Technical Report TR_009

Technical report produced for

Strategic Environmental Assessment – SEA2

AN OVERVIEW OF CEPHALOPODS RELEVANT TO THE SEA2 AREA

Produced by University of Aberdeen, August 2001

AN OVERVIEW OF CEPHALOPODS RELEVANT TO THE SEA2 AREA

Iain A G Young

Department of Zoology, University of Aberdeen

CONTENTS

1. INTRODUCTION

This report is a contribution to the Strategic Environmental Assessment (SEA2) conducted by the Department of Trade and Industry. SEA2 focuses on the mature areas of the North Sea UK continental shelf which is divided into 3 areas - Northern, Central and Southern North Sea.

ICES (International Council for the Exploration of the Sea) have, for fisheries management purposes, divided the ocean into fishing divisions and sub-divisions. ICES subdivision IVa subsumes the SEA2 Northern North Sea area. Subdivision IVa extends southwards to 57º30'N, resulting in the northern half of SEA2 Central North Sea lying in ICES subdivision IVa with the southern part in ICES subdivision IVb. ICES subdivision IVb extends southwards to latitude 53º30' and this parallel almost bisects the SEA2 Southern North Sea area, resulting in the location of the southern half of this SEA2 area being in ICES subdivision IVc (see Figures 6, 7 and 8). The ICES subdivisions are further subdivided into ICES rectangles measuring 30' of latitude x 1º of longitude for the purpose of catch reporting to improve the resolution of estimated species distribution.

Cephalopods are short lived, carnivorous animals that have rapid growth rates and play an important part in oceanic and coastal food webs. The significance of cephalopod stocks to international commercial fisheries is of recent, but growing, importance (Boyle, 1990). The main cephalopod species of economic importance in the northeast Atlantic are the lolinigid squids *Loligo forbesi* and *Loligo vulgaris*, the 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).

Landings of cephalopods from Scottish waters consist mainly of *Loligo forbesi* (Pierce *et al.*, 1994d; Pierce *et al.*, 1998) with very much smaller quantities of *Eledone cirrhosa* and *Todarodes sagittatus* also landed. Individuals of other species – namely *Todaropsis eblanae* and *Illex coindetii* 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 1999, 1199 tonnes of squid were landed into Scottish ports making Scotland the second most important fishery nation for lolinigid squid within the ICES region (Anonymous, 2000a). English cephalopod landings are dominated by catches of cuttlefish from the English Channel - outside the area of interest.

Loligo forbesi and *Loligo vulgaris* are, from a fisheries point of view, the most important squid species in the northeast Atlantic with *L. forbesi* being the squid species caught almost exclusively in Scottish waters (Boyle and Pierce, 1994; Pierce *et al.*, 1994a; Pierce *et al.*, 1994d; Pierce *et al.*, 1998). Catches of lolinigid squid in the southern North Sea tend to be a mix of *L. forbesi* and *L. vulgaris* with the proportion of *L. forbesi* increasing with increasing latitude and landings of squid in England may contain a significant proportion of *L. vulgaris*. 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 concentrations of metals. It is thought that if the habitat has been polluted by industrial effluents containing trace metals, the heavy metal content of seafood will increase (Kunisaki, 2000) and heavy metal accumulation rates in cephalopod species appear to be rapid (Craig, 1996).

This report concentrates mainly on the two loliginid species *Loligo forbesi* and *Loligo vulgaris* with the main focus on the most abundant cephalopod species in the study area, *Loligo forbesi*. However, there are catches of the octopus *Eledone cirrhosa* taken from the North Sea and this species is also considered. The report considers the following:

- Population structure and distribution
- Ecology
- Fisheries and trends
- Sensitivity to metal contamination
- Further conservation considerations

2. POPULATION STRUCTURE AND DISTRIBUTION

Loligo forbesi Steenstrup, 1856, and *Loligo vulgaris* Lamark, 1798, are annual semelparous species (a species which reproduces only once during its lifetime) and the populations usually have a simple demographic structure. Maturation takes approximately 1 year and there is an 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). Most squid have a lifespan of no more than 1-2 years (Boyle and Boletzky, 1996) and studies in Scottish waters and the English Channel suggest a 1 year life-cycle for *Loligo forbesi* (Pierce *et al.*, 1994a).

Although squid are caught offshore in all maturity stages, evidence of egg-strings attached to creel ropes suggests that spawning areas are inshore. Loliginid squid die after spawning (Boyle and Boletzky, 1996; Pierce *et al.*, 1994a).

Using the definition of a recruit as an animal below the modal size in catches (approximately 150 mm mantle length), major peaks in recruitment 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).

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).

Loligo vulgaris is one of the most prevalent 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).

Loligo forbesi is a neritic loliginid which 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).

The two lolinigid species have ranges which 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 (Pierce *et al.*, 1994b; Pierce *et al.*, 1994c). In Scottish waters, only *L. forbesi* is common (Pierce *et al.*, 1994c).

Knowledge of squid distribution in Scottish 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 (Pierce *et al.*, 1994a). 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.*, 1994c). This is supported by data from trawling surveys by R/V Scotia (Pierce *et al.*, 1998).

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

3. ECOLOGY

Cephalopods are important elements in food webs and interact with commercial finfish fisheries (Boyle, 1990; Boyle and Pierce, 1994). Globally, whales, dolphins, seals, birds, and some large fish species take large quantities of squid.

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 species 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 difficult to quantify, cetaceans probably have a greater impact on cephalopods than seabirds or seals. Most species of cetacean consume cephalopods and the 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). Although there is evidence of cephalopods in stomach contents, indications are that dolphins and the harbour porpoise are primarily fish-eating (González *et al.*, 1994; Santos *et al.*, 1994, 1995). The minke whale (*Balenoptera acutorostrata*) is also thought to take squid (Clarke, 1986; Pierce, 1992).

