FALKLAND
ISLANDS
FISHERIES
DEPARTMENT

Loligo Stock Assessment Survey, 2nd Season 2012

Vessel	Beagle F.I. (ZDLZ), Falkland Islands
Dates	30/06/2012 - 14/07/2012
Scientific Crew	A. Winter, Z. Shcherbich, E. Hancox

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Summary

1) A stock assessment survey for *Loligo* squid was conducted in the 'Loligo Box' from 30th June to 14th July 2012. Fifty-nine scientific trawls were taken during the survey, catching 178.3 tonnes of *Loligo*.
2) A geostatistical estimate of 28,998 tonnes *Loligo* (95% confidence interval: 22,776 to 37,199 t) was calculated for the fishing zone. This represents the lowest 2nd-season survey estimate since 2009. Of the total, 10,838 t were estimated north of 52 ºS, and 18,160 t were estimated south of 52 ºS.
3) Predicted *Loligo* density increased with decreasing bottom temperatures, but increased with increasing surface temperatures above 5.2°C, increasing surface salinities below 34 PSU, and increasing bottom salinities from 34.05 to 34.2 PSU.
4) Male *Loligo* had a modal mantle length of 15 cm north of 52 ºS, and 11 cm south of 52 ºS. Female *Loligo* had modal mantle lengths of 12 cm both north and south of 52 ºS. Size and maturity of male and female *Loligo* increased as a function of deeper water.

Introduction

A stock assessment survey for *Loligo* (*Doryteuthis gahi* - Patagonian squid) was carried out by FIFD personnel onboard the fishing vessel *Beagle F.I.* from 30th June to 14th July 2012. This survey continues the series of surveys that have, since February 2006, been conducted immediately prior to *Loligo* season openings to estimate the *Loligo* stock available to commercial fishing at the start of the season, and to initiate the in-season management model based on depletion of the stock.

The survey was designed to cover the 'Loligo Box' fishing zone (Arkhipkin et al., 2008) that extends across the southern and eastern part of the Falkland Islands Interim Conservation Zone (Figure 1). The current delineation of the Loligo Box represents an area of approximately 31,118 km^2.

Objectives of the survey were to:

1) Estimate the biomass and spatial distribution of *Loligo* on the fishing grounds at the onset of the 2nd fishing season, 2012.
2) Provide data for comparative estimates of rock cod (*Patagonotothen ramsayi*) bycatch in *Loligo* trawls.
3) Collect biological information on *Loligo*, rock cod, and opportunistically other commercially important fish and squid taken in the trawls.

The following personnel from FIFD participated in the survey:

Andreas Winter	survey chief scientist
Zhanna Shcherbich	fisheries scientist
Emily Hancox	fisheries observer

The F/V *Beagle F.I.* is a Stanley, Falkland Islands - registered stern trawler of 92.2 m length, 2849 t gross registered tonnage, and 2944 main engine bhp. Additional crew and equipment specifications are listed in May (2010) and Hancox (2012). Like all vessels employed for these pre-season surveys, *Beagle F.I.* operates regularly in the commercial *Loligo* fishery and used its commercial trawl gear for the survey. *Beagle F.I.* was also used for the 1st pre-season survey in 2010 (Arkhipkin et al., 2010).

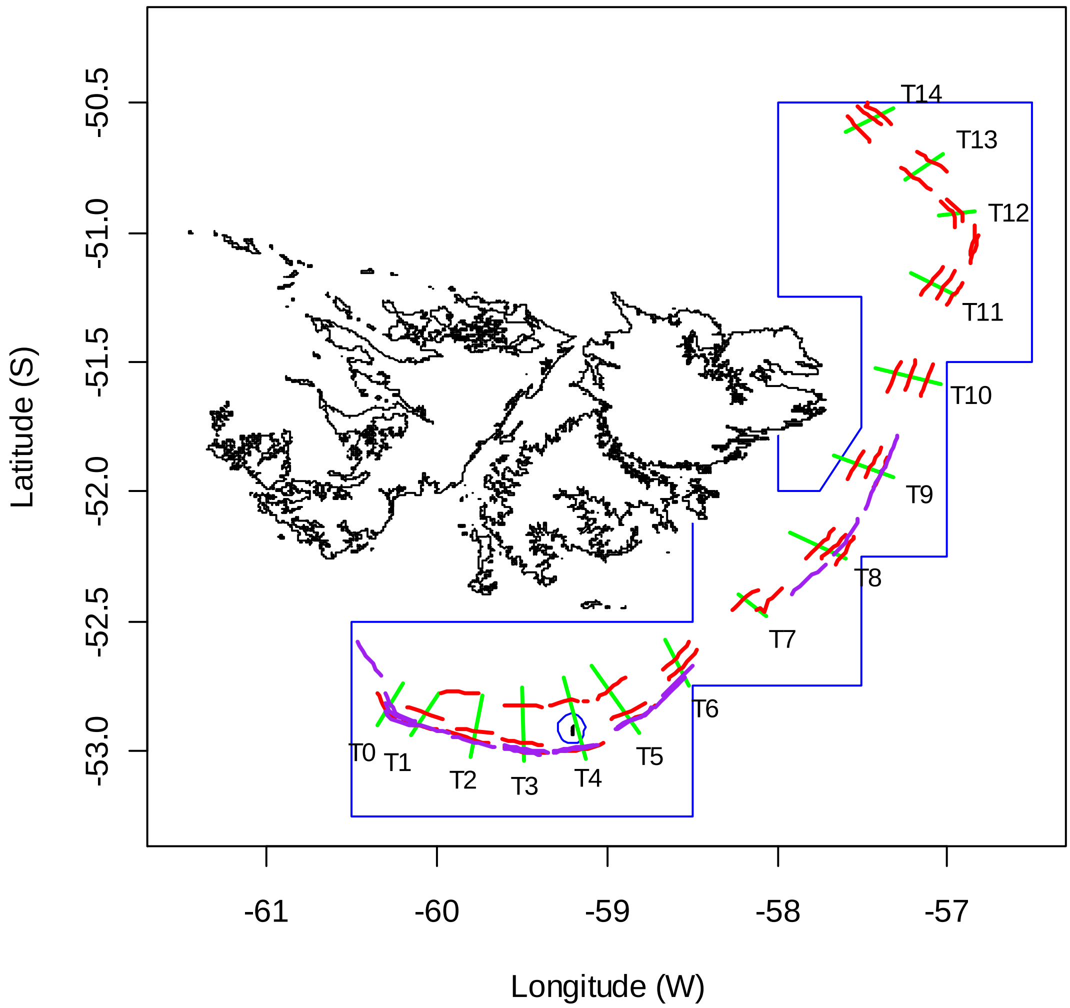


Figure 1. Transects (green lines), fixed-station trawls (red lines), and adaptive-station trawls (purple lines) sampled during the pre-season 2 2012 survey. Boundaries of the 'Loligo Box' fishing zone and the Beauchêne Island exclusion zone are shown in blue.

Methods

Sampling procedures

The survey plan included 39 fixed-station trawls located on a series of 15 transects perpendicular to the shelf break around the Loligo Box (Figure 1), followed by up to 21 adaptive-station trawls selected to increase the precision of *Loligo* biomass estimates in high-density or high-variability locations. The same fixed-station plan as previous surveys (e.g., Winter et al., 2011a; 2011b; 2012) was used, with trawls ranging in distance from 13.6 to 18.1 km (mean 16.1). The trawls were designed for an expected duration of 2 hours each, but this is variable with the fishing power of the vessel. All trawls were bottom trawls. During the progress of each trawl, GPS latitude, GPS 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 increase spatial resolution of the catches. For small catches acoustic apportioning cannot be assessed with accuracy, and any *Loligo* amounts <100 kg were iteratively aggregated by adjacent intervals (if the total *Loligo* catch in a trawl was <100 kg it was assigned to one interval; the middle one).

