Falkland Island Fisheries Department

Fishery Report

Loligo gahi, Second Season 2009

Fishery Statistics, Biological Trends, Stock Assessment and Risk Analysis

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- February 2010 -

INDEX

I. SUMMARY

Loligo catch during the second season (July/15-September/11, 2009) was 17,836 tonnes, a low-medium level in a historical perspective. Catch, Fishing Effort and CPUE were 34%, 27% and 10% lower than in second season 2008. 44% of the squid were caught in the northern area, 40% in the southern area and 16% in the central area. The highest catch rates were achieved in the northern area and the lowest ones in the central area. The whole fleet fished in the northern area during the first 2 days, then it divided for fishing in the northern and southern areas, with some explorations to the central area, and during the last week it fished mainly in the central-northern area. The daily whole catches by area were around 200 tonnes during the first two weeks and then increased to a maximum of 700 tonnes in the southern area, where the whole fleet fished until the end of July, after this the catches decreased in all areas but faster in the southern area. The maximum CPUE (50-40 tonnes/vessel) were achieved during the end of July in the southern area. The CPUE were higher in the southern area until the first week of August, and then the higher CPUE were found in the northern area. The CPUE depletion was more intense in the southern area.

The average dorsal mantle length was 12.7 cm, a 0.7, 1.9 and 0.4 cm shorter than in 2008, 2007 and 2006. The proportion of sexually immature females followed the trends observed in previous second seasons, but had an early decrease after the first month. In the case of the males, the proportion on immature squids was higher than in

previous second seasons and started to decrease later in the season. The arrivals of the different squid waves were identified using CPUE, female proportion and mean weight. Two squid waves were found in the southern area and two squid waves in the central-northern area.

The fishing season was early closed on 11th September, because the biomass on 2nd September was estimated at 11,450 tonnes and the escapement biomass on 15th October was projected at 9,395 tonnes. The risk probability that the projected escapement biomass could be less than 10,000 tonnes, was estimated at 0.63. The historical probability that a new squid pulse arrive after the early closure was estimated at 0.2-0.3.

Immediately after the early closure of the fishing season a post-season scientific survey was done to estimate the biomass and to check for the arrival of new squid waves. The stock assessment model was improved to incorporate the survey biomass estimations at the beginning and end of the fishing season. The improved model fits to commercial catch rates and survey abundances. The survey abundance were related with the stock abundance by a coefficient (survey catchability) estimated by maximum likelihood. The model has different likelihood components that can be combined using different weight factors. The model was fitted using Bayesian inference with prior probabilities of abundance based on the assumption that the survey catchability was equal to 0.8 (survey biomass is 80% of stock biomass). The sensitivity analysis showed that different weights combinations had important impacts on model results: survey catchability ranged from 0.78 to 1.07; biomass on 25th July from 20,449 to 24,995 tonnes; and escapement biomass, from 11,162 to 15,256 tonnes. The model with a survey catchability equal to 0.78 was selected. The initial biomass on 25th July was estimated at 24,995 tonnes. The biomass on 12th September, the end of the fishing season, was estimated at 8,010 tonnes. Later during the second half of September, the arrival of a new squid wave was detected by the post-season survey. The whole biomass was estimated at 15,643 tonnes, which was calculated dividing the survey biomass by the survey catchability. The escapement biomass on 15th October was estimated at 15,256 tonnes, and therefore there was a very low (0.03) probability that biomass were less than the 10,000-tonne conservation limit.

II. INTRODUCTION

The second season of 2008 started on 15th July and ended normally on 30th September. The whole *Loligo* catch was 26,996 tonnes, which in a historical perspective was of a medium-high level. The whole biomass, the one that was present at the start of the season plus the ones that arrived during the season, was estimated at 40,228 tonnes (Payá 2009). The escapement spawning biomass was estimated at 9,798 tonnes and the probability of achieving the conservation limit (10,000 tonnes) was estimated at 0.4.

Just before the beginning of the second season 2009, the *Loligo* standardized biomass was estimated at 22,830 tonnes using a swept area survey (Payá 2009b). The biomass was 1.58, 1.16, and 1.01 times greater than the survey biomasses estimated in the second seasons 2008, 2007 and 2006. *Loligo* were concentrated in the northern area, with scarce abundance in the southern area. The highest *Loligo* densities were correlated with bottom water temperatures of 5.0-5.2°C. *Loligo* densities also increased with salinity.

During the first season 2008 a new area was opened to the fishery, this was restricted to the depth range of the natural northward continuity of trawling tracks that come from the central area. For the analysis this area was added to the central area and therefore the boundary between the central and northern area was moved northward (Fig. 1).

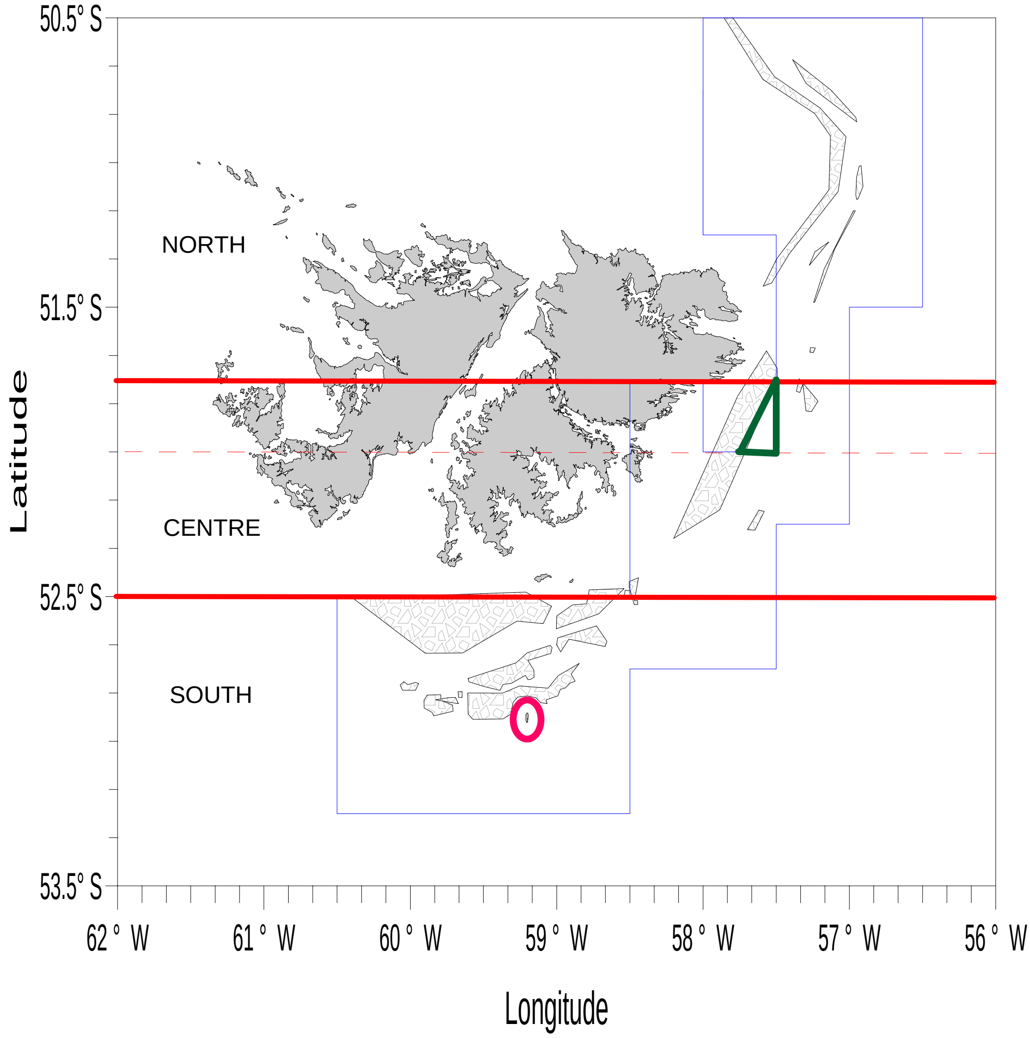


Fig. 1.- Fishing grounds and rocky bottoms around the Falkland Islands. In blue, the *Loligo* box, in green, the fishing area opened in 2008, and in magenta, the three-nm exclusion area around Beauchene Island. The border between the northern and central area was moved northward according to the new opened area, the previous border is shown by a broken red line

During the second season 2009, the daily fishery statistics and biological data covered the whole fishing season. The last stock assessment model (Payá 2007) was modified to fit commercial CPUE and surveys biomasses. In order to warn the fishing industry with two weeks in advance of any chance of early fishery closure the catch during these two weeks and the spawning biomass were projected and the risk of leaving less than 10,000 tonnes was calculated.

III. FISHERY STATISTICS

1. Total Catch and Total Effort in Historical Perspective

The whole catch in the second season was 17,836 tonnes, which was 34% lower than second season 2008 (**Table 1 and Fig. 2**). This catch reduction was because of a 10% decrease in CPUE and a 27% decrease in fishing effort, due to an early closure of the fishing season. In a historical perspective second season 2009 catch was of a low-medium level. Although CPUE has decreased since 2006, it was of a high-medium level. Since 2002 the fishing effort has been relatively stable in comparison to the high levels recorded in 1993-1996 (**Table 1 and Fig. 2**)

Table 1.- Fishery statistics and initial biomass for the known history of the *Loligo gahi* fishery of the Falkland Islands. 'Failure' indicates that stock depletion model could not produce a reasonable estimate of initial biomass. From 1970 to 1985 the source is Csirke (1986), from 1987 to the present the source is either RRAG (for initial biomass up to 2003) or FIFD (catch and effort and initial biomass from 2004). Since 2007 the initial biomass is the sum of the biomass at the beginning of the season and the biomasses of squid groups that arrived during the season.

Year	First Fishing Season Catch (tonnes)	Effort (h)	Initial Biomass (tonnes)	Second Fishing Season Catch (tonnes)	Effort (h)	Initial Biomass (tonnes)	Annual Catch (tonnes)
1970							200
1971							100
1972							100
1973							250
1974							200
1975							140
1976							129
1977							354
1978							911
1979							925
1980							1111
1981							631
1982							18452
1983							38256
1984							36450
1985							36430
1986							
1987	64063		101000	18484		202000	82547
1988	48664		115000	5267		39000	53931
1989	106186	33159	165000	11671	16881	46000	117857
1990	69366	24177	206000	13624	15713	104000	82990
1991	37353	13808	53000	16462	16610	146000	53815
1992	48157	15406	97000	35227	19291	264000	83384
1993	23567	16065	47000	28711	32950	90000	52278
1994	35502	19891	55000	30254	29687	116000	65756
1995	60293	10913	195000	37486	22365	141000	97779
1996	38679	16438	31000	22694	28420	130000	61373
1997	15962	16766	40000	10159	18486	82000	26121
1998	33379	16835	60000	18178	22762		51557
1999	22863	19642	44826	12008	18266	53737	34871
2000	38713	21034	63683	25781	18869		64494
2001	27624	20955	26000	25935	19841	162234	53559
2002	14198	20824	21000	9513	11570		23711
2003	18973	8494	40350	28447	16166	Failure	47420
2004	8609	8740	Failure	18229	17024	62732	26838
2005	28747	7292	114878	30047	17658	47201	58794
2006	19056	8521	39218	23238	13150	26500	42294
2007	17229	8780	***37517***	24171	14740	***48500***	41400
2008	24752	8657	***96753***	26996	18489	***40228***	51748
2009	12764	9367	***38179***	17836	13550	***32282***	30600

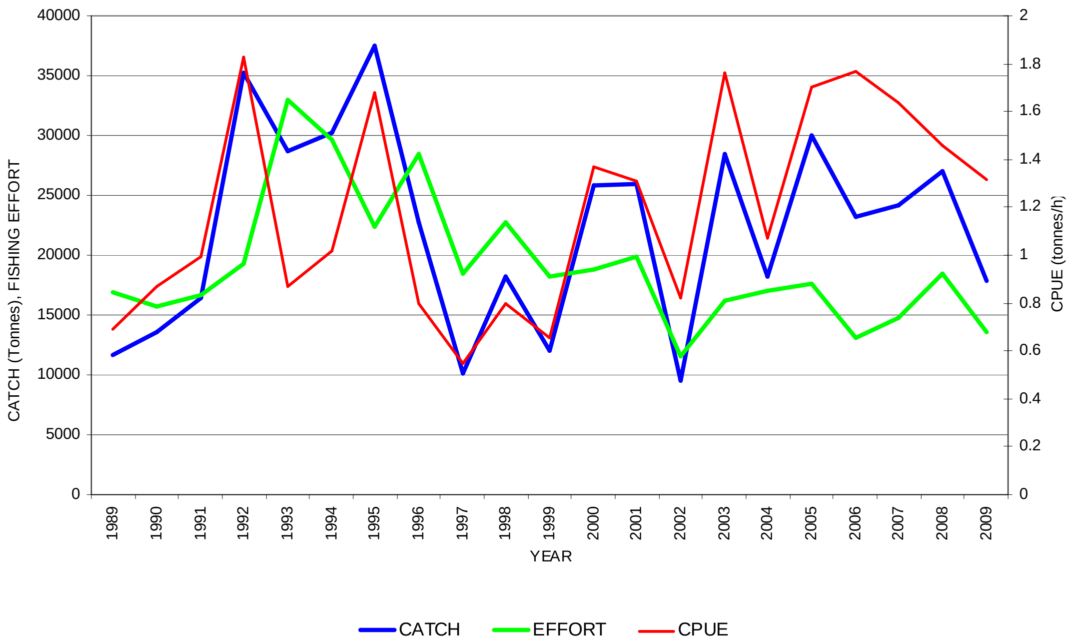


Fig. 2.- Historical catches, fishing effort and CPUE of the second seasons.

2. Catch and Effort per Fishing Ground and Cumulative Catch

44% of the squid were caught in the northern area, 40% in the southern area and 16% in the central area (**Table 2**). The highest catch rates were achieved in the northern area and the lowest ones in the central area. The distribution (percentages) of fishing hours by area was similar to the catch distribution by area.

Table 2.- Effort and catch statistics of *Loligo* second season 2008 by area.

Fishing Ground	Catch tonnes	Effort Vessel-Days	Effort Hours	CPUE tonnes/V-D	CPUE tonnes/h
South	7136	355	5619	20.1	1.27
Centre	2789	203	2263	13.7	1.23
North	7911	360	5668	22.0	1.40
Total	17836	918	13550	19.4	1.32

The daily cumulative catch was at medium level compared with the highest and lowest historical figures (**Fig. 3**).

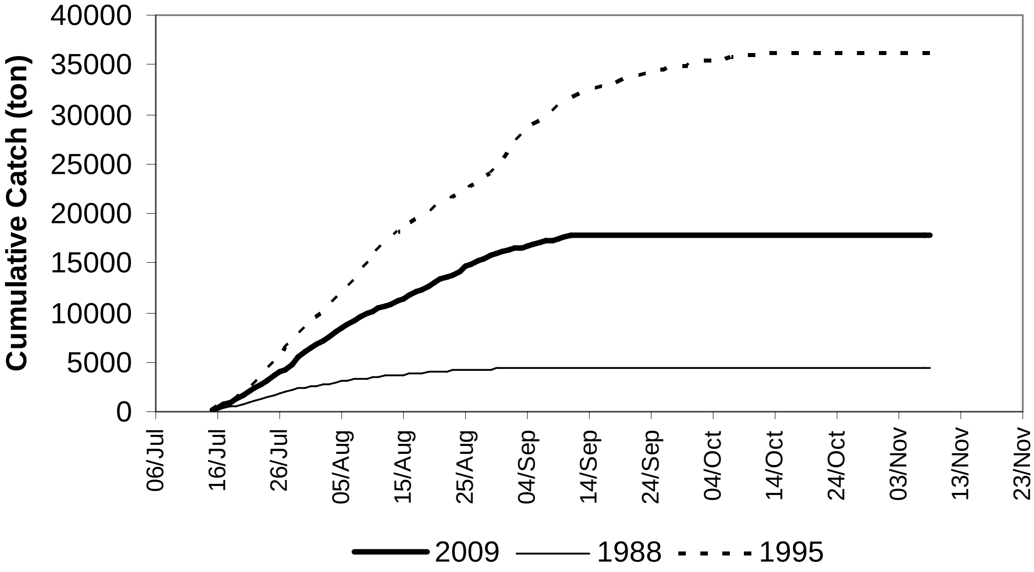


Fig. 3.- Cumulative catch versus date in the second season of 2009 compared to the cumulative catch of the first seasons that yielded the highest (year 1995) and lowest (year 1998) historical catches on exactly the same date range.

3. Fleet Movement Dynamics, Catch and Catch Rate

The whole fleet fished in the northern area during the first 2 days, then it divided for fishing in the northern and southern areas, with some explorations to the central area, and during the last week it fished mainly in the central-northern area (**Fig. 4a**). The daily whole catches by area were around 200 tonnes during the first two weeks and then increased to a maximum of 700 tonnes in the southern area, where the whole fleet fished in this area at the end of July, after this the catches decreased in all areas but faster in the southern area (**Fig. 4b)**. The maximum CPUE (50-40 tonnes/vessel) were achieved during the end of July in the southern area (**Fig. 4c**). The CPUE were higher in the southern area until the first week of August, and then the higher CPUE were found in the northern area. The CPUE depletion was more intense in the southern area.

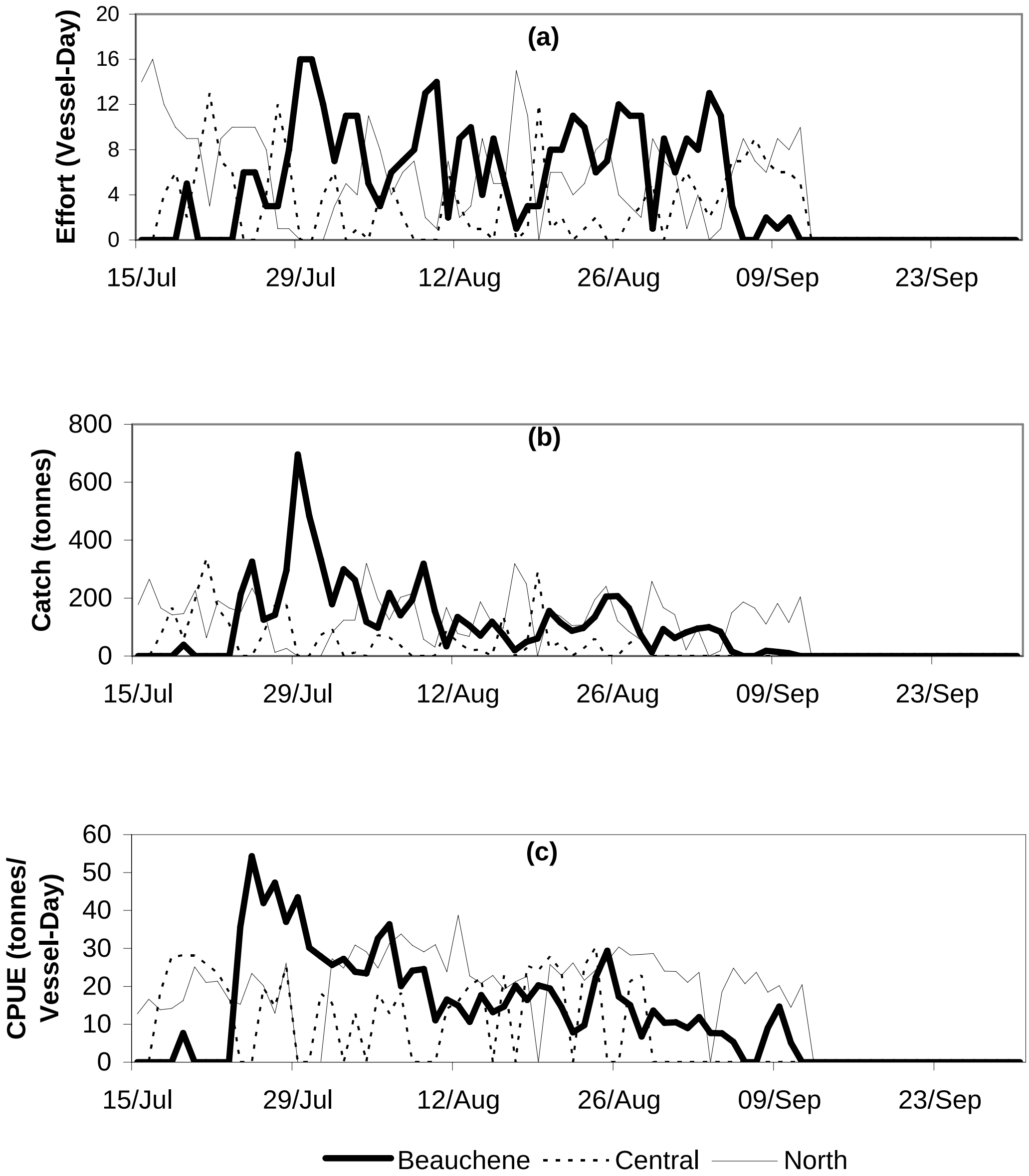


Fig. 4.- Daily evolution of effort (a), catch (b), and average catch per unit of effort (c) in the *Loligo* fishery during the second season of 2009.

