Cruise Report ZDLT1-11-2013

Skate Biomass and Biological Survey

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Contents

Contents **2**

1.0 Introduction **3**

1.1 Cruise objectives 4

2.0 Methods **5**

2.1 Cruise vessel and region 5
2.2 Trawl gear 8
2.3 Biological sampling 9
2.4 Data analyses 10
2.4.1 Skate biomass estimates 10
2.4.2 Skate community and abundance 14
2.4.3 Invertebrate by-catch 15
2.5 Oceanography 15

3.0 Results **16**

3.1 Catch composition 16
3.1.1 Commercial finfish species catch, distribution, biology 17
3.1.2 Skate catch and distribution 23
3.2 Skate biomass estimates 24
3.2.1 Skate biology 27
3.2.2 Skate community and abundance 49
3.2.3 Invertebrate by-catch 54
3.2.4 Invertebrate diversity 57
3.3 Oceanography 59

4.0 General conclusions **64**

5.0 References **66**

6.0 Appendix **69**

1.0 Introduction

Since the establishment of the fishery in the Falkland Islands, a considerable amount of research and sampling effort has gone towards the skate resource. But due to the complexity of both the fishery (targeted and non-targeted trawl, as well as some longline by-catch) and the skate assemblage, managing this resource is not a straightforward process.

The dynamics of skates in the Falkland Islands are not well understood, with at least 15 species composing the assemblage (Arkhipkin et al. 2012). Estimates of total skate biomass have been calculated by Agnew et al. (2000), Wakeford et al. (2004), and Arkhipkin et al. (2010). Agnew et al. (2000) and Wakeford et al. (2004) used fisheries catch and CPUE data series and applied two different models for the entire fishing zones, whereas the swept-area method was used by Arkhipkin et al. (2010) for a restricted region to the North of the islands with highest catches by the targeted skate fishery. Estimates of total skate biomass have also been calculated using the Shaefer production model for the annual licensing advice since 2011 (FIG 2013; Laptikhovsky et al. 2011; Laptikhovsky et al. 2012; Paya et al. 2010) and using the swept area method for years 2009 and 2010 (Paya et al. 2008; Paya et al. 2009). A number of papers on skate biology have also appeared over the years, which have contributed to biological aspects of individual species (e.g. Arkhipkin et al. 2008; Brickle et al. 2002; Brickle et al. 2003; Henderson et al. 2005; Laptikhovsky 2004).

Stock assessments undertaken in 1995 detected a continuing decline in the CPUE from the stock situated to the south of the Islands, due in particular to the declining abundance of *Bathyraja griseocauda*. To protect this area, targeted fishing for skates was prohibited south of 52°S latitude from 1996 onwards (Agnew et al. 1999) and this restriction has remained in place.

An emergent pattern within the skate targeted fishery is the shift in the skate species composition. However it is unclear if this shift is due to fishing pressure, or to a natural change in the skate assemblage throughout the FICZ/FOCZ. To investigate this pattern, we aimed to carry out a “northern” survey within the skate targeted fishing region, and compare results with surveys outside the skate targeted region, including regions that have been restricted from a targeted skate fishery (East and South in this survey).

Within each region, data sufficient for stock assessments was collected, as well as fundamental biological data. Exploration of deeper regions in the south not regularly explored have also been included for biogeographic studies.

1.1 Cruise objectives

Stock assessment

- Estimate the skate biomass for the Northern region using the swept-area method, and compare to the biomass estimates in the same sub-region from the 2010 survey. Of the 52 trawls conducted in 2010 over a 13 day period, 26 will be repeated in a six day period.
- Estimate the skate biomass for the Southern part of the Loligo region (12 grids), and
- Estimate the skate biomass in an Eastern block of four grid squares at the top of the Loligo license region.
- Collect data to aid planned examination of the effects of fishing between northern (skate and finfish licensed regions), the eastern (Loligo and skate licence), and southern (Loligo license only) regions.

Biology/biogeography

- Collect species composition data for all regions and biological information for all species and regions.
- Survey regions beyond the shelf break (350-450m), primarily in the Southern region but also in the North, to investigate whether these depth/regions are refuges for spawning skate, *Bathyraja griseocauda* in particular.
- Conduct fecundity studies on selected species: *B. brachyurops*, *B. griseocauda*, *B. albomaculata*, and *Zearaja chilensis*. If time allows also some of the lesser abundant species.

- Spend maximum 2 days in grid square XUAH, repeating some of the 18 trawl tracks from 1994-1995 research cruises with the PV/RV Cordella (no reports). Data obtained from these trawls could provide an insight in changes that have occurred since 1994-1995, but also hopefully yield some animals tagged in those years.
- Facilitate the PhD work by Francisco Concha, part of which aims to elucidate on the species identity of *Dipturus (Zearaja) chilensis* and other *Dipturus spp.* in Falkland waters.

Oceanography

- Collect oceanographic data in the vicinity of selected trawl stations.

2.0 Methods

2.1 Cruise vessel and region

The skate biomass and biological survey was conducted onboard the FV Castelo (LOA 67.8m, GRT 1,321) between 3 and 20 November 2013. In October 2010, the same vessel had been used for a biomass survey of the so-called Northern skate region (Arkhipkin et al. 2010). In the 2013 survey, 26 of the 52 trawls conducted in 2010 in the so-called Northern skate box were repeated by randomly selecting one trawl in each grid square. In the East and South regions, trawls were also randomly selected, whilst aiming to cover the depth range encountered within each grid square. All trawls were one hour in duration, with the exception of one trawl in the Northern Region targeting spawning *Bathyraja griseocauda* which was 30 min in duration because of time constraints (Figure 1).

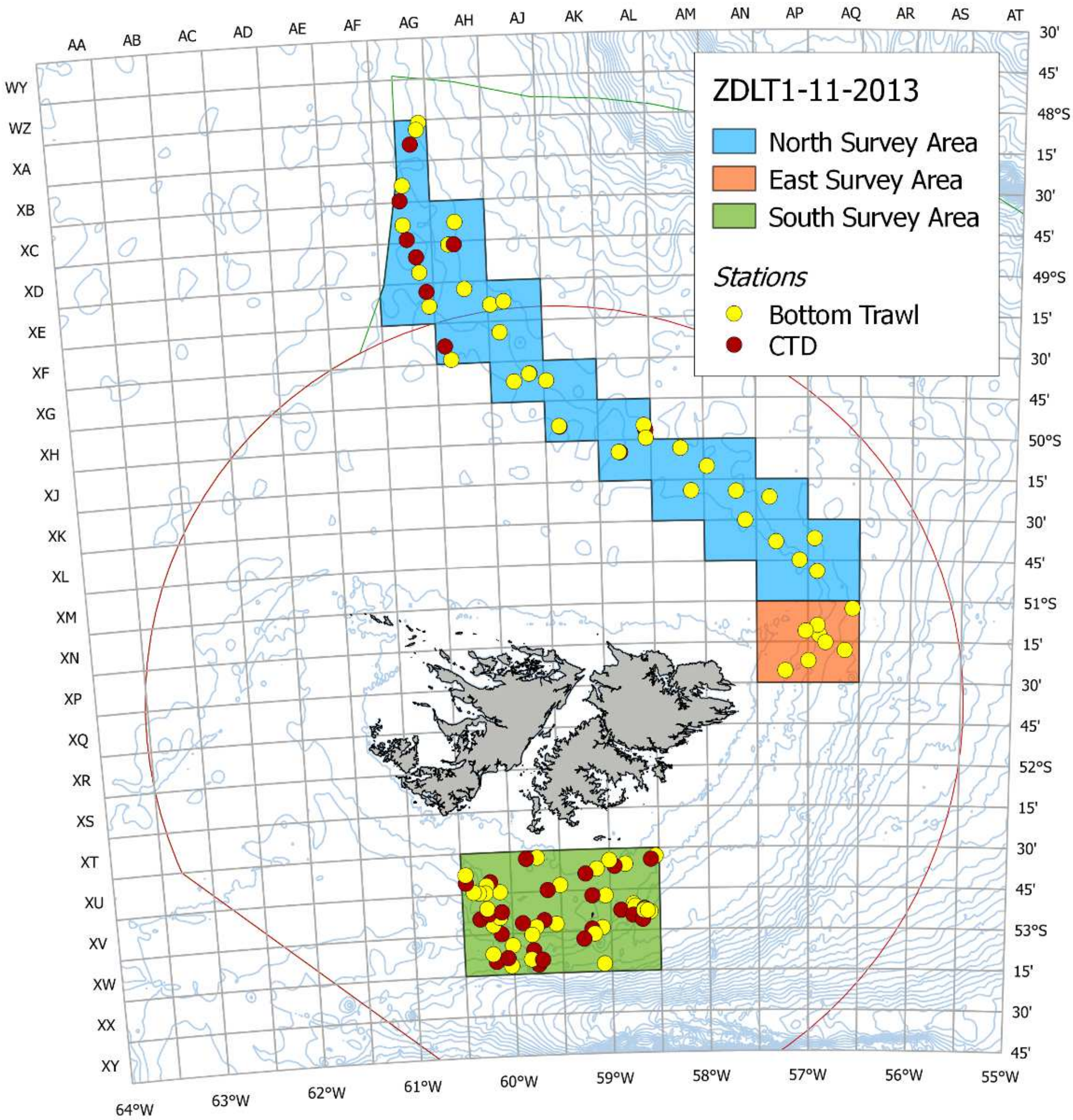


Figure 1: Locations of Bottom Trawls and CTD stations.

Table 1: Trawl and CTD station details.

Station	Date	Lat (^oS)	Lon (^oW)	Modal Depth	Duration	Activity	Comments
1183	03/11/13			302		C	
1184	03/11/13	49.90	58.61	315	30	B	Badly damaged. No sampling, just catch breakdown
1185	03/11/13	49.98	58.58	270	60	B	
1186	03/11/13			157		C	
1187	03/11/13	50.06	58.85	156	60	B	
1188	03/11/13			168		C	
1189	03/11/13	49.89	59.41	170	60	B	
1190	04/11/13			293		C	
1191	04/11/13	49.56	59.67	291	15	B	only short trawl, no catch, badly damaged
1192	04/11/13	49.61	59.81	219	60	B	
1193	04/11/13	49.46	60.38	190	60	B	
1194	04/11/13			195		C	
1195	04/11/13	49.13	60.55	224	60	B	
1196	04/11/13			233		C	
1197	04/11/13	48.91	60.63	241	60	B	
1198	04/11/13			242		C	
1199	05/11/13	48.05	60.59	384		B	trawl did not perform well, so this station is void
1200	05/11/13	48.09	60.61	353	60	B	
1201	05/11/13			345		C	
1202	05/11/13	48.42	60.76	261	60	B	
1203	05/11/13			254		C	
1204	05/11/13	48.67	60.75	239	60	B	
1205	05/11/13			239		C	
1206	05/11/13	48.60	60.27	393	60	B	
1207	06/11/13	48.80	60.33	334	60	B	
1208	06/11/13			338		C	
1209	06/11/13	49.07	60.20	310	60	B	
1210	06/11/13	49.17	59.95	345	60	B	
1211	06/11/13	49.34	59.89	308	60	B	
1212	06/11/13	49.10	59.88	376	30	B	5th shorter trawl, to search for large RGR
1213	07/11/13	49.65	59.44	304	60	B	
1214	07/11/13	50.07	58.19	281	60	B	
1215	07/11/13	50.19	57.94	277	60	B	
1216	07/11/13	50.31	58.15	140	60	B	
1217	08/11/13	50.34	57.66	287	60	B	
1218	08/11/13	50.38	57.35	351	60	B	
1219	08/11/13	50.51	57.58	232	60	B	
1220	08/11/13	50.65	57.28	265	60	B	
1221	09/11/13	50.65	56.92	403	60	B	
1222	09/11/13	50.77	57.06	277	60	B	
1223	09/11/13	50.84	56.89	305	60	B	
1224	09/11/13	51.08	56.57	450	60	B	
1225	10/11/13	51.32	56.67	453	60	B	
1226	10/11/13	51.18	56.87	325	60	B	
1227	10/11/13	51.17	56.93	259	60	B	
1228	10/11/13	51.19	57.05	131	60	B	
1229	11/11/13	51.28	56.83	377	60	B	
1230	11/11/13	51.39	57.02	314	60	B	
1231	11/11/13	51.44	57.24	142	60	B	
1232	12/11/13	52.57	58.56	147	60	B	
1233	12/11/13			153		C	
1234	12/11/13	52.60	58.87	109	60	B	
1235	12/11/13			108		C	
1236	12/11/13	52.58	59.02	103	60	B	
1237	12/11/13	52.63	59.16	119	60	B	
1238	12/11/13			119		C	
1239	13/11/13	52.79	59.08	113	60	B	
1240	13/11/13			115		C	
1241	13/11/13	52.98	59.12	221	60	B	
1242	13/11/13			204		C	
1243	13/11/13	52.95	59.59	171	60	B	
1244	13/11/13			166		C	
1245	13/11/13	52.96	59.80	242	60	B	
1246	13/11/13			237		C	
1247	14/11/13	52.72	59.54	152	60	B	

1248	14/11/13			156		C	
1249	14/11/13	52.54	59.75	114	60	B	
1250	14/11/13			120		C	
1251	14/11/13	52.73	60.14	188	60	B	
1252	14/11/13			189		C	
1253	14/11/13	52.69	60.27	202	60	B	
1254	15/11/13	52.71	60.31	216	60	B	
1255	15/11/13	52.73	60.36	243	60	B	
1256	15/11/13	52.73	60.41	269	60	B	Chain broken
1257	15/11/13			265		C	
1258	15/11/13	52.65	60.44	258	60	B	Chain broken
1259	16/11/13	53.05	60.05	413	60	B	Chain broken; Net slightly ripped
1260	16/11/13			389		C	
1261	16/11/13	52.93	60.24	371	60	B	
1262	16/11/13			375		C	
1263	16/11/13	52.90	60.15	241	60	B	
1264	16/11/13			247		C	
1265	16/11/13	52.85	60.21	200	60	B	Net ripped from mouth nearly to cod-end
1266	16/11/13			193		C	
1267	17/11/13	53.20	59.73	608	60	B	
1268	17/11/13			597		C	
1269	17/11/13	53.19	60.08	640	60	B	Chain loose and belly ripped
1270	17/11/13			648		C	
1271	17/11/13	53.13	60.13	527	60	B	Vessel stalled, chain loose, net ripped
1272	17/11/13			544		C	
1273	17/11/13			397		C	
1274	18/11/13	53.09	59.86	409	60	B	
1275	18/11/13	53.16	59.76	526	20	B	groundrope snapped, and net in shreds
1276	18/11/13			522		C	
1277	18/11/13	53.03	59.21	380	60	B	chain broken and a small rip
1278	18/11/13			383		C	
1279	19/11/13	52.85	58.80	172	60	B	Chain loose again
1280	19/11/13			157		C	
1281	19/11/13	52.86	58.79	271	60	B	Chain loose again
1282	19/11/13			374		C	
1283	19/11/13	52.88	58.70	377	60	B	Chain broke and lost
1284	19/11/13			388		C	
1285	19/11/13	52.91	58.64	463	60	B	Chain loose and rip in net
1286	19/11/13			463		C	
1287	20/11/13	52.89	58.70	408	60	B	
1288	20/11/13	52.90	58.67	429	60	B	Small rip in net

2.2 Trawl gear

A bottom trawl fitted with tickler chains and using polyvalent doors, and a 90 mm cod end was used. Early in the cruise (after the net had become damaged a few times), the captain informed the survey scientist that during the 2010 survey, the same net had been fitted with rockhopper gear and tickler chain, as opposed to the sturdy (approx. 70mm in diameter) ground rope and tickler chain used in the current survey. Since rockhopper gear was not onboard the ship, the 2010 gear set-up could not be exactly replicated, and the survey was continued with the gear configurations as per Figure 2. The trawl doors and net were fitted with sensors for the MarPort Net Monitoring System, transmitting door depth, horizontal spread, angle and tilt, as well as (net) wing spread, all of which was recorded, except for door angle and tilt.

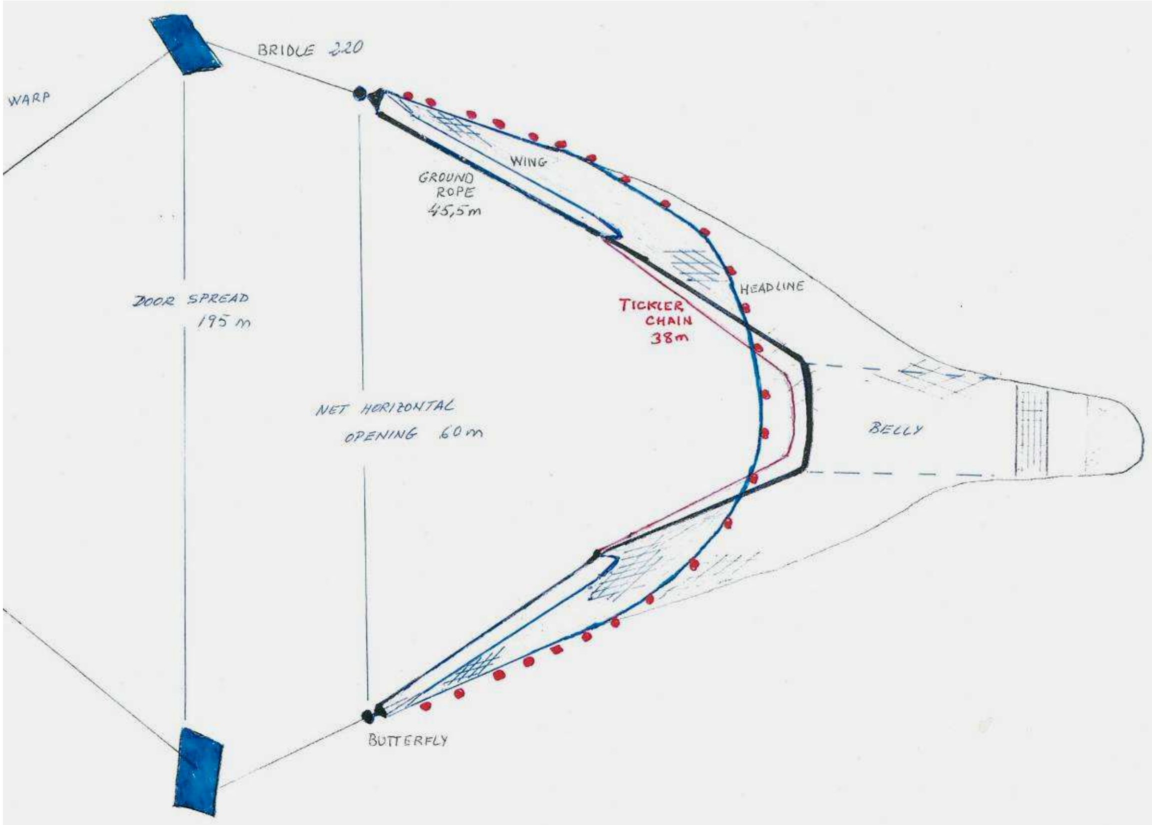


Figure 2: Bottom Trawl design, Castelo-11-2013. Drawn by Captain José Santos.

2.3 Biological sampling

For all trawls, the whole catch was weighed by species (or lowest possible taxonomic level in the case of invertebrates) using the electronic marine adjusted POLS balance. However, when invertebrate by-catch was quite substantial, a random subsample of the invertebrate by-catch was taken to extrapolate a whole-catch estimate for those species.

All skates were analysed for disc-width, sex and maturity, using the 6-stage maturity scale (Arkhipkin et al. 2008) and recorded using the electronic Fishmeter board. Subsamples of skates, generally a few animals per haul, were analysed for fecundity, and age/growth samples were collected from all *Bathyraja multispinis*.

Specimens from the genus *Psammobatis* were not identified by 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 ~120m is

Psammobatis normani (slender claspers) whereas in shallower waters the most common species is *Psammobatis rudis* (short and stout claspers).

Random samples were taken of all commercial finfish species and Loligo squid, typically 100 specimens in the case of fish or 200 specimens in the case of squid, recording length, sex, and maturity stage for all specimens.

Subsamples of squid species were taken to extract statoliths, and subsamples of fish species were taken to extract otoliths. All these specimens were also weighed.

2.4 Data analyses

2.4.1 Skate biomass estimates

Survey biomass of skates was estimated by extrapolating catch density (catch weight per trawl swept-area). Because of the relatively low numbers of trawls in this survey and their high variability, geo-statistical methods gave poor results and instead a cubic spline algorithm (Akima 1996) was used for extrapolating catch densities of all skate species. Trawl swept region was defined as trawl distance × wing spread (horizontal net opening). Trawl start and end positions and wing spread were logged at each survey station by the vessel's bridge officers. Further description of the trawl swept region definition is given in the 2010 skate survey report (Arkhipkin et al. 2010). Four survey stations missed log entries of wing spread due to sensor failures. Wing spreads of these four stations were predicted from a generalized additive model (GAM) of wing spread vs. trawl speed and modal depth calculated with Gaussian error distribution on the 65 stations with complete wing spread, trawl speed, and modal depth data. This GAM resulted in 70.9% deviance explained and the four predicted wing spreads obtained coefficients of variation ranging from 0.94% to 1.25%.

Inferring biomass from a trawl must take into account the trawl's capture efficiency, which is generally not absolute (Dickson 1993). As described for the 2010 skate survey (Arkhipkin et al. 2010), survey skate catch density was scaled by a catchability coefficient adjusting for the relatively light contact gear generally used by Spanish trawlers (including the survey vessel) compared to Korean trawlers. However, it was determined that the survey vessel itself used heavier ground contact gear in the 2013 survey than it had in the 2010 survey (see section 2.2). Changes in gear are a common issue in fishery surveys and are variously addressed by paired trawl comparisons (Warren 1997; Wilderbuer et al. 1998), qualitative comparisons (Rijnsdorp et al. 1996), or discounting those catch species thought to be affected by the gear change (Rogers & Ellis 2000). For the present survey analysis, paired trawls were not available, and quantitative assessment of all skate species was required. An additional scaling factor was therefore calculated to adjust for the 2010/2013 gear difference. Because the gear difference covered two separate years, this scaling factor had to be standardized for dissimilarity in available catch biomass during the time of either year's survey. This was done by calculating an index ratio between the CPUE of commercial skate-fishing vessels in either year vs. the CPUE of the surveys. The surveys in either year were conducted in early November. For commercial CPUEs the index ratio included catch reports of all Spanish and Korean vessels that fished under F (skate) license from September through December in both 2010 and 2013. This comprised six vessels, recording 108 catch reports in 2010 and 117 catch reports in 2013. For the survey CPUEs the index ratio included only northern trawl stations (north of latitude 51ºS) from the 2013 survey because only the north was covered during the 2010 survey. This comprised 52 stations in 2010 and 27 stations in 2013. Three levels of comparison were examined for the index: 1) skate-only CPUE, 2) CPUE of all commercially reported species (i.e., including value fish and squid by-catch, but excluding invertebrates, non-value fish, debris, etc., that are recorded in surveys but never in commercial reports), and 3) CPUE of everything caught. CPUEs are summarized in Table 2.

Table 2: CPUE by Spanish and Korean vessels fishing F license in September to December 2010 and 2013, and by the survey vessel in the 2010 and 2013 (north) skate surveys. 'commercial equivalent' refers to all catch on the surveys corresponding to species that a commercially fishing vessel would record in its catch reports.

Year	Catch type	Quantity	CPUE (kg / hr)
2010	commercial	skate	484.0
		all	1182.2
	survey	skate	177.5
		comm. equiv.	1225.5
		all	1270.9
2013	commercial	skate	493.9
		all	899.4
	survey	skate	416.6
		comm. equiv.	1110.6
		all	1633.9

Using skate-only CPUE would be the most pertinent to the survey objective, and closest to the recommendation that trawl correction factors should be calculated separately for each species group because response characteristics to a trawl are species-specific (Fraser et al. 2007; von Szalay & Brown 2001). However, this is contingent on the assumption that the different trawls are towing on the same biomass, which cannot be stated for the 2010/2013 comparison. Spanish vessels targeting skate normally catch well under 50% skate (it is de facto a licensed by-catch fishery) and therefore skate catch alone can also not be considered a surrogate for the overall capacity of the fishing gear. The 2013/2010 index ratio, based on the skate-only data in the table, would be:

$$(416.6 / 177.5) / (493.9 / 484.0) \quad = \quad 2.300$$

By this ratio, the survey fishing gear in 2013 had more than 2× the catchability of the survey fishing gear in 2010. That is improbably high and was not applied.

Using CPUE of only commercially equivalent species gives a more moderate ratio:

$$(1110.6 / 1225.5) / (899.4 / 1182.2) \quad = \quad 1.191$$

However, partial CPUEs in some trawls may be skewed by haphazardly very large volumes of unwanted catch. For example in the 2013 survey north, one trawl caught almost 5 t of sponge, representing 64% of that trawl's total; another trawl caught 2.94 t of sponge, representing 60% of that trawl's total. With a relatively low number of trawls (27 stations in the 2013 survey) this would make the index unreliable and was also not applied.

Finally, using CPUE of all catch gives the ratio:

(1633.9 / 1270.9) / (899.4 / 1182.2) = 1.690

This ratio is the least specific and disregards the fact that survey catches include items unreported in commercial catches. However, the technical catchability of a trawl net includes everything and commercial trawls aim to avoid non-value catch anyway, so they are less likely to be biased than survey trawls by not reporting it. Using CPUE of all catch is also least susceptible to bias from the long durations (12 – 20 hrs per day) that commercially fishing vessels often tow, whereby the trawl gear may pass a significant proportion of its time semi-saturated and with diminishing correlation between the available biomass and the amount of additional catch. This ratio was applied as the scaling factor between the 2010 and 2013 survey catchabilities.

Variability of the skate biomass estimates was calculated by bootstrap re-sampling (Efron 1981) of the survey data. The biomass estimates included four components, each of which was randomized separately per bootstrap iteration:

1) Survey trawl position. For the empirical estimates, each survey trawl's catch was assumed to have been taken at the midpoint between trawl start and trawl end positions. For the variability estimates, the position was ranged on a random uniform distribution between the trawl start and trawl end positions.

2) Catchability coefficient of Spanish vs. Korean vessels ($q_{\text{Spain / Korea}}$). The lists of Spanish / Korean vessels fishing under F license in each of 2010 and 2013 were re-

sampled with replacement, then the trawls taken by these vessels were re-sampled with replacement to calculate a catchability ratio for the variability estimate.

3) Catchability coefficient of the 2013 vs. 2010 survey ($q_{2013\ /\ 2010}$). Survey total catches and commercial total catches (from those catch reports meeting the criteria for comparability with the surveys, described above) were re-sampled with replacement for both years 2010 and 2013, to calculate a catchability ratio for the variability estimate.

4) Catch per survey trawl. Because trawls caught large quantities of species other than skates, all species with FIFD defined length-weight relationships (not just skates) were randomly re-sampled per trawl. To do so from correct proportions of the catch, the individual composition of each trawl was extrapolated from its length-frequency samples. For trawls that did not have length-frequency samples of some species, the average length frequency distribution – separately for either the north or south survey region - was used instead. Lengths were converted to weight using the defined length-weight parameters. The extrapolated individual composition of each trawl was then randomly re-sampled with replacement. Because 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.

Bootstrap re-samples of Σ (catch per trawl-swept region × $q_{\text{Spain / Korea}}^{-1}$ × $q_{2013\ /\ 2010}^{-1}$) were repeated 10,000×. Monte Carlo tests were used to evaluate differences in skate biomass between 2010 and 2013, by species and in total.

All statistics were done in R v3.0.2 (R Core Team 2013).

2.4.2 Skate community and abundance

The skate assemblage is first compared among survey regions (North, East, South) in the 2013 survey. A comparison of the 2010 survey results to those in the 2013 is made for the northern region only. For 2010/2013 comparisons, 2013 CPUE (kg/hr) is divided by 1.69 to account for differences in gear type used between surveys (see *Skate biomass estimates* 2.4.1).

