An Overview of Cephalopods Relevant to the SEA 4 Area

A review on behalf of the Department of Trade and Industry

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Contents

1. Introduction

This review is a component of the information base of the Strategic Environmental Assessment (SEA 4) conducted by the Department of Trade and Industry. The SEA 4 area is limited by the north Scottish coast in the south, the Orkney and Shetland archipelagos in the east and the former "White zone" (the formerly disputed maritime boundary between Faroese waters and UK waters) on the west (Figure 1). A small part of the white zone (SEA 1, Figure 1) is excluded from SEA 4. Some of the general background material presented here is taken from the report on cephalopods in the SEA 2 and 3 areas (Pierce *et al.*, 2002). In contrast to the SEA 2 and 3 areas, the SEA4 area extends beyond the 200 m isobath into deeper waters along the shelf edge and into the Faroe-Shetland Channel.

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 4 area includes parts of ICES fishery areas IV (Northern division, IVa) and VI (Eastern division, VIa), as well as small parts of areas Vb and IIa (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 molluscs, characterised by rapid growth rates, and are important predators and prey in oceanic and coastal environments. Cephalopods have been found in the stomachs of a wide variety of fish, marine mammals and seabirds. Cannibalism has also been frequently recorded in cephalopods. In contrast to other molluscs, most cephalopods lack an external shell, are highly mobile as adults and occupy similar ecological niches to predatory fish. Cephalopod eyes resemble vertebrate eyes and many species show complex behaviour patterns - cephalopods may be the most intelligent invertebrates.

The class Cephalopoda comprises three major divisions, of which two, the Decapoda (squid) and the Octopoda, are represented in the SEA 4 area. They range in size from bobtail squid (Sepiolidae) a few centimetres in length to giant squid (*Architeuthis* sp.) up to 20m in length. The main cephalopod species of economic importance in the SEA 4 area is the long-finned (loliginid) squid *Loligo forbesi.* Several other species that are of economic importance in other areas are also present: the short-finned (ommastrephid) squids *Todarodes sagittatus, Todaropsis eblanae* and *Illex coindetii* and the octopus *Eledone cirrhosa* (Pierce and Guerra, 1994).

Many other cephalopods have been recorded in UK waters, although little is known about the cephalopod fauna off the continental shelf. Collins *et al.* (2001) lists 29 species as occurring in waters ranging from 150 to 4850 m in the north-east Atlantic: the sepiolids *Sepiola atlantica*, *Sepietta oweniana*, *Rondeletiola minor, Neorossia caroli* and *Rossia macrosoma,* the squids *Loligo forbesi*, *Todaropsis eblanae*, *Todarodes sagittatus*, *Histioteuthis reversa*, *H. bonnellii*, *Teuthowenia megalops*, *Galiteuthis armata*, *Helicocranchia pfefferi*, *Octopoteuthis* sp., *Gonatus steenstrupi* and *Mastigoteuthis* sp. and the octopuses *Eledone cirrhosa*, *Benthoctopus ergasticus*, *B. piscatorum*, *Bathypolypus arcticus*, *B. sponsalis*, *Octopus saluti, Graneledone verrucosa*, *Opistoteuthis massyae*, *O. grimaldii*, *Stauroteuthis syrtensis*, *Cirroteuthis muelleri, Cirrothauma murrayi* and *Grimpoteuthis* spp. This list is not exhaustive; indeed the deep-water octopus *Haliphron atlanticus* was reported in the SEA 4 area by Collins *et al.* (1995).

Although most of these species are not common and have not been the subject of a fishery they may play an important role in the ecosystem and many appear repeatedly in the stomach contents of marine mammals. The small bobtail squid (Sepiolidae) are frequently recorded in the diet of porpoises (Santos *et al.*, In Press) and many oceanic squid species occur in the diets of sperm, northern bottlenose and Cuvier's beaked whales (Santos *et al.*, 1999; 2001b,d; 2002). The Faroe-Shetland Channel is a known habitat and migration route for teuthophagous whales.

Fishery 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* (Anon., 1999). At the end of the 1980s, both *Todarodes sagittatus* and *Todaropsis eblanae* were being caught regularly in Shetland waters and there was a substantial fishery for *Todarodes sagittatus* off Norway (Joy, 1989; Hastie *et al.*, 1994).

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 (Anon., 2002).

Produced water is currently the most significant routine discharge into the environment associated with oil-production operations (Sheahan *et al.*, 2001). Produced wastes contain various metals (Neff *et al.*, 1987). It is thought that if industrial effluents containing trace metals pollute the habitat, the heavy metal content of seafood will increase (Kunisaki, 2000). Demersal shellfish and crustaceans tend to contain particularly high levels of metals. Various studies on cephalopods report high levels of cadmium and mercury (e.g. Craig, 1996; Monteiro *et al.*, 1992; Bustamante *et al.*, 1998a; Frodello *et al.*, 2000). The high concentration of some metals in shellfish is a natural phenomenon, not necessarily related to pollution, but higher concentrations might be expect in polluted waters. Other considerations in relation to the environmental impact of oil extraction include the possible disruption of cephalopod spawning activity by exploration and drilling.

This report focuses mainly on the species of fishery importance: the loliginid squid *Loligo forbesi* and the ommastrephid squid *Todarodes sagittatus* and *Todaropsis eblanae* together with the octopus *Eledone cirrhosa*. Brief accounts of other commonly occurring cephalopod species are also provided, including deep-water species that are present in the Faroe-Shetland Channel.

2. Life history and distribution

2.1. Long-finned squid

The squid species of major commercial importance in European fisheries belong to the Loliginidae or long-finned squids. These are species of the Continental Shelf and are probably not present in waters of more than 400m depth. They live on or near the sea bottom, sometimes ascending into midwater and to the surface (Nesis, 1987). Although all short-lived species, the females produce relatively few (some thousands) large eggs, which are deposited in strings attached to the substrate. In South African waters, spawning of the closely related

Loligo vulgaris reynaudii takes place on coarse sand and reefs (Augustyn, 1990). The populations are thus potentially vulnerable to disturbance of the spawning grounds.

In southern Europe, the main species caught is *Loligo vulgaris* but from the English Channel northwards catches are increasingly dominated by *Loligo forbesi*. Smaller loliginid squid of the genus *Alloteuthis* are also present in UK waters but are of no direct commercial value. Again there are two species, of which only *Alloteuthis subulata* is likely to occur in the SEA4 area.

Loligo forbesi

The veined squid *Loligo forbesi* (Steenstrup, 1856) is a neritic species occurring in coastal waters from 20°N (NW Africa) to 60° N (SW Norway) in the eastern Atlantic, including the North Sea and the Mediterranean but not the Baltic (Guerra and Rocha, 1994; Martins, 1982). It forms the basis of a significant by-catch fishery in UK waters (Pierce *et al.*, 1994b) with landings as high as 3500 t per year (Collins *et al.*, 1997).

In Scottish waters *Loligo forbesi* breeds mainly from December to February, although breeding animals are also recorded in May. There are two main pulses of recruitment, in April and November with small numbers of recruits present throughout most of the year (Lum-Long *et al.*, 1992; Pierce *et al.*, 1994b; Collins *et al.*, 1997, 1999). Comparing with earlier work of *Loligo forbesi* in the English Channel (Holme *et al.*, 1974), which reports the existence of winter and summer breeding populations, it seems that the Scottish population is largely winter breeding.

Animals mature over a range of sizes. Although males often reach a larger size than females, a significant proportion of males mature at a smaller size. The two principal cohorts identified in Scottish waters typically recruit at different sizes into the fished population leading to two different size classes at maturity in both male and female squid (Collins *et al.*, 1997, 1999; Shaw *et al.*, 1999).

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; Pierce *et al.*, 2001). Spawning grounds have not been documented. However, mature squid are recorded throughout Scottish waters in winter and eggs of *Loligo forbesi* have been recorded in trawls off Shetland (Lum-Kong *et al.*, 1992) and are regularly found on creel lines.

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).

The main Scottish fishery for *Loligo forbesi* occurs in coastal waters and usually exhibits a marked seasonal peak around October and November, corresponding to the occurrence of pre-breeding squid (Howard, 1979; Howard *et al.*, 1987; Pierce *et al.*, 1994c). 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. Research trawling surveys record squid in the SEA4 area in all seasons, but with highest concentrations recorded in February, west of Shetland (Pierce *et al.*, 1998).

Alloteuthis subulata

The small loliginid squid *Alloteuthis subulata* (Lamarck, 1798) is often taken in trawl hauls alongside *Loligo forbesi*, although it has no commercial value and is normally discarded. There are no data on abundance in Scottish waters. The only recent study on the biology of this species in UK waters was by Nyegaard (2001), based on samples collected in the Irish Sea.

It is however the cephalopod species most commonly recorded in stomach contents of demersal fish (Daly *et al.*, 2001) and may thus have an important ecological role.

2.2. Short-finned squid

Three of the squid species occurring in the SEA4 area belong to the Ommastrephidae, or short-finned squids: *Todarodes sagittatus*, *Todaropsis eblanae* and *Illex coindetii*. The first two of these species have been recorded with sufficient regularity in the NE Atlantic to be the subject of several studies, including some work carried out in the SEA 4 area.

Ommastrephids occur in both inshore and offshore waters, migrating over long distances between feeding and breeding grounds during their life cycle. They live both at the sea bottom and in the pelagic zone, performing diel vertical migrations to the surface at night (Nesis, 1987). Although some ommastrephid species (e.g. *Illex argentinus* in the SW Atlantic) follow very predictable migration routes and support directed fisheries, the occurrence of *Todarodes sagittatus* and *Todaropsis eblanae* in the SEA 4 area (and UK waters generally) is probably best described as sporadic. Although routinely recorded in small numbers during discard trips (FRS Marine Laboratory, unpublished data), years of high abundance are probably infrequent.

Unlike loliginid squid, ommastrephids produce large numbers of small eggs, deposited on the bottom or in mid-water. Spawning areas of the species occurring in the SEA 4 area are not presently known.

Todarodes sagittatus

The European flying squid *Todarodes sagittatus* (Lamarck, 1798) is a widely distributed bentho-pelagic species. It is found in the Mediterranean and in the North-east Atlantic from the Arctic to around 13°S (Roper *et al.*, 1984; Guerra, 1992). It has been recorded from surface waters to depths of 4500 m (Collins *et al.*, 2001) although most specimens have generally been caught in waters less than 1000 m deep (Roper *et al.*, 1984). Its presence in coastal waters to the west of Norway, Scotland, Ireland and Portugal is seasonal (Lordan *et al.*, 2001) and thought to be a consequence of extensive geographical migrations from coastal feeding grounds in Northern waters to hypothetical spawning grounds in mid-Atlantic deep waters (Borges and Wallace, 1993). Occurrence and catches of *T. sagittatus* in Northern

European waters seem to be related to influxes of Atlantic water and the fluctuating strength of its current-system (Wiborg, 1972; Wiborg and Gjøsæter, 1981).

T. sagittatus is generally considered to be an annual species (Rosenberg *et al.*, 1980; Arkhipkin *et al.*, 1999) although a 2-year life cycle has been suggested (Lordan *et al.*, 2001). Breeding seems to be protracted with two peaks occurring, one in spring and one in autumn (Rosenberg *et al.*, 1980; Wiborg *et al.*, 1983; Wiborg and Beck, 1984; Roper et *al.*, 1984; Lordan *et al.*, 2001). There is evidence for there being two or more populations coexisting in Northern European waters (Borges and Wallace, 1993).

In years of abundance *T. sagittatus* moves inshore during summer and autumn months, where it can be caught in large numbers (Wiborg and Gjøsæter, 1981; Sundet, 1985; Joy, 1989; Lordan *et al.*, 2001). Catches in northern coastal waters are made up mainly of female immature specimens which suggests that inshore migration here is mainly carried out by females and seems to be serving feeding purposes only (Wiborg *et al.*, 1982a; Sundet, 1985; Joy, 1989; Borges and Wallace, 1993; Boyle et *al.*, 1998).

T. sagittatus has been the object of a significant directed fishery by several northern countries in the past, notably in Norway between 1980 and 1987 (see Sundet, 1985). *Todarodes* invaded coastal waters of the Faeroe Islands, Southwest Iceland and west and north coasts of Norway in late summer and autumn, with some squids migrating into the North Sea (Wiborg, 1972; Sundet, 1985). *Todarodes* was also taken as by-catch by demersal trawlers around Shetland where it appeared in large numbers at the same time as in Norway (August to December) (Joy, 1990). However there is no market for the species in Scotland and it is therefore usually discarded by Scottish fishing vessels (Joy, 1989). Since 1990, there has been no directed fishery for this species in Norway due to the disappearances of the yearly invasions, although catches of 352 tonnes and 190 tonnes of short-finned squid, presumed to be *T. sagittatus*, were reported in 1995 and 1997 respectively (Anon., 2002).

