The distribution and abundance of cephalopod species caught during demersal trawl surveys west of Ireland and in the Celtic Sea

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CONTENTS

ABSTRACT

Distributional and abundance data on seventeen cephalopod species from three demersal trawl series are presented. Data from one the CEFAS March Celtic Sea Groundfish Survey cover the years 1994-1998 inclusive and a depth range of 57-580 m. Data from two Marine Institute surveys was for October-November 1997 only. One of these surveys was west and south west of Ireland between depths of 27-328 m, the other was conducted in deepwater (520-1174 m) to the northwest. Eleven cephalopod species were caught (14,981 individual cephalopods) during the five CEFAS surveys. Spatial and bathymetric distribution data are presented for the species caught and the inter-annual variability is discussed. The most numerous species in catches was *Loligo forbesi* (n = 6,803), however, the highest biomass caught was *Illex coindetii* (418.3kg). *Alloteuthis subulata* were common close to shore in water depth of less than 75 m. Swept area density estimates are reported for the most abundant species in catches. Ten cephalopod species were caught during the Marine Institute west coast groundfish survey (774 specimens were examined out of an estimated 8,712 caught). The results show broadly similar patterns in species composition, distribution and abundance to the CEFAS survey. *Todaropsis eblanae* was the second most numerous species in the survey. Only six cephalopod species (n =196) were caught in the Marine Institute deepwater trawl survey. *Todarodes sagittatus* was the most common species caught. Deepwater octopods including *Benthoctopus piscatorum*, *Benthoctopus ergasticus* and *Opisthoteuthis massyae* were also caught. This chapter provides a base line of data on cephalopod species which are caught in trawl surveys west of Ireland and in the Celtic Sea.

1. INTRODUCTION

Demersal trawl surveys are an integral part of the finfish stock assessment process. Data from these surveys provide a unique insight into species distributions and abundance, being independent of the biases and errors of commercial fisheries data, such as discarding, mis-identification and mis-reporting and changes in effort and catchability. Cod-end fine mesh liners are used in demersal surveys. As a result, small individuals and small species not normally caught in commercial gears are caught, thus providing recruitment information for the main commercial species. The surveys are also used to monitor changes in the commercially important stocks, to collect biological data on the more important species and to support the shore-based sampling programs. To date, data on cephalopod distributions have been regarded as of secondary importance to the data on commercial finfish species.

Cephalopods play an extremely important role in marine ecosystem and are becoming an increasingly important fisheries resource in the waters around Ireland (Collins *et al*., 1994 & 1995, Lordan *et al*., 1995, 1998 and in press). There is little information on abundance and fine scale distributions of cephalopod species in this area in the literature. Investigations at the start of the 20th century provide the first information on the occurrence of cephalopod species in the waters around Ireland (Massy, 1909; Massy, 1928). More recently, Collins *et al*., (1995a) used demersal trawl survey data in the Irish Sea to investigate the distribution and demography of *Loligo forbesi* Steenstrup (1856) and also reported catches of other cephalopod species. Pierce *et al*. (1998) used Scottish demersal trawl survey data to describe the spatial distribution and density of *Loligo forbesi* in the North Sea, Rockall, west of Scotland, west and south west of Ireland. The distribution of deepwater benthic and bentho-pelagic cephalopods caught commercial and research trawls has also recently been described (Collins *et al*., 2001).

In this study data from three demersal trawl survey series in waters around Ireland are examined. The aim of this study is firstly, to establish which cephalopod species are routinely caught during these surveys. Secondly, to investigate the spatial and bathymetric distributions of the species caught. Thirdly, a time series of five years is available for one of the surveys and this is used to investigate inter-annual variations in spatial distribution and densities of the more abundant cephalopod species.

2. MATERIALS AND METHODS

The data presented in this paper are from three different survey programmes, by two different countries, conducted in different areas, at different times of year, on different vessels with different gears and using different protocols. The CEFAS Celtic Sea groundfish surveys are conducted annually during in the first quarter in the Celtic Sea and Western Approaches from 47^{o}00 N to 52^{o}30 N at depths of between 57-580 m. The Marine Institute West Coast Groundfish Surveys Part B (WCGFSb) are also conducted annually during the third quarter on chartered commercial vessels west and southwest of Ireland from 50^{o}30 N to 54^{o}00 N at depths of between 27-328 m. Both of these surveys have a long historical time series and originated from a survey series designed to investigate the biology and distribution of mackerel (*Scomber scombrus* L.). Both surveys are now used to provide abundance indices for demersal fish assessments in the

ICES Southern Shelf Working Group. The Marine Institute Deepwater Survey Programme commenced in 1993 to provide background biological data and samples of deepwater fishery resources in the waters off Ireland. To date there have been five long-line and five trawl surveys. The survey investigated here took place west and northwest of Ireland on the eastern slopes of the Rockall Trough from 54°00 N to 58°30 N at depths of between 646-1174 m. The details of the survey dates, vessel used, depth range and number of tows are presented in Table 1. Details of the vessels, gears and survey methods were as follows for the different surveys:

2.1 CEFAS Celtic Sea Groundfish Surveys

During the CEFAS Celtic Sea ground fish the trawl type used was a modified Portuguese high-headline bottom trawl (CEFAS description: PHHT CIRO POLY liner rubber bobbins bunt tickler) with a 20 mm fine mesh liner in the cod-end and 35 cm bobbins in the ground rope. Warp to depth ratio varied from 3.75:1 to 2.5:1. The trawl doors were 1500 kg oval doors. All tows were made in daylight hours. Haul duration was 60 minutes at a towing speed of approximately 4 knots.

Table 1: Survey dates, survey areas and number of tows.

Survey Code/Series	Vessel	Dates	Depth Range (m)	Number of valid tows
CEFAS Celtic Sea Groundfish Surveys				
CIRO 3/94	R.V. Cirolana	27/2/1994-12/3/1994	63-335	33
CIRO 3/95	R.V. Cirolana	15/3/1995-8/4/1995	59-404	71
CORY 3/96	R.V. Corystes	01/03/1996-25/03/1996	60-486	62
CIRO 3/97	R.V. Cirolana	8/3/1997-2/4/1997	61-580	76
CIRO 2/98	R.V. Cirolana	01/03/1998-29/03/1998	57-512	74
Marine Institute West Coast Groundfish Survey Part B.				
WCGFSB/97	M.F.V. Sionnainn	30/10/1997-6/11/1997	27-328	39
Marine Institute Deepwater Survey Programme.				
MMIR291097	M.F.V. Mary-M	29/10/1997-06/22/1997	520-1174	22

SCANMAR™ equipment was used to monitor trawl parameters; headline height, door spread and temperature. Depth, position and SCANMAR™ parameters were all electronically logged every 15 seconds during the tow and later filtered for anomalous readings using a customised Visual Basic™ routine. These data were used to calculate, mean door spread $\overline{S}$ and mean headline height $\overline{H}$. The duration, shoot and haul position and mean depth was recorded from the navigational equipment bridge of the vessel. Distance over ground was calculated using the following equation:

Equation 1 $$D = 60 \times \sqrt{(L_s - L_h)^2 + (O_s - O_h)^2 \times Cos\frac{(L_s + L_h)^2}{2}}$$

Where, D was distance over ground, L_s was latitude shot, L_h was latitude hauled, O_s was longitude shot and O_h was longitude hauled. Estimated swept area A_s (km^2) was calculated using equation 2 and estimated swept volume V_s (km^3) is calculated using equation 3. Cephalopod densities C_d were estimated using equation 4 where, C was the number of individuals caught in a tow.

Equation 2 $$A_s = D \times \overline{S}$$

Equation 3 $$V_s = D \times \overline{S} \times \overline{H}$$

Equation 4 $$C_d = \frac{\sum C}{A_s}$$

Catch weight and number were recorded for each squid species (except for the 1996 survey when ommastrephids were not identified to species level). During tows where the first author was aboard the vessel, further biological sampling i.e. sex, maturity, weight, stomach contents and statoliths, was undertaken for selected squid species. These data are presented elsewhere (e.g. Lordan *et al*. 1998, in press). All octopods caught were identified, counted and weighed. Also, sepiolids and cuttlefish were identified to species, counted, measured and weighed when the author was aboard. Catch weights and numbers were standardised to 60 min duration. Any tows classed as invalid due to gear damage or other factors were excluded from the analysis.

2.2 Marine Institute West Coast Groundfish Survey Part B

The 34 m Dingle based demersal trawler, MFV Sionnainn, the chartered commercial vessel used during the Marine Institute west coast groundfish survey (Table 3.1). The trawl type used was a commercial bottom trawl with 73 m clean-ground ground rope, 760 x 80 mm meshes with an 8.2 m long 20 mm cod-end liner. The bridles consisted of 220 m of 36 mm 4 strand singles and 55 m of 24 mm doubles. The warp used was 22 mm and the wrap to depth ratio was generally about 2.5:1. The trawl doors were 2.44 m, 900 kg Tyberon™ doors. All tows were made in daylight hours; haul duration was 60 minutes at a towing speed of approximately 3 knots. Tow details were logged manually in accordance with the protocols adopted in the Manual for International Bottom Trawl Surveys (IBTS) (Anon., 1996).