Partial redundancy analysis (RDA) is used to compare 2010 skate community data to the 2013 survey (Legendre & Legendre 1998). This is a multivariate analysis of both species composition and their relative abundances, constrained by environmental factors. Skate communities vary with both depth and location (Lat/Lon position). Differences in depth or location could therefore mask any changes between years that are in fact caused by other factors. RDA "partials out" the effects of Depth and Location, allowing the examination of the pure effect of Year (Borcard et al. 1992). RDA also calculates the percentage contribution of each factor in explaining observed variation and its statistical significance.

2.4.3 Invertebrate by-catch

Diversity of invertebrate catch is summarised in two ways. First, standard diversity indices are used to describe number of species (richness – S), number of species and their relative abundance (Shannon diversity - H'), and the distribution of abundance among species (Pielou's evenness – J') (Maurer & McGill 2011). Second, non-metric multidimensional scaling (nMDS) is used to examine invertebrate species composition and abundance between survey regions. This method uses the similarity of stations based on their invertebrate composition and abundance in multivariate space, and reduces it to two-dimensional space through an iterative model fitting process. Unlike partial redundancy analysis above, this nMDS find the best 2 dimensional fit of multivariate data.

All statistics were done in R v3.0.2 (R Core Team 2013), where the 'vegan 2.0' package was used for multivariate statistics. Data used in parametric statistics (ANOVA, MANOVA) were examined for normality assumptions using standard diagnostic plots. Maps were plotted in QGIS v2.0 (www.qgis.org).

2.5 Oceanography

A logging CTD (SBE-25, Sea-Bird Electronics Inc., Bellevue, USA) was used to collect oceanographic data in the vicinity of all trawl stations. Two instruments were used: CTD SN 0247 from to 2/11 to 6/11, then following malfunction of this instrument CTD SN 0389 from 12/11 onwards. At each station the CTD was deployed to a depth of c.10m below surface to flush through and equilibrate the sensors for c. one minute, then raised and lowered from 2 m below surface toward the sea bed at 1m/sec. The CTD collected pressure in dbar, temperature in °C and conductivity in mS/cm. Raw data files in hex format were converted and processed using SBE Data Processing Version.7.22.5, with CON file OldCTD_2013_AUG.xmlcon (amended to remove the external voltages conversion) for CTD SN 0247 and CON file 0389_July_2012.con for CTD SN 0389. Upcast data were filtered out. Depth was derived from pressure adjusted for the latitude of each station. Practical Salinity (PSU) and Density as sigma-t (σ-t) were derived following derivation of depth. PSU is a measure of conductivity which normalizes the salinity to KCl parts per thousand of the seawater at 15° C at 1 atmosphere. Sigma-t measures the density of seawater at a given temperature, σ-t is defined as ρ(S,T)-1000 kg m^{-3}, where ρ(S,T) is the density of a sample of seawater at temperature T and salinity S, measured in kg m^{-3}, at standard atmospheric pressure. Further derived variables of conservative temperature (°C) and Absolute Salinity (g/kg) were calculated in Ocean Data View version 4.5.4 (Schlitzer 2013) for use in Figure 57.

3.0 Results

3.1 Catch composition

Bottom trawling was conducted at 70 stations (68 with catch) as shown in Figure 1, with 30 (28), 8, and 32 trawls respectively in the three regions of interest defined as North, East and South. Seabed trawling times during the survey was aimed to be 60 minutes, which occurred for 65 stations, 26, 8, and 31 in the respective three regions (Table 1).

During the cruise a total of 103,694 kg biomass was caught comprising 147 species or taxa (Appendix Table 11). The largest catches by weight were rock cod (*Patagonotothen ramsayi*), ridge scaled grenadier (*Macrourus carinatus*), hoki (*Macruronus magellanicus*), sponges, and banded whiptail grenadier (*Coelorhynchus fasciatus*), together amounting to over 62% of the total catch.

Table 12 in the appendix lists numbers of specimens analysed from randomly collected samples. 170 specimens of three squid species had their statoliths extracted, and 948 otoliths were extracted of 16 different species.

3.1.1 Commercial finfish species catch, distribution, biology

Commercial finfish species catches are separately listed in Table 3.

Table 3: Commercial finfish and squid catches by region

Code	Species Name	North	East	South	Total	% Total
PAR	*Patagonotothen ramsayi*	9,754.040	389.550	6,954.760	17,098.350	32.53%
GRC	*Macrourus carinatus*	686.020	986.140	15,091.820	16,763.980	31.89%
WHI	*Macruronus magellanicus*	4,376.150	44.460	7,314.030	11,734.640	22.32%
BAC	*Salilota australis*	356.650	0.470	1,332.670	1,689.790	3.21%
KIN	*Genypterus blacodes*	1,335.940		153.440	1,489.380	2.83%
BLU	*Micromesistius australis*	247.058	228.090	996.530	1,471.678	2.80%
LOL	*Loligo gahi*	274.980	19.890	410.350	705.220	1.34%
PAT	*Merluccius australis*	4.980		571.039	576.019	1.10%
TOO	*Dissostichus eleginoides*	149.901	53.640	331.530	535.071	1.02%
HAK	*Merluccius hubbsi*	501.060		2.090	503.150	0.96%
ILL	*Illex argentinus*	2.210			2.210	<0.00%
Totals		**17,688.989**	**33,158.259**	**1,722.240**	**52,569.488**	

Kingclip (*Genypterus blacodes*)

Kingclip were caught at 25 stations throughout the survey in small amounts, however particularly high catches were found at three stations in the north (340–514kg). 301 specimens were sampled from the catch, with sizes ranging from 47-129cm total length, modal maturity was Stage II, and 57% females (Figure 3).

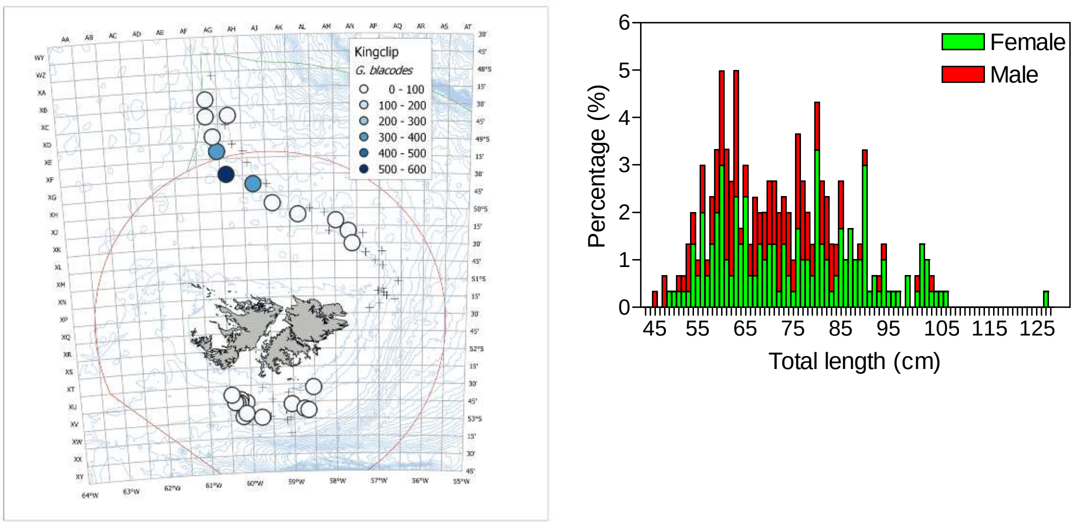


Figure 3: Distribution, CPUE (kg/hr) & length frequency for *Genypterus blacodes*

Hoki (*Macruronus magellanicus*)

Particularly high catches were found in deeper trawls in north (1,773 kg) and south (756-1,221 kg) (Figure 4). However, catches were generally low throughout the surveyed regions. A total of 1,475 hoki were sampled from the catch. Size ranged from 15-40cm (pre-anal length) with a modal size of 27cm. Modal maturity was Stage II, and 63% of sampled fish were female.

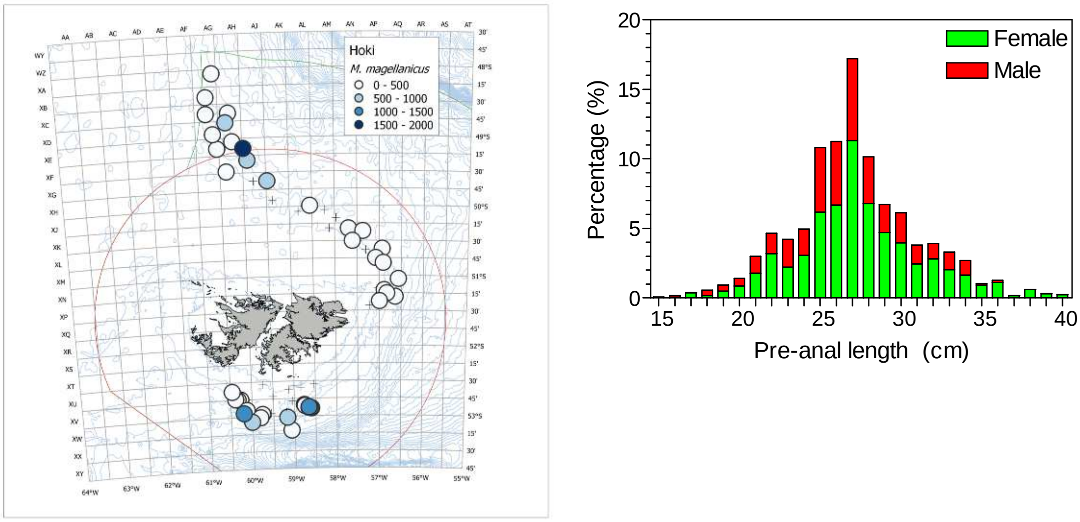


Figure 4: Distribution, CPUE (kg/hr) & length frequency for *Macruronus magellanicus*

Rock cod (*Patagonotothen ramsayi*)

Rock cod were caught at 59 stations, and relatively abundant in shallower trawls throughout the surveyed regions. Mean catch in the northern regions was 312kg

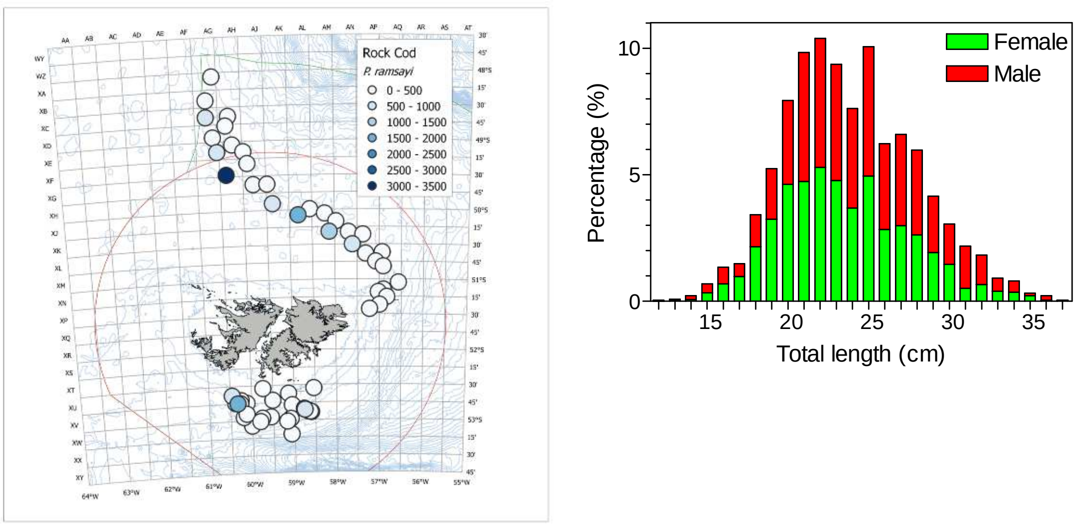


Figure 5: Distribution, CPUE (kg/hr) & length frequency for *Patagonotothen ramsayi*

(max=3,141kg), and 228kg in the south (max=1,667kg). 2,708 rock cod were sampled from the catch, with size ranging from 6.5-36cm (mode=22cm) (Figure 5).

Southern blue whiting (*Micromesistius australis*)

Relatively small amounts of southern blue whiting were caught at 46 stations throughout the surveyed regions, with highest catches in the south (mean=50kg, max=273kg). 1,095 southern blue whiting were sampled from the catch, with a size range of 15–64cm (clear modes at 19, 30, 35, 45, and 50cm), and a modal maturity of Stage II. 45% of sampled fish assessed by sex were female (Figure 6).

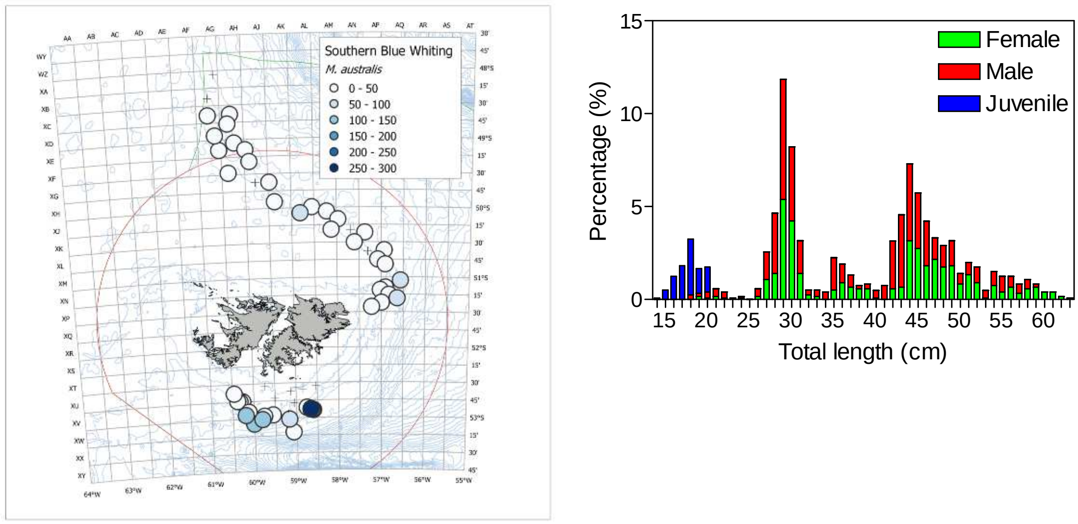


Figure 6: Distribution, CPUE (kg/hr) & length frequency for *Micromesistius australis*

Loligo squid (*Doryteuthis gahi*)

Catches of Loligo were very low throughout the survey. The highest catch was in the south at 159kg, and the remaining catches averaging 11kg per trawl. A total of 2,182 Loligo were sampled from the catch. Modal size (mantle length) was 15cm (range=6–26.5cm). Modal maturity was Stage IV, and a large proportion were female (65%) (Figure 7).

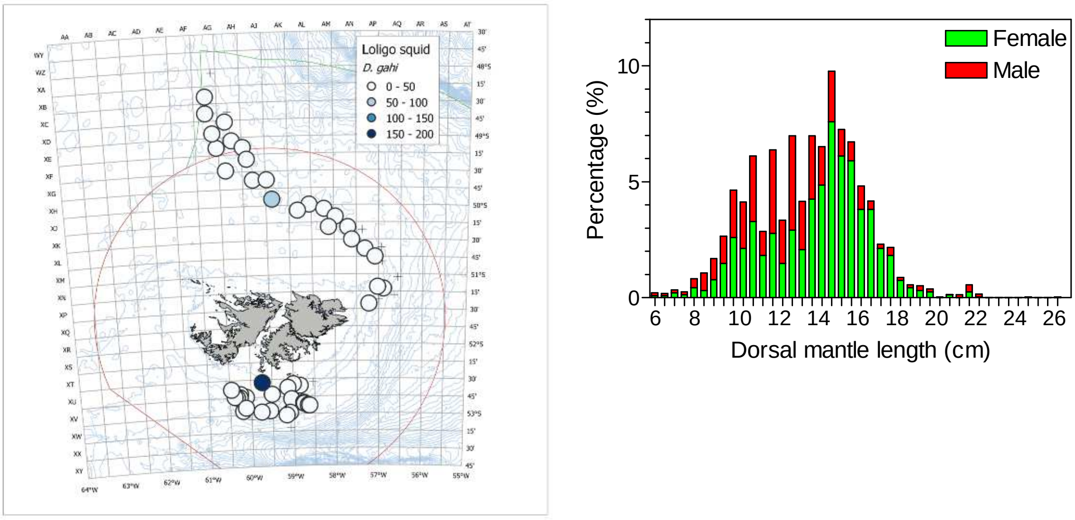


Figure 7: Distribution, CPUE (kg/hr) & length frequency for *Doryteuthis gahi*

Grenadier (*Macrourus carinatus*)

Large catches of Grenadier (*M. carinatus*) were found primarily in the south with catches reaching 1,495kg (mean=433kg per trawl). 1,718 fish were sampled from the catch. Size ranged from 7–32cm (pre-anal length) (mode=23cm) (Figure 8). Maturity of sampled fish had a mode of Stage IV. The majority of sampled fish were female (72%).

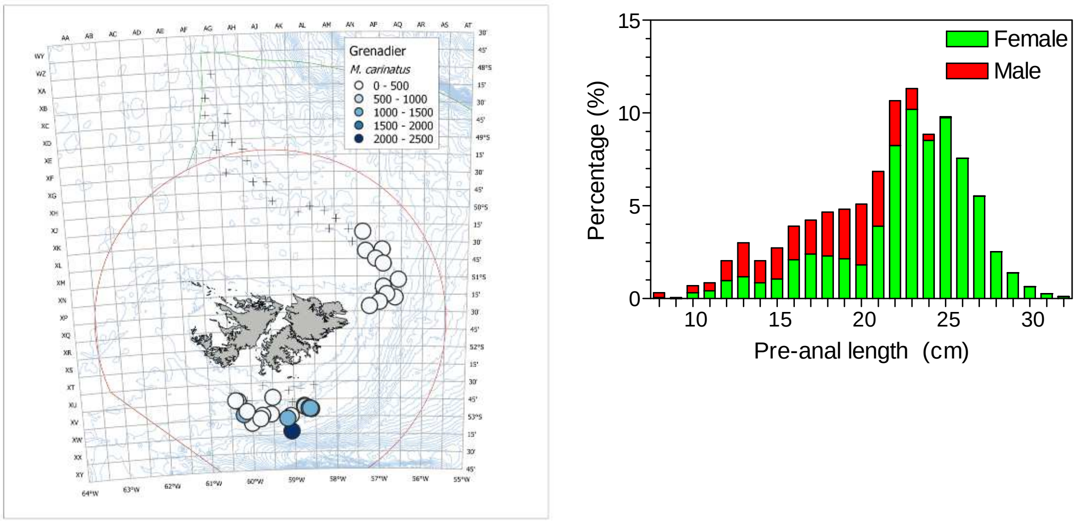


Figure 8: Distribution, CPUE (kg/hr) & length frequency for *Macrourus carinatus*

It is noteworthy that large catches of another grenadier species, *Coelorhynchus fasciatus*, were also found in the south, where highest catches ranged between 967–1,033kg at three stations.

Toothfish (*Dissostichus eleginoides*)

Toothfish were caught at 49 stations throughout the surveyed regions. Catches were generally low (<20kg) however, larger catches (28–35kg) were found at one station in the east and two stations in the south. A total of 552 toothfish were sampled from the catch. Size ranged from 22.5–83cm with clear modes at ~30 and ~43cm) (Figure 9). Modal maturity was Stage II, and 60% of sampled toothfish were female.

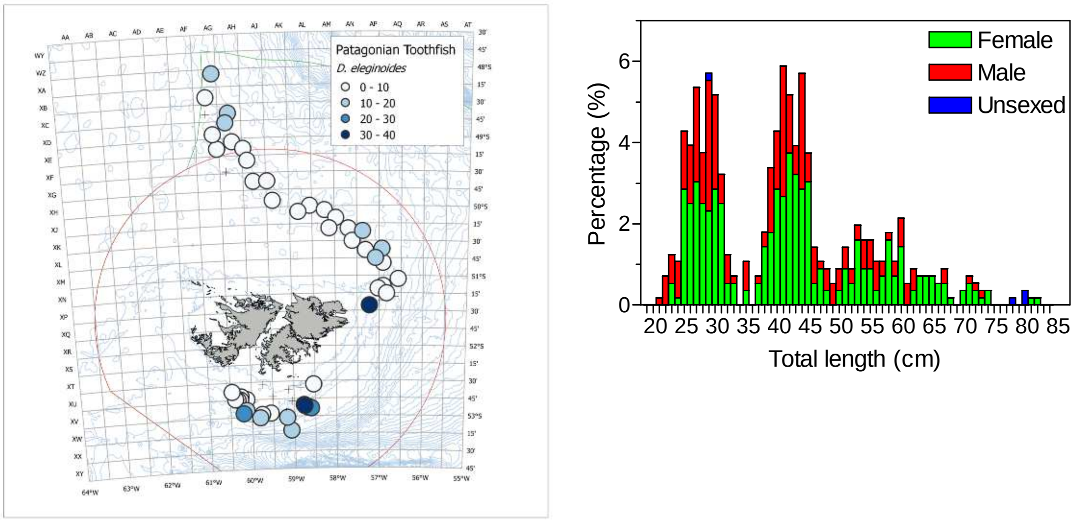


Figure 9: Distribution, CPUE (kg/hr) & length frequency for *Dissostichus eleginoides*

Hake (*Merluccius hubbsi* and *Merluccius australis*)

Common hake (*M. hubbsi*) were found primarily in the north. Catches were generally low (mean=50kg per trawl, max=153kg), among the 10 stations where they were caught. A total of 50 common hake were sampled from the catch, where size ranged from 33–86cm, modal maturity was Stage III, and all fish sampled were female. Patagonian hake (*M. australis*) were found mainly at nine stations in the southern region. Highest catch was 68kg, with the remaining catches much lower. A total of 101 fish were sampled from the catch. Size ranged from 50–91cm. Modal maturity was Stage II, with 87% of fish being female (Figure 10).

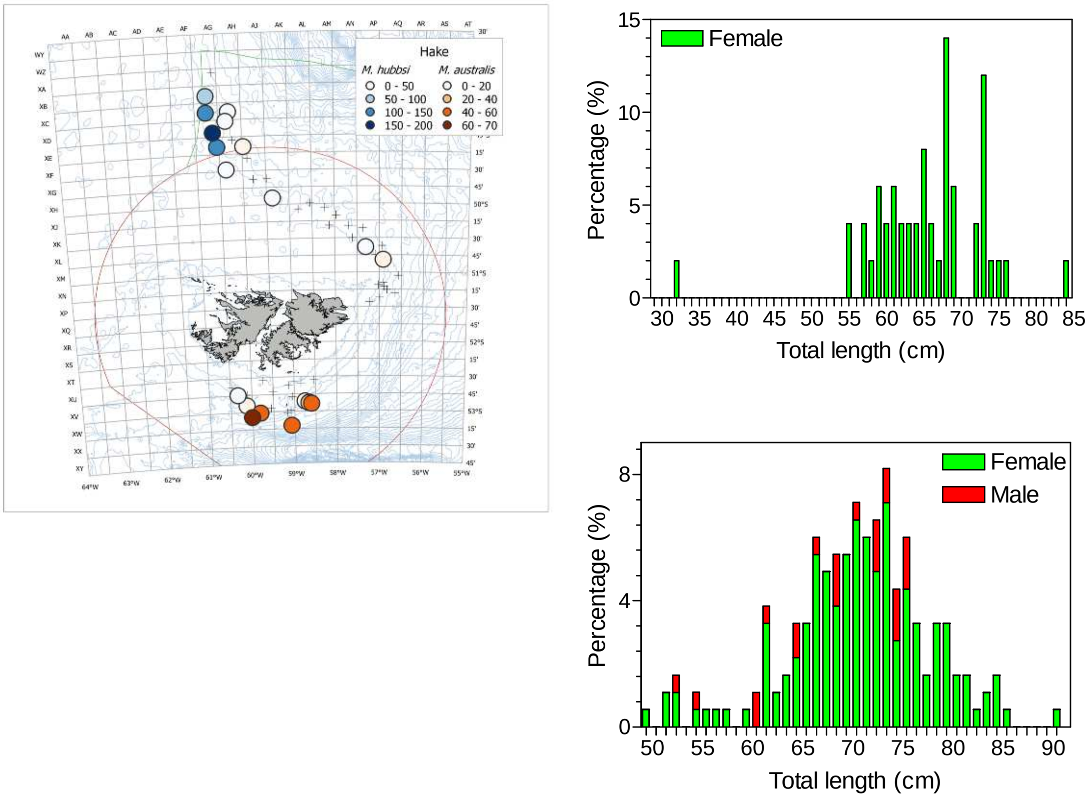
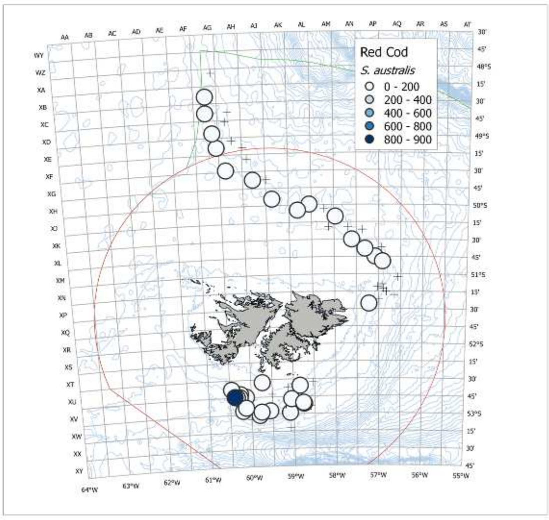


Figure 10: Distribution, CPUE (kg/hr) & length frequency for *Merluccius hubbsi* (top) and *Merluccius australis* (bottom)

Red cod (*Salilota australis*)

Red cod were caught at 33 stations throughout the surveyed regions. Catches were generally low (<30kg) however, 10 were larger than 30kg, with one station in the south yielding 841kg catches (28–35kg). A total of 409 red cod were sampled from four stations. Size ranged from 18–83cm with a clear juvenile mode at ~24 cm. (Figure 11). Modal maturity was Stage II (74%), with some proportions in post spawning stages VII (11%) and VIII (12%). 65% of sampled red cod were female.



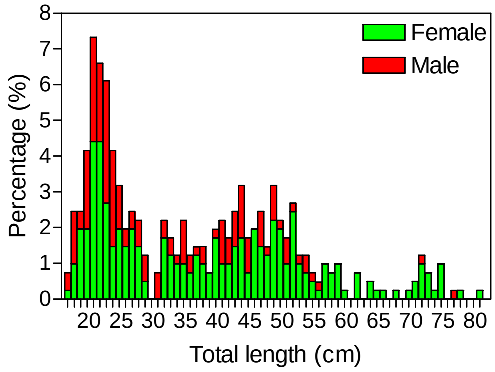


Figure 11: Distribution, CPUE (kg/hr) & length frequency for *Salilota australis*

3.1.2 Skate catch and distribution

The family Rajidae, of which a total of at least 14 species from 5 genera (*Amblyraja, Bathyraja, Dipturus, Psammobatis* and *Zearaja*) were caught, comprised 19.42% of the total catch from the 68 bottom trawl stations. Just 15 of the stations yielded more than 51% of the total skate catch, 9 of which occurred in the North, 2 in the East, and 4 in the South region. Only four stations yielded catches less than 20kg, all in the South: stations 1259, 1269, 1271, and 1279. Station 1275 did not yield any skates.

The four most abundant species comprised 77.2% of the skate catch, totalling 15,547kg (Table 4).

Table 4: Skate Catch (kg) by region.

