Cruise Report
ZDLT1-05-2014

Illex Migration Research Cruise

Alexander Arkhipkin, Joost Pompert, Zhanna Shcherbich, Jessica Jones, Alex Blake , Michaël Gras & Brendan Lee

Falkland Islands Government
Directorate of Nature Resources
Fisheries Department
Stanley, Falkland Islands

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1 Introduction

Argentine shortfin squid *Illex argentinus* is the most important squid fishery resource in the Southwest Atlantic with total annual catch only in Falkland waters attaining 300,000 t in 2014. This squid migrates to the southern part of the Patagonian Shelf in February – March. After 2-3 months of the feeding period, squid start their northward pre-spawning migrations, moving first to the shelf edge, descending to the slope and then migrating along the slope with waters of the Falkland Current.

In June 2007, the first research survey on r/v Dorada revealed that the pre-spawning schools of the late maturing stock migrated from the shelf into deeper waters in a region a strong upwelling area in the northern part of the continental slope and shelf. It was caused by a quasi-stationary meander of the Falkland Current that spreads onto the shelf in this area. Presumably, pre-spawning *I. argentinus* used this oceanographic feature as a cue for migrating to deeper waters of the Patagonian Slope. In May 2014, it was decided to carry out another survey of the northern part of FICZ/FOCZ to further investigate the ecological cues for shelf-slope migrations of the early and late maturing stock that take place usually in May.

1.1 Cruise objectives

1. To make a trawl survey of the area of possible migrations of the *Illex* early maturing stock from the shelf to the continental slope using semi-pelagic net.
2. To study the ecology of deepwater demersal and bathypelagic fish community and its interactions with pre-spawning migrating schools of *Illex*.
3. To carry out an oceanographic survey of the northern part of the Falkland Islands shelf.

1.2 Vessel

The cruise was conducted on the F/V *Castelo*, registered in the Falkland Islands and chartered to do research cruises by the Fisheries Department.

1.3 Personnel and responsibilities

The following FIFD personnel participated in the cruise:

Dr Alexander Arkhipkin	Chief Scientist
Alex Blake	Oceanographic survey
Joost Pompert	Trawl survey
Dr Michaël Gras	Trawl survey
Zhanna Shcherbich	Trawl survey
Jessica Jones	Trawl survey
Brendon Lee	Trawl survey

1.4 Cruise plan and key dates

The vessel departed from Stanley at 8 p.m. of 3 May and proceeded overnight to the first station located at 200 m depths in the northeaster part of the Patagonian Shelf (XLAP gridsquare). During the next five days, the vessel moved north along the 200-m isobath (where possible) and every 20 nautical miles made both trawl (during the daytime) and oceanographic stations (throughout the day). On 8 May, the northernmost station of the survey was carried out at 46º30'S on the shelf of high seas, and the vessel started to move south doing three zigzag transects along the slope (300, 400 and 600 m). In the next nine days, the main part of the survey has been completed, with the last trawl and oceanographic stations located at 50ºS. The cruise was successfully finished on 17 May. Despite several days of rough weather with strong winds (30-50 knots) and high seas, the vessel managed to fish with no days lost because of bad weather.

1.5 Equipment used

1.5.1 Trawling

An ENGEL semi-pelagic trawl with "Super-V" doors was used at all trawl stations. It had a 40.2 m headline and a 38.7 m footrope equipped with rockhoppers. Net monitor sensors were attached to the upper panel of the trawl. The vertical opening was between 7 and 12 m and the codend mesh size was 95 mm.

1.5.2 Oceanographic

CTD SBE 25 was deployed to collect profiles of temperature and salinity during oceanographic stations.

1.6 Sampling

1.6.1 Trawl stations and biological sampling

During the ZDLT1-05-2014 research cruise the station numbers ranged from 1289 to 1383 (Table 1.1). The catches at all stations were weighed using an electronic marine adjusted balance.

Finfish and skates were measured (total, pre-anal and disc width) to the nearest centimetre below. All the sampled skates, some fish and cephalopods were measured on a board and length, pre-anal length and disc width were recorded. The remainder was measured using Fishmeter 100 and Fishmeter50 electronic measuring boards. Sex and stage of maturity were recorded for all specimens sampled. During length-weight sampling (mainly otolith collection), individual weights were measured to the nearest gram.

Cephalopods were analysed for weight, length, sex and maturity, with statoliths extracted from sub samples.

Table 1.1: Dates, locations, modal depth and duration of oceanographic (C), trawl (S&P) and plankton trawls (I).

Station	Date	Lat (°S)	Lon (°W)	Modal Depth (m)	Duration	Activity	Comments
1289	04/05/2014			134		C	
1290	04/05/2014	50.64	57.36	209	120	S	
1291	04/05/2014			210		C	
1292	04/05/2014	50.44	57.76	205	60	S	
1293	04/05/2014			202		C	
1294	04/05/2014	50.24	58.17	200	60	S	
1295	04/05/2014			207		C	
1296	04/05/2014			205		C	
1297	05/05/2014			205		C	
1298	05/05/2014	49.76	59.54	195	60	S	belly of net ripped
1299	05/05/2014			197		C	
1300	05/05/2014	49.56	59.98	199	60	S	
1301	05/05/2014	49.42	60.32	198	60	S	
1302	05/05/2014			200		C	
1303	06/05/2014			203		C	
1304	06/05/2014	49.09	60.65	202	60	S	
1305	06/05/2014	48.88	60.81	200	60	S	
1306	06/05/2014			206		C	
1307	06/05/2014			249		C	
1308	06/05/2014	48.57	60.79	240	60	S	
1309	06/05/2014			325		C	
1310	06/05/2014			380		C	
1311	07/05/2014			407		C	
1312	07/05/2014	47.48	60.72	400	60	S	
1313	07/05/2014			318		C	
1314	07/05/2014	47.18	60.73	289	60	S	
1315	07/05/2014			211		C	
1316	07/05/2014	46.84	60.71	206	60	S	
1317	07/05/2014	46.63	60.55	148	60	S	
1318	07/05/2014			182		C	
1319	08/05/2014			405		C	
1320	08/05/2014	46.61	60.34	430	60	S	
1321	08/05/2014			605		C	
1322	08/05/2014	46.61	60.13	609	60	S	
1323	08/05/2014	46.61	60.27	494	60	S	
1324	08/05/2014	46.60	60.42	306	60	S	
1325	08/05/2014			322		C	
1326	09/05/2014			432		C	
1327	09/05/2014	47.03	60.58	413	60	S	
1328	09/05/2014			601		C	
1329	09/05/2014	47.13	60.25	612	120	S	
1330	09/05/2014	47.11	60.46	500	120	S	
1331	09/05/2014			513		C	
1332	10/05/2014			498		C	
1333	10/05/2014	47.66	60.45	501	120	S	
1334	10/05/2014	47.55	60.24	592	120	S	
1335	10/05/2014			589		C	
1336	10/05/2014	47.80	60.65	400	120	S	
1337	10/05/2014			388		C	
1338	11/05/2014			354		C	
1339	11/05/2014	48.03	60.73	343	120	S	
1340	11/05/2014	48.12	60.21	475	120	S	
1341	11/05/2014			501		C	

1342	11/05/2014	48.02	59.97	555	120	S	
1343	11/05/2014			578		C	
1344	12/05/2014			310		C	
1345	12/05/2014	48.54	60.47	323	120	S	
1346	12/05/2014			414		C	
1347	12/05/2014	48.53	60.22	418	120	S	
1348	12/05/2014	48.53	59.98	476	120	S	
1349	12/05/2014			481		C	
1350	13/05/2014			280		C	
1351	13/05/2014	48.79	60.49	277	120	S	
1352	13/05/2014			359		C	
1353	13/05/2014	48.79	60.24	373	120	S	
1354	13/05/2014	48.80	59.97	433	120	S	
1355	13/05/2014			423		C	
1356	14/05/2014			399		C	
1357	14/05/2014	49.00	59.90	378	120	S	
1358	14/05/2014			337		C	
1359	14/05/2014	49.00	60.17	322	120	S	
1360	14/05/2014	49.01	60.43	275	120	S	
1361	14/05/2014			271		C	
1362	15/05/2014			420		C	
1363	15/05/2014	49.25	59.54	389	120	S	
1364	15/05/2014			365		C	
1365	15/05/2014	49.23	59.82	332	120	S	
1366	15/05/2014			301		C	
1367	15/05/2014	49.26	60.05	300	120	S	
1368	15/05/2014	49.37	59.77	326	60	P	
1369	16/05/2014			346		C	
1370	16/05/2014	49.48	59.55	344	120	S	
1371	16/05/2014			401		C	
1372	16/05/2014	49.49	59.26	387	120	S	
1373	16/05/2014			412		C	
1374	16/05/2014	49.48	58.98	410	120	S	
1375	17/05/2014			348		C	
1376	17/05/2014	49.76	58.82	336	120	S	
1377	17/05/2014			356		C	
1378	17/05/2014	49.74	58.52	348	120	S	
1379	17/05/2014			342		C	
1380	17/05/2014	49.91	58.31	294	120	S	
1381	17/05/2014			288		C	
1382	17/05/2014			295		C	
1383	17/05/2014			307		C	

2 Oceanography

2.1 Methods

A single CTD instrument was uses during the trip, Serial No 0389. At all CTD stations the CTD was deployed to a depth of c. 10m below surface for a soak time of about one minute, to allow the pump to start circulating water, following this the CTD was raised to a minimum depth of 5 m below surface. The CTD was then lowered toward the sea bed at 1m/sec. The CTD collected pressure in dbar, temperature in °C and conductivity in mS/cm. The raw hex file was converted and processed using SBE Data Processing Version.7.22.5 using the CON files 0389_April-2014.xmlcon. Upcast data was filtered out. Depth was derived from pressure using the latitude of each station. Practical Salinity (PSU) and Density as sigma-t (σ-t) were derived following derivation of depth. Further derived variables of conservative temperature (°C) and Absolute Satinity (g/kg) were calculated in Ocean Data View version 4.5.4 (Schlitzer, R., Ocean Data View, http://odv.awi.de, 2013).

2.2 Results

Oceanographic data were collected at 49 stations. At the first station, number 1289, the wire counter malfunctioned and the CTD was only lowered to 58 meters. At the final station, number 1383, on the deep water transect the CTD did not record data due to a battery malfunction. At all other stations good data were collected on the downcast. Figure 2.1 below shows the location of the stations and the four oceanographic sections.

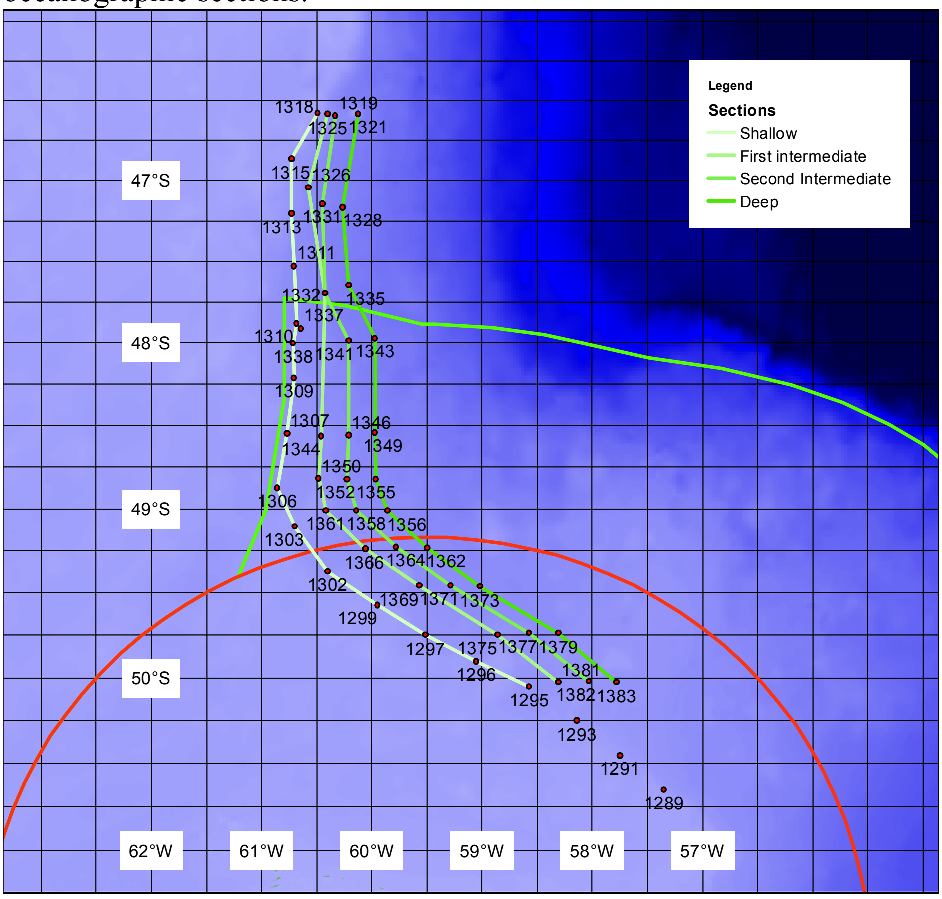
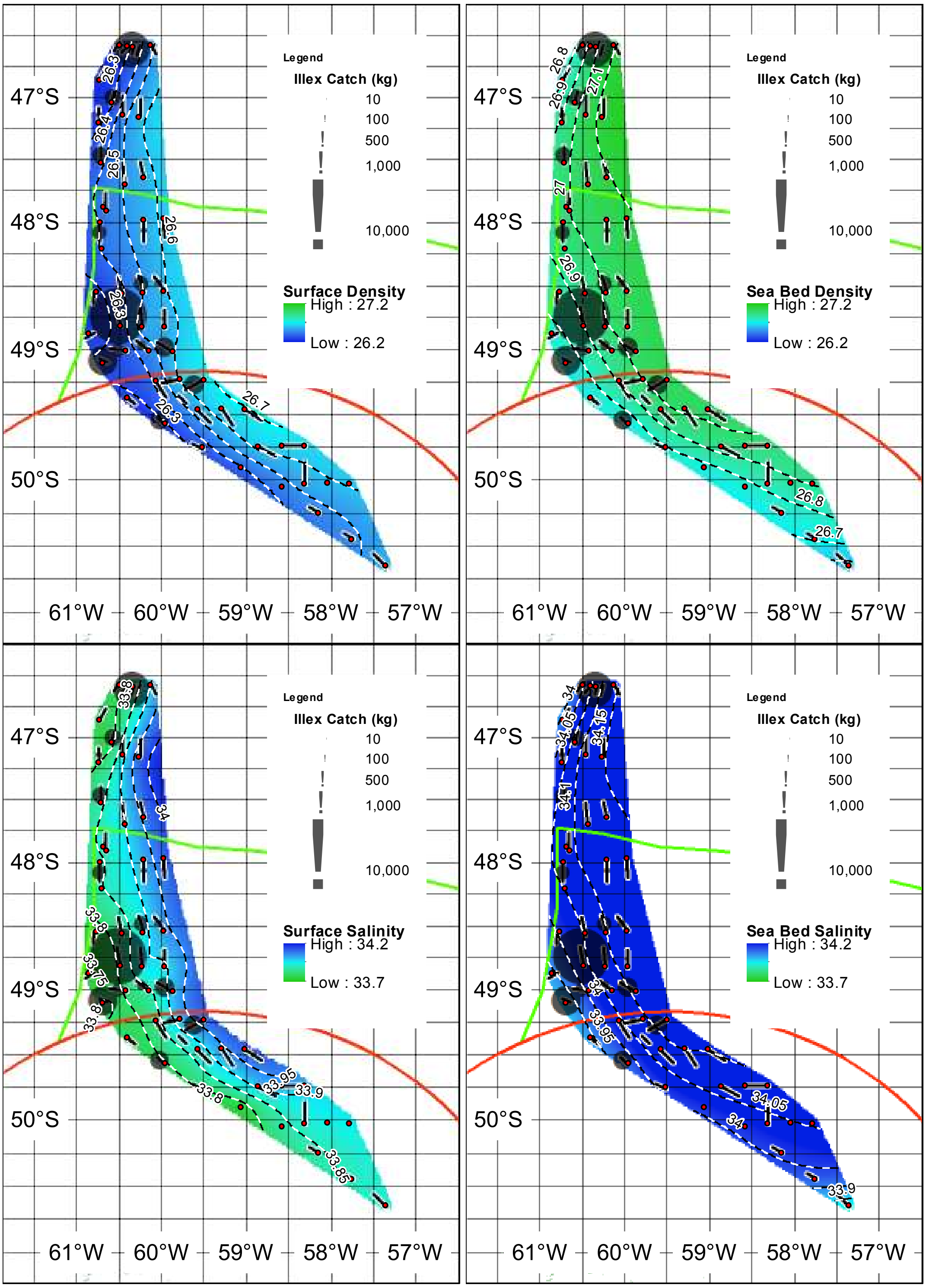


Figure 2.1: Location of CTD stations and transects

Figure 2.2 below shows the temperature, salinity and σ-t density, gridded using ODV4 DIVA[1] gridding algorithm. There is a channel of slightly less dense water visible from the contours in the surface density map that is not clear in the continuous raster image. A zoomed image with thematic salinity bands is shown as Figure 2.3.



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

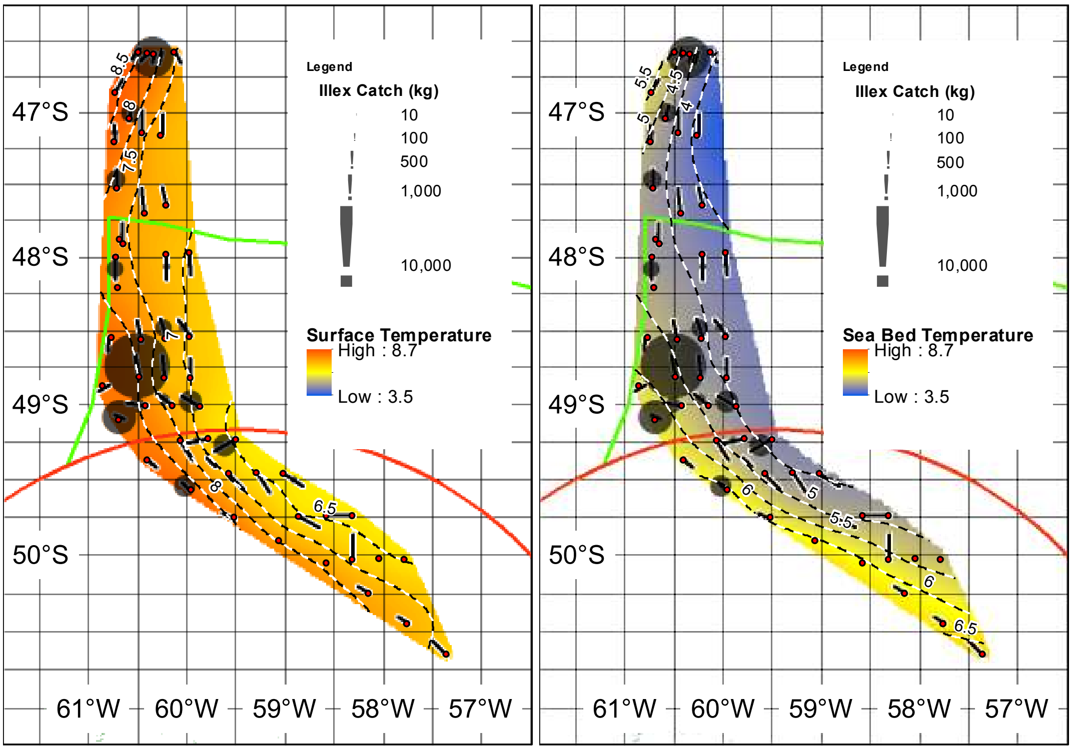


Figure 2.2. σ-t Density Salinity and Temperature (Sea surface on the left, Seabed on the right)

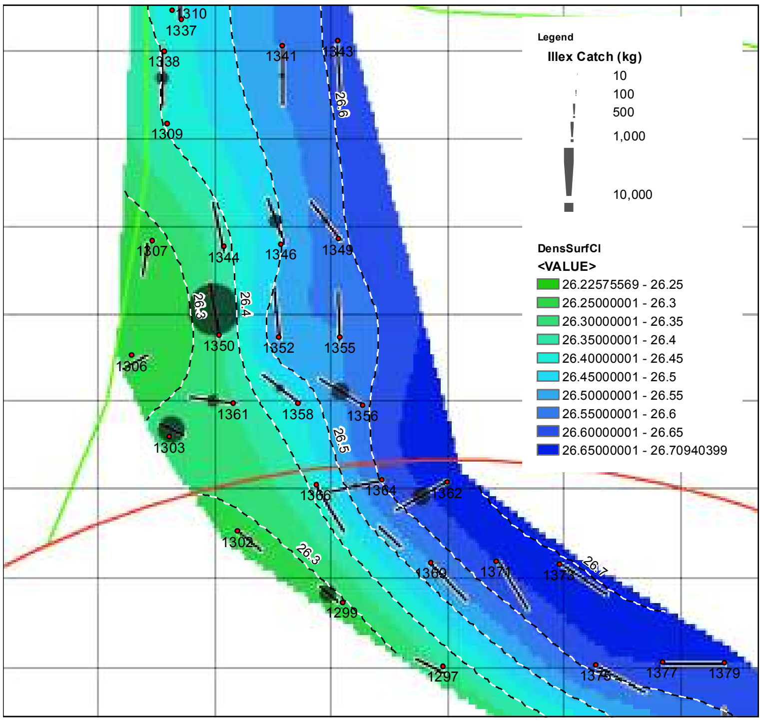


Figure 2.3 Banded thematic density at surface

Stations 1299, 1302 and 1303 indicate a surface flow channel (extending to st 1358) of slightly less dense water, and 2 trawls (1300 & 1351) in the area produced 2 of the 3 biggest catches.
The CTD profiles were plotted as 4 oceanographic sections, the density plots are shown below in Figure 2.4 to Figure 2.7. The shallow water section shows the low density "channel" on the surface at CTD stations 1299 and 1302 with the higher surface density at 1303 and 1297. The lower density is also evident in the shallower of the 2 intermediate sections at stations 1344, 1350, 1361 and 1366.

