FALKLAND
ISLANDS
FISHERIES
DEPARTMENT

Doryteuthis gahi Stock Assessment Survey, 1st Season 2018

Vessel	Castelo (ZDLT1) Falkland Islands
Dates	11/02/2018 – 25/02/2018
Survey Team	Andreas Winter Verónica Iriarte Tomasz Zawadowski

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Summary

1) A stock assessment survey for *Doryteuthis gahi* (Falkland calamari) was conducted in the 'Loligo Box' from 11th to 25th February 2018. Fifty-nine scientific trawls were taken during the survey, including four dedicated trawls to cover a juvenile toothfish transect on one day. The scientific catch of the survey was 114.87 tonnes *D. gahi*.
2) A geostatistical estimate of 32,194 tonnes *D. gahi* (95% confidence interval: 19,552 to 89,938 t) was calculated for the fishing zone. This estimate represents the second-lowest 1st-season survey biomass of the past five years. Of the total, 569 t were estimated north of 52 ºS, and 31,625 t were estimated south of 52 ºS.
3) Male and female *D. gahi* had significantly greater average mantle lengths north of 52 ºS than south of 52 ºS. Males north: mean mantle length 11.70 cm; mean maturity stage 2.23, males south: mean mantle length 10.12 cm; mean maturity stage 2.00. Females north: mean mantle length 11.37 cm; mean maturity stage 2.07, females south: mean mantle length 9.95 cm; mean maturity stage 2.18.
4) 95 taxa were identified in the catches. Jellyfish were the largest species group at 45.9% of total catch by weight, followed by *D. gahi* (33.5%), blue whiting (8.0%), and rock cod (7.4%). Biological measurements and samples were taken from *D. gahi*, rock cod, toothfish, and opportunistic specimens of various other species.

Introduction

A stock assessment survey for *Doryteuthis gahi* (Falkland calamari – Patagonian longfin squid – colloquially *Loligo*) was carried out by FIFD personnel on-board the fishing vessel *Castelo* from the 11th to 25th February 2018; experimental license FK034E18. The survey included one day for consecutively sampling an inshore-offshore transect of four juvenile toothfish trawls (Figures 1, 2). This survey continues the series of surveys that have, since February 2006, been conducted immediately prior to season openings to estimate the *D. gahi* 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 *D. gahi* on the fishing grounds at the onset of the 1st fishing season, 2018.
2) Continue a series of experimental trawls for studying the recruitment and movement of juvenile toothfish (*Dissostichus eleginoides*).
3) Estimate the biomass and distribution of common rock cod (*Patagonotothen ramsayi*) in the 'Loligo Box', for continued monitoring of this stock and in parallel to the finfish research survey being conducted on the F/V *Monteferro*.
4) Collect biological information on *D. gahi*, rock cod, toothfish and opportunistically other commercially important fish and squid taken in the trawls.

*) An additional, ad hoc, objective was to start monitoring for a possible reprise of last season's exceptional pinniped ingression to the *D. gahi* fishing zone (Winter 2017).

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 31,721.5 km^2.

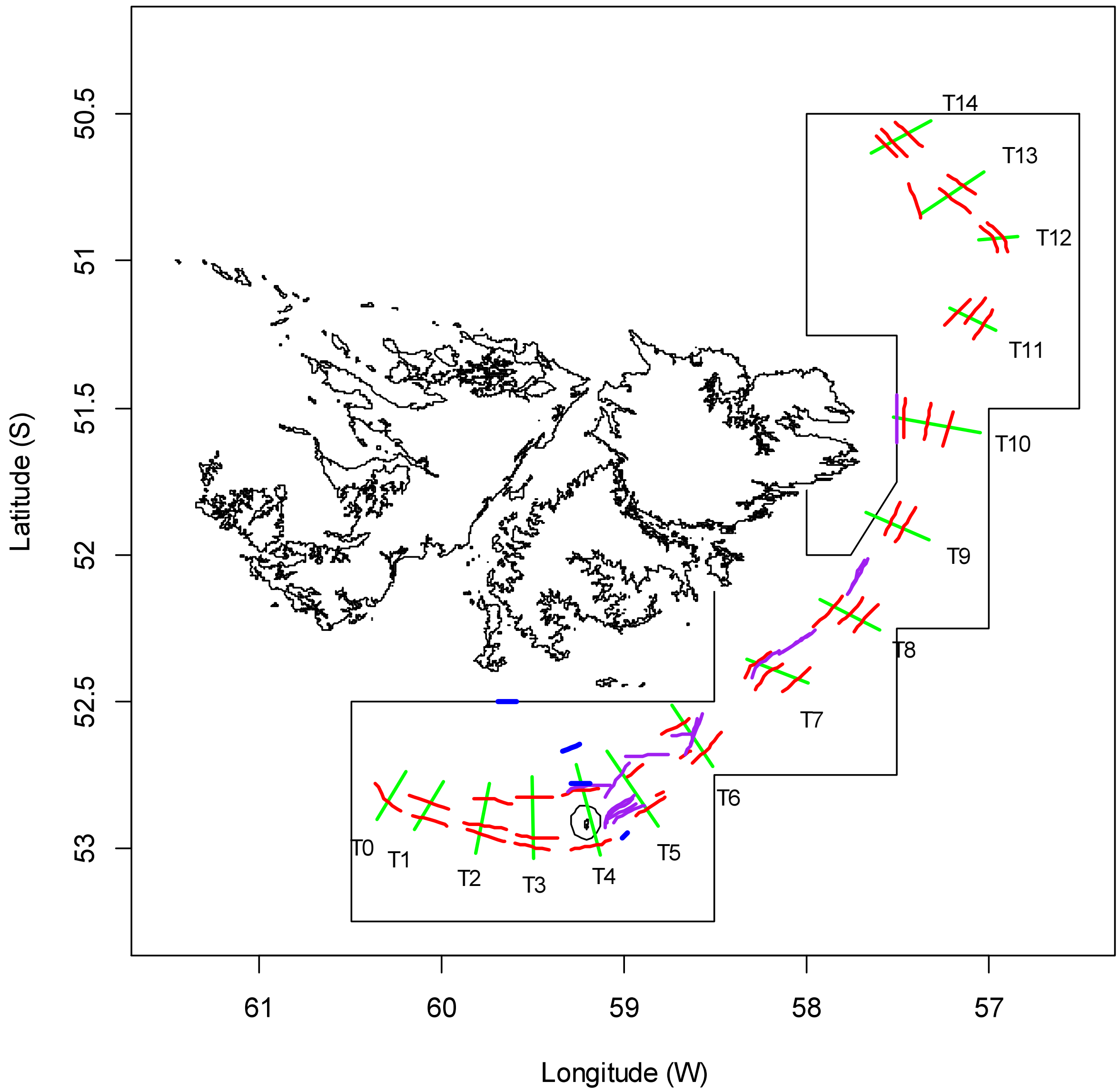

Figure 1. Survey transects (green lines), fixed-station trawls (red lines), adaptive-station trawls (purple lines), and toothfish transect trawls (blue lines) sampled during the 1st pre-season 2018 survey. Some fixed-station trawls have deviations to adapt to the terrain. Boundaries of the 'Loligo Box' fishing zone and the Beauchêne Island exclusion zone are in black.

The F/V *Castelo* is a Falkland Islands - registered stern trawler of 67.78 m length, 1321 gross tonnage, and 2450 main engine bhp. *Castelo* was previously employed for the 1st pre-season 2009 survey (Payá 2009) and the 2nd pre-season 2016 survey (Winter et al. 2016). Like all vessels employed for pre-season surveys, *Castelo* operates regularly in the *D. gahi* fishery and used its commercial trawl gear for the survey catches. The following personnel from the FIFD participated in the 1st pre-season 2018 survey:

Andreas Winter	lead scientist
Verónica Iriarte	fisheries observer
Tomasz Zawadowski	fisheries observer

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 *D. gahi* 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 12.8 to 17.6 km (median 15.9 km). The toothfish trawls were taken on one day as part of an ongoing study to characterize shelf out-migration of juvenile toothfish. These four trawls were designed for an expected duration of 1 hour each and ranged in distance from 6.5 to 7.8 km (median 7.1 km). All trawls were bottom trawls. During the progress of each trawl, GPS latitude, GPS longitude, bottom depth, bottom temperature, cable extent, 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. Following the procedure described in Roa-Ureta and Arkhipkin (2007), the acoustic marks were used to apportion the *D. gahi* 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 *D. gahi* amounts <100 kg were iteratively aggregated by adjacent intervals (if the total *D. gahi* catch in a trawl was <100 kg it was assigned to one interval; the middle interval).