Code	Species Name	North	East	South	Total	%
RBR	*Bathyraja brachyurops*	3,665.070	1,159.540	2,715.280	7,539.890	37.44%
RAL	*Bathyraja albomaculata*	2,009.990	618.955	741.860	3,370.805	16.74%
RGR	*Bathyraja griseocauda*	1,770.600	168.125	683.580	2,622.305	13.02%
RFL	*Zearaja chilensis*	1,331.460	49.590	633.800	2,014.850	10.00%
RSC	*Bathyraja scaphiops*	457.260	436.490	554.900	1,448.650	7.19%
RMC	*Bathyraja macloviana*	650.050	78.270	249.630	977.950	4.86%
RBZ	*Bathyraja cousseauae*	301.770	187.960	306.850	796.580	3.96%
RDO	*Amblyraja doellojuradoi*	370.920	123.250	22.890	517.060	2.57%
RMU	*Bathyraja multispinis*	234.280	29.730	71.792	335.802	1.67%
RPX	*Psammobatis spp.*	166.120	16.890	145.640	328.650	1.63%
RDA	*Dipturus argentinensis*	100.380			100.380	0.50%
RMG	*Bathyraja magellanica*		7.770	63.960	71.730	0.36%
RTR	*Dipturus trachydermus*	14.690			14.690	0.07%
		11,072.590	2,876.570	6,190.182	20,139.342	

3.2 Skate biomass estimates

The empirical value of $q_{\text{Spain / Korea}}$ was calculated as 0.600. Combined with the value of $q_{2013 / 2010} = 1.690$, the resulting overall catchability coefficient of the survey was 1.014, implying that the catchability on the 2013 survey is practically equivalent to that of commercially skate fishing Korean vessels. Skate biomass estimates per survey sub-region and 95% confidence intervals are summarized in Table 5. Compared to 2010, the biomass of RPX was significantly higher ($p < 0.01$) in the 2013 survey, the biomass of RFL was marginally higher ($p < 0.10$) and the biomass of RMU was marginally lower ($p < 0.10$) (see Table 5 in Arkhipkin et al. (2010), and Table 5, this report). RMG was captured in low densities in the 2013 survey (Table 5), but not at all in the 2010 survey. Spatial distributions of the skate species in the 2013 survey are shown in Figure 12. In the 2013 survey, five skate species had significantly higher ($p < 0.0167$; equivalent to $p < 0.05$ Bonferroni-adjusted for 3 parallel comparisons) density in the north sub-region than east sub-region: RDA, RFL, RGR, RMC, and RPX. Four species had significantly higher density in the east sub-region than north sub-region: RBR, RBZ, RMG, and RSC; two species had significantly higher density in the south sub-region than the east sub-region: RMC and RPX; one species had significantly higher density in the north sub-region than south sub-region: RDA; and one species had significantly higher density in the south sub-region than north sub-region: RMG.

Table 5: Estimated skate biomass (tonnes) in the survey regions and 95% confidence intervals from 10000 bootstrap iterations. These estimates include the conversion factor (approx. 1.69) for the difference between 2010 and 2013 survey trawl gear.

Skates	North		East		South	
	Est.	95% C.I.	Est.	95% C.I.	Est.	95% C.I.
RAL	4556	1985 - 11293	564	244 - 1414	374	147 - 1395
RBR	8022	3597 - 20693	1594	709 - 4177	2013	902 - 5939
RBZ	742	343 - 2065	209	97 - 586	182	75 - 880
RDA	291	115 - 893	$1.1 \cdot e^{-3}$	$0 - 143 \cdot e^{-3}$	0	-
RDO	743	321 - 1853	110	49 - 287	17	5 - 54
RFL	2997	1288 - 7424	59	6 - 338	415	160 - 1295
RGR	4629	2013 - 11585	171	60 - 385	490	187 - 1837
RMC	1160	529 - 3018	98	43 - 258	317	137 - 897
RMG	4	1 - 13	16	5 - 53	96	35 - 257
RMU	580	223 - 1447	39	9 - 114	40	13 - 179
RPX	587	257 - 1494	40	17 - 107	208	91 - 604
RSC	1135	485 - 2861	444	188 - 1129	385	163 - 1125
RTR	44	21 - 217	0	-	0	-
Total	25492	11289 - 64135	3345	1498 - 8654	4537	1922 - 14082

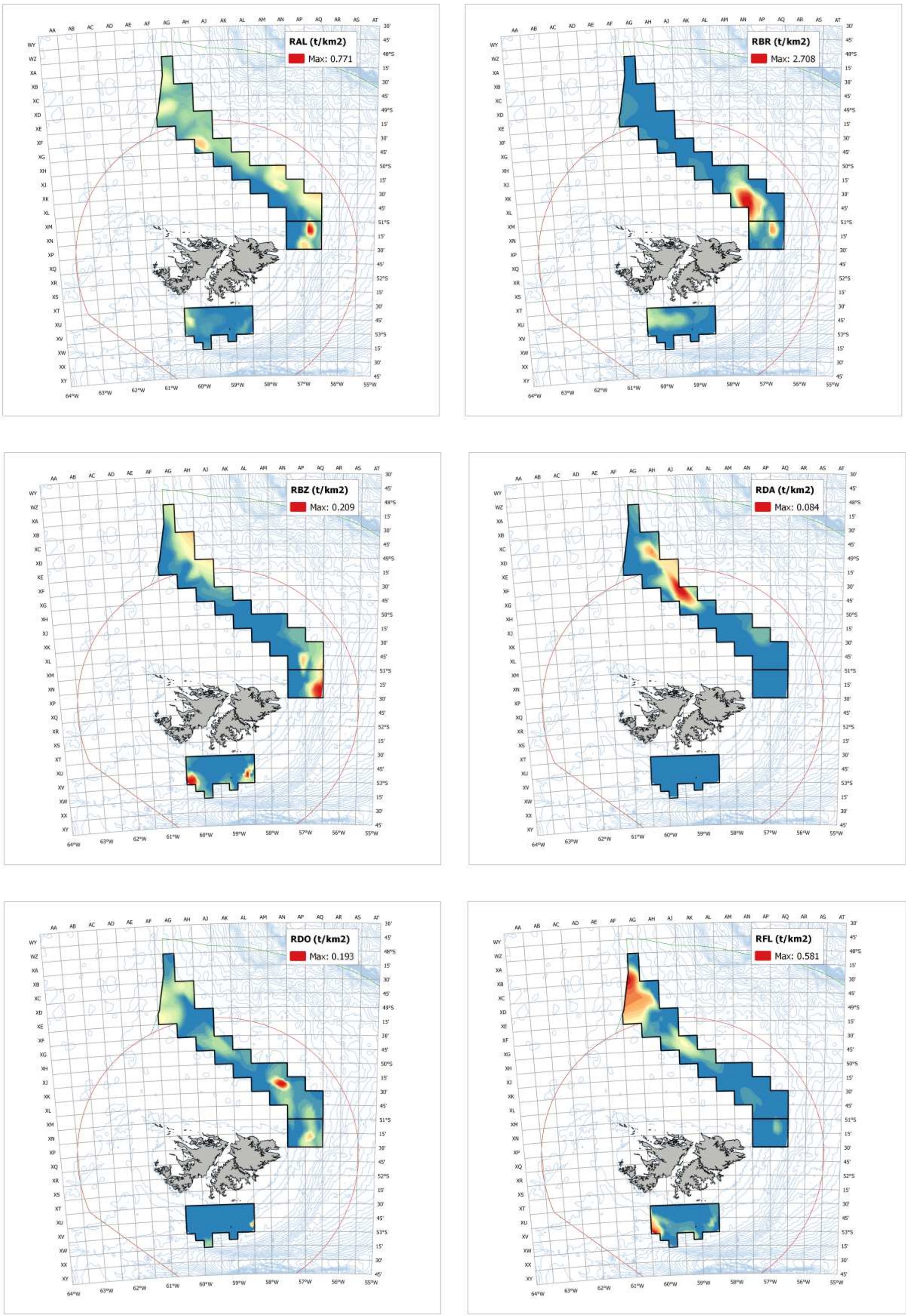


Figure 12: Interpolated density (t/km^2) distributions of skates across the three survey sub-regions. Maximum density is noted in the legend. Minimum density is zero (0) in all plots. Colour scales are individual for each species. Not included here is the density plot of the one individual of RTR that was caught.

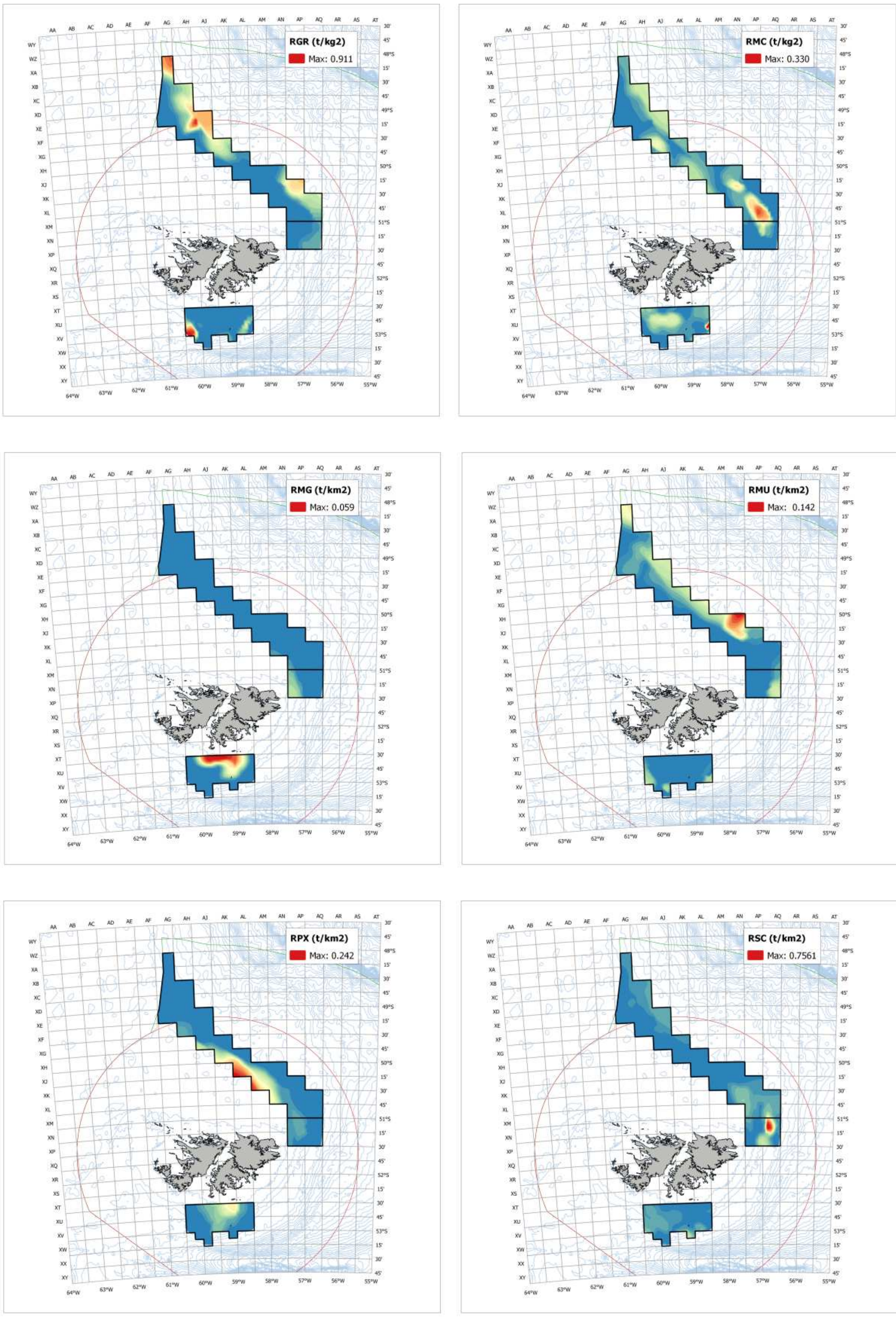


Figure 12 cont.

3.2.1 Skate biology

3.2.1.1 *Bathyraja brachyurops*

A total of 7,540kg was caught in 53 of the 67 stations, comprising 37% of the skate catch. Catches occurred within the depth range 103-450m, with highest catch at a depth of 232m, but on the whole more dominant in the 250-299m depth (Figure 13).

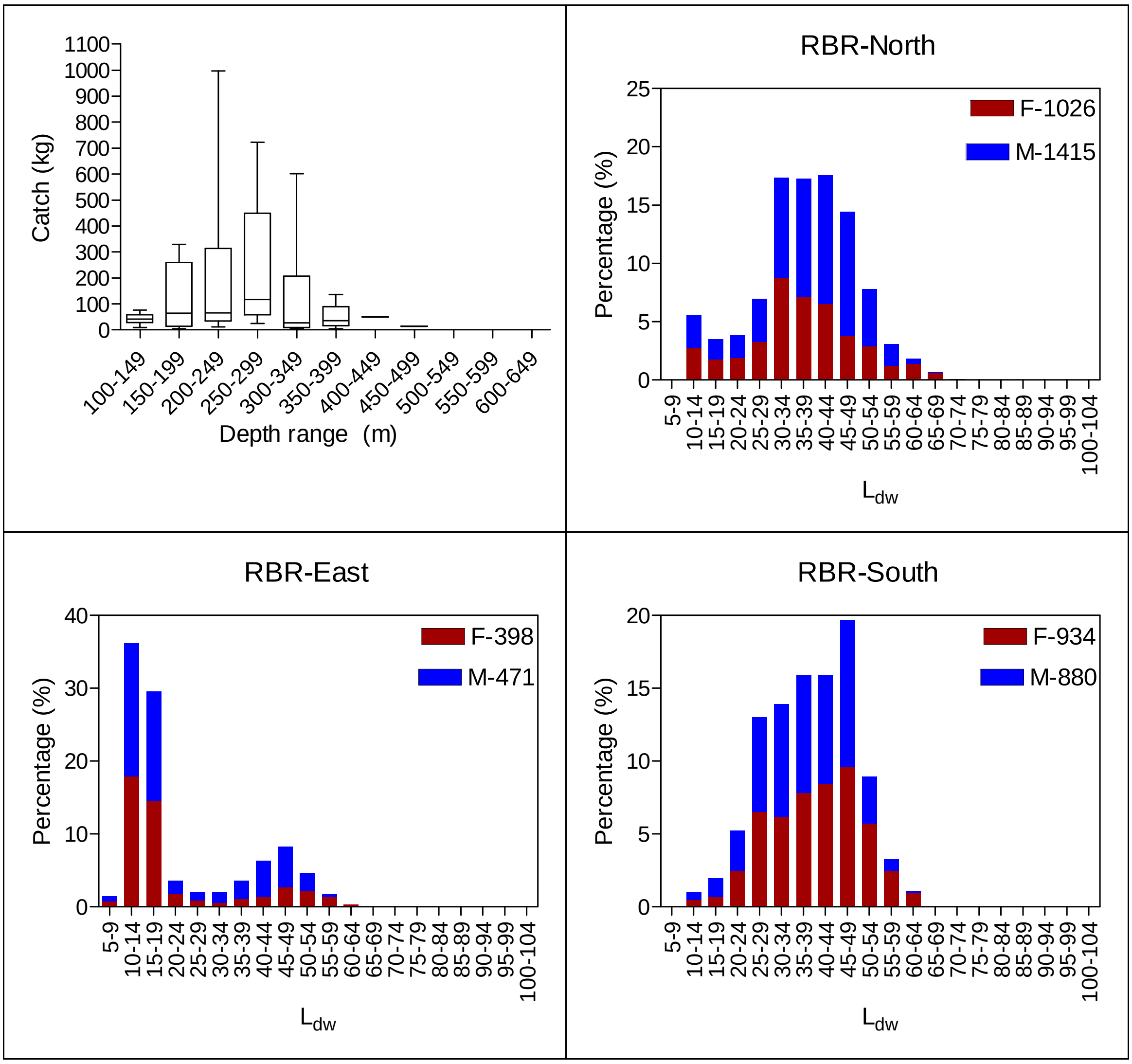
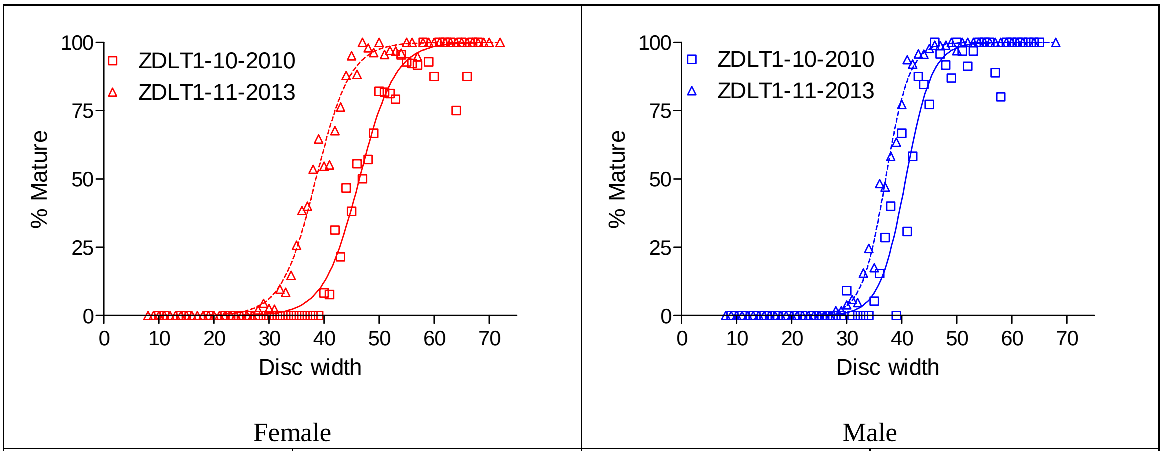


Figure 13: Depth range of catches and size frequency of *Bathyraja brachyurops* by region.

Disc width ranged between 8cm and 72cm with a mean of 35.4cm (XF=35.2, XM 35.5). Overall, the population revealed a 54.0% male predominance. 5.3% of the females were carrying egg capsules, 12.0% of the females above the L_{dw} at 50% maturity of 38.58cm, a significant decrease from 46.43cm in 2010 (Figure 14).



ZDLT1-10-2010	ZDLT1-11-2013	ZDLT1-10-2010	ZDLT1-11-2013
L_{M50}=46.43cm	L_{M50}=38.58	L_{M50}=40.75cm	L_{M50}=37.11cm

Figure 14: *Bathyraja brachyurops* maturity ogives for two surveys.

Specimens were found between 100-450 meters depth, with relatively few individuals found at depths greater than 300m. Smallest animals were found at 150m, increasing in size with increasing depth. However, a few larger animals were found at 100m. Female and male size and frequency varied in similar ways throughout their depth distribution (Figure 15).

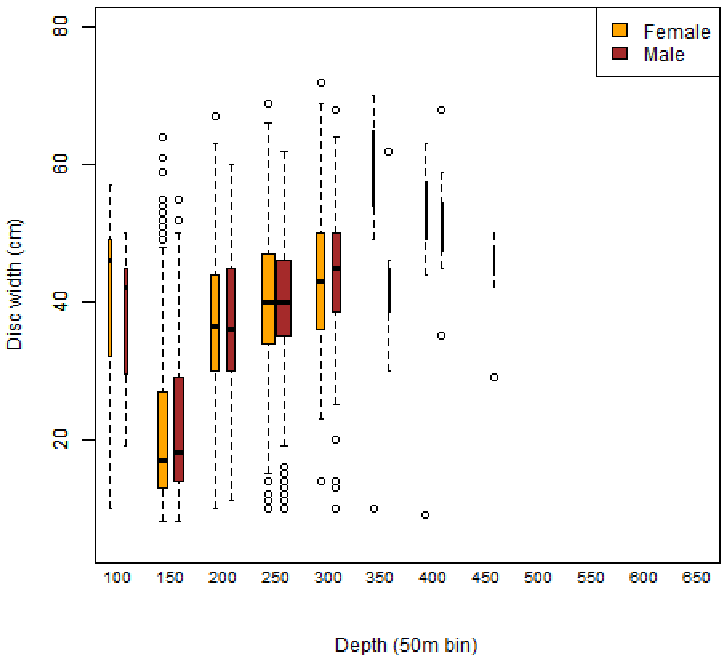


Figure 15: Box and whisker plot of disc width (cm) at 50m depth bins for *Bathyraja brachyurops*. Width of box is proportional to sample size (n). Data from all regions are pooled.

3.2.1.2 *Bathyraja albomaculata*

A total of 3,370kg of this 2nd most abundant species was caught in 57 of the 67 stations, comprising 16.7% of the skate catch. Catches occurred within the depth range 140-640m, with highest catch at a depth of 325m, and on the whole most dominant in the 250-349m depth ranges (Figure 16).

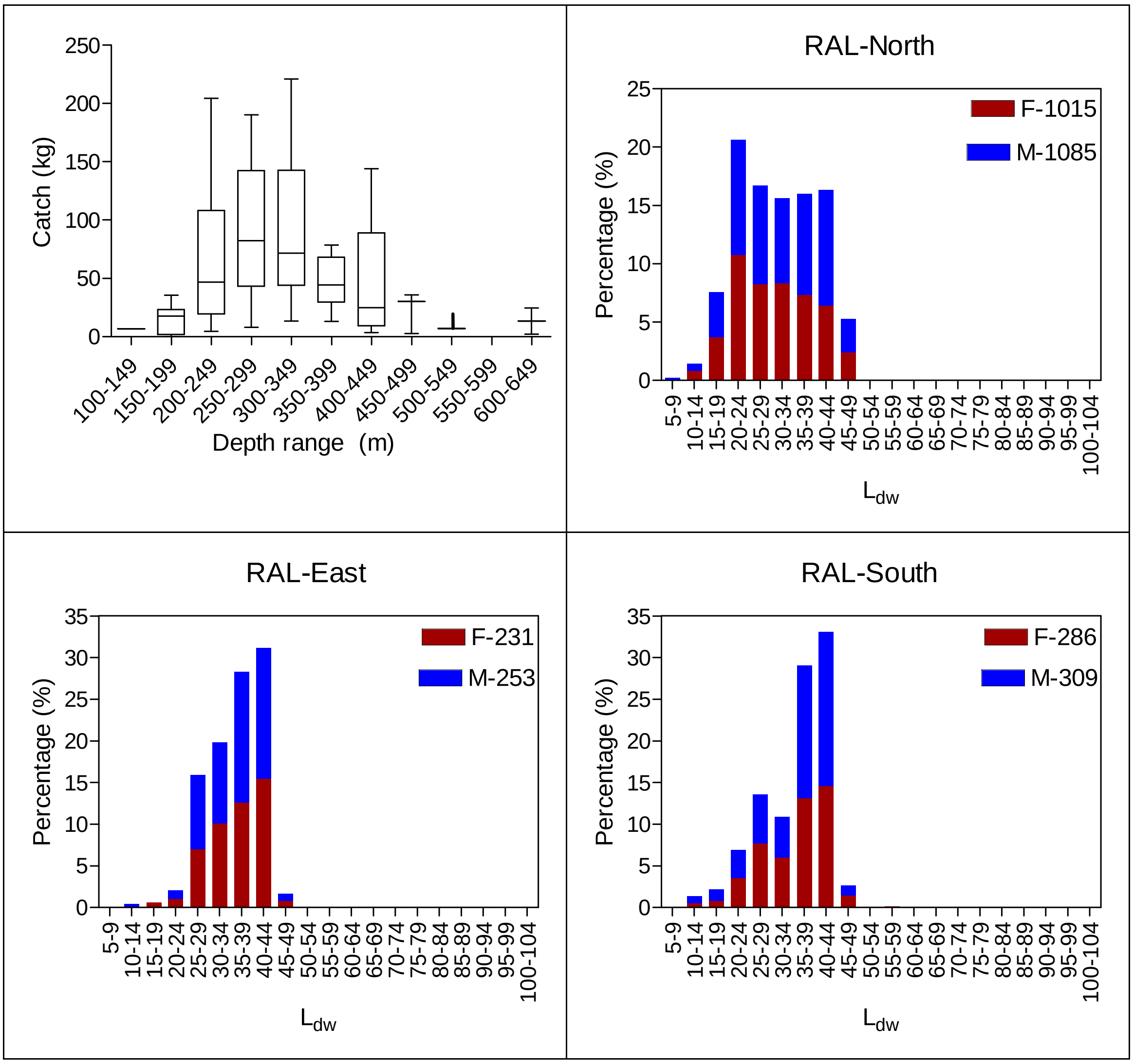
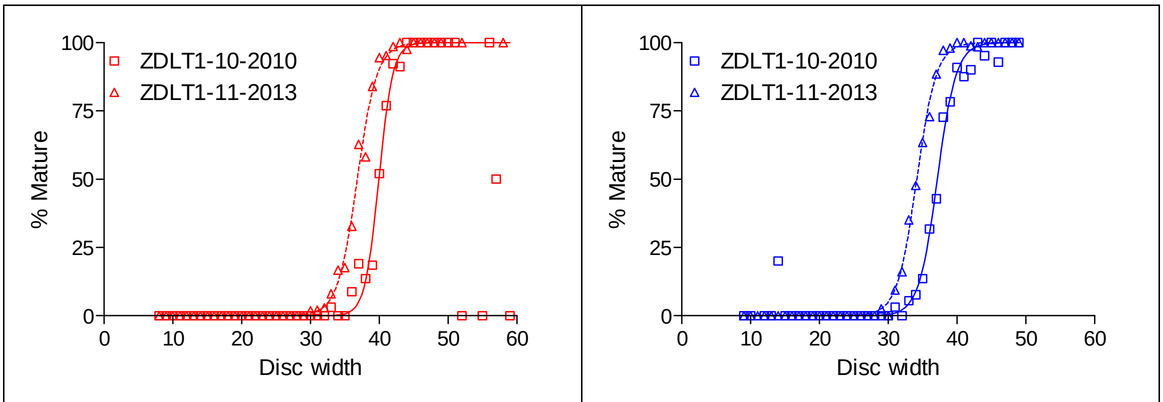


Figure 16: Depth range of catches and size frequency of *albomaculata* by region.

Disc width ranged between 8cm and 58cm with a mean of 32.3cm (XF=31.9, XM 32.7). Overall, the population revealed a slight (51.6%) male predominance. 17 of the females were carrying egg capsules, only 3.2% of females above the L_{dw} at 50% maturity of 36.83, a decrease form 39.95cm in 2010 (Figure 17).



Female		Male	
ZDLT1-10-2010 L_{M50}=39.95cm	ZDLT1-11-2013 L_{M50}=36.83	ZDLT1-10-2010 L_{M50}=37.16cm	ZDLT1-11-2013 L_{M50}=34.18cm

Figure 17: *Bathyraja albomaculata* maturity ogives for two surveys.

Specimens were found between 150-650m, with very few individuals found deeper. Size varied widely at all depths, with female and males skates showing similar frequency and size at throughout their depth distribution (Figure 18).

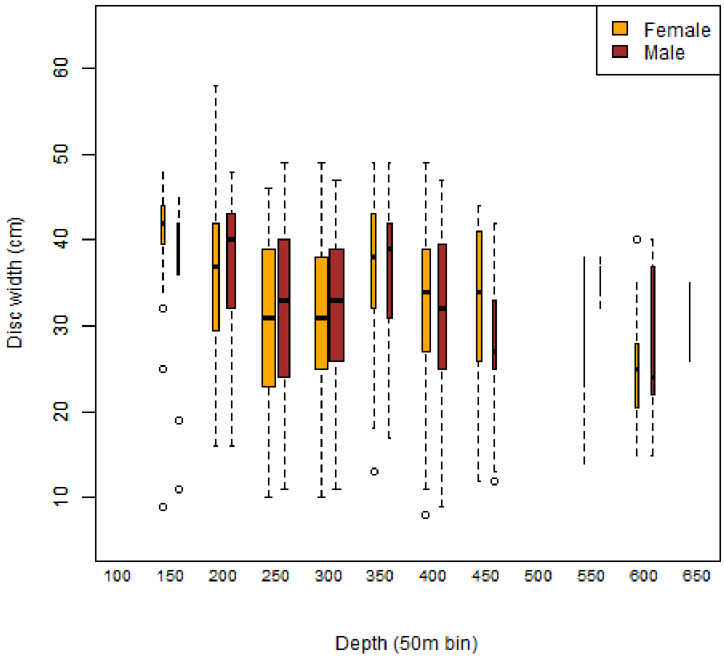


Figure 18: Box and whisker plot of disc width (cm) at 50m depth bins for *Bathyraja albomaculata*. Width of box is proportional to sample size (n). Data from all regions are pooled.

