Cruise Report
ZDLT1-07-2013

Square mesh panel (SMP) trials - 2

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1.0 Introduction

Rock cod *Patagonotothen ramsayi* has been the most important target species in Falkland Islands finfish fisheries since 2008. Total annual catches averaged 63,000 t in 2008-2012, making the species second in importance (by weight) behind *Illex* and *Loligo* squid in the Falkland fishery (Falkland Islands Government 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 below the minimum commercial size of 25 cm total length are currently occurring at a rate that may impact fishery sustainability (FIFD 2013). To ensure stock conservation, the Falkland Islands Fisheries Department has undertaken a series of experimental trials to assess whether modifications to fishing gear could improve size selectivity for rock cod and other commercial species.

A first series of trials investigated trawl codend mesh sizes to reduce by-catch of undersized rock cod (Brickle and Winter 2011, Roux et al. 2012a, Roux et al 2012b). Four diamond mesh sizes were assessed during three experimental surveys: 90 mm mesh (currently the minimum allowable codend mesh size for finfish trawlers in Falkland waters) and the larger 110 mm, 120 mm and 140 mm mesh sizes. Results from these trials demonstrated that a 90 mm diamond mesh codend has poor selectivity. Between 27% and 63% of rock cod caught using the 90 mm mesh were undersized (< 25 cm) fish. An increase in mesh size to 120 mm significantly reduced by-catch of small rock cod, with reductions in discard rates ranging 65%-83% in 120 mm relative to 90 mm mesh. However the larger (120 mm) mesh size also caused a reduction in total catch and commercial-size catch of rock cod. Reductions in total CPUE in 120 mm relative to 90 mm mesh averaged 35% in mixed species (< 50% rock cod and > 50% mixed finfish) trials (April 2012) and 72% when rock cod accounted for ≥ 50% of the catch (October 2012 trials). 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.

Following this, an additional set of experimental 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. 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 first series of SMP trials was conducted in February 2013. A 40-mm mesh size SMP was selected for trials based on rock cod length-girth relationships (Roux et al. 2012b). Results demonstrated that a SMP located inside a 110 mm mesh codend improved selectivity for rock cod and reduced catch of undersized fish by 44% on average relative to a 110 mm mesh codend without SMP (Roux et al. 2013). SMP performance was affected by total catch and by SMP dimensions and positioning. Trawls equipped with a SMP in the net extension had no influence on rock cod selectivity or fishery efficiency. When rock cod accounted for > 50% of the catch, reductions in total catch in 110 mm mesh codend+SMP averaged 33%. This is lower than the 71% reduction in total catch observed in the 120 mm relative to 110 mm mesh codend. The study concluded that a 40-mm mesh SMP located inside a 110-mm diamond mesh codend reduced bycatch of undersized rock cod while retaining commercial-size fish (Roux et al. 2013). Further experimentation was recommended to assess the effect of two different codend-SMP configurations on SMP performance.

This report presents the results of a second series of codend-SMP trials conducted under mixed-species conditions in July 2013. Catch rates (CPUE) and selectivity assessment are presented for the main commercial species: hake *Merluccius hubbsi*, kingclip *Genypterus blacode*, rock cod *Patagonotothen ramsayi* and skates *Bathyraja* spp.

1.1 Cruise objectives

1. To experimentally trial two different codend-SMP configurations.
2. To compare CPUE and selectivity for commercial species between control trawls and SMP configurations.
3. To carry out an oceanographic survey of the fishing areas used for trials.
4. To collect biological information for ageing purposes and dietary/food web studies.

2.0 Methods

2.1 Research Vessel and Survey Area

Research was conducted onboard *FV Castelo* (total length 67.78 m, GRT 1,321) between July 2-13 2013. The same vessel was used during previous mesh size and SMP trials (Brickle and Winter 2011, Roux et al. 2012a and 2012b, Roux et al 2013). Trials were conducted on finfish fishing grounds on the north and north-western 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 30 trawl stations (hauls) were completed during codend trials and 9 oceanographic (CTD) stations (Table 2.1). An additional three hauls (stations 1140-1142) were conducted in order to capture live frogmouth *Cottoperca gobio* on the morning of July 13 (Table 2.1). These hauls are not discussed further in this report.

2.2 Trawl gear

A bottom trawl equipped with 1,800 kg Oval-Foil doors (OF-14) was used at all 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 173-205 m among hauls. Net horizontal/vertical openings varied 49-62 m and 2.8-4.1 m, respectively.

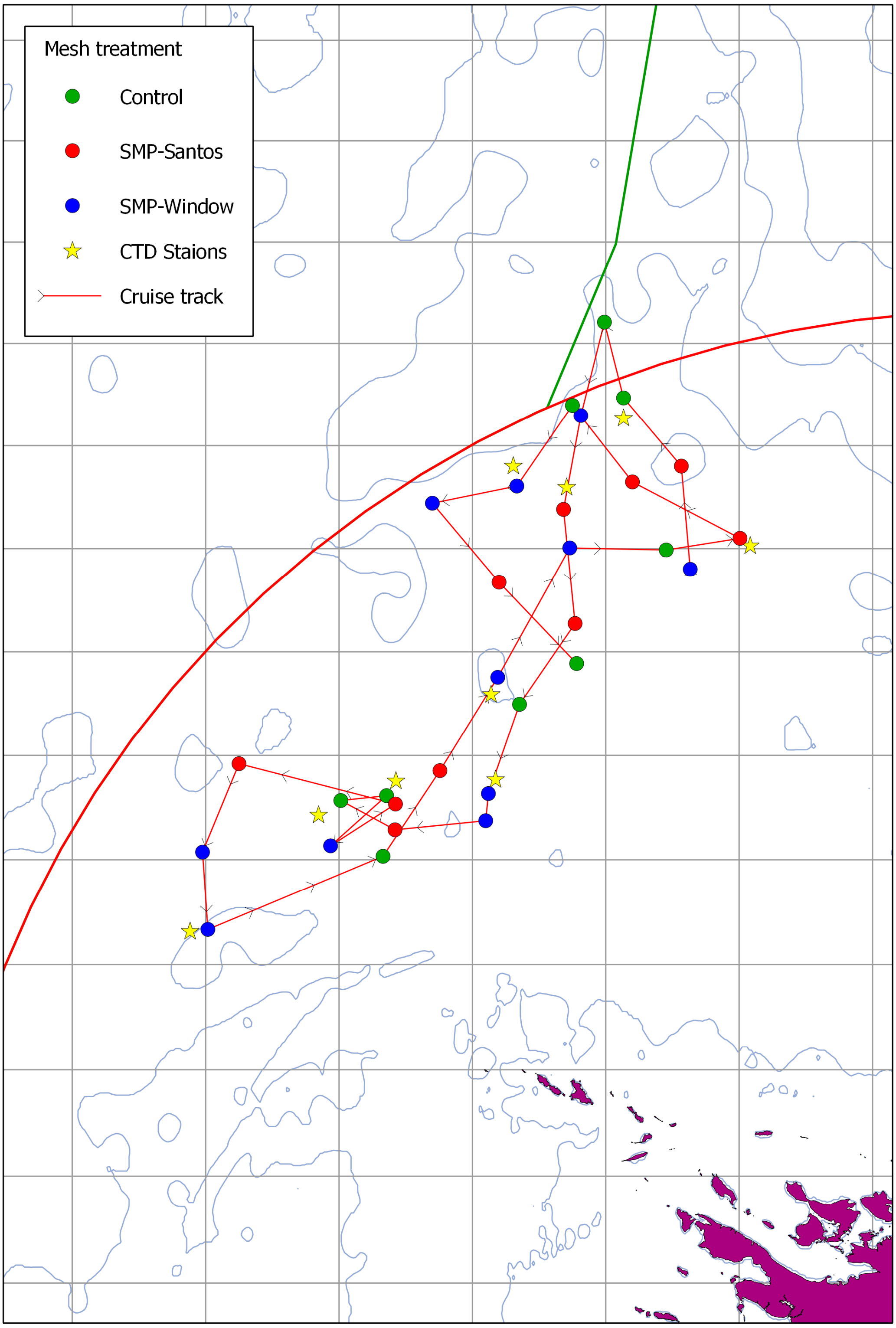


Figure 2.1. Cruise track**,** start location of fishing hauls, and CTD stations.

Table 2.1 Trawl and Oceanographic stations on ZDLT1-07-2013. Location information (Lat, Lon, Course) are relative to start time. Activity B = bottom trawl; Activity C = CTD. Codend configurations: 'Control' = standard 110-mm diamond mesh codend; SMP-window = 110-mm diamond mesh codend with 2-m long SMP in top panel. SMP-Santos = 110-mm diamond mesh codend with 17-m long SMP in top panel.

Station	Date	Time Start	Lat (oS)	Lon (oW)	Course	Duration (min)	Depth (m)	Activity	Codend	Comments
1101	03/07/2013	8:05 AM	49.80	60.68	335	180	166	B	SMP-window	
1102	03/07/2013	12:20 PM	49.55	60.72	316	180	171	B	SMP-Santos	
1103	03/07/2013	4:03 PM					169	C		
1104	03/07/2013	4:45 PM	49.38	60.93	335	180	174	B	Control	
1105	04/07/2013	6:50 AM	49.20	61.01	200	180	169	B	Control	
1106	04/07/2013	10:55 AM	49.43	61.09	210	180	170	B	SMP-window	
1107	04/07/2013	2:25 PM					164	C		
1108	04/07/2013	3:05 PM	49.66	61.16	190	180	164	B	SMP-Santos	
1109	05/07/2013	6:55 AM	49.93	61.12	215	180	160	B	SMP-Santos	
1110	05/07/2013	11:00 AM	50.13	61.32	215	180	159	B	Control	
1111	05/07/2013	2:29 PM					159	C		
1112	05/07/2013	3:05 PM	50.34	61.44	210	180	166	B	SMP-window	Damaged codend
1113	06/07/2013	6:55 AM	50.41	61.45	270	180	164	B	SMP-window	
1114	06/07/2013	10:50 AM	50.43	61.79	265	180	161	B	SMP-Santos	Clogged Net
1115	06/07/2013	2:25 PM					163	C		
1116	06/07/2013	3:15 PM	50.36	61.99	45	180	159	B	Control	
1117	07/07/2013	6:55 AM	50.35	61.82	235	180	165	B	Control	
1118	07/07/2013	10:55 AM	50.47	62.03	30	180	162	B	SMP-window	
1119	07/07/2013	2:23 PM					159	C		
1120	07/07/2013	3:15 PM	50.37	61.79	225	180	171	B	SMP-Santos	
1121	08/07/2013	6:55 AM	50.27	62.38	220	180	152	B	SMP-Santos	
1122	08/07/2013	10:50 AM	50.48	62.51	205	180	158	B	SMP-window	
1123	08/07/2013	2:18 PM					161	C		
1124	08/07/2013	2:45 PM	50.67	62.49	75	180	166	B	SMP-window	
1125	09/07/2013	6:50 AM	50.49	61.84	30	180	170	B	Control	
1126	09/07/2013	11:30 AM	50.29	61.62	25	180	159	B	SMP-Santos	
1127	09/07/2013	2:58 PM					156	C		
1128	09/07/2013	3:30 PM	50.06	61.41	15	180	158	B	SMP-window	
1129	10/07/2013	6:50 AM	49.75	61.14	85	180	164	B	SMP-window	
1130	10/07/2013	10:50 AM	49.75	60.77	70	180	166	B	Control	
1131	10/07/2013	2:21 PM					168	C		
1132	10/07/2013	2:50 PM	49.73	60.50	300	180	169	B	SMP-Santos	
1133	11/07/2013	6:45 AM	49.59	60.90	340	180	165	B	SMP-Santos	
1134	11/07/2013	10:45 AM	49.40	61.13	235	180	162	B	Control	
1135	11/07/2013	2:11 PM					159	C		
1136	11/07/2013	2:50 PM	49.60	61.33	186	180	159	B	SMP-window	
1137	12/07/2013	6:30 AM	49.64	61.65	135	180	157	B	SMP-window	mixed catchweight
1138	12/07/2013	10:25 AM	49.83	61.40	125	180	159	B	SMP-Santos	mixed catchweight
1139	12/07/2013	2:30 PM	50.03	61.11	130	180	160	B	Control	
1140	13/07/2013	6:25 AM	51.44	57.69	145	30	54	B	Control	Frogmouth trials
1141	13/07/2013	8:00 AM	51.54	57.63	170	30	73	B	Control	Frogmouth trials
1142	13/07/2013	9:00 AM	51.56	57.62	290	30	56	B	Control	Frogmouth trials

2.3 Experimental design

Three trawls were conducted daily. A first trawl was on the seabed around 6:30-7:00AM (morning hauls), a second between 10:00-11:00AM (mid-day hauls) and a third between 2:00-3:00PM (afternoon hauls). Only on day 1 were starting times delayed by more than one hour. Trawl duration was 3 hours. Trawl speed varied 3.1-4.1 knots. Trawl operations were paralleled by an oceanographic survey of the fishing areas that consisted in daily vertical water profiling (CTD) stations conducted immediately after the mid-day haul (except for the last day when no CTD station was done).

Trials were conducted using three different trawl configurations: two codends with top panels modified by SMP addition and a control (110-mm diamond mesh without modification). A first experimental codend was fitted with a 2-m long, 40-mm square mesh panel positioned from 6 to 8 m forward of the codline (Fig 2.2A). This configuration, described as 'SMP' by Roux et al. (2013) is referred to as 'SMP-window' in the present document. The second experimental codend was fitted with 17-m × 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 square mesh performance under commercial conditions. It is referred to as 'SMP-Santos' in the present document. The SMP consisted of approximately 10-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 approximately 67 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, the SMP-Santos codend was adjusted during the trials by re-fitting 28 square meshes per 10 diamond meshes in the length direction. The three codends/trawl configurations were fished every day (expect for one day) and alternated for different time of day (morning, mid-day and afternoon hauls).