Catch estimation

The catch of every trawl was processed separately by the factory crew and retained catch weight of *D. gahi*, by size category, was estimated from the number of standard-weight blocks of frozen squid 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 2016). Total catch composition per trawl, including commercially unvalued species, damaged fish, and undersized fish, was estimated using a combination of visual assessment and basket data. Between 1 and 6 observer baskets (median 3) of unsorted catch were collected at intervals from each survey trawl[1], 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 proportioned to the *D. gahi* catch of the whole trawl. Scarce species were collected and weighed entirely from each trawl. Non-commercial bycatches were then added to the factory production weights (as applicable) to give total catch weights of all fish and squid. Uncertainty in catch weight per species per trawl was estimated by two methods: 1) randomly re-sampling, with replacement 10000×, the baskets per trawl, and 2) stochastically re-weighting, also 10000×, the relative importance of each basket per trawl. Because of the differing numbers of baskets per trawl either method could represent more uncertainty, and the higher uncertainty was retained as the measure of variability for each trawl[2]. For trawls that had some catch recorded of a given species but none occurred in the basket samples, an average variability was taken among all trawl stations that did have that species occurring in the basket samples.

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[1] Except two fixed-station trawls that were visually almost pure Medusae, and the four trawls of the toothfish transect which were completely sorted by the FIFD survey personnel.

[2] Of course, neither method retained any variability for those four trawls of which, by circumstance, only a single basket was sampled (see Table A3).

Biomass calculations

Biomass density estimates of *D. gahi* 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):

trawl width = (door distance × footrope length) / (footrope + sweep + bridle)

Measurements of *Castelo*'s trawl, provided by the vessel master, were: footrope = 100 m, sweep = 18 m, bridle = 130 m.

For one trawl on 22nd February, batteries failed on the Marport net sensors, eliminating door distance data from approximately half the trawl duration. Door distances were instead estimated from a generalized additive model (GAM) as a function of predictive variables trawl speed, wind speed, and warp cable out; calculated from all other trawl data of this survey for which the door distance sensor was operational (n = 354). The GAM resulted in 50.4% deviance explained, which is relatively low as the battery failure also eliminated net height sensor data that are typically significant predictor variables for door distance (Winter and Jürgens 2014, Winter et al. 2015). Because, in this case, half the trawl's door distance data were available, the GAM predictions for the missing other half were standardized (divided by their own mean) and multiplied by the mean of the trawl's available door distance data.

Biomass density estimates were extrapolated to the survey area using geostatistical methods (Petitgas 2001). As previously (e.g., Winter et al. 2017a), the delineated survey area was set to 20,000 km^2, partitioned for analysis as 800 area units of 5×5 km. The best geostatistic variogram fit was obtained by modelling all catch densities per interval together (Appendix Figure A1). Biomass values were augmented by the minimal value of 1 g to avoid computational problems with the geostatistic algorithm on biomass densities = 0.

Uncertainty of the geostatistical model of biomass density was estimated by 10,000 conditional simulations of the 800 area units (Woillez et al. 2009), performed in the R software package 'geoR' (Ribeiro and Diggle 2001). Conditional simulations of catch density extrapolations were iterated 250000×. At each iteration one of the 10,000 conditional simulations was selected and a random normal value calculated for each of the 800 area units with mean = the conditional simulation value and s.d. = the absolute conditional simulation value × the coefficient of variation (c.v.) of acoustic apportionment. The 800 random normal values were then standardized by dividing by the mode of the distribution means of the conditional simulations, to avoid bias of outlier values in the conditional simulations, and the mean of these taken as one iteration of uncertainty.

The uncertainty estimation included the c.v. of acoustic apportionment because assessing acoustic marks (described in the Sampling Procedures) is a visual judgement, and does not objectively differentiate *D. gahi* from other echo targets entering the net. There is therefore no definitive way to quantify the potential error of this assessment. In previous surveys (e.g., Jones et al. 2015, Winter 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 *D. gahi* catch per trawl. Acoustic scores are relative values referenced to each individual trawl, but if all are assigned by the same scientist in a survey, their absolute values should also be consistent across all trawls. However, in the 1st pre-season 2018 survey acoustic scores were variously assigned by all three of the *Castelo*'s bridge officers as well as the survey scientist, and obtained inadequate consistency for this measure (Figure A2). Instead, an approximate average of $R^2 = 0.5$ based on previous surveys was used to quantify error. The variability not explained by the linear coefficient of determination (here $1 - R^2 = 0.5$) was multiplied by each interval catch of each trawl and randomly either added to or subtracted from the interval catch:

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

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 *D. gahi* 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, as for the empirical estimate. The full randomization was repeated 10000× and the c.v. of the mean geostatistic density retained as the measure of error of acoustic apportionment[3].

Biological analyses

Random samples of *D. gahi* (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. Additional specimens of *D. gahi* (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 rock cod (PAR) was taken at every trawl station. Catches of toothfish (TOO) were collected from all trawl stations to maximize the time series catch and biological information base for juvenile toothfish, in addition to the samples from the dedicated one-day toothfish transect. Specimens of southern king crab (LIS; *Lithodes santolla*), Patagonian hake (PAT; *Merluccius australis*), porbeagle shark (POR; *Lamna nasus*), and redfish (RED; *Sebastes oculatus*) 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 were taken mostly in the south, where the highest concentrations of *D. gahi* biomass were found (Figures 1; 2, Appendix Table A1). A schedule of 4 survey trawls per day was maintained except for February 25th, the last day of the survey, when the fourth survey trawl was cancelled because the work of cleaning basket stars (*Gorgonocephalus chilensis*) from the net after the previous trawl delayed too late into the evening, given the necessity of packing up sampling gear for disembarkation. In total 59

[3] 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.

scientific trawls were recorded during the survey: 39 fixed station trawls catching 51.93 t *D. gahi*, 16 adaptive trawls catching 56.25 t *D. gahi*, and 4 toothfish trawls catching 6.69 t *D. gahi*. Fifteen optional trawls (made after survey hrs) yielded an additional 76.59 t *D. gahi*, bringing the total catch for the survey to 191.46 t. The scientific survey catch of 114.87 t is below the median for 1st seasons since 2006, and the second-lowest of the last five years (Table 1).

Average *D. gahi* catch density among fixed-station trawls was 0.17 t km^{-2} north of 52° S and 3.45 t km^{-2} south of 52° S. Both densities were above the respective medians compared to the previous seven years; the south was the second-highest of the past eight years. Average *D. gahi* catch density among adaptive-station trawls was 2.37 t km^{-2} north of 52° S and 5.26 t km^{-2} south of 52° S. Both were below their respective medians for the past seven years.

Figure 2 [below]. *D. gahi* CPUE (t km^{-2}) of fixed-station (red), adaptive (purple), and toothfish transect (blue) trawls per 15-minute trawl interval. Boundaries of the 'Loligo Box' fishing zone and the Beauchêne Island exclusion zone are traced in black.

