Cruise Report ZDLT1-2023-02

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 southwest to the north-east through the Falkland Islands (Boltovskoy 1999). The 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; for instance, Argentine shortfin squid (*Illex argentinus*) and hoki (*Macruronus magellanicus*) migrate to frontal zones for feeding and back to non-frontal zones for spawning (Agnew 2002). In contrast, migrations of deep-water fish such as toothfish (*Dissostichus eleginoides*) into the shelf are favoured by intrusions of sub-Antarctic waters (Laptikhovsky *et al*. 2008; Arkhipkin & Laptikhovsky 2010).

Since 2010, the Falkland Islands Fisheries Department (FIFD) has been carrying out annual groundfish surveys. Biomass estimates from groundfish surveys conducted in parallel with calamari pre-season surveys in the 'Loligo Box' revealed the decrease of rock cod, red cod, and southern hake abundances over the last decade. Banded whiptail grenadier, hoki, southern blue whiting, 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).

1.1. Cruise objectives

1. To examine the abundance, distribution, and biology of demersal fish and squid species in the western, northern and north-eastern parts of the Falkland Shelf.
2. To carry out an oceanographic survey of the studied area.

1.2. Vessel

The survey ZDLT1-2023-02 was conducted aboard the F/V Castelo (ZDLT1), registered in the Falkland Islands (LOA 67.8 m, GT 1321).

1.3. Cruise plan and key dates

Scientific surveys are key sources of fisheries independent data for fisheries ecology, benefitting from a standardised sampling plan and constant catchability (Hilborn and Walters, 1992; Alglave *et al*., 2022; Gallo *et al*., 2022). Ten surveys have been conducted consistently in February 2010, 2011, and 2015–2022. These surveys were originally conducted to estimate the biomass of the former index species (i.e., rock cod) to the west and north of the Falkland Islands. In recent years, the aim of the February groundfish survey extended to other commercial and bycatch species. Based on increasing importance of hake on the Falkland Shelf, two winter surveys were undertaken during July in 2017 (ZDLT1-07-2017; Gras et al., 2017) and 2022 (ZDLT1-07-2022; Lee et al., 2022). A hake demography survey was also undertaken during July 2020 (ZDLT1-07-2020; Randhawa et al., 2020).

During the Falkland Islands February groundfish surveys, 80 fixed bottom trawl stations are usually replicated each year according to a systematic transect design based on the division of the shelf area (100 – 300 m) into 0.5 longitude by 0.25 latitude decimal degree grid squares. Each station is allocated to an individual grid square to ensure coverage of the entire study area. Additionally, up to 18 flexible stations are undertaken to broaden the spatial area or to cover additional areas of interest in deeper (>300 m) or shallower (<100 m) waters of the shelf. The cruise plan for the February 2023 groundfish survey consisted of 84 proposed stations, and all stations were conducted. Four stations were added to the cruise plan: Three stations (3812, 3814 and 3818) to the south-west of the surveyed area that were replicated from the February groundfish survey conducted in 2018, and one station (3656) replicated from the February groundfish survey conducted in 2015 to the north-east, just north of the 'Loligo box'.

The vessel departed from Stanley at 19:00 on February 1st 2023, and proceeded overnight to the first station located to the north of East Falkland in order to start fishing early in the morning. Last trawl was hauled on February 22nd 2023 southwest of the West Falkland. The vessel steamed back and arrived to Stanley on February 23rd 2023 in the morning. Scientists disembarked via launch from Port William. Every day, three to five one-hour trawls were hauled in adjacent grid squares (Figure 1); 82 trawls were preceded or succeeded by oceanographic station.

2. Material and Methods

2.1. Trawling

A bottom trawl net owned by the FIFD was used; the net was equipped with rockhopper gear fitted with Morgère V3 (1800 kg, 3180 cm x 2480 cm) bottom doors. The duration of each trawl was 60 min on the bottom. One trawl started to be hauled at minute 43 when net issues were suspected (station 3722) but the trawl was finally considered valid. Trawling speed varied between 3.8 and 4.8 knots. The cod-end had a 90 mm mesh size fitted with a 40 mm cod-end liner. The MarPort Net Monitoring System was used to monitor the net geometry. All readings from measurements were successfully obtained for all stations.

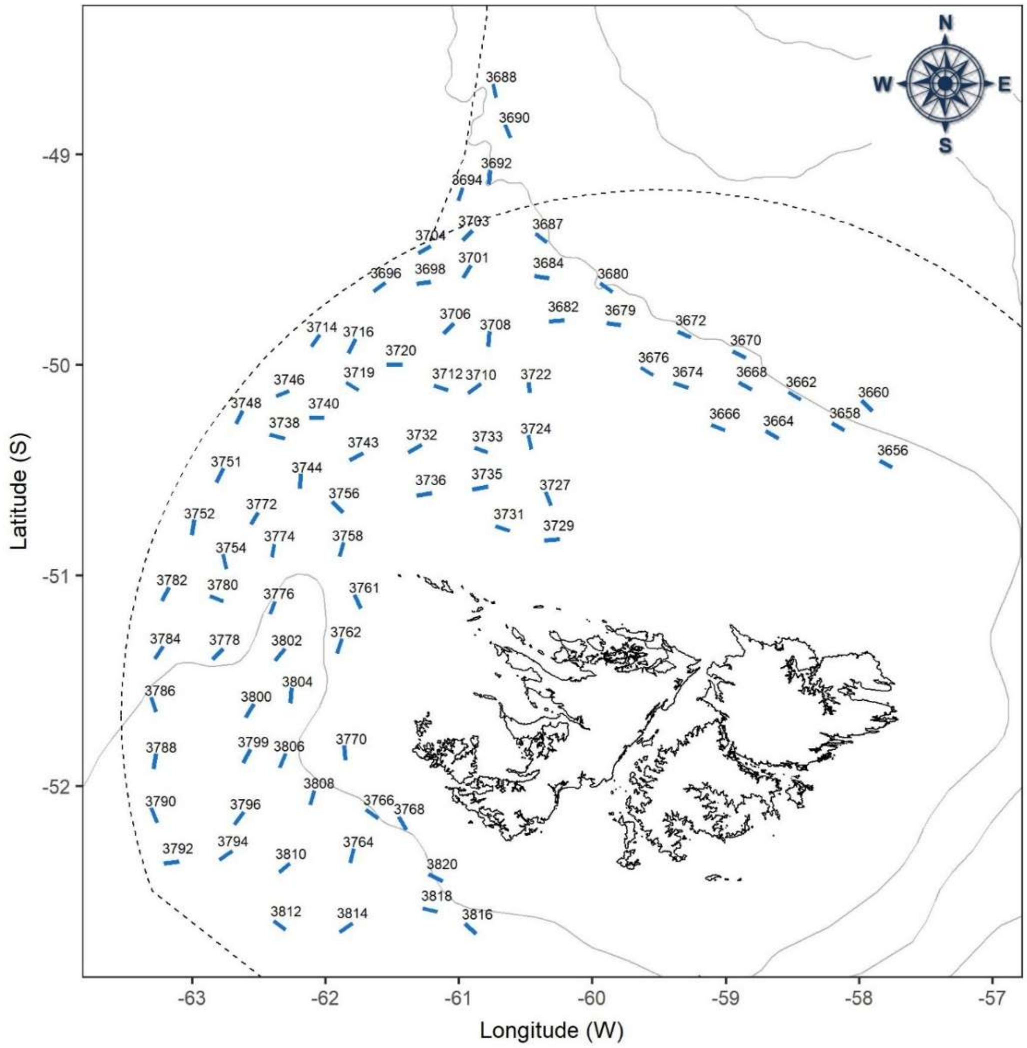

Figure 1. Trawl tracks with station numbers performed during the demersal survey ZDLT1-2023-02 in February 2023.

2.2. Trawl stations and biological sampling

During the ZDLT1-2023-02 groundfish survey, a total of 84 trawls were conducted with corresponding station numbers ranging from 3656 to 3820 (Table I). At each 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 (random samples of up to 100 individuals). Biological sampling of finfish included measurement of total or pre-anal length to the lower cm, as well as the macroscopic assessment of sex and maturity according to an eight-stage maturity scale (Nikolsky, 1963). For skates, total length and disc width were measured to the lower cm; weight, sex, and maturity (six-stage maturity scale) were recorded. For squid, the sampling included the measurement of dorsal mantle length to the lower 0.5 cm, and recording of sex and maturity (six-stage maturity scale).

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 total body weight was measured to the nearest gram. Statoliths were not taken during the cruise but samples of *Illex argentinus* and *Doryteuthis gahi* were frozen for statolith extraction at the FIFD laboratory. In addition, several fish and squid specimens were frozen for further analyses ashore.

Table I. Station data during the groundfish survey ZDLT1-2023-02 in February 2023.

Station	Date	Latitude start	Longitude start	Latitude finish	Longitude finish	Mean depth
3656	02/02/2023	-50.4873	-57.7518	-50.4550	-57.8493	154
3658	02/02/2023	-50.3112	-58.1108	-50.2773	-58.2080	165
3660	02/02/2023	-50.2190	-57.9035	-50.1690	-57.9835	274
3662	02/02/2023	-50.1638	-58.4383	-50.1285	-58.5350	168
3664	03/02/2023	-50.3502	-58.6043	-50.3133	-58.7017	144
3666	03/02/2023	-50.3105	-59.0078	-50.2835	-59.1123	149
3668	03/02/2023	-50.1178	-58.8053	-50.0818	-58.9048	156
3670	03/02/2023	-49.9650	-58.8490	-49.9337	-58.9492	187
3672	03/02/2023	-49.8707	-59.2632	-49.8405	-59.3617	190
3674	04/02/2023	-50.1082	-59.2795	-50.0868	-59.3952	158
3676	04/02/2023	-50.0487	-59.5435	-50.0115	-59.6395	162
3679	04/02/2023	-49.8090	-59.7873	-49.8008	-59.8952	168
3680	04/02/2023	-49.6543	-59.8487	-49.6113	-59.9453	186
3682	05/02/2023	-49.7873	-60.2093	-49.7922	-60.3242	168
3684	05/02/2023	-49.5883	-60.3257	-49.5768	-60.4362	173
3687	05/02/2023	-49.4162	-60.3417	-49.3743	-60.4273	197
3688	06/02/2023	-48.6635	-60.7435	-48.7310	-60.7247	242
3690	06/02/2023	-48.8580	-60.6550	-48.9213	-60.6160	242
3692	06/02/2023	-49.0722	-60.7658	-49.1418	-60.7747	193
3694	06/02/2023	-49.1558	-60.9730	-49.2188	-61.0072	174
3696	07/02/2023	-49.6493	-61.6415	-49.6075	-61.5508	158
3698	07/02/2023	-49.6137	-61.3175	-49.6055	-61.2108	161
3701	07/02/2023	-49.5842	-60.9703	-49.5260	-60.9092	167
3703	07/02/2023	-49.3602	-60.8987	-49.4050	-60.9753	168
3704	07/02/2023	-49.4348	-61.2127	-49.4683	-61.3068	162
3706	08/02/2023	-49.8487	-61.1192	-49.7998	-61.0352	163
3708	08/02/2023	-49.8373	-60.7713	-49.9118	-60.7818	164
3710	08/02/2023	-50.0888	-60.8352	-50.1340	-60.9327	160
3712	08/02/2023	-50.1195	-61.0818	-50.0960	-61.1892	160
3714	09/02/2023	-49.9132	-62.1053	-49.8558	-62.0435	147
3716	09/02/2023	-49.8757	-61.7737	-49.9427	-61.8308	157

Station	Date	Latitude start	Longitude start	Latitude finish	Longitude finish	Mean depth
3719	09/02/2023	-50.0837	-61.8460	-50.1210	-61.7542	158
3720	09/02/2023	-49.9967	-61.5440	-49.9968	-61.4232	157
3722	10/02/2023	-50.0838	-60.4755	-50.1342	-60.4728	158
3724	10/02/2023	-50.3327	-60.4833	-50.4022	-60.4605	154
3727	10/02/2023	-50.6023	-60.3515	-50.6680	-60.3098	146
3729	10/02/2023	-50.8260	-60.2428	-50.8343	-60.3590	136
3731	10/02/2023	-50.7875	-60.6212	-50.7655	-60.7282	133
3732	11/02/2023	-50.4153	-61.3803	-50.3768	-61.2780	160
3733	11/02/2023	-50.3932	-60.8860	-50.4163	-60.7850	153
3735	11/02/2023	-50.5762	-60.7817	-50.5918	-60.9027	152
3736	11/02/2023	-50.6087	-61.2020	-50.6187	-61.3177	151
3738	12/02/2023	-50.3303	-62.4182	-50.3490	-62.3030	152
3740	12/02/2023	-50.2508	-62.1208	-50.2492	-62.0065	158
3743	12/02/2023	-50.4170	-61.7152	-50.4527	-61.8183	168
3744	12/02/2023	-50.5172	-62.1867	-50.5882	-62.1908	167
3746	13/02/2023	-50.1222	-62.2710	-50.1492	-62.3722	147
3748	13/02/2023	-50.2148	-62.6203	-50.2798	-62.6697	146
3751	13/02/2023	-50.4905	-62.7637	-50.5585	-62.8183	149
3752	13/02/2023	-50.7330	-62.9862	-50.8088	-63.0010	152
3754	13/02/2023	-50.8970	-62.7700	-50.9695	-62.7413	166
3756	14/02/2023	-50.6480	-61.9512	-50.7022	-61.8700	181
3758	14/02/2023	-50.8417	-61.8657	-50.9112	-61.8980	170
3761	14/02/2023	-51.0920	-61.7838	-51.1560	-61.7330	181
3762	14/02/2023	-51.3005	-61.8765	-51.3690	-61.9145	200
3764	15/02/2023	-52.3652	-61.8153	-52.2977	-61.7892	320
3766	15/02/2023	-52.1542	-61.6060	-52.1130	-61.6975	254
3768	15/02/2023	-52.1457	-61.4532	-52.2075	-61.3948	187
3770	15/02/2023	-51.8798	-61.8535	-51.8072	-61.8600	190
3772	16/02/2023	-50.6993	-62.5033	-50.7557	-62.5570	166
3774	16/02/2023	-50.8493	-62.3848	-50.9125	-62.4047	183
3776	16/02/2023	-51.1217	-62.3793	-51.1832	-62.4150	190
3778	17/02/2023	-51.3975	-62.8468	-51.3470	-62.7642	184
3780	17/02/2023	-51.1217	-62.7648	-51.0973	-62.8700	170
3782	17/02/2023	-51.0558	-63.1743	-51.1210	-63.2285	153
3784	17/02/2023	-51.3367	-63.2158	-51.3965	-63.2815	165
3786	18/02/2023	-51.5780	-63.3075	-51.6475	-63.2700	183
3788	18/02/2023	-51.8457	-63.2718	-51.9202	-63.2880	203
3790	18/02/2023	-52.1027	-63.3077	-52.1747	-63.2627	226
3792	18/02/2023	-52.3683	-63.2122	-52.3602	-63.0948	256
3794	19/02/2023	-52.3502	-62.7950	-52.3095	-62.6963	272
3796	19/02/2023	-52.1828	-62.6848	-52.1228	-62.6118	256
3799	19/02/2023	-51.8897	-62.6177	-51.8242	-62.5640	230
3800	19/02/2023	-51.6733	-62.5975	-51.6083	-62.5360	211
3802	20/02/2023	-51.3485	-62.3018	-51.4038	-62.3778	211
3804	20/02/2023	-51.5335	-62.2527	-51.6068	-62.2638	249

Station	Date	Latitude start	Longitude start	Latitude finish	Longitude finish	Mean depth
3806	20/02/2023	-51.8440	-62.2982	-51.9125	-62.3447	262
3808	20/02/2023	-52.0212	-62.0825	-52.0898	-62.1165	288
3810	21/02/2023	-52.3668	-62.2663	-52.4097	-62.3507	296
3812	21/02/2023	-52.6415	-62.3883	-52.6847	-62.2993	324
3814	21/02/2023	-52.6938	-61.8970	-52.6508	-61.7998	345
3816	22/02/2023	-52.7020	-60.8700	-52.6540	-60.9572	378
3818	22/02/2023	-52.5993	-61.1603	-52.5802	-61.2758	371
3820	22/02/2023	-52.4203	-61.2287	-52.4543	-61.1237	279

2.3. Density estimations methodology

Density (D; kg/km^2) of the species studied was derived from catch (C), distance covered (d) and horizontal net opening (HNO) following Gras (2016):

$$D = \frac{C}{d \text{ x } HNO}$$

3. Results

3.1. Catch composition

Catch weight and composition of squid, finfish, skate and other demersal and pelagic species are presented in Table II. The most abundant species (in terms of catch weight) were hoki *Macruronus magellanicus,* rock cod *Patagonotothen ramsayi*, kingclip *Genypterus blacodes*, red cod *Salilota australis*, and common hake *Merluccius hubbsi*.

Table II. Catch composition and weight of species caught during the groundfish survey ZDLT1-2023-02 in February 2023.

