

Cruise Report ZDLK3-10-2025

VME bycatch and Patagonian toothfish (*Dissostichus eleginoides*) tagging survey



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ZDLK3 - 10 - 2025



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Summary

The research cruise ZDLK3-10-2025 was conducted on the *CFL Hunter* (ZDLK3) from October 26, 2025 to November 17, 2025, within Falkland Islands waters. The objectives of the cruise included (1) collecting data to estimate bycatch rates of Vulnerable Marine Ecosystem (VME) indicator taxa with and without umbrellas, as well as whale depredation rates associated with each line configuration; (2) tagging 800-900 toothfish; (3) collecting morphological measurements and tissue samples from sleeper sharks (*Somniosus* sp.); and (4) collecting data to update the proportion of each grenadier species (*Macrourus holotrachys* and *Macrourus carinatus*) caught in the longline fishery. No routine Fisheries Observer protocols were performed during the survey. The survey primarily aimed to estimate bycatch rates of VME indicator taxa, both with and without umbrellas, in different VME habitats of Falkland Islands waters. Accordingly, the sampling design was tailored to meet this objective, and tagging was carried out within the designated areas.

A total of 36 VME indicator taxa were sampled at 30 stations distributed across key VME habitats, including sea pen fields in the Falkland Trough and cold-water coral assemblages on the slopes of Burdwood Bank and the Falkland Plateau. Exploratory data analysis indicated that VME bycatch rates were more variable—and on average higher—on line sections equipped with umbrellas, although the magnitude of this umbrella effect differed among sampling areas and taxonomic groups. High depredation rates and the likely occurrence of cryptic depredation on line sections without umbrellas were reported at the two stations where sperm whales were observed around the vessel throughout hauling. Further analyses using appropriate statistical models will be required to provide robust estimates of VME bycatch rates with and without umbrellas and to assess whether restricting the use of umbrellas in certain areas could help reduce the longline fishery's impact on VMEs.

A total of 626 toothfish were tagged using external spaghetti Floy® dart tags (37 fish tagged per day on average). In addition, four sleeper sharks (three male and one female) and 1024 grenadiers (979 *M. holotrachys* and 45 *M. carinatus*) were sampled during the survey. The total of tagged toothfish represents 23.87% of the total toothfish catch numbers during the tagging time. Tag numbers used during the survey ranged from 9265 to 9890. Of these, 107 toothfish were tagged in area 1, 142 in area 2, 130 in area 3, 78 in area 4, 50 in area 5, 69 in area 6, and 50 in the sea pen field between areas 3 and 5 ('grey' area). Total lengths of the tagged toothfish ranged from 47 to 167 cm (mean \pm sd: 100 ± 16.1 cm). Total lengths of the sleeper sharks ranged from 138.5 to 198 cm (mean \pm sd: 167.8 ± 25.9 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 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 onwards (Skeljo and Pearman 2021; Nicholls and Raczynski, 2023; Le Luherne and Peruzzo, 2023; Le Luherne and Desmet, 2025) 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, additional scientific protocols have been added to tagging cruises to improve our knowledge of the Falkland Islands toothfish fishery. From 2017 to 2020, underwater cameras were deployed to assess habitat diversity and the impacts of longline fishing on benthic habitats. In 2020, benthic invertebrates caught as bycatch were collected to compile a reference fauna collection. In 2023 and 2024, toothfish gonads were sampled to help obtain reliable estimates of toothfish reproductive traits, such as age at first maturity, fecundity, and prevalence of skipped spawning in females.

The 2025 tagging cruise aimed to (1) collect data to estimate bycatch rates of Vulnerable Marine Ecosystem (VME) indicator taxa with and without umbrellas, as well as whale depredation rates associated with each line configuration; (2) tag 800-900 Patagonian toothfish; (3) collect morphological data and tissue samples from sleeper sharks; and (4) collect data to review the relative proportions of grenadier species (*Macrourus holotrachys* and *Macrourus carinatus*) caught in the longline fishery.

The comparison of VME bycatch rates with and without umbrellas was recommended by the VME Strategy Action Plan 2023–2026 (Action 2.2) to evaluate whether restricting the use of umbrellas in

certain areas can help reduce the longline fishery's impact on VMEs, while maintaining depredation rates within acceptable limits. The number of toothfish tagged during the survey was set to meet the annual objective of the toothfish tag-recapture program. The collection of morphological data and tissue samples from sleeper sharks formed part of an ongoing research effort to improve the identification of these bycatch species in the longline fishery, following recommendations of the MSC Steering Group. Finally, inconsistencies in the identification of *M. holotrachys* and *M. carinatus* by the Fisheries Observers have been recently highlighted, raising potential concern about the true proportion of each species in the total catch. The tagging cruise provided an opportunity to collect data for re-estimating the relative percentage of each species caught in the longline fishery.

2. Materials and methods

2.1. Cruise itinerary and sampling design

The research cruise lasted 23 days from October 26 to November 17, 2025, with 20 days dedicated to effective fishing. The 26th of October and 17th of November were used for steaming to the first sampling station and returning to Stanley, respectively, while the 5th of November was spent steaming from the southern area to the northern station. Emilie Le Luherne (Toothfish Fisheries Scientist) was the chief scientist of the survey and Erwan Saulnier (Stock assessment scientist) was responsible for the VME sampling design and data collection. The survey was conducted aboard the *CFL Hunter* (ZDLK3) under the direction of Captain Candido Sanchez-Lema and operated under the L license. Routine Fisheries Observer protocols were not carried out during the survey.

The sampling design was developed collaboratively by FIFD scientists and CFL to meet the survey objectives while accounting for steaming time, soaking time, and the minimum fishing effort needed for CFL to operate cost-efficiently. The sampling design produced by FIFD was first discussed on October 10, 2025 during a meeting with Patricio Garces (CFL, Crew and Vessel Admin Manager), Fernando Garcia (CFL, Captain of the Hunter), Erwan Saulnier and Emilie Le Luherne. Following recommendations and feedback provided during the meeting, a second version of the sampling design was sent to CFL on October 17, 2025. It was further discussed during a pre-survey meeting on October 21, 2025 with Janet Robertson (CFL, General Manager), Patricio Garces (CFL, Crew and Vessel Admin Manager), and Fernando Garcia and Candido Sanchez-Lema, the two captains of the Hunter. CFL confirmed the feasibility and approved the following sampling design and schedule.

A total of 15 grid squares distributed across the historical toothfish longline fishing area were selected based on an analysis of the spatial distribution of VME taxa bycatch rates recorded since January 2012, along with fishing effort data from the past five years (Figure 1). This approach aimed to maximise the probability of sampling key VME habitats — including sea pen fields in the Falkland Trough and cold-water coral assemblages on the slopes of Burdwood Bank and the Falkland Plateau — while releasing tagged toothfish across all the main longlining fishing grounds. The target number of grid squares was set by accounting for steaming time between sampling stations and allowing a few days of commercial fishing during the research cruise, as requested by CFL.

Two lines were scheduled to be set and hauled in each grid square. The exact setting location within grid squares was at the captain's discretion, but was requested to be as close as possible to those highlighted in the research proposal. This recommendation helped maximise the probability of setting lines in the targeted VME habitats.

The sampling design was adjusted slightly during the survey. Specifically, (1) one grid square (XWAN) located in the sea pen field was not sampled in order to increase sampling effort in other VME habitats; (2) a single line was set (and sampled) in grid square YDAR due to adverse weather conditions; (3) two lines were sampled in grid squares XQAT and XRAT¹, located in tagging areas 2 and 3, respectively; and (4) 3.5 days were allocated to commercial fishing (i.e., with lines only set with umbrellas) at the end of the survey in area 3, of which 3 days were used for tagging (Figure 1). Following these adjustments, VME taxa were sampled during 16 days and toothfish were tagged during 19 days, out of the 20 fishing days.