The analysis of the fleet movement based on e-logbooks, showed the sequential arrivals of two *Loligo* groups in the central-northern area and one group in the southern area. During the first two days the fleet fished in the northern area where the *Loligo* survey (Paya 2009) found the higher *Loligo* abundance and had similar catch rates that the *Loligo* survey vessel (**Fig. 5**). A second squid groups arrived to the northern area on 24th July (**Fig. 6**). The squid in the northern area were depleted and the fleet searched for them along the central and northern area but had low catch rates (**Fig. 7**). On the last fishing day the whole fleet fished in the central-northern area and had low CPUE, although with an increasing trend to the extreme north and deeper fishing grounds (**Fig. 8**). At the same time, 24th July, another squid group arrived to the western part of the southern area (**Fig. 9**), where the maximum CPUE was achieved on the 25th July (**Fig. 10**), however this squid group was quickly depleted. Some vessels searched for these squid during the first week of September, and had bad CPUE (**Fig. 11**), and so these vessels left the southern area one day before the end of fishing season (**Fig. 12**).

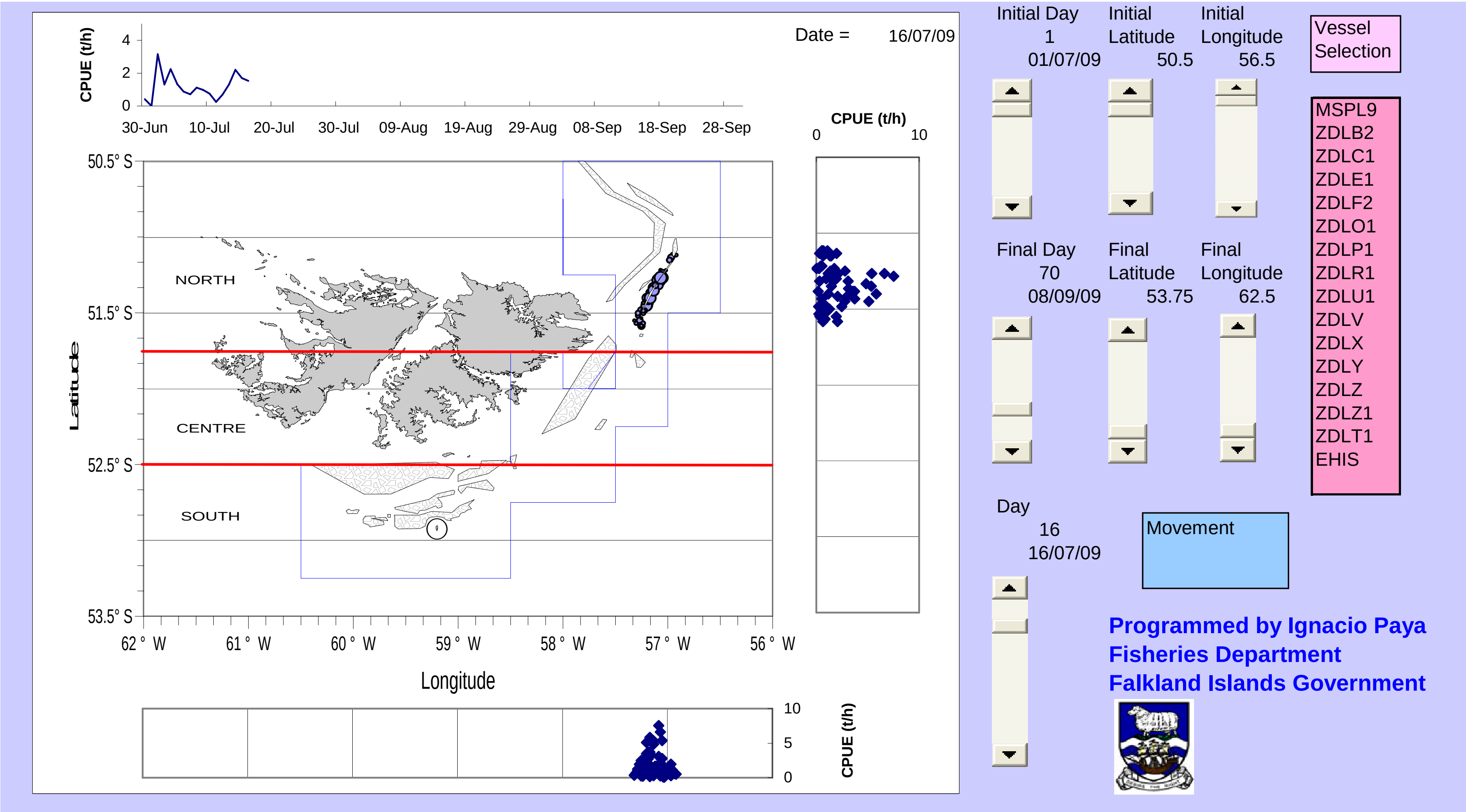


Fig. 5. During the first two days (15-16/7) of the fishing season the fleet fished in the northern area. The data before 15th July are the *Loligo* survey data. The graphical interface displays the fleet movement and CPUE (tonnes/h) and has been described in previous reports.

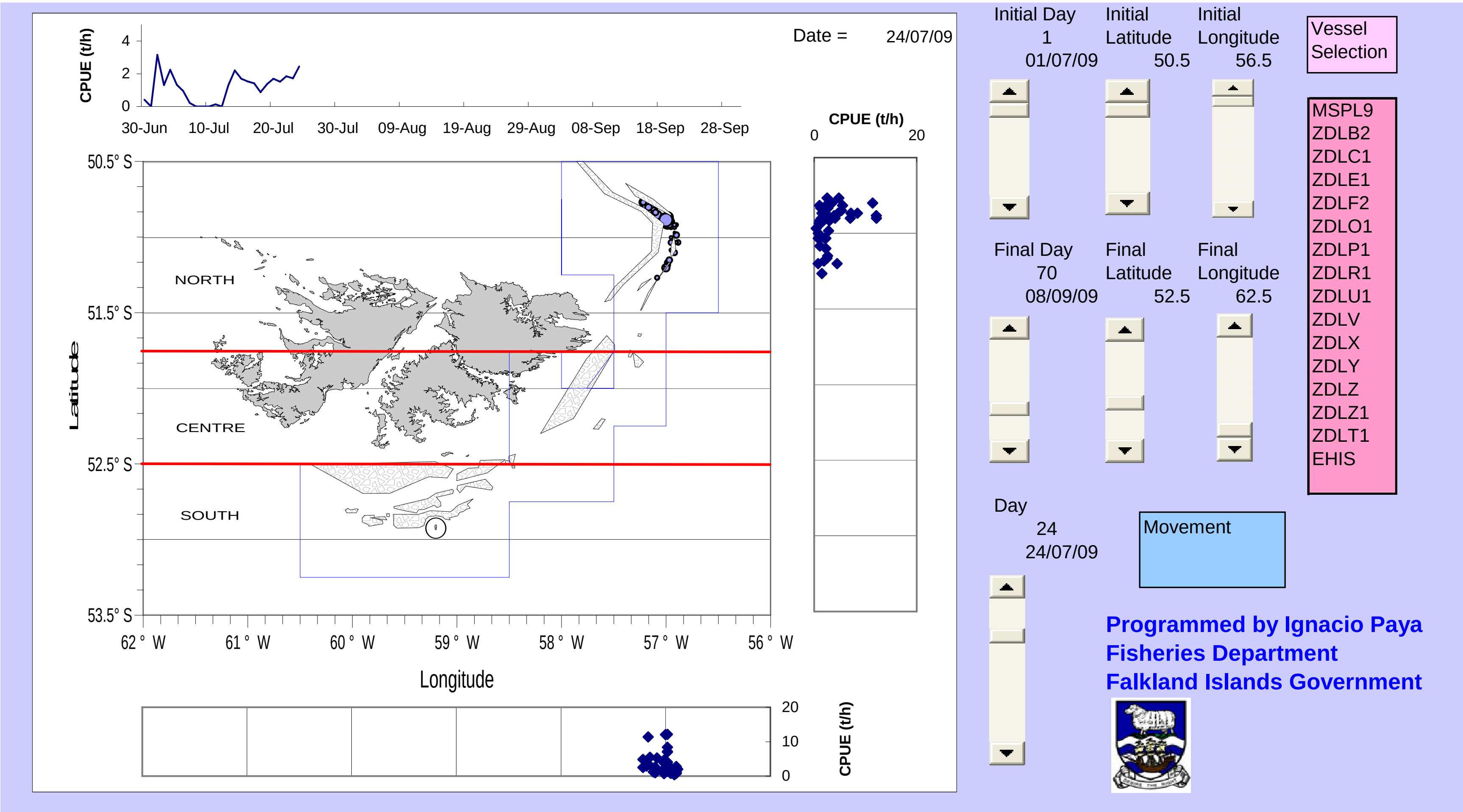


Fig. 6. On 24th July, the second squid group arrived into the northern area (central-northern area data are shown only).

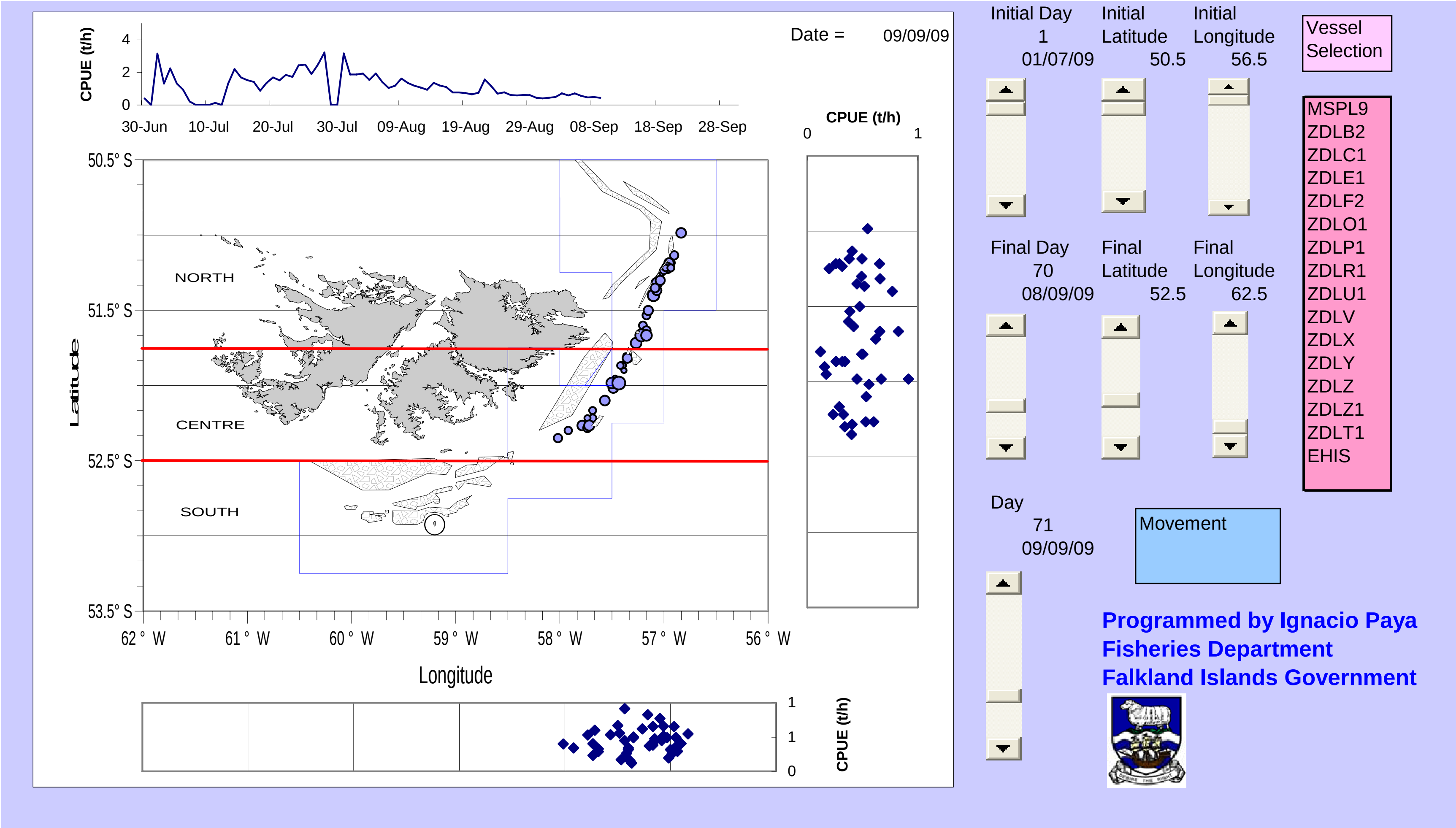


Fig. 7. On 9th September, part of the fleet fished along the central and northern area and had low catch rates (central-northern area data are shown only).

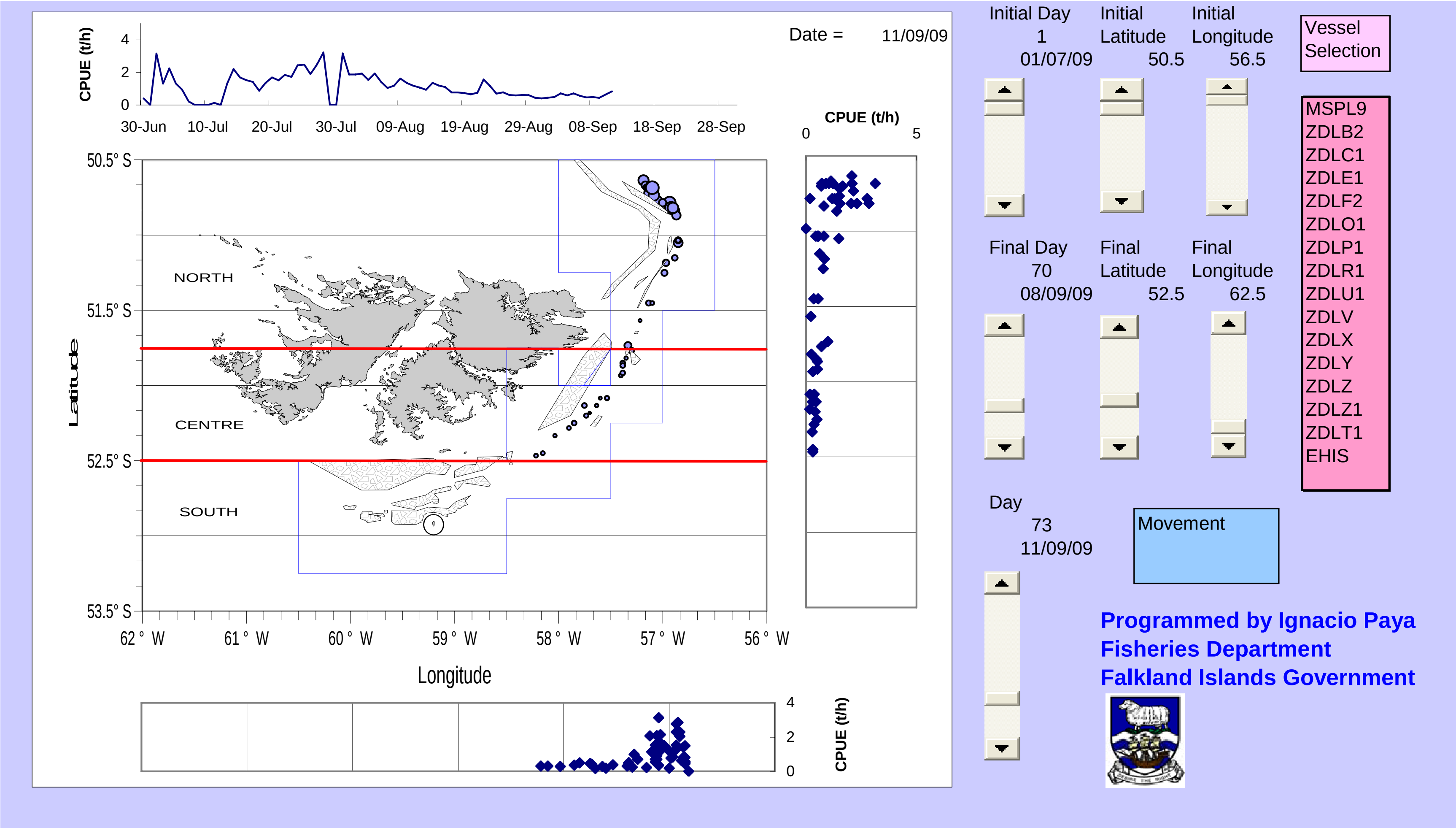


Fig. 8. On 11th September, the fleet fished along the northern area and had low catch rates. The catch rates were higher in the extreme north.

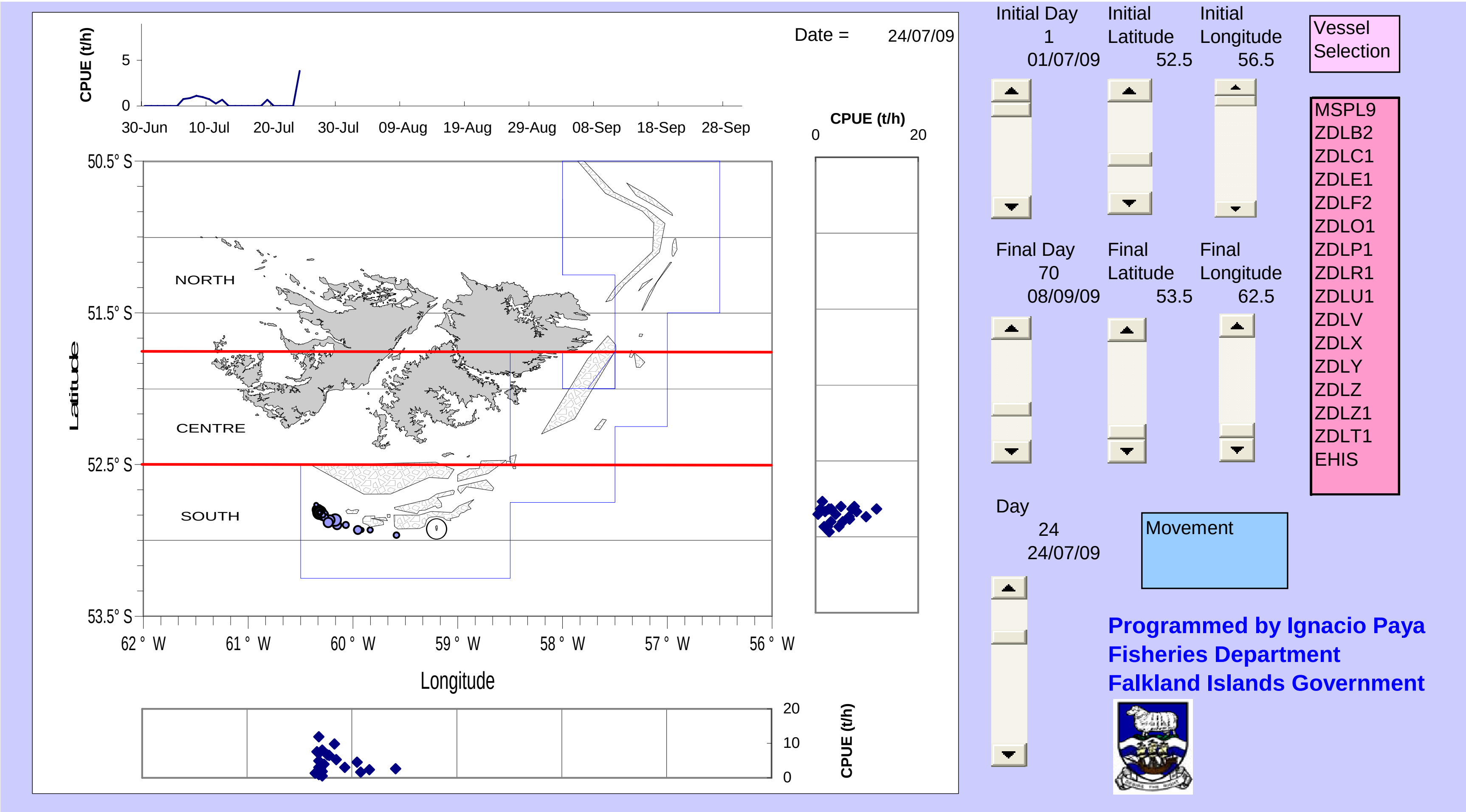


Fig. 9.- On 24th July, the first squid group arrived into the western part of the southern area (southern area data shown only).

