FALKLAND ISLANDS FISHERIES DEPARTMENT

Loligo Stock Assessment Survey, 2nd Season 2015

Vessel	Petrel (ZDLV), Falkland Islands
Dates	14/07/2015 - 28/07/2015
Survey Report	Jessica Jones Andreas Winter Zhanna Shcherbich Tara Boag

Summary

1) A stock assessment survey for *Loligo* squid was conducted in the 'Loligo Box' from 14th to 28th July 2015. A total of fifty-three scientific trawls were undertaken during the survey, catching 137.4 tonnes of *Loligo*.
2) A geostatistical estimate of 25,422 metric tonnes *Loligo* (95% confidence interval: 21,434 to 30,708 t) was calculated for the fishing zone. Of the total, 9,014 t were estimated north of 52 ºS, 16,407 t were estimated south of 52 ºS.
3) Both male and female *Loligo* had significantly higher average maturities south of 52 ºS compared to individuals north of 52 ºS. Females had significantly higher average mantle lengths south of 52 ºS. Females were predominantly stage 2 both north (79.7%) and south (70.1%) of 52 ºS. Males had higher average maturity than females and were predominantly stage 3 (51.0% north and 49.0% south).
4) Ninety-nine taxa were identified in the catches. *Loligo* made up the largest proportion of the catch at 66.7% by weight, followed by rock cod at 18.7% and common hake at 3.4%. Biological measurements and samples were taken from *Loligo*, rock cod, toothfish, *Illex* and opportunistic specimens of various other species.

Introduction

A stock assessment survey for *Loligo* squid (*Doryteuthis gahi* – Patagonian longfin squid) was carried out by FIFD personnel onboard the fishing vessel *Petrel* from the 14th to 28th July 2015. This survey continues a series of surveys that have, since February 2006, been conducted immediately prior to the opening of the *Loligo* season. The primary objective was 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 commercial fishing season, 2015.
2) Estimate the biomass and distribution of rock cod (*Patagonotothen ramsayi*) in the 'Loligo Box' for continued monitoring of this stock.
3) Estimate the bycatch of Patagonian Toothfish (*Dissostichus eleginoides*) in the "Loligo Box", measuring length frequency distribution and collecting otolith samples for ageing.
4) Collect biological information on *Loligo*, rock cod, toothfish, and opportunistically other commercially important fish and squid taken in trawls.

The F/V *Petrel* is a Falkland Islands-flagged stern trawler of 73.8 m length and 12 m beam, with a gross tonnage of 1635 tonnes. As with all vessels employed for these pre-season surveys, *Petrel* operates regularly in the *Loligo* fishery and used its commercial trawl gear for all survey catches. The following personnel from FIFD participated in the current survey:

Jessica Jones	fisheries observer/ lead scientist
Zhanna Shcherbich	scientific officer
Tara Boag	fisheries observer

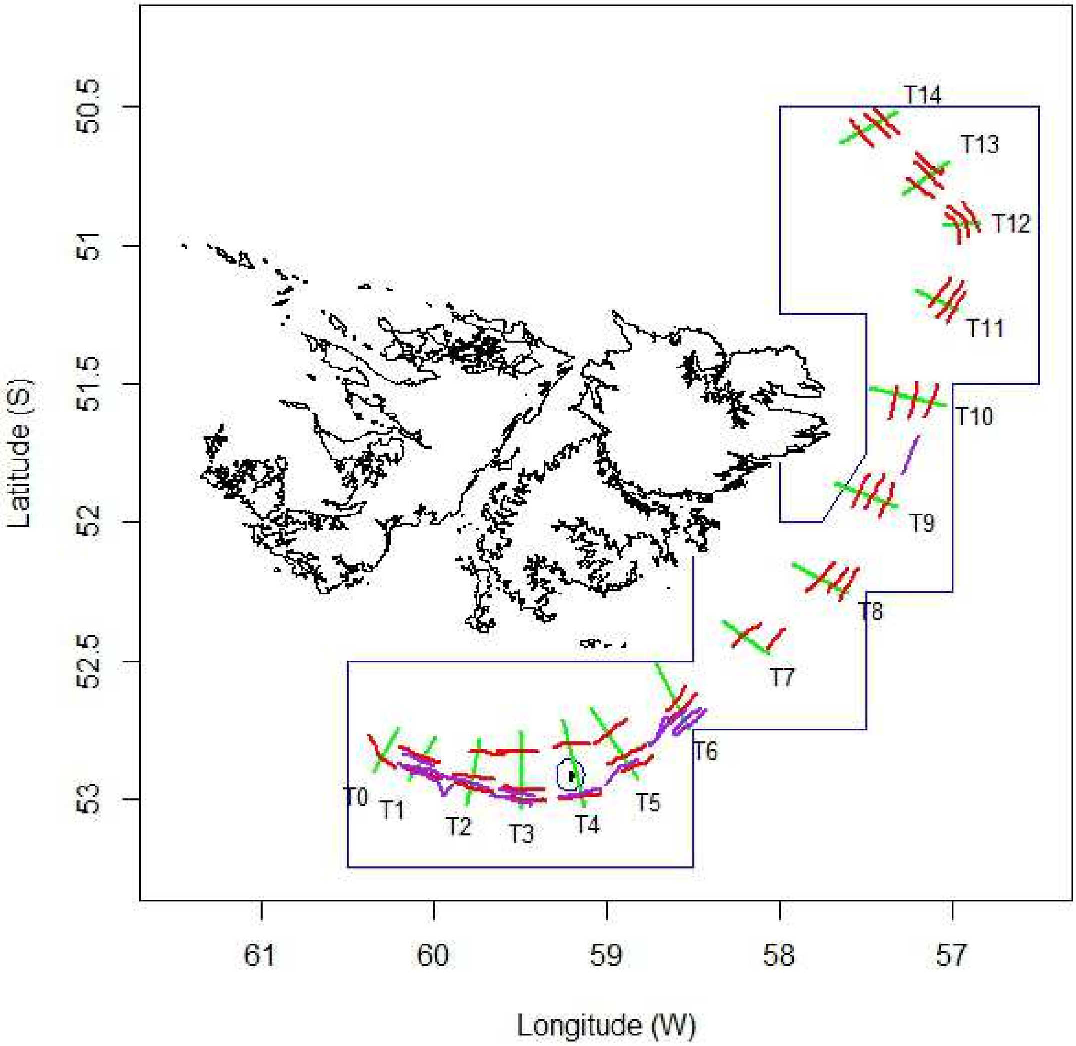

Figure 1. Transects (green lines), fixed-station trawls (red lines), and adaptive-station trawls (purple lines) sampled during the 2^{nd} pre-season 2015 survey. Boundaries of the 'Loligo Box' fishing zone and the Beauchêne Island exclusion zone are shown in blue.

Methods

Sampling procedures

The survey plan consisted of 39 fixed-station trawls located on a series of 15 transects perpendicular to the shelf break around the "Loligo Box" (Figure 1). This was followed by 14 adaptive-station trawls selected to increase the precision of *Loligo* biomass estimates in high-density or high-variability locations. For continuity, fixed-stations were the same as the second season of the previous year (Winter et al., 2014); with some trawl stations placed further offshore than during 1st season surveys.