Seals are also known to take several cephalopod species including *Loligo* sp. (Pierce and Santos, 1996). Fish stomach sampling programmes have shown that a small but significant proportion of the diet of O-group whitefish is composed of cephalopods (Boyle and Pierce, 1994).

Predation on *Eledone cirrhosa* is poorly documented (Boyle, 1983). 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). Cetaceans taking *E. cirrhosa* include the white beaked dolphin (*Lagenorhynchus albirostris*), bottle-nosed dolphin (*Tursiops truncatus*) and Risso's dolphin (*Grampus griseus*). In studies, the latter were found to have mainly cephalopod remains in their stomachs – and *E. cirrhosa* dominated (Santos *et al.,* 1994, 1995).

Cephalopods are predators themselves (Boyle, 1990), feeding on a wide range of other marine animals. *Loligo forbesi* feed primarily on fishes, crustaceans and cephalopods.

Dominant prey species of *L. forbesi* in Scottish waters are sandeels (*Ammodytes* sp.) Gadidae – mainly whiting (*Merlangius merlangus*) and *Trisopterus* sp., and Clupeidae (relative frequency of fish: 82% (Martins, 1982)). However, the proportion of fish in the diet of *L. forbesi* increases with squid size – the corresponding importance of crustacea in the diet declining with squid size (Boyle and Pierce, 1994; Pierce *et al.*, 1994c; Collins and Pierce, 1996). The proportions 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, high in the food chain with *L. forbesi* being assigned to the IV trophic level (Monteiro *et al.*, 1992).

The octopus, *E. cirrhosa* is benthic and feeds mainly on crustaceans and molluscs (Monteiro *et al.*, 1992) 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 (Monteiro *et al.*, 1992).

4. FISHERIES AND TRENDS

In general, squid catches in Scotland 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 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, 2000b). 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 on Scottish catches indicates that 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 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 1). Landing trends for the same year are shown in Figures 1, 2 and 3. (Landings in 1991 were around 2000 tonnes).

Table 1. Landings of squid by area for recent years

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

Over the 7 year period from 1994 to 2000, these figures represent an average of 0.4% by weight and 0.5% by value of the total of all demersal and Norway lobster (*Nephrops norvegicus*) landings into Scotland by UK vessels. More specifically, 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 1) (Scottish Sea Fisheries Statistical Tables, 1994, 1995; Scottish Sea Fisheries Statistics, 1996, 1997, 1998, 1999; figures for 2000 from Fisheries Research Services database).