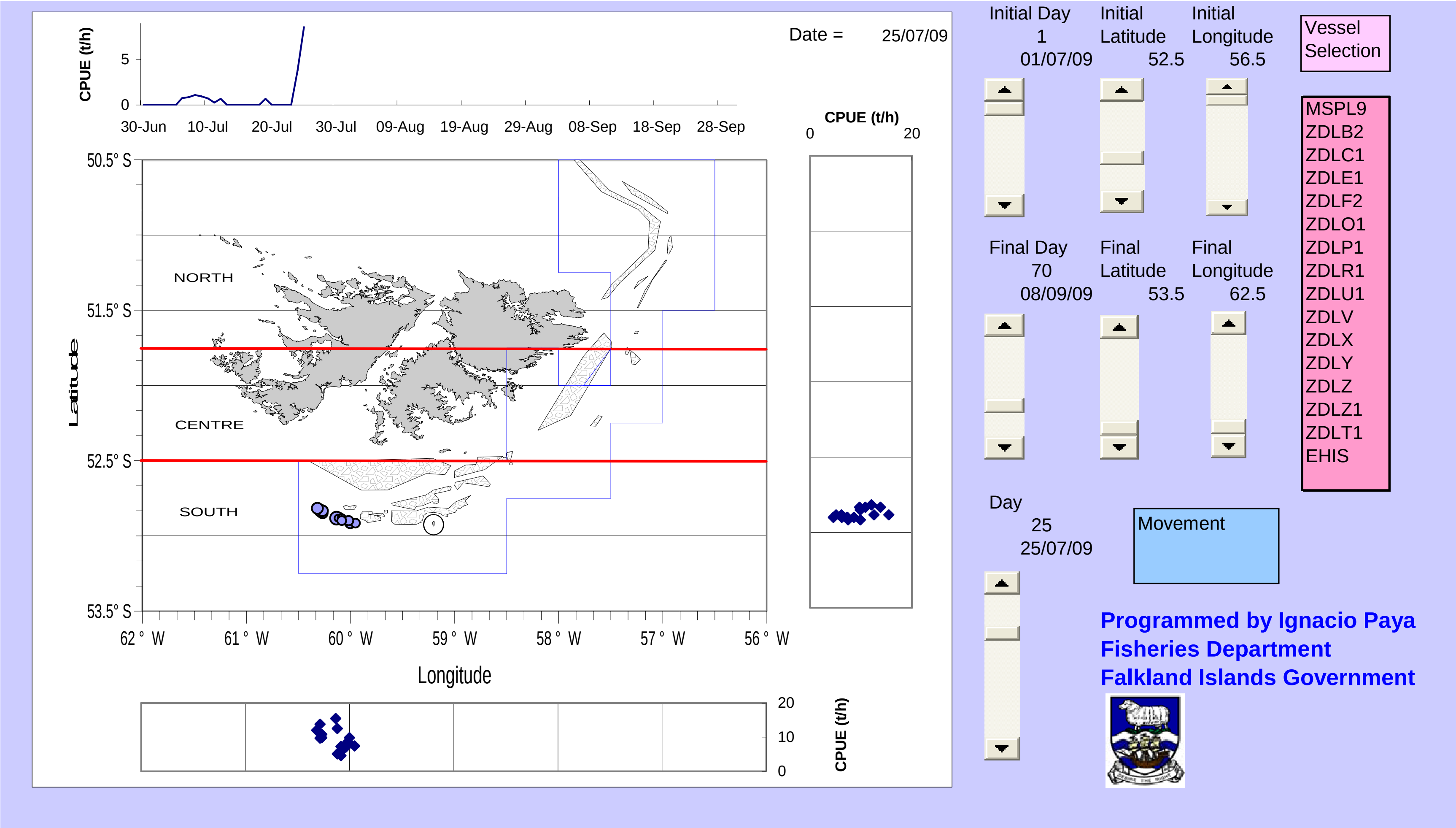


Fig. 10.- On 25th July, the fleet achieved its maximum catch rate in the western part of the southern area (southern area data shown only).

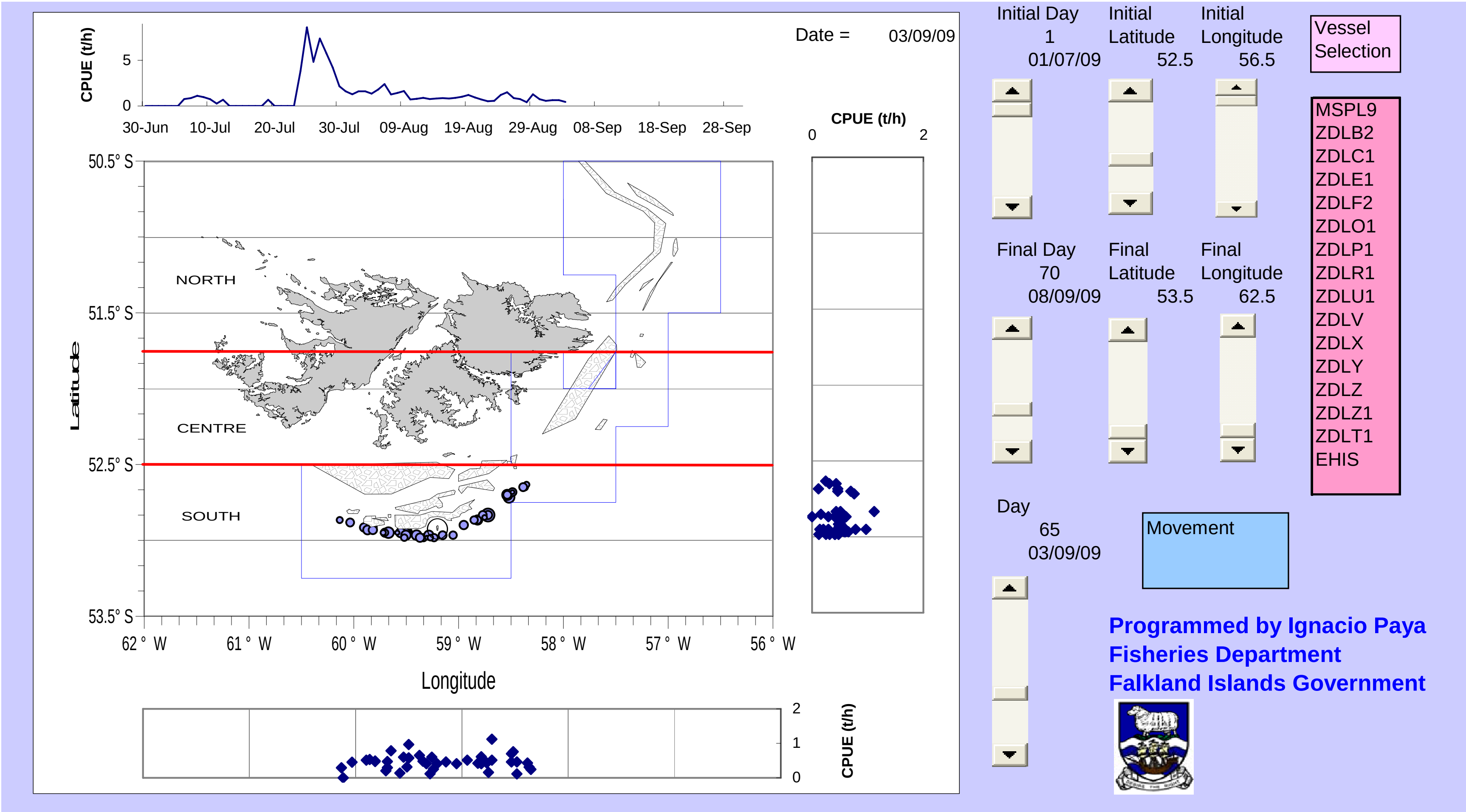


Fig. 11.- On 3rd September, part of the fleet searched along the southern area but had low catch rates (southern area data shown only).

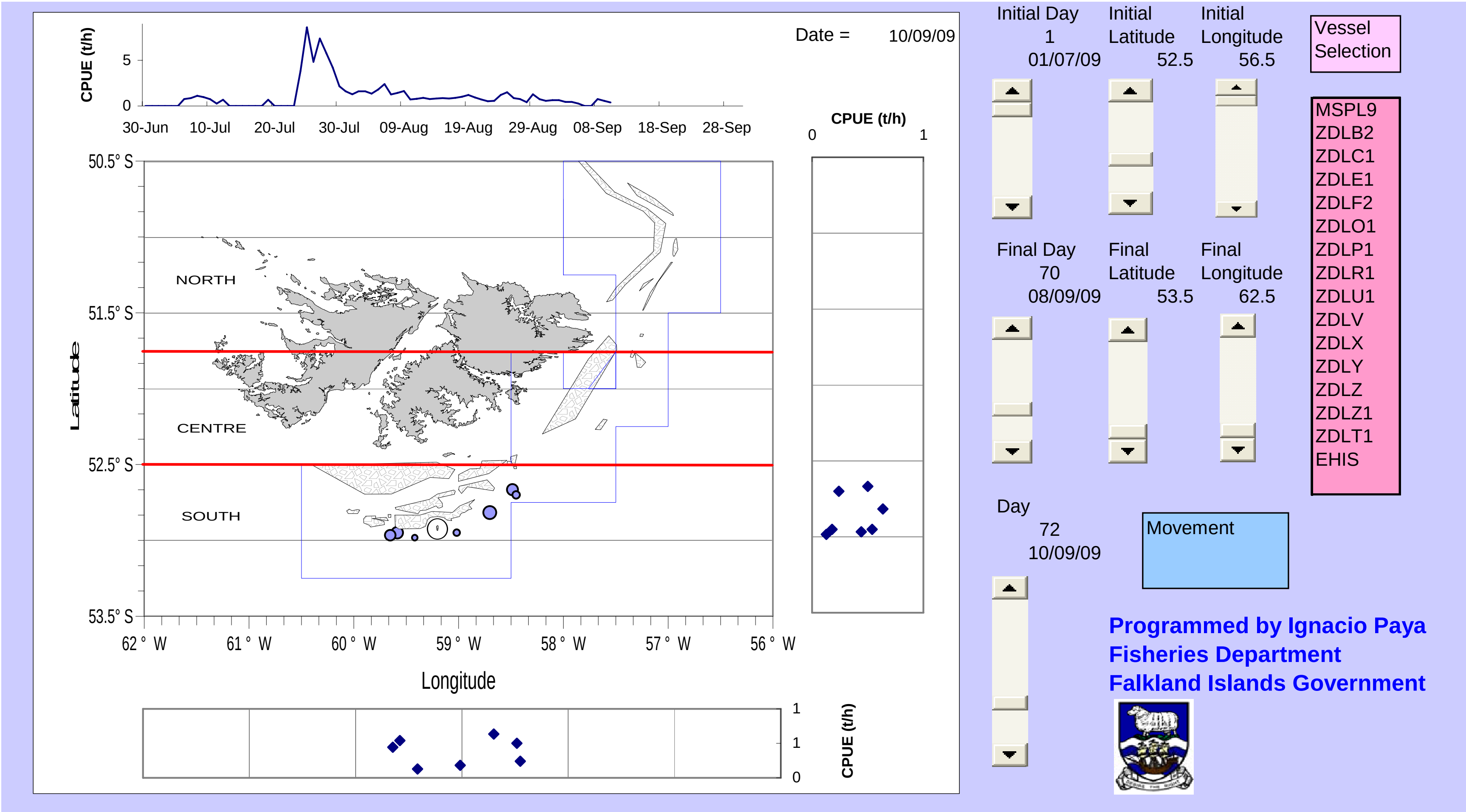


Fig. 12. On 9th September, part of the fleet fished for last time in the southern area (southern area data shown only).

IV. BIOLOGICAL TRENDS

Biological trends of the stock were based on sampling taken by two scientific observers onboard of two different commercial vessels, except for the first 6 days when were three observers onboard of different vessels. Each observer took a sample of approximately 400 animals per day. The sampling covered all the fishing days.

1. Comparison of Daily Mean Biological Characteristics with Recent Years

In the case of females, the proportion of sexually immature squid in the catch followed the trends observed in previous second seasons, but with an early decrease after the first month, which was similar to trend 2005 (**Fig. 13**). In the case of the males, the proportion on immature squids was higher than in previous second seasons and started to decrease later in the season, which was similar to trend 2007. The female proportion in the catches increased from about 0.3 to 0.5 during the first month and then decrease to around 0.3 (**Fig. 14**).

The average dorsal mantle length for the whole season was 12.7 cm (12.0 cm for females and 13.1 cm for males), which was 0.7 cm shorter than in 2008, 1.9 cm shorter than in 2007, 0.4 cm shorter than in 2006 and 2.8 cm shorter than in 2005 (**Fig. 15)**. The variation of length by day was similar between sexes and the length distributions were uni-modals (**Fig. 16**).

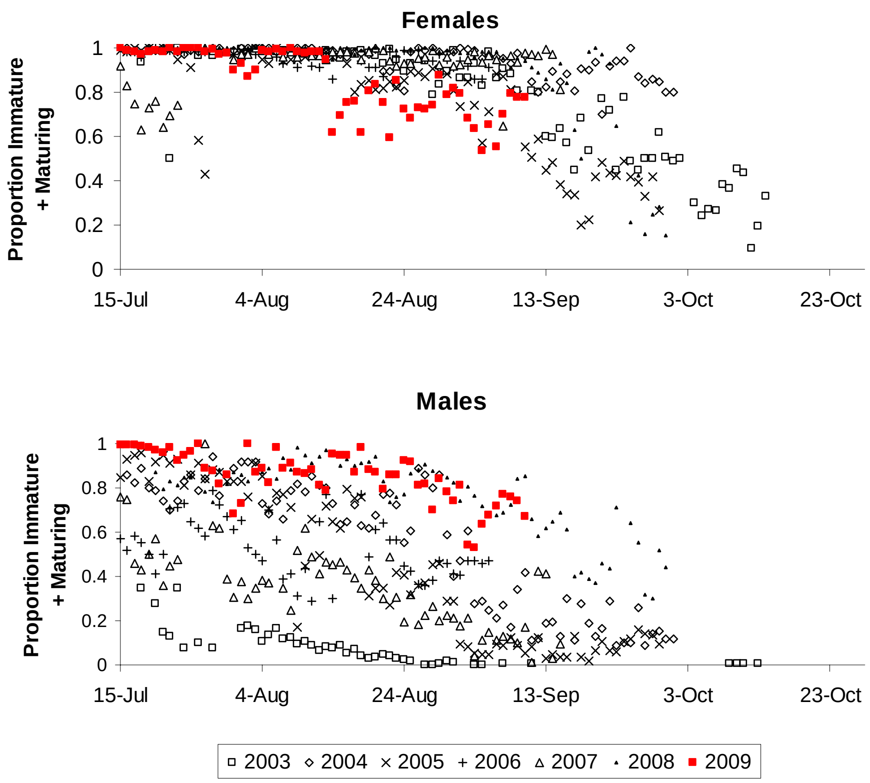


Fig. 13.- Current year trends in the proportion of sexually immature squids in the catch, compared with six previous years.

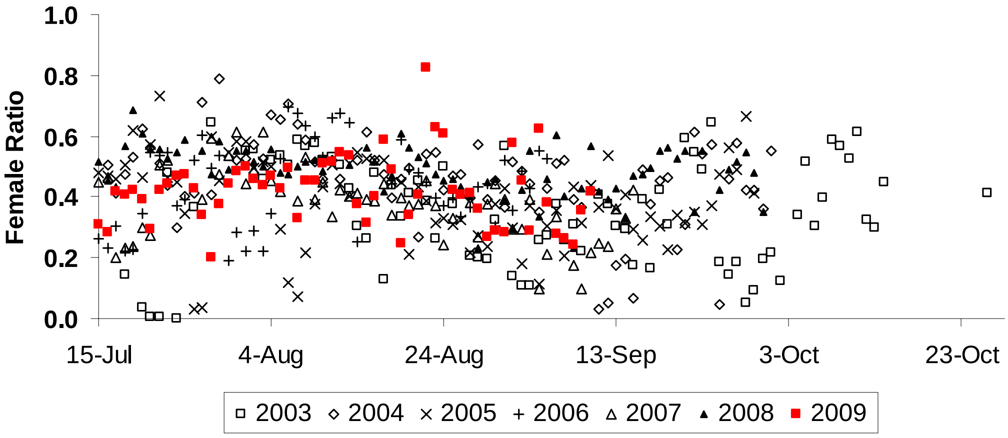


Fig. 14.- Current year trends in the daily evolution of the proportion of female squids in the catch, compared with six previous years.

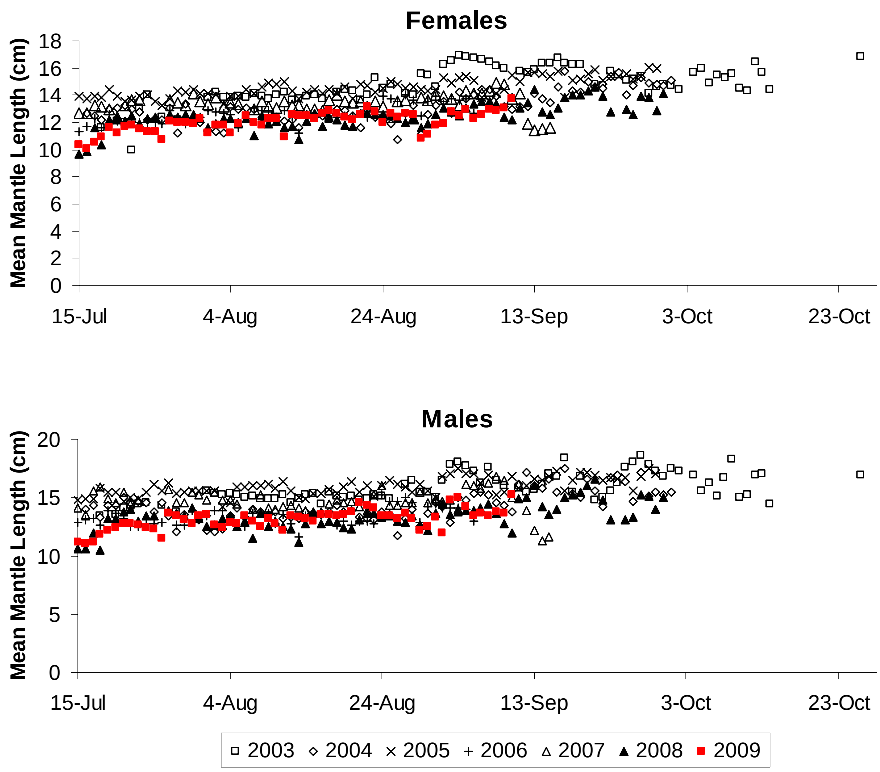


Fig. 15.- Current year trends in the mantle size by sexes, compared with six previous years.

