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An Overview of Cephalopods Relevant to the SEA 6 Area

For the Department of Trade and Industry

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1. General Introduction

This review is a component of the information base of the Strategic Environmental Assessment (SEA 6) conducted by the Department of Trade and Industry. Some of the general background material presented here is taken from the reports on cephalopods in the SEA 2 and 3, SEA 4 and SEA 5 areas (Pierce *et al.*, 2002, 2003, Stowasser *et al*., 2004).

The International Council for the Exploration of the Sea (ICES) have, for fisheries management purposes, divided the northern Atlantic ocean into fishery areas, divisions and sub-divisions. The SEA 6 area falls within ICES fishery area VIIa. The ICES divisions and sub-divisions are further subdivided into statistical rectangles, measuring 30' of latitude x 1º of longitude, for the purpose of catch reporting.

The management of most fishery resources in the Irish Sea and Bristol Channel is subject to European Union (EU) regulations, developed on the basis of scientific advice from the International Council for the Exploration of the Sea (ICES). Fisheries in coastal waters around the Isle of Man are managed by the Manx Fisheries Department and are technically outside the EU (Figure 1 shows the location of ICES fishing zones).

The Common Fisheries Policy, which controls fishing within the EU zone, came into effect in 1983. It was subject to a limited mid-term review of access arrangements in 1992 and a thorough review began in 2002. Under this policy, the UK has declared the area up to 12 nautical miles from the coast to be one within which fishing is restricted to British boats (and, in some areas, vessels from other EC countries with traditional rights) (Territorial Sea Act, 1987). Outside the coastal margin, all EU member countries have equal access to the Exclusive Fishing Zone (EFZ) whereas non-member countries are only allowed to fish if there has been a prior agreement. Fishing in a number of areas around the coastline may also be restricted in order to protect important fish nursery areas or spawning grounds.

The area covered by SEA6 corresponds to the eastern half of St George's Channel and the Irish Sea (Figure 2). This area is a major proportion of the ICES division VIIa, which is the area generally used for fisheries assessment purposes (Figure 1). Division VIIa extends from 52°N (Pembrokeshire) to 55°N (the North Channel).

Fishing is an important activity, with traditional fishing rights in this area. It has a history spanning many centuries, during which time the fortunes of the industry have fluctuated greatly. Since the turn of the 20th century, significant technical developments have taken place in fishing gear and methods, leading to more efficient exploitation of the various commercial fish stocks. Fisheries can be directed at single species but, more commonly, a variety of species are caught (mixed fisheries). In addition to target species, a particular fishery may often take a by-catch of other species, some of which may be landed. Part of the catch of exploited species may also be discarded. The fishing industry can be categorised into four distinct sectors: demersal, pelagic, shellfish and industrial.

Cephalopods are arguably the most promising future fishery resource because of their abundance and rapid stock renewal, related to the short life cycle (Guerra, 1996). Despite these advantages, it is estimated that the world catch of cephalopods represents only 10 % of cephalopod stocks detected (Guerra, 1996).

Cephalopods are short-lived molluscs, characterised by rapid growth rates, and are important predators and prey in oceanic and neritic environments. They can range in length from 1.5 cm in pygmy (bobtail) squid (Sepiolidae) to 20 m in giant squid (Architheutidae). Cephalopods exhibit the highest degree of development in invertebrate nervous systems, expressed through complex behaviour patterns such as the ability to learn and the display of complex colour changes. In contrast to other molluscs, most cephalopods lack an external shell, are highly mobile as adults, and occupy similar ecological niches to predatory fish.

They are active predators at all stages of their life-cycle and generally regarded as opportunistic, taking a wide variety of prey. Cannibalism has been frequently recorded. Cephalopods also sustain a number of marine top predators such as fish, birds and marine mammals, especially whales (e.g. Clarke, 1996, Croxall & Prince, 1996, Smale, 1996, Santos *et al.*, 2001). Many species are powerful swimmers and undertake long feeding and spawning migrations, thus influencing prey and predator communities strongly on a seasonal and regional basis.

As cephalopods are important elements in food webs they interact with commercial fisheries of finfish. Evidence exists that fishing pressure has changed ecological conditions and shifts in community structures have occurred, with cephalopod stocks slowly replacing predatory fish stocks (Caddy & Rodhouse, 1998). The commercial significance of cephalopods to world fisheries is of relatively recent, but growing, importance (Boyle and Pierce, 1994).

Cephalopods play an important role in the Irish marine ecosystem and are becoming an increasingly important fisheries resource in these waters (Collins *et al*., 1994, 1995a, Lordan *et al*., 1995). There is a little information on abundance and fine scale distributions of cephalopod species in this area in the literature. Investigations at the start of the 20th century provide the first data on the occurrence of cephalopod species in the waters around Ireland (Massy, 1909; 1928). Massy (1928) provided the first detailed information on the occurrence and distribution of cephalopods in the waters around Ireland, listing thirty-two cephalopod species.

More recently, Collins *et al*., (1995a) used demersal trawl survey data in the Irish Sea to investigate the distribution and demography of *Loligo forbesi* (Steenstrup, 1856) and also reported catches of other cephalopod species. Pierce *et al*. (1998) used Scottish demersal trawl survey data to describe the spatial distribution and density of *Loligo forbesi* in the North Sea, Rockall, west of Scotland, west and south west of Ireland.

Inputs of pollutants to the marine environment include discharges associated with oil-production operations, industrial emissions and river discharges (Sheahan *et al.*, 2001, Ridgway *et al.*, 2003). Trace elements such as heavy metals and radionuclides contained in these discharges can accumulate in coastal and deeper waters leading to an increase of metal and radioactive burdens in biota and thus increasing contaminant loads for human consumption (Kunisaki, 2000, Bustamante *et al.*, 2000, 2003, Betti *et al.*, 2004).

Demersal shellfish and crustaceans tend to contain particularly high levels of metals. The high concentration of some metals in shellfish is a natural phenomenon, not necessarily related to pollution, but higher concentrations are expected to occur in polluted waters. Heavy metal accumulation rates in cephalopod species appear to be rapid (e.g. Craig, 1996) and various studies on cephalopods report high levels of cadmium (e.g. Caurant & Amiard-Triquet, 1995, Bustamante *et al.*, 1998, Koyama *et al.*, 2000) and, to a lesser extent, mercury

(e.g. Frodello *et al.*, 2000). Since cephalopods represent an essential link in marine trophic chains, the concentration of heavy metals in their tissues plays an important role in the bioaccumulation of these pollutants in their predators (Koyama *et al.*, 2000).

Other considerations in relation to the possible environmental impact of oil exploration include the possible disruption of cephalopod spawning activity by exploration and drilling.

This report focuses mainly on the main species of fishery importance, the loliginid squid *Loligo forbesi*, as well as the small loliginid *Alloteuthis subulata*, which appears to be particularly abundant in the Irish Sea. Brief accounts of other commonly occurring cephalopod species are also provided.

We review the following topics:

- Important squid species in the Irish Sea
- Ecology: trophic interactions
- Fisheries and trends
- Sensitivity to environmental contamination

2. Important squid species in the Irish Sea

2.1. *Loligo forbesi* (Veined squid)

The squid *Loligo forbesi*, Steenstrup, is distributed in coastal waters throughout the north-east Atlantic (Roper *et al*., 1984), and it is currently the most common squid species around the British Isles, with annual landings as high as 3500 metric tonnes (Collins *et al.* 1997). In Irish waters it is caught as a by-catch in commercial trawls and at certain times becomes a target species, notably on the Rockall Bank in summer (Pierce *et al*., 1994a). *Loligo forbesi* is an annual semelparous species and the one-year life-cycle was first proposed based on length-frequency data from the English Channel (Holme, 1974).

Most studies of squid distribution and abundance to the west of the British Isles do not specifically focus on the Irish Sea. Lordan *et al*. (1995) studied the spatial distribution of *L. forbesi* in Irish waters. They found that the highest abundance was near the shelf-break (150-250 m) at approximately 50º N (i.e. on the west coast of Ireland). Given that the largest catches were of squid around 90mm mantle length (ML) - recruitment to the commercial fishery is approximately at ML 100mm (Collins *et al*.,1995b) - it is fair to speculate that the area may be an important feeding and possibly nursery ground for this species.

Bottom trawl surveys of the Irish Sea were conducted in the spring, summer and autumn of 1992 and 1993 in order to obtain data on the seasonal distribution and feeding patterns of *Loligo forbesi*. Collins *et al*., 1995a concluded that the demography of *L. forbesi* in the Irish Sea appears to be complex ; two main cohorts of males and females were present in the autumn, with a third small cohort of larger males. The virtual absence of *L. forbesi* from March provided support for the one-year life cycle hypothesis (Holme, 1974) and indicated that the two sizes classes of squid caught in the autumn had either died or emigrated. On the other hand, from length-frequency and maturity data Collins *et al*. (1995b) identified two

periods of recruitment of small *L. forbesi* into commercial catches in Irish waters in 1991 (August and December), but only one in August 1992.

Pierce *et al*., (1998) presented data from demersal trawl surveys along the west coast during November (1990-1994), which showed that highest catches of *L. forbesi* occurred north of Ireland near the Stanton Bank area (~3,200/hr in one haul). Good catches occurred north and west of the Hebrides and in Donegal Bay, whereas catches south and west of Ireland were relatively poor. Data collected from research cruises carried out in 2004 showed highest catch numbers from waters to the west of the Isle of Man.

2.2. *Alloteuthis subulata* (European common squid)

Another loliginid squid frequently occurring in hauls alongside *L. forbesi* is *Alloteuthis subulata* (Lamarck, 1798). It is of no commercial value and is therefore normally discarded from trawls if caught. Due to its small body size (typically less than 15 cm ML) and slim body form, it is likely that most individuals are not retained in commercial trawling gear. There are no landings data, although some information on abundance is available from trawl surveys. It is the most common cephalopod encountered in the Southern North Sea (Heij & Baayen, 1999), and is also abundant in the Irish Sea (Collins *et al*., 1995a). Bottom trawl surveys of the Irish Sea were conducted in the spring, summer and autumn of 1992 and 1993 (Collins *et al*., 1995a). *A. subulata* was common in all surveys and particularly at depths of less than 50m. Mature animals were found during March and July, and Rodhouse *et al*. (1988) found three broods in the English Channel, spawning in spring, summer and autumn.

Alloteuthis subulata has an important ecological role in coastal food webs since: it is the most commonly recorded cephalopod species in stomach contents of demersal fish in UK waters (Daly *et al.*, 2001) and is also important in the diet of demersal fish in Spanish waters (Velasco *et al.*, 2001).

It is considered to be a demersal species, occurring in shallow waters mainly from 20-120 m (Roper *et al*., 1984), although it has been taken at depths down to 500 m (Guerra, 1982). The maximum size of the species is 20 cm ML in males and 14 cm in females (Roper *et al*., 1984; Rodhouse *et al*., 1988).

Alloteuthis subulata was reported to be the most abundant squid within this area, and was found in mature condition in March and July (Collins *et al*., 1995a). However, little is known about the temporal pattern of occurrence, or of the pattern of reproduction in the Irish Sea.

The only recent studies on the biology of this species in UK waters were by Nyegaard (2001) based on samples collected in the Irish Sea. These studies showed that mature animals occur during spring and summer, and juveniles dominate the population in the autumn. The seasonal migration pattern (if any) is unknown.

Nyegaard (2001) found that the spring and autumn distribution of *Alloteuthis subulata* in the Irish Sea was related to physical factors and local hydrographical features. *Alloteuthis subulata* appear to prefer warm, saline water. Peak abundance was found in association with the warmest part of the Irish Sea in both March and October. Similar observations have been made for both *Loligo forbesi* and *A. subulata* in the North Sea (Waluda & Pierce, 1998; Heij & Baayen, 1999).

Nyegaard (2001) showed that, although *A. subulata* was associated with the distribution of its main prey species (i.e. they tended to occur together in trawls), the squid at stations with high prey abundance did not seem to have been more engaged in feeding activity than those at other stations. This could indicate that *A. subulata* feeds in the pelagic zone rather than close to the bottom. Indeed both sandeel and sprat, which are important prey of *Alloteuthis*, undertake vertical migrations, and were found in higher abundances in the pelagic zone than near the bottom during the day in the North Sea (Pedersen, 1999). The demersal co-occurrence of *Alloteuthis* and its prey might thus have been due to other factors.

3. Other cephalopod species

3.1. *Todaropsis eblanae* (Lesser flying squid)

The lesser flying squid *Todaropsis eblanae* (Ball, 1841) is a demersal species found in the Mediterranean, throughout the Eastern Atlantic from 36°S (South Africa) to the Shetland Islands, and in shelf waters of the South Pacific (Gonzales *et al.*, 1994, Arkhipkin & Laptikhovsky, 2000). It is associated with sandy to muddy bottoms within a temperature range from 9 to 18º C in depths ranging from 20 m to 700 m (but confined to depths less than 200 m in the North Sea) (Guerra, 1992). *Todaropsis eblanae* exhibits a so-called "intermittent spawning pattern" (Boletzky, 1975) or "intermittent terminal spawning pattern". Partial ovulation allows for the presence of oocytes at various stages of development and thus continuous production of ova once spawning has commenced (Rocha *et al*., 1996).

The occurrence of *Todaropsis eblanae* in the Irish Sea was reported by Collins *et al*. (1995a). This animal was occasionally caught with a total of seven specimens from all the cruises carried out in the spring, summer and autumn of 1992 and 1993. It was only caught at deeper stations to the west of the Isle of Man.

Lordan *et al*., 2001 studied the distribution and abundance of cephalopod species caught during demersal trawls surveys west of Ireland and in the Celtic Sea. The most numerous species in catches was *Loligo forbesi* followed by *Todaropsis eblanae,* which was concentrated close to the shelf break in most years. However, in 1994 there were also large catches off the south coast of Ireland.

It is reported to be also abundant in the North Sea in some years and possibly linked to hydrographical anomalies such as high-salinity influxes (Hastie *et al*., 1994).

3.2. *Sepia officinalis* (Common cuttlefish)

Cuttlefish have a short life-span, of around two years. The species is abundant in the Eastern Atlantic and in the Mediterranean Sea. From the North Sea southwards *Sepia officinalis* occurs in coastal waters and on the continental shelf at depths not greater than 150m (Boletzky, 1983). The spawning season is from early spring to mid summer, followed by mass adult mortality and hatching from mid summer to autumn (Boletzky, 1983; Le Goff and Daguzan, 1991; Dunn, 1999).

Previous studies of the spatial and temporal patterns of abundance of cuttlefish show that there is a regular annual spawning migration from offshore to inshore waters and large inter-

annual fluctuations in landings (Boucaud-Camou and Boismery, 1991; Dunn 1999; Denis and Robin, 2001). In early spring, adult cuttlefish aggregate on coastal spawning grounds, mainly along both sides of the English Channel and on the French Atlantic coast. In late autumn, the juveniles migrate from inshore nursery grounds to deeper water in the west part of the English Channel and further west (Irish Sea) and to offshore deep water off the northern part of the French Atlantic coast, where they stay during the winter months. There is no genetic evidence for different populations in these areas, but previous studies suggest that cuttlefish in the Channel are probably a separate stock from those in the Bay of Biscay (Le Goff and Daguzan, 1991; Pawson, 1995, Dunn, 1999).

3.3. *Eledone cirrhosa* (Curled octopus)

Eledone cirrhosa (Lamarck, 1798) is a benthic octopod with a wide distribution over shelf regions from the Mediterranean in the south to the Norwegian Lofoten Islands in the north. Although Collins *et al.* (2001) report records of *E. cirrhosa* from depths of up to 490 m it is generally found between 50 and 300 metres on a wide variety of sea-bed types from soft mud to rocky bottom (Boyle, 1983). Its life spans between 18 and 24 months with individuals dying shortly after spawning. Sexual maturity is attained in late summer (from July to September) with spawning following shortly afterwards (Boyle, 1983).

4. Ecology: trophic interactions

Cephalopods are regarded as key species in many ecosystems (Amaratunga, 1983; Rodhouse, 1989). They represent an essential link in marine trophic chains and are eaten by many marine top predators, i.e. fish, birds and mammals (Clarke, 1996; Croxall & Prince, 1996; Klages, 1996; Smale, 1996), especially whales (Santos *et al*., 2001).

At all life stages after hatching, cephalopods are active voracious carnivores feeding by day or by night on a wide variety of live prey (Nixon, 1987, Boyle 1990, Hanlon & Messenger, 1996) that they detect mainly with their eyes or by touch.

The most important source of information needed to determine what cephalopods eat is the analysis of stomach contents. The material present may include scales, bones, otoliths and lenses from fishes, skeletal parts and eggs from crustaceans, the beaks, pens and lenses from cephalopods and the setae and jaws from polychaetes.

Loligo forbesi has been shown to be an opportunistic predator (Pierce *et al*., 1994b; Collins *et al*., 1994), feeding on demersal and pelagic species of fish and crustacea. Its diet has been studied in Scottish waters by several authors (Boyle and Pierce, 1994; Pierce *et al.*, 1994b; Collins and Pierce, 1996). Fish was found to be the main prey category with crustacean, cephalopod and polychaete species present in the diet to varying degrees. In all studies, *L. forbesi* was found to consume a wide variety of fish and crustacean species.

Apart from regional differences, diets showed seasonal variation (e.g. Pierce *et al.*, 1994a, Collins *et al.*, 1994) and were found to be dependent on squid size (Collins & Pierce, 1996). An ontogenetic shift occurred from a crustacean-dominated diet in juvenile squid to a predominance of fish in the diet of adult squid.

Nyegaard (2001) showed that fish and crustaceans dominated the diet of *Alloteuthis subulata* in March, which is in line with the findings of Bidder (1950) and Lipinski (1985) for *A. subulata.* As for *Loligo forbesi* (Collins *et al*., 1994; Pierce *et al*., 1994b), the majority of *A. subulata* stomachs contained remains from only one prey type (Nyegaard, 2001). The dominant fish prey species of *A. subulata* belonged to the family Clupeidae and it is likely that the Clupeidae vertebrae present in stomachs had originated from sprat, as no herring below 8 cm length was caught on the cruise (Nyegaard, 2001).

A. subulata digests its prey rapidly and may have an empty stomach only 4 hours after the initiation of feeding (Bidder, 1950). The occurrence of stomachs with food present thus reflects relatively recent feeding activity. The lack of any apparent trend in the proportion of empty stomachs during the day indicates that feeding proceeded throughout daylight hours, with a possible trend towards less feeding activity for the females towards the end of the day. Feeding might have taken place also at night.

Nyegaard (2001) found the proportion of empty stomachs, in both spring and autumn, was generally high (79-86%) in *A. subulata*, which is not uncommon among wild caught squid (Amaratunga, 1983). However, in comparison, an overall analysis of *L. forbesi* from the Irish Sea revealed that 48% had food in the stomach (Collins *et al*., 1994), while values varied between 46% and 82% for *L. forbesi* from the NE Atlantic (Pierce *et al*., 1994b). This discrepancy might be due to *A. subulata* feeding predominantly at night, or reflect a comparatively lower energy requirement for growth in the smaller *A. subulata*. In comparison to this small and delicate species, *L. forbesi* reaches larger maximum mantle lengths (410-900 mm) and is more robust in body structure.

