# Cruise Report ZDLT1-10-2010

# Skate Biomass Cruise


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# Participating Scientific Staff


| | |
|---|---|
| Dr Alexander Arkhipkin | Chief Scientist |
| Dr Andreas Winter | Skate biomass/Oceanographic surveys |
| Joost Pompert | Trawl survey |
| Zhanna Shcherbich | Trawl survey |
| Dr Deborah Davidson | Trawl survey |
| Neil Anders | Trawl survey |
| Emma Kallqvist | Trawl survey |
| Dr Michelle Watson | Trawl survey |


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# 1.0 Introduction

Research Cruise ZDLT1-10-2010 was planned to conduct a demersal trawl survey on the shelf break and slope of the north-eastern parts of the FICZ/FOCZ with the objectives to estimate the biomass and to study the species assemblage of skates within their main commercial area. Simultaneously, abundances of other demersal fish and squid were estimated, including those of rock cod, hoki and *Loligo*. The survey was completed in full as planned.

Skates (Rajidae) are an important fishery resource in the Falkland Islands Conservation Zones (FIG, 2010), and represent the only taxonomic group of strictly benthic fish to be commercially targeted. Twenty-two skate species are known to occur in Falkland waters (Dimmlich, 2008), but their species identification is limited to research surveys and catches sampled by FIFD scientific observers. Commercial fishing masters are not required to identify and report skate catches by species. This paucity of information has raised concerns that vulnerable species could decline under fishing pressure (Agnew et al., 2000; Wakeford et al., 2005), but remain undetected within overall biomass levels.
The FIFD survey cruise of October-November 2010 was therefore undertaken to focus on the skate population in Falkland waters.

## *1.1 Region*

Northeastern and northern part of the Falkland Islands Interim Conservation Zone (FICZ) and Falkland Islands Outer Conservation Zone (FOCZ).

## *1.2 Ojectives*

1. To examine distribution, species composition and biology of skates in their fishing area to the northwest of the Falkland Islands.
2. To estimate the standing biomass of skates within the limits of their fishing area.
3. To carry out an oceanographic survey of the area studied.

## *1.3 Cruise Plan and key dates*

The vessel departed Stanley on the evening of 25th October, and proceeded to the first station in the middle of the 'skate box'. After performing four trawls in grid squares XHAL and XHAK the vessel proceeded further north to the northern most stations of the survey outside the FICZ in grid squares XAAG and XAAH. Then, over the following twelve days, the whole survey area was covered from the north to the south finishing grid square XMAG. Each day, two grid squares of the survey were fished. In each grid square, two trawls were conducted at random locations on the shelf break, one trawl in shallower waters (200-250 m) and another one in deeper waters (270-370 m).

Several trawls in shallow waters to the east of Volunteer Point had been planned for the last day of the survey (8 November). However, an unfortunate breakage of the main engine had happened the night before that prevented any further work. After anchoring near Volunteer beach for the whole day of 8 November, the Castelo was towed to Berkeley Sound, where all scientific crew disembarked from the vessel and arrived to Stanley by launch in the evening.

The weather was extremely good during the survey, and no time was lost due to bad weather.

## *1.4 Personnel*

The following 8 scientists from the Fisheries Department participated in the cruise:

| | |
|---|---|
| Dr. Alexander Arkhipkin | Chief Scientist |
| Dr. Andreas Winter | Skate biomass/Oceanographic surveys |
| Joost Pompert | Trawl survey |
| Zhanna Shcherbich | Trawl survey |
| Dr. Deborah Davidson | Trawl survey |
| Neil Anders | Trawl survey |
| Emma Kallqvist | Trawl survey |
| Dr. Michelle Watson | Trawl survey |

### 1.5 Gear

1. Oceanographic survey. STDO SeaBird SBE 25 Sealogger.
2. Bottom trawl with tickler chain and polyvalent doors.
3. Isaacs-Kidd mid-water trawl.

## 2.0 Oceanography

Oceanographic data were collected at 52 oceanographic stations. These stations were conducted either before or after each trawl (Fig. 1). Stations were situated on the northern Falkland Shelf between 131 and 401 m.

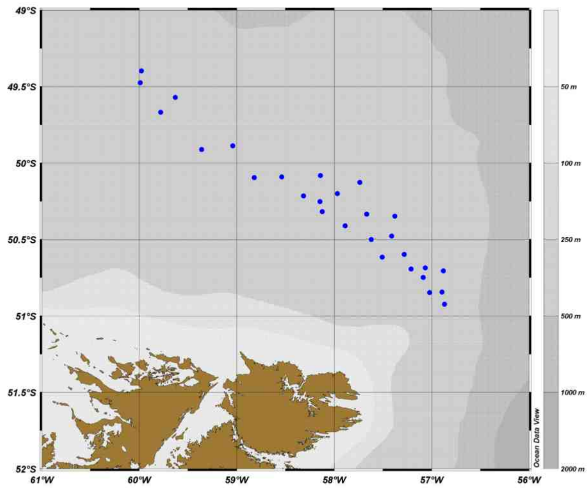



Fig. 1 Oceanographic stations conducted in October - November 2010

### 2.1. Results

The survey was aimed to assess stocks of rays north of the Falkland Islands, and to reveal environmental factors influencing ray distribution. Bottom temperatures ranged from 4.4º to 5.6ºC, salinity was 33.90 to 34.2 psu, and densities from 26.6 to 27.1 kg/m3. Distribution of temperatures and salinities are shown on Fig. 2.

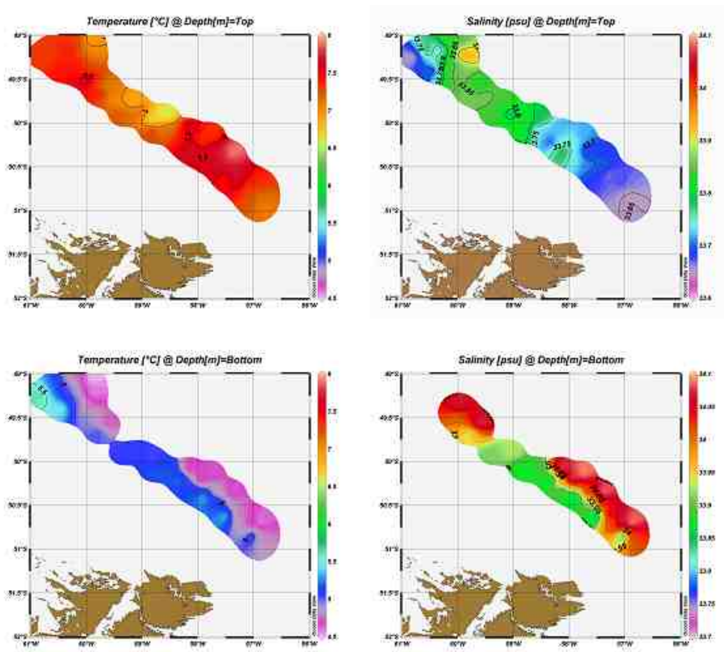



Fig. 2 Distribution of temperature and salinity on the northern Falkland shelf in October - November 2010

# 3.0 Biological Sampling

## 3.1 Catch and by-catch

Bottom trawling was conducted at 52 stations as shown in the chart. Seabed trawling times during the survey was aimed to be 60 minutes, which happened for 51 of the stations. During the penultimate station (679) a problem with the net occurred, and the seabed time was reduced to 35 minutes.

During the cruise a total of 65,560 kg was caught comprising over 111 species (Table 1). In terms of weight, the greatest catches were rock cod (*Patagonotothen ramsayi*) and hoki (*Macruronus magellanicus*), together amounting to over 74% of the total catch.

Table 1: Total catch of all trawl stations during research cruise ZDLT1-10-2010

| Species Code | Species name | Total Catch (kg) | Total Sampled (kg) | Total Discarded (kg) | Proportion (%) |
|---|---|---|---|---|---|
| PAR | *Patagonotothen ramsayi* | 30,447.861 | 670.880 | 12,946.039 | 46.44% |
| WHI | *Macruronus magellanicus* | 18,235.640 | 1,580.690 | 647.291 | 27.82% |
| RBR | *Bathyraja brachyurops* | 2,441.340 | 2,441.240 | 6.915 | 3.72% |
| RGR | *Bathyraja griseocauda* | 2,377.760 | 2,314.760 | 48.319 | 3.63% |
| RAL | *Bathyraja albomaculata* | 1,311.010 | 1,311.010 | 122.354 | 2.00% |
| RFL | *Dipturus chilensis* | 1,118.240 | 1,118.240 | 0.000 | 1.71% |
| EEL | *Iluocoetes fimbriatus* | 1,078.490 | 0.200 | 1,047.490 | 1.65% |
| KIN | *Genypterus blacodes* | 1,075.708 | 1,075.160 | 0.540 | 1.64% |
| GRC | *Macrourus carinatus* | 831.040 | 645.450 | 499.760 | 1.27% |
| HAK | *Merluccius hubbsi* | 676.800 | 667.450 | 0.000 | 1.03% |
| LOL | *Loligo gahi* | 616.694 | 169.630 | 92.574 | 0.94% |
| SPN | Porifera | 585.495 | 0.000 | 585.495 | 0.89% |
| TOO | *Dissostichus eleginoides* | 582.390 | 567.160 | 25.290 | 0.89% |
| RBZ | *Bathyraja cousseauae* | 483.040 | 483.040 | 20.985 | 0.74% |
| ING | *Moroteuthis ingens* | 476.853 | 10.595 | 471.173 | 0.73% |
| BLU | *Micromesistius australis* | 458.921 | 96.440 | 442.985 | 0.70% |
| RSC | *Bathyraja scaphiops* | 405.040 | 397.390 | 27.317 | 0.62% |
| RMU | *Bathyraja multispinis* | 393.970 | 391.180 | 0.713 | 0.60% |
| RDO | *Raja doellojuradoi* | 217.000 | 217.000 | 208.926 | 0.33% |
| RMC | *Bathyraja macloviana* | 209.610 | 209.610 | 51.127 | 0.32% |
| COT | *Cottunculus granulosus* | 194.920 | 0.697 | 194.218 | 0.30% |
| BAC | *Salilota australis* | 158.360 | 124.330 | 50.615 | 0.24% |
| DGH | *Schroederichthys bivius* | 145.120 | 78.480 | 114.590 | 0.22% |
| RDA | *Dipturus argentinensis* | 110.990 | 110.240 | 0.000 | 0.17% |
| POR | *Lamna nasus* | 107.020 | 0.000 | 107.020 | 0.16% |
| CGO | *Cottoperca gobio* | 106.970 | 38.190 | 106.970 | 0.16% |
| GRF | *Coelorhynchus fasciatus* | 86.333 | 0.772 | 85.763 | 0.13% |
| DGS | *Squalus acanthias* | 79.620 | 28.630 | 66.040 | 0.12% |
| PAT | *Merluccius australis* | 63.960 | 61.220 | 0.000 | 0.10% |
| ALG | Algae | 55.690 | 0.000 | 55.690 | 0.08% |
| GYN | *Gymnoscopelus nicholsi* | 49.944 | 8.619 | 43.945 | 0.08% |
| RPX | *Psammobatis spp.* | 45.870 | 45.870 | 42.060 | 0.07% |
| OCC | Octocoralia | 45.060 | 10.000 | 35.060 | 0.07% |
| RTR | *Dipturus trachydermus* | 44.010 | 44.010 | 0.000 | 0.07% |
| STA | *Sterechinus agassizi* | 30.183 | 0.000 | 30.183 | 0.05% |
| ANM | Anemone | 20.767 | 0.000 | 20.767 | 0.03% |

| | | | | | |
|---|---|---|---|---|---|
| *OCT* | Octopus *spp.* | *17.895* | *17.880* | *0.015* | *0.03%* |
| BEE | *Benthoctopus eureka* | 16.322 | 16.082 | 0.000 | 0.02% |
| AST | Asteroidea | 14.845 | 0.000 | 14.845 | 0.02% |
| RED | *Sebastes oculatus* | 14.490 | 14.140 | 0.350 | 0.02% |
| MUO | *Muraenolepis orangiensis* | 12.278 | 9.958 | 2.320 | 0.02% |
| CAS | *Campylonotus semistriatus* | 11.810 | 9.680 | 2.130 | 0.02% |
| AUC | *Austrocidaris canaliculata* | 11.230 | 0.000 | 10.798 | 0.02% |
| BEJ | *Benthoctopus sp.cf. januarii* | 10.209 | 7.189 | 2.210 | 0.02% |
| MAM | *Mancopsetta milfordi* | 9.250 | 9.250 | 0.000 | 0.01% |
| PYM | *Physiculus marginatus* | 8.462 | 4.051 | 4.611 | 0.01% |
| ANT | Anthozoa | 7.950 | 0.000 | 0.430 | 0.01% |
| MUU | *Munida subrugosa* | 6.545 | 0.015 | 6.530 | 0.01% |
| ZYP | *Zygochlamys patagonica* | 6.400 | 0.000 | 6.400 | 0.01% |
| PES | *Peltarion spinosulum* | 4.940 | 0.000 | 4.940 | 0.01% |
| GYM | *Gymnoscopelus spp.* | 3.900 | 0.300 | 3.900 | 0.01% |
| NEM | *Neophyrnichthys marmoratus* | 3.650 | 3.650 | 0.240 | 0.01% |
| GOC | *Gorgonocephalas chilensis* | 3.565 | 0.000 | 3.565 | 0.01% |
| MUG | *Munida gregaria* | 3.542 | 0.090 | 3.452 | 0.01% |
| FUM | *Fusitriton m. magellanicus* | 3.535 | 0.000 | 3.535 | 0.01% |
| CAZ | *Calyptraster* sp. | 2.390 | 0.000 | 2.390 | <0.01% |
| THB | *Thymops birsteini* | 2.374 | 0.600 | 1.734 | <0.01% |
| OCM | *Octopus megalocyathus* | 2.310 | 2.310 | 0.000 | <0.01% |
| ADA | *Adelomelon ancilla* | 1.390 | 0.330 | 1.060 | <0.01% |
| ILL | *Illex argentinus* | 1.196 | 1.196 | 0.000 | <0.01% |
| CTA | *Ctenodiscus australis* | 1.105 | 0.000 | 1.105 | <0.01% |
| COL | *Cosmasterias lurida* | 0.880 | 0.000 | 0.880 | <0.01% |
| MMA | *Mancopsetta maculata* | 0.840 | 0.840 | 0.000 | <0.01% |
| XXX | Unidentified animal | 0.827 | 0.767 | 0.080 | <0.01% |
| OPH | Ophiuroidea | 0.805 | 0.000 | 0.804 | <0.01% |
| MAR | *Martialia hyadesi* | 0.682 | 0.682 | 0.000 | <0.01% |
| CAM | *Cataetyx messieri* | 0.630 | 0.560 | 0.070 | <0.01% |
| ASA | *Astrotoma agassizii* | 0.490 | 0.000 | 0.490 | <0.01% |
| WRM | *Chaetopterus variopedeatus* | 0.390 | 0.000 | 0.390 | <0.01% |
| GON | *Gonatus antarcticus* | 0.375 | 0.375 | 0.000 | <0.01% |
| ODM | *Odontocymbiola magellanica* | 0.370 | 0.000 | 0.370 | <0.01% |
| NEC | *Neorossia caroli* | 0.350 | 0.340 | 0.010 | <0.01% |
| BAL | *Bathydomus longisetosus* | 0.330 | 0.000 | 0.330 | <0.01% |
| POA | *Porania antarctica* | 0.300 | 0.000 | 0.300 | <0.01% |
| CRY | *Crossaster* sp. | 0.280 | 0.000 | 0.280 | <0.01% |
| NUD | *Nudibranchia* | 0.270 | 0.000 | 0.270 | <0.01% |
| EGG | Eggmass | 0.265 | 0.000 | 0.265 | <0.01% |
| FLX | *Flabellum spp.* | 0.260 | 0.000 | 0.260 | <0.01% |
| HOL | Holothuroidea | 0.260 | 0.000 | 0.260 | <0.01% |
| SRP | *Semirossia patagonica* | 0.225 | 0.225 | 0.000 | <0.01% |
| GOR | *Gorgonacea* | 0.210 | 0.010 | 0.200 | <0.01% |
| OPL | *Ophiuroglypha lymanii* | 0.135 | 0.000 | 0.135 | <0.01% |
| SUN | *Labidaster radiosus* | 0.120 | 0.000 | 0.120 | <0.01% |
| BAO | *Bathybiaster loripes* | 0.110 | 0.000 | 0.110 | <0.01% |
| NOW | *Paranotothenia magellanica* | 0.110 | 0.110 | 0.110 | <0.01% |
| MUN | *Munida* spp. | 0.100 | 0.000 | 0.100 | <0.01% |
| PGR | *Paradiplospinus gracilis* | 0.090 | 0.090 | 0.000 | <0.01% |
| PAL | *Patagonotothen longipes* | 0.080 | 0.000 | 0.080 | <0.01% |
| SER | *Serolis* spp. | 0.071 | 0.000 | 0.071 | <0.01% |
| LMK | *Laemonema kongi* | 0.060 | 0.060 | 0.000 | <0.01% |

| | | | | | |
|---|---|---|---|---|---|
| *MXX* | *Myctophidae* | *0.060* | *0.060* | *0.000* | *<0.01%* |
| THN | *Thysanopsetta naresi* | 0.060 | 0.060 | 0.000 | <0.01% |
| HYD | Hydrozoa | 0.060 | 0.000 | 0.060 | <0.01% |
| NEH | *Neomena herwigi* | 0.060 | 0.000 | 0.060 | <0.01% |
| POL | Polychaeta | 0.058 | 0.000 | 0.058 | <0.01% |
| MAV | *Magellania venosa* | 0.056 | 0.000 | 0.056 | <0.01% |
| LIR | *Limopsis marionensis* | 0.050 | 0.000 | 0.050 | <0.01% |
| ARR | *Arctozenus risso* | 0.039 | 0.039 | 0.000 | <0.01% |
| LEE | *Lepidion ensiferus* | 0.034 | 0.034 | 0.000 | <0.01% |
| MAT | *Achiropsetta tricholepis* | 0.030 | 0.030 | 0.000 | <0.01% |
| EUO | *Eurypodius longirostris* | 0.030 | 0.000 | 0.030 | <0.01% |
| MAU | *Maurolicus muelleri* | 0.030 | 0.000 | 0.030 | <0.01% |
| PAA | *Pandalopsis ampla* | 0.024 | 0.000 | 0.000 | <0.01% |
| PYX | Pycnogonida | 0.024 | 0.000 | 0.024 | <0.01% |
| SQT | Ascidiacea | 0.020 | 0.000 | 0.020 | <0.01% |
| ISO | Isopoda | 0.008 | 0.000 | 0.008 | <0.01% |
| CYX | *Cycethra* sp. | 0.006 | 0.000 | 0.006 | <0.01% |
| SAT | *Salpa thomsoni* | 0.002 | 0.000 | 0.002 | <0.01% |
| TED | *Terebratella dorsata* | 0.002 | 0.000 | 0.002 | <0.01% |
| STS | *Stereomastis suhmi* | 0.001 | 0.000 | 0.001 | <0.01% |
| **Totals** | | **65,559.871** | **15,019.186** | **18,281.166** | |

Table 2: Random samples collected for biological analyses

| ***Code*** | ***Name*** | ***Number Sampled*** | ***Proportion (%)*** |
|---|---|---|---|
| LOL | *Loligo gahi* | 3,980 | 23.4% |
| PAR | *Patagonotothen ramsayi* | 3,182 | 18.7% |
| WHI | *Macruronus magellanicus* | 1,830 | 10.8% |
| RAL | *Bathyraja albomaculata* | 1,321 | 7.8% |
| RBR | *Bathyraja brachyurops* | 1,062 | 6.2% |
| RGR | *Bathyraja griseocauda* | 932 | 5.5% |
| KIN | *Genypterus blacodes* | 615 | 3.6% |
| TOO | *Dissostichus eleginoides* | 539 | 3.2% |
| BLU | *Micromesistius australis* | 344 | 2.0% |
| GRC | *Macrourus carinatus* | 343 | 2.0% |
| RSC | *Bathyraja scaphiops* | 341 | 2.0% |
| RFL | *Dipturus chilensis* | 331 | 1.9% |
| RDO | *Raja doellojuradoi* | 292 | 1.7% |
| RMC | *Bathyraja macloviana* | 292 | 1.7% |
| HAK | *Merluccius hubbsi* | 266 | 1.6% |
| PYM | *Physiculus marginatus* | 220 | 1.3% |
| RBZ | *Bathyraja cousseauae* | 185 | 1.1% |
| DGH | *Schroederichthys bivius* | 149 | 0.9% |
| BAC | *Salilota australis* | 138 | 0.8% |
| RPX | *Psammobatis spp.* | 123 | 0.7% |
| CGO | *Cottoperca gobio* | 119 | 0.7% |
| RMU | *Bathyraja multispinis* | 94 | 0.6% |
| BEE | *Benthoctopus eureka* | 79 | 0.5% |
| MUO | *Muraenolepis orangiensis* | 39 | 0.2% |
| RDA | *Dipturus argentinensis* | 39 | 0.2% |
| NEC | *Neorossia caroli* | 32 | 0.2% |
| PAT | *Merluccius australis* | 25 | 0.1% |
| GYN | *Gymnoscopelus nicholsi* | 23 | 0.1% |
| RED | *Sebastes oculatus* | 23 | 0.1% |
| DGS | *Squalus acanthias* | 8 | 0.0% |
| ILL | *Illex argentinus* | 7 | 0.0% |
| MAM | *Mancopsetta milfordi* | 4 | 0.0% |
| **ING** | *Moroteuthis ingens* | 4 | 0.0% |
| *CAM* | Cataetyx messieri | *4* | **0.0%** |
| LMK | *Laemonema kongi* | 3 | 0.0% |
| RTR | *Dipturus trachydermus* | 3 | 0.0% |
| PGR | *Paradiplospinus gracilis* | 3 | 0.0% |
| BEJ | *Benthoctopus sp.cf. januarii* | 2 | 0.0% |
| COT | *Cottunculus granulosus* | 2 | 0.0% |
| GON | *Gonatus antarcticus* | 2 | 0.0% |
| NEM | *Neophyrnichthys marmoratus* | 2 | 0.0% |
| EEL | *Iluocoetes fimbriatus* | 2 | 0.0% |
| MMA | *Mancopsetta maculata* | 1 | 0.0% |
| POR | *Lamna nasus* | 1 | 0.0% |
| MAR | *Martialia hyadesi* | 1 | 0.0% |
| NOW | *Paranotothenia magellanica* | 1 | 0.0% |
| BAG | *Bathylagus gracilis* | 1 | 0.0% |
| | | **17,009** | |

## 3.2 Kingclip *Genypterus blacodes*

Kingclip were taken at 27 of the 52 stations throughout the sampling area, with the total amounting to 1,076kg. 53% (568 kg) of this total was caught in station 663 (Fig. 3). Kingclip size ranged from 36 to 113cm $L_t$, with the mean size 82.1cm (one of the highest) at the station of highest abundance (Fig. 4a). Female proportion was 59%.