Catch estimation

Catch of every trawl was processed separately by the factory crew and retained catch weight of *Loligo*, by size category, was estimated from the number of standard-weight blocks of frozen *Loligo* recorded by the factory supervisor. Catch weights of commercially valued fish species, including rock cod, were recorded in the same way, although without size categorization. Discards of damaged, undersized, or commercially unvalued fish and squid were estimated by FIFD survey personnel either visually (for small quantities) or by noting the ratio of discards to commercially retained fish and squid in sub-portions of the catch (for larger quantities). Discards were added to the product weights (as applicable) to give total catch weights of all fish and squid.

Biomass calculations

Biomass density estimates of *Loligo* per trawl were calculated as catch weight divided by swept-area; which is the product of trawl distance × trawl width. Trawl distance was defined as the sum of distance measurements from the start GPS position to the end GPS position of each 15-minute interval. Trawl width was derived from the distance between trawl doors (determined per interval, from the Marport net sensor system) according to the equation:

trawl width = (door dist. × footrope length) / (footrope + bridle lengths)

(www.seafish.org/media/Publications/FS40_01_10_BridleAngleandWingEndSpread.pdf)

Measurements of *Beagle F.I.*'s trawl were: footrope = 116 m and bridle = 143 m.

In a previous survey report (Winter et al., 2010) it was found that *Loligo* catches taken in daylight were significantly higher than those that extended into darkness, due to *Loligo*'s diel migratory behaviour (Rodhouse, 2005). The daylight effect was re-examined in this survey by assigning to every 15-minute trawl interval (and its corresponding apportioned *Loligo* catch density) an index of whether it was completed within or without the period from sunrise to sunset. Sunrise and sunset times at each location were calculated using the algorithms of the NOAA Earth System Research Laboratory (www.esrl.noaa.gov/gmd/grad/solcalc/calcdetails.html). Generalized additive models (GAM) were then calculated of *Loligo* density per interval as a function of latitude and longitude (converted to projected coordinates), or latitude and longitude plus the daylight index as a factorial variable. The GAM with daylight index did not have a lower Akaike information criterion (AIC) than the GAM with only latitude and longitude, and it was therefore concluded that the daylight effect did not significantly influence *Loligo* catches in this survey.

Biomass density estimates were extrapolated to the fishing grounds area using geostatistical methods described in Roa-Ureta and Niklitschek (2007). The methods are based on the approach of separately modelling positive (non-zero) catch densities, and the probability of occurrence (presence / absence) of the positive catch densities (Pennington, 1983), then multiplying the two together. Positive catch densities were modelled with spatial correlation using a fitted variogram (Cressie, 1993) and Box-Cox transformation to normalize the data (MacLennan and MacKenzie, 1988). Presence/absence was modelled with spatial correlation by simulation using a Monte Carlo Markov Chain (MCMC) (Christensen, 2004; Roa-Ureta and Niklitschek, 2007). Compared to previous surveys, the delineated fishing area (Figures 2 and 4) was slightly expanded southwest to encompass more ground that had been covered by this survey (Figure 1), and by the previous season's survey (Winter et al., 2012) and commercial trawls (Winter, 2012). The current delineated area is 14,865.7 km^2, and partitioned for analysis as 601 area units of 5×5 km.

Uncertainty of total biomass on the fishing grounds was estimated by randomly re-sampling trawls 10000× and fitting the geostatistical methods above to each re-sample. Re-samples differed from a standard bootstrap approach (Efron, 1981) insofar as trawls were selected by replacement, but duplicate selections removed, to preserve the realistic structure of the survey (trawls were not duplicated). Because duplication varied randomly, the re-sampling algorithm thus generated variability in both the number and distribution of trawls.

Sea temperature and salinity measurements

Sea temperature and salinity measurements were recorded using a mini-CTD instrument (Valeport Ltd., UK) attached to the headrope of the trawl. The instrument recorded conductivity (mS/cm), temperature (ºC) and pressure (dBar) continuously at a frequency setting of 1 Hz. Pressure was converted to depth as:

$$\text{Depth (m)} \quad = \quad \text{dBar} / 1.01325 \quad \text{(one atmosphere)}$$

Conductivity was converted to salinity units according to the practical salinity scale PSS-78 (UNESCO, 1983).

For this report, surface temperature and salinity, bottom temperature and salinity, and sea floor depth, were examined. Surface temperature and salinity were defined as the average of measurements within 2 m of the surface after deployment and before retrieval; thus two data each per trawl. Surface positions were assigned as the start and end trawl positions. While this is not technically accurate (start and end trawl positions are recorded when the net is in fishing position), it is a sufficient approximation for area coverage. Bottom temperature and salinity were defined as all measurements sequentially recorded while the trawl was on the sea bottom, determined by inspection of the depth profile. To reduce the volume of data, measurements were sub-sampled from 1 per second (1 Hz) to 1 per minute. Bottom positions were assigned by interpolating the start and end trawl positions. Sea floor depths were obtained from the GEBCO_08 30 arc-second bathymetry produced by the British Oceanographic Data Centre (www.bodc.ac.uk/data/online-delivery/gebco) (although the Valeport mini-CTD itself measures depth, by being attached to the headrope it gives rather fluctuating values). Surface and bottom temperature and salinity, and depth, were then mapped across the fishing area by cubic-spine interpolation (Akima, 1996) from the assigned measurement positions. Relationships between predicted *Loligo* densities from the geostatistical algorithm, and these oceanographic variables, were analyzed using a GAM. Variables were added to the GAM by forward selection and retained as significant if they decreased the AIC.

CTD temperature data were also compared to the vessel's instrument readings of surface temperature (from the Furuno RD30 display) and bottom temperature (from the Marport net sensor system display), by linear correlation. To calculate the correlations, CTD measurements were interpolated back onto the positions at which the Furuno and Marport readings were taken.

Biological analyses

Random samples of approximately 150 *Loligo* were collected from the factory at all trawl stations (as far as available). Biological analysis at sea included measurements of the dorsal mantle length (ML) rounded down to the nearest half-centimetre, sex, and maturity stage. Relationships between average dorsal mantle length or maturity stage, per trawl, and predictor variables latitude, longitude, depth, and survey day, were analyzed using GAM; calculated separately for males and females, and weighted by the number of samples per trawl. Predictor variables again were added to the GAMs by forward selection and retained if they decreased the AIC. A separate GAM was calculated to analyze the relationship of male/female ratio with the predictor variables. The length-weight relationship $W = \alpha \cdot L^{\beta}$ (Froese, 2006) for *Loligo* was calculated by optimization from a subset of individuals that were weighed as well as measured. This subset included non-randomly selected individuals, to increase representation of the size ranges. Samples of *Loligo* were additionally taken according to area stratification (north, central, south) and depth (shallow, medium, deep), and frozen for statolith extraction and age analysis (Arkhipkin, 2005). Random samples of up to 100 rock cod were collected from trawls in which rock cod were caught. Biological analysis of rock cod included measurements of total length (TL) rounded down to the nearest centimetre, sex, and maturity stage, and specimen collection for ID verification of species. Thorns and vertebrae were taken from skates for ageing, and biological samples from miscellaneous other fish and invertebrates when these occurred in trawls.

Results

Catch rates and distribution

The survey started with fixed-station trawls in the north of the Loligo Box and proceeded southward. A schedule of 4 scientific trawls per day was maintained except for July 2nd, when only 2 trawls were taken due to rough weather and one overabundant rock cod catch, and July 3rd, when 5 trawls were taken to partially compensate for the day before (Appendix Table A1). One fixed-station trawl off transect 13 and one fixed-station trawl off transect 12 were relocated southward between transects 12 and 11, because of excess rock cod in the area (Figure 1). However, these were not considered adaptive trawls because there was no anticipation of how much *Loligo* the relocated trawls would catch. In total 59 scientific trawls were recorded during the survey: 39 fixed station trawls catching 81.18 t *Loligo* and 20 adaptive trawls catching 97.11 t *Loligo*. One adaptive trawl (fourth trawl on July 12th) was rejected from analysis because of damage to the net, but its catch is counted in the total. Optional trawls (made after survey hrs) yielded an additional 66.28 t *Loligo*, bringing the overall total catch for the survey to 244.57 t. The scientific catch of 178.29 may be considered average for a 2nd-season survey; substantially lower than in 2006 and 2011, but also substantially higher than in 2007 through 2010 (Table 1).

