An Overview of Cephalopods Relevant to the SEA 2 and SEA 3 Areas

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1. Introduction

This review is a component of the information base of the Strategic Environmental Assessment (SEA 2 and SEA 3) conducted by the Department of Trade and Industry.
The SEA 2 and SEA 3 areas are in the North Sea, between 51^{o} and 62^{o} N, extending from the British coast to the centre of the North Sea (Figure 1).

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 2 and 3 areas fall within ICES fishery area IV, including parts of all three divisions: the Northern (IVa), Central (IVb) and Southern (IVc) North Sea (Figure 2). 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.

Cephalopods are short-lived, carnivorous invertebrates, characterised by rapid growth rates, and play an important part in oceanic and coastal food webs. The class Cephalopoda consists of three major divisions, of which two, the Decapoda (squid and cuttlefish) and the Octopoda, are represented in the SEA area. 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 range in size from bobtail squid (Sepiolidae) a few centimetres in length to giant squid up to 20m in length. Cephalopod eyes resemble vertebrate eyes and many species show complex behaviour patterns - cephalopods may be the most intelligent invertebrates. The significance of cephalopod stocks to international commercial fisheries is of relatively recent, but growing, importance (Boyle, 1990; Boyle and Pierce 1994).

The main cephalopod species of economic importance in the northeast Atlantic are the long-finned (loliginid) squids *Loligo forbesi* and *Loligo vulgaris,* the short-finned (ommastrephid) squids *Todarodes sagittatus, Todaropsis eblanae* and *Illex coindetii,* the cuttlefish *Sepia officinalis* and the octopuses *Octopus vulgaris* and *Eledone cirrhosa* (Pierce and Guerra, 1994).

However, the UK cephalopod fauna extends to at least 48 species (Stephen 1944) According to Stephen (1944), the frequently occurring cephalopod species in the North Sea are: *Eledone cirrhosa, Sepiola atlantica, Sepiola pfefferi, Sepietta oweniana, Rossia macrosoma, Rossia glaucopis, Sepia officinalis, Loligo vulgaris, Loligo forbesi, Alloteuthis subulata, Illex coindetii, Todaropsis eblanae* and *Todarodes sagittatus.* Infrequently occurring species are: *Bathypolypus arcticus, Benthoctopus piscatorum, Sepietta neglecta, Sepia elegans, Onychoteuthis banksi, Architeuthis monachus, Architeuthis harveyi, Sthenoteuthis caroli* and *Brachioteuthis riisei.*

Several of the commercially unimportant cephalopod species may have important roles in marine food webs - from the Sepiolidae which are eaten by porpoises to giant squid which are taken by sperm whales.

Landings of cephalopods from Scottish waters consist mainly of *Loligo forbesi* (Boyle and Pierce, 1994; Pierce *et al.*, 1994a,d, 1998) with very much smaller quantities of *Eledone cirrhosa* and *Todarodes sagittatus* also landed. Individuals of other species – mainly *Todaropsis eblanae* and *Illex coindetii* but also *Alloteuthis subulata* are occasionally landed in boxes of *L. forbesi* (Anonymous, 1999). At the end of the 1980s, both *Todarodes sagittatus* and *Todaropsis eblanae* were being landed in Shetland and there was a substantial

fishery for *Todarodes sagittatus* off Norway (Joy, 1989; Hastie *et al.*, 1994). In the central and southern North Sea, species landed also include *Loligo vulgaris* and *Sepia officinalis*. The latter is the most important cephalopod fishery resource in UK waters, although the bulk of landings are taken in the English Channel.

Since 1995, annual UK landings of loliginid squid have ranged between 1600 and 3200 tonnes, making the UK the second most important fishery nation for loliginid squid within the ICES region after France. Over the same period UK cuttlefish landings have ranged between 2300 and 4600 tonnes, with the UK again taking second place to France (Anonymous, 2002).

Drill cuttings and drilling fluids are among the most significant routine discharges into the environment associated with oil-production operations (Menzie, 1983). These produced wastes contain metals (Neff *et al.*, 1987). Demersal shellfish and crustaceans tend to contain particularly high levels of metals. It is thought that if industrial effluents containing trace metals pollute the habitat, the heavy metal content of seafood will increase (Kunisaki, 2000). 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. Bustamente *et al.*, 1998) and mercury (e.g. Frodello *et al.*, 2000).

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

This report concentrates mainly on the two loliginid species *Loligo forbesi* and *Loligo vulgaris* and the cuttlefish *Sepia officinalis*. Catches of the octopus *Eledone cirrhosa* are taken from the North Sea and this species is also considered, along with brief accounts of other commonly occurring cephalopod species. We review the following topics:

- Life history and distribution
- Ecology
- Fisheries and trends
- Sensitivity to metal contamination
- Further conservation considerations

2. Life history and distribution

2.1 Long-finned squid *Loligo* spp.

Loligo forbesi Steenstrup, 1856, and *Loligo vulgaris* Lamark, 1798, are annual semelparous species and the populations usually have a simple demographic structure.

Loligo forbesi is a neritic loliginid that inhabits temperate waters (generally avoiding temperatures less than 8.5^{o} C) and occurs throughout the northeast Atlantic between 20^{o}N (Guerra and Rocha, 1994) on the northwest coast of Africa and 63^{o}N on the southwest coast of Norway (Martins, 1982). The range extends to the Mediterranean and Azores but excludes the Baltic Sea (Guerra and Rocha, 1994). Of the loliginids, *L. forbesi* has the most northerly distribution and is the largest species of the family Loliginidae (Porteiro and Martins, 1994). Maturation is thought to take approximately 1 year and there is a single extended breeding period from December to May throughout the geographic range (Boyle and Pierce, 1994) with a main peak occurring between December and March in Scottish waters (Pierce *et al.*,

1994b; Collins *et al.*, 1997). A second, summer breeding, population has been reported from the English Channel (Holme, 1974).

Analysis of spatial patterns in fishery data suggests that *Loligo forbesi* move from the West Coast of Scotland into the North Sea to spawn (Waluda and Pierce, 1998). Certainly, spawning also takes place on the West Coast but it can be inferred that the North Sea is an important spawning area.

Although short-lived marine invertebrates are generally thought of as *r*-selected and/or colonising species, and indeed squid may replace overexploited finfish both ecologically and commercially (see Caddy and Rodhouse, 1998; Balguerias *et al.*, 2000), fecundity in loliginid squids is surprisingly low, with female *Loligo forbesi* apparently producing only a few thousand eggs in their lifetime (Boyle *et al.*, 1995).

Using the definition of a recruit as an animal below the modal size in catches (approximately 150 mm mantle length), major peaks in recruitment to the winter breeding population occur in April-May and late summer to autumn, although some recruitment appears to occur throughout the year (Lum-Kong *et al.*, 1992; Pierce *et al.*, 1994b; Collins *et al.*, 1997, 1999).

Loligo vulgaris is one of the most common loliginid species in the northeastern Atlantic and Mediterranean Sea. Distribution is from the North Sea (55^{o}N) to the North African coast (20^{o}N) (Guerra and Rocha, 1994).

The ranges of the two *Loligo* species overlap extensively. However, *L. vulgaris* is less abundant than *L. forbesi* in the northern part of its range but increasingly replaces *L. forbesi* with decreasing latitude and, in the southern part of the range, *L. vulgaris* dominates. In Scottish waters, only *L. forbesi* is common (Pierce *et al.*, 1994b, c).

Knowledge of squid distribution within UK waters is mainly based on information from commercial whitefish vessels that catch squid as a by-catch and therefore the spatial and temporal distribution of the target species may not correspond with the distribution of squid. However, analysis of fishery data collected between 1980 and 1990 indicated that *L. forbesi* was widely distributed on the continental shelf and also occurred on offshore banks – notably Rockall (Pierce *et al.*, 1994a,c). This is supported by data from trawling surveys by R/V Scotia, which also highlight the patchy nature of the distribution at any one point in time (Pierce *et al.*, 1998).

The main Scottish fishery for *Loligo forbesi* occurs in coastal waters and usually exhibits a marked seasonal peak around October and November. The animals coinciding with this peak are therefore mostly pre-breeding (Howard, 1979; Howard *et al.*, 1987; Pierce *et al.*, 1994c). Fishery patterns in the English fishery are complicated by the presence of both *Loligo* species. Data from 1993-94 indicate that most *Loligo forbesi* are caught in summer while *Loligo vulgaris* dominates winter catches (Robin and Boucaud-Camou, 1995).

2.2 Cuttlefish Sepia officinalis

Cuttlefish have a short life-span, of around two years. The spawning season is from early spring to mid summer, followed by mass adult mortality, and hatching follows from mid summer to autumn (Boletzky, 1983; Le Goff and Daguzan, 1991; Dunn, 1999). Previous study of the spatial and temporal patterns of abundance of cuttlefish shows that there is a

regular annual migration and large inter-annual fluctuations in landings (Boucaud-Camou and Boismery, 1991; Dunn 1999; Denis and Robin, 2001). In early spring, adult cuttlefish concentrate in coastal spawning grounds, mainly along both sides of 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 English Channel and further west, and to offshore deep water off the north part of French Atlantic coast, and stay there for winter. 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; Dunn, 1999), and they can be considered as different stocks (Pawson, 1995).

Cuttlefish catches are mainly located in the English Channel and adjacent waters, the French Atlantic coast and the Bay of Biscay (Denis and Robin, 2001). In the English Channel, French Atlantic coast and adjacent waters, cuttlefish landings are dominated by the common cuttlefish *Sepia officinalis.* Although other species such as *Sepia elegans* occur, the landings records do not distinguish between them (Dunn, 1999; Denis and Robin, 2001).

2.3 Octopus Eledone cirrhosa

Eledone cirrhosa Lamark, 1798 is a benthic octopod that has a life-span thought to be between 18 and 24 months. It has a wide distribution over shelf regions from the Mediterranean in the south to the Norwegian Lofoten Islands in the north. Generally occurring in depths between 50 and 300 metres, it can be found on a wide variety of sea-bed types from soft mud to rocky bottom (Boyle, 1983).

2.4 Other cephalopods

Several other cephalopod species are common or of regular occurrence in the SEA2 and 3 area.

The ommastrephid squid *Todaropsis eblanae* was regularly taken in trawl hauls off Aberdeen in the early 1990s. However it is probably of sporadic occurrence most abundant in very warm years (Hastie *et al.*, 1994). No commercial landings of this species have been reported from the North Sea since 1995 (Anonymous, 2002).

The small loliginid squid *Alloteuthis subulata* is often taken in trawl hauls alongside the larger loliginids, although it has no commercial value and is presumably normally discarded.

The bobtail squid *Sepiola atlantica* is one of at least six sepiolid species present in the North Sea. A bottom living inshore species, its very small body size means it tends to be overlooked in catches and has no commercial value. However, it may be very abundant - Stephen (1944) cites a record of 256 specimens being taken in a single trawl haul.

Finally, it is worth mentioning that the giant squid *Architeuthis* spp. is occasionally recorded in the North Sea, with specimens being stranded on the Aberdeenshire coast in the 1970s and in 1998 (Collins, 1998).

3. Ecology

Cephalopods are important elements in marine food webs, both as predators and prey, and as such interact with commercial finfish fisheries (Boyle, 1990; Boyle and Pierce, 1994) and with top predators such as marine mammals.

Globally, whales, dolphins, seals, birds, as well as some large fish species, take large quantities of squid (Furness, 1994; Pierce and Santos, 1996; Daly *et al.*, 2001; Santos *et al.*, 2001a). Voss (1973) estimated that marine mammals, prior to industrial whaling between the 1950s and 1990s, removed 60-70 million tonnes of cephalopods annually from the world's oceans.

Estimates of seabird consumption of cephalopods in the northeast Atlantic are low compared to equivalent seabird populations in the south Atlantic – probably due to differences in the relative abundance of squid, fish and zooplankton between the two hemispheres (Boyle and Pierce, 1994). The main seabird consumers of squid in northwest Europe are fulmar and Manx shearwater but their prey consists mainly of Ommastrephid squid taken from the top 2 or 3 metres of the water column. Analysis of bird diets in the northeast Atlantic has shown that none of the major seabird populations in the area feeds regularly on loliginid squid (Boyle and Pierce, 1994; Furness, 1994).

Although amounts taken are difficult to quantify, cetaceans probably have a greater impact on cephalopods than seabirds or seals. Most species of cetacean consume some cephalopods: mainly octopus and bobtail squid in the smaller cetacean species, whereas some larger species are specialist squid feeders (see González *et al.*, 1994; Santos *et al.*, 1994, 1995; Pierce and Santos, 1996; Santos *et al.*, 1999, 2001b,c,d, 2002; Santos and Pierce, In Press. Striped dolphin (*Stenella coeruleoalba*), pilot whale (*Globicephala melas*) and Risso's dolphin (*Grampus griseus*), all of which occur in western European waters, are known to take *Loligo* sp. (Boyle and Pierce, 1994; González *et al.*, 1994). Predation on *Eledone cirrhosa* is poorly documented in general (Boyle, 1983). However, several cetaceans are recorded as taking *Eledone cirrhosa* including the white beaked dolphin (*Lagenorhynchus albirostris*), bottle-nosed dolphin (*Tursiops truncatus*) and Risso's dolphin (*Grampus griseus*). In recent studies, the latter were found to have mainly cephalopod remains in their stomachs – and *E. cirrhosa* dominated (Santos *et al.*, 1994, 1995). The minke whale (*Balaenoptera acutorostrata*) is also thought to take some squid (Clark, 1986; Pierce, 1992).

Although sepiolids and *Alloteuthis* are relatively frequent in stomach contents, indications are that the most common cetacean species in the North Sea, the harbour porpoises (*Phocoena phocoena*), is primarily fish-eating (Santos and Pierce, In Press).

Seals eat both octopus and squid, although *Loligo forbesi* is recorded relatively infrequently in the diet (Pierce and Santos, 1996). However, in a study of marine mammal diets in Scottish waters, the grey seal (*Halichoerus grypus*) was found to eat more octopus than other cephalopods, and octopus can form an important part of the summer diet of harbour seals in the Moray Firth (Tollit and Thompson, 1996) as well as appearing in diets of harbour seals in Orkney (Pierce *et al.*, 1990) and Shetland (Brown *et al.*, 2001).

Results from large scale fish stomach sampling programmes such as the "ICES year of the stomach", as well as data from smaller studies, have shown that a small but significant proportion of the diet of O-group whitefish is composed of cephalopods (ICES, 1988; Hislop

et al., 1983, 1991; Daan, 1989; Hislop, 1997; Daly *et al.*, 2001; Velasco *et al.*, 2001). Although cephalopods are routinely eaten by many fish, they are major component of the diet in relatively few species such as monkfish (*Lophius piscatorius*). Hislop *et al.* (1991) noted that, where cephalopods in fish stomachs were identified, they were usually *Alloteuthis* spp.