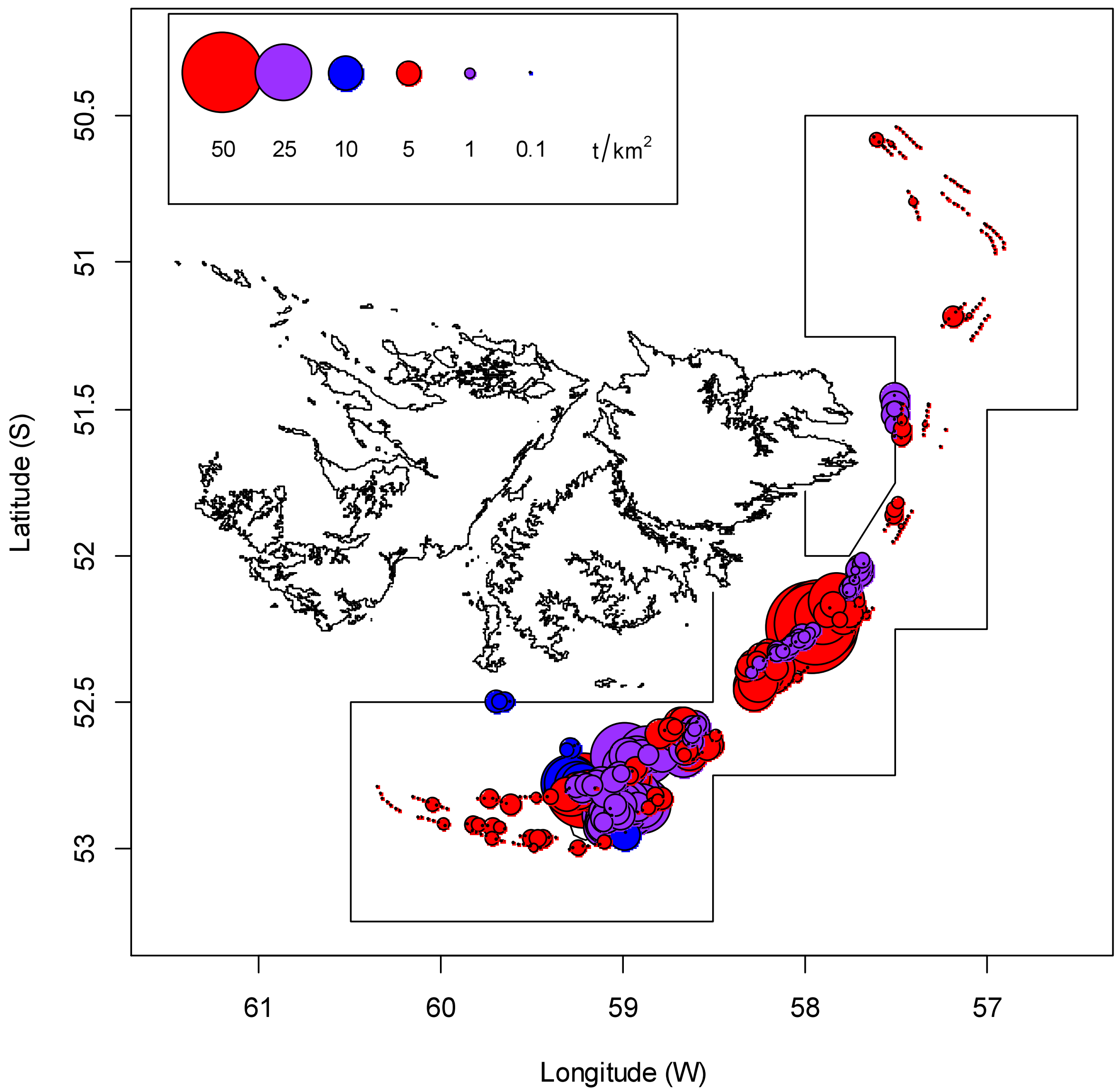


Table 1. *D. gahi* pre-season survey scientific catches and biomass estimates (in metric tonnes). Before 2006, surveys were not conducted immediately prior to season opening.

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	63*	314	56807
2018	59*	115	32194			

* Includes four juvenile toothfish transect trawls.

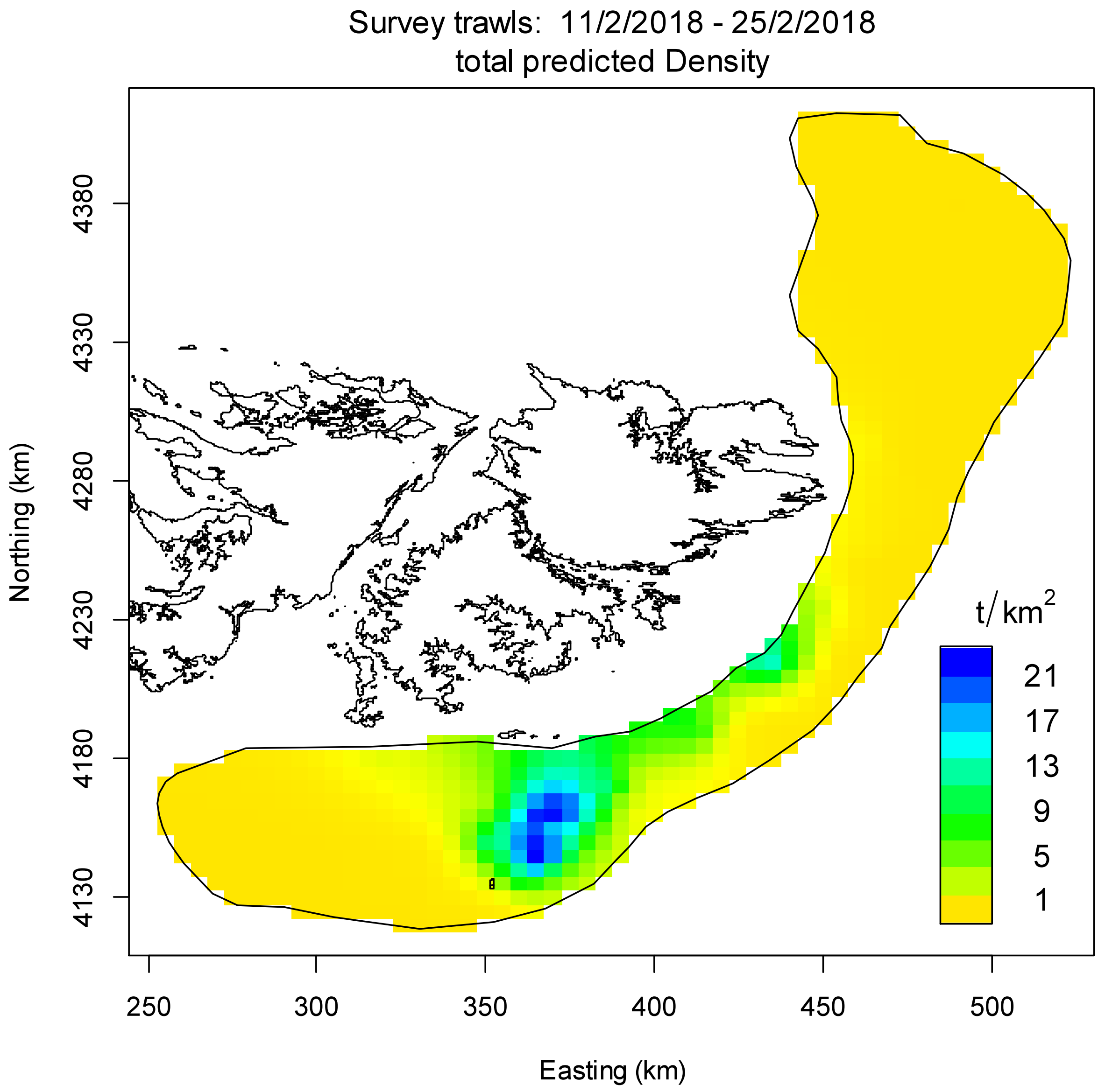


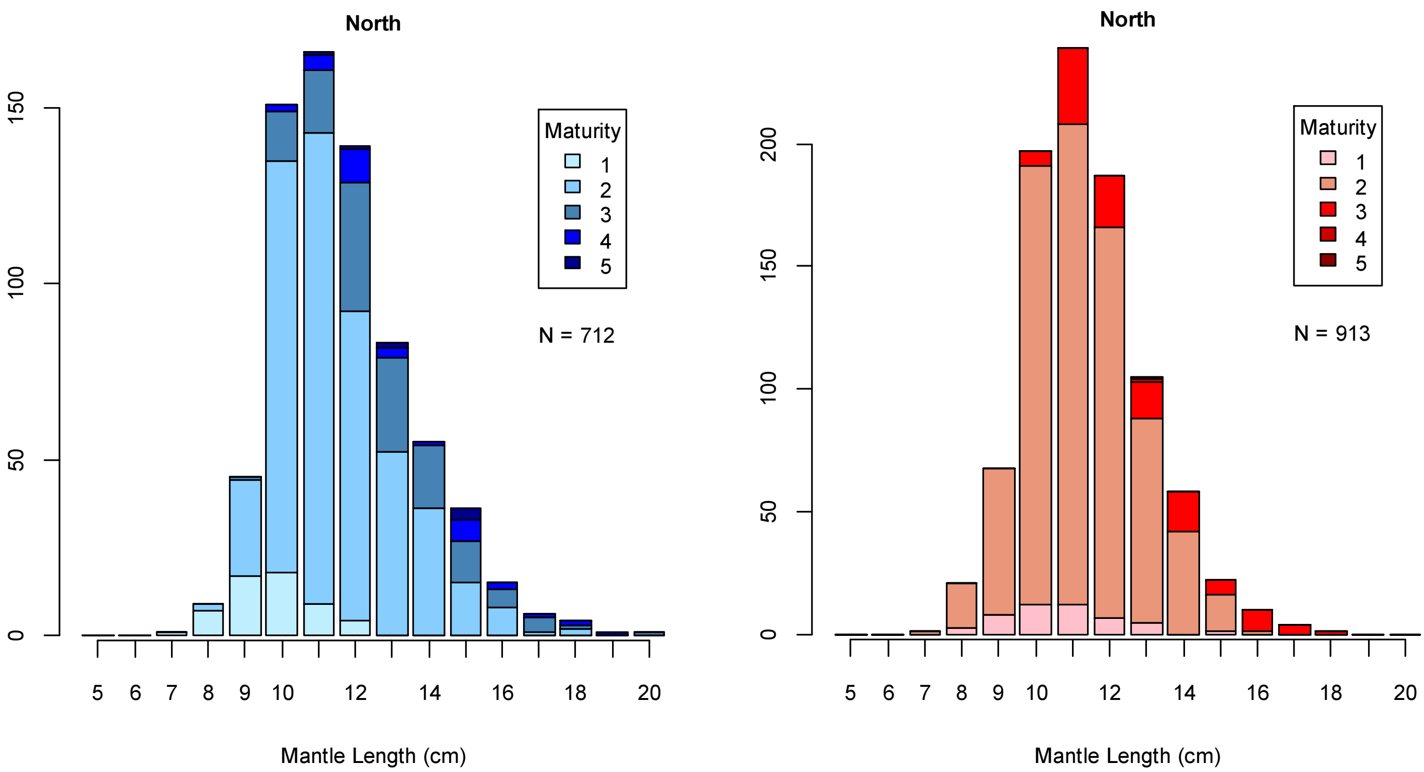
Figure 3 [previous page]. *Doryteuthis gahi* predicted density estimates per 5 km^2 area units. Coordinates were converted to WGS 84 projection in UTM sector 21F using R library rgdal (proj.maptools.org).

