Cruise report

Skate biomass and biological survey

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Falkland Islands Government

Directorate of Natural Resources

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1. INTRODUCTION

Skates (Rajiformes) are an important component of the Falkland Island fisheries, being both managed by a dedicated license (F license) since 1994 and a total allowable effort attributed to licensed vessels (FIFD 2018). However finfish-targeting trawlers are responsible for the majority of skates caught as bycatch (table1). Furthermore, the last survey dedicated to the description of the skate species assemblage in the region, in 2013, identified 1) changes in the distribution of species and 2) shifts in their biological parameters - notably the size at 50% maturity (Pompert *et al.* 2014).

Table 1 - Skate fisheries summary per year

	Total catch (tonnes)	Catch under F license (%)	Number of F license days used	F license days used / purchased (%)
2013	5,923	37.6	246	100
2014	5,552	53.2	259	100
2015	6,357	37.2	249	95
2016	5,882	36.2	152	58.6
2017	3,177	35.8	133	59.6
2018	1,933	25.8	64	24.8

Since then, the total catches of skates throughout the years have followed a decreasing trend associated with a decrease of fishing effort under F-licence (table 1).

In parallel to that, and though extensive research has already been conducted on Rajiformes over the years (Agnew *et al*. 2000, Wakeford *et al*. 2004, Arkhipkin *et al*. 2008, Arkhipkin *et a.l* 2012, Winter *et al.* 2015), the biology or even identification of some species in the Falkland Islands waters are still poorly understood and necessitate further investigation. One of the questions that remain is the identification of the different species of the genus *Psammobatis* (vernacularly named “sand skates”) potentially present in the Falkland Islands waters. Morphometric and associated genetic samples have been collected on a number of specimens but additional individuals still need to be sampled to complete this on-going research project.

Finally, the surveys of 2010 and 2013 were conducted with two different net settings, with rockhopper and groundrope respectively. As these settings affect the catchability rate – and therefore the interpretation of the species assemblage, notably in terms of abundance – the data collected during these last two research cruises necessitated prior standardization.

The Falkland Islands Fisheries Department (FIFD) has therefore opted for the option of a skate-dedicated survey to be conducted in October 2019.

2. AIMS & OBJECTIVES

The purpose of the 2019 survey was to:

- Update our knowledge of the skate species distribution in the northern slope of the continental shelf
- Assess the evolution and changes in the skate assemblage six years after the last dedicated research cruise.
- Collect exhaustive catch / bycatch information , including on teleost and invertebrate species, associated with the skate community
- Collect associated oceanographic data
- Collect individuals of *Psammobatis spp* for genetic and morphometric information
- Assess the catchability rates of the two net settings previously used in 2010 and 2013 to allow an acute comparison of data collected during these cruises.

3. METHODS

3.1 Vessel, trawl gear and prospected area

The research cruise was carried out on the Monteferro ZDLM3, operated by RBC, under an E license (number FK054E19). The Monteferro is a bottom trawler registered in Stanley (Falkland Islands flag), with a gross tonnage of 1499 t and a length overall of 63.7 m.

In 2013, during the last survey dedicated to the skate biomass and distribution estimates, two zones were explored: the south area, covering twelve grids of the Loligo box surrounding Beauchene Island, and the north / north east area, where skates are usually targeted under an F-license. However, it was rapidly noted that the fishing net used during this survey differed from the one used in the 2010 survey, altering catchability efficiency and hence the comparison of the fish assemblage between 2010 and 2013.

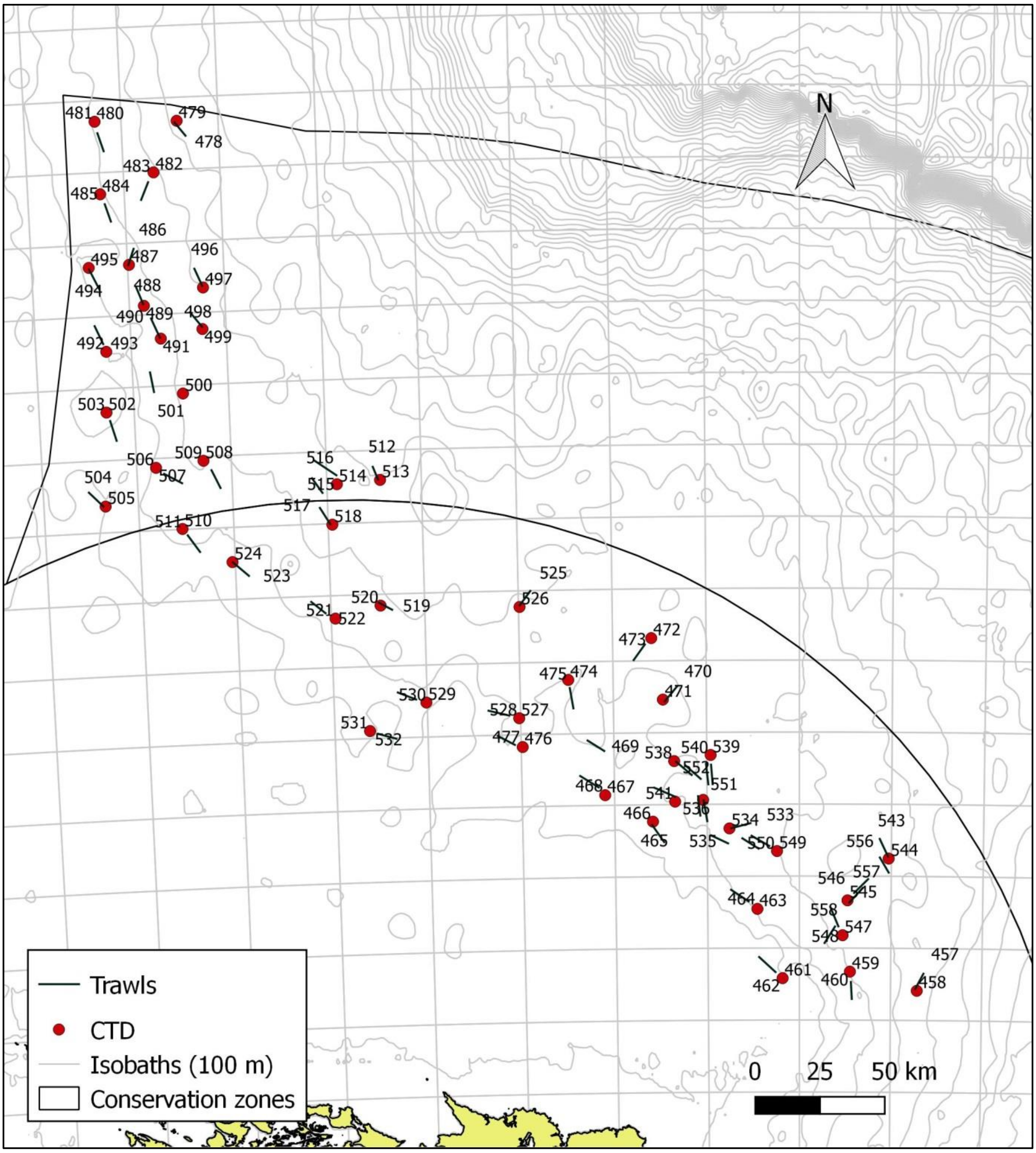


Figure 1- Prospected area

In 2019, it was decided to prospect the northern area only (north of 51°S) to update the assemblage distribution in the skate fishing ground. Twelve days were allocated to this initial mapping, during which 48 stations were sampled (Figure 1- Prospected area). The vessel departed on 11th October at 9:00 pm with the intention of being on the fishing ground the next morning. From 12th October until 23rd October included, the sampling was conducted with a commercial net fitted with a 90 mm cod-end and a ground rope with a tickler chain, as it was the case in 2013. For the last two days of the survey, 8 stations were replicated using the same net and cod end but fitted with rock hopper gear, i.e. following the same setting as in

2010. Each trawl was 60 minutes long (seabed time), with an average trawl speed of 4.0 knots (min 3.4, max 4.6). On the 13th of October, the net was damaged beyond repair and had to be changed for a new, identical one; because the net broke early during the trawling operation, the catch was neither sampled nor integrated into the survey. On 20th October, the net was damaged and hauled after 50 minutes but could be repaired. The total catch was extrapolated to 60 minutes, to be consistent with the other stations sampled. Only 3 trawls were carried out these days, which were compensated by 5 trawls being carried out on 16th October and 22nd October.

3.2 Biological sampling

All finfish, cephalopod and elasmobranch catches were identified to the species level and weighed using an 80 kg Marel balance. Because the use of a groundrope coupled with a tickler chain tends to maximise the bycatch of benthic invertebrates, the latter was sometimes numerous important to be entirely sorted by species. On these occasions, it was decided to divide this bycatch in two parts: the main, dominant mix on one hand, and the rarer species on the other hand. The main components of the bycatch (most often a mix of sponges and crushed sea urchins) were weighed as a whole and randomly subsampled in two to three baskets, which were sorted to the lowest possible taxa, weighed and extrapolated to the total catch. The rarer species (starfish, molluscs, crustaceans…) were sorted, identified and weighed separately, and their total weight was added to the extrapolated one.

All skate disc-widths were measured to the lowest centimetre, and their sex and maturity was determined – however on three occasions, the catches of the skate species were too big to conduct this work. For the most abundant species, it was decided to identify the maturity stage of males only, recording females with a maturity stage of “0” – unidentified.

Psammobatis species were as usual recorded as RPX, however they were sampled for morphometric, genetic and ontogenetic analyses. This separate study aims at refining our understanding of the *Psammobatis* complex present in the Falkland Islands waters, and the results are not included in the present report.

Each species of commercial interest that was caught during the survey was randomly sampled (up to 100 individuals), and their length frequencies were analysed. Otoliths were collected according to the quarterly strategy (2 to 5 individuals per sex per 1cm class size). A sample of *Doryteuthis gahi* was also collected for statolith extraction.

3.3 Data Analyses

3.3.1 Skate biomass estimates

Skate biomass estimates were calculated by extrapolating catch density (catch weight per trawl swept-area) using a cubic spline algorithm (Akima, 1996). The trawl swept area was defined as trawl distance x wing spread (horizontal net opening), whereby trawl start and end positions used during calculation were obtained from logged positions recorded by the vessel officers.

Wing spread values were not recorded during this trip due to sensor technical faults, and as such were calculated using the formula:

$$Trawl\ width = \frac{door\ distance\ \times footrope\ length}{footrope\ length + sweep\ length + bridle\ length}$$

with door distance, sweep area and bridle length recorded for each trawl. The footrope used was the same as the one used previously in skate surveys, thus an average footrope length taken from previous survey data was used for this calculation. Further description of the trawl swept region definition is given in the 2010 skate survey report (Arkhipkin et al., 2010).

For any biomass calculations, the trawl capture efficiency specific to each vessel / net must be taken into consideration (Dickson 1993). As described for the previous 2010 and 2013 skate surveys (Arkhipkin *et al.*, 2010, Pompert *et al.*, 2014), catch density was scaled by a catchability coefficient adjusting for the relatively light contact gear generally used by Spanish / Falkland trawlers - as it is the case for the vessel used during this survey. These were calculated using an index ratio between the CPUE of all catch of commercial skate-fishing vessels in 2010 and 2013 (the last surveyed years) vs. the CPUE of all catch of these two surveys for northern trawl stations (north latitude 51 ºS) (see Arkhipkin *et al.*, 2010, Pompert *et al.*, 2014). The survey catchability coefficient used in 2013 was a combination of two factors: the ratio between Spanish and Korean vessels (0.600), and the ratio between 2010 and 2013 (1.690). This was supposedly the same in 2019 as the same gear setting was used in 2013 and 2019. Because no significant commercial skate fishing occurred in 2019, the catchability coefficient factor used for the 2019 survey was 0.600 x 1.690 = 1.014.

Skate biomass was first estimated with reference to the same 'Skate Box' in the northern region that had been defined for the previous two surveys (Arkhipkin *et al.*, 2010, Pompert *et al.*, 2014), covering 26 FIFD grids and 26082.2 km^2. However, progression of the fishery since 2013 has shown wider distributions of skate stocks, and a new Skate Box was delineated for this survey covering 38 FIFD grids and 38211.95 km^2. For this report the two Skate Boxes are designated as respectively the 'Old Box' and 'New Box'.

To calculate the variability of the skate biomass estimates a bootstrap re-sampling algorithm (Efron, 1981) was applied to the survey data as in 2013 (10,000 iterations). As a fixed catchability coefficient was assumed for the current survey, the catchability coefficient was not varied in the bootstrap. However, three components of the biomass estimation were randomised separately per bootstrap iteration:

1) <u>Survey trawl position.</u>
   For variability estimates, the survey trawl catch was ranged on a random uniform distribution between trawl start and end positions rather than on the trawl midpoint.
2) <u>Catch composition per survey trawl.</u>
   All species (including bycatch) with FIFD-defined length-weight relationships were randomly re-sampled per trawl by extrapolating the individual composition of each trawl from its length-frequency samples. These lengths were converted to weight using calculated length-weight parameters. The extrapolated individual composition

of each trawl was then randomly re-sampled with replacement. Because the total catch filling a trawl relates more to catch weight than to the number of individuals, the re-sample of each trawl was looped until it reached the closest approximation to the original catch weight of all length-weight defined species in that trawl.

3) <u>Total catch per trawl</u>
   Total catch per trawl may itself be considered a partially random variable. A generalized additive model found that 55% of trawl catch weight of FIFD-defined species in this survey was predicted by position parameters east and north (projected coordinates), and depth. Thus, 45% of trawl catch weight of FIFD-defined species was randomly re-sampled, with replacement, per bootstrap iteration, and the catch composition re-sample (above) applied to the sum of the 45% re-sampled plus 55% empirical trawl catch weights.

3.3.2 Skate community and biology

The CPUE ($kg.h^{-1}$) and size distribution of each skate species according to 1) their position and 2) the depth at which they were caught were plotted, and disc-width frequency and distribution along the depth gradient were analysed. The size at 50 % maturity L_{m50}, which is the theoretical disc-width above which 50% of the individuals have reached reproductive size, was determined per species and per sex with the use of logistic regression, and compared to the values observed in 2010 and 2013.

3.3.3 Finfish and cephalopod bycatch

The CPUE and size frequency of each bycatch species of commercial interest was analysed and plotted. The sex ratio and modal maturity stage was also assessed for each species. Non-commercial species were also occasionally sampled for length-frequency or otoliths.

3.3.4 Benthic invertebrate bycatch

The use of a commercial net with a 90 mm mesh size prevents a direct analysis on raw biomass for benthic invertebrate species. Indeed, there are at least two possible biases with such data: the fact that all animals of the smaller species may not be retained by the relatively wide mesh, and the likelihood of the animal not getting to the conveyor belt once on board (trapped on the net / deck /fish bin etc…). Moreover, some species tend to be naturally more abundant or heavy than others, and their presence at a station may overweight the presence of lighter, rarer species. For these three reasons, it has been decided to transform the biomass data with a logarithmic function [$Log_{10}(x+1)$]. Although not as comprehensive as the use of raw data would have been, it allows overcoming the three above-mentioned limits without completely disregarding the differences of abundance between the different stations.

The similarities between stations according to their invertebrate species composition has then been assessed with the use of a similarity matrix (Bray-Curtis index) coupled with hierarchical clustering. Each group of station has been mapped to investigate any potential spatial pattern of the benthic community, and the characteristic species discriminating each group have been identified with the use of SIMPER (Clarke, 1993) and IndVal analyses (De Caceres *et al*, 2009).

3.3.5 *Catchability comparison*

In total, 16 stations of the survey have been used for assessing the catchability rates of the two tested settings (*i.e.* with a groundrope or a rockhopper). The average catches and species richness have first been compared, and then the group of species being caught in higher or lower quantities with the two different settings have been identified with the use of a principal component analysis (PCA).

3.3.6 *Oceanography*

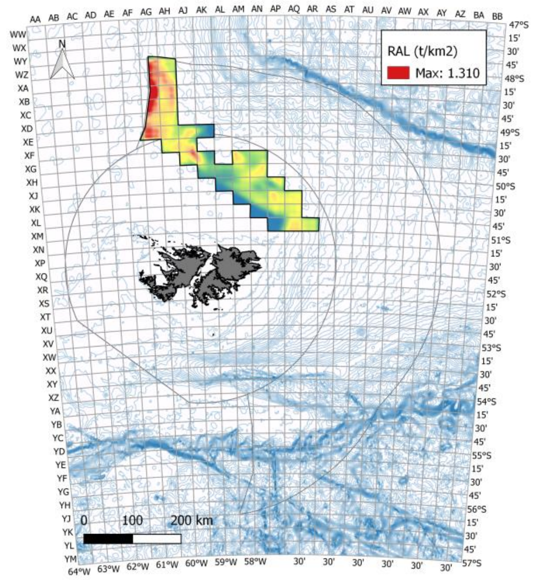
A single CTD (SBE-25, Sea-Bird Electronics Inc., Bellevue, USA) instrument, Serial No 0389, was used to collect oceanographic data in the vicinity of most trawl stations. On the 13th October the final CTD was not run due to bad weather, on the 19th due to the proximity 3 trawls the central CTD was skipped, and on the final 2 days CTD were not collected during the repeated trawls. The CTD instrument was last calibrated in May to June 2016, with an oxygen sensor fitted to the instrument in January 2017 and a Fluorometer fitted in June 2017. At all 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 raw hex file was converted and processed using SBE Data Processing Version.7.22.5 using the CON file 0389_2016-06-O2_Fl.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, R., Ocean Data View, http://odv.awi.de, 2013).

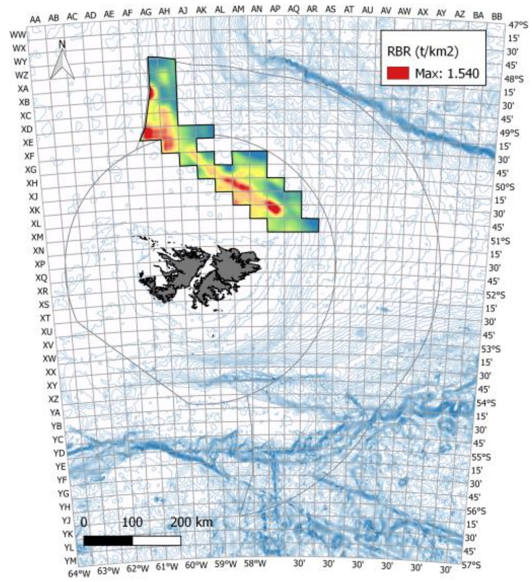
4. RESULTS

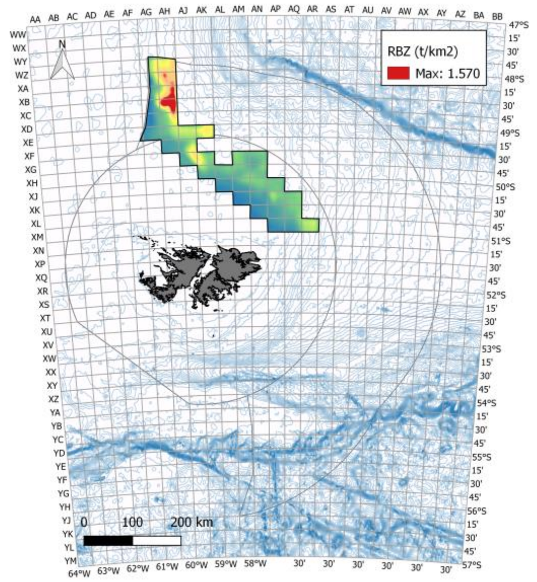
Table 2 shows the biomass estimates and 95% confidence intervals from 10,000 bootstrap iterations in the survey region when using previous skate fishing ground parameters (Old Box), and the new extended box (New Box). 2013 results have also been included for ease of estimate comparisons. All estimates include the conversion factors described in each report (2013 = approx. 1.69/ 2019 = approx. 1.09) that account for the differences in gear usage and fishing effort.

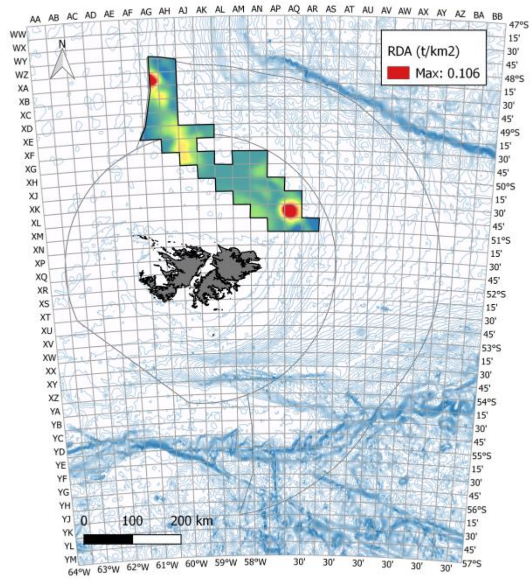
Table 2 - Skate biomass estimate (tonnes) and 95% confidence intervals (CI)

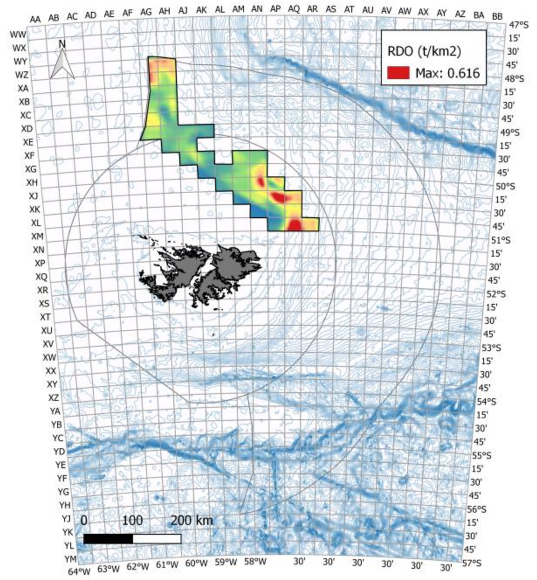
	2013		*2019 (Old Box)*		2019 (New Box)	
Species Code	*Est.*	*95% C.I.*	*Est.*	*95% C.I.*	Est.	95% C.I.
RAL	*4556*	*1985 - 11293*	*3818*	*3058 - 4136*	5475	4819 - 6135
RBR	*8022*	*3597 - 20693*	*4264*	*3972 - 5640*	4680	4674 - 6476
RBZ	*742*	*343 - 2065*	*860*	*764 - 1387*	2195	1979 - 2875
RDA	*291*	*115 - 893*	*126*	*58 - 244*	129	63 - 255
RDO	*743*	*321 - 1853*	*1030*	*661 - 1166*	1783	1485 - 2086
RFL	*2997*	*1288 - 7424*	*3007*	*2131 - 3371*	3234	2372 - 3637
RGR	*4629*	*2013 - 11585*	*4029*	*3711 - 5687*	7781	6990 - 9436
RMC	*1160*	*529 - 3018*	*1019*	*931 - 1458*	1454	1430 - 2039
RMG	*4*	*1 -13*	*4*	*0 - 18*	4	0 - 19
RMU	*580*	*223 - 1447*	*771*	*617 - 1175*	1333	1243 - 2084
RPX	*587*	*257 - 1494*	*206*	*180 - 671*	288	243 - 916
RSC	*1135*	*485 - 2861*	*768*	*563 - 972*	1252	1134 - 1674
RTR	*44*	*21 - 217*	*145*	*4 - 399*	551	236 - 1376
Total	*25492*	*11289 - 64135*	*20045*	*16650 - 26324*	30161	26668 - 39008

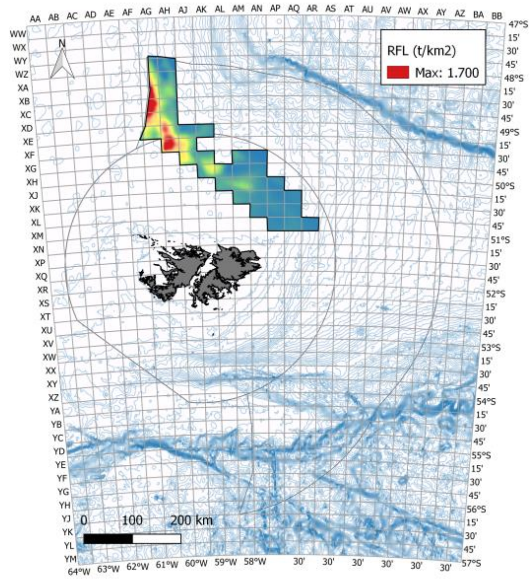

RAL (t/km2)
Max: 1.310
0 100 200 km


RBR (t/km2)
Max: 1.540
0 100 200 km


RBZ (t/km2)
Max: 1.570
0 100 200 km


RDA (t/km2)
Max: 0.106
0 100 200 km


RDO (t/km2)
Max: 0.616
0 100 200 km


RFL (t/km2)
Max: 1.700
0 100 200 km

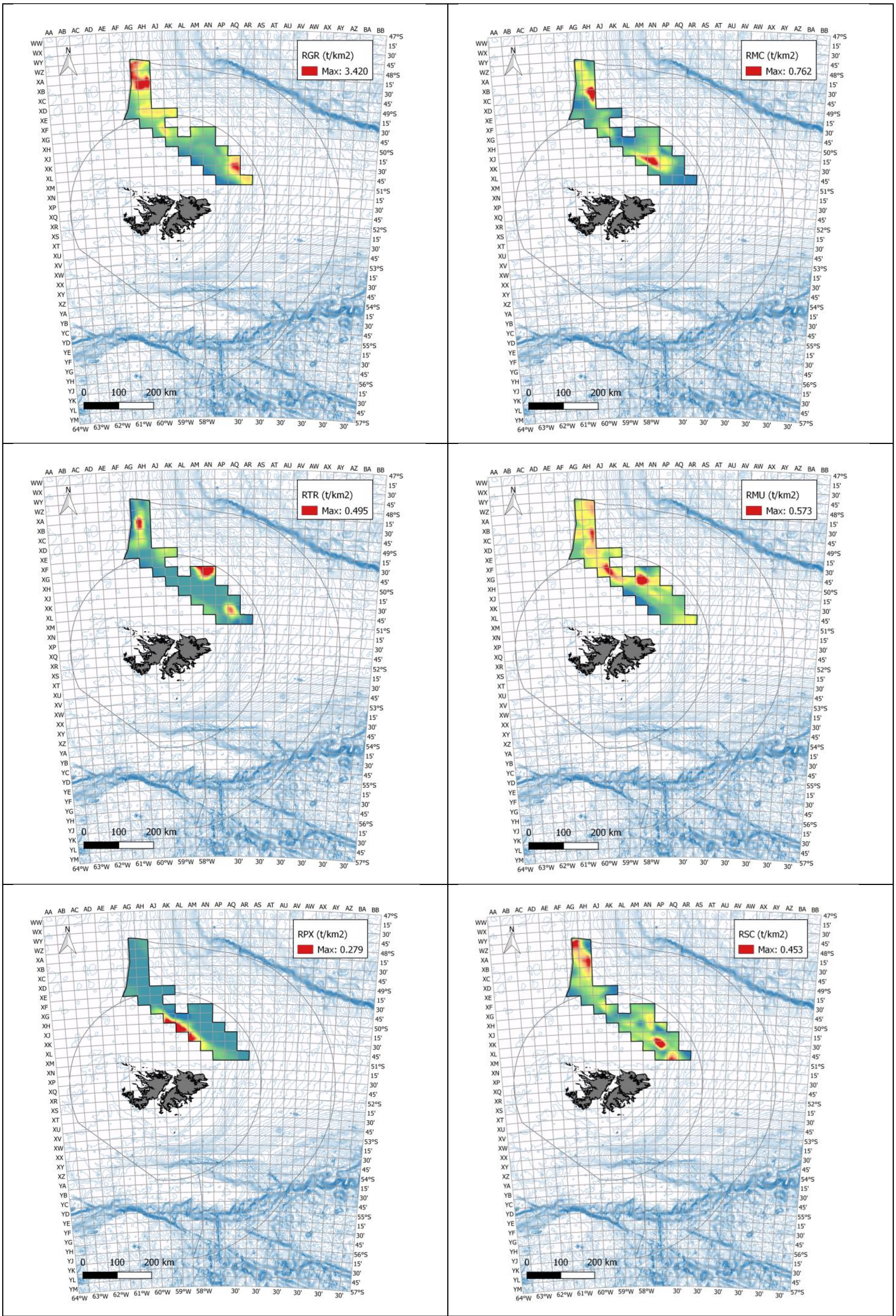


Figure 2 - Interpolated skate density (t/km^2, New Box) across the survey region for 2019. Density varies from 0 (blue) to the value shown in each legend (red). RMG not included (only 2 ind caught in 2019).

