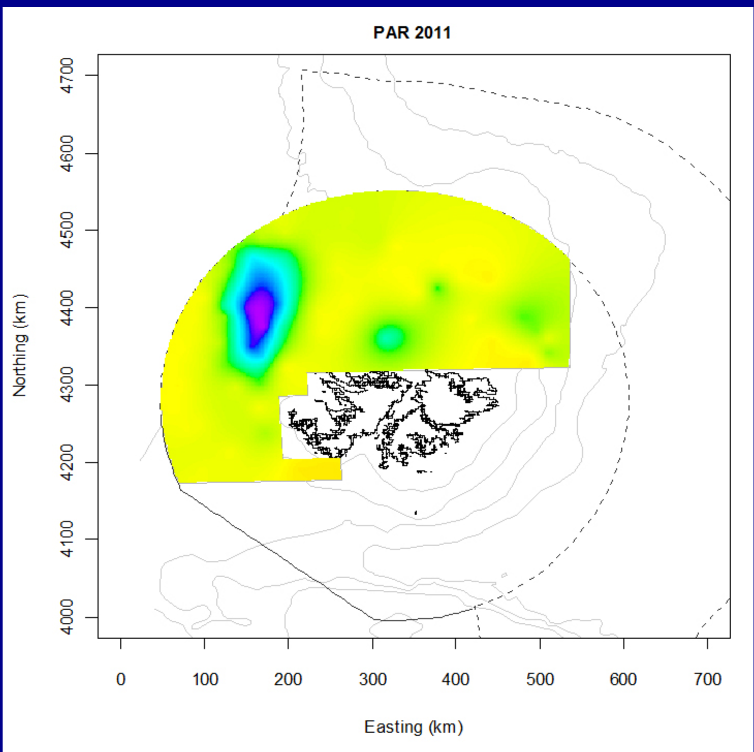
Cruise Report ZDLT1-02-2011

Rock cod Biomass Survey - 2011



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1.0 Introduction

The cruise ZDLT1-02-2011 was a demersal trawl survey on the shelf area from the northeastern to the southwestern parts of FICZ with the main goal of investigating the distribution and estimating the biomass of rock cod (*Patagonotothen ramsayi*) and other demersal and pelagic species. The distribution of catches was correlated with main environmental variables obtained from oceanographic stations.

1.1 Region

The northern and western parts of the Falkland Islands Interim Conservation Zone (FICZ).

1.2 Cruise objectives

1. To examine the distribution, biology and biomass of rock cod on their feeding grounds as a target species and other demersal fishes and squids.
2. To carry out an oceanographic survey of the study area.

1.3 Cruise Plan and key dates

The vessel departed Stanley in the evening of 31 January, and proceeded to the first station in the north-eastern part of FICZ (grid square XNAP). During the following twenty one days of the survey, the whole area was covered by trawl and oceanographic stations in a counter clockwise direction. Every day, four grid squares of the survey were fished. In each grid square, one trawl was performed at random locations. No time was lost due to bad weather.

On the last day of the survey, four shallow water trawls were conducted in the southern part of the *Loligo* box, with two of them to the north of Sea Lion Islands. The survey finished as planned on 23 February 2011.

1.4 Personnel

The following 7 scientists from the Fisheries Department participated in the cruise:

Dr Alexander Arkhipkin	Chief Scientist
Dr Vlad Laptikhovsky	Trawl/Oceanographic surveys
Dr Sergey Bakanev	Trawl survey
Zhanna Shcherbich	Trawl survey
Aristoteles Stavrinaki	Trawl survey
Lars Jurgens	Trawl survey
Neil Anders	Trawl survey

1.5 Gear

1. Oceanographic survey. STDO SeaBird SBE 25 Sealogger.
2. Bottom trawl equipped with polywalent doors.

2.0 Oceanography

Oceanographic data were collected at 88 oceanographic stations. These stations were made either before or after each trawl and situated between 70 and 275 m (Fig. 1).

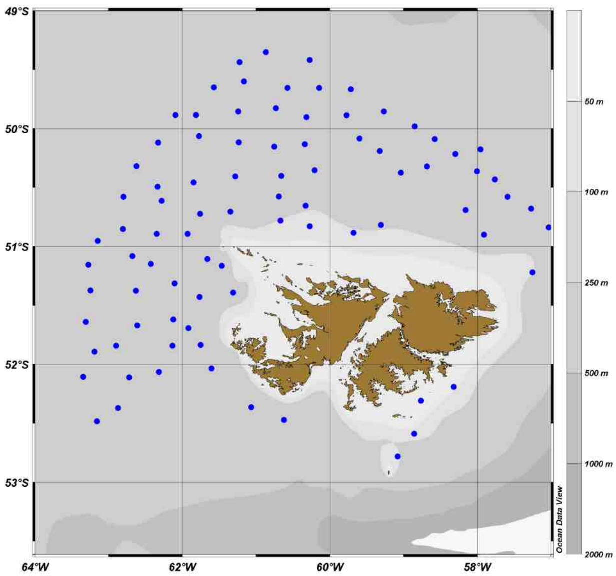


Figure 1: Oceanographic stations in February 2011

2.1. Results

The survey aimed to assess the oceanographic situation over the north- and west part of the Falkland shelf and to reveal environmental factors influencing the distribution and biology of the Falkland rock cod, *Patagonotothen ramsayi*. Surface temperatures ranged from 8.26º to 12.01ºC, surface salinity from 33.34 to 33.76 psu, and densities from 25.44 to 26.26 kg/m3. T-S curves are shown on Figure 2. The oceanographic situation was characterized by a weak development of the western branch of the Falkland Current in contrast to the previous year (Figure 3).

The distribution of both the surface and bottom temperatures and salinities ares shown on Fig. 4. In contrast to the previous year, the bottom environment was much warmer and less saline. A 'tongue' of relatively fresh and warm waters in the western part of the zone was also more strongly developed. The frontal zone along the western border of FICZ in which rock cod was concentrated in the year 2010 was much weaker 2011 (Figure 4).

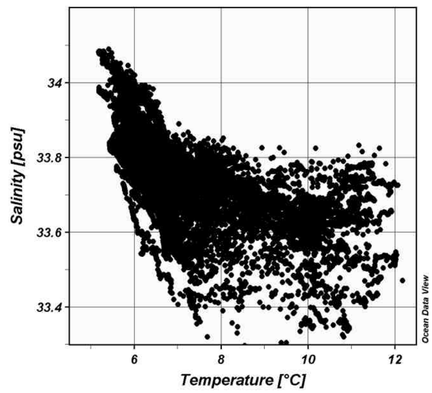


Figure 2: T-S curves throughout the water column on the Falkland shelf in February 2011

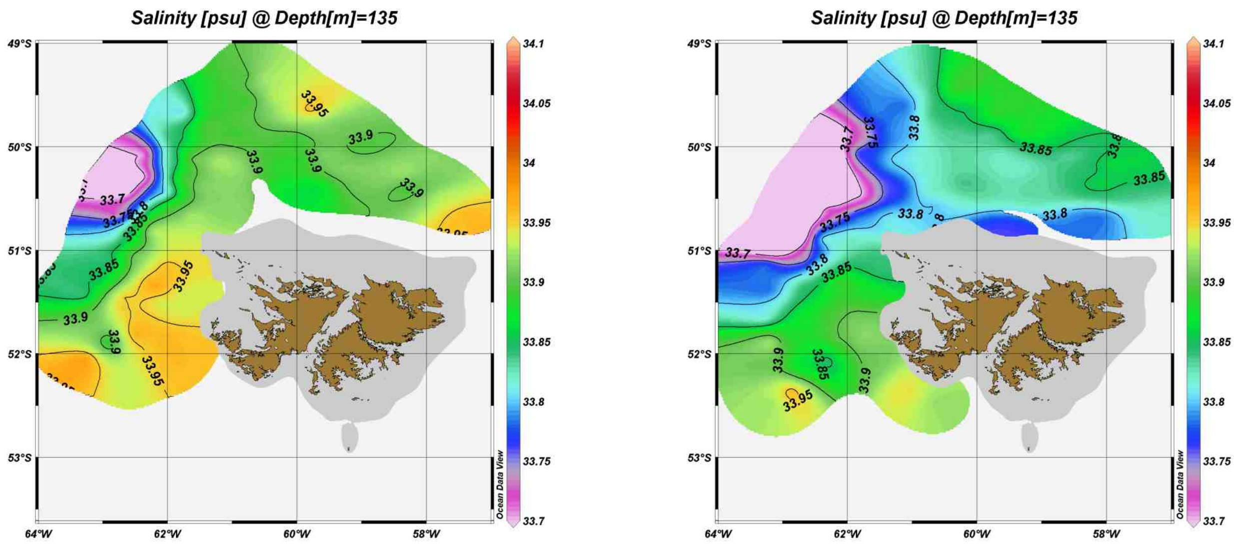


Figure 3: Distribution of salinity at the horizon of 135 m in 2010 (left) and 2011 (right)

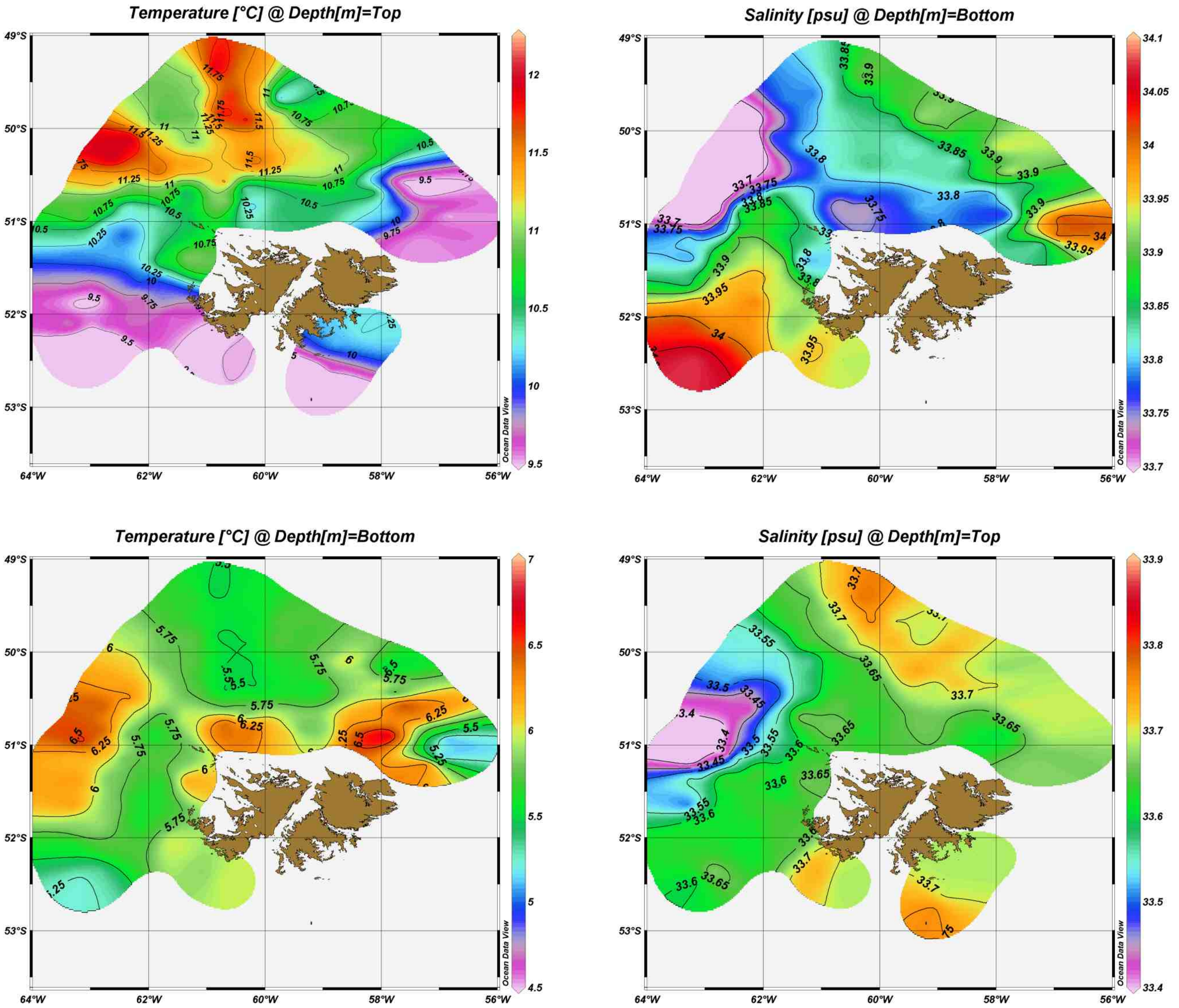


Figure 4: Temperature and salinity on the Falkland shelf in February 2011 (shallow stations of Beauchene – Lively Is. area removed from the bottom graphs to avoid confusion). Scales are different because of the different temperature backgrounds.

3.0 Biological Sampling

3.1 Catch and by-catch

Bottom trawling was conducted at 88 stations. Seabed trawling times during the survey was aimed to be 60 minutes.

During the cruise a total of 212,160 kg was caught comprising over 100 species (Table 1). In terms of weight, the greatest catches were the rockcod (*Patagonotothen ramsayi*), hoki (*Macruronus magellanicus*) and red cod (*Salilota australis*).

Table 1: Total catch of all trawl stations during research cruise ZDLT1-02-2011

Species	Species Name	Total Catch (kg)	Total Sampled (kg)	Total Discarded (kg)	Proportion (%)
PAR	*Patagonotothen ramsayi*	116,097.060	1,708.080	72,390.330	54.72
WHI	*Macruronus magellanicus*	28,405.390	4,903.402	2,750.450	13.39
BAC	*Salilota australis*	23,099.269	2,496.474	1,614.872	10.89
KIN	*Genypterus blacodes*	8,420.480	4,109.032	10.920	3.97
BLU	*Micromesistius australis*	5,596.792	993.549	5,576.233	2.64
GRF	*Coelorhynchus fasciatus*	5,400.800	24.380	5,400.800	2.55
LOL	*Loligo gahi*	3,596.170	446.950	366.600	1.70
SAR	*Sprattus fuegensis*	3,027.170	10.540	2,976.170	1.43
ING	*Moroteuthis ingens*	2,747.540	63.980	2,747.540	1.30
MED	*Medusae sp.*	2,202.870	0.000	2,201.350	1.04
ILL	*Illex argentinus*	1,938.275	717.425	325.819	0.91
CGO	*Cottoperca gobio*	1,771.665	30.522	1,761.865	0.84
HAK	*Merluccius hubbsi*	1,628.116	1,572.016	12.670	0.77
MUN	*Munida spp.*	1,435.595	0.000	1,435.595	0.68
RBR	*Bathyraja brachyurops*	1,435.481	1,435.476	39.226	0.68
TOO	*Dissostichus eleginoides*	1,111.220	1,056.470	22.410	0.52
PAT	*Merluccius australis*	754.440	754.440	0.000	0.36
RGR	*Bathyraja griseocauda*	510.156	510.156	24.130	0.24
RFL	*Dipturus chilensis*	504.353	504.353	4.420	0.24
BUT	*Stromateus brasiliensis*	393.200	64.010	393.120	0.19
RED	*Sebastes oculatus*	369.460	349.130	174.780	0.17
GRC	*Macrourus carinatus*	267.440	265.440	2.000	0.13
POR	*Lamna nasus*	174.200	174.200	0.000	0.08
DGS	*Squalus acanthias*	139.040	37.760	138.940	0.07
RMC	*Bathyraja macloviana*	119.294	119.294	49.364	0.06
RAL	*Bathyraja albomaculata*	107.220	107.220	0.000	0.05
DGH	*Schroederichthys bivius*	106.570	0.000	106.570	0.05
RBZ	*Bathyraja cousseauae*	75.310	75.210	0.000	0.04
SPN	*Porifera*	69.537	0.000	69.537	0.03
RSC	*Bathyraja scaphiops*	66.750	66.750	0.000	0.03
RTR	*Dipturus trachydermus*	62.490	62.490	0.000	0.03
PTE	*Patagonotothen tessellata*	58.510	0.986	56.866	0.03
EEL	*Iluocoetes fimbriatus*	53.001	0.005	52.996	0.02
PRX	*Paragorgia sp.*	52.330	0.000	52.330	0.02
RMU	*Bathyraja multispinis*	49.160	49.160	0.000	0.02
ZYP	*Zygochlamys patagonica*	45.342	0.000	45.342	0.02
NEM	*Neophyrnichthys marmoratus*	31.200	6.410	31.200	0.01
COP	*Congiopodus peruvianus*	28.466	16.370	28.366	0.01
ALG	*Algae*	28.020	0.000	28.020	0.01

RPX	*Psammobatis spp.*	24.832	24.032	23.402	0.01
GOC	*Gorgonocephalas chilensis*	15.869	0.000	15.869	0.01
RDO	*Amblyraja doellojuradoi*	14.878	13.650	10.638	0.01
RDA	*Dipturus argentinensis*	14.280	14.280	0.000	0.01
CHE	*Champsocephalus esox*	11.742	11.542	0.200	0.01
SAL	*Salpa sp.*	11.311	0.000	11.261	0.01
PYM	*Physiculus marginatus*	10.005	0.262	9.755	0.00
STA	*Sterechinus agassizi*	9.839	0.005	9.839	0.00
GOR	*Gorgonacea*	6.347	0.000	6.347	0.00
COT	*Cottunculus granulosus*	4.615	0.005	4.610	0.00
BEJ	*Benthoctopus sp.cf. januarii*	4.610	4.610	0.000	0.00
MUL	*Eleginops maclovinus*	4.570	0.000	4.570	0.00
RMG	*Bathyraja magellanica*	4.270	4.270	1.160	0.00
OCM	*Octopus megalocyathus*	3.740	3.740	0.000	0.00
FUM	*Fusitriton m. magellanicus*	3.567	0.000	3.567	0.00
MUU	*Munida subrugosa*	3.468	0.000	3.468	0.00
CTA	*Ctenodiscus australis*	3.351	0.000	3.351	0.00
ALC	*Alcyoniina*	2.971	0.133	2.838	0.00
ANM	*Anemone*	2.675	0.000	2.675	0.00
BEE	*Benthoctopus eureka*	2.180	2.180	0.000	0.00
OCT	*Octopus spp.*	2.110	2.110	0.000	0.00
COX	*Notothenid spp.*	1.900	1.900	0.000	0.00
CAZ	*Calyptraster sp.*	1.699	0.000	1.699	0.00
COG	*Patagonotothen guntheri*	1.258	1.248	1.048	0.00
SHT	*Mixed invertebrates*	1.220	0.000	1.220	0.00
SUN	*Labidaster radiosus*	1.200	0.000	1.200	0.00
FLX	*Flabellum spp.*	1.138	0.000	1.028	0.00
UHH	*Heart urchin*	1.059	0.000	1.059	0.00
AUC	*Austrocidaris canaliculata*	1.044	0.000	1.044	0.00
ODM	*Odontocymbiola magellanica*	0.870	0.000	0.870	0.00
POA	*Porania antarctica*	0.815	0.000	0.815	0.00
PES	*Peltarion spinosulum*	0.761	0.000	0.761	0.00
GYN	*Gymnoscopelus nicholsi*	0.732	0.000	0.732	0.00
ANT	*Anthozoa*	0.668	0.000	0.668	0.00
AST	*Asteroidea*	0.589	0.000	0.589	0.00
EUL	*Eurypodius latreillei*	0.442	0.000	0.424	0.00
MYX	*Myxine spp.*	0.430	0.000	0.430	0.00
HYD	*Hydrozoa*	0.394	0.000	0.394	0.00
CEX	*Ceramaster sp.*	0.390	0.000	0.390	0.00
OPH	*Ophiuroidea*	0.387	0.000	0.387	0.00
NUD	*Nudibranchia*	0.366	0.000	0.366	0.00
SRP	*Semirossia patagonica*	0.275	0.254	0.021	0.00
MUO	*Muraenolepis orangiensis*	0.260	0.260	0.260	0.00
MAV	*Magellania venosa*	0.253	0.040	0.213	0.00
LIT	*Lithodes turkayi*	0.240	0.240	0.000	0.00
ICA	*Icichthys australis*	0.155	0.155	0.060	0.00
OPL	*Ophiuroglypha lymanii*	0.122	0.000	0.122	0.00
LEA	*Lepas australis*	0.120	0.000	0.120	0.00
COL	*Cosmasterias lurida*	0.110	0.000	0.110	0.00
THB	*Thymops birsteini*	0.090	0.090	0.000	0.00
ISO	*Isopoda*	0.059	0.000	0.059	0.00
THN	*Thysanopsetta naresi*	0.054	0.054	0.000	0.00
CTE	*Ctenophora*	0.050	0.000	0.050	0.00
HOL	*Holothuroidea*	0.050	0.000	0.050	0.00