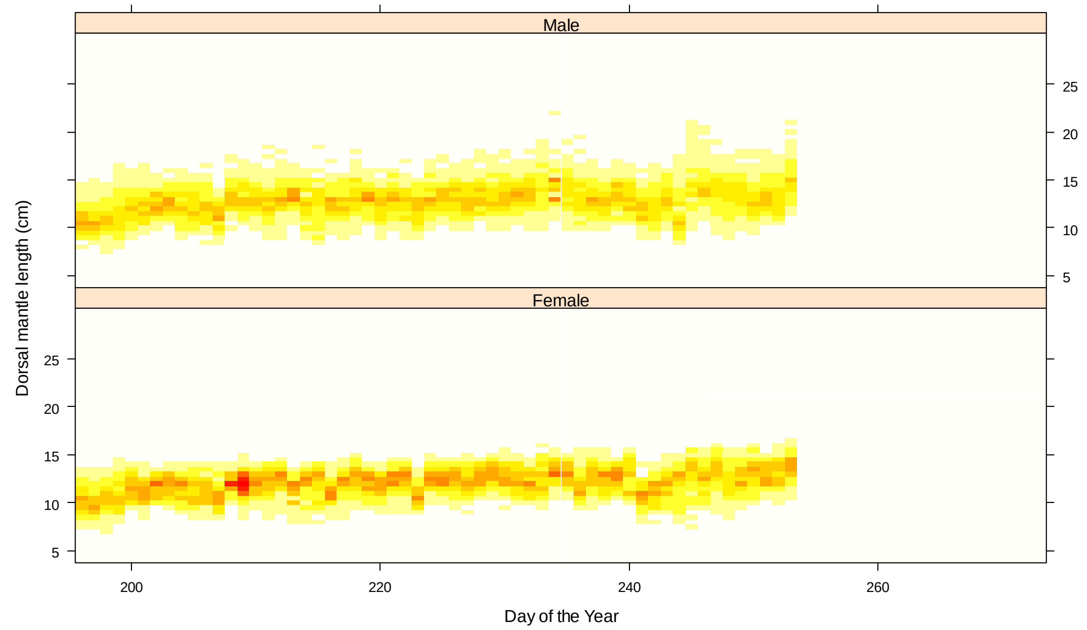
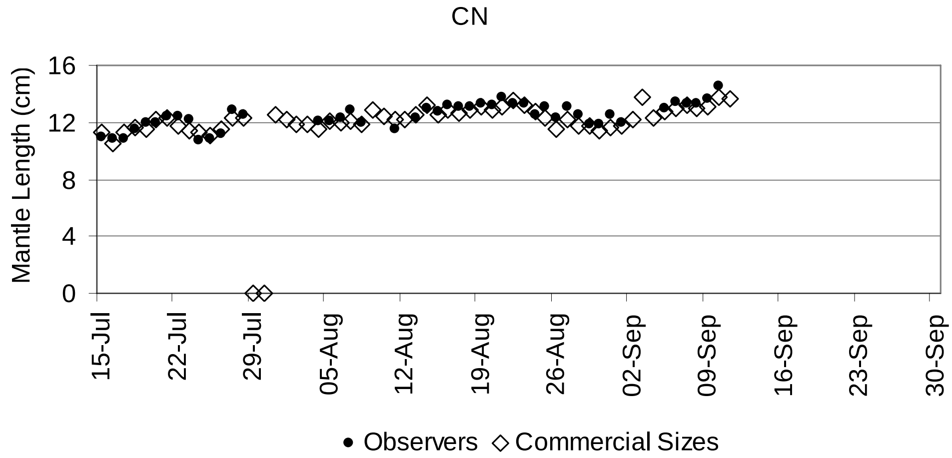


Fig. 16.- Time series of proportions (increases from yellow to red) of dorsal mantle length of squid in the catch during the second season, 2009.

2. Mean Mantle Length and Commercial Size Categories

During 2009, with two scientific observers onboard, it was not possible to take samples from all the areas where the fleet fished. Therefore the mantle size was also estimated based on the e-logbook records of production by ***C***ommercial ***S***ize ***C***ategory (***CSC***) by haul and vessel. The procedure for estimation was the one described in the 2006 second season fishery and stock assessment report (Payá 2006). The mantle size estimated using the CSC were similar to size sampled by the observers, except when the vessel with the observer was not fishing in the same fishing grounds that most of the fleet fished (**Fig. 17**).



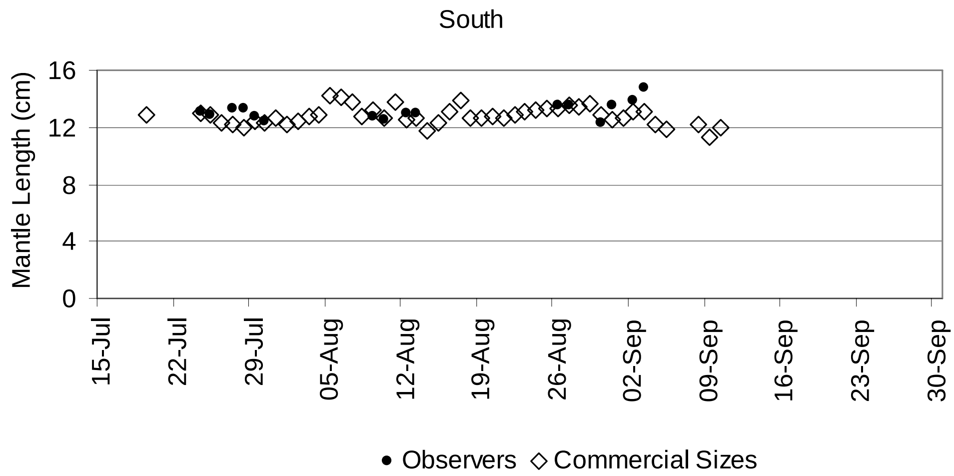
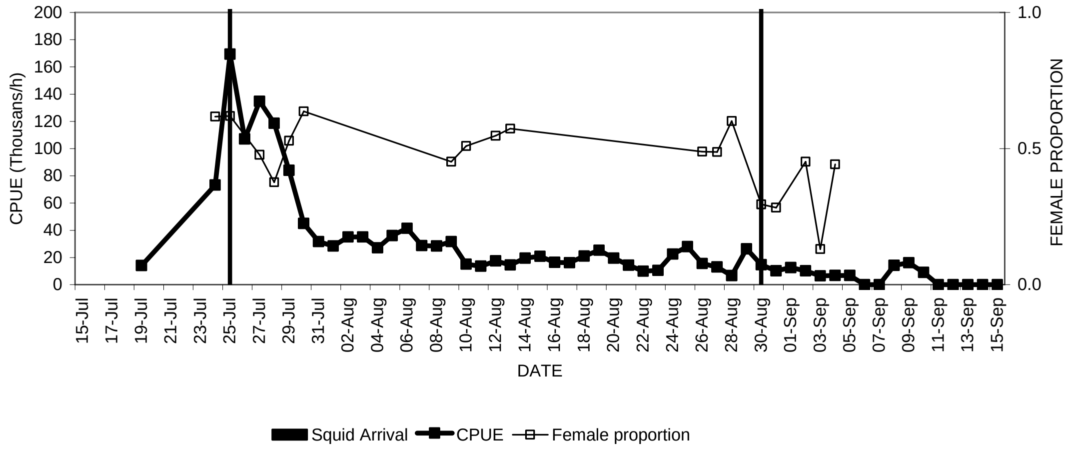


Fig. 17.- Average mantle length by area. Data from scientific observers onboard and estimations based on the commercial size categories (CSC).

3. Arrivals of squid waves by area.

The arrivals of the different squid waves, identified using the spatial distribution of CPUE, were also evident when CPUE trends were compared with female proportion and average weights. In the southern area, two squid waves were identified, the first one arrived on 25th July and the second one on 30th July (**Fig. 18**). In the northern area, two squid waves were identified, the first one was present at the beginning of the fishing season and the second one arrived on 24th July (**Fig. 19**). When the second wave arrived the CPUE increased and the squid weight and the female proportion decreased.



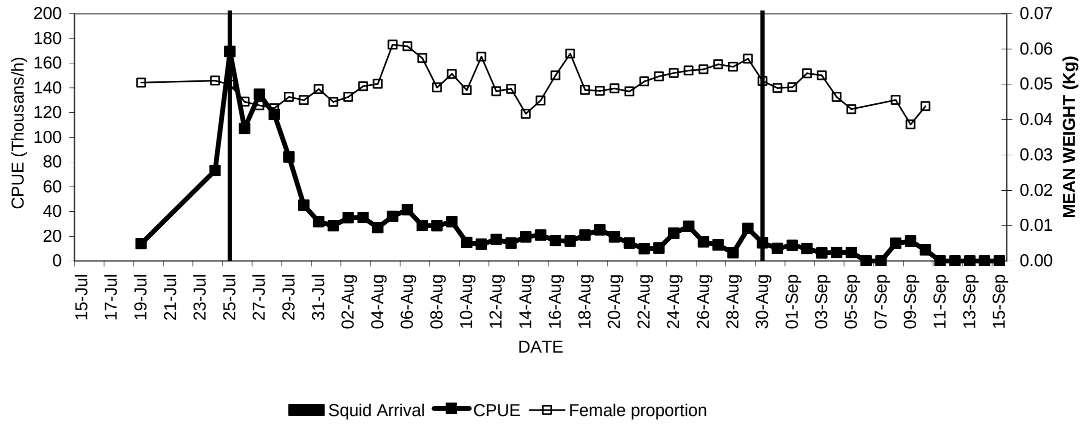


Fig. 18.- The arrival of two squid groups to the southern area was identified based on the behaviour of the CPUE (Thousands/h), the female proportion (upper plot) and the mean weight (down plot). The arrival date is represented by the vertical bars.

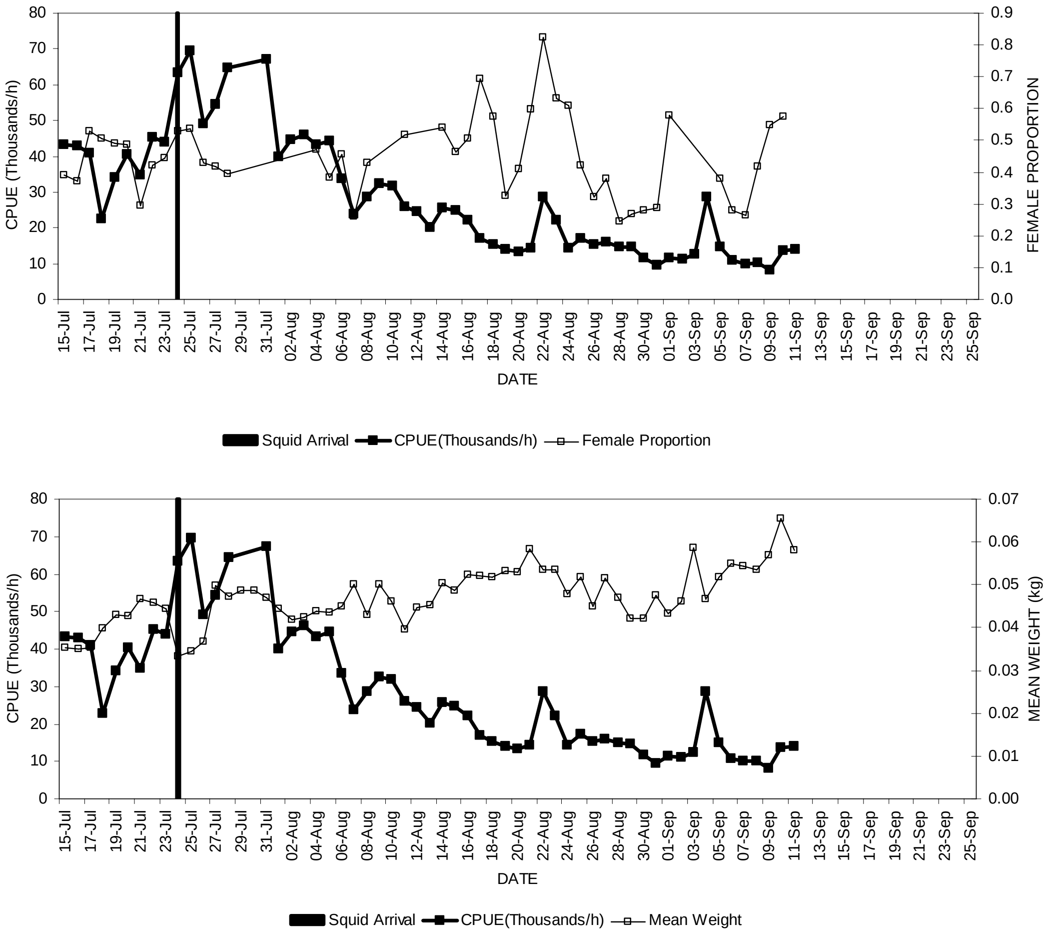


Fig. 19.- The arrivals of two squid groups to the central-northern area was identified based on the behaviour of the CPUE (Thousands/h), the female proportion (upper plot) and the mean weight (down plot).

V. STOCK ASSESSMENT AND RISK ANALYSIS

1. In-Season Stock Assessment and Risk Analysis

In-season stock assessment was used to apply the decision rule to close the fishery if the projected spawning biomass is below 10,000 tonnes, under the restriction to warn the industry with two weeks in advance of the expected closing date. A flowchart of the *Loligo* management procedure is presented in **Figure 20**.

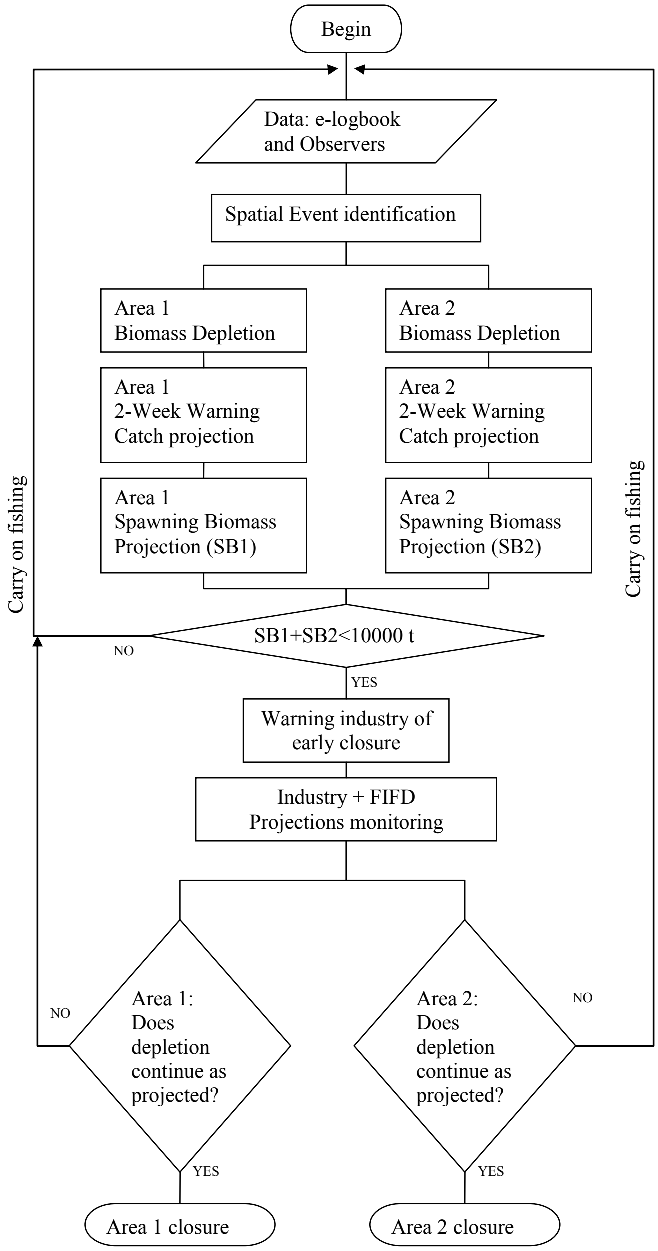


Fig. 20.- Flowchart of spatial management procedure for the early fishery closure decision. For simplicity only two depletion events are shown.

The fishery data was collected by daily catch reports and e-logbook and biological data by scientific observers onboard 2-3 vessels. Depletion events were located spatially and temporally by means of the graphical interface. Current biomass in each area was estimated by depletion models, then the catches and biomass during the 2-week warning period were projected and finally the surviving spawning biomass was estimated. If the projected spawning biomass is lower than 10,000 tonnes then a warning of an early fishery closure is sent to the industry. During the warning period the FIFD daily updates the stock assessment and biomass projections, which are shown to the fishery entrepreneurs for discussion. Real time fleet movements and possible new areas of good catches are also discussed. If the biomass depletion follows the projection and no other new squid appear then the area will be closed.

The stock assessment was done using the depletion model with several recruitment pulses and vessel catchability coefficients estimations by area. The equations for the stock assessment and risk analysis have been previously described in the 2007 second fishery report (Payá 2007), and therefore are not presented here.

The fishing season was early closed on 11th September. The early closure decision was taken based on the in-season stock assessment with data up to 2nd September. The biomass on 2nd September was estimated at 11,450 tonnes, with a 10th percentile estimate of 6,388 tonnes and a 90th percentile of 20,632 tonnes (**Fig. 21**). Most of the abundance was located in the northern area (**Fig. 22**). The escapement biomass on 15th October was estimated at 9,395 tonnes, with a 10th percentile of 5,170 tonnes and a 90th percentile of 20,632 tonnes (**Fig. 23**). The risk probability that the projected escapement biomass could be less than 10,000 tonnes, was estimated at 0.63.

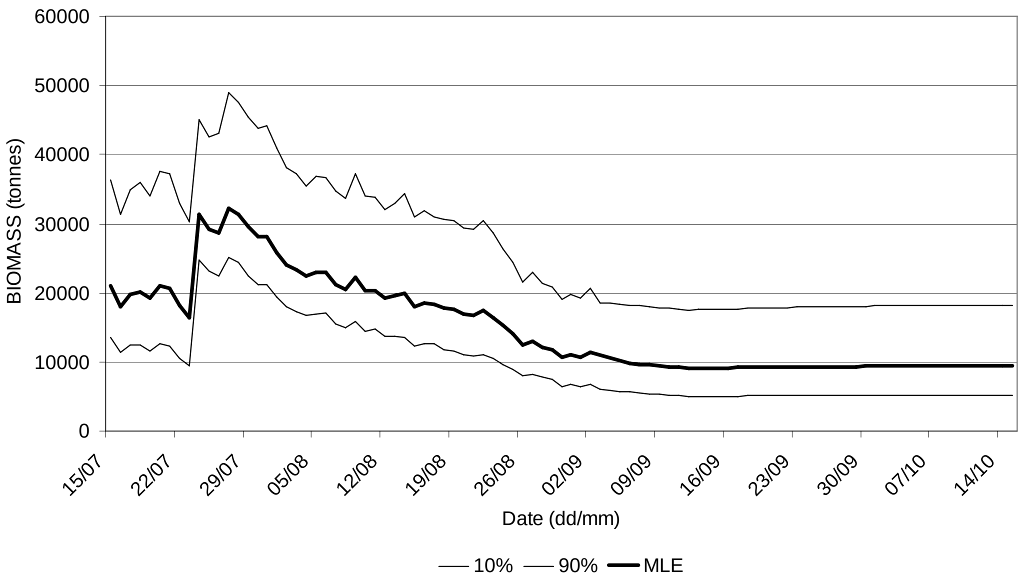


Fig. 21.- In-season stock assessment with data up to 2nd September. Biomass estimated and projected (MLE: Maximum Likelihood Estimation; and percentiles of 10% and 90%).