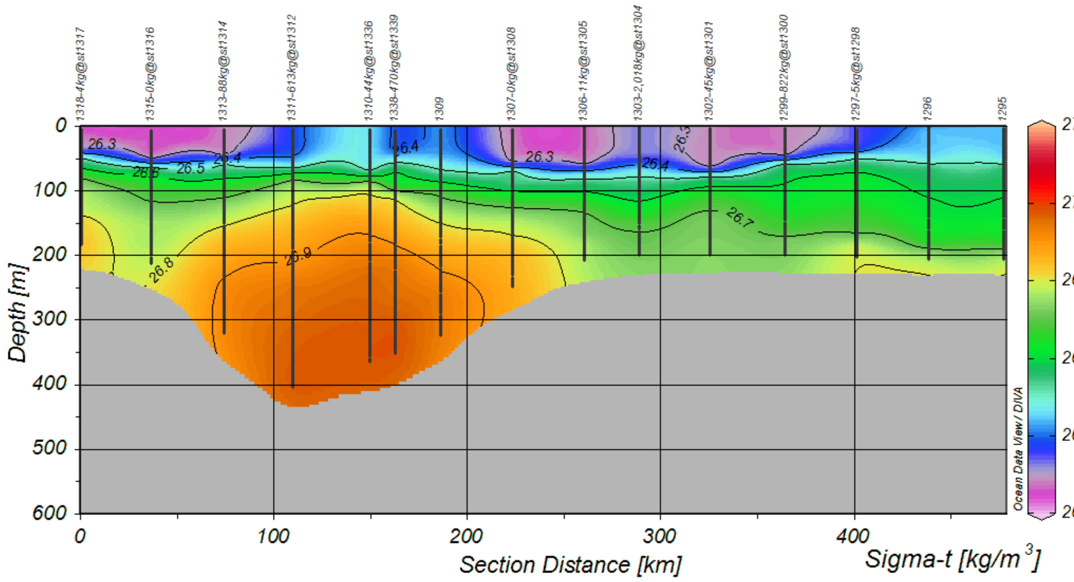


Figure 2.4 Shallow water section (Density)

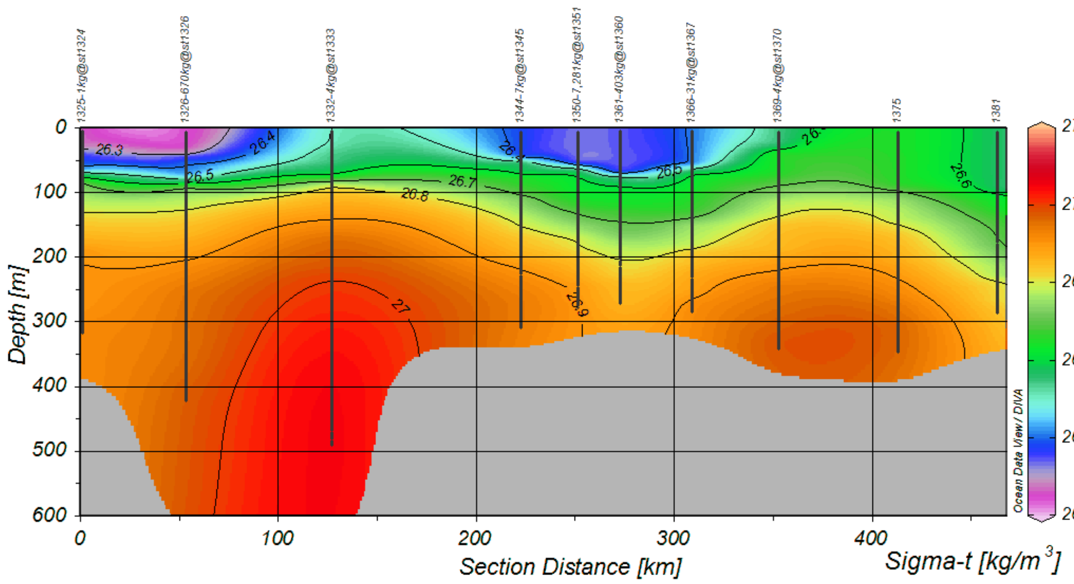


Figure 2.5 Intermediate Section 1(Density)

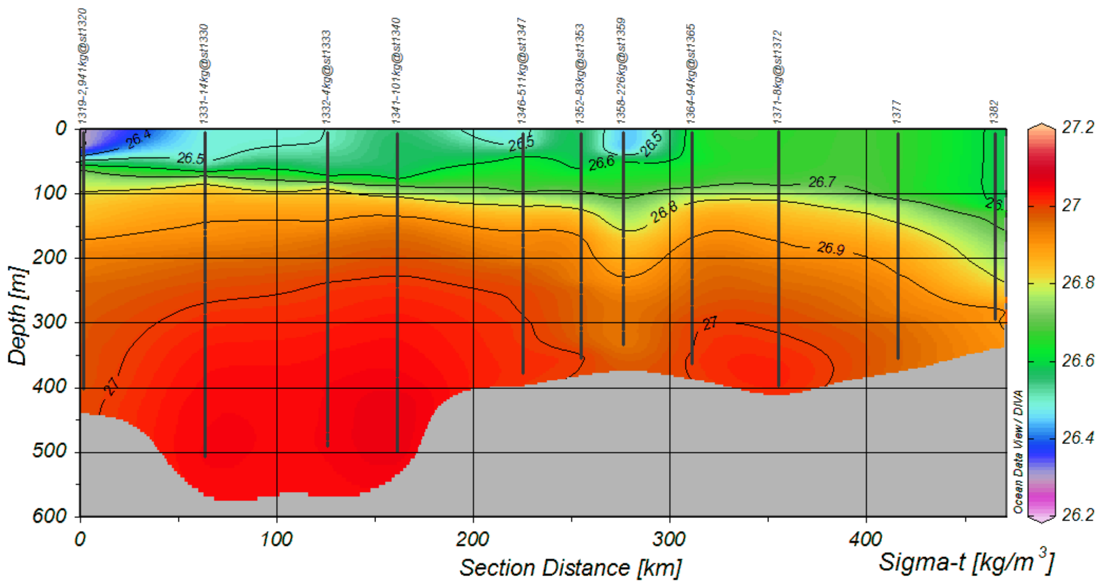


Figure 2.6 Intermediate Section 2(Density)

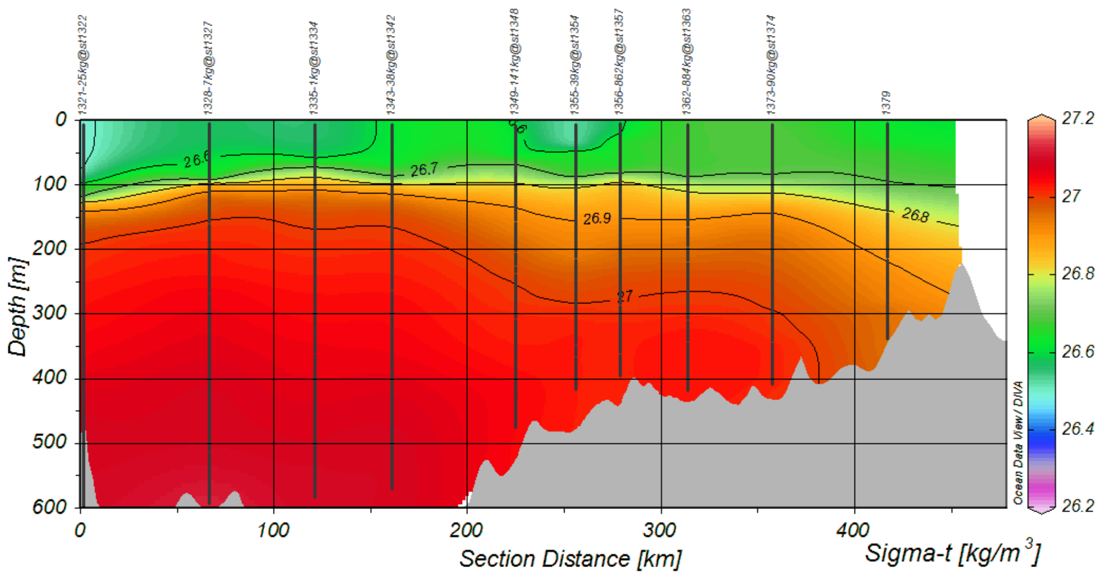


Figure 2.7 Deepest water section (Density)

In Figure 2.8 below temperature and absolute salinity have been plotted to show the profile of all the stations. The stations adjacent to trawls where more than 500 kg of *Illex* were caught had a similar profile, (except CTD stations 1299 and 1303 which were in shallower water). The base of these profiles is highlighted in both scatter plots and there are a number of stations in the poor catch plot that show similar profiles to the better catch stations, which suggests that although the salinity, temperature and density are important, there are factors other than the oceanography that are affecting the catch.

The 2 shallower trawls seabed condition is highlighted by the 2 marker lines. Station 1299 is on the right and 1303 is on the left. Of the 2 shallower stations 1299 follows the general required profiles but is not sufficiently deep to reach the temperature salinity highlighted by the polygon.

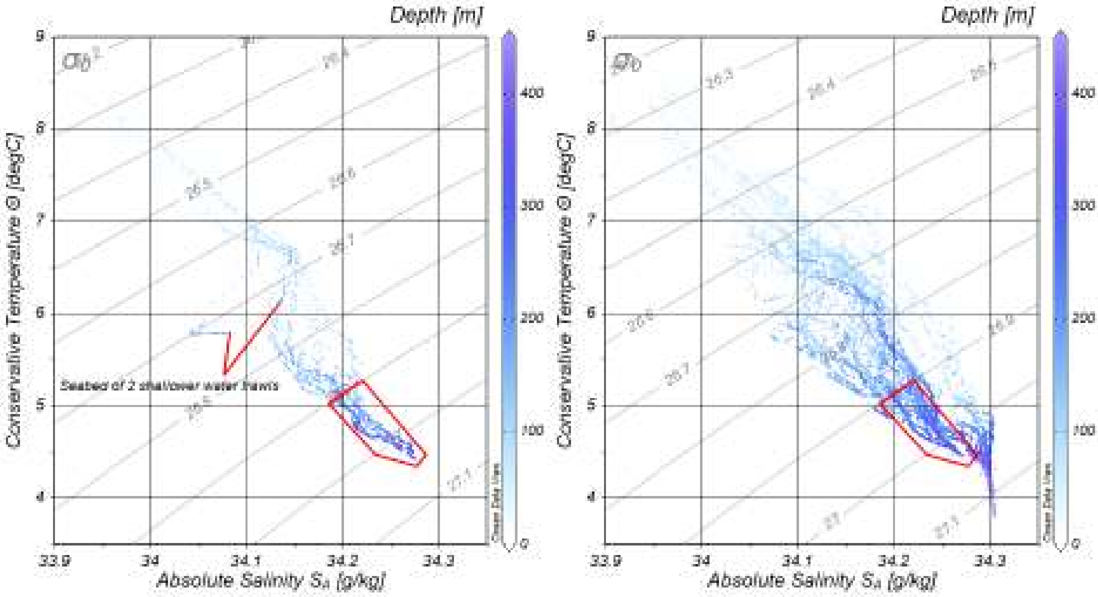


Figure 2.8 Temperature density plots for station with catches over 500kg on left and under 500kg on right

3 Biological Sampling

3.1 Catch and by-catch

Semi-pelagic trawling was conducted at 44 stations and a further one station (st. 1368) partially pelagic, as shown in Figure 3.1. Seabed trawling times during the survey was a mixture of either 60 (18 stations) or 120 minutes (27 stations).

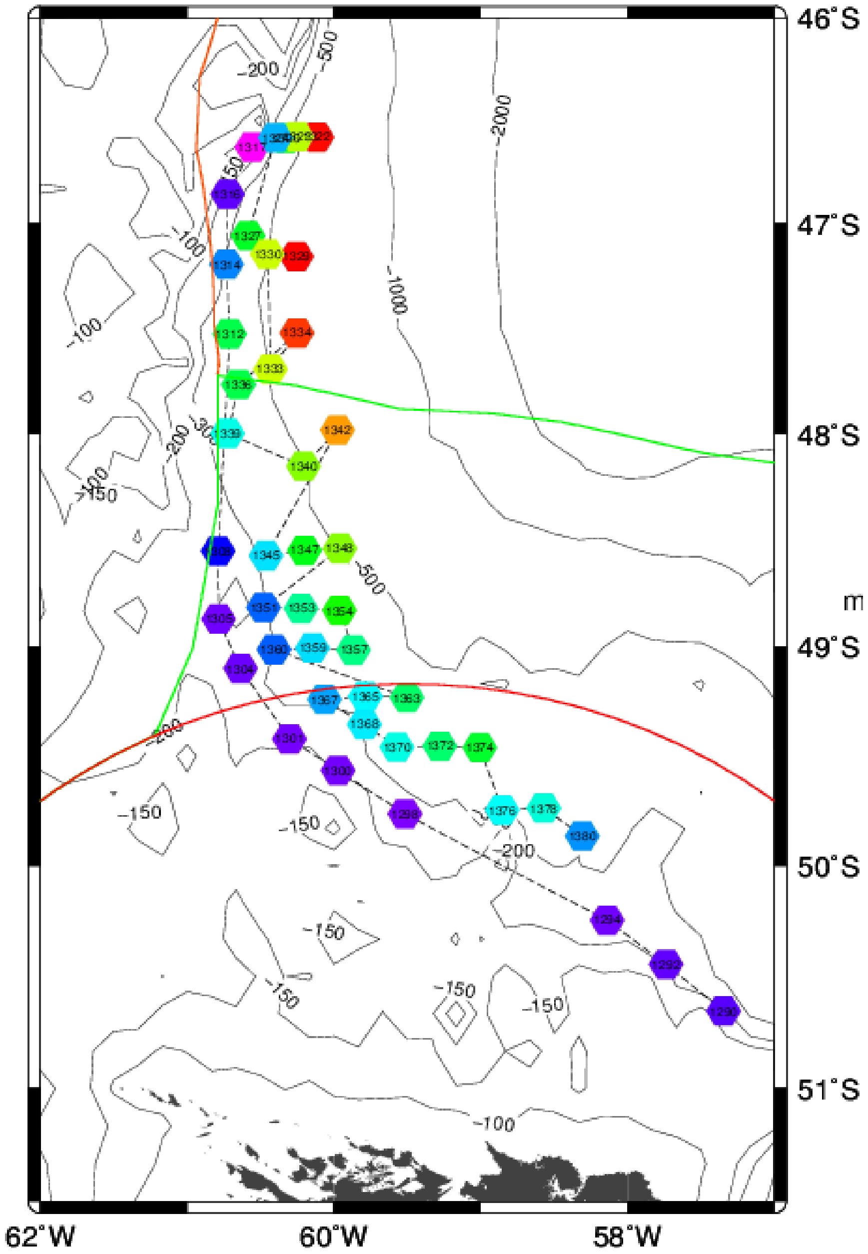


Figure 3.1: Location of biological stations made by semi-pelagic trawl during the survey.

During the cruise a total of 41,494kg of biomass was caught comprising 100 species or taxa (Table 3.1). The largest catches by weight were the Argentine shortfin squid (*Illex argentinus*) and Medusae (most likely *Chrysaora* sp.), together 76.1% of the total, followed by Patagonian longfin squid (*Doryteuthis gahi*), the common rock cod (*Patagonotothen ramsayi*), the grey tail skate (*Bathyraja griseocauda*) and the common hake (*Merluccius hubbsi*), altogether amounting to 94.7% of the total catch.

Table 3.1: Total catch of trawl stations during research cruise

Species Code	*Species name*	*Total Catch (kg)*	*Total Sampled (kg)*	*Total Discarded (kg)*	*Proportion (%)*
ILL	*Illex argentinus*	18,603.600	1,342.950	900.770	44.83%
CHR	*Chrysaora sp.*	12,987.160	0.000	12,987.160	31.30%
LOL	*Loligo gahi*	3,521.746	233.976	249.116	8.49%
PAR	*Patagonotothen ramsayi*	1,894.760	513.460	1,894.320	4.57%
RGR	*Bathyraja griseocauda*	1,280.590	1,280.590	3.240	3.09%
HAK	*Merluccius hubbsi*	1,010.738	833.978	0.000	2.44%
GRC	*Macrourus carinatus*	278.660	252.291	129.590	0.67%
SPN	Porifera	266.222	0.000	266.222	0.64%
RBZ	*Bathyraja cousseauae*	256.900	256.900	1.280	0.62%
BLU	*Micromesistius australis*	211.108	108.528	211.108	0.51%
RBR	*Bathyraja brachyurops*	112.670	102.850	8.740	0.27%
TOO	*Dissostichus eleginoides*	102.180	102.180	3.630	0.25%
RAL	*Bathyraja albomaculata*	94.040	93.220	36.860	0.23%
GYN	*Gymnoscopelus nicholsi*	91.267	2.795	90.237	0.22%
RSC	*Bathyraja scaphiops*	81.220	80.490	11.280	0.20%
EEL	*Iluocoetes fimbriatus*	80.230	15.590	80.230	0.19%
RMU	*Bathyraja multispinis*	66.050	66.050	0.000	0.16%
BAC	*Salilota australis*	61.690	42.640	44.200	0.15%
PSA	*Pseudoxenomystax albescens*	50.780	43.590	50.780	0.12%
COT	*Cottunculus granulosus*	46.395	0.005	46.395	0.11%
POR	*Lamna nasus*	45.420	45.420	45.420	0.11%
WHI	*Macruronus magellanicus*	44.410	35.290	32.710	0.11%
KIN	*Genypterus blacodes*	29.930	23.640	0.000	0.07%
ING	*Moroteuthis ingens*	27.080	3.680	25.950	0.07%
RDO	*Amblyraja doellojuradoi*	25.940	25.940	25.790	0.06%
RMC	*Bathyraja macloviana*	25.688	25.528	20.108	0.06%
DGS	*Squalus acanthias*	21.710	20.860	21.710	0.05%
GYB	*Gymnoscopelus bolini*	19.621	18.881	18.991	0.05%
RFL	*Zearaja chilensis*	14.820	2.500	9.990	0.04%
MUE	*Muusoctopus eureka*	14.680	3.960	8.250	0.04%
STA	*Sterechinus agassizi*	13.721	0.000	13.721	0.03%
HYD	Hydrozoa	13.540	0.000	13.540	0.03%
RDA	*Dipturus argentinensis*	12.800	12.800	1.760	0.03%
PMC	*Protomictophum choriodon*	11.934	1.680	11.934	0.03%
CAS	*Campylonotus semistriatus*	11.308	1.170	4.558	0.03%
PGR	*Paradiplospinus gracilis*	6.540	6.480	6.540	0.02%
EGG	Eggmass	6.200	0.000	6.200	0.01%
CGO	*Cottoperca gobio*	5.180	0.000	5.180	0.01%
GRF	*Coelorhynchus fasciatus*	4.570	2.090	4.570	0.01%
RED	*Sebastes oculatus*	3.950	3.950	0.000	0.01%
ANG	*Anthoptilum grandiflorum*	3.416	0.000	3.416	0.01%
MMA	*Mancopsetta maculata*	3.142	3.142	3.142	0.01%
MYF	*Myxine fernholmi*	3.110	0.000	3.110	0.01%
DGH	*Schroederichthys bivius*	2.830	0.000	2.830	0.01%
PYM	*Physiculus marginatus*	2.556	1.461	2.556	0.01%
ANM	Anemone	2.372	0.000	2.372	0.01%
ICA	*Icichthys australis*	2.188	1.528	2.188	0.01%
MED	Medusae	1.870	0.000	1.870	<0.01%
SYB	*Symbolophorus boops*	1.610	1.570	1.610	<0.01%
SQT	Ascidiacea	1.560	0.000	1.560	<0.01%
MUO	*Muraenolepis orangiensis*	1.480	1.480	1.480	<0.01%