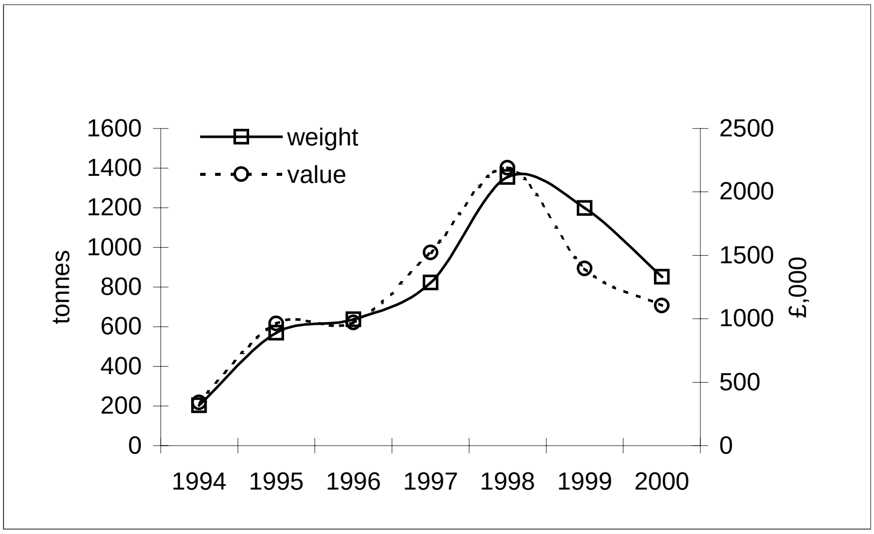

Figure 1. Total squid landings into Scotland between 1994 and 2000

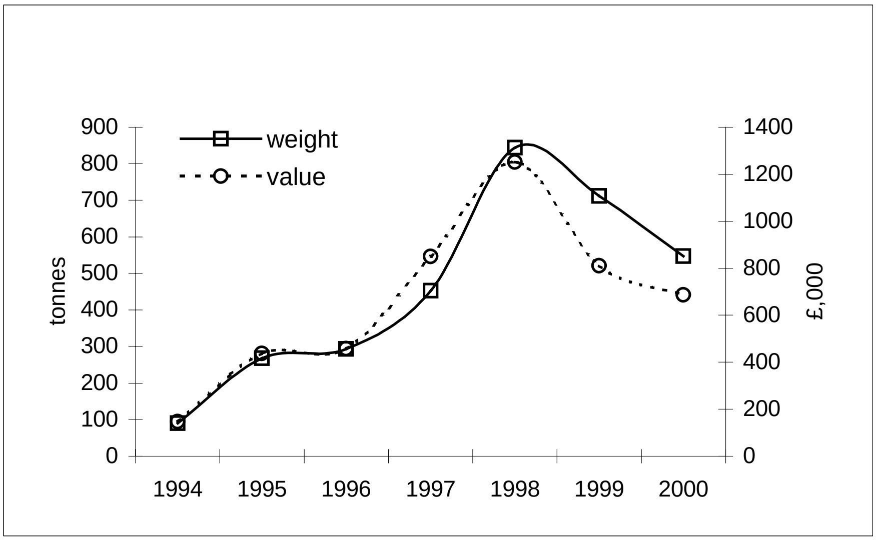

Figure 2. Squid landings into Scotland from Area IVa between 1994 and 2000

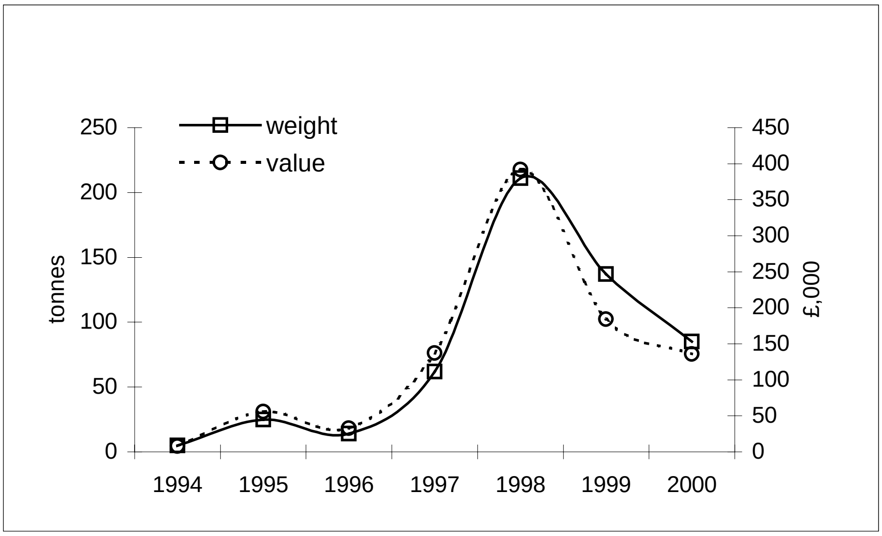

Figure 3. Squid landings into Scotland from Area IVb between 1994 and 2000

The two most important species to Scottish fisheries are the haddock (*Melanogrammus aeglefinus*) and Norway lobster. In order to gauge the relative importance of squid to the Scottish fishing industry, comparisons are made with these two species. If squid landings are 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. Average squid landings for the same period, expressed as a percentage of *Nephrops* landings, were 6% by weight and 4% by value in area IVa and 3% by both weight and value in area IVb.

Trends in relative importance are shown in Figures 4 and 5 and indicate a steady increase in relative weights and value of squid landings to 1998, after which there is a decline. 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.

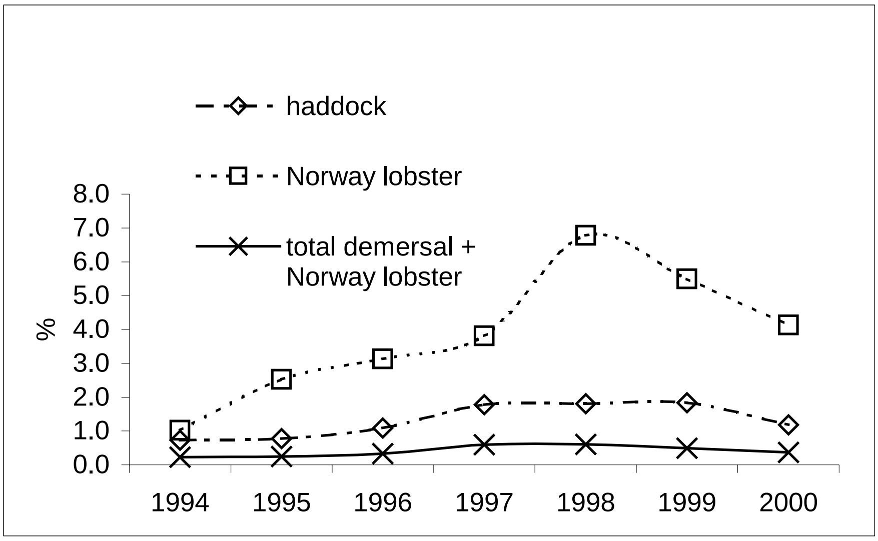

Figure 4. Squid landings by weight expressed as a percentage of the main fished species

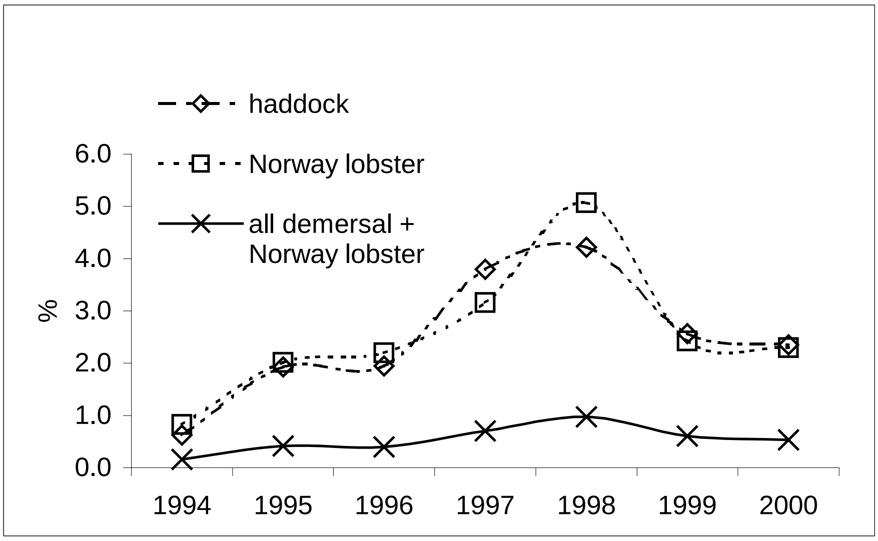

Figure 5. Squid landings by value expressed as a percentage of the main fished species

As both haddock and *Nephrops* are TAC (Total Allowable Catch) species and therefore subject to quota restrictions, the landing figures for demersal, haddock 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.

Landings per unit effort (LPUE) can be used as an index of species abundance and the LPUE of squid (units of kg/hour) are shown for the years 1998-2000 by ICES rectangle in Figures 6, 7 and 8. The indications are that the highest concentrations of squid probably lie outside the areas of interest.