Table 1. *Loligo* pre-season survey vessels, scientific catches and biomass estimates (in metric tonnes). Before 2006, surveys were not conducted immediately prior to season opening.

Year	First season				Second season			
	Vessel	No. trawls	Catch	Biomass	Vessel	No. trawls	Catch	Biomass
2006	ZDLU1	70	376	10213	ZDLF2	52	240	22632
2007	ZDLU1	65	100	2684	ZDLR1	52	131	19198
2008	ZDLC1	60	130	8709	ZDLU1	52	123	14453
2009	ZDLT1	59	187	21636	MSPL9	51	113	22830
2010	ZDLZ	55	361	60500	ZDLC1	57	123	51754
2011	ZDLP1	59	50	16095	ZDLE1	59	276	51562
2012	ZDLB2	56	128	30706	ZDLZ	59	178	28998

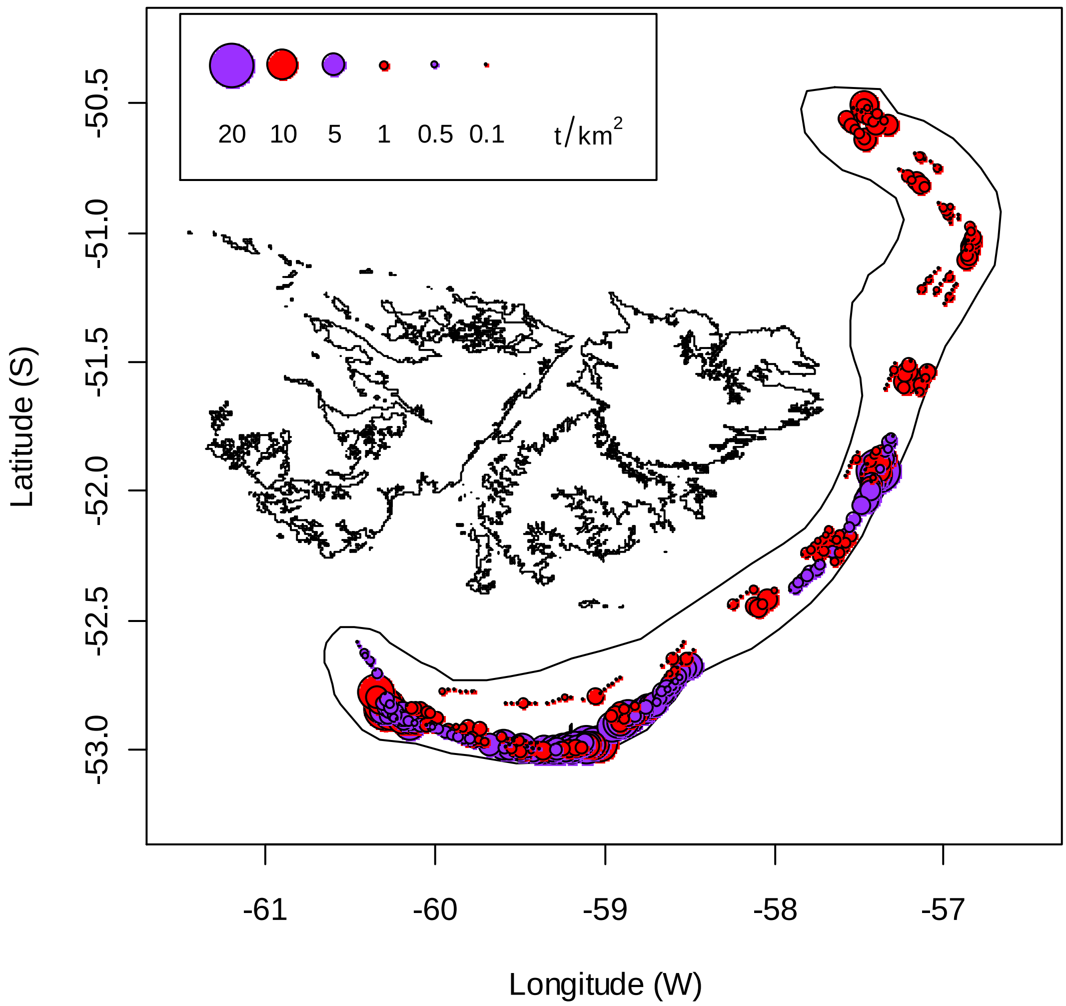


Figure 2. *Loligo* CPUE (t km^{-2}) of fixed-station trawls (red) and adaptive trawls (purple), per 15-minute trawl interval. The boundary of the fishing area is outlined.

Average *Loligo* catch density among fixed-station trawls was 1.50 t km^{-2} north of 52° S and 2.40 t km^{-2} south of 52° S. Average *Loligo* catch density among adaptive-station trawls was 5.39 t km^{-2} north of 52° S and 4.18 t km^{-2} south of 52° S. The highest densities being the adaptive trawls north of 52° S reflects two circumstances: 1) these trawls were only just north of 52° S, unlike the fixed-station trawls which went as far north as 50.5° S (Figure 2), and 2) these trawls were the last ones taken during the survey, maximizing the opportunity for *Loligo* to have out-migrated to the fishing zone. Interestingly, the result of obtaining higher catch densities in the south has been more typical of 1st season surveys than 2nd season surveys in recent years (e.g., Payá, 2009; Arkhipkin et al., 2010; Winter et al., 2010; 2011a; 2011b; 2012). During this survey it was noted by the *Beagle F.I.*'s fishing master that the *Loligo* did not aggregate near-bottom as much as usual.

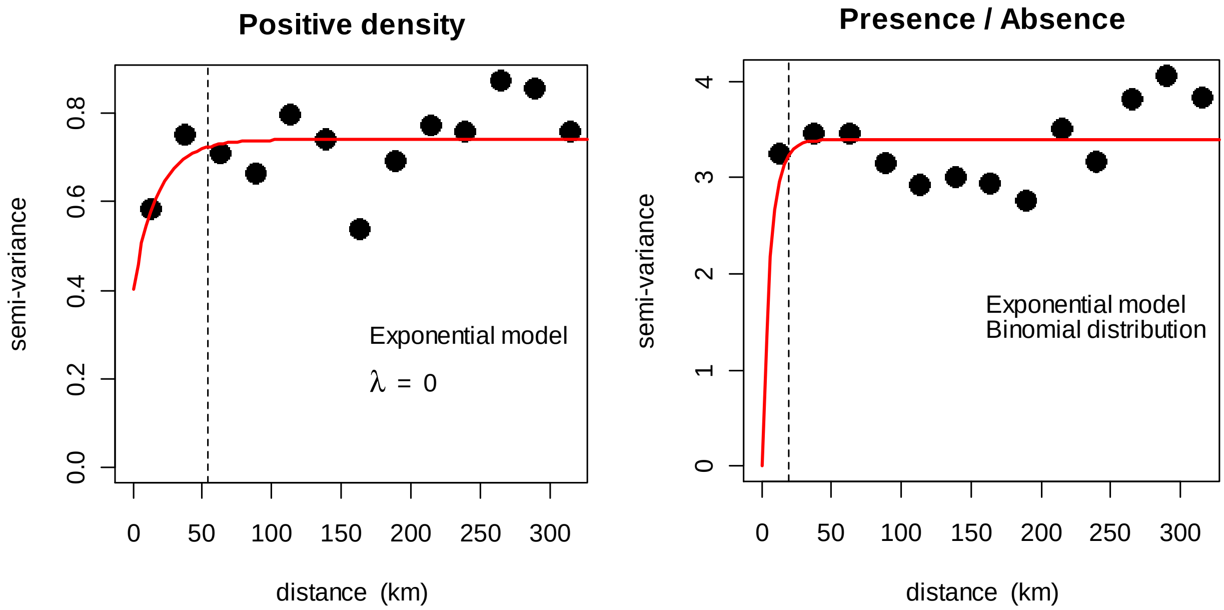


Figure 3. Empirical variogram (black points) and model variogram (red line) of *Loligo* positive catch density distributions (left) and presence / absence (right). Correlation ranges are indicated by dotted lines on the plots; 54.2 km for positive density and 19.2 km for presence / absence.

