Cruise Report ZDLT1-02-2015

Rock cod Biomass survey

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Contents

1.0 Introduction

The Falkland waters are part of the Patagonian Shelf Large Marine Ecosystem, one of the most productive marine ecosystems of the world. Since 1987, and the declaration of the Falklands Interim Conservation Zone (FICZ) by the Falkland Islands Government, every vessel fishing in the FICZ has had to have a licence. The fishery is currently regulated using both Total Allowable Catch (TAC) and Total Allowable Effort (TAE). Before 2007, the southern blue whiting (*Micromesistius a. australis*) was the main finfish species exploited in Falkland waters and its biomass used as a basis for TAC and TAE calculation. Since the decrease in southern blue whiting abundance, rock cod (*Patagonotothen ramsayi*) increased in abundance and became one of the most important finfish resources for trawling activity in Falkland waters (Laptikhovsky et al., 2013). Since 2007, rock cod catches have varied between 30,157 and 76,456 t (FIG, 2015). In 2007, as *P. ramsayi* became the primary species in term of catches, it was decided to use this as a basis for the TAC/TAE calculation.

Two research cruises were carried out in February 2010 (Brickle and Laptikhovsky 2010) and 2011 (Arkhipkin et al., 2011) to estimate the abundance of this species. In 2012 and 2013, 6 research cruises were undertaken to test various gears in order to improve the rock cod catch by decreasing the bycatch of non valuable specimens and species (Brickle and Winter, 2012; Roux et al., 2012a; Roux et al, 2012b; Roux et al, 2013a; Roux et al, 2013b; Roux et al, 2013c). In 2014, as the new regulations were published to come into force at the beginning of 2015, it was the right time to perform a new biomass estimation. Rock cod biomass estimation was therefore carried out based on data collected between 18 October and 8 November 2014 (research cruise ZDLT1-10-2014; Pompert et al., 2014) and showed that abundance was 98,596 t.

The objectives of this current rock cod biomass estimate survey was to examine the distribution, biology and abundance of rock cod (*P. ramsayi*) in the finfish zone in February. An inter–annual comparison with 2010 and 2011 will be possible as well as an inter–seasonal comparison with 2014. This survey was also the opportunity to study other commercial species' biology and carry out a biomass estimation for some of the stocks, in particular for red cod (*Salilota australis*), kingclip (*Genypterus blacodes*), common hake (*Merluccius hubbsi*), hoki (*Macruronus magellanicus*), Falkland calamari (*Doryteuthis gahi*) and Illex squid (*Illex argentinus*). For southern blue whiting (*Micromesistius a. australis*), Patagonian hake (*Merluccius australis*), Patagonian toothfish (*Dissostichus eleginoides*), redfish (*Sebastes oculatus*) and skates (Rajidae) only biological aspects were studied. Finally, this survey was also the opportunity to carry out an oceanographic survey of the finfish zone.

2.0 Material and Methods

2.1 Cruise vessel and surveyed area

The research cruise ZDLT1-02-2015 was conducted onboard the FV Castelo (LOA 67.8 m, GRT 1321) from the 2 to the 22 February 2015. Embarking and disembarking occurred on the 1st and 23rd respectively. In order to be able to compare data with previous biomass estimate surveys carried out in 2010 (Brickle and Laptikhovsky, 2010), 2011 (Arkhipkin et al., 2011) and 2014 (Pompert et al., 2014), it was decided to repeat stations already explored in 2011 and 2014 and to add 3 stations in zones where rock cod could be abundant, 2 northwest and 1 east (Figure 1 and Table 1).

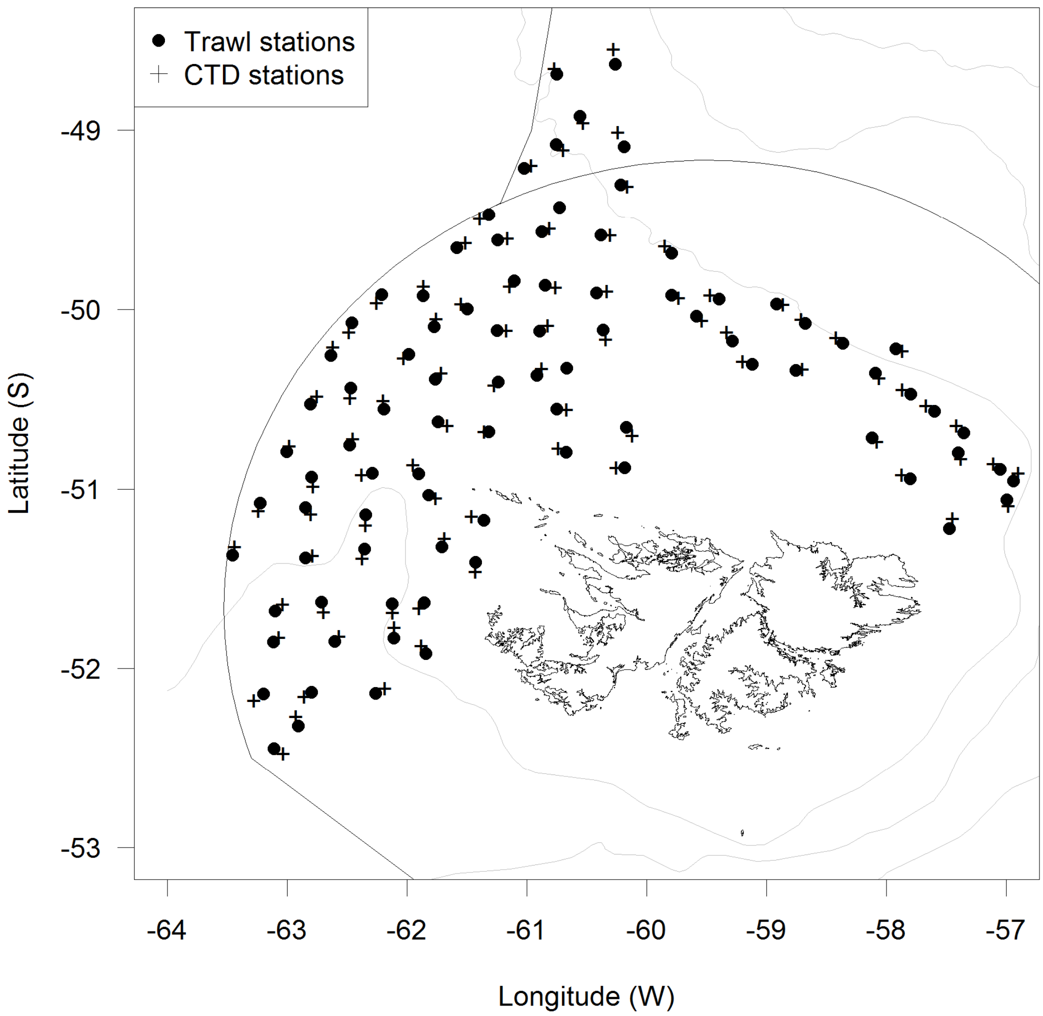

Figure 1: Locations of trawl stations and associated CTD stations.

Table 1: Trawl stations number, date, geographical coordinates, depth, duration and associated comments. A CTD was also carried out before or after each trawl.

Station	Date	Lat (°S)	Lon (°W)	Modal Depth (m)	Duration (min)	Activity	Comments
1559	02/02/15	50.89	60.14	135	60	B	
1562	02/02/15	50.68	60.14	146	60	B	
1564	02/02/15	50.56	60.70	149	60	B	
1566	02/02/15	50.77	60.73	131	60	B	
1567	03/02/15	51.02	61.87	180	60	B	
1570	03/02/15	51.17	61.39	136	60	B	
1572	03/02/15	51.45	61.43	136	60	B	
1574	03/02/15	51.29	61.69	161	60	B	
1575	04/02/15	51.61	61.83	164	60	B	
1578	04/02/15	51.67	62.13	214	60	B	
1580	04/02/15	51.80	62.11	253	60	B	
1582	04/02/15	51.90	61.85	209	40	B	Headline leg broke after 40 min. Hauling done straight after this.
1584	04/02/15	52.12	62.22	278	60	B	
1585	05/02/15	52.12	62.75	246	60	B	
1588	05/02/15	52.29	62.92	260	60	B	
1590	05/02/15	52.46	63.06	270	60	B	
1592	05/02/15	52.17	63.24	229	60	B	
1593	05/02/15	51.88	63.15	208	60	B	
1595	06/02/15	51.88	62.65	226	60	B	
1598	06/02/15	51.67	62.70	203	60	B	
1600	06/02/15	51.66	63.06	192	60	B	
1601	06/02/15	51.41	63.47	154	60	B	
1603	07/02/15	51.39	62.90	182	60	B	
1606	07/02/15	51.37	62.37	205	60	B	
1608	07/02/15	51.18	62.34	193	60	B	
1610	07/02/15	51.13	62.82	169	60	B	
1611	07/02/15	51.05	63.20	151	60	B	
1613	08/02/15	50.83	63.01	151	60	B	
1616	08/02/15	50.97	62.78	166	60	B	
1618	08/02/15	50.92	62.35	188	60	B	
1620	08/02/15	50.88	61.93	178	60	B	
1621	09/02/15	50.78	62.51	169	60	B	
1624	09/02/15	50.52	62.20	164	60	B	
1626	09/02/15	50.47	62.48	154	60	B	
1628	09/02/15	50.50	62.78	149	60	B	
1629	10/02/15	50.29	62.65	146	60	B	
1632	10/02/15	50.11	62.48	145	60	B	
1634	10/02/15	49.95	62.24	145	60	B	
1636	10/02/15	49.89	61.87	157	60	B	
1638	10/02/15	50.07	61.76	159	60	B	
1639	11/02/15	50.24	61.94	160	60	B	
1642	11/02/15	50.36	61.74	162	60	B	
1644	11/02/15	50.64	61.69	176	60	B	
1645	11/02/15	50.68	61.28	144	60	B	
1647	12/02/15	50.39	61.22	158	60	B	
1650	12/02/15	50.34	60.90	154	60	B	
1652	12/02/15	50.10	60.85	160	60	B	
1654	12/02/15	50.12	61.20	159	60	B	
1655	12/02/15	50.02	61.46	158	60	B	
1657	13/02/15	50.36	60.65	154	60	B	
1660	13/02/15	50.15	60.35	158	60	B	
1662	13/02/15	49.90	60.36	164	60	B	

1664	13/02/15	49.87	60.79	164	60	B	
1665	14/02/15	49.82	61.07	163	60	B	
1668	14/02/15	49.61	61.19	161	60	B	
1670	14/02/15	49.64	61.54	157	60	B	
1672	14/02/15	49.49	61.37	160	60	B	
1673	14/02/15	49.59	60.92	170	60	B	
1675	15/02/15	48.72	60.73	244	60	B	
1678	15/02/15	48.58	60.27	390	120	B	Trawl targeting F5 RGR
1680	15/02/15	49.04	60.22	308	120	B	Trawl targeting F5 RGR
1681	16/02/15	48.89	60.57	259	60	B	
1684	16/02/15	49.10	60.72	197	60	B	
1686	16/02/15	49.20	60.99	172	60	B	
1687	16/02/15	49.41	60.69	172	60	B	High swell, no CTD was undertaken
1688	17/02/15	49.29	60.26	250	60	B	
1691	17/02/15	49.59	60.33	172	60	B	
1693	17/02/15	49.66	59.83	181	60	B	
1694	17/02/15	49.92	59.84	167	60	B	
1696	18/02/15	50.02	59.63	162	60	B	
1699	18/02/15	49.93	59.44	168	60	B	
1701	18/02/15	50.15	59.32	153	60	B	
1703	18/02/15	50.29	59.17	148	60	B	
1704	18/02/15	50.34	58.81	145	60	B	
1706	19/02/15	49.96	58.97	166	60	B	
1709	19/02/15	50.07	58.69	164	30	B	Big mark of Illex on the echosounder after 30 min. Doors were closing
1711	19/02/15	50.17	58.41	179	60	B	
1712	19/02/15	50.20	57.97	272	60	B	
1714	20/02/15	50.33	58.13	140	60	B	
1717	20/02/15	50.45	57.84	153	60	B	
1719	20/02/15	50.54	57.64	137	60	B	
1721	20/02/15	50.66	57.39	133	60	B	
1722	21/02/15	50.77	57.43	131	60	B	
1725	21/02/15	50.87	57.09	126	60	B	
1727	21/02/15	50.92	56.91	107	60	B	
1728	21/02/15	51.03	56.99	113	60	B	
1730	22/02/15	50.70	58.16	135	60	B	

2.2 Trawl gear

The FIFD owns a bottom trawl fitted with rockhopper gear and used the Castelo's Morgère V3 bottom doors (1800 kg, 3180 x 2480 cm). The cod–end originally had a 90 mm mesh size. However, it seems to have shrunk and is now in the region of 80–85 mm. The cod–end was also fitted with a 10–15 mm cod end liner. The MarPort Net Monitoring System was used, with sensors on both the trawl doors to monitor door depth, door horizontal spread, angle and tilt as well as one on the net to monitor vertical net opening. Of these data, only door horizontal spread and vertical net opening were recorded. The horizontal net opening (also called wing spread in the data base) was derived as:

$$\text{Horizontal net opening} = \frac{\text{Door spread} \times \text{Net Length}}{\text{Bridle Length} + \text{Net Length}}$$

During the previous research cruise (ZDLT1-10-2014; Pompert et al., 2014), a discussion with the captain about the gear configuration revealed that trawl setup was the same in 2011 (ZDLT1-02-2011) but not in 2010 (ZDLT1-02-2010) when Morgère Ovalfoil OF12,5 (3400 x 2200 cm) doors were used. According to the captain, the doors used since 2011 opens the trawl a bit more than the previously. In February 2015, the trawl setup was asked to be rigorously the same as in 2014.

2.3 Biological sampling

For most of the trawled stations, the entire catch was weighed by species (for finfish, squids, skates and sharks) or by the lowest taxonomic level (for invertebrates) using the electronic marine adjusted POLS balance. At some stations (Table 2), when the catch was too large to be weighed, the crew processed the catch. A sample of the species concerned was taken before factory processing, weighed (green weight; GW), processed by the crew and weighed again (processed weight; PW) to estimate the conversion factor (CF) as

$$CF = \frac{GW}{PW}$$

The catch (C) for this species was then estimated using the number of filled boxes (BN), the average box weight (BW) and the conversion factor as:

$$C = BN \times BW \times CF$$

Table 2: Stations where a conversion factor was used to estimate the catch of the main species caught.

Station number	Species	Conversion Factor
1608	BAC	2.17
1611	BAC	1.88
1613	BAC	1.96
1624	KIN	2.37
1624	ILL	1.85
1629	BAC	2.23
1629	ILL	1.83
1639	ILL	1.87
1655	PAR	2.51
1655	PAR	2.19
1706	WHI	1.96
1709	ILL	1.76
1711	WHI	2.15

Random samples were taken from all commercial finfish species as well as squids *Illex argentinus* and *Doryteuthis gahi*. When it was possible, 100 specimens of each commercial species were randomly taken for all sampled species except *D. gahi* for which 200 specimens were sampled. Maturity stages were determined for all sampled specimens using an 8 stage maturity scale for finfish (Brickle et al., 2006) and a 6 stage maturity scale for both species of squid (Lipinski, 1979). Length frequencies were recorded using one electronic fishmeter or fish measuring board and paper form when necessary.

Otolith extraction was undertaken for 27 finfish species (taken at sea) and statoliths were extracted ashore from *I. argentinus* and *D. gahi* (associated information were length, weight, sex and maturity). In the case of kingclip, besides collecting the usual data for otolith collection, condition factor data (liver, gonad and eviscerated weights were also collected) and a piece of tissue for genetic analysis was collected for a maximum of 15 specimens per station. Finally, vertebrae/thorn samples were taken from 2 species of skates (12 from *Bathyraja brachyurops* and 14 from *Bathyraja multispinis*) and spines were taken from 2 *Squalus acanthias* for ageing ashore.

Specimens from the genus *Psammobatis* were not identified to species, due to confusion with available identification guides and available literature (i.e. McEachran, 1983). It is likely that the most common species found in waters deeper than 120 m is *Psammobatis normani* (slender claspers) whereas in shallower waters the most common species is *Psammobatis rudis* (short and stout claspers). During the survey there were no shallow stations. Some animals were photographed and genetic material collected. To distinguish these from all the other ones, they were recorded as RPS (code for *Psammobatis scobina*), even though they are most likely *Psammobatis normani.*

2.4 Biomass estimation method

Biomass estimations using trawl surveys generally generate auto–correlated data (Rivoirard et al., 2000). To avoid processing biased data and overestimating the biomass of fish in the survey area, geostatistical methods were developed to firstly describe and model data autocorrelation and secondly to estimate by kriging an unbiased mean of the studied variable and provide an interpolated map of the studied variable.

The variable used in this report is the density of each species of interest (derived from the catch and swept-area). The methodology described below uses R scripts developed to perform the 2010 rock cod assessment (Winter et al. 2010) using packages rgdal (geographical coordinates projection) and geoR (geostatistics).

2.4.1 Density estimations using swept area method

The distance covered by the trawl was estimated using the geographical coordinates of the stations. For each station, coordinates of the start were extracted from the database fields DegS_Start_Seabed, MinS_Start_Seabed, DegW_Start_Seabed, MinW_Start_Seabed and end from the database fields DegS_Finish_Seabed, MinS_Finish_Seabed, DegW_Finish_Seabed, MinW_Finish_Seabed and transformed first in decimal degrees (deg) and then in radians (rad) as:

$$rad = \frac{\deg \times \pi}{180}$$

Radian coordinates were then used to calculate the distance between the start and end of the trawl track as:

$$d = a\cos(\sin(latS) \times \sin(latF) + \cos(latS) \times \cos(latF) \times \cos(lonF - lonS) \times R$$

where d is the distance covered in km, latS is the start latitude, lonS is the start longitude, latF is the end latitude, lonF is the end longitude and R is the radius of the earth (6371 km). Density of the studied species (D in kg.km^{-2}) was finally derived using the catch (C), the distance covered (d) and the horizontal net opening (HNO; see section 2.2 for details)

$$D = \frac{C}{d \times HNO}$$

Densities at stations were then used as input data in the geostatistical procedure to estimate the abundance of each species.

2.4.2 Geographical coordinates

Station's geographical coordinates were collected using the World Geodetic System of 1984 (WGS 84). However, as the earth is a sphere and because the Falkland Islands are situated at relatively high latitudes (the study area in our case ranges from 48° to 52°S), one longitude degree does not have the same length as one latitude degree. It was therefore decided to project coordinates in the Universal Transverse Mercator Coordinate System (zone 21; UTM 21) which keeps the distances between stations both in latitude and longitude. The projection was carried out using the project function (with following argument proj="+proj=utm +zone=21 +south +ellps=WGS84 +towgs84=0,0,0,0,0,0,0 +units=m +no_defs") of the rgdal R package. Previously in the Falkland Islands Fisheries Department, the Easting Northing system was used. A comparison between the UTM 21 projection and Easting Northing system showed no significant differences.

2.4.3 Geostatistic methods

Geostatistic methods must be performed in 4 steps, (i) plotting and (ii) modelling the semi–variogram, (iii) using the variogram model to krige data in order to estimate an unbiased mean of the studied variable, and (iv) mapping the estimated data. The following criteria were used at different steps of the process to fit the right variogram model and estimate a realistic biomass for each species of interest.

