Cruise Report
ZDLK3-11-2024

Patagonian toothfish (*Dissostichus eleginoides*) tagging survey

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ZDLK3 - 11 - 2024

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Summary

The research cruise ZDLK3-11-2024 focused on the Patagonian toothfish (*Dissostichus eleginoides*, hereafter toothfish) tagging program. The research cruise was conducted onboard the *CFL Hunter* (ZDLK3) from the 17th of November to the 5th of December 2024, within Falkland Islands waters. The objectives of the research cruise included (1) tagging 600-700 toothfish, (2) collecting morphological measurements and tissue samples from sleeper sharks (*Somniosus* sp.), and (3) sampling toothfish gonads. Routine scientific observation protocols were also performed, as detailed in Observer Report 1420 (FIFD, 2024). In total, we tagged 678 toothfish using external spaghetti Floy® dart tags (45 fish tagged per day on average), sampled 6 sleeper sharks and 48 toothfish gonads. The total of tagged toothfish represents 32.63% of the total catch during the tagging time in terms of number. Tag numbers used during the survey ranged from 8225 to 8903. Of these, 174 toothfish were tagged in area 1, 100 in area 2, 49 in area 3, 76 in area 4, 117 in area 5, and 162 in area 6. The total lengths of the tagged toothfish ranged from 61 to 165 cm, with a mean length of 99 ± 17 cm. We sampled the gonads of 25 females and 23 males, which 85% were macroscopically identified as stages 2 and 3. We sampled 4 female and 2 male sleeper sharks with total lengths ranging from 140 to 229 cm (mean ± sd: 178 ± 35.4 cm).

1. Introduction

The toothfish tagging program for the Falkland Islands began in 2016 to provide data to improve our understanding of toothfish movement patterns in the region. From 2021 onwards, the tagging program was aimed at providing sufficient tag-recapture data to be used in the annual integrated stock assessment model.

The initial goal of tagging 3,000 fish was achieved during four tagging research surveys onboard the longliner between 2016 and 2018 (Randhawa and Lee 2016, Randhawa *et al.* 2017, Farrugia and Keningale 2018, Farrugia *et al.* 2018). In addition to surveys, Fisheries Observers were assigned to tag an average of 25 toothfish per week during their trips on the longliner. However, the success of the tagging program primarily relied on dedicated research surveys, and in their absence, the number of toothfish tagged significantly declined in 2019 and 2020. To address this decline, a 4-year extension of the tagging program was recommended (Lee and Skeljo 2020), and followed by a renewed tagging effort from 2021 (Skeljo and Pearman 2021; Nicholls and Raczynski, 2023; Le Luherne and Peruzzo, 2023) to tag a minimum of 1,040 longline-caught fish annually, approximately one fish per tonne of Total Allowable Catch (TAC). From January 2024 onwards, the tagging effort of the Fisheries Observers was increased to a target up to 10 toothfish per day during observer trips.

Since the inception of the tagging program in 2016, specific protocols have been added to the tagging cruises to improve our knowledge of the Falkland Islands toothfish fishery. For instance, from 2017 to 2020, underwater cameras were deployed to assess habitat biodiversity and the impacts of umbrella-system longline fishing on habitats. In 2020, sampling of benthic invertebrate bycatch was conducted to compile a reference fauna collection. For the current cruise, additional protocols included (1) collecting morphological data and tissue samples from sleeper sharks for genetic analysis and (2) sampling toothfish gonads. Currently, the FIFD database identifies sleeper sharks as Greenland shark (*Somniosus microcephalus*) which appears to be incorrect according to this species distribution (Mecklenburg *et al.* 2018). This issue was raised during the last MSC certification review. It was thus recommended in the minutes of the previous MSC Steering Group meeting (25/09/2024) to improve the identification of these by-catch species of the longline fishery at the species level. Gaps in our knowledge of toothfish reproductive strategy have been highlighted in the annual stock assessment reports (Skeljo *et al*. 2022, 2023). The gonads are thus collected to help obtain reliable estimates of toothfish reproductive traits, such as age at first maturity, fecundity, and prevalence of skipped spawning in females.

The aims of the survey were to (1) tag 600-700 Patagonian toothfish to meet the annual objectives of the toothfish tag-recapture program; (2) collect morphological measurements and tissue samples from sleeper sharks (*Somniosus* sp.); (3) sample toothfish gonads; and (4) collect catch composition and biological data from the toothfish longline fishery according to routine scientific observer protocols.

2. Materials and methods

2.1. Cruise itinerary and setting

The research cruise lasted 19 days from the 17th of November to the 5th of December 2024, with 17 days dedicated to effective fishing. The 17th of November and 5th of December 2024 were respectively allocated to the steaming to the first station and back to Stanley. Emilie Le Luherne (Toothfish Fisheries Scientist) was the chief scientist of the survey and Louis Desmet the Scientific Fisheries Observer in charge of the routine observer protocol. This survey was conducted aboard the *CFL Hunter* (ZDLK3), under the direction of Captain Sanchez-Lema C. and his fishing crew. The survey was conducted under the L license.

The tagging program aims to provide sufficient tag-recapture data for the stock assessment purposes. The tagging plan was designed based on the distribution of the fishing effort to make sure that tagged toothfish throughout the fishing area are going to be fished in the future. We identified 6 areas according to the locations of the main fishing efforts over the last 5 years (Figure 1) and calculated the percentage of fishing effort allocated to each area. We planned to tag approximately 1,040 toothfish in 2024 (one fish per tonne of TAC), distributed among the six areas in proportion to the fishing effort. Considering the distribution of toothfish already tagged in 2024, we allocated an approximate number of toothfish to be tagged per area during the survey. Based on our estimates of daily tagging rates, we determined the approximate number of fishing days allocated to each area (Figure 1 and Table 1).

Table 1. Number of tagged toothfish and tagging days allocated to each area (Figure 1) for the tagging survey.

Area	Number of toothfish to be tagged	Number of tagging days
1	180	4
2	0	0-1
3	70	2-3
4	70	2
5	60	2-3
6	190	4
Total	570	14-17

We advised the captain to follow the fishing schedule used for the tagging survey in 2023. This proven schedule involved hauling two lines per day during the daytime, with the first haul starting around 07:00 and the second between 12:00 and 14:00. The exact position of the stations, soak times, as well as setting and hauling times were at the captain's discretion based on this research proposal. The research proposal was submitted to CFL two weeks prior to the survey and discussed on the day of departure with the Captain of the *CFL Hunter* Candido Sanchez-Lema, CFL General Manager Janet Robertson and CFL Crew and Vessel Administrative Manager Patricio Garces.