Biomass estimates in the Old Box were significantly lower in 2019 than 2013 for RPX, RSC, RDA and RBR, whereas biomass estimates of RBZ, RDO, RMU and RTR were higher. RMG was caught in low quantities as in 2013 as in 2019 (only 2 individuals caught for this present survey).

Altogether, the total biomass estimate of the Rajiformes in the Old Box appeared to have dropped by 21%, from 25452 tonnes in 2013 to 20045 tonnes in 2019 (Table 2).

The New Box is larger than the Old Box by a factor of 38211.95/26082.2 = 1.465. In 2019, six of the 13 skate species had a biomass estimate ratio between the New Box and Old Box greater than 1.465: RBZ, RDO, RGR, RMU, RSC and RTR (Table 2), indicative that for these species, concentrations were distributed further out than previously evaluated. RBR had the highest absolute biomass decrease from 2013 to 2019, and notably RBR in 2019 switched from having the highest skate biomass estimate in the Old Box to only the third-highest skate biomass estimate in the New Box (Table 2).

Spatial distributions of the skate species in 2019 are shown in Figure 2, where eight skate species (RGR, RMC, RMU, RSC, RDA, RBR, RAL and RBZ) showed higher densities in the northern part of the survey area (which is largely the same between the Old Box and the New Box) in 2019 when compared with 2013. RBZ was not found in the south of the box in 2019 as in 2013. RFL and RPX showed similar geographic distribution between 2013 and 2019. RTR had very similar localised hotspots to that of RDA in 2019, with higher densities than in 2013. RDO was much more widespread throughout the fishing area in 2019 and in higher densities than in 2013. However RBR - despite the lower biomass estimate (approximately 50% of 2013) - was much more widespread throughout the fishing box in 2019 than in 2013, with correspondingly lower confidence interval (C.I.) margins.

4.1 Skate community and biology

Bathyraja griseocauda (RGR)

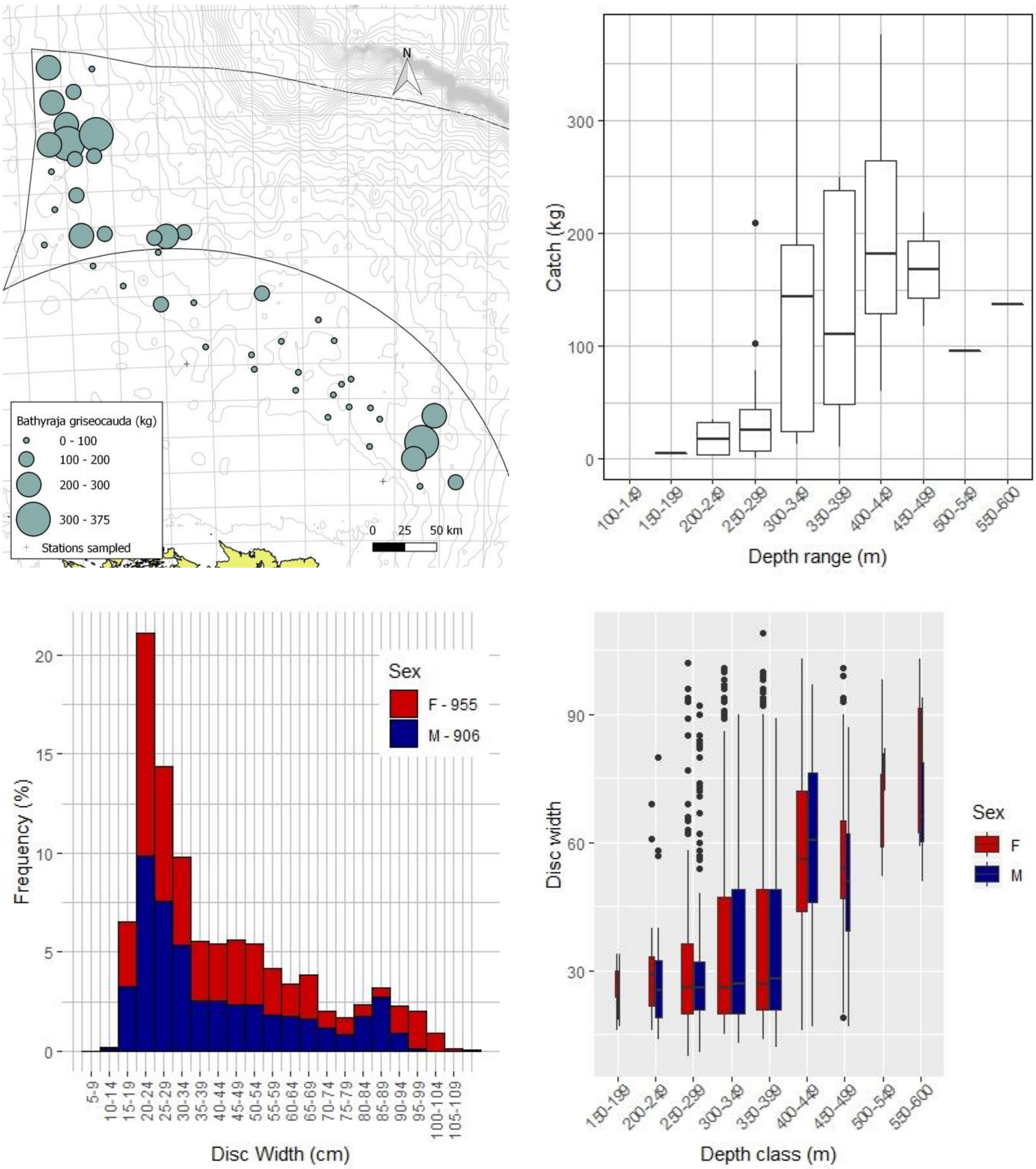
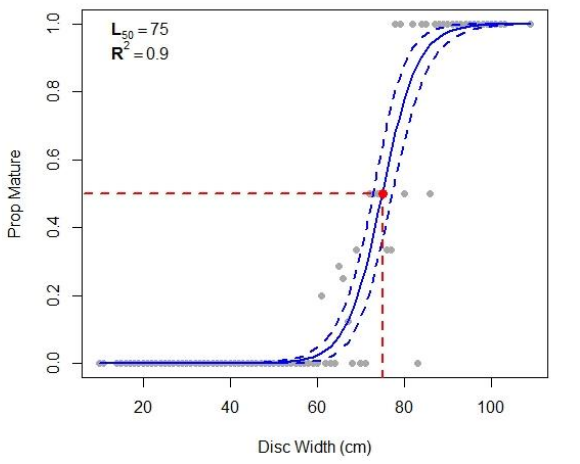
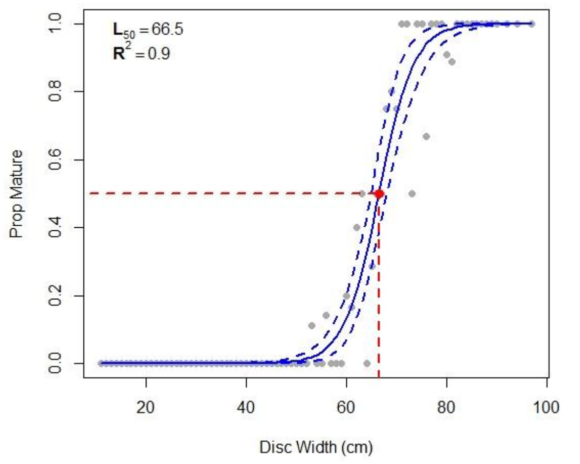


Figure 3 - Distribution and disc-width repartition of RBR

A total of 4,987.5 kg, representing 29.1% of the total skate catch, was caught in 46 of the 48 initial stations (i.e not including the net catchability trial stations), with the highest catch recorded at 434 m. 1861 RGR were caught and sampled, which represents the third highest catch in number of individuals. Disc width ranged between 10 and 109 cm, with a mean of 40.14 cm (µF = 40.61 cm; µM = 39.65 cm) and a slight predominance of females (51.32 %). There is a clear distribution pattern with smaller individuals (< 40 cm) being more abundant altogether but mainly distributed below 400 m, when larger individuals were mainly occupying deeper waters. 17 females were carrying egg capsules. They were all caught north of 49°30’ S, in deeper water. 109 females (11.41 %) were above the L_{dw} at 50 % maturity which was of 75.0 cm, slightly lower than the L_{M50} of 75.87 reported in 2013. The male L_{dw} at 50 % maturity was of 66.5 cm in 2019, 2 cm wider than the one observed in 2013.





Female			Male		
ZDLT1-10-2010	ZDLT1-11-2013	ZDLM3-11-2019	ZDLT1-10-2010	ZDLT1-11-2013	ZDLM3-11-2019
L_{M50} = 83.3 cm	L_{M50} = 75.9 cm	L_{M50} = 75.0 cm	L_{M50} = 72.0 cm	L_{M50} = 64.1 cm	L_{M50} = 66.5 cm

Figure 4 - Maturity ogives of RGR

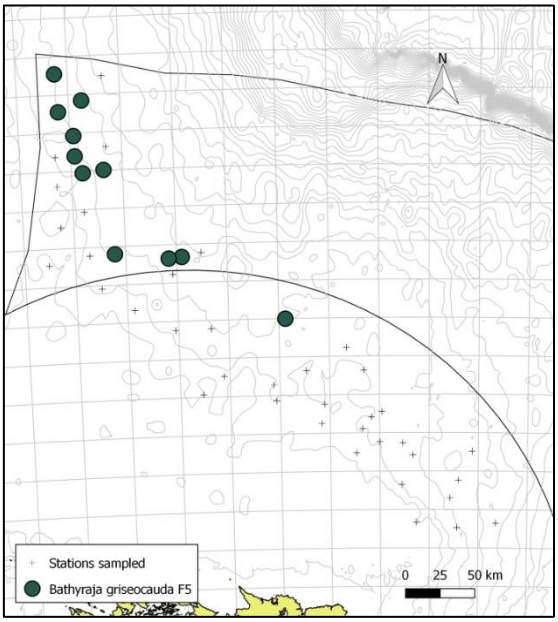


Figure 5 - Distribution of RGR females carrying eggs

Bathyraja albomaculata (RAL)

2,897.41 kg of *Bathyraja albomaculata* (16.9 % of the total skate catch) were caught in 47 of the 48 initial stations. The catches were evenly distributed throughout the zone and depth strata with a slightly higher abundance in the north of the FOCZ (highest catch of 245 kg at 300 m). 2785 RAL were caught and sampled, which was the highest catch in terms of number of individuals.

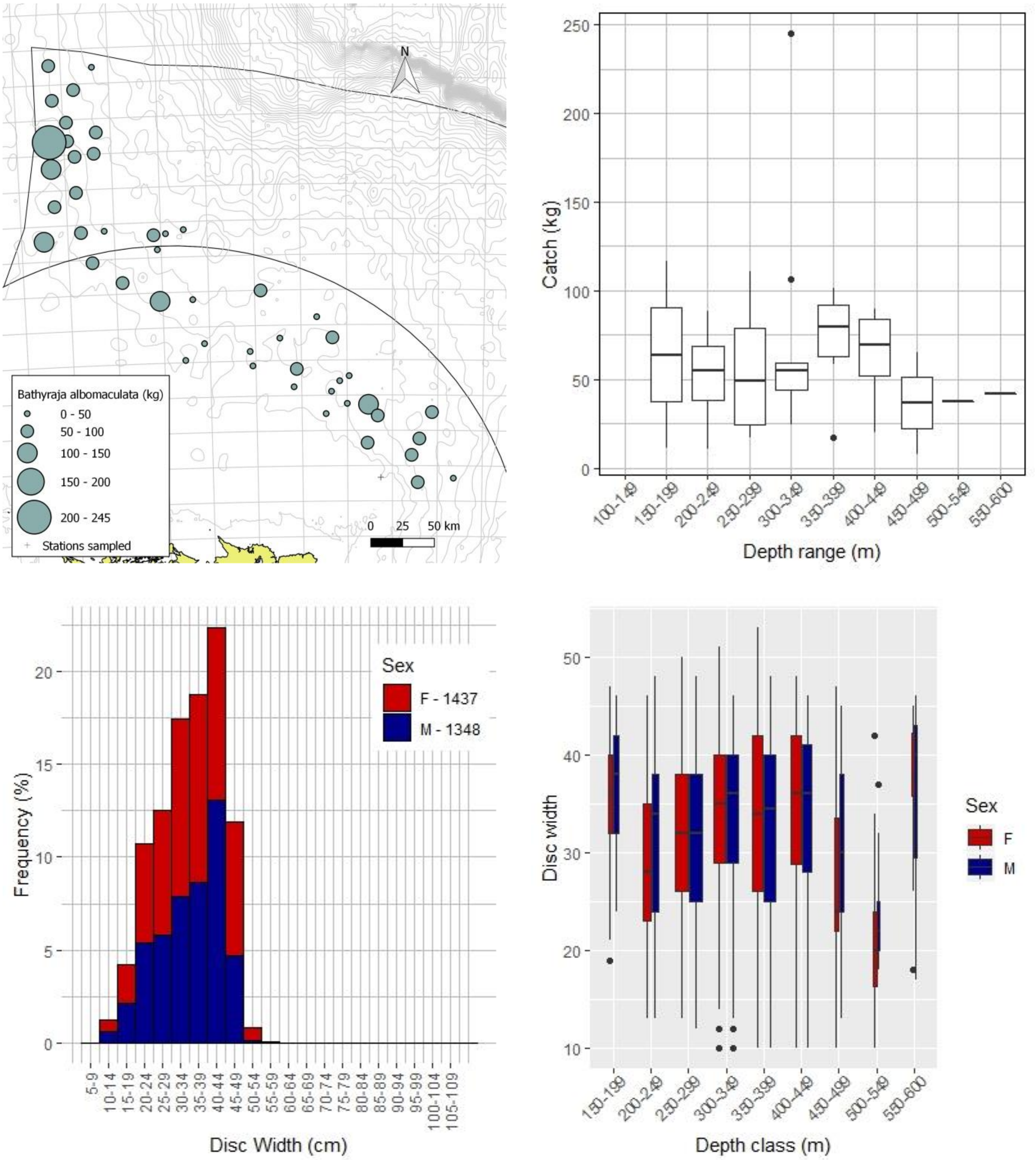
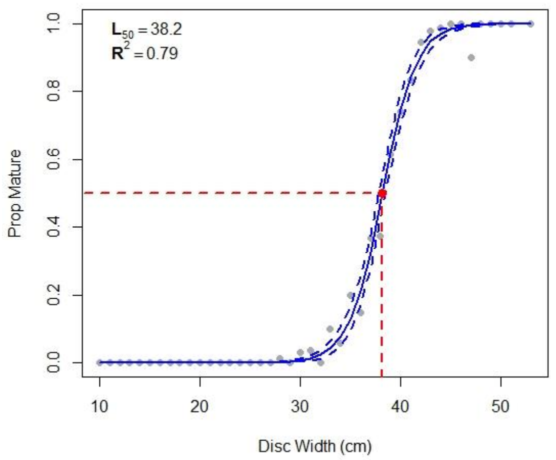
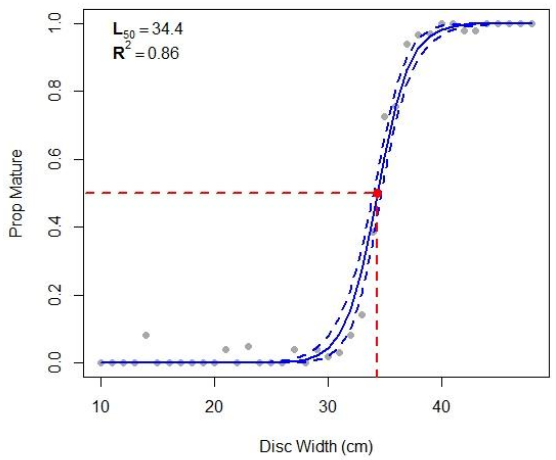


Figure 6 - Distribution and disc-width repartition of RAL

Disc width ranged between 10 and 53 cm, with a mean of 32.53 cm (µF = 32.54 cm; µM = 32.52 cm) and a slight predominance of females (51.60 %). No distribution pattern of individuals in accordance to their size was discernable. 18 females were carrying egg capsules. They were caught throughout the zone, both in shallower and deeper waters. 412 females (28.67 %) were above the L_{dw} at 50 % maturity which was of 38.2 cm, 2 cm wider than to the L_{M50} of 36.8 cm reported in 2013. The male L_{dw} at 50 % maturity was of 34.4 cm in 2019, very similar to the one observed in 2013 (34.2) cm.





Female			Male		
ZDLT1-10-2010 L_{M50} = 39.9 cm	ZDLT1-11-2013 L_{M50} = 36.8 cm	ZDLM3-11-2019 L_{M50} = 38.2 cm	ZDLT1-10-2010 L_{M50} = 37.2.7 cm	ZDLT1-11-2013 L_{M50} = 34.2 cm	ZDLM3-11-2019 L_{M50} = 34.4 cm

Figure 7 - Maturity ogives of RAL

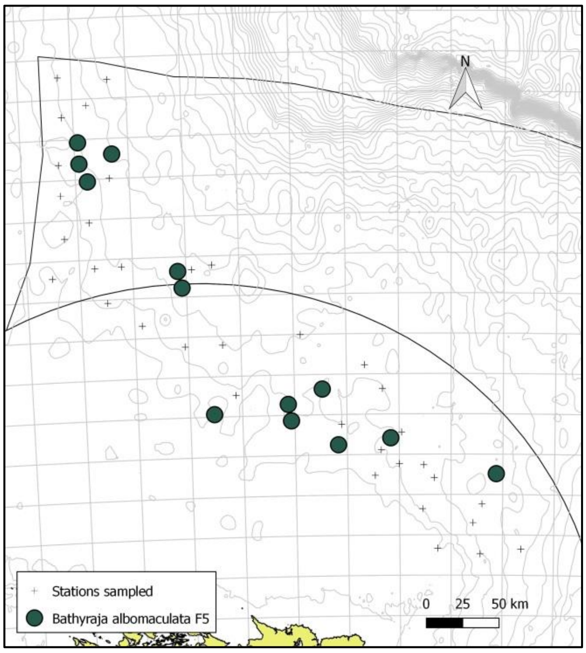


Figure 8 - Distribution of RAL females carrying eggs

Bathyraja brachyurops (RBR)

In 2019, the 3rd highest skate catch was made of *Bathyraja brachyurops*, the dominant species of 2013. 2342.8 kg of RBR were caught at 41 of the 48 initial stations, which represented 13.7 % of the total skate catch. The catches do not seem to be driven by latitude so much as they are by depth, with a clear preference of shallower waters for this species. Although the species was recorded between 127 and 541 m, most of the catches occurred above 350 m, with the highest catch of 192.5 kg at 303 m. 1742 RBR were caught and sampled.

