Cruise Report
ZDLT1-10-2013

Square mesh panel (SMP) trials - 3

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1.0 Introduction

Rock cod *Patagonotothen ramsayi* has been the most important target species in finfish fisheries since 2008. Total annual catches averaged 63,000 t in 2008-2012, making the species third in importance (by weight) behind *Illex* and *Loligo* squid in the Falkland fishery (FIG 2013). It is also the highest volume discard species – accounting for 88%-96% of reported discards in 2010-2012. Incidental catches of small, immature rock cod have been occurring at a rate that may impact fishery sustainability. Since 2008, the minimum HGT-commercial size for rock cod has decreased from 25-cm total length to approximately 23-cm (authors, pers. obs.). During the same period, the length of 50% maturity for female rock cod decreased from 27-cm to 22-cm (FIFD, 2013).

To improve stock conservation, the FIFD has undertaken a series of experimental trials to assess whether modifications to trawl fishing gear could improve size selectivity for rock cod and other commercial species.

A first series of trials investigated the performance of increasing trawl codend mesh sizes (Brickle and Winter 2011, Roux et al. 2012a, Roux et al 2012b). Results demonstrated that a 90 mm diamond mesh codend (currently the minimum allowable codend mesh size for finfish trawlers in Falkland waters) has poor selectivity for rock cod. An increase in mesh size to 120 mm significantly reduced by-catch of small rock cod but caused important reductions in total CPUE ranging from 35% in mixed species trials (Roux et al. 2012a) to 72% when rock cod accounted for ≥ 50% of the catch (Roux et al 2012b). The 110 mm mesh yielded intermediate results, with average reductions in CPUE between 9% (April 2012 trials) and 44% (October 2012 trials) and a consistent reduction in discard rates of undersized rock cod equivalent to 43% among trials.

A second series of trials was designed to assess whether a trawl equipped with a 110 mm diamond mesh codend and fitted with a square mesh panel (SMP) might provide a better alternative for reducing by-catch of undersized fish while sustaining fishery efficiency. In contrast to diamond mesh, square mesh always remains rigidly open irrespective of whether the net is filling with catch. SMP use in demersal trawls has been shown to facilitate the escapement of juvenile fish (Broadhurst and Kennelly 1996, Graham and Kynoch 2001, Graham et al. 2003, O'Neill et al. 2006, Bullough et al. 2007, MacBeth et al. 2012). A 40-mm mesh size SMP was selected for trials based on rock cod length-girth relationships (Roux et al. 2012b). Such square mesh size should allow small rock cod to escape whilst retaining commercial size fish and specimens of all sizes from other commercial species. Initial SMP trials conducted in February 2013 demonstrated that a SMP located inside the top panel of the codend improved selectivity for rock cod. However, SMP performance was affected by total catch and by SMP dimensions and positioning (Roux et al. 2013a). Further experimentation was recommended to assess the performance of two distinct codend-SMP configurations in the context of mixed species and high rock cod volume catches. These include a 2-m length SMP positioned between 6-8 m from the codline (SMP-Ventana) and a 17-m length SMP located between 10-27 m from the codline (SMP-Santos). The two configurations aim to position the SMP either directly ahead of the catch (SMP-Ventana) or sufficiently forward of the catch to cancel or minimize catch size effects on SMP performance (SMP-Santos).

Trials completed in July 2013 showed little or no impacts of SMP presence and configuration in the context of generally small volume, mixed species catches (Roux et al. 2013b). This report presents the results of a third set of codend-SMP trials conducted in October-November 2013. The objective was to assess the performance of the two SMP configurations during targeted fishing on rock cod aggregations.

1.1 Cruise objectives

1. To experimentally trial two SMP configurations in comparison to a control without SMP.
2. To evaluate and compare catch rates (CPUE), discard rates of rock cod, length frequencies and relative selectivity at length for commercial species in all trawls.
3. To characterize oceanographic conditions during the experimental trials.
4. To collect biological data for age determination and dietary/food web studies.

2.0 Methods

2.1 Cruise Vessel and Area

The cruise was conducted onboard *FV Castelo* (total length 67.78 m, GRT 1,321 t) between October 20th and November 2nd 2013. The same vessel had been used during previous mesh size and SMP trials (Brickle and Winter 2011, Roux et al. 2012a; 2012b, Roux et al 2013a; 2013b). Trials were conducted on finfish grounds in the north, north-western and north-eastern shelf areas (Fig 2.1). Fishing locations were selected based on catch reports from finfish trawlers during weeks preceding the cruise and by consultation with the captain. A total of 36 trawl stations and 6 oceanographic (CTD) stations were completed (Table 2.1).

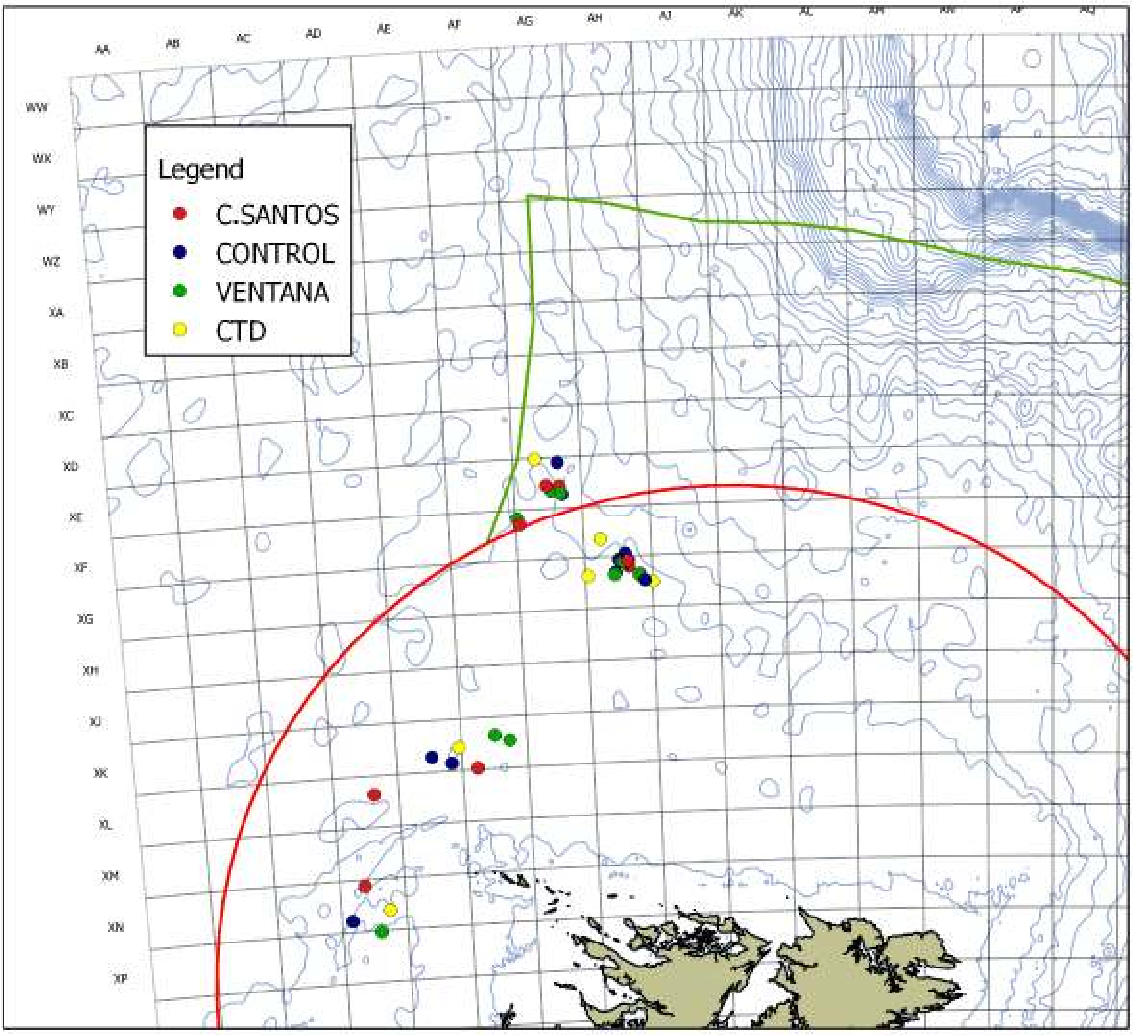


Figure 2.1. Locations of trawl and oceanographic (CTD) stations on ZDLT1-10-2013 (Map by P. Brewin).

2.2 Trawl gear

A bottom trawl equipped with 1,800 kg Oval-Foil doors (OF-14) was used at all trawl stations. No ground gear (e.g. bobbins/rockhoppers) was used. The footrope consisted of a cable protected by cord. An 8 m length of chain weighting 150 kg was attached to the footrope to increase contact between the footrope and the sea bed. See Brickle and Winter (2011) for net configuration details. Bridle length was 220 m. Door spread varied 175-200 m among hauls. Net horizontal/vertical openings varied 53-60 m and 3.0-3.7 m, respectively.

Table 2.1 Trawl and Oceanographic stations on ZDLT1-10-2013. Location information (Lat, Lon,) is the average of start/finish coordinates on the seabed. Course corresponds to starting course on the seabed. Activity B = bottom trawl; Activity C = CTD. Codend configurations: 'CONTROL' = standard 110-mm diamond mesh codend; 'VENTANA' = 110-mm diamond mesh codend with 2-m length SMP in top panel. 'C.SANTOS' = 110-mm diamond mesh codend with 17-m length SMP in top panel.

Station	Date	Time Start (Seabed)	LAT (oS)	LON (oW)	Course	Modal_Depth (m)	Duration (min)	Activity	Codend
1141	21/10/2013	9:15 AM	50.37	61.13	230	157	180	B	VENTANA
1142	21/10/2013	1:25 PM	50.49	61.39	250	164	180	B	C.SANTOS
1143	21/10/2013	5:30 PM	50.46	61.58	290	169	180	B	CONTROL
1144	22/10/2013	5:20 AM	51.20	62.42	175	193	240	B	CONTROL
1145	22/10/2013	10:25 AM	51.26	62.21	95	206	240	B	VENTANA
1146	22/10/2013	2:53 PM	51.15	62.13	187	197		C	
1147	22/10/2013	3:30 PM	51.03	62.31	314	187	240	B	C.SANTOS
1148	23/10/2013	5:10 AM	50.59	62.19	66	169	240	B	C.SANTOS
1149	23/10/2013	10:05 AM	50.43	61.73	75	163	240	B	CONTROL
1150	23/10/2013	2:33 PM	50.39	61.52	281	163		C	
1151	23/10/2013	3:10 PM	50.34	61.24	80	158	240	B	VENTANA
1152	24/10/2013	5:20 AM	49.53	60.18	297	183	240	B	VENTANA
1153	24/10/2013	10:15 AM	49.55	60.17	120	181	240	B	C.SANTOS
1154	24/10/2013	2:43 PM	49.63	59.99		178		C	
1155	24/10/2013	3:20 PM	49.53	60.19	310	184	240	B	CONTROL
1156	25/10/2013	5:10 AM	49.53	60.21	100	185	240	B	CONTROL
1157	25/10/2013	10:10 AM	49.52	60.25	295	184	240	B	VENTANA
1158	25/10/2013	3:15 PM	49.53	60.20	110	185	240	B	C.SANTOS
1159	26/10/2013	5:10 AM	49.52	60.24	296	184	240	B	CONTROL
1160	26/10/2013	10:30 AM	49.53	60.21	110	185	240	B	C.SANTOS
1161	26/10/2013	3:25 PM	49.53	60.22	295	185	240	B	VENTANA
1162	27/10/2013	5:10 AM	49.52	60.17	120	192	240	B	C.SANTOS
1163	27/10/2013	10:25 AM	49.58	60.27	265	177	240	B	CONTROL
1164	27/10/2013	2:56 PM	49.59	60.48		176		C	
1165	27/10/2013	3:35 PM	49.59	60.28	90	178	240	B	VENTANA
1166	28/10/2013	5:10 AM	49.16	60.73	144	191	240	B	VENTANA
1167	28/10/2013	10:30 AM	49.14	60.76	320	192	240	B	C.SANTOS
1168	28/10/2013	2:57 PM	49.01	60.84		194		C	
1169	28/10/2013	3:50 PM	49.03	60.67	145	196	240	B	CONTROL
1170	29/10/2013	5:10 AM	49.32	60.97	189	170	240	B	CONTROL
1171	29/10/2013	10:10 AM	49.29	60.99	345	170	240	B	VENTANA
1172	29/10/2013	3:10 PM	49.32	60.97	183	170	240	B	C.SANTOS
1173	30/10/2013	5:10 AM	49.14	60.66	334	197	240	B	C.SANTOS
1174	30/10/2013	10:05 AM	49.18	60.65	150	196	240	B	CONTROL
1175	30/10/2013	3:02 PM	49.17	60.66	330	196	240	B	VENTANA
1176	31/10/2013	5:10 AM	49.53	60.21	95	186	240	B	VENTANA
1177	31/10/2013	10:10 AM	49.49	60.19	300	194	240	B	CONTROL
1178	31/10/2013	2:37 PM	49.41	60.38		195		C	
1179	31/10/2013	3:10 PM	49.53	60.18	139	187	240	B	C.SANTOS
1180	01/11/2013	4:55 AM	49.59	60.09	119	180	240	B	C.SANTOS
1181	01/11/2013	9:40 AM	49.59	60.10	294	179	225	B	VENTANA
1182	01/11/2013	2:25 PM	49.62	60.06	125	176	225	B	CONTROL

2.3 Experimental design

Three trawls were conducted daily. A first trawl was on the seabed between 5:00-5:30 AM (morning hauls), a second between 10:00-10:30 AM (mid-day hauls) and a third between 2:30-4:00 PM (afternoon hauls). Only on day 1 were starting times delayed by approximately four hours due to a delayed arrival on the fishing grounds because of strong winds. Trawl duration was 4 hours except on day 1 (3 hours) and on day 12 (last two stations were shortened by 15 minutes). Trawl speed varied 3.0-4.2 knots. Trawls were 'clustered' for a few days at a time in four fishing areas (Fig 2.1). Oceanographic information was collected at least once at each location and consisted in vertical water profiling (CTD) stations conducted immediately after the mid-day haul.

Three different trawl configurations were alternated each day: two codends with top panels modified by SMP addition and a Control (110-mm diamond mesh without modification). One experimental codend was fitted with a 2-m long, 40-mm square mesh panel positioned from 6 m and 8 m forward of the codline (Fig 2.2A). This configuration is referred to as 'SMP-Ventana'. The other experimental codend was fitted with a 17-m section of 40-mm square mesh beginning 10-m forward of the codline (Fig 2.2B). This configuration was proposed by Castelo captain Santos Reiriz as a means to reduce catch size effects on SMP performance under commercial conditions. It is referred to as 'SMP-Santos'. The SMP consisted of 4-mm diameter polyethylene single thread and the 110-mm diamond mesh was made of 5 mm double thread.

The total length of each codend was 27-m. Top panel width was 70 diamond meshes. Corresponding SMP width was 24 square meshes (Fig 2.2). Diamond and square mesh were joined together by alternatively tying two and three diamond meshes to each square mesh (2:1-3:1 sequence (Fig. 2.3)). To ensure that the square mesh remained tight and stretched, panels were adjusted by fitting 28 square meshes per 10 diamond meshes in the length direction. Each day, the three codends were randomly alternated in time-of-day sequence (morning, mid-day and afternoon hauls).