Trawls were approximately of 2 hours duration, ranging in distance from 7.3 to 24.4 km (mean 15.5 km). All trawls were bottom trawls. During the progress of each trawl GPS latitude/longitude, bottom depth, bottom temperature, surface temperature, net height, trawl door spread, and trawl speed were recorded on the ship's bridge in 15-minute intervals. A visual assessment was made of the quantity and quality of acoustic marks (0-10 scale) observed on the net-sounder (Figure 2). For the first day of trawling, the quantity and quality of acoustic marks were discussed by the captain and survey lead scientist to ensure that assigned scores were as consistent as possible. After the first day, the captain conducted the acoustic assessments, with the survey lead scientist regularly checking interval scores for continuity.

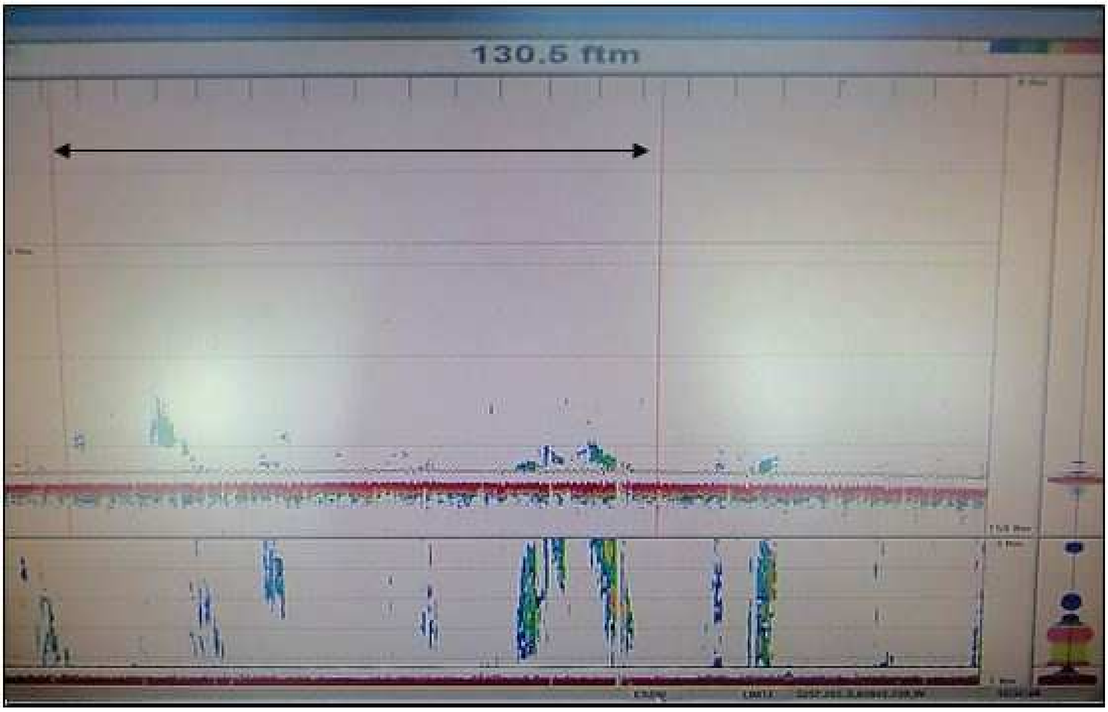

Figure 2. Image of the net-sounder with one 15 minute interval indicated by arrows. This interval had 5 marks of average quality 5.

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 vessel crew, with *Loligo* sorted and packed whole by size category. Catch weight was estimated by multiplying number of blocks of frozen *Loligo* (recorded by the factory supervisor) by the approximate weight of each block (set at 20 kg for all size classes). Catch weights of commercially valuable finfish (predominantly common hake *Merluccius hubbsi*, rock cod, and red cod *Salilota australis*) were recorded and calculated in a similar manner, categorised by size and processing method.

Catch weights of non-commercial species were estimated by proportion from visual analysis of whole catch composition, conducted by FIDF survey personnel. For rare species their entire catches were weighed. Proportions of damaged or undersized individuals of commercial species were also estimated visually and added to the factory production weights (as above) to give total catch weights for the trawl.

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 *Petrel*'s trawl, provided by the captain, were: footrope = 150 m, sweep = 116 m and bridle = 29 m. From the 17th – 20th July the door distance sensor was nonoperational. For this period door distances 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 = 366). The GAM resulted in 48.5% 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), 2nd season 2014 (Winter et al., 2014), and 1st season 2015 (Winter *et al.,* 2015).

As for prior 2nd seasons (winter seasons), a daylight effect was examined because the diel migratory behaviour of *Loligo* (Roper and Young, 1975) is likely to make them less available to trawls during darkness. Each 15-minute trawl interval (and its corresponding apportioned *Loligo* catch density) was assigned a 0 / 1 index of completion within the period of daytime, from sunrise to sunset. Sunrise and sunset times at each trawl location were calculated using the algorithms of the NOAA Earth System Research Laboratory[1]. Two sets of biomass density estimates were then calculated according to the methods described below; one using all trawl intervals, and the other using only trawl intervals completed during daytime. Biomass density distributions using all trawl intervals were found to give more consistent geostatistic models, and were therefore used for calculating the survey estimates.

Biomass density estimates were extrapolated to the survey area using geostatistical methods (Petitgas, 1993). The delineated survey area for 2nd season is 14,800 km^2, partitioned for analysis as 592 area units of 5×5 km. The previous two pre-recruitment surveys had used the approach of modelling all catch densities per interval according to a single distribution. However, the current survey obtained better

[1] www.esrl.noaa.gov/gmd/grad/solcalc/calcdetails.html

variogram fits by separately modelling positive (non-zero) catch densities and the probability of occurrence (presence/absence) of the positive catch densities (Pennington, 1983). 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). Conditional simulations were first calculated separately for the positive catch density and presence / absence geostatistical models. Error measures of acoustic apportionment of the *Loligo* catch data were added to the positive catch density conditional simulations, and random draws of the positive catch density and presence / absence conditional simulations were then multiplied together for 100,000 iterations, to obtain the variability distribution of total biomass density.

Error measures of acoustic apportionment were included because 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 no definitive way to quantify the potential error of this assessment, but a surrogate measure was calculated using the linear coefficient of determination (R^2) between total acoustic score per trawl (Σ (acoustic mark quantity × quality)$_{trawl}$) and total *Loligo* catch per trawl. Acoustic scores are relative values referenced to each individual trawl, however, as all scores were assigned by the same individuals (captain and survey scientist), their absolute values should be consistent also across all trawls. The unexplained error of the linear relationship ($1 - R^2$) between total acoustic score per trawl and total *Loligo* catch per trawl was multiplied by each interval catch of each trawl and randomly either added to or subtracted from the interval catch:

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

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 $r\,C_{interval}$ 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).

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[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 (i.e., 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.

Random samples of rock cod and toothfish (target n = 100, as far as available) were also collected at all trawl stations. Biological analysis at sea included measurements of total length (TL) rounded down to the nearest whole centimetre, sex, maturity stage and otolith extraction. Individuals that had their otoliths removed were also weighed.

The previous first season saw a large-scale ingress of *Illex argentinus* into the "Loligo Box". This resulted in early closure of the C-license fishery north of latitude 52°S and a change of target species to *Illex* south of 52°S (Winter, 2015). To continue monitoring this situation *Illex* were collected at all trawl stations in this survey (target n = 100, where available). Individuals of stomach fullness index 3 or more (3 = 75% full, 0-5 scale; Lebedev, 1946 as cited in Terrats et al., 2000) had their stomachs removed and frozen for microscopic analysis on land.

