FALKLAND
ISLANDS
FISHERIES
DEPARTMENT

Loligo Stock Assessment Survey, 1st Season 2015

Vessel	Baffin Bay (MSPL9), United Kingdom
Dates	09/02/2015 - 23/02/2015
Survey Team	Andreas Winter Jessica Jones Zhanna Shcherbich

Summary

1) A stock assessment survey for *Loligo* squid was conducted in the '*Loligo* Box' from 9th to 23rd February 2015. Fifty-seven scientific trawls were taken during the survey, catching 184.3 tonnes of *Loligo*.
2) A geostatistical estimate of 36,424 tonnes *Loligo* (95% confidence interval: 30,385 to 43,916 t) was calculated for the fishing grounds survey area. This represents the highest 1st-season survey estimate since 2010. Of the total, 7444 t were estimated north of 52 ºS, and 28,979 t were estimated south of 52 ºS.
3) Male and female *Loligo* had significantly higher average maturities and greater average mantle lengths south of 52 ºS than north of 52 ºS. 57.4% of male and 86.3% of female *Loligo* had maturity stage 2 north of 52 ºS; 60.0% of males and 94.7% of female *Loligo* had maturity stage 2 south of 52 ºS.
4) Ninety-five taxa were identified in the catches. *Loligo* made up the largest species group at 44.5% by weight, followed by rock cod at 40.2% and southern blue whiting at 5.3%. Biological measurements and samples were taken from *Loligo*, rock cod, southern blue whiting, toothfish, and opportunistic specimens of various other species.

Introduction

A stock assessment survey for *Loligo* squid (*Doryteuthis gahi* – Falkland calamari) was carried out by FIFD personnel onboard the fishing vessel *Baffin Bay* from the 9th to 23rd February 2015. 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 1st fishing season, 2015.
2) Estimate the biomass and distribution of rock cod (*Patagonotothen ramsayi*) in the *Loligo* Box, in parallel to the rock cod research survey being conducted by the FV *Castelo*.
3) Collect biological information on *Loligo*, rock cod, and opportunistically other commercially important fish and squid taken in the trawls.

The F/V *Baffin Bay* is a UK - registered stern trawler of 68.2 m length, 1871 t gross registered tonnage, and 3300 main engine bhp. Like all vessels employed for these pre-season surveys, *Baffin Bay* operates regularly in the *Loligo* fishery and used its commercial trawl gear for the survey catches. *Baffin Bay* has previously been used for the pre- and post-season surveys of the 2nd season 2009 (Payá, 2009; Payá and Winter, 2009). The following personnel from FIFD participated in the current survey:

Andreas Winter	stock assessment scientist
Jessica Jones	fisheries observer
Zhanna Shcherbich	fisheries biologist

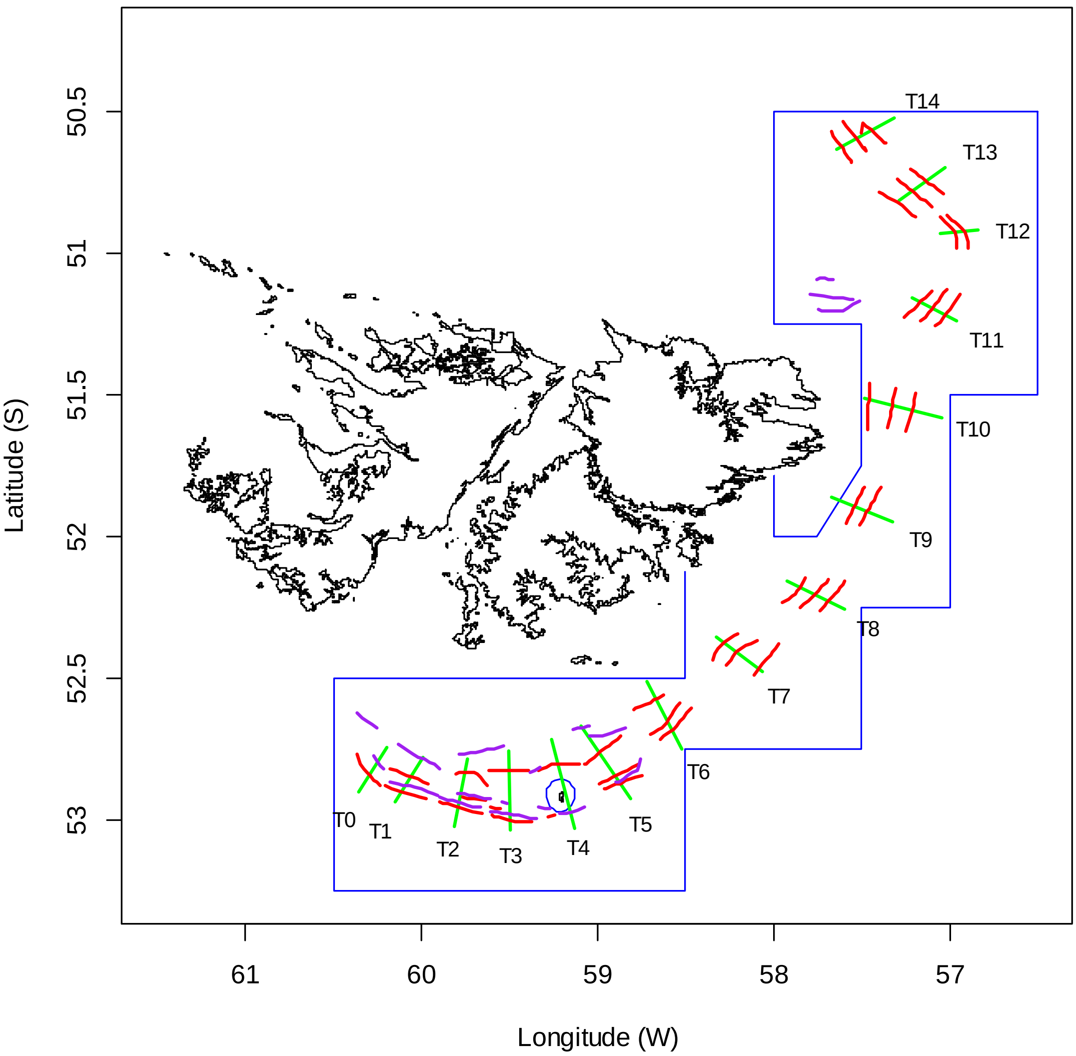


Figure 1. Transects (green lines), fixed-station trawls (red lines), and adaptive-station trawls (purple lines) sampled during the 1st pre-season 2015 survey. Boundaries of the *Loligo* Box fishing zone and the Beauchêne Island exclusion zone are shown in blue.

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 survey plan as the previous 1st season (Winter and Jürgens, 2014) was used, with some trawl stations placed further inshore than those sampled for 2nd seasons. Trawls were designed for an expected duration of 2 hours each, ranging in distance from 8.9 to 18.9 km (mean 15.7 km). 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).