Todaropsis eblanae is also considered a generalist predator, feeding on the prey that are most abundant. As with other cephalopod species the dominant prey is dependent on prey availability, squid size and season. Nevertheless, the diet is primarily piscivorous with crustaceans and cephalopod prey being present to a lesser extent.

Thus the most important prey are pearlsides (*Maurolicus muelleri*), silvery pout (*Gadiculus argenteus*), blue whiting and argentine (*Argentina* sp.) together with the euphausid *Meganyctiphanes norvegica* in Irish waters (Lordan *et al.*, 1998). Ontogenetic variation in diet was recorded from Irish waters (Lordan *et al.*, 1998), with small squid taking mainly crustaceans (euphausids) while bigger squid predominantly ate fish and cephalopods.

Sepia officinalis is an opportunistic predator mainly feeding on crustaceans, bony fish and molluscs as well as polychaete and nematode species (Najai & Ktari, 1979, Guerra, 1985, Hanlon & Messenger, 1996). With increasing size cuttlefish also exhibit cannibalistic behaviour (Nixon, 1987).

The octopus *Eledone cirrhosa* is benthic and feeds mainly on crustaceans and molluscs, with crustaceans predominating (Boyle, 1983). They are known to take large Crustacea including lobster (*Homarus gammarus*), edible crab (*Cancer pagurus*) and Norway lobster (*Nephrops norvegicus*) from creels set for these species (Boyle, 1983).

5. Fisheries and trends in abundances

Data on cephalopod landings from the ICES area are compiled by the ICES Working Group on Cephalopod Fisheries and Life History (WGCEPH) on a country by country basis (see Table 1). The SEA 6 area corresponds to ICES fisheries subdivision VIIa, the Irish Sea, which is fished by Scottish, other UK (English/Welsh/Northern Irish), Irish, Isle of Man, French and Belgian fleets. Data for each of these "fleets" are collected separately and complied by the respective national fisheries laboratories.

Of these countries, only the Isle of Man fishes exclusively in area VIIa. Common squid represent the only significant landings of cephalopods in the Isle of Man in recent years, although the tiny Manx fishing fleet land only around two tonnes annually.

General patterns in cephalopod landings for area VIIa can be inferred from data presented in the ICES WGCEPH report 2004 (Anon, 2004; see Table 1). Common squid (i.e. long-finned squid *Loligo* spp.) is the most important cephalopod fishery resource in area VIIa, with the UK fleet alone typically landing around 100 tonnes annually since 2000. Only France and Belgium report significant landings of cuttlefish (although in the mid-1990s, the UK fleet landed 10-20 tonnes annually from this area, Anon, 2004). Octopus landings (mainly *Eledone cirrhosa* in these latitudes) of around 30 tonnes were reported by Belgium in 2002. Landings of short-finned (ommastrephid) squid from the area are negligible.

Fishery data provide the best available information on cephalopod distribution and abundance. Since most cephalopods are landed in the UK as a by-catch of trawling, landings per unit effort (LPUE) can be used as an index of species abundance (see Pierce *et al.*, 1994a) and such data are available on a monthly, by ICES rectangle, basis.

5.1. Squid

In general, squid catches in the UK, as in most northern European countries, are a by-catch of demersal trawl and seine net fisheries (Boyle and Pierce, 1994). There is, however, increased interest in directed fishing in Scotland, with trawlers in the Moray Firth and Firth of Forth targeting squid in the autumn.

Landings of loliginid squid in area VIIa, by the UK Fleet Landing into the UK and abroad, ranged between 34 and 174 tonnes in the years 2000 and 1998 respectively with corresponding values of between £ 74,000 and £ 374,000 (Scottish Sea Fisheries Statistics, 2003). After a peak in catches in 1998, landings decreased but seemed to follow an upward trend again since 2000 (Table 2, Figure 3).

Taking into account combined fishery data (for Scotland, England and Wales, Northern Ireland and France) from the SEA 6 area, squid landings from this area represent a small part of the total landings of loliginid squid caught in UK waters. Approximately 82 tonnes of loliginid squid was landed from catches in the SEA 6 area in 2002, around 1 % of the UK total for this category for the same year (Figure 4). For Northern Ireland, the Irish Sea is the most important fishery area: boats landed 57 tonnes of loliginid squid from the SEA 6 area as compared to 53.5 tonnes caught in other areas.

Month-to-month trends in loliginid squid landings (Northern Ireland Fishery data) from the SEA 6 area follow a similar trend to UK totals in that peak landings (and peak LPUE) occur during November-December (Figures 5 and 6). The proportion of landings arising from catches in SEA 6 shows a consistent annual cycle, with 70 % to 99 % of squid landings (by Northern Irish boats) from August to October coming from this area.

The spatial distribution of landed catches of loliginid squid from the SEA6 area is illustrated in Figures 7 to 12.

5.2. *Alloteuthis subulata*

Scottish research vessels caught 176.5 kg in UK waters for the period between1996 to 1998, including 12.86 kg from the SEA 6 area. In 2004 catches reached 14 kg for the SEA 6 area. No *Alloteuthis subulata* catches were registered in SEA 6 area during 2005.

The spatial distribution of landed catches of *Alloteuthis subulata* is shown in Figure 13.

5.3. Flying squid

Approximately 551 tonnes of flying squid was caught in UK waters in 2002, including 0.0062 tonnes from the SEA 6 area (likely *Todaropsis eblanae*). Fleets out of England and Wales landed 165 tonnes while French boats landed 385 tonnes. Northern Ireland did not report any flying squid catches for the whole area.

The spatial distribution of landed catches of flying squid is illustrated in Figure 14.

5.4. Cuttlefish

Cuttlefish catches (predominantly *Sepia officinalis*) are mainly located in the English Channel and adjacent waters, the French Atlantic coast and the Bay of Biscay (Denis and Robin, 2001). Landings of cuttlefish into France and England/Wales reached 19210 tonnes in 2002, of which only 0.15 tonnes were caught in the SEA 6 area. The Northern Ireland fishery databases contained no information on cuttlefish landings. The spatial distribution of landed catches of cuttlefish is illustrated in Figures 15 to 19

5.5. Octopus

Landings of octopus (predominantly *Eledone cirrhosa* from Northern European waters) into France and England/Wales reached 259 tonnes in 2002, of which only 0.14 tonnes were caught in the SEA 6 area. The Northern Ireland fishery databases contain no information on octopus landings for the whole of the UK in 2002.

The spatial distribution of landed catches of octopus is illustrated in Figures 20 to 24.

Figures 25 to 27 show the proportion per species for SEA 6 area during the period 1999 – 2002 (up to 2003 for Northern Ireland fishery data).

6. Sensitivity to environmental contamination

Quantifying the effect of anthropogenic activities on the marine ecosystem is problematic since no pristine "baseline" marine habitats exist and historical data are sparse - and may still be impacted by historical human activities (Frid *et al*., 2000).

6.1. Metallic contaminants

Sources of metallic contaminants reach the Irish Sea predominantly via rivers and from some sea-based activities, such as exploitation of offshore resources and disposal of dredged materials. Highest concentrations of trace metals are found near freshwater outlets, with much lower levels in the open sea. The Centre for Environment, Fisheries and Aquaculture Science (CEFAS, 1998) reported that the Irish Sea had higher levels of metals than the English Channel, corresponding with lower salinities associated with freshwater inputs.

The mean concentrations of cadmium, mercury, lead, copper and zinc from Celtic and Irish Seas have been summarised and published by the Quality Status Report (OSPAR Commission 2000):

Cadmium:

Concentrations of dissolved cadmium in seawater from the Celtic and Irish Seas show a negative correlation with salinities above about 34.5 but considerably scatter at lower salinities (< 32.5).

Mercury:

In the Irish Sea concentrations of 0.62-0.85 ng/l reflect historic sources of mercury, in particular from chlor-alkali plants close to the Mersey and Wyre estuaries in north-west England.

Lead:

Dissolved concentrations in offshore waters from the Celtic and Irish Seas tend to be low (0.5-5µg/l) due to the fact that estuarine suspended solids and near shore sediments act as efficient traps for this metal.

Copper:

There is a strong negative correlation with salinity confirming the land-based origin of this metal in Celtic and Irish Seas.

Zinc:

The highest concentrations of zinc are associated with the lowest salinity waters. Typical concentrations in oceanic waters and off the west coast of Ireland are around 0.5µg/l. Concentrations of > 40 µg/l have also been recorded in the Severn, Dee and Mersey estuaries on the eastern side of the Irish Sea.

All these metallic contaminants are incorporated in the body of top marine predators via the food chain. Consequently, diet is the first factor controlling the metal intake (Aguilar *et al*., 1999). Transfer of trace elements from prey to predator greatly depends on the bioavailability of the metal, which is determined by the detoxification processes in prey species. It is largely acknowledged that metals located in the cytosolic fraction are highly bioavailable to higher trophic levels, whereas those bound to the insoluble subcellular fraction have a lower potential of transfer to predators (Wallace and Lopez, 1997). Consequently, the different physico-chemical forms of metals in preys appear to be a key factor that might control the metal bioaccumulation in top marine predators.

6.1.1. Sensitivity of cephalopods to heavy metals

Molluscs are known to naturally accumulate metals to high concentrations, particularly in the digestive gland (also known as the liver or hepatopancreas). Trace elements have been investigated extensively in many marine organisms but relatively rarely in cephalopods. Some elements are essential, others toxic, and for some of them, the role is still not known.

Cephalopods constitute a primary food source for many marine predators: fish, seabirds and marine mammals (reviewed by Clarke, 1996; Croxal and Prince, 1996; Klages, 1996 and Smale 1996). In marine mammals, they have such a high importance that over 80% of odontocete (toothed whales) and seal species regularly include cephalopods in their diet. Cephalopods comprise the main food in 28 odontocete species. Thus, interest in the bioaccumulation of trace elements in cephalopods stems from their role as important prey organisms for top marine predators (Bustamante *et al*., 1998)

Most of the studies on bioaccumulation of trace elements in cephalopods mainly concern levels and distribution of essential elements such as Cu or Fe, and to lesser extent toxic elements. Many focus on a single organ like the digestive gland, but the branchial hearts and appendages have also drawn attention for their implication in the excretion processes (Miramand and Bentley, 1992). However, Cd, Zn and Am metabolisms received most attention and have been better understood compared to other trace elements (Guary *et al*., 1982; Ueda *et al*., 1985; Koyama *et al*., 2000; Bustamante *et al*., 2002).

Studies related to trace elements in cephalopods are limited to species targeted by commercial fisheries such as the cuttlefish *Sepia officinalis* (Decleir *et al*., 1978; Schipp and Hevert, 1978; Miramand and Bentley, 1992; Bustamante, 1998), the octopuses *Octopus vulgaris* and *Eledone cirrhosa* (Ghiretti-Magaldi *et al*., 1958; Rocca, 1969; Renzoni *et al*., 1973; Froesch and Packard, 1979; Ueda *et al*., 1979; Miramand and Guary, 1980; Miramand and Bentley, 1992; Barghigiani *et al*., 1993; Bustamante, 1998; Raimundo *et al*., 2004; Seixas *et al*., 2005), some ommastrephid squids (Martin and Flegal, 1975; Finger and Smith, 1987; Yamada *et al*., 1997; Bustamante, 1998) and some Loliginid squids (Martin and Flegal, 1975; Yamada *et al*., 1997; Bustamante, 1998).

A feeding study on the bioaccumulation of cadmium in digestive gland and whole body tissue of *Sepioteuthis lessoniana* concluded that cadmium was accumulated from food rather than from surrounding seawater and that digestive gland was the main retention organ in the body (Koyama *et al.*, 2000).

The potential for bioaccumulation and biomagnification of metals in the food chain is illustrated by results from a survey conducted by the Marine Laboratory Aberdeen (Fisheries

Research Services (FRS), 1998). The Food Standards Committee's maximum recommended limits are also given for comparisons. In squid, levels of cadmium were thirty times those in whiting and exceeded recommended safe limits for food. Biomagnification could clearly be seen from highly elevated levels of cadmium in marine mammals – especially in teuthophagous species compared to piscivorous species.

6.2. Offshore oil and gas

The information in this section is taken from the JNCC Coastal Directory Series (Crumpton *et al*, 1995; 1996, Crumpton and Goodwin, 1996). Some updated information on oil and gas development and production is given. (Department of Trade and Industry, 1997)

Hydrocarbon exploration and production in the Irish Sea

There is a great deal of interest from the oil and gas industry in areas off the Irish and Celtic Sea coasts. Important sedimentary basins are found to the north and east of Anglesey, and between Cardigan Bay and the Celtic Sea south of the Republic of Ireland. Although sedimentary basins also exist in the Bristol Channel, no oil or gas finds have yet been reported there.

The UK continental shelf area is divided into quadrants for the purposes of licensing hydrocarbon exploration and production. Each block measures 1° by 1° (except where the coastline or a neighbouring country's continental shelf intervene) and each is given a unique number and divided into 30 blocks of average 90 square miles in size. The Irish Sea between Colwyn Bay and Corsewall Point contains approximately 18 of the 110 UK licensed blocks.

Figure 28 shows oil and gas fields discovered in this region, and Table 3 indicates the estimated recoverable reserves of the fields in production. The Morecambe Bay gas field is connected by a 34 km long, 1.5 m diameter pipeline to the Barrow terminal and condensate storage facility. Oil from the Douglas and Lennox fields is transported by tanker, while gas from the Hamilton and Hamilton North fields in Liverpool Bay is piped to the Point of Ayr (Clwyd in North Wales).

In Ireland, the major gas supply is distributed throughout the main population centres via a 55.4 km pipeline from the Kinsale Head and Ballycotton fields off the south coast. At present, imported gas is being used in the Dublin area and will help to augment the diminishing supply of Kinsale gas.

Since the early 1970s, 130 offshore and appraisal wells have been drilled in the Irish sector of the Celtic Sea basins and in the central Irish Sea.

A survey on oil pollution in coastal areas of the UK also named accidental spills from off-shore and land-based oil- and gas installations and other industrial sites as sources of contamination. Bunkering operations in ports and fishing vessel casualties and, to a minor extent, tanker source spillages were the primary reported circumstances leading to pollution incidents in coastal waters (Advisory Committee on the Protection of the Sea, ACOPS, 1998). Statistics on oil pollution incidents in the Irish Sea were collected by ACOPS, between 1980 and 1987 (see Table 4). In most cases the amounts of oil involved were relatively small but the clean-up costs were not inconsiderable.

6.3. Radionucleides from Sellafield Nuclear Plant

Sellafield Nuclear Plant (formerly Windscale) is located on the Northwest Coast of England on the Irish Sea. It is a government owned facility that produces about one-fourth of the United Kingdom's energy. Discharges from this nuclear plant are the main source of artificial radioactivity in the UK marine environment (Department for Environment, Food and Rural Affairs, DEFRA, 2003) turning the Irish Sea into one of the most radioactive bodies of water in the world.

It produces vital energy to the people of the United Kingdom. It also produces weapons grade material needed for the production of nuclear weapons. For these reasons, Sellafield is an important facility for the U.K. in terms of domestic and security needs. Although Sellafield provides important services for the people and government of the United Kingdom, it has had a detrimental effect on the environment.

Since 1952, Sellafield has been dumping radioactive waste into the Irish Sea. This sea is now considered one of the most radioactive bodies of water in the world. Fish, shellfish, and sea plants in the Irish Sea contain substantial amounts of radiation. This is an environmental problem as well as a trade problem. Irish fishermen often catch mutated fish that cannot be sold. Also, nuclear waste clean-up facilities that are being developed at Sellafield cost a great deal to finance and are part of growing industry in Great Britain. The dumping of nuclear waste may put human lives at risk as well. Spray from the Irish Sea turns into radioactive dust, and can be found on beaches and in people's homes.

Over the years, the Sellafield discharges have acted as a large point source of a complex amalgam of α-, β-, and γ-emitting radionuclides originating from fission and neutron activation processes, and resulted in significant increases of artificial radionuclide concentrations in the Irish Sea.

Discharges from Sellafield give rise to the highest exposures from artificial radionuclides and contribute to exposures near many other nuclear sites around the United Kingdom. However, discharges of radioactivity, excluding ^{3}H, to the marine environment from Sellafield in 2000 were around 1% of the peak levels in the 1970s. As a result, the radiation dose to the consumers of large quantities of local seafood from marine discharges has fallen. The estimated dose of 0.15 mSv in 2001 is well within the dose limit of 1mSv/year from artificial radiation (DEFRA, 2003).

Though other minor sources of radionuclide concentration are present (OSPAR 2000), Sellafield represents the dominant source. The magnitude of the releases, authorised by the UK Government, has tended to mask contributions of radionuclide from other sources such as the 1986 Chernobyl accident.

The authorised discharge limits from Sellafield are reviewed periodically. Discharges peaked in the 1970s, since when a number of counter-measures have been introduced and the quantities of radionuclide discharges have changed markedly as a result of changes in throughput, chemical processes, storage and waste treatment. The Site Ion Exchange Effluent Plant (SIXEP), introduced in 1986, controlled ^{137}Cs (Caesium) discharges and since 1994 the Enhanced Actinide Removal Plant (EARP) has allowed the treatment of medium-active, stored liquors.

Research has established the distribution of radionuclides in Ireland and UK sea water and subtidal and intertidal sediments. Most of the input of "soluble" radionuclides such as ^{134}Cs, ^{137}Cs, ^{99}Tc (Technetium), ^{90}Sr (Strontium) and ^{129}I (Iodine) has been transported out of the Irish Sea, whereas most of the Pu (Plutonium) and ^{241}Am (Americium) resides in subtidal, muddy sediments in the eastern Irish Sea.
In general terms, there is a decreasing trend in concentration of ^{137}Cs in seawater. In contrast, the significant increase in the discharge of ^{99}Tc in 1999, combined with its rapid dispersion, led to an important increase in concentrations of ^{99}Tc in the North Channel and western Irish Sea.

The responsibility for monitoring levels of radioactivity in the marine environment lies with the Environment Agency in England and Wales, the Environmental Protection Agency in Scotland (SEPA) and the Environment and Heritage Service in Northern Ireland. In addition, the competent authorities for food safety (DEFRA (former MAFF), Scottish Executive and Department of Agriculture and Rural Development in Northern Ireland (DARD, former DANI) are responsible for monitoring radioactivity in food organisms (including algae, shellfish and fish). DEFRA publish an annual report jointly with SEPA on Radioactivity in food and the environment (i.e. MAFF 1998) that summarises the results of government surveillance. The main dischargers (i.e. British Nuclear Fuels at Sellafield, BNFL) also monitor their own discharges and report the results annually (i.e. BNFL, 1997).

Radionuclides are found in measurable quantities in the water column, suspended sediments, sea-bed sediments and the biota in the Irish Sea (Kershaw *et al.*, 1992). Kennedy *et al* (1988) reported studies where detectable levels of ^{137}Cs were found in sand flats, Arenicola sand flats and coastal embayments and saltmarshes of the Solway estuary and levels of ^{137}Cs and ^{241}Am in the Ravenglass estuary.

Kershaw *et al.*, (1992) reported studies in the Esk estuary where detectable levels of ^{137}Cs, ^{144}Ce (Cerium), ^{106}Ru (Ruthenium), ^{95}Zr (Zirconium), ^{95}Nb (Niobium) and Pu were found. Radionuclides from Sellafield have also been found in the Wyre estuary and in the water column and sediment of the Ribble estuary (Kershaw *et al.*, 1992).

