FALKLAND
ISLANDS
FISHERIES
DEPARTMENT

Falkland calamari Stock Assessment Survey, 1st Season 2017

Vessel	Argos Vigo (ZDLU1), Falkland Islands
Dates	09/02/2017 - 23/02/2017
Survey Report	Andreas Winter Jessica Jones Zhanna Shcherbich Verónica Iriarte

Summary

1) A stock assessment survey for Falkland calamari was conducted in the 'Loligo Box' from 9th to 23rd February 2017. Fifty-nine scientific trawls were taken during the survey, catching 179.94 tonnes of calamari.
2) A geostatistical estimate of 48,785 tonnes calamari (95% confidence interval: 31,537 to 66,085 t) was calculated for the fishing zone. This represents the highest 1st-season survey biomass estimate since 2010. Of the total, 3255 t were estimated north of 52 ºS, and 45,529 t were estimated south of 52 ºS.
3) Male and female calamari had significantly greater average mantle lengths south of 52 ºS than north of 52 ºS, but average maturities were not significantly different between north and south. Males north: mean mantle length 11.99 cm; mean maturity stage 2.13, males south: mean mantle length 12.24 cm; mean maturity 2.12. Females north: mean mantle length 11.69 cm; mean maturity 1.97, females south: mean mantle length 11.75 cm; mean maturity 1.96.
4) One hundred and two taxa were identified in the catches. Falkland calamari was the largest species group at 68.7% of total catch by weight, followed by rock cod (23.7%), blue whiting (2.4%), and red cod (1%). Biological measurements and samples were taken from calamari, rock cod, 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 on-board the fishing vessel *Argos Vigo* from the 9th to 23rd February 2017. This survey continues the series of surveys that have, since February 2006, been conducted immediately prior to season openings to estimate the Falkland 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.

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, 2017.
2) Estimate the biomass and distribution of rock cod (*Patagonotothen ramsayi*) in the 'Loligo Box', for continued monitoring of this stock.
3) Collect biological information on Falkland calamari, rock cod, toothfish (*Dissostichus eleginoides*) and opportunistically other commercially important fish and squid taken in the trawls.

The survey was designed to cover the 'Loligo Box' fishing zone (Arkhipkin et al., 2008; 2013) 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.

The F/V *Argos Vigo* is a Falkland Islands - registered stern trawler of 70.75 m length, 2074 gross tonnage, and 3000 main engine bhp. *Argos Vigo* was previously employed for the 1st pre-season 2007 survey (Payá, 2007) and the 2nd pre-season 2008 survey (Payá, 2008). Like all vessels employed for pre-season surveys, *Argos Vigo* operates regularly in the Falkland calamari fishery and used its commercial trawl gear for the survey catches. The following personnel from the FIFD participated in the 1st pre-season 2017 survey:

Jessica Jones	FIFD PhD student / lead scientist
Zhanna Shcherbich	fisheries biologist
Verónica Iriarte	fisheries observer

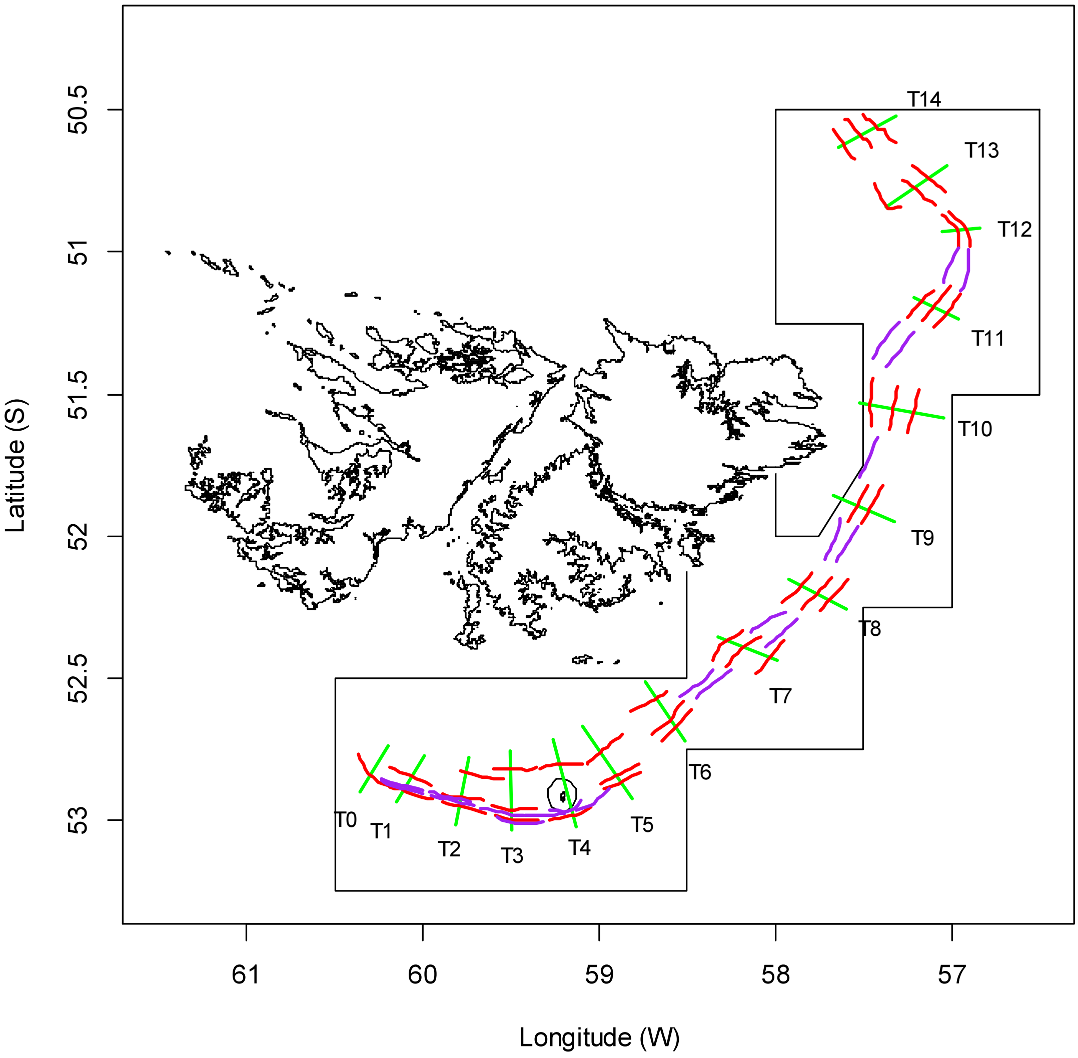

Figure 1. Transects (green lines), fixed-station trawls (red lines), and adaptive-station trawls (purple lines) sampled during the 1st pre-season 2017 survey. Boundaries of the 'Loligo Box' fishing zone and the Beauchêne Island exclusion zone are traced in black.

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 Falkland calamari biomass estimates in high-density or high-variability locations. Trawls were designed for an expected duration of 2 hours each, and ranged in distance from 13.6 to 18.8 km (mean 16.7 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 trawl 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 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

The catch of every trawl was processed separately by the factory 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 were recorded in the same way, but without size categorization. Processed product weights were scaled to whole weights using standard conversion factors (FIG, 2011). Discards of damaged, undersized, or commercially unvalued fish and squid were estimated by FIFD survey personnel either visually (for small quantities) or by noting the ratio of discards to commercially retained fish and squid in sub-portions of the catch (for larger quantities). Discards were added to the product weights as applicable to give total catch weights of all fish and squid.