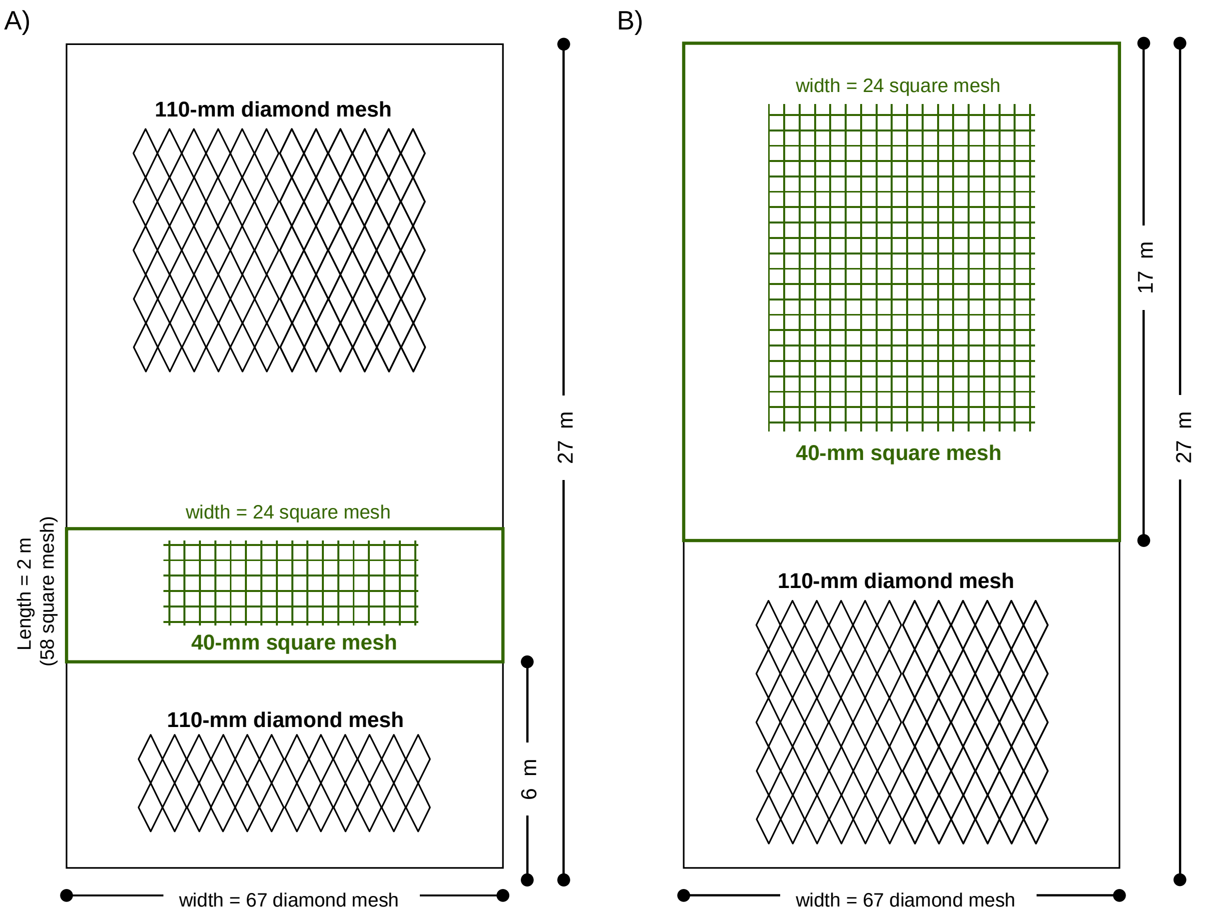


Figure 2.2. Codend-SMP configurations (modified top panels) tested during February 2013 trials. A) ‘SMP-Window’ configuration: 2-m long square mesh panel inserted between 6-8 m from the codline. B) ‘SMP-Santos’ configuration: 17-m of square mesh beginning 10-m from the codline.

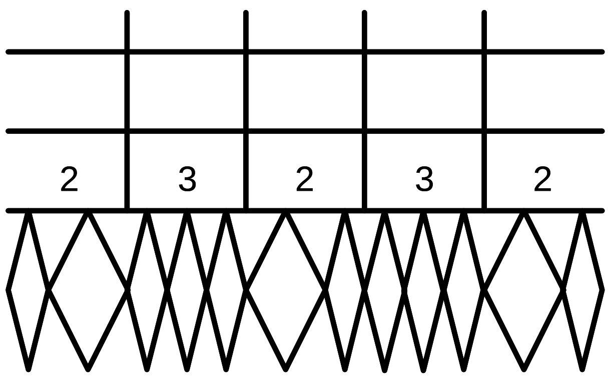


Figure 2.3. Attachment pattern for diamond and square mesh inside the codend. Two and three diamonds were alternatively attached to each square mesh (2:1, 3:1 sequence).

2.4 Biological sampling

Catch weights of hake, the most abundant catch species, were estimated as factory process weights multiplied by the FIFD conversion factor (1.9). No hake was discarded during the cruise. All other fish and squid were weighed by species using an electronic marine adjusted balance (POLS). Discard weight and total catch of rock cod were estimated for one haul (station 1138) following the procedure described in Roux et al. (2013).

Length frequency samples of commercially important species (200 specimens of rock cod and 100 specimens of all other species) were taken. The preferred method of sampling was random. However when the catch was small, all available specimens were opportunistically sampled. Length (L_T, L_M, L_{PA} and L_{DW}), sex and maturity stage were recorded for all specimens. A Bluetooth data importation method developed by R. James for length data collected using the Scantrol electronic FISHMETER is shown in Appendix 2.

Stomach contents were examined on a total of 770 specimens of fish, skates and dogfish from 8 different species. Stomach sampling involved recording length, sex and numerical abundance of different prey items in stomachs (identified to lowest possible taxonomic level). Prey length was recorded whenever possible. Samples of stomach contents were preserved for identification.

Otoliths were collected from 1044 fish specimens from 13 different species. Vertebrae were collected from 20 *Squalus acanthias* specimens. Statoliths were collected from one *Semirossia patagonica* and one *Moroteuthis ingens* specimens. All specimens sampled for otoliths/vertebrae/statoliths were simultaneously sampled for length, weight, sex and maturity.

2.5 Kingclip Conversion Factor analysis

FIFD calculates catch (green weight) using a conversion factor (CF) for each species and processing method multiplied by factory process weight. A summary sheet of CFs is provided during licence briefings (Appendix 3). All catch reports of the fishing vessels are based on calculations using FIFD-statutory CFs. Fisheries observers collect processed and unprocessed catch weight data each year on commercial fishing vessels to control the CFs and update as necessary.

During this research cruise, the scientific team noticed that the vessel's calculated catch report of *Genypterus blacodes* (KIN) was consistently higher than the real weight of the whole catch. The FIFD conversion factor used by the ship was 2.3. The discrepancy between weighed catch and calculated catch was examined in three trials.

Method

In accordance with survey protocol, all kingclip were weighed for the research catch log. Samples were taken for biological analysis and then processed by the factory crew. Kingclip were headed, gutted and tailed (HGT) using a Baader 424 and a circular saw. The trunk was gutted by hand and washed in a washing drum with sea water. After weighing, the trunks were wrapped in plastic foil and packed in carton boxes. The total weight of the packed boxes was 16kg. Kingclip were never observed to have been discarded or missing from the factory.

To calculate CFs for kingclip "Approach 1" of the FIFD Scientific Observer manual (Section2-Conversion Factor Guide, 2010) was used. The green weight and the processed weight were recorded from the same individuals. Before processing all individuals were counted and weighed except for station 1137 where the number of individuals was estimated from a random sample of the length frequency sample. After processing, the trunks were re-counted and re-weighed.

The total CF was calculated by dividing the total green weight by the total processed weight. The CF "per trunk" was calculated by dividing the mean green weight of individual fish by the mean processed weight of the trunk, thus minimizing potential bias occurring as a result of misprocessing. The FIFD statutory CFs are based on total CF evaluation.

2.6 Data Analyses

The performance of square mesh panel configurations in trawl codend was assessed by comparing standardized catch rates (CPUE (kg hr^{-1})), species-specific length structures and relative selectivity between control, SMP-window and SMP-Santos hauls.

Catch rates (CPUE)

Effects of SMP configurations on total and species-specific CPUE were assessed using generalized linear mixed models (GLMM) assuming log-normal errors. This type of model was chosen to handle over-dispersion in the data caused by random day-to-day variability in catch size/composition as well as by sampling design. CPUE data were log-transformed (base 10) for analyses. SMP-codend configuration was used as fixed effect. Sampling day, time-of-day and trawling depth were included as potential random effects. Sampling day corresponded to calendar dates. Time-of-day was used as a 3-levels factor distinguishing between morning, mid-day and afternoon hauls. Depth corresponded to modal trawling depth. All GLMM were fitted using restricted maximum likelihood (REML) estimation. A backward model selection procedure was used starting with the saturated model (i.e. inclusion of all potential random effects) and progressive removals of non-significant terms. Model selection was done by minimizing the Bayesian (BIC) information criterion (Bolker et al 2008). Fixed effect significance was assessed using Wald chi-square (χ^2) tests (Bolker et al 2008).

Length structure

Length structures were described among trawl configurations in terms of median, first and third quartiles, mean and modal lengths. Counts of fish per 1-cm length intervals in each haul were smoothed by treatment (SMP-codend configuration) using generalized additive models (GAM). Only hauls for which $\geq$ 100 specimens 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 pairwise comparisons.

Relative selectivity

A four-parameter double-logistic function (combining an increasing and a decreasing logistic curve) was used to estimate relative selectivity at length (S_L) (equation 2.1).

$$S_L = [1 / (1 + e^{(s1(L - p1))})] * [1-1 / (1 + e^{(s2(L - p2))})] \qquad (2.1)$$

Where L is length, p1 and p2 are inflexion points corresponding to lengths of 50% retention and s1 and s2 are slope parameters. This function allows great flexibility in the shape of selectivity curves (Quinn and Deriso 1999). When discussing model outputs, p2 is referred to as the minimum length of 50% retention (L_{50}^{1}) and p1 is the maximum length of 50% retention (L_{50}^{2}). Length classes comprised between L_{50}^{1} and L_{50}^{2} correspond to the size range of ≥ 50% retention.

Counts of fish per 1-cm length class in haul 'i' (F_{Li}) were related to total sample size ($TFreq_i$) (equation 2.2) and maximized over area 'j'. Selectivity assessment was restricted to a representative size range corresponding to length classes encountered in ≥ 10 hauls. The 'available population' was defined as the maximum number of fish per length class 'L' among hauls 'i' in area 'j' ($MaxF_{Lj}$). Area 'j' in this case corresponded to the entire survey area. The available selection curve was used to estimate relative selectivity at length (S_{Lij}) (equation 2.3).

$$F_{Li} = Freq_i/TFreq_i \qquad (2.2)$$

$$S_{Lij} = F_{Li}/MaxF_{Lj} \qquad (2.3)$$

The double-logistic function was fitted to S_{Lij} data from individual hauls and to treatment-specific data (i.e. including data from all hauls performed using a specific trawl configuration). Fitting was done by minimizing the residuals sum of squares using general purpose Nelder-Mead optimization. Initial parameters values were determined based on visual inspection of the available selection curve. Differences in the minimum length of 50% retention (L_{50}^{1}) among SMP-codend configurations were assessed using the Kruskal-Wallis rank sum test. Pairwise comparisons were conducted using the Wilcoxon rank sum test with Bonferroni adjustment.

All statistical analyses were implemented in 'R' software (R Core Development Team 2012). Specific packages used were 'lme4' (GLMM), 'car' (Wald chi-square test) and 'mgcv' (GAM).

2.6 Oceanography

A conductivity-temperature-depth logger (CTD, SBE-25, Sea-Bird Electronics Inc., Bellevue, WA, USA) was deployed from the surface to 1-20 m above the bottom to obtain profiles of temperature (ºC), conductivity (S/m), and pressure (db). The CTD was deployed for the first one minute at about 10-11 m depth. It was then retrieved to 3 m depth and deployed to the bottom. The speed of deployment was c. 1m/s and was monitored by wire counter. Profiles of salinity (PSS-78 Practical Salinity) and depth (m) were derived in Seasoft v7.22.5 (Sea-Bird Electronics Inc). Derived potential density (kg m^{-3}), CTD profiles and T-S plots were done in the 'R' (R Core Development Team 2012) "oce" package (v0.9-12). Algorithms for all derived variables are based on standard techniques found in Fofonoff and Millard (1983).

3.0 Results

3.1 Oceanography

Oceanographic data were collected at 9 stations (Fig. 2.1). Temperature of surface waters varied from 6.57 ºC towards the north to 7.04ºC towards the south. Bottom temperature varied between 6.02ºC towards the north and 7.04ºC towards the south (Fig 3.1). Surface salinities showed a similar latitudinal trend, ranging between 33.92 psu in the north and 33.67 psu towards the south. There was little apparent latitudinal trend in bottom water salinities, with a more longitudinal trend evident, with highest salinities in the east (33.96 psu) and lowest in the west (33.70 psu). Surface and bottom water densities followed a similar trend to salinity (Fig. 3.1). Water column stratification varied both in terms of depth of the cline (approximately 100m), and gradient across the cline. In some instances, the water column appeared fully mixed to the maximum depth of the profile (Fig 3.1).

Arkhipkin et al (In Review) reviewed the oceanography of the Falklands region. In the present study, all stations showed a strong presence of Falkland Shelf Waters, with evidence of sub-Antarctic Surface Water in northern and mid-latitude stations (Fig. 3.2). An influence of Patagonian Shelf water was seen in southern stations, indicating a southern extension of the Argentinean Drift current (Fig. 3.2), and in part, potentially explaining observed density profiles above.

3.2 Catch composition

Total catch, sample, and discard weights by species for Control, SMP-Santos and SMP-Windows treatments are summarized Tables 3.1, 3.2 and 3.2 respectively. Total catch for SMP-Santos configurations was 43,242 kg, while total catches for the other 2 configurations were somewhat less (SMP-Window – 36,152 kg, Control – 33,684 kg), despite having similar number of trawls per treatments (Table 2.1). Differences in total catch cannot be attributed to any increased or reduced catches in any one particular species.

A)

B)

C)

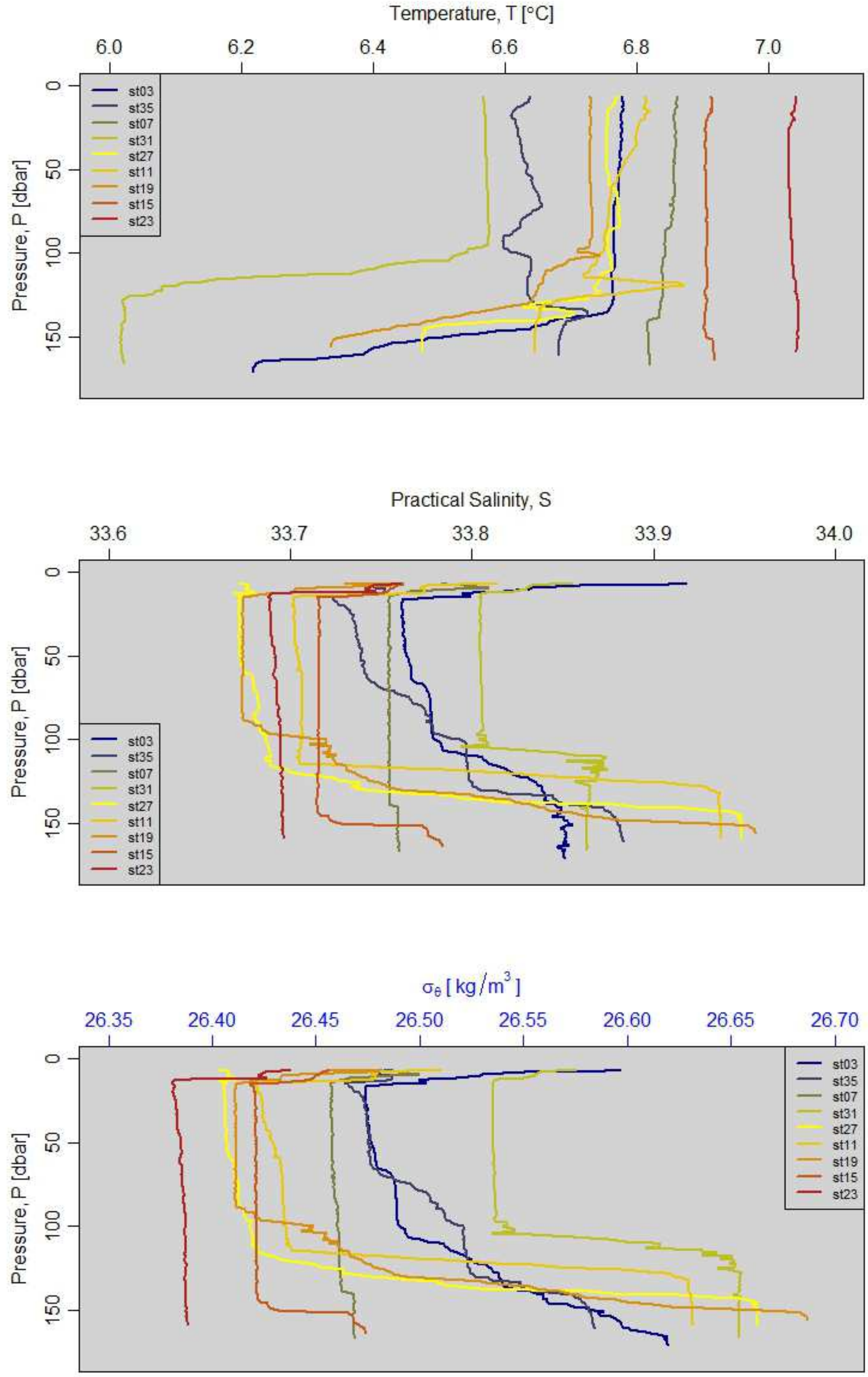


Figure 3.1 Depth profiles of A) temperature, B) salinity and C) density at all stations. Stations are ordered in the legend with respect to increasing southern latitude.