Because of the limitations of conducting the survey aboard a commercial vessel, the following sub-sampling procedure was used during this survey series. The total catch weight was estimated in terms of 40 kg boxes caught during each tow. A sub-sample of two 40 kg boxes was randomly selected from the bulk catch and raised to the total catch. The weight and number of *Eledone cirrhosa* Lamarck (1798) in the sub-sample was recorded at sea and the octopi were released. All the other cephalopods were frozen and returned to the laboratory at N.U.I.C. In the laboratory the cephalopods were sorted into species and sex, counted, measured (mm) and weighed (g) collectively and individually. Catch weights and numbers were raised and standardised to 60 min duration. Any tows classed as invalid due to gear damage were excluded from the analysis.

2.3 Marine Institute Deepwater Survey Programme
The vessel used during the Marine Institute deepwater survey programme was a chartered commercial vessel, the 35 m Killybegs based demersal trawler MFV Mary-M. The trawl types used were two commercial deep-water trawls with 105 mm mesh cod-end. The headline had 120 x 20 cm deepwater floats and a ground gear of 23.5 m in length with 40.6 cm hoppers. The bridles consisted of 91.5 m of singles and 45.7 m of doubles. One of the trawls had a 20 mm mesh cod-end liner. The warp used was 28 mm and the wrap to depth ratios was generally about 2.2:1. The trawl doors were 1200 kg Morgere™ doors. Tows were made both during daylight and at night and the haul duration ranged from 195 to 285 minutes at a towing speed of approximately 3 knots. Tow details were logged manually.

The cephalopods caught in each haul were sorted into species or taxa if a definite identification was not possible, counted and weighed individually. Specimens of *Histioteuthis* sp., *Opisthothethis* sp., *Benthoctopus* sp. and *Teuthowenia megalops* Prosch (1849) were either frozen or fixed in a 10% buffered formalin solution for future detailed examination in the laboratory at N.U.IC and the University of Aberdeen (Collins *et al*., in press).

Throughout the study cephalopods were identified using Nesis (1987) and Roper *et al*. (1984) and cephalopods beaks were identified using Clarke (1986). Photo-identification keys were also developed to enable non-specialist personnel to identify cephalopods.

3. RESULTS

3.1 Results of the CEFAS Celtic Sea Groundfish Surveys
Prior to 1994, cephalopods caught on these surveys were recorded as cuttlefish, sepiolids, long-finned squid and short-finned squid. Photo-identification keys (Appendix 1) were developed during the 1997 and 1998 surveys to enable non-cephalopod specialists to identify cephalopods to the species level routinely on these surveys. During the five surveys 14,981 individual cephalopods were caught and 11 cephalopod species were identified. The total catch numbers of cephalopod species during the 1994 to 1998 surveys are presented in Table 2.

Loligo forbesi was the most numerous species overall, with 6,803 individual caught over the five surveys. *Illex coindetii* Verany (1839) was more numerous than *L. forbesi* in the 1994 survey and possibly again in 1996, although in 1996 ommastrephids were not identified by species. Either *I. coindetii* or *Alloteuthis subulata* Lamarck (1798) was the next most numerous species. There were 3,250 individual *A. subulata* caught over the five surveys and 2,280 *I. coindetii* (plus probably a large proportion of the 1,157 unidentified ommastrephids in 1996). *Todaropsis eblanae* Ball (1841) was the next most numerous squid species caught. *Todarodes sagittatus* Lamarck (1798) was caught in low number in the 1997 and 1998 surveys. These surveys included a few deepwater tows where the *Todarodes sagittatus* were caught. Such deepwater tows were not made in 1994, 1995 and 1996. *Loligo vulgaris* Lamarck (1798)were only occasionally caught. However, it should be noted that separation of the two *Loligo* species is very difficult particularly in smaller individuals so mis-identification may be a problem.

Table 2: The total numbers of cephalopods caught during the CEFAS Celtic Sea groundfish surveys 1994-1998 by species.

Year	**1994**	**1995**	**1996**	**1997**	**1998**	**Totals**
Minutes fished	1,927	3,989	3,695	4,318	4,086	**18,015**
Sepioidae						
Sepiidae*						
Sepia elagans	-	-	-	10	3	**13**
Sepia officinalis	-	-	-	42	0	**42**
Unidentified Sepiidae	3	2	1	0	0	**6**
Sepiolidae*						
Sepiola atlantica	-	-	-	22	13	**35**
Sepietta oweniana	-	-	-	4	5	**9**
Rossia macrosoma	-	-	-	55	23	**78**
Unidentified Sepiolidae	44	4	14	0	0	**62**
Myopsida						
Loliginidae						
Loligo forbesi	876	1,123	974	1,612	2,218	**6,803**
Loligo vulgaris	5	0	0	1	0	**6**
Alloteuthis subulata	92	643	191	974	1350	**3,250**
Oegopsida						
Ommastrephidae						
Illex coindetii	1,078	363	+	571	268	**2,280**
Todaropsis eblanae	139	181	+	98	141	**559**
Todarodes sagittatus	0	0	+	15	1	**16**
Unidentified ommastrephidae†			1157			**1157**
Octopoda						
Octopodidae						
Eledone cirrhosa	281	59	161	119	45	**665**
Totals	**2,518**	**2,375**	**2,498**	**3,523**	**4,067**	**14,981**

***** *Sepiidae and Sepiolidae were not identified to species level until 1997.*
† *Ommastrephidae were not identified to species level during the 1996 survey.*

Eledone cirrhosa was also fairly numerous particularly in 1994 when 281 individuals were caught. Over the five surveys 184 sepiolids were caught, *Rossia macrosoma* Delle Chiaje (1829) was the most numerous species, followed by *Sepiola atlantica* Orbigny (1840), with *Sepietta oweniana* Orbigny (1840) being the least numerous (although data by species is only available for 1997 and 1998). Catches of cuttlefish during the surveys were generally low. However, in the 1997 survey 42 *Sepia officinalis* L. and 10 *Sepia elegans* Blainville (1827) were caught.

The total weights of squid by species caught in the CEFAS groundfish surveys 1994-1998 are presented in Table 3. Nine hundred and sixty nine kilograms of squid were caught during the five surveys. The highest catch weights were of the ommastrephid squid *I. coindetii* with a total weight of 418.3 kg caught in the 1994, 1995, 1997 and 1998 surveys. A large proportion of the 114.7 kg of unidentified ommastrephids caught in 1996 was also probably *I. coindetii*. Catch weights of *L. forbesi* ranged between 58.1 kg in 1994 to 99.1 kg in 1998, 337.9 kg of *L. forbesi* were caught in total. Although numerically very abundant, only 19.0 kg of *A. subulata* were caught in the five surveys.

The spatial distribution of cephalopod catches are mapped in Figures 1 to 6. Squid and octopus catches are presented in terms of numbers caught/hr. Because of the their scarcity in catches the cuttlefish and sepiolids are catches are not plotted Catches of *Sepia officinalis* were limited to the English Channel, whereas *Sepia elegans* were caught slightly deeper in several tows on the Celtic Sea shelf. The most commonly caught sepiolid, *R. macrosoma*, was concentrated along the shelf break (i.e. the 200 m depth contour). However, highest catches were on the continental shelf close to the Irish coast. *Sepietta oweniana* had a slightly more offshore distribution than *Sepiola atlantica* though both species occurred on the shelf (i.e. less than 200 m).

Highest catches of *L. forbesi* were close to the shelf break between 50^{o}N and 51^{o}N in all five surveys (Figure 1). There were high catches off the French coast in 1997 and 1998 and south of the Scilly Isles. Both *L. vulgaris* catches were made in a similar area at the mouth of the English Channel south of Mounts Bay. *Alloteuthis subulata* catches were relatively low in 1994 and 1996 with catches limited to a few stations south of Ireland close to the Celtic Sea deep (Figure 2). In 1995, highest catches were in shallow tows made off the UK coast in the English Channel. In 1997, highest catches were close to the 100m isobath and south of Waterford and also in the English Channel. In 1998 the highest catches occurred south of Cork.

Table 3: The total weights (kg) of squid caught during the CEFAS Celtic Sea groundfish surveys 1994-1998 by species.

Year	**1994**	**1995**	**1996**	**1997**	**1998**	**Totals**
Minutes fished	**1927**	**3989**	**3695**	**4318**	**4086**	**18015**
Myopsida						
Loliginidae						
Loligo forbesi	58.1	60.3	65.2	55.2	99.1	**337.9**
Loligo vulgaris	1.4	0	0	0.1	0	**1.5**
Alloteuthis subulata	0.4	6	0.9	4.4	9.74	**19.04**
Oegopsida						
Ommastrephidae						
Illex coindetii	150.5	56.1	+	109.1	42.6	**418.3**
Todaropsis eblanae	18.5	23.0	+	14.5	18.4	**74.4**
Todarodes sagittatus	0	0	+	2.5	0.4	**2.9**
Unidentified ommastrephidae†			114.7			**114.7**
Totals	**228.9**	**140**	**180.8**	**245.8**	**170.3**	**968.7**

† *Ommastrephidae were not identified to species level during the 1996 survey.*

Illex coindetii catches in 1994 were dominated by one tow made at 335m Southwest of Ireland where 872 squid (128.2kg) were caught (Figure 3). Highest catches of *I. coindetii* in all years tended to be on or beyond the shelf break (>200 m) southwest of Ireland. Catches during the 1998 survey were concentrated north of 52^{o}N, whereas in all other years catches were concentrated further south. *Todaropsis eblanae* catches were also concentrated close to the shelf break in most years. However, in 1994 there were also large catches in the tow of the south coast off Ireland (Figure 4). Similarly, in 1995 there were also good catches of *Todaropsis eblanae* on the shelf in the middle of the Celtic Sea. In 1996 there were large catches of unidentified ommastrephid from 49^{o}N to 52^{o}N along the shelf break. Given the size range of the catches, these squid were most probably *I. coindetii* (Figure 5). Catches of *Todarodes sagittatus* were limited tows to deeper water on the slope between 48^{o}N to51^{o}N.