CAM	*Cataetyx messieri*	1.180	1.180	1.180	<0.01%
AUC	*Austrocidaris canaliculata*	0.935	0.000	0.935	<0.01%
ADA	*Adelomelon ancilla*	0.870	0.000	0.870	<0.01%
ARR	*Arctozenus risso*	0.810	0.570	0.810	<0.01%
THB	*Thymops birsteini*	0.660	0.000	0.280	<0.01%
SER	*Serolis spp.*	0.654	0.000	0.654	<0.01%
MAM	*Mancopsetta milfordi*	0.620	0.620	0.620	<0.01%
RPX	*Psammobatis spp.*	0.620	0.000	0.620	<0.01%
ELS	*Electrona subaspera*	0.564	0.564	0.564	<0.01%
THO	Thouarellinae	0.550	0.000	0.550	<0.01%
MUG	*Munida gregaria*	0.514	0.000	0.514	<0.01%
FUM	*Fusitriton m. magellanicus*	0.490	0.000	0.490	<0.01%
ELE	*Eledoninae-like octopod*	0.400	0.400	0.000	<0.01%
MLA	*Muusoctopus longibrachus akambei*	0.320	0.000	0.000	<0.01%
UCH	*Sea urchin*	0.300	0.000	0.300	<0.01%
GON	*Gonatus antarcticus*	0.293	0.293	0.288	<0.01%
COP	*Congiopodus peruvianus*	0.260	0.260	0.260	<0.01%
NUD	Nudibranchia	0.193	0.000	0.193	<0.01%
AST	Asteroidea	0.187	0.000	0.187	<0.01%
BAO	*Bathybiaster loripes*	0.170	0.000	0.170	<0.01%
GRN	*Graneledone yamana*	0.162	0.060	0.102	<0.01%
POA	*Porania antarctica*	0.125	0.000	0.120	<0.01%
PMX	*Protomictophum spp.*	0.110	0.000	0.110	<0.01%
ZYP	*Zygochlamys patagonica*	0.110	0.000	0.110	<0.01%
PEN	Pennatulacea	0.060	0.000	0.060	<0.01%
PYX	Pycnogonida	0.053	0.000	0.053	<0.01%
NEC	*Neorossia caroli*	0.040	0.040	0.000	<0.01%
UHH	Heart urchin	0.040	0.000	0.040	<0.01%
PAA	*Pandalopsis ampla*	0.034	0.000	0.000	<0.01%
MOP	*Momonatira paulini*	0.030	0.030	0.000	<0.01%
BRR	*Brachioteuthis riisei*	0.029	0.029	0.004	<0.01%
POL	Polychaeta	0.022	0.000	0.022	<0.01%
SET	Sertularioidae	0.022	0.000	0.022	<0.01%
NEH	*Neomena herwigi*	0.020	0.000	0.020	<0.01%
SOR	*Solaster regularis*	0.020	0.000	0.020	<0.01%
ECC	*Echiodon cryomargarites*	0.015	0.012	0.005	<0.01%
ISO	Isopoda	0.015	0.000	0.015	<0.01%
BAL	*Bathydomus longisetosus*	0.010	0.000	0.010	<0.01%
HCR	Paguroidea	0.010	0.000	0.010	<0.01%
MUU	*Munida subrugosa*	0.008	0.000	0.008	<0.01%
ACY	*Armadillogorgia cyathella*	0.006	0.000	0.006	<0.01%
GAG	*Galiteuthis glacialis*	0.005	0.005	0.000	<0.01%
HIE	*Histioteuthis eltarinae*	0.005	0.005	0.000	<0.01%
DIA	*Diaulula spp.*	0.005	0.000	0.005	<0.01%
HOL	Holothuroidea	0.005	0.000	0.005	<0.01%
ODP	*Odontaster pencillatus*	0.005	0.000	0.005	<0.01%
PLU	Primnoellinae	0.005	0.000	0.005	<0.01%
OPH	Ophiuroidea	0.002	0.000	0.002	<0.01%
PRI	Priapulida	0.002	0.000	0.002	<0.01%
		41,494.747	**5,619.201**	**17,276.460**	

Table 3.2 lists numbers of specimens analysed from randomly collected samples. 170 specimens of three squid species had their statoliths extracted. 948 otoliths were extracted of 16 different fish species.

Table 3.2: Random samples

Code	Name	Number Sampled	
LOL	*Loligo gahi*	4,564	32.4%
PAR	*Patagonotothen ramsayi*	2,672	19.0%
ILL	*Illex argentinus*	2,624	18.6%
BLU	*Micromesistius australis*	1,298	9.2%
HAK	*Merluccius hubbsi*	739	5.2%
GRC	*Macrourus carinatus*	579	4.1%
GYB	*Gymnoscopelus bolini*	277	2.0%
RGR	*Bathyraja griseocauda*	215	1.5%
PGR	*Paradiplospinus gracilis*	202	1.4%
BAC	*Salilota australis*	169	1.2%
EEL	*Iluocoetes fimbriatus*	104	0.7%
PSA	*Pseudoxenomystax albescens*	84	0.6%
RAL	*Bathyraja albomaculata*	63	0.4%
WHI	*Macruronus magellanicus*	51	0.4%
RBZ	*Bathyraja cousseauae*	51	0.4%
RSC	*Bathyraja scaphiops*	40	0.3%
SYB	*Symbolophorus boops*	38	0.3%
PYM	*Physiculus marginatus*	37	0.3%
TOO	*Dissostichus eleginoides*	34	0.2%
RBR	*Bathyraja brachyurops*	33	0.2%
RDO	*Amblyraja doellojuradoi*	32	0.2%
ICA	*Icichthys australis*	26	0.2%
RMC	*Bathyraja macloviana*	25	0.2%
ELS	*Electrona subaspera*	23	0.2%
KIN	*Genypterus blacodes*	22	0.2%
MMA	*Mancopsetta maculata*	15	0.1%
DGS	*Squalus acanthias*	14	0.1%
ARR	*Arctozenus risso*	12	0.1%
RMU	*Bathyraja multispinis*	12	0.1%
CAM	*Cataetyx messieri*	9	0.1%
RED	*Sebastes oculatus*	4	0.0%
MUO	*Muraenolepis orangiensis*	3	0.0%
RDA	*Dipturus argentinensis*	3	0.0%
GYN	*Gymnoscopelus nicholsi*	2	0.0%
GRF	*Coelorhynchus fasciatus*	2	0.0%
ECC	*Echiodon cryomargarites*	1	0.0%
COT	*Cottunculus granulosus*	1	0.0%
COP	*Congiopodus peruvianus*	1	0.0%
RFL	*Zearaja chilensis*	1	0.0%
MOP	*Momonatira paulini*	1	0.0%
		14,083	

3.2 Squids

3.2.1 Illex argentinus

Illex argentinus were caught at 43 of 45 stations during the research cruise (Figure 3.2). At stations where *Illex* were caught, the catch ranged 0.42-7281 kg and CPUE ranged 0.3-3641 kg.h^{-1}. *Illex* squids were found to be more abundant in the north of the studied area and between 48.5-49.5°S and 59.5°-61°W. In these 2 zones, three stations (one in the north and the two others around 49°S) showed the highest abundances (>2000 kg.h^{-1}). Between these 2 zones, moderate abundances are observed west (i.e. in the shallower waters). Squids were practically absent at stations south of 49.5°S.

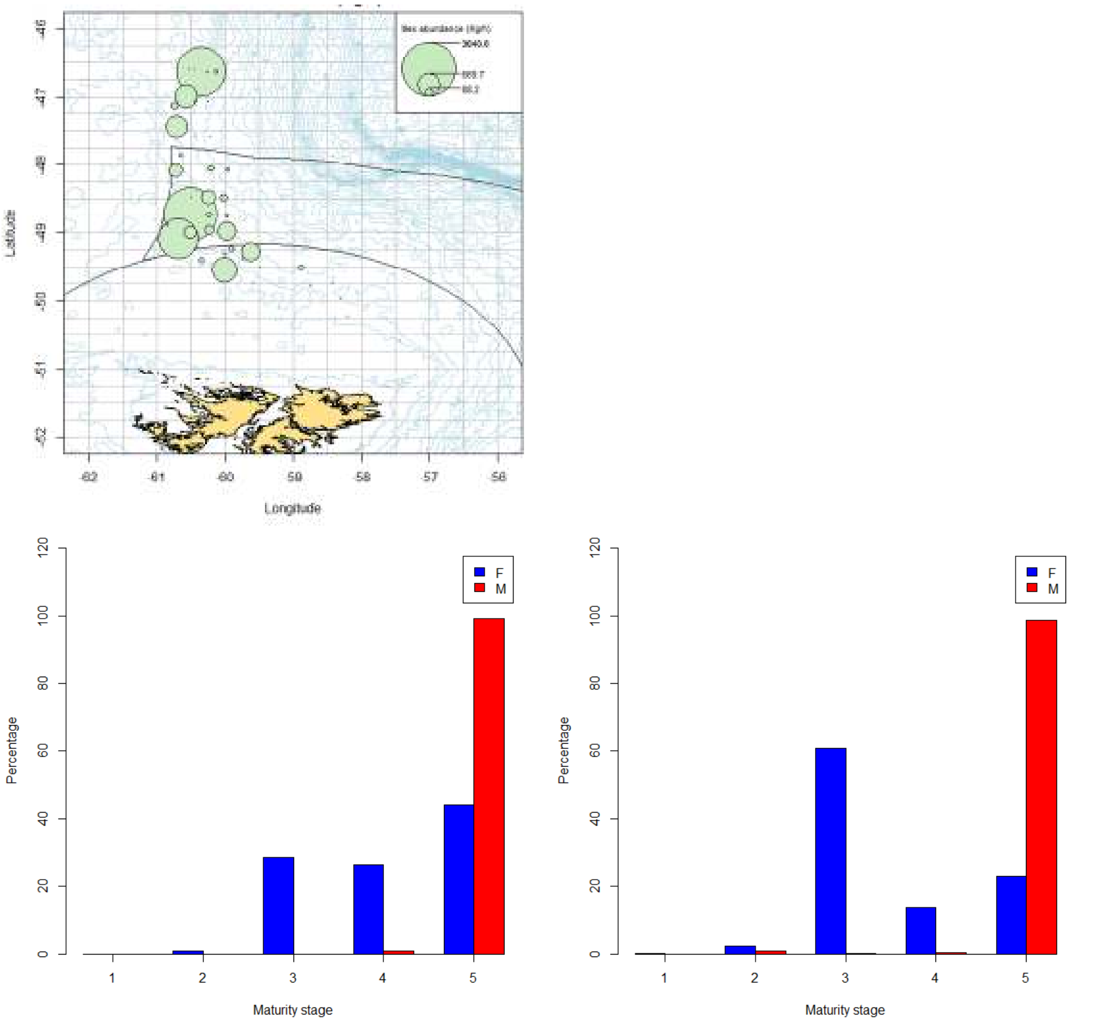


Figure 3.2 : Map of *Illex argentinus* CPUE (top left). Maturity stage percentage of *Illex argentinus* females and males sampled in the catch undertaken north to 48°S (bottom left) and south to 48°S (bottom right)

All *Illex argentinus* sampled belonged to early-maturing South Patagonian Stock with almost all males being at maturity stage 5. It is known that upon maturation *I. argentinus* move northwards from their feeding grounds to spawning grounds. Therefore in the northern part of the survey more females (63%) were mature (stages 4 and 5), whereas in the southern part of the survey ~60% of females were still maturing (maturity stage 3) (Figure 3.2).

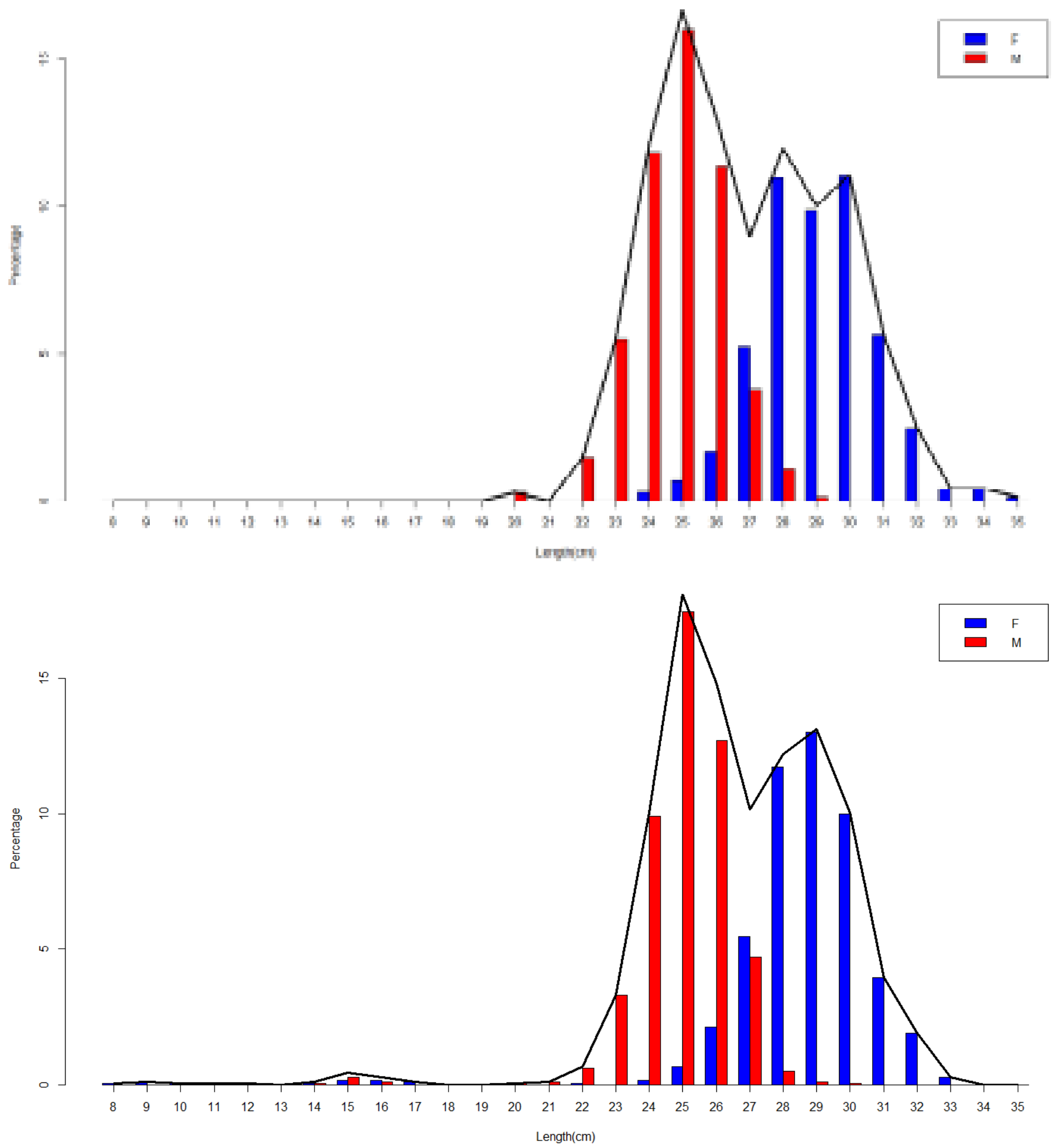


Figure 3.3: Length frequency distribution of *Illex argentinus* females and males sampled in the catch undertaken north to 48°S (top) and south to 48°S (bottom)

Sizes of *I. argentinus* in the northern and southern parts of the survey were practically the same (Figure 3.3), with 25-cm modal group of males and 28-30 modal group of females.

3.2.2 *Doryteuthis gahi*

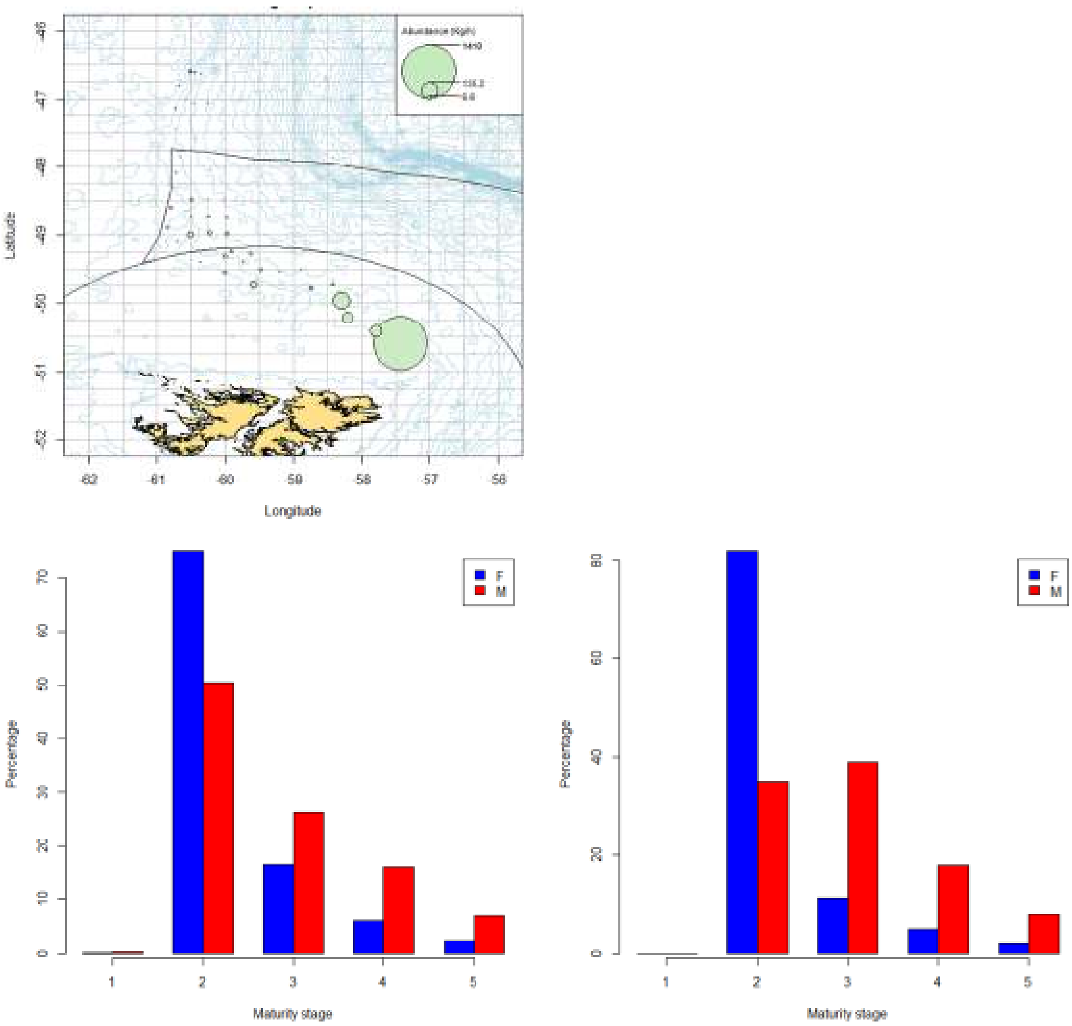


Figure 3.4 : Map of *Doryteuthis gahi* CPUE (top left). Maturity stage percentage of *Doryteuthis gahi* females and males sampled in the catch undertaken north to 49.5°S (bottom left) and south to 49.5°S (bottom right)

Doryteuthis (Loligo) gahi were caught almost at every station during the survey, albeit in low numbers everywhere apart from the southernmost station located just to the north of *Loligo* Box (Figure 3.4).

Sizes of *D. gahi* were the same across the whole surveyed region (Figure 3.5), with modal sizes in females of 12 cm ML and modal sizes in males of 12-13 cm ML. All squid sampled belonged to the autumn-spawning cohort, with ~10% of mature females and 20% of mature males. The rest of squid were either immature or maturing (Figure 3.4).