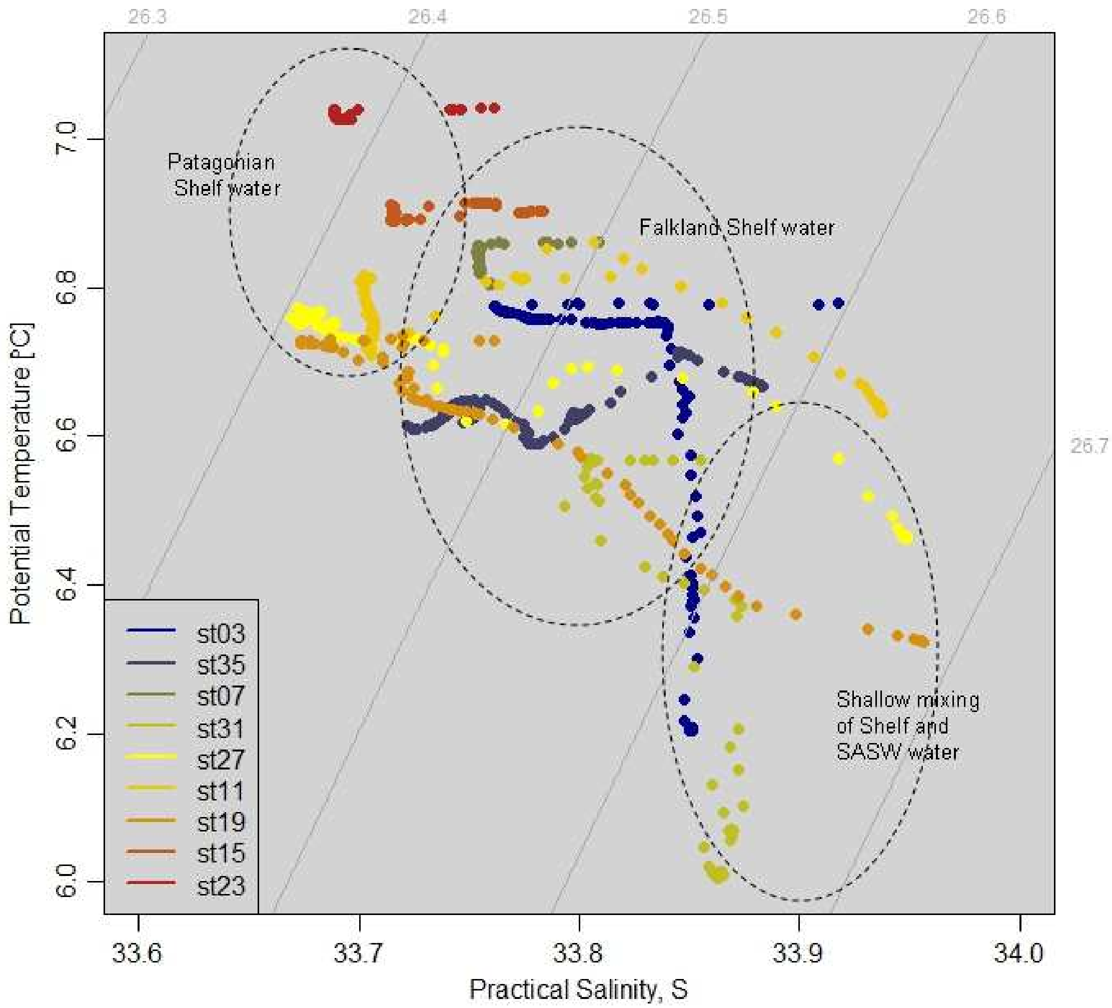


Fig 3.2. T/S plots of all stations with identification of water masses in July 2013. Stations are ordered in the legend with respect to increasing southern latitude. Potential density isopycnals (kg/m^3) are overlaid on the plot. SASW – Sub-Antarctic Superficial Water.

A total of 81 species (or species groups) were collected throughout all stations; 64 taxa recorded among Control treatments, 66 among SMP-Santos treatments, and 67 in SMP-Windows treatments, varying only in the less frequent species. Among treatments, 90% of the catch composition by weight was distributed among only 12 species; *Merluccius hubbsi* (hake), *Genypterus blacodes* (kingclip), *Patagonotothen ramsayi* (rockcod), *Salilota australis* (red cod), *Macruronus magellanicus* (hoki), *Cottoperca gobio* (frogmouth), *Squalus acanthias* (dogfish), and the skates *Bathyraja brachyurops*, *Zearaja chilensis*, *Bathyraja macloviana*, *Psammobatis spp*., *Bathyraja albomaculata* (Tables 3.1 – 3.3).

Table 3.1 Catch composition, sample, and discard weights (kg) and catch proportion for the Control treatment. Species are ordered by increasing catch proportion.

Species code	Species name	Catch Wt	Sample Wt	Discard Wt	Catch Proportion (%)
HAK	*Merluccius hubbsi*	15932.52	1042.42	10.00	47.30
KIN	*Genypterus blacodes*	4514.20	1084.42	0.00	13.40
RBR	*Bathyraja brachyurops*	3582.44	1566.85	222.59	10.64
RFL	*Zearaja chilensis*	2269.11	1639.93	125.00	6.74
PAR	*Patagonotothen ramsayi*	1882.42	316.07	779.57	5.59
BAC	*Salilota australis*	1738.78	124.37	51.93	5.16
WHI	*Macruronus magellanicus*	892.01	195.37	7.23	2.65
RMC	*Bathyraja macloviana*	630.16	518.53	332.12	1.87
DGS	*Squalus acanthias*	577.35	0.00	545.35	1.71
RPX	*Psammobatis spp.*	408.18	59.29	408.18	1.21
RAL	*Bathyraja albomaculata*	338.59	338.59	77.25	1.01
ILL	*Illex argentinus*	193.00	176.83	30.36	0.57
CGO	*Cottoperca gobio*	155.79	30.52	155.79	0.46
SPN	Porifera	119.09	0.00	119.09	0.35
MED	Medusae	113.19	0.00	113.19	0.34
DGH	*Schroederichthys bivius*	104.51	0.00	104.51	0.31
BUT	*Stromateus brasiliensis*	53.00	0.00	53.00	0.16
RDO	*Amblyraja doellojuradoi*	42.66	42.66	42.66	0.13
RMU	*Bathyraja multispinis*	35.09	35.09	10.00	0.10
COP	*Congiopodus peruvianus*	26.64	0.00	26.64	0.08
ING	*Illex argentinus*	13.85	0.00	13.85	0.04
LOL	*Loligo gahi*	8.32	0.00	8.32	0.02
RGR	*Bathyraja griseocauda*	7.86	7.86	7.86	0.02
OCM	*Octopus megalocyathus*	7.35	0.00	7.35	0.02
GOC	*Gorgonocephalas chilensis*	6.75	0.00	6.75	0.02
NEM	*Neophyrnichthys marmoratus*	3.81	0.00	3.81	0.01
TOO	*Dissostichus eleginoides*	2.97	2.97	0.00	0.01
AUL	*Austrolycus laticinctus*	2.65	0.00	2.65	<0.01
ODM	*Odontocymbiola magellanica*	2.55	0.00	2.55	<0.01
CAZ	*Calyptraster sp.*	2.41	0.00	2.41	<0.01
ANM	Anemone	2.31	0.00	2.31	<0.01
STA	*Sterechinus agassizi*	1.59	0.00	1.59	<0.01
RED	*Sebastes oculatus*	1.31	1.31	0.00	<0.01
FUM	*Fusitriton magellanicus*	1.19	0.00	1.19	<0.01
RSC	*Bathyraja scaphiops*	1.15	1.15	0.75	<0.01
SQT	Ascidiacea	1.12	0.00	1.12	<0.01
MUE	*Muusoctopus eureka*	1.06	0.00	1.06	<0.01
HYD	Hydrozoa	1.00	0.00	1.00	<0.01
AUC	*Austrocidaris canaliculata*	0.88	0.00	0.88	<0.01
RBZ	*Bathyraja cousseauae*	0.85	0.85	0.85	<0.01
SEC	*Seriolella caerulea*	0.80	0.00	0.80	<0.01
COL	*Cosmasterias lurida*	0.59	0.00	0.59	<0.01
EGG	Skate egg case	0.54	0.00	0.54	<0.01
GRF	*Coelorhynchus fasciatus*	0.41	0.00	0.41	<0.01
EUO	*Eurypodius longirostris*	0.40	0.00	0.40	<0.01
EUL	*Eurypodius latreillei*	0.33	0.00	0.33	<0.01
POA	*Porania antarctica*	0.22	0.00	0.22	<0.01
SAR	*Sprattus fuegensis*	0.20	0.00	0.20	<0.01
CEX	*Ceramaster sp.*	0.12	0.00	0.12	<0.01
SOR	*Solaster regularis*	0.12	0.00	0.12	<0.01
SHT	*Mixed invertebrates*	0.10	0.00	0.10	<0.01
MUG	*Munida gregaria*	0.09	0.00	0.09	<0.01
THO	Thouarellinae	0.09	0.00	0.09	<0.01
CYX	*Cycethra sp.*	0.08	0.00	0.08	<0.01
AST	Asteroidea	0.05	0.00	0.05	<0.01
SUN	*Labidaster radiosus*	0.05	0.00	0.05	<0.01
ASA	*Astrotoma agassizii*	0.03	0.00	0.03	<0.01
POL	Polychaeta	0.03	0.00	0.03	<0.01
PES	*Peltarion spinosulum*	0.02	0.00	0.02	<0.01
BER	*Berthella spp.*	0.01	0.00	0.01	<0.01
OCT	*Octopus spp.*	0.01	0.00	0.01	<0.01
OPH	*Ophiuroidea*	0.01	0.00	0.01	<0.01
PYX	Pycnogonida	0.01	0.00	0.01	<0.01
MUN	*Munida spp.*	0.01	0.00	0.01	<0.01
Totals		***33684.03***	***7185.08***	***3285.08***	

Table 3.2 Catch composition, sample, and discard weights (kg) and catch proportion for the SMP-Santos treatment. Species are ordered by increasing catch proportion.

Species code	Species name	Catch Wt	Sample Wt	Discard Wt	Catch Proportion (%)
HAK	*Merluccius hubbsi*	23279.23	1334.75	0.00	53.83
KIN	*Genypterus blacodes*	4148.30	1283.24	0.00	9.59
PAR	*Patagonotothen ramsayi*	3863.64	305.11	2663.84	8.93
RBR	*Bathyraja brachyurops*	3388.18	1545.86	170.00	7.84
BAC	*Salilota australis*	2649.74	232.88	111.58	6.13
RFL	*Zearaja chilensis*	1954.33	1662.60	75.00	4.52
RMC	*Bathyraja macloviana*	916.67	784.59	527.07	2.12
WHI	*Macruronus magellanicus*	615.70	40.84	20.72	1.42
RPX	*Psammobatis spp.*	521.09	28.99	521.09	1.21
ILL	*Illex argentinus*	421.46	381.42	128.02	0.97
RAL	*Bathyraja albomaculata*	388.82	365.63	25.65	0.90
CGO	*Cottoperca gobio*	253.51	43.01	253.51	0.59
DGS	*Squalus acanthias*	212.05	29.73	212.05	0.49
SPN	Porifera	161.13	0.00	161.13	0.37
DGH	*Schroederichthys bivius*	114.45	0.00	114.45	0.26
RGR	*Bathyraja griseocauda*	87.78	87.78	0.88	0.20
RDO	*Amblyraja doellojuradoi*	60.56	60.56	60.56	0.14
MED	Medusae	44.58	0.00	44.58	0.10
BUT	*Stromateus brasiliensis*	36.88	0.00	36.88	0.09
RMU	*Bathyraja multispinis*	28.88	28.88	1.49	0.07
GOC	*Gorgonocephalas chilensis*	12.98	0.63	12.98	0.03
OCM	*Octopus megalocyathus*	12.91	0.00	6.91	0.03
ING	*Moroteuthis ingens*	10.67	0.00	10.67	0.02
NEM	*Neophyrnichthys marmoratus*	9.78	0.00	9.78	0.02
COP	*Congiopodus peruvianus*	6.31	0.25	6.31	0.01
LOL	*Loligo gahi*	5.79	0.00	5.79	0.01
MLA	*Muusoctopus longibrachus akamb*	5.42	0.00	0.00	0.01
RSC	*Bathyraja scaphiops*	4.69	4.69	3.59	0.01
RED	*Sebastes oculatus*	4.51	2.34	2.68	0.01
FUM	*Fusitriton m. magellanicus*	4.13	0.00	4.13	<0.01
CAZ	*Calyptraster sp.*	3.03	0.00	3.03	<0.01
SEC	*Seriolella caerulea*	2.89	0.75	2.89	<0.01
SQT	Ascidiacea	2.60	0.00	2.60	<0.01
ANM	Anemone	1.95	0.00	1.95	<0.01
ODM	*Odontocymbiola magellanica*	1.94	0.00	1.94	<0.01
COL	*Cosmasterias lurida*	1.16	0.00	1.16	<0.01
MUE	*Muusoctopus eureka*	0.95	0.00	0.95	<0.01
EGG	Skate egg case	0.76	0.00	0.76	<0.01
TOO	*Dissostichus eleginoides*	0.72	0.00	0.00	<0.01
SHT	Mixed invertebrates	0.43	0.00	0.43	<0.01
EUL	*Eurypodius latreillei*	0.31	0.00	0.31	<0.01
AST	Asteroidea	0.27	0.00	0.27	<0.01
STA	*Sterechinus agassizi*	0.26	0.00	0.26	<0.01
CEX	*Ceramaster sp.*	0.22	0.00	0.22	<0.01
SOR	*Solaster regularis*	0.17	0.00	0.17	<0.01
THO	Thouarellinae	0.16	0.00	0.16	<0.01
POA	*Porania antarctica*	0.15	0.00	0.15	<0.01
BLU	*Micromesistius australis*	0.10	0.00	0.10	<0.01
MAV	*Magellania venosa*	0.10	0.00	0.10	<0.01
OPH	Ophiuroidea	0.08	0.00	0.08	<0.01
MUN	*Munida spp.*	0.06	0.00	0.06	<0.01
AUC	*Austrocidaris canaliculata*	0.05	0.00	0.05	<0.01
BAO	*Bathybiaster loripes*	0.05	0.00	0.05	<0.01
MUG	*Munida gregaria*	0.03	0.00	0.03	<0.01
CTA	*Ctenodiscus australis*	0.02	0.00	0.02	<0.01
CYX	*Cycethra sp.*	0.02	0.00	0.02	<0.01
EUO	*Eurypodius longirostris*	0.02	0.02	0.02	<0.01
RMG	*Bathyraja magellanica*	0.02	0.00	0.02	<0.01
SUN	*Labidaster radiosus*	0.01	0.00	0.01	<0.01
MUS	Smooth mussel	0.01	0.00	0.01	<0.01
MUU	*Munida subrugosa*	0.01	0.00	0.01	<0.01
OPD	*Ophiacantha densispina*	0.01	0.00	0.01	<0.01
OPL	*Ophiuroglypha lymanii*	0.01	0.00	0.01	<0.01
POL	Polychaeta	0.01	0.00	0.01	<0.01
PRI	Priapulida	0.01	0.00	0.01	<0.01
PYX	Pycnogonida	0.01	0.00	0.01	<0.01
Totals		***43242.77***	***8224.55***	***5209.22***	

Table 3.3 Catch composition, sample, and discard weights (kg) and catch proportion for the SMP-Window treatment. Species are ordered by increasing catch proportion.