- Various numbers of distance classes (from 10 to 50 classes) and 3 lambda parameters of the Box–Cox transformation (0, 0.5 and 1) were tested to obtain a scatter plot best describing the auto–correlation at short distances. The semivariance values should increase with distance and reach the sill. The only accepted exception is the pure nugget effect.
- The range must be shorter than the maximum distance observed on the semivariogram. In the studied dataset, some models can fit log transformed data (lambda=0) well, however they exhibit a range further than 400 km which is not biologically consistent in our case.
- Exponential, Gaussian and spherical models were fitted to the semivariogram data and sum of square residuals (SSR) were used as a basis to choose the most suitable model. The lowest SSR suggesting the most suitable model.
- Finally the kriging was performed and accepted if the range of estimated biomass was positive and reasonably close to the range of observed values. If not, another variogram model exhibiting higher SSR was tested until estimated and observed values were close enough.

As the protocol was to conduct one station per grid square, the kriging area boundaries were defined using the grid squares. The total area was 102,617 km^2. In the case of rock cod, the biomass estimation was conducted using data collected in 2010 (ZDLT1-02-2010), in 2011 (ZDLT1-02-2011) and in 2014 (ZDLT1-10-2014) using the same methodology and the same kriging area. For other demersal species, the biomass estimations were only performed using 2015 data.

2.5 Oceanography

A single CTD (SBE–25, Sea–Bird Electronics Inc., Bellevue, USA, Serial No 0247) instrument was used to collect oceanographic data in the vicinity of all trawl stations. At all CTD stations, the instrument was deployed to a depth of c.10 m below surface for a soak time of one minute, to allow the pump to start circulating water and flush the system. Following this, the CTD was raised to a minimum depth of 5 m below surface. The CTD was then lowered towards the sea bed at 1m/sec. The CTD collected pressure in dbar, temperature in °C, conductivity in mS/cm, Oxygen Voltage and Fluorescence. The raw hex file was converted and processed using SBE Data Processing Version.7.22.5 using the CON files OldCTD_2013_AUG.xmlcon. Upcast data was filtered out. Depth was derived from pressure using the latitude of each station, with dissolved oxygen in ml/l derived at the same time as depth. Practical Salinity (PSU) and Density as sigma-t (σ-t) were derived following derivation of depth. Further derived variables of conservative temperature (°C) and Absolute Salinity (g/kg) were calculated in Ocean Data View version 4.5.4 (Schlitzer, R., 2013).

3.0 Results

3.1 Catch composition

During the 2015 rock cod biomass survey, biggest catches were *I. argentinus* and rock cod (32.7 t each). More than 20 t of red cod, 14.6 t of kingclip and 9.8 t of hoki were caught (Table 3). As common hake were probably not back yet from their spawning grounds, the catch was low (3.2 t), and of southern blue whiting, only 2.2 t were caught. More than 1.8 t of Falkland calamari were caught. This species is abundant at this time of the year, but this survey did not cover the *Loligo* box where *D. gahi* is generally abundant. A total of 323 kg of Patagonian hake was caught and 181 kg of toothfish were taken. Finally, 84% of the total catch was composed of commercial finfish or squids.

Table 3: Commercial finfish and squid catches

Species Code	*Species name*	*Total Catch (kg)*	*Total Sampled (kg)*	*Total Discarded (kg)*	*Proportion (%)*
ILL	*Illex argentinus*	31,682.96	1,018.71	1,650.13	23.04%
PAR	*Patagonotothen ramsayi*	31,673.93	1,367.29	12,384.65	23.03%
BAC	*Salilota australis*	20,314.03	1,818.30	1,347.10	14.77%
KIN	*Genypterus blacodes*	14,635.03	3,975.63	10.91	10.64%
WHI	*Macruronus magellanicus*	9,768.23	1,619.80	460.2	7.10%
HAK	*Merluccius hubbsi*	3,165.51	1,668.72	0.1	2.30%
BLU	*Micromesistius australis*	2,169.33	370.547	2,169.33	1.58%
LOL	*Doryteuthis gahi*	1,802.65	284.95	315.65	1.31%
PAT	*Merluccius australis*	323.05	323.05	0	0.23%
TOO	*Dissostichus eleginoides*	181	181	7.59	0.13%
Totals		**115,715.72**	**12,627.99**	**18,345.66**	**84.14%**

3.1.1 Rock cod (*Patagonotothen ramsayi*)

A total of 31,674 kg of rock cod was caught at the 89 trawl stations explored (Figure 2). Catches ranged from 2.4 to 8,169 kg. Among the 89 stations, 51 yielded >100 kg of rock cod, however, only 6 stations yielded >1 t of rock cod in the net. During previous research cruises, the number of trawl yielding >1 t was 27, 25 and 6 in 2010, 2011 and 2014 respectively. Abundance ranged from 0.5 to 17,410 kg.km^{-2} (CPUE ranged 2.4–8,169 kg.h^{-1}). A total of 10,341 specimens were sampled (55 juveniles, 4,911 females and 5,375 males), 3 for length–weight relationship and 255 for otolith collection. Minimum size was observed at 8 and 9 cm and maximum size was 44 and 39 cm for females and males respectively. The length frequency histogram exhibits 3 cohorts (with modes at 14, 20 and 27 cm). The large majority of sampled specimens were either in maturity stage I (41 and 44% for females and males) or II (49 and 52% for females and males). Other females were either III (6%), V (0.02%), VII or VIII (2% each). In males, the other specimens were either III (2%), IV (0.2%), VI, VII (0.02% each) or VIII (1.4%).

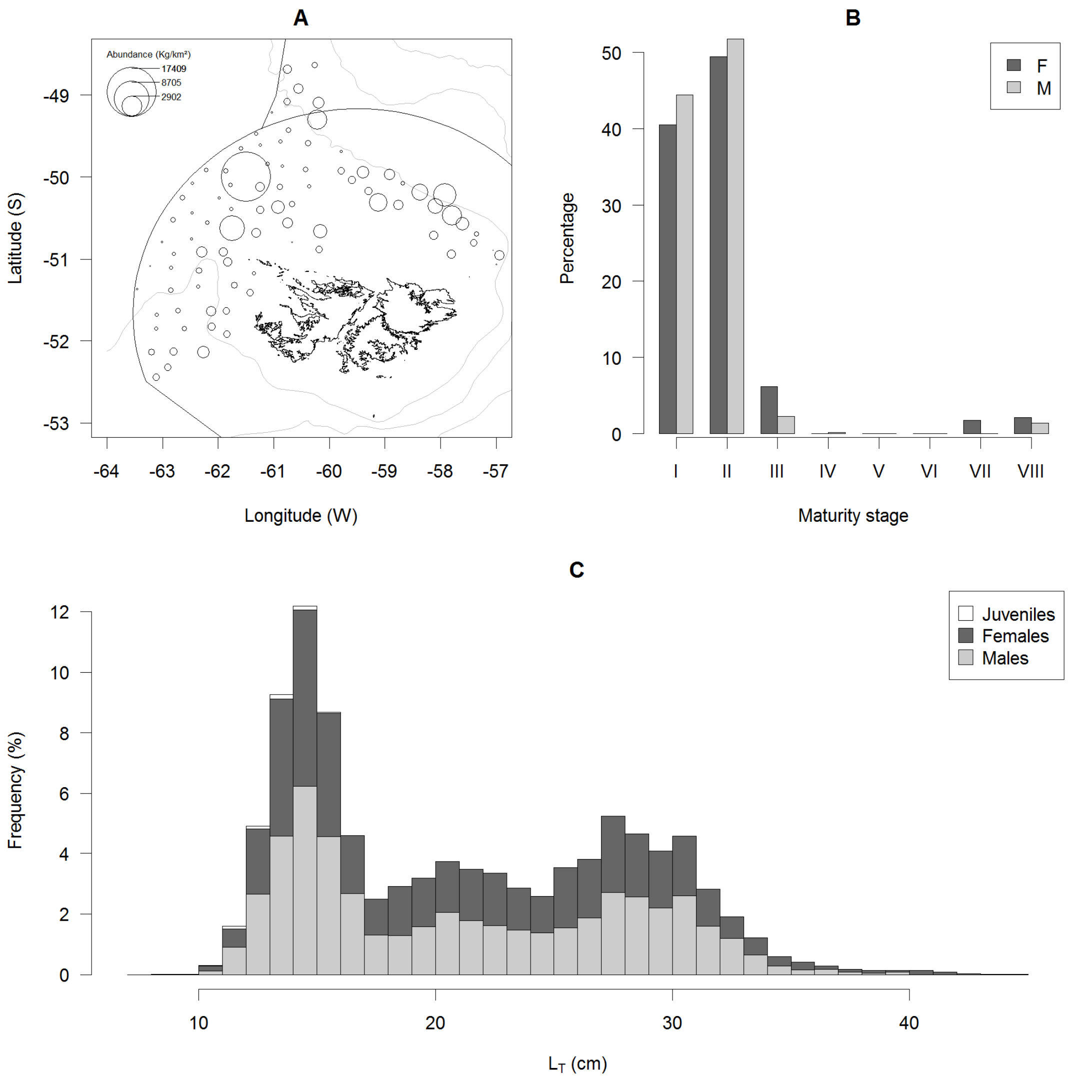

Figure 2: Biological data of *Patagonotothen ramsayi*, map of the densities (A), percentage of specimen of each sex per maturity stage (B) and length frequency of each sex (C).

3.1.2 Red cod (*Salilota australis*)

A total of 20,314 kg of red cod was caught at 75 stations throughout the surveyed area (Figure 3), mainly in the south–western and western parts. When red cod was present in the catch, the catch weight ranged from <1 kg to 5,798 kg. 33 of the 75 stations yielded <10 kg and 60 of them <100 kg. Regarding abundances, densities ranged from 0.02 to 11,080 kg.km^{-2} (CPUE 0.01–5,798 kg.h^{-1}). A total of 4,487 red cod (22 juveniles, 2,441 females and 2,024 males) were sampled: 3,930 for length frequency and 557 for otoliths. Total length ranged from 9 to 85 cm and modes can be identified at 15, 25, 35 cm. For larger specimens, modes are hardly identifiable. Most of the specimens were in maturity stage I–III (97% of the females and 94% of the males), the rest being VII or VIII.

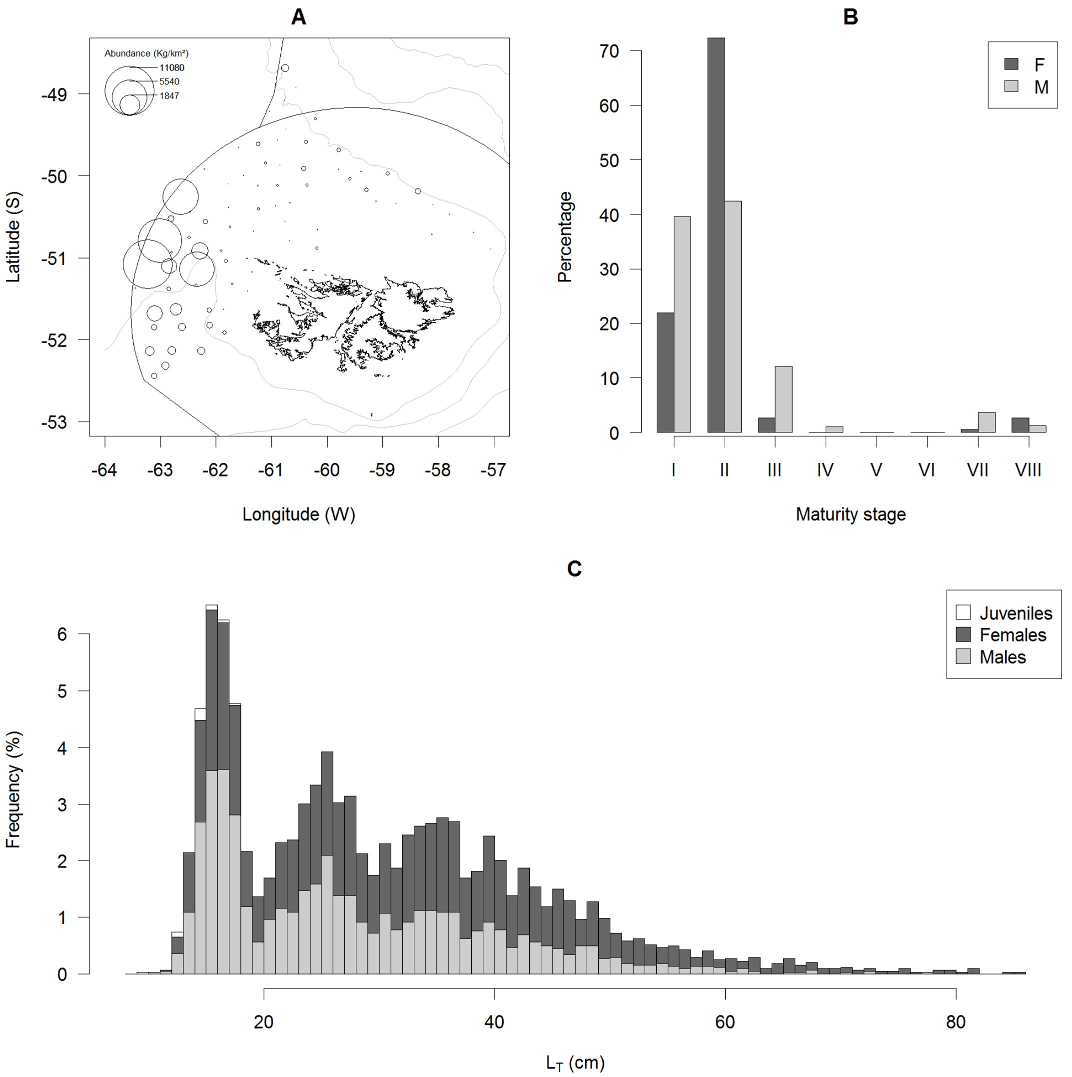

Figure 3: Biological data of *Salilota australis*, map of the densities (A), percentage of specimen of each sex per maturity stage (B) and length frequency of each sex (C).

3.1.3 Southern blue whiting (*Micromesistius a. australis*)

A total of 2,169 kg of southern blue whiting was caught at 38 stations of the surveyed area (Figure 4), mainly in 3 different regions, one southwest, one north and one east of the explored area. Catches ranged from <1 to 977 kg and 6 stations were hauled with more than 100 kg of blue whiting. Abundance ranged from <1 to 2,087 kg.km^{-2} (CPUE ranged <1 to 977 kg.h^{-1}). A total of 1,368 specimens were sampled (411 juveniles, 437 females and 520 males): 1,136 for length frequency and 232 for otoliths. Four cohorts can be identified on the length frequency, the first one (13 cm) consisted of juveniles and the other ones with modes at 25 cm, 30–32 cm and 60 cm. The juveniles were all caught at stations 1721, 1722 and 1733, in the eastern part of the surveyed area. Very few specimens between 38 and 52 cm were caught. Most of the specimens were either in maturity stage I or II (87 and 80% of the females and males respectively), 2% of them were stage III and the rest were either stage VII or VIII.

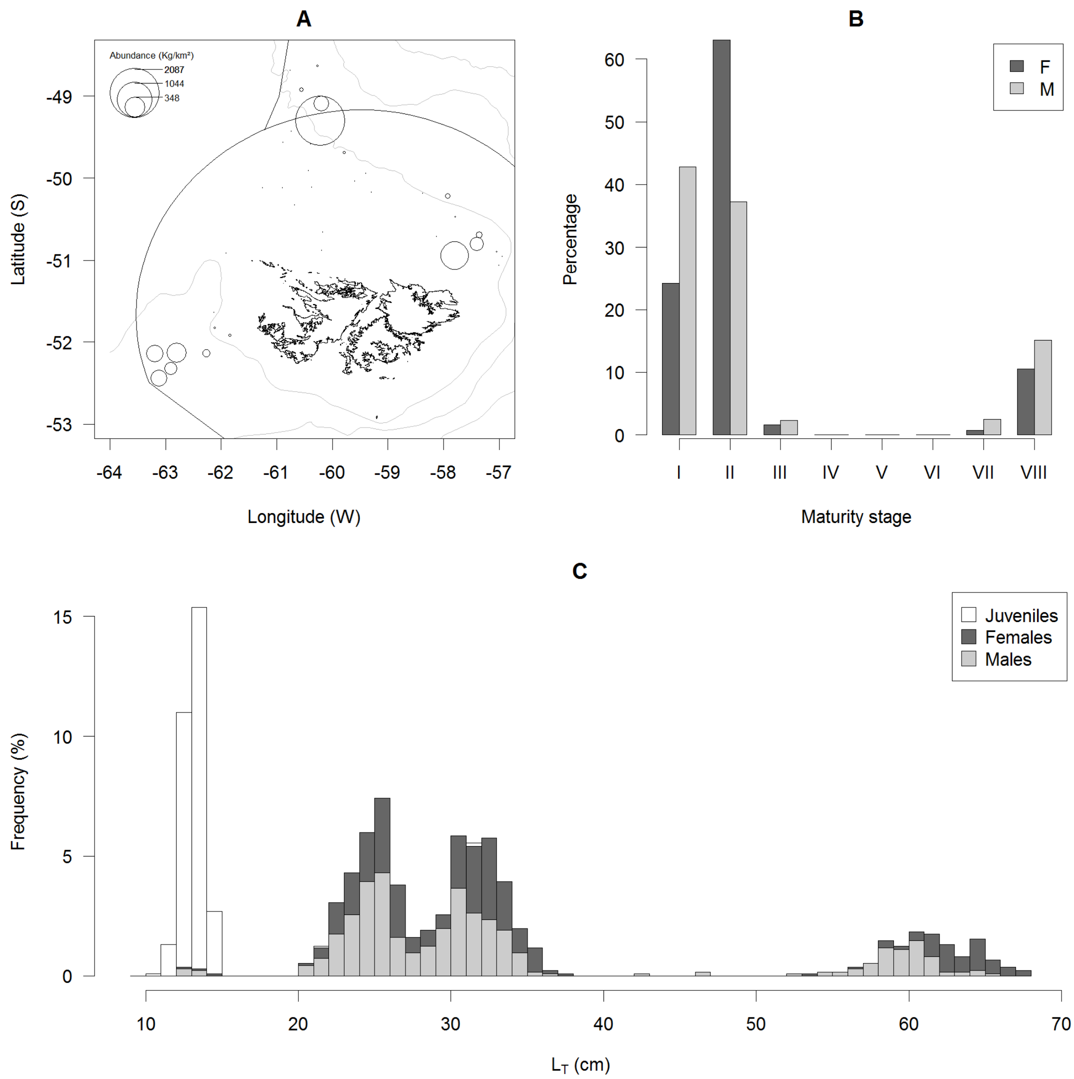

Figure 4: Biological data of *Micromesistius a. australis*, map of the densities (A), percentage of specimen of each sex per maturity stage (B) and length frequency of each sex (C).

3.1.4 Kingclip (*Genypterus blacodes*)

A total of 14,635 kg of kingclip was caught at 74 stations (Figure 5; three times as much as during the ZDLT1-10-2014 survey). Highest catches occurred in the north–western and northern parts of the surveyed area. Catches ranged from <1 to 5,709 kg per station and >100 kg of kingclip were caught at 14 stations. Abundance of this species ranged from 0.26 to 12,650 kg.km^{-2} (with CPUE ranging 0.11–5,709 kg.h^{-1}). A total of 2,346 specimens were sampled (1,419 females and 927 males): 1,600 specimens were taken for length frequency, 746 were sampled for otoliths. Of these, 696 condition factors and 638 genetic samples were also collected. Total lengths ranged from 30 to 124 cm (mean=69 cm) and cohorts are hardly identifiable. Regarding maturity, 91% of the females were either in maturity stage II or III, the rest being I (1%), IV (2%), V (3%), VII or VIII (3%). As in the females, most males were in stage II or III (91%), with the remainder in stage I (2%), IV (3%), V (0.1%), VII and VIII (3%).