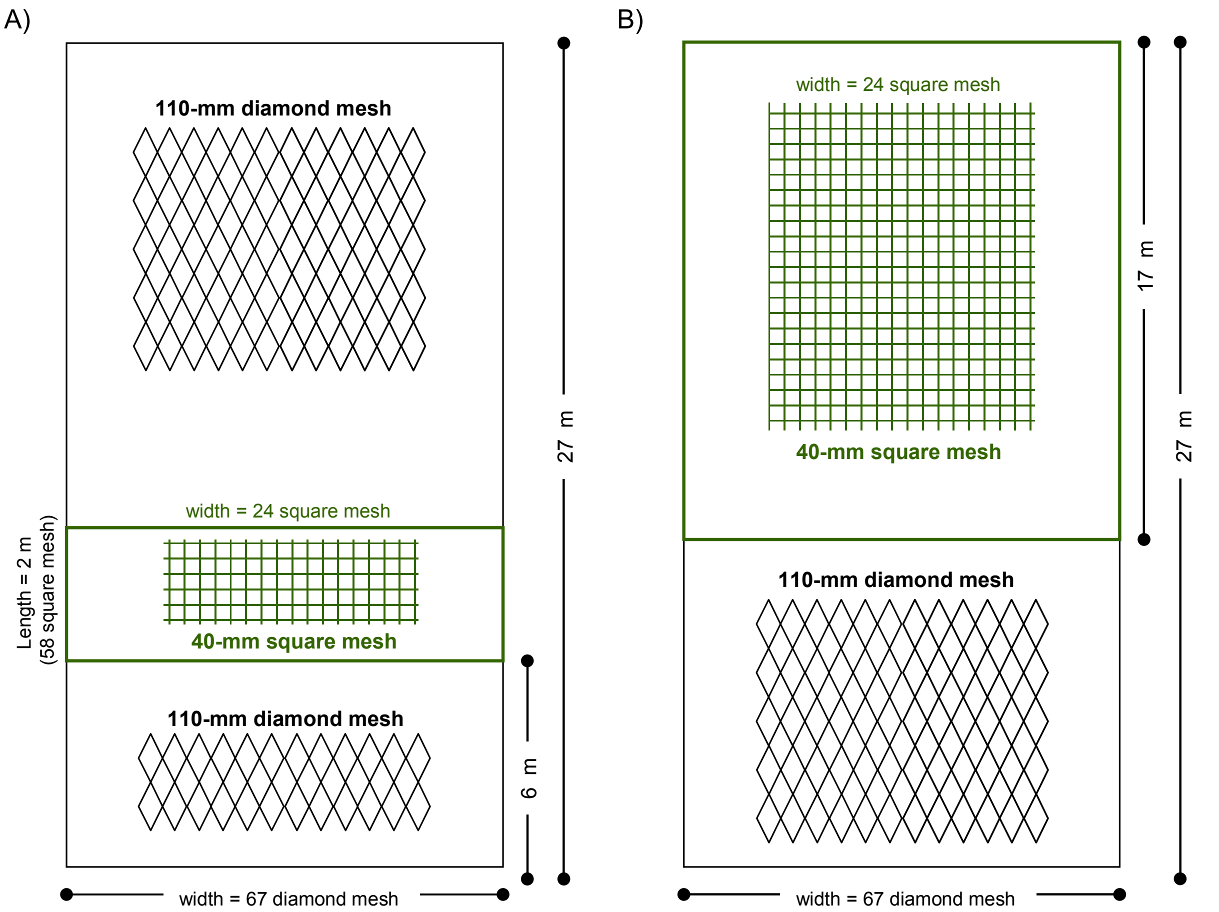


Figure 2.2. Codend-SMP configurations (modified top panels) tested during October 2013 trials. A) ‘SMP-Ventana’ configuration: 2-m long square mesh panel inserted between 6-8 m from the codline. B) ‘SMP-Santos’ configuration: 17-m of square mesh beginning 10-m from the codline.

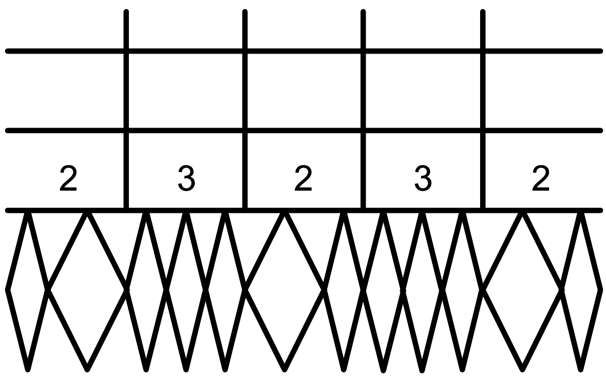


Figure 2.3. Attachment pattern for diamond and square mesh inside the codend. Two and three diamonds were alternatively attached to each square mesh (2:1, 3:1 sequence).

2.4 Biological sampling

For hauls ≤ approx. 5 t, the whole catch was weighed by species (or lowest possible taxonomic level in the case of invertebrates) using an electronic marine adjusted balance (POLS). For hauls > approx. 5 t, discard weight and total catch of rock cod were estimated following the procedure described in Roux et al. (2013a). *B. brachyurops* sample weights were estimated from length-frequencies. All other species were weighed.

Random length frequency samples were taken of rock cod (100-200 specimens) and other commercially important species (80-100 specimens), when available. Length (L_T, L_M, L_{PA} or L_{DW}), sex and maturity stage were recorded for all specimens.

Stomach contents were examined and characterized for 587 specimens of fish, skates and dogfish belonging to 9 different species. Stomach sampling involved recording length, sex and number of different prey items in stomachs (identified to lowest possible taxonomic level). Prey length was measured whenever possible.

Otoliths were collected from 373 specimens from 14 different species. All specimens sampled for otoliths were simultaneously sampled for length, weight, sex and maturity.

2.5 Data Analyses

The performances of codend-SMP configurations were assessed by comparing catch rates (CPUE (kg hr^{-1})), discard rates of rock cod, species-specific length structures and relative selectivity at length between control, SMP-Ventana and SMP-Santos hauls. Because the main objective was to assess the performance of SMPs during fishing targeted on rock cod, data analyses for rock cod were conducted separately for the sub-set of trawls in which rock cod was the dominant species (≥ 50% of catch weight), in addition to the set of all trawls.

Catch rates (CPUE)

Effects of codend-SMP configurations on total and species-specific CPUE were assessed using generalized linear mixed models (GLMM) assuming log-normal errors. This type of model is suitable to handle over-dispersion in the data caused by random day-to-day variability in catch size/composition (Crawley 2007). CPUE data were log-transformed (base 10) for analyses. Codend-SMP configuration was used as fixed effect. Spatial coordinates (latitude and longitude) were included as potential covariates. Calendar day, time-of-day and modal trawling depth were included as potential random effects. Time-of-day was defined as a 3-level factor of morning, mid-day or afternoon hauls. All GLMM were fitted using restricted maximum likelihood (REML) estimation. A backward model selection procedure was used starting with the saturated model (inclusion of all potential random effects) and progressive removals of least significant terms. The acceptance of progressive removals was determined by decreases in the Bayesian (BIC) information criterion (Bolker et al 2008). Significance of fixed-effects terms was assessed using Wald chi-square (χ^2) tests (Bolker et al 2008).

Discard weights of rock cod

Rock cod catch composition by length was used to estimate discard. A size threshold of 25 cm total length was used to distinguish between undersized (< 25-cm) and commercial-size (≥ 25-cm) rock cod, to maintain consistency with the size threshold used in previous trials (Roux et al 2013a). It should be noted, however, that the effective HGT-size threshold for rock cod in commercial trawlers has decreased to about 23-cm in recent years (authors, pers. obs.).
Counts of rock cod per 1-cm length classes were converted to weights using the power length-weight function from Roux et al (2013a):

$$\text{Weight} = 0.00419 * \text{Length}^{3.297}$$

A discard ratio (ratio of undersized to commercial size rock cod) was calculated for each haul. Discard weights of rock cod (kg per hour) were estimated by multiplying haul-specific CPUE by the discard ratio. Trawl configuration effects on discard weights were assessed using GLMM with log-normal error distribution. Discard weights were log-transformed (base 10) for analyses. Spatial coordinates (lat and lon) were included as covariates. Sampling day, time of day and trawl depth were included as potential random effects. GLMM fitting was done as described for CPUE.

Estimated discard weights (from length frequencies) were compared to reported discard weights of rock cod in catch reports from the vessel bridge. This is in order to ensure consistency between length/weight-based estimates and reported catch.

Length distributions

Species-specific length distributions were described per trawl configuration by median, first and third quartiles, mean and modal lengths. Counts of fish per 1-cm length intervals in each haul were smoothed by trawl configuration using generalized additive models (GAM). Only hauls for which ≥ 100 specimens (rock cod and *Loligo* squid) or ≥ 80 specimens (all other species) were sampled for length were considered. Differences in mean length among SMP-codend configurations were assessed using Kruskal-Wallis rank sum tests with Bonferroni-adjusted Wilcoxon rank sum tests for pair-wise comparisons.

Relative selectivity

A four-parameter double-logistic function (combining an increasing and a decreasing logistic curve, Quinn and Deriso 1999) was used to estimate relative selectivity at length (S_L):

$$S_L = [1 / (1 + e^{(s2(L - L50\text{-}2)})] * [1\text{-}1 / (1 + e^{(s1(L - L50\text{-}1)})] \qquad (2.1)$$

where L is specimen length (either total, mantle or disk width), L_{50}-1 and L_{50}-2 are inflexion points corresponding to minimum and maximum lengths of 50% retention, and s1 and s2 are slope parameters. Length classes between L_{50}-1 and L_{50}-2 correspond to the size range of ≥ 50% retention.

Selectivity analysis was restricted to trawl stations in which at least 100 specimens were sampled (for rock cod or *Loligo*), or at least 80 specimens (other species), and restricted to length classes that were observed in at least 5 trawl stations. For each haul 'i', the proportion of fish per 1-cm length class 'k' was calculated as the number of sample fish in length class 'k' divided by the total sample size of haul 'i':

$$F_{Lik} = \Sigma\, Freq_{Lik} / \Sigma\, Freq_{Li} \qquad (2.2)$$

Relative selectivity of length class ‘k’ in haul ‘i’ was then defined as the proportion F_{Lik} divided by the maximum value of F_{Lik} among all hauls in the experimental set ‘j’:

$$S_{Lijk} = F_{Lik} / \max(F_{Lik})_j \qquad (2.3)$$

The experimental set ‘j’ in this case corresponded to the entire survey, or the sub-set of survey hauls with ≥50% rock cod. Relative selectivity was based on proportions per length class rather than numbers, because large hauls may have the largest numbers in nearly all length classes, obscuring any selectivity.

The double-logistic function was fitted to S_{Lijk} data from individual hauls and from hauls aggregated by trawl configuration (i.e., all Control, SMP-Ventana, or SMP-Santos trawls), using general-purpose Nelder-Mead optimization (Nelder and Mead 1965). Initial parameters values were chosen by visual inspection of the empirical selection curve. For aggregated fitting by trawl configuration, individual trawls were weighted by the inverse of the root mean square deviation of their individual fits. Differences in the double-logistic parameters (L_{50}-1, L_{50}-2, s1, s2) among trawl configurations were evaluated by likelihood ratio tests. Successive combinations of parameters were either set identical among trawl configurations, or allowed to vary freely, and the improvement in negative log-likelihood compared to the χ^2 distribution (Mooij et al., 1999). Variability of the trawl configuration selectivity curves was visualized by 1000× bootstrap re-sampling the length distributions of each trawl, re-calculating the selectivity curves, and plotting the 95% quantile contours of the 1000 curves.

Statistical software

All statistical analyses were implemented in ‘R’ software (R Core Development Team 2013). Specific packages used were ‘lme4’ (GLMM), ‘car’ (Wald chi-square test) and ‘mgcv’ (GAM).

2.6 Oceanography

At selected stations throughout the survey, a conductivity-temperature-depth logger (CTD, SBE-25, Sea-Bird Electronics Inc., Bellevue, WA, USA) was deployed from the surface to 4-

9 m (43 m at the first station, due to technical problems) above the bottom, recording temperature (ºC), conductivity (S/m), and pressure (db) continuously at a frequency of 8 Hz, downcast and upcast. The speed of deployment was approx. 1 m/s and was monitored by wire counter. Profiles of temperature, salinity (PSS-78 Practical Salinity) and depth (m) were calculated in Seasoft v7.22.5 (Sea-Bird Electronics Inc).

3.0 Results

3.1 Oceanography

The areal distribution of CTD stations is shown in Figure 2.1. The first station sampled (1146) was the furthest south; from there the survey progressed northeast, then northwest, then a final CTD station was taken towards the middle of the four stations north of 50ºS (Table 2.1). Temperature profiles showed a thermocline at every station (Figure 3.1 -left). Average thermocline depth did not show a trend with either latitude or longitude, but became shallower as the survey cruise progressed. Salinity was distinctly lowest at the station furthest southwest (station 1146), and next lowest at the station next-furthest southwest (station 1150). The four stations north of 50ºS and east of 61ºW had more similar (and higher) salinities. The two mid-longitude stations (1164 and 1168) had near-identical salinity profiles below thermocline depth, and the two stations furthest east (1154 and 1178) had near-identical salinity profiles throughout the water column (Figure 3.1 -right). A similar increasing west-east trend in salinities had been noted in the previous survey (Roux et al., 2013b). Plotting salinity vs. temperature profiles showed a distinct change of directional trend below the thermocline at nearly all stations (Figure 3.2). Comparison with Arkhipkin et al. (2004, 2013) suggests that water masses above the thermocline were primarily shelf water, and water masses below the thermocline were derived from the Falkland Current.

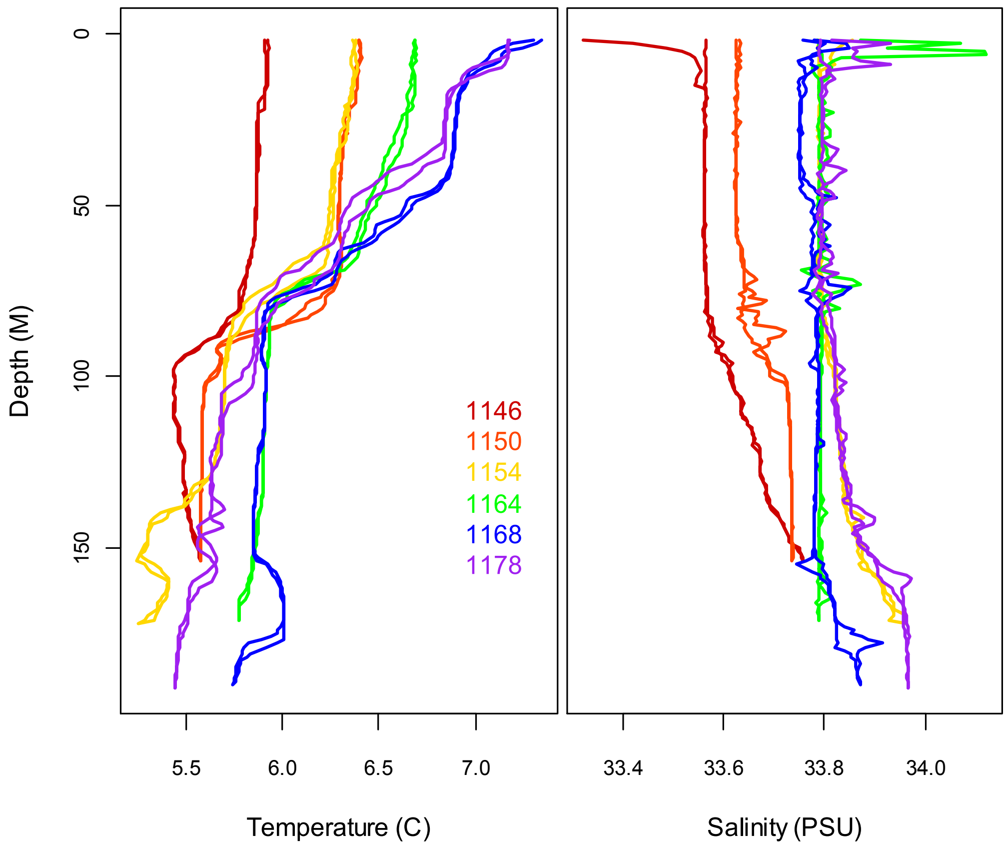


Figure 3.1 Oceanography-depth profiles of temperature (left) and salinity (right) at the CTD stations.

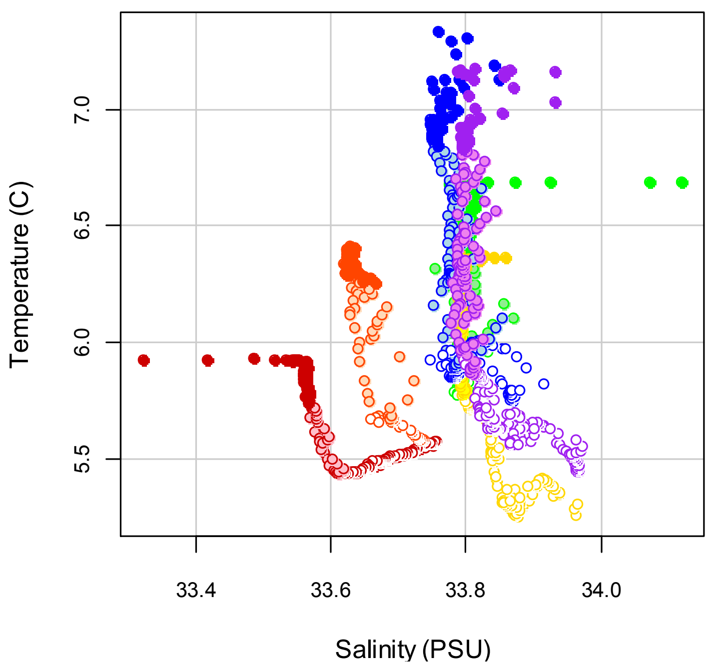


Figure 3.2. Temperature-Salinity scatter plot, by station. Solid circles represent measures taken above thermocline depth, circles with pale filling are within the thermocline and open circles below the thermocline, as determined visually on Figure 3.1 -left.

