Falkland Island Fisheries Department

Loligo gahi Stock Assessment Survey, First Season 2010

Vessel	Beagle F.I. (ZDLZ)
Flag	Falkland Islands
Dates	9/02/2010-23/02/2010
Scientific Crew	A. Arkhipkin, A. Winter, T. May

SUMMARY

A research survey was conducted in the *Loligo* box onboard F/V *Beagle F.I.* between the 9th and 23rd of February 2010. The whole catch of *Loligo* was 453 tonnes. Dense aggregations were found only in the southern part of the *Loligo* box. Schools of squid were distributed from shallow water (110-120 m depths) south of Sea Lion Islands to the shelf break (180-200 m) near Beauchene Island. All squid were immature and belonged to the autumn-spawning cohort that is being fished during the first *Loligo* fishing season. Average squid sizes of 11-13 cm mantle length indicated that they are growing quite fast this year.

It was estimated that 60,500 tonnes of *Loligo* were present in the fishing grounds area of 15,522 km^2. This high recruitment biomass indicated a good fishing year for the first cohort of *Loligo*, likely similar to the first season of 2005. However, relatively early movement of *Loligo* schools to the shelf break may disperse them further north with waters of the Falkland Current later in the fishing season. This could cause a drop in CPUE.

INTRODUCTION

The *Beagle F.I.* is a Stanley registered stern trawler that has a total length of 100.71m, a breadth of 14m and a draught of 6.68m. The gross registered tonnage is 2,849 t with a net registered tonnage 1,156 t. A 4,000bhp engine powers the vessel.

The crew consisted of 49 in total and was made up of Spanish, Peruvian and Chilean nationalities. The scientists were accommodated in the officers' quarters and enjoyed a spacious cabin each.

Region

Southern and eastern part of the Falkland Islands Interim Conservation Zone (FICZ) within the limits of the '*Loligo* box'.

Cruise objectives

1. To estimate the biomass of *Loligo gahi* squid available for the fishery before the start of the first fishing season.
2. To examine distribution and biology of *Loligo* during the survey.
3. To examine distribution and biology of rock cod (*Patagonotothen ramsayi*) during the survey.

Personnel

The following three people from FIFD participated in the survey:

Alexander Arkhipkin	Chief Scientist
Andreas Winter	Trawl / acoustic data analysis
Tiphanie May	Trawl catch composition / biological sampling

METHODS

Sampling procedures

The survey plan was designed to include 45 trawls located on a series of 14 transects perpendicular to the shelf break around the *Loligo* box (Figure 1), followed by 15 adaptive trawls to maximize *Loligo* catch and increase the precision of estimates in high-density localities (hot spots).

