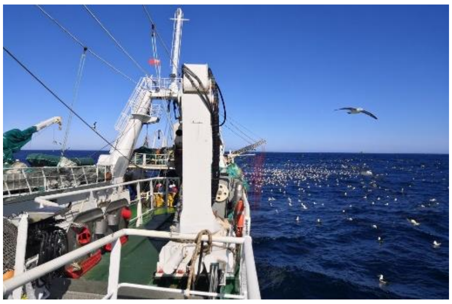
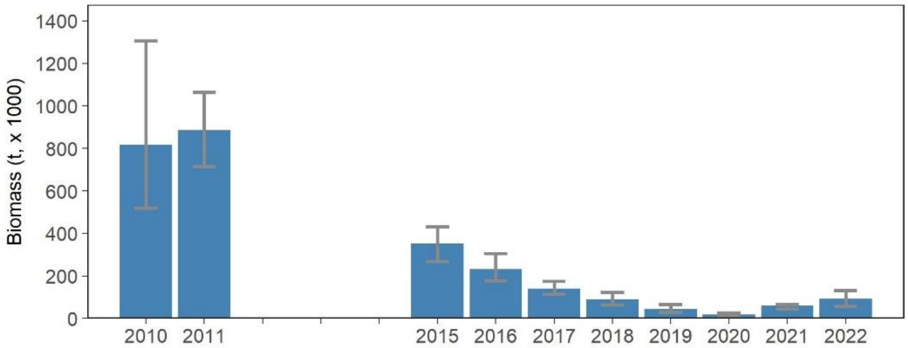
February bottom trawl survey biomasses of fishery species in Falkland Islands waters, 2010–2022





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Reviewed and approved on 19 May 2022 by:

Andrea Clausen
Director of Natural Resources
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February bottom trawl survey biomasses of fishery species in Falkland Islands waters, 2010–2022

1. Summary

Survey biomass assessments of 11 commercial stocks (Argentine shortfin squid, banded whiptail grenadier, common hake, hoki, kingclip, Patagonian squid, red cod, rock cod, southern blue whiting, southern hake, and toothfish) were carried out in Falkland Islands waters. The assessments were based on catch data of 1,395 bottom trawls taken during the February parallel groundfish and calamari pre-season surveys from 2010, 2011, and 2015 to 2022.

Rock cod, red cod, and southern hake had statistically significant declining trends in biomass between 2010 and 2022. The biomass of rock cod in 2022 was only 11% of its biomass in 2010, and the biomass of southern hake in 2022 was 18% of its biomass in 2010. The biomass of red cod had a significant decline from 2010 to 2020, and increased in 2021 and 2022. Banded whiptail grenadier, hoki, southern blue whiting, and toothfish had declining trends from 2010 to 2019–2020, with subsequent biomass increase in 2021 and 2022. Only the common hake had a significant increase in biomass from 2010 to 2022.

Most stocks assessed in Falkland Islands waters are targeted across several nations' Exclusive Economic Zones, and for some stocks the Falkland Islands contribute a small proportion of the total shared catch in the Southwest Atlantic and Southeast Pacific. Declines in biomass of some of these stocks may also be in part due to fishing pressure outside Falkland Islands waters. However, for some stocks the Falkland Islands contribute a major proportion of the total shared catch, and management decisions made by the Falkland Islands Fisheries Department are important for those stocks, e.g., rock cod and red cod.

In February 2022, the geographic distributions of the Argentine shortfin squid and common hake were to the north-west in Falkland Island waters. Red cod occurred along the west, with the highest densities to the north-west. Banded whiptail grenadier, hoki, kingclip, southern blue whiting, southern hake, and toothfish were located mainly to the south-west. Patagonian squid and rock cod were caught around Falkland Islands waters but mainly to the south.

2. Introduction

The Falkland Islands shelf is located within the Patagonian large marine ecosystem, one of the most productive fishing 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). The temperate 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).

Squids and fishes around the Falkland Islands have been targeted by international fishing fleets over decades. However, catch data by species only started to be recorded systematically from the year 1987 (Falkland Islands Government 1989). Total catches reached a maximum of 462,487 t in 2015, in part due to the unusual large intrusion of *I. argentinus* in Falkland Islands waters from April to May 2015 (Winter 2015) that resulted in record catches (332,862 t) for this species that year. Contrastingly, total catches since 2016 (mean 167,076 t) have been amongst the lowest since 1987 (Falkland Islands Government 1989, 2021).

Finfish license allocations in the Falkland Islands used to be set by Total Allowable Effort (TAE) calculated as a function of the catchability of an index species that represents the main target of the fishery. This approach works under the assumption of consistent relationships among catch, effort, and biomass. The first index species for finfish TAE was southern blue whiting (*Micromesistius australis australis*). However, with declining catches of southern blue whiting and increasing catches of rock cod (*Patagonotothen ramsayi*), the index species was re-examined (Payá et al. 2010) and switched in 2011 from southern blue whiting to rock cod in order to set effort allocation. Catches of rock cod decreased since 2010 (Falkland Islands Government 2021; Ramos & Winter 2022a) whereas catches of common hake (*Merluccius hubbsi*) increased, and reached a maximum catch in 2021 (Ramos & Winter *in prep.*). The use of an index species to manage all Falkland Islands commercial species was thus considered unreliable, and the Falkland Islands Government mandated assessing each individual commercial stock. An important step to achieve this goal is to estimate the abundance and distribution of each commercial stock in the Falkland Islands Conservation Zones (FICZ and FOCZ) based on commercial and scientific surveys.

The Falkland Islands Fisheries Department (FIFD) has carried out parallel groundfish and calamari (*Doryteuthis gahi*) pre-season surveys every February since 2010, except for 2012, 2013, and 2014. The groundfish surveys are conducted along the north, west and south-west of Falkland Islands waters. The calamari pre-season surveys are conducted along the '*Loligo Box*' to the east of the Falkland Islands. The original objective of these surveys was to provide a synchronous biomass estimate of rock cod on the entire Falklands fishing grounds (Winter et al. 2010), which has since been expanded to provide information on other commercial stocks. It is noted, however, that Falkland Islands waters represent only part of the range for most stocks examined, and for some migratory stocks February is not a time of peak abundance, i.e. common hake (Arkhipkin et al. 2015), kingclip (Arkhipkin et al. 2012), and southern blue whiting (Barabanov 1982). Stations to the south-west of the FICZ have also not been sampled equally in all years, which may influence biomass estimates for stocks that occur in that area during February, such as banded whiptail grenadier, hoki, southern blue whiting, and toothfish.

This report summarizes catch data jointly from the groundfish survey and the calamari pre-season survey, to estimate the biomass of key stocks in Falkland Islands waters since 2010. Previous index species (southern blue whiting and rock cod), and all species of commercial value are included in this report.

3. Methods

3.1. Trawl stations and biological sampling

Concurrent groundfish and calamari pre-season research surveys were carried out during February 2010–2011 and 2015–2022 on board of chartered fishing trawlers to cover the Falkland Islands fishing zone (Fig. 1). All trawls were bottom trawls; GPS latitude, GPS longitude, net vertical opening, trawl door spread, and trawl speed were recorded on the ship's bridge during the progress of each trawl.

On both surveys, all species from the catch of each trawl station were sorted by FIFD scientific personnel and the vessel's factory crew. FIFD scientific personnel recorded the total catch of each species assessed by a combination of weighing on an electronic balance to the nearest 0.01 kg and factory production records. Random samples of up to 100 individuals of each species were measured to the lowest 1 cm for finfish and to the lowest 0.5 cm for squids. Dorsal mantle length was measured for Argentine shortfin squid and Patagonian squid. Total length was measured for common hake, kingclip, red cod, rock cod, southern blue whiting, southern hake, and toothfish. Pre-anal length was measured for banded whiptail grenadier and hoki. Hereafter, these different length measurements will be referred to as 'length' only. In this report, catches and length frequencies were assessed for eleven species that represent important commercial targets in the Falkland Islands and other nations' fishing zones (Table I).

The duration of each trawl was approximately 60 min on the bottom during groundfish surveys, and 120 min on the bottom during calamari pre-season surveys. Characteristics of the trawl nets, trawl performance, and biological sampling during groundfish and calamari pre-season surveys can be consulted in detail in Arkhipkin et al. (2010, 2011, 2019), Brickle & Laptikhovsky (2010), Gras et al. (2015, 2016, 2017, 2018), Winter et al. (2011, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022), Randhawa et al. (2020), and Trevizan et al. (2021, *in prep.*). These surveys were designed to be consistent in the number and position of stations across years. However, there were variations in the number of stations mainly to the south-west of the FICZ for specific purposes of the February 2018 and 2020 groundfish surveys (Gras et al. 2018; Randhawa et al. 2020). In February 2022, a total of 42 stations were conducted instead of the usual > 80 stations (Trevizan et al. *in prep.*) due to quarantine requirements of the vessel's crew because of the COVID-19 pandemic.

Table I. Species assessed in groundfish and calamari pre-season surveys in Falkland Islands waters during February 2010–2011 and 2015–2022. Geographic distributions taken from http://www.fao.org/fishery/species/search/en

Common name	Scientific name	Distribution
Argentine shortfin squid	*Illex argentinus*	Southwest Atlantic: Brazil, Uruguay, Argentina, Falkland Islands.
Banded whiptail grenadier	*Coelorinchus fasciatus*	Southwest Atlantic: Brazil, Uruguay, Argentina, Falkland Islands. Southern Pacific: Chile, Australia, New Zealand. Southern Indian: Africa, Australia.
Common hake	*Merluccius hubbsi*	Southwest Atlantic: Brazil, Uruguay, Argentina, Falkland Islands.
Hoki	*Macruronus magellanicus*	Southwest Atlantic: Argentina, Falkland Islands. Southeast Pacific: Chile.
Kingclip	*Genypterus blacodes*	Southwest Atlantic: Brazil, Uruguay, Argentina, Falkland Islands. Southern Pacific: Chile, Australia, New Zealand.
Patagonian squid	*Doryteuthis gahi*	Southwest Atlantic: Argentina, Falkland Islands. Southern Pacific: Peru, Chile.
Red cod	*Salilota australis*	Southwest Atlantic: Argentina, Falkland Islands. Southeast Pacific: Chile.
Rock cod	*Patagonotothen ramsayi*	Southwest Atlantic: Argentina, Falkland Islands.
Southern blue whiting	*Micromesistius australis australis*	Southwest Atlantic: Argentina, Falkland Islands. Southeast Pacific: Chile. Southern Ocean: South Georgia, South Shetland, South Orkney Islands.
Southern hake	*Merluccius australis*	Southwest Atlantic: Argentina, Falkland Islands. Southern Pacific: Chile, New Zealand.
Toothfish	*Dissostichus eleginoides*	Southwest Atlantic: Argentina, Falkland Islands. Southeast Pacific: Chile. Southwest Pacific: Macquarie Island. Southern Ocean: South Georgia.

3.2. Abundance calculations

Station and catch data were recorded during the surveys, checked and uploaded to the FIFD database, from which the data were available for analyses. Trawls were excluded if not quantifiable for the following reasons: 1) the doors did not open properly, 2) the net broke during the trawl, or 3) if the net was quickly filled with medusae, which resulted in the trawl being interrupted (Appendix I).

CPUE per species were calculated for every year as the total catch weight of the species in both February surveys divided by the total fishing effort in both February surveys. Biomass densities per species at each trawl station were calculated as the species catch weight divided by the trawl station area (net horizontal opening × distance covered). For calamari pre-season surveys, net horizontal opening was derived from the distance between trawl doors (Seafish 2010). For groundfish surveys, the triangulation method that derives net horizontal opening from the distance between trawl doors is unsuitable because the geometry of the net is different. Since 2016, groundfish survey net horizontal opening has instead been measured directly from Marport sensors fitted to the extremities of the survey vessel's trawl net wings. If net horizontal opening was not recorded due to failure of the Marport sensors, it was calculated from door spread, net vertical opening and trawl speed using a generalized additive model.

Yearly trawl biomass densities were extrapolated to the survey area combining the finfish zone (122,493.7 km^2) and '*Loligo Box*' (31,296.9 km^2), partitioned into grids of 5×5 km^2. Position coordinates of trawls were converted to WGS 84 projection in UTM sector 21, and extrapolation was calculated using inverse distance weighting. The basic inverse distance weighting algorithm assigns a value *u* to any grid location *x* that is the weighted average of a known scattered set of points x_i according to the inverse of the *i* points' distances from the grid location *x*:

$$u(\mathrm{x}) = \begin{cases} \dfrac{\sum_{i=1}^{N} w_i(\mathrm{x}) u_i}{\sum_{i=1}^{N} w_i(\mathrm{x})}, & \text{if } d(\mathrm{x}, \mathrm{x_i}) \neq 0 \\ u_i, & \text{if } d(\mathrm{x}, \mathrm{x_i}) = 0 \end{cases}$$

where

$$w_i(\mathrm{x}) = \frac{1}{d(\mathrm{x}, \mathrm{x_i})^p}$$

The power parameter *p* (a positive real number) adjusts the weight of points x_i as a function of distance (x, x_i); higher values of *p* put higher influence on the points x_i closest to a given interpolated point *x*. For this survey analysis, an empirical approach to selecting *p* was used running the inverse distance weighting algorithm with *p* values from 1 to 25 by 0.25, and for each p calculating the aggregate of log proportional differences between the empirical values of density at every trawl and the interpolation at every trawl from all other trawls. The lowest aggregate of log proportional differences corresponded to the best p value. Because some points may be more clustered than others, an isolation parameter was assigned attributing more weight to points x_i in proportion to being further away from any other point x_i. Isolation parameters (s) per yearly survey were calculated as the standardized mean of distances between each point x_i and all other points x_j:

$$s(\mathrm{x_i}) = \overline{d(\mathrm{x_i}, \mathrm{x_j})}$$

An additional weighting factor was included to adjust for trawl differences in area coverage. Survey trawls are generally standardized (60 min duration in groundfish surveys and 120 min in calamari pre-season surveys), but may be shortened on immediate notice for reasons that include unmanageably large concentrations of fish accumulating in the net. Such instances will result in the trawl being stopped just when its biomass density is maximized, rather than being stopped independently of the biomass density, and thereby create a potential bias of the density estimate at that location. For shoaling fish in sparse, highly aggregated distributions, the effect can be substantial (example for hoki; Appendix II). However, the trawl itself is not an error record that should be invalidated and removed from the data set. To mitigate the potential bias effect, swept area of each trawl was taken as a proportional weighting parameter so that a shortened trawl covering, for example, only half as much ground would have only half as much weight. Like the isolation parameters $s(\mathrm{x_i})$, the area parameters $a(\mathrm{x_i})$ were standardized (divided by their mean among all trawls), then $s(\mathrm{x_i})$ and $a(\mathrm{x_i})$ were added together and divided again by their sum to give a factor centred on 1. The revised inverse distance weighting factor is:

$$w_i(\mathrm{x}) = \left(\frac{\left(\frac{s(\mathrm{x_i}) + a(\mathrm{x_i})}{\overline{\left(s(\mathrm{x_i}) + a(\mathrm{x_i})\right)}} \right)}{d(\mathrm{x}, \mathrm{x_i})} \right)^p$$

Distance $d(x, x_i)$ is inherently calculated as Euclidean (straight-line) distance. However, the survey area surrounds the Falkland Islands and between two remote points a fish or ship would have to travel a real distance longer than straight-line; circumnavigating the landmass.

Therefore, an axial loop was drawn through the survey area (Fig. 1), and $d(x, x_i)$ was defined as the longer of either the Euclidean distance between x and x_i, or the distance on the axial loop between its two points respectively closest to x and x_i (Winter 2019).

As an extrapolation algorithm, calculated biomass over a given area will depend on the spatial distribution of surveyed densities, not just their total or average value. Accordingly, the biomass is considered an estimate.

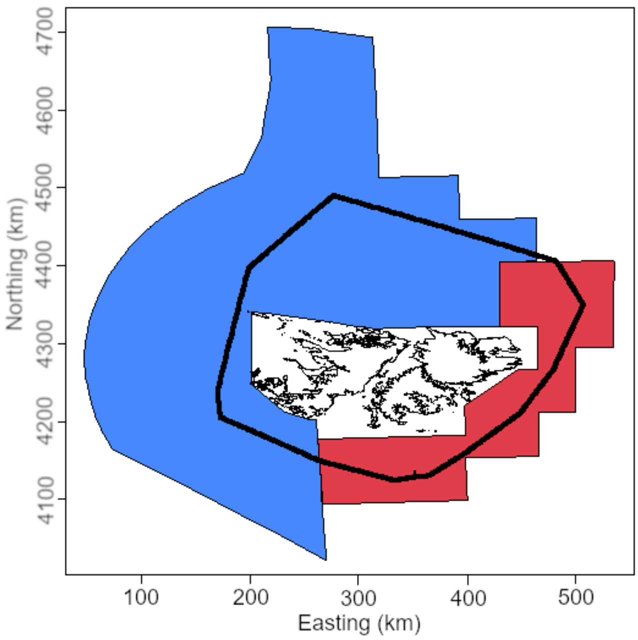

Fig. 1. Groundfish (blue) and calamari pre-season (red) survey areas, with axial loop (black line) used to define relative distances for the inverse distance weighting algorithm.

Uncertainty of the biomass estimate was calculated by a hierarchical bootstrap algorithm. In previous reports (e.g., Ramos & Winter 2021a), the bootstrap algorithm was run over 30,000 iterations with the aim to achieve narrow confidence intervals. In the present report, a comparison was undertaken to determine if the output could be reduced from 30,000 to 10,000 iterations to shorten computing time, and little difference in confidence was found (Appendix II). Therefore, survey trawls and their catches were first randomly re-sampled with replacement for 10,000 iterations, whereby each year's groundfish survey and parallel calamari pre-season survey were re-sampled separately so that both 'halves' of the survey area retained about the same relative coverage. Second, each re-sampled trawl was given a random uniform re-assignment of its coordinate position between start latitude and longitude and end latitude and longitude. Third, the isolation parameters were re-calculated for the randomized set of trawl data, and the inverse distance weighted algorithm re-applied. One iteration might thus re-sample any trawl twice or more, but each would have a slightly different position. The 95% confidence intervals of the 10,000 bootstrap iterations were used to infer uncertainty.

Only 42 trawls were conducted during the February 2022 groundfish survey instead of the usual average of 87 trawls, as the survey was shortened due to vessel quarantine requirements (Trevizan et al. *in prep.*). Because of this reduction, an algorithm was implemented to calculate the additional uncertainty of biomass estimates in February 2022 (Appendix III).

LOESS (span = 1.0, degree = 2) was implemented to examine changes in biomass through time.

4. Results

4.1. Trawls

A total of 1,395 bottom trawls were carried out during the February groundfish and calamari pre-season surveys from 2010–2011 and 2015–2022; a range of 79 to 97 trawls are usually carried out during groundfish surveys per year, and 52 to 60 trawls are carried out during calamari pre-season surveys per year. In 2022, a total of 42 trawls were carried out during the groundfish survey, and 60 trawls were carried out during the calamari pre-season survey (Appendix I).

4.2. Abundance, distribution and size structure

Biomass estimates of each commercial stock assessed are summarized in Table II.

Table II. Biomass calculations (t) of main commercial species during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters. The 95% confidence intervals are indicated in parentheses.

Year	Argentine shortfin squid	Banded whiptail grenadier	Common hake	Hoki	Kingclip	Patagonian squid
2010	8633.92 (3510.35–13384.35)	66622.68 (40514.45–98311.11)	9124.06 (6280.46–12219.25)	278980.21 (188264.88–457666.96)	21274.04 (13705.30–28607.34)	184615.48 (160421.18–239516.37)
2011	9294.45 (6777.82–12564.25)	43482.30 (20547.39–73607.37)	10180.24 (8330.32–12809.67)	221132.74 (172507.38–281186.26)	41485.02 (28424.85–63121.38)	47236.55 (39537.83–62533.45)
2015	210513.16 (129839.58–365643.99)	60434.68 (35864.88–77202.47)	15758.48 (13700.90–18213.42)	134733.17 (44674.67–179592.78)	76722.26 (30150.81–124958.88)	112296.69 (82994.09–164421.27)
2016	201.73 (146.47–263.11)	34897.77 (8500.93–55042.45)	3661.91 (2974.25–4175.68)	158388.16 (79371.74–222823.65)	24782.64 (13955.05–39613.42)	41292.65 (34357.75–53300.16)
2017	11830.16 (7412.76–18225.10)	36736.93 (19596.89–43533.35)	12419.11 (10191.95–15538.58)	28882.54 (16801.50–38817.08)	18831.90 (11873.32–28544.00)	182113.39 (145101.61–234454.73)
2018	45086.43 (30158.94–64394.07)	34256.01 (27633.27–43657.43)	8534.38 (6048.05–10877.41)	141953.50 (92768.34–204228.49)	14788.92 (11069.78–21527.00)	63154.37 (44073.52–96689.36)
2019	60076.25 (40113.04–93531.22)	21976.99 (9186.12–36085.96)	11151.32 (9483.58–14419.93)	41864.81 (5779.47–166317.90)	20869.45 (14764.62–28127.04)	214492.39 (188175.67–259467.94)
2020	148081.91 (89302.24–196203.10)	25225.42 (8358.90–43250.89)	3340.09 (2846.51–3971.84)	75402.28 (20203.23–143531.23)	14531.98 (10052.06–26304.43)	91415.65 (80832.08–126778.53)
2021	42780.70 (20466.20–68912.67)	68844.80 (32834.53–85342.42)	33281.79 (27502.33–40938.52)	245890.30 (92470.50–431476.19)	21216.07 (12901.88–35823.59)	119433.40 (98119.16–165138.90)
2022	5823.75 (2397.40–30856.33)	49558.54 (25192.54–102067.28)	42420.98 (32223.84–55471.45)	144782.83 (12362.55–248962.54)	43437.30 (14738.11–80447.75)	167439.23 (131702.50–235968.93)

Table II. *continued*

Year	Red cod	Rock cod	Southern blue whiting	Southern hake	Toothfish
2010	95050.09 (18335.99–158897.80)	817086.43 (519306.26–1306091.27)	68447.18 (25380.63–91314.04)	5096.76 (3910.63–6443.37)	9492.17 (7096.05–11727.84)
2011	166617.50 (39230.31–258711.16)	884741.55 (716079.56–1064218.58)	154691.35 (42459.43–357267.81)	5223.77 (3445.99–8095.63)	10588.19 (7859.83–13377.29)
2015	106244.23 (45278.81–160780.36)	350913.41 (269667.68–432687.92)	35307.57 (12197.06–80184.05)	2961.07 (1750.69–4350.03)	3730.91 (1359.57–4477.02)
2016	102789.02 (28384.22–149860.74)	232429.14 (177911.14–306135.45)	113986.55 (25096.46–204263.77)	1971.72 (1204.90–2963.73)	7472.12 (5373.64–10194.34)
2017	59568.95 (22863.35–86532.41)	141469.65 (113896.56–176351.05)	54456.87 (1375.47–65699.77)	1829.09 (1021.33–2478.36)	9316.94 (5662.92–11183.99)
2018	57422.88 (19277.51–117355.42)	90679.85 (63308.48–122537.23)	57963.36 (17839.34–69597.20)	1453.02 (978.54–1947.08)	8633.46 (6276.48–10886.50)
2019	83005.12 (35235.62–119480.37)	45669.16 (29040.32–66668.90)	5856.24 (205.30–34084.93)	425.70 (88.45–577.12)	6173.70 (3162.82–7794.58)
2020	21889.98 (10993.21–32014.04)	19079.02 (11656.70–27065.20)	4989.54 (26.73–15435.54)	593.71 (230.37–868.25)	2499.29 (1621.34–3392.18)
2021	35217.39 (22852.74–51663.11)	59670.41 (45689.57–66885.68)	13567.47 (3616.43–25713.15)	1943.34 (919.34–2941.07)	4395.03 (2825.50–4845.25)
2022	81176.73 (34162.13–129660.26)	93177.17 (58753.11–131454.56)	19200.92 (877.49–48977.89)	920.22 (574.62–1471.85)	3877.36 (2080.95–5151.07)

4.2.1. Argentine shortfin squid (*Illex argentinus*)

Catches of Argentine shortfin squid were higher in groundfish surveys compared with calamari pre-season surveys in any year. Catches were usually below 11 t every year, except for 2015 (32 t) and 2020 (18 t) (Fig. 2; Appendix IV). The highest CPUE of this species in the time series was calculated for 2015 (158 kg/h), and the following year saw the greatest decline in CPUE in the time series with only 0.5 kg/h. The year 2022 represented the third lowest CPUE with 4.8 kg/h (Fig. 2; Appendix V). The maximum biomass was estimated in 2015 (210,513 t) whereas the lowest biomass was estimated for 2016 (202 t); the second lowest biomass was estimated for 2022 with 5,824 t (Fig. 2; Table II). Biomass did not have a significant inter-annual trend for the period 2010 to 2022 (Appendix VI).

In 2022, this species was distributed to the north-west of West Falkland, with the highest densities near the limit of the FICZ (541 kg/km^2; Fig. 3). This may be an indication of patches of higher abundance beyond the west limit of FICZ at the time of the surveys, just before this species starts migrating into Falkland Islands waters. Across years, the Argentine shortfin squid was mainly distributed through the north of West and East Falkland, with the highest density in the time series reported to the north of East Falkland during 2015 (74,426 kg/km^2; Appendix VII).

Length frequency histograms show a range of sizes of *I. argentinus* from 5 cm to 36.5 cm across years. Two length-groups were detected every year. The modal dorsal mantle length of the smaller group was highly variable and ranged from 9.5 cm to 18.0 cm, and the modal dorsal mantle length of the larger group ranged from 23.0 cm to 25.0 cm, with 2021 and 2022 having the largest modal length (25 cm) for the large group across years (Fig. 4).