The soak time was calculated as the difference between the mid-set and mid-haul times. Station depth was determined by taking the mean of the depths at the start and end of each haul.

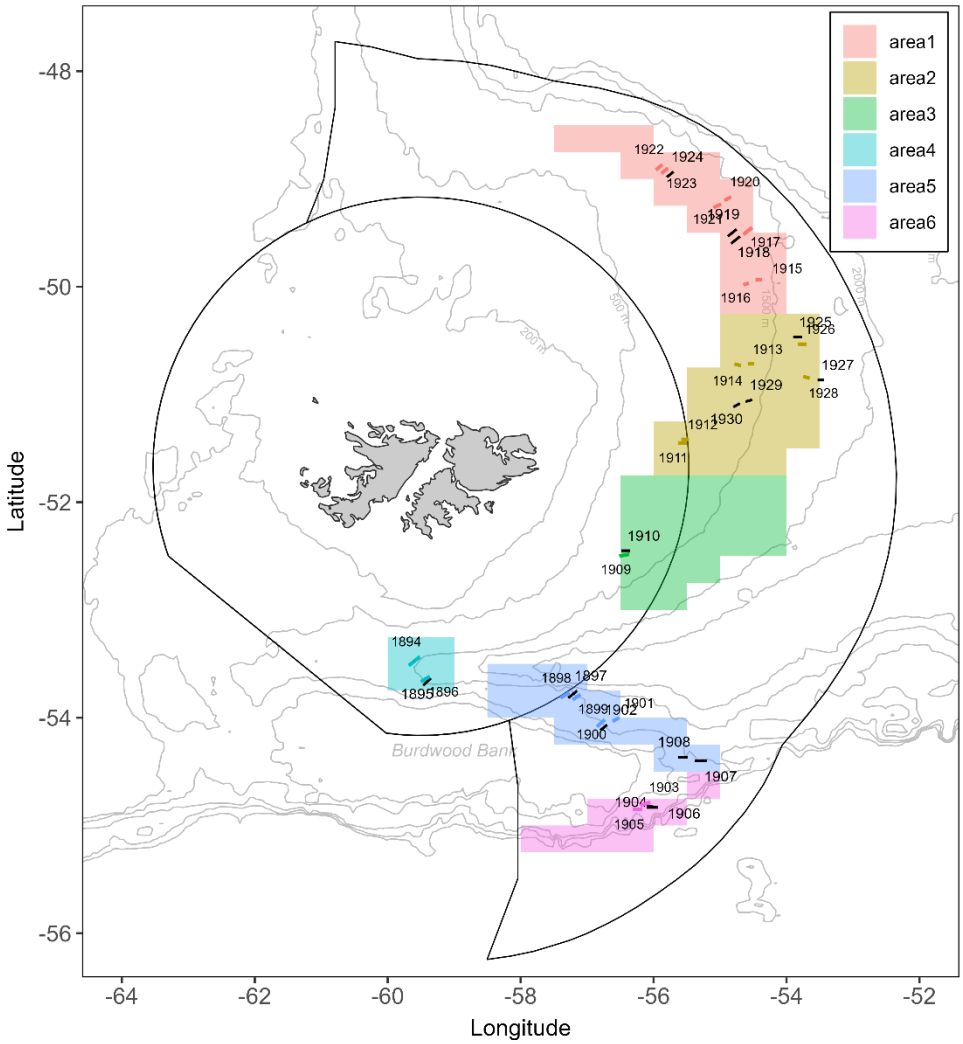

Figure 1. Location of the 37 stations and the six predefined tagging areas during the ZDLK3-11-2024 research cruise. The 22 coloured stations represent the tagging stations, and the 15 black stations represent the stations where no tagging was conducted.

2.2. Tagging protocol

The tagging station was set up in the dry section of the factory, at the far end of the umbrella cleaning table. It was equipped with tools necessary for the tagging process, including a bolt cutter for removing hooks, a 1.50 m measuring tape, a tagging board with pre-prepared tags, a tag applicator, a vial filled with 70% ethanol for disinfecting the applicator and tags before each use, a pencil, a scribing board, and the stretcher (Figure 2). The tag holding board was prepared in advance, typically the night before, with tags arranged in ascending order to streamline the tagging process.

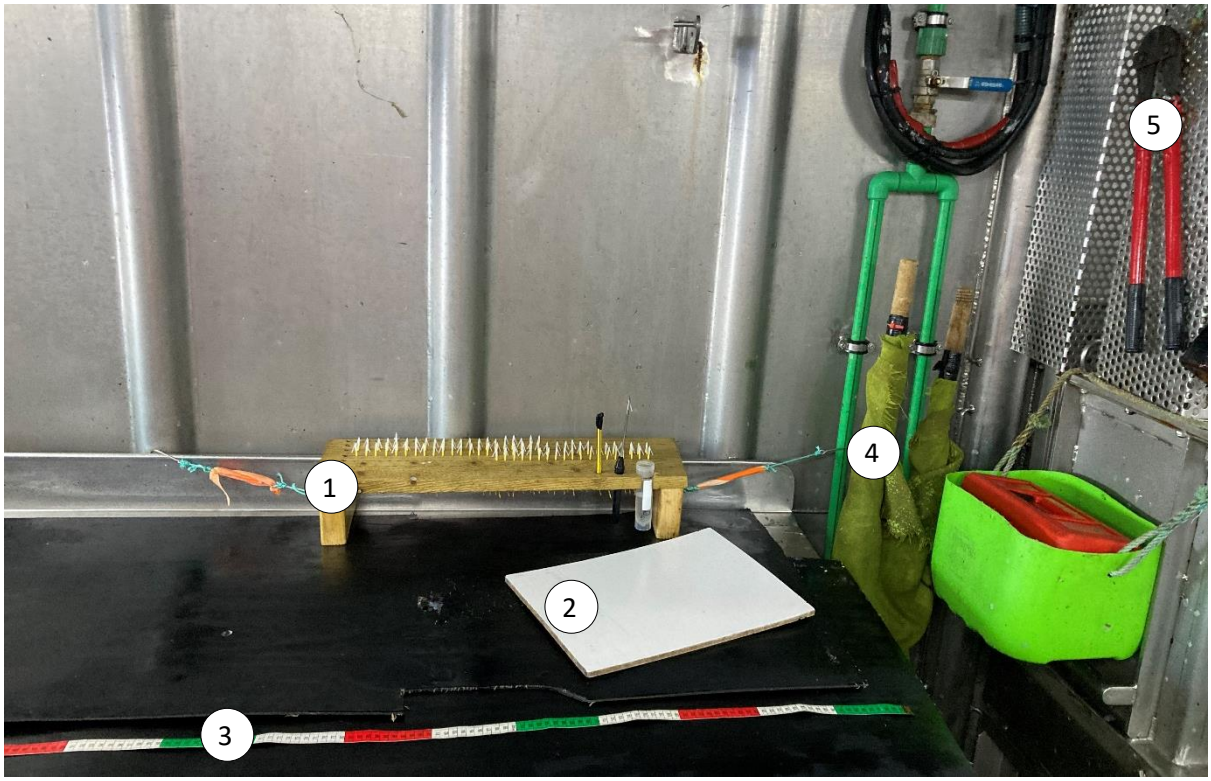

Figure 2. Set up of the tagging station with (1) the tagging board holding the tags, a pencil, the tagging applicator, and the vial filled with 70% ethanol for disinfection, (2) a scribing board, (3) the measuring tape, (4) the stretcher to carry large tagged toothfish to the hauling bay for their releasing, and (5) the bolt cutter.