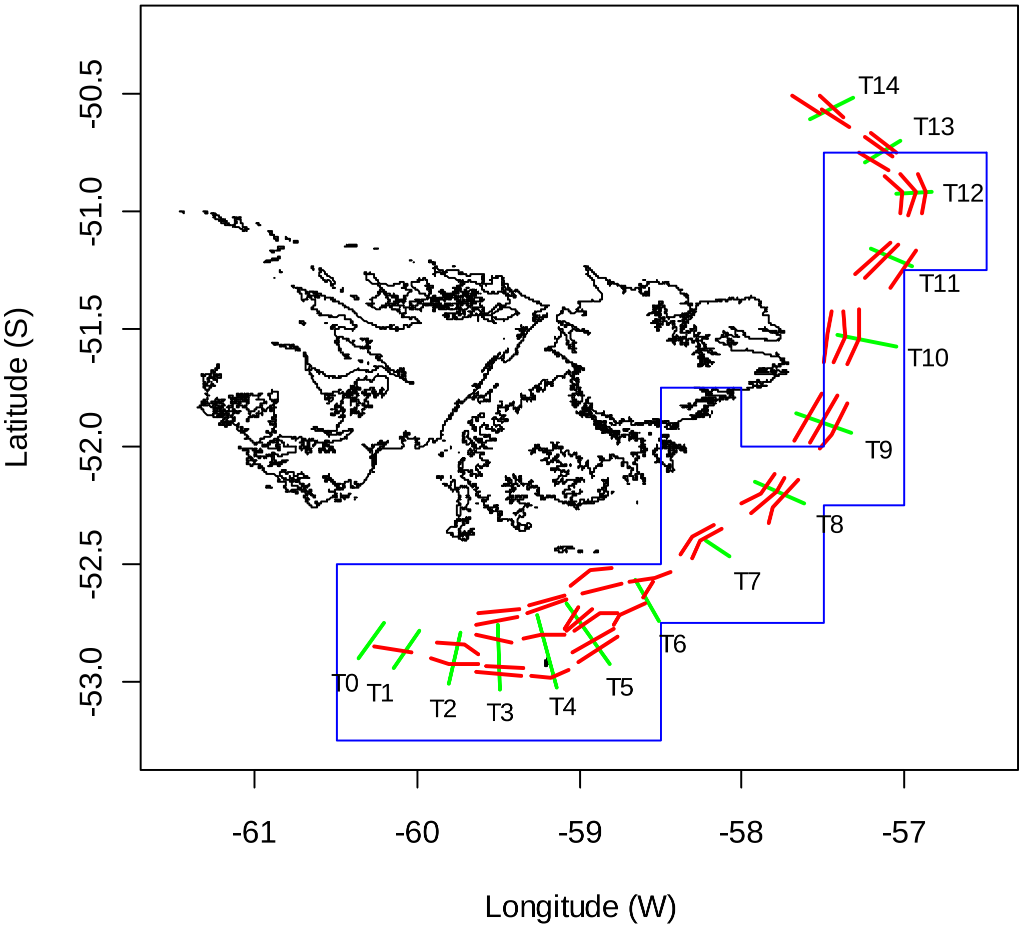

Figure 1. Transects (green lines) and fixed-station trawls (red lines) sampled during the pre-season 1 2010 survey. The ‘Loligo box’ commercial fishing area is shown in blue.

In conformity with previous surveys (Paya, 2009b; Paya and Winter, 2009), the trawls were set to an average duration of 2 hours and conducted 4 times per day during daylight hours. All trawls were bottom trawls. During the progress of each trawl, latitude, longitude, bottom depth, bottom temperature, net height, trawl door spread, and trawling speed were recorded on the ship's bridge in 15 -minute intervals, and a visual assessment was made of the quantity and quality of acoustic marks observed on the net-sounder. Following the procedure described in Roa-Ureta and Arkhipkin (2007), the acoustic marks were used to apportion the *Loligo* catch of each trawl to the 15-minute intervals and thereby increase spatial resolution of the catches.

The acoustic sensors for trawl door spread failed on Feb. 14th, the sixth day of survey activity, and were inoperational for the remainder of the trip. Since the measure of trawl door spread is required for determining swept area, a model was calculated to estimate trawl door spread as a function of other trawl parameters. The model selected was a generalized additive model (GAM; Swartzman et al., 1992) with co-variables trawl depth (m), net height (m), and trawling speed (knots). This model was applied to the 175 trawl interval records (from 21 trawls) that had been logged up to that point, and resulted in 78% deviance explained. The ranges of depth, net height, and speed logged up to that point encompassed >98% of these parameters in all subsequent trawls. Trawl door spread for all subsequent trawls was therefore calculated from this model.

Catch estimation

Catch of every trawl was processed separately by the factory crew and catch weight, by size category, was estimated from the number of 20-kg blocks of whole frozen squid recorded by the factory bosun. Green (unprocessed) catch of rock cod and other abundant finfish species was visually estimated from the amount of product kept onboard, plus the approximate amount of discarded fish.

Biological analyses

A random sample of 150 *Loligo* was collected from the factory conveyer belt at all trawl stations where *Loligo* were caught. Biological analysis included measurements of the dorsal mantle length (ML) rounded down to the nearest half-centimetre, sex, and maturity stage. Several random samples of *Loligo* were taken for statolith extraction at FIFD.

Rock cod was analysed from every trawl where its abundance was more than 5% of the total catch. Biological analysis of rock cod included measurements of total length (TL) rounded down to the nearest centimeter, sex and maturity stage. Rare fish specimens were also frozen for further analysis at FIFD.

Biomass analyses

The relationship between *Loligo* CPUE and co-variables latitude, longitude, bottom temperature and bottom depth was analyzed with GAM. GAM has the advantage that the effects of co-variables are unspecified and not necessarily assumed to be linear. The best-fitting combination of the four co-variables was determined using the Akaike Information Criterion (AIC).