Species Code	Latin name	Total caught (kg)	Total sampled (kg)	Total discarded (kg)	%
WHI	*Macruronus magellanicus*	14401.52	940.572	18.102	19.423
PAR	*Patagonotothen ramsayi*	10243.34	902.611	10243.34	13.815
KIN	*Genypterus blacodes*	10097.28	3661.05	3.14	13.618
BAC	*Salilota australis*	8704.008	2032.328	8.498	11.739
HAK	*Merluccius hubbsi*	8281.195	1582.067	1.72	11.168
LOL	*Doryteuthis gahi*	6132.167	244.407	247.272	8.27
GRF	*Coelorinchus fasciatus*	4993.804	330.89	4993.804	6.735
ILL	*Illex argentinus*	2907.042	835.456	804.008	3.921
BLU	*Micromesistius australis*	1340.538	281.733	1340.538	1.808
BUT	*Stromateus brasiliensis*	1135.56	593	1135.56	1.531
SEP	*Seriolella porosa*	809.12	809.12	0	1.091
MED	*Medusa* spp.	689.676	0	689.676	0.93
GRC	*Macrourus carinatus*	584.66	552	0	0.788
DGS	*Squalus acanthias*	494.875	494.875	494.875	0.667
PYM	*Notophycis marginata*	311.609	7.223	311.609	0.42
RGR	*Bathyraja griseocauda*	295.39	294.35	11.958	0.398
TOO	*Dissostichus eleginoides*	271.608	271.608	0.008	0.366
SPN	Porifera	270.052	0	270.052	0.364
PAT	*Merluccius australis*	252.995	252.995	0	0.341
HYD	Hydrozoa	249.269	0	249.269	0.336
CGO	*Cottoperca gobio*	206.622	189.362	206.622	0.279
RBR	*Bathyraja brachyurops*	150.367	150.367	27.972	0.203
SHT	Mixed invertebrates	148.514	0	148.514	0.2
ALG	Algae	145.278	0	145.278	0.196
RFL	*Dipturus lamillai*	117.642	117.642	4.66	0.159
DGH	*Schroederichthys bivius*	113.94	112.84	113.94	0.154
PMC	*Protomyctophum choriodon*	83.232	0.061	83.232	0.112
PAU	*Patagolycus melastomus*	82.711	30.337	82.711	0.112
SQT	Ascidiacea	74.866	0	74.866	0.101
COP	*Congiopodus peruvianus*	62.492	46.172	62.492	0.084
RED	*Sebastes oculatus*	49.15	49.15	43.79	0.066
RTR	*Dipturus trachyderma*	48.04	48.04	0	0.065

Species Code	**Latin name**	**Total caught (kg)**	**Total sampled (kg)**	**Total discarded (kg)**	**%**
RMU	*Bathyraja multispinis*	40.66	40.66	0	0.055
RMC	*Bathyraja macloviana*	36.764	36.764	33.304	0.05
RAL	*Bathyraja albomaculata*	35.276	35.276	3.78	0.048
BRY	Bryozoa	26.992	0	26.992	0.036
MUN	*Munida* spp.	25.557	0	25.557	0.034
OPV	*Ophiacantha vivipara*	22.558	0	22.558	0.03
ING	*Onykia ingens*	21.215	10.8	21.215	0.029
MXX	Myctophidae	19.4	0	19.4	0.026
GYN	*Gymnoscopelus nicholsi*	12.108	0.33	12.108	0.016
RBZ	*Bathyraja cousseauae*	10.36	10.36	0	0.014
GOC	*Gorgonocephalus chilensis*	8.972	0	8.972	0.012
ZYP	*Zygochlamys patagonica*	8.787	0	8.787	0.012
NEM	*Psychrolutes marmoratus*	8.7	5.6	8.7	0.012
EEL	*Iluocoetes/Patagolycus* mix	7.32	0	7.32	0.01
ALF	*Allothunnus fallai*	7.24	7.24	0	0.01
STA	*Sterechinus agassizii*	7.184	0	7.184	0.01
OCM	*Enteroctopus megalocyathus*	6.79	3.48	6.79	0.009
ANM	Anemonia	6.512	0	6.512	0.009
RDO	*Amblyraja doellojuradoi*	5.7	5.7	5.7	0.008
RPX	*Psammobatis* spp.	5.468	5.468	5.468	0.007
MLA	*Muusoctopus longibrachus akambei*	5.386	4.868	5.386	0.007
AUC	*Austrocidaris canaliculata*	5.148	0	5.148	0.007
CTA	*Ctenodiscus australis*	4.971	0	4.971	0.007
ADA	*Adelomelon ancilla*	4.663	0	4.663	0.006
MUE	*Muusoctopus eureka*	4.22	2.471	4.22	0.006
AUL	*Austrolycus laticinctus*	3.3	3.3	3.3	0.004
ILF	*Iluocoetes fimbriatus*	2.737	0.411	2.737	0.004
THO	Thouarellinae	2.565	0	2.565	0.003
RSC	*Bathyraja scaphiops*	2.36	2.36	0	0.003
FUM	*Fusitriton m. magellanicus*	2.178	0	2.178	0.003
FLX	*Flabellum* spp.	2.133	0	2.133	0.003
TRP	*Tripylaster philippi*	2.024	0	2.024	0.003
SRP	*Semirossia patagonica*	1.962	0	1.962	0.003
OPL	*Ophiura lymani*	1.93	0	1.93	0.003
POA	*Glabraster antarctica*	1.715	0	1.715	0.002
PRX	*Paragorgia* sp.	1.601	0	1.601	0.002
EGG	Eggmass	1.579	0	1.579	0.002
PYX	Pycnogonida	1.407	0	1.407	0.002
CAZ	*Calyptraster* sp.	1.356	0	1.356	0.002
CEX	*Ceramaster* sp.	1.326	0	1.326	0.002
ASA	*Astrotoma agassizii*	1.317	0	1.317	0.002
SUN	*Labidiaster radiosus*	1.306	0	1.306	0.002

Species Code	Latin name	Total caught (kg)	Total sampled (kg)	Total discarded (kg)	%
SAR	*Sprattus fuegensis*	1.294	1.26	1.294	0.002
BAO	*Bathybiaster loripes*	1.194	0	1.194	0.002
SAL	*Salpa* sp.	1.117	0	1.117	0.002
PAG	*Paralomis granulosa*	1.014	0	1.014	0.001
CAS	*Campylonotus semistriatus*	0.977	0	0.977	0.001
WRM	Worms	0.934	0	0.934	0.001
SPM	*Spheniscus magellanicus*	0.92	0	0.92	0.001
HEX	*Henricia* sp.	0.893	0	0.893	0.001
PES	*Peltarion spinulosum*	0.805	0	0.805	0.001
COT	*Cottunculus granulosus*	0.7	0.7	0.7	0.001
MUO	*Muraenolepis orangiensis*	0.687	0.687	0.687	0.001
POL	Polychaeta	0.647	0	0.647	0.001
ASP	Porifera	0.645	0	0.645	0.001
ODM	*Odontocymbiola magellanica*	0.604	0	0.604	0.001
ZYX	dead Zygochlamys	0.591	0	0.591	0.001
HEO	*Henricia obesa*	0.546	0	0.546	0.001
LEA	*Lepas australis*	0.447	0	0.447	0.001
MIR	*Mirostenella* sp.	0.425	0	0.425	0.001
COG	*Patagonotothen guntheri*	0.388	0.388	0.388	0.001
BRM	*Brucerolis macdonnellae*	0.349	0	0.349	<0.001
OPS	*Ophiactis asperula*	0.262	0	0.262	<0.001
MAV	*Magellania venosa*	0.261	0	0.261	<0.001
CON	Congridae	0.25	0.25	0.25	<0.001
EUL	*Eurypodius latreillii*	0.237	0	0.237	<0.001
PLB	Primnoidae	0.232	0	0.232	<0.001
THB	*Thymops birsteini*	0.223	0	0.223	<0.001
CHE	*Champsocephalus esox*	0.206	0.206	0.206	<0.001
MYX	*Myxine* spp.	0.2	0	0.2	<0.001
PLU	Primnoidae	0.198	0	0.198	<0.001
CRY	*Crossaster* sp.	0.162	0	0.162	<0.001
OPH	Ophiuroidea	0.14	0	0.14	<0.001
SOR	*Solaster regularis*	0.136	0	0.136	<0.001
AST	Asteroidea	0.128	0	0.128	<0.001
NOW	*Paranotothenia magellanica*	0.12	0.12	0.12	<0.001
ARR	*Arctozenus risso*	0.111	0.111	0.111	<0.001
NUD	Nudibranchia	0.109	0	0.109	<0.001
ERR	*Errina* sp.	0.108	0	0.108	<0.001
THN	*Thysanopsetta naresi*	0.108	0.108	0.108	<0.001
PSX	Psolidae	0.101	0	0.101	<0.001
CUB	*Cubiceps caeruleus*	0.083	0.083	0.083	<0.001
LIS	*Lithodes santolla*	0.071	0	0.071	<0.001
ISO	Isopoda	0.051	0	0.051	<0.001

Species Code	Latin name	Total caught (kg)	Total sampled (kg)	Total discarded (kg)	%
GYP	*Gymnoscopelus piabilis*	0.049	0.049	0.049	<0.001
MEV	*Metelectrona ventralis*	0.037	0.037	0.037	<0.001
GYB	*Gymnoscopelus bolini*	0.036	0	0.024	<0.001
BIV	Bivalvia	0.033	0	0.033	<0.001
GON	*Gonatus antarcticus*	0.03	0.02	0.03	<0.001
PAO	*Patagonotothen cornucola*	0.028	0	0.028	<0.001
SYD	*Sympagurus dimorphus*	0.028	0	0.028	<0.001
LIR	*Limopsis marionensis*	0.026	0	0.026	<0.001
PMB	*Protomyctophum bolini*	0.026	0	0.026	<0.001
HOL	Holothuroidea	0.023	0	0.023	<0.001
OIB	*Oidiphorus brevis*	0.022	0.022	0.01	<0.001
CRI	Crinoidea	0.02	0	0.02	<0.001
PTE	*Patagonotothen tessellata*	0.02	0.02	0.02	<0.001
CIR	Cirripedia	0.017	0	0.017	<0.001
CYX	*Cycethra* sp.	0.015	0	0.015	<0.001
ANT	Anthozoa	0.014	0	0.014	<0.001
ICA	*Icichthys australis*	0.014	0.014	0.014	<0.001
DIA	*Diaulula* spp.	0.012	0	0.012	<0.001
EUO	*Eurypodius longirostris*	0.01	0	0.01	<0.001
NUH	*Nuttallochiton hyadesi*	0.01	0	0.01	<0.001
ODP	*Odontaster pencillatus*	0.01	0	0.01	<0.001
PRI	Priapulida	0.009	0	0.009	<0.001
PEX	*Pennatula* spp.	0.008	0	0.008	<0.001
PAE	*Patagonotothen elegans*	0.007	0.007	0.007	<0.001
PGR	*Paradiplospinus gracilis*	0.006	0.002	0.006	<0.001
AGO	*Agonopsis chiloensis*	0.003	0.003	0.003	<0.001
CHO	*Chondrocladia* sp.	0.002	0	0.002	<0.001
GAY	Gastropoda	0.002	0	0.002	<0.001
ACS	*Acanthoserolis schythei*	0.001	0	0.001	<0.001
OCC	*Octocorallia* sp	0.001	0	0.001	<0.001
PHA	*Phakellia* sp.	0.001	0	0.001	<0.001

3.2. Biological information of finfish species

3.2.1. *Salilota australis* – Red cod

The total catch of red cod was 8,704 kg. This species was caught at 71 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.002 to 2,945 kg per trawl station, densities were 0.009 to 13,356 kg/km^2, and CPUE ranged from 0.002 to 2,945 kg/h. Catches of red cod occurred mostly at the north-west and the south-west of the Falkland Islands (Figure 2A). Most females were at resting maturity stage (maturity stage II) or recovering spent (maturity stage VIII); males were mainly spent (maturity stages ≥ VII), with minor frequencies of immature, resting or maturing individuals (maturity stages I–III; Figure 2B). Females were 16–82 cm total length, and males were 16–74 cm total length; one juvenile was collected and measured 6 cm total length. The length frequency histogram allowed identifying three length-groups for females, with length modes at 19 cm, 26 cm, and 41 cm total length, respectively (Figure 2C). Length-groups of males were identified at 19 cm, 26 cm, and 40 cm total length (Figure 2D). Overlap of lengths did not allow identifying all the length-groups present.

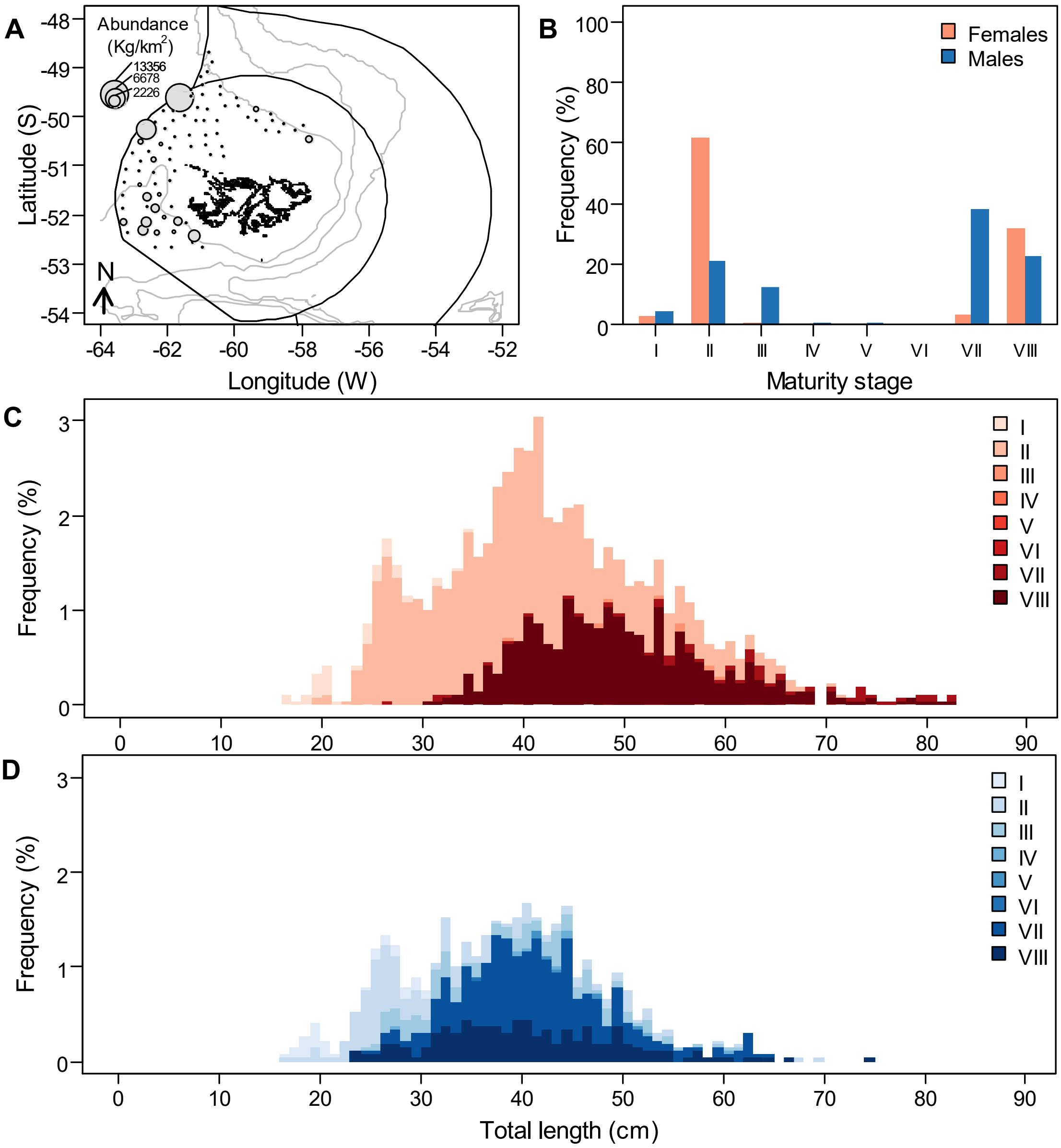

Figure 2. Biological data of *Salilota australis* (Red cod; BAC). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 1,701) and D) males (n = 987) with 1 cm size class.

3.2.2. *Micromesistius australis* – Southern blue whiting

The total catch of southern blue whiting was 1,341 kg. This species was caught at 69 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.002 to 396 kg, densities ranged from 0.009 to 1,799 kg/km^2, and CPUE ranged from 0.002 to 396 kg/h. Southern blue whiting were caught at the south-west of West Falkland and at the north-east of the FICZ (Figure 3A). A total of 2,213 fish were sampled for length frequency (5 juveniles, 847 females, 1,360 males, 1 not sexed). Individuals were mainly immature (maturity stages I-II), and small numbers were recovering spent (maturity stage VIII; Figure 3B). Females were 20–64 cm total length (Figure 3C) and males were 19–57 cm total length (Figure 3D); juveniles were 8–9 cm total length. The limited number of individuals caught during the survey allowed identifying one length-group with mode at 24 cm total length, for both females and males, likely corresponding to one length-group. Length-groups with modal lengths > 30 cm total length were detected.

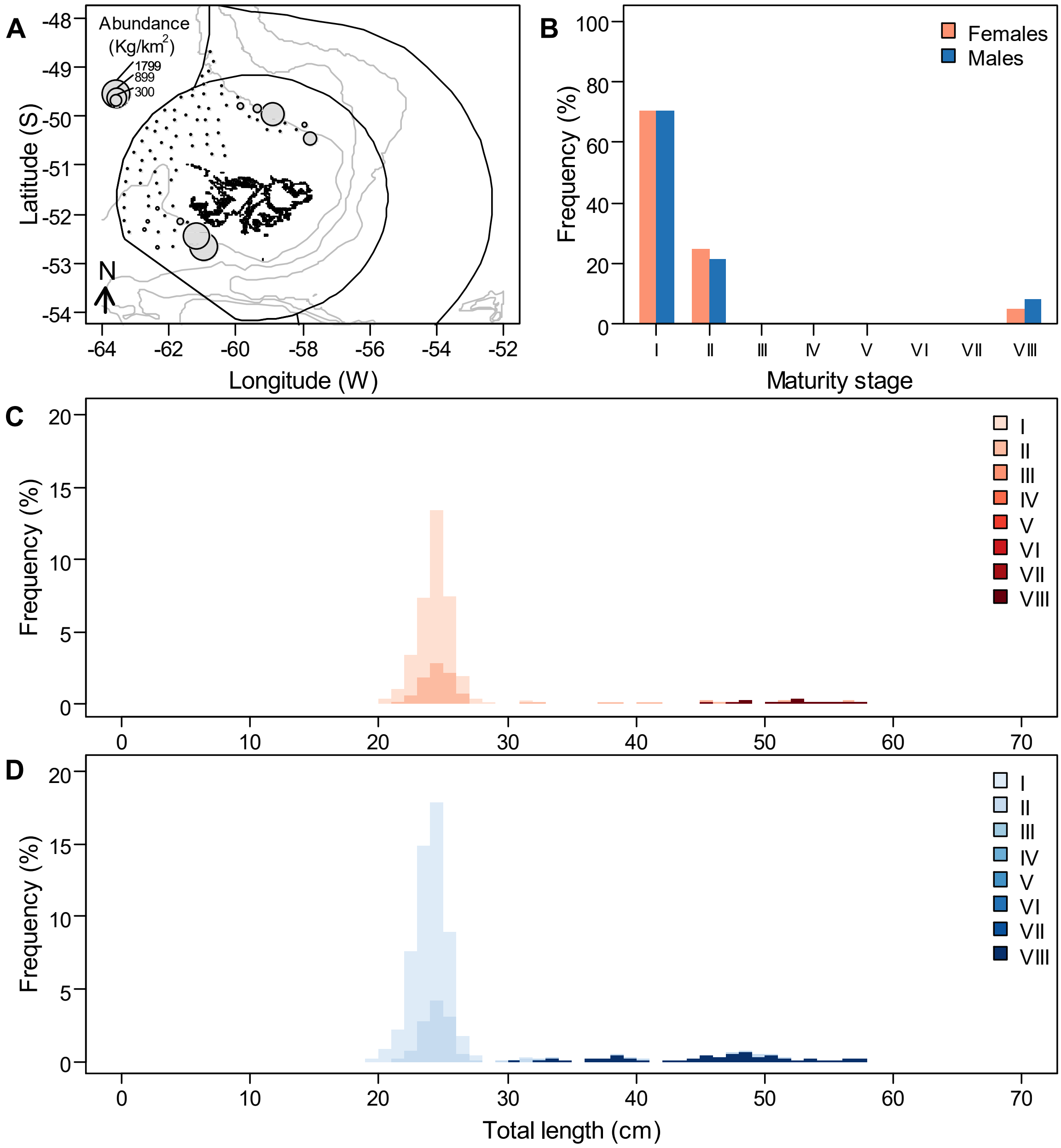

Figure 3. Biological data of *Micromesistius australis* (Southern blue whiting; BLU). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 847) and D) males (n = 1,360) with 1 cm size class.

