Cruise Report ZDLT1-07-2017

Ground Fish survey

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1.0 Introduction

Situated in the southwest Atlantic, the Patagonian shelf large marine ecosystem is one of the most productive zones of the world (Bakun, 1993). In 1986, the Falkland Interim Conservation Zone (FICZ) was declared by the Falkland Islands Government (FIG) and was further extended by the Falkland Outer Conservation Zone (FOCZ) in 1990. The directorate of natural resources – Fisheries (DNRF) delivers, after inspection, licences to ships that would like to fish in the FICZ/FOCZ. The finfish fishery is currently regulated using a total allowable effort (TAE) which is derived from the 5–year average effort required to reach the catch limit of the main finfish species (FIFD, 2016). The main species was southern blue whiting but after its decrease in abundance, rock cod (*Patagonotothen ramsayi*) took over and became in 2010 the most abundant finfish species exploited by trawlers in Falkland waters (Laptikhovsky et al., 2013; FIFD, 2010). In recent years, catches and CPUE of common hake (*Merluccius hubbsi*) increased and this species has become the primary target species for finfish trawlers who applied to fish under A licence.

Two species of hake are encountered in Falkland waters: common hake (*Merluccius hubbsi*) and Patagonian hake (*Merluccius australis*) with the former the more abundant of the two species (Tingley et al., 1995, Arkhipkin et al., 2015). Their distribution areas are primarily to the north and in shallow waters (<200 m) for common hake and to the south in deeper waters (>200 m) for Patagonian hake but distribution areas of the two species overlap. Both species of hake are straddling stocks. After the spawning season, which occurs in Argentine waters from November to April, part of the common hake stock migrates to Falkland waters to forage (Macchi et al., 2004). It is a batch spawner and females spawn once a week to every other week. Common hake is sexually dimorphic with males smaller than females (Macchi et al., 2004).

Since 2010, 6 research cruises were conducted to estimate the biomass of the rock cod stock: in February 2010 (Brickle and Laptikhovsky, 2010), 2011 (Arkhipkin et al., 2011), October–November 2014 (Pompert et al., 2014), February 2015 (Gras et al., 2015), 2016 (Gras et al., 2016) and 2017 (Gras et al., 2017). These surveys covered most of the finfish box, especially the shallow waters. Even though this is the area where common hake is generally abundant, all previous surveys were conducted at periods when most of the common hake is probably in Argentine waters for the spawning season. None of these previous surveys could be used to reliably estimate the hake biomass.

Three types of licences are issued for bottom trawlers targeting finfish, A, G and W. One of the primary target species in the finfish fishery was first southern blue whiting which was then replaced by rock cod. In recent years there has been a growing interest in common hake as its abundance increased. Apart from these species, captains sometimes target or take as a bycatch other finfish species such as common and Patagonian hakes, kingclip, hoki, red cod, southern blue whiting and squids Argentine shortfin squid and Falkland calamari. In recent years, the TAE estimation based on the primary species rock cod has shown its limitations, especially in years when rock cod was not the primary targeted stock (2013, 2015 and 2016; FIFD, 2014; 2015; 2016; 2017). Given the limitations of the TAE estimations as a basis for ITQ calculations DNR scientists suggested that a greater focus should be placed on a more ecosystem based approach to management, and including the biomass of a number of species.

The primary objective of this survey was to assess the biomass and abundance of common hake and other demersal commercial species encountered in the survey zone. Biological data (length, sex, maturity and otoliths) were collected for a sample of each species at each station and used to describe the status of the stocks in July. Finally, this report presents maps of the oceanography based on CTD data collected in the vicinity of each trawl station.

2.0 Material and methods

2.1 Cruise vessel and surveyed area

The ground fish survey ZDLT1–07–2017 was conducted on board the FV Castelo (LOA 67.8 m, GT 1321) from 10 to 27 July 2017. Embarking and disembarking occurred on 9 and 28 July 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), 2014 (Pompert et al., 2014), 2015 (Gras et al., 2015), 2016 (Gras et al., 2016) and 2017 (Gras et al., 2017) it was decided to repeat stations already explored in 2011, 2014, 2015, 2016 and 2017. However, as the number of days of fishing was limited to 18, stations in the northern part of the *Loligo* box were removed. This area would be covered by the *Loligo* pre–recruitment survey conducted from 13 to 28 July (Winter et al., 2017).

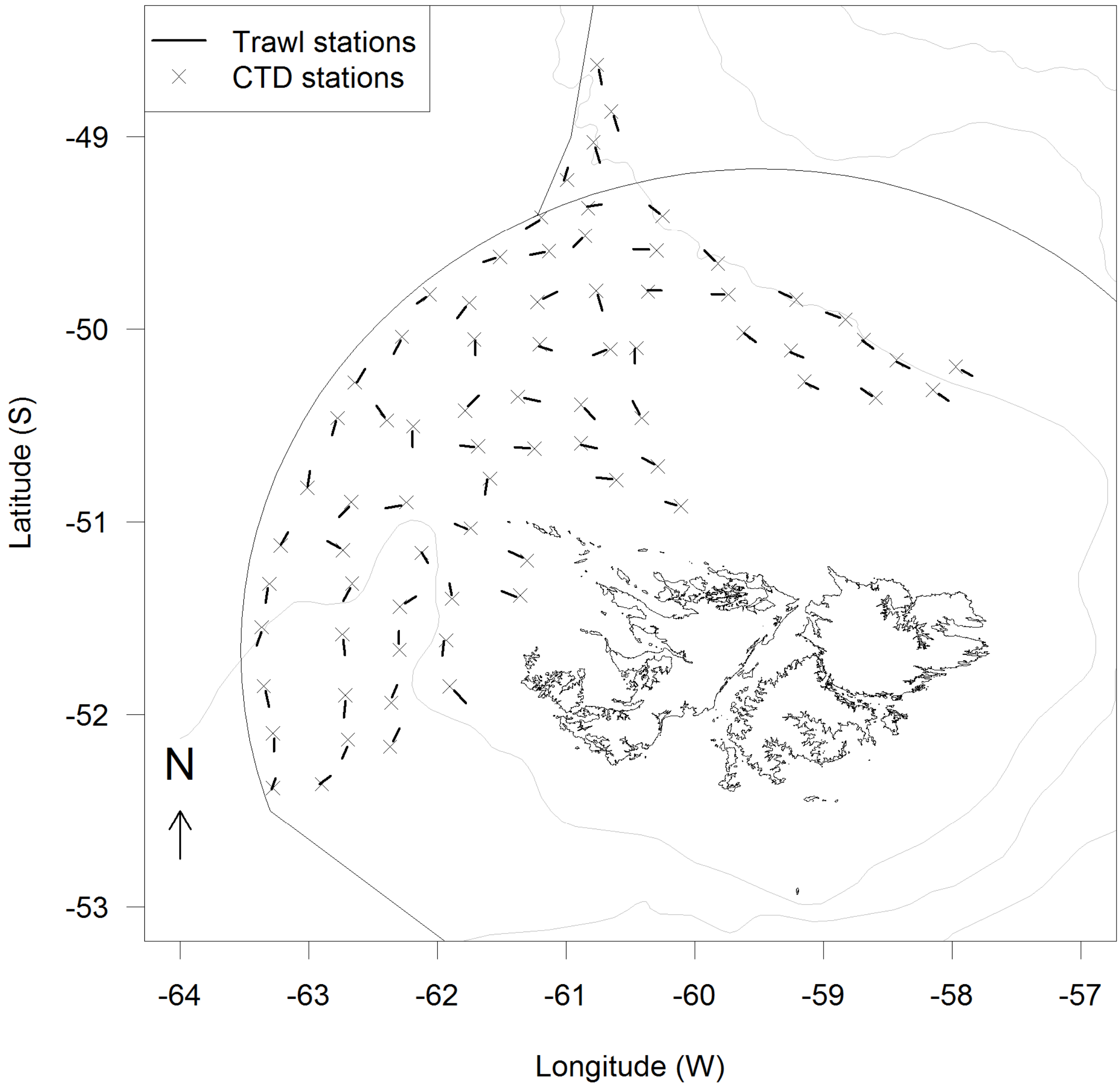


Figure 1: Location of trawl and CTDO stations

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	Latitude (S)	Longitude (N)	Modal	Duration	Activity	Comments
2508	10/07/2017	50.21	57.93	275	60	B	
2509	10/07/2017	50.37	58.03	140	60	B	
2510	10/07/2017	50.21	58.33	177	60	B	
2511	10/07/2017	50.1	58.61	164	60	B	
2516	11/07/2017	50.35	58.62	145	60	B	
2517	11/07/2017	50.31	59.04	151	60	B	
2518	11/07/2017	50.15	59.16	157	60	B	
2519	11/07/2017	50.07	59.52	162	60	B	
2524	12/07/2017	49.94	58.87	209	60	B	
2526	12/07/2017	49.84	59.25	228	60	B	
2528	12/07/2017	49.82	59.77	169	60	B	
2529	12/07/2017	49.8	60.26	167	60	B	
2532	13/07/2017	49.65	59.85	192	60	B	
2534	13/07/2017	49.59	60.35	174	60	B	
2536	13/07/2017	49.4	60.27	209	60	B	
2537	13/07/2017	49.35	60.72	177	60	B	
2540	14/07/2017	48.65	60.75	245	60	B	
2542	14/07/2017	48.89	60.63	242	60	B	
2544	14/07/2017	49.06	60.78	196	60	B	
2545	14/07/2017	49.16	60.99	174	60	B	
2548	15/07/2017	49.53	60.87	167	60	B	
2550	15/07/2017	49.6	61.16	164	60	B	
2552	15/07/2017	49.63	61.55	159	60	B	
2553	15/07/2017	49.48	61.32	164	60	B	
2556	16/07/2017	49.84	61.18	163	60	B	
2558	16/07/2017	49.82	60.76	165	60	B	
2560	16/07/2017	50.11	60.69	160	60	B	
2561	16/07/2017	50.11	61.11	161	60	B	
2564	17/07/2017	50.36	61.33	160	60	B	
2566	17/07/2017	50.41	60.86	152	60	B	
2568	17/07/2017	50.44	60.43	154	60	B	
2569	17/07/2017	50.18	60.47	161	60	B	
2572	18/07/2017	50.91	60.14	134	60	B	
2574	18/07/2017	50.7	60.31	144	60	B	
2576	18/07/2017	50.78	60.64	135	60	B	
2577	18/07/2017	50.62	60.76	150	60	B	
2580	19/07/2017	50.62	61.28	152	60	B	
2582	19/07/2017	50.61	61.72	178	60	B	
2584	19/07/2017	50.4	61.76	163	60	B	
2585	19/07/2017	50.14	61.71	160	60	B	
2588	20/07/2017	49.88	61.78	158	60	B	
2590	20/07/2017	49.83	62.09	147	60	B	
2592	20/07/2017	50.06	62.29	147	60	B	
2593	20/07/2017	50.21	62.56	148	60	B	
2596	21/07/2017	50.53	62.19	165	60	B	

2598	21/07/2017	50.46	62.41	156	60	B
2600	21/07/2017	50.48	62.79	149	60	B
2601	21/07/2017	50.74	62.99	153	60	B
2604	22/07/2017	50.91	62.28	187	60	B
2606	22/07/2017	50.92	62.69	168	60	B
2608	22/07/2017	51.14	62.76	171	60	B
2609	22/07/2017	51.06	63.16	155	60	B
2612	23/07/2017	51.34	63.32	164	60	B
2614	23/07/2017	51.57	63.37	182	60	B
2616	23/07/2017	51.88	63.34	205	60	B
2618	23/07/2017	52.12	63.27	228	60	B
2619	23/07/2017	52.33	63.26	253	60	B
2622	24/07/2017	51.34	62.68	189	60	B
2624	24/07/2017	51.61	62.73	207	60	B
2626	24/07/2017	51.93	62.71	235	60	B
2628	24/07/2017	52.17	62.7	256	60	B
2629	24/07/2017	52.32	62.83	265	60	B
2632	25/07/2017	52.14	62.35	275	60	B
2634	25/07/2017	51.91	62.36	263	60	B
2636	25/07/2017	51.87	61.87	187	60	B
2637	25/07/2017	51.7	61.97	178	60	B
2640	26/07/2017	51.63	62.3	251	60	B
2642	26/07/2017	51.43	62.26	231	60	B
2644	26/07/2017	51.38	61.89	199	60	B
2645	26/07/2017	51.22	62.07	200	60	B
2648	27/07/2017	51.39	61.39	141	60	B
2650	27/07/2017	51.19	61.34	139	60	B
2652	27/07/2017	51.04	61.77	179	60	B
2653	27/07/2017	50.86	61.63	149	60	B

2.2 Trawl gear

The DNR–F owns a Boris Net bottom trawl fitted with rockhopper gear and used the Castelo's Morgère V3 bottom doors (1800 kg, 3180 x 2480 cm). The cod–end had a 90 mm mesh size. The cod–end was also fitted with a 10–15 mm cod end liner. The MarPort Net Monitoring System was used to monitor the geometry of the net. Originally sensors were fitted 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. Until the 2015 research cruise, the only information about the horizontal net opening was the wing spread derived as follows:

$$Wing\ spread = \frac{Door\ Spread\ \times Net\ Length}{Bridle\ Length + Net\ Length}$$

In 2016, two additional sensors were bought by the DNR–F and attached 2 m behind the trawl wings to monitor the horizontal net opening at the same time as the door spread. Significant differences between calculated and measured values of the horizontal net opening were noted during the 2016 research cruise. A method was therefore developed to correct historical net geometry data (Gras, 2016).

During the 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 as in 2011 (ZDLT1–02–2011) but not as 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 previously. The trawl setup was asked to be rigorously the same as in 2014 and 2015 and especially the bridle length, which was 115 m. During the ZDLT1–02–2010 and ZDLT1–02–2011 surveys, the bridle length was 100 and 120 m respectively.

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, when the catch was too large to be weighed, the crew processed the catch. At station 2553, the hake catch was estimated using a conversion factor which turned out to be 1.82 instead of 1.9 officially used in the fisheries department. 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:

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

At each station, random samples were taken from all finfish species as well as squids *Illex argentinus* and *Doryteuthis gahi*. When possible, 100 specimens of each commercial species were randomly taken for all sampled species. Maturity stages were determined for all sampled specimens using an 8 stage maturity scale for finfish (see observer manual), a 6 stage maturity scale for both species of squid (see observer manual) and a 6 stage maturity scale for Chondrichthyans (see observer manual). Length frequencies were recorded using fish measuring board and paper form. All fish and skates were measured to the nearest cm below, whereas all squids were measured to the nearest 0.5 cm below. When plotting size frequencies, all species except skates were plotted using their recorded sizes. For skates however, data was aggregated into 5 cm size bins with the plots showing the nearest 5 cm bin below (*i.e.* 10=10-14 cm, 15=15-19 cm etc.).

Otolith extraction was undertaken for 21 finfish species (species were selected following DNRF protocols; taken at sea) and statoliths were extracted ashore from *D. gahi* and *I. argentinus* (associated information was length, weight, sex and maturity). Vertebrae/thorn samples were taken from 1 species of skate.

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 was *Psammobatis normani* (adult males with slender claspers) whereas in shallower waters the most common species is *Psammobatis rudis* (adult males with short and stout claspers). During the survey there were no shallow stations and all specimens were most likely *Psammobatis normani*.

2.4 Biomass estimation

Biomass estimations using trawl surveys generate auto–correlated data (Rivoirard et al., 2000). To avoid processing auto–correlated data and overestimating the biomass of fish in the survey area, geostatistical methods were used to firstly describe and model data auto–correlation 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).

The distance covered by the trawl was estimated using the geographical coordinates of the stations. For each station, coordinates (recorded by bridge officers) 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:

$$d = \text{acos}(\sin(latS) \times \sin(latF) + \cos(latS) \times \cos(latF) \times \cos(lonF - lonF) \times R$$

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 (6,371 km). Density of the studied species (*D* in $\text{kg}\cdot\text{km}^{-2}$) was finally derived using the catch (*C*), the distance covered (*d*) and the horizontal net opening (*HNO*; see Gras (2016) 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.

2.5 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. Data were therefore projected 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 DNRF, the Easting Northing system was used. A comparison between the UTM 21 projection and Easting Northing system showed no significant differences.

2.6 Geostatistic methods

Geostatistic methods must be performed in 4 steps, (i) plotting and (ii) modelling the semi–variogram (describing the auto–correlation of the data), (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 semi–variance values should increase with distance and reach the sill (values for which semi–variance levels out). The only accepted exception is the pure nugget effect (when data are not auto–correlated).
- The range (distance at which the correlation vanishes) must be shorter than the maximum distance observed on the semi–variogram. In the studied dataset, some models could fit log transformed data (lambda=0) well, however they exhibited a range further than 400 km which is not biologically consistent in our case.
- Exponential, Gaussian and spherical models were fitted to the semi–variogram 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.

The kriging area was 106,609 km^2 for the February 2017 ground fish survey. As stated before, for the July survey the kriging area was reduced. The northern grid squares of the *Loligo* box were removed and the kriging area was hence only 96,802 km^2. In order to be able to compare biomasses with the other ground fish surveys, for the purpose of this report all the biomasses were re–estimated. Biomass estimations for common rock cod, red cod, common hake, toothfish, kingclip, southern blue whiting, Argentine shortfin squid and Falkland calamari were estimated using derived horizontal net opening for data collected in 2010, 2011, 2014 and 2015 (Gras, 2016) and using measured horizontal net opening for 2016 onward datasets and time series displayed for every species. Confidence intervals of the biomass for each species were derived using 10,000 conditional simulations (Gimona and Fernandes, 2003; Woillez et al., 2009). That method was implemented in the geoR package (Ribeiro and Diggle, 2001).

2.7 Abundance estimation

At each survey station, a random sample of 100 specimens was assessed for total length (pre–anal length for hoki and grenadier; dorsal mantle length for squid; total length disk width and body weight for skates), sex and maturity. The total number of fish–at–station N_s was estimated using the number of fish in the sample (n_s), the station catch weight (C_s) and the sample weight (W_s) as

$$N_s = \frac{n_s \times C_s}{W_s}$$

The total abundance in the water N_t was estimated using the total biomass B (estimated following protocol of section 2.6)

$$N_t = \frac{B \times \sum N_s}{\sum C_s}$$

The total number of fish–at–length l for each station ($N_{l,s}$) was then estimated using the total number of fish–at–station (N_s) and the number of fish per size class in the sample

$$N_{l,s} = \frac{n_{l,s} \times C_s}{W_s}$$

Finally the total abundance of fish–at–length in the water was estimated using the biomass estimation (B; see section 2.6)

$$N_{l,t} = \frac{B \times \sum N_{l,s}}{\sum C_{l,s}}$$

The numbers–at–length were then presented in histograms to show how the structures of the stocks have changed over the years and over the seasons.

2.8 Oceanography

A single CTD (SBE-25, Sea-Bird Electronics Inc., Bellevue, USA) instrument, Serial No 0247, was used to collect oceanographic data in the vicinity of all bar 2 trawl stations, an interim station was run between these stations a few days later. At all CTD stations the CTD was deployed to a depth of c.10m below surface for a soak time of more than one minute, this allowed 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 toward sea bed at 1m/sec. The CTD collected pressure in dbar, temperature in °C, conductivity in mS/cm, Oxygen Voltage and Fluorescence. The fluorometer was damaged after station 2,461, and the partial dataset is not discussed here. The raw hex file was converted and processed using SBE Data Processing Version.7.22.5 using the CON file 0247OldCTD_2016_May.xmlcon. Up-cast 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, 2013).

3.0 Results

3.1 Catch composition

Bottom trawling was conducted at 74 stations (Figure 1 and Table 1). Seabed trawling times during the survey was 60 minutes for all trawls. During the survey a total of 44,895.78 kg of biomass was caught comprising 114 species or taxa (Appendix Table 3). The largest catches by weight, all exceeding 1,000kg in total, were in order of importance: 1) common hake (*Merluccius hubbsi*), 2) hoki *(Macruronus magellanicus*), 3) Falkland calamari *(Doryteuthis gahi*), 4) kingclip *(Genypterus blacodes*), 5) common rock cod (*Patagonotothen ramsayi*), 6) Squat Lobster (*Munida gregaria*), 7) red cod *(Salilota australis*), 8) Dogfish (*Squalus acanthias*) and 9) Catshark (*Schroederichthys bivius*), together amounting to 93% of the total catch. Table 4 in the appendix lists numbers of specimens analysed by species and sample type (R, S or N). 170 specimens of two squid species had their statoliths extracted, 1,252 sets of otoliths were extracted from 21 fish species, and 3 specimens of skate from one species had their vertebrae and thorns removed. The finfish component of the catch amounted to 33,612.3 kg which represented 74.9% of the entire catch. The cephalopod component amounted to 4,713.6 kg (10.5%), the elasmobranch component was 4,093.7 kg (9.1%), and the benthos + crustacea component amounted to 2,476.2 kg (5.5%).

3.2 Biological information of finfish species

3.2.1 *Merluccius hubbsi* – common hake – HAK

The total catch of common hake was 18,324 kg. It was caught at all 74 trawl stations sampled throughout the survey (Figure 2). Catches ranged from 2.21 to 2,197 kg. Among the 74 stations, 71 yielded >10 kg, 47 yielded >100 kg, and 3 yielded >1 t. Densities ranged from 12.2 to 9,346 kg·km^{-2} (CPUE ranged 2.21–2,197 kg·h^{-1}). Highest densities were observed in the northern (along the 200 m isobath) and northwestern parts of the survey zone. The number of fish sampled for length frequency was 5,599 (4,623 females, 976 males), 141 were sampled for otolith (including 132 taken randomly). Total lengths ranged from 20 to 88 cm for females and from 21 to 57 cm for males. The histogram exhibits 2 cohorts with modes at 26 cm and 42 cm, however, cohorts most likely overlap and are not visible on the length frequency histogram. Females were immature (2%), resting (69%), early developing (28%), late developing (0.1%) and recovering spent (1%). Males were immature (3%), resting (3%), early developing (4%), late developing (0.1%), spent (87%) and recovering spent (3%).

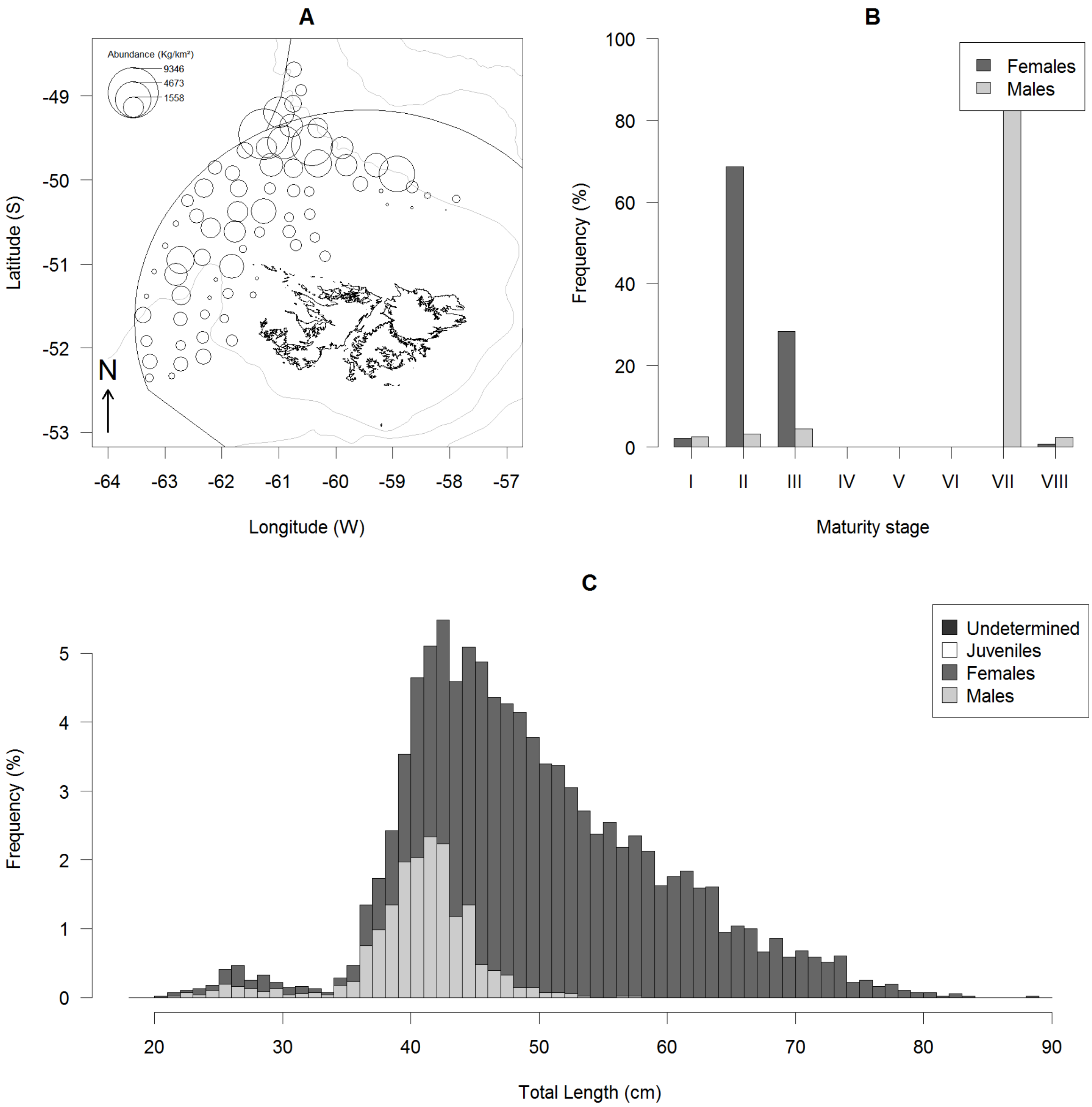


Figure 2: Biological data of *Merluccius hubbsi* (common hake; HAK), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=5,599).

3.2.2 *Macruronus magellanicus* – hoki – WHI

The total catch of hoki was 6,450 kg. It was caught at 50 of the 74 trawl stations (Figure 3). Catches ranged from 0.14 to 2,506 kg. Among the 50 stations, 16 yielded >10 kg, 7 yielded >100 kg, and 2 yielded >1 t. Densities ranged from 0.66 to 12,670 kg·km^{-2} (CPUE ranged 0.14–2,506 kg·h^{-1}). Highest densities were observed in the southwest of the survey zone, especially in deep waters where hoki is usually abundant. The number of fish sampled for length frequency was 2,246 (1174 females and 1072 males), 90 specimens were sampled for otolith (including 87 taken randomly). Pre–anal lengths ranged from 8 to 31 cm for females and from 12 to 30 cm for males. The histogram exhibits 1 cohort with mode at 8 cm, 14 cm, 24 cm and 28–31 cm. There might be other cohorts at 8, 24 and 28–31 cm but the number of fish sampled is too low to identify these as cohorts. Females were immature (98.4%), resting (1.4%), early developing (0.2%) and late developing (0.1%). Males were immature (97.9%), resting (2%) and spent (0.1%).

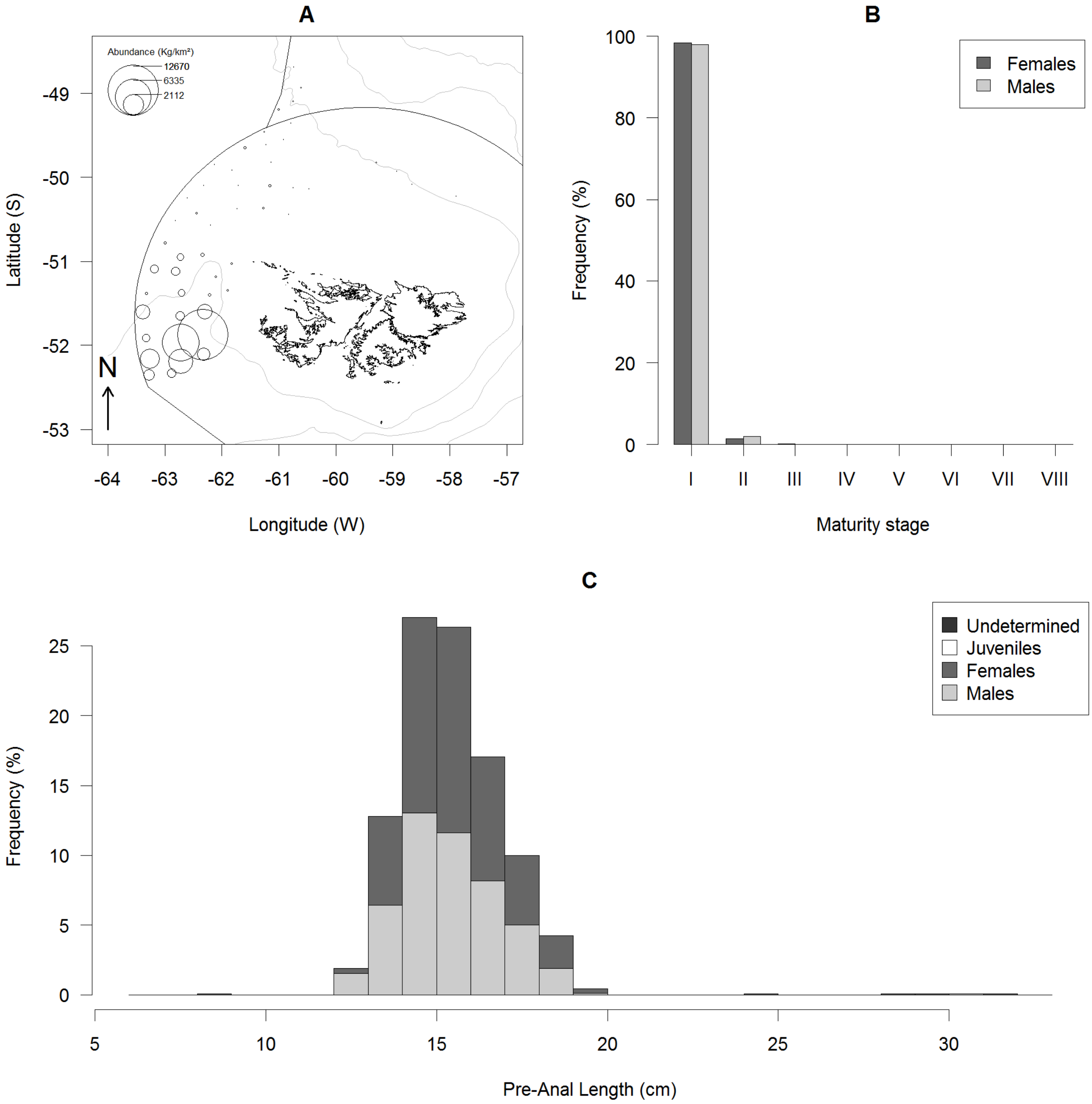


Figure 3: Biological data of *Macruronus magellanicus* (hoki; WHI), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=2,246).

3.2.3 *Genypterus blacodes* – kingclip – KIN

The total catch of kingclip was 4,088 kg. It was caught at 57 of the 74 trawl stations (Figure 4). Catches ranged from 0.33 to 1,402 kg. Among the 57 stations, 19 yielded >10 kg, 5 yielded >100 kg, 2 yielded >1 t. Densities ranged from 1.54 to 6,801 kg·km^{-2} (CPUE ranged 0.33–1,402 kg·h^{-1}). Highest densities were observed in the north of the survey zone where kingclip is also observed in February and to the northwest and to the west of West Falkland. The number of fish sampled for length frequency was 1,308 (672 females, 635 males and 1 undetermined (no gonads present)), 171 were sampled for otolith (including 154 taken randomly). Total lengths ranged from 26 to 114 cm for females and from 32 to 104 cm for males. The histogram exhibits a series of modes that cannot be used to identify cohorts. Females were immature (15%), resting (81%) and early developing (4%). Males were immature (33%), resting (57%), early developing (9%), late developing (0.3%) and spent (0.3%).

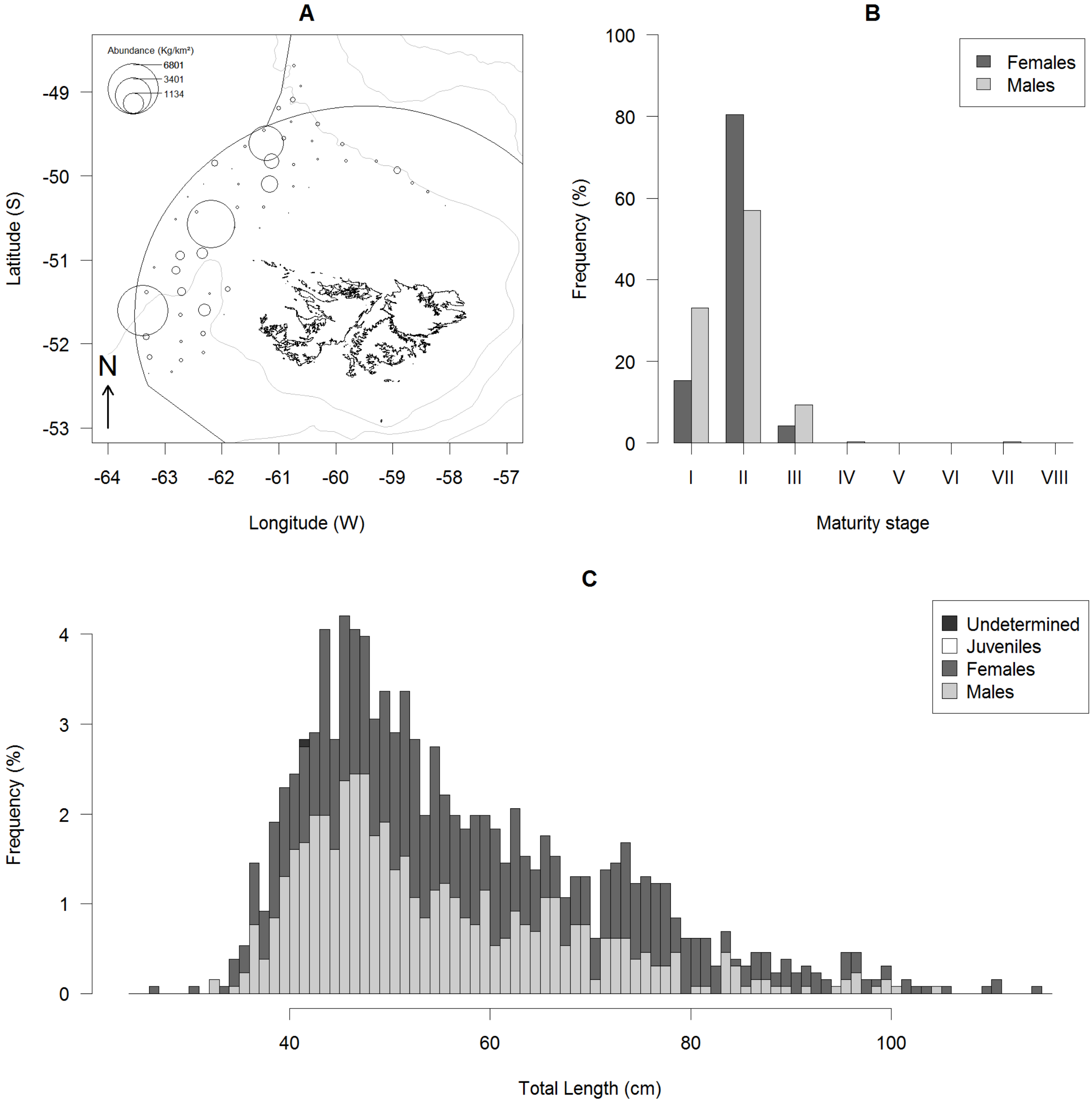


Figure 4: Biological data of *Genypterus blacodes* (kingclip; KIN), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=1,308).