3.2.1.3 *Bathyraja griseocauda*

A total of 2,622kg was caught in 45 of the 67 stations, comprising 13% of the skate catch. Catches occurred within the depth range 142-640m, with highest catch at a depth of 245m, with 350-399m the most dominant depth range (Figure 19).

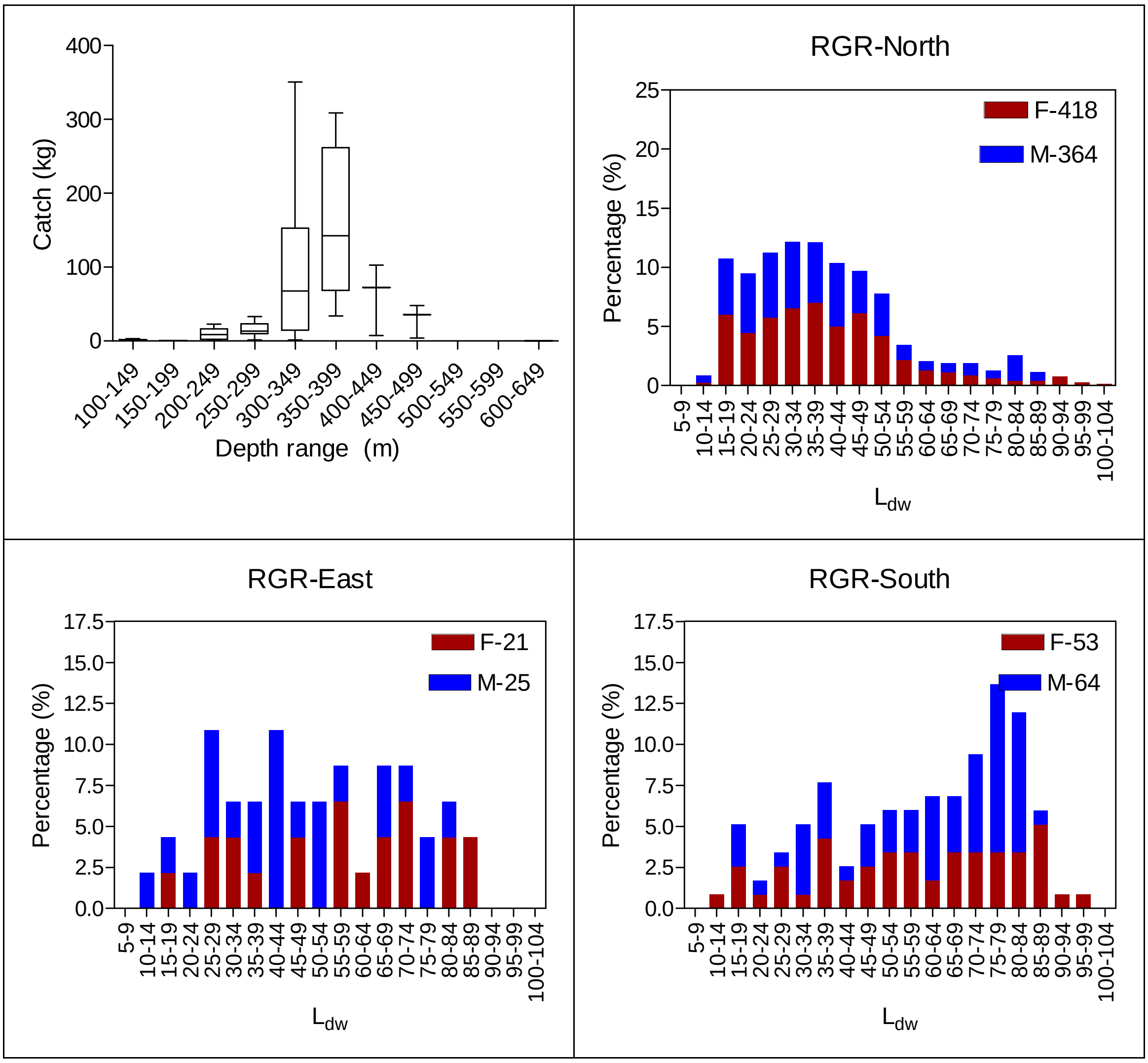
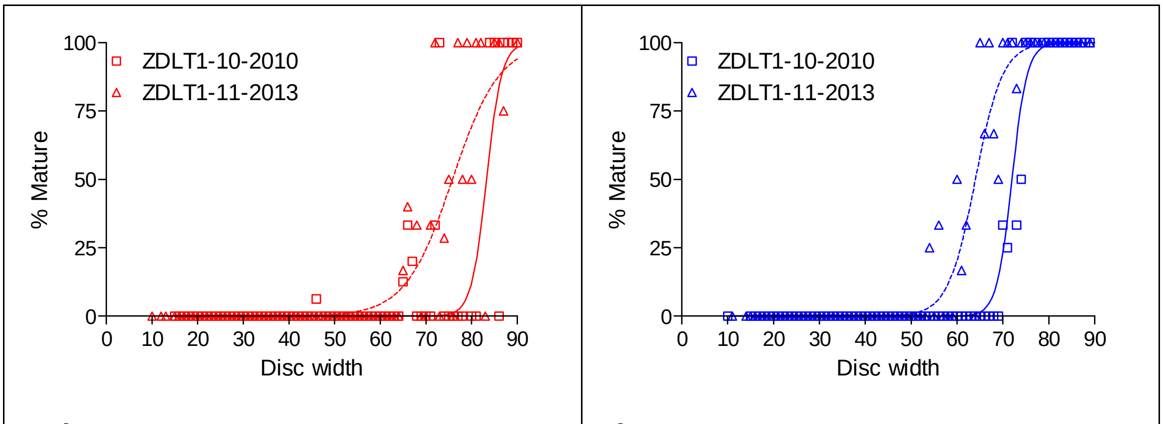


Figure 19: Depth range of catches and size frequency of *Bathyraja griseocauda* by region.

Disc width ranged between 10cm and 103cm with a mean of 42.5cm (XF=42.2, XM 42.9). Overall, the population revealed a slight female predominance (52.5%). Four females were carrying egg capsules, 10.3% of females above the L_{dw} at 50% maturity of 75.87cm, a decrease from 83.31cm in 2010 (Figure 20).



Female		Male	
ZDLT1-10-2010 L_{M50}=83.31cm	ZDLT1-11-2013 L_{M50}=75.87	ZDLT1-10-2010 L_{M50}=72.00cm	ZDLT1-11-2013 L_{M50}=64.06cm

Figure 20: *Bathyraja griseocauda* maturity ogives for two surveys.

Specimens were generally found between 150-450m, although a few individuals were found down to 650m. The species increased in size with increasing depth, but sizes varied widely at all depth strata. Frequency and size of males and females varied similarly at all depths (Figure 21).

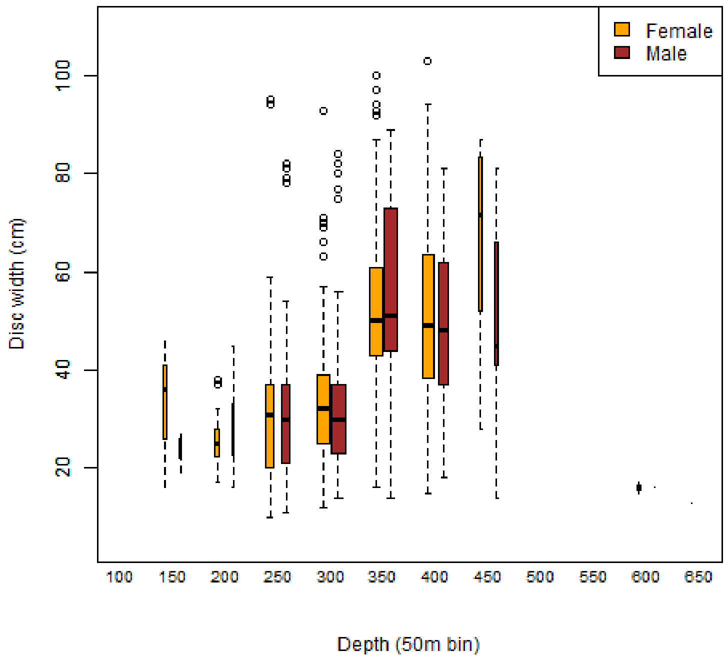


Figure 21: Box and whisker plot of disc width (cm) at 50m depth bins for *Bathyraja griseocauda*. Width of box is proportional to sample size (n). Data from all regions are pooled.

3.2.1.4 *Dipturus (Zearaja) chilensis*

A total of 2,015kg was caught in 38 of the 67 stations, comprising 10% of the skate catch. Catches occurred within the depth range 140-409m, with highest catch at a depth of 261m, but on the whole dominant in depth ranges 200-399m (Figure 22).

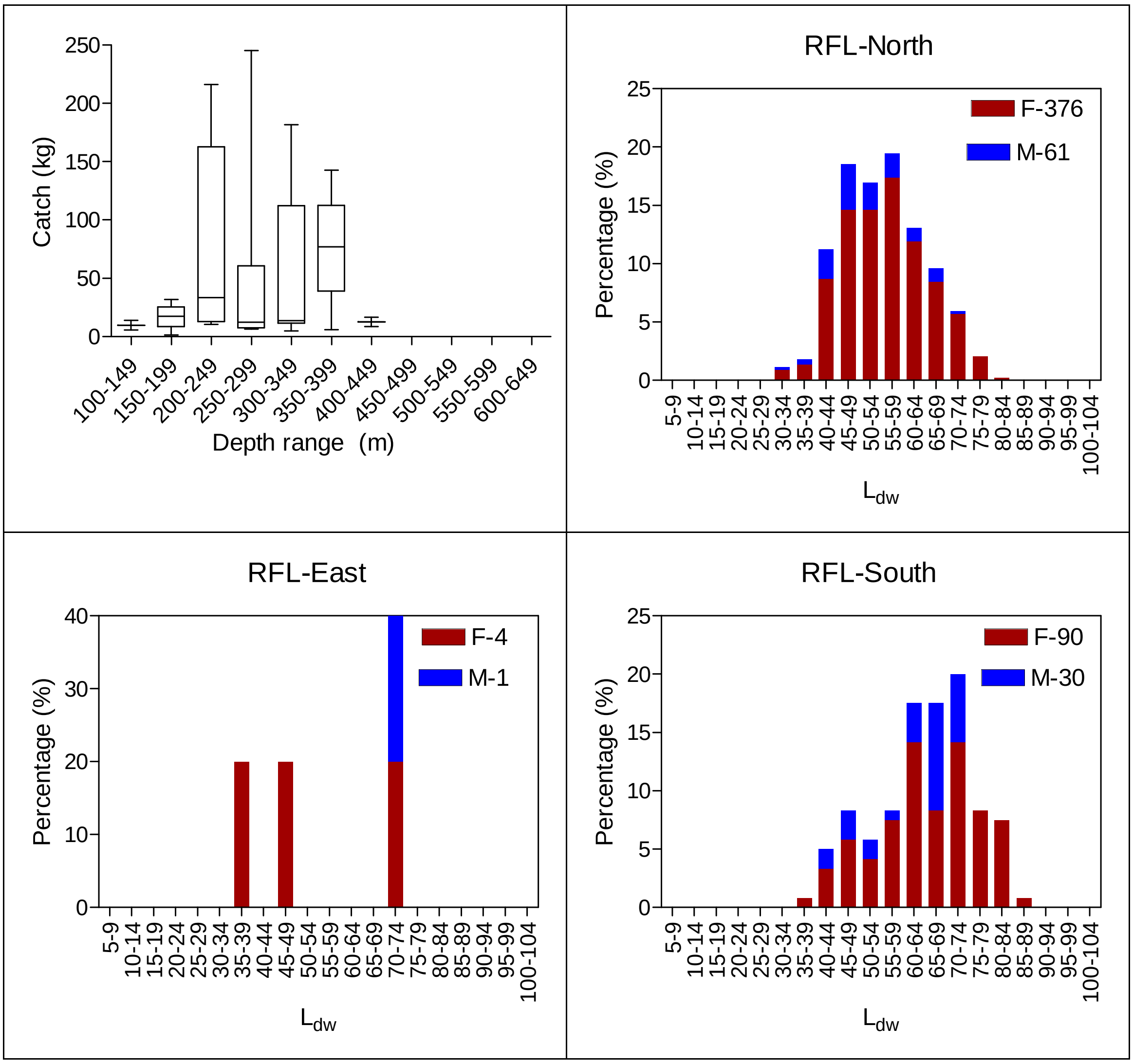
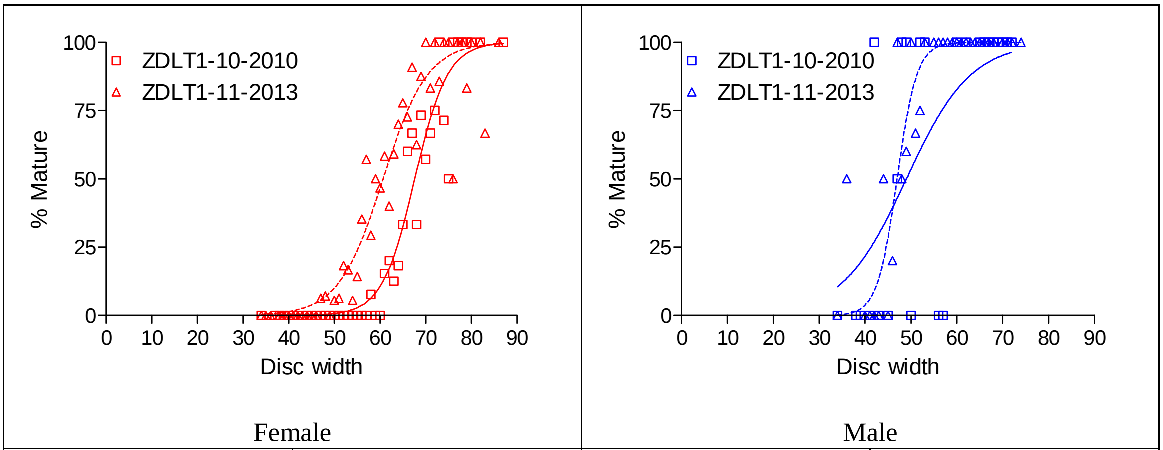


Figure 22: Depth range of catches and size frequency of *Dipturus (Zearaja) chilensis* by region.

Disc width ranged between 34cm and 86cm with a mean of 57.0cm (XF=57.5, XM 54.8). Besides these sampled specimens, a single 154L_{tl}/125L_{dw} undeveloped large female (female maturity stage 1) was caught in the East region at station 1226. Overall, the population revealed a strong (83.6%) female predominance, comparable to the strong female predominance of 89.4% in 2010. None of the 470 females were carrying egg capsules, and L_{dw} at 50% maturity was 60.72cm, a decrease from 67.65cm in 2010 (Figure 23). The low proportion of males, as well as the absence of females with capsules, would suggest that this species' presence in the fished regions is migratory, and possibly part of their reproductive strategy.



ZDLT1-10-2010	ZDLT1-11-2013	ZDLT1-10-2010	ZDLT1-11-2013
L_{M50}=67.65cm	L_{M50}=60.72cm	L_{M50}=49.03cm	L_{M50}=47.03cm

Figure 23: *Dipturus (Zearaja) chilensis* maturity ogives for two surveys.

Specimens were found between 150-400m. There is an apparent increase in size with increasing depth however sizes varied widely at all depths. Females were relatively more abundant at greater depths (Figure 24).

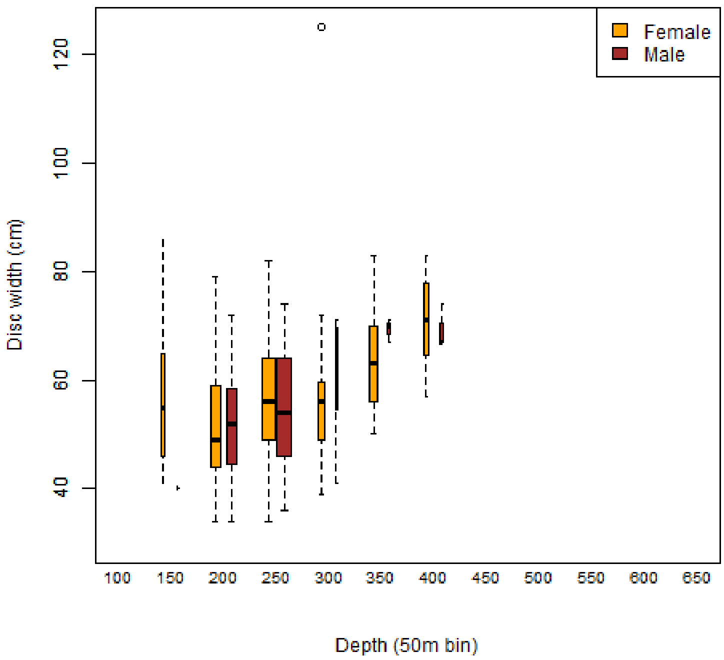


Figure 24: Box and whisker plot of disc width (cm) at 50m depth bins for *Dipturus (Zearaja) chilensis*. Width of box is proportional to sample size (n). Data from all regions are pooled.

3.2.1.5 *Bathyraja scaphiops*

A total of 1,449kg was caught in 59 of the 67 stations, comprising 7.2% of the skate catch. Catches occurred within the depth range 114-640m, with highest catch at a depth of 325m, but on the whole widely distributed in a number of depth ranges (Figure 25).

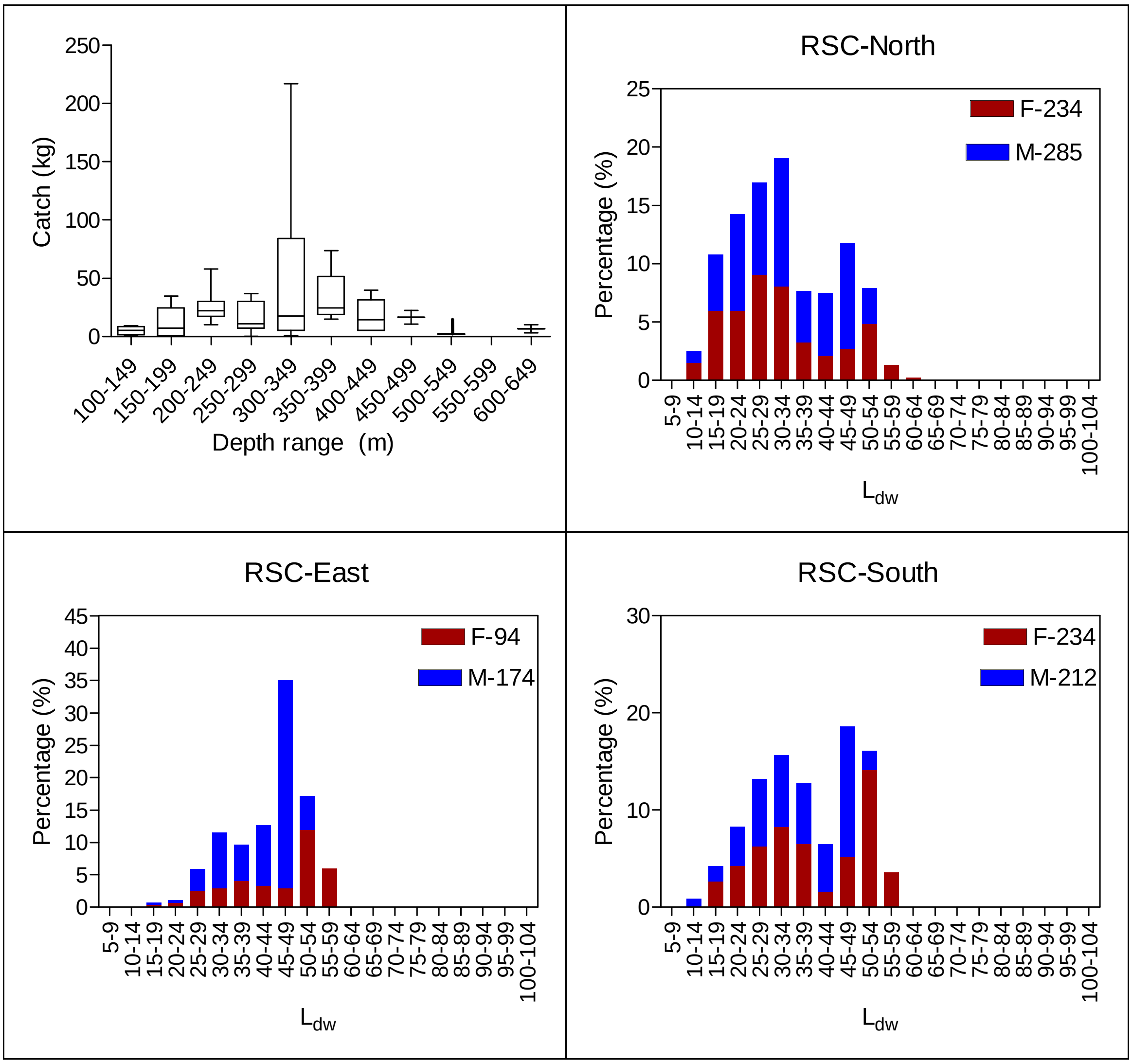
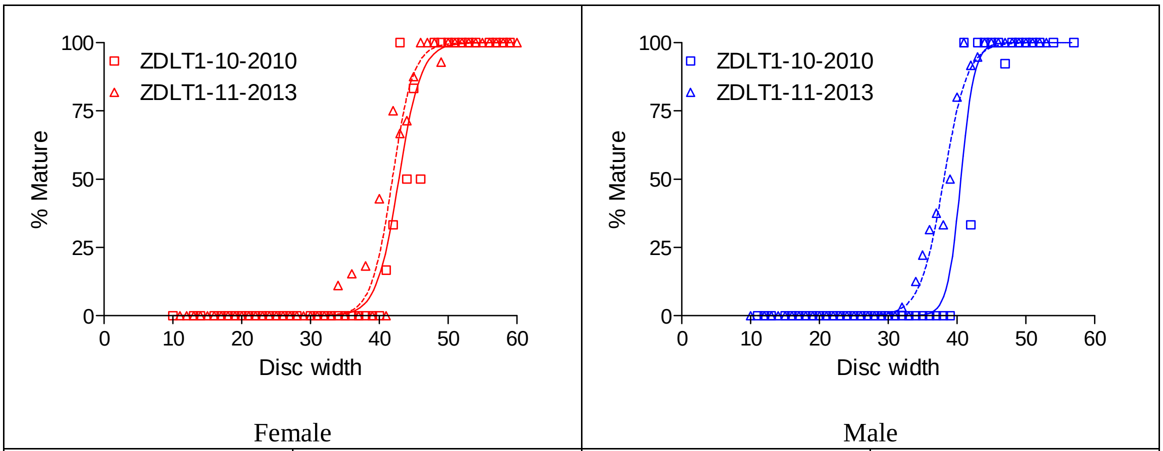


Figure 25: Depth range of catches and size frequency of *Bathyraja scaphiops* by region.

Disc width ranged between 10cm and 60cm with a mean of 36.8 (XF=37.1, XM 36.5). Overall, the population revealed a slight (54.2%) male predominance. 36 of the 229 females above the L_{dw} at 50% maturity of 41.9cm were carrying egg capsules (15.7%). No significant difference in L_{dw} at 50% maturity between 2010 and this survey.



ZDLT1-10-2010	ZDLT1-11-2013	ZDLT1-10-2010	ZDLT1-11-2013
L_{M50}=42.86cm	L_{M50}=41.93cm	L_{M50}=40.58cm	L_{M50}=38.12cm

Figure 26: *Bathyraja scaphiops* maturity ogives for two surveys.

Specimens were found between 150-650m, but most frequently found down to 400m. Size ranged widely at all depths. Male and female size and frequency varied in similar ways throughout their depth range (Figure 27).

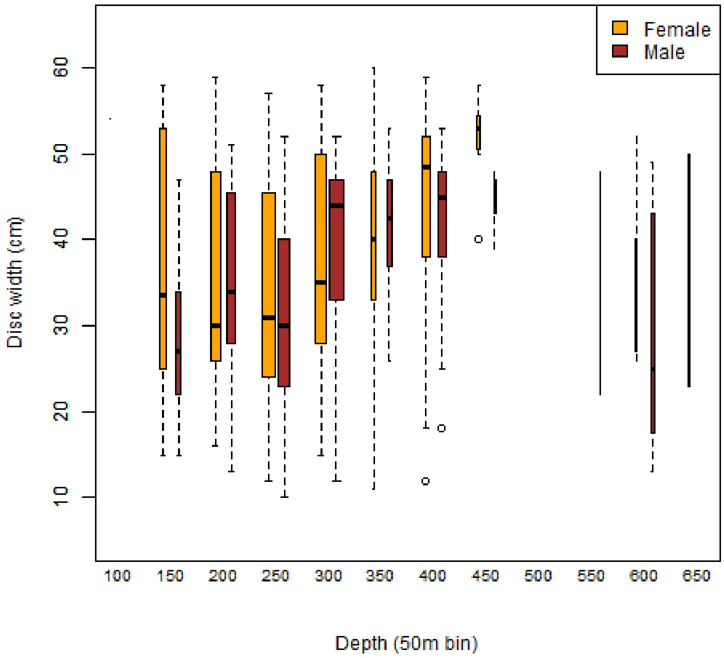


Figure 27: Box and whisker plot of disc width (cm) at 50m depth bins for *Bathyraja scaphiops*. Width of box is proportional to sample size (n). Data from all regions are pooled.

3.2.1.6 *Bathyraja macloviana*

A total of 978kg was caught in 51 of the 67 stations, comprising 4.9% of the skate catch. Catches occurred within the depth range 103-463m, with highest catches at depths of 277 and 305m, but most dominant in the depth range 250-299m (Figure 28).