Before beginning any tagging activities, it is crucial to check for the presence of sperm whales (*Physeter macrocephalus*) and orcas (*Orcinus orca*) around the vessel, as these species are active predators of toothfish. Throughout the tagging process the scientist in charge of tagging communicated with the factory bosun and the bridge official to determine if these predators were nearby. Tagging should not occur if sperm whales or orcas were sighted in the vicinity of the vessel. This protocol was implemented to prevent released toothfish from being eaten by the sperm whales and orcas and to avoid encouraging associated depredation behaviour.

When a toothfish was brought on board, its suitability for tagging was assessed according to the criteria established by Lee (2022). Tagged fish should align with the size distribution of those captured; therefore, the length of the fish was not a determining factor for tagging. However, large toothfish that were lifted onboard without proper support were not tagged due to the risk of spinal damage. If the fish was supported by the umbrella during the lifting onboard, then the condition of the fish was considered suitable for tagging. Fish that did not meet the criteria were sent to the factory for processing.

Suitable toothfish were slid from the hauling bay to the tagging station. The remaining hooks were carefully removed using the bolt cutter, ensuring minimal injury to the fish. Fish were measured (Total length to the nearest cm) and tagged with one external *FT-1-94* spaghetti Floy® dart tags (Floy Tag and Mfg, Inc., Seattle, WA. USA), which contained a unique identification number. A sharp hollow applicator was used to insert the tag into the dorsal musculature, specifically between the 3rd and 4th rays of the second dorsal fin, ensuring that the barb of the tag was locked behind a pterygiophore (Figure 3). Before tagging, both the applicator and the inserted tag were dipped in 70% ethanol to help prevent infection around the tag site. Once tagged, the fish was transported to the hauling bay by crew member and released headfirst into the water. The crew member responsible for the releasing of the tagged fish should inform the scientist of the likely fate of the fish, based on its vigorous swimming after release or its attack by predators.

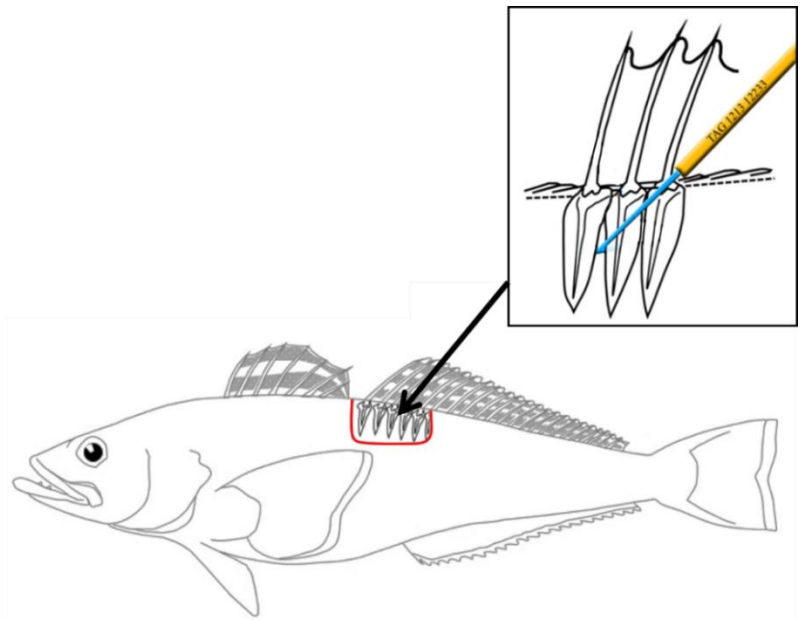

Figure 3. Tagging location between the 3rd and the 4th rays of the second dorsal fin locking the barb of the tag behind a pterygiophore. Modified from *Toothfish and skate tagging methods* (CCAMLR, 2013) (image credits: Alan Hart).

Based on previous tagging research surveys and the annual number of toothfish tagged by the Fisheries Observers, we planned to tag between 600 and 700 toothfish (i.e. between 40 and 50 toothfish per

day). We aimed to deploy a specific number of tags in each designated area (Table 1). At each station/line, we recorded the time we started and finished tagging to monitor our efforts. We also recorded any interruption of the tagging monitoring for sampling sleeper sharks, during lunch breaks, or because of the presence of sperm whale and orca around the vessel. At the bridge, the time at each marking along with the number of toothfish caught between two markings were routinely recorded on the logbook. These data used for two main purposes: (1) to calculate the percentage of the line monitored by the scientist, which included time spent tagging or waiting for suitable toothfish, and (2) to determine the number of toothfish caught in the monitored section of the line. As recommended by Skeljo and Pearman (2021), tagged toothfish were not weighed. Individual weight was calculated using the length-weight relationship set in the database ($W = a\ L^b$, with a= 0.0061 and b= 3.1037).

To effectively monitor the population, the length-frequency of tagged individuals should be representative of the population length-frequency distribution. We thus tested the tag-overlap of sampled and tagged toothfish during the tagging survey using the following formula (CCAMLR, 2022):

$$\theta = \left[1 - \frac{\sum_{i=1}^{n} |P_t - P_c|}{2}\right] \times 100$$

where for 10 cm length bins, P_t is the proportion of all fish tagged in length bin *i*, P_c is the proportion of all fish caught in length bin *i*.

2.3. Sleeper shark sampling protocol

Sleeper shark sampling was conducted throughout the entire fishing area. Sleeper sharks were sampled following a specific protocol consisting of three steps: (1) tissue sampling, (2) photo collection, and (3) morphological measurements and sex determination.