3.2 Catch composition

Total catch, sample, and discard weights by species are summarized in Table 3.1. A total of 97 species (or species groups) were caught during the trials. Total catch for the survey was 92 t. Ninety percent of the catch composition by weight was distributed among 6 species, including rock cod *Patagonotothen ramsayi* (52%), hake *Merluccius hubbsi* (13%), and kingclip *Genypterus blacodes* (12%); skates *Bathyraja brachyurops* (6%) and *Bathyraja flavirostris* (4%); and the Patagonian squid *Doryteuthis gahi* (3%). By-catch of sponges *Porifera spp.* was significant and exceeded 1 tonne.

3.3 Codend-SMP trials

3.3.1 Catch rates

Catch rates were variable over the course of the cruise, as reflected by the importance of 'day' effects on total and species-specific CPUE (Table 3.2). Trawl depth varied from 157 m to 197 m among stations.

Total Catch ($CPUE_T$)

Total CPUE averaged 643 kg hr^{-1} and ranged 92-1978 kg hr^{-1} among hauls. Trawl configuration had no significant effect on total catch rates (Wald test Chisq=2.780, df=2, $p>0.05$). Latitude was a significant, positive covariate (Wald test Chisq=6.868, df=1, $p=0.009$) and sampling day explained 39% of the variance in $CPUE_T$ (Table 3.2). Mean $CPUE_T$ predicted by the GLMM varied from 650 kg hr^{-1} (Control) to 460 kg hr^{-1} (SMP-Ventana) and 544 kg hr^{-1} (SMP-Santos) (Fig. 3.3A).

Rock cod ($CPUE_{PAR}$)

Mean rock cod CPUE was 330 kg hr^{-1}during the trials, ranging from 2.4 kg hr^{-1} to 1 664 kg hr^{-1}. With GLMM including all hauls, gear configuration effects on $CPUE_{PAR}$ were marginally significant (Wald test Chisq=6.091, df=2, $p=0.05$) and corresponded to a lower mean CPUE in the SMP-Ventana (176 kg hr^{-1}) relative to Control (353 kg hr^{-1}) and SMP-Santos (265 kg hr^{-1}) (Fig. 3.3B). Longitude was a significant, positive covariate (Wald test Chisq=51.971, df=1, $p < 0.001$) affecting $CPUE_{PAR}$ and trawling depth explained 64% of the variance (Table 3.2). With GLMM including hauls ≥ 50% rock cod, trawl configuration had a significant effect on $CPUE_{PAR}$ (Chisq=9.429, df=2, p=0.01) corresponding to lower mean CPUE in SMP-Ventana (370 kg hr^{-1}) and SMP-Santos (471 kg hr^{-1}) relative to Control (897 kg hr^{-1}). (Fig 3.3C). Day-to-day variability explained 45% of the variance in the model (Table 3.2).

Merluccius hubbsi ($CPUE_{HAK}$)

Hake CPUE averaged 86 kg hr^{-1} (range 0.4-642 kg hr^{-1}) during trials. Hake catches varied positively with latitude (Chisq=61.688, df=1, p<0.001) and negatively with longitude (Chisq=46.683, df=1, p<0.001). Day effects explained 81% of the variance in the model (Table 3.2). Predicted hake CPUE did not differ among codend configurations (Chisq=0.643, df=2, p>0.05) (Fig 3.3D)

Genypterus blacodes ($CPUE_{KIN}$)

Kingclip dominated the catch in some hauls and was absent from others. CPUE averaged 76 kg hr^{-1} and ranged 0-808 kg hr^{-1} among stations. Latitude was a significant, positive covariate affecting $CPUE_{KIN}$ (Chisq=9.067, df=1, p=0.003). Day effects explained 28% of the variance (Table 3.2). Predicted Kingclip CPUE did not differ among codend configurations (Chisq=0.104, df=2, p>0.05) (Fig. 3.3E).

Skates (B. brachyurops) ($CPUE_{RBR}$)

B. brachyurops CPUE averaged 44 kg per hour and ranged 0.7-173 kg hr^{-1} among stations. Catch rates of RBR were not affected by codend-SMP configuration (Chisq=1.881, df=2, p>0.05) (Fig. 3.4A). Latitude was a significant, positive covariate affecting $CPUE_{RBR}$ (Chisq=11.217, df=1, p=0.001). Day-to-day variability explained 65% of the variance in $CPUE_{RBR}$ (Table 3.2).

Table 3.1 Catch composition by species, sample, and discard weights (kg) and catch proportions during October trials (ZDLT1-10-2013). Species are ordered by decreasing catch proportion.

Species Code	Species Name	Catch Wt	Sample Wt	Discard Wt	Catch proportion (%)
PAR	*Patagonotothen ramsayi*	47435.55	1301.93	12067.21	51.75
HAK	*Merluccius hubbsi*	12296.60	1844.74	9.64	13.42
KIN	*Genypterus blacodes*	10975.49	1727.43	32.52	11.97
RBR	*Bathyraja brachyurops*	5889.80	2952.35	363.92	6.43
RFL	*Raja flavirostris*	3391.34	34.70	164.10	3.70
LOL	*Doryteuthis gahi*	2289.31	208.90	41.09	2.50
RMC	*Bathyraja macloviana*	1415.74	107.75	589.26	1.54
RAL	*Bathyraja albomaculata*	1233.10	16.32	140.91	1.35
SPN	*Porifera*	1188.86	4.20	1159.19	1.30
BLU	*Micromesistius australis australis*	994.26	6.92	994.26	1.08
BAC	*Salilota australis*	899.05	451.19	113.10	0.98
RPX	*Psammobatis sp.*	638.34	0.00	564.64	0.70
DGS	*Squalus acanthias*	329.60	0.00	329.60	0.36
RDO	*Raja doellojuradoi*	283.78	5.26	258.40	0.31
CGO	*Cottoperca gobio*	219.81	87.56	219.81	0.24
SHT	*Mixed invertebrates*	209.25	0.37	209.25	0.23
FUM	*Fusitriton magellanicus*	201.92	0.00	201.92	0.22
RSC	*Bathyraja scaphiops*	193.44	2.41	117.22	0.21
RMU	*Bathyraja multispinis*	153.67	0.00	40.42	0.17
MED	*Medusae sp.*	151.71	0.00	151.71	0.17
DGH	*Schroederichthys bivius*	143.89	0.00	143.89	0.16
RGR	*Bathyraja griseocauda*	140.84	0.00	40.67	0.15
ING	*Moroteuthis ingens*	130.63	0.00	116.71	0.14
ANM	*Anemone*	119.10	0.00	119.10	0.13
LAR	*Lampris immaculatus*	92.00	63.04	0.00	0.10
TOO	*Dissostichus eleginoides*	74.38	43.67	1.34	0.08
STA	*Sterechinus agassizi*	60.18	0.00	60.10	0.07
SQT	*Ascidiacea*	58.38	0.00	58.38	0.06
NEM	*Neophrynichthys marmoratus*	56.22	0.00	56.22	0.06
EEL	*Iluocetes fimbriatus*	50.43	3.29	47.14	0.06
CAZ	*Calyptraster sp.*	50.25	0.00	50.25	0.05
RED	*Sebastes oculatus*	42.00	11.88	1.05	0.05
WHI	*Macruronus magellanicus*	40.71	16.46	38.37	0.04
ODM	*Odontocymbiola magellanica*	24.51	0.00	24.51	0.03
GOC	*Gorgonocephalus chilensis*	21.43		21.43	0.02
RBZ	*Bathyraja cousseauae*	18.62	0.00	13.53	0.02
CEX	*Ceramaster sp.*	17.64	0.00	17.64	0.02
AUC	*Austrocidaris canaliculata*	16.84	0.00	16.84	0.02
COL	*Cosmasterias lurida*	12.86	0.00	12.80	0.01
PAT	*Merluccius australis*	10.37	6.33	0.00	0.01
EGG	*Bathyraja sp. Egg cases*	9.43	0.00	9.43	0.01
ZYP	*Zygochlamys patagonica*	9.27	0.00	9.27	0.01
OPH	*Ophiuroidea*	7.21	0.00	7.21	0.01
CTA	*Ctenodiscus australis*	7.01	0.00	7.01	0.01
FLX	*Flabellum spp.*	5.62	0.00	5.62	0.01
ILL	*Illex argentinus*	5.44	0.00	5.44	0.01
POA	*Porania antarctica*	4.98	0.00	4.89	0.01
TRX	*Trophon sp.*	0.03	0.00	0.03	< 0.01
THO	*Thouarellinae*	2.20	0.00	2.20	< 0.01
TED	*Terebratella dorsata*	0.07	0.00	0.07	< 0.01
SUN	*Labidaster radiosus*	0.44	0.00	0.44	< 0.01
SRP	*Semirossia patagonica*	0.02	0.00	0.02	< 0.01
SOR	*Solaster regularis*	0.58	0.00	0.58	< 0.01
SEP	*Seriolella porosa*	0.83	0.00	0.83	< 0.01
SEC	*Seriolella caerulea*	3.88	0.32	3.88	< 0.01
SAR	*Sparttus fuegensis*	0.23	0.00	0.23	< 0.01
RPA	*Bathyraja papilionifera*	2.01	0.00	2.01	< 0.01
PYX	*Pycnogonida*	0.51	0.00	0.51	< 0.01
POL	*Polychaeta*	0.04	0.00	0.04	< 0.01
PLU	*Primnoellinae*	0.40	0.00	0.33	< 0.01
PES	*Peltarion spinosulum*	0.29	0.00	0.29	< 0.01
OPL	*Ophiuroglypha lymanii*	0.08	0.00	0.08	< 0.01
OPD	*Ophiacantha densispina*	0.16	0.00	0.16	< 0.01
OCM	*Octopus megalocyathus*	2.26	0.00	2.26	< 0.01
NUD	*Nudibranchia*	0.14	0.00	0.14	< 0.01
MUU	*Munida subrugosa*	0.27	0.00	0.18	< 0.01
MUO	*Muraenolepsis orangiensis*	0.64	0.00	0.48	< 0.01
MUN	*Munida spp.*	0.18	0.00	0.18	< 0.01
MUG	*Munida gregaria*	0.24	0.00	0.24	< 0.01
MLA	*Muusoctopus longibrachus akambei*	2.56	0.00	2.56	< 0.01
MAV	*Magellania venosa*	0.51	0.00	0.51	< 0.01
ISO	*Isopoda*	0.01	0.00	0.01	< 0.01
HYD	*Hydrozoa*	3.44	0.00	3.44	< 0.01
HOL	*Holothuroidea*	1.16	0.00	1.16	< 0.01
HCR	*Paguroidea*	0.27	0.00	0.15	< 0.01
GRC	*Macrourus carinatus*	1.10	1.10	1.10	< 0.01
GAF	*Ganaria falklandica*	0.10	0.00	0.10	< 0.01
EUO	*Eurypodius longirostris*	1.61	0.00	1.61	< 0.01
EUL	*Eurypodius latreillei*	1.41	0.00	1.41	< 0.01
CYX	*Cycethra sp.*	1.30	0.00	1.30	< 0.01
CRY	*Crossaster sp.*	0.49	0.00	0.49	< 0.01
COP	*Congiopodus peruvianus*	2.63	0.00	2.63	< 0.01
BUT	*Stromateus brasiliensis*	0.98	0.00	0.98	< 0.01
BUC	*Bulbus carcellesi*	0.01	0.00	0.01	< 0.01
BRY	*Bryzoa*	0.52	0.00	0.52	< 0.01
BER	*Berthella spp.*	0.05	0.00	0.05	< 0.01
BAO	*Bathybiaster loripes*	2.71	0.00	2.71	< 0.01
BAL	*Bathydomus longisetosus*	0.18	0.00	0.18	< 0.01
AST	*Asteroidea*	0.66	0.00	0.66	< 0.01
ASA	*Astrotoma agassizii*	0.01	0.00	0.01	< 0.01
ALC	*Alcyoniina*	3.58	0.00	3.38	< 0.01
ACS	*Acanthoserolis schythei*	0.02	0.00	0.02	< 0.01
Totals		***91661.67***	***8898.12***	***18697.17***	

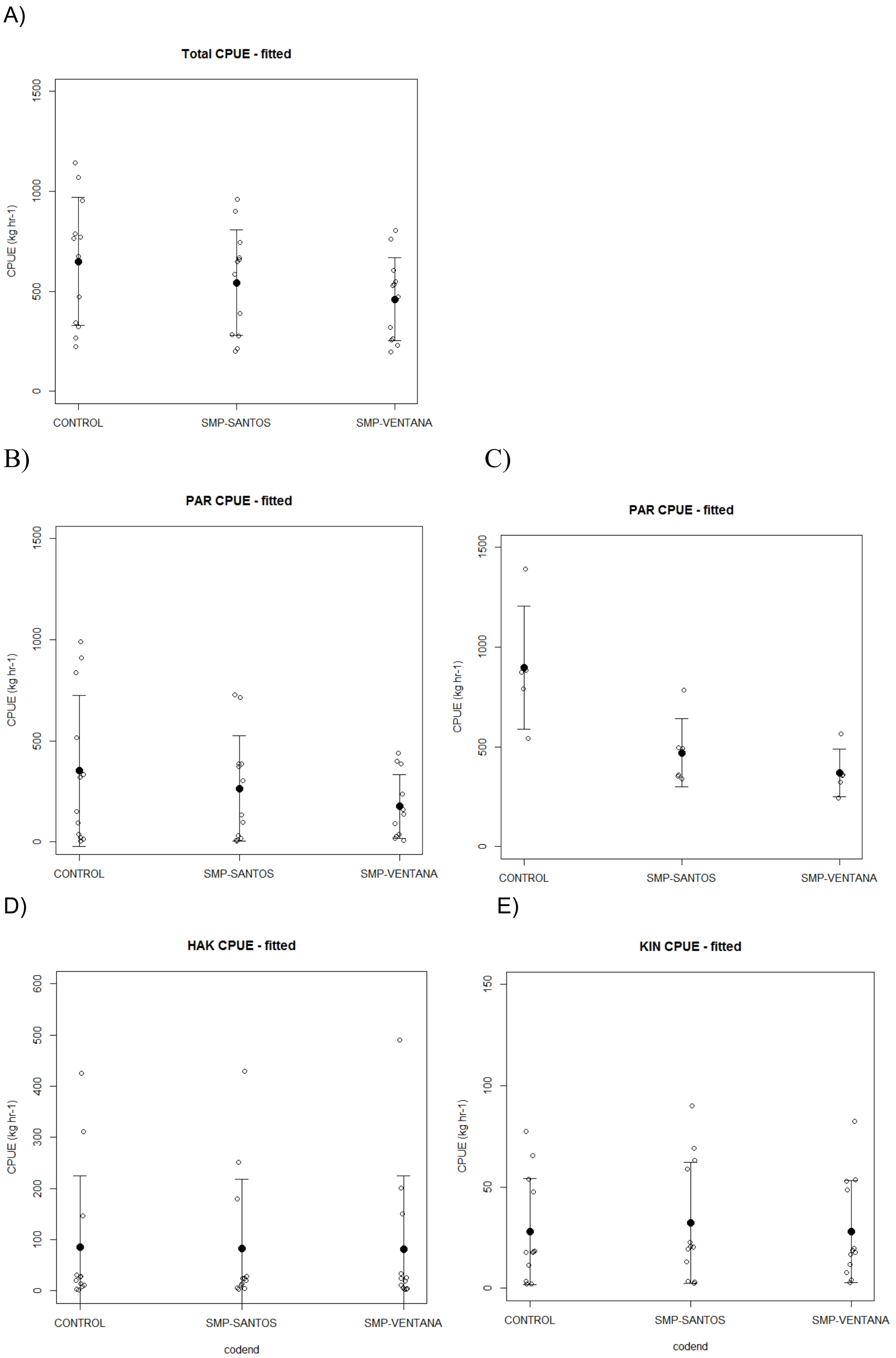


Figure 3.3. Predicted catch rates (CPUE - kg per trawling hour) among codend configurations for (A) total catch and (B-D) target (finfish) species. PAR = *P. ramsayi* (rock cod); HAK = *M. hubbsi* (hake); KIN = *G. blacodes* (kingclip). B) Rock cod CPUE in all hauls. C) Rock cod CPUE in hauls with ≥ 50% rock cod catch. Empty circles represent individual hauls. Filled circles represent mean values. Error bars = ±1 standard deviation.