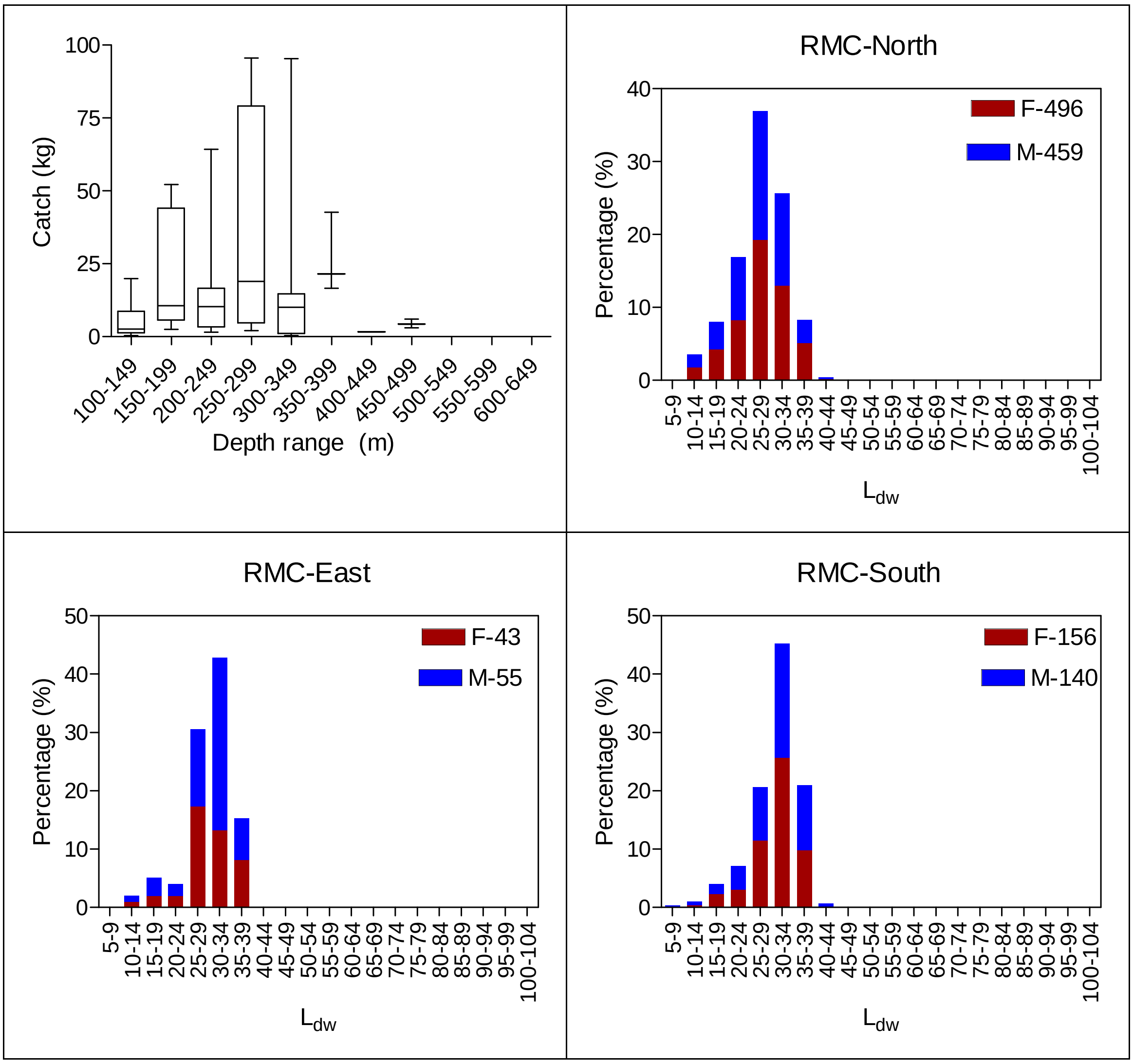
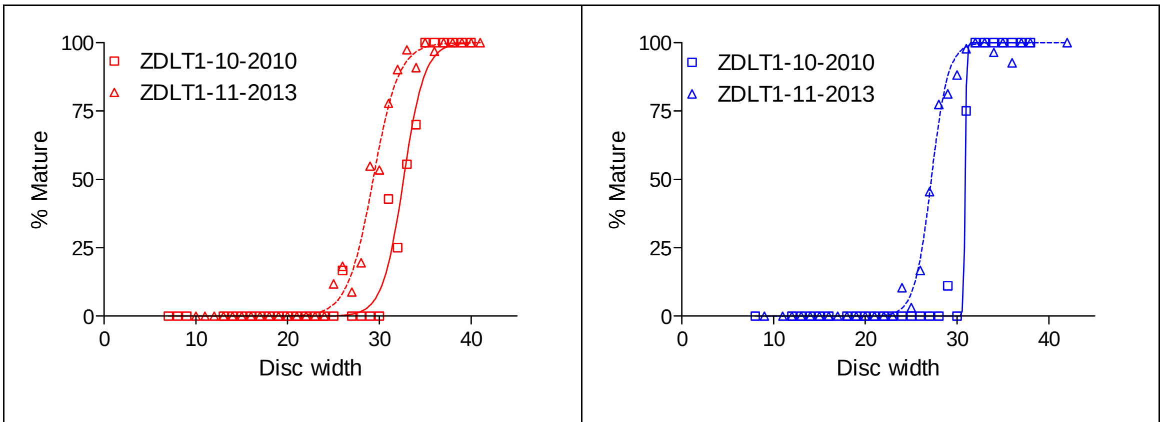


Figure 28: Depth range of catches and size frequency of *Bathyraja macloviana* by region.

Disc width ranged between 9 and 42cm with a mean of 27.9cm (XF=28.0, XM=27.8). Overall, the population revealed a slight female predominance (51.8%). 16 females carrying egg cases were caught, 5.2% of females above the L_{dw} at 50% maturity of 29.35cm, a decrease from 32.65cm in 2010 (Figure 29).



Female		Male	
ZDLT1-10-2010	ZDLT1-11-2013	ZDLT1-10-2010	ZDLT1-11-2013
L_{M50}=32.65cm	L_{M50}=29.35cm	L_{M50}=30.91cm	L_{M50}=27.22cm

Figure 29: *Bathyraja macloviana* maturity ogives for two surveys.

Specimens were found between 100-450m, and were most frequent between 150-350m. Size ranged widely at all depths. Size and frequency of males and females varied similarly throughout their depth range (Figure 30).

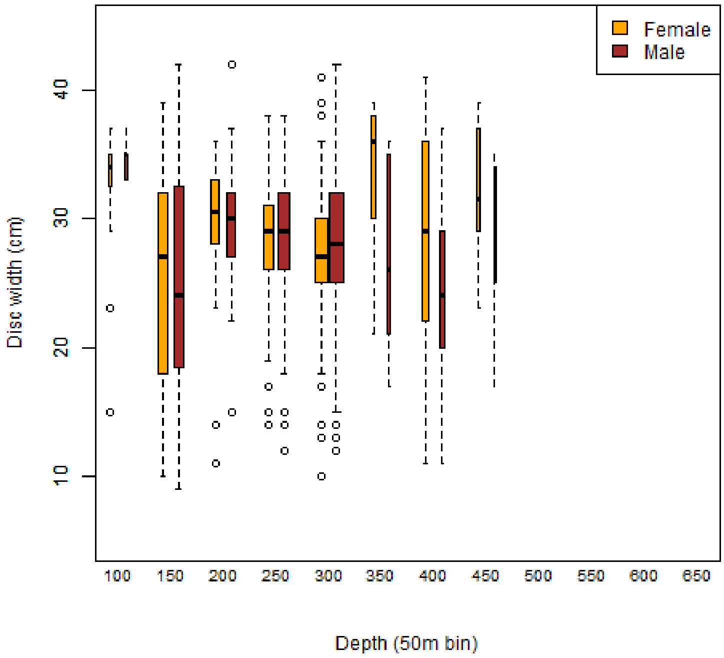


Figure 30: Box and whisker plot of disc width (cm) at 50m depth bins for *Bathyraja macloviana*. Width of box is proportional to sample size (n). Data from all regions are pooled.

3.2.1.7 *Bathyraja cousseauae*

A total of 797kg was caught in 49 of the 67 stations, comprising 4.0% of the skate catch. Catches occurred within the depth range 140-640m, with highest catch at a depth of 377m, and on the whole most dominant in the 250-399m depth ranges (Figure 31).

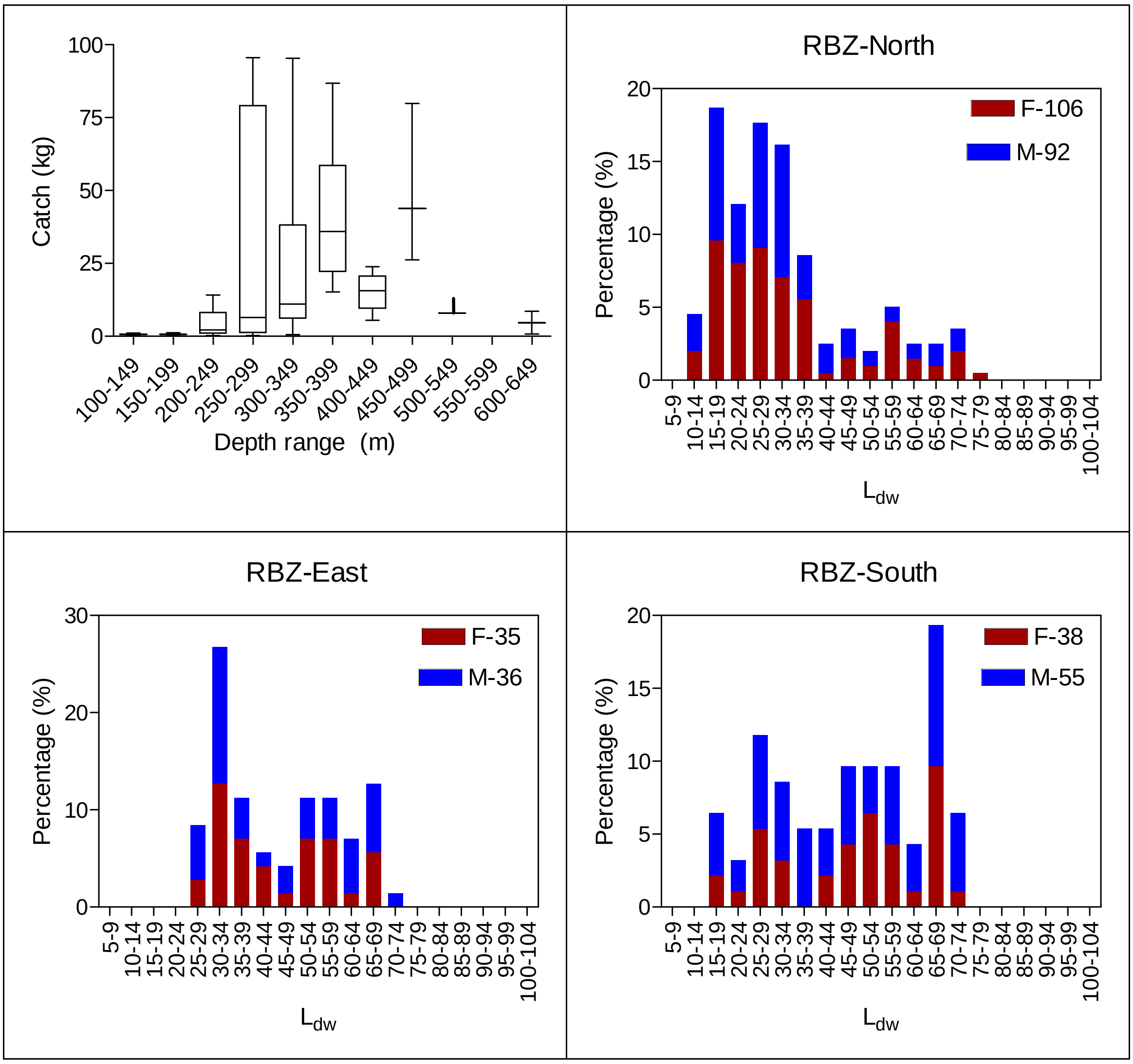
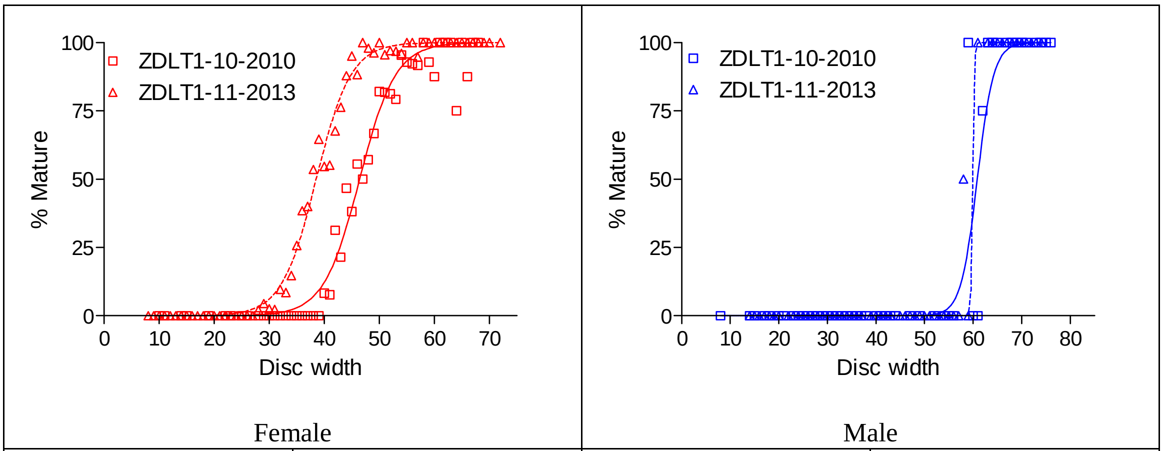


Figure 31: Depth range of catches and size frequency of *Bathyraja cousseauae* by region.

Disc width ranged between 13cm and 77cm with a mean of 38.8cm (XF=38.7, XM 39.0. Overall, the population revealed a slight (50.5%) male predominance. One of the 26 females above the L_{dw} at 50% maturity of 60.30m, decrease from 66.5cm in 2010 (Figure 32), was carrying egg capsules (3.8%).



Female		Male	
ZDLT1-10-2010 L_{M50}=66.56cm	ZDLT1-11-2013 L_{M50}=60.30cm	ZDLT1-10-2010 L_{M50}=60.87cm	ZDLT1-11-2013 L_{M50}=59.95

Figure 32: *Bathyraja cousseauae* maturity ogives for two surveys.

Specimens were generally found between 150-450m, with three individuals found down to 650m. Size of RBZ increased dramatically between 300-350m however, sizes spanned the entire size range even in deeper water. Female and male size range and frequency of occurrence varied similarly throughout their depth range (Figure 33).

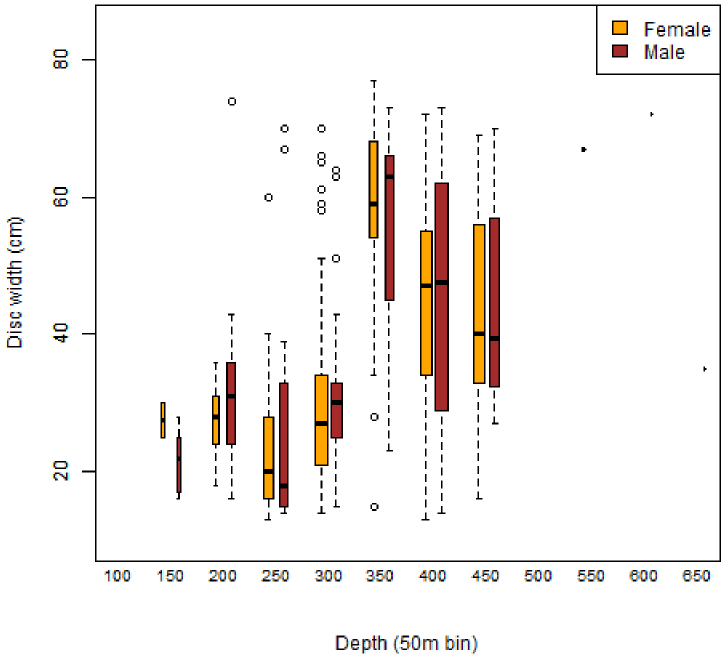


Figure 33: Box and whisker plot of disc width (cm) at 50m depth bins for *Bathyraja cousseauae*. Width of box is proportional to sample size (n). Data from all regions are pooled.

3.2.1.8 *Amblyraja doellojuradoi*

A total of 517kg was caught in 38 of the 67 stations, comprising 2.6% of the skate catch. Catches occurred within the depth range 170-640m, with highest catch at a depth of 287m, but on the whole occurring at modest levels across depth ranges 200-399m (Figure 34).

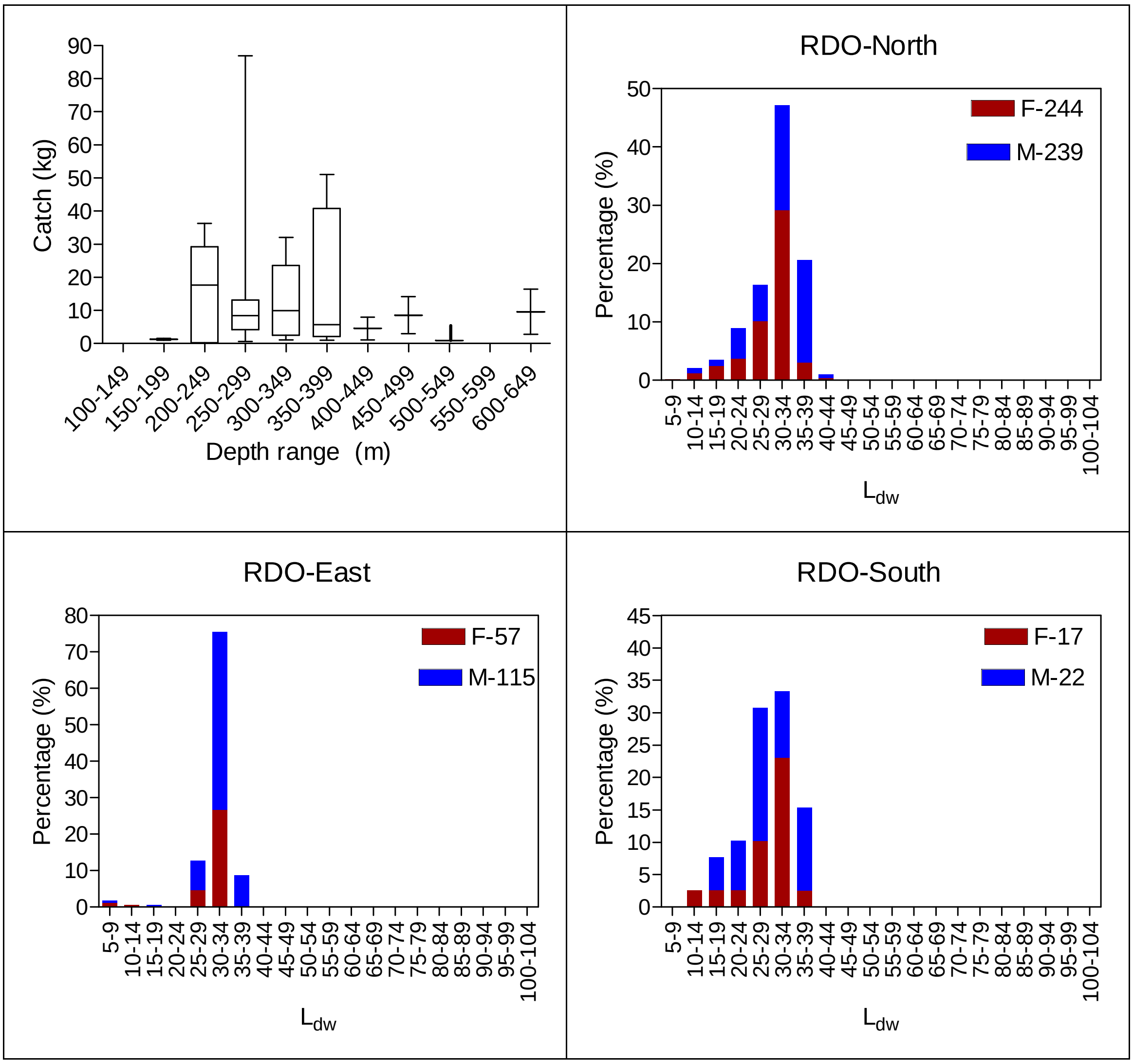
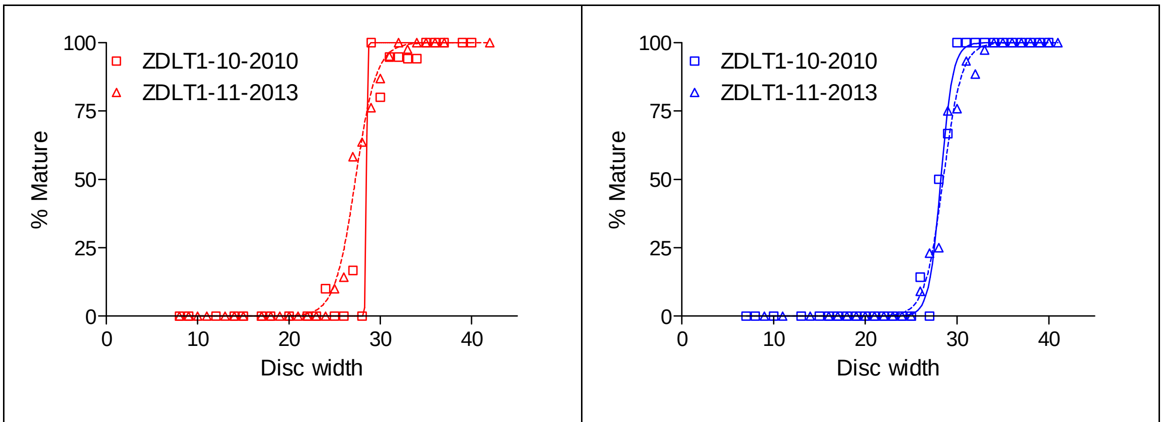


Figure 34: Depth range of catches and size frequency of *Amblyraja doellojuradoi* by region.

Disc width ranged between 8 and 42cm with a mean of 30.4cm (XF=29.4, XM=31.2). Overall, the population revealed a slight male predominance (54.2%). 29 females carrying egg cases were caught, 11.8% of females above the L_{dw} at 50% maturity of 27.31cm, a minor decrease from 28.50cm in 2010 (Figure 35).



Female		Male	
ZDLT1-10-2010	ZDLT1-11-2013	ZDLT1-10-2010	ZDLT1-11-2013
L_{M50}=28.50cm	L_{M50}=27.31cm	L_{M50}=28.26cm	L_{M50}=28.52

Figure 35: *Amblyraja doellojuradoi* maturity ogives for two surveys.

Specimens were found between 150-650m. Smaller individuals were found in shallow depths however, size ranged widely throughout all depth strata. Size and frequency of males and females varied in similar ways throughout their depth range (Figure 36).

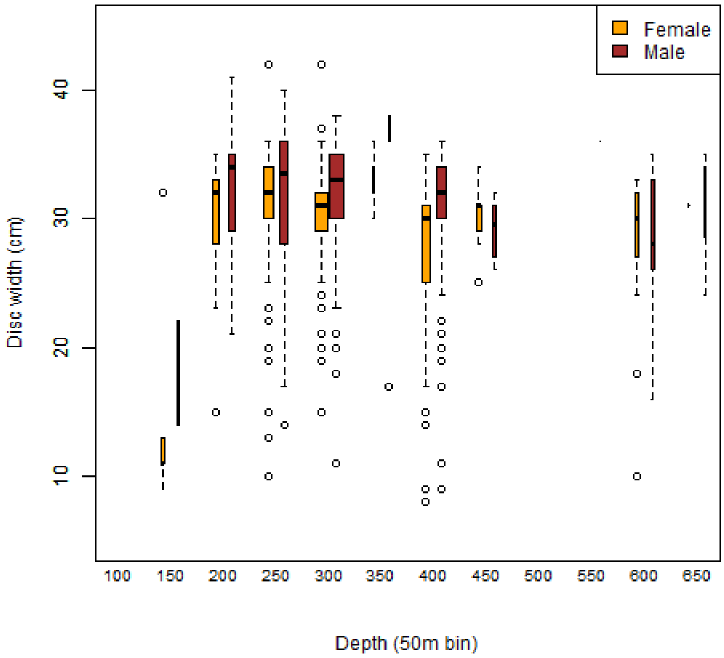


Figure 36: Box and whisker plot of disc width (cm) at 50m depth bins for *Amblyraja doellojuradoi*. Width of box is proportional to sample size (n). Data from all regions are pooled.

3.2.1.9 *Bathyraja multispinis*

A total of 336kg was caught in 28 of the 67 stations, comprising 1.7% of the skate catch. Catches occurred within the depth range 170-463m, with highest catch at a depth of 277m, but on the whole modest catches in the 250-399m depth ranges (Figure 37).

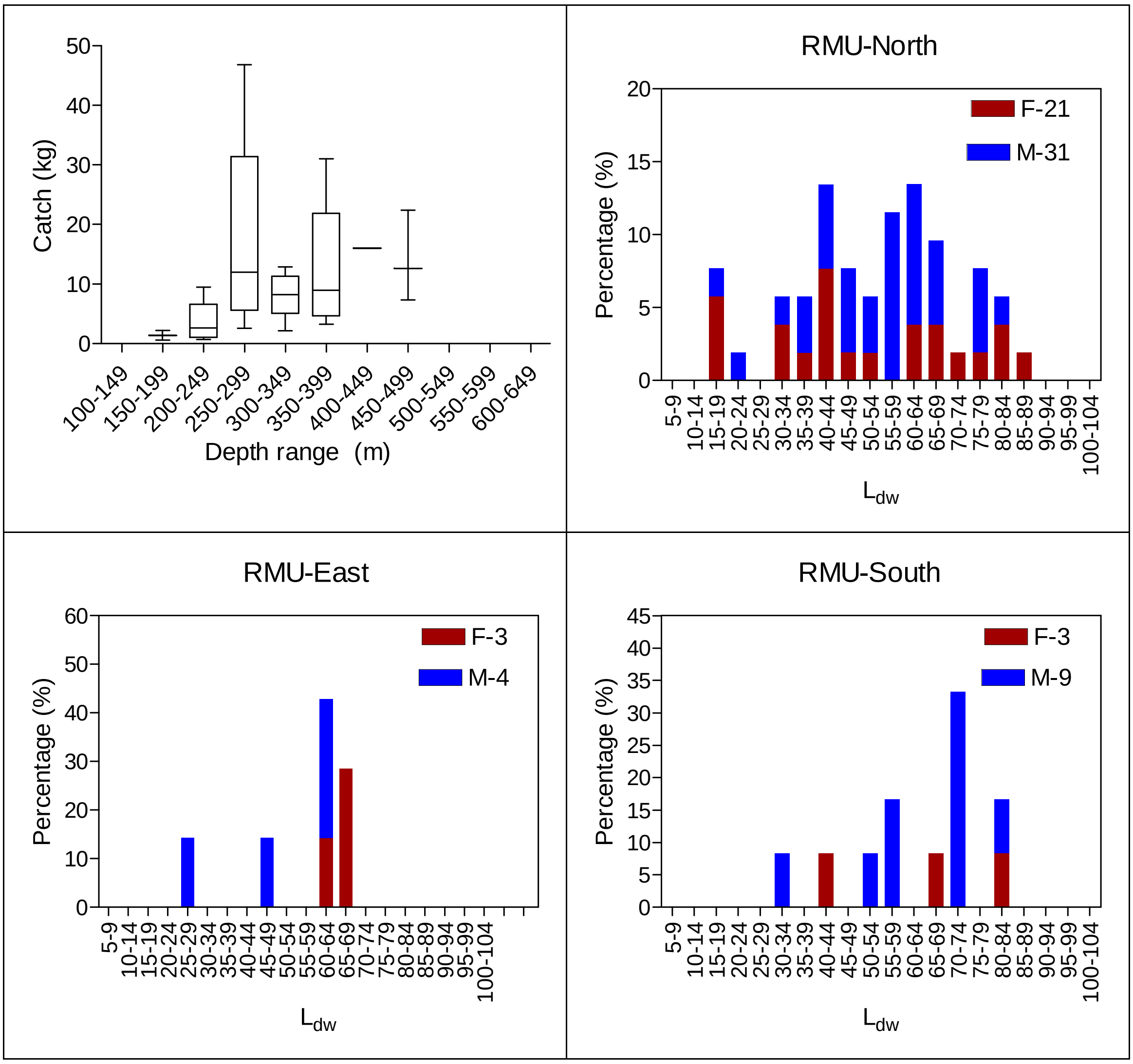
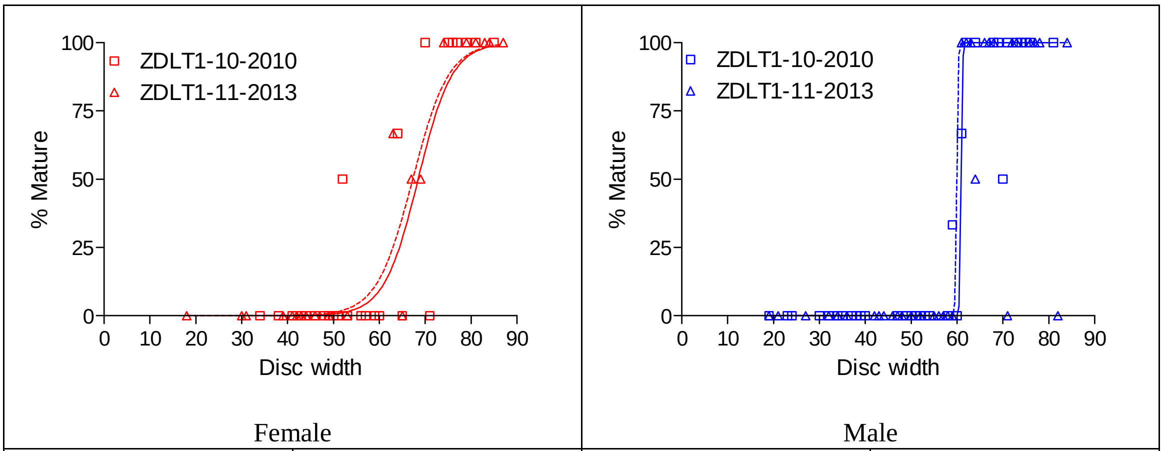


Figure 37: Depth range of catches and size frequency of *Bathyraja multispinis* by region.