Remaining *Illex* individuals were taken for length-frequency measurement with any stomach contents visually assessed and recorded. Stomach contents were predominantly identified as *Euphausia* spp., *Themisto* spp., *Loligo, Myctophid* spp. (lantern fish) or more generally as fish when contents were too digested to identify to genus level. Visual assessment was undertaken by a survey scientist with extensive experience identifying stomach contents microscopically, to ensure the accuracy of this process. Statolith samples were taken from 350 individuals for ageing.

Specimens of red cod, icefish (*Champsocephalus esox*), bigeye grenadier (*Macrourus carinatus*), yellowbelly (*Paranotothenia magellanica*), various rock cod (*Patagonotothen* spp.), Patagonian hake (*Merluccius australis*), fathead (*Neophrynichthys marmoratus),* 3 species of octopus, Porbeagle shark (*Lamna nasus*) and moonfish (*Lampris immaculatus*) were taken for length-weight measurement and / or otolith analysis. In addition, one southern sea lion (*Otaria flavescens*) was drowned incidentally in a trawl; this specimen was also retained and frozen for post-mortem analysis on-shore.

Results

Catch rates and distribution

The survey started with fixed-station trawls in the north of the Loligo Box and proceeded south. A schedule of 4 scientific trawls per day was maintained with the exception of four days: On July 17th steaming time between trawls did not allow for a fourth trawl; on July 19th weather deteriorated throughout the day and became too rough to take a fourth trawl. The vessel sheltered overnight and the following morning around Beauchêne Island (therefore the first two trawls of July 20th were also missed; see Appendix Table A1). On the final day of the survey (July 28th) only one trawl was conducted so crew members could be disembarked in Stanley for medical reasons. In total 53 scientific trawls were recorded during the survey: 39 fixed station trawls catching 75.12 t *Loligo* and 14 adaptive trawls catching 62.28 t *Loligo*. Twelve optional trawls (made after survey hrs) yielded an additional 32.10 t *Loligo*, bringing the total catch for the survey to 169.50 t. The scientific catch of 137.40 t is the lowest for a 2nd season since 2010 (Table 1).

Average *Loligo* catch density among fixed-station trawls was 1.23 t km^{-2} north of 52° S and 1.75 t km^{-2} south of 52° S. Average *Loligo* catch density among adaptive-station trawls was 0.88 t km^{-2} north of 52° S and 3.84 t km^{-2} south of 52° S. The fixed-station catch densities (Figure 3) both north and south were the lowest for a 2nd season since at least 2009.

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	53	137	25422

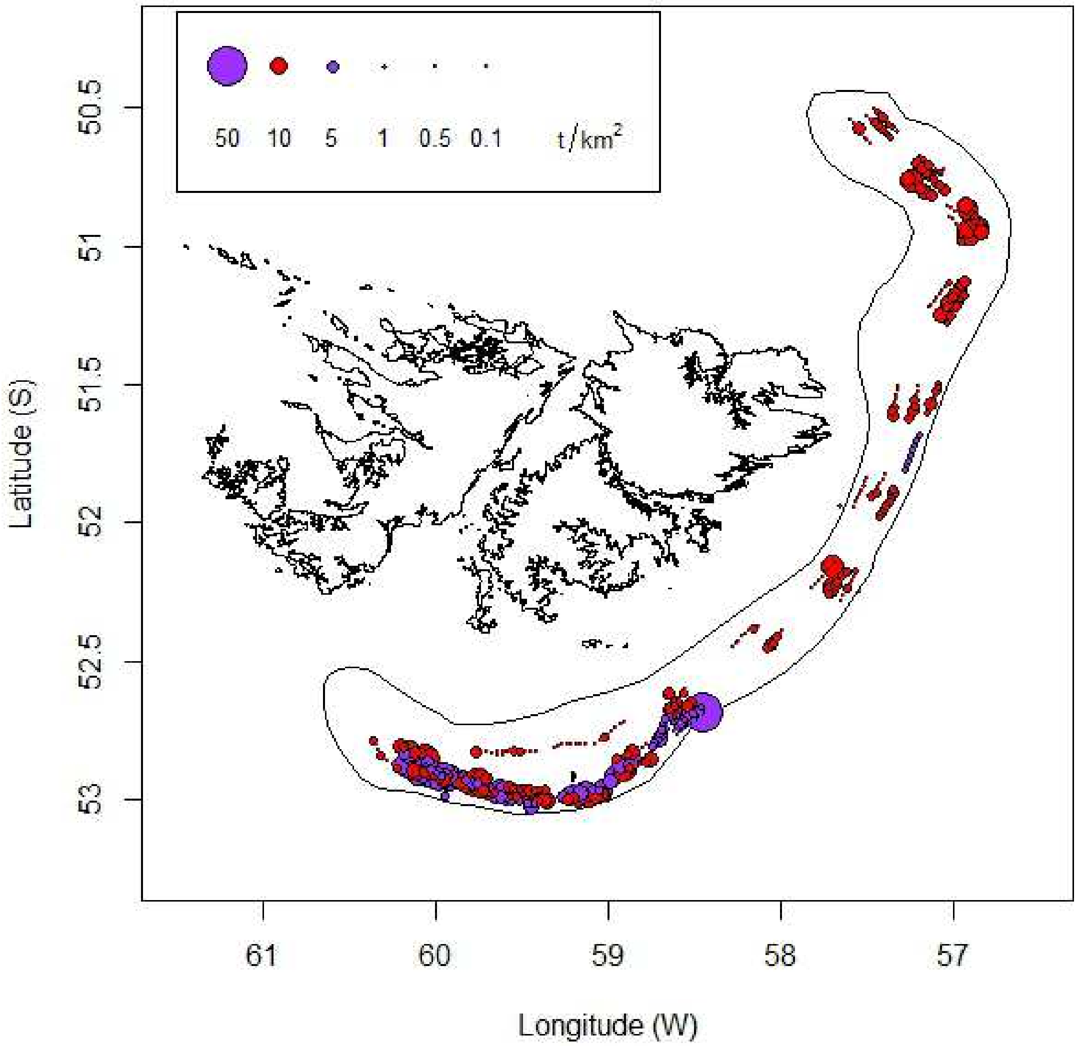


Figure 3. *Loligo* CPUE (t km^{-2}) of fixed-station trawls (red) and adaptive trawls (purple), per 15-minute trawl interval. The boundary of the survey area is outlined.