Biomass calculations

Biomass density estimates of 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 position to the end GPS position of each 15-minute interval. Trawl width was derived from the distance between trawl doors (determined per interval) according to the equation (Seafish, 2010):

$$\text{trawl width} = (\text{door distance} \times \text{footrope length}) / (\text{footrope} + \text{sweep} + \text{bridle})$$

Measurements of *Argos Vigo*'s trawl, provided by the vessel master, were: footrope = 107 m, sweep = 21 m, bridle = 130 m.

Biomass density estimates were extrapolated to the survey area using geostatistical methods (Petitgas, 2001). The delineated survey area for 1st season was 20,000 km^2, partitioned for analysis as 800 area units of 5×5 km. A zero-inflated 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).

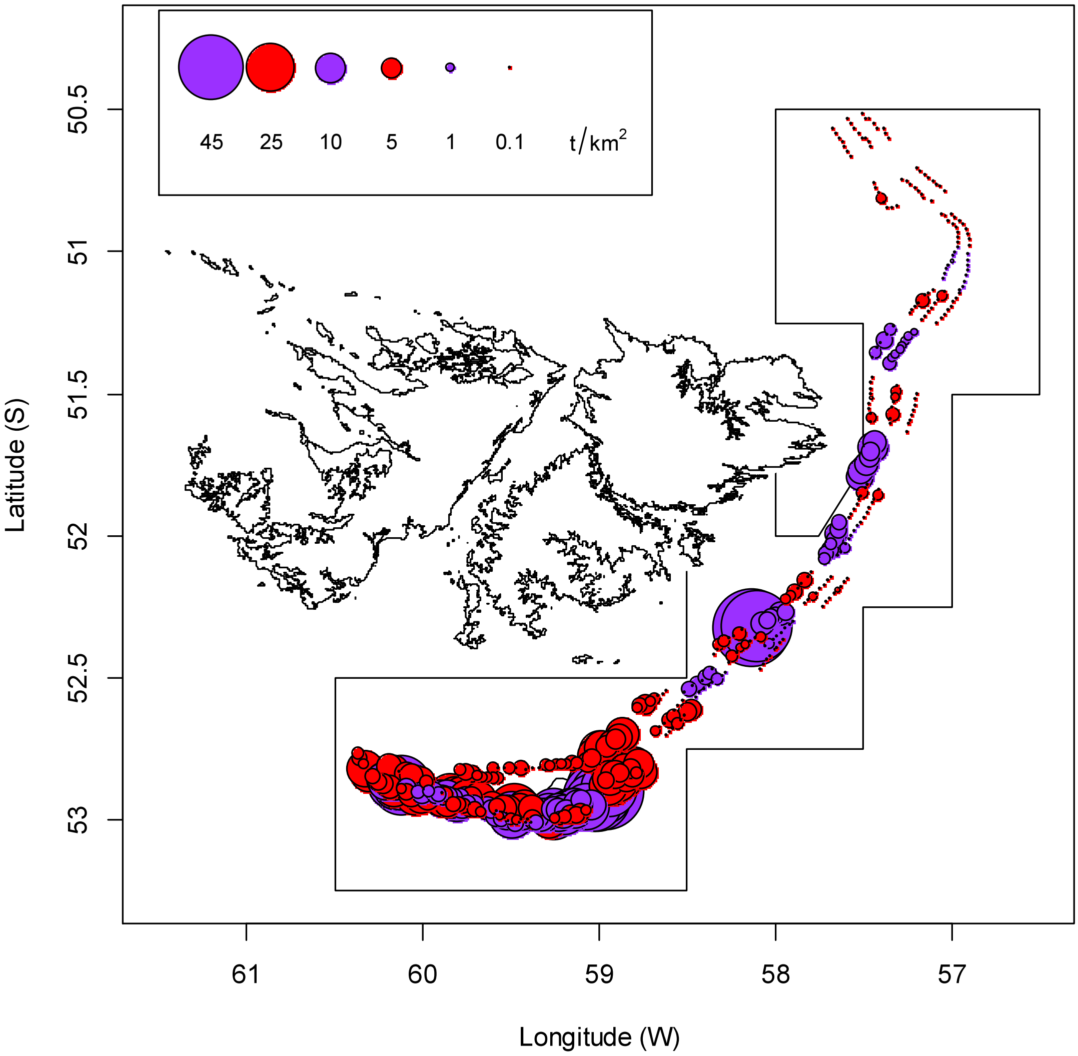

Figure 2. Falkland calamari CPUE (t km^{-2}) of fixed-station trawls (red) and adaptive trawls (purple), per 15-minute trawl interval. Boundaries of the 'Loligo Box' fishing zone and the Beauchêne Island exclusion zone are traced in black.

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 of positive catch densities and presence / absence were randomly drawn and multiplied together 250000× for a combined variability distribution. To this uncertainty 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. 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 calamari catch per trawl. Acoustic scores are relative values referenced to each individual trawl, but their absolute values should be generally consistent across all trawls. To estimate error of acoustic apportionment 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:

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

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 calamari catch weight of that trawl, then processed through the same algorithms of density distribution and geostatistic extrapolation as the empirical results. Iterative aggregations of small catches (< 100 kg) were summed towards intervals randomly selected within each trawl, not automatically the middle interval. The full randomization was repeated 10000× and the coefficient of variation of the mean geostatistic density retained as the measure of error of acoustic apportionment[a].

Biological analyses

Random samples of calamari (target n = 200, as far as available) were collected from the factory at all trawl stations. Of these samples, n = 100 were sub-set for statolith extraction. 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 (LOL) were collected according to area stratification (north, central, south) and depth (shallow, medium, deep), and frozen for statolith extraction and age analysis (Arkhipkin, 2005). A sample of 100 common rock cod (PAR) was taken at every trawl station. All catches of toothfish (TOO) were collected from all trawl stations to maximize the time series catch and biological information base for juvenile toothfish. Specimens of crocodile fish (AGO; *Agonopsis chilensis*), slender tuna (ALF; *Allothunnus fallai*), southern blue whiting (BLU; *Micromesistius australis*), frogmouth (CGO; *Cottoperca gobio*), icefish (CHE; *Champsocephalus esox*), yellowfin rock cod (COG; *Patagonotothen guntheri*), Argentine shortfin squid (ILL; *Illex argentinus*), kingclip (KIN; *Genypterus blacodes*), eel cod (MUO; *Muraenolepis orangiensis*), bobtail squid (NEC; *Neorossia caroli*); fathead (NEM; *Neophyrnichthys marmoratus*), yellowbelly (NOW; *Paranotothenia magellanica*), scaly-head rock cod (PAS; *Patagonotothen squamiceps*), Patagonian hake (PAT; *Merluccius australis*), porbeagle shark (POR; *Lamna nasus*), marbled rock cod (PTE; *Patagonotothen tessellata*), redfish (RED; *Sebastes oculatus*), small flounder (THN; *Thysanopsetta naresi*), and hoki (WHI;

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[a] 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.

Macruronus magellanicus) were taken opportunistically for length-frequency measurement and / or otolith analysis.