Figure 2. *Loligo* squid from a trawl catch with small rock cod inserted into the mantles.

Catch estimation

Catch of every trawl was processed separately by the vessel 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. Catch composition and weights of damaged, undersized, or commercially unvalued fish and squid were estimated from basket samples of the unsorted catch. Between 2 and 7 observer baskets (typically containing ~35 – 40 kg) were collected at intervals from each survey trawl, depending on its volume. These baskets were hand-sorted by the FIFD survey personnel and species weighed separately. The aggregate quantities of bycatch species in baskets were then proportioned to the whole trawl. Scarce species were additionally recorded by visual estimation of their occurrence in the trawl. Non-commercial bycatches were added to the factory production weights (as applicable) to give total catch weights of all fish and squid.

A particular issue during the survey was the presence of large numbers of small rock cod in trawls. Small rock cod tend to insert themselves into the mantles of *Loligo* in the catches (Figure 2), possibly an effect of their natural sheltering behaviour (Arkhipkin et al., 2013). For commercial production, these insertions require time-consuming manual work to extrude the rock cod before the *Loligo* can be packed. For survey data collection, these insertions require adjustment to accurately estimate the biomass of either species. Extruding individual rock cod in basket samples is likewise time-consuming and may damage organs in the mantle cavity of squid, which can then not be assessed for sex and maturity. Instead, weight proportions of inserted rock cod were estimated from random sub-samples of *Loligo* specimens taken for length-frequency measurement. Length-frequency specimens were cut open anyway, so the rock cod removed from them by cutting could be set aside and weighed as a proportion of the *Loligo* weight of the length-frquency sub-sample. That proportion was then extrapolated, deducted from the *Loligo* weight of the entire basket sample, and added to the rock cod weight of the entire basket sample.

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 net sensor) according to the equation:

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

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

Measurements of *Baffin Bay*'s trawl, provided by the vessel master, were: footrope = 120 m, sweep = 150 m and bridle = 40 m.

For three trawls on one day of the survey (18th February) the door distance sensor was nonoperational. Door distances that day were instead estimated from a generalized additive model (GAM) as a function of predictive variables trawl depth, trawl speed, net height and warp cable out; calculated with all other survey days' data on which the door distance sensor was operational (n = 389). The GAM resulted in 86.2% deviance explained. Door sensor failures appear to be a fairly common occurrence, and this GAM procedure was also used to estimate failed door distances during the surveys of the 1st season 2010 (Arkhipkin et al., 2010), 1st season 2014 (Winter and Jürgens, 2014), and 2nd season 2014 (Winter et al., 2014).

Biomass density estimates were extrapolated to the survey area using geostatistical methods (Petitgas, 2001). The delineated survey area for 1st season is

16,911 km^2, partitioned for analysis as 675 area units of 5×5 km[1]. Previous *Loligo* surveys used the approach of separately modelling positive (non-zero) catch densities, and the probability of occurrence (presence/absence) of the positive catch densities (Pennington, 1983), but for the current survey better variogram fits were obtained by modelling all catch densities per interval together. Biomass density values = 0 were augmented by the minimal value of 1 g to avoid computational problems with the geostatistic algorithm.

Uncertainty of the geostatistical model of biomass density was estimated by conditional simulation (Woillez et al., 2009), performed in the R software package 'geoR' (Ribeiro and Diggle, 2001). To this uncertainty was added a measure of error of the acoustic apportionment of the *Loligo* catch data. Assessing the acoustic marks (as described above; Sampling Procedures) is a visual judgement, and does not objectively differentiate *Loligo* from other echo targets entering the net. There is therefore no definitive way to quantify the potential error of this assessment. A surrogate measure was instead calculated using the linear coefficient of determination (R^2) between total acoustic score per trawl (Σ (acoustic mark quantity × quality)$_{\text{trawl}}$) and total *Loligo* catch per trawl. Acoustic scores are relative values referenced to each individual trawl, but as all were assigned by the same survey scientist, their absolute values should also be consistent across all trawls. The unexplained error of the linear relationship ($1 - R^2$) was multiplied by each interval catch of each trawl and randomly either added to or subtracted from the interval catch:

$$r\,C_{\text{interval}} = C_{\text{interval}} + (C_{\text{interval}} \times (1 - R^2) \times \sim r[-1 \mid 1])$$

Thus, if the relationship was perfect ($R^2 = 1$) there would be no random effect, and if the relationship was null ($R^2 = 0$) each interval would be randomly either doubled or set to zero (a negative slope is for this purpose considered equivalent to null). The set of $r\,C_{\text{interval}}$ for each trawl was re-standardized to the total *Loligo* catch weight of that trawl, then put through the same algorithms of density and geostatistic extrapolation as the empirical results. The randomization was iterated 5000× and the coefficient of variation of the mean geostatistic density retained as the measure of error of acoustic apportionment[2].

Biological analyses

Random samples of *Loligo* (target n = 150, as far as available) were collected from the factory at all trawl stations. Biological analysis at sea included measurements of the dorsal mantle length (ML) rounded down to the nearest half-centimetre, sex, and maturity stage. 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. Additional specimens of *Loligo* were collected according to area stratification (north, central, south) and depth (shallow, medium, deep), and frozen for statolith extraction and age analysis (Arkhipkin, 2005). Specimens of slender tuna (*Allothunnus fallai*), red cod (*Salilota australis*), southern

[1] The delineated survey area overlays the *Loligo* Box, but contours more closely around the fishing grounds where *Loligo* vessels actually can and do trawl.
[2] The actual randomization outcomes were not interpretable as true estimates of geostatistic density. Because randomization blurs stretches of high acoustic backscatter vs. low acoustic backscatter (given that the original patterns are not random), spatial correlation is typically weaker, and given the distribution skewness resulting from a small number of high density data, the randomized geostatistic estimates are biased lower. Thus only the relative value of the coefficient of variation is used.

blue whiting (*Micromesistius australis*), frogmouth (*Cottoperca gobio*), icefish (*Champsocephalus esox*), dogfish (*Squalus acanthias*), grenadiers (*Macrourus carinatus* and *Coelorhynchus fasciatus*), eel cod (*Muraenolepis orangiensis*), yellowbelly (*Paranotothenia magellanica*), rock cod, Patagonian hake (*Merluccius australis*) and toothfish (*Dissostichus eleginoides*) were taken for length-frequency measurement and / or otolith analysis.