OPS	*Ophiactis asperula*	0.037	0.000	0.037	0.00
BRY	*Bryozoa*	0.029	0.000	0.029	0.00
EGG	*Eggmass*	0.028	0.000	0.028	0.00
PYX	*Pycnogonida*	0.025	0.000	0.025	0.00
NUH	*Nuttallochiton hyadesi*	0.023	0.000	0.023	0.00
MXX	*Myctophid spp.*	0.020	0.020	0.020	0.00
AGO	*Agonopsis chilensis*	0.020	0.000	0.020	0.00
BAL	*Bathydomus longisetosus*	0.020	0.000	0.020	0.00
UCH	*Sea urchin*	0.019	0.000	0.019	0.00
CYX	*Cycethra sp.*	0.010	0.000	0.010	0.00
BEY	*Beroe spp.*	0.010	0.000	0.010	0.00
BIV	*Bivalve*	0.010	0.000	0.010	0.00
XXX	*Unidentified animal*	0.005	0.000	0.005	0.00
BUC	*Bulbus carcellesi*	0.005	0.000	0.005	0.00
ACP	*Acanthephyra pelagica*	0.003	0.000	0.003	0.00
AMP	*Amphipoda*	0.003	0.000	0.003	0.00
OPV	*Ophiacanta vivipara*	0.002	0.000	0.002	0.00
SAP	*Sagitta planctonis*	0.001	0.000	0.001	0.00
		212,160.082	22,816.760	101,020.840	100.00

4.0 Biomass Estimates

4.1 General methods

Fish and squid stock assessments expressed in numbers and biomass were performed by two different methods. The first method was the same as in previous year based on a geostatistical approximation (see the Cruise Report ZDLT1-10-2010). The second method was based on random stratification. Both methods were applied to the data of the present survey (ZDLT1-02-2011) and compared with the previous one (ZDLT1-02-2010).

4.2 Geostatistical methods

The surveyed biomass of the main commercial species was estimated using a geostatistical extrapolation of catch density per trawl-swept area. Swept area was calculated as the trawl distance × average horizontal net opening (50 m). Trawl distance was calculated as the straight-line distance between bottom-contact start position and end position.

For each species, biomass density was expressed as catch weight (kg) per m^2 of trawl area. A conservative catchability coefficient of 1.0 was assigned to all of the species assessed due to the lack of data on the catchability of the trawl. Biomass densities calculated from each of the 88 trawls were combined in an empirical variogram and applied to a kriging model to infer the spatial correlation. Average krigged (or interpolated) density per area unit (1 km^2) was then multiplied by the total survey area to calculate the total biomass.

4.3 Stratified-random approach

The existing design of the survey allowed for the calculation of biomass and abundance indices according to stratified-random sampling (Cochran, 1977). This method is commonly used for a wide variety of statistical estimates, including bottom fish trawl surveys in the North Atlantic (Doubleday, 1981). The whole survey area of FICZ was divided into 4 regions according environmental features that also turned out to be in agreement with distribution patterns of main the commercial species during the surveys performed in 2010 and 2011. Each region was divided into a number of smaller areas (strata) with similar depth characteristics (Table 2, Figure 5).

The following four regions were defined to estimate stocks:

1. Southwest waters – a part of the shelf where near-bottom water layers are occupied by the western branch of the Falkland Current; high abundance of *Merluccius australis* (PAT), *Coelorhynchus fasciatus* (GRF) and *Micromesistius australis* (BLU).

2. Northwest waters – a part of the shelf where near-bottom water layers are occupied by the Argentine warm drift with a presence of a frontal zone between the drift and western branch of the Falkland Current; high abundance of *Patagonotothen ramsayi* (PAR), *Merluccius hubbsi* (HAK), *Cottoperca gobio* (CGO) and *Illex argentinus* (ILL).

3. Northern waters – an area with a relatively stable bottom environment, though variability in surface waters was very high; low abundance of finfish, sometimes high abundance of *Loligo gahi* (LOL).

4. Eastern waters – an area where near-bottom water layers are occupied by the eastern branch of the Falkland Current

Each region was then divided into strata a-d depending on the depth range (a - <100 m; b – 100-200 m, c – 200-300 m, and d - 300-400 m).

Table 2: Stratification of survey area and number of trawls during the surveys in 2011 and 2010.

Regions		1		2		3			4			Total
Stratum		1b	1c	2b	2c	3a	3b	3c	4a	4b	4c	
Depth, m		100-199	200-299	100-199	200-299	0-99	100-199	200-299	0-99	100-199	200-299	
Area, km^2		4928	20395	25665	2147	10198	24884	11320	976	6050	9759	116322
Trawl numbers	2011	5	11	38	1	0	21	0	0	4	4	84
	2010	5	16	30	3	2	23	1	1	7	0	88

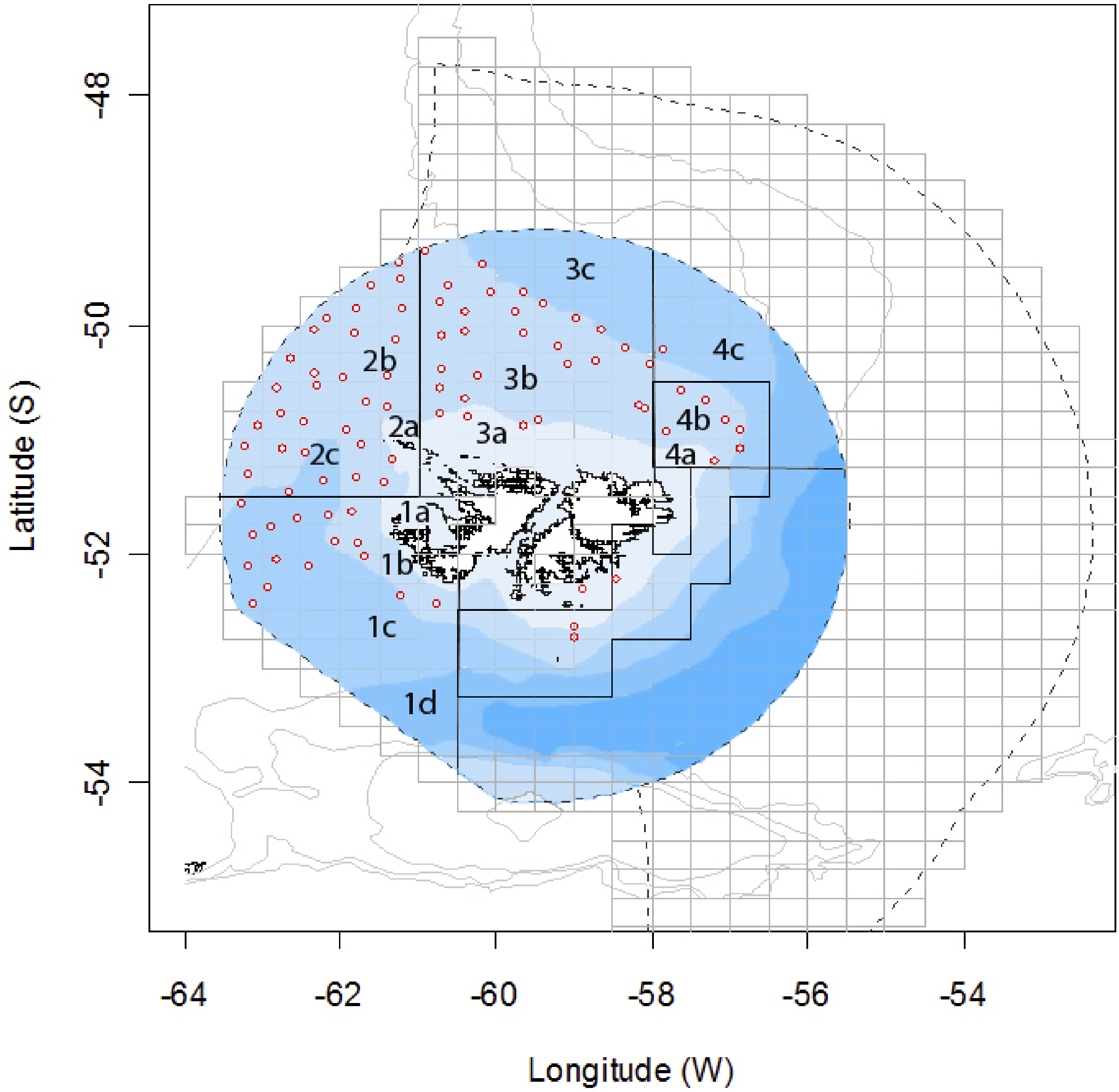


Figure 5: Stratification of FICZ and trawl position (red dots) during the survey 2011.

4.4 Rock cod (PAR) - Patagonotothen ramsayi

Catch distribution

Rock cod was the most abundant species and represented 54.7% (116.1 tonnes) of the total catch. Its catches ranged from 0.0 to 8.1 t, mean 1.32 tonnes. The mean catch of rock cod was 7% higher than observed in February 2010.

As in the previous survey, the highest catches of rock cod were recorded in the northwestern part of FICZ at depths ranging from 100 to 200 m (Figure 6). The average catch for this region was around 2.0 tonnes per trawl. Catches gradually reduced as the survey moved towards shallow waters. The mean catch in southwestern part of FICZ was 0.5 tonnes. As in 2010, high catches were taken in the northeastern part of FICZ as well. However, the area of high catches was larger then in previous year and reached the northern part of the *Loligo* Box.

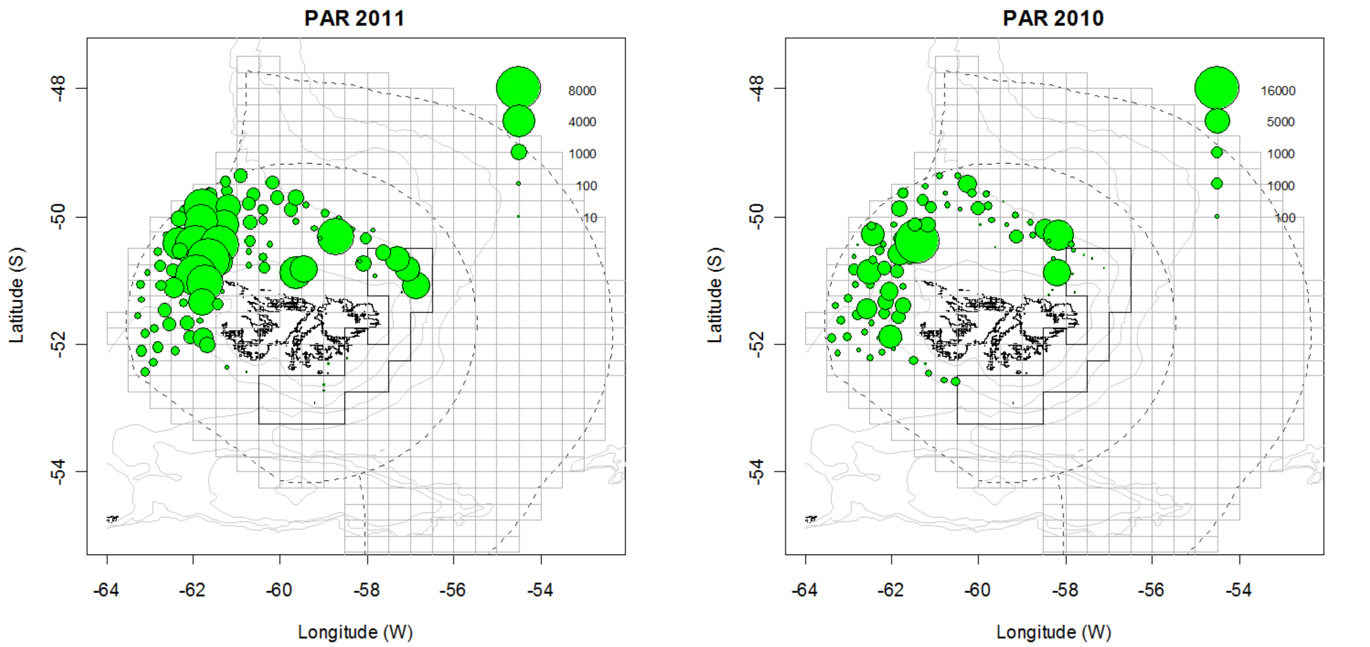


Figure 6: Catch distribution (kg/trawl) of rock cod *Patagonotothen ramsayi* in 2011 and 2010.

Biomass Estimates

Geostatistical extrapolation by the kriging method showed that the average distribution density of rock cod was 3,321 t/km^2, which was 19% higher than in the previous year (Figure 7, Table 3). The best-fitting variogram for rock cod densities was modelled using an exponential covariance function for the survey in 2011 and spherical covariance function for 2010. However all three types of covariance functions were fitted the initial data quite well as shown in Figure 8.

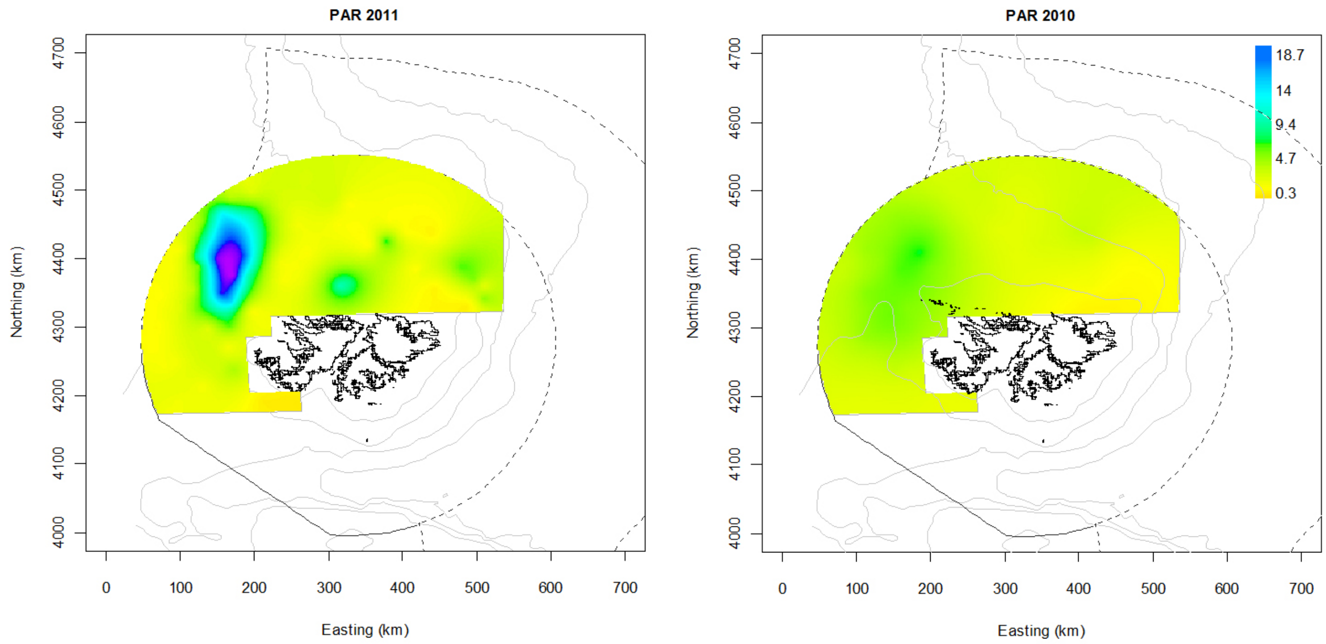


Figure 7: The distribution of density (t/km²) of Patagonotothen ramsayi in 2011 and 2010

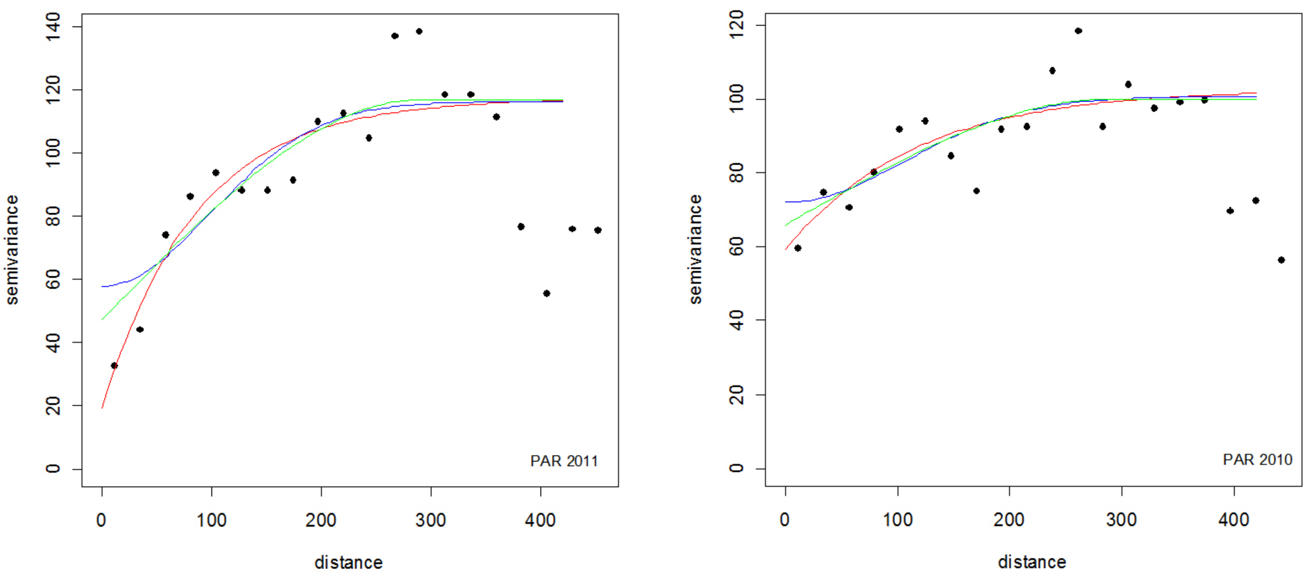


Figure 8: Empirical variogram (black circles) of *Patagonotothen ramsayi* catch densities in 2011 and 2010, with Gaussian, spherical and exponential covariance model variogram (blue, green and red lines, respectively).