Results

Catch rates and distribution

The survey started as usual with fixed-station trawls in the north and proceeded to the south-west end of the Loligo Box. Adaptive trawls covered a wide range of the survey and were interspersed between many of the scheduled transects (Figure 1, Figure 2, Appendix Table A1). 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 the last day, February 23rd, when only three survey trawls were taken to allow time for disembarking the FIFD survey team in the evening. In total 59 scientific trawls were recorded during the survey: 39 fixed station trawls catching 74.08 t calamari and 20 adaptive trawls catching 105.86 t calamari. Fourteen optional trawls (made after survey hrs) yielded an additional 161.50 t calamari, bringing the total catch for the survey to 341.45 t. Discrepancies were noted in two cases of catch quantities being attributed by the vessel records to the day's first survey trawl vs. the previous night's optional trawl, because of factory bins not being empty in time. The FIFD survey team estimates were taken as definitive in both cases. The scientific survey catch of 179.94 t is above median for 1st seasons since 2006 (Table 1).

Average calamari catch density among fixed-station trawls was 0.09 t km^{-2} north of 52° S; the lowest since 2013, and 3.31 t km^{-2} south of 52° S; the second-highest of the past six 1st seasons. Average calamari catch density among adaptive-station trawls was 1.57 t km^{-2} north of 52° S and 7.41 t km^{-2} south of 52° S; respectively the second-lowest and second-highest of the past six 1st seasons.

Table 1. Falkland calamari 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
2016	57	65	21729	58	225	43580
2017	59	180	48785			

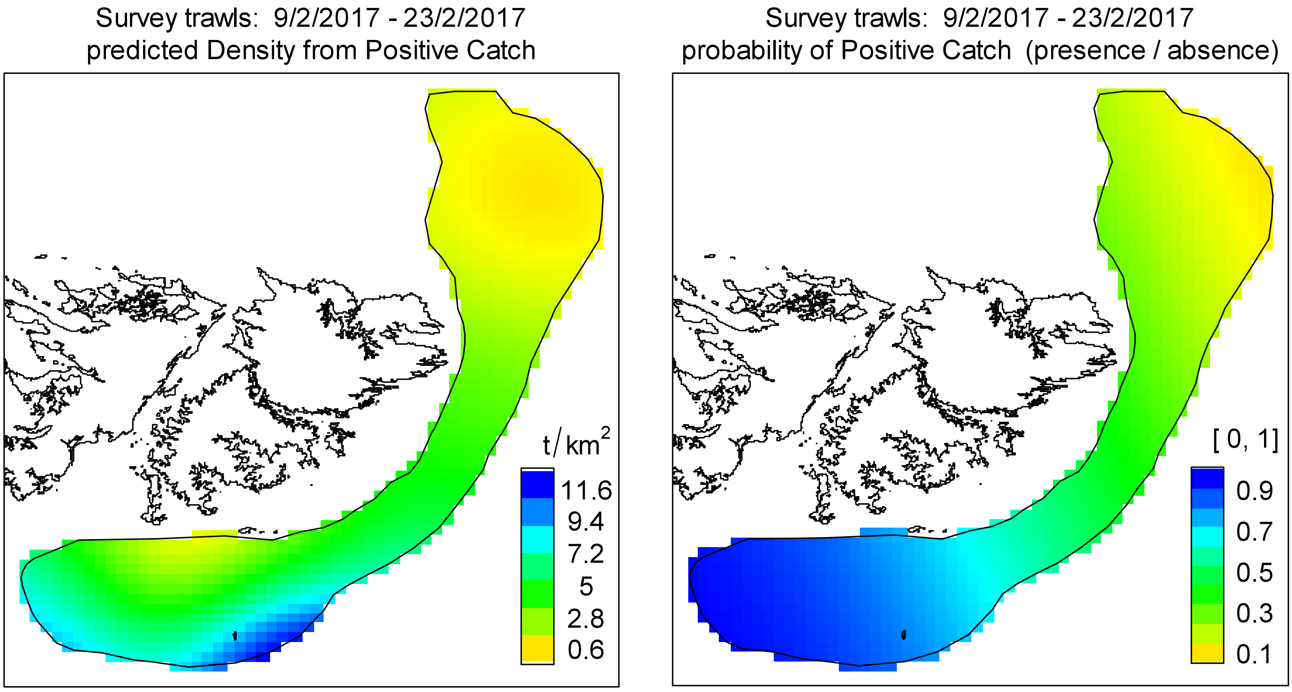
Biomass estimation

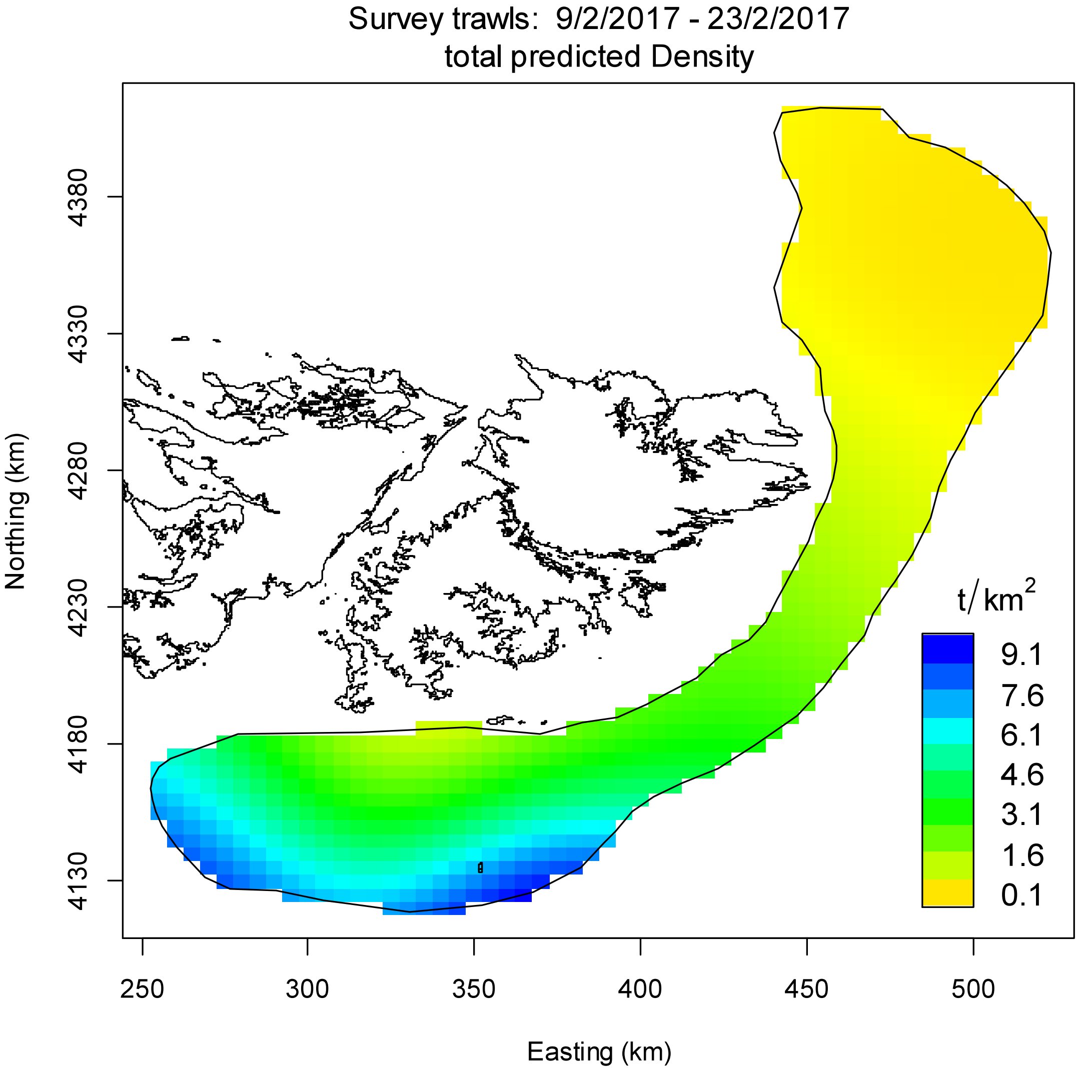
Density estimates from positive catch trawl intervals were modelled with a Cauchy covariance function and $\lambda = 1$ (no Box-Cox transformation; MacLennan and MacKenzie, 1988). The variogram was fit with a maximum lag distance of 150 km