Swept-area biomass density estimates of *Loligo* were calculated as catch weight divided by the product of trawl speed, trawl duration, and trawl width (echo-logged distance between trawl doors × a conversion factor from the trawl net design specifications). These density estimates were extrapolated to the fishing grounds area using geostatistical methods described in previous reports (Paya, 2009a; 2009b; Paya and Winter, 2009).

RESULTS and DISCUSSION

Catch rates and distribution

The survey proceeded generally from north to south. Fifty-five scientific trawls were recorded during the survey: 42 fixed station trawls catching a total of 203.70 t of Loligo and 13 adaptive trawls catching a total of 157.33 t of *Loligo*. Additionally, eight optional trawls (made after daylight hrs) yielded 91.97 t of *Loligo*, bringing the total catch for the survey to 453 t.

Abundant catches of *Loligo* were heavily concentrated towards the southern part of the survey area (Figure 2), with CPUE south of 52.5º S (the statutory demarcation line of the Beauchene zone; Roa-Ureta and Arkhipkin, 2007) averaging 5.70 t per hr (calculated per 15 -minute interval), and CPUE north of 52.5º S averaging 0.12 t per hr. All adaptive trawls were taken in the southern part of the *Loligo* box and these averaged 6.63 t per hr, vs. 4.85 t per hr for the fixed-station trawls in the same area.

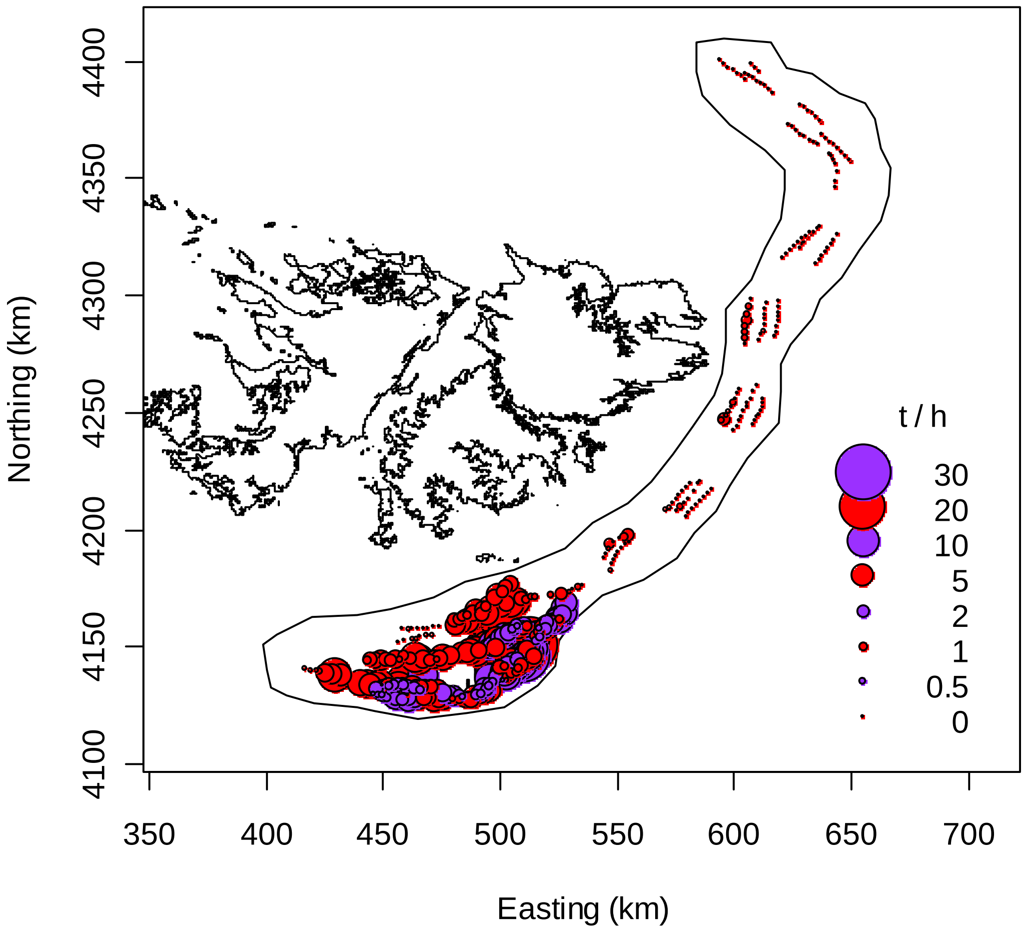

Figure 2. *Loligo* CPUE (tonnes hr^{-1}) of fixed-station trawls (red) and adaptive trawls (purple), per 15 -minute trawl interval.