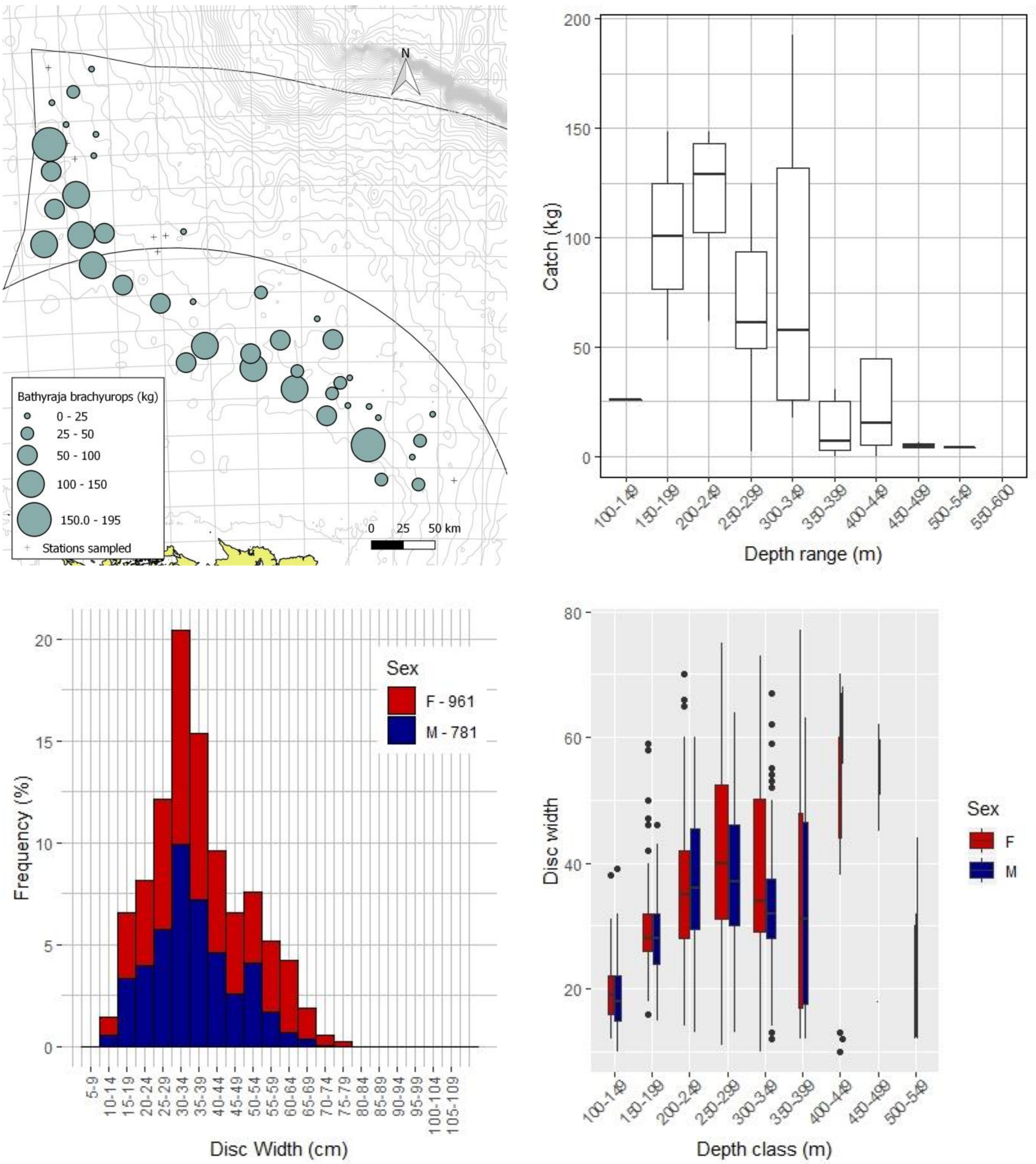
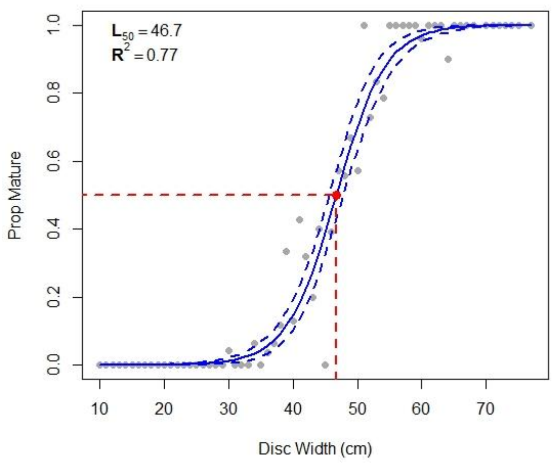
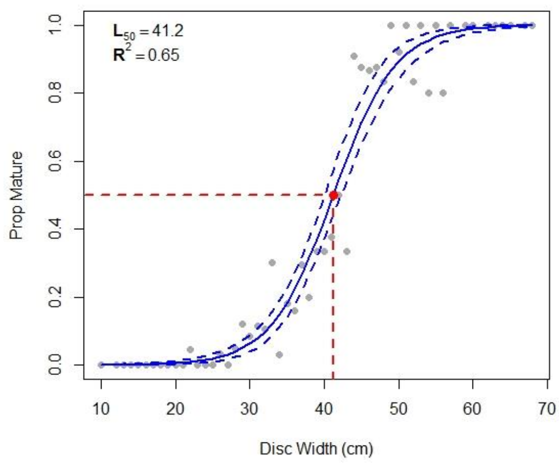


Figure 9 - Distribution and disc-width repartition of RBR

Disc width ranged between 10 and 77 cm, with a mean of 35.15 cm (µF = 36.53 cm; µM = 33.45 cm) and a predominance of females (55.17 %). On average, the wider individuals were recorded at intermediate depths (250 – 300 m). 18 females were carrying egg capsules; they were mainly caught in the shallower waters of the area. 229 females (23.83 %) were above the L_{dw} at 50 % maturity which was of 46.7 cm, 8 cm wider than the one reported in 2013, and comparable to what was observed in 2010. Similarly, the L_{dw} at 50 % maturity of males was of 41.2 cm, 4 cm wider than the one observed in 2013, and similar to the 2010 value.

<table>
<tr><td colspan="3">

Female</td><td colspan="3">

Male</td></tr>
<tr><td>ZDLT1-10-2010
L_{M50} = 46.4 cm</td><td>ZDLT1-11-2013
L_{M50} = 38.6 cm</td><td>ZDLM3-11-2019
L_{M50} = 46.7 cm</td><td>ZDLT1-10-2010
L_{M50} = 40.7 cm</td><td>ZDLT1-11-2013
L_{M50} = 37.1 cm</td><td>ZDLM3-11-2019
L_{M50} = 41.2 cm</td></tr>
</table>

Figure 10 - Maturity ogives of RBR

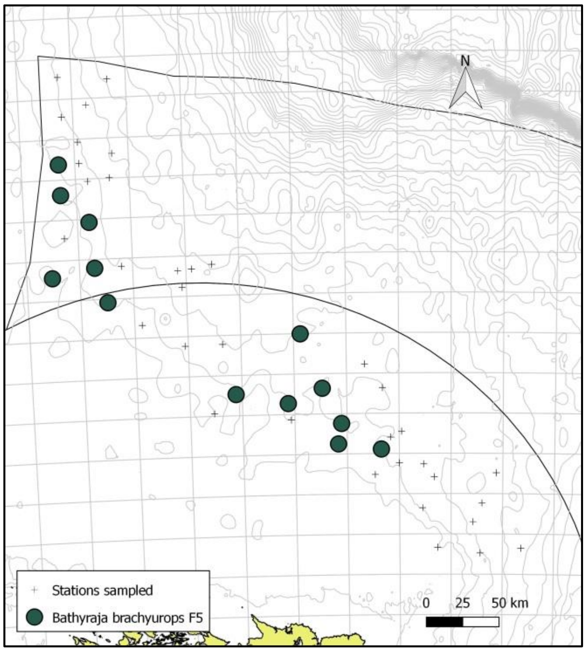


Figure 11 - Distribution of RBR females carrying eggs

Bathyraja cousseauae (RBZ)

A total of 1592.7 kg of *Bathyraja cousseauae*, 9.29 % of the skate catch, was caught in 40 stations – mainly deeper ones (300+ meters), with a highest peak of abundance in the north of the FOCZ. The highest catch of 221 kg was recorded at 346 m depth. Altogether, 647 individuals were caught and sampled.

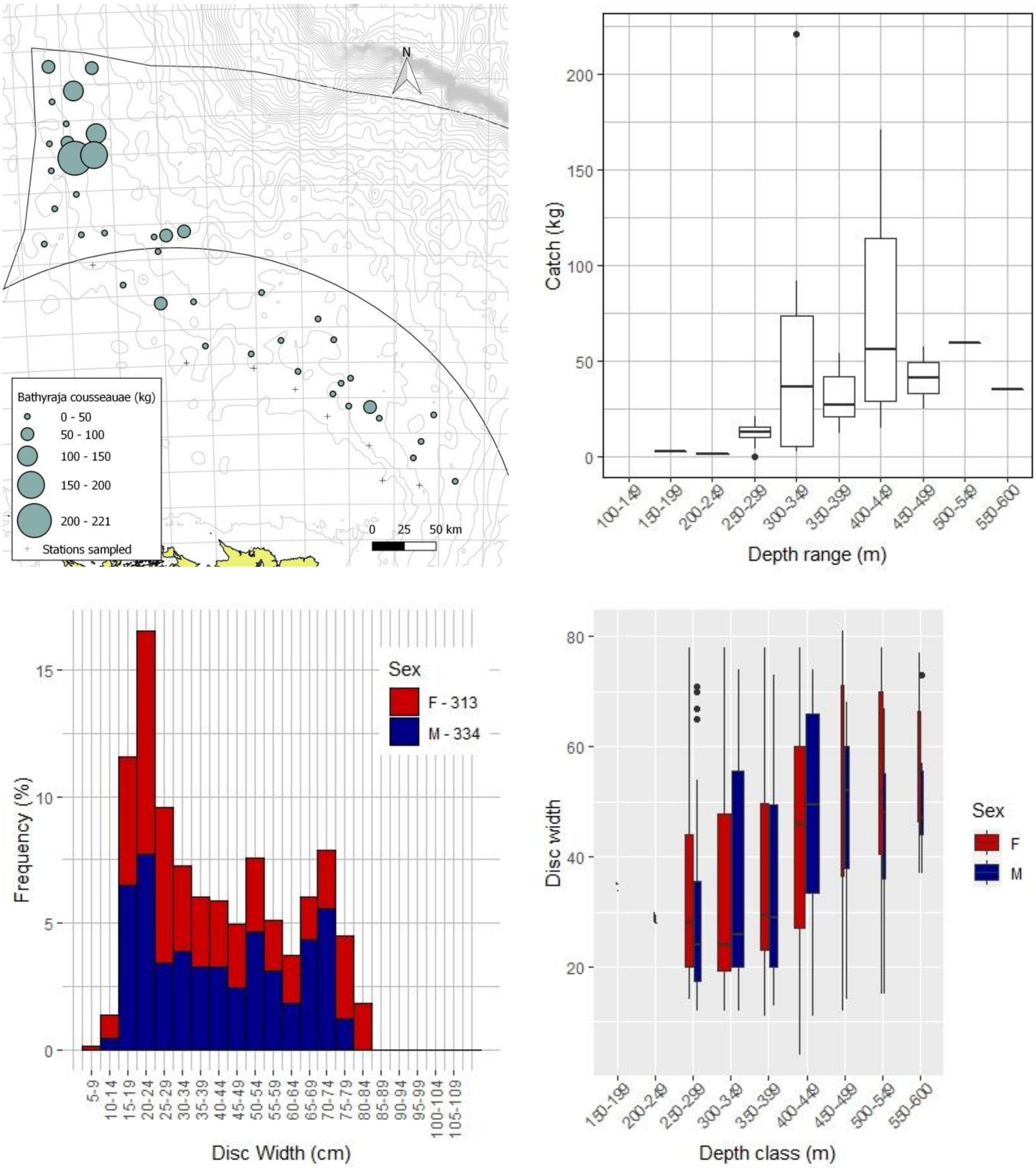
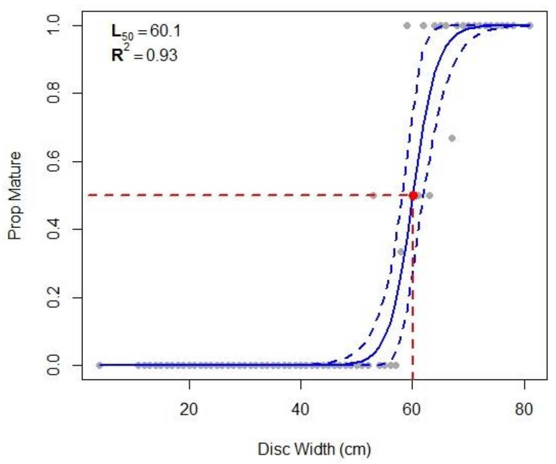
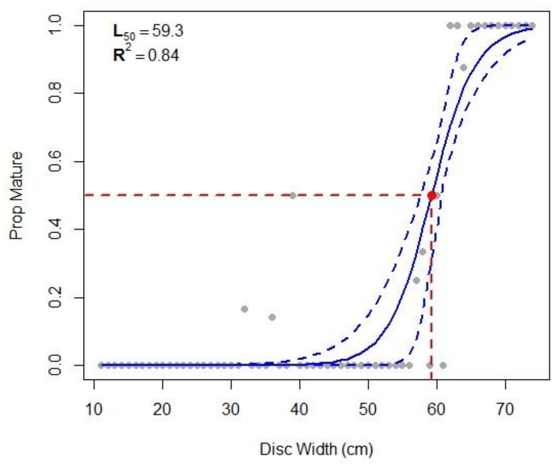


Figure 12 - Distribution and disc-width of RBZ

Disc width ranged between 4 and 81 cm, with a mean of 39.49 cm (µF = 38.56 cm; µM = 40.36 cm) and a slight predominance of males (51.62 %). On average, the size of the individuals appears to be correlated with depth, with wider individuals being more frequent in deeper waters. Only 7 females were carrying egg capsules. 63 females (20.13 %) were above the L_{dw} at 50 % maturity which was of 60.1 cm in 2019 cm, consistent with the one observed in 2013. The L_{dw} at 50 % maturity of males was of 59.3 cm, similar to the ones observed in 2013 and in 2010.



Female



Male

ZDLT1-10-2010	ZDLT1-11-2013	ZDLM3-11-2019	ZDLT1-10-2010	ZDLT1-11-2013	ZDLM3-11-2019
L_{M50} = 66.6 cm	L_{M50} = 60.3 cm	L_{M50} = 60.1 cm	L_{M50} = 60.9 cm	L_{M50} = 59.9 cm	L_{M50} = 59.3 cm

Figure 13 - Maturity ogives of RBZ

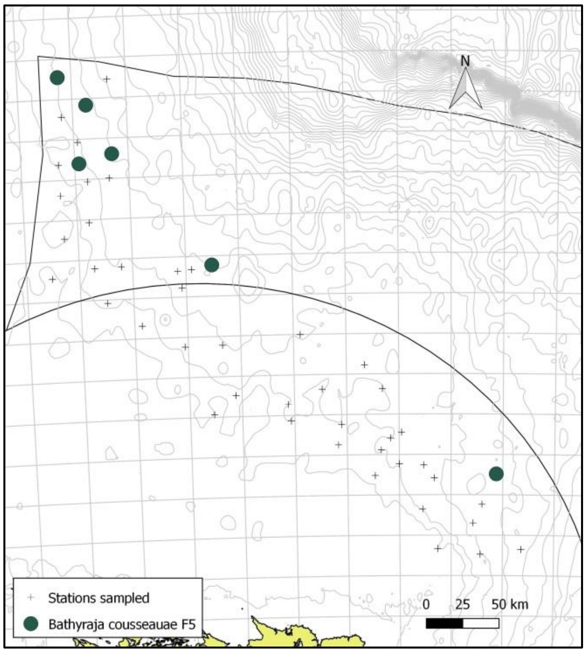


Figure 14 - Distribution of RBZ females carrying eggs

Zearaja chilensis = *Dipturus lamillai* (RFL)

A total of 1502.4 kg *Zearaja chilensis*, which represented 8.76 % of the skate catch, was caught at 38 stations. Although the species was recorded between 159 m and 541 m, the biggest catch were made in between 200 and 250 m, in the north of the FOCZ. The highest catch of 182.6 kg was recorded at 244 m depth, and 639 individuals were caught and sampled.

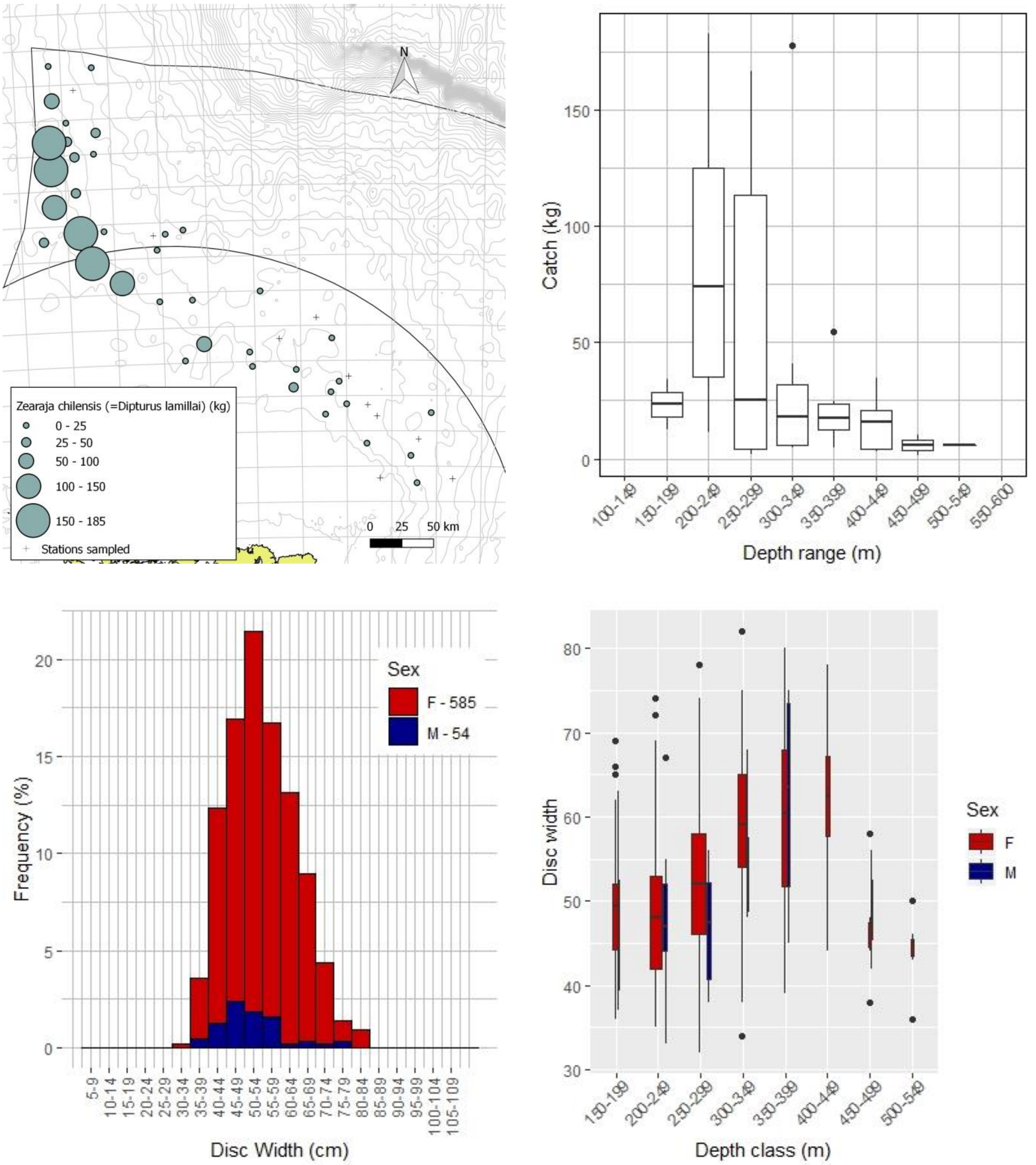
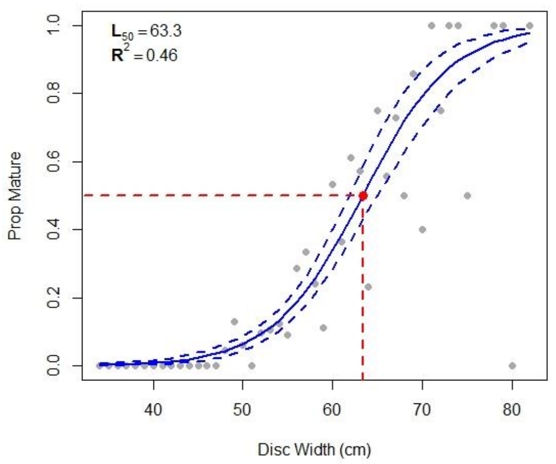
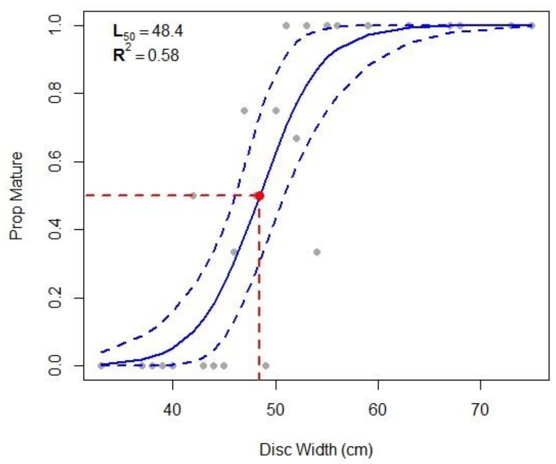


Figure 15 - Distribution and disc-width repartition of RFL

Interestingly, disc width ranged between 32 and 82 cm, with a mean of 52.34 cm (µF = 52.63 cm; µM = 49.17 cm) and a very marked predominance of females (91.55 %). No small juveniles were recorded. On average, the size of the individuals appears to be correlated with depth, with wider individuals being more frequent at intermediate depths, at 400 - 450 m. However these wide individuals were not very numerous and smaller individuals were more frequent, and found in shallower waters No females carrying egg capsules were recorded. 81 females (13.84 %) were above the L_{dw} at 50 % maturity which was of 63.3 cm in 2019 cm, intermediate between the values observed in 2010 and 2013. The L_{dw} at 50 % maturity of males was of 48.4 cm, similar to the ones observed in 2013 and in 2010.

<table>
<tr><td colspan="3">

Female</td><td colspan="3">

Male</td></tr>
<tr><td>ZDLT1-10-2010
L_{M50} = 67.6 cm</td><td>ZDLT1-11-2013
L_{M50} = 60.7 cm</td><td>ZDLM3-11-2019
L_{M50} = 63.3 cm</td><td>ZDLT1-10-2010
L_{M50} = 49.0 cm</td><td>ZDLT1-11-2013
L_{M50} = 47.0 cm</td><td>ZDLM3-11-2019
L_{M50} = 48.4 cm</td></tr>
</table>

Figure 16 - Maturity ogives of RFL

Amblyraja doellojuradoi (RDO)

A total of 1033.4 kg of *Amblyraja doellojuradoi*, which represented 6.03 % of the skate catch, was caught during the initial survey. It is the only species that has been caught at every station (48), but this ubiquitous distribution is not uniform as the biggest catches were recorded in the southern part of the studied area – however at all depths. The highest catch of 76 kg was recorded at 312 m depth. 2638 individuals were caught and sampled, which makes this species the second most abundant after *Bathyraja albomaculata*.

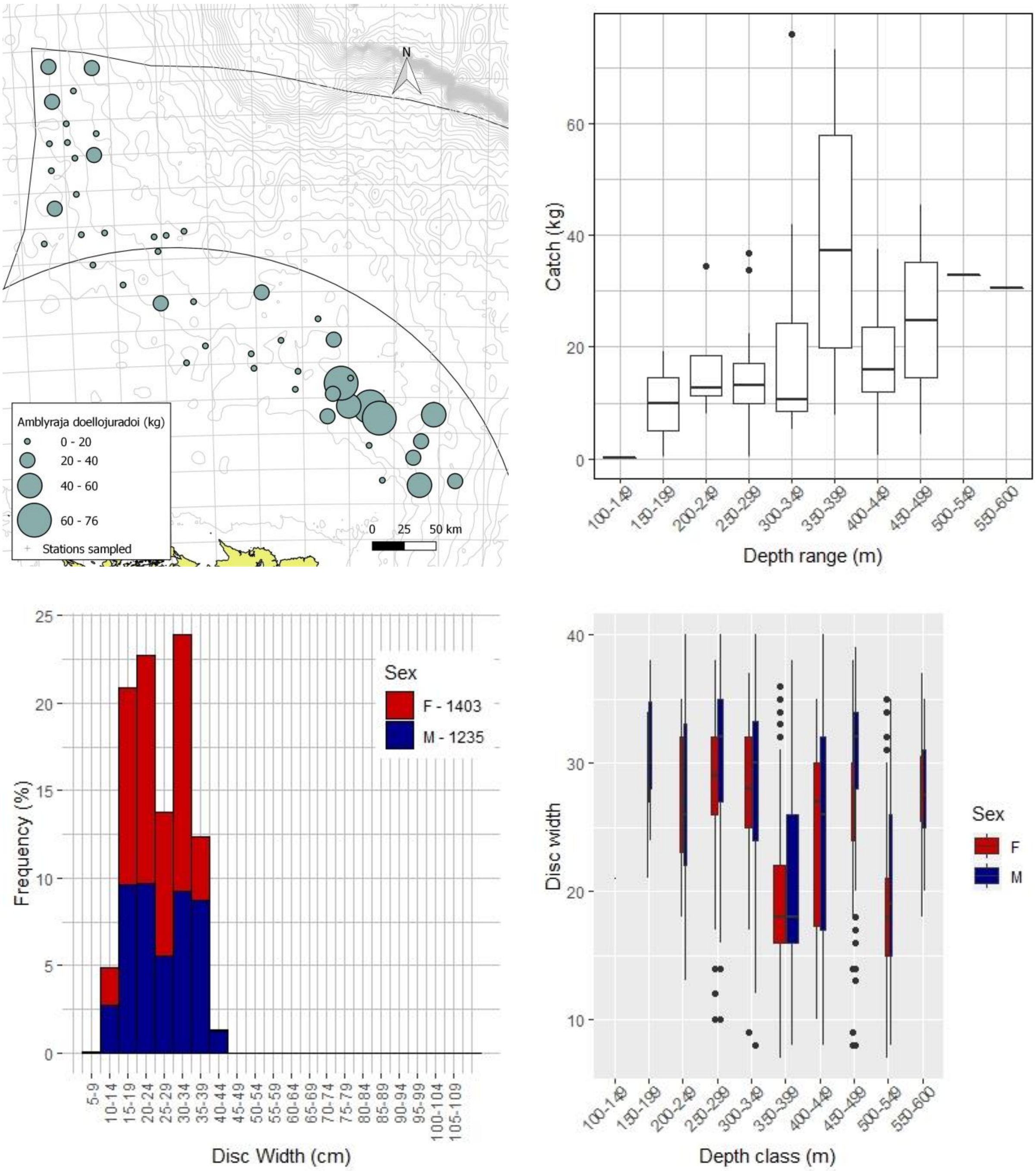
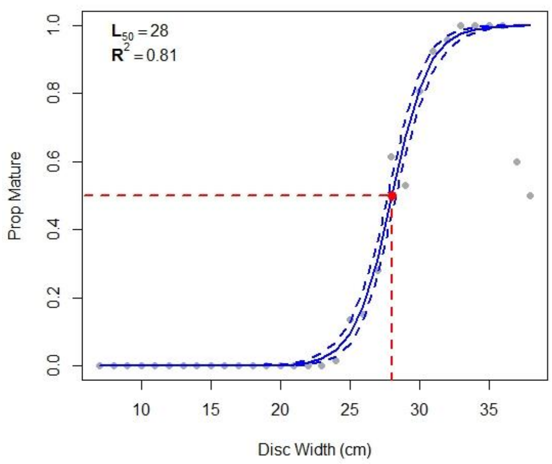
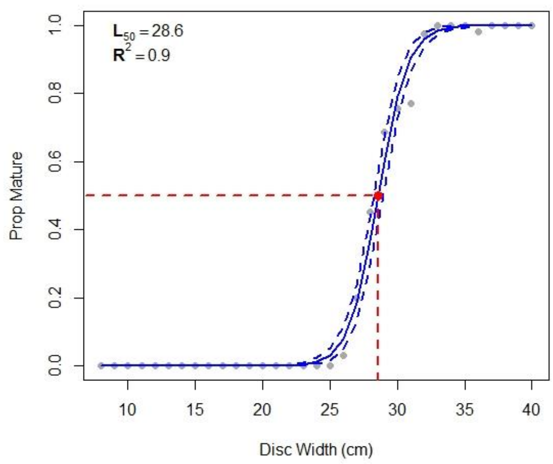


Figure 17 - Distribution and disc-width of RDO

Disc width ranged between 7 and 40 cm, with a mean of 23.59 cm (µF = 23.06 cm; µM = 24.19 cm); females were more abundant than males (53.18 %). Interestingly, the depth ranges in which the highest catches were recorded were also the ones where the smaller individuals occurred, which indicates the presence of juvenile / small skate hotspots. 24 females were carrying egg capsules. 396 females (28.23 %) were above 28.0 cm, the L_{dw} at 50 % maturity observed in 2019. The L_{dw} at 50 % maturity of both females and males appeared very consistent over the years.