3.2.4 *Patagonotothen ramsayi* – common rock cod – PAR

The total catch of rock cod was 2,003 kg. It was caught at all 74 trawl stations (Figure 5). Catches ranged from 0.66 to 178 kg. Among the 74 stations, 38 yielded >10 kg and 4 yielded >100 kg. Densities ranged from 36 to 986 kg·km^{-2} (CPUE ranged 0.66–178 kg·h^{-1}). Highest densities were observed in stations surroundings the Jason Islands. The number of fish sampled for length frequency was 6,355 (11 juveniles, 3208 females, 3109 males and 27 undetermined), 257 were sampled for otoliths (including 251 taken randomly). Total lengths ranged from 7 to 9 cm for juveniles, from 6 to 36 cm for females and from 7 to 33 cm for males. The histogram exhibits 3 cohorts with modes at 8 cm, 16 cm and 24 cm. The second cohort seems skewed and 2 cohorts might overlap. Females were immature (45%), resting (23%), early developing (11%), late developing (20%) and recovering spent (0.1%). Males were immature (50%), resting (35%), early developing (11%) and late developing (3%).

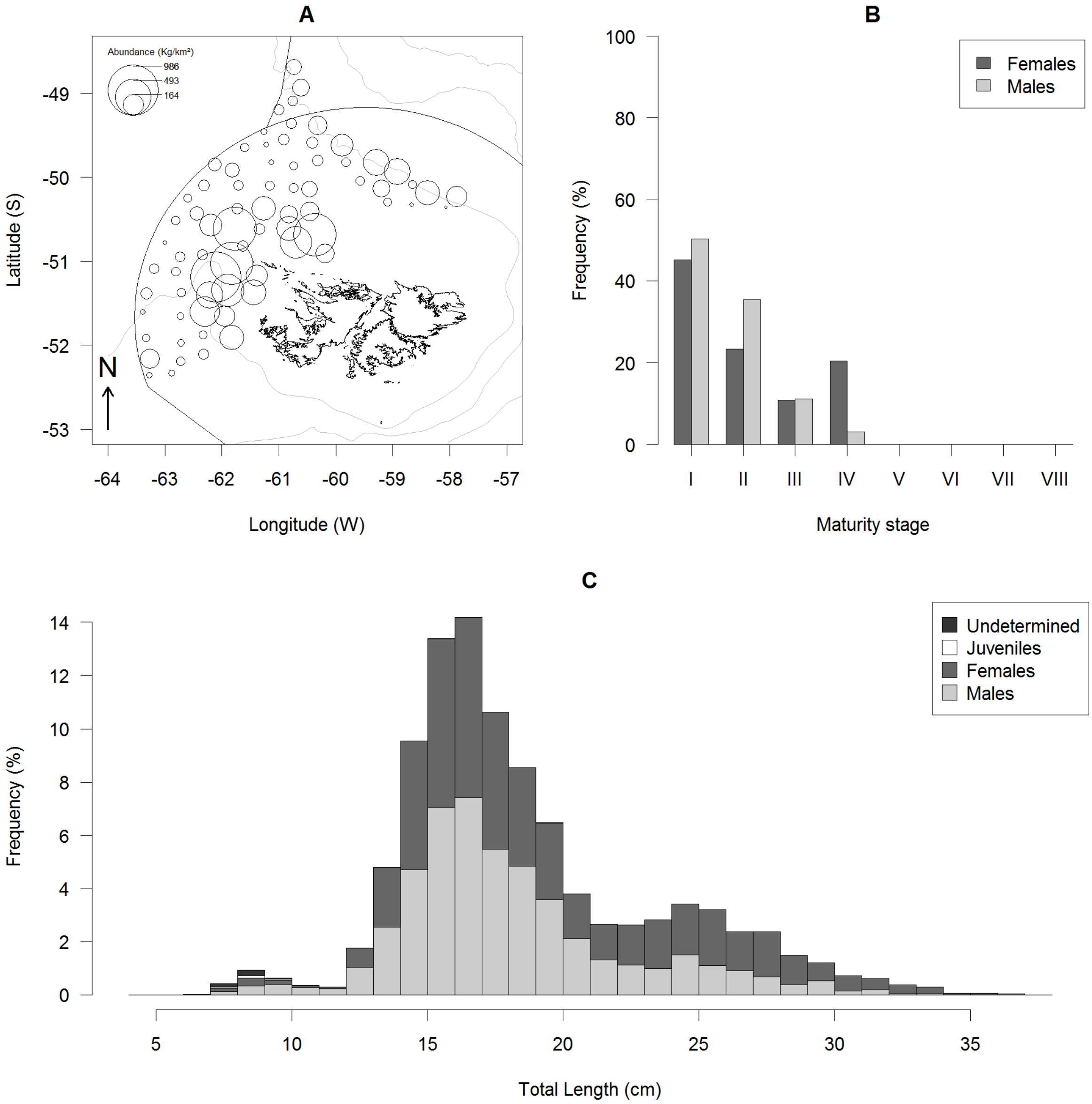


Figure 5: Biological data of *Patagonotothen ramsayi* (common rock cod; PAR), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=6,355).

3.2.5 *Salilota australis* – red cod – BAC

The total catch of red cod was 1,784 kg. It was caught at 64 of the 74 trawl stations (Figure 6). Catches ranged from 0.06 to 430 kg. Among the 64 stations, 24 yielded >10 kg and 4 yielded >100 kg. Densities ranged from 0.26 to 1,951 kg·km^{-2} (CPUE ranged 0.06–430 kg·h^{-1}). Highest densities were observed to the north of the islands at 2 stations in the southwest of the survey zone. The number of fish sampled for length frequency was 3,012 (1,593 females, 1,418 males and 1 undetermined), 126 were sampled for otoliths (including 123 taken randomly). Total lengths ranged from 9 to 75 cm for females and from 10 to 62 cm for males and the undetermined fish was 13 cm. The histogram exhibits 2 clear cohorts at 12 cm and 21 cm. Other cohorts exist (possibly one at 28 cm) but are difficult to identify. Females were immature (61%), resting (37%), early developing (1%) and late developing (1%). Males were immature (66%), resting (22%), early developing (7%), late developing (4%), spent (0.2%) and recovering spent (0.1%).

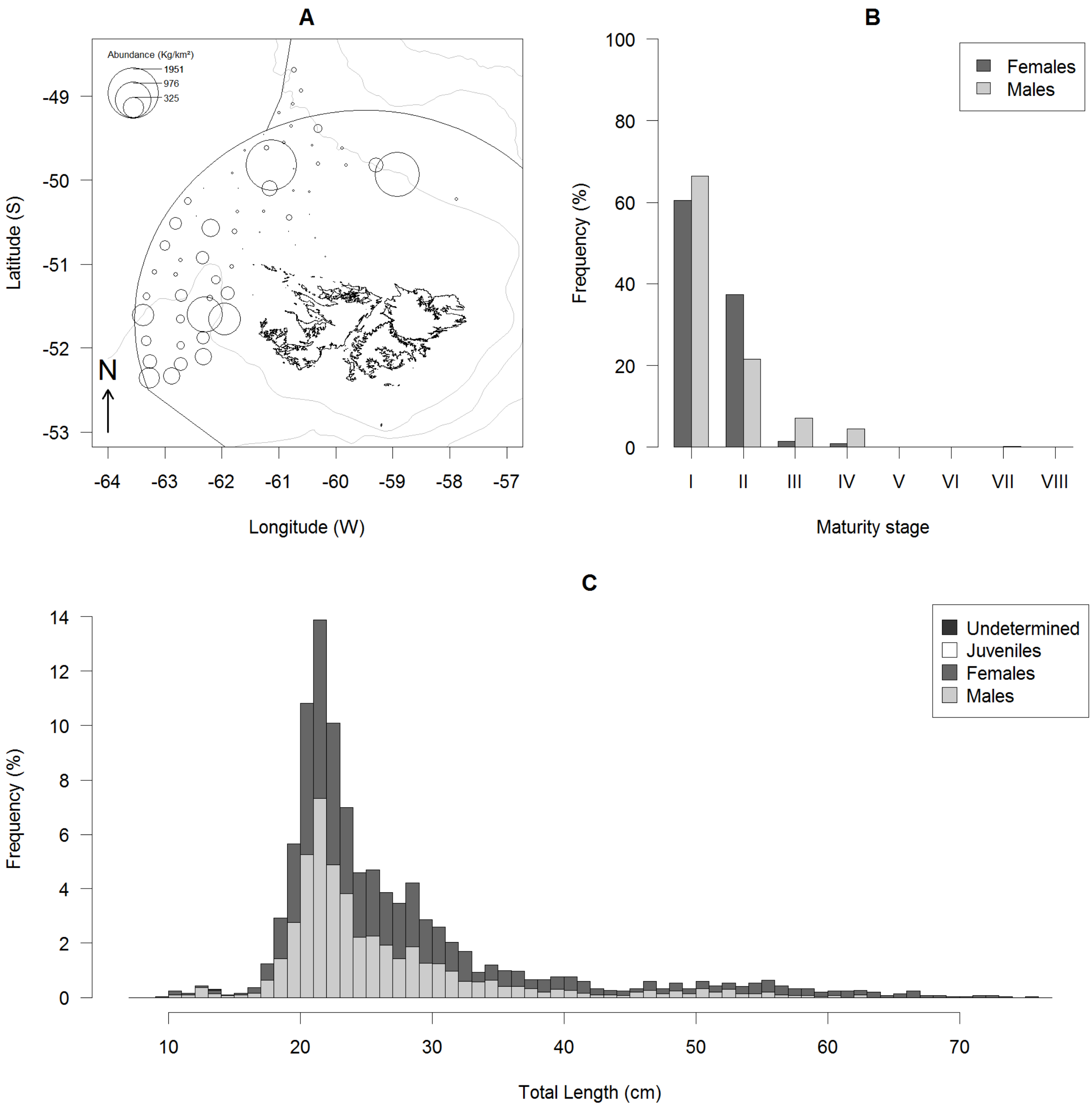


Figure 6: Biological data of *Salilota australis* (red cod; BAC), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=3,012).

3.2.6 *Stromateus brasiliensis* – butterfish – BUT

The total catch of butterfish was 278 kg. It was caught at 23 of the 74 trawl stations (Figure 7). Catches ranged from 0.02 to 165 kg. Among the 23 stations, 4 yielded >10 kg and 1 yielded >100 kg. Densities ranged from 0.09 to 784 kg·km^{-2} (CPUE ranged 0.02–165 kg·h^{-1}). Highest densities were observed to the west of West Falkland and most of the catch was taken along the border of the FICZ. The number of fish sampled for length frequency was 293 (269 females and 24 males), 12 were sampled for length–weight, 6 for otoliths and all these specimens were taken randomly. Total lengths ranged from 27 to 39 cm for females and from 12 to 36 cm for males. The histogram exhibits 1 clear cohort at 34 cm with one juvenile specimen at 12 cm. Females were resting (61%), early developing (26%) and late developing (13%). Males were immature (4%), resting (4%), early developing (54%) and late developing (37%).

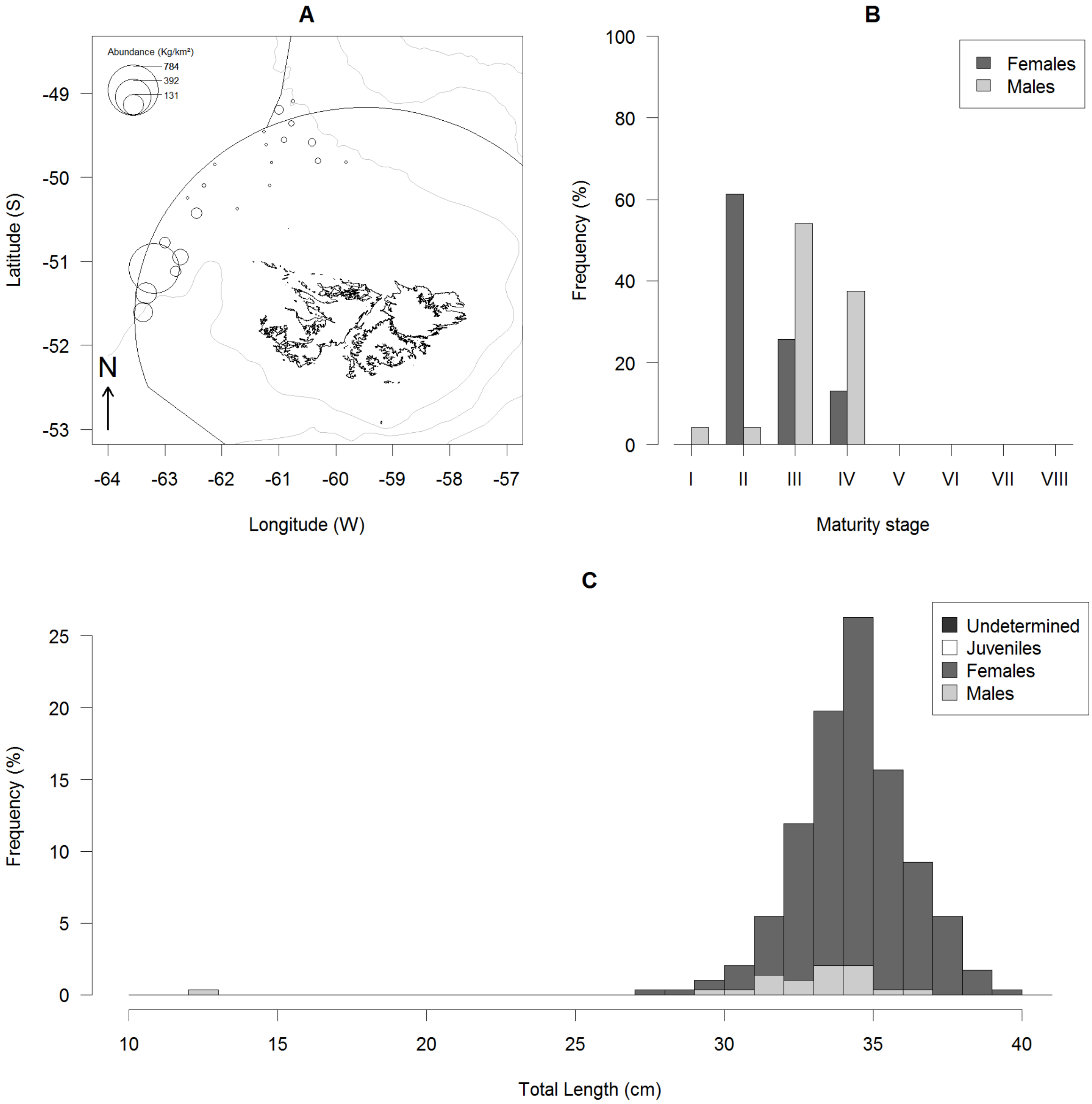


Figure 7: Biological data of *Stromateus brasiliensis* (butterfish; BUT), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=293).

3.2.7 *Cottoperca gobio* – frogmouth – CGO

The total catch of frogmouth was 157 kg. It was caught at 45 of the 74 trawl stations (Figure 8). Catches ranged from 0.02 to 41.4 kg. Among the 45 stations, 2 yielded >10 kg. Densities ranged from 0.09 to 179 kg·km^{-2} (CPUE ranged 0.02–41.4 kg·h^{-1}). Highest densities were observed in the northwest of the survey zone. The number of fish sampled for length frequency was 320 (1 juvenile, 152 females and 167 males and 1 undetermined), 14 were sampled for length–weight, 3 for otoliths, all of them were taken randomly. Total lengths ranged from 7 to 48 cm for females, from 9 to 58 cm for males and the undetermined one was 7 cm. The histogram exhibits many cohorts but due to the low number of fish sampled it is difficult to identify them. Females were immature (13%), resting (51%), early developing (17%), late developing (18%) and ripe (1%). Males were immature (54%), resting (29%), early developing (6%) and late developing (11%).

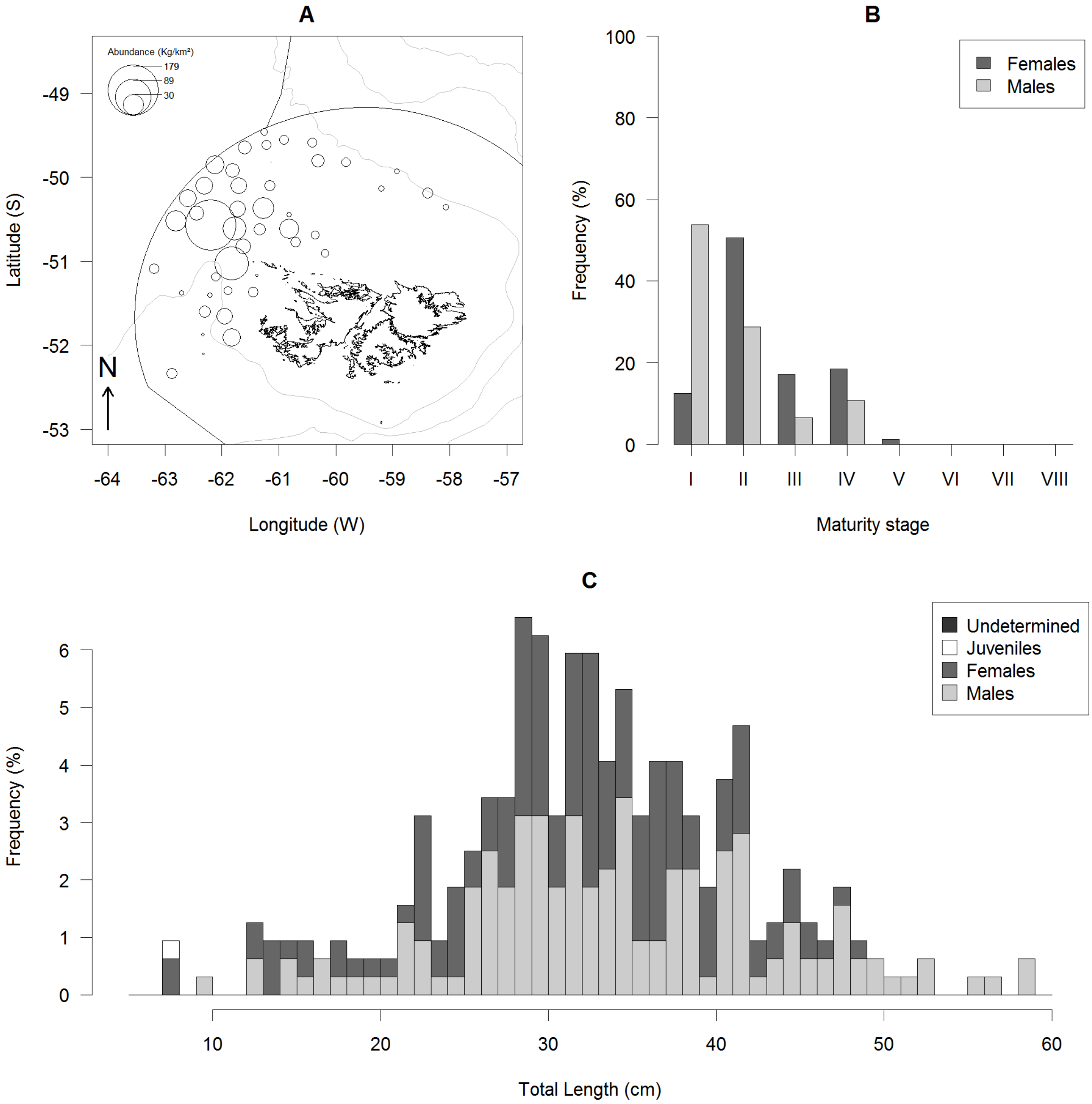


Figure 8: Biological data of *Cottoperca gobio* (frogmouth; CGO), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=320).

3.2.8 *Micromesistius australis* – southern blue whiting – BLU

The total catch of southern blue whiting was 126 kg. It was caught at 16 of the 74 trawl stations (Figure 9). Catches ranged from 0.02 to 118 kg. Among the 16 stations, 1 yielded >100 kg. Densities ranged from 0.09 to 667 kg·km^{-2} (CPUE ranged 0.02–118 kg·h^{-1}). The only relatively high density was observed to the north of Falkland Islands along the 200 m isobath at one station. The number of fish sampled for length frequency was 391 (150 juveniles, 109 females, 129 males and 3 undetermined), 58 were sampled for length–weight and 84 for otoliths, all these specimens were randomly sampled. Total lengths ranged from 14 to 19 cm for juveniles, from 15 to 21 cm for females, from 15 to 20 cm for males and from 17 to 18 cm for undetermined. The histogram exhibits 1 cohort with mode at 17 cm. All the sampled specimens were immature.

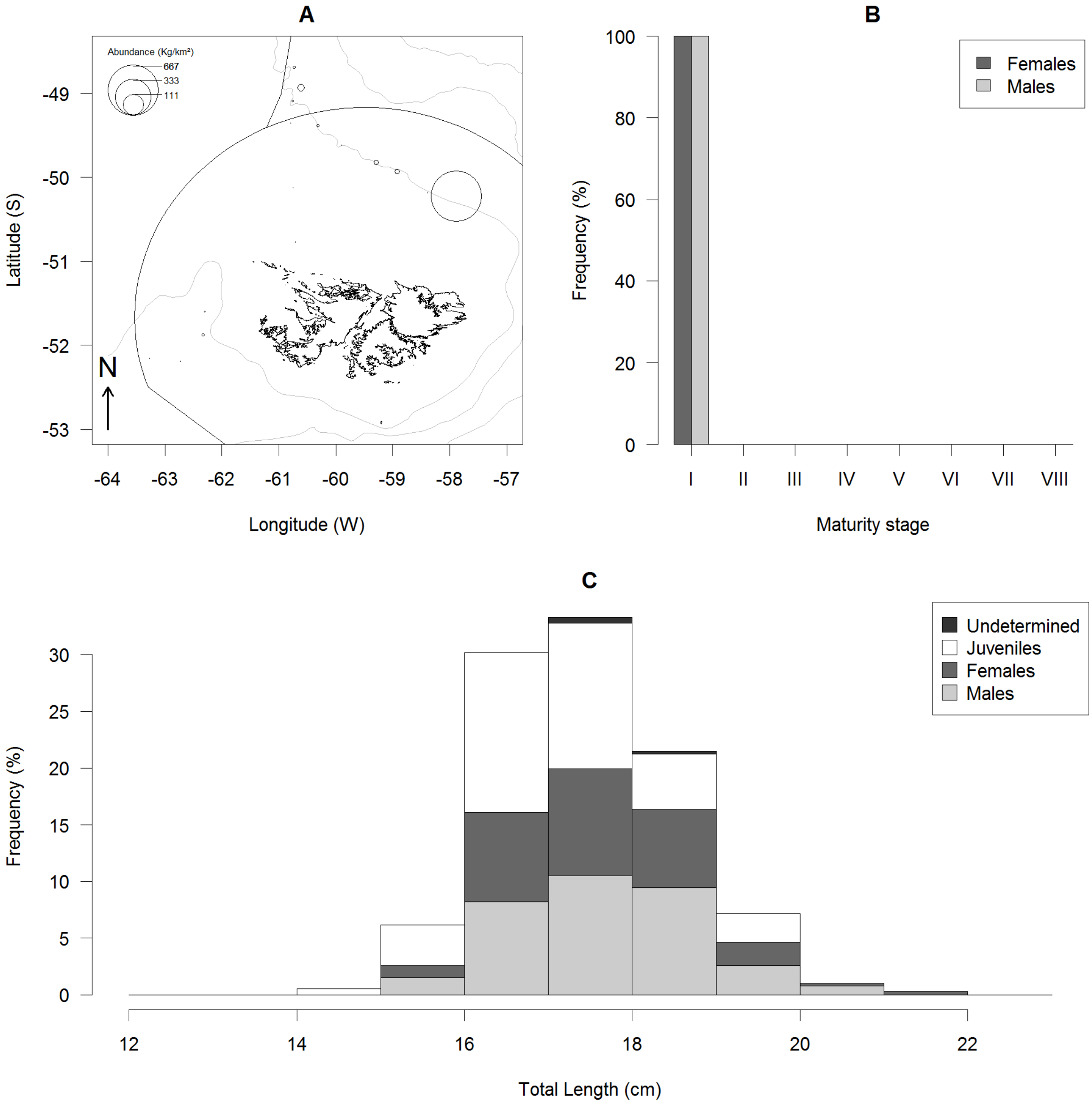


Figure 9: Biological data of *Micromesistius australis* (southern blue whiting; BLU), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=391).

3.2.9 *Dissostichus eleginoides* – Patagonian toothfish – TOO

The total catch of Patagonian toothfish was 122 kg. It was caught at 27 of the 74 trawl stations (Figure 10). Catches ranged from 0.04 to 16.3 kg. Among the 27 stations, 3 yielded >10 kg. Densities ranged from 0.24 to 70 kg·km^{-2} (CPUE ranged 0.04–16.3 kg·h^{-1}). Highest densities were observed in the southwest of the survey zone in deep waters and in the north along the 200 m isobath. The whole catch, *i.e.* 516 specimens (323 juveniles, 120 females, 73 males), was sampled for length frequency. A total of 265 pairs of otoliths were sampled. Total lengths ranged from 17 to 26 cm for juveniles, from 18 to 74 cm for females and from 19 to 75 cm for males. The histogram exhibits one cohort of juveniles (mode at 21 cm). The other cohorts are difficult to identify as the number of specimen sampled was low. Females were immature (87%), resting (13%). Males were immature (97%), resting (3%).

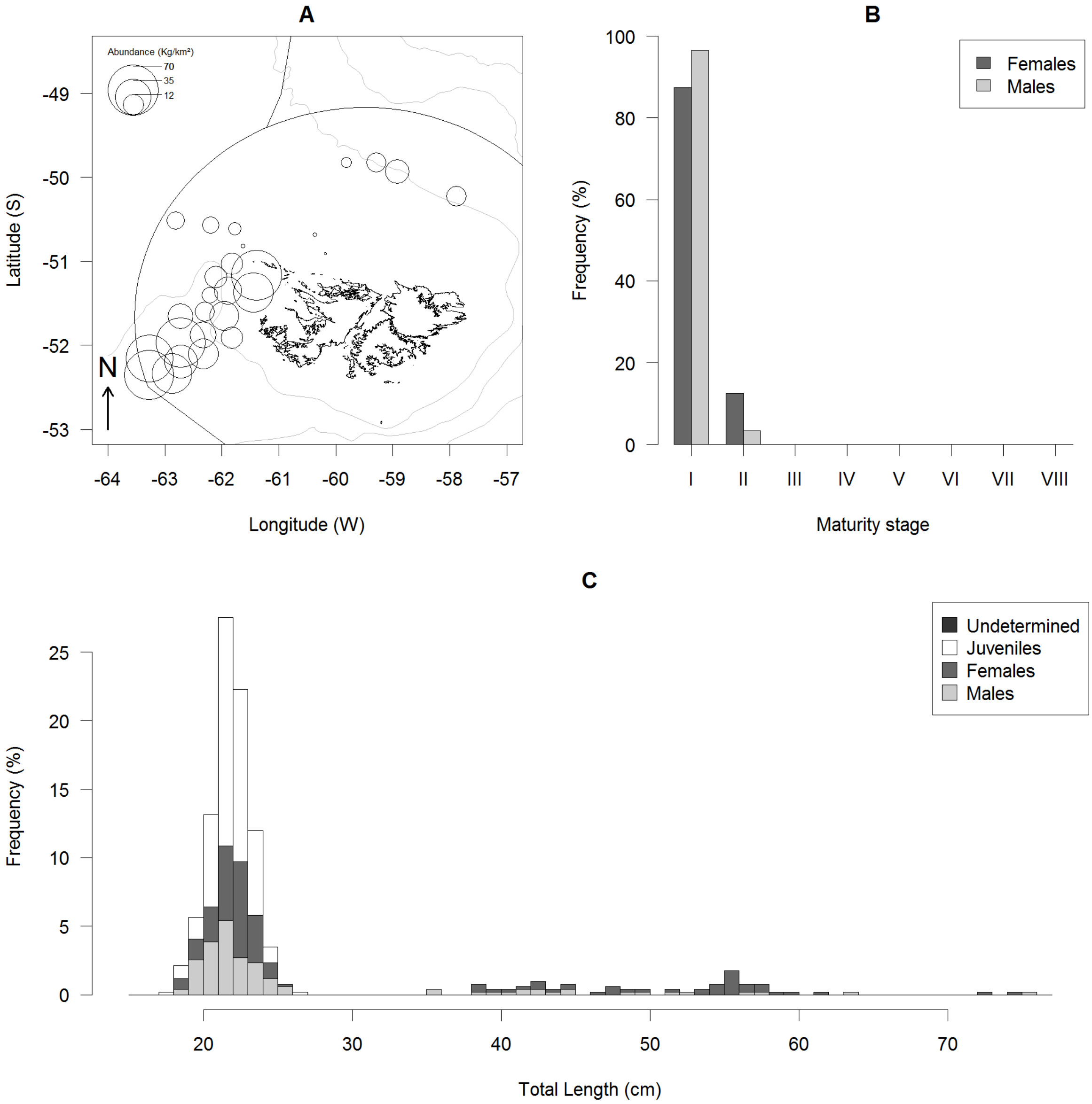


Figure 10: Biological data of *Dissostichus eleginoides* (toothfish; TOO), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=516).

3.2.10 *Merluccius australis* – Patagonian hake – PAT

The total catch of Patagonian hake was 43 kg. It was caught at 8 of the 74 trawl stations (Figure 11). Catches ranged from 0.55 to 12.9 kg. Among the 8 stations, 1 yielded >10 kg. Densities ranged from 2.4 to 61.6 $kg \cdot km^{-2}$ (CPUE ranged 0.55–12.9 $kg \cdot h^{-1}$). Highest densities were observed in the southwest of the survey zone, in waters deeper than 200 m. The number of fish sampled for length frequency was 18 (16 females and 2 males) and all of them were sampled for otolith. Total lengths ranged from 49 to 94 cm for females and from 46 to 77 cm for males. The number of specimens was too low to identify cohorts on the length frequency histogram. Females were resting (75%), early developing (19%) and recovering spent (6%). One male was resting and the other one was running.

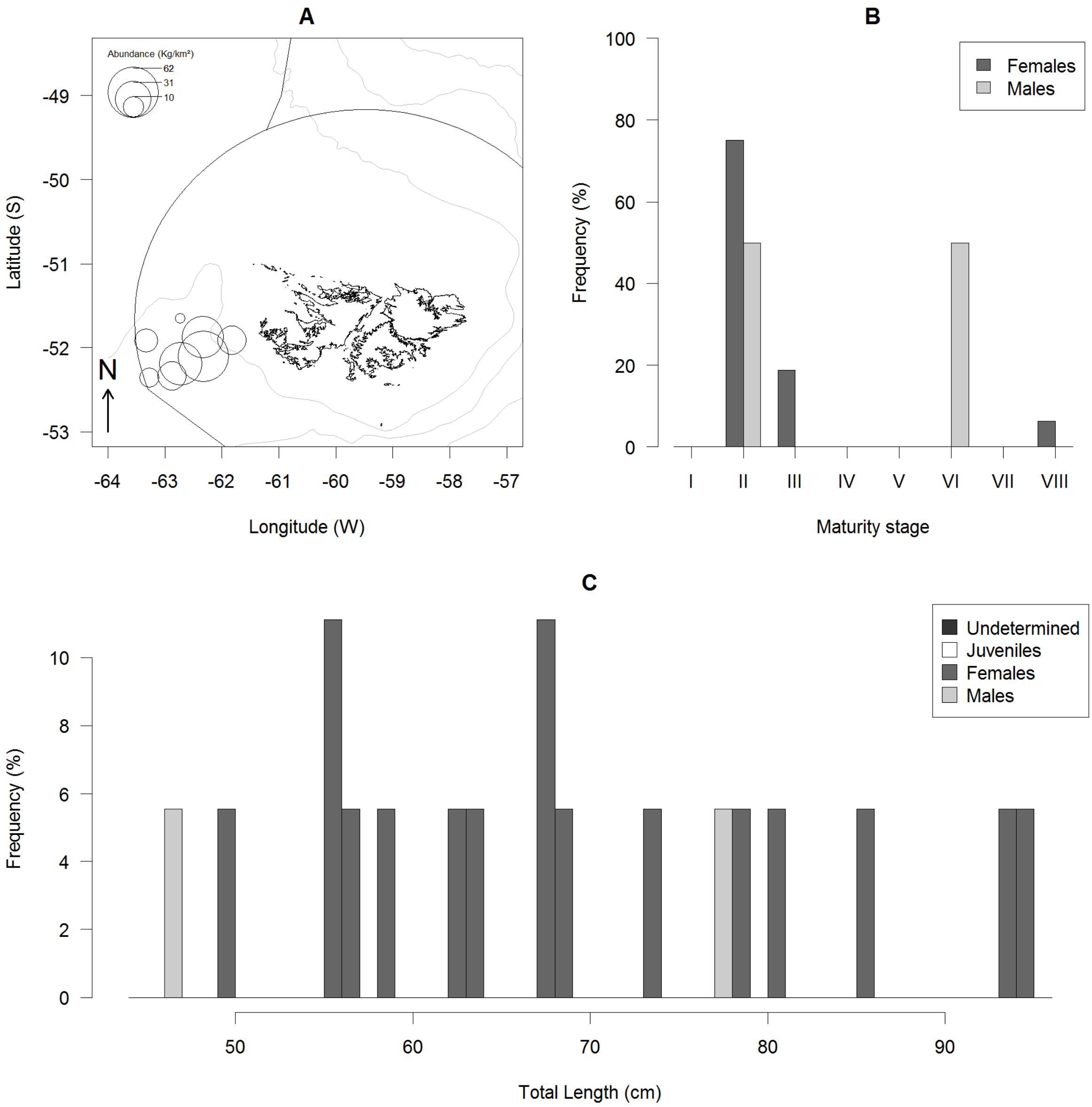


Figure 11: Biological data of *Merluccius australis* (Patagonian hake; PAT), map of the densities in $kg \cdot km^{-2}$ (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=18).