Dorytheutis gahi ($CPUE_{LOL}$)

Loligo squid CPUE averaged 16 kg per hour and ranged 0.9-85 kg hr^{-1} among hauls. Longitude was a significant, positive covariate affecting $CPUE_{LOL}$ (Chisq=18.488, df=1, p< 0.001). Trawl depth explained 78% of the variance in the model (Table 3.2). Codend-SMP configurations had a significant effect on catch rates of Loligo (Chisq=18.528, df=2, p< 0.001). Predicted mean Loligo CPUE were 2× higher in Control trawls (21 kg hr^{-1}) relative to SMP-Santos (13 kg hr^{-1}) and SMP-Ventana (10 kg hr^{-1}) (Fig.3.4B).

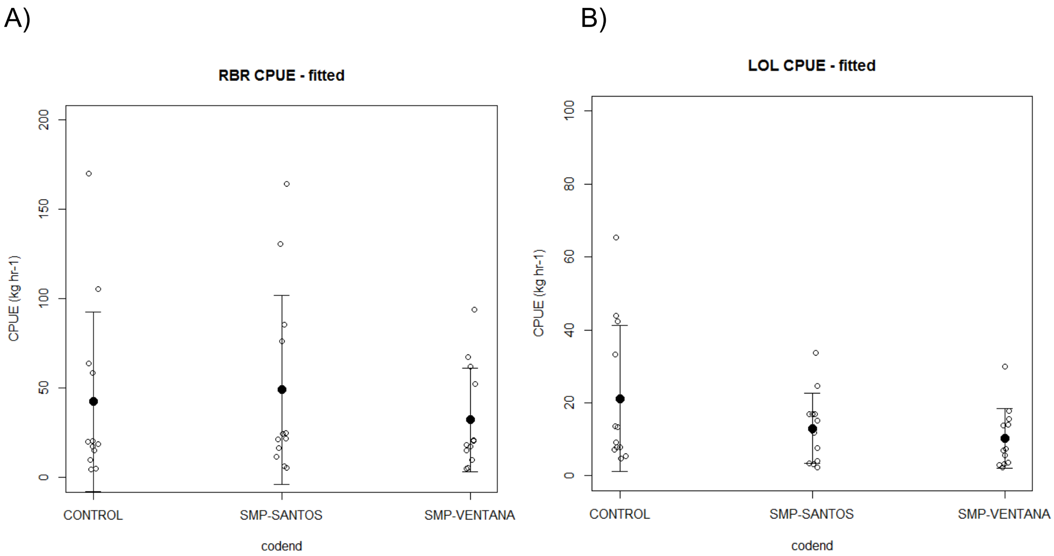


Figure 3.4. Predictedcatch rates (CPUE - kg per trawling hour) among codend configurations for the main by-catch species; (A) The skate *B. brachyurops* (RBR); and (B) Loligo squid *D. gahi* (LOL). Empty circles correspond to individual hauls. Dark (filled) circles represent mean values. Error bars = ±1 standard deviation.

3.3.2 Discard weights of *P. ramsayi* (rock cod)

All hauls considered, discard weights of rock cod were statistically similar among trawl configurations (Chisq=3.001, df=2, p>0.05) and varied from a mean of 123 kg hr^{-1} (Control) to 65 kg hr^{-1} (SMP-Ventana) and 68 kg hr^{-1} (SMP-Santos) (Fig. 3.5A). Longitude was a significant, positive covariate (Chisq=13.381, df=1, p<0.001). Day effects explained half (51%) of the variance in the model (Table 3.2). For hauls in which rock cod accounted for ≥ 50% of the catch, a significant reduction in discard weights of rock cod was observed in trawls equipped with SMP (Chisq=8.538, df=2, p=0.014) (Table 3.2, Fig. 3.5B). This reduction was significant in the SMP-Ventana (GLMM t=-2.849, $p<0.05$) and marginally significant in the SMP-Santos (GLMM t=-1.997, $p=0.05$).

Table 3.2 Summary of selected GLMM procedures for the assessment of codend-SMP effects on total and species-specific CPUE and discard weights of rock cod ($DISCARD_{PAR}$). Trawl configuration (3-levels factor) and spatial coordinates (Lat and Lon) were the fixed effects in all models. Random effects included sampling day (day), time of day (tofday) and trawl depth (depth). 'X' indicates a significant fixed effect. For random effects: ()% is the percentage of the residual variance explained by the random effect in the selected model. BIC is the Bayesian information criterion.

	Response	Fixed effects			Random effects			BIC
		codend	Lat (^{o}S)	Lon (^{o}W)	day	tofday	depth	
Total Catch	$logCPUE_{T}$	-	X	-	39%	-	-	38.71
Target Finfish Species								
P. ramsayi	$logCPUE_{PAR}$	X	-	X	-	-	64%	63.21
*P. ramsayi***	$logCPUE_{PAR}$	X	-	-	45%	-	-	19.31
P. ramsayi	$logDISCARD_{PAR}$	-	-	X	51%	-	-	77.02
*P. ramsayi***	$logDISCARD_{PAR}$	X	-	-	8%	-	-	26.61
M. hubbsi	$logCPUE_{HAK}$	-	X	X	81%	-	-	28.50
G. blacodes	$logCPUE_{KIN}$	-	X	-	28%	-	-	92.45
Commercial by-catch species								
D. gahi	$logCPUE_{LOL}$	X	-	X	-	-	78%	44.91
B. brachyurops	$logCPUE_{RBR}$	-	X	-	65%	-	-	45.98

**Including only hauls in which rock cod accounted for ≥ 50% of total catch.

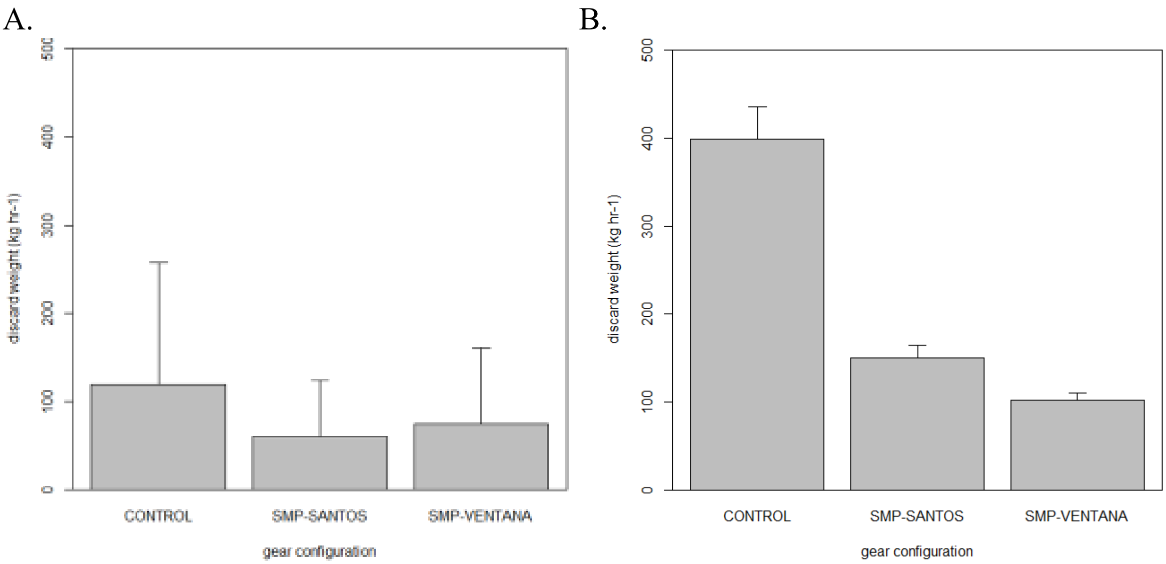


Figure 3.5 Predicted discard weights of rock cod as estimated from length frequencies in A) all hauls; and B) hauls with ≥ 50% rock cod in the catch.

Average discard weights of rock cod as estimated from length frequencies (Fig. 3.5) were generally higher than observed in catch reports from the vessel bridge (Fig. 3.6). This was expected considering the recent reduction in the minimum HGT-size for rock cod, and was especially marked when the species accounted for ≥ 50% of the catch (Fig. 3.5B and 3.6B). The pattern of higher discard weights in control hauls and lower discard weights in trawls equipped with SMP was consistent between length-frequency estimates (Fig 3.5) and reported catch data (Fig 3.6).

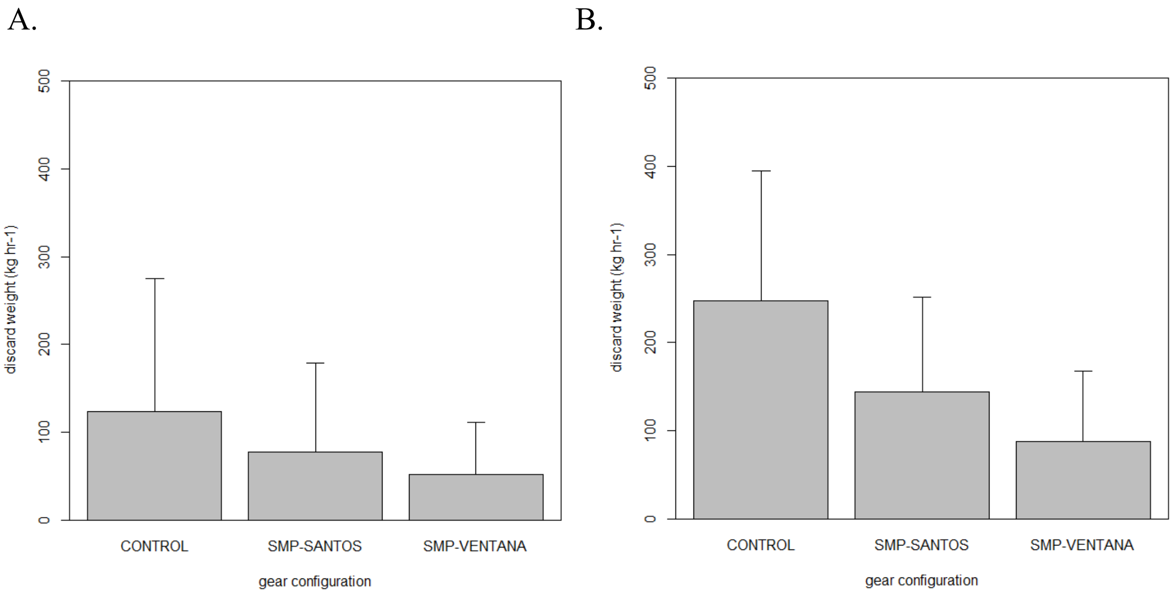


Figure 3.6. Discard weights of rock cod among trawl configurations as estimated from catch reports from the vessel bridge. A) all hauls; B) hauls with ≥ 50% rock cod in the catch.

3.3.3 Length distributions

Patagonotothen ramsayi (Patagonian rock cod)

Rock cod length ranged 8-40 cm during the trials. An exceptionally large male rock cod (44 cm TL, 1326 g) was non-randomly sampled from the catch at station 1162 (Fig. 3.7).

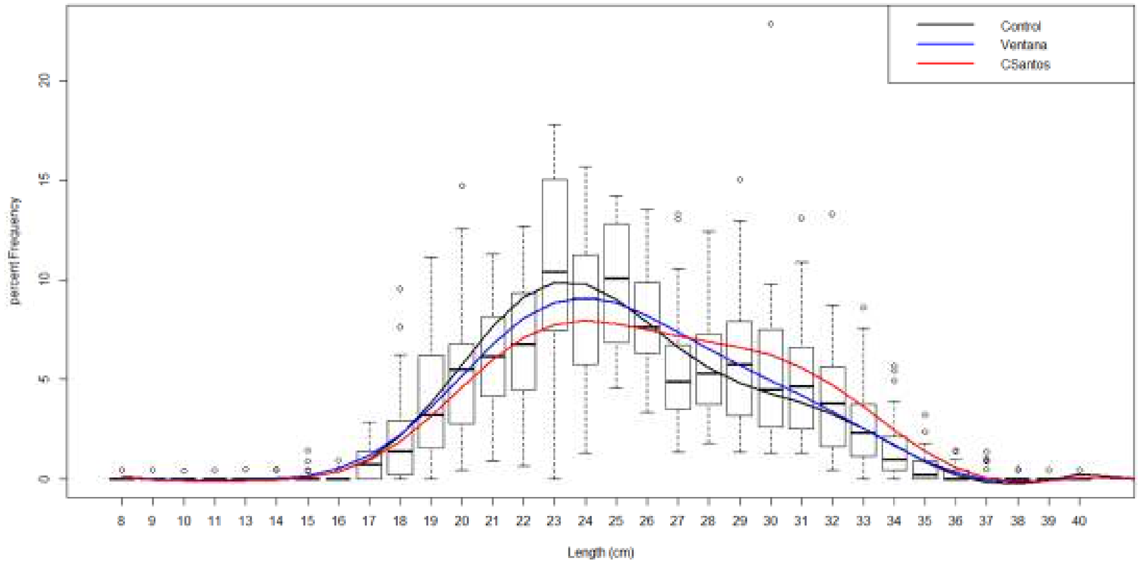
Among all hauls, mean length was 25.4 cm and significantly increased from 25.0 cm (Control) to 25.3 cm (SMP-Ventana) and 25.9 cm (SMP-Santos) (H=47.069, df=2, p<0.001). Predicted length frequencies demonstrated higher proportions of undersized rock cod (< 25 cm) in control hauls and higher proportions of rock cod larger than > 28 cm) in trawls equipped with SMP (Fig. 3.8A). First and third quartile lengths increased by 1-cm in SMP-

Santos relative to control and SMP-Ventana (Table 3.3). Modal length increased from 23 cm (Control) to 24 cm (SMP-Ventana and SMP-Santos) (Table 3.3).

Among hauls ≥50% rock cod, mean length was significantly greater in SMP-Santos (24.7 cm) and SMP-Ventana (24.9 cm) than Control (23.6 cm) ($H=53.890$, $df=2$, $p<0.001$). Mean length did not differ between SMP-Ventana and SMP-Santos. Proportions of undersized (< 25 cm) rock cod were higher in Control hauls and the occurrence of rock cod > 27 cm was higher in both SMP configurations (Fig. 3.8B). First quartile and median lengths increased by 1-cm in SMP configurations relative to Control (Table 3.3). Third quartile length was higher in SMP-Ventana (28 cm) and SMP-Santos (27 cm) relative to Control (25 cm). Modal lengths were similar among trawl configurations (Table 3.3).

Figure 3.7 Male rock cod (TL=44 cm TL, Wt=1326 g, maturity stage= 2) caught at station 1162. *(Photos by R. James).*

A.



B.

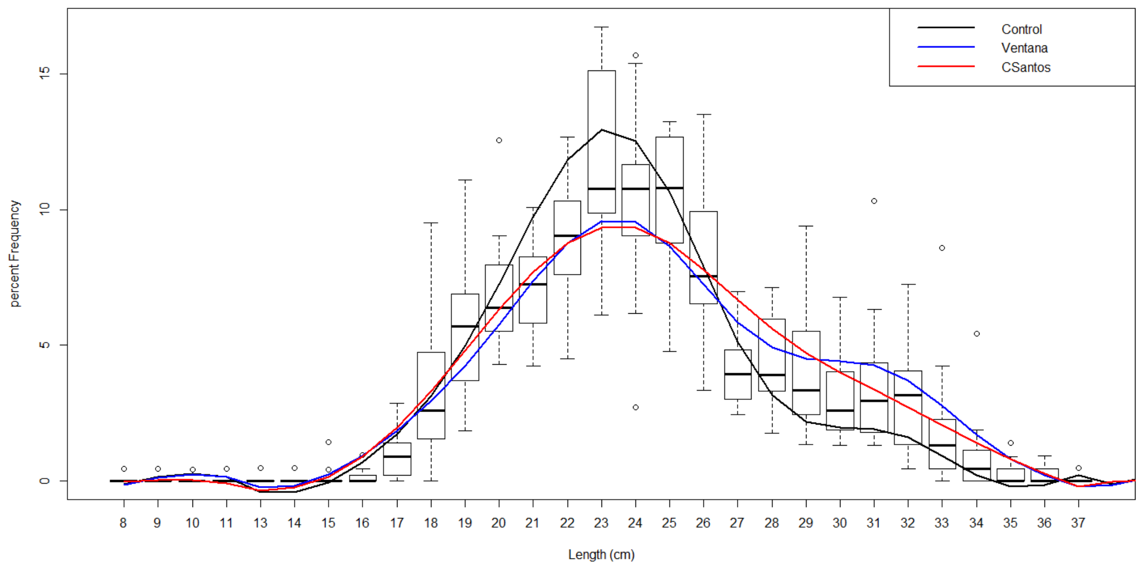


Figure 3.8 GAM-smoothed proportional length frequency distributions for *P. ramsayi* (rock cod) among trawl configurations. A) all hauls; B) Hauls in which rock cod accounted for ≥ 50% of the catch.