Female			Male		
ZDLT1-10-2010 L_{M50} = 28.5 cm	ZDLT1-11-2013 L_{M50} = 27.3 cm	ZDLM3-11-2019 L_{M50} = 28.0 cm	ZDLT1-10-2010 L_{M50} = 28.3 cm	ZDLT1-11-2013 L_{M50} = 28.5 cm	ZDLM3-11-2019 L_{M50} = 28.6 cm

Figure 18 - Maturity ogives of RDO

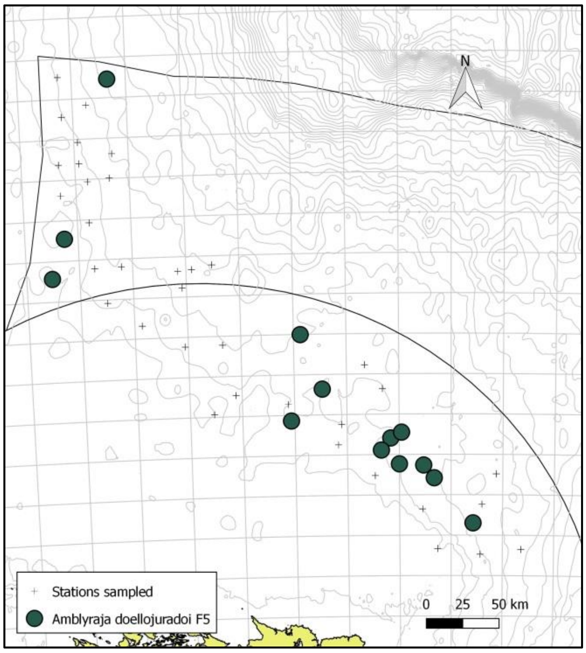


Figure 19 - Distribution of RDO females carrying eggs

Bathyraja macloviana (RMC)

881.28 kg of *Bathyraja macloviana* (RMC), which represented 5.14 % of the skate catch, was caught during the initial survey. The species was found at 45 of the 48 initial stations, with the main catches distributed between 300 and 400 m depth. However, the highest catch was recorded at 420 m and was of 95.3 kg. In total, 1331 individuals were caught and sampled during the 2019 survey.

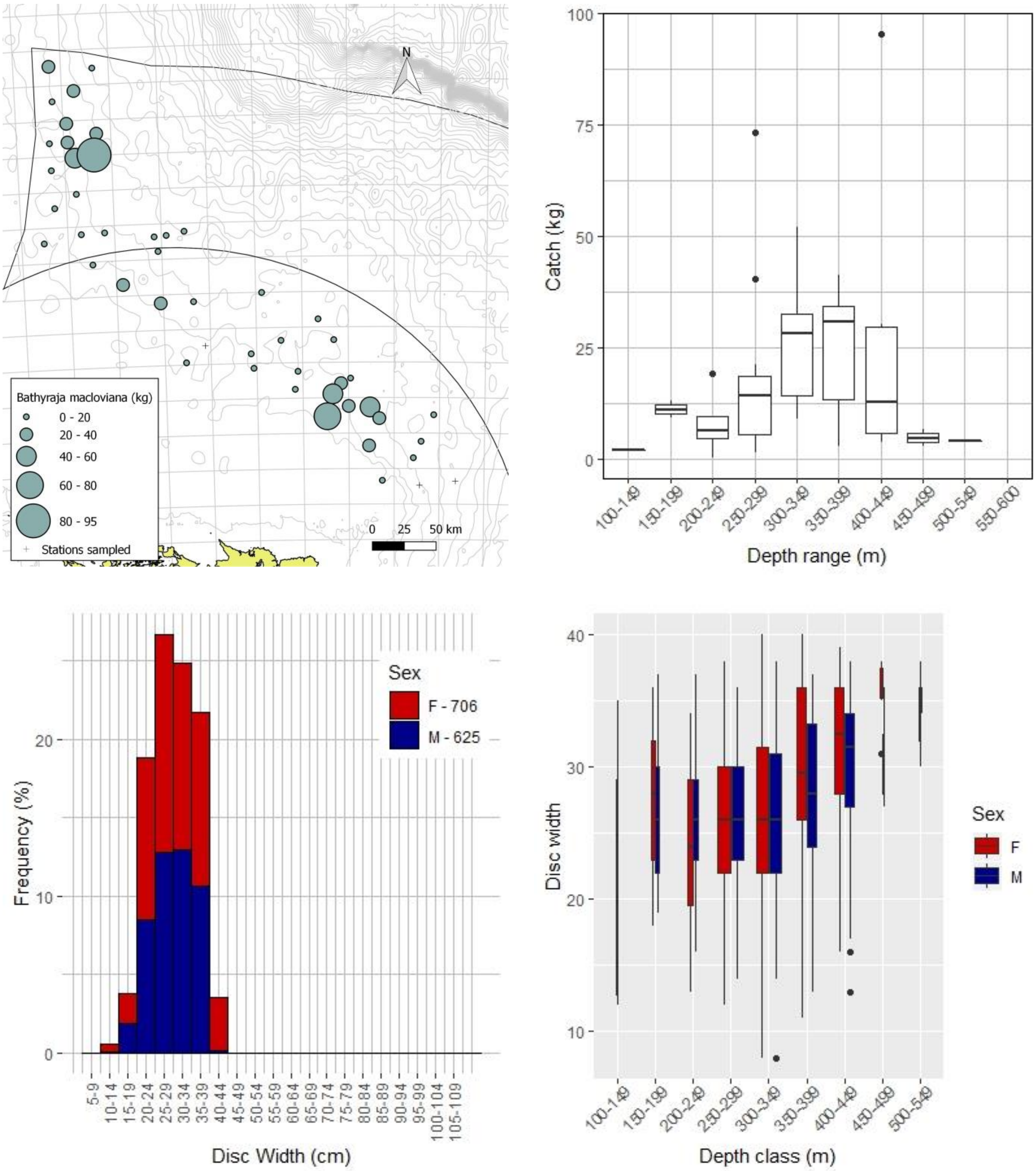
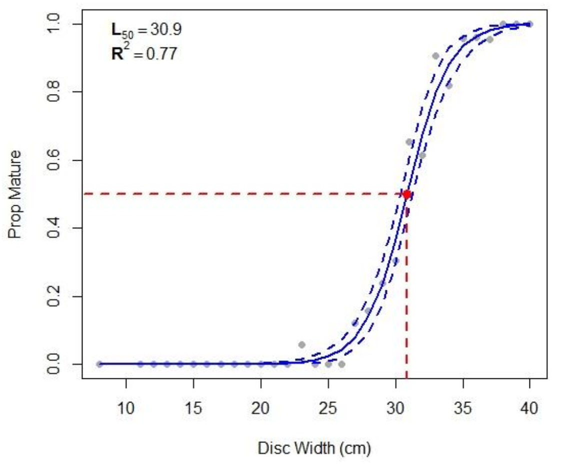
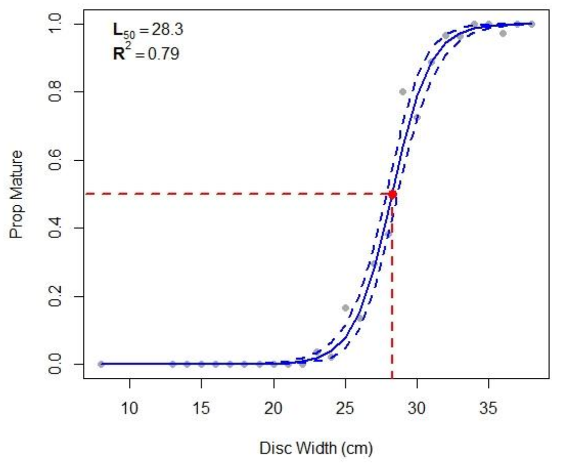


Figure 20 - Distribution and disc-width repartition of RMC

Disc width ranged between 8 and 40 cm, with a mean of 27.55 cm (µF = 27.73 cm; µM = 27.35 cm); females were more abundant than males (53.04 %). Depth seems to play a key role in the distribution of the individuals, with an increase of the average disc width correlated to depth. 15 females were carrying egg capsules, and were all caught in deeper waters. 251 females (35.6 %) were above 30.9 cm, the L_{dw} at 50 % maturity observed in 2019. The L_{dw} at 50 % maturity of both females and males seemed to have slightly dropped between 2010 and 2013, and showed an increase between 2013 and 2019.

<table>
<tr><td colspan="3">

Female</td><td colspan="3">

Male</td></tr>
<tr><td>ZDLT1-10-2010
L_{M50} = 32.6 cm</td><td>ZDLT1-11-2013
L_{M50} = 29.3 cm</td><td>ZDLM3-11-2019
L_{M50} = 30.9 cm</td><td>ZDLT1-10-2010
L_{M50} = 30.9 cm</td><td>ZDLT1-11-2013
L_{M50} = 27.2 cm</td><td>ZDLM3-11-2019
L_{M50} = 28.3 cm</td></tr>
</table>

Figure 21 - Maturity ogives of RMC

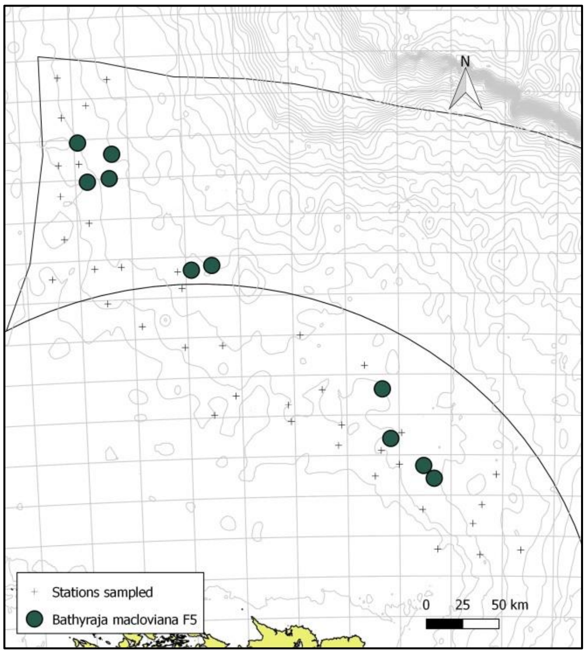


Figure 22 - Distribution of RMC females carrying eggs

Bathyraja multispinis (RMU)

Bathyraja multispinis catches represented 4.68 % of the skate catch, for a total of 802.8 kg caught during the initial survey. The species was found at 43 of the 48 initial stations, with no clear pattern of depth / catch distribution. The highest catch was of 80.32 kg and was recorded at 299 m. In total, only 156 individuals were caught and sampled during the 2019 survey.

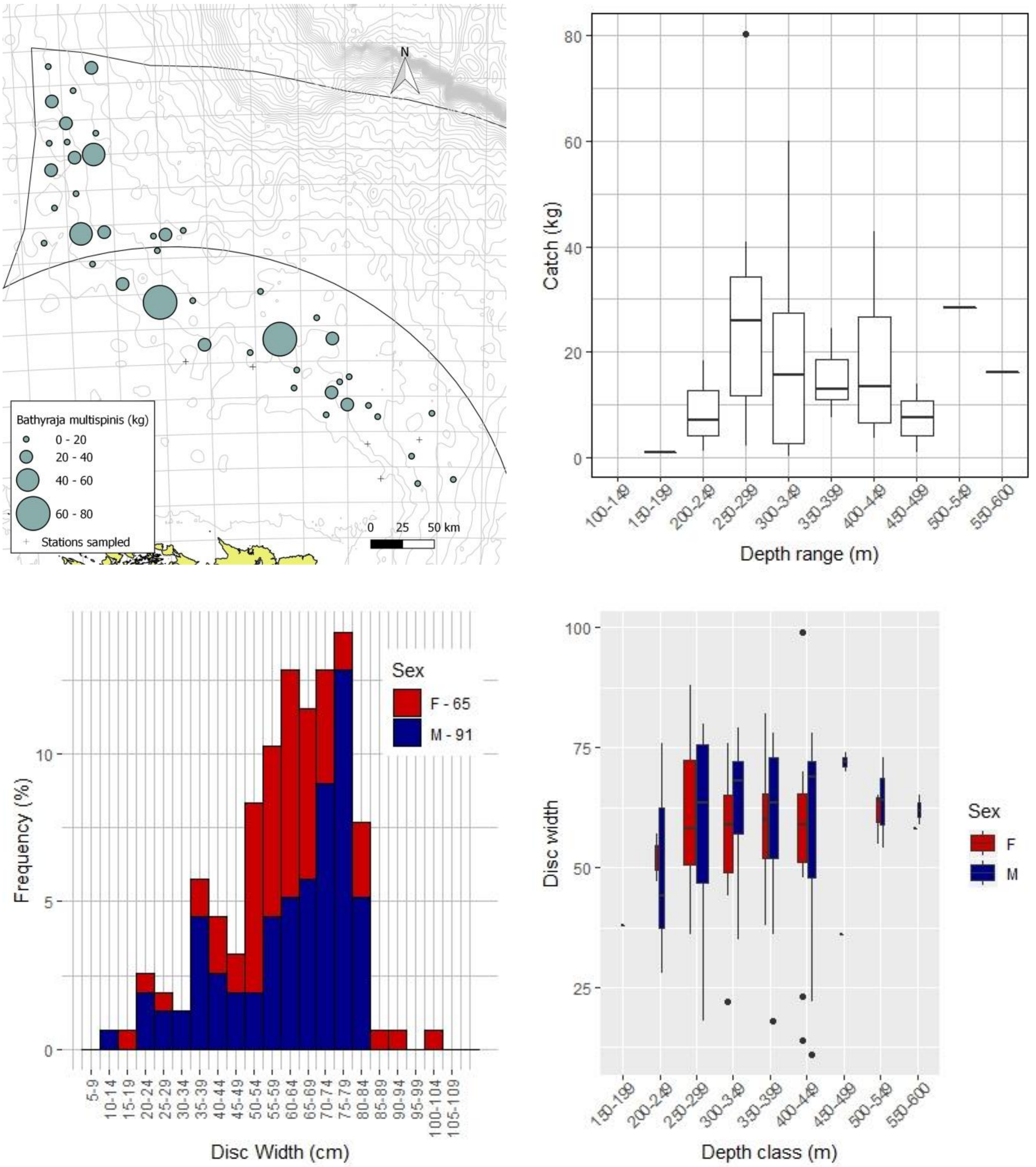
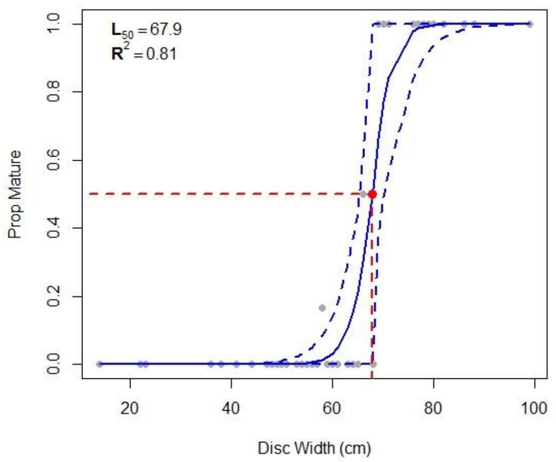
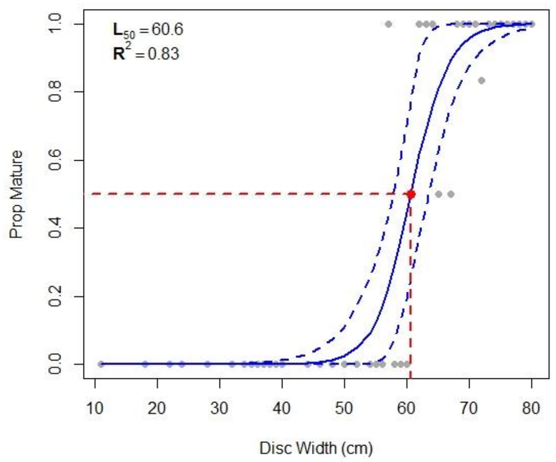


Figure 23 - Distribution and disc-width repartition of RMU

Disc width ranged between 11 and 99 cm, with a mean of 58.97 cm (µF = 58.17 cm; µM = 59.55 cm). Although males tended to be larger than females on average, the largest individuals were females. Males were more abundant than females (58.33 %). The size of this species did not appear to be correlated with depth. No females were carrying egg capsules. Of the 65 females sampled, 15 (23.08 %) were above the L_{dw} at 50 % maturity of 67.9 cm. The L_{dw} at 50 % maturity of both females and males seemed to be consistent with the values observed in 2010 and 2013.

<table>
<tr><td colspan="3">

Female</td><td colspan="3">

Male</td></tr>
<tr><td>ZDLT1-10-2010
L_{M50} = 68.5 cm</td><td>ZDLT1-11-2013
L_{M50} = 67.3 cm</td><td>ZDLM3-11-2019
L_{M50} = 67.9 cm</td><td>ZDLT1-10-2010
L_{M50} = 60.9 cm</td><td>ZDLT1-11-2013
L_{M50} = 60.0 cm</td><td>ZDLM3-11-2019
L_{M50} = 60.6 cm</td></tr>
</table>

Figure 24 - Maturity ogives of RMU

Bathyraja scaphiops (RSC)

Bathyraja scaphiops used to be among the main species caught in the Falkland Islands waters. In 2019, only 679.6 kg – 3.96 % of the skate catch – was caught during the initial survey. The species was found at 45 of the 48 initial stations, with no clear hotspot as the catches were very homogenous between 200 and 450 m. However, the highest catch was recorded at 303 m and was of 67.7 kg. A total of 672 individuals was caught and sampled during the 2019 survey.

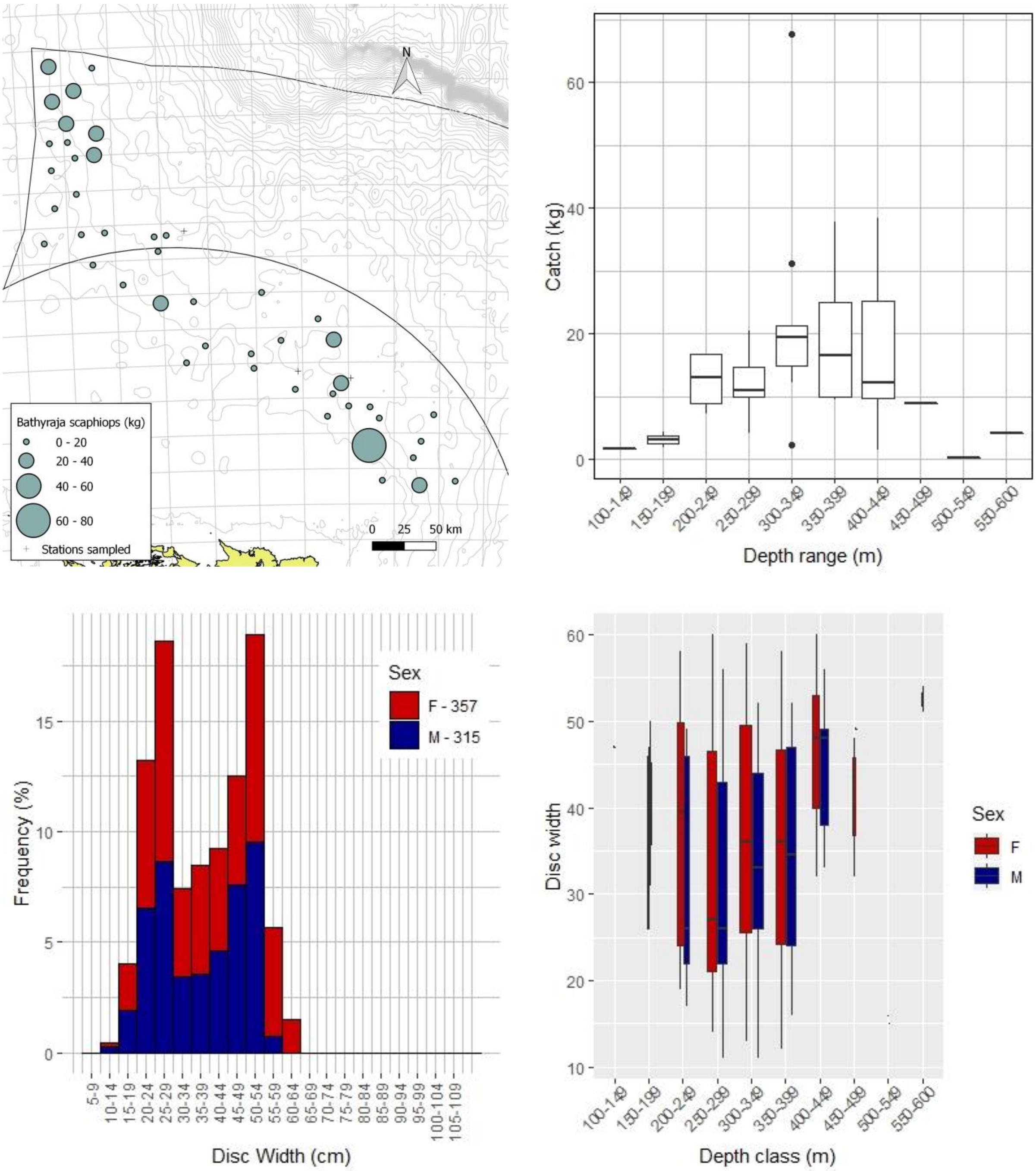
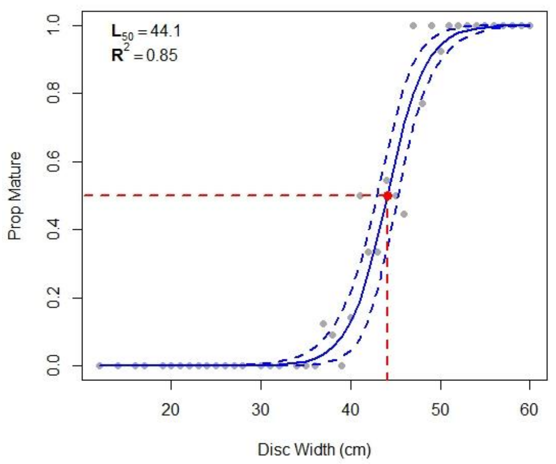
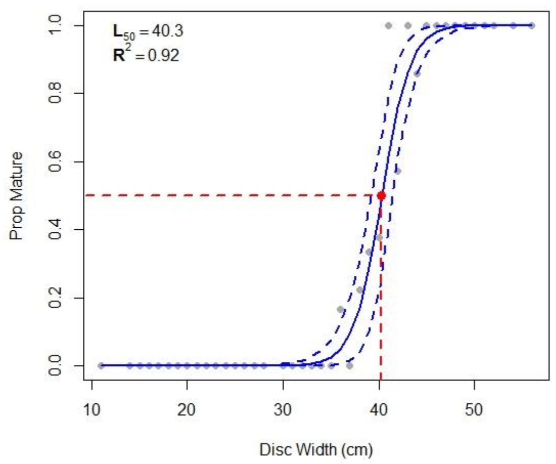


Figure 25 - Distribution and disc-width repartition of RSC

Disc width ranged between 11 and 60 cm, with a mean of 35.99 cm (µF = 36.66 cm; µM = 35.22 cm); females were slightly more predominant (53.12 %). The distribution of small vs wide individuals did not appear to be correlated with depth. Only 2 females were carrying egg capsules, however it is possible that most of the females were in a post-spawning stage (Maturity 6) as 124 of them (34.7 %) were wider than 44.1 cm, the L_{dw} at 50 % maturity observed in 2019. The L_{dw} at 50 % maturity of both females and males seemed to have increased since 2013, both of them by 2.2 cm.