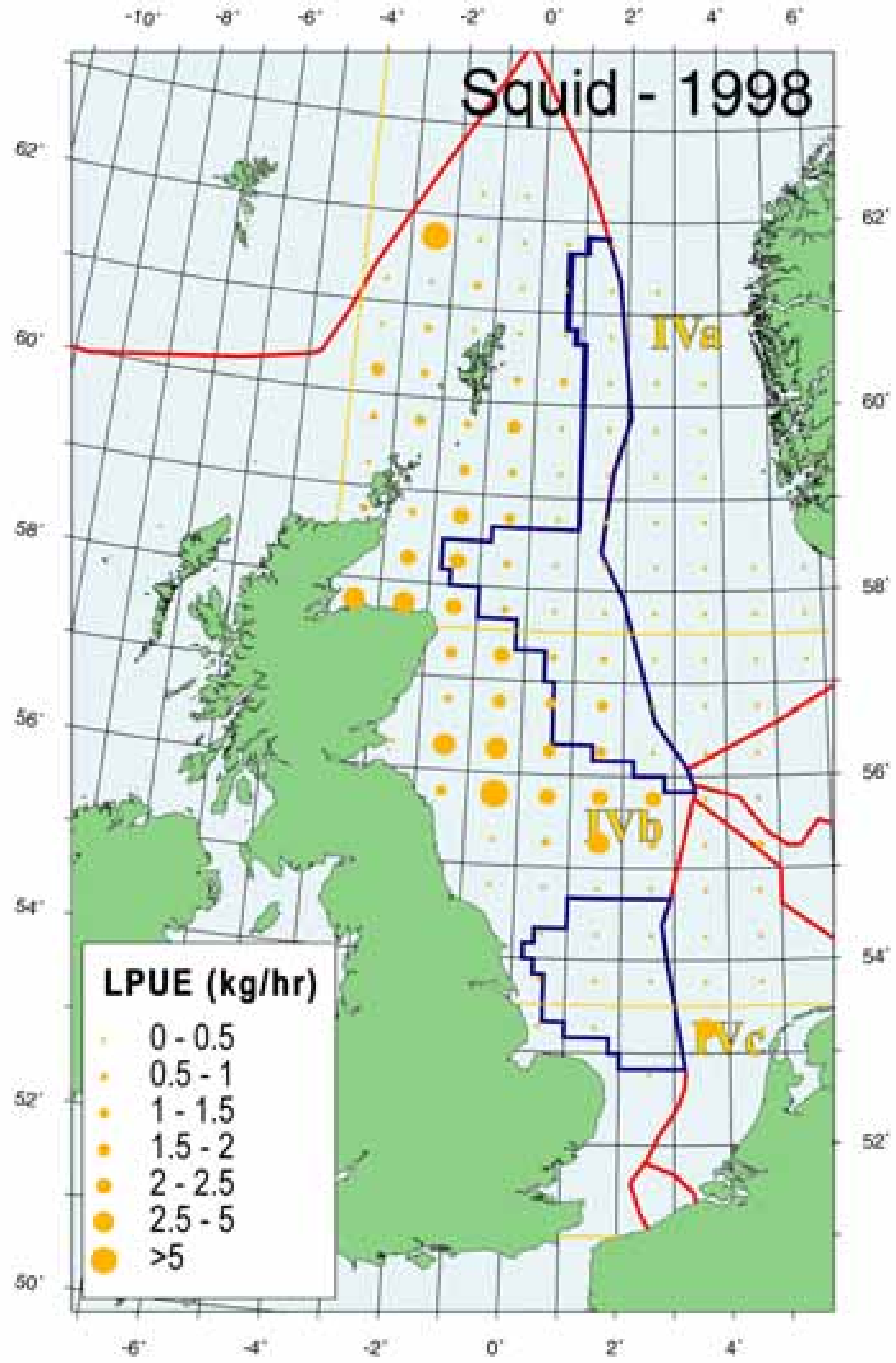

Figure 6. Squid landings per unit effort (LPUE) by ICES rectangle for 1998

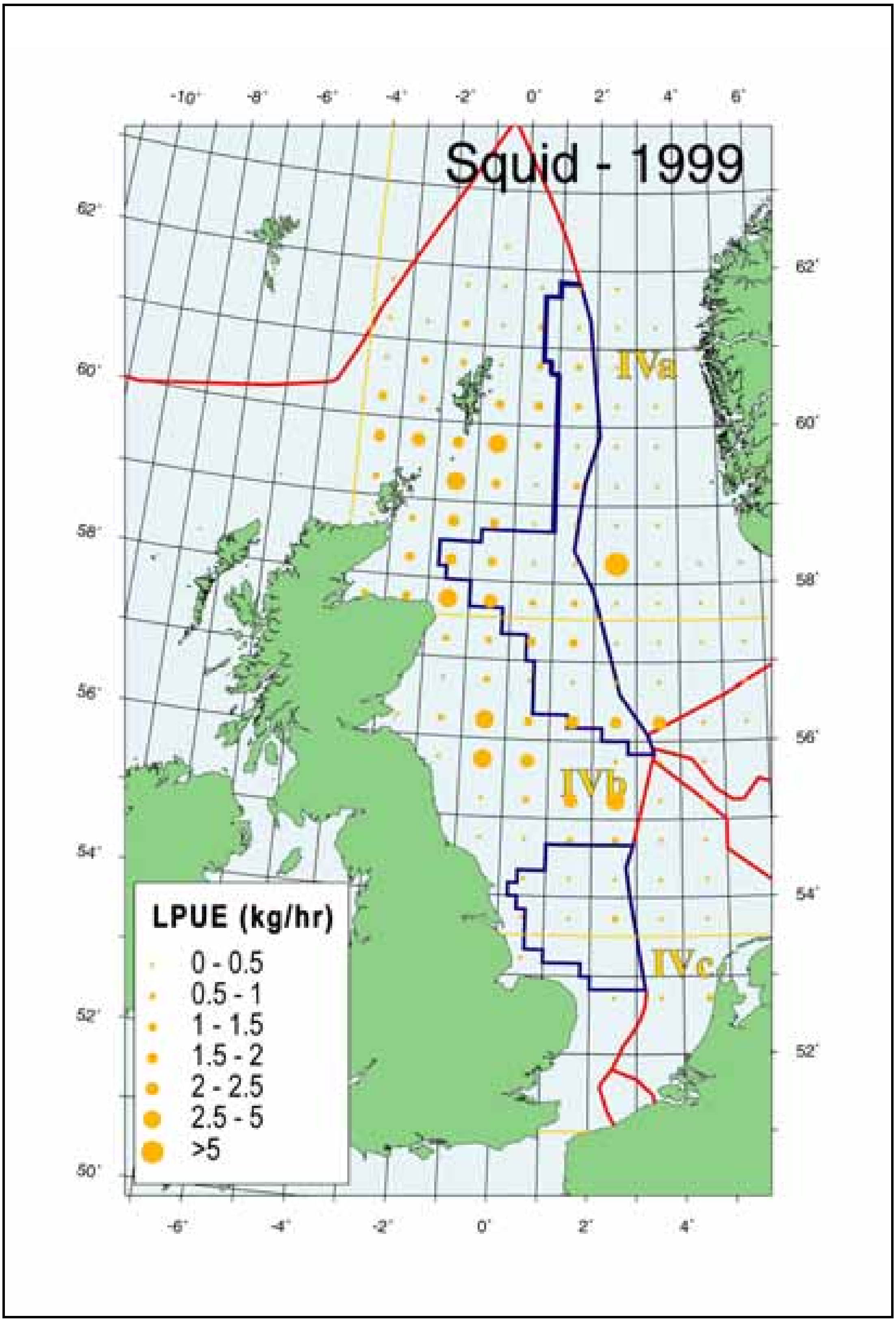

Figure 7. Squid landings per unit effort (LPUE) by ICES rectangle for 1999

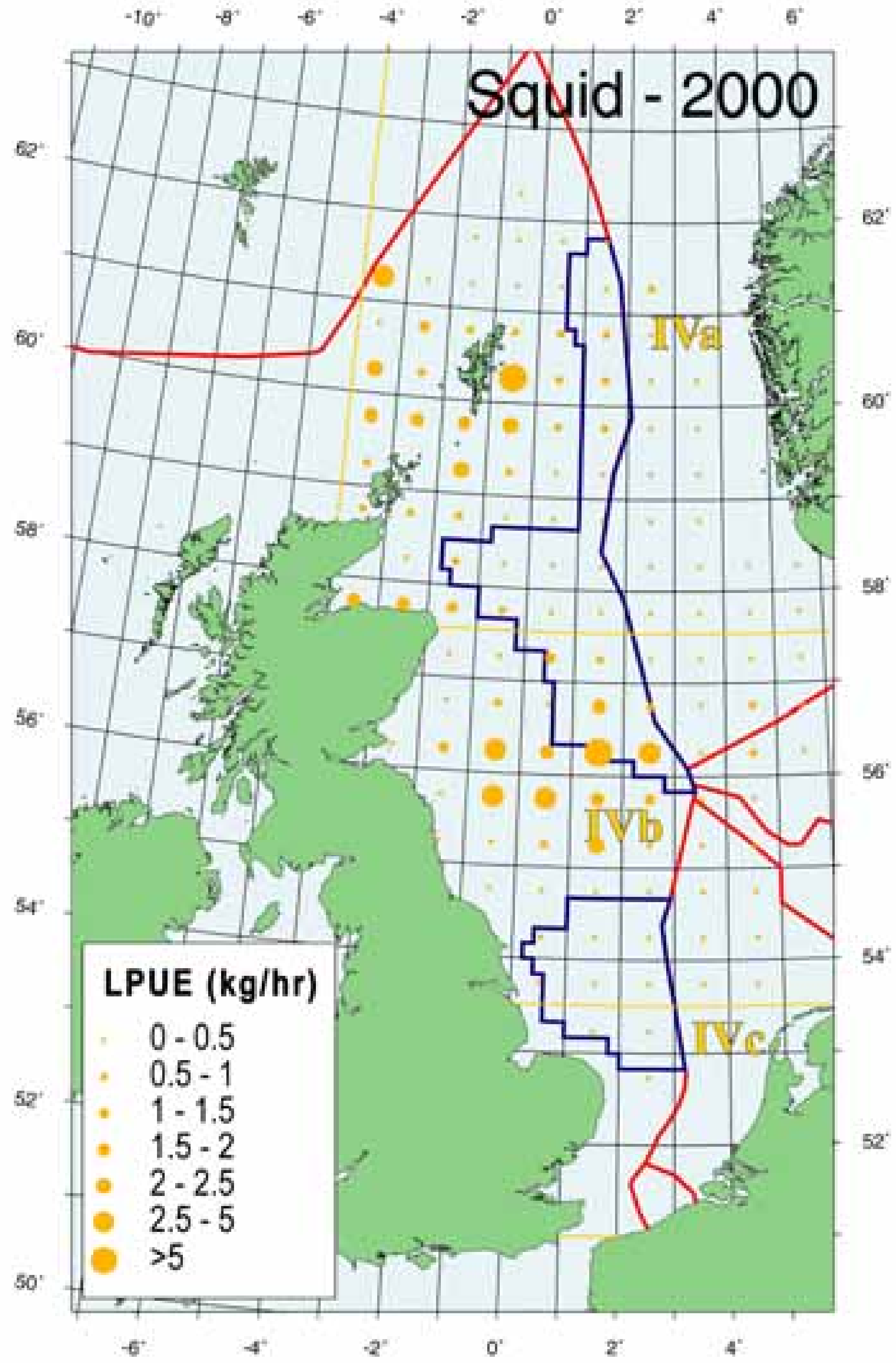

Figure 8. Squid landings per unit effort (LPUE) by ICES rectangle for 2000

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 *E. 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 in the years 1997-1999 came from outside the SEA2 area.