The most critical step in this protocol is tissue sampling for genetic analysis. It is important to ensure that the tissue designated for sampling is not touched during the process to avoid contamination. All materials used must be disinfected with 70% ethanol beforehand. A small piece of tissue (0.5-1.0 cm^3) from the pelvic fin was carefully cut with sanitized scissors and placed into a vial. The vial was then filled with 96% ethanol, maintaining a volumetric ratio of at least 5:1 (ethanol:tissue). A waterproof label indicating the sample ID (which consists of the station number plus the species code, e.g., '1863SOM') was added into the vial. The caps were securely closed and sealed with Parafilm to prevent any spillage. Following this, the scissors were cleaned three times with tap water and then with 70% ethanol. The 96% ethanol in the vial was replaced with fresh 96% ethanol 48 hours after sampling.

For each individual, we took photographs of the following body parts (Figure 4): the whole individual (photo #1), the prebranchial area (from the snout tip to the pectoral end, photo #2), the interdorsal area (including the first and second dorsal fins, photo #3), the caudal area (from the pelvic fin to the end of the caudal fin, photo #4), and the pelvic fin area (photo #5).

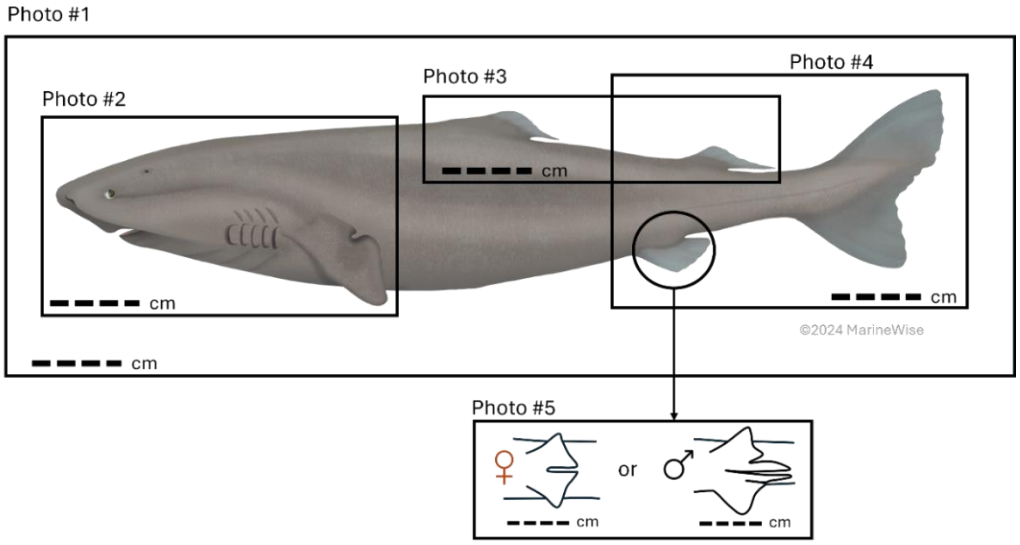

Figure 4. Photo collection protocol. Black rectangles delimit the body parts that must be visible in each photo.

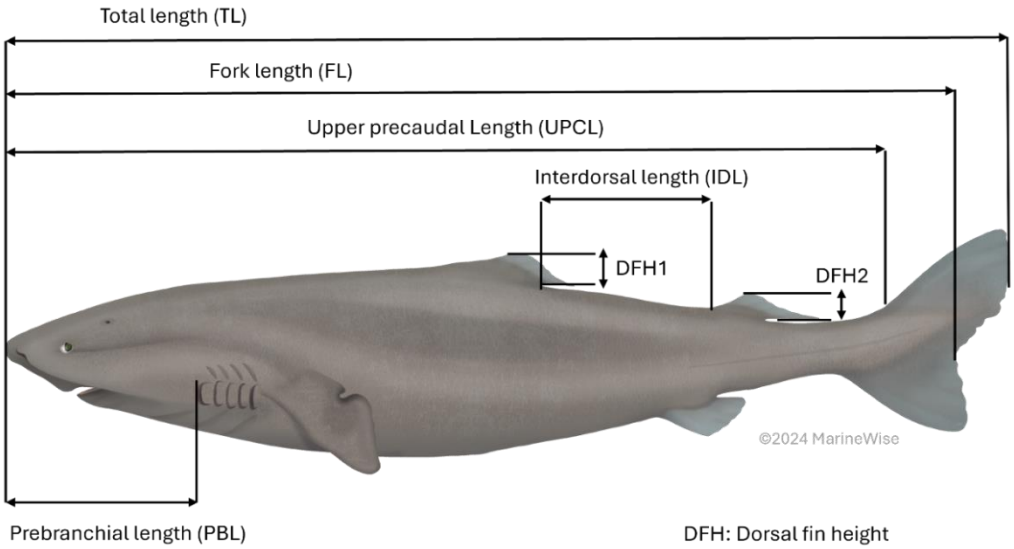

Figure 5. Morphological measurements of sleeper sharks.

The following information was recorded for each sampled fish: sex, total weight (to the nearest 100 g), and seven measurements: total length (TL), fork length (FL), upper precaudal length (UPCL), interdorsal length (IDL), prebranchial length (PBL), height of the first dorsal fin (DFH1), height of the second dorsal fin (DFH2) (Figure 5). All lengths were expressed in cm and rounded to the nearest mm (e.g., TL = 224.6 cm).

2.4. Toothfish gonads sampling protocol

Toothfish reproductive strategy sampling was conducted across the entire fishing area. This survey involved gonad sampling to address existing gaps in gonads data collection. We performed non-random sampling of small and large toothfish (< 60 and >160 cm, respectively) as well as toothfish having a maturity stage ≥ 4 (macroscopically identified).

The sampling took place in the wet factory, and the following information was recorded for each sampled fish: total length (to the nearest cm), total weight (to the nearest 100 g), macroscopic maturity stage (8-stage maturity scale developed by the FIFD; 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 cut, stored in a vial, and labelled (using the format TOO/Station/Sex_Maturity/indiv_histo_number/otolith_serial_number). Otoliths were also extracted and stored according to the routine observer protocol (FIFD, 2023), ensuring that the histological serial number was included on the envelope. At the end of each sampling station, the vials were filled with a 10% Buffer Formalin Solution at the dry factory (not at the sampling factory), and the caps were sealed with Parafilm to prevent any spillage.

3. Results

3.1. Station setting and sampling feature

The *CFL Hunter* (ZDLK3) departed from Stanley and steamed south to set the first lines in the area 4 (stations 1894-1896; Figure 1 and Table 2). Then, from 18th to 23rd November 2024, we followed a southern route from area 4 to area 6 (stations 1903-1905; Figure 1 and Table 2). On the 24th of November the vessel steamed back north to area 4 (station 1909) and then to the northern areas (Figure 1 and Table 2). On the 2nd of December, we steamed the whole day from the South to the North of the fishing area. Among the 17 fishing days of this survey, we hauled 3 stations per day on 4 days (23%), 2 stations per day on 12 days (70%), and 1 station per day on 1 day (6%). A total of 37 stations were conducted, and tagging was performed on 22 stations (Figure 1 and Table 2).