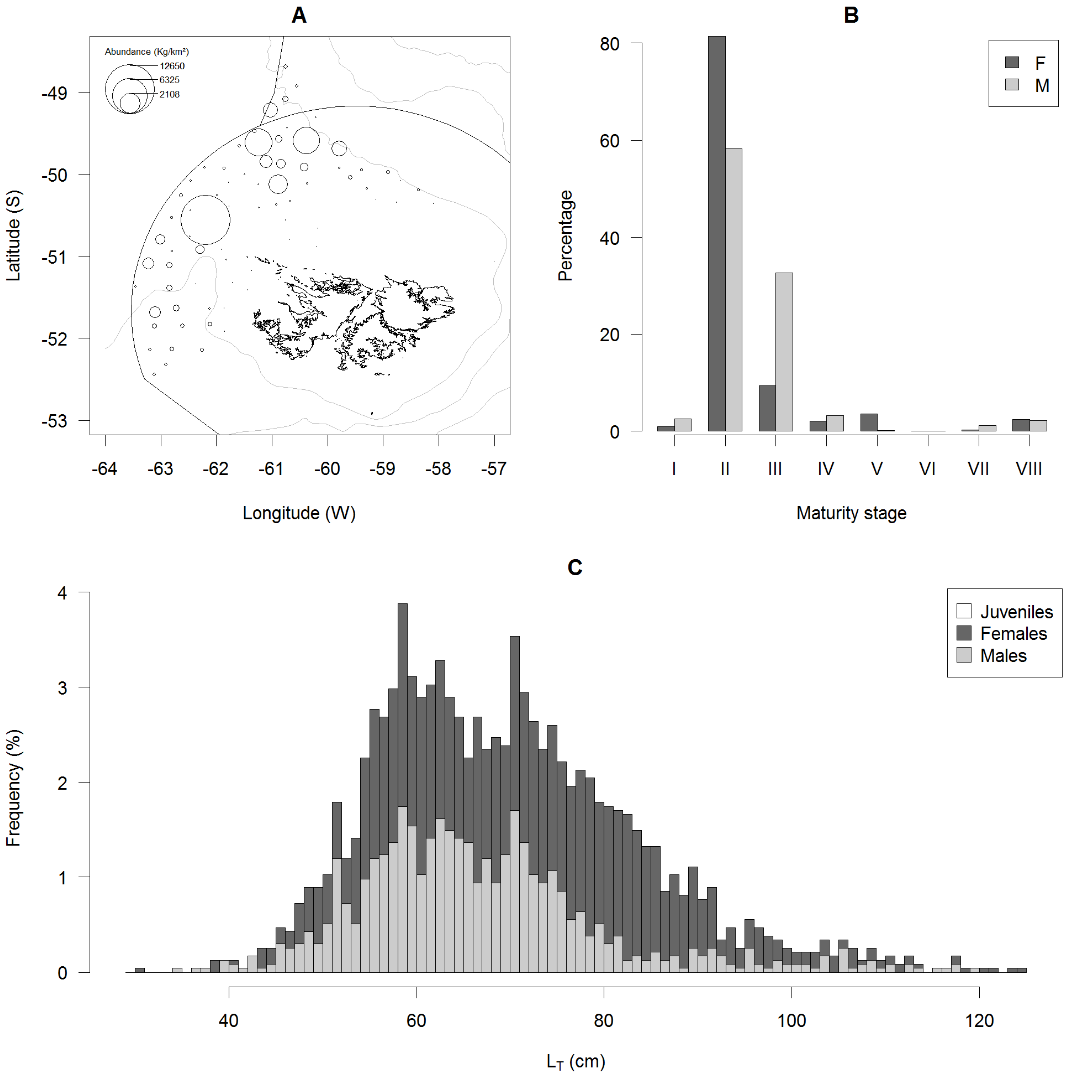

Figure 5: Biological data of *Genypterus blacodes*, map of the densities (A), percentage of specimen of each sex per maturity stage (B) and length frequency of each sex (C).

3.1.5 Common hake (*Merluccius hubbsi*)

A total of 3,166 kg of common hake was caught at 59 stations (Figure 6). Most of the catches occurred west of 60°W and north of 51°S. Catches ranged from <1 kg to 193 kg per station. Abundance was low and ranged between 0.2 and 395 kg.km^{-2} (CPUE ranged 0.1–193 kg.h^{-1}). A total of 3,791 specimens were sampled (2,931 females and 860 males), 3,362 for length frequency and 429 for otoliths. Size ranged from 23 to 77 cm and from 24 to 65 cm for females and males respectively. As usual, females are more numerous (males mainly occur on the high seas) and longer than males. However, the size difference between sexes is less significant than during autumn and winter, bigger animals were probably still on the spawning grounds in Argentinean waters. Two cohorts are identifiable, one at 32 cm and the other one at 38 cm. Most of the females were either in maturity stage II or III (90%), with the remainder in stage I (0.1%), IV (1.7%), V (0.2%), VII and VIII (8%). In males, 37% were in stage VII, between 13 and 17% of animals in stages II to V and the rest being VI or VIII. As the largest proportion of specimens were less than 50 cm and in maturity stages II and III, the catches are likely to have consisted of sub–adults pre–spawning groups mixed with early migrating specimens back to the Falkland waters after reproduction.

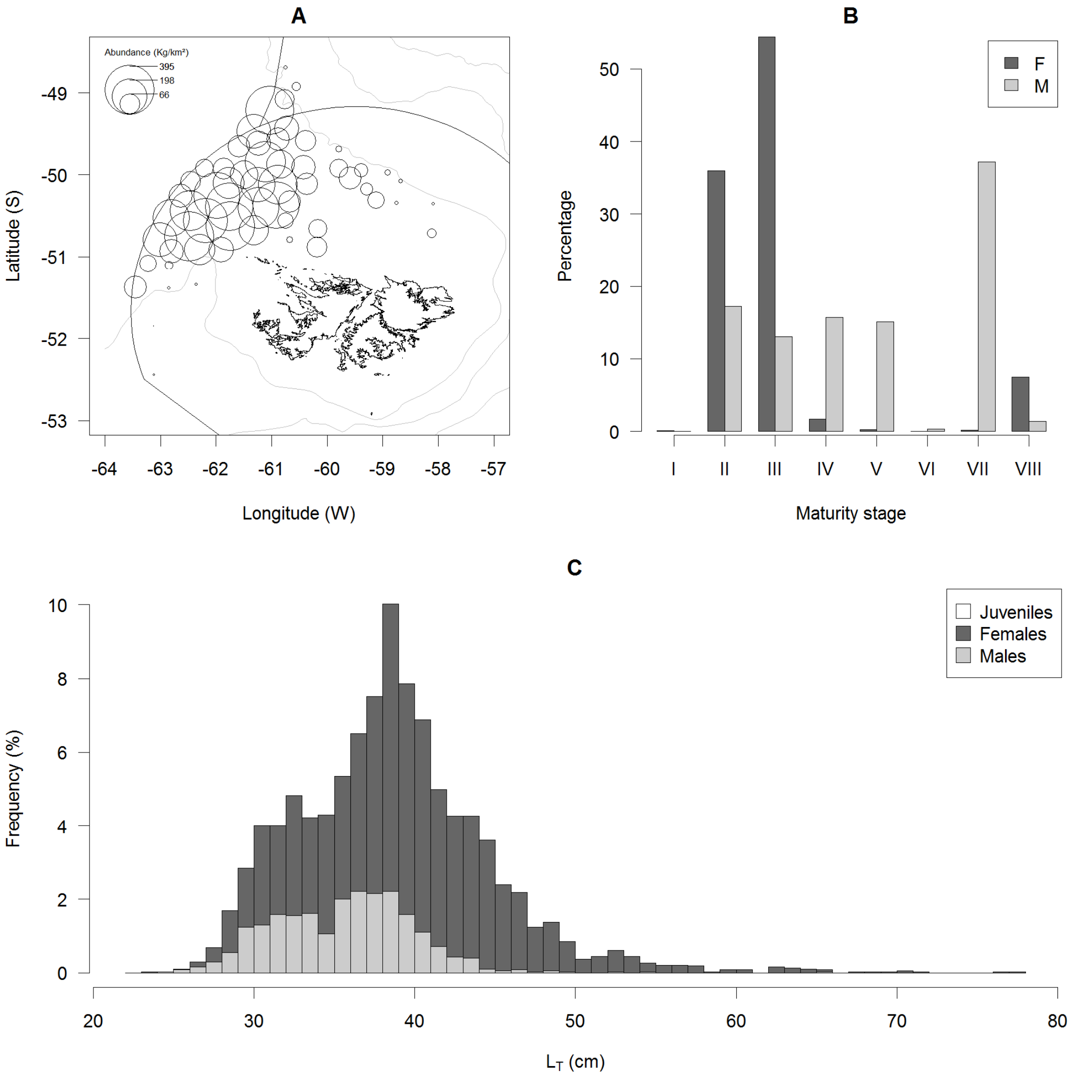

Figure 6: Biological data of *Merluccius hubbsi,* map of the densities (A), percentage of specimen of each sex per maturity stage (B) and length frequency of each sex (C).

3.1.6 Patagonian hake (*Merluccius australis*)

A total of 323 kg of Patagonian hake was caught at 13 stations (Figure 7). 11 of these stations were in the southern part of the surveyed area while the 2 remaining were in the two deeper stations in the north. Catches ranged from 1.4 to 98 kg. Abundance varied between 1.5 and 180 kg.km^{-2} (CPUE ranged 0.7–98 kg.h^{-1}). Such abundance is unusual for this species, which is generally quite rare in the Falkland waters. A total of 130 specimens were sampled (110 females and 20 males) for otoliths. Total length ranged from 52 to 106 cm for females and from 47 to 98 cm for males. If females are more numerous than males as in the common hake stock, size ranges are quite similar between sexes. Females were in majority in maturity stages II, III or IV (97%) the remainder in stages VII or VIII. Males were mainly in stages II or III (85%) with 15% in stages V, VI or VII. The 7 females IV were caught in stations 1580, 1584 and 1592 in depths ranging from 209 to 278 m. The male 5 and the male 6 were caught at stations 1584 (278 m deep) and 1592 (229 m deep) respectively. These 9 specimens were caught in the southwest of the surveyed zone.

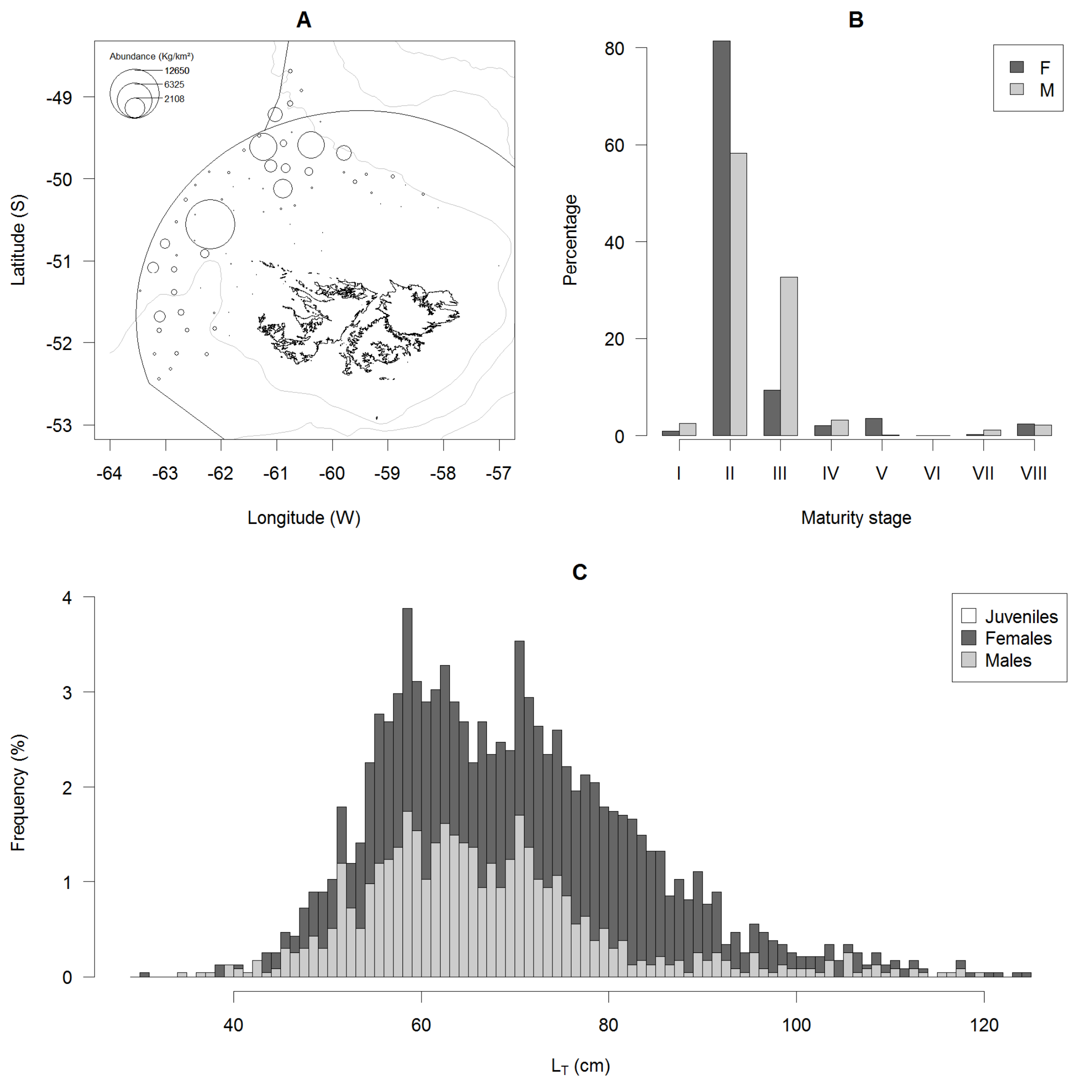

Figure 7: Biological data of *Merluccius australis*, map of the densities (A), percentage of specimen of each sex per maturity stage (B) and length frequency of each sex (C).

3.1.7 Patagonian toothfish (*Dissostichus eleginoides*)

A total of 181 kg of Patagonian toothfish was caught at 41 stations (Figure 8). The highest catches occurred in the north, in the southwest and in the east of the surveyed area. Catches ranged from 0.02 to 61 kg and only 4 stations were hauled with more than 10 kg of toothfish in the net. Densities varied between 0.03 and 75 $kg.km^{-2}$ (with CPUE ranging 0.02 to 31 $kg.h^{-1}$). 241 specimens were sampled (10 juveniles, 138 females and 93 males), 19 for length–weight and 210 for otoliths. Total length ranged from 11 to 90 cm for females and from 12 to 77 cm for males. Generally in toothfish, mainly small animals are found in shallow waters (<200 m deep) and biggest animals are abundant in deeper waters which were not surveyed during this research cruise. Consequently, the majority of sampled specimens were in maturity stage I (79 % of the females and 73% of the males), 21 and 26% of the females and males were stage II and the remainder males were stage III.

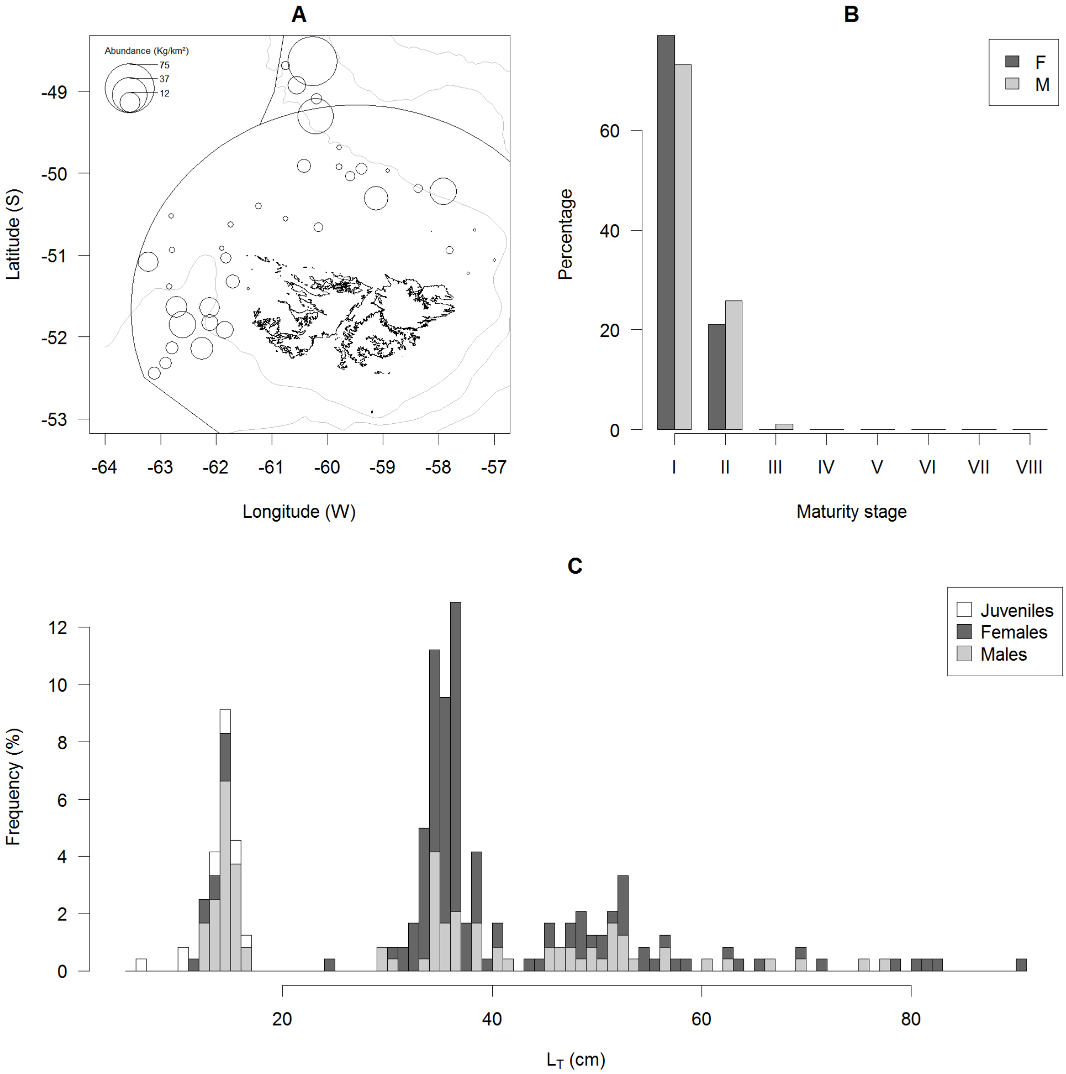

Figure 8: Biological data of *Dissostichus eleginoides*, map of the densities (A), percentage of specimen of each sex per maturity stage (B) and length frequency of each sex (C).

3.1.8 Redfish (*Sebastes oculatus*)

A total of 114 kg of redfish was caught at 19 stations (Figure 9). Most of the catches occurred between 50° and 51°S from west throughout to the east of the surveyed area except for one catch at 52°S (6 kg). Catches were generally small, ranging from 0.25 kg to 27.6 kg and only 4 stations yielded >10 kg. Densities varied between 0.5 and 60 $kg.km^{-2}$ (with CPUE ranging 0.25–28 $kg.h^{-1}$). A total of 183 specimens were collected (88 females and 95 males), 91 for length frequency and 92 for otoliths. Smallest specimens were measured at 19 and 15 cm total length for females and males respectively and largest animals were 39 cm TL. Three modes appear in the histogram at 27, 32 and 34 cm. All maturity stages were observed in females with stages II (19%), III (23%) and VIII (44%) being more frequent than the other ones (all <7%). In males, 68% of the specimens were either stage II or III, 9% were IV, 19% VIII, the rest being either I or VII.