Biomass estimation

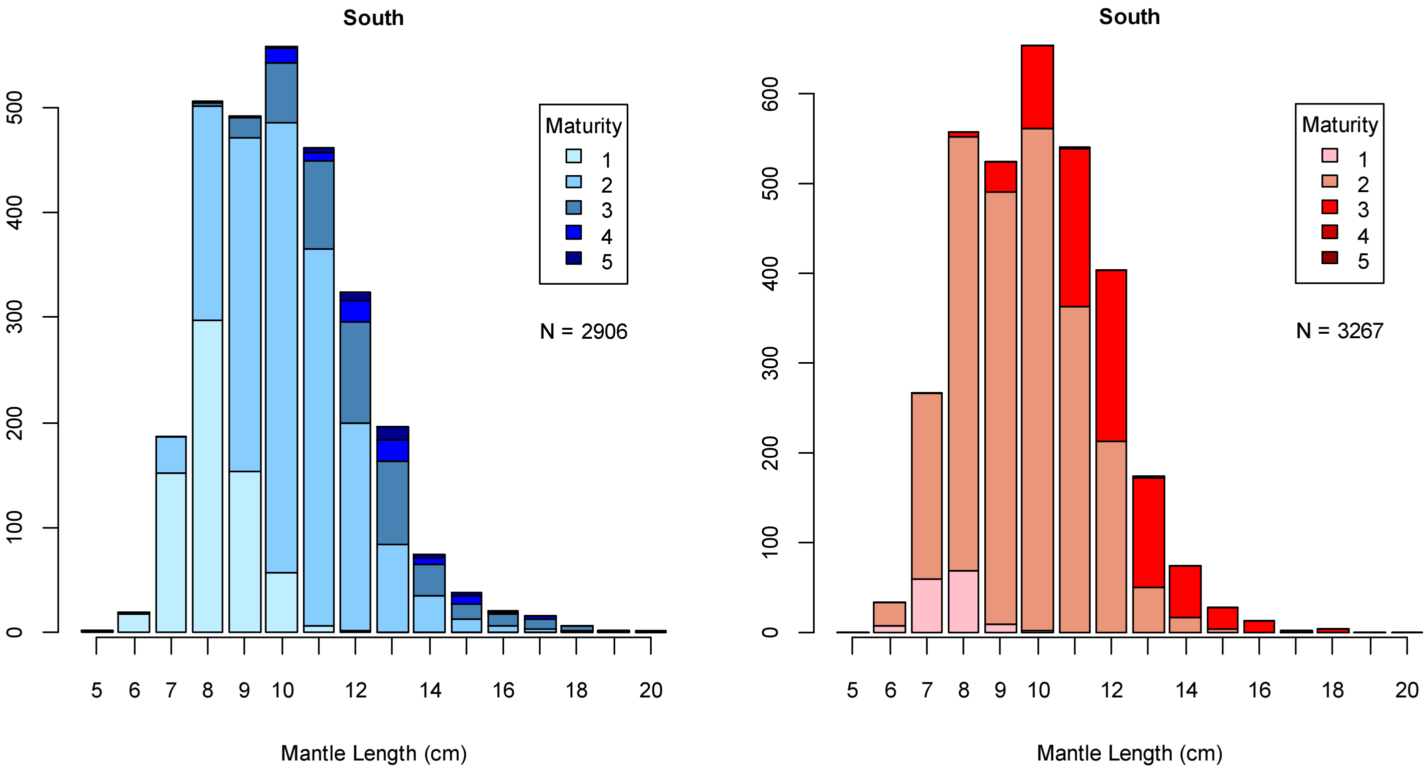
Total *D. gahi* biomass in the fishing area was estimated at 32,194 tonnes, with a 95% confidence interval of [19,552 to 89,938 t]. Distribution of the estimated biomass was strongly preponderant towards the south, with catch projections from 0.001 to 0.43 t km^{-2} in 95% of area units north of 52 ºS, and 0.004 to 17.48 t km^{-2} in 95% of area units south of 52 ºS (Figure 3). Of the estimated total biomass, 569 t [325 to 4,594 t] were north of 52 ºS, and 31,625 t [17,329 to 89,486 t] were south of 52 ºS. Thus <1.8% of the biomass was north, representing the most one-sided north-south distribution for a 1st pre-season since at least 2011. The survey total biomass estimate of 32,194 t was the fifth-highest of the thirteen 1st seasons since 2006, but the second-lowest of the last five years (Table 1)[4].

Biological data

Figure 4 [below]. Length-frequency distributions by maturity stage of male (blue) and female (red) D. gahi from trawls north (top) and south (bottom) of latitude 52 ºS.



[4] However, note that biomass estimates from previous years may not be explicitly equivalent because the delineation of the fishing area over which the geostatistic model is applied has been revised several times.



Ninety-five taxa were identified in the catches (Appendix Table A2). Jellyfish made up the highest proportion on record for a 1st pre-season survey: 44.7% unspecified Medusae plus 1.2% *Chrysaora* sp. and <0.1% *Aurelia* sp. (Table A2). *D. gahi* was second (33.5%) followed by blue whiting *Micromesistius australis* (8.0%). As typical (Winter and Jürgens 2014, Winter et al. 2016), blue whiting catches were highly aggregated: 68.6% of the total of 27.3 t (Tables A2 and A3) was taken in just two trawls. Rock cod (*P. ramsayi*) was fourth (7.4%), the lowest rank and lowest 1st pre-season survey bycatch since at least 2012.

In contrast to the previous pre-season survey in the Loligo Box (Winter et al. 2017b), no pinnipeds were sighted by the FIFD survey team, and no pinniped interactions or incidental catches occurred.

D. gahi mantle length and maturity distributions north and south of 52° S are plotted in Figure 4. For both males and females, size and maturity distributions were significantly different between north and south (Kruskal-Wallis test, $p < 0.001$ all comparisons). For males north: mean mantle length 11.70 cm; mean maturity stage 2.23 (on a scale of 1 to 5), males south: mean mantle length 10.12 cm; mean maturity stage 2.00. Females north: mean mantle length 11.37 cm; mean maturity stage 2.07, females south: mean mantle length 9.95 cm; mean maturity stage 2.18.