Latitude, longitude, bottom temperature and bottom depth were all significantly correlated with *Loligo* CPUE. GAM plots of the latitude and longitude components showed highest catches to be occurring towards the south-east of the survey area, as noted above (and see Figure 2). The GAM plot of bottom depth showed a slight decrease of CPUE around 150 m. The GAM plot of bottom temperature showed an increase of CPUE from 5 ºC to 6 ºC (Figure 3).

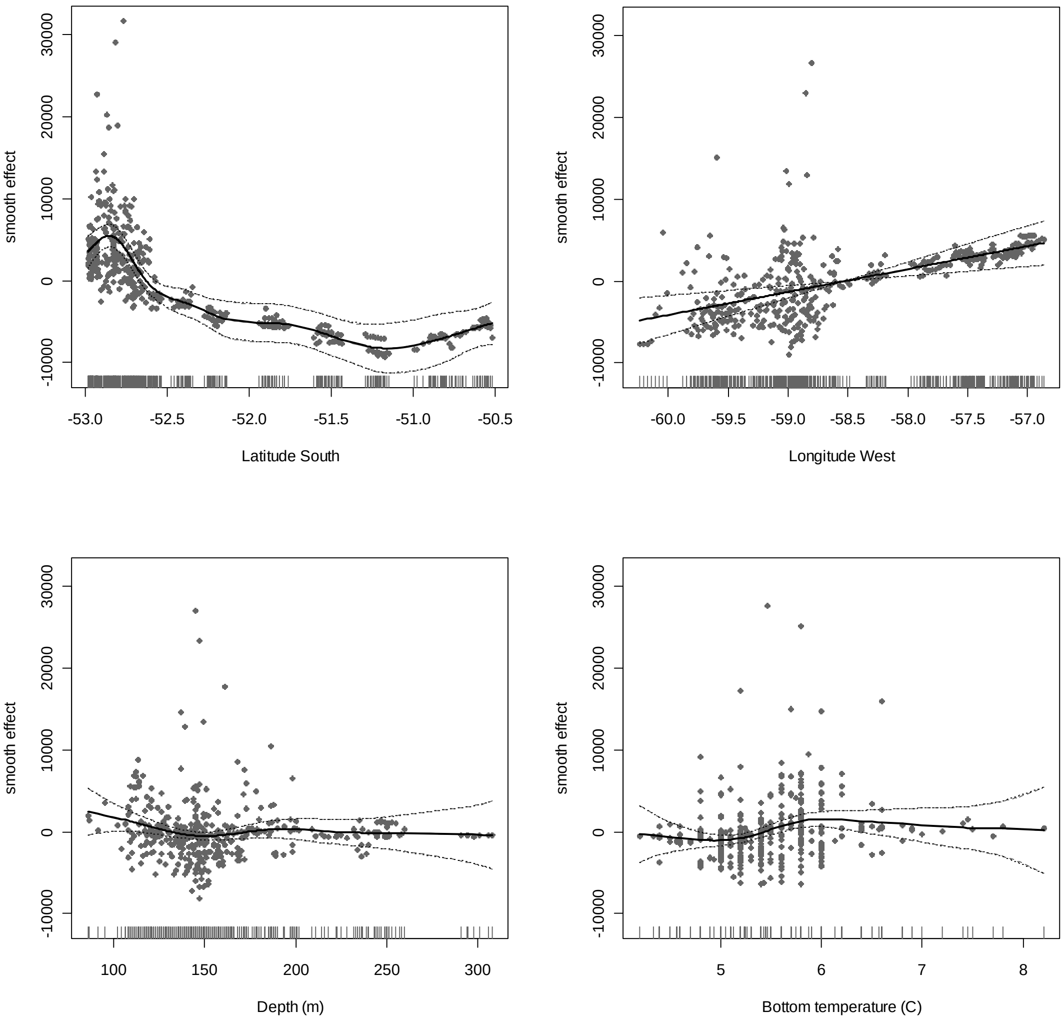

Figure 3. Smooth (black line) and partial residual (gray point) plots of the four GAM variables correlated with *Loligo* survey CPUE. Dotted lines are ±2 standard errors of the smooths.