Eledone cirrhosa catches were particularly high in 1994, with large catches south and southwest of Ireland (Figure 6). Catches in other years were not as high and were concentrated towards the northwest of the survey area. There were few catches of *E. cirrhosa* south of 49^{o}N.

The sample sizes of cuttlefish and sepiolids during the 1997 & 1998 surveys were generally very low. Nevertheless the depths at which they were caught is worth reporting. *Sepia officinalis* was caught in waters less than 100 m, whilst *Sepia elegans* were caught in waters between 100-204m. *Rossia macrosoma* were caught from 65-354 m, *Sepiola atlantica* were caught in water depths less than 100 m whereas *Sepietta oweniana* were caught between 72-176 m.

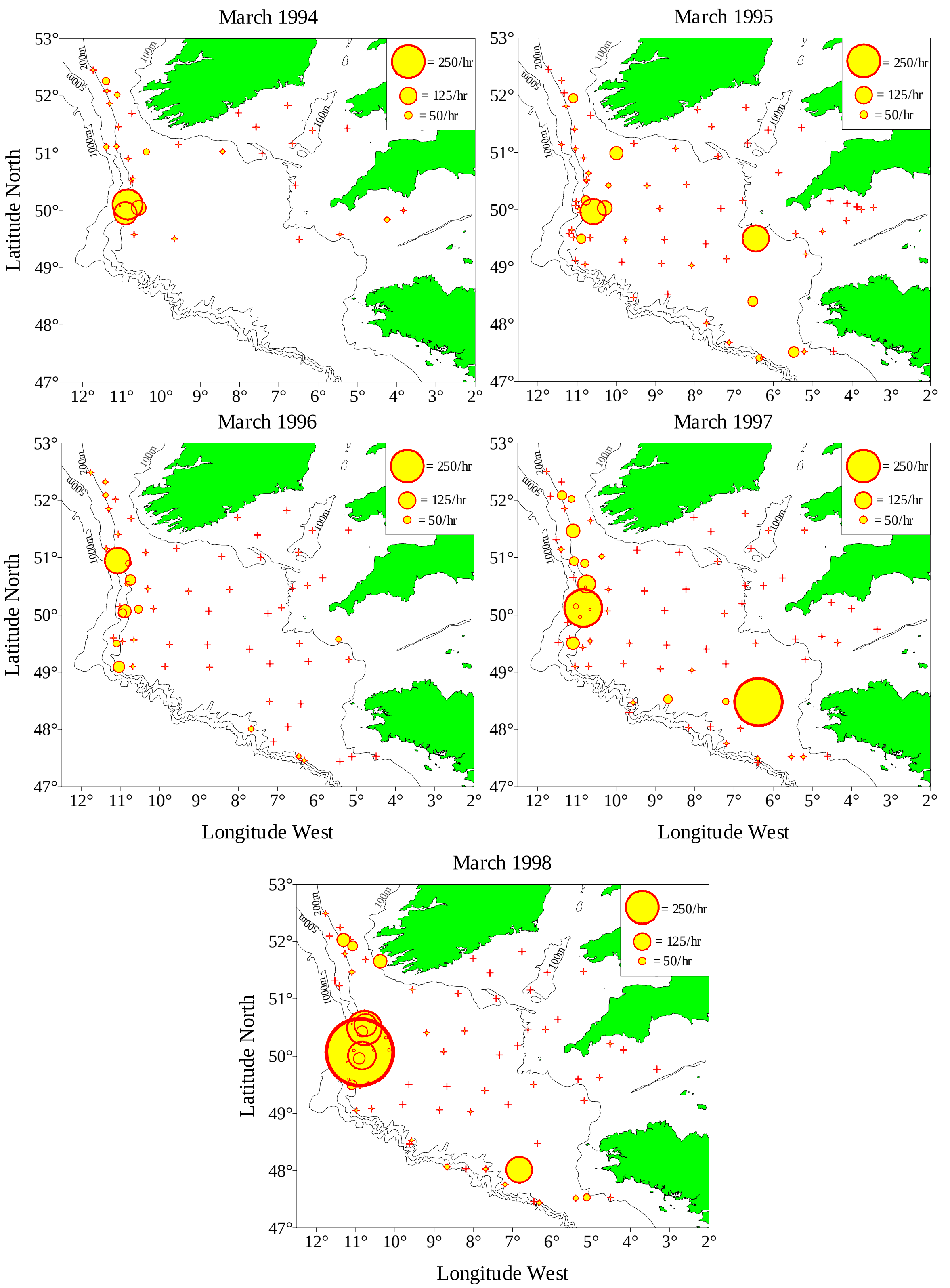


Figure 1: The spatial distributions of catches of *Loligo forbesi* during the CEFAS Celtic Sea ground fish surveys in 1994 to 1998.

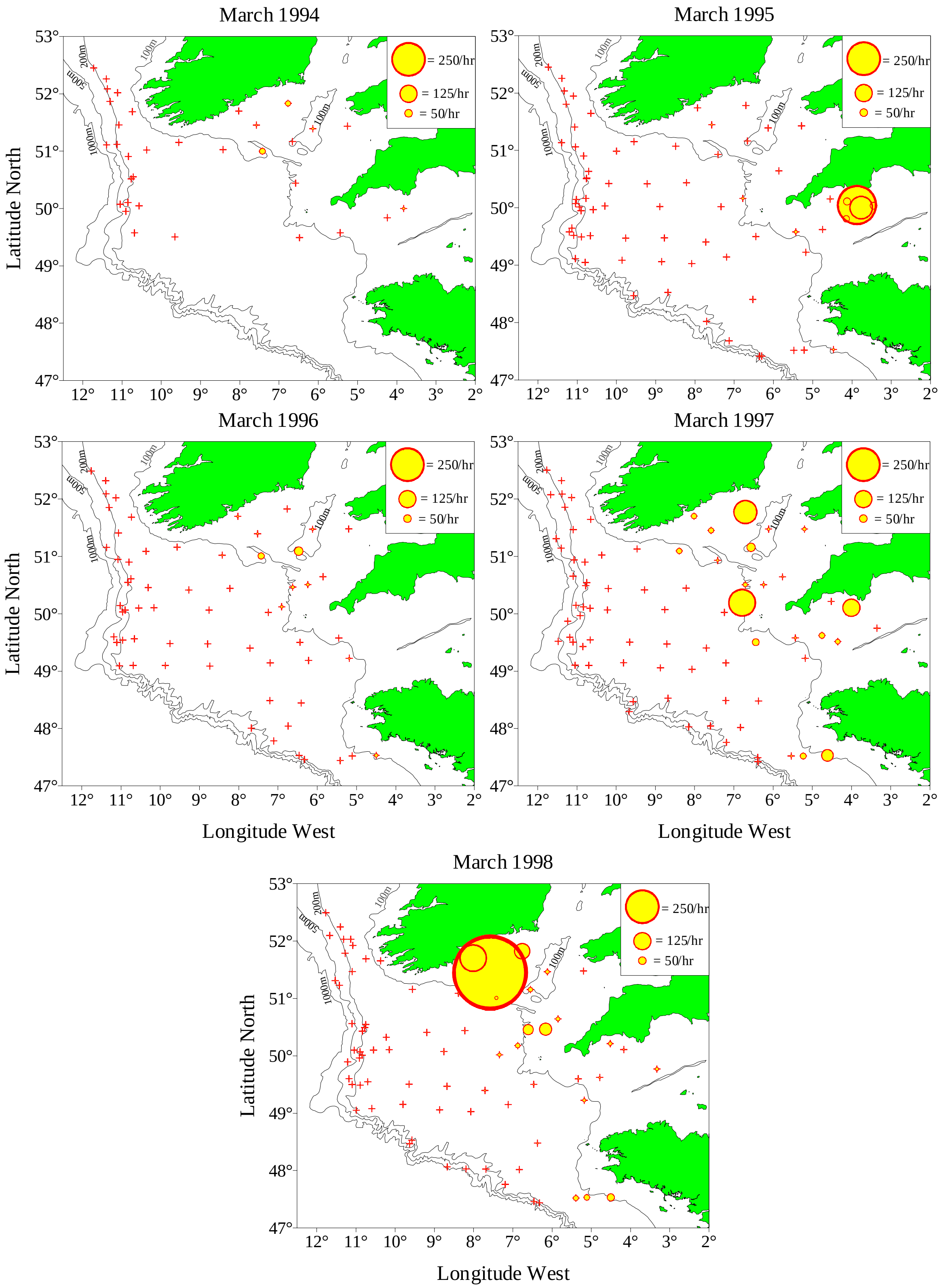


Figure 2: The spatial distributions of catches of *Alloteuthis subulata* during the CEFAS Celtic Sea ground fish surveys in 1994 to 1998.