¹ The lower sampling effort in the grey area and in grid square YDAR - due to the reasons explained in (1) and (2) - combined with the favourable weather conditions from 9 November 2025 to the end of the research cruise, created an opportunity to sample two additional grid squares in areas 2 and/or 3. Grid squares XQAT and XRAT were selected using the same approach as that applied to the entire fishing area (spatial analysis of VME taxa bycatch rates recorded since January 2012), but restricted to areas 2 and 3.

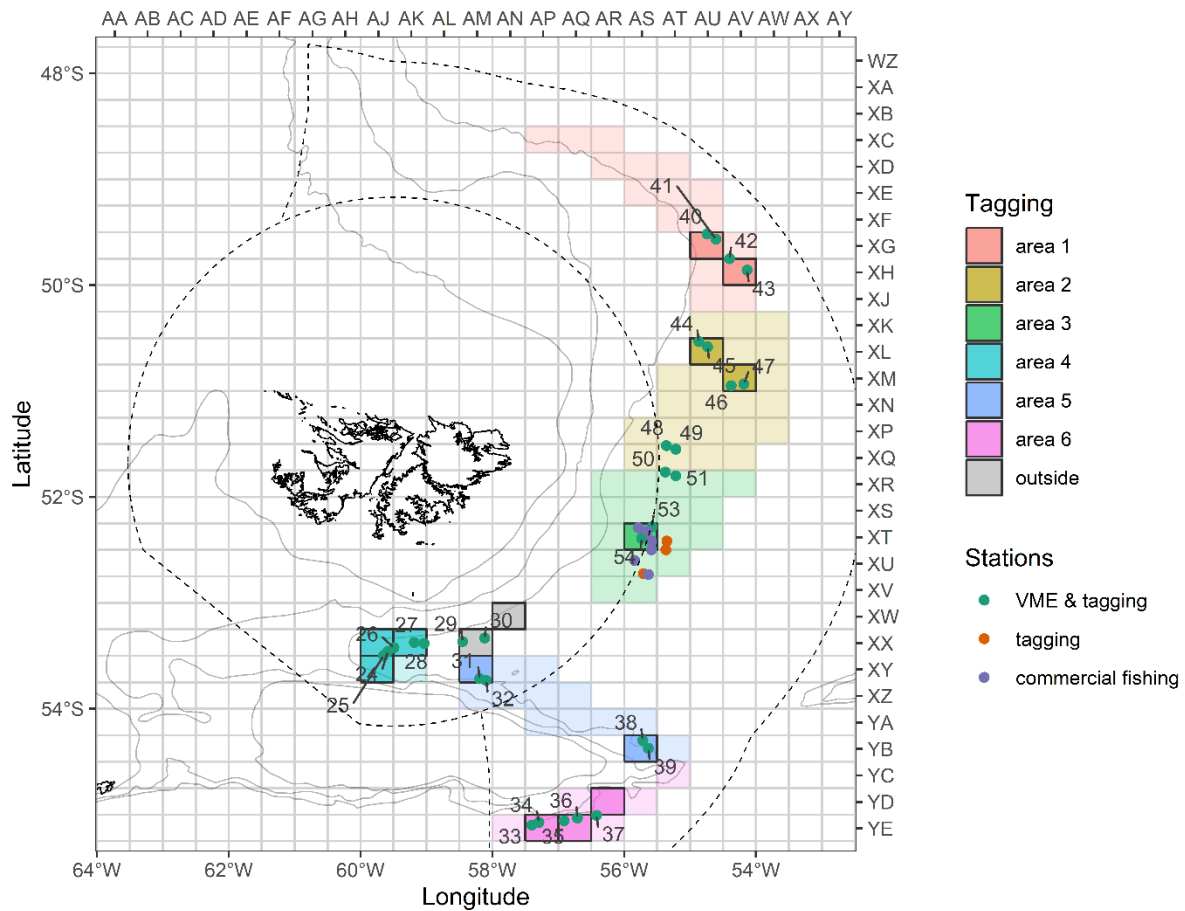


Figure 1. Location of the 15 grid squares selected for sampling VME habitats. Shaded polygons represent the six tagging areas defined based on the analysis of fishing effort over the last 5 years. Green dots represent VME stations where lines were set with alternating sections of 40 clusters of hooks with and without umbrellas; the last two digits of each VME station's number are shown on the map (Table 2). Tagging occurred at all the VME stations except stations 2127, 2128, 2130, 2133, 2138, and 2139 (Table 2). Orange and purple dots represent commercial lines fully set with umbrellas, with tagging conducted only at the orange stations.

Two lines per day were generally hauled during daylight hours: one in the morning (starting around 6:30-07:00) and one in the afternoon (starting around 13:00-14:00). No additional line which could have disrupted this schedule was set. The lines were set at night, where practicable, to minimise seabird interactions as specified in the licence conditions. This recommendation was particularly important during the survey because some line sections were set without umbrellas, potentially increasing seabird interactions. Due to the higher risk of seabird interactions and the absence of a Fisheries Observer onboard during the survey, all fishing operations were required to be recorded using the Electronic Monitoring system. The soak time, calculated as the difference between mid-set and mid-haul times, was requested to range between 7 and 12 h (i.e., 420 to 720 min).

To examine any difference in bycatch rates of VME indicator taxa with and without umbrellas, the line configuration followed the design shown in Figure 2, alternating sections with and sections without umbrellas. Each line contained 400 clusters of hooks, consisting of 10 sections of 40 clusters of hooks in total, 5 with umbrellas and 5 without. To evaluate any effect of section number on VME bycatch rates, some lines were hauled with umbrellas on the first section, whereas others were hauled without. The configuration of each line at setting and hauling were recorded at the bridge in the logbook by marking a “C” (for cachaloteras = umbrellas) next to the section number (“marca”) of any section equipped with umbrellas. This particular setting has been registered by the Activity_Code “W” and activity “U_V_ALTERNATED_LL” in the FIFD database “observer-sql2003.accdb” (i.e. “ObsDta”) and by the EffortType “UMNUM_11” in the “Catch Reporting_AB.accdb” (i.e. “fishdev”) database.

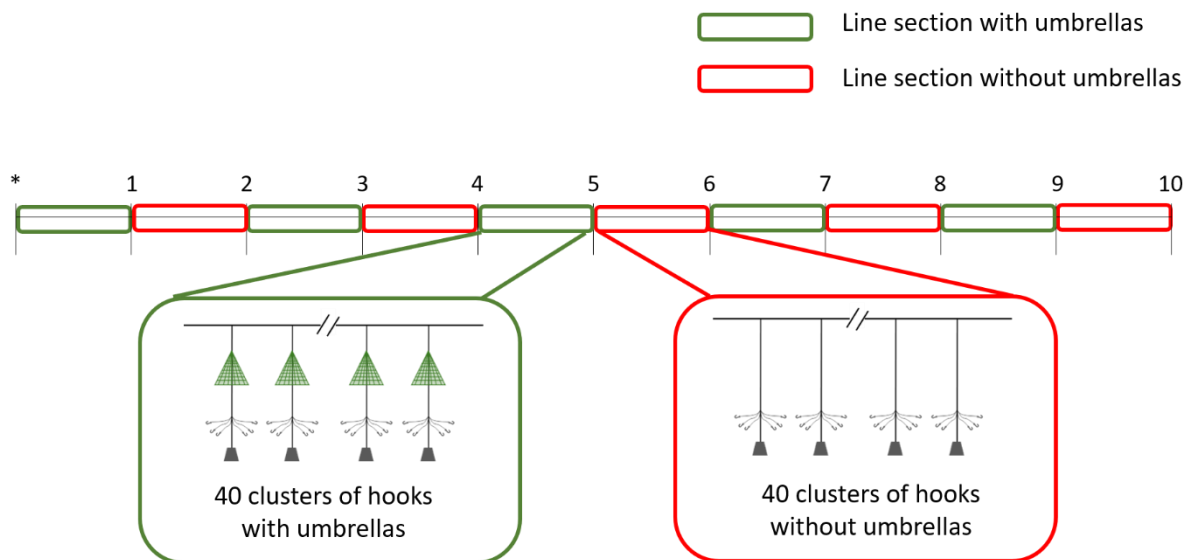


Figure 2. Line configuration showing alternating sections of 40 clusters of hooks with umbrellas and 40 clusters of hooks without umbrellas.