(Appendix Figure A1-left), and resulted in a practical range of 2026.05 km, i.e. calamari densities were inferred to spatially correlate up to a maximum separation distance of 2026.05 km. The mean calamari biomass density estimate of this variogram model was 3.68 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 also modelled with a Cauchy covariance function, $\lambda = 1$ (no transformation, as appropriate for count data; O'Hara and Kotze, 2010), binomial error distribution, and unrestricted lag distance (Figure A2-left). The mean number of positive catch intervals estimated per 5×5 km area unit was 1.28, and centred well on the distribution mode of conditional simulations (Figure A2-right). Regression between total acoustic score per trawl and total calamari catch per trawl resulted in $R^2 = 0.6897$ (Figure A3). The coefficient of variation for acoustic apportionment derived with the randomization algorithm was = 0.037.

From these calculations, total Falkland calamari biomass in the fishing area was estimated at 48,785 tonnes, with a 95% confidence interval of [31,537 to 66,085 t]. Distribution of the estimated biomass was preponderant towards the south (Figure 3), with positive catch projections from 0.55 to 3.63 t km^{-2} in 95% of area units north of 52 °S, and 1.82 to 10.26 t km^{-2} in 95% of area units south of 52 °S (Figure 3, top left). Presence probabilities were even more strongly graduated with 0.10 to 0.35 in 95% of area units north of 52 °S and 0.39 to 0.94 in 95% of area units south of 52 °S (Figure 3, top right). Of the estimated total biomass, 3,255 t [0 to 8820 t] were north of 52 °S, and 45,529 t [29,727 to 61,779 t] were south of 52 °S. The survey biomass estimate of 48,785 t was the highest for a 1st season since 2010 (Table 1).

Figure 3 [below]. 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).





Biological data

One hundred and two taxa were identified in the catches, of which calamari made up 68.7% by weight (Appendix Table A2). Rock cod was the second largest taxon with 23.7% of catch by weight, followed by blue whiting 2.4% and red cod *Salilota australis* 1.0%. Most rock cod were undersized for commercial value and discarded, but approximately 80% of blue whiting and 57% of red cod were processed (Table A2).

10484 calamari were measured for length and maturity in the survey (4452 males, 6032 females). The calamari length-weight relationship was calculated from 431 sub-sampled individuals[b] (195 males, 236 females), resulting in optimized parameters $\alpha = 0.16156$ and $\beta = 2.25281$ (Figure 4).

Calamari mantle length and maturity distributions north and south of 52° S are plotted in Figure 5. For both males and females, size distributions were significantly different between north and south of 52 °S. Males: north mean mantle length 11.99

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[b] The length-weight samples were frozen thawed specimens. This is not considered a biasing factor for *D. gahi* (A. Arkhipkin, FIFD, pers. comm.).

cm, south 12.24 cm, Kruskal-Wallis test $p < 0.001$. Females: north mean mantle length 11.69 cm, south 11.75 cm, Kruskal-Wallis test $p < 0.05$. For both males and females, maturity distributions were not significantly different between north and south of 52 ºS. Males: north mean maturity stage (on a scale of 1 to 5) 2.13, south 2.12, Kruskal-Wallis test $p > 0.5$. Females: north mean maturity stage 1.97, south 1.96, Kruskal-Wallis test $p > 0.5$.