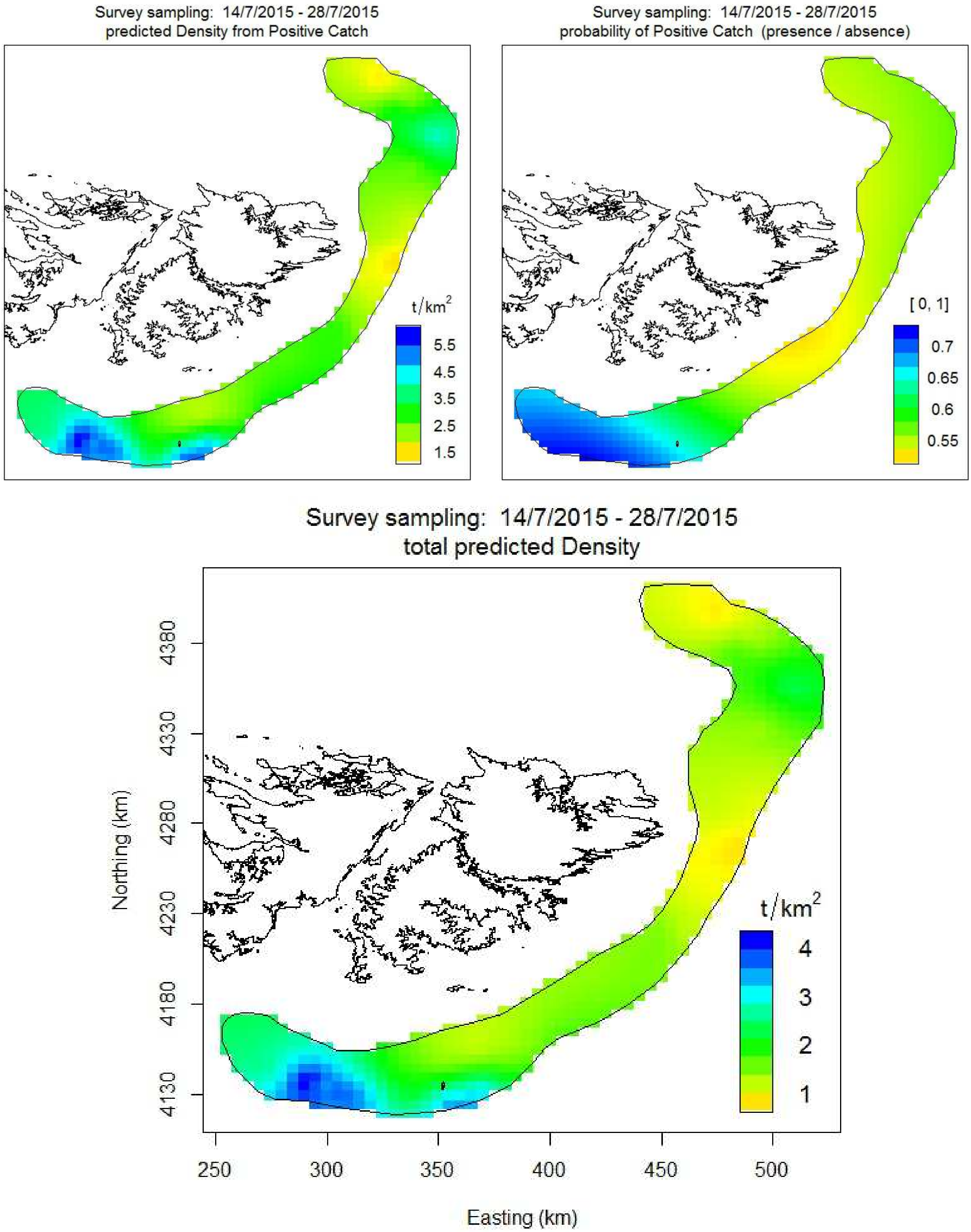


Figure 4. *Loligo* predicted density estimates per 5 km^2 area units. Top left (A): catch density distribution from variogram model of positive catches. Top right (B): probability of positive catch modelled from MCMC of presence/absence. Main plot: Predicted density = A x B. Coordinates were converted to WGS 84 projection in UTM sector 21F using the R library rgdal (proj.maptools.org).

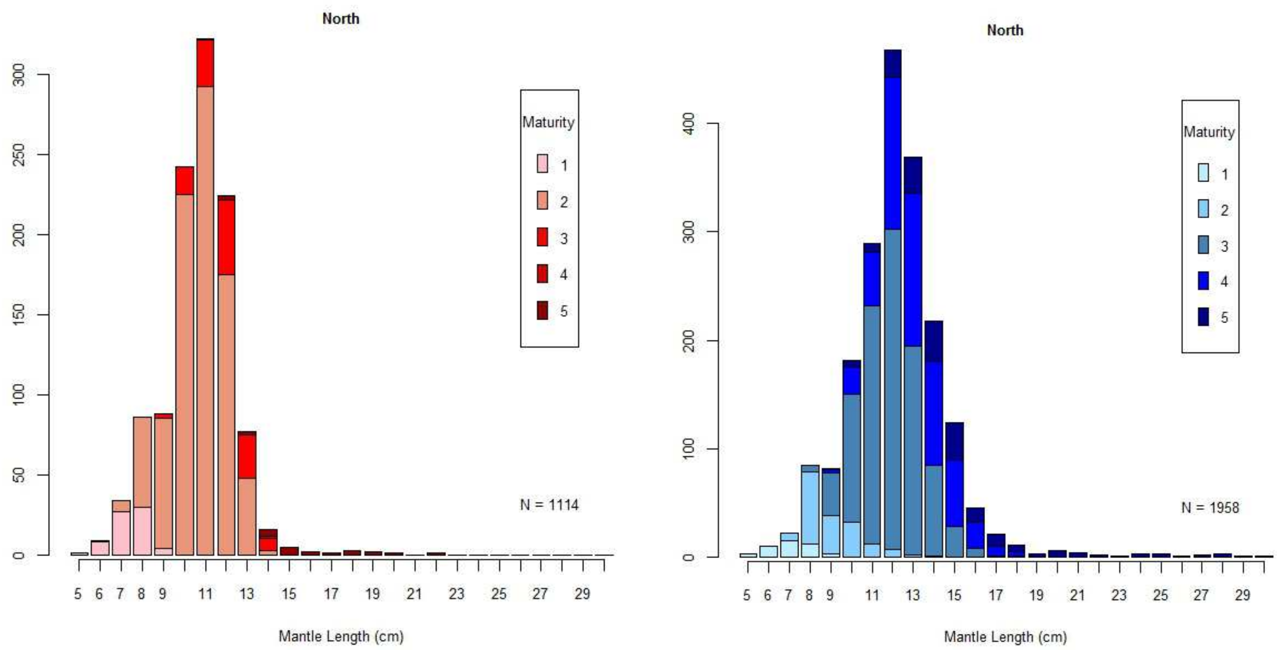
Biomass estimation

Density estimates from positive catch trawl intervals were modelled with an exponential covariance function and λ = 0 Box-Cox transformation (logarithmic transformation). The variogram was fit with unrestricted lag distance (max. = 326.5 km), and resulted in a practical range of 313.5 km, i.e. *Loligo* densities were found to spatially correlate up to a maximum separation distance of 313.5 km (Appendix Figure A1-left). The mean positive catch density estimate of this variogram model was 2.85 t km^{-2}, equivalent to the modal value of its distribution of conditional simulations (Figure A1-right). Presence / absence of catch in trawl intervals was modelled with a Cauchy covariance function and λ = 1 (no transformation, as required for binomial error distribution). This variogram was fit to a maximum lag distance of 300 km (Figure A2-left). Regression between total acoustic score per trawl and total *Loligo* catch per trawl resulted in a relatively low R^2 = 0.125 (Figure A3). Consequently, the coefficient of variation for acoustic apportionment derived with the randomization algorithm was a relatively high 0.463.

From these calculations total *Loligo* biomass in the fishing area was estimated at 25,421.6 t, with a 95% confidence interval of [21,433.9 to 30,707.7]. The highest concentrations of *Loligo* were estimated further west of Beauchêne Island than in previous 2nd seasons (Figure 4). Of the estimated total biomass, 9,014.4 t [6,797.6 to 12,124.8 t] were north of 52 ºS, and 16,407.2 t [13,146.5 to 20,402.4 t] were south of 52 ºS. The pre-season biomass estimate of 25,421.6 t was the lowest for a 2nd season since 2009 (Table 1).