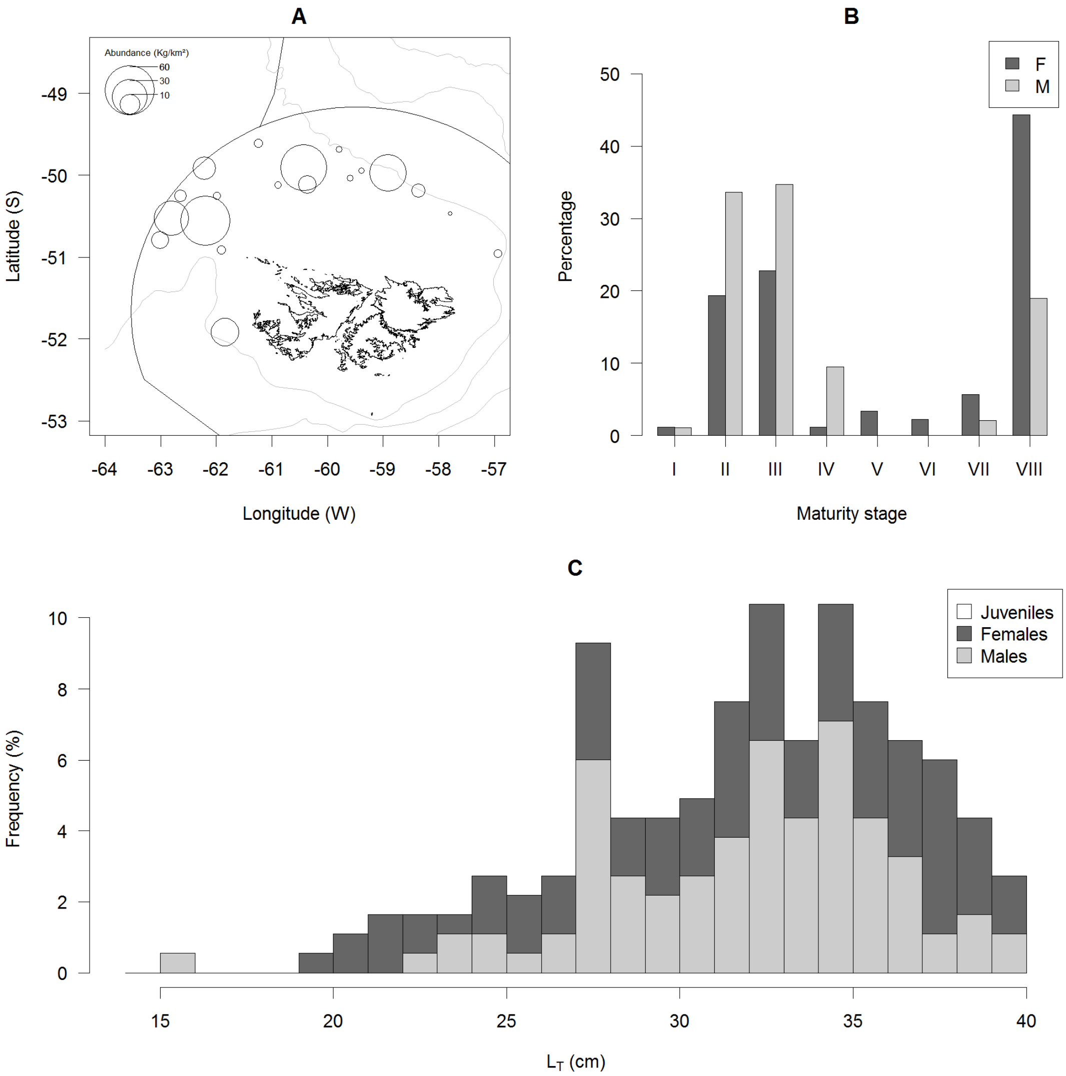

Figure 9: Biological data of *Sebastes oculatus*, map of the densities (A), percentage of specimen of each sex per maturity stage (B) and length frequency of each sex (C).

3.1.9 Hoki (*Macruronus magellanicus*)

A total 9,768 kg of hoki was caught at 54 stations during the survey (Figure 10). Highest catches occurred in 3 different regions, between 58° and 59°W in the eastern part of the surveyed area, one south of 51°S and one in the FOCZ. Throughout the surveyed area, hoki was caught regularly but in small amounts. 11 of the 54 stations yielded >100 kg and two of these >1 t. Density varied between 0.5 and 8,920 kg.km^{-2} with CPUE ranging 0.22–4,441 kg.h^{-1}). A total of 1,886 specimens were sampled (1,167 females and 719 males), 1,481 for pre–anal length frequency, 1 for length–weight and 405 for otoliths. Pre–anal length of hoki ranged from 15 cm for both sexes to 45 and 40 cm for females and males respectively. Four cohorts can be identified with modes at 18, 22, 30 and 34 cm. Finally, most of the females were either in maturity stage II (58%) or III (30%), 9% were stage VIII, 2.5% stage I and 0.5% stage VII. Finally, in males, 80% were either stage II or III, 16% were stage VII or VIII and the rest were stage I (3%) or IV (0.3%).

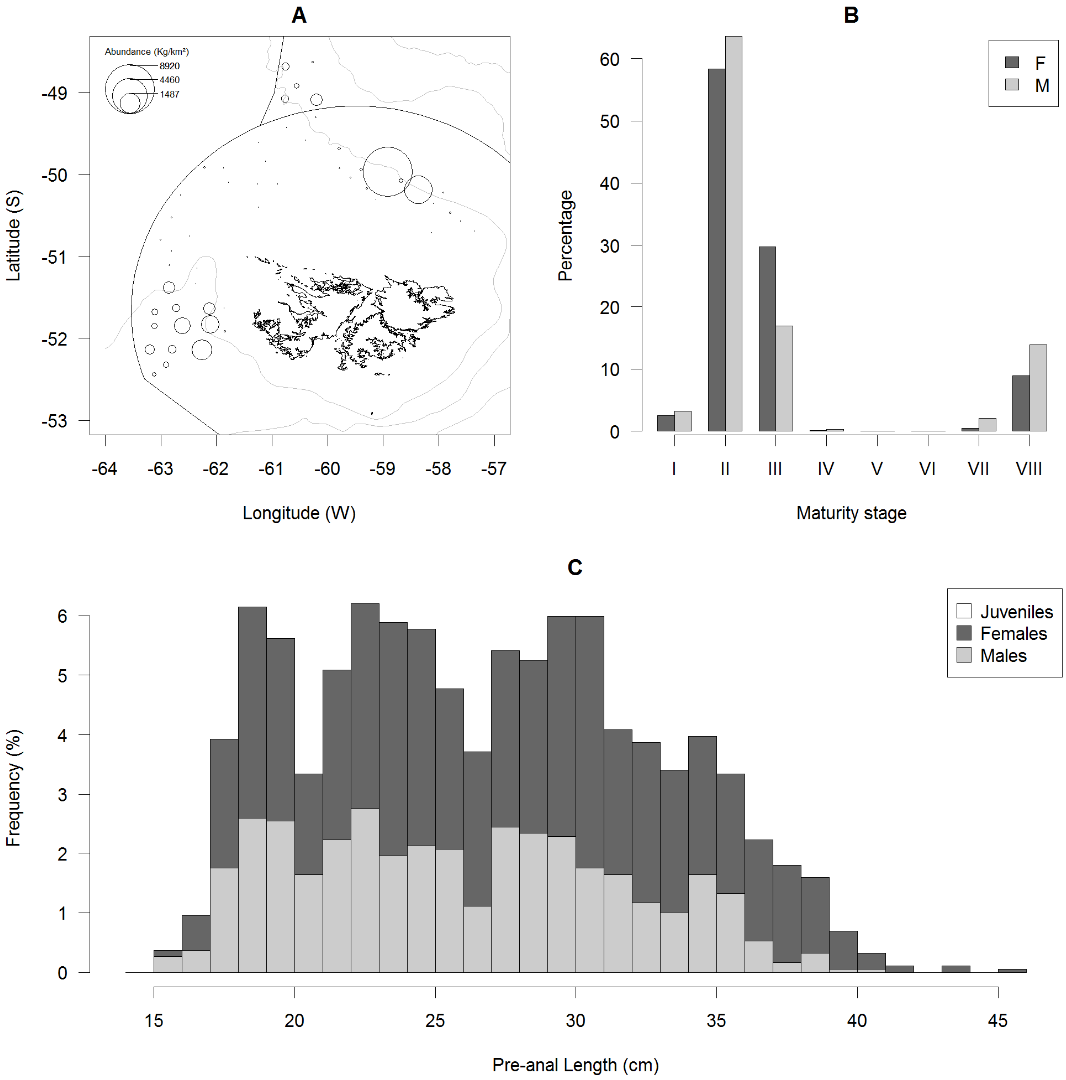

Figure 10: Biological data of *Macruronus magellanicus*, map of the densities (A), percentage of specimen of each sex per maturity stage (B) and length frequency of each sex (C).

3.1.10 Falkland calamari (*Doryteuthis gahi*)

A total of 1,803 kg of Falkland calamari was caught at 86 stations (Figure 11). Catches varied between 0.01 and 249 kg. Half of the stations yielded >10 kg and only one of these with >100 kg. Abundance varied between 0.05 and 228 kg.km^{-2} with CPUE ranging 0.02–249 kg.h^{-1}. A total of 15,567 specimens were sampled (8,891 females and 6,676 males). Dorsal mantle length ranged from 4 to 16 cm for females and from 3.5 to 18 cm for males. A single cohort is visible on the length frequency histogram (mode at 7 cm). A majority of females were either in maturity stage I (32%) or II (66%) and the remainder were in stages III, IV or V. In males, proportions of I and II were 52 and 44% respectively, the rest being III, IV or V.

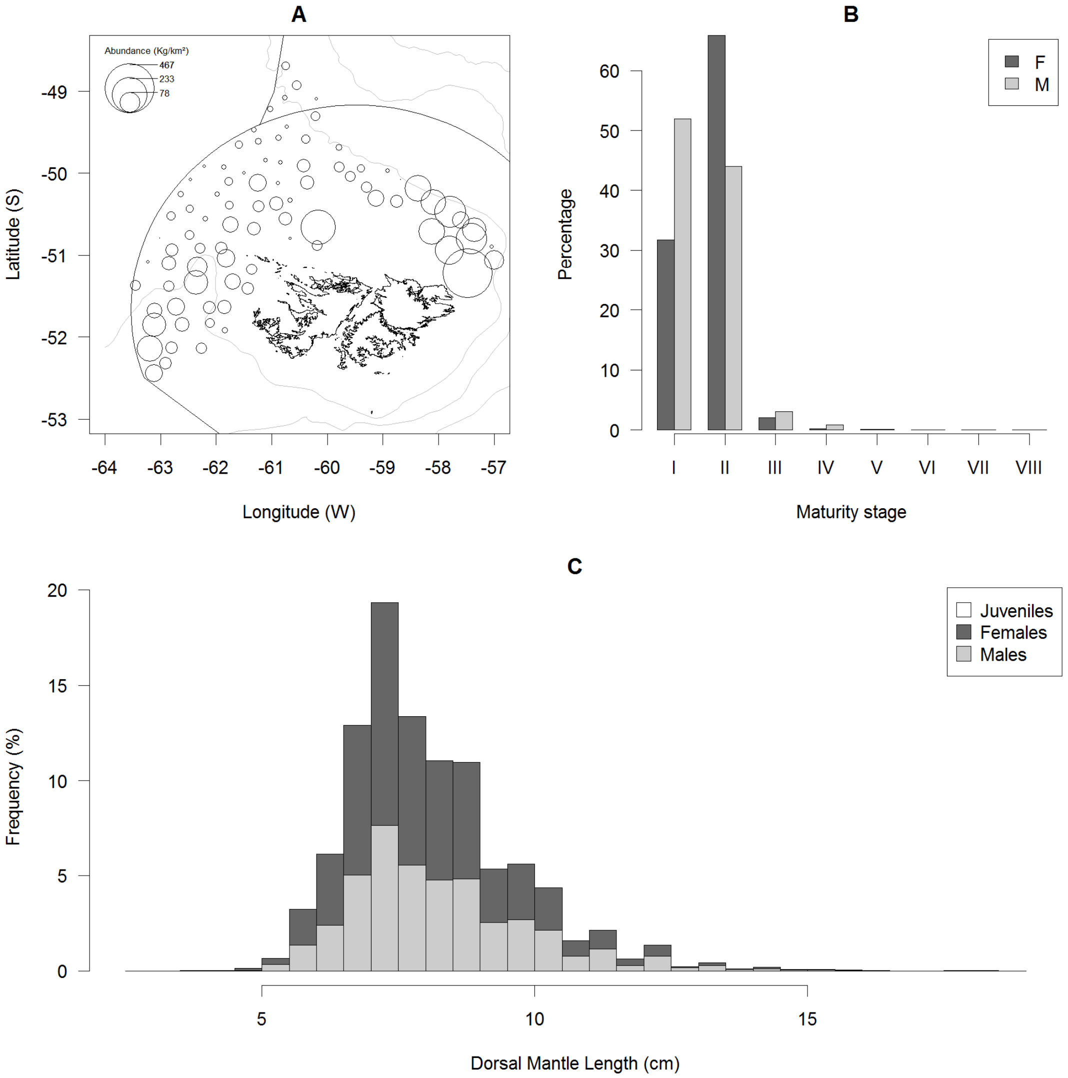

Figure 11: Biological data of *Doryteuthis gahi*, map of the densities (A), percentage of specimen of each sex per maturity stage (B) and length frequency of each sex (C).

3.1.11 Illex squid (*Illex argentinus*)

A total of 31,683 kg of Illex squid was caught at 82 stations (Figure 12). Most of the catches occurred north of the 51°S with the biggest catch at 59°W. Catches ranged from 0.04 to 6,415 kg. 38 stations yielded >100 kg and of these, 9 stations >1 t. Densities varied between 0.02 and 28,740 kg.km^{-2} (CPUE ranged 0.04 – 12830 kg.h^{-1}). A total of 6,822 specimens were sampled (3,589 females and 3,233 males), 6,505 for length frequency, 146 for length–weight and 171 for statoliths. Females ranged from 10.5 to 34 cm DML and from 13 to 29 cm for females and males respectively. Finally, males and females were found at nearly all maturity stages, but most of them were II (68% and 55% of females and males respectively). In females 30% were stage I or III, 2% IV or V. In males 10% were stage I, 16% were stage III, 11% stage IV and 8% stage V.

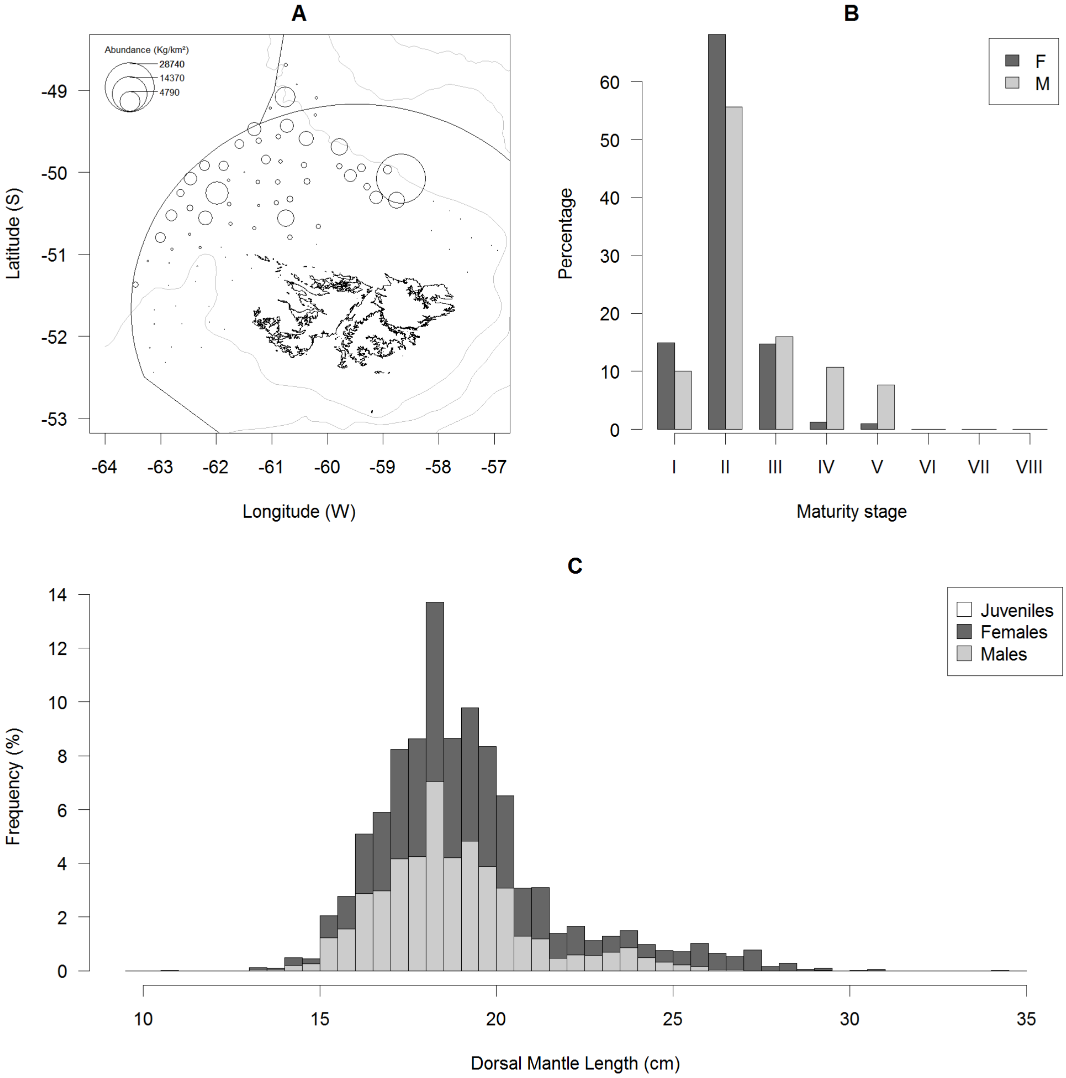

Figure 12: Biological data of *Illex argentinus*, map of the densities (A), percentage of specimen of each sex per maturity stage (B) and length frequency of each sex (C).

3.2 Skate catch, distribution and biology

The family Rajidae, of which a total of at least 13 species from 5 genera (*Amblyraja*, *Bathyraja*, *Dipturus*, *Psammobatis* and *Zearaja*) were caught, comprised 2.4% of the total catch from the 89 bottom trawl stations, 88 of which yielded skates, with a mean of 37.4 kg/trawl and a mean CPUE of 70.6 kg/km^2 or 33.1 kg/hr. The three dominant species were *Bathyraja brachyurops*, *Bathyraja griseocauda* and *Zearaja chilensis*, their combined catches yielding 2,702 kg or 82.2% of the skate total (Table 4). The six most dominant species in terms of total catch are discussed below.