3.2.11 *Congiopodus peruvianus* – Pigfish – COP

The total catch of pigfish was 20.3 kg. It was caught at 10 of the 74 trawl stations (Figure 12). Catches ranged from 0.41 to 5.52 kg. Among the 10 stations, 1 yielded >5 kg. Densities ranged from 1.75 to 30.5 kg·km^{-2} (CPUE ranged 0.41–5.52 kg·h^{-1}). Highest densities were observed in the north–western part of the survey zone and pigfish was also observed at two stations to the west of West Falkland. The number of fish sampled for length frequency was 51 (31 females and 20 males), 10 were sampled for length–weight all of them were randomly taken. Total lengths ranged from 23 to 32 cm for both sexes. The histogram exhibits 2 cohorts with modes at 24 cm and 29 cm and there might be a third one at 32 cm. Females were resting (39%), early developing (13%), late developing, spent (29%) and recovering spent (19%). Males were resting (30%), early developing (45%), late developing (5%), spent (15%) and recovering spent (5%).

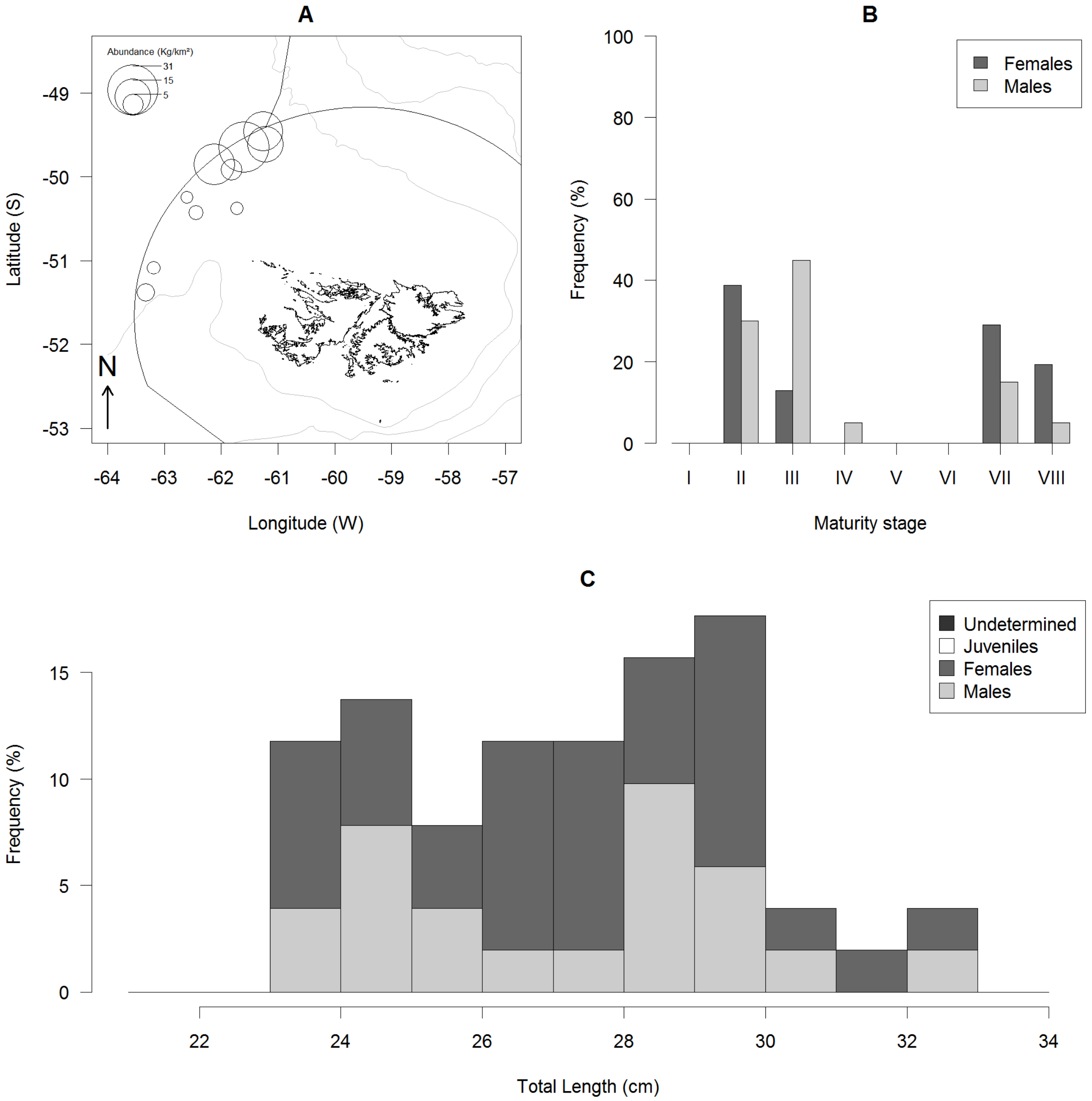


Figure 12: Biological data of *Congiopodus peruvianus* (pigfish; COP), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=51).

3.2.12 *Coelorhynchus fasciatus* – banded whiptail grenadier – GRF

The total catch of banded whiptail grenadier was 17.1 kg. It was caught at 6 of the 74 trawl stations (Figure 13). Catches ranged from 0.04 to 14.6 kg. Among the 6 stations, 1 yielded >2 kg. Densities ranged from 0.1 to 74.9 kg·km^{-2} (CPUE ranged 0.04–14.6 kg·h^{-1}). Highest densities were observed in the southwest of the survey zone in deep waters. The number of fish sampled for length frequency was 125 (102 females and 23 males), 1 was sampled for length–weight, 2 for otoliths (all of them were randomly taken). Pre–anal lengths ranged from 5 to 13 cm for females and from 4 to 8 cm for males. The histogram exhibits 2 cohorts with modes at 7 cm and 11 cm. Females were immature (40%), resting (48%), early developing (9%) and late developing (3%). Males were immature (52%), resting (44%) and early developing (4%).

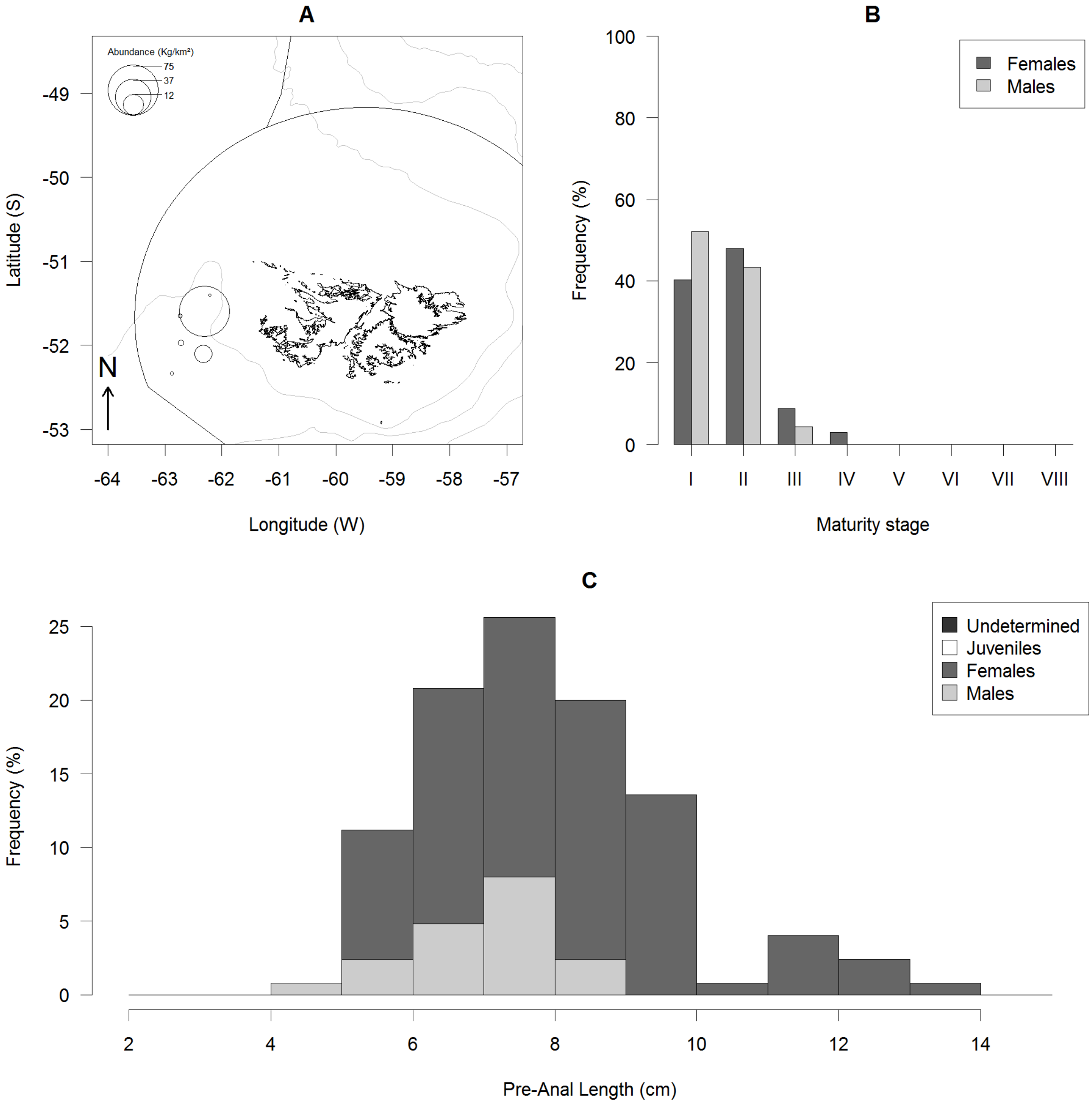


Figure 13: Biological data of *Coelorhynchus fasciatus* (banded whiptail grenadier; GRF), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=125).

3.2.13 *Sebastes oculatus* – redfish – RED

The total catch of redfish was 14.3 kg. It was caught at 6 of the 74 trawl stations (Figure 14). Catches ranged from 0.12 to 7.86 kg. Among the 6 stations, 1 yielded >5 kg. Densities ranged from 0.54 to 35.3 kg·km^{-2} (CPUE ranged 0.12–7.86 kg·h^{-1}). Highest densities were observed to the northwest of West Falkland. The number of fish sampled for length frequency was 28 (13 females, 15 males), 24 were sampled for otolith (all randomly taken). Total lengths ranged from 23 to 39 cm for females and from 19 to 34 cm for males. The histogram exhibits 2 to 3 different cohorts with modes at 27 cm, 32 and 34 cm. Females were early developing (69%), late developing (23%) and ripe (8%). Males were resting (7%), early developing (73%) and late developing (20%).

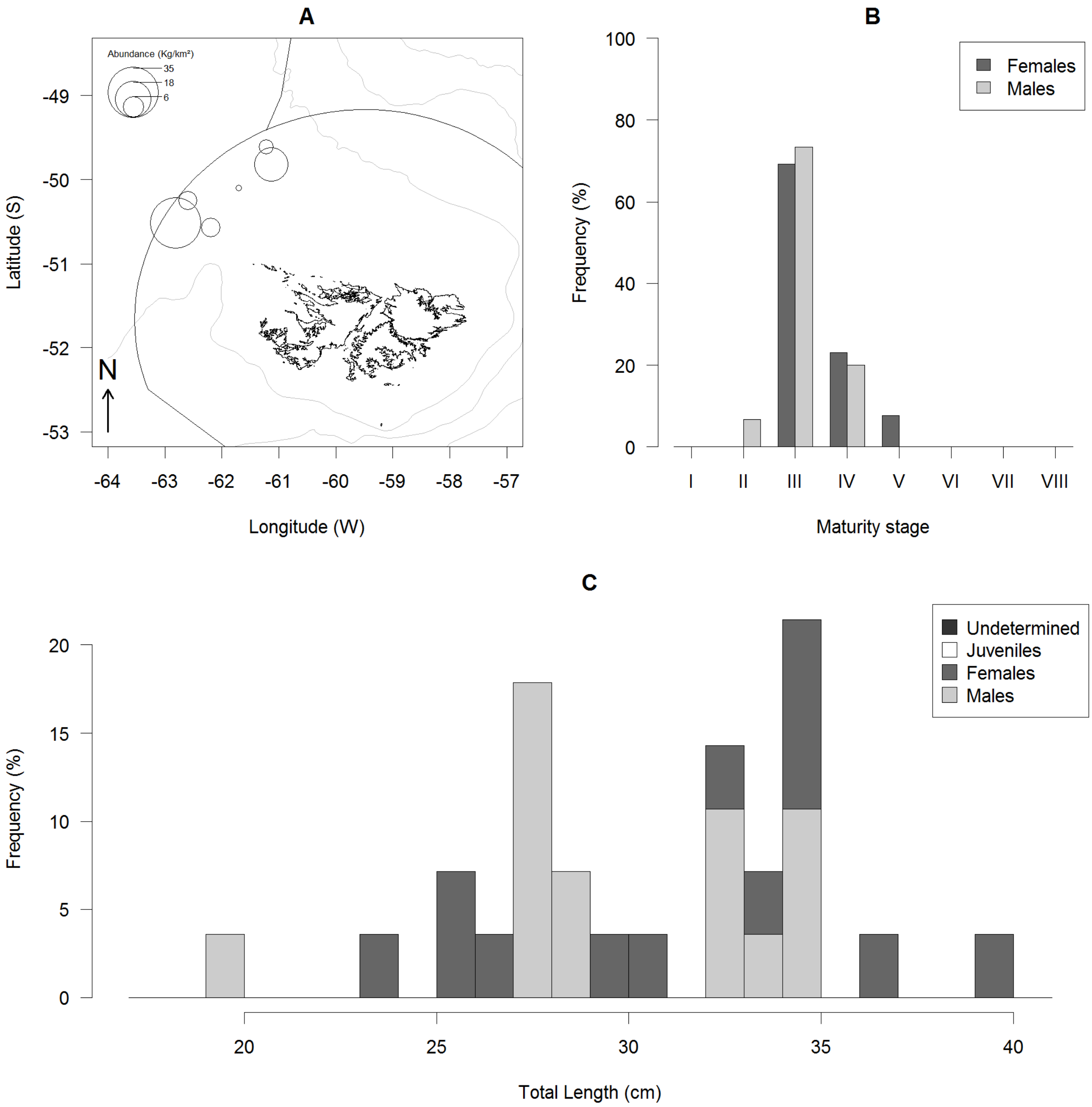


Figure 14: Biological data of *Sebastes oculatus* (redfish; RED), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=28).

3.2.14 *Sprattus fuegensis* – Falkland herring – SAR

The total catch of Falkland herring was 5.4 kg. It was caught at 8 of the 74 trawl stations (Figure 15). Catches ranged from 0.005 to 3.18 kg. Densities ranged from 0.02 to 14.6 kg·km^{-2} (CPUE ranged 0.005–3.18 kg·h^{-1}). Highest densities were observed inshore around the Jason Islands. The number of fish sampled for length frequency was 110 (68 females and 42 males), no fish was taken for length–weight, neither for otoliths. Total lengths ranged from 15 to 21 cm for females and from 14 to 21 cm for males. The histogram exhibits 1 cohort with mode at 18 cm. Females were resting (7%), early developing (40%) and late developing (53%). Males were immature (2%), resting (31%) and early developing (67%).

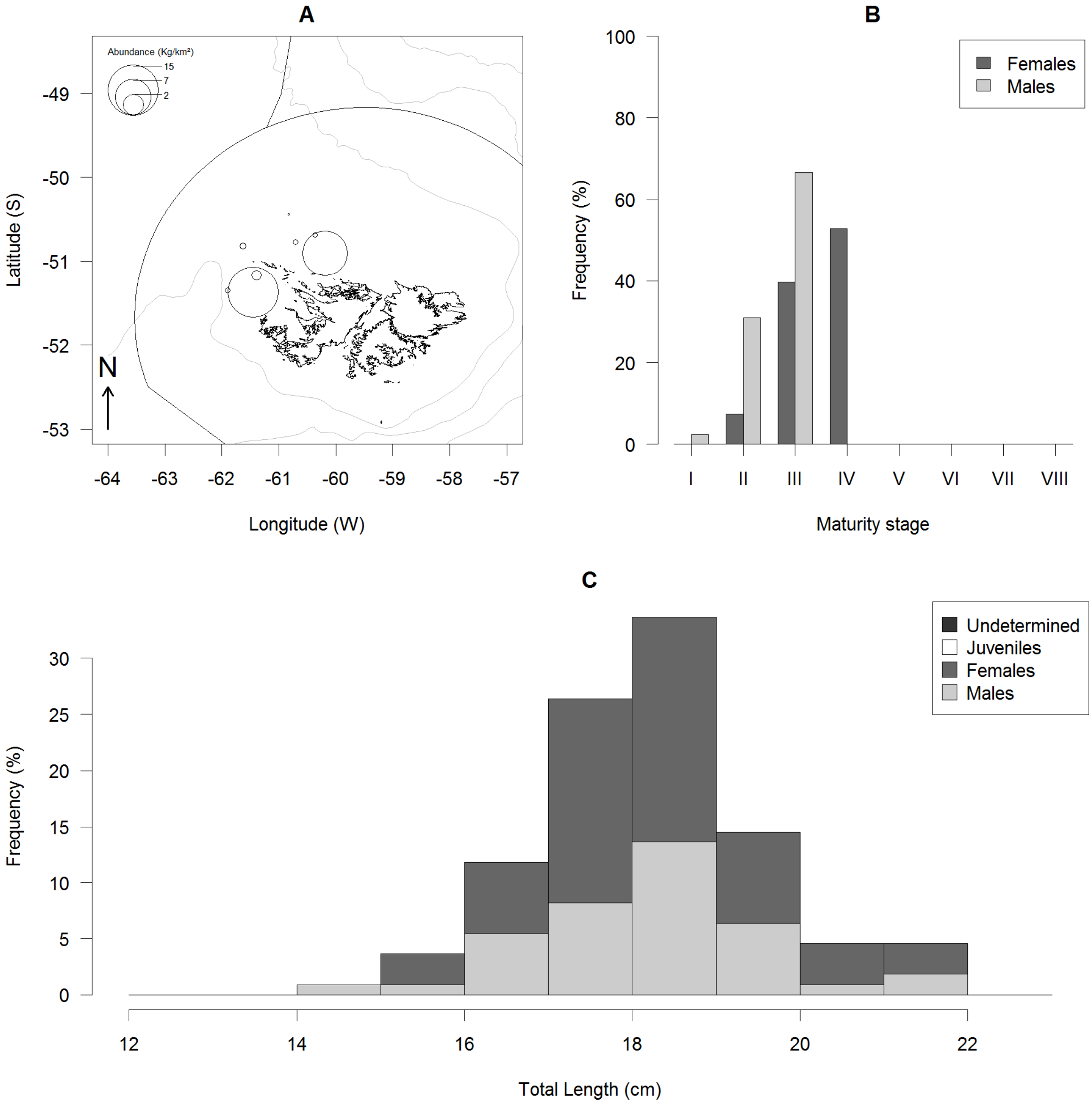


Figure 15: Biological data of *Sprattus fuegensis* (Falkland herring; SAR), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent) and length frequency (in percentage of the total sample assessed) of each sex with 1 cm size class (C; n=110).

3.3 Biological information of squids

3.3.1 *Doryteuthis gahi* (former *Loligo gahi*) – Falkland calamari – LOL

The total catch of Falkland calamari was 4,672 kg. It was caught at all 74 trawl stations (Figure 16). Catches ranged from 1.3 to 581 kg. Among the 74 stations, 55 yielded >10 kg and 12 yielded >100 kg. Densities ranged from 9.2 to 2,800 kg·km^{-2} (CPUE ranged 1.3–581 kg·h^{-1}). Highest densities were observed to the north of East Falkland next to the *Loligo* box but also to the west of West Falkland. The number of squid sampled for length frequency was 8,050 (2 juveniles, 4,036 females, 4,003 males and 9 undetermined), 127 were sampled for length–weight, 103 for otolith (all of them randomly taken). Dorsal mantle lengths were 4.5 and 8.5 cm for the two juveniles, ranged from 3.5 to 23.5 cm for females, from 3.5 to 26.5 cm for males and form 3.5 to 8 cm for undetermined. The histogram exhibits 1 cohort with mode at 8.5 cm. Females were young (12.5%), immature (70%), preparatory (10%), maturing (3%) and mature (5%). Males were young (7%), immature (33%), preparatory (25%), maturing (13%) and mature (22%). 9 females were observed embedded with sperm at station 2650 and sampled for statoliths.

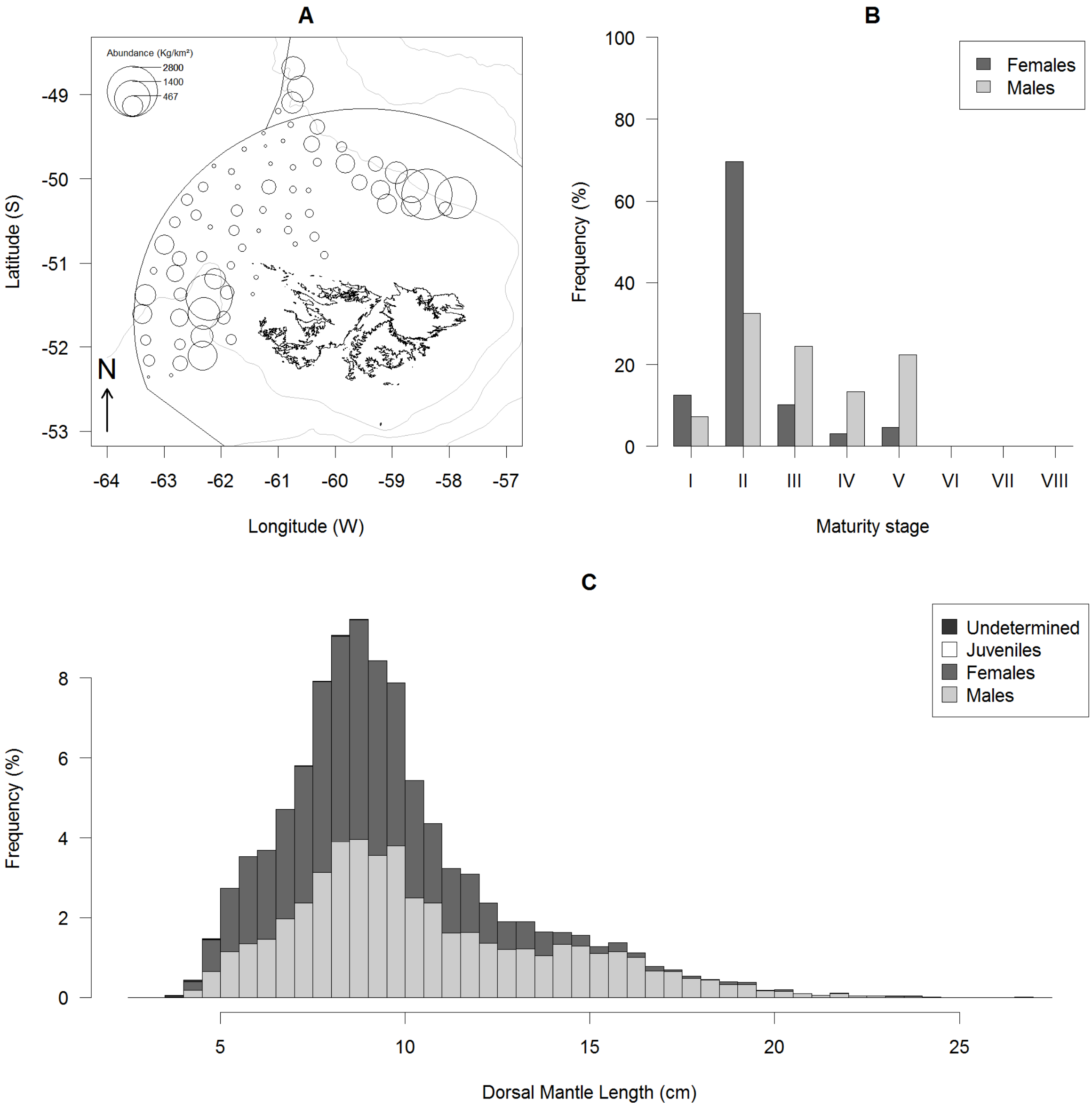


Figure 16: Biological data of *Doryteuthis gahi* (Falkland calamari; LOL), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B; I young; II, immature; III, preparatory; IV, maturing; V, mature; VI, spent) and dorsal mantle length frequency (in percentage of the total sample assessed) of each sex with 0.5 cm size class (C; n=8,050).

3.3.2 *Illex argentinus* – Argentine shortfin squid – ILL

The total catch of Argentine shortfin squid was 18 kg. It was caught at 48 of the 74 trawl stations (Figure 17). Catches ranged from 0.02 to 2.73 kg. Among the 48 stations, 3 yielded >1 kg. Densities ranged from 0.09 to 11.6 kg·km^{-2} (CPUE ranged 0.02–2.73 kg·h^{-1}). Shortfin squid was caught throughout the surveyed zone and were more abundant to the west and to the north of the Falkland Islands. The whole catch was sampled for length frequency, *i.e.* 347 (193 females, 153 males and 1 undetermined), 6 were sampled for length–weight, 67 for statolith (all of them were taken randomly). Total lengths ranged from 7 to 25.5 cm for females and from 8.5 to 20.5 cm for males. The undetermined squid was 9 cm. The histogram exhibits one cohort (mode at 12.5). Other cohorts might be present but are difficult to identify due to the low number of specimens caught. Females were young (44%), immature (52%), preparatory (2%), maturing (1%) and mature (1%). Males were young (30%), immature (54%), preparatory (11%), maturing (4%) and mature (1%).

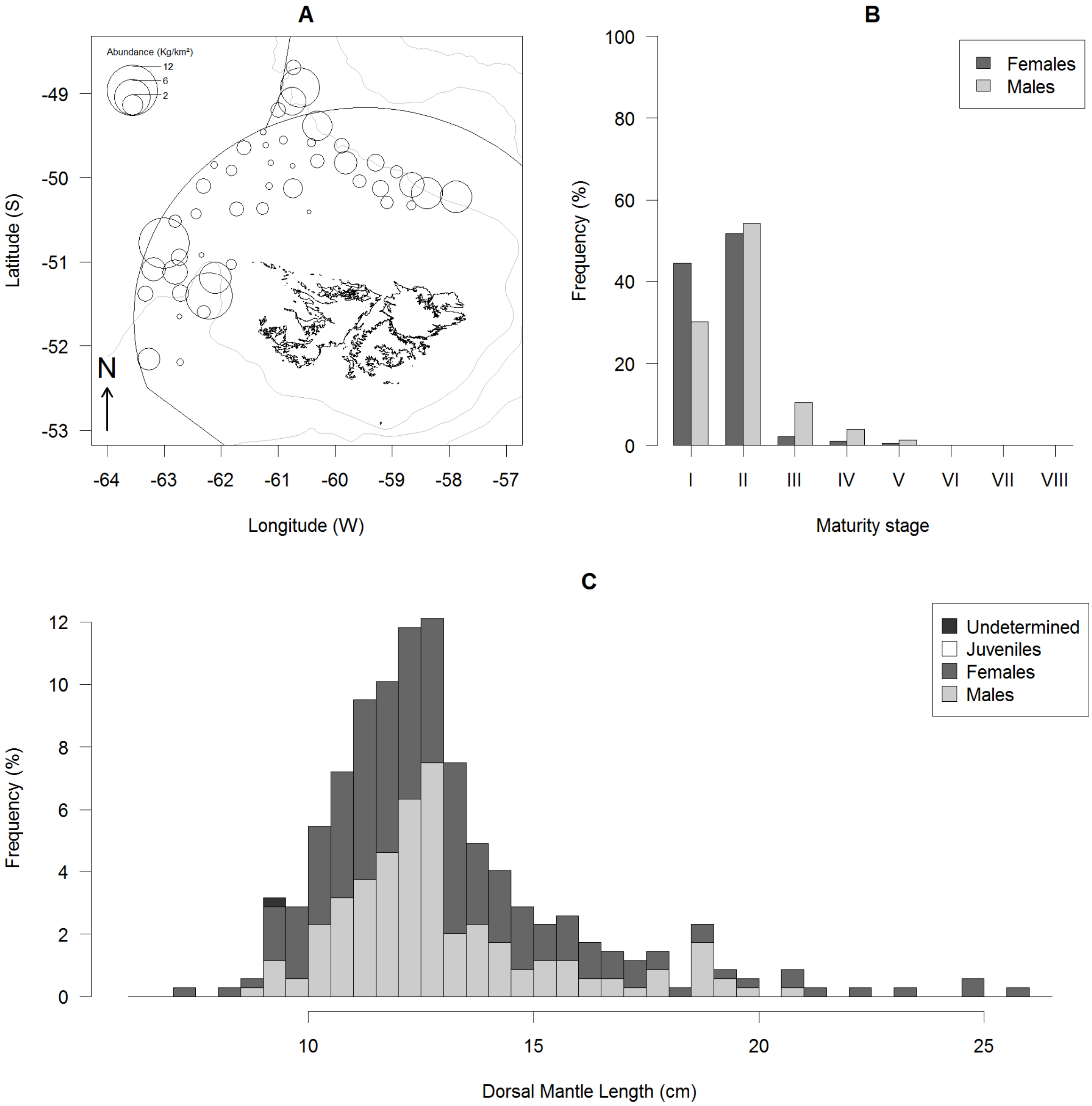


Figure 17: Biological data of *Illex argentinus* (Argentine shortfin squid; ILL), map of the densities in kg·km^{-2} (A), percentage of specimens of each sex per maturity stage (B; I young; II, immature; III, preparatory; IV, maturing; V, mature; VI, spent) and dorsal mantle length frequency (in percentage of the total sample assessed) of each sex with 0.5 cm size class (C; n=347).

3.4 Biological information of skates

3.4.1 *Zearaja chilensis* – yellow nose skate – RFL

The total catch of yellow nose skate was 920.13 kg (62.1% of the skate catch). It was caught at 58 of the 74 trawl stations (Figure 18). Catches ranged from 0.59 to 102.46 kg. Among the 58 stations, 29 yielded >10 kg and 1 yielded >100 kg. Densities ranged from 3.25 to 727.58 kg·km^{-2} (CPUE ranged 0.59–102.46 kg·h^{-1}). Highest densities were observed in the south–western and western parts of the survey zone. The number of skates sampled for size frequency was 380 (260 females and 120 males), all were sampled for length, disc–width, sex/maturity and weight. Disc widths ranged from 31 to 84 cm for females and from 33 to 77 cm for males. The histogram exhibits no clear cohorts with one mode at size class 45-49 cm. Females were observed juvenile (32%), adolescent, maturing (49%), adult, developing (16%), adult, mature (1%) and adult, resting (2%). Males were juvenile (13%), adolescent, maturing (36%), adult, developing (28%), adult, mature (4%), adult, running (20%).