3.2.3. *Merluccius hubbsi* – Common hake

The total catch of common hake was 8,281 kg. This species was caught at 59 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.6 to 700 kg, densities ranged from 2.5 to 2,493 kg/km^2, and CPUE ranged from 0.6 to 700 kg/h. Common hake was caught to the north-west in the FICZ (Figure 4A). Most females were at resting maturity stage (maturity stage II), spent or recovering spent (maturity stages ≥ VII). Most males were spent and recovering spent (maturity stages VII and VIII), or resting (maturity stage II; Figure 4B). Females were 27–67 cm total length and males were 27–45 cm total length. The length frequency histogram allowed identifying two length-groups for females, with length modes at 32 cm and 39 cm total length. Modal length of males was 31 cm total length (Figure 4D). There may be more length-groups with modal lengths > 45 cm total length for females and > 35 cm for males.

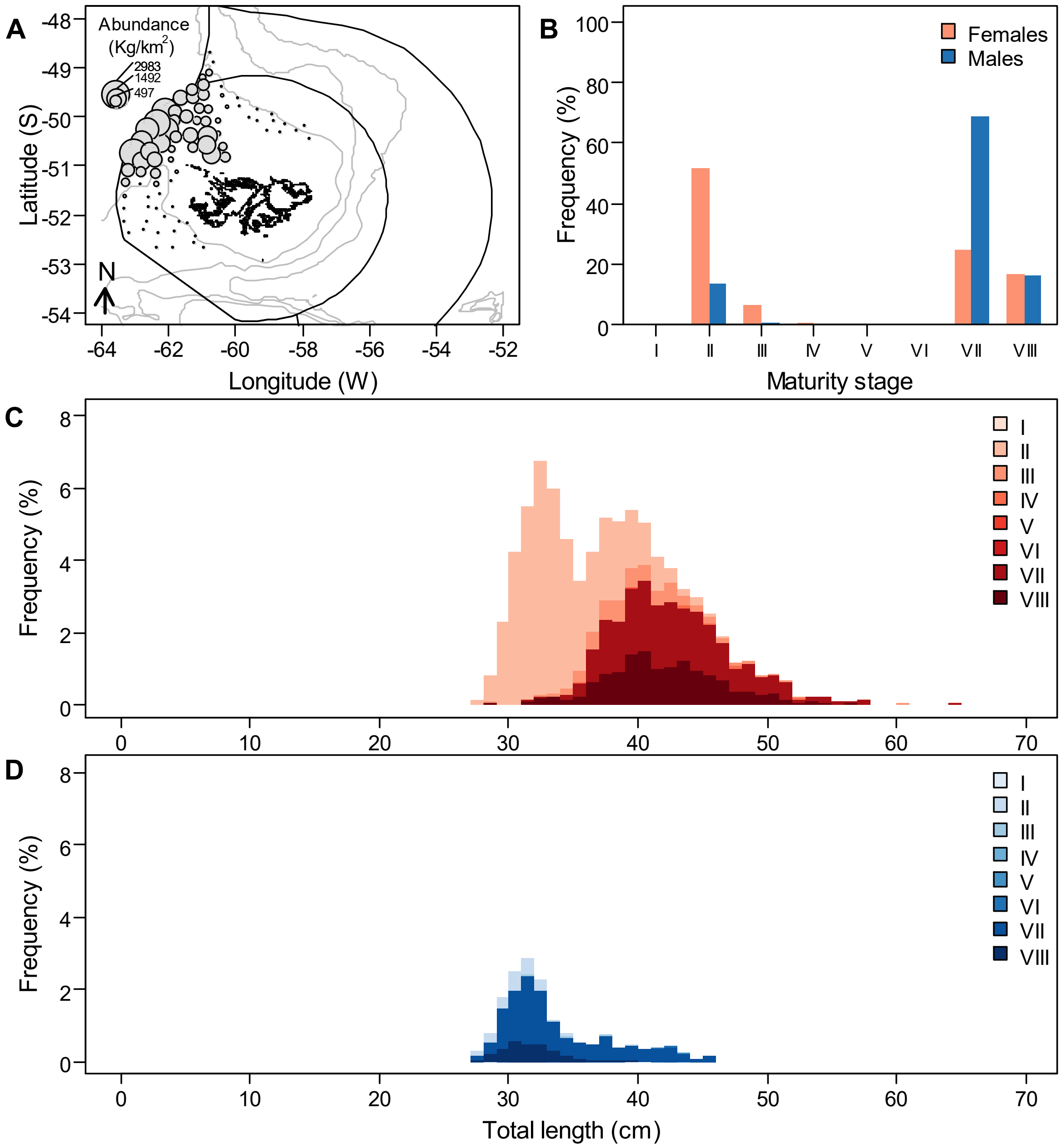

Figure 4. Biological data of *Merluccius hubbsi* (Common hake; HAK). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 3,608) and D) males (n = 723) with 1 cm size class.

3.2.4. *Genypterus blacodes* – Kingclip

The total catch of kingclip was 10,097 kg. This species was caught at 76 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.5 to 2,913 kg, densities ranged from 2.2 to 13,214 kg/km^2, and CPUE ranged from 0.5 to 2,913 kg/h. Catches occurred along the survey area, with highest densities to the north-west, north-east, and south-west in the FICZ (Figure 5A). Most females and males were at resting maturity stage (maturity stage II) or developing (maturity stages III–IV; Figure 5B). Females were 42–124 cm total length, and males were 38–119 cm total length. Length frequency distributions were multimodal and interrupted, with many individuals bounded by length groups with fewer individuals (Figure 5C).

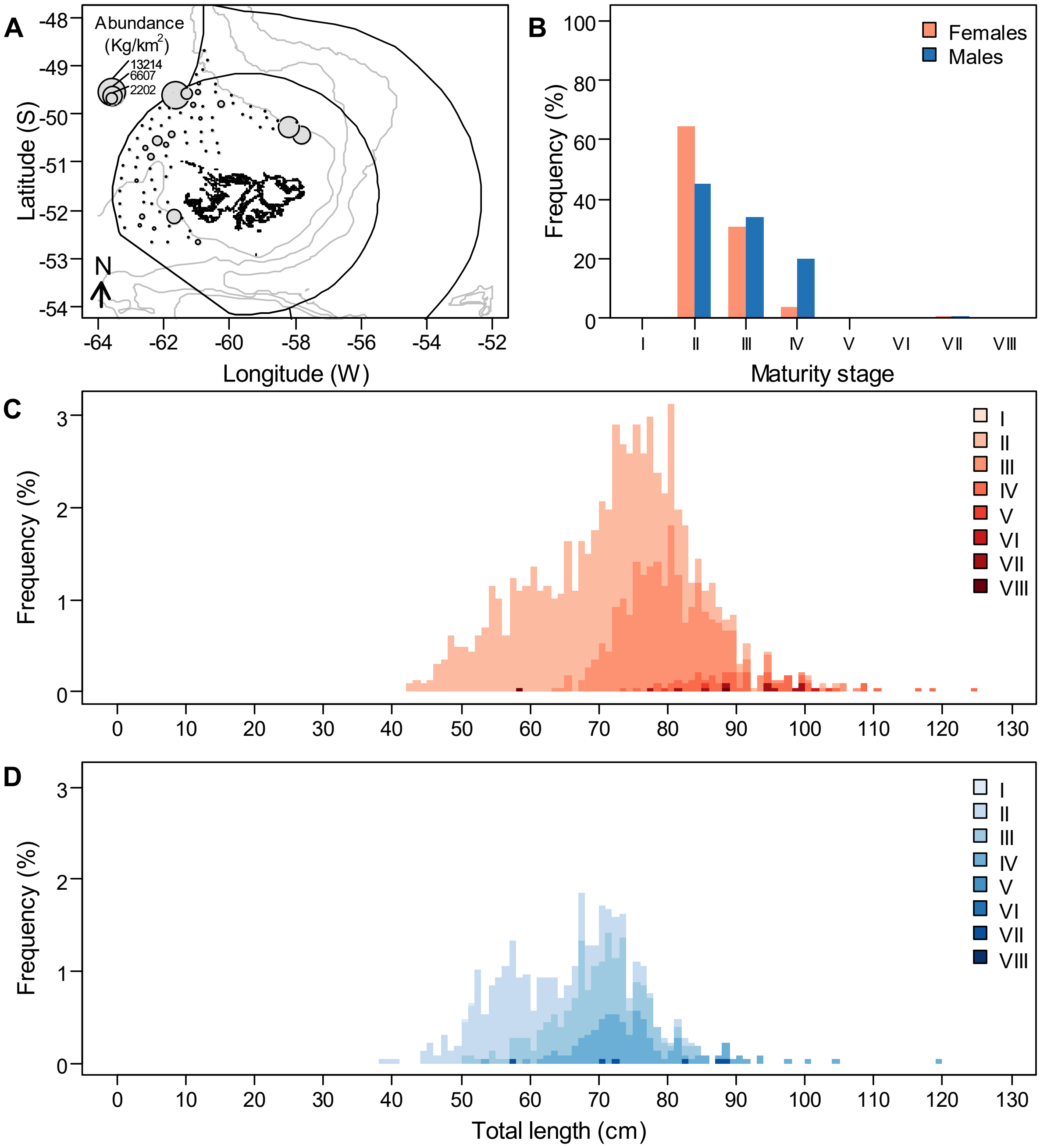

Figure 5. Biological data of *Genypterus blacodes* (Kingclip; KIN). A) Map of densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 1,515) and D) males (n = 757) with 1 cm size class.

3.2.5. *Patagonotothen ramsayi* – Common rock cod

The total catch of rock cod was 10,243 kg. This species was caught at every station, with catches ranging from 3.5 to 2,220 kg, densities ranged from 16.5 to 9,764 kg/km^2, and CPUE ranged from 3.5 to 2,220 kg/h. Higher densities were observed along the north-west in the FICZ (Figure 6A). Most females and males were immature, resting or developing (maturity stages ≤ III), with resting individuals being predominant (Figure 6B). Females were 10–38 cm total length, males were 8–38 cm total length, and 78 juveniles were 4–8 cm total length. Two length-groups were identified; modal lengths of females were 18 cm and 24 cm total length (Figure 6C), whereas modal lengths of males were 18 cm and 25 cm total length (Figure 6D). More than two length-groups may exist but these were not detected because of the overlap in sizes.

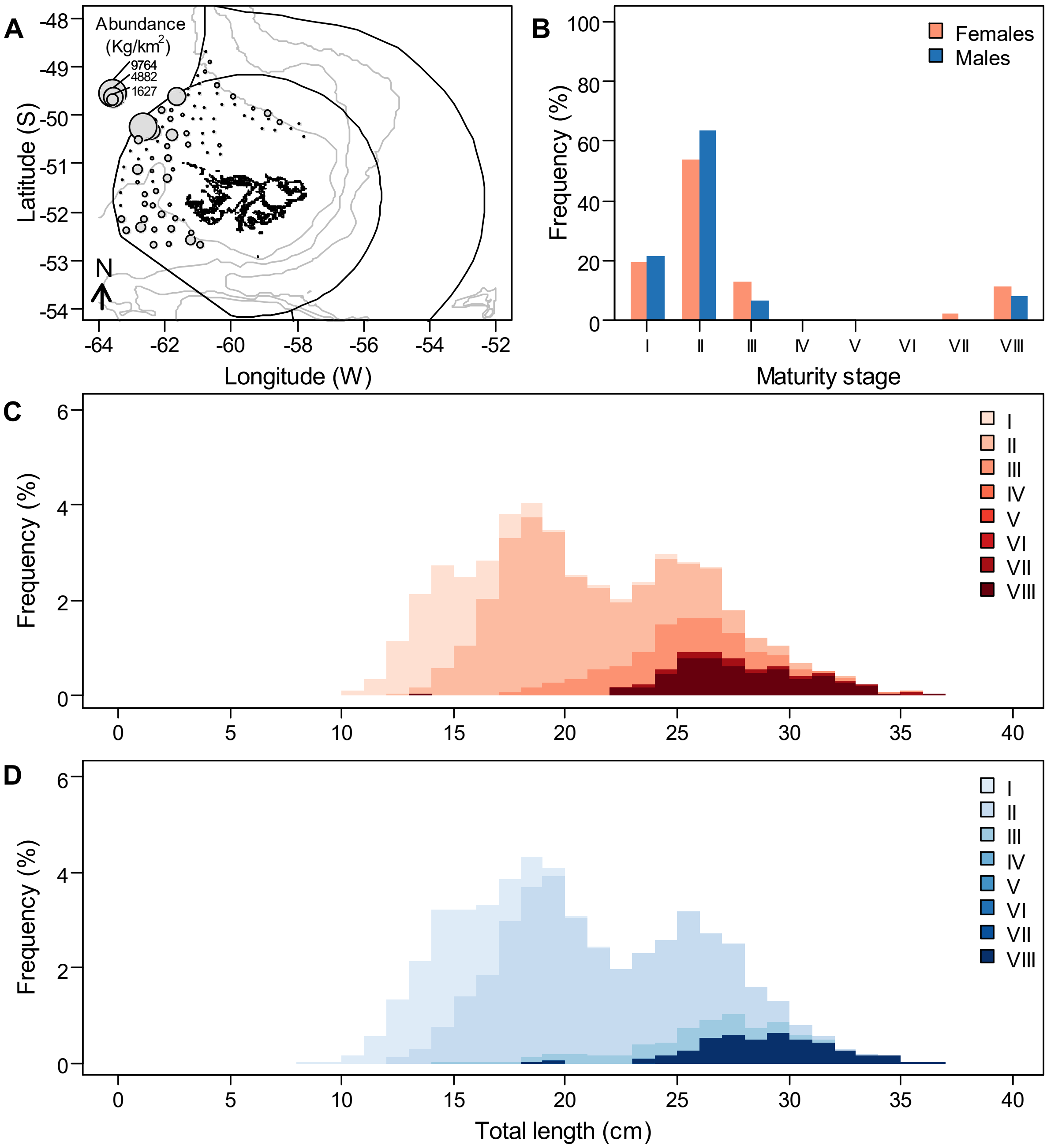

Figure 6. Biological data for *Patagonotothen ramsayi* (Common rock cod; PAR). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 3,954) and D) males (n = 4,370) with 1 cm size class.

3.2.6. *Merluccius australis* – Southern hake

The total catch of southern hake was 253 kg. This species was caught at 14 of the 84 trawl stations sampled throughout the survey. Catches ranged from 1.5 to 75 kg, densities ranged from 6.9 to 333 kg/km^2, and CPUE ranged from 1.5 to 75 kg/h. Southern hake were observed to the south-west near the limit of the FICZ (Figure 7A); this area is in deeper waters where southern hake are most abundant. Most females were resting (maturity stage II), smaller numbers of developing (maturity stage III), spent (maturity stage VII), or recovering spent (maturity stage VIII) were also observed; males were mainly recovering spent (Figure 7B). Females were 32–98 cm total length, and males were 58–75 cm total length. The small number of southern hake caught and the wide range of sizes did not enable identifying length-groups on the length-frequency histograms (Figures 7C–7D).

