Cruise Report
ZDLK3-11-2023

Patagonian toothfish (*Dissostichus eleginoides*) tagging in the High Seas

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ZDLK3-11-2023

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Summary

The research cruise ZDLK3-11-2023 focused on Patagonian toothfish (*Dissostichus eleginoides*, hereafter toothfish) and was conducted onboard the *CFL Hunter* (ZDLK3) between the 12th and the 28th of November 2023 in the High Seas within the area of North Scotia Ridge. The objectives of the research cruise were (1) to tag 400-600 toothfish, (2) to sample toothfish otoliths, gonads and muscle tissues, and (3) to compare the catches between the Falkland Islands Conservation Zones (FCZ) and the High Seas (HS). Routine scientific observation protocols were also performed, as detailed in Observer Report 1383 (FIFD, 2023a). 536 toothfish were tagged using external spaghetti Floy® dart tags (38 fish tagged per day on average), 60 toothfish were sampled for gonads and muscle tissues, and 30 for gonads only. Tag numbers during the survey ranged from 7050 to 7586. The total amount of toothfish tagged corresponded to 41% of the total catches in number, and 43% in weight. The total length of the tagged toothfish ranged from 46 to 165 cm (mean ± sd: 91.4 ± 16.2 cm). Gonads were sampled from 52 females and 38 males and were macroscopically identified to belong mainly to stages 2 and 3. The total length of the toothfish sampled for gonads ranged from 54 to 185 cm (mean ± sd: 99 ± 31 cm). Toothfish catches were significantly lower in the HS compared to the FCZ and individuals were significantly smaller. The main bycatch species were similar between the two fishing areas.

1. Introduction

The tagging programme for the Falkland Islands toothfish was initiated in 2016 with the aim of improving our understanding of toothfish movement patterns within the region. The initial goal of tagging 3000 fish was achieved during four tagging research cruises onboard the longliner from 2016-2018 (Randhawa and Lee 2016, Randhawa *et al.* 2017, Farrugia and Keningale 2018, Farrugia *et al.* 2018). This programme was pursued again between 2019-2020, and from 2021 onwards, the new aim was to tag ~1000 longline-caught fish annually, or one fish per tonne of TAC (Lee and Skeljo 2020). This data is crucial to understanding toothfish migrations and population connectivity within the region.

Since the tagging programme's inception in 2016, specific protocols have been added to the tagging cruises to improve our knowledge of the Falkland Islands toothfish fishery (e.g. the deployment of an underwater camera to assess habitat biodiversity and the impacts of umbrella-system longline fishing on habitats from 2017-2020, or the sampling of benthic invertebrate bycatch to compile a reference fauna collection in 2020). In the current cruise, the additional protocol was to sample toothfish gonads. Gaps in our knowledge of toothfish reproductive strategy have been highlighted in the annual stock assessment reports (Skeljo

et al. 2022, 2023). The gonad samples were thus collected to help obtain reliable estimates of toothfish reproductive traits like age at first maturity, fecundity, and prevalence of skipped spawning in females.

The research cruise was conducted onboard the *CFL Hunter* (ZDLK3), registered in the Falkland Islands. The aims of the survey were (1) to tag 400-600 Patagonian toothfish to improve our understanding of the prevalence and extent of larger migration patterns fuelling connectivity within the region (Patagonian Shelf, Slope and deep-sea plateau), (2) to sample toothfish gonads to improve our knowledge of toothfish reproductive strategy, and (3) to collect catch composition and biological data from the toothfish longline fishery according to routine scientific observer protocols. We also took this opportunity to compare the catches in term of weight and composition between the High Seas (HS) and the Falkland Islands Conservation Zones (FCZ).

2. Materials and methods

2.1. Cruise itinerary and setting

The research cruise lasted 17 days from the 12th of November to the 28th of November 2023 with 14 days of effective fishing. The 12th of November and the 27th of November 2023 were respectively allocated to steaming to the first station and returning to Stanley. The return was delayed until the 28th of November due to additional formalities as fishing was conducted close to an area under CCAMLR jurisdiction.

In total, 36 lines were set up during the cruise and tagging was conducted on all of them (Figure 1 and Table 1). Daily fishing schedule consisted of setting 2-3 lines and hauling 2-3 lines. This schedule was followed every day except on the 19th of November when 4 lines were hauled. The soak time was calculated as the difference between the mid-set and mid-haul times. The mean soak time during the cruise was 15:19 ± 5:29 h (i.e., mean ± standard deviation; corresponding to 919 ± 329 min; Table 1). The soak time ranged from 6:41 to 25:08 h (corresponding to 401 – 1508 min; Table 1). Station depth was calculated as the mean between haul start and haul end depths. The mean station depth during the cruise was 1304 ± 116 m (Table 1). Tagging was conducted at each station throughout the entire line, and gonads were sampled at 27 stations (Table 1). Due to fish scarcity all fish sampled for gonads were part of the random sample. A sperm whale (*Physeter macrocephalus*) was sighted at approximately 100 m away from the vessel on the 15th of November 2023. Tagging was not interrupted, despite this, as reaching the tagging goal was a priority and fish were scarce.

