Cruise Report ZDLT1-11-2011

Cod end mesh size experiments

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Contents

1.0 Introduction

A research cruise was untaken by 6 FIFD personnel on board the *RV Castelo* between the 5th November and 22nd of November 2011. The main aims of the cruise were to experimentally trial 4 commercially sized cod ends with differing diamond mesh size (90 mm, 110 mm, 120 mm, 140 mm) in order to identify the mesh size that results in the optimal retention of commercially sized rock cod, to examine the effect of cod end mesh sizes on the selectivities of the other main commercial finfish species, and to carry out an oceanographic survey of the western parts of the Falkland Islands shelf.

1.1 Cruise Objectives

- To experimentally trial 4 cod ends with differing diamond mesh size (90 mm, 110 mm, 120 mm, 140 mm) in order to identify the mesh size that results in the most efficient retention of commercially sized rock cod.

- To examine the effect of cod end mesh sizes on the selectivities of the other main commercial finfish species.

- To carry out an oceanographic survey of the western parts of the Falkland Islands shelf.

1.2 Cruise Plan and Key Dates

The *RV Castelo* left Stanley at 1900 hrs on 5th November, steamed over night to the fishing grounds and started fishing at 1100 on 6th November. Initially, four trawls were conducted per day, each with different mesh sizes. On the first day the trawl duration was 60 min but it was found that catches were too small. Our intention was to try and fish as close as possible to commercial practices. Over the following three days (7th – 9th), trawl duration increased to 1.5 hrs, but, catches were still not considered adequate so on the 10th, trawl duration was increased to 4hrs and trawl number was reduced to 3/day for the remainder of the cruise. The vessel returned to Stanley at 0800 on the 22nd November. The cruise was not without incident, a crew member broke his leg whilst shooting the first trawl on the 13th November and the vessel had to steam to Stanley so he could receive medical attention. The cruise therefore lost one day. The weather was extremely good with most of the cruise experiencing light winds and calm seas.

Figure 1 illustrates the positions of trawl and oceanographic stations.

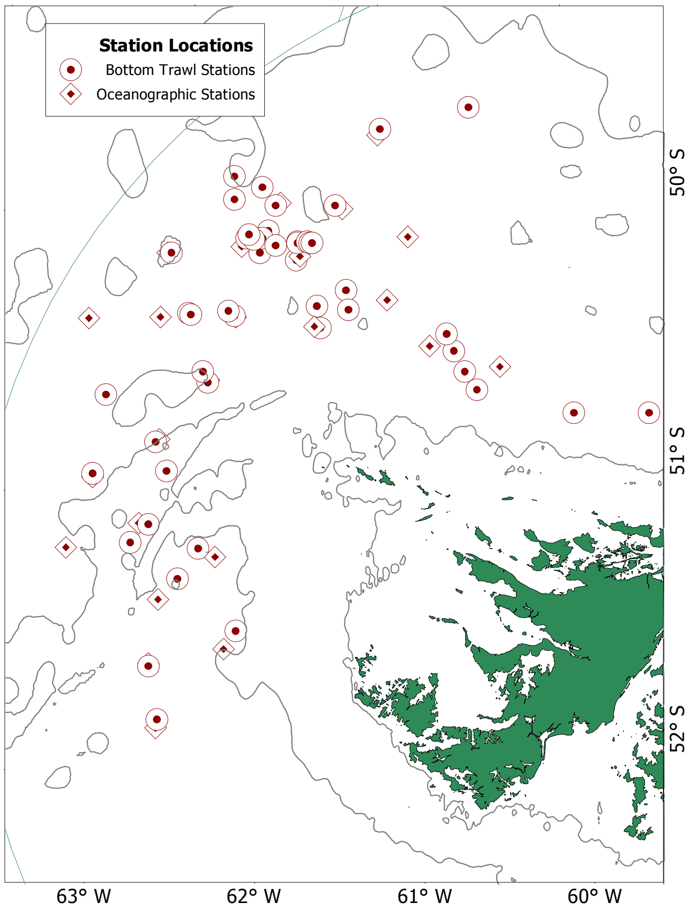


Figure 1: Trawl and Oceanographic stations conducted during ZDLT1-11-2011

1.3 Vessel Characteristics

Table 1: Vessel characteristics

Callsign	ZDLT1
Length	67.78m
GRT	1,321
NRT	474
Crew	30

1.4 Personnel and responsibilities

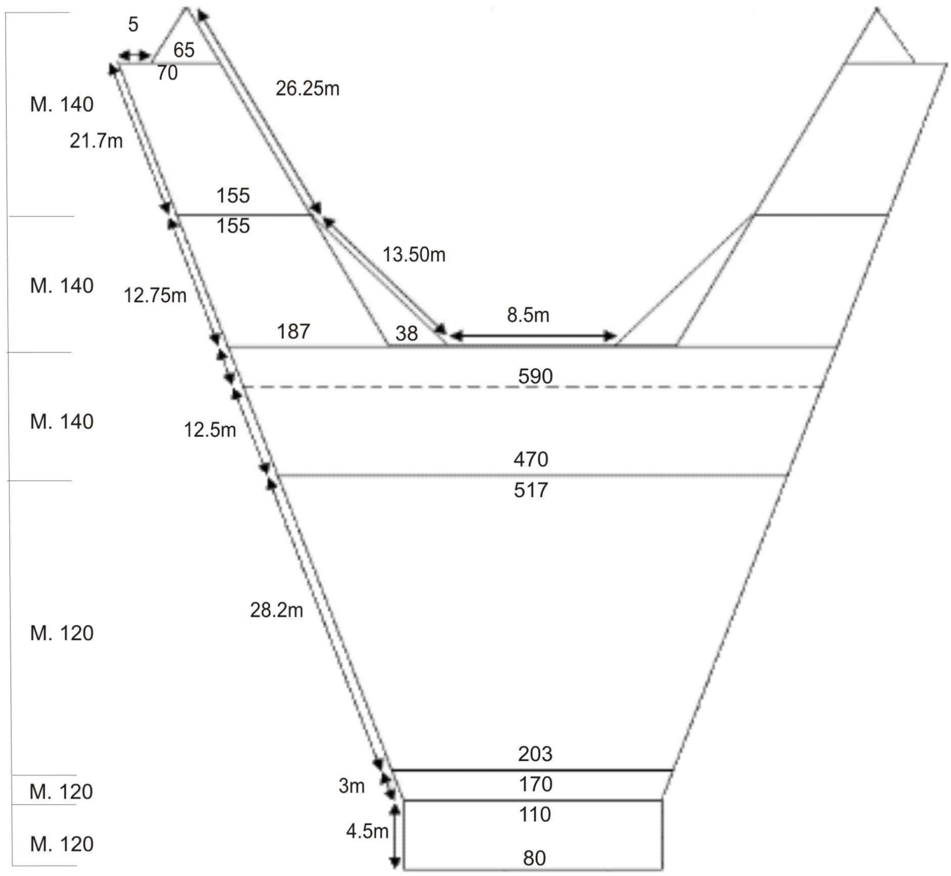
The following Fisheries Department staff participated in the cruise.

Dr. Paul Brickle	Chief Scientist
Dr. Andreas Winter	Oceanography/data analyses
Dr. Deborah Davidson	Trawl survey
Zhanna Shcherbich	Trawl survey
Lars Jürgens	Trawl survey

1.5 Equipment used

1.1.5 Trawling

At all stations a bottom trawl was used equipped with two 1800 kg Oval-Foil doors (OF-14). Four cod ends were used and were interchanged each trawl during the experimental period. The experimental design is described in section 1.7.1. The trawl did not employ any ground gear (e.g. bobbins/rockhoppers); instead the footrope consisted of a cable protected by cord. To increase the contact between the footrope and the seabed, an 8 m length of chain weighing 150 kg was attached to the footrope. Figure 2 illustrates the top and bottom panels of net used during for the experiments during this cruise.



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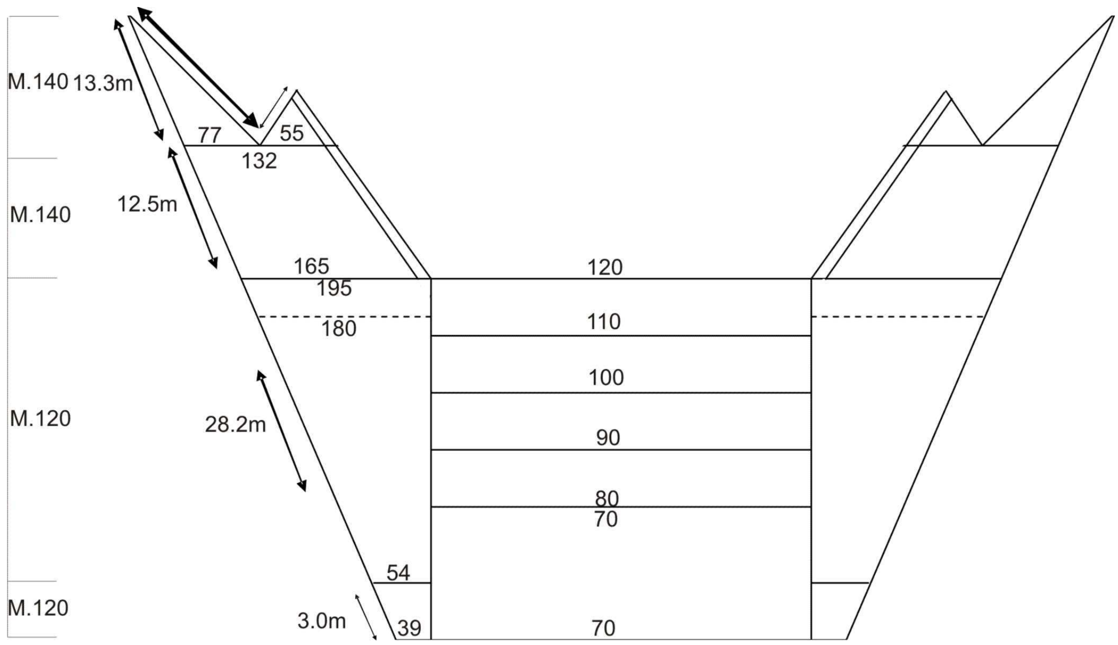


Figure 2: Top (a) and bottom (b) panel schematics of the bottom net used in ZDLT-11-2011

1.5.2 Oceanography

The oceanographic equipment used was the same as was used on previous surveys and included:

1. CTD SBE-25 with Sea Tech fluorometer and oxygen sensor.

1.6 Trawl stations and biological sampling

Forty-eight trawls and twenty-five CTD casts were taken during cruise ZDLT1-11-2011 (station-numbered 878 to 950; Table 2). Catches at most stations were weighed using an electronic marine adjusted balance (POLS, min 10 g, and max 80 kg) except when catches were greater than 5 tonnes. In this case all bycatch (all species except rock cod) was weighed on the POLS balance, but rock cod catch weight was estimated by determining the ratio of discard to retention from length frequency analysis of a catch subsample, then multiplying the factory production weight for that trawl by the ratio and the round weight conversion factor.

Finfish and skate were measured (L_T, L_{PA}, L_{DW}) to the nearest cm below and sex and stage of maturity were recorded for all specimens sampled. Individual weights were recorded with POLS and Marel balances.

Cephalopods were analysed for L_{DML}, sex, maturity and weight with statoliths extracted from sub samples.

Table 2: Trawl and Oceanographic stations conducted on ZDLT1-11-2011. Activity B: bottom trawl; activity C: CTD.

Station	Date	Time	Lat	Lon	Activity	Duration	Cod end
878	06/11/2011	11.05	-50.752	-60.553	B	60	90
879	06/11/2011	13.20	-50.685	-60.617	B	60	110
880	06/11/2011	15.20	-50.612	-60.677	B	60	120
881	06/11/2011	16.54	-50.588	-60.808	C	NA	NA
882	06/11/2011	17.45	-50.547	-60.707	B	60	140
883	07/11/2011	6.55	-50.413	-61.037	C	NA	NA
884	07/11/2011	8.05	-50.372	-61.260	B	60	90
885	07/11/2011	10.30	-50.423	-61.432	B	60	110
886	07/11/2011	13.25	-50.443	-61.255	B	90	120
887	07/11/2011	16.05	-50.503	-61.417	B	90	140
888	07/11/2011	19.20	-50.495	-61.453	C	NA	NA
889	08/11/2011	6.45	-50.253	-61.530	B	90	90
890	08/11/2011	9.05	-50.220	-61.732	B	90	110
891	08/11/2011	13.09	-50.242	-61.508	C	NA	NA
892	08/11/2011	13.45	-50.188	-61.518	B	90	120
893	08/11/2011	16.10	-50.142	-61.673	B	90	140
894	08/11/2011	19.45	-50.078	-61.253	C	NA	NA
895	09/11/2011	5.50	-50.047	-61.598	C	NA	NA
896	09/11/2011	6.10	-50.052	-61.628	B	90	90
897	09/11/2011	8.30	-50.022	-61.857	B	90	110
898	09/11/2011	11.00	-49.985	-61.697	B	90	120
899	09/11/2011	13.30	-49.940	-61.843	B	90	140
900	09/11/2011	19.27	-50.193	-60.898	C	NA	NA
901	10/11/2011	4.55	-50.190	-61.520	B	240	90
902	10/11/2011	9.45	-50.192	-61.462	B	240	110
903	10/11/2011	14.21	-50.193	-61.830	C	NA	NA
904	10/11/2011	15.00	-50.168	-61.710	B	240	120
905	11/11/2011	5.00	-50.163	-61.800	B	240	140
906	11/11/2011	9.43	-50.195	-62.248	C	1	NA
907	11/11/2011	10.00	-50.198	-62.223	B	240	90
908	11/11/2011	14.50	-50.168	-61.760	B	240	110
909	12/11/2011	4.40	-50.195	-61.640	B	240	120
910	12/11/2011	9.44	-50.442	-61.892	C	NA	NA
911	12/11/2011	9.55	-50.440	-61.893	B	240	140
912	12/11/2011	15.15	-50.197	-61.447	B	240	90
913	14/11/2011	9.40	-50.862	-59.585	B	240	110
914	14/11/2011	14.30	-50.853	-60.013	B	240	120
915	14/11/2011	19.37	-50.677	-60.418	C	NA	NA
916	15/11/2011	4.55	-50.197	-61.435	B	240	140
917	15/11/2011	9.55	-50.152	-61.783	B	240	90
918	15/11/2011	14.45	-50.422	-61.930	B	240	110
919	15/11/2011	19.25	-50.427	-62.313	C	NA	NA
920	16/11/2011	4.50	-50.417	-62.155	B	240	120
921	16/11/2011	9.30	-50.662	-62.063	C	NA	NA
922	16/11/2011	10.00	-50.670	-62.073	B	240	140
923	16/11/2011	15.00	-50.422	-62.140	B	240	90
924	17/11/2011	5.00	-50.632	-62.095	B	240	110
925	17/11/2011	9.50	-50.862	-62.368	C	NA	NA
926	17/11/2011	10.05	-50.870	-62.388	B	210	120
927	17/11/2011	14.50	-51.155	-62.523	C	NA	NA
928	17/11/2011	15.15	-51.162	-62.463	B	240	140

Station	Date	Time	Lat	Lon	Activity	Duration	Cod end
929	17/11/2011	20.00	-51.435	-62.442	C	NA	NA
930	18/11/2011	4.50	-51.367	-62.323	B	240	90
931	18/11/2011	10.05	-51.663	-62.527	C	NA	NA
932	18/11/2011	10.20	-51.672	-62.523	B	240	110
933	18/11/2011	15.05	-51.895	-62.515	C	NA	NA
934	18/11/2011	15.30	-51.863	-62.503	B	240	120
935	18/11/2011	20.57	-51.628	-62.088	C	NA	NA
936	19/11/2011	4.50	-51.570	-62.007	B	240	140
937	19/11/2011	9.38	-51.300	-62.102	C	NA	NA
938	19/11/2011	10.20	-51.265	-62.195	B	240	90
939	19/11/2011	15.15	-51.223	-62.575	B	240	110
940	19/11/2011	20.52	-51.225	-62.943	C	NA	NA
941	20/11/2011	4.55	-50.978	-62.343	B	240	120
942	20/11/2011	9.40	-50.980	-62.762	C	NA	NA
943	20/11/2011	10.00	-50.968	-62.758	B	240	140
944	20/11/2011	14.45	-50.690	-62.650	C	NA	NA
945	20/11/2011	15.00	-50.688	-62.648	B	240	90
946	20/11/2011	20.55	-50.408	-62.710	C	NA	NA
947	21/11/2011	4.40	-50.067	-61.295	B	240	110
948	21/11/2011	9.31	-49.823	-61.037	C	NA	NA
949	21/11/2011	9.50	-49.802	-61.020	B	240	120
950	21/11/2011	14.45	-49.740	-60.523	B	240	140

1.7 Cod end Mesh size – experimental methodology

1.7.1 Trawl and sampling procedure

This study compared catch (species) compositions, size distributions, and catch volumes among the four cod end meshes of 90, 110, 120, and 140 mm (Figure 3). The approach of this study differs from other tests of trawl selectivity (Engås and Godø, 1989; Godø et al., 1999; Munro and Somerton, 2001; Jørgensen et al., 2006) insofar as no net coverings or attachments were fitted that could be assumed to make any trawl 100% selective for all catch. The smallest mesh used (90 mm) is currently the minimum allowable size in the commercial finfish fishery. Results of this study thus represent estimates of relative, rather than absolute selectivity.

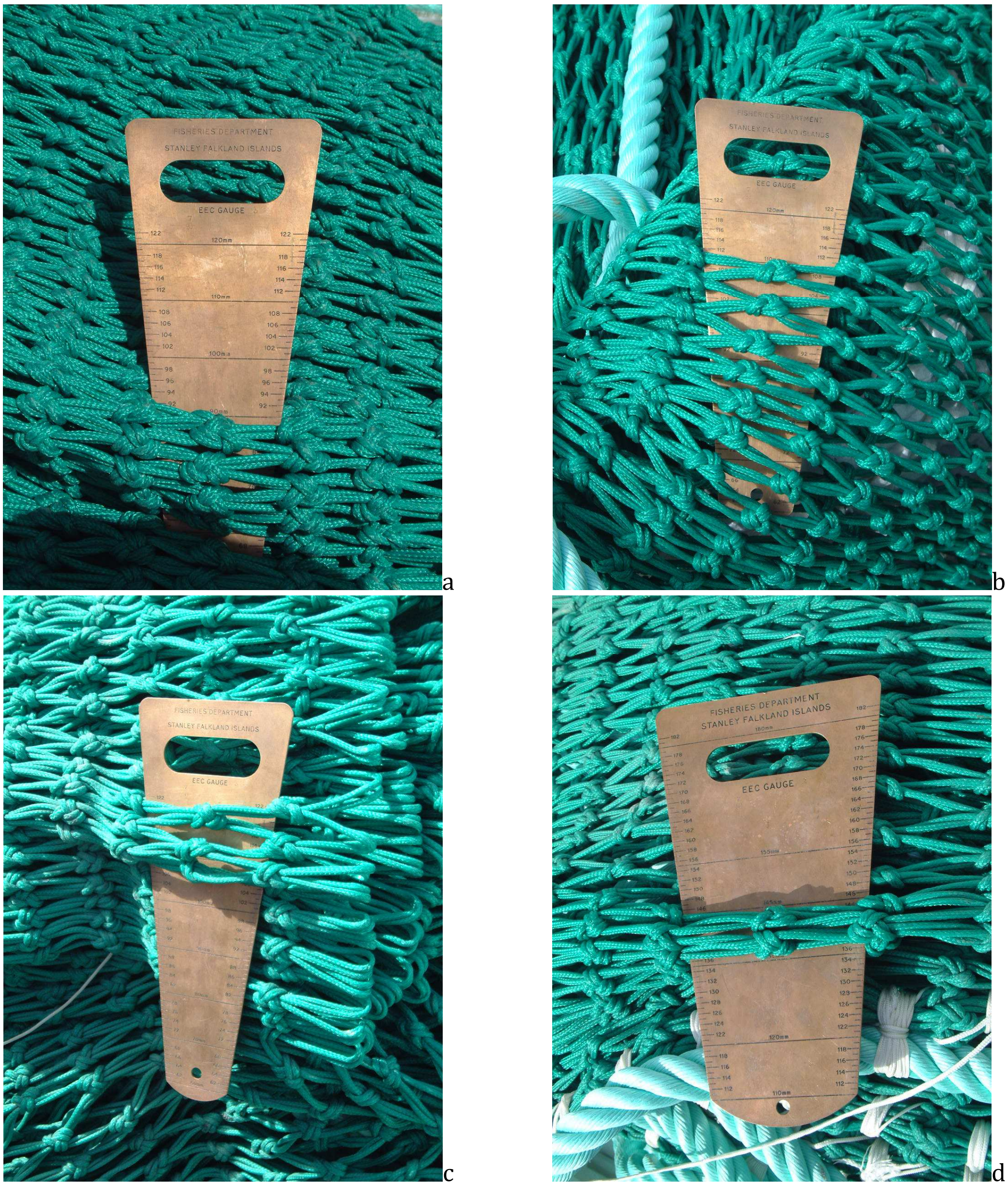


Figure 3: Cod ends used during ZDLT-11-2011; 90 mm (a), 110 mm (b), 120 mm (c) and 140 mm (d)

Each day's trawls were treated as one experimental unit, and therefore conducted in a concise area to cover the same assemblage of fish. A randomization test was carried out which confirmed that catch biomass proportions of rock cod, skate, hoki, and kingclip (the four most frequent species groups) had lower variability within days than among days.