Todaropsis eblanae

The lesser flying squid *Todaropsis eblanae* (Ball, 1841) is a demersal species found in the Mediterranean and throughout the Eastern Atlantic from Shetland to 36°S. It has been recorded at depths from 20 m to 700 m over sandy and muddy bottoms (Guerra, 1992). Males are recorded as being smaller on average than females (maximum sizes were 141 mm for males and 205 mm for females in samples taken from Shetland waters) (Hastie *et al.*, 1994).

In Scottish waters, *T. eblanae* is considered to take 1-2 years to reach maximum size. It mates and spawns from late summer to early autumn (although small numbers of mature squid are found throughout the year (Hastie *et al.*, 1994).

T. eblanae has been listed as scarce in Scottish waters although several incidences of large squid numbers have been recorded in the past - it was regularly taken in trawl hauls off Aberdeen in the early 1990s. Hastie *et al.* (1994) related this sporadic high abundance in northern waters with influxes of high-salinity water in the area. No commercial landings of this species have been reported from the North Sea since 1995 (Anon., 2002).

Illex coindetii

Illex coindetii (Vérany, 1839) is a demersal neritic species found in the Mediterranean and in the North-east Atlantic as far north as the Oslo Fjord and the North Sea (~59°N) (Roper *et al.*, 1998). It has been recorded from the surface to 1100 m depth although more commonly in water between 100-400 m (Guerra, 1992). No commercial landings of this species have been reported in Scottish waters but it is occasionally recorded during research trawling surveys.

2.3. Deep-water squid

Various deep-water squid are likely to be present in the Faroe-Shetland Channel, of which the most important is probably *Gonatus fabricii*.

The northern end of the SEA4 area overlaps the range of the Arctic squid *Gonatus fabricii* (see Bjørke, 1995). This species is a very important food source for marine predators in Arctic waters (Bjørke, 2001). Present interest in its potential as a human food source (Wiborg, 1979) has resulted in surveys being carried out in Norwegian waters. Bjørke (1995) estimated the stock of juvenile *Gonatus* in the Norwegian Sea in July 1994 as 2-3 million tonnes.

G. fabricii is an oceanic species considered to be the most abundant squid in the Arctic and Sub-arctic area of the North Atlantic (Kristensen 1983). Moiseev (1991) recorded the species at depths between 350 m and 1200 m, with no obvious dial vertical migration. Juveniles are caught in the surface layers but, at a length of 50-70 mm, *G. fabricii* disappears from the surface, probably moving to deeper waters (Bjørke 1995). Squids of 80 - 250 mm have been caught at depths of 200-550 m with deep pelagic and bottom trawls (Wiborg et al. 1982b, 1984). Off West Greenland, males are thought to mature at a mantle length of about 200 mm (probably aged 2 years). Females mature at mantle lengths larger than 200 mm, aged 2-3 years (Kristensen 1983).

The main spawning period for *G. fabricii* in the Norwegian Sea is from December to April (Bjørke 1995). However, very few mature specimens or egg masses have ever been found (the first record of putative egg masses, taken in a pelagic trawl, is in Bjørke *et al.* 1997), which led Kristensen (1984) to suggest that spawning probably takes place at depths greater than 200 m. Areas of spawning have not been definitely identified but Wiborg (1979) considered that they may coincide with localities where bottlenose whales (*Hyperoodon ampullatus* Forster) are abundant (well to the North of he SEA 4 area). This is supported by the finding of squid spermatophores in the stomach of a bottlenose whale that had fed exclusively on *G. fabricii* (Lick and Piatkowski 1998).

2.4. The curled octopus

The Octopoda are usually divided into two sub-orders (Cirrata and Incirrata), characterised by the presence or absence of tactile cirri on the sides of the suckers. The cirrates are confined to deep water and of no commercial fishery value. There is only one incirrate octopus of commercial value in the SEA 4 area, the curled octopus *Eledone cirrhosa* (Lamarck, 1798).

Eledone cirrhosa 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. In Scotland, females have been recorded to reach up to 2000 g, although males bigger than 500 g have rarely been found. It is generally found at depths between 50 and 300 m, on a wide variety of sea-bed types from soft mud to rocky bottom (Boyle, 1983). Collins *et al.* (2001) report records of *E. cirrhosa* from depths of up to 490 m.

Eledone cirrhosa has a life-span of 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).

This species is often taken in Scottish waters as by-catch in demersal fishing mainly for cod and haddock, but rarely landed due to the absence of a domestic market in Scotland. It is however eaten in southern Europe. Stephen (1944) noted that catches of *Eledone* showed wide fluctuations, with large numbers of octopus stranded on the shore in some years.

2.5. Other cephalopods

On the Continental Shelf, the Sepiolidae are probably the most significant cephalopod group, other than those discussed above. The bobtail squid *Sepiola atlantica* (Orbigny, 1840) is one of at least six sepiolid species present in Scottish waters. 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.

In deeper water, on the shelf edge and beyond, the cephalopods are generally less well known – and none are of commercial importance. Collins et al. (2001) review records of deep-water benthic and bentho-pelagic cephalopods in the north-east Atlantic, based on specimens collected from commercial and research trawling. The sepiolids *Neorossia caroli* (400-1535 m), and *Rossia macrosoma* (205-515 m) were recorded in deep water. Three incirrate octopod genera were recorded in deep water: *Benthoctopus* and *Bathypolypus* were identified at depths of 250-2700 m while *Graneledone verrucosa* was caught at depths of 1785-2095 m. Cirrate octopods dominated the cephalopod catch from the deeper areas: *Opisthoteuthis massyae* (877 to 1398 m), *O. grimaldii* (2165 to 2287 m), *Stauroteuthis syrtensis* (1425 to 3100 m), *Cirroteuthis muelleri* (700 to 4854 m), *Cirrothauma murrayi* (2430 to 4850 m) and *Grimpoteuthis* sp. (1775 to 4877 m). Comprise a regular by-catch in benthic trawls at 800 m to 1200 m depth off the west coast of Scotland (Daly et al., 1998).

An immature female of the incirrate octopus *Haliphron atlanticus* (Steenstrup, 1861) was captured by a bottom trawler in Shetland at a depth of around 180 m in 1994 (Collins *et al*., 1995). This was the first published record of this species in Scottish waters and even if the species is probably relatively common (*Haliphron* beaks have been found in a number of whale stomachs), it is rarely caught in nets. *H. atlanticus* is a cosmopolitan, gelatinous species that can reach 2 m in length. It is believed to live at the bottom, probably reaching depths of 3,180 m (Guerra, 1992).

It is worth pointing out that oil industry activities can have a positive impact on our knowledge of deep-water cephalopods. Images obtained by ROVs can provide useful data on distribution of rarely seen species.

3. Ecology: trophic interactions

Cephalopods are generally considered to be voracious opportunistic predators (e.g. Boyle, 1990; Lordan *et al.*, 1998) and consume a wide range of crustaceans, fish and other cephalopods. Cephalopods are also important prey for a wide variety of fish, marine mammals and birds (e.g. Furness, 1994; Pierce and Santos, 1996; Daly *et al.*, 2001; Santos *et al.*, 2001a).

There are few estimates of the amounts of cephalopods eaten by predators in the North-east Atlantic. Santos *et al.* (2001a) estimated that sperm whales (*Physeter macrocephalus*) overwintering in Norwegian and Icelandic waters could consume around 540,000 and 996,000 tonnes of cephalopods respectively, indicating that important cephalopod populations must exist in the area to support the sperm whales and other teuthophagous cetacean species, e.g., Northern bottlenose whales *Hyperoodon ampullatus* (Santos *et al.*, 1999, 2001b,d, 2002).

Remains of at least some cephalopods (e.g. *Loligo* sp.) have been found in the stomach contents of most species of cetaceans found in NE Atlantic waters: e.g. bottlenose dolphin (*Tursiops truncatus*), striped dolphin (*Stenella coeruleoalba*), white beaked dolphin (*Lagenorhynchus albirostris*), pilot whale (*Globicephala melas*) and Risso's dolphin (*Grampus griseus*) (Boyle and Pierce, 1994; González *et al.*, 1994; Santos *et al.*, 1994, 1995, 2001c). In recent studies, Risso's dolphins were found to have mainly cephalopod remains in their stomachs, dominated by *Eledone cirrhosa* dominated (Santos *et al.*, 1994, 1995). The minke whale (*Balaenoptera acutorostrata*) is also thought to take some squid (Clarke, 1986; Pierce, 1992).

The most common cetacean species in the SEA 4 area, the harbour or common porpoise (*Phocoena phocoena*), although primarily a fish eater, has often been found with remains of sepiolids and the small loliginid squid *Alloteuthis* in its stomach (Santos and Pierce, 2003).

Cephalopods are commonly found in the diets of both grey seals (*Halichoerus grypus*) and harbour seals (*Phoca vitulina*) in Scotland. The most important cephalopod prey of UK seals appears to be the octopus *Eledone cirrhosa*. Sepiolids are also frequently recorded, with *Loligo forbesi* relatively rare in the diet (e.g. Brown and Pierce, 1997, 1998; Brown et al., 2001; Pierce and Santos, 1996, 2003). *E. cirrhosa*) is 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).

For seabirds, ommastrephids are the main cephalopod prey recorded with none of the major seabird populations in the area feeding regularly on loliginid squid (Boyle and Pierce, 1994; Furness, 1994). Fulmar (*Fulmarus glacialis*) and Manx shearwater (*Puffinus puffinus*) have been recorded as the main cephalopod consumers, taking ommastrephid squid from the top 2 or 3 metres of the water column (Furness, 1994).

Cephalopods have been found in the diet of a wide variety of fish species, although generally as a small proportion (ICES, 1988; Hislop *et al.*, 1983, 1991; Daan, 1989; Hislop, 1997; Daly *et al.*, 2001; Velasco *et al.*, 2001). They have been found to constitute a substantial part of the diet in relatively few species such as monkfish (*Lophius piscatorius*). Not all fish diet studies have identified the cephalopods remains. However, Hislop *et al.* (1991) noted that, where cephalopods in fish stomachs were identified, they were usually the small loliginid squid *Alloteuthis* spp.

Cephalopods are active predators feeding on a wide variety of prey. The diet of *Loligo forbesi* has been studied in Scottish waters by several authors (Boyle and Pierce, 1994; Pierce *et al.*, 1994c; Collins and Pierce, 1996). Results showed that fish is the main prey with sandeels (*Ammodytes* sp.), whiting (*Merlangius merlangus*) and *Trisopterus* sp., and Clupeidae the most important fish taxa. The importance and size of fish in the diet increases with squid size (Boyle and Pierce, 1994; Pierce *et al.*, 1994c; Collins and Pierce, 1996).

Dietary studies on *Todarodes sagittatus* have been carried out in Norwegian waters (e.g. Wiborg and Gjøsæter, 1981, Wiborg *et al.*, 1982, Breiby and Jobling, 1985), Iceland (Jonsson, 1998), Scotland (Joy, 1990) and Ireland (Lordan et *al.*, 2001). Fish (mainly pelagic species from a wide variety of depths) was found to be the most important prey type in all studies, closely followed by euphausiids and decapod shrimps. Cephalopods were also found by most authors, including evidence of cannibalism. Between-area variation in diet has led to the suggestion that *T. sagittatus* is an opportunistic predator (Lordan *et al.*, 2001).

Illex coindetii and *Todaropsis eblanae* have also been described as opportunistic predators, with a diet varying between areas. Thus the most important prey are blue whiting (*Micromesistius poutassou*) off Northwest Spain (Rasero et al., 1996) and 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). Lordan *et al.* (1998) also recorded ontogenetic variation in diet, with small squid taking mainly crustaceans (euphausids) while bigger squid predominantly ate fish and cephalopods.

The diet of *Eledone cirrhosa* in Scottish waters is dominated by crustaceans, although molluscs have also been recorded. Fishermen have reported finding *Eledone* inside creels for lobster (*Homarus gammarus*), edible crab (*Cancer cancer*) and Norwegian lobster (*Nephrops norvegicus*) together with the empty carapaces of their intended catch. In other areas, brittlestars (*Ophiura* sp.) and fish have also been recorded (Boyle, 1983).

4. Fisheries and trends in abundance

Data on cephalopod landings from the ICES area are compiled by the ICES Working Group on Cephalopod Fisheries and Life History (WGCEPH) (e.g. Anon., 2002). However, these compilations are based on ICES fisheries sub-divisions, whereas the SEA 4 area cuts across two major fisheries subdivisions (IVb and VIa) as well as taking in small parts of two others (Vb and IIa). Thus we have reconstructed trends for the SEA 4 area by reference to the source fishery databases.

General patterns in cephalopod landings can be inferred from data presented in the WGCEPH report (Anon., 2002). No landings of short-finned squid or cuttlefish are reported by Scotland and landings of octopus amount to a few tonnes a year (Table 1). Loliginid squid thus represent the only significant landings of cephalopods in Scotland in recent years.