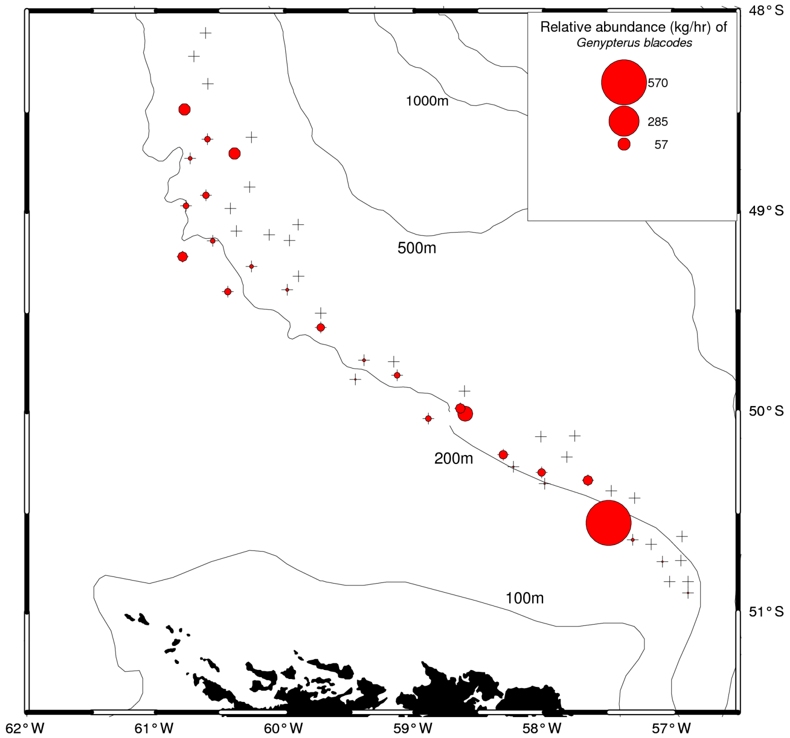
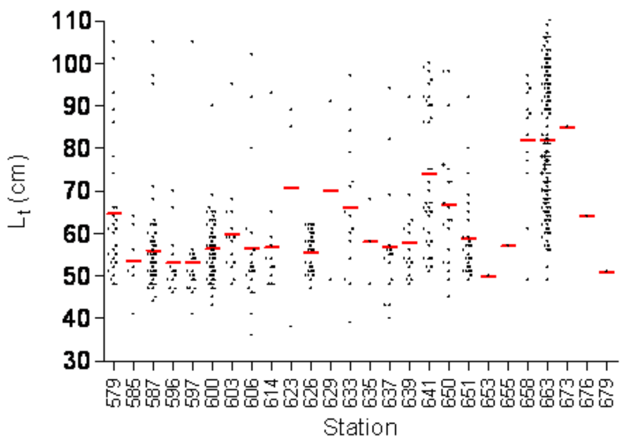
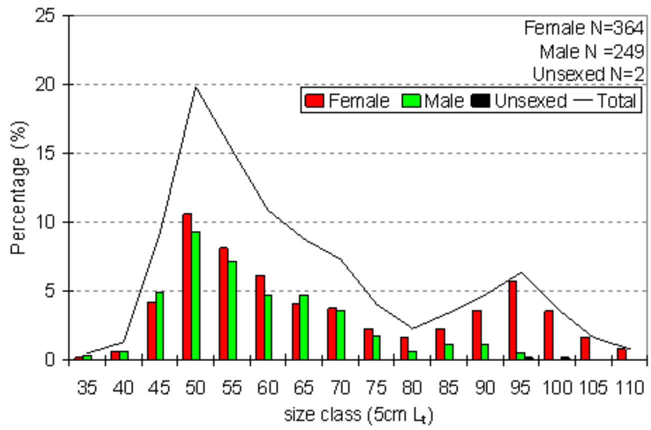



Fig. 3. CPUE of *Genypterus blacodes* caught during ZDLT1-10-2010




a




b

Fig. 4: a) *Genypterus blacodes* mean & size distribution by station, b) size frequency by sex

## *3.3 Grenadier Macrourus carinatus*

Grenadiers were taken at 11 of the 52 stations throughout the sampling area, with the total amounting to 831 kg. 55% of this total was caught in two stations 593 & 682 (Fig. 5). Grenadier size ranged from 12 to 32cm $L_{pa}$, with mean sizes 22.0cm and 17.3cm for females and males respectively (combined mean 21.2cm) (Fig. 6). Females dominated the samples with 83% overall.

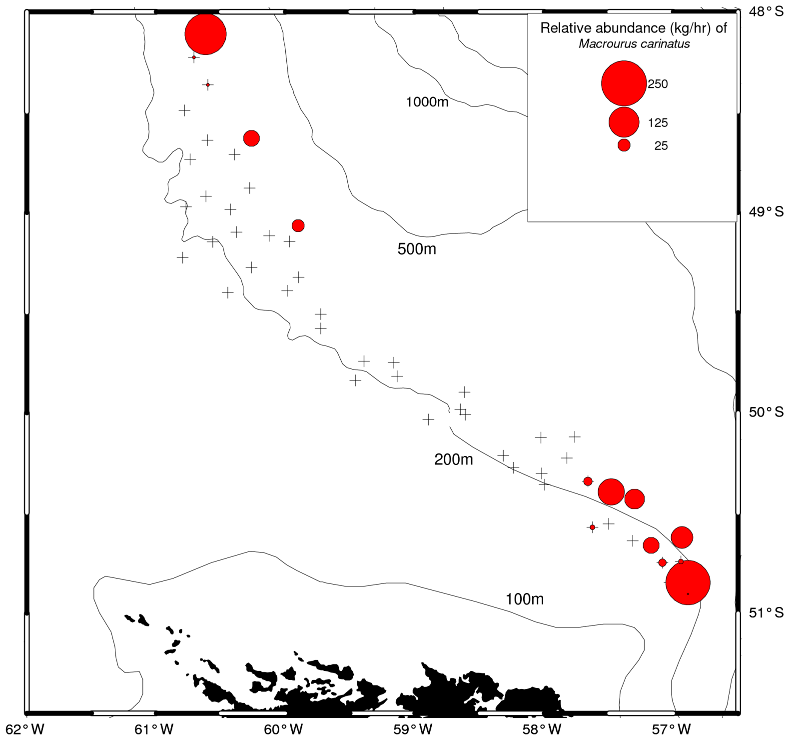



Fig. 5. CPUE of *Macrourus carinatus* caught during ZDLT1-10-2010

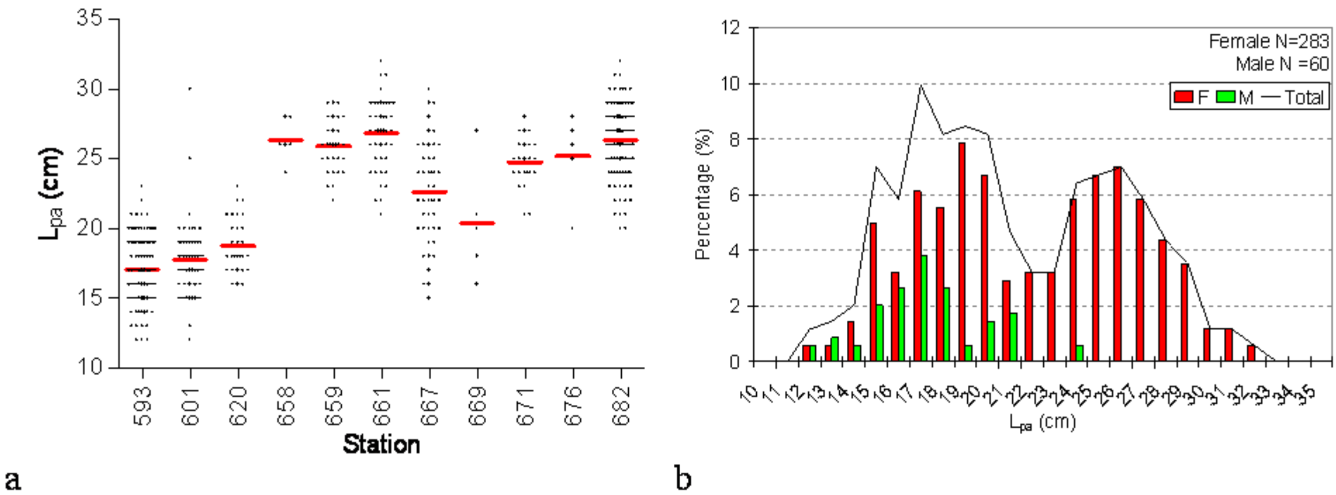



Figure 6: a) *Macrourus carinatus* mean & size distribution by station, b) size frequency by sex

## *3.4 Hakes Merluccius hubbsi and M. australis*

Hakes were taken at 37 of the 52 stations throughout the sampling area, 31 stations yielding *M. hubbs*i, 16 stations yielding *M. australis*, with the total amounting to 729kg (667kg *M. hubbsi*, 61kg *M. australis*) (Fig.7). *M. hubbsi* size ranged from 41 to 88cm $L_t$, with a combined mean size of 68.8cm (Fig. 8). Female *M. hubbs*i dominated the samples with 99.6% overall. *M. australis* size ranged from 60 to 88cm L*t*¬, with 76% of specimens females. Mean combined size was 69.6cm Lt.

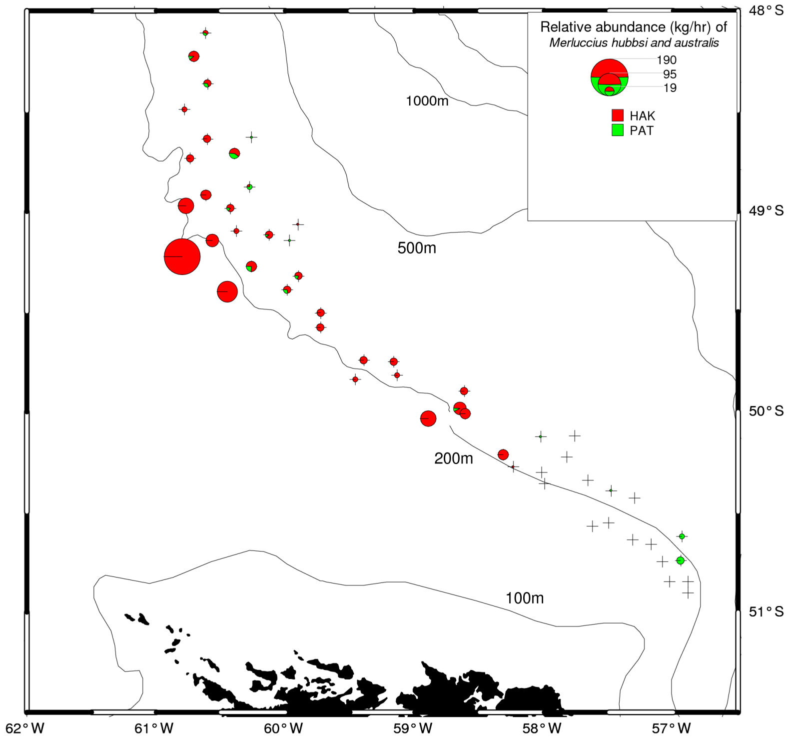
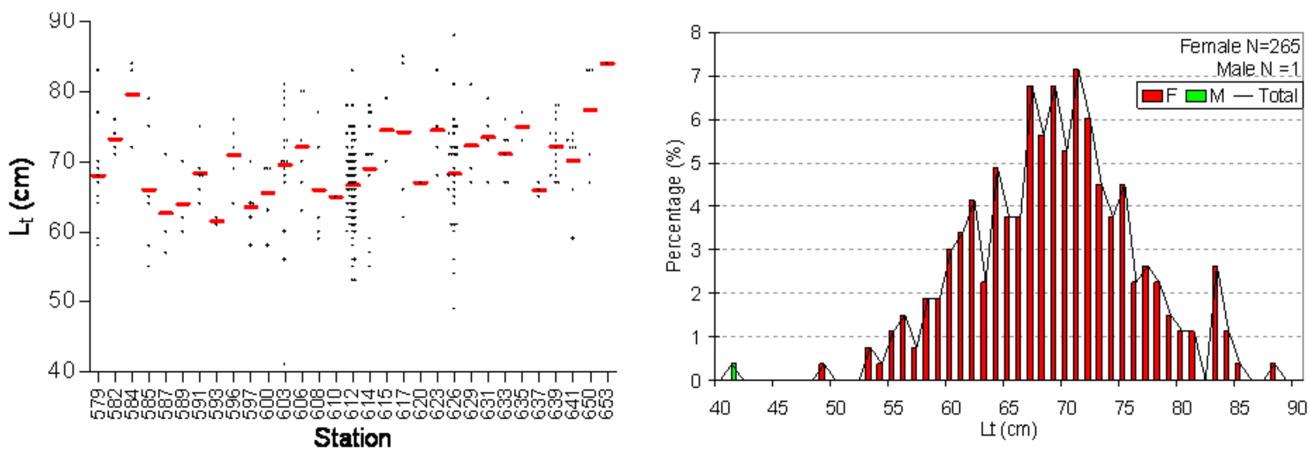



Fig. 7. CPUE of *Merluccius hubbsi* and *M. australis* caught during ZDLT1-10-2010




a b

Fig. 8: a) *Merluccius hubbsi* mean & size distribution by station, b) size frequency by sex

### 3.5 Patagonian toothfish *Dissostichus eleginoides*

Toothfish were taken at 46 of the 52 stations throughout the sampling area, with the total amounting to 582kg (Fig. 9). Catches were modest and consistent throughout, with half of the stations yielding between 10 and 32kg per station, the remainder less than that. Toothfish size ranged from 20 to 81cm $L_t$, with a combined mean size of 45.2cm. A number of stations had a significantly smaller size distribution than others, with a high prevalence of the smallest modal group of around 28-29cm $L_t$ (Fig. 10 and Fig. 11).

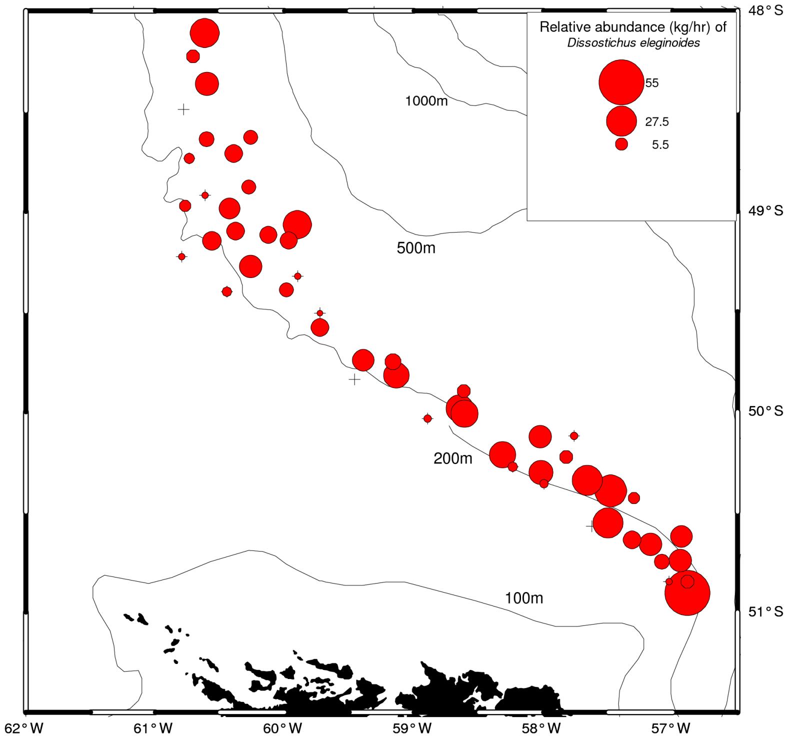



Fig. 9. CPUE of *Dissostichus eleginoides* caught during ZDLT1-10-2010

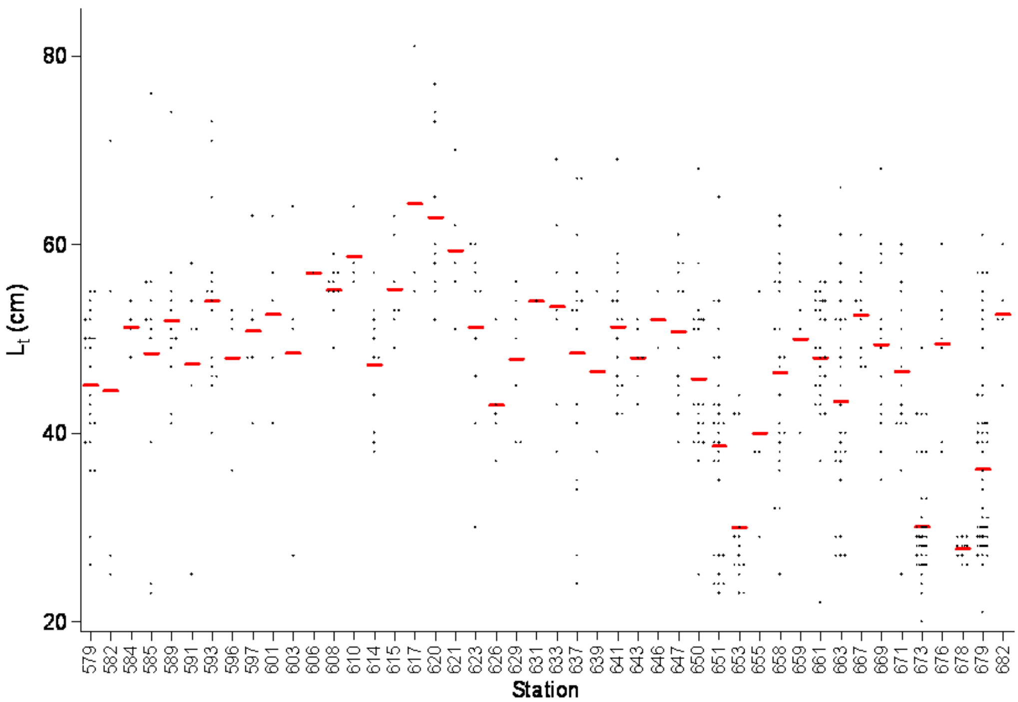



Fig. 10: *Dissostichus eleginoides* mean & size distribution by station

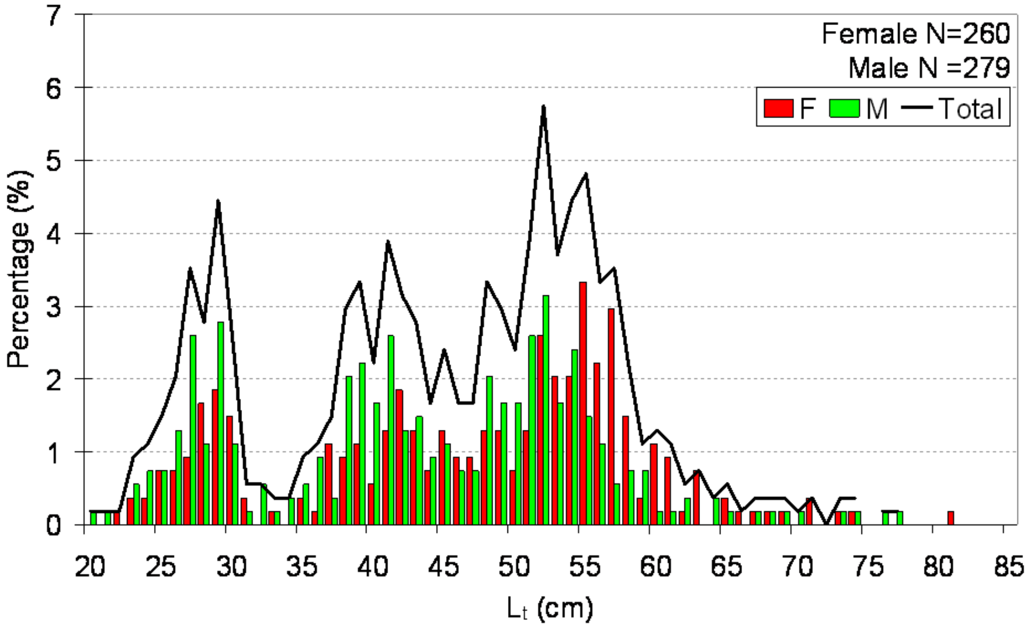



Fig. 11: *Dissostichus eleginoides* size frequency

### 3.6 Southern blue whiting Micromesistius australis

Southern blue whiting were taken at 9 of the 52 stations throughout the sampling area, with the total amounting to 459kg (Fig. 12). 94% of the amount was caught in just 4 stations, with amounts between 30 and 196kg per station, the remainder less than that. Southern blue whiting size ranged from 17 to 59cm $L_t$, with a combined mean size of 29.9cm. Three stations had a significantly smaller size distribution than the others, with a high prevalence of the smallest modal group of around 17-23cm $L_t$ (Fig. 13).