On the first day the trawl duration was 60 min but it was found that catches were too small. Our intention was to try and fish similarly as possible to commercial practice. Over the next three days (7th – 9th), trawl duration increased to 1.5 hrs and this was still not considered enough so on the 10th November trawl duration was increased to 4hrs and trawl number was reduced to 3/day for the remainder of the cruise. For each station, all of the catch was weighed by the scientific crew unless the total exceeded *c.* 5 tonnes, in which case the catch was sub-sampled.

At each trawl station 200 rock cod were selected at random and sampled for length, sex, and maturity. When catches were sub-sampled a length frequency sample was also taken from the discard in order to estimate total catch. In this case total catch was determined by calculation based on the differences in length frequency between catch and discard, a length weight relationship and the processed weight of the catch modified by a conversion factor. All of the bycatch was weighed irrespective of total catch and 100 of each by-catch species were sampled for length frequency analysis if numbers permitted. Current scientific and collection protocols were fulfilled as time allowed.

Cod ends were switched after each trawl in the continuous rotation 90, 110, 120, and 140 mm. Cod ends were attached to the net by a zipper stitch through the extension piece, and switching cod ends took about 20 minutes for the deck crew (Figure 4). Cod ends were cleaned of debris before each redeployment.

Figure 4: A cod end being replaced during ZDLT1-11-2011

1.7.2 Statistical methodology

Selectivity estimates were based on the commonly used measure of fish body length (Millar, 1992). For each experimental unit (each day's set of trawls) and for each species group, the maximum number of fish per 1 cm size interval obtained in any of the set's trawls was considered the baseline number to have encountered every trawl in the set. Maximization over all trawls takes into account that smaller meshes are more retentive for smaller fish, but larger meshes are more retentive for larger fish as these can be harder to detect visually (Prchalová et al., 2009) and to outswim because of the lower back-pressure they generate (Broadhurst and Kennelly, 1995). Per trawl, the number of fish in each length interval was then divided by the set maximum to give the catch proportion. The relationship of length intervals vs. catch proportions was modelled with the logistic curve (Fryer, 1991; Jørgensen et al., 2006):

$$p(l) = \frac{\exp(a + bl)}{1 + \exp(a + bl)}$$

where *p(l)* is the probability that a fish of length *l* will be retained in the cod end, and parameters *a* and *b* define the selectivity curve. Capture probability lengths L_X (for example L_{50}, the length at which a fish has 50% probability of capture) are calculated by:

$$L_X = \left(\log\left(\frac{x}{1-x} \right) - a \right) \Big/ b$$

Parameters *a* and *b* were fit for each trawl by iterative optimization of the sum of squares difference between obtained catch proportions and model catch proportions. High length intervals were excluded if their catch proportions were erratic because of too few individuals. Small length intervals were scaled by the maximum number caught in any length interval (otherwise at least one trawl per set would show an unrealistic 100% selectivity in its smallest length intervals).

Variability of the selectivity curves was estimated by bootstrap re-sampling, with replacement, the fish lengths caught per trawl and re-optimizing parameters *a* and *b* as described above. Bootstraps were iterated 200× per trawl. The distributions of L_{50} values calculated from the bootstraps were used to examine the significance of differences among selectivity curves. Because many of these distributions were non-normal, ANOVA with multiple-range testing could not be used and instead trawls per day were compared pair-wise. For each pair of trawls, one thousand draws were matched randomly among the respective 200 bootstraps and the proportion computed for which one trawl's L_{50} values were greater than the other's. Significance was determined at $p < 0.10$, adjusted for the family-wise error rate. Days with four trawls resulted in six pair-wise comparisons and adjustment of:

$$n = C\binom{4}{2} = 6; \qquad p_{adj\,0.10} = 1 - (1 - 0.10)^{1/n} = 0.0174$$

Based on a two-tailed null hypothesis, L_{50} difference between two trawls was thus significant if either <9 or >991 of 1000 L_{50} bootstrap values were greater for one than the other. For days with three trawls:

$$n = C\binom{3}{2} = 3; \qquad p_{adj\,0.10} = 1 - (1 - 0.10)^{1/n} = 0.0345$$

and L_{50} difference between two trawls was significant if either <18 or >983 of 1000 bootstrap values were greater for one than the other. Boostrap re-sampling was carried out for the two most prevalent species groups: rock cod and skates.

The selectivity range SR determines the steepness of the selectivity curve and thereby how selective the gear is. The smaller the value the greater the selectivity. SR is determined by $L_{75} – L_{25}$.

Generalized linear models (GLM) were computed relating the L_{50} values of selectivity curves to potential predictor variables from the catches. Predictor variables tested were depth, latitude and longitude of the trawls, total catch, and catch proportions of rock cod and skate; the two most abundant species groups. Because selectivity curves are based on a summary of each day's (usually 3 or 4) trawls, GLMs were calculated separately by mesh size, to avoid the autocorrelation among different meshes on the same days. Predictor variables were added to the GLMs by forward selection. First, GLMs were calculated with each single predictor variable. Then, the GLM with the lowest Akaike information criterion (AIC) was retained and in turn each remaining other variable was added. The two-variable GLM with the lowest AIC was again retained, and this process continued until adding any further variable failed to decrease the AIC. The variables of total catch, and rock cod or skate catch proportions, could be parameterized either by trawl or by day. Both versions were tested, but in any given GLM only one or the other was included as the two versions are autocorrelated. GLMs were fit on the Gaussian distribution with the vectors of L_{50} values weighted by inverse variance.

2.0 Oceanography

2.1 Methods

A logging CTDO (SBE-25, Sea-Bird Electronics Inc., Bellevue, USA) was deployed from the surface to near-bottom at c. 1 m/s to obtain profiles of temperature (ºC), salinity (PSU), and dissolved oxygen (ml l^{-1}). The CTD was deployed for the first minute at about 10-11 m depth. It was then retrieved to 1 m depth and deployed again. For each station, vertical profiles of temperature, salinity, chlorophyll A, and density were constructed using the Seasoft software. Iso-surfaces were constructed using the VG gridding method including in the Ocean Data View package v. 3.4.3-2009 (Schlitzer 2009).

CTD data were collected at 25 stations, either before or after the trawls. Depths ranged from 142 to 242 m (Figure 5).

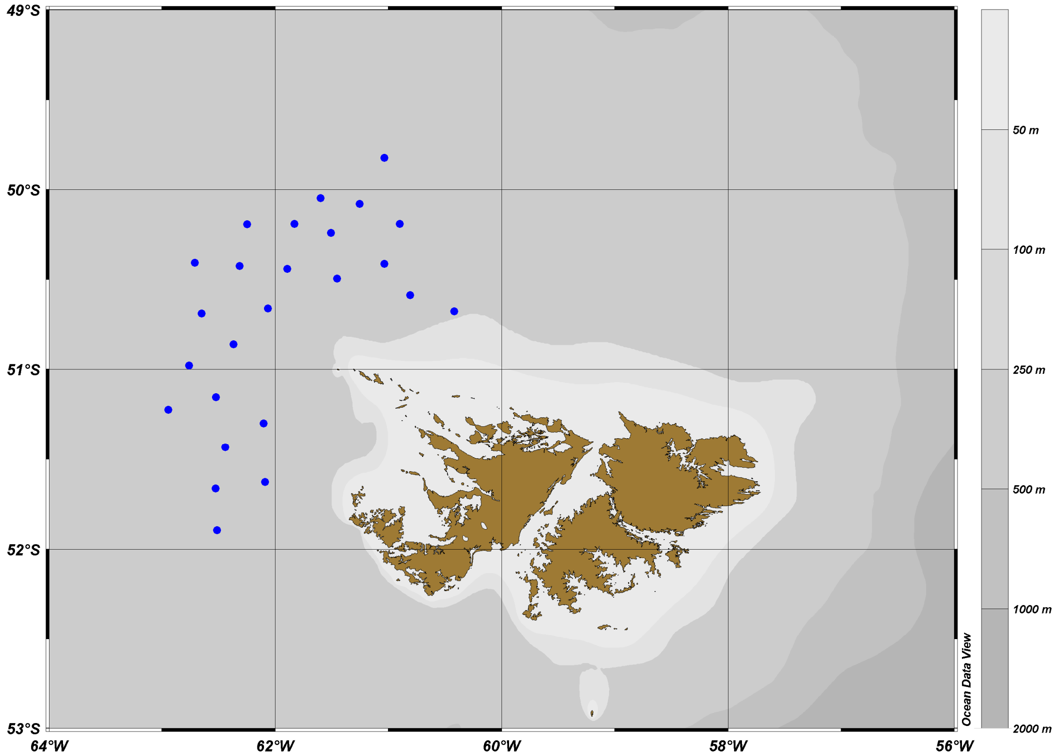


Figure 5: Oceanographic stations conducted on ZDLT1-11-2011

2.2 Results

The oceanographic survey assessed the oceanographic situation over the west part of the Falkland shelf and to reveal environmental factors influencing distribution and biology of the Falkland rock cod, *Patagonotothen ramsayi*. Surface temperatures ranged from 7.4º to 9.6ºC, surface salinity from 33.10 to 33.76 psu, and densities from 25.68 to 26.71 kg/m^3. T-S curves are shown on Figure 6.

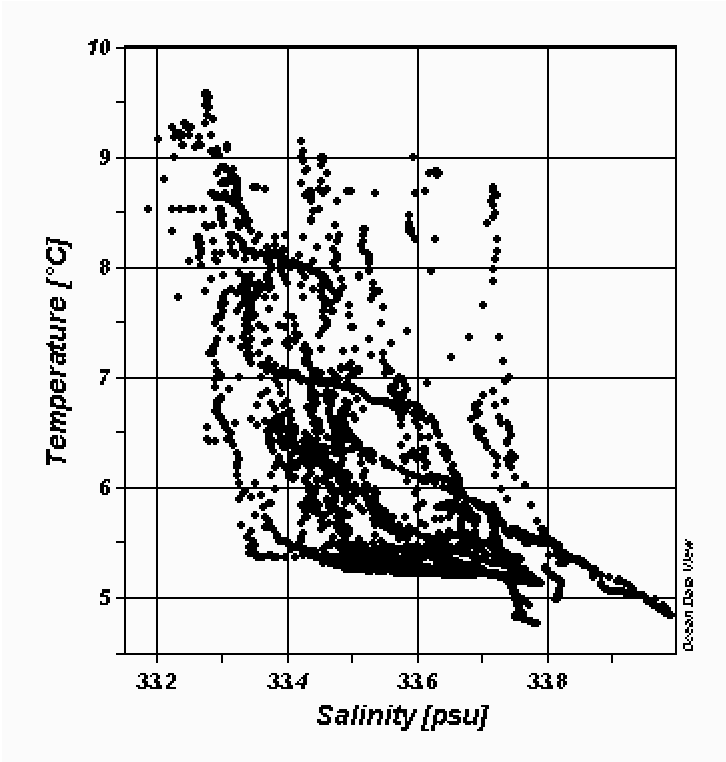
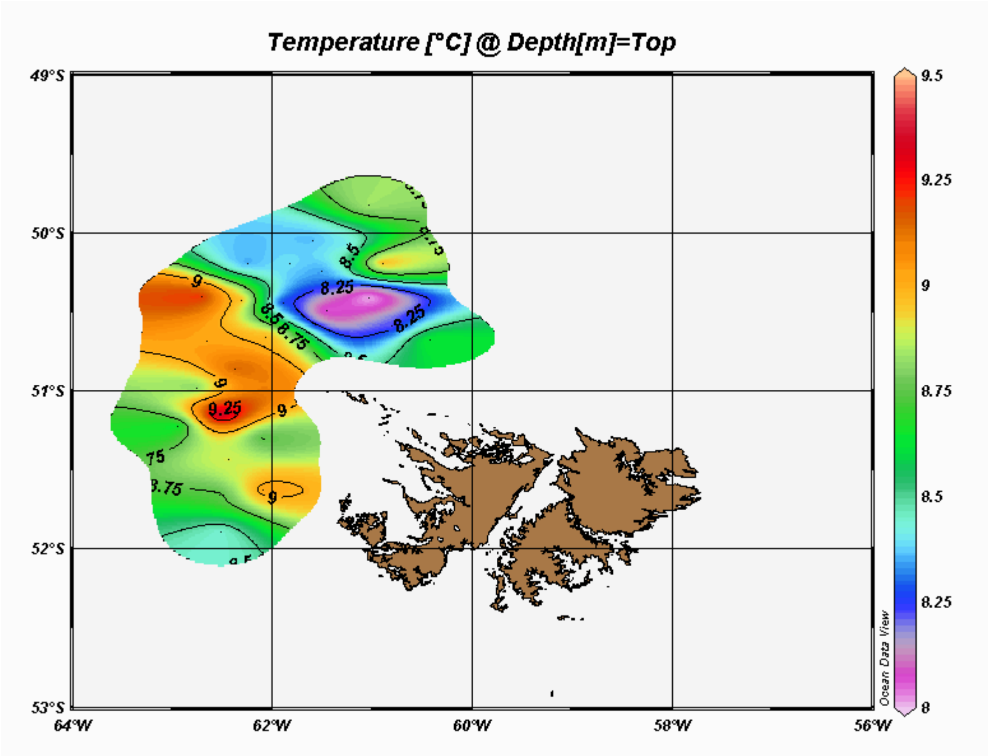


Figure 6: T-S curves calculated on the western shelf for ZDLT1-11-2011

The distribution of surface and bottom temperatures and salinities are shown in Figures 7 and 8. This was a period of positive surface temperature anomalies which was likely related to warmer air temperatures. Shelf waters had very low salinities, the lowest since our observations began in 1998. However, the position of the frontal zone between the Falkland shelf water exhibited a "tongue" of relatively fresh and warm waters from the Argentinean shelf and this was in the same place as usual for this time of year. An intensive upwelling – sinking couple was present between 50°S and 50°45'S across the front.

The recent trend of a "freshening" of shelf water was recorded over the whole year 2011 at transects P1 (east of the islands) and P5 (south of the islands), and was probably related to Antarctic ice melting rather than to changes in water circulation.



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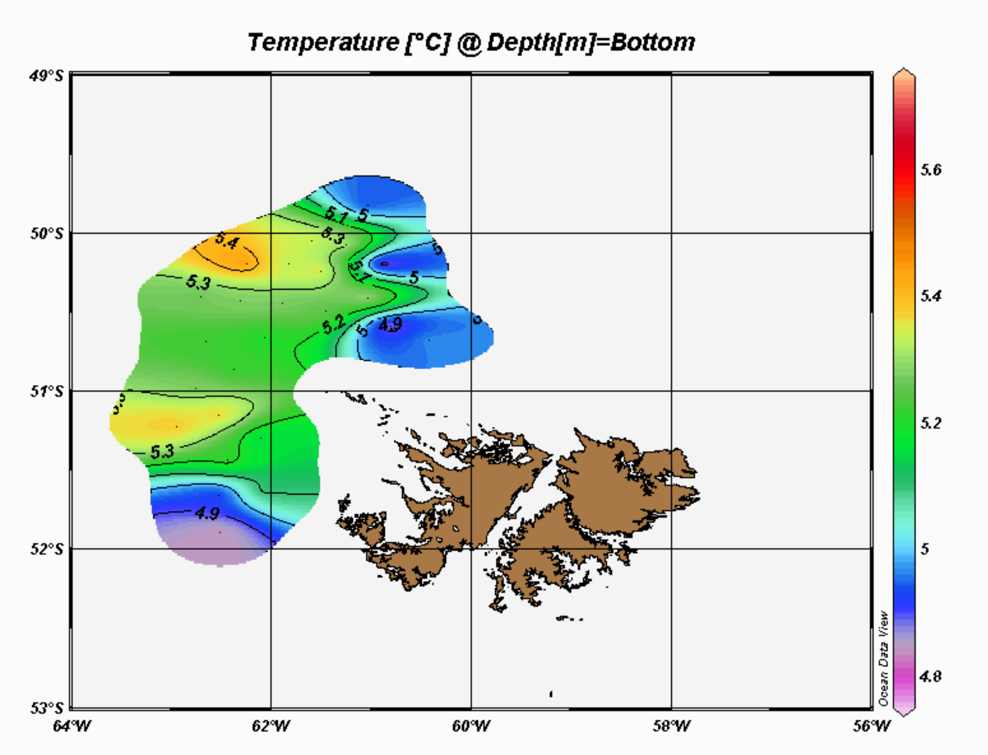
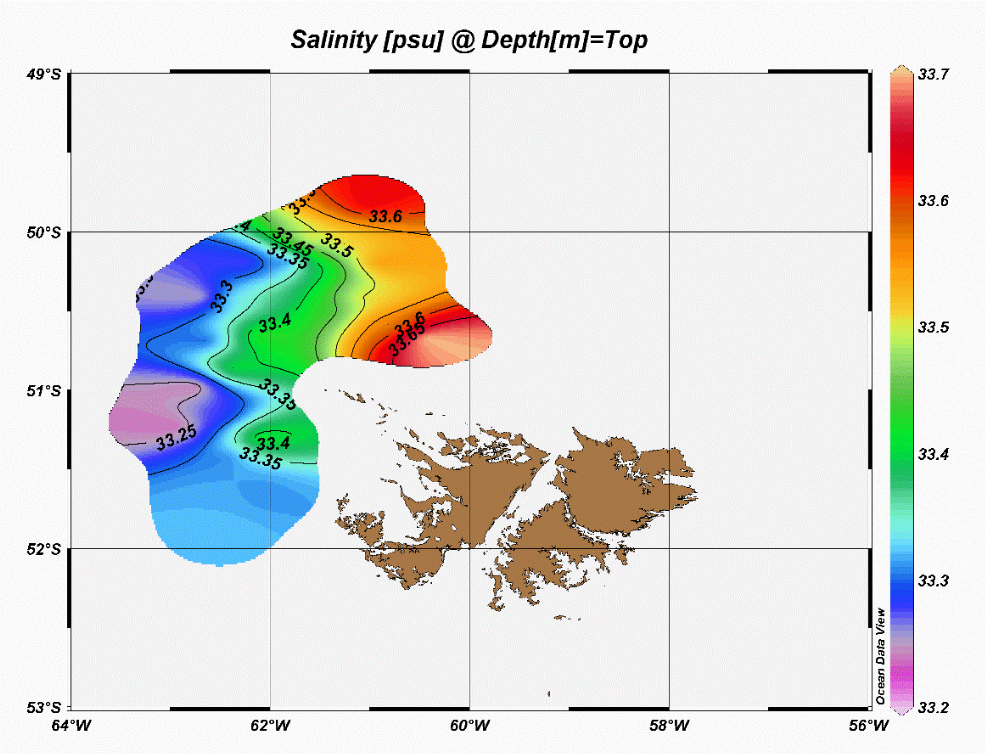


b

Figure 7: Distribution of SST (a) and bottom temperature during ZDLT1-11-2011 (b)



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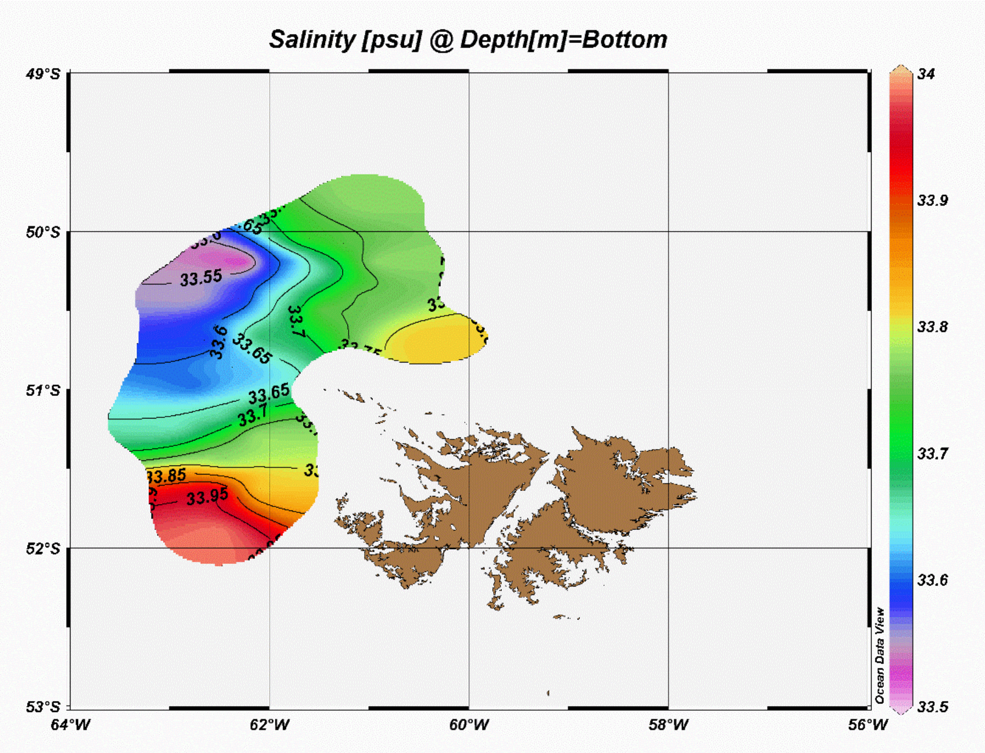

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Figure 8: Distribution of surface salinity(a) and bottom salinity during ZDLT1-11-2011 (b)

3.0 Biological sampling

3.1 Catch and by-catch

During the cruise a total of 241 tonnes were caught comprising more than 55 species (Table 3). In terms of catch weight, the most abundant species were rock cod (*Patagonotothen ramsayi*), broad nose skate (*Bathyraja brachyurops*), common hake (*Merluccius hubbsi*), kingclip (*Genypterus blacodes*) and frogmouth (*Cottoperca gobio*). Together these amounted to 89% of the catch. There was a much larger skate by-catch compared to previous surveys amounting to 32 tonnes (13% of the total catch). This result is significant as flat-bodied fish, in particular, may block meshes and prevent the escape of round-bodied fish (Ryer, 2008).