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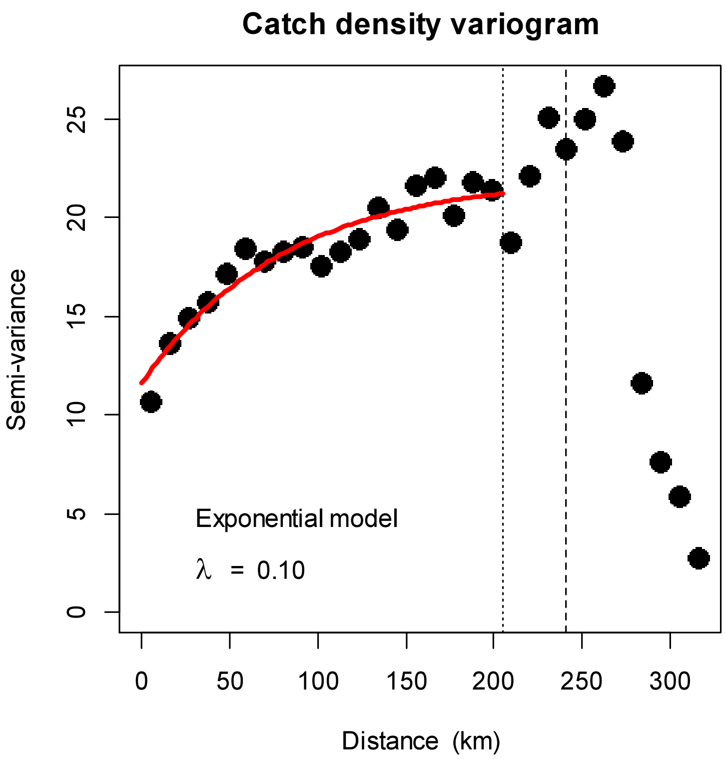
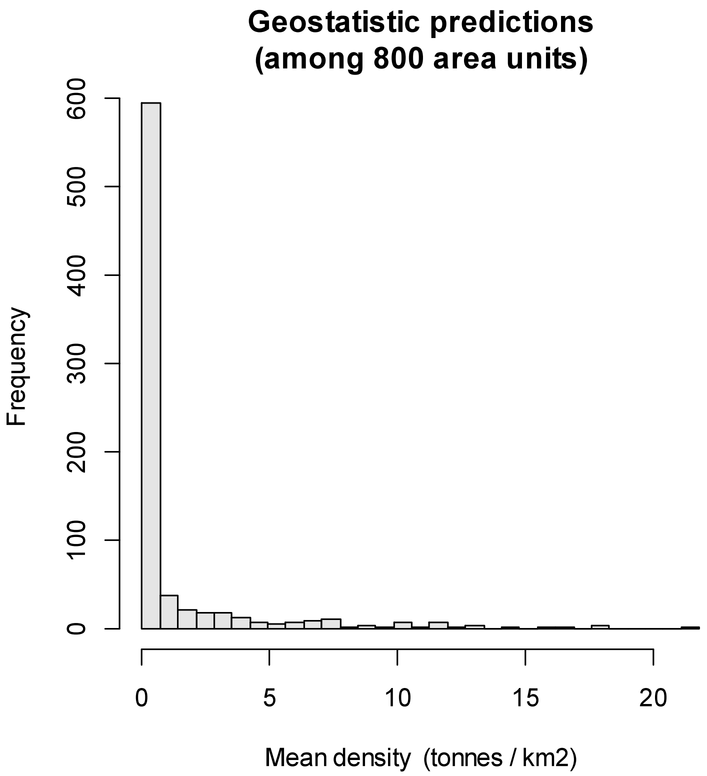
Appendix

Geostatistic models





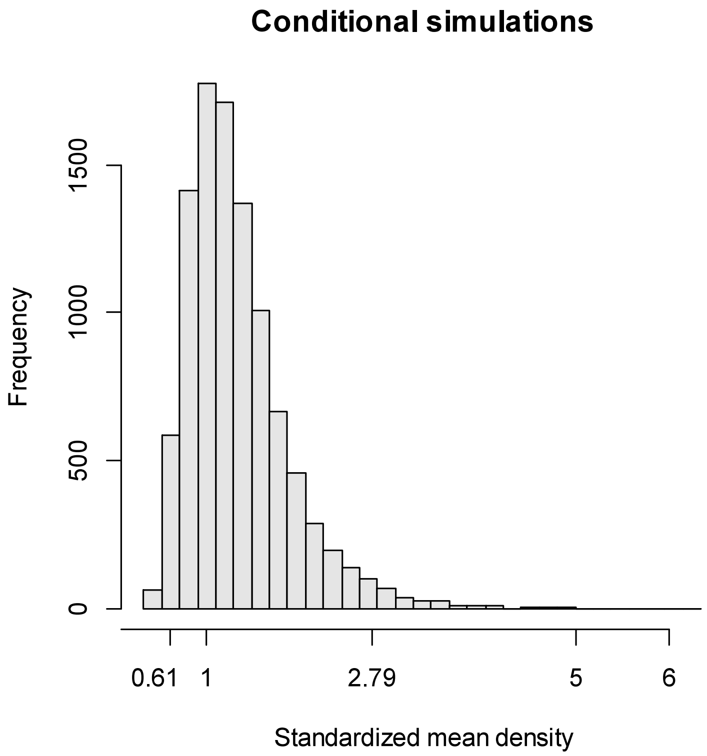


Figure A1 [previous page]. Top: Empirical (black circles) and model variogram (red line) of *D. gahi* biomass density distributions from catch trawl intervals (left). Bottom left: Histogram of geostatistic biomass density predictions for the 800 area units of the survey area. Bottom right: histogram of conditional simulations for mean biomass density resulting from the model variogram (above), standardized to mode = 1; 95% confidence interval 0.61 to 2.79.

A simple geostatistic model (all trawl intervals modelled together, not positive catch intervals separately from presence / absence) was found to give the best fit to the data for the first *D. gahi* survey since 1st pre-season 2015 (Winter et al. 2015). Biomass density estimates from all trawl intervals were modelled with an exponential covariance function and $\lambda = 0.10$ Box-Cox transformation (Box and Cox 1964). The geostatistic variogram was fit up to a maximum lag distance of 205 km, and resulted in a practical range of 241.3 km, i.e., the model extrapolated *D. gahi* densities to spatially correlate up to a maximum separation distance of 241.3 km (Figure A1-top).

The distribution of geostatistic density predictions among the 800 area units was heavily right-skewed, with a maximum of 21.8 tonnes/km^2 but 532 of 800 area units less than 0.25 tonnes/km^2 (Figure A1-bottom left). The mean values of 10,000 conditional simulations (Figure A1-bottom right) had a coefficient of variation of 42.6%.

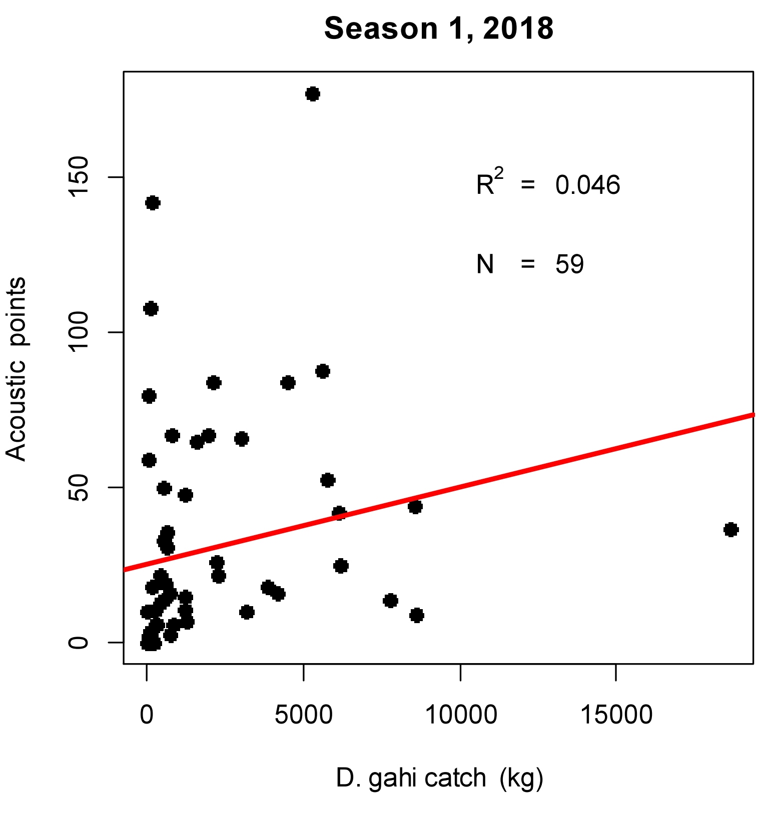


Figure A2. *D. gahi* catch vs. total acoustic score per trawl during the 1st pre-season 2018 survey, with linear regression slope (red line).

Summary tables

Table A1 [next page]. Survey stations with total *D. gahi* catch. Time: vessel's clock; one hour in advance of local (Stanley, F.I.) time, latitude: °S, longitude: °W. Transects labelled A were adaptive trawls; transects labelled T were toothfish trawls.

