FALKLAND ISLANDS FISHERIES DEPARTMENT

Falkland calamari Stock Assessment Survey, 1st Season 2016

Vessel	Sil (ZDLR1), Falkland Islands
Dates	09/02/2016 - 23/02/2016
Survey Report	Andreas Winter Tomasz Zawadowski Zhanna Shcherbich Kirsty Bradley Amanda Kuepfer

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Summary

1) A stock assessment survey for Falkland calamari was conducted in the 'Loligo Box' from 9th to 23rd February 2016. Fifty-seven scientific trawls were taken during the survey, catching 64.67 tonnes of calamari.
2) A geostatistical estimate of 21,729 tonnes calamari (95% confidence interval: 17,212 to 26,228 t) was calculated for the fishing zone. This represents the lowest 1st-season survey biomass estimate since 2013. Of the total, 8520 t were estimated north of 52 ºS, and 13,209 t were estimated south of 52 ºS.
3) Male and female calamari had significantly higher average maturities and greater average mantle lengths north of 52 ºS than south of 52 ºS. Males north of 52 ºS were 32.9% and 55.2% maturity stages 1 and 2; males south of 52 ºS were 46.8% and 44.9% maturity stages 1 and 2. Females north of 52 ºS were 9.3% and 88.9% maturity stages 1 and 2; females south of 52 ºS were 22.0% and 77.0% maturity stages 1 and 2.
4) Ninety-two taxa were identified in the catches. Falkland calamari was the second-largest species group at 28.7% of total catch by weight, the lowest proportion in a 1st season since 2013. The highest catch proportion was southern blue whiting at 33.8%, occurring primarily in a small number of large catches. Biological measurements and samples were taken from calamari, rock cod, southern blue whiting, toothfish, and opportunistic specimens of various other species.

Introduction

A stock assessment survey for Falkland calamari (*Doryteuthis gahi* – Patagonian longfin squid – colloquially *Loligo*) was carried out by FIFD personnel onboard the fishing vessel *Sil* from the 9th to 23rd February 2016. This survey continues the series of surveys that have, since February 2006, been conducted immediately prior to season openings to estimate the calamari 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 Falkland calamari on the fishing grounds at the onset of the 1st fishing season, 2016.
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 Falkland calamari, rock cod, toothfish (*Dissostichus eleginoides*) and opportunistically other commercially important fish and squid taken in the trawls.
4) Evaluate the new Fixed Aerial Array system that had been fitted on the FV *Sil* as an alternate seabird mitigation device, and monitor seabird interactions.

The F/V *Sil* is a Falkland Islands - registered stern trawler of 71.09 m length, 2156 gross register tonnage, and 3850 main engine bhp. Like all vessels employed for these pre-season surveys, *Sil* operates regularly in the Falkland calamari fishery and used its commercial trawl gear for the survey catches. *Sil* has previously been used for the pre-season survey of the 2nd season 2007 (Payá, 2007). The following personnel from the FIFD participated in the 1st season 2016 survey:

Tomasz Zawadowski	fisheries observer / lead scientist
Zhanna Shcherbich	fisheries biologist
Kirsty Bradley	fisheries observer
Amanda Kuepfer	seabird observer

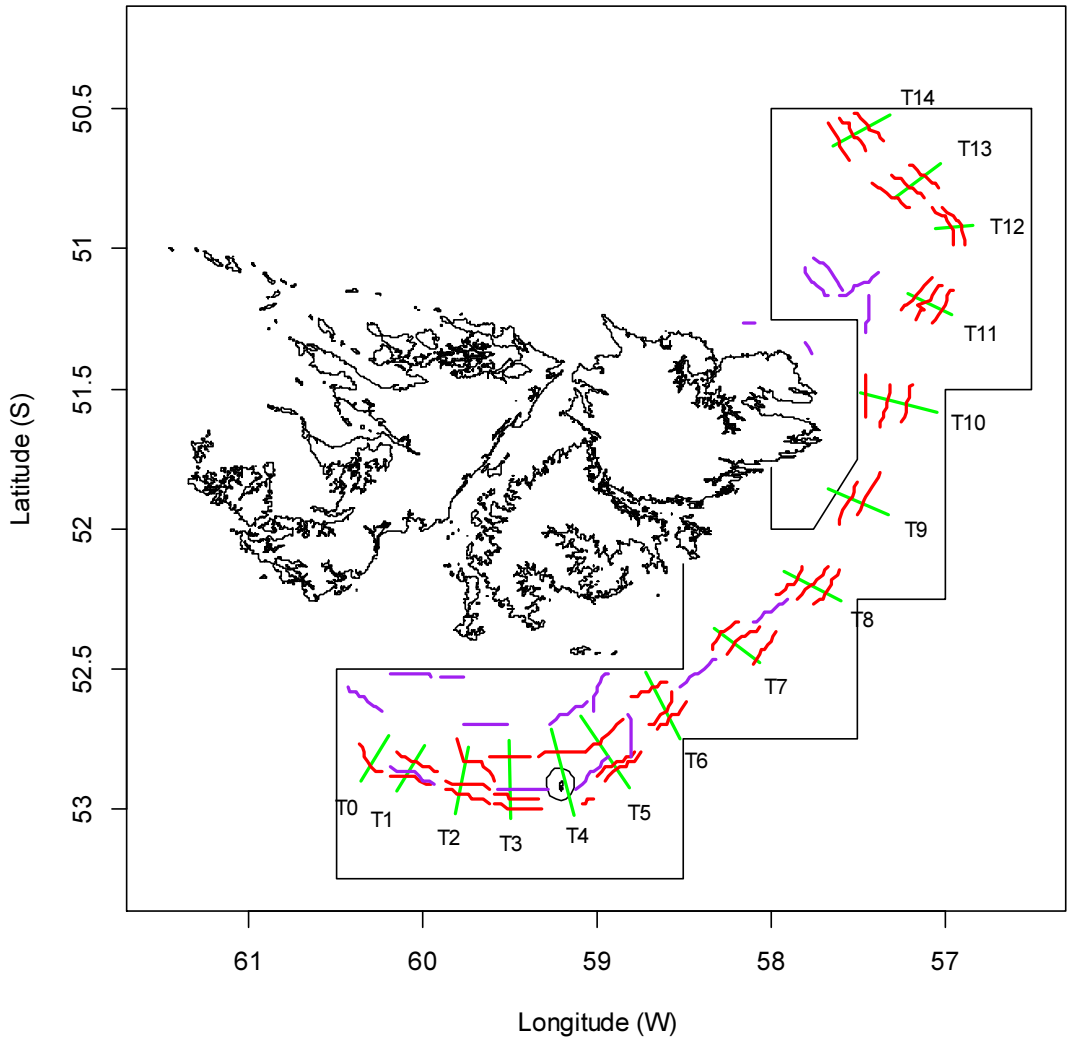


Figure 1. Transects (green lines), fixed-station trawls (red lines), and adaptive-station trawls (purple lines) sampled during the 1st pre-season 2016 survey. Boundaries of the 'Loligo Box' fishing zone and the Beauchêne Island exclusion zone are traced in black.