Cephalopods are predators themselves (Boyle, 1990), feeding on a wide range of other marine animals. *Loligo forbesi* feed primarily on fishes, crustaceans and cephalopods (Martins, 1982; Boyle and Pierce, 1994; Pierce *et al.*, 1994c; Collins and Pierce, 1996).

Dominant prey species of *Loligo forbesi* in Scottish waters are sandeels (*Ammodytes* sp.) Gadidae – mainly whiting (*Merlangius merlangus*) and *Trisopterus* sp., and Clupeidae. The proportion of fish in the diet of *L. forbesi* increases with squid size – the importance of Crustacea declining correspondingly (Boyle and Pierce, 1994; Pierce *et al.*, 1994c). Larger squid, unsurprisingly, tend to take larger fish (Collins and Pierce, 1996). The relative importance values of fish and crustaceans in the diet of *L. vulgaris* are similar to those in the diet of *L. forbesi* (Pierce *et al.*, 1994c).

Squid are, unusually for a short-lived species, placed relatively high in the food chain with *Loligo forbesi* being assigned to the IV trophic level (Monteiro *et al.*, 1992).

The octopus, *Eledone cirrhosa* is benthic and feeds mainly on crustaceans and molluscs (Montiero, Porteiro and Gonçalves, unpublished data) 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). *E. cirrhosa* could be assigned to the III-IV trophic level.

4. Fisheries and trends

There are discrepancies between the various national and international sources of fishery statistics, reflecting various degrees of editing (or in some cases withholding) of the raw data collected nationally. However, similar trends are generally apparent regardless of source.

Data compiled by the ICES Working Group on Cephalopod Fisheries and Life History (Anonymous, 2002) on cephalopod landings from the ICES area during 1995-2002 are summarised in Tables 1-4. The present tabulation focuses on the North Sea, although in Tables 1 (cuttlefish) and 2 (loliginid squid), landings for other fishery areas from which UK fleets take a higher catch are included for comparison. Total reported landings by all European fleets from the ICES area are also given.

It should be noted that, although octopus fisheries are important in southern Europe, landings from the North Sea are of very minor importance (Table 3). The low sale price obtained in UK fish markets means that most octopus catches are discarded at sea. Thus, low landings figures for octopus cannot be taken to indicate low abundance. This may also be true for ommastrephid squid (no reported landings from the North Sea since 1995), although again most catches of these species - certainly in Scottish waters - are probably discarded.

4.1 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 and landings are not recorded by species (Boyle and Pierce, 1994). There is, however, a limited amount of directed squid fishing, including some use of jigs from small boats in the English Channel (Hamabe *et al.*, 1982). In the North Sea, there is a small directed squid fishery prosecuted close inshore in the Moray Firth between Nairn and Macduff. This directed fishery usually lasts for about 8 weeks between September and November and is undertaken by around 20 small trawlers of between 10 and 17 metres in length (Anonymous, 2000). Squid catches from the Moray Firth may contribute over 90% of the total cephalopod landings from Area IVa (Northern North Sea) (Pierce *et al.*, 1994d). Directed squid fisheries in the UK are unregulated apart from an imposition by the European Union of a minimum legal mesh size of 40mm (Pierce *et al.*, 1998).

Time series data from the Scottish fleet indicates that loliginid squid catches appear to fluctuate cyclically with a period of between 12-18 years. As the total area of fishing effort in Scottish waters exceeds the area from where squid are caught and effort in general is not targeted at squid, these fluctuations could be considered to represent real fluctuations in squid abundance (Boyle and Pierce, 1994).

Scottish landings of loliginid squid ranged between 203 and 1355 tonnes in the years 1994 - 2000 with corresponding values of between £0.34M and £2.19M (Scottish Sea Fisheries Statistics, 1999; figures for 2000 from Fisheries Research Services database) (Table 5). Landing trends for the same years are shown in Figures 3-5. (Landings in 1991 were around 2000 tonnes). Total squid landings in Scotland show a peak in 1998, with a subsequent decline (Figure 3), which is also apparent from data for the Northern and Central North Sea (Figures 4 and 5; see also Tables 2 and 5).

Annual squid landings into Scotland from 1994 to 2000 from ICES area IVa (Northern North Sea) ranged from 90 to 844 tonnes in weight and £0.15M to £1.25M in value. For the same period, area IVb (Central North Sea) produced annual landings into Scotland of between 5 and 211 tonnes weight and £0.01M and £0.39M in value (Table 5) (Scottish Sea Fisheries Statistical Tables, 1994, 1995; Scottish Sea Fisheries Statistics, 1996, 1997, 1998, 1999; figures for 2000 from Fisheries Research Services database).

The two most important species to Scottish fisheries are the haddock (*Melanogrammus aeglefinus*) and Norway lobster (*Nephrops norvegicus*). In order to gauge the relative importance of squid to the Scottish fishing industry, comparisons are made with these two species. Over the seven year period from 1994 to 2000, squid landings represent an average of 0.4% by weight and 0.5% by value of the total of all demersal landings into Scotland by UK vessels. Expressed as a percentage of haddock landings, average North Sea squid landings from area IVa for the years from 1994 to 2000 were 1% by weight and 2% by value from both areas IVa and IVb. Expressed as a percentage of *Nephrops* landings, average squid landings for the same period were 6% by weight and 4% by value in area IVa and 3% by both weight and value in area IVb.

Compared to other fished species, there was a steady increase in relative weights and value of squid landings to 1998, after which there is a decline (Figures 6 and 7). Historical data suggest that squid catches will continue to fluctuate widely from year to year and the above trends merely represent the most recent data.

It should also be noted that both haddock and *Nephrops* landings are subject to Total Allowable Catch (TAC) quota restrictions. Hence the landing figures for haddock (as for other demersal fish) and *Nephrops* may be underestimated due to mis-reporting from fishing vessels. There are, however, no such restrictions placed on squid landings and therefore the percentages expressed above may be overestimates.

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.*, 1994d) and such data are available on a monthly, by ICES rectangle, basis.

LPUE data for loliginid squid (units of kg/hour) caught by the Scottish fleet are shown for the years 1998-2000 in Figures 8-10. A more complete picture is given using landings data from English, Scottish and French fleets. Data for 1998 (all squid species combined) appear in Figure 11. Although ommastrephid squid are included within the totals it should be noted that no ommastrephid squid landings were reported from the North Sea in 1998. No French data could be accessed for 1999 and 2000 but maps for English and Scottish catches appear in Figures 12 and 13. It may be seen that squid are caught throughout the SEA 2 and 3 areas, although larger concentrations may be found in the English Channel or on the West Coast of Britain.

4.2 Cuttlefish

Cuttlefish are taken by a combination of directed and (mainly) by-catch fishing, the former using traps and the latter based on trawling. The most important fishery area is the English Channel, but cuttlefish catches extend into the Southern North Sea.

ICES data indicate that cuttlefish landings have fluctuated widely since 1995, with no clear trend. Within the North Sea, the only significant catches are taken in the Southern North Sea, with France taking 420 tonnes in 2000. However, landings into England have declined since 1995 from 163 tonnes to an estimated 5 tonnes in 2001.

Analysis of patterns in trawl LPUE data reveals that cuttlefish has a clear general annual migration pattern, consistently occurring in broadly the same areas in different years. Cuttlefish expand their distribution further north (into the Southern North Sea) in the spawning season in warm years, and shift south in cool years (Wang *et al.*, submitted).

Maps of the spatial distribution of landed catches by the Scottish, English and French fleets during 1998-2000 appear as Figures 14-16. It may be seen that catches routinely extend into area IVc (Southern North Sea) and sometimes into IVb (Central North Sea) but that higher catches are taken in the English Channel.

4.3 Octopus

The octopus *Eledone cirrhosa* is a highly valued species in southern Europe. In Scotland, however, landings are rare as the animal is usually discarded by fishermen (Daly *et al.*, 2001). This is mainly due to a combination of low catches by individual boats, problems maintaining catch quality and poor market prices with the result that, in general, there is no profit in landing the species.

As most *Eledone cirrhosa* is discarded, the use of LPUE as an index of abundance is obviously flawed. However, the landings that do occur will coincide with larger catches and therefore landings should give an indication of where the highest concentrations of octopus might be.

The highest landings into Scotland in the years 1997-1999 came from outside the SEA 2 area. The largest octopus landings (205 kg) in 1997 from the SEA 2 area came from ICES rectangle 44 F0 (see Figure 17). Taking the fishing effort in this ICES rectangle into account this equates to a LPUE of 0.01 $kg.hr^{-1}$. Octopus landings from the area of interest in 1998 and 1999 were higher – both peaks occurring in ICES rectangle 45 E8 which is situated in the west of the Central SEA 2 area (see figures 18 and 19). 1575 kg and 4879 kg were landed in 1998 and 1999 respectively with corresponding LPUE values of 0.06 and 0.19 $kg.hr^{-1}$.

To put these landings into context, the highest squid landing from the SEA 2 area in 1998 also came from ICES rectangle 45 E8, with 67764 kg landed and a corresponding LPUE of 2.36 $kg.hr^{-1}$ – nearly 40 times higher than the LPUE for octopus caught in the same area. Note that this particular value for squid is itself unusually large and cannot be confirmed as genuine.

Looking at total landed catches by UK and French fleets in 1998 and the UK fleet in 1999-2000 (Figures 20-22), it may be seen that the bulk of landings are taken from the English Channel, with rather sparsely distributed records across the North Sea.

5. Sensitivity to metal contamination

A wide variety of wastes are produced during well-drilling and oil and gas production. Some regulated discharge of wastes into the sea is permitted. Permitted discharges include machinery cooling water, deck drainage, domestic sewage, drill cuttings, drilling fluids and produced waters. In addition, submerged parts of platforms and sub-sea equipment may be protected against corrosion and fouling with sacrificial anodes and antifouling coatings that release small quantities of toxic metals to the water column. These include aluminium, copper, mercury, tin, and zinc (Dicks, 1982).

However, the major discharges associated with drilling operations are drill cuttings and drilling fluids (Menzie, 1983). Since more wells are drilled in the production phase than in the exploration phase, the largest volumes of discharged waste in the form of drill cuttings and drilling muds occur during the development stage (Menzie, 1983).

Drill cuttings are particles of crushed sedimentary rock and are relatively inert as their chemistry reflects that of the strata being drilled. They are, however, contaminated with drilling fluid residue (Dann and Mulder, 1996) and a potential source of trace metal pollution. Metals present in drilling fluids include arsenic, barium, chromium, cadmium, copper, iron, lead, mercury, nickel and zinc (Neff *et al.*, 1987).

Most of these metals are present primarily as trace impurities in barite (used as a weighting agent in drilling fluids), bentonite (the major ingredient in water based muds), and the formations of sedimentary rocks being penetrated by the drill. As seen in Table 6, the average concentrations of some of the metals in marine sediments exceed their concentrations in drilling fluids.

Although a broad spectrum of trace metals has been found in sediment samples taken from the vicinity of well sites, barium is the only metal found consistently at elevated concentrations following drilling - probably due to the high concentrations present in drilling fluids (Menzie,1983; Daan and Mulder, 1996).

Cephalopods naturally accumulate high levels of a number of trace metals including cadmium (Martin and Flegal, 1975; Finger and Smith, 1987). Some metals, for example copper and zinc, are biologically essential but toxic in large amounts. However, other metals, including cadmium, have no known biological role.

Comparisons of the copper content of the liver and hepatopancreas respectively of certain species of vertebrates and cephalopods revealed very high levels of copper in cephalopods. Studies of *Octopus vulgaris, Eledone moschata* and *Sepia officinalis,* revealed hepatopancreatic (digestive gland) copper levels one hundred times higher than the mean value for vertebrate liver and 10^5 times that of seawater (Rocca, 1969).

Copper concentrations occurring in the hepatopancreas of *Loligo opalescens* from Monterey Bay, California, were found to be up to three orders of magnitude higher than concentrations found in the visceral masses of scallops, oysters and mussels. These copper concentrations were also highly correlated with silver (Ag) – an element highly toxic to marine organisms (Martin and Flegal, 1975).

A study of copper and zinc concentrations in the organs of *Sepia officinalis* revealed high levels in extracts of the hepatopancreas and branchial gland (Decleir and Vlaeminck, 1978). Also, high concentrations of copper correlated with high levels of silver, cadmium and zinc have been reported in the hepatopancreas of various cephalopods and the hepatopancreas appears to be the main cephalopod organ for the storage of metals (Schipp and Hevert, 1978).

Studies of the hepatopancreas of the squids *Todarodes pacificus, Loligo opalescens, Ommastrephes bartrami* and *Symplectoteuthis oualaniensis* have revealed high concentrations of trace minerals including cadmium (Tanaka *et al.*, 1983). Studies of pilot whales caught off the Faroe Islands – an area free of anthropogenic pollution, have revealed higher levels of cadmium in the species than in other marine mammals. The cadmium was accumulated through their diet, which is thought to consist primarily of squids (Amiard-Triquet and Caurant, 1997).

Concentrations of mercury in *Eledone cirrhosa* are correlated with the animal's length and the species has been found to be capable of accumulating the metal rapidly (Rossi *et al.*, 1993). The potential to accumulate trace minerals is positively correlated with trophic level due to biomagnification through the food web and studies have revealed mean mercury levels in *Loligo forbesi* six times those found in the octopus *Octopus vulgaris* (Montiero, Porteiro and Gonçalves, unpublished data).

The major ecological implication of the bioaccumulation of heavy metals in cephalopod tissue, since it is not clear that there is any adverse effect on the cephalopods themselves, is that species feeding on cephalopods - such as sperm whales and beaked whales - tend to have higher heavy metal levels in their tissues than piscivorous species. This clearly may impact on human populations whose diet includes substantial quantities of cephalopods (e.g. those in southern Europe, who import much of the cephalopod catch from Northern European waters)

or marine mammals (such as the Faroese population). Oil exploration and drilling would exacerbate this problem only so far as it leas to increased input of metals into the food chain. Drilling fluids can contain higher concentrations of cadmium and mercury than naturally present in surrounding marine sediments (Table 6).

6. Further conservation considerations

All cephalopods present in the North Sea will be, to a greater or lesser extent, disturbed by displacement of the bottom sediment. Biodiversity is unlikely to be significantly affected by such displacement due to the localised nature of drilling operations.