Genypterus blacodes (kingclip)

The average length of kingclip was 74 cm and ranged 42-129 cm during the trials. Kingclip caught in the SMP-Santos configuration had lower mean, median, first/third quartiles and modal lengths compared to those caught in Control and SMP-Ventana hauls (Table 3.3). Mean length did not differ between control and SMP-Ventana and was significantly lower in

SMP-Santos (H=41.203, df=2, p<0.001). Length frequency distributions were relatively similar between Control and SMP-Ventana but showed higher proportions of smaller (< 70-cm) kingclip in the SMP-Santos (Fig 3.9). These results corroborate earlier findings by Roux et al (2013b) indicating higher frequencies of smaller (< 60 cm) kingclip in trawls equipped with a SMP.

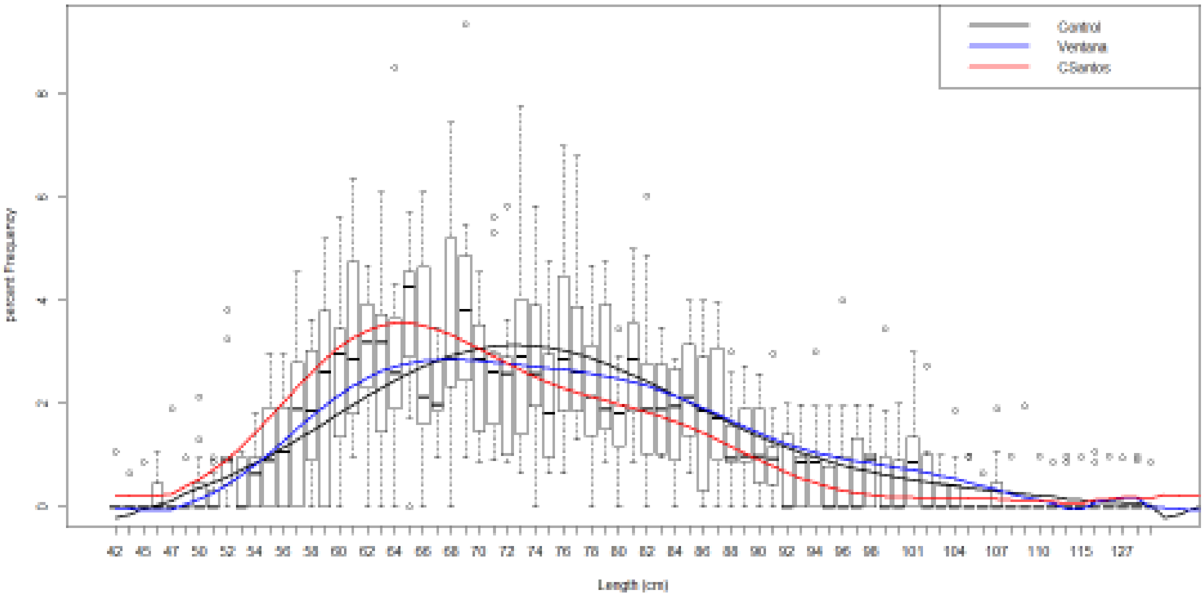


Figure 3.9 GAM-smoothed proportional length frequency distributions for *G. blacodes* (kingclip) among trawl configurations.

Merluccius hubbsi (hake)

Hake length ranged 27-88 cm during the trials. Average length was 65 cm. Mean, median, first/third quartiles and modal lengths increased with SMP use (Table 3.3). However differences in mean length were not statistically significant (H=1.415, df=2, p>0.05). Length frequency distributions were generally similar among trawl configurations but demonstrated lower proportions of smaller (< 60 cm) hake and higher proportions of modal size (62-72 cm) hake in trawls equipped with SMP (Fig. 3.10). These results are consistent with the significant increase in hake sizes in trawls equipped with SMP when hake dominated the catch (Roux et al. 2013b).

Table 3.3 Species-specific length structures among trawl configurations, including mean, median, modal and first/third quartiles lengths. 'n stations' is the number of hauls with sample sizes ≥100 specimens (rock cod and Loligo squid) or ≥80 (all other species).

		Control	SMP-Ventana	SMP-Santos
P. ramsayi (rock cod)				
	1st quartile	22	22	23
	median	25	25	25
	3rd quartile	28	28	29
	mean	25.0	25.3	25.9
	fitted mode	23	24	24
	n (stations)	*11*	*11*	*10*
P. ramsayi (rock cod)**				
	1st quartile	21	22	22
	median	23	24	24
	3rd quartile	25	28	27
	mean	23.6	24.9	24.7
	fitted mode	23	23	23
	n (stations)	*5*	*6*	*5*
G. blacodes (kingclip)				
	1st quartile	67	65	62
	median	74	75	69
	3rd quartile	83	85	79
	mean	75.7	75.9	71.0
	fitted mode	73	68	64
	n (stations)	*3*	*4*	*4*
M. hubbsi (hake)				
	1st quartile	59	61	60
	median	64	65	65
	3rd quartile	69.25	70	70
	mean	64.5	65.1	64.8
	fitted mode	64	65	65
	n (stations)	*3*	*3*	*3*
B. brachyurops (skates)				
	1st quartile	24	19	23
	median	33	28	30
	3rd quartile	46	44	41
	mean	34.8	31.6	32.2
	fitted mode	26	21	27
	n (stations)	*7*	*6*	*8*
D. gahi (loligo squid)				
	1st quartile	12.5	12.5	13.5
	median	14.5	14.5	15.0
	3rd quartile	15.5	16.0	17.0
	mean	14.5	14.7	15.4
	fitted mode	14.0	14.5	15.0
	n (stations)	*12*	*10*	*9*

**Including only hauls in which rock cod accounted for ≥ 50% of total catch.

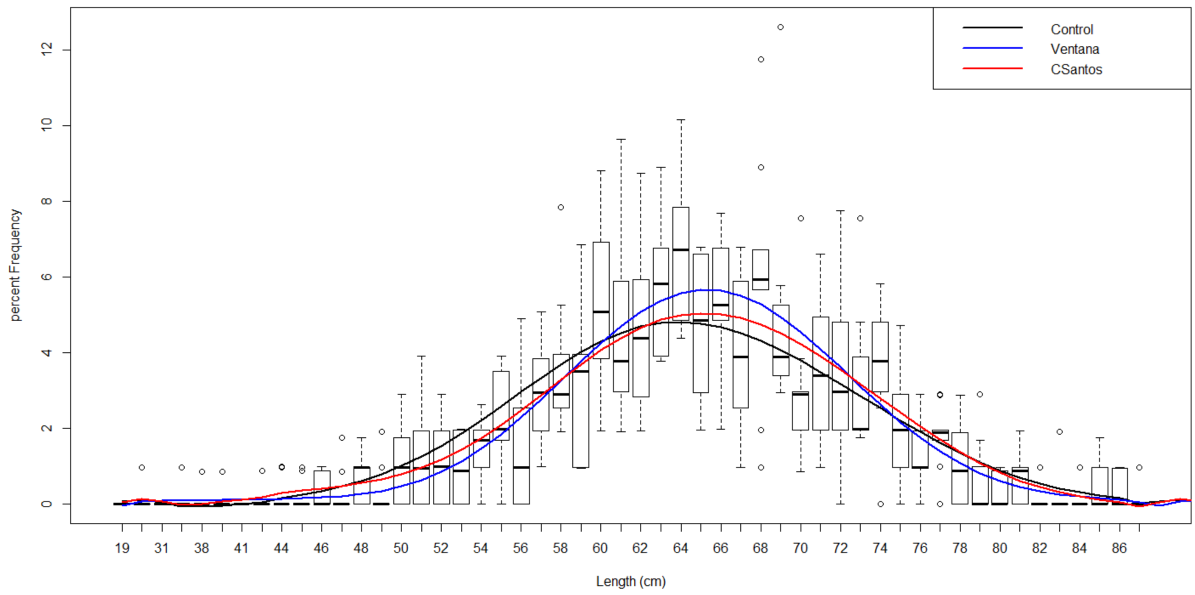


Figure 3.10 GAM-smoothed proportional length frequency distributions for *M. hubbsi* (hake) among trawl configurations.

Rajidae (skates)

The average *B. brachyurops* (RBR) disk width was 33 cm and ranged 7-75 cm during trials. Size frequency distributions showed higher proportions of smaller skates (< 30 cm) in trawls equipped with SMP (Fig 3.11). This was especially marked in the SMP-Ventana (Fig 3.11). Mean disk width was significantly larger in Control hauls relative to trawls equipped with SMP (H=28.262, df=2, p<0.001). Median and first/third quartiles disk widths were larger in Control compared to SMP-trawls c (Table 3.3).

D. gahi (Loligo squid)

Loligo mantle length ranged from 5.5 cm to 35 cm during the trials. The occurrences of smaller (< 14 cm) and larger (> 15 cm) Loligo in the catch were reduced and enhanced in the SMP-Santos, respectively (Fig 3.12). Mean, median, modal and first/third quartile mantle lengths were larger in SMP-Santos relative to Control and SMP-Ventana (Table 3.3). Average mantle length was significantly larger in SMP-Santos (15.4 cm) than Control (14.5 cm) and SMP-Ventana (14.7 cm) (H=77.804, df=2, p<0.001).

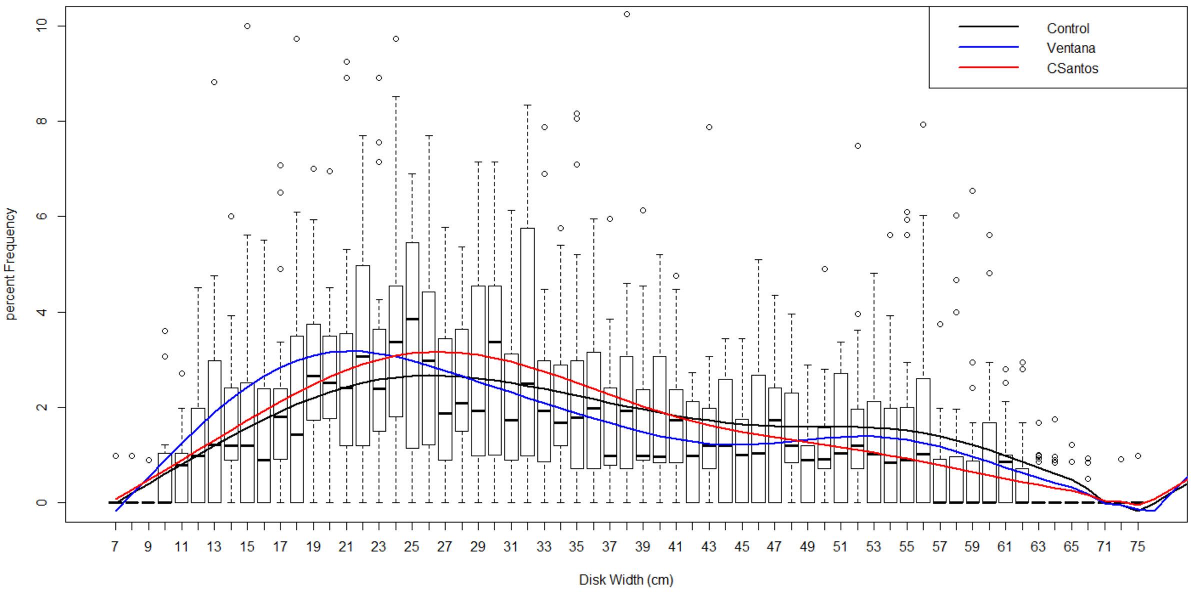


Figure 3.11 GAM-smoothed proportional length frequency distributions for *B. brachyurops* (skates) among trawl configurations.

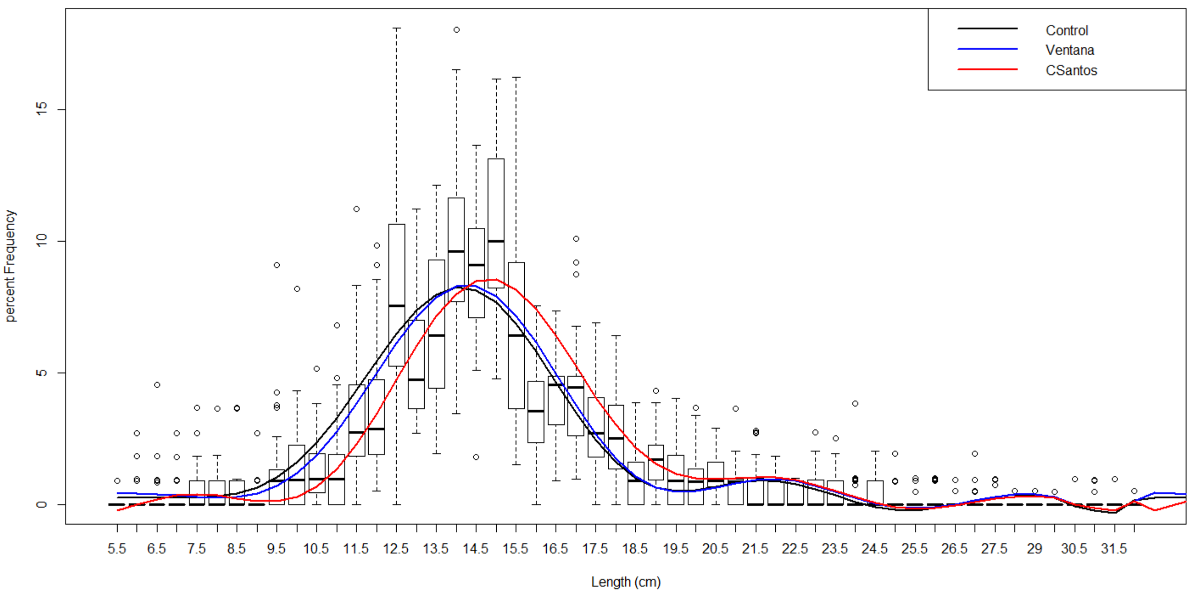


Figure 3.12 GAM-smoothed proportional mantle length frequency distributions for *D gahi* (Loligo squid) among trawl configurations.

3.3.4 Relative selectivity at length

Patagonotothen ramsayi (Patagonian rock cod)

Relative selectivity at length was estimated from 32 trawls with length intervals ranging from 16 to 37 cm. First length of 50% retention (L_{50}-1) in empirical curves varied from 19.2 cm (in Control and SMP-Santos) to 19.9 cm (SMP-Ventana) (Table 3.4). Second length of 50% retention (L_{50}-2) increased from 27.2 cm (Control) to 27.9 cm (SMP-Santos) and 28.4 cm (SMP-Ventana) (Table 3.4). Empirical curves were significantly different between Control and SMP-Santos (Table 3.5). This difference was mainly driven by the decreasing slope parameter (S2), which was shallower in SMP-Santos (Table 3.5). As in previous trials, inter-haul variability in double-logistic parameters fitting was important (Appendix 1).

Bootstrap iterations showed a similar increase in median L_{50}-1 and L_{50}-2 among trawl configurations, although more pronounced in the SMP-Santos (Fig. 3.13). Median L_{50}-1 increased from 19.3 cm (Control) to 19.9 cm (SMP-Santos) and 20.2 cm (SMP-Ventana) while median L_{50}-2 increased from 26.5 cm (Control), to 27.6 cm (SMP-Santos) and 27.8 cm (SMP-Ventana) (Table 3.4). The resulting curves demonstrate overlapping confidence intervals within the 16-19 cm size range and a higher retention of rock cod ≥ 33 cm in SMP-Santos (Fig. 3.13).