Distribution of *Loligo gahi*

Length-frequency distributions and maturities of males and females were analysed separately for the northern and southern regions of the *Loligo* box with the 52º30’S latitude boundary. In the southern region, squid were analysed separately for the western and eastern part (east and west of 59º30’W) and depth ranges less and more than 150 m.

All squid caught during the survey belonged to the autumn-spawning cohort (ASC). Almost all of them were immature, with some maturing males. Interestingly, one mature female of 12.5 cm ML was caught in the northern region of the *Loligo* box.

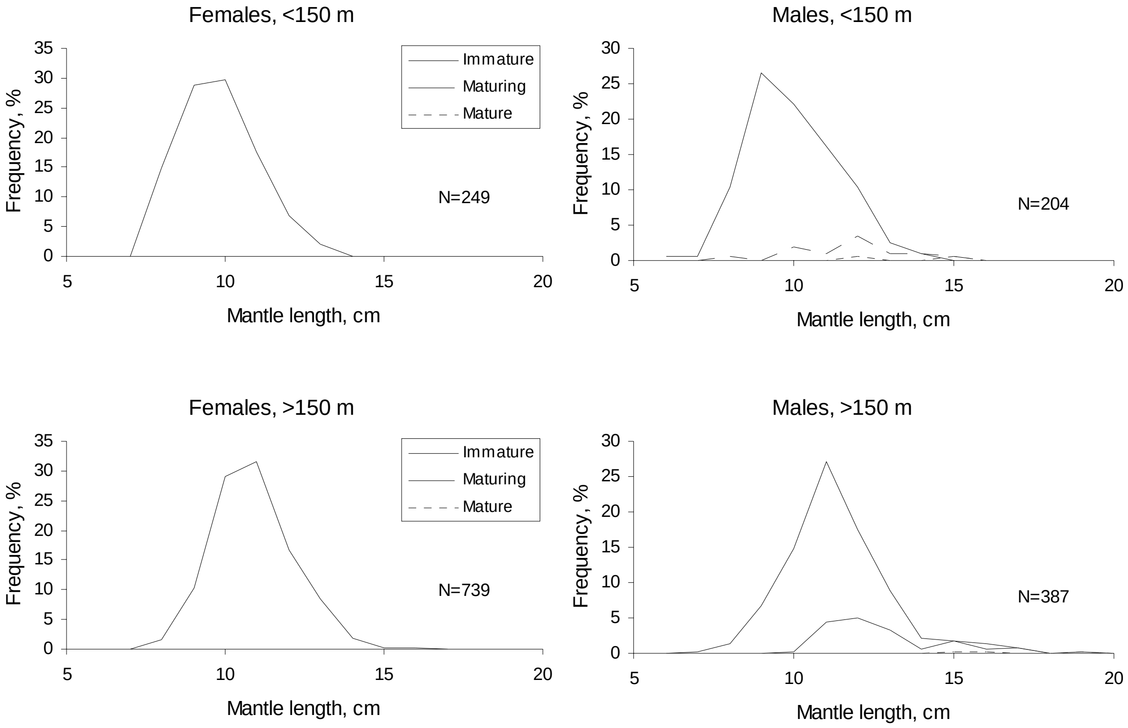

Figure 4. Length frequency distributions of females and males of *Loligo gahi* at different depths in the western part of the southern region of the *Loligo* box.

In the western part of the southern region, immature squid of both sexes were predominant in catches. In shallow waters, squid were smaller (modal sizes of 9-10 cm ML) than in deeper waters (modal sizes 11 cm ML). At depths greater than 150 m, males were also more mature with about 20% being at stage III.