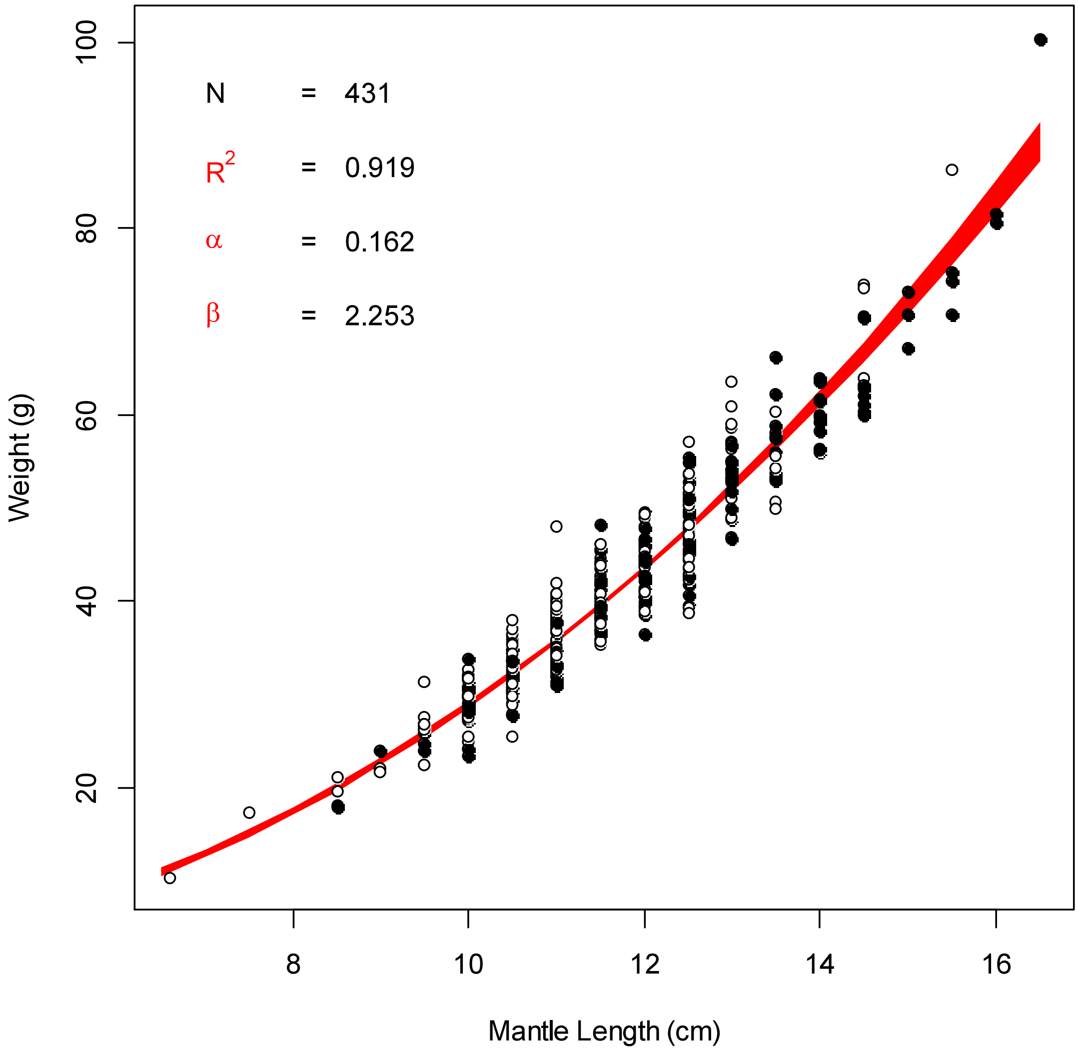
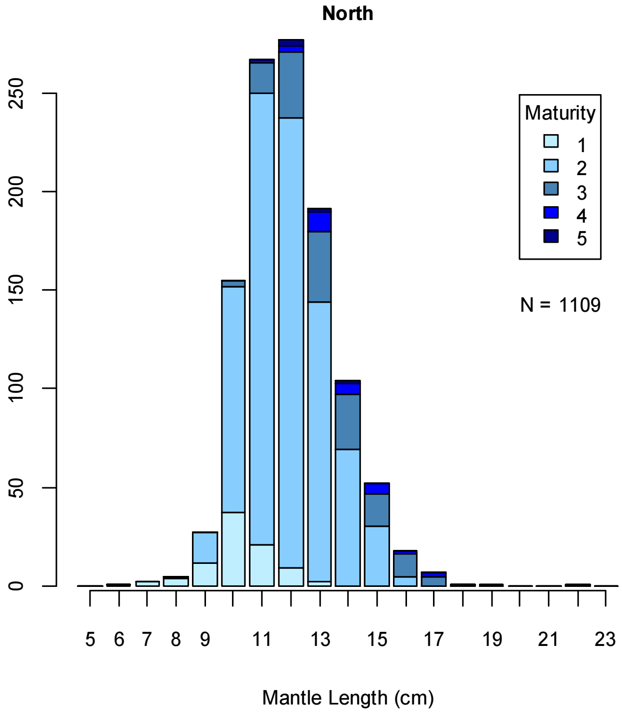
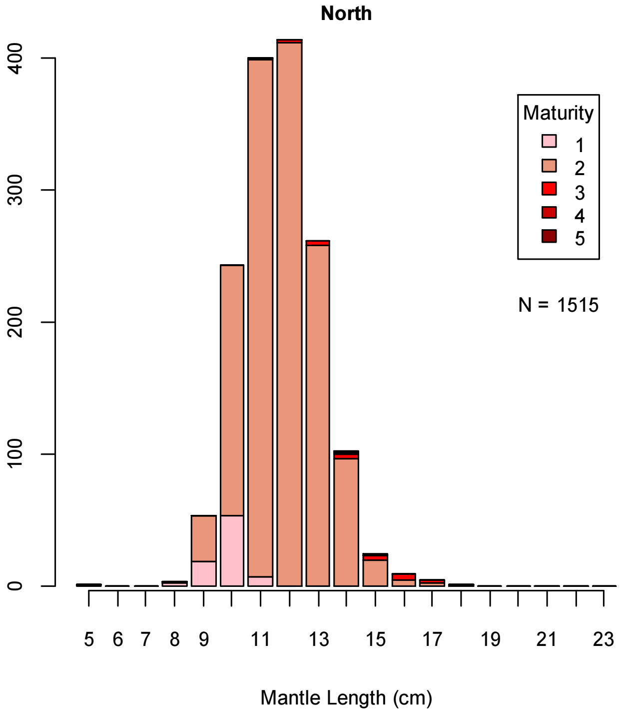
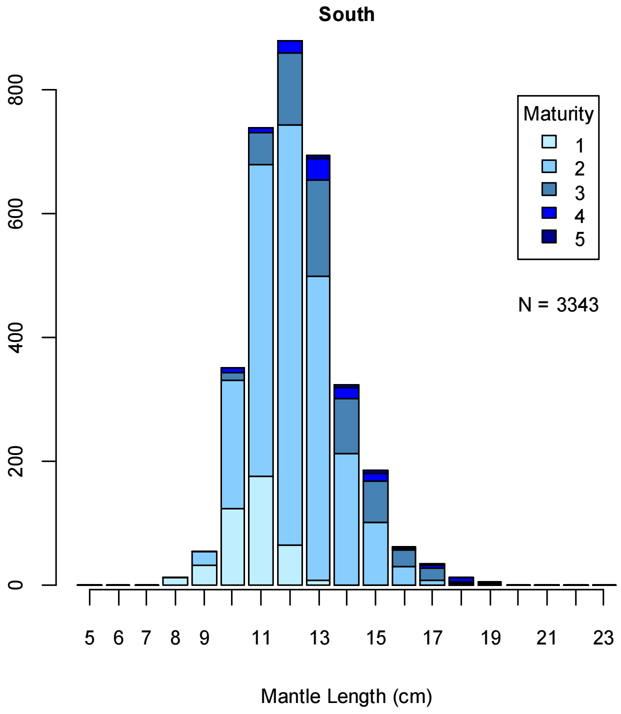


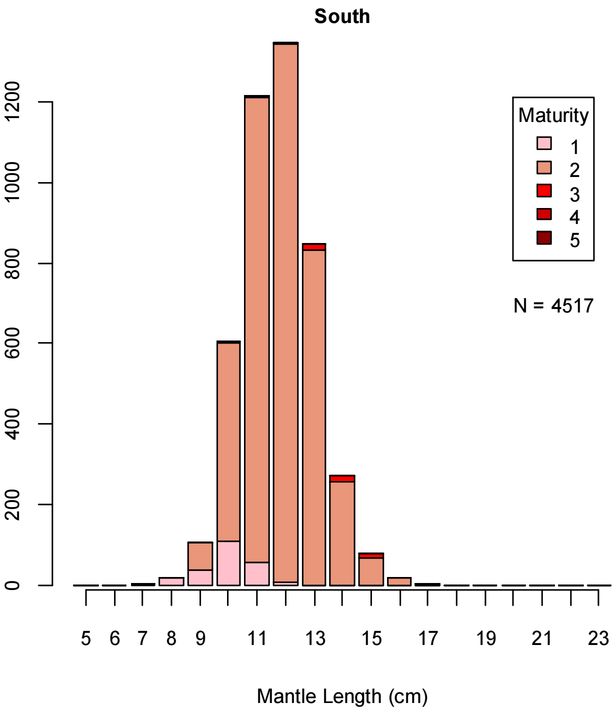
Figure 4. Length-weight relationship of Falkland calamari sampled during the survey. Black points: male, white: female. Parameters refer to the combined sexes' length-weight relationship; the red swath is the 95% confidence interval.

Figure 5 [next page]. 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.