The percentage of tagging effort allocated to each area was calculated according to the fishing effort in the last 5 years over the 6 main fishing areas. We planned to tag approximately 1,040 toothfish per year (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 2025, we allocated an approximate number of toothfish to be tagged per area during the survey (Figure 1, Table 1).

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

Area	Number of toothfish to be tagged
1	160
2	270
3	130
4	60
5	100
6	90
Total	810

2.2. VME and depredation analysis

All benthic invertebrates caught as bycatch were collected by crew members with the help of the scientists on the ‘umbrella cleaning table’ located in the dry section of the factory (Figure 3a). Benthic invertebrates were collected in a different basket for each line section. The scientists were responsible for ensuring that all benthic invertebrates caught by hooks and/or umbrellas were placed in the correct basket, and that the umbrella cleaning table and hauling bench (in the hauling bay) were cleaned of any remaining invertebrates between sections. The baskets used to collect the benthos were provided by CFL and labelled by the scientist to identify the section sampled (section number and configuration, i.e. with or without umbrella). The sampling station was set up in the wet factory on the observer’s bench (Figure 3b). For each section, benthic invertebrates were identified to the lowest possible taxonomic level using identification guides provided by FIFD, and weighted per taxon to the nearest g using a Marel M series 1100 scale. Benthic invertebrates were classified as VME indicator taxa following the CCAMLR VME Taxa Classification Guide (2023).

The number of depredated toothfish and the total number of toothfish caught were recorded per line section by the bridge officer. Depredation rates were calculated as the total number of depredated toothfish divided by the total number of toothfish caught per configuration (with vs without umbrellas) per line. As depredation can occur but remain unnoticed when whales remove the entire body of the fish (cryptic depredation), toothfish catch rates (number of fish per line section) were also calculated and compared with and without umbrellas.

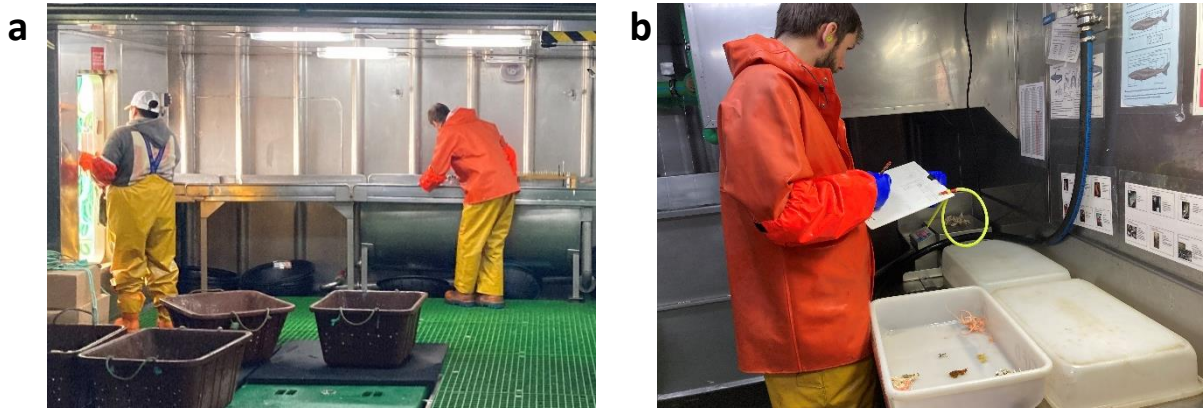


Figure 3. (a) Benthos collection area on the 'umbrella cleaning table' located in the dry section of the factory. The black baskets used to collect the benthos are visible under the cleaning table. (b) The benthos sampling station in the wet factory. The Marel M-Series 1100 scale can be seen in the background of the photo.

2.3. 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 3 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 4). The tag holding board was prepared in advance, typically the night before, with tags arranged in ascending order to streamline the tagging process.

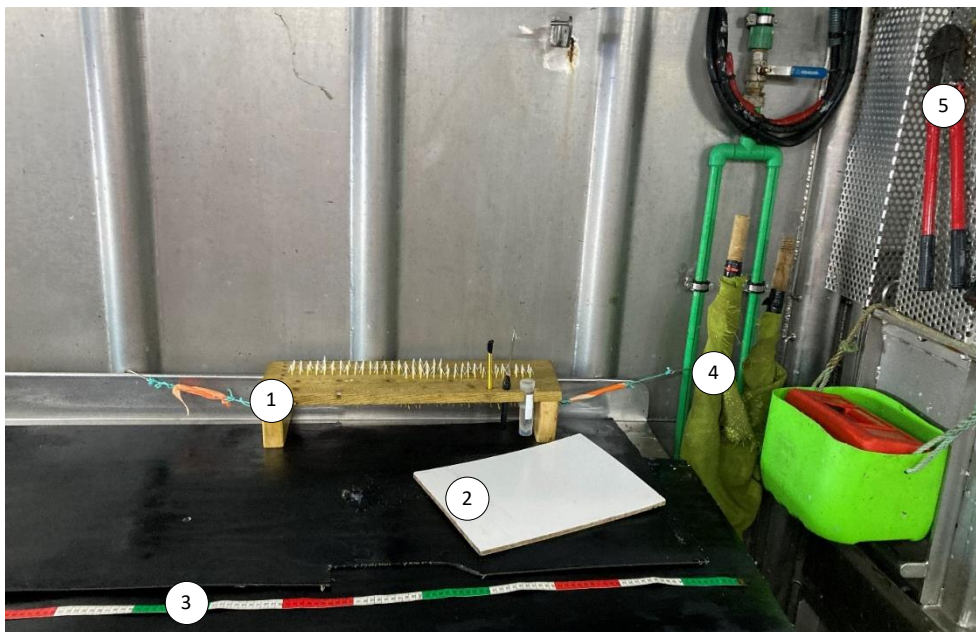


Figure 4. Set up of the tagging station with (1) the tagging board holding the tags, a pencil, the tagging applicator, and the vial filled with 70% ethanol for disinfection, (2) a scribing board, (3) the measuring tape, (4) the stretcher to carry large tagged toothfish to the hauling bay for their releasing, 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 officer to determine if these predators were nearby. Tagging should not occur if sperm whales or orcas are 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.

A specific lifting procedure was implemented in 2025 to recover toothfish caught on line sections set without umbrellas. A landing net was used to handle the fish gently as they were brought into the hauling bay (Figure 5). This manoeuvre requires the help of at least two extra crew members in the hauling bay, and was thus not implemented during sampling days with adverse weather conditions for safety issues.

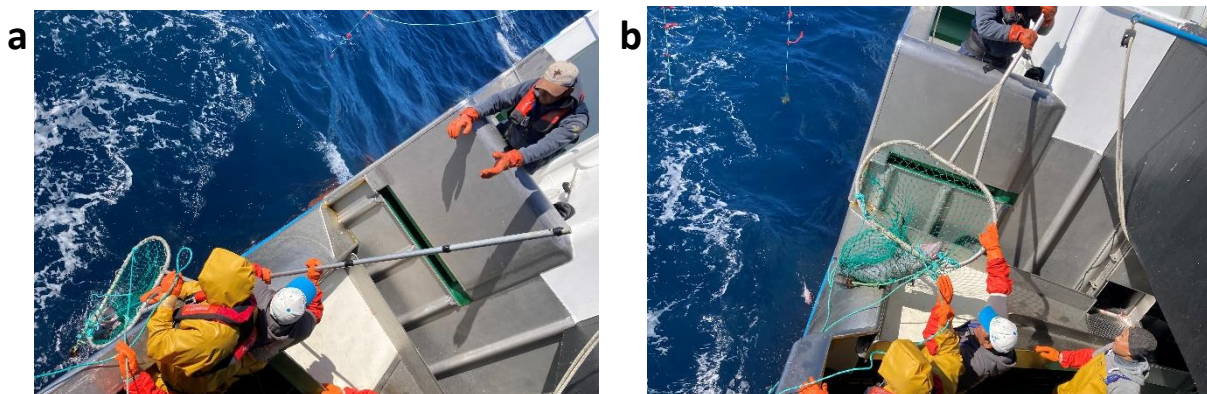


Figure 5. Use of a fish landing net to (a) retrieve the toothfish and (b) haul it in the hauling bay.

