FALKLAND ISLANDS FISHERIES DEPARTMENT

# *Doryteuthis gahi* Stock Assessment Survey, 2nd Season 2018

**Vessel** Venturer (ZDLP1)

Falkland Islands

**Dates** 14/07/2018 – 28/07/2018

**Survey Team** Andreas Winter
Tomasz Zawadowski
Oliver Thomas

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## Summary

1) A stock assessment survey for *Doryteuthis gahi* (Falkland calamari) was conducted in the 'Loligo Box' from 14$^{th}$ to 28$^{th}$ July 2018. Fifty-three scientific trawls were taken during the survey; 39 fixed-station and 14 adaptive trawls. The scientific catch of the survey was 510.33 tonnes *D. gahi*.
2) An estimate of 183,593 tonnes *D. gahi* (95% confidence interval: 132,486 to 295,788 t) was calculated for the fishing zone by inverse distance weighting. This estimate represents the highest 2$^{nd}$-season survey biomass since 2006, and the highest incipient biomass for a 2$^{nd}$ season since 1992. Of the total, 61,262 t were estimated north of 52 ºS, and 122,331 t were estimated south of 52 ºS.
3) Male and female *D. gahi* had significantly greater average mantle lengths south of 52 ºS than north of 52 ºS. Males north: mean mantle length 11.74 cm; mean maturity stage 3.29, males south: mean mantle length 12.24 cm; mean maturity stage 3.44. Females north: mean mantle length 10.90 cm; mean maturity stage 2.22, females south: mean mantle length 11.62 cm; mean maturity stage 2.23.
4) 79 taxa were identified in the catches. *D. gahi* was the largest species group at 90.5% of total catch by weight, followed by common hake (5.2%), rock cod (1.9%), and jellyfish (1.0%). Southern blue whiting catch was the lowest for a 2$^{nd}$ pre-season survey since 2006. Biological measurements and samples were taken from *D. gahi*, rock cod, and toothfish.


## 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 *Venturer* from the 14$^{th}$ to 28$^{th}$ July 2018; experimental license FK044E18. 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 2$^{nd}$ fishing season, 2018.
2) Estimate the biomass and distribution of common rock cod (*Patagonotothen ramsayi*) in the 'Loligo Box', for continued monitoring of this stock.
3) Estimate the bycatch of toothfish (*Dissostichus eleginoides*) in *D. gahi* trawls.
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 monitor for a possible reprise of the previous 2$^{nd}$ season's (Winter 2017) exceptional pinniped ingression to the *D. gahi* fishing zone.

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 delineation of the Loligo Box represents an area of approximately 31,517.9 km$^2$, subtracting the exclusion zone around Beauchêne Island.

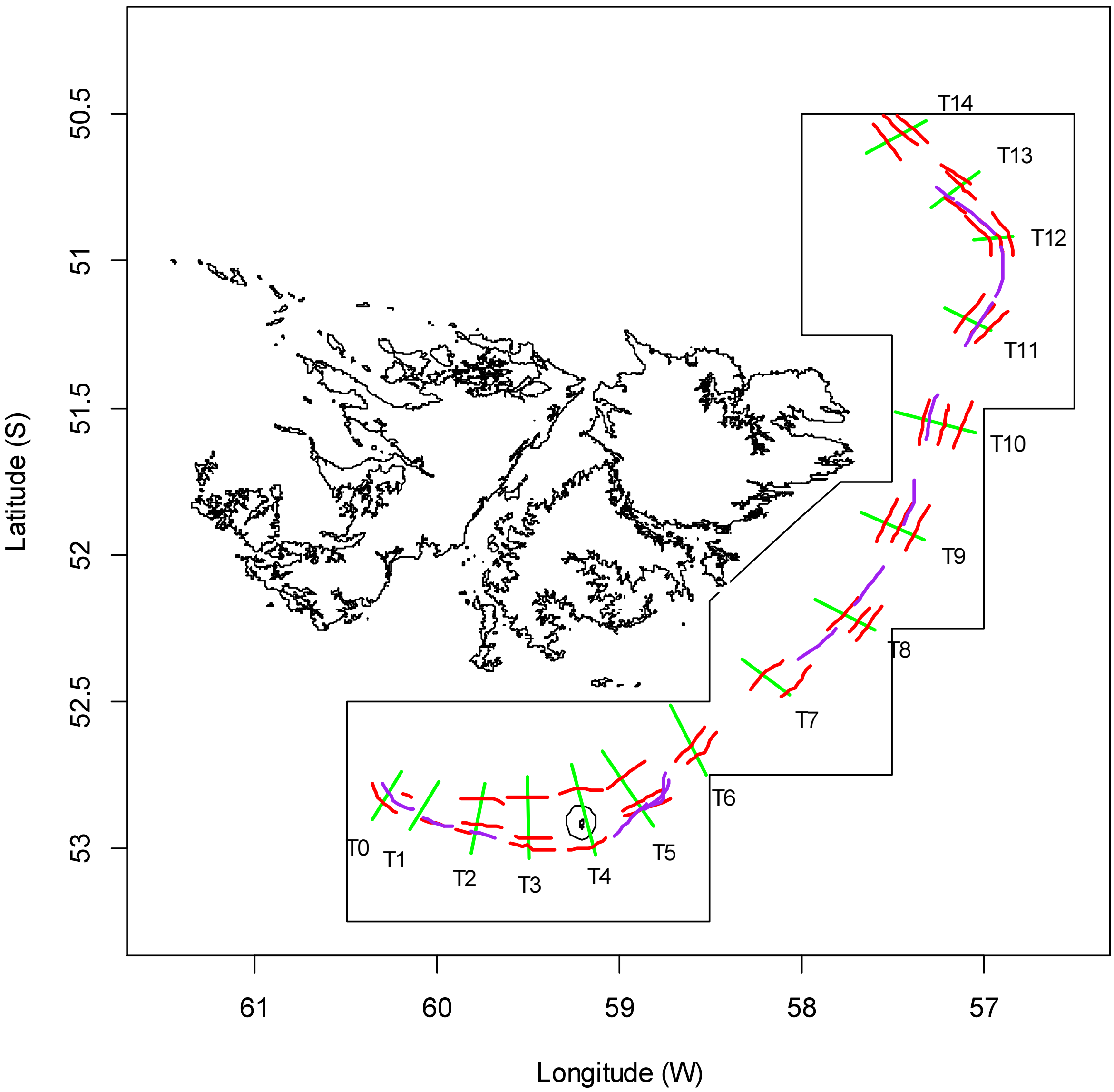



Figure 1. Survey transects (green lines), fixed-station trawls (red lines), and adaptive-station trawls (purple lines) sampled during the 2nd pre-season 2018 survey. Some fixed-station trawls have deviations to adapt to the terrain. Boundaries of the 'Loligo Box' fishing zone and the Beauchêne Island exclusion zone are in black.

The F/V *Venturer* is a Falkland Islands - registered stern trawler of 84.2 m length, 1881 gross tonnage, and 2450 main engine bhp. *Venturer* was previously employed for the 1st pre-season 2011 survey (Winter et al. 2011a) and the 1st pre-season 2014 survey (Winter and Jürgens 2014). Like all vessels employed for pre-season surveys, *Venturer* 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 2nd pre-season 2018 survey:

| | |
|---|---|
| Andreas Winter | lead scientist |
| Tomasz Zawadowski | fisheries observer |
| Oliver Thomas | 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. Trawl tracks were designed for an expected duration of 2 hours each, and ranged in distance from 13.6 to 18.1 km (median 16.1 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 score was assessed 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 thereby 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 one).