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Appendix

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

Transect Station	Obs Code	Date	Start			End			Depth (m)	Calamari (kg)
			Time	Lat	Lon	Time	Lat	Lon		
14 - 39	1000	09/02/2017	07:15	50.52	57.50	09:15	50.62	57.32	258	0.0
14 - 38	1001	09/02/2017	10:05	50.63	57.45	12:05	50.53	57.60	144	0.4
14 - 37	1002	09/02/2017	12:45	50.57	57.67	14:20	50.67	57.55	137	* 0.0
13 - 34	1003	09/02/2017	15:15	50.76	57.44	17:10	50.84	57.29	131	120.0
12 - 33	1004	10/02/2017	07:10	50.98	56.89	09:10	50.86	57.02	123	0.4
13 - 36	1005	10/02/2017	09:50	50.79	57.04	11:50	50.69	57.22	259	0.0
13 - 35	1006	10/02/2017	12:35	50.74	57.27	14:35	50.83	57.09	131	0.4
12 - 32	1007	10/02/2017	15:00	50.87	57.05	17:00	50.98	56.95	118	0.0
11 - 31	1008	11/02/2017	07:10	51.15	56.95	09:10	51.27	57.09	144	0.9
11 - 30	1009	11/02/2017	09:55	51.24	57.16	11:55	51.12	57.01	129	128.0
11 - 29	1010	11/02/2017	13:00	51.13	57.10	15:00	51.23	57.25	115	184.5
10 - 26	1011	11/02/2017	16:35	51.45	57.45	19:00	51.62	57.45	128	135.8
9 - 25	1012	12/02/2017	07:05	51.96	57.51	09:05	51.82	57.39	221	144.8
10 - 28	1013	12/02/2017	10:25	51.63	57.25	12:25	51.48	57.19	228	0.0
10 - 27	1014	12/02/2017	13:15	51.48	57.30	15:15	51.62	57.35	148	498.8
9 - 24	1015	12/02/2017	16:40	51.82	57.47	18:50	51.95	57.58	165	138.7
8 - 21	1016	13/02/2017	07:05	52.13	57.79	09:05	52.24	57.96	137	793.1
7 - 18	1017	13/02/2017	10:15	52.34	58.18	12:15	52.44	58.35	144	514.2
6 - 15	1018	13/02/2017	13:35	52.55	58.61	15:35	52.62	58.82	133	1039.5
5 - 12	1019	13/02/2017	16:25	52.70	58.86	18:45	52.80	59.07	125	7225.0
8 - 23	1020	14/02/2017	07:05	52.15	57.58	09:05	52.27	57.74	263	48.3
7 - 20	1021	14/02/2017	10:10	52.37	57.95	12:10	52.48	58.10	265	4.1
6 - 17	1022	14/02/2017	13:45	52.61	58.47	15:45	52.72	58.64	235	983.9
5 - 14	1023	14/02/2017	16:45	52.83	58.76	18:45	52.89	58.97	157	8833.1
8 - 22	1024	15/02/2017	07:05	52.15	57.68	09:05	52.26	57.85	201	121.2
7 - 19	1025	15/02/2017	10:15	52.36	58.09	12:15	52.46	58.27	186	535.6
6 - 16	1026	15/02/2017	13:30	52.59	58.52	15:30	52.70	58.70	168	656.6
5 - 13	1027	15/02/2017	16:20	52.80	58.77	18:20	52.87	58.99	147	6415.9
1 - 3	1028	16/02/2017	07:15	52.88	60.19	09:15	52.93	59.95	226	7426.0
2 - 6	1029	16/02/2017	09:55	52.94	59.88	11:55	52.98	59.64	229	3658.5
3 - 9	1030	16/02/2017	12:35	52.98	59.59	14:35	53.00	59.34	236	833.8
4 - 11	1031	16/02/2017	15:15	53.00	59.28	17:15	52.96	59.04	202	3513.2
0 - 1	1032	17/02/2017	07:10	52.77	60.37	09:20	52.89	60.18	243	5240.0
1 - 2	1033	17/02/2017	10:25	52.81	60.18	12:25	52.88	59.95	194	4759.3
2 - 5	1034	17/02/2017	13:00	52.91	59.89	15:00	52.93	59.65	173	8102.4
3 - 8	1035	17/02/2017	15:35	52.95	59.61	17:35	52.96	59.35	177	8722.4
2 - 4	1036	18/02/2017	07:10	52.83	59.78	09:10	52.86	59.54	157	1567.8
3 - 7	1037	18/02/2017	09:55	52.82	59.60	11:55	52.82	59.35	145	639.3
4 - 10	1038	18/02/2017	12:30	52.82	59.34	14:30	52.80	59.09	110	1094.8
E	1039	18/02/2017	15:35	52.93	59.10	17:35	52.97	59.28	166	5736.8
E	1040	19/02/2017	07:15	52.85	60.24	09:15	52.90	60.00	196	11970.2
E	1041	19/02/2017	09:45	52.90	59.96	11:45	52.94	59.73	181	3103.1
E	1042	19/02/2017	12:25	52.95	59.71	14:25	52.91	59.95	195	8773.4
E	1043	19/02/2017	15:00	52.91	60.00	17:00	52.86	60.23	209	10008.2
E	1044	20/02/2017	07:10	52.89	58.94	09:10	52.97	59.13	156	23812.0
E	1045	20/02/2017	09:50	52.98	59.20	11:50	52.98	59.42	178	11364.5
E	1046	20/02/2017	12:25	52.98	59.43	14:25	52.96	59.67	200	7086.8
E	1047	20/02/2017	15:10	52.99	59.58	17:10	53.01	59.32	260	1620.0
E	1048	21/02/2017	07:05	52.57	58.45	09:05	52.47	58.25	196	181.5
E	1049	21/02/2017	10:05	52.39	58.05	12:05	52.29	57.87	226	150.1
E	1050	21/02/2017	12:45	52.27	57.94	14:45	52.34	58.13	150	11509.3
E	1051	21/02/2017	16:05	52.47	58.35	18:05	52.57	58.53	160	1048.0

E	1052	22/02/2017	07:20	51.28	57.21	09:20	51.41	57.37	130	914.8
E	1053	22/02/2017	10:00	51.38	57.44	12:00	51.25	57.30	111	652.0
E	1054	22/02/2017	13:20	51.14	56.95	15:20	50.99	56.90	131	1.4
E	1055	22/02/2017	15:50	50.99	56.96	17:50	51.11	57.05	112	17.9
E	1056	23/02/2017	07:05	51.97	57.53	09:05	52.09	57.65	189	109.2
E	1057	23/02/2017	09:45	52.09	57.71	11:45	51.94	57.63	135	2571.3
E	1058	23/02/2017	12:45	51.79	57.52	14:45	51.65	57.42	135	5232.4

* Net broken.

Table A2. Survey total catches by species / taxon.