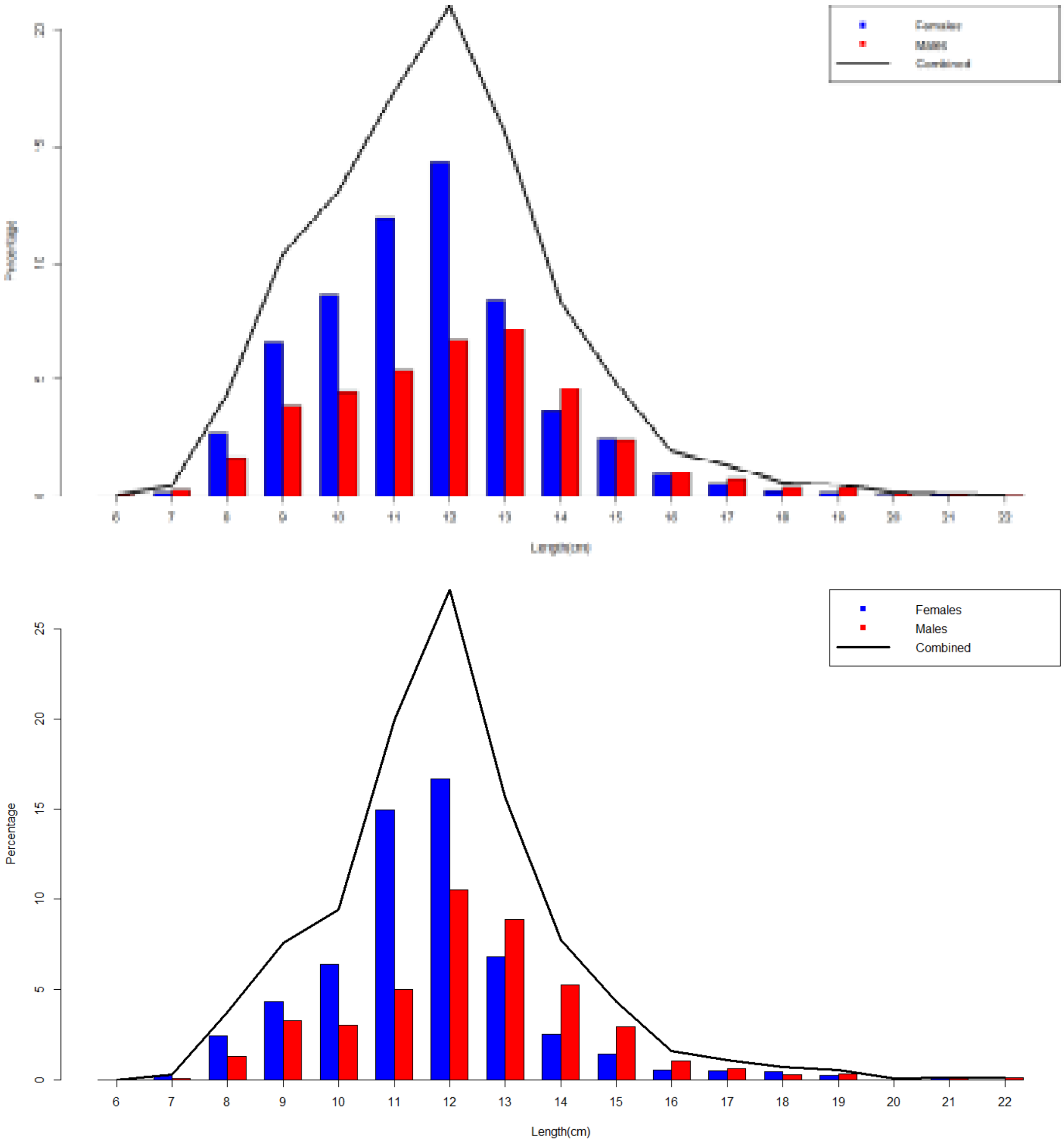


Figure 3.5: Length frequency distribution (top right) of *Doryteuthis gahi* females and males sampled in the catch undertaken north to 49.5°S (top) and south to 49.5°S (bottom).

3.3 Finfish

3.3.1 Rock cod (PAR; *Patagonotothen ramsayi*)

Rock cod was the fourth species in terms of total catch (1895 kg accounting for less than 5% of the total catch). CPUE ranged 0.37-510 $kg.h^{-1}$. The highest CPUE was observed in one of the southern station of the surveyed area (Figure 3.6). A total of 2672 specimens were sampled (1486 females and 1186 males) from the southern area. North of the 50°S, 2503 fishes were sampled (1410 females and 1093 males). Length frequency distribution (Figure 3.7) ranges 11-40 cm and with some modes present (23, 25, 27 cm). Females were generally more numerous than males in each length class. A majority of specimens were at maturity stages 2, 3 or 4 and a few were at stages 1 or 5 (Figure 3.6). South of the 50°S, 169 specimens (76 females and 93 males) were sampled in the catch of two stations. Length frequency distribution (Figure 3.7) ranged 15-38 cm with modes identified at 22, 25, 27 and 30 cm. The prevalent maturity stage was stage 2 (males) and 3 (females). Few males were found to be at stages 1 and 8 (Figure 3.6).

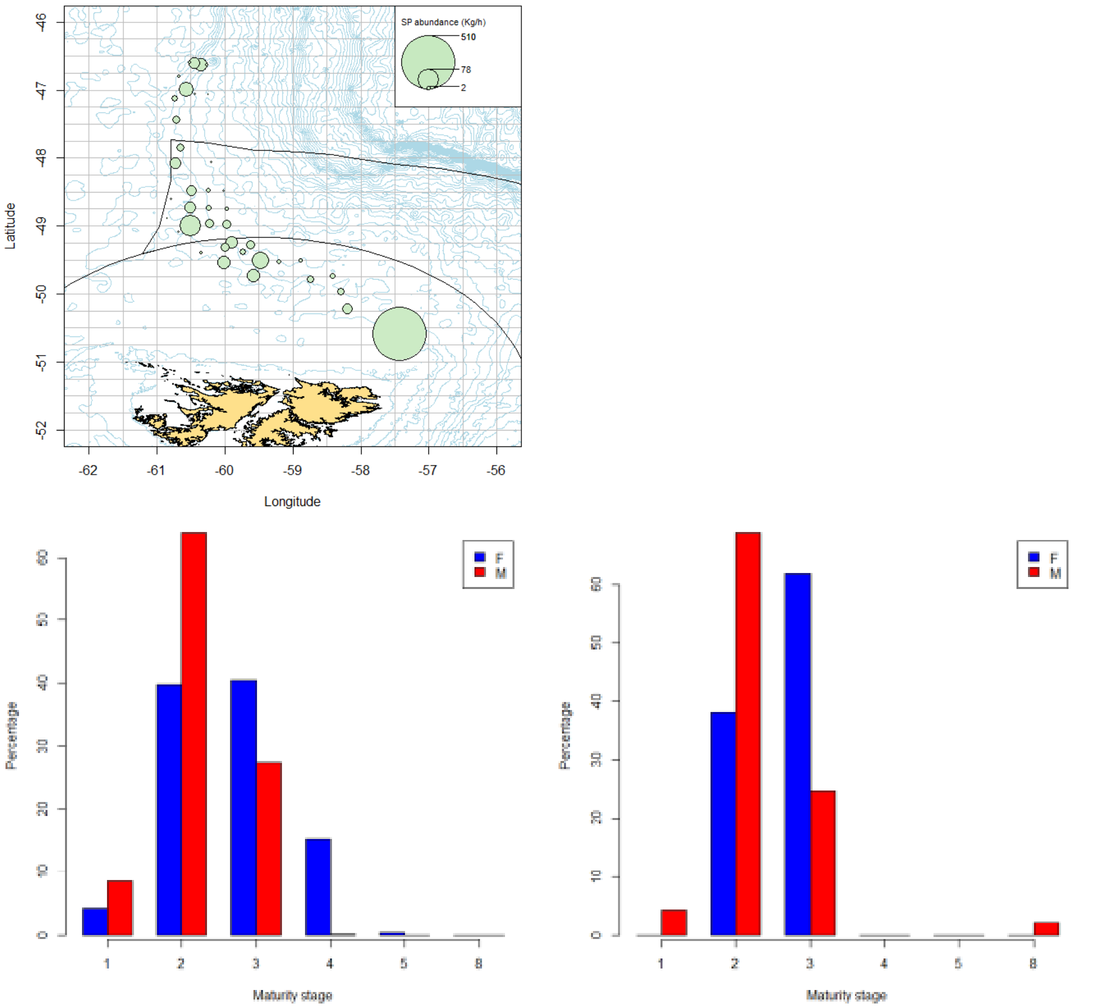


Figure 3.6: Map of Rock Cod CPUE (top left). Maturity stage percentage of Rock Cod females and males sampled in the catch undertaken north to 50°S (bottom left) and south to 50°S (bottom right).

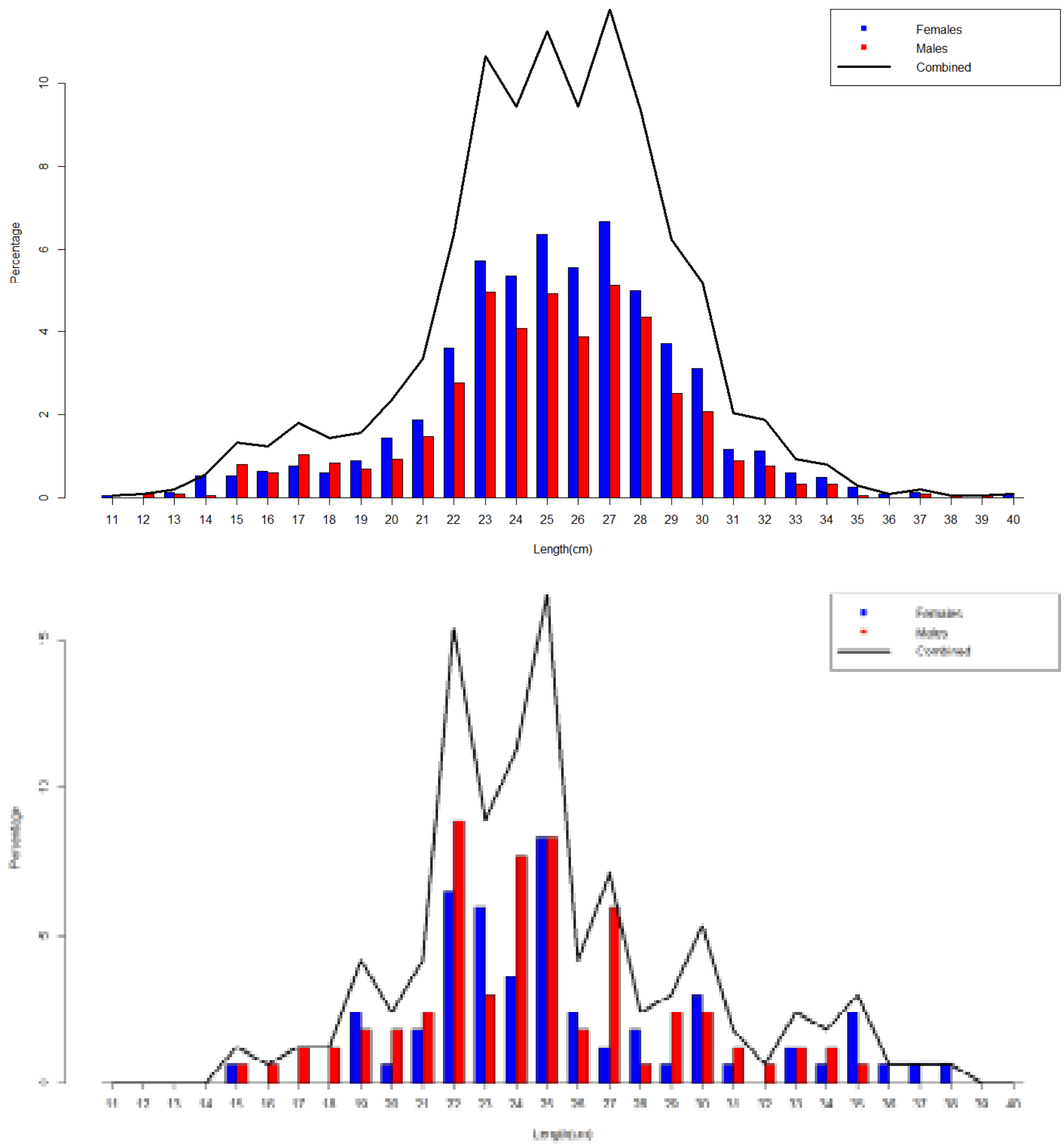


Figure 3.7: Length frequency distribution of Rock Cod females and males sampled in the catch undertaken north to 50°S (top) and southth to 50°S (bottom).

3.3.2 Southern Blue Whiting (BLU; *Micromesistius australis*)

Southern Blue Whiting (SBW) was the tenth species in terms of total catch (211 kg accounting for about 0.5% of the total catch). CPUE ranged 0.02-15.8 kg.h^{-1}. Low CPUE were observed (Figure 3.8) in the northern and in the very southern part of the studied area while stations with high CPUE were more numerous in the southern part of the survey. From the total catch, 1298 specimens were sampled (586 females and 710 males, 1 juvenile and 1 undetermined). Length frequency distribution ranged between 15-32 cm, most specimens ranging 22-27 cm. Males were slightly more abundant than females in each length class. The majority of animals were found to be either at maturity stage 1 (males) or 2 (females) and a very few males were at stage 3.

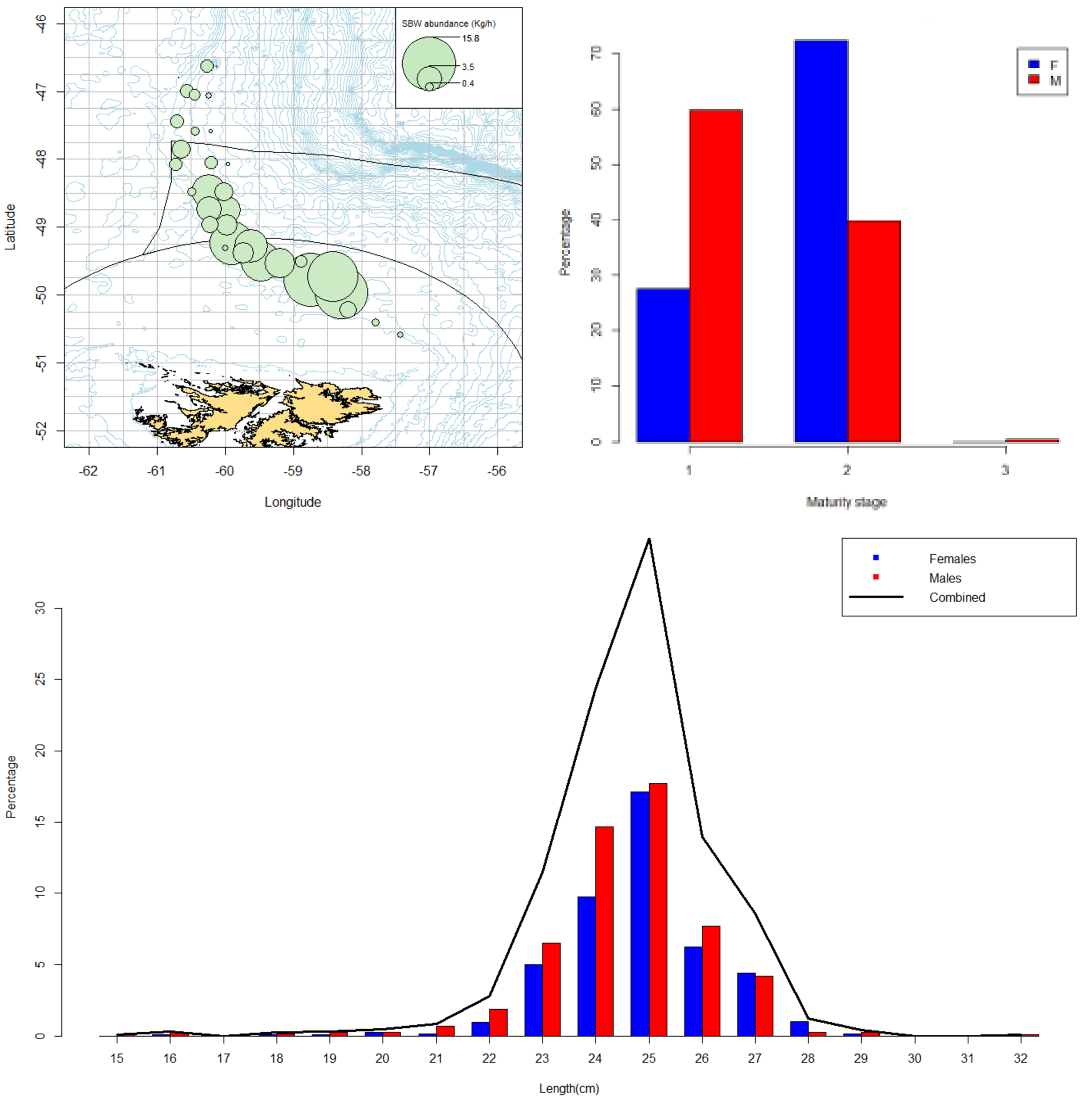


Figure 3.8: Map of Southern Blue Whiting CPUE (top left). Length frequency distribution (bottom) and maturity stage percentage (top right) of Southern Blue Whiting females and males sampled in the catch.

3.3.3 Hake (HAK; *Merluccius hubbsi*)

Hake was the sixth species in terms of total catch (1011 kg accounting for less than 2.5% of the total catch). CPUE ranged 0.64-177.3 kg.h^{-1}. Highest abundances were observed south to 50°S and moderate abundances were observed between 49°S and 50°S (Figure 3.10). North to 49°S, hakes were caught in several stations but in low numbers. Length frequency distribution ranged between 34-82 cm (Figure 3.10). Males, with a maximum size of 48 cm, were much smaller than females. Males were found to be at maturity stages 3 or 7 and females were mainly at maturity stages 2, 3 or 8, with some animals being at stages 4, 6 or 7 (Figure 3.10).

South to 50°S, 236 hakes (225 females and 11 males) were sampled in the catch. Length frequency distribution ranged between 35-84 cm (Figure 3.10). The majority of females were at maturity stage 3 and a very few observed at stages 2, 7 and 8 (Figure 3.9). Males were at stages 4, 6, 7 and 8.

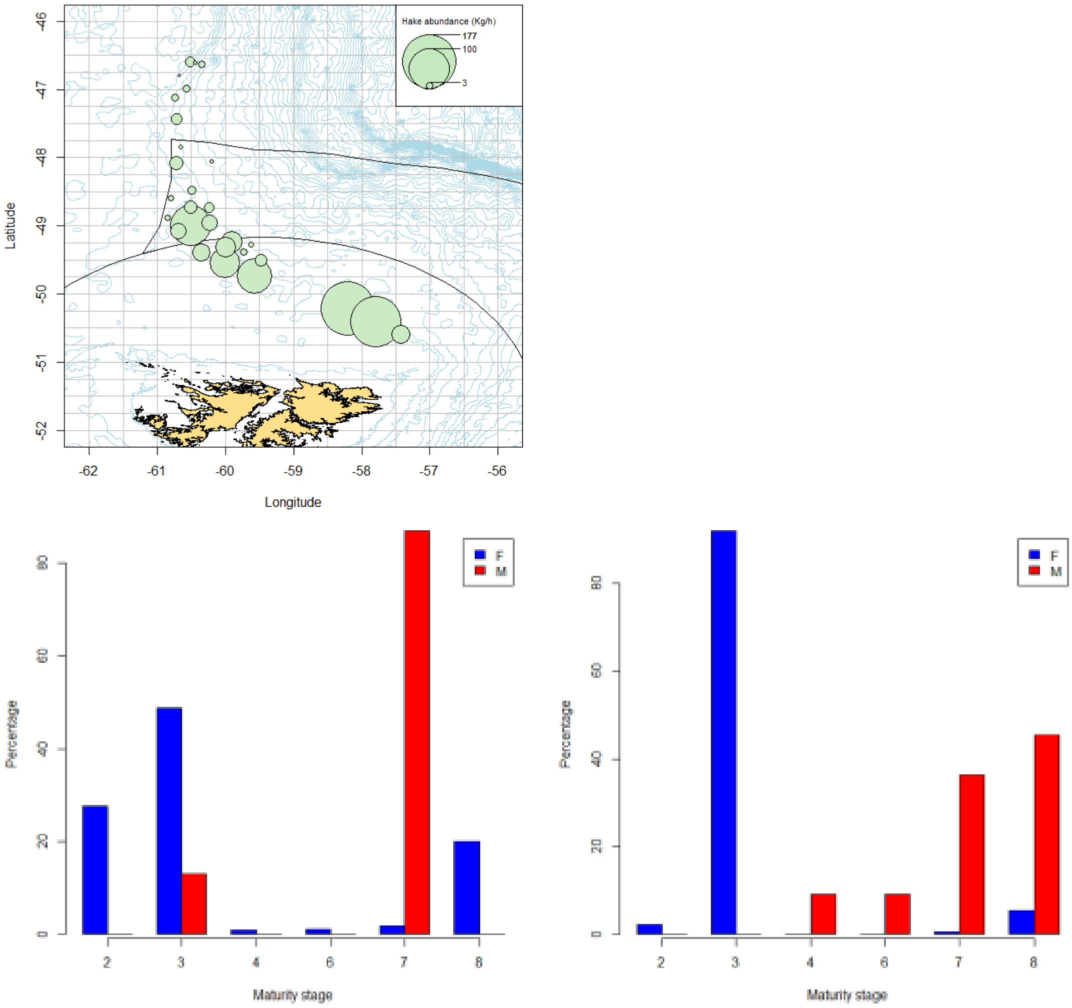
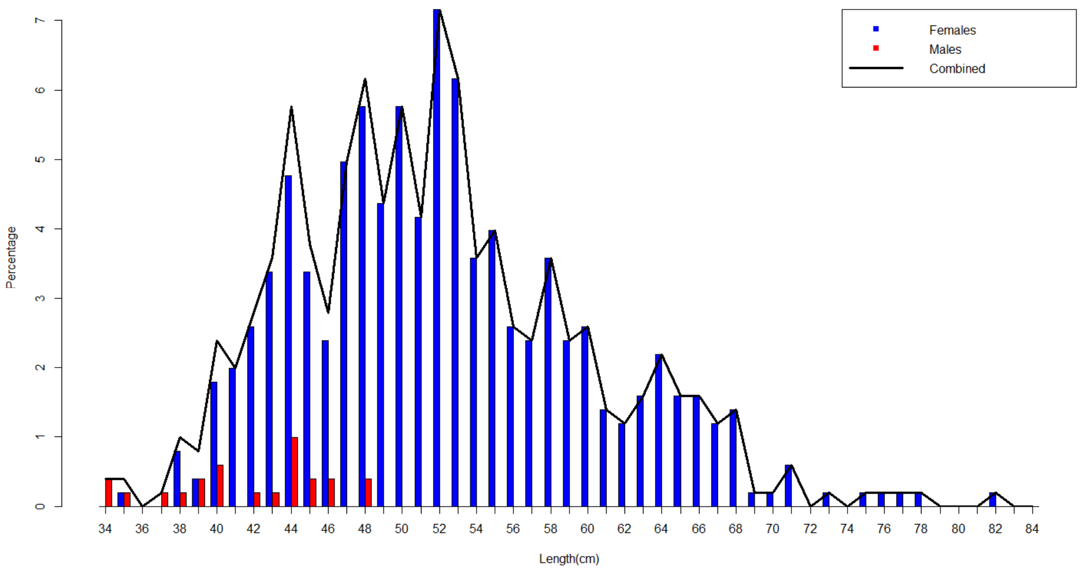