### 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. One or two observer baskets of unsorted catch were collected at intervals from most survey trawls[1], depending on their 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 bycatch 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.

### Biomass calculations

Biomass density estimates of *D. gahi* per trawl were calculated as catch weight divided by swept-area: 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)

[1] Trawls were not basket-sampled if visual inspection showed almost pure squid catch.

Measurements of *Venturer*'s trawl, provided by the vessel master, were: sweep = 125 m and bridle = 60 m. The footrope length changed twice as damaged nets were replaced: from the start of the survey until the 2nd trawl on the 18th July, footrope = 160 m. For the 3rd and 4th trawls on the 18th July, footrope = 140 m. For the remainder of the survey, from the 19th July onwards, footrope = 125.7 m.

Biomass density estimates were extrapolated to the fishing area using an inverse distance weighting algorithm (see Appendix). As previously (e.g., Winter et al. 2018), the fishing area was delineated at 20,062.8 $km^2$, partitioned for analysis into 800 area units of 5×5 km. Forty area units with average depth either <90 m or >400 m, where calamari trawlers do not work, were assumed for this analysis to comprise zero *D. gahi*. Biomass densities from all 800 area units were averaged and multiplied by the total fishing area for total biomass, as well as separately north and south of 52 ºS; the standard sub-area demarcation (Winter and Arkhipkin 2015).

Uncertainty of the biomass density extrapolation was estimated by hierarchical bootstrapping. For 25,000 iterations a number of survey trawls equivalent to the total number were randomly selected with replacement, and within each selected survey trawl its 15-minute intervals were randomly selected with replacement. The trawl's catch was re-proportioned according to the selected intervals' acoustic scores, thus varying the spatial distribution of the catch over that trawl track. When applicable, the aggregation of *D. gahi* amounts <100 kg (see Sampling procedures) was summed to an interval of the trawl also chosen randomly; not necessarily the middle interval. At each of the 25,000 iterations, the inverse distance weighting algorithm was re-calculated over the 5 × 5 km area units.

## 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), as well as calculation of the length-weight relationship $W = \alpha \cdot L^{\beta}$ (Froese 2006). A sample of 100 rock cod (PAR) was taken at every trawl station, as far as available. All catches of toothfish (TOO) were collected from trawl stations to maximize the time series catch and biological information base for juvenile toothfish. A cluster of southern king crab (LIS; *Lithodes santolla*) was caught in one trawl (first trawl on July 21st), and a count of 23 individuals was obtained from the factory manager.

# 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 then taken at regular intervals heading back south-west to north, as *D. gahi* biomass concentrations were found quite evenly throughout the survey zone (Figures 1; 2, Appendix Table A1). A schedule of 4 survey trawls per day was maintained except for July 21st, 22nd, and 24th, when the cumulative catches of the first three trawls exceeded the ship's hold capacity for taking a fourth trawl. In total 53 scientific trawls were recorded during the survey: 39 fixed station trawls catching 304.47 t *D.*

*gahi*, and 14 adaptive trawls catching 205.87 t *D. gahi*. Ten optional trawls (made after survey hrs) yielded an additional 173.60 t *D. gahi*, bringing the total catch for the survey to 683.93 t. The scientific survey catch of 510.33 t is the highest for either season since at least 2006 (Table 1).

Average *D. gahi* catch density among fixed-station trawls was 3.42 t km$^{-2}$ north of 52° S and 12.47 t km$^{-2}$ south of 52° S. The north density was the second-highest of the past seven years following 2014, when *D. gahi* appeared to be pressured from *Illex* further offshore (Winter et al. 2014). The south density was the highest of the past seven years. Average *D. gahi* catch density among adaptive-station trawls was 11.84 t km$^{-2}$ north of 52° S and 16.22 t km$^{-2}$ south of 52° S. Both were the highest of the past seven years.

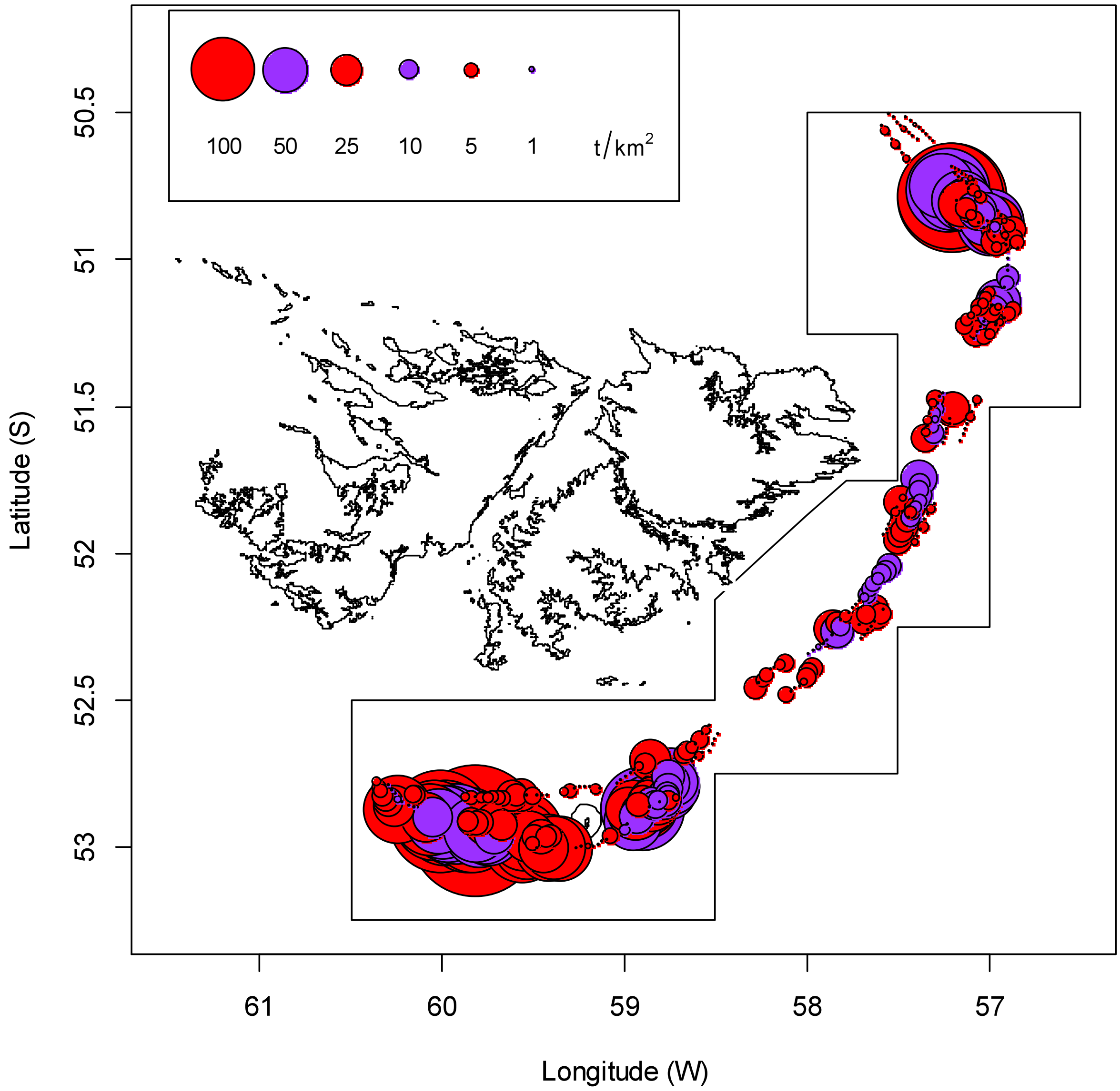



Figure 2. *D. gahi* CPUE (t km$^{-2}$) of fixed-station (red) and adaptive (purple) trawls per 15-minute trawl interval. Boundaries of the 'Loligo Box' fishing zone and the Beauchêne Island exclusion zone are traced in black.