Table 3.4. Double-logistic parameters fitting relative selectivity curves of the three trawl configurations for PAR data among all trawls with ≥100 PAR sampled and all length intervals occurring in ≥ 5 trawls; including the aggregate fit parameters per trawl configuration (empirical curves), and the parameter medians of bootstrap iterations per trawl configuration.

	Trawl configuration	n	L_{50}-1	L_{50}-2	S1	S2
combined fit	Control	11	19.168	27.218	0.566	0.275
per trawl configuration	SMP-Ventana	11	19.871	28.410	0.389	0.271
(empirical curves)	SMP-Santos	10	19.183	27.903	0.520	0.161
median of	Control	1000	19.264	26.495	0.596	0.238
bootstrap iterations	SMP-Ventana	1000	20.213	27.860	0.400	0.246
per trawl configuration	SMP-Santos	1000	19.788	27.603	0.477	0.145

For rock cod-dominant catches (≥ 50% rock cod), relative selectivity at length was estimated from 15 trawls (Table 3.6) with length intervals ranging from 17 to 36 cm. Variations in L_{50}-1 among trawl configurations (Table 3.6) were similar to those observed when all trawls were considered (Table 3.4). A sharper increase in L_{50}-2 in trawls equipped with SMP relative to

Control was evident when rock cod dominated the catch (Table 3.6). Inter-haul variability in double-logistic parameters fitting remained important (Appendix 2).

Table 3.5. Paired likelihood ratio tests between trawl configurations, for the double-logistic functions (i.e., the whole curves), and for parameters individually, of the PAR data referenced in Table 3.4. Note, however, that a likelihood ratio does not specifically test differences between the parameters as shown in Table 3.4. It tests the differences between a model that fits the parameters separately vs. a model that fits the parameters jointly. If entire-curve double-logistic likelihood was not significantly different ($p > 0.05$) between a pair of trawl configurations, individual parameters were not tested.

Trawl configurations	Likelihood ratio test comparison	χ^2	df	p
Control vs. SMP-Ventana	double logistic	1.10	4	> 0.05
Control vs. SMP-Santos	double logistic	17.61	4	< 0.001
	L_{50}-1	3.54	1	> 0.05
	L_{50}-2	2.17	1	> 0.05
	S1	0.88	1	> 0.05
	S2	17.20	1	< 0.001
SMP-Ventana vs. SMP-Santos	double logistic	8.39	4	> 0.05

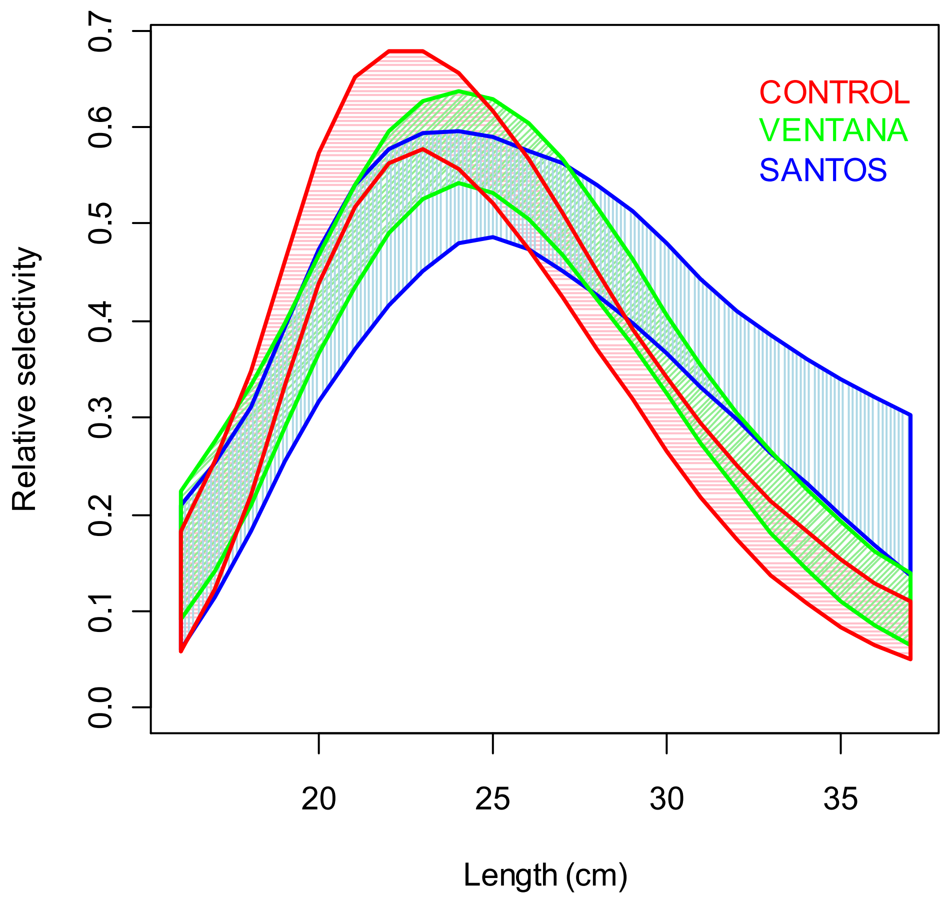


Figure 3.13. Relative selectivity curves with 95% confidence intervals for *P. ramsayi* (rock cod) data as referenced in Table 3.4, in the three trawl configurations. Length = total length.

Empirical relative selectivity curves were significantly different between Control and SMP-Ventana, and Control and SMP-Santos (Table 3.7). Such differences were linked to significant differences in L_{50}-2 and in one or both slope parameters (Table 3.7). SMP-Ventana and SMP-Santos were not significantly differently from each other.

Fitted curves from bootstrap iterations illustrate differences in selectivity patterns among trawl configurations, including a narrower selection range in Control trawls (peak retention between 20-26 cm) and a comparatively broader selectivity range in SMP trawls (peak retention between 20-28 cm in SMP-Santos and 24-33 cm in SMP-Ventana) (Fig 3.14). Whereas confidence intervals overlapped in the smaller length intervals (17-20 cm), the retention of undersized rock cod between 20 cm and 25 cm was lower in the SMP-Ventana relative to Control (Fig 3.14). Both SMP-configurations were more selective of rock cod ≥ 29 cm compared to Control (Fig 3.14). Variability in selectivity curves in Figure 3.14 was largely driven by bootstrap iterations that generated infinite values for one slope/inflexion parameter combination, indicating that the selection curve became single-logistic (Quinn and Deriso 1999).

Table 3.6. Double-logistic parameters fitting relative selectivity curves of the three trawl configurations for PAR among trawls with ≥50% PAR catch, ≥100 PAR sampled and length intervals occurring in ≥5 trawls; including the aggregate fit parameters per trawl configuration (empirical curves), and the parameter medians of bootstrap iterations per trawl configuration
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	Trawl configuration	n	L_{50}-1	L_{50}-2	S1	S2
combined fit	Control	5	18.485	27.557	0.648	0.426
per trawl configuration	SMP-Ventana	5	19.221	30.467	0.296	0.292
(empirical curves)	SMP-Santos	5	18.703	29.473	0.487	0.219
median of	Control	1000	18.717	27.134	0.599	0.392
bootstrap iterations	SMP-Ventana	1000	19.669	30.897	0.233	0.253
per trawl configuration	SMP-Santos	1000	18.754	28.809	0.431	0.199

Important variability in the ascending slope of relative selectivity curves compared to preliminary trials (Roux et al 2013a) may reflect differential selectivity between the commercial codend used in Roux et al (2013a) and the experimental codends used in the present study and in Roux et al (2013b). Experimental codends made of thinner (5 mm) thread thread may allow greater escapement of smaller length-classes compared to the commercial codend made of thicker (6 mm) and less extensible (PE) thread.

Table 3.7. Paired likelihood ratio tests between trawl configurations, for the double-logistic functions (i.e., the whole curves), and for parameters individually, of the PAR data referenced in Table 3.6. See note in Table 3.5. If whole-curve likelihood was not significantly different between a pair of trawl configurations, individual parameters were not tested.

Trawl configurations	Likelihood ratio test			
	comparison	χ^2	df	p
Control vs. Ventana	double logistic	34.96	4	< 0.001
	L_{50}-1	1.84	1	> 0.05
	L_{50}-2	10.47	1	< 0.005
	S1	6.14	1	< 0.025
	S2	23.49	1	< 0.001
Control vs. Santos	double logistic	27.48	4	< 0.001
	L_{50}-1	1.93	1	> 0.05
	L_{50}-2	8.35	1	< 0.005
	S1	2.95	1	> 0.05
	S2	20.12	1	< 0.001
Ventana vs. Santos	double logistic	1.24	4	> 0.05

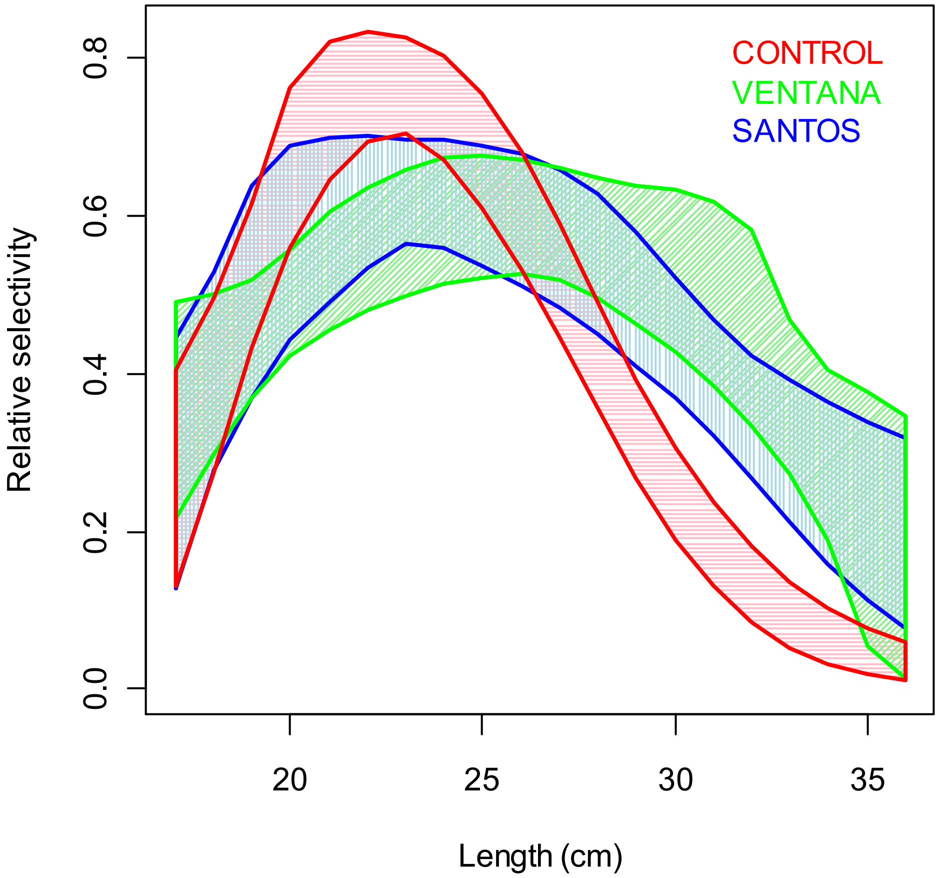

Figure 3.14. Relative selectivity curves with 95% confidence intervals for *P. ramsayi* (rock cod) data as referenced in Table 3.6, in the three trawl configurations. Length= total length

D. gahi (Loligo squid)

Relative selectivity at length was estimated from 29 trawls (Table 3.8) with mantle length (ML) intervals ranging from 6.5 to 24.5 cm. Loligo ML_{50}-1 and ML_{50}-2 increased in SMP-trawls relative to Control, and this increase was most pronounced in the SMP-Santos configuration (Table 3.8). Inter-haul variability in double-logistic parameters fitting for Loligo was relatively important (Appendix 3). Empirical curves were significantly different between Control and SMP-Santos, and between SMP-Ventana and SMP-Santos (Table 3.9). The SMP-Santos curve represented a shift to the right compared to the other two, with significantly higher ML_{50}-1 andM L_{50}-2 relative to Control and a higher ML_{50}-2 relative to SMP-Ventana (Table 3.9).
Selectivity curves generated from bootstrap iterations had tight confidence intervals (Figure 3.15) and illustrate lower selectivity for squid < 15 cm mantle length in the SMP-Santos and enhanced retention of Loligo ≥ 18 cm (Fig 3.15).

Table 3.8. Double-logistic parameters fitting relative selectivity curves of the three trawl configurations for LOL data among all trawls with ≥100 LOL sampled and all length intervals occurring in ≥5 trawls; including the aggregate fit parameters per trawl configuration, and the parameter medians of bootstrap iterations per trawl configuration.

Station	Date	Trawl configuration	n	ML_{50}-1	ML_{50}-2	S1	S2
combined fit per trawl configuration		Control	12	10.915	16.026	0.678	0.258
		SMP-Ventana	10	11.384	16.216	0.799	0.240
		SMP-Santos	9	12.955	19.163	0.695	0.328
median of bootstrap iterations per trawl configuration		Control	1000	11.147	15.309	0.649	0.322
		SMP-Ventana	1000	11.360	15.397	0.708	0.306
		SMP-Santos	1000	12.837	17.668	0.650	0.304

Table 3.9. Paired likelihood ratio tests between trawl configurations, for the double-logistic functions (i.e., the whole curves), and for parameters individually, of the LOL data referenced in Table 3.8. See note in Table 3.5. If whole-curve likelihood was not significantly different between a pair of trawl configurations, individual parameters were not tested.

Trawl configurations	Likelihood ratio test			
	comparison	χ^2	df	p
Control vs. Ventana	double logistic	0.46	4	> 0.05
Control vs. Santos	double logistic	21.60	4	< 0.001
	ML_{50}-1	6.15	1	< 0.025
	ML_{50}-2	8.08	1	< 0.005
	S1	5.15	1	< 0.025
	S2	9.81	1	< 0.005
Ventana vs. Santos	double logistic	14.69	4	< 0.010
	ML_{50}-1	3.17	1	> 0.05
	ML_{50}-2	6.94	1	< 0.010
	S1	3.36	1	> 0.05
	S2	5.84	1	< 0.025

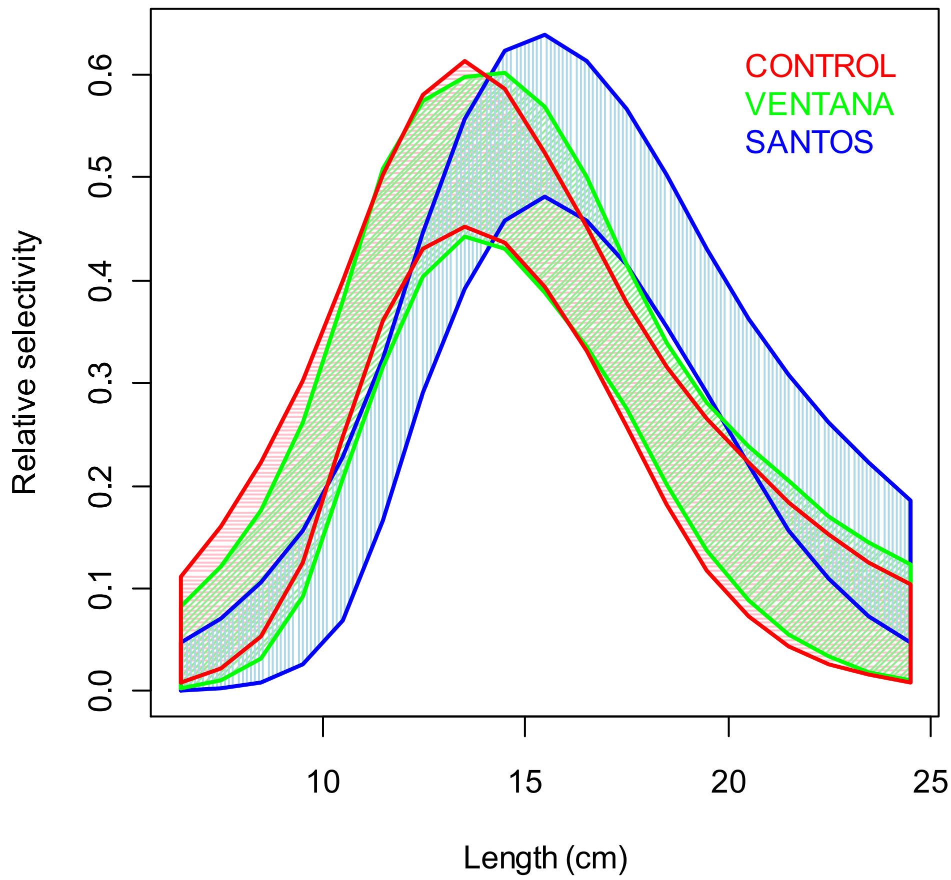

Figure 3.15. Relative selectivity curves with 95% confidence intervals for *D. gahi* data as referenced in Table 3.8, in the three trawl configurations. 'Length' here refers to mantle length (ML).