The only serious impacts are likely to occur if spawning grounds are disturbed. At the southern end of the SEA3 area, it is possible that exploration and drilling activities could impact on the coastal spawning grounds of cuttlefish – although the main spawning grounds are in the English Channel. Spawning grounds of loliginid squid are not well known, although squid eggs are regularly found on creel lines (Lum-Kong *et al.*, 1992). In South African waters, spawning of *Loligo vulgaris reynaudii* takes place on coarse sand and reefs (Augustyn, 1990). Although no spawning grounds have been positively identified in the North Sea, squid in spawning condition are caught every year in the North Sea, particularly during January to March (Pierce *et al.*, 1994a; Boyle *et al.*, 1995).

Squid aggregate to spawn and any factor disrupting spawning aggregations or disturbing the egg masses could have a negative impact on reproductive impact. As noted above, individual females lay relatively few eggs (compared to finfish) and, due to the short life cycle, survival of the population is entirely dependent on successful spawning and recruitment. There is no reservoir of old adults to replenish the population if one year's spawning fails. It is likely however that spawning occurs across a wide area, limiting dependence on any single spawning site.

In terms of possible specific effects of oil industry-related activities, high turbidity is known to disrupt spawning behaviour in *Loligo vulgaris reynaudii* in South African waters, while low oxygen levels can limit distribution (Augustyn, 1991).

Although there has been a great deal written on the acoustic disturbance of cetaceans, little is known about the impact on cephalopods caused by noise. It has however been suggested that sperm whales stun squid using sound emissions (Taylor, 1986) and adverse effects are possible.

7. Conclusion

- The commercially important cephalopod species from the SEA 2 and 3 areas consist primarily of the loliginid squid *Loligo forbesi* and *Loligo vulgaris*, the cuttlefish *Sepia officinalis* and, to a much lesser extent, the octopus *Eledone cirrhosa*. Abundance of both cuttlefish and squid is however is higher in other areas. Many other cephalopod species are present.
- Both *Loligo* spp. and *Eledone cirrhosa* are fished only as by-catch species in the SEA 2 and 3 area (with most of the octopus being discarded) and, as such, are relatively unimportant species to the catching sector. Cuttlefish are taken in a directed fishery, but

this is concentrated in the English Channel, and extends only into the Southern North Sea - where it is largely prosecuted by French vessels.

- There appears to be overwhelming evidence of high accumulation rates of metals in cephalopods, and of high metal burdens in tissues of predators of cephalopods. It is possible therefore that introduction of drilling fluids into the marine environment could lead to increased metal levels in the food chain.
- The most likely impact of oil industry activities on cephalopod populations is disturbance of spawning grounds. Cuttlefish spawn close inshore, but mainly to the south of the SEA 2 and 3 areas. Squid spawning grounds in the North Sea are not well documented but loliginid squid undoubtedly enter the North Sea to spawn.
- It is nevertheless likely that the overall impact on cephalopods and cephalopod fisheries in the SEA 2 and SEA 3 areas caused by further oilfield development would be slight.

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9. References

Amiard-Triquet, C. and Caurant, F., 1997. Adaption of the delphinids *Globicephala melas* (Traill,1809) to cadmium contamination. Bulletin de la Societe Zoologique de France – Evolution et Zoologie. 122, 127-136.

Anonymous, 1999. Data Collection for assessment of Cephalopod fished stocks. Final Project Report CFP CT 96 081.

Anonymous, 2000. Data Collection for Assessment of Cephalopod Fisheries. First Progress Report Study Project 99/063.

Anonymous, 2002. Report of the Working Group on Cephalopod Fisheries and Life History. ICES CM 2002/G:04.

Augustyn, C.J., 1990. Biological studies on the chokker squid *Loligo vulgaris reynaudii* (Cephalopoda: Myopsida) on spawning grounds off the couth-east coast of South Africa. South African Journal of Marine Science 9, 11-26.

Augustyn, C.J., 1991. The biomass and ecology of chokka squid *Loligo vulgaris reynaudii* off the west coast of South Africa. South African Journal of Zoology26, 164-181.

Balguerias E., Quintero M.E. and Hernandez-Gonzalez C.L., 2000. The origin of the Saharan Bank cephalopod fishery. ICES Journal of Marine Science 57, 15-23.

Boletzky, S.V., 1983. *Sepia officinalis.* In Cephalopod life cycles Vol.1. Ed. by Boyle, P.R. Academic Press, London.

Boucaud-Camou, E. and Boismery, J., 1991. The migration of the cuttlefish Sepia officinalis L. in the English Channel. In: E. Boucaud-Camou (Editor), "The cuttlefish", Act. 1st International Symposium on the Cuttlefish Sepia Caen, June 1-3 1989, Centre de publications de l'Université de Caen, pp. 179-189.

Boyle, P.R. (Editor), 1983. *Eledone cirrhosa*. In: Cephalopod Life Cycles Volume 1. Academic Press, London, 475 pp.

Boyle, P.R., 1990. Cephalopod biology in the fisheries context. Fisheries Research. 8, 303-321.

Boyle, P.R. and Pierce, G.J., 1994. Fishery biology of northeast Atlantic squid: an overview. Fisheries Research 21, 1-15.

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

Brown, E.G., Pierce, G.J., Hislop, J.R.G. and Santos, M.B., 2001. Interannual variation in the summer diets of harbour seals (*Phoca vitulina*) at Mousa, Shetland (U.K.). Journal of the Marine Biological Association of the United Kingdom 81, 325-337.

Bustamante P., Caurant F., Fowler S.W. and Miramand P., 1998. Cephalopods as a vector for the transfer of cadmium to top marine predators in the north-east Atlantic Ocean. Science of the Total Environment 220, 71-80.

Caddy J.F. and Rodhouse P.G. (1998) Cephalopod and groundfish landings: evidence for ecological change in global fisheries? Reviews in Fish Biology and Fisheries 8, 431-444.

Clarke, M.R., 1986. Cephalopods in the diet of Odontocetes. In: M.M. Bryden and R.J. Harrison (editors), Research on Dolphins, Clarendon Press, Oxford, pp. 281-321.

Collins, M.A., 1998. A female giant squid (*Architeuthis*) stranded on the Aberdeenshire coast. Journal of Molluscan Studies 64, 489-492.

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

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

Collins, M.A., Boyle, P.R., Pierce, G.J., Key, L.N., Hughes, S.E. and Murphy, J., 1999. Resolution of multiple cohorts in the *Loligo forbesi* population from the west of Scotland. ICES Journal of Marine Science 56, 500-509.

Craig, S., 1996. Total mercury concentration in the cephalopods, *Loligo forbesi* (Steenstrup), *Todaropsis eblanae* (Ball), and *Todarodes sagittatus* (Lamark). Zoology Honours Thesis. University of Aberdeen.

Daan, N. (Editor.), 1989. Data base report of the stomach sampling project 1981. Co-operative Research Report No. 164. International Council for the Exploration of the Sea.

Daan, R. and Mulder, M., 1996. On the short-term and long-term impact of drilling activities in the Dutch sector of the North Sea. ICES Journal of Marine Science 53, 1036-1044.

Daly, H.I., Pierce, G.J., Santos, M.B., Royer, J., Cho, S.K., Stowasser G., Robin, J.-P. and Henderson, S., 2001. Cephalopod consumption by fish in UK waters. Fisheries Research 52, 51-64.

Decleir, W. and Vlaeminck, A., 1978. Determination of protein-bound copper and zinc in some organs of the cuttlefish *Sepia officinalis* L.. Comparative Biochemistry and Physiology 60, 347-350.

Denis, V. and Robin, J.-P., 2001. Present status of French Atlantic fishery for cuttlefish (*Sepia officinalis*). Fisheries Research 182, 1-12.

Dicks, B.M., 1982. Monitoring the biological effects of North Sea platforms. Marine Pollution Bulletin 13, 221-227.

Dunn, M.R., 1999. Aspects of the stock dynamics and exploitation of cuttlefish, *Sepia officinalis* (Linnaeus, 1758), in the English Channel. Fisheries Research 40, 277-293.

Finger, J.M. and Smith, J.D., 1987. Molecular association of Cu, Zn, Cd and ^{210}Po in the digestive gland of the squid *Nototodarus gouldi*. Marine Biology 95, 87-91.

Frodello J.P., Romeo M. and Viale D., 2000, Distribution of mercury in the organs and tissues of five toothed- whale species of the Mediterranean. Environmental Pollution 108, 447-452.

Furness, R.W., 1994. An estimate of the quantity of squid consumed by seabirds in the eastern North Atlantic and adjoining seas. Fisheries Research 21, 165-177.

González, A.F., López, A., Guerra, A. and Barriero, A., 1994. Diets of marine mammals on the northwestern Spanish Atlantic coast with special reference to Cephalopoda. Fisheries Research 21, 179-191.

Guerra, A. and Rocha, F., 1994. The life history of *Loligo forbesi* (Cephalopoa: Loliginidae) in Galician waters (NW Spain). Fisheries Research 21, 43-69.

Hamabe M., Hamuro C. & Ogura M., 1982. Squid jigging from small boats. Fishing News Books Ltd, Dorking, Surrey.

Hastie, L.C., Joy, J.B., Pierce, G.J. and Yau, C., 1994. Reproductive biology of *Todaropsis eblanae* (Cephalopoda: Ommastrephidae) in Scottish waters. Journal of the Marine Biological Association of the United Kingdom 72, 367-382.

Hislop, J.R.G., 1997 Database report of the Stomach Sampling Project 1991. ICES Co-operative Research Report 219. International Council for the Exploration of the Sea, Copenhagen.

Hislop, J.R.G., Robb, A.P., Bell, M.A. and Armstrong, D.W., 1991. The diet and food consumption of whiting (*Merlangius merlangus*) in the North Sea). ICES Journal of Marine Science, 48, 139-156.

Hislop, J.R.G., Robb, A.P., Brown, M.A. and Armstrong, D.W., 1983. A preliminary report on the analysis of the whiting stomachs collected during the 1981 North Sea stomach sampling project. International Council for the Exploration of the Sea CM 1983/G: 59.

Holme, N.A., 1974. The biology of *Loligo forbesi* Steenstrup (Mollusca: Cephalopoda) in the Plymouth area. Journal of the Marine Biological Association of the United Kingdom 54, 481-503.

Howard, F.G., 1979. Recent trends in the Scottish fishery for *Loligo forbesi* together with some notes on the biology of the species. ICES Shellfish and Benthos Committee. 1979/K36.

Howard, F.G., Ngoile, M.A. and Mason, J., 1987. *Loligo forbesi*: its present status in Scottish fisheries. ICES Shellfish Committee. CM 1987/K:5.

ICES, 1988. Report of the Meeting Co-ordinators in the Stomach Sampling Project 1985 to 1987. International Council for the Exploration of the Sea CM 1988/G: 27.

Joy, J.B., 1989. The fishery biology of Ommastrephid squids in the Shetland waters. MSc Thesis, University of Aberdeen.

Kunisaki, N., 2000. Nutritional properties of squid and cuttlefish. In: M. Okozumi and T. Fujii (editors), Nutritional and Functional Properties of Squid and Cuttlefish, National Co-operative Association of Squid Producers, Japan, pp. 22-59.

Le Goff, R. and Daguzan, J., 1991. Growth and life cycles of the cuttlefish *Sepia officinalis* L. (Mollusca: Cephalopoda) in south Brittany (France). Bulletin of Marine Science 49, 341-348.

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

Martin, J.H. and Flegal, A.R., 1975. High copper concentrations in squid livers in association with elevated levels of silver, cadmium and zinc. Marine Biology 30, 51-55.

Martins, H.R., 1982. Biological studies of the exploited stock of *Loligo forbesi* (Mollusca: Cephalopoda) in the Azores. Journal of the Marine Biological Association of the United Kingdom 62, 799-808.

Menzie, C.A., 1983. Muddy issues. Oceanus 26, 33-38.

Monteiro, L.R., Porteiro, F.M and Goncalves, J.M., 1992. Inter- and intra-specific variations of the mercury levels in the muscle of cephalopods from the Azores. Arquipelago 10, 13-22.

Neff, J.M., Rabalais, N.N. and Boesch, D.F., 1987. Offshore oil and gas development activities potentially causing long-term environmental effects. In: D.F. Boesch and N.N. Rabalais (editors), Long-term Environmental Effects of Offshore Oil and Gas Development Long, Elsevier Applied Science, London and New York, pp. 149-173.

Pawson, M.G., 1995. Biogeographical identification of English Channel fish and shellfish stocks. MAFF Fisheries Research technical Report. 99. CEFAS. Lowestoft.

Pierce, G.J., 1992. Cephalopods in the diet of marine mammals. Fishery Potential of North East Atlantic Squid Stocks. Final Report to the Commission of the European Communities on Contract no. MA.1.146, Appendix A.19, Department of Zoology, University of Aberdeen, 22pp.

Pierce, G.J., Bailey, N., Stratoudakis, Y. and Newton, A., 1998. Distribution and abundance of the fished population of *Loligo forbesi* in Scottish waters: analysis of research cruise data. ICES Journal of Marine Science 55, 14-33.

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

Pierce, G.J., Boyle, P.R., Hastie, L.C. and Santos, M.B., 1994c. Diets of squid *Loligo forbesi* in the northeast Atlantic. Fisheries Research 21, 149-163.

Pierce, G.J., Boyle, P.R., Hastie, L.C. and Shanks, A.M., 1994d. Distribution and abundance of the fished population of *Loligo forbesi* in UK waters: analysis of fishery data. Fisheries Research 21, 193-216.

Pierce, G.J., Boyle, P.R. and Thompson, P.M., 1990. Diet selection by seals. In: M. Barnes and R.N. Gibson (editors), Trophic Relations in the Marine Environment, Proceedings of the 24th European Marine Biology Symposium, Aberdeen University Press, Aberdeen, pp 222-238.

Pierce, G.J. and Guerra, A., 1994. Stock assessment methods used for cephalopod fisheries. Fisheries Research 21, 255-285.

Pierce, G.J., Hastie, L.C., Guerra, A., Thorpe, R,S., Howard, F.G. and Boyle P.R., 1994b. Morphometric variation in *Loligo forbesi* and *Loligo vulgaris*: regional, seasonal, sex, maturity and worker differences. Fisheries Research 21, 127-148.

Pierce, G.J. and Santos, M.B., 1996. Trophic interactions of squid *Loligo forbesi* in Scottish waters. In: S.P.R. Greenstreet and M.L. Tasker (editors), Aquatic Predators and their Prey, Fishing News Books, Cambridge, pp. 58-64.