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 down) and tagged with one external FT-1-94 spaghetti Floy® dart tag (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 6). 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.

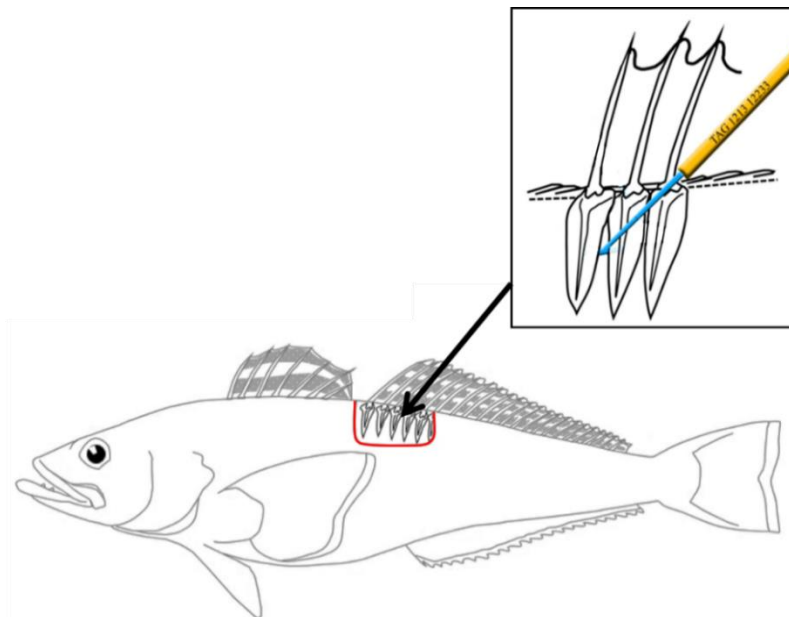


Figure 6. Tagging location between the 3rd and the 4th rays of the second dorsal fin locking the barb of the tag behind a pterygiophore. Modified from *Toothfish and skate tagging methods* (CCAMLR, 2013) (image credit: Alan Hart).

Based on previous tagging research surveys and the annual number of toothfish tagged by the Fisheries Observers, we planned to tag between 800 and 900 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, 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 whales and orcas around the vessel. At the bridge, the time at the end of each section along with the number of toothfish caught during the section were routinely recorded on the logbook. These data are used for two main purposes: (1) to calculate the percentage of the line monitored by the scientist, which includes 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. A particularity of this tagging survey was that no routine Fisheries Observer protocols were performed during the survey. To test the tag-overlap of sampled and tagged toothfish, we used the length-frequency of Patagonian toothfish sampled in 2025 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 .

2.4. Sleeper shark sampling protocol

All sleeper sharks caught during the survey that were small enough to be brought on board were sampled following a three-step protocol: (1) tissue sampling, (2) photo collection, and (3) morphological measurements and sex determination.

The most critical step of the protocol is the collection of tissue for genetic analysis. All tools (e.g., scissors) used for sampling were disinfected with 70% ethanol prior to use. A small piece of tissue (0.5-1.0 cm³) from the pelvic fin was carefully cut with sanitized scissors and placed into a vial. The vial was then filled with 96% ethanol at a minimum volumetric ratio of 5:1 (ethanol:tissue). A waterproof label indicating the sample ID (station number plus species code, e.g., '1863SOM') was placed inside the vial. Caps were securely closed and sealed with Parafilm to prevent any leakage. Following this, the scissors were cleaned three times with tap water and subsequently disinfected with 70% ethanol. The 96% ethanol in each vial was replaced with fresh 96% ethanol 48 hours after sampling.

For each individual, a photo of the following body parts was taken: the whole individual (photo #1), the pre-dorsal fin area (from the snout tip to the first dorsal fin, photo #2), the inter-dorsal area (including the first and second dorsal fins, photo #3), and the pelvic fin area (photo #4) (Figure 7).

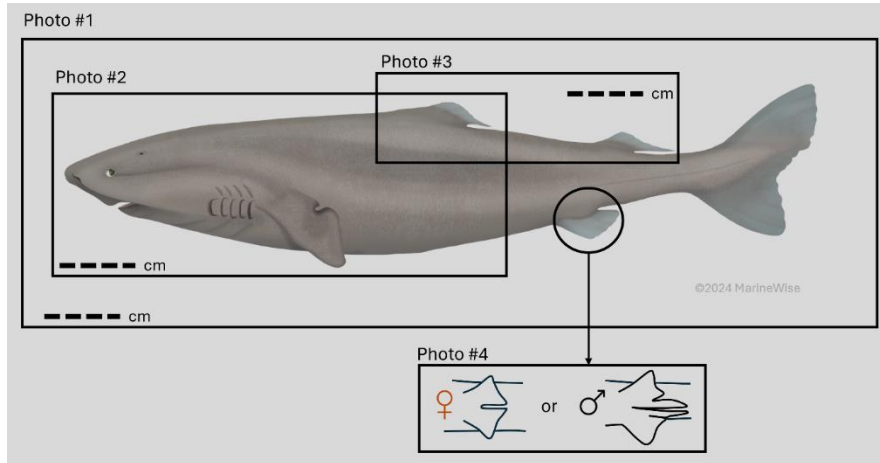


Figure 7. Photo collection protocol. Black rectangles delimit the body parts that must be visible in each photo. Shark image credit: [MarineWise](#).

The following data were recorded for each sampled shark: sex, total weight (to the nearest 100 g), total length (TL), fork length (FL), upper precaudal length (UPCL), predorsal fin length (PDFL), interdorsal length (IDL), prebranchial length (PBL), height of the first dorsal fin (DFH1), and height of the second dorsal fin (DFH2) (Figure 8). All lengths were expressed in cm and rounded to the nearest mm (e.g., TL = 224.6 cm).

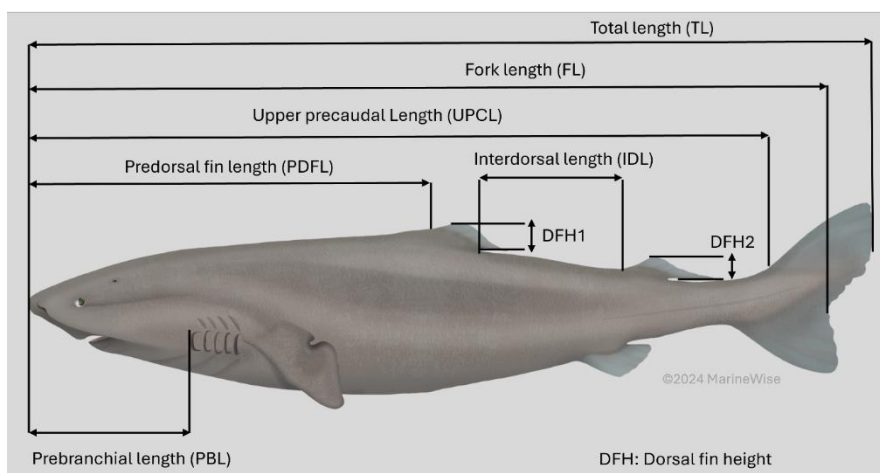


Figure 8. Morphological measurements of sleeper sharks. Shark image credit: [MarineWise](#).