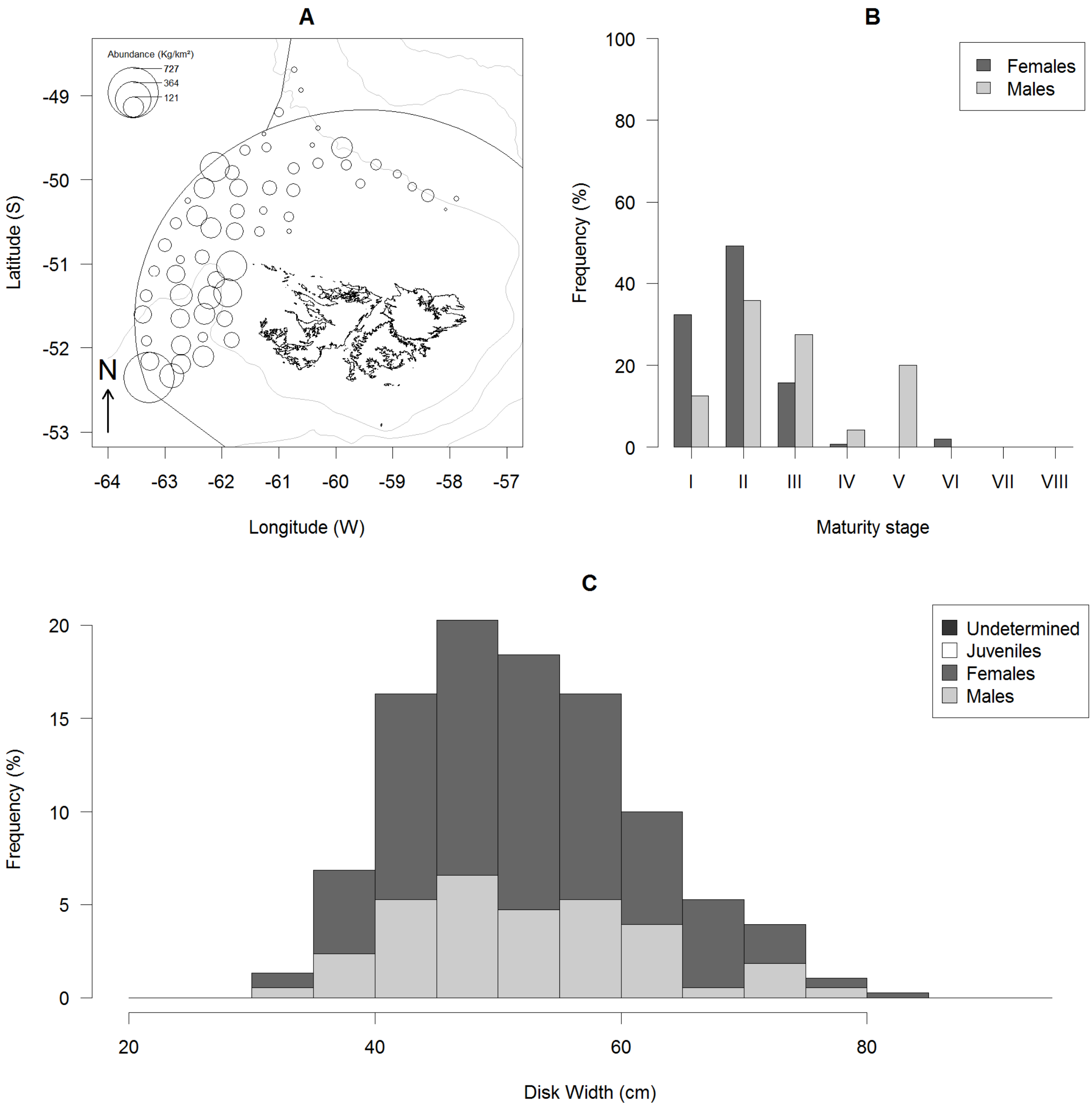


Figure 18: Biological data of *Zearaja chilensis* (yellow nose skate, RFL), map of the densities in kg/km² (A), percentage of specimens of each sex per maturity stage (B; I juvenile; II, adolescent maturing; III, adult, developing; IV, adult, mature; V, adult laying/running; VI, adult resting) and disc width frequency (in percentage of the total sample assessed) of each sex with 5 cm size class (C; n=380).

3.4.2 *Bathyraja brachyurops* – blonde skate – RBR

The total catch of blonde skate was 406.612 kg (27.4% of the skate catch). It was caught at 58 of the 74 trawl stations (Figure 19). Catches ranged from 0.05 to 55.65 kg. Among the 58 stations, 9 yielded >10 kg. Densities ranged from 0.22 to 395.18 $kg \cdot km^{-2}$ (CPUE ranged 0.05–55.65 $kg \cdot h^{-1}$). Highest densities were observed in the western and southwestern part of the survey zone. The number of skates sampled for size frequency was 236 (117 females and 119 males), all were sampled for length, disc width, sex/maturity and weight. Disc widths ranged from 9 to 71 cm for females and from 8 to 64 cm for males. The histogram exhibits one clear juvenile cohort at 10-14 cm, an adolescent cohort at 35-39 cm, and a weaker adult cohort at 50-54 cm. Females were observed juvenile (37%), adolescent, maturing (32%), adult, developing (9%), adult, mature (5%), adult, laying (4%) and adult, resting (12%). Males were juvenile (18%), adolescent, maturing (33%), adult, developing (18%), adult, mature/running (31%).

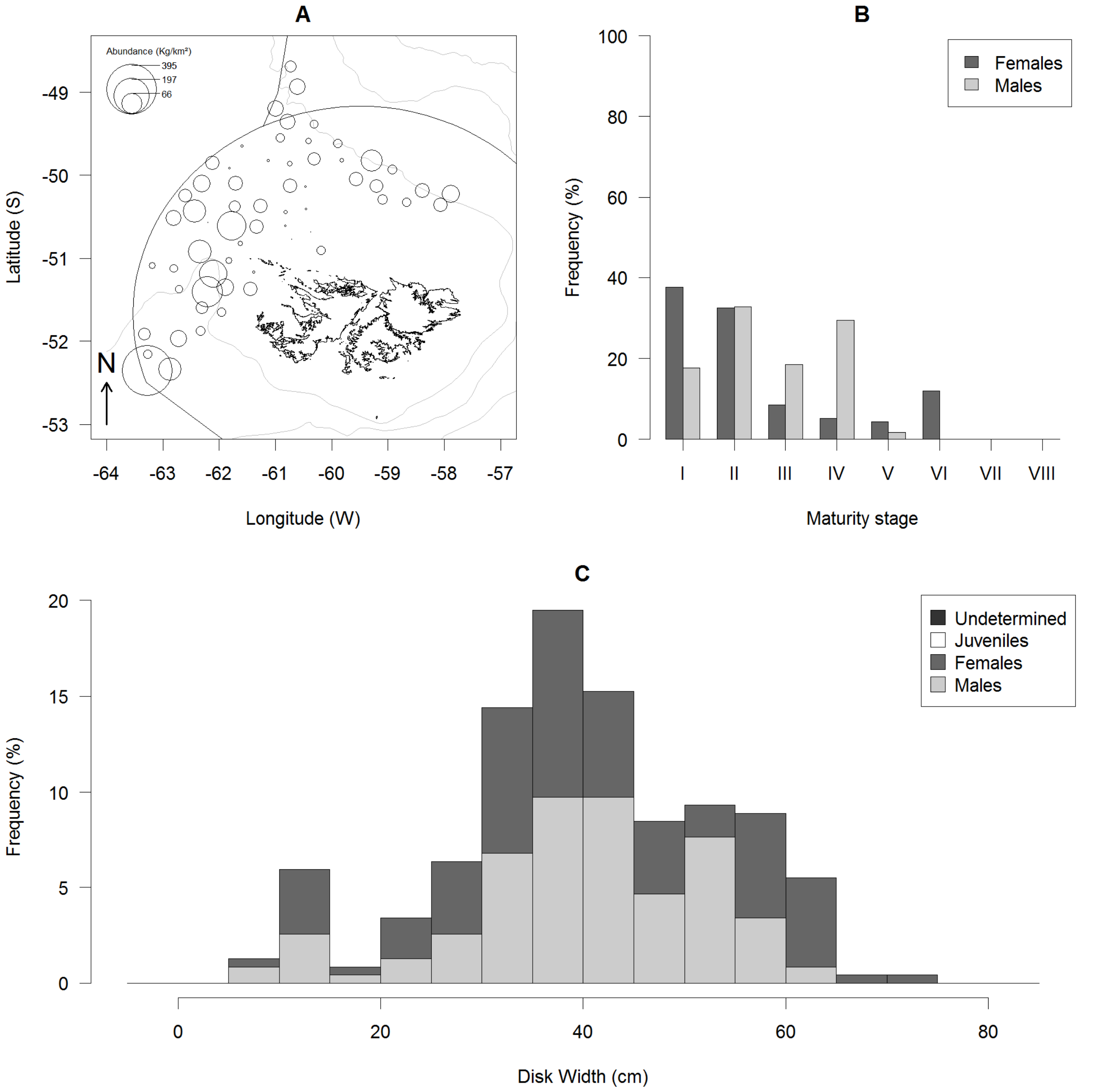


Figure 19: Biological data of *Bathyraja brachyurops* (blonde skate, RBR), map of the densities in kg/km² (A), percentage of specimens of each sex per maturity stage (B; I juvenile; II, adolescent maturing; III, adult, developing; IV, adult, mature; V, adult laying/running; VI, adult resting) and disc width frequency (in percentage of the total sample assessed) of each sex with 5 cm size classes (C; n=236).

3.4.3 *Bathyraja macloviana* – Falkland skate – RMC

The total catch of Falkland skate was 37.595 kg (2.5% of the skate catch). It was caught at 24 of the 74 trawl stations (Figure 20). Catches ranged from 0.015 to 4.39 kg. Among the 24 stations, 3 yielded >3 kg. Densities ranged from 0.06 to 22.41 kg·km^{-2} (CPUE ranged 0.15–4.39 kg·h^{-1}). Highest densities were observed in the northern and north–western part of the survey zone. The number of skates sampled for size frequency was 38 (21 females and 17 males), all were sampled for length, disc width, sex/maturity and weight. Disc widths ranged from 8 to 40 cm for females and from 8 to 38 cm for males. The histogram exhibits a weak juvenile cohort at 5-14 cm, and a prominent adult cohort with a mode at 35-39 cm. Females were observed juvenile (14%), adolescent, maturing (24%), adult, developing (5%), adult, mature (5%), adult, laying (10%) and adult, resting (43%). Males were juvenile (24%), adult, developing (18%), adult, mature (12%), and adult, running (47%).

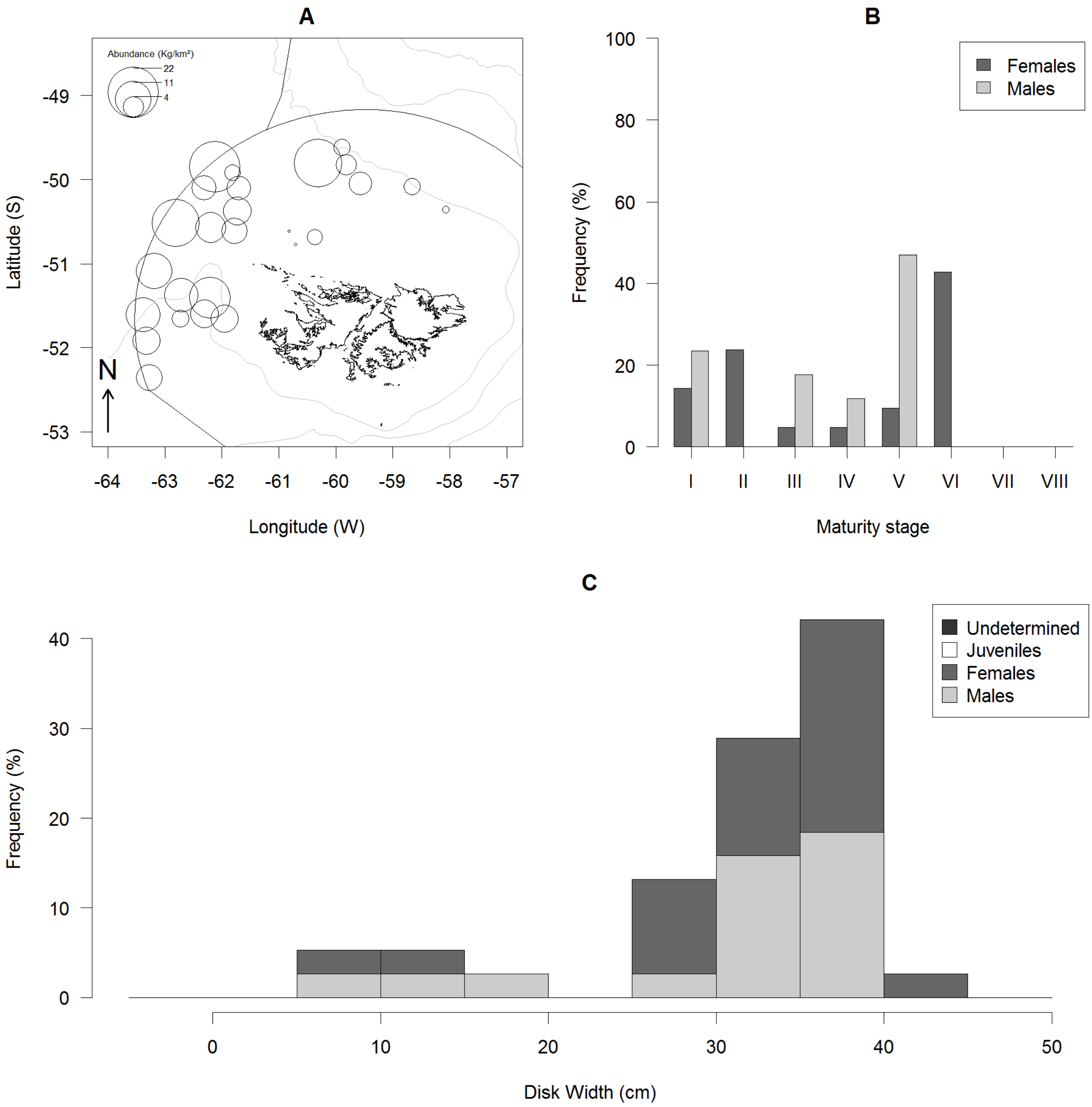


Figure 20: Biological data of *Bathyraja macloviana* (Falkland skate, RMC), map of the densities in kg/km² (A), percentage of specimens of each sex per maturity stage (B; I juvenile; II, adolescent maturing; III, adult, developing; IV, adult, mature; V, adult laying/running; VI, adult resting) and disc width frequency (in percentage of the total sample assessed) of each sex with 5 cm size class (C; n=38).

3.4.4 *Amblyraja doellojuradoi* – Starry Skate – RDO

The total catch of starry skate was 32.052 kg (2.2% of the skate catch). It was caught at 11 of the 74 trawl stations (Figure 21). Catches ranged from 0.12 to 21.06 kg. Among the 11 stations, 2 yielded >5 kg and 1 yielded >20 kg. Densities ranged from 0.05 to 149.55 $kg \cdot km^{-2}$ (CPUE ranged 0.12–21.06 $kg \cdot h^{-1}$). Highest densities were observed in the south–western part of the survey zone. The number of skates sampled for size frequency was 42 (16 females and 26 males), all were sampled for length, disc width, sex/maturity and weight. Disc widths ranged from 7 to 35 cm for females and from 8 to 39 cm for males. The histogram exhibits a prominent adult cohort with a mode at 30–34 cm. Females were observed juvenile (19%), adolescent, maturing (19%), adult, developing (6%), adult, mature (6%), adult, laying (0%) and adult, resting (50%). Males were juvenile (12%), adolescent, maturing (15%), adult, developing (15%), adult, mature (19%), and adult, running (38%).

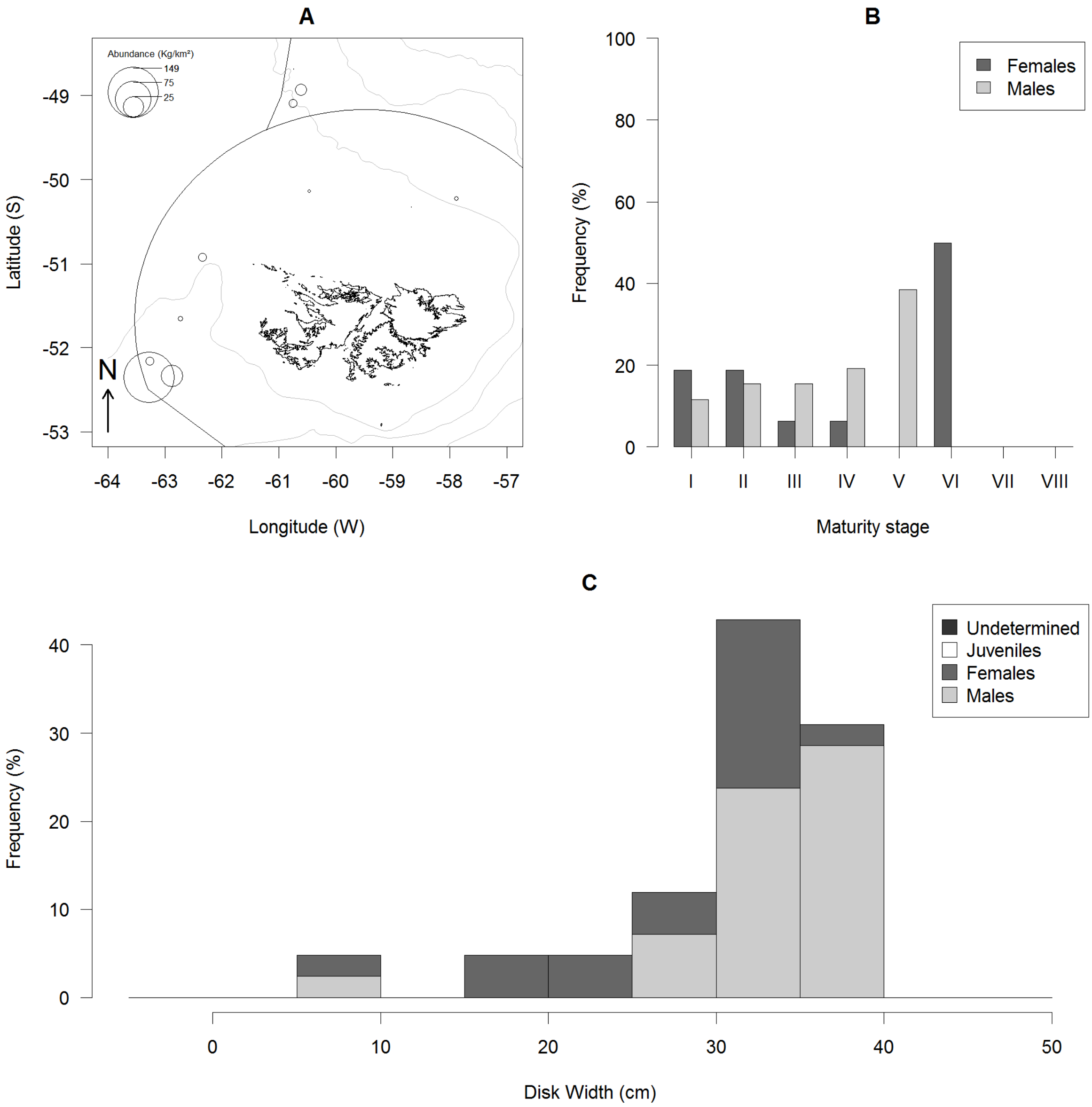


Figure 21: Biological data of *Amblyraja doellojuradoi* (Starry skate, RDO), map of the densities in kg/km² (A), percentage of specimens of each sex per maturity stage (B; I juvenile; II, adolescent maturing; III, adult, developing; IV, adult, mature; V, adult laying/running; VI, adult resting) and disc width frequency (in percentage of the total sample assessed) of each sex with 5 cm size class (C; n=42).

3.4.5 *Bathyraja albomaculata* – white spotted skate – RAL

The total catch of white spotted skate was 20.984 kg (1.4% of the skate catch). It was caught at 9 of the 74 trawl stations (Figure 22). Catches ranged from 0.044 to 11.11 kg. Among the 9 stations, 1 yielded >10 kg. Densities ranged from 0.25 to 78.89 kg·km^{-2} (CPUE ranged 0.044–11.11 kg·h^{-1}). Highest densities were observed in the south–western part of the survey zone. The number of skates sampled for size frequency was 16 (4 females and 12 males), all were sampled for length, disc width, sex/maturity and weight. Disc widths ranged from 12 to 45 cm for females and from 11 to 48 cm for males. The histogram exhibits an adult cohort with a mode at 40–44 cm. Females were observed juvenile (50%) and adult, developing (50%). Males were juvenile (17%), adolescent, maturing (25%), adult, developing (25%), adult, mature (8%), and adult, running (25%).

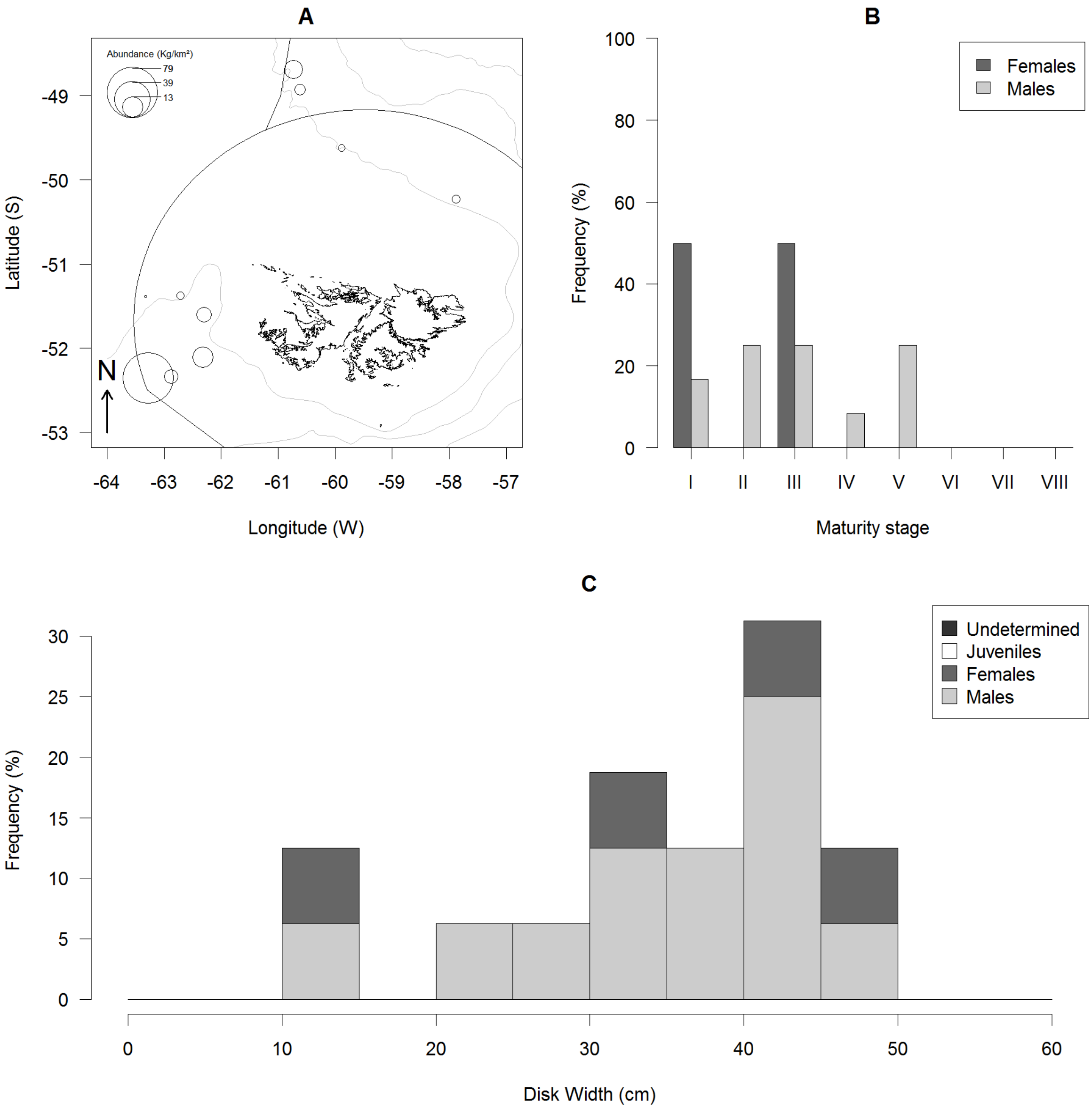


Figure 22: Biological data of *Bathyraja albomaculata* (white spotted skate, RAL), map of the densities in kg/km² (A), percentage of specimens of each sex per maturity stage (B; I juvenile; II, adolescent maturing; III, adult, developing; IV, adult, mature; V, adult laying/running; VI, adult resting) and disc width frequency (in percentage of the total sample assessed) of each sex with 5 cm size class (C; n=16).

3.4.6 *Psammobatis spp*. – Sandray Unidentified – RPX

The total catch of sand rays was 19.525 kg (1.3% of the skate catch). It was caught at 25 of the 74 trawl stations (Figure 23). Catches ranged from 0.005 to 2.27 kg. Among the 25 stations, 2 yielded >2 kg. Densities ranged from 0.03 to 12.91 kg·km^{-2} (CPUE ranged 0.005–2.27 kg·h^{-1}). Highest densities were observed in the north–western part of the survey zone. The number of skates sampled for size frequency was 40 (23 females and 17 males), all were sampled for length, disc width, sex/maturity and weight. Disc widths ranged from 5 to 29 cm for females and also from 5 to 29 cm for males. The histogram exhibits an adult cohort with a mode at 25–29 cm, and a weaker juvenile cohort at 5–9 cm. Females were observed juvenile (22%), adolescent, maturing (13%), adult, developing (4%), adult, mature (20%), adult, laying (13%) and adult, resting (30%). Males were juvenile (24%), adolescent, maturing (12%), adult, developing (12%), adult, mature (6%), and adult, running (47%).

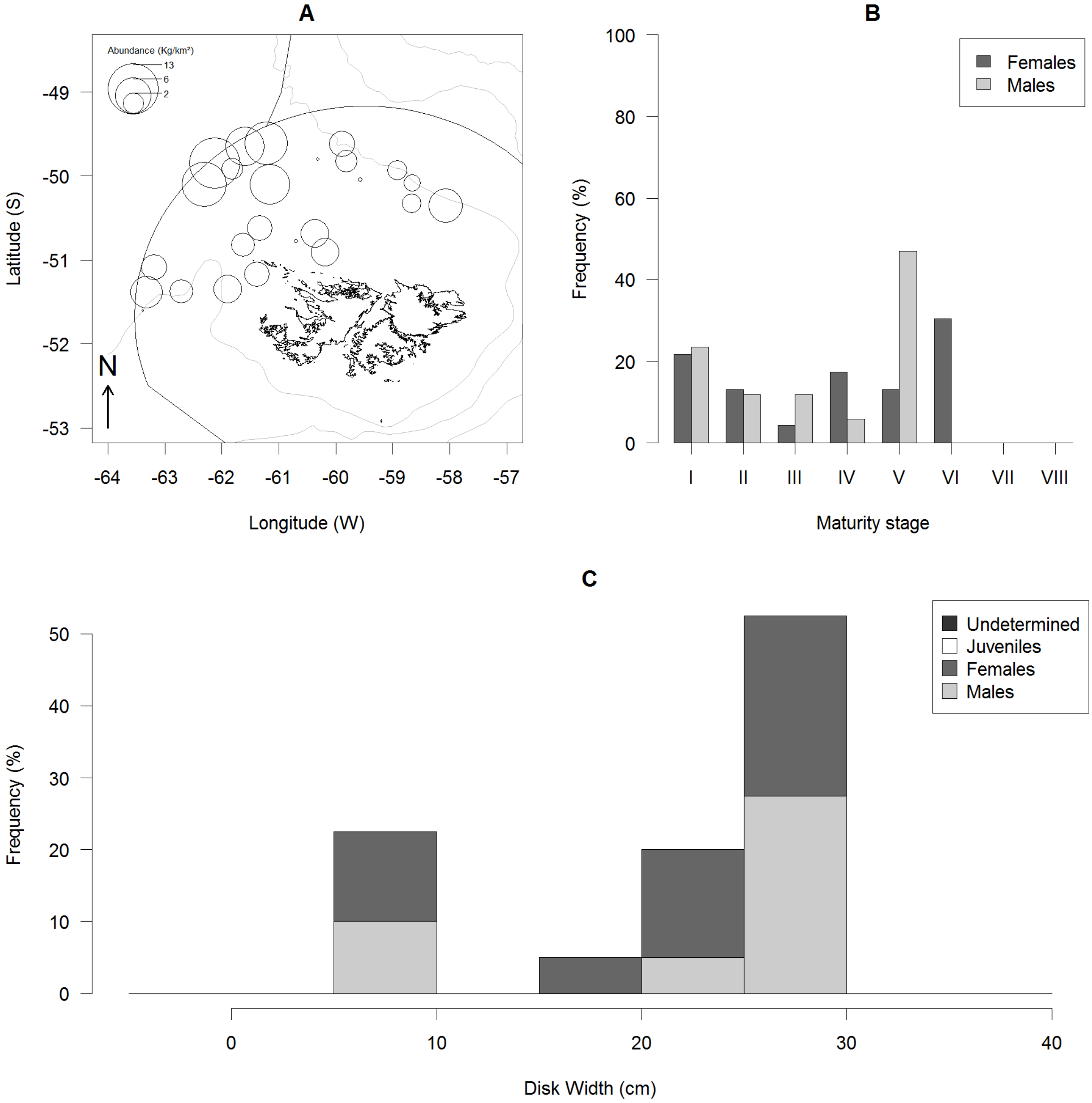


Figure 23: Biological data of *Psammobatis spp*. (Sandray Unidentified, RPX), map of the densities in kg/km² (A), percentage of specimens of each sex per maturity stage (B; I juvenile; II, adolescent maturing; III, adult, developing; IV, adult, mature; V, adult laying/running; VI, adult resting) and disc width frequency (in percentage of the total sample assessed) of each sex with 5 cm size class (C; n=40).

3.4.7 *Bathyraja scaphiops* – cuphead skate – RSC

The total catch of cuphead skate was 18.1 kg (1.2% of the skate catch). It was caught at 10 of the 74 trawl stations (Figure 24). Catches ranged from 0.15 to 5.37 kg. Among the 10 stations, 3 yielded >2 kg, 1 yielded >5 kg. Densities ranged from 0.75 to 27.23 kg·km^{-2} (CPUE ranged 0.15–5.37 kg·h^{-1}). Highest densities were observed in the south–western part of the survey zone. The number of skates sampled for size frequency was low with 11 (7 females and 4 males), all were sampled for length, disc width, sex/maturity and weight. Disc widths ranged from 33 to 54 cm for females and from 19 to 45 cm for males. Females were observed adolescent, maturing (29%), adult, developing (14%), adult, mature (14%) and adult, resting (43%). Males were juvenile (50%) and adult, running (50%).

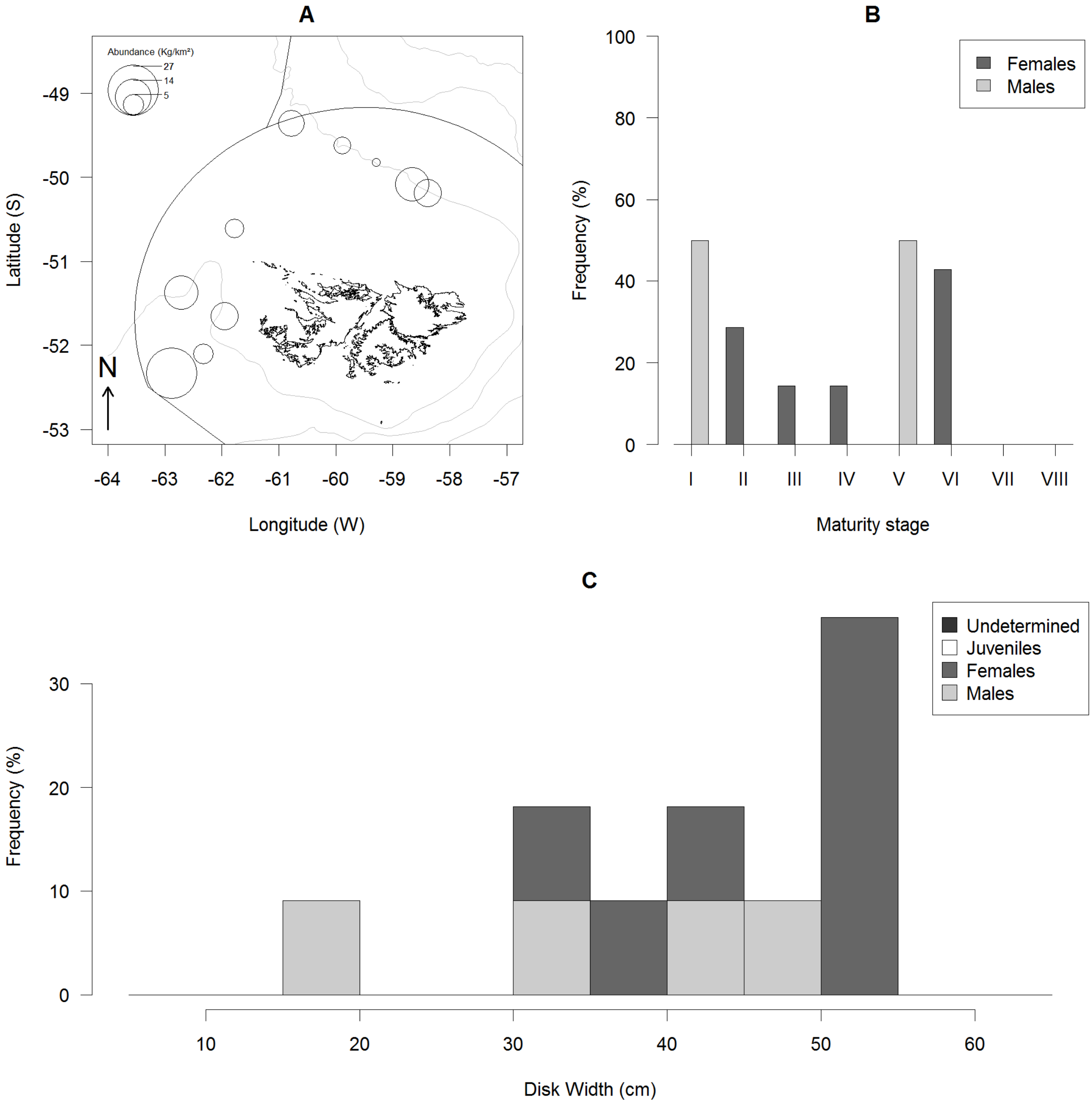


Figure 24: Biological data of *Bathyraja scaphiops* (cuphead skate, RSC), map of the densities in kg/km² (A), percentage of specimens of each sex per maturity stage (B; I juvenile; II, adolescent maturing; III, adult, developing; IV, adult, mature; V, adult laying/running; VI, adult resting) and disc width frequency (in percentage of the total sample assessed) of each sex with 5 cm size class (C; n=11).

3.4.8 *Bathyraja griseocauda* – grey tailed skate – RGR

The total catch of grey tailed skate was 12.61 kg (0.9% of the skate catch). It was caught at 10 of the 74 trawl stations (Figure 25). Catches ranged from 0.2 to 4.74 kg. Among the 10 stations, 1 yielded >4 kg. Densities ranged from 0.81 to 25.29 kg·km^{-2} (CPUE ranged 0.2–4.74 kg·h^{-1}). Highest densities were observed in the western part of the survey zone. The number of skates sampled for size frequency was low with 23 (6 females and 17 males), all were sampled for length, disc width, sex/maturity and weight. Disc widths ranged from 16 to 48 cm for females and from 15 to 44 cm for males. Females were observed juvenile (83%) and adolescent, maturing (17%). Males were juvenile (94%), adolescent, maturing (6%) and adult, running (50%).