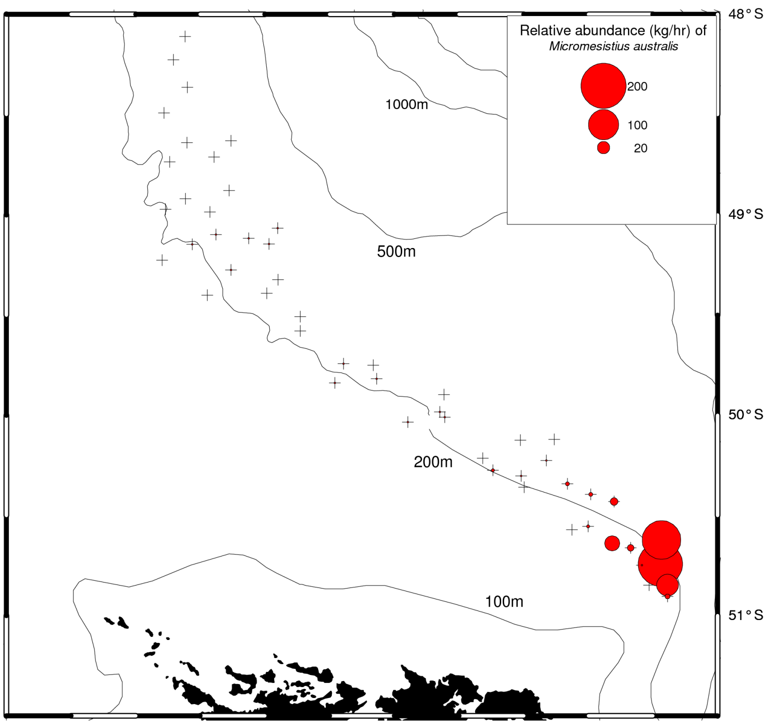



Fig. 12. CPUE of *Micromesistius australis* caught during ZDLT1-10-2010

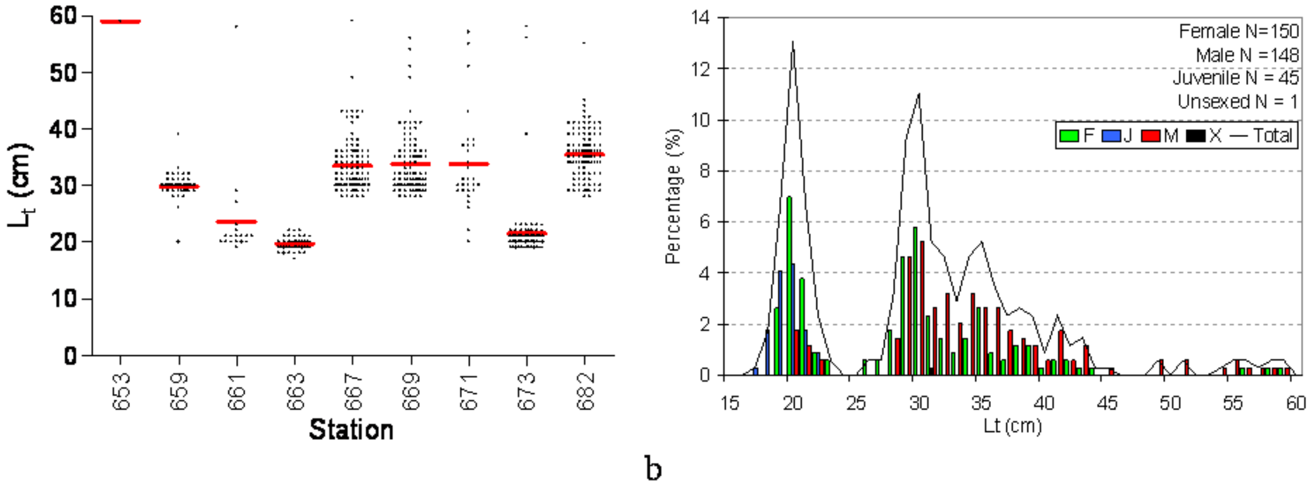



Fig. 13: a) *Micromesistius australis* mean & size distribution by station, b) size frequency by sex

## 3.7 Hoki

Hoki or whiptail hake *Macrouronus magellanicus* occurred almost everywhere during the survey, apart from some shallow water trawls. The fish was most abundant on the shelf break and slope (>250-300 m depths). The maximum catch of hoki was recorded at the central part of the survey, 11,112 kg/hr (Station 627, depth 311 m). Reasonable abundances of hoki were encountered in deep water stations in the southern part of the survey (400-680 kg/hr) (Fig. 14).

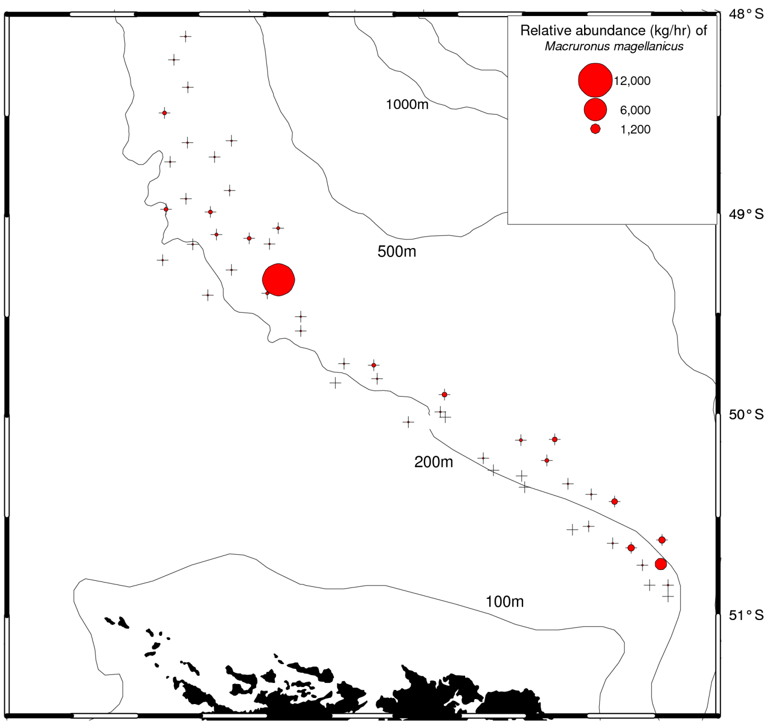



Fig. 14. CPUE of *Macrouronus magellanicus* caught during ZDLT1-10-2010

Length-frequency distributions and maturities of males and females were analysed separately for two regions, northern region (to the west of 59°W) and southern region (to the east of 59°W) (Fig. 15).

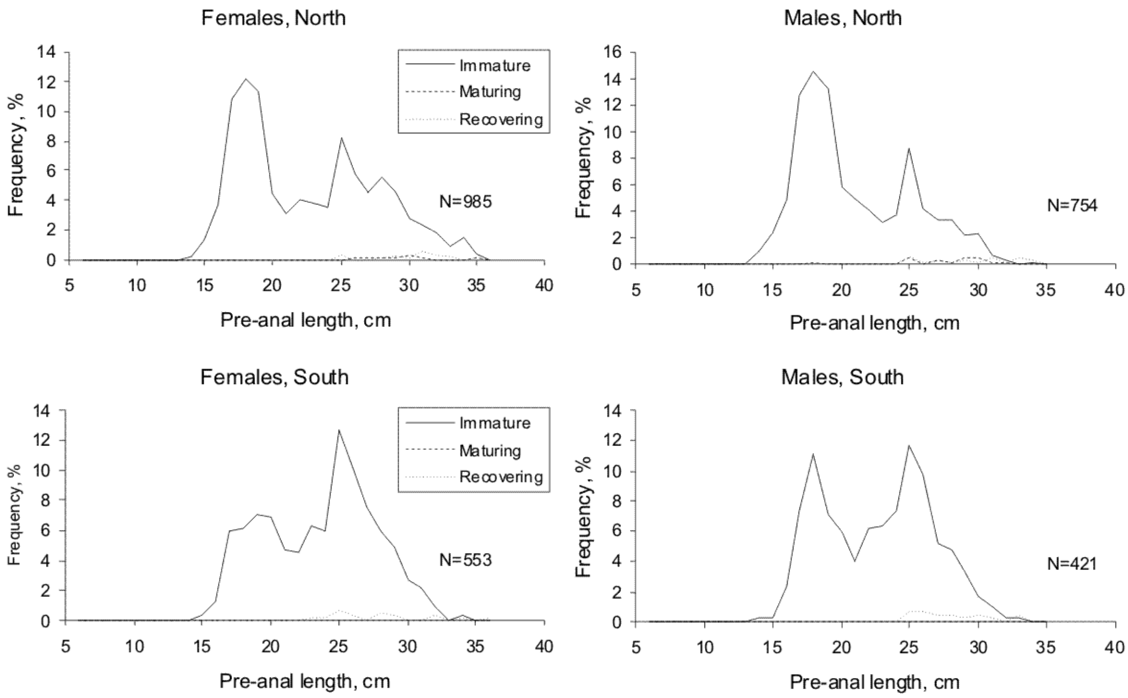



Fig. 15. Length frequency distributions of females and males of *Macrouronus magellanicus* at different depths in the northern and southern regions during ZDLT1-10-2010

Two modes in the length frequency were observed in both regions, small immature fish of 17 cm modal pre-anal length, and large fish being either recovering (stage 8) or completely recovered from the winter spawning, of 25-26 cm modal pre-anal length. There were no differences in modal sizes between males and females. However, in the northern region maximum sizes of females were larger than the males. There was a slight female bias in sex ratios in both regions. All aggregations of hoki were quite mobile, which is common for this time of the year as hoki uses the waters around the Falkland Islands as their feeding grounds.

## 3.8 Rock cod

Rock cod *Patagonotothen ramsayi* occurred in every trawl of the survey (Fig. 16). The overall abundance of this fish was high, especially in the southern part of the survey, where the achieved up to 7,500 kg/hr (Station 679, depth 214 m). Higher catches were encountered in the latter area at shallower depths (~150 m) on the shelf.

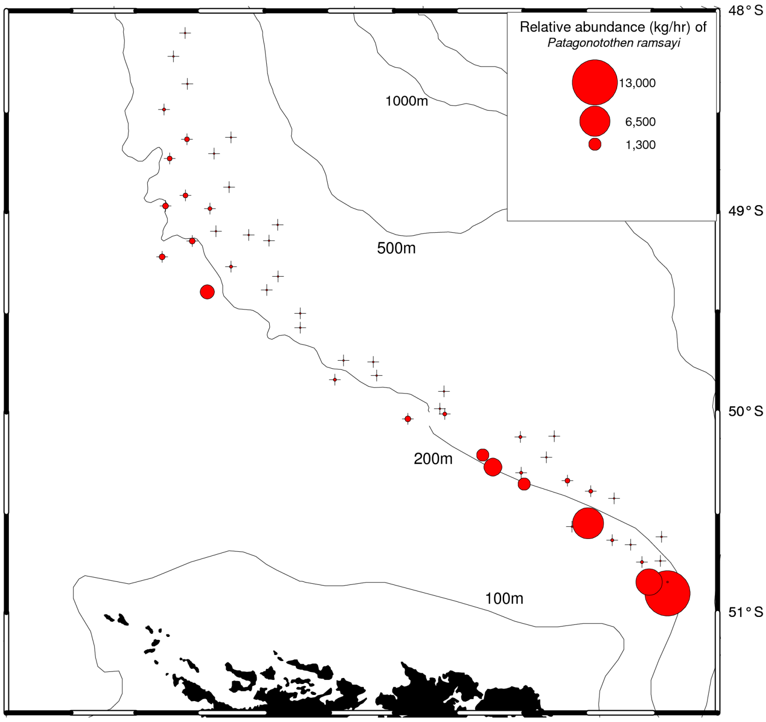



Fig. 16. CPUE of *Patagonotothen ramsayi* caught during ZDLT1-10-2010

Like for *L. gahi*, length-frequency distributions and maturities of males and females were analysed separately for depth ranges less and more than 200 m, and for two regions, northern region (to the west of 59°W) and southern region (to the east of 59°W).

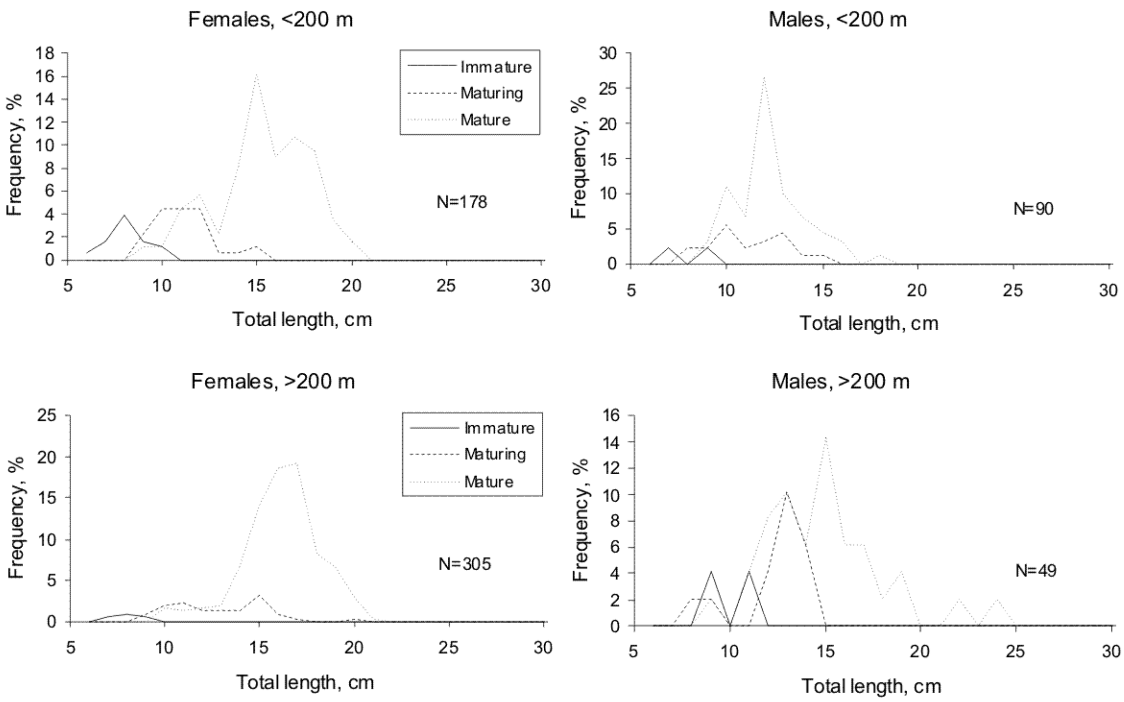



Fig. 17. Length frequency distributions of females and males of *Patagonotothen ramsayi* at different depths in the northern region during ZDLT1-10-2010

In the northern region, the modal sizes of rock cod were greater in shallow waters than those in deeper waters. The fish were mainly immature and recovering from spawning (stage 8). The modal sizes of females (23 cm) were smaller than those of males (28 cm) (Figure 17). Sex ratios in shallow waters were almost equal, but females were prevalent in catches in deeper waters (>200 m).

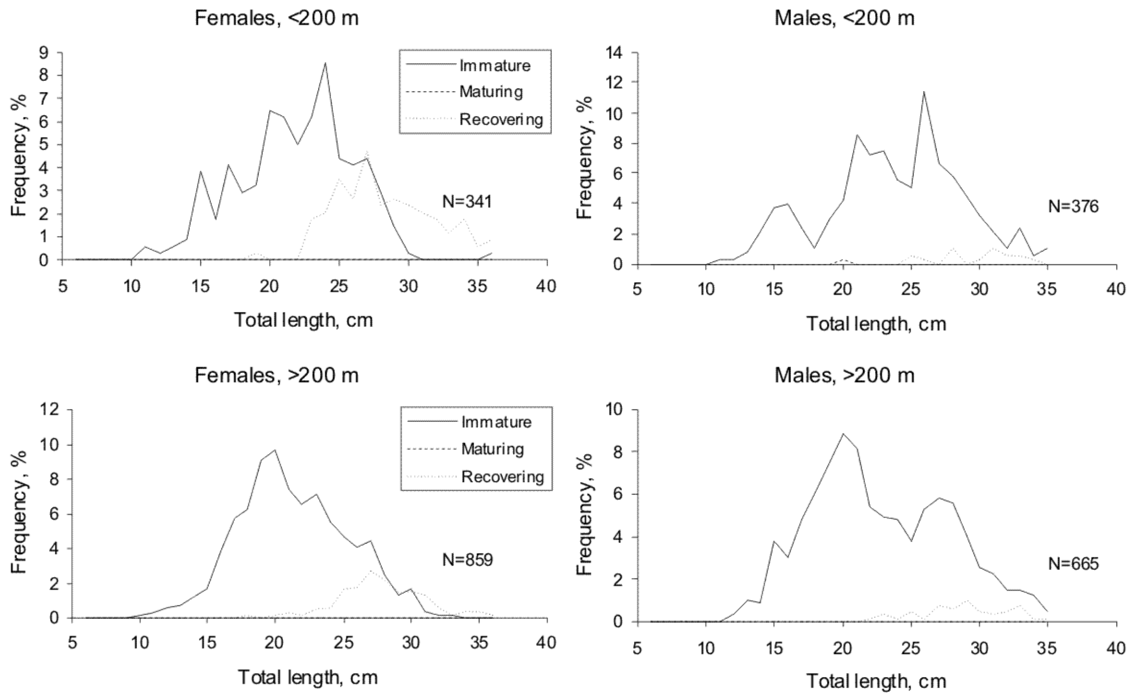



Fig. 18. Length frequency distributions of females and males of *Patagonotothen ramsayi* at different depths in the southern region during ZDLT1-10-2010

In the southern region, the trends in sizes and maturities of rock cod were generally the same as those in the northern region, with larger fish being more abundant in shallow waters and modal sizes of males being larger than those of females. However, more small sized fish occurred in deeper waters (at >200 m depths) in the southern region, with modal length of 20 cm TL (Fig. 18).

The results of the survey confirmed our knowledge about the life cycle of rock cod in the waters around the Falkland Islands. After spawning in winter months (June-August), large rock cod moved onto the shelf to feed. The southern parts of the survey located in the northern part of the Loligo box are well-known nursery grounds for rock cod, which aggregate to feed on abundant zooplankton that have been attracted by the productive upwelling of the Falkland Current on the shelf break.