Transect Station	Obs Code	Date	Start			End			Depth	*D. gahi*
			Time	Lat	Lon	Time	Lat	Lon	(m)	(kg)
14 - 39	2727	11/02/2018	07:10	50.53	57.51	09:06	50.61	57.36	251	0.1
14 - 37	2728	11/02/2018	10:27	50.64	57.50	[B] 12:11	[A] 50.57	[A] 57.62	137	120.0
14 - 38	2729	11/02/2018	[C] 12:57	50.55	57.59	14:55	50.64	57.44	137	28.8
13 - 34	2730	11/02/2018	15:58	50.74	57.43	17:38	[D] 50.85	[D] 57.37	130	60.0
12 - 33	2731	12/02/2018	07:14	50.97	56.90	09:08	50.87	57.01	121	0.9
13 - 36	2732	12/02/2018	10:08	50.77	57.07	12:00	50.70	57.22	244	0.0
13 - 35	2733	12/02/2018	12:54	50.75	57.27	14:45	50.83	57.10	131	2.0
12 - 32	2734	12/02/2018	15:30	50.88	57.04	17:11	50.97	56.95	116	0.5
11 - 31	2735	13/02/2018	07:05	51.17	56.97	08:44	51.26	57.08	142	7.4
11 - 30	2736	13/02/2018	09:37	51.21	57.12	11:11	51.13	57.01	127	30.4
11 - 29	2737	13/02/2018	12:02	51.13	57.10	13:59	51.22	57.24	114	242.6
10 - 26	2738	13/02/2018	15:51	51.47	57.46	17:55	51.60	57.47	128	595.6
10 - 27	2739	14/02/2018	07:10	51.60	57.35	09:05	51.48	57.31	146	29.6
10 - 28	2740	14/02/2018	10:04	51.51	57.20	11:53	51.63	57.25	228	1.9
9 - 25	2741	14/02/2018	13:36	51.84	57.40	15:50	51.96	57.51	219	19.1
9 - 24	2742	14/02/2018	16:42	51.93	57.57	18:19	51.82	57.48	163	582.9
8 - 23	2743	15/02/2018	07:05	52.17	57.60	08:53	52.26	57.73	263	47.6
8 - 22	2744	15/02/2018	09:51	52.24	57.82	11:33	52.15	57.69	198	2251.7
8 - 21	2745	15/02/2018	12:35	52.14	57.80	14:35	52.24	57.96	136	18650.0
7 - 18	2746	15/02/2018	16:42	52.42	58.33	18:26	52.34	58.19	142	3000.0
7 - 20	2747	16/02/2018	07:12	52.47	58.13	08:56	52.39	57.98	256	66.7
7 - 19	2748	16/02/2018	09:48	52.37	58.13	11:28	52.46	58.27	178	8566.1
6 - 15	2749	16/02/2018	13:02	52.56	58.64	14:35	52.61	58.79	132	2177.0
5 - 12	2750	16/02/2018	15:41	52.72	58.90	[E] 16:40	52.76	58.98	124	1240.0
0 - 1	2751	17/02/2018	07:12	52.78	60.36	08:57	52.88	60.23	243	10.8
1 - 3	2752	17/02/2018	09:48	52.89	60.16	11:24	52.92	59.97	224	160.0
2 - 5	2753	17/02/2018	12:06	52.92	59.88	14:05	52.94	59.65	173	820.0
3 - 8	2754	17/02/2018	14:52	52.96	59.59	16:38	52.97	59.36	179	720.0
1 - 2	2755	18/02/2018	07:02	52.82	60.17	09:01	52.87	59.96	194	145.2
2 - 4	2756	18/02/2018	09:55	52.83	59.82	11:46	52.85	59.62	160	385.5
3 - 7	2757	18/02/2018	12:31	52.83	59.59	14:14	52.83	59.39	146	225.0
4 - 10	2758	18/02/2018	15:18	52.82	59.34	16:55	52.80	59.13	110	8570.0
5 - 13	2759	19/02/2018	07:02	52.81	58.78	[B] 07:24	52.82	58.82	147	186.0
4 - 11	2760	19/02/2018	08:53	52.97	59.07	10:48	53.00	59.29	239	305.2
3 - 9	2761	19/02/2018	11:38	53.00	59.41	13:10	52.98	59.60	235	85.7
2 - 6	2762	19/02/2018	14:33	52.94	59.86	16:24	52.98	59.66	228	144.0
5 - 14	2763	20/02/2018	07:02	52.89	58.94	08:33	52.83	58.77	151	784.4
6 - 16	2764	20/02/2018	09:39	52.69	58.69	[B] 10:15	52.67	58.64	150	484.9
6 - 17	2765	20/02/2018	11:24	52.71	58.62	13:25	52.61	58.47	234	1185.1
A - 1	2766	20/02/2018	14:52	52.42	58.30	16:49	52.33	58.14	152	625.2
T - 1	2767	21/02/2018	08:04	52.50	59.59	09:00	52.50	59.69	105	504.5
T - 2	2768	21/02/2018	10:42	52.67	59.33	11:37	52.65	59.24	123	423.0
T - 3	2769	21/02/2018	12:45	52.78	59.19	13:35	52.78	59.29	113	5260.0
T - 4	2770	21/02/2018	15:27	52.97	59.00	[B] 15:50	52.95	58.98	333	500.0
A - 2	2771	22/02/2018	07:05	52.54	58.57	08:52	52.65	58.63	141	1183.9
A - 3	2772	22/02/2018	09:49	52.68	58.76	12:00	52.69	58.99	126	6130.0
A - 4	2773	22/02/2018	12:46	52.71	58.97	14:40	52.82	59.10	113	4130.0
A - 5	2774	22/02/2018	15:26	52.79	59.08	17:30	52.81	59.30	111	3168.0
A - 6	2775	23/02/2018	07:11	52.01	57.66	09:02	52.13	57.76	138	1548.5
A - 7	2776	23/02/2018	10:27	52.27	57.97	12:15	52.34	58.15	149	2105.1

A - 8	2777	23/02/2018	14:20	52.56	58.58	16:03	52.62	58.74	138	4446.3
A - 9	2778	23/02/2018	17:15	52.56	58.60	19:00	52.68	58.66	142	3823.8
A - 10	2779	24/02/2018	07:08	52.91	59.10	09:06	52.82	58.94	137	5565.9
A - 11	2780	24/02/2018	10:00	52.84	58.95	12:02	52.93	59.10	140	5764.1
A - 12	2781	24/02/2018	12:59	52.91	59.06	14:50	52.85	58.89	144	7723.8
A - 13	2782	24/02/2018	15:36	52.85	58.94	17:15	52.92	59.10	142	6180.0
A - 14	2783	25/02/2018	07:18	52.33	58.13	08:58	52.26	57.95	148	740.0
A - 15	2784	25/02/2018	10:13	52.14	57.77	11:50	52.02	57.68	136	1180.0
A - 16	2785	25/02/2018	14:09	51.62	57.50	16:15	51.46	57.50	122	1940.0

A: Track modified to run east of coral bed.
B: Trawl stopped early because the net was filling with Medusae.
C: Starboard door not set correctly. Hauled and re-set.
D: Track modified to run west of hard bottom.
E: Trawl stopped early because the net was filling with *Munida*.

Table A2. Empirical estimates of survey total catches by species / taxon.

Species Code	Species / Taxon	Total catch (kg)	Total catch (%)	Sample (kg)	Discard (kg)
MED	Medusae	153011	44.7	0	152991
LOL	*Doryteuthis gahi*	114875	33.5	313	130
BLU	*Micromesistius australis*	27311	8.0	0	27311
PAR	*Patagonotothen ramsayi*	25468	7.4	341	21714
MUN	*Munida* spp.	7167	2.1	0	7167
CHR	*Chrysaora* cf. *plocamia*	4064	1.2	0	4064
SQT	Ascidiacea	1921	0.6	0	1921
GRC	*Macrourus carinatus*	1603	0.5	0	1195
CGO	*Cottoperca gobio*	752	0.2	0	752
GRF	*Coelorhynchus fasciatus*	683	0.2	0	683
WHI	*Macruronus magellanicus*	682	0.2	0	265
BAC	*Salilota australis*	567	0.2	0	359
TOO	*Dissostichus eleginoides*	540	0.2	540	17
CHE	*Champsocephalus esox*	465	0.1	16	284
SPN	Porifera	464	0.1	0	464
GOC	*Gorgonocephalus chilensis*	447	0.1	0	447
PTE	*Patagonotothen tessellata*	374	0.1	0	374
ING	*Moroteuthis ingens*	293	0.1	0	293
RBR	*Bathyraja brachyurops*	238	0.1	0	81
KIN	*Genypterus blacodes*	235	0.1	0	37
ALG	Algae	175	0.1	0	175
DGH	*Schroederichthys bivius*	142	<0.1	0	142
PAU	*Patagolycus melastomus*	94	<0.1	0	94
ALF	*Allothunnus fallai*	83	<0.1	0	83
POR	*Lamna nasus*	80	<0.1	80	80
NEM	*Neophyrnichthys marmoratus*	80	<0.1	0	80
ANM	Anemone	78	<0.1	0	78
ZYP	*Zygochlamys patagonica*	59	<0.1	0	59
RAL	*Bathyraja albomaculata*	55	<0.1	0	17
EEL	*Iluocoetes*/*Patagolycus* mix	55	<0.1	0	55
RFL	*Zearaja chilensis*	53	<0.1	0	0
RMC	*Bathyraja macloviana*	42	<0.1	0	39
RSC	*Bathyraja scaphiops*	41	<0.1	0	3
RBZ	*Bathyraja cousseauae*	39	<0.1	0	12
RMU	*Bathyraja multispinis*	37	<0.1	0	4
EGG	Eggmass	35	<0.1	0	35
PAT	*Merluccius australis*	33	<0.1	33	0