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 calamari biomass estimates in high-density or high-variability locations. The same fixed-station survey plan as both previous 1st season (Winter and Jürgens, 2014, Winter et al., 2015) 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, and ranged in distance from 5.5 to 25.7 km (mean 17.6 km). On the last survey day (23rd February) two short trawls were taken nearshore northeast outside the Loligo Box (Figure 1), to examine abundance in a probable spawning / nursery area. A similar survey extension to that area had been undertaken in the 1st pre-season survey of 2013 (Winter et al., 2013). 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. During this survey, acoustic marks were assessed by the vessel's bridge officers. Following the procedure described in Roa-Ureta and Arkhipkin (2007), the acoustic marks were used to apportion the calamari catch of each trawl to the 15-minute intervals and thereby increase spatial resolution of the catches. For small catches acoustic apportioning cannot be assessed with accuracy, and any calamari amounts <100 kg were iteratively aggregated by adjacent intervals (if the total calamari 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 and retained catch weight of calamari, by size category, was estimated from the number of standard-weight blocks of frozen calamari 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 0[a] and 6 observer baskets were collected from each survey trawl, depending on its volume and the sampling schedule. 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.

Biomass calculations

Biomass density estimates of calamari 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

[a] One trawl was zero sampled: this trawl contained >60 tonnes blue whiting composing >95% blue whiting and had to be dumped.

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 distance × footrope length) / (footrope + sweep + bridle)[b]

Measurements of the FV *Sil*'s trawl, provided by the vessel master, were: footrope = 120 m, sweep + bridle = 150 m. for the two nearshore survey trawls taken on the last day, a smaller net was used with sweep + bridle = 143 m.

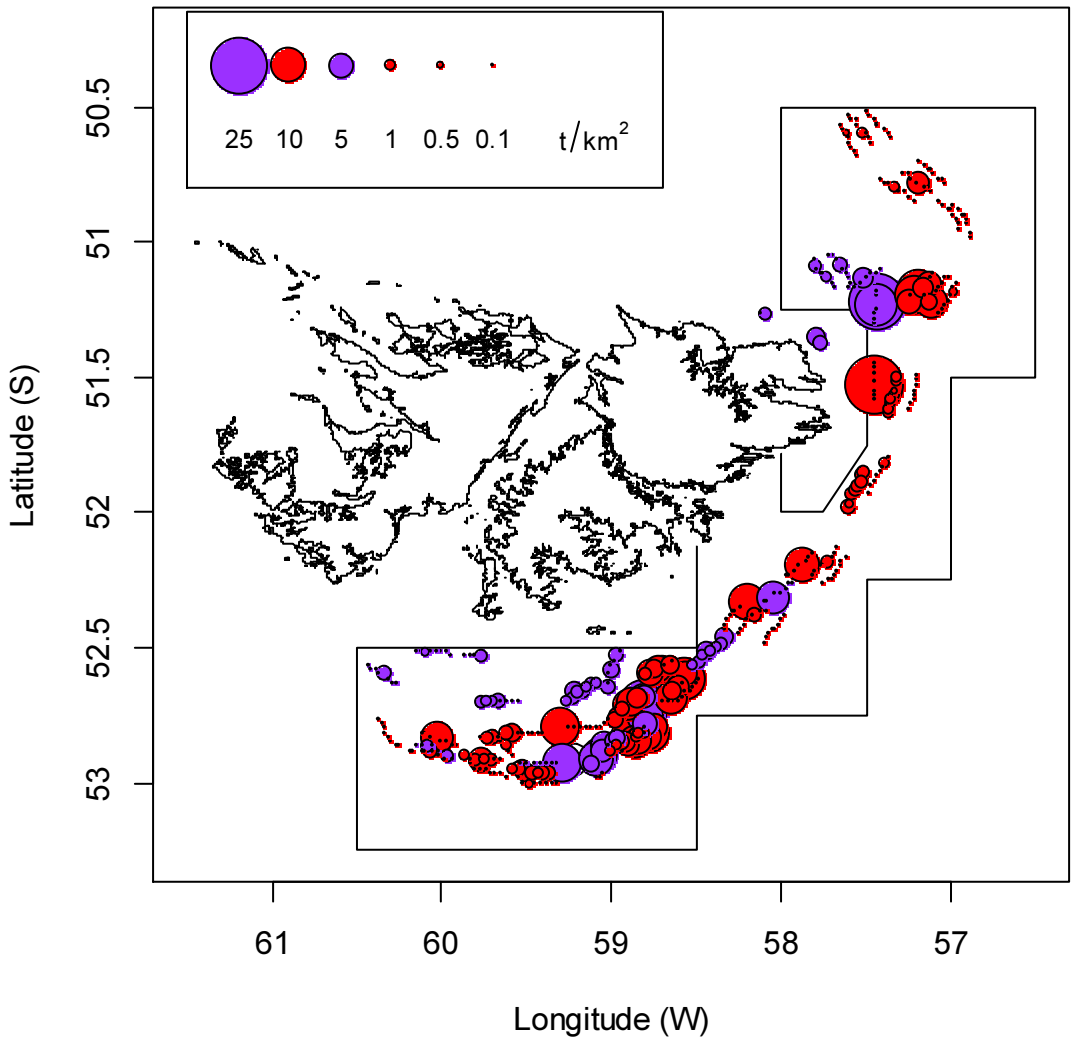


Figure 2. Falkland calamari CPUE (t km^{-2}) of fixed-station trawls (red) and adaptive trawls (purple), per 15-minute trawl interval. The boundary of the survey area is outlined.

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. A zero-inflated

[b] www.seafish.org/Publications/FS40_01_10_BridleAngleandWingEndSpread.pdf

approach was used of fitting geostatistic variograms separately to positive (non-zero) calamari catch densities, and to the probability of occurrence (presence/absence) of the positive catch densities (Pennington, 1983). Positive catch densities were normalized with Box-Cox transformations (MacLennan and MacKenzie, 1988).

Variability of the geostatistical models of biomass density was estimated by conditional simulation (Woillez et al., 2009), performed in R software package 'geoR' (Ribeiro and Diggle, 2001). Conditional simulations of positive catch densities and presence / absence were randomly drawn and multiplied together 250,000× for a combined variability distribution. To this variability was added a measure of error of the acoustic apportionment of the calamari catch data. Assessing the acoustic marks (as described above; Sampling Procedures) is a visual judgement, and does not objectively differentiate calamari from other echo targets entering the net. There is therefore no definitive way to quantify the potential error of this assessment. In the previous three surveys (Winter et al., 2014, 2015, Jones et al., 2015) 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 calamari catch per trawl. Acoustic scores are relative values referenced to each individual trawl, but as all were assigned by the same survey scientist in these surveys, their absolute values should also be consistent across all trawls. In the 1st pre-season 2016 survey acoustic scores were assigned by the vessel's bridge officers instead of the survey scientist and obtained inadequate consistency for this measure. Instead, an approximate average of $R^2 = 0.5$ based on the previous three surveys was used. The unexplained error of the linear relationship ($1 - R^2 = 0.5$) was multiplied by each interval catch of each trawl and randomly either added to or subtracted from the interval catch:

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

The set of $r\,C_{interval}$ for each trawl was re-standardized to the total calamari catch weight of that trawl, then put through the same algorithms of density and geostatistic extrapolation as the empirical results. The randomization was iterated 10000× and the coefficient of variation of the mean geostatistic density retained as the measure of error of acoustic apportionment[c].