Female



Male

ZDLT1-10-2010 L_{M50} = 42.9 cm	ZDLT1-11-2013 L_{M50} = 41.9 cm	ZDLM3-11-2019 L_{M50} = 44.1 cm	ZDLT1-10-2010 L_{M50} = 40.6 cm	ZDLT1-11-2013 L_{M50} = 38.1 cm	ZDLM3-11-2019 L_{M50} = 40.3 cm

Figure 26 - Maturity ogives of RSC

Psammobatis sp (RPX)

Psammobatis catches were very scarce, as they were only caught at 7 stations (48.54 kg, 0.28 % of the skate catch). On one occasion, the catch was of 32.88 kg, at a depth of 159 m. In total, 143 individuals were caught and sampled during the 2019 survey, 93 of them coming from this shallow water station. The distribution of this complex of species seems to be very patchy below 130 m and may not be detected in trawls.

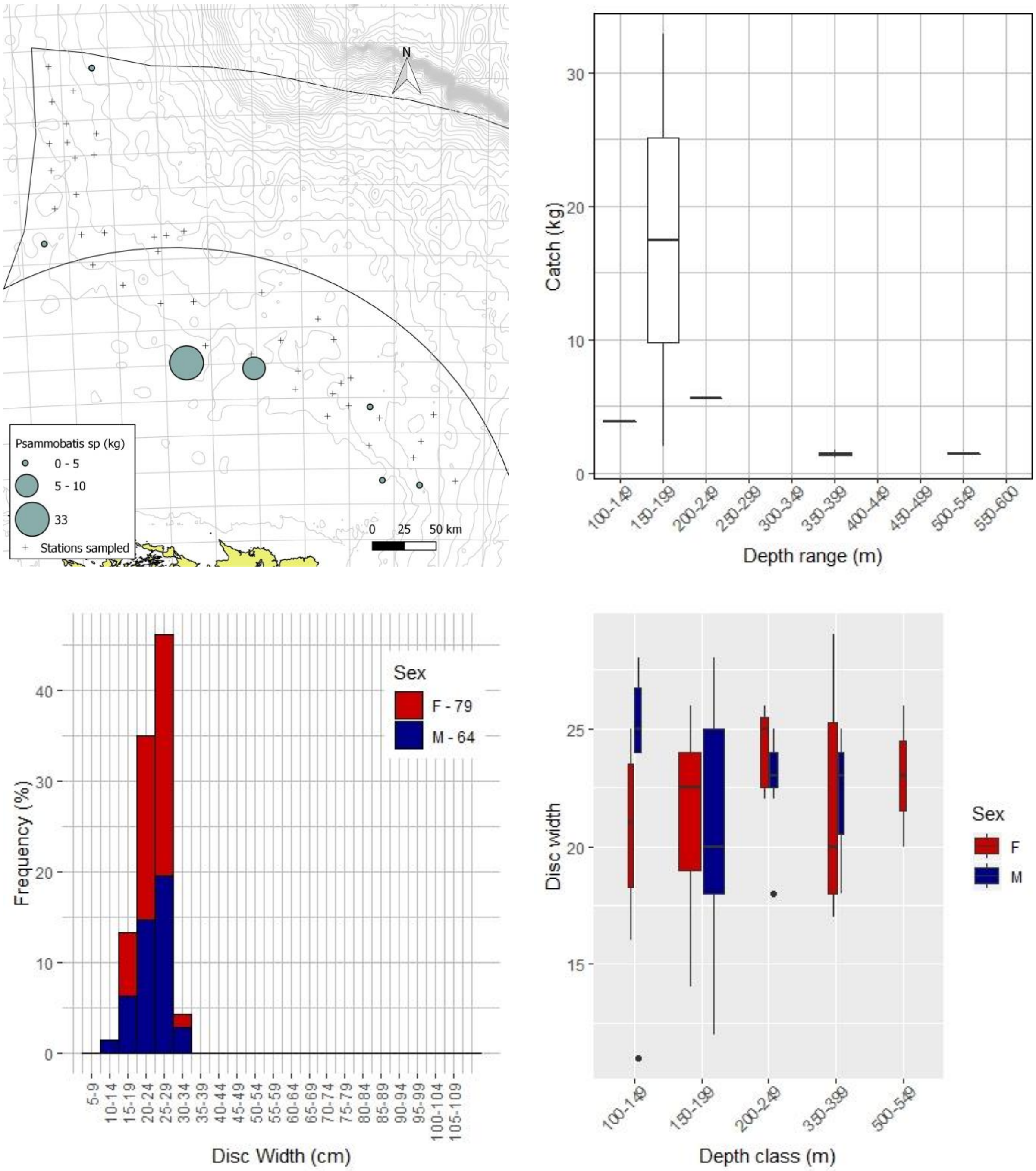
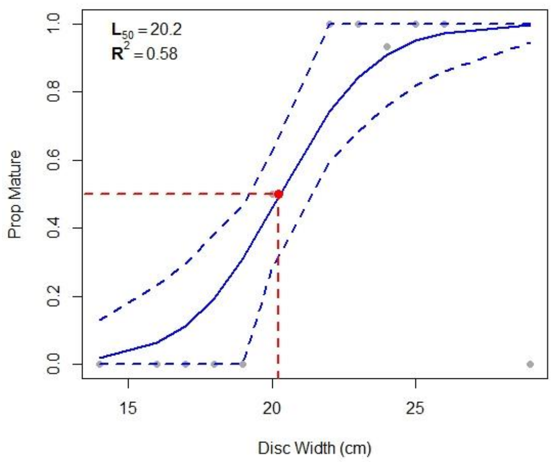
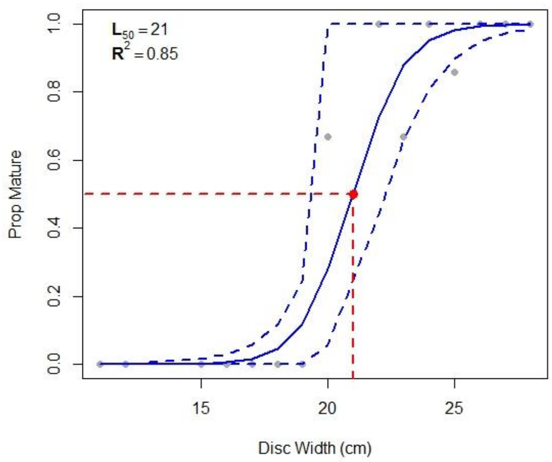


Figure 27 - Distribution and disc-width repartition of RPX

Disc width ranged between 11 and 29 cm, with a mean of 21.73 cm (µF = 21.91 cm; µM = 21.52 cm); females were more abundant than males (55.24 %). Only 1 female was carrying an egg capsule. Because of the paucity of data and the fact that RPX is a complex of potentially 6 species, the following L_{dw} at 50 % maturity values should be treated with caution. In 2019, 51 of the 79 females sampled (64.6 %) were above the L_{dw} at 50 % maturity of 20.2 cm. Both males and females L_{dw} at 50 % maturity values observed in 2019 were consistent with the one reported during the 2010 and 2013 cruises.



Female



Male

Female			Male		
ZDLT1-10-2010 L_{M50} = 21.3 cm	ZDLT1-11-2013 L_{M50} = 20.6 cm	ZDLM3-11-2019 L_{M50} = 20.2 cm	ZDLT1-10-2010 L_{M50} = 21.4 cm	ZDLT1-11-2013 L_{M50} = 20.4 cm	ZDLM3-11-2019 L_{M50} = 21.0 cm

Figure 28 - Maturity ogives of RPX

Dipturus trachyderma (RTR), *Dipturus argentinensis* (RDA), *Bathyraja magellanica* (RMG)

Because these three species were caught in very limited quantity, their statistics are summarized in the following Table 3 - Biological and catch data of RTR, RDA and RMG. Only the distribution of RTR and RDA has been mapped as only two specimen of RMG have been caught in one station – namely station 462.

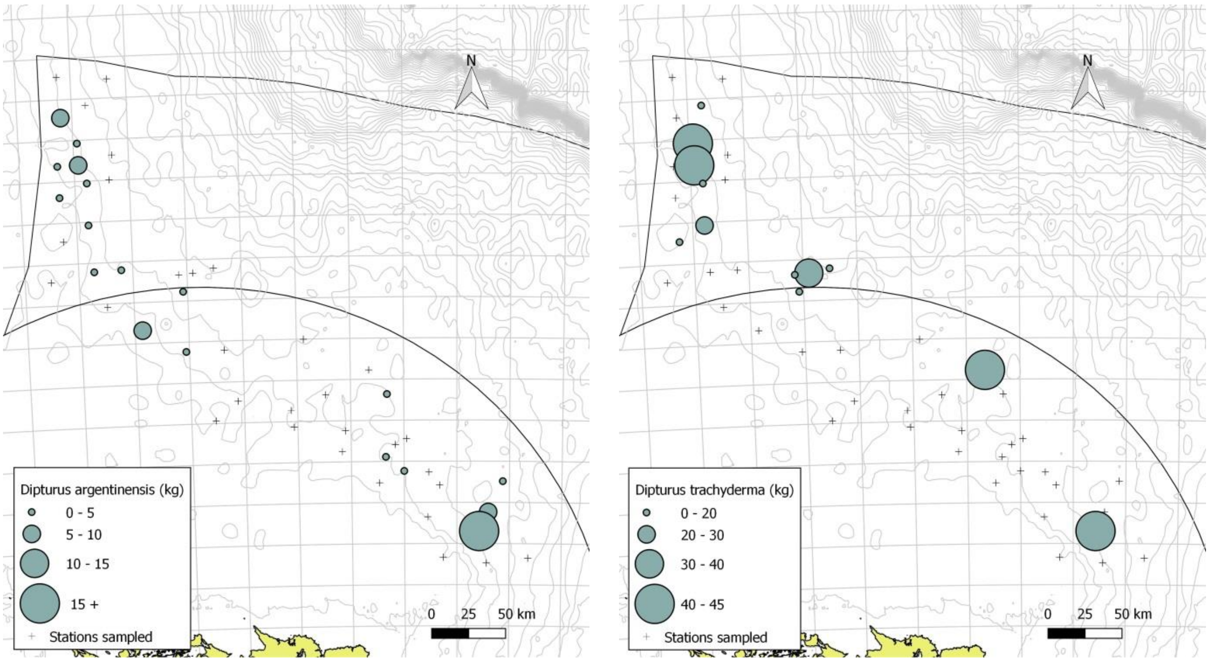


Figure 29 - Distribution of RTR and RDA

Table 3 - Biological and catch data of RTR, RDA and RMG

	N ind	DW min (cm)	DW max (cm)	µDW (cm)	Mat I	Mat II	Total catch (kg)
RTR ♀	13	86	140	104.6	5	8	302.5
RTR ♂	12	80	125	100.8	9	3	
RDA ♀	19	36	66	49.7	16	3	73.7
RDA ♂	16	40	89	59.8	16	0	
RMG ♂	2	20	24	-	1	1	0.56

4.2 Finfish and cephalopod species bycatch

Commercial bycatch

A total of 14,929.04 kg of bycatch species presenting a potential commercial interest were recorded at the 48 initial stations of the survey, of which 18.81 % were discarded and 40.04 % were sampled.

Table 4 - FIFD Codes, Latin and vernacular names of commercial species

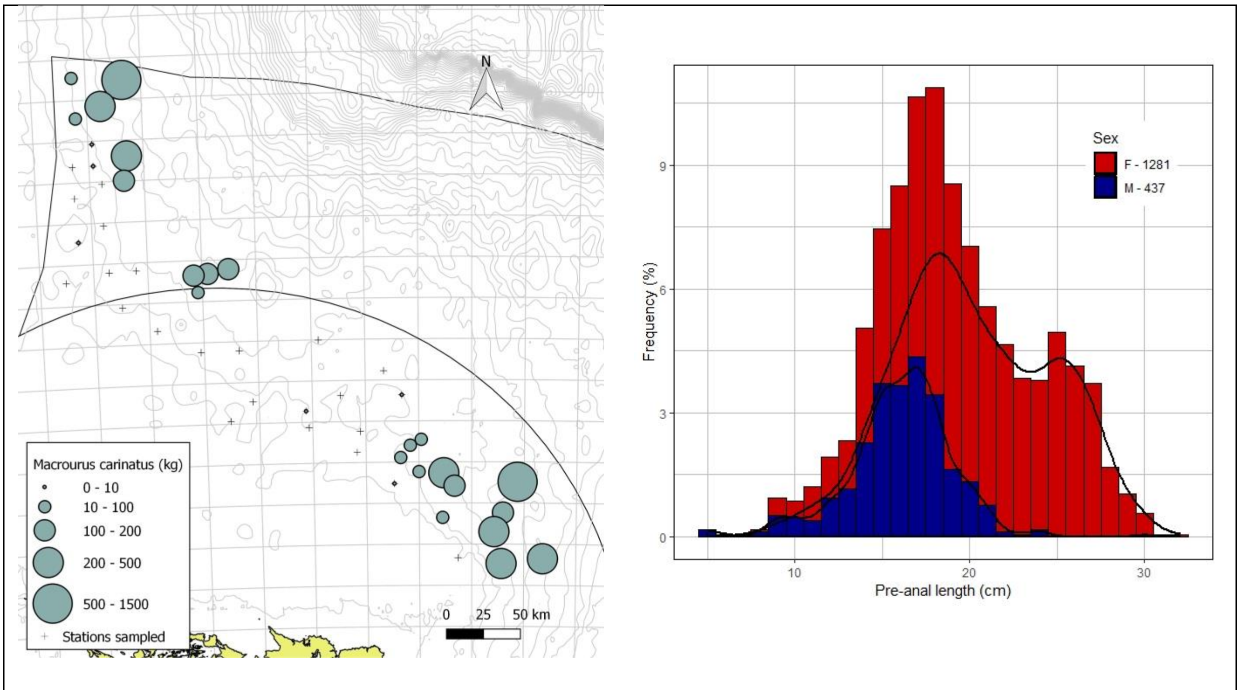
Species code	Species Latin name	Species common name
BAC	*Salilota australis*	Red cod, Tadpole codling
BLU	*Micromesistius australis australis*	Southern blue whiting
GRC	*Macrourus carinatus*	Ridge scaled grenadier
HAK	*Merluccius hubbsi*	Argentine hake
KIN	*Genypterus blacodes*	Kingclip, Pink cusk-eel
LAR	*Lampris immaculatus*	Southern opah
LOL	*Doryteuthis gahi*	Falkland calamari
PAR	*Patagonotothen ramsayi*	Rockcod, Longtail southern cod
PAT	*Merluccius australis*	Southern hake
TOO	*Dissostichus eleginoides*	Patagonian toothfish
WHI	*Macruronus magellanicus*	Hoki, Patagonian grenadier

Table 5 - Catch, discard and sample recorded of commercial species

Species code	Station nb	Catch (kg)	Catch (%)	Discard (kg)	Discard (%)	Sample (kg)	Sample (%)
GRC	28	5730.21	38.38	1671.07	29.16	1782.86	31.11
HAK	44	3876.68	25.97	216.76	5.59	1936.45	49.95
WHI	22	2082.52	13.95	261.58	12.56	513.60	24.66
LOL	41	1462.29	9.79	31.80	2.17	214.18	14.65
TOO	44	703.21	4.71	41.14	5.85	703.21	100.00
PAR	47	420.33	2.82	364.77	86.78	296.17	70.46
KIN	11	296.80	1.99	54.10	18.23	270.78	91.23
BAC	15	176.16	1.18	34.15	19.39	91.04	51.68
BLU	18	129.93	0.87	129.93	100.00	121.16	93.26
PAT	7	28.08	0.19	2.50	8.90	25.58	91.10
LAR	1	22.84	0.15	0.00	0.00	22.84	100.00
Total	**48**	**14929.04**	**-**	**2807.51**	**18.81**	**5977.88**	**40.04**

Ridge scaled grenadier – GRC (*Macrourus carinatus*)

A total of 5,730.2 kg of GRC was caught within 28 stations, mainly in deeper waters with two noticeable catches of 1,403.4 kg at 541 m and 868.5 kg at 459 m. 1718 individuals were sampled, of which 74.56 % were female. The pre-anal length ranged from 5 to 32 cm (µF = 20.21 cm; µM = 16.05 cm), and the majority of the sampled individuals were of maturity stage 2.

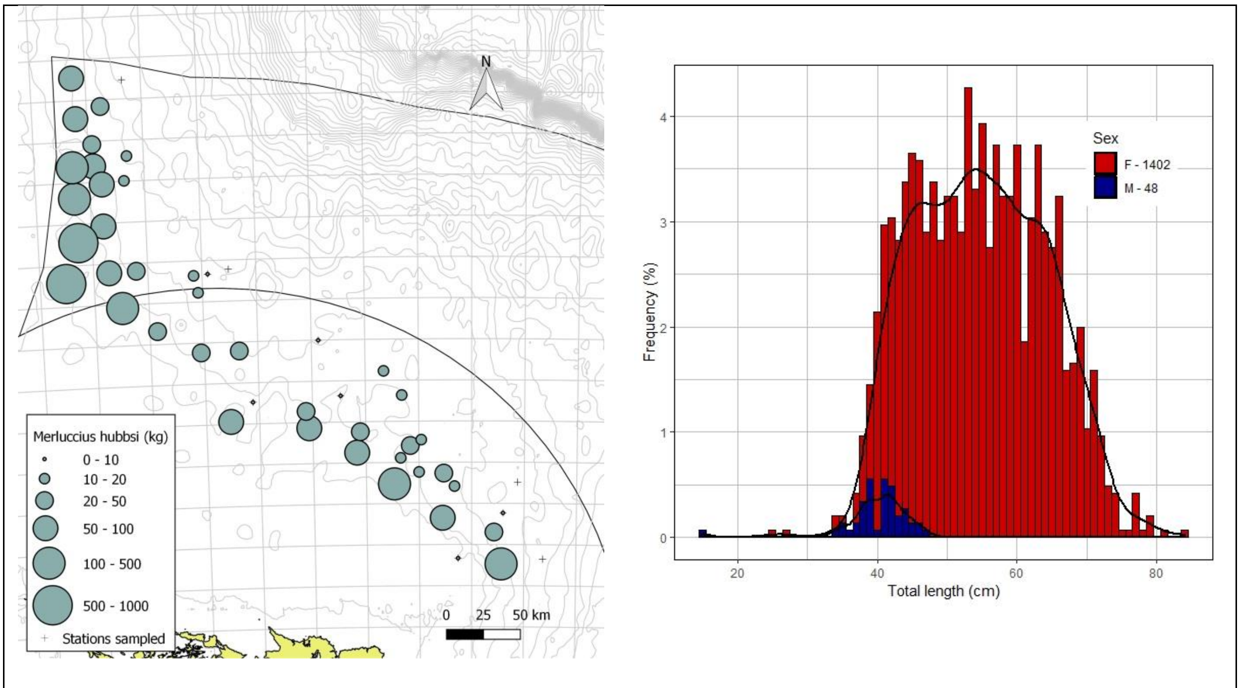


Maturity stage	I	II	III	IV	V	VI	VII	VIII
Female	95	642	290	206	5	4	30	9
Male	79	276	64	16	-	-	2	-

Figure 30 - Distribution, length-frequency and maturity stages of GRC

Argentine hake – HAK (*Merluccius hubbsi*)

Argentine hake was the second species in terms of bycatch, with 3,876.68 kg caught at 44 stations. Although the species was widely distributed in the prospected zone, catches were higher in the north of the FOCZ and in shallower waters (highest catches of 633.78 kg and 606.06 kg at 237 m and 187 m depth respectively. 1450 individuals were sampled, largely represented by females (96.67 %). The total length ranged from 15 to 84 cm (µF = 54.86 cm; µM = 40.15 cm), a dissymmetry between sexes that is also found in the modal maturity stage, most of the females having a maturity stage of III when most males were stage VII.

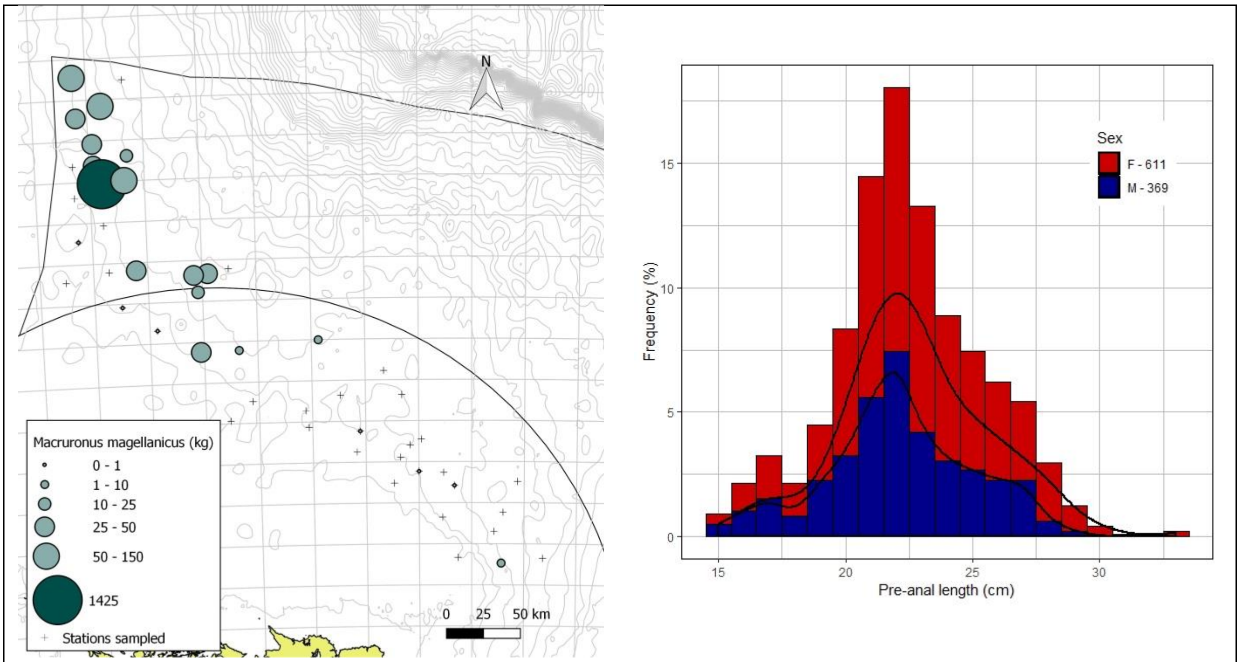


Maturity stage	I	II	III	IV	V	VI	VII	VIII
Female	1	64	1001	4	19	-	61	252
Male	-	2	-	-	-	-	42	4

Figure 31 - Distribution, length-frequency and maturity stages of HAK

Hoki, Patagonian grenadier – WHI (*Macruronus magellanicus*)

A total of 2,082.68 kg of WHI was caught at 22 stations, mainly in the north of the FOCZ – with an exceptional catch of 1,425 kg at one station (depth = 346 m). Altogether, 980 individuals were sampled; 62.35 % of them were female. The pre-anal length ranged from 15 to 33 cm, both sexes showing a comparable average length (µF = 22.72 cm; µM = 22.11 cm). The majority of the sampled individuals were of maturity stage 2.

