Cruise Report ZDLT1-2023-07

Groundfish survey

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1. Introduction

The Falkland Islands shelf is located within the Patagonian large marine ecosystem, one of the most productive areas in the world (Arkhipkin et al. 2012). The Patagonian large marine ecosystem is comprised of a southern temperate ecosystem in the north and a sub-Antarctic ecosystem in the south, divided by a boundary that runs from the south-west to the north-east through the Falkland Islands (Boltovskoy 1999). This marine ecosystem lies within waters of subtropical origin, transported onto the shelf by the Brazil Current and mixed with temperate shelf waters. Several productive zones are revealed in this ecosystem, mainly due to the existence of tidal mixing oceanographic fronts, as well as seasonal fronts originating from cold fresh water inflows into the Strait of Magellan. The sub-Antarctic ecosystem lies within waters of sub-Antarctic origin transported onto the shelf by the Falkland Current (Peterson & Whitworth 1989). The Falkland Current diverges from the main stream of the Antarctic Circumpolar Current in the Drake Passage and turns northwards. The Falkland Current splits at the continental slope south of the Falkland Islands into a weak branch and a stronger branch that flow around the west and east of the Islands, respectively (Bianchi et al. 1982). These oceanographic features affect the distribution and abundance of marine species such as the Argentine shortfin squid (*Illex argentinus*) and hoki (*Macruronus magellanicus*) that migrate to frontal zones for feeding and back to non-frontal zones for spawning (Agnew 2002). In contrast, the intrusion of sub-Antarctic waters favour the migration of deep-water fish such as toothfish (*Dissostichus eleginoides*) into the shelf (Laptikhovsky et al. 2008; Arkhipkin & Laptikhovsky 2010).

Scientific surveys are key sources of fisheries independent data for fisheries ecology and that benefit from a standardised sampling plan and constant catchability (Hilborn & Walters 1992; Alglave et al. 2022; Gallo et al. 2022). The Falkland Islands Fisheries Department (FIFD) has carried out annual fisheries independent groundfish surveys that consist of a fixed array of bottom trawls to the west and north in the Falkland Islands Inner Conservation Zone (FICZ) and in the northern part of the Falkland Islands Outer Conservation Zone (FOCZ) during summer (February 2010, 2011, 2015–2023) and winter (July 2017 and 2022). The February groundfish surveys were originally conducted to estimate the biomass of the former index species (i.e., rock cod *Patagonotothen ramsayi*). However, the aim of the February groundfish survey extended to other commercial and bycatch species in recent years. Biomass estimates from February groundfish surveys conducted in parallel with calamari pre-season surveys in the 'Loligo Box' revealed the decrease of rock cod, red cod (*Salilota australis*), and southern hake (*Merluccius australis*) abundances over the last decade. Banded whiptail grenadier (*Coelorinchus fasciatus*), hoki, southern blue whiting (*Micromesistius australis*), and toothfish had declining trends from 2010 to 2019–2020, with subsequent biomass increase since 2021. Only the common hake had a significant increase in biomass from 2010 to 2023 (Ramos & Winter 2023). The July groundfish surveys, being more recent and therefore having a shorter time series, were also conducted to examine the biomass of commercial species but with emphasis on the common hake *Merluccius hubbsi* (Gras et al., 2017; Lee et al. 2022). Increasing abundance of common hake in the Falkland Shelf in recent years (Ramos & Winter 2022a, 2023) triggered a demography survey conducted exclusively for this species during July 2020 (Randhawa et al., 2020). The FIFD aim to build a solid time series of abundance, distribution, and biological data of commercial species during February and during July, to be able to compare patterns through the years, and between summer and winter, and to examine how these patterns are affected by environmental, ecological, and anthropogenic factors. Therefore, the following objectives were established for the July 2023 groundfish survey:

1.1. Survey objectives

1. To examine the abundance, distribution, and biology of demersal fish and squid species along the west and north in the Falkland Shelf.
2. To carry out an oceanographic survey along the west and north in the Falkland Shelf.
3. To describe the stomach content of common hake (*Merluccius hubbsi*).

4. To calculate the conversion factors (CF) for red cod (*Salilota australis*), kingclip (*Genypterus blacodes*), and driftfish (*Seriolella porosa*).

2. Material and Methods

2.1. Vessel

The July 2023 groundfish survey (ZDLT1-2023-07) was conducted aboard the F/V Castelo (ZDLT1), registered in the Falkland Islands (LOA 67.8 m, GT 1321).

2.2. Survey plan and key dates

The standard plan of the groundfish survey consists of 84 bottom trawl stations of 60 min, with four trawl stations conducted per day over a 21-day sampling period. Each trawl is preceded or succeeded by an oceanographic station (CTD). These stations are replicated each year according to a systematic transect design based on the division of the shelf area into 0.5 longitude by 0.25 latitude decimal degree grid squares, and each trawl station is allocated to an individual grid square to ensure coverage of the entire study area.

The July 2023 groundfish survey was shortened by three days due to repairs of the vessel's winch, which delayed the arrival of the ship to Port Stanley, Falkland Islands from the port of Vigo in Spain. The stations that had to be excluded were the same stations that were deliberately excluded in the July 2022 groundfish survey (also due to the delayed arrival of the F/V Castelo to Port Stanley), with the exception of station 61 that was excluded instead of peripheral station 63 (station numbers from the master list). The retained stations covered the full survey area (Fig. 1). The ship departed from Stanley at 19:00 on July 10th 2023. Unforeseen repairs of the engine after departing Stanley prevented starting the survey to the south-west of West Falkland as originally planned. Given the shorter distance from Stanley to the sampling area in the north-east, the first trawl station was instead conducted to the north of East Falkland early in the morning on July 11th 2023. Four trawls were conducted per day. An oceanographic station (CTD) preceded each trawl, except for the last trawl of the day, which was succeeded by the oceanographic station in order to complete the four trawls during daylight, as there are less hours of daylight during winter[1] compared with summer. The last trawl of the survey was hauled on July 28th 2023 to the south-west of West Falkland. The last two stations of the survey were cancelled due to bad weather, and a total of 70 stations were finally conducted. The ship arrived to Stanley on July 29th 2023, and the scientific crew disembarked at 9:30 at FIPASS.

2.3. Trawling

A bottom trawl net owned by the FIFD was used; the net was equipped with rockhopper gear fitted with Morgère V3 (1,800 kg; 3,180 cm × 2,480 cm) bottom doors. The cod-end had a 90 mm mesh size fitted with a 40 mm cod-end liner. Sweep length was 110 m, bridle length was 29.6 m, and footrope was 36.52 m. The MarPort Net Monitoring System was used to monitor the net geometry; all measurement readings were successfully obtained for all stations. The duration of each trawl was 60 min on the bottom, and trawling speed varied between 4.0 and 4.9 knots. A total of 70 bottom trawls were conducted with corresponding station numbers ranging from 3823 to 3961 (Table I).

[1] Austral seasons are referred to in this report.

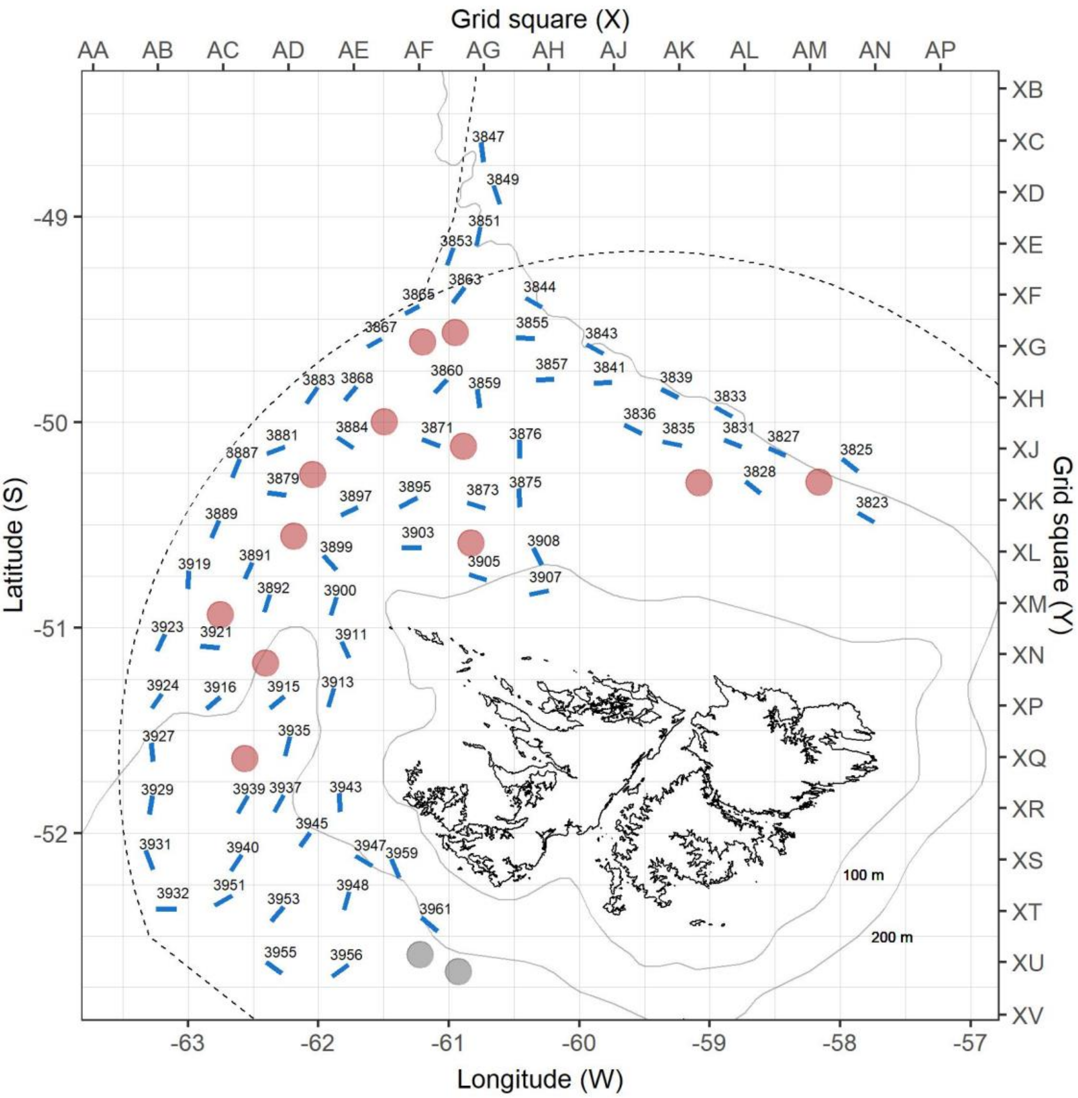

Figure 1. Trawl tracks with station numbers performed during the July 2023 groundfish survey (ZDLT1-2023-07). Stations excluded due to the survey being shortened were highlighted with red circles; stations cancelled due to rough weather were highlighted with grey circles.

2.4. Trawl stations and biological sampling

At each trawl station, all species from the catch were sorted and the total catch was weighed by species with an electronic Marel balance (80 kg capacity). All commercial species and most of the bycatch species were sampled, i.e., up to 100 randomly sampled individuals. Biological sampling of finfish included measurement to the lower cm of total length for common hake, driftfish (*Seriolella porosa*), kingclip (*Genypterus blacodes*), red cod, rock cod, southern blue whiting, and southern hake, or pre-anal length for hoki and grenadiers. Total length, fork length, and standard length were recorded for butterfish (*Stromateus brasiliensis*) to the lower cm. Macroscopic assessment of sex and maturity were conducted following an eight-stage sexual maturity scale (Nikolsky 1963). For squid, the sampling included the measurement of dorsal mantle length to the lower 0.5 cm, and recording of sex and maturity using a six-stage sexual maturity scale (Lipinski 1979). For skates, disc width and total length were measured to the lower cm, and weight was measured to the nearest gram; sex and maturity were examined macroscopically using a six-stage sexual maturity scale (Arkhipkin et al. 2008). For sharks, total length was recorded, and sex and maturity were examined macroscopically using a six-stage sexual maturity scale (Arkhipkin et al. 2008). Skates and sharks were dissected only if they looked in poor shape or if they were going to be processed by the fishing crew, otherwise they were released alive.

Otoliths were taken from fish according to a combined fixed (FOS) and random (ROS) otolith sampling strategy. For the FOS, otoliths were extracted from 2 to 5 individuals for each 1 cm length bin per sex. Otoliths from an additional 5 to 10 individuals (hake, kingclip, red cod, rock cod and toothfish) were also randomly extracted per station as part of the ROS strategy. During otolith collection, individual length was measured to the lower cm and total body weight was measured to the nearest gram. A total of 100 individuals of Argentine shortfin squid (*I. argentinus*) and Patagonian squid (*Doryteuthis gahi*) each, were collected from the north and south, in deep (>200 m) and shallow (<100 m) stations, and frozen for statolith extraction at the FIFD laboratory. In addition, several fish specimens were frozen for further analyses ashore, including 100 common hake for training of scientific observers on maturity stage identification.

Table I. Station data of the July 2023 groundfish survey (ZDLT1-2023-07).

Station	Date	Latitude start	Longitude start	Latitude finish	Longitude finish	Mean depth
3823	11/07/2023	-50.4798	-57.7622	-50.4460	-57.8637	161
3825	11/07/2023	-50.2248	-57.8925	-50.1798	-57.9842	275
3827	11/07/2023	-50.1562	-58.4407	-50.1268	-58.5452	169
3828	11/07/2023	-50.3005	-58.7132	-50.3467	-58.6153	145
3831	12/07/2023	-50.1150	-58.7837	-50.0870	-58.8915	157
3833	12/07/2023	-49.9635	-58.8532	-49.9277	-58.9558	191
3835	12/07/2023	-50.1107	-59.2427	-50.0967	-59.3565	158
3836	12/07/2023	-50.0483	-59.5475	-50.0097	-59.6533	162
3839	13/07/2023	-49.8710	-59.2670	-49.8365	-59.3683	190
3841	13/07/2023	-49.8043	-59.7768	-49.8092	-59.8875	169
3843	13/07/2023	-49.6572	-59.8387	-49.6213	-59.9387	186
3844	13/07/2023	-49.4300	-60.3135	-49.3922	-60.4100	197
3847	14/07/2023	-48.6592	-60.7507	-48.7338	-60.7315	240
3849	14/07/2023	-48.8675	-60.6492	-48.9388	-60.6117	240
3851	14/07/2023	-49.0673	-60.7643	-49.1415	-60.7888	191
3853	14/07/2023	-49.1663	-60.9800	-49.2350	-61.0150	172
3855	15/07/2023	-49.5882	-60.4548	-49.5895	-60.3413	174
3857	15/07/2023	-49.7898	-60.2162	-49.7942	-60.3282	168
3859	15/07/2023	-49.9128	-60.7703	-49.8392	-60.7773	165
3860	15/07/2023	-49.8022	-61.0313	-49.8537	-61.1132	164
3863	16/07/2023	-49.3608	-60.9052	-49.4157	-60.9760	168
3865	16/07/2023	-49.4427	-61.2528	-49.4777	-61.3395	162
3867	16/07/2023	-49.6017	-61.5372	-49.6390	-61.6225	159
3868	16/07/2023	-49.8407	-61.7218	-49.8967	-61.7948	158
3871	17/07/2023	-50.0927	-61.1803	-50.1177	-61.0728	160
3873	17/07/2023	-50.3967	-60.8385	-50.4202	-60.7280	154
3875	17/07/2023	-50.3958	-60.4573	-50.3232	-60.4728	154
3876	17/07/2023	-50.1613	-60.4592	-50.0885	-60.4672	159
3879	18/07/2023	-50.3540	-62.2783	-50.3398	-62.3905	155
3881	18/07/2023	-50.1482	-62.3702	-50.1185	-62.2655	149
3883	18/07/2023	-49.8933	-62.0767	-49.8303	-62.0180	149
3884	18/07/2023	-50.0860	-61.8388	-50.1262	-61.7405	159
3887	19/07/2023	-50.1988	-62.6167	-50.2662	-62.6655	146
3889	19/07/2023	-50.4948	-62.7747	-50.5625	-62.8262	150
3891	19/07/2023	-50.6953	-62.5167	-50.7598	-62.5705	166
3892	19/07/2023	-50.8542	-62.3800	-50.9215	-62.4195	183

Station	Date	Latitude start	Longitude start	Latitude finish	Longitude finish	Mean depth
3895	20/07/2023	-50.3755	-61.2695	-50.4088	-61.3775	162
3897	20/07/2023	-50.4213	-61.7245	-50.4512	-61.8295	167
3899	20/07/2023	-50.6633	-61.9440	-50.7172	-61.8652	180
3900	20/07/2023	-50.8698	-61.8688	-50.9368	-61.9062	175
3903	21/07/2023	-50.6120	-61.3307	-50.6125	-61.2177	152
3905	21/07/2023	-50.7453	-60.8215	-50.7708	-60.7128	134
3907	21/07/2023	-50.8353	-60.3473	-50.8258	-60.2342	137
3908	21/07/2023	-50.6783	-60.3007	-50.6127	-60.3497	145
3911	22/07/2023	-51.0858	-61.8123	-51.1460	-61.7587	184
3913	22/07/2023	-51.3147	-61.8908	-51.3862	-61.9172	199
3915	22/07/2023	-51.3460	-62.2867	-51.3937	-62.3698	212
3916	22/07/2023	-51.3507	-62.7740	-51.3982	-62.8580	183
3919	23/07/2023	-50.7395	-62.9973	-50.8103	-63.0075	152
3921	23/07/2023	-51.0992	-62.7897	-51.0942	-62.9060	170
3923	23/07/2023	-51.0480	-63.1902	-51.1132	-63.2393	155
3924	23/07/2023	-51.3353	-63.2207	-51.3952	-63.2803	166
3927	24/07/2023	-51.5797	-63.2852	-51.6500	-63.2700	182
3929	24/07/2023	-51.8357	-63.2803	-51.9072	-63.3002	203
3931	24/07/2023	-52.1033	-63.3170	-52.1745	-63.2772	228
3932	24/07/2023	-52.3675	-63.2083	-52.3682	-63.0898	260
3935	25/07/2023	-51.5495	-62.2277	-51.6208	-62.2605	248
3937	25/07/2023	-51.8303	-62.2893	-51.8930	-62.3430	262
3939	25/07/2023	-51.8345	-62.5608	-51.8977	-62.6233	232
3940	25/07/2023	-52.1208	-62.6063	-52.1797	-62.6775	257
3943	26/07/2023	-51.8228	-61.8510	-51.8967	-61.8410	190
3945	26/07/2023	-52.0148	-62.0790	-52.0688	-62.1327	289
3947	26/07/2023	-52.1203	-61.6908	-52.1620	-61.5935	252
3948	26/07/2023	-52.3040	-61.7808	-52.3742	-61.8130	322
3951	27/07/2023	-52.3417	-62.7643	-52.3025	-62.6652	271
3953	27/07/2023	-52.3775	-62.2853	-52.4278	-62.3690	296
3955	27/07/2023	-52.6458	-62.3772	-52.6870	-62.2850	326
3956	27/07/2023	-52.6838	-61.8627	-52.6365	-61.7767	344
3959	28/07/2023	-52.1457	-61.4333	-52.2163	-61.3873	185
3961	28/07/2023	-52.4247	-61.1858	-52.4697	-61.0903	274

2.5. Conversion factor

Conversion factor (CF) was calculated for red cod, and for kingclip, from a few baskets containing several intact individuals of random sizes. Calculation of CF for driftfish was not possible due to the small number of individuals caught at any given trawl. The total weight (green weight) of each basket was recorded. Head, guts and tail of the fish in the basket were removed by the factory crew, and the remaining trunks (HGT: headed, gutted, and tail off) were weighed. The CF of each basket was calculated as follows:

$$\mathrm{CF} = \frac{\text{Green weight (kg)}}{\text{HGT weight (kg)}}$$

Average CF was calculated for each species based on each species' number of baskets sampled.