Disc width ranged between 18 and 87cm with a mean of 55.2cm (XF=54.5, XM=55.6). Overall, the population revealed a male predominance (61.3%), but sample numbers were low. No females carrying egg cases were caught, and the L_{dw} at 50% maturity was 67.3cm, a very small decrease from 68.48cm in 2010 (Figure 38).



ZDLT1-10-2010	ZDLT1-11-2013	ZDLT1-10-2010	ZDLT1-11-2013
L_{M50}=68.48cm	L_{M50}=67.33cm	L_{M50}=60.90cm	L_{M50}=60.00cm

Figure 38: *Bathyraja multispinis* maturity ogives for two surveys.

Specimens were generally found between 200-450m. Size varied widely throughout all depth strata. There appeared to be some size differentiation between males and females at greater depths, however there does not seem to be a consistent trend (Figure 39).

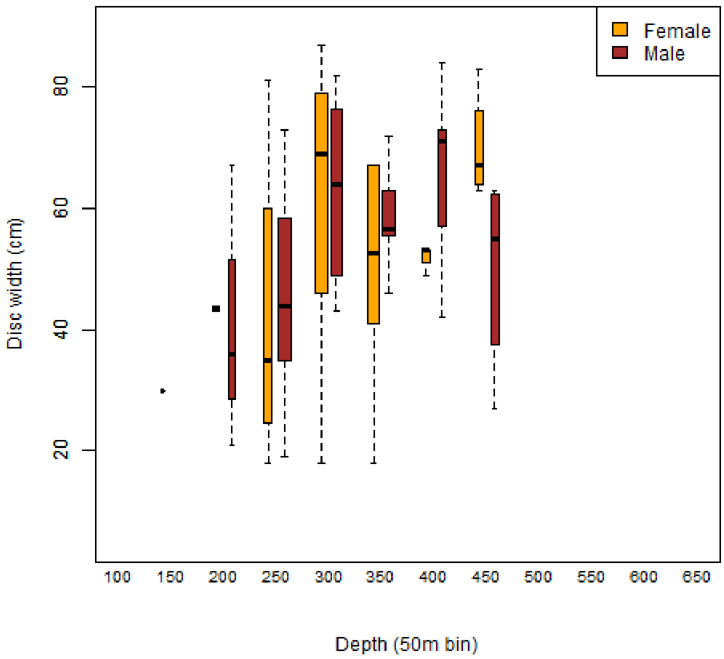


Figure 39: Box and whisker plot of disc width (cm) at 50m depth bins for *Bathyraja multispinis*. Width of box is proportional to sample size (n). Data from all regions are pooled.

3.2.1.10 *Psammobatis spp.*

A total of 329kg was caught, comprising 1.6% of the skate catch in 17 of the 67 stations. Catches occurred within the depth range 103-232m, with highest catch at a depth of 156m, but on the whole occurring at low levels across a relatively narrow depth range 100-249m (Figure 40).

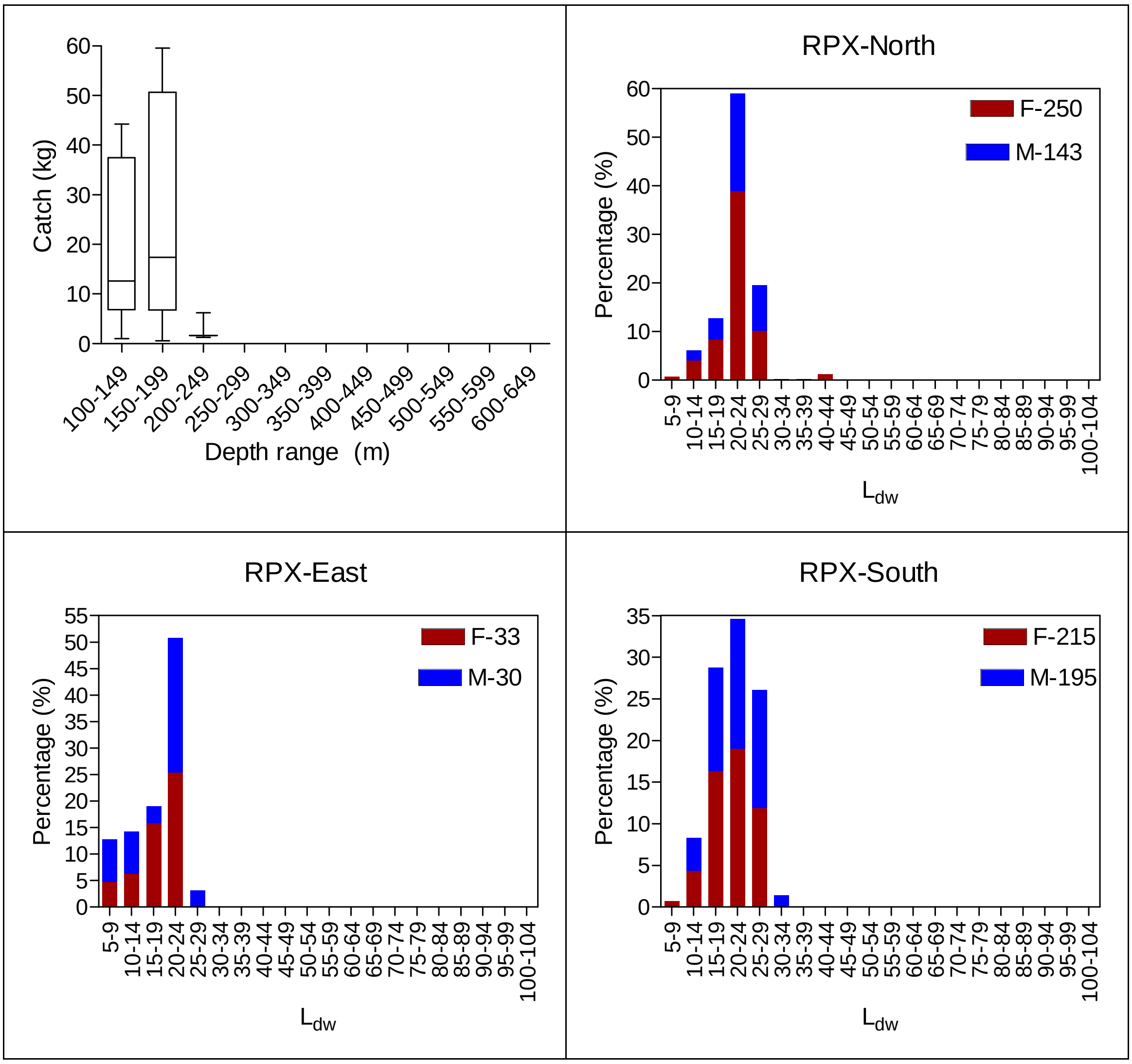
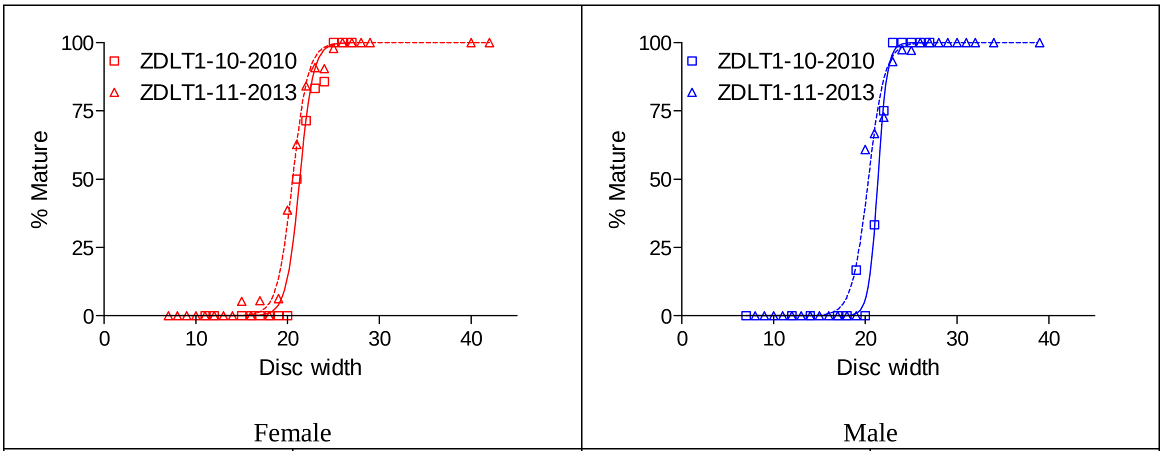


Figure 40: Depth range of catches and size frequency of *Psammobatis spp.* by region.

Disc width ranged between 7 and 42cm with a mean of 21.3cm (XF=21.0, XM=21.7). Overall, the population revealed a female predominance (57.5%). 40 females carrying egg cases were caught, 12.9% of the females above the L_{dw} at 50% maturity of 20.58cm, marginally smaller than 21.34cm in 2010 (Figure 41).



Female		Male	
ZDLT1-10-2010 L_{M50}=21.34cm	ZDLT1-11-2013 L_{M50}=20.58cm	ZDLT1-10-2010 L_{M50}=21.39cm	ZDLT1-11-2013 L_{M50}=20.36cm

Figure 41: *Psammobatis spp.* maturity ogives for two surveys.

Specimens were generally found between 100-150m, with a few individuals found down to 250m. Size varied particularly widely at around 150m depth with the smallest and largest individuals occurring at this stratum. Male and female frequency varied in similar ways throughout their depth range (Figure 42).

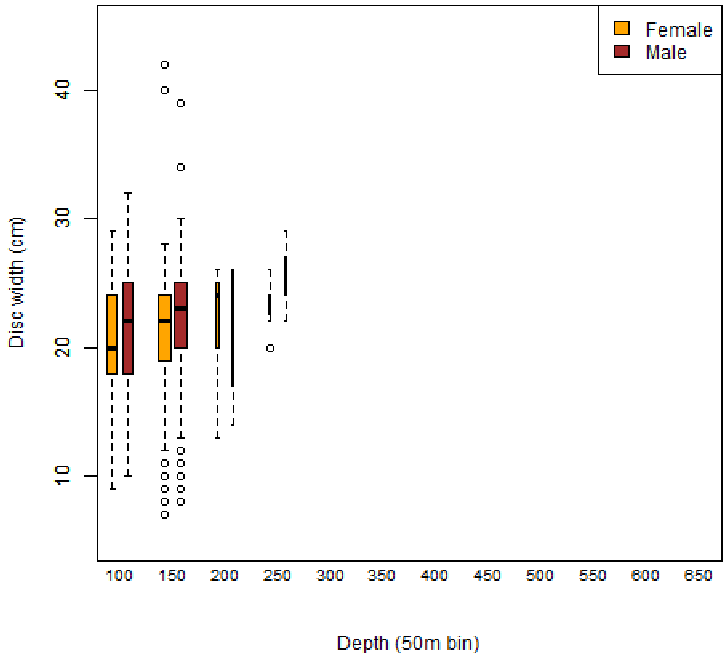


Figure 42: Box and whisker plot of disc width (cm) at 50m depth bins for *Psammobatis spp.*. Width of box is proportional to sample size (n). Data from all regions are pooled.

3.2.1.11 *Dipturus argentinensis*

A total of 100kg was caught in 10 of the 67 stations, but only in the North region, comprising 0.5% of the skate catch. Catches occurred within the depth range 277-393m, with highest catch at a depth of 304m, but on the whole occurring at low levels across a relatively narrow depth range 250-399m peaking in 300-349m (Figure 43).

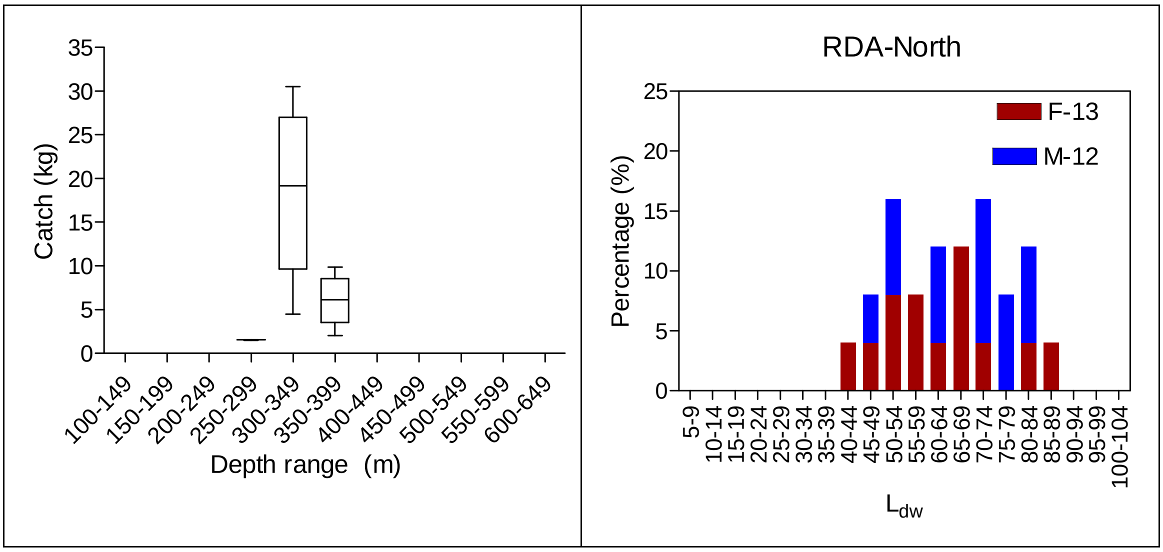


Figure 43: Depth range of catches and size frequency of *Dipturus argentinensis.* North region only

Disc width ranged between 44 and 88cm with a mean of 64.9cm (XF=62.7, XM=66.9). No females carrying egg cases were caught, and no L_{dw} at 50% maturity could be established, as all specimens were in maturity stages I or II.

Specimens were found between 300-400m. Size of males showed some depth structure, showing decreasing size with increasing depth. Males were more frequent through their range (Figure 44).

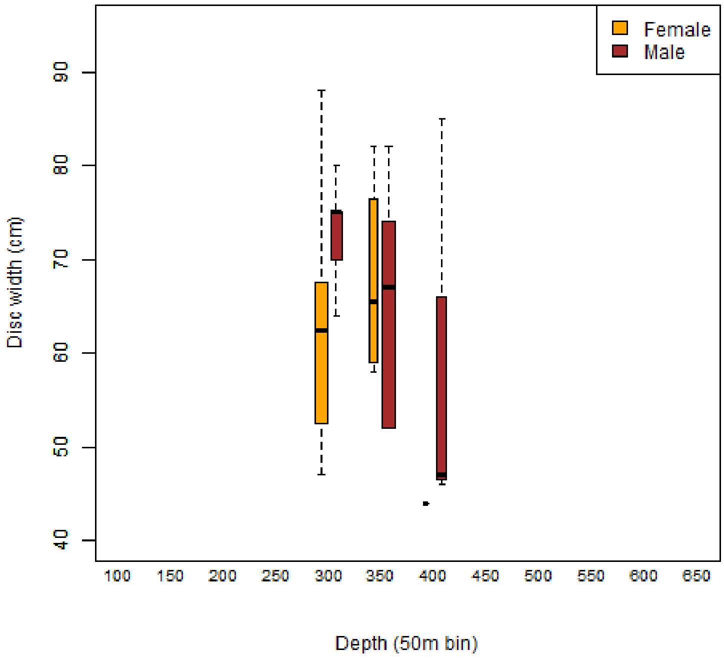


Figure 44: Box and whisker plot of disc width (cm) at 50m depth bins for *Dipturus argentinensis*. Width of box is proportional to sample size (n). Data from all regions are pooled.

3.2.1.12 *Dipturus trachydermus*

One immature male specimen, 136cm TL, 99cm DW and weighing 14.7kg was caught at station 1213 at a depth of 304m.

3.2.2 Skate community and abundance

Distributions (occurrence) and catch of skate catches are summarised in Table 6. Figure 45 shows that six species were distributed widely throughout all surveyed regions (RAL, RBR, RBZ, RFL, RMC, RSC). Some species showed more patchy distributions within their distributional range (e.g. RDO, RGR, RMU, RPX). Two species showed relatively restricted distributions; RMG was restricted to eastern and southern regions, and RDA was only found in the northern regions.

Table 6. Occurrence, mean catch (raw data) and range in catch of skate species.

Species	Code	No. of stations caught	Mean catch	Min catch	Max catch
Bathyraja albomaculata	RAL	53	62.34	0.03	220.86
Bathyraja brachyurops	RBR	52	144.91	4.53	996.58
Bathyraja cousseauae	RBZ	45	17.01	0.09	86.79
Dipturus argentinensis	RDA	9	10.06	1.48	30.50
Amblyraja doellojuradoi	RDO	36	14.24	0.12	86.90
Zearaja chilensis	RFL	37	53.79	1.39	245.33
Bathyraja griseocauda	RGR	43	57.81	0.31	350.36
Bathyraja macloviana	RMC	51	18.75	0.28	95.52
Bathyraja magellanica	RMG	9	7.97	0.14	18.97
Bathyraja multispinis	RMU	28	11.59	0.55	46.80
Psammobatis spp.	RPX	18	18.26	0.59	59.59
Bathyraja scaphiops	RSC	55	25.53	0.28	217.03
Dipturus trachydermus	RTR	1	14.69	14.69	14.69

A comparison of catch results from the 2010 survey to the current survey (adjusted by 1.69 conversion) for the northern region shows that mean catch of skate species has either increased between 2010 and 2013 (RAL, RBR, RDO, RFL, RMC, RPX), decreased (RBZ, RGR, RMU, RTR) or remained similar (RDA, RSC) (Figure 46)

Differences in catch proportion of each skate species between the 2010 and 2013 surveys showed similar patterns to catch (Figure 46). Interestingly, catch proportion of RBR was roughly similar between surveys.

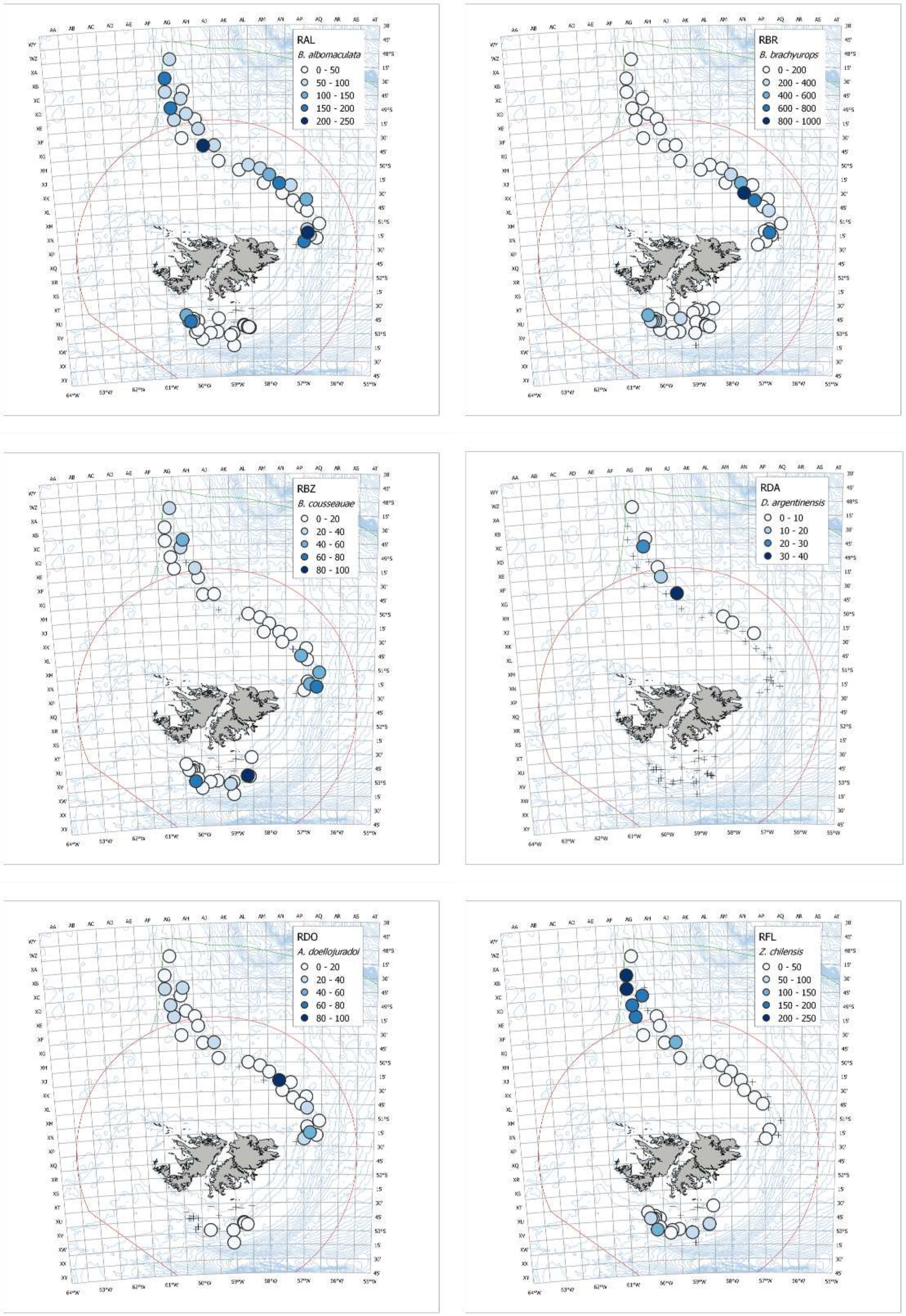


Figure 45. Distribution and CPUE (kg/hr) of skate species.

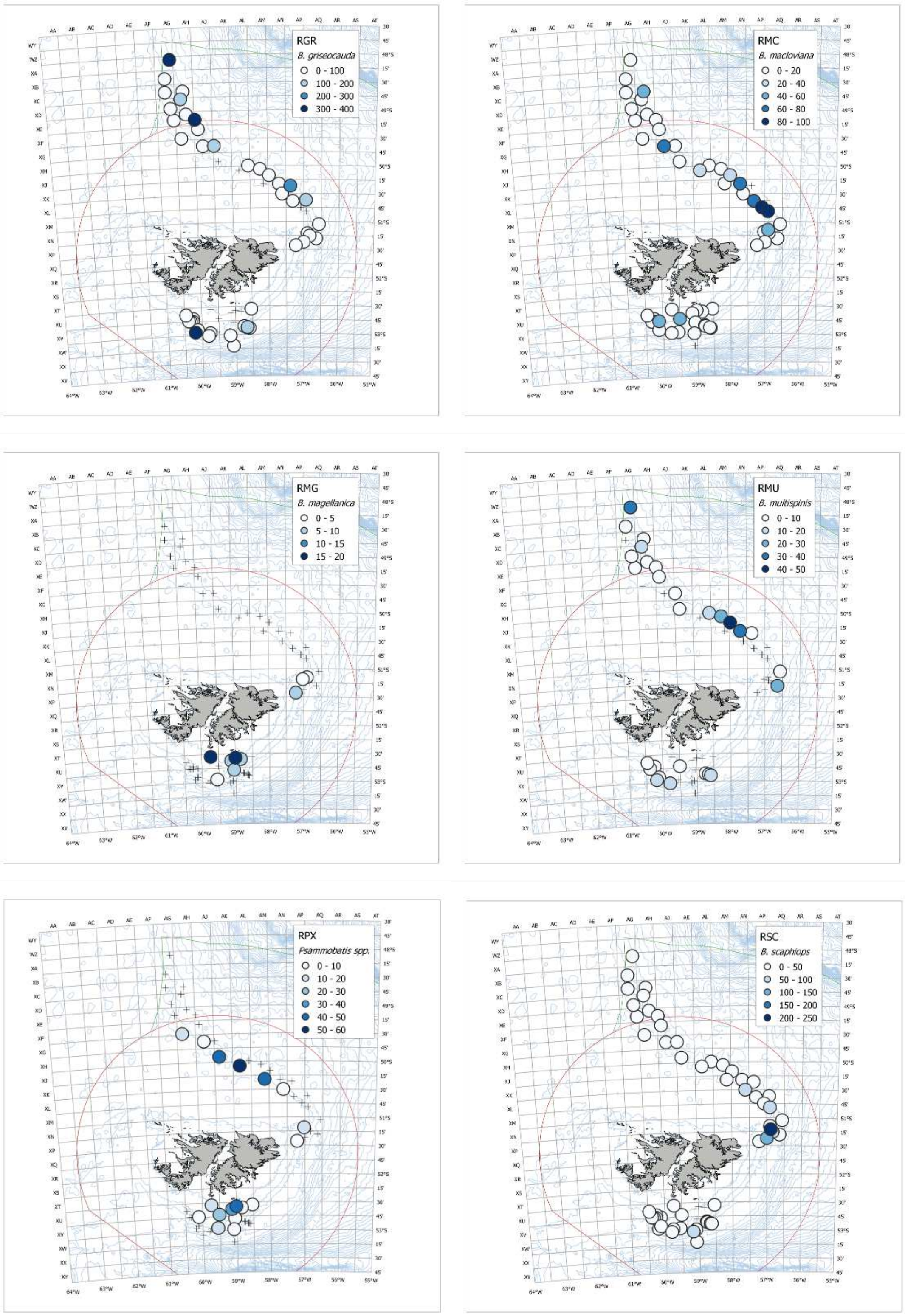


Figure 45 Continued

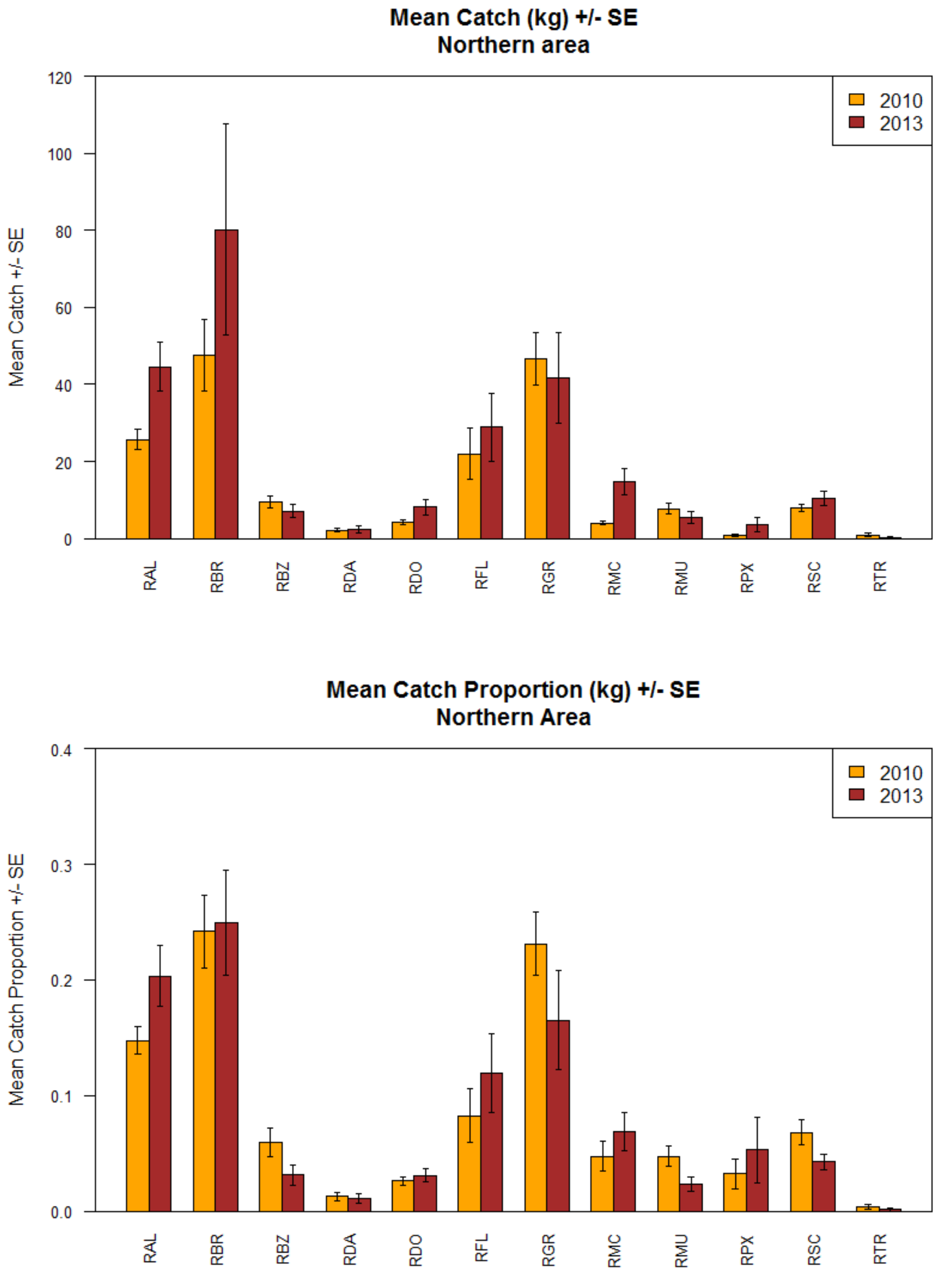


Figure 46: Comparison of catch between 2010 and 2013 surveys. Catch in 2013 is adjusted by 1.69. Top: Mean (+/- SE) catch of skate species. Bottom: Mean catch proportion (+/- SE) of skate species out of total skate catch.