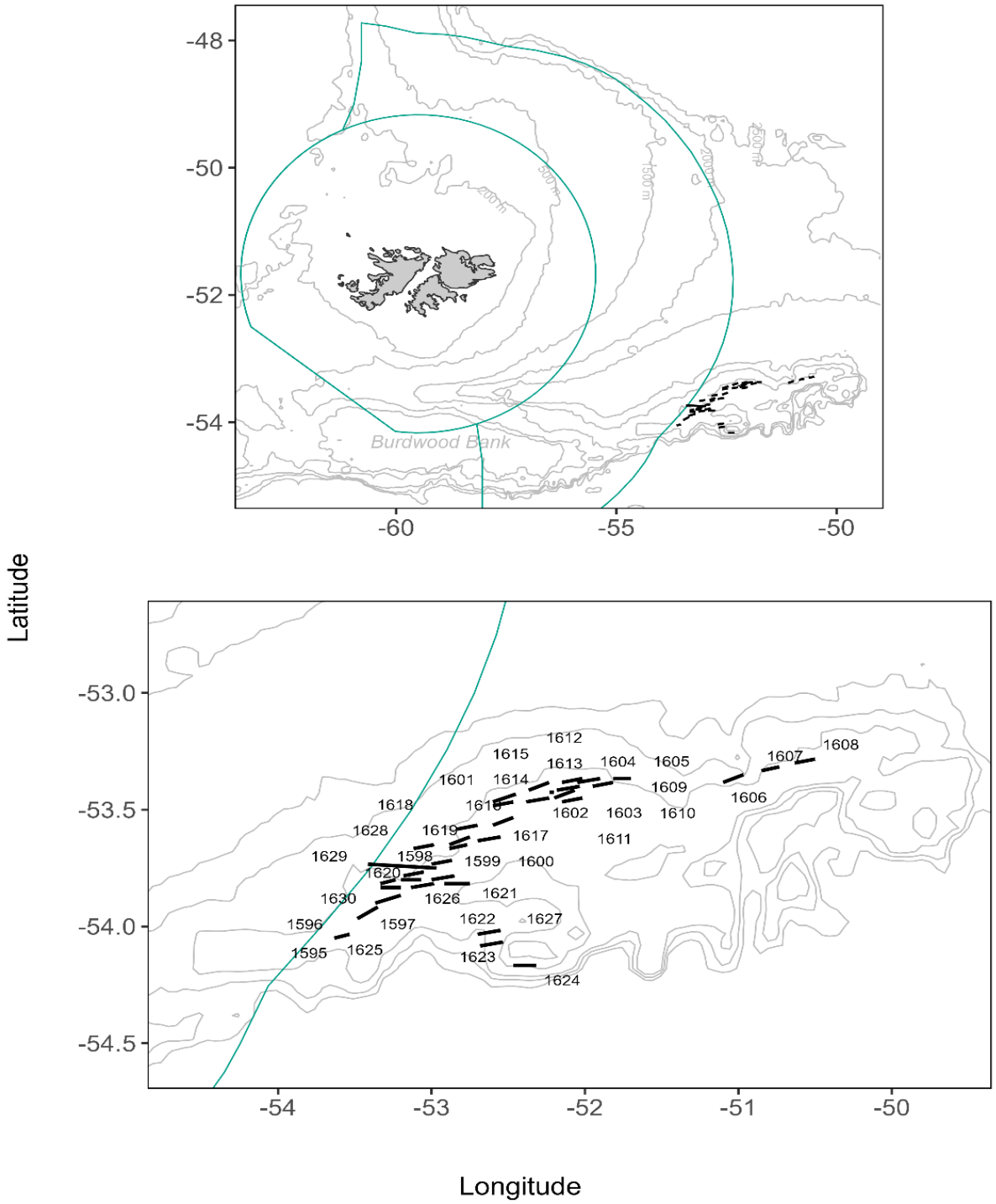

Figure 1: Location of the 36 stations of the ZDLK3-11-2023 HS research cruise. The green lines delineate the Falkland Islands Conservation Zones.

Table 1: Station characteristics: date, time at haul start, station depth (mean and standard deviation in m), soak time (h), percentage on line covered by an observer for tagging, percentage of toothfish tagged, and sampling type (T= Tagging and G= Gonad sampling). Station depth was calculated as the mean between haul start and haul end depths. Soak time was calculated as the difference between the mid-set and mid-haul times. Stations were sorted by haul date.