Species Code	Species / Taxon	Total catch (kg)	Total catch (%)	Sample (kg)	Discard (kg)
LOL	*Doryteuthis gahi*	179863	68.7	511	327
PAR	*Patagonotothen ramsayi*	61907	23.7	282	59690
BLU	*Micromesistius australis*	6164	2.4	106	1207
BAC	*Salilota australis*	2717	1.0	0	1172
CGO	*Cottoperca gobio*	2028	0.8	0	1165
TOO	*Dissostichus eleginoides*	1858	0.7	1220	1
SPN	Porifera	1440	0.6	0	441
GRF	*Coelorhynchus fasciatus*	1436	0.5	0	1396
PTE	*Patagonotothen tessellata*	519	0.2	0	519
WHI	*Macruronus magellanicus*	488	0.2	0	0
EEL	*Iluocoetes fimbriatus*	471	0.2	0	471
ALG	Algae	459	0.2	0	459
GRC	*Macrourus carinatus*	360	0.1	5	10
CHE	*Champsocephalus esox*	222	0.1	21	39
POR	*Lamna nasus*	205	0.1	50	155
RBR	*Bathyraja brachyurops*	195	0.1	0	18
RFL	*Zearaja chilensis*	154	0.1	0	4
ZYP	*Zygochlamys patagonica*	143	0.1	0	143
ING	*Moroteuthis ingens*	142	0.1	0	142
SQT	Ascidiacea	116	<0.1	0	116
GOC	*Gorgonocephalas chilensis*	114	<0.1	0	114
KIN	*Genypterus blacodes*	103	<0.1	1	2
ALF	*Allothunnus fallai*	90	<0.1	90	18
GYM	*Gymnoscopelus* spp.	88	<0.1	0	88
DGH	*Schroederichthys bivius*	54	<0.1	0	54
RSC	*Bathyraja scaphiops*	41	<0.1	0	0
ANM	Anemone	31	<0.1	0	31
STA	*Sterechinus agassizi*	28	<0.1	0	28
ILL	*Illex argentinus*	26	<0.1	3	22
RAL	*Bathyraja albomaculata*	23	<0.1	0	6
RBZ	*Bathyraja cousseauae*	22	<0.1	0	1
RGR	*Bathyraja griseocauda*	17	<0.1	0	4
PAT	*Merluccius australis*	17	<0.1	17	0
SAR	*Sprattus fuegensis*	16	<0.1	1	14
EGG	Eggmass	16	<0.1	0	16
NEM	*Neophyrnichthys marmoratus*	15	<0.1	1	15
GYN	*Gymnoscopelus nicholsi*	15	<0.1	0	15
RMC	*Bathyraja macloviana*	13	<0.1	0	3
SHT	Mixed invertebrates	12	<0.1	0	12
RMG	*Bathyraja magellanica*	11	<0.1	0	2
POA	*Porania antarctica*	9	<0.1	0	9
HAK	*Merluccius hubbsi*	8	<0.1	0	2
RPX	*Psammobatis* spp.	7	<0.1	0	7
LIC	*Lithodes confundens*	5	<0.1	0	3

OPV	*Ophiacanta vivipara*	4	<0.1	0	4
ODM	*Odontocymbiola magellanica*	4	<0.1	0	4
FUM	*Fusitriton m. magellanicus*	4	<0.1	0	4
CAZ	*Calyptraster* sp.	4	<0.1	0	4
ALC	Alcyoniina	4	<0.1	0	4
MLA	*Muusoctopus longibrachus akambei*	2	<0.1	1	1
LIS	*Lithodes santolla*	2	<0.1	0	0
GOR	Gorgonacea	2	<0.1	0	2
COT	*Cottunculus granulosus*	2	<0.1	1	1
WRM	*Chaetopterus variopedeatus*	1	<0.1	0	1
TRP	*Tripilaster philippi*	1	<0.1	0	1
SUN	*Labidaster radiosus*	1	<0.1	0	1
SOR	*Solaster regularis*	1	<0.1	0	0
RED	*Sebastes oculatus*	1	<0.1	1	0
RDO	*Amblyraja doellojuradoi*	1	<0.1	0	1
PYM	*Physiculus marginatus*	1	<0.1	0	1
OCM	*Octopus megalocyathus*	1	<0.1	0	1
MUG	*Munida gregaria*	1	<0.1	0	1
MUE	*Muusoctopus eureka*	1	<0.1	0	1
HYD	Hydrozoa	1	<0.1	0	1
EUL	*Eurypodius latreillei*	1	<0.1	0	1
CTA	*Ctenodiscus australis*	1	<0.1	0	1
COL	*Cosmasterias lurida*	1	<0.1	0	1
THO	Thouarellinae	<1	<0.1	0	0
THN	*Thysanopsetta naresi*	<1	<0.1	0	0
STE	*Sterechinus* sp.	<1	<0.1	0	0
SER	*Serolis* spp.	<1	<0.1	0	0
PYX	Pycnogonida	<1	<0.1	0	0
POL	Polychaeta	<1	<0.1	0	0
PLU	Primnoellinae	<1	<0.1	0	0
PLB	Primnoellinae	<1	<0.1	0	0
PES	*Peltarion spinosulum*	<1	<0.1	0	0
PAS	*Patagonotothen squamiceps*	<1	<0.1	0	0
OPL	*Ophiuroglypha lymanii*	<1	<0.1	0	0
OPH	Ophiuroidea	<1	<0.1	0	0
NUD	Nudibranchia	<1	<0.1	0	0
NOW	*Paranotothenia magellanica*	<1	<0.1	0	0
NEC	*Neorossia caroli*	<1	<0.1	0	0
MYX	*Myxine* spp.	<1	<0.1	0	0
MYA	*Myxine australis*	<1	<0.1	0	0
MUO	*Muraenolepis orangiensis*	<1	<0.1	0	0
MAV	*Magellania venosa*	<1	<0.1	0	0
LOS	*Lophaster stellans*	<1	<0.1	0	0
LOA	*Loxechinus albus*	<1	<0.1	0	0
LEA	*Lepas australis*	<1	<0.1	0	0
ISO	Isopoda	<1	<0.1	0	0
FLX	*Flabellum* spp.	<1	<0.1	0	0
EUO	*Eurypodius longirostris*	<1	<0.1	0	0
CRY	*Crossaster* sp.	<1	<0.1	0	0
COG	*Patagonotothen guntheri*	<1	<0.1	0	0
CIR	Cirripedia	<1	<0.1	0	0
CEX	*Ceramaster* sp.	<1	<0.1	0	0
BRY	Bryozoa	<1	<0.1	0	0
BAO	*Bathybiaster loripes*	<1	<0.1	0	0
AUC	*Austrocidaris canaliculata*	<1	<0.1	0	0
AST	Asteroidea	<1	<0.1	0	0
ANT	Anthozoa	<1	<0.1	0	0
AGO	*Agonopsis chilensis*	<1	<0.1	0	0
		261,712		2,312	67,980