Porteiro, F.M. and Martins, H.R., 1994. Biology of *Loligo forbesi* Steenstrup, 1856 (Mollusca: Cephalopoda) in the Azores: sample composition and maturation of squid caught by jigging. Fisheries Research 21, 103-114.

Robin J.P. & Boucaud-Camou E. (1995) Squid catch composition in the English Channel bottom trawl fishery: proportion of *Loligo forbesi* and *Loligo vulgaris* in the landings and length-frequencies of both species during the 1993-1994 period. International Council for the Exploration of the Sea. CM 1995/K:36.

Rocca, E., 1969. Copper distribution in *Octopus vulgaris* Lam. hepatopancreas. Comparative Biochemistry and Physiology 28, 67-82.

Rossi, A., Pellegrini, D., Belcari, P. and Barghigiani, C., 1993. Mercury in *Eledone cirrhosa* from the northern Tyrrhenian Sea: Contents and relations with life cycle. Marine Pollution Bulletin 27, 683-686.

Santos, M.B., Clarke, M.R. and Pierce, G.J., 2001a. Assessing the importance of cephalopods in the diets of marine mammals and other top predators: problems and solutions. Fisheries Research 52, 121-139.

Santos, M.B. and Pierce, G.J., In Press. Diet of harbour porpoise (*Phocoena phocoena*) in the NE Atlantic: a review. Oceanography and Marine Biology Annual Review.

Santos, M.B., Pierce, G.J., Boyle P.R., Reid, R.J., Ross, H.M., Patterson, I.A.P., Kinze, C.C., Tougaard, S., Lick, R., Piatkowski, U. and Hernández-García, V., 1999. Stomach contents of sperm whales (*Physeter macrocephalus*) stranded in the North Sea 1990-1996. Marine Ecology Progress Series 183, 281-294.

Santos, M.B., Pierce, G.J., Garcia Hartmann, M., Smeenk, C., Addink, M.J., Kuiken, T., Reid, R.J., Patterson, I.A.P., Lordan, C., Rogan, E. and Mente, E., 2002. Additional notes on stomach contents of sperm whales *Physeter macrocephalus* stranded in the NE Atlantic. Journal of the Marine Biological Association of the United Kingdom 82, 501-507.

Santos, M.B., Pierce, G.J., Herman, J., López, A., Guerra, A., Mente, E. and Clarke, M.R., 2001b. Feeding ecology of Cuvier's beaked whale (*Ziphius cavirostris*): a review with new information on the diet of this species. Journal of the Marine Biological Association of the United Kingdom 81, 687-694.

Santos, M.B., Pierce, G.J., Reid, R.J., Patterson, I.A.P., Ross, H.M. and Mente, E. 2001c. Stomach contents of bottlenose dolphins (*Tursiops truncatus*) in Scottish waters. Journal of the Marine Biological Association of the United Kingdom 81, 873-878.

Santos, M.B., Pierce, G.J., Ross, H.M., Reid, R.J. and Wilson, B., 1994. Diets of small cetaceans from the Scottish coast. ICES Council Meeting Papers. ICES CM 1994/N:11.

Santos, M.B., Pierce G.J., Smeenk, C., Addink, M.J., Kinze, C.C., Tougaard, S. and Herman, J., 2001d. Stomach contents of northern bottlenose whales *Hyperoodon ampullatus* stranded in the North Sea. Journal of the Marine Biological Association of the United Kingdom 81, 143-150.

Santos, M.B., Pierce, G.J., Wijnsma, G., Ross, H.M. and Reid, R.J., 1995. Diets of small cetaceans stranded in Scotland 1993-1995. ICES Council Meeting Papers. ICES CM 1995/N:6.

Schipp, R. and Hevert, F., 1978. Distribution of copper and iron in some central organs of *Sepia officinalis* (Cephalopoda). A comparative study by flameless atomic absorption and electron microscopy. Marine Biology 47, 391-399.

Scottish Sea Fisheries Statistical Tables, 1994. The Scottish Office. Agriculture and Fisheries Department.

Scottish Sea Fisheries Statistical Tables, 1995. The Scottish Office. Agriculture, Environment and Fisheries Department.

Scottish Sea Fisheries Statistics, 1996. The Scottish Office. Agriculture, Environment and Fisheries Department.

Scottish Sea Fisheries Statistics, 1997. The Scottish Office. Agriculture, Environment and Fisheries Department.

Scottish Sea Fisheries Statistics, 1998. Scottish Executive. Rural Affairs Department.

Scottish Sea Fisheries Statistics, 1999. Scottish Executive Rural Affairs Department.

Stephen, A.C., 1944. The cephalopoda of Scottish and adjacent waters. Transactions of the Royal Society of Edinburgh 61, 247-270.

Tanaka, T., Hayashi, Y. and Ishizawa, M., 1983. Subcellular distribution and binding of heavy metals in the untreated liver of the squid; comparison with data from the livers of cadmium and silver exposed rats. Experienta 39, 746-748.

Taylor M.A., 1986. Stunning whales and deaf squids. Nature 323, 298-299.

Tollit, D.J. and Thompson, P.M., 1996. Seasonal and between-year variations in the diet of harbour seals in the Moray Firth, Scotland. Canadian Journal of Zoology 74, 1110-1121.

Velasco, F., Olaso, I. and Sanchez, F., 2001. The role of cephalopods as forage for the demersal fish community in the southern Bay of Biscay. Fisheries Research 52, 65-77.

Voss G.L., 1973. Cephalopod resources of the world. FAO Fisheries circular No. 149, 75 pp.

Waluda, C.M. and Pierce, G.J., 1998. Temporal and spatial patterns in the distribution of squid *Loligo* spp. in United Kingdom waters. South African Journal of Marine Science 20, 323-336.

Table 1. Landings (in tonnes) of Cuttlefish (Sepiidae). This table is based on a more extensive tabulation in Anonymous (2002).

Country	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001P**
ICES Division IVb (Central North Sea)							
Belgium	1	1	2	3	3	7	4
Netherlands	+	+	+	+	+	2	n.a.
ICES Division IVc (Southern North Sea)							
Belgium	15	5	4	4	5	12	22
England, Wales & Northern Ireland	163	90	22	28	22	14	5
France	234	174	135	140	231	420	184
Netherlands	+	+	+	+	+	97	n.a.
ICES Divisions VIId, e (English Channel)							
Belgium	19	11	6	15	9	35	25
Channel Islands	1	11	8	20	22	26	4
England, Wales & Northern Ireland	3925	4038	1634	2449	2014	2910	2600
France	8869	8012	5742	7530	8266	10894	6932
Netherlands	+	+	+	+	+	2	n.a.
Grand Total	19601	19736	16652	20275	20725	24008	18028

Table 2. Landings (in tonnes) of Common Squid (includes *Loligo forbesi*, *L. vulgaris*, *Alloteuthis subulata* and *A. media*). This table is based on a more extensive tabulation in Anonymous (2002).

Country	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001P**
ICES Division IVa (Northern North Sea)							
Denmark	1	1	2	5	3	3	2
England, Wales & Northern Ireland	+	0	0	3	2	3	**0**
France	0	0	1	0	+	+	+
Germany	+	+	+	+	+	+	+
Scotland	268	279	453	844	712	547	**350**
ICES Division IVb (Central North Sea)							
Belgium	14	9	7	11	16	24	11
Denmark	+	+	9	3	18	10	1
England, Wales & Northern Ireland	22	21	39	144	65	29	**146**
Germany	3	1	3	5	5	3	2
Netherlands	+	+	+	+	+	4	n.a.
Scotland	25	14	66	214	144	87	**?**
ICES Division IVc (Southern North Sea)							
Belgium	153	87	39	36	72	121	109
England, Wales & Northern Ireland	10	3	3	2	2	4	12
France	188	85	123	93	151	165	244
Germany	6	2	1	6	1	2	2
Netherlands	+	+	+	+	+	758	n.a.
ICES Division VIa (NW coast of Scotland and North Ireland)							
England, Wales & Northern Ireland	16	49	40	7	3	2	**?**
France	98	132	82	136	88	56	8
Ireland	85	114	140	99	106	38	38
Scotland	267	287	301	285	334	210	**195**
Spain	+	+	+	7	8	+	1
ICES Divisions VIId, e (English Channel)							
Belgium	220	163	77	133	113	254	223
Channel Islands	2	1	6	5	11	9	n.a.
England, Wales & Northern Ireland	672	392	496	419	641	449	437
France	2636	2033	2518	2689	3417	3227	2643
Netherlands	+	+	+	+	+	11	n.a.
Grand Total	10001	9632	11519	11245	11115	10186	8471

*Landings consist exclusively of *Loligo forbesi*.

Table 3. Landings (in tonnes) of Octopods (*Eledone* spp. and *Octopus vulgaris*). This table is based on a more extensive tabulation in Anonymous (2002).

Country	1995	1996	1997	1998	1999	2000	2001P
ICES Division IVa (Northern North Sea)							
Scotland	2	2	6	13	17	15	6
ICES Division IVb (Central North Sea)							
Belgium	0	+	+	2	5	5	5
England, Wales & Northern Ireland	0	0	0	1	1	1	+
Scotland	0	0	0	1	1	+	+
ICES Division IVc (Southern North Sea)							
Belgium	2	0	2	+	2	1	1
England, Wales & Northern Ireland	8	4	1	+	+	+	+
Grand Total	16226	17658	15801	13043	15743	16248	11175

*Landings consist exclusively of *Octopus vulgaris.*

Table 4. Total annual cephalopod landings (in tonnes) in whole ICES area by the UK fleet in relation to total landings from the ICES area. This table is based on a more extensive tabulation in Anonymous (2002).

Country	1995	1996	1997	1998	1999	2000	2001P
(a) Cuttlefish (Sepiidae)							
Channel Islands	1	11	8	20	22	26	4
England, Wales & N. Ireland	4339	4607	2202	2760	2259	3076	2696
Total	19601	19736	16652	20275	20725	24008	18028
(b) Common Squid (Loliginidae)							
Channel Islands	2	1	6	5	11	9	??
England, Wales & N. Ireland	2163	2464	2005	1466	1261	776	968
Isle of Man	7	3	2	2	2	+	n.a.
Scotland	570	799	1001	1572	1350	980	588
Total	10001	9632	11519	11245	11115	10186	8471
(c) Short-finned Squid (Ommastrephidae)							
England, Wales & N. Ireland	35	13	26	293	204	186	8
Total	1703	4221	6145	5841	7719	6425	1709
(d) Octopods (Octopodidae)							
Channel Islands	0	0	0	0	+	+	n.a.
England, Wales & N. Ireland	239	221	140	87	33	115	11
Scotland	6	8	8	23	19	20	6
Total	16226	17658	15801	13043	15743	16248	11175

Table 5. Landings of squid in Scotland, by fishing area for recent years. (Scottish Sea Fisheries Statistics, 1999; figures for 2000 from Fisheries Research Services database)

Landings by area	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Weight in tonnes							
Total for Scotland	203	569	637	823	1355	1199	852
IVa	90	268	293	453	844	712	547
Ivb	5	25	14	62	211	137	85
Value in £,000							
Total for Scotland	340	962	970	1523	2189	1395	1104
IVa	147	437	458	850	1252	810	687
IVb	8	56	33	137	392	184	136

Table 6. Concentration ranges of trace metals in drilling fluids and in typical marine sediments (concentrations in mg/kg dry weight, ppm) (Reproduced from Neff et al., 1987).

Metal	Concentration in marine sediments (ppm)	Concentration in drilling fluids (ppm)
Barium	60-8100	720-449000
Chromium	10-200	0.1-5960
Cadmium	0.3-1	0.16-54.4
Copper	8-700	0.05-307
Iron	20000-60000	0.002-27000
Mercury	0.05-3	0.017-10.4
Lead	6-200	0.4-4226
Zinc	5-4000	0.06-12270
Nickel	2-10	3.8-19.9
Arsenic	2-20	1.8-2.3
Vanadium	10-500	14-28
Aluminium	10000-90000	10800
Manganese	100-10000	290-400

Figure 1. Map of UK waters showing the SEA areas. This image is taken from the website http://www.habitats-directive.org/sea/dev/html_file/library.php