Biological data

Ninety-nine taxa were identified in the catches (Appendix Table A2), of which *Loligo* made up 66.7% by weight, a similar catch proportion to previous second seasons. 8900 *Loligo* were measured for length and maturity in the survey (5059 males, 3841 females).



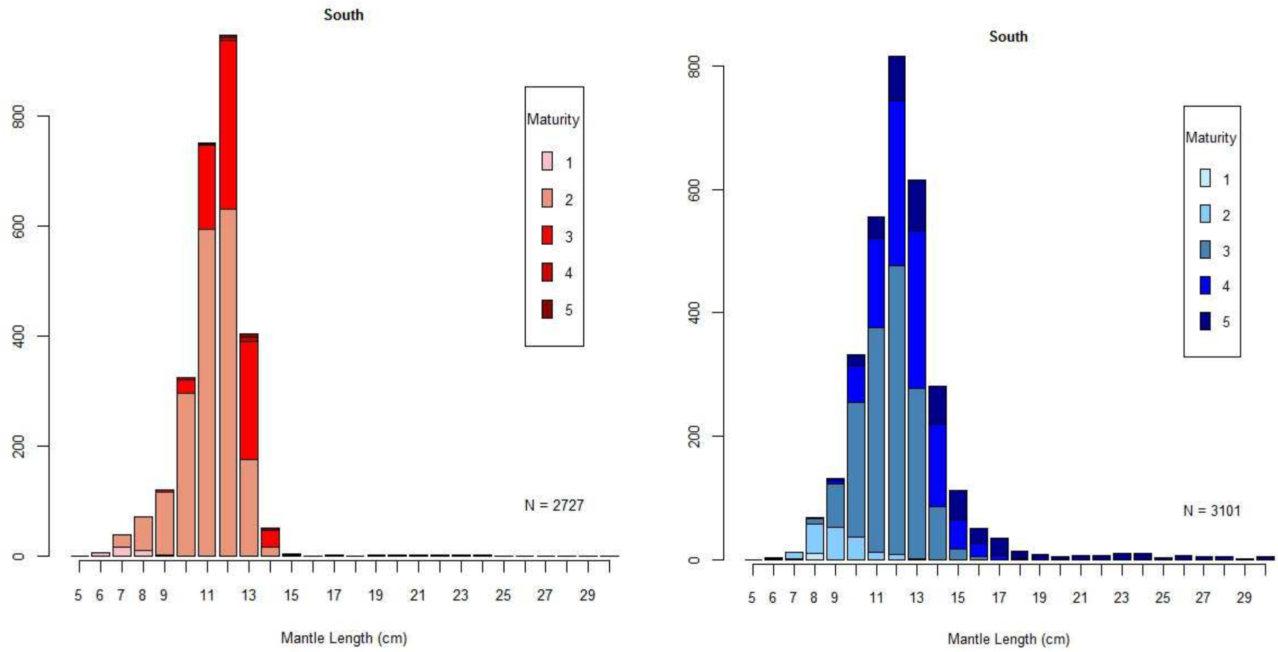
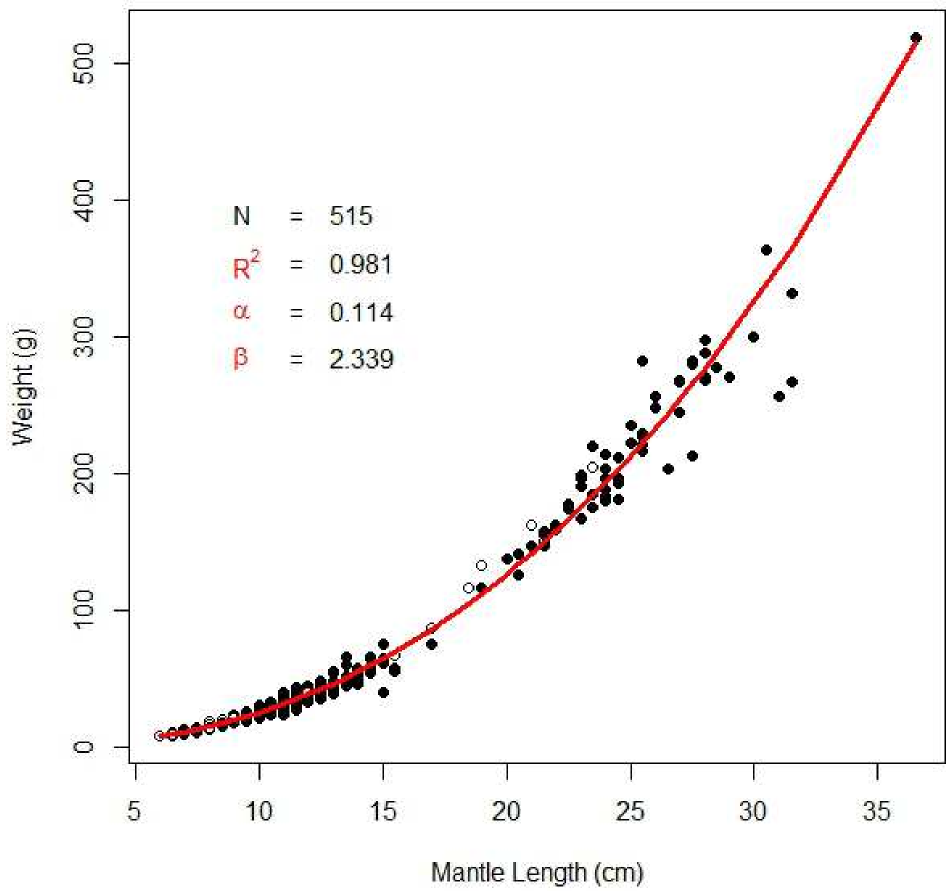


Figure 5. Length-frequency distributions by maturity stage of male (blue) and female (red) *Loligo* from trawls north (top) and south (bottom) of latitude 52 °S.

Figure 6 [below]. 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 5. The plots indicate a uni-modal distribution for both sexes in both regions. Male *Loligo* north of 52° S had significantly higher proportions of immature individuals than south of 52° S (t-test, $p < 0.001$), though there was no significant difference between their lengths (t-test, $p = 0.419$). Female *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 12.22 cm; mean maturity stage 3.36, males south: mean mantle length 12.28 cm; mean maturity stage 3.54. Females north: mean mantle length 10.69 cm; mean maturity stage 2.12, females south: mean mantle length 11.39 cm; mean maturity stage 2.30.

The *Loligo* length-weight relationship was calculated from 618 sub-sampled individuals (77 males, 541 females), resulting in optimized parameters $\alpha = 0.114$ [0.107, 0.122] and $\beta = 2.339$ [2.312, 2.365] (Figure 6).

