea, to 100 m depth. Adults undertake an offshore migration to deeper water during October and November, where eggs are laid between November and February. This offshore migration is followed by an inshore migration to shallower water during the spring. The eggs hatch between April and May and the young settle onto the seabed between July and August. Each female will produce only one batch of eggs during the breeding season, and may live up to 3 years. Adults feed on small crustacea and worms (Muus & Dahlstrom 1974).

3.2.15 Norway lobster (*Nephrops norvegicus*)

Nephrops are mud-burrowing animals, and are limited in their distribution by the extent of suitable sediments which range from quite sandy mud (70% sand, 30% silt and clay) to very soft mud (100% silt and clay). They do not migrate, and spend their life in the area in which they settle as larvae. *Nephrops* population characteristics appear to vary considerably with sediment type, although it is probably due to factors related to the sediment (water currents, prey animals in the sediment), rather than the sediment itself. *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.

As *Nephrops* do not migrate far from their burrows, the distribution of spawning grounds is best illustrated by the distribution of landings (see section 4.1.6). 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.

3.2.16 Edible crab

Edible crab are widespread on mixed substrates of sand, gravel and rock around the coasts of England and Scotland. Although it has a reputation for being a scavenger, the edible crab feeds mainly on living food, including marine worms, virtually all types of shellfish and even fish. Dispersion is mainly by larval drift, but adult females are known to migrate considerable distances, and can often follow consistent migration routes from year to year.

Crabs grow by moulting their hard outer shell at regular intervals. The main moult occurs between July and October. The females moult first, followed by the males a month or so later. Mature female crabs mate just after the moult when still in a soft condition, spawn in November or December, and the eggs are carried for about seven months before they hatch. In English waters, the distribution of crab spawning grounds have been described from surveys of early stage zoea, and suggests that crab spawning activity is most intense off the east coast of England, north-east of the Humber (Fig. 3.2.16.1). The larvae live in the plankton for about one month before settling on the seabed and assuming adult form at about 3 mm in size.

3.2.17 Scallop *(Pecten maximus)*

The scallop is a mollusc that lives in discrete populations all around the British Isles on suitable sediments (Fig. 3.2.17.1). It is important to this Strategic Assessment because of its high value to commercial fishermen and the heavy, penetrating gear used to harvest them. The scallop 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 is capable of swimming, particularly if disturbed**,** by jetting water from either side of the hinge. It occupies sandy, gravelly mud sediments throughout the northern North Sea and is found from just below low water mark to depths of beyond 100 m. The scallop is a hermaphrodite, but avoids self fertilisation by releasing the male gametes first. In Scottish waters, scallops spawn 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 to the sea bed. Scallops can live for 20 or more years and grow in excess of 175 mm in length.

3.3 Spawning seasons of the main commercially exploited stocks

From the information supplied in section 3.2, it is apparent that the majority of the fish species which are of commercial importance and which spawn in or close to the three SEA regions, show peak spawning activity between February and June. Several spawn over a longer period from December until July or August, and some shellfish species spawn throughout the year (Fig. 3.3.1; Fig. 3.3.2).

Although the maps only indicate the likely presence of spawning activity (see section 3.1), and should not be taken as a precise guide, when they are combined they can be used to identify regional concentrations of spawning for all commercially important fish species (Fig. 3.3.3). This figure combines the spawning activity of cod, haddock, whiting, saithe, plaice and sole for the entire area over which they spawn, and the most intense areas of spawning of Norway pout and mackerel. Much of the northern SEA2 region supports spawning activity of between one and four of these commercially important species, while in the central region spawning activity is more sporadic. In the southern region the greatest spawning activity during the spring occurs to the east and north-west (Fig. 3.3.3). These data suggest levels of regional sensitivity, and will be of most value when planning seismic surveys, which may have an adverse impact on spawning success (see Section 4.3.1).

3.4 Fish species conservation issues

So far, this section has dealt with abundant fish species that are commercially important. Their exploitation is managed through a system of catch quotas and technical measures aimed at protecting juveniles and / or spawning adults. There are, however, a number of species in the North Sea which are rare and threatened and which may also be vulnerable to human impacts.

3.4.1 Species and legislation

The designation of fish species requiring special protection in UK waters has received increased attention recently as a result of a number of national and international initiatives. Traditionally, it has often been considered that marine fish are not at risk of extinction, though, there has recently been increased concern over the status of some marine fish species, particularly large, slow growing species such as the sharks and rays (Musick, 1998). In general, examples of the extinction of fish species come primarily from freshwater environments, where habitat degradation, the effects of introduced species, pollution, hybridisation and over-exploitation have been the major causes (Miller *et al.*, 1989).

In Great Britain, the principal mechanism for the legislative protection of wildlife is The Wildlife and Countryside Act 1981, which implements the Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention). Seven species of marine and estuarine fish (Table 3.4.1.) are protected under section 9 (schedule 5) of the Wildlife and Countryside Act, which prohibits the intentional killing, injuring or taking of, or possession and trade in, specified animals.

The EC Habitats Directive "Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora" is the European Community's contribution to the Convention agreed at the 1992 Rio Earth Summit. In the UK, the implementation of this directive has been translated into UK legislation by The Conservation (Natural Habitats, etc) Regulations 1994. There is currently a network of sites known as Special Areas of Conservation (SAC) in the coastal waters of the UK which have been designated when the site supports certain rare, endangered or vulnerable species. None of these SAC occur within the area specified as the boundary of the present Strategic Assessment. However, SAC at Flamborough Head and The Wash and N Norfolk coast are only approximately 20km from the nearest SEA2 boundary.

There are six fish species that require the designation of SAC in UK waters under Annex II and IV of the Directive (Table 3.4.1). Only the European sturgeon *Acipenser sturio* and the whitefish *Coregonus lavaretus* require strict protection within SAC under Annex IV.

The recent High Court ruling after the Greenpeace Judicial Review established that the Habitats Directive applies to both Territorial Waters and the UK Continental Shelf out to the 200 mile limit. Two habitats in Annex I of the Habitats Directive are appropriate in this region: 'sandbanks which are slightly covered by seawater all the time' and 'reefs'; as are two species: harbour porpoise and bottle-nose dolphin. This offshore extension of the Habitats Directive will have no direct implications for fish species or populations in the North Sea. There may, however, be indirect consequences for fish populations and human activities if reefs or sandbanks are selected for further protection, especially where they coincide with populations of threatened or declining species.

Another recent commitment to international marine conservation is through Annex V of OSPAR, which requires the protection and conservation of the ecosystem and the biological diversity of the maritime area. Recent work within the OSPAR Biodiversity Committee has developed selection criteria and a priority list of threatened species and habitats. This work is still in progress, but it is likely that a number of marine fish species that occur in the North Sea will be selected. It will be some time, however, before appropriate management actions are identified which can halt the decline in abundance of these threatened fish species, and encourage their recovery.

Within Europe, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) has listed several fish species for which trade is prohibited or restricted (World Conservation Monitoring Centre, 1993). Only two of these (the coelacanth *Latimeria chalumnae* and totoaba *Cynoscion macdonaldi*) are exclusively marine fish, and neither occur in the North Sea.

The International Union for the Conservation of Nature and Natural Resources (IUCN) has assessed the conservation status of a limited number of fish groups through its Species Survival Commission. Recommendations on the Red List of threatened species includes two species of relevance to the North Sea, basking shark *Cetorhinus maximus*, and common skate *Leucoraja batis* (Table 3.4.1).

The UK also has commitments to a number of Biodiversity Action Plans, published in response to the Convention on Biological Diversity. Fish species which occur in the North Sea, and which are the subject of Species Action Plans, are the basking shark *C. maximus*, common skate *L. batis*, allis shad *Alosa fallax*, and twaite shad *Alosa alosa*. There are also Action Plans for grouped commercial marine fish species, and deep-water fish.

3.4.2 Implications for SEA2

Few of the fish species described in section 3.4.1 have distributions that extend into the offshore waters of the North Sea, and may thus be considered vulnerable to human activity in this region. Of these, the European sturgeon is relatively rare and there are only sporadic catches of adults around the North Sea coasts. The species is at its northerly limit here, as it occurs in greater abundance on the French west coast in rivers such as the Gironde. The basking shark, tope and porbeagle are likely to occur seasonally in small numbers throughout the North Sea. The common skate, can be found at low density throughout the northern part of the North Sea, but is rare in, or absent from, the southern North Sea. The angel shark is rarely seen in the North Sea.

The majority of the remaining fish species of conservation importance are coastal and occur in greatest abundance in relatively shallow coastal water. The allis shad and twaite shad, and the lampreys (*L. fluviatilis and P. marinus*) are migratory, making spawning migrations into the tidal and freshwater reaches of rivers and occupying estuarine and inshore waters to feed. These species are rarely encountered in large numbers.

Two species of goby, the giant goby and Couch's goby, are extremely rare in the coastal waters of the British Isles, and have not been recorded from the offshore waters of the North Sea. The whitefish (Coregonids) are related to the salmon family and are distributed almost exclusively in lakes and rivers of northwest Europe, but may enter brackish waters in the northern part of the North Sea.

Table 3.4.1 List of marine fish species which are afforded protection under national legislation and international conventions.

Common name	Latin name	Wildlife & Countryside Act	EC Habitats Directive	UK BAP	IUCN	CITES
European sturgeon	*Acipenser sturio*	Schedule 5	Annex II & IV	-	-	Appendix 1
Allis shad	*Alosa alosa*	Schedule 5	Annex II	Y	-	-
Twaite shad	*Alosa fallax*	Schedule 5	Annex II	Y	-	-
River lamprey	*Lampetra fluviatilis*	-	Annex II & V	-	-	-
Sea lamprey	*Petromyzon marinus*	-	Annex II	-	-	-
Basking shark	*Cetorhinus maximus*	Schedule 5	-	Y	endangered	Appendix 3
Whitefish	*Coregonus lavaretus*	Schedule 5	Annex IV	-	-	-
Giant goby	*Gobius cobitis*	Schedule 5	-	-	-	-
Couch's goby	*Gobius couchii*	Schedule 5	-	-	-	-
Common skate	*Leucoraja batis*	-	-	Y	endangered	-
Tope	*Galeorhinus galeus*	-	-	-	vulnerable	-
Porbeagle	*Lamna nasus*	-	-	-	vulnerable	-
Angel shark	*Squatina squatina*	-	-	-	vulnerable	-

3.5 Data quality in relation to fish distribution and life-history

Commercial fish landings and effort data in the North Sea are collected on the scale of an ICES rectangle (Fig 1.1), and samples of fish populations taken by research vessel surveys on a similarly coarse scale. This has made it difficult to identify the precise distribution of fish at the scale of the much smaller oil and gas licensing block. This lack of precise information has made it even more difficult to identify whether rare or threatened fish species occur in the SEA2 regions. Nevertheless, as already mentioned in section 3.1, the annual variability in fish abundance suggests that using the scale of an ICES rectangle is appropriate.

It has only been possible to show total international landings of cod and sandeel since these have been collated at a community level in relation to special management needs. Corresponding information for all other commercially exploited stocks are not available.

Information presented on fish life-history describing, for example, the duration of the spawning season and the extent of spawning grounds and nursery areas, if the best that is currently available.

4. THE IMPACT OF HUMAN ACTIVITY ON FISH POPULATIONS

There are a number of human activities in the North Sea which have the potential to impact fish populations. These include both the direct and indirect effects of commercial fish exploitation, the input of trace organic contaminants and nutrients from land, the input of oil and PAHs from land and by the offshore oil and gas industry, and the input of oil, PAHs and antifoulants by shipping. In addition to these human activities, there are natural changes caused by large scale climatic events. Changes to the oceanic circulation patterns could also have long-lasting consequences for fish and other marine fauna.

In the recent quality status report for the Greater North Sea (OSPAR 2000), OSPAR ranked over 30 human activities using a number of qualitative criteria. Within the highest impact category of the OSPAR assessment were the following consequences of commercial fisheries exploitation; a) removal of target species, b) disturbance to the seabed, and c) the effect of discards and mortality of non-target species. The inputs by the offshore oil and gas industry of hazardous substances, oil and PAHs, and the physical disturbance caused by exploration and production, were considered as intermediate scale impacts.

The intention of this report is not to provide a comprehensive description of the impacts on fish populations of all human activities in the North Sea. It is necessary, however, to briefly describe the main impacts of commercial exploitation on fish populations, to summarise the status of the major fish stocks in the North Sea, and to put this in context of the potential impact of the activities of the offshore oil and gas industry.

The following sections describe UK and international fishing fleets in the southern, central and northern North Sea which target fish stocks of major commercial importance, and describe the population status of these stocks. Section 4.2 identifies the relevant management issues related to these fisheries, and those which may have implications for the offshore oil and gas industry.

4.1 Major North Sea fisheries

Data used to describe the distribution of the major North Sea fisheries have been obtained from a number of different sources, including official landing statistics, anecdotal information from local ports, and surveillance data. Some of these data have been incorporated into the Fisheries Sensitivity Maps in British Waters (Coull *et al*., 1998) which have been used extensively during the production of this report.

Official landing statistics of the major species by ICES rectangle are available for all English, Welsh and Scottish vessels landing into UK ports. While this provides a reasonably comprehensive picture of fishing activity by UK vessels, it does not provide a good description of international effort. It has generally not been possible to use the landing statistics from other European countries for most fisheries. Only for cod and sandeel have international landings by rectangle data been prepared by the ICES Working Group that is responsible for their annual stock assessment. Even these data sets are not complete, as French landings data are not included in the International cod landings, and Norwegian data describing fishing effort for sandeel have only been available since 1999.

A further source of fisheries data, at a finer level of resolution than the ICES rectangle, are the aerial observations made by the UK Sea Fisheries Inspectorate. British Fishery

Protection flights regularly survey the UK EEZ to monitor commercial fishing activity, and ensure that UK and foreign vessels do not infringe the various regional and gear restrictions that are in force around the coast. Aerial observations of vessels are undertaken by spotter planes that, over English waters, fly routes covering each quarter of an ICES rectangle (1° longitude by 0.5° latitude), approximately once a week throughout the year. Surveillance in Scottish waters describes fishing vessel activity throughout each rectangle that is visited. Different parts of the Scottish EEZ may be visited more frequently during seasons when more intense fishing effort takes place. The data have been further described in Jennings *et al*., (2000).

When any fishing vessel is observed, information on its nationality, activity (fishing or steaming), type of gear used, and the date, time and latitude and longitude of the observation are recorded. Overflight data in all English waters for the period 1990 to 2000 were used to describe the distribution of the otter trawl fleet. As sub-rectangles were seldom visited on the same number of occasions per month, it was necessary to standardise the vessel observations to take account of the variable frequency of overflights. The numbers of vessels observed in each oil and gas license block were, therefore, expressed as the number of observations per overflight. Average sightings per unit effort data (SPUE) were calculated for all English and Welsh otter trawlers (identified in the categories trawlers and demersal stern and side trawlers) for the period 1990 to 2000, by quarter year. Data describing the overflight frequency in Scottish waters were not available, and so SPUE was not calculated. Presentations of Scottish overflight data therefore represent the total uncorrected sightings by quarter, averaged for the years 1999 and 2000. Sightings of Scottish 'otter trawlers' in this report represent combined sightings for Nephrops trawls, otter trawls, pair seines, Scottish seines and twin otter trawls. Scottish overflight data will therefore only indicate relative differences in international fishing effort across the entire region. Within an ICES rectangle, however, the relative differences in effort between adjacent licensing blocks should approximate to the actual distribution of vessels.

4.1.1 Mixed demersal fisheries

One of the most important fisheries in the North Sea is the mixed demersal fishery that targets cod, haddock and whiting in the central and northern parts of the region. There are also a number of important by-catch species in this fishery, particularly of monkfish in Scottish waters.

Usually, otter trawl and seine net vessels catch cod as part of a mixed fishery in which haddock and whiting form an important component of the catch. Cod also form an important by-catch in the beam trawl fisheries targeting plaice and sole.

The distribution of UK, Danish, Norwegian, German and Dutch otter trawlers in the North Sea has recently been described by Jennings *et al*., (2000). For the six-year period 1990 to 1995 for which these data are available, otter trawling accounted for the majority of fishing effort in the northern North Sea, where beam trawls were rarely used, but in central and southern areas otter trawls were less common. The spatial distribution of annual otter trawling effort by rectangle showed that the grounds subject to the greatest fishing intensity have not changed in recent years (Jennings *et al*., 2000). Most effort was confined to the northeast coast of the UK, northeast of Scotland and east of the Shetland Islands. Parts of the Norwegian Deep and the central North Sea were relatively lightly fished (Fig. 4.1.1). Recent overflight data for English waters (Fig. 4.1.2a-d) showed that most otter trawl effort was concentrated in the 1st and 4th quarters of the year on the northeast coast of England in the vicinity of the Farn Deep, and during the spring and summer months further offshore south and west of the Dogger Bank, and near the Silver Pit. There was relatively little otter trawl effort in the southern SEA2 region (Fig 4.1.2 a-d). Scottish overflight data suggested that otter trawlers fished the Papa Bank/Otter Bank area to the north and west of the Orkney and Shetland Islands throughout the year. During the first half of the year, effort was concentrated on grounds to the east of the Pentland Skerries and on the Fladen Ground, while later in the year otter trawling appeared to become dispersed to the north of the Fladen Ground (Fig. 4.1.2 a-d).

The cod fishery operates throughout the year, although some fleets exhibit seasonal fishing patterns. International landings of cod by ICES rectangle for 1999 showed that, in the 1st and 2nd quarters of the year, the highest catches were taken in the southern North Sea, particularly along the Belgian and Dutch coast, off the coast of Denmark and into the Skagerrak, and throughout the northern North Sea (Fig. 4.1.3 a-b). In the second half of the year a similar fishing pattern remained, but cod were also landed from offshore waters of the Central North Sea and in the northern North Sea from the Halibut Bank and Bergen Bank (Fig 4.1.3 c-d). This seasonal pattern of cod landings is influenced by the migration of adult fish to spawning grounds and the availability of young fish as they grow and recruit to the fishery. In 1999 Denmark landed about 31% of the international landings, Scotland landed 25%, the UK (England, Wales and Northern Ireland) accounted for about 12%, and the Netherlands took about 10%.

ICES advises that the fishery for North Sea cod is outside safe biological limits, and that recent fishing mortality rates are not sustainable and carry a very high risk of stock collapse. The spawning stock is supported by only a few age groups of fish, and since the mid-1980s, with the exception of the above-average 1996 year class, the recruitment of one year old cod has been at or below the long-term average. On average, about 50 % of the stock of 2 to 8 year old fish is removed by fishing each year.

Haddock are also caught in this mixed demersal fishery, with the majority of the catch being taken by Scottish light trawlers, seiners and pair trawlers. In 1999, Scotland reported about 81% of the total international landings of haddock from the North Sea, and 6% was taken by Norway. Smaller quantities were taken by *Nephrops* trawlers, and by-catches of haddock were also taken in the small mesh industrial fisheries. A significant quantity of juvenile haddock (age groups 0 and 1) are either caught in industrial fisheries or discarded by the human consumption fleets. Haddock are caught throughout the year over a wide area. Landings are concentrated in the northwestern North Sea, and although haddock are largely absent from the southern North Sea, they do occur there during years of strong recruitment.

Whiting in the North Sea are taken as part of a mixed demersal fishery including cod and haddock, with the majority of the catch being taken by Scottish light trawlers and seiners, working out of Aberdeen, Peterhead and Fraserburgh. In 1999, Scotland reported about 56% of the total international landings of whiting from the North Sea. Approximately 28% was taken by France, and 8% by England and Wales. Smaller quantities were taken by trawlers targeting *Nephrops* and by beam trawlers targeting flatfish. By-catches of whiting, particularly juveniles (age groups 0, 1 and 2) were also taken in the fisheries for industrial species such as Norway pout. Whiting are caught throughout the year over a wide area, but especially in the northern North Sea southeast of the Shetland Islands, and off the north-east coast of England.

In the recent advice given by ICES for North Sea whiting, the Advisory Committee for Fisheries Management (ACFM) considers that the stock is outside safe biological limits. The spawning stock biomass has declined over the last 20 years to reach an historic low in

1998, and recruitment has declined consistently since 1980. On average, about 50 % of the stock of 2 to 6 year old fish is removed by fishing each year.

4.1.2 Saithe

Since the early 1960s, the saithe fishery in the northeast Atlantic has been dominated by the French, German and Norwegian trawler fleets, with a traditional gill net fishery targeting spawning fish. Norway currently take over 50% of the catch, France 22% and Germany 10%. A small number of UK vessels are active participants in the North Sea fishery for saithe. The fishery operates all year-round, although UK landings data suggest that peak landings of saithe are made in the final quarter of the year. Fisheries are largely restricted to the deeper water (>150 m) in the northern North Sea, to the west and north of Shetland and on the southern and western limits of the Norwegian Deep (Fig. 4.1.2.1).

4.1.3 Plaice and sole

North Sea plaice and sole are taken in a mixed flatfish fishery by beam trawlers in the southern and southeastern North Sea. There are also directed fisheries for plaice carried out with seine and gill nets and by beam trawlers in the central North Sea, and a directed gill net fishery for sole in Danish coastal areas in the second quarter of the year. The distribution of the international beam trawl fleet for the most recent period available 1990-95 (Jennings *et al*., 2000), indicates that activity is concentrated in the Southern Bight of the North Sea, particularly along the Continental coast from Denmark to the Straits of Dover. Effort is high in the offshore areas of the southern SEA2 region (Fig. 4.1.3.1).

The UK seine fleet has declined in recent years and now contributes only a small amount to total plaice landings. The level of discarding of plaice in the beam trawl fishery is currently estimated at about 50% in numbers. In 1999, Dutch vessels took about 47% of the total landings of plaice from the North Sea, the UK accounted for 20%, and Danish landings totalled 17%.