Biological analyses

Random samples of calamari (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 rounded down to the nearest half-centimetre, sex, and maturity stage. The length-weight relationship $W = \alpha \cdot L^{\beta}$ (Froese, 2006) for calamari was calculated by optimization from a subset of individuals that were weighed as well as measured. The 95% confidence interval of the length-weight relationship was calculated by Monte-Carlo resampling. Additional specimens of calamari 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*), southern blue

[c] 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 was used.

whiting (*Micromesistius australis*), icefish (*Champsocephalus esox*), patchy benthoctopus (*Muusoctopus eureka*), yellowfin rock cod (*Patagonotothen guntheri*), common rock cod, grenadier (*Macrourus carinatus*), Argentine shortfin squid (*Illex argentinus*), Patagonian hake (*Merluccius australis*), kingclip (*Genypterus blacodes*), porbeagle shark (*Lamna nasus*), redfish (*Sebastes oculatus*), grey-tailed skate (*Bathyraja griseocauda*) and toothfish (*Dissostichus eleginoides*) were taken for length-frequency measurement and / or otolith analysis.

Seabird observations

The 1st pre-season 2016 survey was joined by the FIFD seabird observer, with the primary assignment of evaluating the efficacy of the FV *Sil*'s new Fixed Aerial Array for seabird mitigation. Additionally, the seabird observer monitored seabird interactions throughout the survey, in accordance with Fisheries Department standard protocol (FIFD, 2016).

Results

Catch rates and distribution

The survey started as usual with fixed-station trawls in the north of the Loligo Box and proceeded south. From about the middle of the survey a more interspersed schedule was taken of adaptive trawls alternating with remaining fixed-station trawls (Appendix Table A1). The two nearshore trawls on the last day were included in the geostatistical model with all other survey trawls. The same delineation of the survey area was kept for comparability with previous years. A schedule of 4 survey trawls per day was maintained except for February 21st, when only three survey trawls were taken before transiting back to the north, and February 23rd, when only the two nearshore trawls outside the Loligo Box were scheduled. In total 57 scientific trawls were recorded during the survey: 39 fixed station trawls catching 41.36 t calamari and 18 adaptive trawls catching 23.30 t calamari. Fifteen optional trawls (made after survey hrs) yielded an additional 77.57 t calamari, bringing the total catch for the survey to 142.24 t. The scientific survey catch of 64.67 t is the lowest for a 1st season since 2013 (Table 1).

Table 1. Falkland calamari pre-season survey catches (scientific trawls only) 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
2016	57	65	21729			

Average calamari catch density among fixed-station trawls was 0.73 t km^{-2} north of 52º S and 1.28 t km^{-2} south of 52º S. Average calamari catch density among adaptive-station trawls was 1.23 t km^{-2} north of 52º S and 5.52 t km^{-2} south of 52º S. The fixed-station catch density north (0.73 t km^{-2}) was the highest for a 1st season since at least 2011; whereas the fixed-station catch density south (1.28 t km^{-2}) was average. As a result, the north / south catch density ratio (0.73 / 1.28 = 0.57, see Figure 2) was the most even since at least 2011.

Biomass estimation

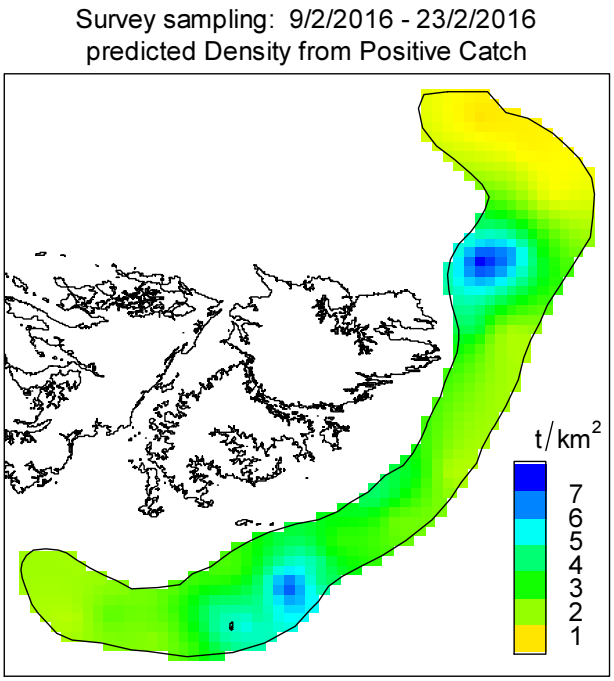
Density estimates from positive catch trawl intervals were modelled with an exponential covariance function and $\lambda = 0.30$ Box-Cox transformation. The variogram was fit with unrestricted lag distance, and resulted in a practical range of 251.1 km, i.e. calamari densities were found to spatially correlate up to a maximum separation distance of 251.1 km (Appendix Figure A1-left). The mean calamari biomass density estimate of this variogram model was 2.81 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 an exponential covariance function and $\lambda = 1$ (no transformation, as required for binomial error distribution). This variogram was fit to a maximum lag distance of 280 km (Figure A2-left). The mean number of positive catch intervals estimated per 5×5 km area unit was 0.667, and centred well on the distribution mode of conditional simulations (Figure A2-right). The coefficient of variation for acoustic apportionment derived with the randomization algorithm using $R^2 = 0.5$ was = 0.038.

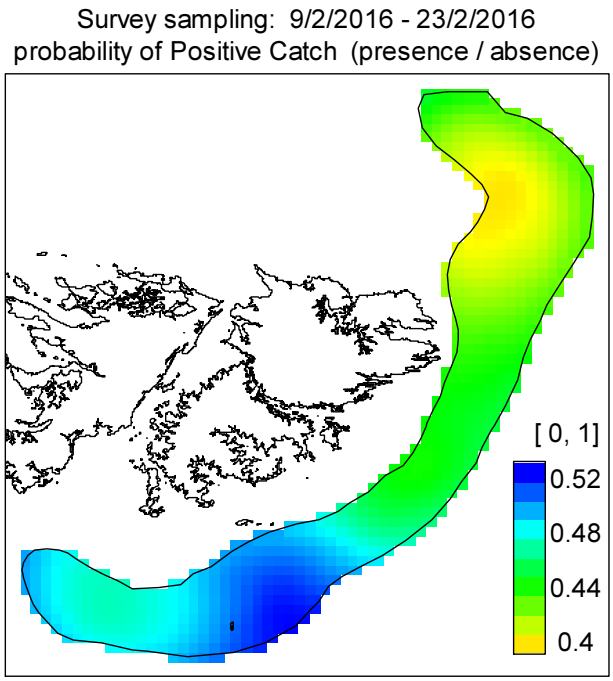
From these calculations, total Falkland calamari biomass in the fishing area was estimated at 21,729 t, with a 95% confidence interval of [17,212 to 26,228]. Two calamari concentrations were obtained by the geostatistical models, both in usual locations: east of Beauchêne Island and near the northern spawning area (Figure 3). the evenness of catch density ratios between north and south was reflected in the probabilities of positive catch ranging only from 0.40 to 0.52 (Figure 3, top right). Of the estimated total biomass, 8520 t [5901 to 11,382 t] were north of 52 ºS, and 13,209 t [9813 to 16,729 t] were south of 52 ºS. Like the survey catch of calamari, the survey biomass estimate of 21,729 t was the lowest for a 1st season since 2013 (Table 1); however, it was approximately equivalent to the median since 2006.