Biomass estimation

Geostatistical modelling of the positive catch densities and presence / absence showed relatively restricted spatial correlations. The best variogram fit for positive catch densities was obtained with an exponential model function and λ = 0 Box-Cox transformation (i.e., logarithmic transformation) of catch densities (Figure 3, left). This variogram function converged with a range of 54.2 km, indicating that *Loligo*, where present, spatially correlated over an average maximum of 54.2 km separation distance. Semi-variances showed decreases first at ~95 km, then more strongly at ~160 km (Figure 3, left), these being the approximate linear distances between the three highest concentrations of positive catch density (Figure 4, top left: dark blue at

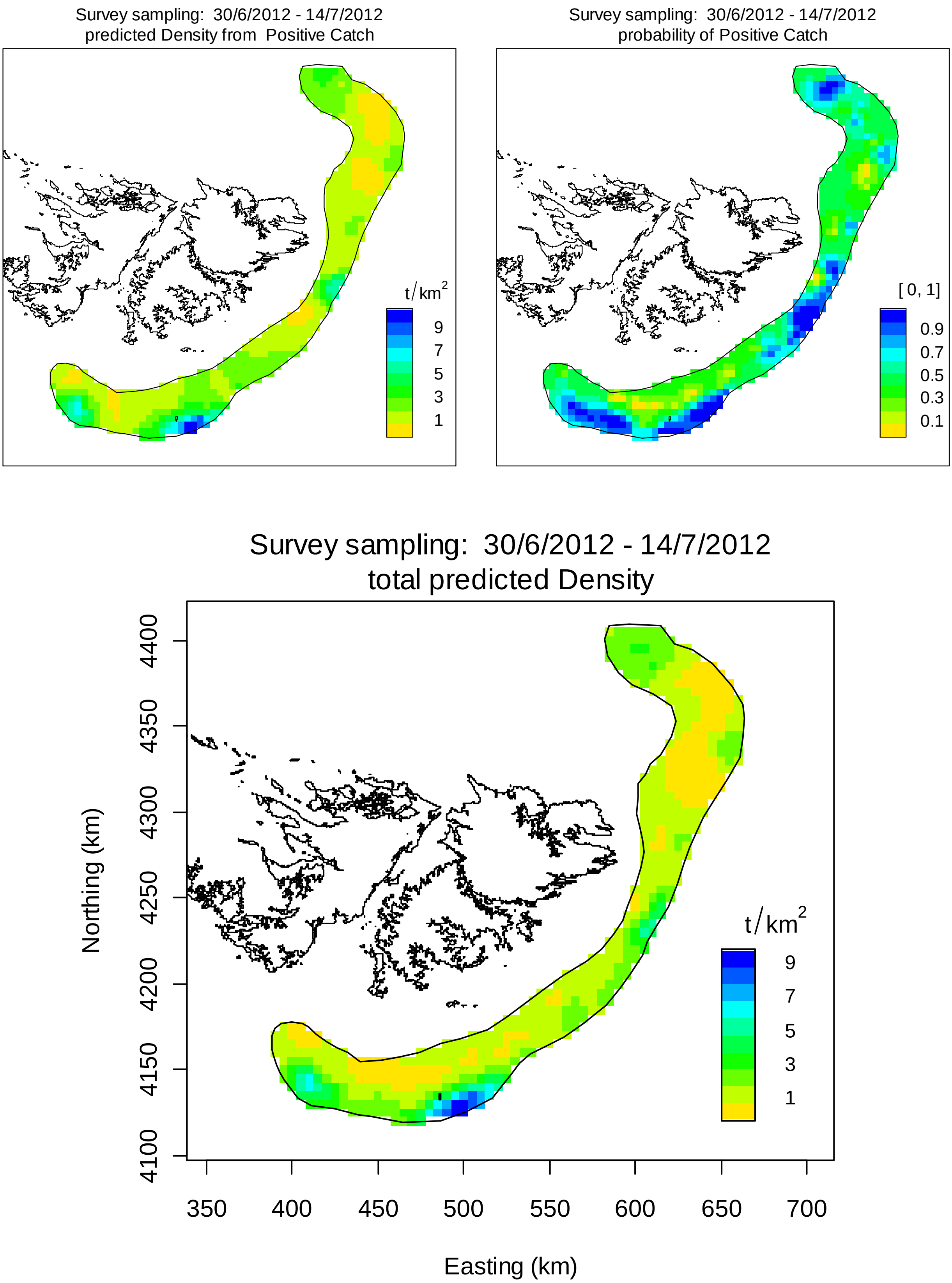


Figure 4. *Loligo* density estimates per 5 × 5 km area units. Top left (A): catch density distribution from variogram model of positive catches. Top right (B): probability of positive catch modelled from MCMC of presence / absence. Main plot (C): predicted density = A × B. For calculating geostatistical estimates, coordinates were converted to WGS 84 projection (GeoConv software, www.kolumbus.fi/eino.uikkanen/geoconvgb/index.htm).

Easting 500 - Northing 4125; light blue at Easting 406 - Northing 4140, and light blue at Easting 610 - Northing 4241. Distances: sqrt((500 - 406)^2 + (4125 - 4140)^2) = 95, and sqrt((500 - 610)^2 + (4125 - 4241)^2) = 160). The MCMC for presence / absence was modelled on the binomial distribution with likewise an exponential function for spatial correlation. This variogram function showed relatively weak spatial correlation and an even shorter range at 19.2 km (Figure 3, right), given the aggregated distribution of trawl intervals that were 'zero' (46 out of 58 trawls had either ≤1 'zero' interval or ≥5 'zero' intervals).

Total *Loligo* biomass in the fishing area was estimated by the geostatistical model at 28,998 t, with a 95% confidence interval of [22,776 to 37,199 t]. Of this estimated total, 10,838 t [8,256 to 14,885 t] were north of 52 ºS, and 18,160 t [13,456 to 23,509 t] were south of 52 ºS. The total of 28,998 t was the lowest 2nd-season estimate since 2009, and also represented the smallest difference between 1st season and 2nd season since 2009 (Table 1).

Sea temperature and salinity

The Valeport mini-CTD returned useable temperature and salinity data from 58 of the 59 scientific trawls. Spatial distributions are shown in Figures 5 and 6. All four oceanographic variables (sea surface temperature, bottom temperature, surface salinity, bottom salinity), as well as depth, showed statistically significant effects on predicted *Loligo* density, although the combined GAM explained only 31.1% of model deviance (r^2). The trends are summarized in Table 2. Influences of oceanographic and climatic variables have been reported on *Loligo* populations in various systems (Roberts and Sauer, 1994; Robin and Denis, 1999; Denis et al., 2002; Pierce and Boyle, 2003).