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.

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 (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). Landings appear to have declined since 1998 (Table 1, Figure 3). However, historical fishery 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 (Pierce et al., 1994d).

Landings from the SEA 4 area represent a significant part of the total UK landings for cephalopods only for loliginid squid. Approximately 320 tonnes of loliginid squid was landed from catches in the SEA 4 area in 1998, around 15% of the UK total for this category for 1998 (Figure 4). The proportion of landed catches in the SEA 4 area remained very similar in 1999 (12.7%) and 2000 (15.2%). French boats landed around 3.6 tonnes of loliginid squid caught in the SEA4 area in 1998 - plus 10 kg of short-finned squid. French data from 1999 onwards were not available to us at the time of writing this report.

It is instructive to examine month-to-month trends in loliginid squid landings (Figure 5). Landings from the SEA4 area follow a similar trend to UK totals in that peak landings occur in the winter. However, the proportion of landings arising from catches in SEA 4 also shows a consistent annual cycle, with between 25% and 50% of UK squid landings in June coming from this area. Mid-summer is typically the low point of squid abundance as the old adults die off and the main period of recruitment lies ahead. Thus the biological significance of the SEA4 area for *Loligo forbesi* in summer is presently difficult to interpret but it is possible that the first recruits of the year appear in this area.

The spatial distribution of landed catches of squid is illustrated in Figures 6 to 8. French fishery data were available for 1998 and are therefore included in Figure 6. The bulk of catches in 1998 were taken in shallower waters on the continental shelf. This pattern is essentially repeated in 1999 (Figure 7) and 2000 (Figure 8).

Landings per unit effort data provide a rough estimate of *Loligo* abundance. Maps of the distribution of LPUE (Figures 9-11) broadly support the idea that most squid are found on the continental shelf, but some high abundance values are recorded beyond the 200m isobath, suggesting that landings of squid from deeper water may be limited by low fishing effort.

4.2. Octopus

The octopus *Eledone cirrhosa* is a highly valued species in southern Europe. In Scotland, due to a combination of low catches by individual boats, problems with maintaining it in good condition and poor market prices, there is generally little profit in landing the species. Hence, it is usually discarded by Scottish fishermen (Daly *et al.*, 2001). In the UK as a whole, landings of octopus reached around 130 tonnes in 2000 according to ICES data (Anon., 2002), including 20 tonnes landed in Scotland. The UK fishery databases contain information on only 18 tonnes of octopus landings for the whole of the UK in 2000. This discrepancy is far greater than seen for other cephalopod categories and may be due to landings by smaller boats not entering the databases.

As most *Eledone cirrhosa* is discarded (or does not enter the database), 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 can give an indication of where the highest concentrations of octopus might occur. In fact, only two catches of octopus are recorded in the SEA 4 area during 1998-2000, both in 1998 (Figure 12). Since the amounts involved were extremely small (2 kg in each case), these results do no more than confirm the presence of octopus in the SEA 4 area.

5. Environmental and conservation issues

Having discussed the biology and ecology of cephalopods in Scottish waters in general and the SEA 4 area in particular, this section reviews conservation issues, including possible threats to cephalopod populations, in the context of relevant environmental legislation.

The United Kingdom is subject to international environmental legislation (principally directives agreed by the Council of the European Union). Directives of possible relevance (leaving aside the proposed amendments to the EC water pollution control legislation that will result from the Water Framework Directive) include the Dangerous Substances Directive (76/464/EEC), the Shellfish Growing Waters Directive (79/923/EEC), the Habitats Directive (92/43/EEC) and the Wild Birds Directive (79/409/EEC).

5.1. Environmental contamination

European and other international legislation increasingly emphasizes the importance of using Best Environmental Practice (BEP) as a complementary approach to discharge controls using Environmental Quality Standards (EQS) (OSPAR/PARCOM –The Paris Commission recommendations, proposed Water Framework Directive-WRF). This “combined approach” (BEP and EQS) to pollution control is suitable for the regulation of the environmental contaminants to the water. In addition to the EU directives, there is also the UK Red List Substances (their discharge to water should be minimised as far as possible).

The Dangerous Substances Directive (76/464/EEC) lists toxic substances, i.e. those that have deleterious effects on the aquatic environment and provide a framework for eliminating or reducing pollution by particularly dangerous substances. Toxic substances of concern to UK and European regulatory authorities appear on various lists of chemicals identified for priority action, such as Lists I and II of the Dangerous Substances Directive and the UK Red List established by the North Sea Conferences. List I substances include cadmium, chloroform, mercury, DDT, dichlorvos and carbon tetrachloride. List II substances include zinc, copper, nickel, chromium, lead, titanium and molybdenum.

Monitoring of the concentrations of contaminants in the marine environment is also undertaken to supply data to national and international baseline studies such as the Joint Assessment and Monitoring Programme (JAMP) of the Oslo and Paris Commissions and the United Kingdom National Monitoring Plan (Brown and Balls, 1997). The Marine Laboratory Aberdeen has provided data on marine contaminants in Scottish waters for the UK National Monitoring Plan and for Quality Status Reports that have been produced for waters around the UK. Other organisations involved in the National Monitoring Programme (NMP) for the marine monitoring in the United Kingdom are the following: Centre for Environment, Fisheries and Aquaculture Science (CEFAS); Department of the Environment, Transport and Regions (DETR); Environment Agency (EA); Environment and Heritage Service (EHS); Scottish Environment Protection Agency (SEPA) and the Scottish Executive's Environment and Rural Affairs Department (SEERAD).

Contamination related to the oil industry

The oil industry discharges large amounts of chemicals into the sea (e.g. 180,000 tonnes of chemicals were discharged into the UK sector of the North Sea in 1999). The associated issues have been described for the SEA 2 and 3 areas by Sheahan *et al.* (2001). Within the SEA4 area, the presence of oil receiving terminals at Sullom Voe (Shetland) and Flotta (Orkney) in the SEA 4 area has increased the potential for accidental spills and the risk of chronic environmental pollution.

Produced water is currently the main source of contaminants. Other inputs of oil include atmospheric inputs to the sea from flaring, accidental spillages from platforms or ships and the transport of oil in tankers. There are also oil discharges from land-based sources mainly as ballast water from tankers and oily water separated from the oil-water mix flowing through the pipelines. 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 metals include aluminium, copper, mercury, tin, and zinc (Dicks, 1982).

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 (Daan 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). Note however that oil-based muds have been largely replaced by less harmful alternatives, reducing the significance of drill cuttings as a source of contamination (Sheahan *et al.*, 2001)

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 (Daan and Mulder, 1996). However, maximum concentrations of cadmium recorded in drilling fluids are up to 50 times normal concentrations in marine sediments and maximum mercury concentrations are up to three times higher than in sediments (Table 2).

Impact of contaminants on cephalopods and the food chain

Cephalopods are known to accumulate high levels of certain contaminants, notably cadmium and mercury (Craig, 1996; Monteiro *et al.*, 1992; Bustamante *et al.*, 1998a; Frodello *et al.*, 2000). Cadmium is mainly accumulated in the digestive gland (hepatopancreas) of cephalopods (Finger and Smith, 1987; Miramand and Bentley, 1992; Bustamante, 1998; Bustamante *et al.*, 1998b) reaching up to 98% of the total body cadmium in some species. Cephalopods from sub-polar areas showed higher levels of cadmium than those living in temperate areas (Bustamante, 1998; Bustamante *et al.*, 1998a, b), despite exposure to soluble metals in natural seawater being extremely low in polar regions (Mart *et al.*, 1982; Donat and Bruland, 1995).

Cephalopods are regarded as key species in many marine ecosystems (Amaratunga, 1983; Rodhouse, 1989). They represent an essential link in marine trophic chains and are eaten by many marine top predators such as fish, birds and mammals (Clarke, 1996; Croxall and Prince, 1996; Klages, 1996; Smale, 1996). Thus, their role in the transfer of contaminants up the food chain is of particular interest. Cephalopods are considered to be a vector for the transfer of cadmium to top marine predators (Honda and Tatsukawa, 1983; Muirhead and Furness, 1988; Bustamante *et al.*, 1998b). The high bioavailability of cadmium in the digestive gland cells indicates a high potential for the trophic transfer of the metal to predators such as marine mammals and seabirds (Bustamante *et al.*, 2002).

Miramand and Bentley (1992) suggested that the digestive gland of cephalopods constitutes a good potential indicator of heavy metal concentrations in the marine environment. They measured the concentrations of 11 heavy metals (silver, cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead, vanadium and zinc) in a variety of tissues (digestive gland, branchial hearts, gills, digestive tract, kidney, genital tract, muscle, skin and shell) of two cephalopods, the octopus *Eledone cirrhosa* and the cuttlefish *Sepia officinalis*, collected from the French coast of the English Channel in October 1987. Both species displayed a similar pattern of accumulation: the digestive gland, branchial hearts and kidney were the major sites of concentration for all 11 metals; the digestive gland accumulated silver, cadmium, cobalt, copper, iron, lead and zinc, the branchial hearts accumulated high concentrations of copper, nickel and vanadium, and the kidney accumulated high concentrations of manganese, nickel and lead. The digestive gland, which constituted 6 to 10% of the animal by weight, contained over 80% of the total body burden of silver, cadmium and cobalt and from 40 to 80% of the total body burden of the other metals.

Storelli and Marcotrigiano (1999) measured cadmium and total mercury concentrations in flesh and hepatopancreas of 512 specimens of two species of cephalopods. Higher concentrations were observed in hepatopancreas than flesh and, for both elements, higher levels were found in spider octopus (*Octopus salutii*) than in broadtail squid (*Illex coindetii*).

The potential for bioaccumulation and biomagnification of metals in the food chain is illustrated by results from a survey was conducted by the Marine Laboratory Aberdeen (FRS, 1998). The mean concentrations of trace metals in squid (presumably *Loligo forbesi*), a fish (whiting) and various marine mammals are presented in Table 3. The Food Standards Committee's maximum recommended limits are also given for comparisons. The first point to make is that, in squid, levels of cadmium were thirty times those in whiting and exceeded recommended safe limits for food. Secondly, levels of all metals except copper were considerably higher in the marine mammals and the teuthophagous species had much higher levels of cadmium in their tissues than the piscivorous species.

The same study also provides some data on persistent organic pollutant levels in squid from Scottish waters although it should be stressed that the chemicals measured are not those normally associated directly with oil spills (Table 4). No sample contained a chlorinated biphenyl (CB) concentration falling into the "upper" category as proposed by OSPARCOM. However, the results confirm the influence of terrestrial inputs on marine contaminant concentrations and demonstrate that cephalopods do take up organic contaminants from the water.

Oil pollution and cephalopods

There have been various studies on the toxicity, uptake and depuration of petroleum hydrocarbons for shellfish, including cephalopods (Scott *et al.*, 1984). The effects of exposure to oil are influenced by the inherent sensitivity and susceptibility of the species and are a function of their life-history stage, habitat preference, behaviour and diet. Each stage has characteristics that directly control the likelihood and degree of impact during an incident (RPI, 1989). The physiological indicators of stress in shellfish and cephalopods have been documented (Scott *et al.*, 1984). Sub-lethal effects of oil exposure include depressed feeding, changes in respirations rates (both decreases and increases) reduced growth, decreased gonadal condition, tissue necrosis, and behavioural changes such as decreased burrowing and slower tactile responses. Application of chemical dispersants to an oil spill was thought, by Long and Holdway (2002) to be unlikely to adversely affect the Australian octopus *Octopus pallidus*.

As noted above, the contaminants in cephalopods that occasion most concern are the heavy metals. Oil exploration and drilling would exacerbate this problem only so far as they lead to increased input of metals into the food chain. As noted, drilling fluids can contain higher concentrations of cadmium and mercury than naturally present in surrounding marine sediments. Such increases can be biomagnified in teuthophagous cetaceans and similar effects are likely in human communities that have a substantial per-capita consumption of seafood. It may be noted that the human population in the SEA 4 area probably consumes very little squid or octopus caught in the area, but the squid caught are exported to southern Europe for human consumption.

5.2. Other conservation issues

The Habitats Directive (92/43/EEC) and the Wild Birds Directive (79/409/ECC) concern the protection and conservation of natural habitats and species. The main aim of the Directive is to promote the maintenance of biodiversity and requires Member States to work together to maintain or restore natural habitats and species. Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) collectively known as European marine sites (i.e. any SAC or SPA which extends below mean low water mark of spring tides) are designated in response to conservation needs. Marine SACs are designed to support and implement the Habitats Directive.