Table 2. Characteristics of the tagging stations: area, date, time at haul start, station depth (mean and standard deviation), and soak time. 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 are sorted by area and haul date.

Area	Date	Station	Haul start	Depth mean	Soak time
1	28/11/2024	1915	11:07	1295 ± 27	08:41
	28/11/2024	1916	16:38	1251 ± 61	15:24
	29/11/2024	1917	07:39	1232 ± 23	09:05
	30/11/2024	1920	11:40	1269 ± 71	08:03
	30/11/2024	1921	16:49	1126 ± 76	14:32
	01/12/2024	1922	09:28	1058 ± 30	09:04
	01/12/2024	1923	15:45	1051 ± 33	13:38
2	26/11/2024	1911	12:25	1154 ± 90	07:13
	26/11/2024	1912	18:08	1134 ± 87	11:20
	27/11/2024	1913	12:36	1388 ± 15	10:02
	27/11/2024	1914	18:53	1316 ± 11	17:02
	03/12/2024	1926	08:38	1690 ± 76	16:13
	04/12/2024	1928	07:24	1742 ± 30	16:09
3	25/11/2024	1909	13:38	1318 ± 4	08:31
4	18/11/2024	1894	06:50	1456 ± 63	10:34
	19/11/2024	1896	06:52	1452 ± 26	15:41
5	20/11/2024	1898	09:02	1440 ± 354	16:15
	20/11/2024	1899	17:03	1398 ± 409	21:07
	21/11/2024	1900	07:39	1540 ± 62	09:07
	21/11/2024	1901	15:00	1631 ± 143	13:02
6	22/11/2024	1903	12:24	1106 ± 30	08:35
	23/11/2024	1905	06:39	1250 ± 205	15:32

The average station depth was 1341 ± 223 m (min depth = 1017 m and max depth = 1805 m; Table 2). The average soak time across the stations was 12:53 ± 4:00 h (i.e., mean ± standard deviation; corresponding to 773 ± 240 min; Table 2). Soak times ranged from 7:13 to 21:07 h (corresponding to 433 – 1267 min; Table 2 and Figure 6). Data showed that the correlation between proportion of toothfish tagged and the line soak time was significant (p value = 0.0262 *).

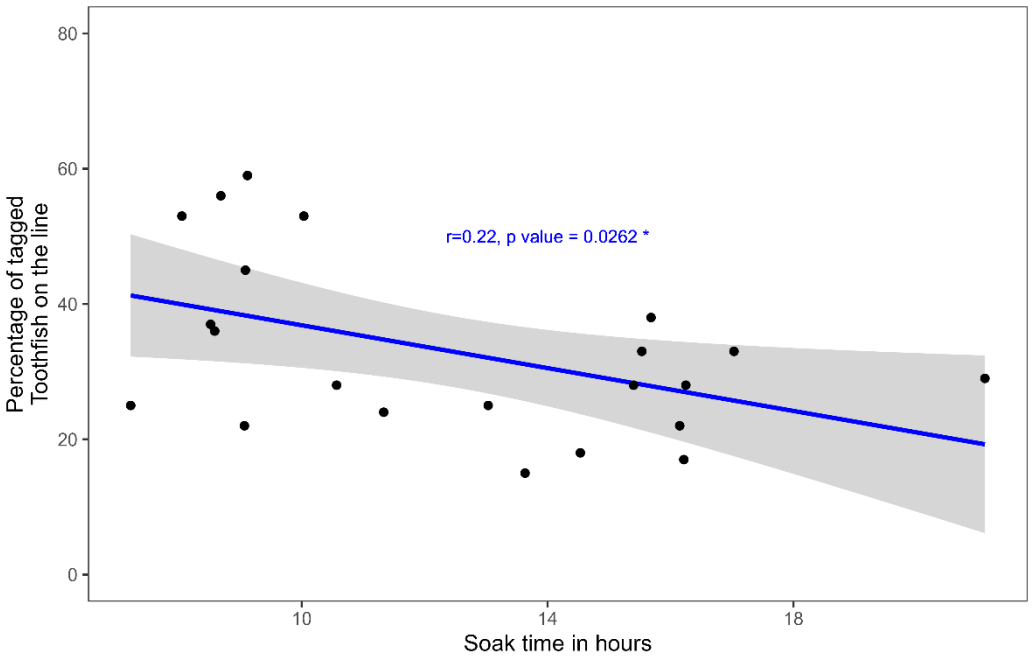

Figure 6. Relationship between the proportion of tagged toothfish per line and the line soak time. The Pearson's correlation coefficient r and p-value are shown. Blue line: regression line of proportion tagged on soak time. Shaded area: regression line 95% confidence intervals. Soak time was calculated as the difference between the mid-set and mid-haul times. Stations are sorted by area and haul date.

3.2. Toothfish tagging

Tagging was conducted at 22 stations: 7 in area 1, 6 in area 2, 1 in area 3, 2 in area 4, 4 in area 5 and 2 in area 6 (Figure 1 and Table 3). We tagged 1 line per day for 8 days and 2 lines per day for 7 days (Table 3). Toothfish tagging was prioritised during the first daily station, with the entire line monitored to ensure that the target of 40-50 tagged toothfish was met each day (Table 3). If the target was not achieved during the first station, the second station was utilised to reach the goal. As a result, the percentage of the line monitored was lower for the second daily lines compared to the first (Table 3). Tagging was occasionally interrupted for sampling sleeper sharks, during lunch breaks, or because of the presence of sperm whale and orca around the vessel.

Table 3. Tagging information (percentage of the line monitored by the scientist to tag toothfish and the percentage of tagged toothfish) and characteristics of the tagged toothfish (total length mean and standard deviation and, total length range) by station. The percentage of the line monitored by the scientist was calculated in term of time spend to tag and wait for suitable toothfish to tag. 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. Stations are sorted by area and haul date. Tagging was stopped at the stations (*) 1896 and 1923 because of the presence of sperm whales and orcas, respectively.