Station	Date	Haul start time	Mean depth (m)	Soak time (h)	Line covered (%)	Fish tagged (%)	Sampling
1595	13/11/2023	09:35	1420 ± 28	07:02	100	40	T/G
1596	13/11/2023	18:29	1060 ± 148	13:55	100	50	T/G
1597	14/11/2023	04:26	1242 ± 130	14:14	100	55	T/ G
1598	14/11/2023	16:21	1322 ± 3	16:38	100	42	T/ G
1599	14/11/2023	22:40	1488 ± 263	12:25	100	29	T/ G
1600	15/11/2023	09:55	1290 ± 84	22:17	100	43	T/ G
1602	15/11/2023	19:35	1284 ± 35	15:20	100	41	T/ G
1601	16/11/2023	01:45	1400 ± 65	22:40	100	32	T/ G
1603	16/11/2023	13:40	1374 ± 2	22:09	100	55	T/ G
1605	16/11/2023	21:07	1638 ± 143	12:25	100	67	T
1604	17/11/2023	02:45	1432 ± 9	19:18	100	48	T/ G
1606	17/11/2023	17:46	1500 ± 219	08:22	100	33	T
1607	18/11/2023	02:55	1376 ± 77	16:23	100	39	T/ G
1608	18/11/2023	09:55	1198 ± 59	21:50	87	30	T/ G
1609	19/11/2023	00:05	1396 ± 63	06:41	100	50	T
1610	19/11/2023	05:55	1289 ± 6	11:32	100	60	T/ G
1611	19/11/2023	15:50	1201 ± 16	19:37	100	23	T/ G
1613	19/11/2023	21:53	1452 ± 13	09:47	100	93	T/ G
1612	20/11/2023	08:54	1440 ± 8	21:53	100	39	T/ G
1615	20/11/2023	15:02	1426 ± 124	09:42	100	12	T/ G
1614	21/11/2023	02:05	1417 ± 81	22:26	100	38	T/ G
1616	21/11/2023	19:07	1386 ± 122	22:14	100	26	T/ G
1617	21/11/2023	08:19	1134 ± 112	10:13	100	56	T/ G
1618	22/11/2023	12:55	1472 ± 63	22:44	100	31	T/ G
1619	22/11/2023	01:15	1430 ± 238	09:57	100	42	T/ G
1621	22/11/2023	19:46	1156 ± 8	11:32	100	29	T
1620	23/11/2023	02:00	1262 ± 174	18:54	100	30	T
1622	23/11/2023	16:06	1130 ± 170	07:58	100	68	T/ G
1623	24/11/2023	00:50	1083 ± 680	15:23	100	27	T/ G
1624	24/11/2023	08:01	1133 ± 242	11:42	100	48	T
1625	25/11/2023	17:10	1287 ± 78	25:08	100	45	T/ G
1626	25/11/2023	06:55	1092 ± 131	14:04	100	61	T/ G
1627	25/11/2023	01:10	742 ± 175	07:11	100	38	T/ G
1628	26/11/2023	06:35	1494 ± 64	19:30	100	50	T
1629	26/11/2023	01:00	1198 ± 224	12:43	100	44	T
1630	26/11/2023	12:19	1311 ± 123	15:39	100	36	T

2.2. Tagging protocol

The tagging station was set up in the dry section of the factory at the end of the umbrella cleaning table. The station was prepared with pliers to remove hooks from fish (provided by factory crew), a tape measure, a tag board with tags ready to be deployed, a tag applicator, a vial filled with 96% ethanol to disinfect the applicator and the tag before tagging each fish, and a scribing board. The tag board used was a holding board which allowed numbered tags to be prepared in advance in ascending order. Once a toothfish was brought on board, it was assessed for tagging suitability according to the criteria set by Lee (2022). Tagged fish should match the size distribution of captured fish. The length of each fish was thus not a criterion for fish suitability. However, large toothfish that were lifted onboard without support were not tagged due to the potential for spinal damage. If the weight was supported by the umbrella, the fish was slid from the hauling bay to the tagging station and the condition of the fish was considered for tagging suitability. If deemed unsuitable, the fish was forwarded to the factory for sampling and processing. Fish deemed suitable would have all remaining hooks removed using pliers, taking care to cause minimum injury to the fish. Fish were measured (total length to the nearest cm) and tagged with one external spaghetti Floy® dart tag (*FT*-1-*94*, Floy Tag and Mfg, Inc., Seattle, WA. USA). A sharp hollow applicator was used to insert the tag into the dorsal musculature between the 3rd and 4th rays of the second dorsal fin rays, ensuring that the barb of the tag was locked behind a pterygiophore (Figure 2). Before tagging, the applicator and inserted tag were dipped in 96% ethanol to disinfect the material and avoid infection around the tag. The tagged fish was then carried carefully to the hauling bay and returned headfirst into the water.

At each station, all suitable fish were tagged because catches were low and there was no need for subsampling. Wounded or dead fish were passed to the factory for sampling and processing. At the bridge, the time at each mark, and the number of toothfish caught between two marks, were routinely recorded on the logbook. This data was used to calculate the percentage of the line monitored by the scientist and the percentage of tagged fish (by number) during the portion of the line monitored by the scientist. As recommended in Skeljo and Pearman (2021), tagged toothfish were not weighed. Individual weight was calculated using the length-weight relationship set in the database ($W = a L^b$, where a= 0.0061 and b= 3.1037).