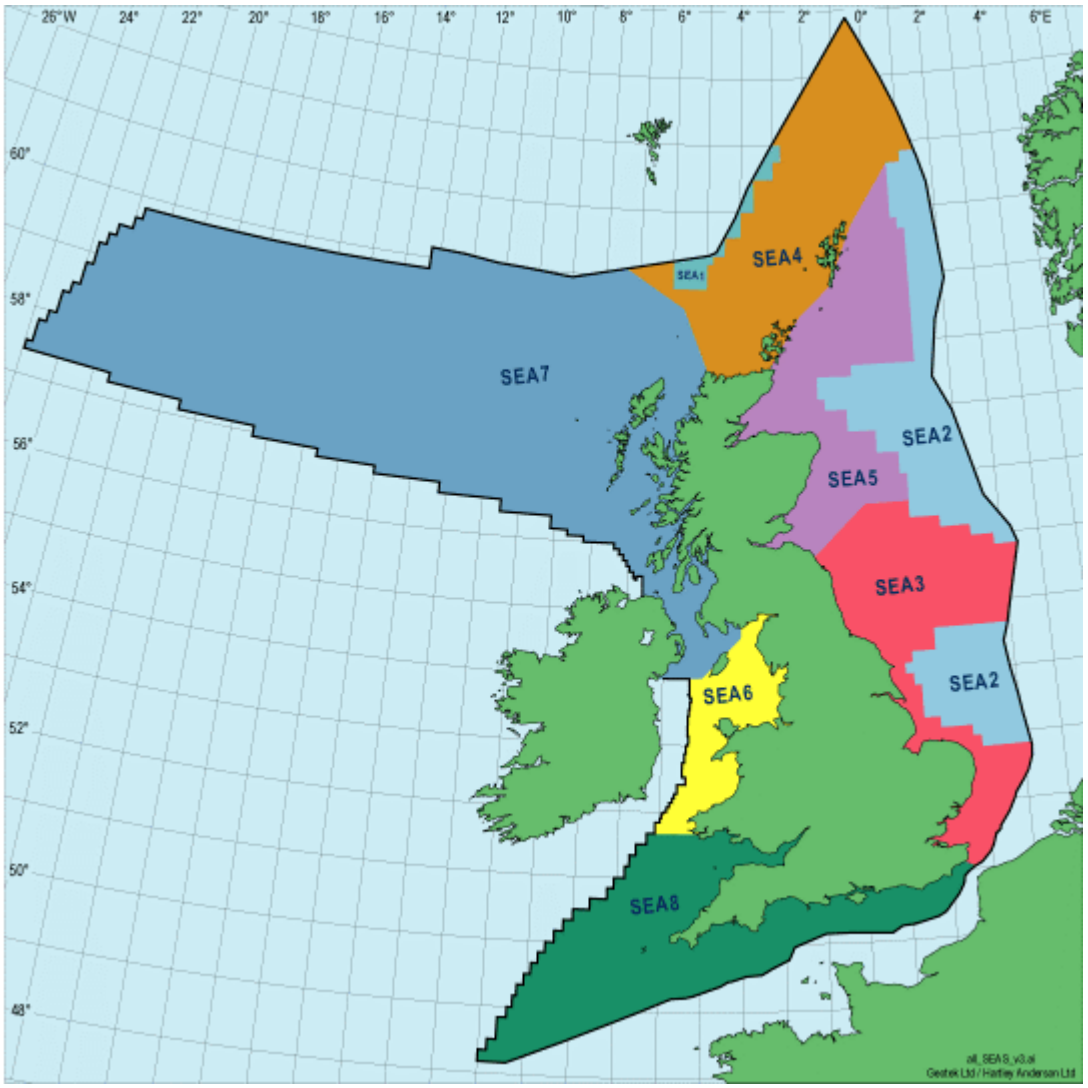

Figure 2. Map showing ICES fishery areas and divisions

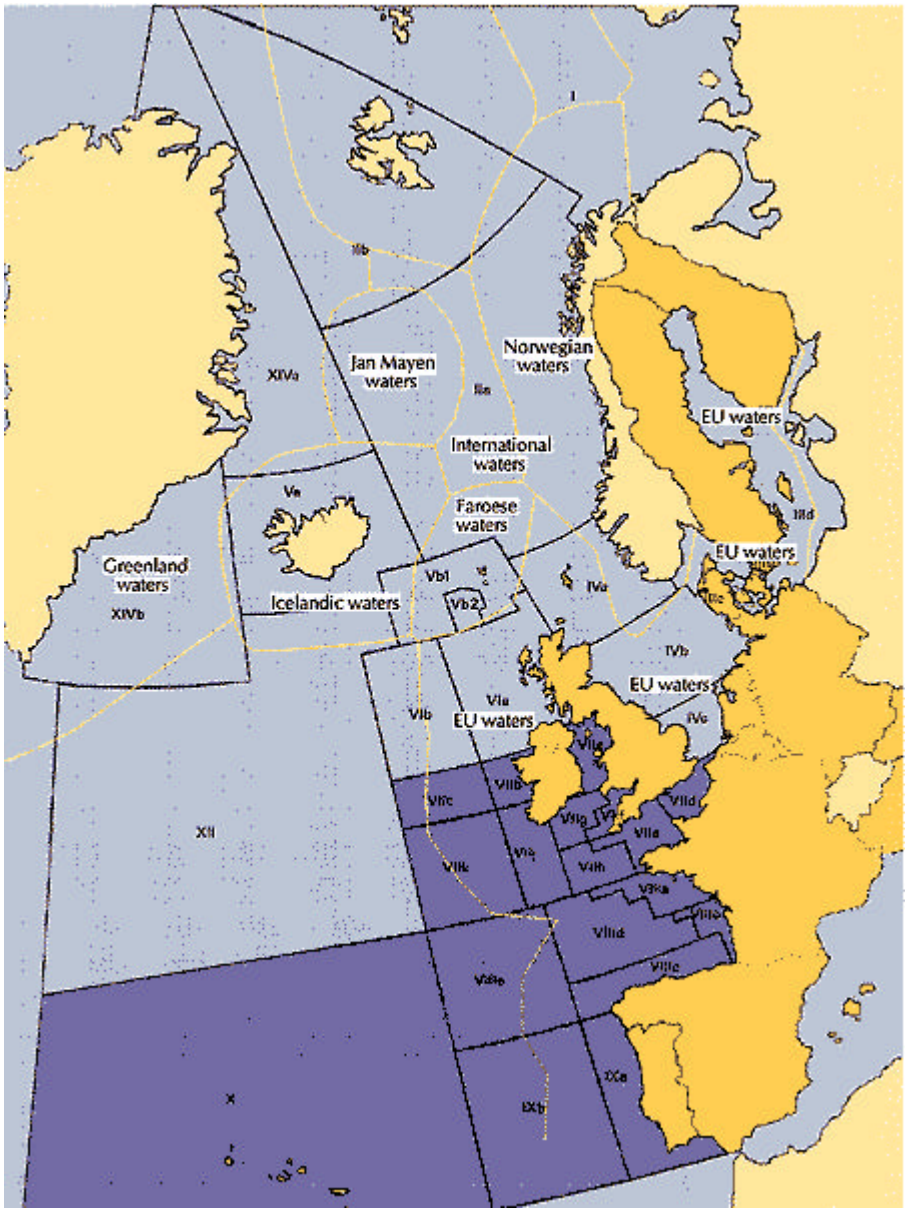

Figure 3. Total squid landings into Scotland between 1994 and 2000 (Scottish Sea Fisheries Statistics, 1999; figures for 2000 from Fisheries Research Services database)

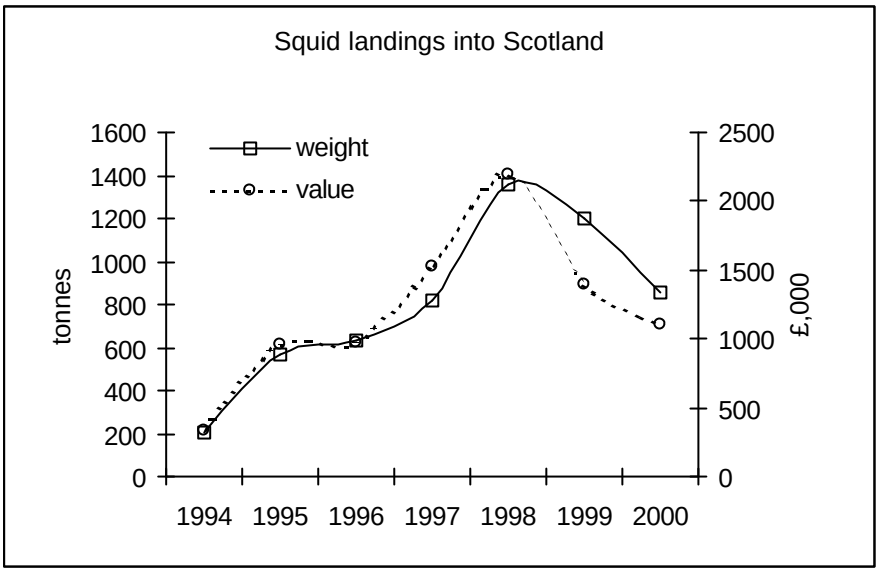

Figure 4. Squid landings into Scotland from Area IVa between 1994 and 2000 (Scottish Sea Fisheries Statistics, 1999; figures for 2000 from Fisheries Research Services database)

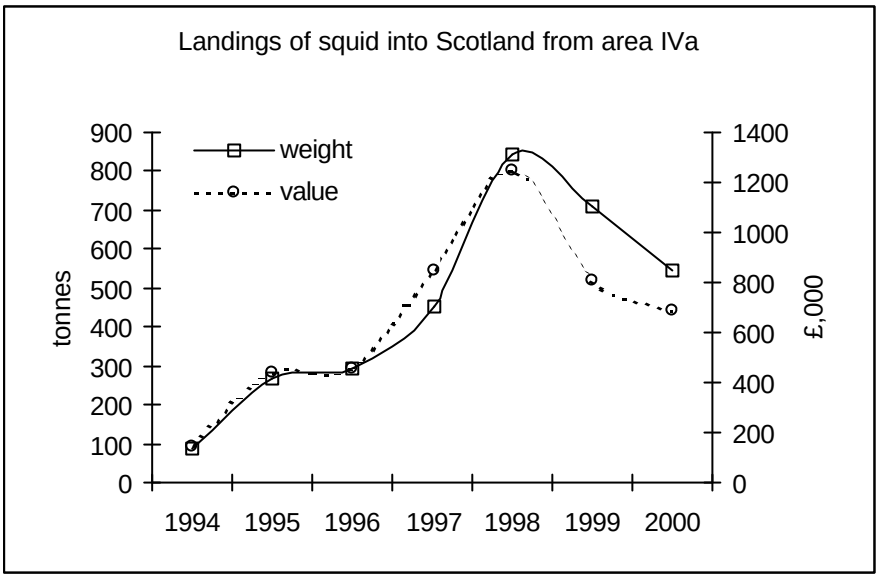

Figure 5. Squid landings into Scotland from Area IVb between 1994 and 2000. (Scottish Sea Fisheries Statistics, 1999; figures for 2000 from Fisheries Research Services database)

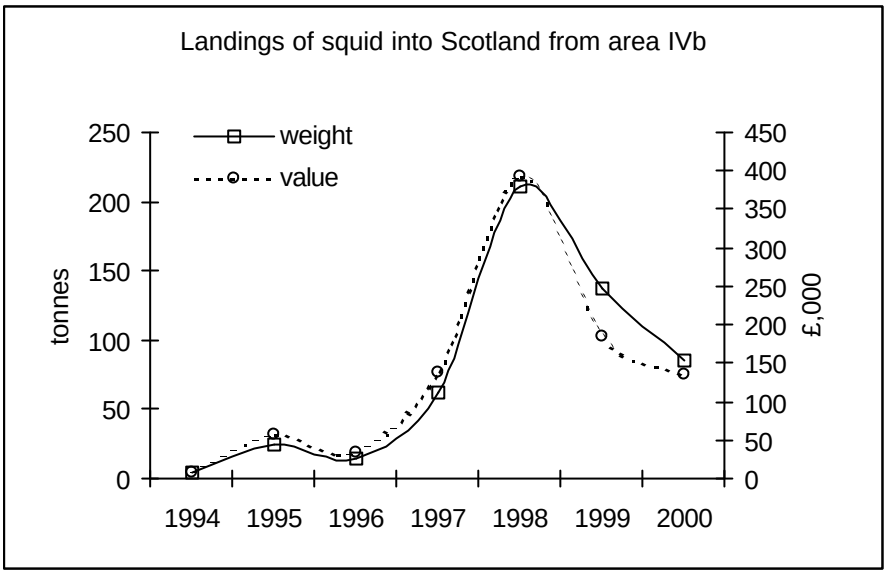

Figure 6. Squid landings by weight, for Scotland, expressed as a percentage of the main fished species (Scottish Sea Fisheries Statistical Tables, 1994, 1995; Scottish Sea Fisheries Statistics, 1996, 1997, 1998, 1999; figures for 2000 from Fisheries Research Services database).

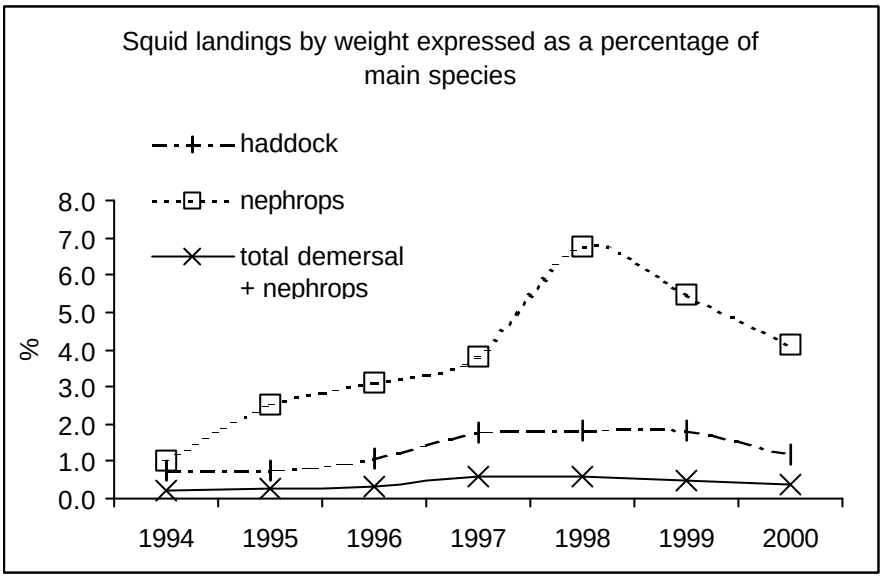

Figure 7. Squid landings by value expressed as a percentage of the main fished species (Scottish Sea Fisheries Statistical Tables, 1994, 1995; Scottish Sea Fisheries Statistics, 1996, 1997, 1998, 1999; figures for 2000 from Fisheries Research Services database).

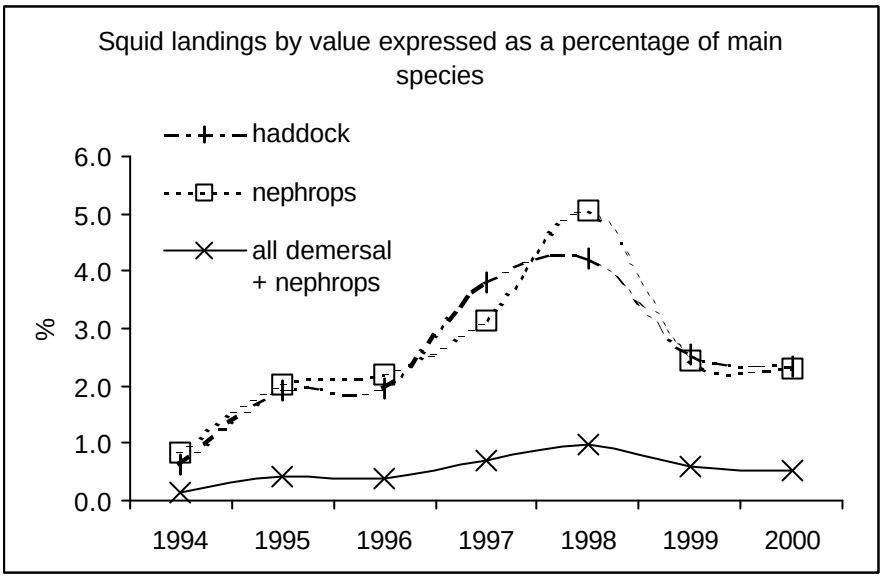

Figure 8. Squid landings per unit effort (LPUE) for the Scottish fleet, by ICES rectangle, for 1998.