Table 3: Biomass estimates of rock cod in 2011 and 2010 by random-stratified and kriging method

Year	Random-stratified method			Kriging method			Difference in density, %
	Area, km^2	Biomass, mt	Density, mt/km^2	Area, km^2	Biomass, mt	Density, mt/km^2	
2011	103018	300092	3.198	114439	380025	3.321	3.70
2010	106563	276744	2.597	114439	318918	2.787	6.82
% 2011/2010	97	108	123	100	119	119	

Estimates of rock cod density by the random-stratified method were very similar to values obtained by the kriging method (Table 3). Differences between densities of biomass distribution were 3.7 and 6.8 % for 2011 and 2010, respectively. Distribution density was 23% and 19% higher than in previous year by random-stratified and kriging methods respectively.

Total rock cod biomass in 2011 was estimated to be 300,092 tonnes based on the random-stratified method and 380,025 tonnes based on the kriging method (Table 3). The confidence intervals and coefficients of variation (CV) of biomass estimates are reasonable when compared to most common bottom fish surveys (Table 4, Doubleday, 1981).

Table 4: Mean biomass (tonnes), standard deviation (SD), 95% confidence interval limits, coefficient of variation (CV) of rock cod in 2010 and 2011

Year	2011	2010
Mean	300092	276744
SD	41638	48937
-1.96SD	218482	180828
+1.96SD	381702	372660
CV	14	18

According to Table 5, a significant contribution to the whole biomass of rock cod was made by two strata, “2b” and “3b”.

Nevertheless, the total biomass of rock cod was higher, and the total abundance (in numbers) was 7 % lower than in the previous year (Table 5). The abundance in all strata decreased from 2010 to 2011 except the stratum “1b” where the biomass increased by 30%.

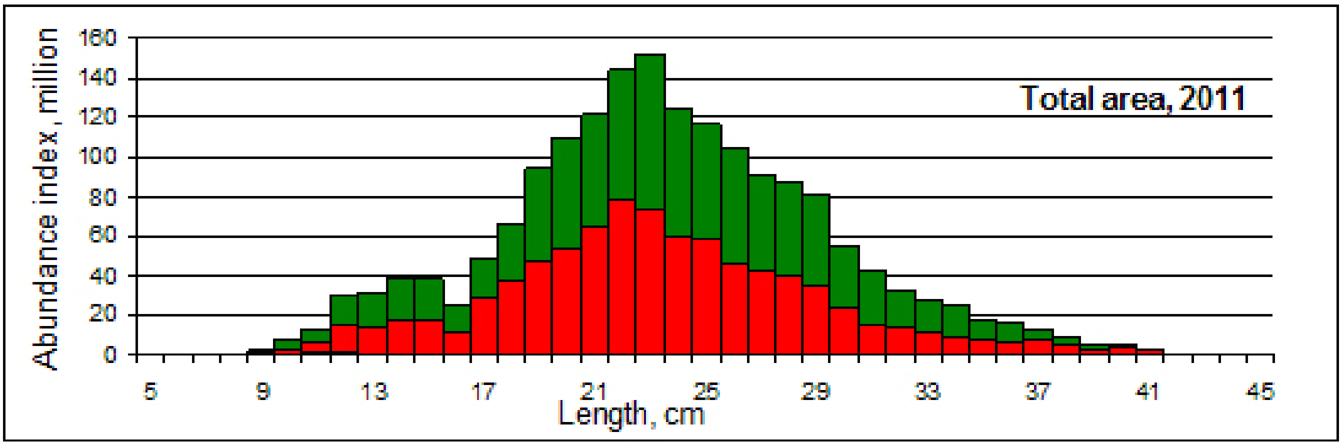
The increase of biomass with a simultaneous decrease in abundance commonly occurs when a population is ageing without sufficient recruitment. However it could be also explained by re-arrangement of different population units inside or outside of the survey area. The survey results showed an increase in the average weight of rock cod over the whole area (Table 5).

Table 5: Trawl numbers, biomass (tonnes), density (tonnes/km^2), abundance (millions) and average weight (g) of rock cod by strata in 2011 and 2010

Region	Year	1		2		3			4			Total
Stratum		b	c	b	c	a	b	c	a	b	c	
Square area, km2		4928	20395	25665	2147	10198	24884	11320	976	6050	9759	116322
Trawl numbers	2011	5	11	38	1		21			4	4	84
	2010	5	16	30	3	2	23	1	1	7		88
	%2011/2010	0	-31	27	-67	-100	-9	-100	-100	-43		-5
Biomass, t	2011	8564	27288	138098	1955		68819			15378	39989	300092
	2010	9065	38826	124707	18035	33	68389	1995	9	15684		276744
	%2011/2010	-6	-30	11	-89		1			-2		8
Density, mt/km2	2011	1.74	1.34	5.38	0.91		2.77			2.54	4.1	3.2
	2010	1.84	1.9	4.86	8.4	0	2.75	0.18	0.01	2.59		2.6
	%2011/2010	-6	-30	11	-89		1			-2		23
Abundance , mill.	2011	70	128	909	28		370			118	146	1769
	2010	54	159	997	125	4	386	18	0	165		1906
	%2011/2010	31	-20	-9	-78		-4			-28		-7
Weight, g	2011	122	213	152	70		186			130	274	170
	2010	169	244	125	144	8	177	113	30	95		145
	%2011/2010	-28	-13	21	-52		5			36		17

Length composition and maturity stage

The length frequency distributions of females, males and juveniles in the whole survey area in 2010 and 2011 are shown in Figure 9. The distribution of rock cod in 2011 was mostly unimodal with an average length from 21 to 25 cm. On the contrary, distribution of rock cod in 2010 was bi-modal with two significant peaks of 16-20 cm and 23-25 cm. Small modal groups of young fishes (5-7 cm and 11-13 cm TL) were recorded in 2010 as well.



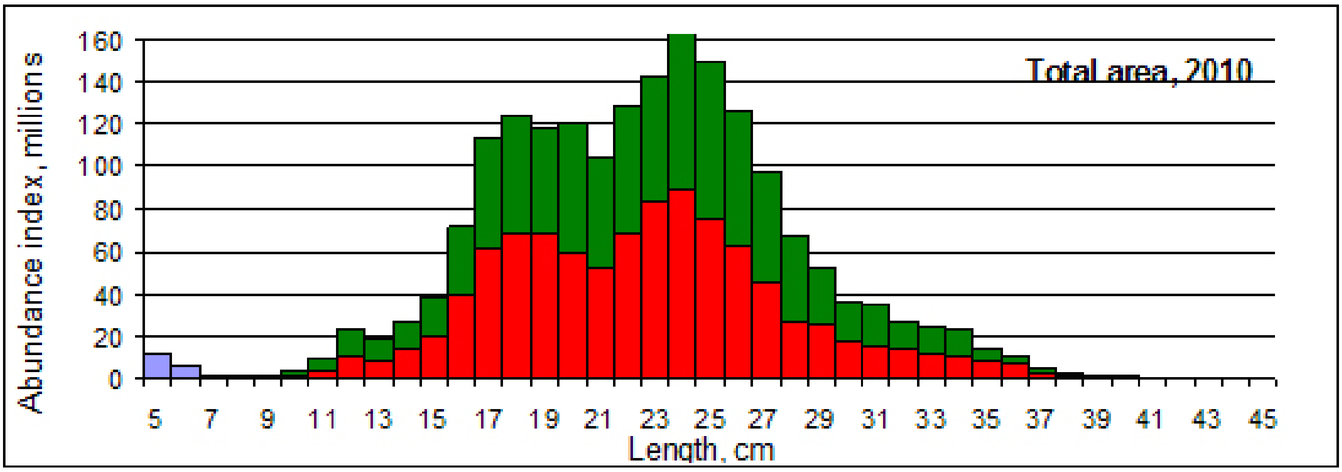


Figure 9: Length frequency distribution of females (green), males (red) and juveniles (blue) in 2011 and 2010

The population was represented mostly by immature fish at Stage I and resting fish at Stage II (Figure 10). However, some fish has started their maturation, being at Maturity stage III.

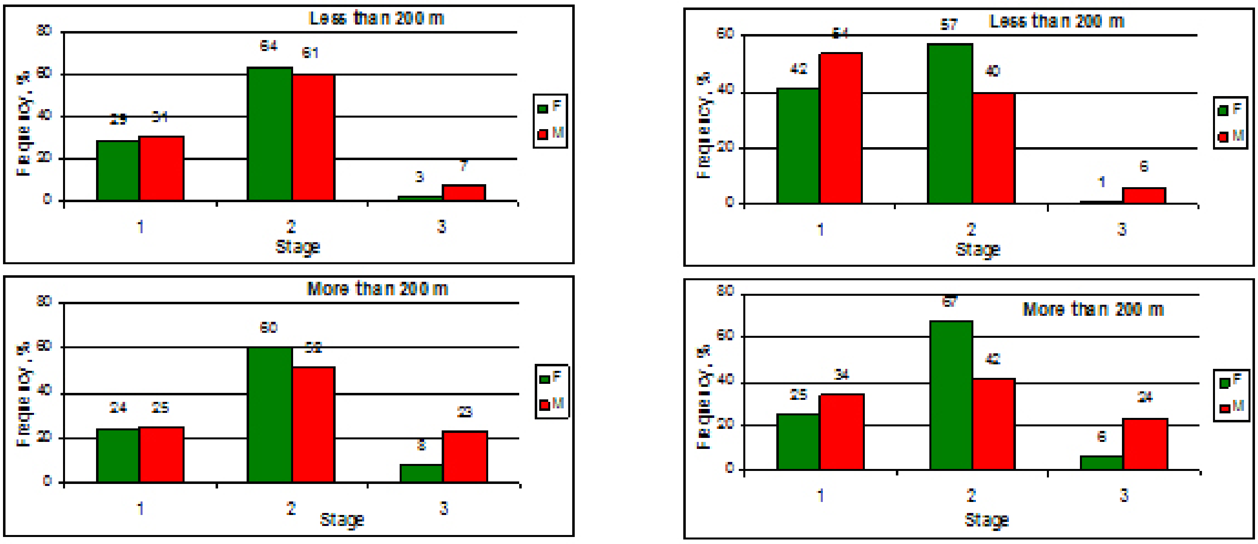


Figure 10: Maturity distribution of females (green) and males (red) of rock cod in shallow and deepwater areas in 2011 and 2010

Rock cod length composition and abundance indices by regions and strata

The length frequency distributions of females, males and juveniles in each stratum for the years 2011 and 2011 are shown in Appendix I. Most of distributions are polymodal with one or two dominant modes. The distributions in the most abundant strata “2b” shaped the general distribution presented on Figure 9.

The abundance of rock cod for the region 1 (stratum b and c) was 11% of total stock abundance for years 2011 and 2011 (Table 4). Difference between two surveys was insignificant. Length distribution of rock cod in the stratum “1b” had one significant modal peak at 17-22 cm which can correspond to the 3-year class. Animals caught in deeper waters (stratum “1c”) were considerably larger with average length of 20-35 cm.

The abundance of rock cod for the region 2 (strata b and c) composed 53% and 58% of the total stock abundance in 2011 and 2010 respectively. Stratum “2b” is most important area for rock cod in FICZ. Highest density was observed over almost the whole stratum in 2011 and 2010. Catches consisted of comparatively young animals with total length less than 25 cm. Small rock cod of the 2009-year class with average lengths 5-7 cm were recorded in 2010. This year-class is seen in 2011 as a mode of 12-14 cm. However the stock in 2011 was dominated by year-classes older than 3-year-old fishes with modal peak at around 23 cm.

5.0 Fisheries Biology - Other species

5.1 Hoki (WHI) - *Macruronus magellanicus*

Catch distribution

Hoki was the second most abundant species and represented 13.7% (28.4 tonnes) of the total catch. Its catches ranged from 0.0 to 2.3 tonnes, mean 323 kg. The mean catch of hoki was 43% lower than in the February 2010 survey. As in the previous year highest catches of hoki were recorded from southwest to northeast of the FICZ (Figure 11).

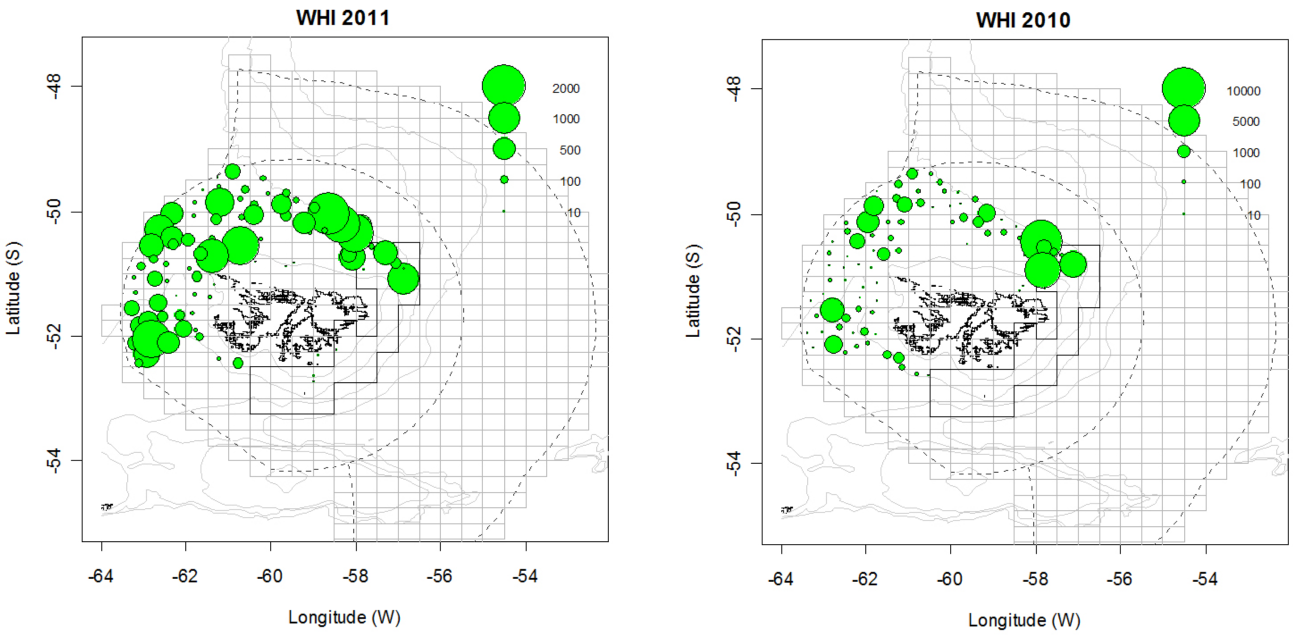


Figure 11: Catch distribution (kg/tow) of Hoki in 2011 and 2010.

Biomass Estimates

Estimates of density of hoki by the random-stratified method were similar to values of the kriging method especially for 2011 (Table 6). Differences between densities of biomass distribution were 2.1 and 12.5 % for 2011 and 2010, respectively. Distribution density was 29% and 22% lower then in the previous year by random-stratified and kriging methods respectively.

Total biomass of hoki in 2011 was 94,234 tonnes based on random-stratified method and 102,551 tonnes based on kriging method (Table 6).

Geostatistical extrapolation of kriging method showed that average distribution density of hoki was 0.932 mt/km2; 22% lower than in the previous year (Figure 12, Table 6). However variogram for hoki densities was very poor for the 2010 (Figure 13). In this case the data did not reveal any consistent pattern of spatial correlation.

Table 6: Biomass estimates of hoki in 2011 and 2010

Year	Random-stratified method			Kriking method			Difference in density, %
	Area, km^2	Biomass, mt	Density, mt/km^2	Area, km^2	Biomass, mt	Density, mt/km^2	
2011	103018	94234	0.915	114439	102551	0.932	-2.08
2010	106563	137845	1.294	114439	131546	1.149	-12.53
% 2011/2010	-3	-32	-29	0	-22	-22	

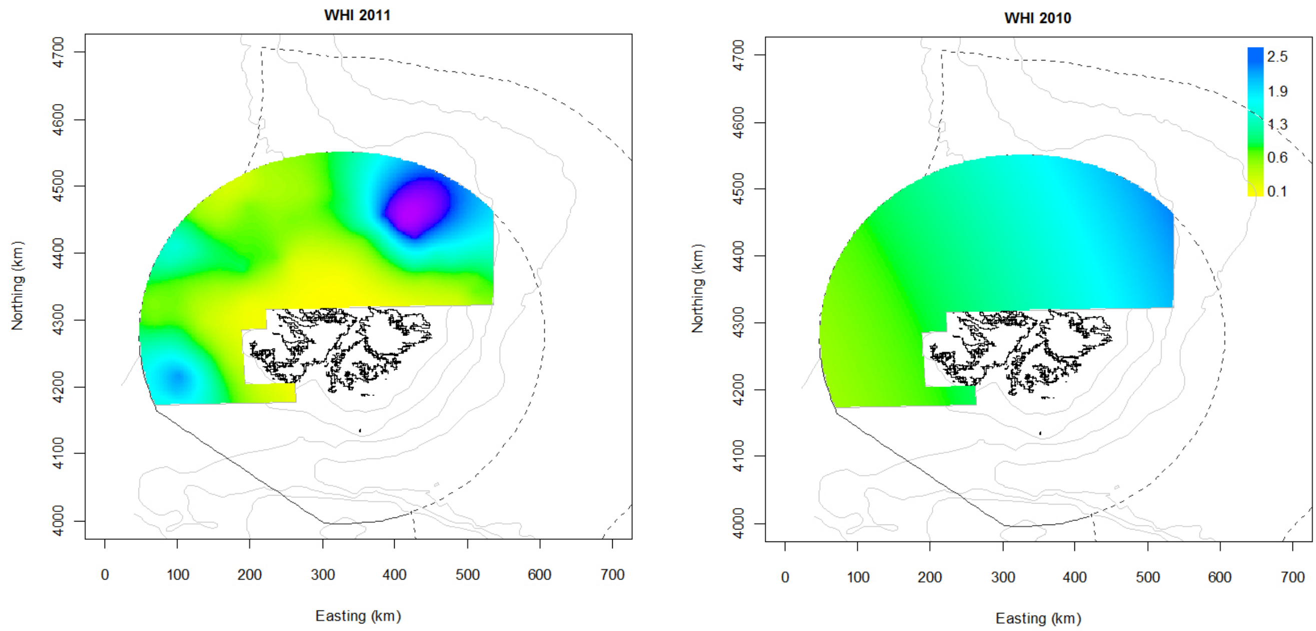


Figure 12: The distribution of density (mt/t) of hoki in 2011 and 2010

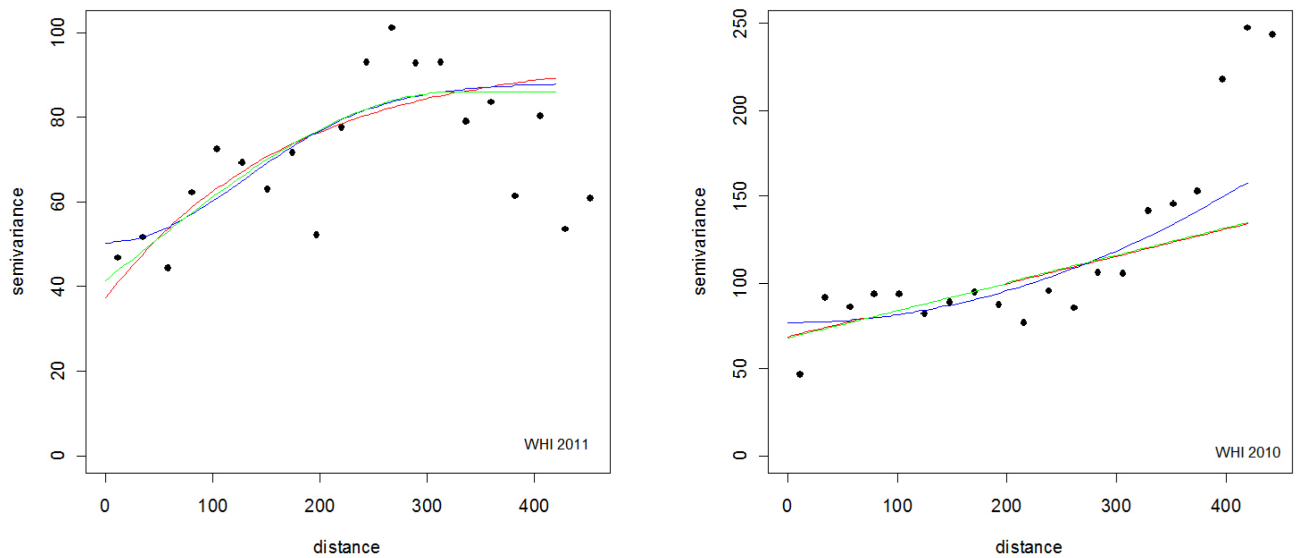


Figure 13: Empirical variogram (black circles) of hoki catch densities in 2011 and 2010, with Gaussian, spherical and exponential covariance model variogram (blue, green and red lines, respectively).