2.6. Catch density

Catch density per species (D; kg/km^2) was calculated at each trawl station following Gras (2016):

$$D = \frac{C}{d \times HNO}$$

where C = catch (kg), d = trawl distance covered (km) calculated as the distance between the initial and the final position of the net at the seabed, and HNO = horizontal net opening (km) recorded by the MarPort Net Monitoring System.

2.7. Stomach content of *Merluccius hubbsi* – common hake

The high density of common hake across the fishing area, including the 'Loligo Box', during the groundfish and calamari pre-season surveys motivated the examination of stomach content to increase our understanding of the impacts of this species on the *D. gahi* fishery. A subsample of common hake was examined per station, from 8 stations. Sex, maturity, and total length of common hake were recorded as per the standard protocol. Stomachs were extracted and cut open to examine the presence of prey. Visual identification of the prey based on macroscopic features was conducted to the higher taxonomic level possible. Common hake have sexual dimorphism, where females are larger than males. To test if proportions of prey changed between females and males, and at size, individuals were separated by sex and size in medium (Females ≤50 cm; Males ≤39 cm) and large (Females >50 cm; Males >39 cm) groups, and Chi-square test of independence was conducted implementing Yates' continuity correction for small number of samples.

2.8. Interactions with pinnipeds

The presence of pinnipeds around the vessel during shooting, hauling, or manoeuvring, and incidental bycatch and mortality were recorded.

2.9. Oceanography

A CTD (SBE-25, Sea-Bird Electronics Inc., Bellevue, USA) was used to record oceanographic data in the vicinity of every trawl station. The CTD was deployed to a depth of c.10 m below the surface for a soak time of two minutes to allow the pump to start circulating water and to flush the system. Then the CTD was raised to about 2 m below surface, and it was immediately lowered towards the seabed at 1 m/sec to a maximum depth of 1 m above seabed. The CTD recorded temperature (°C), dissolved oxygen (ml/l), salinity (PSU), and density (sigma t = kg/m^3 - 1000). The raw hex file was converted and processed using SBE Data Processing Version.7.22.5 using the CON file 0247_2019_09.xmlcon with the instruments calibrated in July 2019. Up-cast data were filtered out. Depth was calculated from pressure using the latitude of each station. Ocean Data View version 5.15 (Schlitzer, R., Ocean Data View, http://odv.awi.de, 2013) was used to make the plots of each environmental variable at 10 m, 100 m, and seabed. The CTD memory capacity allows storing about 30 runs; nonetheless, oceanographic data were downloaded after every CTD run to corroborate that the CTD was working properly and to avoid loss of data.

3. Results

3.1. Catch composition

Catch weight and composition of squid, finfish, skate, and other demersal and semi-pelagic species are presented in Table II. The most abundant species in terms of catch weight were common hake (61.8%), red cod (11.5%), Patagonian squid (8.8%), rock cod (8.3%), and kingclip (6%).

Table II. Catch composition and weight by species during the July 2023 groundfish survey (ZDLT1-2023-07).

Species Code	Latin name	Total caught (kg)	Total sampled (kg)	Total discarded (kg)	Proportion (%)
HAK	*Merluccius hubbsi*	45808.768	3856.400	0.000	61.796
BAC	*Salilota australis*	8496.320	803.983	49.380	11.462
LOL	*Doryteuthis gahi*	6490.190	266.282	263.082	8.755
PAR	*Patagonotothen ramsayi*	6165.086	297.452	5910.426	8.317
KIN	*Genypterus blacodes*	4450.566	1702.876	0.000	6.004
BOM	*Bougainvillia macloviana*	1311.750	0.000	1311.750	1.770
DGS	*Squalus acanthias*	253.880	253.880	253.880	0.342
DGH	*Schroederichthys bivius*	200.435	200.435	200.435	0.270
WHI	*Macruronus magellanicus*	133.380	93.360	133.380	0.180
CGO	*Cottoperca gobio*	128.704	128.704	128.704	0.174
RFL	*Dipturus lamillai*	112.542	112.542	20.454	0.152
SPN	Porifera	84.888	0.000	84.888	0.115
TOO	*Dissostichus eleginoides*	46.284	46.284	1.090	0.062
COP	*Congiopodus peruvianus*	43.898	43.898	43.898	0.059
BLU	*Micromesistius australis*	41.138	27.722	41.058	0.055
RGR	*Bathyraja griseocauda*	39.126	39.126	3.606	0.053
SQT	Ascidiacea	39.608	0.000	39.608	0.053
RED	*Sebastes oculatus*	38.380	38.380	1.060	0.052
RBR	*Bathyraja brachyurops*	28.894	28.894	15.232	0.039
MUN	*Grimothea gregaria*	28.074	0.000	28.074	0.038
BUT	*Stromateus brasiliensis*	26.100	26.100	26.100	0.035
ALG	Algae	18.675	0.000	18.675	0.025
ZYP	*Zygochlamys patagonica*	18.682	0.000	18.682	0.025
MED	*Medusa* sp.	17.160	0.000	17.160	0.023
SHT	Mixed invertebrates	14.742	0.000	14.742	0.020
ING	*Moroteuthopsis ingens*	9.556	9.440	9.556	0.013
SEP	*Seriolella porosa*	9.420	9.420	1.060	0.013
ILL	*Illex argentinus*	8.562	7.964	8.562	0.012
PAT	*Merluccius australis*	9.180	9.180	0.000	0.012
GOC	*Gorgonocephalus chilensis*	5.352	0.000	5.352	0.007
ANM	Anemonia	3.650	0.000	3.650	0.005
BDU	*Brama australis*	3.340	3.340	0.000	0.005
EEL	*Iluocoetes* sp./*Patagolycus* sp. mix	3.142	0.002	3.142	0.004
GRF	*Coelorinchus fasciatus*	3.180	3.180	3.180	0.004
LIS	*Lithodes santolla*	2.700	0.000	0.000	0.004
RAL	*Bathyraja albomaculata*	3.132	3.132	3.132	0.004
RPX	*Psammobatis* spp.	3.280	3.280	3.280	0.004
STA	*Sterechinus agassizii*	3.075	0.000	3.075	0.004
ASA	*Astrotoma agassizii*	2.204	0.000	2.204	0.003
BRY	Bryozoa	2.016	0.000	2.016	0.003
NEM	*Psychrolutes marmoratus*	2.280	2.280	2.280	0.003
RMC	*Bathyraja macloviana*	2.460	2.460	2.460	0.003
MLA	*Muusoctopus longibrachus akambei*	1.138	1.138	1.138	0.002

Species Code	Latin name	Total caught (kg)	Total sampled (kg)	Total discarded (kg)	Proportion (%)
OPV	*Ophiosabine vivipara*	1.545	0.000	1.545	0.002
RDO	*Amblyraja doellojuradoi*	1.768	1.768	1.768	0.002
AUC	*Austrocidaris canaliculata*	0.984	0.000	0.984	0.001
CIR	Cirripedia	0.596	0.000	0.596	0.001
COT	*Cottunculus granulosus*	0.500	0.500	0.500	0.001
CTA	*Ctenodiscus australis*	0.396	0.000	0.396	0.001
CUB	*Cubiceps caeruleus*	0.560	0.560	0.560	0.001
FUM	*Fusitriton magellanicus*	0.375	0.000	0.375	0.001
HYD	Hydrozoa	0.377	0.000	0.377	0.001
MUG	*Grimothea gregaria*	0.873	0.008	0.873	0.001
MUU	*Munida subrugosa*	0.480	0.000	0.480	0.001
POA	*Glabraster antarctica*	0.478	0.000	0.478	0.001
SUN	*Labidiaster radiosus*	0.444	0.000	0.444	0.001
THO	Thouarella	1.092	0.000	1.092	0.001
ACS	*Acanthoserolis schythei*	0.006	0.000	0.006	<0.001
ALC	Alcyoniina	0.055	0.000	0.055	<0.001
AST	Asteroidea	0.144	0.000	0.144	<0.001
AUL	*Austrolycus laticinctus*	0.001	0.000	0.001	<0.001
BAO	*Bathybiaster loripes*	0.174	0.000	0.174	<0.001
BRM	*Brucerolis macdonnellae*	0.162	0.000	0.162	<0.001
CAS	*Campylonotus semistriatus*	0.114	0.000	0.114	<0.001
CAZ	*Calyptraster* sp.	0.093	0.000	0.093	<0.001
CEX	*Ceramaster* sp.	0.218	0.000	0.218	<0.001
COG	*Patagonotothen guntheri*	0.134	0.134	0.134	<0.001
COL	*Cosmasterias lurida*	0.267	0.000	0.267	<0.001
CRY	*Crossaster* sp.	0.024	0.000	0.024	<0.001
CYX	*Cycethra* sp.	0.078	0.000	0.078	<0.001
DIA	*Diaulula* spp.	0.028	0.000	0.028	<0.001
EGG	Eggmass	0.129	0.000	0.129	<0.001
ERR	*Errina* sp.	0.036	0.000	0.036	<0.001
EUL	*Eurypodius latreillii*	0.030	0.000	0.030	<0.001
EUO	*Eurypodius longirostris*	0.010	0.000	0.010	<0.001
FLX	*Flabellum* spp.	0.368	0.000	0.368	<0.001
GAY	Gastropoda	0.012	0.000	0.012	<0.001
GOR	Gorgonacea	0.032	0.000	0.032	<0.001
GYN	*Gymnoscopelus nicholsi*	0.021	0.000	0.021	<0.001
HCR	Paguroidea	0.018	0.000	0.018	<0.001
HEX	*Henricia* sp.	0.006	0.000	0.006	<0.001
ILF	*Iluocoetes fimbriatus*	0.040	0.040	0.040	<0.001
ISO	Isopoda	0.004	0.000	0.004	<0.001
LIR	*Limopsis marionensis*	0.034	0.000	0.034	<0.001
LYB	*Lycenchelys bachmanni*	0.020	0.020	0.020	<0.001
MAT	*Achiropsetta tricholepis*	0.020	0.020	0.020	<0.001
MAV	*Magellania venosa*	0.171	0.000	0.171	<0.001
MIR	*Mirostenella* sp.	0.076	0.000	0.076	<0.001

Species Code	Latin name	Total caught (kg)	Total sampled (kg)	Total discarded (kg)	Proportion (%)
NOW	*Paranotothenia magellanica*	0.220	0.220	0.220	<0.001
NUH	*Nuttallochiton hyadesi*	0.020	0.000	0.020	<0.001
ODP	*Odontaster penicillatus*	0.042	0.000	0.042	<0.001
OPH	Ophiuroidea	0.018	0.000	0.018	<0.001
OPL	*Ophiuroglypha lymani*	0.189	0.000	0.189	<0.001
PEN	Pennatuloidea	0.010	0.000	0.010	<0.001
PES	*Peltarion spinulosum*	0.080	0.000	0.080	<0.001
POL	Polychaeta	0.015	0.000	0.015	<0.001
POX	*Chaetopterus variopedatus*	0.004	0.000	0.004	<0.001
PRI	Priapulida	0.004	0.000	0.004	<0.001
PYX	Pycnogonida	0.120	0.000	0.120	<0.001
SAL	*Salpa* sp.	0.016	0.000	0.016	<0.001
SAR	*Sprattus fuegensis*	0.078	0.060	0.078	<0.001
SET	Sertulariidae	0.004	0.000	0.004	<0.001
SOR	*Solaster regularis*	0.078	0.000	0.078	<0.001
SRP	*Semirossia patagonica*	0.012	0.008	0.012	<0.001
SYD	*Sympagurus dimorphus*	0.030	0.000	0.030	<0.001
TED	*Terebratella dorsata*	0.014	0.000	0.014	<0.001
THB	*Thymops birsteini*	0.062	0.000	0.062	<0.001
TRP	*Tripylaster philippii*	0.018	0.000	0.018	<0.001
WRM	Annelida	0.022	0.000	0.022	<0.001

3.2. Biological information of finfish species

3.2.1. *Salilota australis* – Red cod

Red cod were caught at 47 of the 70 trawl stations sampled throughout the survey. Total catch was 8,496 kg, and catches ranged from 0.02 to 6,291 kg per trawl (CPUE: 0.02–6,291 kg/h). Densities ranged from 0.1 to 30,951 kg/km^2, with higher densities occurring mostly to the north-west of the Falkland Islands (Fig. 2, top left panel). Most females were at resting maturity stage (maturity stage II); males were mainly developing (maturity stages III–IV) or resting (maturity stage II; Fig. 2, top right panel). Females were 16–80 cm, and males were 16–67 cm. Length frequency distributions were multimodal, and overlap of lengths did not allow identifying all the length-groups present. Some length modes of females were detected at 21 cm, 37 cm, around 40 cm, 51 cm, and 60 cm length (Fig. 2, middle panel). Length modes of males were identified at 21 cm, 30 cm, and 40 cm (Fig. 2, bottom panel).

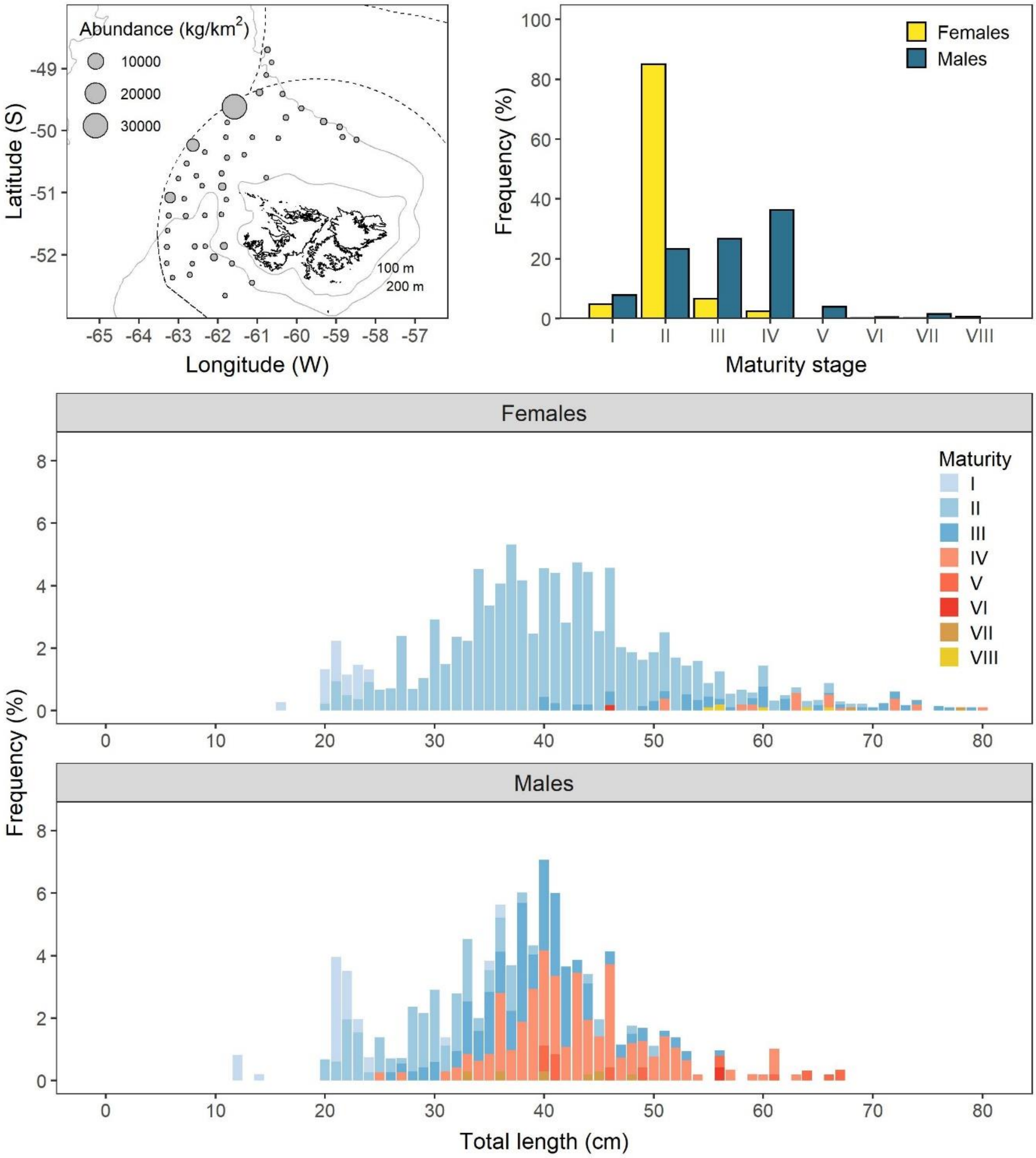

Figure 2. Biological data of *Salilota australis* (Red cod; BAC). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); Middle panel) Relative frequency (%) of female lengths (n = 571); Bottom panel) Relative frequency (%) of male lengths (n = 311) with 1 cm size class.

3.2.2. *Micromesistius australis* – Southern blue whiting

Southern blue whiting were caught at 37 of the 70 trawl stations sampled throughout the survey. Total catch was 41 kg, and catches ranged from 0.01 to 13 kg per trawl (CPUE: 0.01–13 kg/h). Densities ranged from 0.03 to 53 kg/km^2, with higher densities at the north in the FICZ and in the FOCZ, and to the south-west of West Falkland (Fig. 3, top left panel). Females and males were mainly immature (maturity stages I); few individuals were at resting or developing maturity stages (maturity stages II–IV; Fig. 3, top right panel). Females were 15–52 cm length (Fig. 3, middle panel) and males were 14–61 cm length (Fig. 3, bottom panel). One length-group with mode at 17 cm length was detected for both females and males.

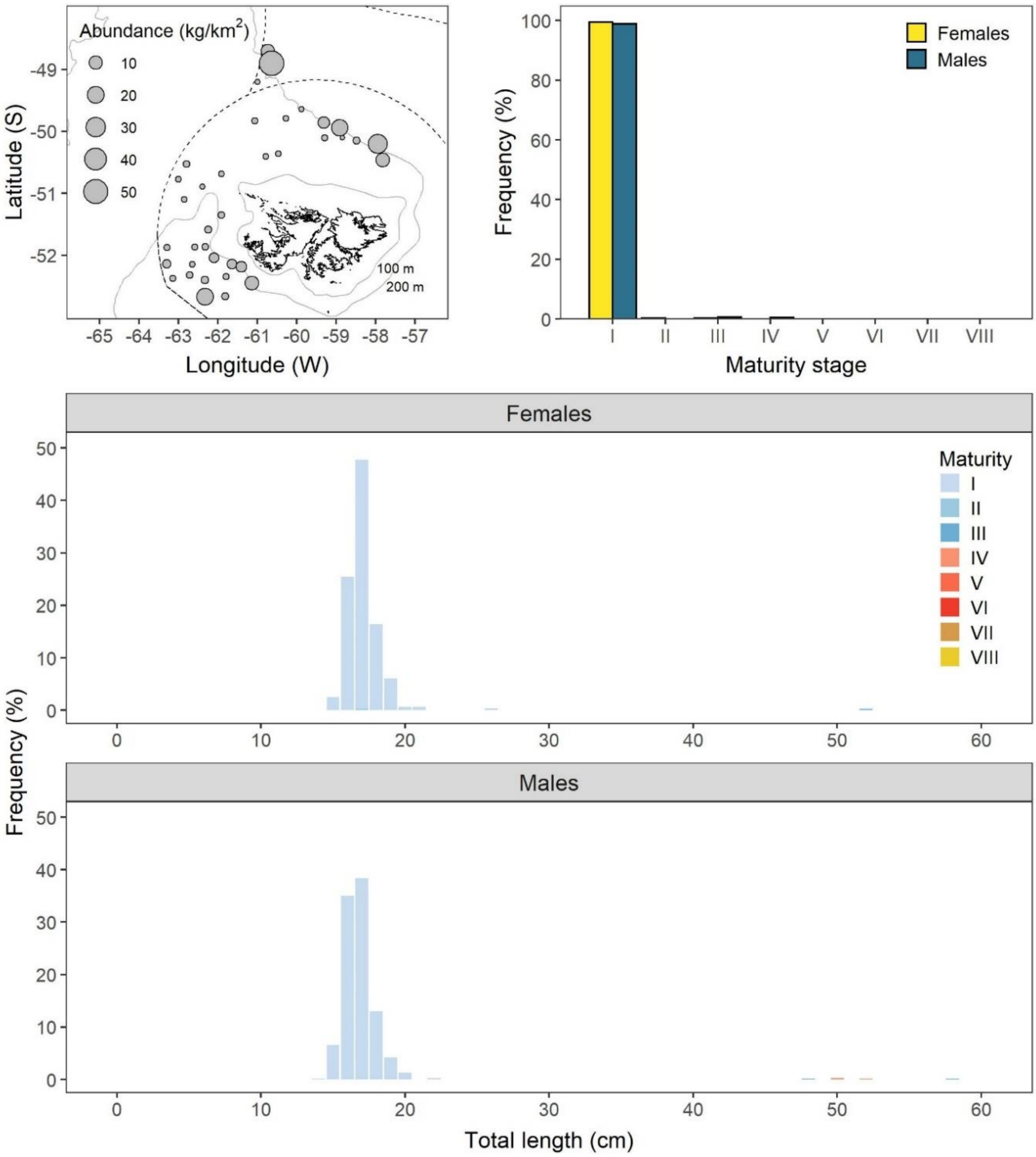

Figure 3. Biological data of *Micromesistius australis* (Southern blue whiting; BLU). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); Middle panel) Relative frequency (%) of female lengths (n = 351); Bottom panel) Relative frequency (%) of male lengths (n = 436) with 1 cm size class.