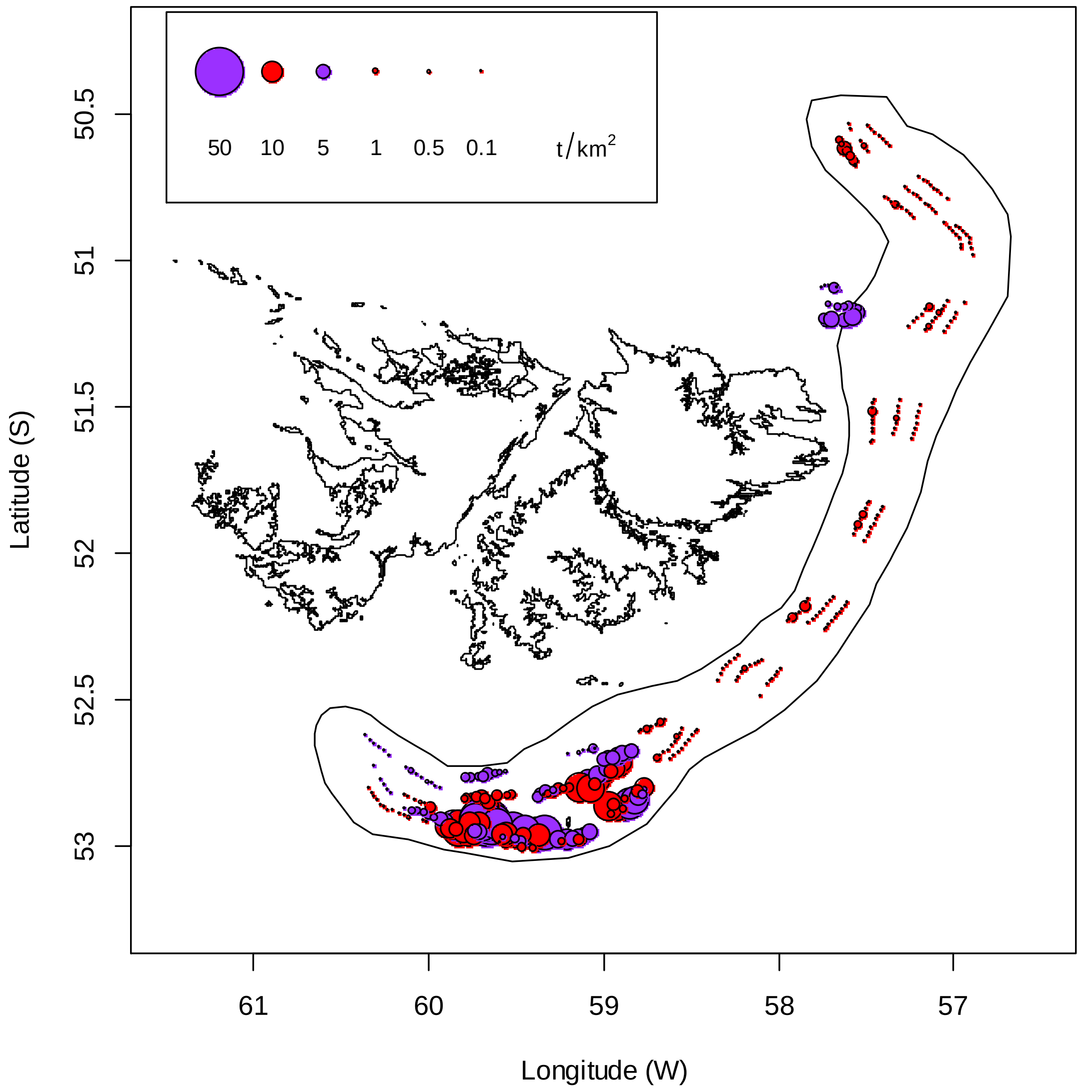


Figure 3. *Loligo* CPUE (t km^{-2}) of fixed-station trawls (red) and adaptive trawls (purple), per 15-minute trawl interval. The boundary of the survey area is outlined.

Results

Catch rates and distribution

The survey started as usual with fixed-station trawls in the north of the *Loligo* Box and proceeded south. The last day's adaptive trawls extended outside the survey area (Figure 3), as had also occurred in the 1st pre-season survey of 2013 (Winter et al., 2013), but the same delineation of the survey area was kept for comparability. A schedule of 4 scientific trawls per day was maintained except for three days: on Feb. 11th a cable broke on retrieval of the third trawl, and repairs left insufficient time for a fourth trawl; on Feb. 19th and Feb. 22nd very large trawls were taken with high proportions of small rock cod, requiring processing times too long for fourth trawls. The missed fixed-station from Feb. 11th was reprised on Feb. 23rd (Appendix Table A1). In total 57 scientific trawls were recorded during the survey: 39 fixed station trawls catching 73.63 t *Loligo* and 18 adaptive trawls catching 110.70 t *Loligo*. Eleven optional trawls (made after survey hrs) yielded an additional 62.89 t *Loligo*, bringing the total catch for the survey to 247.22 t. The scientific catch of 184.33 t is the highest for a 1st season since 2010 (Table 1).

Average *Loligo* catch density among fixed-station trawls was 0.24 t km^{-2} north of 52º S and 3.70 t km^{-2} south of 52º S. Average *Loligo* catch density among adaptive-station trawls was 3.36 t km^{-2} north of 52º S and 7.99 t km^{-2} south of 52º S. The ratio difference between north and south fixed-station catch densities (0.24 / 3.70; see Figure 3) was the highest since 1st season 2012 (Winter et al., 2012).

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

Year	First season			Second season		
	No. trawls	Catch	Biomass	No. trawls	Catch	Biomass
2006	70	376	10213	52	240	22632
2007	65	100	2684	52	131	19198
2008	60	130	8709	52	123	14453
2009	59	187	21636	51	113	22830
2010	55	361	60500	57	123	51754
2011	59	50	16095	59	276	51562
2012	56	128	30706	59	178	28998
2013	60	52	5333	54	164	36283
2014	60	124	34673	58	207	40090
2015	57	184	36424			

Biomass estimation

Density estimates from all trawl intervals were modelled with an exponential covariance function and $\lambda = 0.40$ Box-Cox transformation. The variogram was fit up to the maximum lag distance of 309.9 km, and resulted in a practical range of 225.8 km, i.e. *Loligo* densities were found to spatially correlate up to a maximum separation distance of 225.8 km (Appendix Figure A1-left). The mean *Loligo* biomass density estimate of this variogram model was 2.15 t km^{-2}, and centred well on the distribution mode of conditional simulations (Figure A1-right). Regression between total acoustic score per trawl and total *Loligo* catch per trawl resulted in $R^2 = 0.726$ (Figure A2). The coefficient of variation for acoustic apportionment derived with the randomization algorithm was = 0.010. The total coefficient of variation, combining variogram conditional simulations and acoustic apportionment, was = 0.094.

From these calculations total *Loligo* biomass in the survey area was estimated at 36,424 t, with a 95% confidence interval of [30,385 to 43,916]. The highest concentrations of *Loligo* were estimated further west of Beauchêne Island than in previous 1st seasons, around grid unit XVAJ, and for the first time in a 1st season since 2010, the north-east locus around grid unit XNAP-XPAP was found to have only marginally elevated *Loligo* densities (Figure 4). Of the estimated total biomass, 7444 t [5108 to 11634 t] were north of 52 ºS, and 28,979 t [23,375 to 35,600 t] were south of 52 ºS. Like the survey catch of *Loligo*, the pre-season biomass estimate of 36,424 t was the highest for a 1st season since 2010 (Table 1).