Partial redundancy analysis shows that community composition in the northern regions changed between the 2010 and 2013 surveys (Figure 47). Stations, as represented in multivariate space, are grouped by YEAR in terms of their relative skate species composition and abundance. YEAR groupings are significantly different (MANOVA; $p < 0.001$) (Legendre & Legendre 1998). This difference in skate community between 2010 and 2013 is evident despite any difference in the skate community that might be attributed to either DEPTH or LOCATION.

The pure effects of DEPTH, LOCATION (Lat/Lon), and YEAR components of variation were significant (Table 7). In the overall analysis, Depth explained 12.1% of the constrained variation in skate composition and abundance between stations, Location accounted for 10.4% of the constrained variation, and Year accounted for 2.8% of constrained variation.

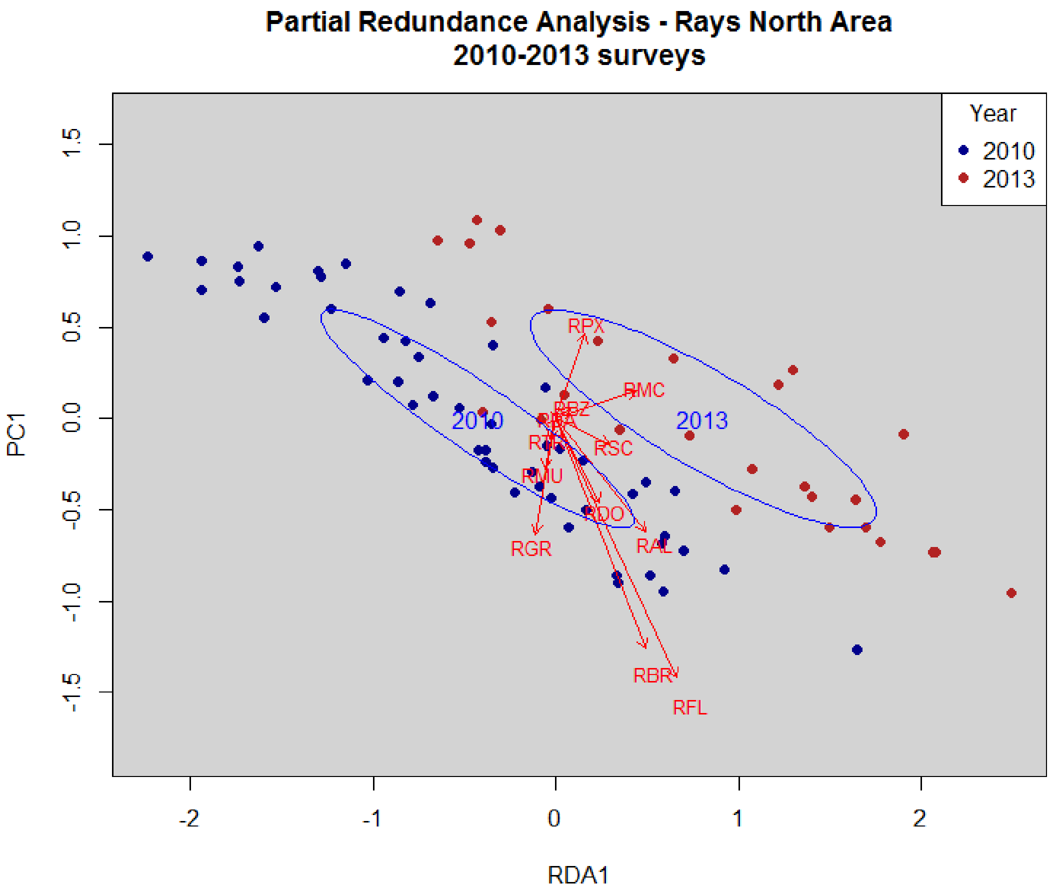


Figure 47: Partial redundancy analysis of skate community composition in the northern region for 2012 and 2013 surveys. Ellipsoids are the standard deviation around the "Year" centroid. Arrows are species vectors indication species characteristics of each station.

Table 7: Summary of partial redundancy analysis. Partitions shown are the pure effects of Depth, Location (Lat/Lon) and Year.

Partition	df	Adj R-square	F	Pr (>F)
Depth only	1	0.121	14.399	0.005
Year only	1	0.054	7.199	0.005
Location only	2	0.096	6.596	0.005

3.2.3 Invertebrate by-catch

A total of 17,646kg of invertebrate by-catch was recorded (excluding bad trawls). Highest invertebrate catches were generally in the shallower depths of the southern survey region (Figure 48). However, there were two particularly large catches of sponge in the northern survey region.

The inventory of invertebrate taxa is listed in Table 8. Asteroids (starfish) were the most speciose group, followed by the Crustacea (crabs), and Anthozoa (corals). A total of 33 species were found in all three surveyed regions, 13 species share by at least two regions, and 26 species found in only 1 region.

Notably, one very large Paragorgia (bubble gum) coral was found weighing 156kg at station 1271 (Figure 49). This was not included in this analysis due the net being badly damaged for that station.

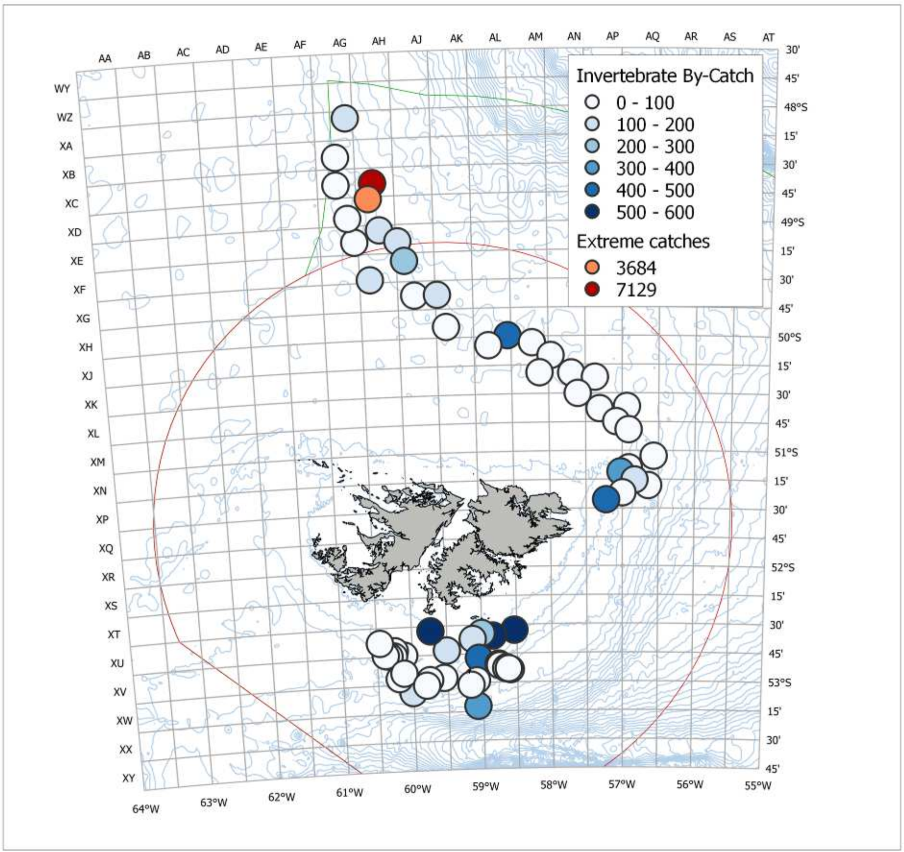


Figure 48 Invertebrate total catch (kg).

Figure 49: Paragorgia coral at station 1271

Table 8 Inventory of invertebrate by-catch and their occurrence in each survey region

Species		East	North	South
Porifera	Unidentified Porifera	+	+	+
Anthozoa	Alcyoniina	+	+	+
	Anthoptilum grandiflorum	+	-	+
	Desmophyllum dianthus	-	-	+
	Enallopsammia sp.	-	+	-
	Flabellum spp.	+	+	+
	Isidiidae	-	+	-
	Mirostenella sp.	-	-	+
	Pennatulacea	-	-	+
	Thouarellinae	+	+	+
	Unidentified Anemone	+	+	+
	Unidentified Primnoellinae 1	-	-	+
	Unidentified Primnoellinae 2	-	+	+
Hydrozoa	Unidentified Hydrozoa 1	+	-	+
	Unidentified Hydrozoa 2	-	+	+
Polychaeta	Unidentified Polychaeta	+	+	+
Pycnogonida	Unidentified Pycnogonida	+	+	+
Crustacea	*Acanthoserolis schythei*	-	-	+
	Eurypodius latreillei	+	+	+
	Eurypodius longirostris	+	+	+
	Isopoda	-	+	-
	Libidoclaea granaria	-	-	+
	Munida gregaria	-	+	-
	Munida spp.	-	+	-
	Munida subrugosa	-	+	-
	Paguroidea	-	+	+
	Pagurus comptus	-	+	-
	Peltarion spinosulum	+	+	+
	Stereomastis suhmi	-	-	+
	Thymops birsteini	+	+	+
Bivalvia	*Limopsis marionensis*	-	+	-
	Zygochlamys patagonica	-	+	+
Gastropoda	*Nuttallochiton hyadesi*	-	-	+
	Adelomelon ancilla	+	+	+
	Bathydomus longisetosus	+	+	+
	Fusitriton m. magellanicus	+	+	+
	Odontocymbiola magellanica	+	+	+
Nudibranchia	Unidentified Nudibranchia	-	+	+
Solenogastre	*Neomena herwigi*	-	+	+
Cephalopoda	*Muusoctopus eureka*	-	+	+
	Muusoctopus longibrachus akambei	+	+	+
	Neorossia caroli	-	+	-
	Octopus megalocyathus	-	-	+
	Octopus spp.	-	+	-
Brachiopoda	*Magellania venosa*	+	+	+
	Terebratella dorsata	-	+	+

Table 8 continued.

Species		East	North	South
Asteroidea	*Anseropoda antarctica*	-	+	-
	Bathybiaster loripes	+	+	+
	Calyptraster sp.	+	+	+
	Ceramaster sp.	+	+	+
	Cosmasterias lurida	+	+	+
	Crossaster sp.	+	+	+
	Ctenodiscus australis	+	+	+
	Cycethra sp.	+	+	+
	Ganaria falklandica	+	-	+
	Henricia sp.	-	+	-
	Labidaster radiosus	+	+	+
	Lophaster stellans	-	+	-
	Odontaster pencillatus	+	-	+
	Porania antarctica	+	+	+
	Solaster regularis	-	+	+
	Unidentified Asteroidea	+	+	+
Ophiuroidea	Astrotoma agassizii	+	+	+
	Gorgonocephalas chilensis	+	+	+
	Ophiactis asperula	-	+	-
	Ophiuroglypha lymanii	-	-	+
	Unidentified Ophiuroidea	+	+	+
Bryozoa	Unidentified Bryoza	-	-	+
Echinoidea	*Austrocidaris canaliculata*	+	+	+
	Heart urchin	+	+	+
	Sterechinus agassizi	+	+	+
Holothuroidea	Unknown Holothuroidea	+	+	+
Crinoidea	Unidentified Crinodea	-	+	-
Ascidiacea	Unidentified Ascidiacea	+	+	+

3.2.4 Invertebrate diversity

The three survey regions varied significantly in their species richness (S) with the northern region having lower richness than eastern and southern regions (Figure 50). Shannon diversity (H') also varied significantly between regions, with the northern regions showing lower overall diversity (H'). All sites showed similar species Pielou's evenness (J'); that is, of the species present in each region, species' abundance was similarly distributed among species in the assemblage.

All surveyed regions can be characterised by their species composition and relative abundance. Non-metric multidimensional scaling analysis (Figure 51) shows that the northern region is particularly distinct from the southern and eastern regions. Southern and eastern regions appear to be similar in their community composition.

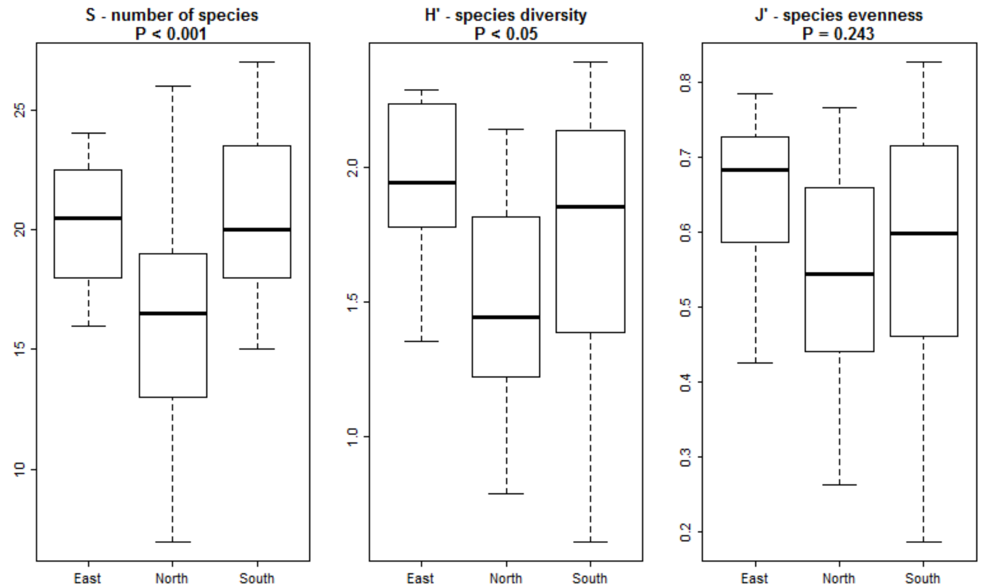


Figure 50 Box and whisker plots of diversity indices comparing three surveys regions. P-value is the significance after ANOVA.

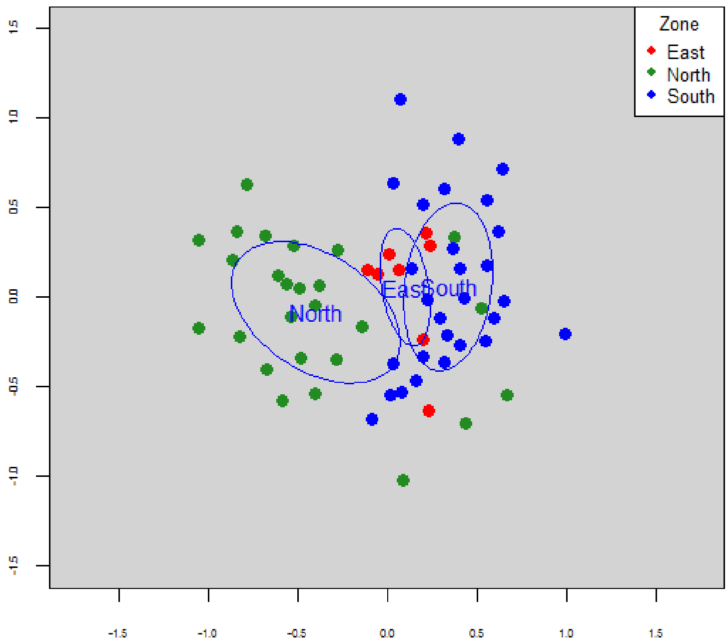


Figure 51 NMDS plot of invertebrate by-catch composition and abundance. Three survey regions are shown. Blue ellipsoids are the standard deviation around the Region centroid.

3.3 Oceanography

Oceanographic data were collected at 27 stations, 2 in the north during the first week (Table 9) and 25 in the south (Table 10) in a region bounded by 52°30'S and 53°15'S latitude and 58°30'W and 60°30'W longitude.

Table 9. Data collected at northern CTD Stations

Station		Minimum	Maximum
1203	Temperature °C	5.089	7.8648
	Salinity PSU	33.6106	34.0281
	Density σ t kg/m^3	26.2059	26.894
1205	Temperature °C	5.2197	7.8352
	Salinity PSU	33.7318	34.0069
	Density σ t kg/m^3	26.3027	26.8571

Table 10. Data collected at seabed in southern region

Seabed	Temperature °C	Salinity	Density σ t kg/m3
Minimum	3.7601	33.6991	26.5118
Maximum	6.1028	34.1849	27.162

Figure 52 shows the temperature, salinity and σ-t density for the southern regions, gridded using ODV4 DIVA[1] gridding algorithm.

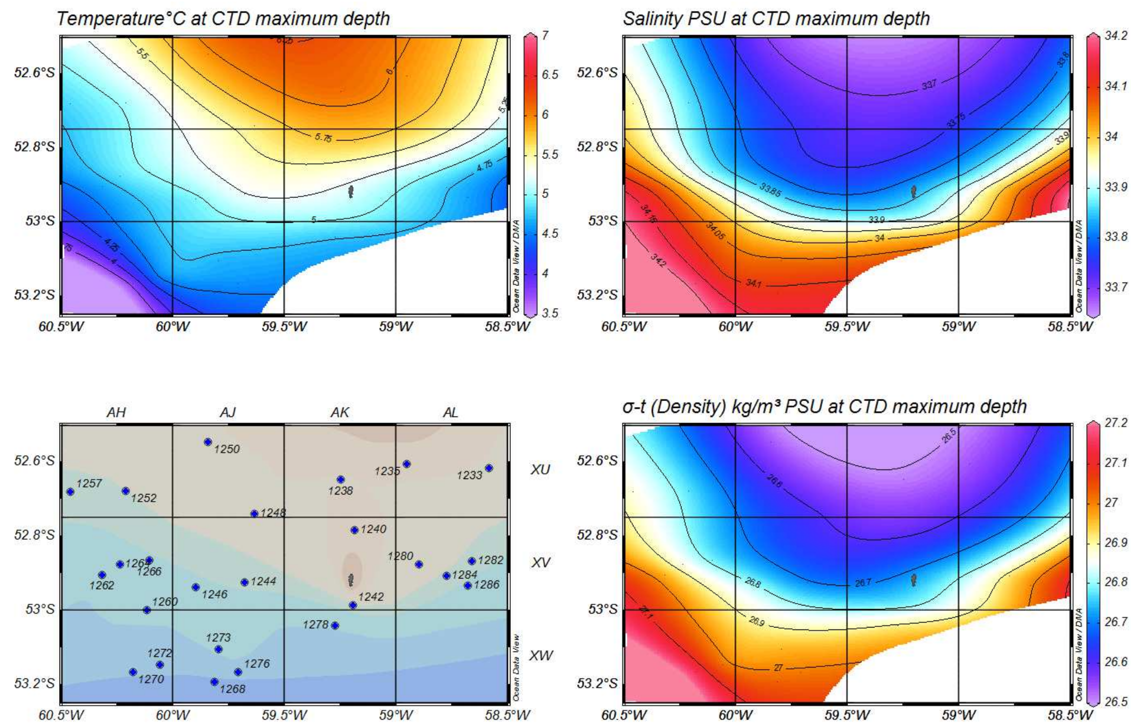


Figure 52. Temperature Salinity and σ-t Density

The stations have been grouped into three categories, <155m, 155-450m and >450 metres, values at which natural breaks occurred.

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

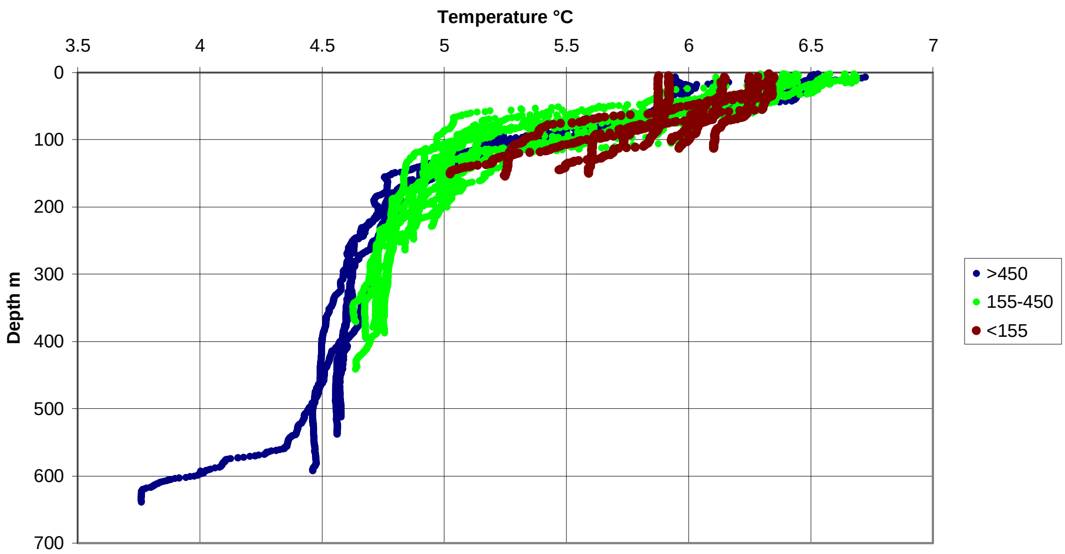


Figure 53. Temperature Profiles separated into depth bands

Figure 25 shows temperature plotted against depth, there is a strong thermocline visible in all the mid-depth and deep water stations at 50-100 meters. This feature is less pronounced at the shallower stations with only stations 1234 and 1280 showing marked temperature changes. At station 1233 there is a potential thermocline just above the seabed whilst at 1248 the temperature change is considerably less than seen at stns 1234 and 1280. At the remaining stations there appears to be more mixing of the water masses.

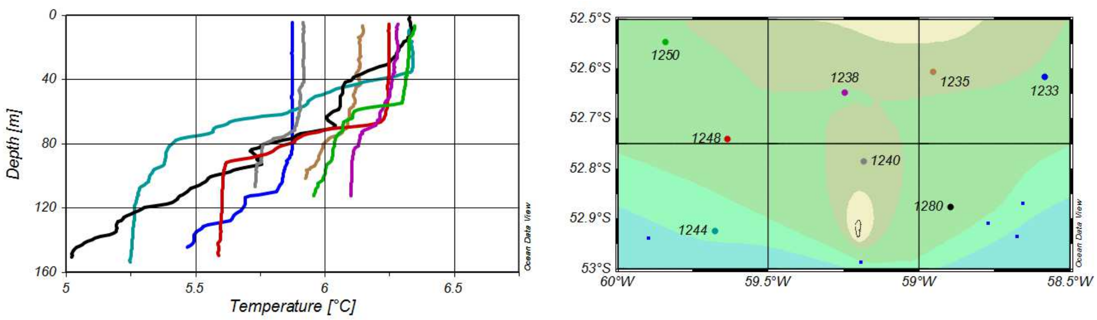


Figure 54. Stations in less than 155m of water temperature (°C) profile

The mid depth and deep water stations all show a similar profile except station 1,282 where there is a thin layer of cooler water (0.5°C) between 50 and 75 metres. The profile over the first 150 metres is shown below in Figure 55, with all mid and deep water stations are shown in Figure 56

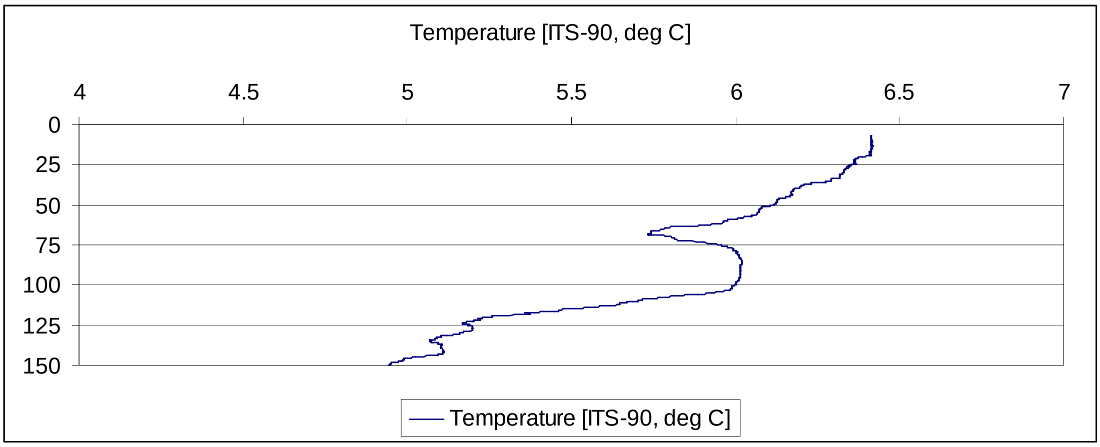


Figure 55. Upper water column temperature profile station 1282

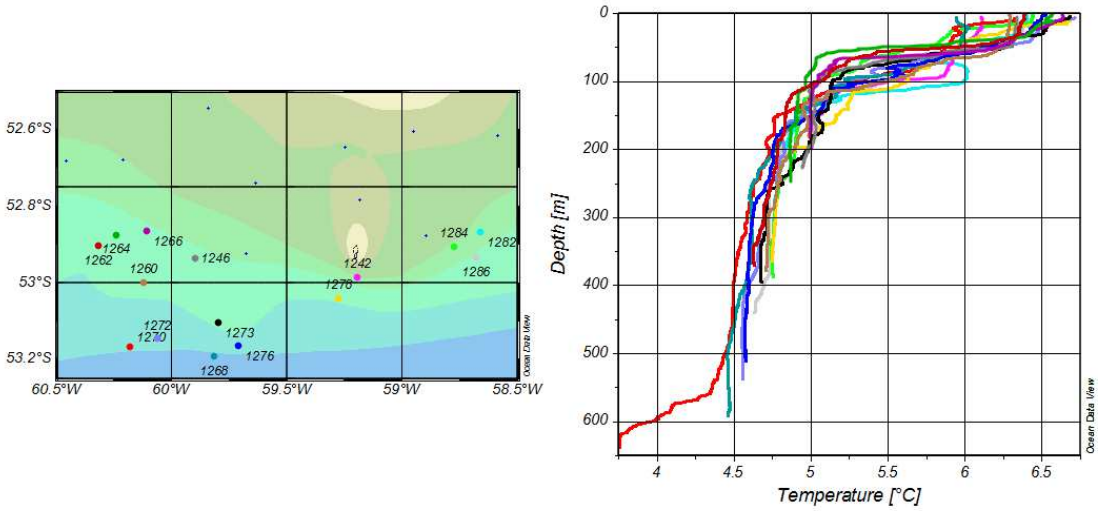


Figure 56. Mid and deep water stations water temperature (°C) profile (stn 1282 in cyan)

The density profile for the stations is similar to that seen in previous research cruises, although deeper water was sampled during this trip. Figure 57 below shows the temperature-salinity plot with isopycnals for σ-t density. Arkhipkin et al.(2013) identified water masses in the region near Beauchêne island, four of these would appear to exist in the temperature salinity profile at sampled stations:- Shelf water, Sub-Antarctic Superficial water (SASW), Transient Zone water and Atlantic-Antarctic Intermediate water(AAIW). Using the density of the water and salinity-temperature profile Figure 57 classifies these water masses based on σ-t density.