PYM	*Physiculus marginatus*	30	<0.1	0	30
SUN	*Labidaster radiosus*	23	<0.1	0	23
STA	*Sterechinus agassizi*	23	<0.1	0	23
COL	*Cosmasterias lurida*	22	<0.1	0	22
ILF	*Iluocoetes fimbriatus*	19	<0.1	0	19
RGR	*Bathyraja griseocauda*	16	<0.1	0	11
ODM	*Odontocymbiola magellanica*	15	<0.1	0	15
RPX	*Psammobatis* spp.	11	<0.1	0	11
LIS	*Lithodes santolla*	10	<0.1	3	7
ILL	*Illex argentinus*	10	<0.1	0	8
MUE	*Muusoctopus eureka*	9	<0.1	0	9
RMG	*Bathyraja magellanica*	8	<0.1	0	8
SOR	*Solaster regularis*	6	<0.1	0	6
RDO	*Amblyraja doellojuradoi*	6	<0.1	0	6
MLA	*Muusoctopus longibrachus akambei*	6	<0.1	0	2
CAZ	*Calyptraster* sp.	6	<0.1	0	6
OCM	*Octopus megalocyathus*	5	<0.1	0	5
FUM	*Fusitriton m. magellanicus*	4	<0.1	0	4
DGS	*Squalus acanthias*	4	<0.1	0	4
WRM	*Chaetopterus variopedatus*	3	<0.1	0	3
POA	*Porania antarctica*	3	<0.1	0	3
BDU	*Brama dussumieri*	2	<0.1	2	0
AUR	*Aurelia* sp.	2	<0.1	0	2
RED	*Sebastes oculatus*	1	<0.1	1	0
PLU	Primnoellinae	1	<0.1	0	1
PLB	Primnoellinae branched	1	<0.1	0	1
OPV	*Ophiacanta vivipara*	1	<0.1	0	1
EUO	*Eurypodius longirostris*	1	<0.1	0	1
COT	*Cottunculus granulosus*	1	<0.1	0	1
CEX	*Ceramaster* sp.	1	<0.1	0	1
BRY	Bryozoa	1	<0.1	0	1
AUC	*Austrocidaris canaliculata*	1	<0.1	0	1
AST	Asteroidea	1	<0.1	0	1
ASA	*Astrotoma agassizii*	1	<0.1	0	1
UHH	Spatangoida	<1	<0.1	0	0
SMT	*Smilasterias triremis*	<1	<0.1	0	0
SEP	*Seriolella porosa*	<1	<0.1	0	0
PYX	Pycnogonida	<1	<0.1	0	0
PES	*Peltarion spinosulum*	<1	<0.1	0	0
OPL	*Ophiuroglypha lymanii*	<1	<0.1	0	0
ODP	*Odontaster pencillatus*	<1	<0.1	0	0
NUD	Nudibranchia	<1	<0.1	0	0
NOW	*Paranotothenia magellanica*	<1	<0.1	0	0
MXX	Myctophid spp.	<1	<0.1	0	0
MAV	*Magellania venosa*	<1	<0.1	0	0
ICA	*Icichthys australis*	<1	<0.1	0	0
HEX	*Henricia* sp.	<1	<0.1	0	0
GOR	Gorgonacea	<1	<0.1	0	0
EUL	*Eurypodius latreillei*	<1	<0.1	0	0
DIB	*Diplasterias brucei*	<1	<0.1	0	0
CTA	*Ctenodiscus australis*	<1	<0.1	0	0
COG	*Patagonotothen guntheri*	<1	<0.1	0	0
CAM	*Cataetyx messieri*	<1	<0.1	0	0
BUT	*Stromateus brasiliensis*	<1	<0.1	0	0
BAO	*Bathybiaster loripes*	<1	<0.1	0	0
AUL	*Austrolycus laticinctus*	<1	<0.1	0	0
ANN	Annelida	<1	<0.1	0	0
ALC	Alcyoniina	<1	<0.1	0	0
		342,599		1,328	221,743

Table A3. Catches by survey trawl (observer station = Stat) of principal species, together with 95% confidence intervals (L95, U95) as determined from basket samples. N = number of basket samples per trawl. Species that had no discard in a trawl were quantified entirely from the factory production and therefore had no confidence interval estimation (“-“).

Stat	N	Species	Catch	L95	U95	Stat	N	Species	Catch	L95	U95
		LOL	0.1	0.1	0.1			LOL	145.2	-	-
2727	2	PAR	540.0	459.3	638.2	2755	3	PAR	896.7	724.9	1282.7
		TOO	49.2	-	-			TOO	21.2	15.2	25.4
		RAY	15.5	12.8	19.7			RAY	21.5	8.0	41.7
		BAC	20.0	-	-			BAC	26.5	0.0	37.8
		WHI	100.0	45.2	268.9			WHI	3.0	0.5	10.7
		BLU	230.0	99.9	459.2			CGO	39.5	36.8	42.9
		ILL	1.5	0.0	4.0						
		KIN	56.4	39.3	76.9						
		LOL	120.0	119.7	120.3			LOL	385.5	-	-
2728	2	PAR	90.0	41.4	136.7	2756	3	PAR	690.3	600.2	866.2
		RAY	15.0	13.0	17.1			TOO	3.8	-	-
		WHI	1.5	0.3	5.3			RAY	7.0	0.0	21.8
		BLU	0.3	0.1	0.6			BAC	17.5	0.0	31.1
		CGO	0.4	0.2	0.6			CGO	17.5	2.3	28.7
								ILL	1.0	0.0	2.6
		LOL	28.8	-	-			LOL	225.0	-	-
2729	1	PAR	70.0	-	-	2757	2	PAR	122.3	91.2	157.4
		RAY	15.0	-	-			TOO	5.5	-	-
		WHI	2.1	0.4	7.5			CGO	19.0	12.3	26.6
		CGO	1.2	0.7	1.9						
		ILL	0.3	0.0	0.8						
		KIN	1.4	0.1	2.9						
		LOL	60.0	56.4	63.6			LOL	8570.0	-	-
2730	2	PAR	772.5	490.0	1305.6	2758	6	PAR	0.8	-	-
		RAY	22.6	21.1	25.4						
		WHI	0.8	0.1	2.7						
		CGO	10.0	0.0	28.9						
		KIN	2.1	1.2	3.2						
		LOL	0.9	0.7	1.0			LOL	186.0	-	-
2731	2	PAR	0.4	0.4	0.5	2759	2	PAR	15.0	2.6	35.6
		RAY	0.2	0.1	0.4			TOO	0.4	-	-
		CGO	1.8	1.3	2.3						
		PAR	400.0	330.7	484.3			LOL	305.2	-	-
2732	3	TOO	48.5	-	-	2760	3	PAR	150.0	72.5	949.8
		RAY	11.6	4.7	22.5			TOO	16.4	-	-
		BAC	1.0	0.5	1.8			BAC	51.0	36.0	264.2
		WHI	14.0	-	-			WHI	300.0	-	-
		BLU	500.0	217.2	998.2			BLU	1200.0	284.1	11892.4
		CGO	6.0	3.6	9.3			CGO	20.0	12.1	31.0
		ILL	2.0	0.0	5.2						