Irish Sea has shown the highest observed levels of ^{137}Cs in north European waters due to historic discharges from Sellafield. Since 1985 discharges of ^{137}Cs have remained at about 10-20 TBq a^{-1} (Bq = Becquerel, equivalent to the quantity of radioactive material showing one transformation per second). Concentrations are still relatively high (above 100 Bq m^{-3} along the Cumbrian coast) due to remobilization from the seabed, which holds significant amounts of ^{137}Cs from earlier releases (Hunt & Kershaw, 1990; Cook *et al*., 1997, Morris *et al*., 2000).

The EC project MAST-52 investigated the concentrations of ^{99}Tc in seawater from the English Channel to the Kattegat and the south-western Norwegian coast along the European coast in 1983-1993. The highest ^{99}Tc levels were found in Goury in the English Channel. In 1986-1994, the ^{99}Tc levels in the Irish Sea were not high, even in the east Irish seawater. ^{99}Tc levels in shellfish started to increase in 1994 in the Irish Sea and Scottish waters, but the highest concentrations occurred in 1997 in the Irish Sea and in 1998 in the Scottish water.

^{90}Sr is the major anthropogenic radionuclide released from Sellafield. The highest levels of ^{90}Sr were reported in the Irish Sea by BNFL; the annual means in the east Irish Sea ranged between 200-400 Bq m^{-3}.

Plutonium isotopes are important anthropogenic radionuclides and due to the high reactivity most of the Pu discharged from Sellafield reprocessing plant is associated with Irish sediments, and very little has been transferred out of the Irish Sea. However, a recent investigation suggested that some of this sediment-bound plutonium could be remobilised (Cook *et al*., 1997).

^{241}Am is a very important alpha-emitting radionuclide, which is mainly distributed in the surface waters of the Irish Sea with the highest levels occurring in the East Irish Sea, especially in Sellafield coastal waters (MARINA II).

6.3.1. Effects of radioactive substances on marine organisms

Radionuclides are considered to be mutagenic substances with carcinogenic and teratogenic effects, but it is difficult to assess effects on biota (Ducrotoy *et al*., 2000). In particular, benthic algae, molluscs (mussels, winkles, limpets, whelks, scallops, queens), crustacea (crab, lobster, Nephrops, shrimps) and fish (including plaice, cod, flounder, herring) have been found to accumulate some radionuclides based on monitoring information collected by MAFF in the Irish Sea (Kershaw *et al.*, 1992). The principal concern has been to determine the risk to the human population and so the fish and shellfish species selected for monitoring have been commercially important ones. These species have been found to accumulate a number of radionuclides but the most important appear to be ^{106}Ru and ^{137}Cs. Both have been found to accumulate in fish muscle (plaice) and in crab *Cancer pagurus* hepatopancreas and muscle tissue. Crabs were found to accumulate ^{144}Ce and ^{95}Zr/^{95}Nb in addition to ^{106}Ru and ^{137}Cs. The most significant uptake route for these species is believed to be via the diet.

Studies on anthropogenic radionuclides in UK waters found that concentrations declined over the last decade and reflected decreasing emissions from the Sellafield plant in the same period (Scientific and Technological Options Assessment of the European Parliament (STOA), 2001 and Table 6).

Attempts have been made to quantify the total environmental inventory of caesium and transuranic nuclides in the water column and sediments of the Irish Sea. Poole *et al*. (1997) presented estimates of ^{137}Cs inventories in the subtidal sediments of the Cumbrian coast, the eastern Irish Sea and the whole Irish Sea for 1988 and 1995. A summary of the data is presented in Table 7. Similar calculations for $^{239,\ 249}$Pu and ^{241}Am inventories in subtidal sediments for 1978, 1983, 1988 and 1995 have also been reported by Kershaw *et al*. (1999) and are summarized in Table 8.

Studies of the uptake of radionuclides by marine organisms have been undertaken since the early 1960s. Calculation of doses to consumers (see Table 5) of fish and shellfish has formed part of a comprehensive programme to assess the radiological impact of the Sellafield operations. The effect of radiation from all sources on a large group of people is measured in terms of that group´s collective dose and is expressed in man-sieverts (man-Sv).

Parrett (1998) considered the following issues in a consideration of the effects of radioactivity on North Sea fish stocks: lethal effects; effects on reproductive success; genetic effects.

Studies reported in Parrett (1998) indicated that the range of lethal levels in adults of different species of fish was in the range 3.75 to 100 Gy (gray = amount of radiation absorbed, equivalent to 1 joule of energy absorbed per kg tissue), and for invertebrates ranging from 0.2 to above 500 Gy. Earlier developmental stages have been identified as more susceptible and mortality of fish embryos has been shown to occur at about 0.16 Gy.

The effects on reproductive success in fish that have been demonstrated include sterility, reduction in counts of primordial germ cells and reduced testicular weight. The lowest dose rate at which effects of chronic radiation exposure on fertility of aquatic invertebrates and fish were demonstrated was about 0.25 mGy $hour^{-1}$ (Parrett 1998). The implied mechanism for these effects was damage to germ cells and the induction of dominant lethal mutations in gametes.

Mutation rates increase in relation to radiation exposure and so therefore does the chance of deleterious mutations occurring. While natural selection will act to keep these mutations at low level in the gene pool, some expression might occur in the short-term (in the form of sterility or dominant lethal mutations) or in the long term (in the form of genetic disease).

6.3.2. Sensitivity of cephalopods to radionuclides

Little is known of the processes involved in radionuclide uptake and retention to be able to predict those species which will be most efficient at accumulating environmental radioactivity, but as for heavy metals, the danger of radionuclides lies in their accumulation during the reproductive stages in growing tissues and the consequent uptake through the food chain.

A food web study from the Norwegian and Barents Sea found radiocaesium concentrations to be low for this area (Heldal *et al.*, 2003). However concentrations were found to multiply from lowest levels in krill and squid *Gonatus fabricii* by a factor of 10 to highest values found in harbour porpoise (*Phocoena phocoena*).

Studies on naturally occurring radionuclides in marine organisms found polonium concentrations to be dependent of the diet of the organism (Cherry *et al.*, 1989, Carvalho & Fowler, 1993). High concentrations were found in benthic molluscs and marine mammals through bioaccumulation from lower trophic levels. Both fish and squid (*Loligo vulgaris reynaudii*) showed lower levels than either shellfish or marine mammals (Cherry *et al.*, 1994, Heyraud *et al.*, 1994, Dahlgaard, 1996, Betti *et al.*, 2004). Contamination levels in molluscs seemed to be related to reproductive cycles in *Mytilus galloprovincialis* (Charmasson *et al*., 1999) and ontogenetic changes in feeding in the case of *Loligo vulgaris reynaudii* (Heyraud *et al*., 1994).

7. Conclusions

- Cephalopod species of economical and ecological importance in the SEA 6 area are the long-finned squid species *Loligo forbesi* and *Alloteuthis subulata*.
- From the commercial point of view, the most important cephalopod species in SEA 6 area is *L. forbesi*, which is landed as by-catch of the demersal trawl fishery (82 tonnes in 2002).
- Specimens of *A. subulata* frequently occur in hauls alongside *L. forbesi*. Even though it is of no commercial value this species has an important ecological role in the coastal food webs since it is the most commonly recorded cephalopod species in stomach contents of demersal fish in UK waters.
- Top marine predators are naturally submitted to very high metallic contaminants exposure when they include cephalopods in their diet. Trace elements in cephalopods also raise public health concerns due to their consumption by humans.
- Although most soluble radionuclides have been transported out of the Irish Sea the bulk of Plutonium and Americium still resides in subtidal muddy sediments, which might be re-suspended, should the seabed be disturbed due to exploration activities. This might consequently lead to dangerous dosages in organisms along the food chain.
- Drilling operations and oil spills might have an effect on the propagation of cephalopod stocks should they occur in spawning areas.

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Table 1. Total annual cephalopod landings (in tonnes) from catches in ICES area VIIa by national fleets from the ICES area. Also shown are total landings for each category in the whole ICES area. This table is based on a more extensive tabulation in ICES WGCEPH Report 2004. Data for 2003 were provisional (P).

Category and country	1997	1998	1999	2000	2001	2002	2003P
(a) Cuttlefish (Sepiidae)							
Belgium	1	1	1	1	2	4.7	
England, Wales & Northern	1	1	1	1	0.1	0	0.8
France	0	0	0.1	0.9	0.7	7.1	0.5
Total (whole ICES area)	16652	20275	20210	23754	18034	22614	19492
(b) Common Squid (Loliginidae)							
Belgium	2	5	3	3	2.3	9.4	2.3
England, Wales & N. Ireland	125	173	40	31	102.6	116.3	96.3
France	5	17	11.4	11.8	21.8	37.1	5.8
Ireland	6	22	13	5	0.8	2	
Isle of Man	2	2	2	+		0.4	
Scotland	3	2	2	2			
Total (whole ICES area)	11519	11245	11049	10253	8234	9939	7527
(c) Short-finned Squid (Ommastrephidae)							
England, Wales & N. Ireland	0	0	0	+			0
France			0.2	0.2		0	
Ireland	+	+	0	0			
Total (whole ICES area)	6145	5841	7693	5607	4260	2571	1348
(d) Octopods (Octopodidae)							
Belgium	18	26	4	5	10.9	31.1	
England, Wales & N. Ireland	1	+	+	+	0.4	0.1	0.3
Ireland	0	1	0	+		1	
Total (whole ICES area)	15801	13043	15718	16500	11461	12831	12191

Table 2. Landings of squid from VIIa area of capture, by the UK Fleet landing into the UK and abroad for recent years. (DEFRA, UK Sea Fisheries Statistics, 1997-2003).

Landings by area	1997	1998	1999	2000	2001	2002	2003
Weight in tonnes							
VIIa	127	174	42	34	114	122	111
Value in £,000							
VIIa	246	374	77	74	293	262	238

Table 3. Oil and Gas fields in Production in the Irish Sea.

Field	Discovered	Production started	Hydrocarbon	Estimated original recoverable reserves
Douglas	1990	Jan. 1996	Oil	11.3 mt
Hamilton	1990	Feb. 1996	Gas	14.6 bm^3
Hamilton North	1991	Dec. 1995	Gas	6.7 bm^3
Lennox	1992	Mar. 1996	Oil	7.6 mt
Morecambe North	Feb 1976	Oct. 1994	Gas	27.4 bm^3
Morecambe South	Sep 1974	Jan. 1985	Gas	136.3 bm^3

Table 4. Oil pollution incidents in the Irish Sea. Source: ACOPS (1998)

	1980	1981	1982	1983	1984	1985	1986	1987
Open sea	2	3	3	2	4	3	7	6
Tidal river/estuary	0	2	3	0	0	0	0	0
Bay/nearshore water	0	3	0	4	1	5	1	2
Beach/shore	10	3	5	7	4	3	3	2
Port	2	22	20	3	10	19	19	13
Total	14	33	31	16	19	30	30	23
Oil spilled (t/yr)	<250	<150	50-100	<50	100-150	4	263	51
Clean up costs (£ 000)	9	8	-	5	10	1	74	49

Table 5. Estimated collective doses from consumption of fish and shellfish in the UK between 1990 and 1997. Most of the collective dose estimated is due to radiocaesium in fish. Other radionuclides contributing in small proportions are ^{90}Sr, ^{14}C, ^{99}Tc. Liquid discharges from Sellafield are the main source of collective dose in the UK. The recommended dose per person per year is set at 1mSv. Source: DEFRA, e-Digest of Environmental statistics, published August 2003.

Year	Collective dose rate[2] (man-Sv[3] per year)	Average dose per person (µSv[4] per person per year)
1990	10	0.20
1991	8	0.14
1992	5	0.09
1993	4	0.07
1994	5	0.09
1995	3	0.05
1996	4	0.07
1997	4	0.07

Table 6. Radioactivity concentrations in some samples of fish at selected sites: 1990-2001. Sellafield shoreline area is close inshore in the Sellafield vicinity and Sellafield offshore is defined as a rectangle, one nautical mile wide and two nautical miles long, situated south of the pipeline. Source: DEFRA, e-Digest of Environmental statistics, published August 2003.

Year	Cod ^{137}Cs conc. Sellafield shoreline (Bq kg^{-1})	Cod ^{137}Cs conc. Sellafield offshore waters (Bq kg^{-1})	Plaice ^{137}Cs conc. Sellafield offshore waters (Bq kg^{-1})	Whiting ^{137}Cs conc. Sellafield offshore waters (Bq kg^{-1})
1990	0.8	0.5	0.2	0.6
1991	0.9	0.7	0.2	0.3
1992	0.25	---	---	0.34
1993	0.37	0.17	0.04	0.19
1994	0.27	---	0.15	---
1995	0.11	---	0.08	---
1996	0.06	---	0.07	0.05
1997	< 0.23	< 0.17	< 0.07	< 0.16
1998	< 0,17	< 0,13	< 0,04	< 0,11
1999	< 0,16	< 0,1	< 0,05	< 0,07
2000	< 0,1	< 0,12	< 0,04	< 0,07
2001	< 0,12	< 0,11	< 0,05	< 0,15

Table 7. Cumulative ^{137}Cs discharge data and subtidal sediment inventory data for the whole of the Irish Sea, the Cumbrian coast and the eastern Irish Sea (from: Poole *et al*., 1997)

Year	**^{137}Cs inventory (TBq)**				**% of total discharge**		
	All Irish Sea	**E Irish Sea**	**Cumbrian coast**	**Annual discharge (TBq)**	**All Irish Sea**	**E Irish Sea**	**Cumbrian coast**
1988	1532	1098	420	308976	5.0	3.5	1.4
1988*	1309	938	359				
1995	959	648	258	26469	3.6	2.5	1.0

* data decay-corrected to 1995

Table 8. Estimated inventories of ^{239,240}Pu and ^{241}Am in subtidal sediments of the Irish Sea, expressed as total activities (TBq) and as percentages of the total, decay-corrected inputs to the environment (from: Kershaw *et al*., 1999)

	1978		**1983**		**1988**		**1995**	
	TBq	**%**	**TBq**	**%**	**TBq**	**%**	**TBq**	**%**
^{239,240}Pu								
All Irish Sea	248	52.3	n/a	n/a	341	58.1	360	60.8
E Irish Sea	196	41.3	236	41.2	286	48.7	284	47.9
Cumbrian coast	115	24.2	146	25.5	172	29.3	151	25.5
^{241}Am								
All Irish Sea	308	49.9	n/a	n/a	487	56.7	545	56.7
E Irish Sea	248	40.2	275	36.2	415	48.3	439	45.6
Cumbrian coast	144	23.3	163	21.5	250	29.1	242	25.2

Table 9. Annual liquid radioactive discharges by Sellafield: 1986-2001 Source: DEFRA, e-Digest of Environmental statistics, published August 2003.

	1996	1997	1998	1999	2000	2001
Tritium	3.009	2.560	2.300	2.500	2.300	2.600
Carbon-14	10,6	4,4	3,7	5,8	4,6	9,5
Sulphur-35	0,88	0,45	0,43	0,32	0,36	0,16
Manganese-54	0,05	0,06	0,07	0,04	0,01	0,03
Iron-55	0,04	0,01	0,01	0,02	0,04	0,02
Cobalt-60	0,43	1,47	2,4	0,89	1,2	1,2
Nickel-63	0,34	0,41	0,4	0,58	0,43	0,27
Zinc-65	0,12	0,13	0,14	0,07	0,03	0,05
Strontium-89	0,29	0,33	0,88	0,60	0,64	0,76
Strontium-90	16,0	37,3	18	31	20	26
Zirconium-95	0,52	0,18	0,30	0,10	0,10	0,13
Niobium-95	0,63	0,18	0,35	0,08	0,09	0,14
Technetium-99	150	84	53	69	44	79
Ruthenium-103	0,20	0,13	0,15	0,13	0,11	0,15
Ruthenium-106	9,0	9,8	5,6	2,7	2,7	3,9
Silver-110m	0,13	0,12	0,12	0,09	0,08	0,10
Antimony-125	6,7	3,4	4,8	7,9	7,8	13
Iodine-129	0,41	0,52	0,55	0,48	0,47	0,63
Caesium-134	0,27	0,30	0,32	0,34	0,23	0,48
Caesium-137	10,3	7,9	7,5	9,1	6,9	9,6
Cerium-144	0,78	0,49	0,76	0,60	0,55	0,79
Promethium-147	0,42	0,39	0,39	0,41	0,35	0,42
Europium-152	0,14	0,12	0,16	0,11	0,07	0,11
Europium-154	0,08	0,16	0,10	0,05	0,06	0,08
Europium-155	0,05	0,06	0,09	0,04	0,05	0,07
Neptunium-237	0,04	0,03	0,04	0,04	0,03	0,04
Plutonium-alpha	0,21	0,15	0,14	0,12	0,11	0,16
Plutonium-241	4,4	3,3	3,5	2,9	3,2	4,6
Americium-241	0,07	0,05	0,05	0,03	0,03	0,04
Curium-242	0,009	0,004	0,006	0,003	0,003	0,006
Curium-243/244	0,007	0,004	0,003	0,002	0,003	0,003
Total alpha	0,27	0,18	0,17	0,13	0,12	0,20
Total beta	143	138	86	110	77	120

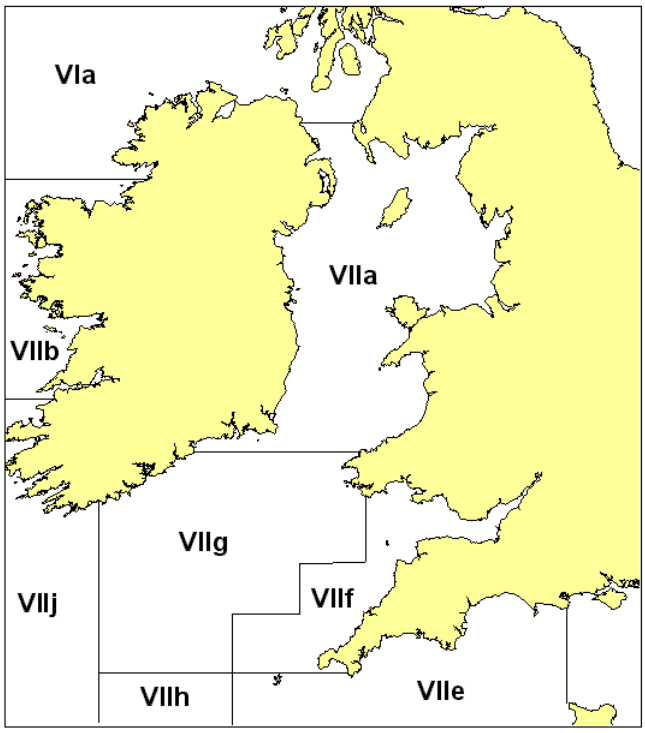


Figure 1. ICES fishing areas around the UK coastline

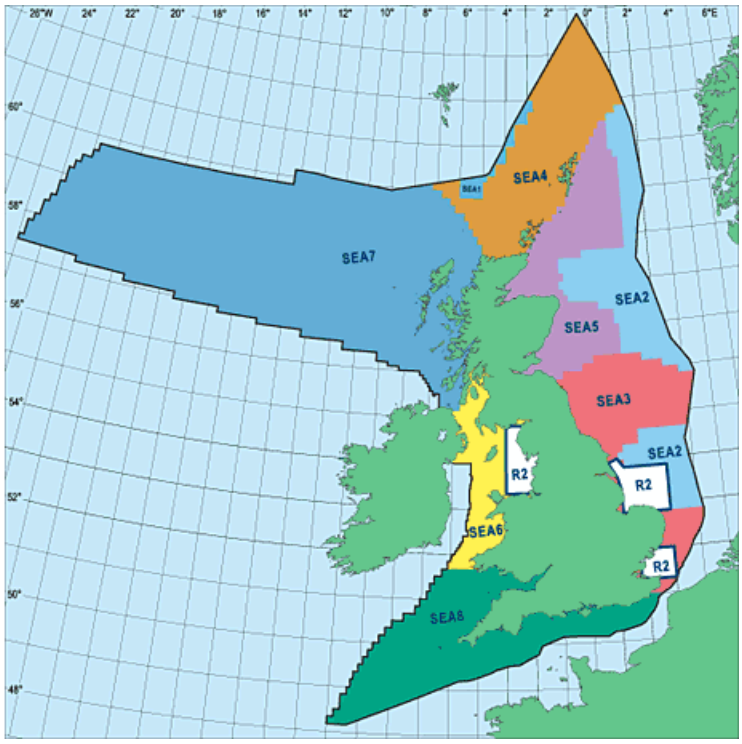


Figure 2. Maps showing the SEA areas (SEA 6 area in yellow)