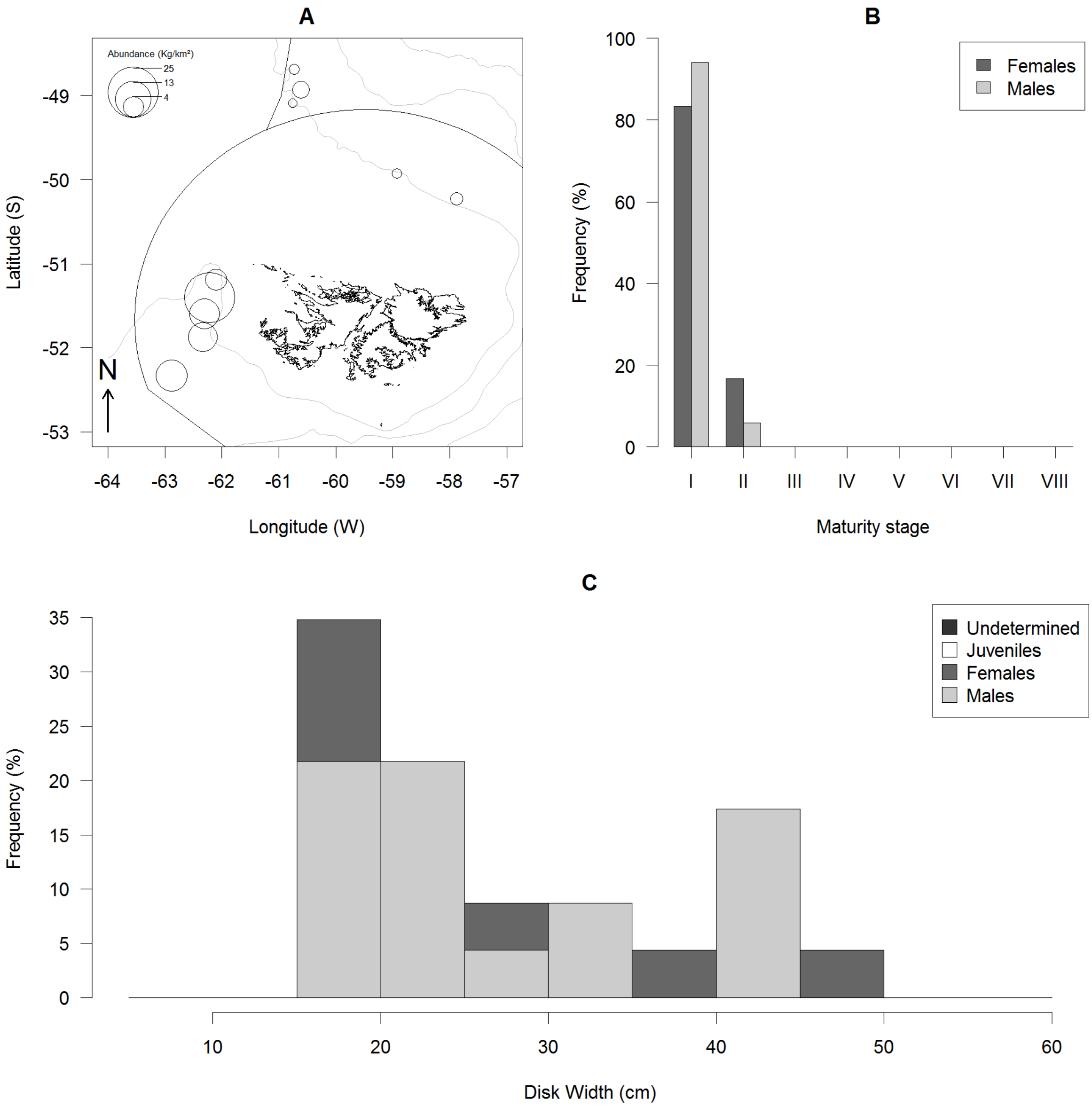


Figure 25: Biological data of *Bathyraja griseocauda* (grey tailed skate, RGR), map of the densities in kg/km² (A), percentage of specimens of each sex per maturity stage (B; I juvenile; II, adolescent maturing; III, adult, developing; IV, adult, mature; V, adult laying/running; VI, adult resting) and disc width frequency (in percentage of the total sample assessed) of each sex with 5 cm size class (C; n=23).

3.4.9 *Bathyraja multispinis* – multispined skate – RMU

The total catch of multispined skate was 10.08 kg (0.7% of the skate catch). It was caught at 2 of the 74 trawl stations (Figure 26), both in the southwest of the survey zone. The two catches were 4.68 and 5.4 kg, with respective densities 27.39 and 33.23 kg·km^{-2} (CPUEs 4.68 and 5.4 kg·h^{-1}). The number of skates sampled for size frequency was only 3 (1 female and 2 males), all were sampled for length, disc width, sex/maturity and weight and vertebrae/thorns. Disc widths were 49 cm for the juvenile female and 53 & 62 cm for the two males which were both adolescent, maturing.

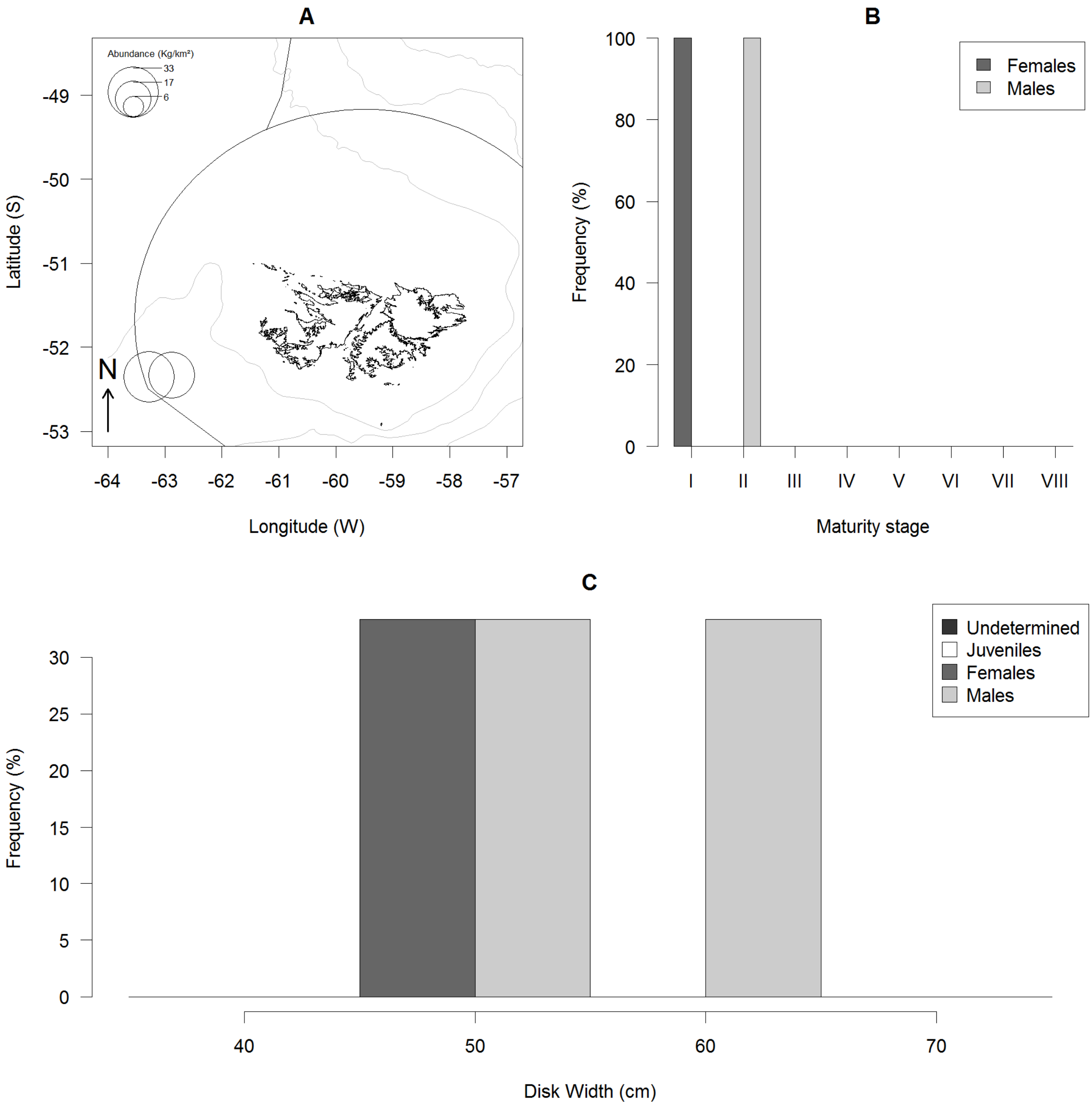


Figure 26: Biological data of *Bathyraja multispinis* (multispined skate, RMU), map of the densities in kg/km² (A), percentage of specimens of each sex per maturity stage (B; I juvenile; II, adolescent maturing; III, adult, developing; IV, adult, mature; V, adult laying/running; VI, adult resting) and disc width frequency (in percentage of the total sample assessed) of each sex with 5 cm size class (C; n=3).

3.4.10 *Bathyraja magellanica* – Magellanic skate – RMG

The total catch of Magellanic skate was 2.2 kg (0.1% of the skate catch). It was caught at 2 of the 74 trawl stations (Figure 27), both close to the Jason Islands. Catches were 0.07 and 2.13 kg, with associated densities 0.33 and 9.68 kg·km^{-2} (CPUEs 0.07 and 2.13 kg·h^{-1}). The number of skates sampled for size frequency was only 2 (both female), all were sampled for length, disc width, sex/maturity and weight. Disc widths were 14 and 42 cm. The 14 cm female was juvenile, whereas the 42cm female was adult, resting.

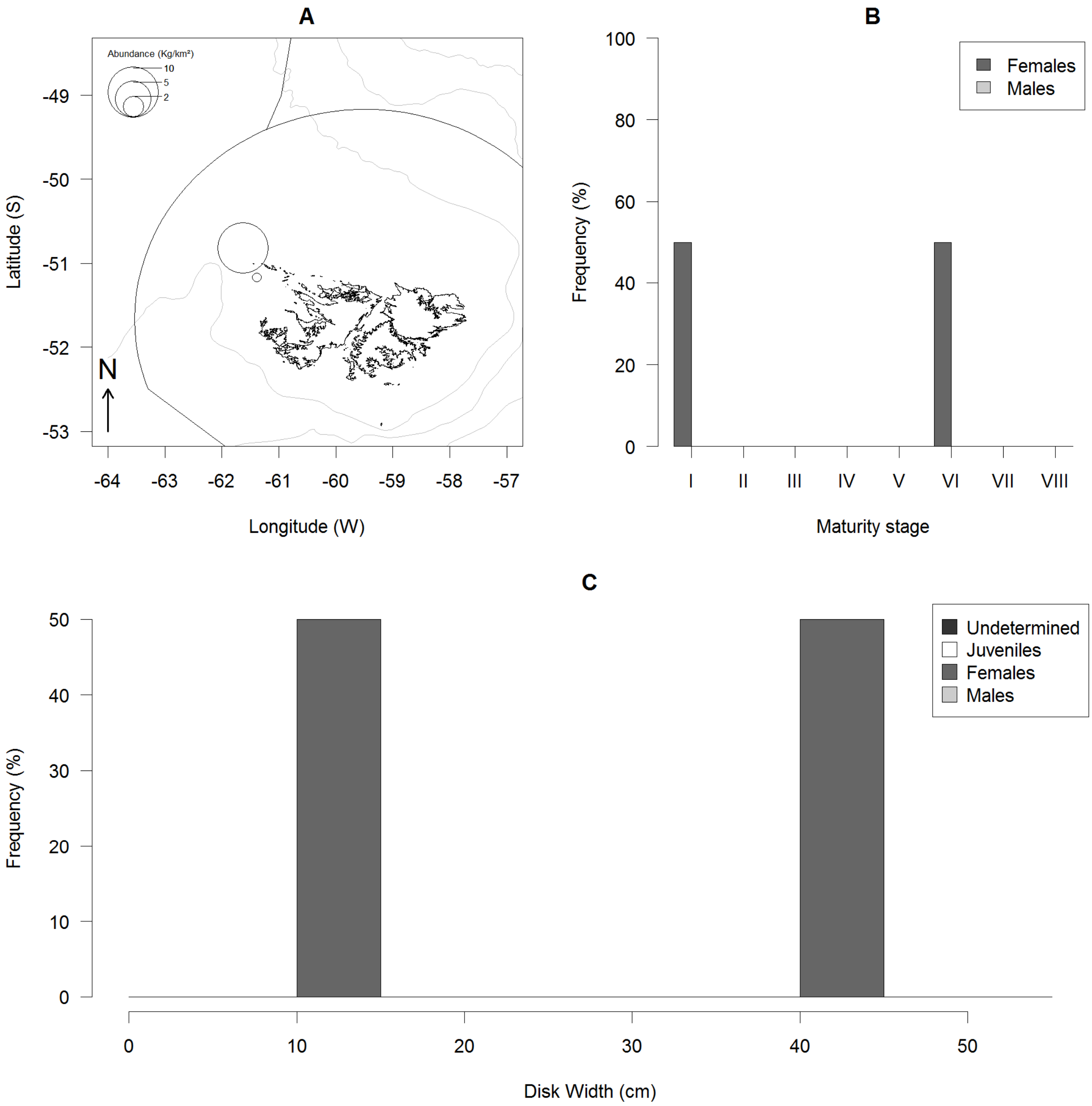


Figure 27: Biological data of *Bathyraja magellanica* (Magellanic skate, RMG), map of the densities in kg/km² (A), percentage of specimens of each sex per maturity stage (B; I juvenile; II, adolescent maturing; III, adult, developing; IV, adult, mature; V, adult laying/running; VI, adult resting) and disc width frequency (in percentage of the total sample assessed) of each sex with 5 cm size class (C; n=2).

3.4.11 *Bathyraja cousseauae* – joined–fin skate – RBZ

The total catch of joined-fin skate was 2.12 kg. It was caught at only 1 of the 74 trawl stations in the south-western part of the survey zone (Figure 28). The density was 11.02 kg·km^{-2} (CPUE 2.12 kg·h^{-1}). The single adolescent, maturing female had a disc width of 46 cm.

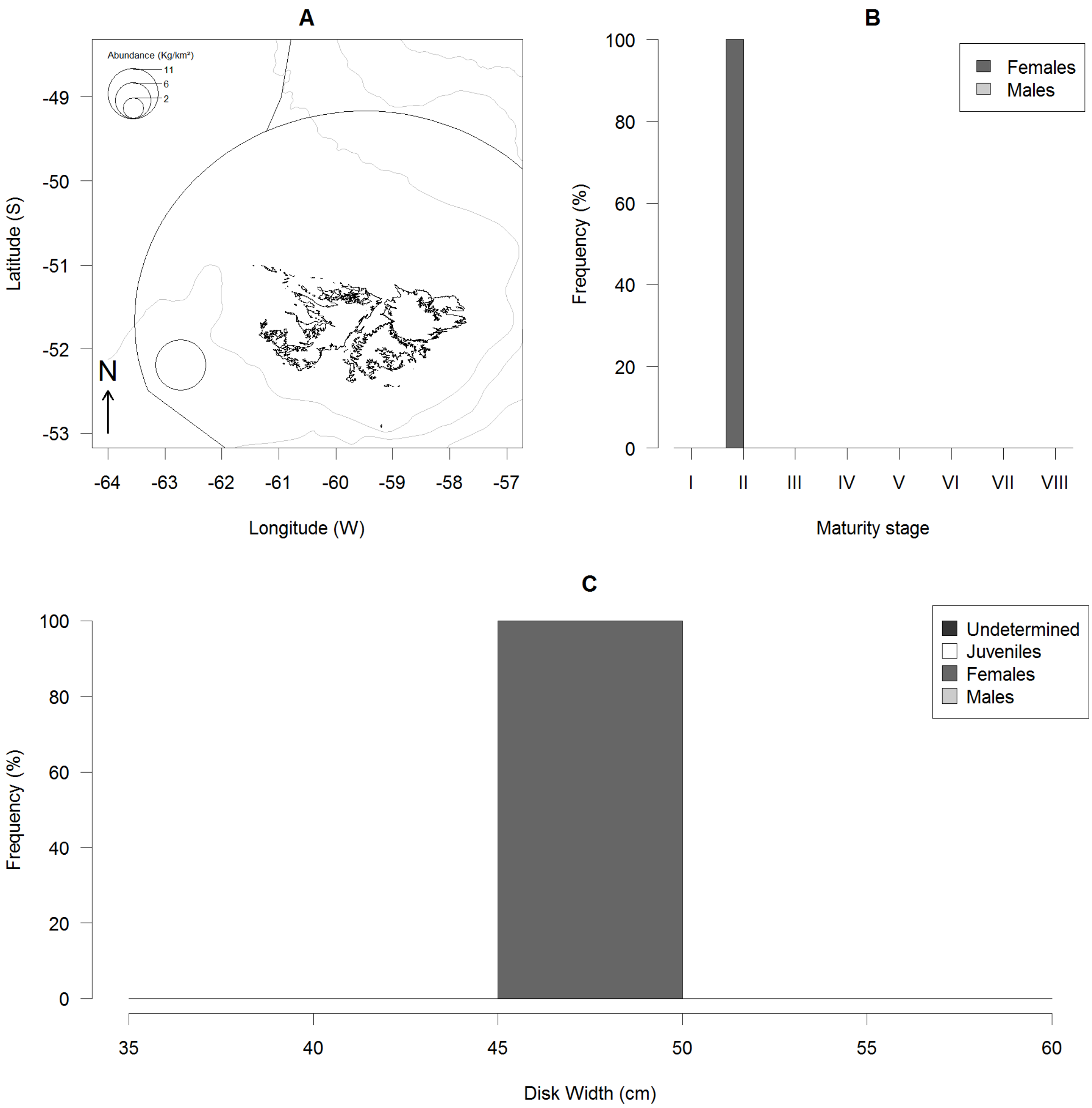


Figure 28: Biological data of *Bathyraja cousseauae* (joined–fin skate, RBZ), map of the densities in kg/km² (A), percentage of specimens of each sex per maturity stage (B; I juvenile; II, adolescent maturing; III, adult, developing; IV, adult, mature; V, adult laying/running; VI, adult resting) and disc width frequency (in percentage of the total sample assessed) of each sex with 5 cm size class (C; n=1).

3.5 Biomass estimation and cohort analysis

3.5.1 Hake

Hake was observed in higher densities in the north of the survey zone. It is generally where hake is the more abundant in Falkland waters (Figure 29). It was also abundant to the northwest of West Falkland, but to a lesser extent. Observed densities ranged from 12.8 kg·km^{-2} to 9.35 t·km^{-2} and were Box–Cox transformed (λ=0.5). The semi–variogram was plotted with 38 distance classes and an exponential model with no nugget effect fitted to the observed values. The model reached the sill (1,428) at 186 km. Kriged densities ranged from 34 to 8,697 kg·km^{-2} and averaged 1,003 kg·km^{-2}. The estimated biomass was 97,072 t. Over the years that the ground fish surveys have been conducted, hake biomass in February ranged from 7,336 to 17,357 t and was 13,550 t in October 2014. All these surveys were conducted when hake was in Argentine waters for the spawning season. Abundance in July 2017 did not increase as much as the biomass highlighting the presence of bigger fish than in February. This is further showed by the length frequency histograms (Figure 30) where one can see the increase in abundance for all the size classes and especially the biggest ones.

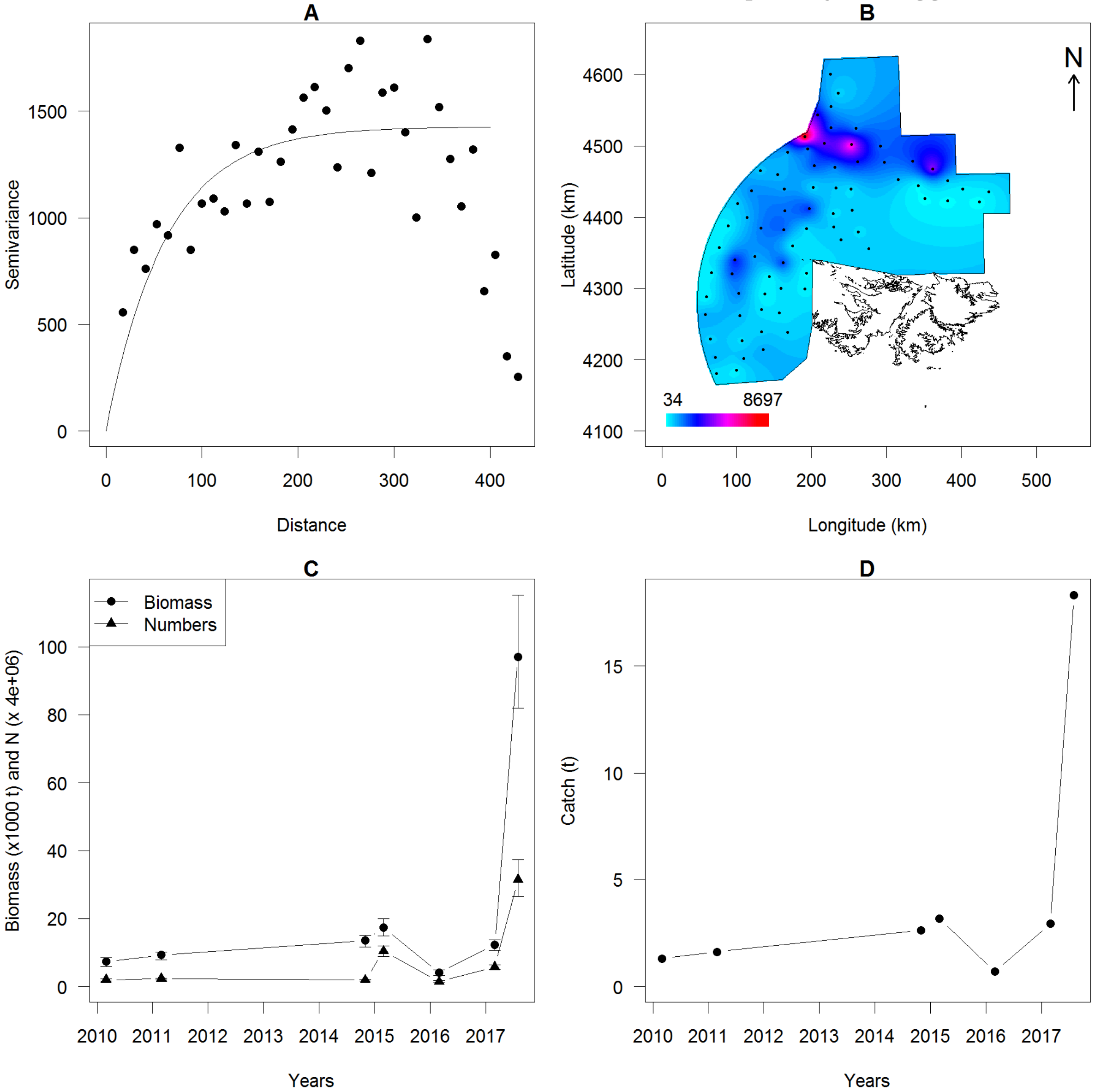


Figure 29: Experimental variogram with exponential model fitted (A), kriged map of hake density (B), time series of estimated biomass and abundance of fish (with associated 95% confidence intervals) using the ground fish surveys conducted from 2010 (C) and total catch of each survey (D). Biomass and abundance estimations in 2014 and 2017 second season were carried out in October–November and July respectively and illustrate the seasonal trends.

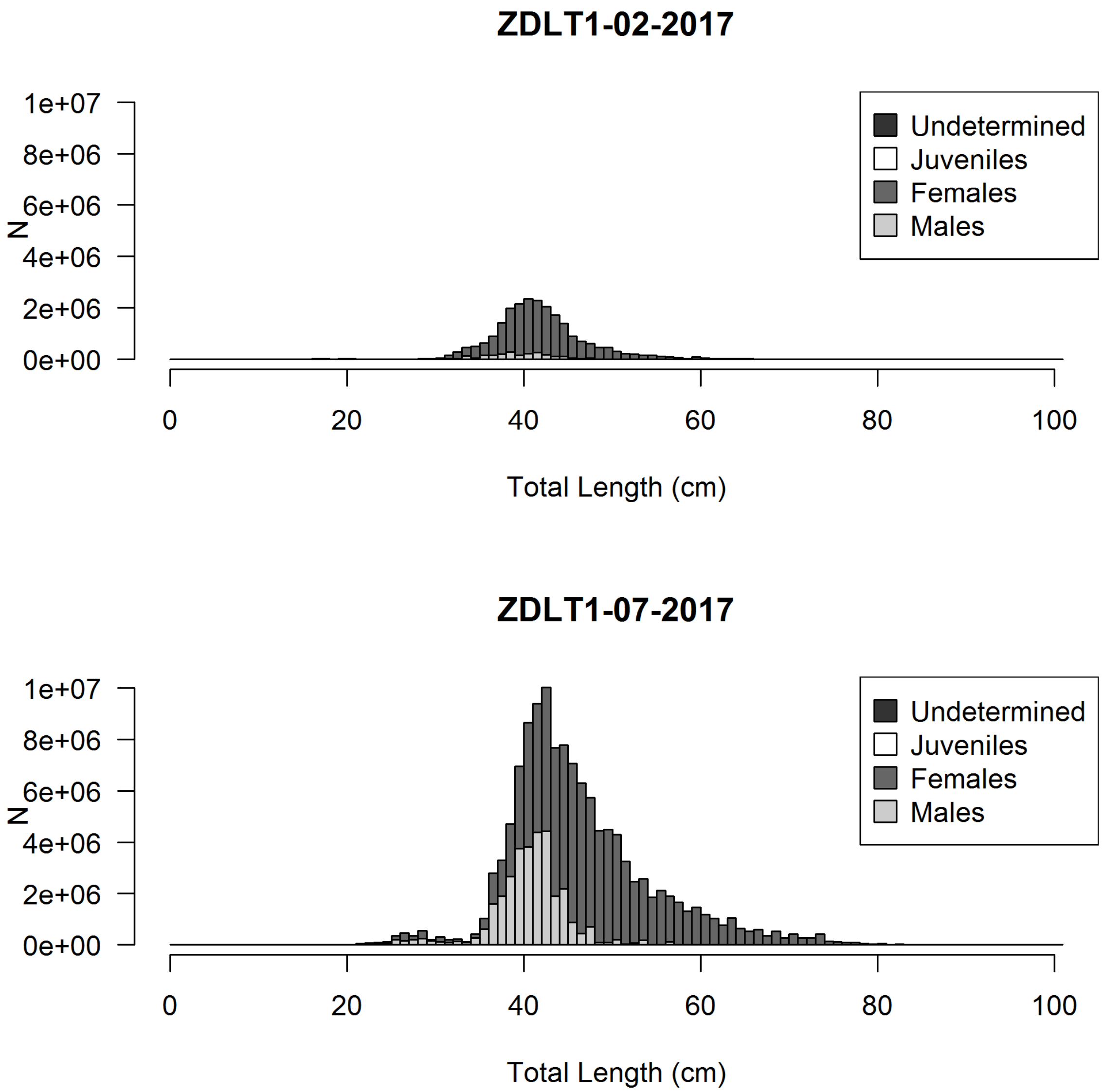


Figure 30: Length frequency histograms of common hake extrapolated to the estimated total biomass for February and July 2017.

3.5.2 Common rock cod

Common rock cod biomass was estimated using density–at–station ranging from 3.6 kg·km^{-2} to 985 kg·km^{-2}. Observed densities were Box–Cox transformed (λ=0.5) and the experimental variogram was plotted with 44 distance classes (Figure 31). The variogram model that best fitted the data was spherical with no nugget effect, a range of 87 km and reached the sill at 180. The average kriged density was 133 kg·km^{-2} and ranged from 7 to 917 kg·km^{-2}. Finally, the estimated total biomass on the survey zone was 12,883 t. Biomass of rock cod first increased from 2010 to 2011, from 606,736 t to 739,867 t but then decreased significantly to 221,500 t in 2014 (estimated in October). In 2015 and 2016 a non–significant decrease was observed to 190,371 t followed by a significant decrease in 2017 to reach 75,379 t and 12,883 t in February and July respectively. The estimated number of rock cod in the water also decreased over the period but to a lesser extent highlighting a change in the size structure of the stock with an increase of abundance of small animals. Inter–seasonal comparison presented on Figure 32 shows that the number of fish in July decreased as well as the size. Only one cohort appears on the length frequency for July and it seems that fish between 20 and 30 cm that were observed in February were absent from the surveyed zone.

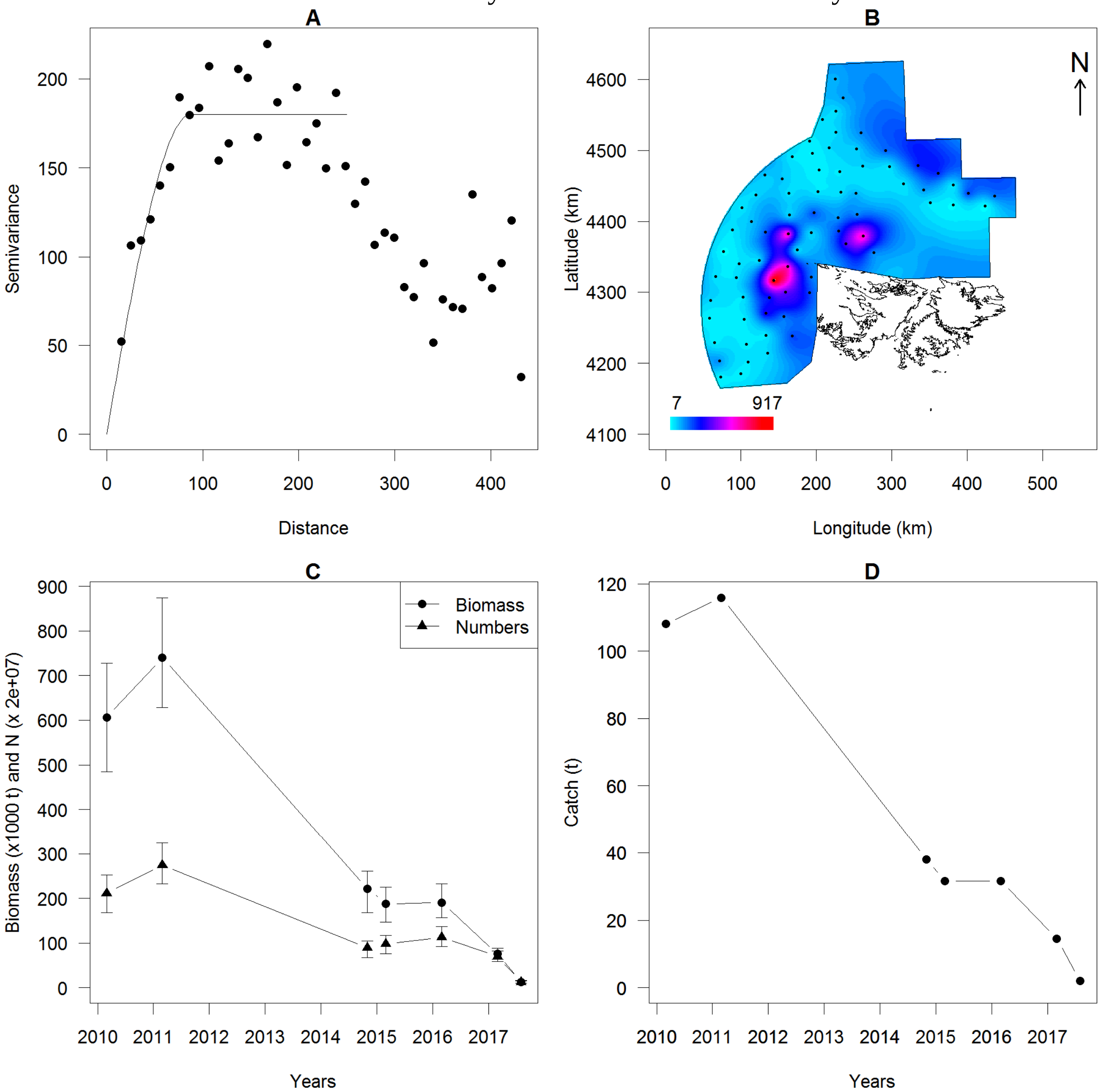


Figure 31: Experimental variogram with spherical model fitted (A), kriged map of rock cod density (B), time series of estimated biomass and abundance of fish (with associated 95% confidence intervals) using the ground fish surveys conducted from 2010 (C) and total catch of each survey (D). Biomass and abundance estimations in 2014 and 2017 second season were carried out in October–November and July respectively and illustrate the seasonal trends.