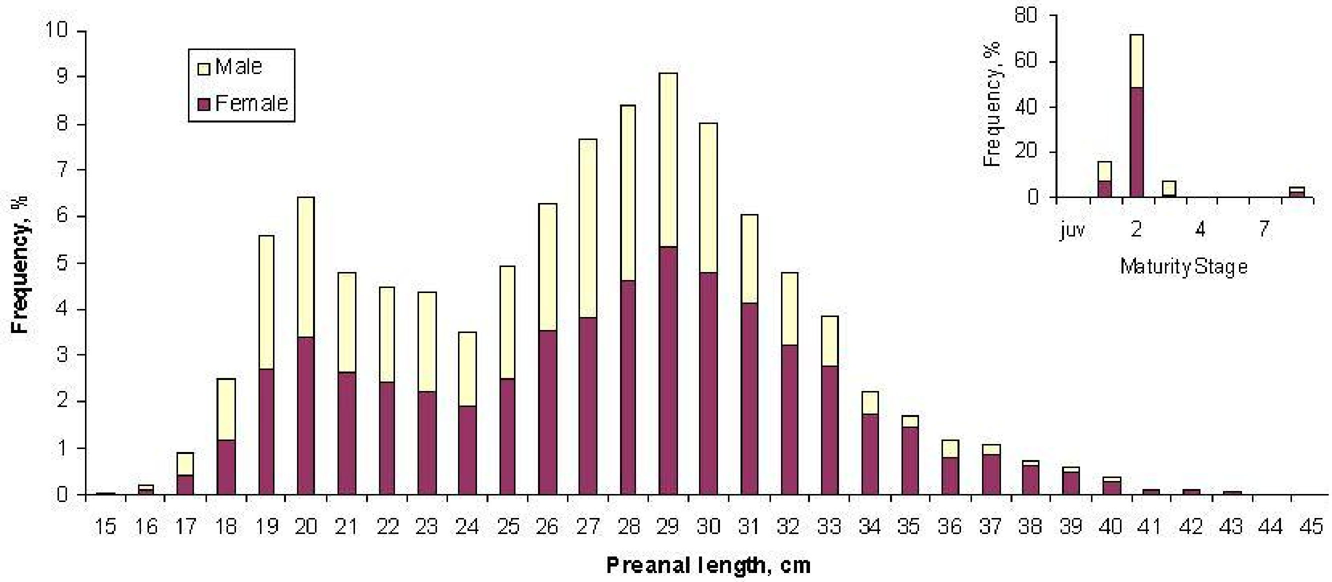


Fig. 14: Length – frequencies and maturity of hoki.

Fish size varied from 13 to 46 cm TL with two modal groups present both in males and in females: 19-22 cm and 27-30 cm. Most of hoki were at the maturity stage II and well recovered after the spring (October – November) spawning, though some of them still had spent gonads (Figure 14).

5.2 Red cod (BAC) - *Salilota australis*

Catch distribution

Red cod was the third most abundant species and represented 10.9% (23.1 tonnes) of the total catch. Its catches ranged from 0.0 to 7.4 tonnes, mean 262 kg. The mean catch of red cod was 72% higher than in February 2010 during the previous bottom survey. The highest catches of red cod were recorded northwest of the FICZ (Figure 15).

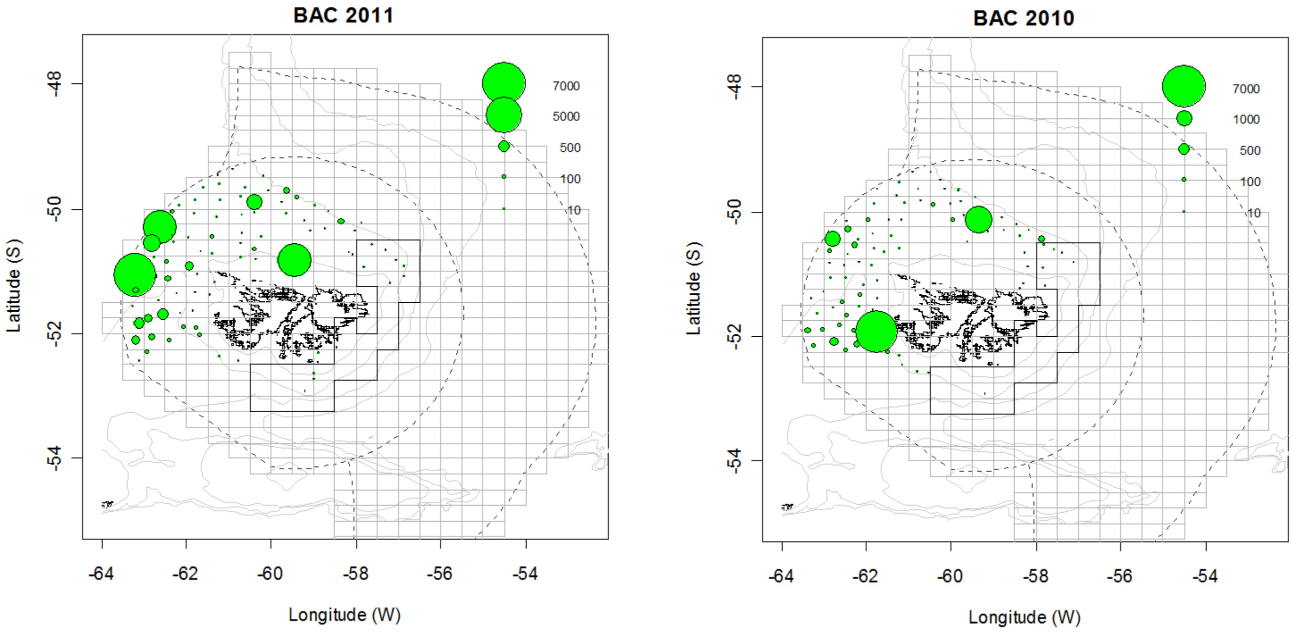


Figure 15: Catch distribution (kg/tow) of - *Salilota australis* in 2011 and 2010.

Biomass Estimates

Density estimates of red cod by the random-stratified method were different to values of the kriging method especially for 2010 (Table 7). Differences between densities of the biomass distribution were 108 and 151 % for 2011 and 2010, respectively. Distribution density was 51% and 83% lower then in the previous year by random-stratified and kriging methods respectively. The total biomass of red cod in 2011 was 56,038 tonnes based on the random-stratified method and 29,983 tonnes based on the kriging method (Table 7).

Geostatistical extrapolation of the kriging method showed that the average distribution density of red cod was 0.262 mt/km^2; 22% higher than the previous year (Figure 16, Table 7). However variograms for red cod densities were very poor for surveys (Figure 16). In this case these data did not reveal any consistent pattern of spatial correlation.

Table 7. Biomass estimates of *Salilota australis* in 2011 and 2010

Year	Random-stratified method			Kriking method			Difference in density, %
	Area, km^2	Biomass, mt	Density, mt/km^2	Area, km^2	Biomass, mt	Density, mt/km^2	
2011	103018	56038	0.544	114439	29983	0.262	-107.62
2010	106563	38269	0.359	114439	16365	0.143	-151.13
% 2011/2010	-3	46	51	0	83	83	

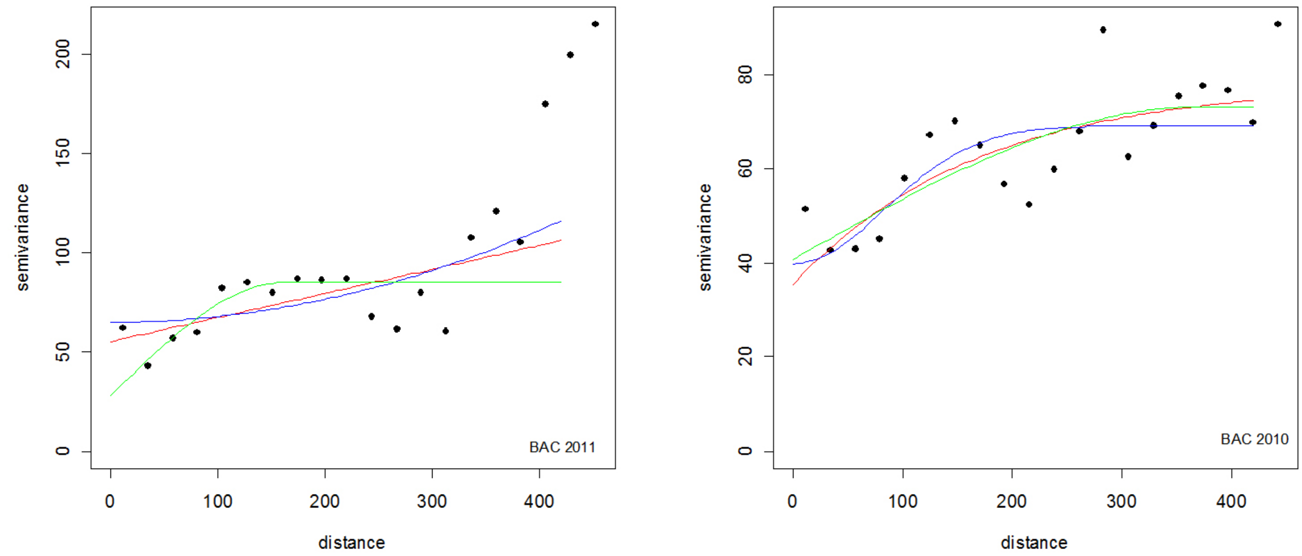


Figure 16: Empirical variogram (black circles) of - *Salilota australis* catch densities in 2011 and 2010, with Gaussian, spherical and exponential covariance model variogram (blue, green and red lines, respectively).

Length-frequency distribution of red cod was polymodal with two predominating sizes of 16-19 cm and 25-28 cm (Figure 17). Most of the representatives of both sexes were either immature (Stage 2) or early maturing (Stage 3).

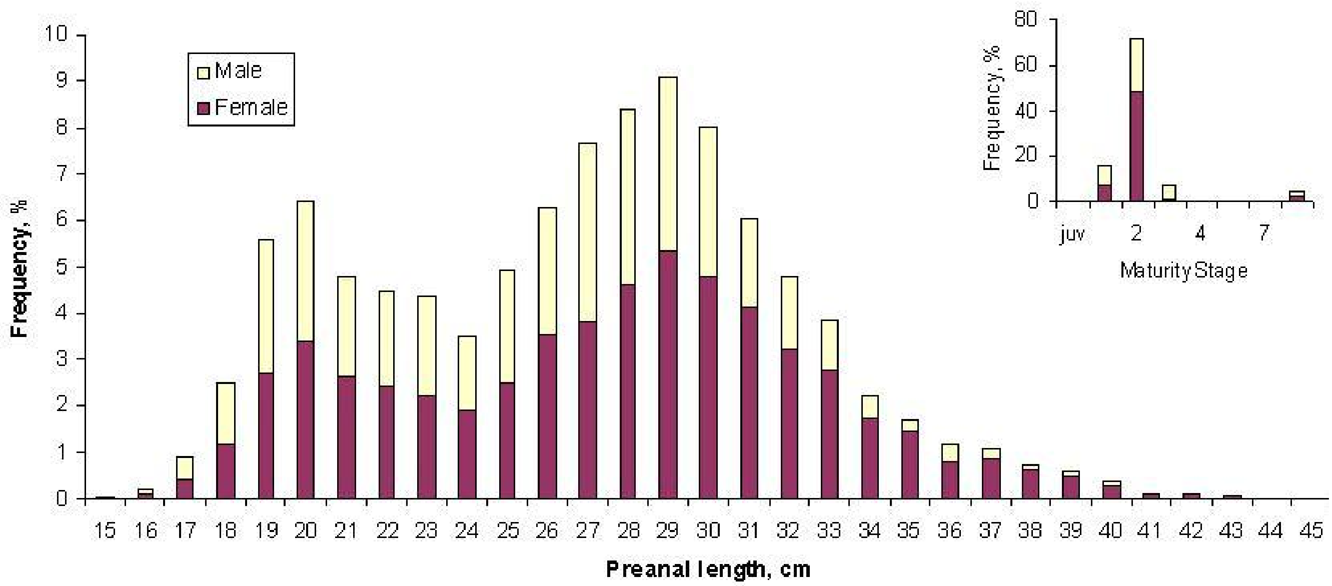


Figure 17: Length – frequencies and maturity of red cod

5.3 Kingclip (KIN) - *Genypterus blacodes*

Catch distribution

Kingclip was the forth most abundant species and represented 4.0% (8.4 tonnes) of the total catch. Its catches ranged from 0.0 to 1.5 tonnes, mean 95.7 kg. The mean catch of kingclip was 175% higher than in February 2010. As in the previous year highest catches of kingclip were recorded from southwest to northeast of the FICZ (Figure 18).

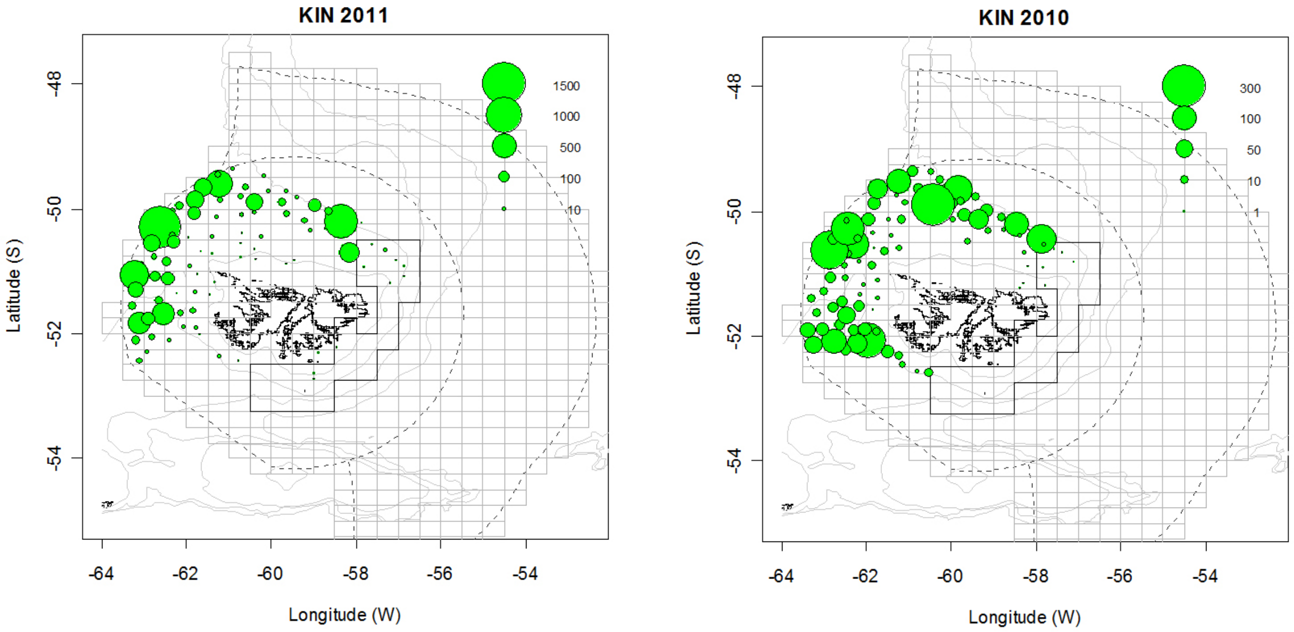


Figure 18: Catch distribution (kg/tow) of - Genypterus blacodes in 2011 and 2010.

Biomass Estimates

Estimates of kingclip density by the random-stratified method were more or less similar to values of kriging method (Table 8). Differences between densities of biomass distribution were 13 and 25 % for 2011 and 2010, respectively. Distribution density was 152% and 178% higher than in the previous year by random-stratified and kriging methods respectively. Total biomass of kingclip in 2011 was 22,005 tonnes based on random-stratified method and 21,629 tonnes based on kriging method (Table 8).

Geostatistical extrapolation of kriging method showed that average distribution density of kingclip was 0.189 mt/km^2; 178% higher than the previous year (Table 8). However, the variograms were very poor for surveys as shown in Figure 19. In this case these data did not reveal a consistent pattern of spatial correlation.