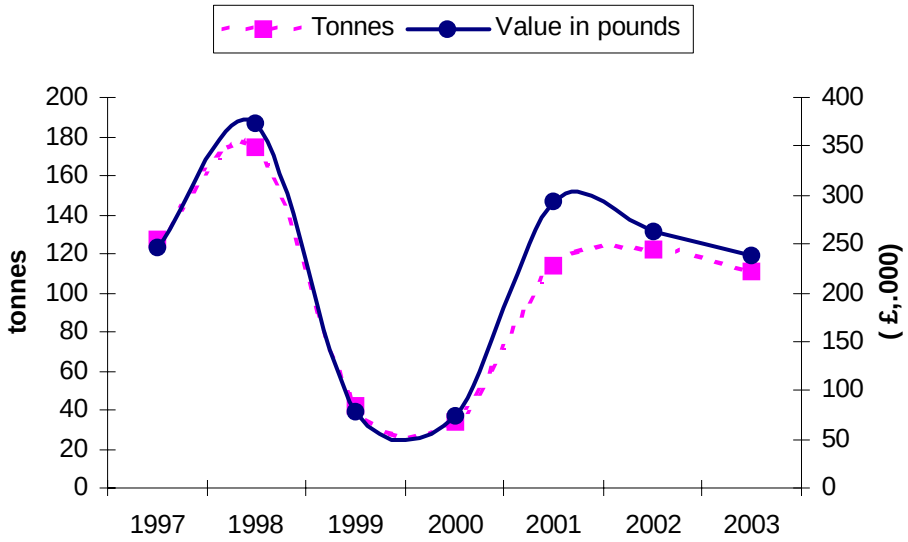


Figure 3. Total squid landings from the Irish Sea by the UK fleet between 1997 and 2003 (DEFRA, UK Sea Fisheries Statistics).

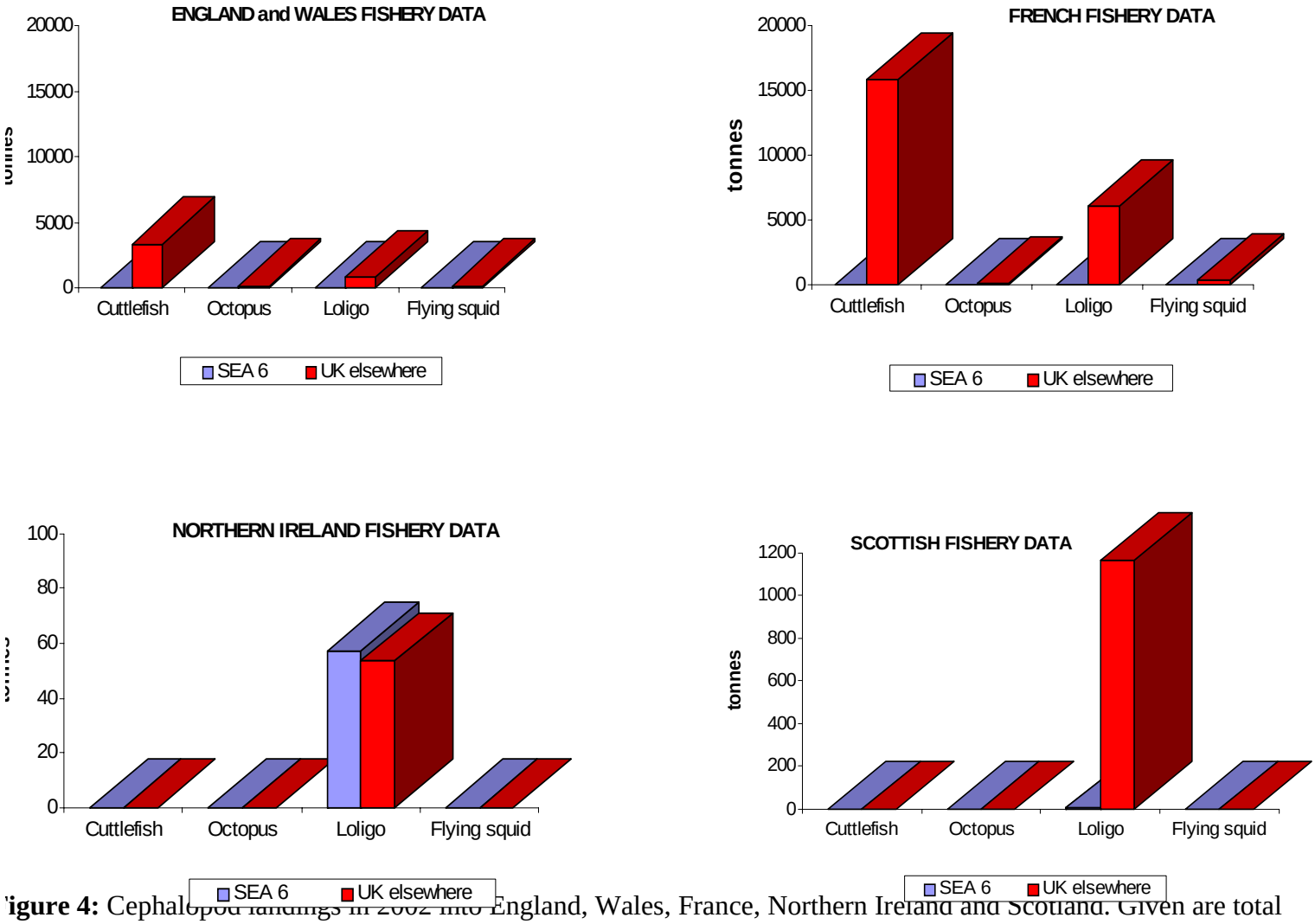


Figure 4: Cephalopod landings in 2002 into England, Wales, France, Northern Ireland and Scotland. Given are total landings for cephalopods caught in the SEA6 area and UK waters (other than SEA6).

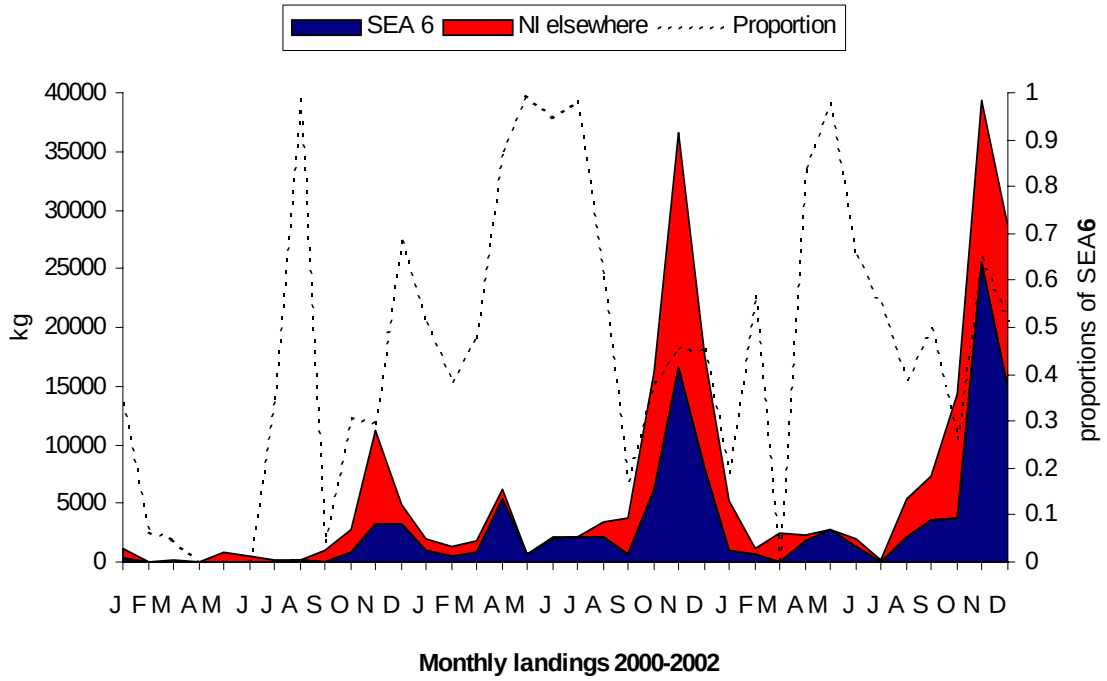


Figure 5. Month-to-month trends in landings of loliginid squid into Northern Ireland. The dotted line shows the proportion of landings arising from catches in the SEA 6 area.
* Northern Ireland Fishery data

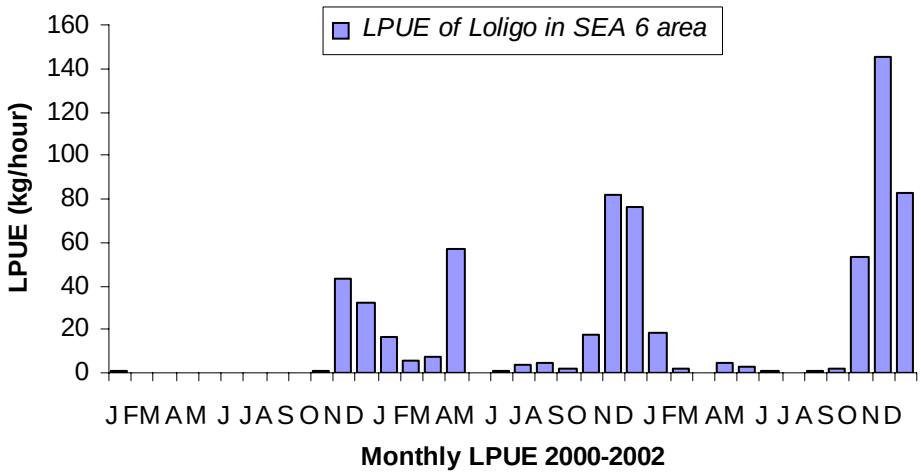
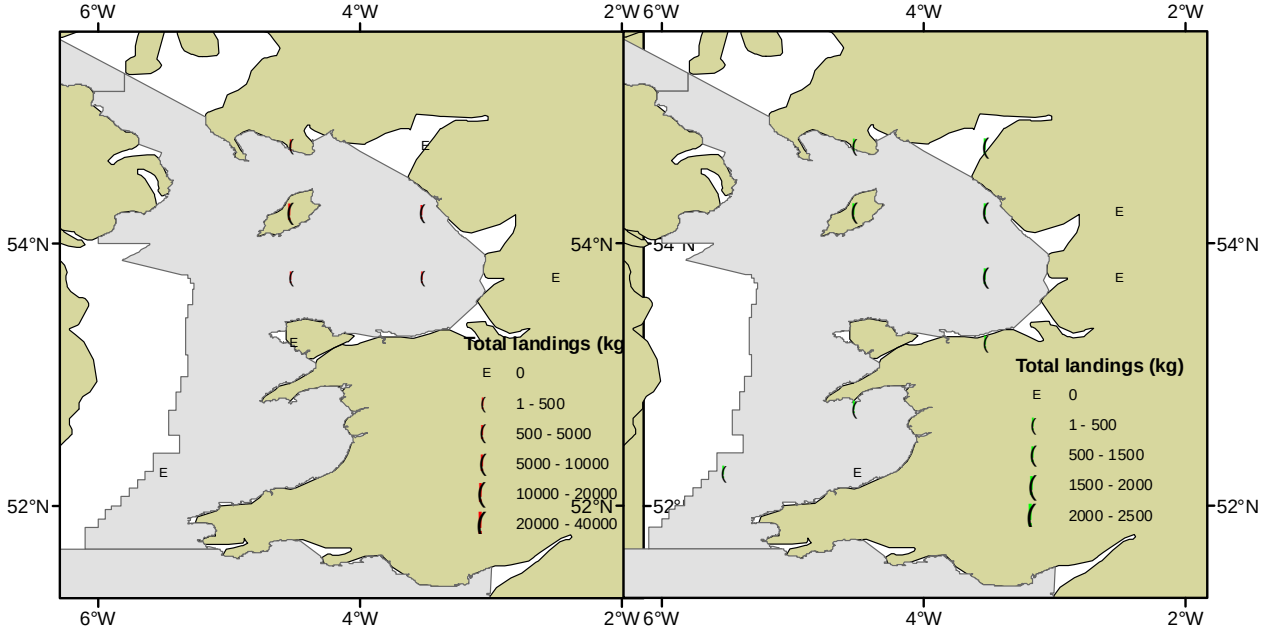
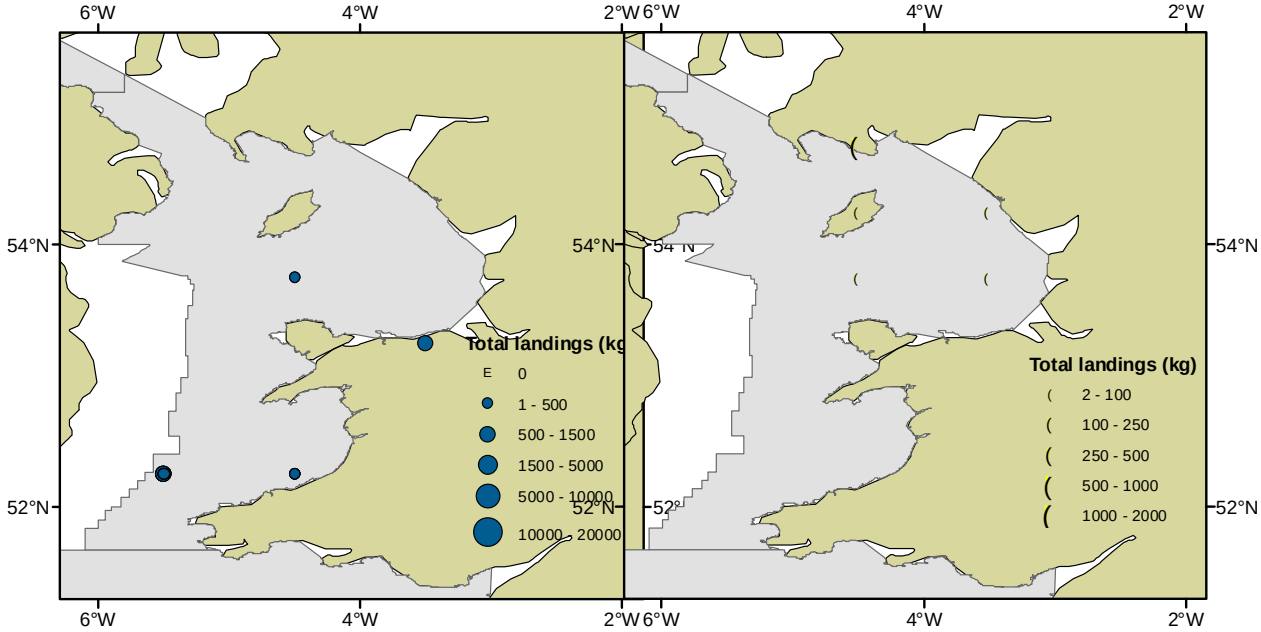


Figure 6. Month-to-month trends in landings per unit of effort (LPUE) of loliginid squid for the SEA 6 area.
* Northern Ireland Fishery data

Total *Loligo* spp. landings (kg) in 1998



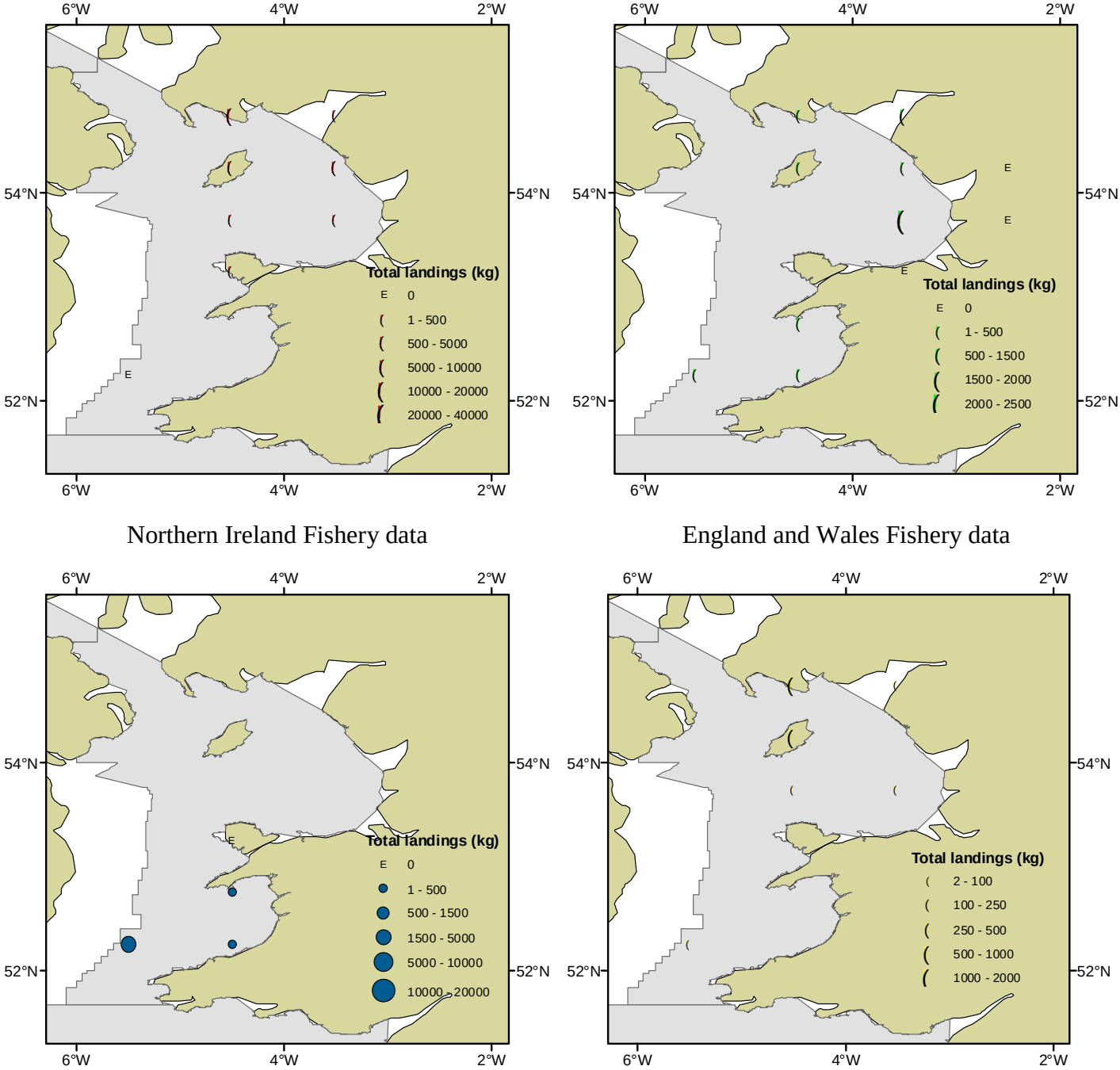
Northern Ireland Fishery data England and Wales Fishery data