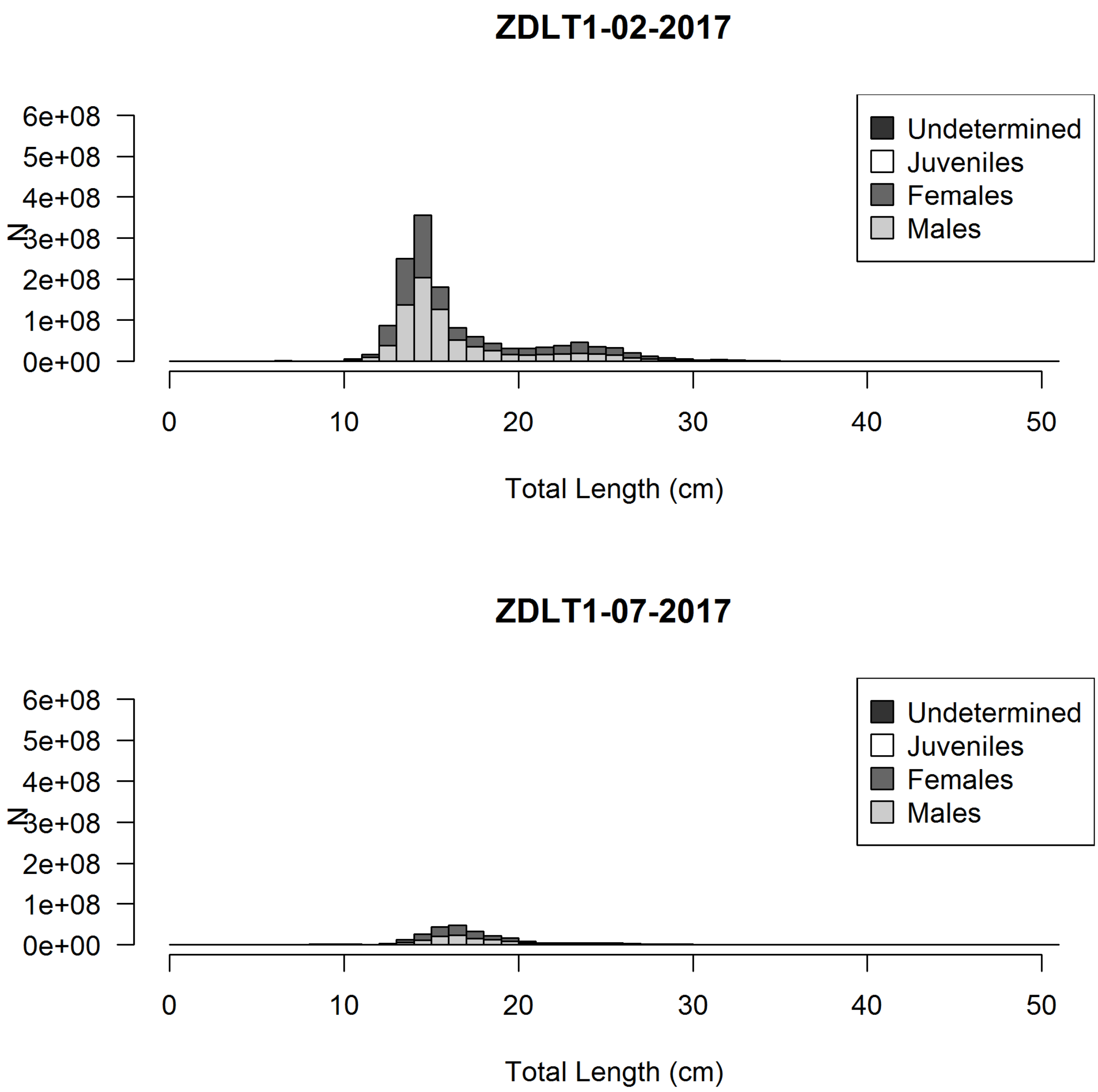


Figure 32: Length frequency histograms of common rock cod extrapolated to the estimated total biomass for February and July 2017.

3.5.3 Red cod

Red cod observed densities ranged from 0.2 kg·km^{-2} to 1,951 kg·km^{-2}. These densities were Box–Cox transformed (λ=0.5) and used to plot the semi–variogram using 18 distance classes (Figure 33). The best variogram model was spherical and reached the sill (297) at a range of 38 km. The average kriged density was 121 kg·km^{-2} and the biomass estimation was 11,694 t. Three hot spots were identified throughout the survey, two in the north of the survey zone and one to the west of West Falkland, the latter exhibiting a lower abundance than the formers. From 2010 to 2016, red cod biomass varied but was not significantly different between years. However, in February 2017, a significant decrease in biomass and abundance was observed. In July, the biomass was significantly lower and the abundance did not decrease as much as the biomass. This is further highlighted by the length frequency histogram that shows a decrease of abundance for fish >30 cm (Figure 34).

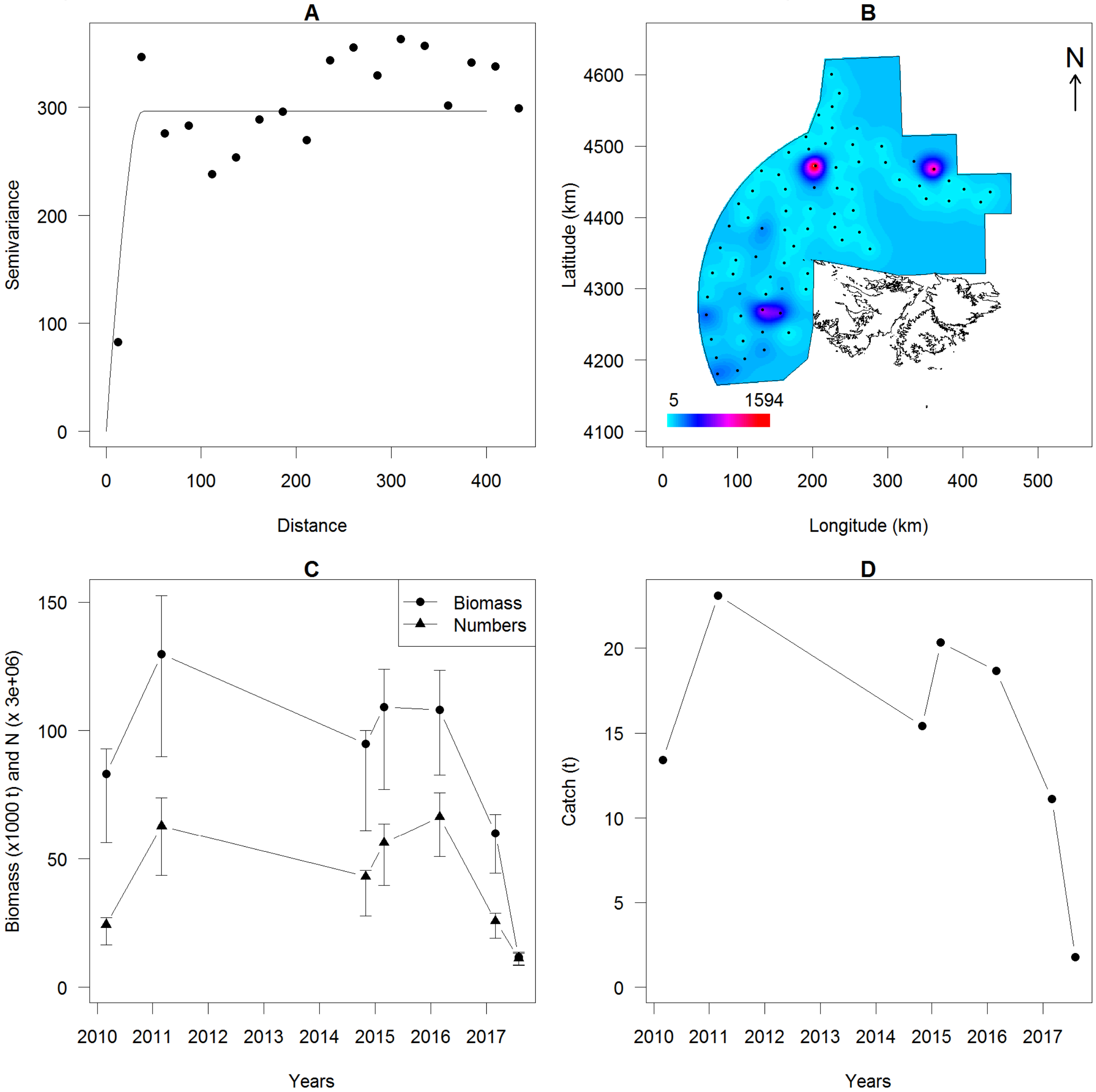


Figure 33: Experimental variogram with spherical model fitted (A), kriged map of red cod density (B), time series of estimated biomass and numbers of fish (with associated 95% confidence intervals) using the ground fish survey conducted from 2010 (C) and total catch of each survey (D). Biomass and abundance estimation in 2014 were carried in October–November and illustrate the seasonal trends.

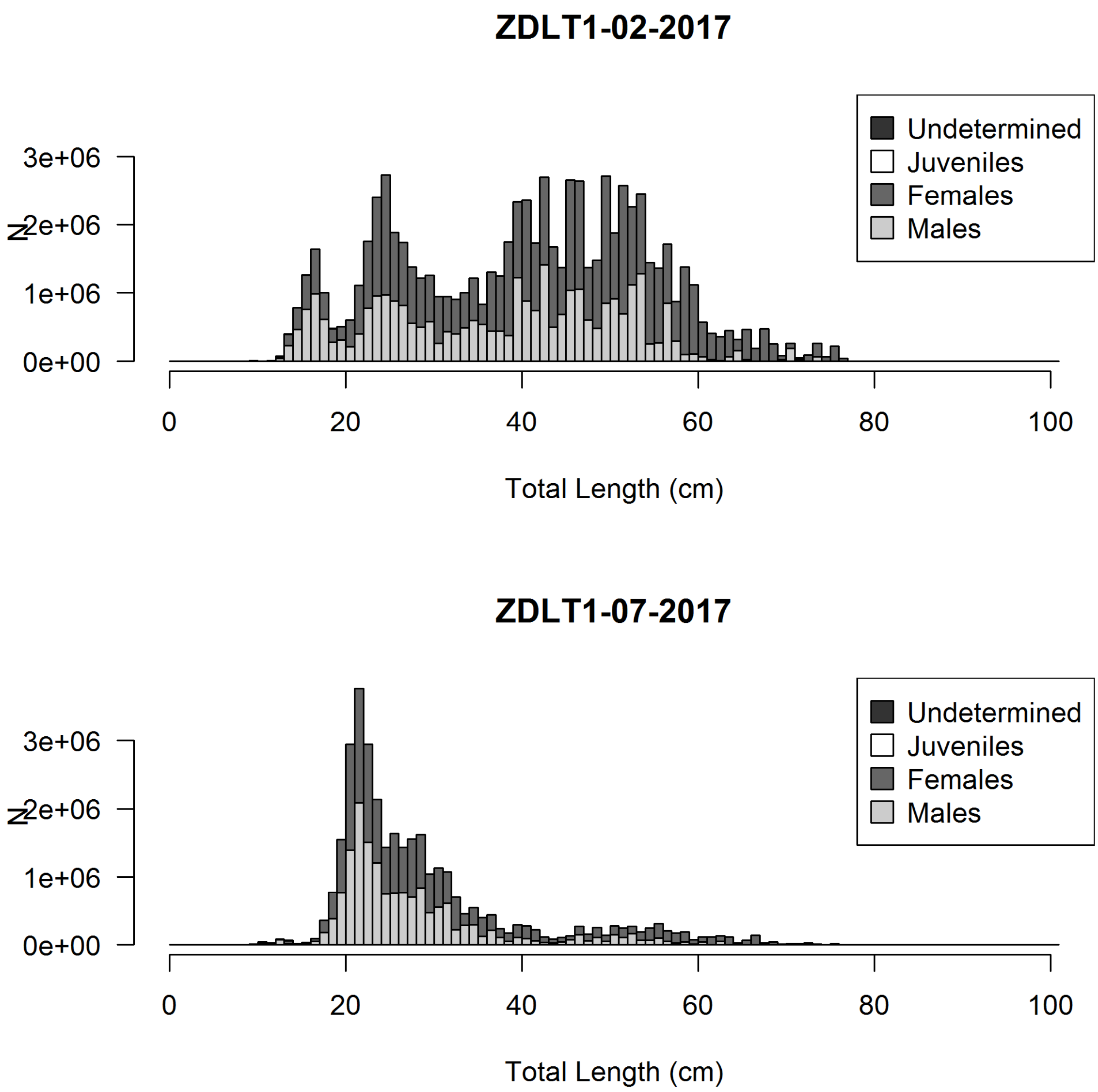


Figure 34: Length frequency histograms of red cod extrapolated to the estimated total biomass for February and July 2017.

3.5.4 Southern blue whiting

Southern blue whiting was caught at 16 stations. The observed densities ranged from 0.09 $kg \cdot km^{-2}$ to 666 $kg \cdot km^{-2}$. Observed densities were used to plot a semi–variogram after Box–Cox transformation (λ=0.5) and using 25 distance classes (Figure 35). The model that best fitted the data was the spherical model without any nugget effect. The variogram was fitted to a maximum distance lag of 200 km. The model reached the sill (14) at a range of 32 km. The kriged density ranged from 0 to 537 $kg \cdot km^{-2}$, averaging 5.4 $kg \cdot km^{-2}$. The biomass estimation was 519 t across the survey area. Southern blue whiting was only caught in the north of the surveyed zone and one station exhibited a high density. Southern blue whiting biomass was stable in 2010 and 2011 and then followed a decreasing trend until July 2017. The abundance did not follow the same trajectory as the biomass, decreased first in 2010 and 2011, then increased until February 2016. The lowest abundance was reached in February 2017 and was followed by an increase in July. The length frequency histogram shows that in February 2017, at least 3 cohorts were sampled while only the smallest one appeared in July samples (Figure 36).

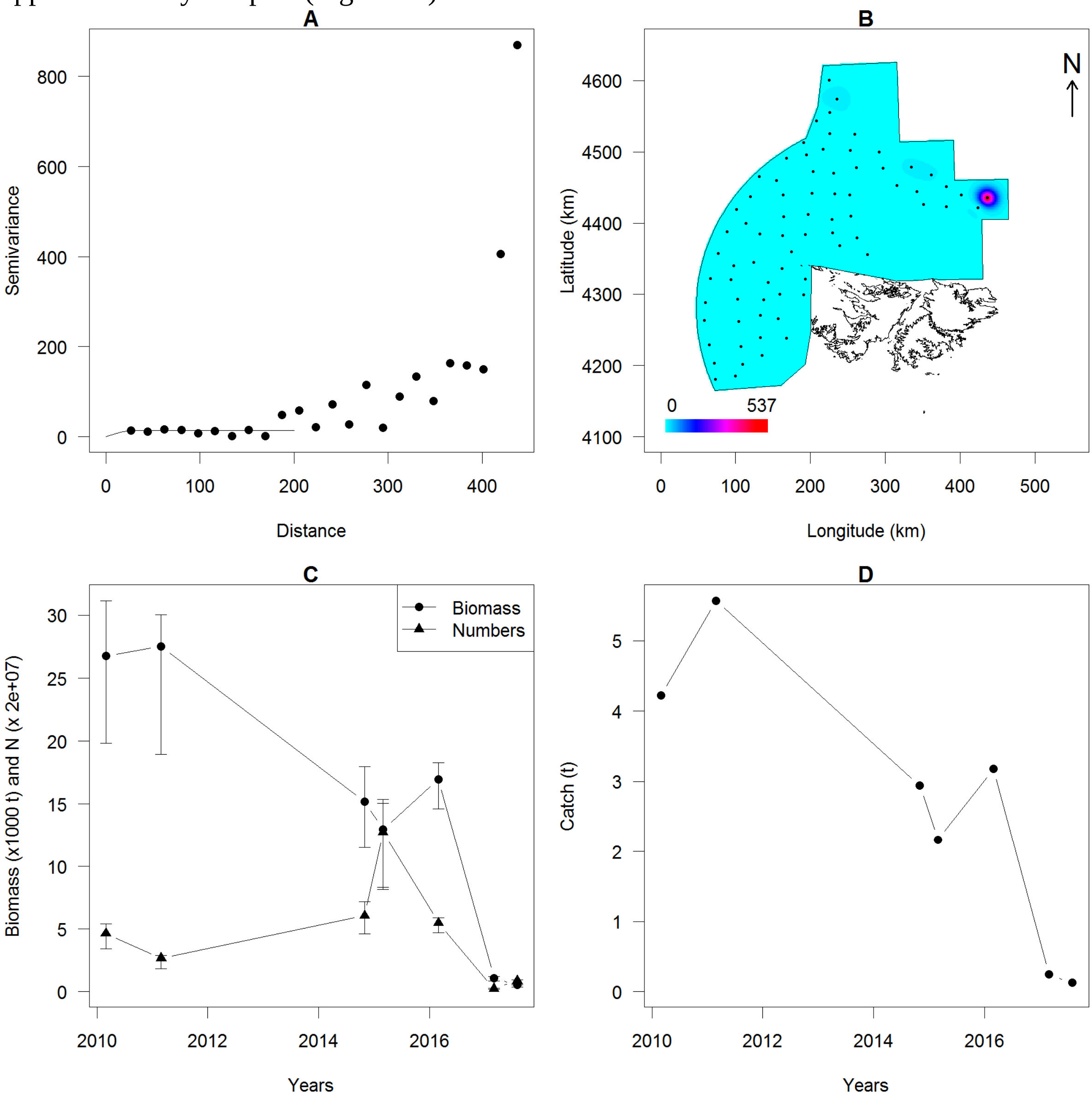


Figure 35: Experimental variogram with spherical model fitted (A), kriged map of southern blue whiting density (B), time series of estimated biomass and numbers of fish (with associated 95% confidence intervals) using the ground fish survey conducted from 2010 (C) and total catch of each survey (D). Biomass and abundance estimation in 2014 were carried in October–November and illustrate the seasonal trends.

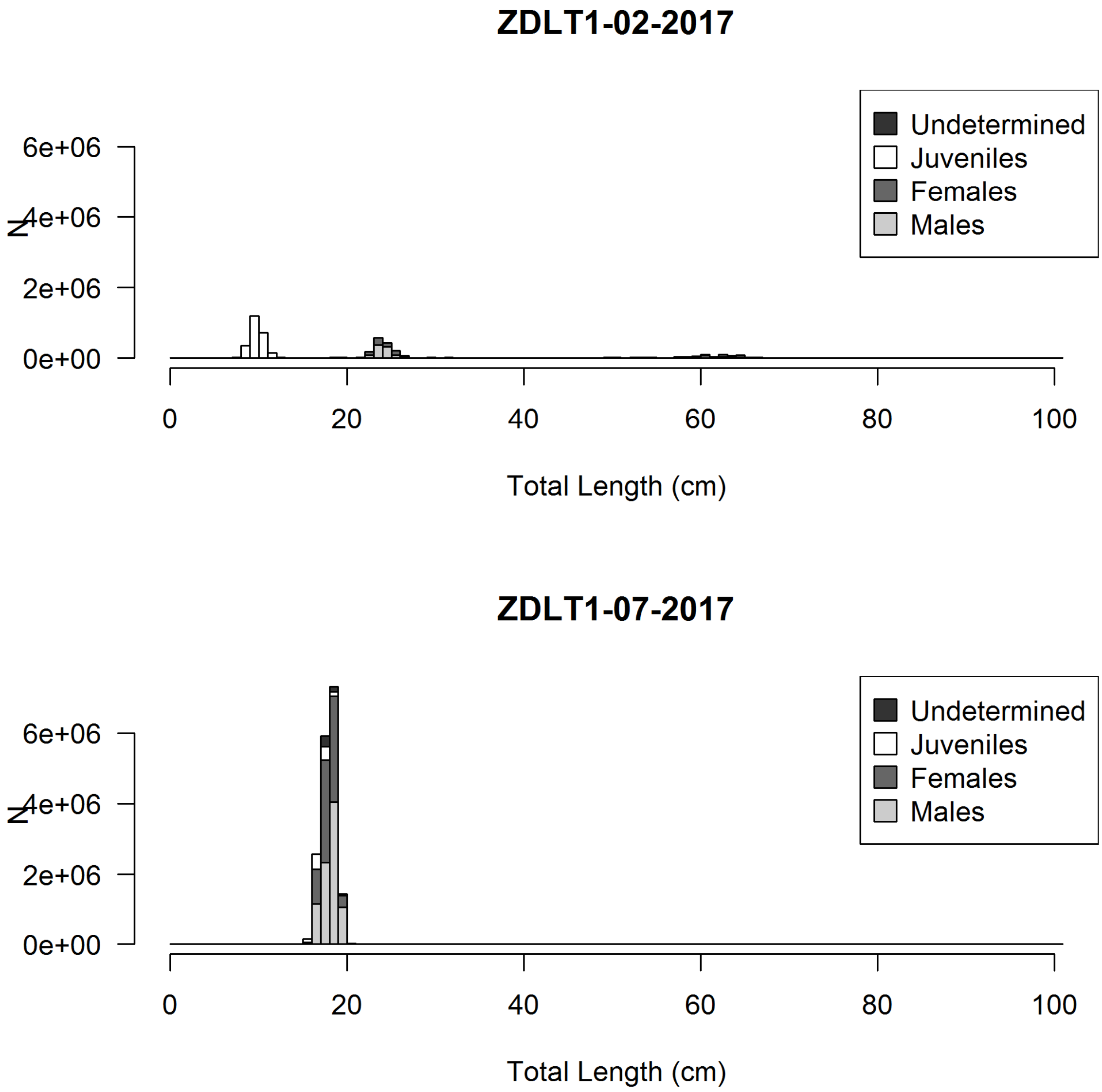


Figure 36: Length frequency histograms of southern blue whiting extrapolated to the estimated total biomass for February and July 2017.

3.5.5 Argentine shortfin squid

Observed densities of Argentine shortfin squid ranged from 0.09 to 11.6 kg·km^{-2}. The semi–variogram was plotted with 10 distance classes and an exponential model with a nugget effect (0.97) was fitted (Figure 37). It reached the sill (1.75) at 153 km. The averaged kriged density was 1.4 kg·km^{-2} ranging from 1 to 5 kg·km^{-2}. The total estimated biomass was 139 t. In July, highest densities were observed at three stations, two to the west of West Falkland and one to the north in the FOCZ. Over the years that the ground fish survey has been conducted, *Illex argentinus* biomass ranged from 19 to 13,116 t. The only exception was observed in 2015 when the biomass estimation was 217,371 t prior to the record catch taken in the fishery by jiggers and trawlers. The length frequency histograms that compare abundances in February and July show the decrease in abundance of the shortfin squid between February and July (Figure 38). Moreover, the cohorts seen in February were absent from the survey zone and a new cohort (mode at 12 cm) was present in Falkland waters.

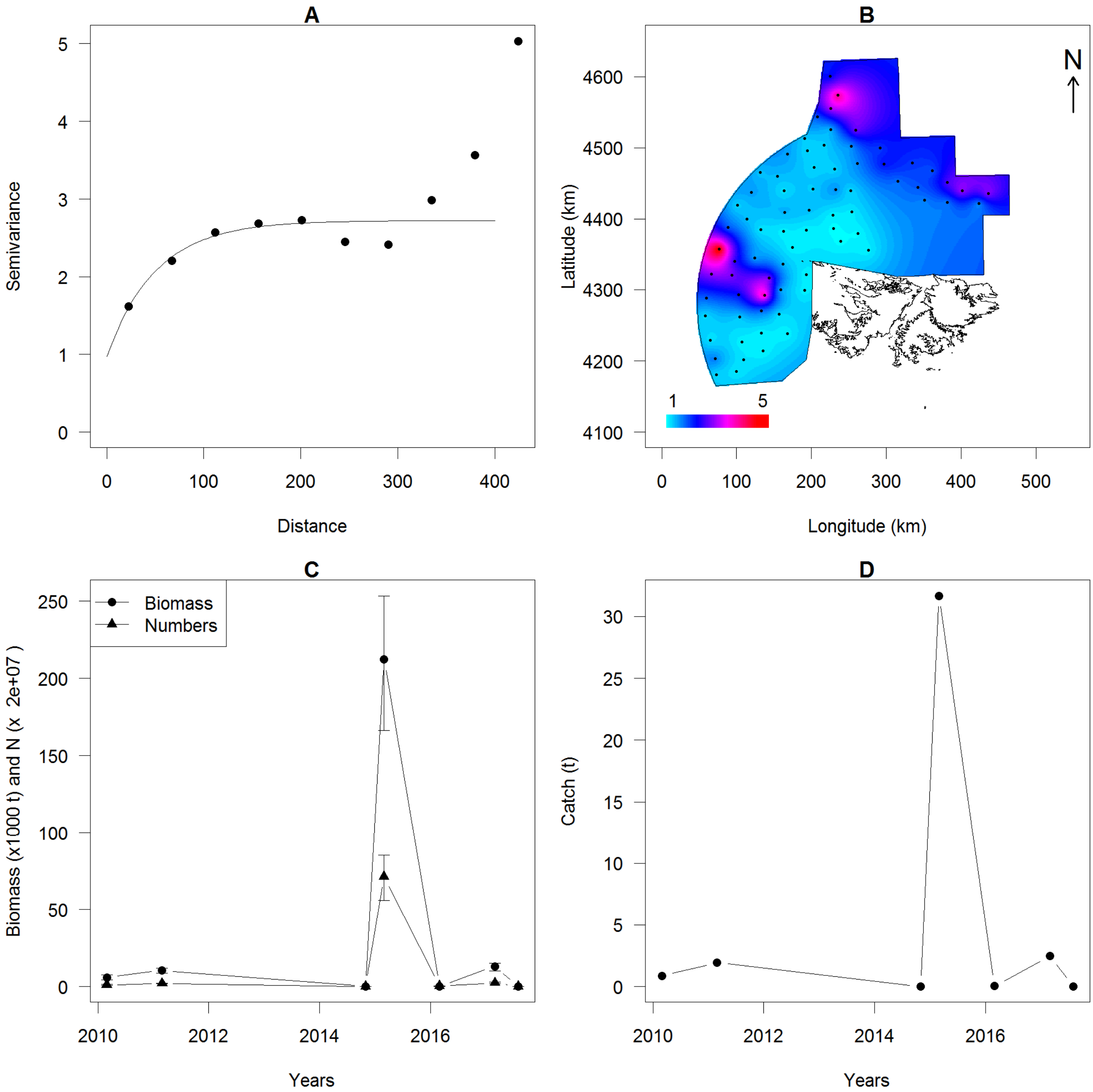


Figure 37: Experimental variogram with exponential model fitted (A), kriged map of Argentine shortfin squid density (B), time series of estimated biomass and numbers of fish (with associated 95% confidence intervals) using the ground fish survey conducted from 2010 (C) and total catch of each survey (D). Biomass and abundance estimation in 2014 were carried in October–November and illustrate the seasonal trends.

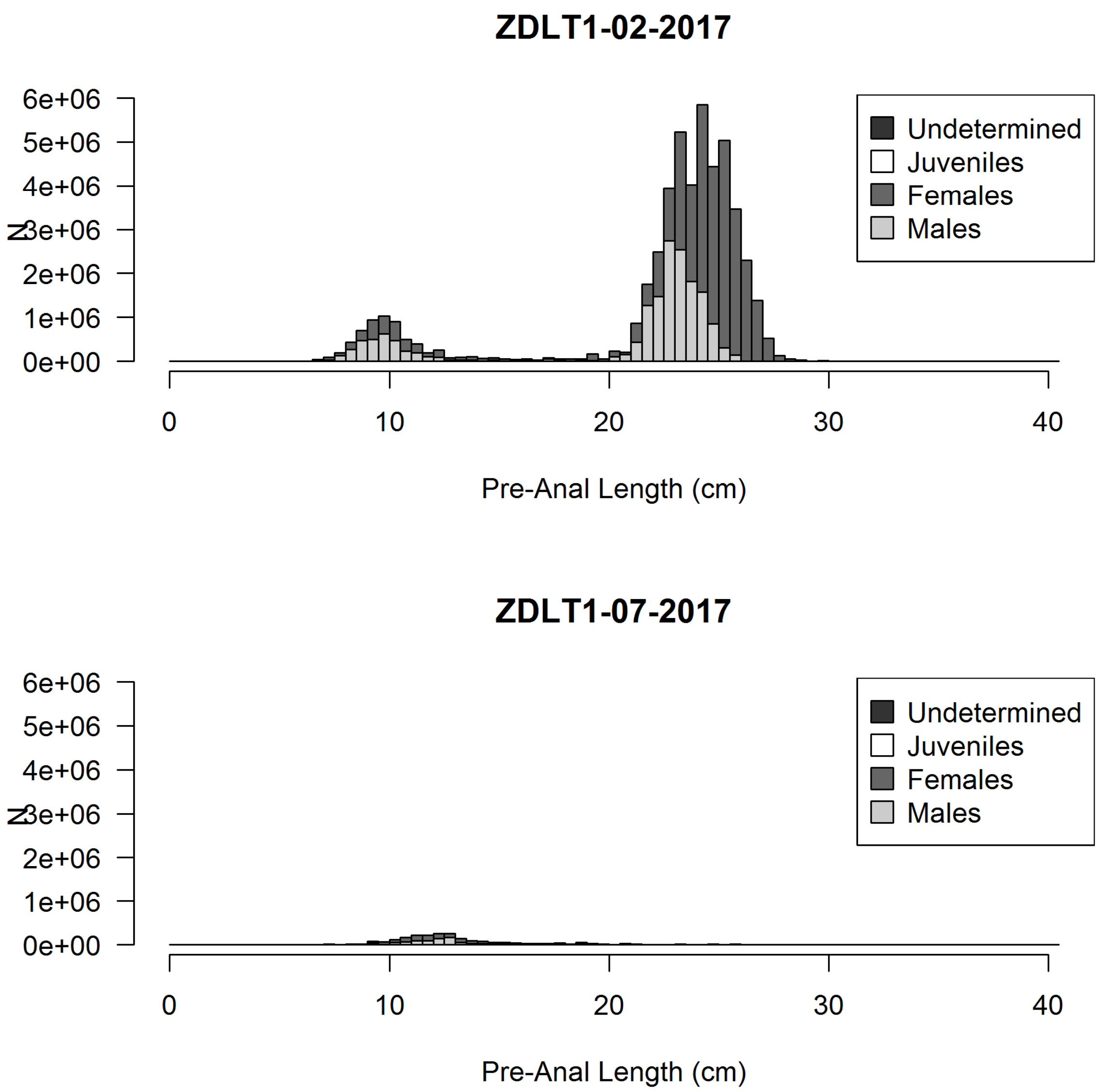


Figure 38: Length frequency histograms of Argentine shortfin squid extrapolated to the estimated total biomass for February and July 2017.

3.5.6 Kingclip

Observed densities for kingclip ranged from 1.5–6801 kg·km^{-2}. These densities were Box–Cox transformed (λ=0.5) and used to plot a semi–variogram with 39 distance classes. The best model that fitted the data was spherical with no nugget effect. The model reached the sill (869) at 53 km. The kriged densities ranged from 8 kg·km^{-2} to 5,563 kg·km^{-2} and averaged 270 kg·km^{-2}. The biomass estimation was 26,133 t. Three hot spots were identified throughout the survey in the southwest, west and north of the survey zone. From a temporal perspective, kingclip abundance increased from 2010 to 2011. In 2015 the highest abundance of the series was observed (91,884 t). A decrease was then observed until February 2017 and was followed by a non–significant increase in July 2017. Abundances increased more between February and July as fish were smaller in the July sample.

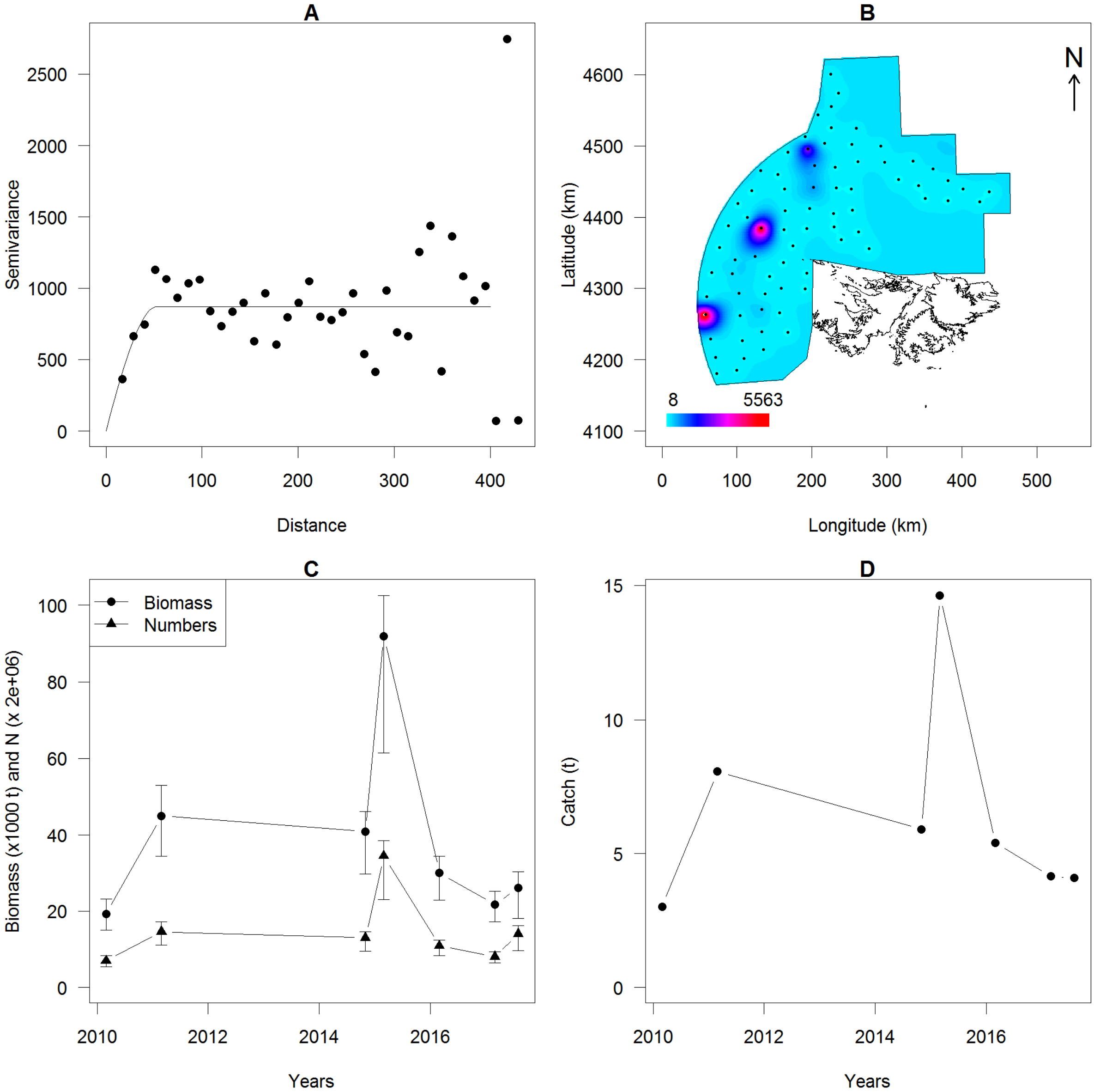
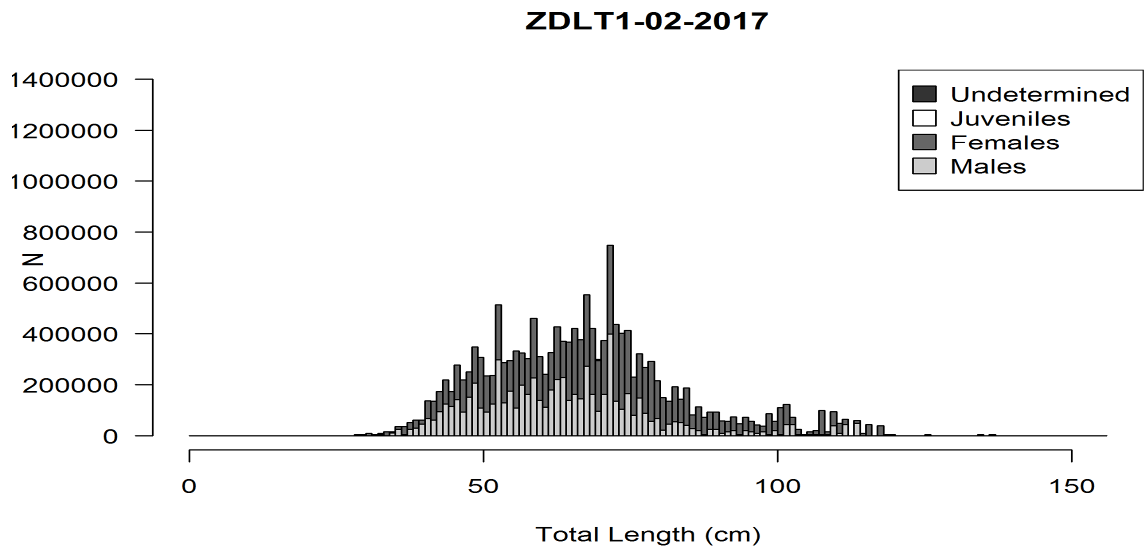


Figure 39: Experimental variogram with spherical model fitted (A), kriged map of kingclip density (B), time series of estimated biomass and numbers of fish (with associated 95% confidence intervals) using the ground fish survey conducted from 2010 (C) and total catch of each survey (D). Biomass and abundance estimation in 2014 were carried in October–November and illustrate the seasonal trends.