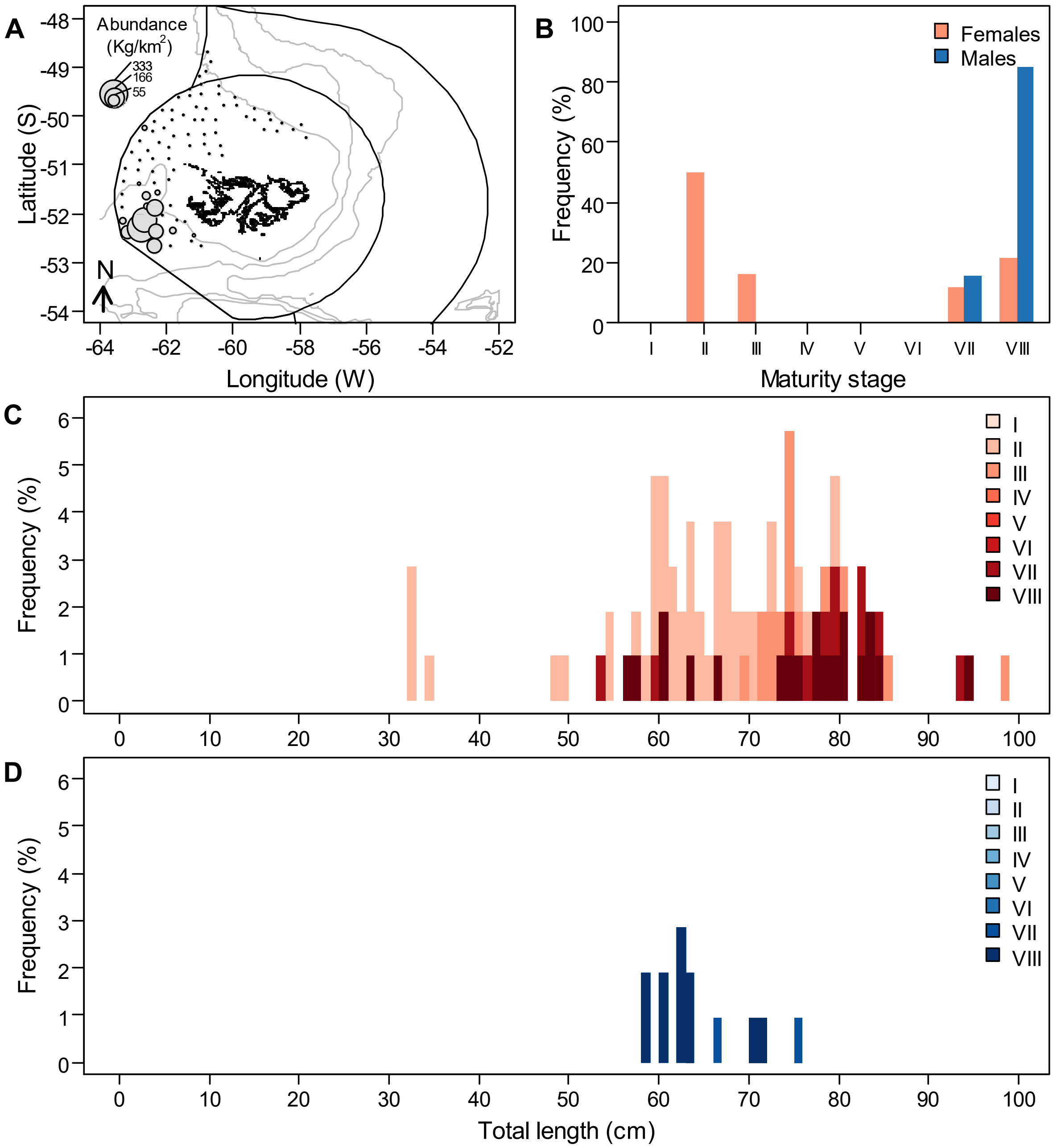

Figure 7. Biological data of *Merluccius australis* (Southern hake; PAT). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 92) and D) males (n = 13) with 1 cm size class.

3.2.7. *Dissostichus eleginoides* – Patagonian toothfish

The total catch of Patagonian toothfish was 272 kg. This species was caught at 34 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.008 to 36 kg, densities ranged from 0.04 to 158 kg/km^2, and CPUE ranged from 0.008 to 36 kg/h. Highest densities were observed in the south-west in the FICZ at stations deeper than 200 m (Figure 8A). Most individuals were immature or resting (maturity stages ≤ II) (Figure 8B). Females were 37–86 cm total length, males were 40–78 cm total length; one juvenile was 11 cm total length. No distinct cohorts were evident in the length frequency distribution. The small number of Patagonian toothfish caught and the wide range of sizes did not enable identifying length-groups on the length-frequency histograms (Figures 8C–8D).

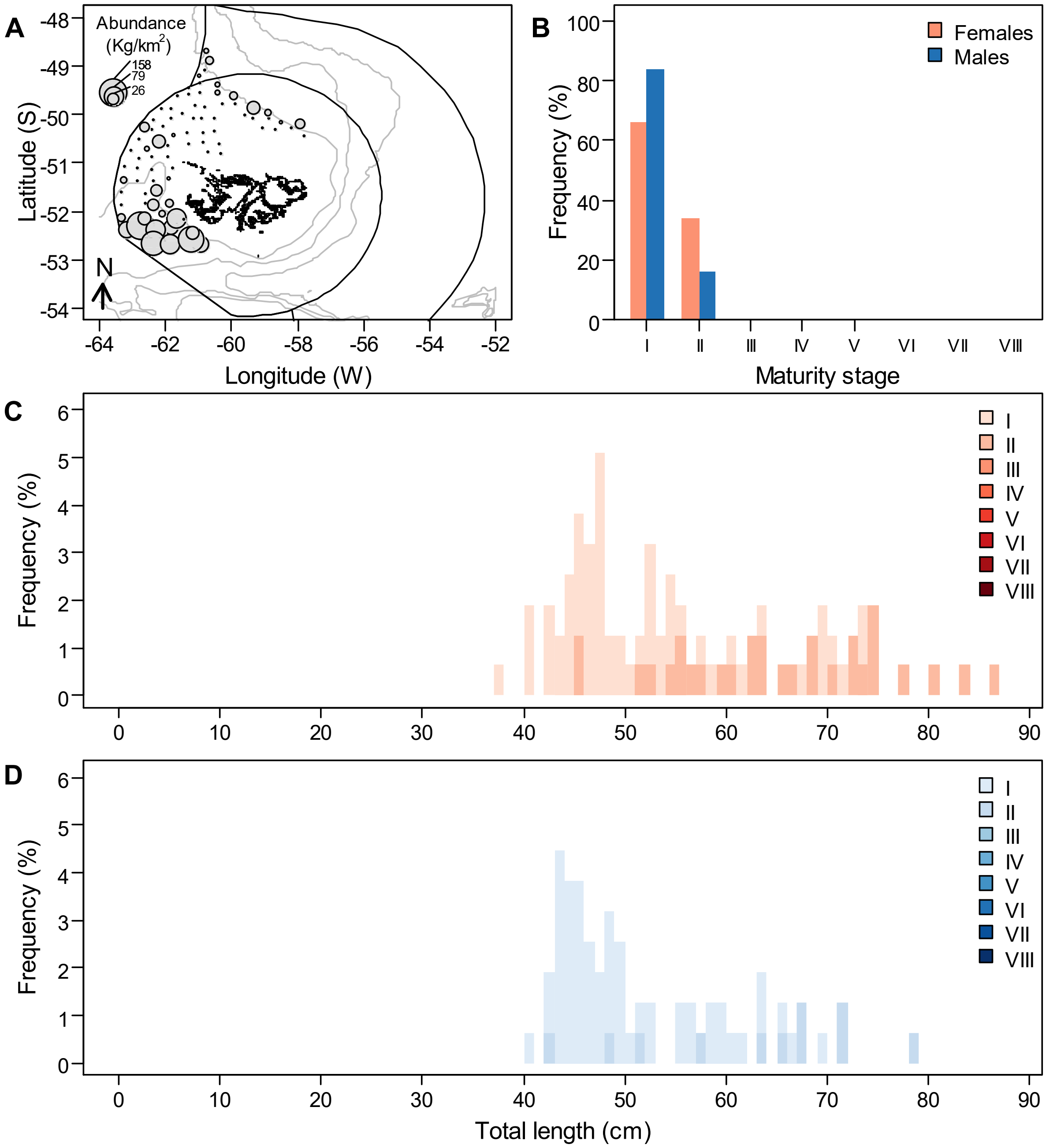

Figure 8. Biological data of *Dissostichus eleginoides* (Patagonian toothfish; TOO). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 89) and D) males (n = 67) with 1 cm size class.

3.2.8. *Macruronus magellanicus* – Hoki

The total catch of hoki was 14,402 kg. This species was caught at 38 of the 84 stations sampled throughout the survey. Catches ranged from 0.08 to 4,891 kg, densities ranged from 0.34 to 22,240 kg/km^2, and CPUE ranged from 0.08 to 4,891 kg/h. Highest densities were observed at the south-west in the FICZ (Figure 9A). Most females and males were resting (maturity stage II) or recovering spent (maturity stage VIII). A minor proportion of individuals were immature (maturity stage I) or spent (maturity stage VII; Figure 9B). Females were 12–40 cm pre-anal length (Figure 9C), and males were 12–33 cm pre-anal length (Figure 9D). The length frequency histograms exhibit three potential length-groups with modal lengths at 14 cm, 20 cm and 26 cm pre-anal length for females and at 14 cm, 20 cm and 25 cm pre-anal length for males.

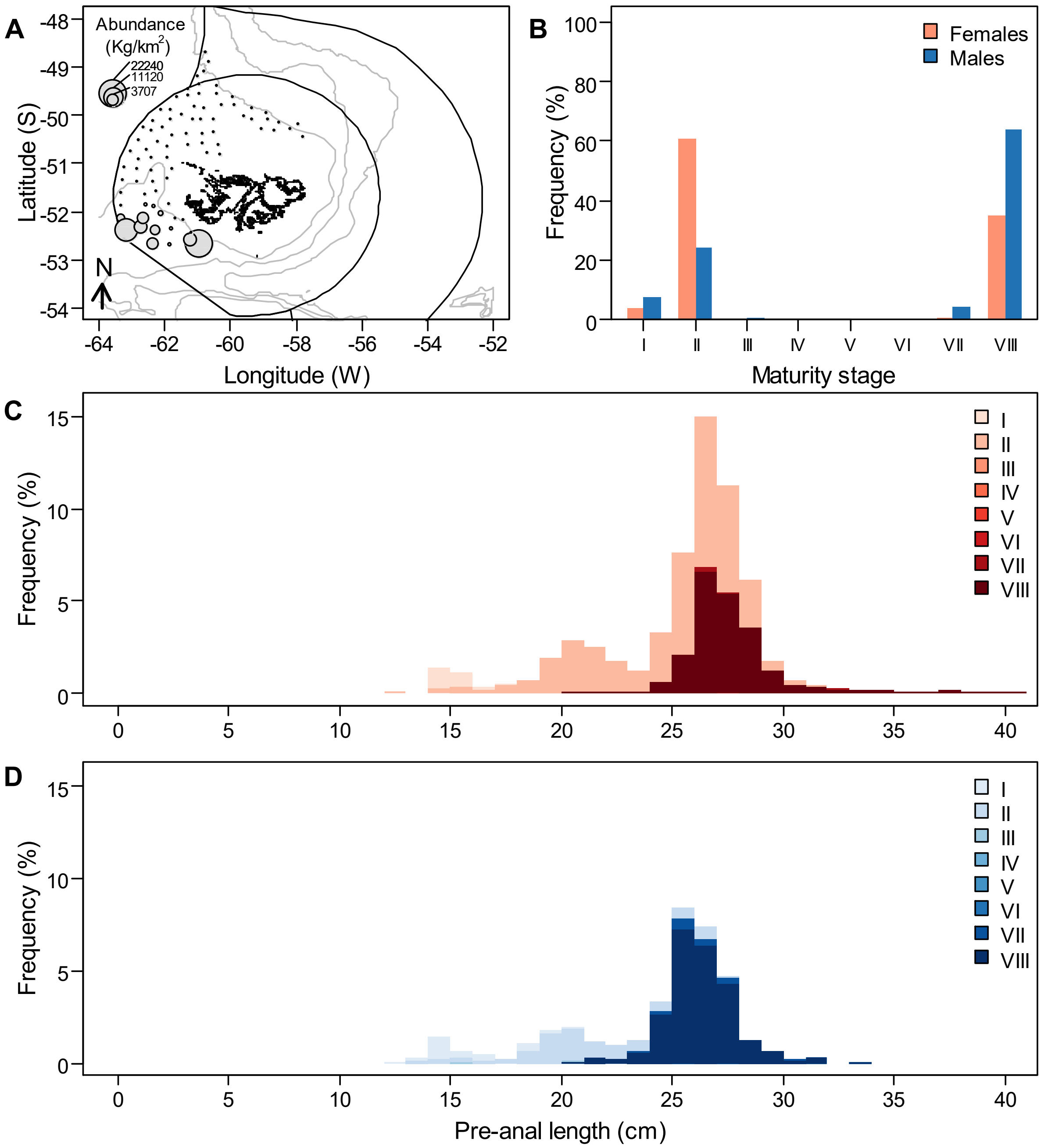

Figure 9. Biological data of *Macruronus magellanicus* (Hoki; WHI). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 903) and D) males (n = 549) with 1 cm size class.

3.2.9. *Stromateus brasiliensis* – Butterfish

The total catch of butterfish was 1,136 kg. This species was caught at 51 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.2 to 145 kg, densities ranged from 0.8 to 722 kg/km^2, and CPUE ranged from 0.2 to 145 kg/h. Butterfish were caught along the north-west in the FICZ (Figure 10A). Females and males were mostly early developing (maturity stage III); males were also at resting maturity stage (maturity stage II); few individuals were ripe, spent or recovering spent (maturity stages V, VII–VIII; Figure 10B). Females were 19–38 cm total length and males were 18–34 cm total length. Two length-groups were detected with modal lengths at 23 cm and 32 cm total length for females (Figure 10C), and at 23 cm and 30 cm total length for males (Figure 10D).

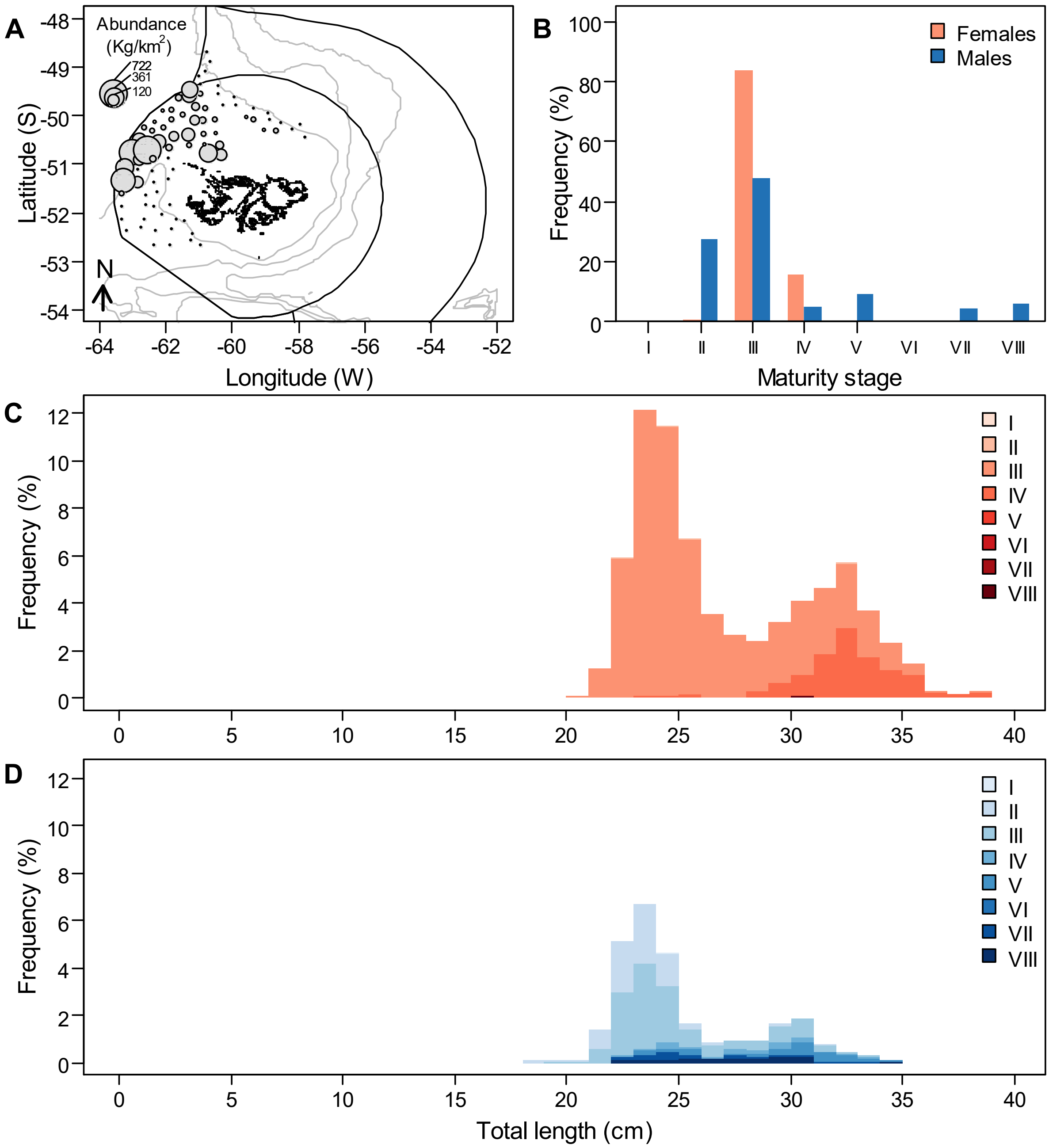

Figure 10. Biological data of *Stromateus brasiliensis* (Butterfish; BUT). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 1,662) and D) males (n = 642) with 1 cm size class.

3.2.10. *Macrourus carinatus* – Ridge scaled rattail

The total catch of banded whiptail grenadier was 585 kg. This species was caught at 4 of the 84 trawl stations sampled throughout the survey. Catches ranged from 87 to 209 kg, densities ranged from 384 to 990 kg/km2, and CPUE ranged from 87 to 209 kg/h. Highest densities were observed in the south-west in the FICZ (Figure 11A). Females and males were mostly developing (maturity stage IV) or spent (maturity stage VII; Figure 11B). Females were 19–30 cm pre–anal length; males were 17–23 cm pre–anal length. The length-frequency histogram allowed detecting a single length-group with modal lengths at 25–26 cm pre–anal length for females (Figure 11C). The small number of sampled males did not enable identifying length-groups (Figures 11D).