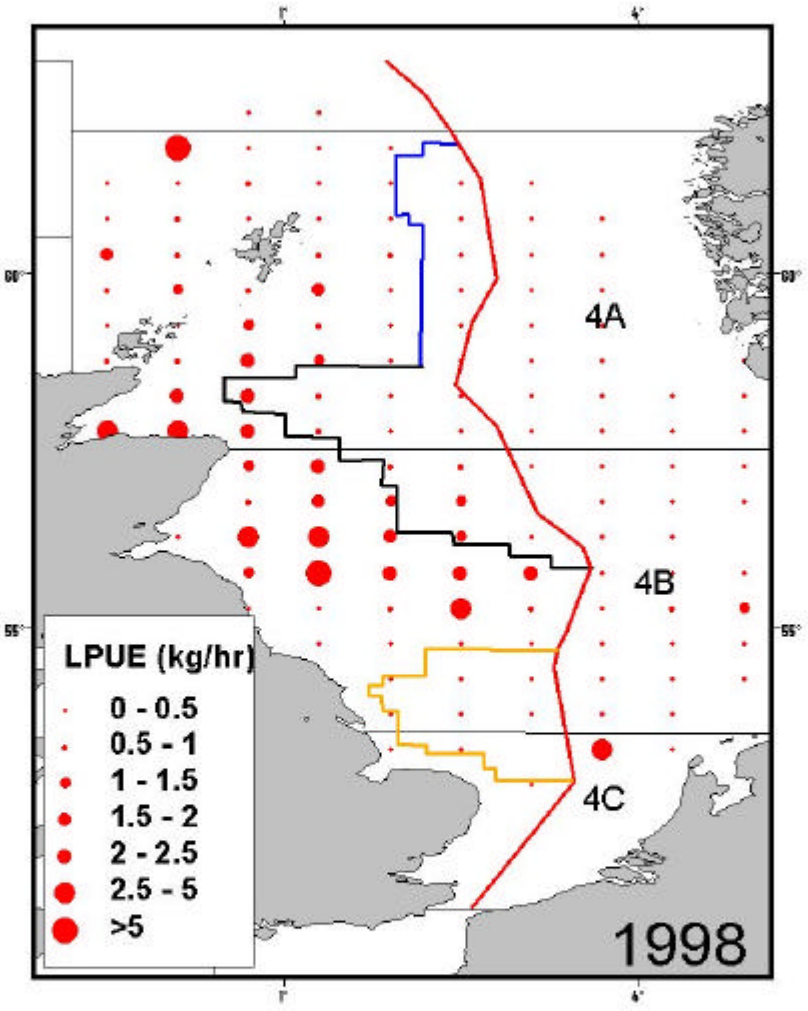

Figure 9. Squid landings per unit effort (LPUE) for the Scottish fleet, by ICES rectangle for 1999

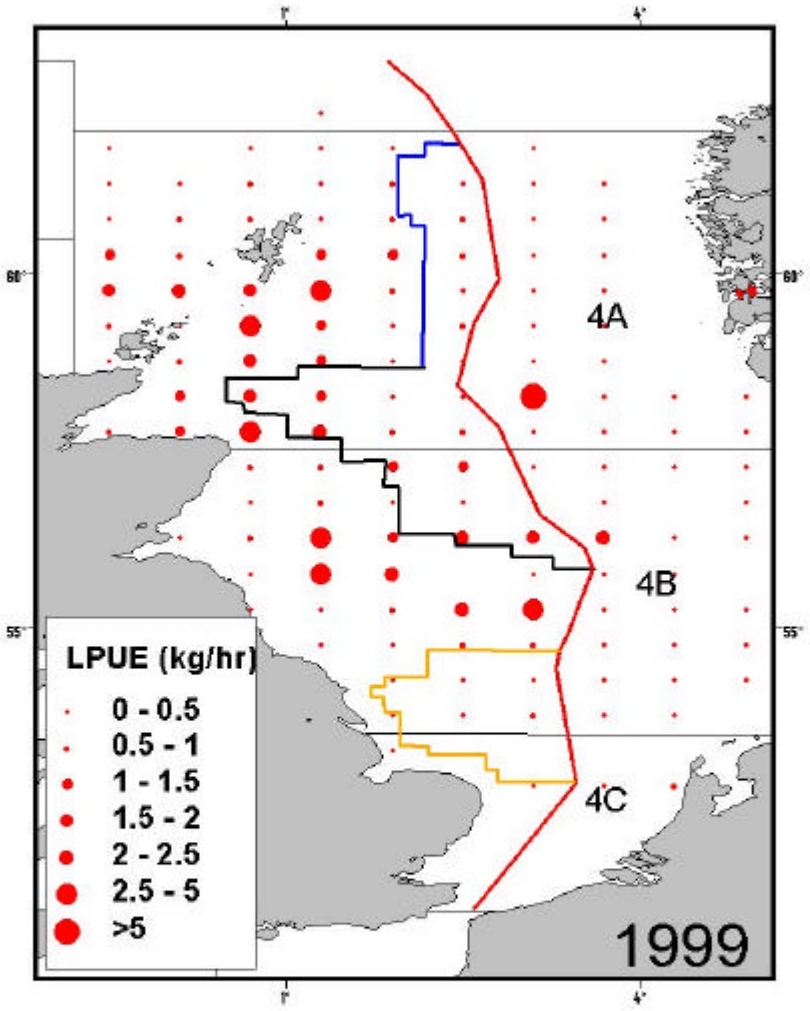

Figure 10. Squid landings per unit effort (LPUE) for the Scottish fleet, by ICES rectangle, for 2000

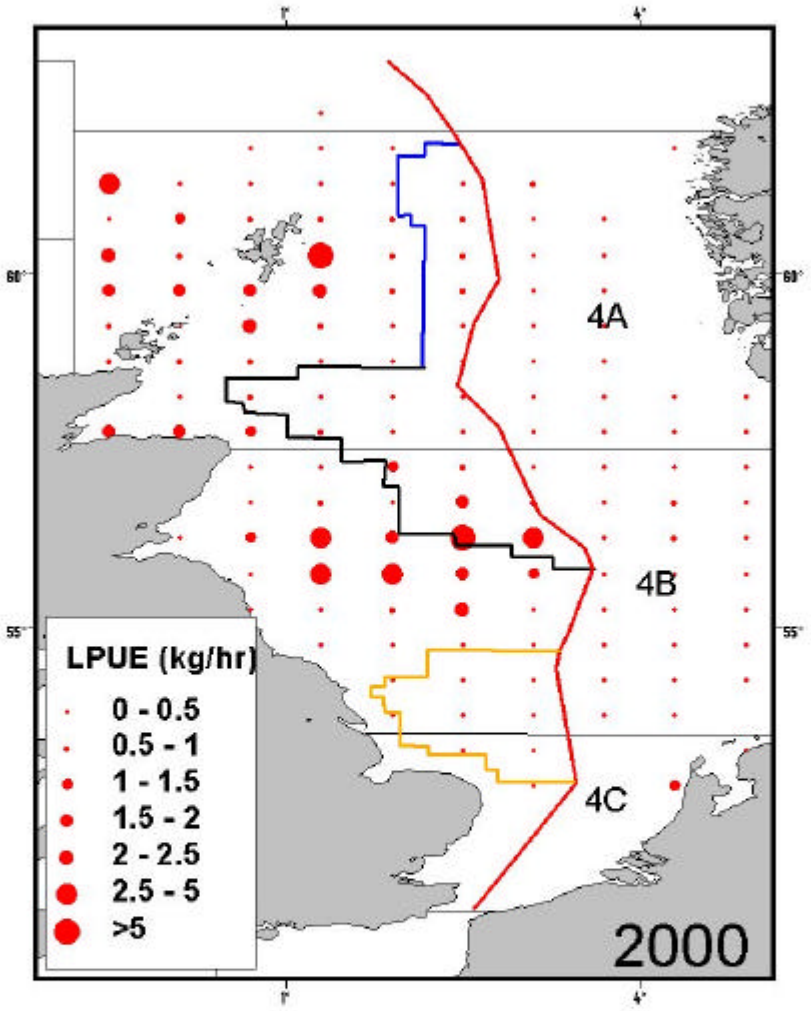

Figure 11. Landed catches of squid (all species) from ICES areas IV and VII by Scottish, English and French vessels in 1998.

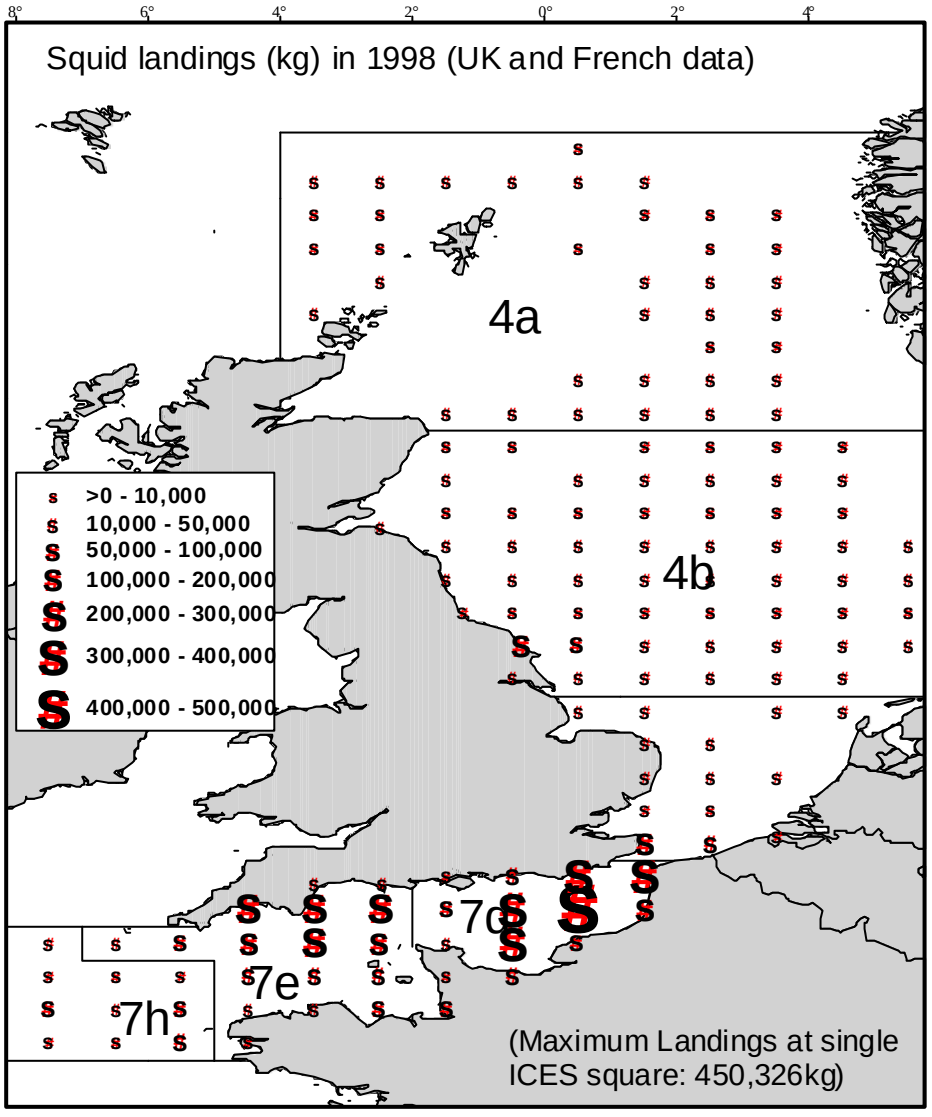

Figure 12 Landed catches of squid (all species) from ICES areas IV and VII by Scottish and English vessels in 1999.

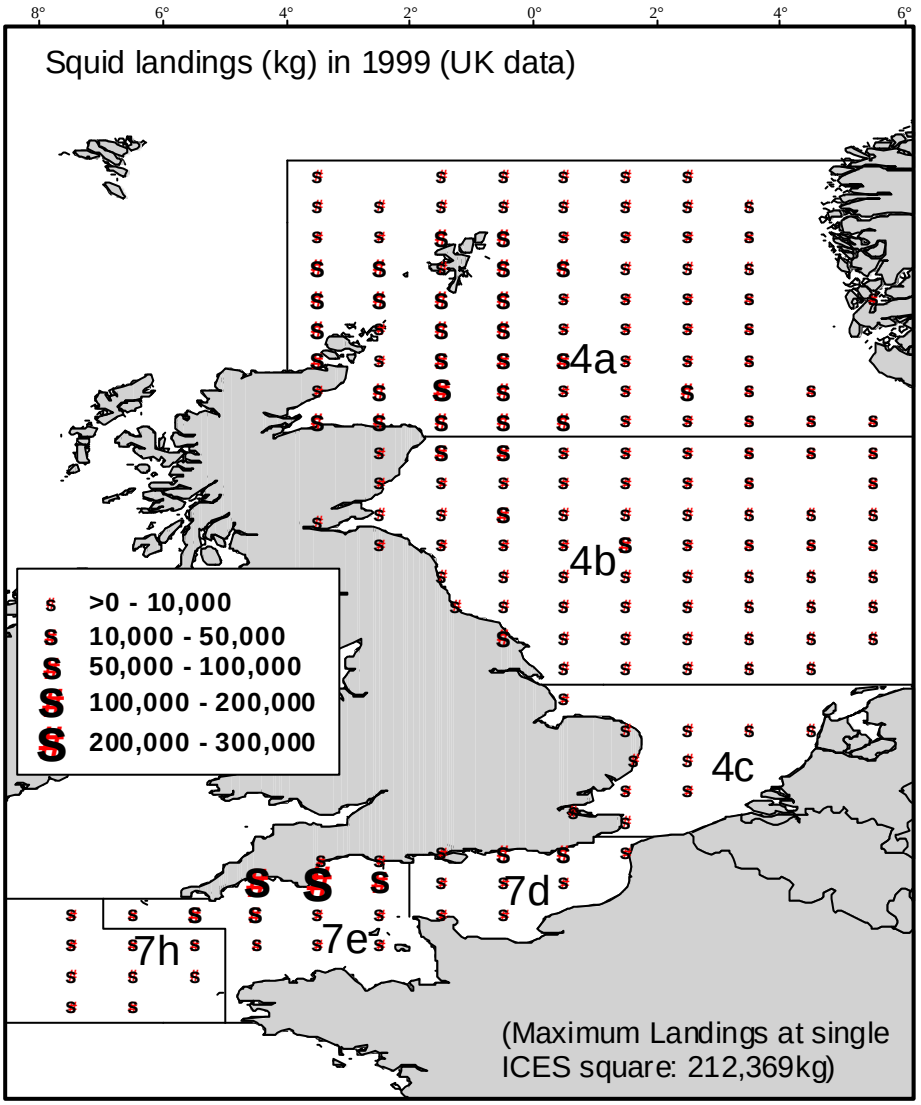

Figure 13 Landed catches of squid (all species) from ICES areas IV and VII by Scottish and English vessels in 2000.