Figure 3.9: Map of Hake CPUE (top left). Maturity stage percentage of Hake females and males sampled in the catch undertaken north to 50°S (bottom left) and south to 50°S (bottom right)



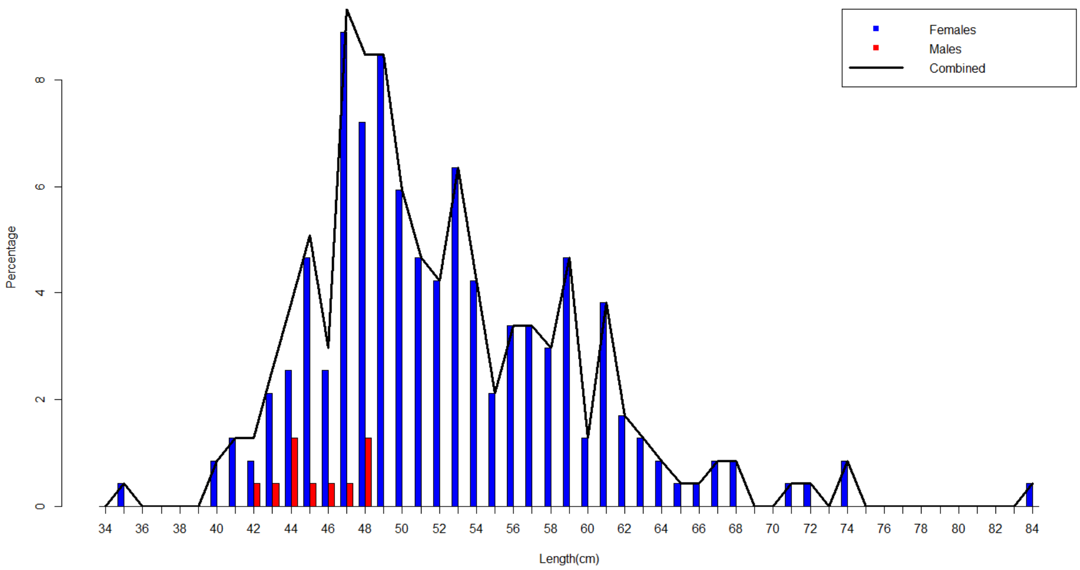


Figure 3.10: Length frequency distribution of Hake females and males sampled in the catch undertaken north to the 50°S (top) and south to 50°S (bottom).

3.3.4 Grenadier (GRC; *Macrourus carinatus*)

Grenadier was the seventh species in terms of total catch (279 kg accounting for less than 0.7% of the total catch). CPUE ranged 0.27-45 kg.h^{-1}, Animals were caught north of 49°S (Figure 3.11). The lowest CPUE are observed close to 49°S while the highest abundances were observed in the north of the studied area. Length frequency distribution (pre-anal length) ranged from 7-26 cm with one mode observed at 18 cm. Males were more numerous than females below the mode and the sex ratio was inverted above the mode. The majority of specimens were found to be at maturity stage 2.

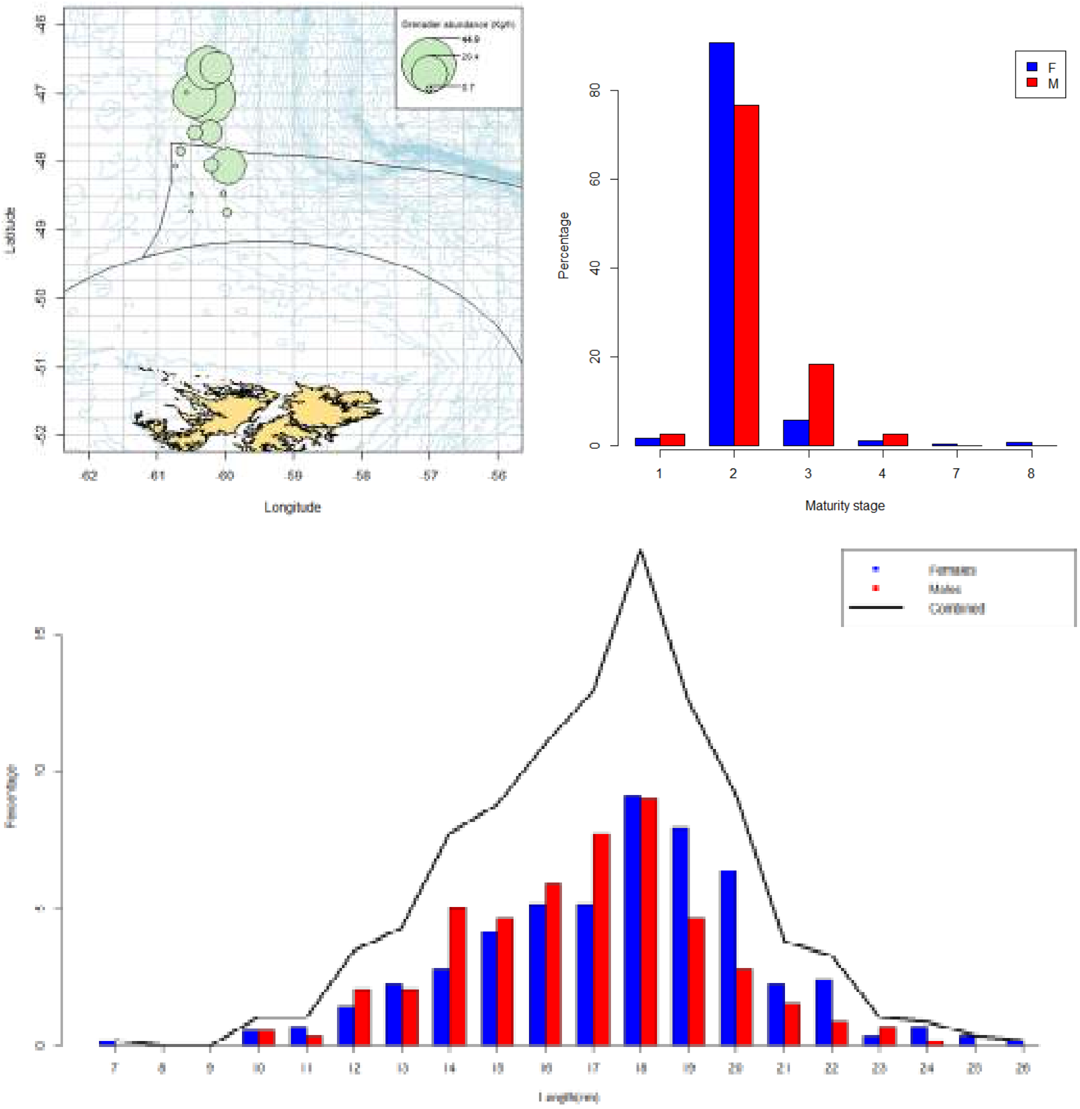


Figure 3.11: Map of Grenadier CPUE (top left). Length frequency distribution (bottom; pre-anal length) and maturity stage percentage (top right) of Grenadier females and males sampled in the catch.

3.3.5 Red cod (BAC; *Salilota australis*)

Red Cod was the seventeenth species in terms of total catch (62 kg accounting for 0.15% of the total catch). CPUE ranged 0.45-17.5 kg.h^{-1} (Red Cod was caught in 7 stations), high abundances were observed south to 49°S (Figure 3.12). Length frequency distribution ranged between 16-76 cm, with the majority of fish ranging between 22-30 cm. Males were more numerous at larger length classes and females slightly more numerous at smaller length classes. A majority of specimens were found to be in maturity stage 2.

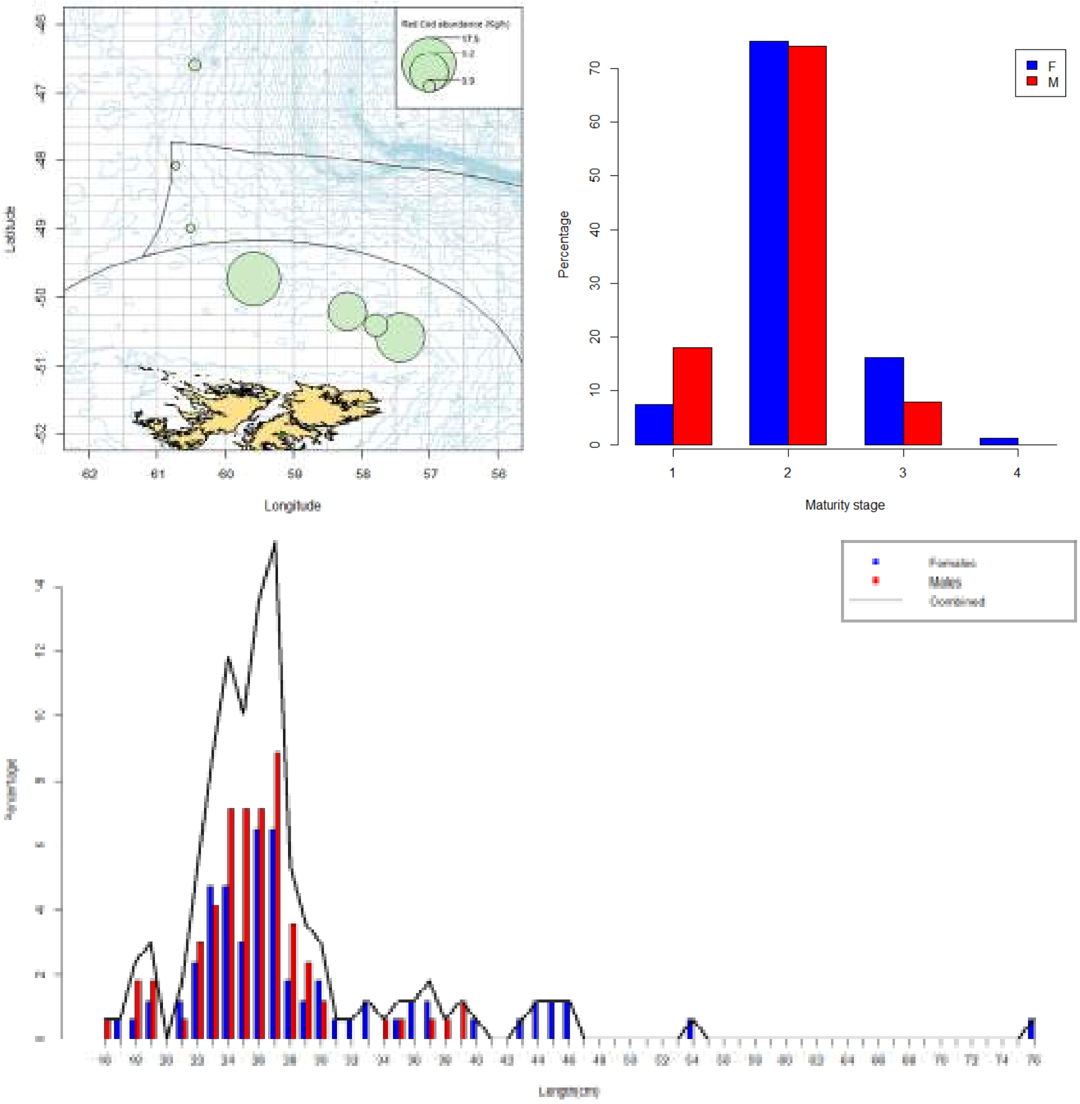


Figure 3.12: Map of Red Cod CPUE (top left). Length frequency distribution (bottom) and maturity stage percentage (top right) of Red Cod females and males sampled in the catch.

3.3.6 Hoki (WHI; *Macruronus magellanicus*)

Hoki was the twenty-first species in terms of total catch (44 kg accounting for 0.11% of the total catch). CPUE ranged 0.17-5 $kg.h^{-1}$. Hoki were encountered everywhere in the area studied, with the highest abundances between 48 and 49.5°S (Figure 3.13). Length frequency distribution (pre-anal length) ranges between 19-36 cm. Males were more abundant in smaller length classes and females were more abundant in large length classes. The majority of specimens were found to be in maturity stage 2.

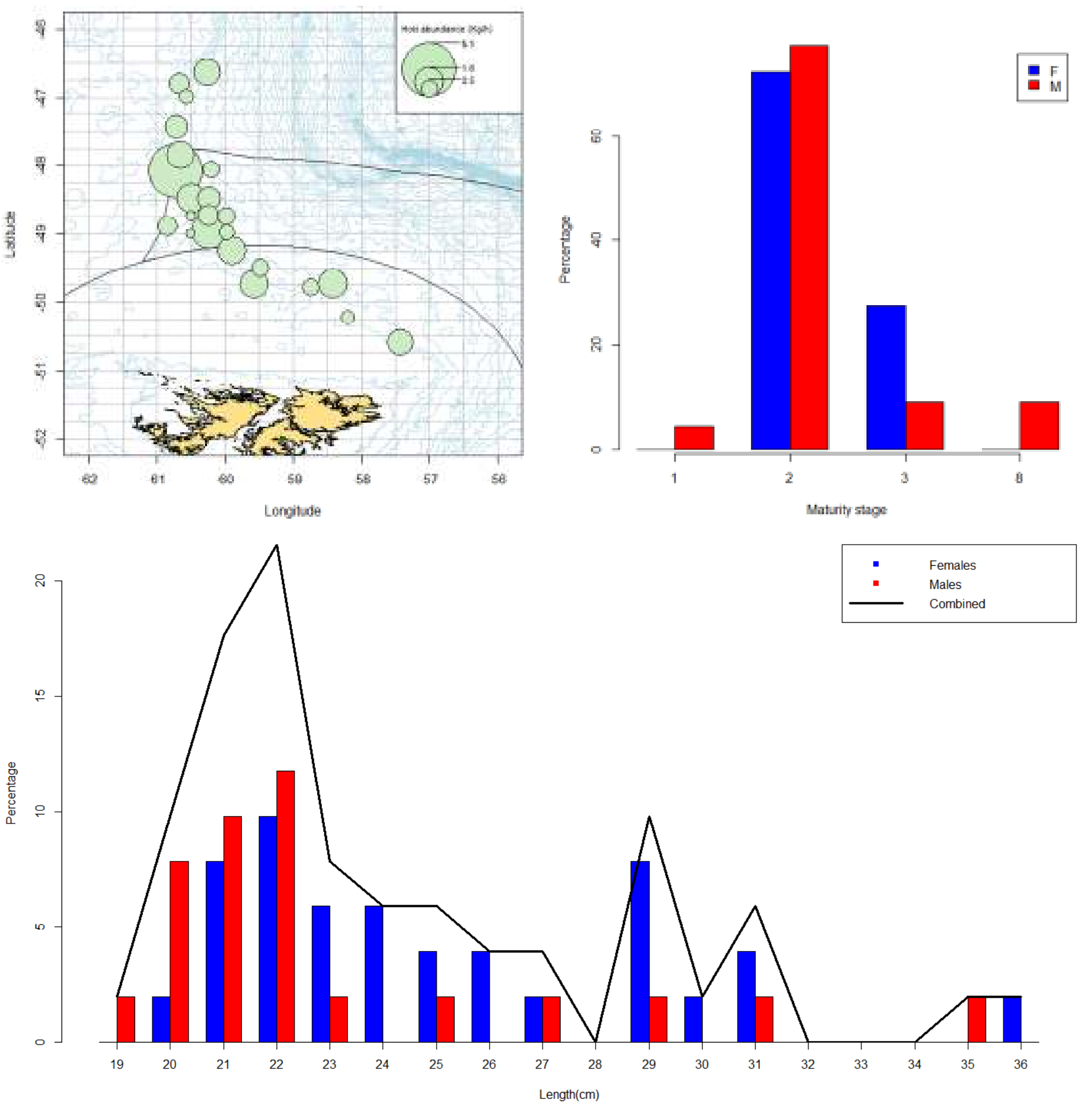


Figure 3.13: Map of Hoki CPUE (top left). Length frequency distribution (bottom; pre-anal length) and maturity stage percentage (top left) of Hoki females and males sampled in the catch.

3.3.7 Toothfish (TOO; *Dissostichus eleginoides*)

Toothfish was the eleventh species in terms of total catch (102 kg accounting for 0.25% of the total catch). CPUE ranged 0.33-11.5 kg.h^{-1}. These fishes were caught north of the 50°S mainly in deep waters (Figure 3.14). Length frequency distribution ranged between 38-104 cm with the majority of fish recorded between 40 and 70 cm. All fishes sampled were immature.

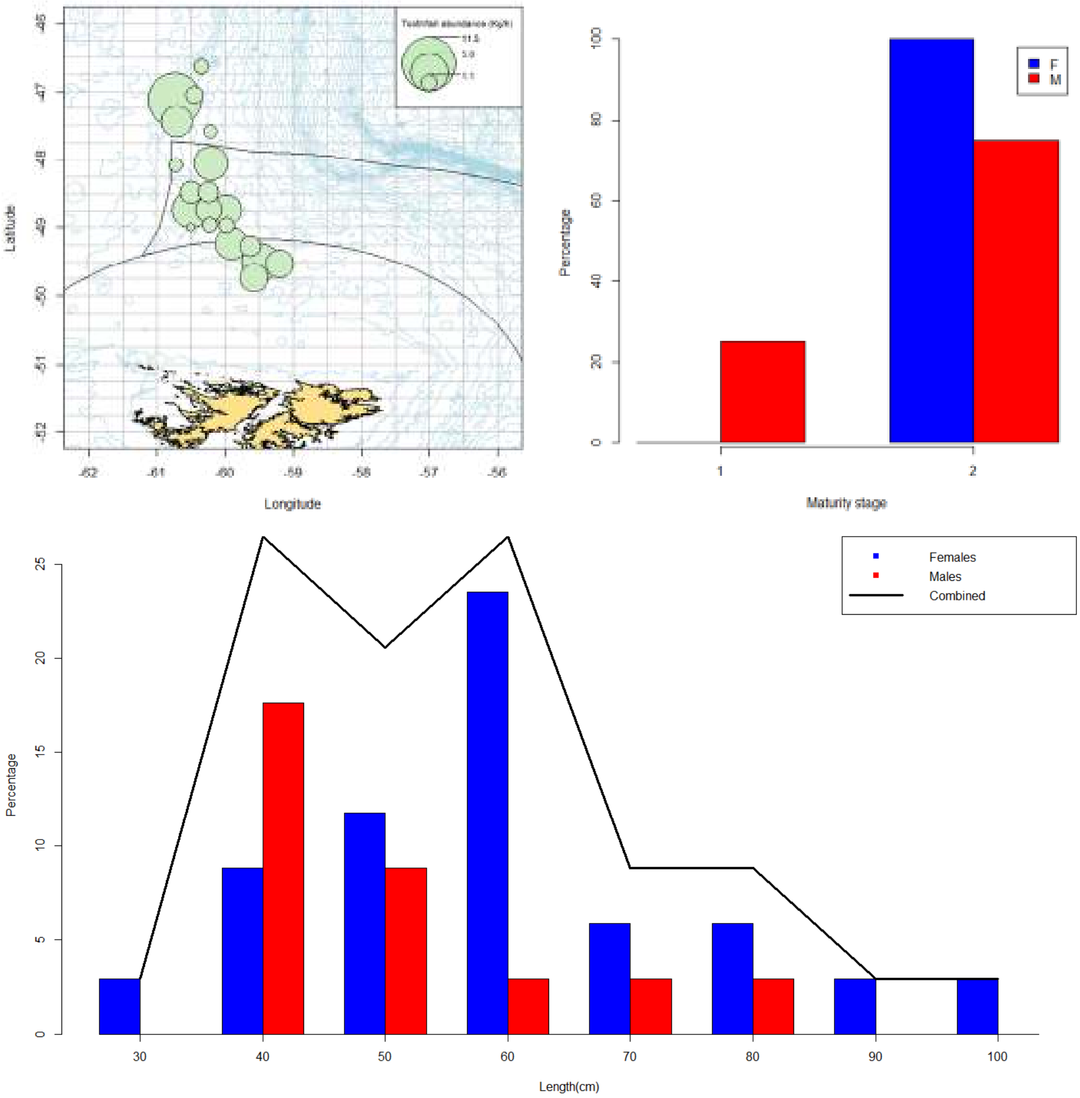


Figure 3.14: Map of Toothfish CPUE (top left). Length frequency distribution (bottom) and maturity stage percentage (top right) of Toothfish females and males sampled in the catch.