3.2.3. *Merluccius hubbsi* – Common hake

Common hake were caught at the 70 trawl stations sampled throughout the survey. Total catch was 45,809 kg, and catches ranged from 9 to 4,210 kg per trawl (CPUE: 9–4,210 kg/h). Densities ranged from 40 to 18,737 kg/km^2, with high densities through the survey area (Fig. 4, top left panel). Most females were at resting or early developing maturity stages (maturity stages II–III). Most males were at late developing maturity stage (maturity stage IV; Fig. 4, top right panel). Females were 27–76 cm length and males were 29–52 cm length. The length frequency histogram allowed identifying one length-group with mode at 37 cm length and 39 cm length for females and males, respectively (Fig. 4, middle and bottom panels).

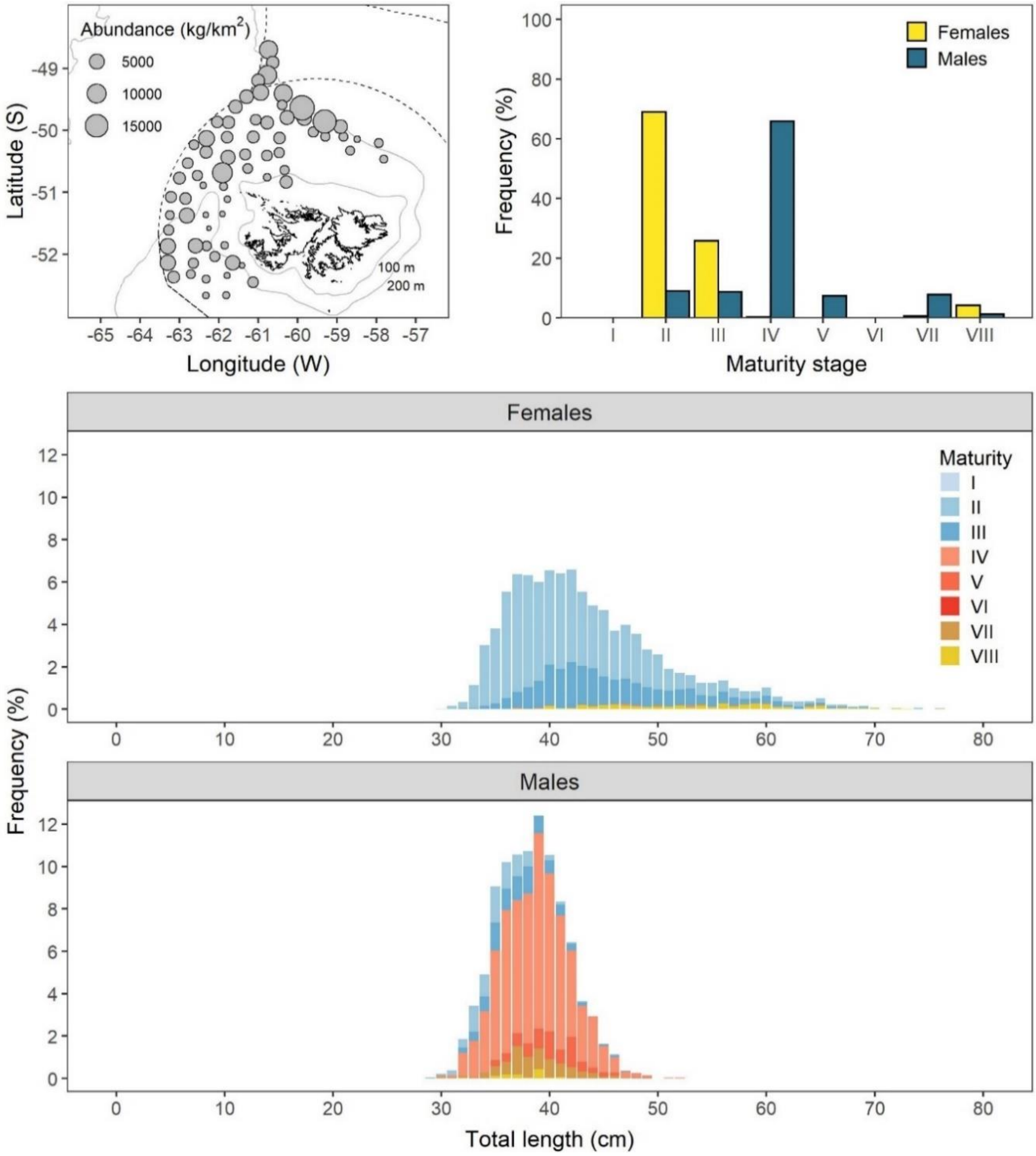

Figure 4. Biological data of *Merluccius hubbsi* (Common hake; HAK). Top left panel) Map of densities in kg/km^2; top right panel) Relative frequency (%) per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); Middle panel) Relative frequency (%) of female lengths (n = 4,525); Bottom panel) Relative frequency (%) of male lengths (n = 1,868) with 1 cm size class.

3.2.4. *Genypterus blacodes* – Kingclip

Kingclip were caught at 42 of the 70 trawl stations sampled throughout the survey. Total catch was 4,451 kg, and catches ranged from 0.6 to 1,903 kg per trawl (CPUE: 0.6–1,903 kg/h). Densities ranged from 2.6 to 8,515 kg/km^2, with higher densities observed to the north and south-west of West Falkland (Fig. 5, top left panel). Most females and males were at resting maturity stage (maturity stage II) or developing (maturity stages III–IV; Fig. 5, top right panel). Females were 38–111 cm length, and males were 37–114 cm length. Length frequency distributions were multimodal, and overlap of lengths did not allow identifying all the length-groups present. The main modes were detected at 83 cm length for females and at 69 cm length for males (Fig. 5, middle and bottom panels).

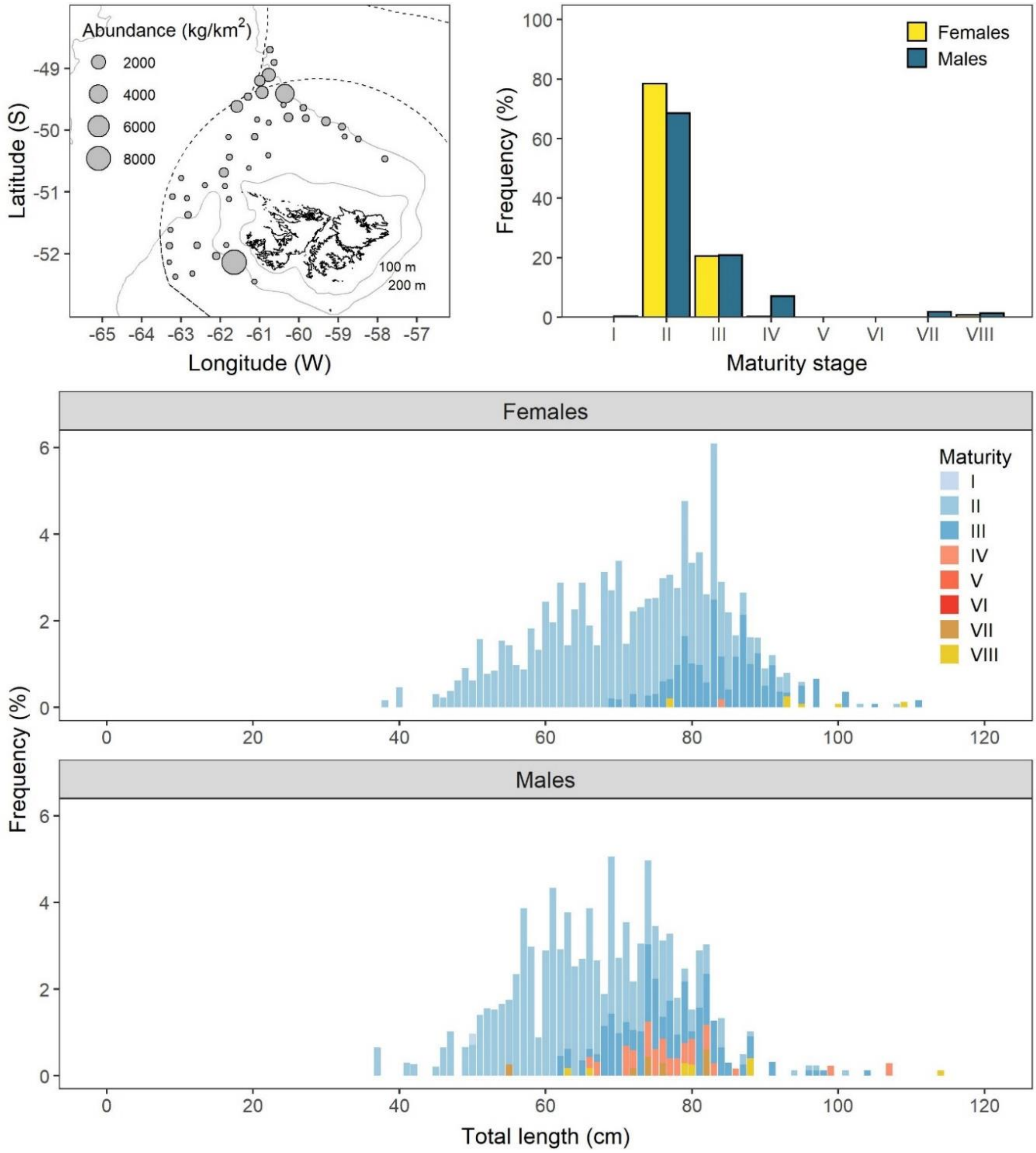

Figure 5. Biological data of *Genypterus blacodes* (Kingclip; KIN). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); Middle panel) Relative frequency (%) of female lengths (n = 567); Bottom panel) Relative frequency (%) of male lengths (n = 419) with 1 cm size class.

3.2.5. *Patagonotothen ramsayi* – Common rock cod

Rock cod were caught at 69 of the 70 trawl stations sampled throughout the survey. Total catch was 6,165 kg, and catches ranged from 0.06 to 3,078 kg per trawl (CPUE: 0.06–3,078 kg/h). Densities ranged from 0.26 to 13,955 kg/km^2, with higher densities observed to the north-west in the FICZ (Fig. 6, top left panel). Most females and males were at immature, resting or developing maturity stages (maturity stages ≤IV), with resting individuals being predominant (Fig. 6, top right panel). Females were 6–36 cm length, males were 6–32 cm length, and 41 juveniles were 5–8 cm length. Three length-groups were identified; modal lengths of females were 8 cm, 16 cm and 25 cm for females (Fig. 6, middle panel), whereas modal lengths of males were 8 cm, 17 cm, and 21 cm (Fig. 6, bottom panel). More than three length-groups may exist but these were not detected because of the overlap in lengths.

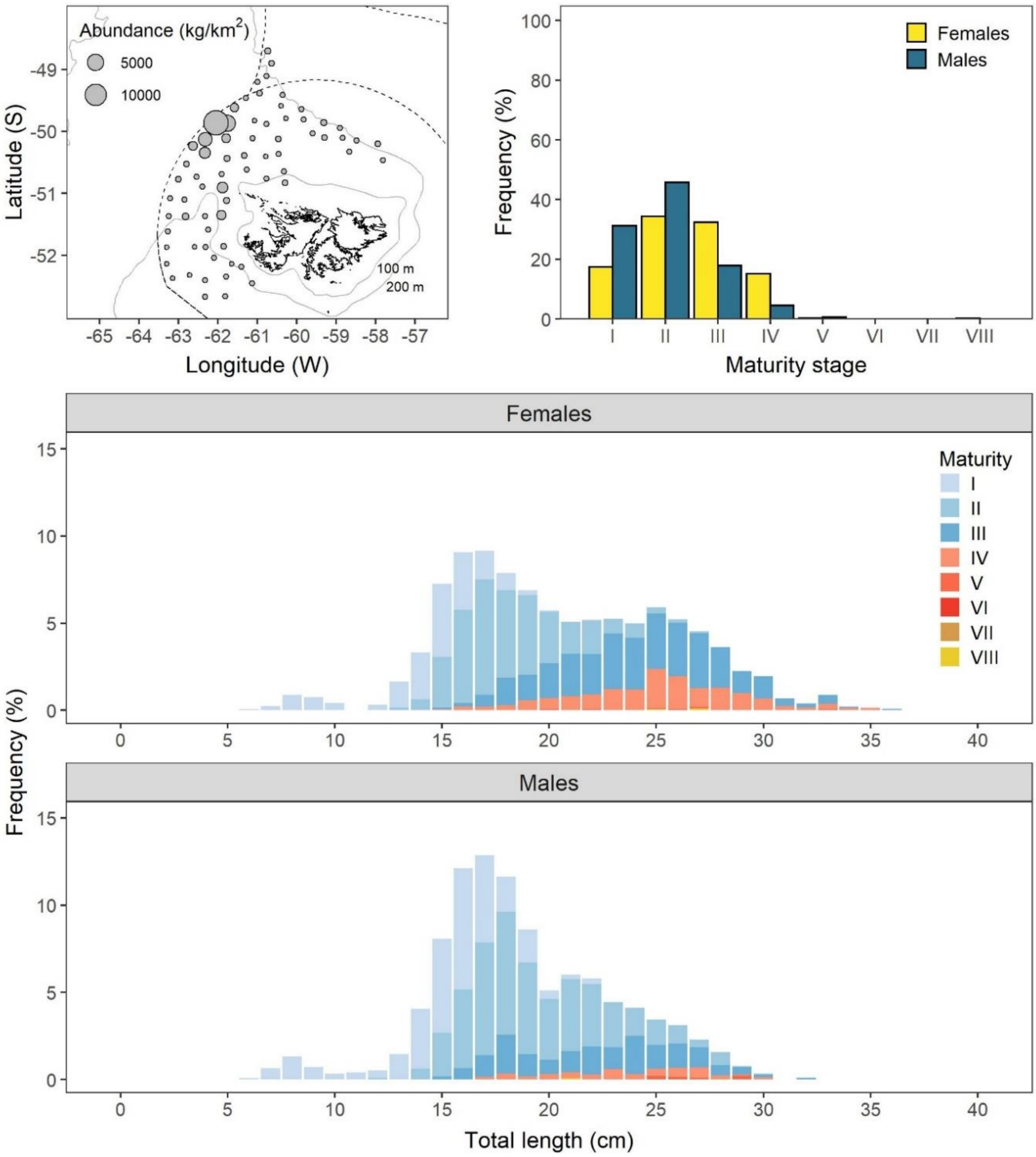

Figure 6. Biological data for *Patagonotothen ramsayi* (Common rock cod; PAR). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); Middle panel) Relative frequency (%) of female lengths (n = 1,654); Bottom panel) Relative frequency (%) of male lengths (n = 1,419) with 1 cm size class.

3.2.6. *Merluccius australis* – Southern hake

One southern hake (9 kg) was caught at one of the 70 trawl stations sampled throughout the survey. Density was 41 kg/km^2 to the south-west near the limit of the FICZ (Fig. 7, top left panel); this area is in deeper waters where southern hake are more abundant. The individual caught was a female at early developing maturity stage (maturity stage III; Fig. 7, top right panel). The female was 108 cm length (Fig. 7, middle panel). Southern hake is often misidentified as common hake *M. hubbsi*, so more southern hake could have been present given the large volumes of hake caught during the survey.

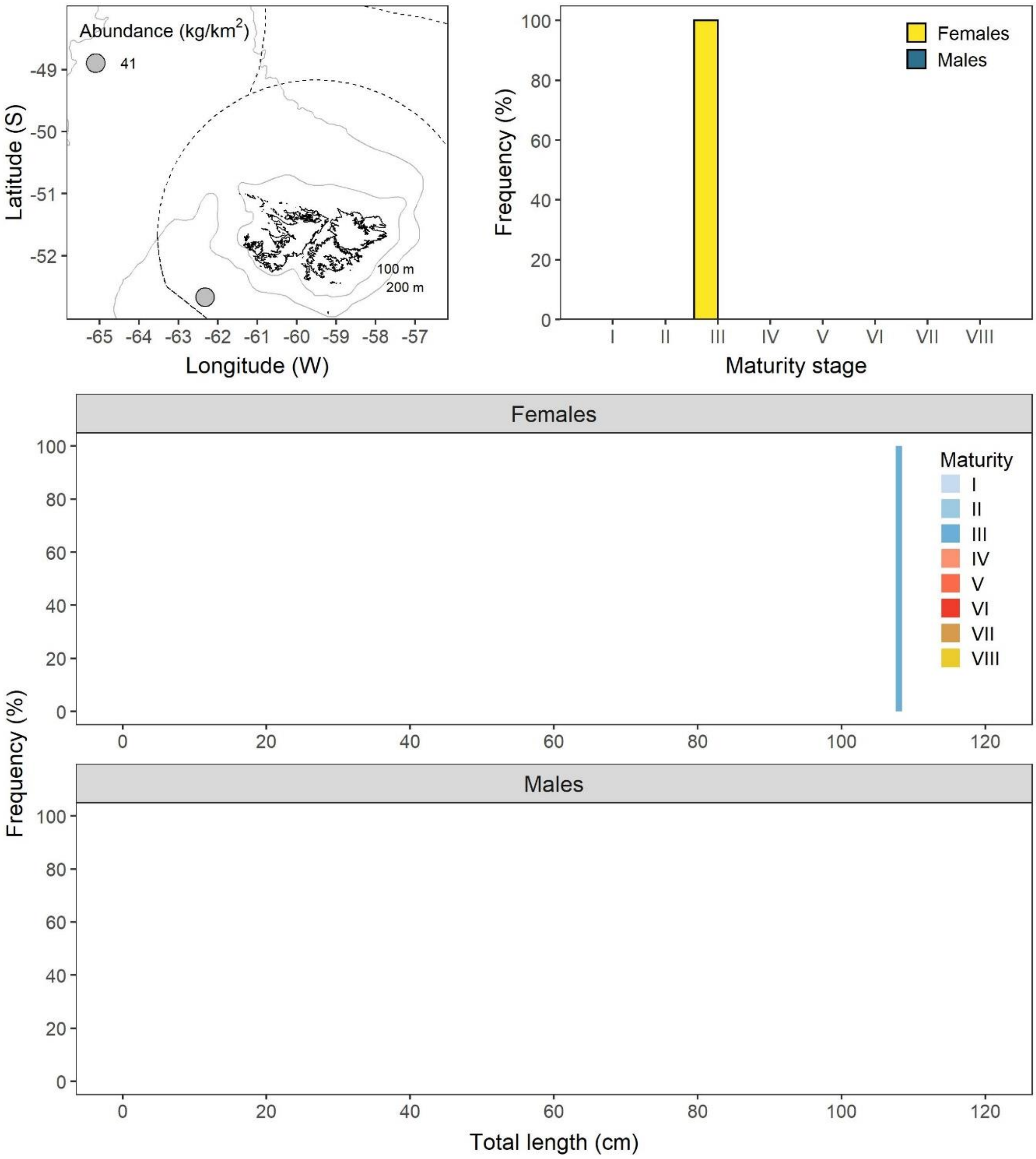

Figure 7. Biological data of *Merluccius australis* (Southern hake; PAT). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); Middle panel) Relative frequency (%) of female lengths (n = 1); Bottom panel) Relative frequency (%) of male lengths (n = 0) with 1 cm size class.