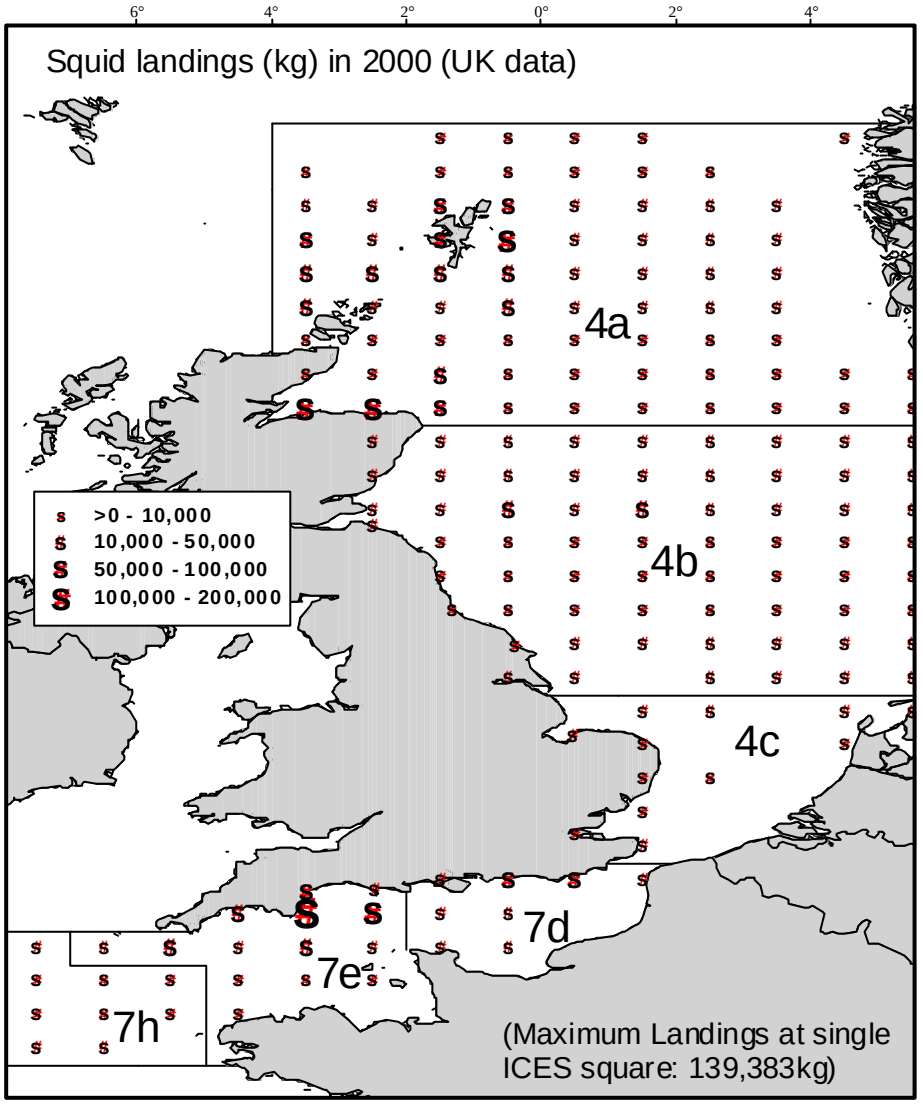

Figure 14. Landed catches of cuttlefish from ICES areas IV and VII by Scottish, English and French vessels in 1998.

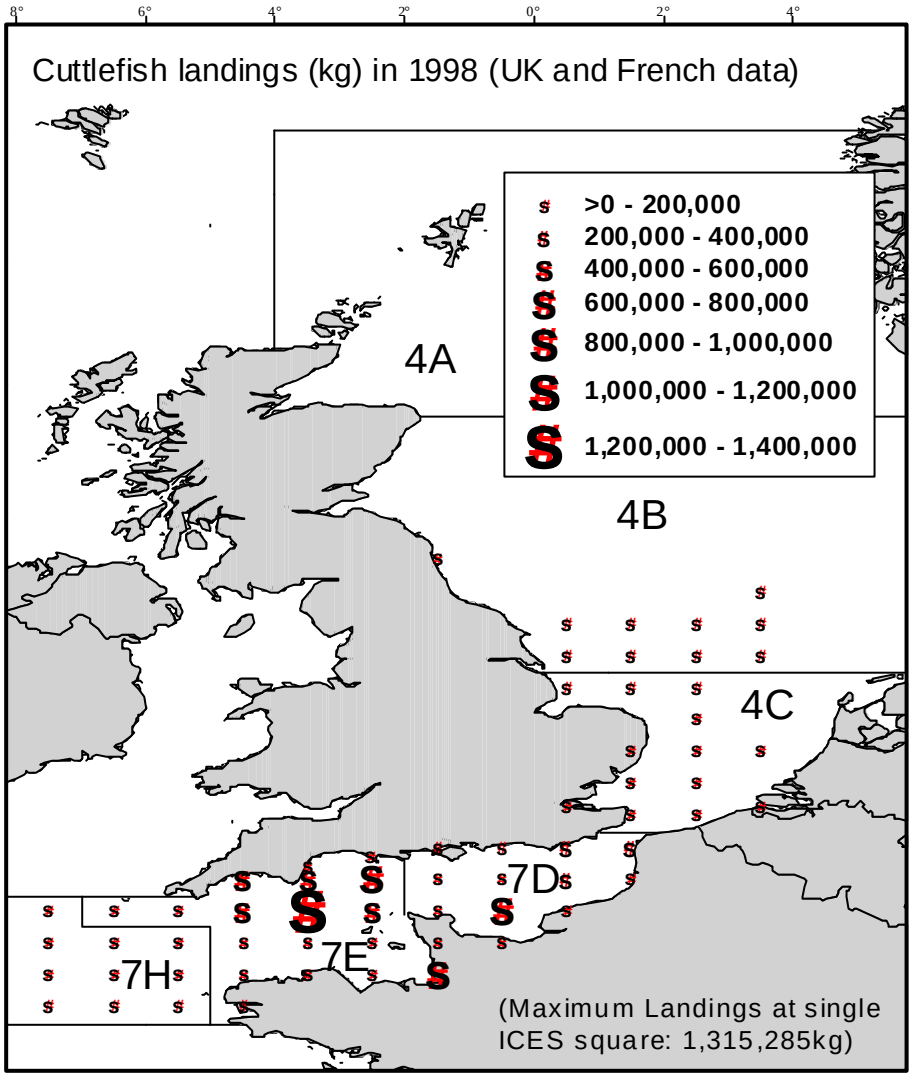

Figure 15 Landed catches of cuttlefish from ICES areas IV and VII by Scottish and English vessels in 1999.

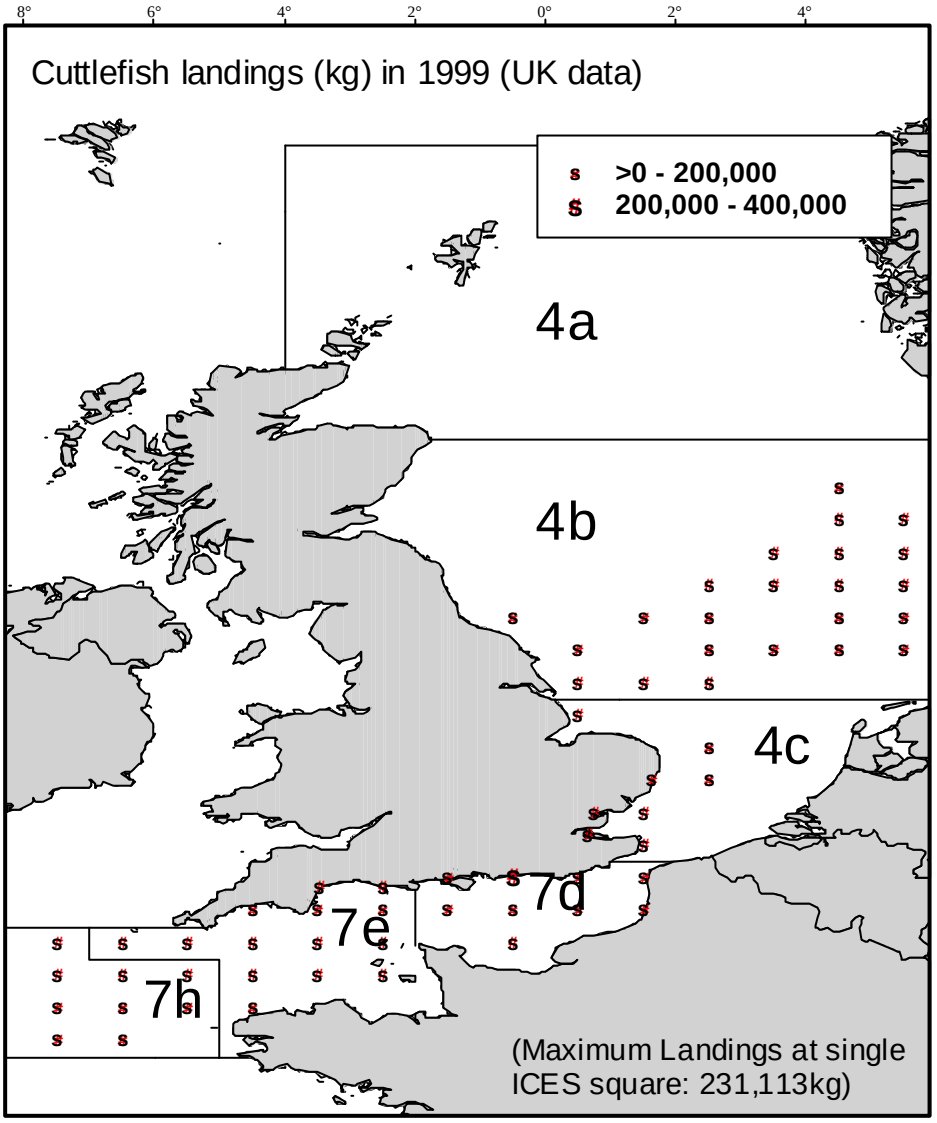

Figure 16 Landed catches of cuttlefish from ICES areas IV and VII by Scottish and English vessels in 2000.