Cephalopods are (perhaps unsurprisingly) not listed in any of the Annexes of the Habitats Directive and are essentially unprotected. 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). However, the importance of cephalopods as a food source for top predators (fish, seabirds and marine mammals), their proposed value as environmental indicators, as well as general appeals to the maintenance of biodiversity, provide reasons for wishing to conserve their populations and the habitat that supports them.

All cephalopods present in the SEA 4 would, to a greater or lesser extent, be disturbed by displacement of the bottom sediment. However, cephalopod biodiversity is unlikely to be significantly affected by such displacement due to the localised nature of drilling operations.

As in other UK coastal areas, the only serious impacts are likely to occur if spawning grounds are disturbed. Although no spawning grounds of *Loligo forbesi* have been positively identified in the SEA 4 area, squid in spawning condition are caught every year in the area, particularly during January to March (Pierce *et al.*, 1994a; Boyle *et al.*, 1995).

Loliginid 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 thus possible.

Compared to the SEA 2 and 3 areas, the extension of the SEA 4 area into deep water potentially includes the spawning areas of deep-water cephalopods. Another point to note is that migrating *Loligo forbesi* will reach the SEA 4 area slightly earlier in the year than they reach the SEA 2 and 3 areas. The implication of this is unclear – breeding squid may be found slightly earlier or a greater proportion may simply migrate through the area and on into the North Sea.

6. Conclusions

- Cephalopod species of commercial importance in the SEA 4 area are the loliginid squid *Loligo forbesi*, the ommastrephid squids *Todarodes sagittatus* and *Todaropsis eblanae* and the octopus *Eledone cirrhosa*. At present no commercial catches of *T. sagittatus* or *T. eblanae* are being recorded. Many other cephalopod species are present in the area, including various poorly known deep-water species. Cephalopods are important prey items for various marine mammals and seabirds in both coastal and offshore waters.
- Cephalopods are taken almost exclusively as by-catch species in the SEA 4 area (with most of the short-finned squid and octopus being discarded) and, as such, are relatively unimportant species to the catching sector.

- 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. As in other areas, spawning grounds in the SEA 4 have not been documented. Loliginid squid undoubtedly enter the area to spawn.
- Video records obtained by oil industry ROVs may provide useful data on the distribution of deep-water cephalopods.
- It is probable that the overall impact on cephalopods and cephalopod fisheries in the SEA 4 area caused by further oilfield development would be slight.

7. Acknowledgements

Work on this report was commissioned and funded by Geotek Ltd and Hartley-Anderson Ltd as part of the UK Government Department of Trade and Industry's Strategic Environmental Assessment programme. The authors thank Fisheries Research Services Marine Laboratory, Aberdeen, Dr Jean-Paul Robin of the University of Caen, and staff at IFREMER for provision of fishery data.

8. References

Amaratunga, T., 1983. The role of cephalopods in the marine ecosystem. In I.F. Caddy (editor), Advances in assessment of world cephalopod resources. FAO Fishery Technical Paper 231, pp.379-415.

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

Anonymous, 2002. Report of the Working Group on Cephalopod Fisheries and Life History. International Council for the Exploration of the Sea CM 2002/G:04.

Arkhipkin, A., Laptikhovsky, V. and Golub, A., 1999. Population structure and growth of the squid *Todarodes sagittatus* (Cephalopoda: Ommastrephidae) in north-west African waters. Journal of the Marine Biological Association of the United Kingdom 79, 467-477.

Augustyn, C.J., 1990. Biological studies on the chokker squid *Loligo vulgaris reynaudii* (Cephalopoda: Myopsida) on spawning grounds off the south-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 Zoology 26, 164-181.

Balguerías 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.

Bjørke, H. 1995. Norwegian investigations on *Gonatus fabricii* (Lichenstein). International Council for the Exploration of the Sea CM 1995/K:12

Bjørke, H., 2001. Predators of the squid *Gonatus fabricii* (Lichtenstein) in the Norwegian Sea. Fisheries Research 52, 113–120.

Bjørke, H., Hansen, K. and Sundet, R.C., 1997. Egg masses of the squid *Gonatus fabricii* (Cephalopoda, Gonatidae) caught with pelagic trawl off northern Norway. Sarsia 82, 149-152.

Borges, T. C. and Wallace, J. C., 1993. Some aspects of the fishery biology of the ommastrephid squid *Todarodes sagittatus* (Lamarck, 1798) from the Northeast Atlantic.

In: T. Okutani, R. K. O'Dor and T. Kubodera (editors), Recent Advances in Cephalopod Fisheries Biology. Tokai University Press, Tokyo, pp. 25-36.

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., Collins, M.A. and Williamson, G.R., 1998. The cephalopod by-catch of deep-water trawling on the Hebrides slope. Journal of the Marine Biological Association of the United Kingdom 78, 1023-1026.

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.

Breiby, A. and Jobling, M., 1985. Predatory role of the flying squid (*Todarodes sagittatus*) in north Norwegian waters. Northwest Atlantic Fisheries Organisation Scientific Council Studies 9, 125-132.

Brown, E.G. and Pierce, G.J., 1997. Diet of harbour seals at Mousa, Shetland, during the third quarter of 1994. Journal of the Marine Biological Association of the United Kingdom 77, 539-555.

Brown, E.G. and Pierce, G.J., 1998. Monthly variation in the diet of harbour seals in inshore waters along the southeast Shetland (UK) coastline. Marine Ecology Progress Series 167, 275-289.

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.

Brown, F.M.J. and Balls, P.W., 1997. Trace metals in fish and shellfish from Scottish waters. Scottish Fisheries Research Report 60, 1-36.

Bustamante, P., 1998. Etude des processus de bioaccumulation et de detoxication d'elements traces (metaux lourds et terres rares) chez les mollusques cephalopodes et bivalves pectinides. Implication de leur biodisponibilite pour le transfert vers les predateurs. Thesis, University of La Rochelle, France.

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

Bustamante, P., Cherel, Y., Caurant, F. and Miramand, P., 1998b. Cadmium, copper and zinc in octopuses from Kerguelen Islands, Southern Indian Ocean. Polar Biology 19, 264-271.

Bustamante, P., Cosson, R.P., Gallien, I., Caurant, F. and Miramand, P., 2002. Cadmium detoxification processes in the digestive gland of cephalopods in relation to accumulated cadmium concentrations. Marine Environmental Research 53, 227-241.

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.

Clarke, M.R., 1996. Cephalopods as prey. III. Cetaceans. Philosophical Transactions of the Royal Society London Series B 351, 1053-1065.

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.

Collins, M.A., Brown, E.G. and Pierce, G.J., 1995. The octopus *Haliphron atlanticus* Steenstrup caught in Shetland waters. The Shetland Naturalist 1, 123-124.

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., Yau, C., Allcock, L. and Thurston, M.H., 2001. Distribution of deep-water benthic and bentho-pelagic cephalopods from the north-east Atlantic. Journal of the Marine Biological Association of the United Kingdom 81, 105-117.

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.

Croxall, J.P. and Prince, P.A., 1996.Cephalopods as prey. I. Seabirds. Philosophical Transactions of the Royal Society London Series B 351, 1023-1043.

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., Boyle, P.R. and Collins, M.A., 1998. Reproductive status of *Opisthoteuthis* sp. over an annual cycle. South African Journal of Marine Science 20, 187-192.

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.

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

Donat, J.R. and Bruland, K.W., 1995. Trace elements in the oceans. In: B. Salbu and E. Steinnes (editors), Trace elements in natural waters. Boca Raton: CRC Press, pp. 247-281.

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., 1992. Mollusca, Cephalopoda. In: M.A. Ramos Sánchez et al. (editors), Fauna Ibérica, Madrid: Museo Nacional de Ciencias Naturales, CSIC, 327 pp.

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

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., 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. International Council for the Exploration of the Sea C.M.1979/K36.

Howard, F.G., Ngoile, M.A. and Mason, J., 1987. *Loligo forbesi*: its present status in Scottish fisheries. International Council for the Exploration of the Sea 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.

Joy, J.B., 1990. The fishery biology of *Todarodes sagittatus* in Shetland waters. Journal of Cephalopod Biology 1, 1-19.

Klages, N.T.W., 1996. Cephalopods as prey. II. Seals. Philosophical Transactions of the Royal Society London Series 351, 1045-1052.

Kristensen, T.K., 1983. *Gonatus fabriicii*. In: Boyle PR (ed) Cephalopod Life Cycles, Volume 1. Species Accounts. Academic Press, London, p 159-174.

Kristensen, T.K., 1984. Biology of the squid *Gonatus fabricii* (Lichtenstein, 1818) from West Greenland waters. Meddelelser om Gronland, Bioscience 13, 3-20.

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.

Lick, R. and Piatkowski, U., 1998. Stomach contents of a northern bottlenose whale (*Hyperoodon ampullatus*) stranded at Hiddensee, Baltic Sea. Journal of the Marine Biological Association of the United Kingdom 78, 643-650.

Long, S.M. and Holdway, D.A., 2002. Acute toxicity of crude and dispersed oil to *Octopus pallidus* hatchlings. Water Research 36, 2769-2776.

Lordan, C., Burnell, G.M. and Cross, T.F., 1998. The diet and ecological importance of *Illex coindetii* and *Todaropsis eblanae* (Cephalopoda: Ommastrephidae) in Irish waters. South African Journal of Marine Science 20, 153-163.

Lordan, C., Collins, M.A., Key, L.N. and Browne, E.O., 2001. The biology of the ommastrephid squid, *Todarodes sagittatus,* in the north-east Atlantic. Journal of the Marine Biological Association of the United Kingdom 81, 299-306.

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.

Mart, L., Rutzel, H., Klahre, P., Sipos, L., Platzek, U., Valenta, P. and Nurnberg, H.W., 1982. Comparative studies on the distribution of heavy metals in the oceans and coastal waters. The Science of the Total Environment 26, 1-17.

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.

Miramand, P. and Bentley, D., 1992. Concentration and distribution of heavy metals in tissues of two cephalopods, *Eledone cirrhosa* and *Sepia officinalis* from the French coast of the English Channel. Marine Biology 114, 407-414.

Moiseev, S.I., 1991. Observation of the vertical distribution and behaviour of necktonic squids using manned submersibles. Bulletin of Marine Science 49, 446-456.

Monteiro, L.R., Porteiro, F.M and Gonçalves, 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.

Nesis, K.N., 1987. Cephalopods of the world: squid, cuttlefishes, octopuses, and allies. English-language edition. TFH Publications, Neptune City, New Jersey.

Nyegaard, M., 2001. What does it for a squid? An analysis of reproductive behaviour, demography, diet and spatial distribution of the European common squid (*Alloteuthis subulata*) in the Irish Sea. Unpublished MSc thesis, University of Tromsø.

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, 22 pp.

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.

Pierce, G.J. and Santos, M.B., 2003. Diet of harbour seals (*Phoca vitulina*) in Mull and Skye (Inner Hebrides, W. Scotland, UK). Journal of the Marine Biological Association of the United Kingdom.

Pierce, G.J., Wang, J., Zheng, X., Bellido, J.M., Boyle, P.R., Denis, V. and Robin, J.-P., 2001. A cephalopod fishery GIS for the Northeast Atlantic: development and application. International Journal of Geographical Information Science 15, 763-784.

Pierce, G.J., Young, I.A.G. and Wang, J., 2002. An overview of cephalopods relevant to the SEA 2 and SEA 3 areas. Report No TR_009_Rev1. Department of Trade and Industry (available at http://www.offshore-sea.org.uk).

Rasero, M., González, A.F., Castro, B.G. and Guerra, A., 1996. Predatory relationships of two sympatric squid, *Todaropsis eblanae* and *Illex coindetii* (Cephalopoda: Ommastrephidae) in Galician waters. Journal of the Marine Biological Association of the United Kingdom 76, 73-87.

Rodhouse, P.G., 1989. Antarctic cephalopods .a living marine resource? Ambio 18, 56-59.

Roper, C.F.E., Lu, C.C. and Vechione, M., 1998. A revision of the systematics and distribution of *Illex* species (Cephalopoda: Ommastrephidae). Smithsonian Contributions to Zoology 586, 405-423.

Roper, C.F.E., Sweeney, M.J. and Nauen, C.E., 1984. Cephalopods of the world. An annotated and illustrated catalogue of species of interest to fisheries. Memoirs of the National Museum, Victoria 44, 49-63.

Rosenberg, A.A., Wiborg, K.F. and Bech, I.M., 1980. Growth of *Todarodes sagittatus* L. (Cephalopoda, Ommastrephidae) from the Northeast Atlantic, based on counts of statolith growth rings. Sarsia 66, 53-57.

RPI (Research Planning Inc.), 1989. Natural resource response guide: Marine shellfish. Prepared for NOAA by Research Planning Inc. Columbia, SC, 86 pp.

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., 2003. Diet of harbour porpoise (*Phocoena phocoena*) in the NE Atlantic: a review. Oceanography and Marine Biology Annual Review 41.