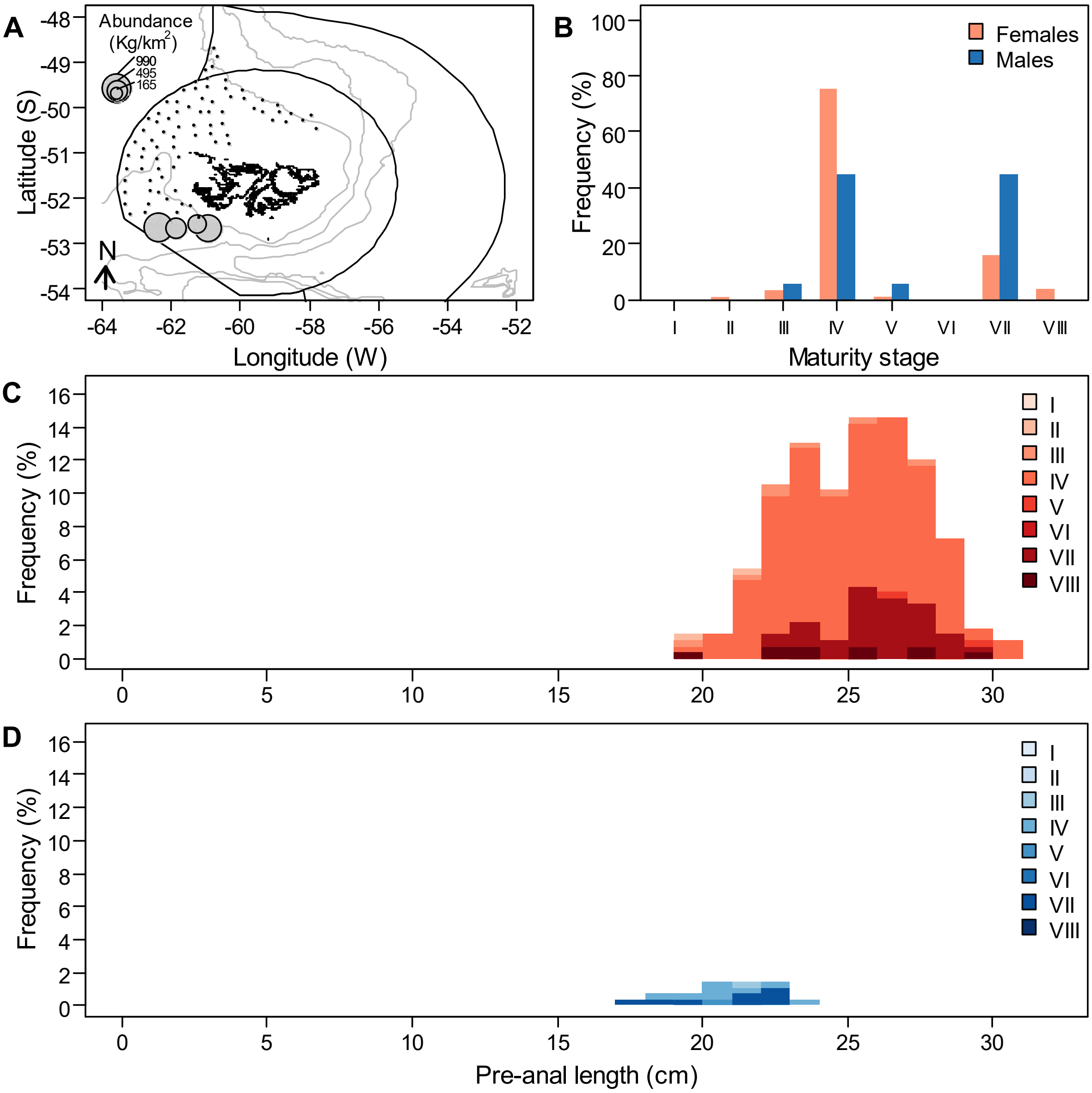

Figure 11. Biological data of *Macrourus carinatus* (Ridge scaled rattail; GRC). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 257) and D) males (n = 18) with 1 cm size class.

3.2.11. *Coelorinchus fasciatus* – Banded whiptail grenadier

The total catch of banded whiptail grenadier was 4,994 kg. This species was caught at 26 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.08 to 563 kg, densities ranged from 0.4 to 2,489 kg/km^2, and CPUE ranged from 0.08 to 563 kg/h. Highest densities were observed in the south-west in the FICZ (Figure 12A). Females and males were mostly developing (maturity stage III), resting (maturity stage II), spent or recovering spent (maturity stages ≥ VII; Figure 12B). Females were 4–13 cm pre–anal length; males were 4–11 cm pre–anal length, one sampled juvenile was 4 cm pre-anal length. The length-frequency histogram allowed detecting a single length-group with modal length at 10 cm pre–anal length for females (Figure 12C) and at 8 cm pre-anal length for males (Figure 12D).

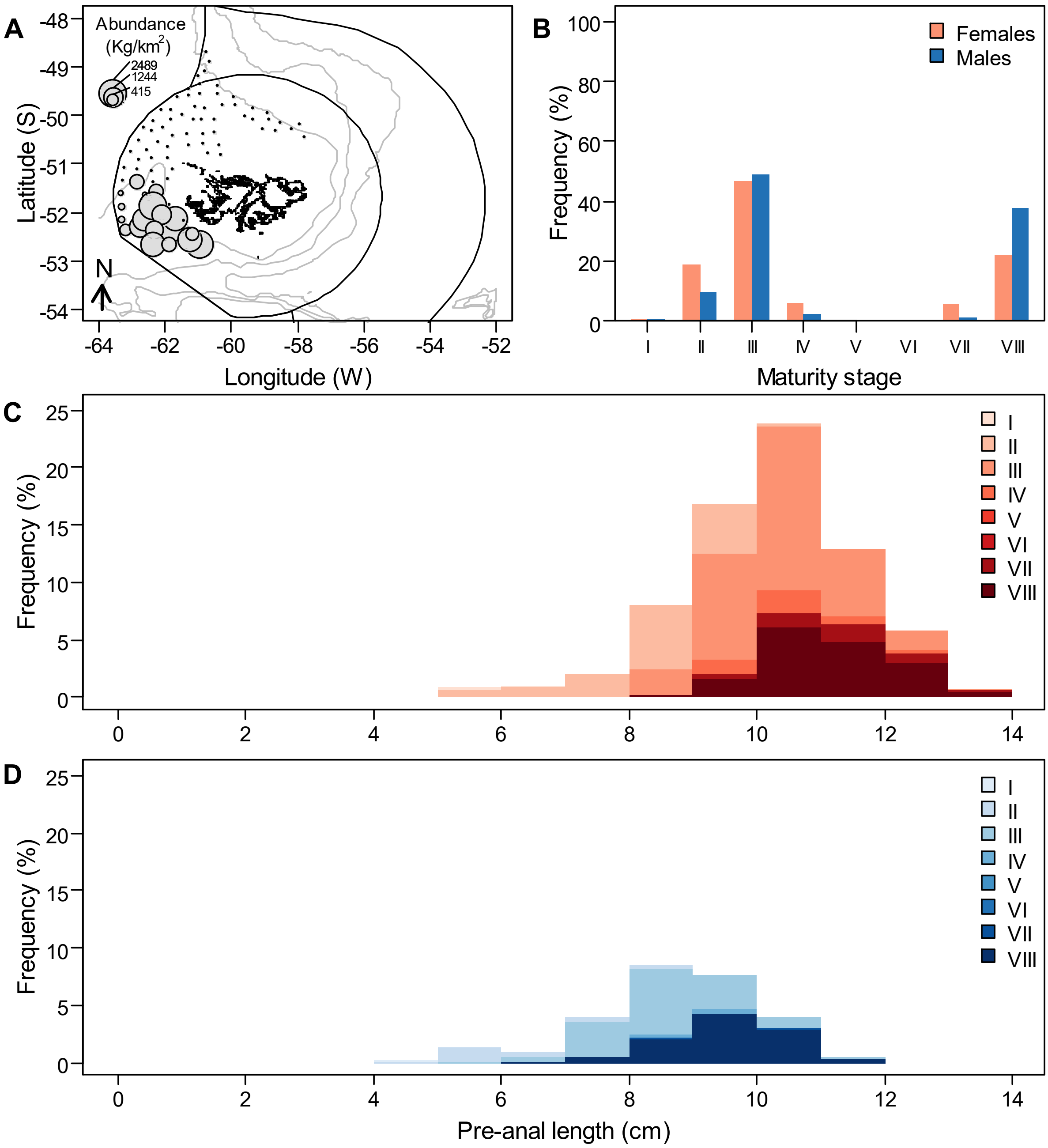

Figure 12. Biological data of *Coelorinchus fasciatus* (Banded whiptail grenadier; GRF). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 1,459) and D) males (n = 550) with 1 cm size class.

3.2.12. *Seriolella porosa* – Driftfish

The total catch of driftfish was 809 kg. This species was caught at 21 of the 84 trawl stations sampled throughout the survey. Catches ranged from 1.5 to 189 kg, densities ranged from 6.4 to 841 kg/km^2, and CPUE ranged from 1.5 to 189 kg/h. Highest densities were observed to the south-west in the FICZ (Figure 13A). Females and males were mainly spent or recovering spent (maturity stages ≥ VII; Figure 13B). Females were 45–58 cm total length and males were 39–57 cm total length. One length-group was detected with modal length of 51 cm total length for females and males (Figure 13C–13D).

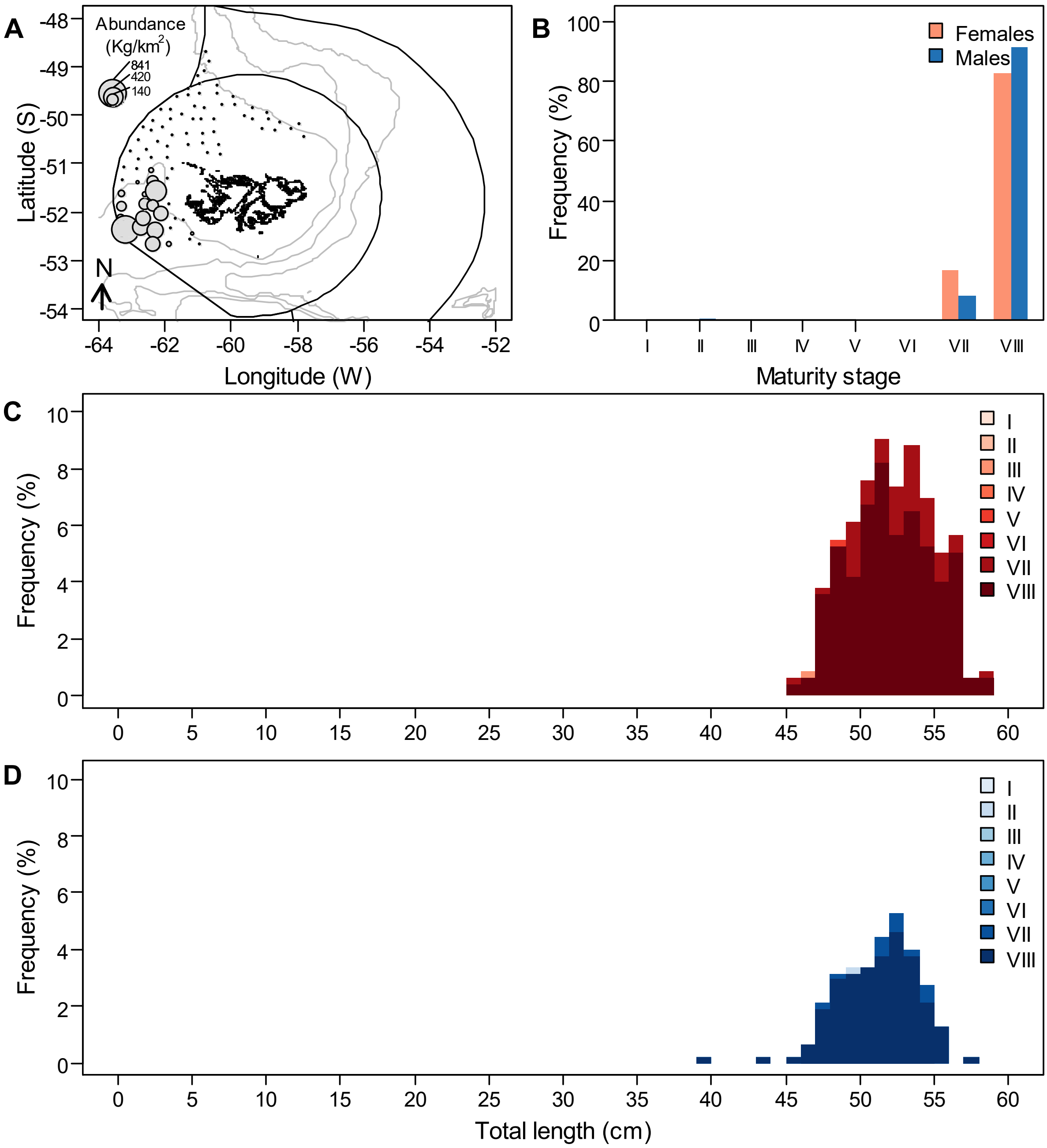

Figure 13. Biological data of *Seriolella porosa* (Driftfish; SEP). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 327) and D) males (n = 148) with 1 cm size class.

3.3. Biological information of squid species

3.3.1. *Illex argentinus* – Argentine shortfin squid

The total catch of Argentine shortfin squid was 2,907 kg. This species was caught at 72 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.02 to 535 kg, densities ranged from 0.8 to 2,284 kg/km^2, and CPUE ranged from 0.02 to 535 kg/h. Highest densities occurred to the north-west in the FICZ (Figure 14A). Most females were immature (maturity stages ≤ III). Most males were mature (maturity stage V), or immature or maturing (maturity stages ≤ IV) in smaller proportions (Figure 14B). Juveniles (n = 45) were 6.5–12.5 cm dorsal mantle length. Females size ranged between 7.5 cm and 29.5 cm dorsal mantle length, with length-groups identified at modal lengths of 9.5 cm and 24.0 cm dorsal mantle length (Figure 14C). Males size ranged between 8.0 cm and 26.5 cm, with modes at 10.0 cm and 23.0 cm dorsal mantle length (Figure 14D).

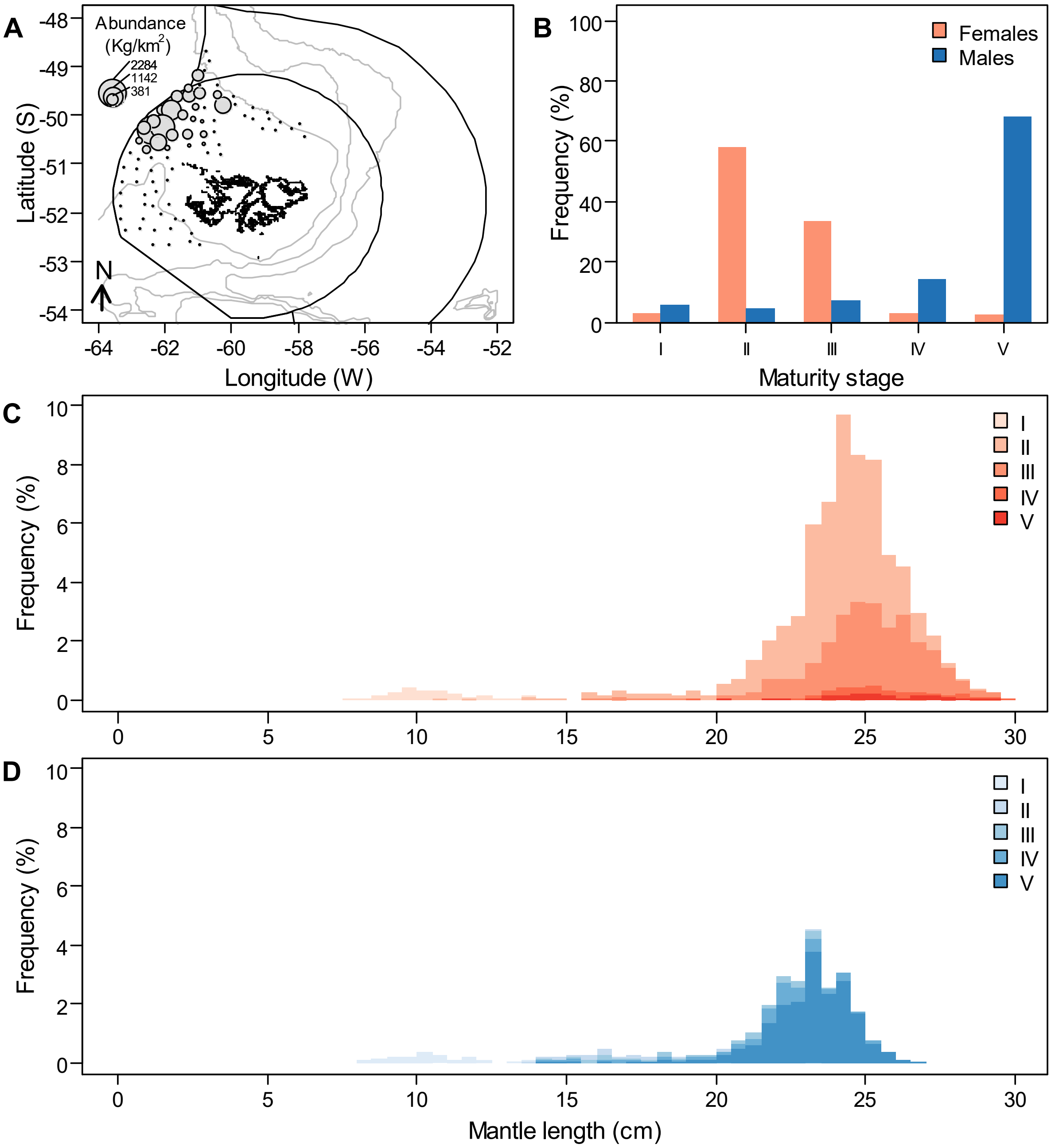

Figure 14. Biological data of *Illex argentinus* (Argentine shortfin squid; ILL). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 2,056) and D) males (n = 805) with 0.5 cm size class.

3.3.2. *Doryteuthis gahi* – Patagonian squid

The total catch of Patagonian squid was 6,132 kg. This species was caught at the 84 trawl stations sampled throughout the survey. Catches ranged from 0.22 to 701 kg, densities ranged from 0.98 to 3,073 kg/km^2, and CPUE ranged from 0.22 to 701 kg/h. Patagonian squid were caught throughout the survey zone, with the highest densities to the south-west of West Falkland (Figure 15A). Most females and males were immature (maturity stage ≤ II) (Figure 15B). The only one juvenile sampled was 6 cm dorsal mantle length, females were 4.5–15.5 cm dorsal mantle length (Figure 15C), and males were 5.0–25.0 cm dorsal mantle length (Figure 15D). Modal length of females and males were detected at 8.0 cm dorsal mantle length, respectively (Figures 15C–15D).