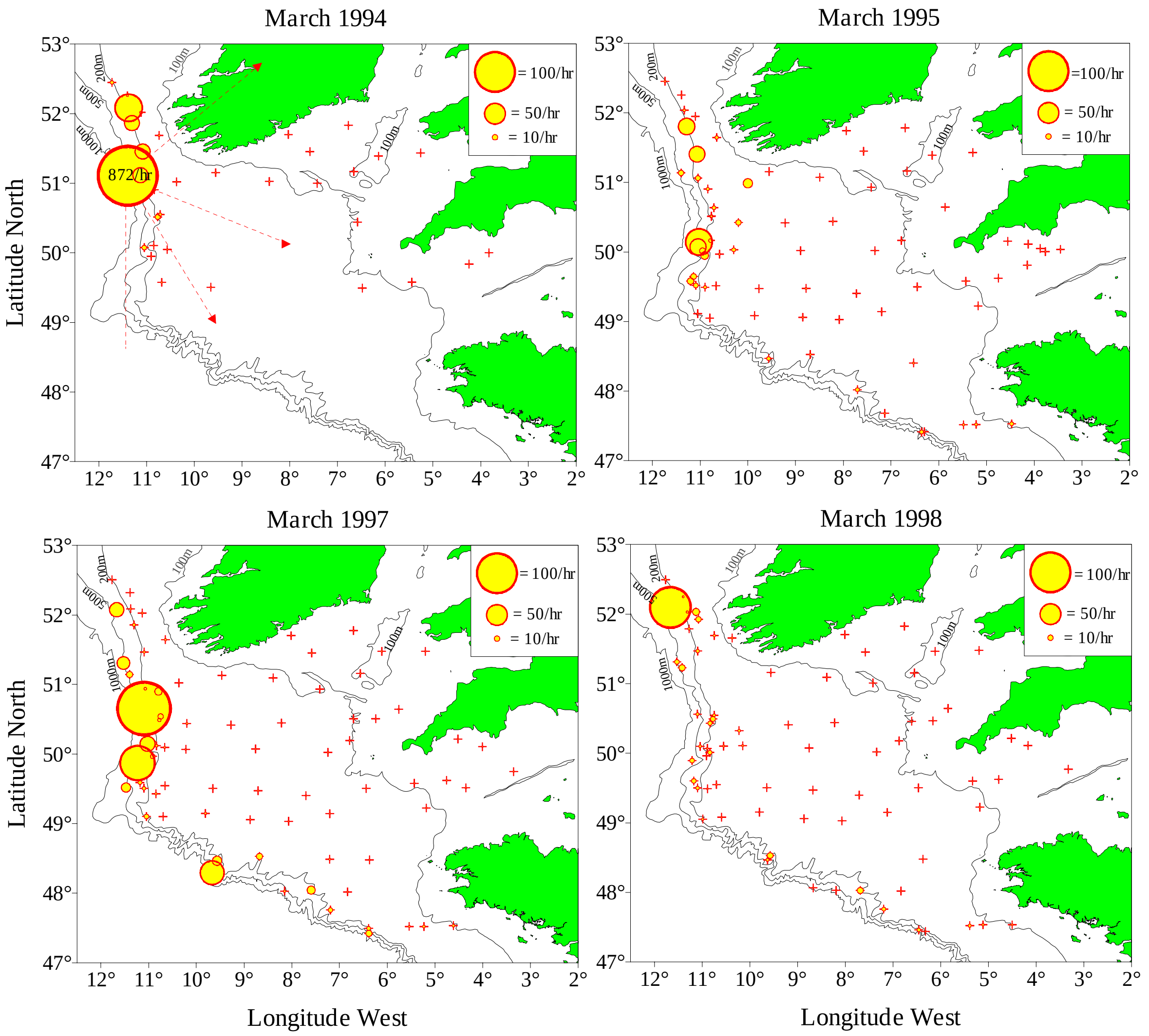


Figure 3: The spatial distributions of catches of *Illex coindetii* during the CEFAS Celtic Sea ground fish surveys in 1994, 1995, 1997 and 1998.

The depth distributions of the squid species caught are presented graphically as average numbers/hr in different depth strata (Figure 7). Catch rates were skewed with a substantial proportion of zeros, so aggregating and averaging catch data produces large variances. However, despite this, trends in depth distribution can be seen in the aggregated data. Highest *L. forbesi* catches occur towards the shelf break (200 m), catches in water less than 125 m deep are very low and catches decrease quickly between 200-274 m. No *L. forbesi* were caught deeper than 400 m. Between 150-230 m the modal length of *L. forbesi* was 90 mm. Modal length increased in shallower water, where lower numbers of larger individuals were caught. Midsize individuals (ML 120-200 mm) were most common in the catch in deeper waters (>250 m).

All the *L. vulgaris* caught were caught between 79-99 m. *Alloteuthis subulata* catches were highest at depths of less than 75 m before decreasing to zero, deeper than 150 m.

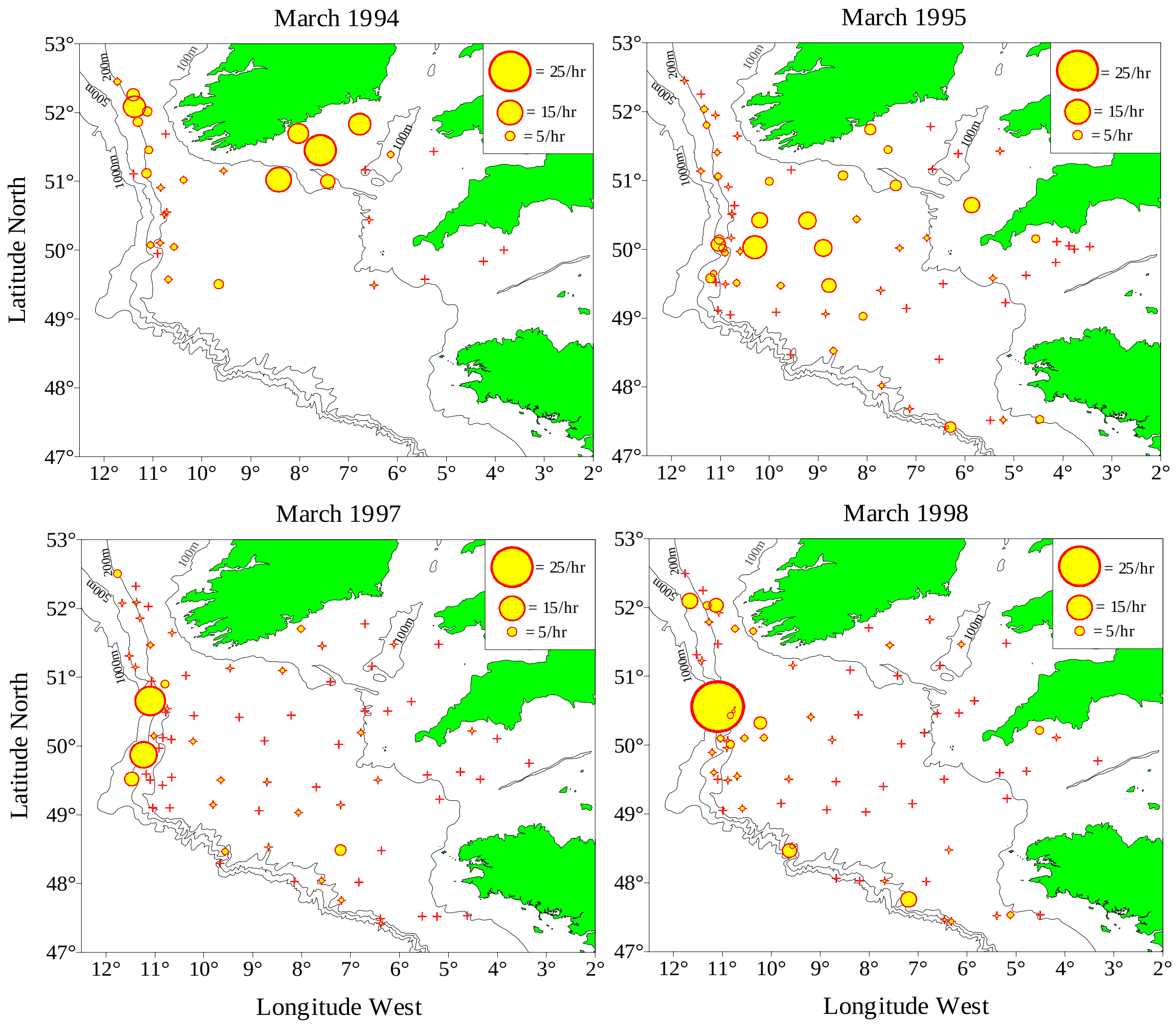


Figure 4: The spatial distributions of catches of *Todaropsis eblanae* during the CEFAS Celtic Sea ground fish surveys in 1994, 1995, 1997 and 1998.