Inshore fleets are heavily dependent on sole, especially during the second half of the year. In 1999, Dutch vessels reported about 70% of the total landings of sole in the North Sea, Belgium accounted for 8% and France, Germany, the UK and Danish landings made up the remaining 23%.

4.1.4 Herring and mackerel fisheries

Herring is one of the most important species landed by the UK pelagic fleet. During the 1970s there was a decrease in their spawning stock biomass, largely caused by over exploitation and poor recruitment. In 1977, the North Sea herring fishery was closed to safeguard the future of the stock. In response to management measures and a succession of strong year-classes, the stock eventually recovered and the North Sea fishery reopened in 1983. In recent years, the fishing mortality on the adult North Sea herring stock has declined, and although there are some concerns about the state of this stock, the biomass of the spawning stock continues to rebuild slowly.

Fishing for herring offshore is mainly undertaken with purse seines and trawls and to a very minor extent by fixed nets in coastal waters. While North Sea stocks are fished throughout the year, landings are greatest in the third quarter of the year, predominantly from the Orkney/Shetland area, Buchan, northwest of the Dogger Bank and in coastal waters of eastern England (Fig. 4.1.4.1).

An extensive, directed, mackerel fishery by pelagic trawlers occurs in the northern North Sea, taking advantage of the migration of the western stock to the feeding area. This is a very important species for the Scottish fleet, and by weight it is one of the most abundant pelagic species landed. Moderate levels of fishing activity take place between the Faeroe Islands and the Norwegian coast during the first half of the year. Fishing in the North Sea occurs throughout the year, with peak landings in the 3rd quarter (July to September).

4.1.5 Industrial fisheries

Sandeel are taken by trawlers using fine-meshed gears. The majority of landings come from the central North Sea, with fleets from Denmark and Norway accounting for ~95% of the international landings from the North Sea in 1999. International landings data by ICES rectangle show that fishing for sandeel takes place mainly during the summer months, especially throughout May, June and July, and is focused on the Dogger Bank in much of the Southern SEA2 region, on the Wee Bankie off Scotland, and in the central North Sea (Fig. 4.1.5.1). The spatial distribution of the catch during 1999 changed slightly from the pattern that had been observed during the previous five years, and over the past 15 years there has been a trend towards an increased proportion of the total catch coming from the Dogger and Viking Banks.

Norway pout are of great importance to European industrial fisheries, and are the focus a large Danish trawl fishery and a Norwegian fishery that targets pout for fishmeal products. These fisheries also employ small-meshed bottom trawls or pair trawls with a cod end mesh size of 22 to 35mm. Fishing takes place throughout the year, with landings peaking from April / May to October (Johannessen *et al*., 1964).

4.1.6 Crustacean fisheries

Crustacean fisheries are generally of high value and target specific grounds at different times of the year. A range of gears, such as bottom trawls, prawn trawls, seines and pots are used in these fisheries, as well as scallop dredges

Norway lobster (*Nephrops norvegicus*) are landed from the north and west of the Dogger Bank in the central North Sea, along the northeast coast of England, the eastern coast of Scotland, and on the Fladen ground in the northern North Sea (Fig. 4.1.6.1). Whilst there are no strict fishing seasons for Norway lobster effort in the Farn Deeps and Firth of Forth fisheries is concentrated in the autumn and winter, but in the spring and summer in the Moray Firth and Fladen Ground. Catch rates are highest in the autumn and winter. Danish landings are at their highest during November to June, with a peak in March.

The edible crab fishery is an important source of income to UK shellfishers, and the introduction of a live market to Europe in the 1980's based on an expanding west coast fishery helped raise prices.

The traditional fishery is seasonal with peak catches in May and June, but the fishery is now prosecuted throughout the year by many fishermen, supplying both the live continental market and the home processing market. Two distinct types of vessels prosecute the crab fishery: smaller inshore vessels working a mix of crab and lobster pots; and larger Vivier crabbers (boats equipped to carry their catches live for extended periods) which work the offshore grounds. Crabs are captured in traps, called pots or creels, which are baited with fresh fish. The traps are shot in fleets of 20 or more depending on vessel size and are usually hauled once every 24 hours. Some of the larger vessels will work up to 1000 traps.

In Scottish waters, the main crab fisheries occur on course grounds in the coastal waters of Eastern and northern Scotland extending north-eastwards to the Shetland Islands (Fig 3.2.16.1). Crab fisheries off the English coast are prosecuted by vessels from Bridlington, Grimsby and ports along the north Norfolk coast. Although crab grounds in this region are mainly inshore, they can extend eastwards into the gas fields beyond the Silver Pit.

Fisheries for lobster and brown shrimp are valuable for coastal communities in both Scotland and England, however, exploitation is largely restricted to inshore waters outside the area of interest to SEA2, and they are not discussed here.

The pink shrimp fishery is concentrated at the deep muddy areas of the Fladen Ground. The fishery is normally operated between March and June, by vessels using shrimp trawls, but has continued into September in years when the market and price have remained good. The extent of the fishery tends to be determined by the market and price, and does not continue beyond June if landings are good in Denmark, where a far larger fishery is based. The market is limited in Scotland, and some vessels have landed in Norway and Denmark in order to get a better price. In recent years the fishery has involved 10 vessels from Fraserburgh, landing between 400 and 1,800 tonnes each year.

Important scallop fisheries exist on suitable sand and gravel sediment around Shetland and Orkney, and along the east coast of Scotland. Most landings are made by scallop dredgers (vessels from 10m up to 30m in length using 2 arrays of gear, consisting of 2 to 18 1m wide toothed dredges, fished from either side of the boat), but in the Orkney area divers also make a significant contribution. The North Sea fisheries expanded during the early 1990’s, but have remained stable in more recent years. Some of the Scottish scallop fisheries have been subject to closure, owing to PSP, DSP and ASP outbreaks, for varying lengths of time in the last decade. The scallop fisheries are generally characterised by pronounced seasonality, but closures in some areas and diversion of effort to others also contributes to the pattern of landings. Most landings are taken from relatively inshore areas, but some grounds are over 60 miles offshore.

4.2 The implications of Fisheries Management Measures for the offshore oil and gas industry

The purpose of this section is to describe how the management measures implemented to attempt to ensure the sustainability and recovery of these fisheries, may also impact the offshore oil and gas industry in the North Sea. In this section the discussion of fisheries management measures deals only with technical measures such as area and seasonal closures of the North Sea which restrict access to specific fleets in order to offer protection to juveniles and spawning adults and encourage stock recovery. It is also necessary to identify how such areas of restricted access relate to areas with oil and gas deposits that may come on-line during the next few years.

4.2.1 The North Sea mixed demersal trawl fishery

The required reduction in fishing mortality (equivalent to fishing effort) on cod, haddock and whiting cannot only be achieved by a reduction in the total allowable catches set under quota management regulations. Management measures need to also include a provision to deter directed fishing, reduce by-catch in fisheries for other species, and deter discarding and mis-reporting in all fisheries. ICES also notes that benefits for all three species could be achieved through implementation of advice for individual species, because they are all taken in a mixed demersal fishery. Hence, the rebuilding of whiting and haddock stocks could be somewhat greater if the advice on North Sea cod, and measures to reduce discarding, are implemented and effectively enforced.

There are a range of technical measures applied to the North Sea fisheries for cod, haddock and whiting, which specify minimum mesh sizes and identify gear modifications such as the use of square mesh panels. These are of no relevance to SEA2 as they do not affect the operation of the oil and gas industry. However, in 2001, an additional emergency measure to protect cod was introduced by agreement between the EU and Norway. For the period 14 February to 30 April a closed area was implemented which restricted access to fishing but allowed limited access by pelagic vessels and those fishing for sandeels (Fig. 4.2.1.1). The closure covered the main spawning season for cod and was the first step in a series of measures forming a cod recovery plan. It was designed to protect mature cod to allow them to produce as many eggs as possible, and thus encourage a greater abundance of young cod.

The EU and Norway will discuss the implementation of a full recovery plan for cod in the North Sea and west of Scotland later in 2001. It has already been decided that industrial fisheries for Norway pout, blue whiting and sandeel will be prohibited in an area identified as the Norwegian Zone Closure in Fig. 4.2.1.1. No decisions have been made regarding the future of the cod closed area. If repeated, it is likely that a similar area will be closed, but for different time periods to take account of the earlier spawning of cod in the southern North Sea.

4.2.2 The North Sea beam trawl fishery

The most recent ICES assessment of the plaice and sole stocks shows that the fishing mortality on both stocks has been rising since the early 1960s. Plaice stocks were considered to be outside safe biological limits as the level of fishing was unsustainable and the stock size was too low. The spawning stock of sole was above precautionary reference points but the level of fishing was too high to be sustainable.

In the southern North Sea a protected area (the plaice box) (Fig. 4.2.1.1.) was established in 1989 to reduce the mortality of juvenile plaice in the beam trawl fishery. Trawlers larger than 300hp were not allowed to fish during the second and third quarter in the shallow coastal waters of the eastern North Sea where the main nursery grounds of plaice are located. The plaice box was extended to the fourth quarter in 1994, and since 1995 it has been closed for the whole year. The plaice box has moved the large beam trawlers further offshore and increase the activity around the edge of the Box.

Total international beam trawl effort increased rapidly in the 1960s, but has remained relatively stable since the early 1970s (ICES, 2000). During the past 10 years there has been an apparent increase in the UK beam trawl effort, but this has been caused by the addition of Dutch vessels to the UK register. There have been some changes to the distribution of this effort in the northern North Sea, but these have been limited in extent. The majority of the beam trawl effort remains concentrated south of 56^0N with a smaller amount extending between 56^0- 57.5^0N and 2^0-4^0W. The northern extent of this beam trawl effort extends to rectangle 45F2, where some fishing has taken place since the late 1980s. Some of this effort may encroach on the southern part of the Central SEA2 region.

Since the main income of the beam trawl fleet is derived from sole fishing, it is expected that activity will continue to be concentrated south of 56^0N for the foreseeable future. However, if stocks of plaice remain at historically low levels, there may be some attempt to divert effort to other species such as anglerfish and lemon sole. If this occurs, it could lead to some additional effort north of 56^0N though this would still be expected to be low in comparison to the main effort in the southern North Sea.

4.2.3 Industrial fisheries

There is no management objective set for the sandeel stock. However, as sandeel provide food for a variety of marine species, there is a need to ensure that the stock size remains high. Current ACFM advice is that the stock can sustain the current levels of fishing mortality but that this should not be allowed to increase further. In light of studies which linked low sandeel availability to poor breeding success of kittiwake on the east coast of Scotland, ICES advised a closure of the sandeel fisheries east of Scotland on the Wee Bankie and Marr Bank for the year 2000 (Fig. 4.1.5.1), and all commercial fishing has been excluded from this area. The closed area will be maintained for three years and re-evaluated each year, and it is probable that the closed area will be extended southwards to include parts of the northeast of England and Yorkshire coast.

The sandeel population at Shetland is close inshore and the vessels involved in the fishery are generally small and local. Seasonal closures were introduced in 1989 following poor breeding success of sandeel-dependent seabird populations, and only a restricted fishery has operated since 1995. The fishery is currently closed during the months of June and July to avoid any potential impact on the availability of 0-group sandeels to Shetlands seabird populations during the chick-rearing season.

Norway pout is also the subject of an important industrial fishery, and provides food for many marine fish species. The fishery is dominated by the Danish and Norwegian small meshed trawler fleets fishing mainly in the northern North Sea. The fishery operates throughout the year, but mainly targets 0-group fish in the 3rd and 4th quarters as well as 1-groups in the 1st quarter of the following year. Currently the stock is considered to be within safe biological limits and, in managing this fishery, by-catches of other species are taken into account. In order to protect juvenile gadoids from the fishery a protected area in the northern North Sea, called the Norway pout box, was established.

4.2.4 Conclusion

The effects of fisheries in the North Sea are widespread and ecologically important, and the removal of target species impacts the whole North Sea ecosystem. At present, 30 - 40 % of the biomass of commercially exploited fish species in the North Sea is caught each year. There is concern about the stocks of herring, cod, haddock, whiting, saithe, plaice and sole which are close to or outside Safe Biological Limits. Catch levels for many fish stocks are almost certainly not sustainable (OSPAR 2000).

Commercial fisheries also provide the greatest threat to rare fish species that have a widespread distribution in offshore waters. Although they are not the target all the direct exploitation, they can be taken occasionally as a by catch. The continuing decline in vulnerable species, such as those which have slow growth rates and which are late maturing, is a continuing cause for concern. Many of the other fish species of conservation importance are coastal and occur in greatest abundance in relatively shallow coastal water.

The main cause of decline in abundance of these species has been pollution in rivers, and the construction of weirs and other obstructions that have denied access for spawning fish. These species are seldom encountered in large numbers, and are not considered to be vulnerable to human activities in offshore waters of the North Sea.

The decline in fish stock abundance has been addressed by the European Commission, and has led to a number of management actions that have been taken to try and alleviate the problem of declining fish stocks. Relevant issues for SEA2 concern ways in which these measures may have implications for the offshore oil and gas industry. In particular, declining stocks and increased regulation may lead to increasing conflicts between the two industries over particular grounds.

Both the cod closure and plaice box (Fig. 4.2.1.1) have caused the displacement of fishing activity away from traditional grounds and towards the oil and gas fields of the North Sea. For the otter trawl fleet this represents an increase in existing levels of local effort in regions where the two industries already co-exist. There is some evidence of a slight increase in beam trawl activity in the Central and Northern SEA2 regions, since the gear was first used in the southern North Sea during the 1960s. This may have implications for the safety of both the fishing vessels and underwater structures associated with the hydrocarbon industry when they come into contact. The interaction between fishing gears and subsea structures such as pipelines is discussed further in section 4.3.1.4.

In 2002 the plaice box will still be in force, and the exclusion of beam trawlers from these coastal waters will maintain the more northerly distribution of this fleet. Despite this, the majority of beam trawl effort will remain below 56°N, and there will be only limited activity in the southern part of the Central SEA2 region. It is unclear whether the cod closed area will be maintained, but some form of spatial exclusion during the spawning season is likely, and this will tend to increase the density of otter trawlers within the Central and Northern SEA2 regions.

4.3 The impact of offshore oil and gas exploration

It is important to ensure that all other users of the sea are managed in an environmentally sustainable way. The offshore oil and gas industry has become a major economic activity in the North Sea since the late 1960s, and during the 1990s oil production almost doubled. There are now almost 500 platforms and 10,000 kilometres of rigid and flexible oil and gas pipelines running between offshore production wells and terminals on land (OSPAR 2000). There are several different ways in which offshore oil and gas exploration and production may impact fish populations and restrict the commercial exploitation of fish stocks. These involve techniques used during the exploration for hydrocarbon reserves, and the direct effects of infrastructure placed on the sea bed during oil and gas production. Foremost amongst these impacts are the potential effects of seismic surveys on fish populations during the spawning season, the impact on the seabed of drill cuttings at well sites, and the exclusion of fishing vessels from subsea wellheads, the area adjacent to the platform, and associated structures which require protection. The interaction between exploration and production infrastructure and fishing activity is well known, but the potential impact of these activities on fish populations is described in more detail in this section.

To minimise the risk of adverse impact on the marine environment during exploration and production, there is a range of legislation that ensures consistent environmental standards throughout the offshore oil and gas industry. In particular, the Offshore Petroleum Production and Pipelines Regulations (1999) require operators to submit an Environmental

Statement for all new offshore developments, or to obtain a dispensation from this requirement. The Petroleum Act (1998) requires a consent to discharge chemically treated water used during a pipeline commissioning, and this details the permitted volume, the chemical constituents, and rate of discharge.

During each round of offshore licensing, Government Departments and their Agencies recommend appropriate conditions and restrictions on each block to minimise the potential environmental impact of exploration and production. Conditions cover a wide range of issues including impacts of drilling and seismic activity on fish, sea birds, marine habitats, interference with other sea users, and the formulation of drill muds.

It is understood that broad scale environmental impacts from, for example, chemical discharges during pipeline commissioning, and produced water discharges, will be considered during the part of the SEA dealing with contaminants.

It has been assumed that activities such as gaseous emissions due to flaring at the well site have no impact on fish populations.

4.3.1 Seismic activity

Seismic surveys are undertaken at sea to locate the geological structures that are associated with hydrocarbon deposits. High energy sound sources are discharged in the water column, and the sound reflected from the underlying strata is then recorded by hydrophones and analysed to determine the geological structure of the seabed. Good echoes require repeatable, short duration and high energy pulses emitted from air gun arrays which are generally deployed from a survey vessel. The duration of a seismic survey may extend from one day to several weeks, depending on the size of the area. The sound levels emitted are typically of the order 226 dB re 1µPa @ 1m for a single airgun, or 248dB re 1µPa @ 1m for an array. Frequencies are generally up to 120 Hz.

It is not considered necessary to complete a review of the effects of underwater acoustic noise on fish populations, however, further reviews of seismic activity and descriptions of their effects on fish are provided by Engas *et al*., (1993); Carter & Hall, (1998), Wardle *et al*., (1998) and Turnpenny and Nedwell (1994).

When organisms are in close proximity to such an air gun array there is thought to be a high risk of injury or death. However for fish populations, concern generally focuses on the non-lethal behavioural effects of the disturbance. The main issue of concern with respect to fish is the potential disruption of spawning activity if seismic surveys were to be undertaken close to aggregations of spawning fish. Evidence to support the disruptive effect of such surveys was shown by recent Norwegian studies, which suggested that the use of air gun arrays could reduce catches of cod and haddock over a large area, and for several days after completion of the survey (Engas *et al.,* 1993). Although the impacts of seismic activity outside the spawning season will be largely transient, and result merely in the temporary redistribution of fish, during the spawning season this effect could be more serious and may lead to the severe disruption of spawning activity.

Although there is no evidence of an adverse impact of seismic activity on the spawning success of fish, there is sufficient concern to suggest that a precautionary approach to the use of this equipment at these times is adopted. Licence condition B 1 (ii) imposed by the Fisheries Departments and relating only to the exploration phase, prevents seismic surveys during specified periods of the year in specific blocks. This condition has been applied widely in the North Sea during recent licensing rounds to limit the potential adverse impact of seismic activity on spawning fish. It is considered that this mitigation effectively removes all potential threat to fish spawning that may be caused by these surveys. The information provided in section 3.3 on the geographical distribution and duration of spawning can be used to advise this mitigation.

4.3.2 Cuttings disposal

It is increasingly common for operators to select environmentally acceptable drilling muds such as conventional water-based muds (WBM) or low toxicity oil based mud (LTOBM). The constituents of mud Systems must be identified in the Offshore Chemical Notification Scheme (OCNS) which categorises chemicals according to their toxicity, persistence and bioaccumulation potential. Further details of the OCNS scheme can be found in the section of SEA2 dealing with contaminants.

Many wells currently drilled in the North Sea retain all LTOBM for transfer to shore for processing and disposal, while WBM is generally left on site. In the relatively shallow and dispersive waters of the southern North Sea, it is generally considered that cuttings do not accumulate at the well site but are transported away from the platform and dispersed naturally. Only in the deep waters of the northern North Sea have accumulated cuttings piles become the focus for more specific research.

WBM released into the water column becomes separated from the cuttings and is diluted, and rock particles in the water column are unlikely to be distinguishable from natural suspended solids. The most common effect of the WBM is an elevation of barium concentrations in the sediments, which may extend up to 1,000m from the drilling location along the predominant tidal axis. Barium is persistent in sediments, in the form of barium sulphate or carbonate, which are essentially insoluble and therefore inert.

In deeper, low-energy water, physical changes attributable to drilling discharges can be long-lasting. Cuttings piles may still be clearly visible for some time, smothering the benthic fauna at the well site and resulting in reduced densities of benthic organisms nearby. While these cuttings piles remain within the 500 m safety zone they are considered to be relatively inert and to have a minimal impact on fish populations and trawling activity. However, recent attention has focused on the fate of cuttings piles after platform decommissioning. The preferred oil and gas industry option for decommissioning is to leave cuttings piles *in situ*. The option of decommissioning of cutting piles is currently the subject of an extensive UKOOA joint industry funded research project. Concerns about contamination spread caused by over-trawling of cuttings piles left *in situ* are the subject of current FRS-ML research programmes. Other fishing hazards associated with trawling through drill cuttings, including potential snagging, entrainment of material in nets and the possibility of tainting fish within the nets. These issues are the subject of ongoing research (see section 5.1).

The smothering of seabed fauna and sediments is a potential threat to species that require particular sediments on which to feed and spawn. The most important of these is the herring (section 3.2.10) which spawns on gravel beds at specific locations in the North Sea. In order to prevent permanent loss of these habitats (Fig. 3.2.10.1) the Fisheries Departments attach licence conditions to blocks in sensitive areas which require the assessment of the suitability of the substrate for herring spawning.

Although there have been studies of the site-specific impact of contaminants on benthic fauna (Gray *et al*., 1990), there are no data which describe the impact of cuttings on fish populations, or the secondary effects on populations through loss of feeding areas.

4.3.3 Hydrocarbon spill

The damage caused to the marine environment by an accidental release of oil, condensate or diesel depends on a number of factors, including the size of the spill, the characteristics of the hydrocarbon, the prevailing weather conditions, and the proximity of sensitive populations. Both diesel and condensate are liquids of low viscosity, and so when spilt at sea they spread rapidly on the sea surface and disperse. The accidental release of oil presents a greater risk, particularly in the event of an oil well blow-out in which the hydrocarbons cannot be contained. There have been no such incidents during drilling activity in the North Sea to date.