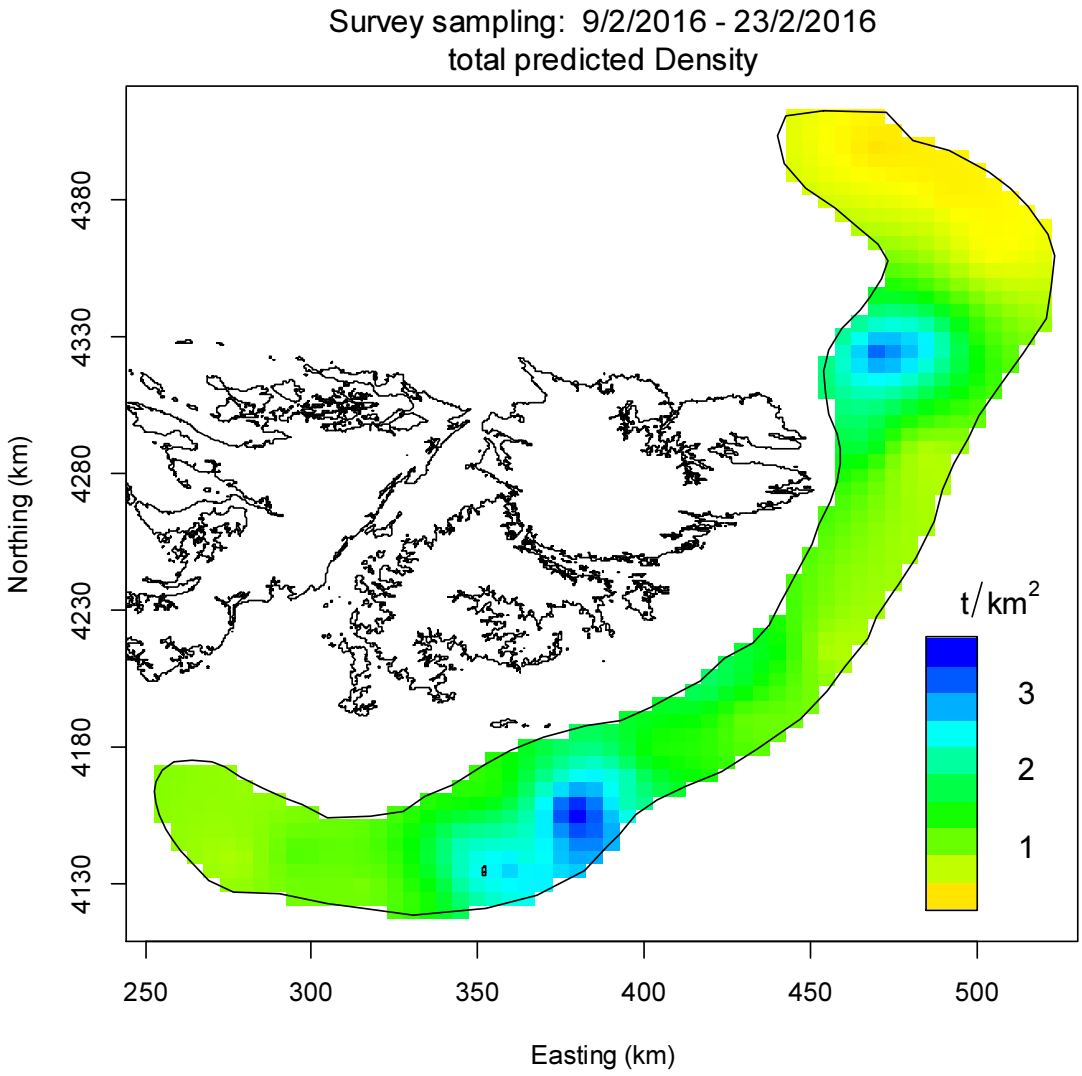
Biological data

Ninety-two taxa were identified in the catches (Appendix Table A2), of which calamari made up 28.7% by weight, the smallest proportion in a 1st season since 2013 (Winter et al., 2013). The biggest proportion was taken by blue whiting (Table A2), which at 33.8% was the highest percentage for that species in a 1st season for at least the past 6 years. The catch of blue whiting was highly aggregated with 98.5% of the 76,182 kg taken in just two trawls, vs. 40 of the 57 survey trawls taking <1 kg. Rock cod had the third-biggest proportion at 20.3%.

Figure 3 [next page]. Falkland calamari predicted density estimates per 5 km^2 area units. Top left: catch density distribution from variogram model of positive catches. Top right: probability of positive catch modelled from MCMC of presence/absence. Main plot: Predicted density = positive catch × probability of positive catch. Coordinates were converted to WGS 84 projection in UTM sector 21F using the R library rgdal (proj.maptools.org).


Survey sampling: 9/2/2016 - 23/2/2016
predicted Density from Positive Catch
t/km2
7
6
5
4
3
2
1


Survey sampling: 9/2/2016 - 23/2/2016
probability of Positive Catch (presence / absence)
[0, 1]
0.52
0.48
0.44
0.4


Survey sampling: 9/2/2016 - 23/2/2016
total predicted Density
Northing (km)
4380
4330
4280
4230
4180
4130
250
300
350
400
450
500
Easting (km)
t/km2
3
2
1

8631 calamari were measured for length and maturity in the survey (3479 males, 5152 females). The calamari length-weight relationship was calculated from 646 sub-sampled individuals (279 males, 367 females), resulting in optimized parameters $\alpha = 0.11245$ and $\beta = 2.37432$ (Figure 4).

Calamari size (mantle length) and maturity distributions north and south of 52° S are plotted in Figure 5. Calamari north of 52° S had significantly higher proportions of larger and more mature males and females than south of 52° S (t-test, $p < 0.001$ all comparisons). This is a reversal of the 1st pre-season 2015 survey, when calamari south of 52° S were larger and more mature (Winter et al., 2015). In the 1st pre-season 2016 survey, males north: mean mantle length 10.06 cm; mean maturity stage 1.81, males south: mean mantle length 9.45 cm; mean maturity stage 1.63. Females north: mean mantle length 9.93 cm; mean maturity stage 1.95, females south: mean mantle length 9.34 cm; mean maturity stage 1.79.