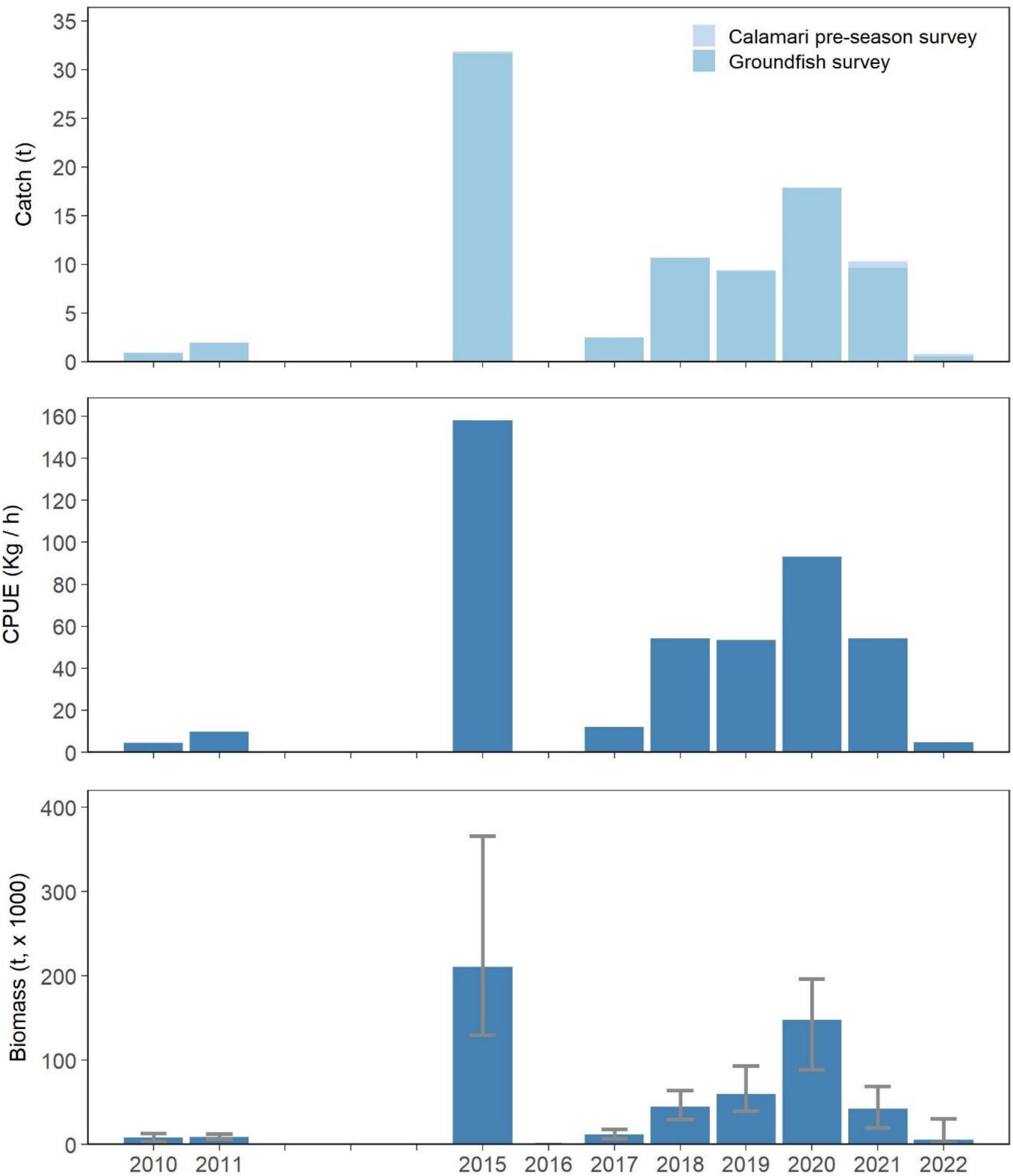

Fig. 2. Catch (t), CPUE (kg/h), and mean biomass (t) ± 95% confidence intervals of the Argentine shortfin squid (*Illex argentinus*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

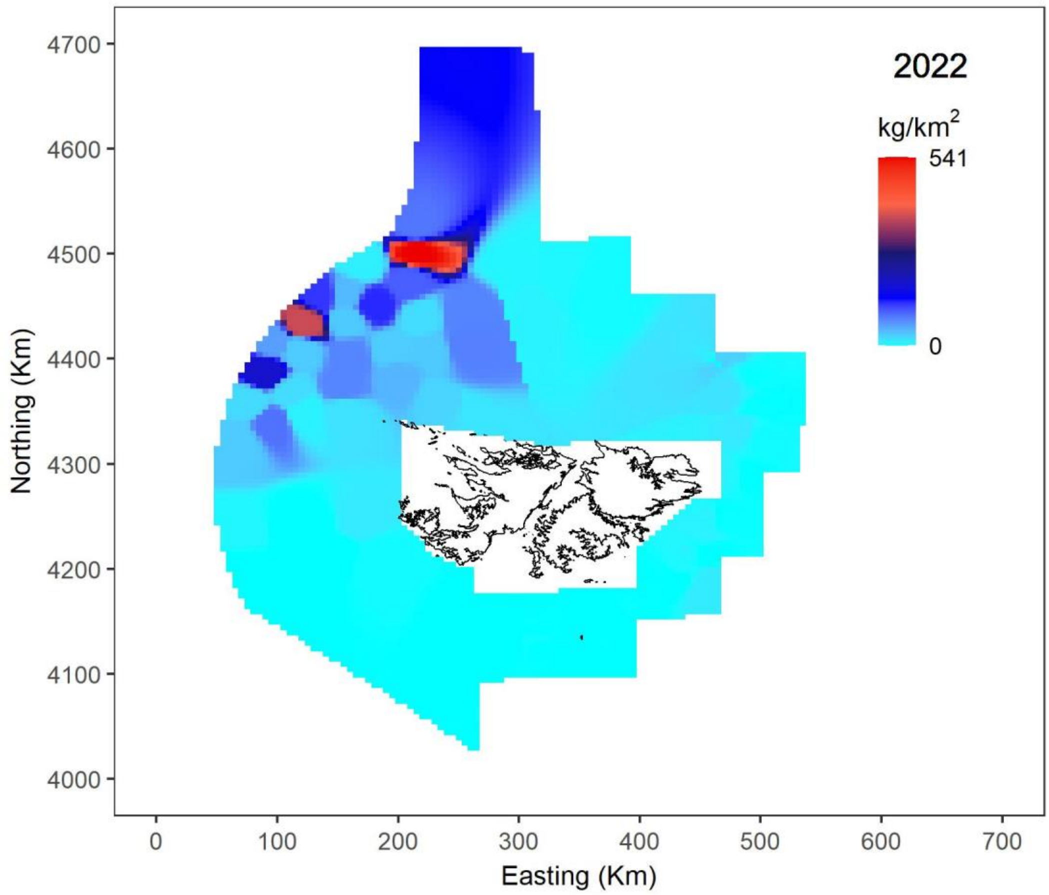

Fig. 3. Distribution and abundance of the Argentine shortfin squid (*Illex argentinus*) calculated from the February 2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

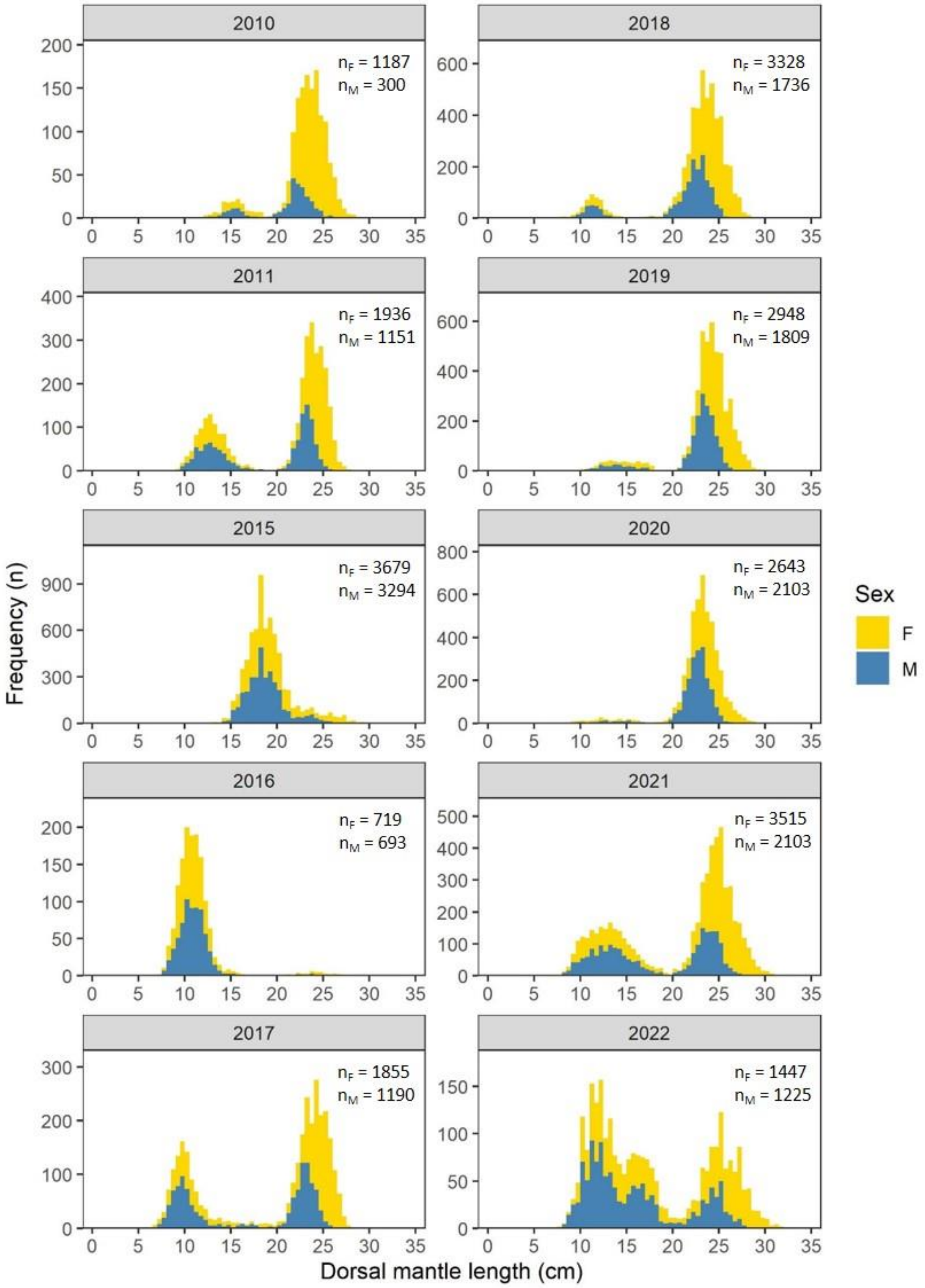

Fig. 4. Length-frequency distribution of Argentine shortfin squid (*Illex argentinus*) during the February groundfish and calamari pre-season surveys in Falkland Islands waters. Blue and yellow bars are superimposed.

4.2.2. Banded whiptail grenadier (*Coelorinchus fasciatus*)

Patterns of catch and biomass across years were variable, likely due to the small catches and patchy distributions of this species, which also reflects in wide biomass confidence intervals (Table II). Catches of banded whiptail grenadier were higher in groundfish surveys compared with calamari pre-season surveys in any year, and catches ranged between 2.5 t and 8 t (Fig. 5; Appendix IV). CPUE of banded whiptail grenadier oscillated across years, with the highest CPUE recorded for 2010 (40.9 kg/h). Relatively high CPUE was also observed in 2011, 2015, 2018, and 2021 (> 30 kg/h each); CPUE in 2022 was 27.9 kg/h (Fig. 5; Appendix V). The biomass of banded whiptail grenadier had a decreasing trend from 2010 (66,623 t) to 2019 (22,977 t), followed by an increase from 2019 to 2021 (66,845 t); biomass declined again in 2022 (49,559 t) (Fig. 5; Table II; Appendix VI). These findings suggest that the stock of banded whiptail grenadier remains relatively stable within a range of variability.

Banded whiptail grenadier was predominantly distributed to the south-west of West Falkland during 2022, with the maximum density calculated at 3,971 kg/km^2 (Fig. 6). Across years, there was a consistent pattern of distribution to the south-west of West Falkland with the highest density calculated for 2011 (9,127 kg/km^2; Appendix VIII).

Length frequency histograms of banded whiptail grenadier show a range of sizes from 2 cm to 20 cm pre-anal length. One mode was evident every year and remained constant through time, i.e. 9–10 cm pre-anal length for females and for males (Fig. 7).

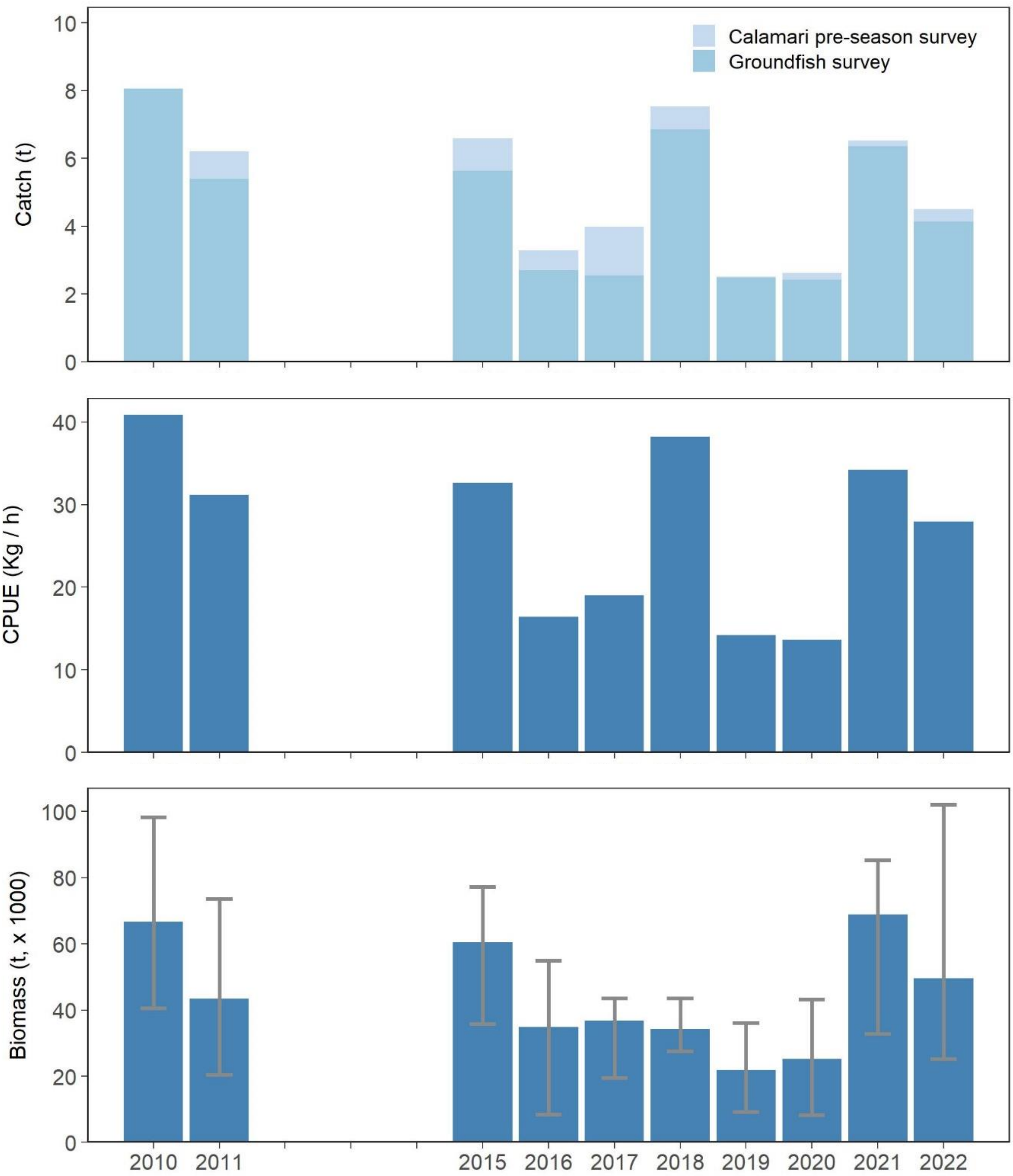

Fig. 5. Catch (t), CPUE (kg/h), and mean biomass (t) ± 95% confidence intervals of banded whiptail grenadier (*Coelorinchus fasciatus*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

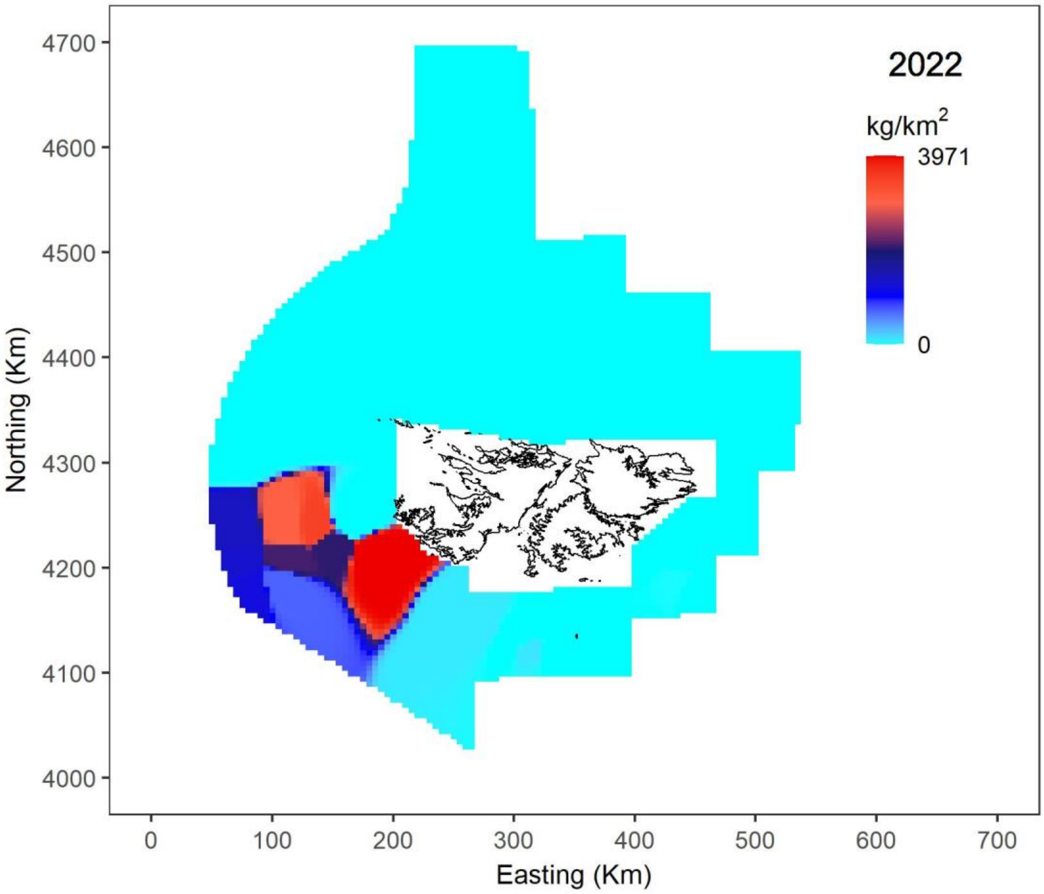

Fig. 6. Distribution and abundance of banded whiptail grenadier (*Coelorinchus fasciatus*) calculated from the February 2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

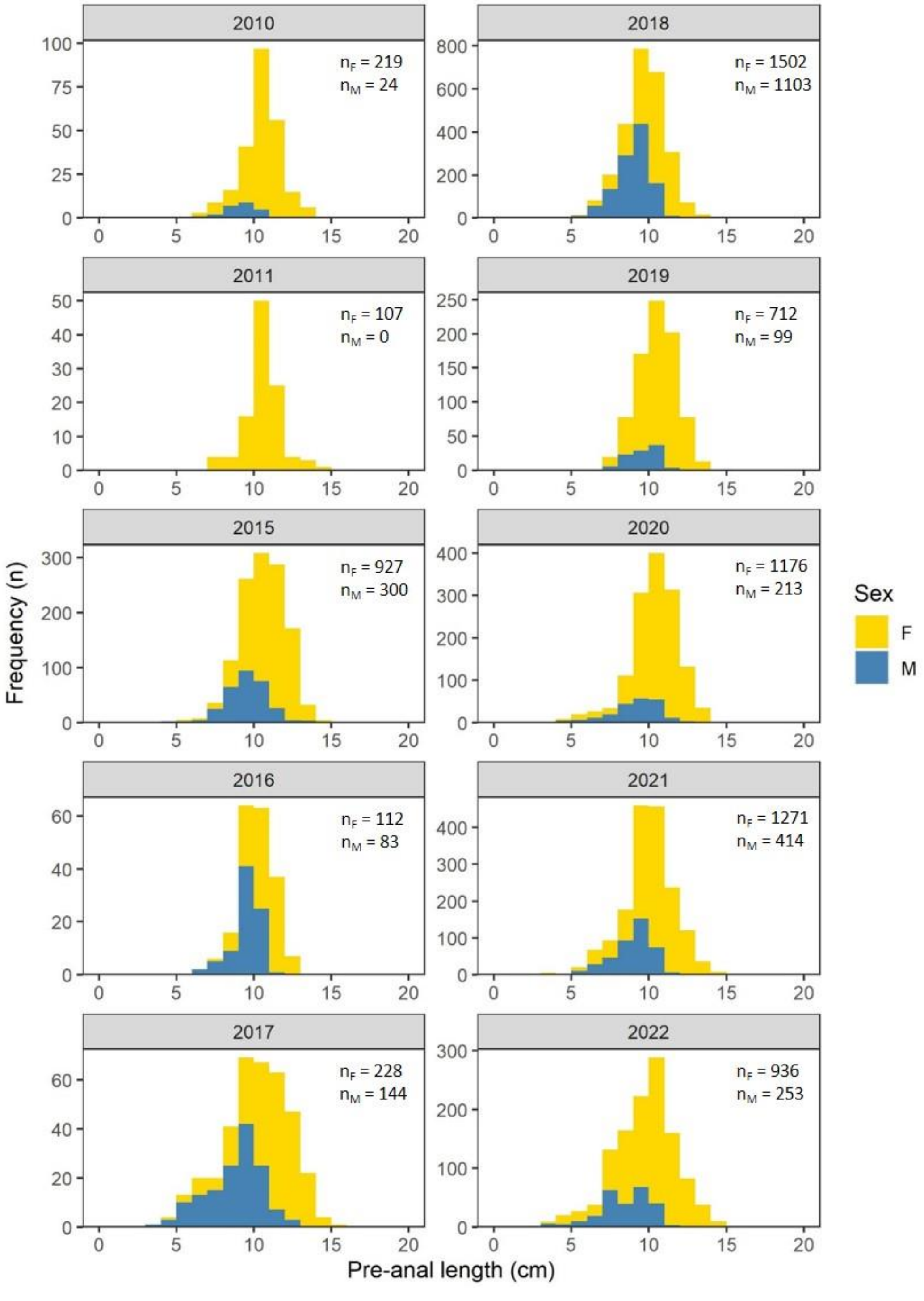

Fig. 7. Length frequency of banded whiptail grenadier (*Coelorinchus fasciatus*) during the February groundfish and calamari pre-season surveys in Falkland Islands waters. Blue and yellow bars are superimposed.

4.2.3. Common hake (*Merluccius hubbsi*)

Common hake were mainly caught in groundfish surveys through the time series. Catches reached a maximum in 2021 (8.2 t); the second highest catch was reported in 2022 (5.7 t), whereas it remained below 3.2 t in all other years (Fig. 8; Appendix IV). CPUE of common hake ranged between 3.8 kg/h in 2020 and 42.7 kg/h in 2021, with most years below 16 kg/h; CPUE in 2022 was 35.1 kg/h (Fig. 8; Appendix V). The biomass of common hake remained under 16,000 t every February from 2010 to 2020. Biomass increased in 2021 (33,282 t) and reached its highest value in 2022 with 42,420 t (Fig. 8; Table II). There was a statistically significant increase in biomass in 2021 and 2022 (Appendix VI).

In 2022, common hake was mainly distributed to the north-west of West Falkland with the highest density estimated at 2,974 kg/km^2 (Fig. 9). Migration of common hake into Falkland Islands waters is likely driven by specific oceanographic conditions, and it takes place in February when the surveys are being conducted. Hence, changes in oceanographic conditions may result in year-to-year abundance variability for this species during February in Falkland Islands waters. Across years, high densities were detected to the north-west offshore or near the limit of the FICZ, with the highest density calculated for 2021 (3,393 kg/km^2; Appendix IX).

Length frequency histograms show a wide range of common hake sizes, from 13 cm to 95 cm total length, across the time series. In 2022, the modal length was 41 cm total length for females; a small number of males were caught during February 2022 and the modal length was 36 cm total length (Fig. 10).

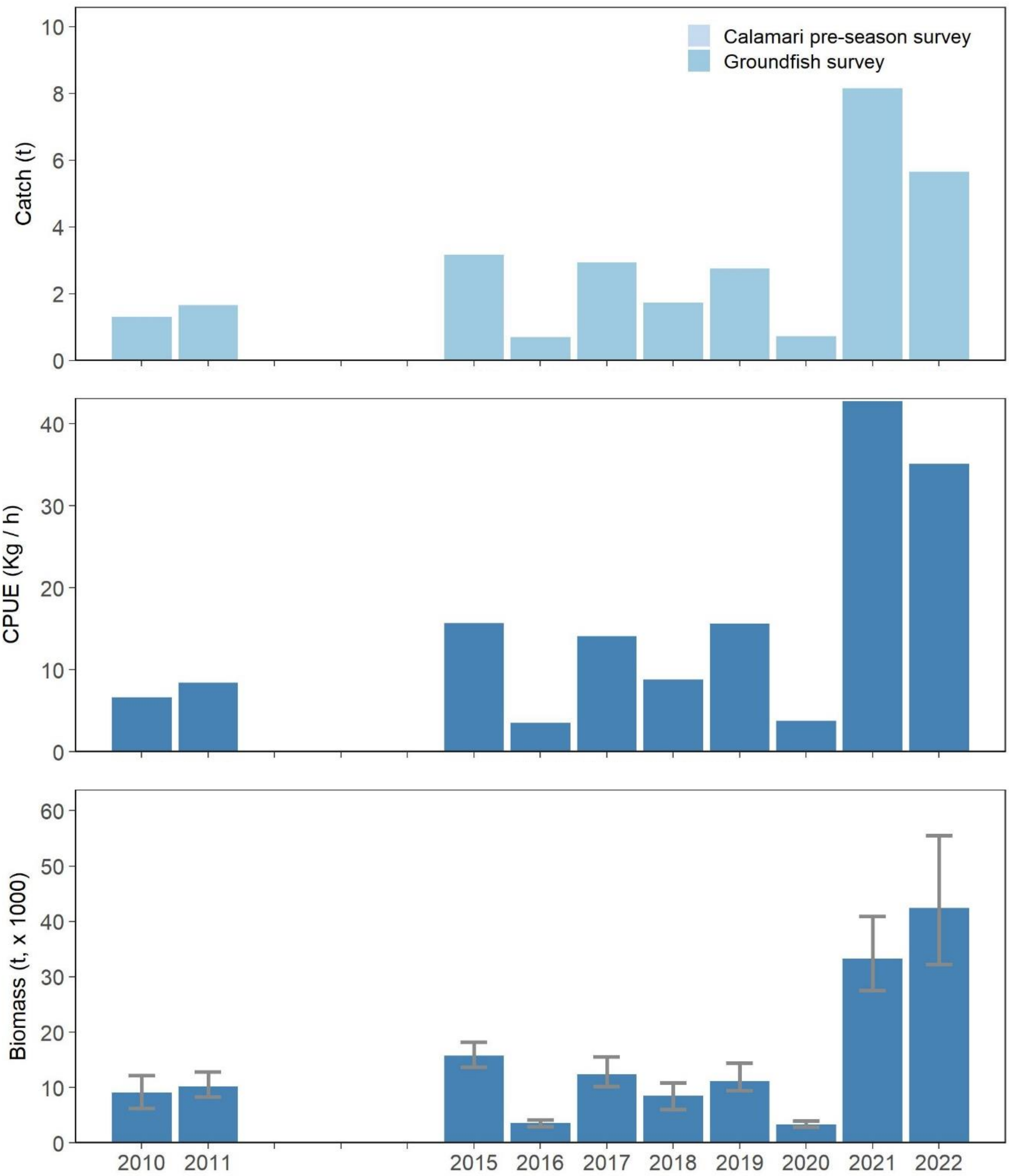

Fig. 8. Catch (t), CPUE (kg/h), and mean biomass (t) ± 95% confidence intervals of common hake (*Merluccius hubbsi*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

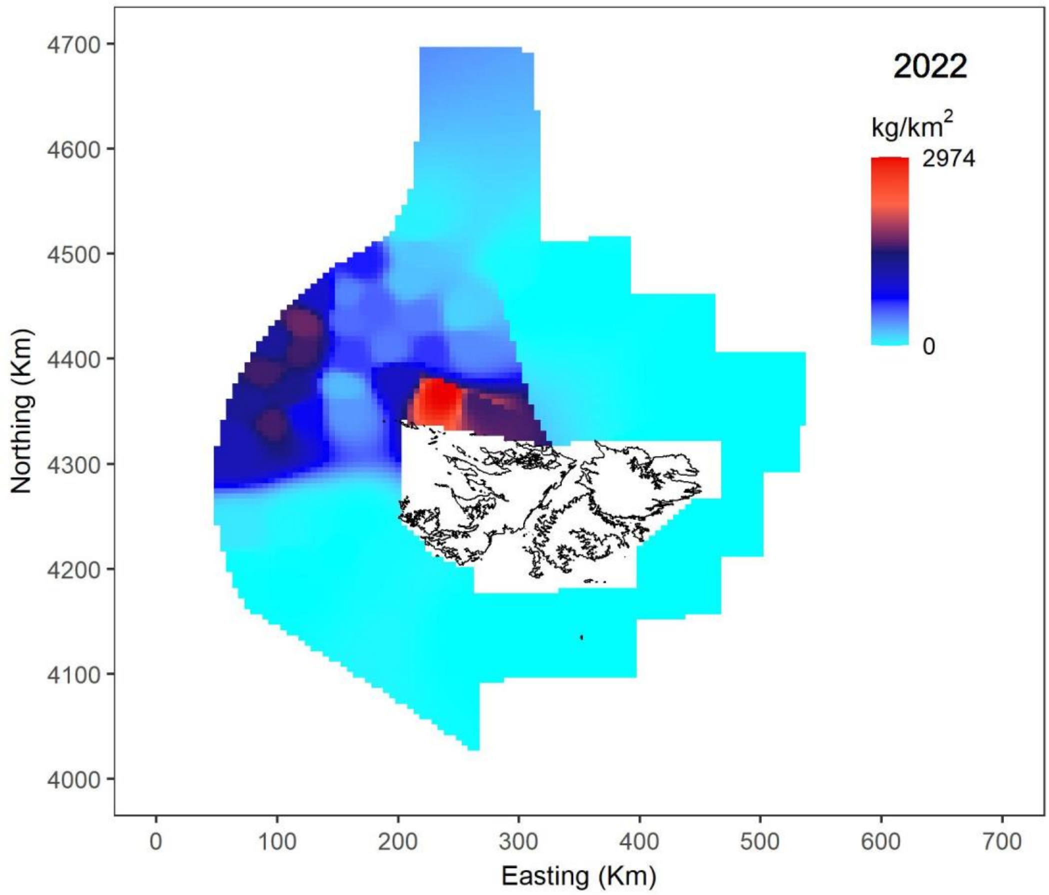

Fig. 9. Distribution and abundance of common hake (*Merluccius hubbsi*) calculated from the February 2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

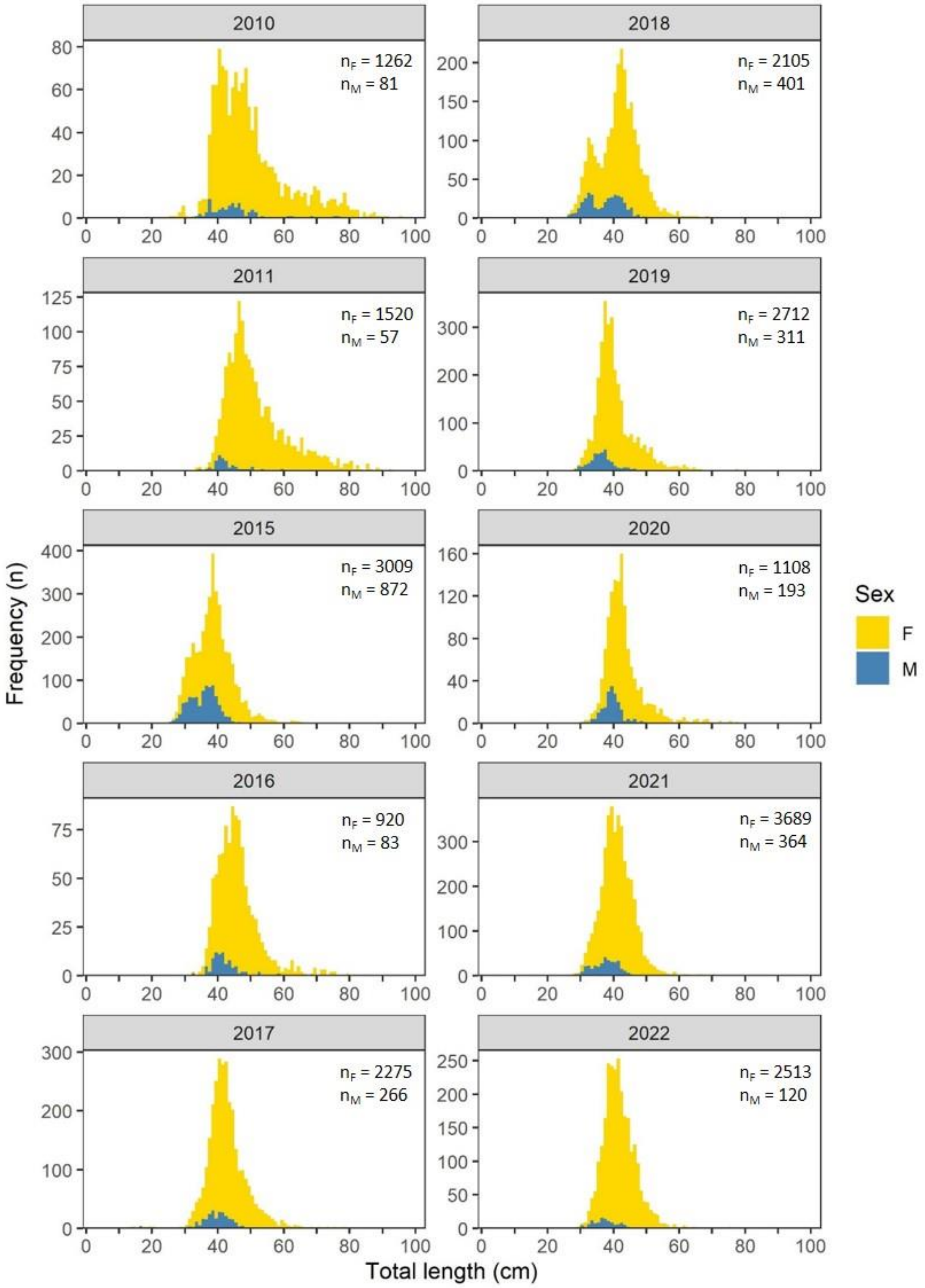

Fig. 10. Length frequency of common hake (*Merluccius hubbsi*) during the February groundfish and calamari pre-season surveys in Falkland Islands waters. Blue and yellow bars are superimposed.