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 | 53 | 510 | 183593 |

* Includes four juvenile toothfish transect trawls.

## Biomass estimation

Total *D. gahi* biomass in the fishing area was estimated at 183,593 tonnes, with a 95% confidence interval of [132,486 to 295,788 t]. High biomass concentrations were obtained both north of 52 ºS, with 61,262 tonnes estimated [51,998 to 116,091 t], and south of 52 ºS, with 122,331 tonnes estimated [80,488 to 179,697 t] (Figure 3). Thus, either the north or the south had a higher biomass estimate than the whole-area total in any pre-season survey since at least 2006 (Table 1)[2]. The total estimate of 183,593 t was the highest for a second season since the RRAG initial biomass estimate of 264,000 t in 1992 (Table 1 in Payá 2010).

## Biological data

Seventy-nine taxa were identified in the survey catches (Appendix Table A2). *D. gahi* was the predominant catch with the highest proportion for a second season since at least 2006 (90.5% - Table A2). Common hake *Merluccius hubbsi* followed, with also the highest survey catch and catch proportion since at least 2006. 46% of common hake was taken in the four trawls furthest south-west. The most conspicuously diminished species was blue whiting *Micromesistius australis*, with the lowest second-season survey catch since 2006 and <100 kg for the first time since 2010.

Pinnipeds were sighted on multiple occasions by the FIFD survey team around the vessel and near the trawls, but no pinniped incidental catches occurred. Seal exclusion devices (SED) were not used in the trawl gear throughout the survey.

8010 *D. gahi* were measured for length and maturity in the survey (4026 males, 3984 females, from 50 of the trawls). The total sex ratio was not significantly different from 50 / 50 ($p > 0.10$). Thirteen trawls had a significant preponderance of females, mostly in the far north and south. Sixteen trawls had a significant preponderance of males. The length-weight

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

relationship was calculated from 401 sub-sampled individuals[3] (212 males, 189 females), resulting in optimized parameters α = 0.25004 and β = 1.99883 (Figure 4).

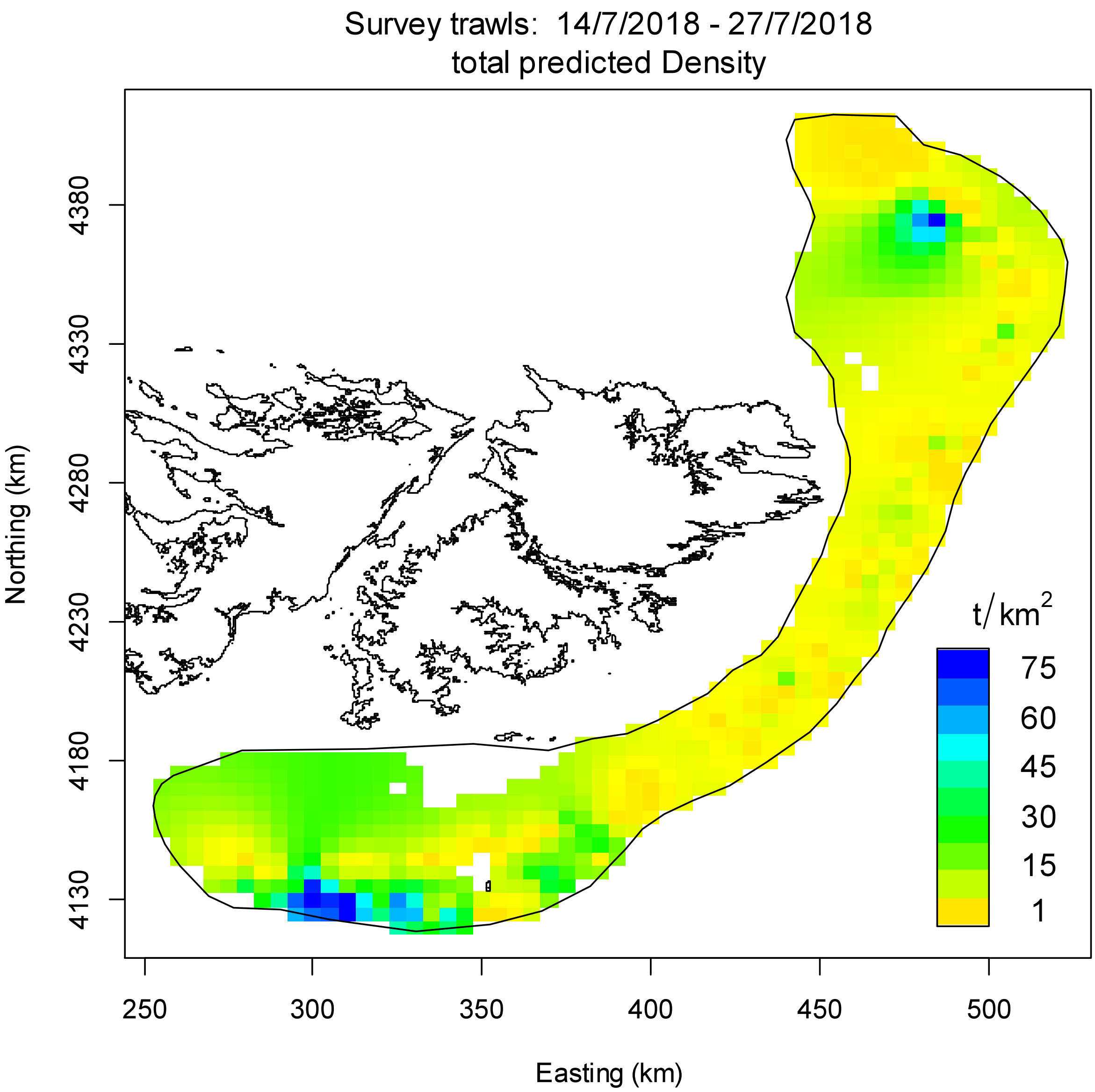



Figure 3. *Doryteuthis gahi* predicted density estimates per 5 $km^2$ area units. Blank area units within the perimeter are either <90 or >400 m average depth. Coordinates were converted to WGS 84 projection in UTM sector 21F using the R library rgdal (proj.maptools.org).

*D. gahi* 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 (Kruskal-Wallis test, $p < 0.001$ all comparisons). Maturity distributions were significantly different between north and south for males ($p < 0.001$) but not females ($p > 0.5$). For males north: mean mantle length 11.74 cm; mean maturity stage

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

3.29 (on a scale of 1 to 5), males south: mean mantle length 12.24 cm; mean maturity stage 3.44. Females north: mean mantle length 10.90 cm; mean maturity stage 2.22, females south: mean mantle length 11.62 cm; mean maturity stage 2.23.