Species code	Species name	Catch Wt	Sample Wt	Discard Wt	Catch Proportion (%)
HAK	*Merluccius hubbsi*	21006.91	1511.98	0.00	58.11
RBR	*Bathyraja brachyurops*	4416.64	1703.92	170.00	12.22
RFL	*Zearaja chilensis*	2868.59	2077.55	228.16	7.93
KIN	*Genypterus blacodes*	1764.62	816.55	0.00	4.88
PAR	*Patagonotothen ramsayi*	1698.11	412.83	1040.06	4.70
RMC	*Bathyraja macloviana*	814.99	726.42	583.16	2.25
DGS	*Squalus acanthias*	627.31	98.74	627.31	1.74
WHI	*Macruronus magellanicus*	550.87	165.86	78.55	1.52
RPX	*Psammobatis spp.*	474.28	31.46	474.28	1.31
CGO	*Cottoperca gobio*	419.85	45.71	419.85	1.16
RAL	*Bathyraja albomaculata*	394.66	394.66	15.00	1.09
MED	Medusae	252.41	0.00	252.41	0.70
ILL	*Illex argentinus*	250.53	198.58	72.39	0.69
SPN	Porifera	164.55	0.00	164.55	0.46
DGH	*Schroederichthys bivius*	164.07	0.00	164.07	0.45
BAC	*Salilota australis*	67.82	17.08	42.02	0.19
RDO	*Amblyraja doellojuradoi*	40.40	40.40	40.40	0.11
RMU	*Bathyraja multispinis*	24.33	24.33	5.68	0.07
COP	*Congiopodus peruvianus*	22.07	0.00	22.07	0.06
BUT	*Stromateus brasiliensis*	18.83	0.00	18.83	0.05
ING	*Moroteuthis ingens*	11.92	0.00	11.92	0.03
RGR	*Bathyraja griseocauda*	10.19	10.19	0.00	0.03
LOL	*Loligo gahi*	8.99	0.00	8.99	0.02
NEM	*Neophyrnichthys marmoratus*	8.90	0.00	8.90	0.02
GOC	*Gorgonocephalas chilensis*	8.48	0.00	8.48	0.02
AST	Asteroidea	6.94	0.00	6.94	0.02
TOO	*Dissostichus eleginoides*	6.04	6.04	0.00	0.02
RED	*Sebastes oculatus*	5.49	5.49	0.00	0.02
CAZ	*Calyptraster sp.*	4.51	0.00	4.51	0.01
RSC	*Bathyraja scaphiops*	4.49	4.49	3.15	0.01
ANM	Anemone	4.02	0.00	4.02	0.01
BRY	Bryozoa	3.31	0.00	3.31	<0.01
MLA	*Muusoctopus longibrachus akam*	2.95	2.75	0.20	<0.01
MUE	*Muusoctopus eureka*	2.42	0.00	2.42	<0.01
SQT	Ascidiacea	2.37	0.00	2.37	<0.01
HYD	Hydrozoa	2.31	0.00	2.31	<0.01
FUM	*Fusitriton magellanicus*	2.00	0.00	2.00	<0.01
RMG	*Bathyraja magellanica*	2.00	2.00	2.00	<0.01
SEC	*Seriolella caerulea*	2.00	0.98	2.00	<0.01
COL	*Cosmasterias lurida*	1.92	0.00	1.92	<0.01
SHT	Mixed invertebrates	1.42	0.00	1.42	<0.01
ODM	*Odontocymbiola magellanica*	1.34	0.00	1.34	<0.01
CEX	*Ceramaster sp.*	1.16	0.00	1.16	<0.01
EGG	Skate eggs case	1.03	0.00	1.03	<0.01
RDA	*Dipturus argentinensis*	0.68	0.68	0.00	<0.01
MUG	*Munida gregaria*	0.67	0.00	0.67	<0.01
THO	*Thouarellinae*	0.65	0.00	0.65	<0.01
ALC	Alcyoniina	0.41	0.00	0.41	<0.01
AUC	*Austrocidaris canaliculata*	0.31	0.00	0.31	<0.01
STA	*Sterechinus agassizi*	0.28	0.00	0.28	<0.01
MAN	*Mancopsetta sp.*	0.26	0.00	0.26	<0.01
GRF	*Coelorhynchus fasciatus*	0.18	0.00	0.18	<0.01
POA	*Porania antarctica*	0.18	0.00	0.18	<0.01
BAL	*Bathydomus longisetosus*	0.09	0.00	0.09	<0.01
EUL	*Eurypodius latreillei*	0.07	0.00	0.07	<0.01
SUN	*Labidaster radiosus*	0.05	0.00	0.05	<0.01
EUO	*Eurypodius longirostris*	0.05	0.00	0.05	<0.01
CYX	*Cycethra sp.*	0.04	0.00	0.04	<0.01
OPH	Ophiuroidea	0.03	0.00	0.03	<0.01
MAV	*Magellania venosa*	0.02	0.00	0.02	<0.01
MUU	*Munida subrugosa*	0.02	0.00	0.02	<0.01
BAO	*Bathybiaster loripes*	0.01	0.00	0.01	<0.01
BLU	*Micromesistius australis*	0.01	0.00	0.01	<0.01
EEL	*Iluocoetes fimbriatus*	0.01	0.00	0.01	<0.01
MUN	*Munida spp.*	0.01	0.00	0.01	<0.01
OPD	*Ophiacantha densispina*	0.01	0.00	0.01	<0.01
POL	Polychaeta	0.01	0.00	0.01	<0.01
Totals		***36152.09***	***8298.68***	***4502.55***	

Proportion of catch composition among treatments was highest in hake (*M. hubbsi*) throughout all stations (mean: 47.5% - 56.5%) (Figure 3.3). The catch proportion of pooled skate species was also relatively high among treatments (mean: 22.3% - 26.4%) as was kingclip (*G. blacodes*) (mean: 5.7% - 12.0%). The remaining fish and invertebrate species caught accounted for less than 10% individually of the total catch. (Fig 3.3). Mean catch proportions of each species were generally similar between mesh treatments.

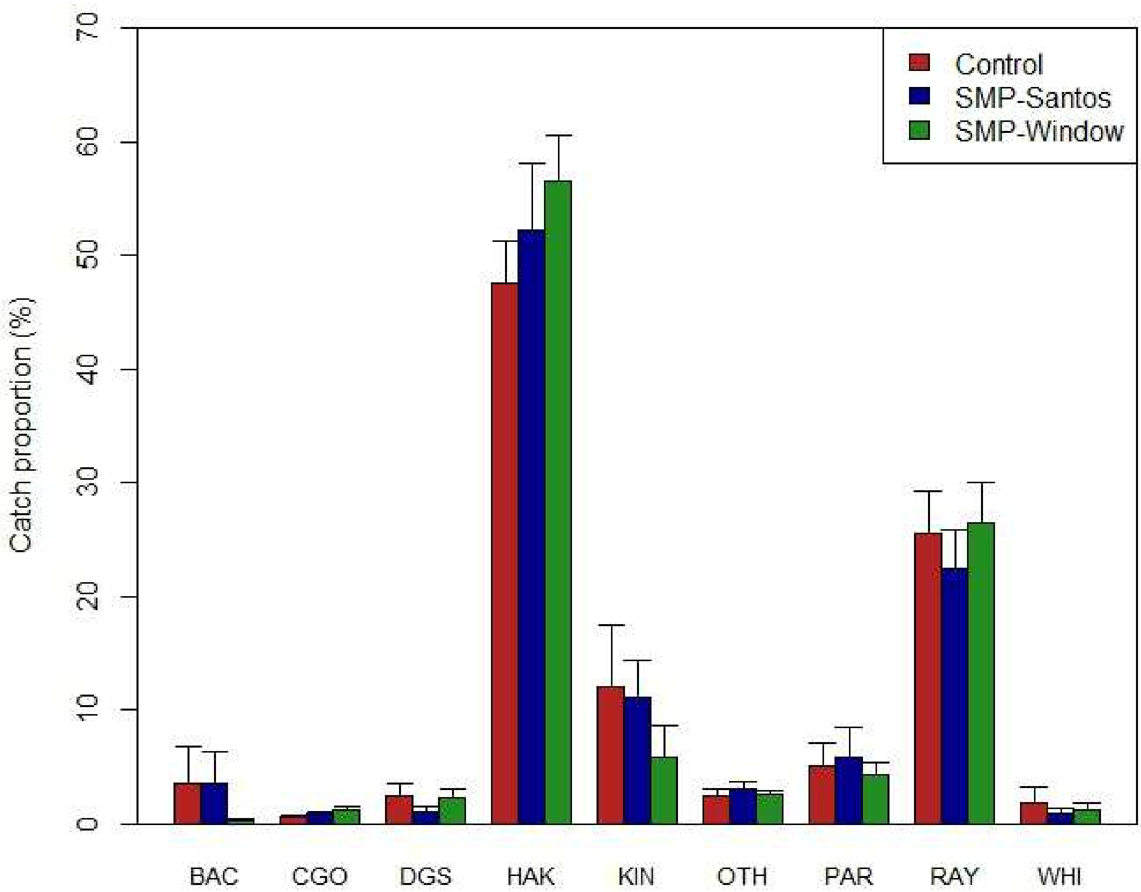


Figure 3.3 Catch composition by species per mesh treatment as percentage of total catch weight (mean ± sd). BAC=*S. australis*; CGO=*C. gobio*; HAK=*M. hubbsi*; DGS = *S. acanthus*; KIN=*G. blacodes*; OTH = all other species; PAR= *P. ramsayi*; RAY =all skates; WHI=*M. magellanicus.*

Species composition and catch proportion by mesh treatment of skates are show in Figure 3.4. Twelve species of skate were found throughout all stations. Highest catch proportions by weight of total skates were RBR (mean: 39.23% - 43.2%), followed by RFL (mean: 29.7% – 35.5%). RAL, RMC and RPX were also proportionally high among the skate catches (mean: 13.2% – 6.2%). Skate species composition catch proportion was similar among treatments (Figure 3.4).

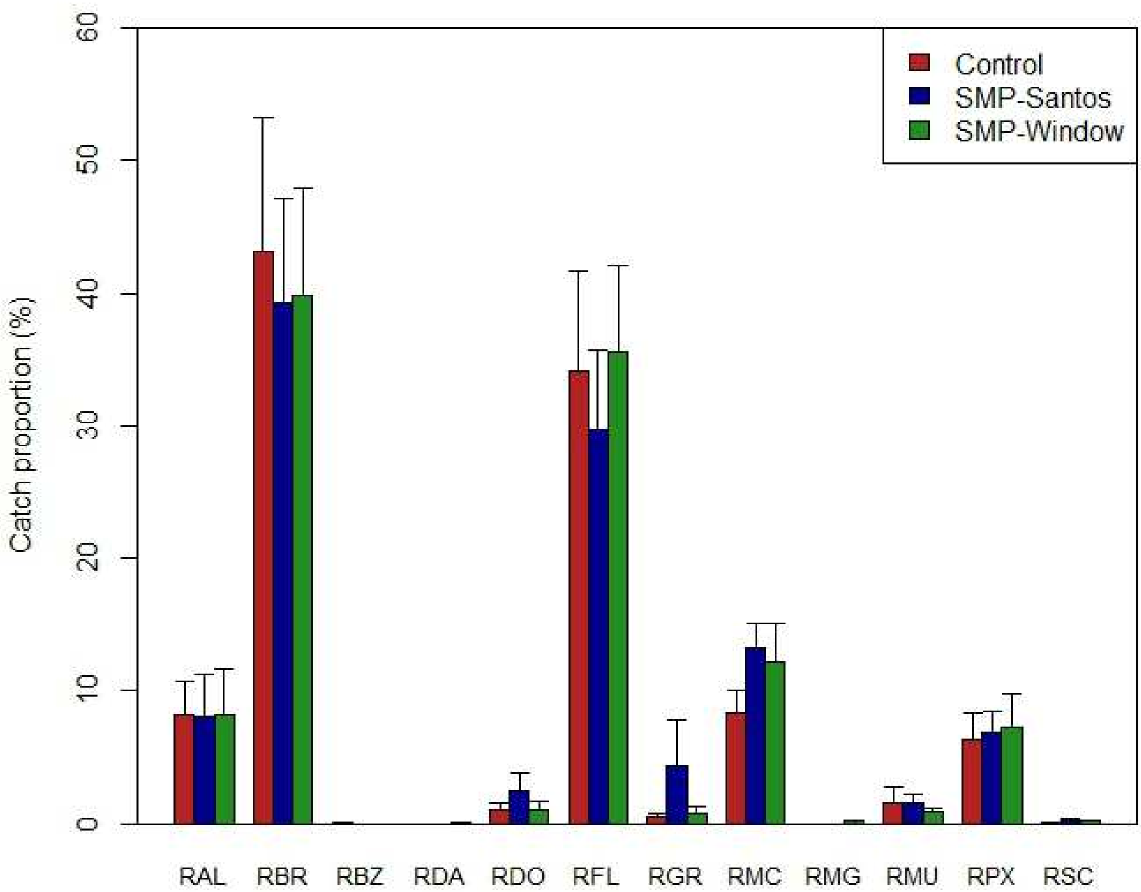


Figure 3.4 Catch composition by species as percentage of total catch weight (mean ± sd) for 3 mesh treatments, ZDLT1-07-2013. RAL= *Bathyraja albomaculata*; RBR= *Bathyraja brachyurops*; RBZ= *Bathyraja cousseauae*; RDA= *Dipturus argentinensis*; RDO= *Amblyraja doellojuradoi*; RFL= *Zearaja chilensis*; RGR= *Bathyraja griseocauda*; RMC= *Bathyraja macloviana*; RMG= *Bathyraja magellanica*; RMU= *Bathyraja multispinis*; RPX= *Psammobatis spp.*; RSC= *Bathyraja macloviana*

3.3 Codend-SMP trials

3.3.1 Catch rates

Impacts of codend-SMP configurations on catch per unit effort (CPUE) were assessed on total catch ($CPUE_T$), on catches of species encountered in all hauls (hake, kingclip, rockcod, *Illex* and skates) and on catches of commercial species occasionally encountered during the trials (red cod and hoki). Four stations (1112, 1114, 1138 and 1139) were not considered for CPUE analyses due to trawl damage and/or mixing of the catch. Trawl depth varied 152-174 m during trials.