Table 3: Total catch of all trawl stations during research cruise ZDLT-11-2011

Species code	Species name	Catch (kg)	Sample (kg)	Discard (kg)	Proportion (%)
PAR	*Patagonotothen ramsayi*	178443.31	2446.20	68625.96	74.039
RBR	*Bathyraja brachyurops*	19963.26	8178.23	822.02	8.283
HAK	*Merluccius hubbsi*	6014.34	4281.05	0.00	2.495
KIN	*Genypterus blacodes*	5720.67	2890.87	8.64	2.374
CGO	*Cottoperca gobio*	4871.27	2273.27	4871.27	2.021
BAC	*Salilota australis*	4730.94	1114.68	909.06	1.963
WHI	*Macruronus magellanicus*	4285.69	1956.59	790.94	1.778
RFL	*Dipturus chilensis*	4069.49	1885.03	119.86	1.689
RMC	*Bathyraja macloviana*	3903.02	1812.05	479.50	1.619
SHT	Mixed invertebrates	2014.00	0.00	2014.00	0.836
RPX	*Psammobatis spp.*	1848.34	1052.43	1777.18	0.767
RGR	*Bathyraja griseocauda*	1182.72	459.62	95.52	0.491
LOL	*Loligo gahi*	863.34	323.24	114.41	0.358
RAL	*Bathyraja albomaculata*	796.48	403.35	25.89	0.330
DGH	*Schroederichthys bivius*	619.64	543.34	619.64	0.257
DGS	*Squalus acanthias*	337.22	291.16	337.22	0.140
TOO	*Dissostichus eleginoides*	263.40	238.76	3.25	0.109
GRF	*Coelorhynchus fasciatus*	255.13	44.92	255.13	0.106
RMU	*Bathyraja multispinis*	143.48	95.03	1.24	0.060
RDO	*Amblyraja doellojuradoi*	124.58	94.63	124.58	0.052
RSC	*Bathyraja scaphiops*	79.99	48.84	3.53	0.033
NEM	*Neophyrnichthys marmoratus*	78.83	18.66	78.83	0.033
POR	*Lamna nasus*	49.22	49.22	0.00	0.020
ING	*Moroteuthis ingens*	45.88	10.41	38.90	0.019
PAT	*Merluccius australis*	44.37	44.37	0.00	0.018
RBZ	*Bathyraja cousseauae*	36.83	21.98	0.00	0.015
SAR	*Sprattus fuegensis*	35.52	14.96	35.52	0.015
RDA	*Dipturus argentinensis*	32.34	32.34	0.00	0.013
OCM	*Enteroctopus megalocyathus*	22.91	5.89	17.02	0.010
SPN	Porifera	18.40	0.00	18.40	0.008
MUE	*Muusoctopus eureka*	18.25	17.23	1.02	0.008
BUT	*Stromateus brasiliensis*	13.66	1.55	13.66	0.006
RMG	*Bathyraja magellanica*	12.12	12.12	3.88	0.005
EEL	*Iluocoetes fimbriatus*	11.33	0.00	11.33	0.005
COP	*Congiopodus peruvianus*	10.19	5.49	7.42	0.004

Species code	Species name	Catch (kg)	Sample (kg)	Discard (kg)	Proportion (%)
ILL	*Illex argentinus*	9.49	9.49	0.00	0.004
BLU	*Micromesistius australis*	9.43	8.08	9.43	0.004
RED	*Sebastes oculatus*	7.78	7.04	4.18	0.003
AUL	*Austrolycus laticinctus*	6.71	6.71	6.71	0.003
MUL	*Eleginops maclovinus*	6.58	3.84	6.58	0.003
MED	Medusae sp.	5.60	0.00	5.60	0.002
ALC	Alcyoniina	1.15	1.13	0.02	0.000
MUG	*Munida gregaria*	1.04	1.04	0.00	0.000
COT	*Cottunculus granulosus*	0.87	0.00	0.87	0.000
MLA	*Muusoctopus longibrachus akambei*	0.63	0.63	0.00	0.000
SRP	*Semirossia patagonica*	0.56	0.56	0.00	0.000
LIA	*Lithodes antarcticus*	0.38	0.00	0.38	0.000
GOR	Gorgonacea	0.33	0.00	0.33	0.000
MUU	*Munida subrugosa*	0.27	0.10	0.17	0.000
CHE	*Champsocephalus esox*	0.23	0.23	0.00	0.000
COG	*Patagonotothen guntheri*	0.11	0.11	0.00	0.000
PYM	*Physiculus marginatus*	0.04	0.00	0.04	0.000
PYX	Pycnogonida	0.02	0.02	0.00	0.000
AGO	*Agonopsis chilensis*	0.02	0.02	0.00	0.000
KOL	*Kondakovia longimana*	0.01	0.01	0.00	0.000
	Total	**241011.39**	**30706.51**	**82259.13**	**100.000**

4.0 Mesh trial and selectivity results

A total of 48 trawls were conducted during the cruise with 12 replicates each for the 90 mm, 110 mm, 120 mm and 140 mm cod end mesh sizes. Rock cod was the most dominant species in terms of total catch followed by skates.

4.1 Patagonotothen ramsayi (Patagonian rock cod)

4.1.1 Mean L_T *vs* mesh size

Over the whole survey median L_T increased with increasing mesh size, and differences were significant pair-wise between all mesh sizes (Kruskal-Wallis and Dunn's post test; K-W = 735.5; $P<0.001$) (Table 4).

Table 4: Results of a Kruskal-Wallis test and Dunn' post test to examine the median L_T of *Patagonotothen ramsayi* between mesh size treatments on ZDLT1-11-2011

	90mm	110mm	120mm	140mm
Number of values	2932	2443	2727	1766
Minimum	10	8	13	11
25% Percentile	22	24	24	25
Median	25	26	26	27
75% Percentile	27	28	29	29
Maximum	36	39	41	43
Mean	24.25	25.96	26.47	27.05
Std. Deviation	3.653	3.866	3.62	3.551
Std. Error	0.06747	0.07821	0.06932	0.08451
Lower 95% CI of mean	24.11	25.81	26.34	26.88
Upper 95% CI of mean	24.38	26.12	26.61	27.21
Kruskal-Wallis test				
P value	P<0.0001			
Exact or approximate P value?	Gaussian Approximation			
P value summary	***			
Do the medians vary signif. (P < 0.05)	Yes			
Number of groups	4			
Kruskal-Wallis statistic	735.5			
Dunn's Multiple Comparison Test	Difference	P value	Summary	
90mm vs 110mm	-1274	P < 0.001	***	
90mm vs 120mm	-1558	P < 0.001	***	
90mm vs 140mm	-2090	P < 0.001	***	
110mm vs 120mm	-284	P < 0.001	***	
110mm vs 140mm	-816.8	P < 0.001	***	
120mm vs 140mm	-532.8	P < 0.001	***	

4.1.2 Selectivity

Selectivity curves were calculated for rock cod on each trawl and are presented in Appendix 1. Figure 9 illustrates the mean selectivity curves for rock cod over the entire trip. The selectivity curves indicate an increase in average L_{50} with increasing mesh size: 15.35cm, 17.10cm, 18.81cm and 25.50cm for 90mm, 110mm, 120mm and 140mm respectively. Differences were statistically significant except for 90-110 and 110-120 mm (Figure 10). Mean sizes (L_T) in these trawls were 24.25cm, 25.96cm, 26.47cm and 27.05cm respectively (Table 4).

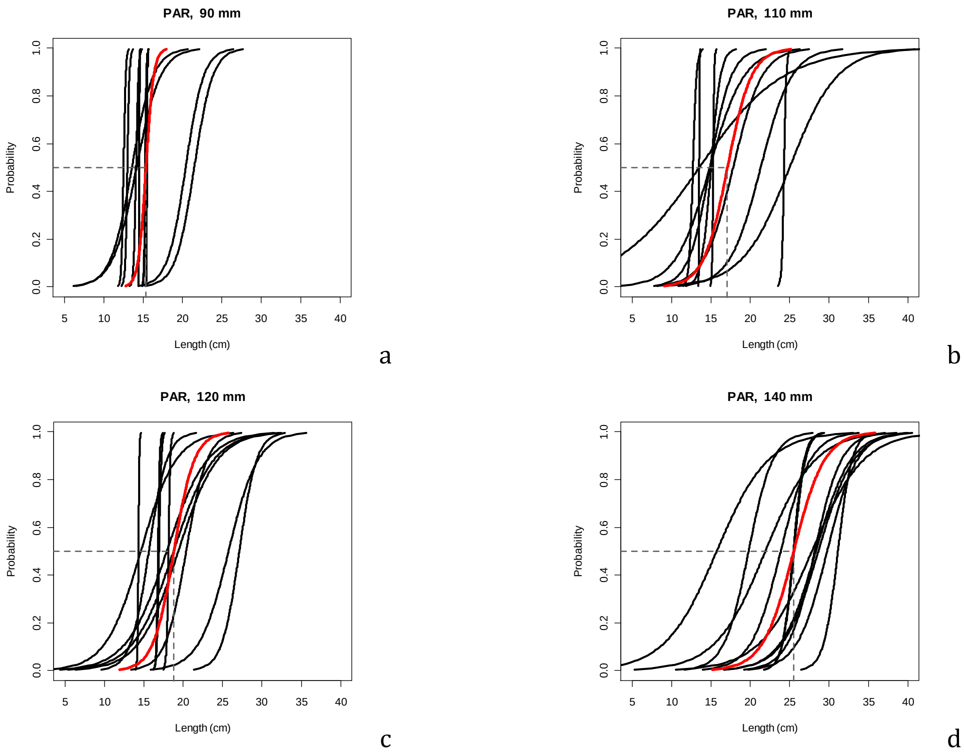


Figure 9: Mean selectivity curves for *Patagonotothen ramsayi* for 90 mm (a), 110 mm (b), 120 mm (c) and 140 mm (d) cod end mesh sizes.

Estimates of modelled selectivity parameters for *P. ramsayi* by individual trawl are given in Table 5.

Table 5: Modelled selectivity parameters of *Patagonotothen ramsayi* determined during ZDLT1-11-2011

Station	Cod end Treatment	aa	bb	L25	L50	L75	SR
878	90	-97.392	7.492	12.853	13.000	13.147	5.655
884		-17.952	0.880	19.146	20.394	21.642	20.762
889		-18.370	0.855	20.195	21.479	22.764	21.909
896		-570.307	36.795	15.470	15.499	15.529	-21.266
901		-10.100	0.744	12.097	13.573	15.049	14.305
907		-96.925	6.874	13.941	14.101	14.261	7.387
912		-9.388	0.663	12.510	14.168	15.826	15.164
917		-95.850	7.658	12.373	12.516	12.659	5.001
923		-605.520	41.759	14.474	14.500	14.527	-27.233
930		-193.042	12.643	15.182	15.269	15.356	2.713
938		-202.799	13.269	15.201	15.283	15.366	2.097
945		-615.553	42.452	14.474	14.500	14.526	-27.927
879	110	-11.068	0.744	13.399	14.875	16.352	15.608
885		-8.320	0.333	21.684	24.983	28.282	27.949
897		-10.860	0.510	19.157	21.313	23.468	22.959
902		-6.867	0.462	12.479	14.855	17.232	16.770
908		-2.553	0.189	7.706	13.528	19.351	19.162
913		-54.287	4.272	12.450	12.707	12.964	8.692
918		-24.946	1.662	14.351	15.012	15.673	14.011
924		-489.332	36.246	13.470	13.500	13.531	-22.715

932		-165.041	6.796	24.123	24.285	24.447	17.651
939		-9.742	0.547	15.809	17.819	19.828	19.282
947		-212.122	13.872	15.212	15.291	15.371	1.499
880	120	-7.845	0.405	16.665	19.379	22.093	21.688
886		-150.056	8.275	18.000	18.133	18.266	9.990
892		-6.583	0.450	12.182	14.623	17.063	16.612
898		-13.839	0.537	23.705	25.749	27.793	27.256
904		-13.778	0.881	14.391	15.638	16.885	16.004
909		-226.205	15.804	14.243	14.313	14.382	-1.422
914		-120.591	7.117	16.789	16.943	17.097	9.980
920		-15.434	0.757	18.926	20.376	21.826	21.069
926		-153.108	9.107	16.692	16.813	16.934	7.827
934		-24.794	0.914	25.920	27.122	28.324	27.410
941		-7.410	0.395	15.991	18.775	21.558	21.163
949		-7.001	0.391	15.107	17.919	20.731	20.340
882	140	-12.836	0.453	25.886	28.309	30.732	30.278
887		-37.053	1.456	24.698	25.453	26.208	24.752
893		-35.551	1.392	24.751	25.540	26.330	24.938
899		-12.692	0.443	26.148	28.626	31.104	30.660
905		-8.531	0.307	24.229	27.811	31.392	31.085
911		-4.816	0.306	12.146	15.735	19.325	19.019
916		-12.759	0.535	21.805	23.859	25.914	25.379
922		-12.954	0.655	18.102	19.779	21.457	20.802
928		-16.712	0.593	26.322	28.174	30.026	29.433
936		-34.949	1.123	30.139	31.117	32.095	30.972
943		-6.966	0.318	18.450	21.905	25.359	25.041
950		-15.704	0.528	27.664	29.745	31.826	31.298

These data indicated a large between haul L_{50} and SR variation within and between treatment groups (mesh sizes) suggesting that factors other than just mesh size are contributing to L_{50} and SR. Figure 10 illustrates the haul by haul L_{50} for each day of the cruise and highlights this variation well.

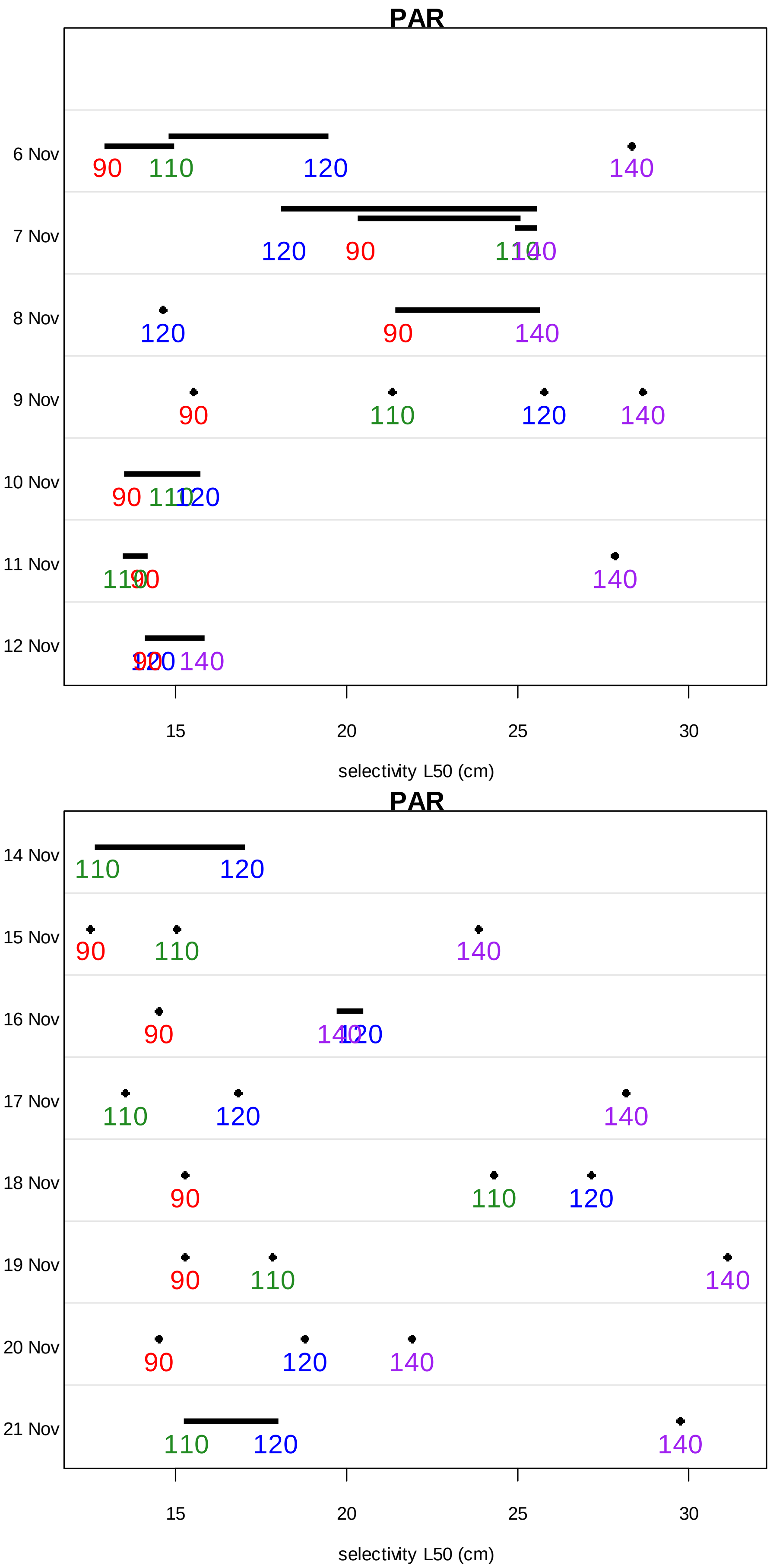


Figure 10: L_{50} per station per day on ZDLT1-11-2011. Black bars indicate no significant difference between treatments.

Mean rock cod CPUEs were 1769 kg/hr, 854 kg/hr, 1528 kg/hr and 347 kg/hr for 90mm, 110mm, 120mm, and 140mm cod ends respectively. The CPUE was significantly different between 90 mm and 140 mm mesh trawls (Kruskal-Wallis and Dunn's post test; $P<0.05$; K-W = 9.335; difference in rank sum = 16.67) but not for the remainder of the comparisons.

4.1.3 Factors affecting *P. ramsayi* selectivity

L_{50} and SR were compared against total catch. The general trends were a decreasing L_{50} and an increasing SR with increasing total catch for each mesh size (Figure 11). None of these relationships were significant (Spearman Rank Order Correlation) with the exception of L_{50} and total catch for the 140mm mesh size ($P<0.05$; SR = -0.678).