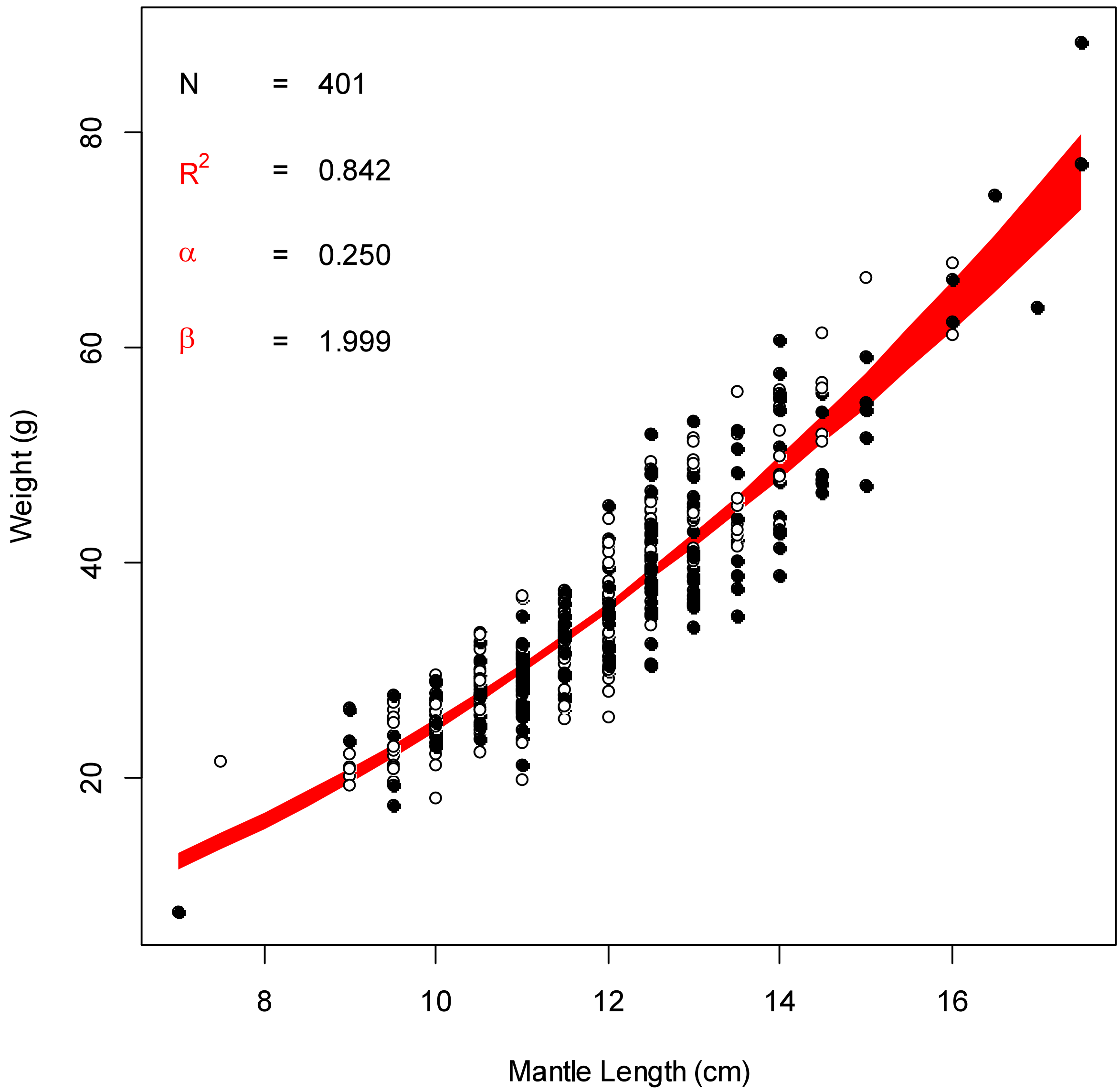
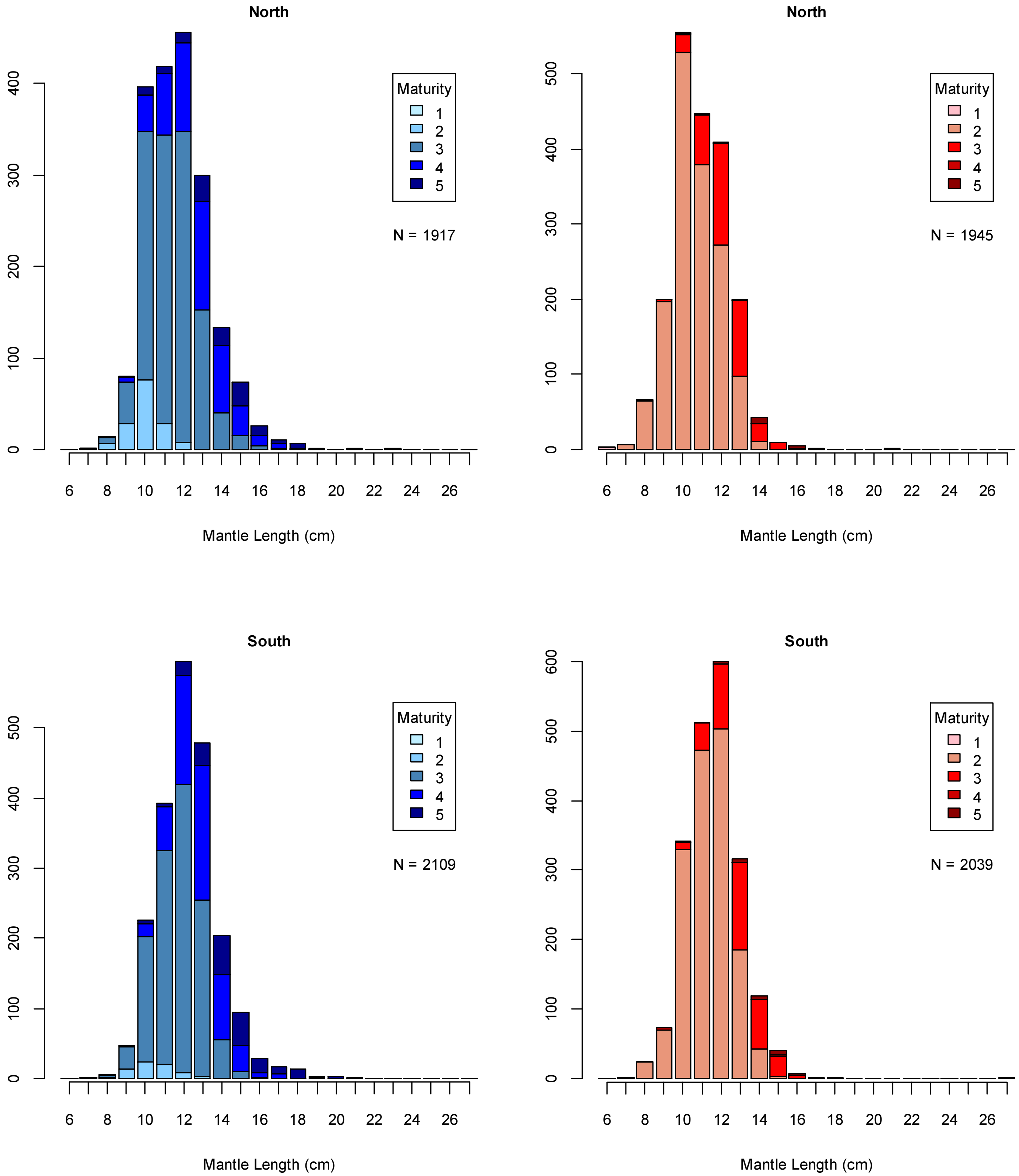



Figure 4. Length-weight relationship of Falkland calamari sampled during the survey. Black points: male, white: female. Parameters refer to the combined sexes' length-weight relationship; red swath: 95% confidence interval.