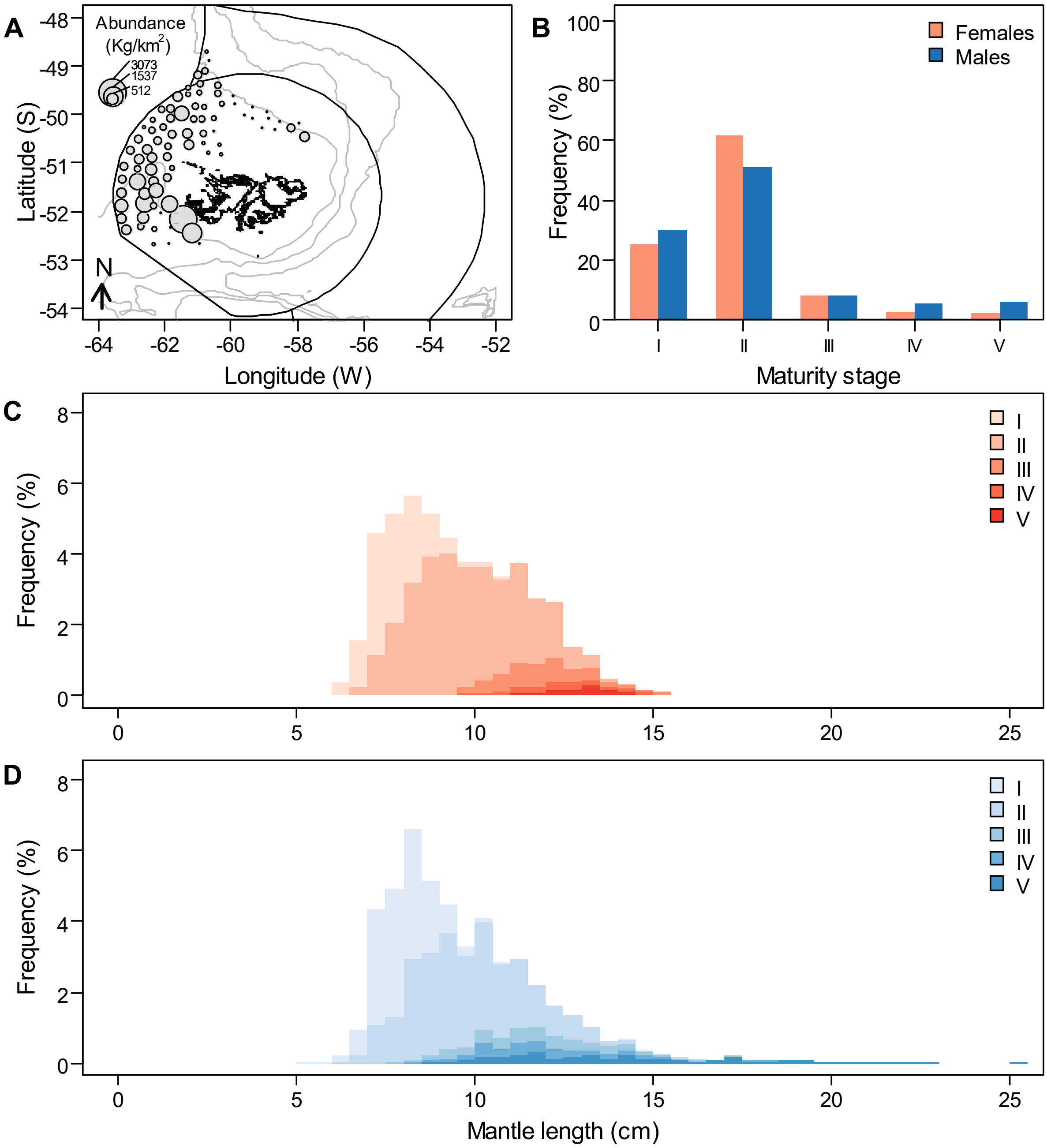

Figure 15. Biological data of *Doryteuthis gahi* (Patagonian squid; LOL). A) Map of the densities in kg/km²; B) relative frequency (%) of specimens of each sex per maturity stage (I, immature; II, resting; III, early developing; IV, late developing; V, ripe; VI, running; VII, spent; VIII, recovering spent); length frequencies (%) of C) females (n = 4,366) and D) males (n = 4,236) with 0.5 cm size class.

3.4. Biological information of skate species

3.4.1. *Bathyraja albomaculata* – White spotted skate

The total catch of white spotted skate was 35 kg. This species was caught at 13 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.5 to 10 kg, densities ranged from 2.1 to 45 kg/km^2, and CPUE ranged from 0.5 to 10 kg/h. Higher densities were observed in the north-west of the survey zone (Figure 16A). Most females were maturing (maturity stage II), although also mature (maturity stage IV) and laying females were reported (maturity stage V). Mature males were more common than any other maturity stage (Figure 16B). Females were 31–46 cm disc width (Figure 16C). Males were 29–49 cm disc width (Figure 16D).

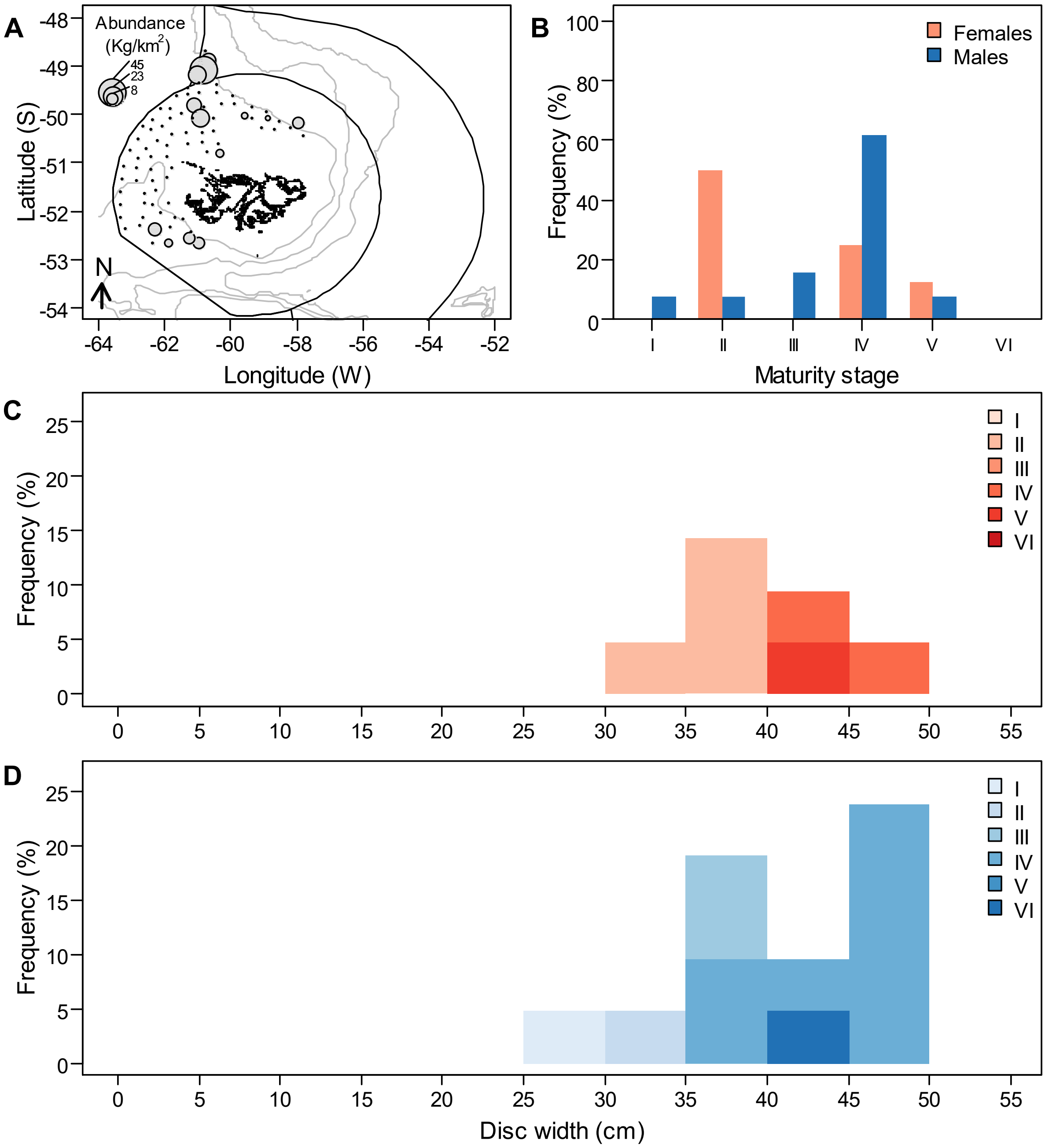

Figure 16. Biological data of *Bathyraja albomaculata* (White spotted skate; RAL). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); length frequencies (%) of C) females (n = 8) and D) males (n = 13) with 5 cm size class.

3.4.2. *Bathyraja brachyurops* – Blonde skate

The total catch of blonde skate was 150 kg. This species was caught at 34 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.04 to 23 kg, densities ranged from 0.2 to 109 kg/km^2, and CPUE ranged from 0.04 to 23 kg/h. High densities were patchy and observed along the north and west in the FICZ (Figure 17A). Most females and males were juvenile or maturing (maturity stages ≤ II) (Figure 16B). Females were 12–69 cm disc width and males were 14–62 cm disc width. The length-frequency histograms show one length-group with modal lengths at 25–29 cm disc width size class for females, and at 30–34 cm disc width size class for males. There may be more length-groups with modal lengths > 45 cm (Figure 17C–17D).

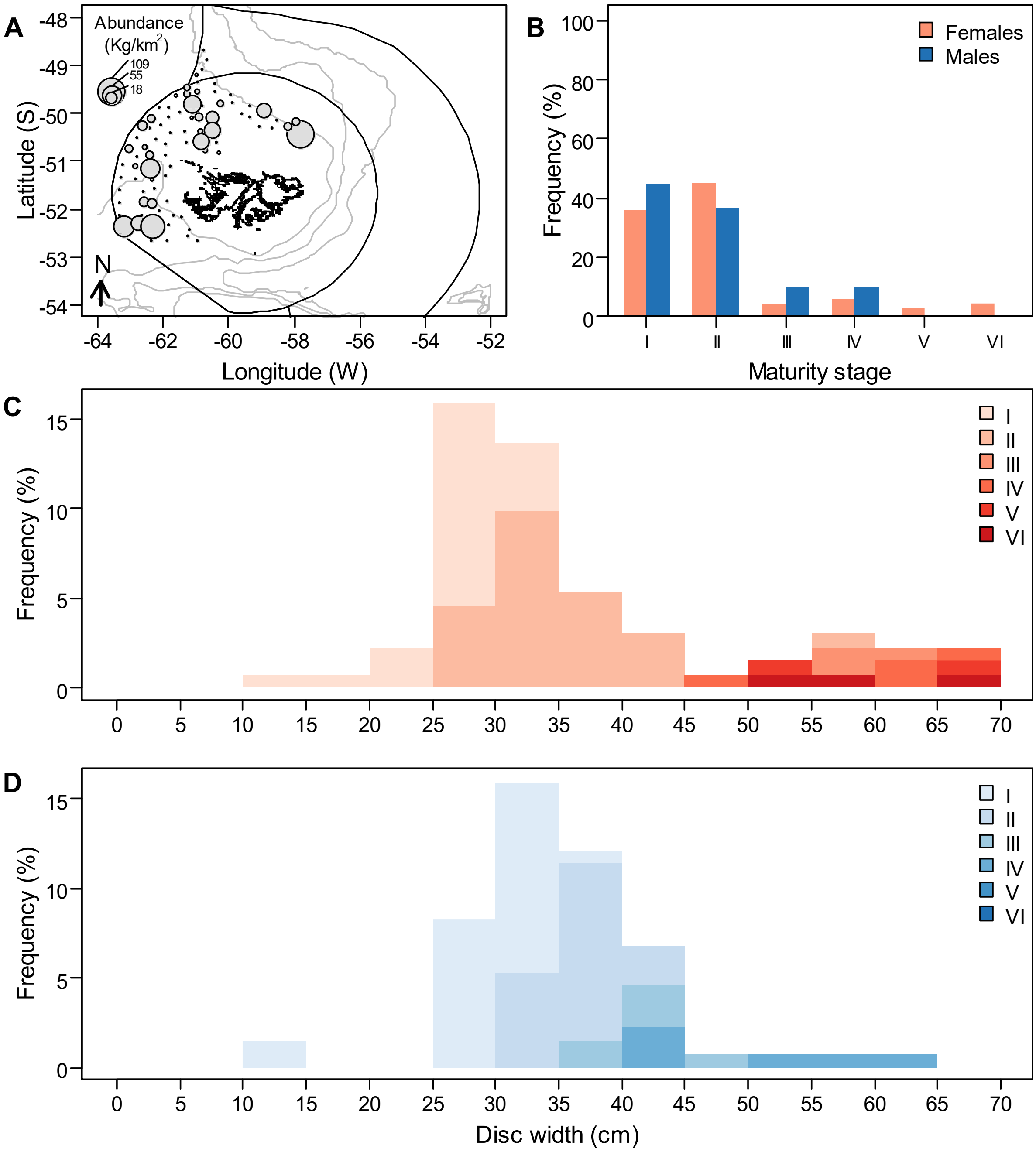

Figure 17. Biological data of *Bathyraja brachyurops* (Blonde skate; RBR). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); length frequencies (%) of C) females (n = 69) and D) males (n = 63) with 5 cm size class.

3.4.3. *Dipturus lamillai* – Warrah skate

The total catch of the warrah skate was 118 kg. This species was caught at 30 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.9 to 11 kg, densities ranged from 4 to 54 kg/km^2, and CPUE ranged from 0.9 to 11 kg/h. Higher densities were observed to the north and to the south-west in the FICZ (Figure 18A). Most females were maturing (maturity stage II), while males were juvenile (maturity stage I), maturing or adult developing (maturity stage III; Figure 18B). Females were 37–78 cm disc width and modal disc width was identified at 50–54 cm disc width size class (Figure 18C). Males were 38–60 cm disc width; the small number of males sampled does not allow identifying the modal length for males (Figure 18D).

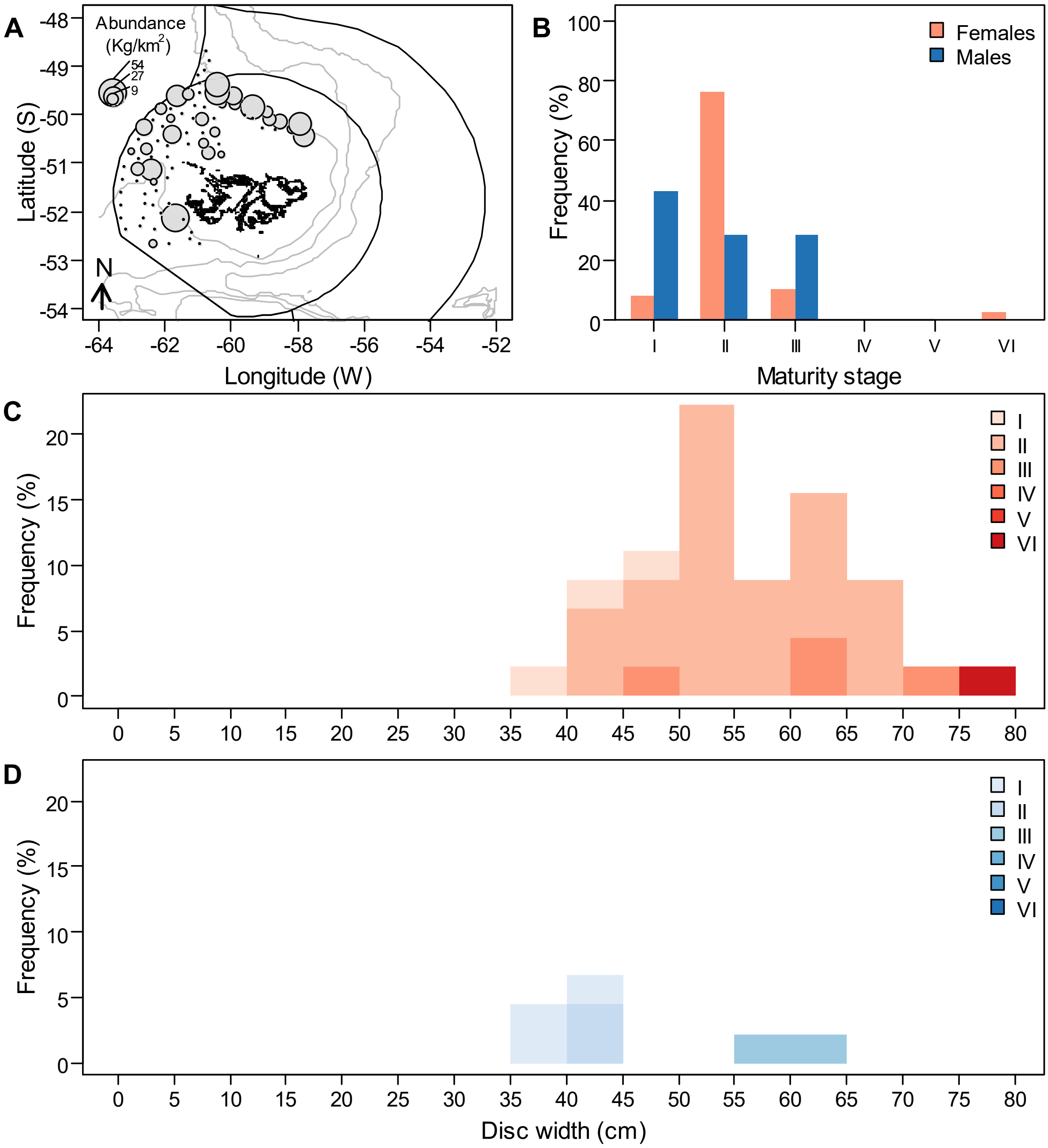

Figure 18. Biological data of *Dipturus lamillai* (Yellow nose skate; RFL). A) Map of the densities in kg/km²; B) relative frequency (%) of specimens of each sex per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); length frequencies (%) of C) females (n = 38) and D) males (n = 7) with 5 cm size class.

3.4.4. *Bathyraja griseocauda* – Grey-tailed skate

The total catch of the grey-tailed skate was 295 kg. This species was caught at 22 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.2 to 47 kg, densities ranged from 0.8 to 229 kg/km^2, and CPUE ranged from 0.2 to 47 kg/h. Highest densities were observed to the south-west and in some stations to the north in the FICZ (Figure 19A). A total of 68 individuals (35 females, 33 males) were sampled; most females were juveniles (maturity stage I), whereas males were mainly juveniles or maturing individuals (maturity stage II; Figure 19B). The size of females ranged between 19 cm and 100 cm disc width (Figure 19C). Males size ranged between 15 cm and 90 cm disc width (Figure 19D).