Total Catch ($CPUE_T$)

Total CPUE averaged 1,123 kg hr^{-1} during trials and ranged 535-2143 kg hr^{-1} among hauls. Time of day explained 14% of the variance in the model (Table 3.4). Mean $CPUE_T$ varied from 1,346 kg hr^{-1} in control hauls to 1,072 kg hr^{-1} (SMP-window) and 965 kg hr^{-1} (SMP-Santos) (Fig. 3.5A).The use of 40-mm square mesh in the trawl codend had no impact on total catch rates (Chisq=2.742, df=2, p>0.05).

Merluccius hubbsi ($CPUE_{HAK}$)

Hake was the most abundant species caught during the trials, on average accounting for 52% of the catch by weight (range 18-83% among hauls). Hake CPUE averaged 642 kg hr^{-1} in control trawls and varied 619 kg hr^{-1} (SMP-window) and 542 kg hr^{-1} (SMP-Santos) (Fig. 3.5B). Time of day explained 16% of the variance (Table 3.4). There were no significant effects of codend-SMP configurations on catch rates of hake (Chisq=0.973, df=2, p>0.05).

Genypterus blacodes ($CPUE_{KIN}$)

Kingclip was encountered in all hauls though in highly variable proportions. Kingclip CPUE averaged 105 kg hr^{-1} and ranged 0.8-775 kg hr^{-1} among trawls. Daily variability explained 63% of the variance in $CPUE_{KIN}$ (Table 3.4). Mean catch rates of kingclip decreased from 184 kg hr^{-1} in control hauls to 85 kg hr^{-1} in trawls equipped with SMP-Santos and 58 kg hr^{-1} in hauls with SMP-window. However SMP-codend configuration effects on kingclip CPUE lacked statistical significance (Chisq=4.582, df=2, p>0.05).

Rock cod ($CPUE_{PAR}$)

Rock cod was encountered in small numbers throughout the trials. Average rock cod CPUE was 52 kg per hour and ranged 3-327 kg hr^{-1} among hauls. Trawling depth explained 58% of the variance in $CPUE_{PAR}$ (Table 3.4). Catch rates of rock cod were did not differ among SMP-codend configurations (Chisq=0.259, df=2, p>0.05) (Fig. 3.5D).

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

Skates accounted for 25% of the catch on average during the trials (range 5-50%). *B. brachyurops* CPUE averaged 121 kg per hour and ranged 9-417 kg hr^{-1} among hauls. Day-to-day variability explained 97% of the random variation in $CPUE_{RBR}$ (Table 3.4). Catch rates of skates were unaffected by codend-SMP configurations (Chisq=1.078, df=2, p>0.05) (Fig. 3.5E).

Salilota australis ($CPUE_{BAC}$)

Red cod generally occurred in low numbers except in one haul. $CPUE_{BAC}$ averaged 25 kg per hour and ranged 0-557 kg hr^{-1} among trawls. Day-to-day variability explained 9% of the random variation in $CPUE_{BAC}$ (Table 3.4). There were no effects of codend-SMP configurations on catch rates of red cod (Chisq=1.788, df=2, p>0.05) (Fig. 3.5F).

Macruronus magellanicus ($CPUE_{WHI}$)

Hoki was encountered in small numbers and its occurence in the catch was highly variable both within and among fishing days. Hoki CPUE averaged 19 kg per hour and ranged 0-253 kg hr^{-1} among hauls. Trawling depth explained 33% of the variance in $CPUE_{WHI}$ (Table 3.4). Codend-SMP configurations had no significant effects on Hoki CPUE (Chisq=3.410, df=2, p>0.05) (Fig. 3.5G).

Illex argentinus ($CPUE_{ILL}$)

Illex squid occurred in small numbers in all trawls. CPUE averaged 11 kg per hour and ranged 0.3-30 kg hr^{-1} among hauls. Trawling day explained 37% of the variance in $CPUE_{ILL}$ (Table 3.4). Codend-SMP configurations had a marginally significant influence on catch rates of Illex (Chisq=5.872, df=2, p=0.05). Mean Illex CPUE were higher in trawls equipped with the SMP-Santos codend (17 kg hr^{-1}) relative to control and SMP-window configurations (both 8 kg hr^{-1}) (Fig.3.5H).

Table 3.4 Summary of selected GLMM procedures for the assessment of codend-SMP effects on total and species-specific CPUE. Codend-SMP configuration (3-levels factor) was the fixed effect in all models. Random effects included sampling day (day), time of day (tofday) and trawling depth (depth). 'X' indicates a significant fixed effect. For random effects: ()% is the percentage of the variance explained by the random effect in the selected model. BIC is the Bayesian information criterion.

	Response	Fixed effect	Random effects			model	error structure	BIC
		codend	day	tofday	depth			
Total Catch	$logCPUE_T$	-	-	14%	-	GLMM	gaussian (log-normal)	7.63
M. hubbsi	$logCPUE_{HAK}$	-	-	16%	-	GLMM	gaussian (log-normal)	19.38
G. blacodes	$logCPUE_{KIN}$	-	63%	-	-	GLMM	gaussian (log-normal)	65.02
P. ramsayi	$logCPUE_{PAR}$	-	-	-	58%	GLMM	gaussian (log-normal)	48.57
B. brachyurops	$logCPUE_{RBR}$	-	97%	-	-	GLMM	gaussian (log-normal)	44.03
S. australis	$logCPUE_{BAC}$	-	9%	-	-	GLMM	gaussian (log-normal)	63.99
M. magellanicus	$logCPUE_{WHI}$	-	-	-	33%	GLMM	gaussian (log-normal)	61.07
Illex argentinus	$logCPUE_{ILL}$	X	37%	-	-	GLMM	gaussian (log-normal)	63.99

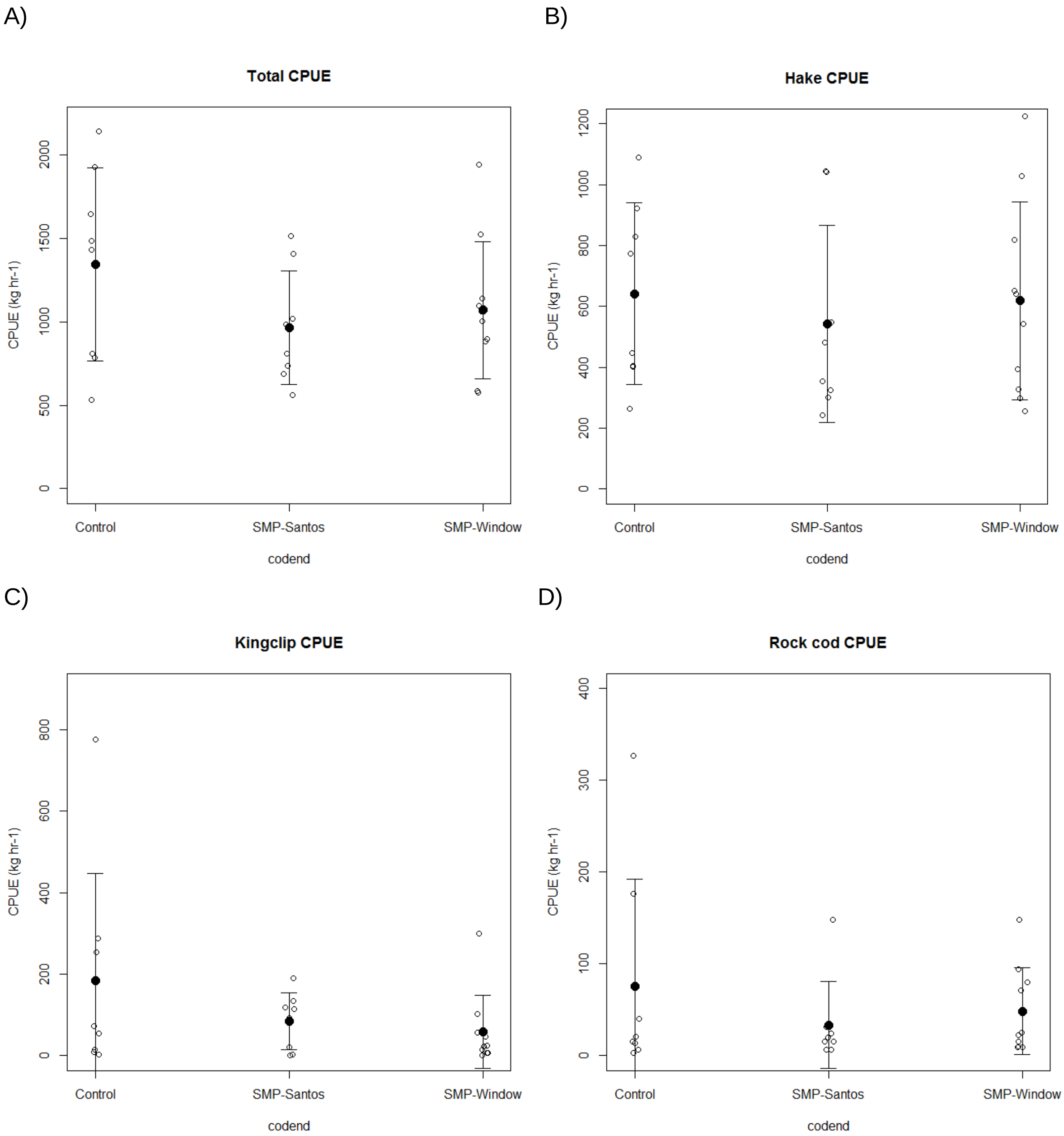
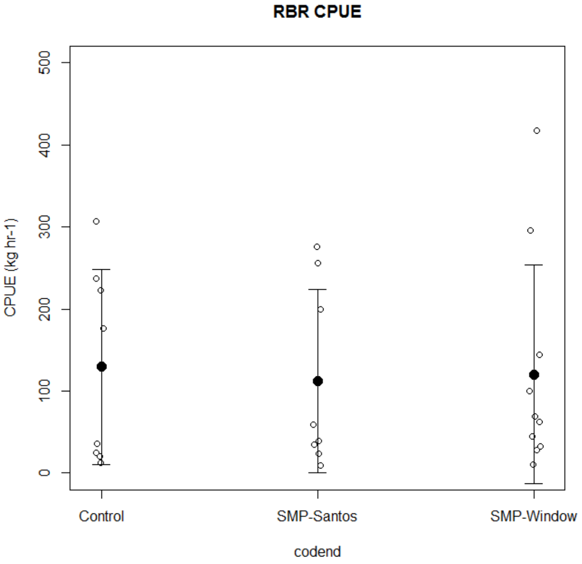
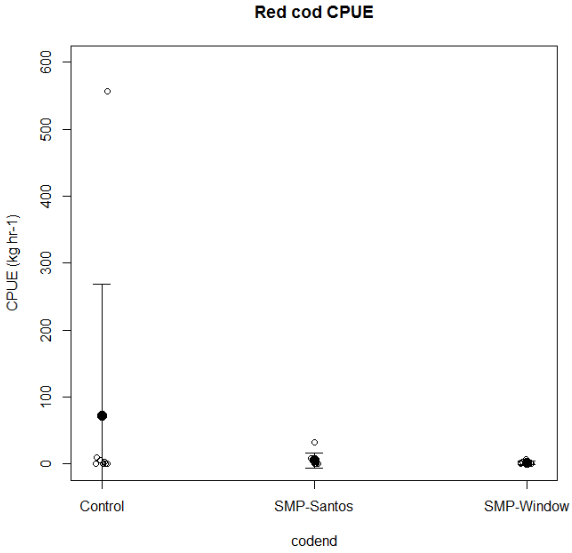


Figure 3.5. Catch rates (CPUE - kg per trawling hour) among codend configurations (control, SMP-window and SMP-Santos. A) total catch; B*) M. hubbsi* (hake); C) *G. blacodes* (kingclip); D*) P. ramsayi* (rock cod). Empty circles correspond to individual hauls. Dark (filled) circles represent mean values. Error bars = ±1 standard deviation.

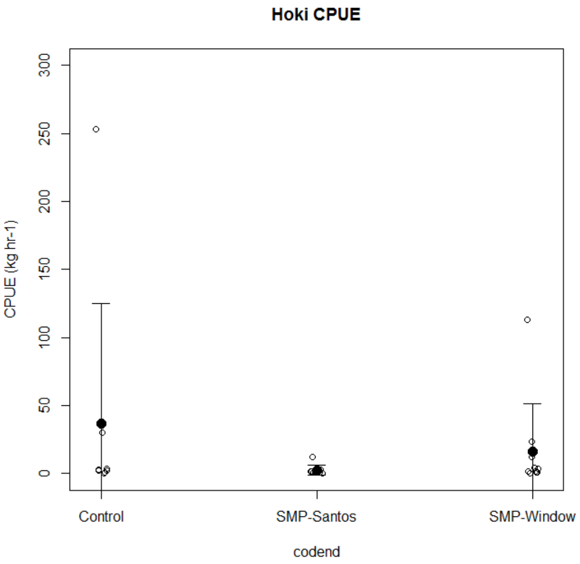
E)



F)



G)



H)

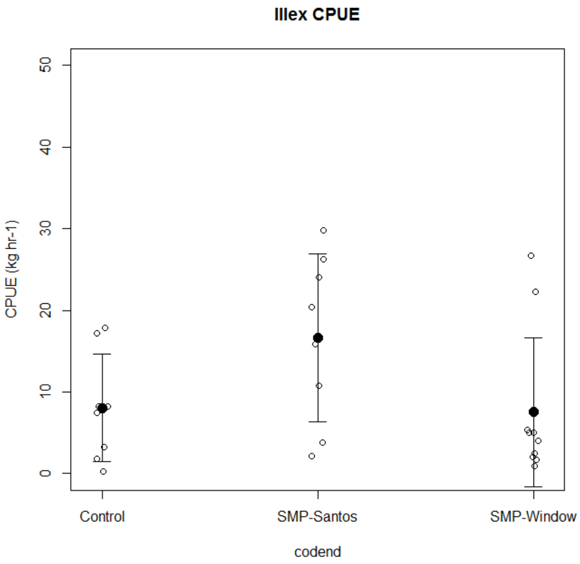


Figure 3.5. (continued) E) *B. brachyurops* (RBR); F) *S. australis* (red cod); G*) M. magellanicus* (hoki) and H*) Illex argentinus*. Empty circles correspond to individual hauls. Dark (filled) circles represent mean values. Error bars = ±1 standard deviation.