Table 4: Skate Catch (kg)

Species Code	Species name	Total Catch (kg)	Total Sampled (kg)	Total Discarded (kg)	Proportion (%)
RBR	*Bathyraja brachyurops*	1,134.430	1,134.430	29.930	0.82%
RGR	*Bathyraja griseocauda*	811.050	811.050	2.420	0.59%
RFL	*Zearaja chilensis*	756.990	756.990	3.100	0.55%
RMC	*Bathyraja macloviana*	141.600	141.600	14.260	0.10%
RAL	*Bathyraja albomaculata*	122.200	122.200	7.330	0.09%
RBZ	*Bathyraja cousseauae*	91.770	91.770	0.000	0.07%
RMU	*Bathyraja multispinis*	86.496	86.496	0.000	0.06%
RTR	*Dipturus trachydermus*	50.640	50.640	50.640	0.04%
RSC	*Bathyraja scaphiops*	31.270	31.270	0.320	0.02%
RPX	*Psammobatis spp.*	25.080	25.080	24.990	0.02%
RDO	*Amblyraja doellojuradoi*	15.710	15.710	15.710	0.01%
RDA	*Dipturus argentinensis*	10.070	10.070	10.070	0.01%
RMG	*Bathyraja magellanica*	9.080	9.080	7.260	0.01%
RPS	*Psammobatis cf. scobina*	2.320	2.320	2.320	0.00%
Totals		**3,288.706**	**3,288.706**	**168.350**	**2.39%**

3.2.1 *Bathyraja brachyurops*

A total of 1,134 kg was caught in 69 of the 88 stations, comprising 34.5% of the skate catch. The species was caught throughout the survey area with the largest catch (77 kg) and CPUE (142.6 kg/km^2 or 76.6 kg/hr) at station 1712, in the N of the FICZ at 272 m. All 441 specimens (55% Female) were sampled, with sizes ranging from 6–70 cm DW (Figure 13). 60% of the females were adults or sub–adults (stages III–VI), the remainder juveniles/immature (stages I–II). 50% of the males were in maturity stages III–V. Thirty four females carrying egg capsules (F5) were encountered, 14% of all females and 30% of all females above the L_{dw} at 50% maturity of 47.9 cm DW. This is possibly the highest proportion ever encountered for this species during any of our surveys, suggesting that a summer spawning peak is an important aspect of this species' reproductive cycle. The majority of the F5s were caught in 1s and 2s at shelf stations W of 60°W. Two stations (st. 1711 and 1712 in the NNE part of the FICZ) yielded 4 F5s each, a relative hotspot.

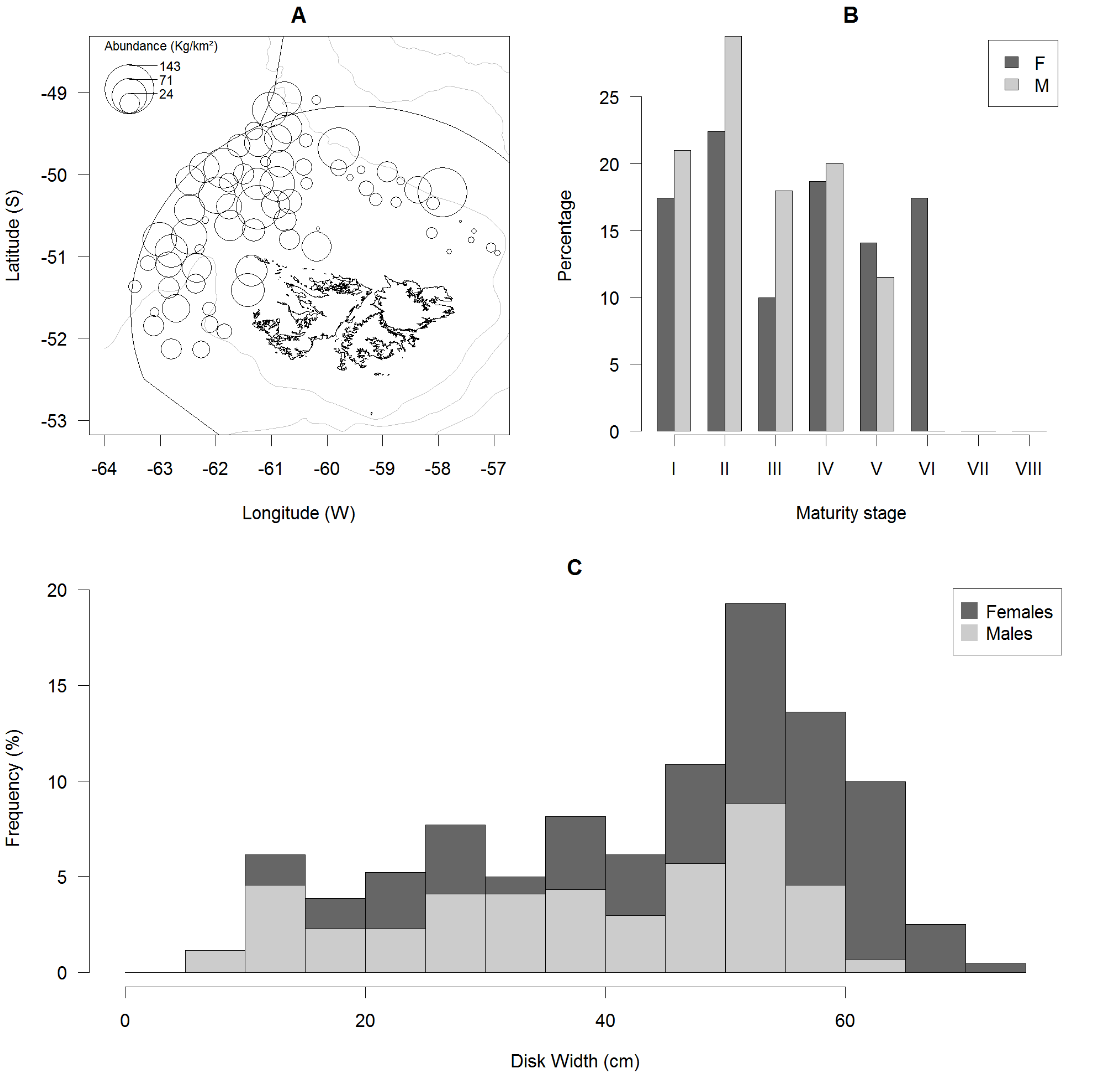

Figure 13: Distribution, abundance (kg/km^2), size structure (5 cm pooled), and maturity of *Bathyraja brachyurops*

3.2.2 *Bathyraja griseocauda*

A total of 811 kg was caught in 20 of the 88 stations, comprising 25% of the skate catch. All catches occurred in deeper water over the shelf break both in the South and but more so in the North (Figure 14). The largest two catches (435 kg and 113 kg) all occurred at the two targeted RGR stations 1678 and 1680 in the NW of the FOCZ. All 138 specimens (63% Female) were sampled, with sizes ranging from 19–108 cm DW (Figure 14). Two of the females (96 and 102 cm L_{dw}) were encountered carrying egg capsules (F5), 9% of all females above the L_{dw} at 50% maturity of 75.9 cm DW. The largest female at 108 cm L_{dw} did not but was a F6. As before capsule carrying females (F5) had previously been encountered at the locations of these targeted RGR stations.

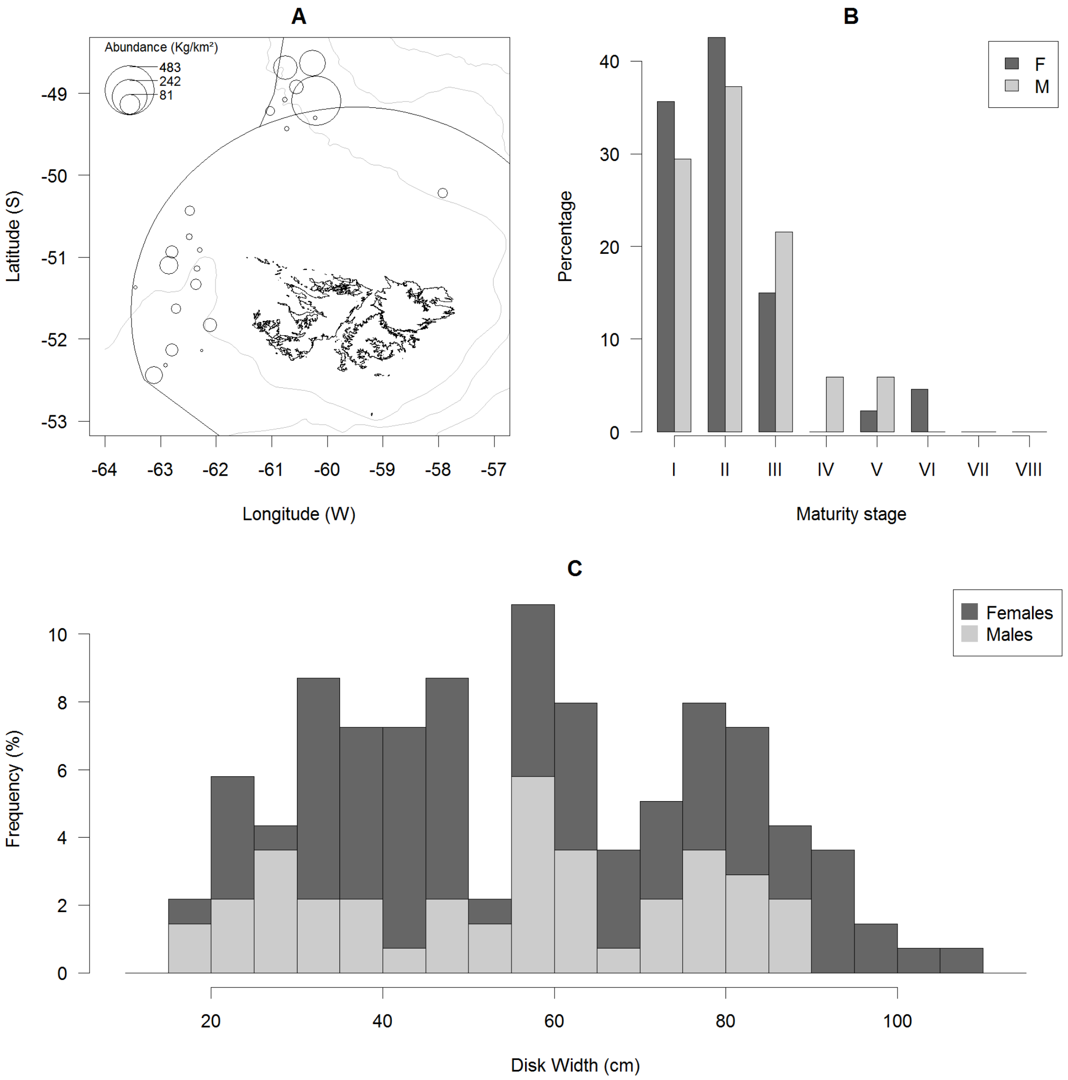

Figure 14: Distribution, abundance (kg/km^2), size structure (5cm pooled), and maturity of *Bathyraja griseocauda*

3.2.3 Dipturus (Zearaja) chilensis

A total of 757 kg was caught in 48 of the 88 stations, comprising 23% of the skate catch. The species was more commonly caught in stations on the shelf and on the northern shelf break, with the largest catch (85 kg) and CPUE (188 kg/km^2 or 85 kg/hr) at station 1652 in the NW of the FICZ at 160 m, followed by 78 kg and CPUE (127 kg/km^2 or 78 kg/hr) at station 1566, relatively close to the Jason Islands at a depth of 131 m. 248 specimens (86% Female) were sampled, with sizes ranging from 33–82cm DW. The majority of the specimens sampled were juveniles or sub–adults, with only 4% of the females in maturity stages IV–VI, and 14% of the males in stages IV and V. One 69 cm DW female carried egg capsules (Figure 15), this was at st. 1693 on the shelf break in the Northern FICZ.

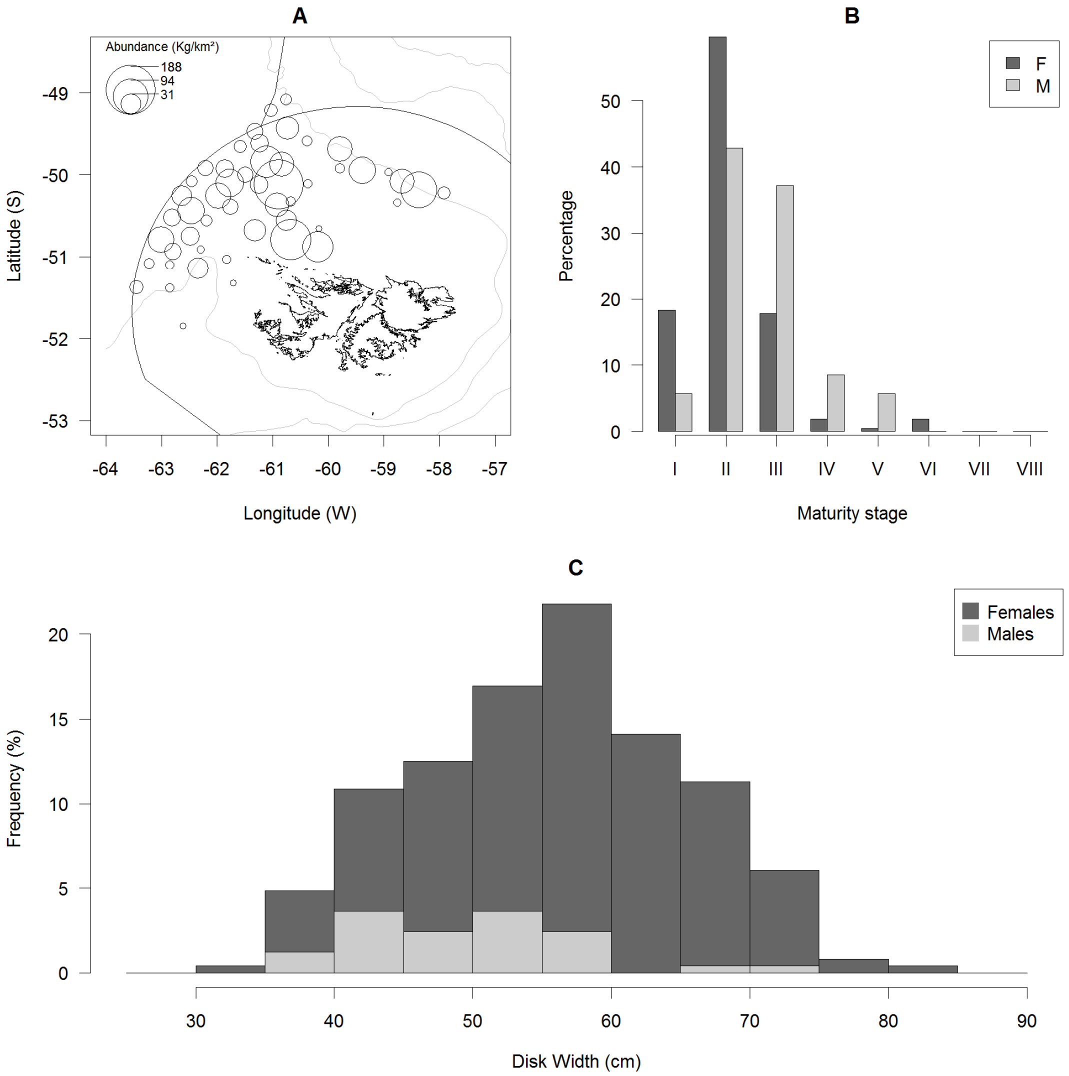

Figure 15: Distribution, abundance (kg/km^2), size structure (5cm pooled), and maturity of *Zearaja chilensis*

3.2.4 *Bathyraja macloviana*

A total of 142 kg of this 4^{th} most abundant species was caught in 46 of the 88 stations, comprising 4.3% of the skate catch. Specimens were caught in small numbers throughout the area, with greatest catch (25.5 kg) and abundance (31 kg/km^2 or 12.8 kg/hr) off the shelf in the deepest station 1678 (390 m) (Figure 16). Of the 128 specimens, 48% were female, sizes ranged from 9–43 cm L_{dw}, and 4 (8.9%) of the 45 females above L_{dw} at 50% maturity of 32.1 cm had egg capsules. 3 of these F5s were caught on the shelf, the 4^{th} one at the deepwater station.

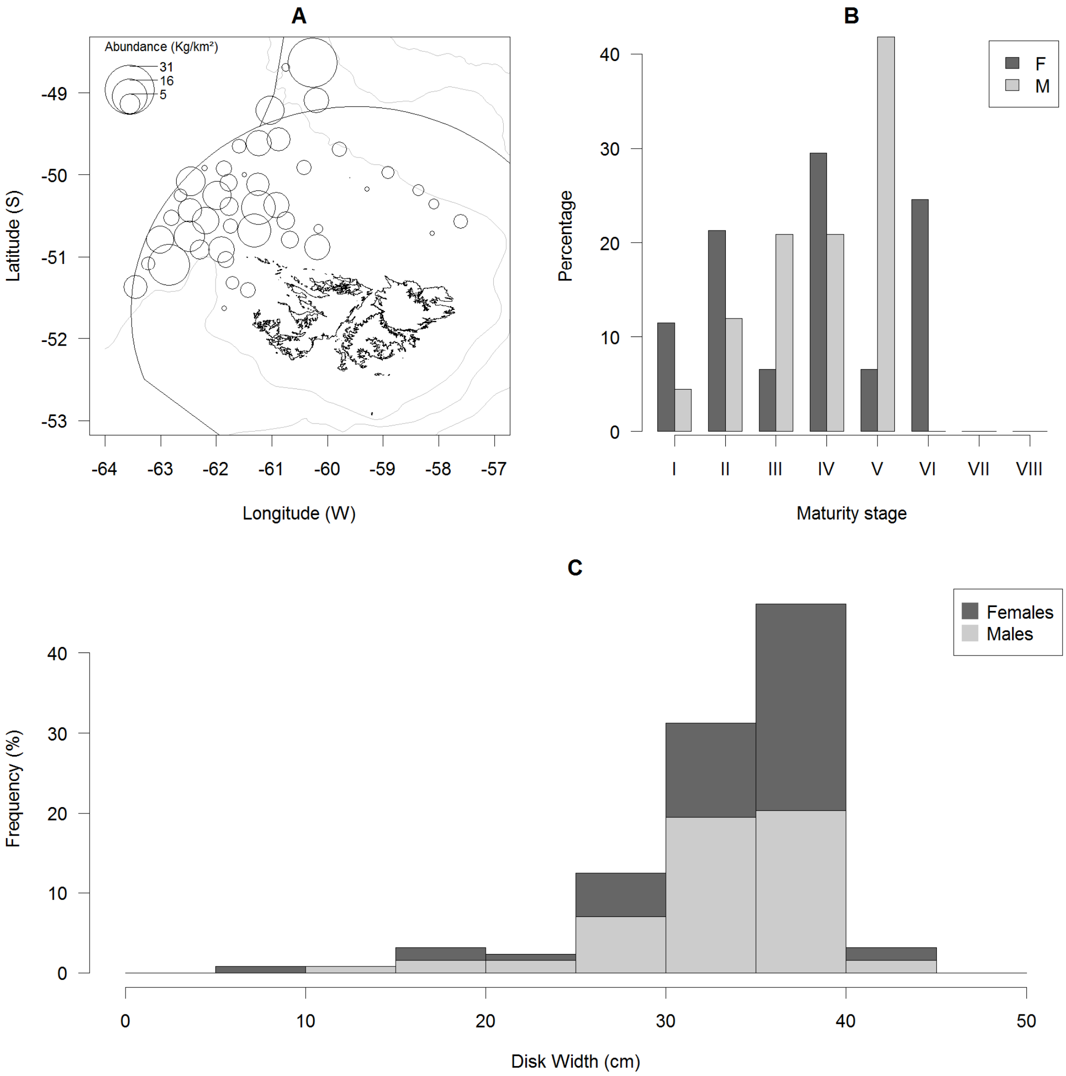

Figure 16: Distribution, abundance (kg/km^2), size structure (5cm pooled), and maturity of *Bathyraja macloviana*

3.2.5 *Bathyraja albomaculata*

A total of 122 kg of this 5th most abundant species was caught in 27 of the 88 stations, comprising 3.7% of the skate catch. Specimens were caught sporadically throughout the area, with greatest catch and abundance in the northern sector. Of the 64 specimens, 52% were female, sizes ranged from 9–50cm L_{dw}, and only 1 (3.6%) of the 28 females above L_{dw} at 50% maturity of 39.1cm had egg capsules.