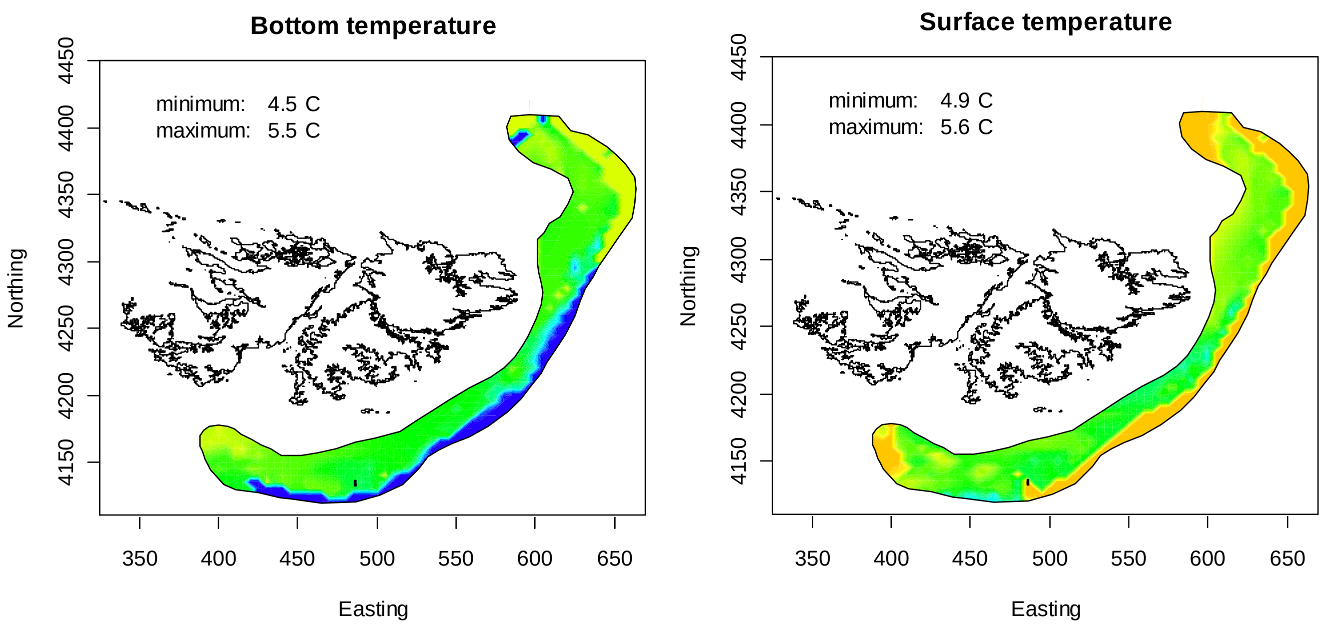


Figure 5. Bottom and surface sea temperatures interpolated from measurements of the mini-CTD attached to the trawl. Both plots to same scale; temperature increasing purple → yellow.

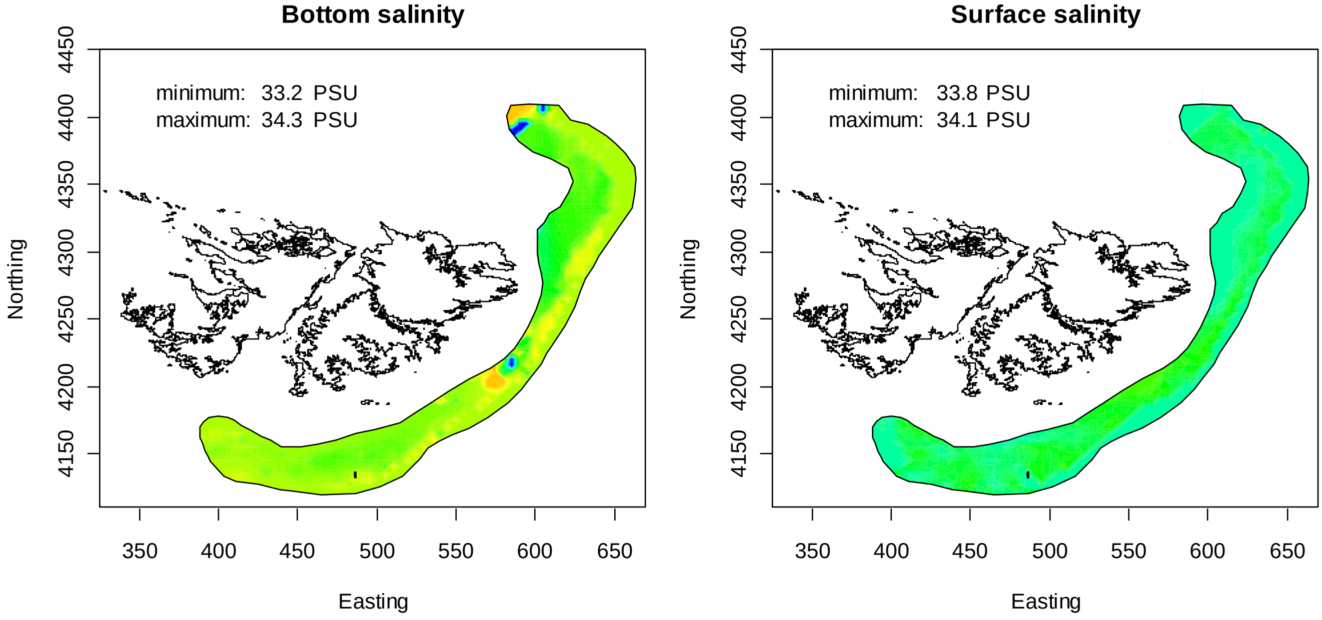


Figure 6. Bottom and surface salinities interpolated from measurements of the mini-CTD attached to the trawl. Both plots to same scale; salinity increasing purple → yellow.

Table 2. Statistically significant effects of oceanographic variables on predicted *Loligo* density, calculated by GAM.

Oceanographic variable	Effect on *Loligo* density
Bottom temperature	Decrease with increasing temperature, 4.5°C to 5.5°C.
Surface temperature	Increase with increasing temperature, 5.2°C to 5.8°C.
Bottom salinity	Increase with increasing salinity, 34.05 to 34.2 PSU.
Surface salinity	Increase with increasing salinity, 33.8 to 34.0 PSU.
Depth	Increase with deeper water 336 to 430 m.

Sea surface temperature and surface salinity had a strong (negative) correlation with each other at r = -85.4%. Bottom temperature and bottom salinity, where different water masses are present, had a moderate (positive) correlation at r = +42.5%. All other pair-wise correlations between oceanographic variables were weak ($r \leq$ 21.1%).

CTD temperature readings had strong positive linear relationships with vessel instrument readings: $p < 0.001$ and r^2 = 82.7% for bottom temperature; $p < 0.001$ and r^2 = 29.0% for surface temperature (whereby the interpolations were edited for spurious values). The r^2 results reflect the more fluctuating nature of surface temperatures than bottom temperatures.

Biological data

Seventy taxa were identified in the catches (Appendix Table A2), of which *Loligo* made up 70% by weight. 15,073 *Loligo* were measured for length and maturity, and 458 *Loligo* were sampled for the length-weight relationship. Significant GAM co-variables are summarized in Table 3. The most consistent relationship was increasing size and maturity of both male and female *Loligo* in deeper water. Day progression was mostly not significant, suggesting that the *Loligo* were not growing much (nor receiving migration impulses of younger squid) during the course of the survey. A slight positive trend of increasing maturity with day progression did occur in females, which on average have significantly lower maturity than males at this stage (Figure 7) and therefore more potential for increase.

Table 3. Statistically significant effects of day and position variables on *Loligo* mantle length, maturity, and female proportion, calculated by GAM. 'Interaction only' means that the variable was not significant (at $p < 0.05$) as a main effect, but contributed to lowering the overall AIC.