B. brachyurops (skates)

Relative selectivity was estimated from 21 trawls (Table 3.10) and for disk width intervals ranging from 10 to 63 cm. Relative selectivity curves were not significantly different among trawl configurations and individual parameter differences were therefore not evaluated. Both Control and SMP trawl configurations showed weak selectivity-disk width relationships for RBR (Fig 3.16). This is consistent with previous demonstrations of the absence of relative selectivity for skates in trawls equipped with small diamond meshes (90 mm and 110 mm) codends (Roux et al. 2012a, 2012b) and in the presence/absence of a SMP (Roux et al. 2013b).

Table 3.10. Double-logistic parameters fitting relative selectivity curves for the three trawl configurations for RBR data among all trawls with ≥80 RBR sampled and all length intervals occurring in ≥5 trawls;Including the aggregate fit parameters per trawl configuration, and the parameter medians of bootstrap iterations per trawl configuration.

Station Date	Trawl configuration	n	DW_{50}-1	DW_{50}-2	S1	S2
combined fit	Control	7	24.996	38.678	0.079	0.053
per trawl configuration	SMP-Ventana	6	22.541	37.186	0.061	0.073
(empirical curve)	SMP-Santos	8	23.382	37.929	0.083	0.091
median of	Control	1000	20.475	39.932	0.001	0.001
bootstrap iterations	SMP-Ventana	1000	20.160	40.110	-0.002	0.025
per trawl configuration	SMP-Santos	1000	23.560	34.217	0.080	0.071

Table 3.11. Paired likelihood ratio test between all three trawl configurations having the same four double-logistic parameters for RBR data, The whole-curve likelihood was not significantly different and therefore individual parameters were not tested.

Trawl	Likelihood ratio test			
configurations	comparison	χ^2	df	p
All combined	double logistic	11.68	8	> 0.05

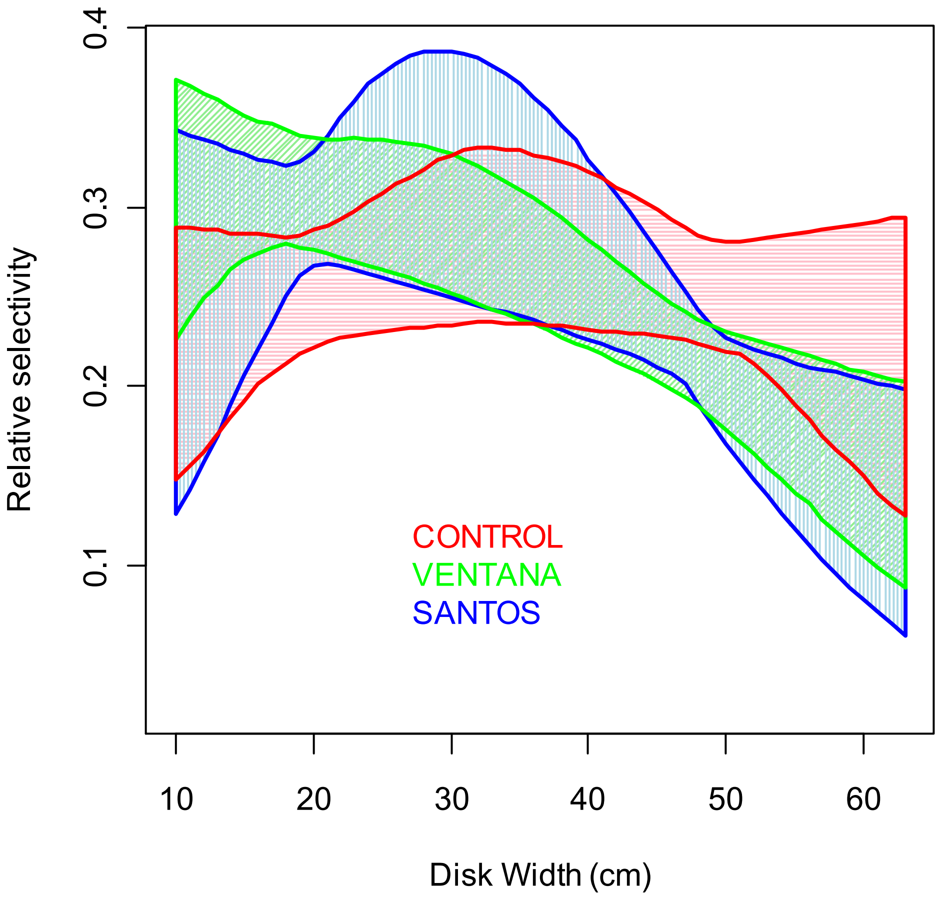

Figure 3.16. 95% confidence intervals of relative selectivity curves for RBR data as referenced in Table 3.10, in the three trawl configurations.

3.3.5 Additional observations

Hauling operations were monitored by the FIFD survey scientist from the bridge of the vessel to observe how different fish were distributed within the trawl as it was leaving the water, and thereby better understand and characterize the effects of SMP. Observations repeatedly revealed the presence of rock cod, kingclip and skates in the SMP sections themselves. Rock cod consistently occurred in SMP in moderate numbers (Fig 3.17). Kingclip occurred especially frequently in the SMP of the Santos configuration. Loligo squid accumulated in the net extension directly in front of the SMP in SMP-Santos trawls.

These observations support the hypothesis (Krag et al. 2008) and experimental demonstration (Broadhurst et al. 1999) that SMP affect water flow through the trawl gear. The presence of square meshes inside the codend increases water displacement forward, into the trawl (Broadhurst et al 1999). The SMP acts as a vacuum, enhancing flow velocity within the trawl body by allowing water to escape from the gear at the level of the codend. Flow acceleration directs fish towards the SMP and/or stimulates their lateral line receptors and overall escape behaviour (Broadhurst et al. 1999).

Active responses to water flow may explain the presence of rock cod and kingclip in SMP during the trials. However, our observations indicate that while the 40-mm square mesh allowed small rock cod to escape, it retained kingclip of all sizes. It is possible that smaller-sized kingclip that could escape through the 110-mm diamond mesh instead responded to water displacement near SMP where they failed to escape, hence the higher retention of < 70 cm kingclip in SMP-trawls.

In contrast, poor swimming capacities and a related passive response to water flow may explain skates occurrence in SMP. Skates are slow swimmers that remain near the bottom in demersal trawls (Kotwicki and Weinberg 2005). Enhanced water flow with SMP presence may accelerate the transport of skates from the trawl mouth to the codend. The magnitude of such passive transport should be inversely related to body size, as smaller-sized skates are probably less efficient swimmers. Within the codend, water displacement near SMP can be expected to interfere with skates ability to actively swim and escape through the lower panel, resulting in higher retention of smaller (< 30 cm disk width) skates in SMP-trawls.

On one SMP-Santos haul (station 1158; total catch > 7 t consisting of 89% rock cod), the middle of the SMP became clogged by a large amount of rock cod during hauling. This prompted the captain to recommend increasing the width of the SMP on the SMP-Santos configuration to 48 square meshes (Appendix 5). Such addition of square meshes should provide the codend with the expansion capacity that is necessary to avoid clogging and potential damage with large catches.

Figure 3.17. Rock cod retained in the SMP of the SMP-Ventana configuration (Photo by M-J Roux).

3.3.6 Summary of findings

The presence of a SMP in the trawl codend had no significant effect on total CPUE and on catch rates of commercial finfish species (kingclip and hake) in generally small-volume, mixed species catches. However when rock cod dominated the catch, SMP presence caused a significant reduction in rock cod CPUE linked to a significant reduction in discard weights of undersized rock cod. These results confirmed that SMP use effectively reduces by-catch of undersized rock cod that are ultimately discarded.

Size-selectivity improvement for rock cod was evident in both SMP configurations. SMP use increased the average length of rock cod in the catch. Lower proportions of undersized (< 25 cm) rock cod and higher proportions of commercial size specimens were observed in SMP trawls relative to Controls. Relative selectivity at length differed in SMP-Santos relative to Control (with selectivity modelled on all hauls) and in both SMP-Santos and SMP-Ventana relative to Control (selectivity modelled on hauls with ≥ 50% rock cod). This underlined the effect of rock cod catch size on SMP-Ventana performance. Predicted L_{50}-1 and L_{50}-2 were both larger in SMP trawls than Control. However statistical inference indicated that differences in relative selectivity curves were mainly related to an enhanced retention of commercial-size rock cod with SMP use. Selectivity improvement corresponding to a decreased retention of undersized fish was only evident in the SMP-Ventana configuration when rock cod dominated the catch.

The small mesh-size of the square mesh panel under trial, which is intended to specifically allow escapement of small rock cod, should have limited effects on larger-bodied species. SMP effects on length distributions of hake were minimal, as previously demonstrated in Roux et al (2013b). However the results suggest that indirect effects of SMP on water flow through the gear and associated behavioural (active or passive) responses to flow velocity can affect kingclip and skates retention in demersal trawls.

Trawls equipped with SMP retained higher proportions of small to medium-sized kingclip relative to controls. Further analyses are required to determine whether SMP effects on size selectivity for kingclip can offset the effects of an increase in codend mesh size from 90 mm to 110 mm.

A 110-mm diamond mesh codend is generally not size-selective for skates. Yet SMP presence was associated with higher proportions of smaller-sized skates in the catch. The same was observed during previous trials (Roux et al. 2013b). These results indicate that SMP use in trawl codend could pose a conservation challenge for small and immature *B. brachyurops*. However total catch rates of skates remained unaffected by SMP.

Catch rates of *Loligo* were significantly reduced in trawls equipped with SMP and there was a significant increase in *Loligo* ML_{50}-1 and ML_{50}-2 in SMP trawls. These results indicate that a 110-mm diamond mesh codend with SMP may serve to significantly reduce by-catch of *Loligo* squid in finfish trawlers.

4.0 General conclusions

A third series of SMP trials was conducted on finfish fishing grounds during October-November 2013. Trials involved two different panel configurations of 40-mm square mesh fitted inside the top panel of a 110-mm diamond mesh codend: the SMP-Ventana (2-m SMP inserted between 6-8 m from the codline) and the SMP-Santos (17-m SMP starting 10-m away from the codline). The 110-mm diamond mesh codend without SMP was used as Control.

The objective was to assess the performance of SMP configurations during fishing that targeted rock cod aggregations. Rock cod density on the fishing grounds was relatively low for this time of year during the trials and commercial-size catches of rock cod were achieved in some, but not all hauls. Analyses of the results were adjusted accordingly.

The use of a 110 mm diamond mesh codend with SMP improves selectivity and significantly reduces discard weights of rock cod with limited impacts on total catch and on catch rates of other commercial finfish species. The available data indicate that the SMP-Ventana configuration most efficiently reduces the retention of undersized rock cod. Further observations should be undertaken to contrast the performance of the SMP-Santos and SMP-Ventana configurations with large catches typical of the commercial fishery. SMP use in trawl codend may serve to reduce by-catch rates of *Loligo* squid in finfish trawlers. Potential negative impacts of SMP include higher retention of smaller-sized kingclip and skates.

5.0 Addendum: Seabird Mortality

A dead black-browed albatross (*Thalassarche melanophris)* was discovered in the codend of trawl station 1158. On examination of the corpse the plumage was found to be heavily waterlogged and muddy indicative of the bird being caught in the net during shooting and dragged underwater for the duration of the trawl.

A necropsy was carried out ashore and the bird was found to be an adult female. By use of moult patterns and bill colouration it was possible to ascertain that it was an adult of six or more years.

The albatross had a completely bald brood patch indicating that she had been actively incubating an egg. Incubation and chick rearing requires two adults and so the egg would have eventually been abandoned on the nest by the male. Being monogamous, the male may take several seasons before he successfully finds a new mate and so the mortality of a single albatross may reduce the potential lifetime reproduction of its mate (Sagar et al. 2002).

The stomach contained two undigested cut heads of PAR showing that the albatross had recently been feeding on discards from a fishing vessel. Whilst the *Castelo* did not discharge offal and by-catch during shooting, this was the third trawl of the day and so the bird may have been feeding from the *Castelo* during a previous trawl or from a nearby vessel.

The crew of the *Castelo* cleaned the fishing gear thoroughly between trawls and discharge of discards ceased before shooting began. Although Tori lines would do nothing to negate mortality during shooting or hauling, they were used correctly and deployed soon after the trawl doors entered the water and retrieved just before hauling commenced. Thus all bird friendly fishing practices had been adhered to and the vessel could not have practically done more to reduce risks to foraging seabirds.

Figure 5.1 Passive smoking in albatrosses is a little researched area (Photo: R. James).

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Appendix 1. Double-logistic parameters fitting relative selectivity curves of the trawl stations for PAR data among all trawls with ≥100 PAR sampled and length intervals occurring in ≥ 5 trawls; '∞' represents parameters where either side of the double-logistic curve fit maximum selectivity beyond the plausible range of PAR lengths.

Station	Date	Trawl configuration	L_{50}-1	L_{50}-2	S1	S2
1141	21/10/2013	SMP-Ventana	22.547	31.471	0.260	0.798
1142	21/10/2013	SMP-Santos	∞	25.311	∞	∞
1143	21/10/2013	Control	20.089	29.825	16.678	0.137
1147	22/10/2013	SMP-Santos	19.880	35.122	3.789	0.003
1149	23/10/2013	Control	23.579	31.491	0.543	0.384
1151	23/10/2013	SMP-Ventana	18.118	26.916	11.269	0.198
1152	24/10/2013	SMP-Ventana	19.588	27.306	1.094	0.519
1153	24/10/2013	SMP-Santos	21.219	29.860	0.551	0.402
1155	24/10/2013	Control	20.171	26.796	0.774	1.168
1156	25/10/2013	Control	18.376	25.808	27.800	0.444
1157	25/10/2013	SMP-Ventana	21.152	29.071	0.287	0.443
1158	25/10/2013	SMP-Santos	18.328	26.455	0.435	0.738
1159	26/10/2013	Control	19.040	26.593	0.543	0.749
1160	26/10/2013	SMP-Santos	20.179	28.608	0.511	0.367
1161	26/10/2013	SMP-Ventana	18.128	20.764	0.763	0.032
1162	27/10/2013	SMP-Santos	16.905	38.512	9.478	0.015
1163	27/10/2013	Control	17.820	25.666	0.851	0.452
1165	27/10/2013	SMP-Ventana	21.002	27.897	1.822	0.405
1166	28/10/2013	SMP-Ventana	19.604	27.784	0.695	0.490
1167	28/10/2013	SMP-Santos	19.290	28.274	0.417	0.203
1169	28/10/2013	Control	17.843	26.711	0.543	0.526
1170	29/10/2013	Control	21.228	30.067	2.446	0.076
1171	29/10/2013	SMP-Ventana	21.000	∞	∞	∞
1172	29/10/2013	SMP-Santos	22.068	31.508	12.209	0.093
1173	30/10/2013	SMP-Santos	20.191	27.271	0.966	x
1174	30/10/2013	Control	17.197	26.583	0.279	0.685
1175	30/10/2013	SMP-Ventana	22.954	30.345	1.039	0.355
1176	31/10/2013	SMP-Ventana	24.400	∞	∞	0.134
1177	31/10/2013	Control	29.640	35.001	0.055	14.879
1179	31/10/2013	SMP-Santos	16.332	25.285	0.999	0.367
1181	01/11/2013	SMP-Ventana	36.617	24.617	∞	0.155
1182	01/11/2013	Control	16.517	17.926	32.130	∞

Appendix 2. Double-logistic parameters fitting relative selectivity curves of the trawl stations for PAR data among trawls with ≥50% PAR catch, ≥100 PAR sampled and length intervals occurring in ≥5 trawls. '∞' represents parameters where either side of the double-logistic curve fit maximum selectivity beyond the plausible range of PAR lengths.