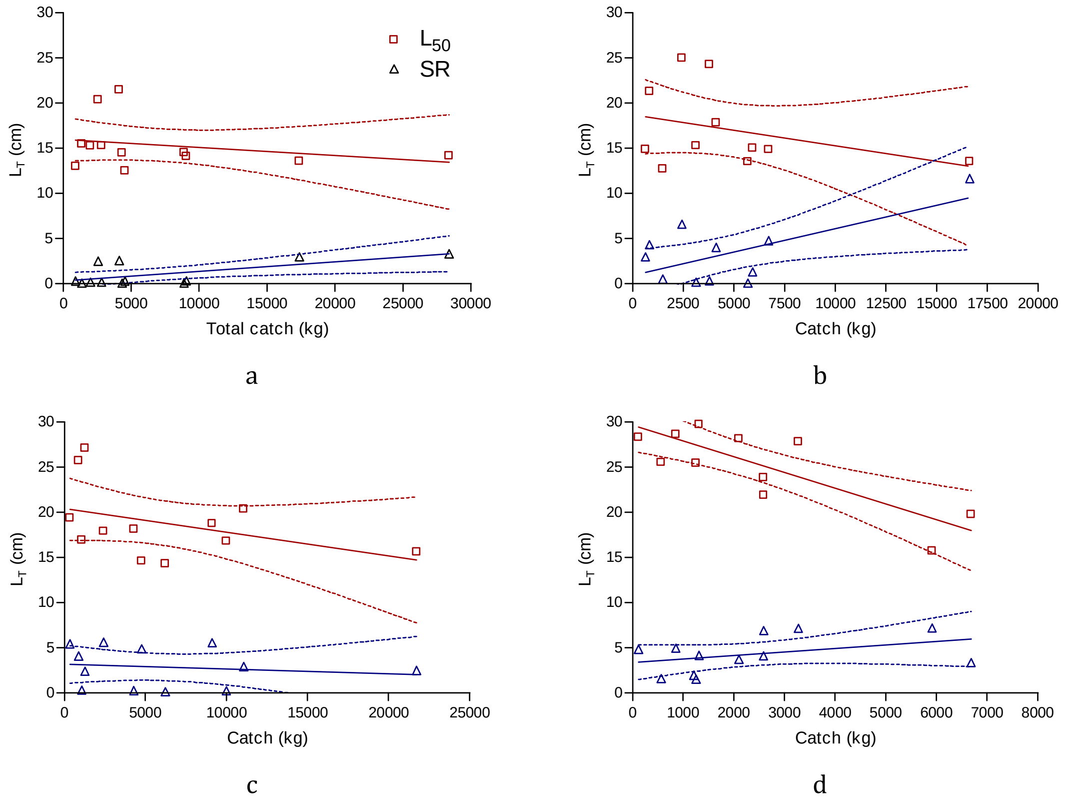


Figure 11: Spearman Rank Order Correlation between total catch, L_{50} and SR for 90mm (a), 110mm (b), 120mm (c) and 140mm (d)

For rock cod, L_{50} values had a positive GLM relationship with depth in 3 of the 4 mesh categories. L_{50} values had a negative GLM relationship with either total catch by day, or total catch by trawl, in 3 of the 4 mesh categories. The one mesh that did not have a significant relationship with either depth or total catch was 120 mm. L_{50} had a positive relationship with PAR proportion (by day or by trawl) at 90 and 110 mm, but a negative relationship with PAR proportion at 120 and 140 mm. (Table 6).

Table 6: GLM results relating L50 to predictor variables from the catches for *Patagonotothen ramsayi* during ZDLT1-11-2011

Rock cod, 90 mm mesh.

Variable	Coefficient	*p*
Depth	5.44E-02	<0.005
Latitude	1.23E-02	0.177
Day Total catch	–09.53e-5	0.079
Day PAR proportion	3.63E-02	0.201
N: 12	R2: 0.772	

Rock cod, 110 mm mesh.

Variable	Coefficient	*p*
Depth	2.20E-01	<0.001
Trawl Total catch	–02.15e-3	<0.001
Trawl PAR proportion	1.66E-01	0.011
N: 11	R2: 0.938	

Rock cod, 120 mm mesh.

Variable	Coefficient	*p*
Longitude	–03.10e-2	0.073
Trawl PAR proportion	–11.01e-2	<0.001
N: 12	R2: 0.816	

Rock cod, 140 mm mesh.

Variable	Coefficient	*p*
Depth	9.42E-02	0.021
Longitude	1.54E-02	0.169
Day Total catch	–02.11e-4	0.068
Trawl PAR proportion	–03.05e-2	0.134
N: 12	R2: 0.870	

4.2 Rajidae *(skates)*

4.2.1 Mean L_T *vs* mesh size

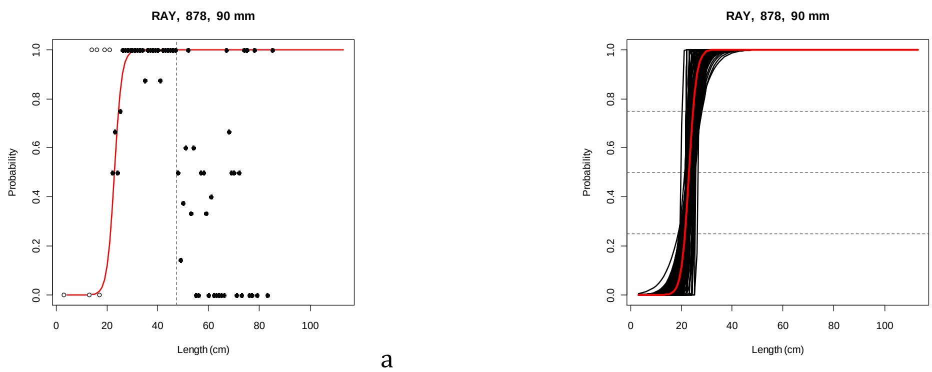
Skate species were pooled under RAY (Rajidae) for the purposes of these analyses. Over the whole survey median L_T increased with increasing mesh size, and differences were significant pair-wise between all mesh sizes (Kruskal-Wallis and Dunn's post test; K-W = 73.55; $P<0.001$) (Table 7).

Table 7: Results of a Kruskal-Wallis test and Dunn' post test to examine the median L_T of Rajidae species between mesh size treatments on ZDLT1-11-2011

Number of values	2290	2290	2290	2290
Minimum	8	7	10	10
25% Percentile	22	23	24	25
Median	28.5	31	33	34
75% Percentile	43	43	45.5	47
Maximum	83	89	94	82
Mean	33.31	33.79	35.47	35.97
Std. Deviation	14.31	13.66	13.93	13.95
Std. Error	0.299	0.2854	0.2911	0.2916
Lower 95% CI of mean	32.72	33.23	34.9	35.39
Upper 95% CI of mean	33.89	34.35	36.04	36.54
Kruskal-Wallis test				
P value	P<0.0001			
Exact or approximate P value?	Gaussian Approximation			
P value summary	***			
Do the medians vary signif. (P < 0.05)	Yes			
Number of groups	4			
Kruskal-Wallis statistic	73.55			
Dunn's Multiple Comparison Test	Difference	P value	Summary	
90mm vs 110mm	-162.4	P < 0.001	***	
90mm vs 120mm	-482.3	P < 0.001	***	
90mm vs 140mm	-587.3	P < 0.001	***	
110mm vs 120mm	-319.8	P < 0.001	***	
110mm vs 140mm	-424.9	P < 0.001	***	
120mm vs 140mm	-105	P < 0.001	***	

4.2.2 Selectivity

Selectivity curves were calculated for skates on each trawl and are presented in Appendix 2. Figure 12 illustrates the selectivity curves and bootstrap re-samples for skate on the first day on the cruise. L_{50} increased with increasing mesh size, averaging 27.41cm, 29.59cm, 29.64cm and 32.15cm for 90mm, 110mm, 120mm and 140mm respectively. Mean sizes (L_T) in these trawls were 33.31 cm, 33.79 cm, 35.47 cm and 35.97 cm respectively (Table 7).



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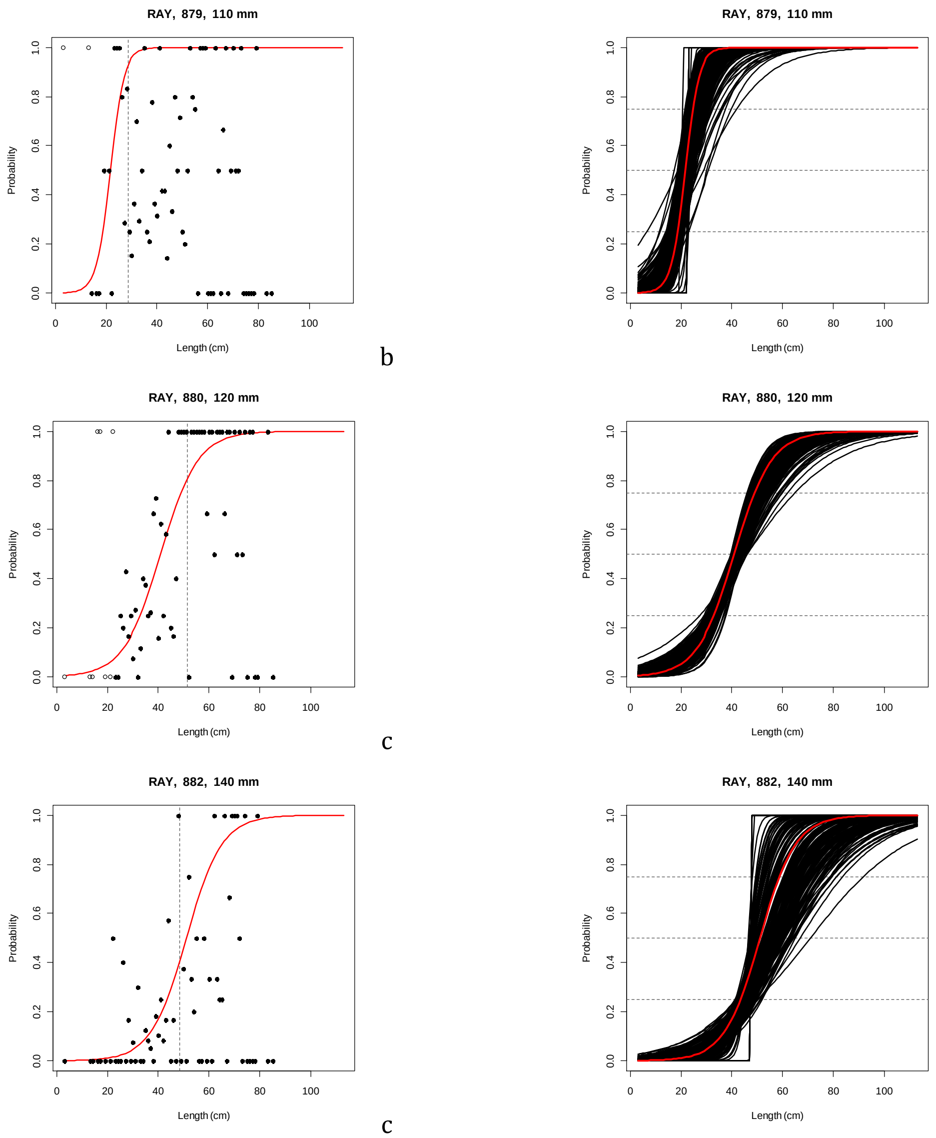


Figure 12: Selectivity curves for Rajidae for 90 mm (a), 110 mm (b), 120 mm (c) and 140 mm (d) cod end mesh sizes. Figures on the left show the optimized selectivity curves; figures on the right show bootstrap variations generated by randomly re-sampling the data.

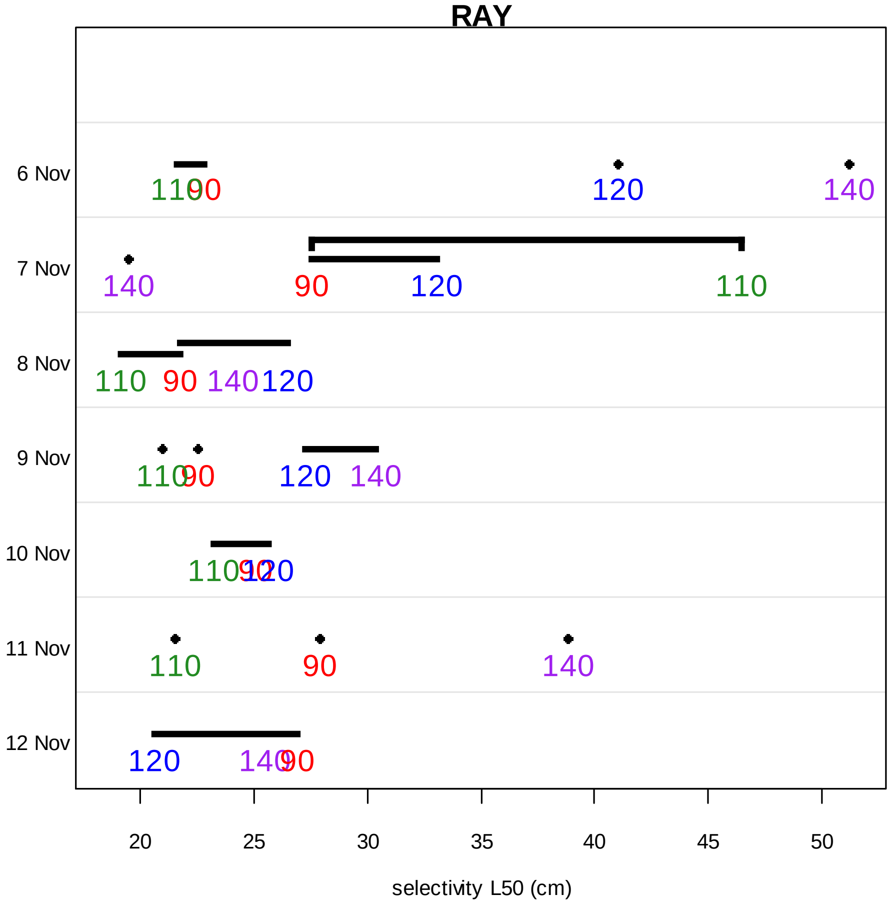
Estimates of modelled selectivity parameters for rajids by individual trawl are given in Table 8.

Table 8: Modelled selectivity parameters of Rajidae determined during ZDLT1-11-2011

Station	Cod end Treatment	aa	bb	L25	L50	L75	SR
938	90	-250.353	9.906	25.162	25.273	25.384	0.222
917		-6.558	0.263	20.752	24.928	29.104	8.352
912		-11.815	0.439	24.404	26.906	29.408	5.004
889		-6.956	0.320	18.305	21.738	25.171	6.866
930		-639.933	15.420	41.430	41.501	41.573	0.142
896		-79.361	3.526	22.198	22.510	22.821	0.623
901		-15.284	0.609	23.294	25.098	26.902	3.608
923		-7.879	0.314	21.619	25.122	28.625	7.005
884		-62.696	2.279	27.024	27.506	27.988	0.964
878		-16.073	0.704	21.280	22.841	24.403	3.122
945		-4.149	0.111	27.598	37.536	47.475	19.877
907		-7.718	0.276	23.949	27.924	31.898	7.950

Station	Cod end Treatment	aa	bb	L25	L50	L75	SR
902	110	-4.921	0.212	18.048	23.235	28.422	10.375
897		-144.653	6.907	20.782	20.942	21.101	0.318
908		-20.280	0.941	20.378	21.545	22.712	2.334
918		-4.404	0.116	28.470	37.931	47.392	18.922
913		-3.107	0.108	18.533	28.674	38.815	20.281
890		-11.544	0.604	17.282	19.099	20.917	3.635
932		-14.824	0.297	46.219	49.919	53.618	7.399
885		-779.672	16.768	46.432	46.498	46.563	0.131
939		-8.808	0.291	26.468	30.240	34.012	7.544
947		-207.181	10.762	19.150	19.252	19.354	0.204
879		-7.914	0.367	18.586	21.582	24.578	5.992
924		-18.555	0.513	33.997	36.136	38.276	4.279
892	120	-10.730	0.405	23.763	26.474	29.184	5.421
904		-5.949	0.232	20.920	25.658	30.396	9.476
898		-8.137	0.298	23.605	27.289	30.973	7.369
886		-7.833	0.237	28.442	33.082	37.722	9.280
880		-5.603	0.137	32.966	41.007	49.048	16.082
926		-6.708	0.194	28.954	34.624	40.295	11.341
909		-2.029	0.099	9.441	20.586	31.730	22.289
949		-5.689	0.231	19.913	24.678	29.444	9.531
914		-24.665	0.974	24.189	25.317	26.444	2.255
920		-9.309	0.343	23.966	27.173	30.380	6.414
941		-12.178	0.449	24.687	27.135	29.583	4.896
934		-5.032	0.118	33.306	42.610	51.913	18.607
943	140	-8.869	0.288	27.021	30.842	34.662	7.641
882		-7.356	0.144	43.538	51.182	58.827	15.289
936		-4.555	0.092	37.511	49.433	61.355	23.844
887		-672.989	34.512	19.468	19.500	19.532	0.064
911		-6.651	0.261	21.303	25.518	29.733	8.430
922		-15.302	0.431	32.945	35.494	38.042	5.097
905		-5.985	0.154	31.727	38.860	45.993	14.266
893		-8.638	0.359	20.987	24.045	27.103	6.116
916		-8.893	0.361	21.594	24.638	27.682	6.087
899		-6.030	0.199	24.803	30.330	35.856	11.052
950		-11.448	0.380	27.225	30.115	33.005	5.780
928		-15.045	0.499	27.944	30.146	32.347	4.403

As with rock cod these data indicated a large between-haul L_{50} and SR variation within and between treatment groups (mesh sizes) suggesting that factors other than just mesh size are contributing to L_{50} and SR. Figure 13 illustrates the haul by haul L_{50} for each day of the cruise and highlights this variation well.



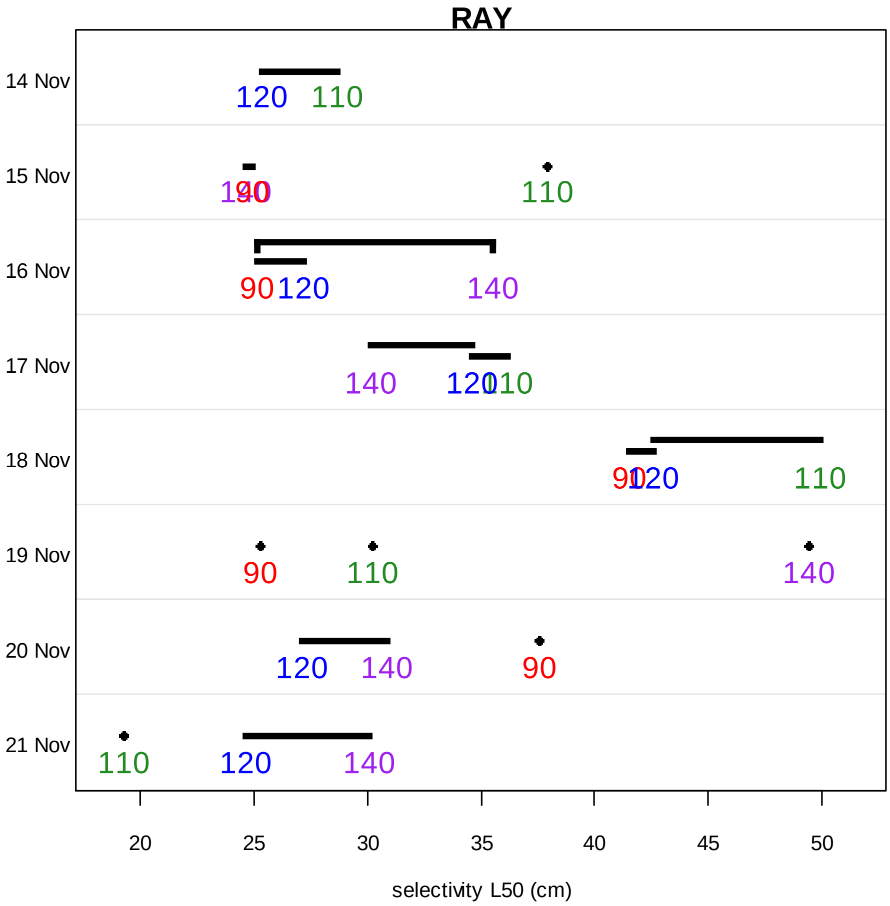


Figure 13: L_{50} per station per day on ZDLT1-11-2011. Black bars indicate no significant difference between treatments.