Legislation prohibits the discharge of oil to the sea from both installations and pipelines, and it is now a requirement for all operators to have an effective response procedure in the form of an oil spill contingency plan. The International Maritime Organisation (IMO), an agency of the United Nations dealing with maritime safety and the prevention of marine pollution, has actively promoted the protection of Special Areas. For example, under MARPOL Annex 1, the discharge of oily water from vessels and installations is prohibited in Special Areas, one of which is the North Sea.

All hydrocarbon spills have the potential to affect fish populations by tainting, caused by ingestion of hydrocarbon residues in the water column and on the sea bed. If large-scale releases of oil were to reach the sea bed then there is potential for smothering of features that are used by fish either as spawning, feeding or nursery grounds.

In the event of a substantial oil spill from an offshore installation, the Food and Environment Protection Act 1985 (FEPA) enables Ministers to establish temporary fishing exclusion zones which prevent fishing for a fixed period of time in order to maintain public confidence in the standard of fish and shellfish as food. As a recent example, such fisheries exclusion zones were established in the aftermath of the Braer and Sea Empress oil spill incidents which were, of course, related to the transport rather than to the exploration and production of hydrocarbons in offshore waters. The Braer spill had particularly severe effects on the fish farming industry in the Shetland Islands, while commercial fishing activities were only affected in a small area of the Burra Haaf.

The exclusion of commercial fishing activity would only be lifted when monitoring studies showed that fish and shellfish in potentially contaminated areas were of a suitable standard for human consumption. Only one such example exists, when as a precaution, a FEPA exclusion zone was established in the aftermath of the ~600 tonne spill at the Captain field in the outer Moray Firth in 1997. Monitoring studies conducted by FRS Marine Laboratory (SEERAD) showed a very localised area of shellfish taint that, after exhaustive chemical fingerprinting analysis, was shown not to have been derived from the spilt oil.

For more information on the potential for offshore activities to contribute to hydrocarbon contamination of fish please refer to the section of the SEA dealing with contaminants.

4.3.4 Safety zones at surface installations and subsea structures

The following two sections describe interactions between the oil and gas industry and fishing activity, rather than the fish resource.

The Petroleum Act (1987) allowed for the creation of safety zones at all offshore surface installations and subsea structures, excluding pipelines. Under this legislation, a zone of 500 m radius (an area of approximately 78 hectares) is created when surface structures such as platforms become operational. All sub-sea installations can also be protected by safety zones of similar size. These zones are normally patrolled by support vessels, and the proximity of other vessels can be monitored from the installations themselves.

In the early 1980's, it was estimated that the loss of fishing area in the North Sea caused by these zones was ~0.25% of the total area of the North Sea. Although this has increased over the last decade, the maximum loss of fishing area is less than 1%. The exclusion of fishing activity from these zones does not adversely affect fish catch rates, as fishing effort is simply diverted to other regions. The loss of area does not result in a proportional loss of catch, and the individual zones themselves are so small that they do not completely obscure any one fishing ground.

It has been thought that these safety zones may act as closed areas, protecting populations and individuals from capture by fishing gears and thereby enhancing the stock. There is little evidence to support this assertion. Regular incursions into the safety zones by trawlers occasionally occur, and these are unlikely to allow the establishment of protected populations of fish.

4.3.5 Obstruction caused by well heads and pipelines

The safety of all users of the sea must be of primary concern during the design and construction of sub-sea structures, particularly to ensure that they are over-trawlable and that gears do not become snagged. Where possible, vulnerable structures such as well head clusters and valves are placed within a safety zone and provided with further protection such as a composite structure with a steel framework, designed with sloping sides to deflect trawls. Pipelines are protected by the addition of a protective coating or by burial. In all cases these extra measures are expensive and the offshore industry has recently revised its' guidelines to take account of recent advances in technology and the changing requirements of the industry (DNV, 1997). For structures designed and built 10 or more years ago, the loads determined at the time may no longer be applicable to the heavier gears used by the more powerful fleets now operating in the North Sea.

The decision as to whether a pipeline is trenched or placed on the sea bed is complex, and balances the need for pipeline protection with the need to limit the obstruction it may cause to fishing gears. Although pipelines can cause accidental interference, it has been reported that they are used by some trawlers as tows, presumably on the assumption that pipelines aggregate fish and so provide greater catch rates that similar tows nearby. A recent Norwegian study involving experimental trawling of pipelines with gill nets and otter trawls concluded that they had only limited ability to aggregate fish (Valdemarsen, 1993; Soldal, 1997). Since the loss of the trawler Westhaven, however, there have been a number of initiatives to ensure that pipeline spans and sub-sea structures do not pose a threat to fishing vessels.

Traditionally, pipelines of diameter less than 16 inches were buried for their own protection, while larger diameter pipelines were left on the sea bed and were unlikely to be seriously damaged. Although there is evidence that pipelines up to a diameter of 40 inches cause only minimal gear damage, they can affect the gear geometry and efficiency once past the obstruction (Valdemarsen, 1993). Even pipelines which are protected on the surface by rock dumping can also present a hazard to towed fishing gears (Soldal, 1997).

It is normal practice to apply for a safety zone at all sub-sea developments, but these are not marked with surface buoys. Without such visible markers, the offshore oil and gas industry is dependent on fishing vessels maintaining a safe distance from all sea bed structures.

4.3.6 Conclusion

The total input of oil into the North Sea from the offshore oil and gas industry has decreased significantly since 1985, but has stabilised during the 1990s. Approximately two thirds of this input was from discharges of produced water, while the input of oil from cuttings has progressively decreased with the decline in use of WBM and cessation of discharge of contaminated oil based cuttings following a recommendation at the 4th North Sea Conference (OSPAR 2000).

There is now a broad a range of legislation that ensures consistent environmental standards throughout the offshore oil and gas industry. In particular, the Offshore Petroleum Production and Pipelines Regulations (1999) and the Petroleum Act (1998), require consistent environmental assessment of offshore developments and pipeline discharges. Detailed recommendations for appropriate conditions and restrictions are applied at each round of offshore licensing by Government Departments and their Agencies. This ensures that environmental issues in relation to, for example, fish, sea birds and marine habitats, are taken into consideration.

The greatest threats to rare species that occur in offshore waters are trawl fisheries which may take them as part of the by-catch. None of the species described in Section 3.4 occupy discreet habitats that are directly impacted by the licence blocks identified in the SEA2 region. Their widespread distribution will make these species considerably less vulnerable to disturbance or mortality from seismic survey operations, drilling at well sites, or construction of well heads or pipelines. Indeed it is possible that in those areas where exclusion zones are adhered to, these may afford some protection for these species from demersal trawling activity.

5. ASSESSMENT AND CONCLUSIONS

5.1 Interaction between the offshore oil and gas industry and fish and fisheries

The offshore oil and gas industry is regulated to ensure that it meets increasingly stringent environmental requirements. Some of these regulations, for example which restrict seismic activity and the discharge of contaminants in produced water, have been described in section 4.3. This regulation is an ongoing process, and recent developments have seen the introduction of new legislation to ensure that oil and gas production complies with the requirements of the Habitats Directive, and the decision by OSPAR (98/3) that dumping of disused offshore installations within the maritime area should be prohibited.

There is some concern within Fisheries Departments and the fishing industry that seismic activity could have an adverse impact on the spawning success of fish. Despite a lack of supporting evidence of an adverse effect of population viability, a precautionary approach has been recommended and widely adopted. The current licensing programme imposed by the Fisheries Departments prevents seismic surveys in those areas, and at certain times of year, which are most sensitive to spawning fish. These controls have been used effectively for the last decade, and are regularly reviewed. This suggests that the production of underwater noise by the offshore industry now has only a minor impact on fish populations. The other main impact of exploration activity is drilling, which because of its episodic and localised distribution can be considered to have only minor physical and chemical impacts.

In recent years there has been substantial reduction in the quantities of contaminated material discharged from offshore installations during production drilling. The input to the sea of oil from cuttings has progressively decreased owing to the replacement of oil-based drilling muds with water-based and organic-phase drilling fluids. Since 1996 the discharge of oil based cuttings from platforms has ceased. Analysis of benthic communities affected by contaminated cuttings suggests that persistent effects are relatively localised, but there has been insufficient research to determine the precise scale of impact, and particularly of the cumulative effects of multiple well sites in a field. It is thought, however, that the threat to fish populations by tainting from existing cuttings piles is negligible. There has been some discussion within the offshore industry of what to do with cuttings piles when fields are decommissioned. The preferred oil and gas industry option for decommissioning is to leave cuttings piles *in situ*, and this topic is currently the subject of an extensive UKOOA joint industry funded research project. It is possible that if piles are left *in situ* on the sea bed they may be rapidly dispersed by trawls, thereby increasing the potential for contamination. Concerns about the impact of over-trawling of such cuttings piles are currently the subject of FRS-ML research programmes.

A range of potentially toxic materials can be discharged with produced water, including heavy metals, PAHs and production chemicals. The quantities of discharged produced water by the offshore industry have recently been reduced using techniques which rely on the re-injection into the reservoir. The Offshore Chemical Notification Scheme has ensured that the discharge of oil and contaminants in produced water is now the subject of increased control.

OSPAR Decision 98/3, agreed at the Ministerial Meeting of the Contracting Parties at Sintra, Portugal in 1998, requires all redundant North Sea oil and gas installations to be removed for recycling ashore. There are several implications of this decision for the marine environment, including the fate of cuttings piles, the decommissioning and removal of pipelines and other sub-sea structures, and the impact on the marine environment of removing the platforms themselves. Of most relevance to the fishing industry will be decisions concerning the disposal of disused pipelines and cables. Several options are under consideration, including leaving in place and burial by rock dumping, partial or complete removal or reuse. As it is thought that the total degradation time of steel pipelines is in the range of 300 to 500 years (Soldal, 1997), any option which leaves material on the sea bed must include the requirement for regular monitoring to ensure that pipelines do not develop free spans or become severely damaged.

The direct and indirect effects of fisheries, including industrial fishing and shell-fisheries, occur at all levels in the ecosystem. A number of management actions have recently been taken by the European Commission to try and alleviate the problem of declining fish stocks, and these have included closed areas which prevent access by certain parts of the fishing fleet during sensitive times of the year. These measures will displace vessels from traditional grounds and this may cause some increased fishing effort in the oil and gas fields.

There are well established means of liaison between the fishing industry and offshore oil and gas industry, which ensure that claims for compensation and general safety issues are dealt with promptly. UKOOA and the fishing industry together run a non-attributable compensation claims scheme, which will consider claims for loss or damage to fishing gears, paid out of the central fund. There is also a joint Government and industry forum, the Fisheries and Offshore Operators Consultative Group (FOOCG), where representatives of the UK fishing industry, the oil and gas industry, seismic operators and key Government departments can raise and discuss industry concerns, and advise on best practice. Although there will inevitably be interactions between the two industries in future, these are valuable ways of ensuring that liaison occurs.

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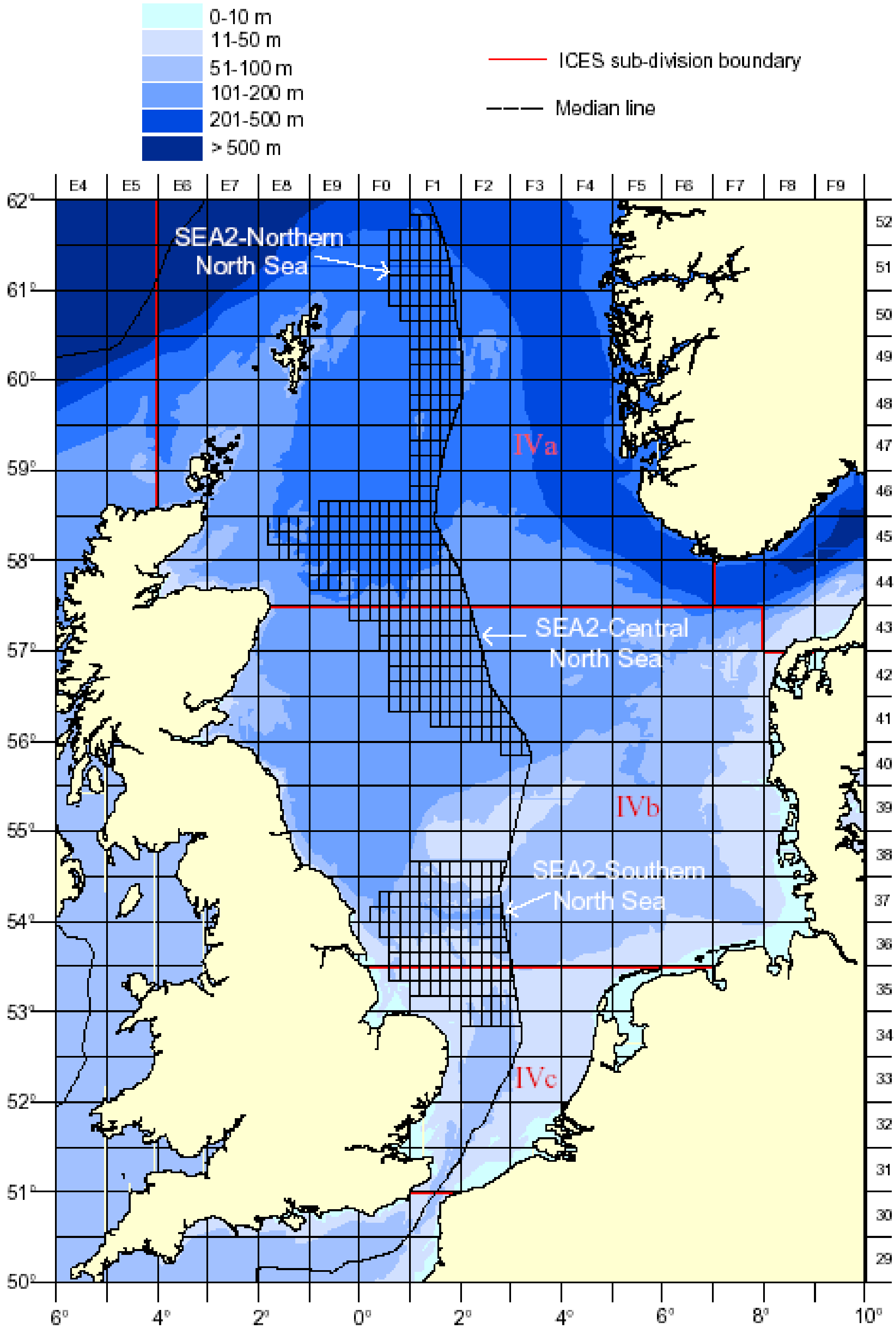


Figure 1.1 The North Sea area showing the position of the northern, central and southern SEA2 regions, the median line and ICES sub-division boundaries.

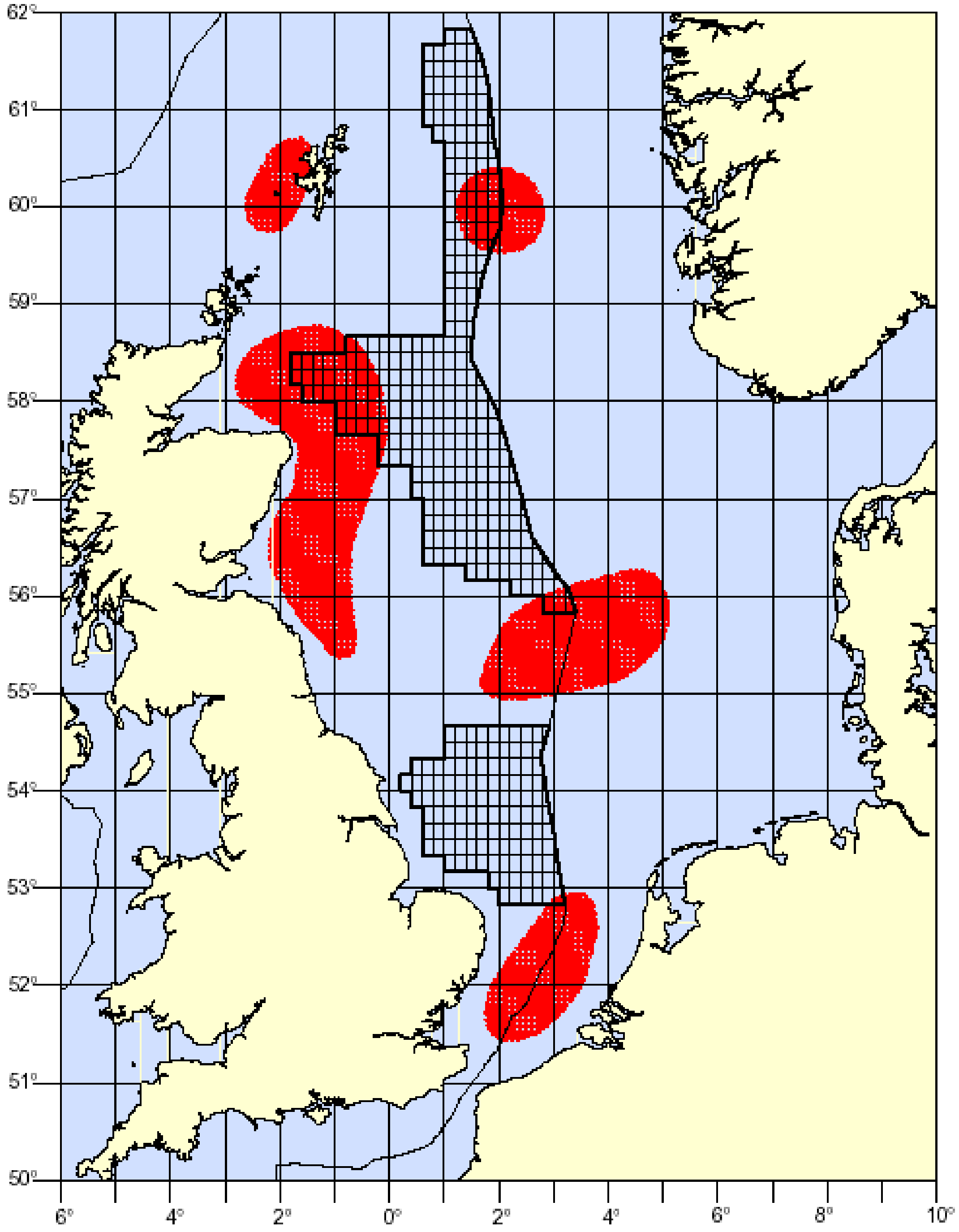


Figure 3.2.1.1 Distribution of whiting *Merlangius merlangius* spawning activity.

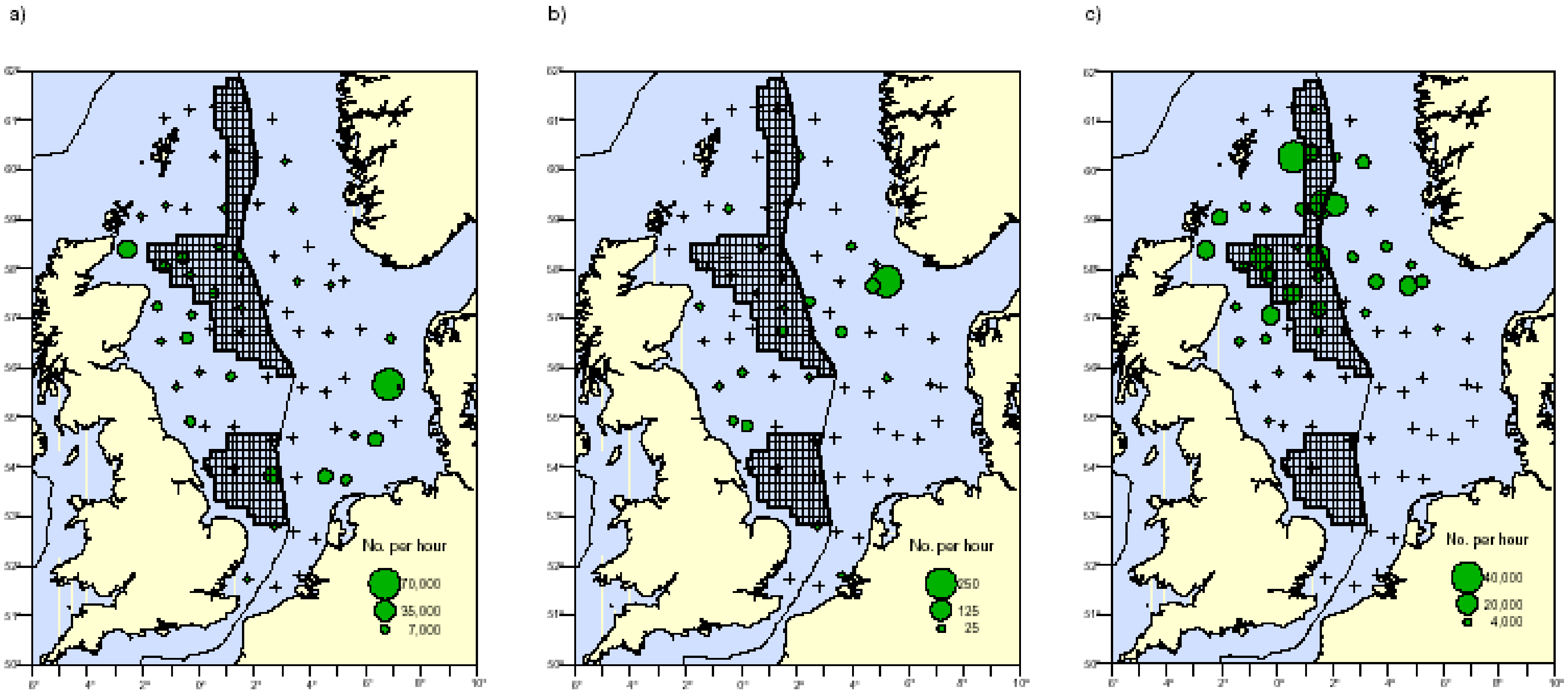


Figure 3.2.1.2 Catch rates of juvenile (0 and 1-group) a) whiting, b) cod and c) haddock in the North Sea, sampled during English international bottom trawl surveys from August to September 1999.