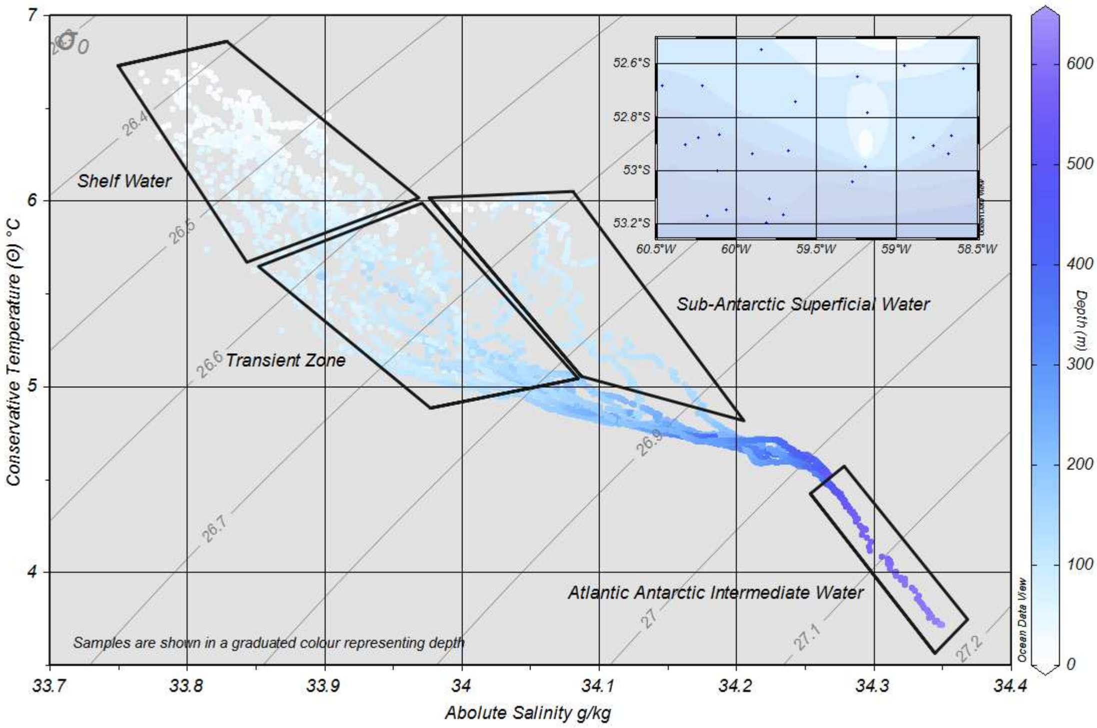


Figure 57. Conservative Temperature vs Absolute Salinity, overlaid with Isopycnal σ-t in kg/m³

4.0 General conclusions

Total skate biomass in the north sub-region was estimated at 25,492 tonnes. This estimate is slightly lower, and not significantly different, from the 2010 estimate (25,753 tonnes). By species, the biomass of *Psammobatis spp.* was significantly higher in 2013 than it had been in 2010, the biomass of *Dipturus (Zearaja) chilensis* was marginally higher, and the biomass of *Bathyraja multispinis* was marginally lower. Other species were not significantly different between 2010 and 2013.

Of the three regions surveyed in 2013, the south had the highest biomass density of only two species: *Bathyraja magellanicus* and *Psammobatis spp.*. This result suggests that the part of the southern region that was surveyed does not generally serve as a population refuge for skates.

Gear specifics do have a significant impact on the catchability of skates, as shown by the significantly greater catches as reported from this survey compared with the October 2010 survey. Future surveys may include some gear comparative element to further elucidate this aspect.

Changes in biological parameters, in particular decreases in size at 50% maturity, were noticed for most skate species. The implications of this are generally suggested to be an effect of a stock stressed by fishing pressure. This aspect merits further analyses.

There has been a significant change in the skate species assemblage in the northern skate targeted fishing area, in terms of species composition and relative abundance. This is despite any difference in sampling location or depth factors that are known to contribute to variations in the skate assemblage throughout the region. The cause of such change will be investigated, where factors such as time of year, oceanographic variations, and changing fishing effort cannot as yet be ruled out.

Analyses of the invertebrate by-catch between the southern and eastern survey regions show that these assemblages were similar in terms of the species composition and relative abundance. These regions were however different to the invertebrate assemblage in the northern area. These data will form the basis for future invertebrate community monitoring in these regions.

5.0 References

Agnew, D.J., Nolan, C.P., Beddington, J.R. & Baranowski, R. (2000) Approaches to the assessment and management of multispecies skate and ray fisheries using the Falkland Islands fishery as an example. *Canadian Journal of Fisheries and Aquatic Sciences*, 57, 429-440.

Agnew, D.J., Nolan, C.P. & Pompert, J. (1999) Management of the Falkland Islands skate and ray fishery. *In:* Shotton, R., *Case studies of the management of elasmobranch fisheries*. FAO: Rome, 268-284.

Akima, H. (1996) Algorithm 761: scattered-data surface fitting that has the accuracy of a cubic polynomial. *ACM Transactions on Mathematical Software*, 22, 362-371.

Arkhipkin, A., Brickle, P. & Laptikhovsky, V. (2013) Links between marine fauna and oceanic fronts on the Patagonian Shelf and Slope. *Arquipélago-Life and Marine Sciences*, 30, 9-37.

Arkhipkin, A., Brickle, P., Laptikhovsky, V., Pompert, J. & Winter, A. (2012) Skate assemblage on the eastern Patagonian Shelf and Slope: structure, diversity and abundance. *Journal of Fish Biology*, 80, 1704-1726.

Arkhipkin, A., Winter, A. & Pompert, J. (2010) Cruise Report, ZDLT1-10-2010, Skate Biomass survey. FIG Directorate of Natural Resources Fisheries Department: Stanley, Falkland Islands, 1-43.

Arkhipkin, A.I., Baumgartner, N., Brickle, P., Laptikhovsky, V.V., Pompert, J.H.W. & Shcherbich, Z.N. (2008) Biology of the skates *Bathyraja brachyurops* and *B. griseocauda* in waters around the Falkland Islands, Southwest Atlantic. *ICES Journal of Marine Science*, 65, 560-570.

Borcard, D., Legendre, P. & Drapeau, P. (1992) Partialling out the spatial component of ecologocal variation. *Ecology*, 73, 1045-1055.

Brickle, P., Laptikhovsky, V., Pompert, J. & Bishop, A. (2003) Ontogenetic changes in the feeding habits and dietary overlap between three adundant rajid species on the Falkland Islands' shelf. *Journal of the Marine Biological Association of the United Kingdom*, 83, 1119-1125.

Brickle, P., Pompert, J. & Poulding, D. (2002) The Occurrence of *Otodistomum plunketi* Fyfe, 1953 (Digenea: Azgiidae), in Rays (Chondrichthyes: Rajidae) Around the Falkland Islands. *Comparative Parasitology*, 69, 86-89.

Dickson, W. (1993) Estimation of the capture efficiency of trawl gear, I:Development of a theoretical model. *Fisheries Research*, 16, 239-253.

Efron, B. (1981) Nonparametric estimates of standard error: the jackknife, the bootstrap and other methods. *Biometrika*, 68, 589-599.

FIG. (2013) Vessel units, allowable effort, and allowable catch 2014. Technical Document. Falkland Islands Fisheries Department.

Fraser, H.M., Greenstreet, S.P.R. & Piet, G.J. (2007) Taking account of catchability in groundfish survey trawls: implications for estimating demersal fish biomass. *ICES Journal of Marine Science*, 64, 1800-1819.

Henderson, A.C., Arkhipkin, A.I. & Chtcherbich, J.N. (2005) Distribution, Growth and Reproduction of the White-spotted Skate *Bathyraja albomaculata* (Norman, 1937) Around the Falkland Islands. *Journal of Northwest Atlantic Fishery Science*, 35, 79-87.

Laptikhovsky, V., Winter, A., Brickle, P. & Arkhipkin, A. (2011) Vessel units, allowable effort, and allowable catch 2012. Technical Document. Falkland Islands Fisheries Department.

Laptikhovsky, V., Winter, A., Brickle, P., Roux, M.-J., Arkhipkin, A. & Brewin, P. (2012) Vessel units, allowable effort, and allowable catch 2013. Technical Document. Falkland Islands Fisheries Department.

Laptikhovsky, V.V. (2004) Survival rates for rays discarded by the bottom trawl squid fishery off the Falkland Islands. *Fishery Bulletin*, 102, 757-759.

Legendre, P. & Legendre, L. (1998) *Developments in Environmental Modelling 20*. Elsevier Science BV: Eastbourne.

Maurer, B.A. & McGill, B.J. (2011) Measurement of species diversity. *In:* Magurran, A.E. & McGill, B.J., *Biological Diversity: Frontiers in measurement and assessment*. Oxford University Press: Oxford, 55-56.

McEachran, J.D. (1983) Results of the research cruises of FVR "Walther Herwig" to South America, LXI. Revision of the South American skate genus *Psammobatis* Günther, 1870 (Elasmobranchii: Rajiformes, Rajidae). *Archiv für Fischereiwissenschaft*, 34, 23-80.

Paya, I., Brickle, P., Laptikhovsky, V. & Winter, A. (2010) Vessel units, allowable effort, and allowable catch 2011. Technical Document. Fisheries Department Falkland Islands Government.

Paya, I., Schuchert, P. & Brickle, P. (2009) Vessel units, allowable effort, and allowable catch 2010. Technical Document. Fisheries Department Falkland Islands Government.

Paya, I., Schuchert, P., Dimmlich, W. & Brickle, P. (2008) Vessel units, allowable effort, and allowable catch 2009. Technical Document. Fisheries Department Falkland Islands Government.

R Core Team. (2013) R: A language and environment for statistical computing.

Rijnsdorp, A.D., Leeuwen, P.J.v., Daan, N. & Heessen, H.J.L. (1996) Changes in abundance of demersal fish species in the North Sea between 1906-1909 and 1990-1995. *ICES Journal of Marine Science*, 53, 1,054-1,062.

Rogers, S.A. & Ellis, J.R. (2000) Changes in the demersal fish assemblages of Britsh coastal waters during the 20th century. *ICES.Journal of Marine Science*, 57, 866-881.

Schlitzer, R. (2013) Ocean Data View.

von Szalay, P.G. & Brown, E. (2001) Trawl comparisons of fishing power differences and their applicability to National Marine Fisheries Service and Alaska Department of Fish and Game trawl survey gear. *Alaska Fishery Research Bulletin*, 8, 85-95.

Wakeford, R.C., Middleton, D.A.J., Agnew, D.J., Pompert, J.H.W. & Laptikhovsky, V.V. (2004) Management of the Falkland Islands Multispecies Ray Fishery: Is Species-specific Management Required? *Journal of Northwest Atlantic Fishery Science*, 35, 309-324.

Warren, W.G. (1997) Report on the Comparative Fishing Trial Between the *Gadus Atlantica* and *Teleost. NAFO Scientific Council Studies*, 29, 81-92.

Wilderbuer, T.K., Kappenman, R.F. & Gunderson, D.R. (1998) Analysis of fishing power correction factor estimates from a trawl comparison experiment. *North American Journal of Fisheries Management*, 18, 11-18.

6.0 Appendix

Table 11: Total catch of all trawl stations, by species and by survey sub-region.

Code	Species Name	North	East	South	Total	% Total
PAR	*Patagonotothen ramsayi*	9,754.040	389.550	6,954.760	17,098.350	16.49%
GRC	*Macrourus carinatus*	686.020	986.140	15,091.820	16,763.980	16.17%
WHI	*Macruronus magellanicus*	4,376.150	44.460	7,314.030	11,734.640	11.32%
SPN	Porifera	8,616.760	211.500	1,112.810	9,941.070	9.59%
GRF	*Coelorhynchus fasciatus*	3.820	3.860	8,912.840	8,920.520	8.60%
RBR	*Bathyraja brachyurops*	3,665.070	1,159.540	2,715.280	7,539.890	7.27%
RAL	*Bathyraja albomaculata*	2,009.990	618.955	741.860	3,370.805	3.25%
RGR	*Bathyraja griseocauda*	1,770.600	168.125	683.580	2,622.305	2.53%
STA	*Sterechinus agassizi*	1,600.015	302.240	201.080	2,103.335	2.03%
RFL	*Zearaja chilensis*	1,331.460	49.590	633.800	2,014.850	1.94%
BAC	*Salilota australis*	356.650	0.470	1,332.670	1,689.790	1.63%
KIN	*Genypterus blacodes*	1,335.940		153.440	1,489.380	1.44%
BLU	*Micromesistius australis*	247.058	228.090	996.530	1,471.678	1.42%
RSC	*Bathyraja scaphiops*	457.260	436.490	554.900	1,448.650	1.40%
RMC	*Bathyraja macloviana*	650.050	78.270	249.630	977.950	0.94%
RBZ	*Bathyraja cousseauae*	301.770	187.960	306.850	796.580	0.77%
EEL	*Iluocoetes fimbriatus*	417.474	100.160	262.210	779.844	0.75%
ING	*Moroteuthis ingens*	622.330	103.840	34.130	760.300	0.73%
LOL	*Loligo gahi*	274.980	19.890	410.350	705.220	0.68%
ANM	Anemone	247.675	72.510	339.540	659.725	0.64%
FUM	*Fusitriton m. magellanicus*	513.810	22.100	91.030	626.940	0.60%
AUC	*Austrocidaris canaliculata*	560.590	12.950	23.810	597.350	0.58%
PAT	*Merluccius australis*	4.980		571.039	576.019	0.56%
TOO	*Dissostichus eleginoides*	149.901	53.640	331.530	535.071	0.52%
RDO	*Amblyraja doellojuradoi*	370.920	123.250	22.890	517.060	0.50%
HAK	*Merluccius hubbsi*	501.060		2.090	503.150	0.49%
COT	*Cottunculus granulosus*	412.520	51.870	32.680	497.070	0.48%
SQT	Ascidiacea	15.690	28.520	422.980	467.190	0.45%
BAL	*Bathydomus longisetosus*	437.790	6.268	2.770	446.828	0.43%
BAO	*Bathybiaster loripes*	324.005	61.770	24.580	410.355	0.40%
CGO	*Cottoperca gobio*	27.750	35.080	315.340	378.170	0.36%
SHT	Mixed invertebrates	373.430		2.230	375.660	0.36%
RMU	*Bathyraja multispinis*	234.280	29.730	71.792	335.802	0.32%
RPX	*Psammobatis spp.*	166.120	16.890	145.640	328.650	0.32%
CAZ	*Calyptraster sp.*	52.810	114.030	158.330	325.170	0.31%
ANG	*Anthoptilum grandiflorum*		1.140	310.530	311.670	0.30%
GOC	*Gorgonocephalas chilensis*	4.050	126.800	131.420	262.270	0.25%
DGH	*Schroederichthys bivius*	3.510	0.840	246.100	250.450	0.24%
ZYP	*Zygochlamys patagonica*	3.540		233.270	236.810	0.23%
PYM	*Physiculus marginatus*	2.924	0.280	227.431	230.635	0.22%
POA	*Porania antarctica*	9.535	44.350	167.760	221.645	0.21%
THO	Thouarellinae	167.110	2.360	47.410	216.880	0.21%
ISI	Isidiidae	168.320		0.010	168.330	0.16%
SAR	*Sprattus fuegensis*		15.250	142.890	158.140	0.15%
PRX	Paragorgia sp.			155.780	155.780	0.15%
AST	Asteroidea	60.690	25.670	54.532	140.892	0.14%
SUN	*Labidaster radiosus*	2.615	32.920	101.120	136.655	0.13%
COL	*Cosmasterias lurida*	39.465	15.960	61.267	116.692	0.11%
WRM	*Chaetopterus variopedeatus*			103.690	103.690	0.10%
RDA	*Dipturus argentinensis*	100.380			100.380	0.10%
GRN	*Graneledone yamana*	0.380	55.010	29.450	84.840	0.08%

HYD	Hydrozoa	83.230		0.230	83.460	0.08%
ODM	*Odontocymbiola magellanica*	6.485	12.980	57.220	76.685	0.07%
DGS	*Squalus acanthias*	60.830		13.620	74.450	0.07%
RMG	*Bathyraja magellanica*		7.770	63.960	71.730	0.07%
ADA	*Adelomelon ancilla*	11.330	21.890	25.050	58.270	0.06%
MLA	*Muusoctopus longibrachus akambei*	50.340	1.060	5.480	56.880	0.05%
BRY	Bryozoa			55.369	55.369	0.05%
CRY	*Crossaster sp.*	8.780	35.050	10.600	54.430	0.05%
MAM	*Mancopsetta milfordi*	16.440	2.954	26.600	45.994	0.04%
EUO	*Eurypodius longirostris*	0.260	28.330	8.818	37.408	0.04%
ICA	*Icichthys australis*		1.673	34.370	36.043	0.03%
CEX	*Ceramaster sp.*	1.250	5.130	25.060	31.440	0.03%
ASA	*Astrotoma agassizii*	1.430	8.820	18.812	29.062	0.03%
NEM	*Neophyrnichthys marmoratus*	1.130	1.680	21.380	24.190	0.02%
MMA	*Mancopsetta maculata*	5.010	15.462	1.545	22.017	0.02%
MAV	*Magellania venosa*	3.310	7.890	9.300	20.500	0.02%
ODP	*Odontaster pencillatus*		19.630	0.030	19.660	0.02%
PTE	*Patagonotothen tessellata*		8.650	10.470	19.120	0.02%
GAF	*Ganaria falklandica*		11.460	4.780	16.240	0.02%
RTR	*Dipturus trachydermus*	14.690			14.690	0.01%
FLX	*Flabellum spp.*	0.650	9.630	1.410	11.690	0.01%
CTA	*Ctenodiscus australis*	8.530	0.120	0.340	8.990	0.01%
SOR	*Solaster regularis*	0.390		7.800	8.190	0.01%
CAH	Hydrozoa		0.150	7.840	7.990	0.01%
MYC	*Mysidopsis acuta*	7.350			7.350	0.01%
MED	Medusae	1.620	5.540		7.160	0.01%
MIR	*Mirostenella sp.*			6.860	6.860	0.01%
CAS	*Campylonotus semistriatus*	2.671	0.120	3.260	6.051	0.01%
OPH	Ophiuroidea	3.120	2.580	0.315	6.015	0.01%
MUO	*Muraenolepis orangiensis*	4.980	0.850		5.830	0.01%
HOL	*Holothuroidea*	1.440	0.320	3.885	5.645	0.01%
OCM	*Octopus megalocyathus*			4.300	4.300	<0.01%
ALC	Alcyoniina	1.480	1.380	1.400	4.260	<0.01%
PAO	*Patagonotothen cornucola*	3.790			3.790	<0.01%
THB	*Thymops birsteini*	3.370	0.110	0.270	3.750	<0.01%
CHE	*Champsocephalus esox*		0.930	2.810	3.740	<0.01%
GYN	*Gymnoscopelus nicholsi*	0.530	0.020	2.450	3.000	<0.01%
PLB	Primnoellinae			2.925	2.925	<0.01%
CYX	*Cycethra sp.*	0.410	0.650	1.670	2.730	<0.01%
NUD	*Nudibranchia*	2.130		0.420	2.550	<0.01%
ILL	*Illex argentinus*	2.210			2.210	<0.01%
PYX	Pycnogonida	1.651	0.380	0.151	2.182	<0.01%
MUE	*Muusoctopus eureka*	0.770		1.360	2.130	<0.01%
MUL	*Eleginops maclovinus*			1.770	1.770	<0.01%
UHH	Heart urchin	0.290	0.030	1.120	1.440	<0.01%
POL	Polychaeta	0.770	0.230	0.380	1.380	<0.01%
HCR	Paguroidea	0.340		0.900	1.240	<0.01%
PES	*Peltarion spinosulum*	0.450	0.120	0.600	1.170	<0.01%
EUL	*Eurypodius latreillei*	0.020	0.030	1.024	1.074	<0.01%
MUU	*Munida subrugosa*	1.020			1.020	<0.01%
ISO	Isopoda	1.010			1.010	<0.01%
MUG	*Munida gregaria*	1.000			1.000	<0.01%
LOS	*Lophaster stellans*	0.905		0.020	0.925	<0.01%
DDT	*Desmophyllum dianthus*			0.770	0.770	<0.01%
GUG	*Guttigadus globosus*			0.720	0.720	<0.01%
CRB	Crab			0.620	0.620	<0.01%
OCT	*Octopus spp.*	0.557			0.557	<0.01%

CRI	Crinoidea	0.530			0.530	<0.01%
NEH	*Neomena herwigi*	0.130		0.375	0.505	<0.01%
PSA	*Pseudoxenomystax albescens*	0.500			0.500	<0.01%
RED	*Sebastes oculatus*	0.470			0.470	<0.01%
OPS	*Ophiactis asperula*	0.450			0.450	<0.01%
LIT	*Lithodes turkayi*			0.430	0.430	<0.01%
BOA	*Borostomias antarcticus*	0.300		0.120	0.420	<0.01%
SRP	*Semirossia patagonica*	0.390			0.390	<0.01%
NEC	*Neorossia caroli*	0.367			0.367	<0.01%
SEC	*Seriolella caerulea*	0.350			0.350	<0.01%
LIG	*Libidoclaea granaria*			0.280	0.280	<0.01%
CAM	*Cataetyx messieri*			0.270	0.270	<0.01%
BIV	Bivalve			0.260	0.260	<0.01%
PAS	*Patagonotothen squamiceps*			0.220	0.220	<0.01%
BRA	Brachyura	0.200			0.200	<0.01%
GYM	*Gymnoscopelus spp.*	0.200			0.200	<0.01%
COK	*Coelorinchus kaiyomaru*			0.160	0.160	<0.01%
PLS	*Plesienchelys stehmanni*	0.155			0.155	<0.01%
ELO	*Enallopsammia sp.*	0.140			0.140	<0.01%
LIR	*Limopsis marionensis*	0.140			0.140	<0.01%
ACS	*Acanthoserolis schythei*	0.010		0.120	0.130	<0.01%
HEX	*Henricia sp.*	0.100			0.100	<0.01%
LYB	*Lycenchelys bachmanni*	0.083			0.083	<0.01%
CAV	*Campylonotus vagans*	0.080			0.080	<0.01%
EGG	Eggmass	0.010	0.050		0.060	<0.01%
PLU	Primnoellinae	0.050		0.010	0.060	<0.01%
HIE	*Histioteuthis eltarinae*	0.050			0.050	<0.01%
MUN	*Munida spp.*	0.050			0.050	<0.01%
PAM	*Pagurus comptus*	0.050			0.050	<0.01%
OPL	*Ophiuroglypha lymanii*			0.035	0.035	<0.01%
NUH	*Nuttallochiton hyadesi*			0.030	0.030	<0.01%
LMK	*Laemonema kongi*	0.029			0.029	<0.01%
TED	*Terebratella dorsata*	0.011		0.010	0.021	<0.01%
LEY	*Lepas spp.*			0.020	0.020	<0.01%
PEN	Pennatulacea			0.020	0.020	<0.01%
AGO	*Agonopsis chilensis*			0.010	0.010	<0.01%
ALG	Algae	0.010			0.010	<0.01%
ANC	*Anseropoda antarctica*	0.010			0.010	<0.01%
STS	*Stereomastis suhmi*			0.010	0.010	<0.01%
	Totals	**6,252**	**43,756**	**53,686**	**103,694**	
	Region Catch as % of total	**6.03%**	**42.20%**	**51.77%**		

Table 12: Random sample numbers

Code	Name	Number Sampled	%
RBR	*Bathyraja brachyurops*	5,125	19.1%
RAL	*Bathyraja albomaculata*	3,215	12.0%
PAR	*Patagonotothen ramsayi*	2,746	10.2%
LOL	*Loligo gahi*	2,305	8.6%
GRC	*Macrourus carinatus*	1,865	6.9%
WHI	*Macruronus magellanicus*	1,633	6.1%
RMC	*Bathyraja macloviana*	1,378	5.1%
RSC	*Bathyraja scaphiops*	1,248	4.6%
BLU	*Micromesistius australis*	1,206	4.5%
RGR	*Bathyraja griseocauda*	991	3.7%
RPX	*Psammobatis spp.*	866	3.2%
RDO	*Amblyraja doellojuradoi*	695	2.6%
RFL	*Zearaja chilensis*	562	2.1%
TOO	*Dissostichus eleginoides*	561	2.1%
GRF	*Coelorhynchus fasciatus*	510	1.9%
BAC	*Salilota australis*	409	1.5%
RBZ	*Bathyraja cousseauae*	370	1.4%
KIN	*Genypterus blacodes*	301	1.1%
SAR	*Sprattus fuegensis*	199	0.7%
PAT	*Merluccius australis*	183	0.7%
RMG	*Bathyraja magellanica*	124	0.5%
MMA	*Mancopsetta maculata*	112	0.4%
RMU	*Bathyraja multispinis*	75	0.3%
MAM	*Mancopsetta milfordi*	51	0.2%
HAK	*Merluccius hubbsi*	50	0.2%
RDA	*Dipturus argentinensis*	27	0.1%
ICA	*Icichthys australis*	19	0.1%
LYB	*Lycenchelys bachmanni*	12	0.0%
NEC	*Neorossia caroli*	11	0.0%
PYM	*Physiculus marginatus*	10	0.0%
PLS	*Plesienchelys stehmanni*	8	0.0%
ILL	*Illex argentinus*	4	0.0%
EEL	*Iluocoetes fimbriatus*	2	0.0%
LMK	*Laemonema kongi*	1	0.0%
OCT	*Octopus spp.*	1	0.0%
HIE	*Histioteuthis eltarinae*	1	0.0%
DGS	*Squalus acanthias*	1	0.0%
RTR	*Dipturus trachydermus*	1	0.0%
		26,878	