French Fishery data Scottish Fishery data

Figure 7

Total *Loligo* spp. landings (kg) in 1999



Northern Ireland Fishery data

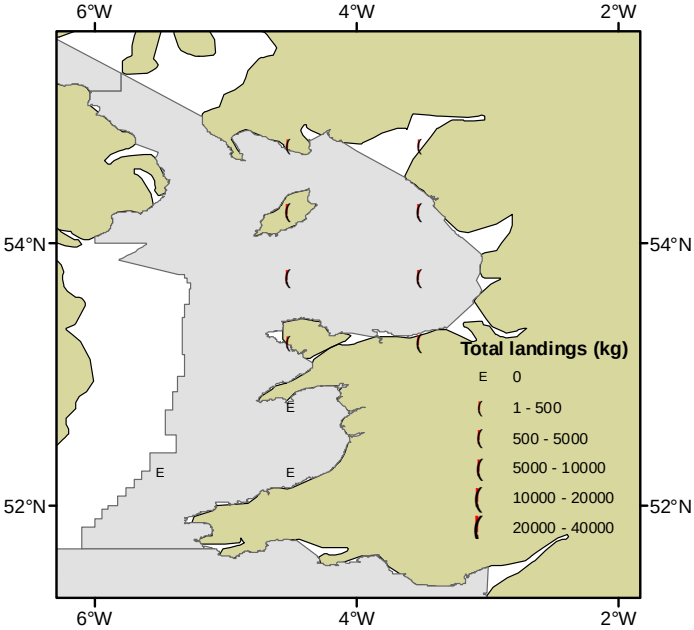
England and Wales Fishery data

French Fishery data

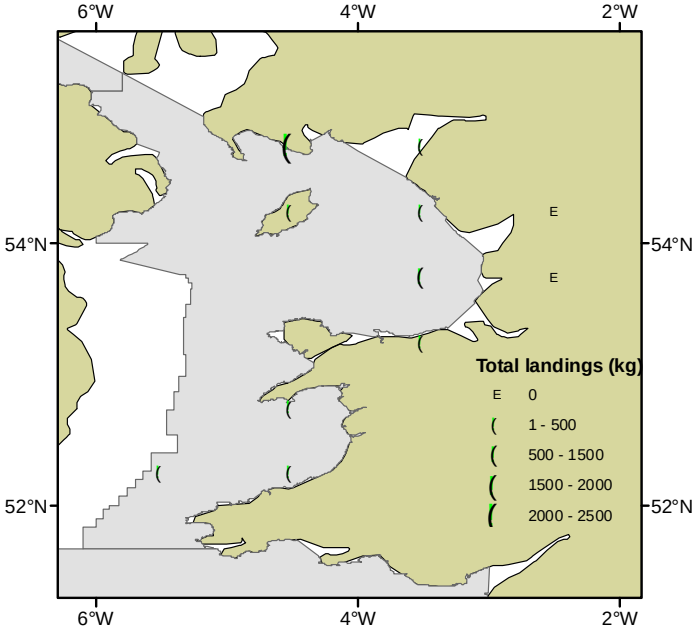
Scottish Fishery data

Figure 8

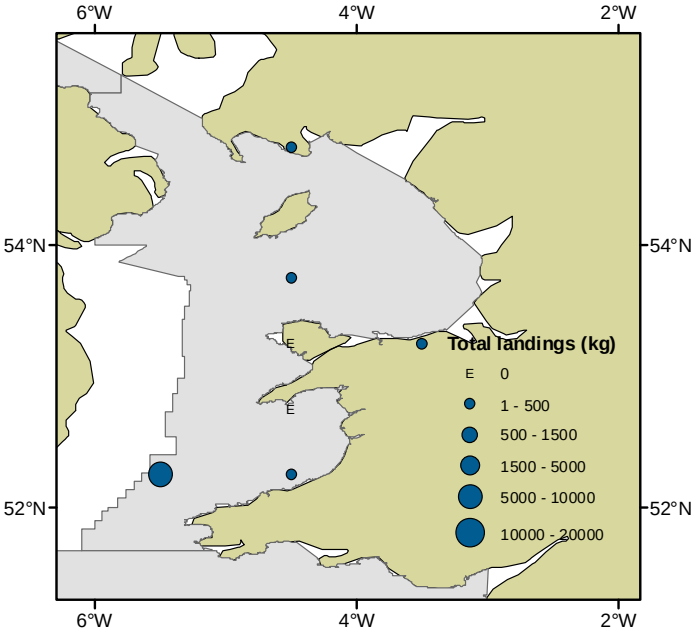
Total *Loligo* spp. landings (kg) in 2000



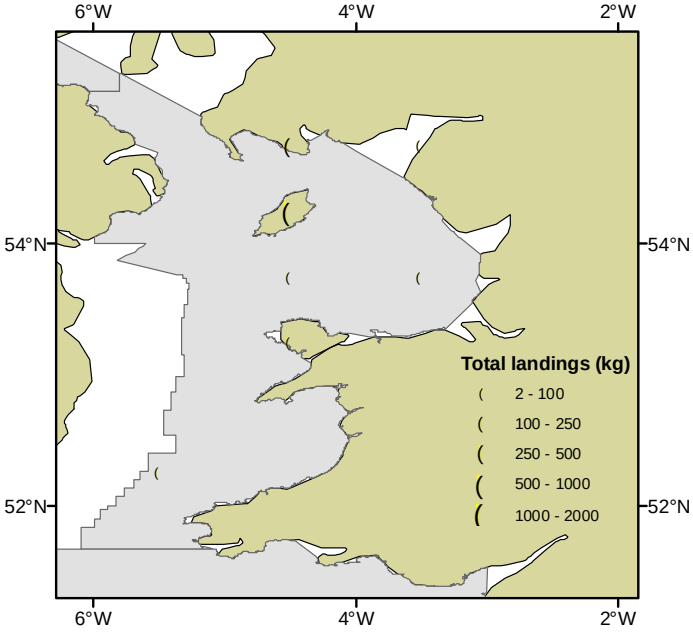
Northern Ireland Fishery data



England and Wales Fishery data



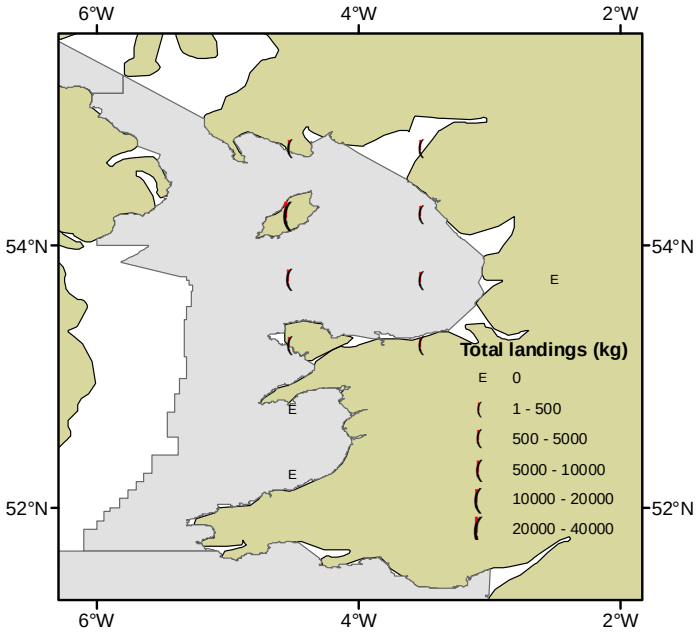
French Fishery data



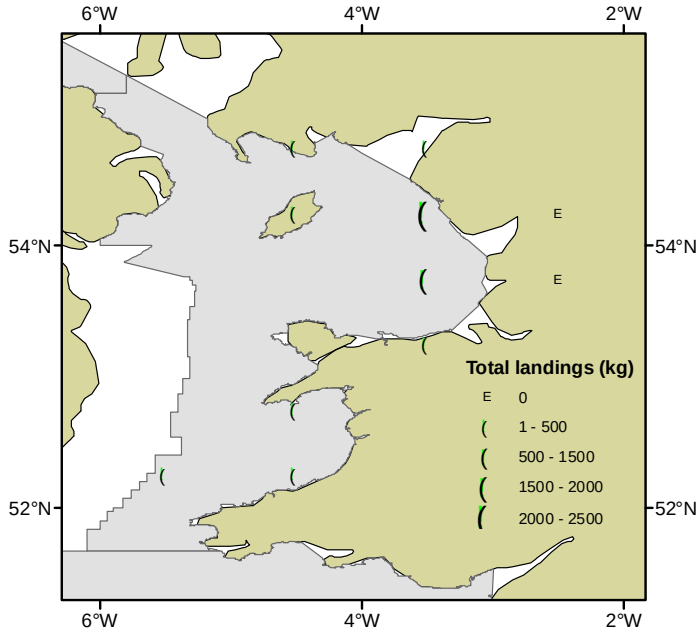
Scottish Fishery data

Figure 9

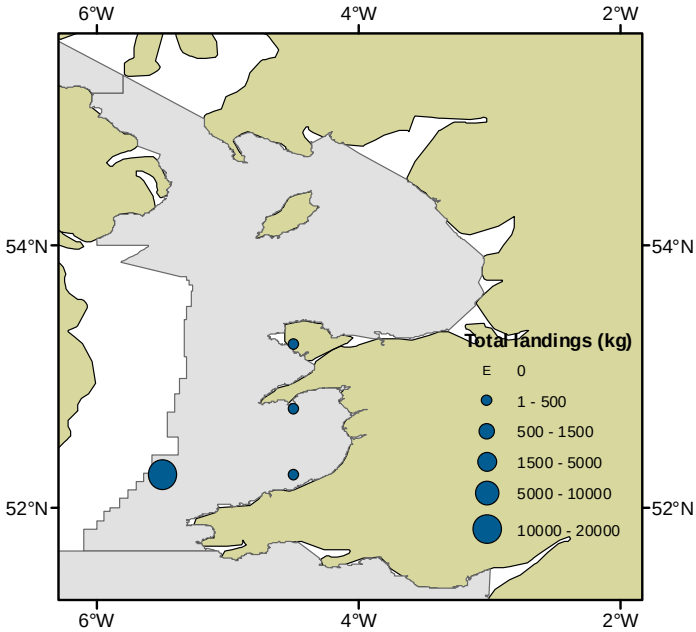
Total *Loligo* spp. landings (kg) in 2001



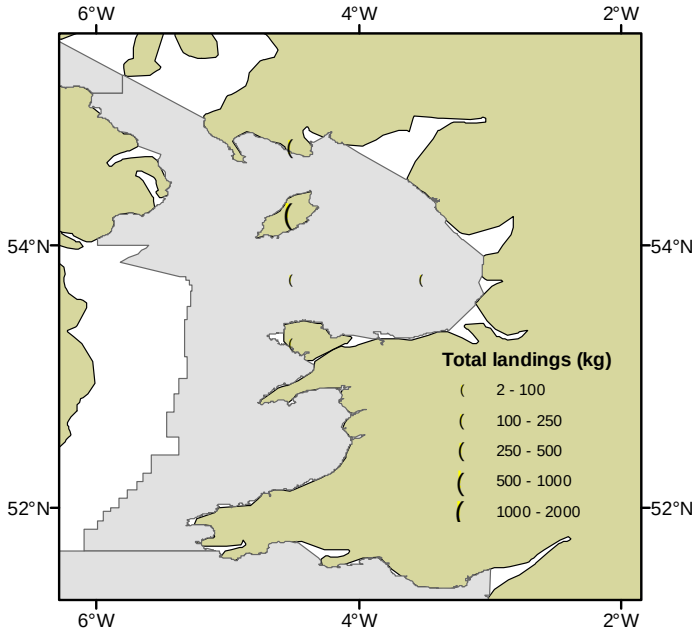
Northern Ireland Fishery data



England and Wales Fishery data



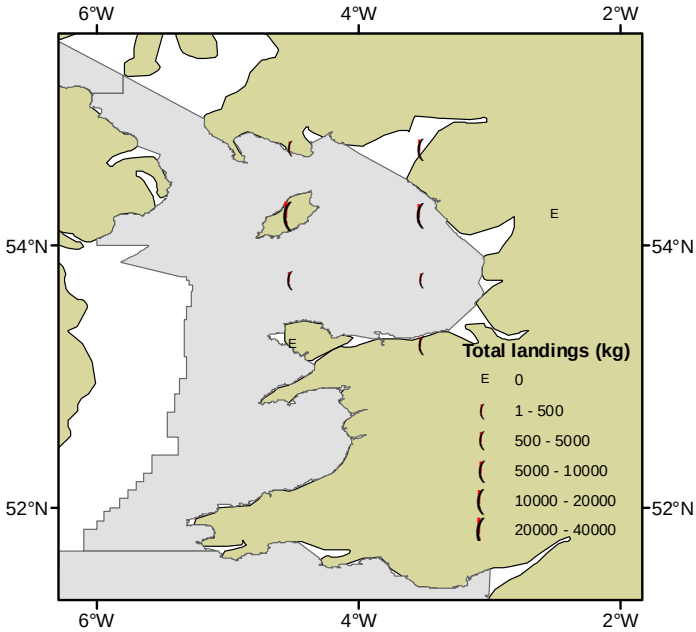
French Fishery data



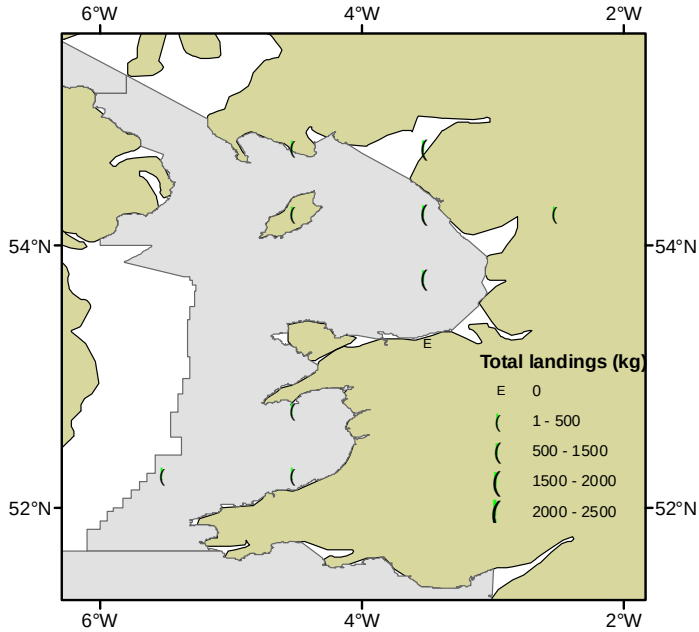
Scottish Fishery data

Figure 10

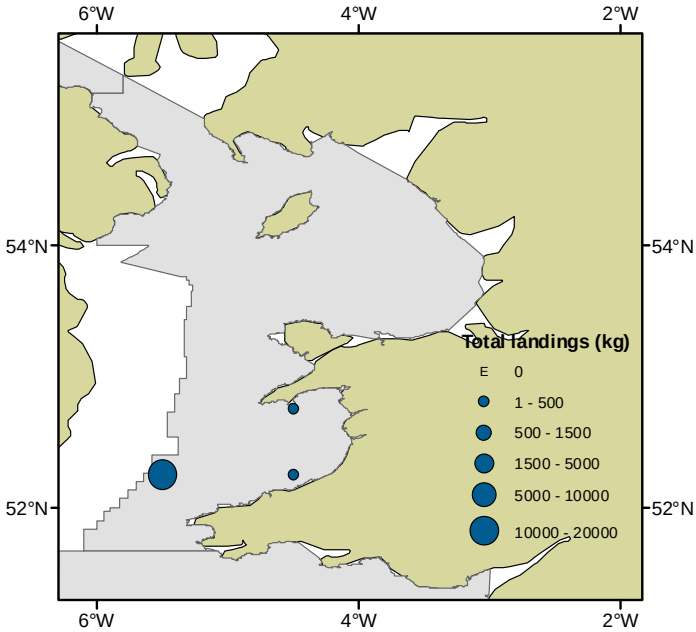
Total *Loligo* spp. landings (kg) in 2002