4.2.4. Hoki (*Macruronus magellanicus*)

Hoki catch was nearly evenly split between February groundfish and calamari pre-season surveys in 2010, 2011, and 2015, 2016. However, hoki catches in groundfish surveys were dominant since 2017 (Fig. 11; Appendix IV); the highest catch was reported in 2011 (56 t), and the lowest catch in 2016 (0.7 t). CPUE of hoki had its highest value in 2010 with 405.4 kg/h; the third lowest CPUE in the time series was calculated for 2022 with 60.3 kg/h (Fig. 11; Appendix V). The highest biomass in the time series was estimated for 2010 (278,980 t), and the biomass in 2022 was the fourth lowest (144,783 t; Fig. 11; Table II). There was no significant trend in biomass from 2010 to 2022 (Appendix VI).

In 2022, hoki was found to the south-west edge of the FICZ with the highest density calculated at 25,342 kg/km^2 (Fig. 12). The distribution of hoki was patchy and variable from year to year. From 2010 to 2015, hoki occurred over the entire FICZ and FOCZ but its distribution was localized mainly to the south-west of West Falkland from 2016 to 2022 (Appendix X); the highest density in the time series occurred to the south-west limit of the FICZ in 2021 (146,193 kg/m^2).

Length frequency histograms show a range of sizes from 11 cm to 46 cm pre-anal length across the time series. Several length-groups were present each year but these cannot be identified with certainty given the overlap in sizes. In 2022, the modal length was 25 cm pre-anal length for females and for males (Fig. 13).

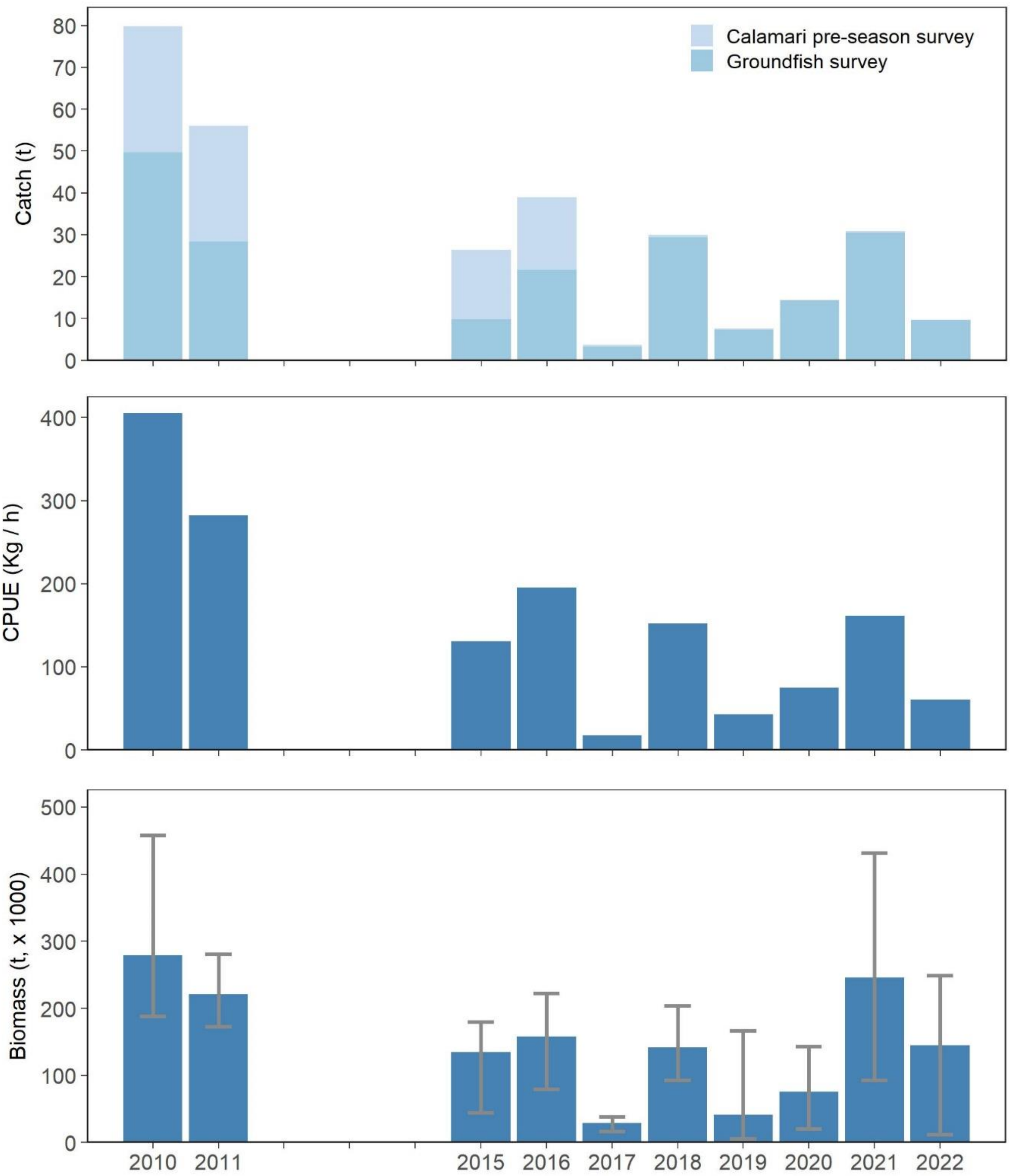

Fig. 11. Catch (t), CPUE (kg/h), and mean biomass (t) ± 95% confidence intervals of hoki (*Macruronus magellanicus*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

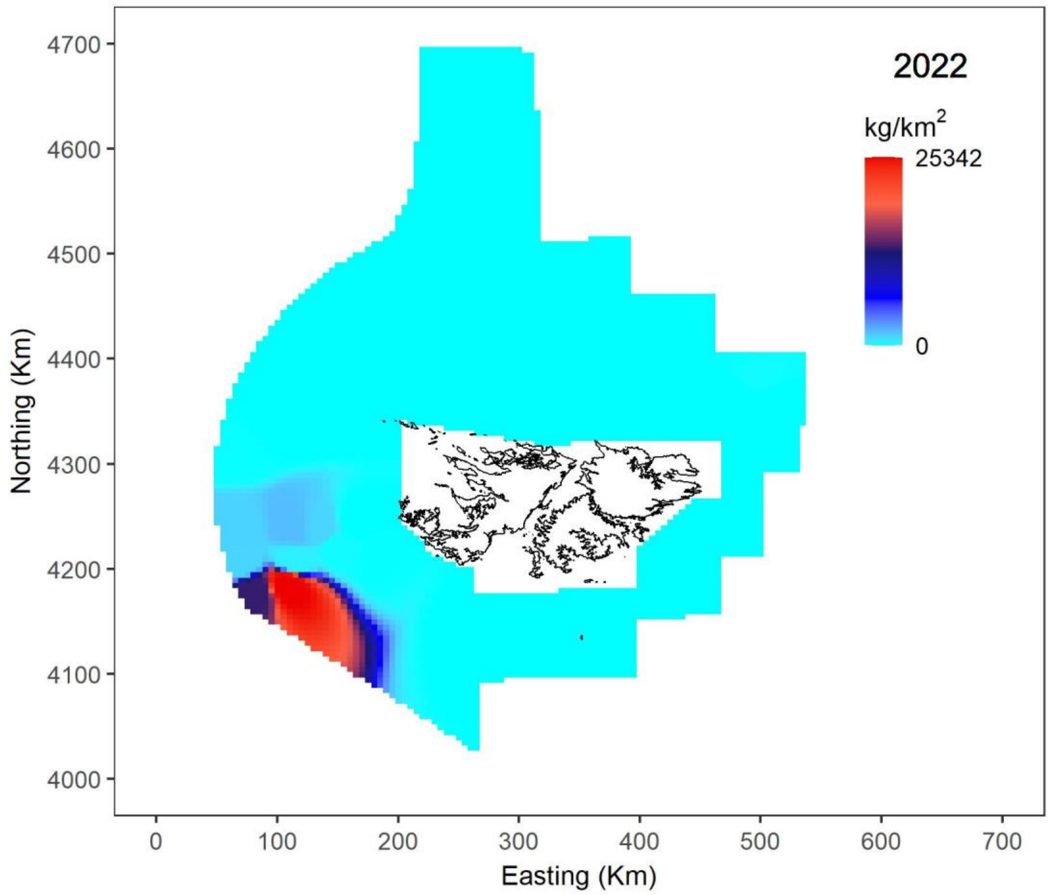

Fig. 12. Distribution and abundance of hoki (*Macruronus magellanicus*) calculated from the February 2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

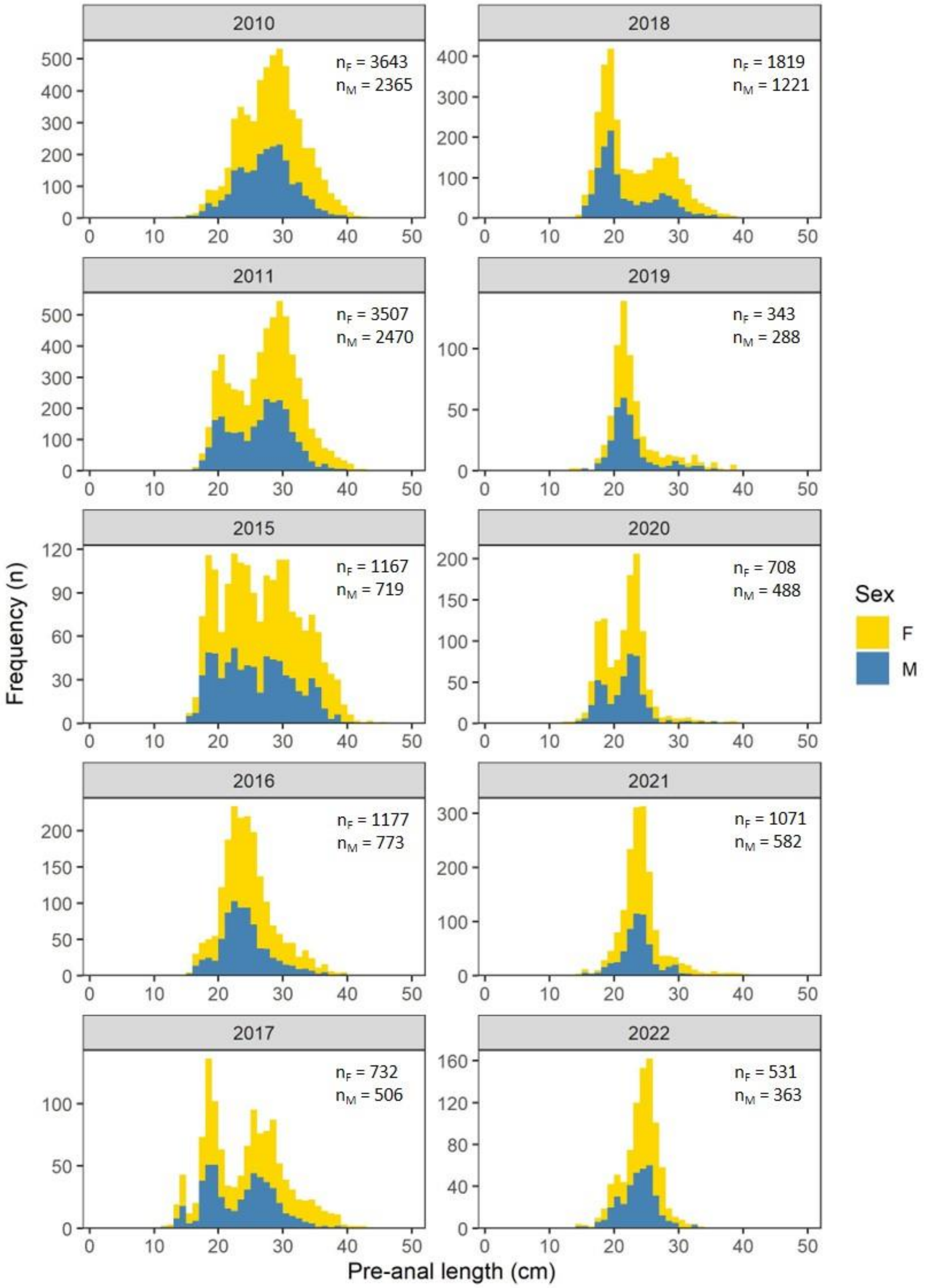

Fig. 13. Length frequency of hoki (*Macruronus magellanicus*) during the February groundfish and calamari pre-season surveys in Falkland Islands waters. Blue and yellow bars are superimposed.

4.2.5. Kingclip (*Genypterus blacodes*)

Most kingclip were caught in groundfish surveys compared with calamari pre-season surveys. The highest catch of kingclip occurred in 2015 with 14.7 t, whereas 2.8 t were caught in 2022 (Fig. 14; Appendix IV). CPUE of kingclip was relatively stable across years, with one peak in 2015 (73.1 kg/h) and a second smaller peak in 2011 (43.2 kg/h); the CPUE of kingclip in 2022 was calculated at 17.3 kg/h, which is the second lowest in the time series (Fig. 14; Appendix V). Kingclip biomass was usually < 45,000 t every February, except for February 2015 that had the highest biomass (76,722 t) in the time series. In 2022, the biomass of kingclip was calculated at 43,437 t (Fig. 14; Table II). There was no statistically significant trend in biomass from 2010 to 2022 (Appendix VI).

In 2022, the highest density (4,735 kg/km^2) occurred to the south-west near West Falkland and to the north (Fig. 15). Throughout the time series, kingclip was dispersed around the FICZ and FOCZ, except for the south-east. The highest density in the time series was 32,777 kg/km^2 to the north-west in 2015 (Appendix XI).

Length frequency histograms show a wide range of kingclip sizes across the time series, from 23 cm to 153 cm total length. In 2022, the modal length was 73 cm for females and 63 cm for males (Fig. 16).

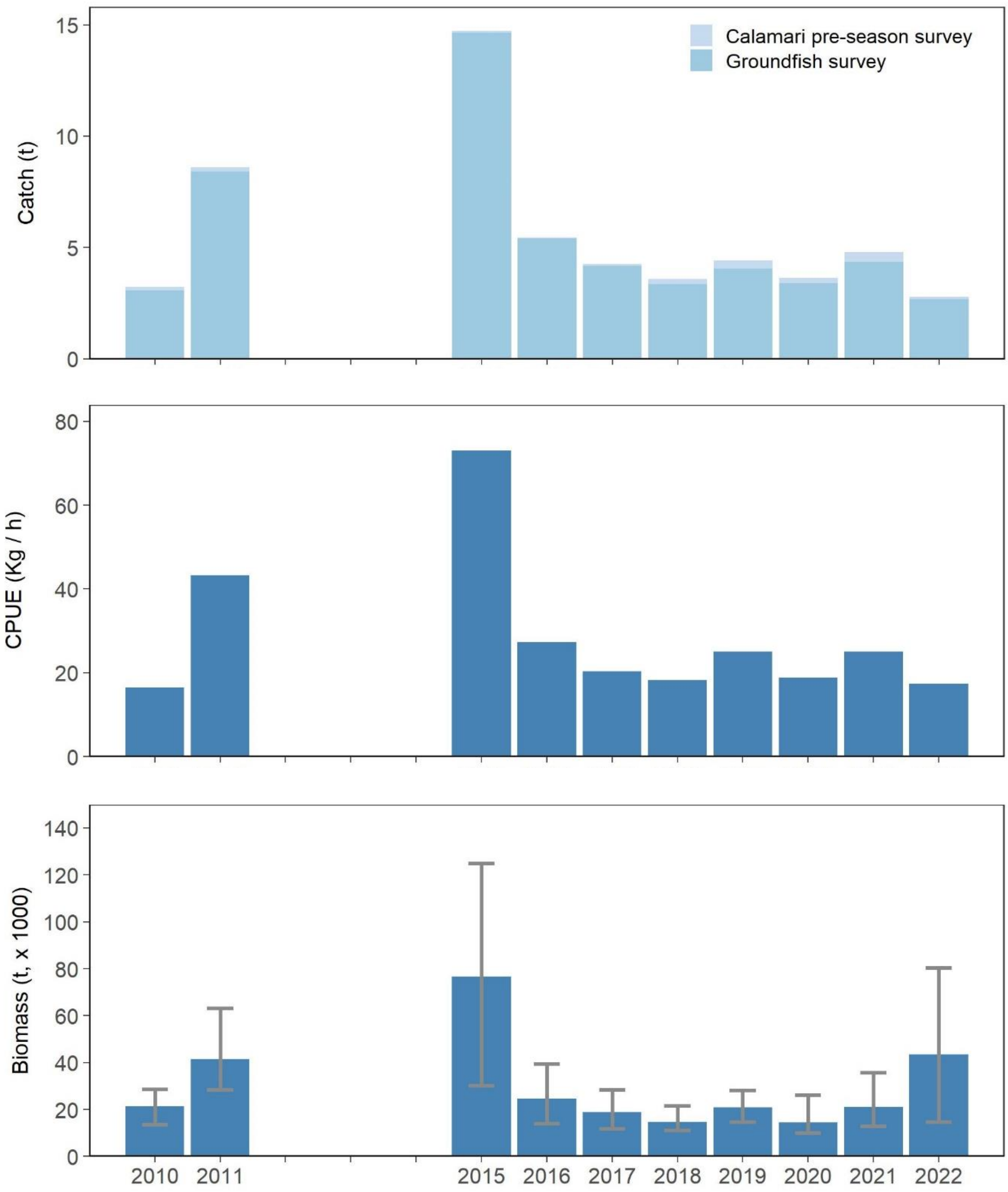

Fig. 14. Catch (t), CPUE (kg/h), and mean biomass (t) ± 95% confidence intervals of kingclip (*Genypterus blacodes*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

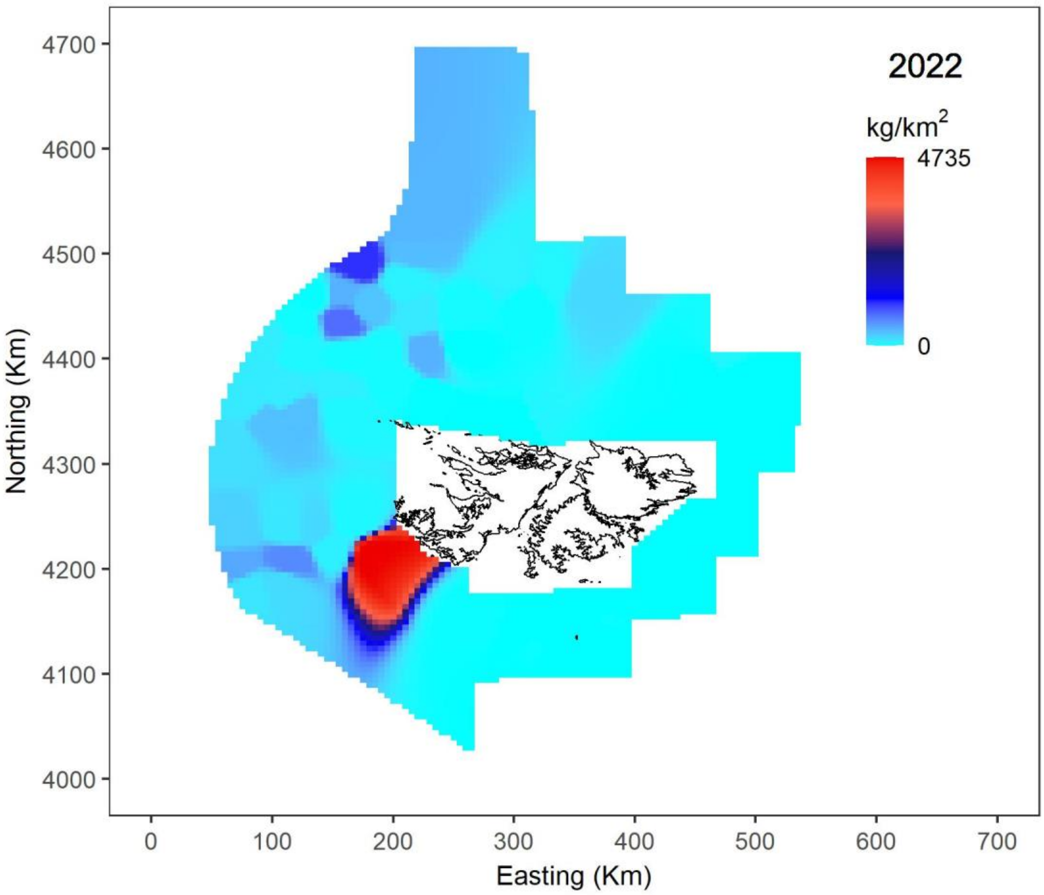

Fig. 15. Distribution and abundance of kingclip (*Genypterus blacodes*) calculated from the February 2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

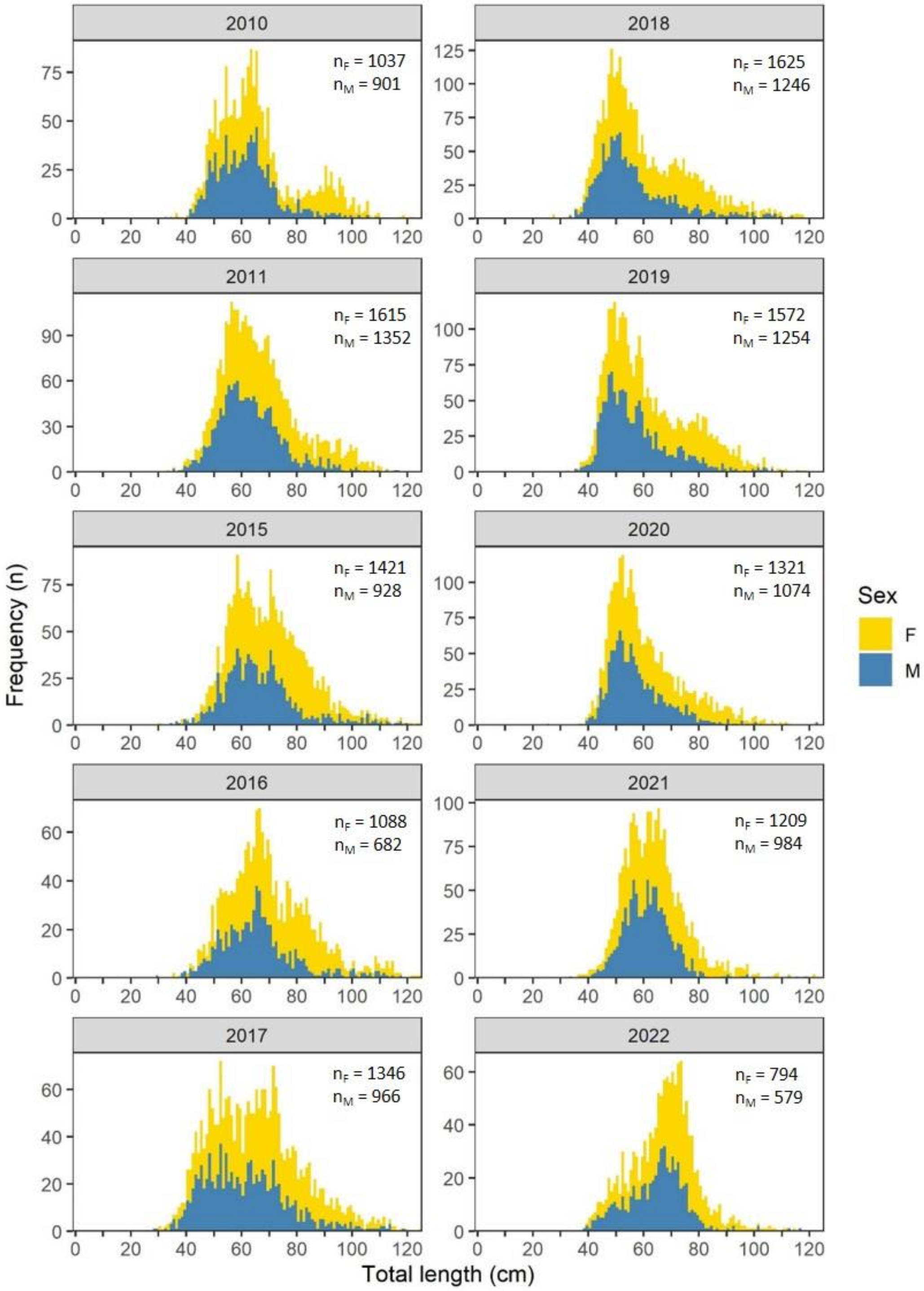

Fig. 16. Length frequency of kingclip (*Genypterus blacodes*) during the February groundfish and calamari pre-season surveys in Falkland Islands waters. Blue and yellow bars are superimposed.

4.2.6. Patagonian squid (*Doryteuthis gahi*)

The highest catch of Patagonian squid was obtained for 2022 (422.7 t), with most catches from the calamari pre-season survey (Fig. 17; Appendix IV). CPUE of the Patagonian squid ranged from 254 kg/h in 2011 to 2,625.9 kg/h in 2022 (Fig. 17; Appendix V). The highest biomass in the time series was estimated in 2019 with 214,492 t. In 2022, the biomass was estimated at 167,439 t (Fig. 17; Table II). There was no statistically significant trend in biomass from 2010 to 2022 (Appendix VI).

Patagonian squid were mainly found to the south and south-east of East Falkland. In 2022, the maximum density was 21,209 kg/km^2 to the south of East Falkland (Fig. 18), whereas the highest density throughout the time series was 36,970 kg/km^2 in the same area in 2015 (Appendix XII).

Length frequency histograms show a wide range of Patagonian squid sizes, from 2.5 cm to 36 cm, across the time series. Two length-groups were evident only in some years. In 2022, the modal lengths of females and males were 9 cm, respectively (Fig. 19).