Metric	r^2 (%)	Significant variable	Effect
M - ML	72.1	Depth	Increase with increasing depth, 150 to 300 m.
		Latitude	Interaction only.
		Longitude	Interaction only.
F - ML	83.6	Depth	Increase with increasing depth, 105 to 318 m.
		Latitude	Increase towards south, 52.20°S to 53.01°S.
		Longitude	Increase towards east, 59.63°W to 56.84°W.
		Day	Interaction only.
M - Maturity	64.5	Depth	Increase with increasing depth, 170 to 250 m.
		Latitude	Increase towards north, 53.01°S to 52.15°S.
		Day	Interaction only.
F - Maturity	38.6	Depth	Increase with increasing depth, 105 to 156 m. Decrease with increasing depth, 156 to 220 m.
		Day	Increase from day 182 to day 196.
		Longitude	Increase towards east, 59.50°W to 56.84°W.
F - Proportion	77.2	Depth	Increase with increasing depth, 105 to 194 m. Decrease with increasing depth, 194 to 250 m.
		Latitude	Interaction only.
		Longitude	Increase towards west, 56.84°W to 58.88°W.
		Day	Interaction only.

Loligo size and maturity distributions north and south of 52° S are plotted in Figure 7. Females had the same modal length of 12 cm ML north and south of 52° S, while males had a modal length of 15 cm ML north and 11 cm ML south of 52° S. Males had broader size distributions and larger size maxima; females reached a maximum ML of 22 cm north and 18.5 cm south, whereas 1.8% of males north were longer than 22 cm and 6.4% of males south were longer than 18.5 cm. Males had much higher average maturity with 83.2% of males at maturity stage > 2 and 4.5 of females at maturity stage > 2.

The *Loligo* length-weight relationship was calculated from 458 individuals, resulting in parameters $\alpha = 0.27809 \pm 0.01536$ and $\beta = 1.99877 \pm 0.02359$ (± 1 sd). The data were heavily skewed towards lengths < 20 cm (Figure 8). Optimized separately, the 255 male and 203 female data gave significantly different length-weight relationships (likelihood ratio test, df = 2, $\chi^2 = 109.3$, $p < 0.001$), characterized by males having higher weight per mantle length below 11.86 cm, and lower weight per mantle length above 11.86 cm. The difference was largely driven by the lone female at ML = 23.5 cm (Figure 8), forcing the relationship curve for females upward at higher lengths.

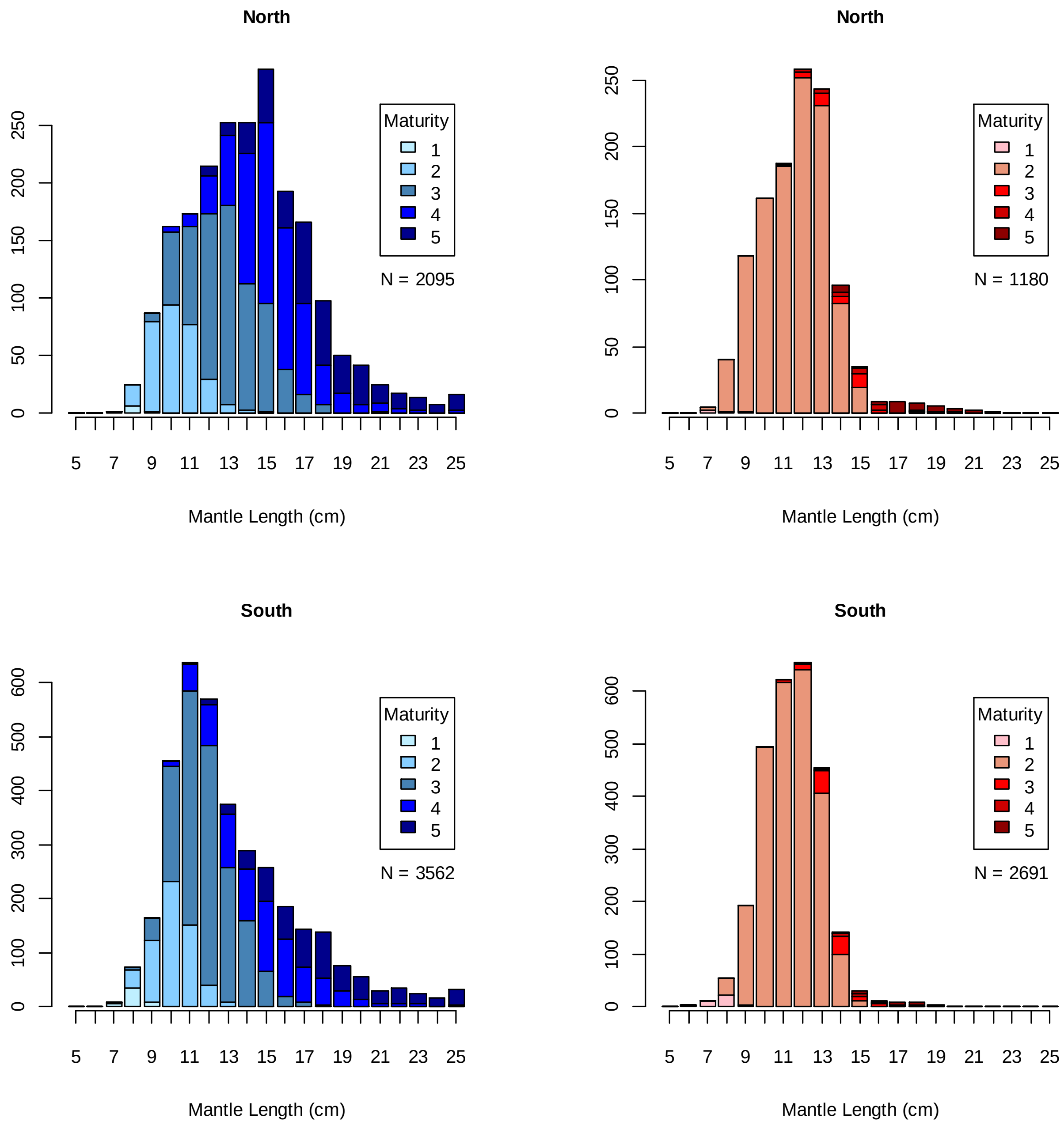
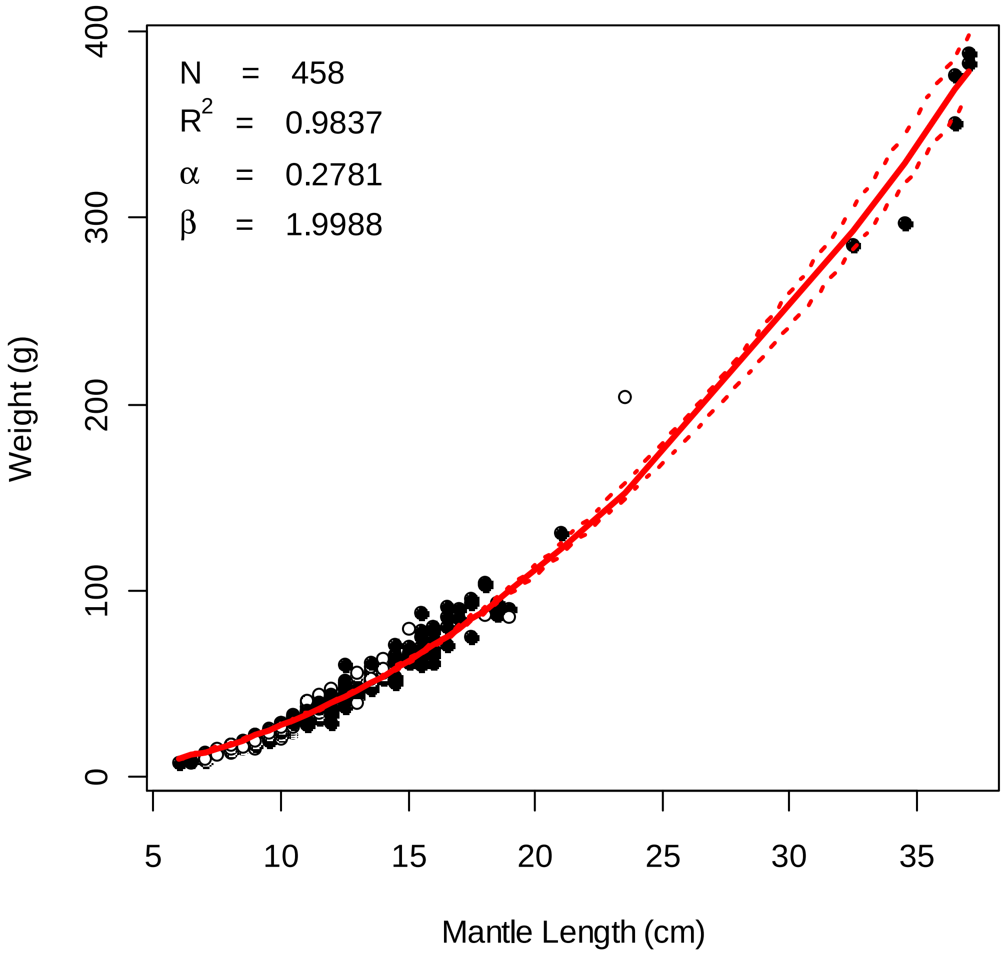