Figure 5 [next page]. Length-frequency distributions by maturity stage of male (blue) and female (red) *D. gahi* from survey trawls north (top) and south (bottom) of latitude 52 ºS.


North
Maturity
1
2
3
4
5
N = 1917
Mantle Length (cm)
North
N = 1945
Mantle Length (cm)
South
N = 2109
Mantle Length (cm)
South
N = 2039
Mantle Length (cm)

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## Appendix
### Inverse distance density prediction

The kriging methods usually employed for geostatistic extrapolation of *D. gahi* trawl catch densities to the fishing area did not yield realistic estimates from this survey's data. An inverse distance weighting algorithm was used instead. In its basic form (Shepard 1968), the inverse distance weighting algorithm assigns a value u to any grid location x that is the weighted average of a known scattered set of points $x_i$ according to the inverse of the i points' distances from the grid location x:

$$u(\mathrm{x}) = \begin{cases} \dfrac{\sum_{i=1}^{N} w_i(\mathrm{x}) u_i}{\sum_{i=1}^{N} w_i(\mathrm{x})}, & \text{if } d(\mathrm{x}, \mathrm{x_i}) \neq 0 \\ u_i, & \text{if } d(\mathrm{x}, \mathrm{x_i}) = 0 \end{cases}$$

where

$$w_i(\mathrm{x}) = \frac{1}{d(\mathrm{x}, \mathrm{x_i})^p}$$

The power parameter $p$ (a positive real number) adjusts the weight of points $x_i$ as a function of distance; higher values of $p$ put higher influence on the points $x_i$ closest to a given interpolated point x. For this study, the value of $p$ was computationally optimized so that the coefficient of variation of the interpolated points x (the 800 area units of 5×5 km) matched the coefficient of variation of the actual survey catches.

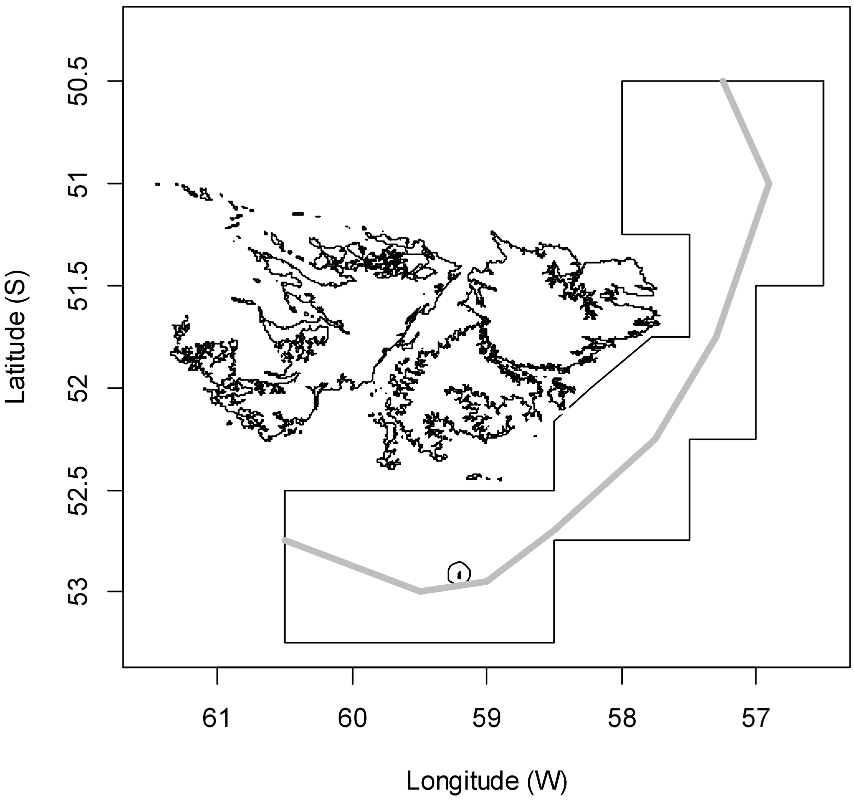


Figure A1. Axial line (grey) for calculating distances through the Loligo Box.

Two other adjustments were made to the inverse distance weighting algorithm. First, the distance $d(\mathrm{x}, \mathrm{x_i})$ is inherently calculated as Euclidean (straight-line) distance. However, the Loligo Box follows the contour of shelf break east of the Falkland Islands, and between two remote points a squid (or ship) would have to travel a real distance longer than straight-line. Therefore, an axial line was drawn through the length of the Loligo Box (Figure A1), and $d(\mathrm{x}, \mathrm{x_i})$ was defined as the longer of either the Euclidean distance between x and $\mathrm{x_i}$, or the distance on the axial line between its two points respectively closest to x and $\mathrm{x_i}$. Second, points $\mathrm{x_i}$ were assigned an isolation parameter. Because the survey procedure calls for high-density areas in particular to be re-visited for the adaptive-station trawls, the estimation can potentially bias upwards as all trawls are included in the inverse distance weighting algorithm. This bias may be counteracted if trawls (cf. their corresponding points $\mathrm{x_i}$) are given more weight in proportion to being further away from any other point $\mathrm{x_i}$. Isolation parameters ($s$) were calculated as the mean of distances between each point $\mathrm{x_i}$ and all other points $\mathrm{x_j}$:

$$s(\mathrm{x_i}) = \overline{d(\mathrm{x_i}, \mathrm{x_j})}$$

Pair-wise distances $d(\mathrm{x_i}, \mathrm{x_j})$ were again the longer of either Euclidean or axial line distance. The adjusted inverse distance weighting factor thus became:

$$w_i(\mathrm{x}) = \left(\frac{s(\mathrm{x_i})}{d(\mathrm{x}, \mathrm{x_i})}\right)^p$$

A previous *D. gahi* survey (Winter et al. 2011b) had also failed to obtain realistic geostatistic extrapolation with any kriging algorithm, under similar circumstances: large biomass and comparatively even north-south distribution. Kriging algorithms are widely used in fishery studies, but typically for acoustic surveys with continuous echo-integration data (Petitgas 1993, Maravelias et al. 1996, Simard and Lavoie 1999, Kern and Coyle 2000, Honkalehto et al. 2002, Walline 2007), or for trawl surveys with high densities of stations (Simard et al. 1992, Petitgas 1997). In Falkland Islands trawl surveys kriging algorithms have been used regularly for *D. gahi* (Roa-Ureta and Arkhipkin 2007), and more recently groundfish (Gras et al. 2016). Uncertainty of a kriging algorithm can be estimated by conditional simulation (Gimona and Fernandes 2003, Woillez et al. 2009), while uncertainty of the acoustic mark interval scoring can at best be approximated (Winter et al. 2014). However, any uncertainty estimate only represents that particular model which was selected, and model selection itself comprises a potentially large source of structural uncertainty (Draper 1995). For kriging, selection includes the choice of the semi-variogram function such as Gaussian, spherical, or exponential (Venables and Ripley 1997, Nishida and Chen 2004); data transformation (Box and Cox 1964); breadth of binning intervals; maximum distance; and whether to fix the nugget effect. Inverse distance weighting is simpler and much more deterministic, and it will be pertinent to examine whether inverse distance weighting may generally be more suited to the relatively sparse trawl surveys conducted by the Falkland Islands Fisheries Department.