## 3.9 Loligo gahi

Patagonian squid *Loligo gahi* was present almost at all stations of the survey, apart from the deepwater stations (>300 m) in the northern part of FICZ/FOCZ (Fig. 19). The overall abundance of squid was low during the survey, with catches not exceeding 100 kg/hr. *Loligo* were more abundant on the shelf break and slope in the southern part of the survey (east of 59ºS) than in the northern part. The maximum catch was observed in shallow waters of the northern part of the *Loligo* box (89.7kg/hr, Station 665, depth 138 m).

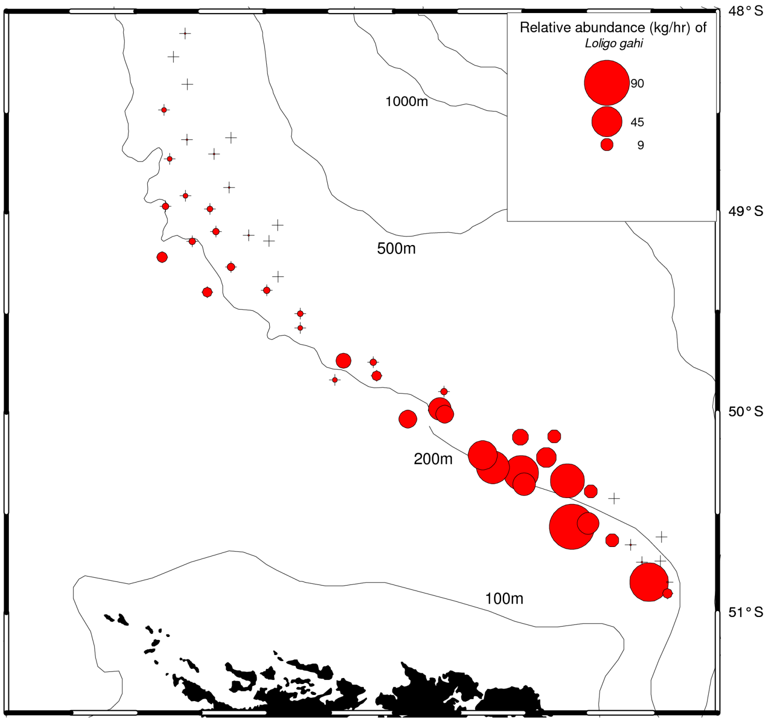



Fig. 19. CPUE of *Loligo gahi* caught during ZDLT1-10-2010

During the survey, squid of both cohorts were present in catches, mature and large squid of the spring-spawning cohort (SSC) and small immature squid of the autumn-spawning cohort (ASC).

Length-frequency distributions and maturities of males and females were analysed separately for depth ranges less and more than 200 m, and for two regions, northern region (to the west of 59°W) and southern region (to the east of 59°W).

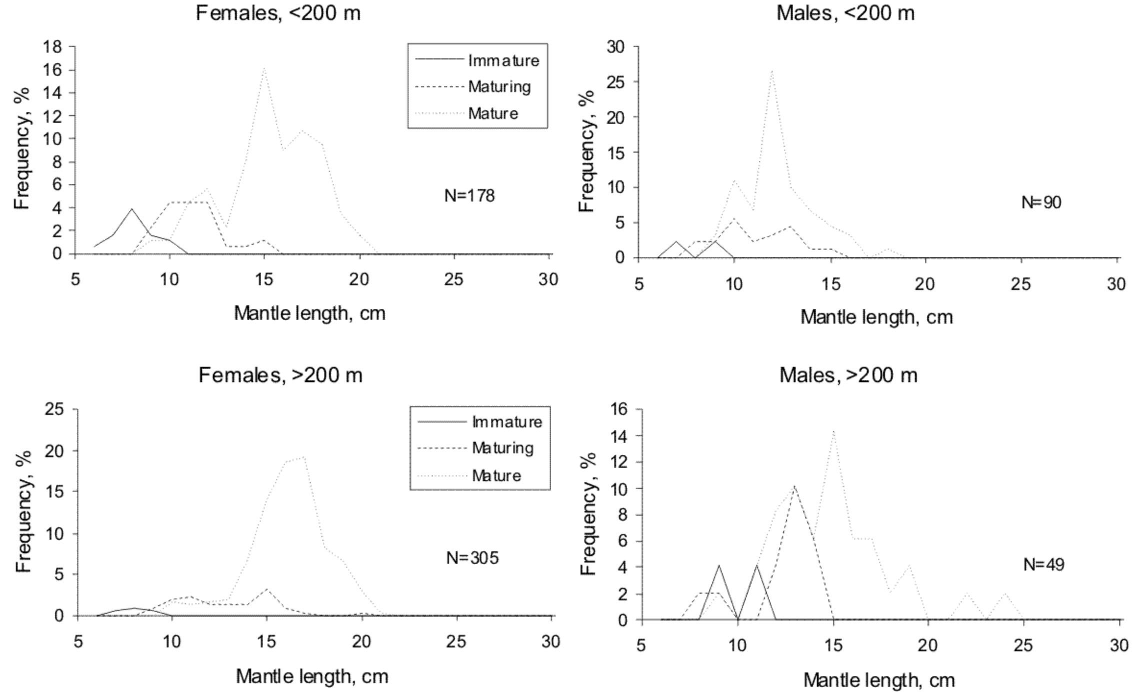



Fig. 20. Length frequency distributions of females and males of *Loligo gahi* at different depths in the northern region during ZDLT1-10-2010

In the northern region, large mature squid were predominant in catches at all depths. Modal length of females (15-17 cm ML) was greater than that of males (12-14 cm ML), but the maximum sizes of males were larger. Prevalence of females in sex ratios was much greater at >200 m depths than in shallow waters. Small and immature squid of ASC occur in small numbers mainly at <200 m depths. Their sex ratio was close to equal (1:1) (Fig. 20).

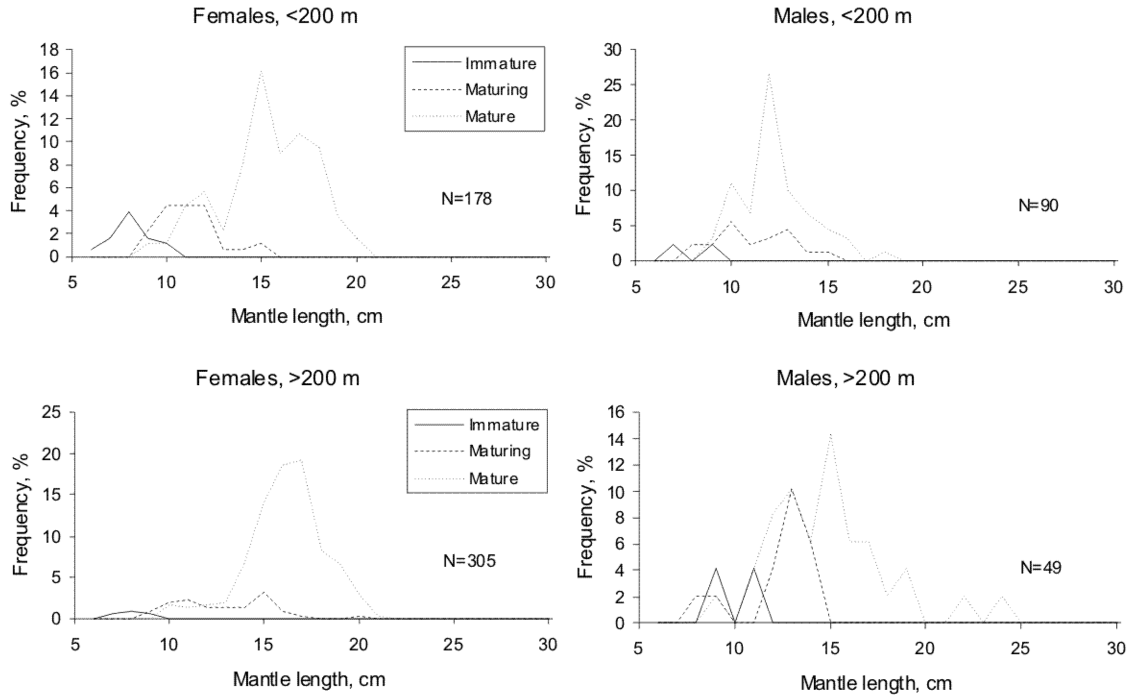



Fig. 21. Length frequency distributions of females and males of *Loligo gahi* at different depths in the southern region during ZDLT1-10-2010

In the southern region, size ranges and modal lengths of both males and females were quite similar to those observed in the northern region, but the distribution of squid of both cohorts was different. Compared to the northern region, more immature ASC squid were encountered in deep water (>250 m). In shallow waters (<200 m) mature squid were almost absent, however small ASC squid were abundant. Among SSC squid, sex ratios showed a female bias in the southern region over the shelf break (>200 m) (Fig. 21).

As in October last year, the majority of large and mature females of the SSC with ready to spawn and occurred in deepwater far from the Falkland coasts with only a few animals occurring in shallow waters. It indicates (albeit indirectly) a possibility of deepwater spawning of *Loligo* on the rocky grounds on the shelf break. The abundance of the SSC squid was quite low as the peak of spawning occurred before the survey, and most squid died after spawning. The presence of significant abundances of small ASC squid in shallow waters in the northern part of the *Loligo* box may indicate of another good first season for Loligo in 2011.

# 4.0 Rajidae

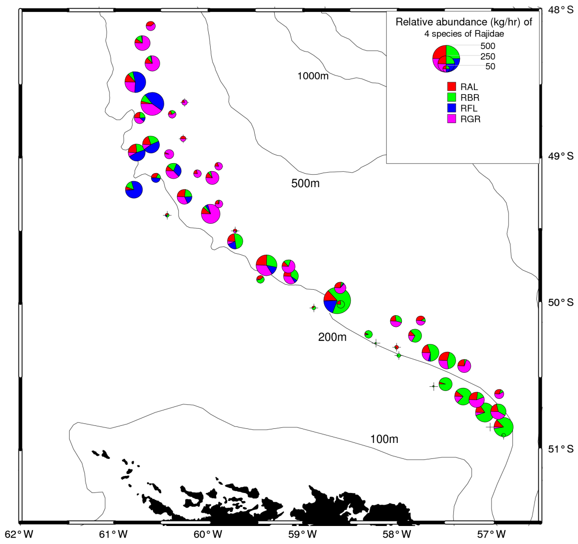
This family, of which a total of some 12 species from 3 (or 4) genera (*Bathyraja, Dipturus, Psammobatis*, and arguably *Zearaja*) were caught, comprised 13.97% of the total catch from the 52 bottom trawl stations, all of which yielded Rajidae in varying amounts. The highest skate catch occurred at the first station 579 with 537kg, followed by station 585 with 398kg, and station 597 with 396kg. Only three stations yielded catches of less than 20kg, namely stations 679, 653, and 678.

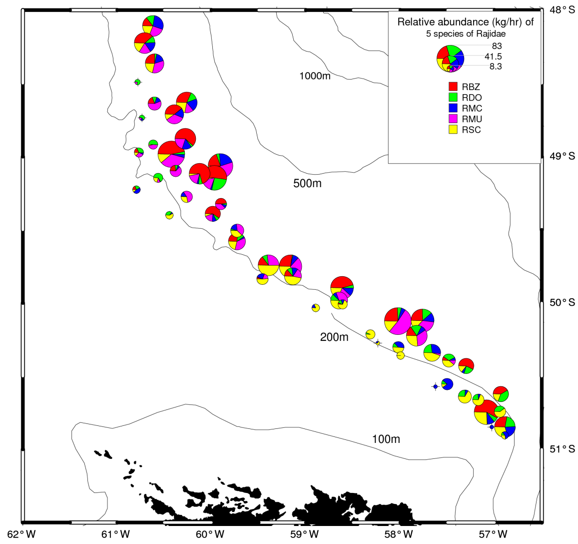
The four most abundant species comprised 79% of the skate catch, totalling 7,248kg (Table 3).

Table 3: Total Rajidae catch of all trawl stations during research cruise ZDLT1-10-2010

| Species Code | Species name | Total Catch (kg) | Total Sampled (kg) | Total Discarded (kg) | Proportion (%) |
|---|---|---|---|---|---|
| RBR | *Bathyraja brachyurops* | 2,441.340 | 2,441.240 | 6.915 | 26.66% |
| RGR | *Bathyraja griseocauda* | 2,377.760 | 2,314.760 | 48.319 | 25.96% |
| RAL | *Bathyraja albomaculata* | 1,311.010 | 1,311.010 | 122.354 | 14.32% |
| RFL | *Dipturus (Zearaja) chilensis* | 1,118.240 | 1,118.240 | 0.000 | 12.21% |
| RBZ | *Bathyraja cousseauae* | 483.040 | 483.040 | 20.985 | 5.27% |
| RSC | *Bathyraja scaphiops* | 405.040 | 397.390 | 27.317 | 4.42% |
| RMU | *Bathyraja multispinis* | 393.970 | 391.180 | 0.713 | 4.30% |
| RDO | *Raja doellojuradoi* | 217.000 | 217.000 | 208.926 | 2.37% |
| RMC | *Bathyraja macloviana* | 209.610 | 209.610 | 51.127 | 2.29% |
| RDA | *Dipturus argentinensis* | 110.990 | 110.240 | 0.000 | 1.21% |
| RPX | *Psammobatis spp.* | 45.870 | 45.870 | 42.060 | 0.50% |
| RTR | *Dipturus trachydermus* | 44.010 | 44.010 | 0.000 | 0.48% |
| | | **9,157.880** | **9,083.590** | **528.716** | |

Relative abundance charts for skates have been split into three separate figures (Fig.14), with the first one showing species with highest abundance (RBR, RGR, RAL, and RFL), the second one showing those of moderate abundance (RBZ, RSC, RMU, RDO and RMC), and the third showing three of low abundance (RDA, RPX, and RTR).



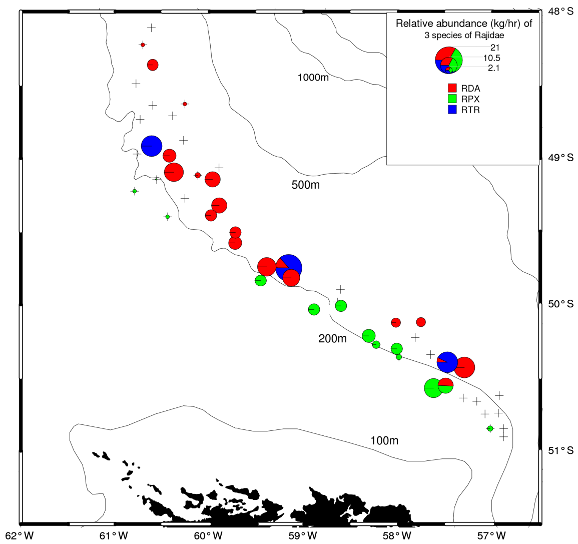




Figure 22: Relative abundance (kg/hr) of skate caught on ZDLT1-10-2010

## *4.1 Skate Biology*

### *4.1.1 Bathyraja brachyurops*

A total of 2,441kg was caught in 46 of the 52 stations, comprising 27% of the skate catch. Catches occurred within the depth range 130-409m, with highest catch at a depth of 237m, but on the whole more dominant in the 250-299m depth range.

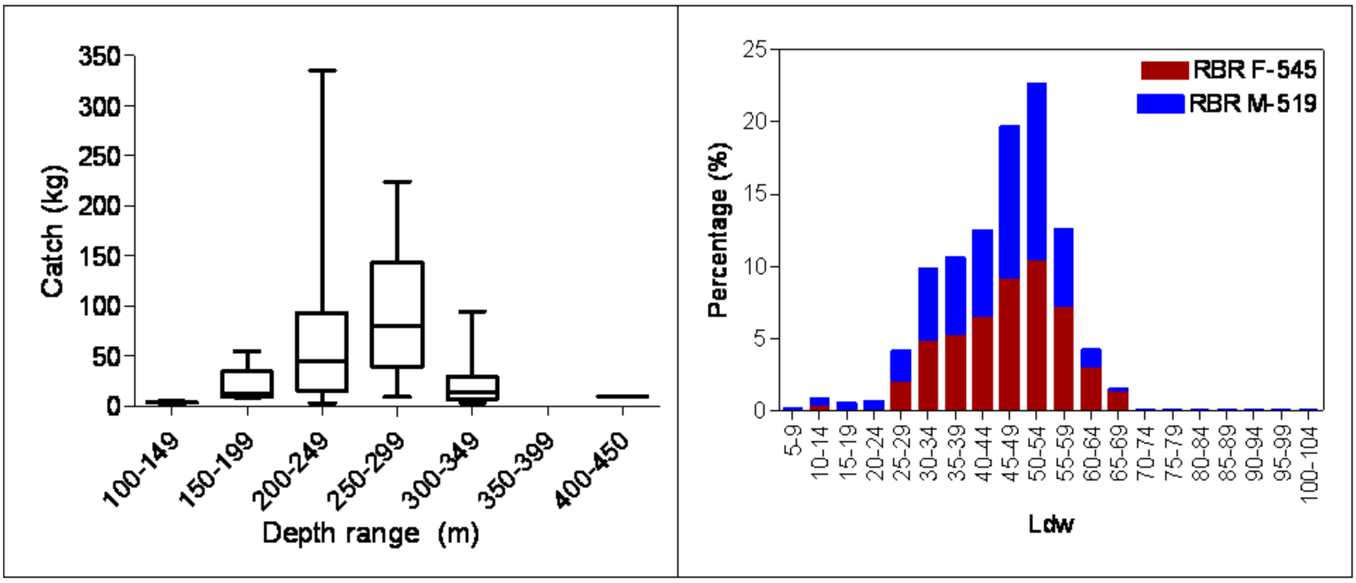



Fig. 23: Depth range of catches and size frequency of *Bathyraja brachyurops*

Disk width ranged between 9cm and 68cm with a mean of 45.5 (XF=46.3, XM 44.7) (Fig. 23). Overall, the population revealed a slight (51.1%) female predominance. 9.9% of all females were carrying egg capsules, which equates to 16.7% of females above the Ldw at 50% maturity of 46.6cm.

### *4.1.2 Bathyraja griseocauda*

A total of 2,378kg was caught, comprising 26% of the skate catch in 43 of the 52 stations. Catches occurred within the depth range 170-409m, with highest catch at a depth of 240m, but on the whole more dominant in the 300-349m depth range.

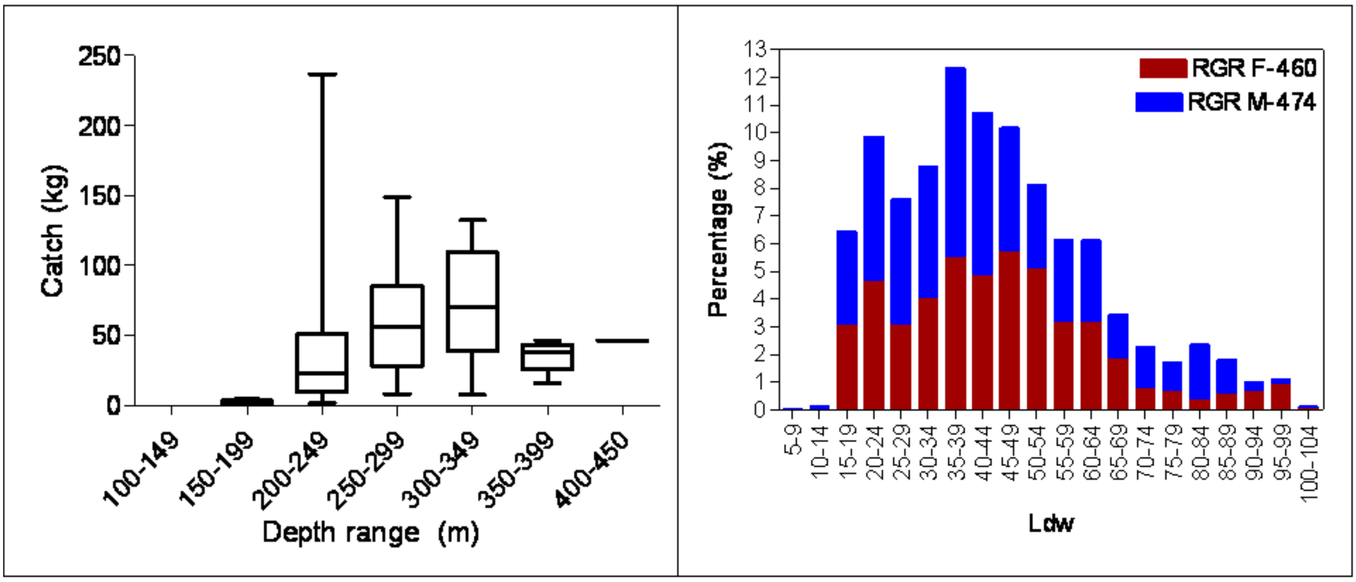



Fig. 24: Depth range of catches and size frequency of *Bathyraja griseocauda*

Disk width ranged between 10cm and 102cm with a mean of 44.1 (XF=45.0, XM 43.2) (Fig. 24). Overall, the population revealed a slight (50.8%). 2 females were carrying egg capsules, 8.3% of females above the Ldw at 50% maturity of 83.3cm.