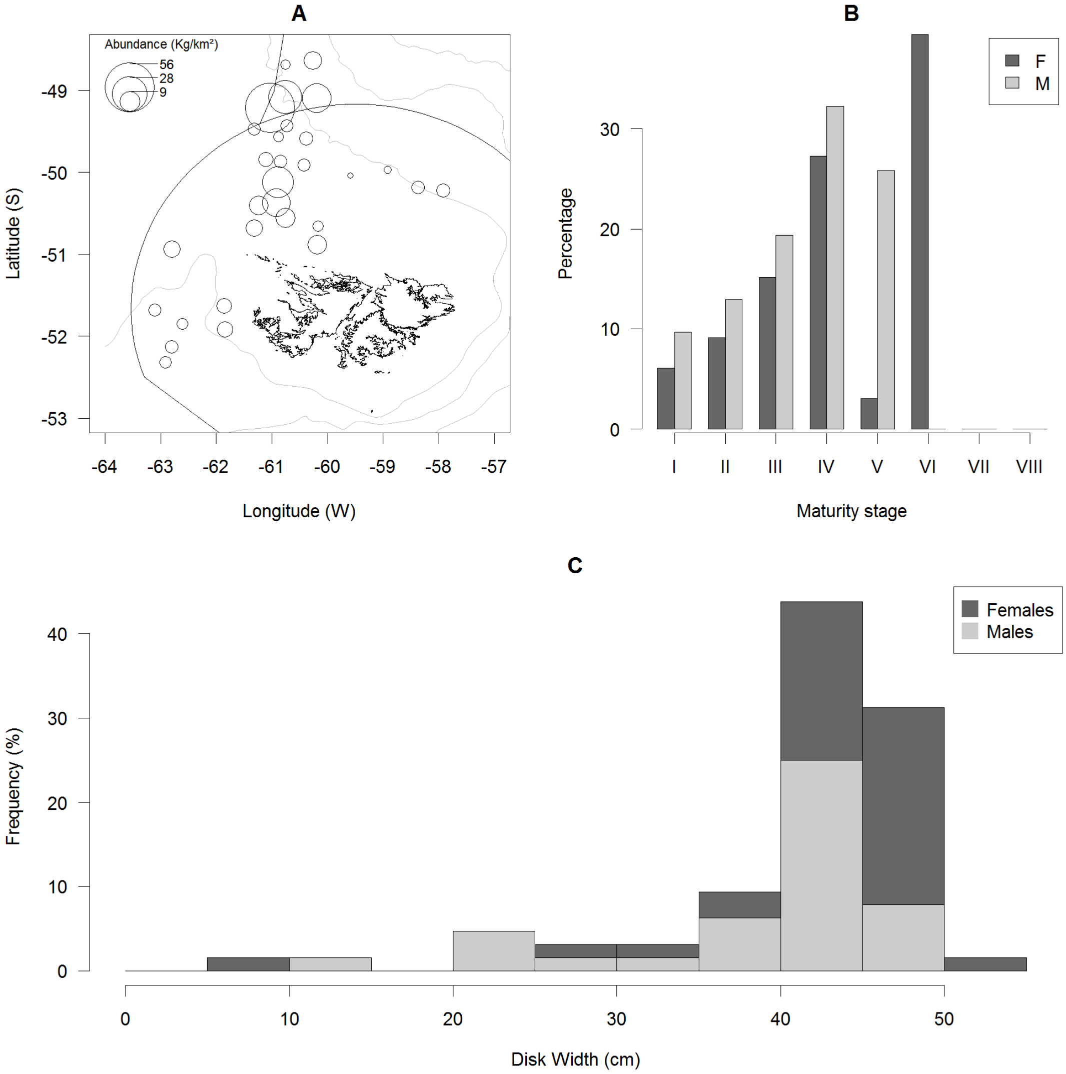

Figure 17: Distribution, abundance (kg/km^2), size structure (5cm pooled), and maturity of *Bathyraja albomaculata*

3.2.6 *Bathyraja cousseauae*

A total of 92 kg of this 6th most abundant species was caught at only 5 of the 88 stations, 70 kg at one station alone (the deepwater station 1678; Figure 18). The species comprised 2.8% of the skate catch. Specimens were caught in deeper waters on the shelf break and slope. None of the females had egg capsules.

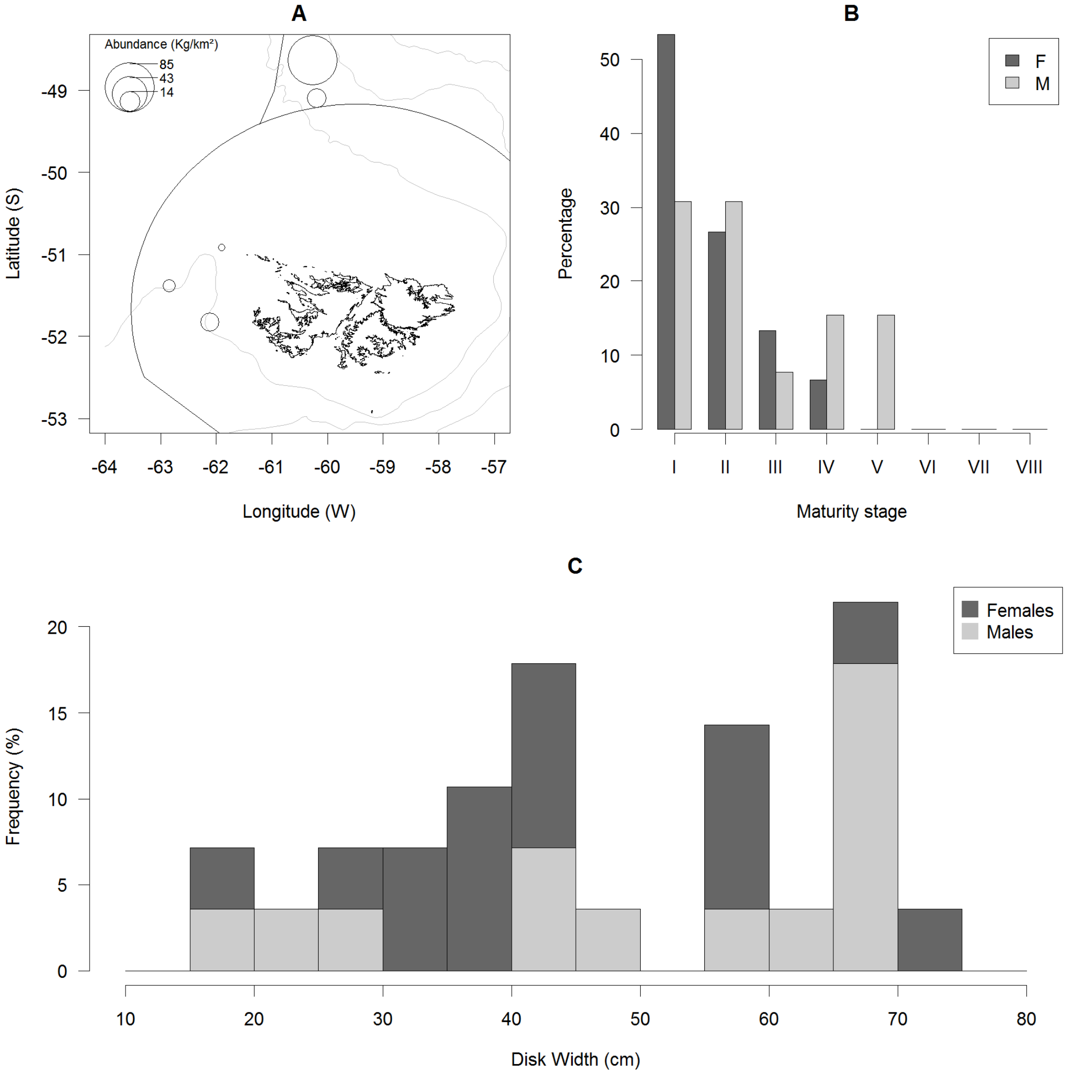

Figure 18: Distribution, abundance (kg/km^2), size structure (5cm pooled), and maturity of *Bathyraja cousseauae*

3.3 Biomass estimates

3.3.1 Rock cod

Four semi–variograms were plotted using 30 distance classes (Table 5 and Figure 19 left). This number of classes was suitable to describe the increase in semi–variance at short distances well. Two models were used to fit the data, the exponential (2010 and 2015) and the spherical (2011 and 2014) showing that rock cod densities collected during these research cruises were not that auto–correlated (range varied between 16 km in 2015 and 93 km in 2011). Highest densities of rock cod generally occur in the north–western FICZ, regardless of the season studied (Figure 19 right).

In 2010, one station exhibited a high density of rock cod (north of the Jason Islands) and the kriged rock cod density was quite homogeneous within the surveyed area. In that survey, the average density was 3,344 $kg.km^{-2}$ giving a first biomass estimation of 343,124 t.

In 2011, unlike in 2010, the rock cod density was less homogeneous with a larger patch of high densities observed in the north–western FICZ. In the rest of the surveyed area, density seemed to vary more than the year before with a zone of higher density in the south–eastern part of the area while in the rest of the zone density was lower. In the 2011 survey, the average density was higher with an average of 3,821 $kg.km^{-2}$ and a total biomass of 392,053 t.

In October 2014, two of the three patches of high densities were observed in the north–western part of the FICZ as observed in other years, approximately the same region as in 2010 and 2011. However, in the far east of the surveyed zone, another high density spot was observed but this zone consisted mostly of small specimens (most likely 1 year olds). For this year's survey, the average density was 961 $kg.km^{-2}$ and the total biomass estimated at 98,596 t.

In February 2015, one single spot of high density was observed, again in the north–western part of the FICZ. Also some other spots of higher densities were observed in different areas: northwest of the Jason Islands, north around the border between FICZ and FOCZ and in the eastern surveyed zone where we caught, like in October–November 2014, primarily small animals. Rock cod abundance was the lowest of the 4 surveys with an average of 744 $kg.km^{-2}$ and a total biomass of 76,298 t.

The low amount of biomass estimated in 2014 compared to 2010 and 2011 could be related to inter–seasonal variation. At this time of the year, rock cod, which has taken part in the reproduction in winter (Brickle et al., 2006) could still be on the spawning grounds that are probably located outside of the surveyed area. Even if Brickle et al. (2006) showed that rock cod is generally back to the feeding grounds in October, the low abundance observed could be the consequences of specific environmental conditions encountered in this particular year and not necessarily a depletion of the stock due to overexploitation.

The rock cod biomass estimate survey undertaken in 2015 was conducted at the same time as in 2010 and 2011 and the same stations as those in 2011 and 2014 were repeated. However, the biomass estimation was the lowest of the 4 surveys. If the fishing activity is suggested to be the cause of this low abundance, another cause of variation should be discussed. For instance, not the entire distribution area of the species was covered by this survey. It is therefore not possible to conclude that the entire stock has been depleted. Highest abundances are generally located in the north–western part of the FICZ (where finfish trawlers concentrate to target this resource). A slight movement of the stock into Argentine waters could have occurred leading to this low abundance situation within Falkland waters. This movement could have been driven by environmental parameters. Environmental parameters such as temperature could also influence the stock abundance from one year to the next. Finally, abundance of other species (predators, preys and competitors) could influence rock cod abundance.

Table 5: Parameters used to plot the semi–variogram, fit the variogram model, variogram model sill, range and nugget and average biomass per unit area total biomass estimation using the data collected in 2010, 2011, 2014 and 2015.

	ZDLT1-02-2010	ZDLT1-02-2011	ZDLT1-10-2014	ZDLT1-02-2015
N of distance classes	30	30	30	30
Lambda	0.5	0.5	0.5	0.5
Model	Exponential	Spherical	Spherical	Exponential
Range	18	93	51	16
Sill	4,440	5,030	2,330	1,240
Nugget	0	0	0	0
Mean estimation (kg.km^{-2})	3,344	3,821	961	744
Biomass estimation (mt)	343,124	392,053	98,596	76,298

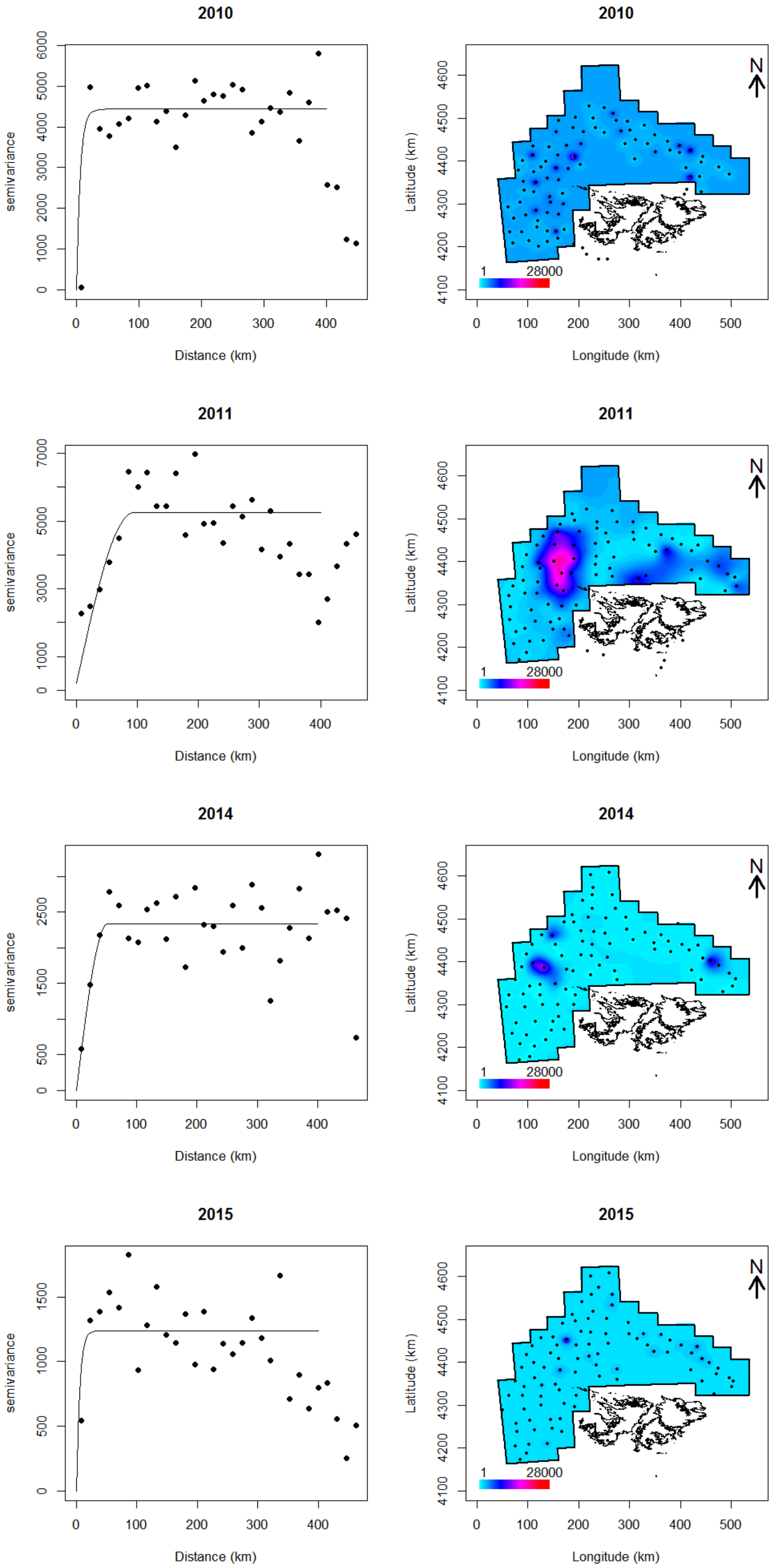

Figure 19: Semi–variogram of observed densities fitted with variogram model (model type is described in Table 5; left column) and kriged map of rock cod densities (right column) for years 2010, 2011, 2014 and 2015 from the first to the fourth row respectively.

3.3.2 Red cod

A semi–variogram was plotted using 26 distance classes and λ=0.5 (Figure 20). The spherical model was the only model fitting the observed data, reaching the sill (1370) at a range of 44 km. Mean density was estimated at 458 kg.km^{-2} and total abundance at 47,047 t. This density is higher than the one observed in 2014 (38,909 t). The map of kriged data shows densities ranging from 1 kg to 11 t per km². Highest abundances were observed in the west northwest of the Falklands.

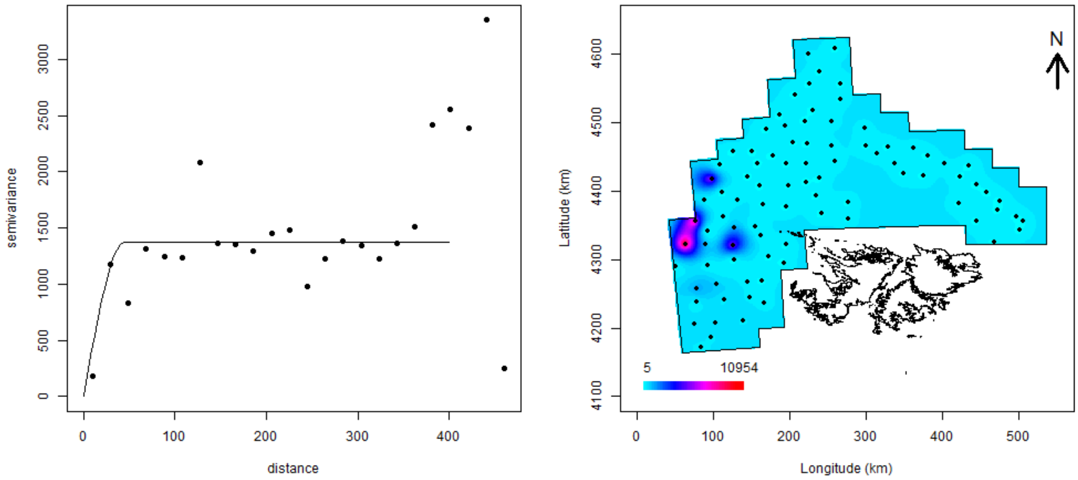

Figure 20: Semi–variogram with variogram model describing the data auto–correlation vs distance between stations (left) and map of red cod density interpolated by kriging (right).

3.3.3 Hake

A semi–variogram was plotted using 35 distance classes and λ=0.5 (Figure 21). The best fit was obtained using the spherical model, reaching the sill (210) at 215 km. Hake abundances seem to be more auto–correlated then other species. This was also the case in the October 2014 rock cod biomass survey. Average density was estimated at 69 kg.km^{-2} and the total biomass was 7084 t. Kriged densities ranged from 2 to 393 kg. Highest densities were observed north of 51°S and west of 61°W. Two patches of high abundance can be identified on the map. The abundance of hake was low presumably because the survey was conducted when most of the hakes were in the Argentinean waters to take part in the reproduction period.