3.3.8 Kingclip (KIN; *Genypterus blacodes*)

Kingclip was the twenty-second species in terms of total catch (30 kg accounting for 0.07% of the total catch). CPUE ranged 0.25-8.75 kg.h^{-1} and animals were caught at 10 stations throughout the studied area (Figure 3.15). Length frequency distribution ranged between 49-112 cm, with most fish being immature (stage 2).

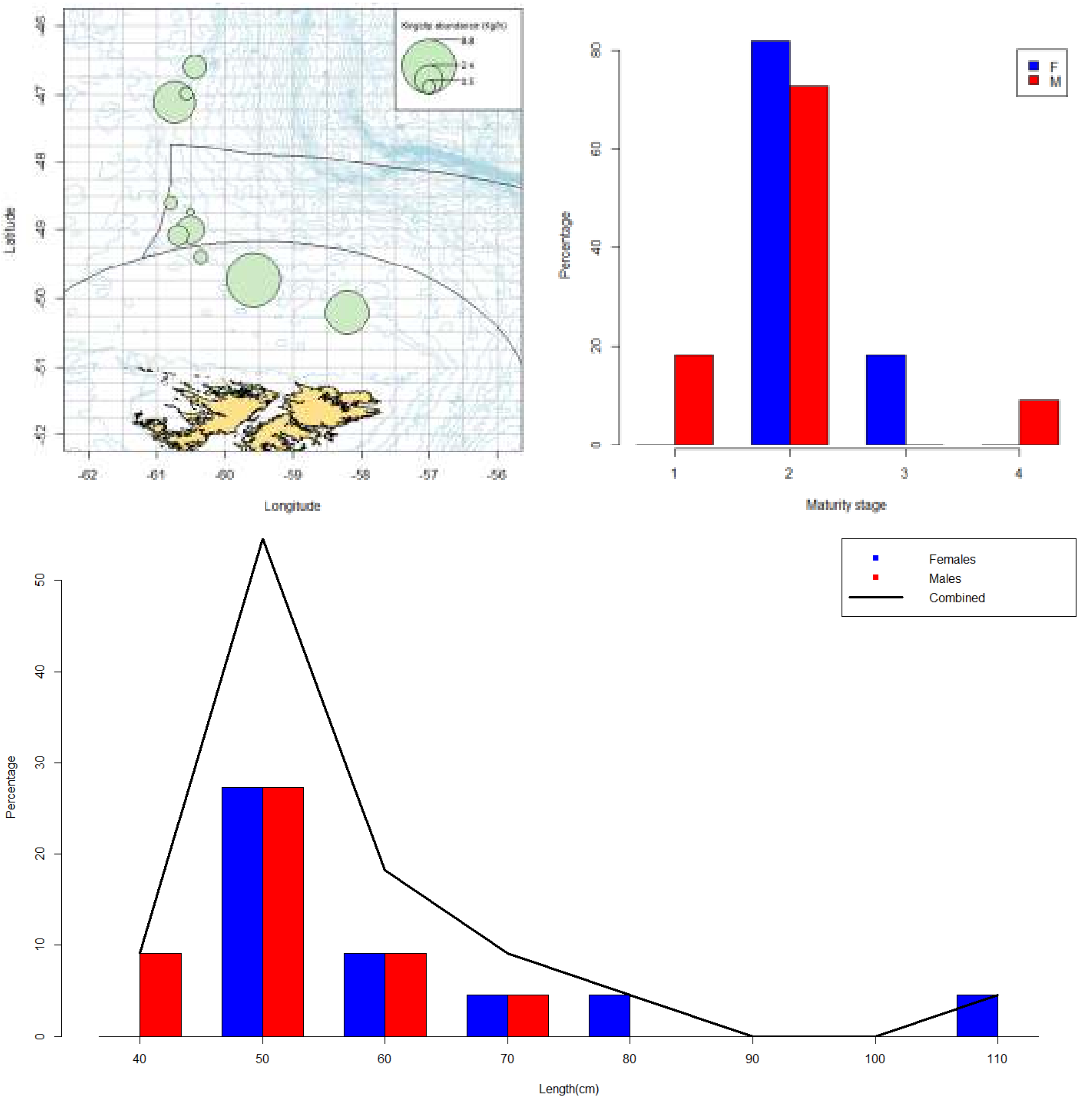


Figure 3.15: Map of Kingclip CPUE (top left). Length frequency distribution (bottom) and maturity stage percentage (top right) of Kingclip females and males sampled in the catch.

3.4 Skates

A total of 11 species of skates belonging to 5 genera (*Amblyraja*, *Bathyraja*, *Dipturus*, *Psammobatis* and *Zearaja*) were caught, comprised just 4.75% of the total catch from the 44 trawl stations, of which 35 yielded skates. Over 26% (521 kg) of the total catch was caught in just one station (st. 1345), with further 5 stations yielding between 119 and 150 kg, and nine stations yielding catches less than 10 kg each (Figure 3.16). *Bathyraja griseocauda* was the most dominant species with 65% of the total skate catch (1,971 kg, Table 3.3).

Table 3.3: Skate catch, ZDLT1-05-2014

Code	Species name	Catch (kg)	Sample (kg)	Discard (kg	%
RGR	*Bathyraja griseocauda*	1,280.590	1,280.590	3.240	64.96%
RBZ	*Bathyraja cousseauae*	256.900	256.900	1.280	13.03%
RBR	*Bathyraja brachyurops*	112.670	102.850	8.740	5.72%
RAL	*Bathyraja albomaculata*	94.040	93.220	36.860	4.77%
RSC	*Bathyraja scaphiops*	81.220	80.490	11.280	4.12%
RMU	*Bathyraja multispinis*	66.050	66.050	0.000	3.35%
RDO	*Amblyraja doellojuradoi*	25.940	25.940	25.790	1.32%
RMC	*Bathyraja macloviana*	25.688	25.528	20.108	1.30%
RFL	*Zearaja chilensis*	14.820	2.500	9.990	0.75%
RDA	*Dipturus argentinensis*	12.800	12.800	1.760	0.65%
RPX	*Psammobatis* spp.	0.620	0.000	0.620	0.03%
		1,971.338	**1,946.868**	**119.668**	

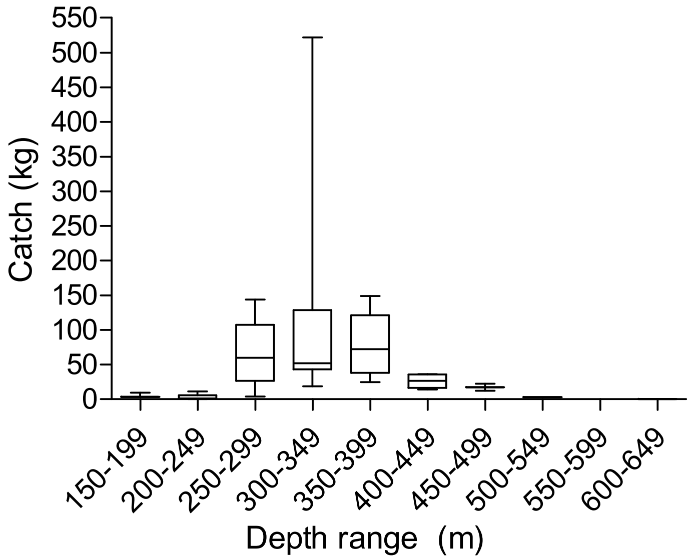


Figure 3.16: Rajidae catches by station

3.4.1 *Bathyraja griseocauda*

A total of 1,280kg was caught in 23 of the 44 stations, comprising 65% of the skate catch. Catches occurred within the depth range 275-494 m, with highest catch and relative abundance (kg/hr) at a depth of 323 m (Figure 3.17, Figure 3.18), and most dominant in the depth range of 300-399 m.

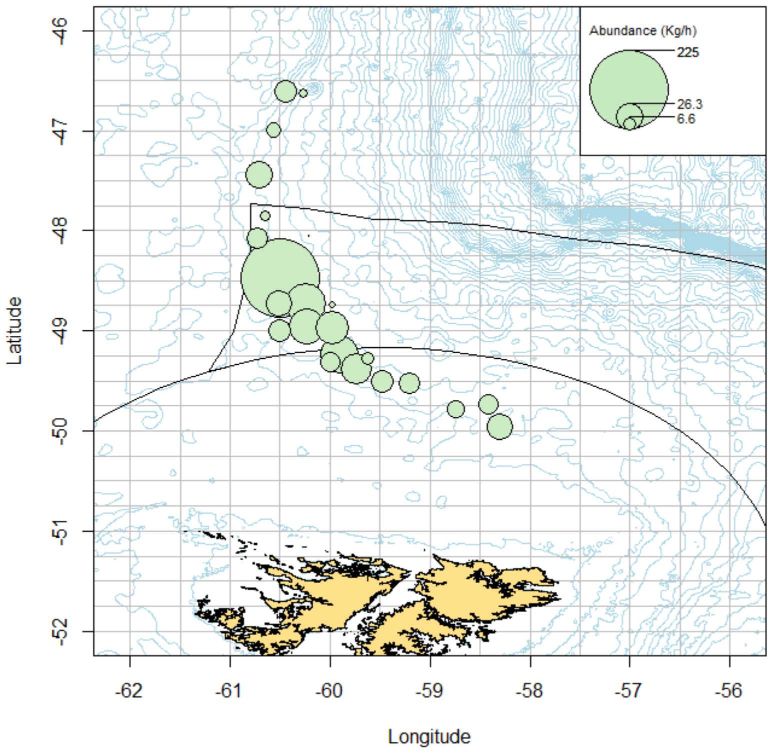


Figure 3.17: Relative abundance (kg/h) of *Bathyraja griseocauda*

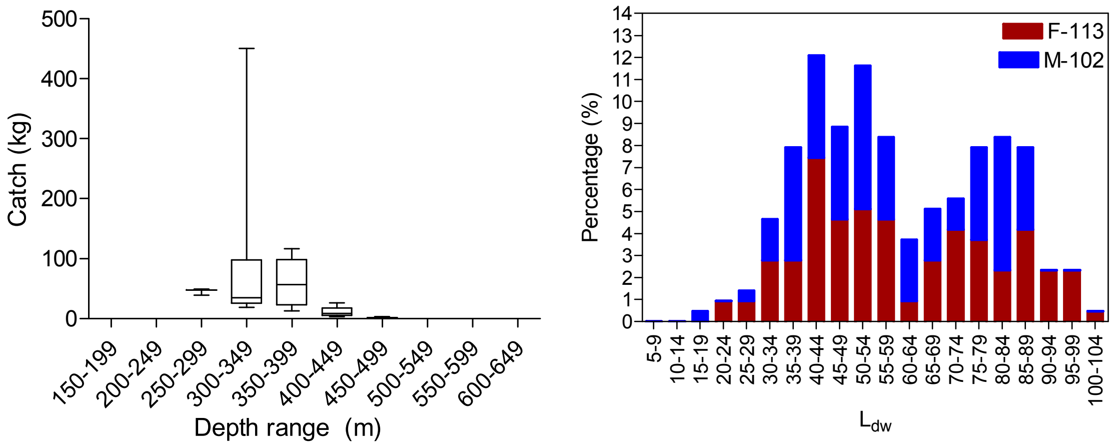


Figure 3.18: Depth range of catches and size frequency of *Bathyraja griseocauda*

Disk width ranged between 15cm and 100cm representing two modal groups. Overall, the population revealed a 52.6% female predominance. 2.7% of the females were carrying egg capsules, 10.0% of the females above the L_{dw} at 50% maturity of 77.3cm.

3.4.2 Bathyraja cousseauae

A total of 257 kg was caught in 18 of the 44 stations, comprising 13% of the skate catch. Catches occurred within the depth range 294-475 m, with highest catch and relative abundance (kg/hr) at a depth of 344 m (Figure 3.19, Figure 3.20), and most dominant in the depth range 300-450 m.

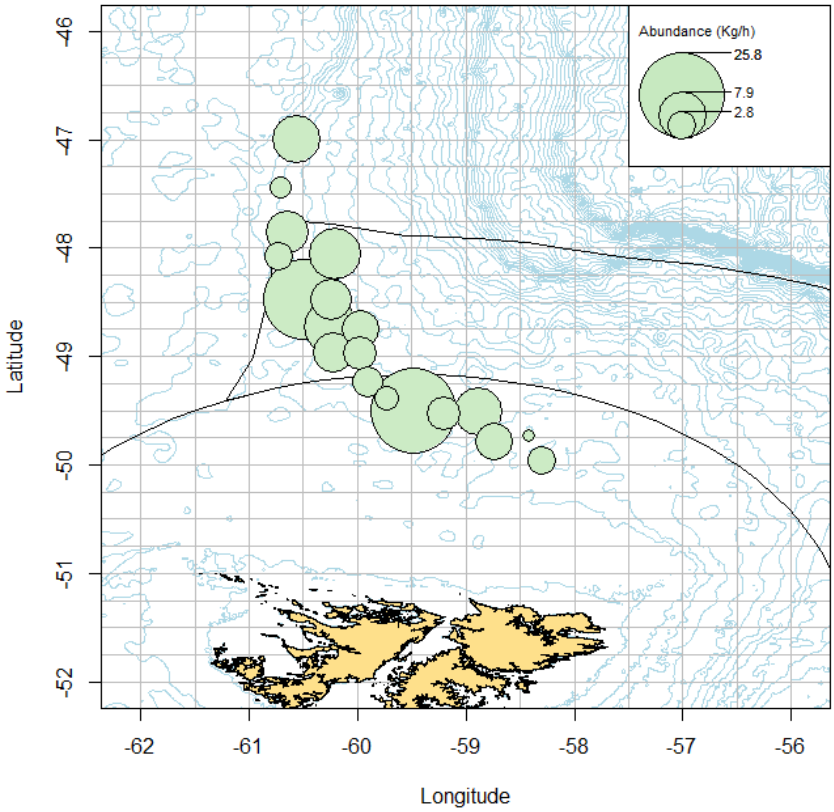
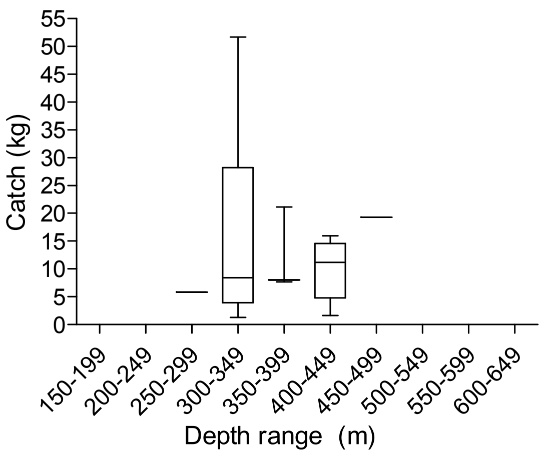


Figure 3.19: Relative abundance (kg/h) of *Bathyraja cousseauae*



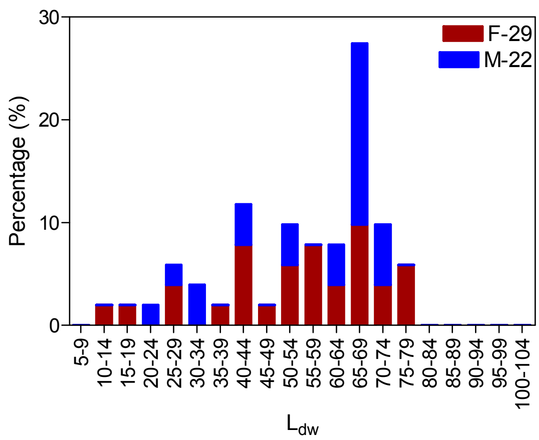


Figure 3.20: Depth range of catches and size frequency of *Bathyraja cousseauae*

Disk width ranged between 13cm and 78cm with a mean of 55.0cm (XF=53.7, XM 56.7). Overall, the population revealed a 56.9% female predominance. None of the females were carrying egg capsules, but only 9 of the females were larger than L_{dw} at 50% maturity calculated as 64.5cm.

3.4.3 *Bathyraja brachyurops*

A total of 112 kg was caught in 9 of the 44 stations, comprising 5.7% of the skate catch. Catches occurred within the depth range 275-413 m, with highest catch and relative abundance (kg/hr) at a depth of 294 m (Figure 3.21, Figure 3.22), and most dominant in the depth range 300-450 m.

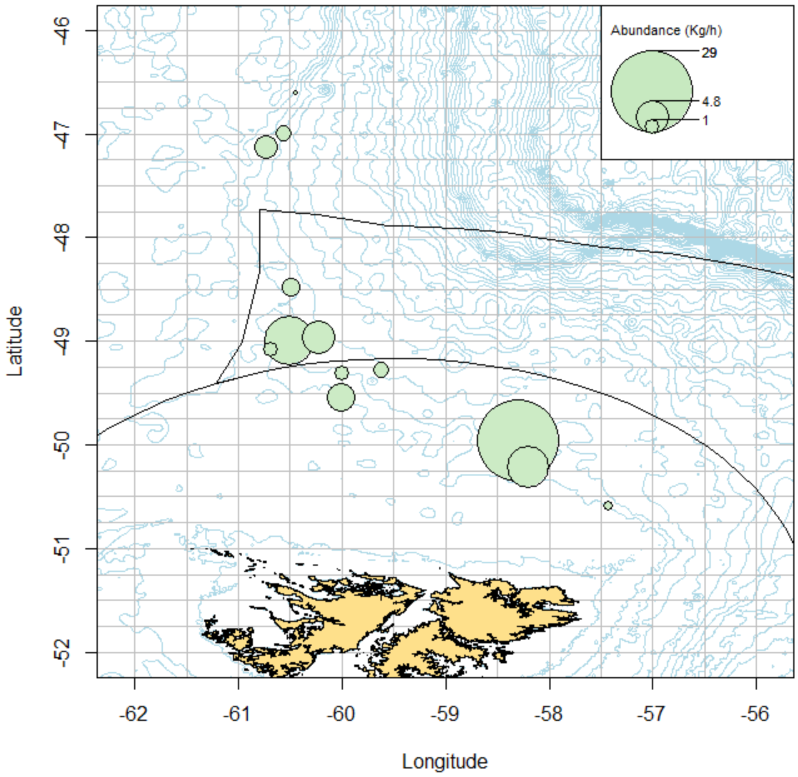
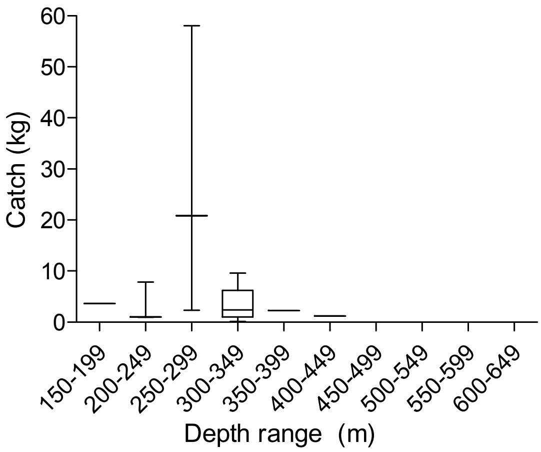


Figure 3.21: Relative abundance (kg/h) of *Bathyraja brachyurops*



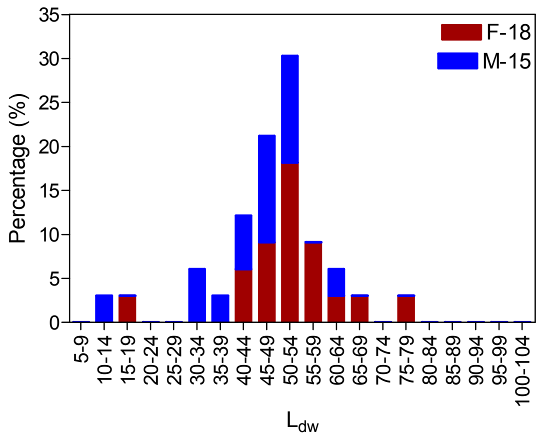


Figure 3.22: Depth range of catches and size frequency of *Bathyraja brachyurops*

Disk width ranged between 13cm and 75cm with a mean of 48.3cm (XF=51.6, XM 44.3). Overall, the population revealed a 54.5% female predominance, but samples size was small. One female was carrying egg capsules, 12 of the females were larger than the L_{dw} at 50% maturity calculated as 49.5cm. One 58cm L_{dw} female was at maturity stage 2.