		KIN	4.5	-	-
		LOL	7.4	-	-
2735	1	PAR	1000.0	-	-
		TOO	0.3	-	-
		RAY	59.4	55.7	65.2
		BAC	0.2	0.1	0.4
		WHI	2.4	0.4	8.5
		CGO	3.2	1.9	5.0
		KIN	0.7	0.1	1.5
		LOL	30.4	-	-
2736	1	PAR	400.0	-	-
		RAY	10.0	9.4	10.9
		CGO	1.5	0.9	2.3
		ILL	0.5	0.0	1.3
		LOL	242.6	233.5	250.4
2737	3	PAR	0.5	0.0	1
		RAY	2.8	1.1	5.4
		BLU	0.0	-	-
		CGO	1.8	1.1	2.8
		KIN	0.8	0.1	1.6
		LOL	595.6	591.9	602.8
2738	3	PAR	2.0	0.0	6.5
		RAY	7.0	5.8	8.9
		BLU	0.0	-	-
		CGO	2.0	1.2	3.1
		ILL	1.0	0.0	2.6
		KIN	0.7	0.1	1.5
		LOL	29.6	22.3	37.1
2739	2	PAR	60.0	48.2	86.8
		RAY	1.8	0.8	3.6
		CGO	2.5	1.5	3.9
		LOL	1.9	1.6	2.2
2740	1	PAR	1500.0	1103.5	1982.2
		TOO	8.8	-	-
		RAY	18.1	15.5	22.1
		BAC	4.0	1.9	7.2
		WHI	3.0	0.5	10.7
		BLU	15.0	6.5	29.9
		CGO	3.0	1.8	4.7
		KIN	1.6	0.2	3.3
		LOL	85.7	-	-
2761	2	PAR	586.4	477.0	736.3
		TOO	18.9	-	-
		RAY	3.4	0.0	5.9
		BAC	10.0	4.7	18.0
		BLU	15.0	6.5	29.9
		CGO	30.0	9.5	58.1
		KIN	1.6	-	-
		LOL	144.0	-	-
2762	3	PAR	1350.0	1030.3	2012.1
		TOO	38.9	-	-
		RAY	99.0	83.2	127.0
		BAC	0.1	0.0	0.1
		CGO	36.0	11.1	83.5
		KIN	0.8	0.1	1.7
		LOL	784.4	-	-
2763	4	PAR	176.0	114.7	333.9
		TOO	0.3	-	-
		LOL	484.9	-	-
2764	4	PAR	36.3	6.1	51.1
		LOL	1185.1	-	-
2765	4	PAR	779.1	491.0	1443.3
		TOO	31.4	26.3	39.5
		RAY	8.0	-	-
		BAC	179.1	44.2	519.0
		WHI	104.5	0.0	249.3
		BLU	3067.0	1614.8	6281.2
		CGO	100.0	0.0	332.5
		KIN	2.8	-	-
		LOL	625.2	-	-
2766	4	PAR	1500.0	1147.1	1756.0
		TOO	7.8	-	-
		RAY	10.5	-	-
		BLU	800.0	0.0	1349.2

		LOL	19.1	8.5	41.4
2741	3	PAR	500.0	116.8	1183.1
		TOO	0.5	-	-
		RAY	5.7	4.1	8.2
		BAC	3.5	1.6	6.3
		CGO	4.0	2.4	6.2
		LOL	582.9	-	-
2742	3	PAR	150.0	95.6	195.9
		WHI	2.0	0.3	7.1
		BLU	12.0	5.2	24.0
		CGO	4.0	2.4	6.2
		ILL	0.6	0.0	1.6
		LOL	47.6	-	-
2743	3	PAR	381.0	376.6	392.0
		TOO	52.2	-	-
		RAY	30.8	24.4	40.9
		BAC	15.0	0.0	57.2
		WHI	34.0	-	-
		BLU	6730.0	1798.2	15880.0
		CGO	15.0	9.1	23.3
		KIN	8.0	0.8	16.7
		LOL	2251.7	-	-
2744	4	PAR	856.4	728.5	1005.5
		TOO	4.6	-	-
		BAC	15.0	7.0	27.1
		WHI	2.5	0.4	8.9
		BLU	3.0	0.0	8.7
		CGO	20.0	12.1	31.0
		KIN	3.0	0.3	6.2
		LOL	18650.	-	-
2745	3	PAR	0.2	0.0	0.6
		ILL	0.8	0.0	2.1
		LOL	3000.0	-	-
2746	4	PAR	20.0	-	-
		LOL	66.7	-	-
2747	3	PAR	186.0	36.0	251.6
		TOO	39.2	-	-
		RAY	0.8	0.3	1.5
		BAC	17.0	15.9	18.6
		WHI	30.0	5.1	106.8
		BLU	12000.	4183.7	41988.9
		CGO	15.0	9.1	23.3
		LOL	1183.9	1180.7	1188.2
2771	5	PAR	118.0	84.7	187.6
		TOO	0.4	-	-
		RAY	1.5	-	-
		CGO	15.0	9.1	23.3
		LOL	6130.0	6129.7	6130.2
2772	3	PAR	528.6	528.3	528.8
		WHI	0.8	-	-
		LOL	4130.0	-	-
2773	3	PAR	17.0	11.5	20.8
		LOL	3168.0	-	-
2774	2	PAR	27.4	11.3	44.2
		RAY	2.3	1.8	3.0
		CGO	10.0	6.0	15.5
		LOL	1548.5	1546.2	1550.7
2775	4	PAR	10.0	0.0	28.3
		RAY	0.8	0.3	1.5
		CGO	10.0	6.0	15.5
		ILL	0.1	0.0	0.2
		LOL	2105.1	2104.7	2105.4
2776	3	PAR	750.0	651.8	799.6
		TOO	3.5	-	-
		RAY	2.5	-	-
		CGO	8.0	0.0	21.3
		LOL	4446.3	4446.0	4446.5
2777	4	PAR	157.0	125.3	184.1
		TOO	0.4	0.2	0.8

		LOL	8566.1	-	-
2748	5	PAR	3575.4	2854.0	4423.3
		TOO	5.7	-	-
		RAY	1.5	0.0	4.8
		BAC	15.0	7.0	27.1
		BLU	85.0	0.0	180.8
		CGO	10.0	0.0	29.9
		LOL	2177.0	-	-
2749	4	PAR	600.0	-	-
		LOL	1240.0	-	-
2750	4	PAR	3.0	1.9	4.4
		LOL	10.8	-	-
2751	3	PAR	1500.0	1147.0	2991.1
		TOO	124.1	-	-
		RAY	44.0	41.6	47.7
		BAC	150.0	127.6	183.8
		WHI	20.0	0.0	50.2
		BLU	2500.0	557.3	15860.0
		CGO	15.0	0.0	24.3
		KIN	50.0	-	-
		LOL	160.0	-	-
2752	5	PAR	100.0	75.5	163.5
		TOO	9.3	-	-
		RAY	28.0	16.3	60.0
		BAC	40.0	12.7	98.4
		BLU	30.0	2.1	122.6
		CGO	30.0	8.1	68.0
		KIN	100.0	-	-
		LOL	820.0	-	-
2753	3	PAR	1880.0	1317.1	2411.6
		TOO	25.2	-	-
		RAY	15.0	13.8	16.9
		CGO	100.0	27.4	193.4
		LOL	720.0	-	-
2754	2	PAR	350.0	332.2	366.7
		TOO	5.3	-	-
		RAY	3.0	1.2	5.8
		CGO	35.0	22.9	46.3
		LOL	3823.8	3823.1	3824.5
2778	3	PAR	96.0	84.7	104.6
		TOO	0.3	0.1	0.5
		CGO	8.0	4.8	12.4
		LOL	5565.9	5565.8	5566.1
2779	3	PAR	262.0	187.4	388.3
		TOO	1.8	-	-
		RAY	0.8	0.3	1.5
		CGO	45.0	0.0	131.7
		LOL	5764.1	5763.8	5764.3
2780	3	PAR	356.0	262.8	404.6
		CGO	30.0	18.1	46.5
		LOL	7723.8	7723.1	7724.5
2781	4	PAR	30.0	3.3	72.8
		TOO	1.6	-	-
		WHI	0.8	0.1	2.8
		CGO	15.0	9.1	23.3
		LOL	6180.0	-	-
2782	3	PAR	999.0	782.8	1442.3
		TOO	1.1	-	-
		LOL	740.0	-	-
2783	3	PAR	400.0	348.4	462.4
		TOO	4.5	-	-
		RAY	3.5	2.0	6.7
		BAC	1.0	0.5	1.8
		CGO	10.0	4.4	14.9
		LOL	1180.0	1178.7	1181.4
2784	2	PAR	15.0	13.3	16.4
		TOO	1.2	-	-
		RAY	0.8	0.3	1.5
		BAC	1.5	-	-
		CGO	18.0	10.9	27.9
		LOL	1940.0	1936.7	1945.1
2785	3	PAR	10.0	0.0	14.9
		RAY	5.5	4.0	9.3
		CGO	8.0	4.8	12.4