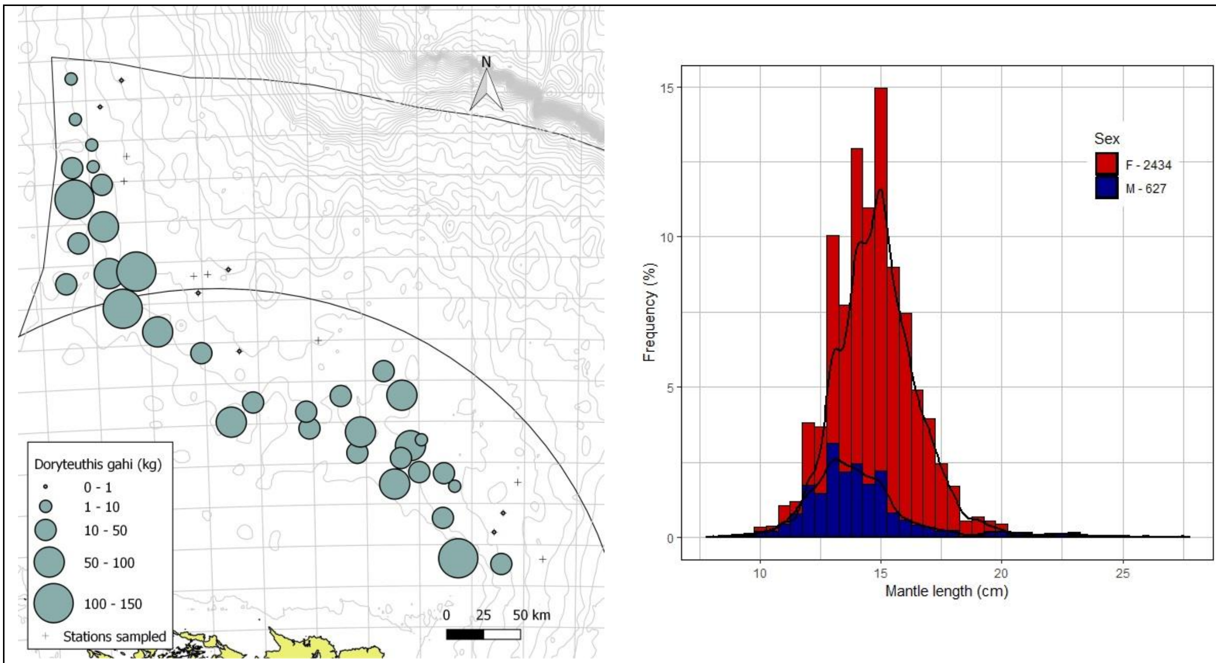


Maturity stage	I	II	III	IV	V	VI	VII	VIII
Female	22	541	28	-	-	-	9	11
Male	17	318	29	-	-	-	5	-

Figure 32- Distribution, length-frequency and maturity stages of WHI

Falkland calamari – LOL (*Doryteuthis gahi*)

Falkland calamari was caught in relatively high quantity, the total catch reaching 1,462.29 kg in 41 out of the 48 initial stations – the catches repartition being somewhat homogenous in the shallower waters (biggest catch: 149.34 kg at 127 m). 3061 individuals were sampled, among which 79.52 % were female. The smallest individual was 8 cm and the largest 27.5 cm (µF = 14.84 cm; µM = 14.19 cm). For both sexes, the large majority of the sampled individuals were of maturity stage 5.

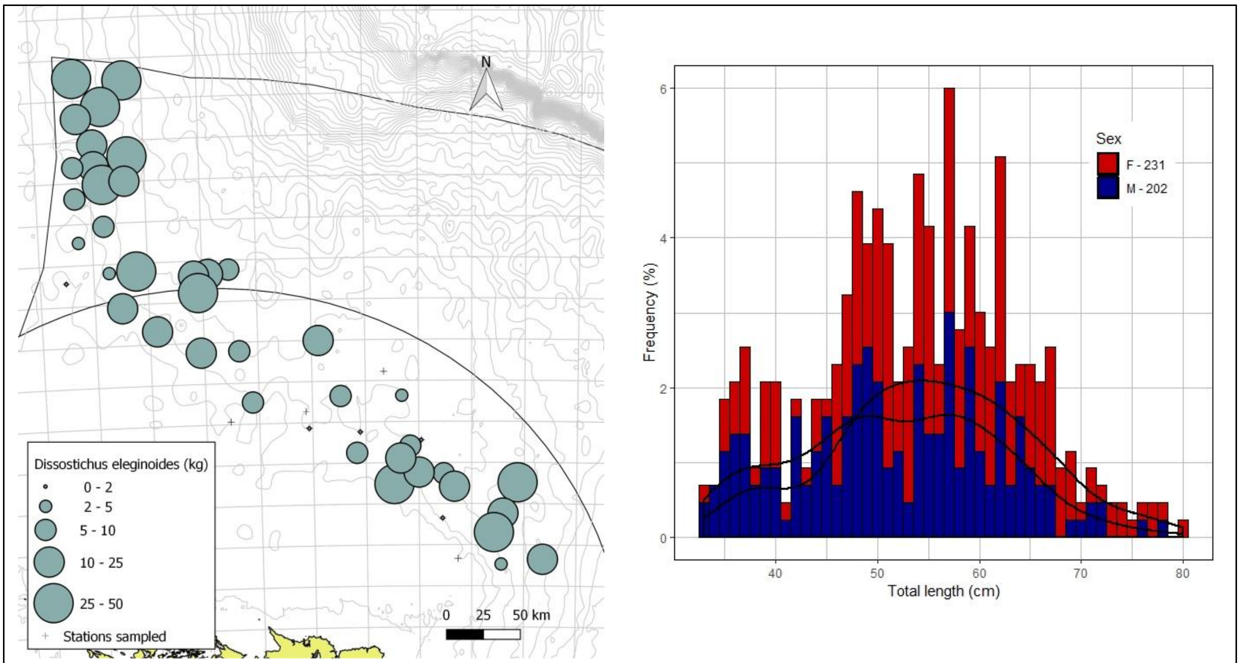


Maturity stage	I	II	III	IV	V	VI
Female	-	2	14	55	2362	1
Male	2	2	-	86	537	-

Figure 33 - Distribution, length-frequency and maturity stages of LOL

Patagonian toothfish – TOO (*Dissostichus eleginoides*)

Patagonian toothfish was caught at 44 stations, for a total of 703.21 kg. No clear hotspot was identified for this species in the prospected zone. The biggest catch of 49.10 kg was made at 414 m depth. Altogether, 433 individuals were sampled, with similar amounts of females (53.35 %) and males (46.65 %). These individuals ranged from 33 to 80 cm, females tending to be slightly bigger than males on average (μF = 55.37 cm; μM = 51.78 cm). The majority of the sampled individuals were immature - stage 1.

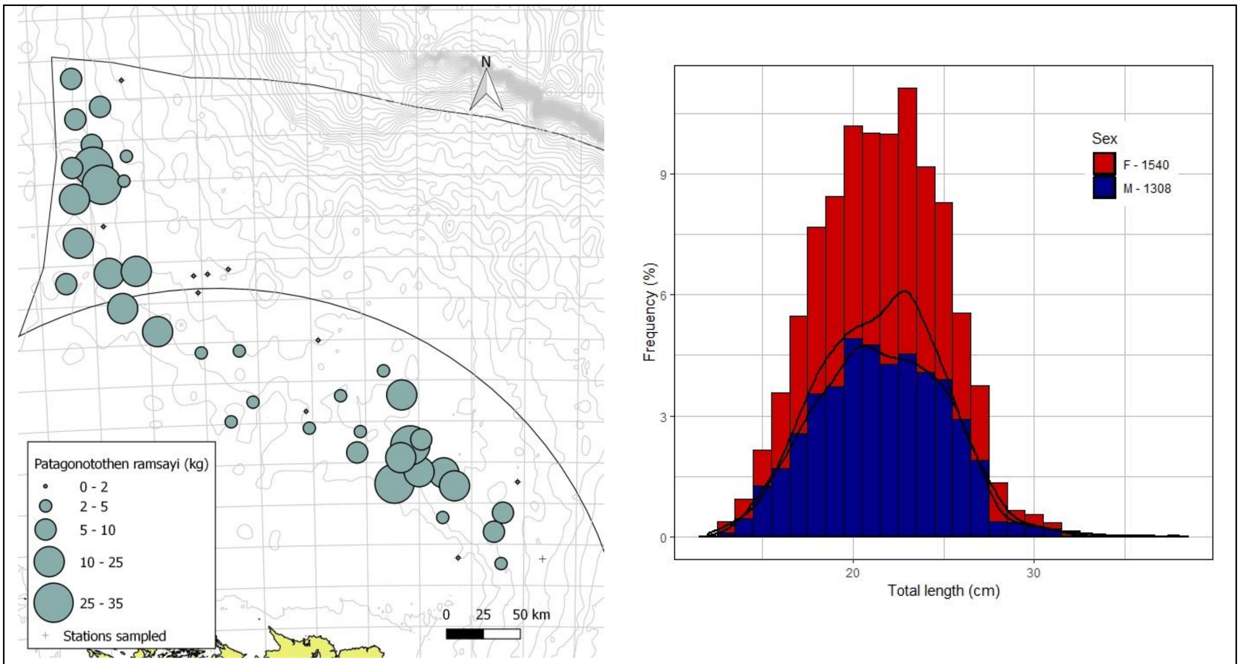


Maturity stage	I	II	III	IV	V	VI	VII	VIII
Female	164	65	2	-	-	-	-	-
Male	139	63	-	-	-	-	-	-

Figure 34 - Distribution, length-frequency and maturity stages of TOO

Rockcod, Longtail southern cod – PAR (*Patagonotothen ramsayi*)

A total of 420.33 kg of rock cod was caught among 47 stations, which makes this species the most widespread one. Although there seems to be some heterogeneity in the distribution of this species, it was never caught in high abundance as the highest catch was of 33.90 kg (346 m depth). 2842 individuals were sampled, females slightly outnumbering males (54.07 %). The individual sampled ranged from 12 cm to 38 cm (µF = 21.61 cm; µM = 21.55 cm), with a modal maturity stage of II.

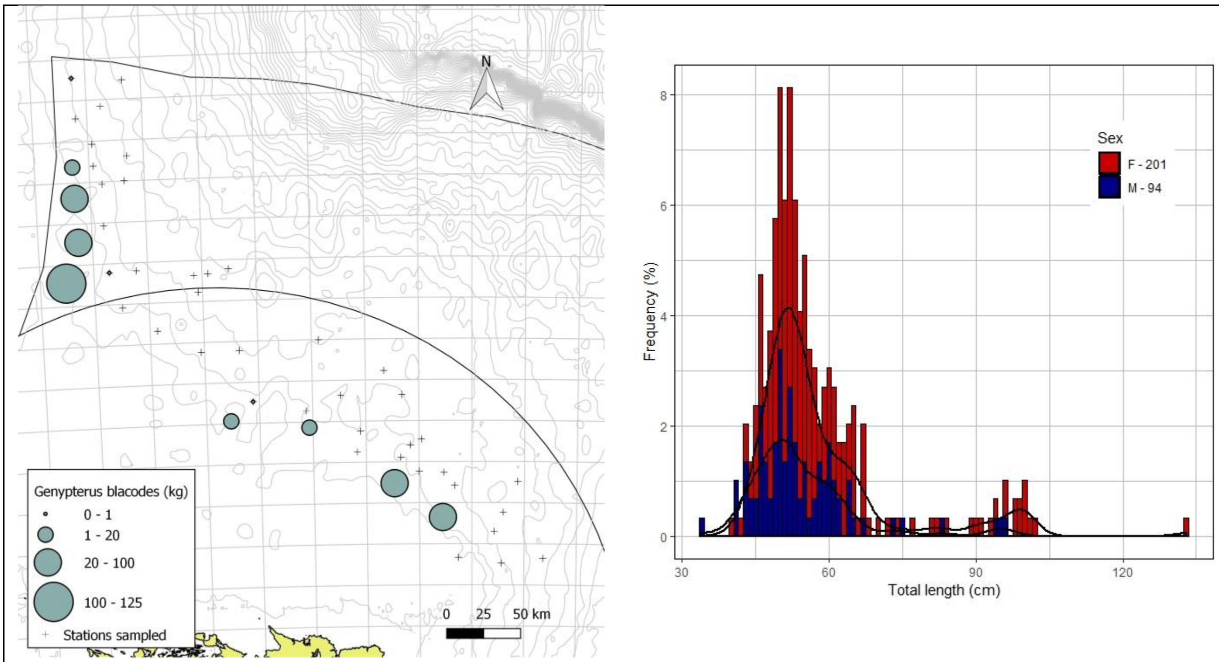


Maturity stage	I	II	III	IV	V	VI	VII	VIII
Female	242	1194	23	-	-	-	6	75
Male	311	900	87	-	-	-	9	1

Figure 35 - Distribution, length-frequency and maturity stages of PAR

Kingclip, Pink cusk-eel – KIN (*Genyypterus blacodes*)

296.80 kg of kingclip were caught among 11 stations, with a clear preference of this species for shallower waters – the main catch of 125.86 kg having been made at a depth of 187. 295 individuals were sampled, 68.14 % of them being females. The individual sampled ranged from 34 cm to 133 cm (µF = 58.31 cm; µM = 54.22 cm). Females were mostly of maturity stage II, when male - maturity stage I were more abundant.

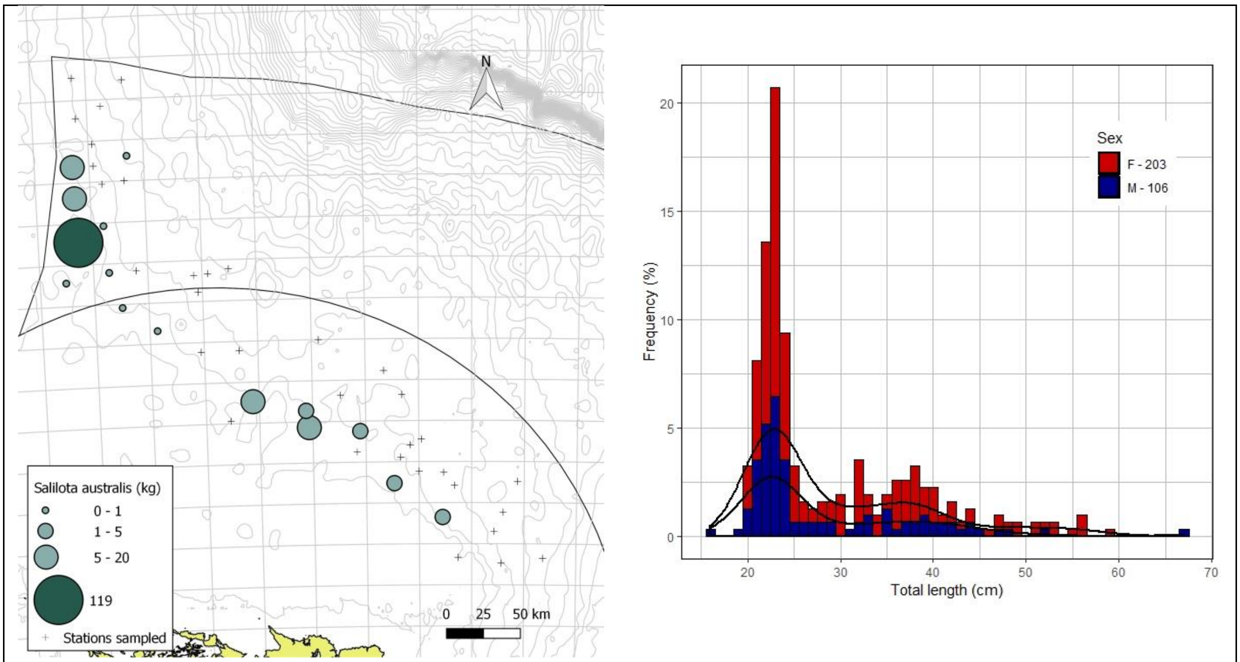


Maturity stage	I	II	III	IV	V	VI	VII	VIII
Female	54	130	14	-	-	-	-	3
Male	56	34	4	-	-	-	-	-

Figure 36 - Distribution, length-frequency and maturity stages of KIN

Red cod, Tadpole codling – BAC (*Salilota australis*)

A total of 176.16 kg of red cod was caught at 15 stations – however 119 kg were caught at one station (depth = 237 m) in the north of the FOCZ, the rest of the catch only exceeding 10 kg per station on one occasion. Of the 309 individuals sampled, 65.70 % were females. The total size of the individuals spanned from 16 cm to 67 cm (μF = 29.22 cm; μM = 27.97 cm). Both females and males of maturity stage II were predominant.

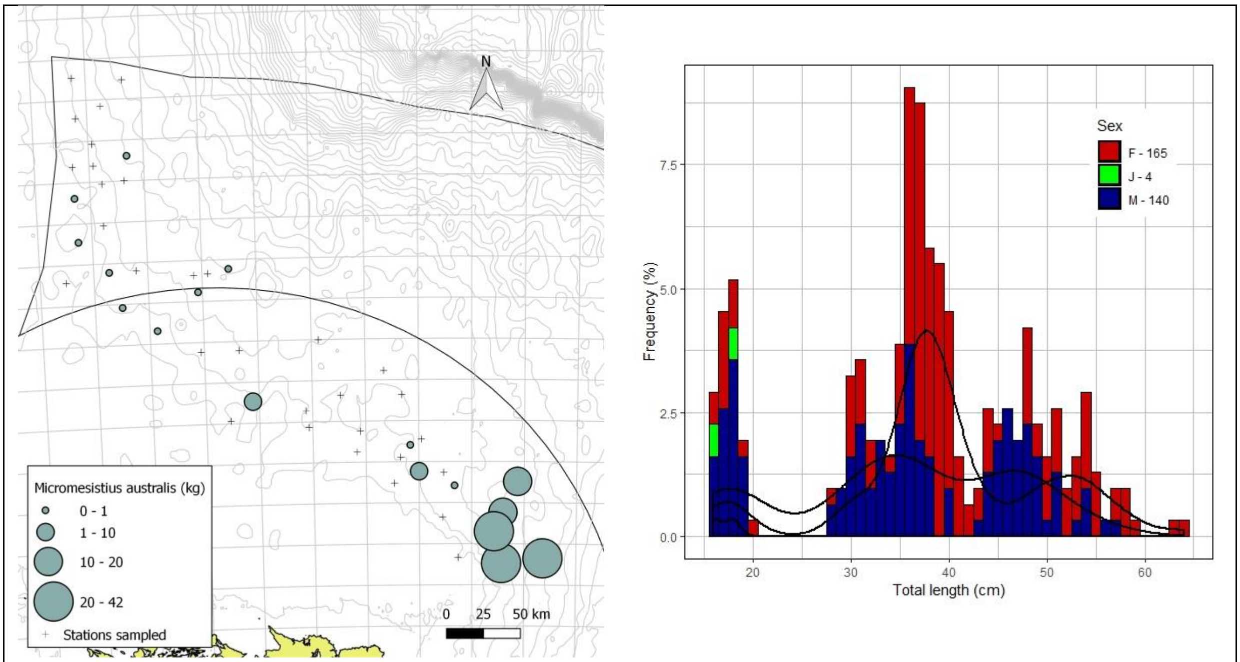


Maturity stage	I	II	III	IV	V	VI	VII	VIII
Female	47	151	4	-	-	-	-	1
Male	31	54	18	-	-	-	3	-

Figure 37 - Distribution, length-frequency and maturity stages of BAC

Southern blue whiting – BLU (*Micromesistius australis australis*)

129.93 kg of blue whiting have been caught among 18 stations during the initial part of the survey, with a dominant hotspot in the southern part of the prospected zone (north of the Loligo box). The highest catches are also linked to deeper stations, with 41.6 kg and 30.2 kg having been caught at 556 and 414 respectively. Altogether, 309 individuals were sampled, of which 54.10 % were female. The total length ranged from 16 to 64 cm (µF = 39.73 cm; µM = 35.43 cm); all maturity stages were present, with a higher proportion of female maturity stage II and male maturity stage I.



Maturity stage	X	I	II	III	IV	V	VI	VII	VIII
Female	-	42	73	12	5	5	1	13	14
Male	-	51	19	16	19	13	-	20	2
Juveniles	4	-	-	-	-	-	-	-	-

Figure 38 - Distribution, length-frequency and maturity stages of BLU

4.3 Benthic invertebrate bycatch

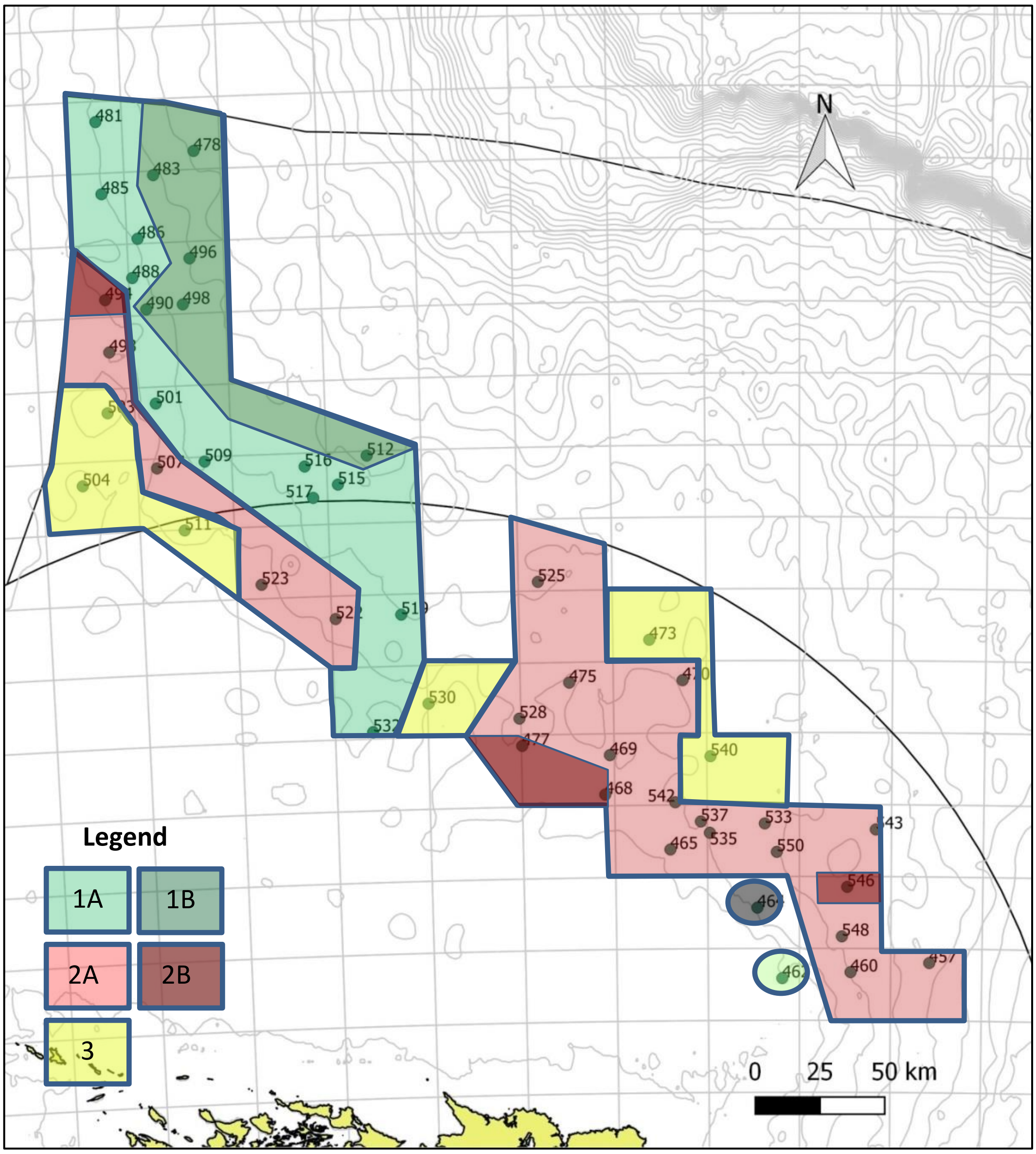


Figure 39 - Distribution of the benthic invertebrate assemblages

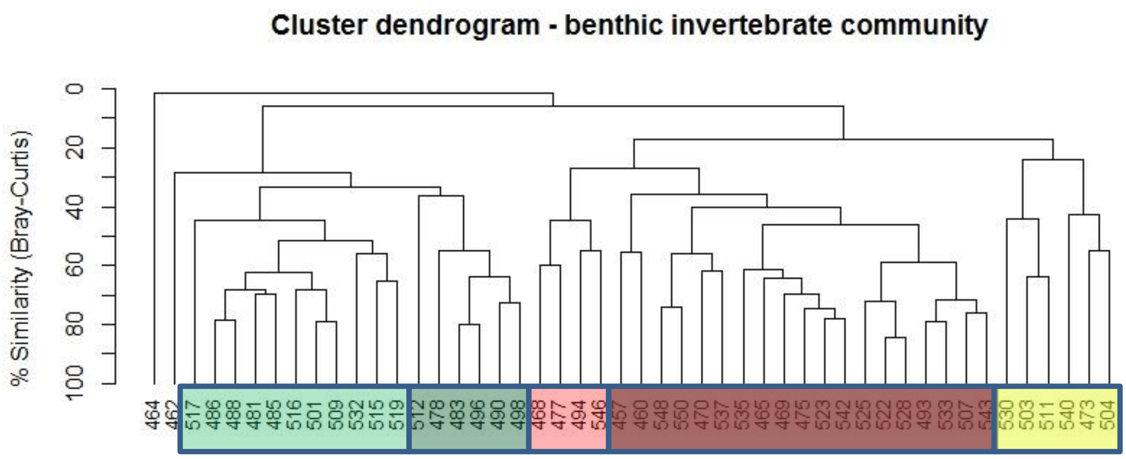


Figure 40 - Groups discriminated by the hierarchical clustering analysis

The hierarchical cluster analysis of the benthic community based on the Bray-Curtis similarity matrix allowed to identify three groups + 1 station at a level of similarity of 20%. Two of these groups can be divided in two subgroups each, with a similarity level of 30 %.