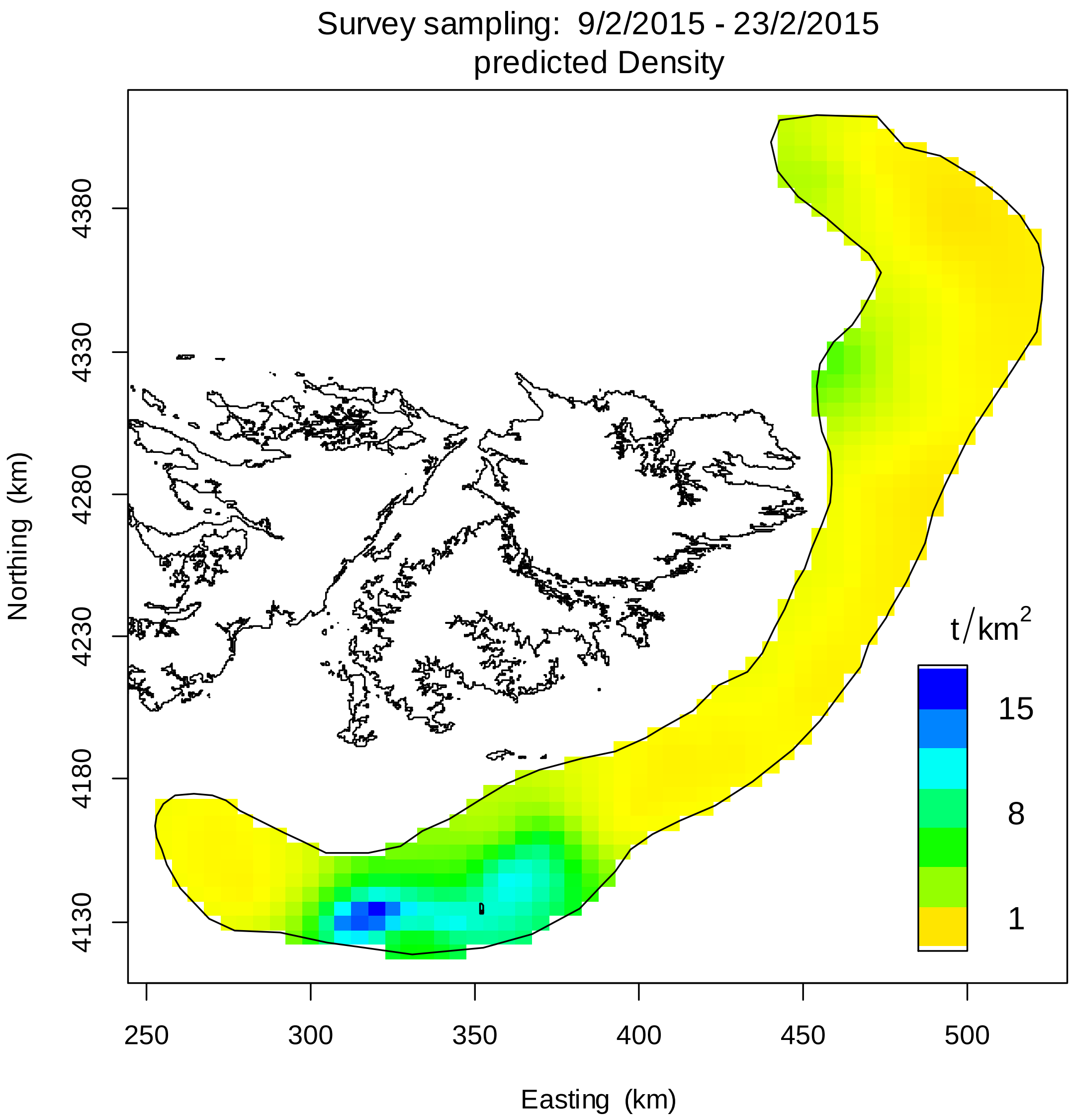


Figure 4. *Loligo* predicted density estimates per 5 km^2 area units. Coordinates were converted to WGS 84 projection in UTM sector 21F using the R library rgdal (proj.maptools.org).

Biological data

Ninety-five taxa were identified in the catches (Appendix Table A2), of which *Loligo* made up 44.5% by weight, the highest proportion in a 1st season since 2012 (Winter et al., 2012). The incidence of jellyfish had receded considerably, from representing the second-highest catch during the 1st pre-season 2014 survey (21.7%; Winter and Jürgens, 2014), to only the eighth-highest catch in this survey (Medusae + *Chrysaora* sp. = 0.5%; Appendix Table A2).

8208 *Loligo* were measured for length and maturity in the survey (2905 males, 5301 females, 2 unsexed juveniles). The *Loligo* length-weight relationship was calculated from 978 sub-sampled individuals (333 males, 643 females, 2 unsexed juveniles), resulting in optimized parameters α = 0.1279 [0.1110, 0.1491] and β = 2.3472 [2.2845, 2.4045] (Figure 5).