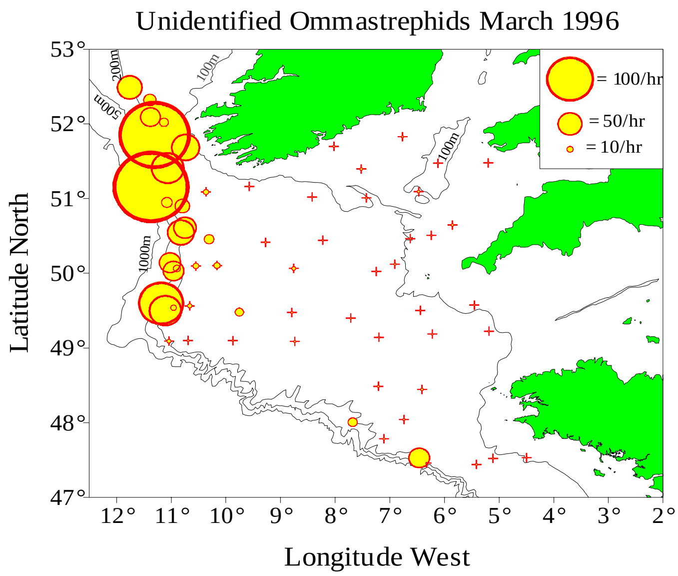


Figure 5: The spatial distributions of catches of unidentified ommastrephids during the CEFAS Celtic Sea ground fish survey in 1996.

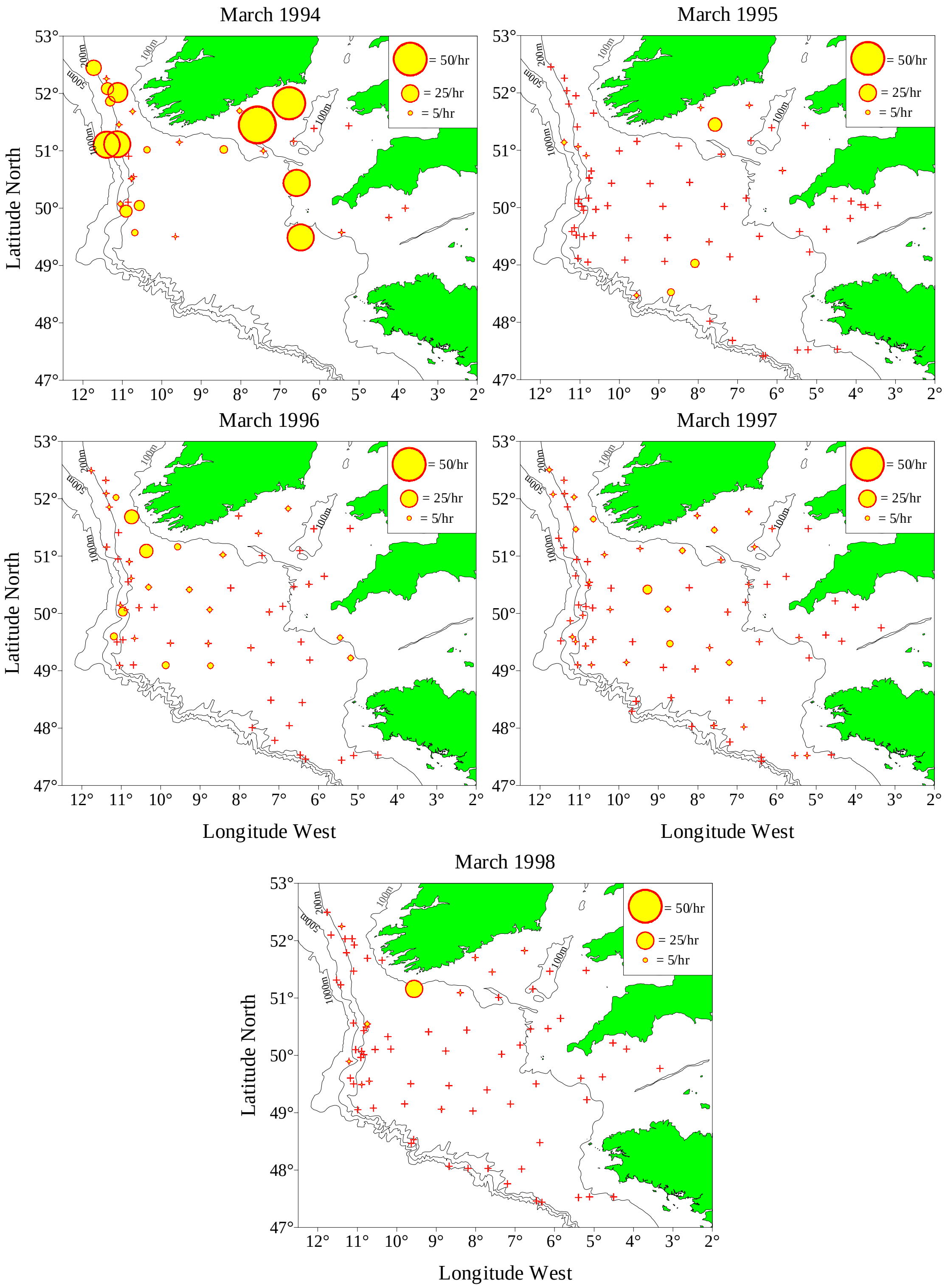
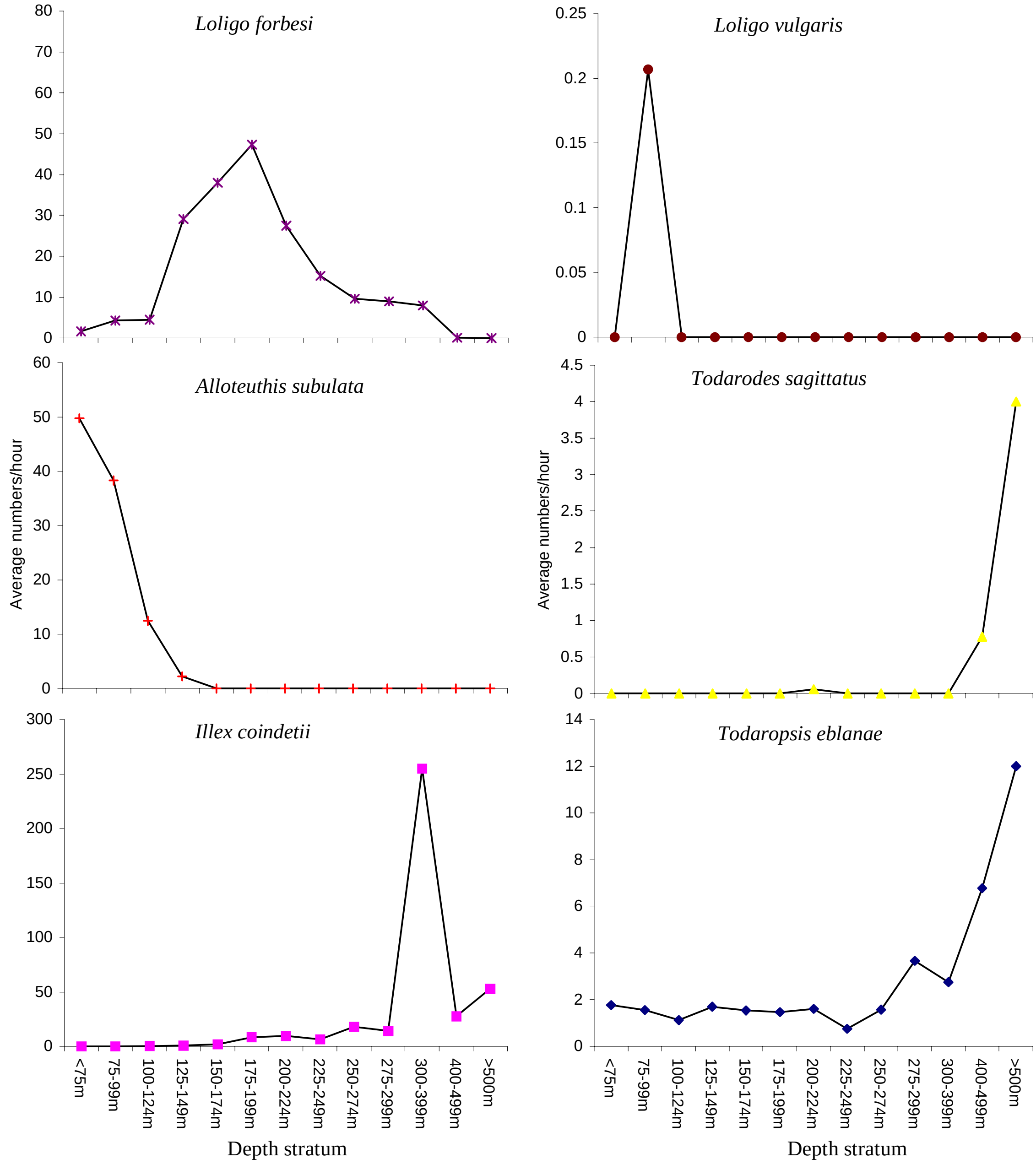


Figure 6: The spatial distributions of catches of *Eledone cirrhosa* during the CEFAS Celtic Sea ground fish surveys in 1994, 1995, 1997 and 1998.

Illex coindetii catches were highest between 300-400 m. However, this is largely due to the big catch of 872 individuals at one station in 1994. If these data are ignored a trend of increasing catch with depth can been seen. At depths less than 150 m catches were very low but increased steadily to the deepest depth category (>500 m). There was also some evidence of increasing size with depth in *I. coindetii*. The modal mantle length of males increased from less than 140 mm below 150 m to 180 mm above 400 m. Similarly, in females modal mantle length increased from 160 mm to 220 mm.

Figure 7: Squid species catch rates per depth stratum during the CEFAS Celtic Sea ground fish surveys in 1994 to 1998.