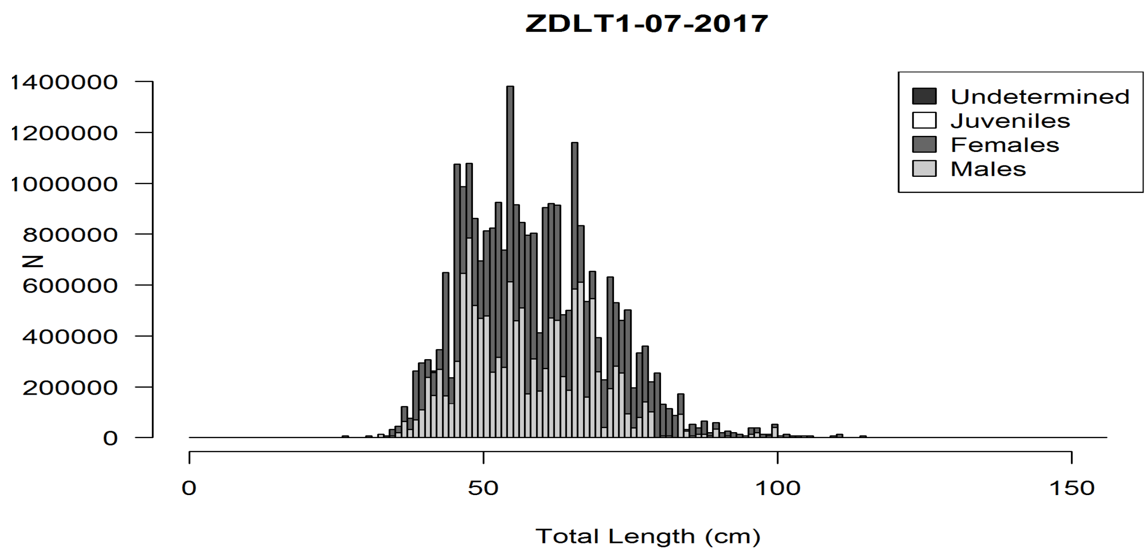


Figure 40: Length frequency histograms of kingclip extrapolated to the estimated total biomass for February and July 2017.

3.5.7 Toothfish

Toothfish observed densities ranged from 0.24–70 kg·km^{-2} and were Box–Cox transformed (λ=0.5) before using them to plot a semi–variogram with 30 distance classes (Figure 41). The model that fitted the best the data to a maximum distance of 200 km was spherical without any nugget effect. It reached the sill (20) at 139 km. Using this variogram model, the kriged density averaged 7.4 kg·km^{-2} ranging from 0 to 66 kg·km^{-2}. The total biomass was estimated to be 714 t. Highest biomasses of toothfish were observed in deep waters especially in the southwest of the survey zone where adults were taken. Another hot spot was found to the south of the Jason Islands inshore where small specimens were sampled. Biomasses as well as abundance were found to be stable between 2010 and 2011. However a significant decrease of the biomass was observed in 2015 followed by an increase and another decrease in 2016 and 2017. In July 2017, a further decrease of the biomass was observed but the abundance did not decrease as much. The length frequency histogram comparison shows that the proportion of small fish was higher in July (one cohort is well represented) than in February (at least three cohorts were sampled; Figure 42).

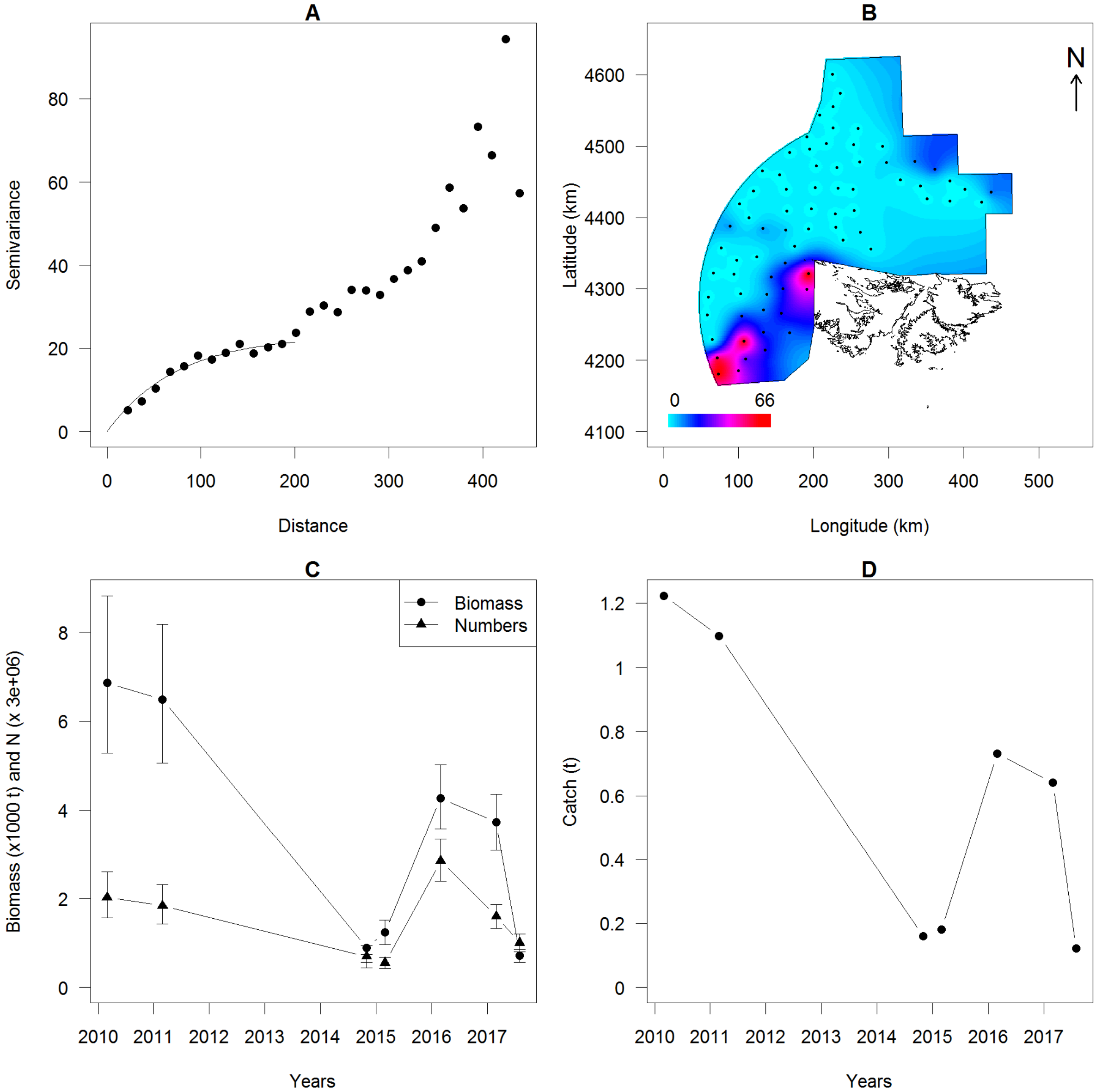


Figure 41: Experimental variogram with exponential model fitted (A), kriged map of toothfish density (B), time series of estimated biomass and numbers of fish (with associated 95% confidence intervals) using the ground fish survey conducted from 2010 (C) and total catch of each survey (D). Biomass and abundance estimation in 2014 were carried in October–November and illustrate the seasonal trends.

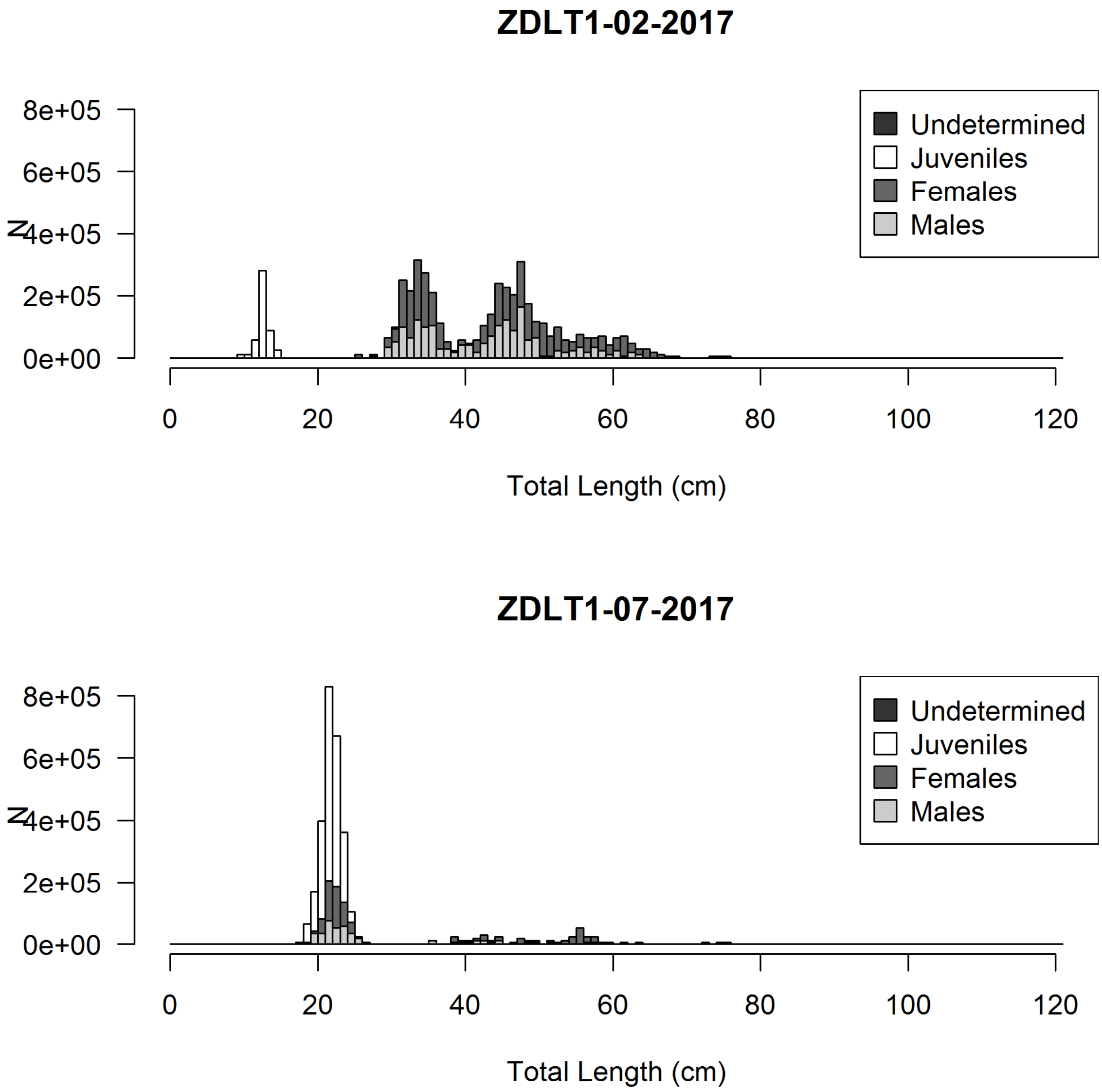


Figure 42: Length frequency histograms of toothfish extrapolated to the estimated total biomass for February and July 2017.

3.5.8 Falkland calamari

Falkland calamari catches ranged from 1.3 to 581 kg. Higher catches were observed to the north of the *Loligo* box and in the southwest of the surveyed zone. Densities ranged from 9 kg·km^{-2} to 2.8 t·km^{-2}. After Box–Cox transformation (λ=0.5), observed densities were used to plot the semi–variogram and the best model that fitted the data was Gaussian with a nugget effect of 172 (Figure 43). Its sill was 397 and was reached at 262 km. Kriged densities ranged from 77 to 1,250 kg·km^{-2} (average was 353 kg·km^{-2}). The estimated total biomass in the survey area was 34,169 t. Over the years, Falkland calamari biomass appeared to be stable in 2010, 2011 and 2014, decreasing in 2015 and then following an increasing trend to reach its maximum of the time series in July 2017. The length frequency histogram of February and July samples (Figure 44) show that the range of size in July was bigger than in February.

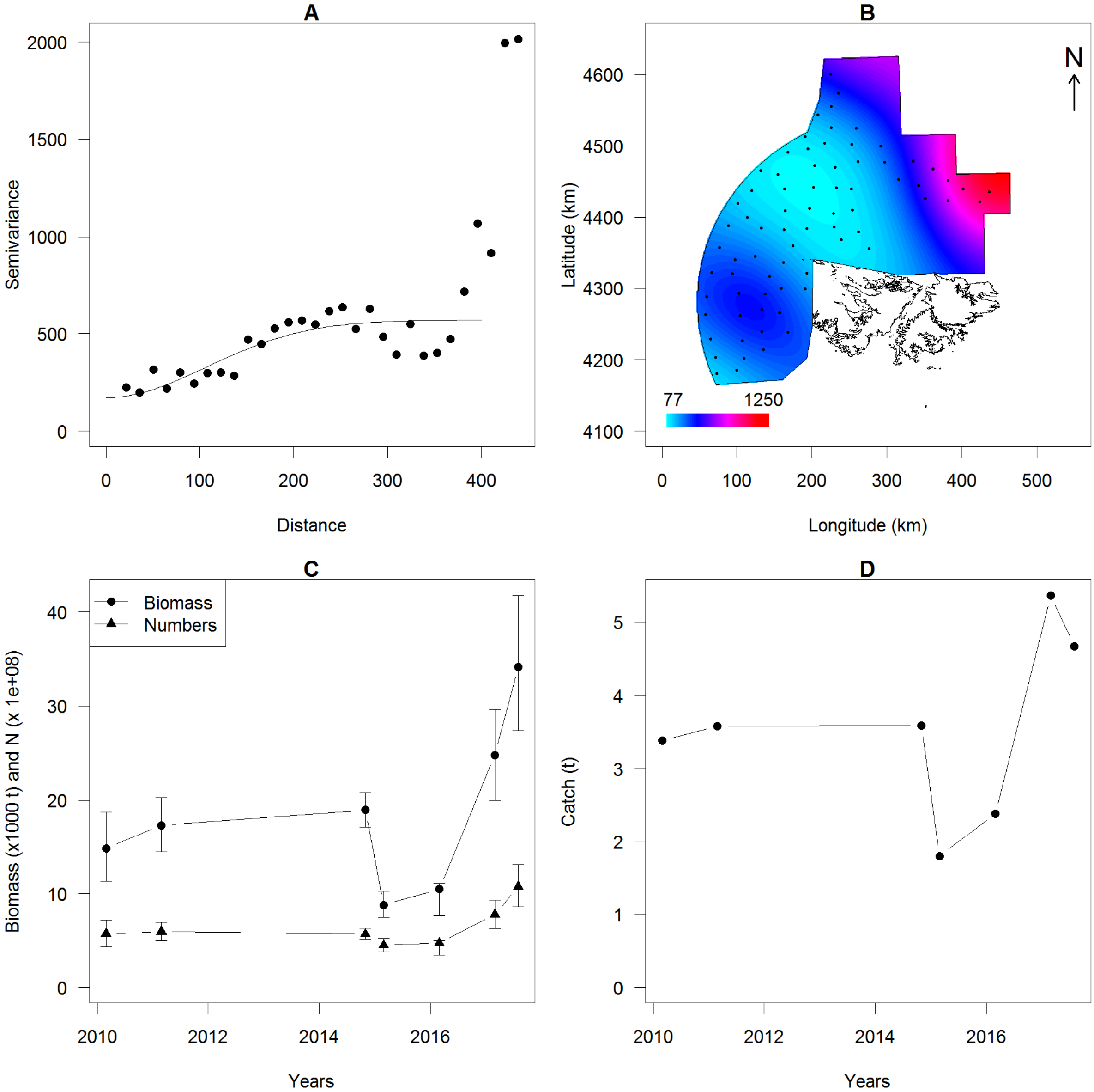
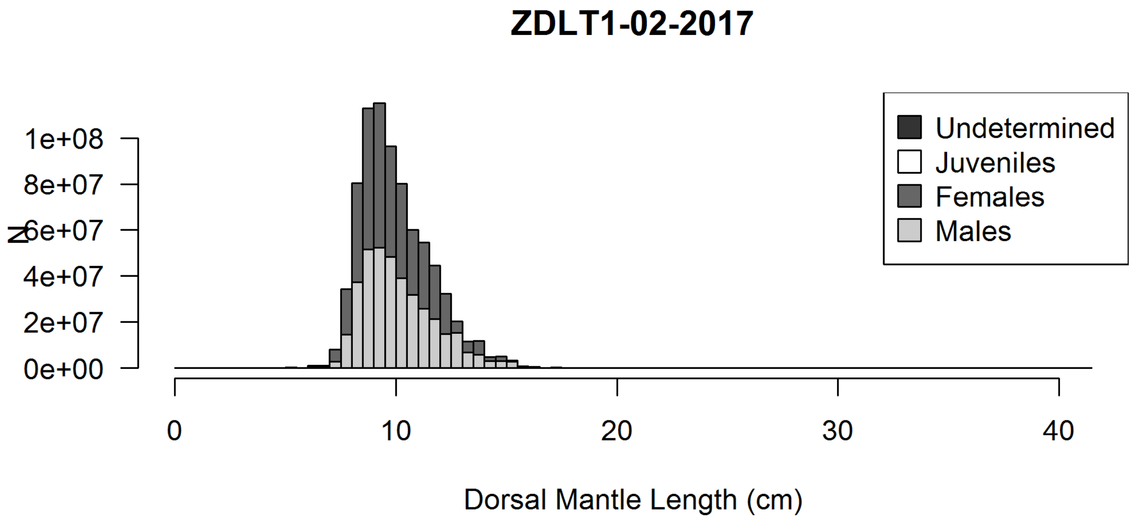


Figure 43: Experimental variogram with gaussian model fitted (A), kriged map of Falkland calamari density (B), time series of estimated biomass and numbers of fish (with associated 95% confidence intervals) using the ground fish survey conducted from 2010 (C) and total catch of each survey (D). Biomass and abundance estimation in 2014 were carried in October–November and illustrate the seasonal trends.



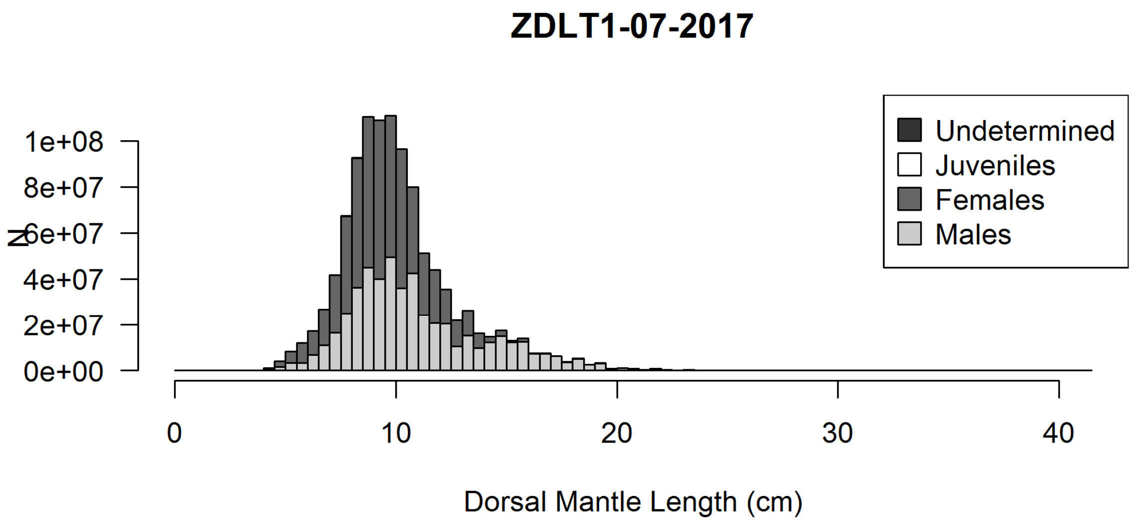


Figure 44: Length frequency histograms of Falkland calamari extrapolated to the estimated total biomass for February and July 2017.

3.5.9 Hoki

Hoki densities varied from 0.66 kg·km^{-2} to 12,670 kg·km^{-2}. After Box–Cox transformation with λ=0.5, a semi–variogram was plotted with 33 distance classes and the best model that fitted the data was exponential with no nugget effect (Figure 45). The sill (1,016) was reached at 40 km. The estimated kriged density averaged 318 kg·km^{-2} (ranging from 9 to 20,199 kg·km^{-2}). The total biomass on the survey area was 30,752 t. Most of the hoki was observed in the southwest of the survey zone in deep waters (>200 m) where hoki is usually abundant. Over the years 2010–2017, hoki biomass first decreased, albeit not significantly, between 2010 and 2011 (from 273,377 to 182,440 t). The biomass further decreased in 2015, increased in 2016 and decreased again in 2017. In July 2017, the biomass increased significantly compared to February and the abundance increased even more. As detailed on the length frequency histogram (Figure 46), the smallest cohort was the only cohort observed in July whereas at least 3 cohorts appeared in the February samples.

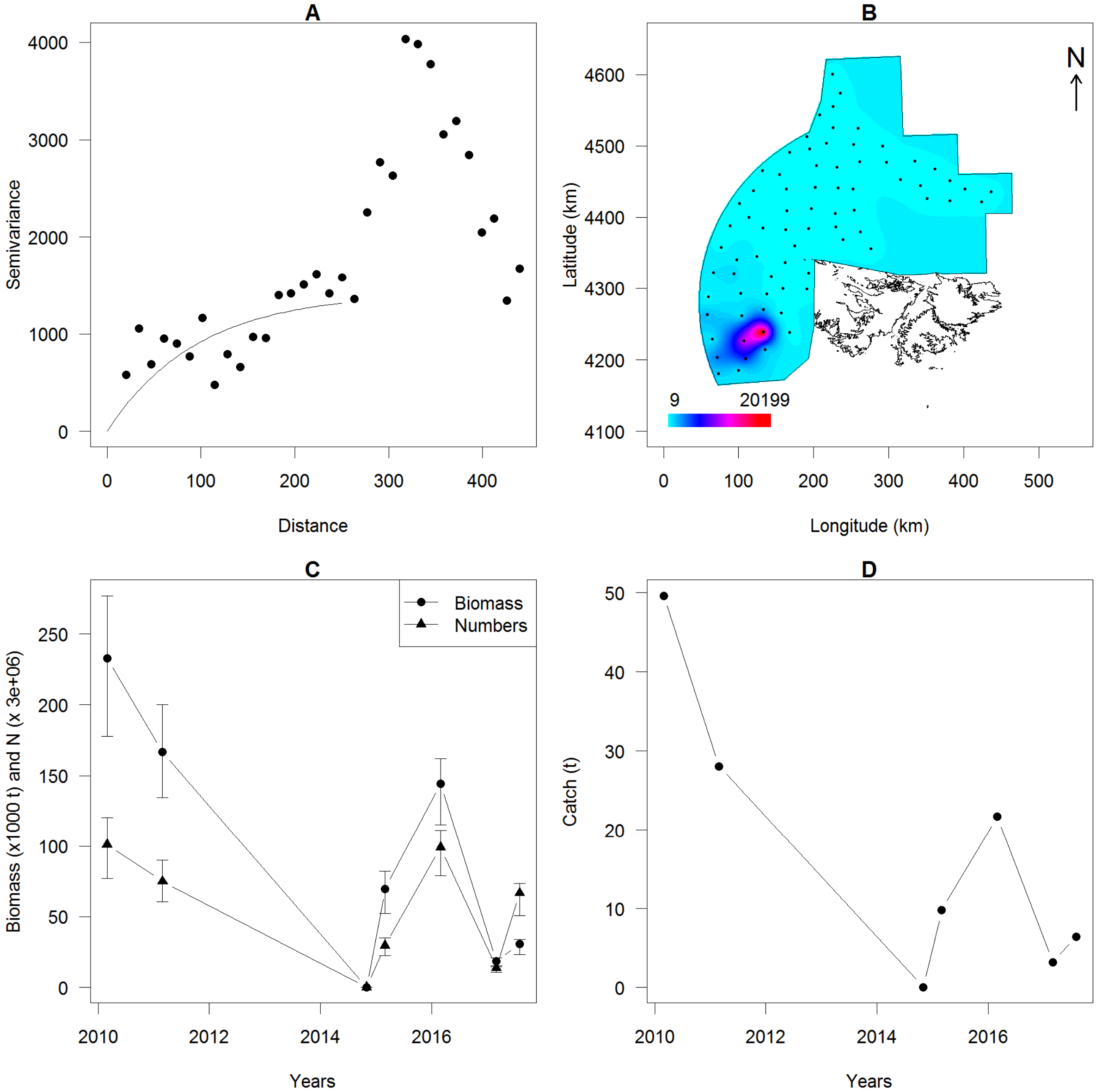


Figure 45: Experimental variogram with exponential model fitted (A), kriged map of kingclip density (B), time series of estimated biomass and numbers of fish (with associated 95% confidence intervals) using the ground fish survey conducted from 2010 (C) and total catch of each survey (D). Biomass and abundance estimation in 2014 were carried in October–November and illustrate the seasonal trends.

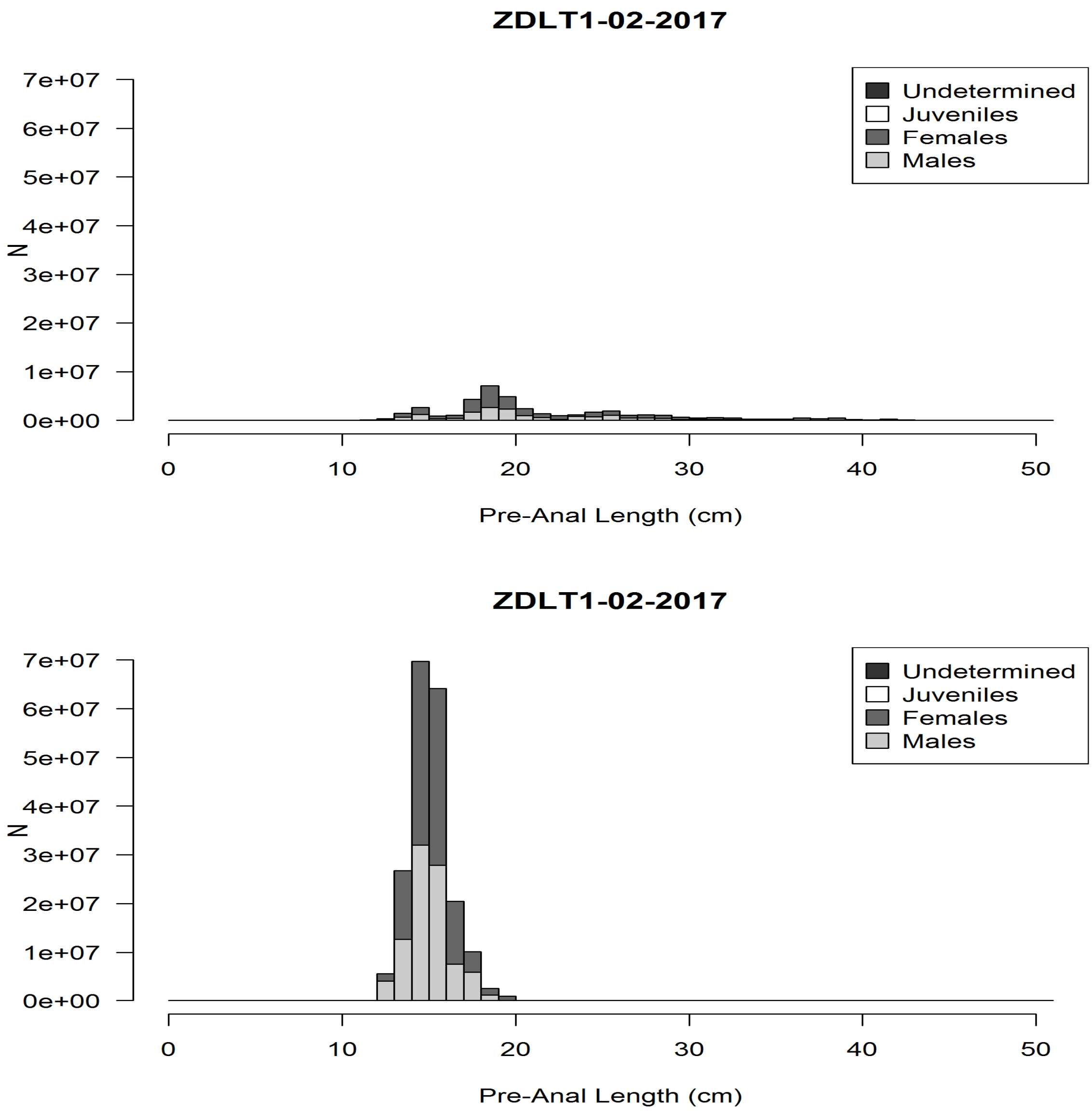


Figure 46: Length frequency histograms of hoki extrapolated to the estimated total biomass for February and July 2017.

3.6 Oceanography

Oceanographic data were collected at 74 stations throughout the survey. The area covered ranged from 48° 37.8'S to 52° 22.9'S and 57° 58.5'W to 63° 22.2'W. Good data were collected on all the down–casts. Figure 47 shows the location of the stations.

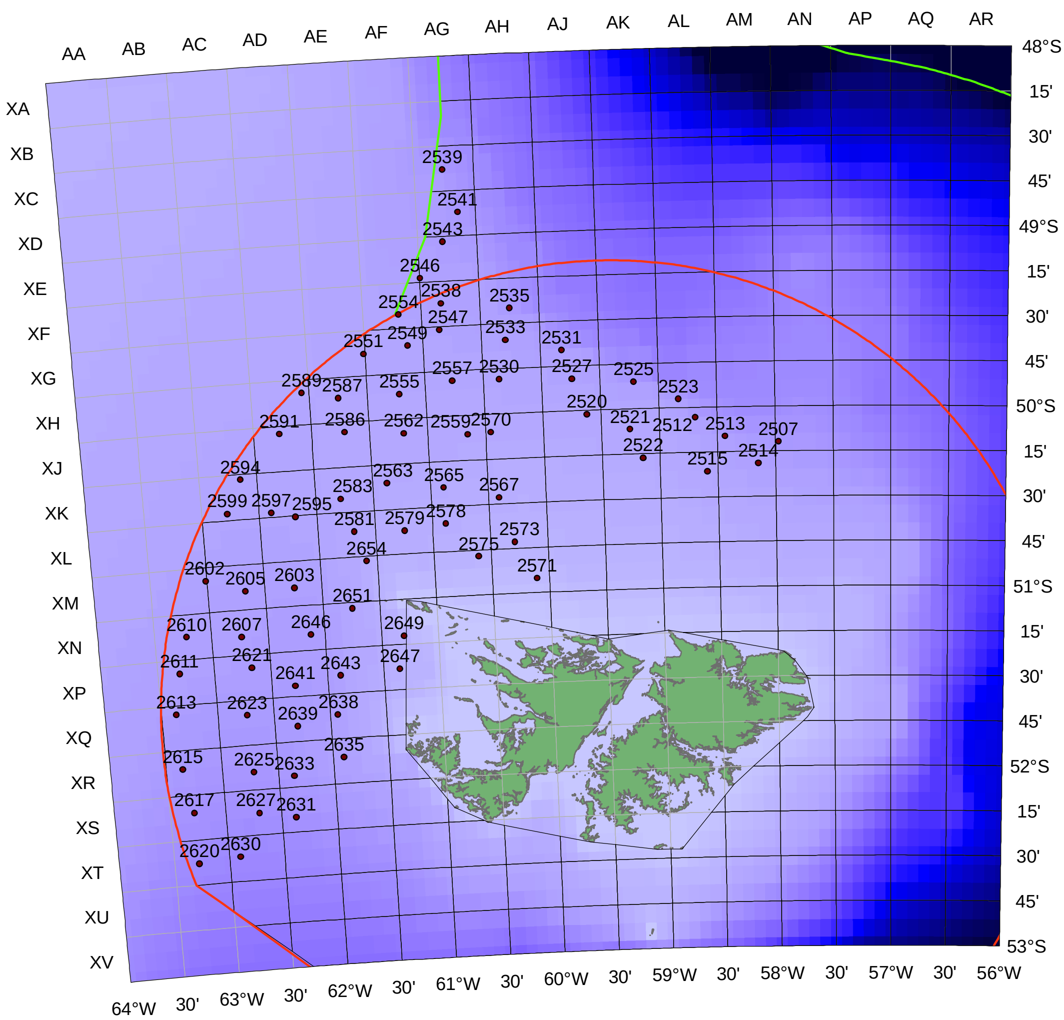


Figure 47 Location and number of CTD stations

Figure 48, Figure 49 Figure 50 show the temperature, salinity and σ–t density, gridded using ODV4 DIVA[1] gridding algorithm, at depths 10, 50, 100 and Seabed. The first layer at 10 m is the shallowest depth common to all CTD casts. The surveyed area covered depth range from 133 to 277 m.