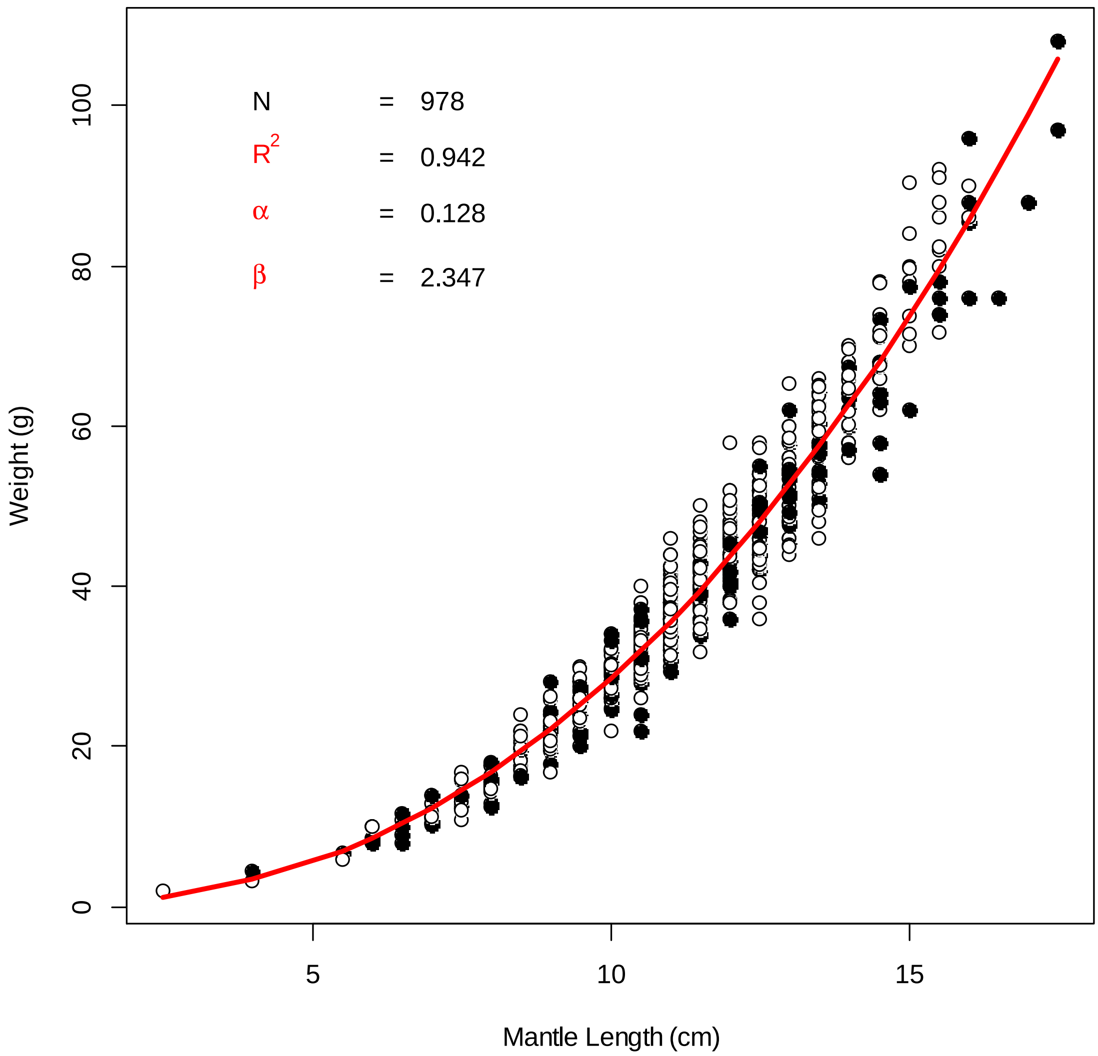


Figure 5. Length-weight relationship of *Loligo* sampled during the survey. Black points: male, white: female. Parameters refer to the combined sexes relationship (red line).

Loligo size and maturity distributions north and south of 52° S are plotted in Figure 6. *Loligo* north of 52° S had significantly higher proportions of smaller and immature males and females than south of 52° S (t-test, $p < 0.001$ all comparisons). Males north: mean mantle length 10.44 cm; mean maturity stage 1.93, males south: mean mantle length 12.39 cm; mean maturity stage 2.41. Females north: mean mantle length 10.69 cm; mean maturity stage 1.95, females south: mean mantle length 11.93 cm; mean maturity stage 2.04.

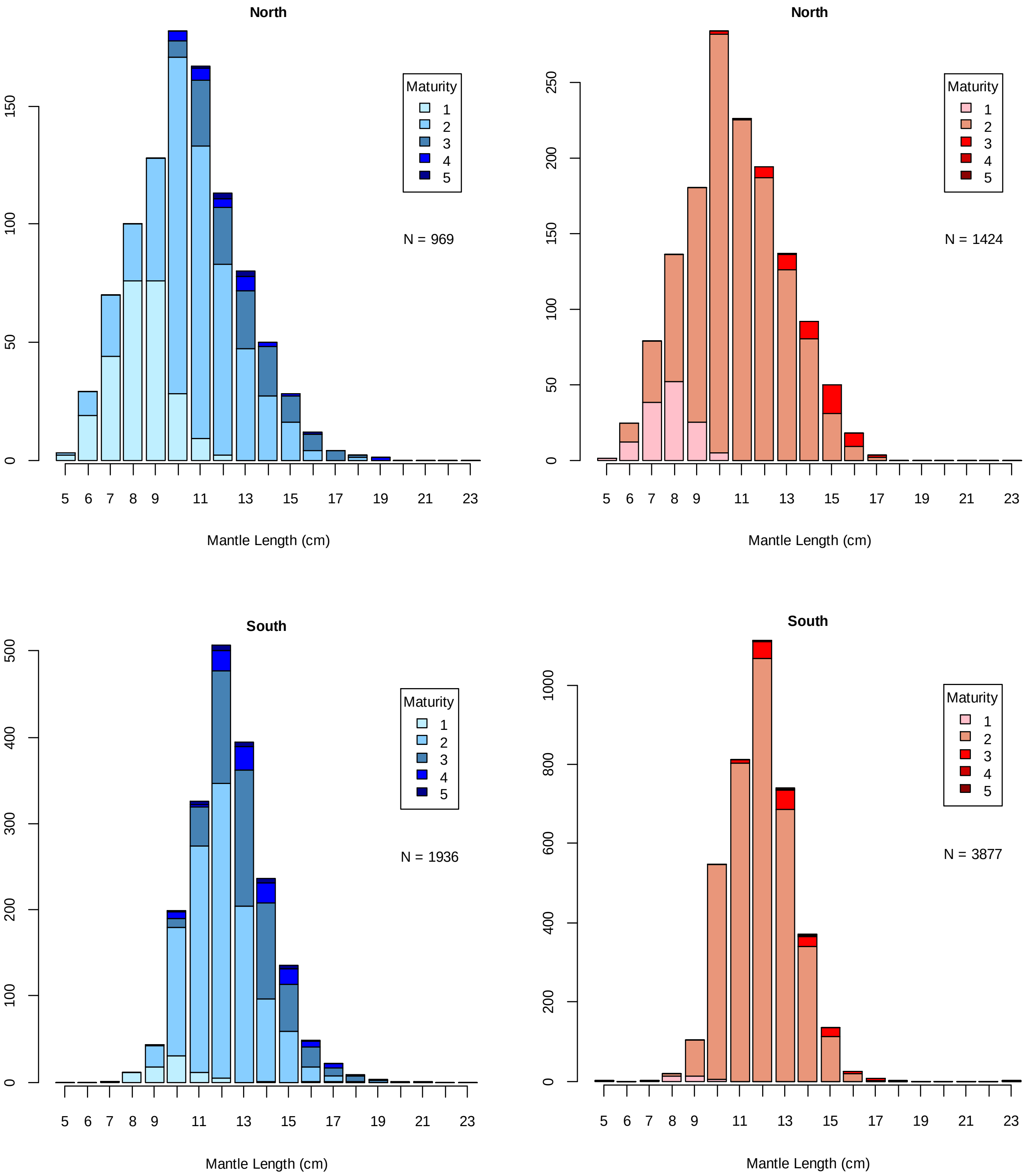


Figure 6. Length-frequency distributions by maturity stage of male (blue) and female (red) *Loligo* from trawls north (top) and south (bottom) of latitude 52 ºS.