Area	Date	Station	Percentage of line monitored	Percentage of tagged fish	Number of tagged fish	Total length (mean ± sd)	Total length range
1	28/11/2024	1915	100	56	24	101 ± 16	66 - 140
		1916	89	26	25	105 ± 13	81 - 141
	29/11/2024	1917	89	42	50	101 ± 16	61 - 142
	30/11/2024	1920	100	53	31	100 ± 17	69 - 138
		1921	13	4	9	111 ± 11	96 - 127
	01/12/2024	1922	78	18	31	94 ± 13	77 - 128
		1923*	12	4	4	117 ± 17	100 - 138
2	26/11/2024	1911	100	25	14	97 ± 23	68 - 141
		1912	87	22	18	99 ± 10	78 - 115
	27/11/2024	1913	100	53	26	142 ± 176	66 - 999
		1914	41	16	14	101 ± 16	73 - 124
	03/12/2024	1926	90	16	24	119 ± 23	75 - 165
	04/12/2024	1928	60	16	4	116 ± 14	100 - 130
3	25/11/2024	1909	87	30	49	93 ± 12	66 - 118
4	18/11/2024	1894	77	21	52	98 ± 12	69 - 119
	19/11/2024	1896*	58	22	24	90 ± 12	70 - 114
5	20/11/2024	1898	78	25	36	105 ± 23	67 - 156
		1899	45	16	20	111 ± 21	70 - 142
	21/11/2024	1900	58	36	50	100 ± 16	72 - 140
		1901	46	11	11	122 ± 24	84 - 158
6	22/11/2024	1903	86	33	82	90 ± 11	67 - 123
	23/11/2024	1905	100	33	80	93 ± 12	74 - 129

At station 1896, tagging was stopped because 2 sperm whales (*Physeter macrocephalus*) were sighted near the vessel (Figure 1 and Table 3). We did not tag at stations 1907 and 1908 because 11 sperm whales remained around the vessel for the entire day (Figure 1 and Table 3). Tagging was also interrupted at station 1923 due to the presence of 13 orcas (8 in one pod and 5 in another) actively depredating the line by feeding on toothfish. The counts of sperm whales and orcas do not fully align with the numbers reported in the observer report (FIFD, 2024) because the observer conducted a post-survey photographic identification and updated the count. At stations 1912, 1917, and 1921, we stopped tagging after a few toothfish had been tagged because we achieved the daily target (Table 3).

A total of 678 toothfish was tagged during the research cruise, weighing a combined total of 7,120 kg. This represents 32.63% of the total catch during the tagging time by number. The breakdown of tagged toothfish by area is as follows: 174 in area 1, 100 in area 2, 49 in area 3, 76 in area 4, 117 in area 5, and 162 in area 6 (Table 3). The number of tagged toothfish varied from 4 to 82 per day, with an average of 45 ± 20 individuals. Tag numbers used during the survey ranged from 8225 to 8903.

Except for area 2 and 3, the actual numbers tagged matched the expected (allocated) numbers (Table 4). The discrepancy in areas 2 and 3 was due to an error by the Captain, who incorrectly attributed stations 1911 and 1912 to area 3, when they should have been classified under area 2. If we allocate the 32 toothfish tagged at these stations (Table 3) to area 3, the numbers tagged would align with the expected numbers (Table 4). Since stations 1911 and 1912 are close to the northern boundary of area 2, the toothfish scientist believes that this will not bias future analyses.

Table 4. Number of tagging days and resultant number of tagged toothfish allocated to each area for the tagging survey, and actually realised.

	Number of tagging day		Number of tagged toothfish	
Area	Allocated	Realised	Allocated	Realised
1	4	4	180	174
2	0-1	4	0	100
3	2-3	1	70	49
4	2	2	70	76
5	2-3	2	60	117
6	4	2	190	162
Total	14-17	15	570	678

The total length of tagged toothfish ranged from 61 to 165 cm (mean TL ± sd: 99.1 ± 17 cm) (Table 3 and Figure 7.a), and the total length of sampled fish (i.e. sampled for length-frequency and otoliths) ranged from 49 to 189 cm (mean TL ± sd: 100 ± 21.4 cm) (Figure 7.b). There was no significant difference in the mean length between the tagged and sampled toothfish (ANOVA, p-value = 0.2089; Figure 7). The tag-overlap statistic (CCAMLR, 2022) showed a 95.62 % overlap between the length frequencies of sampled and tagged toothfish. The larger fish, with a total length superior to 150 cm, were yet not often selected for tagging (Figure 7).

The mean length of sampled and tagged toothfish differed significantly between areas (ANOVA, p-value $_{sampled}$ = 9.344e-06 *** and p-value $_{tagged}$ = < 2.2e-16 ***). Toothfish tagged in area 6 (south) were smaller than in the rest of the longline fishing area (Figures 1 and 4). The toothfish tagged in areas 1 and 2 (north) were larger than in southern areas (Figures 1 and 4).