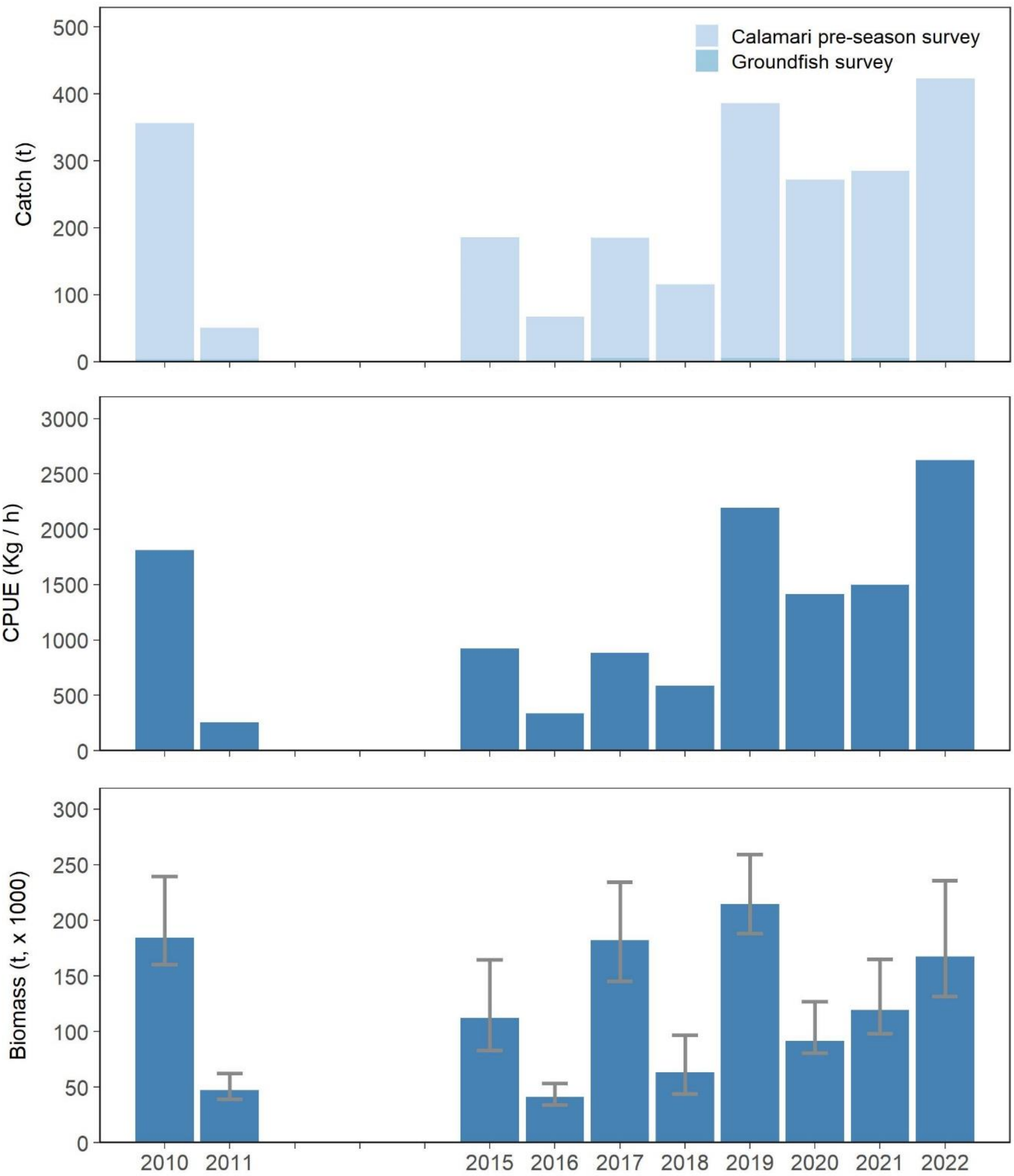

Fig. 17. Catch (t), CPUE (kg/h), and mean biomass (t) ± 95% confidence intervals of the Patagonian squid (*Doryteuthis gahi*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

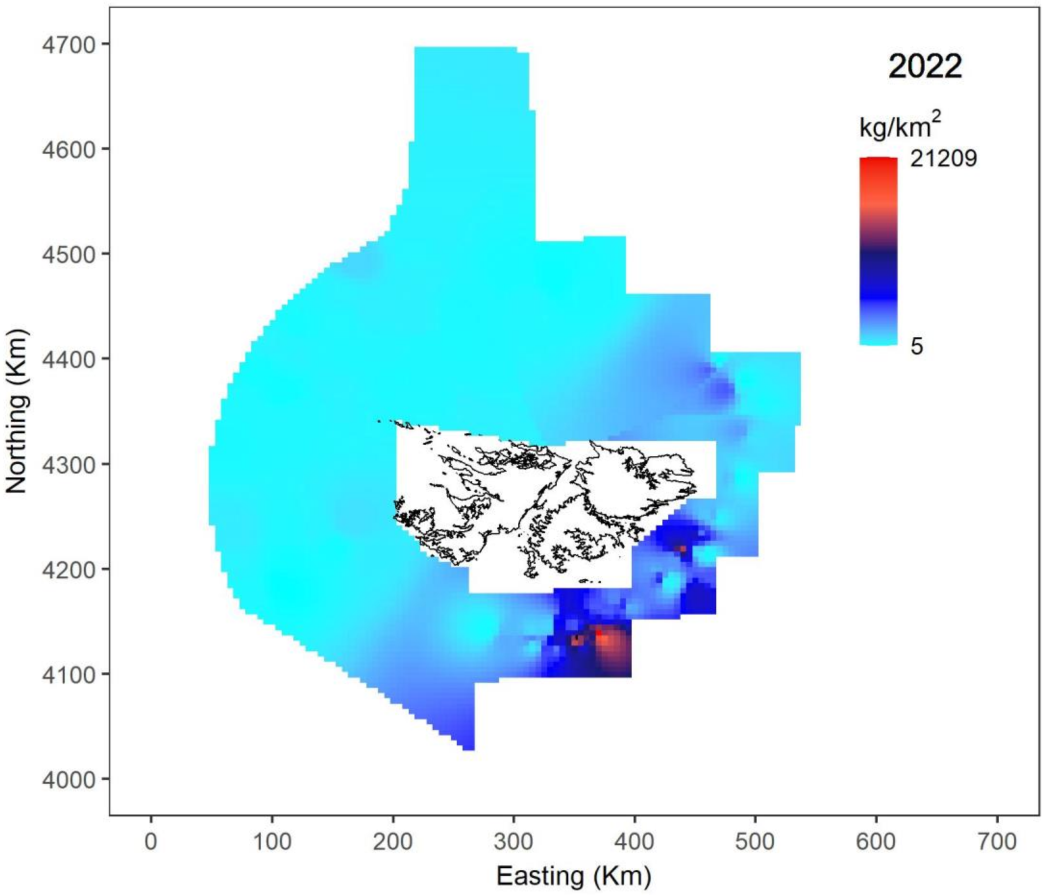

Fig. 18. Distribution and abundance of the Patagonian squid (*Doryteuthis gahi*) calculated from the February 2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

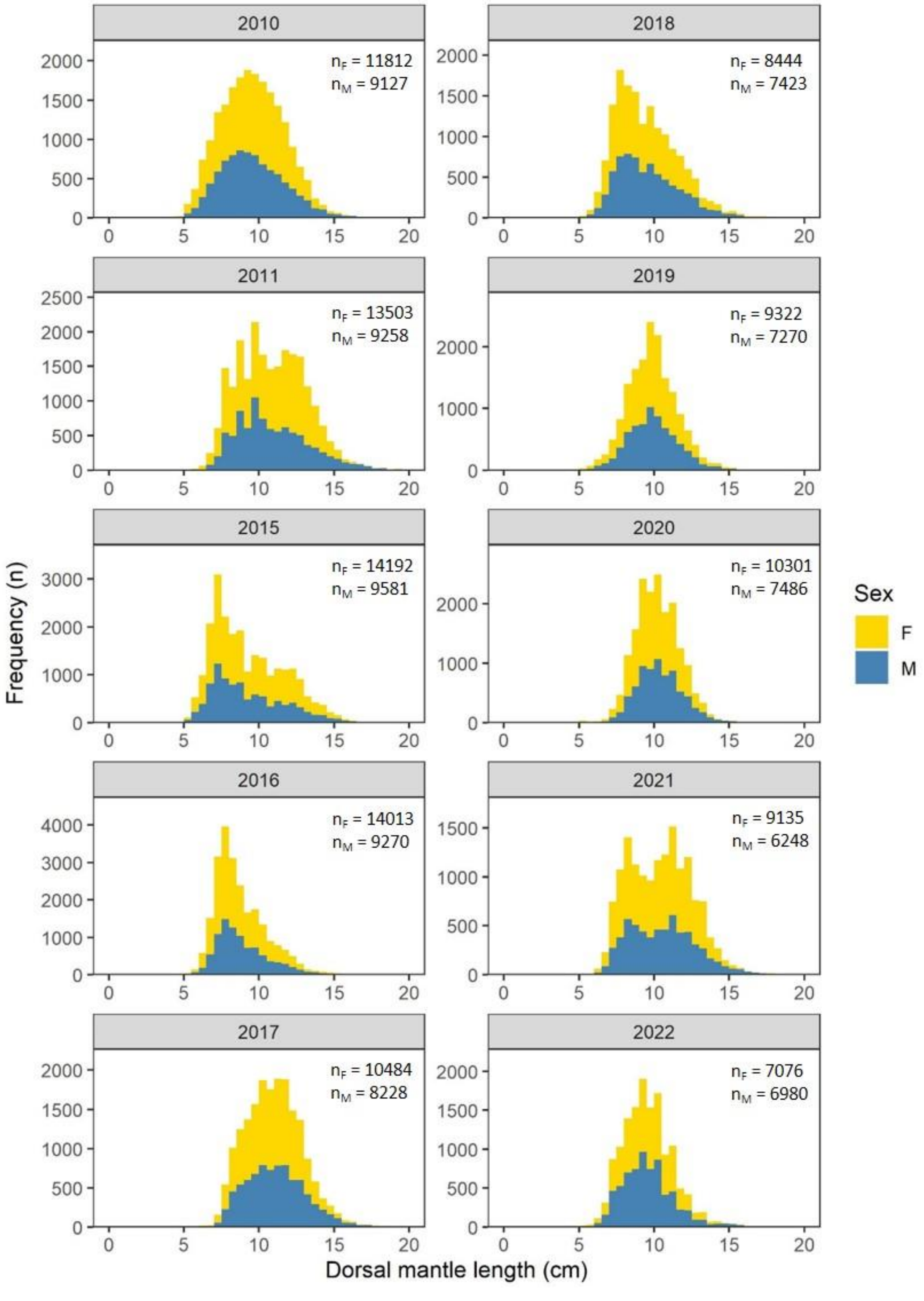

Fig. 19. Length frequency of the Patagonian squid (*Doryteuthis gahi*) during the February groundfish and calamari pre-season surveys in Falkland Islands waters. Blue and yellow bars are superimposed.

4.2.7. Red cod (*Salilota australis*)

Red cod was predominantly caught in groundfish surveys compared with calamari pre-season surveys. Catch declined from 2011 and reached its lowest value in 2020 (3.7 t); however, there was a consecutive increase in catches since 2020 (Fig. 20; Appendix IV). The highest CPUE was calculated for 2011 (118.5 kg/h), followed by a decline to reach the lowest value (19.3 kg/h) in 2020. CPUE increased from 2020 and reached 64.7 kg/h in 2022 (Fig. 20; Appendix V). The biomass of red cod had its highest value in 2011 (166,618 t). Biomass decreased the following years to 21,890 t in 2020, the lowest biomass calculated in the time series. In 2022, the biomass of red cod was estimated at 81,177 t (Fig. 20; Table II). There was a statistically significant decline in biomass from 2010 to 2020 (Appendix VI).

In 2022, the highest densities occurred near the north-west limit of the FICZ (21,143 kg/km^2), although also there were high densities to the south-west limit of the FICZ (Fig. 21). Through the time series, red cod was found mainly to the west of West Falkland. From 2010 to 2017, high densities were mainly located near the west limit of the FICZ. The highest density in the time series was 38,175 kg/km^2 in 2016 (Appendix XIII).

Length frequency histograms show a wide range of red cod sizes across the time series (i.e. 4–85 cm total length) due to the presence of several length-groups. Poor recruitment to the fishery occurred in 2010, 2018, 2020, and 2021; individuals recently recruited to the fishery had modal lengths between 15 cm and 19 cm total length across years. In 2022, the modal lengths of females were 19 cm and 28 cm; for males these were 18 cm and 28 cm (Fig. 22).

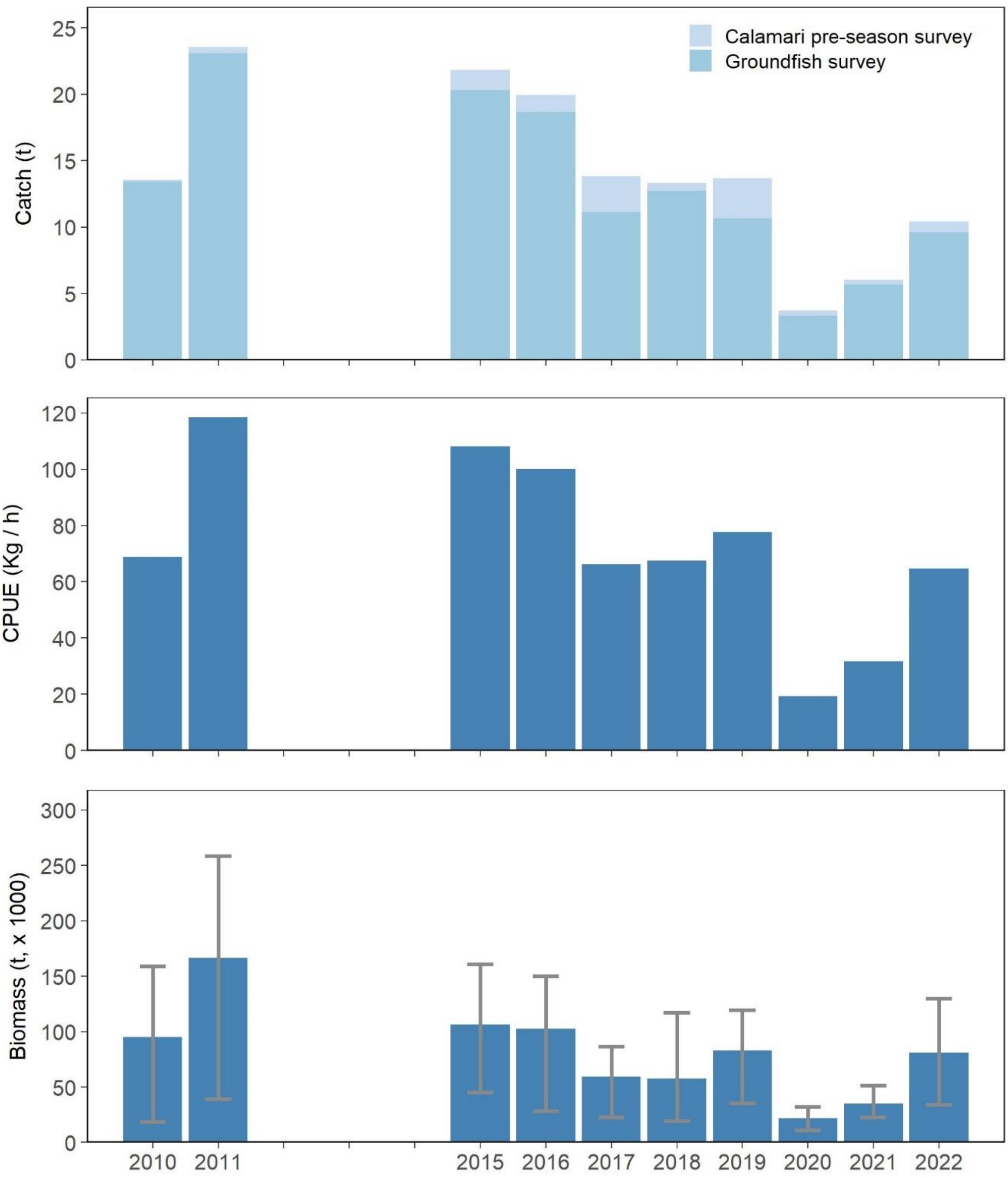

Fig. 20. Catch (t), CPUE (kg/h), and mean biomass (t) ± 95% confidence intervals of red cod (*Salilota australis*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

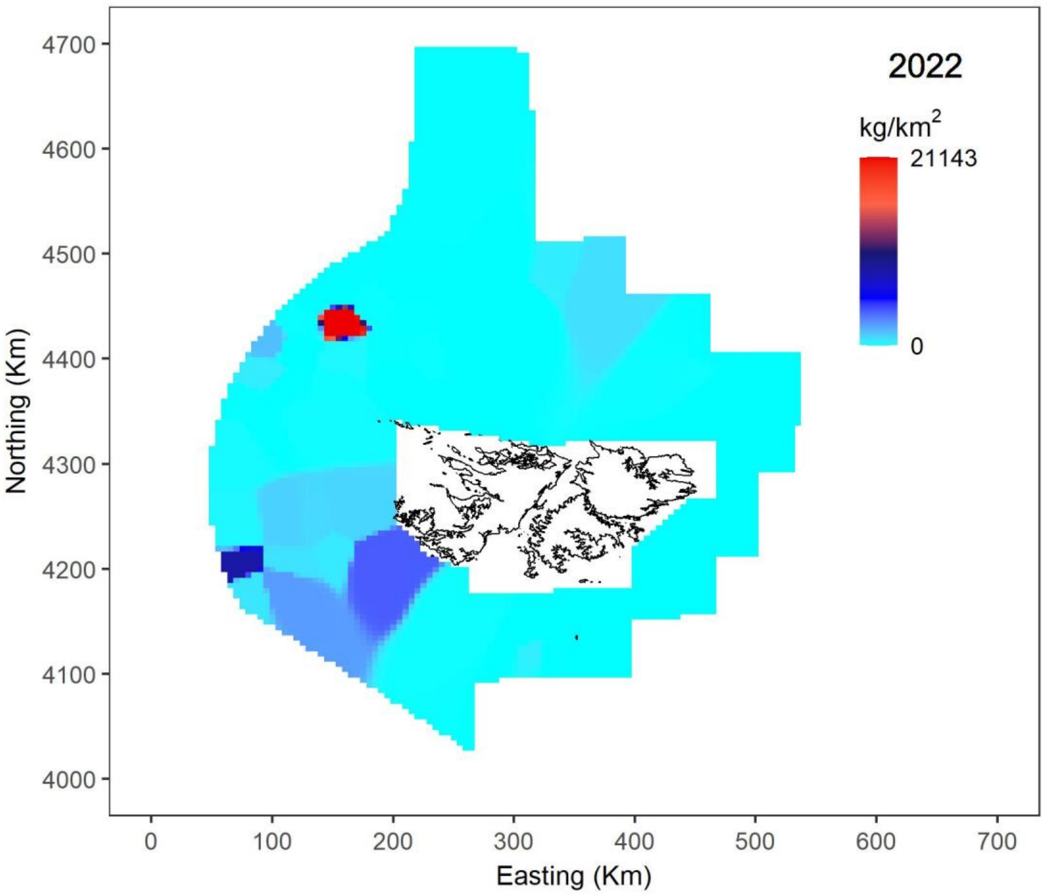

Fig. 21. Distribution and abundance of red cod (*Salilota australis*) calculated from the February 2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

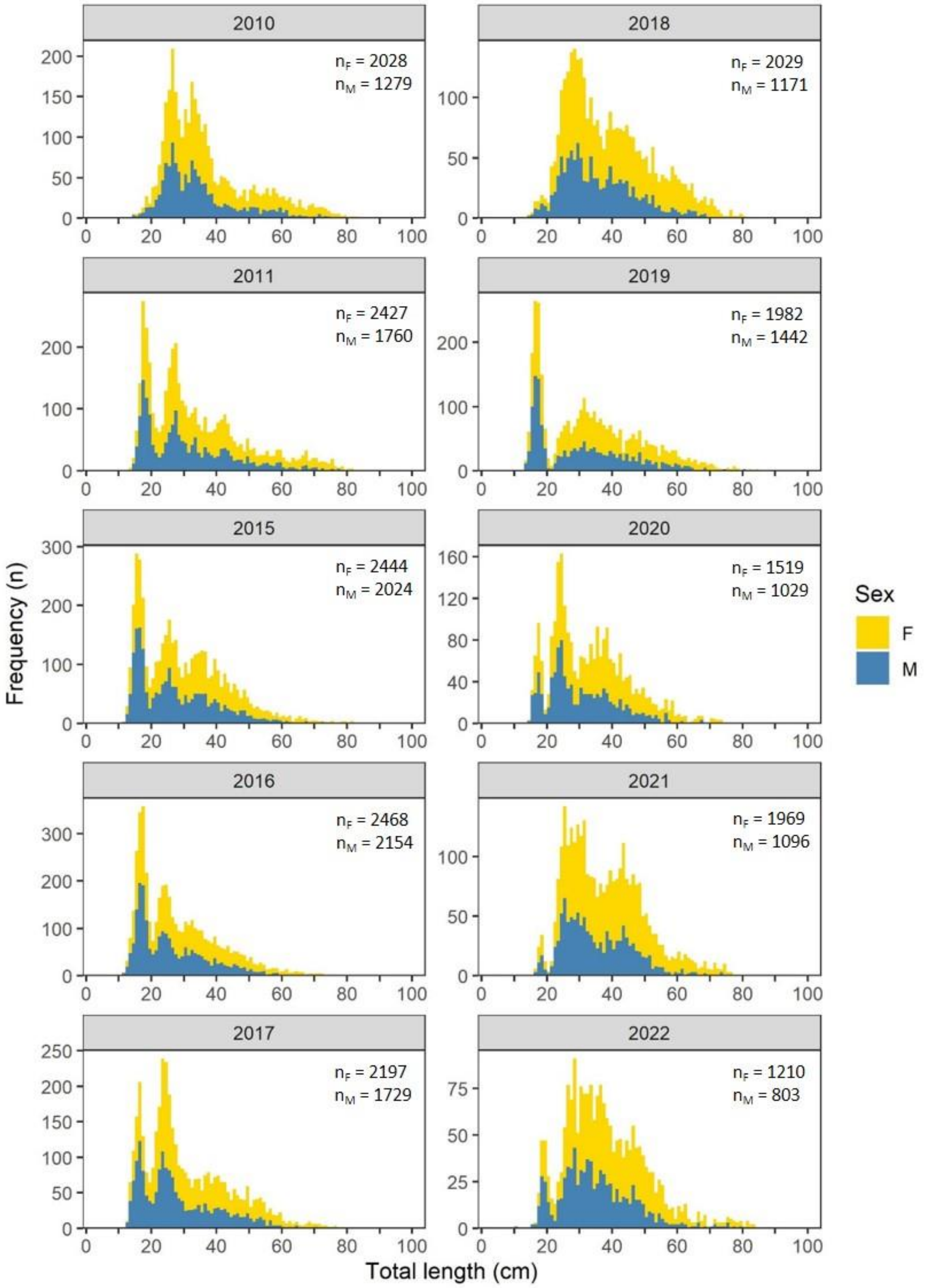

Fig. 22. Length frequency of red cod (*Salilota australis*) during the February groundfish and calamari pre-season surveys in Falkland Islands waters. Blue and yellow bars are superimposed.

4.2.8. Rock cod (*Patagonotothen ramsayi*)

In February 2010, rock cod catches were higher in the groundfish survey compared with the calamari pre-season surveys; however, since 2011 the majority of rock cod catches were reported from calamari pre-season surveys. The highest catch of rock cod was reported in 2011 (249.4 t) and the lowest catch in 2020 (10.9 t). A total of 30.8 t of rock cod were caught in 2022 (Fig. 23; Appendix IV). CPUE of rock cod had its highest value in 2011 with 1,255.5 kg/h followed by a declining trend to its lowest value in 2020 with 57.0 kg/h; in 2022 the CPUE was calculated at 191.4 kg/h (Fig. 23; Appendix V). Rock cod biomass increased from 2010 (817,086 t) to 2011 (884,742 t); however, there was a declining trend since 2011 with the lowest biomass estimated in 2020 (19,079 t) (Appendix VI). There was an increase in biomass since 2020, and 93,177 t were estimated in 2022 (Fig. 23; Table II).

In 2022, rock cod occurred in high densities (15,879 kg/km^2) to the north-west limit of the FICZ (Fig. 24). Rock cod had a patchy distribution around the Falkland Islands throughout the time series (Appendix XIV), and the highest density in the time series was calculated for 2011 to the north-east of East Falkland (602,141 kg/km^2).

Sizes of rock cod ranged widely throughout the time series (i.e. 4–43 cm). In some years, at least two length-groups were detected. In 2022, females and males had the same modal lengths, i.e., 14 cm for the smaller group and 21 cm for a larger group (Fig. 25).