### 4.1.3 *Bathyraja albomaculata*

A total of 1.311kg was caught, comprising 14% of the skate catch in 48 of the 52 stations. Catches occurred within the depth range 136-409m, with highest catch at a depth of 262m, and on the whole most dominant in the 200-299m depth ranges.

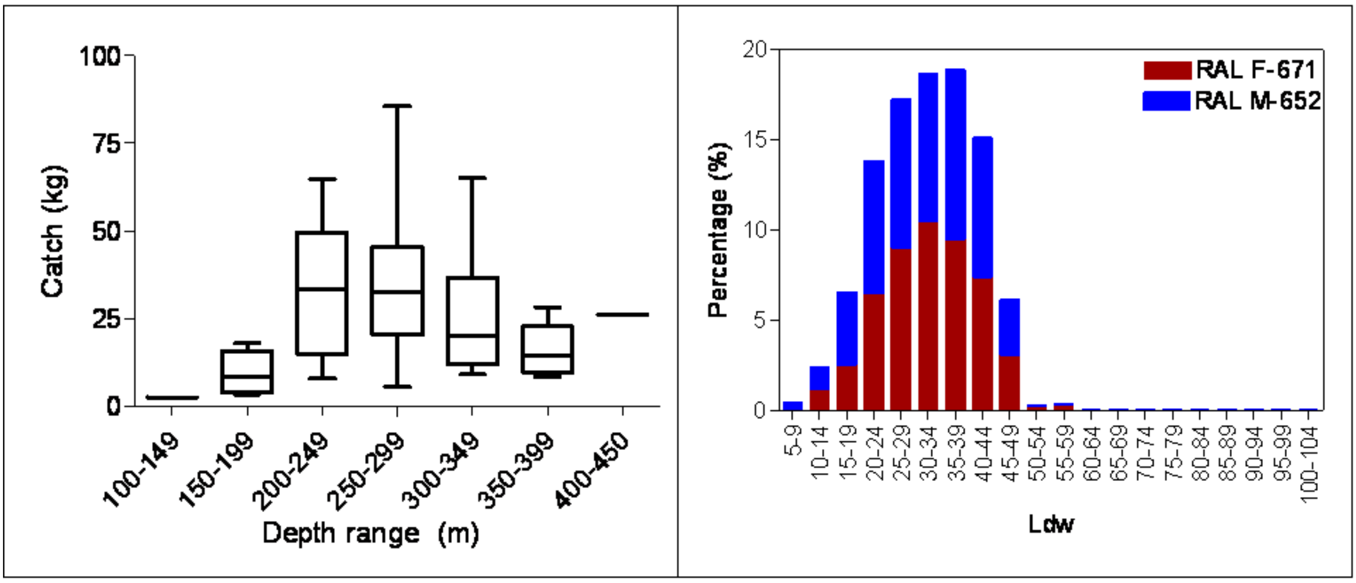



Fig. 25: Depth range of catches and size frequency of *Bathyraja albomaculata*

Disk width ranged between 8cm and 59cm with a mean of 31.7 (XF=32.1, XM 31.3) (Fig. 25). Overall, the population revealed a slight (50.7%) female predominance. 6 of the females were carrying egg capsules, only 4.1% of females above the Ldw at 50% maturity of 40.0cm. The emaciated appearance, very dark livers, and a general poor condition in a number of the adult specimens (both female and male), which may be attributed to post-spawning loss in condition, should be considered for future

### 4.1.4 *Dipturus chilensis*

A total of 1.118kg was caught, comprising 12% of the skate catch in 17 of the 52 stations. Catches occurred within the depth range 183-335m, with highest catch at a depth of 265m, and on the whole most dominant in the 200-299m depth ranges.

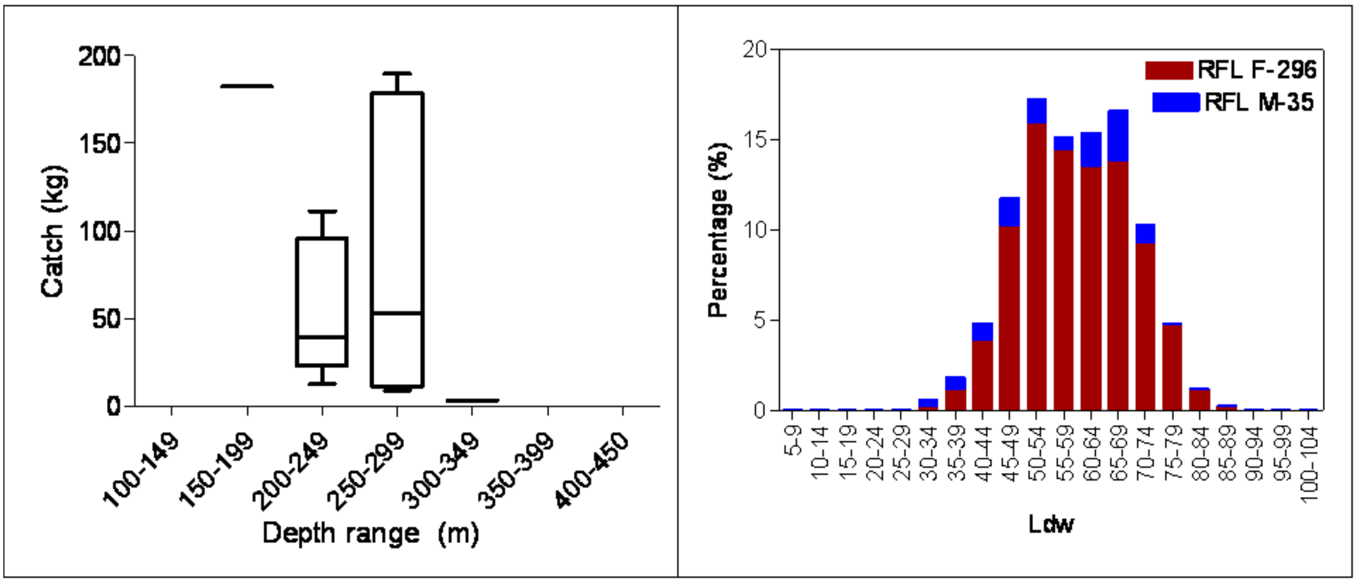



Fig. 26: Depth range of catches and size frequency of *Dipterus chilensis*

Disk width ranged between 34cm and 87cm with a mean of 59.2 (XF=59.5, XM 56.4) (Fig. 26). Overall, the population revealed a strong (89.4%) female predominance. None of the 70 females above the Ldw at 50% maturity of 67.7cm were carrying egg capsules. This, as well as the very low proportion of males might suggest that this species was migrating through the fishing area.

### 4.1.5 *Bathyraja cousseauae*

A total of 483kg was caught, comprising 5% of the skate catch in 33 of the 52 stations. Catches occurred within the depth range 170-409m, with highest catch at a depth of 345m, and on the whole most dominant in the 250-399m depth ranges.

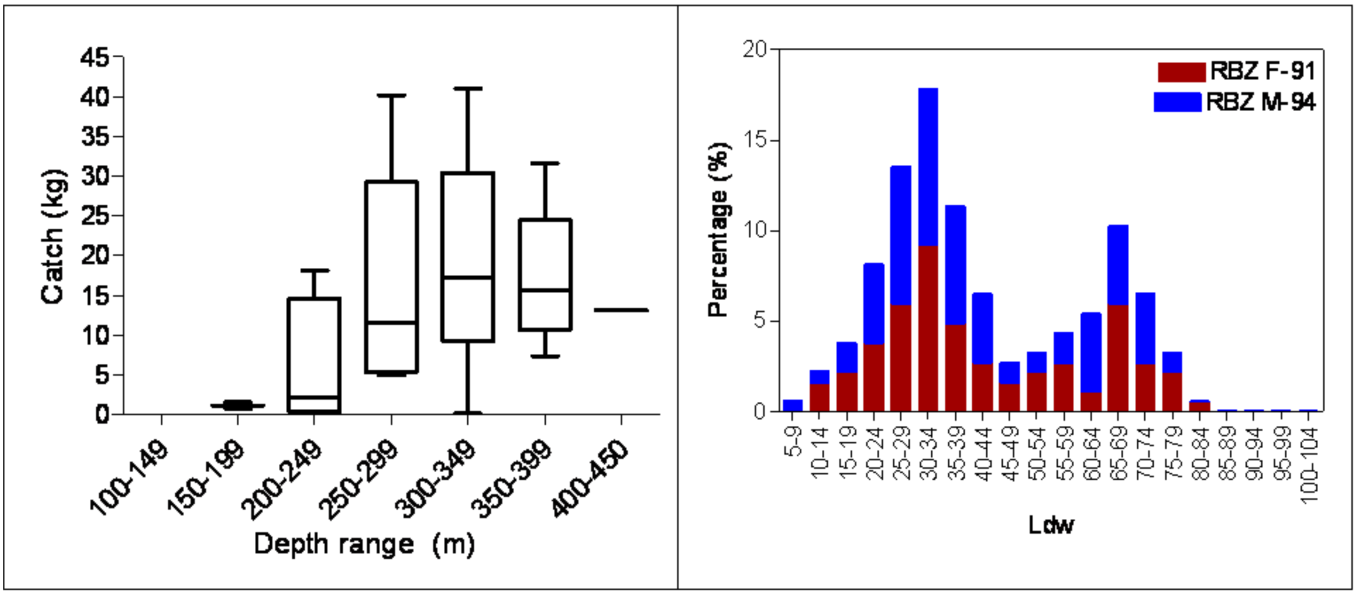



Fig. 27: Depth range of catches and size frequency of *Bathyraja cousseauae*

Disk width ranged between 8cm and 82cm with a mean of 42.3 (XF=42.7, XM 41.8) (Fig. 27). Overall, the population revealed a slight (50.8%) male predominance. One of the 16 females above the Ldw at 50% maturity of 66.6cm was carrying egg capsules (6.3%).

The size frequency showed a distinct bi-modal distribution, with the larger animals >45cm Ldw predominantly caught in deeper waters (>300m), and the smaller animals predominantly caught in waters <300m. At station 601 at 399m, a large number of egg capsules from this species were encountered encrusted within the Octocorals prevalent at this station, suggesting we found a spawning site for this species. The previous station (600) had yielded the one egg-carrying female.

### 4.1.6 *Bathyraja scaphiops*

A total of 405kg was caught, comprising 4% of the skate catch in 43 of the 52 stations. Catches occurred within the depth range 138-409m, with highest catch at a depth of 262m, and on the whole most dominant in the 250-299m depth range.

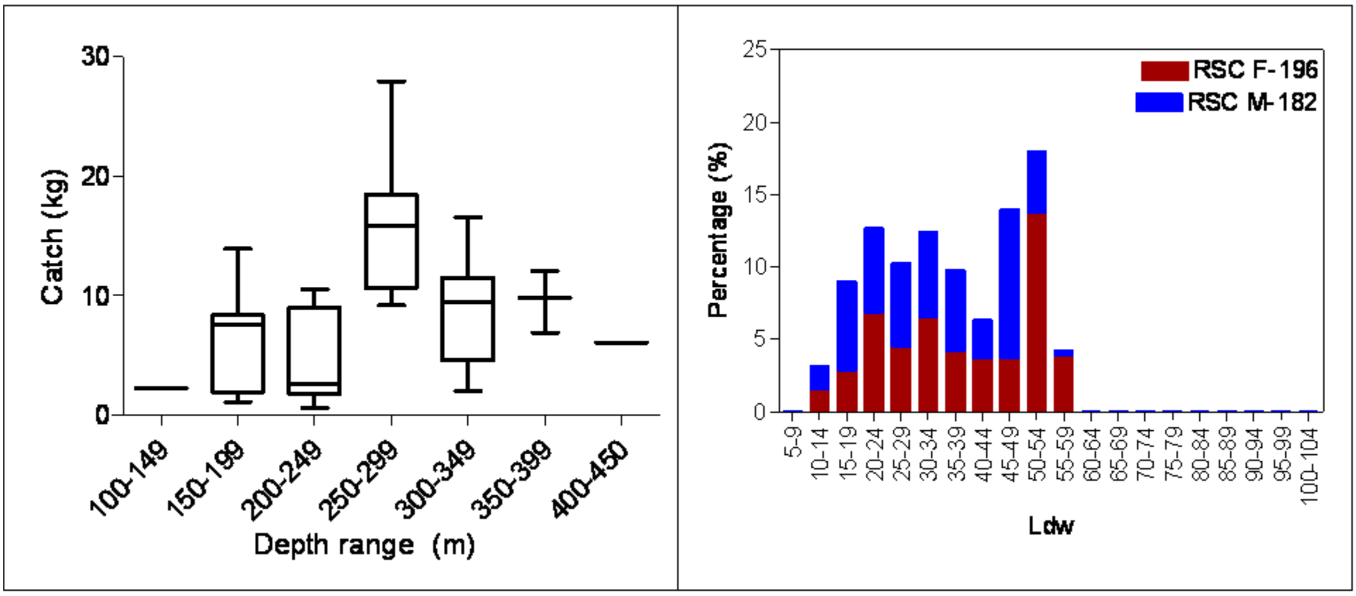



Fig. 28: Depth range of catches and size frequency of *Bathyraja scaphiops*

Disk width ranged between 11cm and 59cm with a mean of 35.8 (XF=37.2, XM 34.4) (Fig. 28). Overall, the population revealed a slight (50.4%) male predominance. Four of the 31 females above the Ldw at 50% maturity of 42.9cm were carrying egg capsules (6.2%).

### 4.1.7 Bathyraja multispinis

A total of 394kg was caught, comprising 4% of the skate catch in 33 of the 52 stations. Catches occurred within the depth range 170-399m, with highest catch at a depth of 283m, and on the whole most dominant in the 250-399m depth ranges.

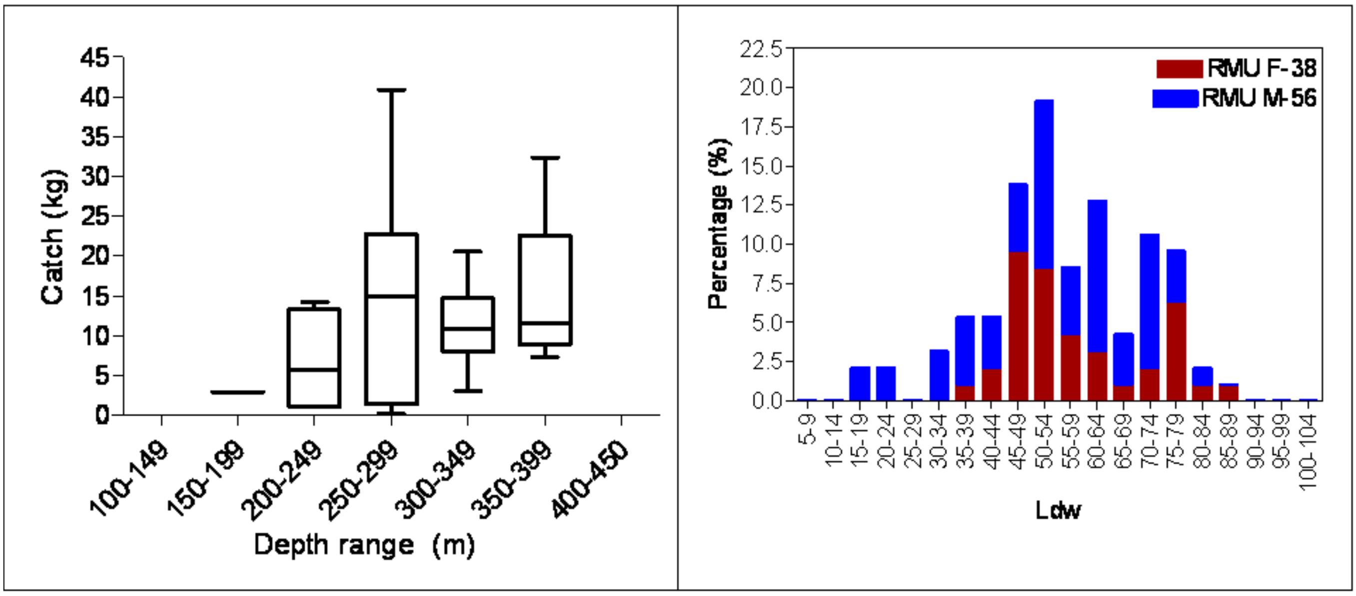



Fig. 29: Depth range of catches and size frequency of *Bathyraja multispinus*

Disk width ranged between 19 and 85cm with a mean of 55.9cm (XF=58.1, XM=54.3) (Fig. 29). Overall, the population revealed a male predominance (59.6%). No females carrying egg cases were caught, and the Ldw at 50% maturity was 69.1cm.

### 4.1.8 Amblyraja doellojuradoi

A total of 217kg was caught, comprising 2% of the skate catch in 45 of the 52 stations. Catches occurred within the depth range 170-409m, with highest catch at a depth of 345m, but on the whole occurring at low levels across depth ranges 200-399m.

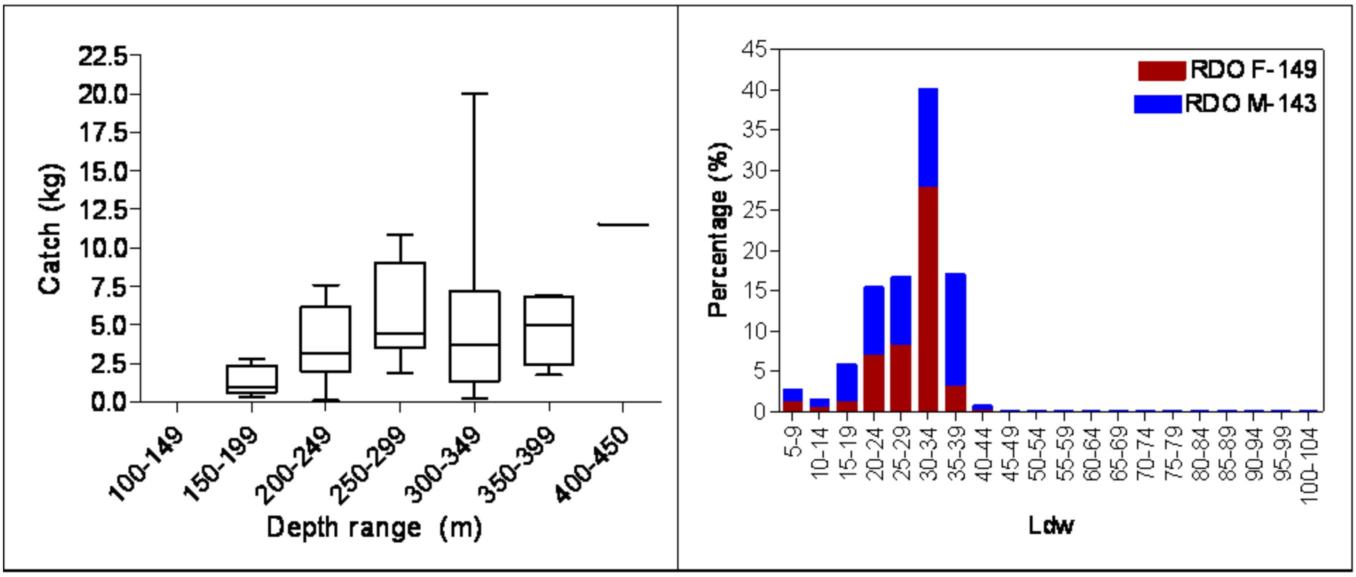



Fig. 30: Depth range of catches and size frequency of *Amblyraja deollojuradoi*

Disk width ranged between 7 and 40cm with a mean of 28.8cm (XF=29.0, XM=28.5) (Fig. 30). Overall, the population revealed a slight female predominance (51.0%). 8 females carrying egg cases were caught, 8.0% of females above the Ldw at 50% maturity of 28.5cm.

### 4.1.9 Bathyraja macloviana

A total of 210kg was caught, comprising 2% of the skate catch in 47 of the 52 stations. Catches occurred within the depth range 130-409m, with highest catch at a depth of 381m, but on the whole occurring at low levels across depth ranges 100-349m peaking in 350-399m.