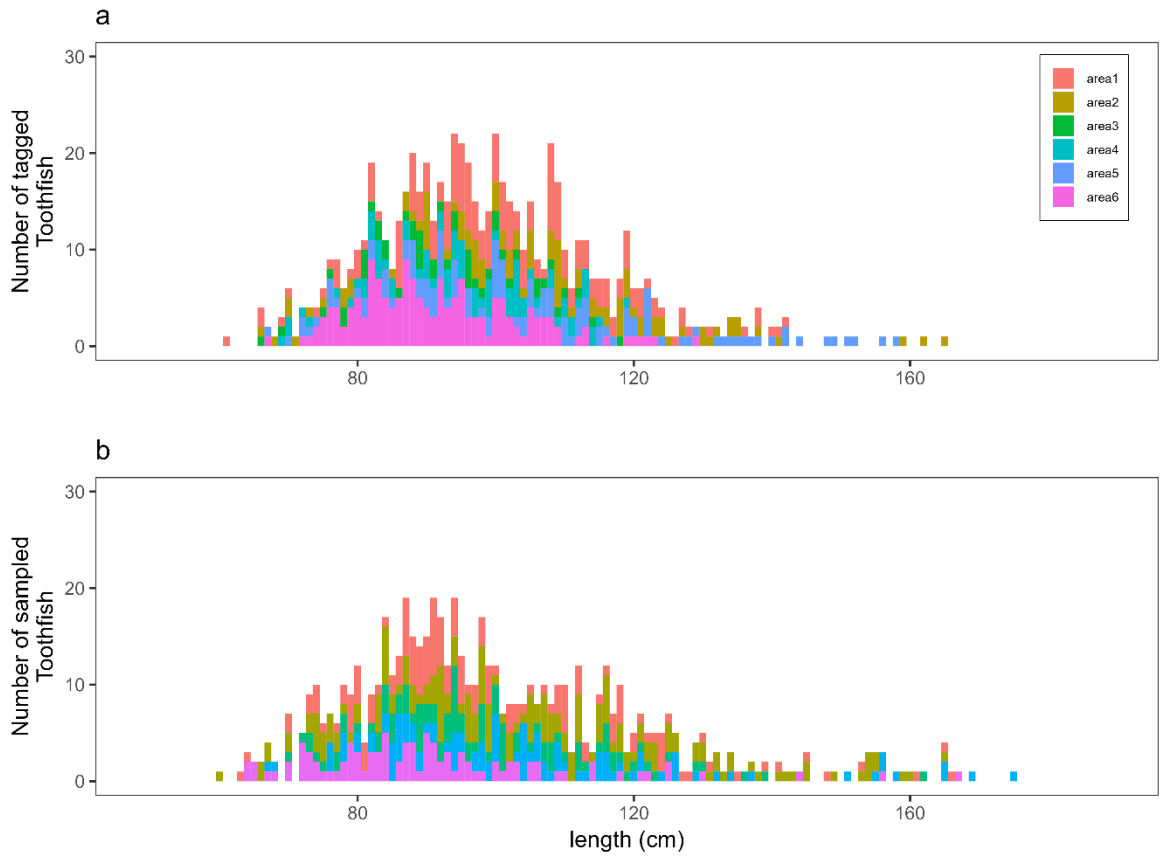

Figure 7. Cumulative length-frequency of (a) tagged and (b) sampled toothfish during the research cruise ZDLK3-11-2024 partitioned by area (Figure 1). Sampled toothfish comprised random and sub-sample toothfish collected for length-frequency and otoliths.

3.3. Sleeper shark

Opportunistic sampling of sleeper sharks occurred whenever one was caught. The 6 sleeper sharks caught during the survey were sampled. Three female sleeper sharks were caught in area 5, 1 male and 1 female in area 2, and 1 male in area 3 (Figure 8). All the individuals were immature. Female total length ranged from 140 to 200 cm (mean TL ± sd: 161 ± 27.6 cm), and male total length ranged from 194 to 229 cm (mean TL ± sd: 212 ± 24.7 cm).

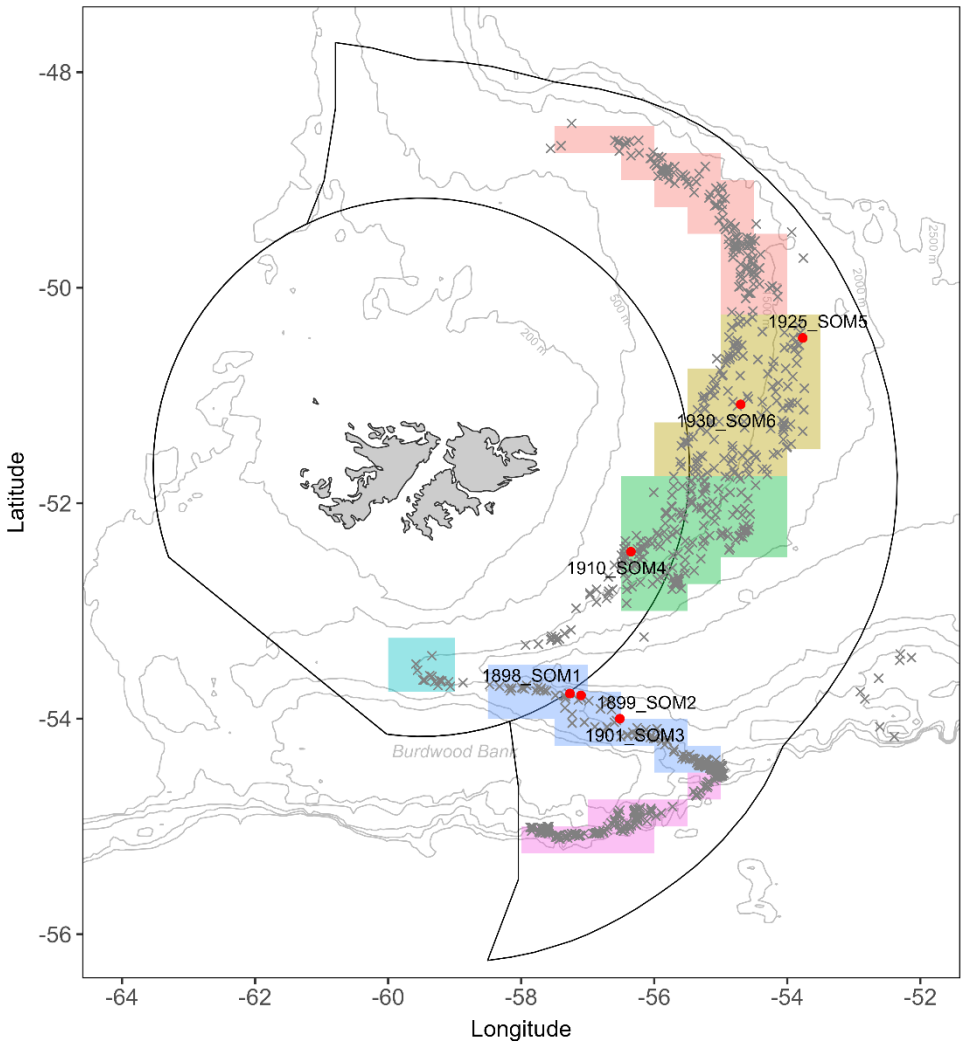

Figure 8. Location of the sleeper sharks sampled in the longline fisheries from 2008 onwards (grey cross), and the six sleeper sharks sampled during the tagging survey (red dots).

3.4. Toothfish gonads

Toothfish gonads were sampled at 10 stations. Among them, 21 gonads were sampled in area 1, 14 in area 2, 4 in area 5, and 9 in area 6. A total of 48 gonads were sampled during the cruise, comprising 25 female and 23 male gonads. The length of toothfish sampled for gonads ranged from 60 to 175 cm (mean TL ± sd: 90.5 ± 24.6 cm). The mean length of toothfish sampled for gonads varied by sex (ANOVA, p-value = 0.07683 .). Females sampled for gonads were larger than males (mean TL ± sd_{Female}: 96.5 ± 29.4 cm, mean TL ± sd_{Male}: 83.9 ± 16.3 cm).

Toothfish gonads sampled were at 85% form maturity stages 2 and 3 for both sexes (Table 5). Two F4 were sampled at station 1922 in area 1, one was sampled at station 1928 in area 2, and one was sampled at station 1898 in area 5 (north of Burwood Bank) (Table 5 and Figure 1). One M6 was sampled at station 1928 in area 5 (Table 5 and Figure 1). The two sampled F8 were sampled at Burwood Bank;

one at station 1898 (area 5, north of Burwood Bank) and one at station 1903 (area 6, south of Burwood Bank) (Table 5 and Figure 1).