3.4.4 *Bathyraja albomaculata*

A total of 97 kg was caught in 21 of the 44 stations, comprising 4.8% of the skate catch. Catches (all less than 12.2kg/trawl) occurred within the depth range 275-500 m, with highest catch and relative abundance (kg/hr) at a depth of 348 m (Figure 3.23, Figure 3.24), and most dominant in the depth range 300-450 m.

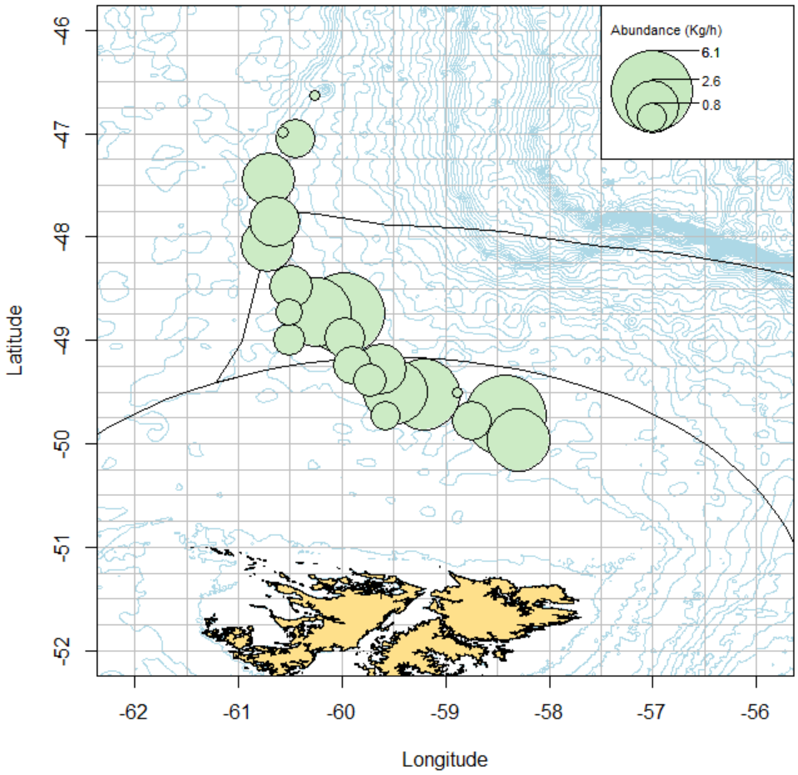


Figure 3.23: Relative abundance (kg/h) of *Bathyraja albomaculata*

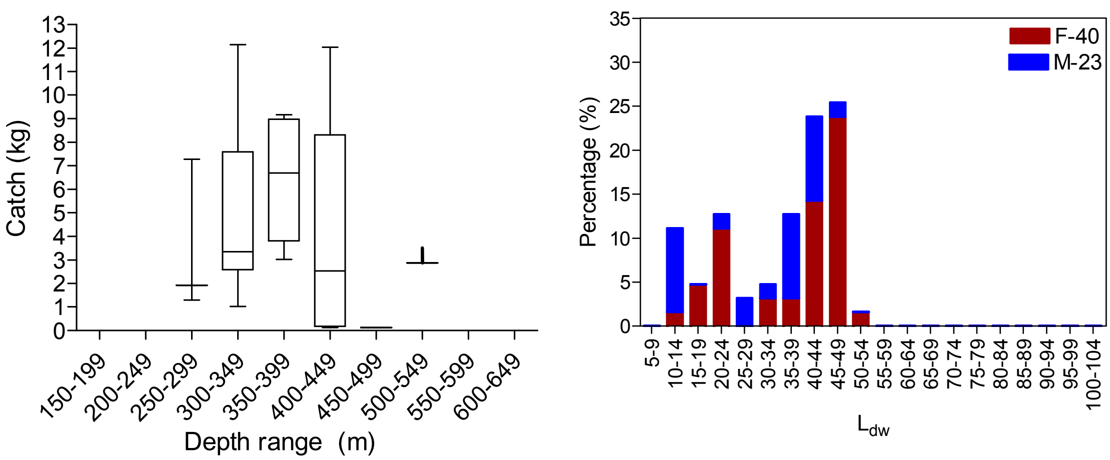


Figure 3.24: Depth range of catches and size frequency of *Bathyraja albomaculata*

Disk width ranged between 10cm and 50cm with a mean of 34.8cm (XF=37.2, XM 30.5). Overall, the population revealed a 63.5% female predominance. Two females were carrying egg capsules, 7.4% of the females larger than the L_{dw} at 50% maturity calculated as 37.7cm.

3.4.5 *Bathyraja scaphiops*

A total of 81 kg was caught in 16 of the 44 stations, comprising 4.1% of the skate catch. Catches (all less than 12.2 kg/trawl) occurred within the depth range 289-500 m, with highest catch and relative abundance (kg/hr) at a depth of 344m (Figure 3.25, Figure 3.26), and most dominant in the depth range 300-450 m.

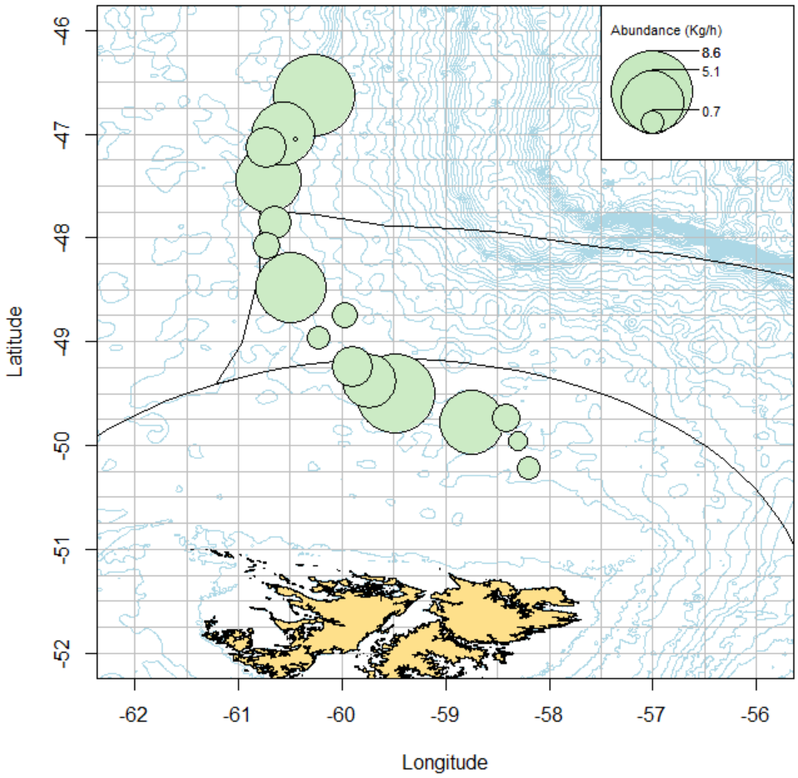


Figure 3.25: Relative abundance (kg/h) of *Bathyraja scaphiops*

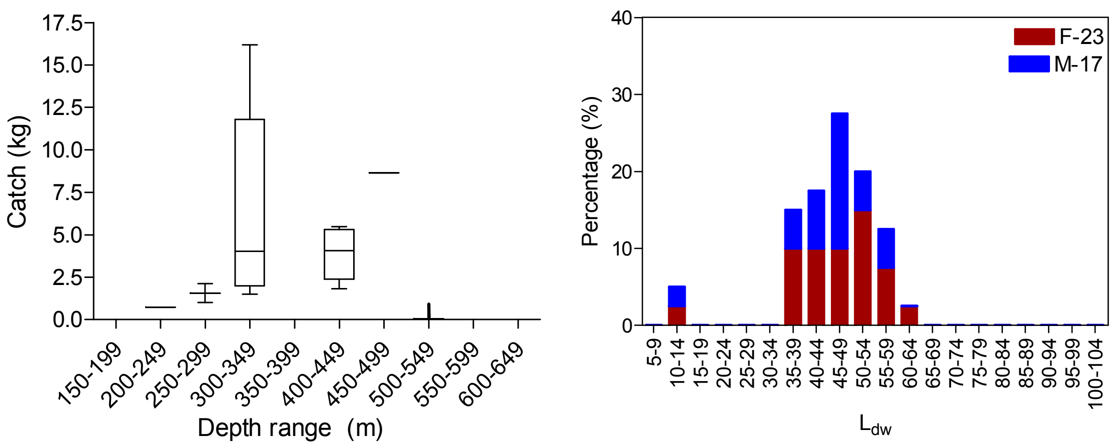


Figure 3.26: Depth range of catches and size frequency of *Bathyraja scaphiops*

Disk width ranged between 10 cm and 60 cm with a mean of 45.6 cm (XF=46.2, XM 44.8). Overall, the population revealed a 57.5% female predominance. One female was carrying egg capsules, 5.9% of the females larger than the L_{dw} at 50% maturity calculated as 44.0 cm.

3.4.6 *Bathyraja multispinis*

A total of 66 kg was caught in 10 of the 44 stations, comprising 3.4% of the skate catch. Catches occurred within the depth range 275-400 m, with highest catch and relative abundance (kg/hr) at a depth of 294 m (Figure 3.27, Figure 3.28), and most dominant in the depth range 250-350 m.

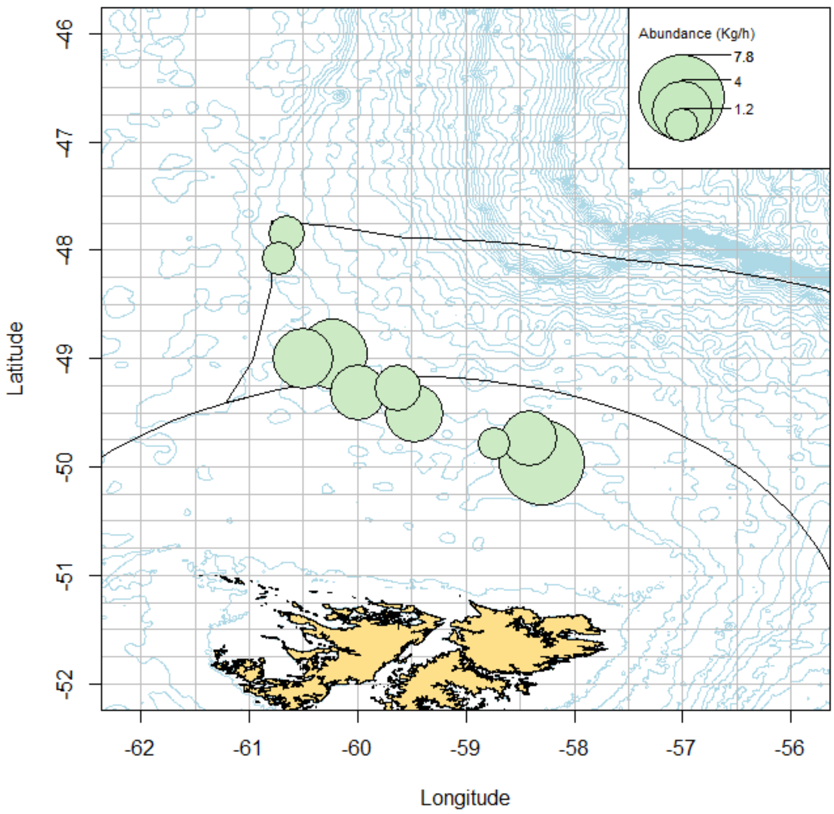


Figure 3.27: Relative abundance (kg/h) of *Bathyraja multispinis*

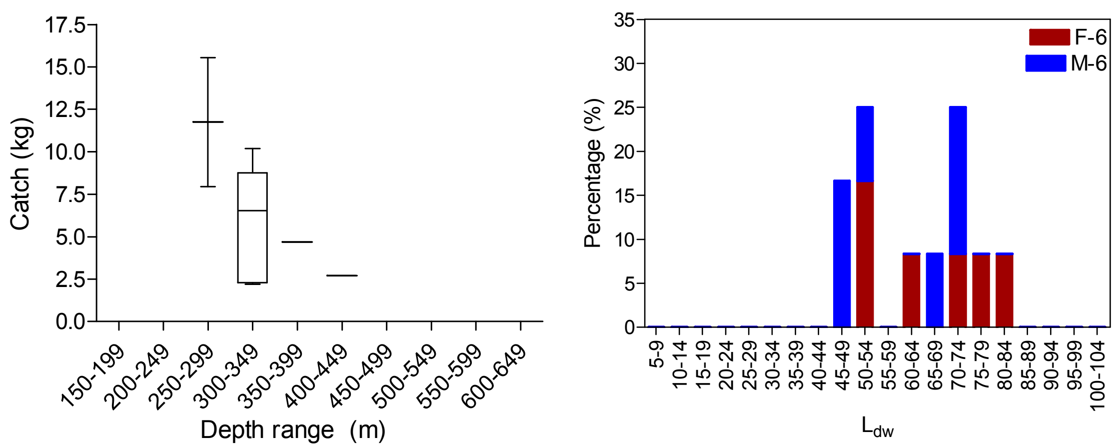


Figure 3.28: Depth range of catches and size frequency of *Bathyraja multispinis*

Disk width ranged between 48 cm and 80 cm with a mean of 62.8 cm (XF=65.8, XM 59.7). There was no sex bias. None of the females were carrying egg capsules, 3 of which were females larger than the L_{dw} at 50% maturity calculated as 68.9 cm.

3.4.7 *Amblyraja doellojuradoi*

A total of 26 kg was caught in 15 of the 44 stations, comprising 1.3% of the skate catch. Catches occurred within the depth range 275-400 m, with highest catch at 294 m, and relative abundance (kg/hr) at 413 m (Figure 3.29, Figure 3.30), and most dominant in the depth range 250-500 m.

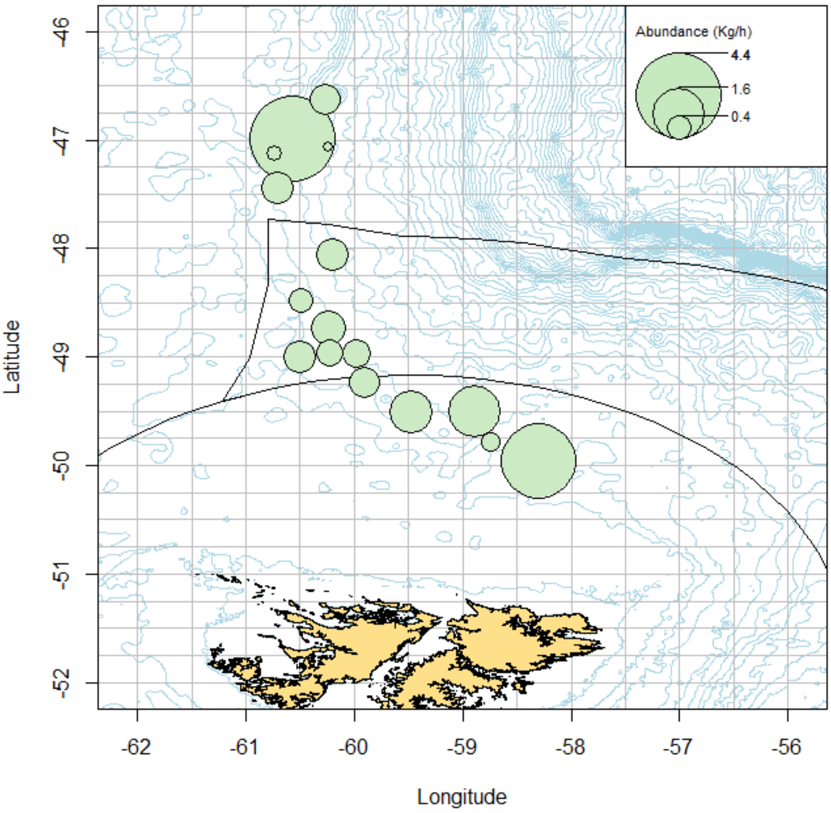


Figure 3.29: Relative abundance (kg/h) of *Amblyraja doellojuradoi*

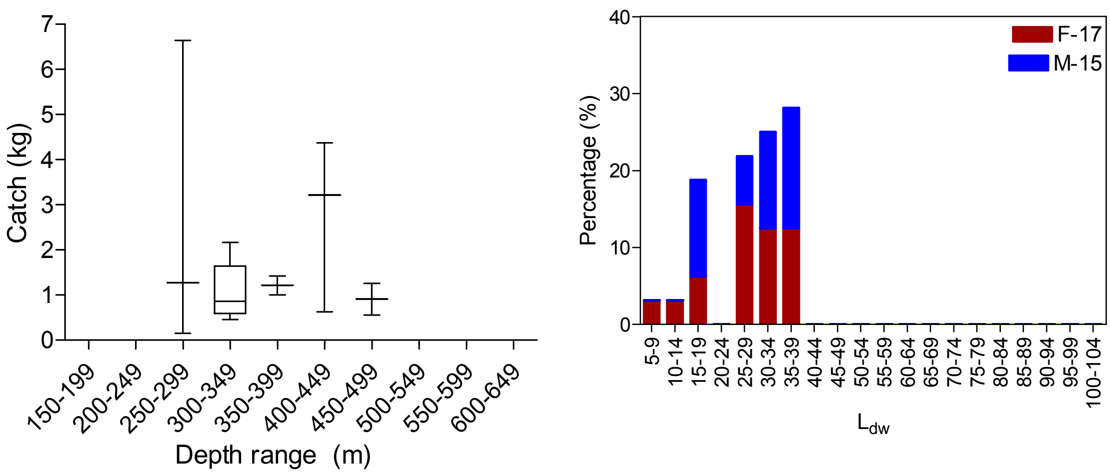


Figure 3.30: Depth range of catches and size frequency of *Amblyraja doellojuradoi*

Disk width ranged between 8c m and 38 cm with a mean of 28.0 cm (XF=27.1, XM 28.9). There was a slight female predominance (53.1%) but sample size was small. None of the females were carrying egg capsules, 6 of which were females larger than the L_{dw} at 50% maturity calculated as 31.0 cm. One 37cm L_{dw} female had entirely undeveloped reproductive structures, despite being the largest specimen of the sample. As such the specimen was classed as Maturity 0.

3.4.8 *Bathyraja macloviana*

A total of 26 kg was caught in 15 of the 44 stations, comprising 1.3% of the skate catch. Catches occurred within the depth range 294-475 m, with highest catch and relative abundance (kg/hr) at 322 m, (Figure 3.31, Figure 3.32), and most dominant in the depth range 300-500 m.