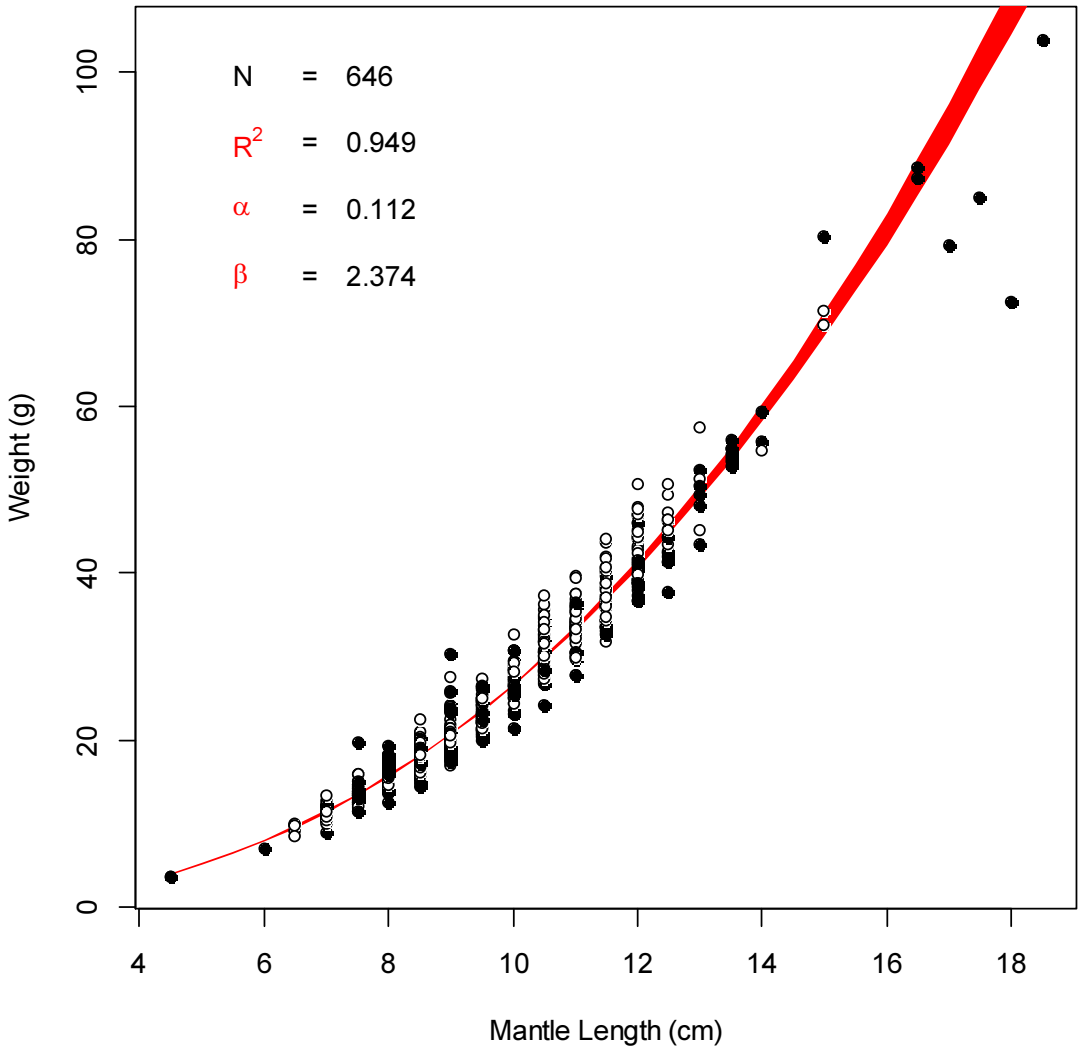


Figure 4. Length-weight relationship of Falkland calamari sampled during the survey. Black points: male, white: female. Parameters refer to the combined sexes' length-weight relationship; the red swath is the 95% confidence interval.

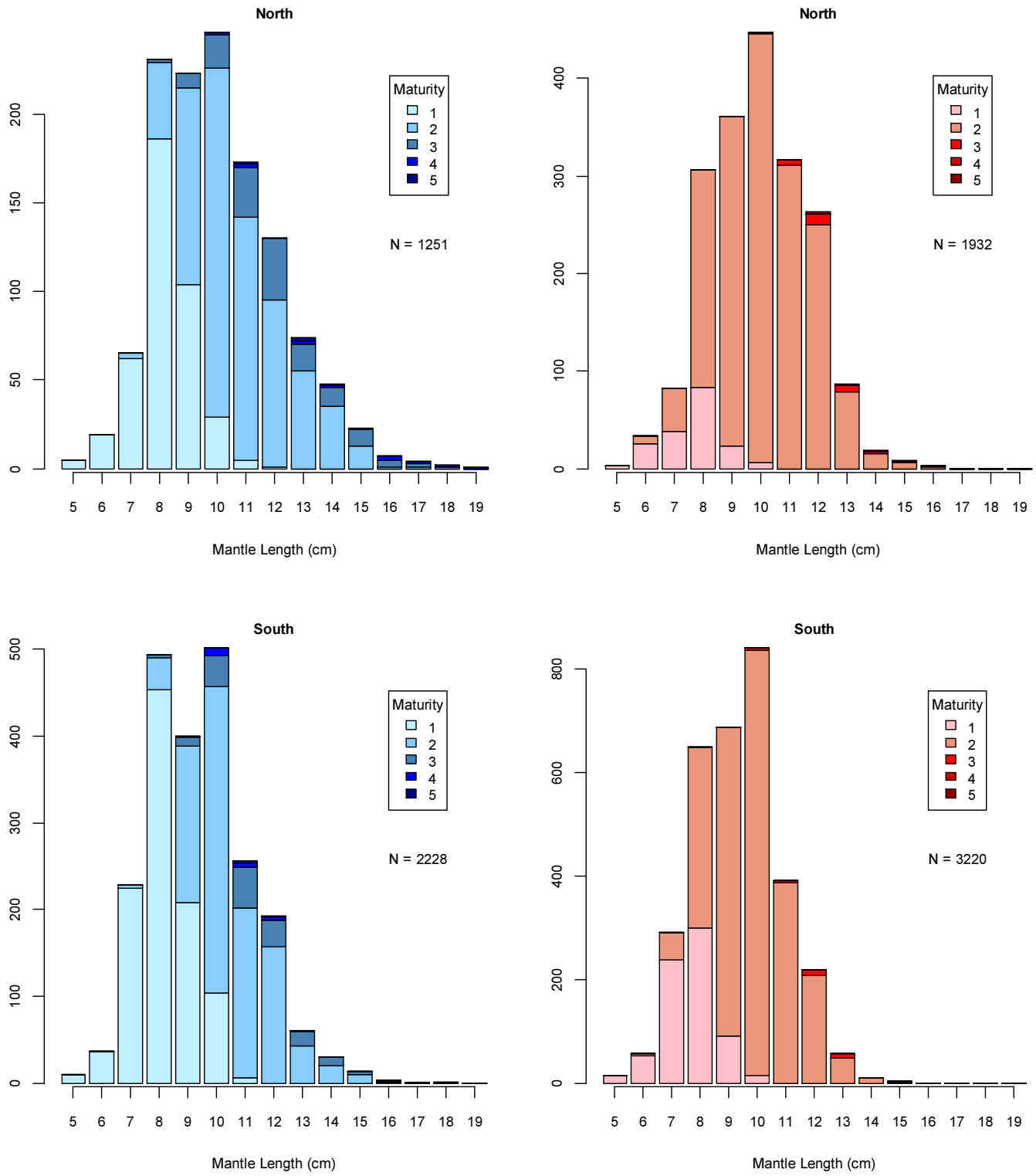


Figure 5. Length-frequency distributions by maturity stage of male (blue) and female (red) Falkland calamari from trawls north (top) and south (bottom) of latitude 52 ºS.