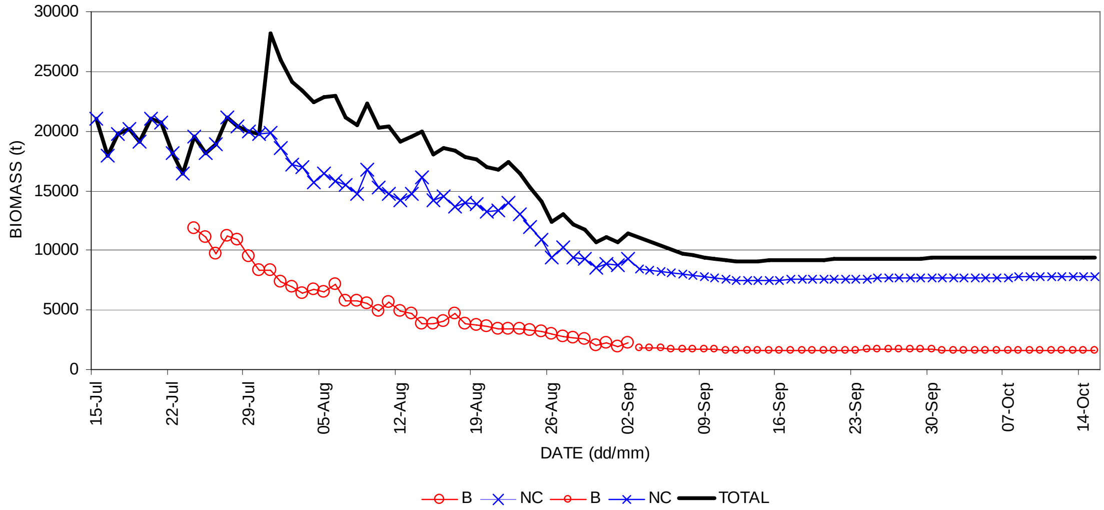


Fig. 22.- In-season stock assessment with data up to 2nd September. Biomass estimated (-o-) and projected (-x-) by area (B: Southern Area; NC: Central-North Area) and whole area (TOTAL).

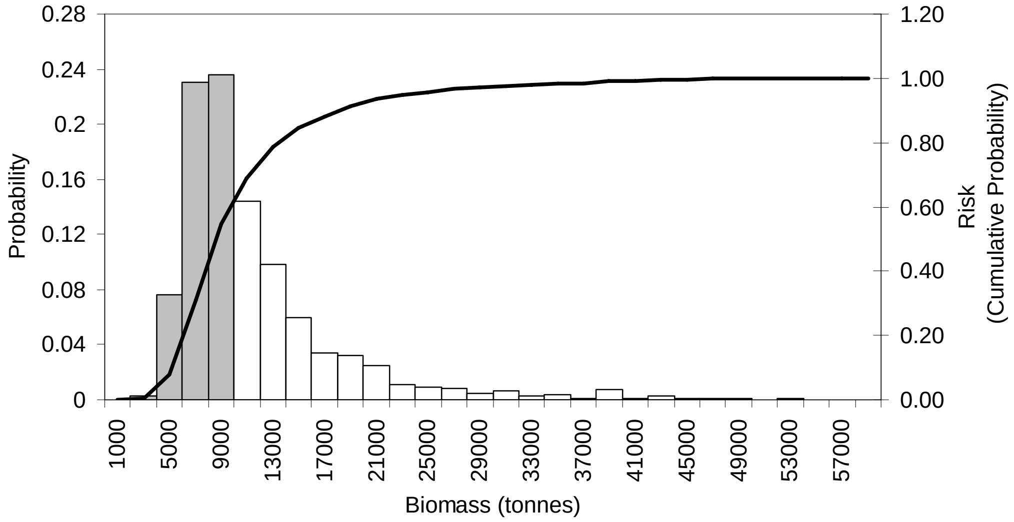


Fig. 23.- In-season stock assessment with data up to 2nd September. The bars show the probability distribution of the escapement biomass and the line the cumulative probability. The risk of Biomass <10,000 tonnes was estimated at 0.63 (grey bars).

The probability of no more groups arrive to the central-northern area was estimated at 0.8 (**Fig. 24**) and in the southern area at 0.7 **(Fig. 25).** The combined risk, the probability of no more squid groups multiply by the probability that escapement biomass is less than 10,000 tonnes, was estimated at 0.47 (= 0.63 × avg(0.7, 0.8)).

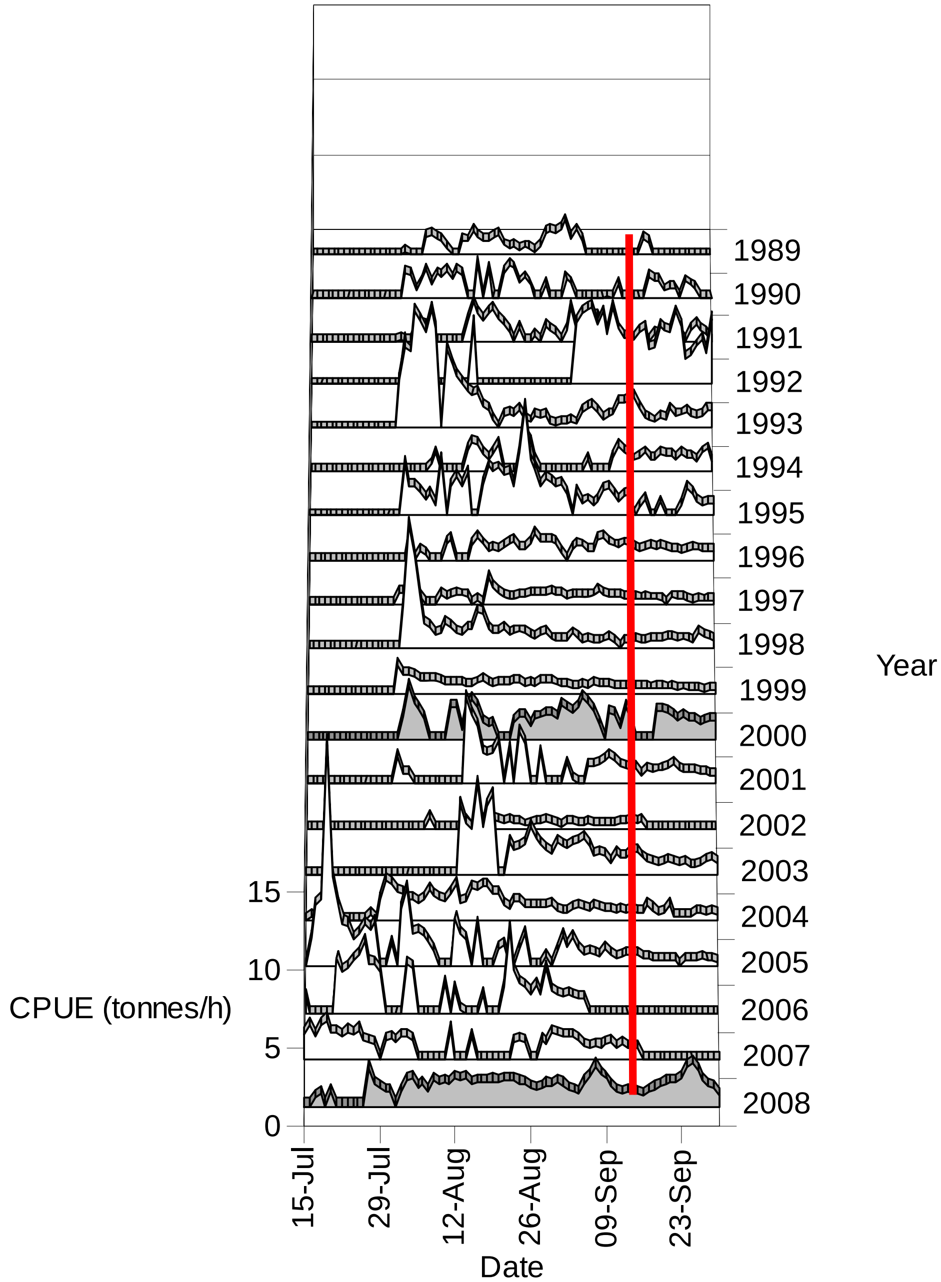


Fig. 24.- Historical second season CPUE trends in the central-northern area. The red line shows the 11th of September; the grey colour years that had increase in CPUE between this date and the end of fishing season. There was a 0.80 probability that no more squid groups arrive to this area.

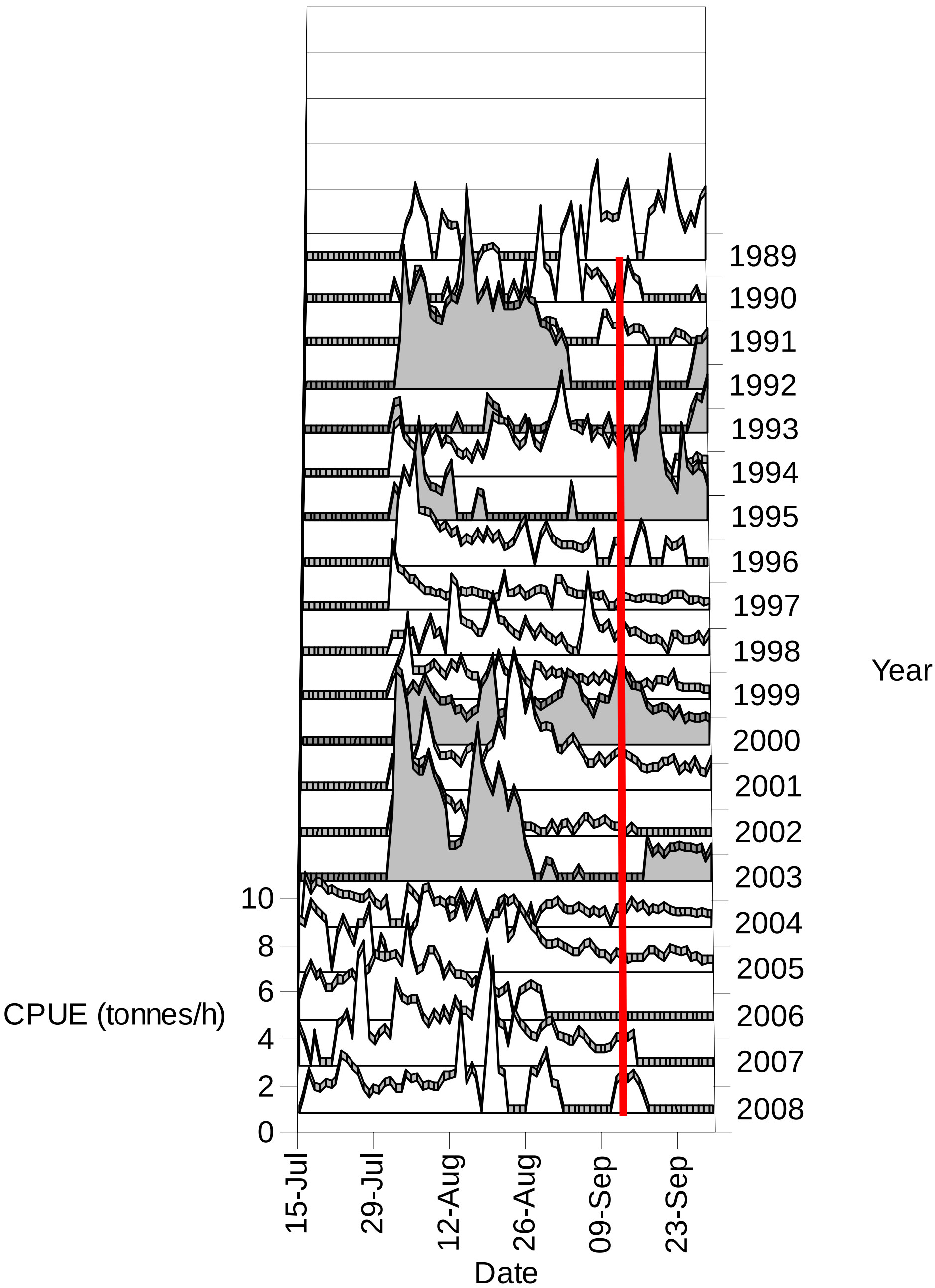


Fig. 25.- Historical second season CPUE trends in the southern area. The red line shows the 11th of September; the grey colour years that had increase in CPUE between this date and the end of fishing season. There was a 0.7 probability that no more squid groups arrive to this area.

2. After-Season Stock Assessment and Risk Analysis

2.1 Stock assessment model and escapement biomass projection

Immediately after the early closure of the fishing season a post-season scientific survey was done (Payá and Winter 2009). This survey was proposed by the *Loligo* producers group and conducted by the FIFD to estimate the biomass and to check for the arrival of new squid waves. Having available the survey abundances before and after the fishing season, the stock assessment model was improved to be fitted to survey abundance as well.

The detailed formulation of the improved model is presented in the ANNEX. The main model components are:

1) Several sequential depletion events by area
2) Catchability coefficients by vessel, squid group and area.
3) A survey catchability coefficient
4) Predictions of commercial CPUE by vessel and area
5) Predictions of survey abundances by area
6) Penalty function of similarity level between vessel catchability coefficients by area.

There were 4 model parameters to be estimated, 2 for each area: the initial number of individuals and the number of individuals that arrive in the second squid group.

The escapement biomass on 15th October was modified to include the abundance of third group that arrived on the 20th September (Payá and Winter 2009), which was not included in fitting the depletion model because arrived later. The stock abundance on 20th September was calculated as the survey abundance divided by the survey catchability (estimated in the depletion model).

2.2 Bayesian inference

The model was fitted using Bayesian inference. The posterior probability of the $\boldsymbol{\theta_i}$ parameters, $\boldsymbol{P(\theta_i|X)}$ is calculated as:

$$P(\theta_i \mid X) = \frac{P(X \mid \theta_i) * p(\theta_i)}{\sum_i P(X \mid \theta_i) * p(\theta_i)}$$

where $\boldsymbol{X}$ is the data; $\boldsymbol{P(X|\theta_i)}$ is the likelihood and $\boldsymbol{p(\theta_i)}$ is the prior distribution of $\boldsymbol{\theta_i}$ parameter.

The priors were normal distributions with mean values that correspond to a survey catchability coefficient equal to 0.8 (survey abundance is 80% of stock abundance).

The model parameters were found maximizing a loss function, which has the following components:

1) Priors: Parameter priors;
2) q Penalty: Penalty of catchability similarity by area
3) CN CPUE: Model fitting to commercial CPUE in the central-northern area;

4) CN Survey: Model fitting to survey abundance in the central-northern area
5) S CPUE: Model fitting to CPUE in the southern area;
6) CN Survey: Model fitting to survey abundance in the southern area

The weights of these components in the loss function are inversely proportional to their statistical uncertainties (coefficient of variation, CV). These weights are not easy to define and therefore different fitting model cases, with different weights combinations, were analysed.

To compute the posterior distribution a Metropolis-Hastings Markov Chain Monte Carlo algorithm (MCMC) programmed in VisualBasic was used (Payá 2007). Three chains of 6000 iterations were generated using a normal distribution as a global jumping rule, the mean was the maximum posterior density and dispersion parameter was a coefficient of variation of 1.5 (Gelman ***et al.*** 2004). The first 1000 iterations of each chain were discarded as a burn-in section. The number of iterations was determined using the convergence index ***R***, which is like the ratio between the variances within and between chains (Gelman ***et al.*** 2004). The convergence is achieved when ***R*** is lower than 1.1. The three chains were pulled together in a 15000-iteration chain that was used to compute the posterior densities. To estimate the biomass distribution (marginal density) 3000 set of parameters were randomly taken from the posterior distributions. For each of the 3000 biomass estimations the spawning biomass was projected and the risk of leaving at the sea less than 10000 tonnes of spawning biomass was computed.

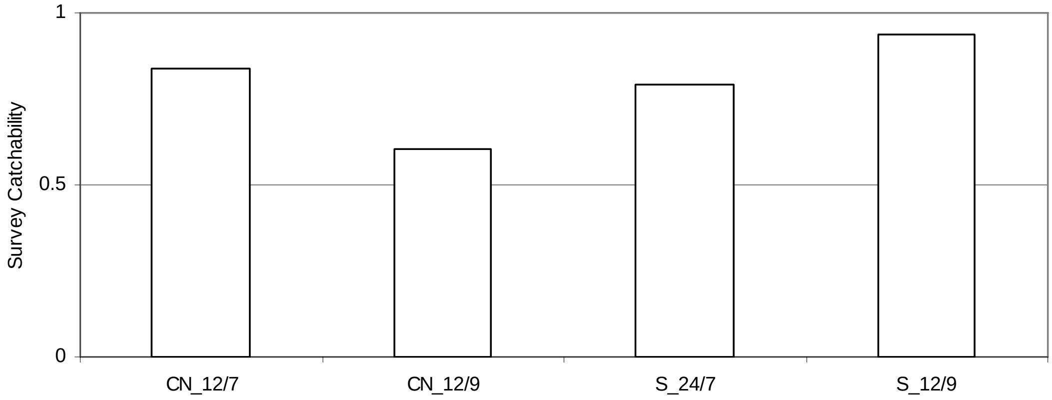
2.3 Sensitivity analysis of model components weights

The results of different weight combinations are shown in the Table 3. Survey catchability ranged from 0.78 to 1.07; biomass on 25th July from 20,449 to 22,833 tonnes; biomass on 12th September, end of the fishing season, from 3,921 to 6,278 tonnes; biomass on 15th October, escapement biomass, from 11,162 to 13,682 tonnes.

Case 9, which estimated the average survey catchability at 0.78, was selected for further computation because of two reasons. First, a catchability value of 0.78 seems to be more reasonable than one close to 1 (as in case 4), because there is an unknown fraction of *Loligo* in the water column that is not available to the height of net used in the surveys. Second, case 9 survey catchability coefficients had a more homogeneous distribution around the average survey catchability than other cases (**Fig. 26**). For example, case 4 catchabilities of pre-season surveys (one survey two areas) were greater than the one, while post-season catchabilities were lower than 1 (**Fig. 27**).

Table 3. Sensitivity analysis of model components weights. Parameter: maximum posterior density parameter (billions); CV: coefficient of variation, which is the inverse of component weight; Ln Likelihood: logarithm of likelihood; LOSS: loss function value; Biomass on 12/9: Biomass in thousand tones at the end of fishing season; Biomass on 15/10: Escapement biomass; CN: Central-northern area; S: Southern area. The case 9 in grey had the survey catchability closest to the prior.