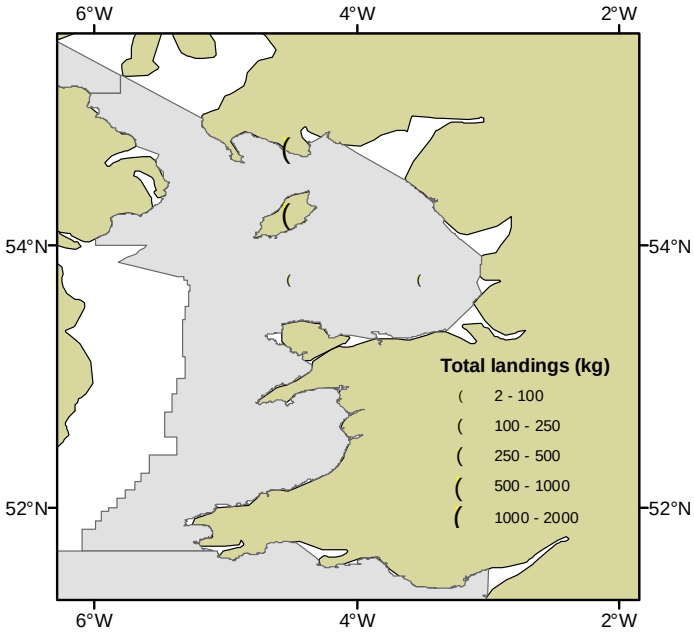
Northern Ireland Fishery data



England and Wales Fishery data



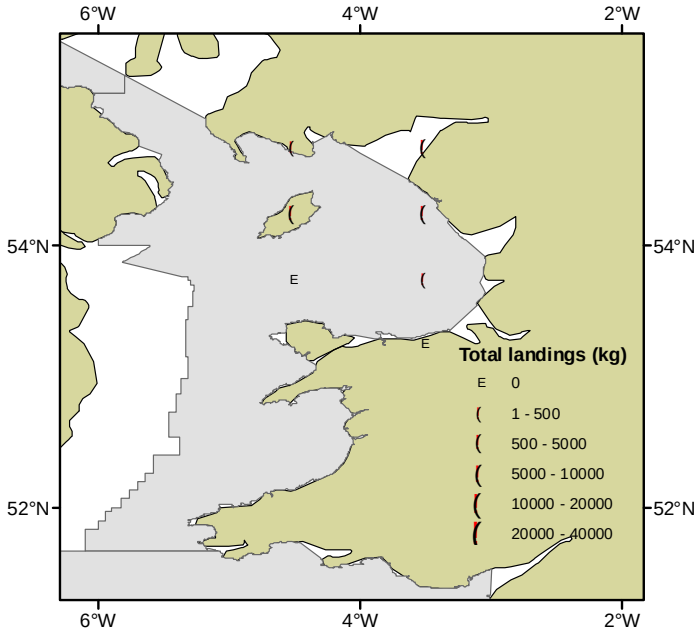
French Fishery data



Scottish Fishery data

Figure 11

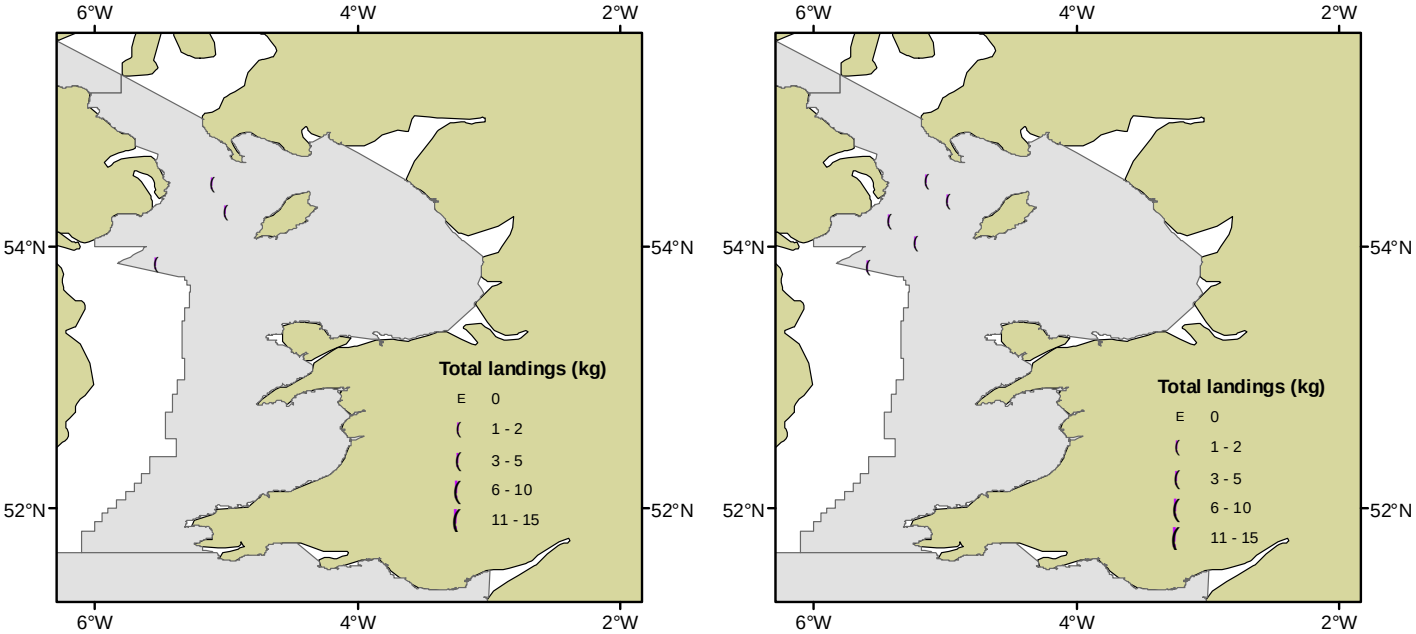
Total *Loligo* spp. landings (kg) in 2003



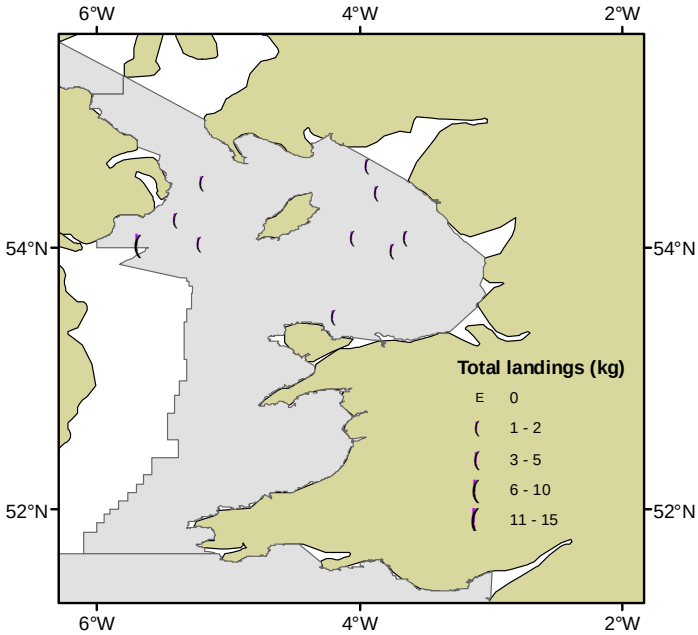
Northern Ireland Fishery data

Figure 12

Total *Alloteuthis subulata* (kg) caught
Scottish research cruise data



1996 1997



1998

Figure 13

Total Ommastrephid landings (kg)
French Fishery Data

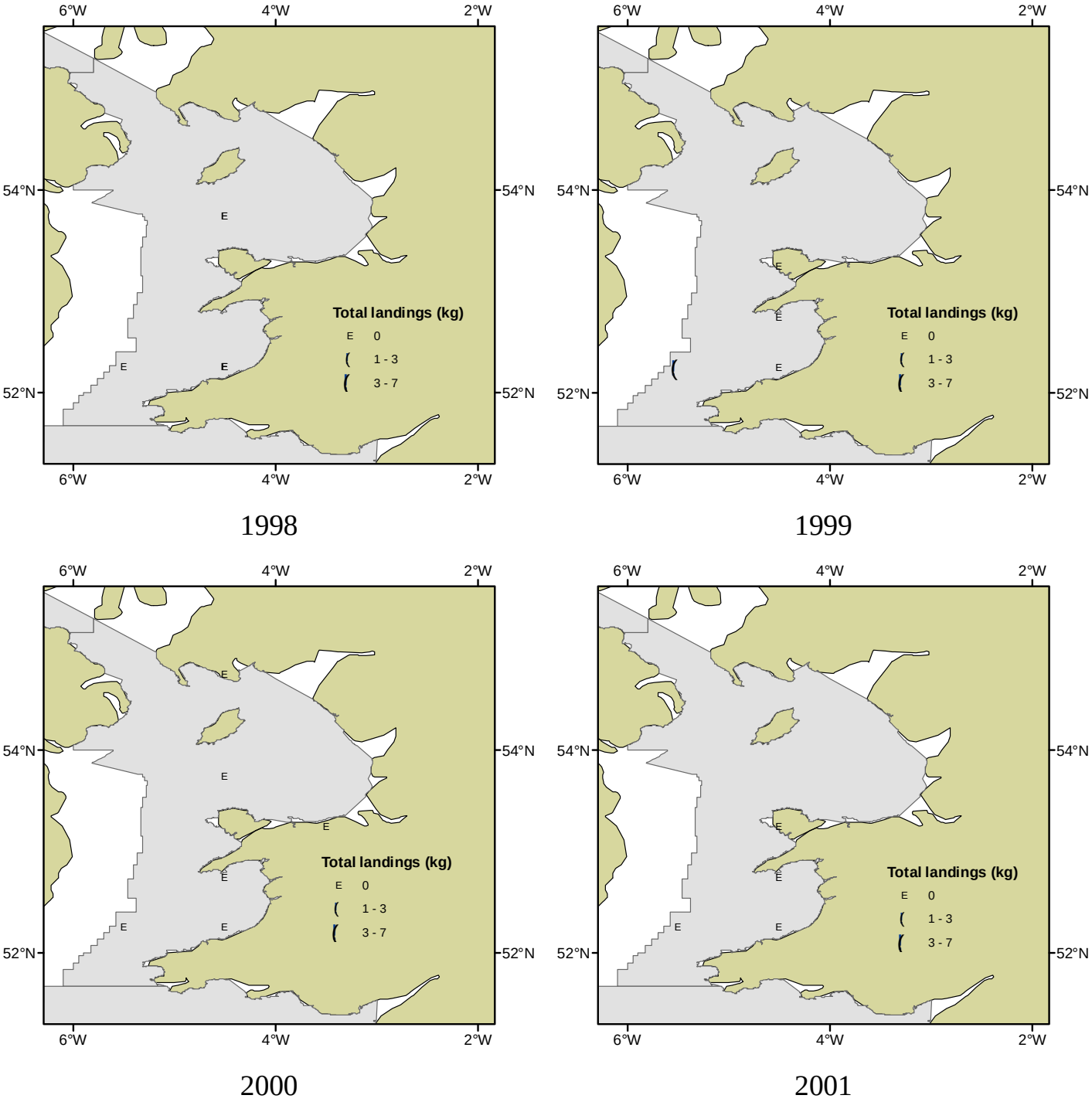
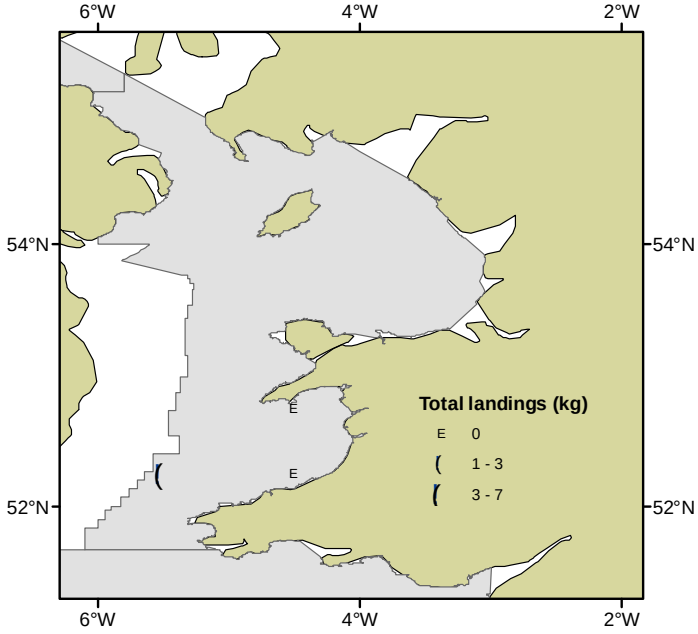


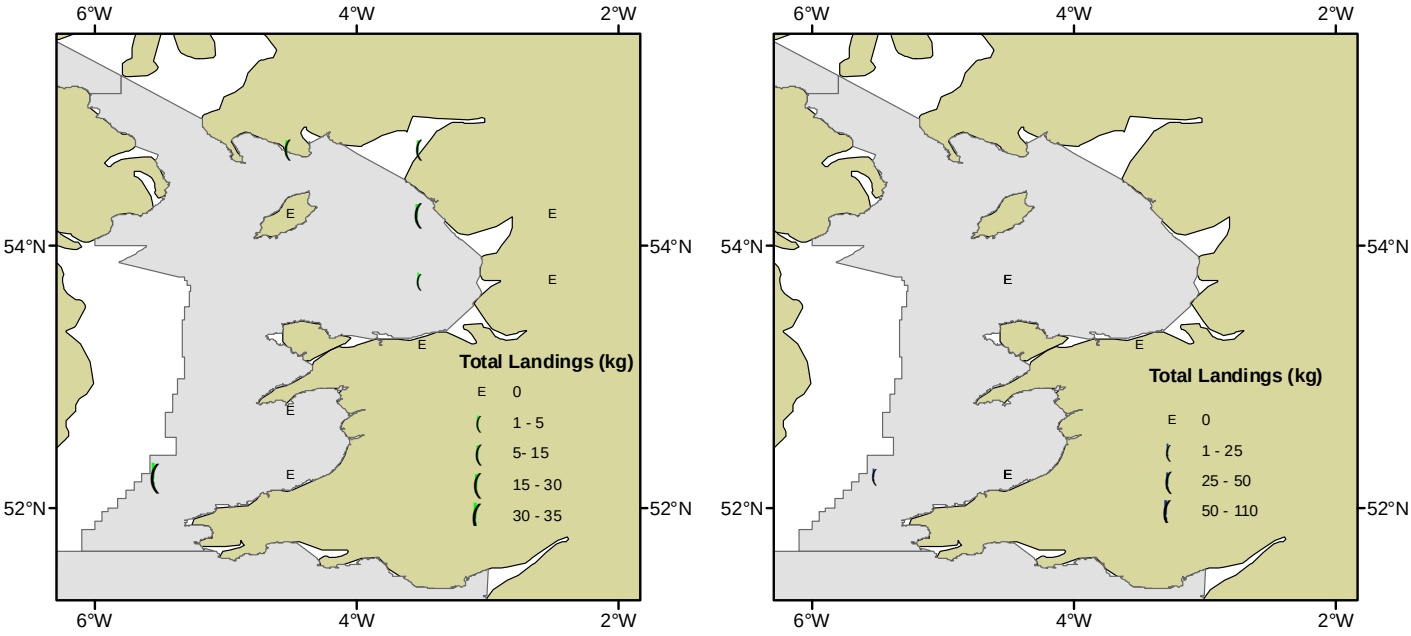
Figure 14



2002

Figure 14 cont. Total Ommastrephid landings (kg) of specimens caught in SEA6 (French fishery data).