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, GJ., 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. International Council for the Exploration of the Sea 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. International Council for the Exploration of the Sea CM 1995/N:6.

Scott, G.I., Ballou, T.G. and Dahlin, J.A., 1984. Summary and evaluation of the toxicological and physiological effects of pollutants on Shellfish- Part 2: Petroleum hydrocarbons. Report No. 84-31, Research Planning INC., Columbia, SC, 64 pp.

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.

Shaw, P.W., Pierce, G.J. and Boyle, P.R., 1999. Subtle population structuring within a highly vagile marine invertebrate, the veined squid *Loligo forbesi*, demonstrated with microsatellite DNA markers. Molecular Ecology 8, 407-417.

Sheahan, D., Rycroft, R, Allen, Y., Kenny, A., Mason, C. & Irish, R., 2001. Contaminant Status of the Morth Sea. SEA2 Technical Report TR_004. Department of Trade and Industry (available at http://www.offshore-sea.org.uk).

Smale, M.J., 1996. Cephalopods as prey. IV. Fishes. Philosophical Transactions of the Royal Society London Series B 351, 1067-1081.

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

Storelli, M.M. and Marcotrigiano G.O., 1999. Cadmium and total mercury in some cephalopods from the South Adriatic Sea (Italy). Food Additives and Contaminants 16, 261-265.

Sundet, J.H., 1985. A short review on the biology and fishery of the squid *Todarodes sagittatus*. International Council for the Exploration of the Sea C.M.1985/K:44.

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

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.

Wiborg, K.F., 1972. The squid *Todarodes sagittatus* (Lamarck). Norwegian investigations in the Norwegian Sea and North Atlantic waters 1970-1972. International Council for the Exploration of the Sea C.M. 1972/K:25.

Wiborg, K.F., 1979. *Gonatus fabricii* (Lichtenstein), en mulig fiskeriressurs i Norskehavet. Fisken og Havet 1979, 33-46.

Wiborg, K.F. and Beck, I.M., 1984. The squid *Todarodes sagittatus* (Lamarck) investigations in Norwegian coastal and bank waters, July 1983-January 1984, and west of the British Isles, March-April 1984. International Council for Exploration of the Sea C.M. 1984/K:20.

Wiborg K.F., Beck, I.M. and Gjøsæter, J., 1984. The squid *Gonatus fabricii* (Lichtenstein). Investigations in the Norwegian Sea and western Barents Sea 1982-1983. International Council for the Exploration of the Sea, CM 1984/K:19

Wiborg, K.F. and Gjosæter, J., 1981. Squid *Todarodes sagittatus* (Lamarck) distribution and biology in northern waters, April 1980 - April 1981. International Council for the Exploration of the Sea C.M. 1981/K:14.

Wiborg, K.F., Gjøsæter, J. and Beck, I.M., 1982b. The squid *Gonatus fabricii* (Lichtenstein). Investigations in the Norwegian Sea and western Barents Sea 1978-1981. International Council for the Exploration of the Sea, CM 1982/K:31

Wiborg, K.F., Gjosaeter, J., Beck, I.M. and Fossum, P., 1982a. Squid *Todarodes sagittatus* (Lamarck) distribution and biology in northern waters, April 1981 - April 1982. International Council for the Exploration of the Sea C.M./K:30.

Wiborg, K.F., Gjosaeter, J., Beck, I.M. and Fossum, P., 1983. Squid *Todarodes sagittatus* (Lamarck) distribution and biology in northern waters, April 1982 - June 1983. International Council for the Exploration of the Sea C.M./K:7.

Table 1. 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 Anon. (2002). Data for 2001 were provisional.

Category and 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 2. 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

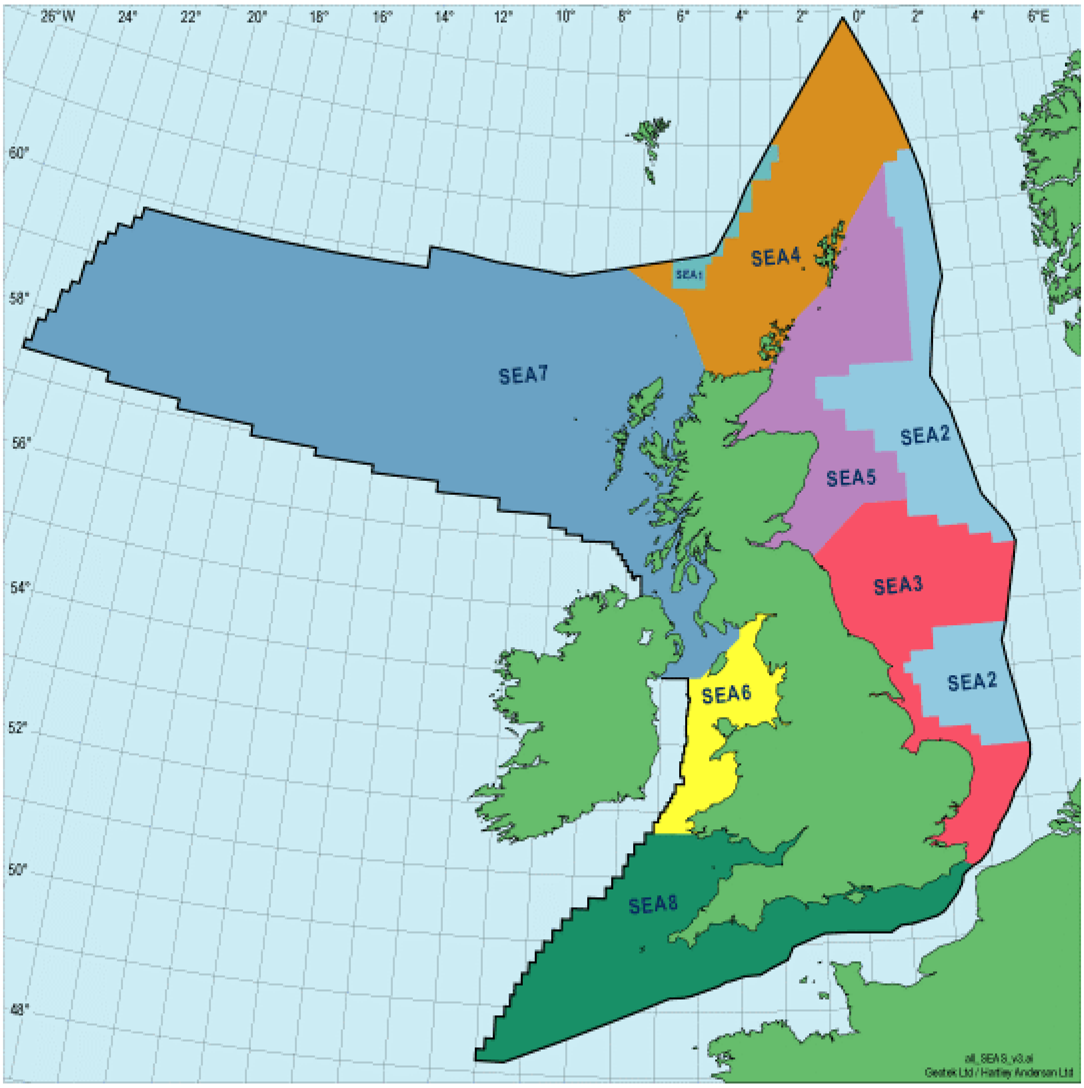
Table 3. Mean concentrations of trace metals in squid and whiting, and median values recorded in piscivorous (porpoise, minke whale) and teuthophagous (Risso's dolphin, sperm whale) marine mammals in Scottish waters (mg/kg wet weight) (FRS, 1998). Limits set by the Food Standard Committee (FSC) are shown for comparison.

	Cadmium	Copper	Lead	Zinc	Mercury	Arsenic
Squid	0.030	7.12	0.02	11.0	0.03	7.91
Whiting	0.001	0.14	<0.01	3.75	0.04	4.27
Risso's dolphin	5.00-8.73	4.18-9.09	0.10-0.89	26.7-46.2	1.47-5.22	-
Sperm whale	17.0	5.00	0.73	48.3	22.7	-
Porpoise	0.016	11.5	0.11	48.5	1.02	-
Minke whale	0.13	3.93	<0.07	87.4	1.84	-
FSC	0.02	20	2	50	0.5	-

Table 4. Median concentrations of organic contaminants (chlorinated biphenyls, hexachloro-biphenyls, hexachloro-cyclohexanes) and insecticides in squid caught in Scottish coastal waters (µg/kg lipid) (FRS, 1998).

	ΣCB	CB77	CB126	HCB	a-HCH	Dieldrin
Skye	366	0.43	0.10	10.7	4.30	31.9
South Arran	594	1.12	0.11	7.03	3.58	46.9
Tay/ Forth	587-682	0.25-1.71	0.10-0.40	13.1-20.9	3.41-4.01	42.7-61.2