Overall the seasonal influences have reduced the oceanic variability, with temperature and salinity fairly steady through the water column. The only real variation occurs in the southwest where the western branch of the Falklands Current is in evidence at the sea bed, pushing under the shelf water.

The temperature data (Figure 48) shows cold water flows in from the southwest, unlike the February cruise there is no warm water gyre over the shelf to the north of the Falklands. Overall the temperature range is very short, with a minimum measured temperature of 5.56°C (interpolation suggests a value of 4.9°C in the mapped area) at seabed and a maximum temperature of 7.06°C (7.3°C interpolated over mapped area) at the surface. There is little variation in the temperature profile at each station at 2 stations the temperature range exceeds 1°C, at 5 station the range exceeds 0.75°C and at 11 stations the range exceeds 0.5°C.

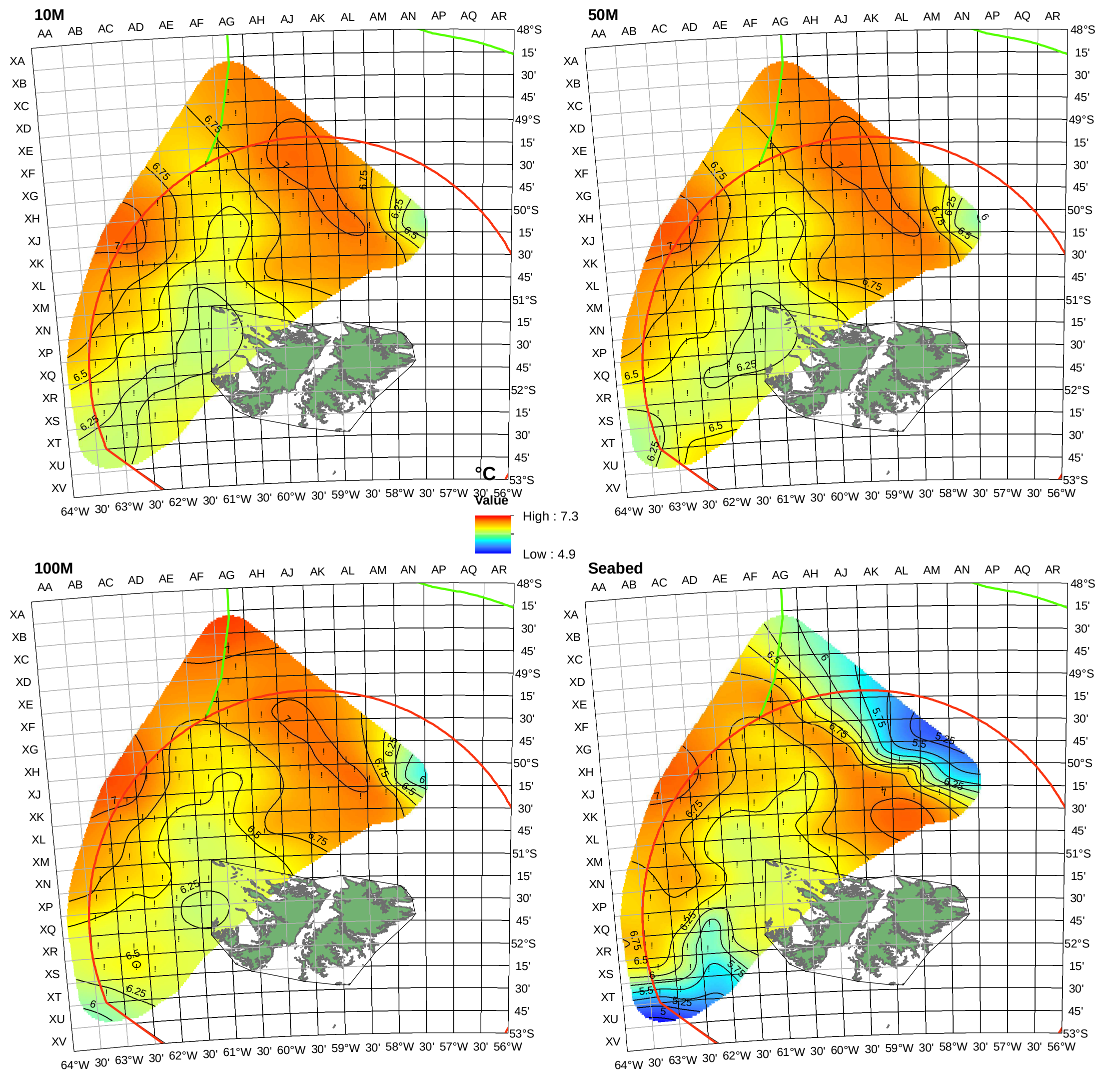


Figure 48 Temperature at 10m, 50m, 100m and seabed (contours at 0.25°C)

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

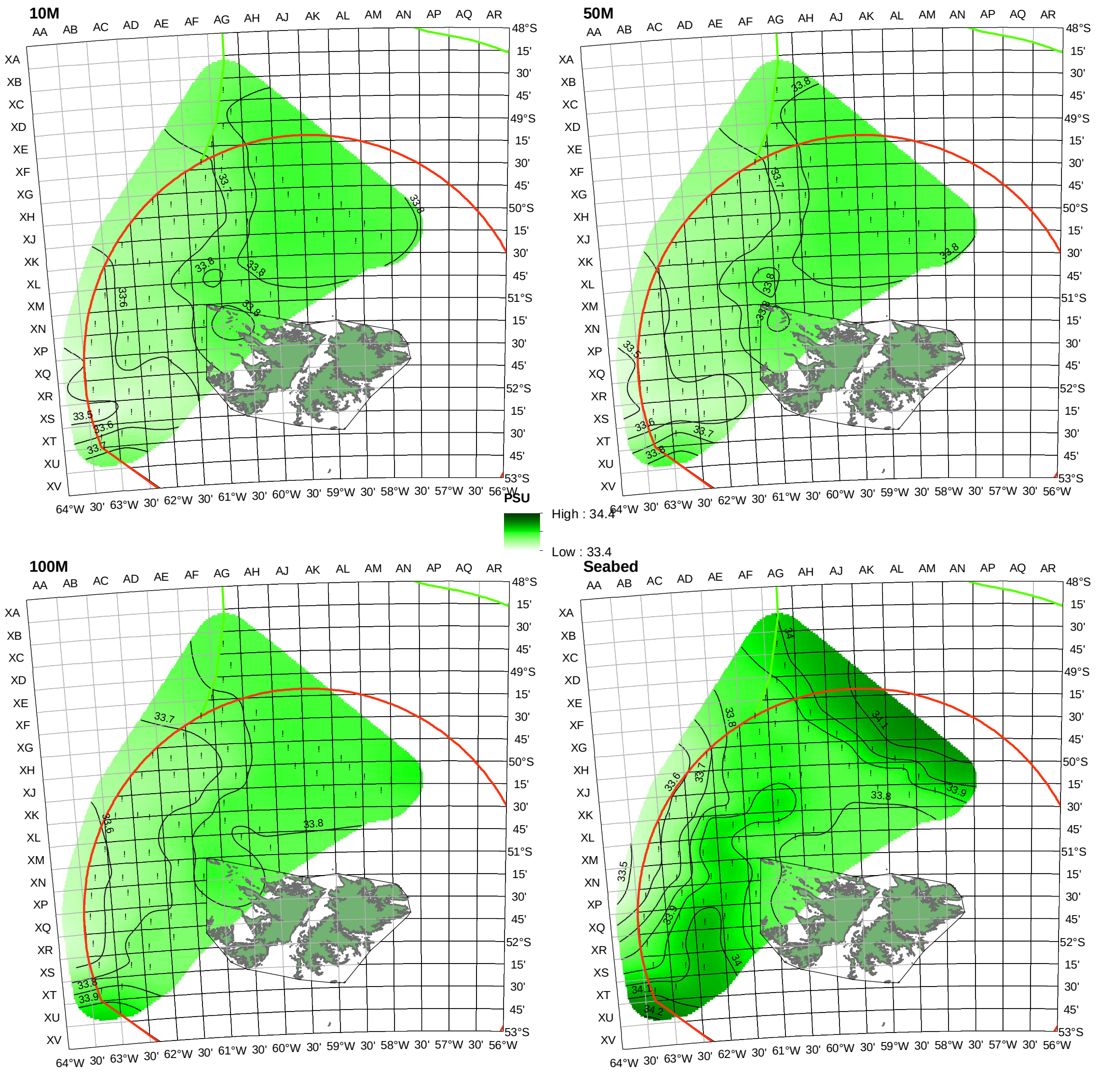


Figure 49 Salinity at 10m, 50m, 100m and seabed (contours at 0.05 PSU)

Figure 49 shows the salinity over the surveyed area. At surface the salinity is fairly stable 33.5 and 33.8 PSU. As depth increases there is a greater variation, with significant differences at the seabed. At seabed, salinity is higher the water close to the 2 branches of the Falklands Current. The waters to the north east along the shelf and in the trough to the south west show measured salinity greater than 34.1 PSU. It is possible to clearly see the colder more saline water from the eastern branch of the Falklands Current.

The density map (Figure 50) shows lowest density water at 10 metres over the shelf. As depth increases density increases slowly, however it is only at the seabed that the density shows any variation, with the same water mass to the south-west and north-east of the islands in the deep water, below the less dense shelf water seen in the surface and 50 m depth map.

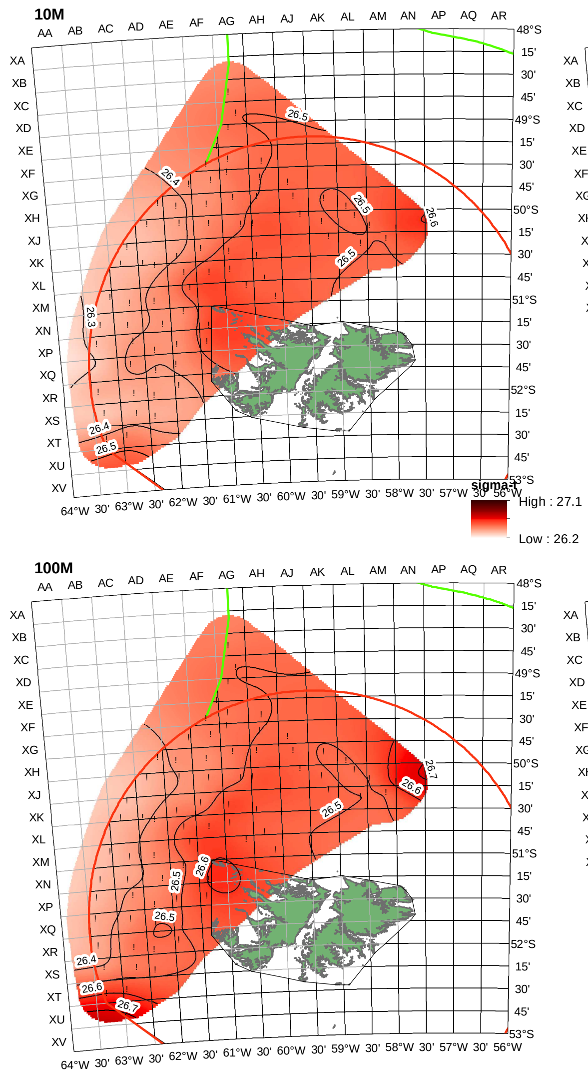


Figure 50 Density at 10m, 50m, 100m and seabed (contours at 0.05 sigma-t)

Figure 51 shows the oxygen level at 10, 50, 100 and seabed in ml/l of water. Oxygen concentration is highest at the surface, with levels of 6.2-6.7 ml/l over area. In deeper water the oxygen levels fall slightly with the range between 6.1 and 6.6 ml/l at 100 meters. On the seabed the in contrast to the February survey (where the west branch of the Falklands Current brought higher levels of oxygen) the oxygen level is lower. There is also a marked low to the north of the Falklands where the lowest oxygen levels are at 5.39 ml/l. The CTD Profiles to the north and west of this showed a marked decrease in O2 at 90 to 110 m from c 6.5 ml/l to between 6.0 and 5.5ml/l. the low oxygen stream matches closely to the high Salinity path to the west of the Falklands. However the sudden drop in O2 is far more prominent than the rise in Salinity around stations 2567 and 2570.

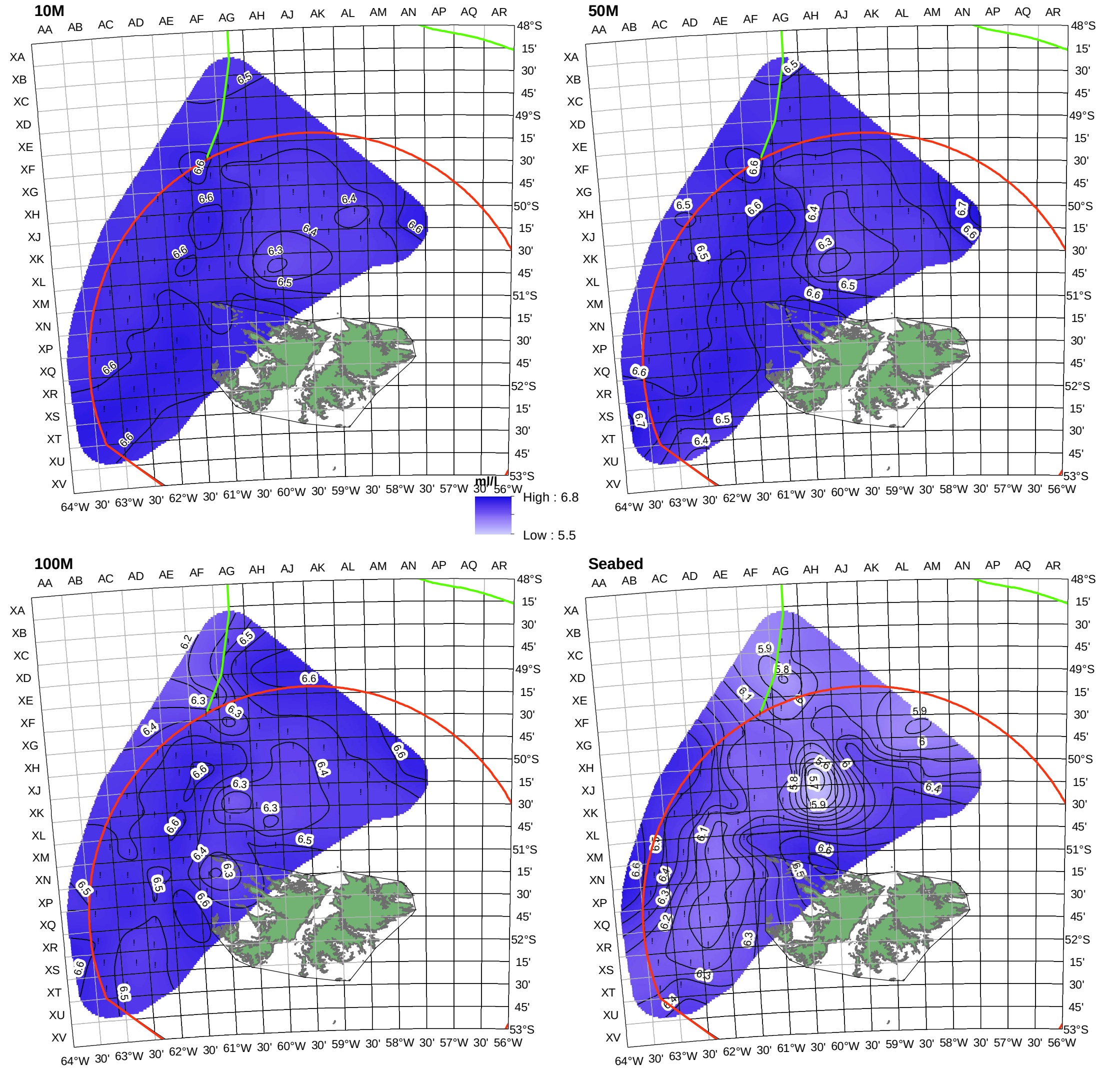


Figure 51 Oxygen at 10m, 50m, 100m and 200m (contours at 0.1ml/l)

4.0 Discussion

The survey conducted from 10 to 27 July 2017 was the 7^{th} ground fish survey since 2010. Five surveys were conducted in February and one in October–November 2014. This year was the first time a ground fish survey took place in July concurrent to the second season *Loligo* pre–recruitment survey. The data collected throughout this survey gave a new insight into the Falkland marine ecosystem, especially the population structure of species encountered (length, sex ratio and maturity stages), their total biomass (summarised in Table 2), abundance, spatial structure and the oceanographic situation.

The species of primary interest during this survey was common hake *Merluccius hubbsi*. Data collected throughout the survey enabled a reliable estimate of the biomass available within Falkland waters. The spatial structure of the stock was also highlighted and highest abundances observed to the north and to a lesser extent to the northwest of West Falkland. This cruise was also an ideal opportunity to obtain information about size structure, sex ratio and maturity stages and take note of temporal changes. Fish appeared to be bigger than in February highlighting the migration of fish from spawning grounds to Falkland waters. Females were bigger and more abundant than males as they are in February and females appeared to be at the start of the reproductive cycle (resting or early developing) while most of the males were spent. Although this survey gave a good insight in the population foraging within Falkland waters, it is only part of the stock that was sampled as no information was gathered from Argentine waters nor from the high seas where a significant part of the stock is also generally present and exploited.

Collecting data on common hake was the primary objective of this research cruise, data were also collected on all other demersal species. Interestingly, some finfish stocks exhibited significant differences compared to February 2017. The size structure was found different for red cod, rock cod, hoki, southern blue whiting and toothfish. For these species, several cohorts were observed during the most recent February ground fish survey whereas only one cohort was evident in the July survey. The July survey took place during rock cod and red cod spawning seasons. As a result, fish appeared to be in developing stages. Judging by the resulting biomass and size structure it seems that part of the stocks were outside the survey zone as we observed fish primarily of the smaller cohorts but not many of the larger sized cohorts observed in February 2017. Fish may have been present on spawning grounds that were not well covered by the survey. In the case of hoki and southern blue whiting the survey design was not ideal to sample these two species as it covered primarily the shelf (shallower than 200 m) while these two species are abundant on the slope (deeper than 200 m). It is then difficult to conclude if current results are showing an inter–seasonal pattern or if fish was outside the surveyed zone. Only the smallest cohort of the toothfish stock appeared in the samples suggesting that age 2 and 3 cohorts that appeared in the February surveys have migrated outside the survey zone.

The oceanographic situation appeared to be significantly different from that in February. Ocean temperatures were colder and their range smaller. Moreover, the water column did not exhibit any clear temperature structure and the gyre observed over the Falkland shelf in February 2017 was not observed in the July survey. The only water temperature gradient that was found was observed near the bottom in the south of the surveyed zone in waters deeper than 200 m.

Since 2010 and the first ground fish survey, biomass of demersal commercial species were estimated using geostatistical methods. Geostatistics have been recognized as the best tool to estimate biomass taking into account spatial auto–correlation of the data. Kriging methods are known to smooth values and derived confidence intervals are small (Gimona and

Fernandes, 2003). In order to address that issue conditional simulations were used to derive more realistic confidence intervals (Woillez et al., 2009).

The July research cruise enabled a data collection directly comparable to all the other ground fish surveys conducted since 2010. It showed how the ecosystem and the oceanographic situation were different compared to the summer survey. In the February 2017 report a significant decrease of the biomass for a number of species over the years was highlighted and this was further observed in July. However, it is difficult to conclude if the lower biomass observed in July 2017 was merely a seasonal effect or if the overall biomass is still on a decreasing trend.

The July survey was a first snapshot of our understanding of the marine ecosystem around the Islands in winter time. Even though the spatial nature and structure of the various stocks was described, no suitably comparable information is currently available on the inter–annual variability. It is therefore recommended to repeat this survey in July 2018 to further study the annual variability of both the biological and oceanographic components. Moreover, as some species are not well sampled due to the survey design not going into deep waters, an extension of the surveyed zone to the south could be discussed in the near future.

Data gathered during the current survey that this report deals with, and indeed all other surveys conducted since February 2010, will be of importance to provide scientifically robust advice that will help the management make evidence–based decisions in the context and framework of the 2019 licence advice.

Table 2: Summary of the biomass estimated for commercial species using geostatistic methods

Species	Estimated biomass (t)
Common hake (HAK)	97,072
Common rock cod (PAR)	12,883
Red cod (BAC)	11,694
Southern Blue Whiting (BLU)	519
Argentine shortfin squid (ILL)	139
Kingclip (KIN)	26,133
Toothfish (TOO)	714
Falkland calamari (LOL)	34,169
Hoki	30,752

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Appendix

Table 3: Catch table ZDLT1-07-2017

Species Code	Species name	**Total Catch (kg)**	**Total Sampled (kg)**	**Total Discarded (kg)**	**Proportion (%)**
HAK	*Merluccius hubbsi*	18,323.630	5,381.112	0.000	40.85%
WHI	*Macruronus magellanicus*	6,450.400	368.950	5,110.460	14.38%
LOL	*Doryteuthis gahi*	4,671.510	244.432	16.730	10.41%
KIN	*Genypterus blacodes*	4,087.501	1,274.920	0.380	9.11%
PAR	*Patagonotothen ramsayi*	2,003.330	472.724	1,681.010	4.47%
MUG	*Munida gregaria*	1,865.454	0.703	1,865.454	4.16%
BAC	*Salilota australis*	1,784.050	853.928	505.290	3.98%
DGS	*Squalus acanthias*	1,345.140	0.000	1,237.140	3.00%
DGH	*Schroederichthys bivius*	1,266.600	12.110	1,263.960	2.82%
RFL	*Zearaja chilensis*	920.130	920.130	16.380	2.05%
RBR	*Bathyraja brachyurops*	406.612	406.612	41.570	0.91%
BUT	*Stromateus brasiliensis*	277.610	161.870	269.230	0.62%
SPN	Porifera	181.480	0.000	181.480	0.40%
CGO	*Cottoperca gobio*	156.850	154.740	156.850	0.35%
BDU	*Brama dussumieri*	139.250	139.250	0.000	0.31%
BLU	*Micromesistius australis*	126.000	11.514	125.450	0.28%
TOO	*Dissostichus eleginoides*	122.256	122.256	0.160	0.27%
SQT	Ascidiacea	99.050	0.000	99.050	0.22%
SIB	Siboglinidae	62.332	0.450	61.882	0.14%
BRY	Bryozoa	61.010	0.000	61.010	0.14%
STA	*Sterechinus agassizi*	47.210	0.000	47.210	0.11%
PAT	*Merluccius australis*	43.430	43.430	0.000	0.10%
RMC	*Bathyraja macloviana*	37.595	37.595	16.795	0.08%
RDO	*Amblyraja doellojuradoi*	32.052	32.052	32.052	0.07%
ING	*Moroteuthis ingens*	23.911	12.260	23.900	0.05%
RAL	*Bathyraja albomaculata*	20.984	20.984	2.164	0.05%
COP	*Congiopodus peruvianus*	20.130	20.130	20.130	0.04%
RPX	*Psammobatis spp.*	19.525	19.525	18.475	0.04%
SUN	*Labidaster radiosus*	18.712	0.000	18.712	0.04%
ILL	*Illex argentinus*	18.178	18.178	13.608	0.04%
RSC	*Bathyraja scaphiops*	18.100	18.100	5.060	0.04%
GRF	*Coelorhynchus fasciatus*	17.060	12.710	17.060	0.04%
FUM	*Fusitriton m. magellanicus*	16.140	5.000	11.140	0.04%
ANM	Anemone	15.830	0.000	15.640	0.04%
RED	*Sebastes oculatus*	14.300	14.300	0.120	0.03%
RGR	*Bathyraja griseocauda*	12.610	12.610	1.630	0.03%
GOC	*Gorgonocephalus chilensis*	11.965	0.000	11.965	0.03%
RMU	*Bathyraja multispinis*	10.080	10.080	0.000	0.02%
ALF	*Allothunnus fallai*	9.760	9.760	0.000	0.02%
SEP	*Seriolella porosa*	9.030	9.030	0.000	0.02%
CAZ	*Calyptraster sp.*	8.280	0.000	8.280	0.02%
POA	*Porania antarctica*	6.517	0.000	6.517	0.01%
AUC	*Austrocidaris canaliculata*	6.155	0.000	6.155	0.01%
ZYP	*Zygochlamys patagonica*	6.117	0.000	6.117	0.01%
SAR	*Sprattus fuegensis*	5.385	5.380	2.205	0.01%
MUL	*Eleginops maclovinus*	4.930	4.930	0.000	0.01%
PAU	*Patagolycus melastomus*	4.080	0.000	4.080	0.01%
COL	*Cosmasterias lurida*	3.460	0.000	3.460	0.01%
NEM	*Neophyrnichthys marmoratus*	3.410	3.410	3.410	0.01%
CEX	*Ceramaster sp.*	3.310	0.000	3.310	0.01%
ADA	*Adelomelon ancilla*	2.910	1.630	1.280	0.01%
CTA	*Ctenodiscus australis*	2.883	0.000	2.883	0.01%
COT	*Cottunculus granulosus*	2.400	0.040	2.400	0.01%
MUE	*Muusoctopus eureka*	2.390	0.920	1.470	0.01%
OPV	*Ophiacanta vivipara*	2.313	0.000	2.313	0.01%

RMG	*Bathyraja magellanica*	2.200	2.200	0.070	<0.01%
RBZ	*Bathyraja cousseauae*	2.120	2.120	0.000	<0.01%
THO	Thouarellinae	2.063	0.000	2.063	<0.01%
OPL	*Ophiuroglypha lymanii*	1.584	0.000	1.584	<0.01%
GYN	*Gymnoscopelus nicholsi*	1.525	0.000	1.525	<0.01%
SEC	*Seriolella caerulea*	1.310	1.310	0.000	<0.01%
PES	*Peltarion spinosulum*	1.244	0.000	1.244	<0.01%
MAV	*Magellania venosa*	1.122	0.000	1.122	<0.01%
MUU	*Munida subrugosa*	1.117	0.000	1.117	<0.01%
ODM	*Odontocymbiola magellanica*	1.115	0.340	0.775	<0.01%
POL	Polychaeta	0.982	0.000	0.982	<0.01%
BAO	*Bathybiaster loripes*	0.975	0.000	0.975	<0.01%
EUO	*Eurypodius longirostris*	0.951	0.000	0.951	<0.01%
FLX	*Flabellum spp.*	0.790	0.000	0.790	<0.01%
MLA	*Muusoctopus longibrachus akambei*	0.740	0.000	0.000	<0.01%
WRM	*Chaetopterus variopedatus*	0.730	0.000	0.730	<0.01%
ZYX	Dead Zygochlamys	0.700	0.000	0.700	<0.01%
CHE	*Champsocephalus esox*	0.690	0.690	0.370	<0.01%
UHH	Heart urchin	0.677	0.000	0.677	<0.01%
ALC	Alcyoniina	0.617	0.000	0.617	<0.01%
CYX	*Cycethra sp.*	0.615	0.000	0.615	<0.01%
SOR	*Solaster regularis*	0.595	0.000	0.595	<0.01%
NUD	Nudibranchia	0.361	0.000	0.361	<0.01%
ASA	*Astrotoma agassizii*	0.310	0.000	0.310	<0.01%
EUL	*Eurypodius latreillei*	0.307	0.000	0.307	<0.01%
CAM	*Cataetyx messieri*	0.300	0.300	0.300	<0.01%
TED	*Terebratella dorsata*	0.287	0.000	0.287	<0.01%
MAT	*Achiropsetta tricholepis*	0.250	0.000	0.250	<0.01%
AST	Asteroidea	0.248	0.000	0.248	<0.01%
OCC	Octocoralia	0.200	0.000	0.200	<0.01%
MED	Medusae	0.200	0.000	0.200	<0.01%
SER	*Serolis spp.*	0.159	0.000	0.159	<0.01%
ANT	Anthozoa	0.150	0.000	0.150	<0.01%
COG	*Patagonotothen guntheri*	0.146	0.076	0.146	<0.01%
PYX	Pycnogonida	0.127	0.000	0.127	<0.01%
OPH	Ophiuroidea	0.077	0.000	0.077	<0.01%
PYM	*Physiculus marginatus*	0.050	0.050	0.050	<0.01%
HOL	Holothuroidea	0.046	0.000	0.046	<0.01%
HCR	Paguroidea	0.045	0.000	0.045	<0.01%
MMA	*Mancopsetta maculata*	0.030	0.000	0.030	<0.01%
BAL	*Bathydomus longisetosus*	0.030	0.000	0.030	<0.01%
THB	*Thymops birsteini*	0.030	0.000	0.030	<0.01%
SRP	*Semirossia patagonica*	0.020	0.000	0.020	<0.01%
NUH	*Nuttallochiton hyadesi*	0.020	0.000	0.020	<0.01%
CAS	*Campylonotus semistriatus*	0.015	0.000	0.015	<0.01%
BUC	*Bulbus carcellesi*	0.015	0.000	0.015	<0.01%
CRI	Crinoidea	0.015	0.000	0.015	<0.01%
PMX	*Protomictophum spp.*	0.015	0.000	0.015	<0.01%
SYB	*Symbolophorus boops*	0.010	0.000	0.010	<0.01%
SET	Sertulariidae	0.010	0.000	0.010	<0.01%
CRY	*Crossaster sp.*	0.010	0.000	0.010	<0.01%
BIV	Bivalve	0.010	0.000	0.010	<0.01%
LYB	*Lycenchelys bachmanni*	0.010	0.000	0.010	<0.01%
ODP	*Odontaster pencillatus*	0.009	0.000	0.009	<0.01%
MUN	*Munida spp.*	0.005	0.000	0.005	<0.01%
ISO	Isopoda	0.005	0.000	0.005	<0.01%
PLB	Primnoellinae	0.005	0.000	0.005	<0.01%
		44,859.326	**10,844.841**	**13,024.056**	

Table 4: Sample numbers by sample type

Code	Species Name	N	R	S	Total	
LOL	*Doryteuthis gahi*		7,697	353	8,050	26.9%
PAR	*Patagonotothen ramsayi*	6	3,912	2,443	6,361	21.3%
HAK	*Merluccius hubbsi*	9	2,701	2,898	5,608	18.8%
BAC	*Salilota australis*	3	2,426	586	3,015	10.1%
WHI	*Macruronus magellanicus*	3	1,324	922	2,249	7.5%
KIN	*Genypterus blacodes*	17	581	727	1,325	4.4%
TOO	*Dissostichus eleginoides*	50	516		566	1.9%
BLU	*Micromesistius australis*		38	353	391	1.3%
RFL	*Zearaja chilensis*		380		380	1.3%
ILL	*Illex argentinus*		299	48	347	1.2%
CGO	*Cottoperca gobio*		317	3	320	1.1%
BUT	*Stromateus brasiliensis*		258	35	293	1.0%
RBR	*Bathyraja brachyurops*		235	1	236	0.8%
GRF	*Coelorhynchus fasciatus*		125		125	0.4%
SAR	*Sprattus fuegensis*		110		110	0.4%
MUG	*Munida gregaria*		105		105	0.4%
BDU	*Brama dussumieri*		88	2	90	0.3%
COP	*Congiopodus peruvianus*		51		51	0.2%
RDO	*Amblyraja doellojuradoi*		42		42	0.1%
RPX	*Psammobatis spp.*		40		40	0.1%
RMC	*Bathyraja macloviana*		38		38	0.1%
RED	*Sebastes oculatus*		28		28	0.1%
RGR	*Bathyraja griseocauda*		23		23	0.1%
PAT	*Merluccius australis*		18		18	0.1%
RAL	*Bathyraja albomaculata*		16		16	0.1%
SEP	*Seriolella porosa*		15		15	0.1%
ING	*Moroteuthis ingens*		13		13	<0.1%
CHE	*Champsocephalus esox*		11		11	<0.1%
RSC	*Bathyraja scaphiops*		11		11	<0.1%
NEM	*Neophyrnichthys marmoratus*		6		6	<0.1%
COG	*Patagonotothen guntheri*		5		5	<0.1%
MUL	*Eleginops maclovinus*		4		4	<0.1%
RMU	*Bathyraja multispinis*		3		3	<0.1%
SEC	*Seriolella caerulea*		3		3	<0.1%
RMG	*Bathyraja magellanica*		2		2	<0.1%
ALF	*Allothunnus fallai*		1		1	<0.1%
CAM	*Cataetyx messieri*		1		1	<0.1%
DGS	*Squalus acanthias*		1		1	<0.1%
PYM	*Physiculus marginatus*		1		1	<0.1%
RBZ	*Bathyraja cousseauae*		1		1	<0.1%
					29,905	