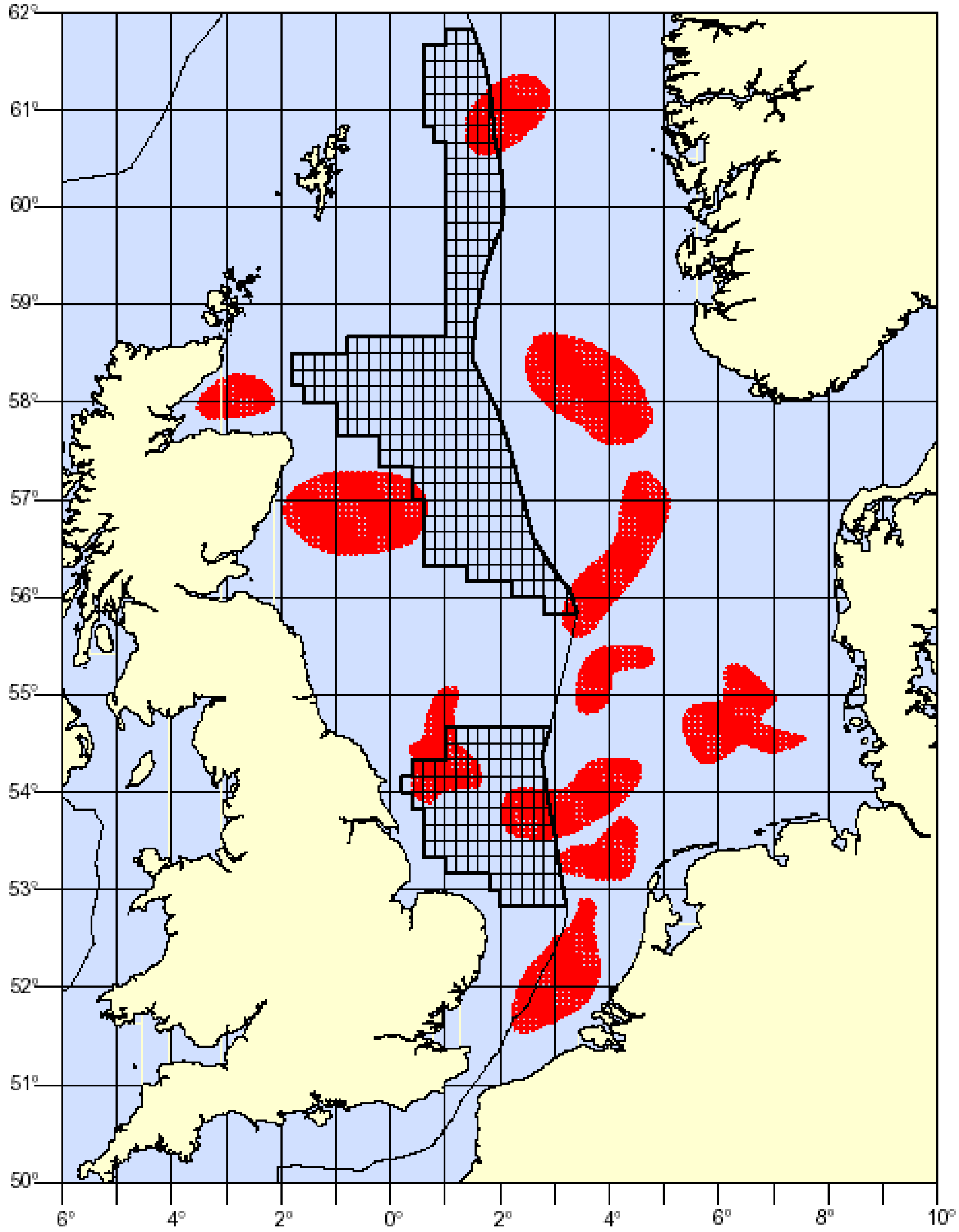


Figure 3.2.2.1 The distribution of cod *Gadus morhua* spawning activity.

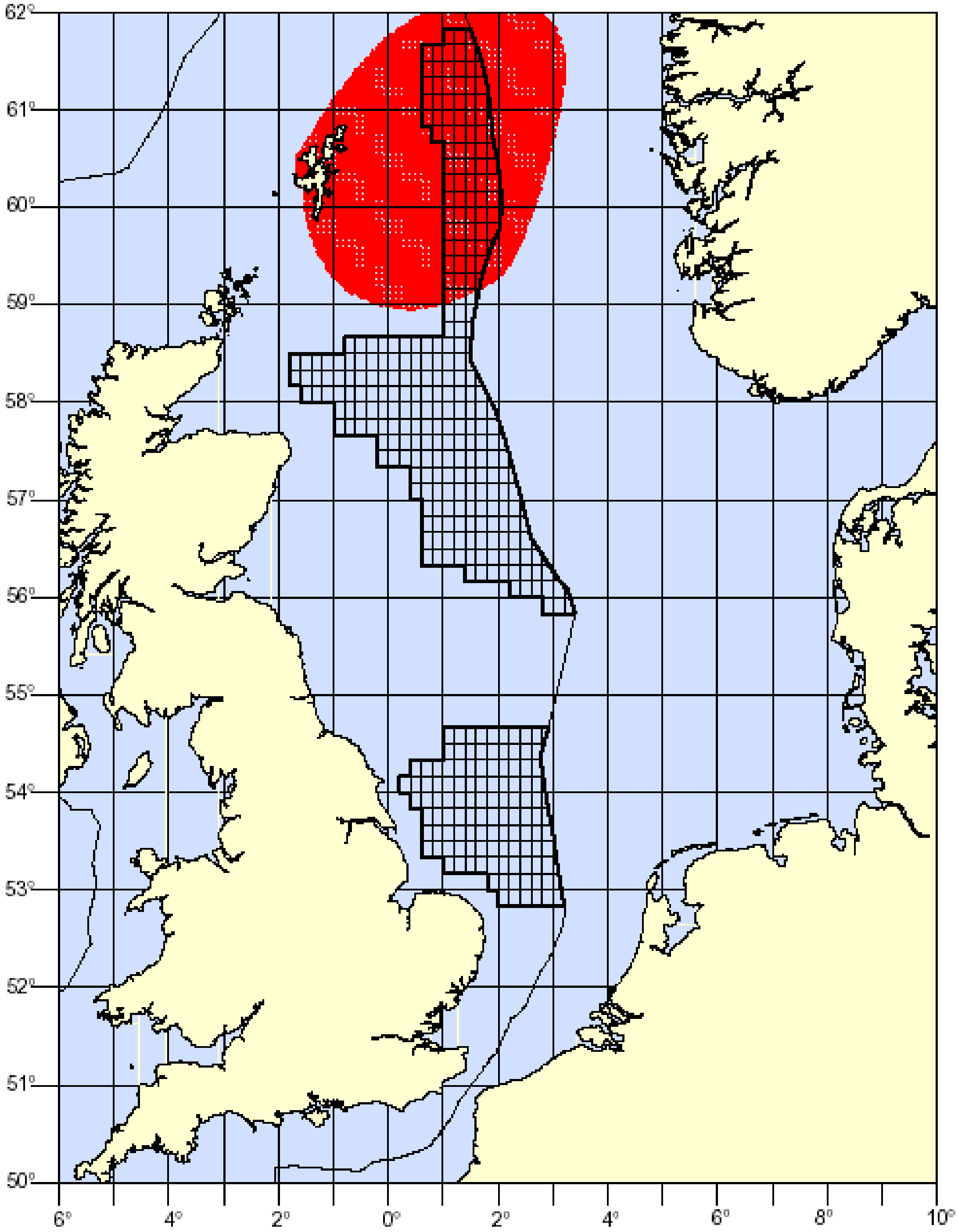


Figure 3.2.3.1 Distribution of haddock *Melanogrammus aeglefinus* spawning activity.

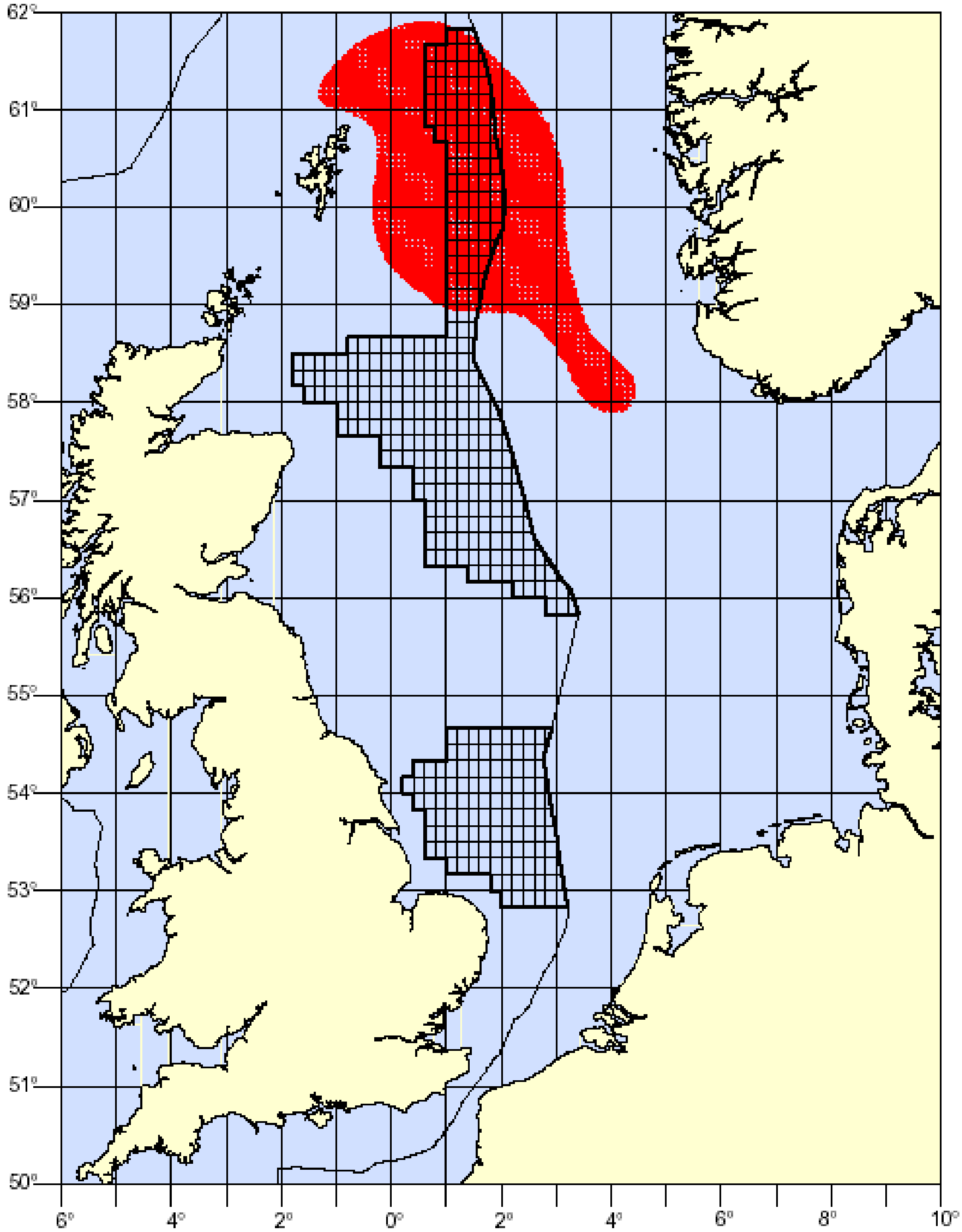


Figure 3.2.4.1 Distribution of saithe *Pollachius virens* spawning activity.

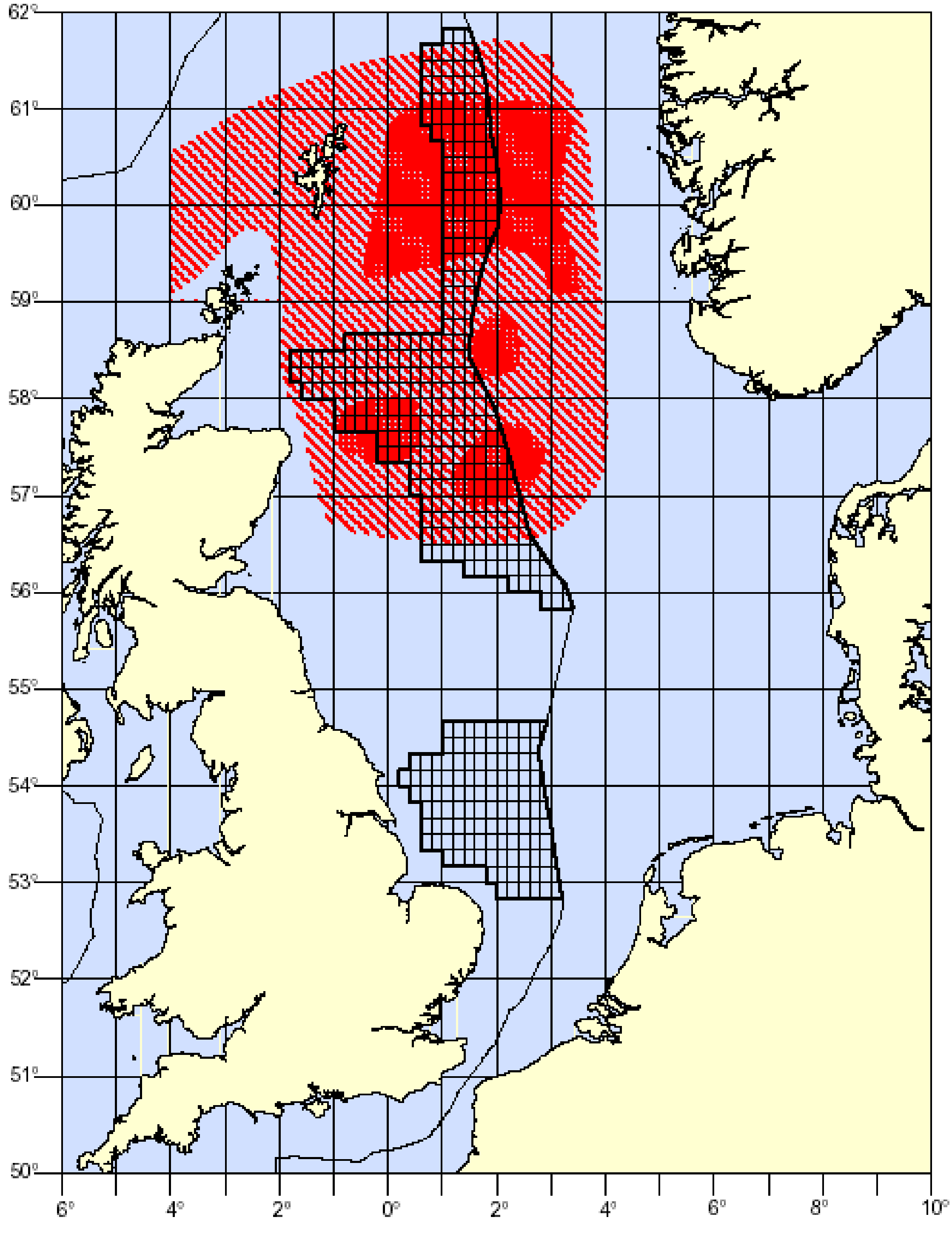


Figure 3.2.5.1 Distribution of Norway pout *Trisopterus esmarkii* spawning activity. Different intensity of spawning is marked by different colour intensity.

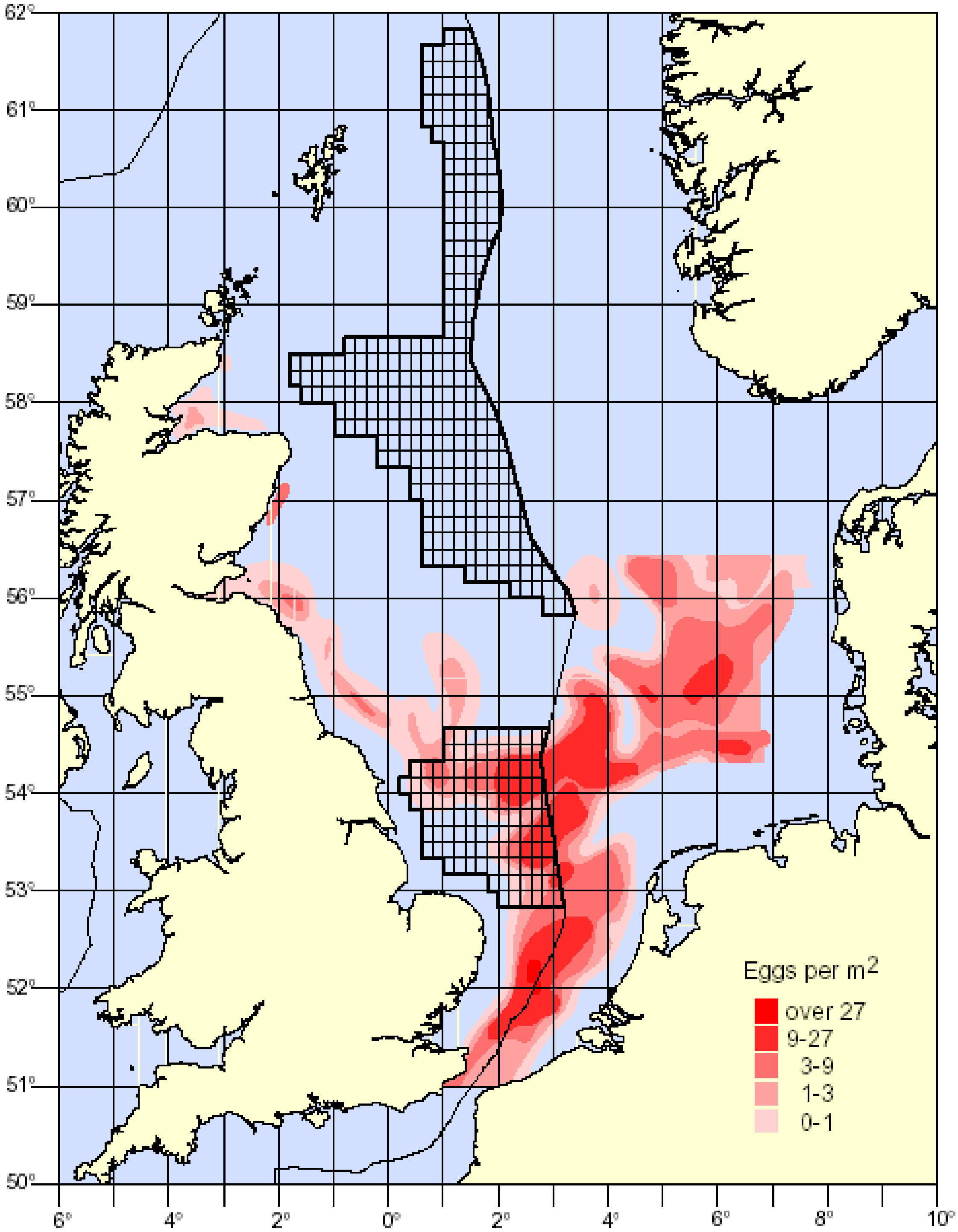


Figure 3.2.6.1 The distribution of plaice *Pleuronectes platessa* spawning activity.

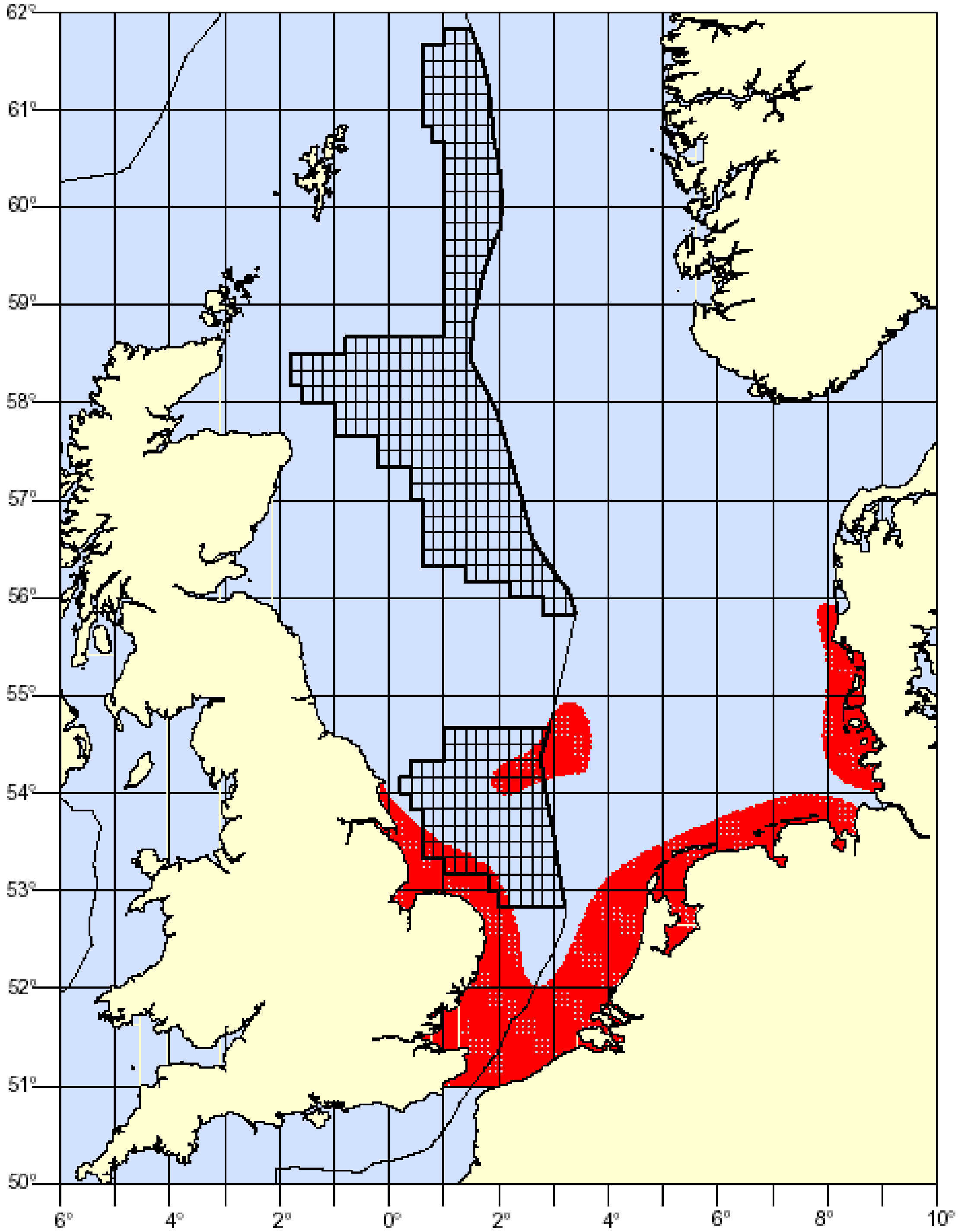


Figure 3.2.7.1 Distribution of sole *Solea solea* spawning activity. Different intensity of spawning is marked by shading.