Table 5. 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
2	8	16
3	11	6
4	4	-
6	-	1
8	2	-

4. Discussion

During the ZDLK3-11-2024 research cruise, we successfully met the objectives of the research cruise by tagging 678 toothfish with external spaghetti Floy® dart tags, averaging 45 fish tagged per day. Additionally, we sampled 6 sleeper sharks and collected the gonads of 48 toothfish.

Following the recommendations from the previous tagging Cruise Report ZDLK3-10-2023 (Le Luherne and Peruzzo, 2023), we defined 6 specific areas for tagging, ensuring the allocated percentage of tagged toothfish per area reflected the distribution of fishing effort. In half of the areas (1, 4, and 5), the predetermined number of fishing days allocated to each area was respected. However, in area 6, we were only able to fish for two days instead of the planned 4 days. This area, located in the southern part of Burwood Bank, is known for its strong currents making the area unsuitable for fishing (pers. com. Captain Sanchez-Lema C.). Nevertheless, we managed to tag the expected number of toothfish within this reduced timeframe. Conversely, the number of fishing days allocated to areas 2 and 3 varied by three and one day, respectively, leading to differences in the number of tagged toothfish: 100 in area 2 and 21 in area 3. These discrepancies largely arose from a misattribution of stations 1911 and 1912 to area 2 by the Captain, when they are actually located in area 3.

The requested fishing schedule, involving the hauling of two lines per day during the daytime, with the first haul starting around 07:00 and the second between 12:00 and 14:00, was not fully followed for this survey. This schedule was followed only 4 days on the 17 fishing days of the survey (23% of the research survey). The chief scientist understands that this schedule could not always be followed due to either weather conditions or steaming time between areas. However, such reasons did not explain why this schedule was not followed most of the time. This research survey should focus on the

objectives outlined in the research proposal, and no additional lines that alter the established fishing schedule should be included.

The average soak time during this cruise was 773 ± 240 min. The soak time during this survey was considerably longer than in previous tagging surveys (705 ± 125 min at the ZDLK3-10-2023 (Le Luherne and Peruzzo, 2023), 550 ± 215 min at the ZDLK3-02-2018 research cruise (Farrugia and Keningale, 2018), and the 622 min at the ZDLK3-10-2022 research cruise (Nicholls and Raczynski, 2023)). While earlier findings indicated that soak time did not affect the condition of toothfish or their suitability for tagging (Skeljo and Pearman, 2021), our results suggest that soak time does influence the proportion of tagged toothfish per line. The soak times reported by Skeljo and Pearman (2021) were in a narrower range, which may explain the differences observed in our results. Specifically, their soak times ranged from 570 to 1146 min (9:30 to 19 h), whereas our tagging survey had soak times ranging from 433 to 1267 min (7:13 to 21:07 h), with 36% of the lines having soak times shorter than 600 min (10 h). Given our findings, we recommend using shorter soak times for tagging surveys to fish toothfish in better condition for tagging, ideally between 7 to 15 hours. Additionally, we advise following the recommendations of Captain Garcia Portas F., particularly by avoiding long soak times in areas with scavengers, as this can further impact the condition of the toothfish and their suitability for tagging.

The length distribution of tagged toothfish overlap at 95.62 % overlap with that of sampled toothfish, aligning with the objectives of the research cruise program. The mean total length of tagged toothfish was 99.1 ± 17 cm, comparable to the lengths recorded in the last two tagging surveys (2023: 101 ± 17.1 cm and 2022: 98.4 ± 16.2 cm) and in Farrugia et al. (2018) (102.1 ± 13.7 cm). It was slightly higher than the lengths reported by Farrugia and Keningale (2018) and Skeljo and Pearman (2021), which were 94.5 ± 13.1 cm and 87.4 ± 13.7 cm, respectively. These results confirm that toothfish tagged in the southern waters were generally smaller than those in the northern regions. Farrugia and Keningale (2018) and Skeljo and Pearman (2021) covered mostly southern and south-eastern areas while Nicholls and Raczynski (2023) tagged toothfish in southern and northern areas and Farrugia *et al*. (2018) covered the north-eastern area. This result was yet unexpected, as Burdwood Bank, located in the southern area, is known as a spawning ground for toothfish (Laptikhovsky *et al*. 2006) and should, therefore, hold larger toothfish. Indeed, we sampled the largest individuals in the south (length-frequency and otoliths sampling). These results highlighted that larger toothfish were often unsuitable for tagging, likely due to injuries occurring during the catching process (e.g. with other hooks) or when brought onboard using a gaff.

The outcomes for tagged fish appeared generally favourable, as toothfish were observed swimming downwards shortly after release. Tagging was either paused or not initiated on the 19th and 24th of

November 2024 (stations 1896 and 1907-1908) and on the 1st of December 2024 (stations 1923 and 1924) to prevent released tagged toothfish from being consumed by sperm whales (*Physeter macrocephalus*) and orcas (*Orcinus orca*), respectively. This precaution was also taken to avoid encouraging any associated depredation behaviour.

The number of gonads sampled, along with the maturity stages collected for the toothfish reproductive strategy project, met our expectations, and the gonads were added to the ongoing collection of samples for this project.

In conclusion, the ZDLK3-11-2024 research cruise successfully met the objectives outlined in the scientific proposal and followed the recommendations from the ZDLK3-10-2023 report (Le Luherne and Peruzzo, 2023). To keep improving the tagging survey and its outputs, we recommend to follow the listed recommendations in the next tagging survey.

Recommended actions for the next tagging research cruise from the chief scientist (tagging survey 2024)

- Establish the toothfish tagging program as a permanent program. The outcomes of this program are essential for the toothfish stock assessment and should be maintained. This is addressed in the stock assessment report 2025 (Skeljo and Winter, in prep.).
- Create a R project or a Git to improve the replicability of the tagging research cruise scheduling and outputs.
- Follow the fishing schedule set up in 2023. This schedule was to haul 2 lines per day during the daytime, the first hauling starting around 07:00 and the second one around 12:00-14:00. No extra lines resulting in a change of this fishing schedule should be conducted.
- Write a logbook during the survey that includes the following key information: the date, station and line numbers, area, the number of toothfish tagged at each station, the presence of toothfish predators, and weather conditions. A logbook was created in 2024 by the chief scientist and proved to be valuable for writing the tagging report.
- Record daily weather conditions (wave height and wind speed) to assess any influence of these factors on toothfish suitability for tagging.
- Write a memo to assist the observer in determining the suitability of toothfish for tagging.
- Change the 150 cm sewing measuring tape used to measure the toothfish to a 200 cm sewing measuring tape to facilitate the measurement of larger individuals (i.e. up to 150 cm).

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