2.3. Gonad sampling

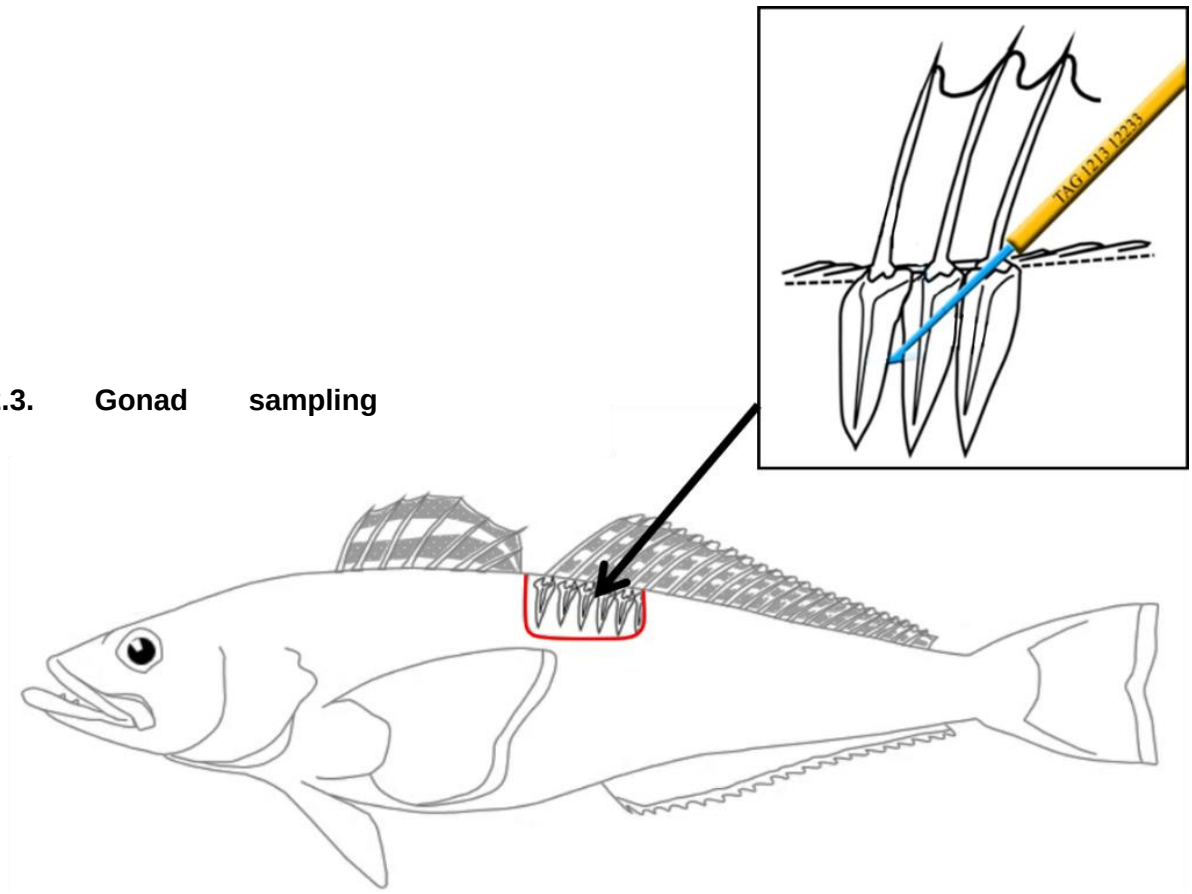

Figure 2: Tagging location between the 3rd and the 4th rays of the second dorsal fin rays locking the barb of the tag behind a pterygiophore. Modified from Toothfish and skate tagging methods (CCAMLR, 2013) (drawing credited to: Alan Hart).

protocol

Toothfish reproductive strategy sampling was conducted across the entire fishing area. The goal was to collect a minimum of one and a maximum of five gonad samples per sex/maturity stage/10 cm size class, while also giving priority to fish <70 cm and >145 cm as well as maturity stages ≥ 4 (macroscopically identified based on 8-stage maturity scale developed by the FIFD; Brickle *et al*. 2006). Gonad sampling was conducted in the wet factory and the following information were recorded for each sampled fish: total length (to the nearest cm), total weight (to the nearest 100 g), macroscopic maturity stage (Brickle *et al*. 2006), total liver weight (to the nearest g) and total gonad weight (to the nearest g). A small piece of the gonads (~2 cm^2) was also sampled, labelled (TOO/Station/Sex_Maturity/indiv_histo_number/otolith_serial_number), and stored in a vial. Otoliths were sampled and stored following the routine observer protocol (FIFD, 2023b) and adding the histological serial number on the envelope. At the end of the station, vials were topped with 10% Buffer Formalin Solution in the dry factory, and the caps were sealed with Parafilm to avoid any spilling.

3. Results

3.1. Toothfish tagging and sampling

A total of 536 toothfish were tagged during the research cruise with a calculated total weight of 4432.4 kg, corresponding to 41% of the total catch in terms of number and 43% in terms of weight. Tag numbers used during the survey ranged from 7050 to 7586. The number of tagged toothfish varied per day between 12 and 59, averaging 38 individuals.

Toothfish tagging and sampling were conducted on all lines due to low catches. 100% of each line was covered, except for station 1608 where the first mark was missed (approximately 30 minutes), resulting in the loss of 15 fish potentially suitable for tagging.