Table 8. Biomass estimates of *Genypterus blacodes* in 2011 and 2010

Year	Random-stratified method			Kriking method			Difference in density, %
	Area, km^2	Biomass, mt	Density, mt/km^2	Area, km^2	Biomass, mt	Density, mt/km^2	
2011	103018	22005	0.214	114439	21629	0.189	-13.02
2010	106563	9047	0.085	114439	7782	0.068	-24.85
% 2011/2010	-3	143	152	0	178	178	

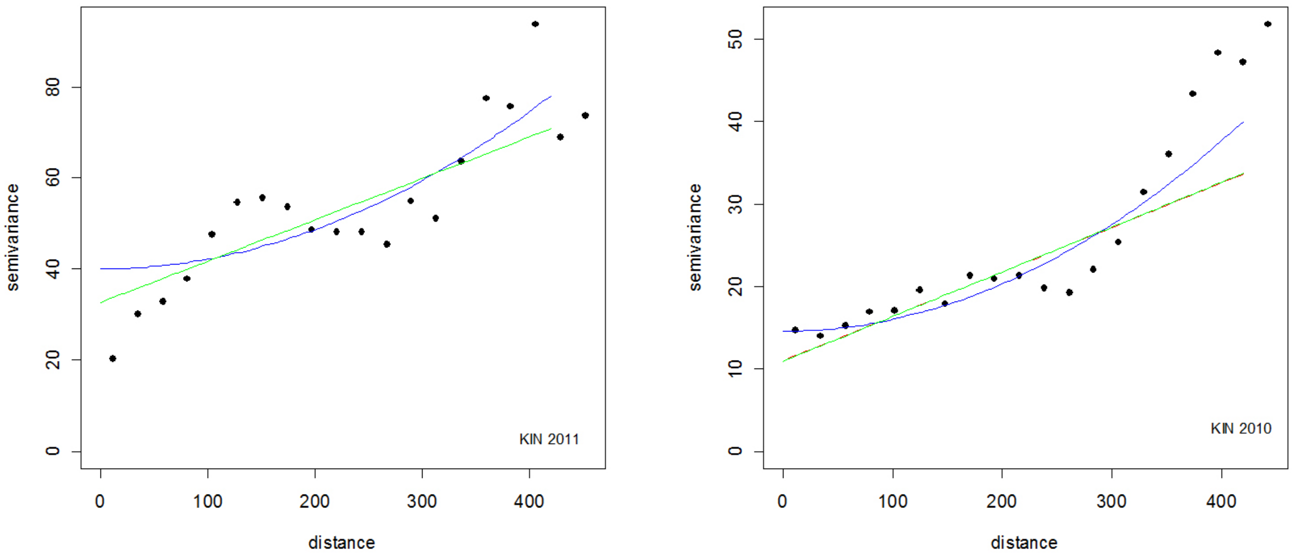


Figure 19: Empirical variogram (black circles) of *Genypterus blacodes* catch densities in 2011 and 2010, with Gaussian, spherical and exponential covariance model variogram (blue, green and red lines, respectively).

Kingclip size varied from 33 to 136 cm without any prominent mode, most fish were resting (Stage 2) 50-75 cm TL. However, a small number of spawning fish (76-116 cm TL) also occurred in catches as in the previous year.

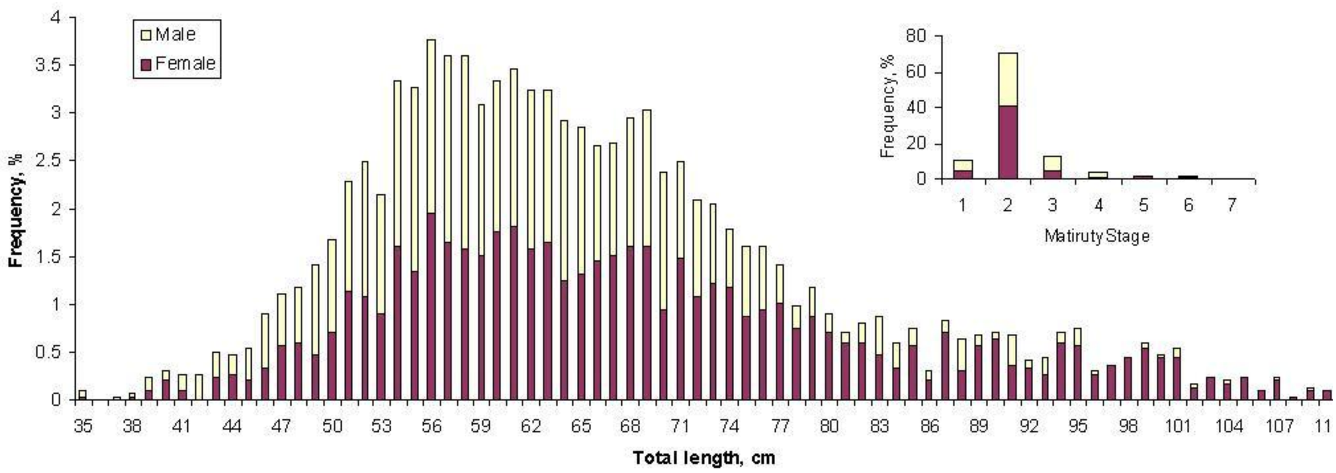


Figure 20: Length – frequencies and maturity of kingclip

5.4 Southern blue whiting (BLU) - *Micromesistius australis*

Catch distribution

Blue whiting was the fifth most abundant species and represented 2.6% (5.6 tonnes) of the total catch. Its catches ranged from 0.0 to 1.2 tonnes, mean 63.5 kg. The mean catch of blue whiting was 32% higher than in February 2010. As in the previous year high catches of blue whiting were recorded southwest of the FICZ (Figure 21). However, the highest catch, in 2001, (1.2 tonnes) was obtained in the northern part of the *Loligo* Box.

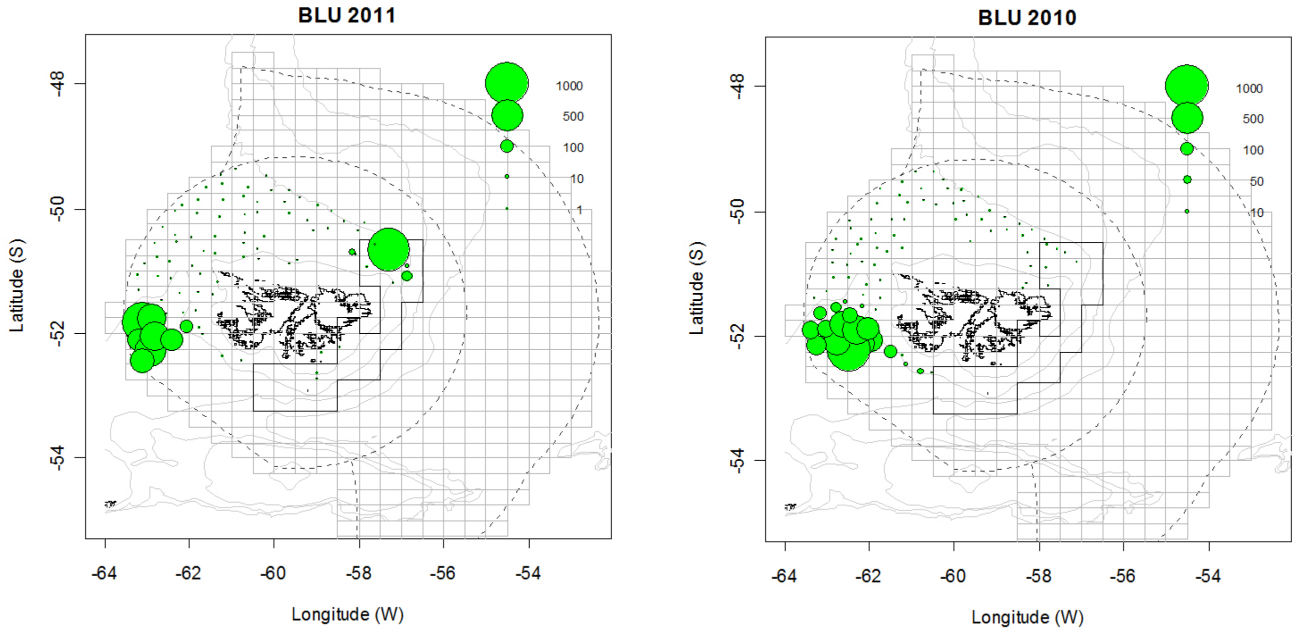


Figure 21: Catch distribution (kg/tow) of - *Micromesistius australis* in 2011 and 2010.

Biomass Estimates

Density estimates of blue whiting by the random-stratified method were completely different to values obtained by the kriging method (Table 9). Differences between densities of biomass distribution were 1722 and 265 % for 2011 and 2010, respectively. Distribution density was 109 % higher and 57 % lower than in the previous year by random-stratified and kriging methods respectively. Total biomass of blue whiting in 2011 was 30,005 tonnes based on random-stratified method and 1,831 tonnes based on kriging method (Table 9).

Geostatistical extrapolation of the kriging method showed that average distribution density of blue whiting was 0.016 mt/km2; 57% lower than the previous year (Table 9). However the variograms were very poor for survey in 2011 and 2010 (Figure 22). In this case these data did not reveal a consistent pattern of spatial correlation.

Table 9. Biomass estimates of *Micromesistius australis* in 2011 and 2010

Year	Random-stratified method			Kriking method			Difference in density, %
	Area, km^2	Biomass, mt	Density, mt/km^2	Area, km^2	Biomass, mt	Density, mt/km^2	
2011	103018	30027	0.291	114439	1831	0.016	-1721.71
2010	106563	14391	0.135	114439	4234	0.037	-264.99
% 2011/2010	-3	109	116	0	-57	-57	

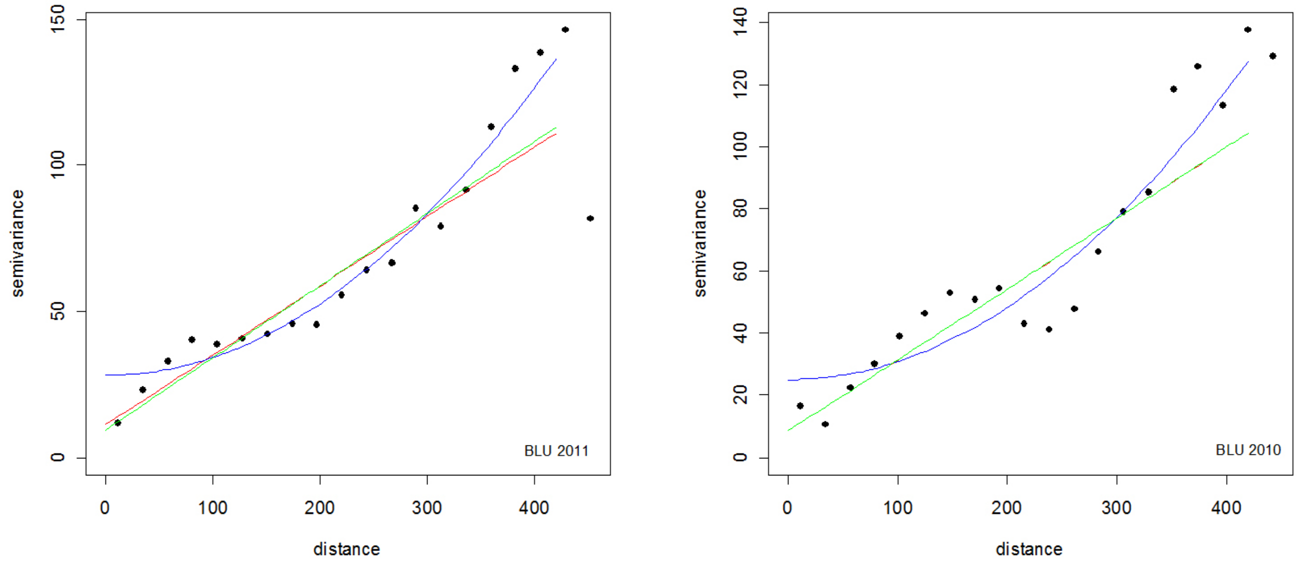


Figure 22 Empirical variogram (black circles) of - *Micromesistius australis* catch densities in 2011 and 2010, with Gaussian, spherical and exponential covariance model variogram (blue, green and red lines, respectively).

Size of blue whiting in catches varied from 6 to 67 cm (Figure 23) with three predominating size groups: 23-26 cm, 32-34 cm and 58-62 cm. Fish was either spent (stage 8) or mostly at maturity stages 1 and 2.

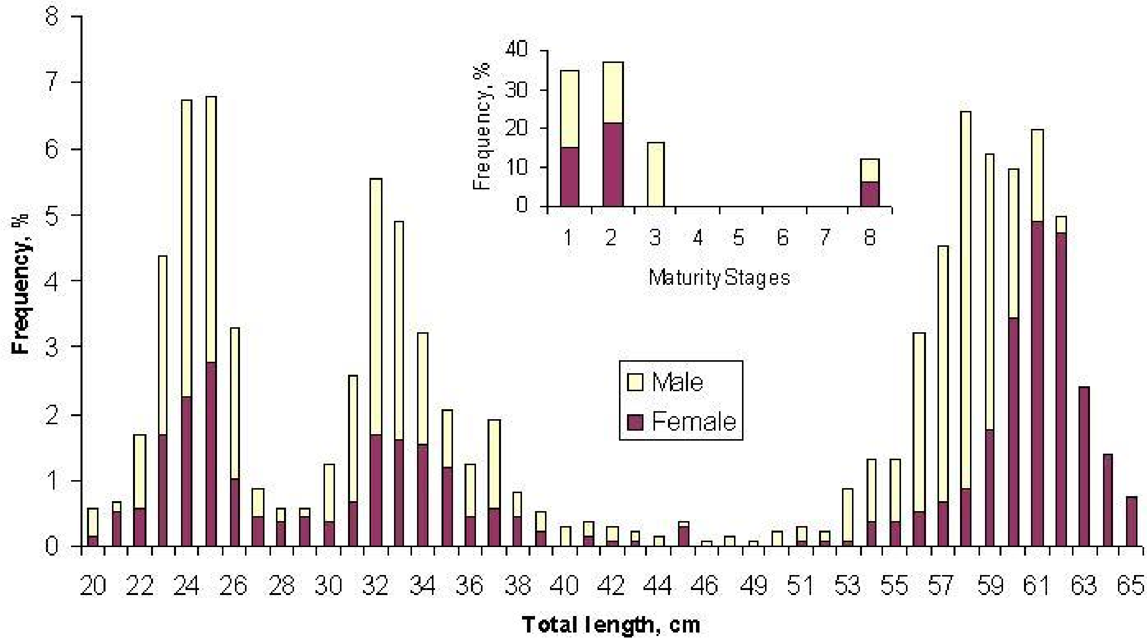


Figure 23: Length-frequencies and maturity of blue whiting.

5.6 Patagonian toothfish (TOO) - Dissostichus eleginoides

Catch distribution

Toothfish represented 0.05% (1.1 tonnes) of the total catch. Its catches ranged from 0.0 to 108 kg, mean 12.6 kg. The mean catch of toothfish was 10% lower than in February 2010 during the previous bottom survey. As in the previous year the highest catches of toothfish were recorded in the southwest and northeast of the FICZ (Figure 24).

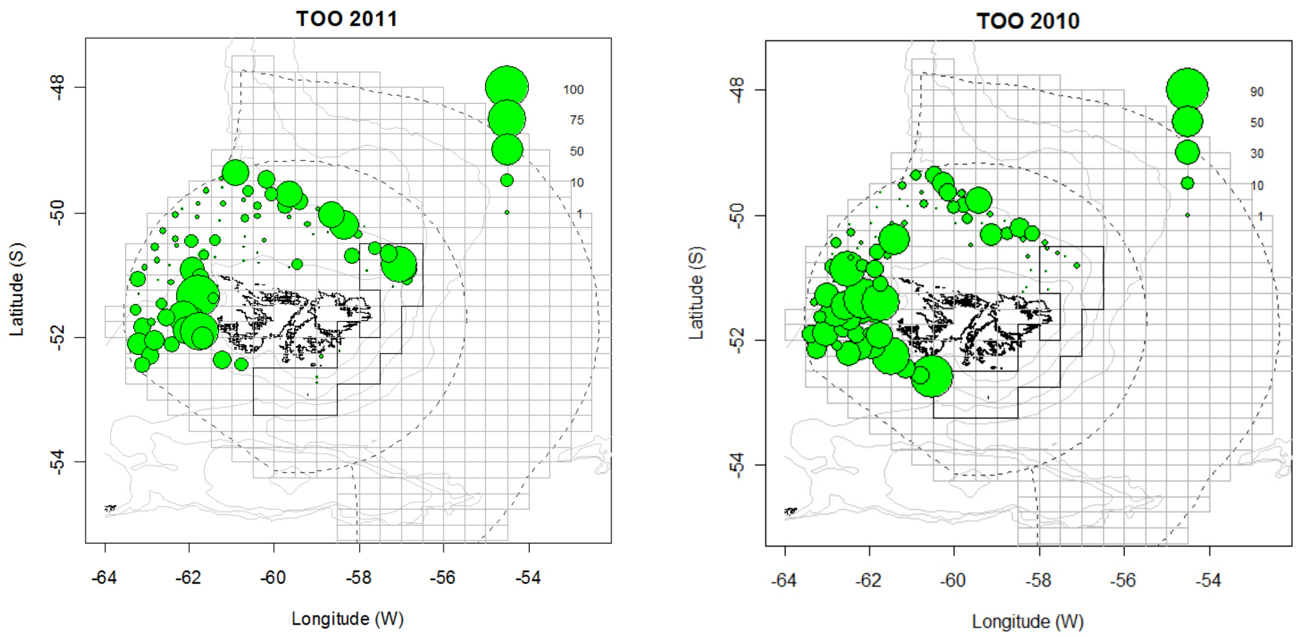


Figure 24: Catch distribution (kg/tow) of - *Dissostichus eleginoides* in 2011 and 2010.

Biomass Estimates

Estimates of toothfish density by the random-stratified method were similar to values of the kriging method especially for the 2011 survey (Table 10). Differences between densities of biomass distribution were 1 and 17 % for 2011 and 2010, respectively. Distribution density was 14% lower and 3 % higher than in the previous year by random-stratified and kriging methods respectively. Total biomass of toothfish in 2011 was 3,863 tonnes based on random-stratified method and 4,234 tonnes based on kriging method (Table 10).

Geostatistical extrapolation of the kriging method showed that average distribution density of toothfish was 0.037 mt/km^2; 3% higher than the previous year (Figure 25, Table 10). Good variograms from the survey data in both years (Figure 26).