3.3.2 Length structure and relative selectivity

Table 3.5 summarizes length information collected for fish, skates and fish species during the trials. Effects of codend-SMP configuration on length structure and relative selectivity were assessed for species encountered in large enough samples sizes (≥ 100 specimens measured per haul) at least once in each of the gear configuration under study.

Merluccius hubbsi (hake)

Hake length ranged 29-83 cm during the trials. Average length was 50 cm. Mean, median, first/third quartiles and modal lengths increased with SMP use (Table 3.5). Mean and median lengths increased by 1-cm and 2-cm in SMP-window and SMP-Santos codends, respectively, relative to controls. Differences in mean length between codend configurations were statistically significant (Kruskal-Wallis chi-squared = 19.3863, df = 2, p-value = 6.171e-05). Proportions of hake < 45-cm were lower in trawls equipped with codend-SMP relative to controls (Fig 3.6). The SMP-Santos configuration yielded higher proportions of larger hake (50-65 cm) (Fig 3.6). Relative selectivity was highly variable among trawls (Fig 3.7, Appendix 1). All hauls considered, first and second lengths of 50% retention (L_{50}^1 and L_{50}^2) were higher in codends with fitted SMP (Fig. 3.7). Variability in estimates of L_{50}^1 for hake among gear configurations shows a tendency towards smaller L_{50}^1 in controls relative to SMP-trawls (Fig 3.8A). However differences in L_{50}^1 lacked statistical significance (Kruskal-Wallis chi-squared = 1.9904, df = 2, p-value = 0.3697).

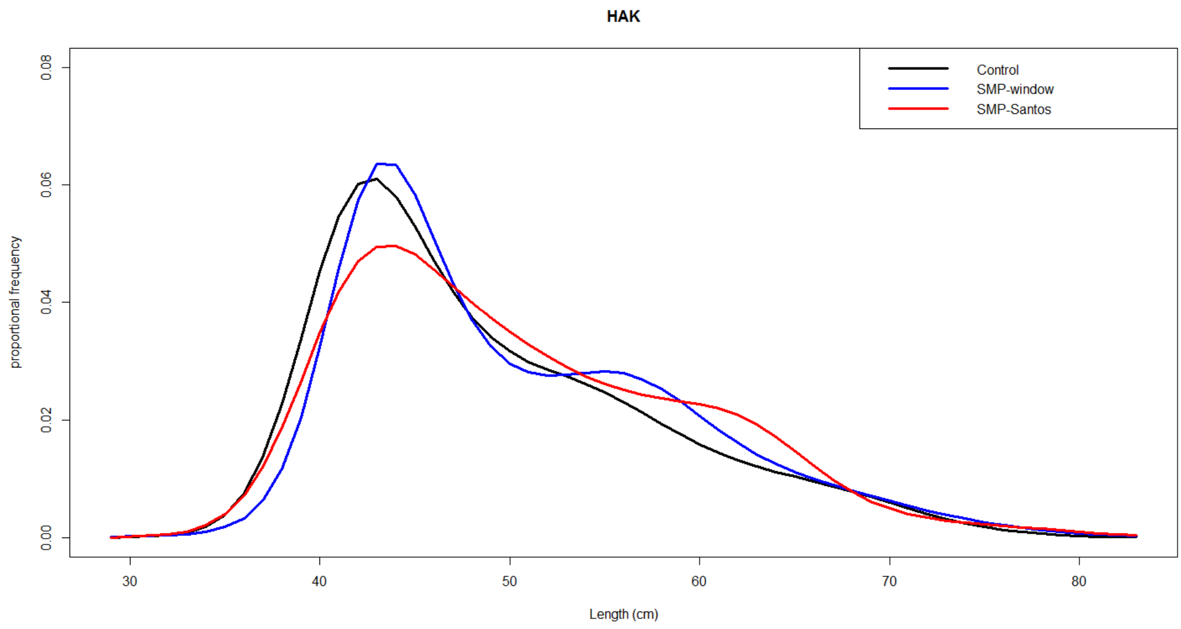


Figure 3.6. GAM-smoothed proportional length frequency distributions for *M. hubbsi* (hake) among SMP-codend configurations.

Genypterus blacodes (kingclip)

The average total length of kingclip was 68 cm and ranged 44-136 cm during the trials. Kingclip caught using the control gear had larger mean, median, first/ third quartiles and modal lengths compared to those caught in SMP-codends (Table 3.5). Differences in mean size were only significant between the control and SMP-window configuration (Kruskal-Wallis chi-squared = 17.7252, df = 2, p-value = 0.0001416; Wilcoxon (control vs SMP-Window) p-value=0.0001). The average size of kingclip caught using the SMP-Santos codend did not differ from controls. Kingclip length frequency distributions were relatively similar between treatments, although higher proportions of smaller (< 60-cm) kingclip occurred in the SMP-window (Fig 3.9). Relative selectivity was similar between control and SMP-Santos trawls (Fig. 3.10). Selectivity assessment for kingclip caught using the SMP-window codend yielded generally poor fits (Fig 3.10). The minimum length at which 50% of kingclip were recruited to the fishing gear (L_{50}^{1}) was slightly larger in control hauls and lower in the SMP-window codend (Fig 3.8B). However these differences lacked statistical significance (Kruskal-Wallis chi-squared = 2.7527, df = 2, p-value = 0.2525), in part due to small sample sizes.

Table 3.5 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.

		Control	SMP-window	SMP-Santos
M. hubbsi (hake)				
	25th percentile	42	43	43
	median	47	48	49
	75th percentile	55	56	57
	mean	49.1	50.3	50.5
	fitted mode	43	43	44
	n (stations)	*9*	*11*	*9*
G. blacodes (kingclip)				
	25th percentile	62	59	61
	median	68	65	66
	75th percentile	75	72	74
	mean	69.8	66.1	68.7
	fitted mode	66	65	64
	n (stations)	*4*	*3*	*6*
P. ramsayi (rock cod)				
	25th percentile	22	22	22
	median	24	24	24
	75th percentile	27	28	28
	mean	24.5	24.7	25.0
	fitted mode	22	22	23
	n (stations)	*7*	*10*	*7*
B. brachyurops (skates)				
	25th percentile	31	26	26
	median	47	34	41
	75th percentile	54	49	52
	mean	42.7	37.0	39.7
	fitted mode	54	26	54
	n (stations)	*6*	*8*	*5*
M. magellanicus (hoki)				
	25th percentile	24	21	
	median	25	24	
	75th percentile	26	25	
	mean	24.7	23.5	
	fitted mode	25	25	
	n (stations)	*2.00*	*3.00*	*0.00*
S. australis (red cod)				
	25th percentile	34		34
	median	40		38
	75th percentile	51		45
	mean	43.5		41.7
	fitted mode			
	n (stations)	*1*	*0*	*1*
Illex argentinus				
	25th percentile		14.5	
	median		32.0	
	75th percentile		33.0	
	mean		27.3	
	fitted mode			
	n (stations)	*0*	*2*	*0*

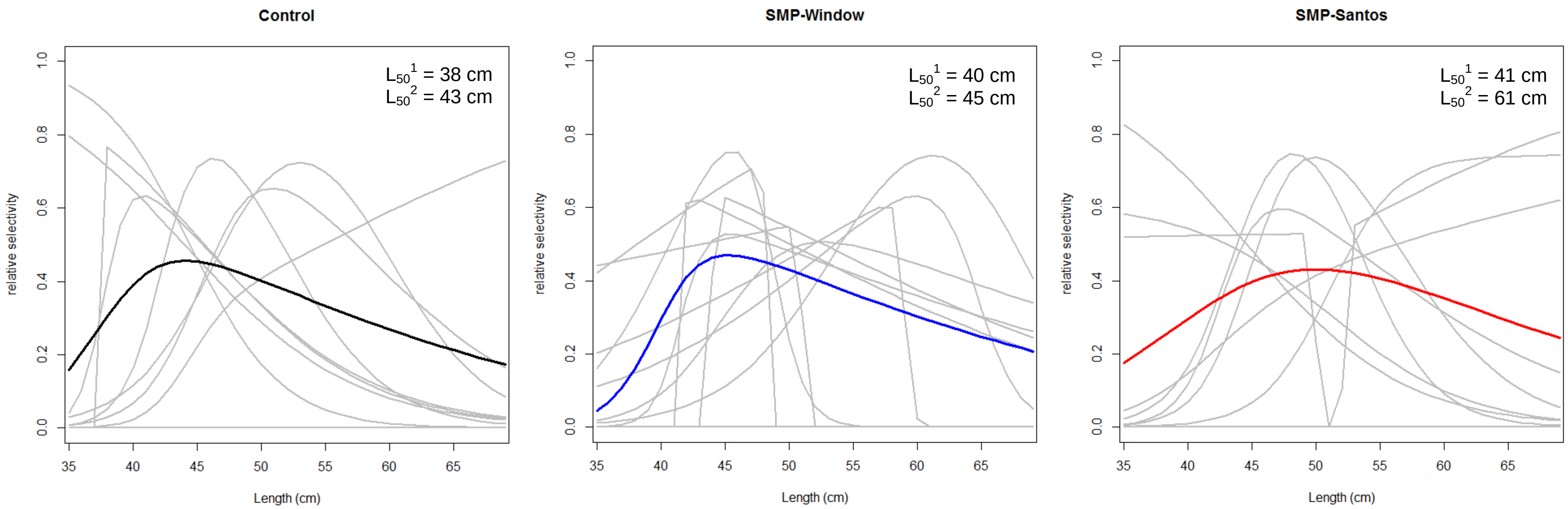
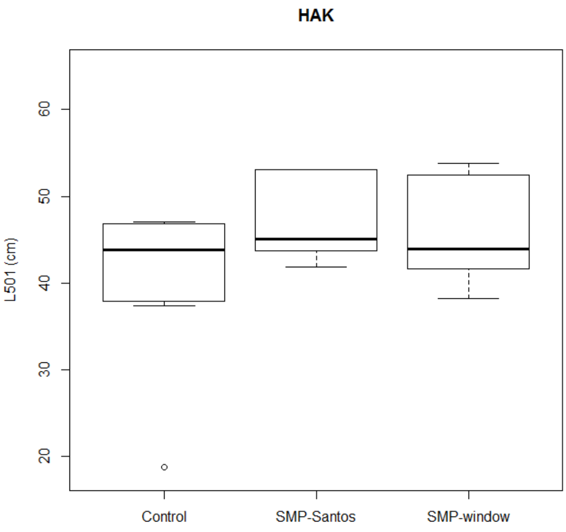
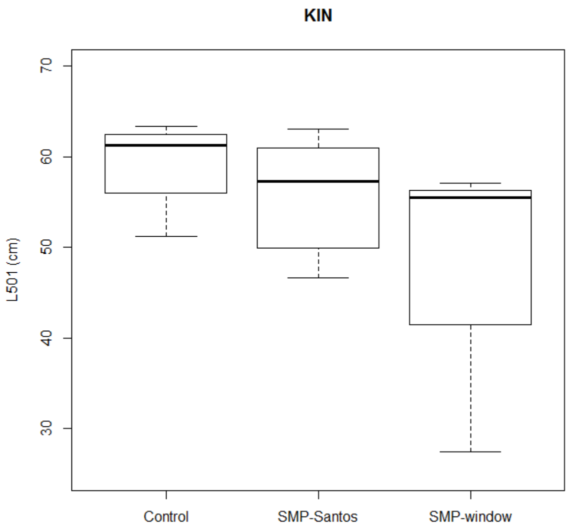


Figure 3.7 Relative selectivity at length for *M. hubbsi* (hake) among SMP-codend configurations. Grey-curves = fitted selectivity for individual hauls. Bold curves (black, blue and red) = treatment-specific selectivity (fitted selectivity using data from all hauls of a given trawl configuration).

A)



B)



C)

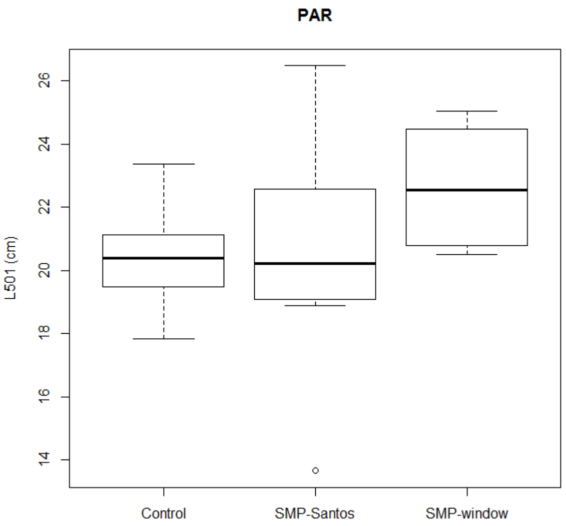


Figure 3.8 Differences in length of 50% retention among codend-SMP configurations in A) Hake; B) Kingclip; and C) Rock cod.

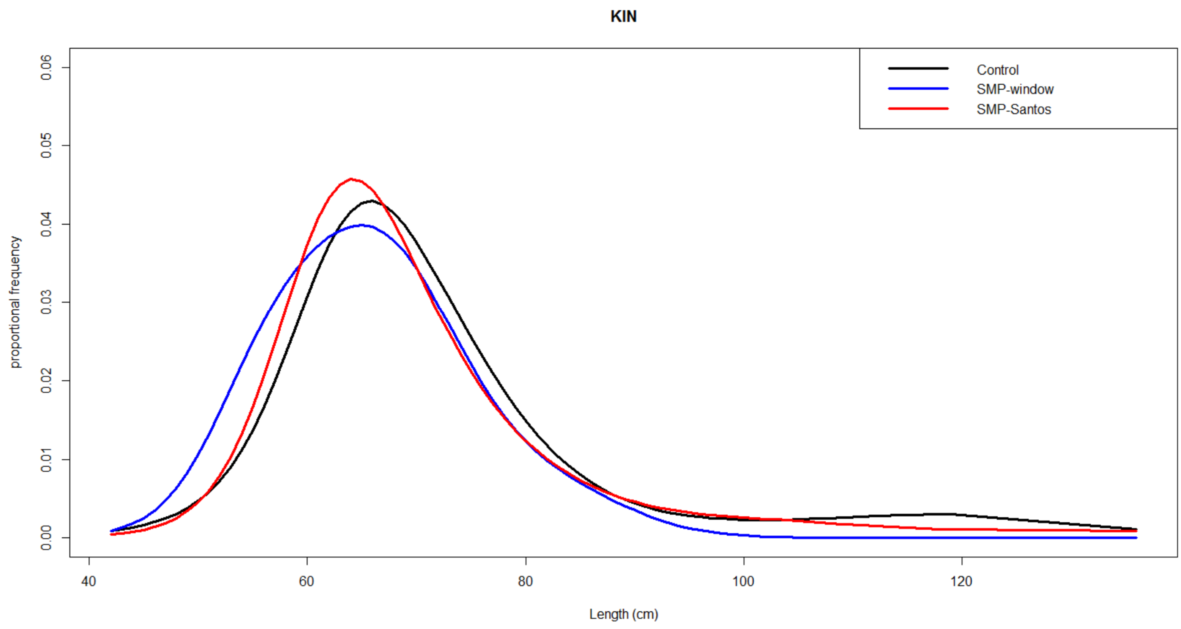


Figure 3.9 GAM-smoothed proportional length frequency distributions for *G. blacodes* (kingclip) among SMP-codend configurations.