Seabird observations

The FV *Sil*'s Fixed Aerial Array was found to be deficient in preventing seabird interactions, by having extensions that were too small to cover the entire

hazard zone of the warp-water interface. A number of seabird mortalities were recorded during the survey. Details of the Fixed Aerial array evaluation, recommendations, and seabird interactions are described in Kuepfer (2016).

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Appendix

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

Transect	Obs	Date	Start			End			Depth	Calamari
Station	Code		Time	Lat	Lon	Time	Lat	Lon	(m)	(kg)
14 - 37	600	09/02/2016	6:00	50.55	57.67	8:00	50.68	57.55	138	46
14 - 38	601	09/02/2016	9:00	50.65	57.45	11:00	50.53	57.60	139	68
14 - 39	602	09/02/2016	11:40	50.52	57.52	13:40	50.62	57.35	251	0.5
13 - 36	603	09/02/2016	14:40	50.70	57.20	16:40	50.78	57.03	259	1
13 - 34	604	10/02/2016	6:00	50.85	57.20	8:00	50.77	57.42	130	167.7
13 - 35	605	10/02/2016	8:50	50.73	57.30	10:50	50.82	57.12	133	291.6
12 - 33	606	10/02/2016	11:35	50.85	57.02	13:35	50.98	56.88	118	8.1
12 - 32	607	10/02/2016	14:20	50.98	56.95	16:20	50.85	57.07	120	11.4
11 - 29	608	11/02/2016	5:55	51.10	57.07	7:55	51.22	57.25	114	5003.5
11 - 30	609	11/02/2016	8:40	51.25	57.17	10:40	51.13	57.02	129	1043.0
11 - 31	610	11/02/2016	11:15	51.15	56.95	13:15	51.27	57.07	142	82
10 - 28	611	11/02/2016	14:40	51.48	57.18	16:40	51.62	57.25	222	2
9 - 24	612	12/02/2016	5:55	51.83	57.50	7:55	51.98	57.60	151	1477
9 - 25	613	12/02/2016	8:40	51.95	57.50	10:40	51.80	57.37	219	130.7
10 - 27	614	12/02/2016	12:35	51.48	57.32	14:35	51.63	57.37	146	919.3
10 - 26	615	12/02/2016	15:20	51.60	57.45	17:20	51.45	57.45	126	2532.3
8 - 23	616	13/02/2016	5:55	52.13	57.82	7:55	52.23	57.97	136	1046
8 - 22	617	13/02/2016	8:40	52.25	57.85	10:40	52.13	57.67	201	171.6
8 - 21	618	13/02/2016	11:25	52.15	57.60	13:25	52.27	57.75	264	[A] 1
7 - 20	619	13/02/2016	14:35	52.37	57.97	16:35	52.48	58.10	263	1.8
A - 1	620	14/02/2016	5:55	52.85	60.18	7:55	52.92	59.93	191	352.1
1 - 3	621	14/02/2016	8:30	52.92	59.95	10:30	52.88	60.18	229	130.6
0 - 1	622	14/02/2016	11:05	52.87	60.23	13:05	52.77	60.37	263	23
1 - 2	623	14/02/2016	14:15	52.80	60.15	16:15	52.87	59.92	184	1059.4
A - 2	624	15/02/2016	5:55	52.70	59.52	7:55	52.70	59.77	150	537.1
2 - 4	625	15/02/2016	8:50	52.75	59.80	10:50	52.90	59.58	155	618.8
2 - 5	626	15/02/2016	11:20	52.93	59.62	13:20	52.90	59.87	167	988
2 - 6	627	15/02/2016	14:00	52.93	59.87	16:00	52.98	59.62	236	14.7
3 - 7	628	16/02/2016	5:55	52.82	59.38	7:55	52.82	59.62	148	659.9
A - 3	629	16/02/2016	8:50	52.93	59.57	10:50	52.93	59.28	157	1582
3 - 8	630	16/02/2016	11:35	52.97	59.33	13:35	52.95	59.58	182	2184
3 - 9	631	16/02/2016	14:15	52.98	59.58	16:15	53.00	59.32	255	86.4
A - 4	632	17/02/2016	5:55	52.62	59.05	7:55	52.70	59.27	124	1490.1
4 - 10	633	17/02/2016	9:00	52.82	59.33	11:00	52.80	59.07	107	1922.3
A - 5	634	17/02/2016	11:45	52.82	58.93	13:45	52.93	59.12	141	4298.3
4 - 11	635	17/02/2016	14:30	52.97	59.02	15:15	52.98	59.08	249	[B] 0
A - 6	636	18/02/2016	5:55	52.65	60.23	7:55	52.57	60.43	183	219.2
A - 7	637	18/02/2016	9:00	52.52	60.18	11:00	52.53	59.95	133	84.9
A - 8	638	18/02/2016	11:25	52.53	59.90	12:25	52.53	59.77	116	[C] 157.7
A - 9	639	18/02/2016	14:50	52.52	58.93	16:50	52.65	59.02	101	659.7
5 - 14	640	19/02/2016	5:55	52.90	58.95	7:55	52.80	58.75	156	6784
5 - 13	641	19/02/2016	8:35	52.80	58.78	10:35	52.88	59.00	142	3118.9
5 - 12	642	19/02/2016	11:25	52.80	59.07	13:25	52.68	58.85	123	3474.8
A - 10	643	19/02/2016	14:05	52.67	58.82	16:05	52.82	58.80	144	6656.3
A - 11	644	20/02/2016	5:55	52.47	58.32	7:55	52.57	58.52	160	1469.1
6 - 16	645	20/02/2016	8:30	52.58	58.57	10:30	52.70	58.70	152	4123.2
6 - 17	646	20/02/2016	11:10	52.72	58.65	13:10	52.62	58.48	227	10
6 - 15	647	20/02/2016	14:10	52.55	58.60	16:10	52.60	58.80	130	2115.3
A - 12	648	21/02/2016	5:55	52.25	57.90	7:55	52.33	58.10	163	1048.4
7 - 19	649	21/02/2016	8:35	52.35	58.07	10:35	52.45	58.25	184	344.1
7 - 18	650	21/02/2016	11:35	52.33	58.18	13:35	52.43	58.33	142	700.4
A - 13	651	22/02/2016	6:05	51.08	57.38	8:05	51.17	57.60	111	188.5

A - 14	652	22/02/2016	8:45	51.17	57.67	10:45	51.07	57.80	118	342.4
A - 15	653	22/02/2016	11:20	51.03	57.75	13:20	51.15	57.58	118	219.4
A - 16	654	22/02/2016	14:10	51.17	57.43	16:10	51.30	57.45	92	3273.7
A - 17	655	23/02/2016	6:35	51.27	58.16	7:05	51.27	58.09	66	126.0
A - 18	656	23/02/2016	8:20	51.34	57.80	8:50	51.38	57.76	56	598.4

A: 188 cm porbeagle shark in net.