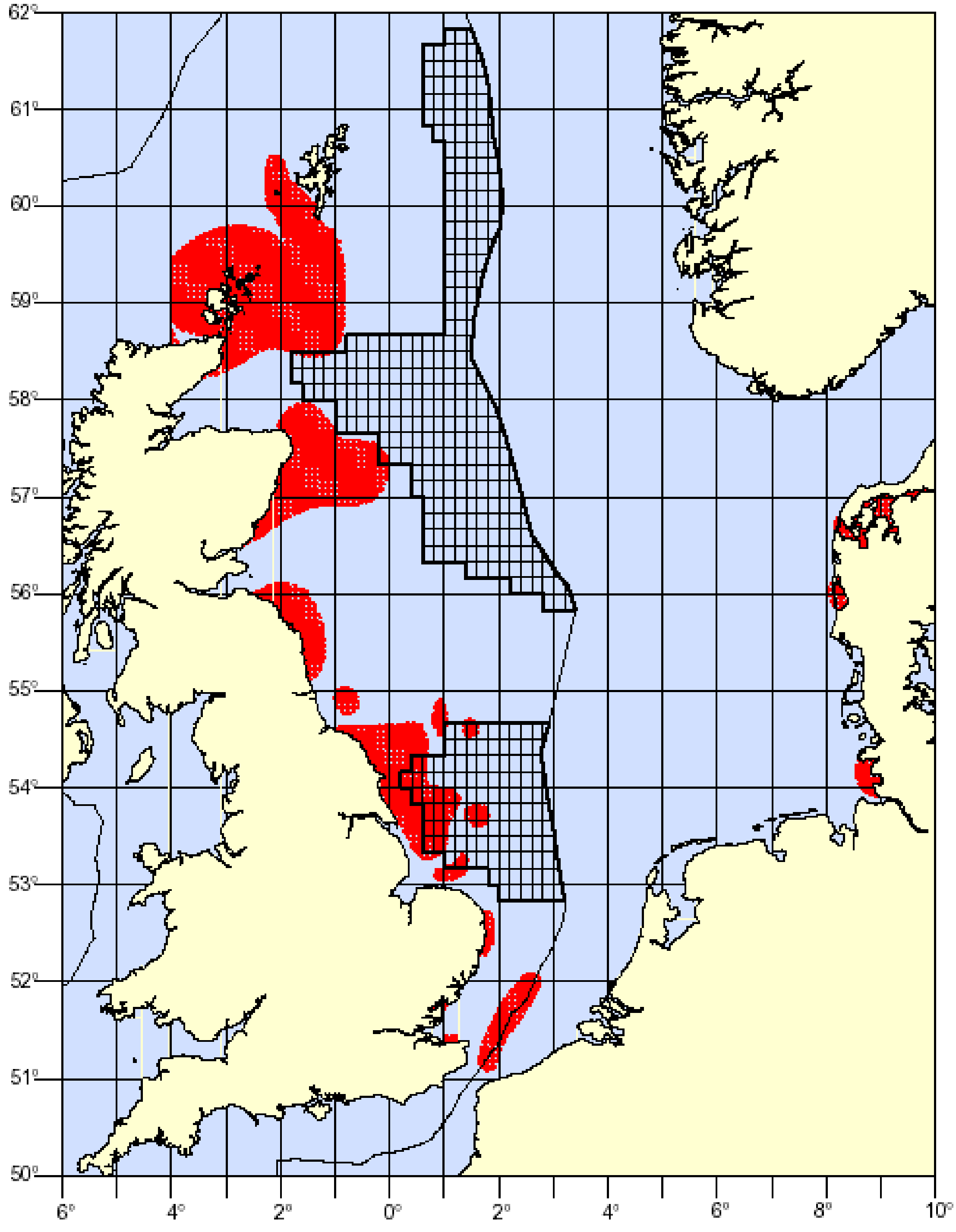


Figure 3.2.10.1 Areas of the seabed known to be used as herring *Clupea harengus* spawning grounds.

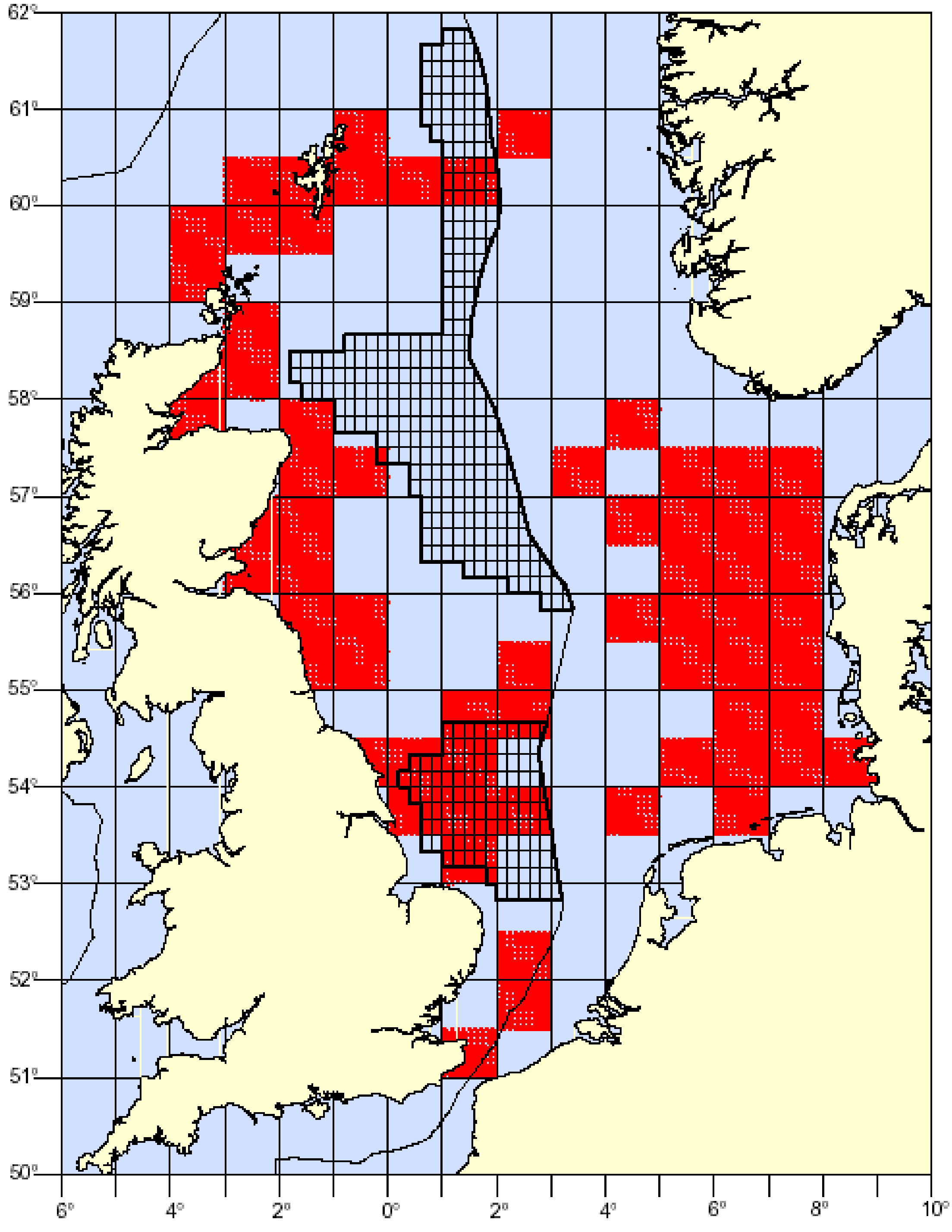


Figure 3.2.11.1 The distribution of sandeel spawning areas, based on the presence of early stage larvae sampled between 1908 and 1997.

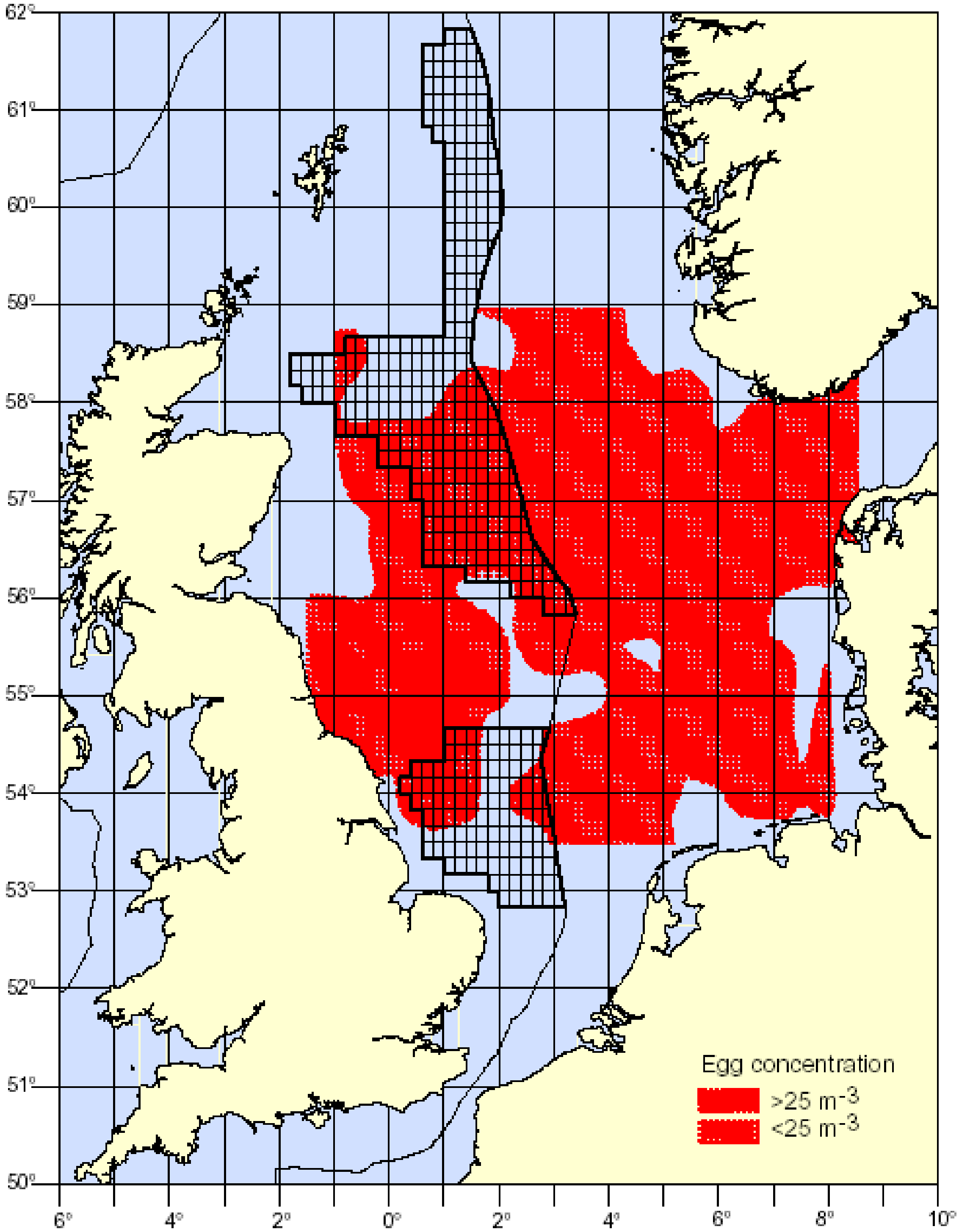


Figure 3.2.12.1 Distribution of mackerel *Scomber scombrus* spawning activity, based on the catch rates of eggs sampled during spring 1999.

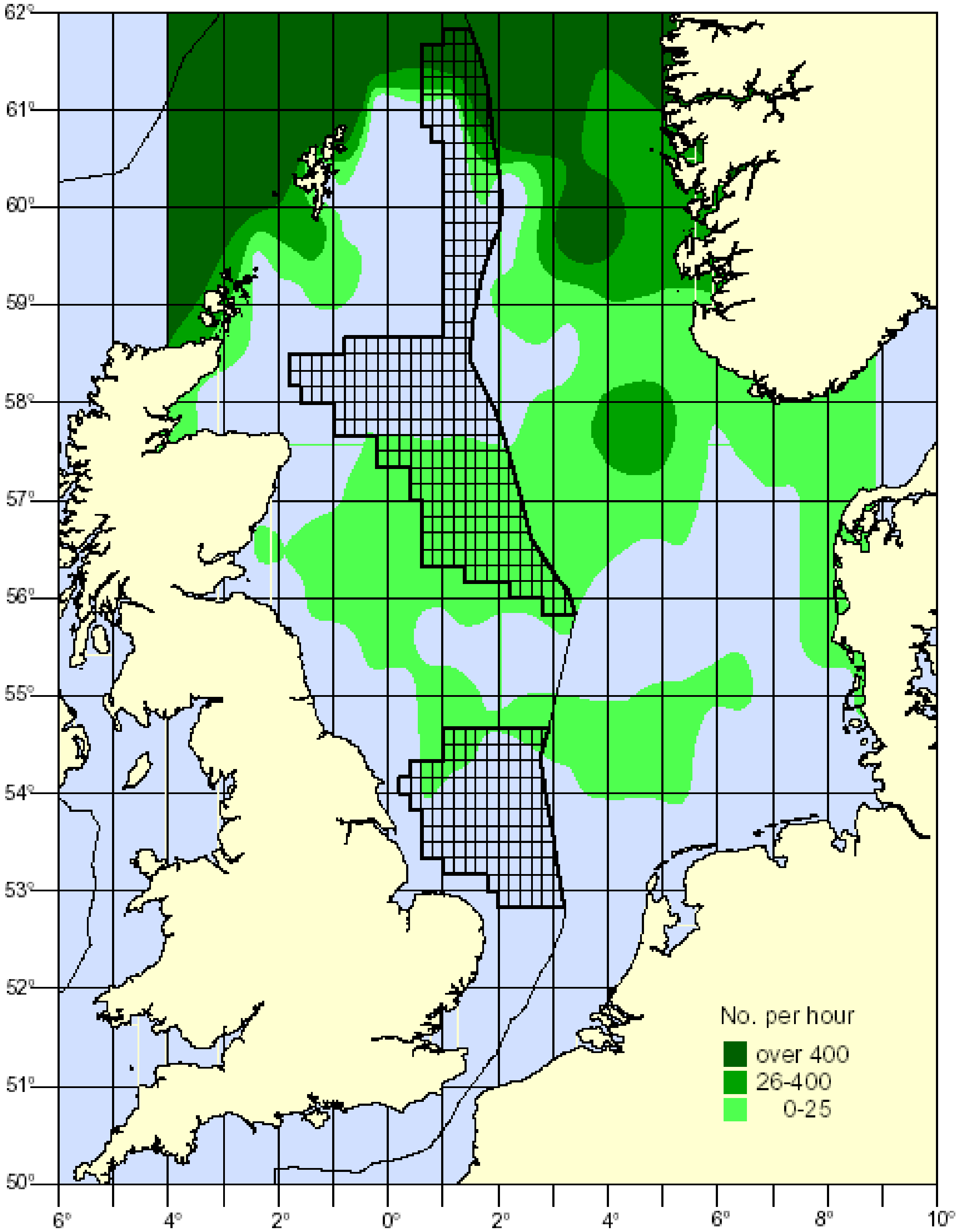


Figure 3.2.12.2 The distribution of juvenile mackerel using data from the 1997 and 1998 International Bottom Trawl Survey during quarter 1.

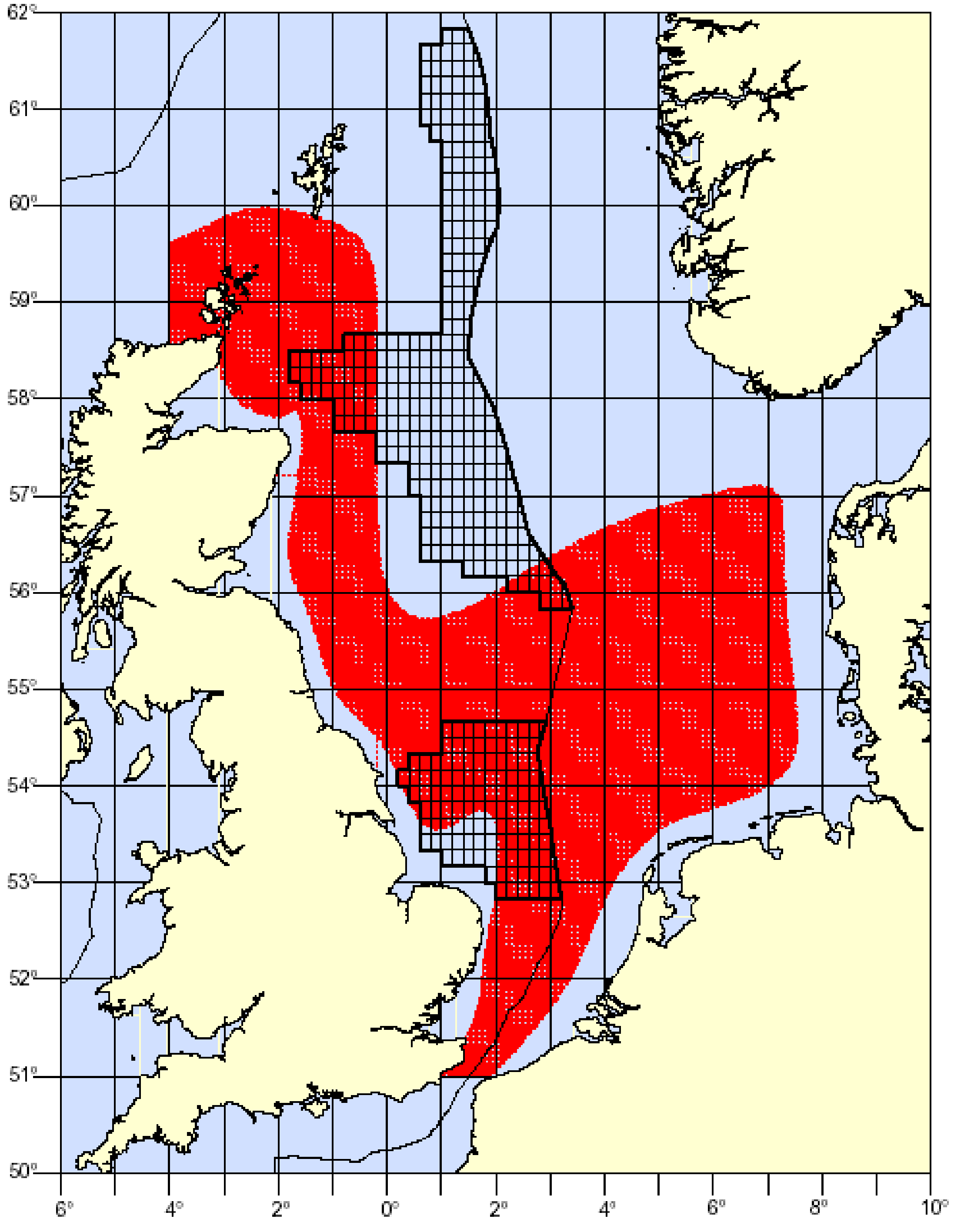


Figure 3.2.13.1 The distribution of sprat *Sprattus sprattus* spawning activity.