3.2.7. *Dissostichus eleginoides* – Patagonian toothfish

Patagonian toothfish were caught at 26 of the 70 trawl stations sampled throughout the survey. Total catch was 46 kg, and catches ranged from 0.34 to 8 kg per trawl (CPUE: 0.34–8 kg/h). Densities ranged from 1 to 34 kg/km^2, with higher densities observed mainly to the south-west in the FICZ at stations deeper than 200 m (Fig. 8, top left panel). Most individuals were immature or resting (maturity stages ≤II; Fig. 8, top right panel). Females were 35–83 cm, males were 35–73 cm. Modal lengths were detected at 41 cm and at 37 cm for females and males, respectively. However, no distinct length-groups were evident in the length frequency distribution due to the small number of Patagonian toothfish caught and the wide range of sizes (Fig. 8, middle and bottom panels).

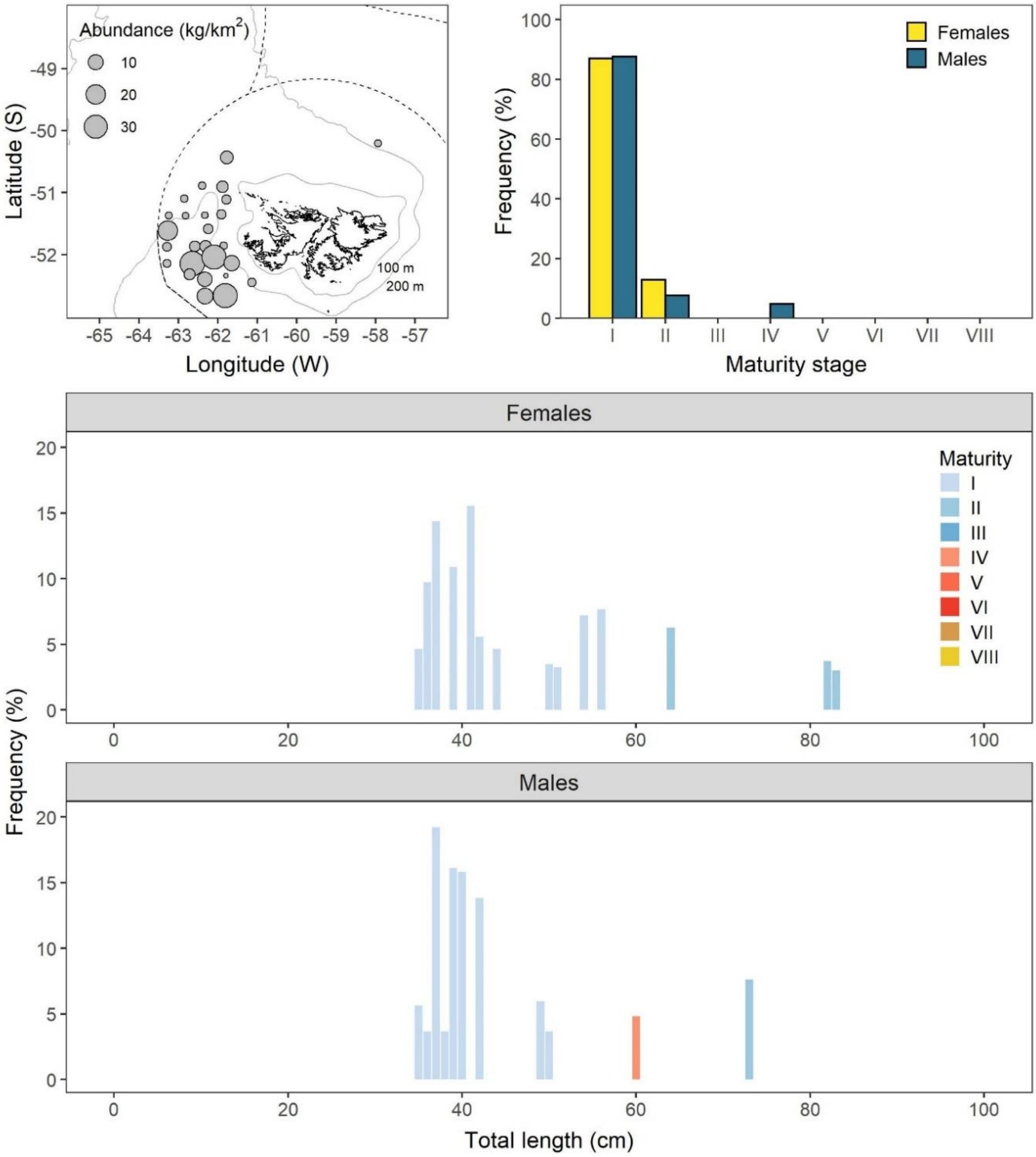

Figure 8. Biological data of *Dissostichus eleginoides* (Patagonian toothfish; TOO). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); Middle panel) Relative frequency (%) of female lengths (n = 22); Bottom panel) Relative frequency (%) of male lengths (n = 19) with 1 cm size class.

3.2.8. *Macruronus magellanicus* – Hoki

Hoki were caught at 25 of the 70 stations sampled throughout the survey. Total catch was 133 kg, and catches ranged from 0.14 to 53 kg per trawl (CPUE: 0.14–53 kg/h). Densities were 0.6 to 239 kg/km^2, with higher densities observed to the south-west in the FICZ (Fig. 9, top left panel). Most females and males were immature or resting (maturity stages ≤II; Fig. 9, top right panel). Females were 13–23 cm length, and males were 14–22 cm length. Length frequency distributions allowed detecting modal lengths at 16 cm for females and for males (Fig. 9, middle and bottom panels).

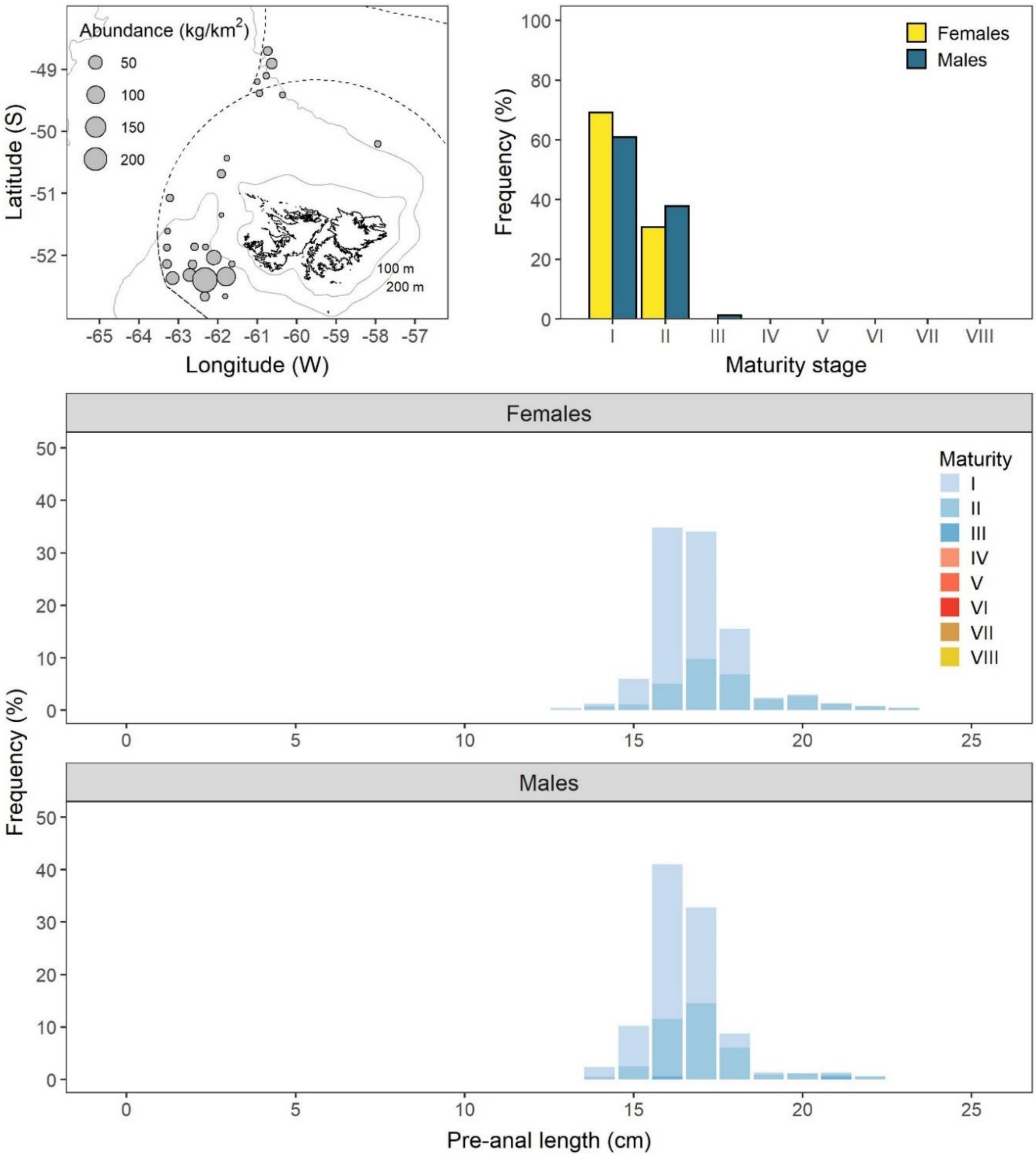

Figure 9. Biological data of *Macruronus magellanicus* (Hoki; WHI). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); Middle panel) Relative frequency (%) of female lengths (n = 255); Bottom panel) Relative frequency (%) of male lengths (n = 205) with 1 cm size class.

3.2.9. *Stromateus brasiliensis* – Butterfish

Butterfish were caught at 19 of the 70 trawl stations sampled throughout the survey. Total catch was 26 kg, and catches ranged from 0.2 to 9 kg (CPUE: 0.2–9 kg/h). Densities ranged from 1 to 40 kg/km^2, with higher densities to the north and to the west in the FICZ (Fig. 10, top left panel). Females were mostly at early developing maturity stage (maturity stage III); minor proportions of late developing to recovering spent females were also observed (maturity stages ≥IV). Males were mainly at recovering spent maturity stage (maturity stage VIII; Fig. 10, top right panel). Females were 25–41 cm length and the one male caught was 32 cm length. Modal length of females was detected at 34 cm (Fig. 10, middle panel).

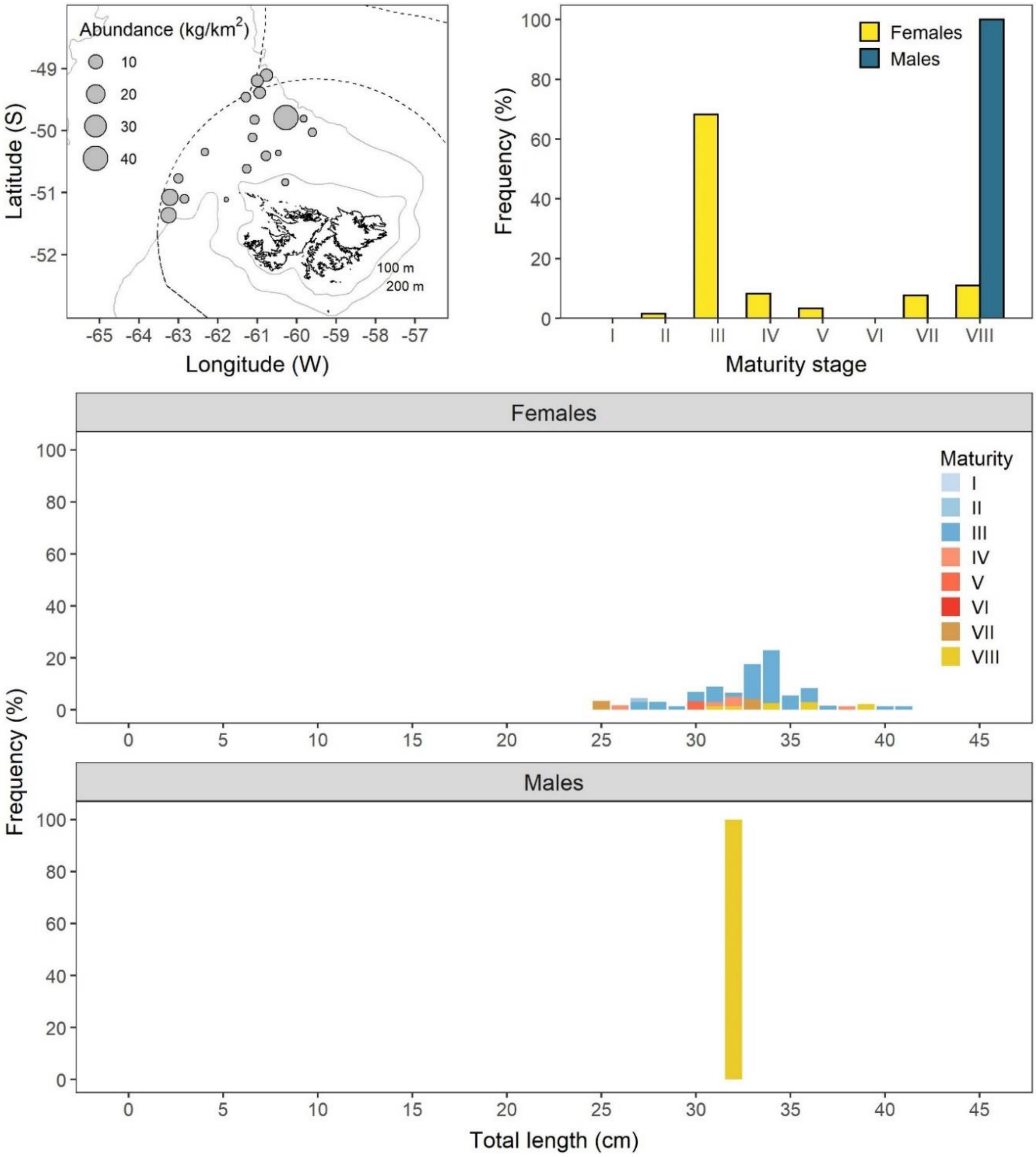

Figure 10. Biological data of *Stromateus brasiliensis* (Butterfish; BUT). Top left panel) Map of densities in kg/km2; Top right panel) Relative frequency (%) per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); Middle panel) Relative frequency (%) of female lengths (n = 50); Bottom panel) Relative frequency (%) of male lengths (n = 1) with 1 cm size class.

3.2.10. *Coelorinchus fasciatus* – Banded whiptail grenadier

Banded whiptail grenadier were caught at 10 of the 70 trawl stations sampled throughout the survey. Total catch was 3 kg, and catches ranged from 0.06 to 1.4 kg per trawl (CPUE: 0.06–1.4 kg/h). Densities ranged from 0.3 to 7 kg/km^2, observed to the south-west in the FICZ (Fig. 11, top left panel). Females and males were mostly at resting maturity stage (maturity stage II); few individuals were immature (maturity stage I), or early developing (maturity stage III; Fig. 11, top right panel). Females were 6–14 cm length; males were 5–10 cm length. The length frequency distributions allowed detecting a single length-group with modal length at 8 cm for females (Fig. 11, middle panel) and at 7 cm for males (Fig. 11, bottom panel).

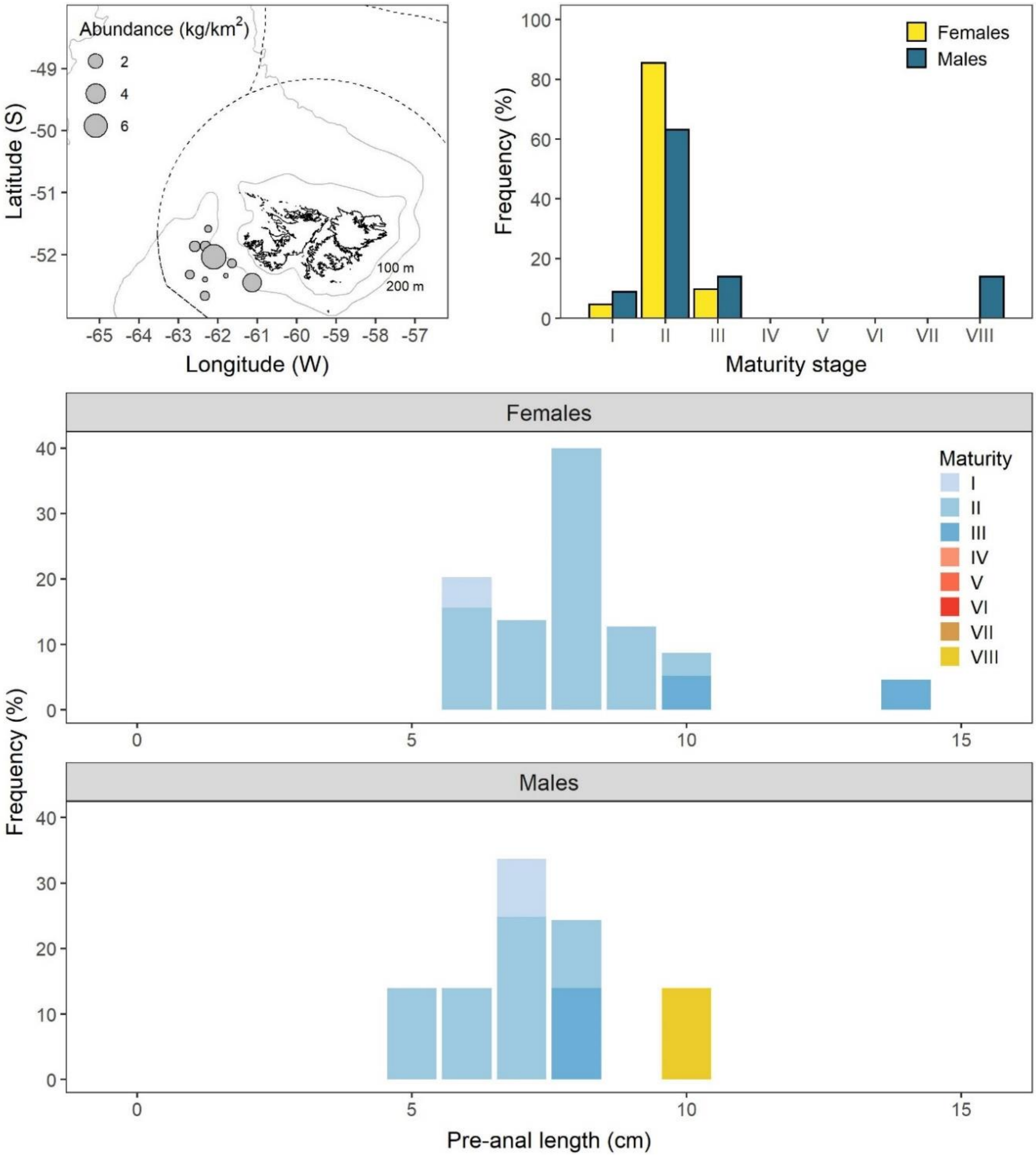

Figure 11. Biological data of *Coelorinchus fasciatus* (Banded whiptail grenadier; GRF). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); Middle panel) Relative frequency (%) of female lengths (n = 21); Bottom panel) Relative frequency (%) of male lengths (n = 9) with 1 cm size class.