Figure 1. Maps showing the SEA areas and detail of the SEA4 area



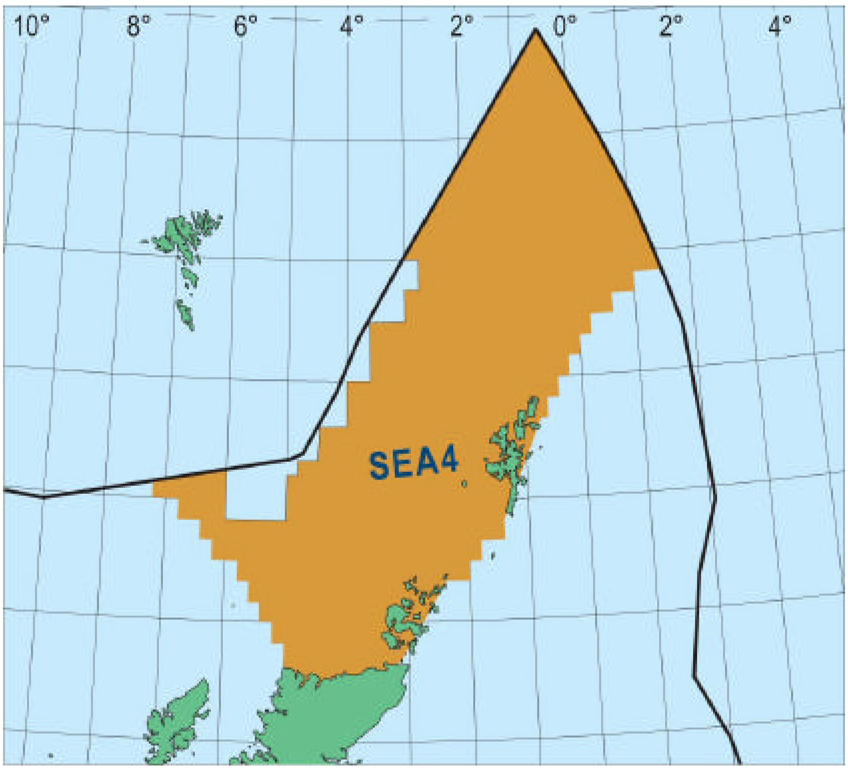


Figure 2. Map showing ICES fishery areas and divisions

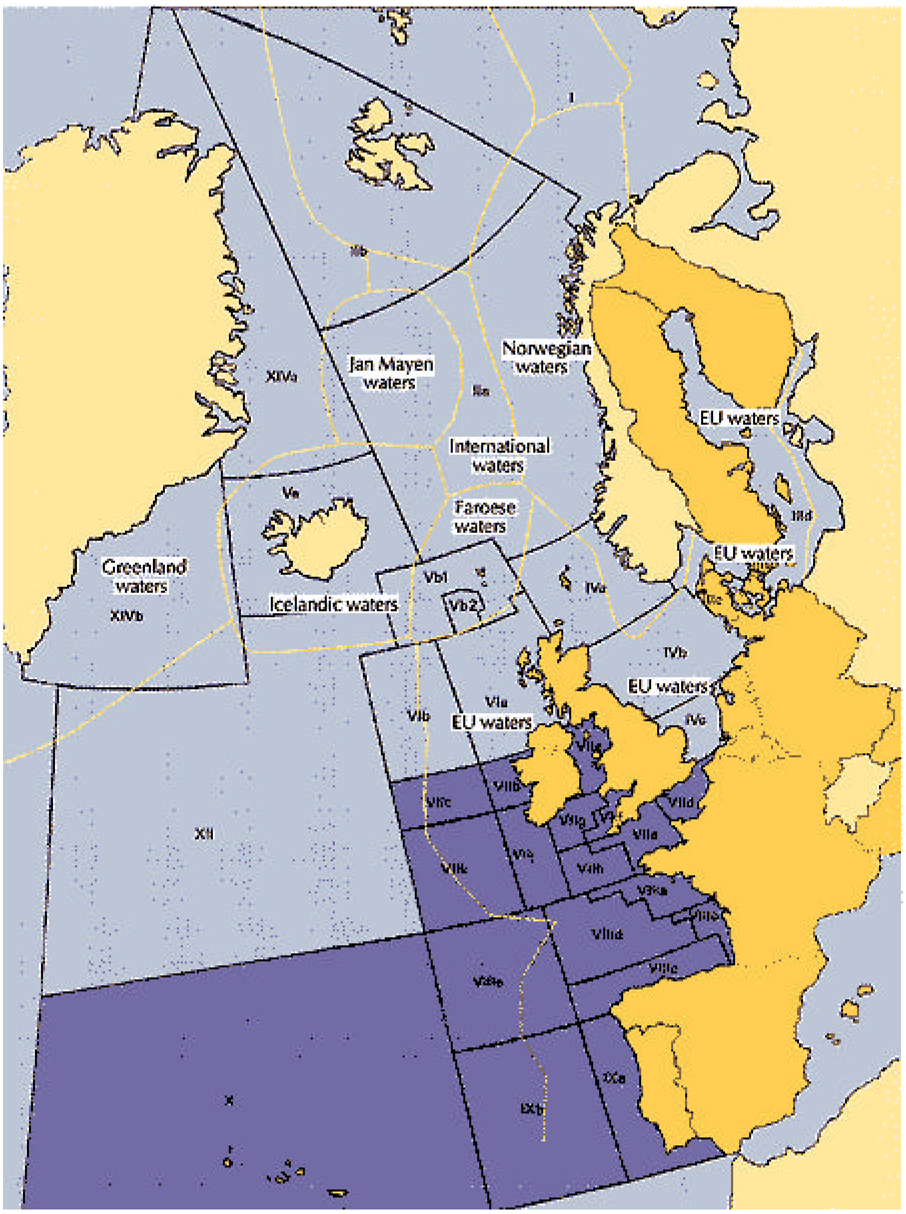


Figure 3. Total squid landings into Scotland between 1994 and 2000 (Scottish Sea Fisheries Statistics, 1999; figures for 2000 from Fisheries Research Services database)

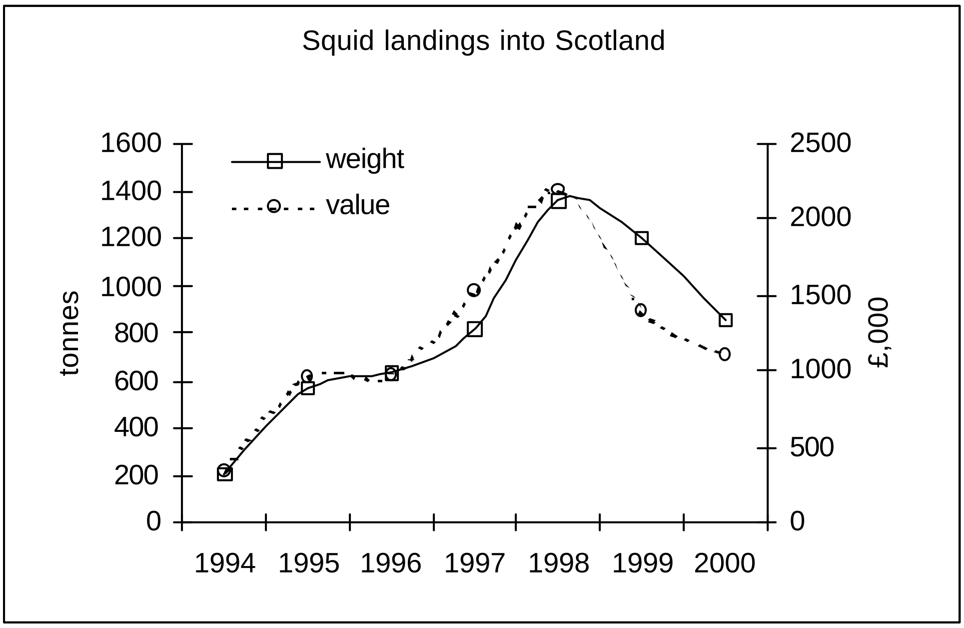


Figure 4. Landings of cephalopods in 1998, by commercial category by UK-registered fishing boats landing in the UK: landings from the SEA 4 area are distinguished from those taken elsewhere.

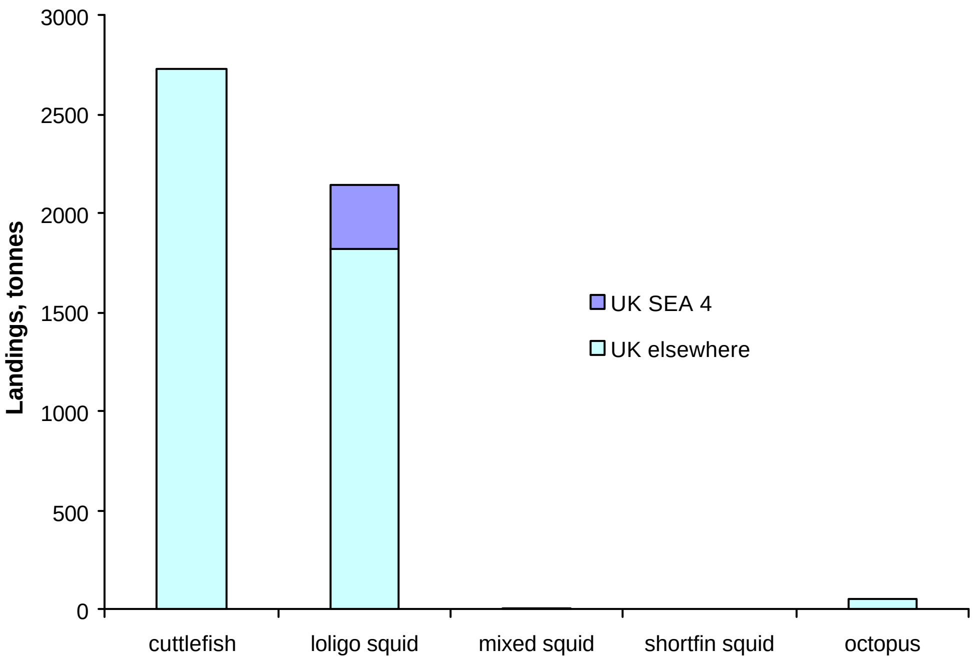
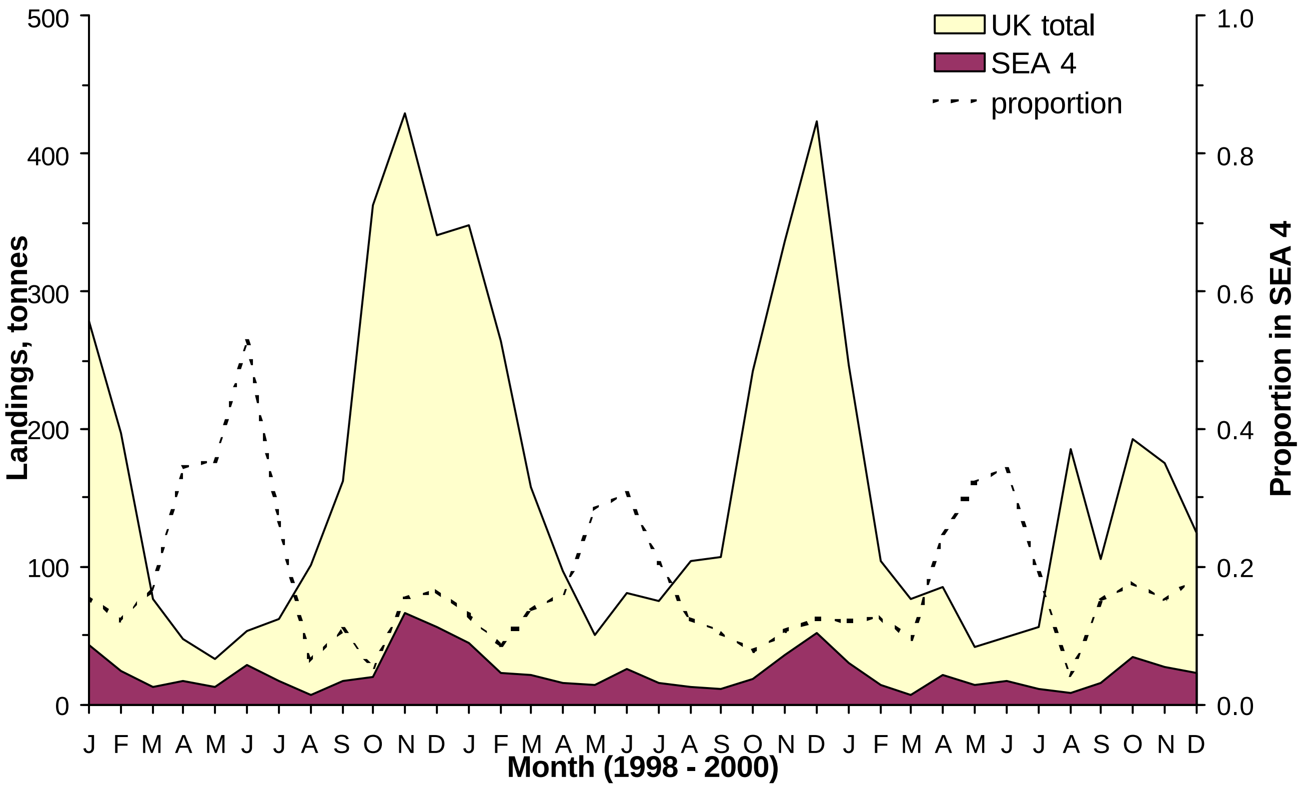
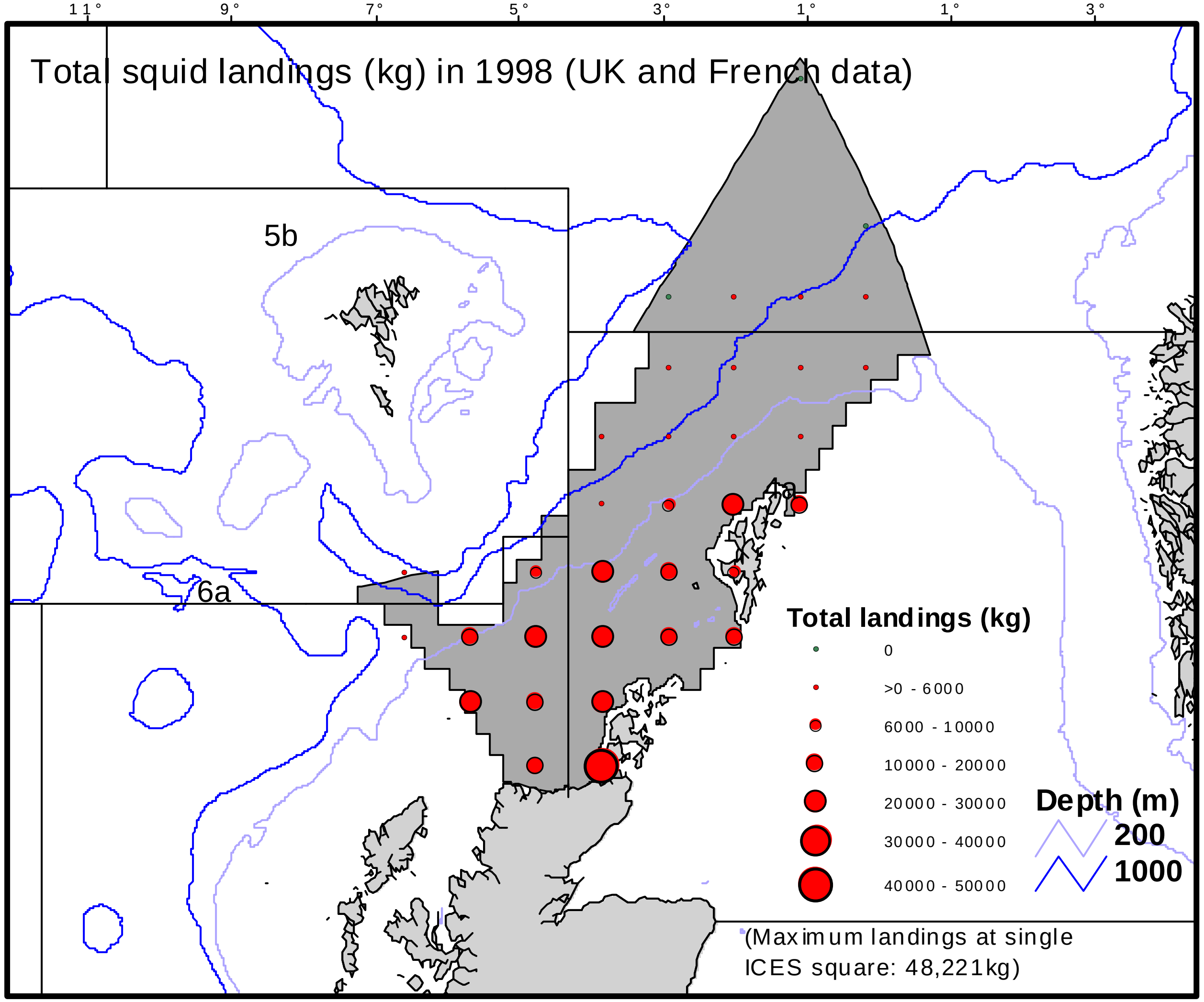


Figure 5. Month-to-month trends in landings of loliginid squid in the UK and for the SEA 4 area. The dotted line shows the proportion of UK landings arising from catches in the SEA 4 area.