Total Cuttlefish landings (kg) in 1998

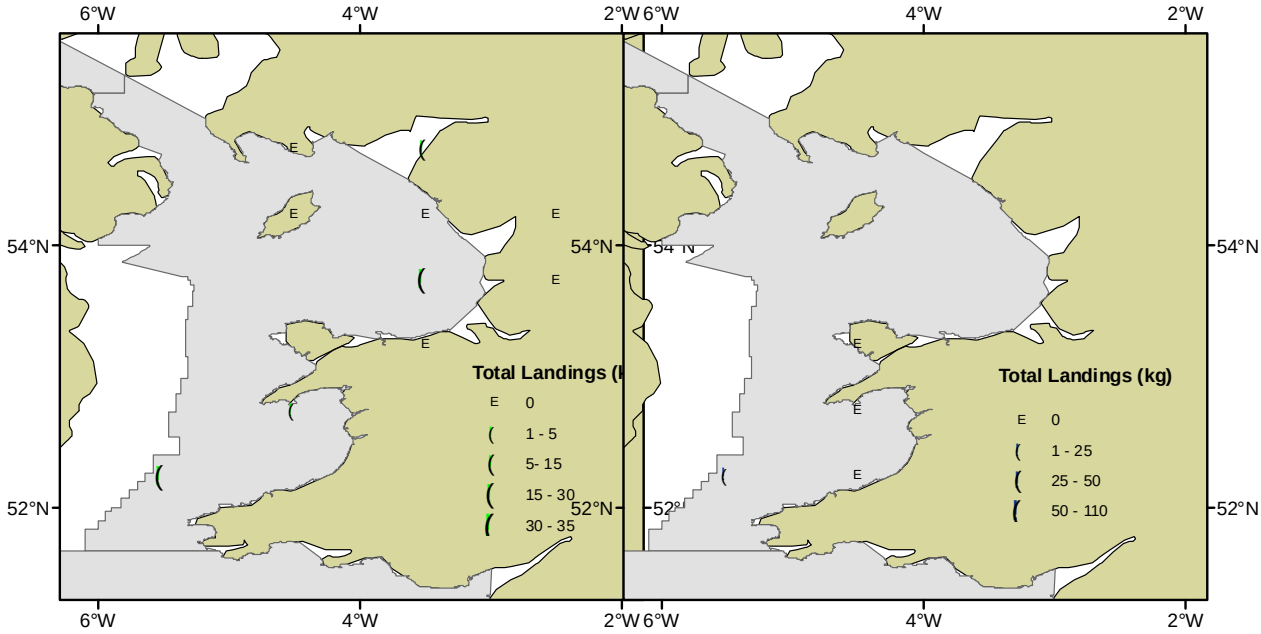


England and Wales Fishery data

French Fishery data

Figure 15

Total Cuttlefish landings (kg) in 1999

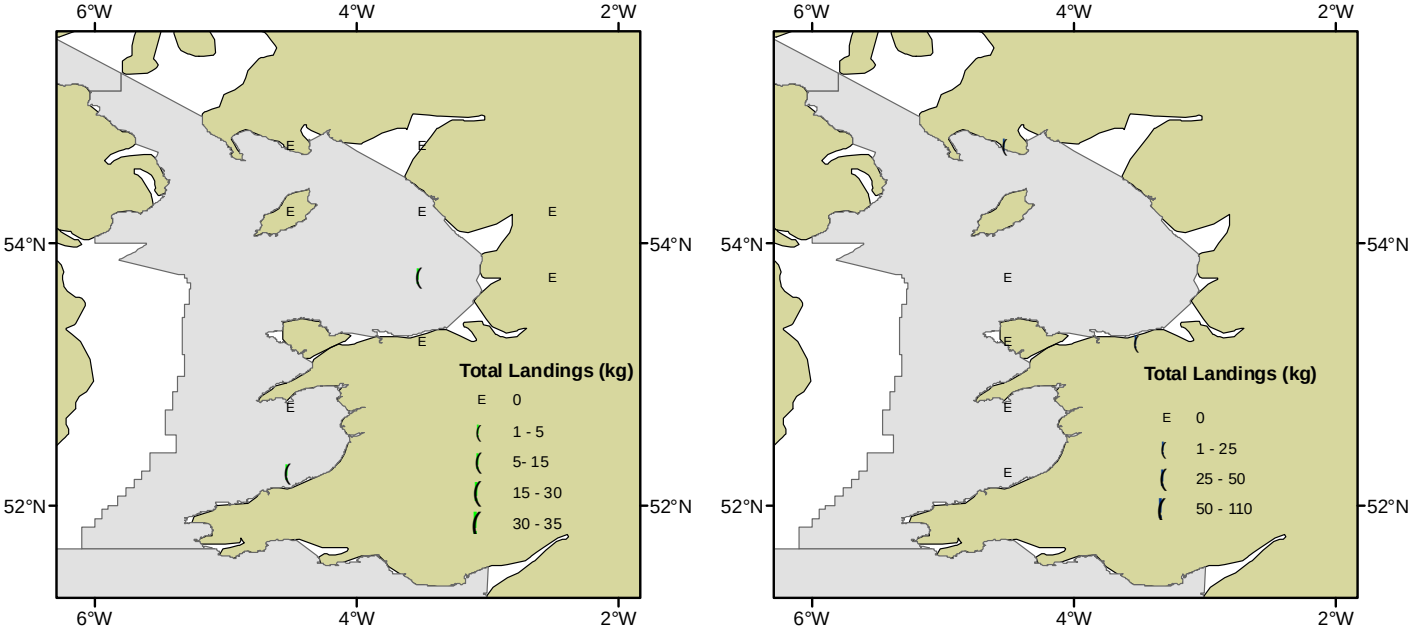


England and Wales Fishery data

French Fishery data

Figure 16

Total Cuttlefish landings (kg) in 2000

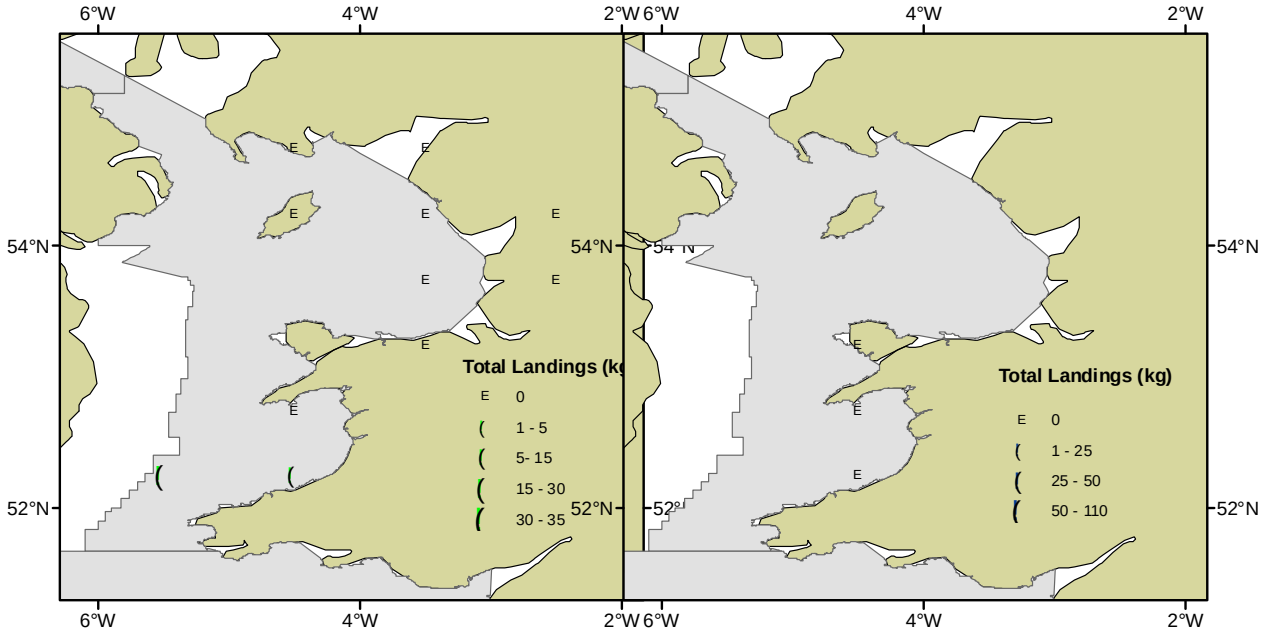


England and Wales Fishery data

French Fishery data

Figure 17

Total Cuttlefish landings (kg) in 2001

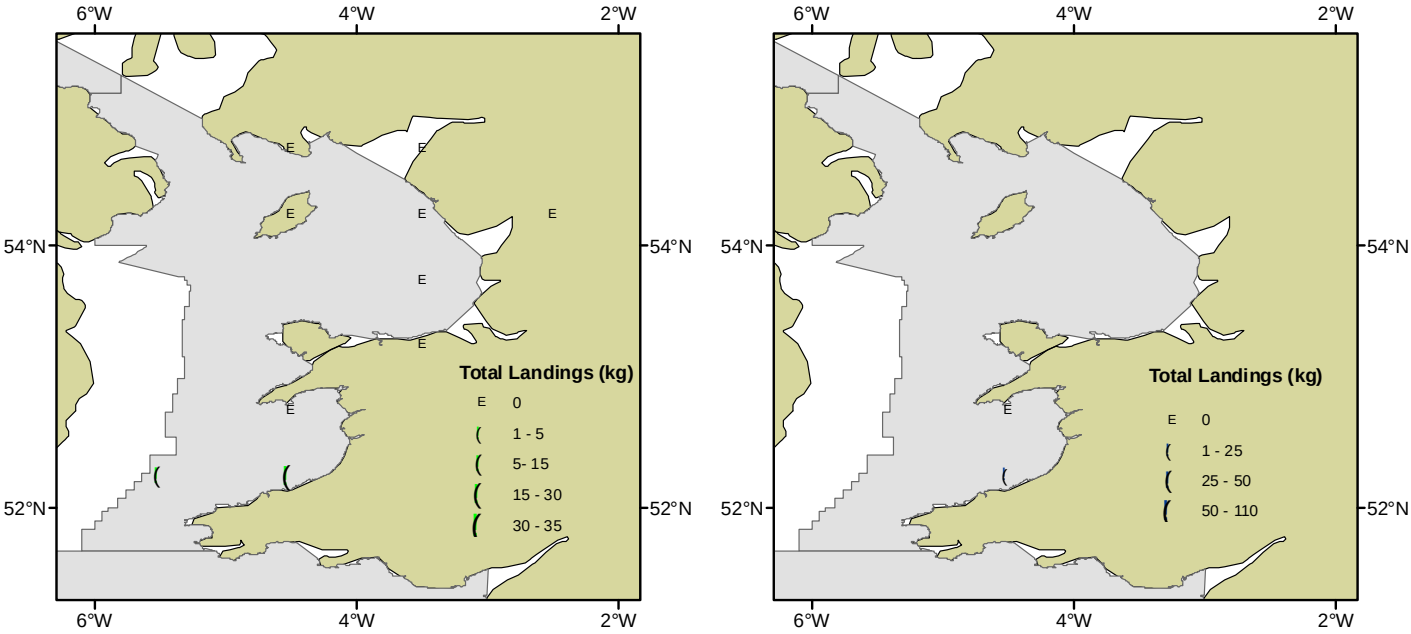


England and Wales Fishery data

French Fishery data

Figure 18

Total Cuttlefish landings (kg) in 2002

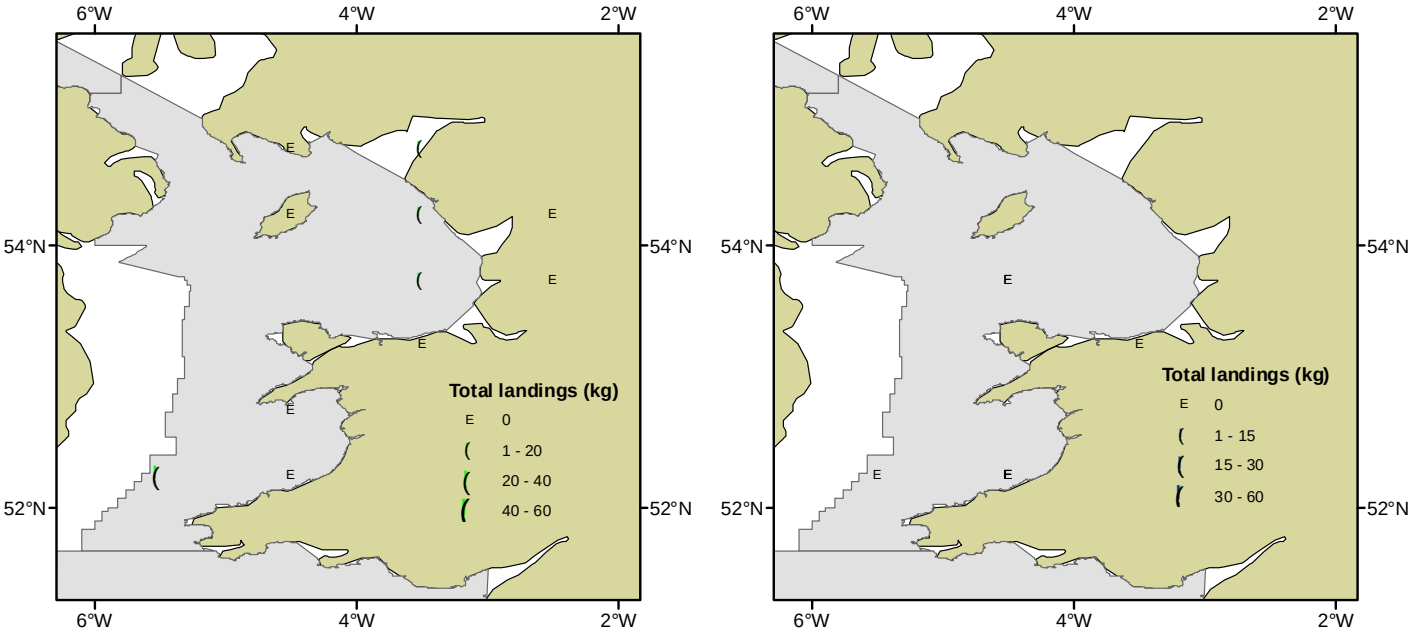


England and Wales Fishery data

French Fishery data

Figure 19

Total Octopus landings (kg) in 1998

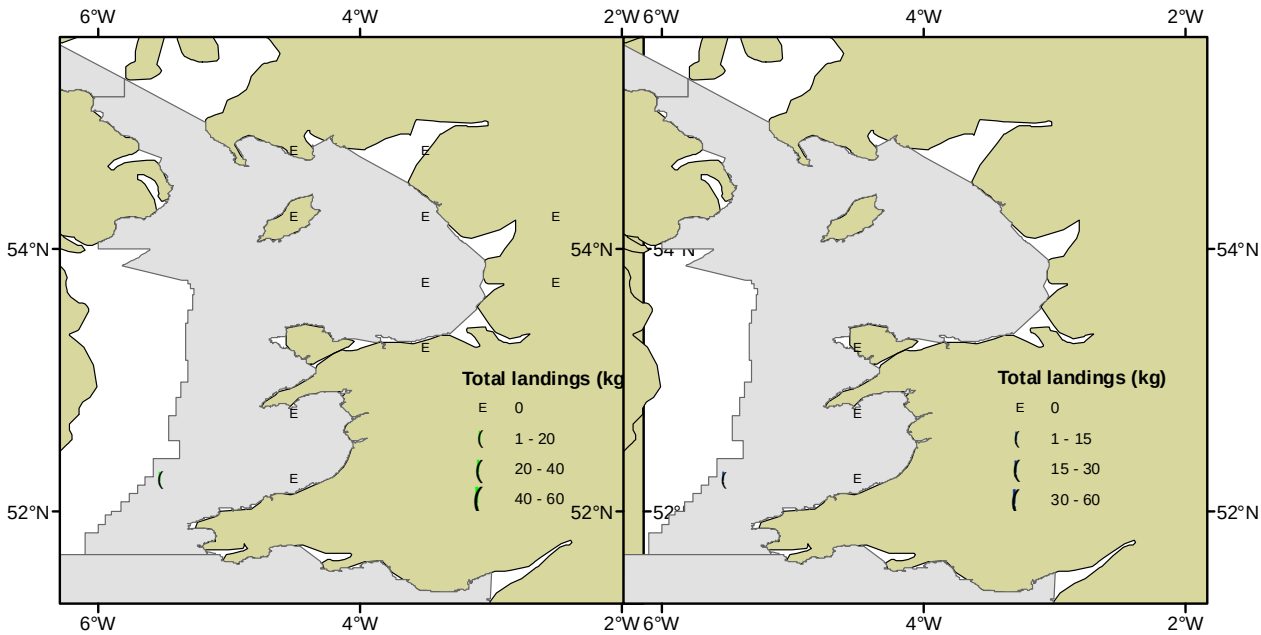


England and Wales Fishery data

French Fishery data

Figure 20

Total Octopus landings (kg) in 1999

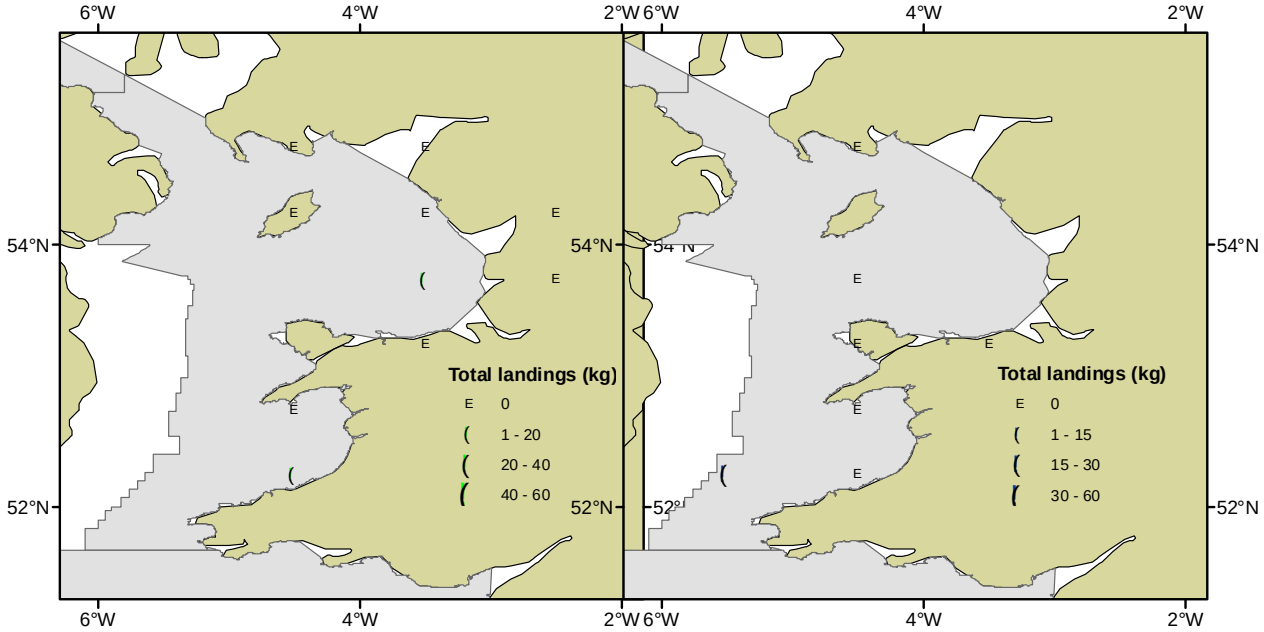


England and Wales Fishery data

French Fishery data

Figure 21

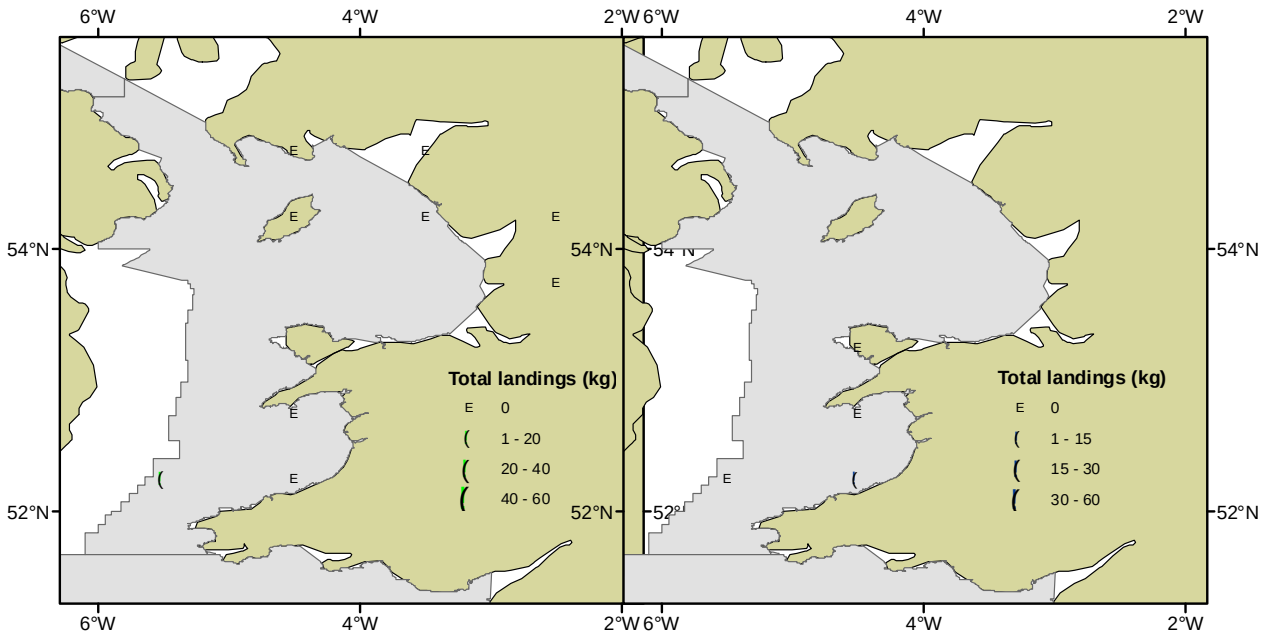
Total Octopus landings (kg) in 2000



England and Wales Fishery data French Fishery data