There was no significant difference in CPUE for rays between mesh size treatments during this survey (Kruskal-Wallis test $P>0.05$; K-W = 0.1437).

4.2.3 Factors affecting skate selectivity

L_{50} and SR were compared against total catch. The general trends were a decreasing L_{50} and SR with increasing total catch for each mesh size with the exception of the 90mm mesh where there was a slight increase in SR (Figure 14). These correlations were not significant with the exception of Catch and SR for the 90mm mesh size ($P<0.05$; SR = 0.587).

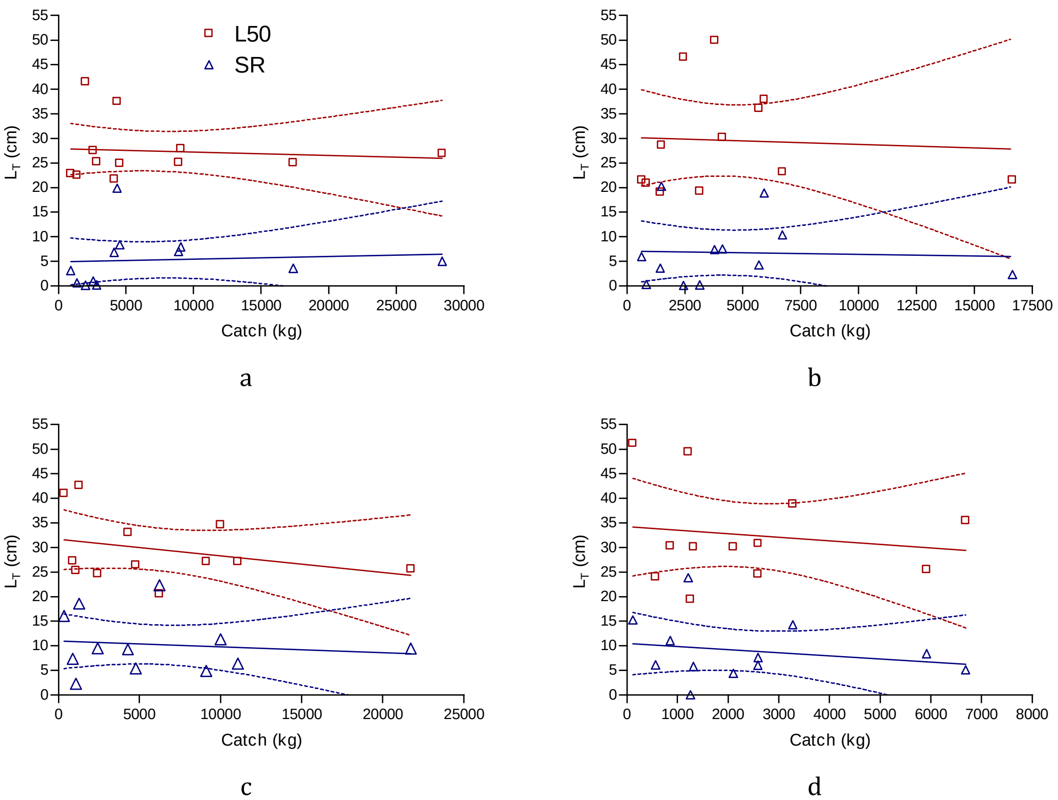


Figure 14: Spearman Rank Order Correlation between total catch, L_{50} and SR for 90mm (a), 110mm (b), 120mm (c) and 140mm (d)

For skates, L_{50} values showed inconsistent GLM relationships. Depth was the only variable retained as significant for more than 2 of the 4 mesh categories, but depth was negatively correlated with L50 at 90 mm and positively correlated at 110 and 120 mm. Inversely from rock cod, skate L_{50} had a negative relationship with RAY proportion at 90 mm but a positive relationship with RAY proportion at 140 mm (Table 9).

Table 9: GLM results relating L50 to predictor variables from the catches for skates during ZDLT1-11-2011

Rock cod, 90 mm mesh.

Variable	Coefficient	*p*
Depth	5.44E-02	<0.005
Latitude	1.23E-02	0.177
Day Total catch	–09.53e-5	0.079
Day PAR proportion	3.63E-02	0.201
N: 12		R2: 0.772

Rock cod, 110 mm mesh.

Variable	Coefficient	*p*
Depth	2.20E-01	<0.001
Trawl Total catch	–02.15e-3	<0.001
Trawl PAR proportion	1.66E-01	0.011
N: 11		R2: 0.938

Rock cod, 120 mm mesh.

Variable	Coefficient	*p*
Longitude	–03.10e-2	0.073
Trawl PAR proportion	–11.01e-2	<0.001
N: 12		R2: 0.816

Rock cod, 140 mm mesh.

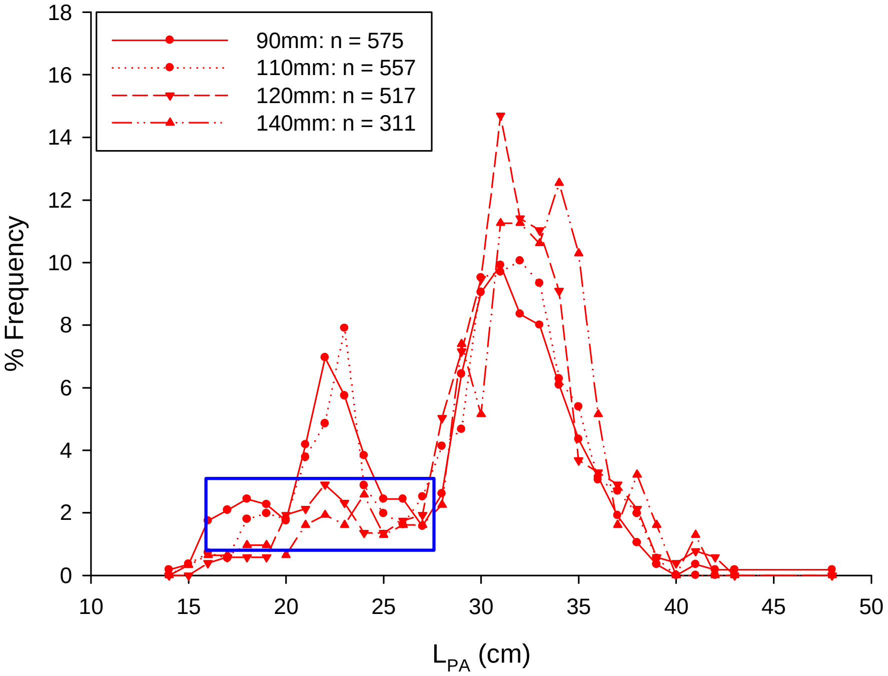
Variable	Coefficient	*p*
Depth	9.42E-02	0.021
Longitude	1.54E-02	0.169
Day Total catch	–02.11e-4	0.068
Trawl PAR proportion	–03.05e-2	0.134
N: 12		R2: 0.870

4.3 Macruronus magellanicus (hoki)

During ZDLT1-11-2011 there was a significant difference in hoki size between mesh size treatments (Table 10). Figure 15a and 15b illustrates the length frequency distribution of hoki during the cruise and it is clear that there are reduced proportions of the 15 – 25 cm L_{PA} size classes for the 120mm and 140mm mesh size treatments.

Table 10: Results of a Kruskal-Wallis test and Dunn' post test to examine the median L_{PA} of *Macruronus magellanicus* species between mesh size treatments on ZDLT1-11-2011

	90mm	110mm	120mm	140mm
Number of values	575	557	517	311
Minimum	14	15	16	15
25% Percentile	23	24	29	29
Median	30	30	31	32
75% Percentile	33	33	33	34
Maximum	48	39	42	41
Mean	28.26	29.02	30.58	31.27
Std. Deviation	5.854	5.39	4.664	4.851
Std. Error	0.2441	0.2284	0.2051	0.2751
Lower 95% CI of mean	27.78	28.57	30.18	30.73
Upper 95% CI of mean	28.74	29.47	30.98	31.81
Kruskal-Wallis test				
P value	P<0.0001			
Exact or approximate P value?	Gaussian Approximation			
P value summary	***			
Do the medians vary signif. (P < 0.05)	Yes			
Number of groups	4			
Kruskal-Wallis statistic	81.46			
Dunn's Multiple Comparison Test	Difference	P value	Summary	
90mm vs 110mm	-72.34	P < 0.001	***	
90mm vs 120mm	-207.6	P < 0.001	***	
90mm vs 140mm	-320.6	P < 0.001	***	
110mm vs 120mm	-135.2	P < 0.001	***	
110mm vs 140mm	-248.3	P < 0.001	***	
120mm vs 140mm	-113	P < 0.001	***	



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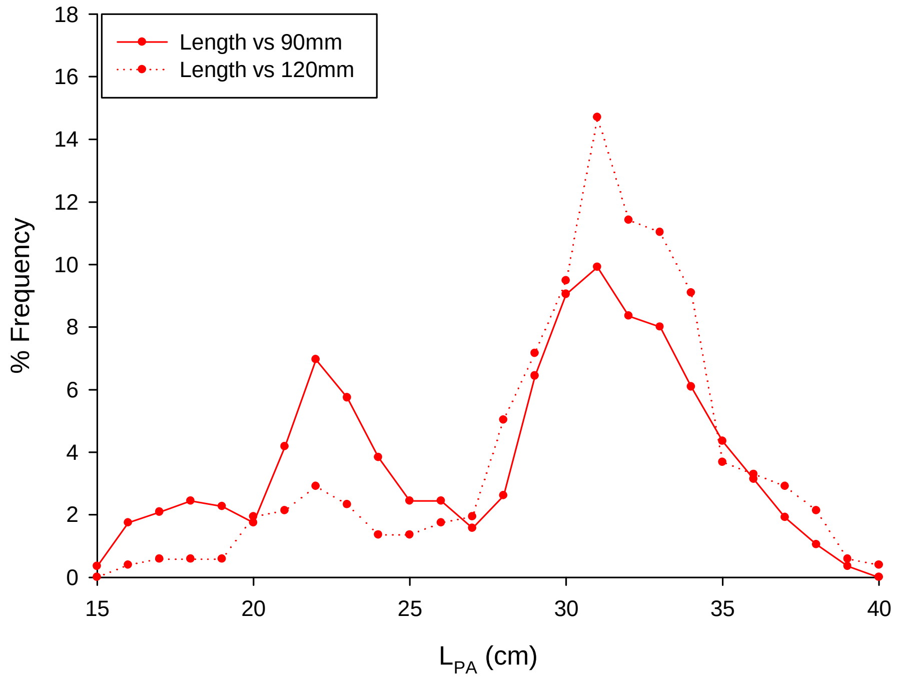

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Figure 15: Length frequency distribution of *Macruronus magellanicus* for each mesh size treatment during (a) and for 90mm and 120 mm (b) during ZDLT1-11-2011

There was no significant difference in CPUE for hoki between each mesh size treatment during the course of ZDLT1-11-2011 (Kruskal-Wallis test $P>0.05$; 3.329).

Estimates of modelled selectivity parameters for hoki for individual hauls are given in Table 11.

Table 11: Modelled selectivity parameters of hoki determined during ZDLT1-11-2011

Station	Cod end treatment	aa	bb	L25	L50	L75
878	90	-2.951	0.122	15.196	24.207	33.217
884		-2.759	0.130	12.730	21.151	29.572
889		-991.812	34.801	28.468	28.499	28.531
896		-25.301	0.801	30.211	31.582	32.954
901		-3.885	0.163	17.124	23.876	30.629
907		-69.142	2.899	23.470	23.849	24.228
912		-9.559	0.421	20.087	22.696	25.304
917		-20.802	1.011	19.495	20.582	21.669
923		-192.025	6.194	30.823	31.000	31.178
930		-10.638	0.404	23.625	26.346	29.066
938		-156.958	9.232	16.882	17.001	17.120
945		-594.168	33.954	17.467	17.499	17.532
885	110	-5.995	0.268	18.300	22.406	26.512
890		-17.339	0.508	31.989	34.153	36.317
897		-6.652	0.202	27.453	32.885	38.316
902		-24.211	1.292	17.888	18.738	19.589
908		-5.318	0.151	27.931	35.203	42.475
918		-21.832	1.325	15.646	16.475	17.304
924		-136.072	6.172	21.869	22.047	22.225

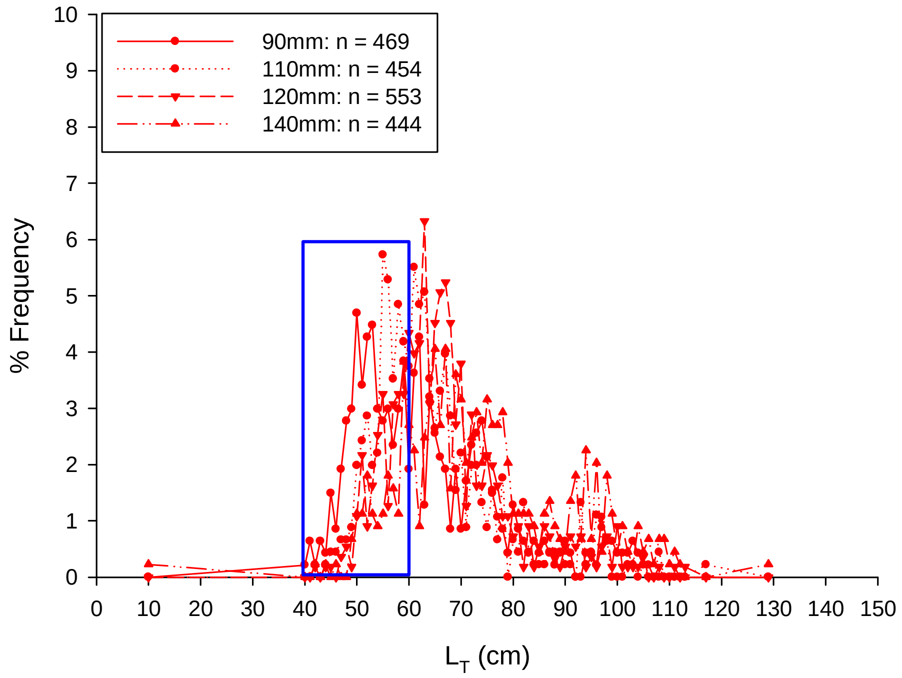
Station	Cod end treatment	aa	bb	L25	L50	L75
932		-13.035	0.470	25.399	27.737	30.075
939		-6.963	0.315	18.598	22.081	25.565
947		-924.021	34.869	26.469	26.500	26.532
886	120	-1013.713	40.403	25.063	25.090	25.117
892		-5.292	0.164	25.570	32.270	38.970
898		-13.259	0.410	29.692	32.374	35.056
904		-13.800	0.410	30.947	33.624	36.301
909		-5.487	0.181	24.210	30.271	36.331
920		-12.121	0.478	23.057	25.355	27.654
926		-685.608	35.162	19.468	19.499	19.530
934		-11.893	0.456	23.677	26.087	28.497
941		-9.423	0.377	22.094	25.010	27.926
949		-856.678	34.967	24.468	24.499	24.531
887	140	-5.132	0.129	31.365	39.909	48.452
893		-1322.517	51.860	25.480	25.502	25.523
899		-1112.065	33.196	33.467	33.500	33.533
905		-6.576	0.290	18.916	22.710	26.504
911		-4.167	0.164	18.762	25.481	32.199
916		-497.298	17.762	27.936	27.998	28.060
922		-5.112	0.215	18.683	23.797	28.911
928		-942.910	35.581	26.469	26.500	26.531
936		-15.583	0.512	28.301	30.448	32.594
943		-6.086	0.172	28.961	35.341	41.721
950		-6.369	0.100	52.706	63.692	74.678

4.4 *Genypterus blacodes* (kingclip)

During ZDLT1-11-2011 there was a significant difference in kingclip size between mesh size treatments (Table 12). Figure 16a and 16b illustrate the length frequency distribution of kingclip during the cruise and it is clear that there are reduced proportions of the 40 – 60 cm L_T size classes for the 120mm and 140mm mesh size treatments.

Table 12: Results of a Kruskal-Wallis test and Dunn' post test to examine the median L_{PA} of *Genypterus blacodes* species between mesh size treatments on ZDLT1-11-2011

	90mm	110mm	120mm	140mm
Number of values	469	454	553	444
Minimum	40	42	42	10
25% Percentile	53	56	60	63
Median	61	62	65	72
75% Percentile	72	69	72	83
Maximum	106	117	113	129
Mean	63.66	64.65	67.35	74
Std. Deviation	14.21	12.2	11.9	15.53
Std. Error	0.6564	0.5728	0.506	0.7371
Lower 95% CI of mean	62.37	63.53	66.36	72.55
Upper 95% CI of mean	64.95	65.78	68.34	75.44
Kruskal-Wallis test				
P value	P<0.0001			
Exact or approximate P value?	Gaussian Approximation			
P value summary	***			
Do the medians vary signif. (P < 0.05)	Yes			
Number of groups	4			
Kruskal-Wallis statistic	164.8			
Dunn's Multiple Comparison Test	Difference	P value	Summary	
90mm vs 110mm	-56.62	P < 0.001	***	
90mm vs 120mm	-202.8	P < 0.001	***	
90mm vs 140mm	-432.7	P < 0.001	***	
110mm vs 120mm	-146.2	P < 0.001	***	
110mm vs 140mm	-376.1	P < 0.001	***	
120mm vs 140mm	-229.9	P < 0.001	***	



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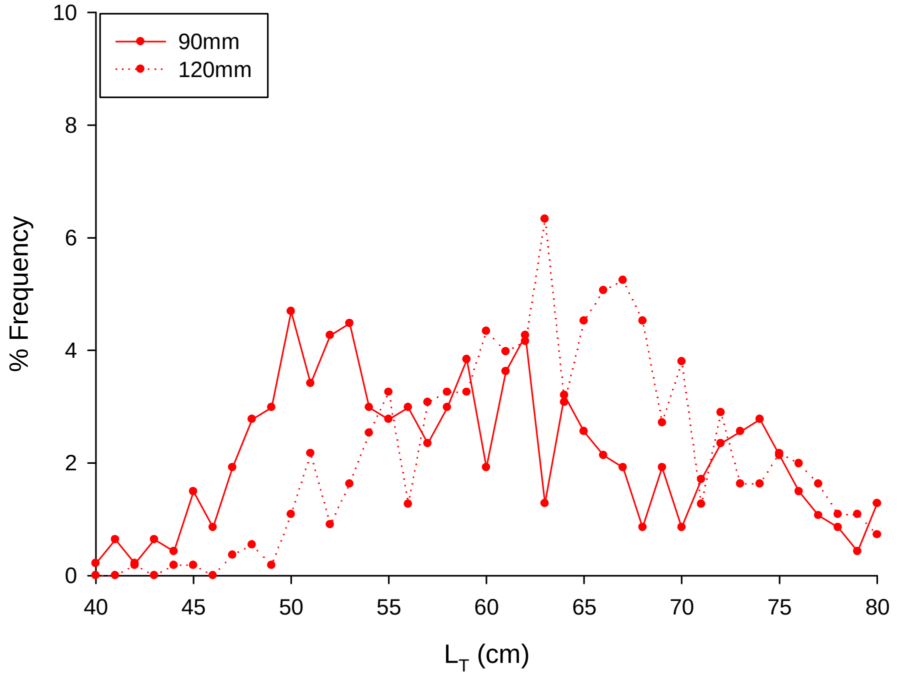

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Figure 16: Length frequency distribution of *Genypterus blacodes* for each mesh size treatment (a) and for 90mm and 120mm (b) during ZDLT1-11-2011

There was no significant difference in CPUE for kingclip between each mesh size treatment during the course of ZDLT1-11-2011 (Kruskal-Wallis test $P>0.05$; 0.279).

Estimates of modelled selectivity parameters for kingclip for individual hauls are given in Table 13.