Table 10. Biomass estimates of *Dissostichus eleginoides* in 2011 and 2010

Year	Random-stratified method			Kriking method			Difference in density, %
	Area, km^2	Biomass, mt	Density, mt/km^2	Area, km^2	Biomass, mt	Density, mt/km^2	
2011	103018	3863	0.037	114439	4234	0.037	-1.35
2010	106563	4492	0.042	114439	4120	0.036	-17.09
% 2011/2010	-3	-14	-11	0	3	3	

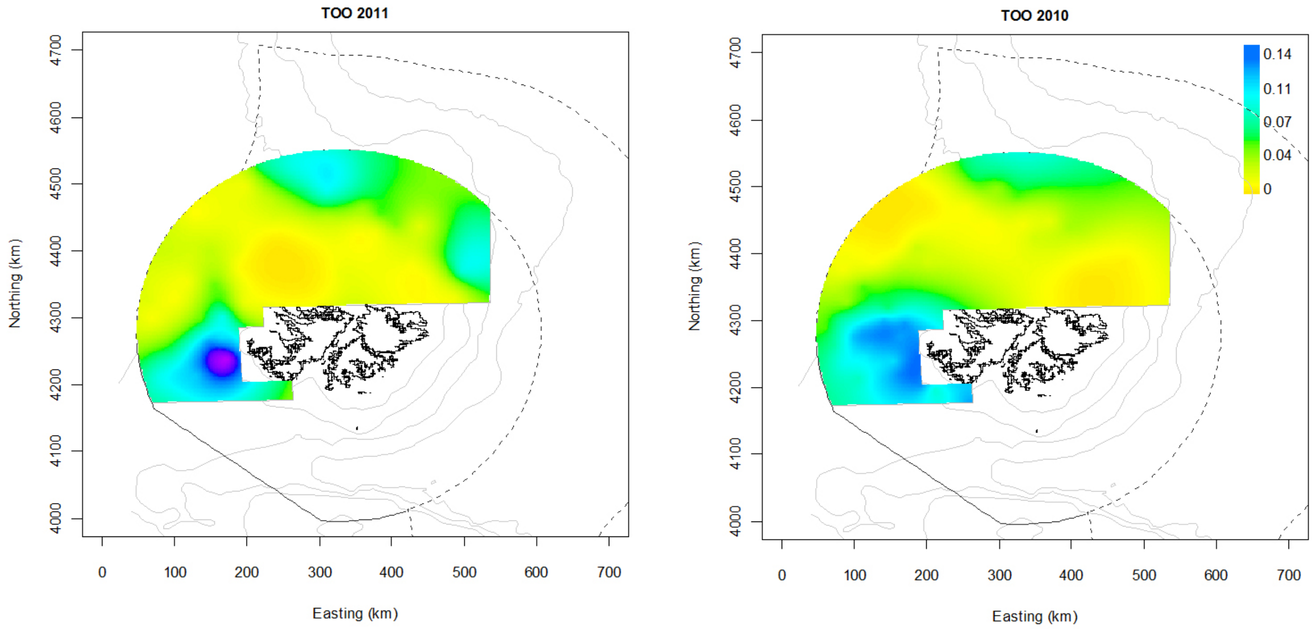


Figure 25: The distribution of density (mt/t) of - *Dissostichus eleginoides* in 2011 and 2010

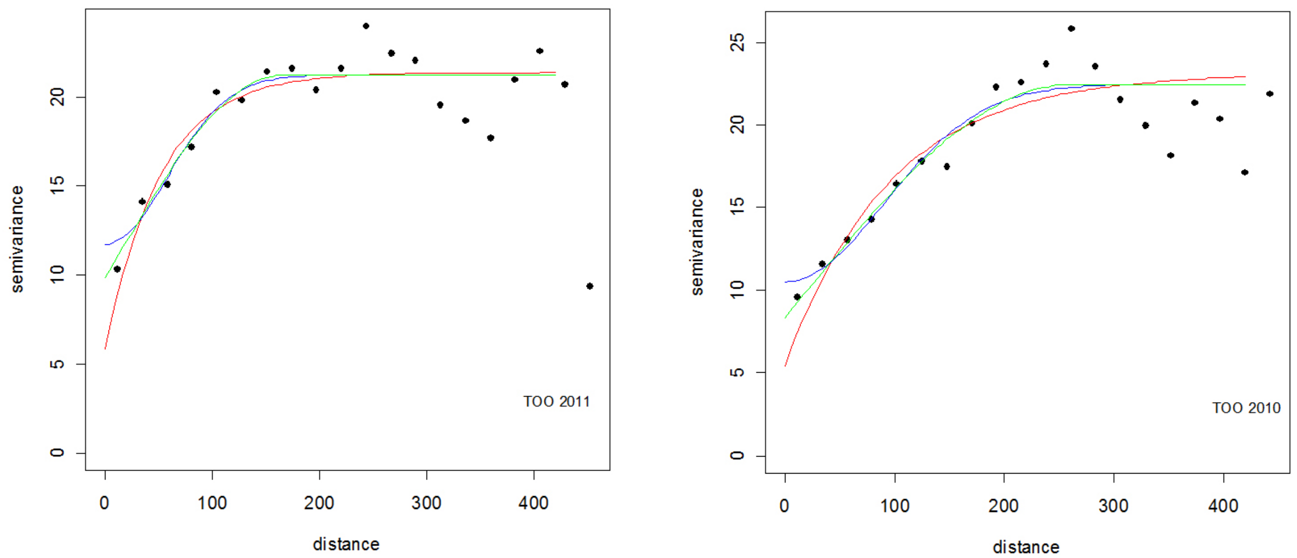


Figure 26: Empirical variogram (black circles) of- *Dissostichus eleginoides* catch densities in 2011 and 2010, with Gaussian, spherical and exponential covariance model variogram (blue, green and red lines, respectively).

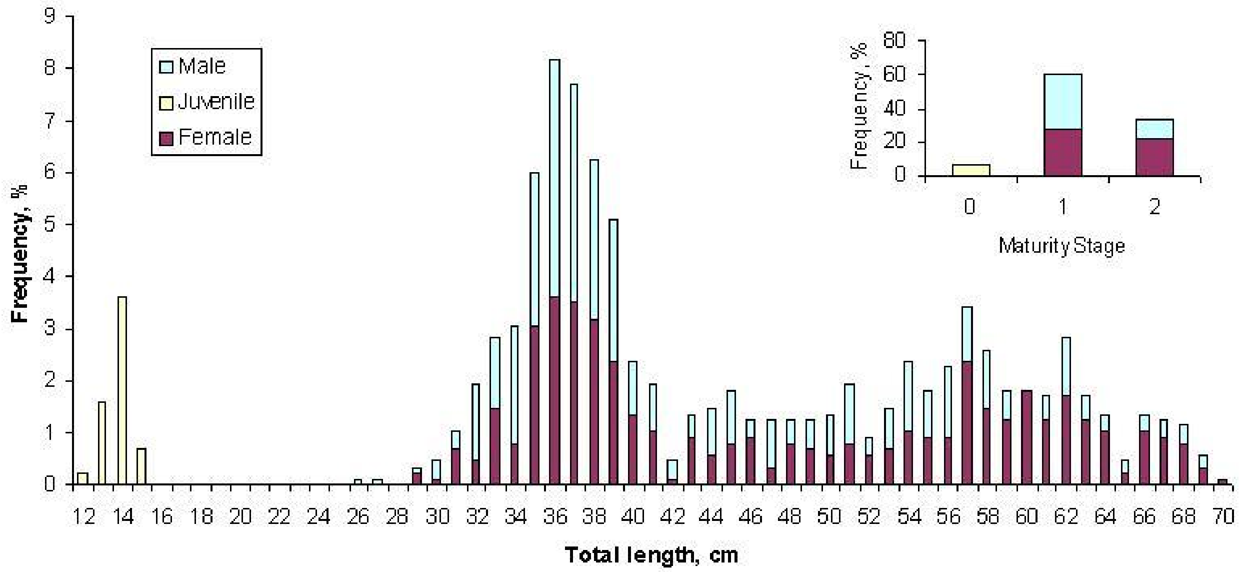


Figure 27: Length-frequencies and maturity of Patagonian toothfish.

Fish size in catches varied from 12 to 90 cm, with the most abundant cohort of 35-38 cm TL (presumably fish of 3+ y.o.). A new generation born in the year 2009 (0+ y.o.) of 12-15 cm TL was also obvious and reasonably abundant (Fig. 27). All fish was immature (Stage 1 and 2) as expected on the shelf waters.

5.7 Patagonian squid (LOL) - Loligo gahi

Catch distribution

Loligo gahi was the most abundant species of squid and represented 1.7% (3.6 tonnes) of the total catch. Its catches ranged from 0.0 to 334 kg, mean 40.6 kg. The mean catch of *Loligo* was 6% higher than in February 2010. As in the previous year high catches of *Loligo* were recorded in shallow waters near by the *Loligo* Box and north of the FICZ (Figure 28).

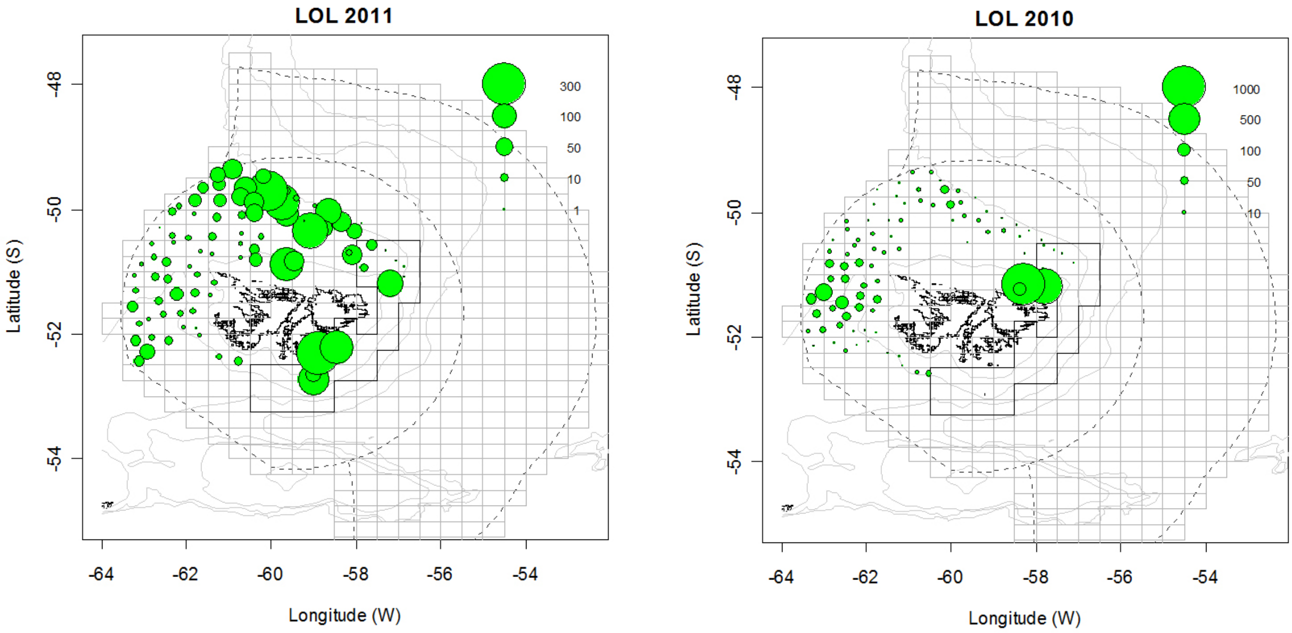


Figure 28: Catch distribution (kg/tow) of - *Loligo gahi* in 2011 and 2010.

Biomass Estimates

Estimates of *Loligo* density using the random-stratified method were similar to values of the kriging method for the 2011 survey and completely different for the 2010 survey (Table 11). Differences between densities of biomass distribution were 7 and 298 % for 2011 and 2010, respectively. Distribution density was 60 % lower and 73 % higher than in the previous year by random-stratified and kriging methods respectively. The total biomass of *Loligo* in 2011 was 8,591 tonnes based on the random-stratified method and 10,300 tonnes based on kriging method (Table 11).

Geostatistical extrapolation of the kriging method showed that average distribution density of Loligo was 0.090 mt/km^2; 73% higher than in the previous year (Figure 29, Table 11). The variograms were poor for the surveys (Figure 30). In this case the data did not reveal a consistent pattern of spatial correlation.

Table 11. Biomass estimates of *Loligo gahi* in 2011 and 2010

Year	Random-stratified method			Kriking method			Difference in density, %
	Area, km^2	Biomass, mt	Density, mt/km^2	Area, km^2	Biomass, mt	Density, mt/km^2	
2011	103018	8591	0.083	114439	10300	0.090	7.34
2010	106563	22033	0.207	114439	5951	0.052	-297.62
% 2011/2010	-3	-61	-60	0	73	73	

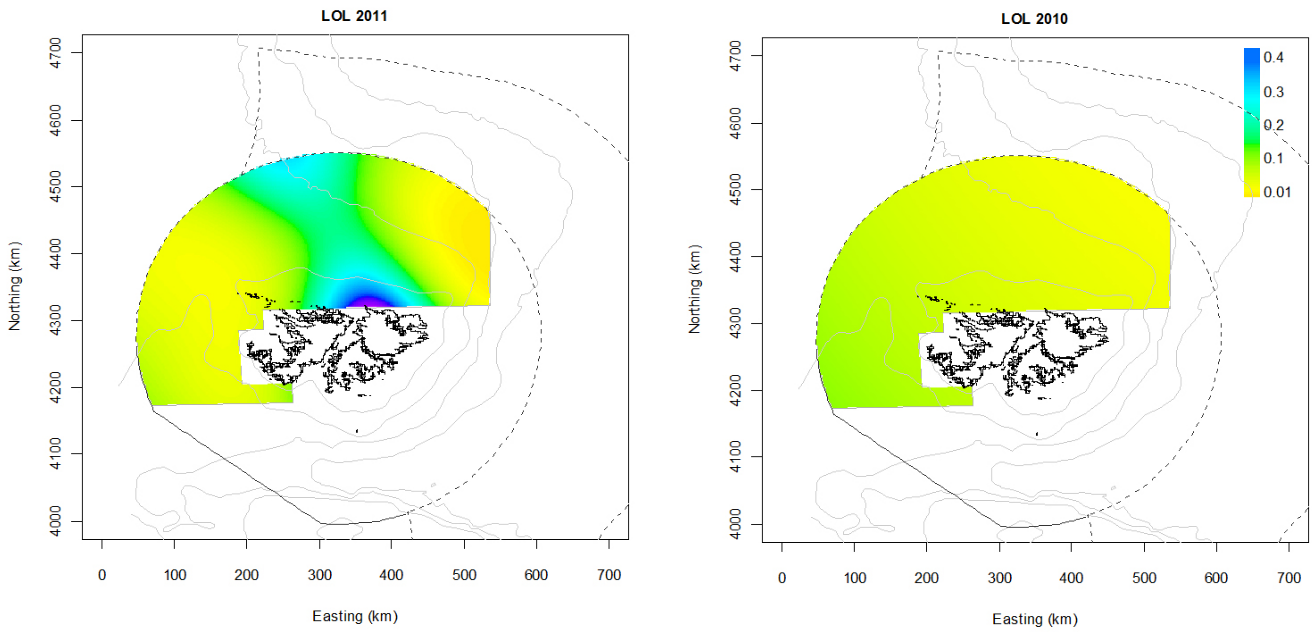


Figure 29: The distribution of density (mt/t) of *Loligo gahi* in 2011 and 2010

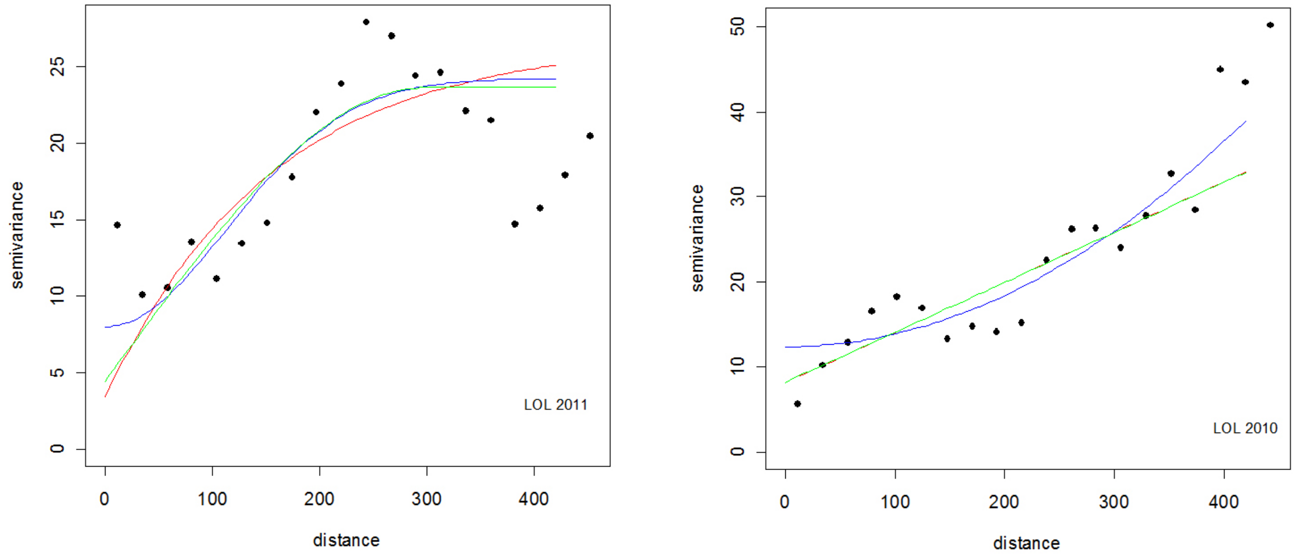


Figure 30: Empirical variogram (black circles) of - *Loligo gahi* catch densities in 2011 and 2010, with Gaussian, spherical and exponential covariance model variogram (blue, green and red lines, respectively).

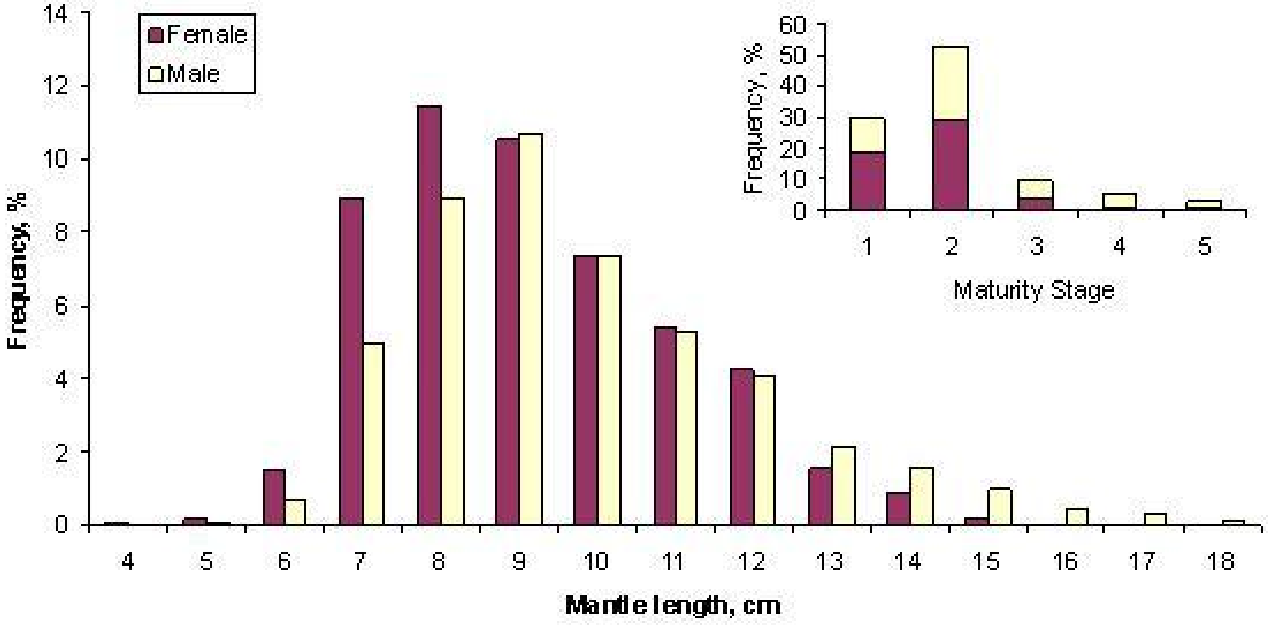


Fig. 31 Length-frequencies and maturity of the squid *Loligo gahi*

Squid size in catches varied from 4 to 25 cm. Most of the females were 7-9 cm ML, most of males – 8-10 cm ML. The bulk of population was represented by immature squids.