	CASES								
	1	2	3	4	5	6	7	8	**9**
Parameter									
CN N1	0.253	0.225	0.243	0.309	0.270	0.343	0.320	0.403	**0.470**
CN N2	0.151	0.165	0.223	0.153	0.221	0.129	0.103	0.104	**0.107**
S N1	0.210	0.232	0.193	0.193	0.194	0.201	0.232	0.196	**0.195**
S N2	0.015	0.016	0.018	0.019	0.019	0.015	0.014	0.014	**0.014**
CV									
Priors	0.3	0.5	0.5	0.5	0.5	0.3	0.1	0.1	**0.1**
q Penalty	0.01	0.001	0.1	0.1	0.1	0.1	0.001	0.1	**0.1**
CN Cpue	0.3	0.3	0.5	0.3	0.5	0.3	0.3	0.3	**0.5**
CN Survey	0.5	0.5	0.15	0.1	0.1	0.1	0.15	0.5	**0.5**
S Cpue	0.4	0.4	0.3	0.4	0.3	0.4	0.4	0.4	**0.3**
S Survey	0.5	0.5	0.15	0.1	0.1	0.1	0.15	0.5	**0.5**
Ln Likelihood									
Priors	7.36	6.51	4.44	6.94	4.52	9.34	6.13	12.72	**14.19**
q Penalty	-0.9	1.3	-1.3	-1.2	-1.4	-1.2	-4.6	-1.6	**-2.1**
CN Cpue	-531.0	-530.6	-777.7	-532.2	-778.5	-533.7	-535.5	-536.5	**-787.3**
CN Survey	-10.7	-10.7	-8.3	-7.5	-7.5	-7.5	-8.3	-10.7	**-10.7**
S Cpue	-410.1	-411.5	-327.0	-409.3	-327.1	-409.6	-411.5	-409.4	**-327.1**
S Survey	-17.5	-18.6	-15.4	-14.7	-14.3	-14.5	-21.6	-17.0	**-17.1**
LOSS	-962.7	-963.6	-1125.3	-958.1	-1124.3	-957.2	-975.4	-962.4	**-1130.1**
Main Results									
Survey q	1.07	1.02	1.01	0.96	0.94	0.91	0.88	0.87	**0.78**
CN Cpue q	0.00018	0.00019	0.00013	0.00013	0.00012	0.00013	0.00016	0.00011	**0.00009**
S Cpue q	0.00026	0.00020	0.00031	0.00030	0.00030	0.00029	0.00021	0.00032	**0.00033**
Biomass on 25/7	20449	21169	21845	21455	22678	22043	21965	22833	**24995**
Biomass on 12/9	3921	4194	5541	5235	6278	5460	4771	6151	**8010**
Biomass on 15/10	11162	11692	11795	12412	12759	13107	13508	13682	**15256**



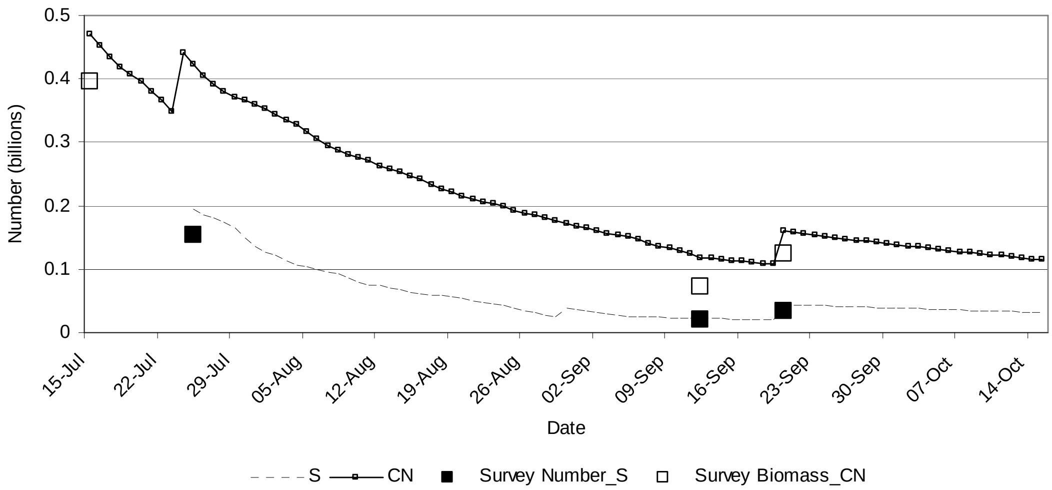
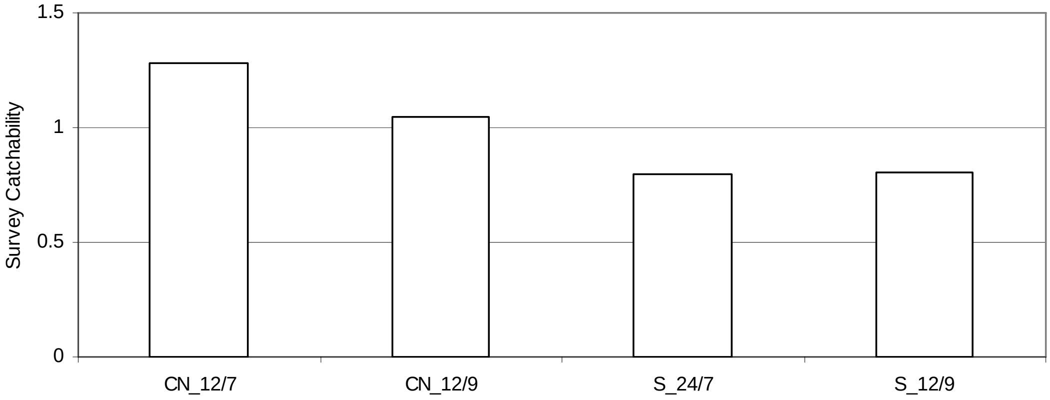


Fig. 26. **C**ase 9 had an average survey catchability of 0.78. The catchability coefficients by survey are shown in the upper plot. Stock abundance by area (lines) and abundance in the *Loligo* swept area surveys (squares) are shown in the down plot.



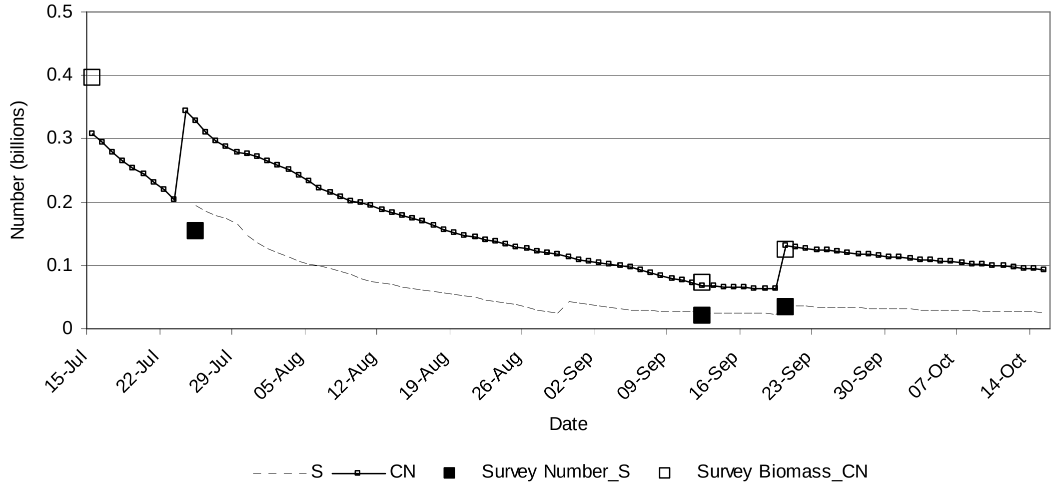


Fig. 27. **C**ase 4 had an average survey catchability of 0.96. The catchability coefficients by survey are shown in the upper plot. Stock abundance by area (lines) and abundance in the *Loligo* swept area surveys (squares) are shown in the down plot.

2.4 MCMC results

MCMC were done for case 9. After the 1000-iteration burn-in section the chains reached the convergence criterion at iteration 3000 (**Fig. 28**). The lower and upper limits of the prior distribution were wide enough for covering all the possible values of the posterior distribution and the prior distributions did not constrained the posterior values (**Fig. 29**).

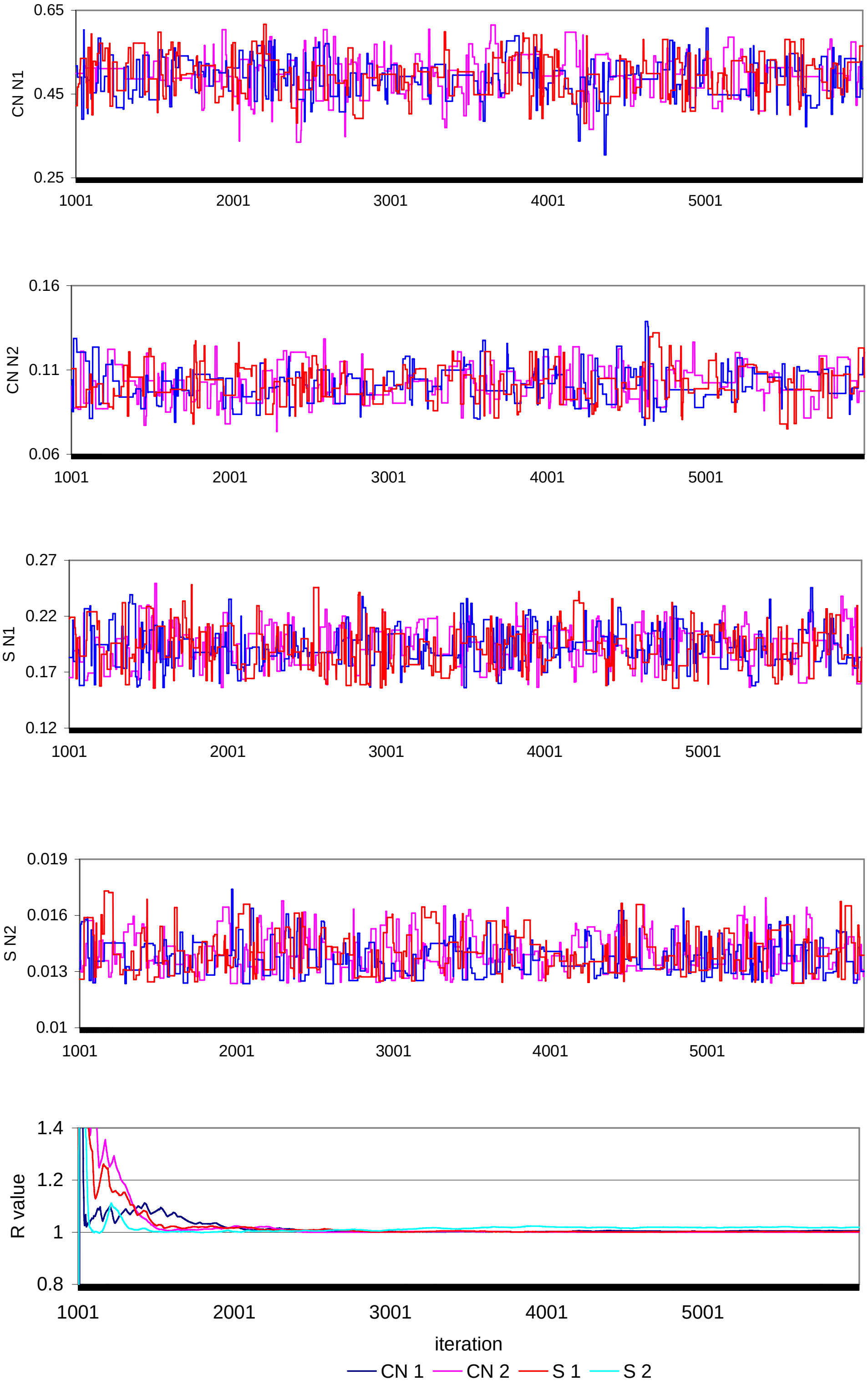


Fig. 28.- MCMC of three chains for each parameter (first 4 upper plots) and the convergence index (***R***), which must be lower than 1.1 (down plot). (CN: Central-northern area; S: Southern area)

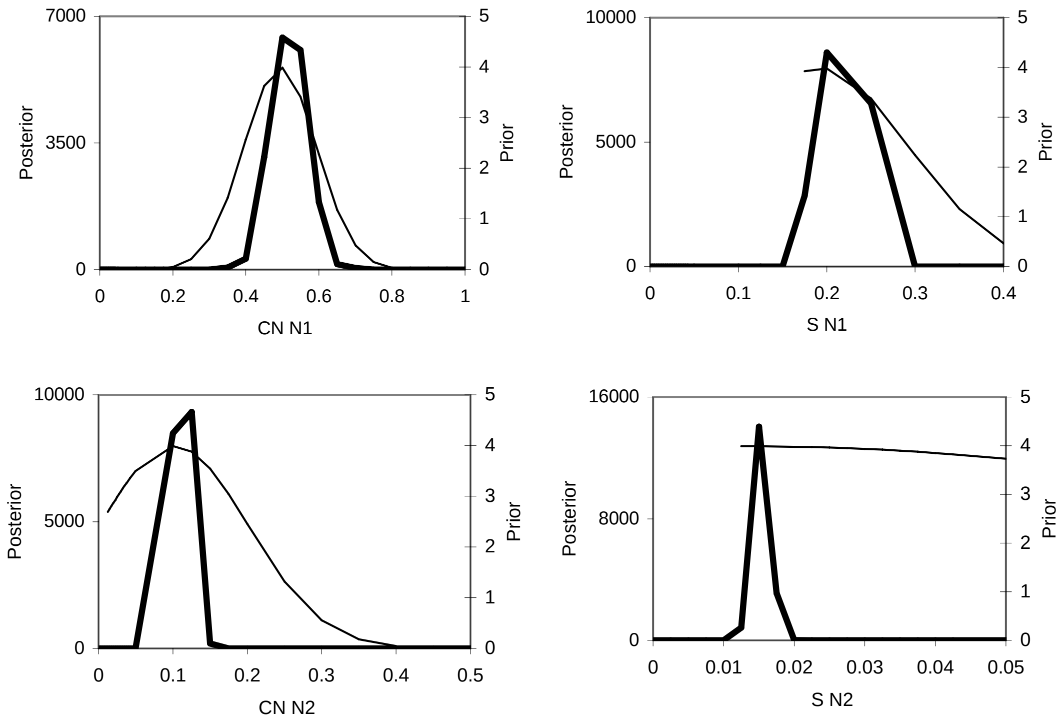


Fig. 29.- Prior (thin line) and posterior (thick line) distributions of model parameters. CN N1: Central-northern area squid group 1; CN N2: Central-northern area squid group 2; S N1: Southern area squid group 1; S N2: Southern area squid group 2.

2.5 Case 9 model Fittings by Area

Case 9 model fitted well to the survey abundance by area (**Fig. 30**) and to the commercial CPUE by vessel and area (**Fig. 31 and 32**).

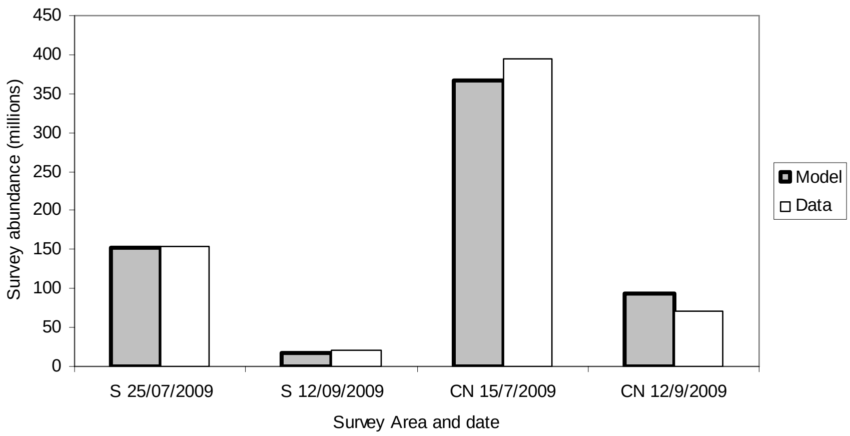


Fig. 30.- Case 9 model fitting to survey abundance. CN: Central-northern area; S: Southern area.

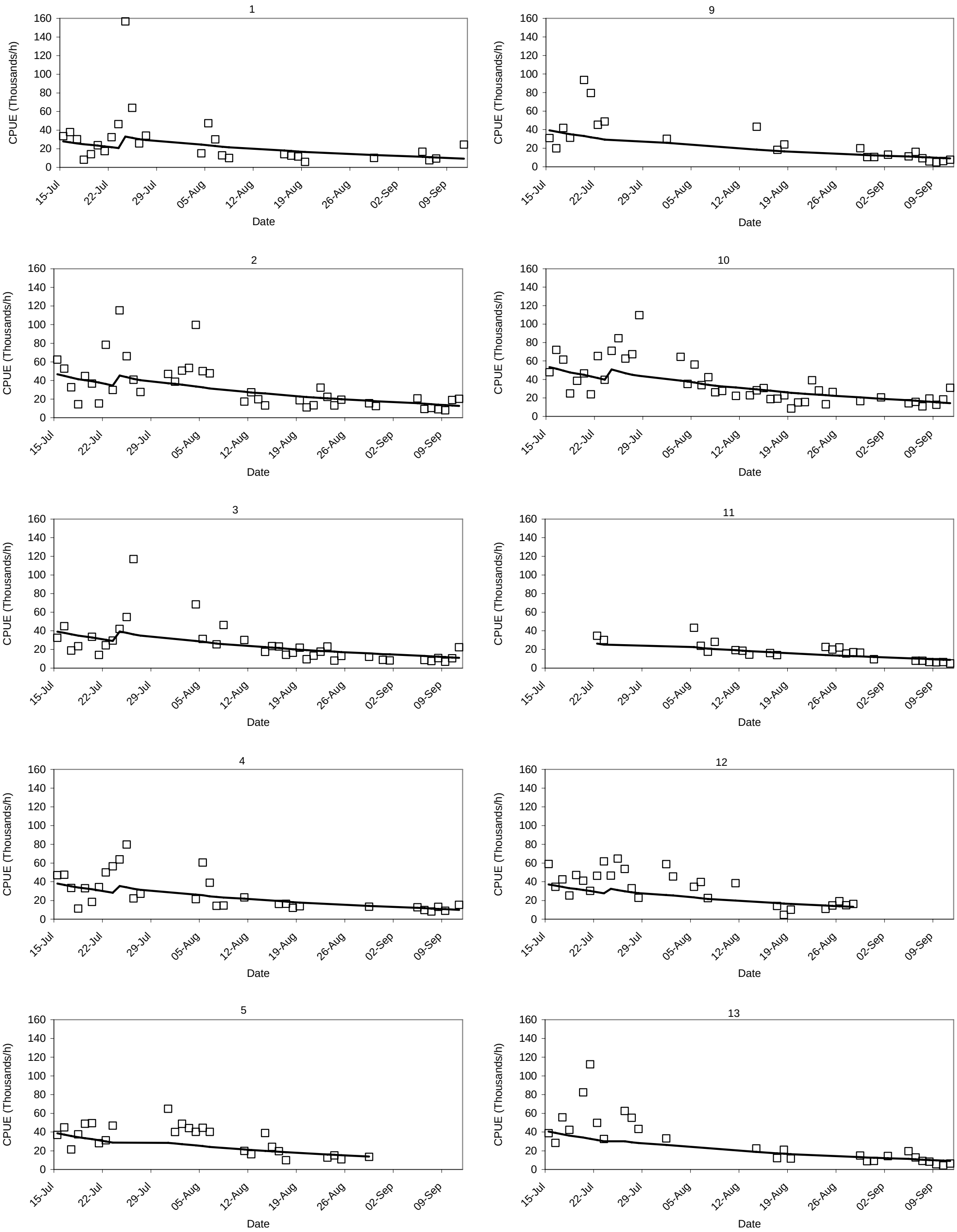


Fig. 31.- Fitting model (line) to CPUE (thousands/h) data (squares) by vessel in the central-northern area.