2.5. Grenadiers sampling protocol

Grenadiers were sampled to (1) assess the proportion of *Macrourus holotrachys* and *Macrourus carinatus* in the grenadier catches and (2) collect specimens representative of the length distribution of each population. For the first objective, the first 50 grenadiers were sampled every day and identified to the species level using the criteria highlighted in the FFD longliner grenadier identification guide. After the random sampling, the bycatch basket was monitored to collect any *M. carinatus* to meet the second objective.

3. Results

3.1. Cruise itinerary and sampling design

A total of 39 lines were deployed during the survey with station numbers ranging from 2124 to 2162, and line numbers from 3853 to 3891. All but one of the first 31 lines (station 2152) were set up according to the required line configuration – alternating sections with and without umbrellas for a total of 400 clusters of hooks – and were sampled for VME analysis (stations 2124 to 2154, except 2152). VME taxa were not sampled at station 2152, where the line was set with and without umbrellas but included 500 clusters of hooks. Lines deployed at stations 2155 to 2162 were set up for commercial fishing (500 clusters of hooks with umbrellas). Tagging was conducted on a total of 27 stations, including 24 lines set up for VME analysis and 3 for commercial fishing (Table 2). Six lines were hauled only for commercial purpose (stations: 2152, 2155, 2157, 2158, 2161, and 2162).

The *CFL Hunter* (ZDLK3) departed from Stanley on October 26, 2025 and steamed south to first sample sea pen fields located in the Falkland Trough (stations 2124-2130, Figure 1). Lines were then deployed on the slopes of Burdwood Bank (stations 2131-2139) and on the Falkland Plateau (stations 2140-2154) to sample cold-water coral assemblages. The first lines were set in area 4 (stations 2124-2128), before moving to the 'grey' area on October 30, 2025 (stations 2129 and 2130), and to the northern part of area 5 on October 31, 2025 (stations 2131 and 2132) (Figure 1, Table 2). The *CFL Hunter* then steamed to area 6 and set lines at stations 2133 to 2137 between November 1 and 3, 2025, before moving to the southeastern part of area 5 on November 4, 2025 (stations 2138 and 2139). November 5, 2025 was allocated to steaming from station 2139 to the northernmost station (2140; Figure 1, Table 2). Lines were then set in area 1 (stations 2140-2143), in area 2 (stations 2144-2149) and in area 3 (stations 2150-2154). From station 2155 to 2162, lines were fully equipped with umbrellas for commercial fishing. Tagging was conducted on stations 2156, 2159, and 2160 in area 3 (Figure 1, Table 2).

Between October 27 and November 12, two lines were hauled per day and per grid square, except in grid squares XYAJ and YDAR where only one station was set and hauled (Figure 1, Table 2).

Table 2. Characteristics of the tagging stations: area, date, station number, time at haul start, station depth (mean and standard deviation), soak time, and sampling type. 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	Sampling
1	06/11/2025	2141	06:31	1175 ± 47	09:23	VME/tagging
	06/11/2025	2140	12:37	1147 ± 18	16:55	VME/tagging
	07/11/2025	2143	06:14	1366 ± 36	10:58	VME/tagging
	07/11/2025	2142	12:52	1270 ± 29	19:08	VME/tagging
2	08/11/2025	2145	07:14	1325 ± 6	08:05	VME/tagging
	08/11/2025	2144	13:12	1254 ± 122	15:23	VME/tagging
	09/11/2025	2147	05:45	1553 ± 11	09:17	VME/tagging
	09/11/2025	2146	12:28	1486 ± 76	16:48	VME/tagging
	10/11/2025	2149	09:27	1256 ± 23	08:43	VME/tagging
	10/11/2025	2148	14:56	1215 ± 35	14:58	VME/tagging
3	11/11/2025	2151	05:08	1305 ± 40	09:11	VME/tagging
	11/11/2025	2150	11:00	1246 ± 37	15:58	VME/tagging
	12/11/2025	2153	06:40	1384 ± 36	12:20	VME/tagging
	12/11/2025	2154	12:54	1398 ± 18	10:39	VME/tagging
	13/11/2025	2156	08:33	1562 ± 6	15:08	tagging
	14/11/2025	2159	15:06	1600 ± 7	17:46	tagging
	15/11/2025	2160	09:30	1672 ± 40	24:34	tagging
grey	30/10/2025	2129	07:17	1546 ± 168	11:09	VME/tagging
	30/10/2025	2130	15:12	1600 ± 142	12:32	VME
4	27/10/2025	2124	14:45	1508 ± 73	07:19	VME/tagging
	28/10/2025	2125	07:10	1382 ± 27	11:17	VME/tagging
	28/10/2025	2126	14:54	1410 ± 57	11:53	VME/tagging
	29/10/2025	2127	07:10	1360 ± 146	10:23	VME
	29/10/2025	2128	13:35	1414 ± 194	10:41	VME
	5	31/10/2025	2131	07:19	1388 ± 175	10:26
31/10/2025		2132	13:57	1292 ± 662	11:37	VME/tagging
04/11/2025		2139	07:47	1220 ± 170	11:20	VME
04/11/2025		2138	13:49	1344 ± 277	21:25	VME
6	01/11/2025	2134	09:53	1227 ± 109	07:02	VME/tagging
	01/11/2025	2133	16:05	1680 ± 43	14:31	VME
	02/11/2025	2136	07:10	1712 ± 53	09:30	VME/tagging
	02/11/2025	2135	13:48	1424 ± 104	17:13	VME/tagging
	03/11/2025	2137	07:54	1330 ± 383	12:10	VME/tagging

The average depth of the sampled stations was 1396 ± 192 m (min depth = 824 m and max depth = 1760 m; Table 2). Soak times across the sampled stations ranged from 7:01 to 24:34 h (corresponding to 421 – 1474 min; Table 2). The average soak time across the sampled stations was $12:05 \pm 4:07$ h (mean \pm standard deviation; corresponding to 725 ± 247 min; Table 2), and across the stations following the sampling protocol was $12:16 \pm 3:33$ h (mean \pm standard deviation; corresponding to 736 ± 213 min; Table 2).

3.2. Influence of umbrellas on VME bycatch and depredation rates

3.2.1. VME bycatch

VME indicator taxa were caught as bycatch at all 30 VME stations sampled during the survey, on both line sections set with and without umbrellas (Figures 9, 10). In total, 36 VME taxa were identified (Figure 11), representing 15 taxonomic groups (Figure 12). Hydrocorals (Stylasteridae) were the most frequently encountered group, occurring on 50% of all line sections, followed by gorgonians (Gorgonacea, 31%), basket and snake stars (Euryalida, 27%), stony corals (Scleractinia, 23%), sponges (Porifera, 21%), and sea pens (Pennatulacea, 19%). All other VME groups were encountered less frequently (<15%, Figure 12). At least one VME taxon was observed on 85% of line sections with umbrellas and 72% of those without.

Exploratory data analysis indicates that VME bycatch rates were more variable — and on average higher — on line sections equipped with umbrellas (Figure 13). However, the magnitude (and direction) of the umbrella effect appears to vary across sampling areas and VME groups (Figures 13, 14).

Statistical analyses that account for relevant covariates (e.g., sampling area, soak time) and spatiotemporal autocorrelation will be required to fully assess the umbrella effect on VME bycatch rates. These analyses will be presented in a separate report.



Figure 9. VME indicator taxa entangled in an umbrella (a) and hooked on a section without umbrellas (b). Taxon IDs from the FIFD database are indicated in brackets. (a.1) *Austrocidaris canaliculata* [AUC]; (a.2) *Bathelia candida* [BCD]; (b) *Stylaster densicaulis* [SSD].