Figure A2 [next page]. Second pre-season survey 2017. Left: distribution of total biomass estimates from kriging and inverse distance weighting algorithms. Right: plot of density predictions from the kriging vs. inverse distance weighting algorithms. Red line: 1:1 ratio. Blue shading: distribution of actual catch densities (following the y-axis).

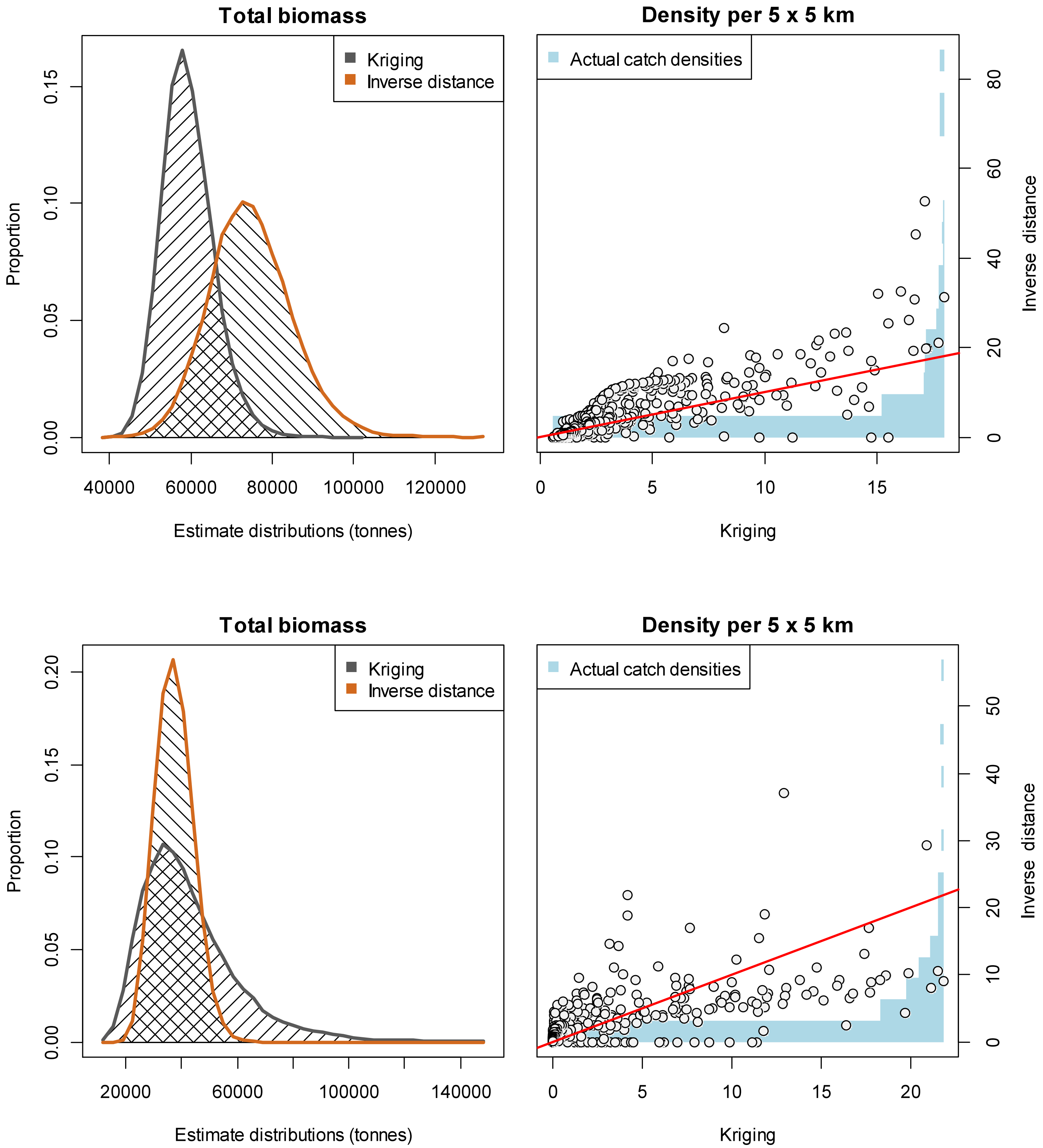


Figure A3. First pre-season survey 2018. Plot descriptions as for Figure A2.

To evaluate differences in biomass estimation, the inverse distance weighting algorithm described above was applied retroactively to each of the past two pre-season surveys, 2nd season 2017 (Winter et al. 2017) and 1st season 2018 (Winter et al. 2018), for comparison with the kriging algorithms that had been used. In both of those seasons the empirical estimate from inverse distance weighting was higher than from kriging: in the 2nd pre-season 2017 survey 68875 tonnes vs. 56807 tonnes (21.2% higher), and in the 1st pre-season 2018 survey 35570 tonnes vs. 32194 tonnes (10.5% higher). In the 2nd pre-season 2017 the kriging estimation had a lower coefficient of variation than the inverse distance weighting estimation: 10.6% vs. 13.6% (Figure A2-left), whereas in the 1st pre-season 2018 the kriging estimation had a higher coefficient of variation: 42.7% vs. 17.7% (Figure A3-left). A common pattern in both surveys showed that the inverse distance weighting algorithm came much closer to reproducing the few observations of high density (Figures A2- and A3-right). Kriged distribution maps are typically smoother than reality (Gimona and Fernandes 2003), suggesting that with relatively sparse data a kriging geostatistic algorithm may be more susceptible to strongly over- or underestimating the biomass in a survey area.

Table A1. Survey stations with total *D. gahi* catch. Time: vessel's clock; which on the *Venturer* was synchronous with local (Stanley, F.I.) time, latitude: °S, longitude: °W. Transects labelled A were adaptive trawls.