The length of tagged toothfish ranged from 46 to 165 cm (mean TL ± sd: 91 ± 16.2 cm) (Table 2 and Figure 3a), and the length of sampled fish (i.e. sampled for length-frequency and otoliths) ranged from 54 to 185 cm (mean TL ± sd: 88 ± 17.4 cm) (Figure 3b). Anova showed a statistically significant difference ($p < 0.05$) in the mean length of the randomly sampled and tagged fish. However, the difference was only 3 cm, which is negligible for practical purposes. Tag-overlap statistic (CCAMLR, 2022) showed an overlap of 94% between the length distributions of the sampled and tagged fish (comparison based on a bin length of 10 cm).

Table 2: Tagging information and characteristics of the tagged toothfish (total length [mean and standard deviation], and total length range, in cm) by station. The percentage of tagged fish was calculated as the number of toothfish tagged according to the number of toothfish caught on the portion of the line monitored by the scientist.

Station	Date	Number of tagged fish	Percentage of tagged fish	Total length (mean + sd)	Total length range
1595	13/11/2023	2	40	98 ± 2	97 - 100
1596	13/11/2023	21	49	93 ± 26	58 - 165
1597	14/11/2023	42	53	102 ± 18	65 - 160
1598	14/11/2023	13	41	84 ± 12	66 - 112
1599	14/11/2023	4	29	81 ± 17	66 - 105
1600	15/11/2023	18	40	83 ± 10	68 - 100
1601	16/11/2023	9	29	84 ± 9	69 - 95
1602	15/11/2023	12	40	93 ± 19	68 - 143
1603	16/11/2023	21	52	85 ± 12	71 - 125
1604	17/11/2023	16	48	94 ± 13	79 - 138
1605	16/11/2023	18	67	103 ± 17	76 - 138
1606	17/11/2023	4	36	94 ± 11	87 - 110
1607	18/11/2023	13	38	83 ± 11	66 - 109
1608	18/11/2023	24	29	92 ± 15	67 - 125
1609	19/11/2023	9	50	91 ± 14	69 - 119
1610	19/11/2023	25	58	100 ± 22	62 - 161
1611	19/11/2023	8	23	84 ± 17	46 - 99

1612	20/11/2023	11	38	98 ± 20	74 - 139
1613	19/11/2023	13	87	90 ± 13	73 - 116
1614	21/11/2023	14	37	91 ± 21	68 - 137
1615	20/11/2023	1	12	NA	80 - 80
1616	21/11/2023	12	27	89 ± 18	64 - 134
1617	21/11/2023	19	53	90 ± 12	68 - 122
1618	22/11/2023	16	30	96 ± 14	82 - 140
1619	22/11/2023	8	38	87 ± 10	72 - 103
1620	23/11/2023	11	27	88 ± 10	75 - 107
1621	22/11/2023	32	28	87 ± 15	64 - 130
1622	23/11/2023	15	65	94 ± 11	72 - 108
1623	24/11/2023	14	39	97 ± 11	71 - 104
1624	24/11/2023	16	48	87 ± 14	69 - 122
1625	25/11/2023	19	44	90 ± 9	76 - 106
1626	25/11/2023	25	58	87 ± 13	63 - 124
1627	25/11/2023	5	36	71 ± 7	63 - 81
1628	26/11/2023	9	47	81 ± 12	64 - 99
1629	26/11/2023	32	38	94 ± 12	74 - 130
1630	26/11/2023	5	31	93 ± 29	67 - 142