Todaropsis eblanae catches peak at the deepest depth category but *Todaropsis eblanae* are caught at low numbers at all depth categories. Highest catches of the unidentified ommastrephids during the 1996 survey were between 225-249 m. With the exception of a single specimen caught at 200 m all the *Todarodes sagittatus* were caught deeper than 400 m.

Identical gears were used during all five surveys, but in 1996 RV Corystes was used instead of R.V. Cirolana. The number of observation, means and standard deviations of door spread and headline height as monitored using the SCANMAR™ equipments are presented in Table 4. A one-way ANOVA was used to ascertain whether there were significant differences in swept area (A_s) between years. There was no significant difference in mean swept areas from year to year (p= 0.263). This suggests that an analysis of density estimates between surveys is valid as variations are not attributable to gear parameters.

Table 4: The mean and standard deviation of door spread and headline height from the SCANMAR™ sensors used during the CEFAS Celtic Sea groundfish surveys 1994-1998.

Door spread			
Year	**N**	**Mean**	**St. Dev**
1994	30	84.4	4.263
1995	59	85.962	4.25
1996	32	83.224	5.062
1997	50	87.493	3.996
1998	106	82.162	5.538

Headline Height			
Year	**N**	**Mean**	**St. Dev**
1994	29	4.1517	0.2064
1995	59	4.1276	0.435
1996	34	9206	1.1351
1997	65	4.3908	0.6406
1998	108	4.8774	0.4884

The swept area abundance estimates (Table 5) show that the highest ground area swept was during the 1997 survey and the lowest was in 1994 when the survey was cut short due to technical difficulties in the second half. The density estimates for the squid and octopus species caught are presented in Table 5. *Loligo forbesi* was caught in the highest densities, though there is considerable variation in density estimates from year to year. The 1998 *L. forbesi* density estimate is approximately twice the estimates between 1994-1996. There is also variation in the density estimates for *A. subulata*, again the 1998 estimate is the highest in the time series of surveys. The density estimate is particularly low for *A. subulata* in 1994, this is despite that the tows that yielded good catches in other years were fished that year. Of the ommastrephid species, *I. coindetii* was caught in the highest densities from 14.1-57.7/km^2. The unidentified ommastrephid species, which were caught at a density of 60.8/km^2, 1996 were probably mainly *I. coindetii*. Density estimates for *Todaropsis eblanae* remained fairly stable compared to other species caught, only varying from 5.2-9.5/km^2. Highest density estimate of *E. cirrhosa* were in 1999 with 14.8/km^2 and the lowest were in 1998 with 2.4/km^2. The cephalopod species with the highest biomass density was *I. coindetii* with estimates ranging from 2.2-8.9kg/km^2. *Loligo forbesi* also had fairly high biomass densities particularly in 1998 with 5.2kg/km^2. Most of the other species occurred at biomass density estimates of less than 1kg/km^2.

Table 5: Swept area estimates and squid and octopus densities for the CEFAS Celtic Sea groundfish surveys 1994-1998.

Survey	**Cirolana 3/94**	**Cirolana 3/95**	**Corystes 3/96**	**Cirolana 3/97**	**Cirolana 2/98**
Estimated swept area (km^2)	19.0	38.9	38	44.9	38.1
Estimate of numbers caught per km^2 swept					
Myopsida					
Loliginidae					
Loligo forbesi	46.1	59.0	51.2	84.8	116.6
Loligo vulgaris	0.3	0.0	0.0	0.1	0.0
Alloteuthis subulata	4.8	33.8	10.0	51.2	71.0
Oegopsida					
Ommastrephidae					
Illex coindetii	56.7	19.1	n/a	30.0	14.1
Todaropsis eblanae	7.3	9.5	n/a	5.2	7.4
Todarodes sagittatus	0.0	0.0	n/a	0.8	0.1
Unidentified ommastrephidae†	n/a	n/a	60.8	n/a	n/a
Octopoda					
Octopodidae					
Eledone cirrhosa	14.8	1	8.5	6.3	2.4
Estimate of weight caught (kg) per km^2 fished					
Myopsida					
Loliginidae					
Loligo forbesi	3.1	3.2	3.4	2.9	5.2
Loligo vulgaris	0.1	0.0	0.0	0.0	0.0
Alloteuthis subulata	0.0	0.2	0.0	0.2	0.5
Oegopsida					
Ommastrephidae					
Illex coindetii	7.9	2.9	n/a	5.7	2.2
Todaropsis eblanae	1.0	1.2	n/a	0.8	1.0
Todarodes sagittatus	0.0	0.0	n/a	0.1	0.0
Unidentified ommastrephidae†	n/a	n/a	6.0	n/a	n/a

† *Ommastrephidae were not identified to species level during the 1996 survey.*

3.2 Results of the Marine Institute WCGFSb (October 1997)

A total of 744 cephalopods (12.93kg) were frozen during the survey and returned to the laboratory for further examination. Ten different species were identified (Table 6). Since these samples came from a sub-sample of the total catch these were raised to estimate the total numbers caught during the survey. The total estimated weight of cephalopods caught during the survey was 347 kg (n = 8,712).

Table 6: The total numbers and weight of cephalopods examined and raised estimates of numbers and weights of species caught during the Marine Institute West Coast Groundfish Survey Part A October 1997.

	No. examined	Wt. examined (kg)	Estimated no. caught	Estimated wt. caught (kg)
Sepioidae				
Sepiidae*				
Sepia elagans	24	0.27	174	203
Sepiolidae*				
Sepiola atlantica	16	0.03	125	0.25
Sepietta oweniana	45	0.40	303	2.68
Rossia macrosoma	4	0.03	39	0.30
Myopsida				
Loliginidae				
Loligo forbesi	264	4.50	3,884	47.01
Alloteuthis subulata	104	0.33	1,128	30
Oegopsida				
Ommastrephidae				
Illex coindetii	127	57	1,326	33.83
Todaropsis eblanae	155	3.33	1,545	23.63
Todarodes sagittatus	5	0.47	49	4.63
Octopoda				
Octopodidae				
Eledone cirrhosa	-	-	139	28.42
Totals	**744**	**12.93**	**8,712**	**347.05**

Loligo forbesi was both numerically and in terms of weight, the most abundant cephalopod species caught with a raised estimate of 3,884 individuals or 47.01kg caught during the survey. *Illex coindetii* was the next most abundant species with an estimated 33.83kg or 1,326 individuals caught. *Todaropsis eblanae* was also very common in the catches with an estimated 1,545 individuals (23.63kg) caught. *Alloteuthis subulata* were also common numerically, with an estimated 1,128 individuals being caught. *Todarodes sagittatus* was the least abundant squid with only 5 specimens examined and an estimated 49 caught. *Sepia elegans* was fairly common with an estimated 174 caught, while no *Sepia officinalis* were caught. *Sepietta oweniana* were the most common sepiolid species caught with an estimated 303 individuals being caught.

Sepia elegans were more common in catches towards the southern part of the survey area with highest catches southwest of Mizen Head. *Rossia macrosoma* were caught in tows off the Kerry coast. *Sepietta oweniana* were most commonly caught past the shelf break at the southern end of the survey and also south of the Aran Islands. *Sepiola atlantica* were caught in highest numbers off the Clare coast and south of Mizen Head.