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Appendix

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

Transect	Obs	Date	Start			End			Depth	*Loligo*
Station	Code		Time	Lat	Lon	Time	Lat	Lon	(m)	(kg)
14-39	687	14/07/2015	06:10	50.64	57.45	08:10	50.54	57.59	141.4	560
14-38	688	14/07/2015	09:05	50.52	57.51	11:05	50.61	57.35	253.4	1000
14-37	689	14/07/2015	12:00	50.59	57.30	14:00	50.51	57.45	292.9	820
13-34	690	14/07/2015	15:50	50.66	57.21	17:50	50.72	57.05	298.8	780
13-36	691	15/07/2015	07:35	50.83	57.10	09:35	50.76	57.26	133.2	2746.1
13-35	692	15/07/2015	10:40	50.70	57.22	12:40	50.80	57.05	247.3	3220
12-31	693	15/07/2015	13:45	50.84	56.93	15:45	50.95	56.84	257.0	4420
12-32	694	15/07/2015	16:50	50.97	56.90	18:50	50.85	57.03	122.8	2688.55
12-33	695	16/07/2015	06:50	50.88	57.04	08:50	51.00	56.96	116.0	200
11-30	696	16/07/2015	10:05	51.12	57.01	12:05	51.22	57.14	128.2	180
11-29	697	16/07/2015	12:45	51.26	57.09	15:00	51.13	56.93	143.3	4360
11-28	698	16/07/2015	15:50	51.16	56.92	17:50	51.28	57.03	253.7	1340
10-26	699	17/07/2015	06:50	51.49	57.19	08:50	51.63	57.25	227.8	1180 *
10-27	700	17/07/2015	10:05	51.62	57.15	12:05	51.50	57.08	289.4	1180 *
10-25	701	17/07/2015	14:30	51.63	57.36	16:30	51.51	57.31	153.4	840 *
9-22	702	18/07/2015	06:45	51.83	57.48	08:45	51.94	57.58	165.3	80 *
9-23	703	18/07/2015	09:35	51.95	57.50	11:35	51.83	57.39	222.2	1040 *
9-24	704	18/07/2015	12:20	51.86	57.33	14:20	51.98	57.42	287.1	2000 *
8-21	705	18/07/2015	16:10	52.17	57.54	18:10	52.28	57.64	325.3	320 *
8-19	706	19/07/2015	06:45	52.25	57.84	08:45	52.14	57.68	199.9	1320 *
8-20	707	19/07/2015	09:45	52.16	57.60	11:45	52.26	57.73	266.0	2280 *
7-18	708	19/07/2015	14:10	52.38	57.97	16:10	52.46	58.07	262.9	920 *
6-16	709	20/07/2015	12:15	52.59	58.53	14:15	52.68	58.66	170.0	1320 *
6-15	710	20/07/2015	15:15	52.72	58.65	17:15	52.62	58.48	230.8	2660 *
7-17	711	21/07/2015	05:55	52.37	58.11	07:55	52.45	58.27	188.6	220
5-12	712	21/07/2015	10:45	52.71	58.88	12:45	52.80	59.07	122.2	220
5-13	713	21/07/2015	12:40	52.87	59.00	14:40	52.80	58.77	146.3	1220
5-14	714	21/07/2015	16:30	52.84	58.73	18:30	52.90	58.91	297.8	2820
4-10	715	22/07/2015	06:10	52.80	59.09	08:10	52.81	59.30	109.7	40
3-7	716	22/07/2015	09:00	52.83	59.39	11:00	52.83	59.63	149.6	440
3-8	717	22/07/2015	12:15	52.95	59.61	14:15	52.97	59.36	180.1	2140
4-11	718	22/07/2015	15:10	53.00	59.27	17:10	52.97	59.02	263.2	6800
2-4	719	23/07/2015	06:10	52.83	59.80	08:10	52.82	59.56	160.0	440
2-5	720	23/07/2015	09:25	52.93	59.65	11:25	52.91	59.89	170.9	2585.76
2-6	721	23/07/2015	12:30	52.94	59.89	14:30	52.97	59.66	240.1	4986.93
3-9	722	23/07/2015	15:30	52.98	59.59	17:30	53.01	59.35	242.3	3735.5
0-1	723	24/07/2015	07:00	52.77	60.37	09:00	52.89	60.22	260.2	660
1-3	724	24/07/2015	09:55	52.88	60.19	11:55	52.93	59.95	232.1	4860
1-2	725	24/07/2015	13:00	52.87	59.97	15:00	52.81	60.20	197.2	6500
E-40	726	24/07/2015	16:15	52.87	60.22	18:15	52.91	59.97	201.7	6560
E-41	727	25/07/2015	07:10	52.96	59.68	08:25	52.95	59.79	208.8	2300 **
E-42	728	25/07/2015	09:20	52.94	59.79	11:20	52.91	59.99	196.1	6080
E-43	729	25/07/2015	12:30	52.88	60.00	14:30	52.84	60.19	194.0	5860
E-44	730	25/07/2015	15:25	52.90	60.14	17:30	52.95	59.89	257.0	8137
E-45	731	26/07/2015	06:45	52.99	59.41	08:45	52.96	59.63	201.3	6200
E-46	732	26/07/2015	09:55	52.98	59.67	11:55	53.03	59.44	263.9	4520
E-47	733	26/07/2015	12:55	53.00	59.29	14:55	52.96	59.03	192.8	6558
E-48	734	26/07/2015	15:50	52.95	59.00	17:50	52.85	58.82	202.0	5640
E-49	735	27/07/2015	07:00	52.80	58.76	09:00	52.7	58.65	216.0	1740
E-50	736	27/07/2015	10:10	52.68	58.54	12:10	52.78	58.70	240.7	1755
E-51	737	27/07/2015	13:05	52.77	58.60	15:05	52.67	58.45	277.4	1789
E-52	738	27/07/2015	16:00	52.67	58.42	18:00	52.77	58.60	303.6	4000
E-53	739	28/07/2015	07:10	51.83	57.28	09:10	51.69	57.19	291.8	1140

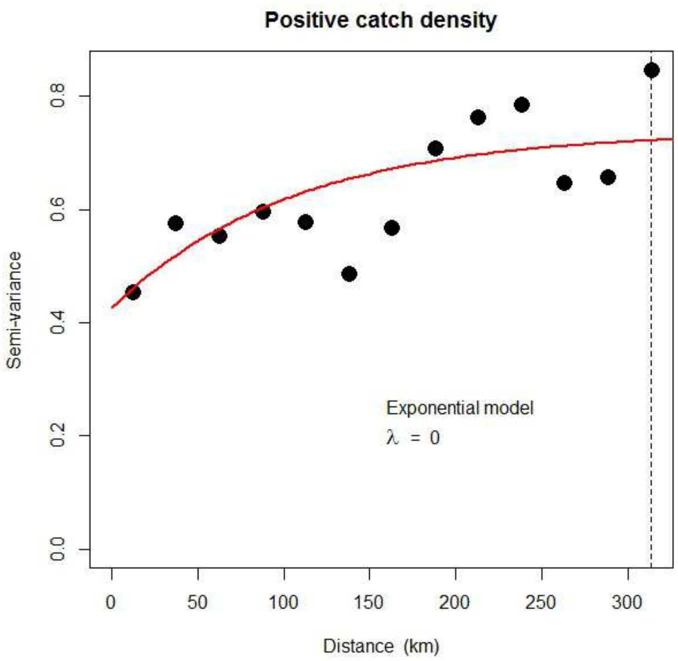
* : Door Sensors not working.
** : Net damaged by rocky substrate, trawl time reduced to 70 min.