Table 13: Modelled selectivity parameters of *Genypterus blacodes* determined during ZDLT1-11-2011

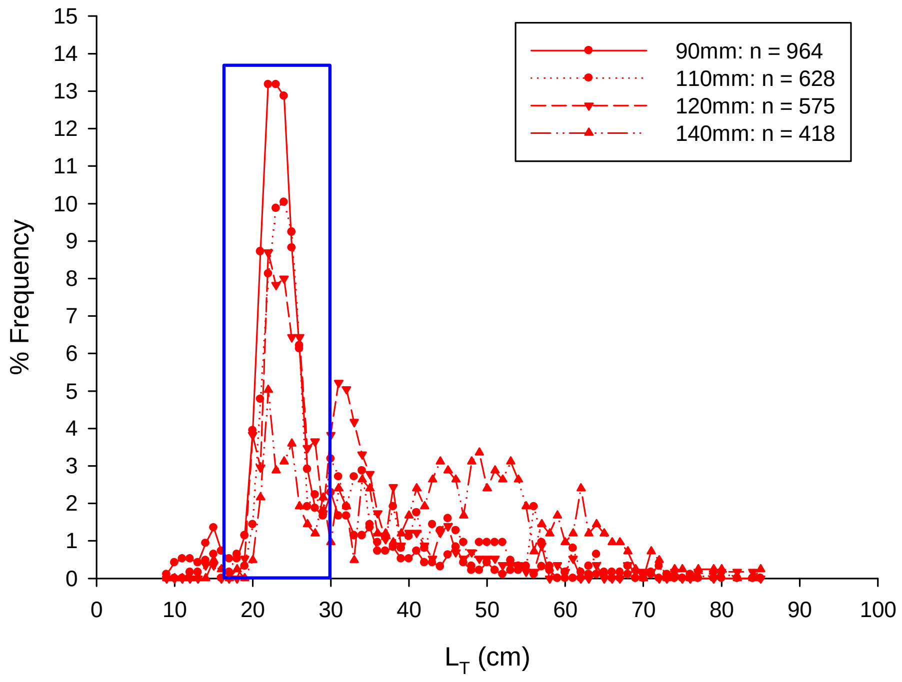
Station	Cod end treatment	aa	bb	L25	L50	L75
884	90	-6.208	0.155	32.871	39.939	47.007
889		-0.001	0.100	-10.980	0.006	10.992
896		-2.361	0.016	79.310	148.335	217.359
901		-34.890	0.778	43.452	44.865	46.278
907		-3.020	0.100	19.218	30.205	41.191
917		-7.899	0.123	55.372	64.317	73.262
923		-1.616	0.026	19.561	61.073	102.584
930		-569.165	8.309	68.368	68.500	68.632
938		-17.708	0.302	55.023	58.663	62.302
945		-8.388	0.133	54.991	63.279	71.566
885	110	-733.728	10.556	69.407	69.511	69.615
890		-3.008	0.031	62.338	98.204	134.069
897		-42.216	0.815	50.436	51.783	53.131
902		-15.041	0.260	53.579	57.801	62.023
908		-501.063	6.465	77.330	77.500	77.670
918		-578.001	11.918	48.404	48.497	48.589
924		-348.725	5.876	59.158	59.345	59.532
932		-641.845	11.670	54.906	55.000	55.094
939		-534.621	9.994	53.386	53.496	53.606
947		-9.640	0.139	61.555	69.472	77.389
886	120	-24.643	0.258	91.311	95.572	99.833
892		-576.834	5.655	101.809	102.003	102.197
898		-8.372	0.147	49.450	56.919	64.388
904		-388.580	5.592	69.296	69.493	69.689
909		-881.941	18.183	48.443	48.503	48.564
920		-6.506	0.118	45.663	54.939	64.216
926		-10.994	0.200	49.460	54.951	60.443
934		-90.284	1.577	56.571	57.268	57.965
941		-82.874	1.550	52.750	53.459	54.167
949		-9.583	0.177	47.983	54.196	60.409
893	140	-375.136	5.557	67.305	67.503	67.700
899		-13.706	0.204	61.703	67.080	72.456
905		-5.270	0.070	59.243	74.847	90.451
916		-6.517	0.060	90.407	108.737	127.067
922		-5.645	0.103	44.329	55.042	65.755
928		-21.237	0.292	68.924	72.684	76.444
936		-15.767	0.218	67.394	72.442	77.490
943		-22.584	0.400	53.661	56.405	59.149
950		-11.538	0.195	53.669	59.316	64.964

4.5 Salilota australis (red cod)

During ZDLT1-11-2011 there were no significant differences in red cod size between mesh sizes (Table 14). Figure 17 illustrates the length frequency distribution of red cod during the cruise and it is clear that there are increasingly reduced proportions of the 16 – 30 cm L_T size classes for the 110mm, 120mm and 140mm mesh size treatments.

Table 14: Results of a Kruskal-Wallis test and Dunn' post test to examine the median L_{PA} of *Salilota australis* between mesh size treatments on ZDLT1-11-2011

	90mm	110mm	120mm	140mm
Number of values	12	12	12	11
Minimum	1.278	0.22	0.12	0.06
25% Percentile	2.924	2.706	1.369	0.4733
Median	9.672	4.226	3.975	1.105
75% Percentile	43.8	55.05	13.89	14.7
Maximum	153.9	247	33.3	188.5
Mean	35.04	49.3	8.76	25.16
Std. Deviation	52.61	89.03	10.32	56.29
Std. Error	15.19	25.7	2.98	16.97
Lower 95% CI of mean	1.616	-7.267	2.202	-12.66
Upper 95% CI of mean	68.47	105.9	15.32	62.97
Kruskal-Wallis test				
P value	0.3808			
Exact or approximate P value?	Gaussian Approximation			
P value summary	ns			
Do the medians vary signif. (P < 0.05)	No			
Number of groups	4			
Kruskal-Wallis statistic	3.071			



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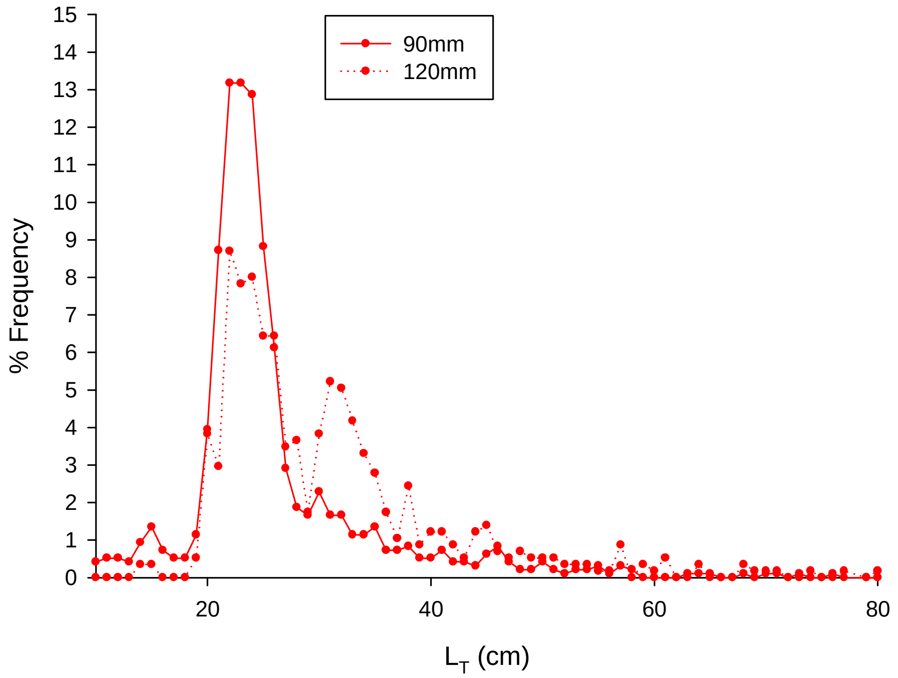

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17: Length frequency distribution of *Salilota autralis* for each mesh size treatment (a) and for 90mm and 120mm (b) during ZDLT1-11-2011

There was no significant difference in CPUE for red cod between each mesh size treatment during the course of ZDLT1-11-2011 (Kruskal-Wallis test *P*>0.05; 3.071).

4.5 Merluccius hubbsi and *Merluccius australis* (hakes)

During ZDLT1-11-2011 there was no significant difference in hake size between mesh size treatments (Table 15). Figure 18 illustrates the length frequency distribution of hakes during the cruise and it is clear that there is no difference in the length frequency distributions between mesh sizes.

Table 15: Results of a Kruskal-Wallis test and Dunn' post test to examine the median L_{PA} of hakes species between mesh size treatments on ZDLT1-11-2011

	90mm	110mm	120mm	140mm
Number of values	430	421	455	464
Minimum	27	41	48	25
25% Percentile	61	62	62	62
Median	67	68	67	67
75% Percentile	72	73	73	73
Maximum	92	86	93	91
Mean	66.67	67.79	67.58	67.25
Std. Deviation	7.948	7.669	7.555	7.999
Std. Error	0.3833	0.3738	0.3542	0.3713
Lower 95% CI of mean	65.91	67.06	66.89	66.52
Upper 95% CI of mean	67.42	68.53	68.28	67.98
Kruskal-Wallis test				
P value	0.1949			
Exact or approximate P value?	Gaussian Approximation			
P value summary	ns			
Do the medians vary signif. (P < 0.05)	No			
Number of groups	4			
Kruskal-Wallis statistic	4.703			

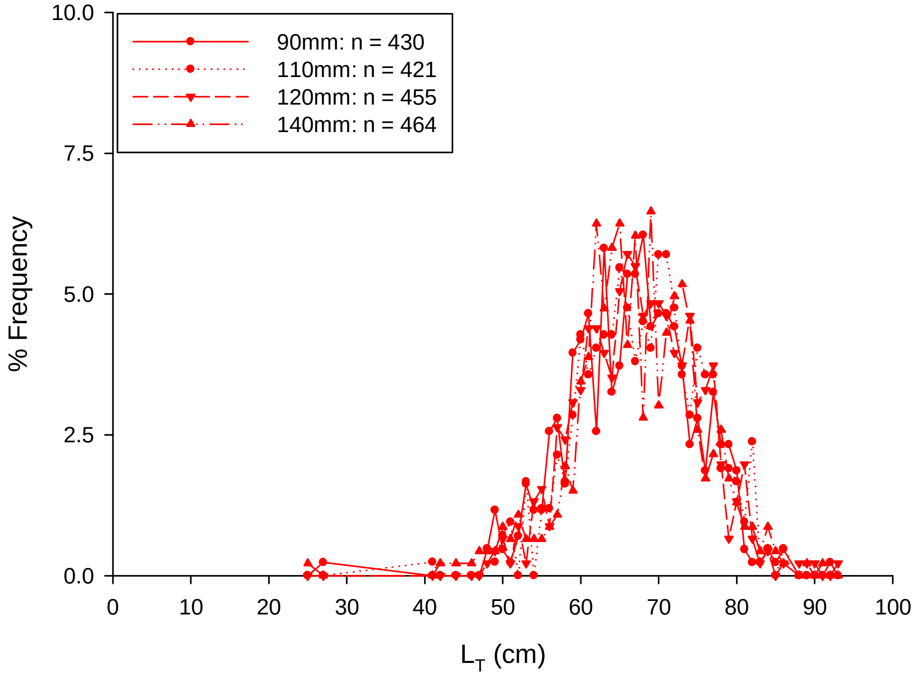
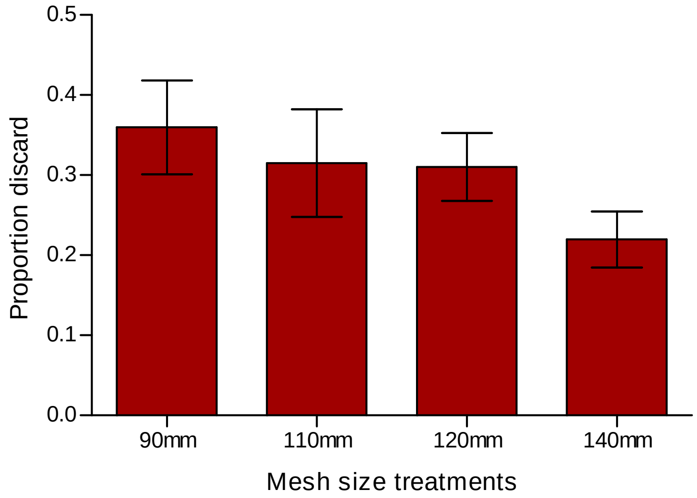


Figure 18: Length frequency distribution of hakes for each mesh size treatment during ZDLT1-11-2011

There was no significant difference in CPUE for hakes between each mesh size treatment during the course of ZDLT1-11-2011 (Kruskal-Wallis test *P*>0.05; 0.2551).

4.5 Proportion discard

The proportion of total discard (all species) in total catch per trawl decreased with increasing mesh size, and the same pattern was found with proportion of rock cod discard in total rock cod catch (Figure 19a and b). However, neither of these relationships was statistically significant (P>0.05; F = 1.312 and P>0.05; F = 0.451).



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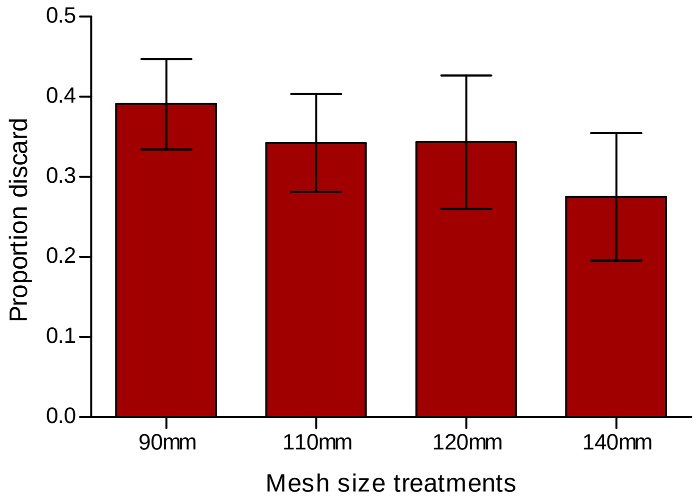

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Figure 19: Mean discard (proportion of catch) for total catch and total discard (a) and for *Patagonotothen ramsayi* catch and discard (error bars = SEM)

5.0 Discussion

Currently the finfish fleet discards a large quantity of undersized rock cod. The reported discard for 2010 was c. 23%, which FIFD consider to be an underestimate. One of the recommendations to come out of the rock cod stock assessment report (Winter et al 2010) was that an investigation into mesh sizes used in the fishery be carried out, with the objective of increasing the minimum length at capture to one that is commercially utilised. Reducing the discard of rock cod should have a major conservation benefit and result in a more profitable fishery in the future. It will also reduce the significant effort which currently goes into discarding rock cod. Reducing the discard of small rock cod will also make reporting easier and will of course have implications for discard management with respect to seabird mortality.

These trials represent a comprehensive study of the effect of differing mesh sizes on the selectivity of target species, rock cod, and by catch species encountered on the finfish grounds in the north western FICZ under normal commercial conditions.

The measures of selectivity used in these trials include L_{50} and SR. L_{50} is the length at which a fish has 50% probability of capture whilst SR is the difference between L_{75} and L_{25} and is therefore a measure of the steepness of the selectivity curve. It is the objective of fisheries management in the Falkland Islands to reduce the capture of juvenile rock cod and reduce the amount of discard in the fishery. Therefore, the overall objective would be to use a mesh size or trawl configuration that results in the smallest SR possible with a commercially useful L_{50} without increasing the catch rate of by-catch species encountered in this mixed species assemblage.

With rock cod there were increases in mean L_T and L_{50} with increasing mesh size, but large between-haul variations in L_{50} and SR within and between mesh sizes suggested that other factors were contributing to these differences. Further examination of other factors using GLMs indicated that L_{50} had a positive relationship with depth in 3 of the 4 mesh size treatments (90mm, 110mm, 140mm), suggesting that larger rock cod were encountered in deeper water. L_{50} was found to have a negative relationship with either total catch by day or by trawl in 3 of the four treatments suggesting that a fuller cod end will reduce the escape opportunity for smaller fish irrespective of the mesh size. L_{50} had a positive relationship with rock cod proportion (by day or by trawl) at 90 and 110 mm, but a negative relationship with rock cod proportion at 120 and 140 mm. This suggests that in larger meshes rock cod itself was mostly the species responsible for blocking the cod end and preventing smaller fish from escaping, whereas in smaller meshes other organisms were more likely to block the cod end. With rock cod there was a significant difference in CPUE and mesh size with 140mm being significantly lower.

Similarly, for combined skate, there was a statistically significant increasing trend of mean L_T with increasing mesh size. A similar pattern was noted for mean L_{50} with increasing mesh size but this was not significant. As with rock cod, data indicated a large between-haul variation within and between treatment groups (mesh sizes) suggesting other factors were at play. Further investigations using GLMs highlighted that depth had a negative relationship with L_{50} for the 90mm mesh but a positive one for the 110mm and 120mm cod end. This lack of a pattern could be due to skates being a mixed species assemblage rather than a single species, with some species more common in deeper waters and others more prevalent in shallower waters. Conversely to rock cod, the relationship between skate L_{50} and the proportion of skates in the catch at 90mm was a negative one but was positive at 140mm. This suggests that at smaller mesh sizes, more small skates were caught because they themselves were blocking the meshes, while in large meshes other fish (e.g. rock cod) tended to block the meshes. For skate there was not significant difference in CPUE per mesh size.

Between-haul variation in L_{50} for diamond mesh cod ends is not uncommon and has been report by a number of authors (e.g. O'Niell and Kynock, 1996; Herrmann and O'Neill, 2005; Wienbeck et al 2011). Fryer (1991) considered how the selectivity of fishing gear varies between hauls and categorised the variation as either being 'controlled' or 'uncontrolled'. 'Controlled' refers to the variation of selectivity as a result of changes to factors such as mesh sizes and gear design, whereas 'uncontrolled' refers to variations as a result of operational, environmental, biological or a combination of a number of these and can occur without the net being altered. With regards to the 'uncontrolled' variation Herrmann (2005) discusses the importance of understanding the escape process during the beginning stage of the trawl when the catch size is small. Under these circumstances when the hydrodynamic forces and therefore tension in the mesh bars at the end of the cod end are small, it is assumed that fish can deform the meshes in order to affect escape. As the catch increases hydrodynamic forces acting on the codend netting and the tensile forces on the mesh bars increase making it more difficult for fish to deform the mesh bars when trying to escape. These patterns are evident with the larger catches encountered during this survey.

For hoki, kingclip and red cod there were significant differences in mean size with increasing mesh size; generally with reduced numbers of smaller immature fish. However, there were no significant differences in CPUE between treatments. For combined hakes, however, there were no significant differences in mean L_T between mesh sizes and no significant differences in CPUE between mesh sizes. Therefore in terms of CPUE, for the major finfish species there was no negative impact with increasing mesh size even to 140mm.

There are decreasing trends in discard with increasing mesh size, and although not statistically significant, the trends are clear for both total discard and rock cod discard. This and the net benefits in terms of mean size, L_{50} increases and stable CPUEs with mesh size increases would suggest that increasing the mesh size regulations across finfish licences to 120mm would be appropriate. There are also added benefits in terms of size structure in the catches for some of the larger finfish species with reductions in the number of smaller immature fish caught.

The overall objective of this project was to increase the landing size of rock cod to a size above the length at 50% maturity and to one that is considered commercial. The minimum length at which rock cod is considered commercial is 26 cm L_T, equivalent to 80 – 100 g HGT (observer data; commercial data). The introduction of 120mm cod end meshes brings the mean length of capture up 26.47 cm L_T. This increase in mean size also brings it closer to the L_T at 50% maturity which was determined to be 27.6 cm and 24.8 cm for females and males respectively (Brickle et al 2005).

Assuming the total catch of all species and benthos was 100,424 tonnes during 2011 under finfish/ray licences to be correct then a move from a 90mm mesh size to 120mm would reduce total by-catch and discard by 6,025 tonnes. The figure for rock cod in the finfish fishery is a little more difficult. If one assumes that the 52,157 tonnes of rock cod caught in 2011 (including discards) in the finfish and skate fisheries is accurate then a move to 120mm from 90 mm will reduce rock cod discard by 3,131 tonnes. However, the total rock cod catch figure reported by the fleet is likely to be an underestimate as it does not reflect an accurate representation of rock cod discard. Therefore the net benefits in terms of discard are likely to be greater for a move from 90mm to 120mm mesh size.

6.0 Recommendations

- Change cod end mesh size regulations to 120mm for the finfish fishery.
- It is important that *Illex* selectivity is considered. It is therefore recommended that these mesh trials are repeated in April in *Illex* fishing areas.
- Consider examining the selectivity of a 130mm cod end to ascertain whether this will further reduce discards without further impacting catch rates and commercial productivity.
- Future investigations should include examining mesh size in other parts of the trawl in conjunction with cod end mesh size (e.g. wings, belly and extension piece).
- The use of sorting grids should also be examined in this fishery.