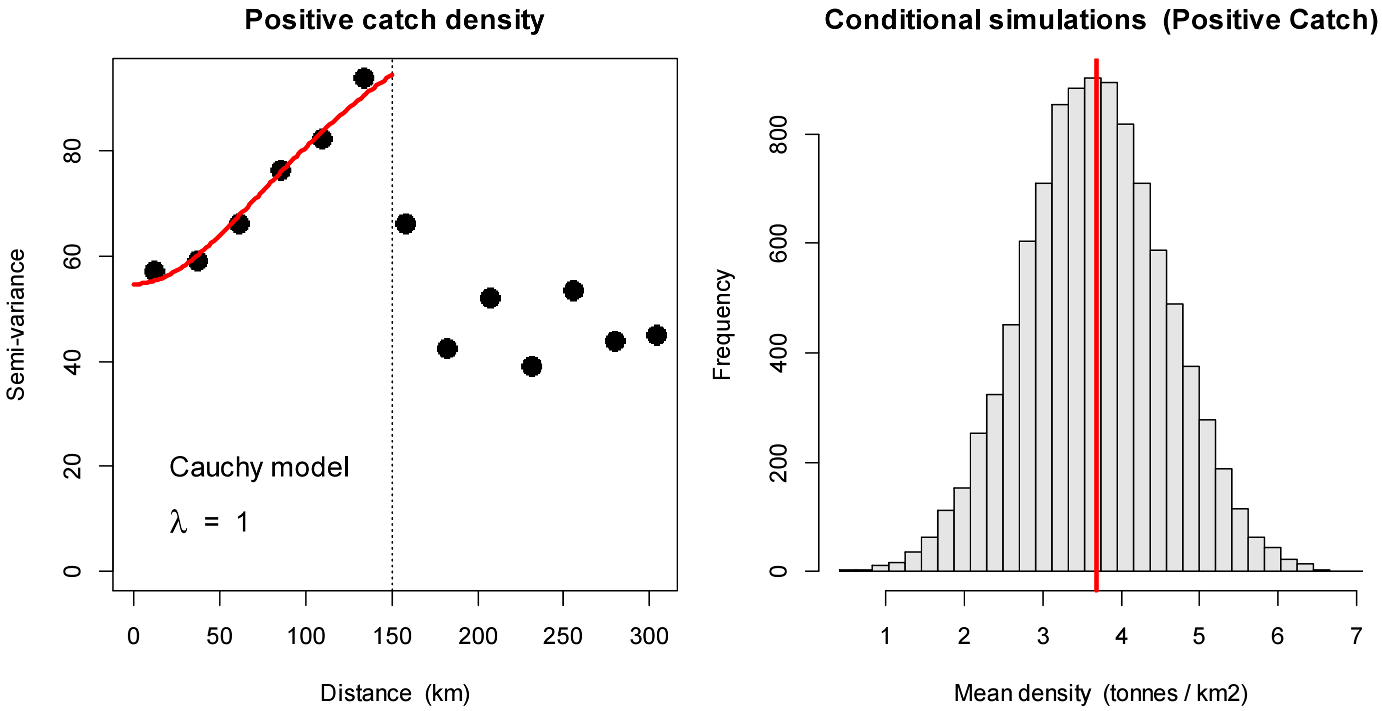

Figure A1. Left: Empirical variogram (black circles) and model variogram (red line) of calamari biomass density distributions from positive catch trawl intervals. Dotted line: maximum modelled lag distance at 150 km. Right: histogram of conditional simulations of mean density estimates resulting from the model variogram at left. Vertical red line: empirical mean density estimate at 3.68 t km^{-2}.

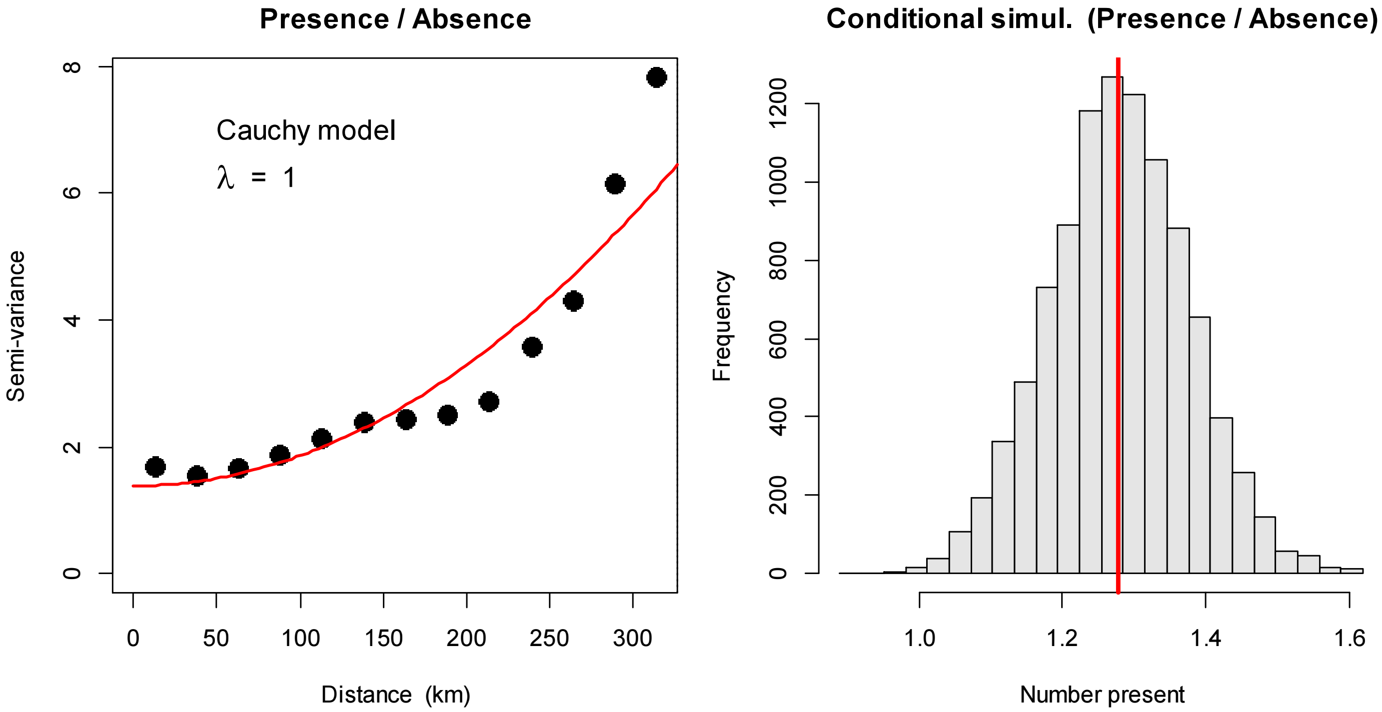

Figure A2 [previous page]. Left: Empirical variogram (black circles) and model variogram (red line) of numbers of positive catch intervals present per 5 × 5 km area unit. Right: histogram of conditional simulations of positive catch interval numbers resulting from the model variogram at left. Vertical red line: empirical mean number of positive catch intervals present at 1.28.

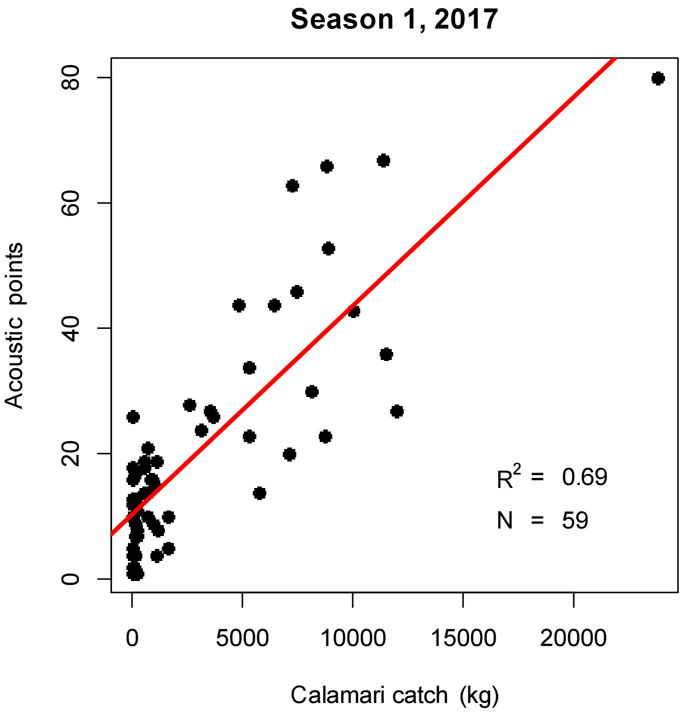

Figure A3. Calamari catch vs. total acoustic score per trawl during the 1st preseason 2017 survey, with linear regression slope (red line).