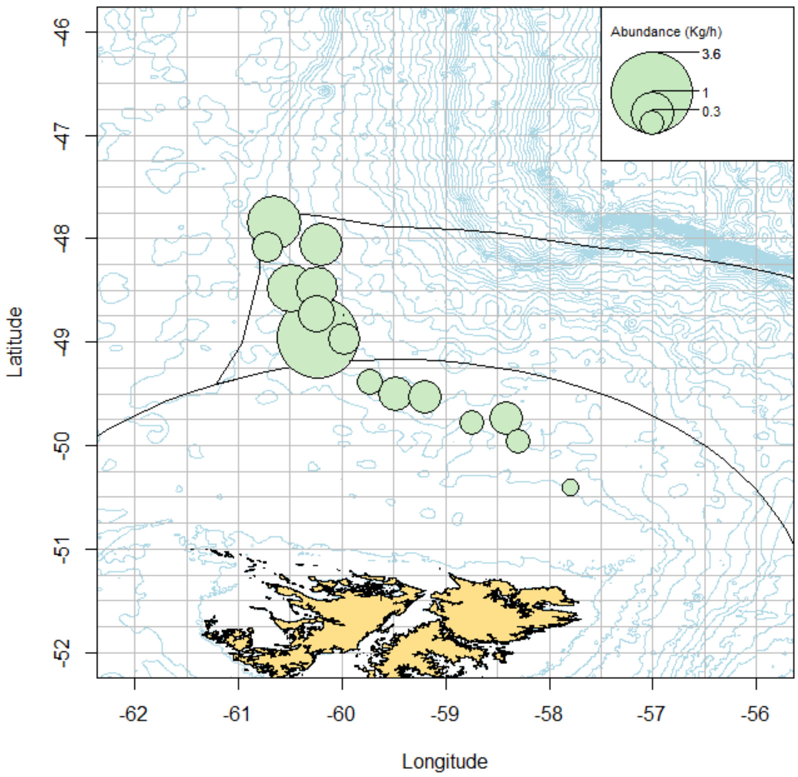
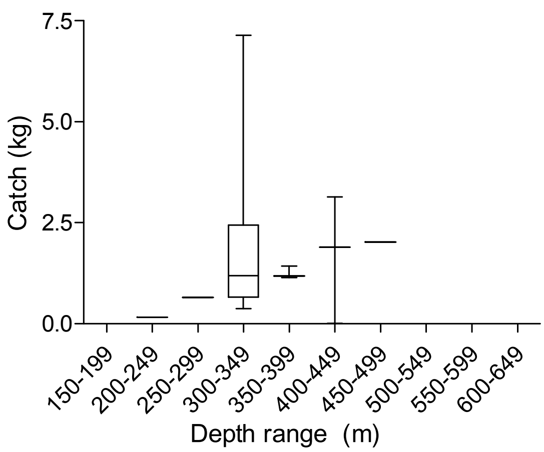


Figure 3.31: Relative abundance (kg/h) of *Bathyraja macloviana*



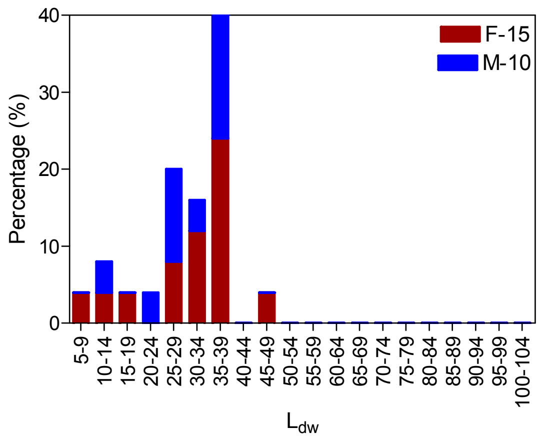


Figure 3.32: Depth range of catches and size frequency of *Bathyraja macloviana*

Disk width ranged between 8 cm and 49cm with a mean of 30.0cm (XF=30.5, XM 29.2). There was a female predominance (60.0%) but sample size was small. One of the females was carrying egg capsules, 12.5% of the 8 females larger than the L_{dw} at 50% maturity calculated as 32.5cm.

3.4.9 *Zearaja chilensis*

A total of 15 kg was caught in 3 of the 44 stations, comprising 0.8% of the skate catch. Catches occurred within a very narrow depths range on 195-200m, with highest catch and relative abundance (kg/hr) at 198 m (Figure 3.33).

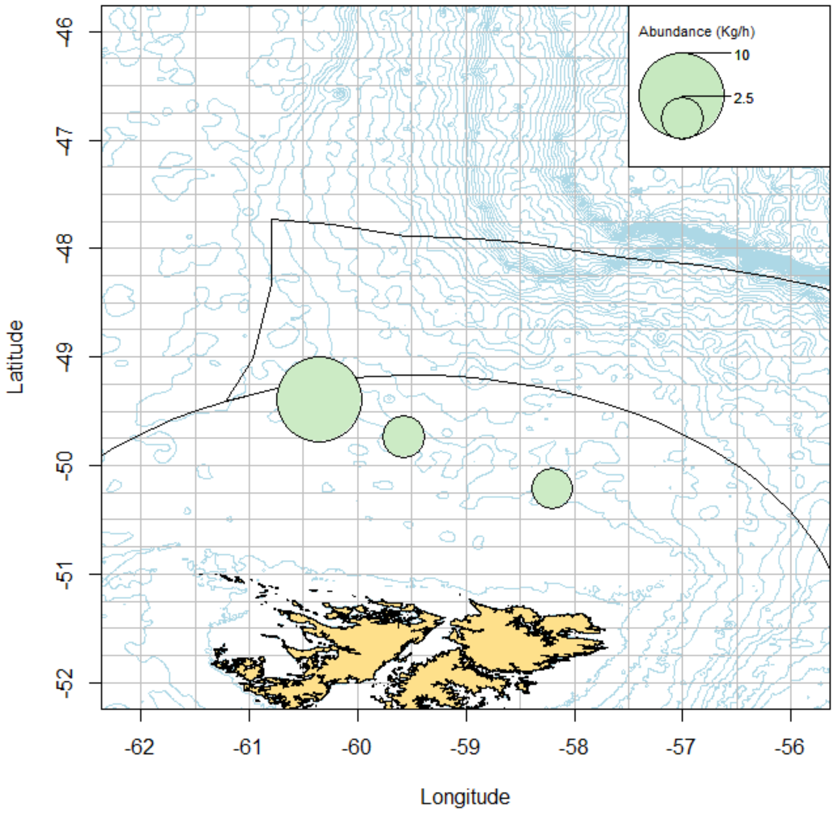


Figure 3.33: Relative abundance (kg/h) of *Zearaja chilensis*

Only one of the three catches was sampled, and so no biological data can usefully be presented.

3.4.10 *Dipturus argentinensis*

A total of 13 kg was caught in 3 of the 44 stations, comprising 0.7% of the skate catch. Catches occurred within a very narrow depths range on 300-323 m, with highest catch and relative abundance (kg/hr) at 300 m (Figure 3.34).

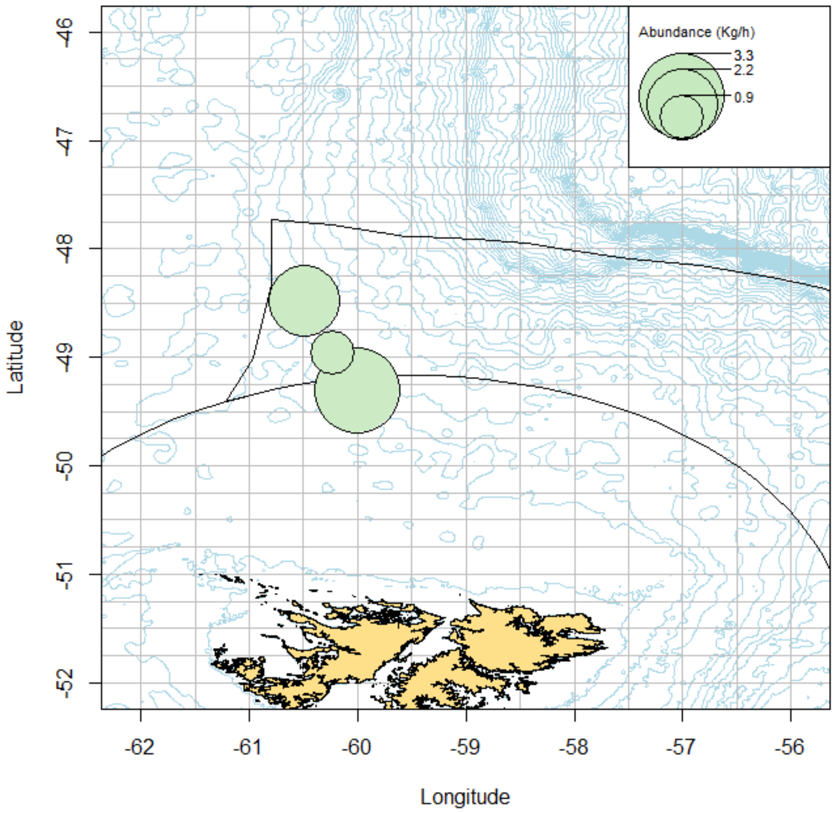


Figure 3.34: Relative abundance (kg/h) of *Dipturus argentinensis*

Disk width ranged between 53 cm and 77 cm. As the sample size consisted of just 3 specimens, no useful conclusions can be drawn. All animals were immature.

3.4.11 *Psammobatis* spp.

Only one trawl at 200m yielded one animal, probably *P. normani*. It was not sampled.

3.5 Myctophidae

This family, of which some 5 species were caught, comprised just 0.3% of the total catch from the 44 trawl stations, of which only 33 yielded catches, ranging between 0.005-23.740 kg. 25 of the stations yielded less than 5 kg each, and 23.7% of the total catch was caught in just one station (st. 1365). *Gymnoscopelus nicholsi* was by far the most dominant species with 73% of the Myctophid catch, totalling 125 kg (Table 3.4, Figure 3.35). Otolith samples were collected from all of these species, but during future surveys using similar trawl gear, a specific effort should be made for some random population sampling.

Table 3.4: Myctophidae catch, ZDLT1-05-2014

Code	Species name	Catch (kg)	Sample (kg)	Discard (kg	%
GYN	*Gymnoscopelus nicholsi*	91.267	2.795	90.237	72.95%
GYB	*Gymnoscopelus bolini*	19.621	18.881	18.991	15.68%
PMC	*Protomictophum choriodon*	11.934	1.680	11.934	9.54%
SYB	*Symbolophorus boops*	1.610	1.570	1.610	1.29%
ELS	*Electrona subaspera*	0.564	0.564	0.564	0.45%
PMX	*Protomictophum spp.*	0.110	0.000	0.110	0.09%
		125.106			

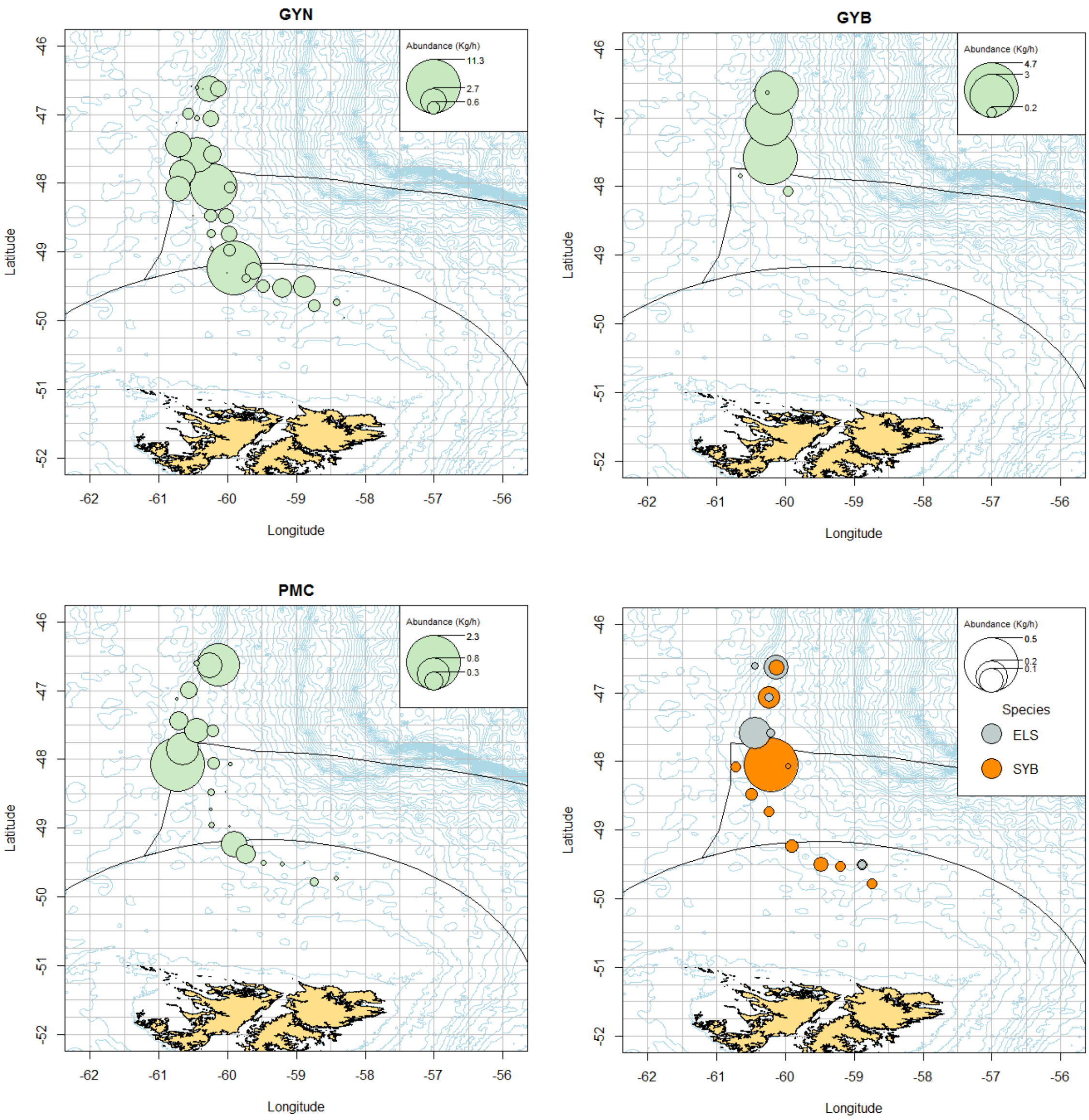


Figure 3.35: Relative abundance and distribution of Myctophidae

4 Buoyancy of *Illex argentinus*

Cephalopods do not have a swim bladder like some fishes to regulate their buoyancy and help them swimming through the water column. During the research cruise, the relative density was measured in several hundred *Illex argentinus* to reveal any possible changes with sex, maturity stage and depth.

4.1 Materials and methods

4.1.1 Data

A total of 783 specimens were collected during the research cruise at depths ranging from 199-612 m (modal depth of the trawl) to measure for density.
Individual Dorsal Mantle Length (DML) and weight (W_{squid}) were measured. Sex and maturity stages were also determined. For this analysis, females 4 and 5 were pooled together considering that, in *Illex argentinus*, the 4th stage is quick and represent the beginning of mature stage. This group was called females 4-5 (F.4-5)

The volume of squid was measured using a 2 litre plastic measuring cylinder. The cylinder was first filled with 1.1–1.2 l of sea water (V_{SW}) and the volume was read to the nearest 5 ml. The entire squid was then added in the tube and the total volume ($V_{SW,\ squid}$) measured to the nearest 5 ml. Volume (V_{squid}) and density (D_{squid}) of the squid were then estimated as

$V_{squid} = V_{SW,\ squid} - V_{SW}$
$D_{squid} = W_{squid} / V_{squid}$

4.1.2 Statistical analyses

Variations of density according to depth and maturity were analysed using linear modelling. The density was used as dependant variable while sex and maturity stage, depth and 100 m depth classes were considered as the independent variables. Four models were fitted to study the effect of the independent variables:

- Density (D) ~ Sex and maturity stage (Sex.Mat) + Depth
- Density (D) ~ Sex and maturity stage (Sex.Mat)
- Density (D) ~ Depth
- Density (D) ~ Depth classes

4.2 Results

4.2.1 Density of seawater

Density of seawater measured with the CTD at trawling stations gave an average density of 1.0269 g/ml^3 (densities range 1.0267-1.0271).

4.2.2 Data collected

Size of squids ranged 24-34 cm for females (mode at 28 cm) and 22-29 cm for males (mode at 25 cm; Figure 4.1).

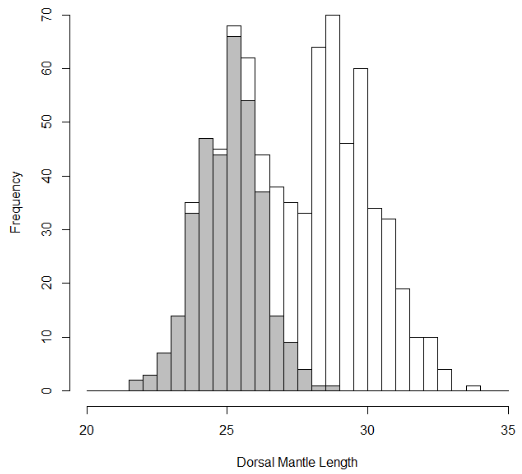
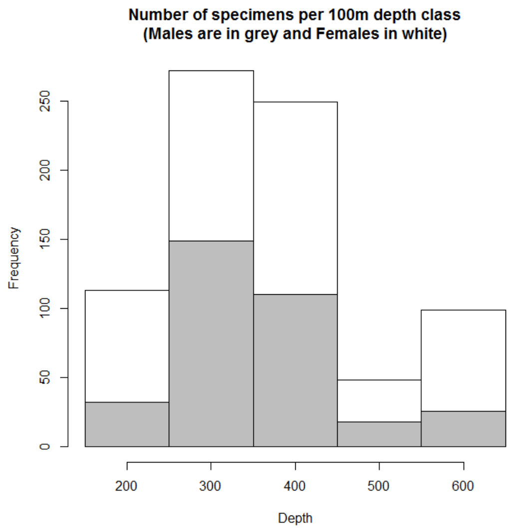


Figure 4.1: Length frequency of females (white) and males (grey) collected during the research cruise to measure individual length, weight and volume

A high number of specimens were collected from 250 and 449 m. Specimens from the 200 m, 500 m and 600 m depth intervals were less numerous (Figure 4.2).



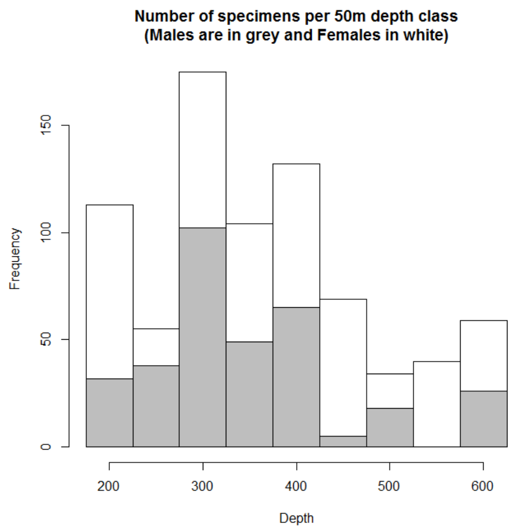


Figure 4.2: Number of specimens collected to measure their length, weight and volume per 100 m horizons (left) and 50 meter horizon (right).

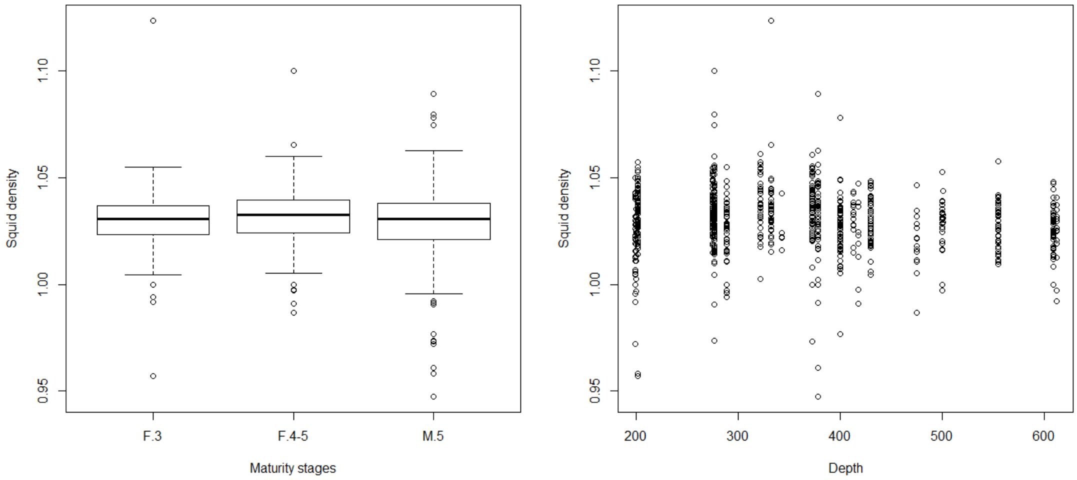


Figure 4.3: Boxplot of density per sex and maturity stage (left) and plot of densities vs depth of catch.

The average densities of squids (Table 4.1 and Figure 4.3) estimated by sex and maturity stage varied between 1.029 and 1.032 g/cm^3. Observed average densities are therefore always higher than the observed density of sea water which was measured at 1.0269 g/cm^3.

Table 4.1: Average minimum and maximum values for densities of females 3, 4-5 and males 5 collected during the research cruise

Sex and Maturity	Average density, g/cm^3	Min / Max densities
Females 3	1.0304	0.9569 / 1.1240
Females 4-5	1.032	0.9867 / 1.10
Males 5	1.029	0.9474 / 1.089

4.2.3 Statistical analyses

Statistical analyses were performed to study sex and maturity stages and depth as independent variables to explain the variation of average densities in squids. Significant effects of those variables were observed for all the linear models fitted (Table 4.2). However, as estimated R^2 were less than 5%, these linear models were weak and the independent variables used explained less than 5% of the squid density variation. We can therefore consider that squids are negatively buoyant and that the density is not dependent on the sex, maturity stage and depth of catch.

Table 4.2: Linear models applied to study the effect of sex and maturity stages and depth as independent variables to explain the density of the squids.

Model	P-value	R^2
D ~ Sex.Mat + depth (linear model)	Sex.Mat 0.03 Depth 0.006	2%
D ~ Sex.Mat (ANOVA)	0.03	<1% (F5 ≠ M5)
D ~ depth (linear model)	0.02	<1%
D ~ depth classes (ANOVA)	<1%	4% D3 ≠ D2 D4 D5 D6