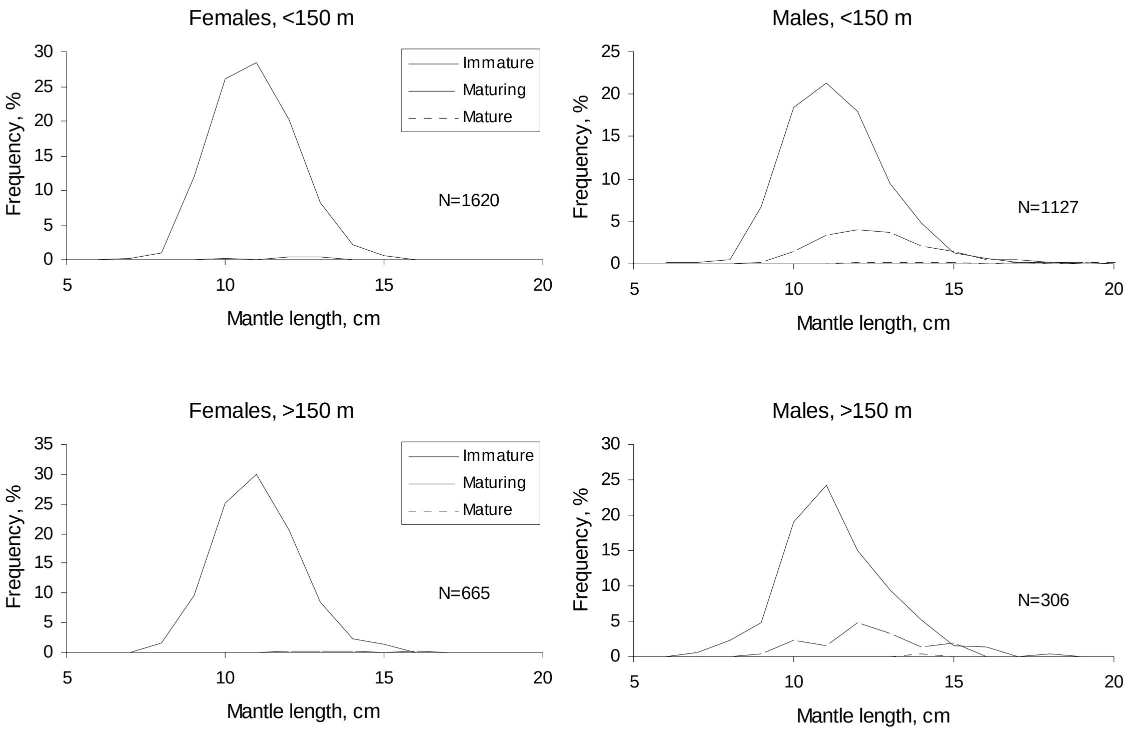

Figure 5. Length frequency distributions of females and males of *Loligo gahi* at different depths in the eastern part of the southern region of the *Loligo* box.

In the eastern part, immature females and immature and maturing males were predominant in catches. As expected for immature squid, modal length of males was almost the same as that of females, however their maximum sizes were larger. Modal lengths of squid (11 cm ML) were the same at both depth ranges, however the proportion of larger squid was greater in deeper waters. Modal length of squid in the eastern part was quite similar to those of squid observed in deeper waters of the western part.

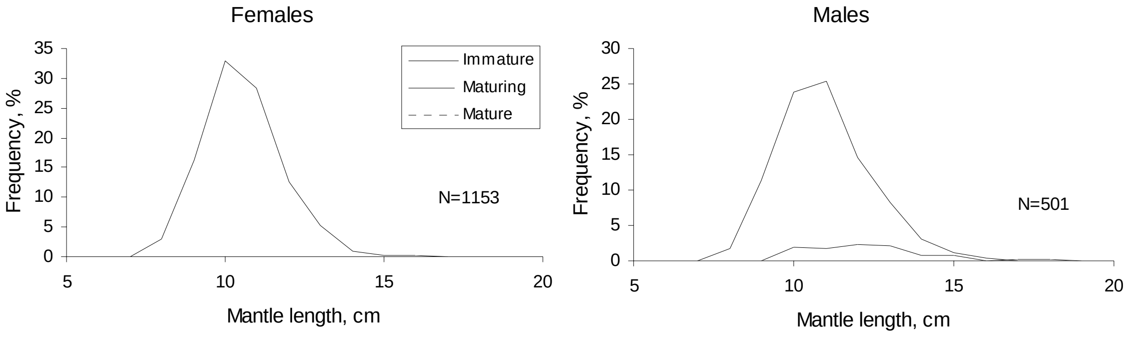

Figure 6. Length frequency distributions of females and males of *Loligo gahi* at different depths in the northern region of the *Loligo* box.

Modal sizes of squid in the northern region of the *Loligo* box were somewhat smaller than those observed in the southern region. Maturity stages were similar in both regions.