The largest octopus landings (205 kg) in 1997 from the SEA2 area came from ICES rectangle 44 F0 (see figure 9). 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 SEA2 area (see figures 10 and 11). 1575 kg and 4879 kg were landed in 1998 and 1999 respectively with corresponding LPUE's of 0.06 and 0.19 $kg.hr^{-1}$.

To put these landings into context, the highest squid landing from the SEA2 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.

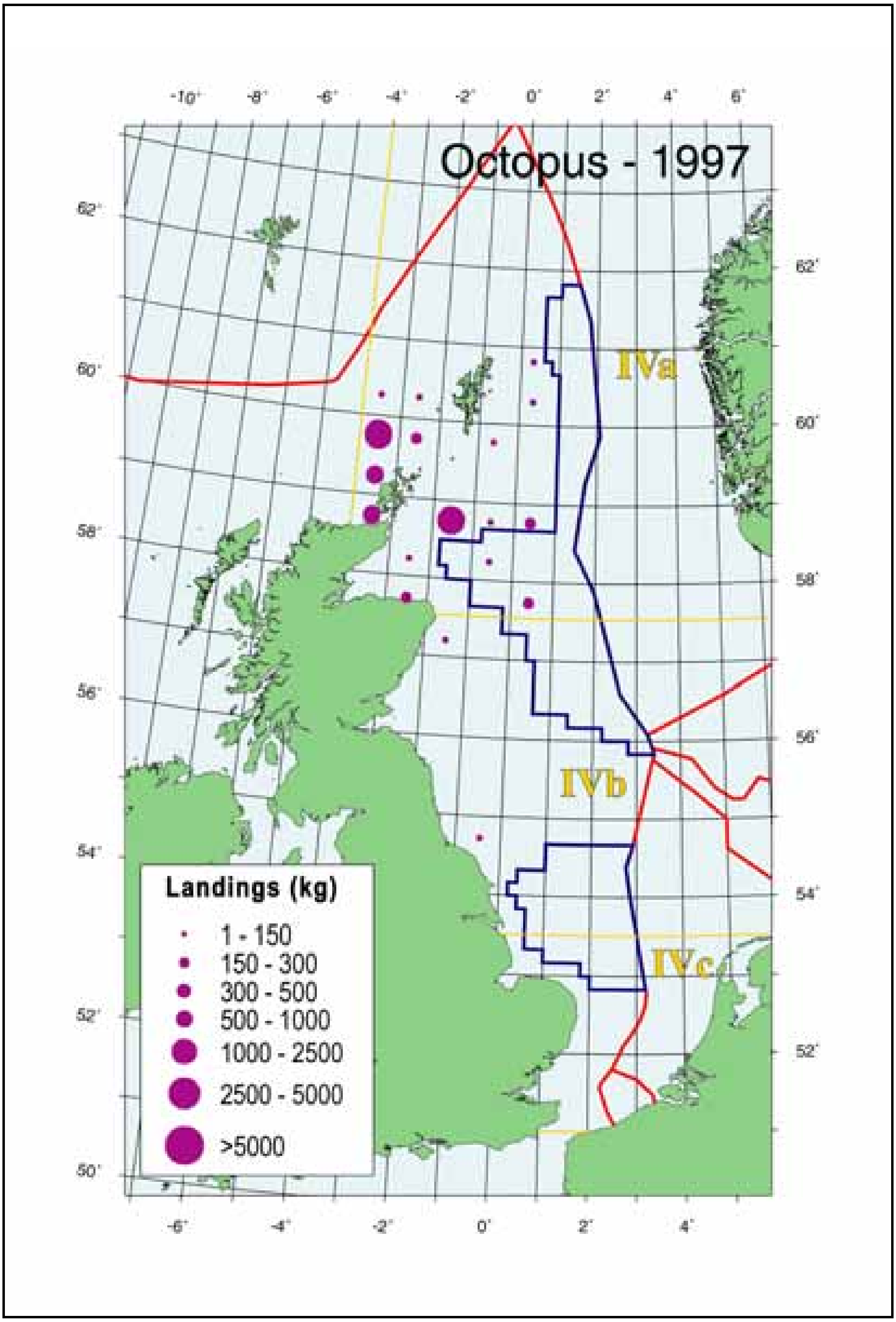

Figure 9. Octopus landings by ICES rectangle for 1997

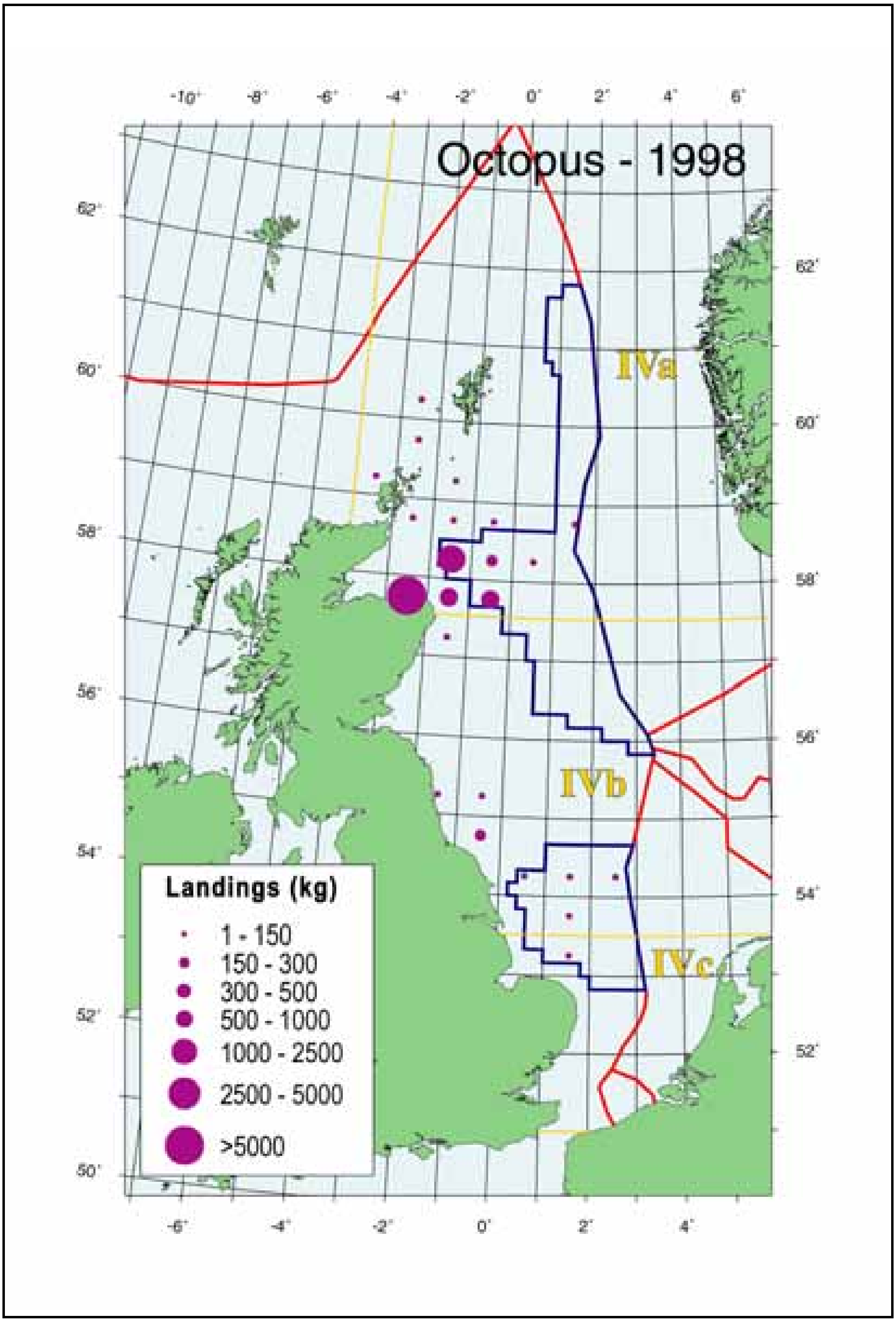

Figure 10. Octopus landings by ICES rectangle for 1998

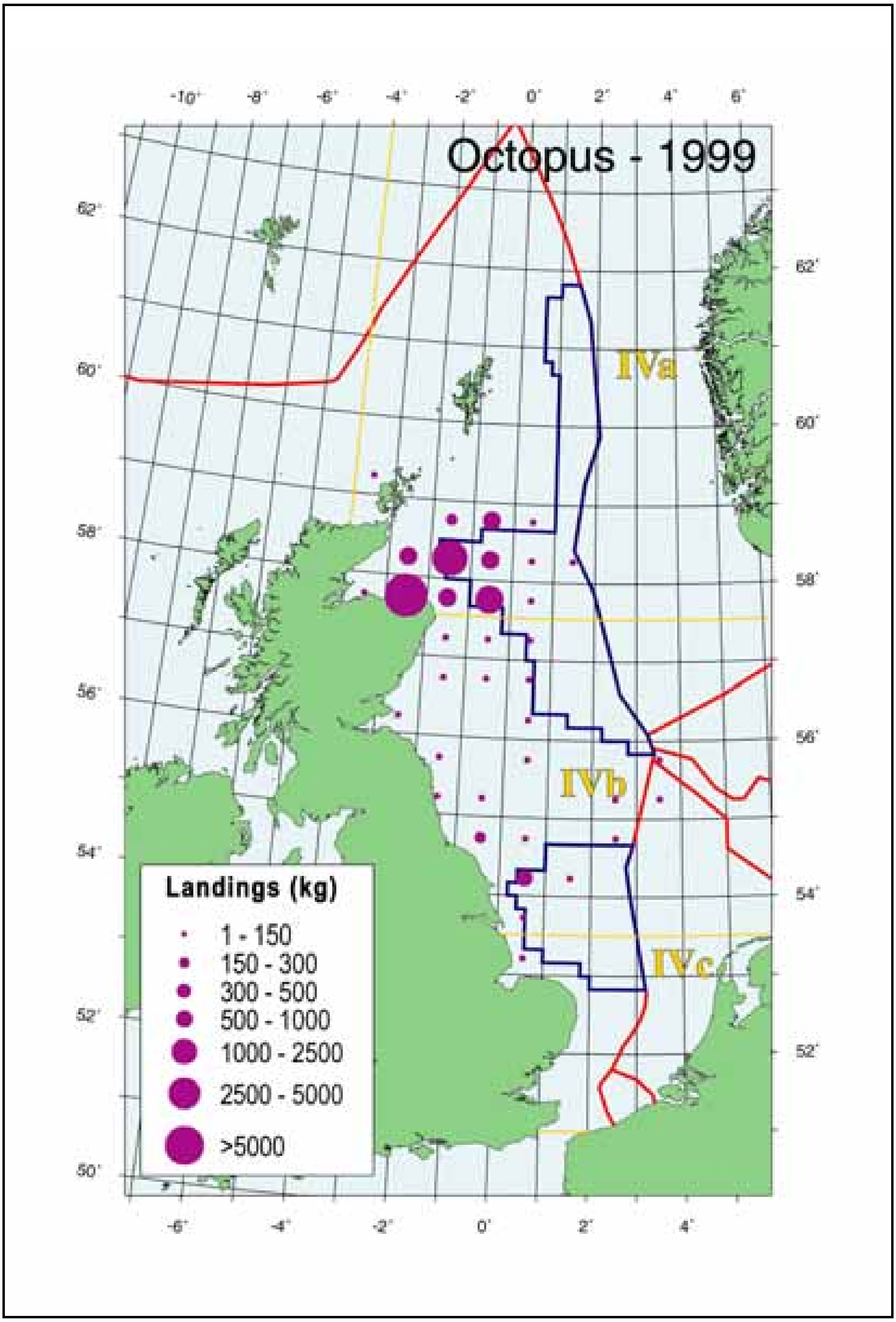

Figure 11. Octopus landings by ICES rectangle for 1999

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 Al, Cu, Hg, In, Sn, and Zn (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 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).