3.2.11. *Seriolella porosa* – Driftfish

Driftfish were caught at 4 of the 70 trawl stations sampled throughout the survey. Total catch was 9 kg, and catches ranged from 0.7 to 7 kg per trawl (CPUE: 1–7 kg/h). Densities ranged from 3 to 29 kg/km^2, observed to the north-west in the FICZ (Fig. 12, top left panel). Females were at early developing maturity stage (maturity stage III), and males were immature or developing (maturity stages I, III, or IV; Fig. 12, top right panel). Females were 52–57 cm length and males were 37–44 cm length. The limited number of driftfish caught did not allow identifying length-groups nor modal lengths (Fig. 12, middle and bottom panels).

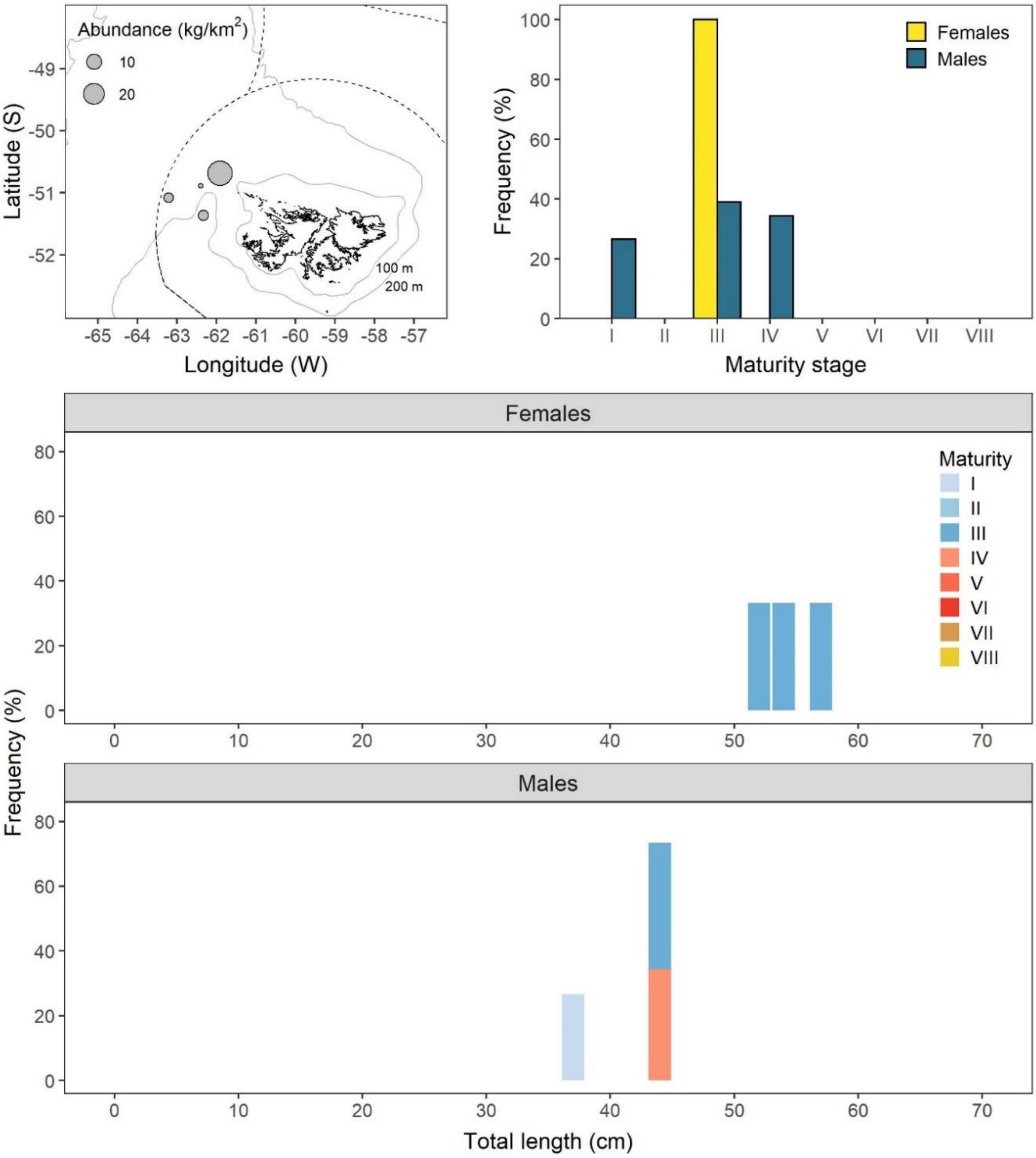

Figure 12. Biological data of *Seriolella porosa* (Driftfish; SEP). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); Middle panel) Relative frequency (%) of female lengths (n = 3); Bottom panel) Relative frequency (%) of male lengths (n = 3) with 1 cm size class.

3.3. Biological information of squid species

3.3.1. *Illex argentinus* – Argentine shortfin squid

Argentine shortfin squid were caught at 28 of the 70 trawl stations sampled throughout the survey. Total catch was 9 kg, and catches ranged from 0.01 to 1.6 kg per trawl (CPUE: 0.01–1.6 kg/h). Densities ranged from 0.06 to 7 kg/km^2, observed to the north in the FICZ and in the FOCZ (Fig. 13, top left panel). Most females and males were immature (maturity stages ≤II); smaller proportions of preparatory to mature individuals were also observed (maturity stages >III; Fig. 13, top right panel). Females were 7.0–25.0 cm length, and males were 7.5–16.5 cm length. Length frequency distributions allowed detecting modal lengths at 10.5 cm and 10.0 cm for females and males, respectively (Fig. 13, middle and bottom panels).

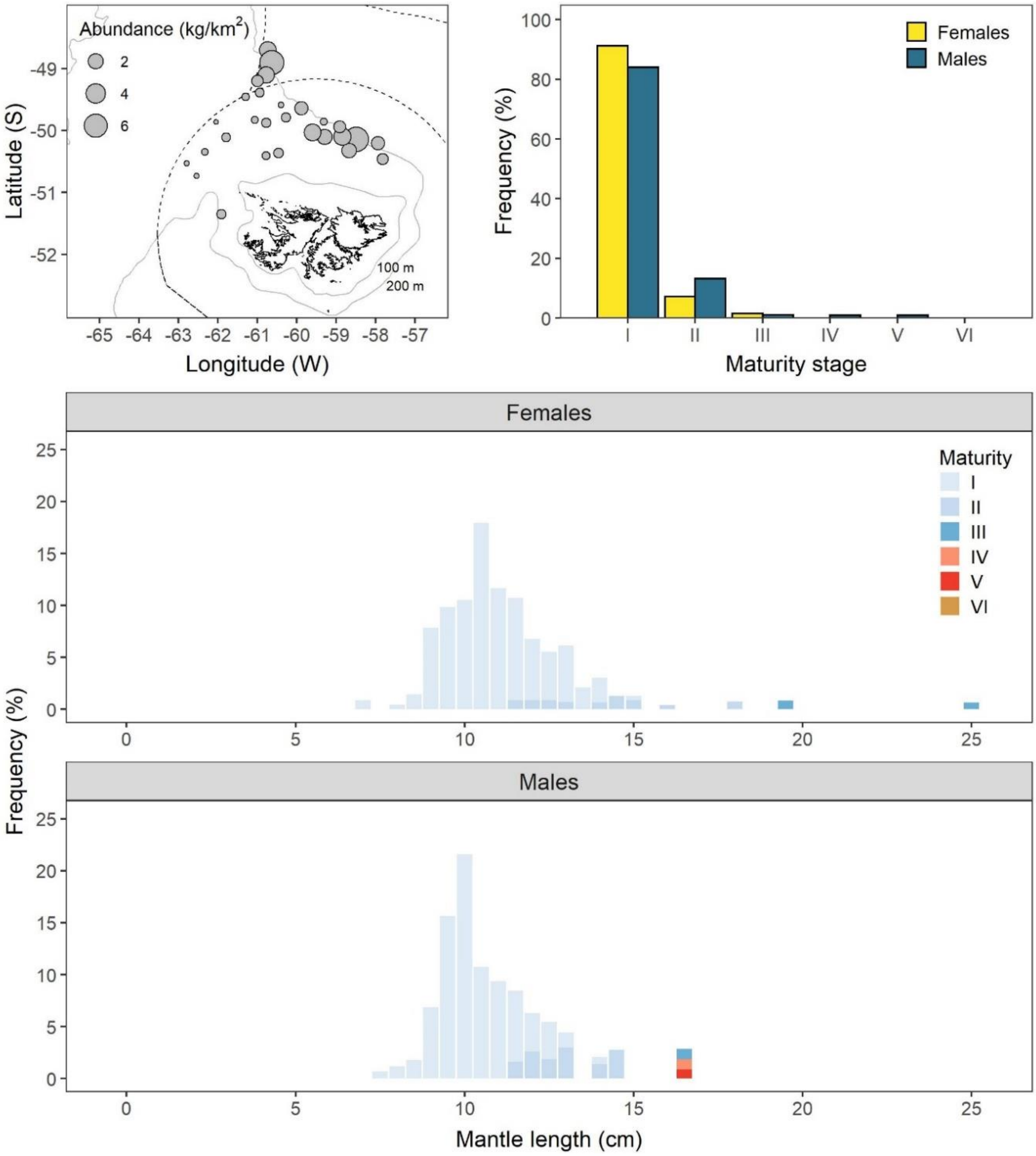

Figure 13. Biological data of *Illex argentinus* (Argentine shortfin squid; ILL). Top left panel) Map of densities in kg/km2; Top right panel) Relative frequency (%) per maturity stage (I, young; II, immature; III, preparatory; IV, maturing; V, mature; VI, spent); Middle panel) Relative frequency (%) of female lengths (n = 147); Bottom panel) Relative frequency (%) of male lengths (n = 126) with 0.5 cm size class.

3.3.2. *Doryteuthis gahi* – Patagonian squid

Patagonian squid were caught at the 70 trawl stations conducted throughout the survey. Total catch was 6,490 kg, and catches ranged from 2 to 614 kg per trawl (CPUE: 2–614 kg/h). Densities ranged from 9 to 2,828 kg/km^2 along the survey area, with higher densities to the south-west of West Falkland and to the north of the Falkland Islands (Fig. 14, top left panel). Most females were immature or preparatory (maturity stages II–III), whereas males were mainly preparatory to mature (maturity stages >III; Fig. 14, top right panel). The only one juvenile sampled was 4.5 cm length. Females were 4.5–20.5 cm length (Fig. 14, middle panel), and males were 5.0–28.0 cm length (Fig. 14, bottom panel). Modal length of females and males were detected at 9.5 cm, respectively.

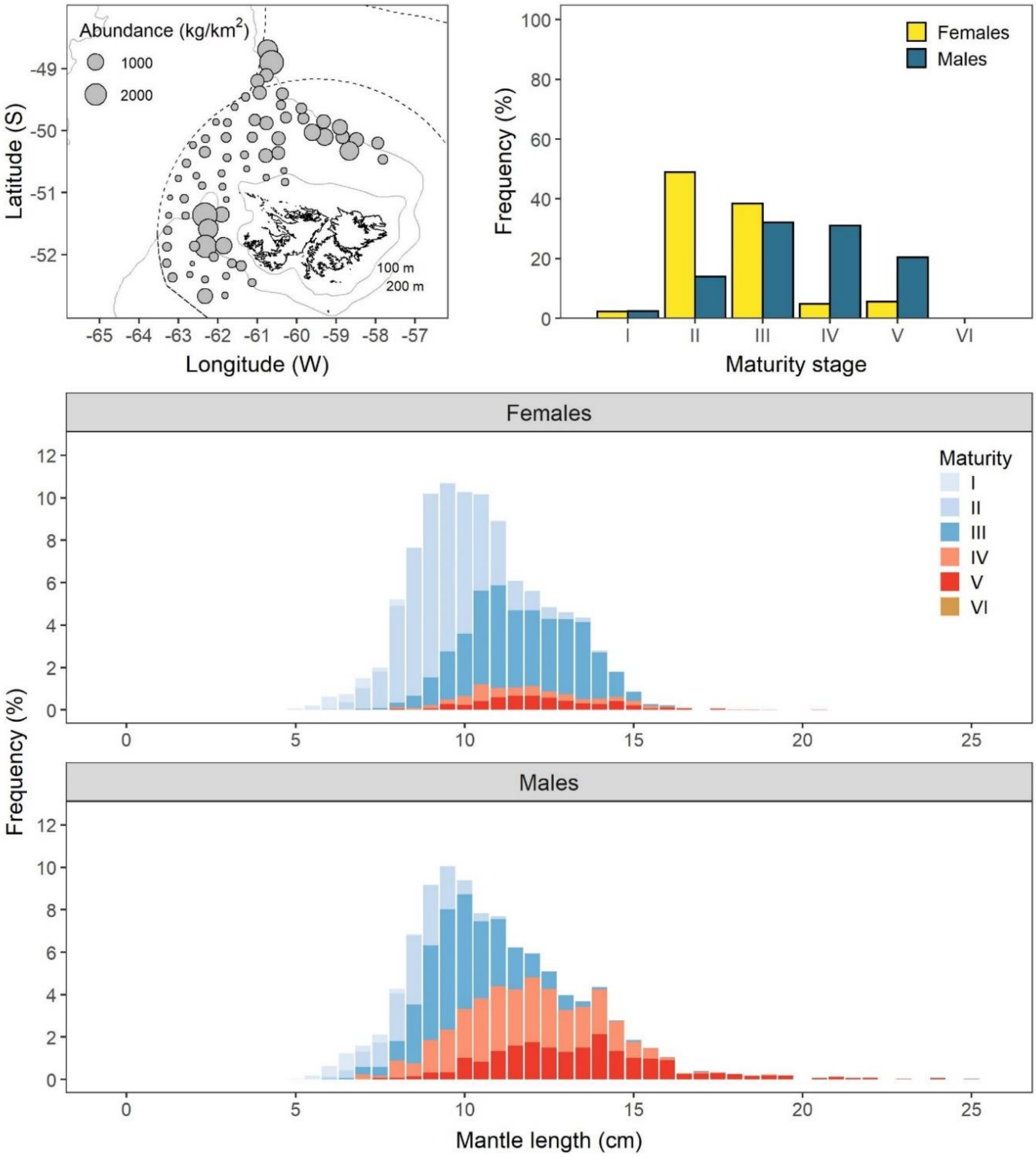

Figure 14. Biological data of *Doryteuthis gahi* (Patagonian squid; LOL). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, young; II, immature; III, preparatory; IV, maturing; V, mature; VI, spent); Middle panel) Relative frequency (%) of female lengths (n = 4,037); Bottom panel) Relative frequency (%) of male lengths (n = 3,411) with 0.5 cm size class.

3.4. Biological information of skate species

3.4.1. *Bathyraja albomaculata* – White spotted skate

White spotted skates were caught at 3 of the 70 trawl stations sampled throughout the survey. Total catch was 3 kg, and catches ranged from 0.3 to 2 kg per trawl (CPUE: 0.3–2 kg/h). Densities ranged from 1 to 8 kg/km^2, observed to the north in the FICZ (Fig. 15, top left panel). Most females were developing (maturity stage III), and males were developing or juvenile (maturity stages III or I, respectively; Fig. 15, top right panel). Females were 33–35 cm disc width (Fig. 15, middle panel); males were 22–34 cm disc width (Fig. 15, bottom panel).

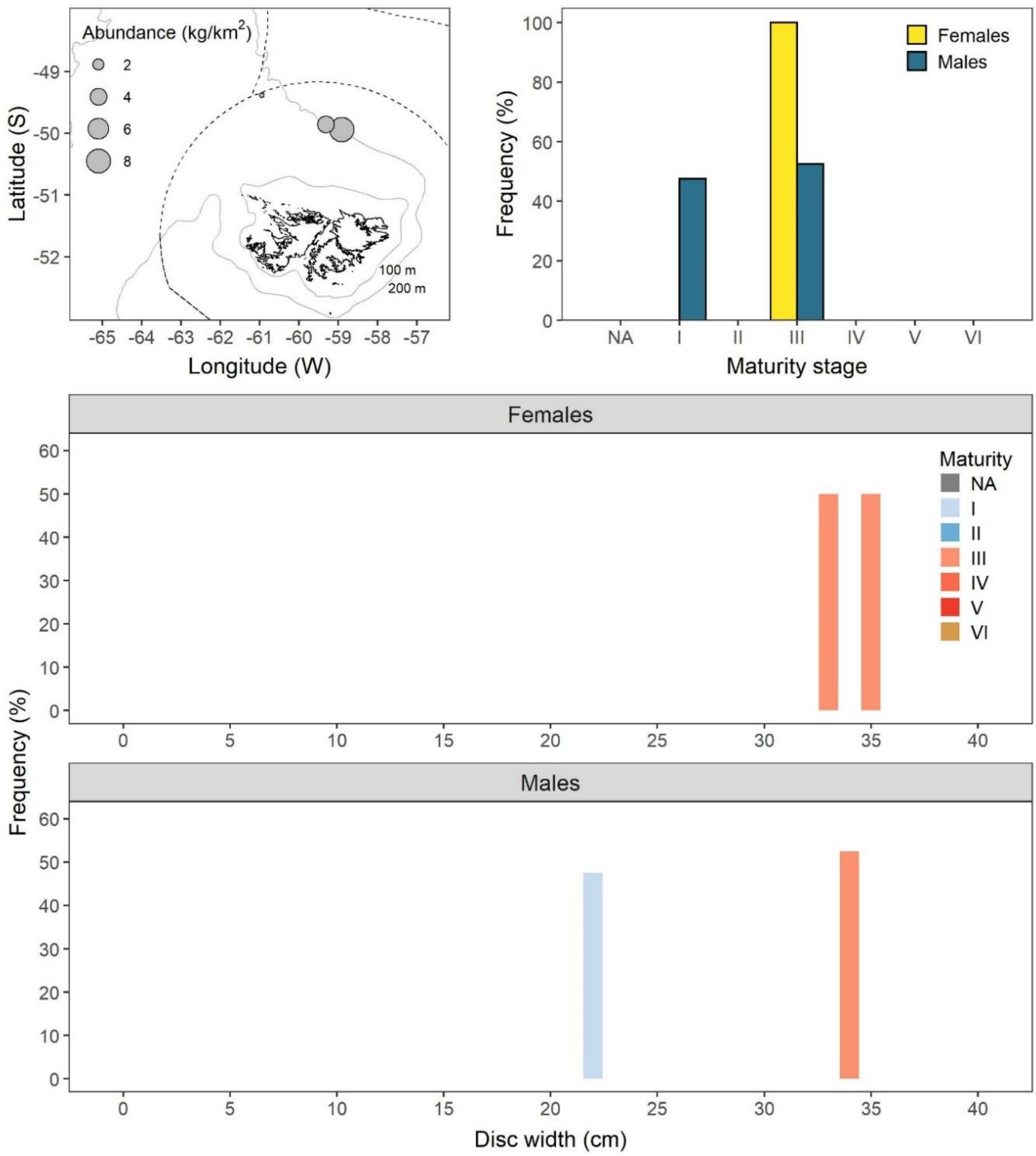

Figure 16. Biological data of *Bathyraja albomaculata* (White spotted skate; RAL). Top left panel) Map of densities in kg/km2; Top right panel) Relative frequency (%) per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); Middle panel) Relative frequency (%) of female lengths (n = 2); Bottom panel) Relative frequency (%) of male lengths (n = 2) with 1 cm size class.