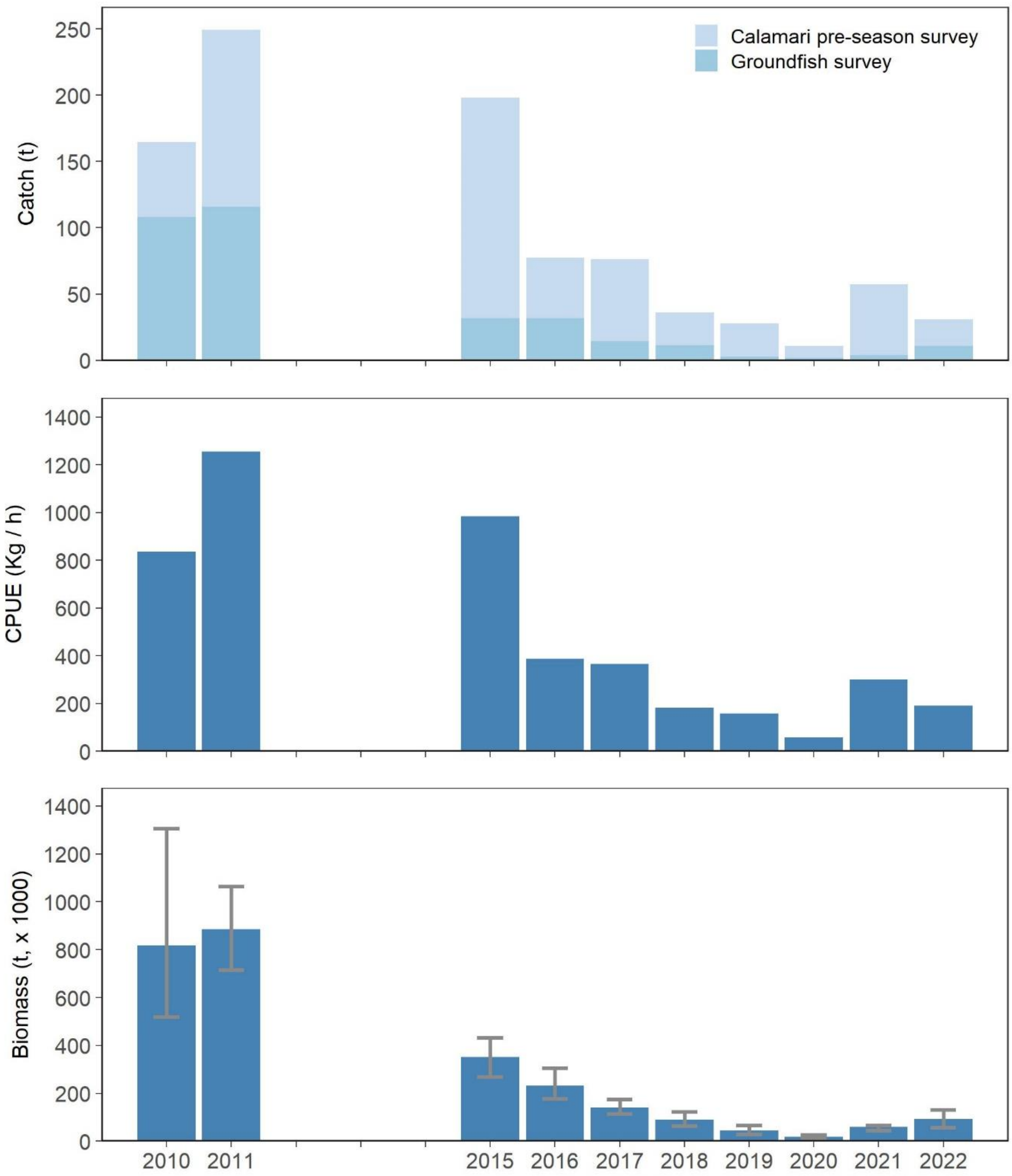

Fig. 23. Catch (t), CPUE (kg/h), and mean biomass (t) ± 95% confidence intervals of rock cod (*Patagonotothen ramsayi*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

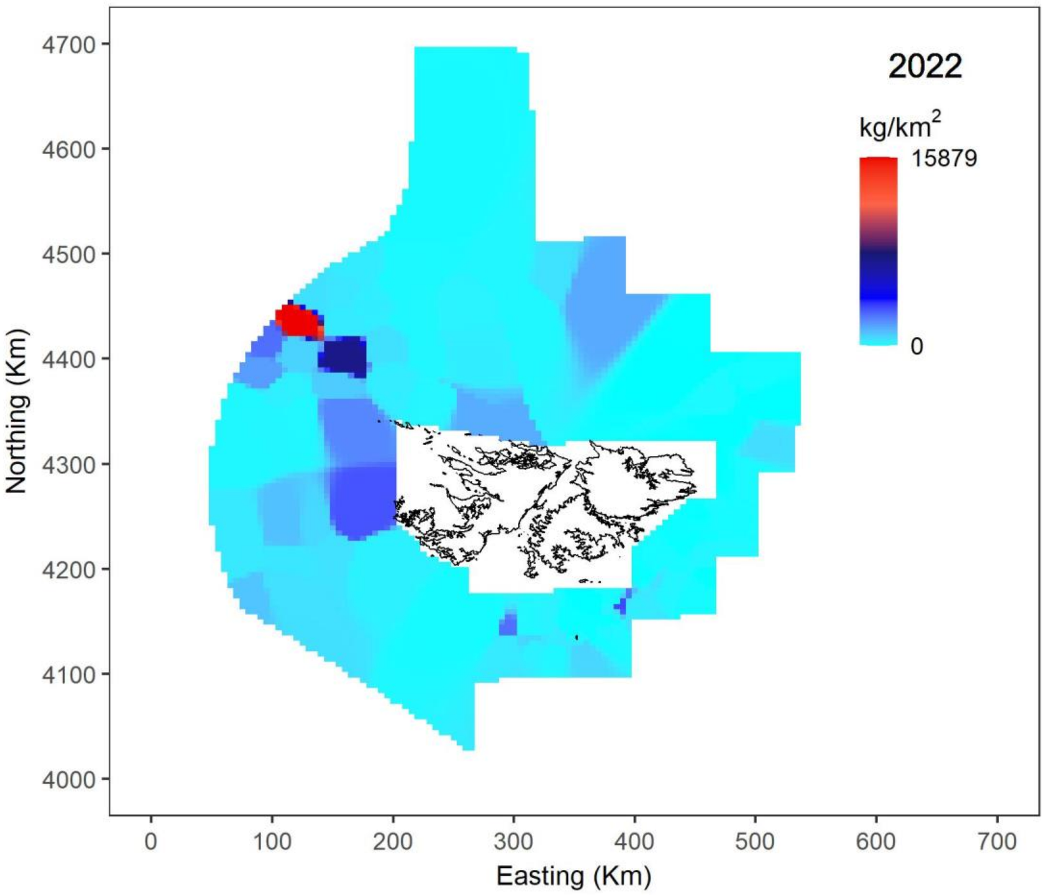

Fig. 24. Distribution and abundance of rock cod (*Patagonotothen ramsayi*) calculated from the February 2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

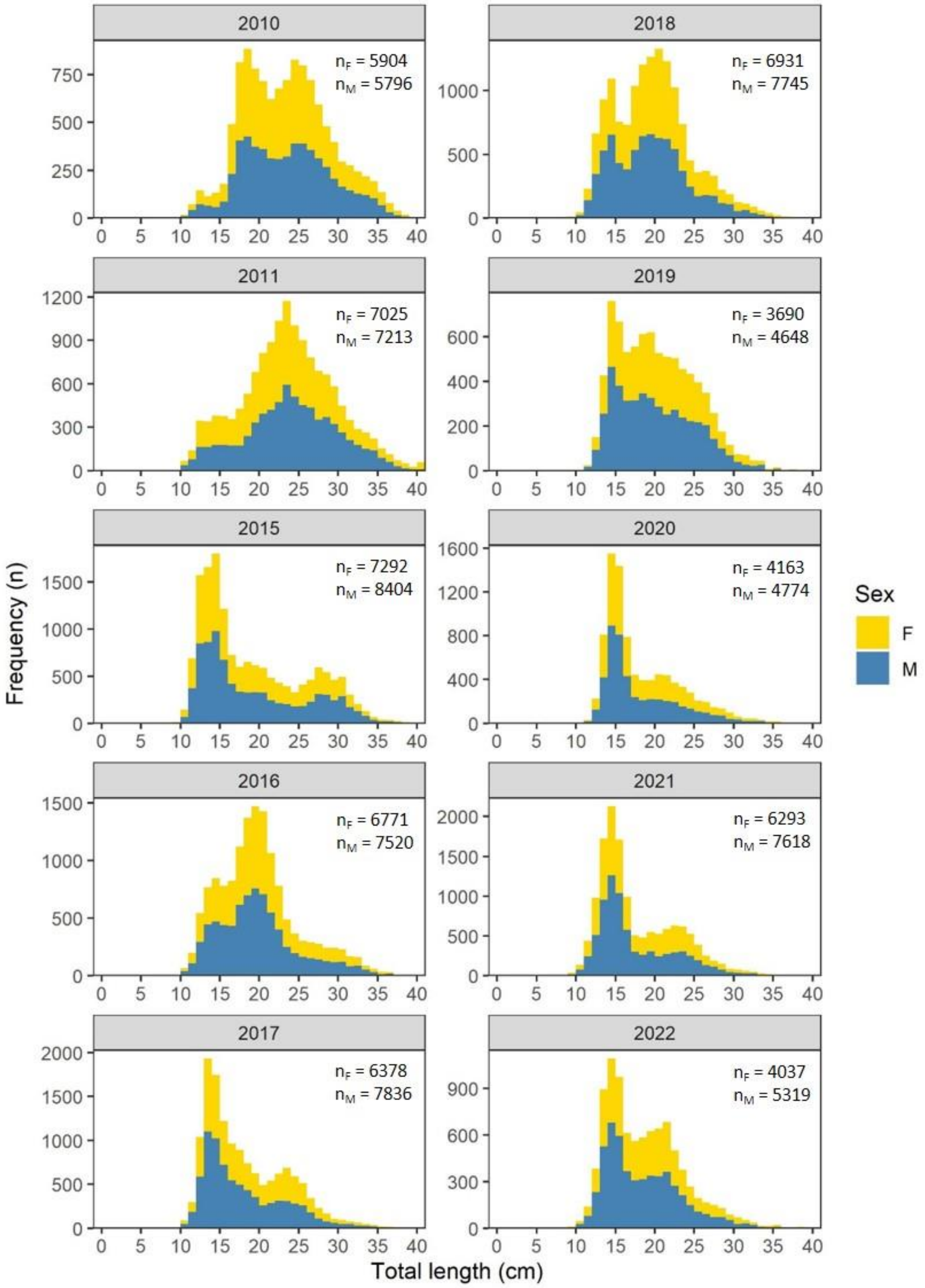

Fig. 25. Length frequency of rock cod (*Patagonotothen ramsayi*) during the February groundfish and calamari pre-season surveys in Falkland Islands waters. Blue and yellow bars are superimposed.

4.2.9. Southern blue whiting (*Micromesistius australis australis*)

Southern blue whiting was mainly caught in the calamari pre-season surveys compared with the groundfish surveys. The highest catch was reported in 2016 (79.4 t) and the lowest catch in 2022 (3.3 t) (Fig. 26; Appendix IV). CPUE of southern blue whiting had a peak in 2016 with 398.1 kg/h and a smaller peak in 2011 with 263.3 kg/h. CPUE was below 150 kg/h all other years, and 20.3 kg/h were calculated for 2022, which is the lowest in the time series (Fig. 26; Appendix V). The highest biomass was estimated for 2011 (154,691 t), and the lowest biomass was estimated for 2019 (5,856 t). However, biomass has increased since 2019 and it was 19,201 t in 2022 (Fig. 26; Table II). There was no significant trend in biomass from 2010 to 2022 (Appendix VI).

In 2022, southern blue whiting occurred mainly to the south of the FICZ, with the highest density calculated at 1,483 kg/km^2 (Fig. 27). Throughout the time series, southern blue whiting occurred mainly to the south of the FICZ and to the north-east of East Falkland, with the highest density calculated for 2016 to the south of East Falkland (203,954 kg/km^2; Appendix XV).

Southern blue whiting was caught in small numbers through the time series, therefore the small numbers of individuals sampled in 2022 (n = 1252). Total length ranged from 6 cm to 72 cm through the time series. A small length-group with total length at 23–25 cm was present across years. In 2022, mainly a small group with modal length at 24 cm was present. Larger individuals were also caught at around 32 cm but in small numbers (Fig. 28).

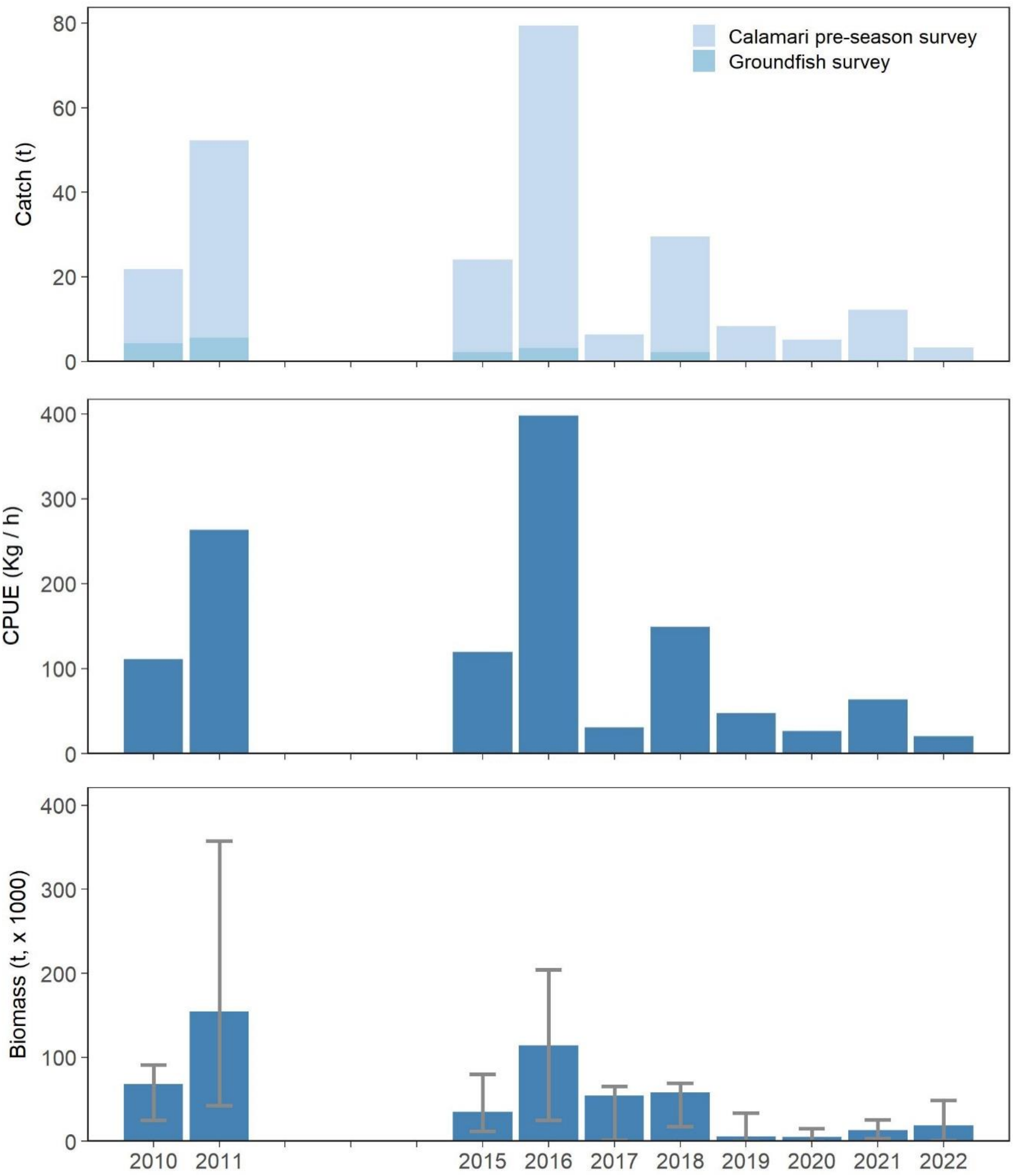

Fig. 26. Catch (t), CPUE (kg/h), and mean biomass (t) ± 95% confidence intervals of southern blue whiting (*Micromesistius australis australis*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

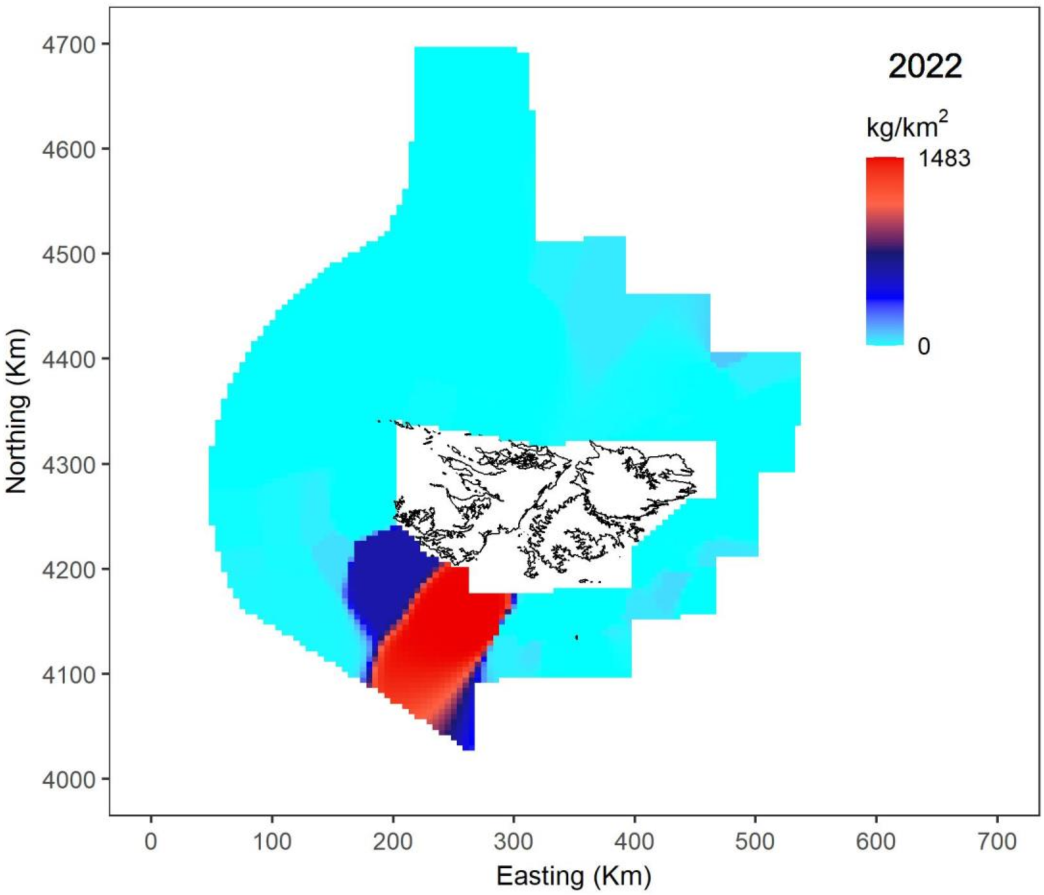

Fig. 27. Distribution and abundance of southern blue whiting (*Micromesistius australis australis*) calculated from the February 2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

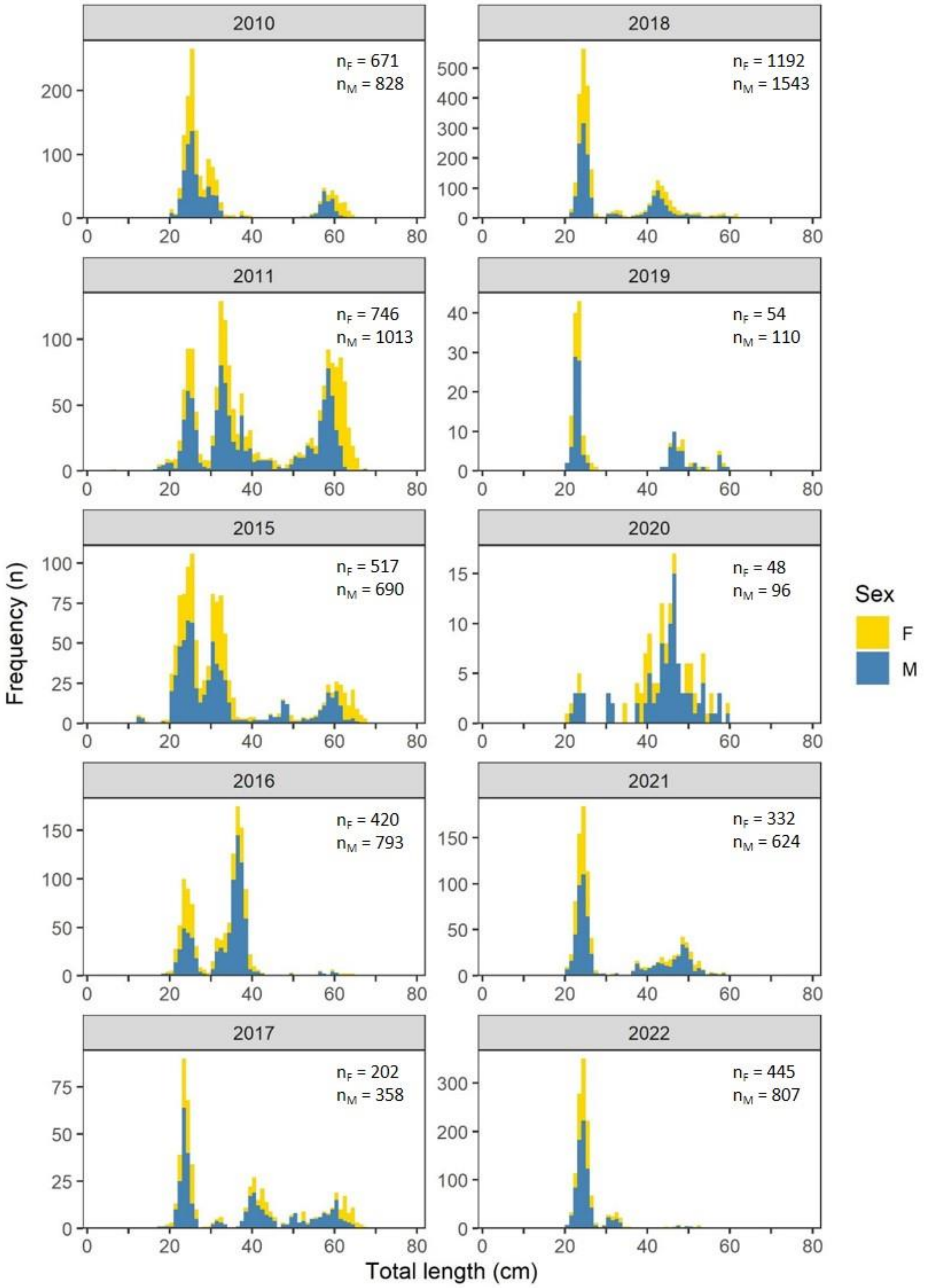

Fig. 28. Length frequency of southern blue whiting (*Micromesistius australis australis*) during the February groundfish and calamari pre-season surveys in Falkland Islands waters. Blue and yellow bars are superimposed.

4.2.10. Southern hake (*Merluccius australis*)

The highest catch in the time series was reported in 2010 (822 kg) and the lowest catch was reported in 2019 (51 kg); a total of 110 kg of southern hake were caught in 2022 (Fig. 29; Appendix IV). CPUE of southern hake was < 5 kg/h through the time series, with the highest values in 2010 (4.2 kg/h) and 2011 (3.9 kg/h). From 2015, CPUE remained below 2 kg/h and in 2022 it was 0.7 kg/h, the third lowest in the time series (Fig. 29; Appendix V). Biomass estimates of southern hake have remained below 6,000 t every February since 2010, with the lowest biomass estimated for 2019 (426 t). The third lowest biomass was estimated for 2022 with 920 t (Fig. 29; Table II). There was a statistically significant decrease in biomass from 2010 to 2020 (Appendix VI).

In 2022, the highest densities of southern hake were detected to the south-west of West Falkland (131 kg/km^2; Fig. 30). Southern hake was aggregated to the south-west of West Falkland throughout the time series, with the highest density reported in 2011 (923 kg/km^2; Appendix XVI).

Southern hake is caught in small numbers in Falkland Islands waters; hence the small number of samples. Length frequency histograms show range of sizes from 29 cm to 106 cm throughout the time series (Fig. 31).

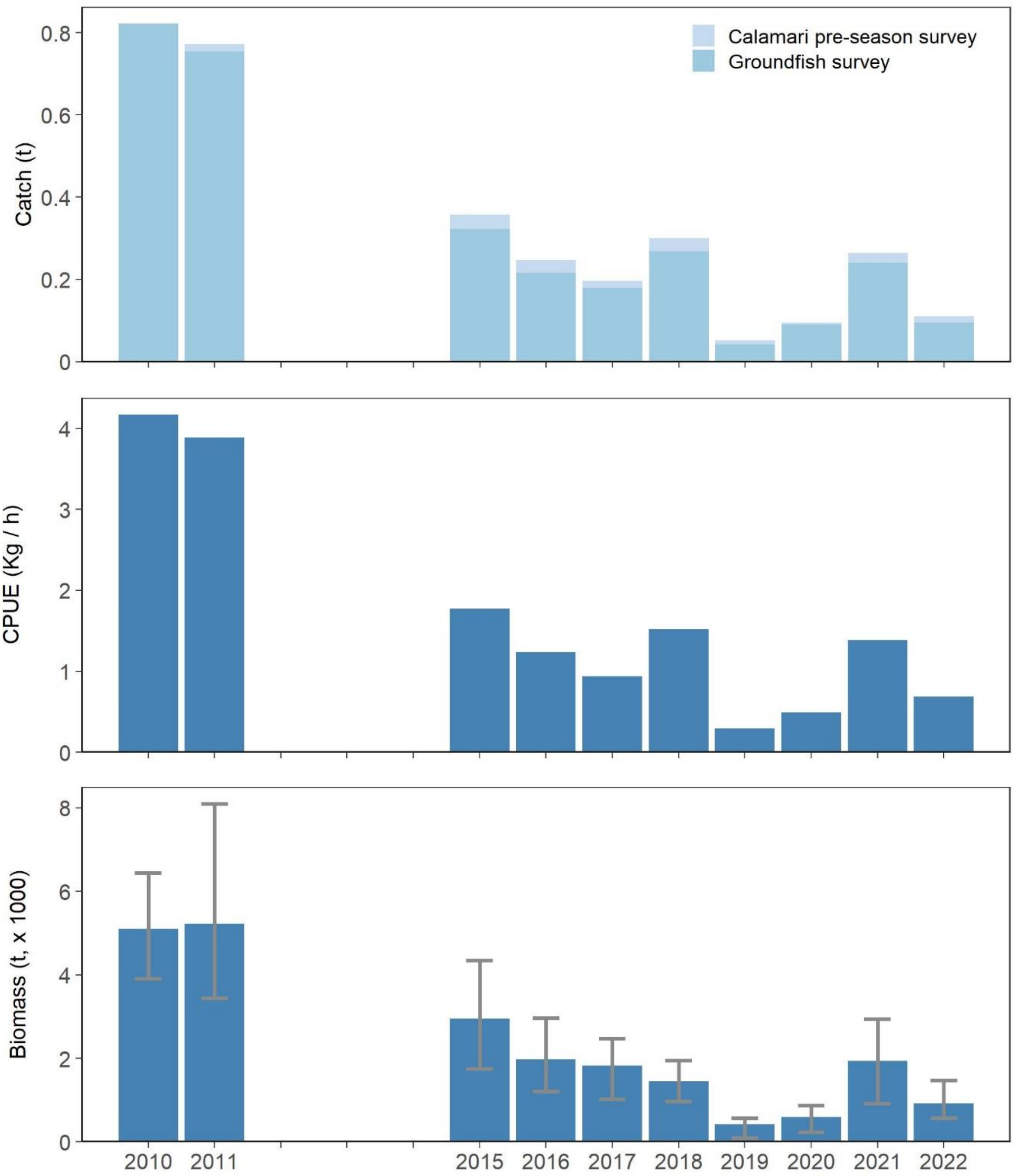

Fig. 29. Catch (t), CPUE (kg/h), and mean biomass (t) ± 95% confidence intervals of southern hake (*Merluccius australis*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

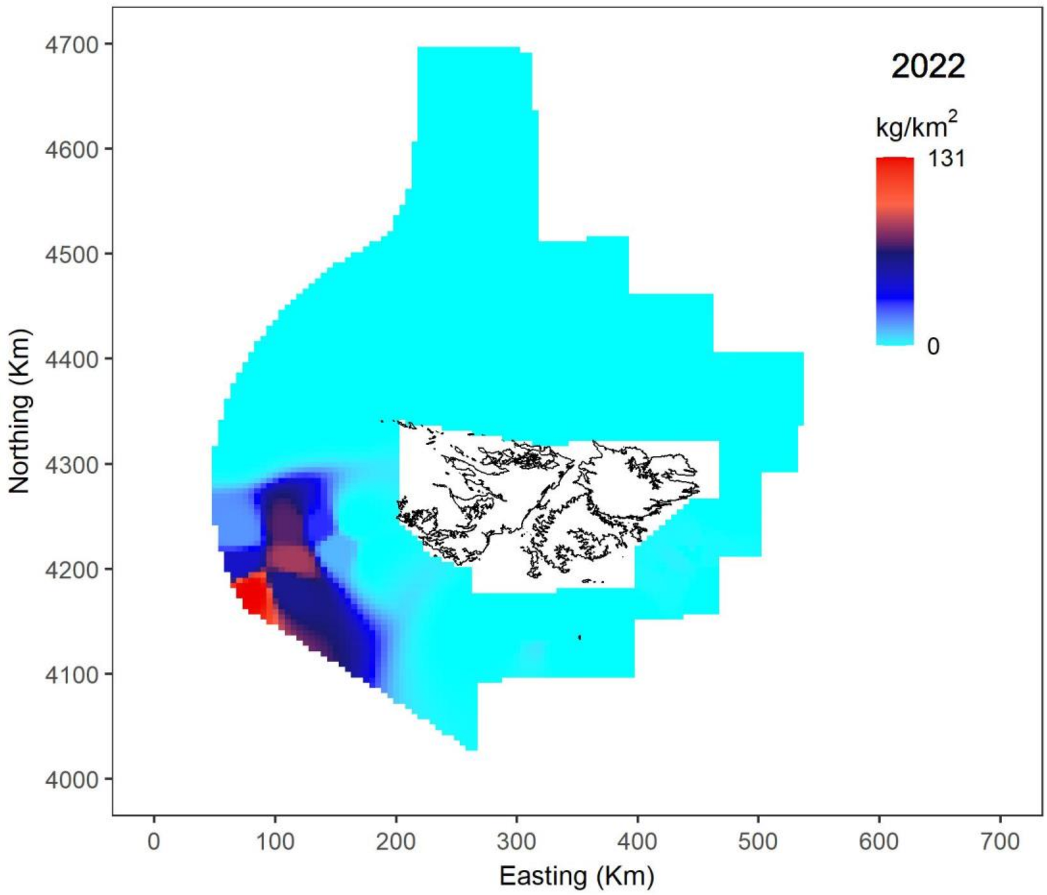

Fig. 30. Distribution and abundance of southern hake (*Merluccius australis*) calculated from the February 2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

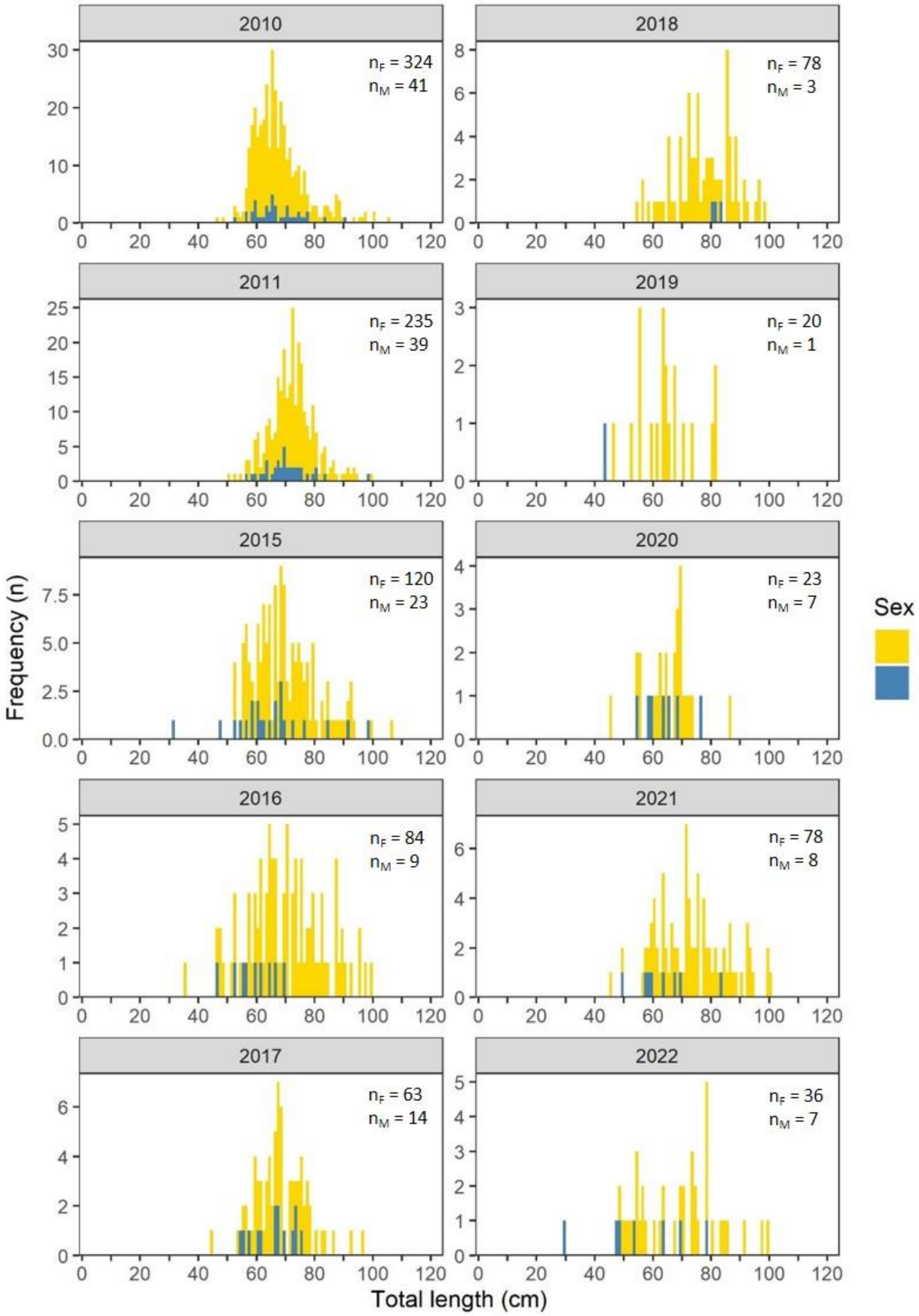

Fig. 31. Length frequency of southern hake (*Merluccius australis*) during the February groundfish and calamari pre-season surveys in Falkland Islands waters. Blue and yellow bars are superimposed.