5.8 Illex squid (ILL) - *Illex argentinus*

Catch distribution

Illex was the second most abundant species of squid and represented 0.9% (1.9 tonnes) of the total catch. Its catches ranged from 0.0 to 288 kg, mean 21.27 kg. Mean catch of *Illex* was 114% higher than in February 2010 during previous bottom survey. As in previous year high catches of *Illex* were recorded northwest of the FICZ (Figure 32).

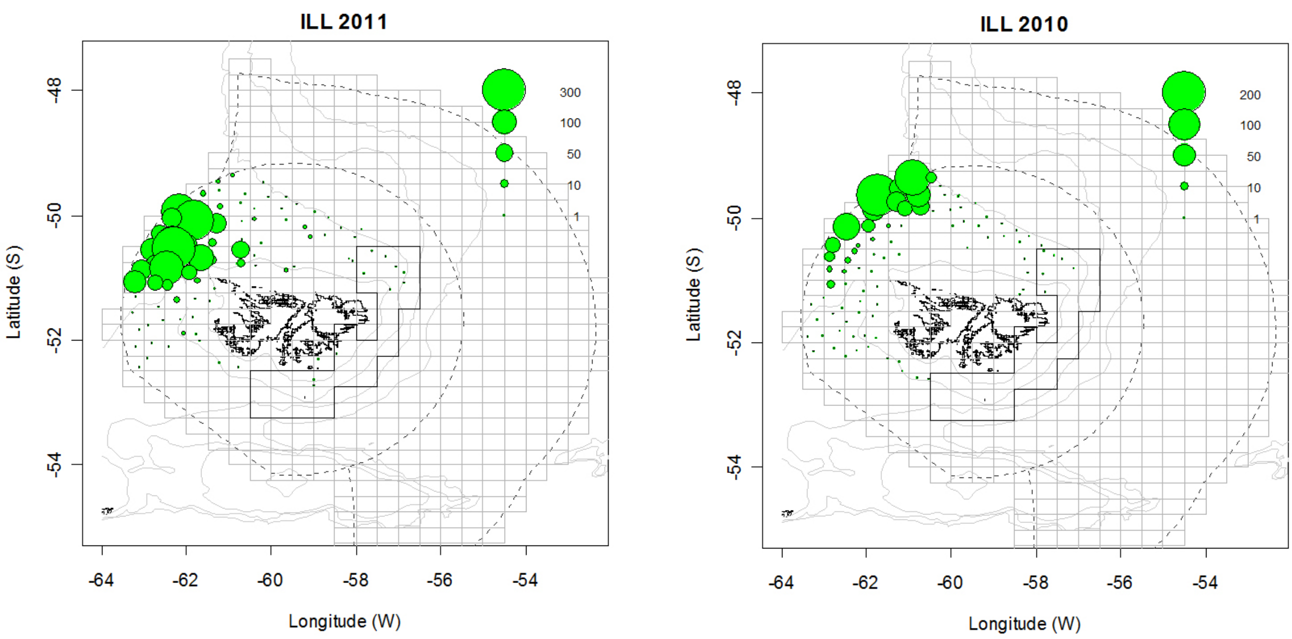


Figure 32: Catch distribution (kg/tow) of *Illex argentinus* in 2011 and 2010.

Biomass Estimates

Estimates of *Illex* density by the random-stratified method were quite similar to values of the kriging method (Table 12). Differences between densities of biomass distribution were 4 and 21 % for 2011 and 2010, respectively. Distribution density was 64% and 106 % higher than in the previous year by random-stratified and kriging methods respectively. The total biomass of *Illex* in 2011 was 3,465 tonnes based on random-stratified method and 4,005 tonnes based on kriging method (Table 12).

Geostatistical extrapolation of the kriging method showed that average distribution density of *Illex* was 0.035 mt/km^2; 106% higher than in previous year (Figure 33, Table 12). However the variograms were poor for the surveys in 2011 and 2010 as is shown in Figure 34. In this case the data did not reveal consistent pattern of spatial correlation.

Table 12. Biomass estimates of *Illex argentinus* in 2011 and 2010

Year	Random-stratified method			Kriking method			Difference in density, %
	Area, km^2	Biomass, mt	Density, mt/km^2	Area, km^2	Biomass, mt	Density, mt/km^2	
2011	103018	3465	0.034	114439	4005	0.035	3.90
2010	106563	2192	0.021	114439	1945	0.017	-21.00
% 2011/2010	-3	58	64	0	106	106	

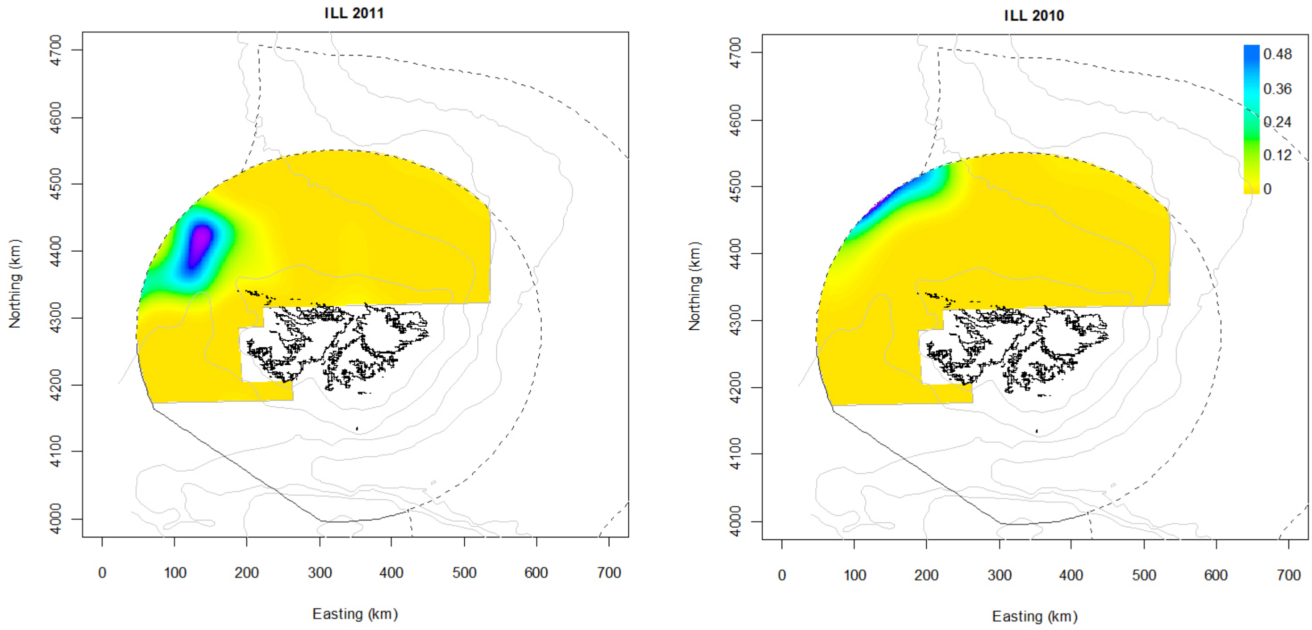


Figure 33: The distribution of density (mt/t) of *Illex argentinus* in 2011 and 2010

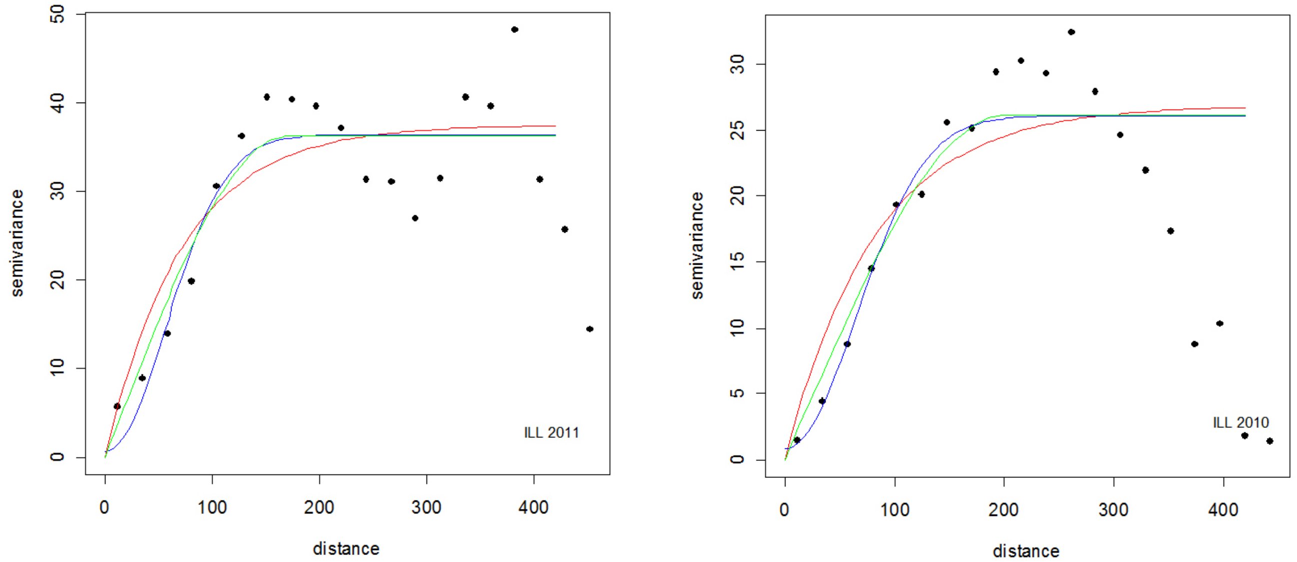


Figure 34: Empirical variogram (black circles) of *Illex argentinus* catch densities in 2011 and 2010, with Gaussian, spherical and exponential covariance model variogram (blue, green and red lines, respectively).

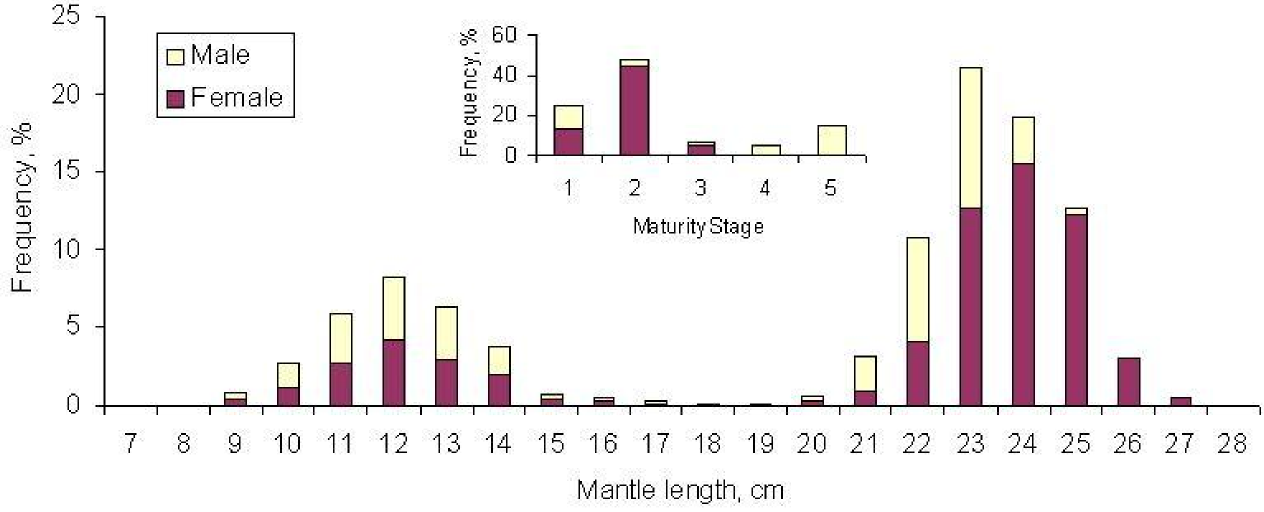
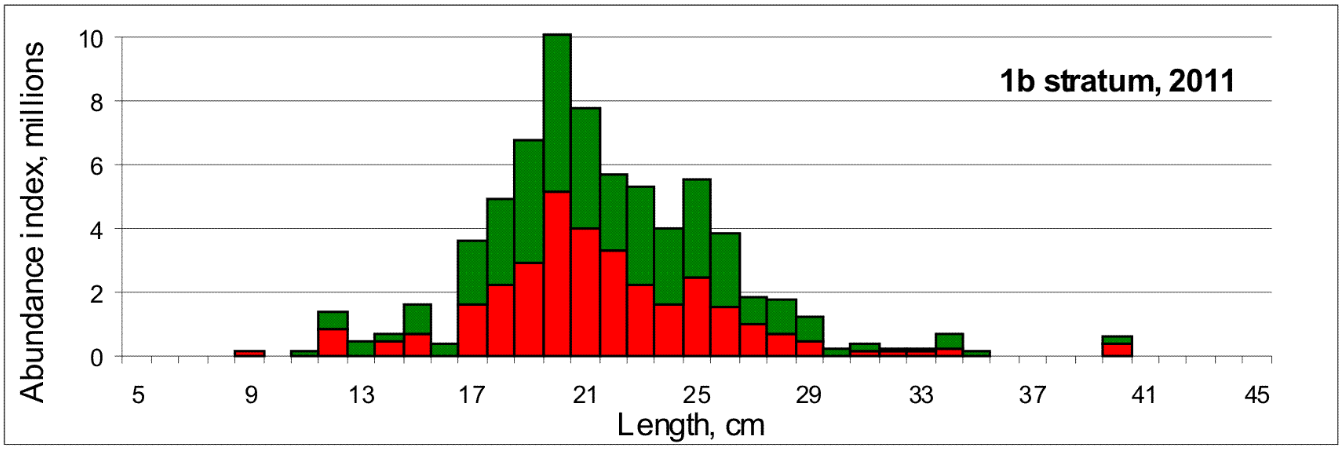
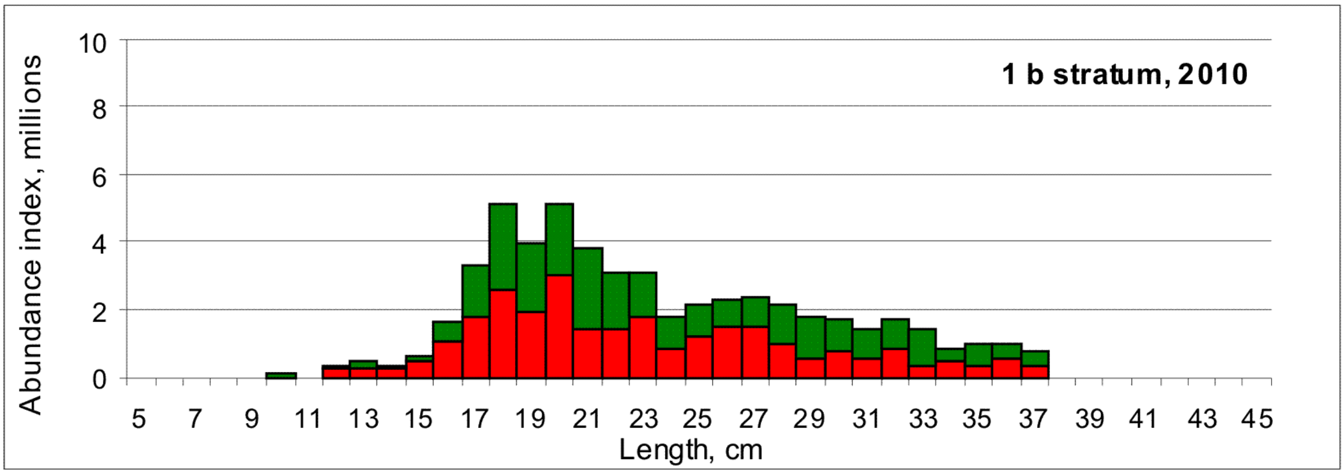


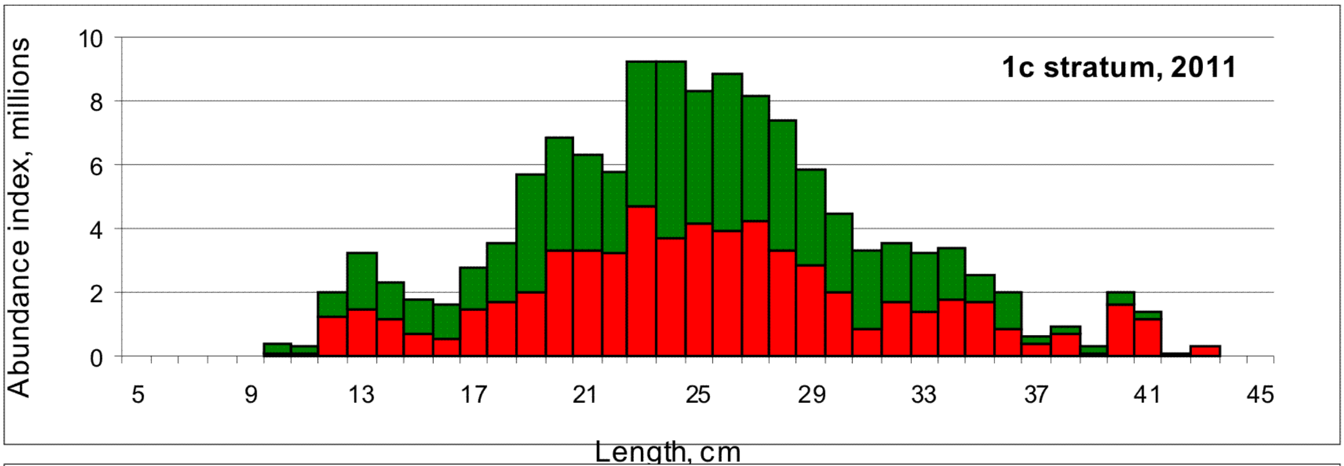
Figure 35: Length-frequencies and maturity of the squid *Illex argentinus*

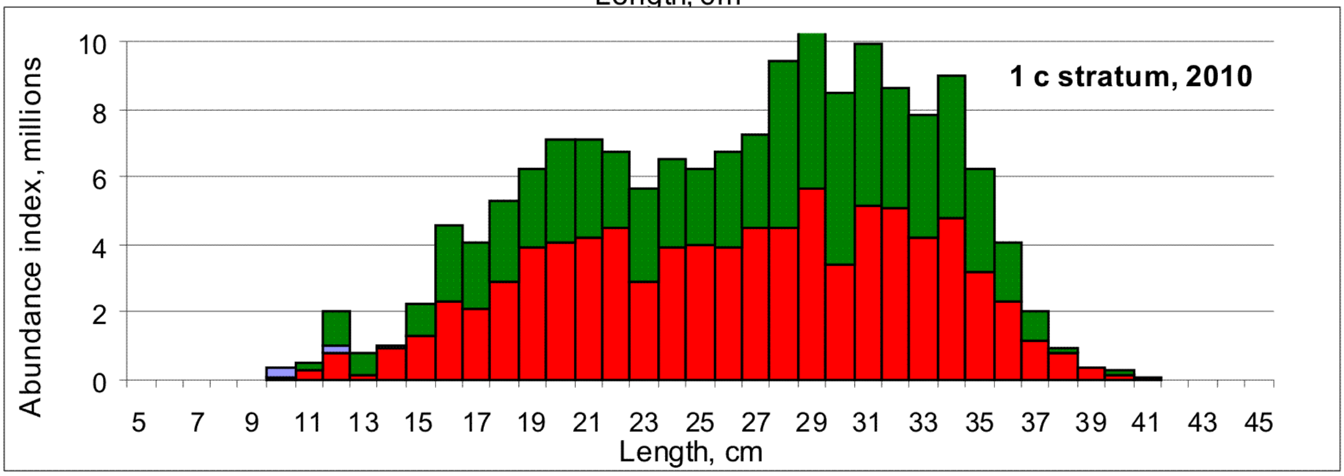
Squid size in catches was 7-28 cm ML. The population was represented by two distinctive cohorts. One of them, that of 19-28 cm, was represented by animals of the South Patagonian Stock that normally forages in the Falkland waters in autumn. Most of females were immature, males – either maturing or mature. Small – sized squids were immature and probably belonged to poorly known spring spawning cohort.