Figure 22

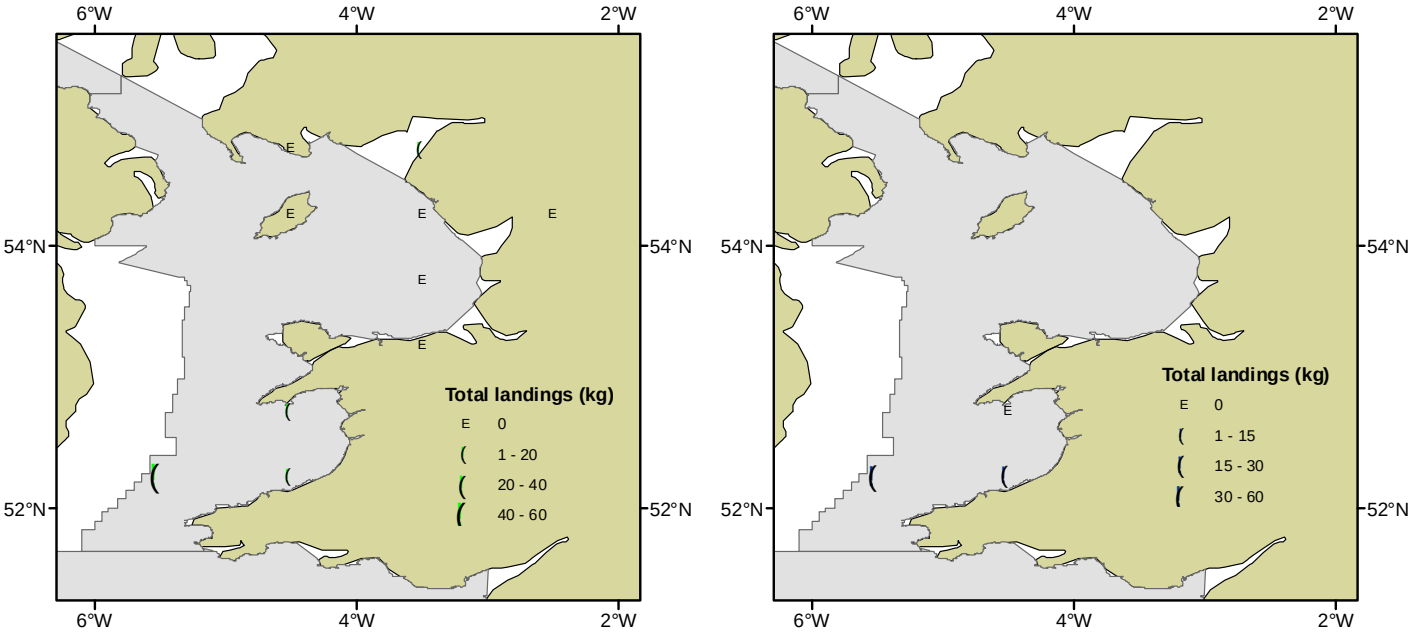
Total Octopus landings (kg) in 2001



England and Wales Fishery data French Fishery data

Figure 23

Total Octopus landings (kg) in 2002



England and Wales Fishery data

French Fishery data

Figure 24

French Fishery data – Distribution of landings for SEA6 across species

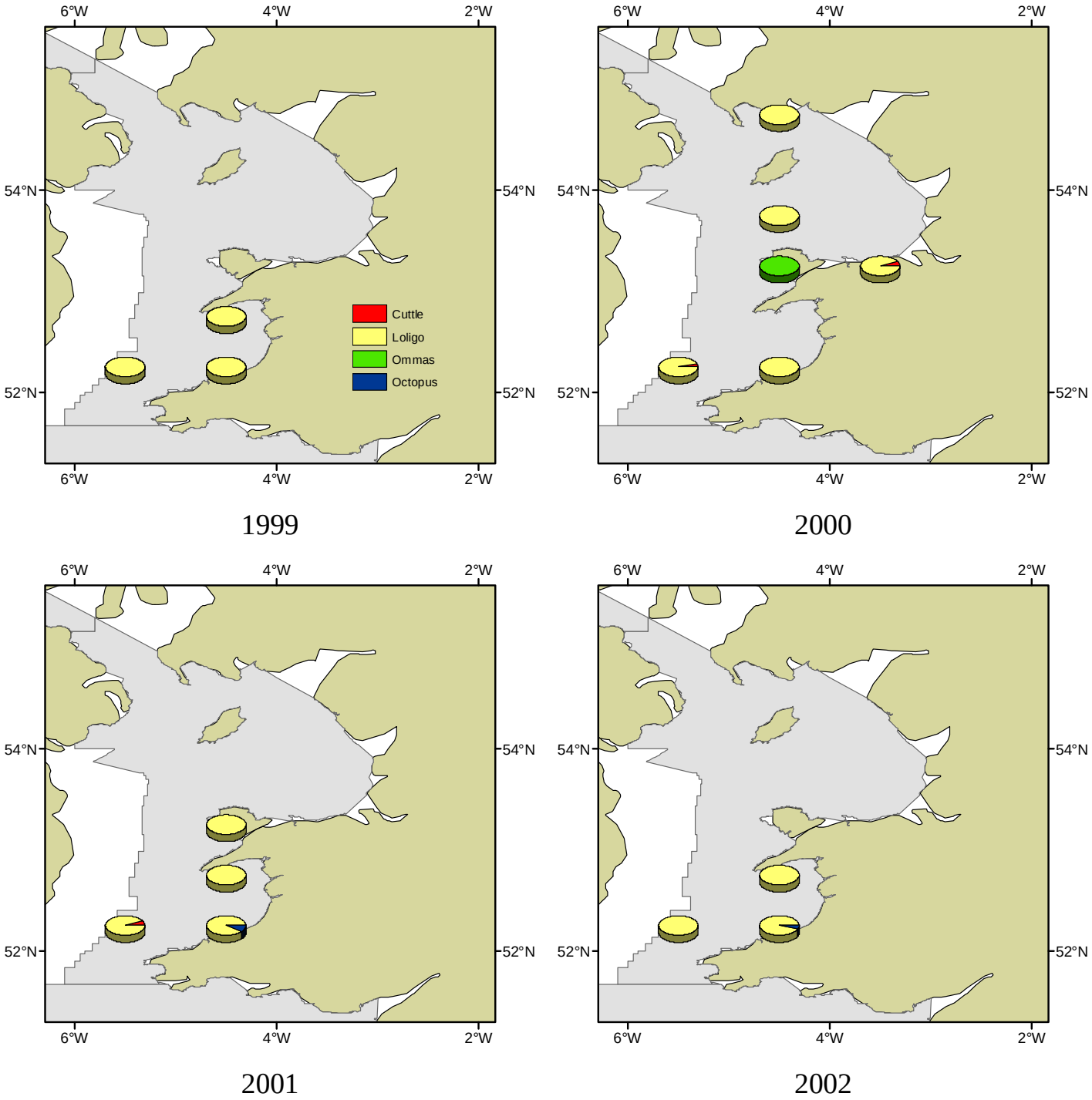


Figure 25

England and Wales Fishery data - Distribution of landings for SEA6 across species

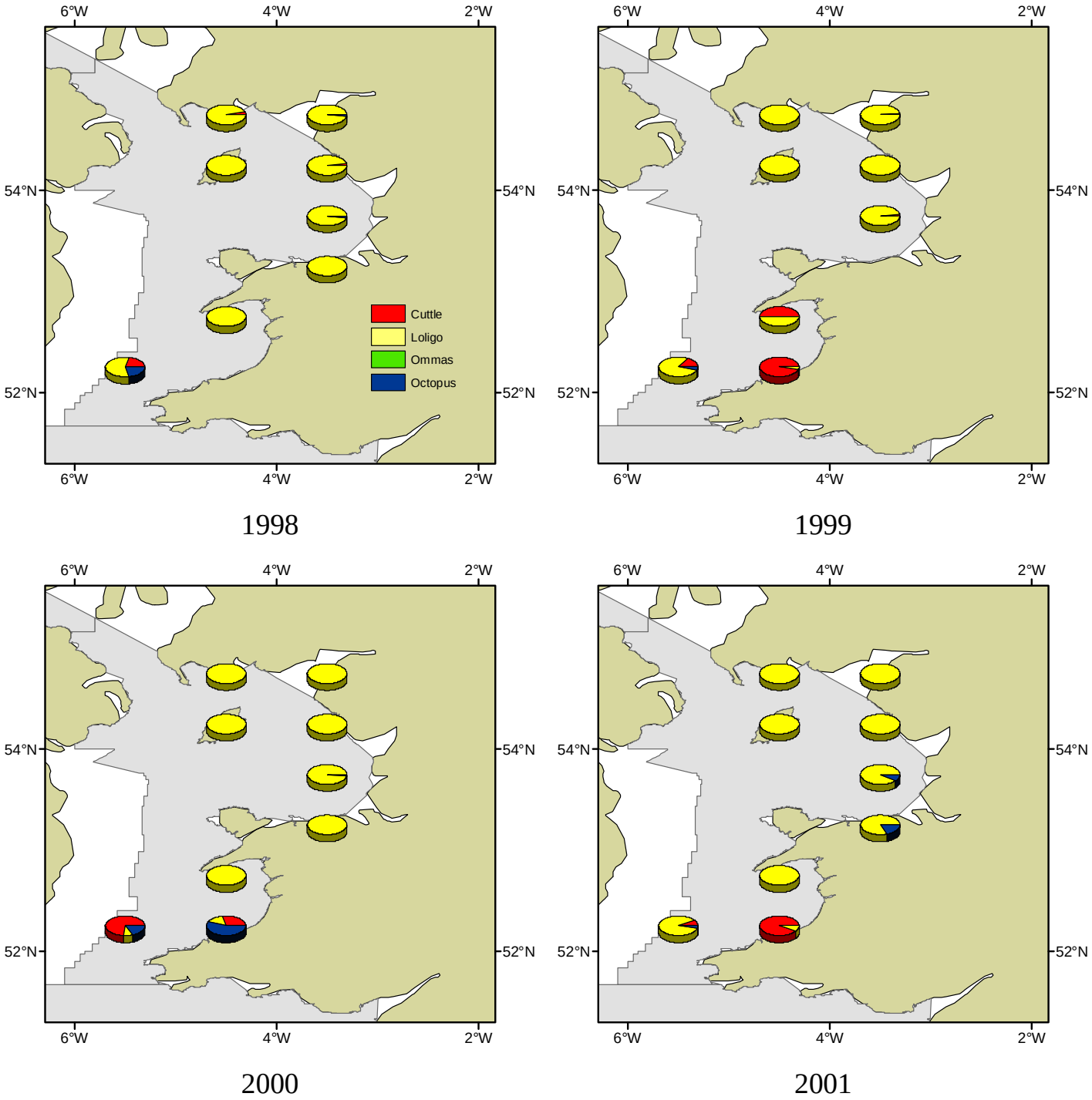
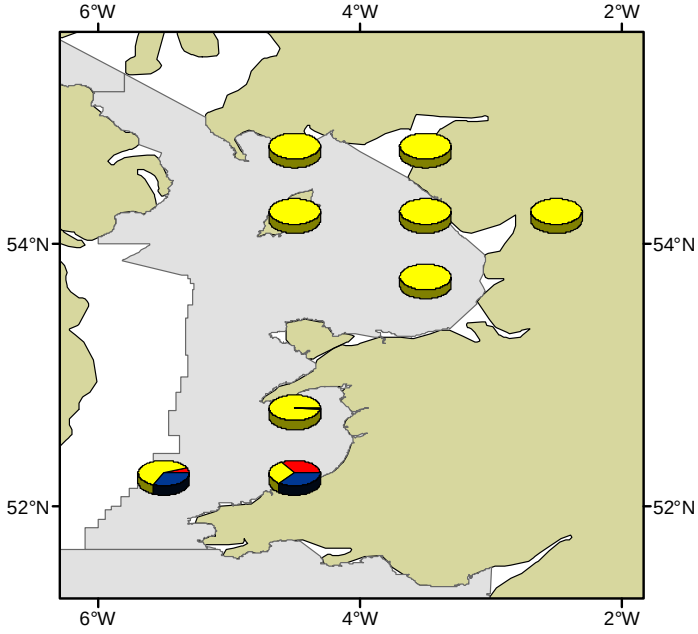


Figure 26



2002

Figure 26 cont.: Distribution of landings for SEA6 across species (England and Wales fishery data)

Northern Ireland Fishery data - Distribution of landings for SEA6 across species

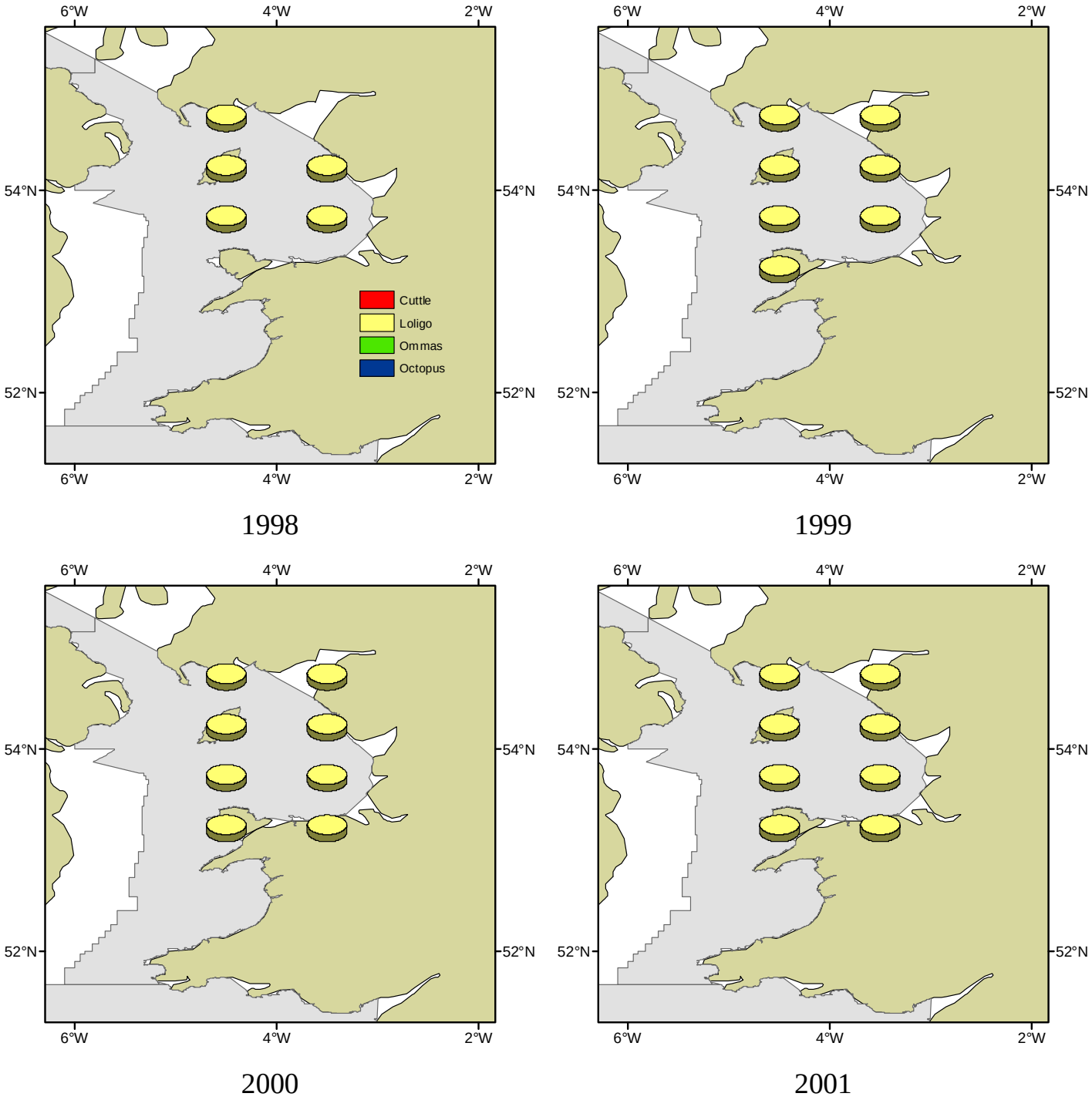
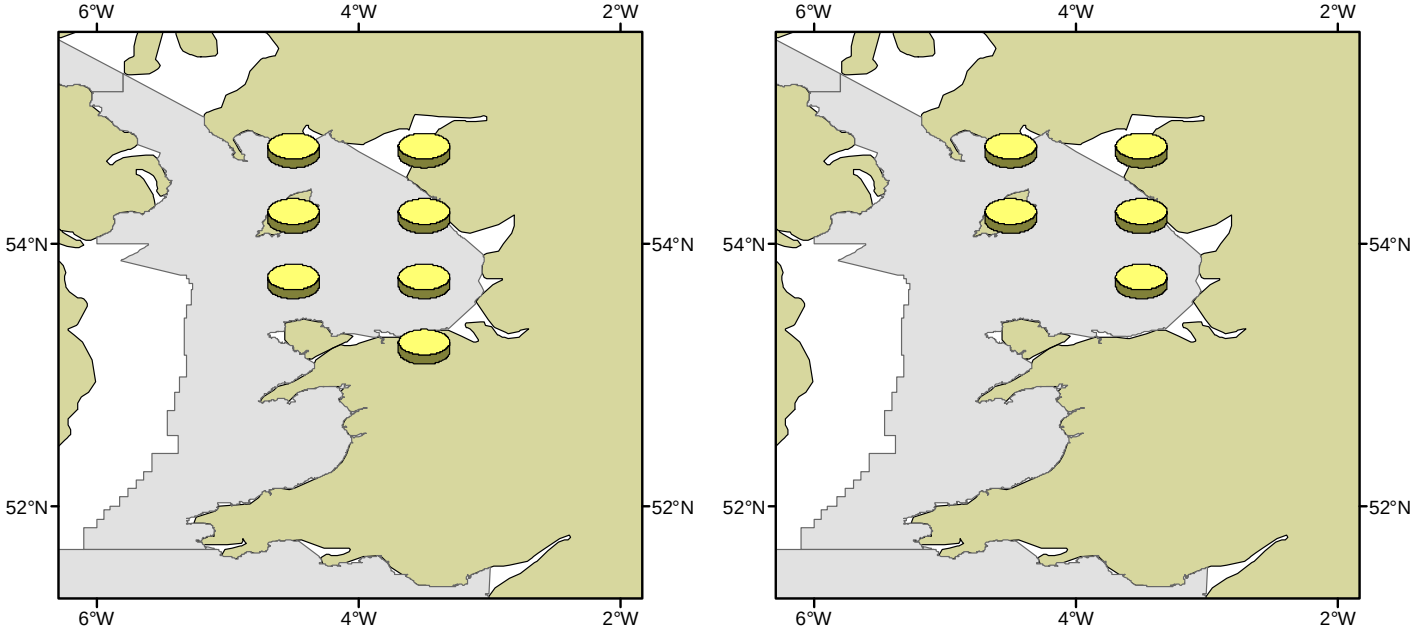


Figure 27



2002 2003

Figure 27 cont.: Distribution of landings for SEA6 across species (Northern Ireland data)

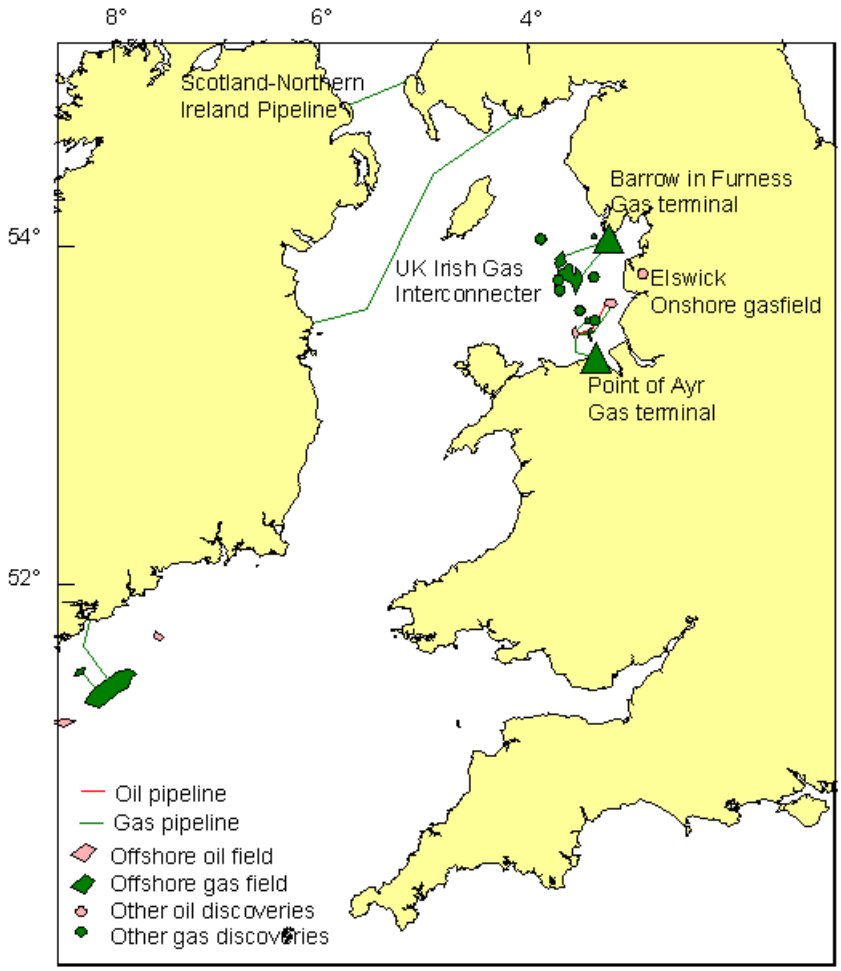


Figure 28.: Location of oil and gas fields in the Irish Sea and Bristol Channel
Source: Department of Trade and Industry, 1997