References

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

Arkhipkin, A., Jürgens, E., Howes, P.N. 2013. Spawning, egg development and early ontogenesis in rock cod *Patagonotothen ramsayi* (Regan, 1913) caught on the Patagonian Shelf and maintained in captivity. Polar Biology 36: 1195-1204.

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. 13 p.

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

Payá, I. 2009. *Loligo gahi* Stock Assessment Survey, Second Season 2009. Technical Document, FIG Fisheries Department. 47 p.

Payá, I., Winter, A. 2009. *Loligo gahi* Stock Assessment Survey, post-Second Season 2009. Technical Document, FIG Fisheries Department. 30 p.

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

Petitgas, P. 1993. Geostatistics for fish stock assessments: a review and an acoustic application. ICES Journal of Marine Science 50: 285-298.

Ribeiro, P.J., Diggle, P.J. 2001. geoR: a package for geostatistical analysis. R-NEWS 1: 15-18.

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.

Winter, A., Davidson, D., Hancox, E. 2012. *Loligo gahi* stock assessment survey, 1st season 2012. Technical Document, FIG Fisheries Department. 24 p.

Winter, A., Jones, J., Herrera, D. 2014. *Loligo* stock assessment survey, 2nd season 2014. Technical Document, FIG Fisheries Department. 22 p.

Winter, A., Jürgens, L. 2014. *Loligo* stock assessment survey, 1st season 2014. Technical Document, FIG Fisheries Department. 18 p.

Winter, A., Jürgens, L., Monllor, A. 2013. *Loligo* stock assessment survey, 1st season 2014. Technical Document, FIG Fisheries Department. 15 p.

Woillez, M., Rivoirard, J., Fernandes, P.G. 2009. Evaluating the uncertainty of abundance estimates from acoustic surveys using geostatistical simulations. ICES Journal of Marine Science 66: 1377-1383.

Appendix

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

Transect Station	Obs Code	Date	Start Time	Start Lat	Start Lon	End Time	End Lat	End Lon	Depth (m)	*Loligo* (kg)
14 - 39	929	09/02/2015	6:30	50.58	57.51	8:17	50.61	57.36	247	0
14 - 38	930	09/02/2015	9:12	50.64	57.47	11:59	50.53	57.60	144	123
14 - 37	931	09/02/2015	12:45	50.57	57.67	14:32	50.68	57.56	138	1558
13 - 36	932	09/02/2015	16:10	50.70	57.22	18:20	50.79	57.04	247	0
13 - 35	933	10/02/2015	6:10	50.74	57.29	8:30	50.83	57.10	132	10.5
12 - 33	934	10/02/2015	9:12	50.87	57.01	11:20	50.98	56.89	120	1.6
12 - 32	935	10/02/2015	11:58	50.98	56.96	13:53	50.87	57.05	119	15
13 - 34	936	10/02/2015	14:43	50.87	57.19	17:13	50.79	57.39	130	120
10 - 28	937	11/02/2015	6:11	51.62	57.25	8:02	51.49	57.19	226	0
11 - 31	938	11/02/2015	9:40	51.26	57.08	11:30	51.14	56.94	142	5
11 - 30	939	11/02/2015	12:15	51.13	57.01	14:19	51.24	57.16	129	[A] 225
9 - 25	940	12/02/2015	6:10	51.83	57.39	8:24	51.96	57.51	221	0.2
9 - 24	941	12/02/2015	9:15	51.95	57.59	11:07	51.82	57.48	162	396
10 - 27	942	12/02/2015	12:37	51.61	57.35	14:31	51.48	57.31	147	144
10 - 26	943	12/02/2015	15:48	51.46	57.45	18:44	51.62	57.47	130	185
8 - 21	944	13/02/2015	6:08	52.14	57.82	8:21	52.23	57.95	137	410
8 - 22	945	13/02/2015	9:11	52.25	57.85	11:07	52.15	57.69	196	41
8 - 23	946	13/02/2015	12:08	52.16	57.59	14:36	52.26	57.74	263	7.6
7 - 20	947	13/02/2015	16:22	52.38	57.97	18:45	52.49	58.11	258	21
6 - 16	948	14/02/2015	6:16	52.59	58.53	8:26	52.70	58.70	165	[B] 267
6 - 17	949	14/02/2015	9:06	52.72	58.64	11:10	52.61	58.46	226	21
7 - 19	950	14/02/2015	12:29	52.45	58.27	14:24	52.36	58.09	184	123
7 - 18	951	14/02/2015	15:10	52.34	58.20	17:02	52.44	58.34	145	41
6 - 15	952	15/02/2015	6:14	52.56	58.62	7:51	52.61	58.79	134	451
5 - 12	953	15/02/2015	8:41	52.70	58.87	11:01	52.80	59.08	123	8200
5 - 13	954	15/02/2015	11:50	52.88	58.99	13:53	52.80	58.76	147	6560
5 - 14	955	15/02/2015	14:36	52.84	58.75	16:34	52.89	58.96	192	2768
4 - 10	956	16/02/2015	6:11	52.80	59.10	8:05	52.83	59.34	109	4982
3 - 7	957	16/02/2015	8:45	52.83	59.40	10:35	52.83	59.61	152	2029
3 - 8	958	16/02/2015	11:46	52.95	59.61	13:40	52.97	59.37	182	10598
4 - 11	959	16/02/2015	14:23	52.99	59.28	15:25	52.98	59.15	173	2542
3 - 9	960	17/02/2015	6:14	53.01	59.37	8:03	52.98	59.60	246	1476
2 - 6	961	17/02/2015	8:45	52.98	59.65	10:56	52.94	59.90	235	11562
2 - 5	962	17/02/2015	11:40	52.91	59.88	13:30	52.93	59.63	168	14596
2 - 4	963	17/02/2015	14:19	52.88	59.62	16:16	52.83	59.80	159	3013
0 - 1	964	18/02/2015	6:45	52.77	60.37	8:47	52.88	60.23	251	[C] 15
1 - 3	965	18/02/2015	10:27	52.92	59.98	12:40	52.88	60.20	230	[C] 267
1 - 2	966	18/02/2015	13:38	52.82	60.18	15:22	52.87	59.96	188	533
A - 1	967	18/02/2015	16:10	52.92	59.90	18:04	52.95	59.66	187	14960
A - 2	968	19/02/2015	6:15	52.74	59.53	8:13	52.77	59.78	160	2276
A - 3	969	19/02/2015	9:35	52.91	59.79	11:06	52.93	59.61	160	[D] 24128
A - 4	970	19/02/2015	11:50	52.94	59.55	13:54	52.96	59.27	162	22550
A - 5	971	20/02/2015	6:15	52.70	59.26	8:09	52.67	59.04	117	472
A - 6	972	20/02/2015	8:55	52.70	59.04	10:44	52.68	58.84	122	4982
A - 7	973	20/02/2015	11:43	52.72	58.93	13:45	52.79	59.14	129	8057
A - 8	974	20/02/2015	14:25	52.79	59.19	16:19	52.83	59.38	124	2050
A - 9	975	21/02/2015	6:21	52.82	59.89	8:25	52.74	60.13	178	267
A - 10	976	21/02/2015	9:05	52.71	60.18	10:53	52.62	60.36	199	20
A - 11	977	21/02/2015	11:40	52.68	60.35	13:40	52.82	60.22	228	62
A - 12	978	21/02/2015	14:20	52.87	60.18	16:22	52.91	59.91	189	2932
A - 13	979	22/02/2015	6:22	52.79	58.76	8:03	52.87	58.89	149	9573
A - 14	980	22/02/2015	12:49	52.97	59.60	14:50	52.99	59.35	200	3342