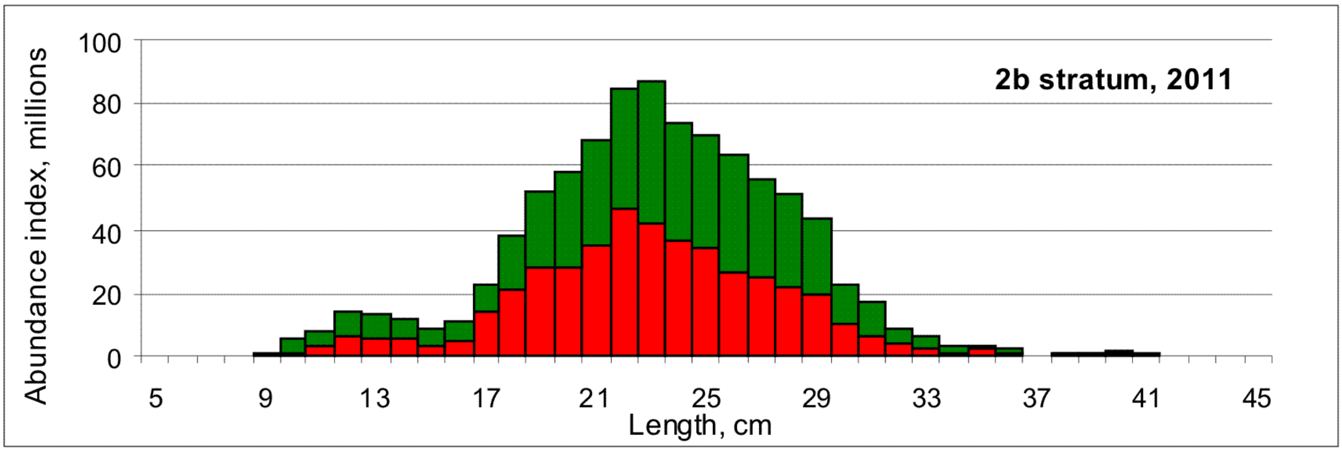
6.0 Appendix I - Abundance of rock cod by length and stratum in 2011 and 2010

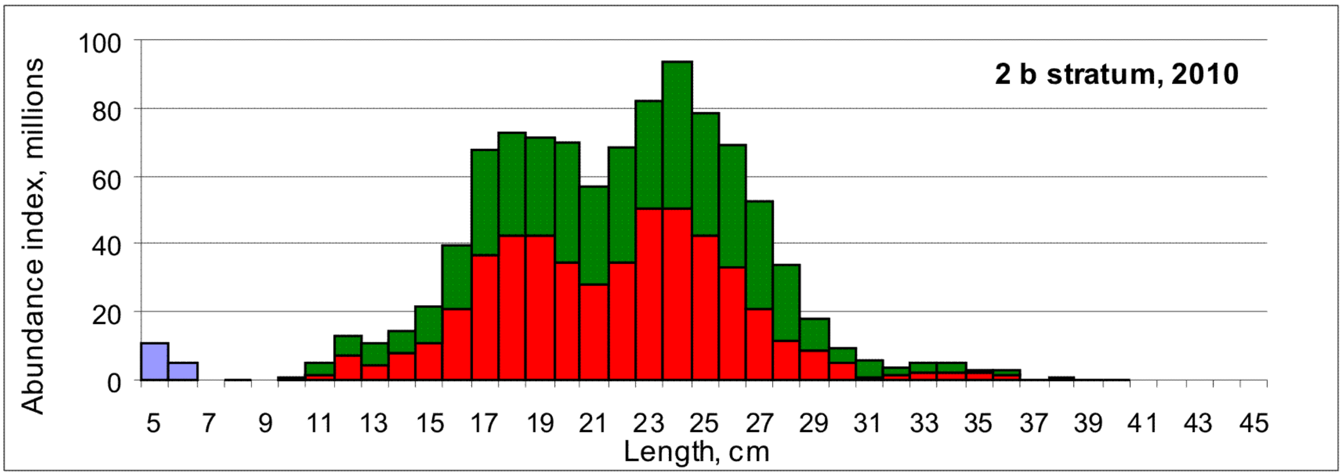


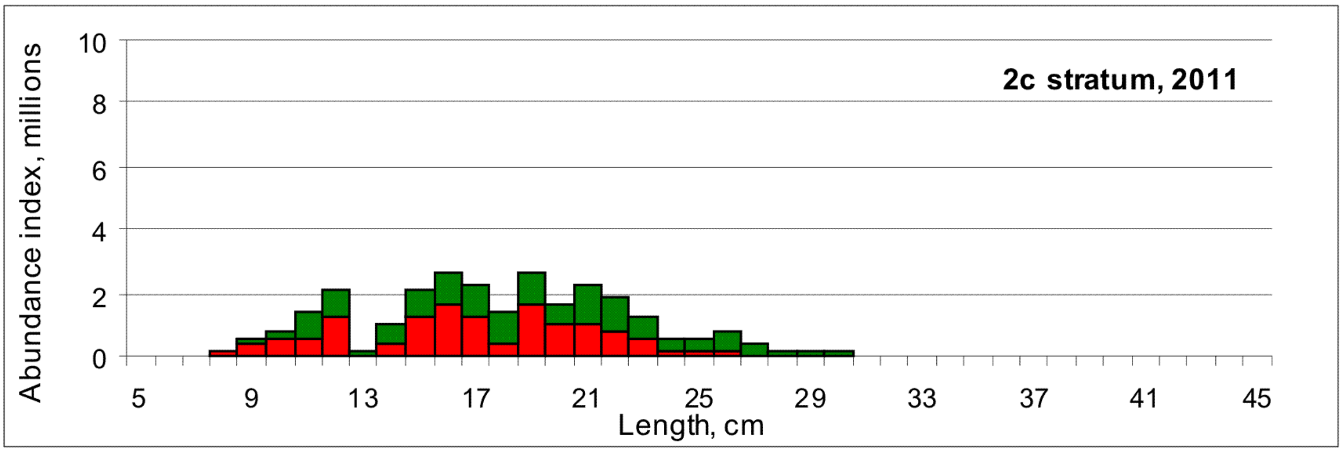


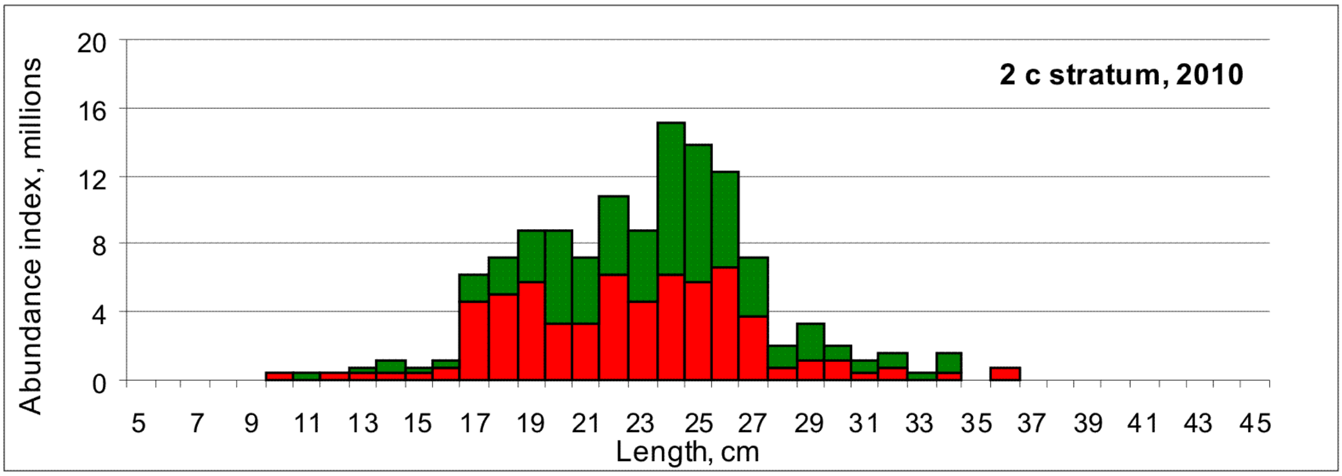


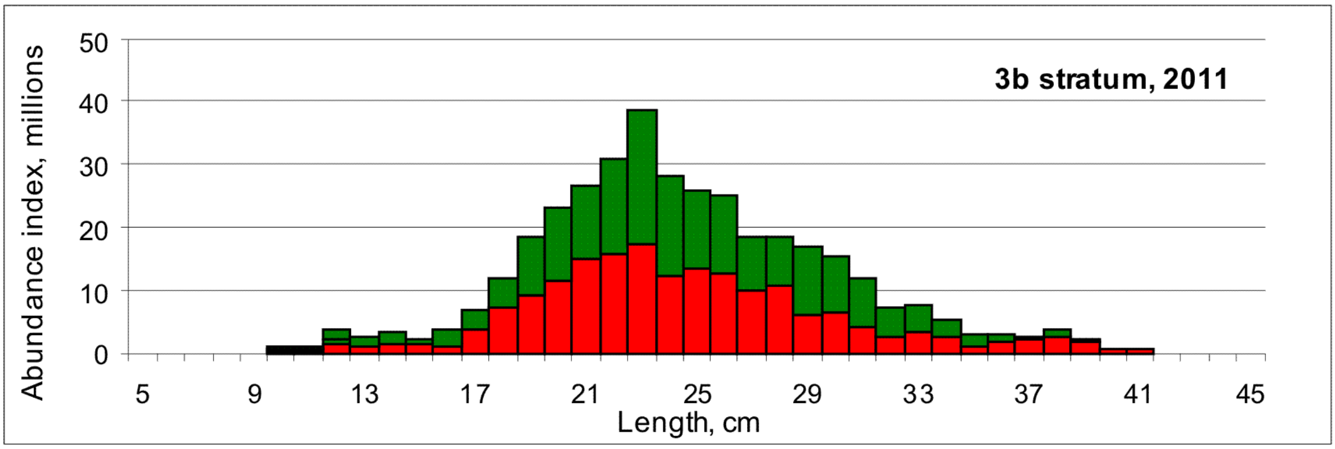


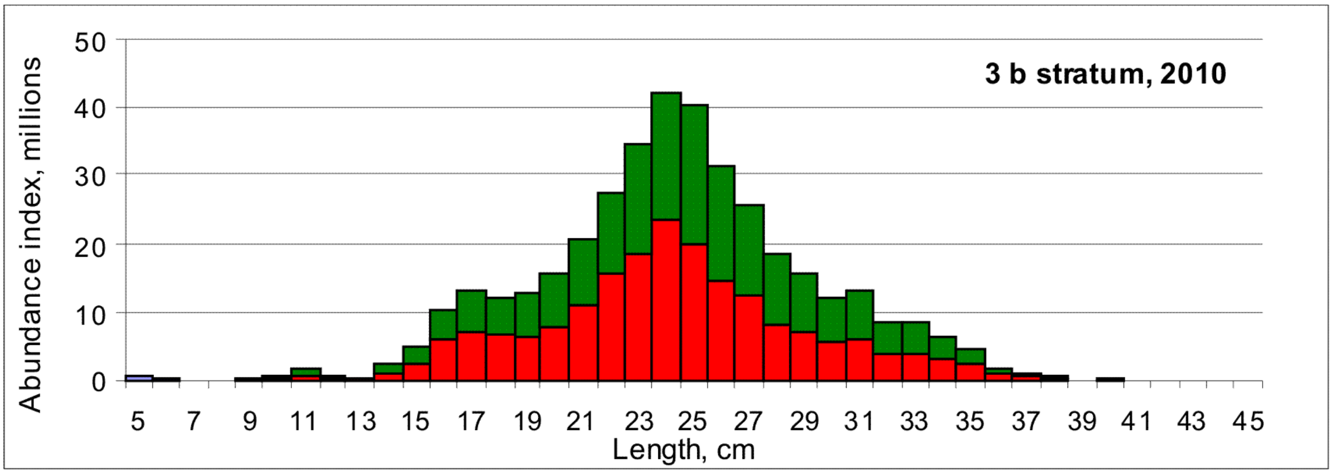

2b stratum, 2011
Abundance index, millions
Length, cm
100
80
60
40
20
0
5
9
13
17
21
25
29
33
37
41
45

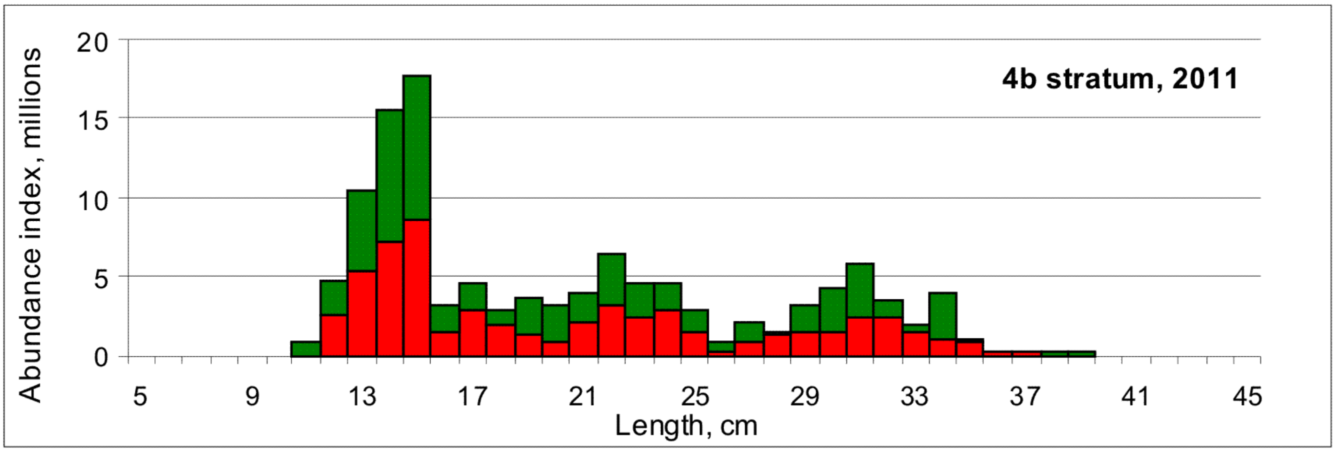

2 b stratum, 2010
Abundance index, millions
Length, cm
100
80
60
40
20
0
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45

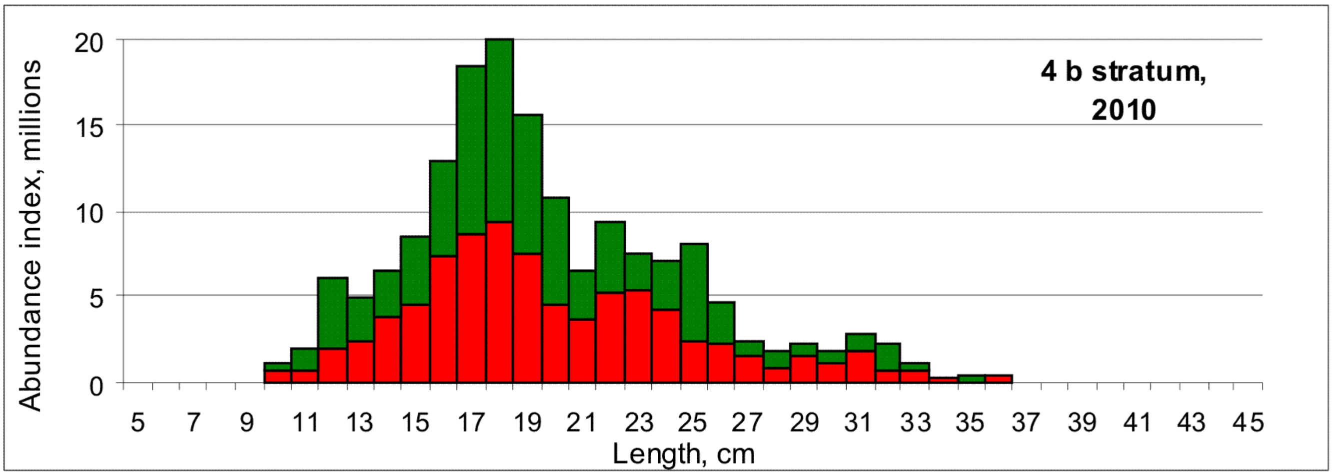

2c stratum, 2011
Abundance index, millions
Length, cm
10
8
6
4
2
0
5
9
13
17
21
25
29
33
37
41
45


2 c stratum, 2010
Abundance index, millions
Length, cm
20
16
12
8
4
0
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45


3b stratum, 2011
Abundance index, millions
50
40
30
20
10
0
5
9
13
17
21
25
29
33
37
41
45
Length, cm


3 b stratum, 2010
Abundance index, millions
50
40
30
20
10
0
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
Length, cm


4b stratum, 2011
Abundance index, millions
20
15
10
5
0
5
9
13
17
21
25
29
33
37
41
45
Length, cm


4 b stratum, 2010
Abundance index, millions
20
15
10
5
0
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25
27
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31
33
35
37
39
41
43
45
Length, cm