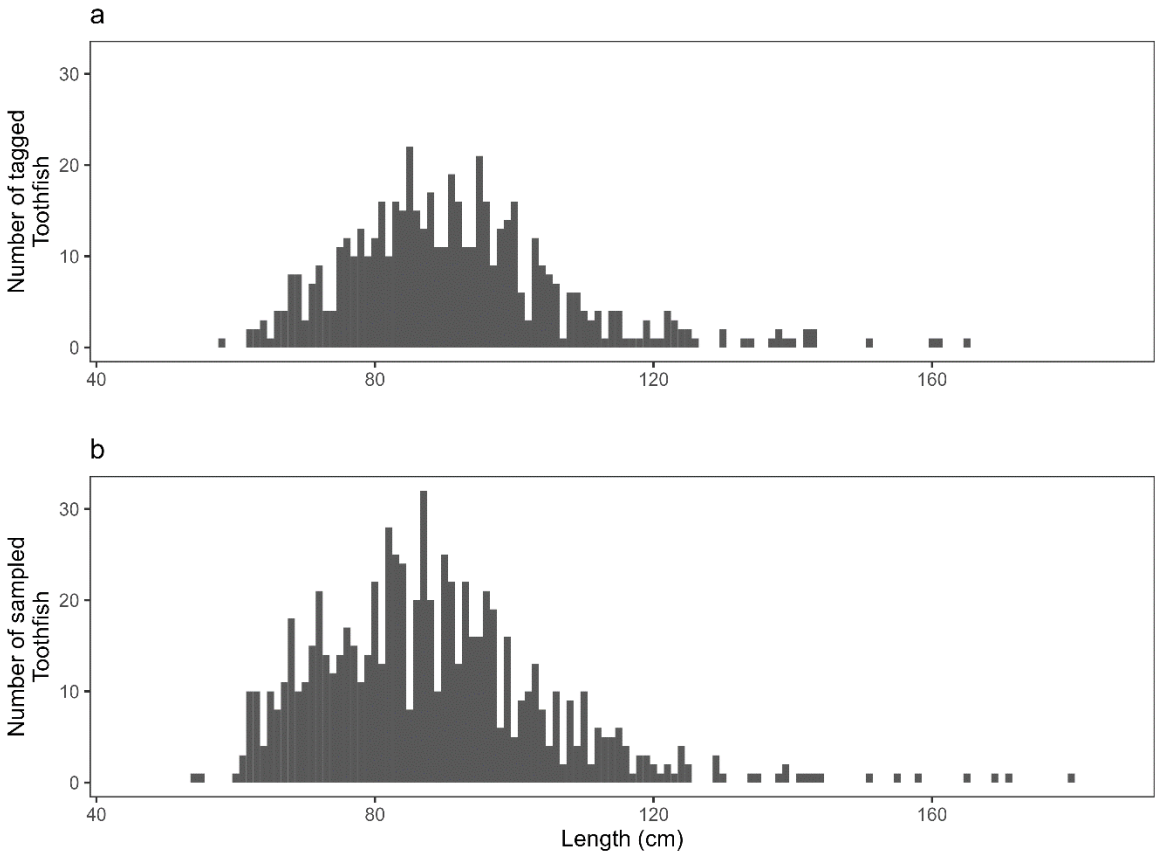

Figure 3: Cumulative length-frequency of (a) tagged and (b) sampled toothfish during the research cruise ZDLK3-11-2023. Sampled toothfish comprised random and sub-sample toothfish collected for length-frequency and otoliths.

A total of 90 gonads (52 female and 38 male gonads) were sampled. The length of toothfish sampled for gonads ranged from 54 to 185 cm (mean TL ± sd: 99 ± 31.1 cm). Females sampled for gonads were larger than males (mean TL ± sd Female: 106 ± 33.7 cm, mean TL ± sd Male: 89 ± 24.5 cm). Maturity stages sampled were mainly stages 2 and 3 for both sexes (Table 3). One F5 was sampled at the station 1597.

Table 3: Number of toothfish sampled for gonads by sex and maturity stage (8-stage maturity scale developed by the FIFD; Brickle *et al*. 2006).

Maturity stage	Female	Male
1	5	9
2	29	21
3	17	8
5	1	-

3.2. Comparison of the catches between High Seas and Falkland Islands Conservation Zones

We compared toothfish catches in terms of weight, length distribution, and maturity composition, as well as the main bycatch species composition between the HS and the FCZ in 2023. Toothfish catches per line were significantly lower in the HS than in the FCZ (FCZ catches mean ± sd: 1912 ± 1172 kg, and HS catches mean ± sd: 294 ± 199 kg; p-value$_{Anova}$ < 0.001, Figure 4). Catches per line of the main bycatch species were significantly lower in the HS compared to the FCZ for ANR (*Antimora rostrata*) and GRH (*Macrourus holotrachys*) (p-value$_{Anova}$ < 0.001, Figure 4). For the other species, no significant difference was found between the two fishing areas (Figure 4). No RME (*Bathyraja meridionalis*) was captured in the HS. GRH, RAY and ANR were the three main bycatch taxa (in terms of weight) in both fishing areas. The scientists noticed skate sizes to be smaller than commonly caught in the FCZ, however no skate sampling was conducted to confirm this suspicion.

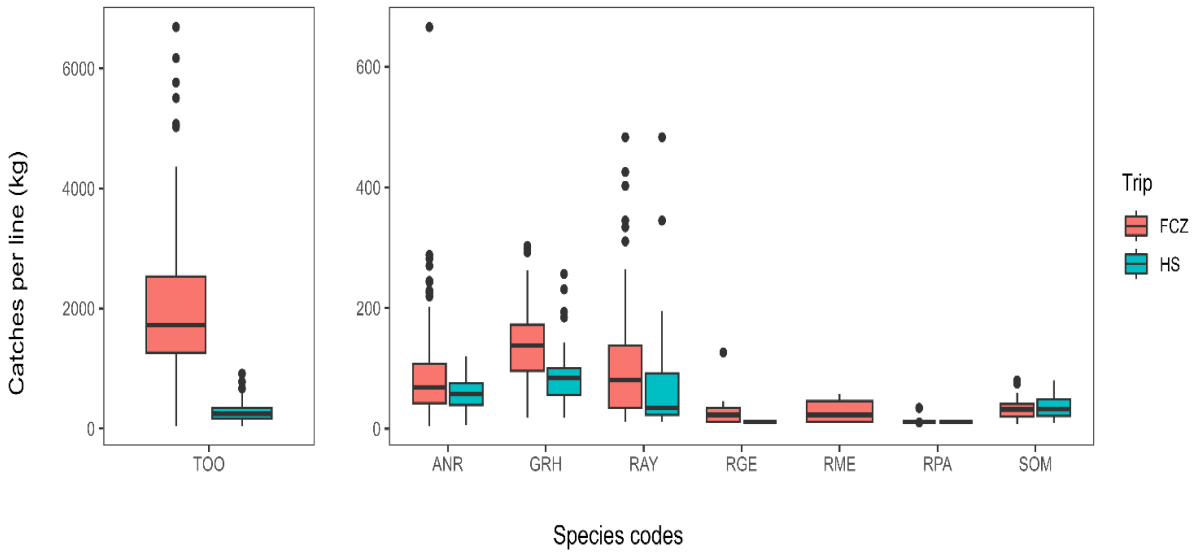

Figure 4: Catches per line of TOO (*Dissostichus eleginoides*) and the main bycatch species ANR (*Antimora rostrata*), GRH (*Macrourus holotrachys*), RAY (Rajidae), RGE (*Raja georgiana*), RME (*Bathyraja meridionalis*), RPA (*Bathyraja papilionifera*) and SOM (*Somniosus* spp.) in the FCZ (red) and High Seas (blue).