11°
9°
7°
5°
3°
1°
1°
3°
Total squid landings (kg) in 1998 (UK and French data)
5b
6a
4a
Total landings (kg)
0
>0 - 6000
6000 - 10000
10000 - 20000
20000 - 30000
30000 - 40000
40000 - 50000
Depth (m)
200
1000
(Maximum landings at single ICES square: 48,221kg)

Figure 6.

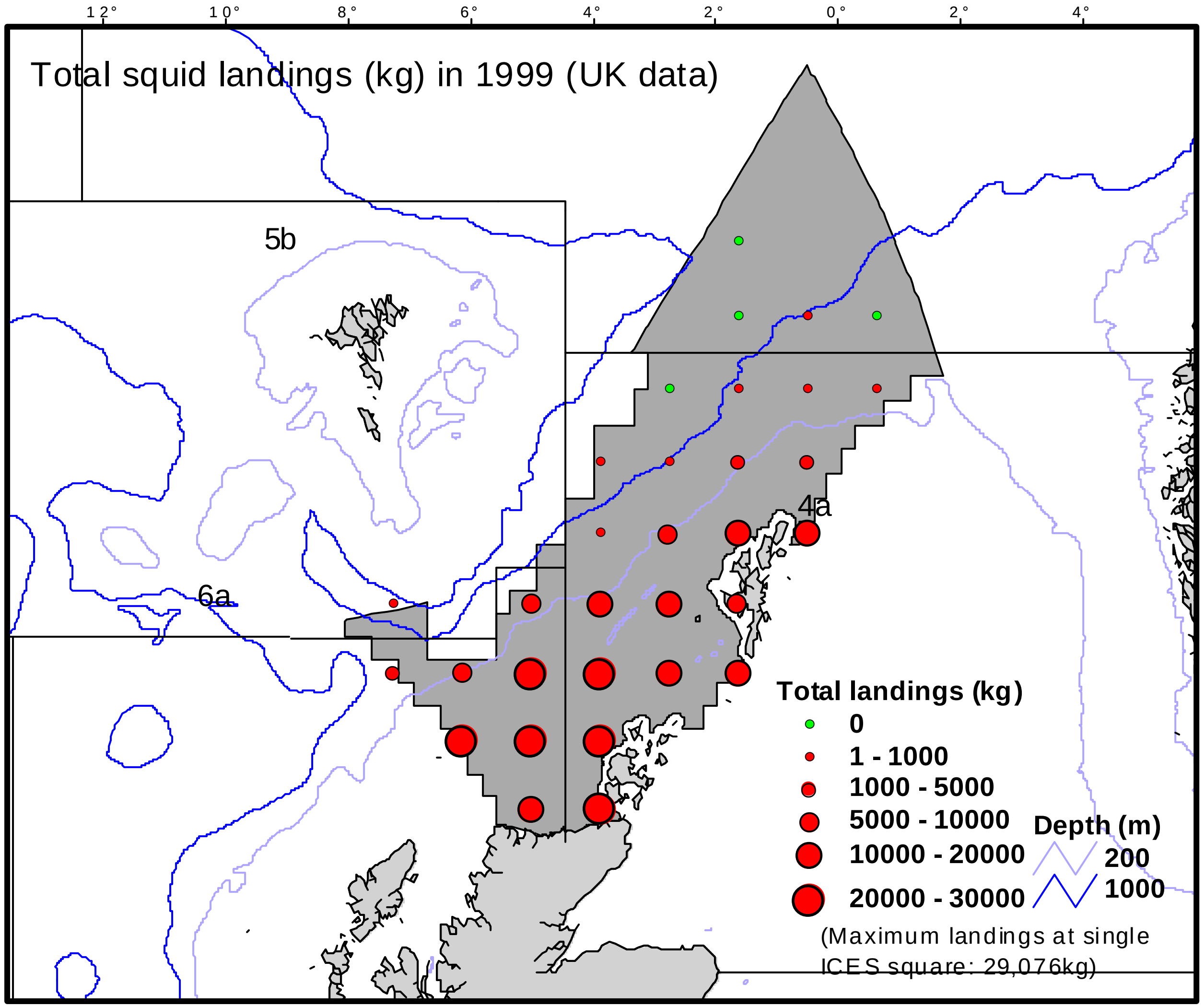

Total squid landings (kg) in 1999 (UK data)
12°
10°
8°
6°
4°
2°
0°
2°
4°
5b
6a
4a
Total landings (kg)
0
1 - 1000
1000 - 5000
5000 - 10000
10000 - 20000
20000 - 30000
Depth (m)
200
1000
(Maximum landings at single ICES square: 29,076kg)

Figure 7.

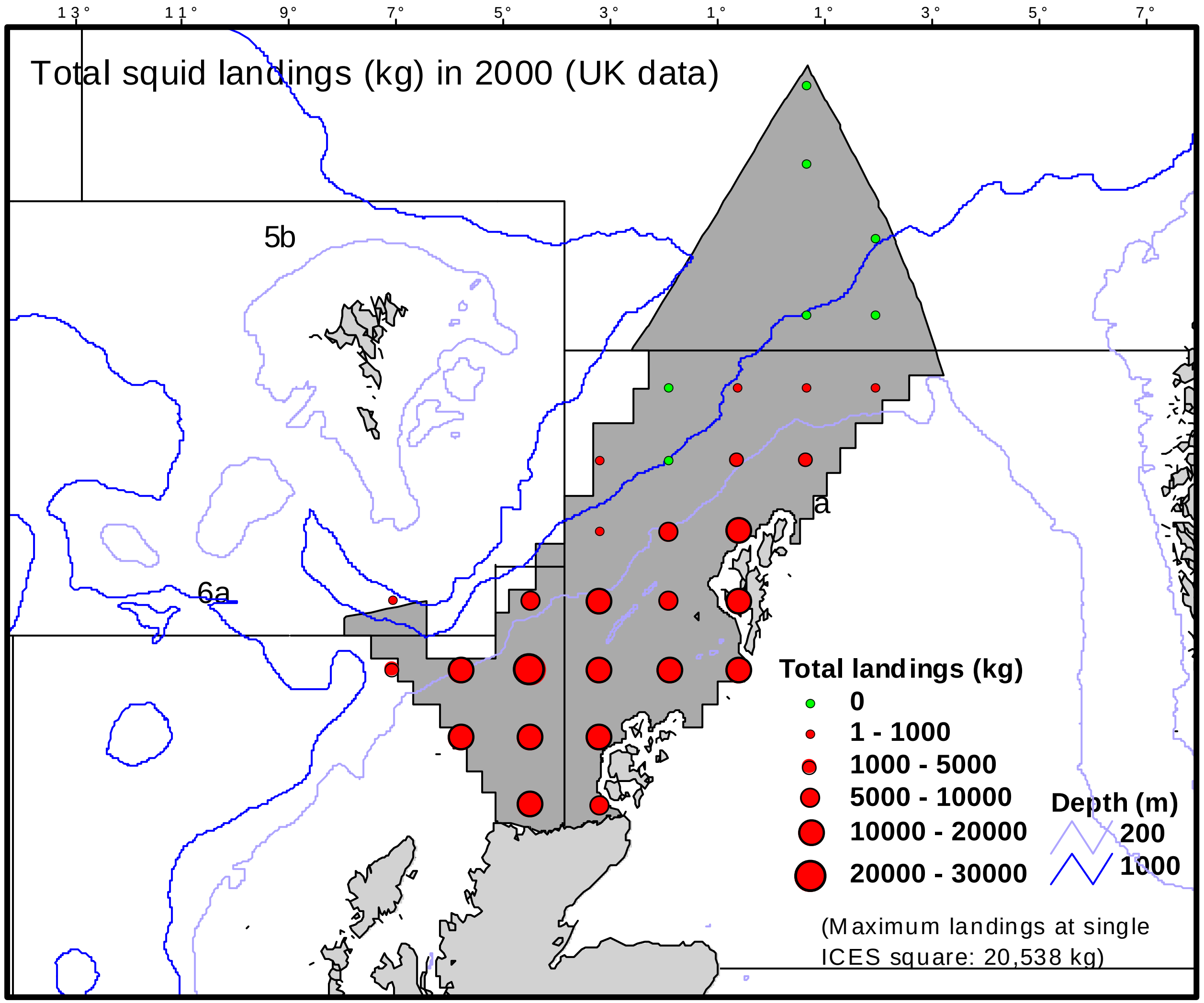

13°
11°
9°
7°
5°
3°
1°
1°
3°
5°
7°
Total squid landings (kg) in 2000 (UK data)
5b
6a
a
Total landings (kg)
0
1 - 1000
1000 - 5000
5000 - 10000
10000 - 20000
20000 - 30000
Depth (m)
200
1000
(Maximum landings at single ICES square: 20,538 kg)

Figure 8.