Figure 7. Length-frequency distributions by maturity stage of male (blue) and female (red) *Loligo* from trawls north (top) and south (bottom) of latitude 52 ºS.

Figure 8 [next page]. Length – weight relationship of *Loligo* sampled during the survey. Filled circles: males, open circles: females. Dotted lines: 95% confidence interval of the relationship.



References

Akima, H. 1996. Algorithm 761: scattered-data surface fitting that has the accuracy of a cubic polynomial. ACM Transactions on Mathematical Software 22: 362-371.

Arkhipkin, A.I. 2005. Statoliths as 'black boxes' (life recorders) in squid. Marine and Freshwater Research 56: 573-583.

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.

Arkhipkin, A., Winter, A., May, T. 2010. *Loligo gahi* stock assessment survey, first season 2010. Technical Document, FIG Fisheries Department.

Christensen, O.F. 2004. Monte Carlo maximum likelihood in model-based geostatistics. Journal of computational and graphical statistics 13: 702-718.

Cressie, N.A.C. 1993. Statistics for spatial data. John Wiley & Sons Inc., New York, 900 pp.

Denis, V., Lejeune, J., Robin, J.P. 2002. Spatio-temporal analysis of commercial trawler data using General Additive models: patterns of Loliginid squid abundance in the north-east Atlantic. ICES Journal of Marine Science 59:633-648.

Efron, B. 1981. Nonparametric estimates of standard error: the jackknife, the bootstrap and other methods. Biometrika 68:589-599.

Froese, R. 2006. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology 22:241-253.

Hancox, E. 2012. Observer Report 913. Technical Document, FIG Fisheries Department.

MacLennan, D.N., MacKenzie, I.G. 1988. Precision of acoustic fish stock estimates. Canadian Journal of Fisheries and Aquatic Sciences 45: 605-616.

May, T. 2010. Observer Report 807. Technical Document, FIG Fisheries Department.

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

Pierce, G.J., Boyle, P.R. 2003. Empirical modelling of interannual trends in abundance of squid (Loligo forbesi) in Scottish waters. Fisheries Research 59:305-326.

Pennington, M. 1983. Efficient estimators of abundance, for fish and plankton surveys. Biometrics 39:281-286.

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.

Roa-Ureta, R., Niklitschek, E. 2007. Biomass estimation from surveys with likelihood-based geostatistics. ICES Journal of Marine Science 64: 1723-1734.

Roberts, M.J., Sauer, W.H.H. 1994. Environment: the key to understanding the South African chokka squid (*Loligo vulgaris reynaudii*) life cycle and fishery? Antarctic Science 6: 249-258.

Robin, J.-P., Denis, V. 1999. Squid stock fluctuations and water temperature: temporal analysis of English Channel Loliginidae. Journal of Applied Ecology 36: 101-110.

Rodhouse, P.G. 2005. C2 World squid resources. In: Review of the state of world marine fishery resources. FAO Fisheries Technical Paper 457, 235 pp.

UNESCO. 1983. Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science 44:1-55.

Winter, A. 2012. *Loligo gahi* stock assessment, first season 2012. Technical Document, Falkland Islands Fisheries Department.

Winter, A., Davidson, D., Shcherbich, Z. 2010. *Loligo gahi* stock assessment survey, second season 2010. Technical Document, FIG Fisheries Department.

Winter, A., Davidson, D., Watson, M. 2011a. *Loligo gahi* stock assessment survey, first season 2011. Technical Document, FIG Fisheries Department.

Winter, A., Jürgens, L., Shcherbich, Z. 2011b. *Loligo gahi* stock assessment survey, second season 2011. Technical Document, FIG Fisheries Department.

Winter, A., Davidson, D., Hancox, E. 2012. *Loligo gahi* stock assessment survey, first season 2011. Technical Document, FIG Fisheries Department.

Appendix

Table A1. Survey stations with total *Loligo* catch. Time: local (Stanley, F.I.), latitude: °S, longitude: °W.

Station	Date	Start			End			Depth	Loligo
		Time	Lat	Lon	Time	Lat	Lon	Avg. (m)	Catch (kg)
743	30/06/2012	07:05	50.76	57.00	09:05	50.69	57.18	301	540
744	30/06/2012	10:20	50.58	57.32	12:20	50.50	57.47	290	2740
745	30/06/2012	13:40	50.59	57.39	15:20	50.51	57.53	255	1560
746	30/06/2012	16:15	50.55	57.59	17:55	50.65	57.45	139	2940
747	01/07/2012	07:00	50.75	57.27	08:41	50.83	57.10	131	1940
748	01/07/2012	09:20	50.88	57.04	10:50	50.98	56.96	116	580
749	01/07/2012	11:31	50.96	56.90	12:50	50.87	57.00	118	320
750	01/07/2012	14:01	50.97	56.84	15:39	51.09	56.87	246	1100
751	02/07/2012	09:35	51.01	56.82	11:32	51.12	56.86	276	3360
752	02/07/2012	14:37	51.20	56.91	16:24	51.28	57.00	294	100
753	03/07/2012	06:57	51.25	57.07	08:24	51.15	56.95	142	260
754	03/07/2012	09:05	51.13	57.02	10:48	51.24	57.16	128	260
755	03/07/2012	12:18	51.51	57.09	13:57	51.63	57.16	288	1360
756	03/07/2012	14:49	51.61	57.24	16:14	51.49	57.19	224	3520
757	03/07/2012	16:57	51.50	57.28	18:27	51.62	57.35	156	160
758	04/07/2012	06:59	51.85	57.50	08:30	51.95	57.59	164	160
759	04/07/2012	09:15	51.95	57.48	10:46	51.83	57.39	227	720
760	04/07/2012	11:30	51.86	57.35	13:08	51.98	57.43	278	5080
761	04/07/2012	14:30	52.15	57.66	16:26	52.26	57.83	211	1040
762	05/07/2012	07:01	52.28	57.66	08:35	52.17	57.55	321	1860
763	05/07/2012	09:17	52.16	57.60	10:52	52.26	57.74	261	2200
764	05/07/2012	11:59	52.37	57.97	13:29	52.45	58.12	247	3058
765	05/07/2012	14:22	52.38	58.12	15:55	52.46	58.27	182	360
766	06/07/2012	06:55	52.69	58.67	08:35	52.58	58.52	169	340
767	06/07/2012	09:20	52.61	58.47	11:08	52.72	58.64	238	640
768	06/07/2012	12:03	52.81	58.78	13:40	52.87	58.98	146	2300
769	06/07/2012	14:22	52.90	58.92	16:09	52.82	58.71	272	6800
770	07/07/2012	06:57	52.72	58.89	08:37	52.80	59.06	121	400
771	07/07/2012	09:13	52.80	59.11	10:58	52.83	59.34	107	140
772	07/07/2012	12:25	52.98	59.60	14:10	53.01	59.34	248	3020
773	07/07/2012	14:52	53.00	59.26	16:35	52.97	59.02	262	7300
774	08/07/2012	06:53	52.83	59.60	08:24	52.83	59.39	147	240
775	08/07/2012	09:30	52.97	59.38	11:15	52.95	59.62	183	480
776	08/07/2012	11:54	52.93	59.67	13:30	52.91	59.89	171	2080
777	08/07/2012	14:09	52.88	59.97	15:47	52.83	60.17	193	2040
778	09/07/2012	07:00	52.77	59.97	08:33	52.77	59.76	171	100
779	09/07/2012	09:55	52.97	59.70	11:43	52.93	59.94	232	2780
780	09/07/2012	12:20	52.92	60.00	13:50	52.88	60.20	233	5280
781	09/07/2012	14:30	52.87	60.25	15:55	52.78	60.35	251	12020
782	10/07/2012	06:55	52.58	60.47	08:50	52.71	60.33	220	620
783	10/07/2012	09:34	52.77	60.30	11:37	52.89	60.13	216	6100
784	10/07/2012	12:16	52.89	60.12	13:55	52.82	60.31	222	3560
785	10/07/2012	14:35	52.84	60.31	16:03	52.90	60.14	257	4500
786	11/07/2012	07:19	52.89	60.17	09:06	52.93	59.93	233	1660
787	11/07/2012	09:47	52.94	59.91	11:45	52.98	59.67	251	2040
788	11/07/2012	12:20	52.99	59.60	14:02	53.01	59.39	251	3936
789	11/07/2012	14:40	53.01	59.31	16:16	52.99	59.10	240	8100
790	12/07/2012	06:56	52.98	59.60	08:48	53.00	59.35	222	4640
791	12/07/2012	09:32	53.00	59.30	11:24	52.98	59.06	225	8760
792	12/07/2012	12:05	52.97	59.08	13:46	53.00	59.31	207	6920
793	12/07/2012	14:28	53.01	59.29	16:11	52.99	59.06	269	1740
794	13/07/2012	06:58	52.72	58.54	08:54	52.83	58.71	278	2680
795	13/07/2012	09:37	52.83	58.73	11:32	52.92	58.95	285	8078
796	13/07/2012	12:13	52.91	58.94	13:58	52.83	58.74	268	9120
797	13/07/2012	14:40	52.79	58.67	16:30	52.67	58.50	265	4980