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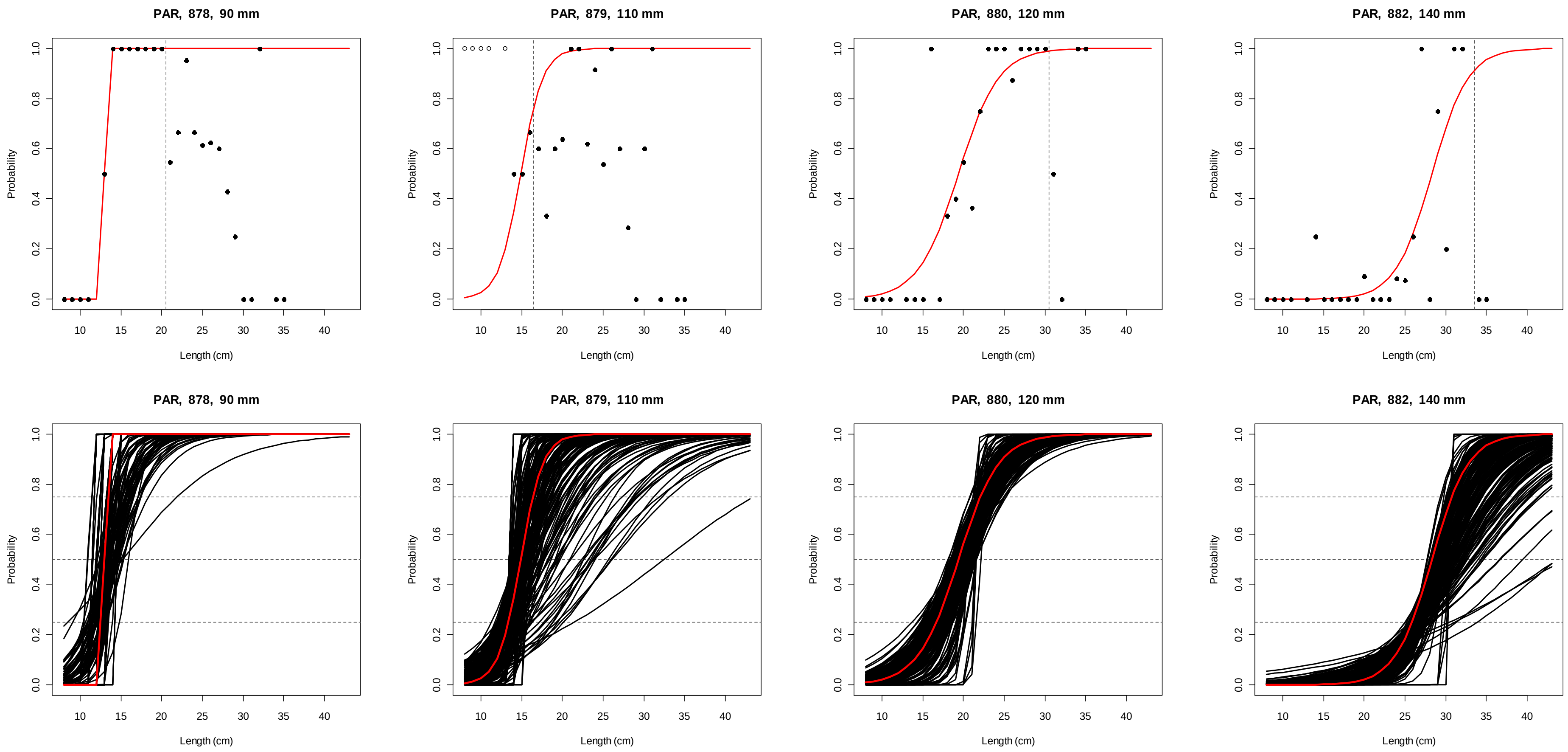
Appendix 1 – *Patagonotothen ramsayi* selectivity by haul



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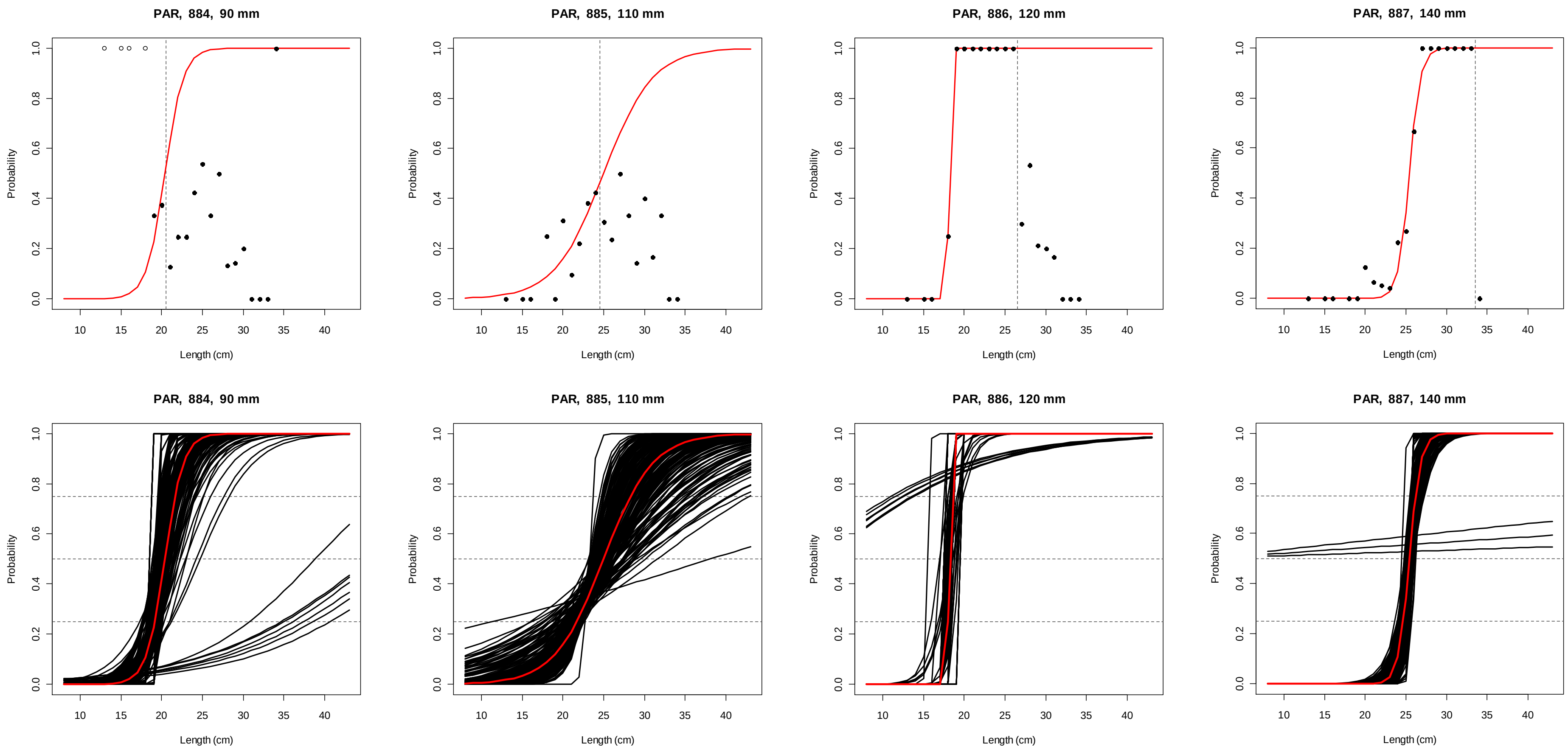

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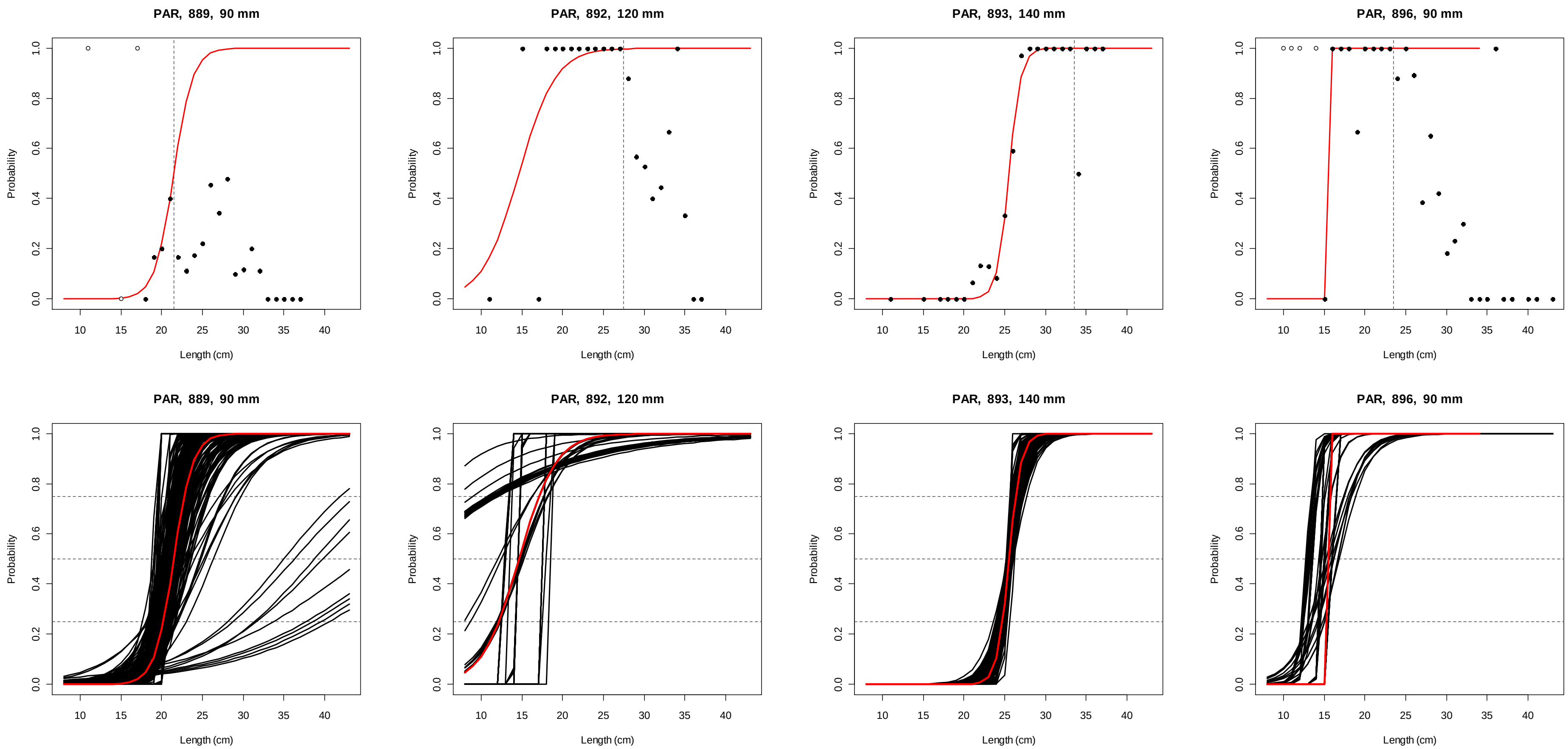

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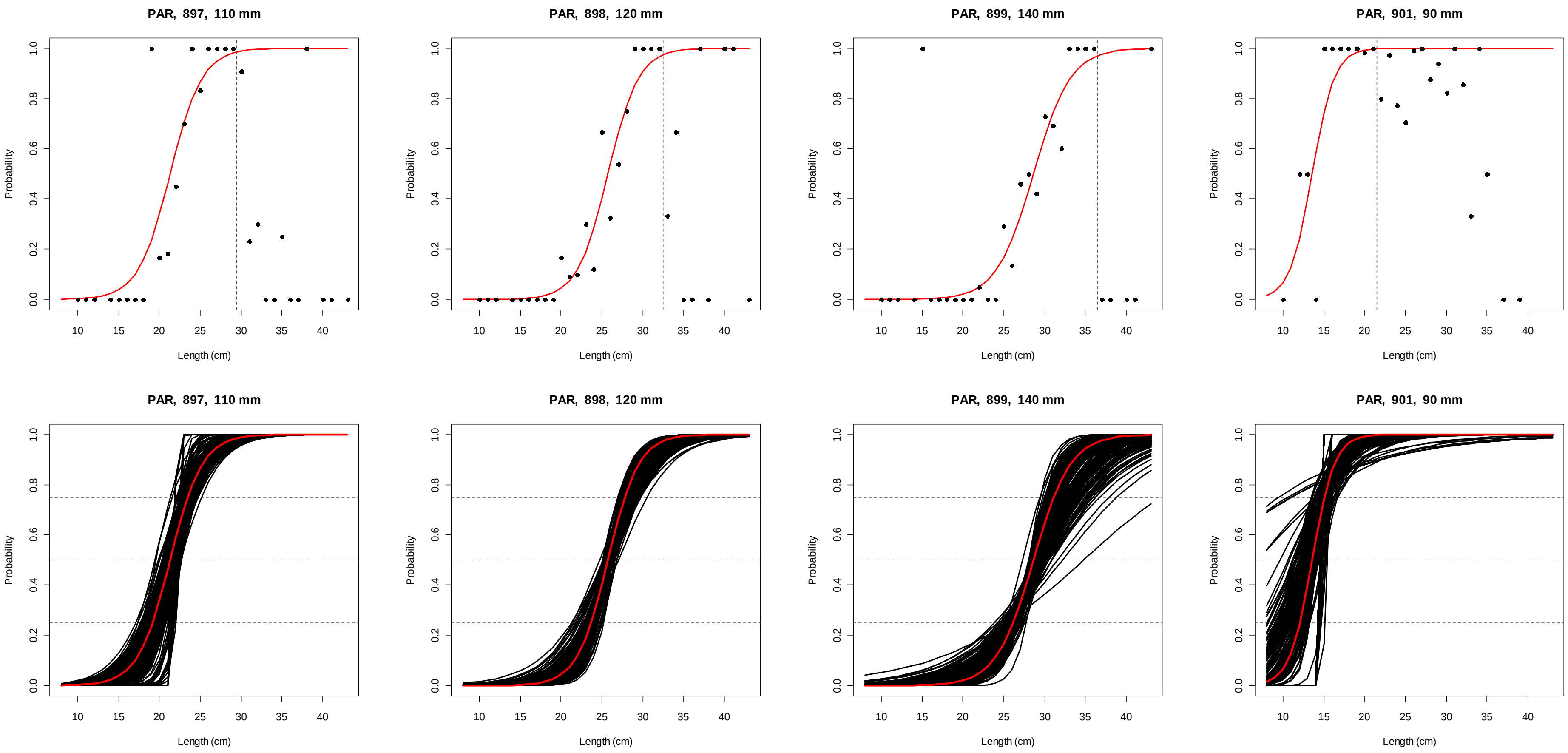

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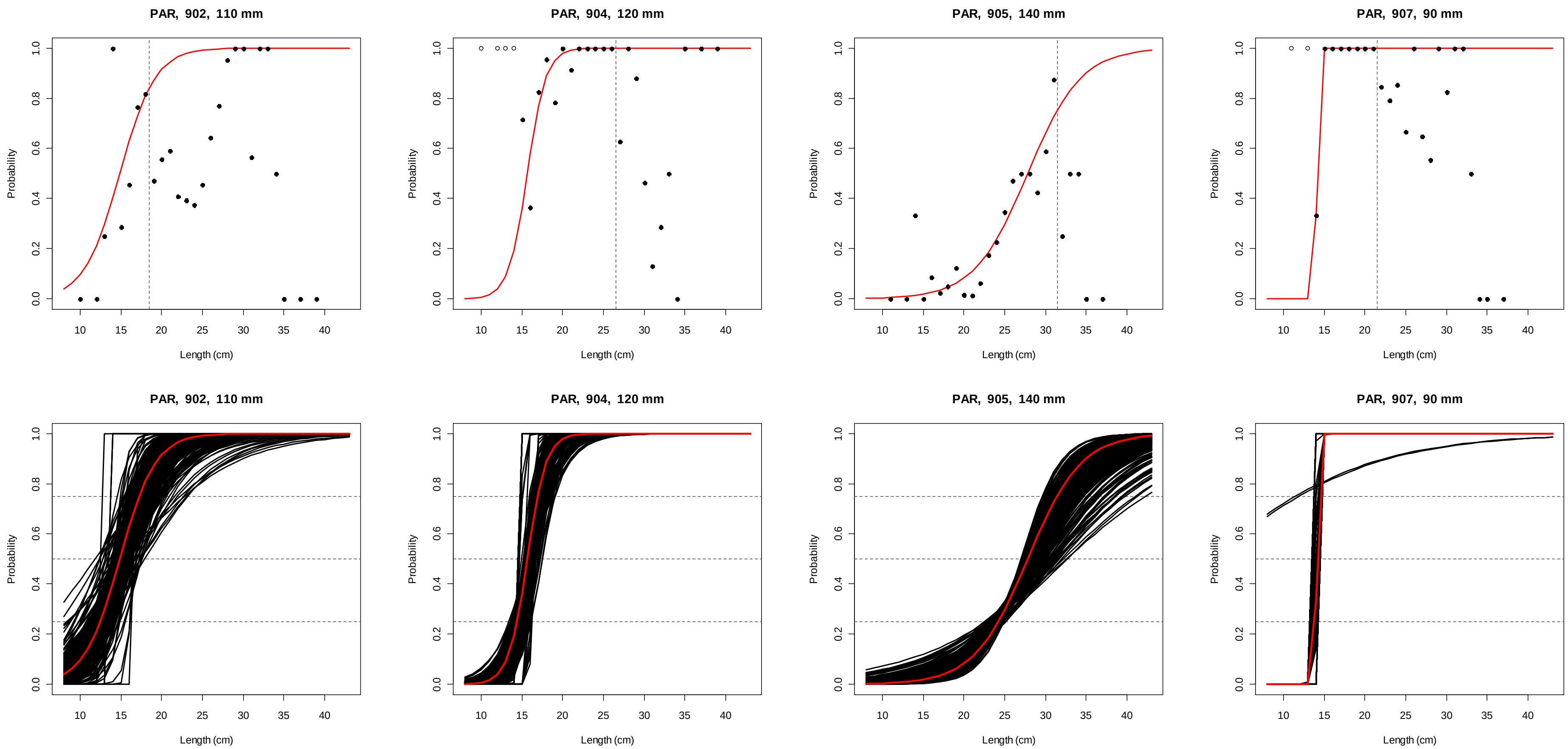
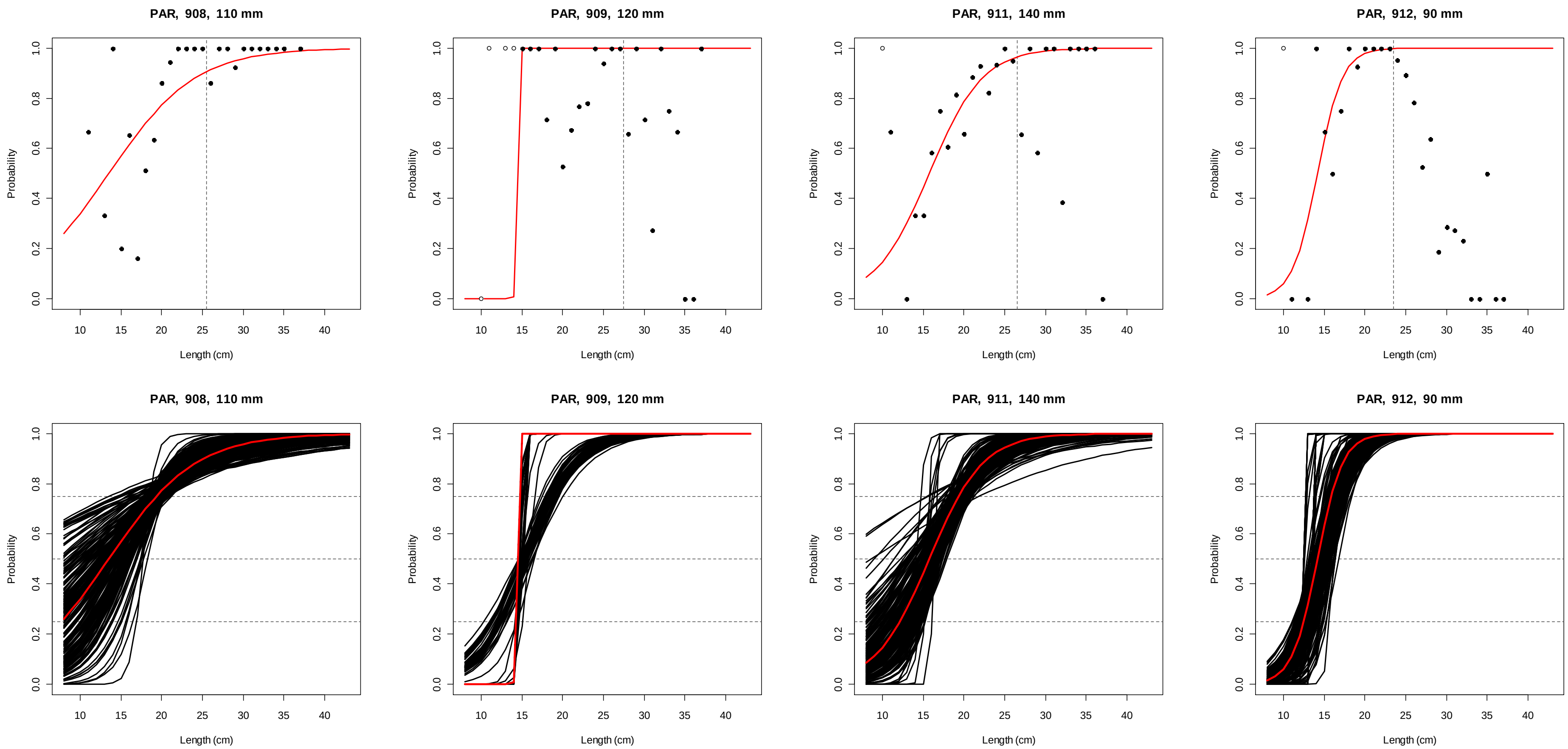
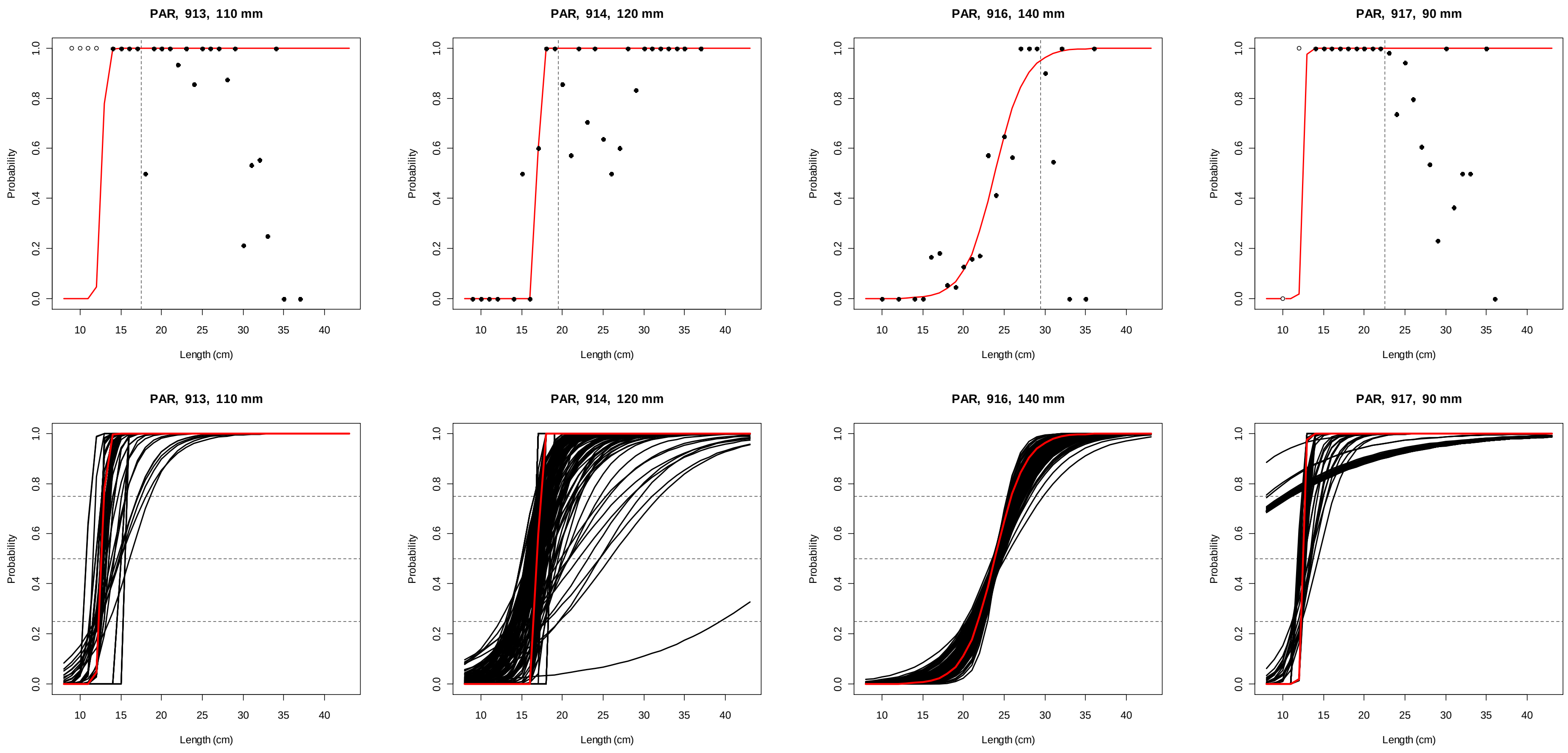