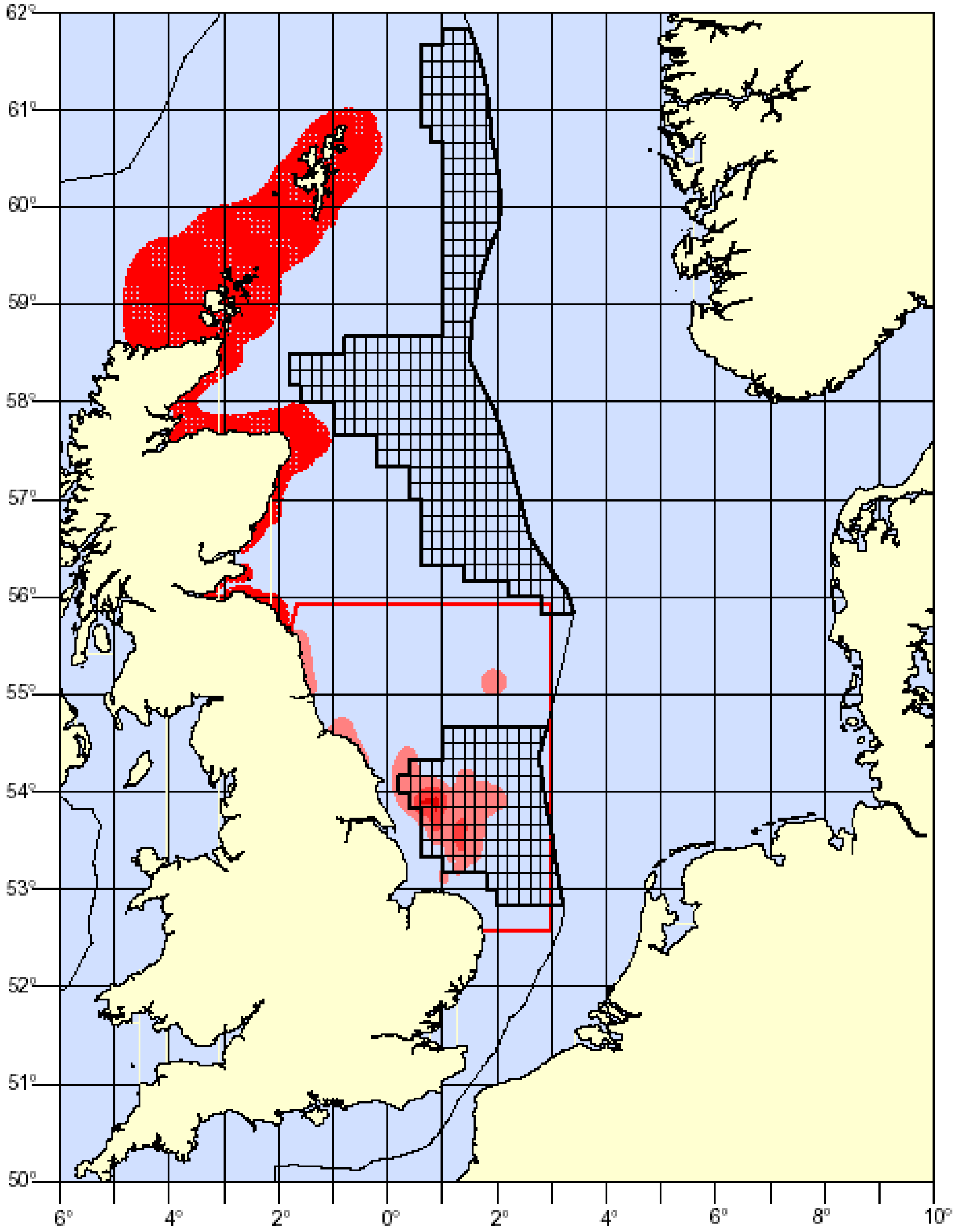


Figure 3.2.16.1 Areas of crab spawning and over-wintering. In English waters contours represent catches of early stage zoea, sampled during 1993 within red box, while the area in Scottish waters shows assumed spawning activity.

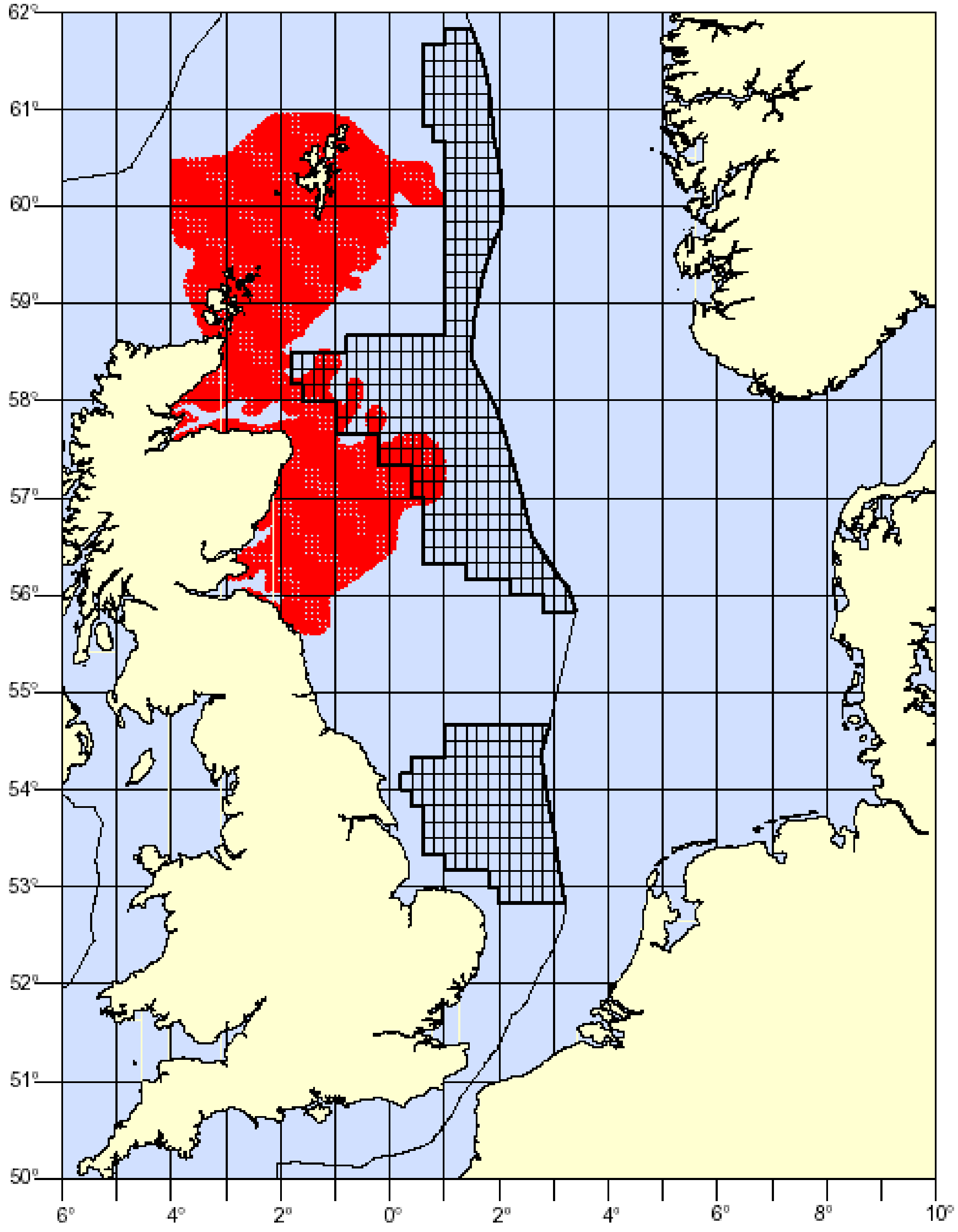


Figure 3.2.17.1 Distribution of scallop *Pecten maximus* grounds in the North Sea.

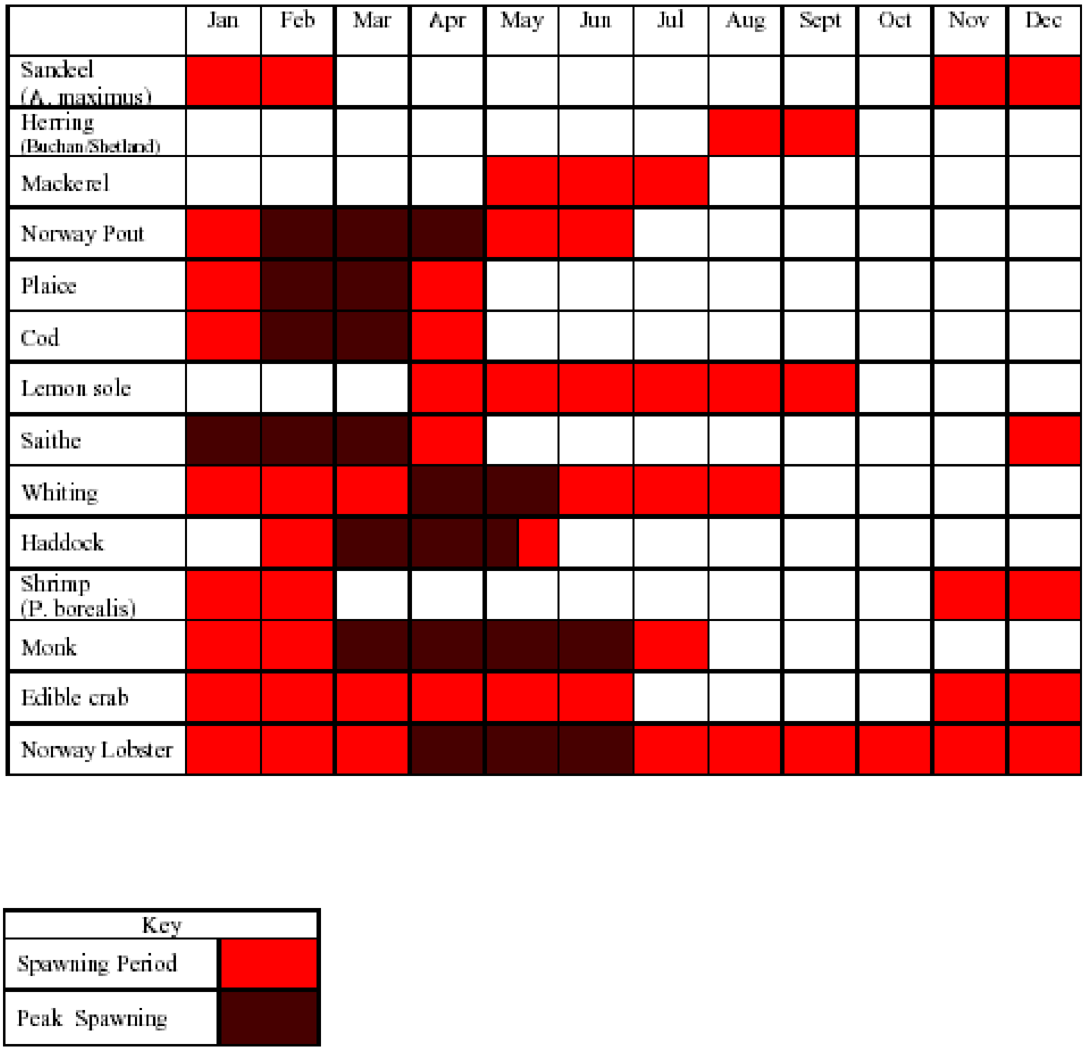


Figure 3.3.1. Main spawning periods of commercially important fish and shellfish in the Central and Northern SEA2 regions.

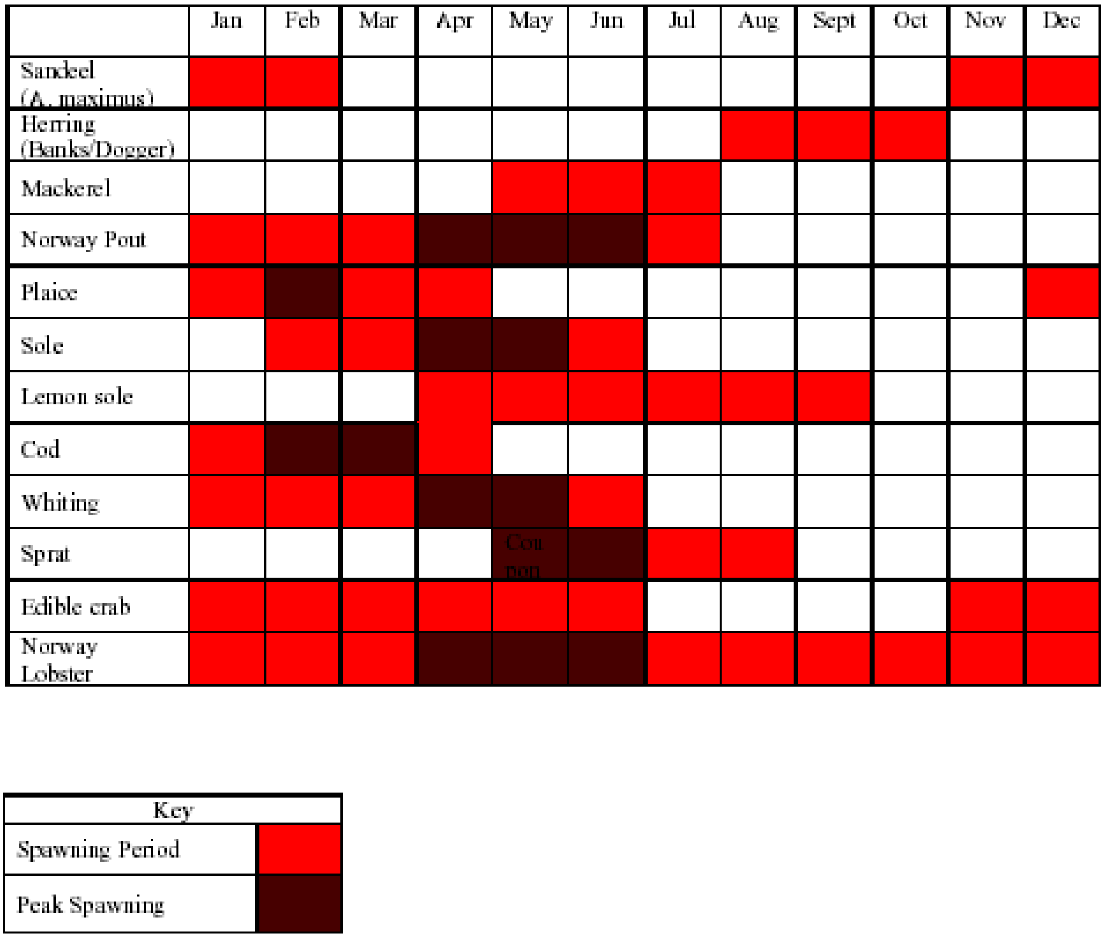


Figure 3.3.2. Main spawning periods of commercially important fish and shellfish in the southern SEA2 region.

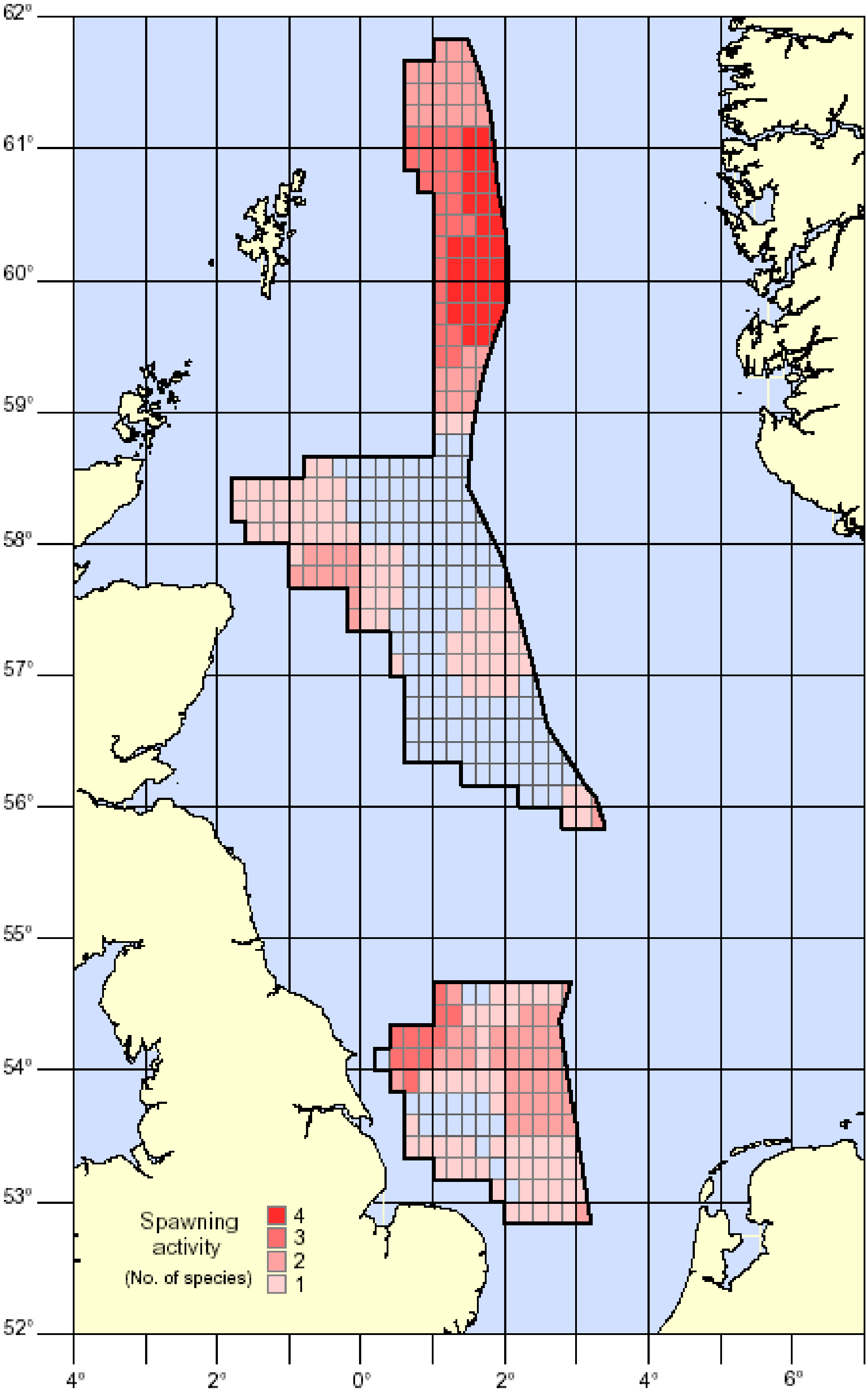


Figure 3.3.3 Different spawning intensities of finfish (cod, haddock, whiting, saithe, Norway pout, plaice, sole, and mackerel) by licence block, during February to June.

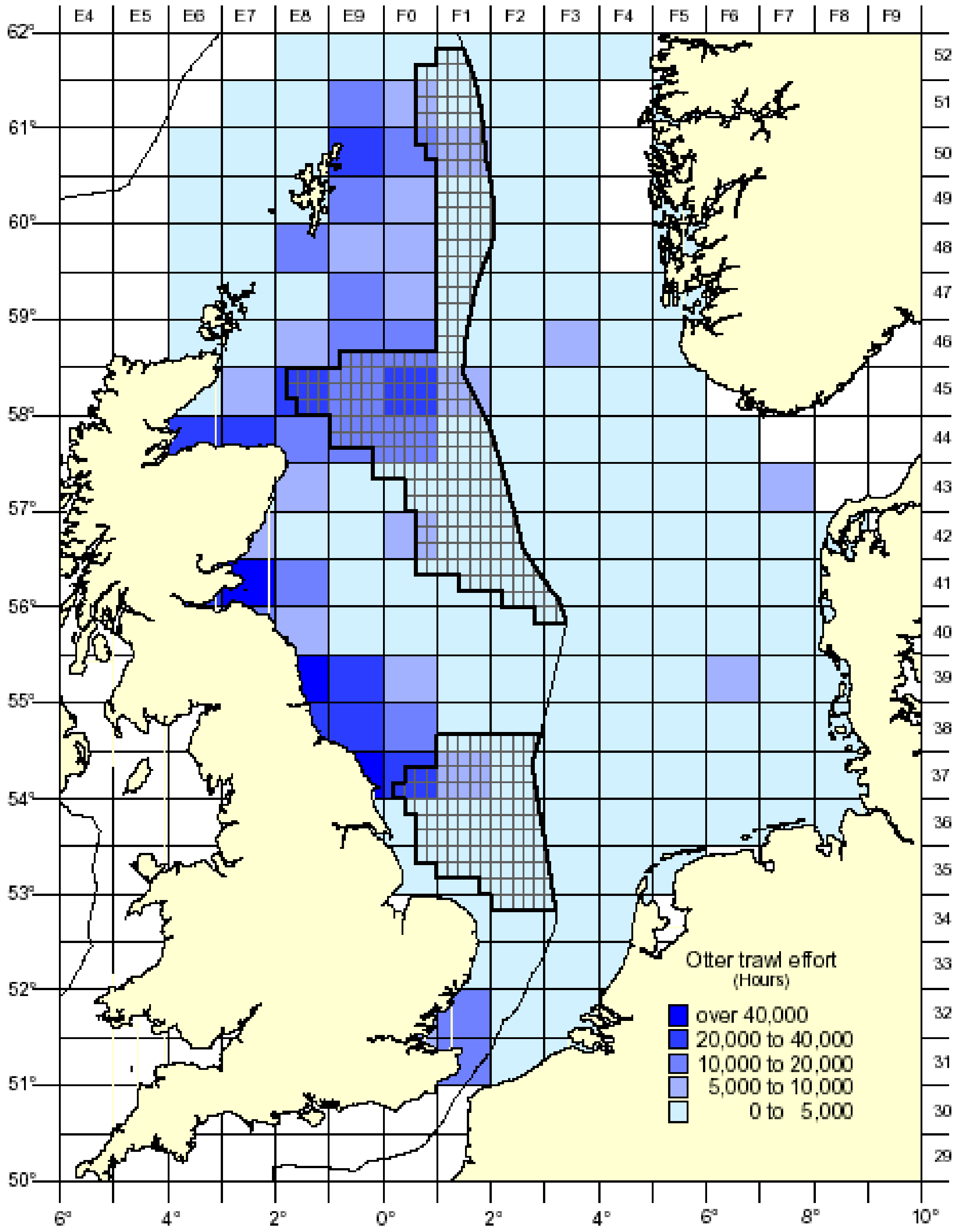


Figure 4.1.1 Spatial distribution of international otter trawl effort (England, Scotland, Wales, Norway, Denmark, Germany and The Netherlands) in 1995 (Jennings *et al.* 1999).