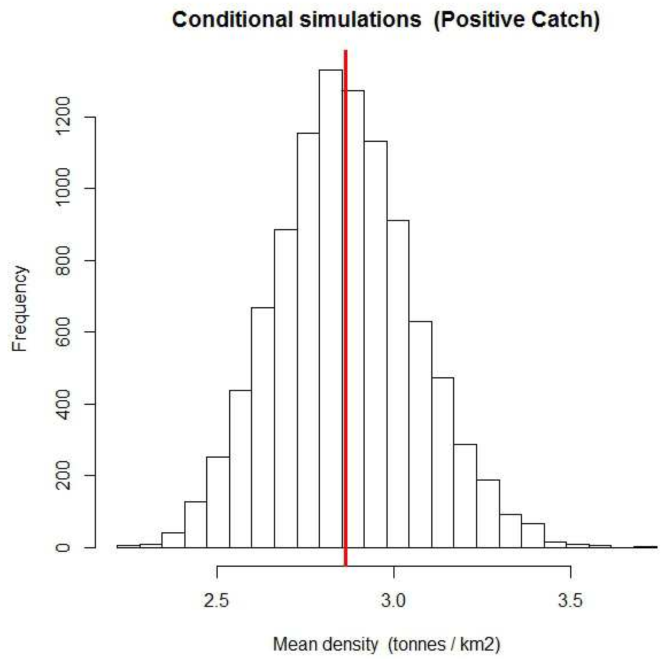
Table A2. Survey total catches by species / taxon.

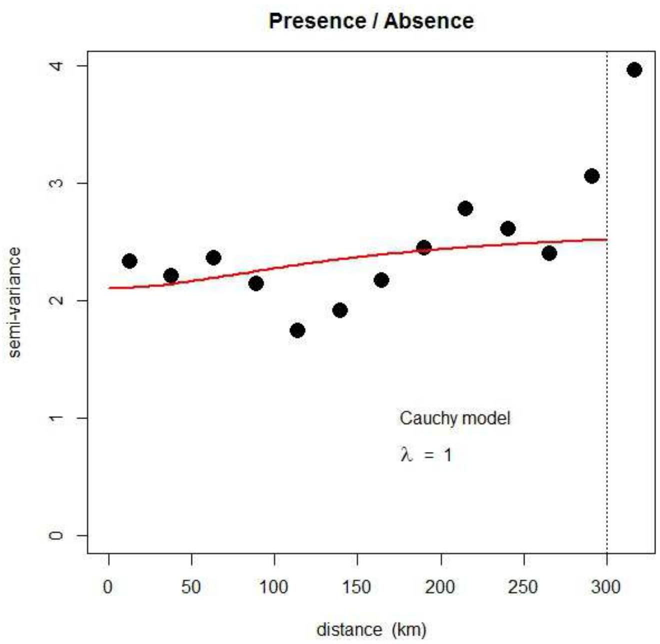
Species Code	Species	Total Catch (kg)	Total Catch (%)	Sample Weight (kg)	Discard (kg)
LOL	*Doryteuthis gahi*	137402	66.7	346	0
PAR	*Patagonotothen ramsayi*	38428	18.7	367	36485
HAK	*Merluccius hubbsi*	7064	3.4	0	60
BAC	*Salilota australis*	5253	2.5	2	1364
WHI	*Macruronus magellanicus*	2461	1.2	0	15
CGO	*Cottoperca gobio*	1986	1.0	0	1976
ILL	*Illex argentinus*	1878	0.9	492	127
GOC	*Gorgonocephalas chilensis*	1572	0.8	0	1572
DGH	*Schroederichthys bivius*	1408	0.7	0	1368
TOO	*Dissostichus eleginoides*	1265	0.6	450	227
PTE	*Patagonotothen tessellata*	1175	0.6	0	1175
MED	Medusae sp.	1172	0.6	0	1172
RBR	*Bathyraja brachyurops*	723	0.4	0	302
ZYP	*Zygochlamys patagonica*	582	0.3	0	582
SPN	Porifera	569	0.3	0	569
SUN	*Labidaster radiosus*	515	0.3	0	515
SQT	Ascidiacea	385	0.2	0	385
POR	*Lamna nasus*	300	0.1	300	0
BLU	*Micromesistius australis*	297	0.1	0	297
EEL	*Iluocoetes fimbriatus*	272	0.1	0	272
STA	*Sterechinus agassizi*	210	0.1	0	210
ANM	Anemone	171	0.1	0	171
KIN	*Genypterus blacodes*	169	0.1	0	11
RSC	*Bathyraja scaphiops*	76	<0.1	0	26
RMC	*Bathyraja macloviana*	72	<0.1	0	32
RPX	Psammobatis spp.	62	<0.1	0	62
LAR	*Lampris immaculatus*	55	<0.1	55	0
ODM	*Odontocymbiola magellanica*	50	<0.1	0	50
RAL	*Bathyraja albomaculata*	42	<0.1	0	14
RBZ	*Bathyraja cousseauae*	41	<0.1	0	8
PAT	*Merluccius australis*	37	<0.1	37	0
RMG	*Bathyraja magellanica*	36	<0.1	0	33
CAZ	Calyptraster sp.	35	<0.1	0	35
GRC	*Macrourus carinatus*	34	<0.1	1	7
CHE	*Champsocephalus esox*	33	<0.1	1	32
FUM	*Fusitriton m. magellanicus*	25	<0.1	0	25
ING	*Moroteuthis ingens*	17	<0.1	0	17
RDO	*Amblyraja doellojuradoi*	13	<0.1	0	13
RGR	*Bathyraja griseocauda*	12	<0.1	0	10
MUL	*Eleginops maclovinus*	10	<0.1	0	10
BOA	*Borostomias antarcticus*	10	<0.1	0	10
POA	*Porania antarctica*	9	<0.1	0	9

HYD	Hydrozoa	7	<0.1	0	7
OCM	*Octopus megalocyathus*	6	<0.1	6	0
MLA	*Muusoctopus longibrachus akambei*	6	<0.1	5	1
GRF	*Coelorhynchus fasciatus*	6	<0.1	0	6
COT	*Cottunculus granulosus*	6	<0.1	0	6
AST	Asteroidea	6	<0.1	0	6
ZYX	*Dead Zygochlamys*	5	<0.1	0	5
EGG	Eggmass	5	<0.1	0	5
SAR	*Sprattus fuegensis*	4	<0.1	0	4
NOW	*Paranotothenia magellanica*	4	<0.1	4	0
NEM	*Neophyrnichthys marmoratus*	4	<0.1	1	3
MUE	*Muusoctopus eureka*	4	<0.1	4	0
BAO	*Bathybiaster loripes*	3	<0.1	0	3
EUO	*Eurypodius longirostris*	2	<0.1	0	2
UCH	Sea urchin	1	<0.1	0	1
SEC	*Seriolella caerulea*	1	<0.1	1	0
RMU	*Bathyraja multispinis*	1	<0.1	0	1
RFL	*Zearaja chilensis*	1	<0.1	0	1
RED	*Sebastes oculatus*	1	<0.1	1	0
OPL	*Ophiuroglypha lymanii*	1	<0.1	0	1
OCC	Octocoralia	1	<0.1	0	1
MYX	Myxine spp.	1	<0.1	0	1
MAR	*Martialia hyadesi*	1	<0.1	1	0
EUL	*Eurypodius latreillei*	1	<0.1	0	1
CTA	*Ctenodiscus australis*	1	<0.1	0	1
COG	*Patagonotothen guntheri*	1	<0.1	1	0
CEX	Ceramaster sp.	1	<0.1	0	1
ASA	*Astrotoma agassizii*	1	<0.1	0	1
ANT	Anthozoa	1	<0.1	0	1
WRM	*Chaetopterus variopedeatus*	<0.1	<0.1	0	0
THO	Thouarellinae	<0.1	<0.1	0	0
SOR	*Solaster regularis*	<0.1	<0.1	0	0
PYX	Pycnogonida	<0.1	<0.1	0	0
POL	Polychaeta	<0.1	<0.1	0	0
PES	*Peltarion spinosulum*	<0.1	<0.1	0	0
PAS	*Patagonotothen squamiceps*	<0.1	<0.1	0	0
OPV	*Ophiacanta vivipara*	<0.1	<0.1	0	0
OPH	Ophiuroidea	<0.1	<0.1	0	0
OCT	Octopus spp.	<0.1	<0.1	0	0
NUD	Nudibranchia	<0.1	<0.1	0	0
MYA	*Myxine australis*	<0.1	<0.1	0	0
MUU	*Munida subrugosa*	<0.1	<0.1	0	0
MAV	*Magellania venosa*	<0.1	<0.1	0	0
LOS	*Lophaster stellans*	<0.1	<0.1	0	0
LOA	*Loxechinus albus*	<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
CYX	Cycethra sp.	<0.1	<0.1	0	0
CRY	Crossaster sp.	<0.1	<0.1	0	0