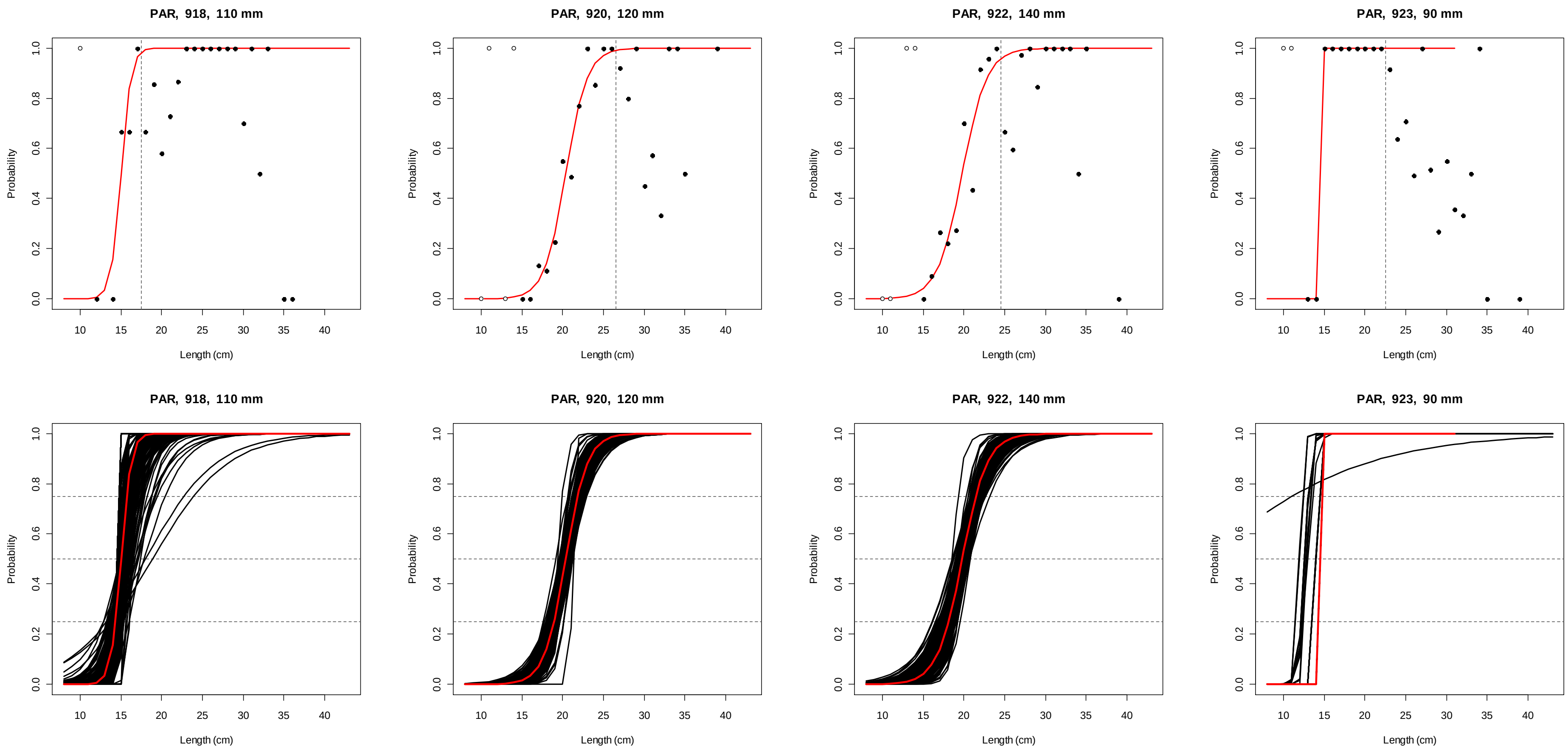
Appendix 1 – *Patagonotothen ramsayi* selectivity by haul



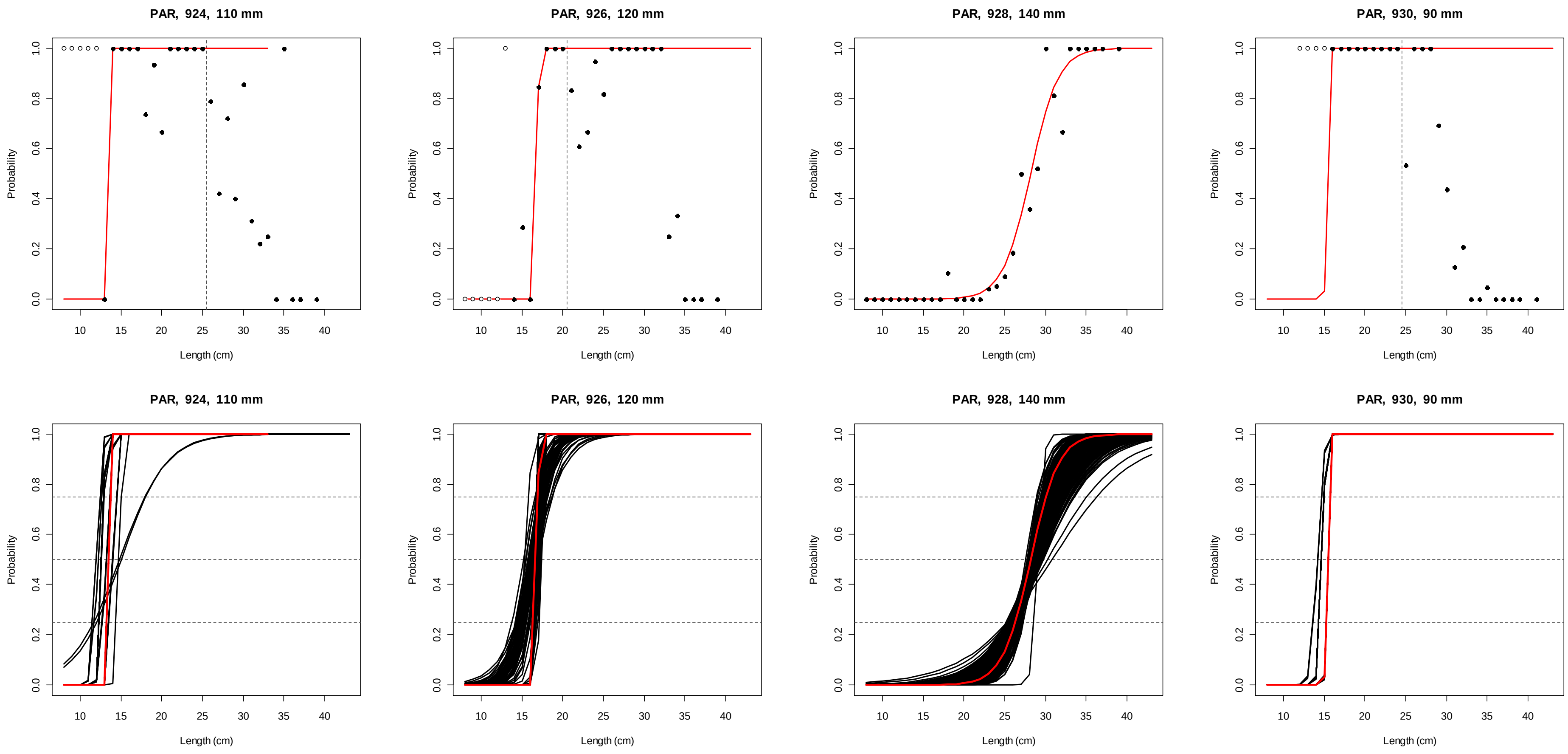
Appendix 1 – *Patagonotothen ramsayi* selectivity by haul



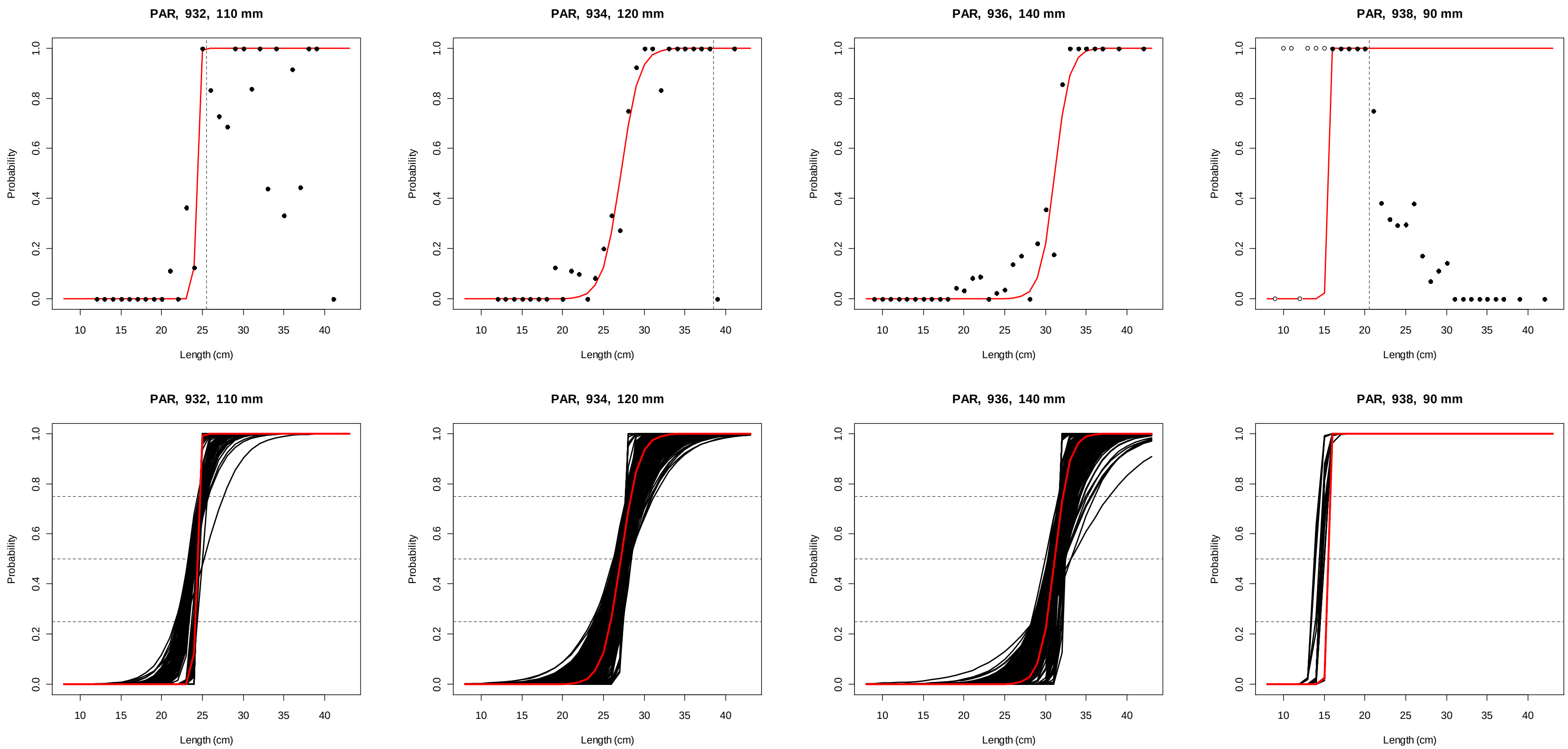
Appendix 1 – *Patagonotothen ramsayi* selectivity by haul



Appendix 1 – *Patagonotothen ramsayi* selectivity by haul



Appendix 1 – *Patagonotothen ramsayi* selectivity by haul



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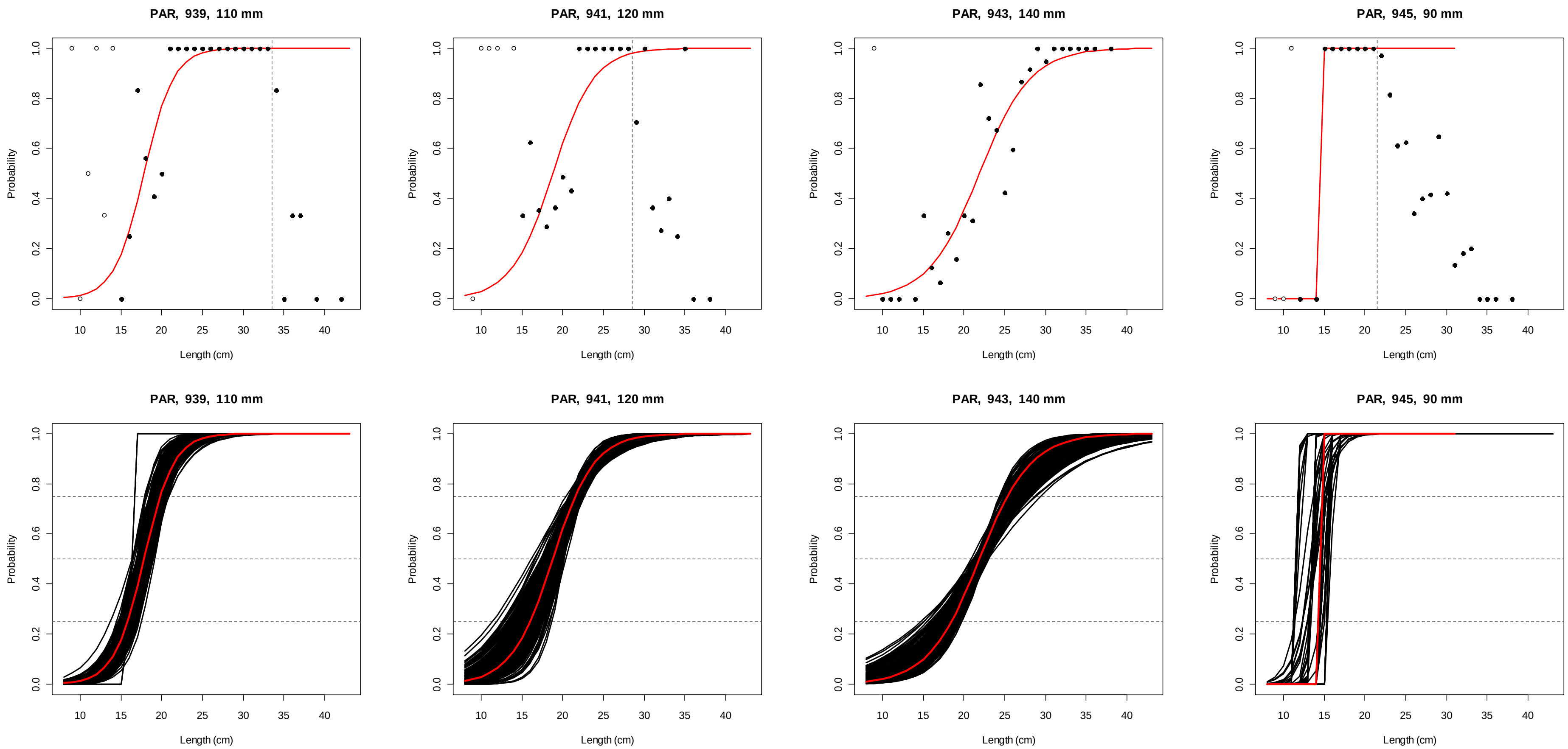

Appendix 1 – *Patagonotothen ramsayi* selectivity by haul