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

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 2, the average concentrations of some of the metals in marine sediments exceed their concentrations in drilling fluids.

Although a broad spectrum of trace metals have 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 (Cd) (Martin and Flegal, 1975; Finger and Smith, 1987). Some metals, for example copper (Cu) and zinc (Zn), 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 *O. vulgaris, Eledone moschata* and *Sepia officinalis*, revealed hepatopancreatic 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 *S. 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 relatively 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 (Hg) 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). A study has revealed high mercury levels in the mantle muscle of *L. forbesi* and *T. eblanae* caught in the North Sea 15km off the Aberdeen-shire coast. These levels were positively correlated with animal size (Craig, 1996) and Monteiro *et al.,*(1992), found an exponential relationship between mercury concentration in mantle muscle and size in *L. forbesi, O. bartrami* and *O. vulgaris.*

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 *L. forbesi* 6 times those found in the octopus *O. vulgaris* (Monteiro *et al.*, 1992).

6. FURTHER CONSERVATION CONSIDERATIONS

Cephalopod species known to have occurred in the SEA2 area (from Stephen, 1944):
Frequent occurrences:

Octopoda:
Eledone cirrhosa.

Decapoda:
Sepiola atlantica; Sepiola pfefferi; Sepietta oweniana; Rossia macrosoma; Rossia glaucopis; Sepia officinalis; Loligo vulgaris; Loligo forbesi; Alloteuthis subulata; Illex coindetii; Todaropsis eblanae; Todarodes sagittatus sagittatus.

Infrequent occurrences:

Octopoda:
Bathypolypus arcticus; Benthoctopus piscatorum.

Decapoda:
Sepietta neglecta; Sepia elegans; Onychoteuthis banksi; Architeuthis monachus; Architeuthis harveyi; Sthenoteuthis caroli; Brachioteuthis riisei.

All the above species will be, to a greater or lesser extent, disturbed by displacement of the bottom sediment. Bio-diversity is, however, unlikely to be significantly affected by such displacement due to the localised nature of drilling operations.

Squids, cuttlefishes and octopuses are apparently deaf – a handicap that may advantage toothed whales when using sonar in order to locate their prey (Taylor, 1986). However, 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.

7. CONCLUSION

- There appears to be overwhelming evidence of high accumulation rates of metals in cephalopods
- The cephalopod species landed from the SEA2 area mainly consist of *Loligo forbesi* and, to a much lesser extent, *Eledone cirrhosa*. However, the areas of highest abundance appear to lie outside the SEA2 area for both species.
- Both *L. forbesi* and *E. cirrhosa* are fished only as by-catch species in the SEA2 area (with most of the octopus being discarded) and, as such, are relatively unimportant species to the catching sector.

The overall impact on cephalopods and cephalopod fisheries in the SEA2 area by further oilfield development would therefore be slight.

8. 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, 2000a. Report of the Working Group on Cephalopod Fisheries and Life History. ICES CM 2000/G:4

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

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. Fish. Res. 8: 303-321.

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

Boyle, P.R. and Boletzky, S.V., 1996. Cephalopod populations: definition and dynamics. Phil. Trans. R. Soc. Lond. B 351: 985-1002.

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.). J. Mar. Biol. Ass. U.K. 81.

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. and Pierce, G.J., 1996. Size selectivity in the diet of *Loligo forbesi* (Cephalopoda: Loliginidae). J. Mar. Biol. Ass. U.K. 76:1081-1090.

Collins, M.A., Pierce, G.J. & 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. & 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, 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. & Henderson, S.,

2001. Cephalopod consumption by fish in UK waters. Fish. Res. 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.. Comp. Biochem. Physiol. 60: 347-350.

Dicks, B.M., 1982. Monitoring the biological effects of North Sea platforms. Mar. Poll. Bull. 13: 221-227.

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.

Furness, R.W., 1994. An estimate of the quantity of squid consumed by seabirds in the eastern North Atlantic and adjoining seas. Fish. Res. 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. Fish. Res. 21: 179-191.

Guerra, A. and Rocha F., 1994. The life history of *Loligo forbesi* (Cephalopoa: Loliginidae) in Galician waters (NW Spain). Fish. Res. 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. J. Mar. Biol. Assoc. UK 72: 367-382.

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.

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.

Lum-Kong, A., Pierce, G.J. & 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. J. Mar. Biol. Assoc. UK, 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.

Pierce, G.J., Boyle, P.R. and Thompson, P.M., 1990. Diet selection by seals. In: M. Barnes & 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., 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. and Guerra, A., 1994. Stock assessment methods used for cephalopod fisheries. Fish. Res., 21: 255-285.

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

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. Fish. Res. 21: 127-148.

Pierce, G.J., Boyle, P.R., Hastie, L.C. and Santos, M.B., 1994c. Diets of squid *Loligo forbesi* in the northeast Atlantic. Fish. Res. 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. Fish. Res. 21: 193-216.

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., 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 J. Mar. Sci. 55: 14-33.

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. Fish. Res. 21: 103-114.

Rocca, E., 1969. Copper distribution in *Octopus vulgaris* Lam. hepatopancreas. Comp. Biochem. Physiol. 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. Mar. Poll. Bull. 27: 683-686.

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., 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 absorbtion 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. Trans. Roy. Soc. Edin. 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. Can. J. Zool./ Rev. Can. Zool. 74: 1110-1121.