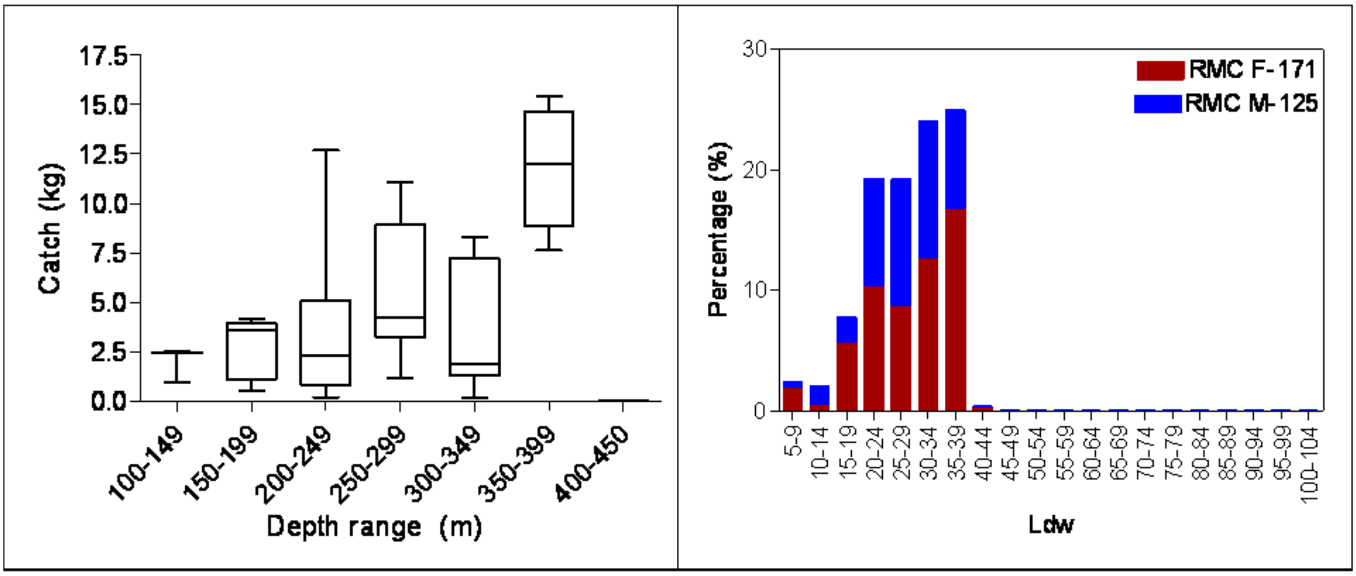



Fig. 31: Depth range of catches and size frequency of *Bathyraja maclovina*

Disk width ranged between 7 and 40cm with a mean of 28.2cm (XF=28.3, XM=28.1) (Fig. 31). Overall, the population revealed a female predominance (57.5%). 5 females carrying egg cases were caught, 7.5% of females above the Ldw at 50% maturity of 32.7cm.

### 4.1.10 *Dipturus argentinensis*

A total of 111kg was caught, comprising 1% of the skate catch in 19 of the 52 stations. Catches occurred within the depth range 220-399m, with highest catch at a depth of 347m, but on the whole occurring at low levels across a relatively narrow depth range 200-399m peaking in 250-299m.

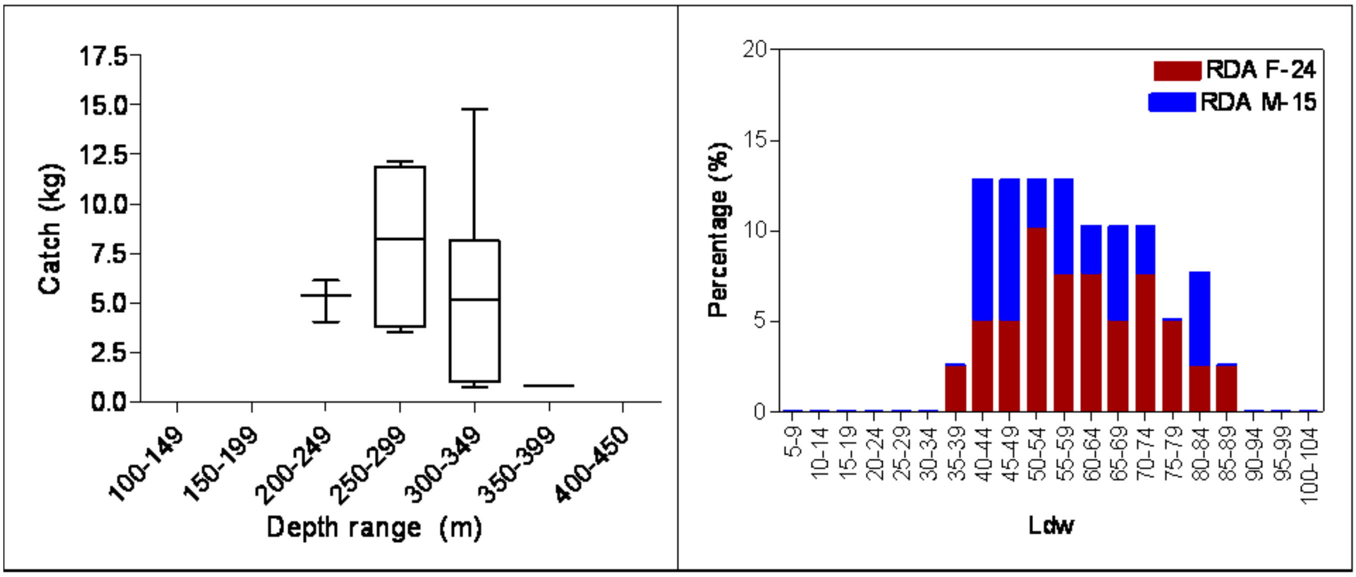



Fig. 32: Depth range of catches and size frequency of *Dipturus argentinensis*

Disk width ranged between 39 and 88cm with a mean of 59.5cm (XF=60.7, XM=57.7) (Fig. 32). Overall, the population revealed a female predominance (61.5%). No females carrying egg cases were caught, and no Ldw at 50% maturity could be established, as all specimens were in maturity stages I or II.

### 4.1.11 *Psammobatis spp.*

A total of 46kg was caught, comprising <1% of the skate catch in 13 of the 52 stations. Catches occurred within the depth range 130-225m, with highest catch at a depth of 136m, but on the whole occurring at low levels across a relatively narrow depth range 100-249m.

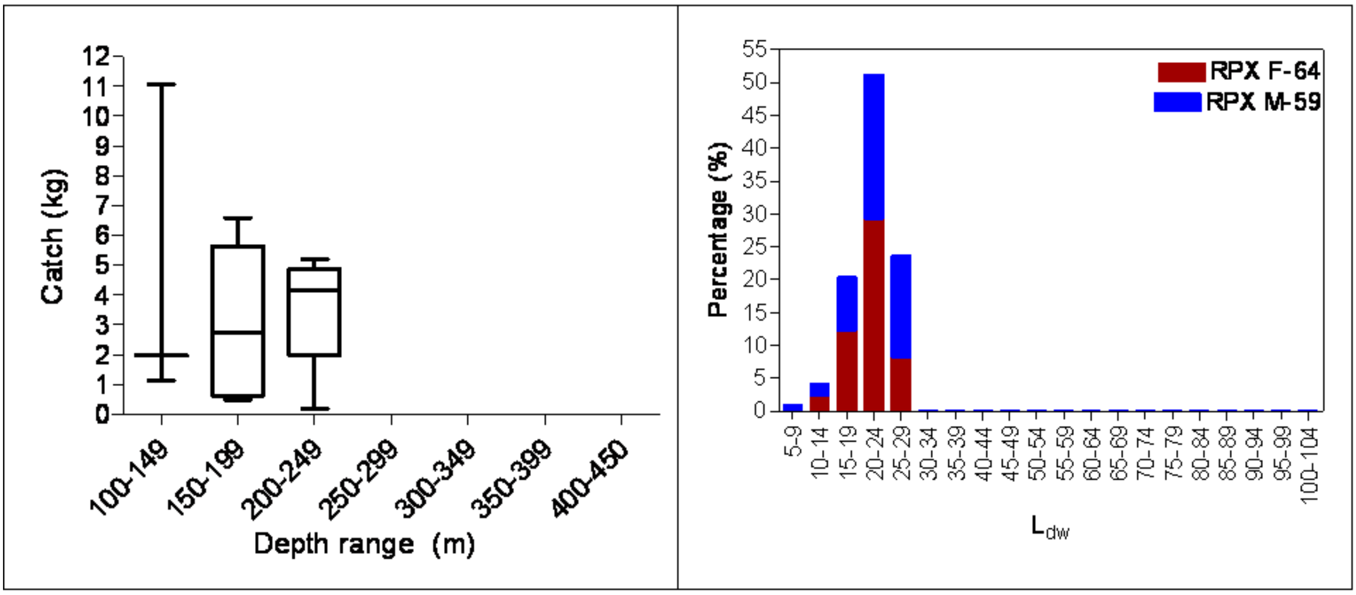



Fig. 33: Depth range of catches and size frequency of *Psammobatis spp.*

Disk width ranged between 7 and 27cm with a mean of 21.7cm (XF=21.2, XM=22.2) (Fig. 33). Overall, the population revealed a slight female predominance (52.0%). No females carrying egg cases were caught, and the Ldw at 50% maturity was 21.3cm.

### 4.1.12 *Dipturus trachydermus*

A total of 44kg was caught, comprising <1% of the skate catch in only 3 of the 52 stations. The three specimens were caught within the depth range 245-312m.

Disk width ranged between 99 and 116cm and the two females and one male were all immature.

# 5.0 Stock assessment of skates

The survey cruise was scheduled for duration of two weeks. The survey plan was designed to occupy two Falkland Conservation Zone grid units per day, as the best option for covering a significantly large area while also sampling at sufficiently high density. Twenty-six grid units were occupied (two per 13 days; allowing one day for unfavourable conditions). Grid units were chosen to represent the contiguous area of highest catches in the skate target fishery. The resulting survey area comprises the area from which 60% of all commercial skate catches (Fig. 34), and 89% of F/R-licensed skate catches were taken between July 2007 and September 2010. Survey area grid units ranged in depth from 100 to 509 m (Table 4), and a goal of the survey was to cover different depths as much as possible within the requirements for areal coverage. Exact placement of trawls within each grid unit was determined by the vessel master.

## *5.1 Skate assessment*

***Methods***

Similar to other commercial target species (rock cod; Winter et al., 2010a; *Loligo*; Winter et al, 2010b), the survey biomass of skates was estimated using a geostatistical extrapolation of catch density per trawl-swept area. Swept area was calculated as the trawl distance × horizontal net opening. Trawl distance was calculated as the straight-line distance between bottom-contact start position and end position. Net opening (rather than door spread) is generally used by FIFD as the horizontal distance measurement for catch area of bottom and near-bottom species (Brickle and Laptikhovsky, 2010; Winter et al, 2010b). The trawl behavioural response of skates is similar to that of flatfish (Weinberg et al., 2002), which typically follow inward ‘herding’ along the trawl bridles between the doors and net opening (Somerton and Munro, 2001; Ryer, 2008), but have reduced catch efficiency in the bridle path compared to the net path (Somerton et al., 2007). Skates have been found to have lower catchabilities than flatfish (Walsh, 1992, Kotwicki and Weinberg, 2005). Net opening is therefore an appropriate approximation for the trawl width that effectively catches skates.

For each skate species, biomass density was expressed as catch weight (g) divided by the catchability coefficient (q) per m$^2$ of trawl area. The catchability coefficient was calculated as the ratio of average CPUE of Spanish vessels to Korean vessels fishing under F/R license in 2010. Skates live close to the bottom and are susceptible to escaping underneath a trawl net (Kotwicki and Weinberg, 2005). Korean vessels routinely use heavier trawl footgear (Anders, 2009; 2010a; 2010b) and report higher CPUE of skates than Spanish vessels (Fig. 35), likely due to reduced escapement. The survey vessel Castelo is Spanish, and a catchability coefficient based on the CPUE ratio therefore represents a more precise estimate of its trawl efficiency. The CPUE ratio was applied equally to all skate species. Since commercial catches are not reported by species, no discrimination could be made that some species are undercaught relatively more or less than others.

For each skate species, biomass densities calculated from each of the 52 trawls were combined in an empirical variogram and fit to a kriging model to infer spatial correlation. For species density distributions that failed to show a significant fit in the variogram, cubic interpolation was used instead. Average kriged (or interpolated) density per area unit (1 $km^2$) was then multiplied by the total survey area to calculate total biomass. Variability distributions of the biomass totals were estimated by a randomization algorithm that included three components: trawl position, krige model error, and CPUE ratio. Trawl positions were randomized among three options: start, middle and end of the trawl, to model the status that catch may have been taken from anywhere along the trawl path (Winter et al., 2010a). Krige model error was randomized as a value generated from the normal distribution, such that:

$$\text{r.norm}\left(\text{mean} = \overline{(\text{area unit krige predictions})},\ \text{sd} = \overline{\left(\frac{\sqrt{\text{var (area unit krige predictions)}}}{\text{area unit krige predictions}}\right)} / \sqrt{n}\right)$$

where n is the number of trawl samples (52). For species with interpolated - rather than kriged - density this step was omitted. (Interpolation is deterministic and has no associated error). CPUE ratio was randomized by re-sampling, with replacement, the individual Spanish vessels and the individual Korean vessels that participated in the fishery in 2010 and for each re-sampled vessel, re-sampling with replacement its trawl CPUEs. The algorithm was iterated 2000×. At each iteration, the krige model (or interpolation) for the species was calculated using one randomly selected set of trawl positions; a total biomass estimate was calculated as the random normal-distributed average value of the area unit predictions of that krige model (or just the interpolation average), multiplied by the survey area; and that total biomass estimate was then scaled by the re-sampled CPUE ratio. The set of 2000 iterations represented the variability distribution of the estimate.

Generalized additive models (GAM) were calculated between species' trawl catch densities and depth, latitude, longitude, and bottom temperature. Primarily depth was examined as the variable of interest, because depth is itself correlated with latitude, longitude, and bottom temperature.

***Results***

A total of 9157.9 kg of skate was caught in the 52 survey trawls, between 3.9 and 537.5 kg per trawl, with 12 species identified in the catches. Biomass estimates per species extrapolated to the survey area are listed in Table 2 together with their 95% confidence intervals. The average CPUE ratio of Spanish to Korean vessels was 0.578. Spatial distributions modelled over the survey area are shown in Fig. 35b (right-side plots), and variability distributions of the total biomass estimates are shown in Fig. 35a (left-side plots). Spatial correlations among skate densities per trawl sample were generally weak, but only three species failed entirely to give significant kriging models (Table 5). Aggregate skate biomass in the survey was predominantly represented by 3 species (>70% of total biomass): RGR, RBR, and RAL; consistent with earlier studies that found these to be the most abundant skate species in Falkland waters (Agnew et al., 2000; Brickle et al., 2003; Wakeford et al., 2005; Arkhipkin et al., 2008). Species' total biomass estimates were not strongly related to the number of survey stations at which each species was found. Total biomass estimates were not significantly different (Tukey's test, $p > 0.05$) between RGR and RBR (the two most abundant skates), between RMU and RBZ, and between RDA and RTR. The spatial distributions of RGR and RBR were largely segregated (compare Figures 35b(RGR) and again consistent with earlier studies (Wakeford et al., 2005; Arkhipkin et al., 2008). Catch biomass densities of most skate species (8 out of 12) were significantly correlated with depth (Table 6).

# 6.0 Rock cod assessment

***Methods***

Rock cod biomass in the survey area was estimated by the same algorithm as for skates (above), except for catchability. For rock cod, Spanish vessels are not assumed to have lower trawl catchability than Korean vessels. However, rock cod are more mobile than skates, and the catch coefficient is realistically < 1 for either Spanish or Korean vessels. The catch coefficient was therefore modelled as a random uniform distribution in the range of 0.3 to 1 (see Winter et al., 2010a), with mean expectation 0.65. A Gaussian krige model was used for the rock cod spatial distribution (Table 7).
One objective for assessing rock cod in this survey was to compare with the rock cod biomass caught during the survey cruise in January / February (Brickle and Laptikhovsky, 2010). However, the January / February survey had fished generally further south, so that only a subset of trawls overlapped areally (Fig.36). These overlapping trawls were selected by eye (Table 8 and 9), and the densities of rock cod they caught were compared between the two surveys using a t-test.

***Results***

A total of 30447.9 kg of rock cod was caught in the 52 survey trawls, ranging from 0.3 to 7500.8 kg per trawl. The total biomass estimate for rock cod is given in Table 4. Variability of the total biomass estimate was strongly right-skewed, and densities of rock cod showed an increasing trend from northwest to southeast over the survey area (Fig. 37). The trawls that areally overlapped between the January-February survey and October-November survey did not show a statistically significant difference in rock cod densities (t-test: N = (12, 16); p = 0.335).

Table 4. FIFD conservation zone grids selected for survey sampling, at two trawls per grid. Depths in m.

| Index | Grid | LonStart | LonEnd | LatStart | LatEnd | minDepth | maxDepth |
|---|---|---|---|---|---|---|---|
| 1 | XLAQ | -57 | -56.5 | -50.5 | -50.75 | 301 | 505 |
| 2 | XMAQ | -57 | -56.5 | -50.75 | -51 | 100 | 490 |
| 3 | XKAP | -57.5 | -57 | -50.25 | -50.5 | 270 | 428 |
| 4 | XLAP | -57.5 | -57 | -50.5 | -50.75 | 126 | 408 |
| 5 | XMAP | -57.5 | -57 | -50.75 | -51 | 105 | 284 |
| 6 | XJAN | -58 | -57.5 | -50 | -50.25 | 242 | 345 |
| 7 | XKAN | -58 | -57.5 | -50.25 | -50.5 | 110 | 323 |
| 8 | XLAN | -58 | -57.5 | -50.5 | -50.75 | 103 | 262 |
| 9 | XJAM | -58.5 | -58 | -50 | -50.25 | 194 | 318 |
| 10 | XKAM | -58.5 | -58 | -50.25 | -50.5 | 107 | 250 |
| 11 | XHAL | -59 | -58.5 | -49.75 | -50 | 100 | 374 |
| 12 | XJAL | -59 | -58.5 | -50 | -50.25 | 104 | 304 |
| 13 | XGAK | -59.5 | -59 | -49.5 | -49.75 | 244 | 430 |
| 14 | XHAK | -59.5 | -59 | -49.75 | -50 | 167 | 330 |
| 15 | XEAJ | -60 | -59.5 | -49 | -49.25 | 320 | 499 |
| 16 | XFAJ | -60 | -59.5 | -49.25 | -49.5 | 172 | 435 |
| 17 | XGAJ | -60 | -59.5 | -49.5 | -49.75 | 155 | 355 |
| 18 | XCAH | -60.5 | -60 | -48.5 | -48.75 | 287 | 509 |
| 19 | XDAH | -60.5 | -60 | -48.75 | -49 | 206 | 482 |
| 20 | XEAH | -60.5 | -60 | -49 | -49.25 | 224 | 407 |
| 21 | XFAH | -60.5 | -60 | -49.25 | -49.5 | 175 | 335 |
| 22 | XAAG | -61 | -60.5 | -48 | -48.25 | 230 | 442 |
| 23 | XBAG | -61 | -60.5 | -48.25 | -48.5 | 197 | 368 |
| 24 | XCAG | -61 | -60.5 | -48.5 | -48.75 | 211 | 320 |
| 25 | XDAG | -61 | -60.5 | -48.75 | -49 | 207 | 341 |
| 26 | XEAG | -61 | -60.5 | -49 | -49.25 | 169 | 295 |

Table 5. Estimated skate biomass in the survey area, number of trawls in which each species was found to occur, and the spatial algorithm used to extrapolate trawl densities to the survey area.

| Species | No. trawls | Spatial algorithm | Tonnes | 95% conf.int. |
|---|---|---|---|---|
| RGR | 43 | Krige, Gaussian model | 7232.3 | [4023.5, 11764.3] |
| RBR | 46 | Krige, Gaussian model | 7192.6 | [3892.4, 11801.7] |
| RAL | 48 | Krige, Gaussian model | 4016.0 | [2201.3, 6658.2] |
| RFL | 19 | Krige, Gaussian model | 1549.5 | [862.2, 2423.0] |
| RSC | 44 | Krige, Gaussian model | 1319.2 | [713.7, 2175.9] |
| RMU | 34 | Krige, exponential model | 1154.8 | [640.2, 1867.8] |
| RBZ | 33 | Krige, Gaussian model | 1118.5 | [615.8, 1802.8] |
| RMC | 47 | Cubic interpolation | 952.5 | [545.5, 1498.4] |
| RDO | 47 | Cubic interpolation | 829.2 | [474.9, 1304.4] |
| RDA | 19 | Krige, Gaussian model | 191.6 | [107.7, 296.5] |
| RTR | 3 | Cubic interpolation | 149.4 | [85.6, 235.1] |
| RPX | 13 | Krige, spherical model | 47.0 | [25.5, 73.9] |
| Total | 52 | Summation | 25752.6 | [14468.4, 40908.2] |

Table 6. Relationship between skate trawl density, per species, and average depth of the trawl station.