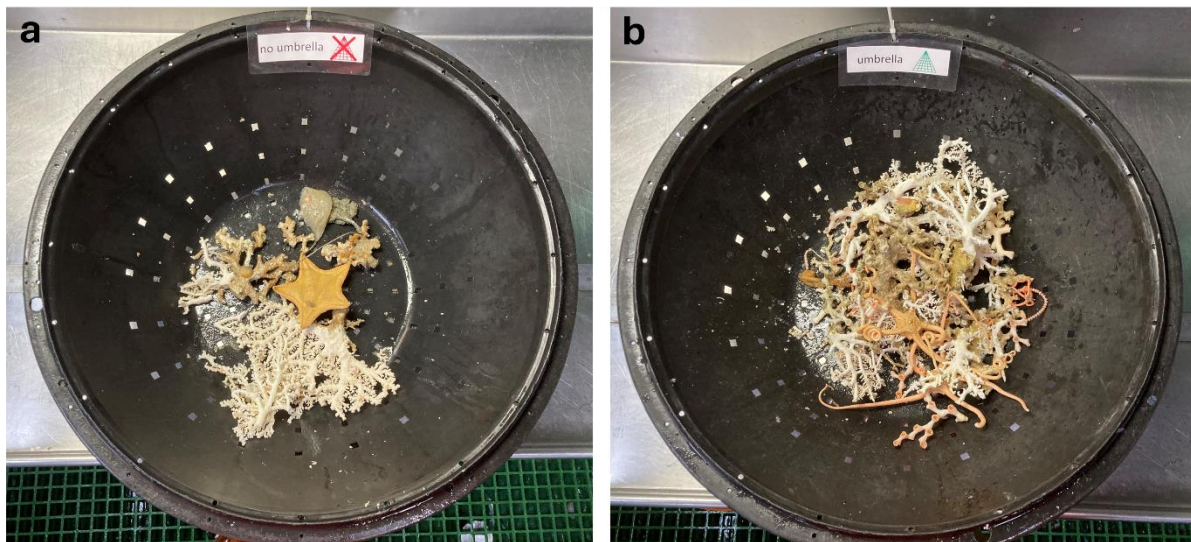


Figure 10. Total benthic invertebrate bycatch from two consecutive line sections set (a) without and (b) with umbrellas at station 2140. The VME bycatch rate on the section without umbrellas (section 7; 629 g per section, all taxa combined; photo a) was three times lower than that on the subsequent section with umbrellas (section 8; 1876 g per section; photo b), but 1.6 times higher than that on the previous section with umbrellas (section 6; 395 g per section; not shown). Note that baskets were labelled according to the line configuration of each section.

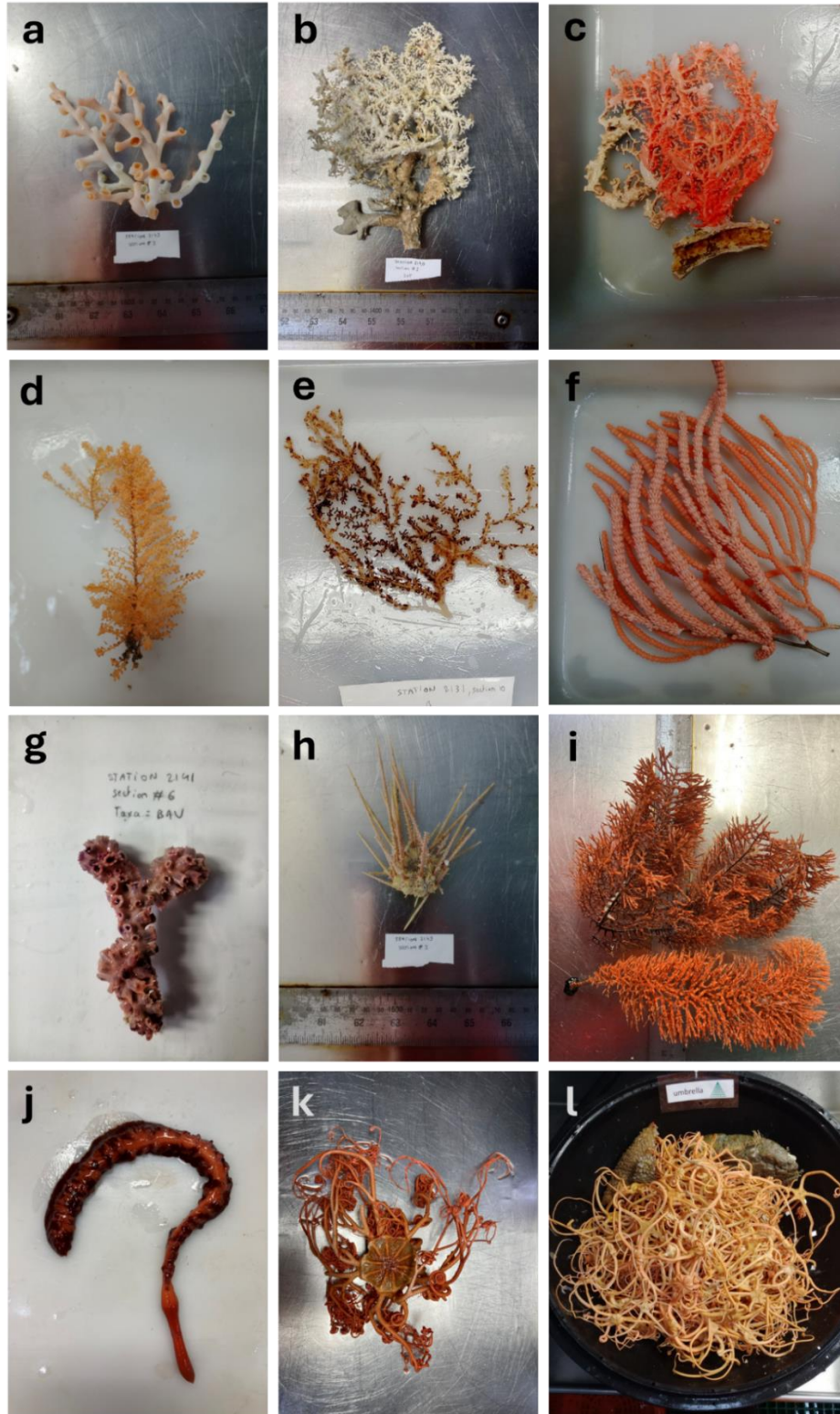


Figure 11. Examples of VME indicator taxa caught as bycatch during the survey. Taxon IDs from the FIFD database are indicated in brackets. (a) *Bathelia candida* [BCD]; (b) Stylasteridae [SST]; (c) Another stylasterid species, possibly *Erina* sp. [ERR]; (d) *Thouarella* sp. [THO]; (e) Isidiidae [ISI]; (f) Primnoidae [PLB]; (g) *Bayergorgia vermidoma* [BAV]; (h) *Austrocidaris canaliculata* [AUC]; (i) *Dendrobathypathes* sp. [DEG]; (j) *Anthoptilum grandiflorum* [ANG]; (k) *Gorgonocephalus* sp. [BSK]; (l) a basket full of snake stars *Astrotoma agassizii* [ASA].