CRI	Crinoidea	<0.1	<0.1	0	0
COL	*Cosmasterias lurida*	<0.1	<0.1	0	0
CIR	Cirripedia	<0.1	<0.1	0	0
CAV	*Campylonotus vagans*	<0.1	<0.1	0	0
CAS	*Campylonotus semistriatus*	<0.1	<0.1	0	0
AGO	*Agonopsis chilensis*	<0.1	<0.1	0	0
ACS	*Acanthoserolis schythei*	<0.1	<0.1	0	0







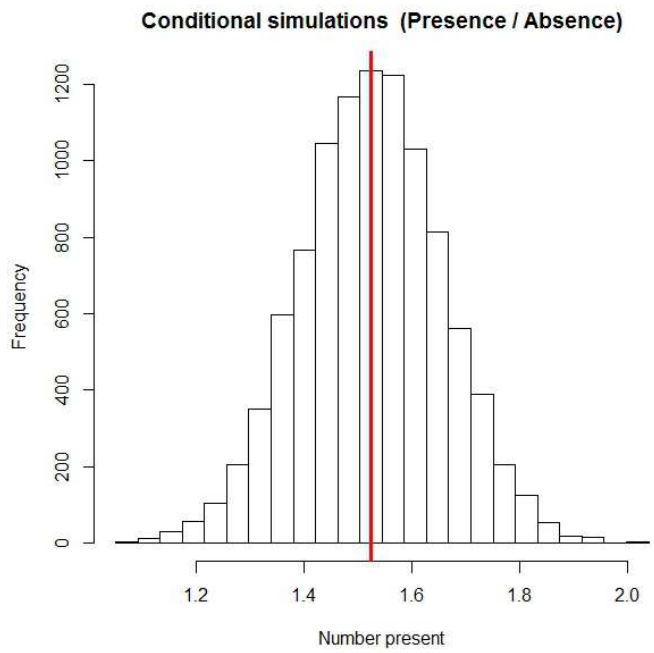


Figure A1 [above, upper]. Left: Empirical variogram (black circles) and model variogram (red line) of *Loligo* biomass density distributions from positive catch trawl intervals. Dotted vertical line: maximum modelled lag distance at 326.5 km. Right: histogram of conditional simulations of mean density estimates resulting from the model variogram at left. Vertical red line: empirical mean density estimate at 2.85 t km^{-2}.

Figure A2 [above, lower]. Left: Empirical variogram (black circles) and Cauchy model variogram (red line) of numbers of positive catch intervals present per 5×5 km area unit. Dotted vertical line: maximum modelled lag distance at 300 km. Right: histogram of conditional simulations of positive catch interval numbers resulting from the model variogram at left. Vertical red line: empirical mean number present at 1.52.

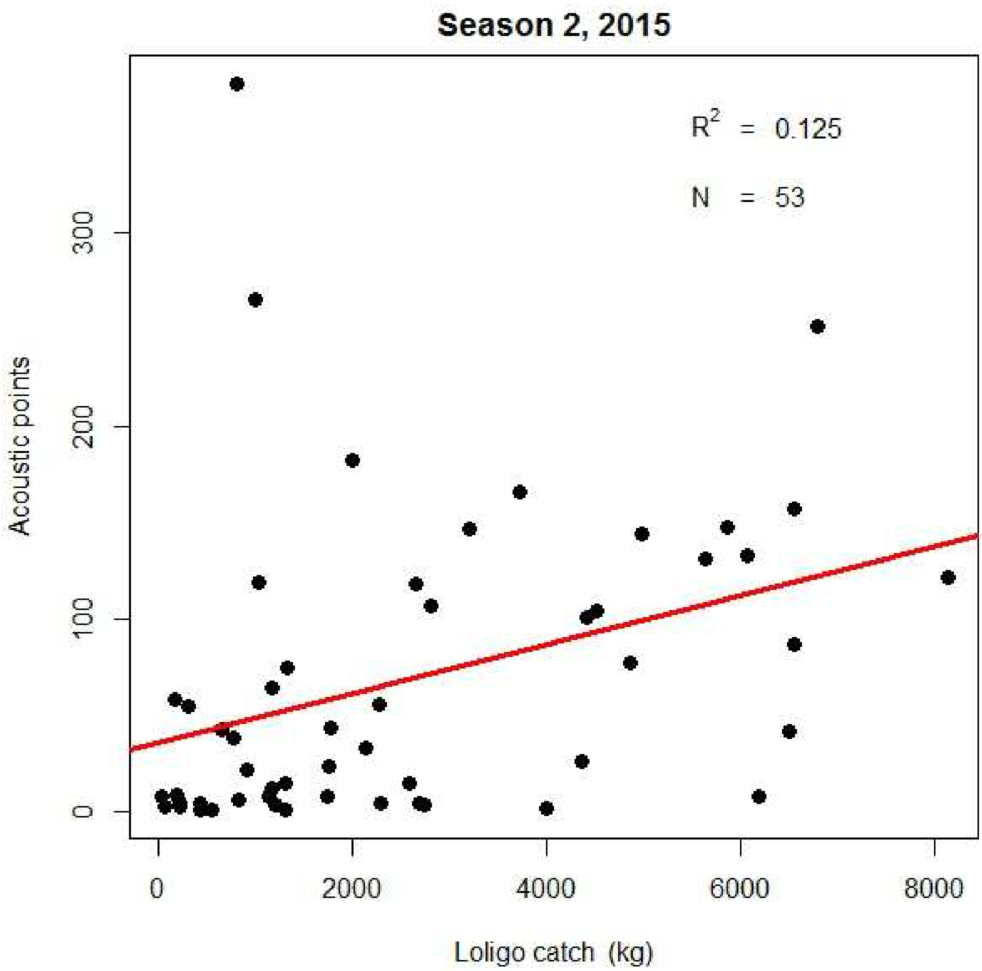


Figure A3. Total *Loligo* catch (kg) vs. total acoustic score per trawl during the 2nd pre-season 2015 survey, with linear regression slope (red line), R^2 value and number of samples included.