3.4.2. *Bathyraja brachyurops* – Blonde skate

Blonde skates were caught at 13 of the 70 trawl stations sampled throughout the survey. Total catch was 29 kg, and catches ranged from 0.24 to 6 kg (CPUE: 0.24–6 kg/h). Densities ranged from 1 to 28 kg/km^2, with patchy distribution to the north and west mainly in the FICZ (Fig. 16, top right panel). Most females were maturing to mature (maturity stages II–IV); males were mainly mature or juvenile (maturity stages IV or I, respectively), with smaller proportions of maturing, developing, or running individuals (maturity stages II, III, or V, respectively; Fig. 16, top right panel). Females were 32–56 cm disc width and males were 24–56 cm disc width. The small numbers of individuals caught did not allow detecting length-groups nor modal lengths (Fig. 16, middle and bottom panels).

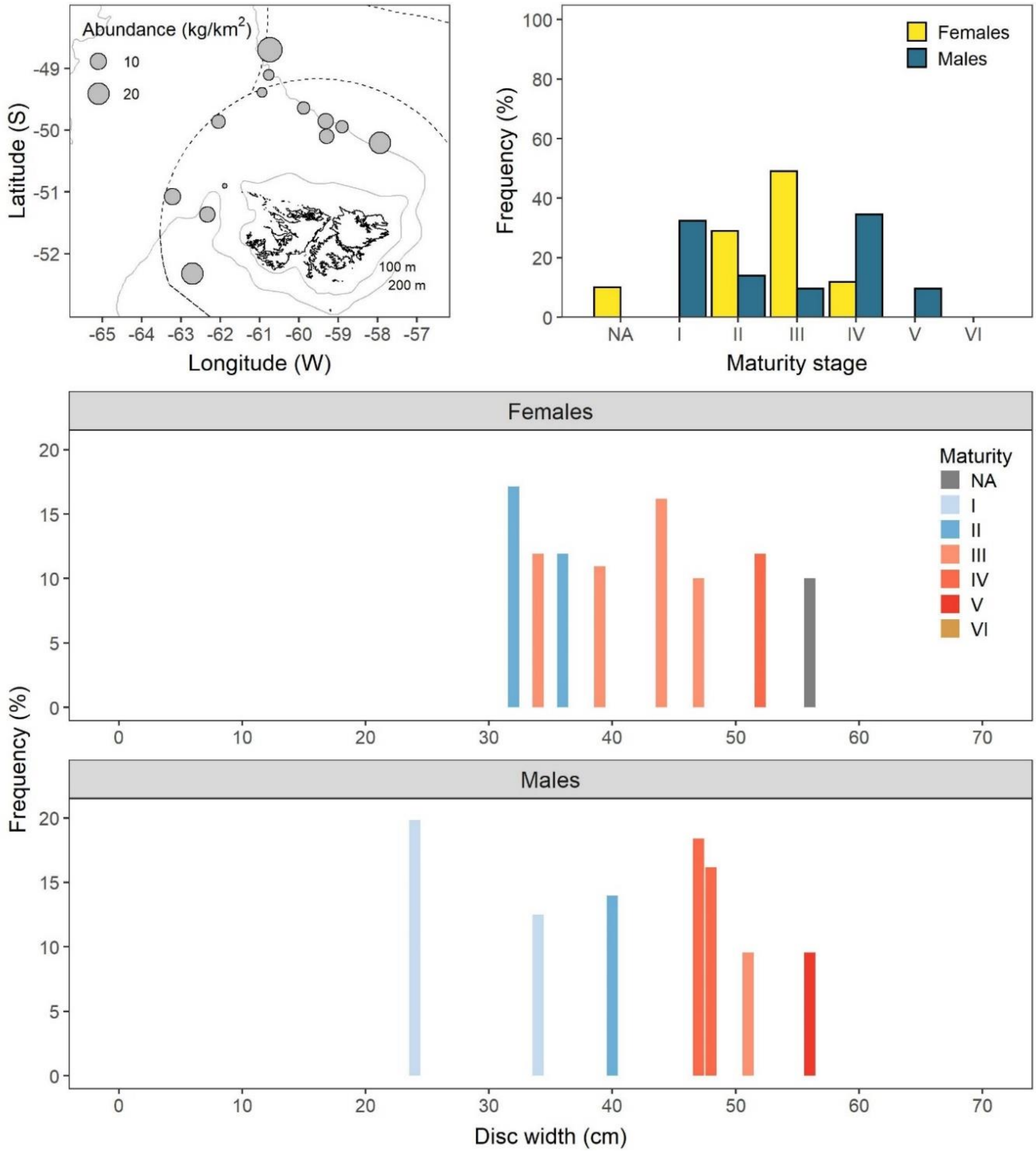

Figure 16. Biological data of *Bathyraja brachyurops* (Blonde skate; RBR). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); Middle panel) Relative frequency (%) of female lengths (n = 9); Bottom panel) Relative frequency (%) of male lengths (n = 7) with 1 cm size class.

3.4.3. *Dipturus lamillai* – Warrah skate

Warrah skates were caught at 27 of the 70 trawl stations sampled throughout the survey. Total catch was 113 kg, and catches ranged from 0.6 to 19 kg per trawl (CPUE: 0.6–19 kg/h). Densities ranged from 2 to 85 kg/km^2, with patchy distribution through the survey area (Fig. 17, top left panel). Most females were maturing or developing (maturity stages II and III), while males were developing or running (maturity stages III or V), with smaller proportions of juvenile or mature individuals (maturity stages I and IV; Fig. 17, top right panel). Females were 35–75 cm disc width and modal disc width was identified at 60 cm disc width size class (Fig. 17, middle panel). Males were 47–61 cm disc width; the small number of males caught during the survey did not allow identifying the modal length for males (Fig. 17, bottom panel).

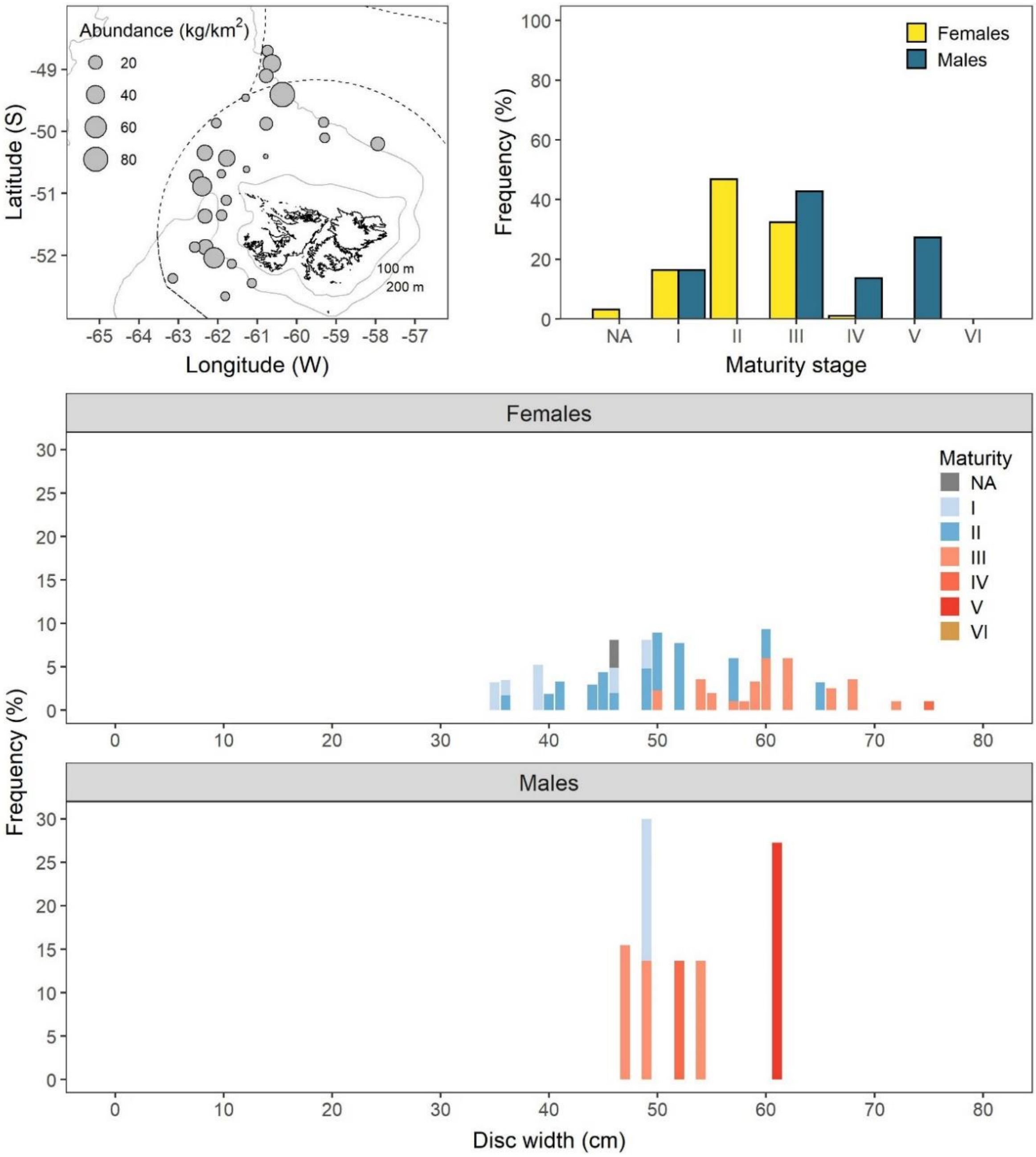

Figure 17. Biological data of *Dipturus lamillai* (Yellow nose skate; RFL). Top left panel) Map of densities in kg/km2; Top right panel) Relative frequency (%) per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); Middle panel) Relative frequency (%) of female lengths (n = 39); Bottom panel) Relative frequency (%) of male lengths (n = 7) with 1 cm size class.

3.4.4. *Bathyraja griseocauda* – Grey-tailed skate

Grey-tailed skates were caught at 5 of the 70 trawl stations sampled throughout the survey. Total catch was 39 kg, and catches ranged from 0.6 to 26 kg per trawl (CPUE: 0.6–26 kg/h). Densities ranged from 2.6 to 111 kg/km^2, with higher densities observed to the south-west in the FICZ (Fig. 18, top left panel). Most females and males were juvenile (maturity stage I); males were also mature (maturity stage IV), and a small proportion of females were also at resting maturity stage (maturity stage VI; Fig. 18, top right panel). Females were 21–111 cm disc width, and males were 31–79 cm disc width. The small number of individuals caught during the survey did not allow identifying length-groups nor modal lengths (Fig. 18, middle and bottom panels).

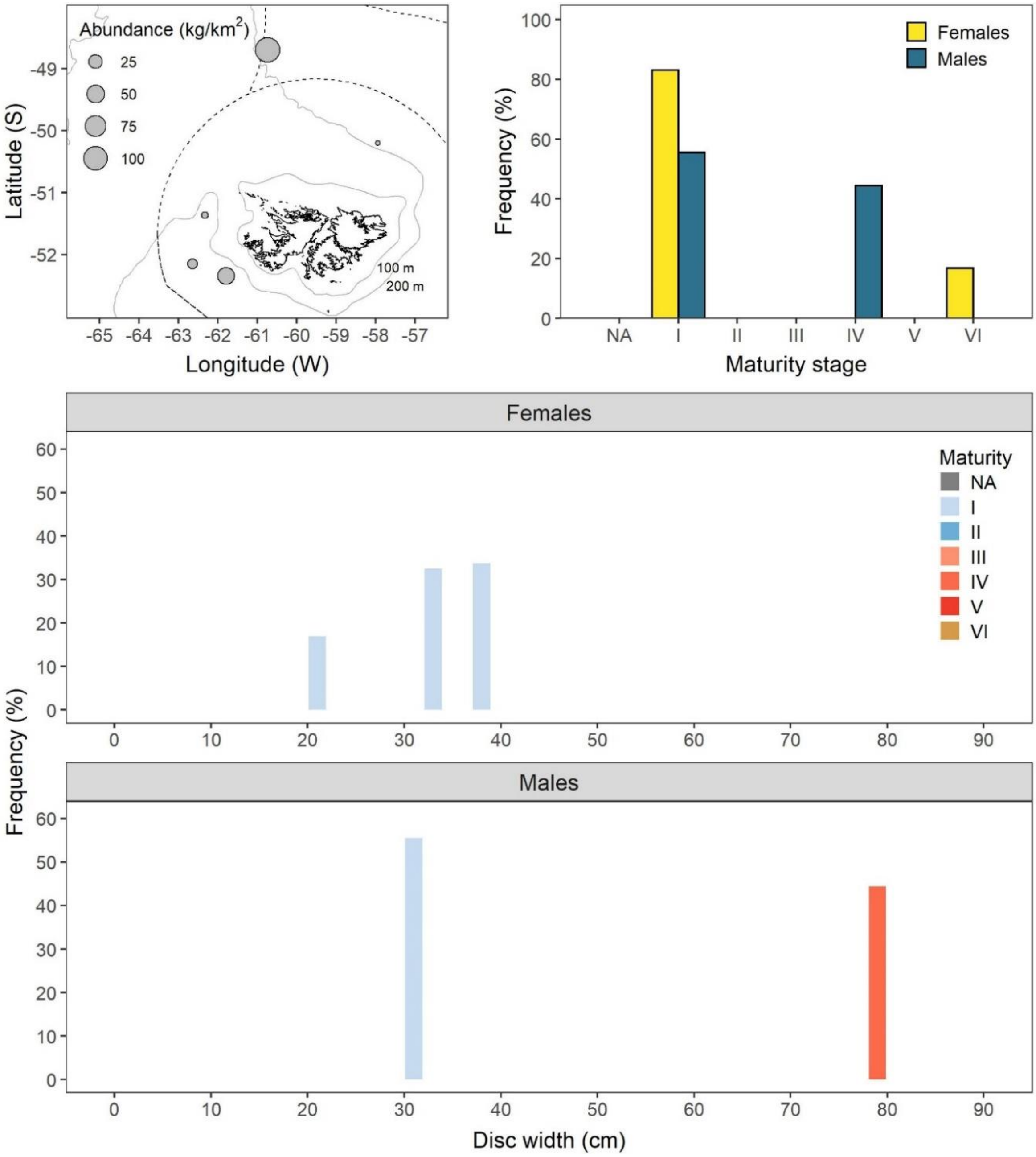

Figure 18. Biological data of *Bathyraja griseocauda* (Grey tailed skate; RGR). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); Middle panel) Relative frequency (%) of female lengths (n = 5); Bottom panel) Relative frequency (%) of male lengths (n = 2) with 1 cm size class.

3.4.5. *Bathyraja macloviana* – Falkland skate

Falkland skates were caught at 2 of the 70 trawl stations sampled throughout the survey. Total catch was 2 kg, and catches ranged from 1.2 to 1.3 kg per trawl (CPUE: 1.2–1.3 kg/h). Densities ranged from 5 to 6 kg/km^2, observed to the north-west of West Falkland (Fig. 19, top left panel). The two females caught were mature (maturity stage IV; Fig. 19, top right panel), and measured 34 and 36 cm disc width, respectively (Fig. 19, middle panel). No males were caught during the survey (Fig. 19, bottom panel).

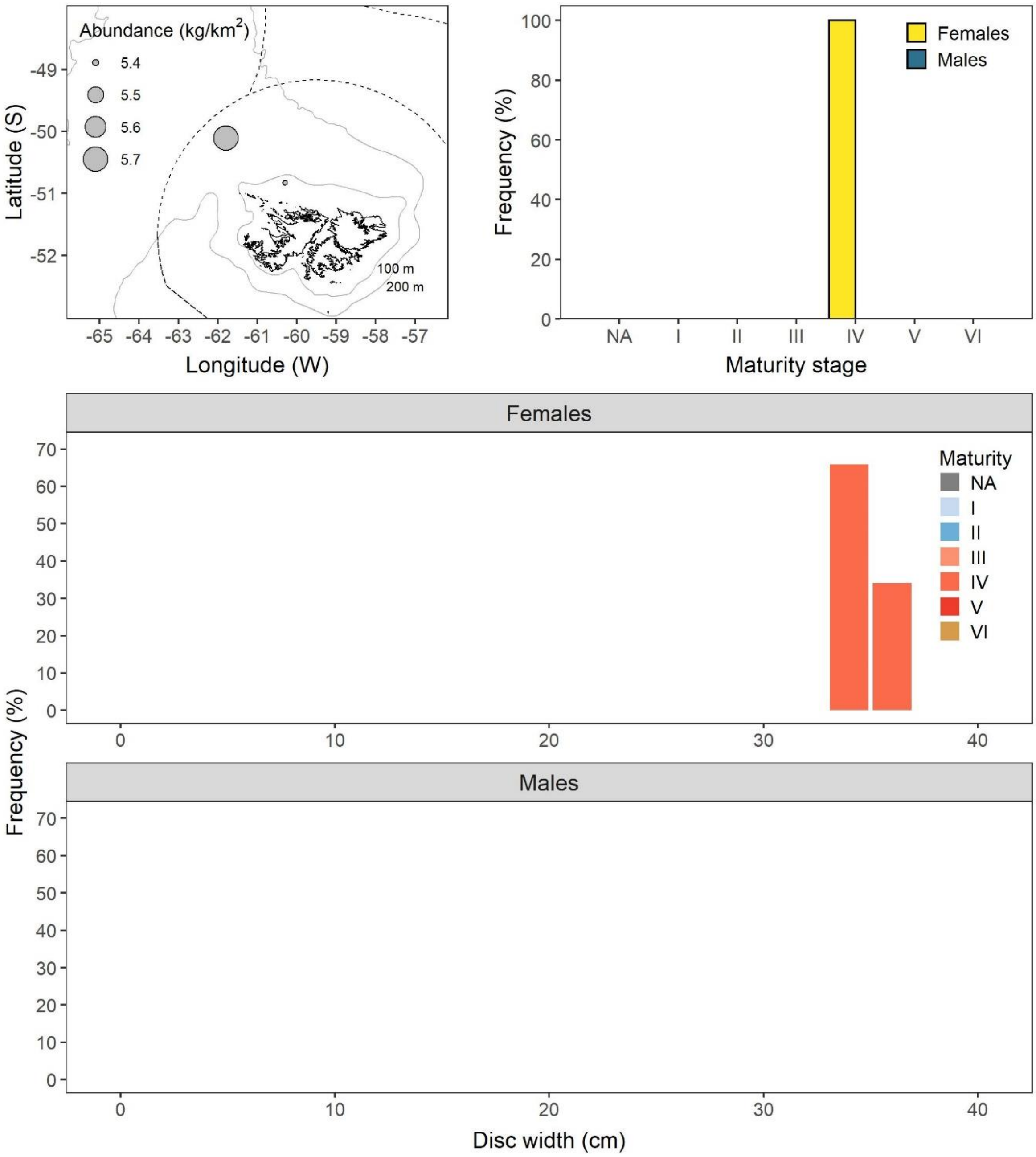

Figure 19. Biological data of *Bathyraja macloviana* (Falkland skate; RMC). Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); Middle panel) Relative frequency (%) of female lengths (n = 2); Bottom panel) Relative frequency (%) of male lengths (n = 0) with 1 cm size class.