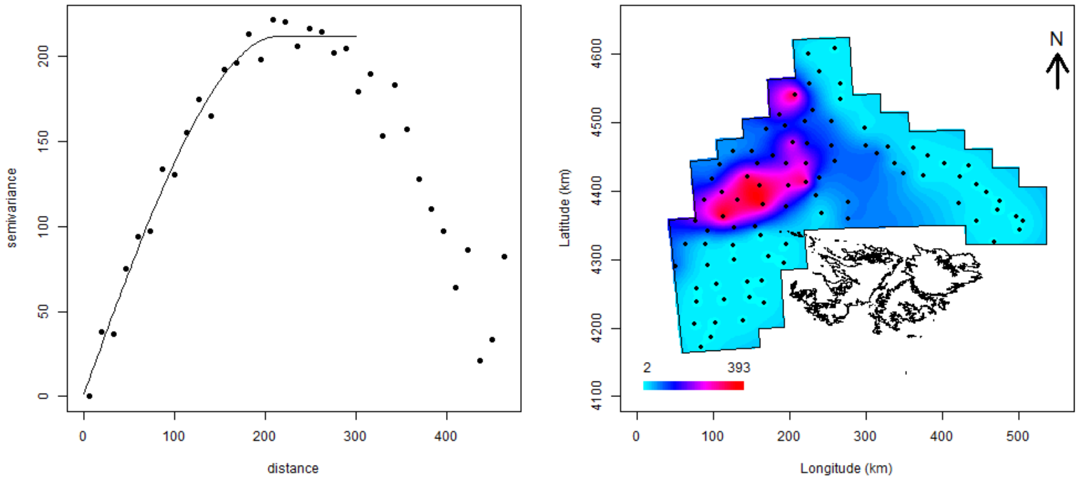

Figure 21: Semi–variogram with variogram model describing the data auto–correlation vs distance between stations (left) and map of hake density interpolated by kriging (right).

3.3.4 Kingclip

A semi–variogram for kingclip was plotted using 32 distance classes and λ=0.5 (Figure 22). The only variogram model which fitted the data was the Gaussian model reaching the sill (1069) at 29 km. Kingclip densities ranged from 1 to 12.6 t. Mean density was estimated at 370 kg.km^{-2} and the total biomass was estimated at 38,042 t. For kingclip, low auto–correlation of the data was identified. The highest density of kingclip was observed northwest of West Falkland in one station. Five other stations north of West Falkland exhibited high densities.

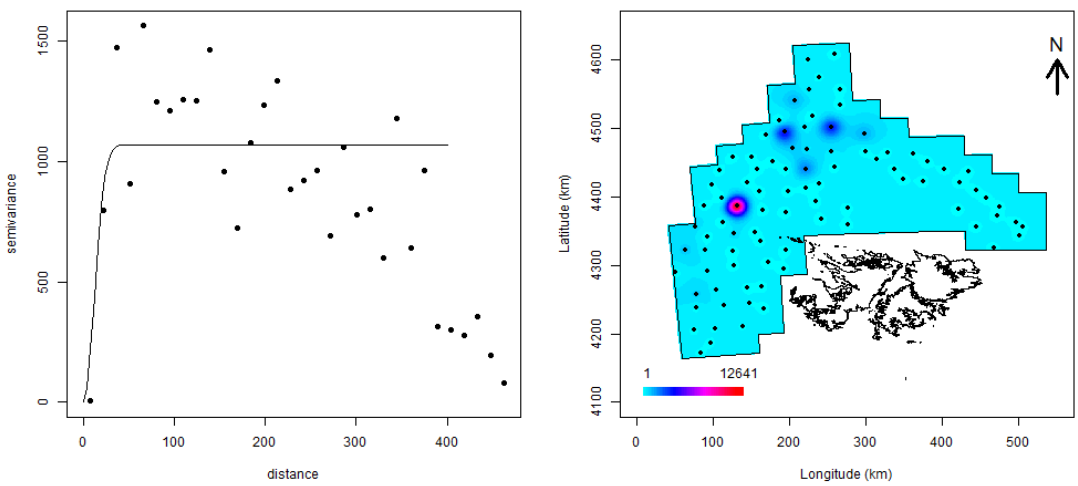

Figure 22: Semi–variogram with variogram model describing the data auto–correlation vs distance between stations (left) and map of kingclip density interpolated by kriging (right).

3.3.5 Hoki

A semi–variogram of hoki was plotted using 30 distance classes and λ=0 (log transformation of the density). The spherical model gave the best fit to the observed data and reached the sill (6.7) at a range of 232 km. Kriged densities ranged between 1 and 5,138 kg.km^{-2}, mean density estimated at 183 kg.km^{-2} and total biomass at 18,802 t. The highest density was observed north of East Falkland close to the 200 m bathymetric line. In the southwest part of the surveyed area, a zone of higher density can be identified. This zone is known by the fishers who generally concentrate there to target hoki.

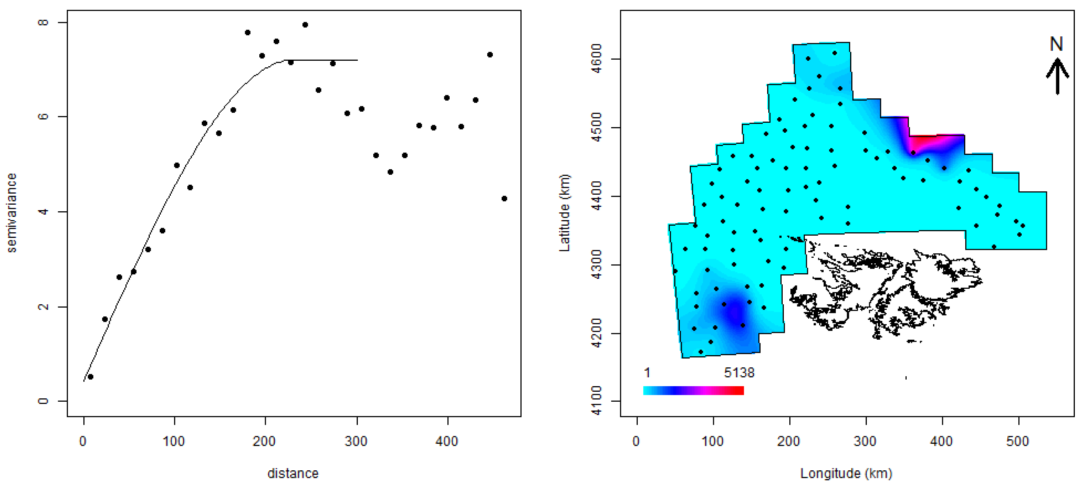

Figure 23: Semi–variogram with variogram model describing the data auto–correlation vs distance between stations (left) and map of hoki density interpolated by kriging (right).

3.3.6 Illex squid

A semi–variogram for Illex squid was plotted using 32 distance classes and λ=0 (log transformation of the densities; Figure 24). The spherical model provided the best fit to the data and reached the sill (11) at a range of 302 km. Kriged densities ranged between 1 and 26,376 kg.km^{-2}, with mean density estimated at 677 kg.km^{-2} and the total biomass at 69,487 t. Illex squid was caught north of 50°30’S. Highest density was observed around the 200 m bathymetric line (where jiggers usually concentrate at the beginning of the Illex season). Some other high densities occurred along the north–western border of the FICZ and along the 200 m bathymetric line.

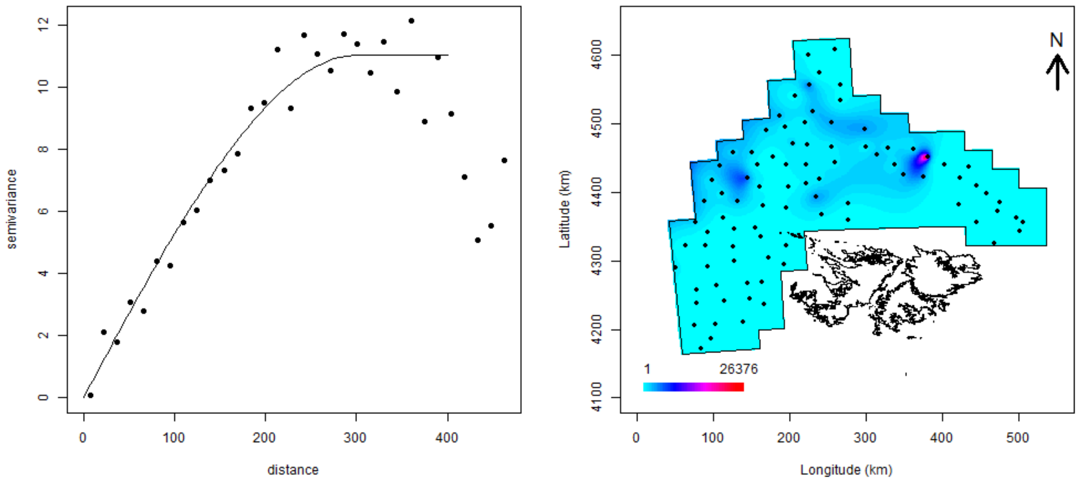

Figure 24: Semi–variogram with variogram model describing the data auto–correlation vs distance between stations (left) and map of Illex squid density interpolated by kriging (right).

3.3.7 Loligo squid

Different attempts to fit variogram models have shown that the estimated range was at several thousands km depending on the model used. It is unlikely that Loligo squid abundances are correlated on thousands of km. This situation is most likely due to low and similar abundances observed throughout the surveyed area. It was therefore decided to apply the same methodology as in Pompert et al. (2014) i.e. to consider that estimated abundances are independent. The average density can therefore be calculated using densities without geostatistical corrections and is 41 kg.km^{-2} with a total biomass estimation of 4,254 t. The spatial distribution of the species can be seen in Figure 11.

3.4 Oceanography

Oceanographic data were collected at 88 stations. The area covered ranged from 48° 3.13'S to 52° 28.39'S and 56° 53.89'W to 63° 26.45'W. Good data were collected on all the downcasts and so upcast data were removed from analyses. The CTD had an issue coping with a strong thermocline with salinity spiking similar to that experienced on the ZDLT1-10-2014 research cruise. Figure 25 below shows the location of the stations.

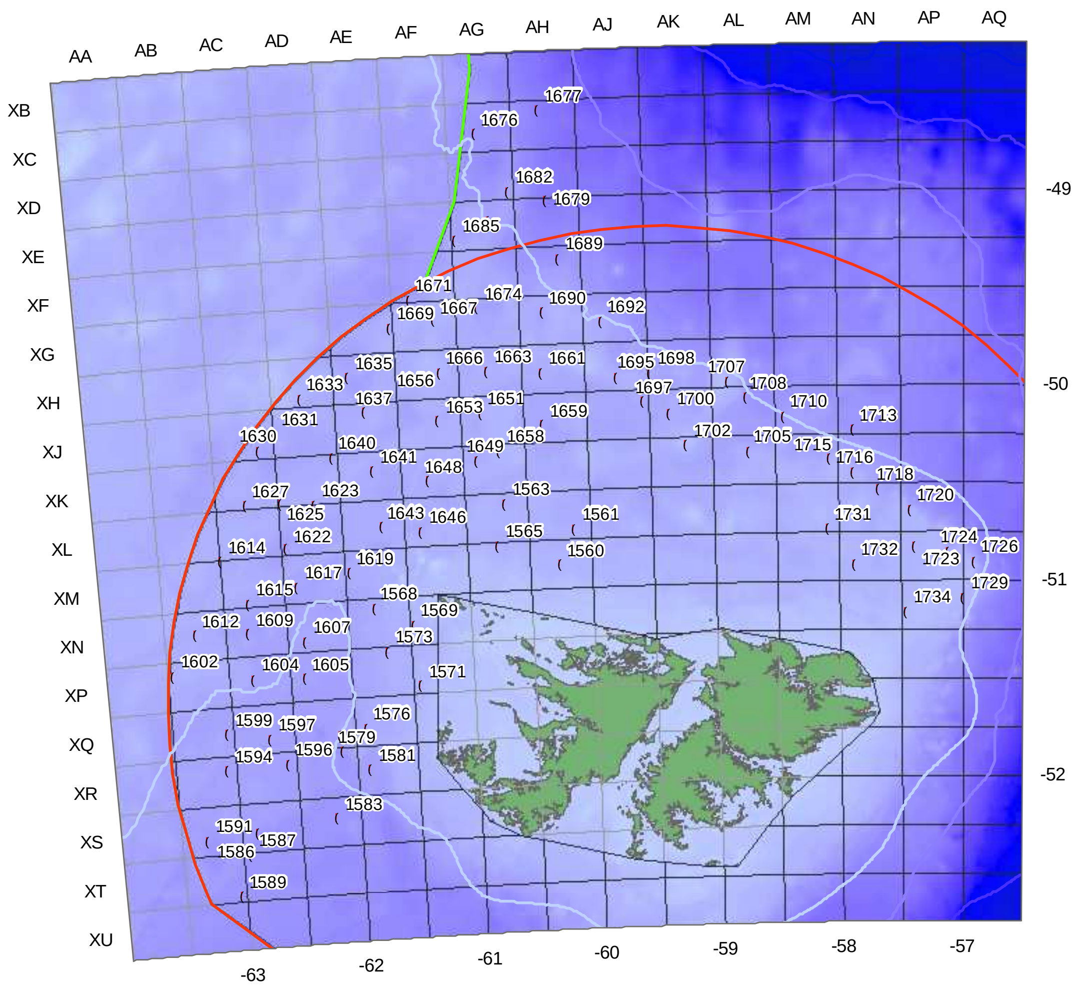

Figure 25 Location and number of CTD stations

Figure 26, Figure 27 and Figure 28 shows the temperature, salinity and σ-t density, gridded using ODV4 DIVA[1] gridding algorithm. Surface temperature was higher in the north–west and decreased to the south and east. At the seabed there was a cooler barrier of water to the west of the islands through to the north of the survey area. The southern part of this was probably caused by the western branch of the Falkland currant, whilst to the north there appeared to be cooler water coming from the north east and swing in a counter clockwise motion.

[1] DIVA is a gridding software developed at the University of Liege (http://modb.oce.ulg.ac.be/projects/1/diva)

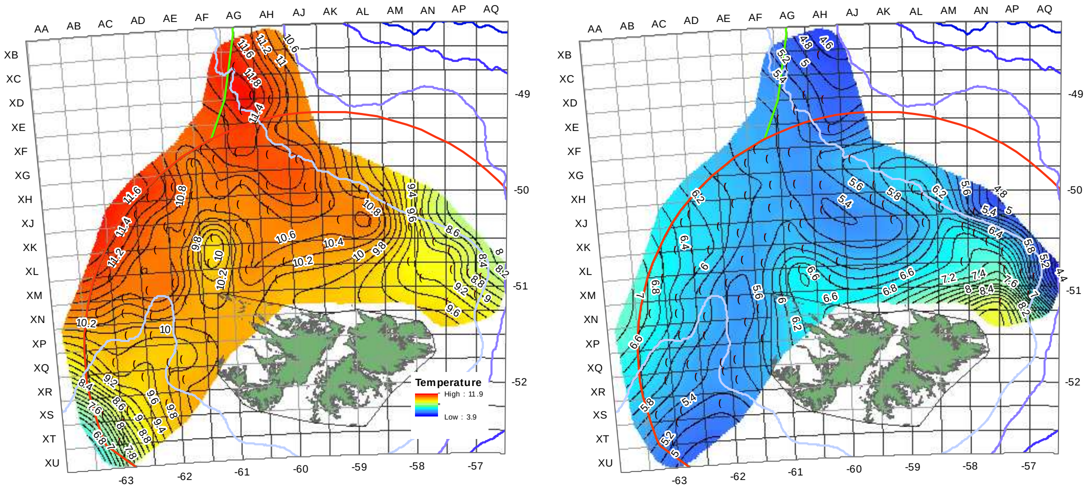

Figure 26 Temperature (Sea surface on the left, Seabed on the right)

Figure 26 shows the warm water at the surface being fed from the north west, with the west branch of the Falkland current staying close to the coast. North of the Falklands a counter clockwise gyre appeared to be moving south east through XFAG, XGAG, XHAH and XJAH, particularly evident in the seabed temperature map.

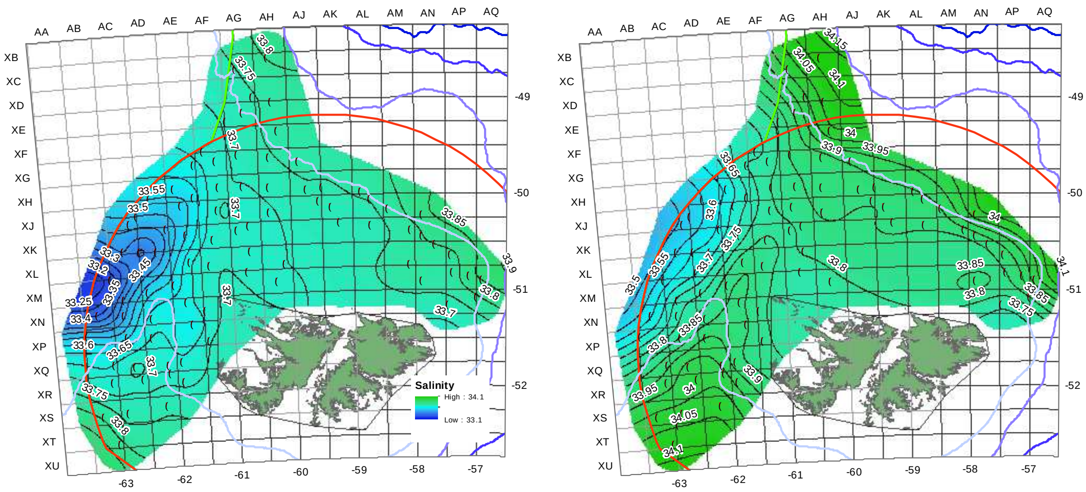

Figure 27 Salinity (Sea surface on the left, Seabed on the right)

The cooler waters of the western branch of the Falklands current, seen in the temperature map is evident as a higher salinity water mass in the sea bed salinity. The gyre seen to the north of the Falklands was not visible as a changer in salinity in the map.

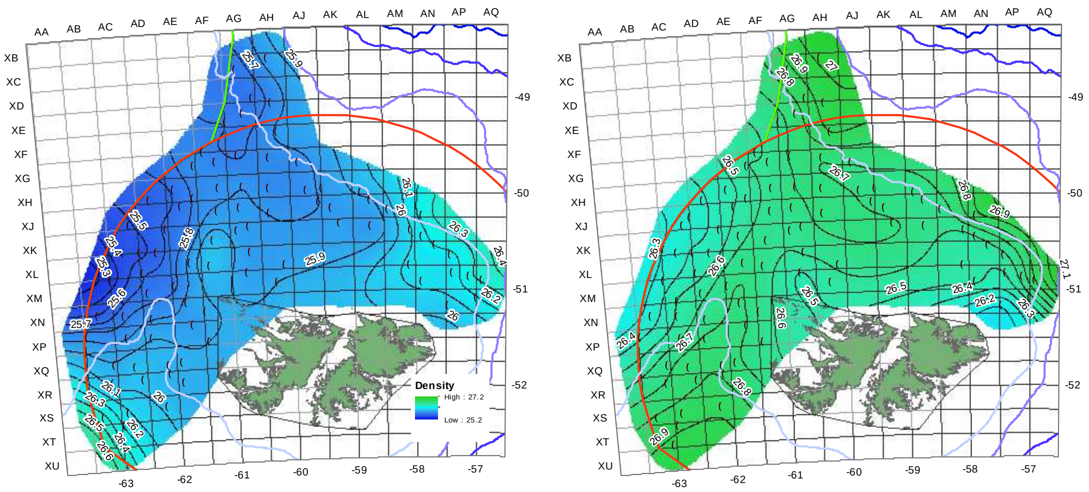

Figure 28 σ-t Density (Sea surface on the left, Seabed on the right)

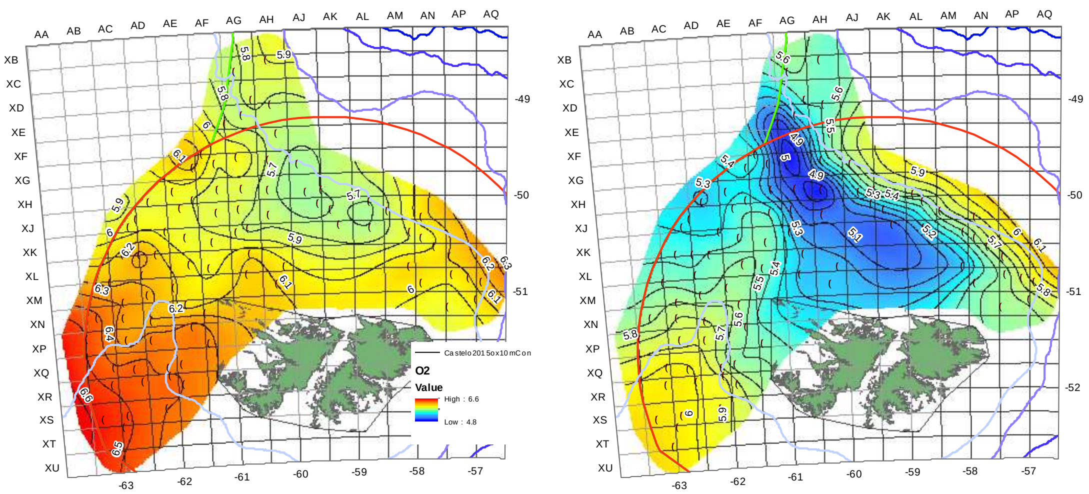

Figure 29 Oxygen content in ml/l of water (Sea surface on the left, Seabed on the right)

The oxygen seabed plot shows a similar profile to the temperature plot, with the west branch of the Falkland current containing a higher O_2 content than the surrounding water masses. The colder North Falklands gyre shows very low oxygen content (Figure 30 below). Even though excluding the interpolated data in XKAJ and XLAK is excluded, the CTDs in XEAF, XGAG, XHAG and XHAH all show a low oxygen water mass at the seabed. The red contour in Figure 30 represents temperature and the black contour represents oxygen content. The contours over the western branch of the Falklands current and the northern gyre are closely aligned seen in Figure 30 right below.