Strong negative anomalies in water temperatures observed in the austral summer of 2009-2010 did not impact the timing of squid migrations to their feeding grounds. In fact, it was quite unusual to encounter dense schools of squid at depths > 150 m. Usually, squid migrate to deep water later (March-April) with further warming of the near-bottom water layers at the shelf edge at 180-200 m depths (Arkhipkin et al., 2004). Squid sizes were also about 1 cm larger than usual and that may be explained by better trophic conditions in the upwelling region in the Beauchene area this year. Significant amounts of small immature squid (8-9 cm ML) caught in shallow waters indicated that there should be further influxes of migrating squid to the fishing grounds later in the season.

Biomass estimation

An exponential model was used to fit the variogram of positive catch distributions. The exponential model showed two different convergence solutions: one at a range of 99.1 km and one at a range of 314.1 km (Figure 7). The near-range solution was selected, both for having a better likelihood value (lower AIC) and for being more conservative; i.e., it implies that catch densities have any spatial auto-correlation only up to a maximum of 99.1 km separation distance.

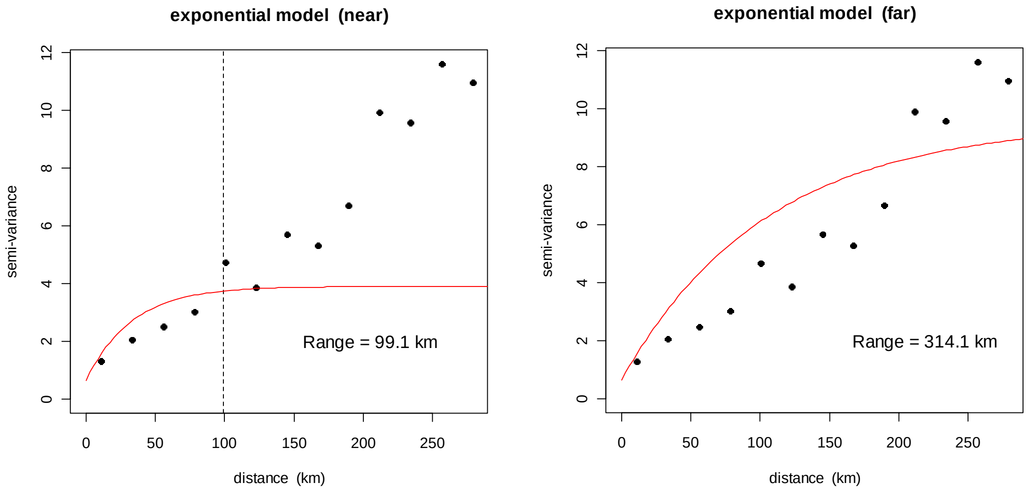

Figure 7. Empirical (black point) and model (red line) variograms of positive *Loligo* density distributions. The near model was used for geostatistical extrapolation.

A fishing area of 15,522.1 km^2 was assumed ad hoc around the contours of the trawls, giving an average distance of 14 km from any trawl position to the nearest boundary (cf. Figure 2). By comparison, a fishing area of 9496.5 km^2 had been assumed for the pre-season 1 2009 survey. For geostatistical extrapolation, this season's fishing area was modelled as 496 grid squares of 5×5 km. The extrapolation reflected the highly concentrated catch distributions of Loligo: 90% of aggregate density was comprised in just 159 of the 496 grid squares (Figure 8). Total *Loligo* biomass in the fishing area was estimated by the geostatistical model at 60,500 t. Extrapolating the same model to the previous year's fishing area (9496.5 km^2) would have resulted in a total of 49,900 t; i.e. 17.5% less biomass over 38.8% less area. The model is therefore moderately sensitive to the assumption of what area is occupied by the *Loligo* stock.