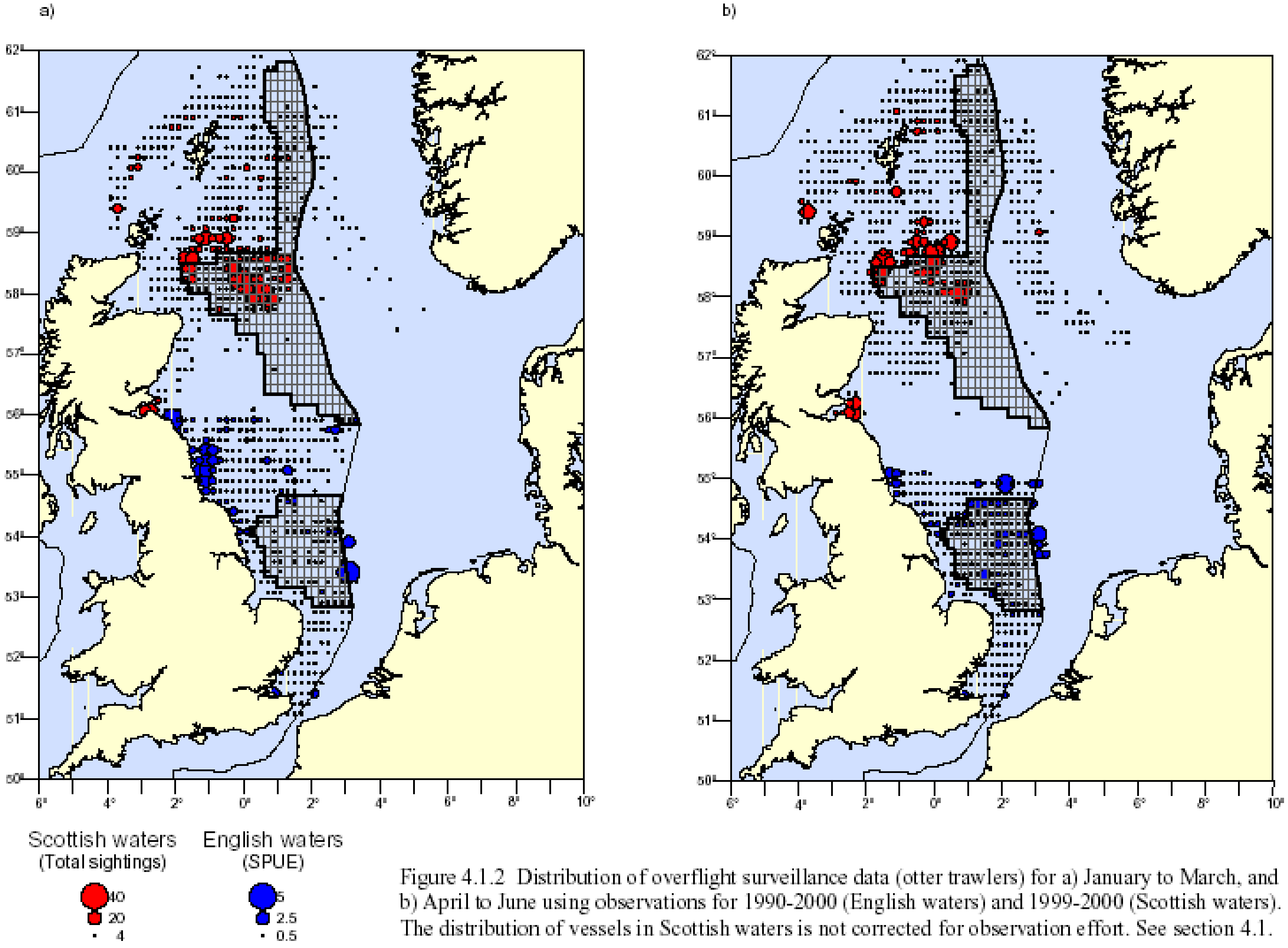
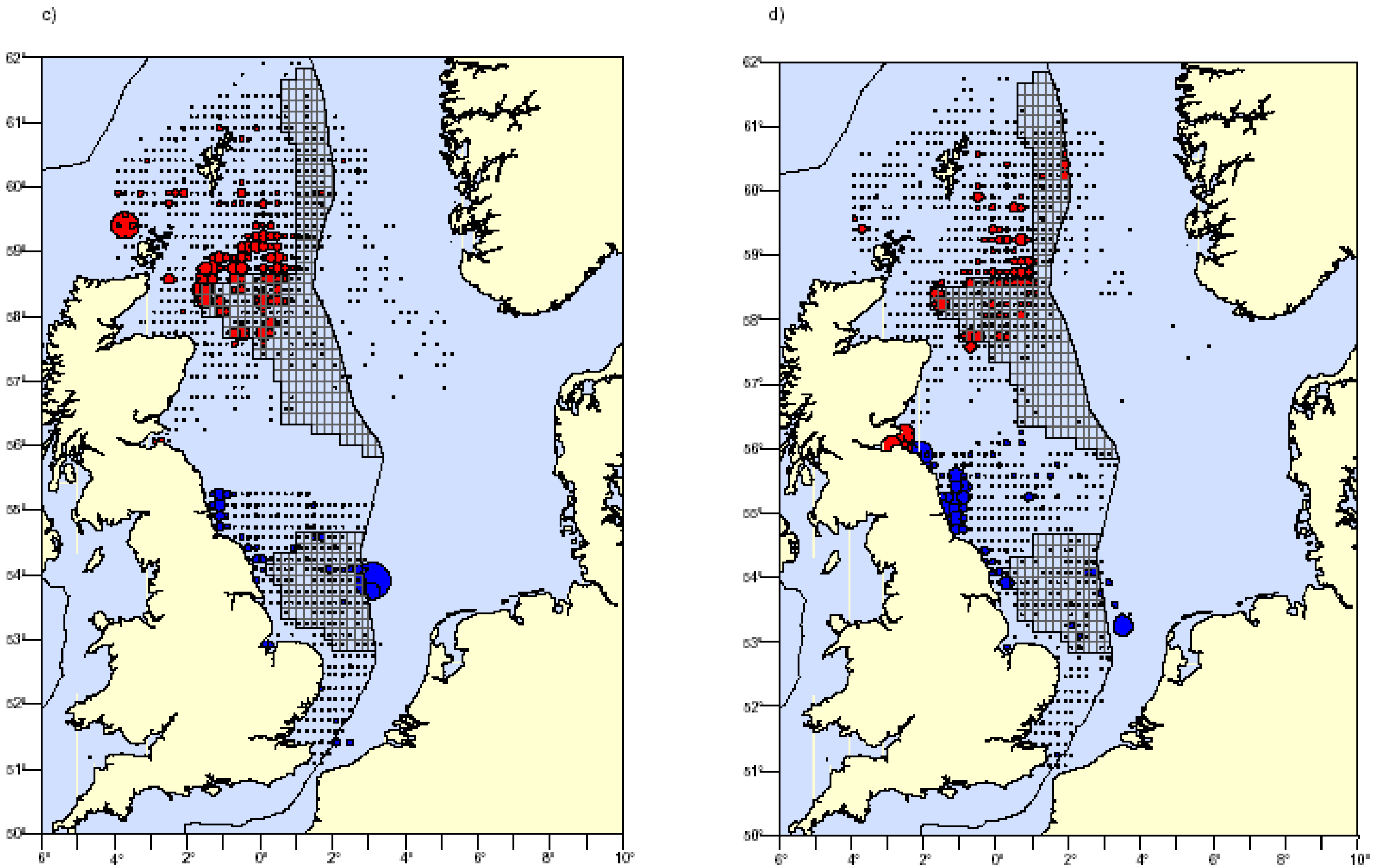


Figure 4.1.2 Distribution of overflight surveillance data (otter trawlers) for a) January to March, and b) April to June using observations for 1990-2000 (English waters) and 1999-2000 (Scottish waters). The distribution of vessels in Scottish waters is not corrected for observation effort. See section 4.1.



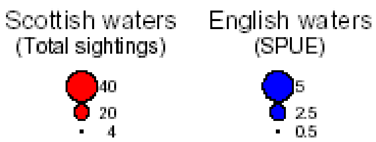


Figure 4.1.2 Distribution of overflight surveillance data (otter trawlers) for c) July to September, and d) October to December using observations for 1990-2000 (English waters) and 1999-2000 (Scottish waters). Distribution of vessels in Scottish waters is not corrected for observation effort. See section 4.1.

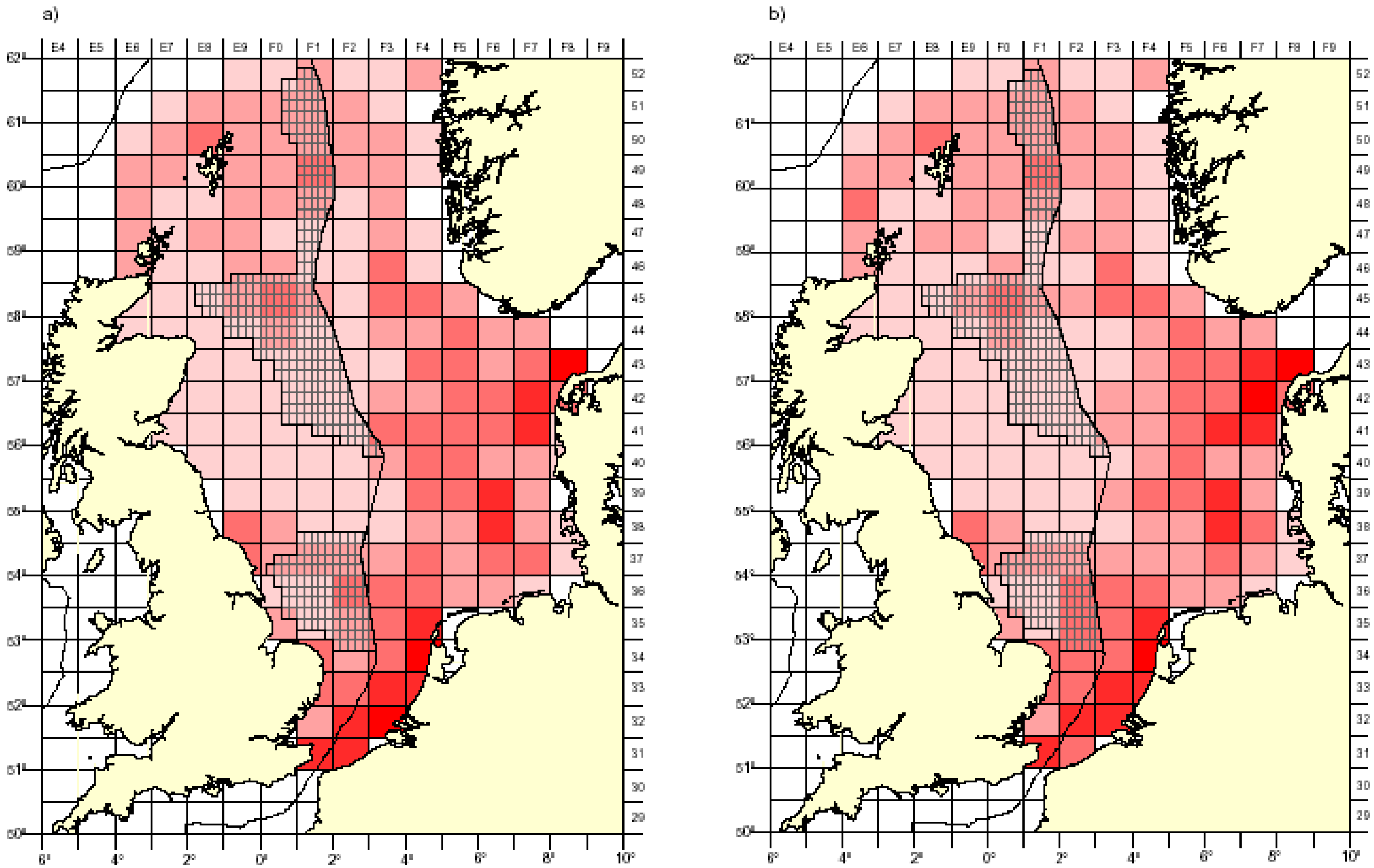


Figure 4.1.3 Mean (1998-1999) total international landings of cod from ICES sub-area IV during a) January to March and b) April to June.

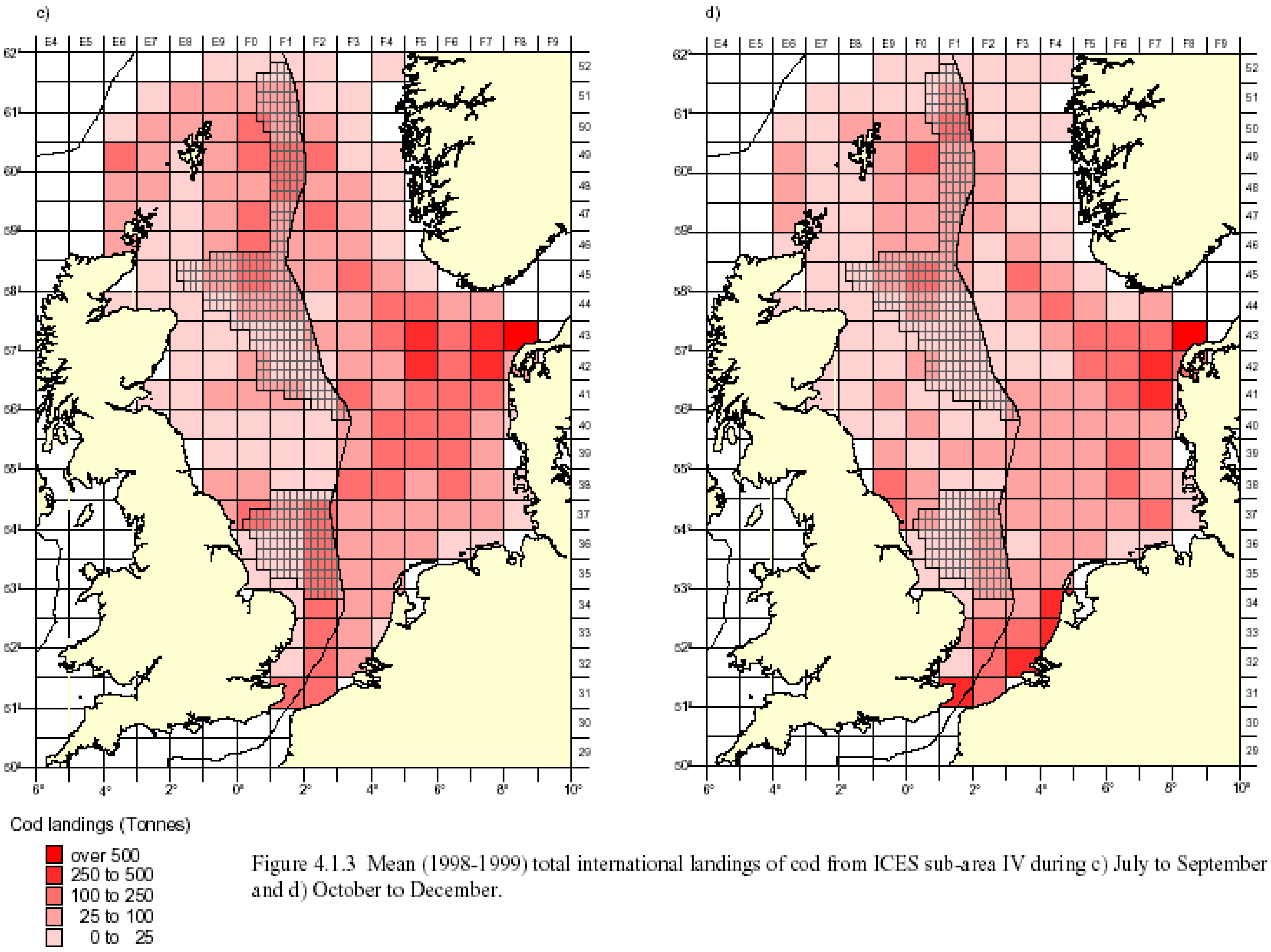


Figure 4.1.3 Mean (1998-1999) total international landings of cod from ICES sub-area IV during c) July to September and d) October to December.

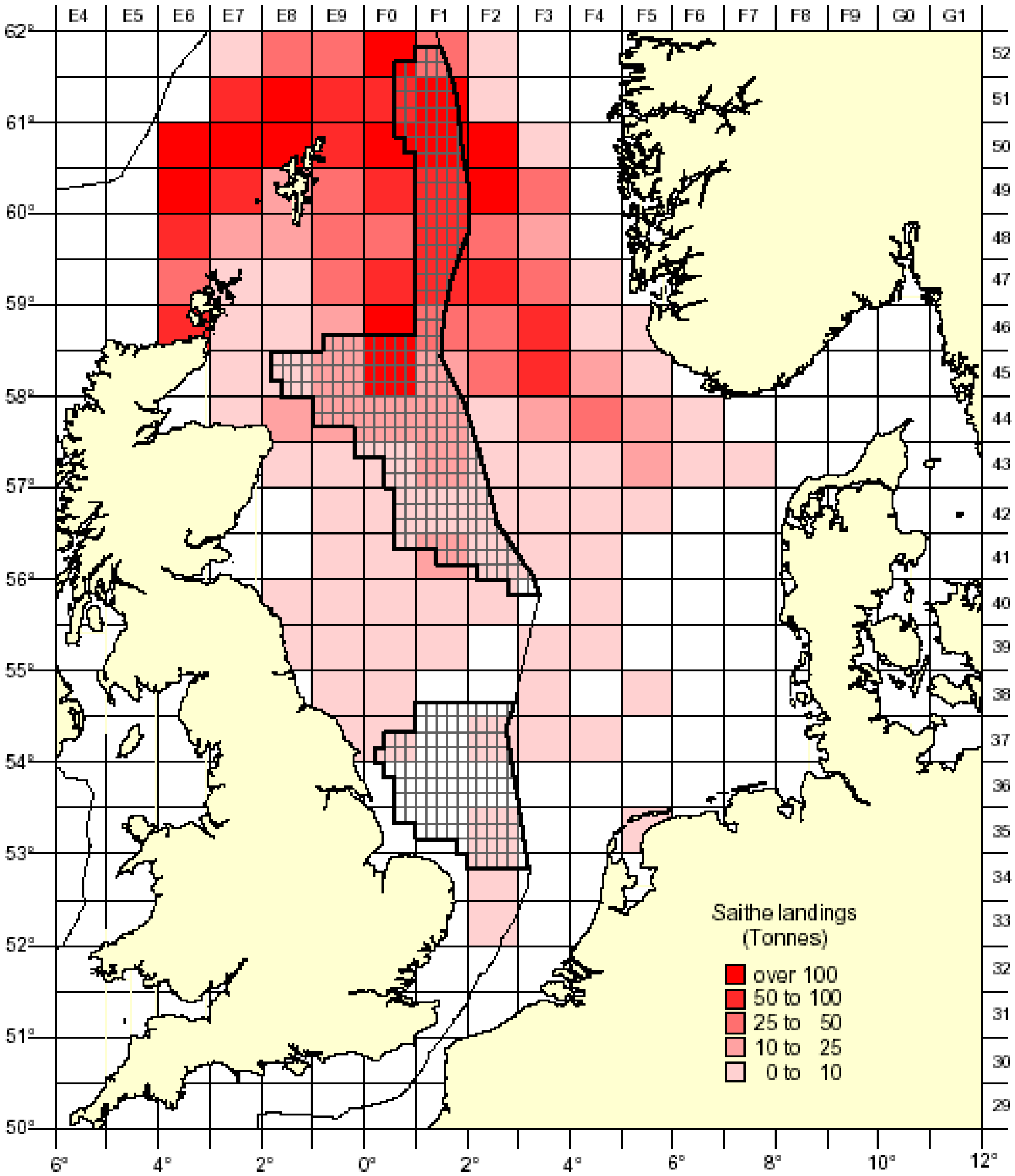


Figure 4.1.2.1 Mean (1999-2000) English, Welsh and Scottish landings to the UK of saithe from ICES sub-area IV.