B: Trawl interrupted: >60 tonnes of blue whiting caught.

C: Trawl interrupted: 1.5 tonnes of lobster krill closed the door.

Table A2. Survey total catches by species / taxon.

Species Code	Species / Taxon	Total catch (kg)	Total catch (%)	Sample (kg)	Discard (kg)
BLU	*Micromesistius australis*	76182	33.8	66	76182
LOL	*Doryteuthis gahi*	64666	28.7	241	4431
PAR	*Patagonotothen ramsayi*	45653	20.3	391	38308
WHI	*Macruronus magellanicus*	17248	7.7	0	920
CHR	*Chrysaora* sp.	9209	4.1	0	9209
CHE	*Champsocephalus esox*	1830	0.8	1	146
ING	*Moroteuthis ingens*	1812	0.8	270	1812
BAC	*Salilota australis*	1303	0.6	0	372
MUG	*Munida gregaria*	1146	0.5	0	1146
TOO	*Dissostichus eleginoides*	1021	0.5	938	0
CGO	*Cottoperca gobio*	932	0.4	0	932
SPN	Porifera	647	0.3	0	647
GRF	*Coelorhynchus fasciatus*	575	0.3	0	575
SQT	Ascidiacea	538	0.2	0	538
PTE	*Patagonotothen tessellata*	387	0.2	0	387
ALF	*Allothunnus fallai*	382	0.2	97	340
GRC	*Macrourus carinatus*	272	0.1	2	6
EEL	*Iluocoetes fimbriatus*	237	0.1	0	237
ZYP	*Zygochlamys patagonica*	170	0.1	0	120
MXX	Myctophid spp.	155	0.1	0	155
EGG	Eggmass	107	<0.1	0	107
DGH	*Schroederichthys bivius*	96	<0.1	0	96
RBR	*Bathyraja brachyurops*	81	<0.1	0	15
RBZ	*Bathyraja cousseauae*	75	<0.1	0	1
POR	*Lamna nasus*	69	<0.1	69	0
ILL	*Illex argentinus*	52	<0.1	11	45
KIN	*Genypterus blacodes*	46	<0.1	17	0
RFL	*Zearaja chilensis*	44	<0.1	0	0
ALG	Algae	37	<0.1	0	37
PAT	*Merluccius australis*	31	<0.1	31	0
NEM	*Neophyrnichthys marmoratus*	25	<0.1	0	25
RAL	*Bathyraja albomaculata*	19	<0.1	1	6
RGR	*Bathyraja griseocauda*	17	<0.1	16	1
GOC	*Gorgonocephalas chilensis*	17	<0.1	0	17
GYN	*Gymnoscopelus nicholsi*	15	<0.1	0	15
ANM	Anemone	15	<0.1	0	15
RSC	*Bathyraja scaphiops*	12	<0.1	0	0
NED	*Neolithodes diomedeae*	11	<0.1	0	1
STA	*Sterechinus agassizi*	8	<0.1	0	8
RMG	*Bathyraja magellanica*	7	<0.1	0	7
PYM	*Physiculus marginatus*	7	<0.1	0	7
PSG	*Pseudoechinus magellanicus*	6	<0.1	0	6
MED	Medusae sp.	6	<0.1	0	6

RED	*Sebastes oculatus*	5	<0.1	5	1
ODM	*Odontocymbiola magellanica*	5	<0.1	0	5
SAR	*Sprattus fuegensis*	3	<0.1	0	3
FUM	*Fusitriton m. magellanicus*	3	<0.1	0	3
COL	*Cosmasterias lurida*	3	<0.1	0	3
WRM	*Chaetopterus variopedeatus*	2	<0.1	0	2
SUN	*Labidaster radiosus*	2	<0.1	0	2
SHT	Mixed invertebrates	2	<0.1	0	2
RPX	*Psammobatis* spp.	2	<0.1	0	2
RMC	*Bathyraja macloviana*	2	<0.1	0	2
OCM	*Octopus megalocyathus*	2	<0.1	0	2
OCC	Octocoralia	2	<0.1	0	2
MLA	*Muusoctopus longibrachus akambei*	2	<0.1	0	0
CAZ	*Calyptraster* sp.	2	<0.1	0	2
RDO	*Amblyraja doellojuradoi*	1	<0.1	0	1
OPV	*Ophiacanta vivipara*	1	<0.1	0	1
MUE	*Muusoctopus eureka*	1	<0.1	1	0
ICA	*Icichthys australis*	1	<0.1	0	1
EUO	*Eurypodius longirostris*	1	<0.1	0	1
CYX	*Cycethra* sp.	1	<0.1	0	1
CTA	*Ctenodiscus australis*	1	<0.1	0	1
COT	*Cottunculus granulosus*	1	<0.1	0	0
BUT	*Stromateus brasiliensis*	1	<0.1	1	0
AST	Asteroidea	1	<0.1	0	1
TRP	*Tripilaster philippi*	<0.1	<0.1	0	0
PYX	Pycnogonida	<0.1	<0.1	0	0
POA	*Porania antarctica*	<0.1	<0.1	0	0
PES	*Peltarion spinosulum*	<0.1	<0.1	0	0
PAM	*Pagurus comptus*	<0.1	<0.1	0	0
OPS	*Ophiactis asperula*	<0.1	<0.1	0	0
OPL	*Ophiuroglypha lymanii*	<0.1	<0.1	0	0
OPH	Ophiuroidea	<0.1	<0.1	0	0
ODP	*Odontaster pencillatus*	<0.1	<0.1	0	0
NUD	Nudibranchia	<0.1	<0.1	0	0
MAV	*Magellania venosa*	<0.1	<0.1	0	0
ISO	Isopoda	<0.1	<0.1	0	0
HYD	Hydrozoa	<0.1	<0.1	0	0
HOL	Holothuroidea	<0.1	<0.1	0	0
EUL	*Eurypodius latreillei*	<0.1	<0.1	0	0
ERR	*Errina* sp.	<0.1	<0.1	0	0
CRY	*Crossaster* sp.	<0.1	<0.1	0	0
COG	*Patagonotothen guntheri*	<0.1	<0.1	0	0
CEX	*Ceramaster* sp.	<0.1	<0.1	0	0
BRY	Bryozoa	<0.1	<0.1	0	0
BAL	*Bathydomus longisetosus*	<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
		225,212		2,158	136,916