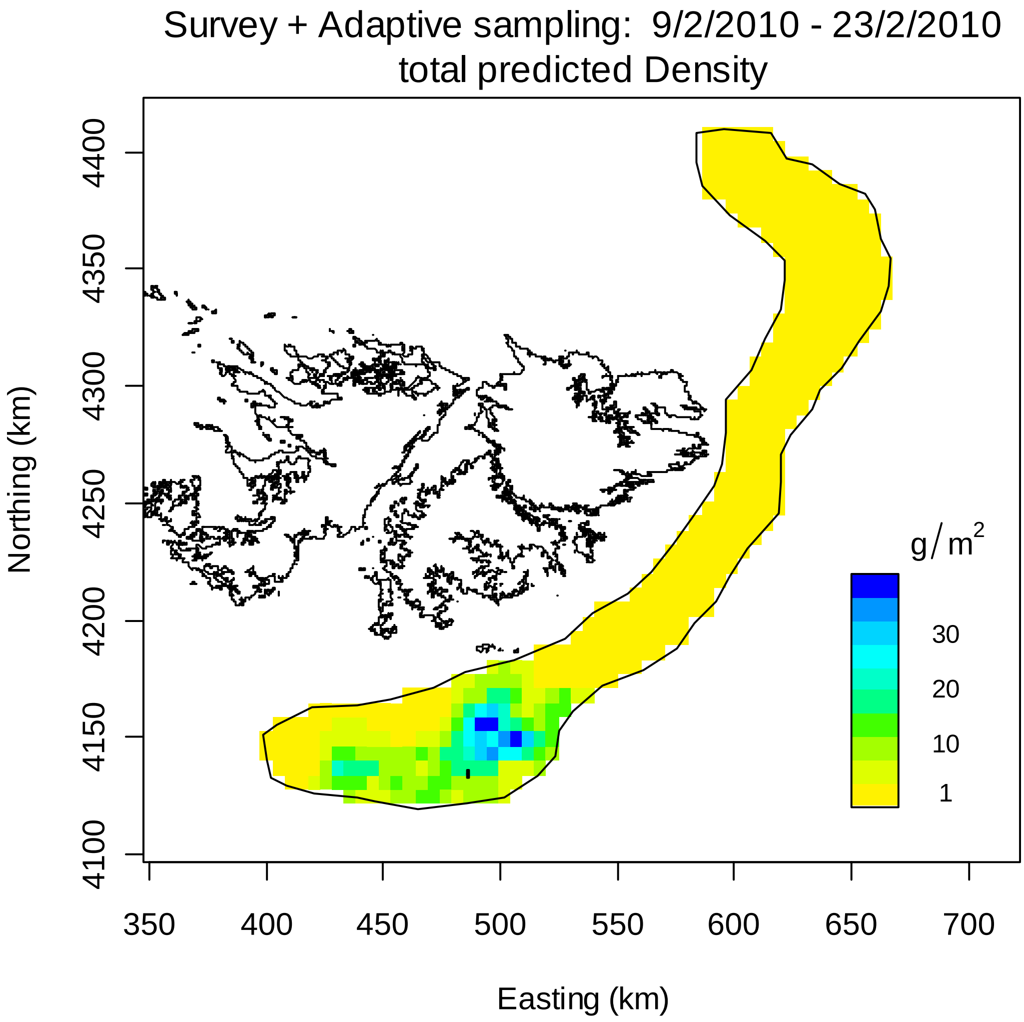

Figure 8. *Loligo* density estimates by 5 × 5 km survey grid cells. Estimates calculated from kriged probabilities of presence × kriged densities of positive catches.

REFERENCES

Arkhipkin, A.I., Grzebielec, R., Sirota, A.M., Remeslo, A.V., Polishchuk, I.A., Middleton, D.A. 2004. The influence of seasonal environmental changes on ontogenetic migrations of the squid *Loligo gahi* on the Falkland shelf. Fisheries Oceanography 13:1-9.

Arkhipkin, A.I., Middleton, D.A., Barton, J. 2008. Management and conservation of a short-lived fishery-resource: *Loligo gahi* around the Falkland Islands. American Fisheries Societies Symposium 49:1243-1252.

Hearne, S. 2009. Observer Report 767. Technical Document, Falkland Islands Fisheries Department.

Payá, I. 2009a. *Loligo gahi* stock assessment survey, first season 2009. Technical Document, Falkland Islands Fisheries Department.

Payá, I. 2009b. *Loligo gahi* stock assessment survey, second season 2009. Technical Document, Falkland Islands Fisheries Department.

Payá, I., Winter, A. 2009. *Loligo gahi* Stock Assessment Survey, post-Second Season 2009. Technical Document, Falkland Islands Fisheries Department.

Roa-Ureta, R., Arkhipkin, A.I. 2007. Short-term stock assessment of *Loligo gahi* at the Falkland Islands: sequential use of stochastic biomass projection and stock depletion models. ICES Journal of Marine Science 64:3-17.

Swartzman, G., Huang, C., Kaluzny, S. 1992. Spatial analysis of Bering Sea groundfish survey data using generalized additive models. Canadian Journal of Fisheries and Aquatic Sciences 49:1366-1378.