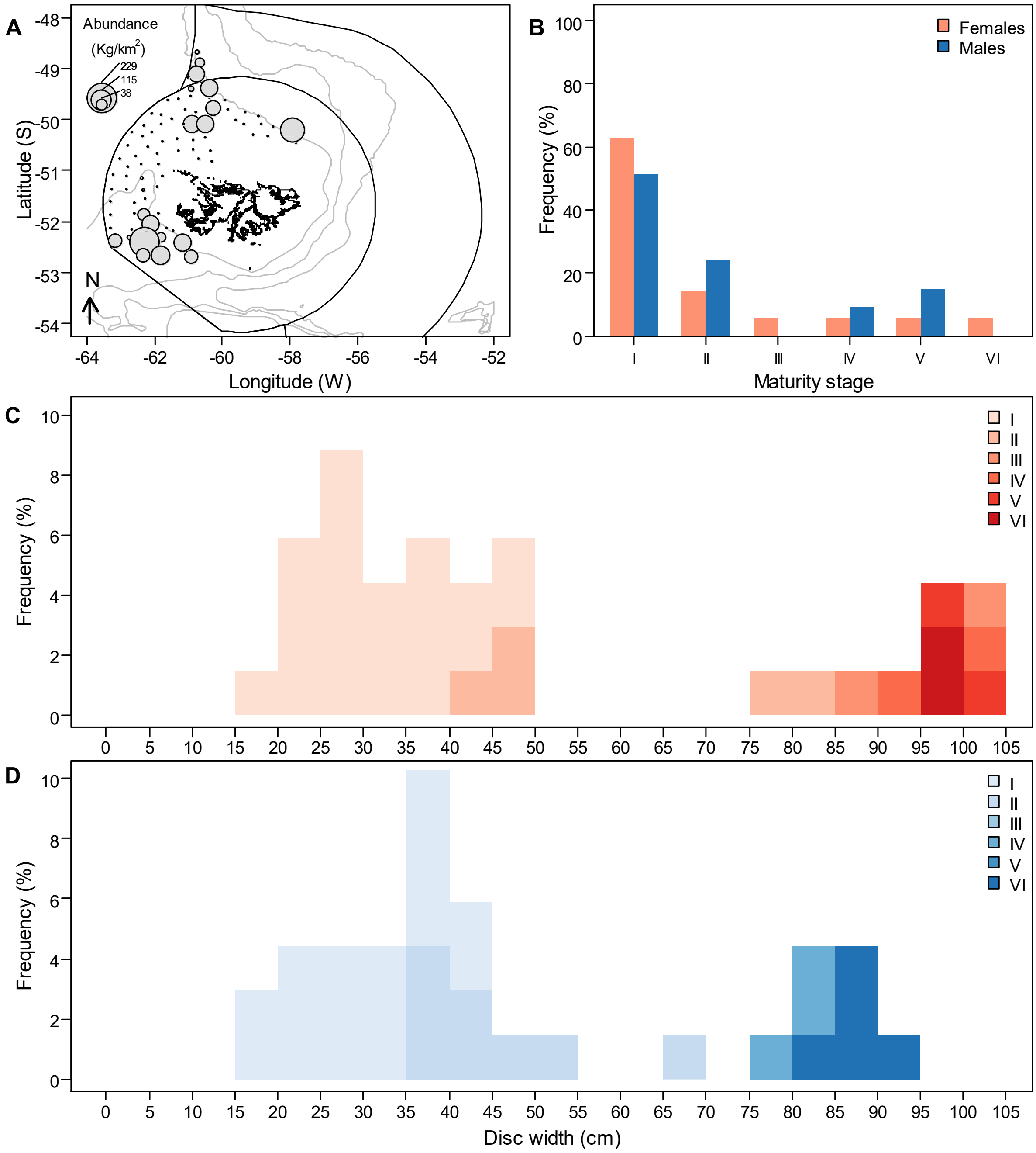

Figure 19. Biological data of *Bathyraja griseocauda* (Grey tailed skate; RGR). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); length frequencies (%) of C) females (n = 35) and D) males (n = 33) with 5 cm size class.

3.4.5. *Bathyraja macloviana* – Falkland skate

The total catch of the Falkland skate was 19 kg. This species was caught at 19 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.1 to 11 kg, densities ranged from 0.6 to 53 kg/km^2, and CPUE ranged from 0.1 to 11 kg/h. Highest densities were observed to the north-east of East Falkland and to the north-west of West Falkland, near the limit of the FICZ (Figure 20A). Most females were maturing (maturity stage II), juveniles (maturity stage I) or resting (maturity stage VI), and most males were mature (maturity stages IV), or juveniles (Figure 20B). Females were 23–37 cm disc width (Figure 20C), and males were 17–37 cm disc width (Figure 20D).

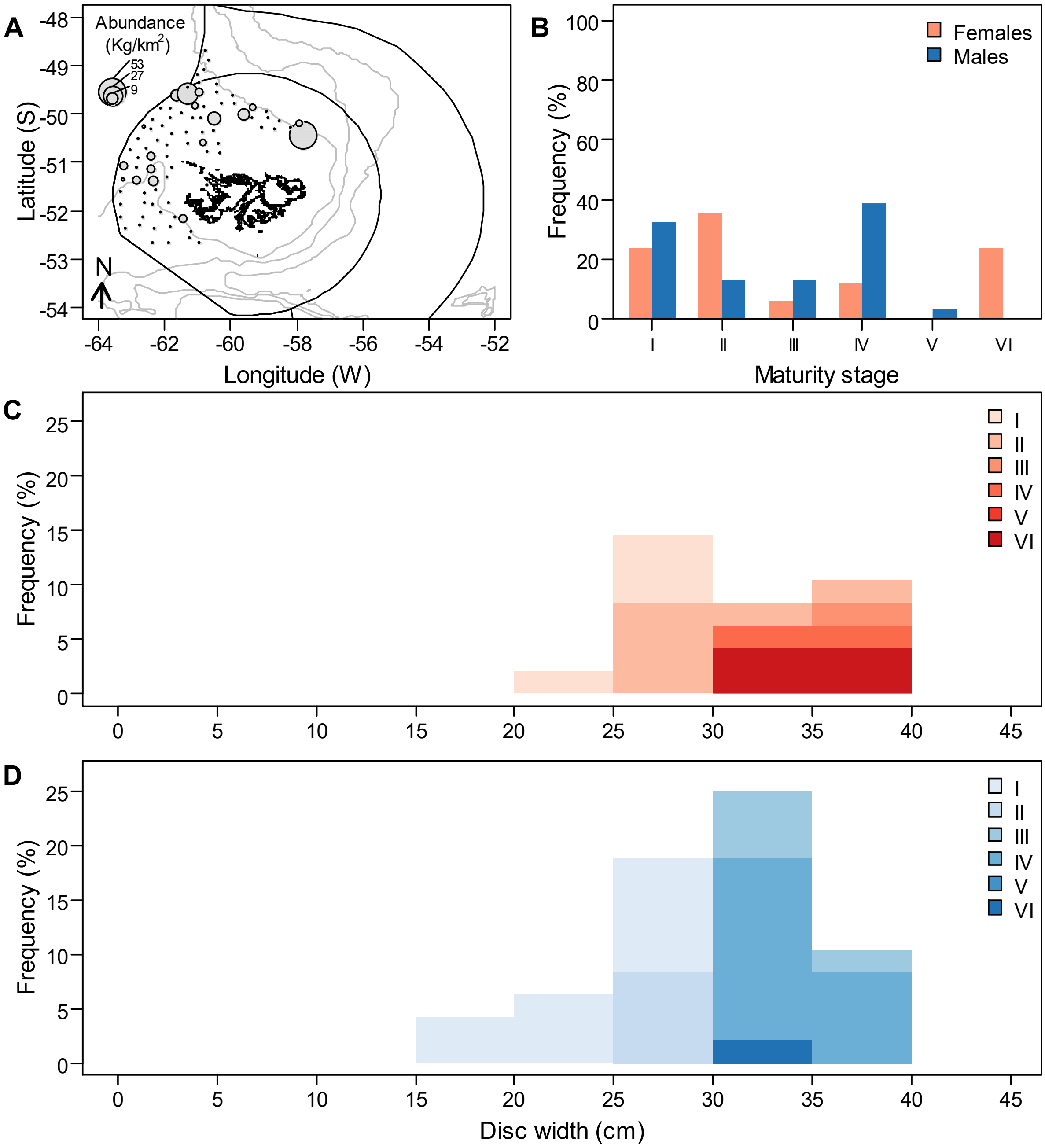

Figure 20. Biological data of *Bathyraja macloviana* (Falkland skate; RMC). A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); length frequencies (%) of C) females (n = 17) and D) males (n = 31) with 5 cm size class.

3.5. Biological information of sharks species

3.5.1. *Schroederichthys bivius* – Catshark

The total catch of catshark was 114 kg. This species was caught at 49 of the 84 trawl stations sampled throughout the survey. Catches ranged from 0.01 to 17 kg, densities ranged from 0.03 to 83 kg/km^2, and CPUE ranged from 0.01 to 17 kg/h. High densities were observed to the north and north-east in the FICZ (Figure 21A). Most females found alive were released as soon as possible without assessing maturity stages, and their maturity stage was recorded as zero. Most males were juvenile (maturity stage I), or mature (maturity stage IV; Figure 21B). Females were 16–61 cm total length (Figure 21C). Males were 25–77 cm total length (Figure 21D).

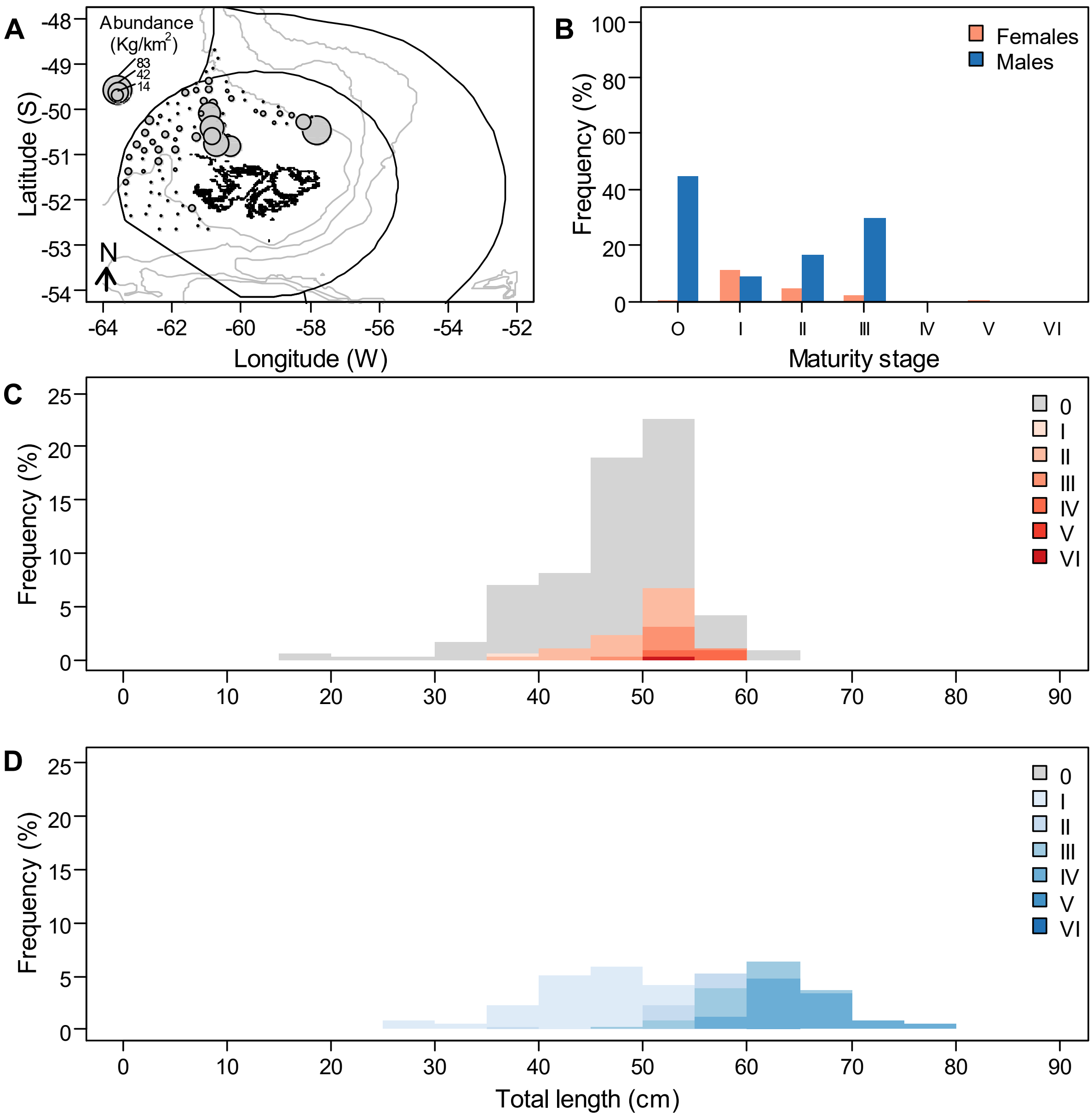

Figure 21. Biological data of *Schroederichthys bivius* (Catshark; DGH); A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); length frequencies (%) of C) females (n = 42 + n = 189 with maturity 0) and D) males (n = 127) with 5 cm size class.

3.5.2. *Squalus acanthias* – Dogfish

The total catch of dogfish was 495 kg. This species was caught at 50 of the 84 trawl stations sampled through the survey. Catches ranged from 0.9 to 102 kg, densities ranged from 4.3 to 475 kg/km2, and CPUE ranged from 0.9 to 102 kg/h. High densities were observed to the north in the limit between the FICZ and the FOCZ (Figure 22A). Most females found alive were released as soon as possible without assessing maturity stages, and their maturity stage was recorded as zero. Most males were mature (maturity stage IV; Figure 22B). Females were 46–90 cm total length, with modal length at 60–64 cm total length (Figure 22C). Males were 53–77 cm total length, with modal length at 65–69 cm total length (Figure 22D) .

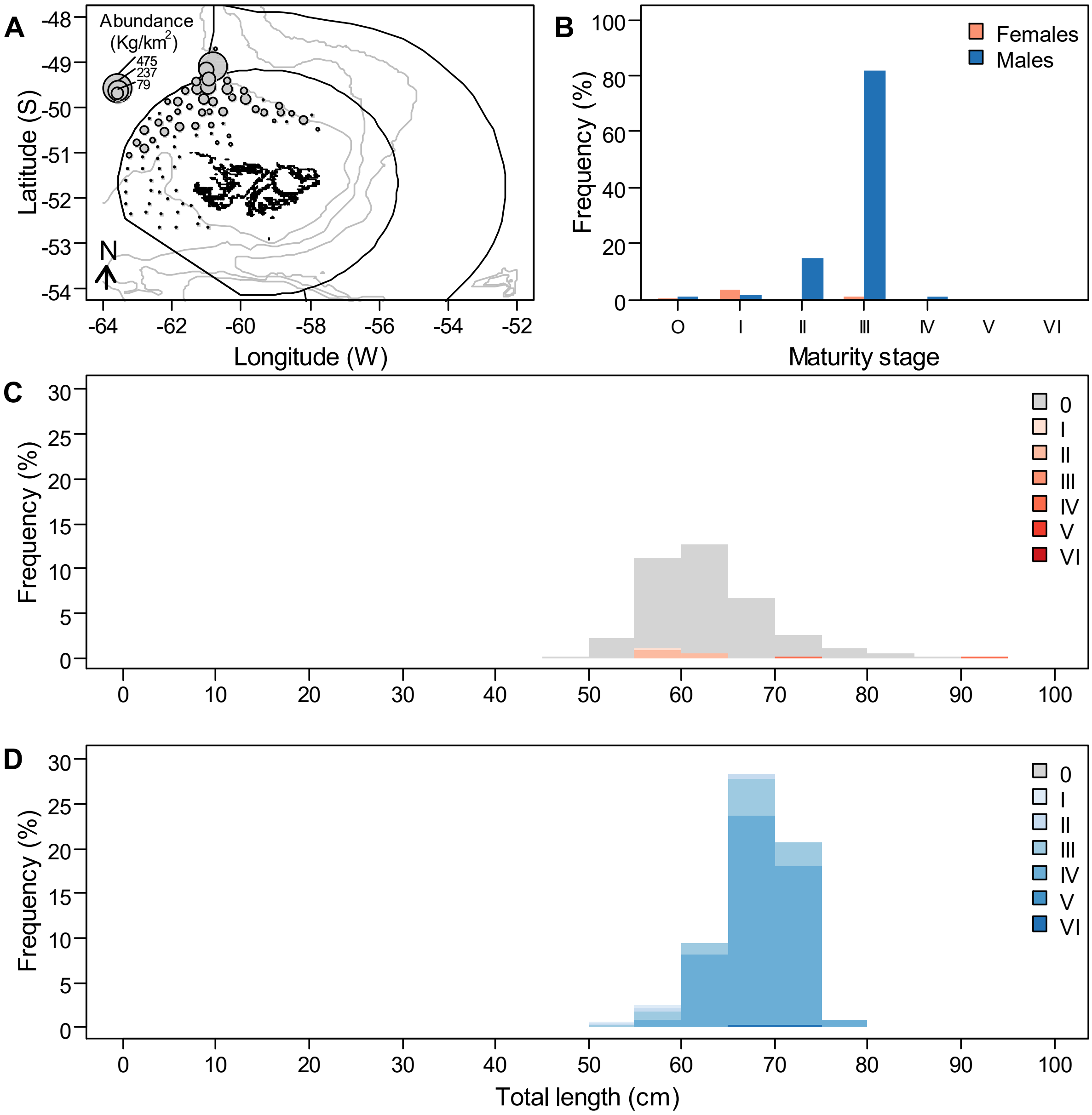

Figure 22. Biological data of *Squalus acanthias* (Dogfish; DGS); A) Map of the densities in kg/km^2; B) relative frequency (%) of specimens of each sex per maturity stage (I, juvenile; II, adolescent maturing; III, adult developing; IV, adult mature; V, adult laying/running; VI, adult resting); length frequencies (%) of C) females (n = 9 + n = 161 with maturity 0) and D) males (n = 283) with 5 cm size class.