| Transect Station | Obs Code | Date | Start | | | End | | | Depth (m) | *D. gahi* (kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Time | Lat | Lon | Time | Lat | Lon | | |
| 14 - 37 | 717 | 14/07/2018 | 07:15 | 50.55 | 57.59 | 09:00 | 50.65 | 57.45 | 140 | 540 |
| 14 - 38 | 718 | 14/07/2018 | 10:25 | 50.59 | 57.39 | 12:10 | 50.50 | 57.55 | 252 | 80 |
| 14 - 39 | 719 | 14/07/2018 | 13:25 | 50.51 | 57.45 | 15:10 | 50.60 | 57.30 | 291 | 40 |
| 13 - 36 | 720 | 14/07/2018 | 16:35 | 50.68 | 57.20 | 18:20 | 50.73 | 57.07 | 293 | 100 |
| 13 - 34 | 721 | 15/07/2018 | 07:20 | 50.82 | 57.12 | 08:14 | 50.78 | 57.21 | 131 | 31480 |
| 13 - 35 | 722 | 15/07/2018 | 09:40 | 50.71 | 57.18 | 11:25 | 50.79 | 57.04 | 260 | 840 |
| 12 - 32 | 723 | 15/07/2018 | 12:45 | 50.87 | 57.00 | 14:30 | 50.97 | 56.89 | 119 | 9520 |
| 12 - 33 | 724 | 15/07/2018 | 15:45 | 50.96 | 56.84 | 17:30 | 50.84 | 56.95 | 251 | 3080 |
| 11 - 30 | 725 | 16/07/2018 | 07:15 | 51.26 | 57.02 | 09:00 | 51.17 | 56.87 | 288 | 2200 |
| 11 - 29 | 726 | 16/07/2018 | 10:55 | 51.16 | 56.95 | 12:40 | 51.25 | 57.07 | 146 | 7120 |
| 11 - 28 | 727 | 16/07/2018 | 13:55 | 51.22 | 57.14 | 15:40 | 51.12 | 57.00 | 127 | 2640 |
| 12 - 31 | 728 | 16/07/2018 | 16:55 | 50.96 | 56.96 | 18:40 | 50.85 | 57.10 | 121 | 2640 |
| 9 - 22 | 729 | 17/07/2018 | 07:15 | 51.94 | 57.57 | 09:00 | 51.81 | 57.47 | 162 | 2200 |
| 9 - 23 | 730 | 17/07/2018 | 10:15 | 51.85 | 57.41 | 12:00 | 51.95 | 57.50 | 220 | 7120 |
| 10 - 25 | 731 | 17/07/2018 | 14:15 | 51.61 | 57.35 | 15:59 | 51.47 | 57.30 | 146 | 2640 |
| 10 - 26 | 732 | 17/07/2018 | 17:05 | 51.51 | 57.19 | 18:50 | 51.63 | 57.25 | 226 | 2640 |
| 8 - 19 | 733 | 18/07/2018 | 07:10 | 52.16 | 57.70 | [A]09:00 | 52.26 | 57.86 | 197 | 5200 |
| 8 - 20 | 734 | 18/07/2018 | 10:15 | 52.25 | 57.71 | 11:15 | 52.18 | 57.63 | 263 | 4920 |
| 9 - 24 | 735 | 18/07/2018 | 13:25 | 51.96 | 57.41 | 15:10 | 51.83 | 57.30 | 289 | 660 |
| 10 - 27 | 736 | 18/07/2018 | 16:45 | 51.62 | 57.15 | 18:30 | 51.48 | 57.06 | 288 | 500 |
| 8 - 21 | 737 | 19/07/2018 | 07:35 | 52.19 | 57.57 | 09:20 | 52.29 | 57.69 | 310 | 1608 |
| 7 - 18 | 738 | 19/07/2018 | 11:00 | 52.39 | 57.97 | 12:45 | 52.49 | 58.10 | 275 | 2620 |
| 7 - 17 | 739 | 19/07/2018 | 14:10 | 52.37 | 58.12 | 15:55 | 52.46 | 58.27 | 182 | 2260 |
| 6 - 16 | 740 | 19/07/2018 | 17:30 | 52.62 | 58.49 | 19:15 | 52.71 | 58.63 | 235 | 180 |
| 5 - 12 | 741 | 20/07/2018 | 07:15 | 52.79 | 59.04 | 09:00 | 52.70 | 58.86 | 124 | 2840 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 - 13 | 742 | 20/07/2018 | 10:15 | 52.81 | 58.79 | 12:00 | 52.87 | 58.98 | 147 | 16544 |
| 5 - 14 | 743 | 20/07/2018 | 13:15 | 52.88 | 58.93 | 15:03 | 52.83 | 58.72 | 201 | 26036 |
| 6 - 15 | 744 | 20/07/2018 | 16:30 | 52.69 | 58.67 | 18:15 | 52.59 | 58.53 | 166 | 2200 |
| 4 - 10 | 745 | 21/07/2018 | 07:16 | 52.80 | 59.13 | 09:00 | 52.82 | 59.32 | 109 | 560 |
| 3 - 8 | 746 | 21/07/2018 | 10:30 | 52.97 | 59.40 | [B]11:56 | 52.96 | 59.57 | 181 | 18368 |
| 3 - 9 | 747 | 21/07/2018 | 13:30 | 52.99 | 59.56 | 15:14 | 53.01 | 59.35 | 240 | 39856 |
| 3 - 7 | 748 | 22/07/2018 | 07:15 | 52.83 | 59.42 | 08:59 | 52.83 | 59.62 | 150 | 3200 |
| 2 - 5 | 749 | 22/07/2018 | 10:25 | 52.93 | 59.67 | 12:06 | 52.92 | 59.86 | 169 | 12560 |
| 2 - 6 | 750 | 22/07/2018 | 13:35 | 52.94 | 59.86 | [C]13:59 | 52.95 | 59.81 | 231 | 34376 |
| 2 - 4 | 751 | 23/07/2018 | 07:10 | 52.84 | 59.66 | 08:55 | 52.84 | 59.87 | 162 | 1660 |
| 1 - 3 | 752 | 23/07/2018 | 10:15 | 52.92 | 59.98 | 11:15 | 52.90 | 60.08 | 231 | 39576 |
| 0 - 1 | 753 | 23/07/2018 | 13:30 | 52.87 | 60.24 | [C]15:14 | 52.78 | 60.36 | 252 | 12484 |
| 1 - 2 | [D] | 23/07/2018 | 17:00 | 52.82 | 60.15 | [D]17:10 | 52.83 | 60.14 | 208 | 880 |
| A - 1 | 754 | 24/07/2018 | 07:10 | 52.79 | 60.29 | 08:55 | 52.87 | 60.13 | 215 | 100 |
| A - 2 | 755 | 24/07/2018 | 10:20 | 52.90 | 60.05 | 11:25 | 52.93 | 59.92 | 217 | 37412 |
| A - 3 | 756 | 24/07/2018 | 14:00 | 52.96 | 59.71 | 14:59 | 52.94 | 59.81 | 212 | 22646 |
| 4 - 11 | 757 | 25/07/2018 | 07:10 | 53.01 | 59.26 | 08:55 | 52.97 | 59.07 | 265 | 500 |
| A - 4 | 758 | 25/07/2018 | 10:15 | 52.94 | 59.00 | 11:58 | 52.85 | 58.85 | 176 | 27932 |
| A - 5 | 759 | 25/07/2018 | 13:20 | 52.86 | 58.84 | 15:05 | 52.75 | 58.75 | 155 | 15528 |
| A - 6 | 760 | 25/07/2018 | 16:15 | 52.78 | 58.73 | 17:59 | 52.87 | 58.86 | 196 | 15528 |
| A - 7 | 761 | 26/07/2018 | 07:20 | 52.35 | 57.99 | 09:05 | 52.25 | 57.81 | 223 | 2960 |
| A - 8 | 762 | 26/07/2018 | 10:20 | 52.15 | 57.68 | 12:05 | 52.04 | 57.54 | 219 | 5100 |
| A - 9 | 763 | 26/07/2018 | 13:30 | 51.88 | 57.43 | 15:15 | 51.75 | 57.38 | 222 | 7320 |
| A - 10 | 764 | 26/07/2018 | 16:35 | 51.59 | 57.31 | 18:20 | 51.45 | 57.25 | 155 | 1960 |
| A - 11 | 765 | 27/07/2018 | 07:15 | 51.27 | 57.08 | 09:00 | 51.14 | 56.95 | 141 | 9380 |
| A - 12 | 766 | 27/07/2018 | 10:17 | 51.10 | 56.91 | 12:00 | 50.95 | 56.90 | 128 | 1400 |
| A - 13 | 767 | 27/07/2018 | 13:45 | 50.89 | 56.96 | 15:31 | 50.80 | 57.14 | 128 | 28040 |
| A - 14 | 768 | 27/07/2018 | 16:55 | 50.78 | 57.20 | 17:30 | 50.75 | 57.26 | 132 | 30560 |

A: Trawl stopped early because the net was broken.
B: Trawl stopped early because the net was full.
C: Trawl stopped early because high acoustic sign was showing on the net sounder. Squid would just wash out of the net again as soon as they entered.
D: Trawl stopped after only a short time because the net was broken. The trawl could not be sampled because the deck had to be cleared to repair the broken cables, and was therefore not assigned an observer station number.