| Species | GAM *p* | Relationship | Note |
|---|---|---|---|
| RGR | < 0.02 | Increasing w/ depth to 320 m. | |
| RBR | = 0.14 | Increasing w/ depth to 265 m, decreasing w/ depth >265 m. | Signif. interaction with longitude. |
| RAL | n.s. | | |
| RFL | < 0.01 | Increasing w/ depth to 300 m. | Signif. co-variable bottom temp. |
| RSC | n.s. | | Longitude is marginally signif. |
| RMU | < 0.01 | Increasing w/ depth to 400 m. | Signif. co-variables lon. & lat. |
| RBZ | < 0.01 | Increasing w/ depth to 370 m. | |
| RMC | n.s. | | |
| RDO | < 0.08 | Increasing w/ depth. | Signif. interaction with latitude. |
| RDA | < 0.04 | Increasing w/ depth to 380 m. | Signif. interaction with latitude. |
| RTR | n.s. | | |
| RPX | < 0.01 | Decreasing w/ depth to 400 m | Signif. co-variables lon. & lat. |

Table 7. Estimated rock cod biomass in the survey area and the spatial algorithm used to extrapolate trawl densities to the survey area.

| Species | Spatial algorithm | Tonnes | 95% conf.int. |
|---|---|---|---|
| PAR | Krige, Gaussian model | 30919.3 | [29141.3, 100662.4] |

Table 8. Density of rock cod (mt / km$^2$) caught in selected 'areal overlap' trawls during the January-February 2010 research survey. Refer to Figure 5 for the codes.

| Code | Station | Lon | Lat | Depth | PAR density |
|---|---|---|---|---|---|
| A | 456 | -60.85 | -49.34 | 168 | 1.674 |
| B | 459 | -60.42 | -49.38 | 196 | 2.562 |
| C | 461 | -60.20 | -49.51 | 186 | 15.272 |
| D | 466 | -59.83 | -49.69 | 198 | 2.941 |
| E | 480 | -59.38 | -49.79 | 231 | 0.336 |
| F | 482 | -59.08 | -49.99 | 165 | 2.462 |
| G | 490 | -58.75 | -50.13 | 152 | 2.259 |
| H | 492 | -58.42 | -50.23 | 158 | 17.407 |
| I | 494 | -58.11 | -50.32 | 140 | 39.555 |
| J | 498 | -57.78 | -50.47 | 160 | 1.641 |
| K | 510 | -57.33 | -50.68 | 136 | 0.151 |
| L | 512 | -57.05 | -50.84 | 132 | 0.458 |

Table 9. Density of rock cod (mt / km²) caught in selected 'areal overlap' trawls during the October-November 2010 research survey. Refer to Figure 5 for the codes.

| Code | Station | Lon | Lat | Depth | PAR density |
|---|---|---|---|---|---|
| M | 612 | -60.80 | -49.18 | 183 | 0.960 |
| N | 626 | -60.41 | -49.44 | 188 | 4.536 |
| O | 633 | -59.76 | -49.63 | 222 | 0.029 |
| P | 585 | -59.47 | -49.72 | 262 | 0.106 |
| Q | 635 | -59.41 | -49.88 | 170 | 0.274 |
| R | 637 | -59.08 | -49.86 | 260 | 0.129 |
| S | 639 | -58.85 | -50.07 | 158 | 1.059 |
| T | 650 | -58.40 | -50.20 | 172 | 3.328 |
| U | 653 | -58.17 | -50.30 | 138 | 7.416 |
| V | 651 | -58.09 | -50.27 | 202 | 0.224 |
| W | 655 | -57.93 | -50.39 | 169 | 3.727 |
| X | 663 | -57.57 | -50.52 | 220 | 20.187 |
| Y | 665 | -57.56 | -50.60 | 136 | 0.085 |
| Z | 673 | -57.25 | -50.67 | 259 | 0.301 |
| £ | 678 | -57.11 | -50.83 | 130 | 14.281 |
| $ | 676 | -57.03 | -50.78 | 280 | 0.274 |

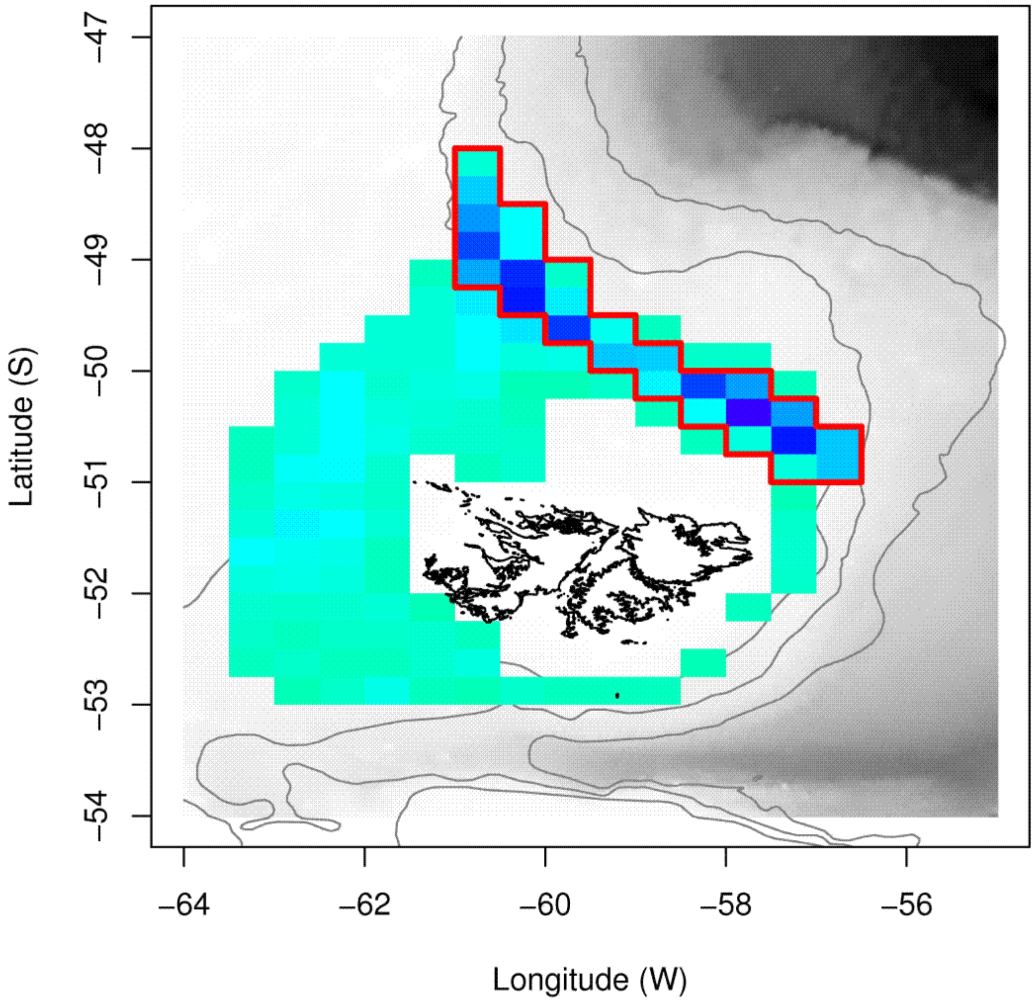



Fig. 34. Relative distribution of skate commercial catch weight between July 2007 and September 2010 (blue scale). For clarity, only the 120 grid units comprising ?99% of the catch weight are shown. An additional 165 grid units comprised <1% of the catch weight. Red border: outline of the survey area.

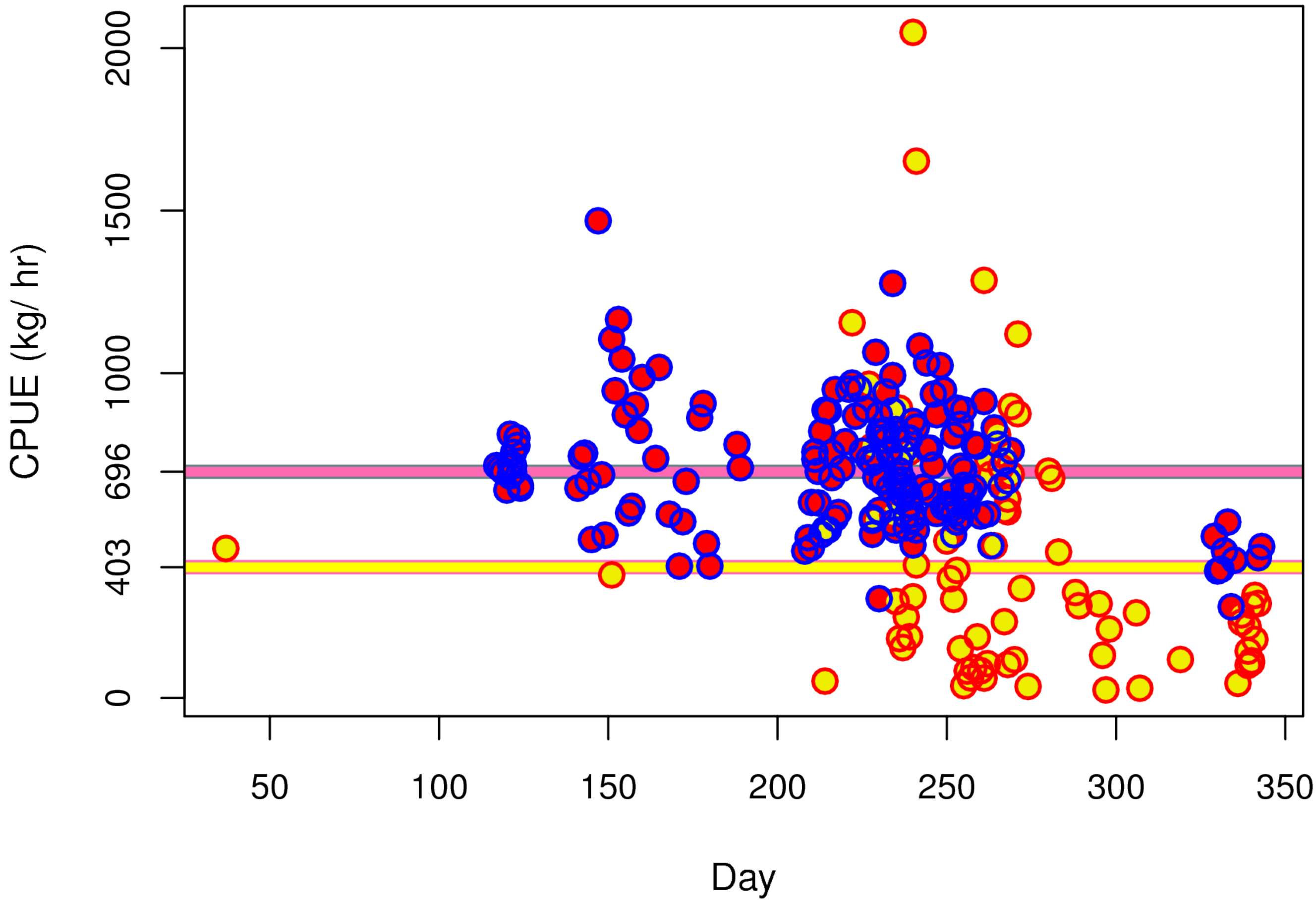
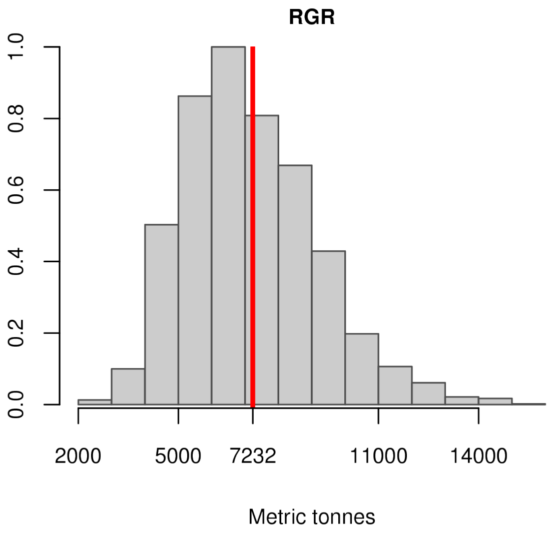
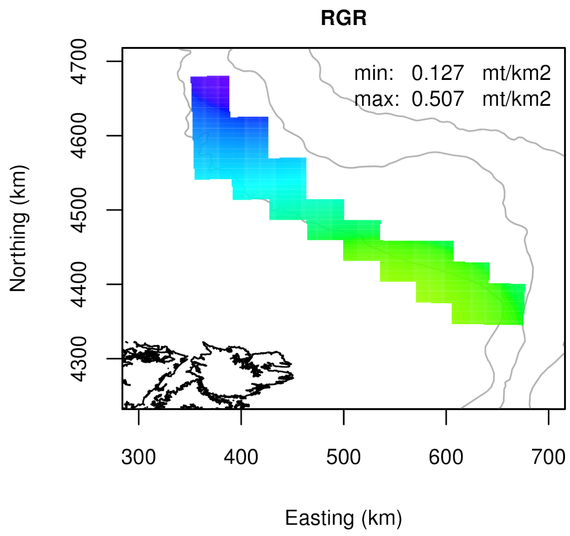
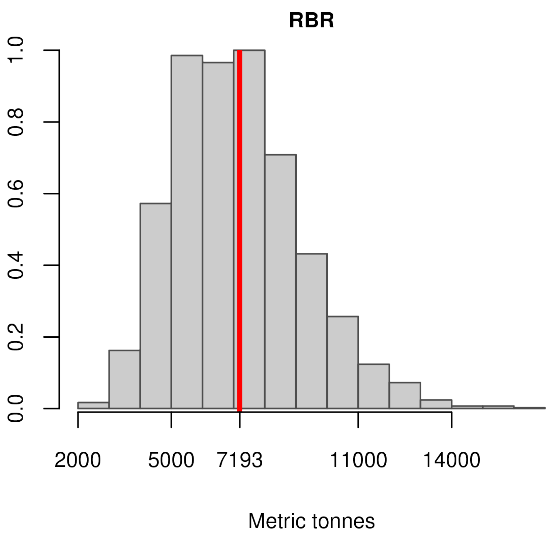
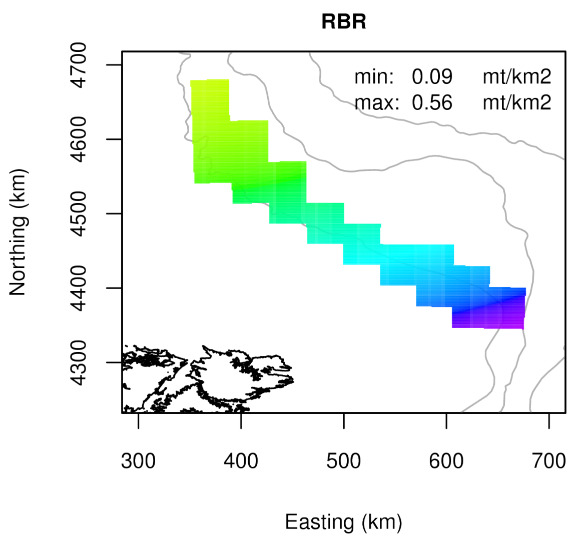


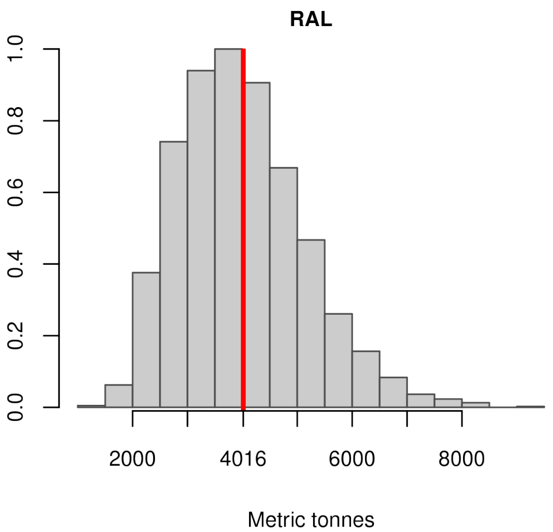

Fig. 35. Skate CPUE of 76 trawls taken by Spanish vessels under F licence in 2010 (red / yellow; mean = 402.5 kg hr-1), and of 177 trawls taken by Korean vessels under F licence in 2010 (blue / red; mean = 696.1 kg hr-1).

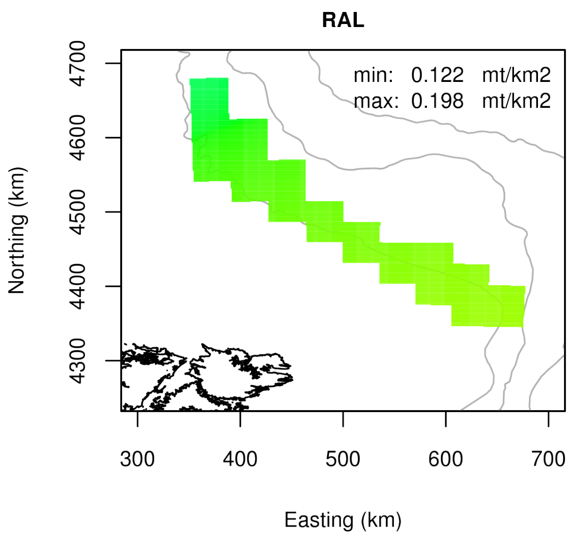

RGR
1.0
0.8
0.6
0.4
0.2
0.0
2000
5000
7232
11000
14000
Metric tonnes

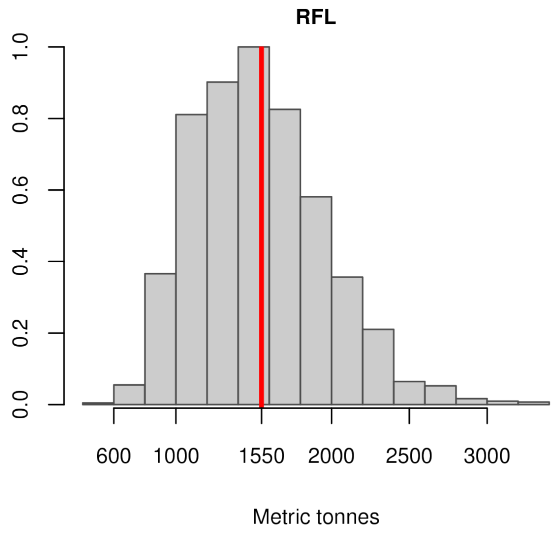

RGR
min: 0.127 mt/km2
max: 0.507 mt/km2
Northing (km)
4700
4600
4500
4400
4300
300
400
500
600
700
Easting (km)

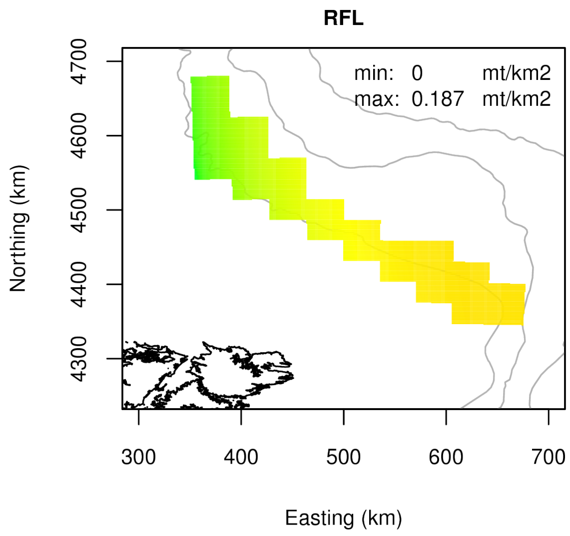

RBR
1.0
0.8
0.6
0.4
0.2
0.0
2000
5000
7193
11000
14000
Metric tonnes

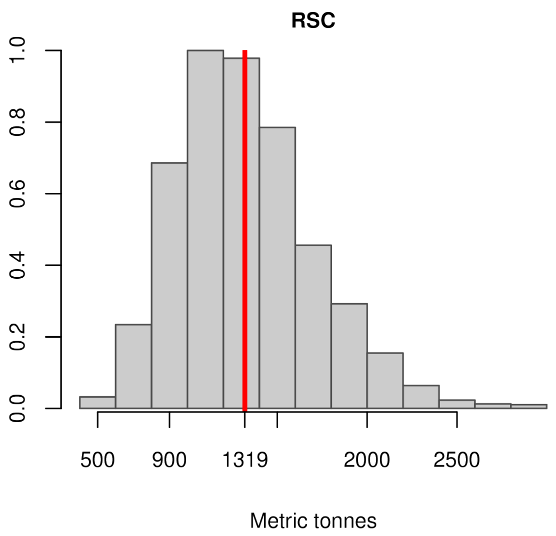

RBR
min: 0.09 mt/km2
max: 0.56 mt/km2
Northing (km)
4700
4600
4500
4400
4300
300
400
500
600
700
Easting (km)