3.5. Biological information of sharks species

3.5.1. *Schroederichthys bivius* – Catshark

Catshark were caught at 54 of the 70 trawl stations sampled throughout the survey. Total catch was 200 kg, and catches ranged from 0.2 to 24 kg per trawl (CPUE: 0.2–24 kg/h). Densities ranged from 0.8 to 113 kg/km^2, with higher densities observed to the north-west in the FICZ (Fig. 20, top left panel). Most females were found alive and released as soon as possible without assessing maturity stage, and their maturity stage was recorded as NA. Most males were juvenile (maturity stage I), developing or mature (maturity stages III–IV; Fig. 20, top right panel). Length frequency distributions were multimodal, and overlap of lengths did not allow identifying all the length-groups present. Females were 34–67 cm length, with mode at 53 cm length (Fig. 20, middle panel). Males were 25–76 cm length, with mode at 63 cm length (Fig. 20, bottom panel).

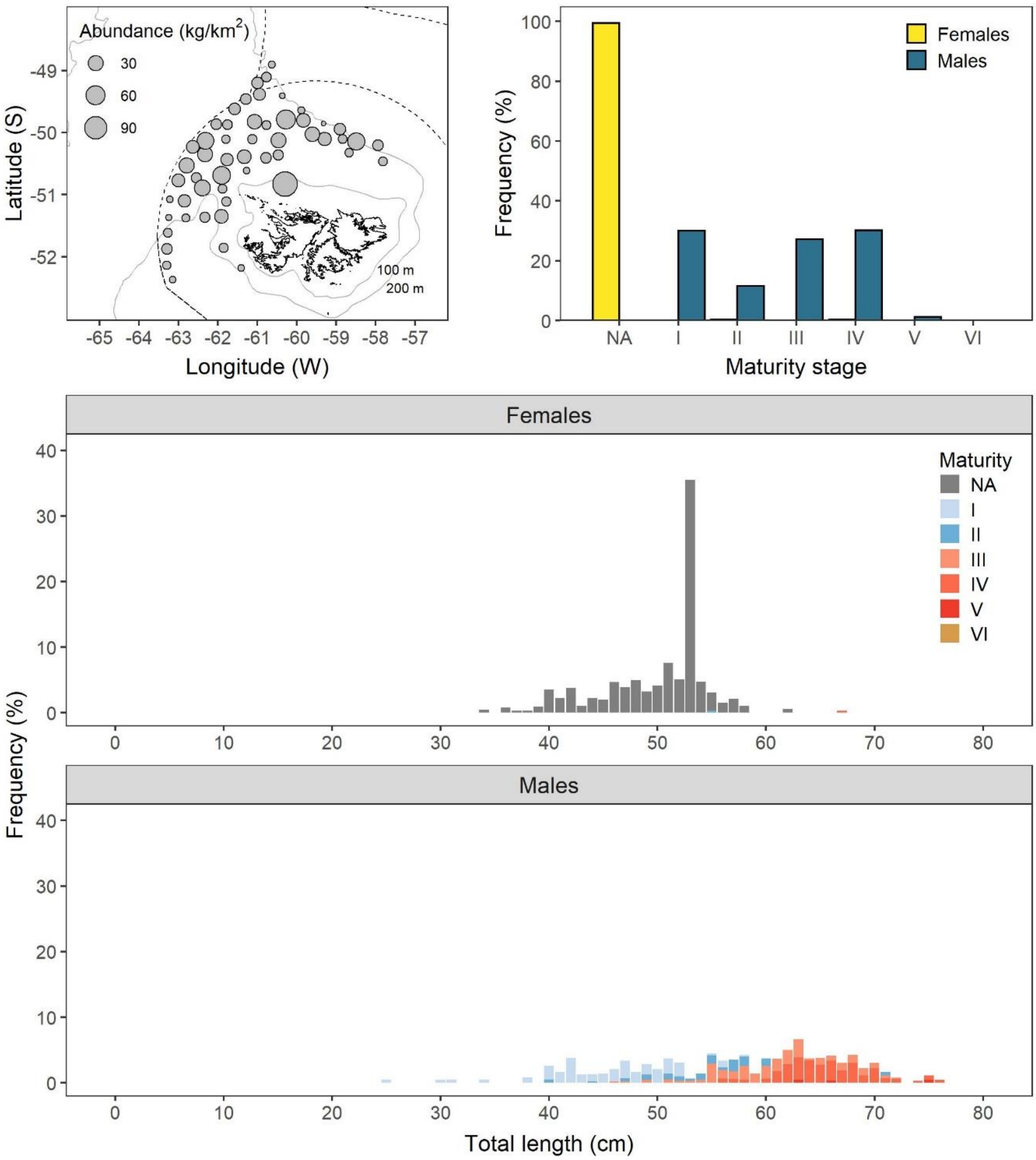

Figure 20. Biological data of *Schroederichthys bivius* (Catshark; DGH); Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); Middle panel) Relative frequency (%) of female lengths (n = 231); Bottom panel) Relative frequency (%) of male lengths (n = 259) with 1 cm size class.

3.5.2. *Squalus acanthias* – Dogfish

Dogfish were caught at 21 of the 70 trawl stations sampled through the survey. Total catch was 254 kg, and catches ranged from 0.3 to 54 kg per trawl (CPUE: 0.3–54 kg/h). Densities ranged from 1 to 226 kg/km^2, with higher densities observed to the north in the FICZ (Fig. 21, top left panel). Most females were found alive and released as soon as possible without assessing maturity stage, and their maturity stage was recorded as NA. Most males were developing or mature (maturity stages III–IV), with smaller proportions of juvenile or maturing individuals (maturity stages I–II; Fig. 21, top right panel). Length frequency distributions were multimodal, and overlap of lengths did not allow identifying all the length-groups present. Females were 44–82 cm length, with the main mode at 54 cm length (Fig. 21, middle panel). Males were 47–71 cm length, with the main mode at 63 cm length (Fig. 21, bottom panel).

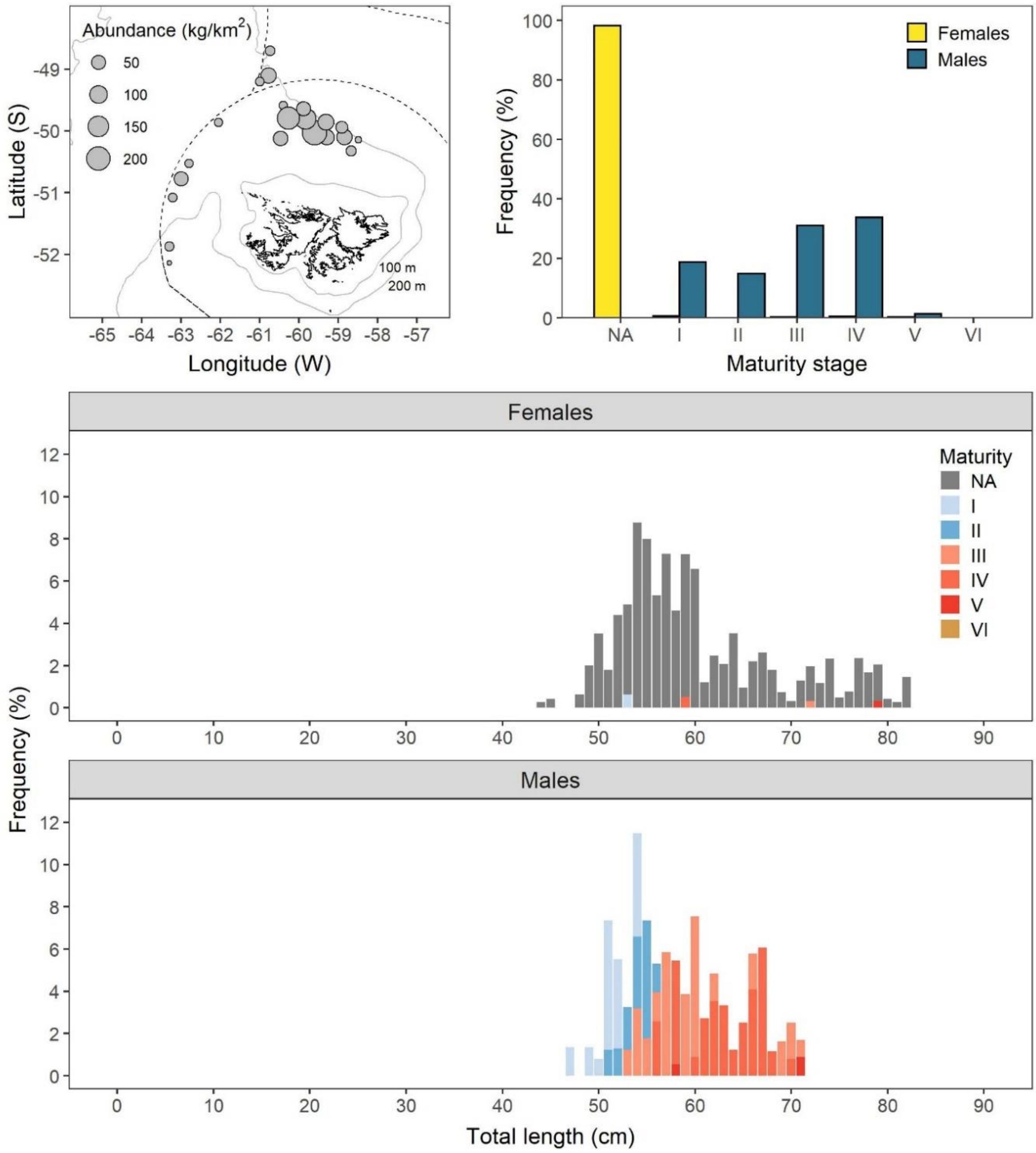

Figure 21. Biological data of *Squalus acanthias* (Dogfish; DGS); Top left panel) Map of densities in kg/km^2; Top right panel) Relative frequency (%) per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); Middle panel) Relative frequency (%) of female lengths (n = 209); Bottom panel) Relative frequency (%) of male lengths (n = 77) with 1 cm size class.

3.6. Conversion factor

Average conversion factor for red cod was 1.81, and for kingclip it was 1.93 (Table III).

Table III. Conversion factor for red cod (*Salilota australis*, BAC) and for kingclip (*Genypterus blacodes*, KIN) HGT product conducted during the July 2023 groundfish survey (ZDLT1-2023-07). N) Number of individuals; Green) Whole animal; HGT) Headed, gutted, and tail off; CF) Conversion factor. *Average.

Station	Species code	Basket	N, green	Weight, green (kg)	N, HGT	Weight, HGT (kg)	CF
3923	BAC	1	27	21.70	27	11.32	1.92
3923	BAC	2	28	22.14	28	11.48	1.93
3923	BAC	3	25	17.86	25	9.06	1.97
3945	BAC	1	47	21.80	47	11.88	1.83
3945	BAC	2	16	7.22	16	3.82	1.89
Total		5	143	90.72	143	47.56	1.81*

Station	Species code	Basket	N, green	Weight, green (kg)	N, HGT	Weight, HGT (kg)	CF
3947	KIN	1	11	23.46	11	12.02	1.95
3947	KIN	2	9	25.70	9	13.52	1.90
3947	KIN	3	9	21.72	9	11.22	1.93
3947	KIN	4	10	28.54	10	14.64	1.94
3947	KIN	5	9	19.68	9	10.30	1.91
3947	KIN	6	11	24.44	11	12.74	1.91
3947	KIN	7	12	25.16	12	12.68	1.98
3947	KIN	8	10	24.76	10	12.90	1.91
3947	KIN	9	9	18.86	9	9.48	1.98
Total		9	90	212.32	90	109.5	1.93*

3.7. Stomach content of *Merluccius hubbsi* – common hake

A subsample of 22–102 common hake stomachs was examined per station from 8 of the 70 stations conducted during the survey (Fig. 22, top panel), resulting in 653 stomachs examined (n = 414 with prey, 239 empty). Of the stomachs that contained prey, 353 were from females and 61 were from males. Three prey groups were detected: 1) Cephalopoda, 2) Crustacea, and 3) Teleostei. Crustaceans were present in the majority of *M. hubbsi* stomachs and in higher proportions regardless of sex or size, except for large females. Cephalopods were the second main prey group, of which *D. gahi* was the main contributor (Fig. 22, bottom panel).

There were no significant differences in the proportions of prey groups between females and males ($p > 0.05$). The proportion of *D. gahi* was higher in large females compared with medium size female *M. hubbsi* ($X^2 = 10.809$, df = 1, $p = 0.001$). However, there was no significant difference in the frequency of *D. gahi* in the stomachs of medium size males compared with large males ($p > 0.05$). The proportion of other cephalopods was not statistically significantly different between medium size females and large females ($p > 0.05$), but it was higher in large males compared with medium size males ($X^2 = 8.015$, df = 1, $p = 0.005$). The proportion of crustaceans was higher in medium size females compared with large females ($X^2 = 13.453$, df = 1, $p < 0.001$), but there was no statistically significant difference between medium size males and large males ($p > 0.05$). The proportion of fishes was higher in large females compared with medium size females ($X^2 = 7.499$, df = 1, $p = 0.006$), but there was no statistically significant difference between medium size males and large males ($p > 0.05$) (Fig. 22, bottom panel).

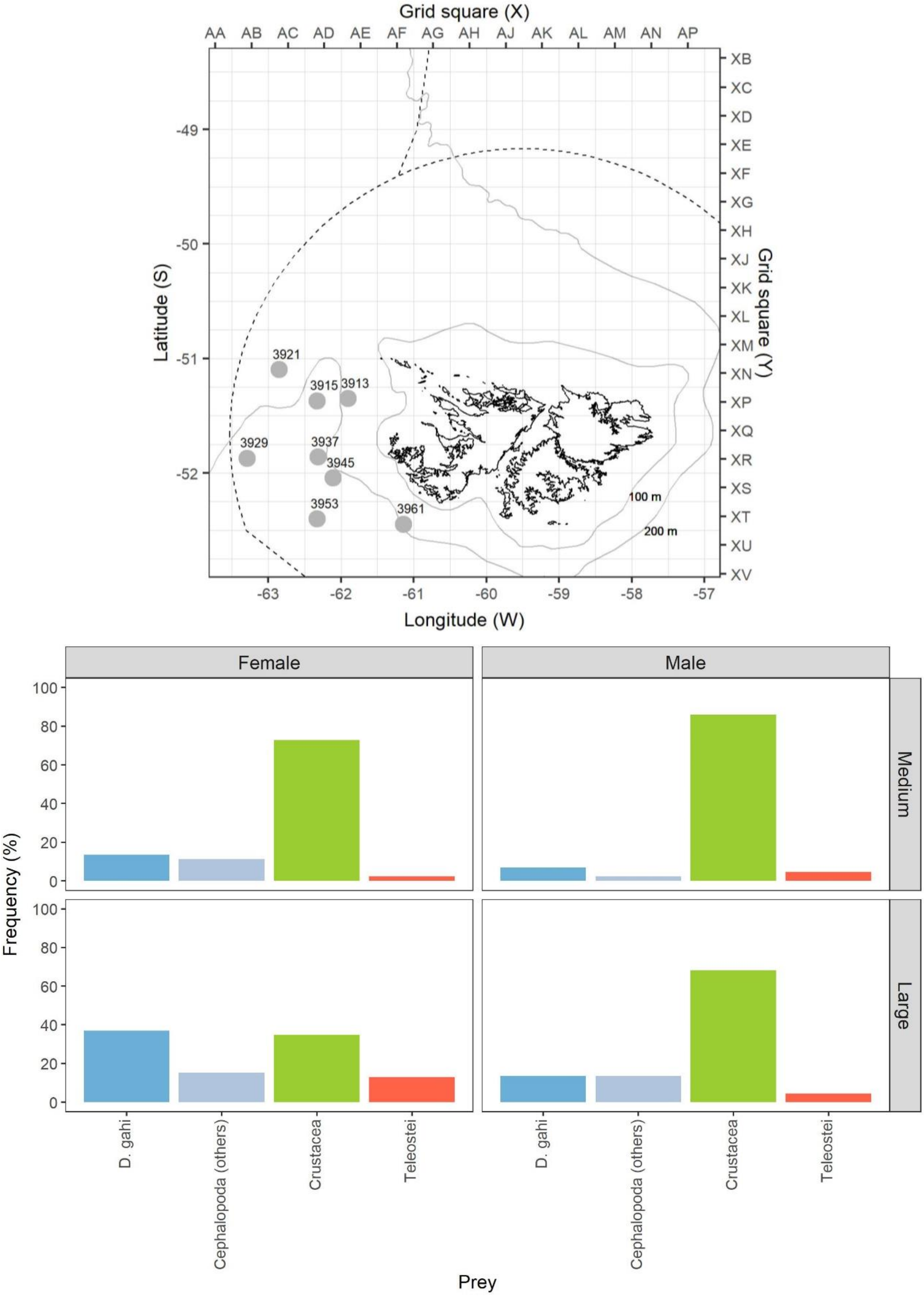

Figure 22. Stomach content analysis of common hake *Merluccius hubbsi* during the July 2023 groundfish survey (ZDLT1-2023-07). Top panel) Sampling stations for stomach content analysis. Bottom panel) Relative frequency (%) of common hake stomachs with presence of prey group. Females: n = 346 medium and 46 large; Males = 43 medium and 22 large. *D. gahi* is presented separate from other cephalopods.

3.8 Interactions with pinnipeds

Pinnipeds were detected around the vessel during shooting, trawling, and/or hauling at 15 of the 70 trawl stations conducted during the survey, respectively. There was one mortality of an American fur seal (*Arctocephalus australis*; male of 1.68 m total length) at trawl station 3951 to the south-west of West Falkland, near the limit of the FICZ (Fig. 23). Rigor mortis suggest that the seal drowned during shooting of the net.

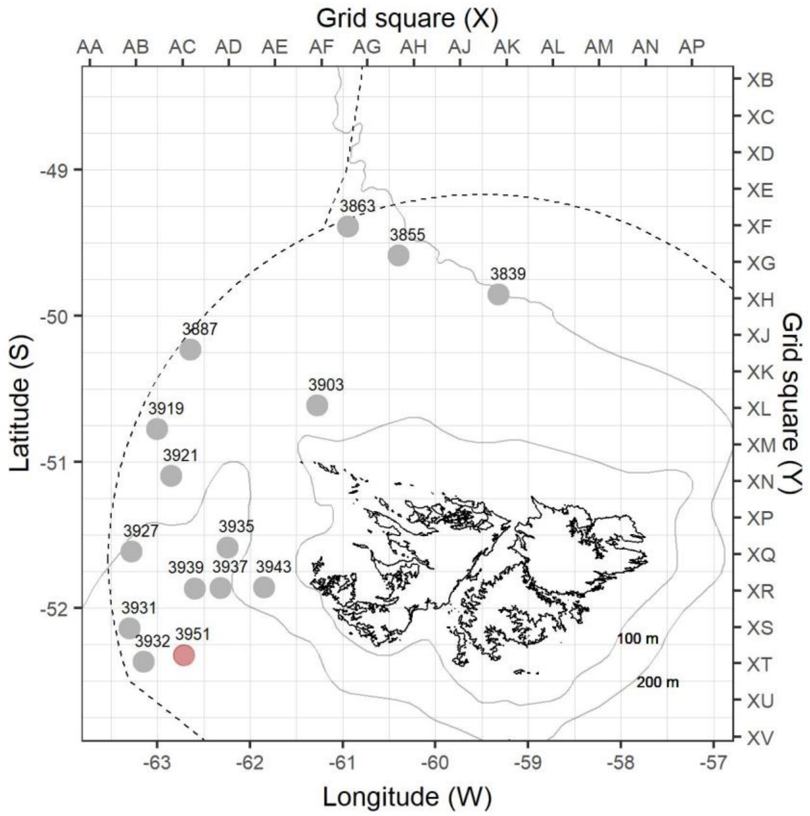

Figure 23. Presence (grey circles) and mortality (red circle; one mortality) of pinnipeds during the July 2023 groundfish survey (ZDLT1-2023-07).