798	14/07/2012	06:57	52.39	57.91	08:56	52.28	57.71	286	2600
799	14/07/2012	09:45	52.24	57.66	11:38	52.11	57.52	290	3140
800	14/07/2012	12:18	52.07	57.49	14:15	51.91	57.38	281	11340
801	14/07/2012	15:05	51.92	57.38	16:53	51.79	57.29	281	2600

Table A2. Survey total catches by species / taxon.

Species Code	Species / Taxon	Total catch (kg)	Total catch (%)	Sample (kg)	Discard (kg)
LOL	*Loligo gahi*	178,332	67.3	510	60
PAR	*Patagonotothen ramsayi*	63,437	24.0	560	45,774
BAC	*Salilota australis*	10,005	3.8	0	213
BLU	*Micromesistius australis*	2,657	1.0	1	2,627
DGH	*Schroederichthys bivius*	2,160	0.8	0	2,160
HAK	*Merluccius hubbsi*	1,511	0.6	0	0
CGO	*Cottoperca gobio*	1,182	0.5	20	1,182
MED	Medusae sp.	1,032	0.4	0	1,032
TOO	*Dissostichus eleginoides*	710	0.3	11	15
KIN	*Genypterus blacodes*	681	0.3	0	0
WHI	*Macruronus magellanicus*	603	0.2	0	122
RBR	*Bathyraja brachyurops*	550	0.2	0	62
RGR	*Bathyraja griseocauda*	320	0.1	17	13
POR	*Lamna nasus*	200	0.1	200	200
PTE	*Patagonotothen tessellata*	193	0.1	0	193
RAL	*Bathyraja albomaculata*	180	0.1	0	13
RBZ	*Bathyraja cousseauae*	132	0.1	0	2
ZYP	*Zygochlamys patagonica*	128	0.1	0	128
RFL	*Dipturus chilensis*	118	<0.1	0	0
EEL	*Iluocoetes fimbriatus*	104	<0.1	3	102
SPN	Porifera	69	<0.1	0	69
RMC	*Bathyraja macloviana*	67	<0.1	0	55
GRC	*Macrourus carinatus*	62	<0.1	0	61
RDO	*Amblyraja doellojuradoi*	48	<0.1	0	48
ING	*Moroteuthis ingens*	45	<0.1	1	44
RMU	*Bathyraja multispinis*	42	<0.1	26	10
RSC	*Bathyraja scaphiops*	36	<0.1	0	1
STA	*Sterechinus agassizi*	29	<0.1	0	29
PAT	*Merluccius australis*	28	<0.1	23	0
NEM	*Neophyrnichthys marmoratus*	23	<0.1	0	23
RPX	*Psammobatis* spp.	22	<0.1	0	22
MUL	*Eleginops maclovinus*	19	<0.1	0	19
OCM	*Octopus megalocyathus*	14	<0.1	11	0
POA	*Porania antarctica*	11	<0.1	0	11
ANM	Anemone	7	<0.1	0	7
GOC	*Gorgonocephalas chilensis*	6	<0.1	0	6
GRF	*Coelorhynchus fasciatus*	6	<0.1	0	6
BUT	*Stromateus brasiliensis*	3	<0.1	0	3
AST	Asteroidea	3	<0.1	0	3
GRH	*Macrourus holotrachys*	3	<0.1	3	0
ILL	*Illex argentinus*	2	<0.1	2	0
ODM	*Odontocymbiola magellanica*	2	<0.1	0	2
SQT	Ascidiacea	2	<0.1	0	2
FUM	*Fusitriton m. magellanicus*	2	<0.1	0	2
CAZ	*Calyptraster* sp.	2	<0.1	0	2
MLA	*Muusoctopus longibrachus akambei*	1	<0.1	1	0

COX	*Notothenid* spp.	1	<0.1	1	0
AUC	*Austrocidaris canaliculata*	1	<0.1	0	1
OCT	*Octopus* spp.	1	<0.1	1	0
MYA	*Myxine australis*	1	<0.1	0	1
OCC	Octocoralia	1	<0.1	0	1
SUN	*Labidaster radiosus*	1	<0.1	0	1
NOW	*Paranotothenia magellanica*	1	<0.1	1	0
OPV	*Ophiacanta vivipara*	1	<0.1	0	1
DGS	*Squalus acanthias*	1	<0.1	0	1
CHE	*Champsocephalus esox*	0	<0.1	0	0
WRM	*Chaetopterus variopedeatus*	0	<0.1	0	0
COG	*Patagonotothen guntheri*	0	<0.1	0	0
OPH	Ophiuroidea	0	<0.1	0	0
MAV	*Magellania venosa*	0	<0.1	0	0
OPL	*Ophiuroglypha lymanii*	0	<0.1	0	0
EUL	*Eurypodius latreillei*	0	<0.1	0	0
COT	*Cottunculus granulosus*	0	<0.1	0	0
ACP	*Acanthephyra pelagica*	0	<0.1	0	0
PES	*Peltarion spinosulum*	0	<0.1	0	0
CEX	*Ceramaster* sp.	0	<0.1	0	0
NUD	Nudibranchia	0	<0.1	0	0
MUG	*Munida gregaria*	0	<0.1	0	0
PYX	Pycnogonida	0	<0.1	0	0
ANT	Anthozoa	0	<0.1	0	0
		254,798		1,380	45,309