3.6. Inshore survey

Inshore stations were conducted at the beginning of the February 2019 and 2020 groundfish surveys, and at the end of the February 2021 groundfish survey to collect data on the distribution and ecology of juvenile Patagonian toothfish (*D. eleginoides*). Inshore stations were not conducted in the February 2022 and 2023 groundfish surveys.

3.7. Conversion factor

Following recommendation from the 2022 February groundfish biomass survey (ZDLT1-2022-02; Trevizan *et al*., 2022), conversion factor (CF) work was conducted on *Seriolella porosa* – driftfish when there were more than 20 animals to sample at a station. FIFD used a conversion factor of 1.5 for head-gutted-tail off (HGT) driftfish from 2015 (M. Jenkins, FIFD, *pers. comm.*). Conversion factor was changed to 2.0 in 2023 (FIFD, 2023). Results of the work conducted can be found in Table III.

Precaution should be taken as some of the following points could affect the calculation of CF:

- Sampling was conducted on a relatively small number of animals;
- Sampling was conducted during a few days in February when most animals were in post-spawning stages;
- Sampling was conducted on similar size classes and CF might change with the size of the fish;
- ZDLT1 crew and factory setup are intended to process squid as a priority;
- Catches were relatively small and workload in the factory was not intense, therefore it may not be comparable with processing during commercial fishing.

Table III. Conversion factor for *Seriolella porosa* HGT product conducted during the groundfish survey ZDLT1-2023-02. CF = Conversion factor.

Station	Number sampled	Weight, green (kg)	Weight, HGT (kg)	CF
3792	112	188.82	116.08	1.63
3794	39	69.78	40.82	1.71
3796	31	52.62	32.90	1.60
3799	23	37.06	23.12	1.60
3802	23	38.18	22.40	1.70
3804	66	114.76	68.87	1.67
3806	20	32.60	19.36	1.68
3808	32	57.78	35.40	1.63
3810	32	57.70	35.38	1.63
3812	30	55.98	34.58	1.62
Total	**408**	**705.28**	**428.91**	**1.64**

3.8. Oceanography

Oceanographic data were collected at 78 of the 84 stations conducted during the survey. The CTD memory capacity posed a significant challenge as it could only store about 30 runs. Therefore, data had to be downloaded every third day to prevent data loss. However, the cable connection between the CTD and the computer was faulty. The problem persisted until the CTD memory capacity was reached for the first time during the survey, and the team had to delete some of the data to free up space. This meant that about 1.5 days' worth of data were lost (CTD stations 3721, 3723, 3725, 3726, 3728 and 3730 from 09/02/2023 to 10/02/2023). Additionally, on 11/02/2023 two trawls were not covered with CTD as the issue remained unsolved at this point. Cleaning the cable contacts with pressured air from residues of grease helped improving the connection, even though two people were necessary to operate the data transfer through the survey: one person securing the connection between the cable and the CTD, and the other person operating the computer. The team was able to continue conducting the CTD measurement as usual, before or after every trawl.

The density map shows the lowest-density water at 10 m in the north-east of the zone (<25 kg/m^3), adjacent to an area of higher density to its south as a result of a peak in salinity. At 100 m and on seabed level, density measures were mostly uniform with a higher density water mass (>27 kg/m^3) pushing from the south west up the west of the Falklands to join the gyre formed by eastern branch of the Falklands Current at sea bed level (Figure 23).

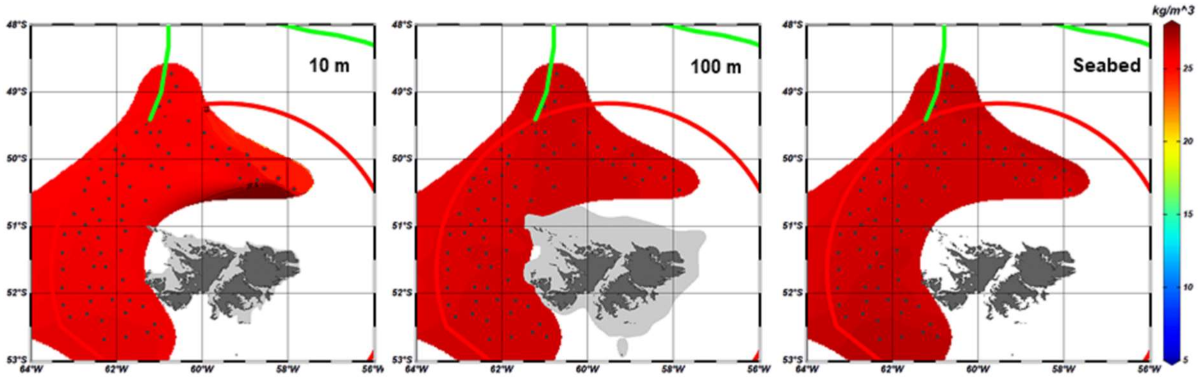

Figure 23. Density at 10 m, 100 m, and seabed.

At the surface, salinity was between 33.3 and 35 PSU with the lowest salinity in the north-east, and the highest salinity closer to the Falklands in the north-east. As depth increases less variation was observed, with 33.5–34.3 PSU at the seabed. At seabed level salinity was higher in the water close to the western branch of the Falklands Current; same applies at 100 m depth. In the waters to the north and to the south-west salinity was >34.0 PSU. On the shelf to the west of the Falklands salinity was > 34.3 PSU (Figure 24).

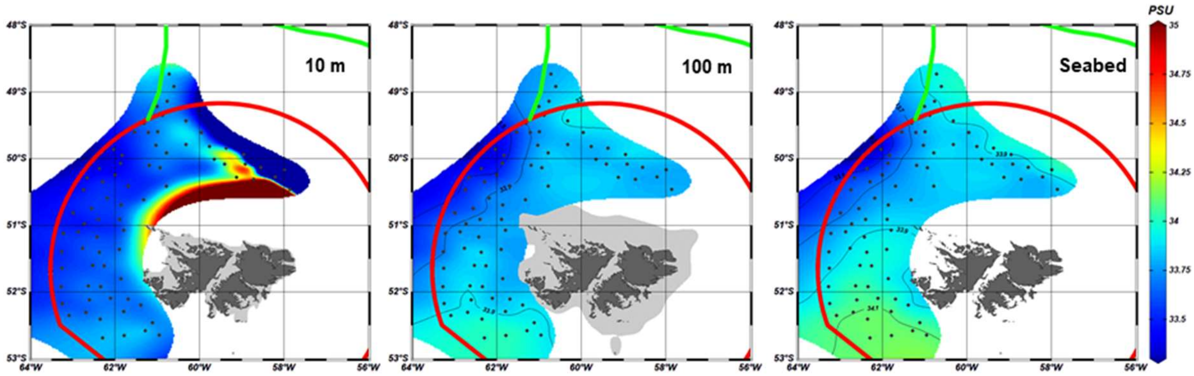

Figure 24. Salinity at 10 m, 100 m and seabed (contours at 0.2 PSU)

The first layer at 10 m was the shallowest depth common to all CTD casts. Temperature data shows two patterns, with warm water at the surface along the edge of the shelf, and cooler water pushing north from the south-west. As depth increases there is considerable mixing at 100 m and further decrease of sea temperature in the south-west due to the influence of the Falkland current transporting colder water from the Antarctic Circumpolar current (Figure 25).

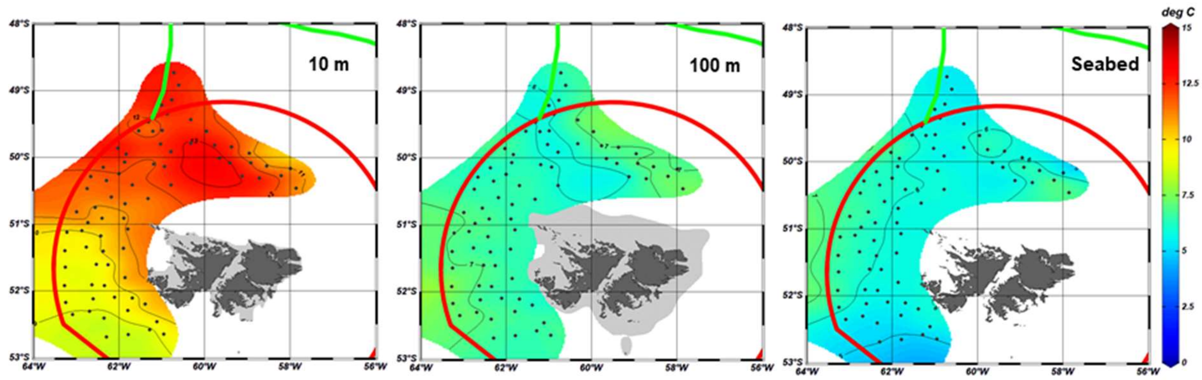

Figure 25. Temperature at 10 m, 100 m and seabed (contours at 1 degree C)

At 10 m depth, fluorescence levels over 10 and up to 15 RFU (relative fluorescence units) were measured in the north-east of the Falklands. While fluorescence depletes with depth an unusual peak of up to 28 RFU was measured at seabed level to the north-west of the Islands (Figure 26).

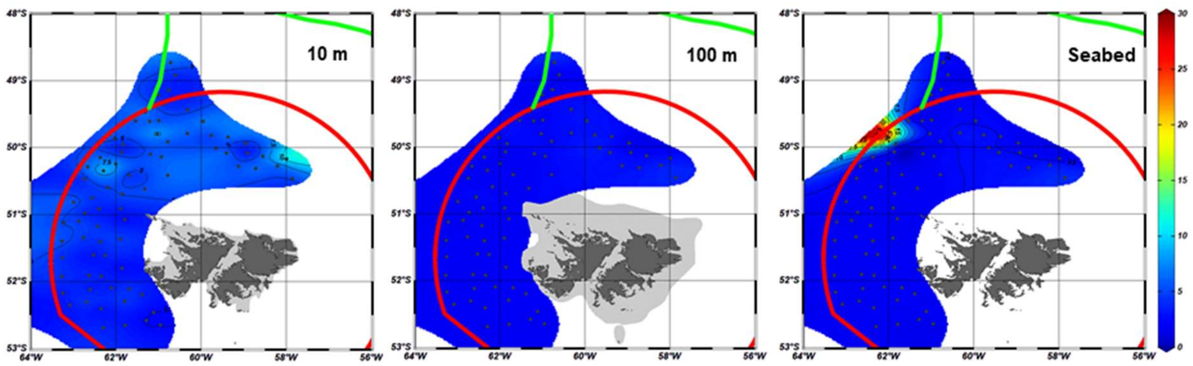

Figure 26. Fluorescence at 10 m, 100 m and seabed (contours at 2.5 RFU)

4. Discussion and Conclusions

Red cod highest density occurred to the north-west limit of the FICZ during the February 2023 groundfish survey, with secondary aggregations to the south-west, consistent with patterns observed in most February groundfish surveys since 2010. Immature and resting individuals were more frequent, also consistent with previous February groundfish surveys, suggesting that red cod uses Falkland Islands waters as feeding grounds during February, whereas spawning occurs between August and October to the south and south-west of West Falkland (Arkhipkin et al. 2010; Brickle et al. 2011). The length-group of <20 cm animals was represented in lower numbers in February 2023 compared with most February groundfish surveys since 2010, a sign of poor recruitment. This year, red cod comprised 11.7% of the total survey catch, below average compared with the previous February groundfish surveys. Red cod biomass calculated from February parallel groundfish and calamari pre-recruitment surveys (from now on referred as 'February parallel demersal surveys') has decreased since 2010 (Ramos & Winter 2023).

Southern blue whiting aggregations occurred to the south-west and north-west of the FICZ, at stations deeper than 200 m; this pattern has been observed since 2016 but to the south-west of the FICZ only. Immature individuals are frequent during February in Falkland Islands waters, and resting maturity stage in minor proportion. This finding is consistent with the reproductive timing of this species in Falkland Islands waters, i.e., spawning occurs during September and October to the south of West Falkland (Macchi et al. 2005; Arkhipkin et al. 2022). Southern blue whiting comprised 1.8% of the total survey catch, which is near the average southern blue whiting catch proportion (1.3%) since the February 2010 groundfish survey. The biomass of southern blue whiting during the February 2023 parallel demersal surveys was calculated at 39,575 t, lower than in 2010 but with constant increase since 2020 (Ramos & Winter 2023). This species is demersal-pelagic, and it must be noted that the parallel demersal surveys only represent a portion of the stock that was collected near the seabed.

Common hake started to migrate to Falkland Islands waters with the Argentine inflow. The highest densities occurred to the north-west of the FICZ, consistent with previous February groundfish surveys. Falkland Islands waters are used as feeding ground by this species (Arkhipkin et al. 2003). This explains why mainly post-spawning hake migrated to Falkland Islands waters, as suggested by the higher frequency of adult males at maturity stages VII and VIII, and adult females at maturity stages II, VII and VIII. Hake was in the range of sizes between 30 cm and 90 cm total length during the February groundfish surveys in 2010 and 2011. However, individuals were smaller in most February surveys since 2015 when the largest individuals were up to 60 cm (Ramos & Winter 2023). The catch proportion of hake in February groundfish surveys has increased since 2010, and reached its highest value in 2022. This is consistent with the highest biomass calculated for 2022 (42,421 t), while the biomass estimation for February 2023 (32,617 t) was the third highest during February parallel demersal surveys since 2010 (Ramos & Winter 2023).

Kingclip was scattered across the survey area, as in previous February groundfish surveys. Mainly resting individuals are present this time of the year in Falkland Islands, and in small numbers given that most of the kingclip stock moves out of Falkland Islands from January through March to spawn (Arkhipkin et al. 2012). However, February 2023 saw an increase in developing individuals. Modal length was detected at about 80 cm total length for females and at 67 cm total length for males, which were higher than those reported during the February 2018–2021 groundfish surveys. The catch proportion of kingclip during the February 2023 groundfish survey was 13.6%, nearly twice the average since 2010 (6.4%). Accordingly, the biomass of kingclip was calculated at 35,880 t for February 2023, above the biomass average since 2010 for February parallel demersal surveys (Ramos & Winter 2023).

Rock cod occurred throughout the survey area, with denser concentrations to the north-west of the FICZ; dense aggregations of rock cod are located mainly along the west this time of the year. Consistent with previous February groundfish surveys, rock cod were mainly in resting or immature maturity stages, as spawning occurs in austral autumn on the Argentine Shelf at 42°S, at the end of austral autumn and in part of austral winter at the shelf break in Falkland Islands waters, and in austral spring at the Burdwood Bank (Ekau 1982; Brickle et al. 2006). This year, rock cod was the second most abundant species in terms of weight caught, and comprised 13.8% of the total survey catch. However, this is below the average catch proportion (22.2%) since the February 2010 groundfish survey, with catch proportions decreasing every February groundfish survey from 2010 to 2021. The biomass of rock cod was calculated at 64,729 t from February parallel demersal surveys, the third lowest since February 2010 (Ramos & Winter 2023).

Hoki denser aggregations occurred to the south-west of the FICZ, at stations deeper than 200 m; this pattern has been observed since 2016. Post-spawning hoki are common during February in Falkland Islands waters, in particular at resting maturity stage. However, a high proportion of recovering spent individuals were reported during the February 2023 groundfish survey. Spawning occurs during austral winter outside of Falkland Islands waters, and part of the hoki population migrates in spring to feeding grounds in the slope areas of the Falkland Current Front (west of the Falkland Islands) (Brickle et al. 2009; Arkhipkin et al. 2012). Hoki was the most abundant species in terms of weight caught during this survey, and comprised 19.4% of the total survey catch, which is the average hoki catch proportion (19.2%) since the February 2010 groundfish survey. The biomass of hoki during the February 2023 parallel demersal surveys was calculated at 131,715 t, lower than in 2021 and 2022 (Ramos & Winter 2023). As this species is demersal-pelagic, it must be noted that the parallel demersal surveys only represent a portion of the stock that was collected near the seabed.

Banded whiptail grenadier denser aggregations occurred at stations deeper than 200 m to the south-west of the FICZ, consistent with patterns of distribution observed since the February 2016 groundfish survey. Individuals were mainly post-spawning at resting maturity stage or recovering spent, whereas resting or early developing individuals were more common in previous surveys. The banded whiptail grenadier contributed 6.7% of the total catch proportion during the survey, above the average catch proportion (5.1%) since the February groundfish survey 2010. However, the biomass of banded whiptail grenadier was 34,369 t, calculated from the February 2023 parallel demersal surveys, which is the third lowest biomass calculated since the February 2010 parallel demersal surveys (Ramos & Winter 2023).

In February 2023, a total of 10,483 t of *I. argentinus* were estimated in Falkland Islands waters (Ramos & Winter 2023). This biomass estimated was below average compared to research surveys in last years. Over the years that the groundfish survey has been conducted, *I. argentinus* biomass ranged from 201 t in 2016 to 210,513 t in 2015, which is year with the record Illex commercial catch. Two length groups were detected every year.

Patagonian squid was abundant everywhere on the shelf of the surveyed area, with largest densities to the south-west and west of the FICZ.

The two predominant skate species historically targeted in the FICZ showed evidence of declines in abundance from the February 2010 to the February 2023 groundfish surveys. The blonde skate *B. brachyurops* showed declines in CPUE, with highest CPUE being recorded in 2011 at 16.3 kg/h and lowest CPUE in 2023 with 1.8 kg/h. Similar declining trend was evident for the warrah skate *D. lamillai*, with highest recorded CPUE in the February 2015 groundfish survey at 8.4 kg/h, and the lowest CPUE at 1.4 kg/h during the February 2023 groundfish survey.

The current conversion factor (CF) for driftfish used by FIFD is 2.0; CF calculated for driftfish during the February 2023 groundfish surveys was 1.64 based on 408 animals processed.

5. Recommendations

1. The number and location of stations should be consistent across groundfish surveys. The inclusion or omission of stations from one year to the next may bias biomass estimates and prevent examination of biomass trends through time.
2. Apparent declines in the occurrence of skate species require further investigation. Future research objectives should be identified to improve our understanding of the spatial-temporal interactions of species assemblages as well as describing aspects of their biology, ecology and susceptibility to fisheries exploitation.
3. Conversion factor research for driftfish should be continued in upcoming years as preliminary results showed significant difference with the conversion factor that is currently being used.

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