3.9. Oceanography

Oceanographic data were collected at all 70 stations conducted during the survey. Temperature ranged between 5 and 7.4°C. At 10 m depth, temperature was lower along the west and at the north-east in the FICZ; higher temperature (up to 7.4°C) was recorded to the north from about 50.5°S and towards the FOCZ, as well as to the north-west limit of the FICZ. A similar pattern of temperature was observed at 100 m depth and at the seabed; however, temperature was lower (~ 5°C) to the south-west and to the north-east, with temperatures between 6.5 and 7°C from the central north to the north-west in the FICZ (Fig. 24). At 10 m and 100 m depths, oxygen was above 6.5 ml/l along the survey area. At the seabed, there was a wider range of oxygen values (5.25–7 ml/l), with low oxygen levels to the north-west (Fig. 24). At 10 m and 100 m depths, salinity ranged between 33.3 and 33.9 PSU, with higher values to the north-east in the FICZ. At the seabed, salinity ranged between 33.5 and 34.1 PSU, with higher values to the south-west and to the north, with average values along the north-west; the lower values were detected along the west limit of the FICZ (Fig. 24). Density was in a range of values from 26.3 to 27 sigma t, with lower values towards the surface. At 10 m depth, low densities (<26.4 sigma t) were recorded to the west in the FICZ, and density increased towards the east to reach a maximum of 26.7 sigma t; similar densities were measured at 100 m depth. At the seabed, density reached 27 sigma t in the south-west and at the north-east in the FICZ, extending towards the north in the FOCZ (Fig. 24).

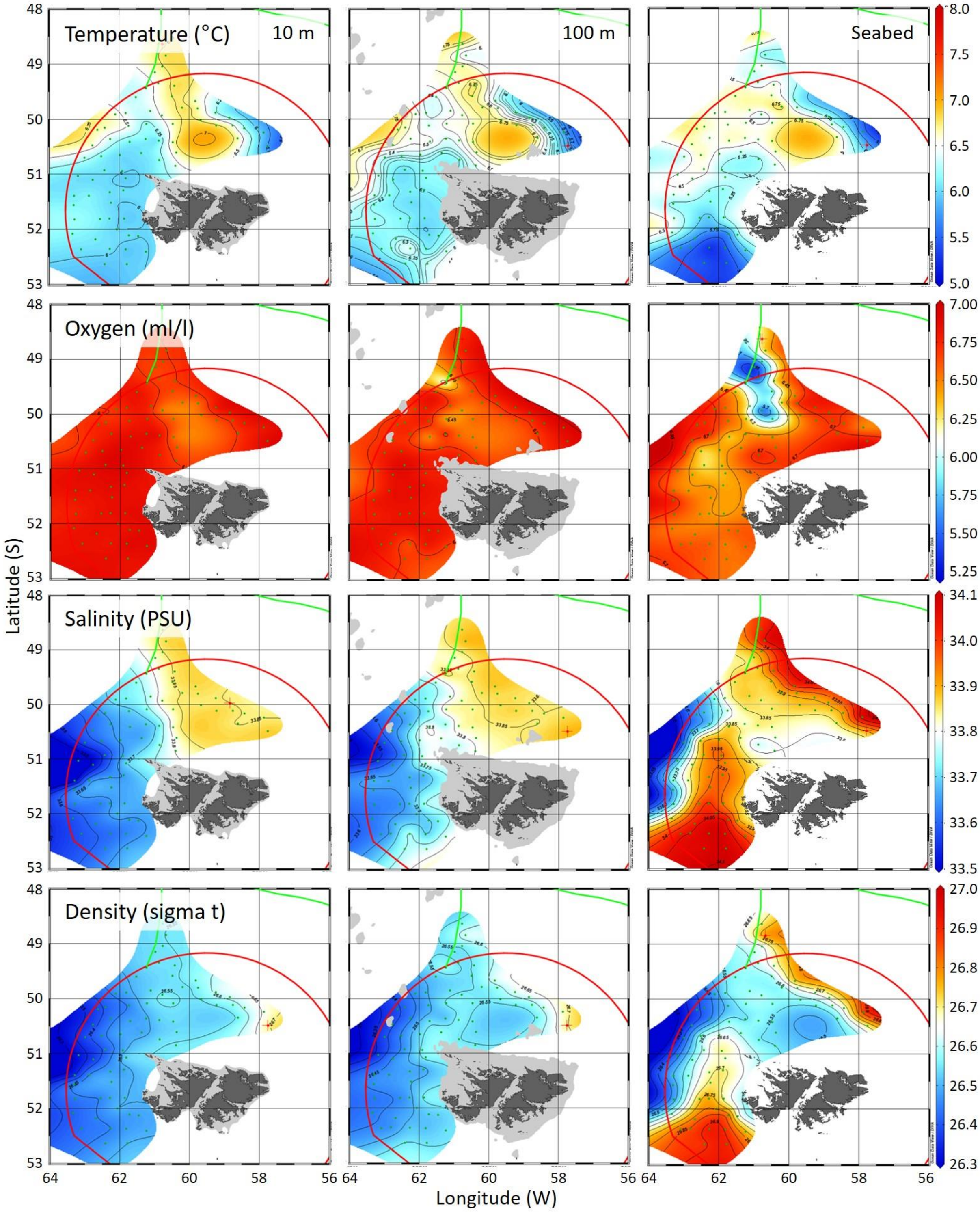

Figure 24. Temperature, oxygen, salinity, and density at 10 m, 100 m, and seabed. Contours at 0.25°C, 0.25 ml/l, 0.05 PSU, and 0.05 sigma t, respectively.

4. Discussion and Conclusions

This report summarises the findings of the third groundfish survey conducted during July in the FICZ and FOCZ. The first July survey of this kind was conducted in 2017 (Gras et al. 2017), and the second in 2022 (Lee et al. 2022). These surveys follow an array of stations in the FICZ similar to the array of stations of the February groundfish surveys conducted during 2010, 2011, and from 2015 to 2023. The February (summer) and July (winter) fisheries-independent surveys are crucial to better understand the spatial and temporal (seasonal and inter-annual) patterns in species distribution and abundance, and demographic patterns (sex, maturity, and length frequency distributions), in response to environmental, ecological, and anthropogenic factors (e.g. Hilborn & Walters 1992). The abundance of common hake has increased in the FICZ in recent years (Ramos & Winter 2022a, 2023). Therefore, a hake demography survey was conducted in July 2020 instead of the regular July groundfish survey. The July 2020 hake demography survey followed a different array of stations that covered part of the FICZ and the high seas to the north of the FOCZ (Randhawa et al. 2020). Comparability of patterns observed in the July groundfish surveys and in the July 2020 hake demography survey should be taken with caution.

Common hake was the main catch (45.8 t) during the present survey, comprising 62% of the total catch. Common hake was the main catch in the previous July groundfish (July 2017: Gras et al. 2017; July 2022: Lee et al. 2022) and hake demography surveys (July 2020: Randhawa et al. 2020). High densities occurred through the survey area, consistent with high commercial CPUE at this time of the year in the FICZ (Ramos & Winter 2022a). Increasing abundance of common hake has also been detected from February groundfish surveys (Ramos & Winter 2023). The Falkland Islands waters are used as feeding ground by this species (Arkhipkin et al. 2003). A pattern of the maturity status of common hake in Falkland Islands waters was described by Arkhipkin et al. (2015): "The post-spawning period runs from March to June, while the resting/feeding period occurs from July to November. The spawning period, when the majority of fish was absent from Falklands waters, was from December to February". However, all maturity stages were reported during July, except for immature individuals (Arkhipkin et al. 2015). During the July 2023 groundfish survey, females were found to be mainly at resting or early developing maturity stages, and males were found mainly at late developing maturity stage, with minor proportions that covered the maturity spectrum from resting to recovering spent. These maturity patterns are consistent with the maturity patterns described during the July 2020 hake demography survey (Randhawa et al. 2020) but differ from the maturity patterns described during the July 2017 and July 2020 surveys. During July 2017, females were described as resting and early developing, and males as spent, with minor proportions as immature, resting, early developing, or recovering spent (Gras et al. 2017). During July 2022, females were described as resting, spent, or recovering spent, and males were described mainly as spent or recovering spent (Lee et al. 2022). These contrasting maturity patterns may be due to alterations in reproductive phenology associated with environmental variability (Pörtner & Farrell 2008; Alix et al. 2020; Elisio et al. 2020), or may be an artifact caused by the misidentification of maturity stages as noted during the survey.

Common hake was in the range of sizes between 27 cm and 76 cm length, and modal length at about 40 cm during the July 2023 groundfish survey. A wider range of sizes were recorded in the July 2017 survey (19–90 cm length; Gras et al. 2017). Small individuals were also detected during the July 2020 survey (<30 cm length; Randhawa et al. 2020). However, individuals >80 cm length have not been reported since the July 2020 survey (Randhawa et al. 2020; Lee et al. 2022). The decline in the frequency of >80 cm length individuals is consistent with the decline in modal length of females from 60 cm in 2012 to 40 cm in 2021, based on commercial and survey data during June and July (Ramos & Winter 2022a).

A shift of prey from medium size (more crustaceans than cephalopods and fishes) to large common hake females (more cephalopods and fishes than crustaceans) was detected. Large hake can outswim and prey upon squid and fishes that otherwise would be capable of escaping from medium size hake. Large hake were observed in the 'Loligo Box' during the July 2023 calamari pre-season survey, compared with the groundfish survey to the north and west in the FICZ (Appendix I). This finding suggests that large hake may prey mainly upon *D. gahi* in the 'Loligo Box', contributing an additional source of natural mortality and representing competition with the calamari fishery for this resource. However, it must be noted that common hake were caught in less amounts in the 'Loligo Box' during the calamari pre-season survey (CPUE = 511 kg/h) compared with the finfish area during the groundfish survey (654 kg/h) in July 2023. Further studies are thus required to better understand the drivers of common hake distribution and abundance in the FICZ, and the magnitude of the predation by this species upon *D. gahi*.

Red cod was the second highest catch (8.5 t; 11.5% of the total survey catch) during the July 2023 groundfish survey, contrary to previous July surveys where it was caught in less amounts (1.8 t or 4% in 2017, Gras et al. 2017; 2.2 t or 0.4% and 2.7% in 2020 and in 2022, respectively, Randhawa et al. 2020, Lee et al. 2022). The high catch of red cod during the July 2023 groundfish survey was mainly due to its high density at station 3867, located near the north-west limit of the FICZ. This area showed high densities of red cod in the July 2017 (Gras et al. 2017) and July 2020 surveys (Randhawa et al. 2020). Resting or immature individuals were frequent, also consistent with previous July groundfish surveys (Gras et al. 2017; Randhawa et al. 2020; Lee et al. 2022), as red cod starts the maturation process to spawn typically between August and October to the south and south-west of West Falkland (Arkhipkin et al. 2010; Brickle et al. 2011). A survey conducted in late September 2022 found low biomass of spawning red cod, and concluded that this stock has decreased in the Falkland Islands fishing area (Arkhipkin et al. 2022), which is consistent with low CPUE in recent years calculated from commercial fishery data (Ramos & Winter 2022b). The length-group of <20 cm animals was represented in lower numbers in the July 2020, 2022 (Randhawa et al. 2020; Lee et al. 2022) and 2023 surveys compared with the July 2017 survey (Gras et al. 2017).

The Patagonian squid *D. gahi* comprised the third highest catch (6.5 t; 8.8%) during the survey; it was distributed across the survey area, and the largest densities were found to the north and to the south-west. This species has been in the top three catches of the July surveys, with catches that were in the range of 4.7 to 6.4 t (7.8–37.2%) per survey, and patterns of distribution were similar across surveys (Gras et al. 2017; Randhawa et al. 2020; Lee et al. 2022). Consistent with previous surveys, most females were immature, whereas males were immature, preparatory or maturing; length frequency distributions showed similar patterns across surveys, with modal lengths from 8.5 to 10 cm (Gras et al. 2017; Randhawa et al. 2020; Lee et al. 2022).

Rock cod was the fourth highest catch (6.2 t; 8.3%) during the survey and it was caught through the survey area, with denser aggregations to the north-west limit of the FICZ. In previous July surveys, rock cod total catches were in the range from 757 kg to 6.2 t (1.7–7.6%), and the distribution of the catch varied across surveys. The abundance of rock cod is usually low from July to November (Ramos & Winter 2023), as this species emigrates from Falkland Islands waters and remains in low abundances during winter (July to September) (Arkhipkin et al. 2012). Rock cod were mainly in immature through early developing maturity stages, with smaller proportions of late developing and ripe individuals, as rock cod prepare for spawning at the end of autumn and in part of winter at the shelf break in Falkland Islands waters (Ekau 1982; Brickle et al. 2006). The maturity status observed in the July 2023 survey detected smaller proportions of late developing individuals compared with the July 2020 and July 2022 surveys (Randhawa et al. 2020; Lee et al. 2022). Length frequency distributions allowed detecting three length-groups, with patterns similar to the ones described in the July 2017 and July 2020 surveys (Gras et al. 2017; Randhawa et al. 2020), except for the July 2022 survey where the smaller length-group was not present (<10 cm length; Lee et al. 2022).

Kingclip comprised one of the main catches (4.5 t; 6%) in the survey area, with higher densities compared with previous July surveys (1.8–4 t, or 1.1–9.1%). Individuals were consistently at resting and at early developing maturity stages across July surveys (Gras et al. 2017; Randhawa et al. 2020; Lee et al. 2022). Kingclip migrate in autumn (April to June) from Argentine waters into Falkland Islands waters, and remains abundant in feeding grounds to the north, north-west, and west of the Falkland Islands during winter (July to September) and spring (October to December) (Ramos & Winter 2022c; Falkland Islands Government 2023). An increasing trend in modal length was observed from July 2017 to July 2023, with relatively small individuals (mode at 46 cm length) being dominant during July 2017, modal lengths at 53–55 cm during July 2020 and July 2022, and also at >65 cm length during July 2022 and during July 2023 (Gras et al. 2017; Randhawa et al. 2020; Lee et al. 2022).

Hoki catch during the July 2023 survey was small (133 kg) and mainly at deep stations (>200 m deep) to the south-west in the FICZ, as described in previous July surveys (Randhawa et al. 2020; Lee et al. 2022), except for the July 2017 survey when it was the second highest catch (6.5 t; 14.4%) (Gras et al. 2017). Females and males were mainly immature or at resting maturity stages. The maturity status observed during the July surveys was expected considering that spawning occurs during winter outside of Falkland Islands waters (Brickle et al. 2009; Arkhipkin et al. 2012). The length frequency distributions were similar between the July 2017 (Gras et al. (2017) and the July 2023 surveys, with narrow range of lengths (14–23 cm) and mode at 16 cm length. In contrast, the July 2020 and July 2022 surveys reported a wider range of lengths (14–32 cm) and modes at 16 cm, 21–22 cm, and 28 cm length (Randhawa et al. 2020; Lee et al. 2022).

Southern blue whiting represented a minor catch (41 kg; 0.06%) during the survey, and mainly caught at stations >200 m deep to the south-west and to the north in the FICZ and in the FOCZ. This was the second lowest catch across July surveys (126 kg or 0.3% in July 2017, Grass et al. 2017; 630 kg or 0.1% in July 2020, Randhawa et al. 2022; 23 kg or 0.03% in July 2022, Leet et al. 2022). The majority of individuals were of small size (<20 cm length) and sexually immature. Animals >25 cm length have been infrequent during the July surveys, except for the July 2020 survey (Randhawa et al. 2022). Large and developing individuals are expected during July in preparation for spawning that takes place during September and October to the south of West Falkland (Macchi et al. 2005; Arkhipkin et al. 2022).

Toothfish was a minor catch (46 kg; 0.06%) during the survey, where relatively small individuals at immature or resting maturity stages were caught at stations >200 m deep to the south-west in the FICZ. This was the lowest catch across July surveys (122 kg or 0.3% in July 2017, Grass et al. 2017; 473 kg or 1.2% in July 2020, Randhawa et al. 2022; 105 kg or 0.1% in July 2022, Leet et al. 2022). However, adult toothfish are caught mainly using longline; therefore, the information provided in this report is not representative of the adult portion of the toothfish population.

Argentine shortfin squid, banded whiptail grenadier, butterfish, and driftfish contributed minor catches (<27 kg each) during the survey, some of which were amongst the lowest catches across July surveys (Gras et al. 2017; Randhawa et al. 2022; Lee et al. 2022). Skates had minor catches (<115 kg each species), with the white spotted skate and the Falkland skate showing the lowest catches across July surveys (Gras et al. 2017; Randhawa et al. 2020; Lee et al. 2022). Skates discards in the Falkland Islands fishery increased considerably in the late 1990s and again in 2017, with average levels from 2018 to 2021 (Parkyn et al. 2021). Some skate species caught in Falkland Islands waters are classified as endangered (i.e., grey tailed skate; Pollom et al. 2020a), vulnerable (i.e., white spotted skate; Pollom et al. 2020b), or near threatened (i.e., blonde skate and Falkland skate; Pollom et al. 2020c, d) by IUCN. Catshark and dogfish were caught in relatively small amounts, i.e., 200 kg and 254 kg, respectively. The highest catches of these species were reported during the July 2017 survey (Gras et al. 2017). The dogfish is classified as vulnerable by the IUCN (Finucci et al. 2020).

The calculation of CF can be affected by 1) the number of samples, as a smaller than intended number of random samples (n = 100) may increase variability in the calculation of CF; 2) reproductive stage; for instance, the gonads of mature animals will be heavier and CF will be lower, whereas the gonads of immature individuals will be lighter and CF will be higher; 3) stomach fullness, as animals with full stomachs will result in lower CF compared with animals with empty stomachs; 4) the workload, given that the workload during the survey is not as intense as during the regular commercial fishing day, allowing the scientific staff to calculate CF from more animals and more precisely.

5. Recommendations

1. Further studies are required to better understand the drivers of common hake distribution and abundance in the FICZ, and the magnitude of the predation by this species upon other commercially important stocks, i.e., *D. gahi*.
2. Dogfish, catshark, and several skates showed lower catches than in previous surveys. The generally low productivity of chondrichthyes, and the poor conservation status of some skates and sharks (described by IUCN) that occur in Falkland Islands waters pinpoint the need for research on these species to better understand their distribution, abundance, biology, and the effects of the fisheries on their populations.
3. Operational delays should be minimized so that the survey period and therefore the number of stations sampled can be maintained consistent across groundfish surveys. Changes in the number of stations from one year to the next reduces comparability of distribution, abundance, and other demographic patterns through time, limiting our capacity to examine the state and trends of the fisheries stocks.

4. The Nikolsky (1963) eight-stage sexual maturity scale used for fishes at the FIFD is a broad maturity scale. A detailed description of this scale is recommended for each individual species according to their gonads' macroscopic features, validated with histology. This should facilitate the identification of maturity stages for each species and minimize subjectivity in the interpretation of the scale by different observers/scientists. It's also important to note that the identification of maturity stages of some species may require the use of a stereomicroscope, and pertinent arrangements should be made to facilitate the use of the required equipment at sea if possible.
5. The catch must be sorted only by species before it's sent to the conveyor to record the weight of each basket. This should be reminded to the factory bosun before the first station, and supervised as necessary to prevent errors. In one occasion it was noted by the FIFD scientific staff that large rock cod were put aside for commercial processing, and sent for weighting at the end of the total catch weighting and once the samples of rock cod were already processed. Sorting the catch by size before it goes through the conveyor affects the taking of random samples, and therefore the description of length frequencies and maturity stages, or the calculation of CF.
6. Oceanographic data provides valuable insights towards understanding the distribution, abundance, and other demographic patterns of the stocks, and should be recorded and described in every survey report. The FIFD CTD should be serviced regularly to ensure correct functioning, and spare accessories in working condition should be in stock at FIFD.

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Appendix I. Length frequency distribution of common hake (*Merluccius hubbsi*) in the July 2023 calamari pre-season and groundfish surveys.