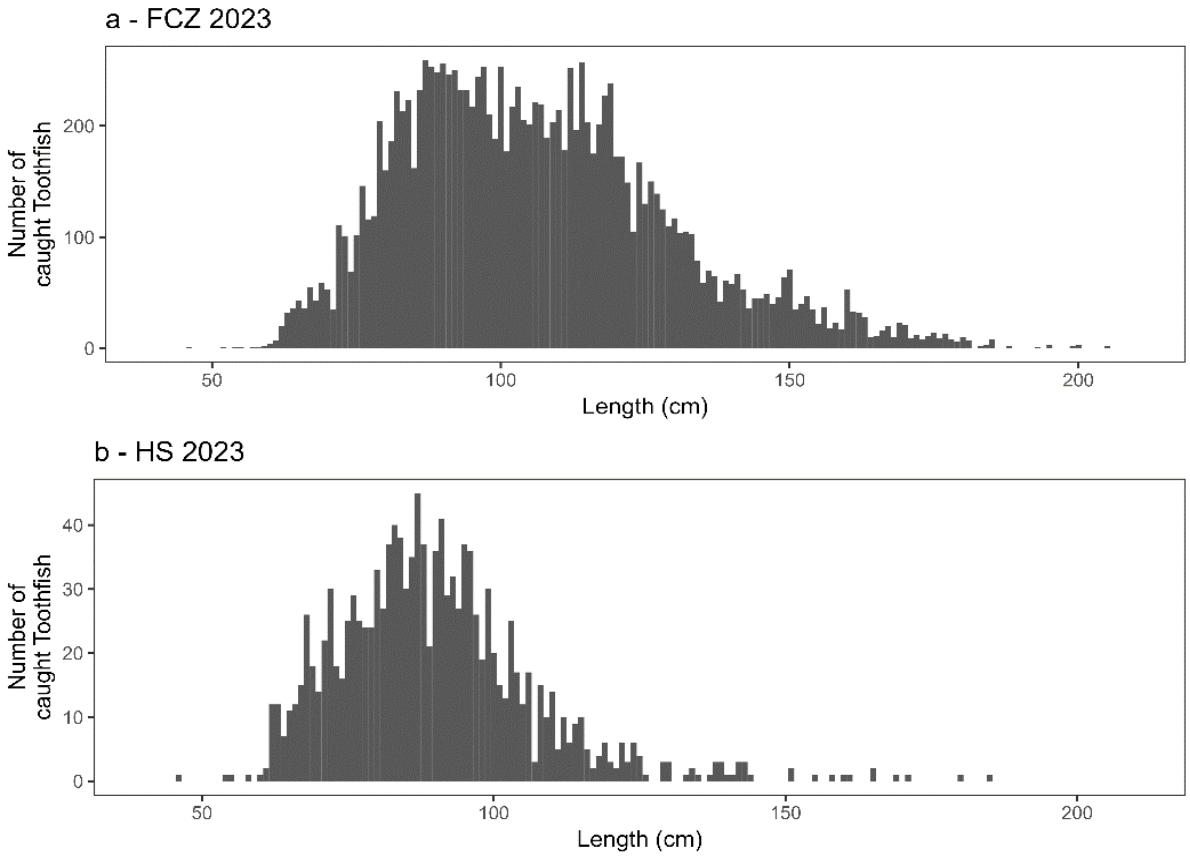

Figure 5: Length distribution of toothfish caught (a) in the FCZ and (b) in the HS.

Size distribution of sampled toothfish was significantly different between the two areas (p-value$_{Anova}$ < 0.001, Figure 5). Larger toothfish (> 100 cm) were more abundant in the FCZ than in the HS (Figure 5).

To compare the maturity stages between the two areas, we focused our analysis on November 2023. Maturity stages 1, 2, 3, and 5 were sampled in both areas, while maturity stages 7 and 8 were only sampled in the FCZ (Figure 6). The length distributions of the maturity stages 1 and 2 were significantly different between the FCZ and the HS (p-value$_{Anova}$ < 0.001, Figure 6). In both areas, the main maturity stage sampled were the stages 1, 2, and 3 in November 2023.