The assemblage of group 1 is the most structured one and is present in stations located above 50°S with only one exception (462). This assemblage is particularly abundant and rich in species, this benthic community being characterized by high biomasses of Porifera and the Sea Urchin *Sterechinus agassizii.* Two indicator taxa have been identified by the Indval procedure for this group: 1) mixed octocorals and 2) the whelk *Americominella longisetosus.* Furthermore, the presence of the pencil sea urchin *Austrocidaris canaliculata* at every station and in high abundance discriminate this group of stations from the other ones. At a lower similarity level, two sub-groups can be isolated. The community constituting group 1A is mainly covering shallower grounds, with an average biomass of 403 kg and an average richness of 26.9 taxa. In deeper waters, the group 1B is made of stations both very abundant (average biomass of 2957 kg) and rich (average species richness of 30), with a composition similar to those of the group 1A – with however some differences, such as the abundance of hydrozoans in 1B, which allows the distinction of these two benthic communities.

The group 2 is more widespread but mainly distributed in shallower waters (mainly above 400 m), in the southern part of the studied zone. The benthic assemblage characteristic of this group is both less abundant and less diversified than the one of group 1; however, the starfish *Bathybiaster loripes* was identifided as an indicator species of this community. At a higher similarity level of 30%, two sub-groups can be discriminated. The community represented by group 2A is the most widespread in the zone; it has a species richness of 21.5 on average and an abundance of 99 kg. It is distinct from the sub-community of 2B by two species in particular, the lobster krill *Munida subrugosa* and the starfish *Calyptraster sp*. The community of group 2B contains fewer species (average S: 16.2) and biomass (average total: 17.8 kg), but no specific species discriminate this sub-community from the other one.

The assemblage characteristic of group 3 is not particularly paucispecific (average S: 16.8) but appears to be very poor in terms of biomass (average: 12.8 kg). The bubblegum coral *Paragorgia sp.*is specific of this assemblage that is scattered in the middle part of the prospected zone. This community differs also from the other ones as it contains very few Porifera and almost no common sea urchin *Sterechinus agassizii*, two taxa that are strongly predominant both in groups 1 and 2.

Finally, two stations stand out of this clustering analysis: station 462 has a high number of species (32) and total biomass (465.5 kg), with three crustacean species that were found only there: *Eurypodius longirostris*, *Neolithodes diomedeae* and *Peltarion spinulosum*. Although very close geopgraphically, station 464 is almost the opposite: it is very paucispecific with a very low biomass, as only 5 species for a total of 3.1 kg have been recorded at this station.

4.4 Catchability comparison

The last two days of the survey were dedicated to the determination of the catchability efficiency of the two different settings used in 2010 (rockhopper) and 2013 (groundrope). Eight stations were trawled with one setting, and then replicated with the other net setting, following as much as possible a similar direction / depth but 1500 - 2500 m apart to avoid following the same fished track. In 2013, a catchability coefficient of 1.690 between groundrope vs. rockhopper was determined using a combination of commercial and survey CPUEs.

In 2019, the average catch per station with the use of a groundrope was of 734.4 kg, whereas the average catch with rockhopper was of 465.0 kg. This results of a catchability coefficient of 1.579, somewhat comparable to the one calculated in 2013 when considering the variability of 1) fishing efficiency between trawls and 2) species abundance based on location. However, the catchability coefficient is not uniform among different taxa as the groundrope setting, having stronger contacts with the seafloor, is expected to catch significantly higher benthic species biomass than demersal ones when compared to a rockhopper setting.

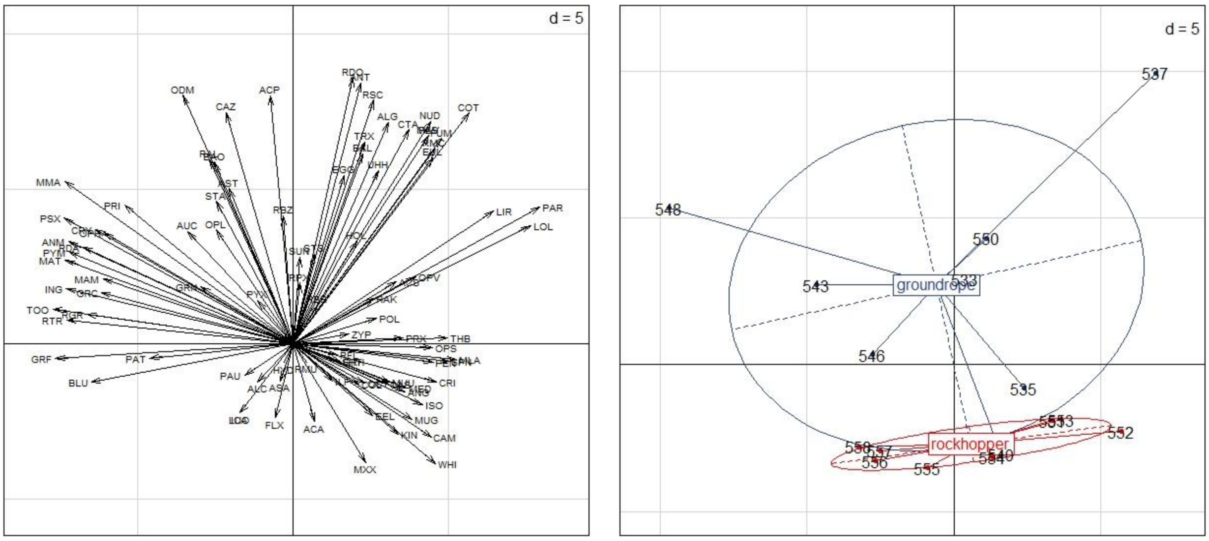


Figure 41 - PCA of the stations trawled with rockhopper and those trawled with groundfish

The first two axes account for 17.93 % and 15.84 % respectively of the total inertia explained by the principal component analysis. This number is relatively low and attests that the stations are fairly similar in terms of community composition – the catchability coefficient may be different, but the targeted assemblage remains consistent. The first (horizontal) axis is mainly driven by demersal species: of the eleven taxa having a correlation superior to 70 % with this axis, eight are finfish / cephalopod species, two are benthic invertebrate species and the last one is a skate species. The second, vertical axis is much more representative of benthic species: of the nine species having a correlation superior to 70 % with this axis, six are invertebrate species, two are skate species and the last one is a finfish species.

The analysis of the catch rate / composition per station with the use of a principal component analysis shows a clear discrimination between the stations trawled with a groundrope and the ones trawled with rockhopper. This discrimination is particularly strong along the vertical axis, with the groundrope stations showing a positive correlation to this axis when the rockhopper ones are negatively correlated to it. However, the correlation of the catch composition and the first axis is not very strong. This clearly indicates that the catchability efficiency of the two settings varies significantly depending on the different phyla, with the finfish / cephalopod species having similar probabilities of getting caught by either setting when skates and invertebrate benthic species are caught in higher density with the groundrope than they are with a rockhopper setting.

4.5 Oceanography

Oceanographic data were collected at 46 stations. The area covered ranged from 47° 49.30'S to 50° 53.85'S and 56° 21.09'W to 60° 42.13'W. Good data were collected at all stations, all the down-casts were good, and so up-cast data were removed.

Figure 42 below shows the location of the stations.

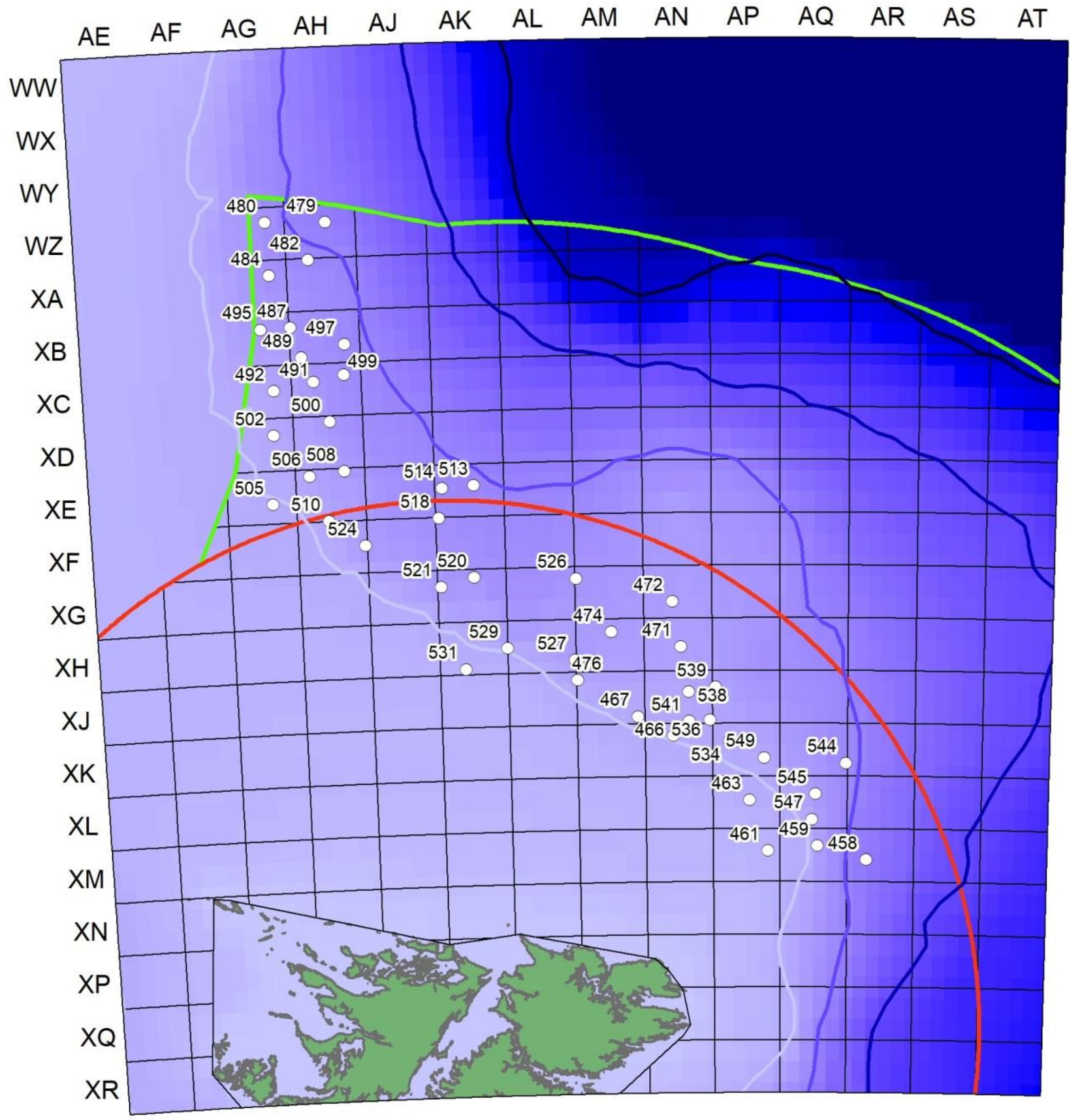


Figure 42 Location and number of CTD stations

Figure 44, Figure 46 Figure 48 and below shows 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 10m is the shallowest depth common to all CTD casts. The surveyed area covered depth range of 124 to 564 m.

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

For comparison 2 cross sections of the data have been created, location shown in Figure 43 below. One connecting the shallower stations, the other connecting the deeper stations, the northern most station is to the left.

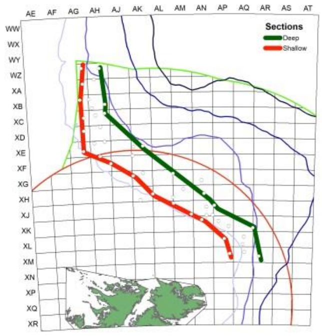


Figure 43 Location of Sections

Overall the data shows less variation than has been experienced over the wider Ground fish survey.

The temperature data (in Figure 44) varies between 3.93 and 6.22°C. The surface temperature is up to 6°C cooler than the maximum experienced during the ground fish

survey in February 2019.

The influence of the warmer Brazil current can be seen in the north-west of the survey area, particularly at the surface. This is can also be seen in the shallow temperature cross section (and to a lesser extent in the deep section) in Figure 45. The temperature at seabed is significantly related to depth, with the 5°C isotherm closely matching the 200 m bathymetric contour.

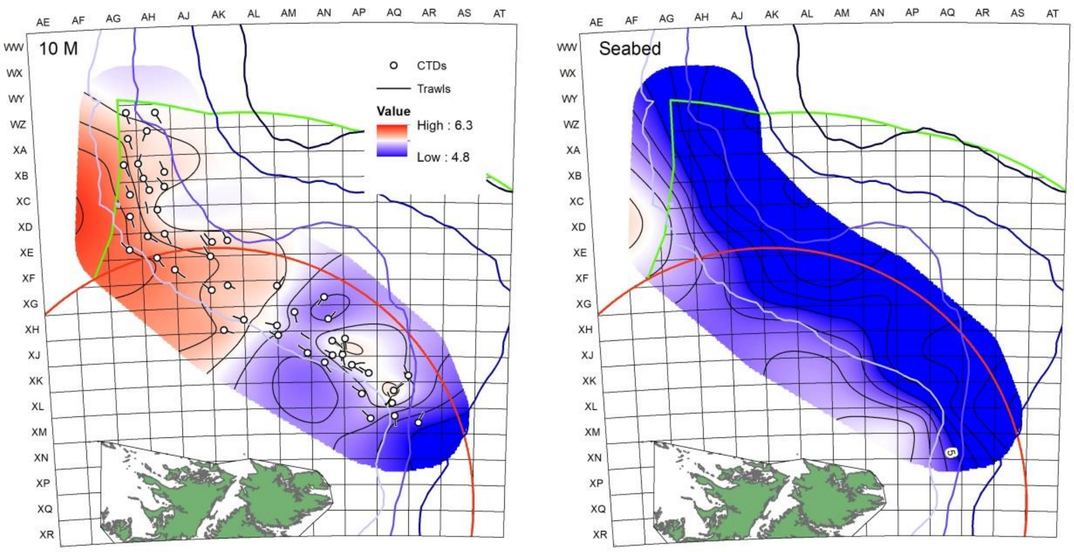


Figure 44 Temperature at 10m and seabed (contours at 0.2°C)

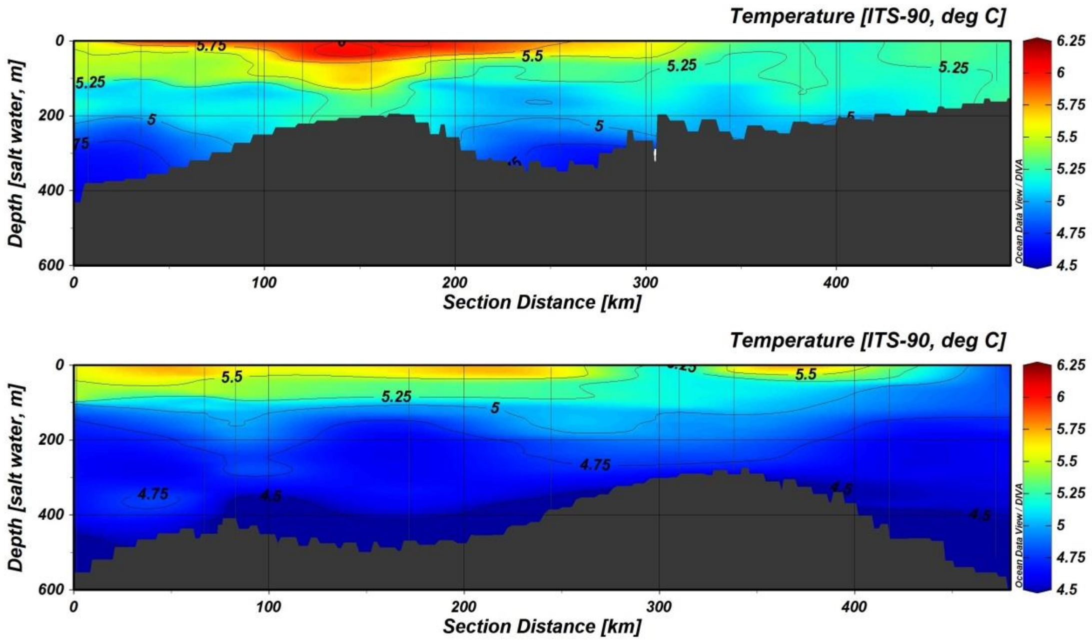


Figure 45 Temperature cross section with the shallow (top) and deep sections (bottom)

Figure 46 below shows the salinity over the surveyed area. The salinity is uniform through the first 50 m of the water column with the all bar 1 station being within 0.15 PSU, with the least saline water over the shelf, becoming slightly more saline to the north east. In the south east the interpolation suggest a steep increase in the salinity, but this is probably be the result of the eastern most station being 0.1 PSU higher than the 4 nearest stations and the interpolation extrapolating this to extend to the border.

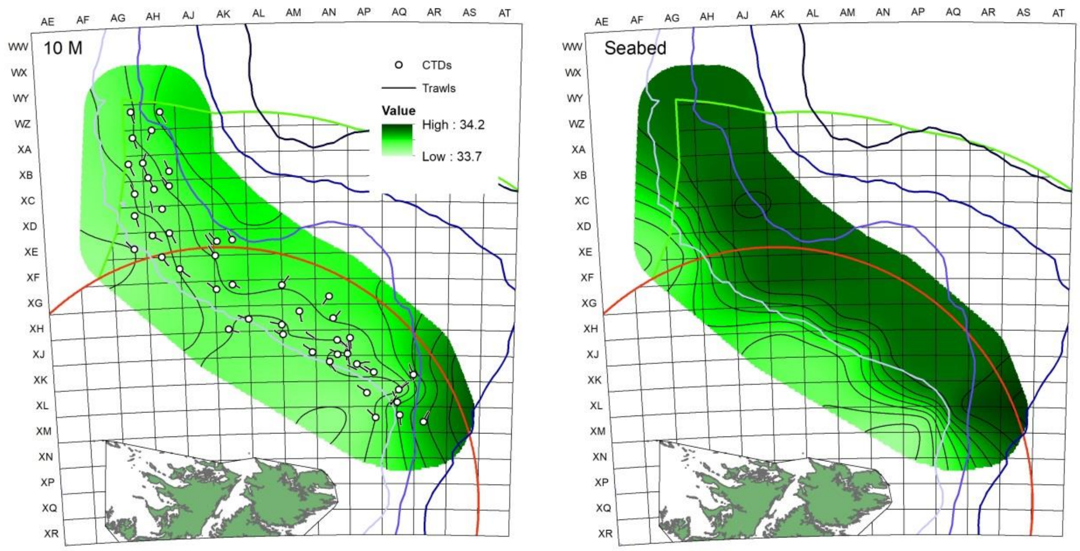


Figure 46 Salinity at 10m and seabed (contours at 0.05 PSU)

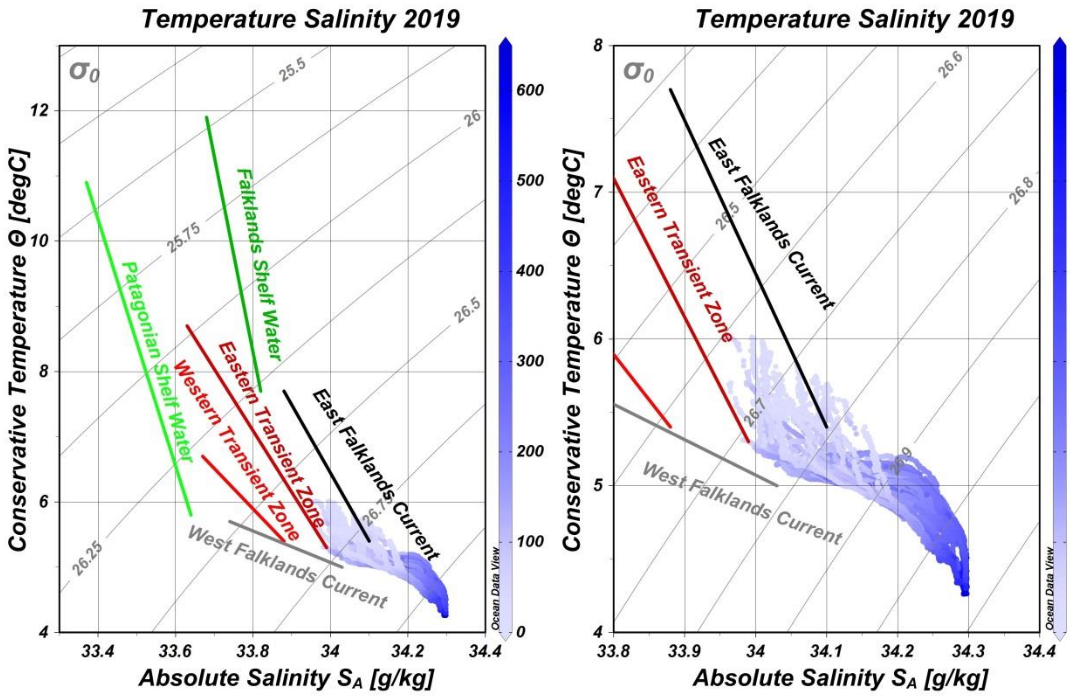


Figure 47 TS plots, Zoomed on right(water mass terminology Arkhipkin et al 2013)

A plot of conservative temperature against absolute salinity is shown in Figure 47 above. The waters experienced are from the East Falklands Current and the eastern transient zone, which is to be expected. However with the lower temperatures the salinity range is also limited.

The density map, Figure 48, follows the temperature and salinity pattern (seen in Figure 44 and Figure 46) with little variation in the surface water and the 50m water layer. The influence of the warmer Brazil Current water can be seen in the north west all the way to the 100 metre water layer with the lower density, reflecting the slightly lower salinity and higher temperature. The Brazil current is highlighted in the shallower density section (Figure 49)

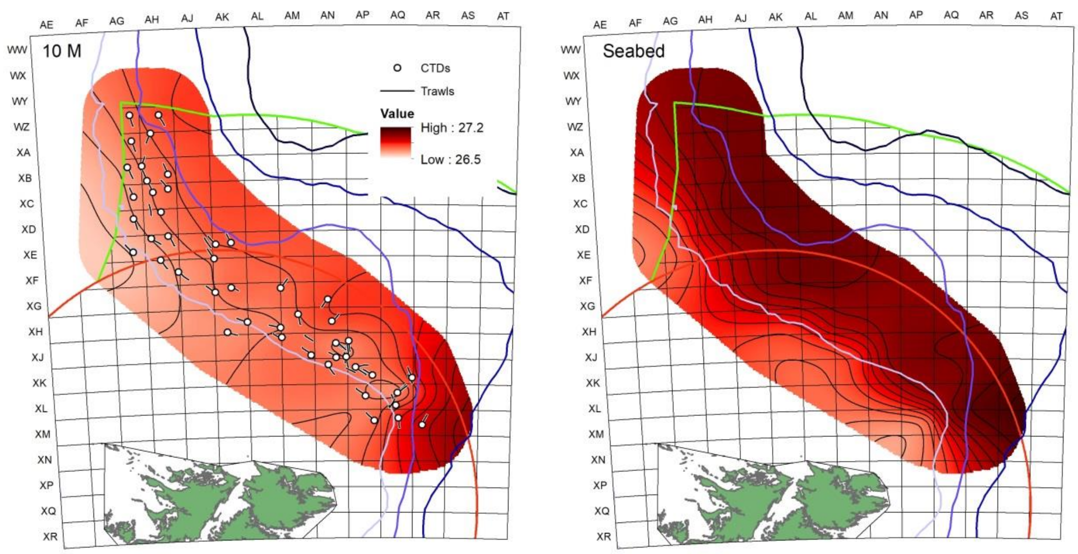


Figure 48 Density at 10m and seabed (contours at 0.05 sigma-t)

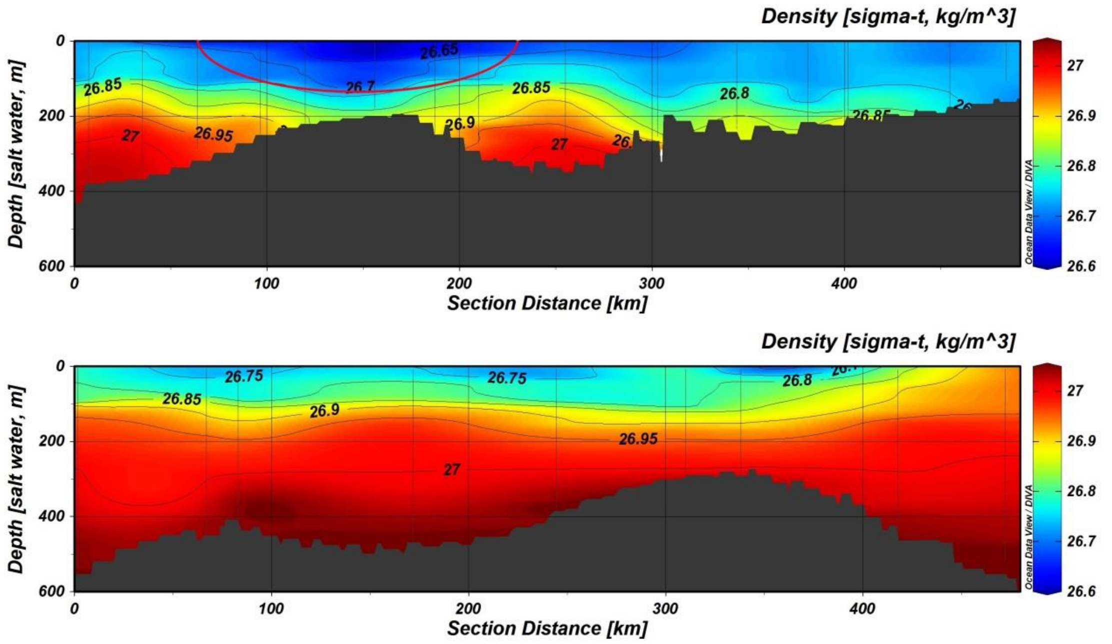


Figure 49 Density across the shallow (top) and deep section (bottom)

Figure 50 below shows the oxygen level at 10m and seabed in ml/l of water. Oxygen concentration is highest at the surface, with levels between 6.8 and 7.8 ml/l over the area. The shallower stations had lower oxygen levels (c6.8ml/l) than the stations in deeper water (c7.7ml/l), due to the influence of the Falklands Current in deeper water.