4.2.11. Toothfish (*Dissostichus eleginoides*)

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.

The proportion of toothfish catches between groundfish and calamari pre-seasons surveys was variable across years. The maximum total catch was reported in 2017 (2.5 t) followed by 2011 (2.4 t); the lowest catch was reported in 2022 (331 kg) (Fig. 32; Appendix IV). CPUE of toothfish was < 13 kg/h across years, with the highest CPUE calculated in 2011 and in 2017 (nearly 12 kg/h each); the lowest CPUE in the time series was calculated for 2022 at 2.1 kg/h (Fig. 32; Appendix V). The February biomass of toothfish has remained below 11,000 t since 2010, with the lowest biomass estimated in 2020 (2,499 t). In 2022, the biomass of toothfish was estimated at 3,877 t (Fig. 32; Table II). There was no significant trend in biomass from 2010 to 2022 (Appendix VI).

In 2022, the highest densities of toothfish were detected across the south-west of West Falkland (176 kg/km^2; Fig. 33). Toothfish had a patchy distribution around the Falkland Islands through the time series, with the highest density reported in 2018 to the west and south-west of West Falkland (902 kg/km^2; Appendix XVII).

Length frequency histograms show that toothfish had a range of sizes from 5 cm to 115 cm throughout the time series, with several length-groups present. A small group had modal length at 30–36 cm, which in 2022 was evident at 35 cm for females and for males; recruitment was low in recent years (Fig. 34).

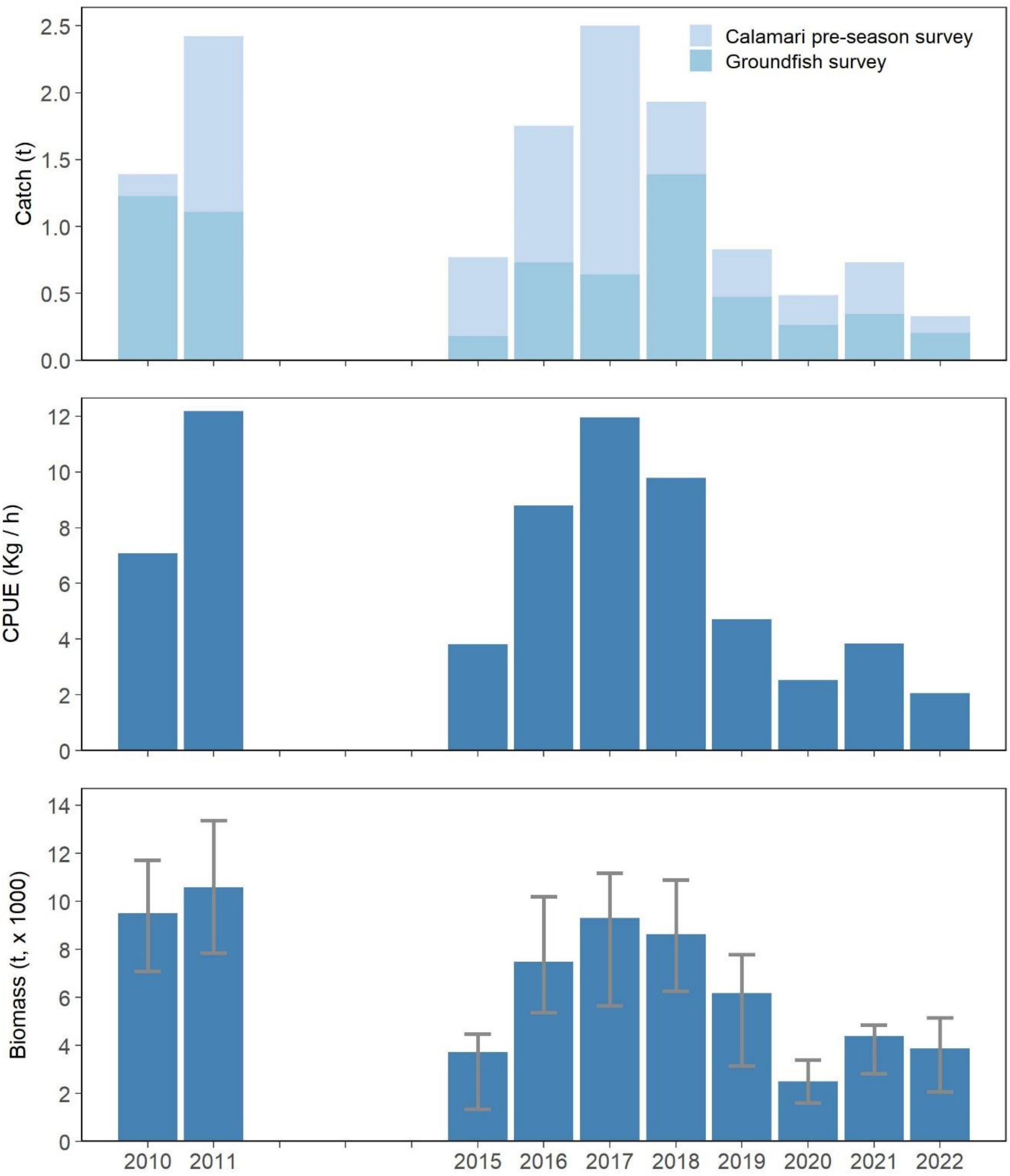

Fig. 32. Catch (t), CPUE (kg/h), and mean biomass (t) ± 95% confidence intervals of toothfish (*Dissostichus eleginoides*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

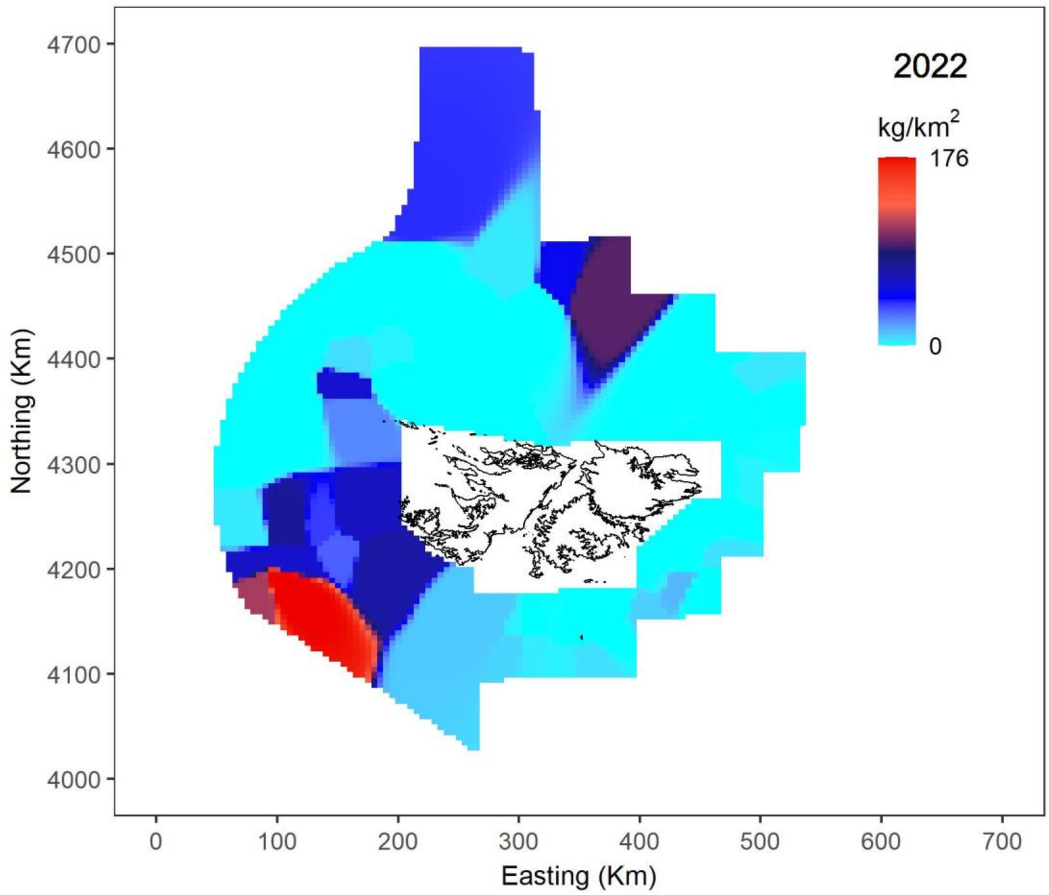

Fig. 33. Distribution and abundance of toothfish (*Dissostichus eleginoides*) calculated from the February 2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

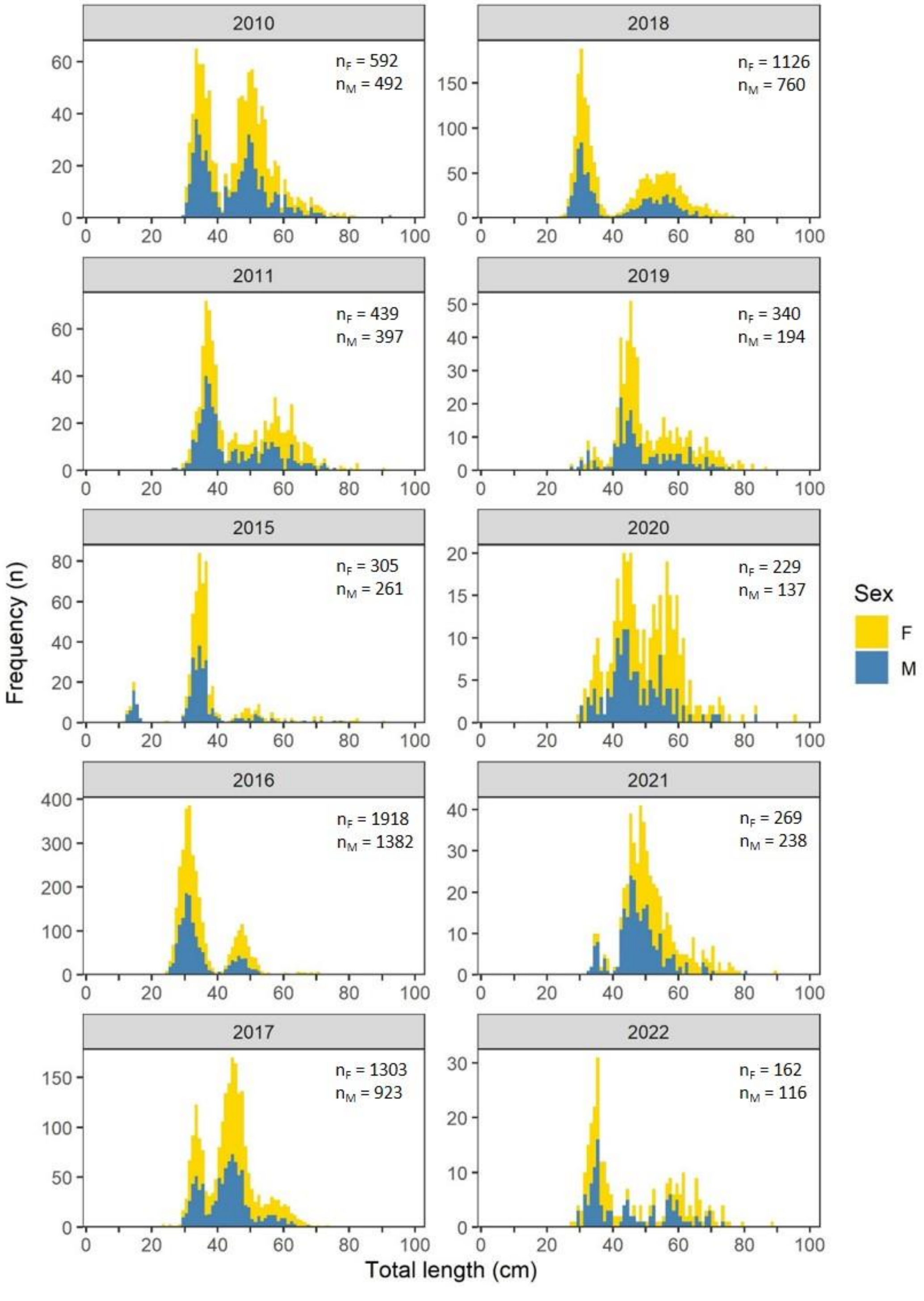

Fig. 34. Length frequency of toothfish (*Dissostichus eleginoides*) during the February groundfish and calamari pre-season surveys in Falkland Islands waters. Blue and yellow bars are superimposed.

5. Discussion

The biomass of three commercial stocks calculated from the February surveys had statistically significant declines from 2010 to 2022: rock cod, red cod, and southern hake. Rock cod had the greatest decrease in biomass; it was calculated that its biomass in 2022 (93,177 t) was only 11% of its biomass in 2010 (817,086 t). Southern hake biomass in 2022 (920 t) was 18% of its biomass in 2010 (5,097 t). The declining February trend of southern hake is consistent with its biomass decrease calculated from July surveys in 2017 (524 t) and 2020 (169 t) (Winter & Ramos 2021). The biomass of red cod had a significant decline from 2010 to 2020, and then increased in 2021 and 2022. Other stocks had declining trends from 2010 to 2019–2020, with subsequent biomass increase in 2021 and 2022 although none of these were statistically significant, i.e., banded whiptail grenadier, hoki, southern blue whiting, and toothfish. Overall, however, southern blue whiting biomass in 2022 (19,200 t) was only 28% of its biomass in 2010 (68,447 t), whereas toothfish biomass in 2022 (3,877 t) was 41% of its biomass in 2010 (9,492 t). Only the common hake had a significant increase in biomass in recent years, i.e., 2021 (33,282 t), and 2022 (42,421 t).

The large decrease in rock cod abundance is concurrent with increasing proportions of rock cod discard by the commercial fisheries, i.e., 2010 = 22%; 2011 = 12%; 2015 = 14%; 2016 = 51%; 2017 = 79%; 2018 = 77%; 2019 = 58%; 2020 = 64%; 2021 = 94% (Falkland Islands Government *unpublished data*). Rock cod are discarded because of their small size and most of these small individuals have not reproduced during their lifetime, which can affect recruitment to the fishery (Gilman et al. 2020). The declining biomass trend of rock cod in February surveys is consistent with the declining biomass trend from 2005 to 2019 based on commercial data (Winter 2020), and with the declining trend of CPUE since 2011, which has stabilized at low levels since 2020 (Ramos & Winter 2022a). An apparent change in its geographic distribution inferred from increasing out-of-zone catches may also have contributed to the decrease in abundance of this stock in Falkland Islands waters from 2016 to 2018 (Winter 2021, Table A1).

The recent stabilization of hoki and southern blue whiting abundance may be a consequence of the establishment of a no-fishing area to the south and south-west of the Falkland Islands from 1 July to 15 October since 2007, mandated for S-licensed vessels targeting both southern blue whiting and hoki stocks (Falkland Islands Government 2021). Both stocks may be further benefited by reduced fishing pressure because of the S-licence not being used since 2017. However, it must be noted that current abundances of these stock are still considerably low compared with 1987 (Ramos & Winter 2019a, 2021b). The pattern of southern blue whiting biomass found in this study is consistent with commercial catch stock assessments using CASAL, which also showed stabilization and slow increase in biomass in recent years (Ramos & Winter 2021b). Hoki stock assessments using data-poor methods such as LBB, OCOM and CMSY also found declining biomass trends with stabilization over the past few years; nevertheless, the most recent biomass calculation (i.e., for the year 2018) was only 13% of the biomass calculated for 1987 (Ramos & Winter 2019a).

Toothfish biomass estimated in February surveys has remained below 11,000 t since 2010, with the lowest biomass estimate in 2020 (2,499 t). However, these findings represent only a portion of the population given that trawlers rarely catch adult toothfish. A shift in fishing behaviour by finfish vessels (A–, G–, and W– licences), i.e., vessels fishing deeper and further south in the FICZ to capture ridge scaled rattail *Macrourus carinatus*, led the finfish fishery to catch more toothfish in 2016–2017. Catches declined again since 2018 to levels comparable with catches in 2011 (Falkland Islands Government 2019). The pattern of toothfish biomass from the February surveys is consistent with the negative trends in biomass detected using CASAL and CMSY+ on commercial data, with JABBA showing stabilization over the last decade (Skeljo & Winter 2021a, b).

Most stocks assessed in this study are targeted across several nations' Exclusive Economic Zones. For some stocks, the Falkland Islands contribute only a small proportion of the total shared catch in the Southwest Atlantic and Southeast Pacific. For instance, the Falkland Islands contributed nearly 9% and 11% of the 10-year average catch of southern blue whiting and hoki respectively, shared with Argentina and Chile (Ramos & Winter 2021b, c). Biomass declines of these stocks may therefore be largely due to high fishing pressure outside Falkland Islands waters. However, for some stocks the Falkland Islands contribute a major proportion of the total shared catch. For example, the Falkland Islands contribute 59% and 84% of the 10-year average catch of red cod and rock cod respectively, shared with Argentina (Ramos & Winter 2021d, 2022a). Management decisions made by the FIFD are important for these stocks.

Length data are routinely examined in FIFD stock assessments in the form of von Bertalanffy length infinity (L_{Inf}) and length at 50% maturity (L50), from which trends through years are presented. L_{Inf} and L50 of rock cod had declining trends since 2011 and since 2009, respectively (Ramos & Winter 2022a); L50 of kingclip declined since 1988 (Ramos & Winter 2019b), and L50 of male hoki declined since 2002 (Ramos & Winter 2021c). These patterns suggest a decrease in size of rock cod, kingclip, and male hoki, likely due to fishing pressure; these species are also reaching maturity at smaller sizes, which may be an adaptation to fishing pressure as well (Hunter et al. 2015). In contrast, L_{Inf} and L50 remained stable or increased for southern blue whiting (Ramos & Winter 2021b), red cod (Ramos & Winter 2021d), and common hake (Ramos & Winter *in prep.*).

The FIFD has made efforts to search for juvenile toothfish during austral spring or summer over the last few years, by juvenile toothfish surveys (e.g., Pompert et al. 2015; Arkhipkin et al. 2017; Lee et al. 2018) or by including four inshore stations in February groundfish surveys (e.g., see Arkhipkin et al. 2019; Randhawa et al. 2020; Trevizan et al. 2021). In the February groundfish surveys, toothfish smaller than 20 cm total length (ages ≤ 1) have been scarce through the time series (n_{2010} = 0; n_{2011} = 60; n_{2015} = 237; n_{2016} = 57; n_{2017} = 109; n_{2018} = 0; n_{2019} = 1; n_{2020} = 2; n_{2021} = 26; n_{2022} = 0); however, it must be noted that juvenile toothfish were not systematically searched for at least during the February 2010, 2011, and 2022 surveys. Nevertheless, higher numbers of juveniles found in the February 2015 and 2017 surveys are consistent with higher recruitment in 2015 and 2017, with persistent recruitment hotspots for newly-settled toothfish found to the north-west in the FICZ, along with opportunistic areas to the north (2016), south (2017) and north-east (2015), coinciding with the main areas of upwelling and high productivity. The state of toothfish recruitment has remained low apart from 2015 and 2017; during years of low recruitment, juvenile toothfish are largely constrained to sheltered inshore regions to the north-west of the Falkland Islands (Lee et al. 2021). Juveniles of other species are recorded and measured opportunistically, but are not currently the objective of a systematic study.

The algorithm for calculating biomass estimates was adjusted this year (see Methods, and Appendices II and III) to give more effective weighting to survey trawls that are shortened but nevertheless valid, and therefore not excluded from analyses. As the adjustment was applied retroactively, species biomass estimates in Table II differ somewhat from the equivalent tables in previous years' reports. Shortened but valid trawls occurred in several years, and can affect biomass estimation especially of species that have strongly aggregated distributions. For example, the hoki biomass estimate was particularly high in February 2021 due to the exceptionally large catch of this species on station 3362 of the groundfish survey, which had to be ended after just 20 minutes to avoid overloading the net (Ramos & Winter 2021a; Trevizan et al. 2021). This trawl was valid as the gear was not defective, and the schooling behaviour of hoki makes such a high localized density realistic, but the influence of this one trawl on the overall biomass estimate needed to be down-weighted. An additional adjustment was applied to the February 2022 groundfish survey, which had only 42 trawl stations instead of the usual average 87 stations due to quarantine requirements. This adjustment for 2022 (only) provided a more realistic output of the biomass estimation uncertainties in the shortened survey.

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Appendix I. February surveys summary

February groundfish (gf) and calamari pre-season (pr) surveys information. Catches per survey and combined total include Argentine shortfin squid, banded whiptail grenadier, common hake, hoki, kingclip, Patagonian squid, red cod, rock cod, southern blue whiting, and toothfish.

Year	Vessel		No. of trawls			Stations excluded		Catch (t)		
	gf	pr	gf	pr	total	gf	pr	gf	pr	total
2010	Castelo (ZDLT1)	Beagle F.I. (ZDLZ)	87	55	142	478, 501	NA	195.8	458.0	653.8
2011	Castelo (ZDLT1)	Venturer (ZDLP1)	88	58	146	NA	NA	196.7	257.4	454.1
2015	Castelo (ZDLT1)	Baffin Bay (MSPL9)	89	57	146	NA	NA	121.8	392.9	514.7
2016	Castelo (ZDLT1)	Sil (ZDLR1)	90	56	146	NA	638	87.7	206.7	294.4
2017	Castelo (ZDLT1)	Argos Vigo (ZDLU1)	90	58	148	2328	1002	48.1	254.3	302.5
2018	Monteferro (ZDLM3)	Castelo (ZDLT1)	97	59	156	143,144,156,164,183	NA	81.4	169.6	251.1
2019	Monteferro (ZDLM3)	Argos Cíes (ZDLS3)	79	52	135	240,242,244,246	25,29,37	47.0	418.7	465.6
2020	Castelo (ZDLT1)	Argos Cíes (ZDLS3)	80	59	139	NA	NA	49.9	283.9	333.8
2021	Castelo (ZDLT1)	Capricorn (ZDLY)	80	55	135	3388,3391,3392,3393	NA	76.4	348.0	424.4
2022	Castelo (ZDLT1)	Argos Cíes (ZDLS3)	42	60	102	NA	NA	46.1	445.7	491.8

Appendix II. Algorithm adjustments

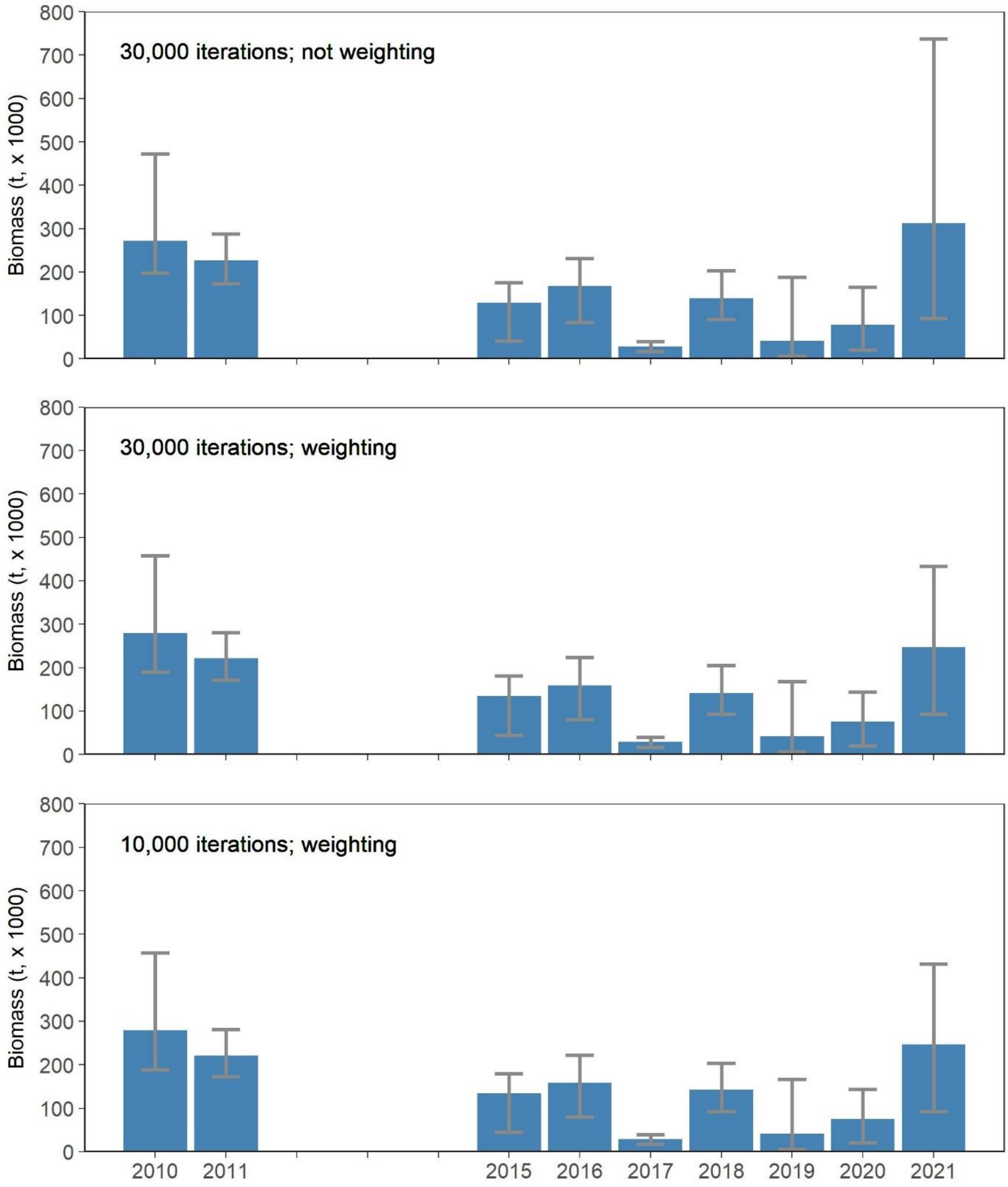
Example for trawl area weighting adjustment and reduced number of bootstrap iterations.

The 2021 groundfish survey had a trawl that was ended after just 20 minutes due to high catch of hoki; this trawl was good and was included in the analysis but it affected the calculation of biomass. Weighting for trawl area allowed addressing this bias; note for hoki the wide upper and lower biomass limits for 2021 with no weighting adjustment, compared with the narrower limits for 2021 with weighting adjustment, as well as the lower empirical estimate from the weighting-adjusted algorithm (Table A-II, Figure A-II). Confidence intervals of the biomass estimates are negligibly different between 30,000 and 10,000 bootstrap iterations (Table A-II). This finding indicates that 10,000 iterations are sufficient for the calculation of biomass limits, and at shorter computational times (up to 4 hours per species per year rather than 12 hours per species per year) without compromising the confidence in biomass.