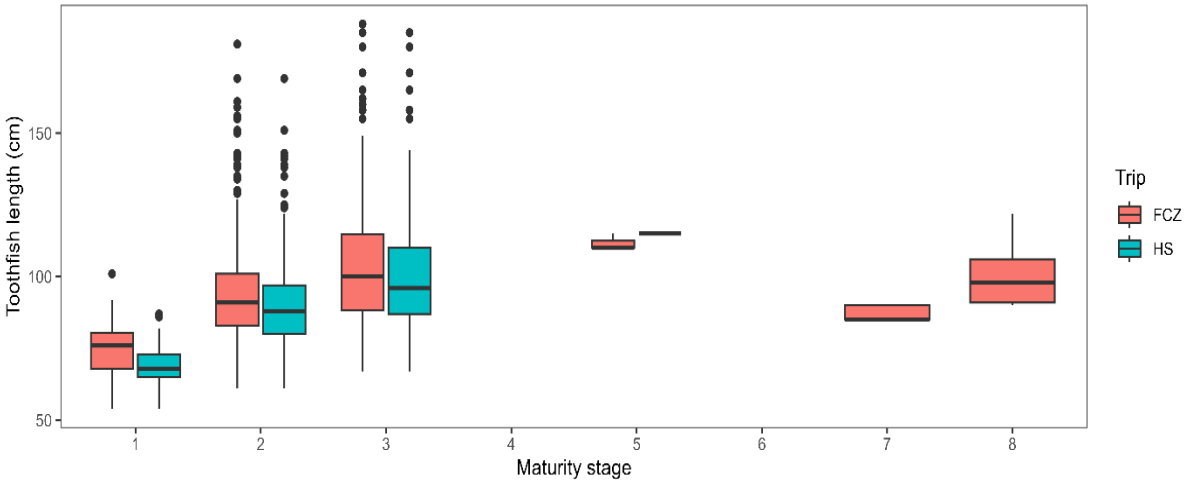

Figure 6: Toothfish maturity stage distribution by length in the FCZ (red) and the HS (blue) in November 2023.

4. Discussion

All objectives of the ZDLK3-11-2023 tagging research cruise in the High Seas were completed: 536 toothfish were tagged with external spaghetti Floy® dart tags, and 321 otolith samples, 90 gonad samples, and 60 muscle samples were collected.

Setting positions were selected at the captain's discretion based on multiple factors such as depth, currents, and presence of other fishing vessels. The number of tagged toothfish was mainly dependent on toothfish abundance. Areas with higher catches provided more healthy fish for tagging, and this was especially evident in the West close to the FCZ border. Lines set in the central and southern regions of North Scotia Ridge had significantly lower catches. The average soak time during the cruise was 919 ± 329 min, compared to 705 ± 125 min at the ZDLK3-10-2023 tagging research cruise (Le Luherne and Peruzzo, 2023). Previous findings suggested that the soak time did not impact the suitability of the condition of the toothfish

(Skeljo and Pearman, 2021); however, it was recommended to follow the captain's advice and avoid long soak times in areas with scavengers as it seemed to affect the suitability of toothfish for tagging.

36 lines were set during the research cruise with the target of tagging ~30 fish per day. While the daily number of suitable toothfish for tagging was highly variable, the target was reached and 38 toothfish were tagged per day on average. Tagged fish length distribution matched the sampled fish length distribution with a 94% overlap. The mean total length of tagged toothfish (mean ± sd: 91 ± 16.2 cm) was in the same order as Farrugia and Keningale (2018) and Skeljo and Pearman (2021) (94.5 ± 13.1 cm and 87.4 ± 13.7 cm, respectively), and slightly lower than Farrugia *et al*. (2018) and Nicholls and Raczynski (2023) (102.1 ± 13.7 cm and 98.4 ± 16.2 cm, respectively).
Although North Scotia Ridge had not been surveyed before, these results correspond to results from previous research trips highlighting that toothfish tagged in the South and South-east were significantly smaller than in the North. Farrugia and Keningale (2018) and Skeljo and Pearman (2021) covered mostly South and South-east sub-areas, Nicholls and Raczynski (2023) tagged toothfish in South and North sub-areas, and Farrugia *et al*. (2018) covered the North-east sub-area.

These results also revealed that large toothfish were mainly unsuitable for tagging and seemed to be most frequently injured both during the catch process (e.g. with other hooks) and with the gaff to bring them onboard. The outcomes for tagged fish seemed generally favourable, with toothfish reported swimming downwards a few seconds following release. During the trip one sperm whale was noticed in the distance but due to low numbers of toothfish, tagging was not interrupted and predation was potentially possible.

The number of gonads and the maturity stages sampled for the toothfish reproductive strategy project were in accordance with expectations, and gonads were added to the collection of samples of this ongoing project. Catch comparisons between the FCZ and the HS showed that toothfish catches were significantly higher per line in the FCZ in 2023 than in the HS, and that larger toothfish were caught in the FCZ. GRH (*Macrourus holotrachys*), RAY (Rajidae) and ANR (*Antimora rostrata*) were the three main bycatch taxa in both areas. ANR and GRH catches per line were significantly lower in the HS. The maturity composition of toothfish population in November 2023 was quite similar between the two fishing areas with maturity stages 1, 2, and 3 being the most sampled.

To conclude, the ZDLK3-11-2023 research cruise achieved the targets defined in the scientific proposal and several recommendations were made for the next tagging research cruise.

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