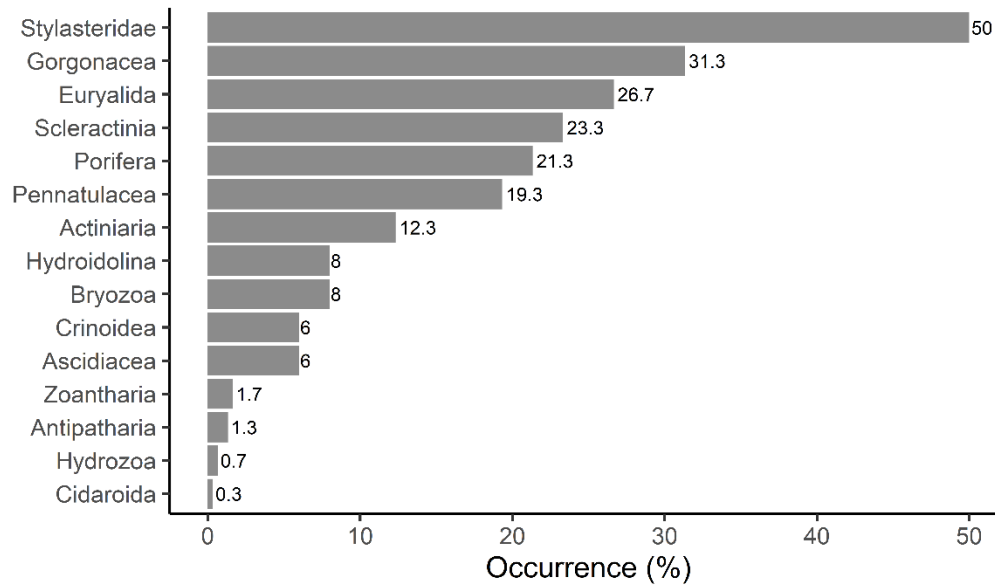


Figure 12. Occurrence of VME taxonomic groups encountered on the 300 line sections (150 with and 150 without umbrellas) sampled during the survey.

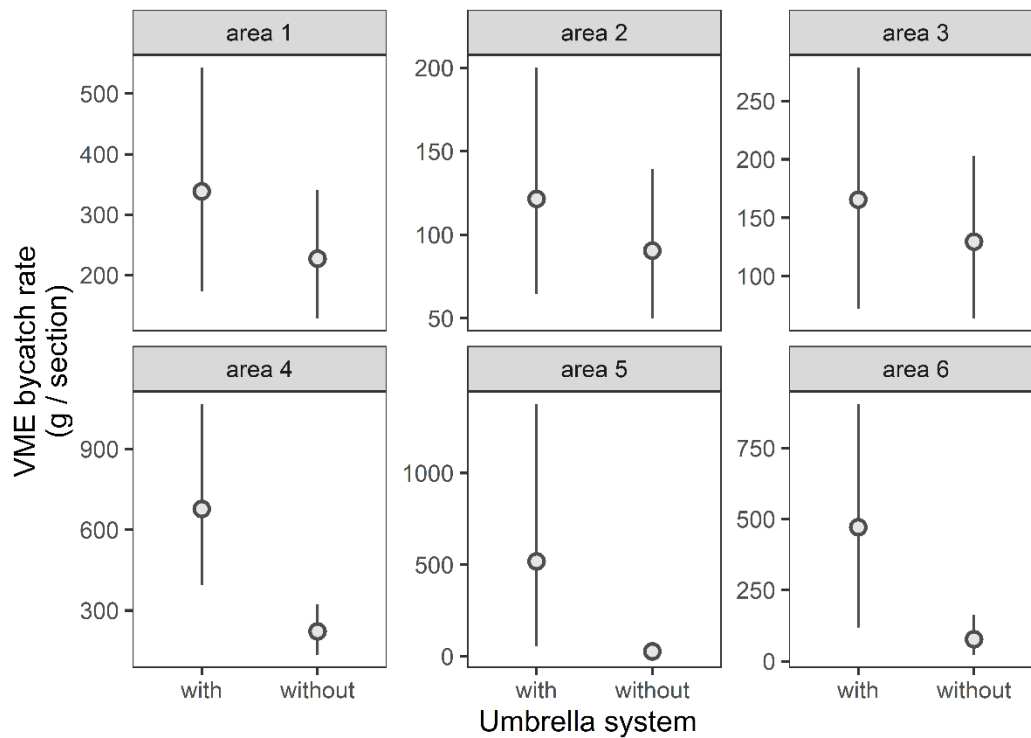


Figure 13. Mean VME bycatch rates (g per line section, all taxa combined) with and without umbrellas across the six areas sampled during the survey. Vertical bars represent 95% confidence intervals estimated via non-parametric bootstrap resampling. Note that the y-axis scale differs among panels.

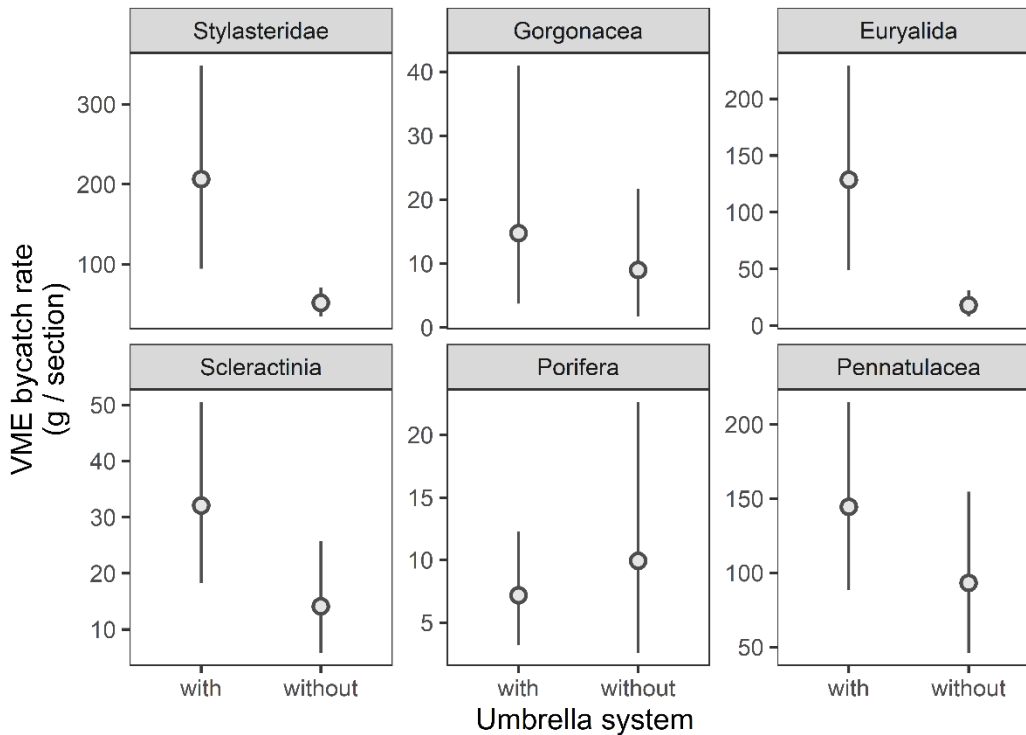


Figure 14. Mean bycatch rates (g per line section) with and without umbrellas for the 6 most common VME groups. Vertical bars represent 95% confidence intervals estimated via non-parametric bootstrap resampling. Note that the y-axis scale differs among panels. Stylasteridae: hydrocorals; Gorgonacea: gorgonians; Euryalida: basket and snake stars; Scleractinia: stony corals; Porifera: sponges; Pennatulacea: sea pens.

3.2.2. Depredation rates and whale sightings

A few depredated toothfish were recorded at six of the 30 VME stations, mainly on the line sections set without umbrellas (Table 3). At stations 2138 and 2139, sperm whales were observed around the vessel throughout hauling, whereas no whales were seen at the other four stations. Depredation rates² without umbrellas reached 28.6% and 33.3% at stations 2138 and 2139, respectively, but remained between 0% and 3.9% at the other four stations. In contrast, depredation rates with umbrellas were below 2.5% at all six stations. No depredated fish were recorded at all remaining stations, including stations 2128 and 2142 where sperm whales were sighted.

Toothfish catch rates³ with umbrellas were, on average, five times higher than those without at stations 2138 and 2139 (Figure 15). In contrast, catch rates with umbrellas were only marginally higher (1.0–1.4×) at the four other stations where depredated fish were recorded but no whales were sighted

² calculated as the total number of depredated toothfish divided by the total number of toothfish caught per configuration (with vs without umbrellas) per line. See Materials and methods for details.

³ number of fish per line section.