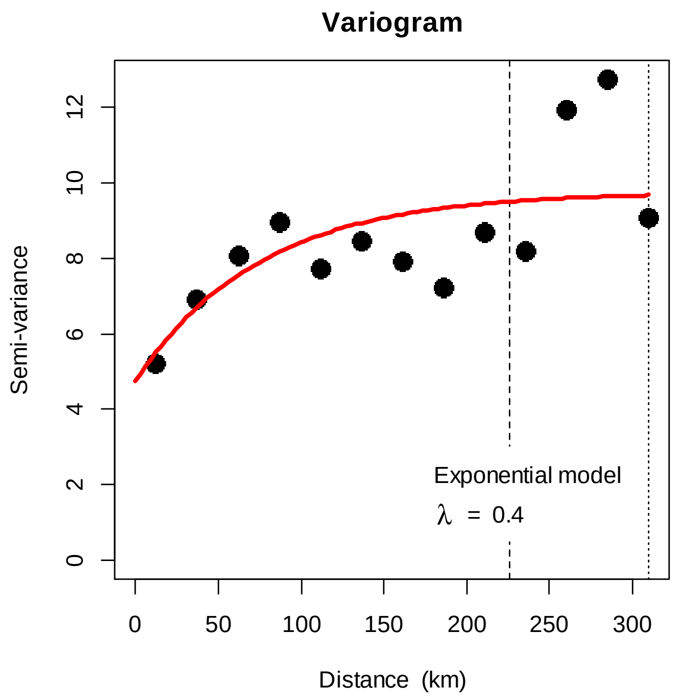
A - 15	981	22/02/2015	15:30	52.98	59.32	17:21	52.96	59.07	163		8405
11 - 29	982	23/02/2015	7:00	51.13	57.10	8:43	51.22	57.26	116		328
A - 16	983	23/02/2015	10:00	51.17	57.51	12:01	51.20	57.74	105		4961
A - 17	984	23/02/2015	12:55	51.14	57.79	14:49	51.16	57.55	115		1415
A - 18	985	23/02/2015	15:35	51.11	57.61	17:07	51.09	57.75	122	E	246

A: Broke starboard cable on retrieval. Trawl catch was not affected.
B: Track deviated slightly east because of rocky ground.
C: Started late because the night trawl was still being processed.
D: Net full; hauled back about 15 minutes earlier than planned.
E: Trawl ended early, sensors indicated too much net loading.

Table A2. Survey total catches by species / taxon.

Species Code	Species / Taxon	Total catch (kg)	Total catch (%)	Sample (kg)	Discard (kg)
LOL	*Loligo gahi*	184333	44.5	416	372
PAR	*Patagonotothen ramsayi*	166598	40.2	311	159766
BLU	*Micromesistius australis*	21951	5.3	79	18171
WHI	*Macruronus magellanicus*	16596	4	0	1375
CHE	*Champsocephalus esox*	8219	2	32	6397
SAR	*Sprattus fuegensis*	3576	0.9	0	3576
PTE	*Patagonotothen tessellata*	2629	0.6	0	2629
MED	Medusae sp.	1906	0.5	0	1906
BAC	*Salilota australis*	1495	0.4	0	864
CGO	*Cottoperca gobio*	1431	0.3	3	1431
GRF	*Coelorhynchus fasciatus*	946	0.2	7	940
TOO	*Dissostichus eleginoides*	589	0.1	163	83
RAY	Rajidae	504	0.1	0	0
SPN	Porifera	483	0.1	0	483
SQT	Ascidiacea	448	0.1	0	448
EEL	*Iluocoetes fimbriatus*	417	0.1	1	415
RGR	*Bathyraja griseocauda*	289	0.1	0	1
RBR	*Bathyraja brachyurops*	277	0.1	0	28
EGG	Eggmass	218	0.1	0	218
CHR	*Chrysaora* sp.	212	0.1	0	212
ILL	*Illex argentinus*	184	<0.1	21	157
ZYP	*Zygochlamys patagonica*	172	<0.1	0	169
RBZ	*Bathyraja cousseauae*	136	<0.1	0	1
GRC	*Macrourus carinatus*	111	<0.1	86	85
KIN	*Genypterus blacodes*	97	<0.1	0	1
RAL	*Bathyraja albomaculata*	88	<0.1	0	17
ALF	*Allothunnus fallai*	71	<0.1	71	0
RFL	*Zearaja chilensis*	69	<0.1	0	2
DGH	*Schroederichthys bivius*	69	<0.1	0	69
ING	*Moroteuthis ingens*	58	<0.1	0	58
COG	*Patagonotothen guntheri*	39	<0.1	2	37
POR	*Lamna nasus*	37	<0.1	37	0
PAT	*Merluccius australis*	34	<0.1	33	0
RMC	*Bathyraja macloviana*	28	<0.1	0	9
NEM	*Neophyrnichthys marmoratus*	25	<0.1	0	25
GOC	*Gorgonocephalas chilensis*	23	<0.1	0	23
RSC	*Bathyraja scaphiops*	20	<0.1	0	1
DGS	*Squalus acanthias*	18	<0.1	4	18
ANM	Anemone	14	<0.1	0	14
RMG	*Bathyraja magellanica*	12	<0.1	0	2