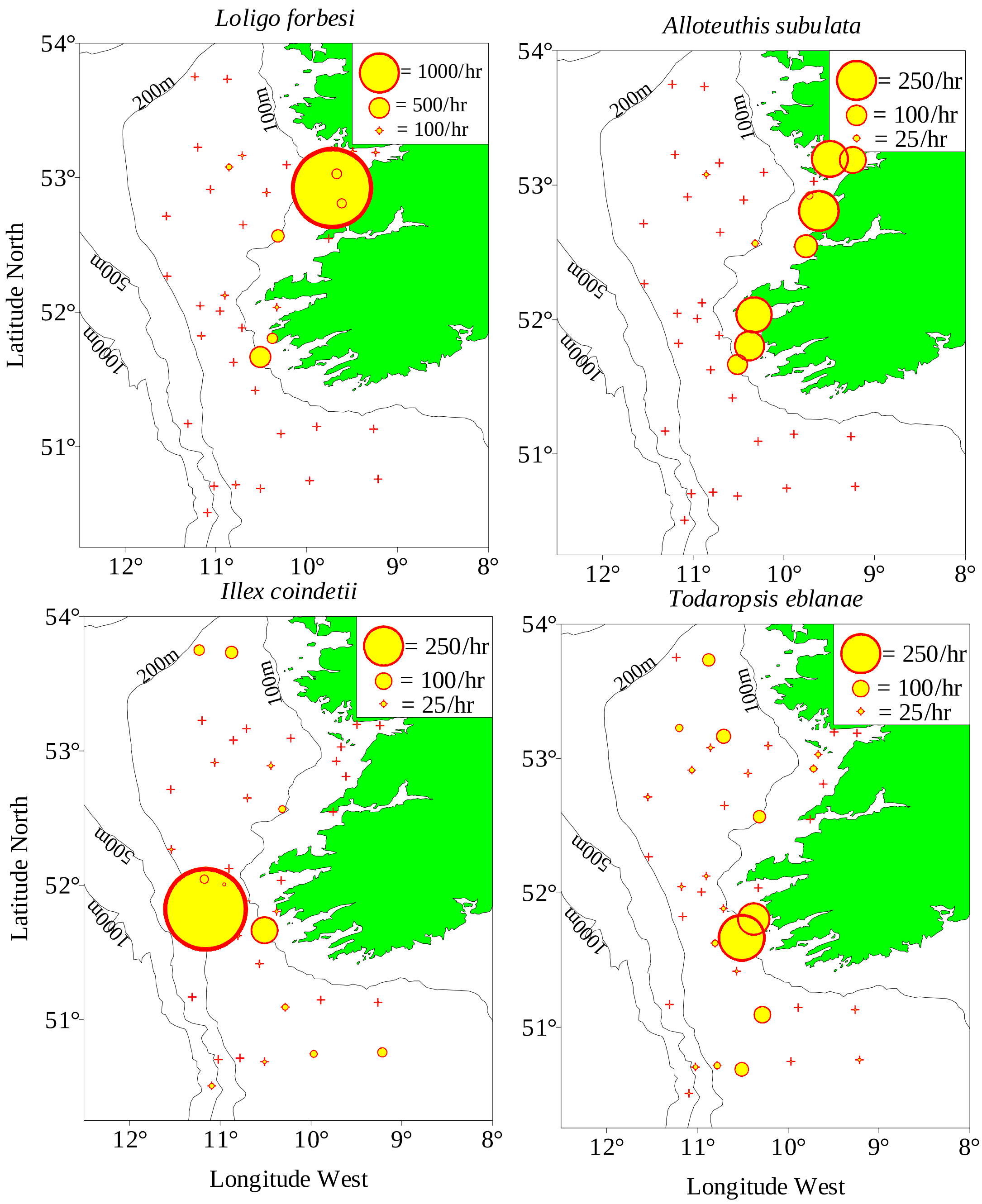


Figure 8: The spatial distributions of catches of *Loligo forbesi*, *Alloteuthis subulata Illex coindetii* and *Todaropsis eblanae* during the Marine Institute West Coast Groundfish Survey Part B November 1997.

Loligo forbesi were caught in highest numbers south of the Aran Islands, there were also good catches west of Ballinaskelligs (Figure 7). *Alloteuthis subulata* catches were concentrated in the most inshore tows in Dingle Bay, Ballinaskelligs, at the mouth of the Shannon, off the Clare coast and in Galway Bay (Figure 7). *Illex coindetii* catches were concentrated west of Dingle Bay inside the shelf break and south of the Skelligs, there were also good catches in the two northernmost tows west of Clew Bay (Figure 7). Highest catches of *Todaropsis eblanae* were southwest of the Skelligs but there were good catches southwest of Mizen Head and west of Loop Head and the Aran Islands (Figure 7). *Todarodes sagittatus* were caught in low numbers close to the shelf break throughout the range of the survey.

Highest numbers of *E. cirrhosa* were caught west of Dingle Bay and west of Ballinaskelligs, but there were catches throughout the survey area in lower numbers.

3.3 Results of the Marine Institute Deepwater Survey (November 1997)

One hundred and ninety six individual cephalopods weighing 252.0kg were caught during the survey (Table 7). The most commonly caught species was the ommastrephid squid species *Todarodes sagittatus* with 163 individuals caught. The next most common species was *Opisthoteuthis massyae* Grimpe (1920) with 15 individual caught (see Villanueva *et al*., in press). The two *Benthoctopus* species were caught, *B. ergasticus* P. & H. Fischer (1892) was the more common of the two with 12 individuals caught. Three *B. piscatorum* Verrill (1879) were also caught. Two *Histioteuthis* specimens were caught these were badly damaged in the trawl making definite identification impossible however both specimens were tentatively identified as *H. bonnellii* Férussac (1835). Two specimens of *Teuthowenia megalops* were also caught in the meshes of the trawl.

Table 7: The total numbers and weight of cephalopods caught during a Marine Institute deepwater survey in the Rockall Trough during November 1997.

	No. caught	Wt. caught (kg)
Oegopsida		
Ommastrephidae		
Todarodes sagittatus	163	217.9
Histioteuthidae		
Histioteuthis sp.	2	2.3
Cranchiidae		
Teuthowenia megalops	2	0.1
Octopoda		
Bathypolypodinae		
Benthoctopus piscatorum	3	1.3
Benthoctopus ergasticus	13	10.6
Opisthoteuthidae		
Opisthoteuthis massyae	14	19.8
Total	196	252.0

Highest catches of *Todarodes sagittatus* were made on the slope north-west of Donegal between 55°N and 56°N and west of the Hebrides (Figure 9). Catches of the other species were very low *O. massyae* were most numerous in catches on the northern slope of the Porcupine Bank. *Benthoctopus ergasticus* were caught in small numbers from the northern slope of the Porcupine bank north to 57^{o}N. The *B. piscatorum* specimens caught were west of Donegal and on the northern slope of the Porcupine Bank. The two specimens tentatively identified as *H. bonnellii* were caught west of the Hebrides and on the northern slope of the Porcupine bank. The two *T. megalops* specimens were both caught northwest of Ireland.

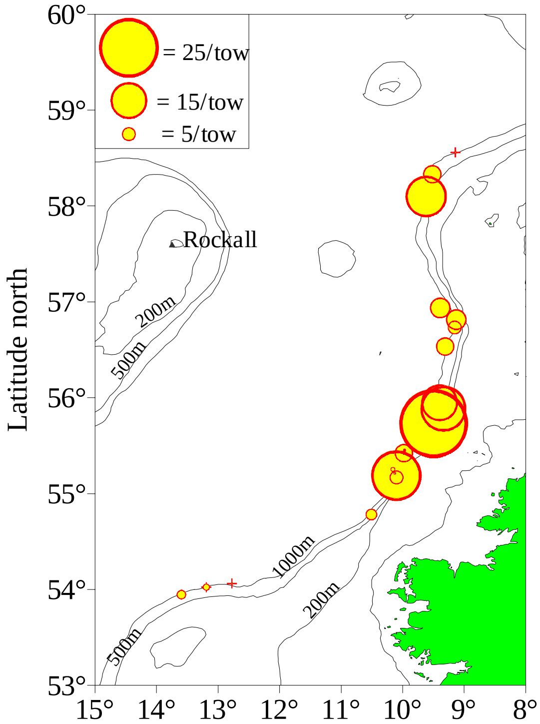


Figure 9: The spatial distribution of *Todarodes sagittatus* caught during the Marine Institute Deepwater Trawl Survey November 1997.

4. DISCUSSION

For many years expensive demersal trawl survey programmes have provided valuable time series of fisheries independent biological and distribution data on fish stocks in the waters around Ireland (e.g. Warnes and Jones, 1995). In recent years, concerns over the ecosystem effects of fishing and changes in climate, ecosystems and biodiversity have highlighted the possibility of using fisheries surveys data sets to investigate these effects and changes (Jennings and Kaiser, 1998). This has meant that demersal survey protocols have been broadened to collect detailed information on non-commercial species caught. Cephalopods are commonly caught in these surveys but identification difficulties, survey protocols and/or personnel limitations has meant that the cephalopods caught were either not identified or loosely identified into multi-species categories. The development of identification keys such as that shown in Appendix 1 and the inclusion of routine cephalopod sampling in survey protocols has meant that in the future more detailed data on cephalopod distributions and abundance will become available. This chapter provides detailed information on cephalopod species composition and distribution in the Celtic Sea and along the continental shelf and slope west of Ireland.

The range of cephalopod species caught in the five CEFAS Celtic Sea groundfish surveys and the Marine Institute west coast ground fish are very similar. *Loligo vulgaris* and *Sepia officinalis* were not caught in the Marine Institute survey but that is not surprising given the more northern range of this survey. Both survey series cover a similar bathymetric range (in recent years the CEFAS survey has been extended into deeper waters). The fact that the same species composition occurs in both survey series suggests that those species caught occur in that area in both the first and last quarter of the year. The range of cephalopods species caught in the Marine Institute deepwater survey was completely different from the shallower surveys. This is not surprising given the deeper distribution of the tows and the different latitudinal range of the survey. *Todarodes sagittatus* replaces *L. forbesi* as numerically the most common species in the deeper water. The more inshore species are absent and deepwater octopods and oceanic species occur occasionally in catches.

Massy (1928) provided the first detailed information on the occurrence and distribution of cephalopods in the waters around Ireland, listing thirty-two cephalopod species. All but two of the species listed here were also recorded by Massy. *Loligo vulgaris* was not recorded by Massy, though the specimens recorded in the present study were caught outside Irish waters in the English Channel. However, Collins *et al*. (1995b) found a single specimen of *Loligo vulgaris* among 4,663 *L. forbesi* that were examined from commercial landings in Ireland. Thus it is fair to conclude that the species, albeit uncommon, occasionally occurs in the waters around Ireland.