Table AII Estimated biomass (t) of hoki during the February 2010–2011 and 2015–2021 groundfish and calamari pre-season surveys in Falkland Islands waters. The 95% confidence intervals are indicated in parentheses. Calculations not implementing and implementing weighting adjustment for trawl area, with 30,000 iterations vs 10,000 bootstrap iterations.

Year	Hoki 30,000 iterations (not weighting)	Hoki 30,000 iterations (weighting)	Hoki 10,000 iterations (weighting)
2010	272080.22 (197644.96–472481.97)	278980.21 (190192.61–457789.08)	278980.21 (188264.88–457666.96)
2011	225981.56 (173396.03–287362.59)	221132.74 (171881.82–280556.65)	221132.74 (172507.38–281186.26)
2015	129562.42 (40753.69–175529.10)	134733.17 (44210.08–180817.67)	134733.17 (44674.67–179592.78)
2016	167312.12 (83510.52–231697.65)	158388.16 (80038.62–223488.68)	158388.16 (79371.74–222823.65)
2017	28863.12 (16842.07–39751.29)	28882.54 (16765.64–39005.55)	28882.54 (16801.50–38817.08)
2018	139665.90 (91380.06–203699.81)	141953.50 (92508.98–204924.59)	141953.50 (92768.34–204228.49)
2019	41346.89 (6569.34–188598.04)	41864.81 (5934.01–168335.87)	41864.81 (5779.47–166317.90)
2020	77727.54 (20133.68–165424.57)	75402.28 (20101.65–143447.72)	75402.28 (20203.23–143531.23)
2021	312118.42 (93792.22–737156.05)	246936.26 (92996.55–433618.52)	245890.30 (92470.50–431476.19)

Fig. AII-1 Calculated biomass (t) of hoki during the February 2010–2011 and 2015–2021 groundfish and calamari pre-season surveys in Falkland Islands waters. The 95% confidence intervals are indicated by the grey lines. Calculations not implementing (upper panel) and implementing weighting for trawl area (middle and bottom panels), with 30,000 iterations vs 10,000 iterations.



Appendix III. Exclusion analysis

The February 2022 groundfish survey was shortened to 11 fishing days (Trevizan et al. *in prep.*), requiring removal of roughly half the normal complement of trawl stations. To maintain efficacy of the survey schedule, most trawls were deselected in several contiguous exclusion blocks (Fig. AIII-1), rather than dispersed throughout the survey area.

Extrapolating biomass estimates over these blocks with the standard inverse distance weighting algorithm could increase estimate uncertainty, by a margin exceptionally higher depending on how much of a species' abundance was located within the blocks. A supplementary procedure was therefore implemented to approximate this gap in the data more closely. For each species, the proportion of its biomass over the whole groundfish survey area, derived from the standard inverse distance weighting algorithm, that was not within the aggregate of the exclusion blocks, was calculated for each February groundfish survey 2010, 2011, and 2015 to 2022. A LOESS (span = 1.0, degree = 2) of these proportions by survey year was calculated (Fig. AIII-2), and the standard error of the LOESS fit corresponding to 2022 retained. The hierarchical bootstrap algorithm for uncertainty in 2022 was then calculated as before, and at each iteration the biomass within the non-excluded area of the survey was divided by a value drawn from the random normal distribution with mean equal to the proportion in the non-excluded area and standard deviation equal to the 2022 LOESS standard error.

This supplementary procedure increased the coefficient of variation of biomass estimates by margins ranging from 30% for banded whiptail grenadier to 98% for hoki. Long-term trends of biomass can thus be additionally informed by how much less weight should be ascribed to the 2022 estimates, given the higher uncertainty of this shortened survey.

Fig. AIII-1. Survey trawl stations conducted during the February 2022 groundfish survey. The red dots are the stations excluded from the survey; exclusion areas (red areas) were used for supplementary uncertainty calculation in 2022.

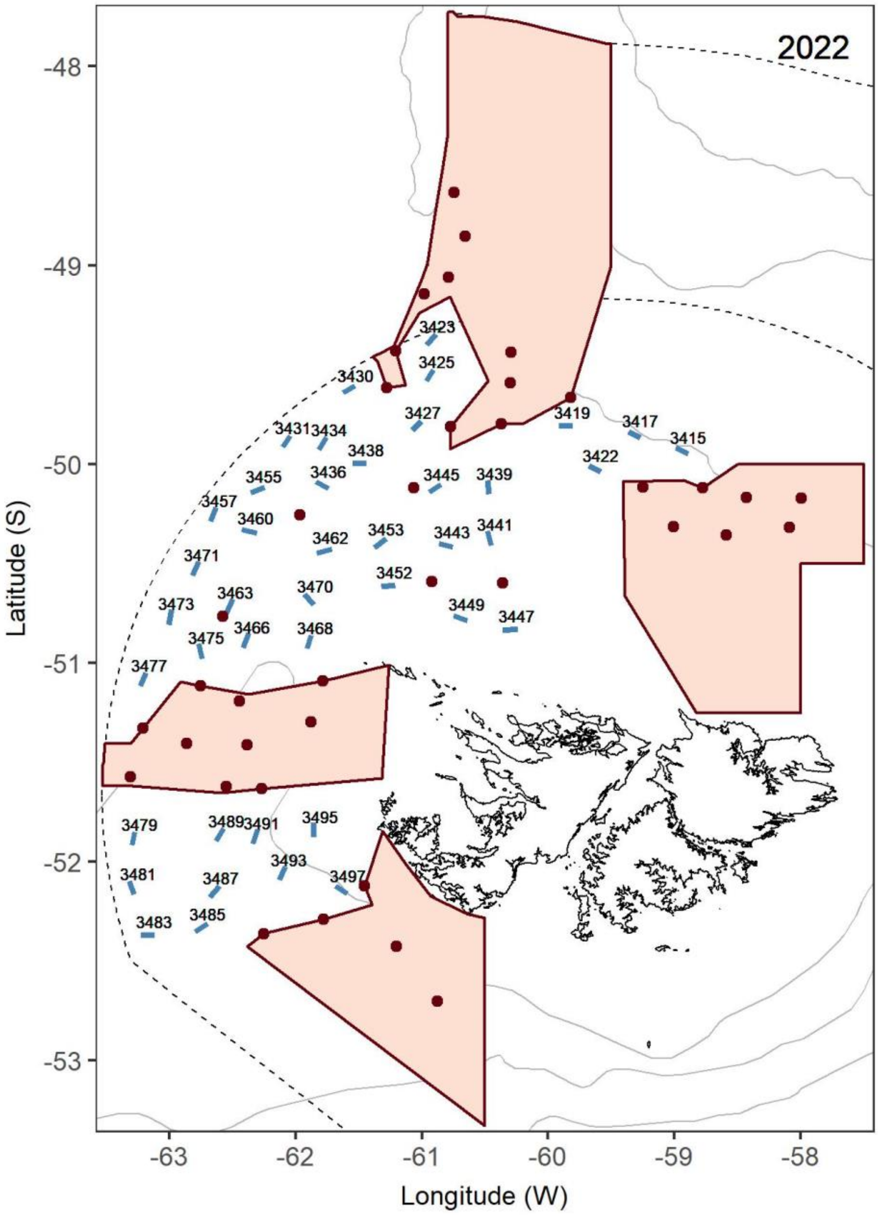
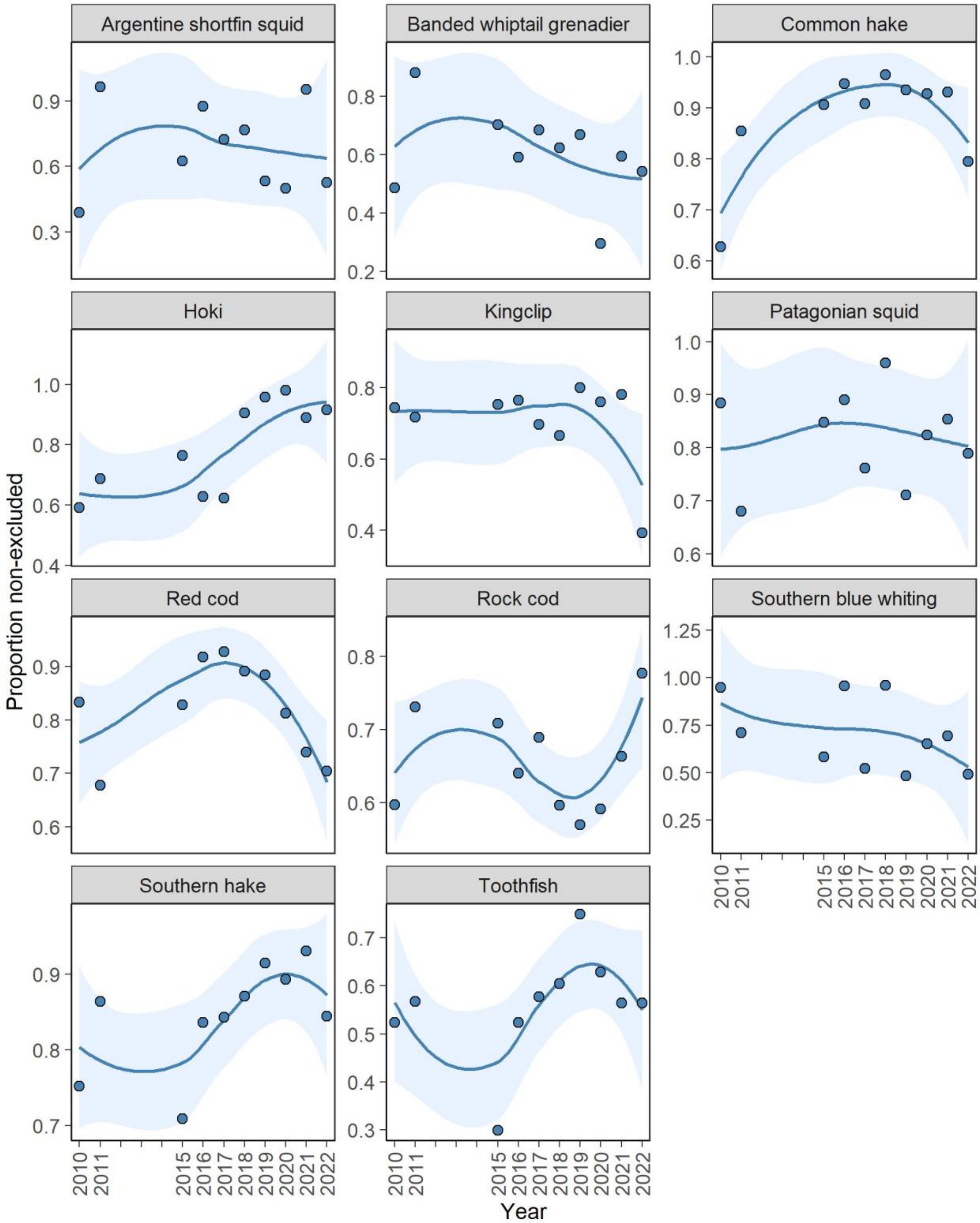


Fig. AIII-2. LOESS smooth ± 95% confidence intervals of biomass proportions, by survey year, in the survey area designated as non-excluded in 2022.



Appendix IV. February surveys catches

Catches (t) of main commercial species during the February 2010–2011, and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

Year	Argentine shortfin squid	Banded whiptail grenadier	Common hake	Hoki	Kingclip	Patagonian squid	Red cod
2010	0.88	8.05	1.31	79.78	3.24	356.76	13.54
2011	1.95	6.20	1.67	56.00	8.59	50.51	23.54
2015	31.87	6.58	3.17	26.36	14.73	186.14	21.81
2016	0.10	3.28	0.69	38.91	5.45	66.89	19.95
2017	2.48	3.97	2.94	3.69	4.26	185.23	13.82
2018	10.70	7.54	1.73	30.02	3.59	115.84	13.30
2019	9.41	2.50	2.75	7.55	4.42	386.26	13.68
2020	17.91	2.62	0.72	14.38	3.62	272.08	3.71
2021	10.31	6.53	8.15	30.83	4.79	285.54	6.04
2022	0.78	4.50	5.65	9.71	2.79	422.74	10.41
Total	86.39	51.77	28.78	297.23	55.49	2327.75	139.8
Mean	8.64	5.18	2.88	29.72	5.55	232.78	13.98

Appendix IV. *continued*

Year	Rock cod	Southern blue whiting	Southern hake	Toothfish	Total	Mean
2010	164.59	21.87	0.82	1.39	652.23	59.29
2011	249.38	52.29	0.77	2.42	453.32	41.21
2015	198.27	24.12	0.36	0.77	514.18	46.74
2016	77.31	79.36	0.25	1.75	293.94	26.72
2017	76.13	6.41	0.20	2.50	301.63	27.42
2018	35.92	29.51	0.30	1.93	250.38	22.76
2019	27.94	8.38	0.05	0.83	463.77	42.14
2020	10.98	5.10	0.10	0.49	331.71	30.16
2021	57.16	12.17	0.26	0.73	422.51	38.41
2022	30.82	3.27	0.11	0.33	491.11	44.65
Total	928.49	242.48	3.22	13.14		
Mean	92.85	24.25	0.32	1.31		

Appendix V. February surveys CPUE

CPUE (kg/h) of main commercial species during the February 2010–2011, and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.

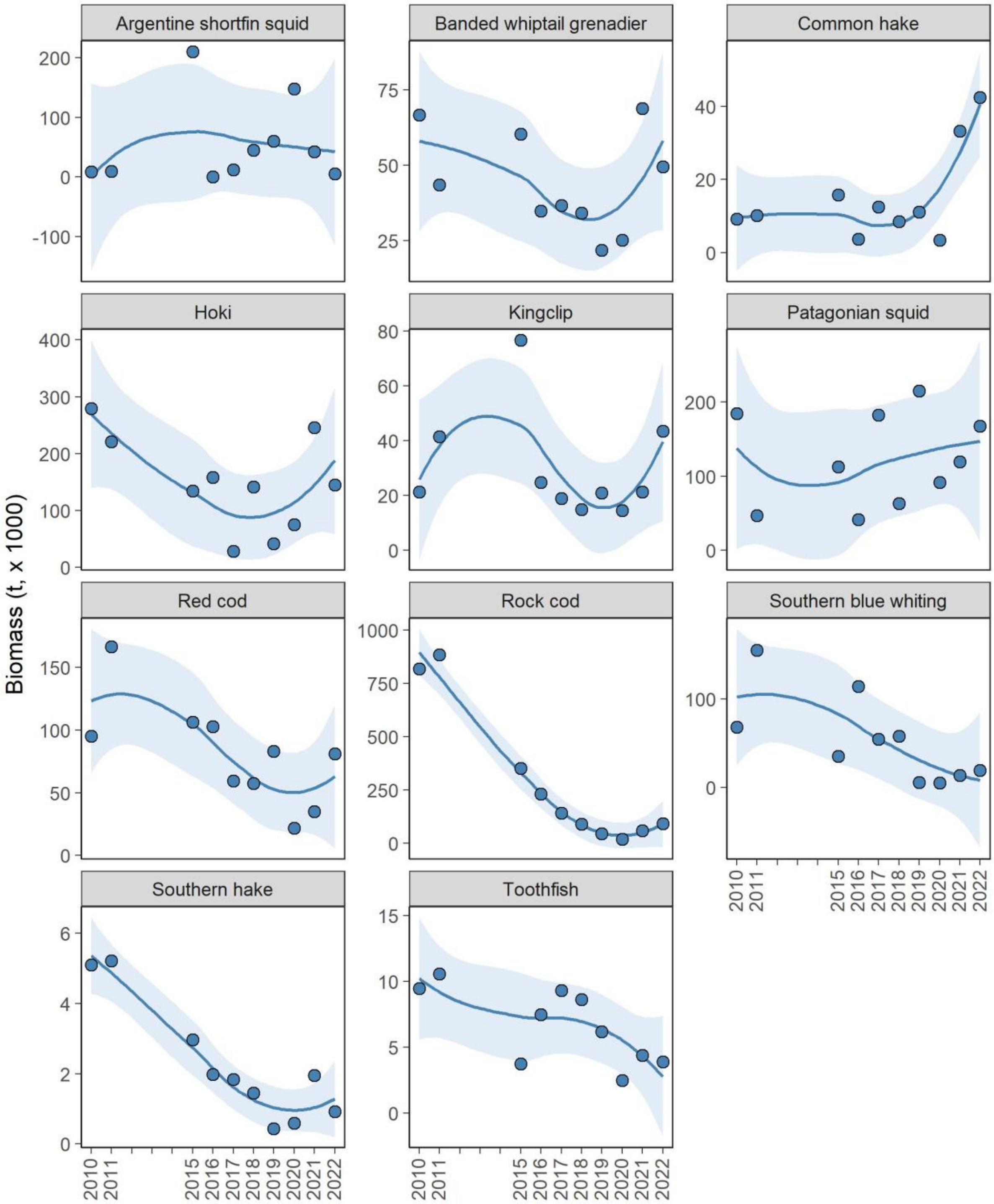
Year	Argentine shortfin squid	Banded whiptail grenadier	Common hake	Hoki	Kingclip	Patagonian squid	Red cod
2010	4.48	40.89	6.65	405.42	16.45	1812.97	68.80
2011	9.80	31.21	8.42	281.92	43.24	254.29	118.51
2015	158.02	32.63	15.70	130.73	73.05	922.99	108.15
2016	0.50	16.44	3.48	195.23	27.33	335.59	100.07
2017	11.89	19.01	14.07	17.68	20.38	886.27	66.13
2018	54.27	38.21	8.78	152.18	18.18	587.29	67.43
2019	53.46	14.23	15.64	42.91	25.10	2192.65	77.72
2020	93.08	13.63	3.77	74.73	18.83	1413.65	19.26
2021	54.06	34.25	42.74	161.68	25.10	1497.34	31.67
2022	4.82	27.98	35.11	60.33	17.33	2625.98	64.69
Total	444.37	268.49	154.33	1522.8	285	12529.03	722.43
Mean	44.44	26.85	15.43	152.28	28.5	1252.9	72.24

Appendix V. *continued*

Year	Rock cod	Southern blue whiting	Southern hake	Toothfish	Total	Mean
2010	836.41	111.13	4.17	7.07	3314.45	301.31
2011	1255.50	263.26	3.89	12.19	2282.24	207.48
2015	983.17	119.60	1.77	3.82	2549.62	231.78
2016	387.84	398.13	1.24	8.79	1474.62	134.06
2017	364.27	30.65	0.94	11.96	1443.26	131.21
2018	182.12	149.62	1.52	9.79	1269.38	115.4
2019	158.66	47.57	0.29	4.71	2632.94	239.36
2020	57.04	26.50	0.50	2.53	1723.51	156.68
2021	299.72	63.81	1.38	3.83	2215.59	201.42
2022	191.42	20.33	0.68	2.06	3050.72	277.34
Total	4716.14	1230.6	16.39	66.74		
Mean	471.61	123.06	1.64	6.67		

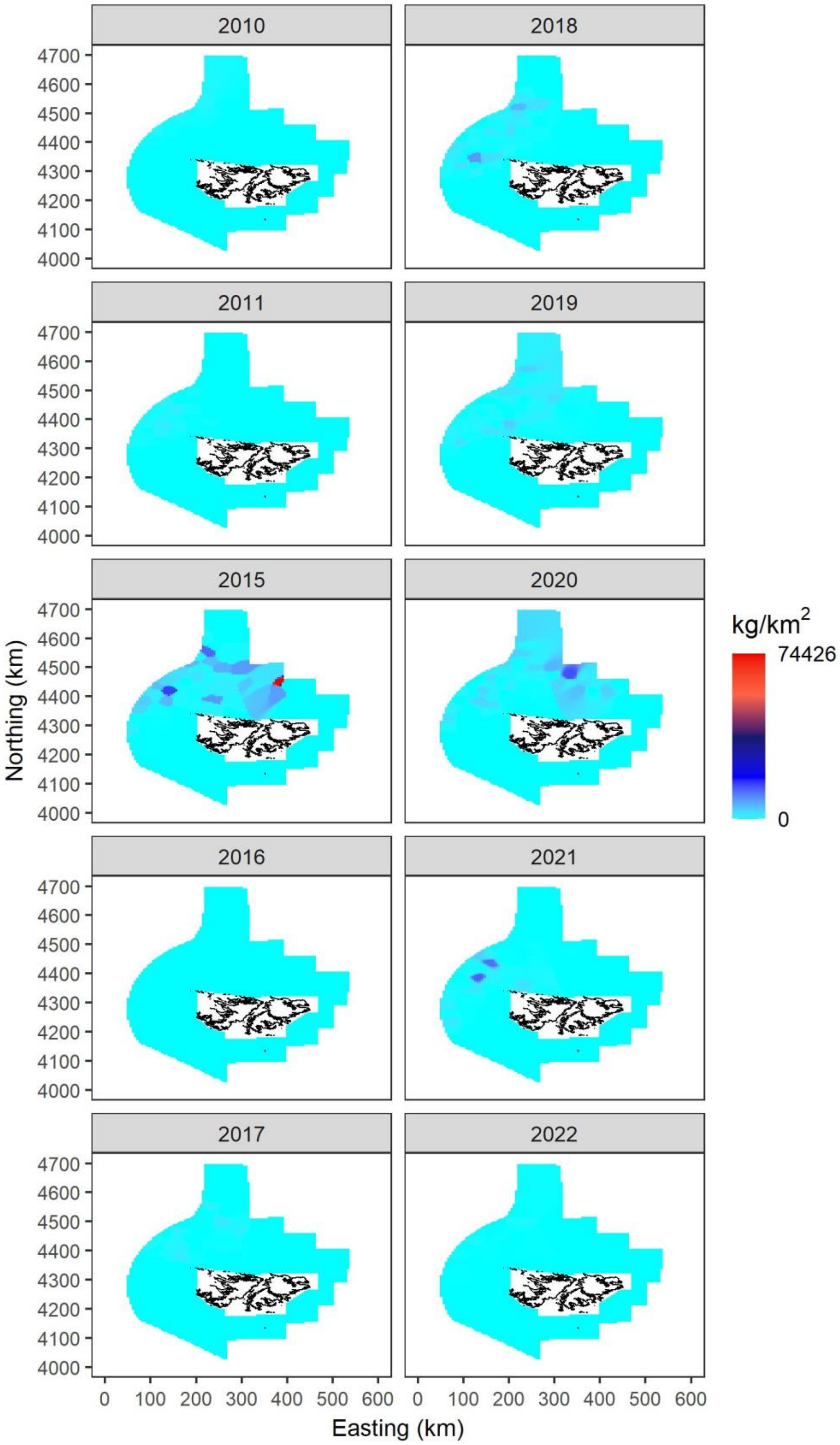
Appendix VI. February survey biomass trends

Biomass (t) of commercial species in February groundfish and calamari pre-season surveys during 2010-2011 and 2015-2022. LOESS smooth ± 95% confidence intervals.



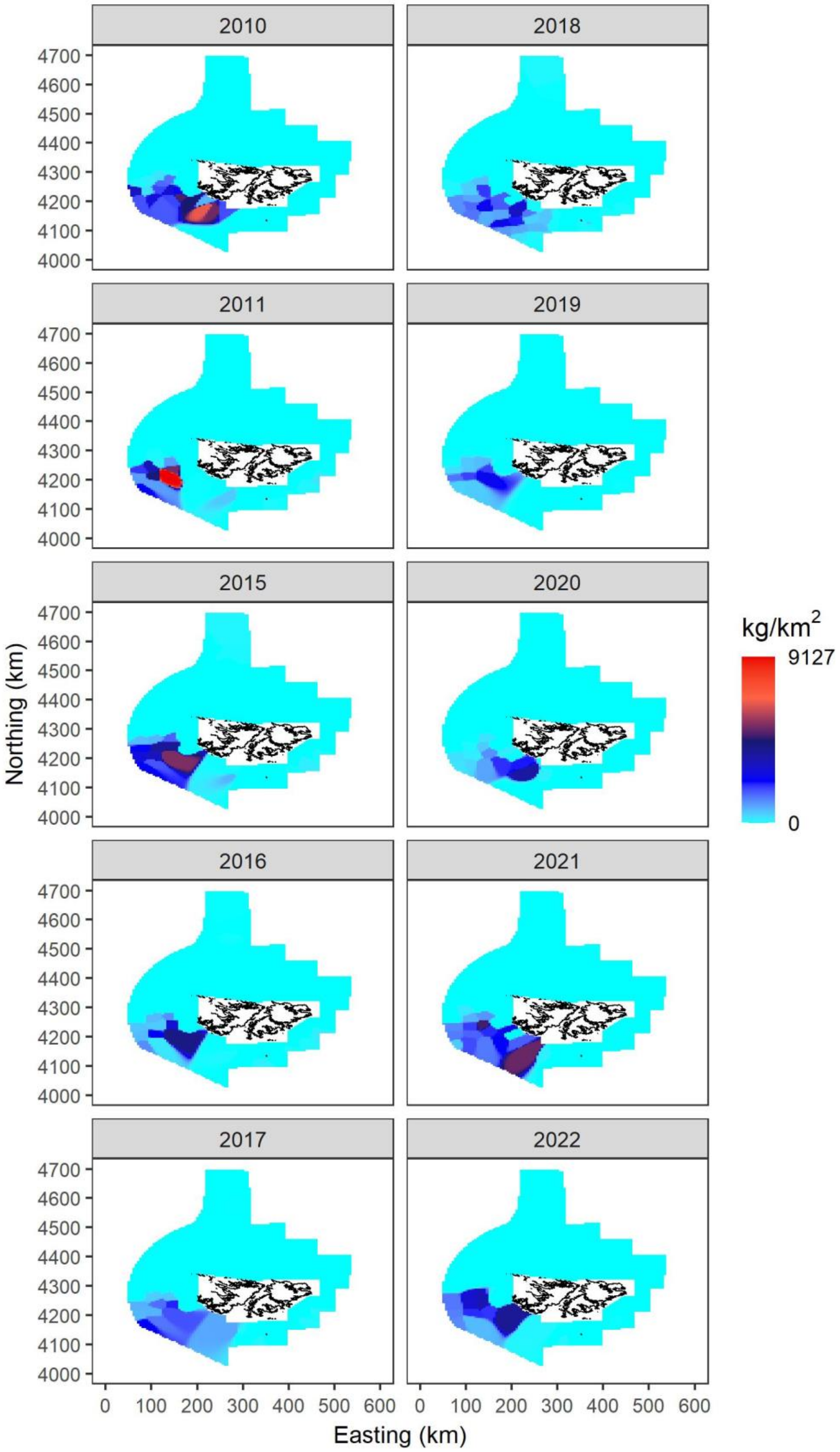
Appendix VII. Argentine shortfin squid inter-annual distribution

Comparative density of the Argentine shortfin squid (*Illex argentinus*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.



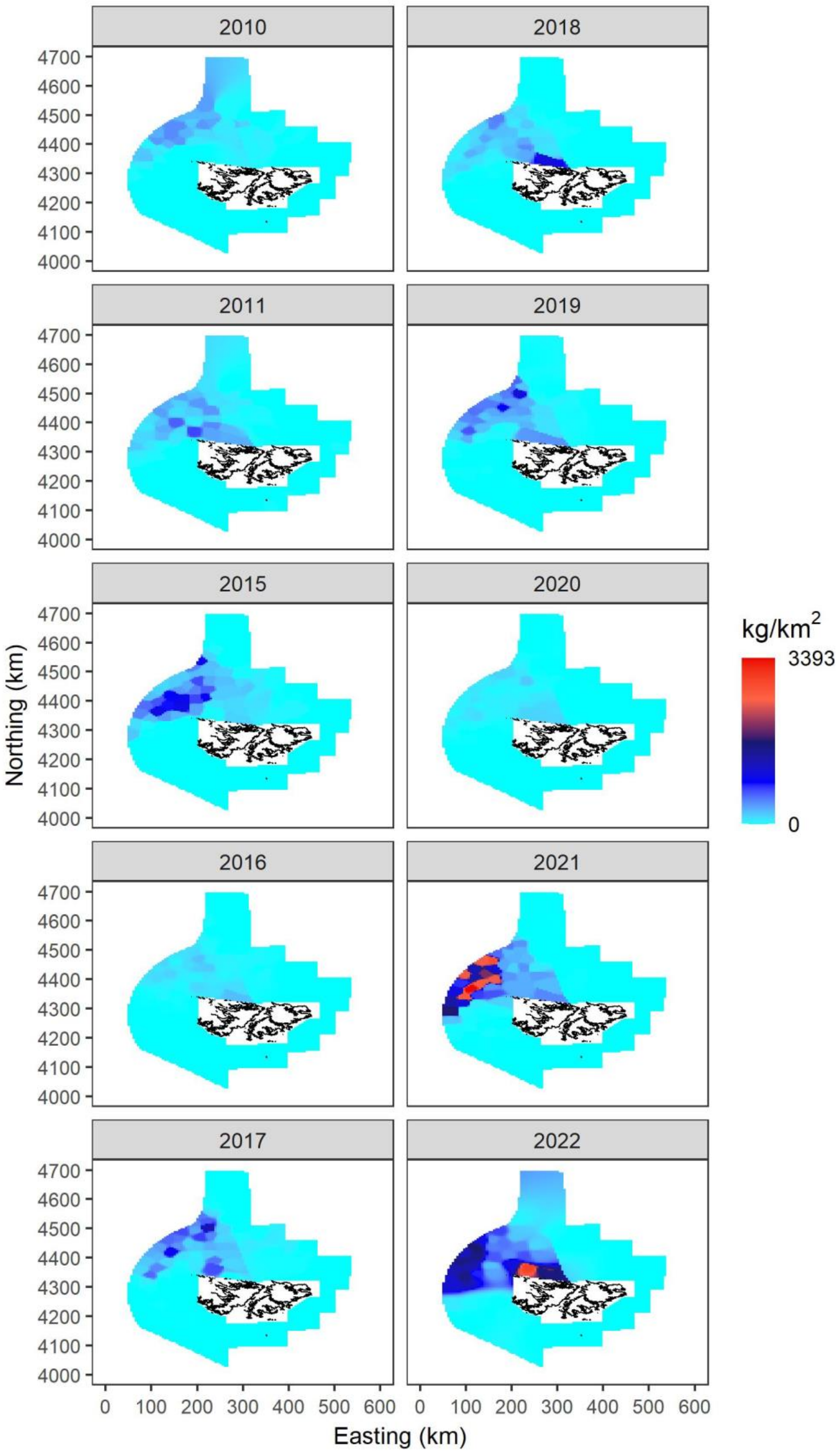
Appendix VIII. Banded whiptail grenadier inter-annual distribution

Comparative density of banded whiptail grenadier (*Coelorinchus fasciatus*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.