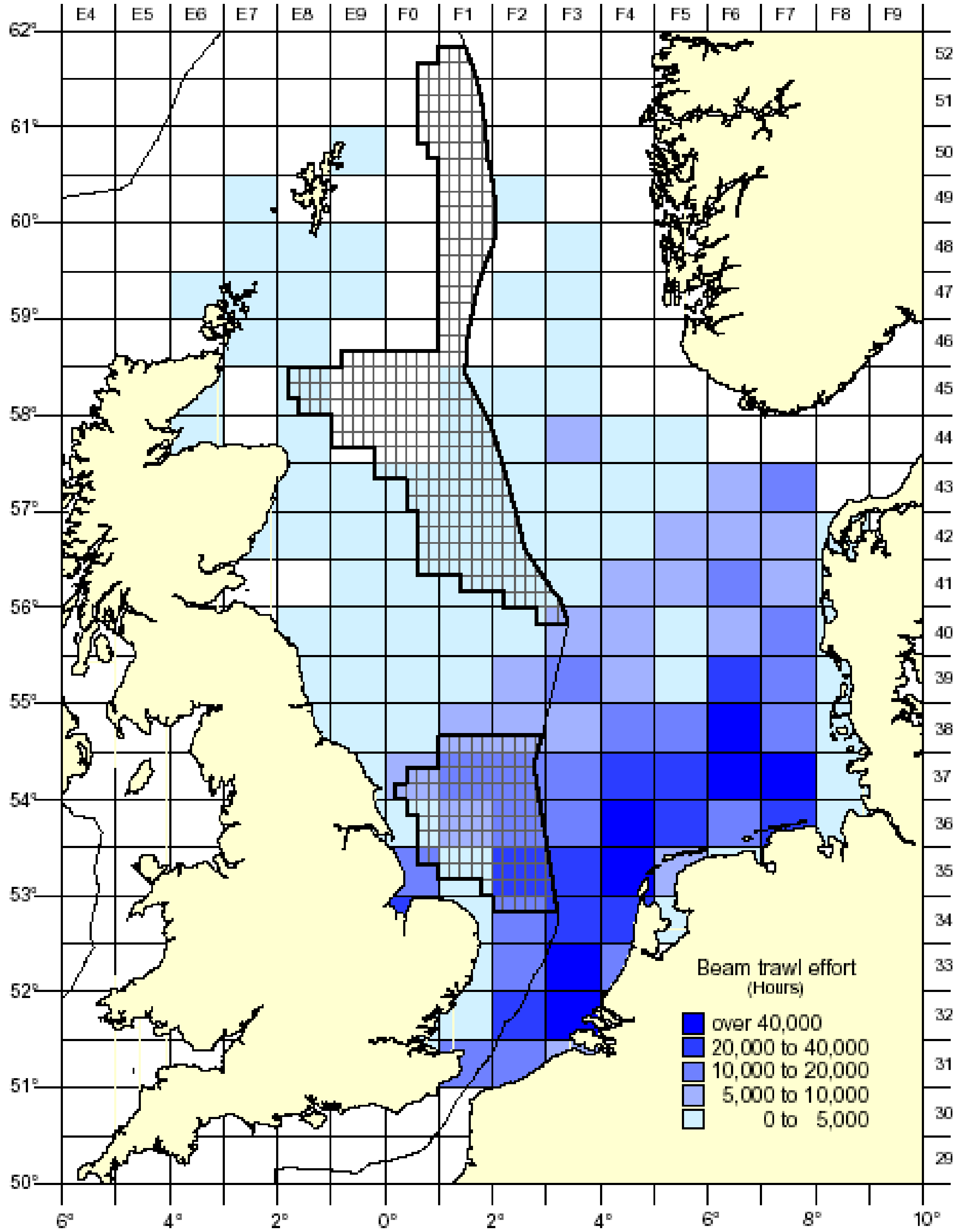


Figure 4.1.3.1 Spatial distribution of international beam trawl effort (England, Scotland, Wales, Norway, Denmark, Germany and The Netherlands) in 1995 (Jennings *et al.* 1999).

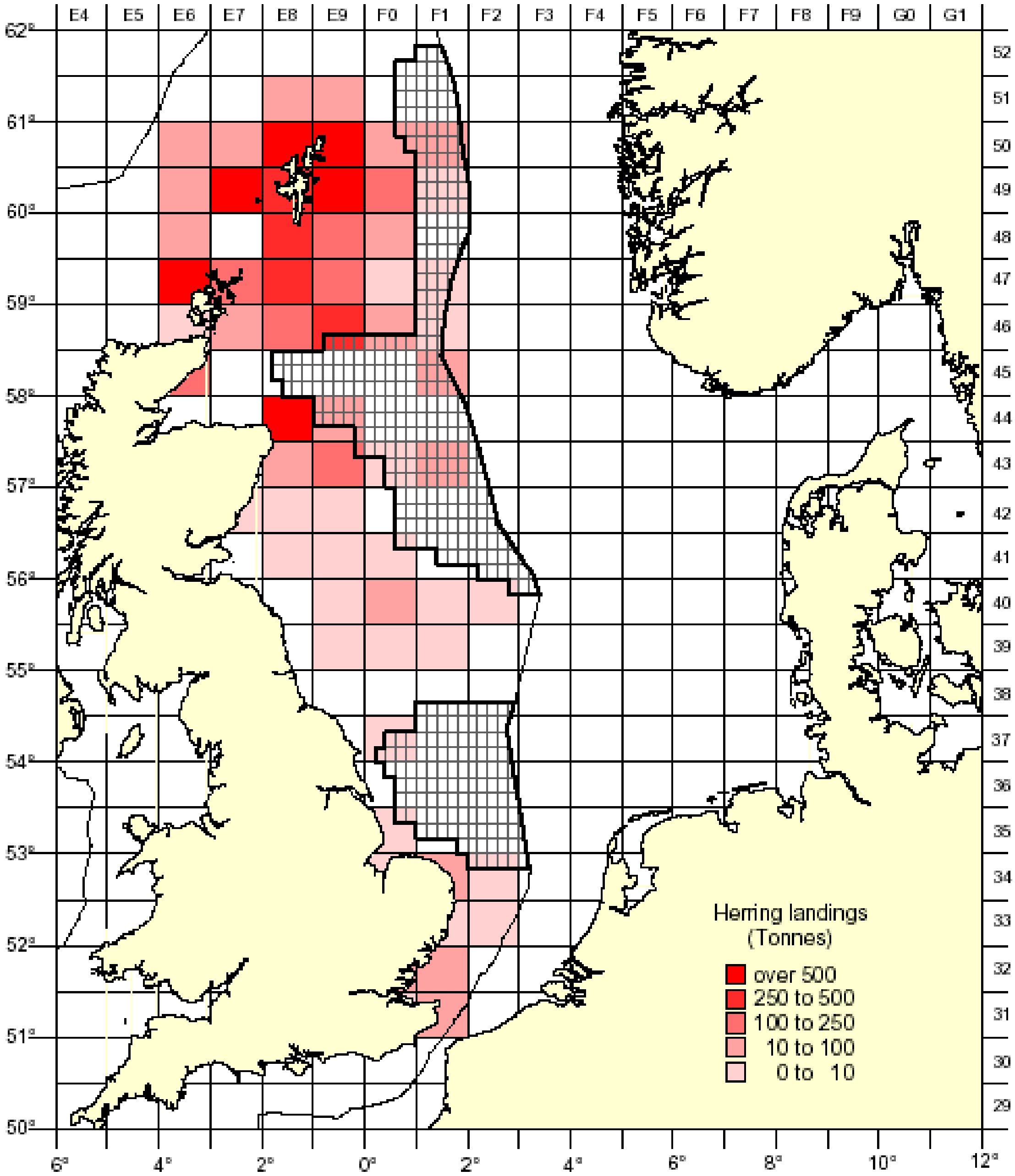


Figure 4.1.4.1 Mean (1999-2000) English, Welsh and Scottish landings to the UK of herring from ICES sub-area IV.

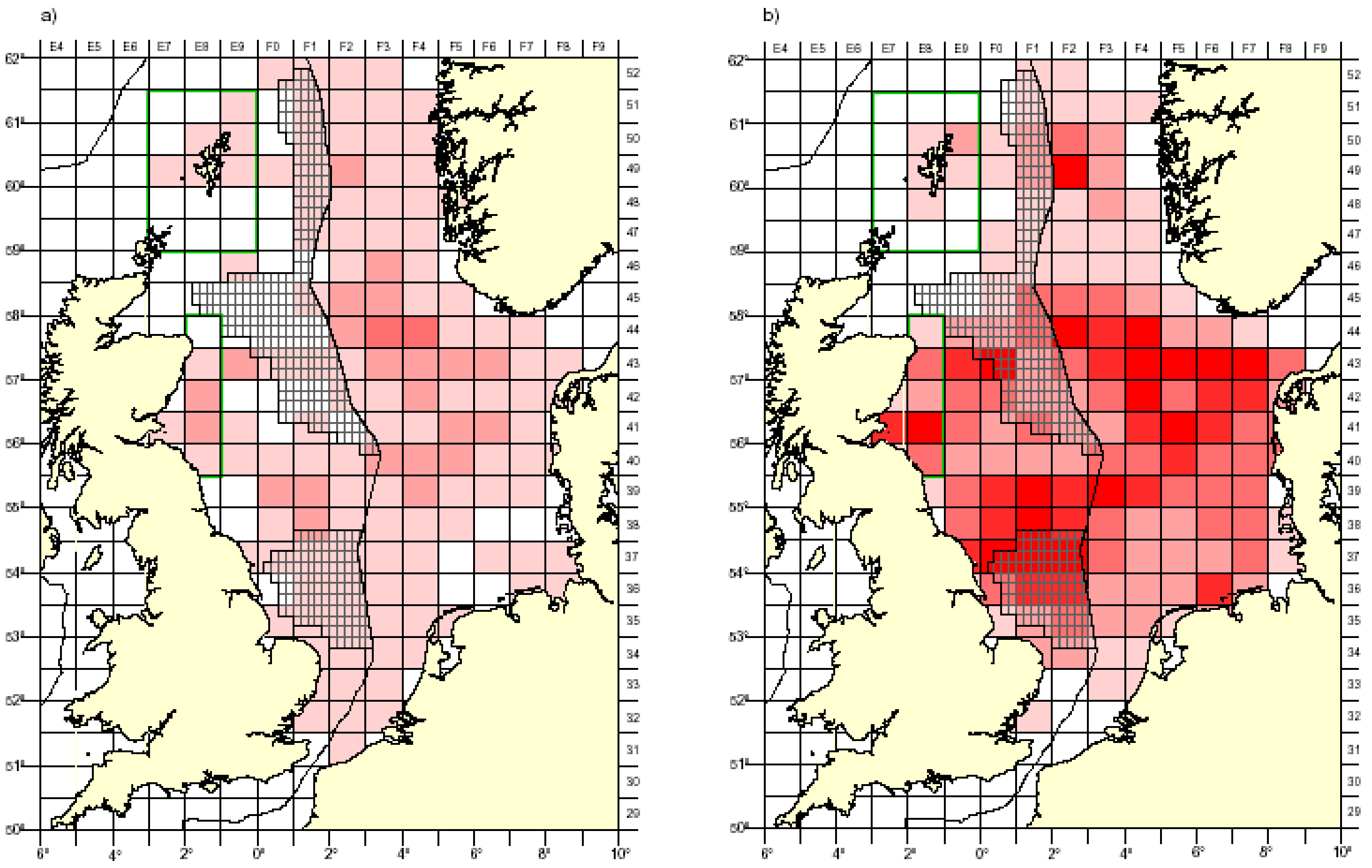


Figure 4.1.5.1 Mean (1992-1999) total international landings (Denmark, Norway and Scotland) of sandeels from ICES sub-area IV during a) January to March and b) April to June.

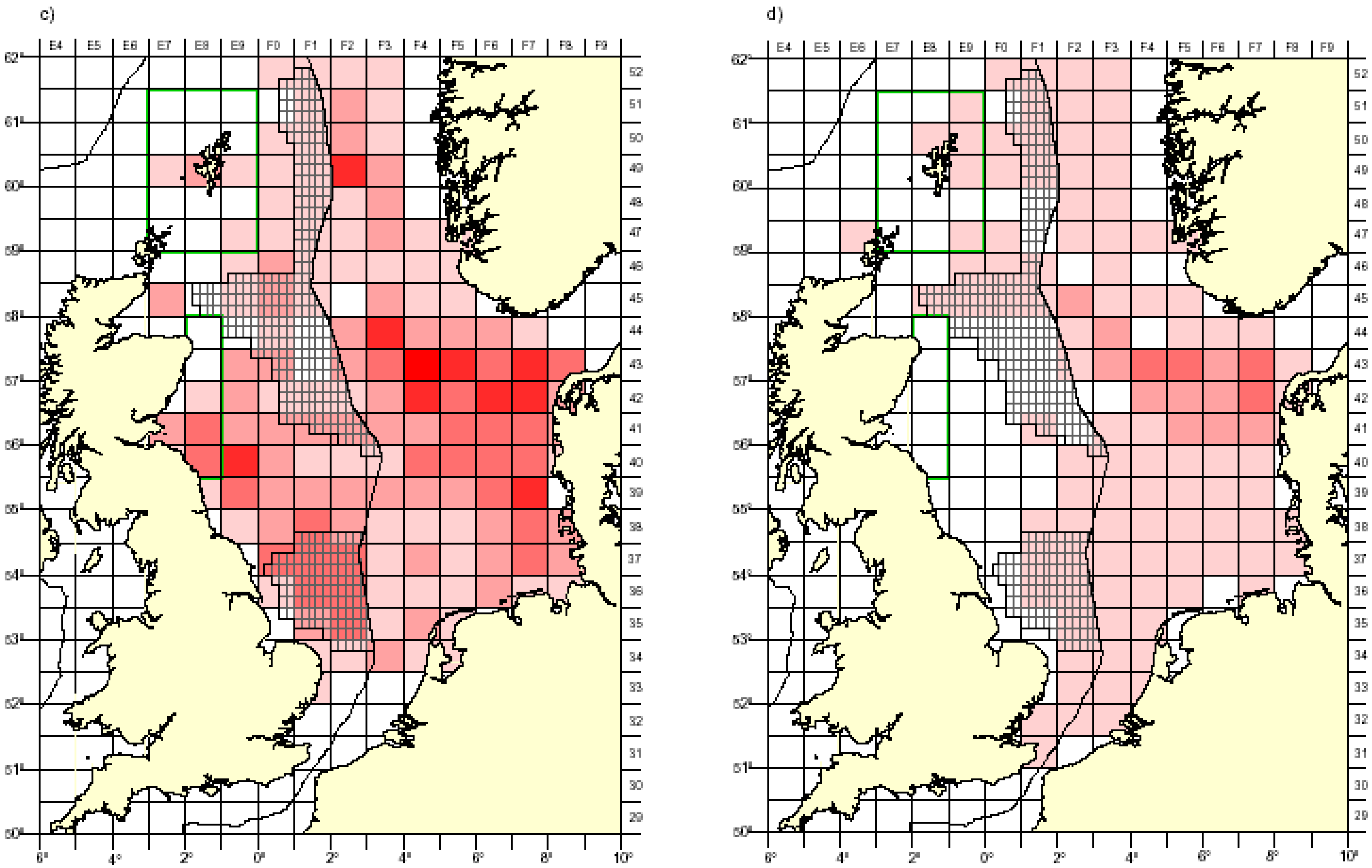


Figure 4.1.5.1 Mean (1992-1996 & 1998-1999) total international landings (Denmark, Norway and Scotland) of sandeels from ICES sub-area IV during c) July to September and d) October to December.

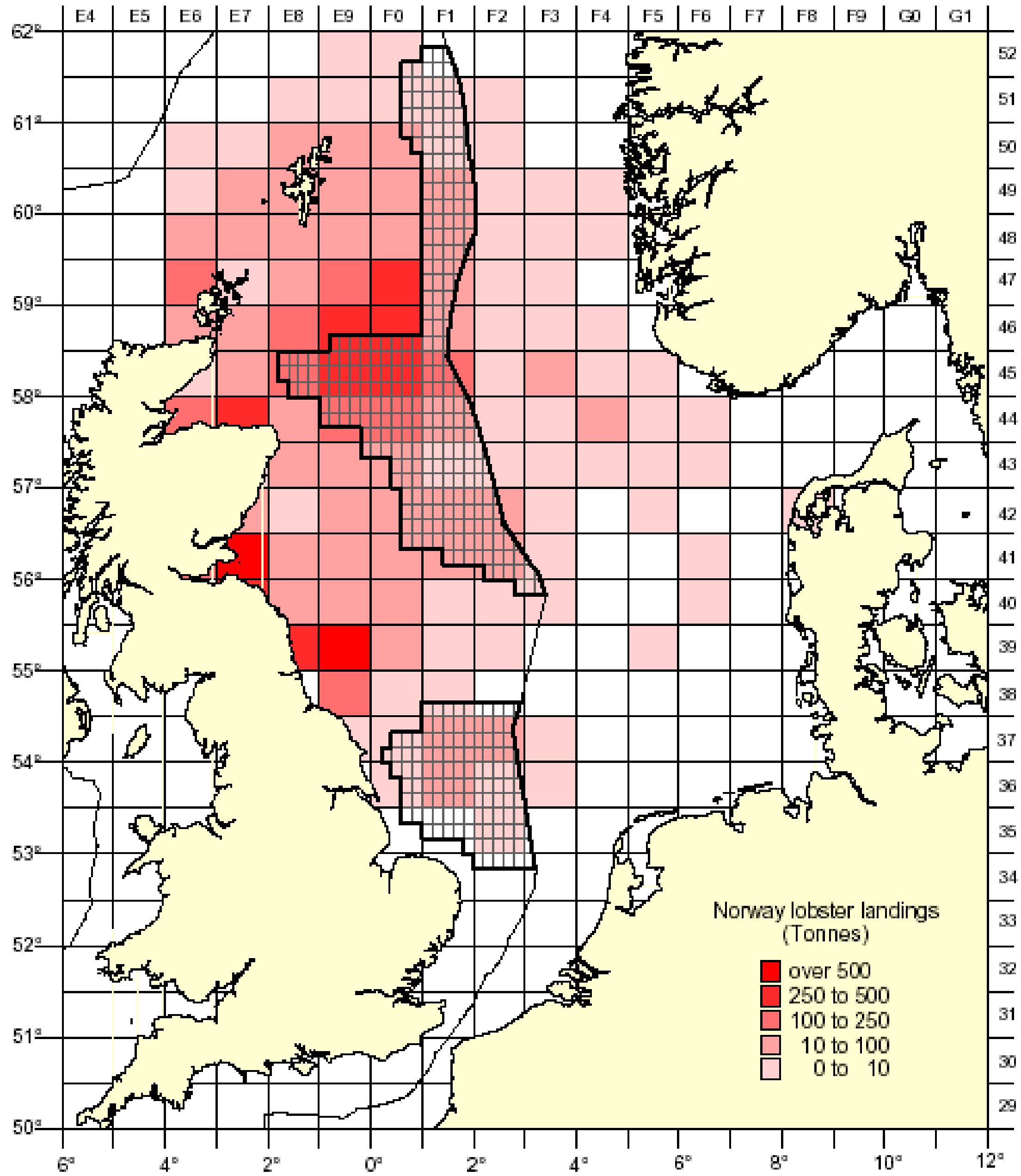


Figure 4.1.6.1 Mean (1999-2000) English, Welsh and Scottish landings to the UK of Norway lobster from ICES sub-area IV.

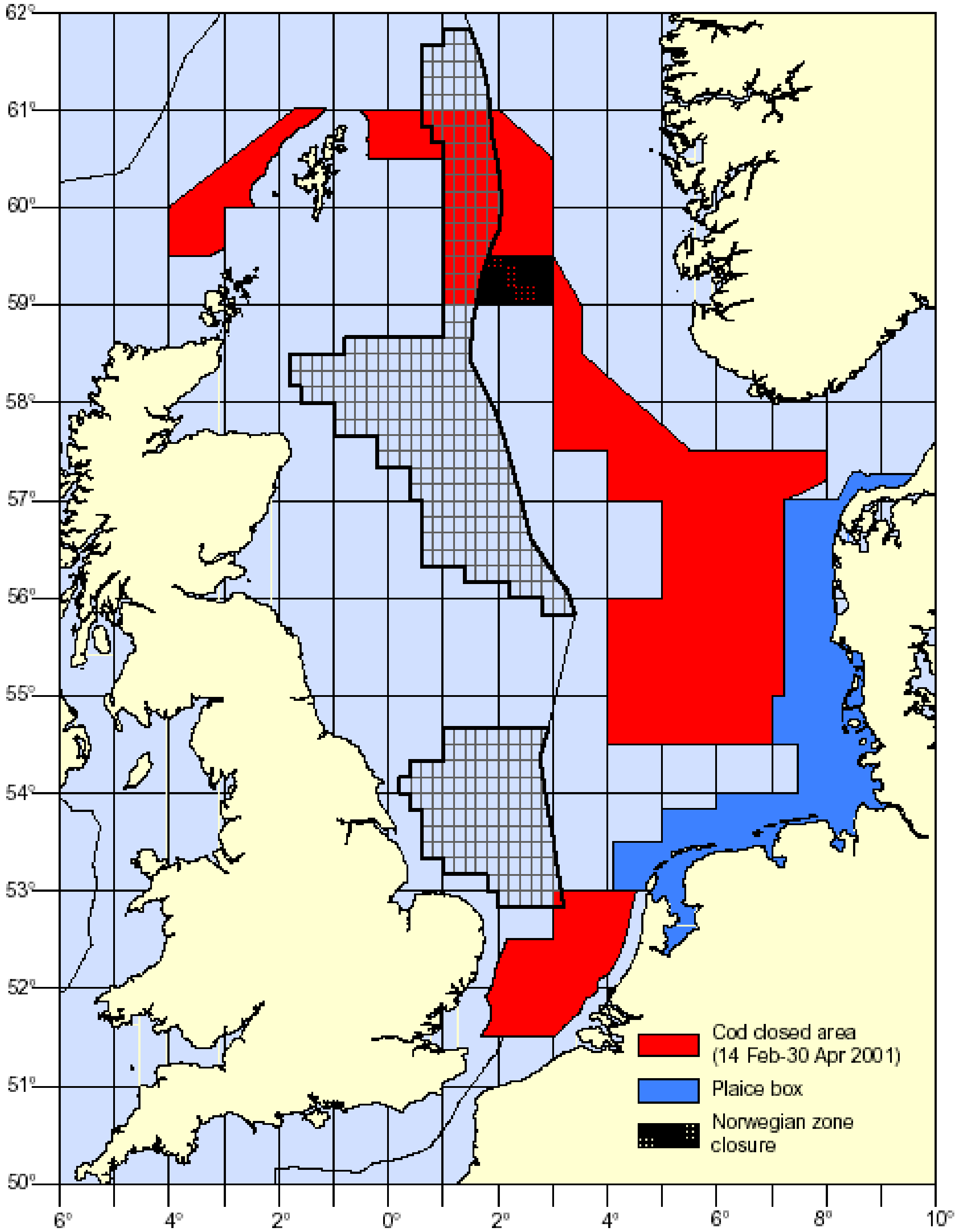


Figure 4.2.1.1 Areas in the North Sea closed for fisheries management purposes.