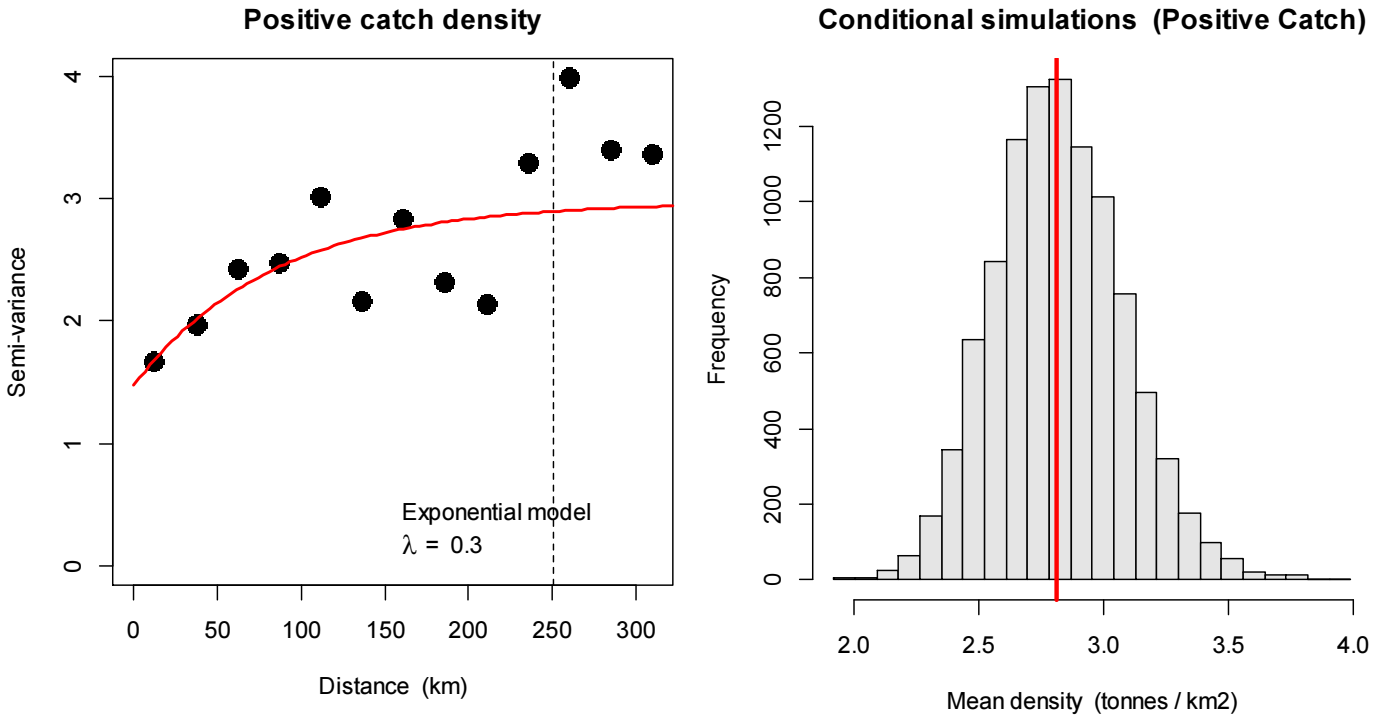

Figure A1. Left: Empirical variogram (black circles) and model variogram (red line) of calamari biomass density distributions from positive catch trawl intervals. Broken vertical line: practical correlation range of the model at 251.1 km. Right: histogram of conditional simulations of mean density estimates resulting from the model variogram at left. Vertical red line: empirical mean density estimate at 2.81 t km^{-2}.

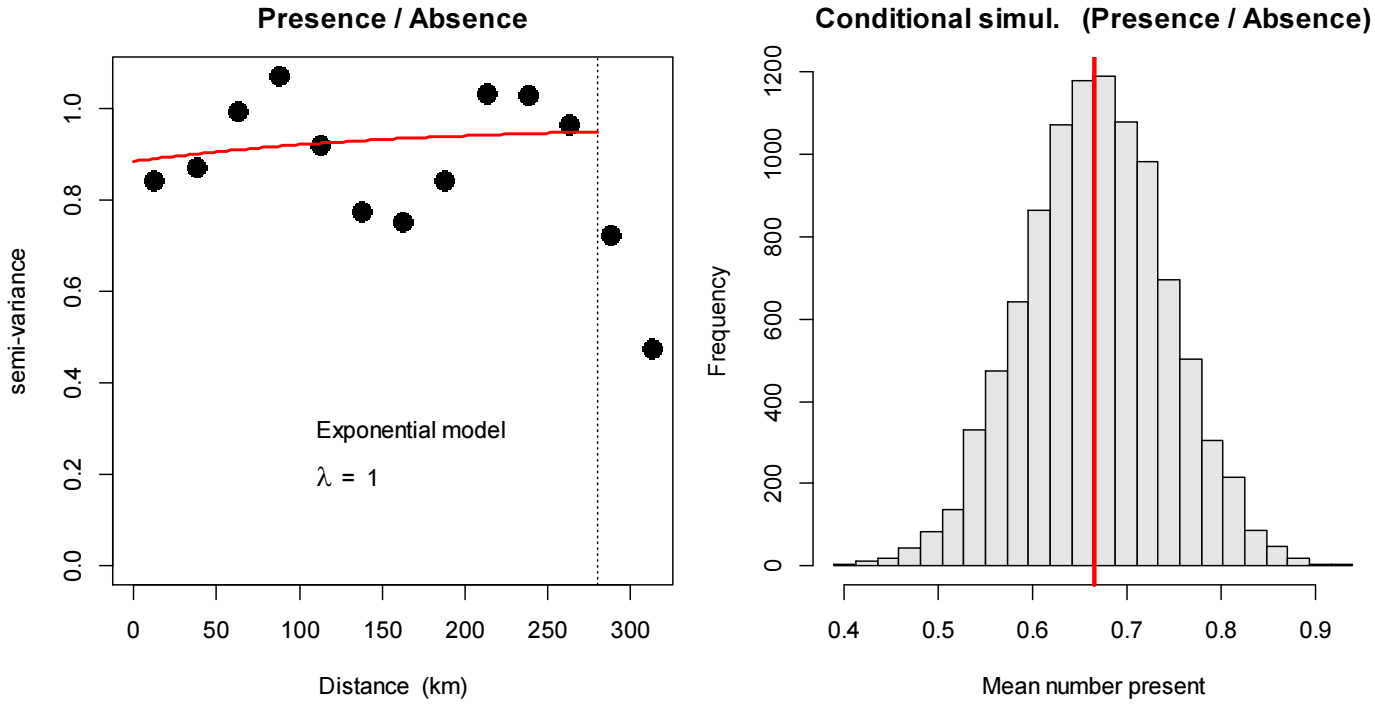

Figure A2 [previous page]. Left: Empirical variogram (black circles) and model variogram (red line) of numbers of positive catch intervals present per 5 × 5 km area unit. Dotted vertical line: maximum modelled lag distance at 280 km. Right: histogram of conditional simulations of positive catch interval numbers resulting from the model variogram at left. Vertical red line: empirical mean number present at 0.667.