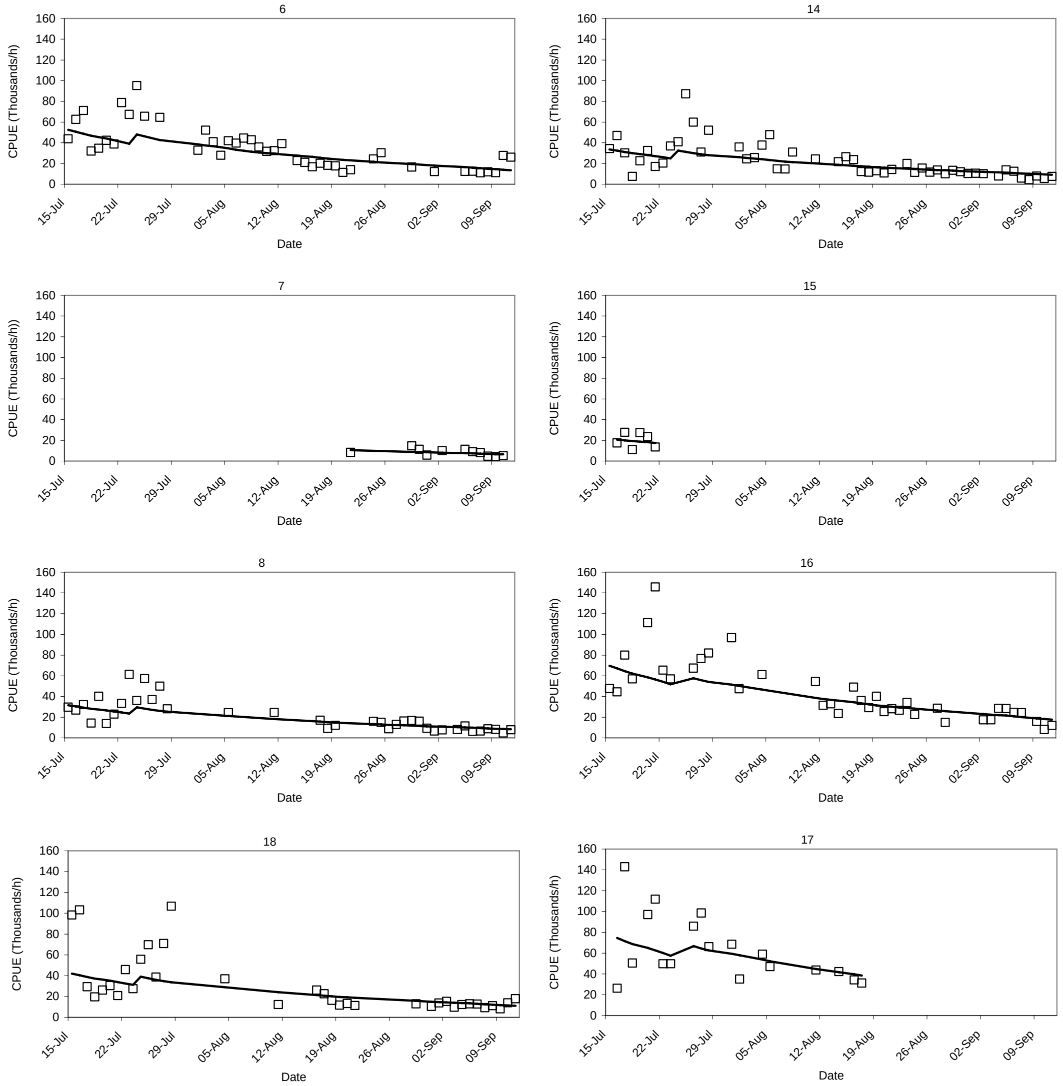


Fig. 31.- Continued

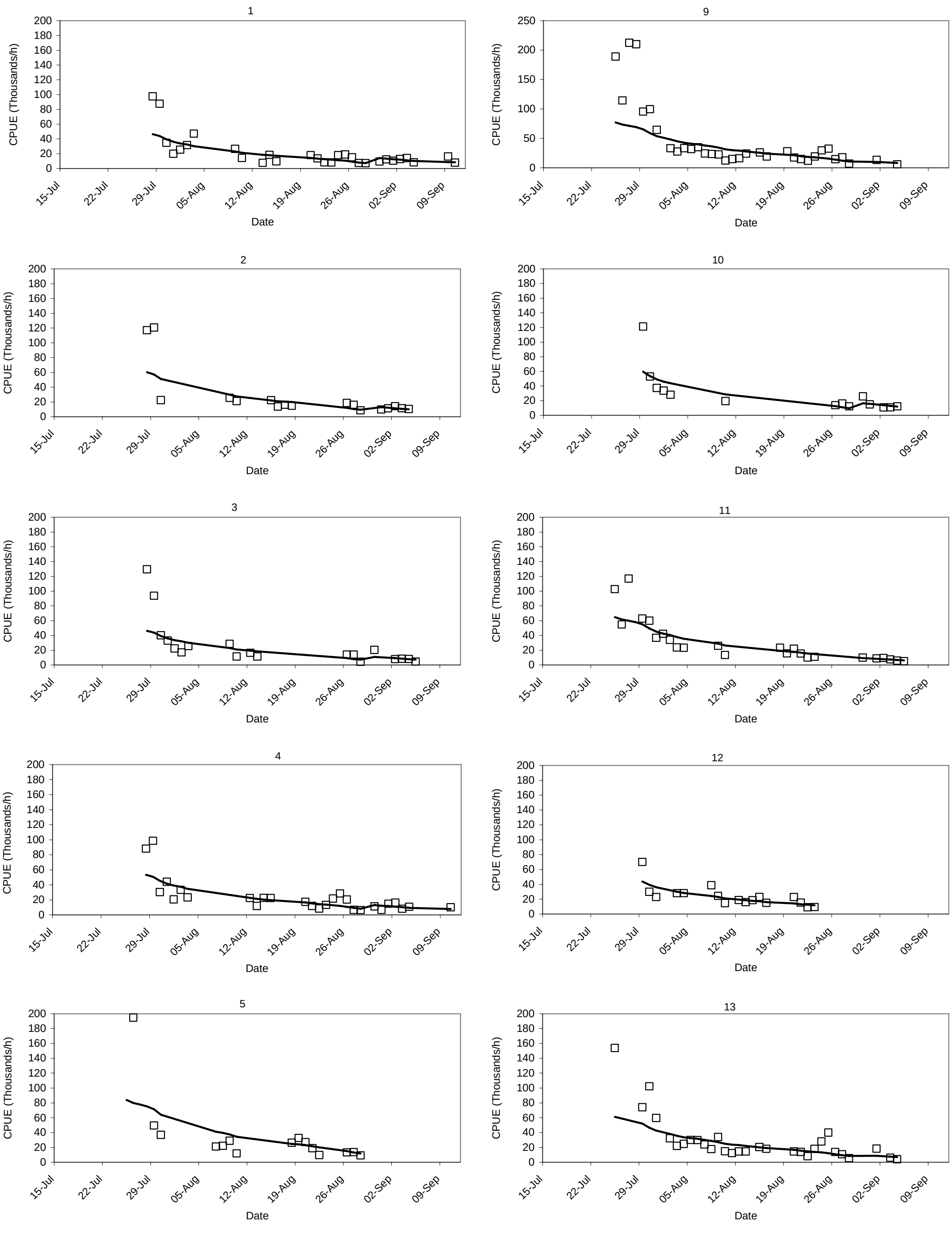


Fig. 32.- Fitting model (line) to CPUE (thousands/h) data (squares) by vessel in the southern area.

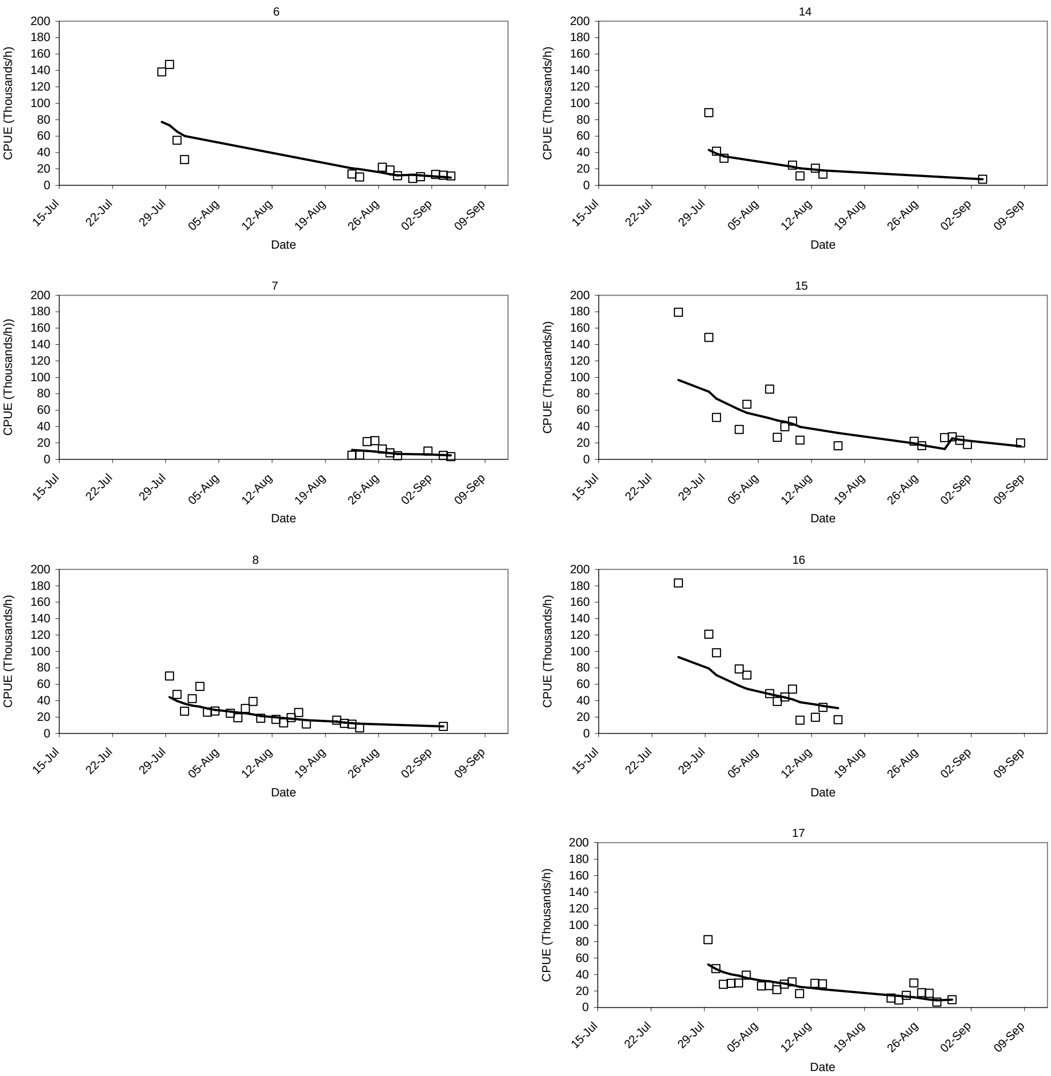


Fig. 32.- Continued

2.6 Catchability Coefficients and Fishing Powers by Vessels

The catchability coefficients by vessel were similar by squid group in one area, but different between areas, with the highest catchabilities were in the southern area (**Fig. 33).**

The relative fishing powers (vessel catchability / reference vessel catchability) had good relationships with the main engine horse power (R^2=0.74), and with the gross registered tonnage (R^2=0.53) (**Fig. 34)**.

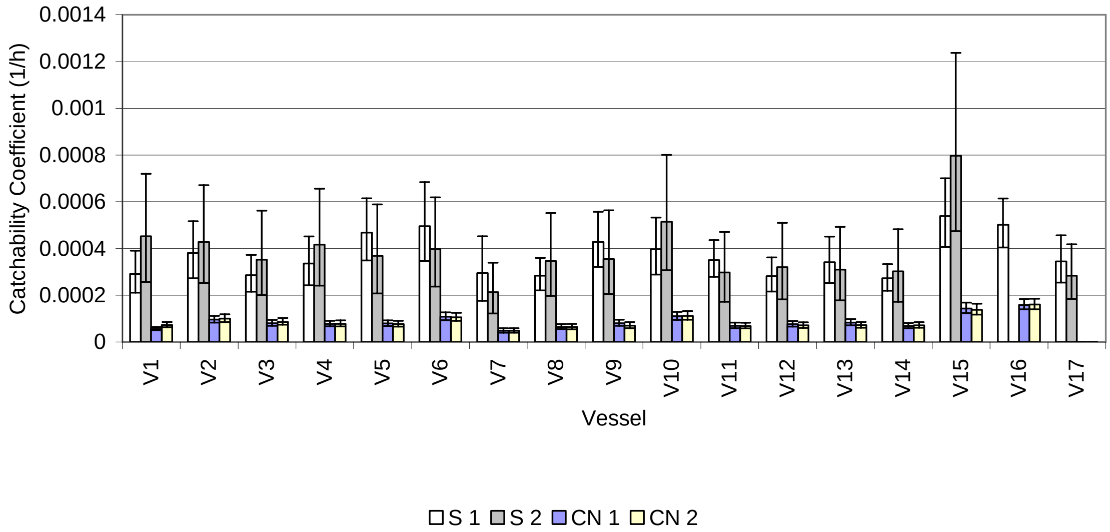
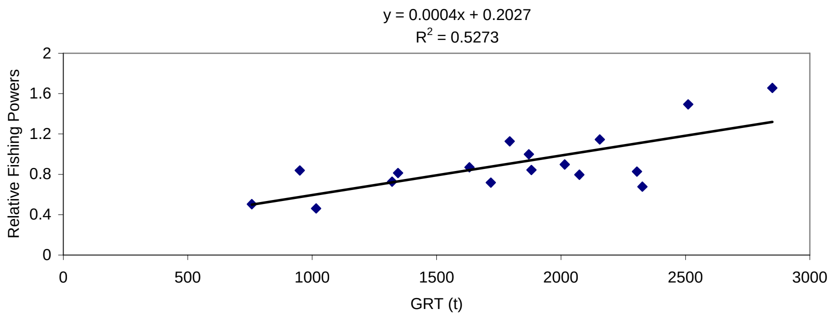


Fig. 33.- Catchability coefficients by vessel, squid group and area (S 1: Southern area group 1; S 2: Southern area group 2; CN 1: Central-northern area group 1 and CN 2: Central-northern area group 2). The vertical bars represent the 95% confident interval.



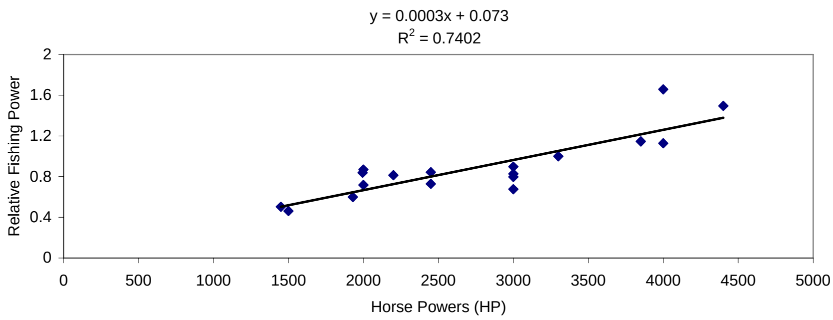


Fig. 34.- Relation between relative fishing power (relative catchability coefficients) and GRT (gross registered tonnage) (upper plot) and HP (down plot), based on catchability coefficients of vessels on first squid group in the central-northern area.

2.7 Biomass Estimations and Risk

In case 9 model, the biomass in the whole *Loligo* box was estimated at 24,995 tonnes on the 25th of July and at 8,010 tonnes on the 12th of September (**Fig. 35)**. Most of the biomass was in the central-northern area (**Fig. 36).** The whole biomass that arrived to fishing grounds during the season was estimated in 32,282 tonnes and corresponds to the sum of the biomass at the start of the season and the biomasses of the squid groups that arrived during the season (**Figures 37 and Table 4**).

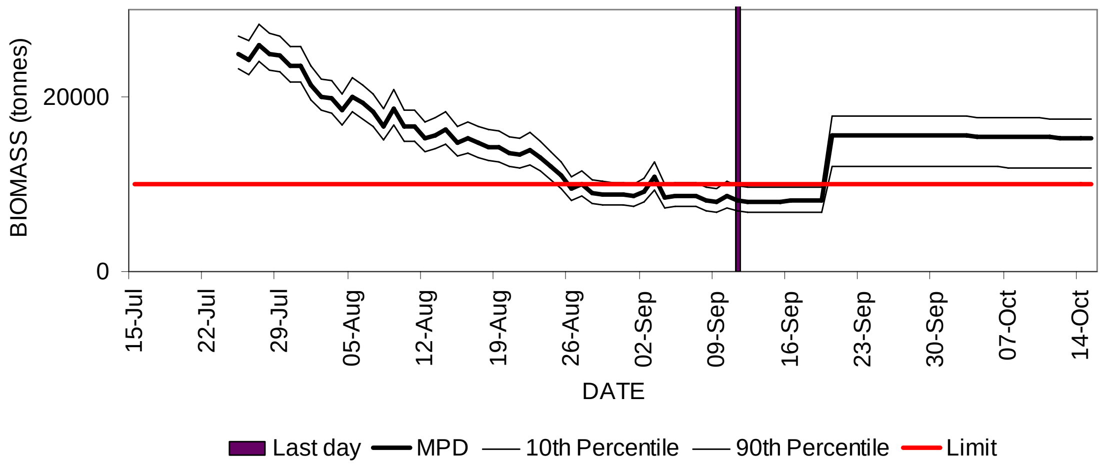


Fig. 35.- Biomass depletion and projection in the whole *Loligo* box (MPD= Maximum Posterior Density).

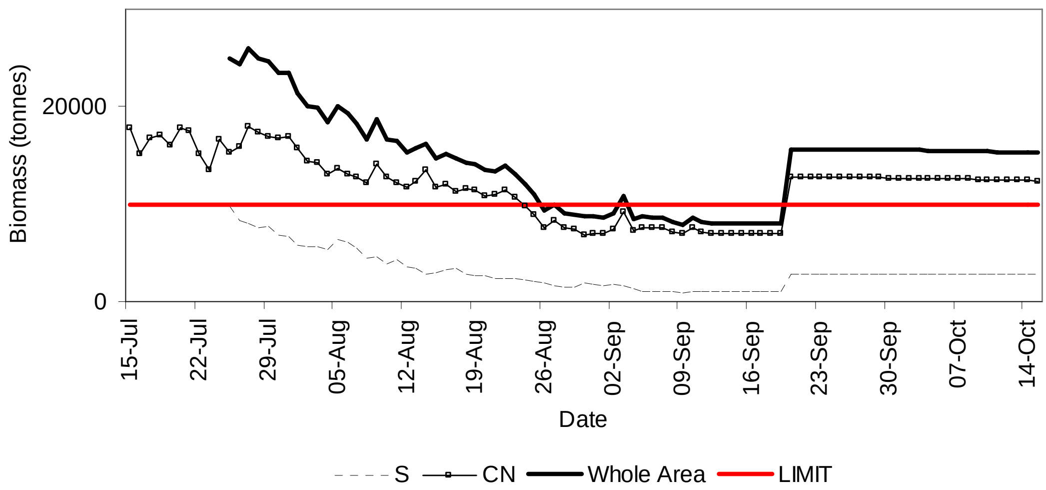


Fig. 36.- Depletion biomass and projected biomass in the whole *Loligo* box and by area. Two squid waves were observed in each area during the fishing season and one group arrive after the fishing season. Before 25th July, there were no depletion data to estimate the southern biomass.

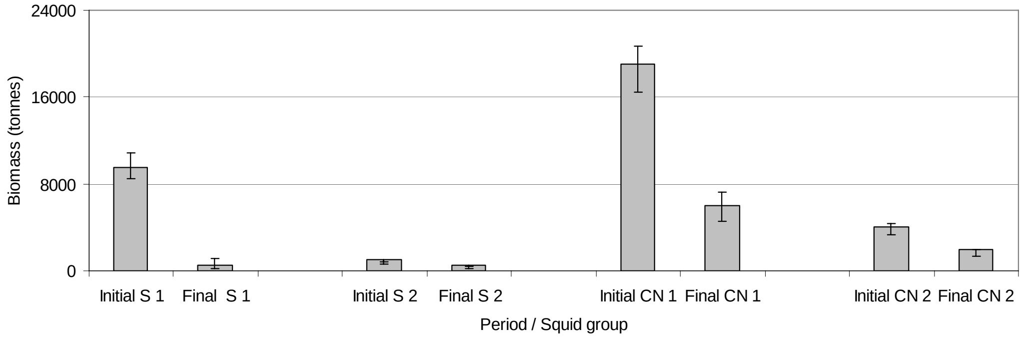


Fig. 37.- Initial and final biomass of the squid groups by area (S 1: Southern area group 1; S 2: Southern area group 2; CN 1: Central-northern area group 1; CN 2: Central-northern area group 2). Vertical bars represent the 80% confident intervals.

Table 4.- Stock assessment of *Loligo gahi* in the Falkland Islands by a stock depletion model. Numbers in parentheses are the measures of statistical precision (coefficients of variation). (S = southern; C = Central; N = Northern; and CN = central-northern area). (*) It is the average of catchability by vessel. (**) This biomass is the sum of all squid group biomasses.