Patagonotothen ramsayi (Patagonian rock cod)

Rock cod length ranged 13-39 cm during the trials. Mean size was 25 cm. There was a slight increase in third quartile and mean lengths in trawls equipped with SMP in the codend relative to controls (Table 3.5). Average length was significantly larger in the SMP-Santos relative to controls but did not differ between control and SMP-window (Kruskal-Wallis chi-squared = 6.9573, df = 2, p-value = 0.03085). Modal length increased from 22 cm in control and SMP-window to 23 cm in SMP-Santos (Table 3.5). Proportions of small (< 20 cm) fish were generally similar between treatments (Fig. 3.11). The occurrence of large (> 30 cm) rock cod in the catch was greater in SMP-trawls. This was especially marked in the SMP-Santos (Fig. 3.11). Relative selectivity assessment was subject to important inter-trawl variability (Fig 3.12). The SMP-Santos codend generally yielded higher probabilities of retaining commercial-size rock cod relative to controls and the SMP-window (Fig. 3.12). Minimum length of 50% retention (L_{50}[1]) increased with SMP-use but differences among gear configurations were not statistically significant (Kruskal-Wallis chi-squared = 5.0209, df = 2, p-value = 0.08123) (Fig 3.8C).

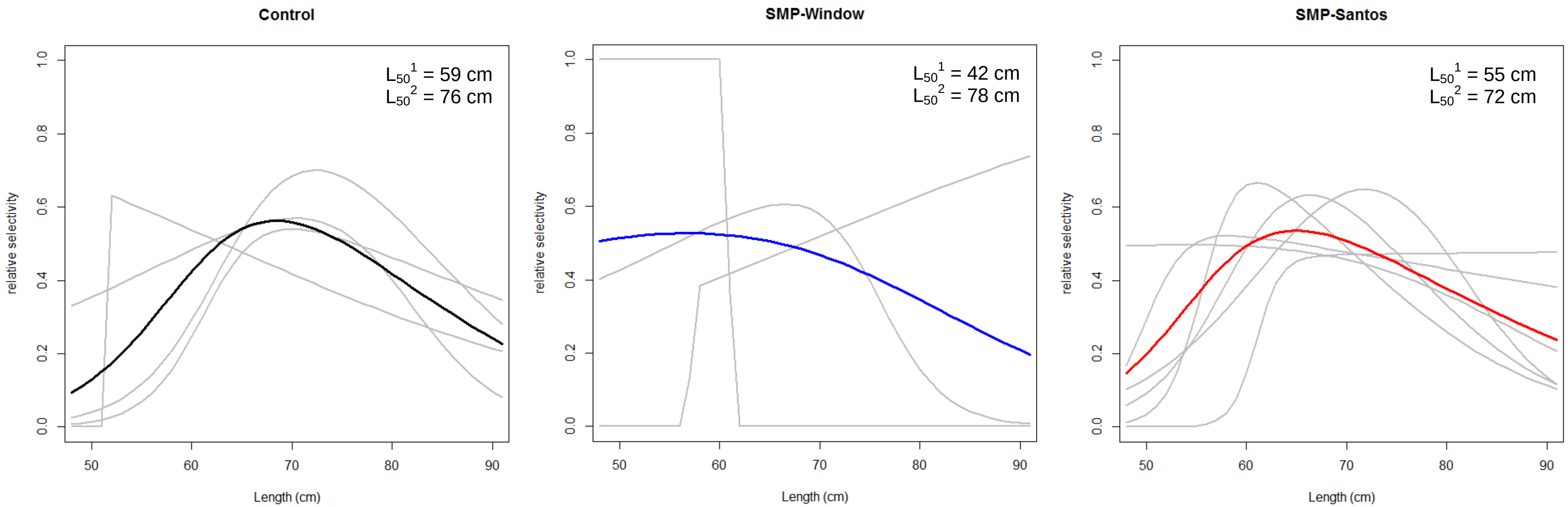


Figure 3.10 Relative selectivity at length for *G. blacodes* (kingclip) among SMP-codend configurations. Grey-curves = fitted selectivity for individual hauls. Bold curves (black, blue and red) = treatment-specific selectivity (fitted selectivity using data from all hauls of a given trawl configuration).

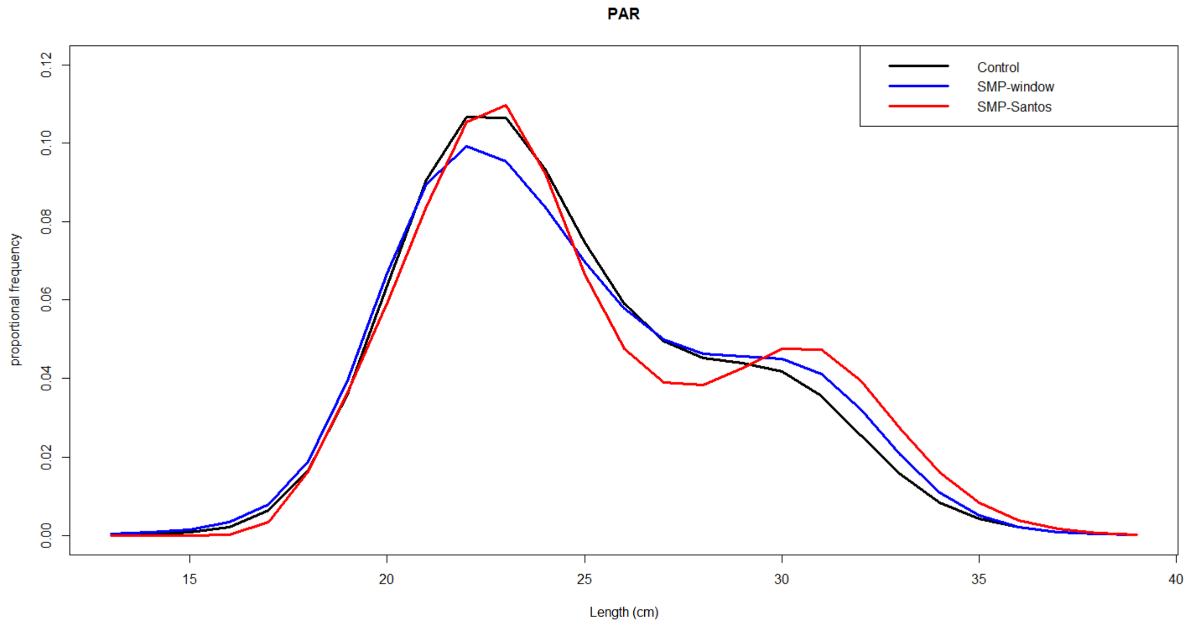


Figure 3.11 GAM-smoothed proportional length frequency distributions for *P. ramsayi* (rock cod) among SMP-codend configurations.

Rajidae (skates)

The average size of *B. brachyurops* (RBR) was 39 cm disk width and ranged 10-67 cm. Larger RBR were harvested in control trawls relative to trawls equipped with SMP (Table 3.5). Average disk width significantly differed among trawl configurations and varied from 43-cm in control hauls to 37-cm and 40-cm in SMP-window and SMP-Santos codends, respectively (Kruskal-Wallis chi-squared = 71.1508, df = 2, p-value = 3.547e-16). RBR size frequency distributions were characterized by higher proportions of smaller skates (< 30 cm) in trawls equipped with SMP in the codend and by higher proportions of larger (50-60 cm) skates in controls (Fig 3.13). Selectivity assessment yielded poor fits and a recurrent lack of convergence, suggesting that (i) the double-logistic model is not appropriate to describe size selectivity in skates; and/or (ii) the three codend configurations under trials were not selective for skates (Fig 3.14). This corroborates earlier findings by Roux et al (2012) which showed limited size-selectivity for skates in small mesh (90 mm and 110 mm) codends.

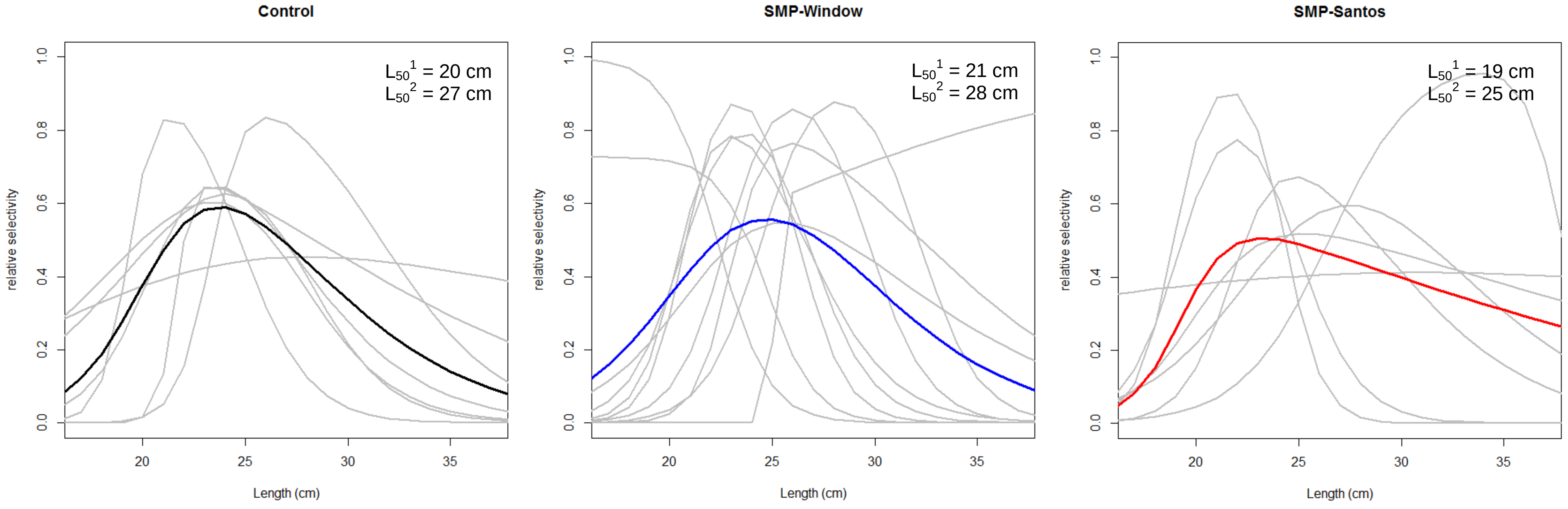


Figure 3.12 Relative selectivity at length for *P. ramsayi* (rock cod) among SMP-codend configurations. Grey-curves = fitted selectivity for individual hauls. Bold curves (black, blue and red) = treatment-specific selectivity (fitted selectivity using data from all hauls of a given trawl configuration).

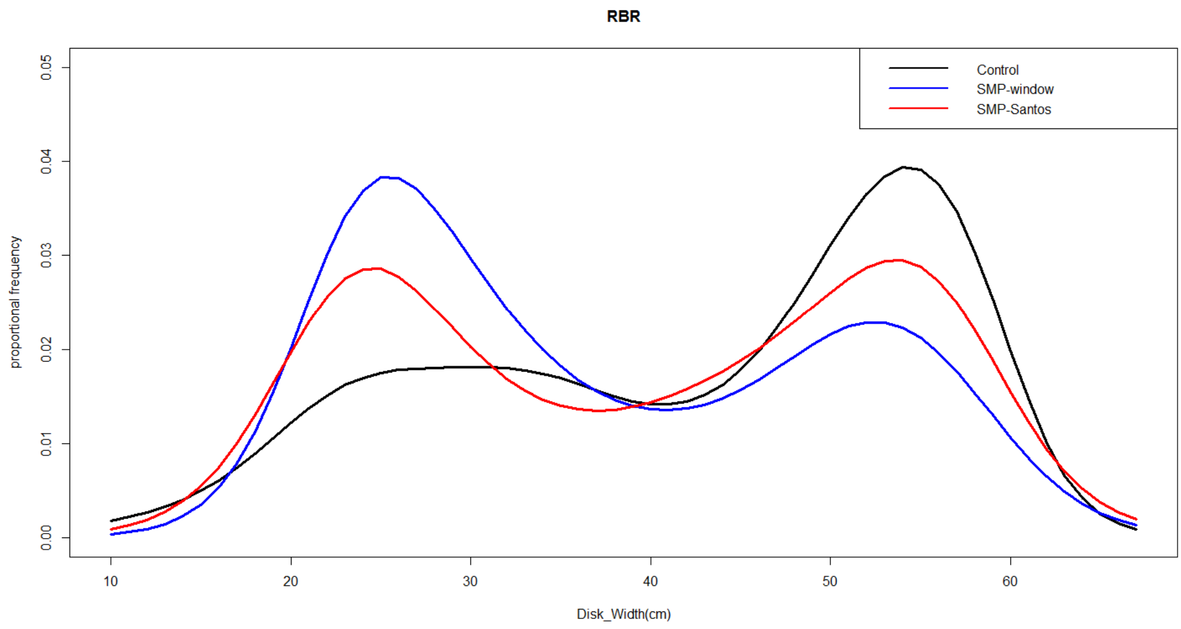


Figure 3.13 GAM-smoothed proportional size frequency distributions for *B. brachyurops* (skates) among SMP-codend configurations.

3.3.3 Summary of findings

- There were no effects of fitted square mesh panels in trawl codends on catch rates of finfish species under conditions of mixed species catch composition.

- In all species, relative selectivity at length was highly variable among hauls and generally independent from trawl configuration.

- Significant effects of codend-SMP on the length structure of dominant species in the catch were detected. These included:

- An increase in hake sizes in trawls equipped with SMP in the codend relative to controls, including higher proportions of larger hake (50-65 cm) in the SMP-Santos configuration.

- Larger mean and modal rock cod lengths (as linked to higher proportions of > 30 cm rock cod) in the SMP-Santos codend relative to control and SMP-window.

- Greater occurrence of smaller (< 60 cm) kingclip in trawls equipped with the SMP-window.

- Smaller sizes and higher proportions of smaller skates (< 30 cm disk width) in trawls equipped with SMP in the codend.