More interestingly, Massy (1928) did not record the occurrence of *I. coindetii* in Irish waters. However, *Illex coindetii* were numerically abundant off the southwest of Ireland in both survey series presented here and are also commonly caught in commercial trawling west of Ireland (Chapter 2). It is unlikely that Massy a misidentified *I. coindetii* as another species therefore the omission from her records is curious. One possible explanation is that there has been a shift in distribution of the species since the early 1900's. It was reported that *I. coindetii* was virtually absent from Galician waters between 1973-1983 and now occurs in abundance (González *et al*., 1994). However, it is also plausible that the fishing gear used during their early surveys of deeper waters were not efficient enough to catch fast moving ommastrephids. This is supported by the fact that only two *Todaropsis eblanae* were caught in water deeper than 75m and no *Todarodes sagittatus* were caught by trawl during Massy's investigations (Massy, 1909; Massy, 1928). Similarly, Collins *et al*. (In press) did not catch any specimens of *I. coindetii* in the Porcupine Sea Bight using a semi-balloon otter trawl (OTSB) though small number of *Todarodes sagittatus* and *Todaropsis eblanae* were caught. Another possible explanation is that *Illex coindetii* also appear to be highly seasonal in the waters around Ireland (Lordan *et al*., 1998). One would not expect to catch *I. coindetii* in surveys during the summer months.

More recently, Lordan *et al*. (1995) reviewed the status and potential of squid fisheries in Ireland. They commented on the abundance and fisheries potential for nine squid species in Irish waters. Of those nine species, all but *Ommastrephes bartrami and*

Architeuthis dux were caught during these surveys. This is due to the seasonality (caught in summer months only) and pelagic habit of the former and the rarity of the latter. Lordan *et al*. (1995) identified the potential for a fishery targeting *I. coindetii* and *Todaropsis eblanae* on the west coast. This is supported by the findings here, that show both species to be relatively numerous.

Collins *et al*. (In press) record two species of *Histioteuthis* in the Porcupine Sea Bight. The specimens caught here are also of large (a mature male 156mm ML 1.06kg and an unsexed individual of 115mm ML and 0.70kg) Given the size and location of capture of the specimens in the present we have tentatively assigned them to *H. bonnellii* although significant trawl damage meant a definitive identification was impossible. Collins *et al*. (1997) reported on a capture of a single specimen of *Sepia elegans* off the northwest coast of Ireland. The results here suggest that *Sepia elegans* are relatively common and widespread in waters to the south and west of Ireland.

Collins *et al*. (in press) recorded five species of sepiolids in the Porcupine Sea Bight. *Neorossia caroli* Joubin (1902) were at depth of between 400-1535 m beyond the depth of most hauls in the CEFAS Celtic Sea Groundfish and Marine Institute WCGFSb. Given the commercial gear with large meshes used in the Marine Institute Deepwater Survey it is not surprising that a small species like *N. caroli* was not caught. Another species *Rondoletiola minor* Naef (1912) was common at shallower depth so it is interesting that the species was not caught on any of the surveys here.

Demersal trawl surveys provide a “snap shot” of the distribution of species and density of the species caught during the time window of the survey. Information collected on surveys may give some important clues into the life cycle and inter-annual variability in abundance and distribution of the species that are caught. This is particularly true for ommastrephid species which can have very variable distributions and abundances particularly towards the northern limits of their range (O’Dor, 1998). However, for reasons outlined later in the discussion this data should be interpreted cautiously.

The spatial distribution of *L. forbesi* catches in all five CEFAS surveys is very similar, occurring in highest abundance near the shelf-break (150-250 m) at approximately 50^{o}N in most years. Given that the largest catches were of squid around 90mm ML (recruitment to the commercial fishery is approximately at ML $\approx$100mm (Collins *et al*., 1995b)) it is fair to speculate that the area may be an important feeding and possibly nursery area for this species at that time of year. There were also occasional large catches off the north coast of France or at the mouth of the Channel indicating that those areas may be important too. Pierce *et al*. (1998) presented data from Scottish demersal trawl surveys during November (1990-1994) which showed that highest catches of *L. forbesi* occurred north of Ireland near the Stanton Bank area (~3,200/hr in one haul). Good catches occurred north and west of the Hebrides and in Donegal Bay, whereas catches south and west of Ireland were relatively poor. Maximum catches in the Scottish survey were considerably higher than the maximum catch in an individual haul during the CEFAS surveys (520/hr). However, given the different vessels and gears used the catch rates are not really comparable.

The distributions of *A. subulata* catches were more variable, with numerically high catches in the English Channel in some years and huge catches south of Ireland in 1998. The large fluctuations in catches may be due to the patchy distribution of the resource. The bathymetric distribution shows a definite trend for increasing catches in shallower tows. The same trend is evident in the Marine Institute West Coast Groundfish Survey where all the high catches of *A. subulata* were in inshore areas.

Catch distributions for *I. coindetii*, although concentrated along the shelf were latitudinally quite variable. The very large catch, on the shelf edge at 51^{o}N, during the 1994 survey indicates that *I. coindetii* can be very concentrated in certain areas. This was also apparent in commercial vessel logbook data (Lordan, in prep). The reasons for the patchiness in distribution may be related to prey abundance. Where prey are very abundant and feeding aggregations occur (possibly in the mid-water at night). This is followed by a resting/digesting phase on or near the bottom during the day where *I. coindetii* are vulnerable to demersal trawls (Lordan et. al 1988).

The data on bathymetric distribution of *I. coindetii* suggest that the survey did not cover the depth range of this species which is thought to extend down to 800 m (Sanchez *et al*., 1998). Evidence from commercial vessels where there is a by-catch of ommastrephids west of Ireland (Lordan, in prep) suggests that these surveys cover the depth of maximum CPUE for *I. coindetii*. Data in the present study suggests that large individuals are caught in deeper water, as was found in *Todarodes sagittatus* (Lordan *et al*., in press). This may indicate that an ontogenetic migration down the slope occurs in *I. coindetii*. There are some indications that this may also occur in the Sicilian Channel, although there may be some seasonal migrations in that area also (Sanchez *et al*., 1998). Similarly, surveys in the Northwest Atlantic showed there was a decrease catches of juvenile *Illex illecebrosus* with depth and a bathymetric pattern of larger sized individuals with increasing depth (Brodziak and Hendrickson, 1999).

The spatial distribution of *Todaropsis eblanae* was quite interesting. In general, *Todaropsis eblanae* were caught in low numbers throughout the CEFAS and Marine Institute survey areas. However in 1994, there were high catches off the south of Ireland where there were only small catches in the other years. The results suggest that in some years there are migrations onto the shelf. The bathymetric range of *Todaropsis eblanae* extends from 20-700 m (Roper *et al*., 1984). Like *I. coindetii* , catch rates increased with depth highest catches were in waters greater than 250 m. There were not enough data to show evidence of depth related changes in population structure in *Todaropsis eblanae*.

Density estimates should be treated cautiously as firstly, not all stations were fished in all years. This is particularly true in 1994 when the survey was cut short and only half the stations were fished and in 1997 and 1998 when the survey was extended into deeper waters. Secondly, estimates of density are restricted to <4m off the sea bottom. Both *Todarodes sagittatus* and *I. coindetii* are known to feed primarily on pelagic species (Lordan *et al*. 1998 and in press). *Loligo forbesi* and *Todaropsis eblanae* are associated with the bottom but have been caught up to 50m off the bottom by pelagic gears by Irish vessels (Lordan, unpublished data). Similarly, *Alloteuthis subulata* may swim off the bottom occasionally. Thirdly, density estimates assume that there is zero escapement. This is also probably untrue particularly for cephalopods, which are know not to herd like fish in nets but hold station and dart sideways to avoid the net (Pierce *et al.*, 1998). Finally, there may be some errors associated with cephalopods that mesh in the wings, belly or bunt of the net and are washed down to the cod-end in subsequent tows. Generally, these cephalopods could be identified (particularly, *I. coindetii*, *Todaropsis eblanae* and *E. cirrhosa*, where the chromatophores tend to blanch and signs of rigour are apparent in the muscle of previously caught individuals) and were not included in the analysis. However, for species like *L. forbesi* and male *Todarodes sagittatus*, that are often badly trawl damaged even after short tows, previously caught individuals may not always have been identified. Therefore, density estimates presented here should be treated as minimum estimates.

The only comparable published data on squid densities in this area are the density estimates for the North Sea and Rockall by Pierce *et al*. (1998). However, their swept area estimates were calculated using wingspread rather than door-spread, as was done here. Wing-spread is probably a better parameter to use since cephalopods are unlikely to be herded by the doors like fish, and the effective fishing area is more likely to be wing to wing of a demersal net (Pierce *et al*. 1998). Unfortunately wing sensor data were not routinely collected in the CEFAS surveys. Hence it is not possible to compare the results of Pierce *et al*., (1998) with the present results. These data provide base line density estimate for the CEFAS surveys (It may be possible to estimate wing spread in the future, since it is likely to be highly correlated with door spread).

Detailing the distribution of cephalopods is fundamental to any biological and fisheries study. In this chapter a base line of data has been presented from which to build future studies. This is particularly important in areas such as the Celtic Sea and West of Ireland where little or no data on cephalopod distributions have been available to date.

Future studies should analyse the effects of environmental factors on survey catches, as was done in the Northwest Atlantic (Brodziak and Hendrickson, 1999). Also, they should address the question as to whether these groundfish surveys can be used to forecast recruitment of species such as *L. forbesi*, *I. coindetii* and *Todaropsis eblanae* to the commercial fishery. This is of particular importance from both the commercial fishery and management perspective. Future studies should attempt to reconcile density estimate from surveys with historical catches. This type of detailed investigation would require considerable data on population structure, growth parameters and commercial CPUEs which is beyond the scope of this study. Ultimately however, survey data may play a key role in ascertaining how environmental conditions effect recruitment, distribution and productivity of these important cephalopod stocks.

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