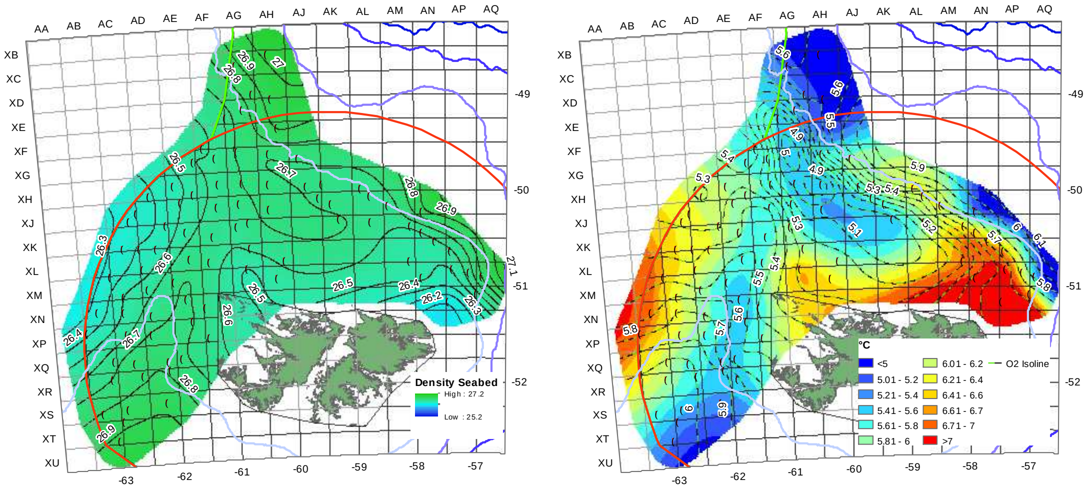

Figure 30 Density (left) and Temperature with O2 Isoline (right) at seabed

The two obvious features in the oceanographic survey are the western branch of the Falklands current which brings colder, low oxygenated with higher salinity water around the west of the Falklands, and a low temperature/low oxygen trough from the FICZ/FOCZ corner to the south east. The trough is potentially a deep water mass from the slope, with the density map showing a potential inflow through XFAG or XGAH. A visual comparison of the density and temperature/O_2 maps suggests theses are the same water mass, the western branch of the Falklands current flowing north and a gyre from the eastern branch rotating counter clockwise flowing in from the north at the FICZ/FOCZ boundary.

Figure 31 shows the stations within the 26.7 to 26.8 sigma–t at seabed density band. In the upper part of the water column the profiles are dissimilar, but all reach a similar temperature/salinity/density value when plotted against absolute salinity and conservative temperature, with the 5 southern most profiles and the northern most profile (highlighted in grey), approaching a sigma–t density of 26.8 at 34.1 to 34.15 g/kg Salinity and 5.45 to 5.71 °C conservative temperature showing that despite a depth range of 149–231 m the water masses show a significant degree of similarity.

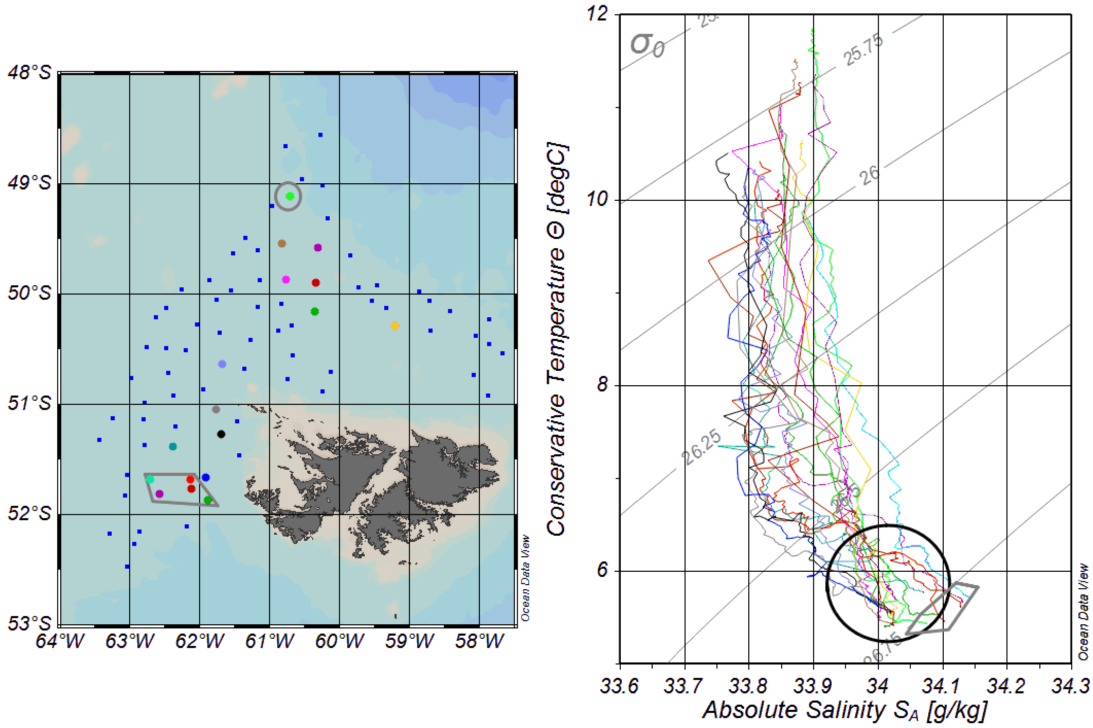

Figure 31 Temperature salinity plot of stations in 26.7–26.8 density band

4.0 Conclusions and perspectives

This fourth rock cod biomass survey conducted in February 2015 was the opportunity to estimate the rock cod abundance in summer using the same protocol, gear and vessel as in 2010, 2011 and 2014 (same station positions as in 2011 and 2014 were repeated). Results show that the spatial distribution of the resource was similar between years and season with high abundances in the north–western part of the FICZ. In 2014 and 2015 the rock cod abundance was significantly lower than in 2010–2011. As discussed in section 3.3.1, various parameters could have caused this low abundance situation, including fishing pressure, environmental conditions and trophic relationships with other species. This current work will be followed up with a global rock cod biomass estimation using the data collected during the Falkland calamari pre–recruitment survey conducted in the Loligo box between 9–23 February 2015. To understand the rock cod stock dynamic, other studies will be carried out using commercial fishing data, stock assessment models and oceanographic and biological data.

This research cruise was also an opportunity to collect data on other commercial finfish species such as kingclip and red cod which showed a higher biomass than in October 2014. The abundance of such species and of rock cod may be correlated, especially because rock cod plays an important role as predator and prey in the Falkland Islands marine ecosystem. Moreover, in the mean time, a pre–recruitment survey was conducted in the *Loligo* box to monitor and assess the Falkland calamari stock. Data on rock cod collected during this pre–recruitment survey were and will be used to help provide a biomass estimation of the rock cod stock based in Falkland waters. Conducting two surveys concurrently every year helps with monitoring of finfish species and this should be continued in coming years.

It is recommended that when monitoring the finfish zone, the same vessel and gear are used, and the same protocols are used as during this last rock cod biomass estimate survey in the same time of year. This survey also enables a monitoring of other commercial species such as red cod, kingclip and Illex squid (which is migrating into the Falkland waters in February). Moreover, it takes place at the beginning of the year and could be considered as a pre–season survey and used for the Licensing advice due in June of each year. However, this survey could not be useful to monitor hake, one of the major finfish in the trawl fishery of the Falkland waters as it is not back in the zone at this time of the year.

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Appendix

Table 6: Total catch of all trawl stations by species

Species Code	**Species name**	**Total Catch (kg)**	**Total Sampled (kg)**	**Total Discarded (kg)**	**Proportion (%)**
ILL	*Illex argentinus*	31,682.960	1,018.710	1,650.130	23.04%
PAR	*Patagonotothen ramsayi*	31,673.930	1,367.291	12,384.650	23.03%
BAC	*Salilota australis*	20,314.030	1,818.297	1,347.101	14.77%
KIN	*Genypterus blacodes*	14,635.030	3,975.630	10.910	10.64%
WHI	*Macruronus magellanicus*	9,768.230	1,619.800	460.200	7.10%
GRF	*Coelorhynchus fasciatus*	5,634.200	231.540	5,634.200	4.10%
CHR	*Chrysaora sp.*	5,146.130	0.000	5,146.130	3.74%
SAR	*Sprattus fuegensis*	3,757.720	17.760	3,757.720	2.73%
HAK	*Merluccius hubbsi*	3,165.510	1,668.719	0.100	2.30%
BLU	*Micromesistius australis*	2,169.326	370.547	2,169.326	1.58%
LOL	*Doryteuthis gahi*	1,802.650	284.950	315.650	1.31%
RBR	*Bathyraja brachyurops*	1,134.430	1,134.430	29.930	0.82%
RGR	*Bathyraja griseocauda*	811.050	811.050	2.420	0.59%
RFL	*Zearaja chilensis*	756.990	747.370	3.100	0.55%
CGO	*Cottoperca gobio*	702.290	0.390	702.290	0.51%
MED	Medusae	658.140	0.000	658.140	0.48%
DGS	*Squalus acanthias*	344.056	22.046	338.916	0.25%
PAT	*Merluccius australis*	323.050	323.050	0.000	0.23%
EEL	*Iluocoetes fimbriatus*	294.430	0.000	204.370	0.21%
MYC	*Mysidopsis acuta*	263.200	0.000	263.200	0.19%
SPN	Porifera	234.560	0.000	234.560	0.17%
SQT	Ascidiacea	203.100	0.000	203.100	0.15%
TOO	*Dissostichus eleginoides*	181.000	181.000	7.590	0.13%
ING	*Moroteuthis ingens*	174.960	12.362	171.220	0.13%
PTE	*Patagonotothen tessellata*	154.950	0.000	154.950	0.11%
RMC	*Bathyraja macloviana*	141.600	141.600	14.260	0.10%
RAL	*Bathyraja albomaculata*	122.200	122.200	7.330	0.09%
RED	*Sebastes oculatus*	114.050	103.110	39.900	0.08%
CHE	*Champsocephalus esox*	112.660	17.120	110.140	0.08%
DGH	*Schroederichthys bivius*	107.080	0.000	107.080	0.08%
STA	*Sterechinus agassizi*	104.200	0.660	103.860	0.08%
RBZ	*Bathyraja cousseauae*	91.770	91.770	0.000	0.07%
RMU	*Bathyraja multispinis*	86.496	86.496	0.000	0.06%
COT	*Cottunculus granulosus*	76.040	0.000	76.040	0.06%
PYM	*Physiculus marginatus*	72.540	0.000	72.540	0.05%
ALF	*Allothunnus fallai*	57.060	57.060	48.750	0.04%
RTR	*Dipturus trachydermus*	50.640	50.640	50.640	0.04%
RSC	*Bathyraja scaphiops*	31.270	31.270	0.320	0.02%
COP	*Congiopodus peruvianus*	29.530	0.000	29.530	0.02%
FUM	*Fusitriton m. magellanicus*	26.840	0.000	26.561	0.02%
THO	Thouarellinae	25.982	0.000	25.982	0.02%
RPX	*Psammobatis spp.*	25.080	25.080	24.990	0.02%
TOR	Torpediniformes	21.620	21.620	21.620	0.02%

ANM	Anemone	20.070	0.000	20.070	0.01%
SHT	Mixed invertebrates	18.990	0.000	18.990	0.01%
RDO	*Amblyraja doellojuradoi*	15.710	15.710	15.710	0.01%
GYM	*Gymnoscopelus spp.*	14.370	0.010	14.370	0.01%
CAZ	*Calyptraster sp.*	12.651	0.000	12.651	0.01%
GOC	*Gorgonocephalas chilensis*	12.310	0.000	12.310	0.01%
UHH	Heart urchin	11.260	0.000	11.260	0.01%
CTA	*Ctenodiscus australis*	10.192	0.000	10.192	0.01%
RDA	*Dipturus argentinensis*	10.070	10.070	10.070	0.01%
RMG	*Bathyraja magellanica*	9.080	9.080	7.260	0.01%
AUC	*Austrocidaris canaliculata*	8.830	0.000	8.830	0.01%
ZYP	*Zygochlamys patagonica*	8.320	0.000	8.320	0.01%
NEM	*Neophyrnichthys marmoratus*	7.720	0.000	7.720	0.01%
BUT	*Stromateus brasiliensis*	6.830	0.500	6.830	<0.01%
ODM	*Odontocymbiola magellanica*	5.880	0.000	5.880	<0.01%
MLA	*Muusoctopus longibrachus akambei*	5.840	0.000	5.840	<0.01%
MUE	*Muusoctopus eureka*	5.610	0.000	5.610	<0.01%
MMA	*Mancopsetta maculata*	5.480	5.480	5.480	<0.01%
POA	*Porania antarctica*	5.240	0.000	5.240	<0.01%
EGG	Eggmass	5.110	0.000	5.110	<0.01%
ACS	*Acanthoserolis schythei*	4.690	0.000	4.690	<0.01%
COL	*Cosmasterias lurida*	4.080	0.000	4.080	<0.01%
MUG	*Munida gregaria*	3.215	0.000	3.215	<0.01%
RPS	*Psammobatis scobina*	2.320	2.320	2.320	<0.01%
FLX	*Flabellum spp.*	2.300	0.000	2.300	<0.01%
SUN	*Labidaster radiosus*	2.238	0.000	2.238	<0.01%
CEX	*Ceramaster sp.*	1.850	0.000	1.850	<0.01%
MAR	*Martialia hyadesi*	1.660	0.520	1.460	<0.01%
AUL	*Austrolycus laticinctus*	1.470	0.000	1.470	<0.01%
OPL	*Ophiuroglypha lymanii*	1.390	0.000	1.390	<0.01%
OPD	*Ophiacantha densispina*	1.300	0.000	1.300	<0.01%
EUL	*Eurypodius latreillei*	1.250	0.000	1.250	<0.01%
PES	*Peltarion spinosulum*	1.120	0.000	1.120	<0.01%
MUO	*Muraenolepis orangiensis*	0.960	0.000	0.960	<0.01%
CRY	*Crossaster sp.*	0.910	0.000	0.910	<0.01%
SYB	*Symbolophorus boops*	0.907	0.907	0.907	<0.01%
BAL	*Bathydomus longisetosus*	0.900	0.000	0.900	<0.01%
ALC	Alcyoniina	0.870	0.060	0.810	<0.01%
BAO	*Bathybiaster loripes*	0.870	0.000	0.870	<0.01%
MUU	*Munida subrugosa*	0.860	0.000	0.860	<0.01%
MAV	*Magellania venosa*	0.800	0.000	0.800	<0.01%
CYX	*Cycethra sp.*	0.790	0.000	0.790	<0.01%
LOS	*Lophaster stellans*	0.760	0.000	0.760	<0.01%
GRN	*Graneledone yamana*	0.754	0.754	0.754	<0.01%
MYX	*Myxine spp.*	0.710	0.000	0.710	<0.01%

ASA	*Astrotoma agassizii*	0.680	0.000	0.680	<0.01%
AST	Asteroidea	0.620	0.000	0.620	<0.01%
NUD	Nudibranchia	0.590	0.010	0.590	<0.01%
COG	*Patagonotothen guntheri*	0.526	0.506	0.526	<0.01%
BRY	Bryozoa	0.480	0.000	0.480	<0.01%
SRP	*Semirossia patagonica*	0.460	0.000	0.460	<0.01%
OCT	*Octopus spp.*	0.460	0.000	0.460	<0.01%
PYX	*Pycnogonida*	0.417	0.000	0.417	<0.01%
PSA	*Pseudoxenomystax albescens*	0.350	0.000	0.350	<0.01%
ICA	*Icichthys australis*	0.308	0.258	0.308	<0.01%
MIR	*Mirostenella sp.*	0.300	0.000	0.300	<0.01%
GYO	*Gymnoscopelus opisthopterus*	0.274	0.274	0.274	<0.01%
THB	*Thymops birsteini*	0.210	0.000	0.210	<0.01%
GAT	*Gaimardia trapesina*	0.190	0.000	0.190	<0.01%
PLU	Primnoellinae	0.130	0.000	0.130	<0.01%
CAV	*Campylonotus vagans*	0.110	0.000	0.110	<0.01%
BIV	Bivalve	0.100	0.000	0.100	<0.01%
PAG	*Paralomis granulosa*	0.100	0.000	0.100	<0.01%
GYP	*Gymnoscopelus piabilis*	0.093	0.093	0.093	<0.01%
CAH	Hydrozoa	0.080	0.000	0.080	<0.01%
HYD	Hydrozoa	0.080	0.000	0.080	<0.01%
ISO	Isopoda	0.080	0.000	0.080	<0.01%
THN	*Thysanopsetta naresi*	0.070	0.070	0.070	<0.01%
EUO	*Eurypodius longirostris*	0.050	0.000	0.050	<0.01%
NED	*Neolithodes diomedeae*	0.050	0.000	0.050	<0.01%
POL	Polychaeta	0.050	0.000	0.050	<0.01%
SOR	*Solaster regularis*	0.050	0.000	0.050	<0.01%
CRI	Crinoidea	0.040	0.000	0.040	<0.01%
HOL	Holothuroidea	0.020	0.000	0.020	<0.01%
NUH	*Nuttallochiton hyadesi*	0.020	0.000	0.020	<0.01%
OPS	*Ophiactis asperula*	0.020	0.000	0.020	<0.01%
PAM	*Pagurus comptus*	0.020	0.000	0.020	<0.01%
SIX	Siphonophera	0.020	0.000	0.020	<0.01%
ISI	Isidiidae	0.015	0.000	0.015	<0.01%
AGO	*Agonopsis chilensis*	0.010	0.000	0.010	<0.01%
AMP	Amphipoda	0.010	0.000	0.010	<0.01%
OPR	*Ophiura rouchi*	0.010	0.000	0.010	<0.01%
Totals		**137,528.210**	**16,400.190**	**36,852.996**	