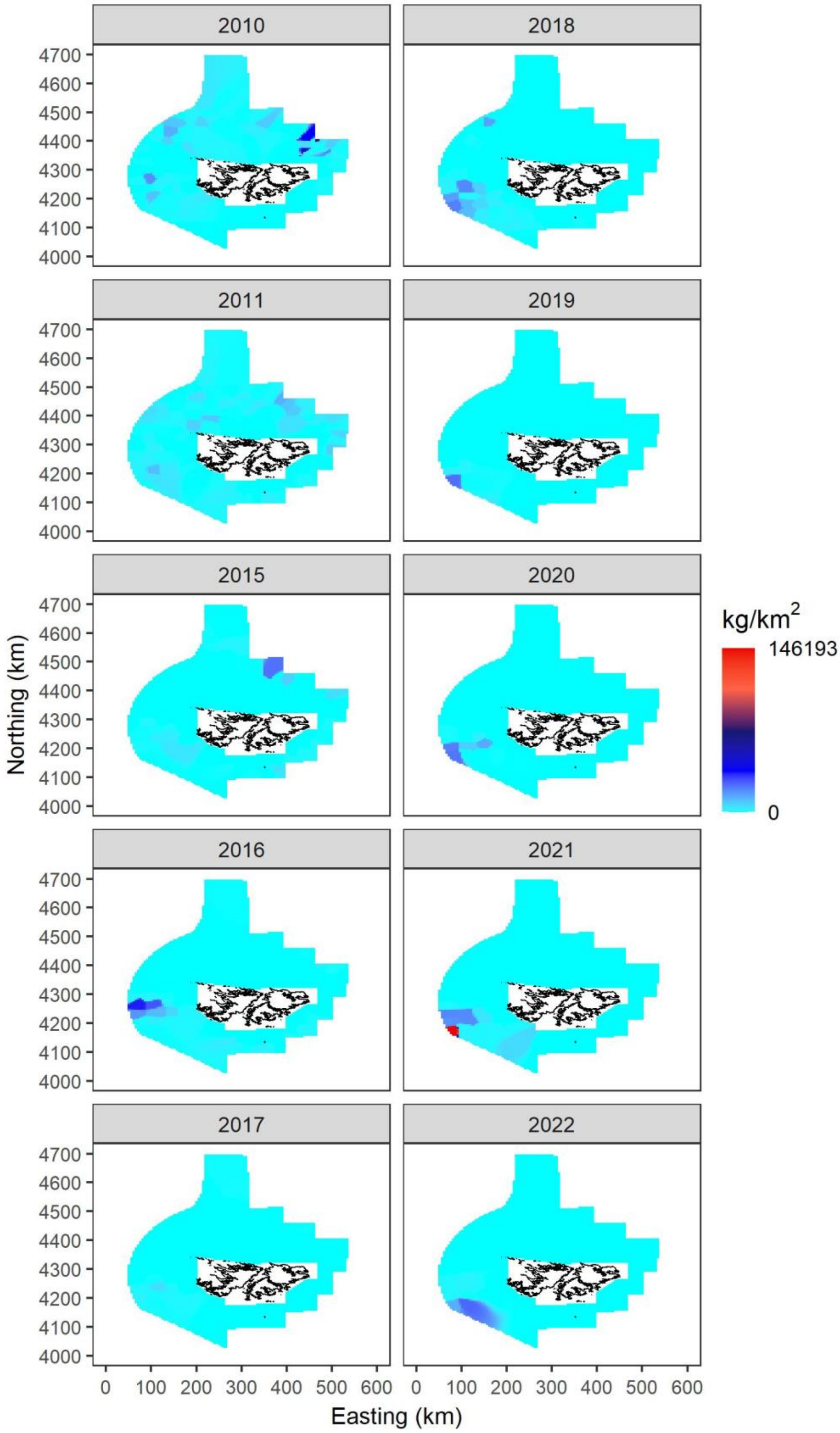
Appendix IX. Common hake inter-annual distribution

Comparative density of common hake (*Merluccius hubbsi*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.



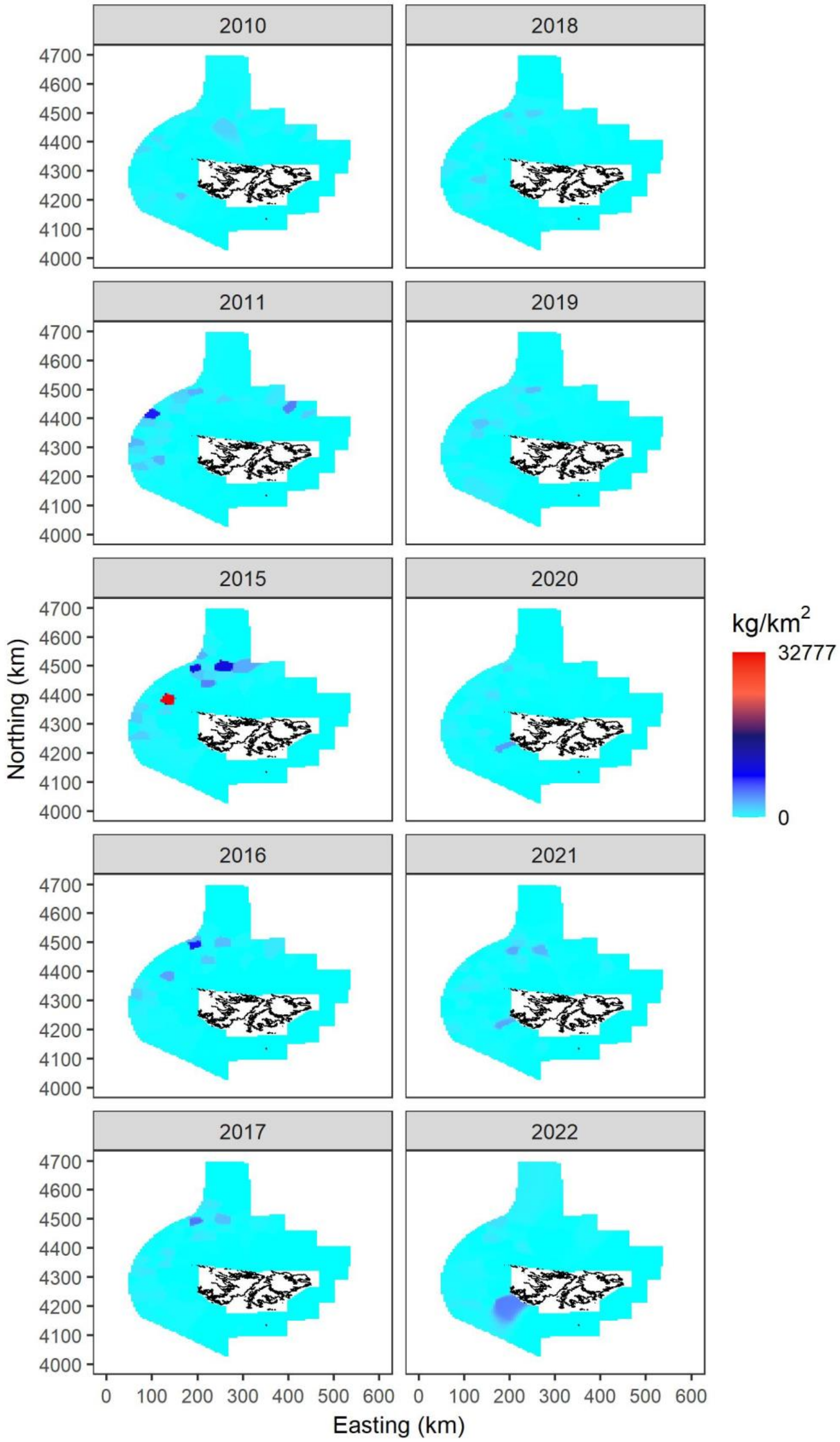
Appendix X. Hoki inter-annual distribution

Comparative density of hoki (*Macruronus magellanicus*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.



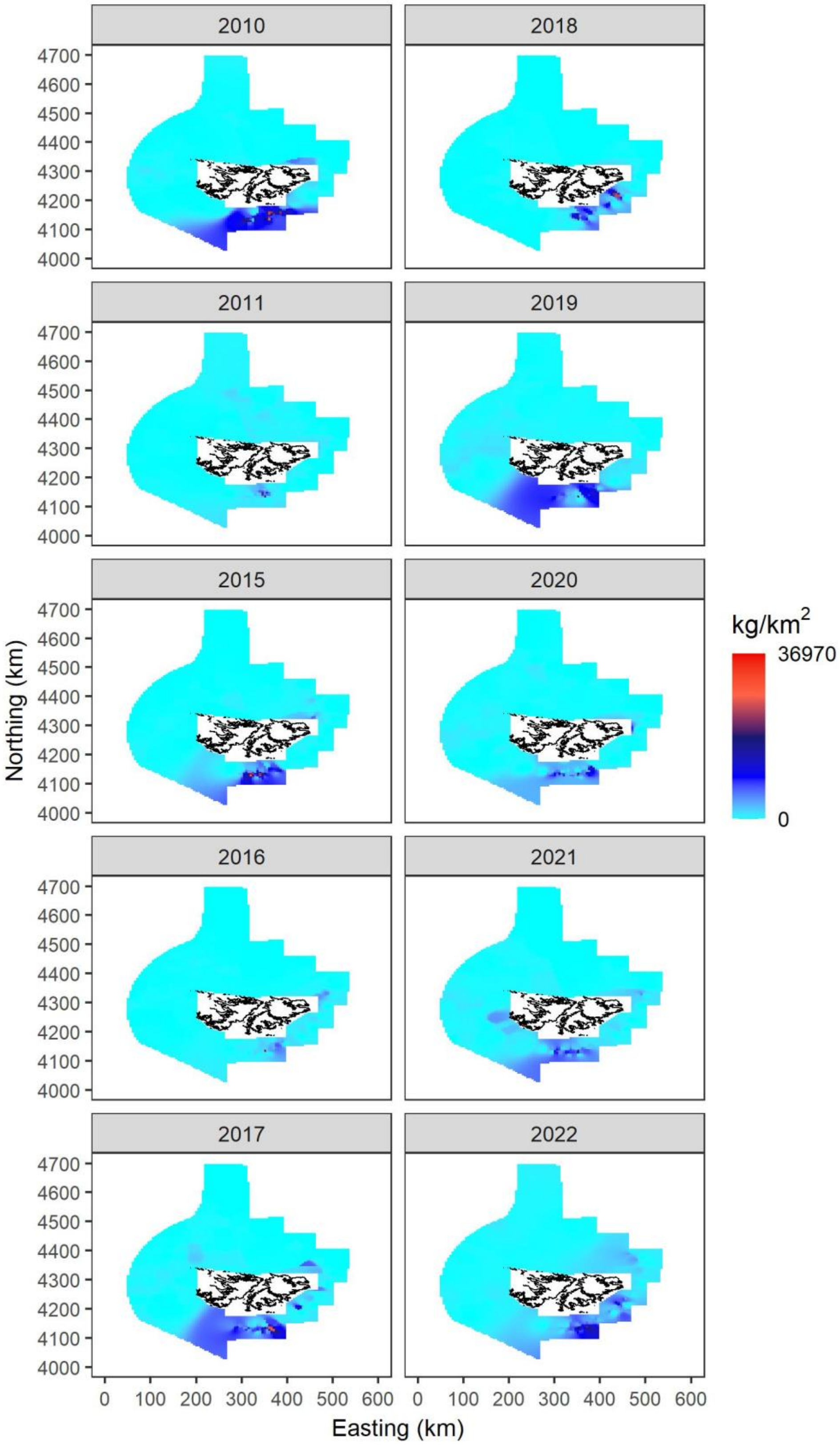
Appendix XI. Kingclip inter-annual distribution

Comparative density of kingclip (*Genypterus blacodes*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.



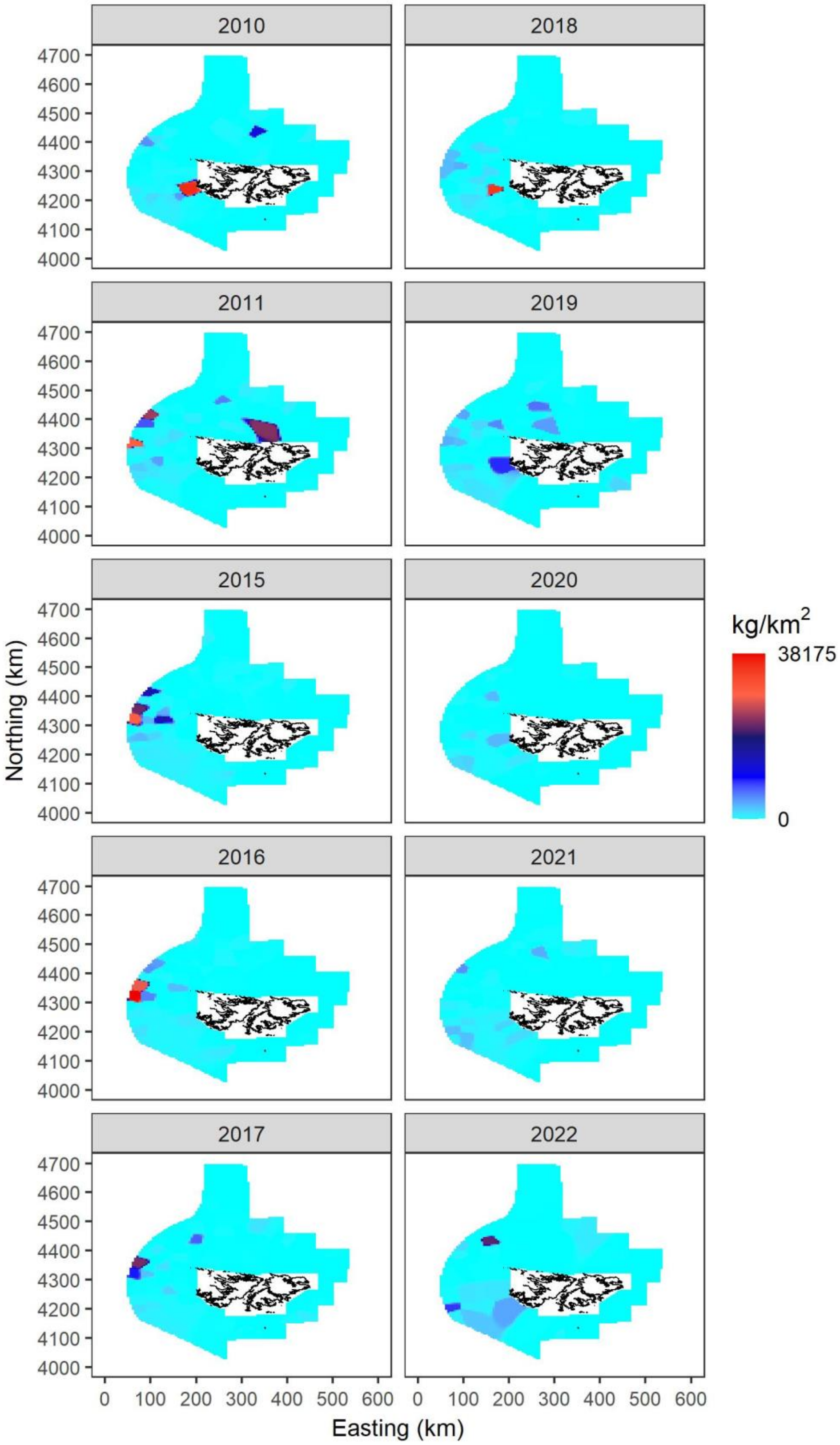
Appendix XII. Patagonian squid inter-annual distribution

Comparative density of the Patagonian squid (*Doryteuthis gahi*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.



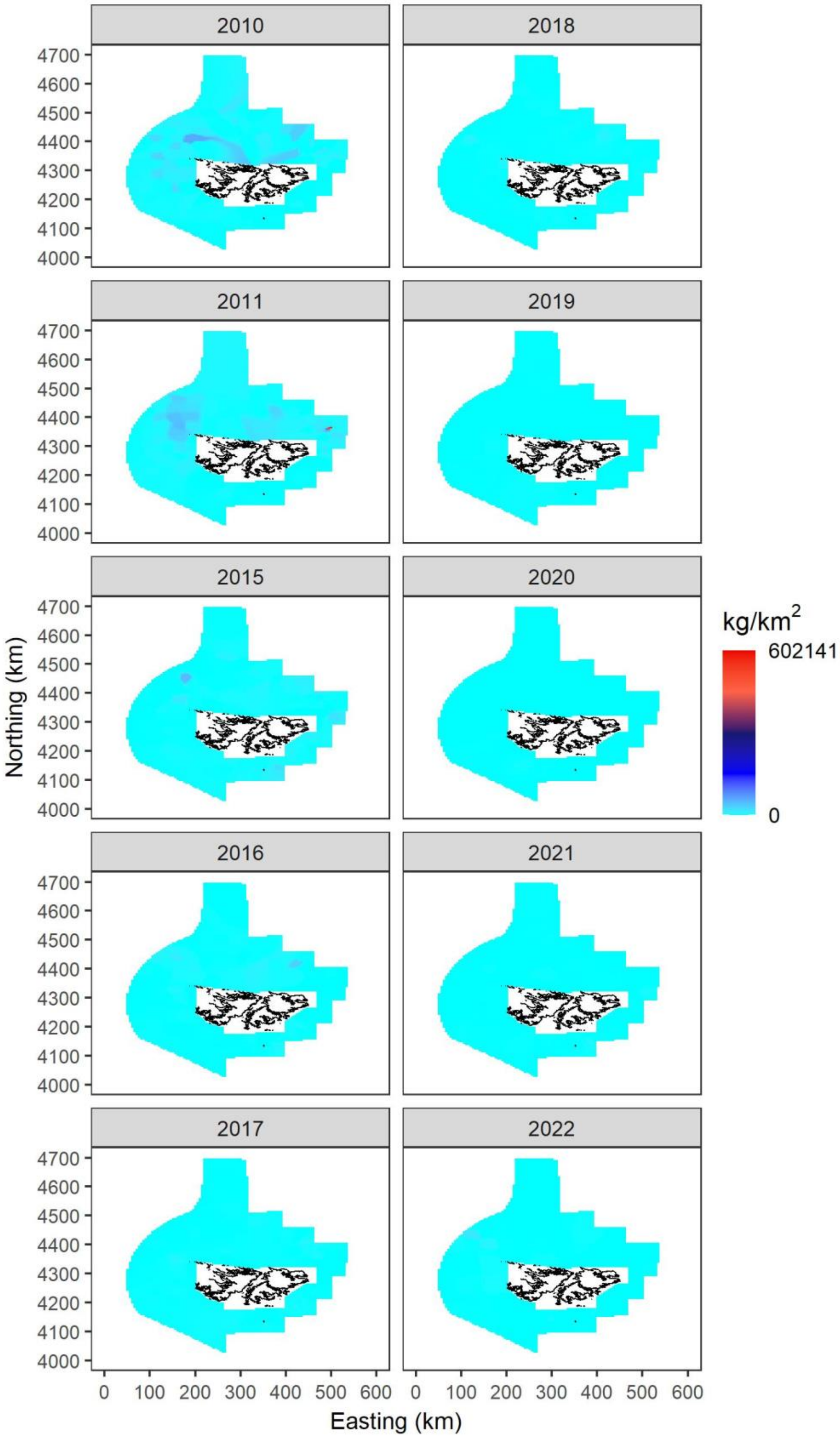
Appendix XIII. Red cod inter-annual distribution

Comparative density of red cod (*Salilota australis*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.



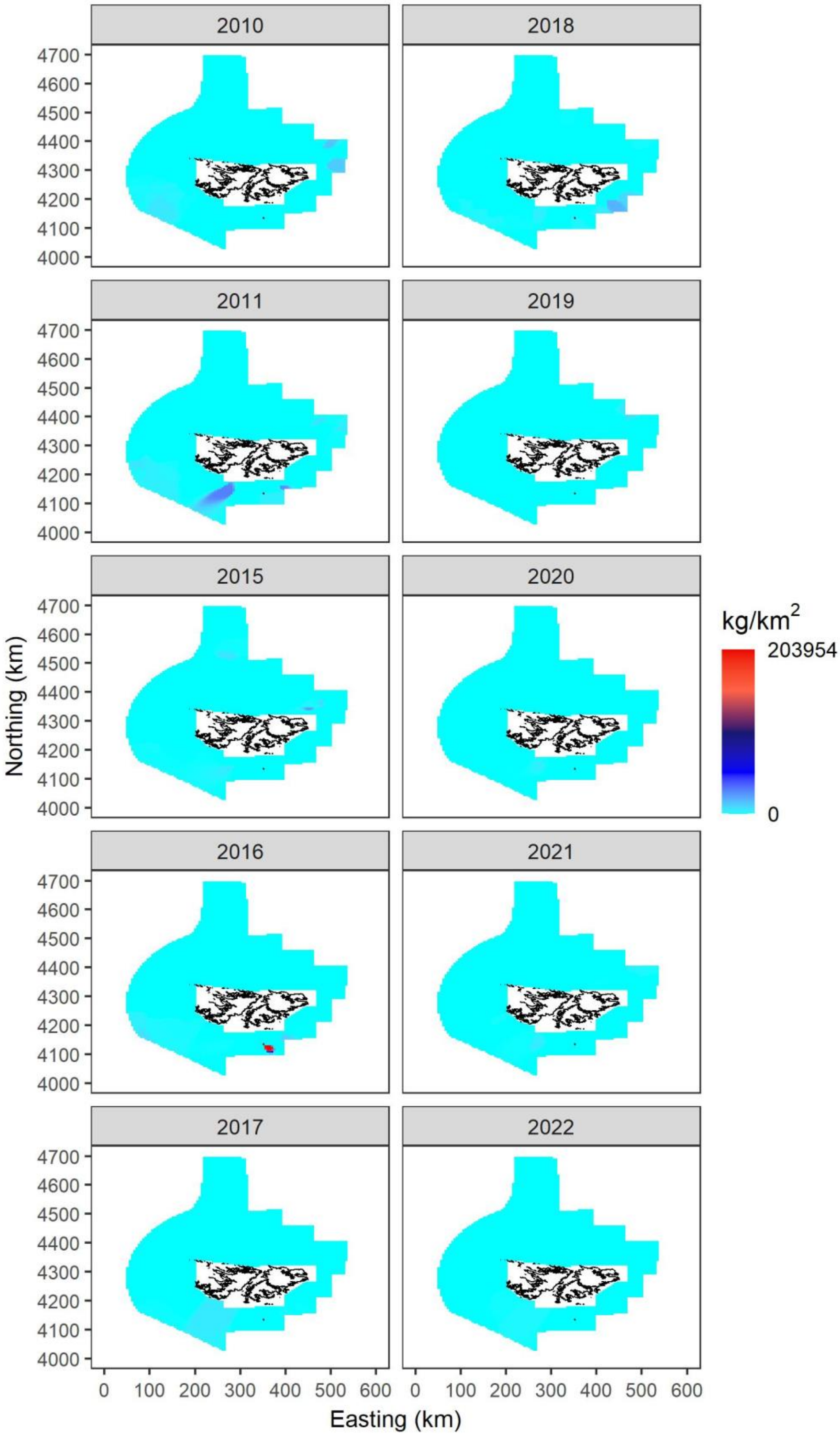
Appendix XIV. Rock cod inter-annual distribution

Comparative density of rock cod (*Patagonotothen ramsayi*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.



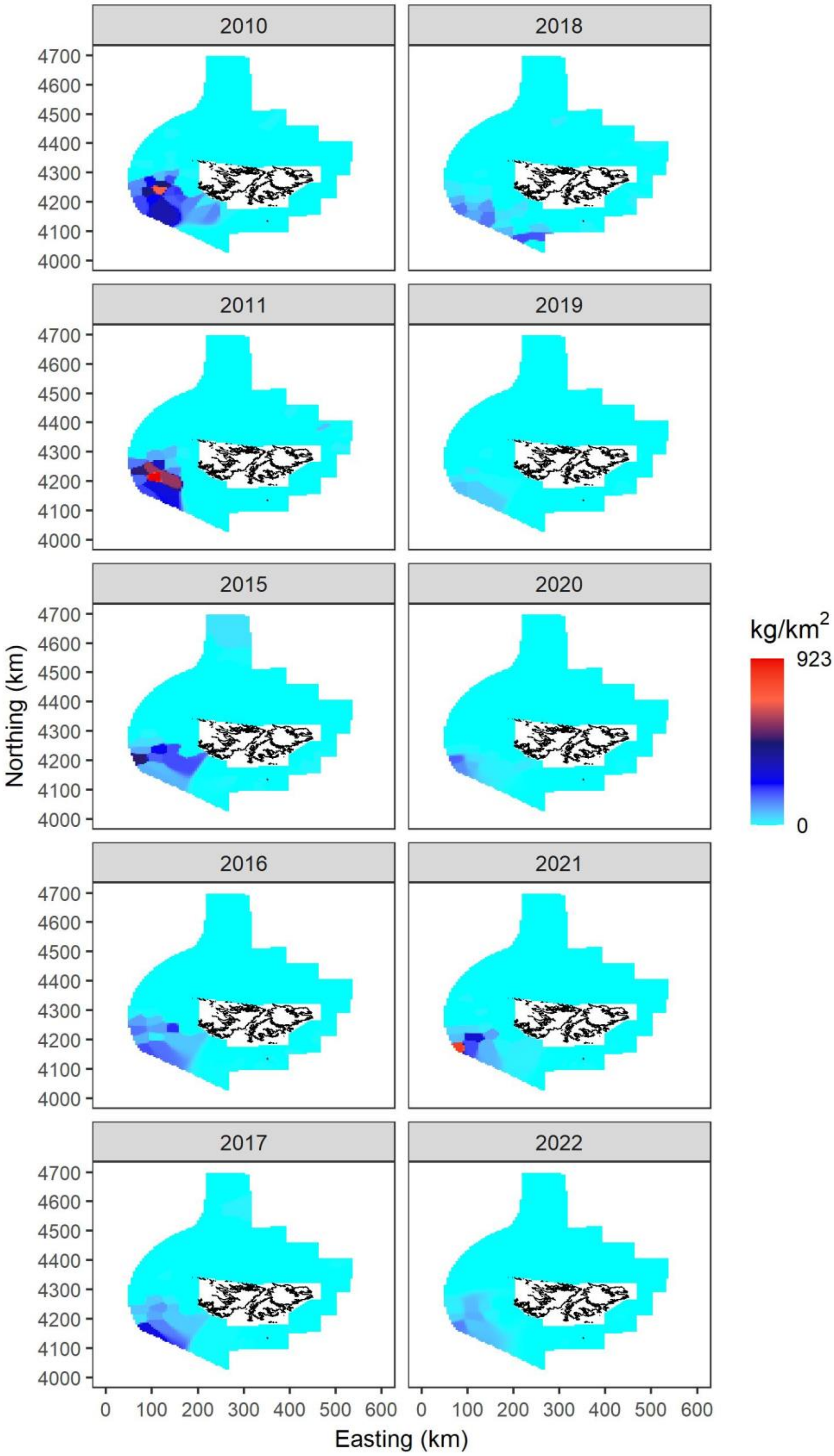
Appendix XV. Southern blue whiting inter-annual distribution

Comparative density of southern blue whiting (*Micromesistius australis australis*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.



Appendix XVI. Southern hake inter-annual distribution

Comparative density of southern hake (*Merluccius australis*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.



Appendix XVII. Toothfish inter-annual distribution

Comparative density of toothfish (*Dissostichus eleginoides*) during the February 2010–2011 and 2015–2022 groundfish and calamari pre-season surveys in Falkland Islands waters.