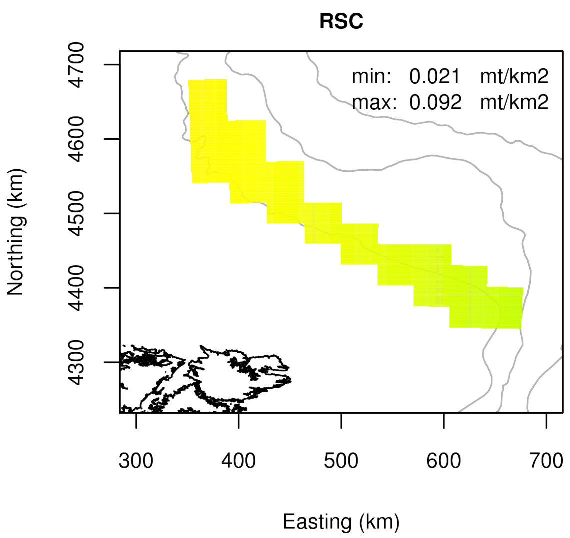

RAL
1.0
0.8
0.6
0.4
0.2
0.0
2000
4016
6000
8000
Metric tonnes

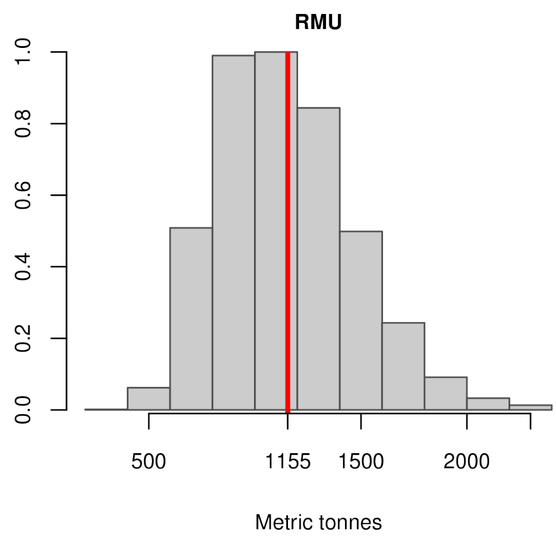

RAL
min: 0.122 mt/km2
max: 0.198 mt/km2
Northing (km)
4700
4600
4500
4400
4300
300
400
500
600
700
Easting (km)

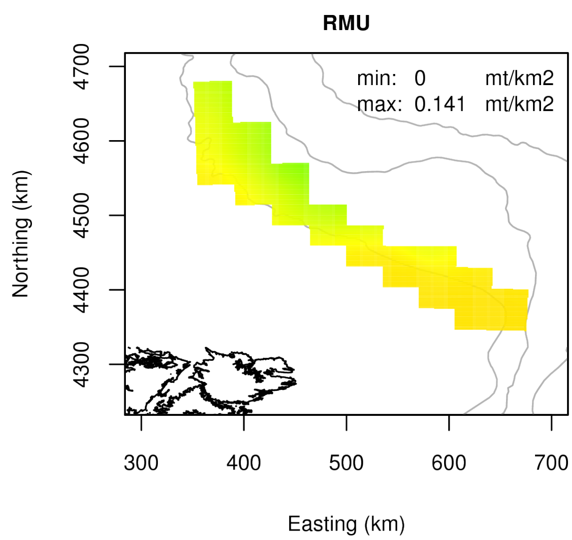

RFL
Metric tonnes
600
1000
1550
2000
2500
3000
0.0
0.2
0.4
0.6
0.8
1.0

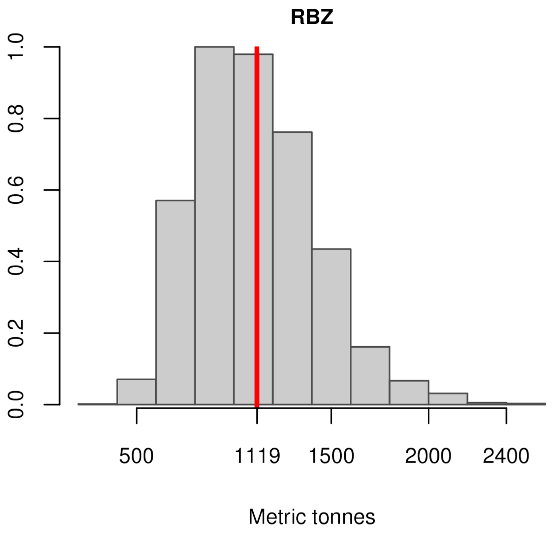

RFL
min: 0 mt/km2
max: 0.187 mt/km2
Northing (km)
Easting (km)
300
400
500
600
700
4300
4400
4500
4600
4700

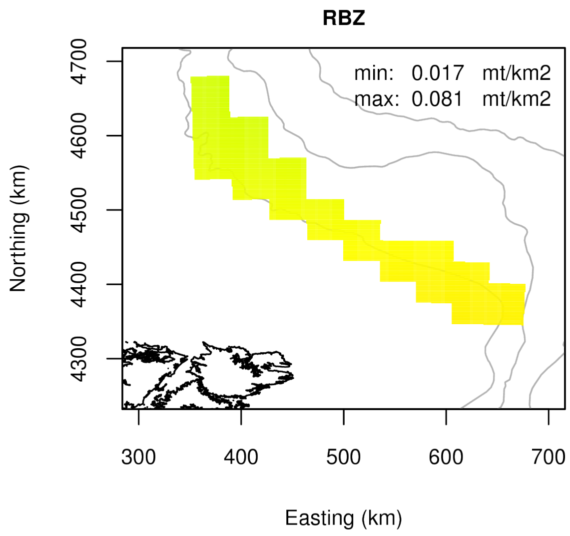

RSC
Metric tonnes
500
900
1319
2000
2500
0.0
0.2
0.4
0.6
0.8
1.0

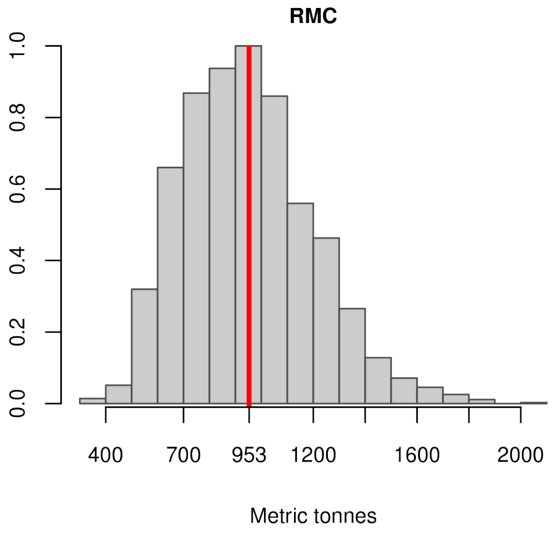

RSC
min: 0.021 mt/km2
max: 0.092 mt/km2
Northing (km)
Easting (km)
300
400
500
600
700
4300
4400
4500
4600
4700

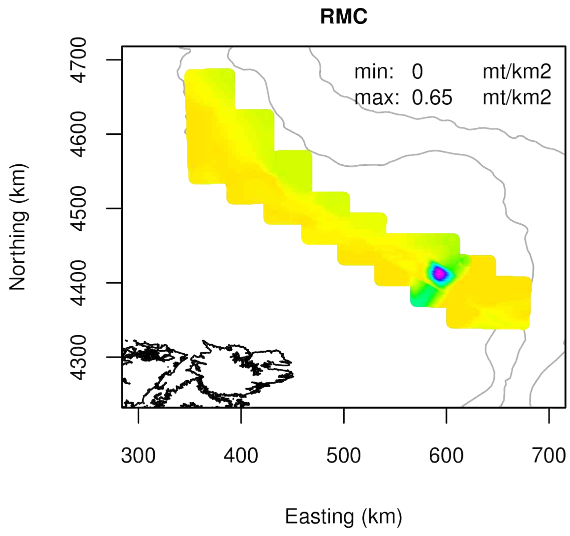

RMU
Metric tonnes
500
1155
1500
2000
0.0
0.2
0.4
0.6
0.8
1.0

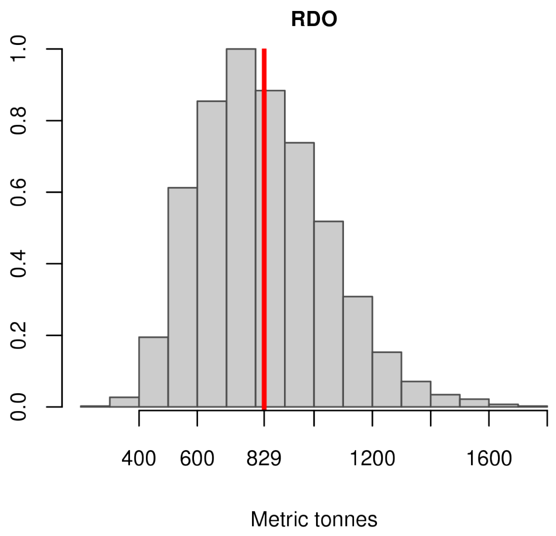

RMU
min: 0 mt/km2
max: 0.141 mt/km2
Northing (km)
Easting (km)
300
400
500
600
700
4300
4400
4500
4600
4700

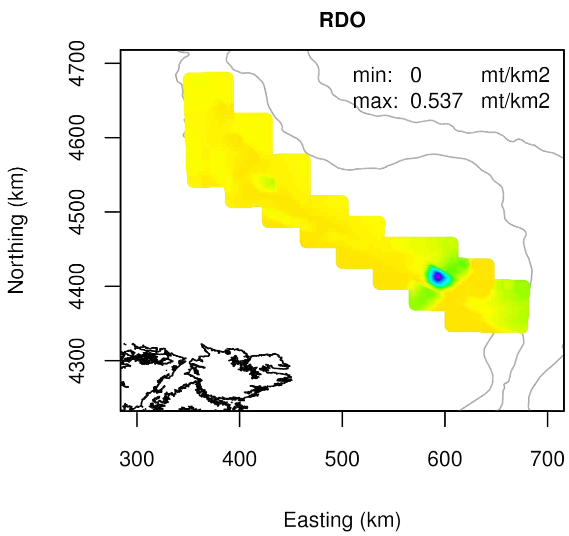

RBZ
0.0
0.2
0.4
0.6
0.8
1.0
500
1119
1500
2000
2400
Metric tonnes


RBZ
min: 0.017 mt/km2
max: 0.081 mt/km2
Northing (km)
4300
4400
4500
4600
4700
300
400
500
600
700
Easting (km)


RMC
0.0
0.2
0.4
0.6
0.8
1.0
400
700
953
1200
1600
2000
Metric tonnes


RMC
min: 0 mt/km2
max: 0.65 mt/km2
Northing (km)
4300
4400
4500
4600
4700
300
400
500
600
700
Easting (km)


RDO
0.0
0.2
0.4
0.6
0.8
1.0
400
600
829
1200
1600
Metric tonnes


RDO
min: 0 mt/km2
max: 0.537 mt/km2
Northing (km)
4300
4400
4500
4600
4700
300
400
500
600
700
Easting (km)

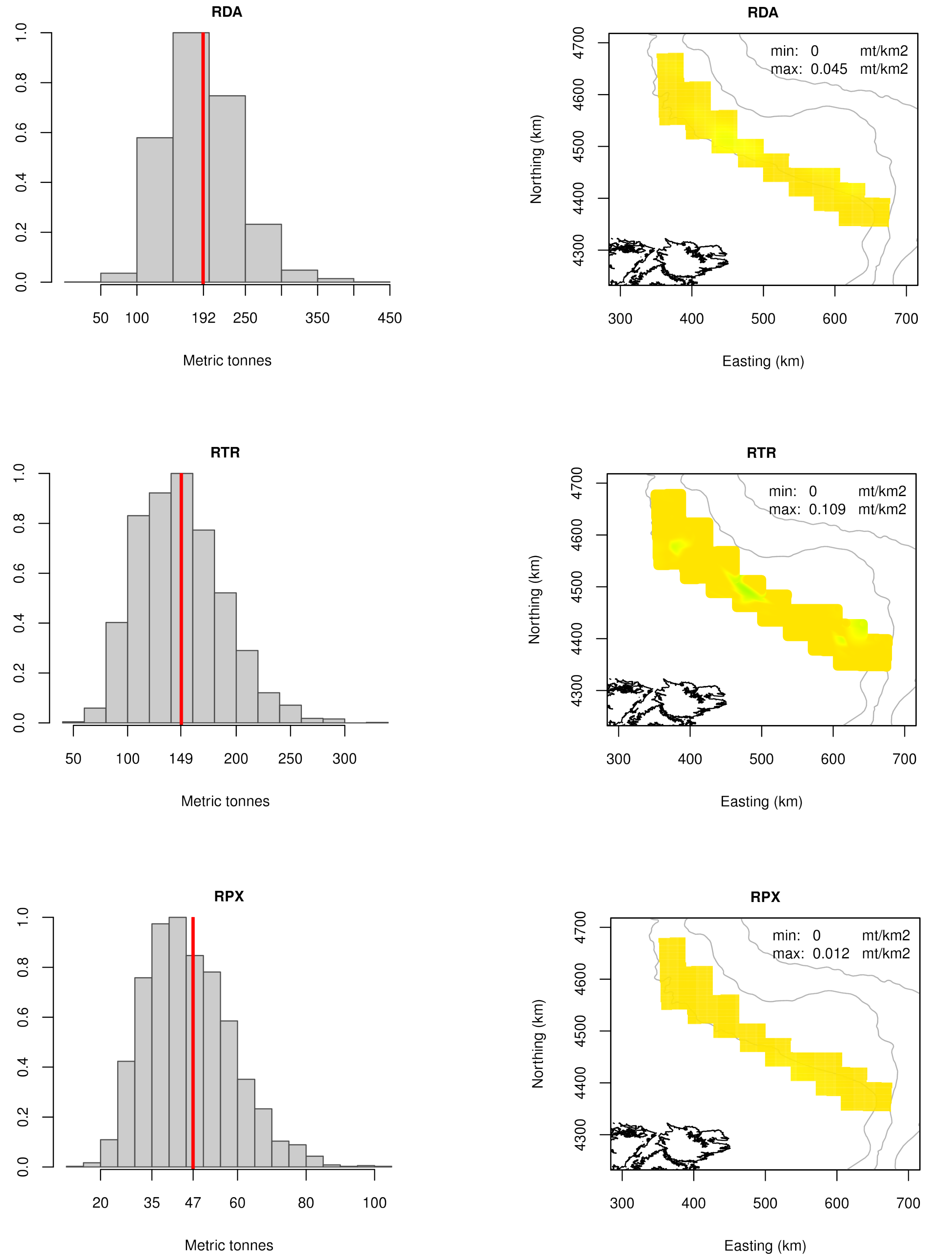



Fig. 35. (Left) per species, statistical distributions of skate biomass estimates from randomized combinations of catchability (q), trawl locations, kriging error, and CPUE ratio. Vertical red lines indicate the maximum likelihood estimates. (Right) per species, spatial distributions of skate biomass from the kriging or interpolation models; density increases yellow → green → purple. Maximum and minimum densities are indicated on the plots.

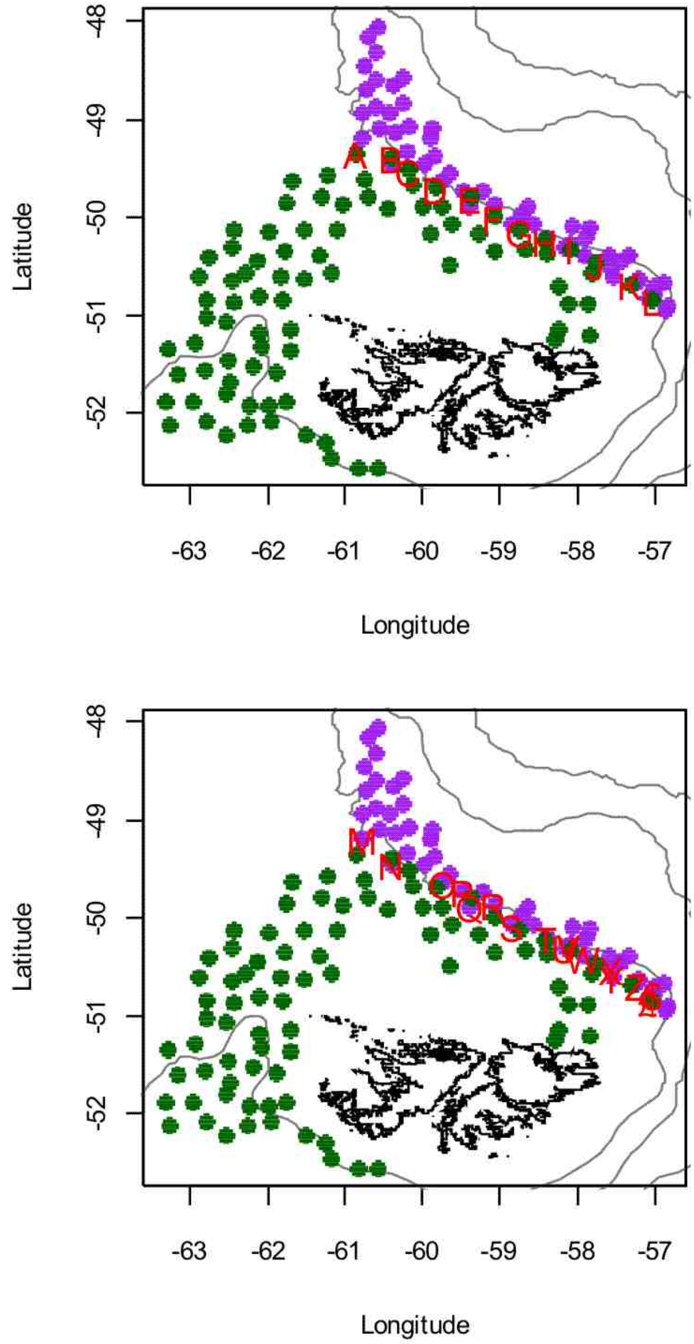



Fig 36. Trawl locations of the January-February survey cruise (green) and the October-November survey cruise (purple). Letter codes in red indicate those trawls of the January-February cruise (top plot) and October-November cruise (bottom plot) that were selected by eye as areally overlapping (refer to Tables 5 and 6).

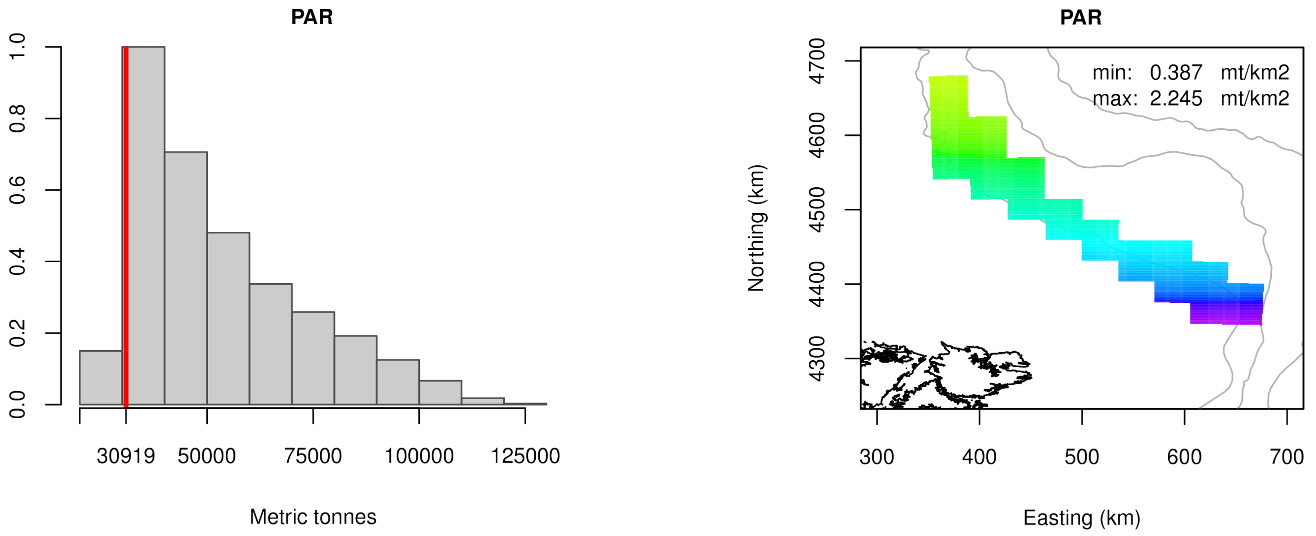



Fig. 37. (Left) statistical distribution of rock cod biomass estimates from randomized combinations of catchability (q), trawl locations, and kriging error. Vertical red line indicates the maximum likelihood estimate. (Right) spatial distribution of rock cod biomass from the kriging model; density increases yellow → green → purple. Maximum and minimum densities are indicated on the plot.

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