STA	*Sterechinus agassizi*	10	<0.1	0	10
RMU	*Bathyraja multispinis*	10	<0.1	0	0
MLA	*Muusoctopus longibrachus akambei*	10	<0.1	10	0
OCT	*Octopus* spp.	9	<0.1	0	9
RPX	*Psammobatis* spp.	6	<0.1	0	6
SHT	Mixed invertebrates	5	<0.1	0	5
ODM	*Odontocymbiola magellanica*	4	<0.1	0	4
MUE	*Muusoctopus eureka*	3	<0.1	2	1
RED	*Sebastes oculatus*	2	<0.1	2	1
OCM	*Octopus megalocyathus*	2	<0.1	2	0
PYM	*Physiculus marginatus*	1	<0.1	0	1
POA	*Porania antarctica*	1	<0.1	0	1
NOW	*Paranotothenia magellanica*	1	<0.1	1	1
MYK	*Myxine knappi*	1	<0.1	0	1
MYA	*Myxine australis*	1	<0.1	0	1
MAR	*Martialia hyadesi*	1	<0.1	1	0
ICA	*Icichthys australis*	1	<0.1	0	0
HYD	Hydrozoa	1	<0.1	0	1
FUM	*Fusitriton m. magellanicus*	1	<0.1	0	1
EUO	*Eurypodius longirostris*	1	<0.1	0	1
EUL	*Eurypodius latreillei*	1	<0.1	0	1
CTA	*Ctenodiscus australis*	1	<0.1	0	1
COT	*Cottunculus granulosus*	1	<0.1	0	1
BUT	*Stromateus brasiliensis*	1	<0.1	0	1
UCH	Sea urchin	<0.1	<0.1	0	0
TRP	*Tripilaster philippi*	<0.1	<0.1	0	0
THN	*Thysanopsetta naresi*	<0.1	<0.1	0	0
SUN	*Labidaster radiosus*	<0.1	<0.1	0	0
SOR	*Solaster regularis*	<0.1	<0.1	0	0
RDO	*Amblyraja doellojuradoi*	<0.1	<0.1	0	0
PYX	Pycnogonida	<0.1	<0.1	0	0
PES	*Peltarion spinosulum*	<0.1	<0.1	0	0
OPV	*Ophiacanta vivipara*	<0.1	<0.1	0	0
OPL	*Ophiuroglypha lymanii*	<0.1	<0.1	0	0
ODP	*Odontaster pencillatus*	<0.1	<0.1	0	0
NUD	Nudibranchia	<0.1	<0.1	0	0
MYX	Myxine spp.	<0.1	<0.1	0	0
MUU	*Munida subrugosa*	<0.1	<0.1	0	0
MUO	*Muraenolepis orangiensis*	<0.1	<0.1	0	0
MMA	*Mancopsetta maculata*	<0.1	<0.1	0	0
MEV	*Metelectrona ventralis*	<0.1	<0.1	0	0
LOS	*Lophaster stellans*	<0.1	<0.1	0	0
ISO	Isopoda	<0.1	<0.1	0	0
HOL	Holothuroidea	<0.1	<0.1	0	0
HCR	Paguroidea	<0.1	<0.1	0	0
GAF	*Ganaria falklandica*	<0.1	<0.1	0	0
CYX	*Cycethra* sp.	<0.1	<0.1	0	0
COL	*Cosmasterias lurida*	<0.1	<0.1	0	0
CEX	*Ceramaster* sp.	<0.1	<0.1	0	0
CAZ	*Calyptraster* sp.	<0.1	<0.1	0	0
BAO	*Bathybiaster loripes*	<0.1	<0.1	0	0
AUC	*Austrocidaris canaliculata*	<0.1	<0.1	0	0
ASA	*Astrotoma agassizii*	<0.1	<0.1	0	0
ANT	Anthozoa	<0.1	<0.1	0	0
AGO	*Agonopsis chilensis*	<0.1	<0.1	0	0
		414,501		1,283	200,055



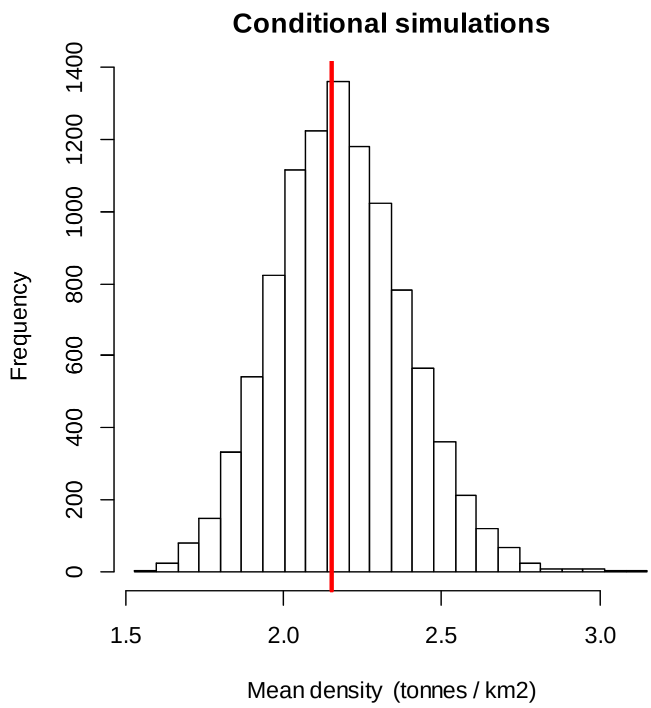


Figure A1. Left: Empirical variogram (black circles) and model variogram (red line) of *Loligo* biomass density distributions. Broken vertical line: practical correlation range of the model at 225.8 km. Dotted vertical line: maximum modelled lag distance at 309.9 km. Right: histogram of conditional simulations of mean density estimates resulting from the model variogram at left. Vertical red line: empirical mean density estimate at 2.15 t km^{-2}.

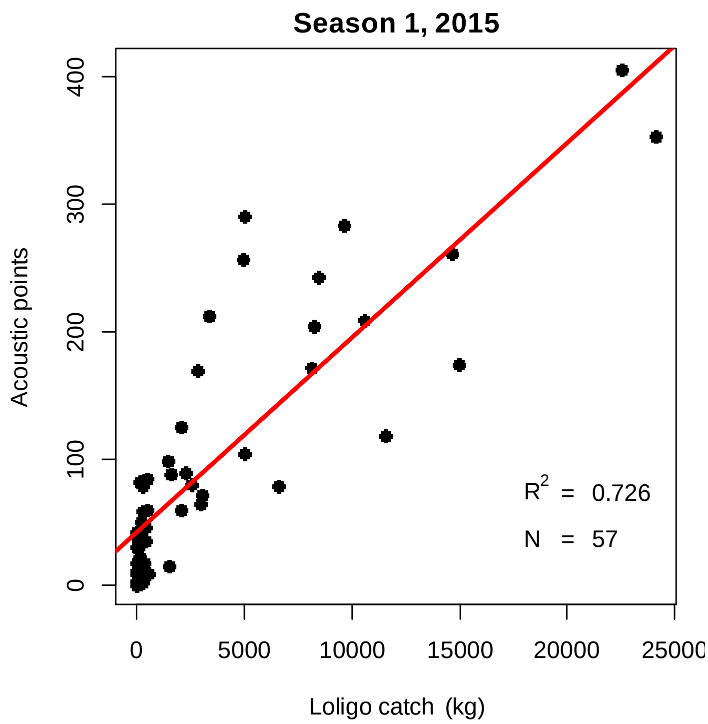


Figure A2. Total *Loligo* catch vs. total acoustic score per trawl during the 1^{st} pre-season 2015 survey, with linear regression slope (red line).