	2nd Season 2004			2nd Season 2005			2nd Season 2006		
Parameter	S	C	N	S	C	N	S	1rst CN	2nd CN
Starting Date	15/07	16/08	28/07	10/08	25/07	21/07	4/08	23/07	22/8
Final Date	30/09	30/09	30/09	30/09	30/09	30/09	29/08	21/08	5/9
N° of days	66	16	58	52	25	39	25	30	15
Catchability (1/vessel-day)	5.9x10-4 (5.4)	3.4x10-3 (9.9)	2.7x10-3 (14.9)	2.3x10-3 (1.2)	3.7x10-2 (703.5)	2.1x10-3 (25.6)	1.9x10-3 (12.5)	1.2x10-2 (12.4)	3.7x10-3 (18.3)
Catchability (1/h) *									
Initial numbers (billions)	8.5x10-1 (23.0)	1.4x10-1 (50.3)	2.7x10-1 (3.0)	3.2x10-1 (5.4)	1.6x10-2 (363.5)	4.1x10-1 (8.3)	5.2x10-1 (11.1)	5.8x10-3 (9.6)	1.7x10-1 (15.4)
Initial biomass (tonnes)	42239 (39.6)	6983 (61.2)	13510 (34.0)	20417 (30.2)	1070 (365.7)	25714 (32.0)	25500 (10.8)	2600 (10.0)	7900 (15.3)
Final Numbers NT (billions)	2.2x10-1 (31.1)	3.3x10-2 (100.9)	4.4x10-2 (21.0)	6.2x10-2 (13.9)	1.4x10-3 (2778.4)	5.6x10-2 (53.5)	0.21 (18.7)	0.02 (19.5)	0.08 (18.7)
Final Biomass (tonnes)	15191 (49.2)	2229 (107.8)	3009 (43.6)	5203 (39.8)	112 (2778.6)	4505 (56.4)	9500 (18.7)	1000 (19.5)	3500 (28.4)
Initial Biomass * * (tonnes)									
Final Biomass ** (tonnes)									

Table 4.- Continuing.

	2nd Season 2007				2nd Season 2008					
Parameter	1rst S	2nd S	3rd S	CN	1rst S	2nd S	3rd S	1rst CN	2nd CN	3rd CN
Starting Date	22/07	2/08	22/8	17/7	22/07	3/08	13/8	9/08	6/9	23/9
Final Date	1/08	13/08	15/9	15/09	2/8	12/08	16/9	5/09	22/9	30/9
N° of days	11	11	34	60	12	10	35	28	17	8
Catchability (1/vessel-day)					2.13x10-3 (10.0)	2.13x10-3 (10.0)	2.13x10-3 (10.0)	2.3x10-3 (5.0)	7.65x10-4 (28.5)	7.65x10-4 (28.5)
Catchability (1/h) *	1.54x10-4 (27.0)	1.54x10-4 (27.0)	1.54x10-4 (27.0)	1.46x10-4 (31.0)						
Initial numbers (billions)	1.9 x10-1 (8.3)	2 x10-1 (7.2)	1.3 x10-1 (7.5)	2.4 x10-1 (6.1)	2.9x10-1 (7.0)	0.1x10-1 (83.0)	0.8x10-1 (45.0)	0.4 x10-1 (8.2)	0.3 x10-2 (108)	0.9 x10-2 (25.0)
Initial biomass (tonnes)	12500 (8.3)	12000 (7.2)	7500 (7.5)	16500 (6.1)	15919 (7.0)	943 (83.0)	3948 (45.0)	13430 (8.2)	1075 (108)	4912 (25)
Final Numbers NT (billions)	1.4 x10-1 (10.2)	1.2 x10-1 (9.9)	4 x10-2 (8.0)	1.2 x10-1 (9.5)	1.9 x10-1 (7.0)	1.7 x10-1 (83.0)	1.14x10-1 (45.0)	0.9 x10-1 (19.0)	0.5 x10-2 (168)	0.4 x10-1 (41)
Final Biomass (tonnes)	8000 (10.2)	7000 (9.9)	2500 (28.4)	6500 (9.5)	9509 (7.0)	714 (83.0)	2446 (45.0)	3957 (19.0)	249 (168)	2500 (41)
Initial Biomass * * (tonnes)	12500 (7.4)	20500 (6.0)	19000 (4.6)		15919 (7.4)	10451 (15.0)	11865 (14.8)	13430 (8.2)	5032 (31.9)	6078 (31.8)
Final Biomass ** (tonnes)	8500 (8.8)	12000 (8.6)	5500 (10)		9144 (9.0)	8598 (15.8)	7349 (17)	4468 (16.8)	1753 (78.3)	2560 (58.5)

Table 4.- Continuing.

	2 nd Season 2009			
Parameter	S 1	S2	CN 1	CN 2
Starting Date	25/07	30/08	15/7	24/07
Final Date	29/8	11/09	23/7	11/09
N° of days	36	13	9	84
Catchability (1/vessel-day)				
Catchability (1/h) *	3.42x10-4	3.18x10-4	8.8x10-5	9x10-5
Initial numbers (billions)	1.9x10-1 (8.0)	0.14x10-1 (21.5)	4.6x10-1 (8.5)	1.1 x10-1 (8.3)
Initial biomass (tonnes)	9732 (8.0)	693 (21.5)	17829 (8.5)	4028 (8.3)
Final Numbers NT (billions)	0.2 x10-1 (28.8)	0.08x10-1 (28.0)	3.3x10-1 (9.9)	0.3 x10-1 (13.8)
Final Biomass (tonnes)	1271 (28.8)	347 (28.0)	12541 (9.9)	1750 (13.8)
Initial Biomass * * (tonnes)	9732 (8.0)	1964 (21.0)	17829 (8.5)	16569 (8.3)
Final Biomass ** (tonnes)	1271 (28.8)	983 (28.0)	12541 (9.9)	7197 (13.8)

After the early closure of the fishing season, during the second half of September, the arrival of a new squid wave was detected by the post-season survey. The whole biomass was estimated at 15,643 tonnes, which was calculated dividing the survey biomass by the survey catchability.

The escapement biomass projected to the 15th of October ranged from 5,000 to 20,500 tonnes with a maximum likelihood at 15,256 tonnes. The risk probability that biomass is less than 10,000 escapement limit was estimated at 0.03 (**Table 5 and Fig. 38**).

Table 5.- Biomass of squid projected from the end of the season with starting numbers as estimated from the stock depletion model. The numbers in parentheses are the measures of statistical precision (percentage coefficients of variation). NA: No Available.

	Dates	Biomass (tonnes)	Probability Biomass <10,000 tonnes
Second Season 2004	30/09 to 15/10	20,721 (24.3)	NA
Second Season 2005	30/09 to 15/10	8,665 (38.0)	NA
Second Season 2006	5/9 to 15/10	13,500 (15.9)	0.01
Second Season 2007	15/9 to 15/10	11,458 (9.4)	0.09
Second Season 2008	30/9 to 15/10	9,798 (62.7)	0.4
Second Season 2009	12/9 to 15/10	15,256 (14.7)	0.03

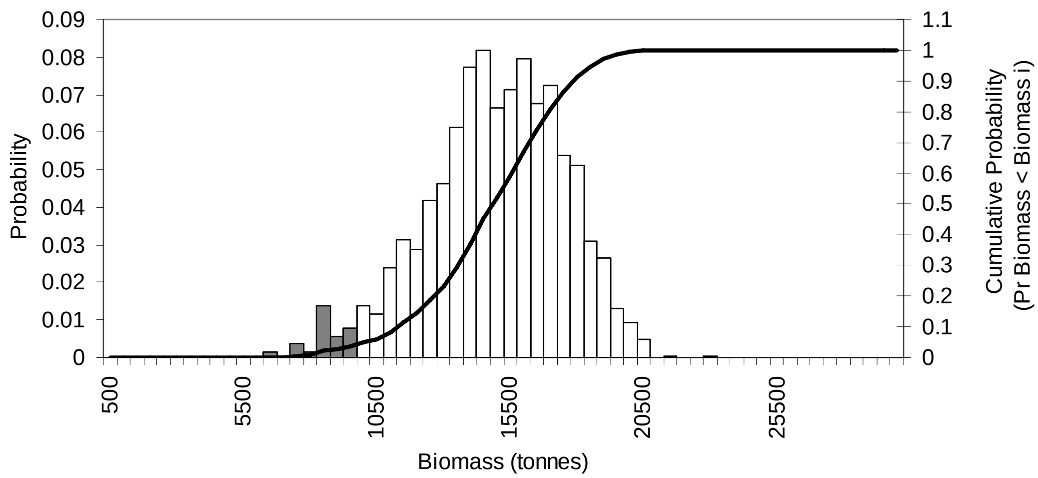


Fig. 38.- Escapement spawning biomass projected to the 15th of October. The probability distribution is shown in bars; the bars below the 10,000 limit are in grey colour. The cumulative probability is the risk curve.

VI. CONCLUSIONS

1) The whole *Loligo* catch was 17,836 tonnes, a low-medium level in historical perspective.
2) Catch, Fishing Effort and CPUE were 34%, 27% and 10% lower than in second season 2008.
3) 44% of the squid were caught in the northern area, 40% in the southern area and 16% in the central area.
4) The average dorsal mantle length was 12.7 cm (12.0 cm for females and 13.1 cm for males), which was 0.7 cm shorter than in 2008.
5) Initial biomass on 25th July was estimated at 24,995 tonnes.
6) Two squid groups arrived sequentially to the southern area and two to the central-northern area.
7) The fishery was early closed on 11th September because escapement biomass was estimated at 9,365 tonnes and had a high (0.63) probability to be less than the conservation limit.
8) The historical probability that a new squid pulse arrive after the early closure was estimated at 0.2-0.3.
9) The stock assessment model was improved to incorporate the survey biomass estimations done just before and after the fishing season.
10) The initial biomass on 25th July was estimated at 24,995 tonnes, and the biomass at the end of the fishing season was estimated at 8,010 tonnes.
11) The whole biomass, the one that was present at the start of the season plus the ones that arrived during the season, was estimated at 32,282 tonnes.
12) After the fishing season, a new squid arrived, which increased the whole biomass at 15,643 tonnes.
13) The escapement spawning biomass was estimated at 15,256 tonnes, with a coefficient of variation of 15%.
14) There was a very low (0.03) probability that the escapement biomass was less than the conservation limit (10,000 tonnes).

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ANNEX

Depletion model with several recruitment pulses, vessel catchability coefficients and survey abundance by area.

By Ignacio Payá

Payá (2007) developed a depletion model, which integrates the estimations of several recruitment pulses and vessel catchability coefficients by area by means of a penalized maximum likelihood function. Now a new component was added to fit the model to survey abundances as well. There were survey abundance estimations done just before and after the fishing season. For clarity the model formulation is presented in several steps of increasing complexity:

1. Estimation of one squid pulse abundance, commercial vessel catchability coefficients and survey catchability coefficient in only one fishing area

The model is based on the DeLury model (DeLury 1947) formulation in Rosenberg *et al.* (1990). These authors estimated the catchability by fleet using weekly data, in this study catchability coefficients were estimated by vessel based on daily data. The dynamic of the abundance and the CPUE was calculated as:

$$\begin{aligned}\hat{U}_{v,t} &= q_v N_t e^{-M/2} \\ &= q_v e^{-M/2}\left(N_0 e^{-Mt} - e^{-M/2}\sum_{v=1}^{V}\sum_{j=0}^{t-1} C_{v,j} e^{-(t-j-1)M}\right)\cdots \quad \text{for } t<=T,\end{aligned} \tag{1}$$

where $\boldsymbol{t}$ is time in days and $\boldsymbol{T}$ is time at the end of the depletion event (t=1,2, ..,$\boldsymbol{T}$), $\boldsymbol{v}$ vessel ($\boldsymbol{v}$=1,2,…,$\boldsymbol{V}$), $\hat{U}$ catch in numbers per unit of effort (number/trawling hour), $\boldsymbol{N}$ stock abundance in numbers, N_0 initial abundance in numbers, $\boldsymbol{q}$ catchability coefficient, and $\boldsymbol{M}$ rate of natural mortality per day. $\boldsymbol{M}$ was assumed constant and equal to 0.013, which is the value estimated by Roa-Ureta and Arkhipkin (2007) based on longevity and age information from Arkhipkin and Roa-Ureta (2005).

The observed CPUE, $\boldsymbol{U}$, in numbers at t-day was calculated as

$$U_t = \frac{Y_t}{\overline{w}_t} / E_t, \tag{2}$$

where Y is catch in grams and $\overline{w}$ the mean body weight calculated by

$$\overline{w}_t = \frac{\sum_s \sum_i f_{t,i,s} \hat{a}_s l_{t,i,s}^{\hat{b}_s}}{\sum_s \sum_i f_{t,i,s}}, \tag{3}$$

where ***f*** is the number of sampled squids, ***l*** mantle size, ***i*** mantle size interval, ***s*** sex, and $\hat{a}$ and $\hat{b}$ are length-weight relationship parameters.

The biomass at *t*-day was calculated as

$$B_t = \overline{w}_t N_t = \overline{w}_t \left(N_0 e^{-Mt} - e^{-M/2} \sum_{j=0}^{t-1} C_j e^{-(t-j-1)M} \right) , \tag{4}$$

The catchability coefficient of ***v***-vessel, q_v, was computed as a nuisance parameter:

$$q_v = \exp(\sum_{t=1}^{T} \ln(U_{v,t} / N_t e^{-M/2}) / T) , \tag{5}$$

The survey abundance at *t*-day, S_t , was estimated as:

$$\hat{S}_t = q^s N_t e^{-M/2} \tag{6}$$

The survey catchability coefficient, q^S, was computed as a nuisance parameter:

$$q^S = \exp(\sum_{x=1}^{X} \ln(S_x / N_{t_x} e^{-M/2}) / X) , \tag{7}$$

where ***S*** is the observed survey abundance, ***X*** number of surveys and t_x the ***t***-day when ***x*** survey was done.

This non-linear model was fitted by maximum likelihood. The normal distribution likelihood of ln U is:

$$L \ln U = \prod^{T} \frac{1}{2\sqrt{\pi}\sigma} \exp\left[-\frac{1}{2\sigma^2} \sum_{t=1}^{T} (\ln \hat{U}_t - \ln U_t)^2 \right] , \tag{8}$$

and its natural logarithm is:

$$\ln L \ln U = -\frac{T}{2} \ln(2\pi\sigma^2) - \frac{1}{2\sigma^2} \sum_{t=1}^{T} (\ln \hat{U}_t - \ln U_t)^2 , \tag{9}$$

where σ is the standard deviation of ln CPUE.

The normal distribution likelihood of ln S is:

$$L \ln S = \prod^{X} \frac{1}{2\sqrt{\pi}\sigma^{S}} \exp\left[-\frac{1}{2\sigma^{S^2}} \sum_{x=1}^{X} (\ln(N_{t_x} e^{-M/2}) - \ln S_x)^2 \right], \qquad (10)$$

and its natural logarithm is:

$$\ln L \ln S = -\frac{X}{2} \ln(2\pi\sigma^{S^2}) - \frac{1}{2\sigma^{S^2}} \sum_{x=1}^{X} (\ln \hat{S}_x - \ln S_x)^2 , \quad (11)$$

where σ^S is the standard deviation of ln S.

2. Estimation of several recruitment pulses in one area.

The vessel catchability coefficients, $\boldsymbol{q_v}$, were calculated (equation 5) for each squid group. It is a model more flexible than previous model, which assumed the same catchability coefficient for all squid groups (Payá 2007). When a new squid group arrive to the same area, it is not possible to discriminate it in the catch statistic, and therefore the CPUE is related with the whole biomass, which is the sum of the new squid group biomass and the remaining previous group biomass. Let make $\boldsymbol{t}$ the day of the season and $\boldsymbol{g}$ the arrival day of a new squid group, then the biomass $\boldsymbol{B_{t=g}}$ was calculated as:

$$B_{t=g} = {}^{G}B_{t=g} + {}^{R}B_{t=g} , \qquad (12)$$

$${}^{G}B_{t=g} = {}^{G}N_{t=g}\overline{w}_{t=g} , \qquad (13)$$

$${}^{R}B_{t=g} = \overline{\mathrm{w}}_{\mathrm{t=g}} \, [(\mathrm{N}_{\mathrm{t}=g\text{-}1}\mathrm{e}^{\text{-M/2}}) - \mathrm{C}_{\mathrm{t}=g\text{-}1}]\mathrm{e}^{\text{-M/2}} , \qquad (14)$$

where $\boldsymbol{B}$ is the whole biomass, $\boldsymbol{^{R}B}$ remaining biomass of previous group, $\boldsymbol{N}$ number of individuals estimated by the depletion model, $\boldsymbol{^{G}N}$ number of individuals of the new squid group (parameter to be estimated).

To estimate the biomass composition by squid group at the end of the fishing season, it was assumed that biomass proportions by squid were the same at the beginning and end of the fishing season.

3. Integrating estimations from several areas

To integrate several depletion models of different areas it was necessary to define the level of similitude between vessel catchability coefficients by area. This was done by means of a penalty function, which is a lognormal likelihood of the mean vessel catchability coefficient by area:

$$Lq = \frac{1}{2\sqrt{\pi}\sigma^V} \exp\left[-\frac{1}{2\sigma^{V2}} (\ln \overline{CNq} \ - \ln \overline{Sq}_t)^2 \right], \tag{15}$$

where σ^V is the standard deviation of the logarithm of vessel catchability coefficients, $\overline{CNq}$ average vessel catchability coefficient in the central-northern area, and $\overline{Sq}$ average vessel catchability coefficient in the southern area. The natural logarithm of this likelihood is:

$$\ln Lq = -\ln(2\pi\sigma^{V2}) - \frac{1}{2\sigma^2} (\ln \overline{CNq} - \ln \overline{Sq})^2 \tag{16}$$

4. Prior distribution of model parameters.

The model parameters were the initial numbers, $\boldsymbol{N_{t=0}}$, and the number of different squid groups, $\boldsymbol{{}^{G}N_{t=g}}$, by area. Their priors were normal distributions with mean values that produce a survey catchability equal to 0.8. These mean values where found fitting the model with the survey catchability fixed to 0.8 instead using equation 7. The prior likelihood for a ***G*** group is:

$$L\Pr ior\,{}^{G}N_{t=g} = \frac{1}{2\sqrt{\pi}\,{}^{G}\sigma^{P}} \exp\left[-\frac{1}{2\,{}^{G}\sigma^{P2}} ({}^{G}N_{t=g} - {}^{G}\overline{N}^{P}{}_{t=g})^2 \right], \tag{17}$$

where $\boldsymbol{{}^{G}N_{t=g}}$ is the initial number of individual of G group, ${}^{G}\overline{N}^{P}$ mean of the prior for the initial number of individual of G group, and $\boldsymbol{{}^{G}\sigma^{P}}$ standard deviation of the ***G*** group prior distribution. The natural logarithm of the prior likelihood is:

$$\ln L\Pr ior\,{}^{G}N_{t=g} = -\ln(2\pi\,{}^{G}\sigma^{P2}) - \frac{1}{2\,{}^{G}\sigma^{P2}} ({}^{G}N_{t=g} - {}^{G}\overline{N}^{P}{}_{t=g})^2 \qquad 18)$$

The same formulas were used for the initial number of individual by area, $\boldsymbol{N_{t=0}}$. Therefore the total logarithm of priors by ***A*** areas and ***G*** groups is:

$$\ln L\Pr iors = \sum_{a=1}^{A} \sum_{G=1}^{2} \ln \Pr ior\,{}^{G}N_{t=g,a} + \ln L\Pr ior N_{t=0,a}\,, \tag{19}$$

5. Loss function.

The final parameters were found maximizing the loss function:

$$LOSS = \ln L\Pr iors + \ln Lq + \sum_{a=1}^{A} \ln L \ln U_a + \ln L \ln S_a\,, \tag{20}$$

The weights of each component in loss function are related with the inverse of each standard deviation or with the inverse of each coefficient of variance. These weights are not easy to define and therefore different fitting model cases, with different weights combination, should be analysed.

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