The variation across the area reduces as depth increases, at 200m there is 0.3ml/l difference between the stations, but the higher values are still at the station over the deeper water.

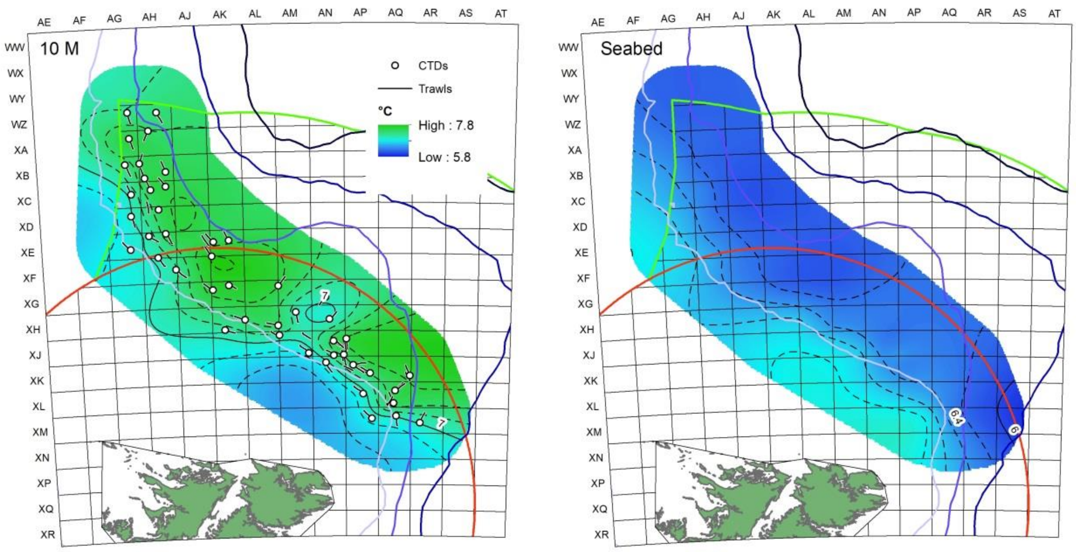


Figure 50 Oxygen at 10m and seabed (contours at 0.1ml/l)

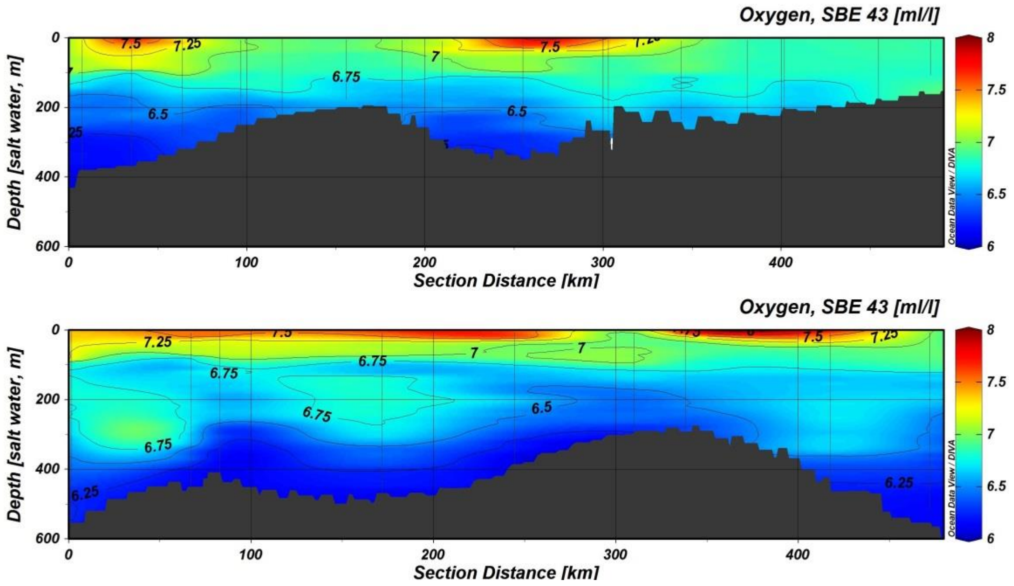


Figure 51 Oxygen concentration across the shallow (top) and deep section (bottom)

In the deeper water section, there is a clear layer of water 150 m deep at the seabed that is uniform in temperature, density and O2 (Figure 45, Figure 49 Figure 51) from the north to station 471 (49°53'S). When compared to the casts in the TS plot all these data are in the area below the 26.9 isopycnal in a box created by an absolute salinity higher than 34.2 and a conservative temperature less than 4.5°C.

5. CONCLUSION

As it has been observed in the past, the skate community appears to be strongly structured both spatially and bathymetrically, *i.e.* depending on the depth. Some species, such as *Bathyraja albomaculata*, appear to have an ubiquitous distribution, regardless of the size of the sampled individuals, when others show both marked abundance hotspots and / or gradients of disk-width values correlated to depth. This is for instance the case of *Bathyraja griseocauda*, a species caught throughout the zone but with wider individuals mostly distributed in deeper waters, or for *Amblyraja doellojuradoi*, for the individuals of different size-classes are distributed evenly along the depth gradient, but with marked hotspots – notably in the south of the zone.

When compared to 2013, the species showing the highest catch value is *Bathyraja griseocauda*, when it was *Bathyraja brachyurops* in 2013. However, it is difficult to attribute this discrepancy to a shift in species abundance as the prospected area of 2019 included deeper stations than it did in 2013, which maximises the probability to catch large individuals of RGR over RBR – a species mostly distributed in shallower waters.

The changes in biological parameters that had been identified in 2013 - notably the reduction of disc-width at 50 % maturity - has not been confirmed in 2019. Instead, values similar to those observed in 2010 were recorded in 2019, which, without concluding to an improvement of the population health, is at least a sign of stability.

If the skate community appears to be spatially structured, it is similarly the case for the benthic community with clear assemblages spatially and bathymetrically distinct between each other. Such a spatial discrimination of sessile / semi-motile species is a clear indicator of the habitat diversity of the northern part of the Falkland Island Conservation Zones, which plays a key role in the skate community diversity and complexity.

The catchability coefficient calculated in 2013 between the two gear settings has been tested and confirmed in 2019, with however a non-linear relationship between the catch rates and the caught / bycaught taxa. Demersal and motile species catches such as finfish and cephalopod ones are not influenced by the different settings as significantly as benthic species, for example skates or invertebrates, are.

Genetic and morphometric samples have been collected on the *Psammobatis* complex, however the results are not available at the time of this report.

Once again, the variability of biological parameters depending on a) years and b) sampling effort has been highlighted during this cruise, when compared to results obtained in 2010 and 2013. However, the biomass estimates of the Rajiformes community show continuous trends of decrease. We therefore highly recommend the repetition of skate-dedicated surveys in the years to come, to better understand and identify the spatiotemporal extend of such changes.

6. APPENDIX

Station table

Station	Date	Latitude	Longitude	Modal depth (m)	Activity	Duration (min)
457	12-Oct-19	50°47.94'	56°17.32'	556	B	60
458	12-Oct-19	50°53.81'	56°21.35'	549	C	
459	12-Oct-19	50°49.90'	56°43.39'	388	C	
460	12-Oct-19	50°49.94'	56°43.19'	378	B	60
461	12-Oct-19	50°51.29'	57°05.52'	124	C	
462	12-Oct-19	50°51.21'	57°05.65'	127	B	60
463	12-Oct-19	50°36.83'	57°13.75'	317	C	
464	12-Oct-19	50°36.50'	57°13.77'	303	B	60
465	13-Oct-19	50°24.27'	57°42.10'	254	B	60
466	13-Oct-19	50°18.51'	57°47.63'	260	C	
467	13-Oct-19	50°12.87'	58°03.05'	245	C	
468	13-Oct-19	50°12.67'	58°03.08'	247	B	60
469	13-Oct-19	50°04.45'	58°01.41'	283	B	60
470	14-Oct-19	49°49.00'	57°37.66'	296	B	60
471	14-Oct-19	49°53.10'	57°44.03'	296	C	
472	14-Oct-19	49°40.26'	57°47.57'	316	C	
473	14-Oct-19	49°40.50'	57°48.26'	310	B	60
474	14-Oct-19	49°48.75'	58°14.43'	311	C	
475	14-Oct-19	49°49.22'	58°14.20'	299	B	60
476	14-Oct-19	50°02.25'	58°29.52'	240	C	
477	14-Oct-19	50°02.22'	58°29.74'	237	B	60
478	15-Oct-19	47°56.18'	60°08.08'	541	B	60
479	15-Oct-19	47°49.91'	60°12.79'	602	C	
480	15-Oct-19	47°49.35'	60°38.16'	395	C	
481	15-Oct-19	47°49.27'	60°38.05'	395	B	60
482	15-Oct-19	48°00.44'	60°20.62'	444	C	
483	15-Oct-19	48°00.86'	60°20.93'	424	B	60
484	15-Oct-19	48°04.50'	60°37.47'	358	C	
485	15-Oct-19	48°04.36'	60°37.23'	357	B	60
486	16-Oct-19	48°13.97'	60°26.64'	368	B	60
487	16-Oct-19	48°19.46'	60°29.53'	360	C	
488	16-Oct-19	48°22.09'	60°28.85'	348	B	60
489	16-Oct-19	48°28.12'	60°25.45'	345	C	
490	16-Oct-19	48°28.75'	60°24.91'	346	B	60
491	16-Oct-19	48°35.10'	60°20.60'	352	C	
492	16-Oct-19	48°37.33'	60°37.90'	262	C	
493	16-Oct-19	48°37.36'	60°37.12'	260	B	60
494	16-Oct-19	48°26.43'	60°37.63'	300	B	60
495	16-Oct-19	48°19.70'	60°42.13'	301	C	
496	17-Oct-19	48°18.51'	60°10.70'	446	B	60
497	17-Oct-19	48°24.83'	60°06.72'	450	C	
498	17-Oct-19	48°28.04'	60°13.40'	420	B	60
499	17-Oct-19	48°33.47'	60°07.42'	420	C	
500	17-Oct-19	48°46.72'	60°14.39'	358	C	
501	17-Oct-19	48°48.44'	60°23.22'	297	B	60
502	17-Oct-19	48°49.97'	60°38.74'	238	C	

503	17-Oct-19	48°50.00'	60°38.55'	237	B	60
504	18-Oct-19	49°04.94'	60°47.54'	187	B	60
505	18-Oct-19	49°09.51'	60°40.45'	190	C	
506	18-Oct-19	49°01.94'	60°23.91'	270	C	
507	18-Oct-19	49°01.95'	60°23.74'	278	B	60
508	18-Oct-19	49°00.90'	60°08.80'	326	C	
509	18-Oct-19	49°00.96'	60°08.60'	326	B	60
510	18-Oct-19	49°14.90'	60°16.37'	246	C	
511	18-Oct-19	49°15.12'	60°15.82'	244	B	60
512	19-Oct-19	49°00.91'	59°17.20'	480	B	60
513	19-Oct-19	49°06.18'	59°13.09'	474	C	
514	19-Oct-19	49°06.80'	59°26.82'	446	C	
515	19-Oct-19	49°06.77'	59°26.61'	444	B	60
516	19-Oct-19	49°02.77'	59°36.97'	428	B	60
517	19-Oct-19	49°09.37'	59°34.59'	416	B	60
518	19-Oct-19	49°15.19'	59°28.68'	412	C	
519	20-Oct-19	49°34.27'	59°07.67'	376	B	50
520	20-Oct-19	49°32.36'	59°14.10'	375	C	
521	20-Oct-19	49°34.77'	59°28.66'	314	C	
522	20-Oct-19	49°34.76'	59°28.71'	312	B	60
523	20-Oct-19	49°27.08'	59°52.02'	273	B	60
524	20-Oct-19	49°22.23'	60°00.90'	273	C	
525	21-Oct-19	49°28.10'	58°23.70'	389	B	60
526	21-Oct-19	49°33.36'	58°29.65'	386	C	
527	21-Oct-19	49°56.54'	58°30.46'	300	C	
528	21-Oct-19	49°56.52'	58°30.46'	292	B	60
529	21-Oct-19	49°52.81'	59°00.28'	258	C	
530	21-Oct-19	49°52.96'	58°59.69'	252	B	60
531	21-Oct-19	49°58.41'	59°18.71'	160	C	
532	21-Oct-19	49°58.57'	59°18.73'	159	B	60
533	22-Oct-19	50°18.95'	57°11.28'	350	B	60
534	22-Oct-19	50°20.04'	57°22.76'	334	C	
535	22-Oct-19	50°20.85'	57°29.19'	313	B	60
536	22-Oct-19	50°14.06'	57°31.27'	316	C	
537	22-Oct-19	50°08.48'	57°32.10'	312	B	60
538	22-Oct-19	50°05.94'	57°40.56'	306	C	
539	22-Oct-19	50°04.72'	57°28.75'	332	C	
540	22-Oct-19	50°04.88'	57°28.82'	296	B	60
541	22-Oct-19	50°14.38'	57°40.37'	295	C	
542	22-Oct-19	50°14.43'	57°40.36'	292	B	60
543	23-Oct-19	50°20.17'	56°35.13'	459	B	60
544	23-Oct-19	50°26.31'	56°30.87'	460	C	
545	23-Oct-19	50°35.05'	56°44.26'	426	C	
546	23-Oct-19	50°35.17'	56°44.37'	434	B	60
547	23-Oct-19	50°42.32'	56°45.84'	412	C	
548	23-Oct-19	50°42.49'	56°46.08'	414	B	60
549	23-Oct-19	50°24.79'	57°07.30'	383	C	
550	23-Oct-19	50°24.88'	57°07.39'	368	B	60
551	24-Oct-19	50°12.55'	57°29.53'	326	B	60
552	24-Oct-19	50°05.62'	57°38.52'	317	B	60

553	24-Oct-19	50°11.65'	57°33.15'	309	B	60
554	24-Oct-19	50°20.74'	57°31.21'	316	B	60
555	24-Oct-19	50°21.15'	57°21.27'	354	B	60
556	25-Oct-19	50°24.45'	56°35.09'	457	B	60
557	25-Oct-19	50°30.98'	56°35.81'	435	B	60
558	25-Oct-19	50°38.77'	56°46.79'	400	B	60

Catchlog table

Elasmobranch, finfish and commercial cephalopod species

Species code	Latin name	Catch (kg)	Sampled (kg)
GRC	*Macrourus carinatus*	6995.89	2460
RGR	*Bathyraja griseocauda*	5585.504	5585.504
HAK	*Merluccius hubbsi*	4007.174	2066.94
RAL	*Bathyraja albomaculata*	3098.054	3098.054
RBR	*Bathyraja brachyurops*	2467.24	2467.21
WHI	*Macruronus magellanicus*	2095.86	525
RBZ	*Bathyraja cousseauae*	1697.314	1697.314
LOL	*Doryteuthis gahi*	1545.148	244.064
RFL	*Zearaja chilensis*	1529.94	1529.94
RDO	*Amblyraja doellojuradoi*	1143.08	1141.65
RMC	*Bathyraja macloviana*	925.08	923.54
TOO	*Dissostichus eleginoides*	846.31	846.31
COT	*Cottunculus granulosus*	839.294	0
RMU	*Bathyraja multispinis*	832.129	832.129
ING	*Onykia ingens*	737.849	0
RSC	*Bathyraja scaphiops*	730.5	730.5
PAR	*Patagonotothen ramsayi*	500.987	350.375
RTR	*Dipturus trachyderma*	360.2	360.2
KIN	*Genypterus blacodes*	304.02	278
BLU	*Micromesistius australis*	250.045	241.284
DGS	*Squalus acanthias*	186	181.48
BAC	*Salilota australis*	176.16	91.04
PAU	*Patagolycus melastomus*	115.009	0
RDA	*Zearaja argentinensis*	76.26	76.26
DGH	*Schroederichthys bivius*	70.57	52.59
MAM	*Neoachiropsetta milfordi*	68.1	18.64
RPX	*Psammobatis spp.*	48.541	48.541
GRF	*Coelorinchus fasciatus*	45.865	24.262
PAT	*Merluccius australis*	41	38.5
PYM	*Notophycis marginata*	39.398	0
NEM	*Psychrolutes marmoratus*	30.014	0
LAR	*Lampris immaculatus*	22.84	22.84
MMA	*Mancopsetta maculata*	9.35	7.32
ILF	*Iluocoetes fimbriatus*	8.996	0
MXX	*Myctophidae spp.*	7.669	0
ICA	*Icichthys australis*	5.2	1.2
CON	*Congridae*	4.95	0
GYN	*Gymnoscopelus nicholsi*	4.422	0
MAT	*Achiropsetta tricholepis*	2.952	1.04
CGO	*Cottoperca gobio*	2.48	0
GRH	*Macrourus holotrachys*	2.3	2.3
MYX	*Myxine spp.*	1.965	0
EEL	*Iluocoetes/Patagolycus mix*	1.229	0.004
MAN	*Mancopsetta sp.*	1.12	0
CAM	*Cataetyx messieri*	1.106	0
RMG	*Bathyraja magellanica*	0.56	0.56

ARR	*Arctozenus risso*	0.4	0
LYB	*Lycenchelys bachmanni*	0.232	0.01
ILL	*Illex argentinus*	0.23	0
GYB	*Gymnoscopelus bolini*	0.19	0
THN	*Thysanopsetta naresi*	0.14	0
LUO	*Lucigadus ori*	0.038	0.038

Invertebrates and misc. non commercial species

Species code	Latin name	Catch (kg)	Sampled (kg)
SPN	Porifera	9825.399	0
SHT	Mixed invertebrates	3840.62	0
STA	*Sterechinus agassizii*	3343.792	0
ANG	*Anthoptilum grandiflorum*	3232.848	0
MIR	*Mirostenella sp.*	702.89	0
HYD	*Hydrozoa*	669.408	0
CAZ	*Calyptraster sp.*	583.859	0
AUC	*Austrocidaris canaliculata*	549.643	0
ANM	*Anemonia*	463.224	0
ALG	*Algae*	454.874	0
AST	*Asteroidea*	389.152	0
OCC	*Octocorallia sp*	175.204	0
MLA	*Muusoctopus longibrachus akambei*	153.899	0
BAO	*Bathybiaster loripes*	128.335	0
GOC	*Gorgonocephalus chilensis*	92.145	0
CRY	*Crossaster sp.*	91.724	0
SUN	*Labidiaster radiosus*	75.858	0
BAL	*Americominella longisetosus*	44.656	0
FUM	*Fusitriton m. magellanicus*	42.09	0
ODM	*Odontocymbiola magellanica*	35.572	0
MUE	*Muusoctopus eureka*	30.114	0
PEN	*Pennatulacea*	26.646	0
EGG	*Eggmass*	23.355	0
ANT	*Anthozoa*	23.093	0
THO	*Thouarellinae*	21.19	0
THB	*Thymops birsteini*	19.439	0
OPL	*Ophiura lymani*	15.67	0
POA	*Glabraster antarctica*	8.604	0
CAS	*Campylonotus semistriatus*	8.572	0
COL	*Cosmasterias lurida*	7.056	0
CAV	*Campylonotus vagans*	6.832	0
CTA	*Ctenodiscus australis*	6.175	0
GOR	*Gorgonacea*	6.146	0
HOL	*Holothuroidea*	5.907	0
BRY	*Bryozoa*	5.88	0
GAF	*Ganaria falklandica*	5.71	0
ACS	*Acanthoserolis schythei*	5.444	0
CEX	*Ceramaster sp.*	4.94	0
NUD	*Nudibranchia*	4.099	0
CYX	*Cycethra sp.*	4.08	0
MED	*Medusa sp*	3.512	0
ASA	*Astrotoma agassizii*	3.098	0
OCT	*Octopus spp.*	2.804	0

CHR	*Chrysaora cf. plocamia*	1.68	0
ISO	*Isopoda*	1.663	0
NED	*Neolithodes diomedeae*	1.57	0
HEX	*Henricia sp.*	1.496	0
MAV	*Magellania venosa*	1.348	0
POL	*Polychaeta*	1.28	0
CRI	*Crinoidea*	1.082	0
MUU	*Munida subrugosa*	1.068	0
UHH	*Tripilaster sp.?*	1.057	0
WRM	*Chaetopterus variopedatus*	1.043	0
OPH	*Ophiuroidea*	1.033	0
OPV	*Ophiacantha vivipara*	0.951	0
PYX	*Pycnogonida*	0.796	0
ALC	*Alcyoniina*	0.74	0
LIR	*Limopsis marionensis*	0.719	0
MAR	*Martialia hyadesi*	0.6	0.6
TRX	*Trophon sp.*	0.537	0
EUL	*Eurypodius latreillii*	0.528	0
PRI	*Priapulida*	0.525	0
OPS	*Ophiactis asperula*	0.466	0
HCR	*Paguroidea*	0.305	0
GRN	*Graneledone yamana*	0.24	0
ZYP	*Zygochlamys patagonica*	0.22	0
PSX	*Psolidae*	0.21	0
PES	*Peltarion spinulosum*	0.18	0
ACA	*Acesta patagonica*	0.144	0
EUO	*Eurypodius longirostris*	0.13	0
MUG	*Munida gregaria*	0.103	0
SQT	*Ascidiacea*	0.1	0
SRP	*Semirossia patagonica*	0.09	0
MUN	*Munida spp.*	0.086	0
NUH	*Nuttallochiton hyadesi*	0.082	0
PRD	*Primnoidae*	0.081	0
ACP	*Acanthephyra pelagica*	0.076	0
PRX	*Paragorgia sp.*	0.07	0
PLS	*Plesienchelys stehmanni*	0.06	0
STS	*Stereomastis suhmi*	0.052	0
NEC	*Neorossia caroli*	0.046	0
FLX	*Flabellum spp.*	0.016	0
WLK	*Whelks*	0.014	0
OIB	*Oidiphorus brevis*	0.01	0.01
SET	*Sertulariidae*	0.002	0
ERR	*Errina sp.*	0.001	0
Grand Total		**62632.962**	**25945.249**

Sample table

Species code	Nb of individual sampled	of which Otoliths
LOL	3438	
PAR	3357	108
RAL	2993	
RDO	2886	
GRC	2243	159
RGR	2161	
RBR	1782	
HAK	1519	121
RMC	1396	
WHI	995	137
RBZ	720	
RSC	717	
RFL	649	
BLU	543	252
TOO	537	402
GRF	354	63
BAC	309	74
KIN	301	78
RMU	162	
DGS	155	
RPX	143	73
DGH	119	
MMA	42	23
MAM	39	30
RDA	35	
RTR	25	
PAT	17	17
GYN	16	16
LYB	4	4
MAT	3	2
ARR	2	2
GRH	2	2
MLA	2	
RMG	2	
GYB	1	1
ICA	1	1
ILF	1	1
LAR	1	1
LUO	1	1
NEC	1	1
OIB	1	1
PLS	1	1
Grand Total	**27676**	**1571**

Commercial size table

It has been observed that on average, only individuals wider than 40 cm were processed. The following table shows the number of individuals of theoretical commercial value caught during this trip.

Species code	DW < 40 cm (presumably discarded)	DW ≥ 40 cm (presumably kept)	Percentage kept
RAL	2196	797	26.63%
RBR	1196	586	32.88%
RBZ	412	308	42.78%
RDA	1	34	97.14%
RDO	2882	4	0.14%
RFL	47	602	92.76%
RGR	1299	862	39.89%
RMC	1390	6	0.43%
RMG	2		0.00%
RMU	25	137	84.57%
RPX	143		0.00%
RSC	402	315	43.93%
RTR		25	100.00%

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