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

| Species Code | Species / Taxon | Total catch (kg) | Total catch (%) | Sample (kg) | Discard (kg) |
|---|---|---|---|---|---|
| LOL | *Doryteuthis gahi* | 510334 | 90.5 | 351 | 0 |
| HAK | *Merluccius hubbsi* | 29532 | 5.2 | 0 | 904 |
| PAR | *Patagonotothen ramsayi* | 10992 | 1.9 | 190 | 10432 |
| MED | Medusae | 5503 | 1.0 | 0 | 5503 |
| MUN | *Munida* spp. | 1730 | 0.3 | 0 | 1730 |
| TOO | *Dissostichus eleginoides* | 797 | 0.1 | 385 | 255 |

| | | | | | |
|---|---|---|---|---|---|
| DGH | *Schroederichthys bivius* | 696 | 0.1 | 0 | 696 |
| CGO | *Cottoperca gobio* | 558 | 0.1 | 0 | 558 |
| BAC | *Salilota australis* | 444 | 0.1 | 0 | 261 |
| PTE | *Patagonotothen tessellata* | 434 | 0.1 | 0 | 434 |
| RBR | *Bathyraja brachyurops* | 356 | 0.1 | 0 | 231 |
| STA | *Sterechinus agassizi* | 282 | <0.1 | 0 | 282 |
| SQT | Ascidiacea | 281 | <0.1 | 0 | 281 |
| KIN | *Genypterus blacodes* | 268 | <0.1 | 0 | 90 |
| SPN | Porifera | 213 | <0.1 | 0 | 213 |
| ANM | Anemone | 133 | <0.1 | 0 | 133 |
| ALG | Algae | 104 | <0.1 | 0 | 104 |
| RGR | *Bathyraja griseocauda* | 93 | <0.1 | 0 | 33 |
| ZYP | *Zygochlamys patagonica* | 90 | <0.1 | 0 | 90 |
| RSC | *Bathyraja scaphiops* | 88 | <0.1 | 0 | 29 |
| RFL | *Zearaja chilensis* | 83 | <0.1 | 0 | 52 |
| GRC | *Macrourus carinatus* | 79 | <0.1 | 0 | 79 |
| GOC | *Gorgonocephalus chilensis* | 75 | <0.1 | 0 | 75 |
| RDO | *Amblyraja doellojuradoi* | 70 | <0.1 | 0 | 70 |
| RAL | *Bathyraja albomaculata* | 70 | <0.1 | 0 | 48 |
| AST | Asteroidea | 55 | <0.1 | 0 | 55 |
| PAU | *Patagolycus melastomus* | 48 | <0.1 | 0 | 48 |
| ING | *Moroteuthis ingens* | 45 | <0.1 | 0 | 45 |
| CAZ | *Calyptraster* sp. | 44 | <0.1 | 0 | 44 |
| MUG | *Munida gregaria* | 43 | <0.1 | 0 | 43 |
| BLU | *Micromesistius australis* | 33 | <0.1 | 0 | 33 |
| PAT | *Merluccius australis* | 30 | <0.1 | 0 | 20 |
| MUL | *Eleginops maclovinus* | 30 | <0.1 | 0 | 16 |
| RMU | *Bathyraja multispinis* | 28 | <0.1 | 0 | 6 |
| SUN | *Labidaster radiosus* | 21 | <0.1 | 0 | 21 |
| OPV | *Ophiacanta vivipara* | 16 | <0.1 | 0 | 16 |
| OCT | Octopus spp. | 16 | <0.1 | 0 | 16 |
| NEM | *Neophyrnichthys marmoratus* | 16 | <0.1 | 0 | 16 |
| WHI | *Macruronus magellanicus* | 15 | <0.1 | 0 | 13 |
| OCC | *Octocoralia* | 13 | <0.1 | 0 | 4 |
| RPX | *Psammobatis* spp. | 11 | <0.1 | 0 | 11 |
| CHR | *Chrysaora* cf. *plocamia* | 10 | <0.1 | 0 | 10 |
| CHE | *Champsocephalus esox* | 9 | <0.1 | 0 | 9 |
| FUM | *Fusitriton m. magellanicus* | 8 | <0.1 | 0 | 8 |
| RMC | *Bathyraja macloviana* | 7 | <0.1 | 0 | 7 |
| OPL | *Ophiuroglypha lymanii* | 7 | <0.1 | 0 | 7 |
| ODM | *Odontocymbiola magellanica* | 7 | <0.1 | 0 | 7 |
| ICA | *Icichthys australis* | 6 | <0.1 | 0 | 6 |
| EUL | *Eurypodius latreillei* | 6 | <0.1 | 0 | 6 |
| CRB | Crab | 6 | <0.1 | 0 | 6 |
| MYX | *Myxine* spp. | 5 | <0.1 | 0 | 5 |
| PAP | *Paralomis spinosissima* | 4 | <0.1 | 0 | 4 |
| OCM | *Octopus megalocyathus* | 4 | <0.1 | 0 | 4 |
| NOW | *Paranotothenia magellanica* | 4 | <0.1 | 0 | 4 |
| ILF | *Iluocoetes fimbriatus* | 4 | <0.1 | 0 | 4 |
| COT | *Cottunculus granulosus* | 4 | <0.1 | 0 | 4 |
| ARD | *Arbacia dufresni* | 4 | <0.1 | 0 | 4 |

| | | | | | |
|---|---|---|---|---|---|
| PES | *Peltarion spinosulum* | 3 | <0.1 | 0 | 3 |
| MUO | *Muraenolepis orangiensis* | 3 | <0.1 | 0 | 3 |
| GRF | *Coelorhynchus fasciatus* | 3 | <0.1 | 0 | 3 |
| CTA | *Ctenodiscus australis* | 3 | <0.1 | 0 | 3 |
| BDU | *Brama dussumieri* | 3 | <0.1 | 0 | 3 |
| AUL | *Austrolycus laticinctus* | 3 | <0.1 | 0 | 3 |
| RMG | *Bathyraja magellanica* | 2 | <0.1 | 0 | 2 |
| AMS | *Amphipneustes similis* | 2 | <0.1 | 0 | 2 |
| WRM | *Chaetopterus variopedatus* | 1 | <0.1 | 0 | 1 |
| SAR | *Sprattus fuegensis* | 1 | <0.1 | 0 | 1 |
| RED | *Sebastes oculatus* | 1 | <0.1 | 0 | 1 |
| POA | *Porania antarctica* | 1 | <0.1 | 0 | 1 |
| MUE | *Muusoctopus eureka* | 1 | <0.1 | 0 | 1 |
| ILL | *Illex argentinus* | 1 | <0.1 | 0 | 1 |
| EUO | *Eurypodius longirostris* | 1 | <0.1 | 0 | 1 |
| BUT | *Stromateus brasiliensis* | 1 | <0.1 | 0 | 1 |
| ASA | *Astrotoma agassizii* | 1 | <0.1 | 0 | 1 |
| PYX | Pycnogonida | <1 | <0.1 | 0 | 0 |
| PYM | *Physiculus marginatus* | <1 | <0.1 | 0 | 0 |
| MXX | Myctophid spp. | <1 | <0.1 | 0 | 0 |
| ISO | Isopoda | <1 | <0.1 | 0 | 0 |
| AGO | *Agonopsis chilensis* | <1 | <0.1 | 0 | 0 |
| | | 563,899 | | 926 | 23,116 |