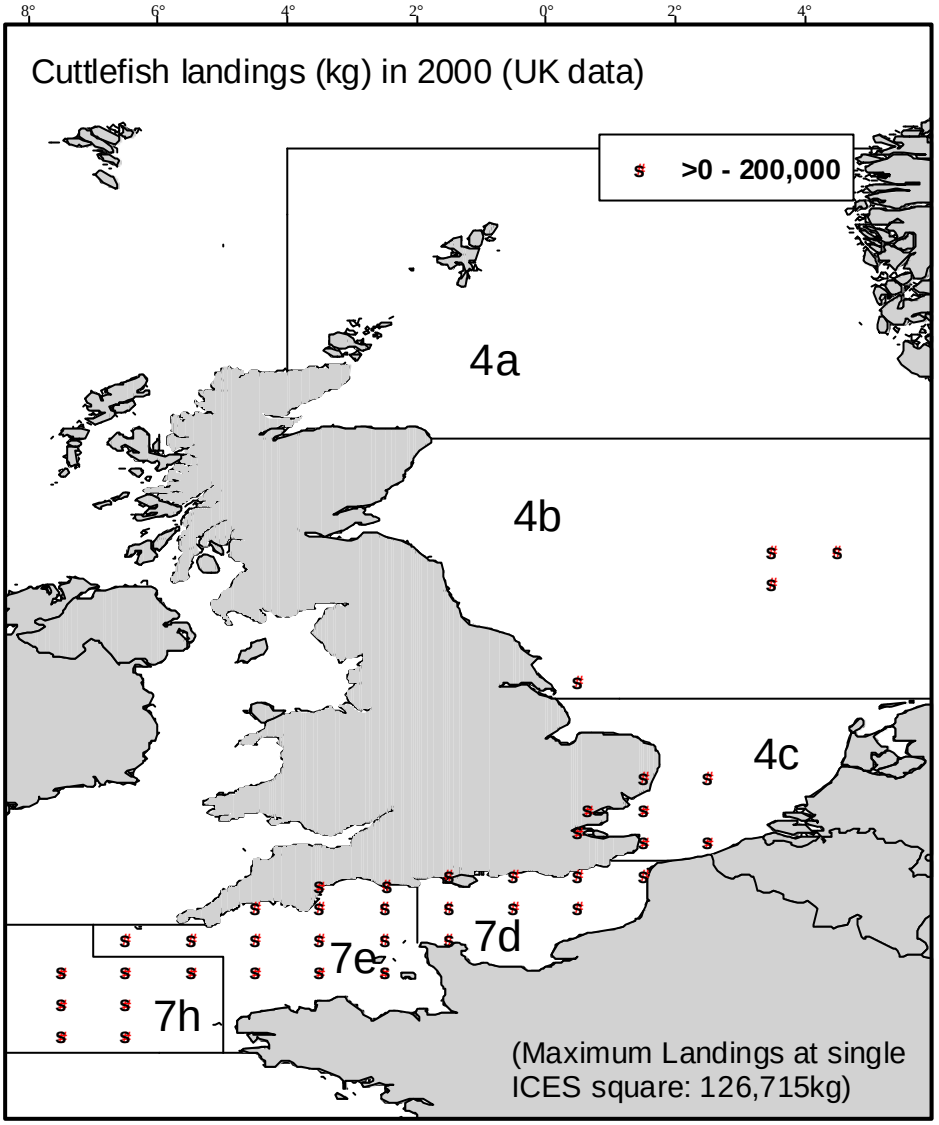

Figure 17. Octopus landings for the Scottish fleet, by ICES rectangle, for 1997

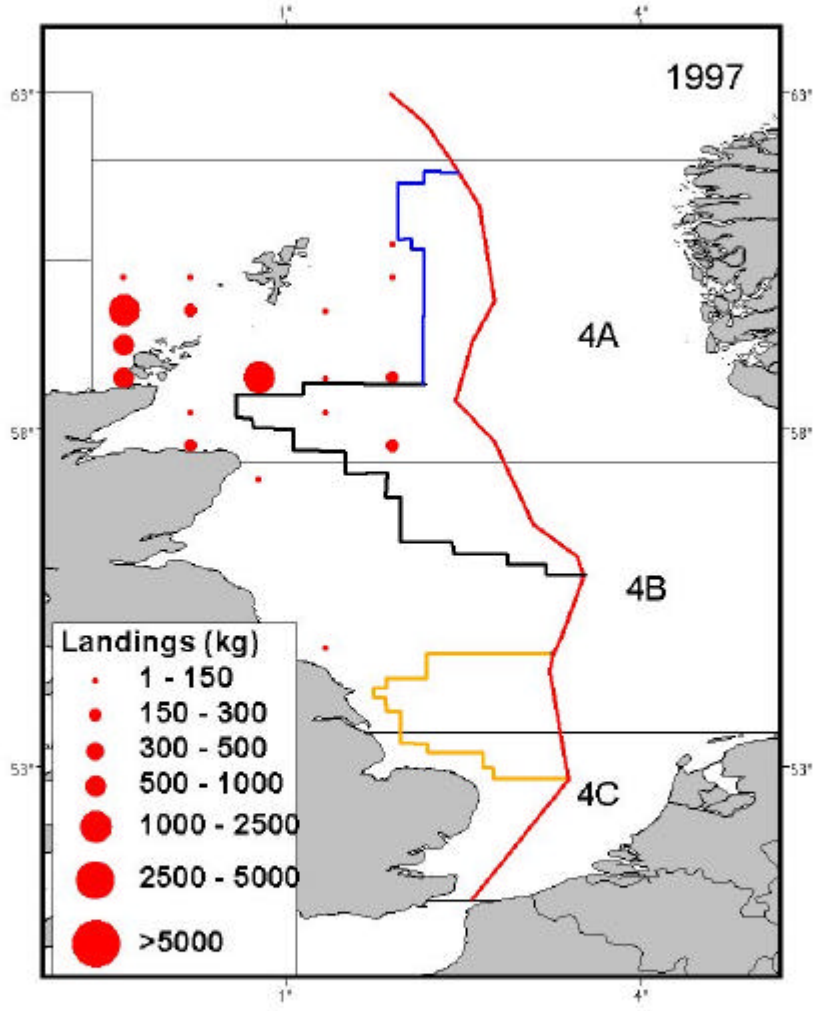

Figure 18. Octopus landings for the Scottish fleet, by ICES rectangle, for 1998

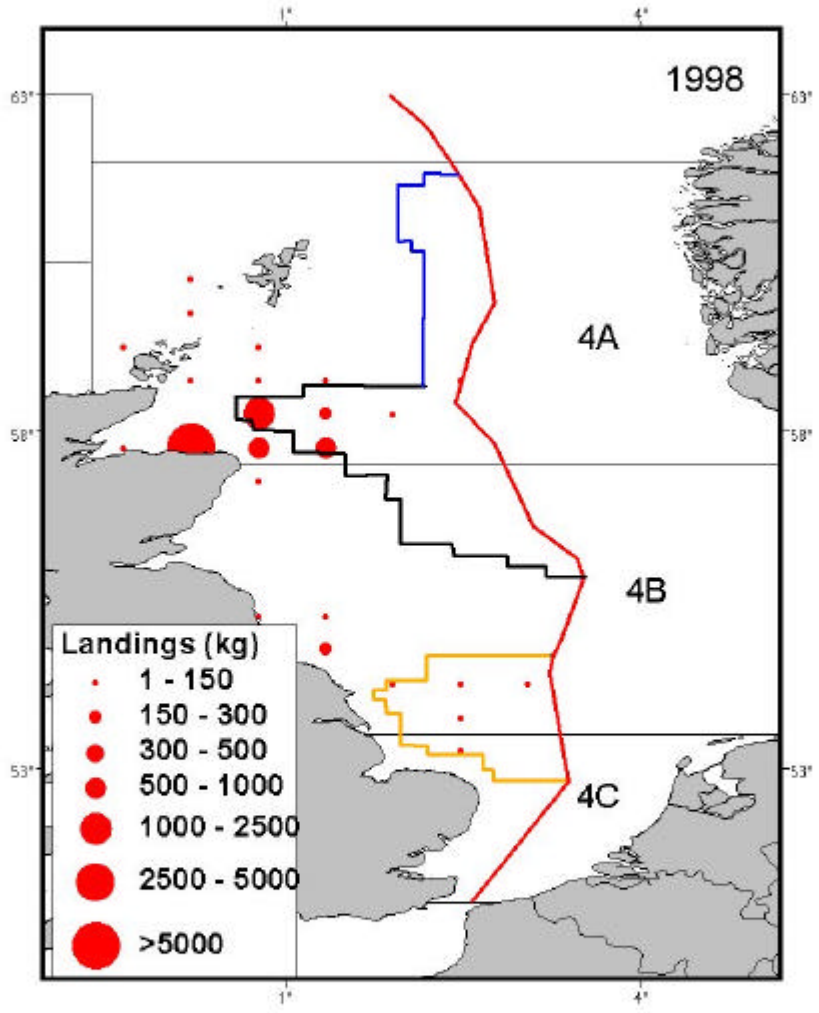

Figure 19. Octopus landings for the Scottish fleet, by ICES rectangle, for 1999

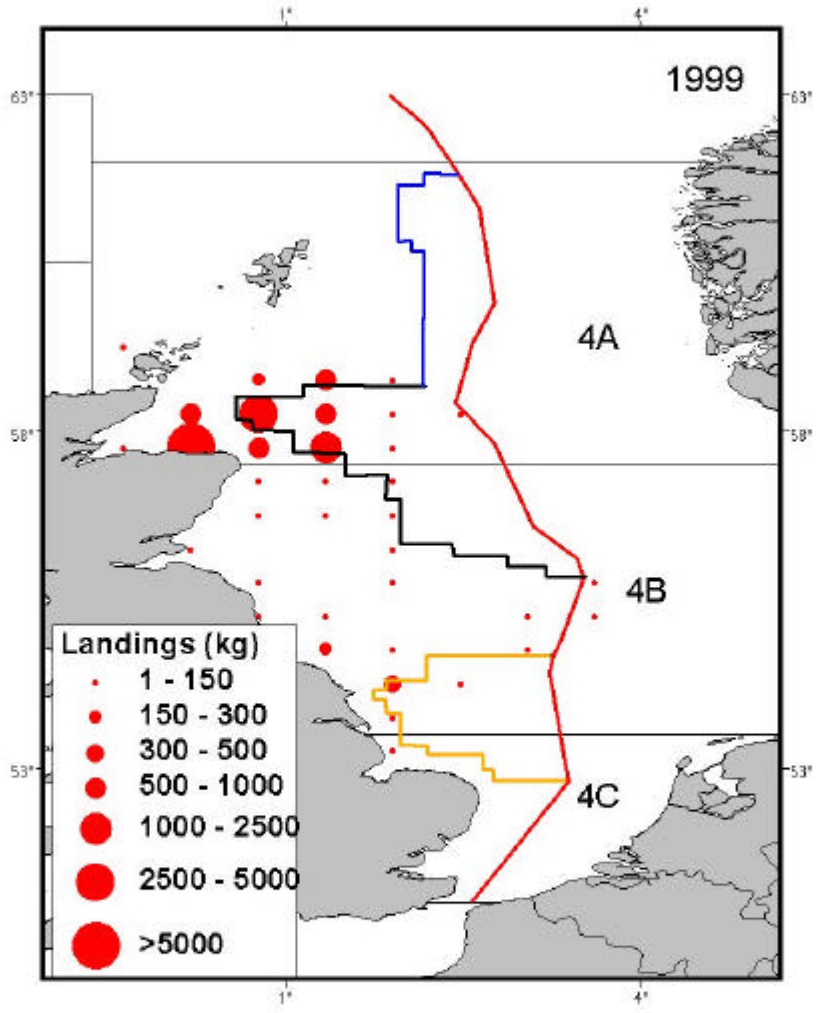

Figure 20. Landed catches of octopus from ICES areas IV and VII by Scottish, English and French vessels in 1998.

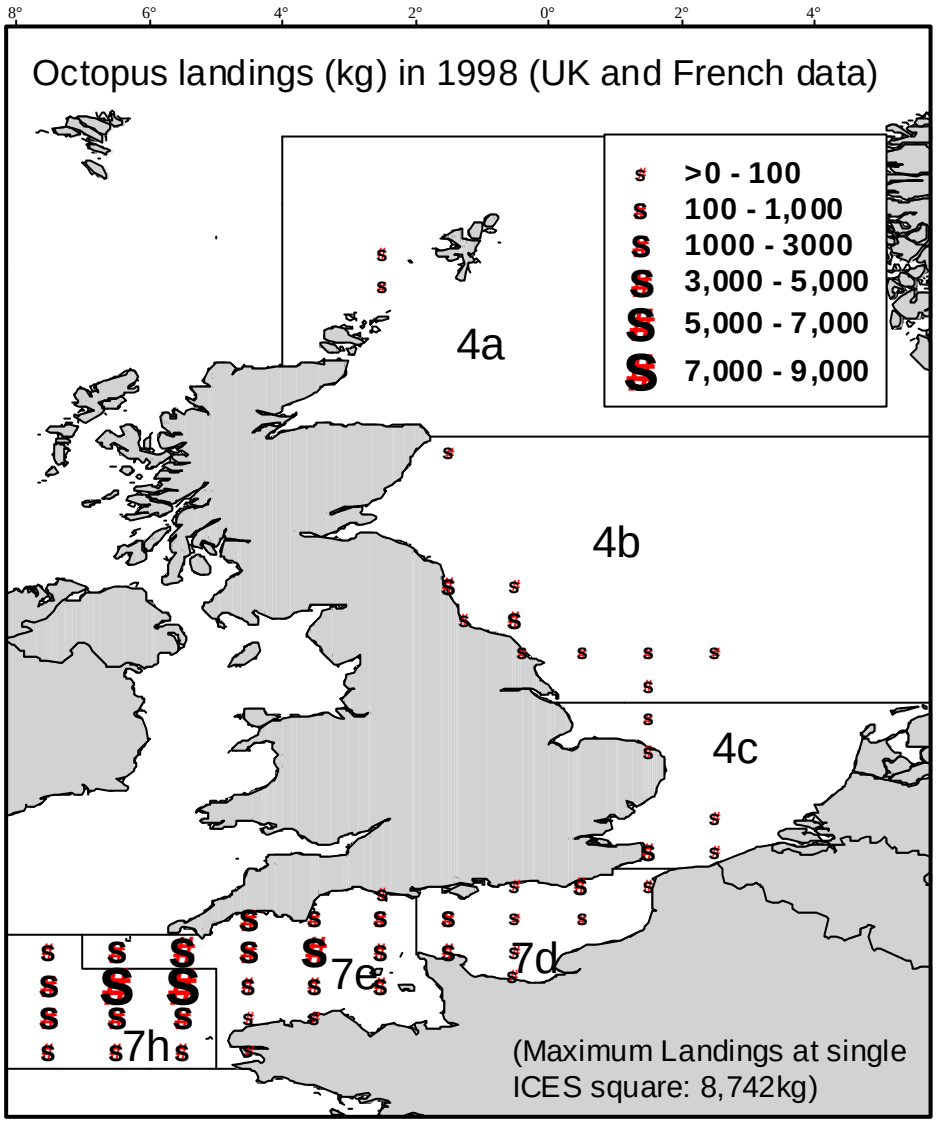

Figure 21. Landed catches of octopus from ICES areas IV and VII by Scottish and English vessels in 1999.

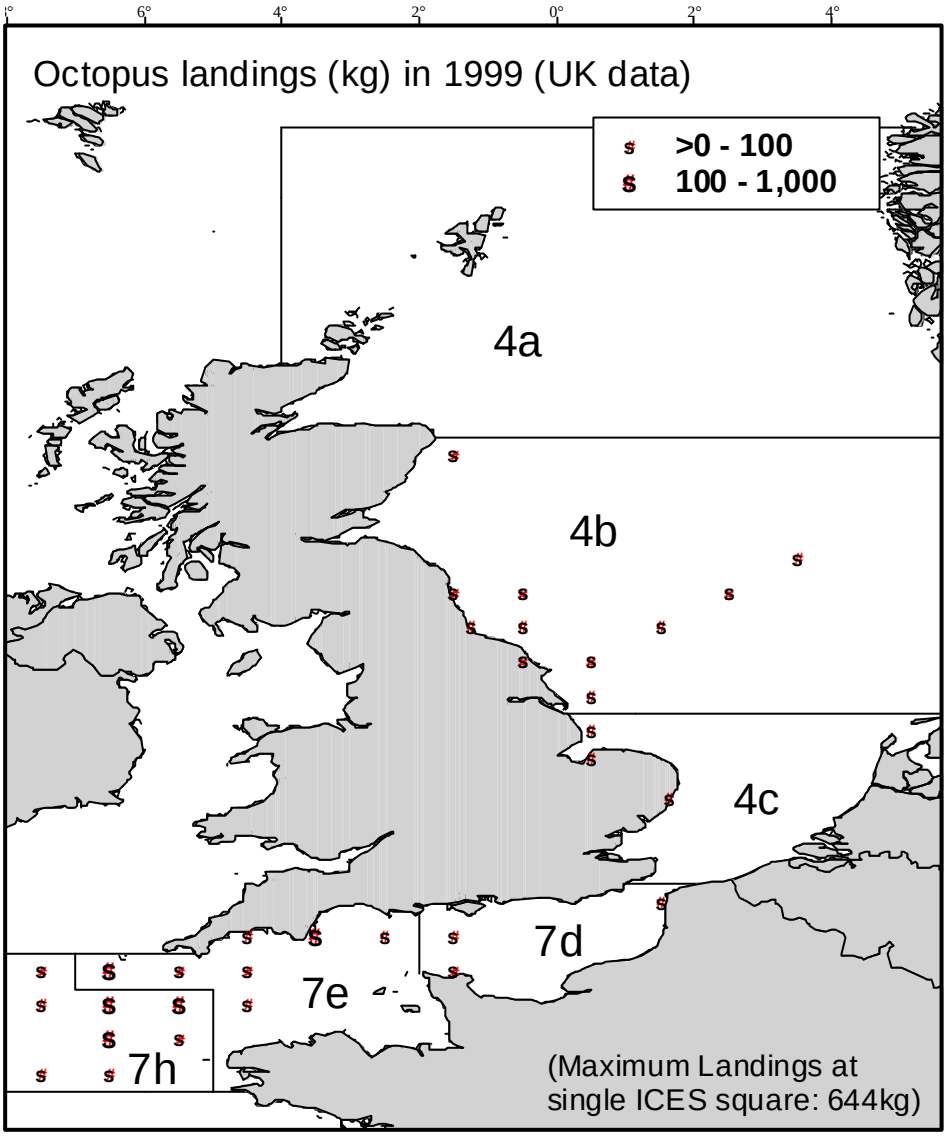

Figure 22. Landed catches of octopus from ICES areas IV and VII by Scottish and English vessels in 2000.