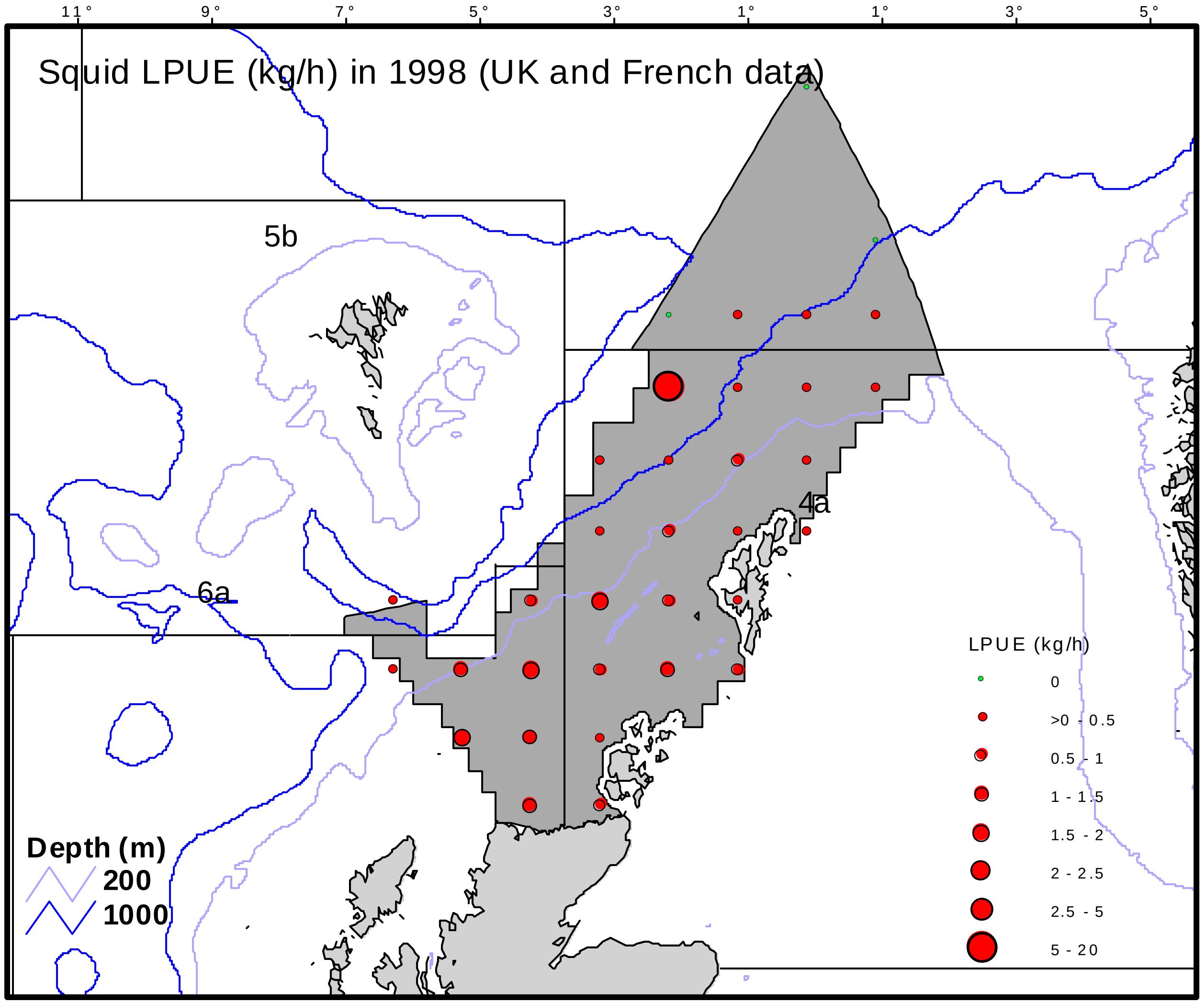
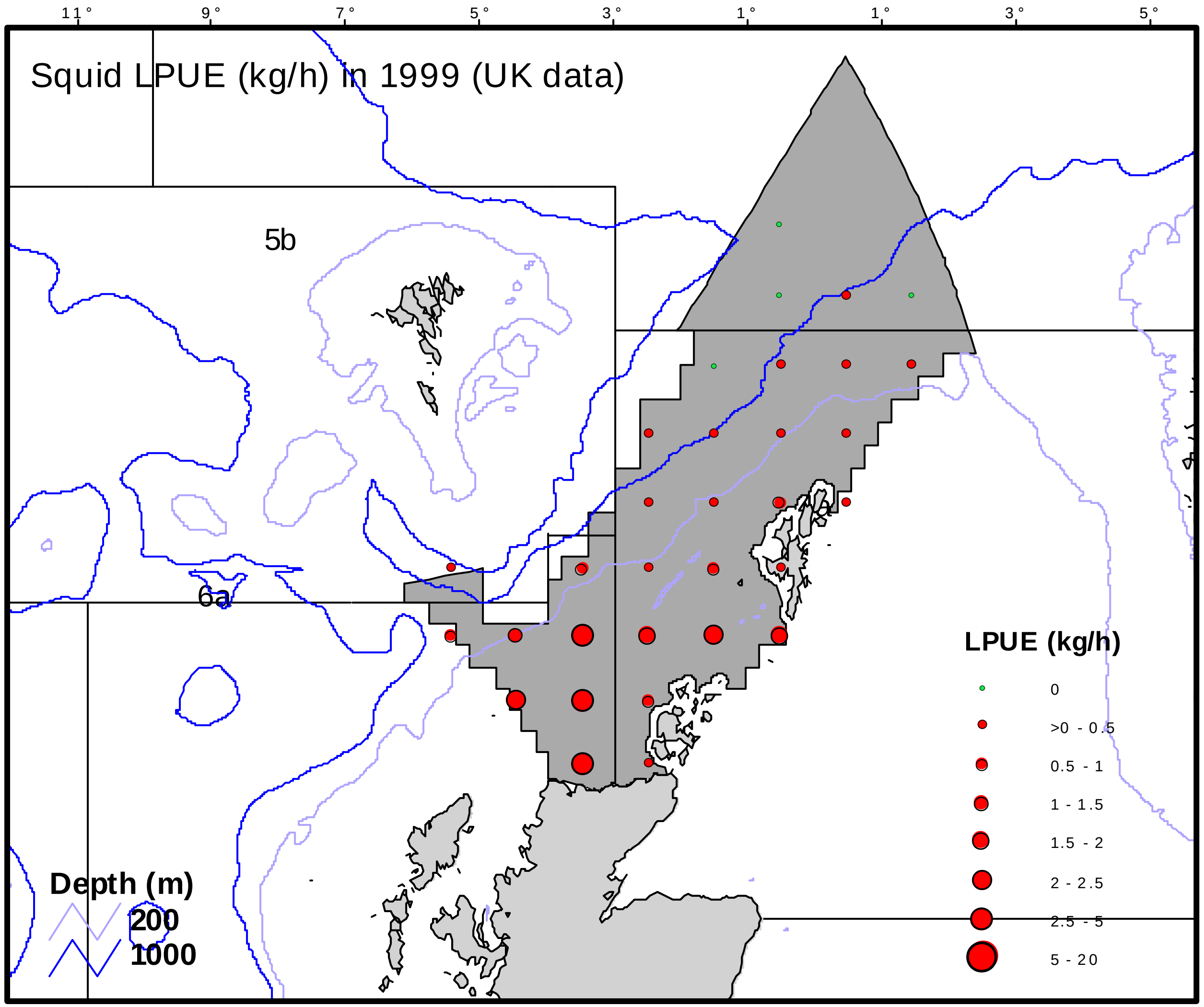

11°
9°
7°
5°
3°
1°
1°
3°
5°
Squid LPUE (kg/h) in 1998 (UK and French data)
5b
4a
6a
Depth (m)
200
1000
LPUE (kg/h)
0
>0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 5
5 - 20

Figure 9.



11°
9°
7°
5°
3°
1°
1°
3°
5°
Squid LPUE (kg/h) in 1999 (UK data)
5b
6a
LPUE (kg/h)
0
>0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 5
5 - 20
Depth (m)
200
1000

Figure 10.

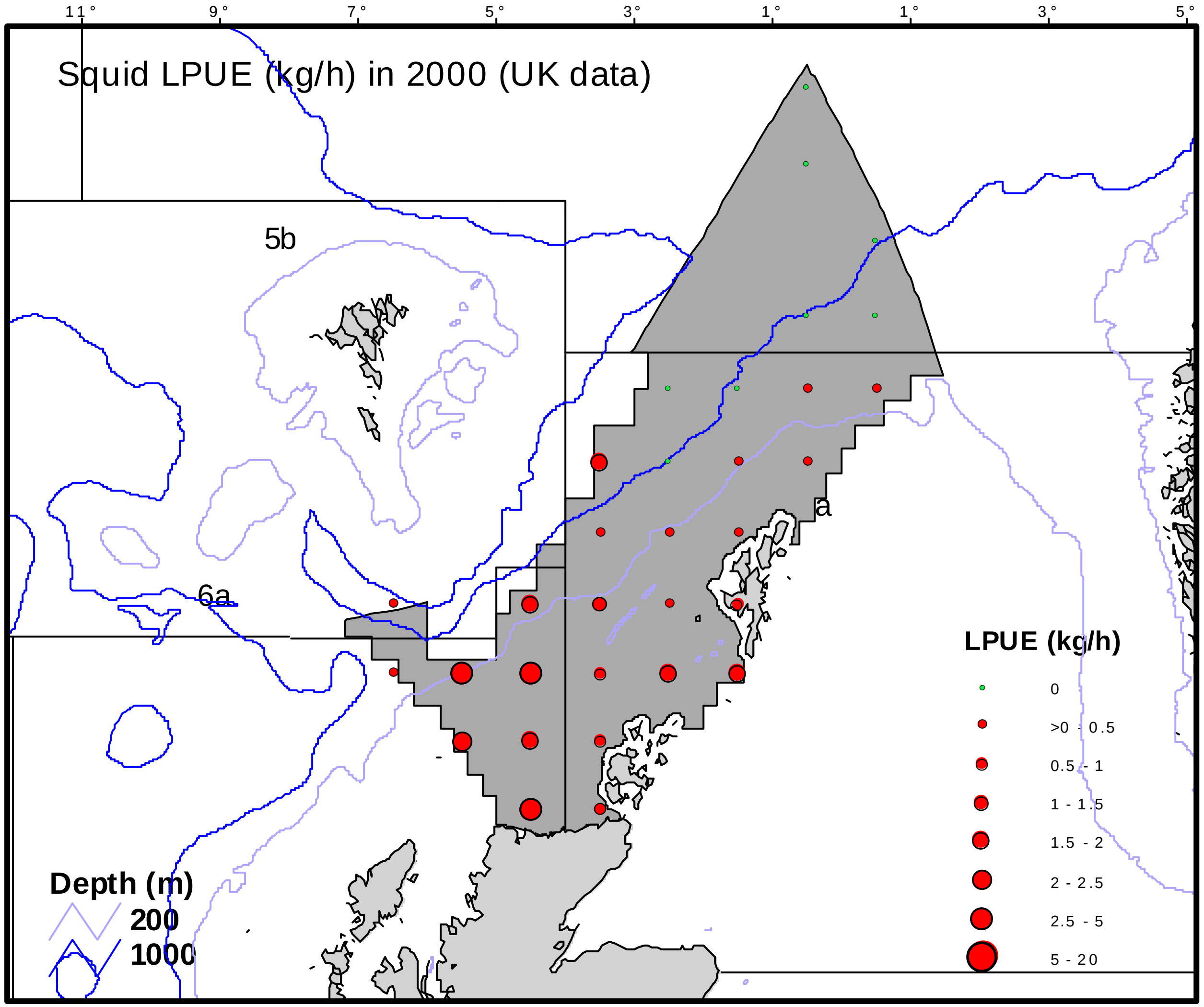
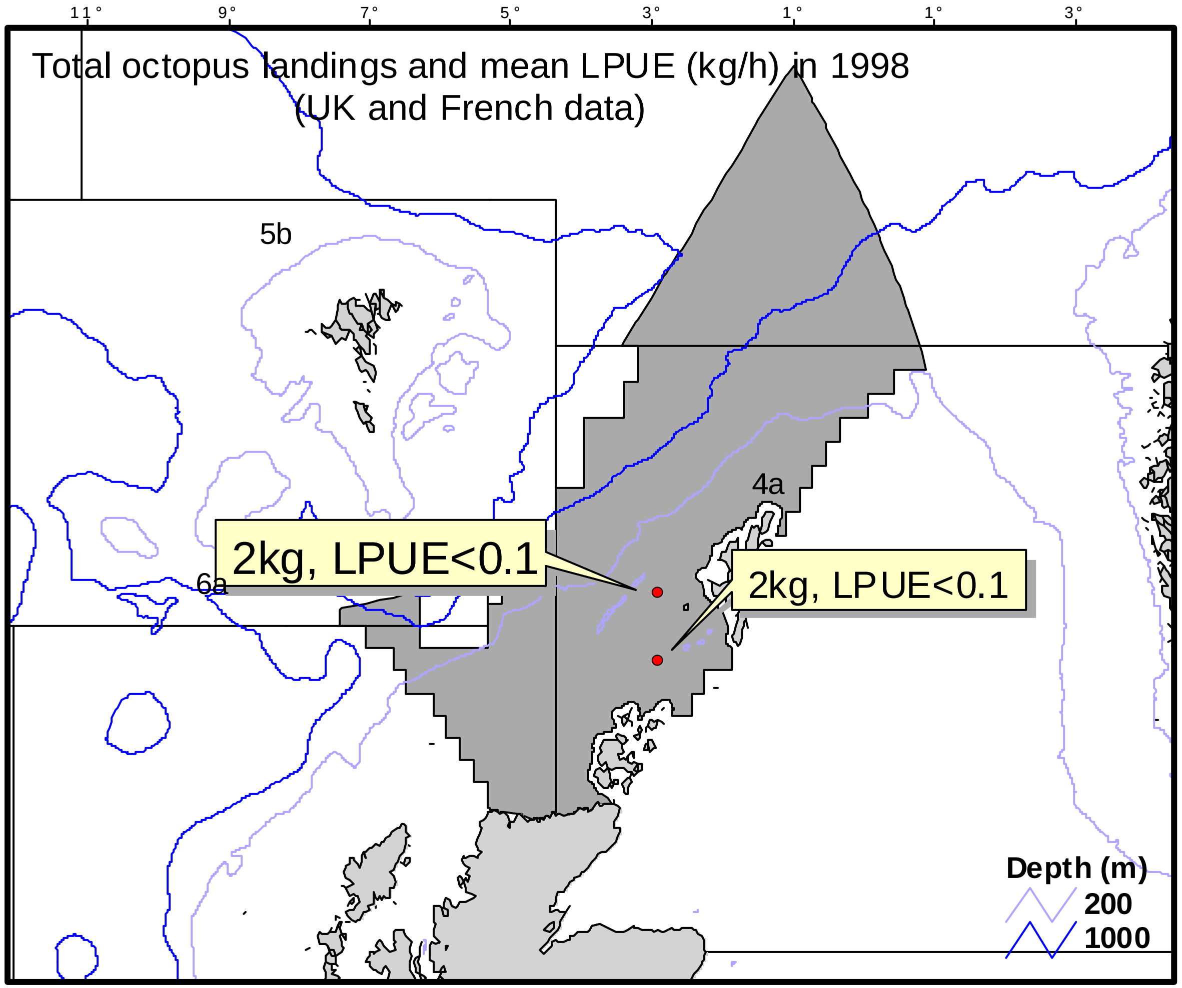

11°
9°
7°
5°
3°
1°
1°
3°
5°
Squid LPUE (kg/h) in 2000 (UK data)
5b
6a
a
LPUE (kg/h)
0
>0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 5
5 - 20
Depth (m)
200
1000

Figure 11.



11° 9° 7° 5° 3° 1° 1° 3°
Total octopus landings and mean LPUE (kg/h) in 1998
(UK and French data)
5b
4a
6a
2kg, LPUE<0.1
2kg, LPUE<0.1
Depth (m)
200
1000

Figure 12.