Station	Date	Trawl configuration	L_{50}-1	L_{50}-2	S1	S2
1152	24/10/2013	SMP-Ventana	19.561	28.292	1.184	0.350
1153	24/10/2013	SMP-Santos	21.983	32.004	0.434	0.813
1155	24/10/2013	Control	19.852	27.990	0.865	0.529
1156	25/10/2013	Control	18.473	27.030	27.978	0.366
1157	25/10/2013	SMP-Ventana	20.713	31.503	0.247	0.718
1158	25/10/2013	SMP-Santos	18.660	27.535	0.732	0.404
1159	26/10/2013	Control	18.484	27.798	0.511	0.499
1160	26/10/2013	SMP-Santos	20.422	30.955	0.440	0.352
1161	26/10/2013	SMP-Ventana	5.647	23.837	3.846	∞
1162	27/10/2013	SMP-Santos	16.406	22.560	4.301	∞
1166	28/10/2013	SMP-Ventana	19.591	29.546	0.639	0.367
1169	28/10/2013	Control	16.879	27.693	0.339	0.379
1174	30/10/2013	Control	17.496	27.512	0.452	0.422
1176	31/10/2013	SMP-Ventana	∞	27.117	0.109	0.130
1179	31/10/2013	SMP-Santos	16.986	26.255	2.420	0.262

Appendix 3. Double-logistic parameters fitting relative selectivity curves of the trawl stations for LOL data among all trawls with ≥100 LOL sampled and all length intervals occurring in ≥5 trawls. '∞' represents parameters where either side of the double-logistic curve fit maximum selectivity beyond the plausible range of LOL mantle lengths.

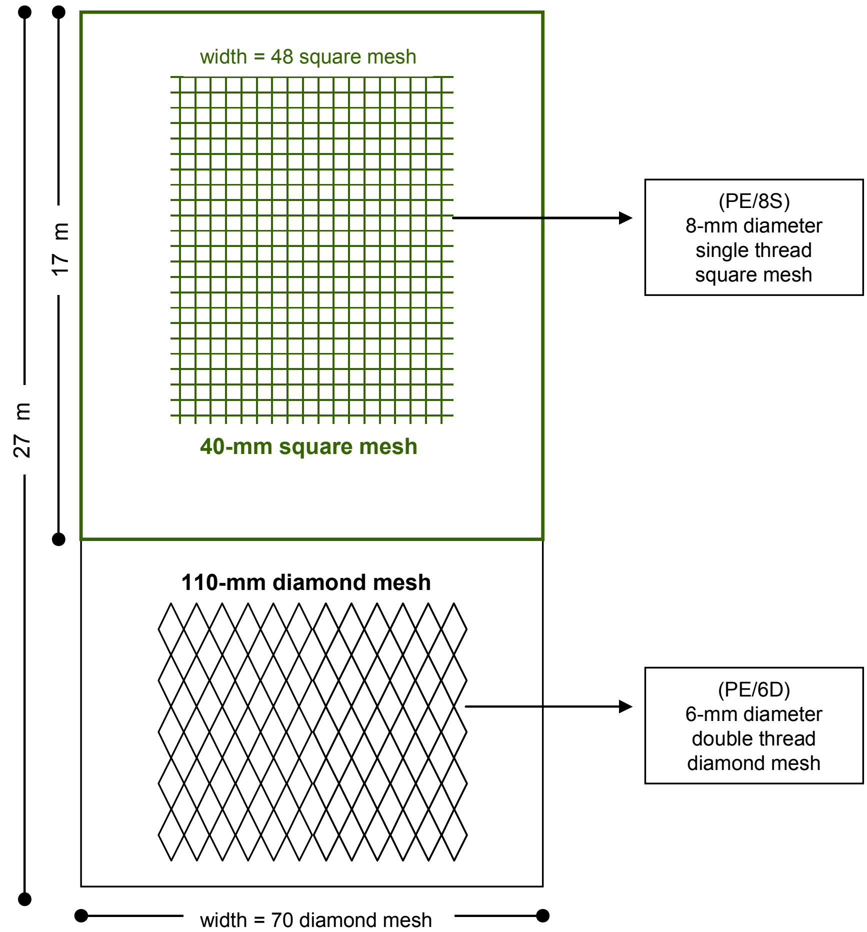
Station	Date	Trawl configuration	ML_{50}-1	ML_{50}-2	S1	S2
1143	21/10/2013	Control	9.224	19.569	8.123	0.133
1144	22/10/2013	Control	12.976	∞	2.237	∞
1145	22/10/2013	SMP-Ventana	13.592	18.962	12.543	0.464
1147	22/10/2013	SMP-Santos	11.563	8.262	10.222	∞
1149	23/10/2013	Control	9.531	14.248	3.125	0.431
1151	23/10/2013	SMP-Ventana	9.550	14.507	15.111	0.415
1152	24/10/2013	SMP-Ventana	10.614	16.921	2.143	0.183
1153	24/10/2013	SMP-Santos	12.339	18.794	0.651	0.344
1155	24/10/2013	Control	12.547	16.362	15.604	0.469
1156	25/10/2013	Control	10.845	20.524	0.849	0.038
1157	25/10/2013	SMP-Ventana	12.491	17.959	14.943	0.094
1158	25/10/2013	SMP-Santos	13.924	20.258	0.243	2.339
1159	26/10/2013	Control	15.676	18.627	0.048	1.021
1160	26/10/2013	SMP-Santos	14.108	21.338	0.929	0.342
1162	27/10/2013	SMP-Santos	13.583	∞	13.052	∞
1163	27/10/2013	Control	11.898	15.482	3.924	1.276
1165	27/10/2013	SMP-Ventana	10.919	14.619	2.659	0.246
1166	28/10/2013	SMP-Ventana	3.425	∞	∞	0.065
1167	28/10/2013	SMP-Santos	12.634	18.453	14.513	0.438
1169	28/10/2013	Control	10.380	21.172	x	22.518
1170	29/10/2013	Control	11.071	17.524	2.230	0.252
1171	29/10/2013	SMP-Ventana	10.964	18.789	0.523	0.418
1172	29/10/2013	SMP-Santos	11.112	17.819	1.234	0.151
1173	30/10/2013	SMP-Santos	11.723	18.074	1.811	0.097
1174	30/10/2013	Control	11.469	15.711	0.631	2.612
1175	30/10/2013	SMP-Ventana	9.500	∞	∞	∞
1176	31/10/2013	SMP-Ventana	2.971	37.488	∞	0.219
1177	31/10/2013	Control	12.551	17.782	0.693	0.344
1179	31/10/2013	SMP-Santos	11.393	16.815	0.558	0.201
1181	01/11/2013	SMP-Ventana	11.817	16.795	0.711	1.072
1182	01/11/2013	Control	11.019	17.924	2.488	0.273

Appendix 4. Double-logistic parameters fitting relative selectivity curves of the trawl stations for RBR data among all trawls with ≥80 RBR sampled and all length intervals occurring in ≥ 5 trawls. '∞' represents parameters where either side of the double-logistic curve fit maximum selectivity beyond the plausible range of RBR mantle lengths.

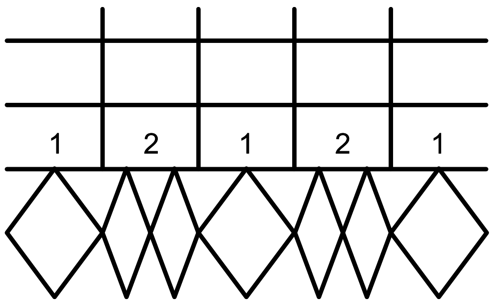
Station	Date	Trawl configuration	DW_{50}-1	DW_{50}-2	S1	S2
1141	21/10/2013	SMP-Ventana	19.730	36.011	∞	1.313
1142	21/10/2013	SMP-Santos	23.171	37.311	0.035	0.004
1143	21/10/2013	Control	31.169	45.900	0.055	∞
1144	22/10/2013	Control	16.688	23.950	0.527	0.021
1145	22/10/2013	SMP-Ventana	8.694	25.493	0.029	0.015
1147	22/10/2013	SMP-Santos	19.063	26.271	0.244	2.739
1148	23/10/2013	SMP-Santos	18.629	27.673	0.280	0.290
1149	23/10/2013	Control	20.390	44.454	0.029	∞
1151	23/10/2013	SMP-Ventana	21.096	36.541	∞	0.024
1153	24/10/2013	SMP-Santos	29.583	44.509	0.082	0.247
1156	25/10/2013	Control	23.703	45.727	0.050	0.417
1158	25/10/2013	SMP-Santos	21.289	46.195	∞	0.132
1163	27/10/2013	Control	21.289	36.144	0.099	0.175
1165	27/10/2013	SMP-Ventana	17.916	31.116	0.247	0.194
1170	29/10/2013	Control	19.974	32.010	0.763	0.077
1171	29/10/2013	SMP-Ventana	19.699	30.275	7.199	0.046
1172	29/10/2013	SMP-Santos	20.444	32.446	0.727	0.044
1177	31/10/2013	Control	33.719	48.470	0.104	0.426
1179	31/10/2013	SMP-Santos	35.315	47.946	0.063	9.613
1180	01/11/2013	SMP-Santos	25.025	38.309	0.611	0.147
1181	01/11/2013	SMP-Ventana	27.052	42.203	0.462	0.205

Appendix 5. Proposed adjustments to SMP-Santos configuration for use under commercial conditions. A) Increase in SMP-width to 48 square meshes; B) Looser attachment pattern for square/diamond meshes corresponding to a sequence of 1 and 2 diamond meshes for each square mesh. Thread diameter specifications in A) also apply to Control (PE/6D) and SMP-Ventana (PE/6D and PE/8S) configurations.

A)



B)



ZDLT1-10-2013 Daily Log (Freestyle)

Inspired by Observers Reports, a revamped version of the Daily Log was completed during the research cruise. Daily log duties were alternated among team members each day. Daily loggers were randomly selected or chosen as a result of various events, including a rock cod tombola, a paper-rock-scissor-in-R-software competition, various guessing the weight of that skates basket or the sex of the largest *P. ramsayi* lotteries, and some getting-into-boiler-suits and putting-on-your-survival-suits races. The resulting daily log includes both facts and fiction (i.e. no gentoo penguin was caught during the cruise), hence it is freestyle. Daily log writing was a successful team-building undertaking. Daily log reading may cause laughter (or concerns).

20/10/2013 (E. Visauta)

Today the observers arrive to get embarked on the Castelo at 3 pm (all the crew and the rest of Scientifics are waiting for us!!!! oops and we thought that we were on german time!). We sort everything at the lab and then we start sewing the epilets for Marie Julie new captain! At dinner time (we all seem dealing well with seasickness). We are told about the name of the new chapter of the research cruise trilogy PROBLEMO MARUJA. After dinner we play 7 and a half, a childish game with the "weird deck cards" (also known as Spanish deck!) on a "romantic-ambient" atmosphere! We have some laughs and after that went to bed! Good night PROBLEMO MARUJA team!

21/10/2013 (L. Jürgens)

The vessel was steaming the whole night and the morning. The soup to lunch was a bit challenging because the rough sea. The catches were very scientific. Wine and salad were the highlights of the dinner and afterwards RBR was already waiting in the factory to be sampled. Unfortunatly it got enforced by LOL.

21/10/2013 (M-J. Roux)

Day one. No sleep. Closet doors banging and chairs and rubbish bins moving around all night. Science crew members are already showing signs of mental distress, which is expressed by obsessive sticky tape usage. The world is a Bathyraja spp. Average sampling-per-unit-effort today was about 2 skates per half-hour. Improvement required.

22/10/2013 (R. James)

After the sticky-tape debacle of the previous night (involving Francisco and wardrobe doors) a restful night was had. The GPS track illustrates a previously unknown anomaly to the west of the Jason Islands henceforth known as the '*Hole of Emptiness*'. It would seem all marine life has fled this desert seascape, with total PAR catches (n=6) measured by the individual. Even the great black-browed wanderers of the ocean dropped from the sky littering the deck with awkward glances and oversized feet. The scientific team hypothesize that all biomass has been sucked out of the area and turned into flan. Paco will need to answer some serious questions in the morrow…

23/10/2013 (L. Jürgens)

The first trawl wasn't much of a success. A lot of rays were caught but only few PAR. Even with PAR out from the gentoo penguin stomachs we couldn't make a sample. But we had to get quietly rid of the penguin on behalf of chief scientist and captain to avoid any attention for the bycatch species composition. The second trawl was better and with much more quantity even without dead birds. One observer noticed on the catch of the third trawl by doing stomach analysis of CGO specifically different isotopes in one female 2. Experience and training paid off today.

24/10/2013 (F. Sobrado Llompart)

Three trawls were sampled. The main catch was PAR with RBR the main by-catch. Regarding LOL population dynamics, Female 5 and Male 5 were the stages of maturity more abundant.

25/10/2013 (A. Winter)

- A nice sunny day.
- The biggest rock cod catch to date.
- Pink Friday – Appropriate dress worn by Marie-Julie, Ross and Lars.
- Someone double-dipped Eva-peach-marmalade to go with their lunchtime yoghurt, eliciting the observation:
  "Olé tus huevos!"

- At dinner, after the bottle of wine, the importance of grabbing *Loligo* (not picking *Loligo*) was sternly reinforced.

<u>26/10/2013</u> (F. Sobrado Llompart)

Three trawls were sampled. The main catch was PAR (9359 kg). It is interesting to point out that more than 18% of the PAR caught was discarded. "*We caution that the road to recovery is not always simple and without short-term costs. Yet, it remains our only option for insuring fisheries and marine ecosystems against further depletion and collapse".*

<u>27/10/2013</u> (L. Jürgens)

Some people where still sad today because Real Madrid lost yesterday against FC Barcelona. The captain was so depressed that he had to talk to his plant. Information what in detail he told to the plant is unknown. In the first trawl there was an exceptional big PAR of 44cm. One scientist (no name mentioned) guesses the sex of fish right before open it. There is a German saying that "also a blind chicken can find sometimes a grain" which is well fitting to this situation. The highlight of the day was the "tarta de Santiago" which came in challenging size classes. Tomorrow some of team should consider to start fasten.

<u>28/10/2013</u> (E. Visauta)

Fishing in the North THE NORTH IS KINGKLIP WORTH! Quiet day in the Factory, well except the shouts of Lars saying "Marujou" and Eddy saying "Paraaaaaa" when he sees the baskets to the top! Also some "Allez" from Marie-Julie are heard every once in a while. Oh and at the Castelo Café we are running out of Tea!!!!!! What a big disgrace! Apart from that the day could be considered as a Zen day or a Moment of Piss day.

29/10/2013 (R. James)

Rosada, rosada, no hay nada except rosada. Day ten and the mental health of the team is beginning to weaken. Tea supplies have hit an all time low and the effects of withdrawal are devastating. The chief scientist suggests a race to climb the A frame but she is gently persuaded that such actions would result in death or injury and difficult questions would be asked on arrival to Stanley. Other team members are showing signs of impaired motor skills and a lack of coordination, for one it was almost impossible to don his boiler suit, whilst others fell about in hysterical laughter.

30/10/2013 (M-J Roux)

Bubble day. Agreement reached over lunch: living on a ship is like living in a bubble. Notion of time has now been lost. Team members are crawling between factory, lab, cabins and dining table in a relentless pattern. Champagne bubbles were cracked for the captain's birthday. This took the misery out of the last few days. Paper-Rock-Scissor exercise demonstrated with a significant probability that Andreas is a cheat.

31/10/2013 (A. Winter)

- Small catches today; the first one contained a stack of freezer pans.
- Lunchtime conversation was spent reminiscing about the FIPASS, which we left about a year ago.
- The refreshment corner of the laboratory was upgraded to 'Café Castelo', complete with seasonally themed décor.
- After nightfall; processing the late trawl; Marie-Julie and Eva revealed their true identities wearing appropriate head-dress prepared by the ship's officers.

01/11/2013 (F. Sobrado Llompart)

Last day of the research cruise… It has been only 12 days of research cruise but it seems and entire life … We have worked very hard to accomplish all the work on time… but also… We have had lots of fun… The contest with the boiler suits… The race with the survival suits …The set up of Castelo Café …The Halloween party …The party with the cruise… seeing the ladies dancing salsa… drinking lots of sangria with "los Gallegos"… … AND WORKING WITH THIS AMAZING RESEARCH TEAM…Have been the highlights of this awesome voyage…

"Let's Make Science"