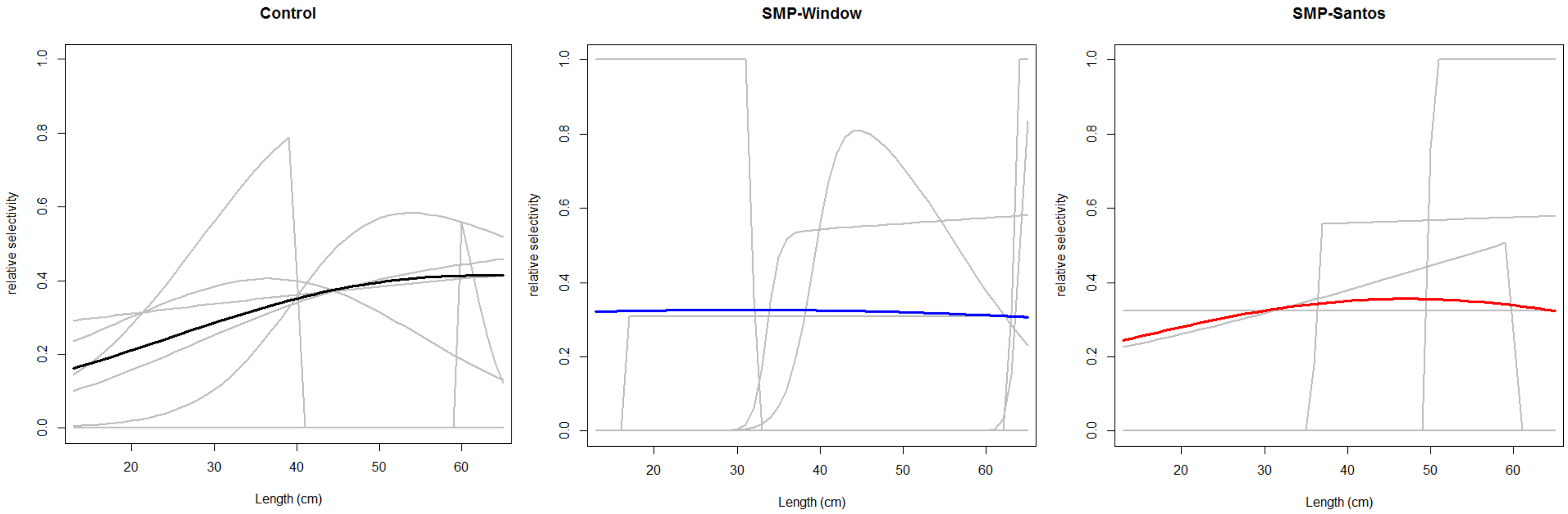


Figure 3.14 Relative selectivity at disk width intervals ('Length' on figures) *for B. brachyurops* (skates) among SMP-codend configurations. Grey-curves = fitted selectivity for individual hauls. Bold curves (black, blue and red) = treatment-specific selectivity (fitted selectivity using data from all hauls in a given trawl configuration).

3.4 Kingclip conversion factor analysis

Calculated conversion factors (CFs) in all 3 trials were lower than the FIFD-statutory CF (KIN HGT CF=2.3) by 9% to 14% (Table 3.6). Station 1137 represents the best data set with sample size similar to commercial condition. The CF value on this station was less than 2.0. Average range of CFs (total and per trunk) were between 2.01 and 1.98 (Table 3.6), or approximately 13% lower than the recommended CF.

The physical condition of the caught kingclip might explain low CFs. For example a higher liver weight could significantly raise the CF. It will be useful to compare the CF data reported here to data from the same vessel but during another season of the year or to another fishing area. Also, the impact of the net selectivity on the CFs is unknown. It is recommended to repeat the CF work on the next research cruise. It would be prudent to confirm that packed trunks in boxes do weigh 16 kg, as reported by the ship. Box weight was checked only once during the cruise and a small discrepancy was found (16.8kg). Observers commonly report differences and variations in the weight of the filled boxes in the commercial fleet.

Table 3.6 Conversion fact data and analysis for kingclip, ZDLT1 – 07-2013

	Number of animals			**Green weight (kg)**		**Processed trunk weight (kg)**		**Conversion factor**	
Station	**Unprocessed**	**Returned after processing**	**Mean length (cm)**	**Total**	**Per animal**	**Total**	**Per trunk**	**Total**	**Per trunk**
1129	97	95	66.44	140.42	1.448	68.4	0.72	2.053	2.011
1136	79	78	57.56	69.32	0.877	32.77	0.42	2.115	2.089
1137	~245	~245	64.28	310.23	1.266	157.11	0.64	1.975	1.975
Total	**421**	**418**		**519.97**		**258.28**		**2.013**	
Average	**140**	**139**	**63.17**	**173.32**	**1.235**	**86.09**	**0.62**	**2.048**	**1.999**

4.0 General conclusions and recommendations

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

The results indicate little or no impacts of SMP in trawl codend during trials consisting of generally small-volume, mixed species catches. The small-size of the square mesh panel under trial, which is intended to specifically allow escapement of small rock cod, appears to have limited effects on catch rates and size-selectivity in larger-bodied, commercial species. Catch rates and relative selectivity at length were highly variable during trials and generally unaffected by trawl configuration. Limited, positive impacts on length structure were observed in hake (dominant species) and rock cod and corresponded to increased sizes and larger proportions of larger fish in trawls with SMP. This was especially marked in the SMP-Santos configuration. Oceanography varied widely between stations, in particular vertical stratification at each station, indicating variation in Argentine Drift current on the shelf. This may have driven some of the observed variability in catch.

The observation of higher proportions of smaller-size skates in trawls equipped with SMP in the codend requires further investigation. This may suggest reduced escapement of smaller-size skates through the more rigid 40-mm square mesh, in comparison with the 110-mm diamond mesh. The same applies to the higher proportions of smaller kingclip observed in the SMP-window configuration. Small spatial scale variation in juvenile skate aggregations may also partly account for the observed catch proportions.

Kingclip conversion factor results indicated that the FIFD-statutory CF for the species was in this instance overestimated. Potential reasons for this may include seasonal variations in body condition. Variability in conversion factors for this, and other commercial species, should continue to be monitored.

A third and final series of SMP-trials is scheduled for October 2013.

5.0 Addendum: Seabird Mortality

Seabird interaction monitoring was not carried out over the duration of the cruise however one incidence of seabird mortality was observed and recorded on the 8^{th} of July at station 1122.

The incident took place in relatively calm conditions with good visibility. The vessel was not discarding by-catch and seabird abundance was low. The black-browed albatross, *Thalassarche melanophris,* became entangled with the buoy on the starboard tori line. On discovery of the entangled seabird, the tori line was hauled but the bird had already died.

A necropsy was carried out and the bird was found to be male and by use of moult patterns and bill colour it was possible to ascertain that it was an adult of six or more years. The stomach was empty showing that the bird had not been feeding recently.

It was observed by members of the scientific team that seabird abundance around the vessel appeared unusually low whilst the corpse was tangled in the tori line, and perhaps there was a 'scarecrow effect'. However the vessel had ceased discarding some time before, thus it was not possible to distinguish between discarding and potential 'scarecrow' effects.

Mortality was not caused by any failure of the vessel; the tori line had been deployed correctly and was made to FIFD specifications. Tori lines have been shown to significantly reduce seabird mortality by trawlers (Reid & Edwards 2005) however as with any object being towed from the vessel there is a risk of entanglement and the chance of causing mortality.

6.0 References

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Appendix 1: Individual hauls parameters estimates of the double-logistic function used to describe selectivity at length in *M. hubbsi* (hake), *G. blacodes* (kingclip) and *P. ramsayi* (rock cod).

Species	Station	Codend	s1	s2	p1	p2
Hake	1104	Control	0.281	33.623	44.453	18.807
Hake	1105	Control	0.152	-0.204	44.024	Inf
Hake	1110	Control	0.252	0.297	59.546	46.799
Hake	1116	Control	0.149	1.038	45.426	37.864
Hake	1117	Control	0.157	23.585	45.592	37.368
Hake	1125	Control	-3.996	-1.023	62.205	47.026
Hake	1130	Control	-0.070	0.596	54.733	43.876
Hake	1134	Control	0.254	0.650	51.651	42.424
Hake	1139	Control	0.140	0.451	57.460	45.635
Hake	1101	SMP-window	0.840	0.294	48.711	40.643
Hake	1106	SMP-window	5.301	0.029	51.039	43.138
Hake	1112	SMP-window	0.051	0.358	55.852	45.200
Hake	1113	SMP-window	0.610	0.113	64.405	53.524
Hake	1118	SMP-window	4.245	2.995	43.512	53.111
Hake	1122	SMP-window	0.293	0.233	67.858	53.851
Hake	1124	SMP-window	10.400	0.098	48.199	38.180
Hake	1128	SMP-window	0.070	9.881	50.022	41.681
Hake	1129	SMP-window	0.051	0.970	48.570	41.555
Hake	1136	SMP-window	3.280	0.081	58.978	51.889
Hake	1137	SMP-window	0.069	5.722	52.604	43.898
Hake	1102	SMP-Santos	26.873	-0.077	55.621	41.828
Hake	1108	SMP-Santos	0.342	0.436	53.299	43.682
Hake	1109	SMP-Santos	0.211	0.559	55.412	45.091
Hake	1120	SMP-Santos	119.117	0.000	49.998	Inf
Hake	1121	SMP-Santos	-0.141	23.626	54.222	43.320
Hake	1126	SMP-Santos	-45.820	0.076	52.031	50.303
Hake	1132	SMP-Santos	0.265	0.131	68.051	53.122
Hake	1133	SMP-Santos	926.190	0.000	46.000	Inf
Hake	1138	SMP-Santos	0.097	19.127	51.851	43.950
Kingclip	1104	Control	0.120	0.236	83.146	63.378
Kingclip	1117	Control	0.048	29.734	63.085	51.256
Kingclip	1130	Control	0.218	0.055	80.729	60.835
Kingclip	1134	Control	0.044	0.340	76.617	61.624
Kingclip	1101	SMP-window	-0.046	8.908	68.391	57.071
Kingclip	1124	SMP-window	17.746	15.094	60.968	27.389
Kingclip	1137	SMP-window	0.308	0.054	75.430	55.461
Kingclip	1102	SMP-Santos	-0.001	0.817	170.237	60.953
Kingclip	1108	SMP-Santos	0.108	0.007	85.474	46.624
Kingclip	1121	SMP-Santos	0.123	0.253	74.395	58.851
Kingclip	1132	SMP-Santos	0.189	0.144	80.335	63.056
Kingclip	1133	SMP-Santos	0.101	0.553	69.604	55.814
Kingclip	1138	SMP-Santos	0.019	0.480	65.088	49.887
Rock cod	1110	Control	0.432	0.256	27.122	19.594
Rock cod	1116	Control	0.594	1.467	24.724	19.349
Rock cod	1117	Control	0.337	1.219	31.615	23.363
Rock cod	1125	Control	0.499	0.276	27.597	20.382
Rock cod	1130	Control	0.052	0.184	29.828	17.828

Rock cod	1134	Control	0.312	0.660	26.929	20.618
Rock cod	1139	Control	0.132	2.353	28.373	21.620
Rock cod	1106	SMP-window	0.679	0.803	29.650	22.779
Rock cod	1112	SMP-window	5.688	-0.805	33.494	22.306
Rock cod	1113	SMP-window	0.861	0.000	24.739	Inf
Rock cod	1118	SMP-window	0.680	0.732	32.125	24.468
Rock cod	1122	SMP-window	-0.099	14.155	20.622	25.041
Rock cod	1124	SMP-window	0.210	1.163	32.255	23.046
Rock cod	1128	SMP-window	0.653	0.746	26.734	20.731
Rock cod	1129	SMP-window	0.177	0.431	28.848	21.465
Rock cod	1136	SMP-window	0.860	1.117	26.239	20.779
Rock cod	1137	SMP-window	0.472	1.035	26.564	20.501
Rock cod	1108	SMP-Santos	0.263	0.840	28.680	21.917
Rock cod	1109	SMP-Santos	0.034	0.073	34.257	13.650
Rock cod	1120	SMP-Santos	0.232	0.368	31.560	23.225
Rock cod	1121	SMP-Santos	1.063	0.470	37.897	26.481
Rock cod	1126	SMP-Santos	0.659	0.779	24.822	19.252
Rock cod	1132	SMP-Santos	0.069	0.573	28.000	20.228
Rock cod	1138	SMP-Santos	1.097	1.118	24.324	18.895

Appendix 2: Stepwise method for Transferring Fishboard Data via Bluetooth (SCANTROL Electronic FISHMETER – Long board)

- Pair devices for sharing via Bluetooth. First make sure the receiving device is ‘discoverable’ by other Bluetooth devices.

  START – ACTIVE SYNC – MENU – CONNECT VIA BLUETOOTH – YES – DEVICES TAB (bottom left)

  select the receiving device

  SAVE – OK – X (close)

- Use File Explorer on PDA to find the file FMDATA.xls

  START – FILE EXPLORER – MY DEVICE – PROGRAM FILES - FishMeterWL

- Select the file by holding the stylus on the file for 2 seconds, then select

  BEAM FILE

  The PDA will then search for your device. When your device name shows on the screen click

  TAP TO SEND

  The display should tell you that the file transfer is ‘pending’. On the receiving device you will need to accept the download. Once the file has transferred the PDA will notify you whether it was ‘successful’ or ‘failed’

Clearing old data from PDA and installing blank FMDATA file

- Once FMDATA.xls is safely on the receiving device check it before deleting from PDA.

- To delete file from the PDA use File Explorer and select the file by holding the stylus on the file name for 2 seconds. A menu will appear, select ‘delete’ and ‘ok’.

- Then make a copy of FMDATAblank.xls by selecting the file and ‘Copy’. Then select the background until the menu appears, select ‘Paste’

- Change the name of FMDATAblank(1).xls by selecting the file name and deleting the blank(1) part, so that you are left with a new FMDATA.xls. The device is now ready for next use.

Appendix 3: Recommended FIFD conversion factors.

Falkland Islands Government

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CONVERSION FACTORS 2011

Following work conducted by Fisheries Observers some conversion factors used to calculate green weight from processed fish have been changed. The conversion factors to be used from 1 March 2011 onwards are listed below.

Headed, Gutted and Tailed Fish (HGT)				
Scientific Name	English Name	Spanish Name	FIFD Code	Conversion Factor
Salilota australis	Red cod	Brotola	BAC	**2.0**
Micromesistius australis	Southern blue whiting	Polaca	BLU	**2.0**
Macrourus spp.	Grenadier	Rata	GRV	**2.7**
Merluccius spp.	Hake	Merluza	HAK/PAT	**1.9**
Genypterus blacodes	Kingclip	Rosada	KIN	**2.3**
Patagonotothen ramsayi	Rockcod	Marujo	PAR	**2.0**
Sebastes oculatus	Redfish	Cabra	RED	**2.1**
Dissostichus eleginoides	Toothfish	Robalo	TOO	**2.0**
Macruronus magellanicus	Hoki	Merluza de cola	WHI	**2.0**

Filleted fish (skin on)				
Scientific Name	English Name	Spanish Name	FIFD Code	Conversion Factor
Micromesistius australis	Southern blue whiting	Polaca	BLU	**3.1**
Macrourus spp.	Grenadier	Rata	GRV	**4.0**
Dissostichus eleginoides	Toothfish	Robalo	TOO	**2.5**
Macruronus magellanicus	Hoki	Merluza de cola	WHI	**2.6**

Filleted fish (skin off)				
Scientific Name	English Name	Spanish Name	FIFD Code	Conversion Factor
Macrourus spp.	Grenadier	Rata	GRV	**4.3**
Merluccius spp.	Hake	Merluza	HAK/PAT	**3.3**
Macruronus magellanicus	Whiptail Hake or Hoki	Merluza de cola	WHI	**3.2**

Ray wings				
Scientific Name	English Name	Spanish Name	FIFD Code	Conversion Factor
Rajidae	Skates/Rays	Raya	RAY	**4.0** (Skin Off)
Rajidae	Skates/Rays	Raya	RAY	**2.9** (Skin On)

Illex tubes				
Scientific Name	English Name	Spanish Name	FIFD Code	Conversion Factor
Illex argentinus	Illex squid	Pota	ILL	**1.9** (Skin and Wings on)
Illex argentinus	Illex squid	Pota	ILL	**3.0** (Skin, Tail and Wings Taken off)

Conversion Factors will remain as before for species not mentioned above.