(Figure 15). These patterns suggest that cryptic depredation occurred on line sections without umbrellas when sperm whales remained around the vessel throughout hauling. This interpretation is supported by the observation that umbrellas do not appear to influence toothfish catch in the absence of depredation (Figure 16), although this needs to be confirmed using adequate statistical analyses (e.g., generalised linear mixed models).

Table 3. Number of depredated toothfish per station and line section. Only stations and line sections with recorded depredated fish are included.

Date	Station	Line section #	Umbrellas	Nb of depredated toothfish	Whale sightings
01/11/2025	2133	6	with	1	no
02/11/2025	2136	2	with	1	no
04/11/2025	2138	3	without	1	yes
04/11/2025	2138	5	without	2	yes
04/11/2025	2138	7	without	1	yes
04/11/2025	2139	1	without	2	yes
04/11/2025	2139	3	without	1	yes
08/11/2025	2144	7	without	1	no
08/11/2025	2144	9	without	1	no
11/11/2025	2150	5	without	1	no
11/11/2025	2150	7	without	1	no

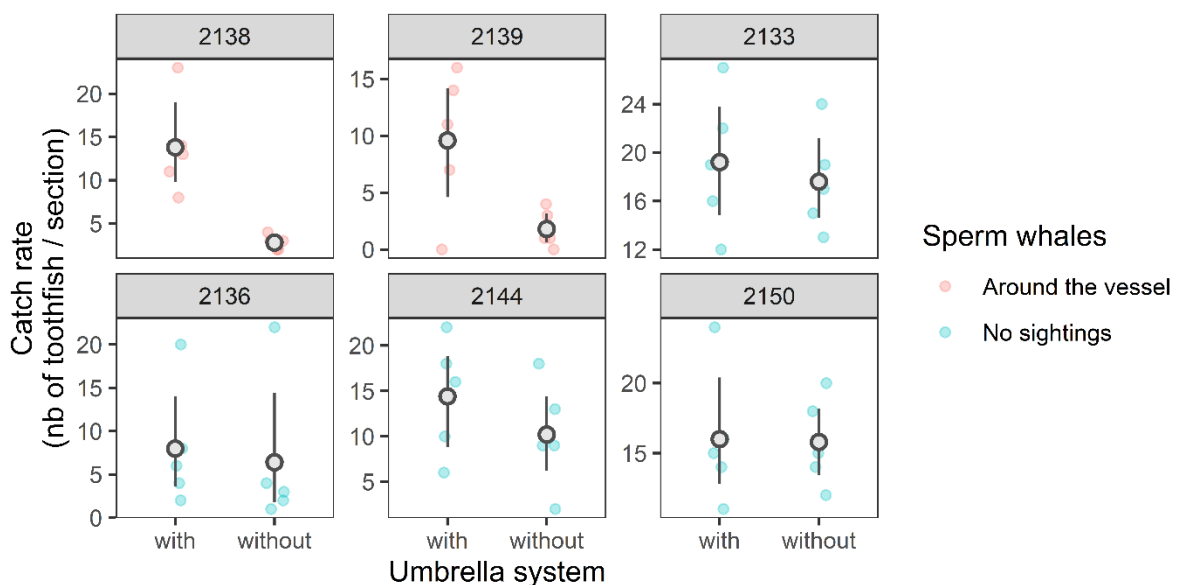


Figure 15. Toothfish catch rates (number of fish per line section) with and without umbrellas at the six stations where depredated fish were recorded. Grey dots denote mean catch rates, while vertical bars represent 95% confidence intervals estimated via non-parametric bootstrap resampling. Coloured dots represent raw data, which were horizontally jittered for clarity. Note that the y-axis scale differs among panels.

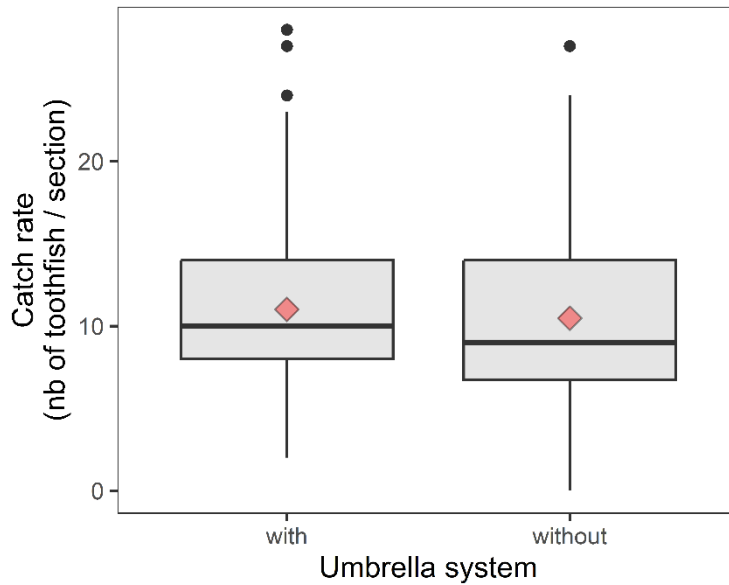


Figure 16. Toothfish catch rates (number of fish per line section) with and without umbrellas. Stations with recorded depredation (n = 6) were excluded. Red diamonds represent the mean.

3.3. Toothfish tagging

Tagging was conducted at 27 stations: 4 in area 1, 6 in area 2, 7 in area 3, 1 in the 'grey' area, 3 in area 4, 2 in area 5, and 4 in area 6 (Figure 1, Table 4). A total of 626 toothfish were tagged (tag numbers [9265-9890]). We tagged 1 line per day for 7 days and 2 lines per day for 10 days (Table 4). 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 4). 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 could be lower for the second daily lines compared to the first (Table 4). Tagging was occasionally interrupted for sampling sleeper sharks, during lunch breaks, or because of the presence of sperm whales around the vessel. Due to rough weather conditions, tagging at stations 2135, 2136, and 2137 was conducted only during umbrella sections for safety reasons, to avoid requiring the crew to use the landing net to retrieve the fish.

Table 4. 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, standard deviation, and range) by station. The percentage of the line monitored by the scientist was calculated in terms of time spent tagging and waiting for suitable toothfish to tag. The percentage of tagged fish was calculated from the number of toothfish caught on the monitored portion of the line. Stations are sorted by area and haul date. Tagging was stopped at the stations (*) 2142 and 2160 because of the presence of sperm whales in the vicinity of the vessel.

Area	Date	Station	Percentage of line monitored	Percentage of tagged fish	Number of tagged fish	Total length (mean \pm sd)	Total length range
1	06/11/2025	2141	100	39	33	98 \pm 17	47 - 136
	06/11/2025	2140	100	28	37	97 \pm 15	54 - 131
	07/11/2025	2143	100	28	25	98 \pm 11	75 - 118
	07/11/2025	2142*	46	20	12	101 \pm 14	86 - 139
2	08/11/2025	2145	100	41	33	91 \pm 11	66 - 113
	08/11/2025	2144	100	24	29	104 \pm 17	76 - 136
	09/11/2025	2147	100	41	14	108 \pm 18	81 - 132
	09/11/2025	2146	100	11	9	119 \pm 15	103 - 143
	10/11/2025	2149	100	32	24	92 \pm 14	72 - 131
	10/11/2025	2148	100	26	32	101 \pm 17	70 - 161
3	11/11/2025	2151	100	22	30	97 \pm 14	75 - 127
	11/11/2025	2150	100	21	34	134 \pm 154	70 - 999
	12/11/2025	2153	100	25	21	99 \pm 16	65 - 153
	12/11/2025	2154	100	19	11	102 \pm 14	86 - 130
	13/11/2025	2156	100	9	14	106 \pm 10	89 - 129
	14/11/2025	2159	62	22	14	103 \pm 18	64 - 139
	15/11/2025	2160*	39	18	7	100 \pm 10	89 - 117
grey	30/10/2025	2129	100	31	50	97 \pm 9	76 - 117
4	27/10/2025	2124	100	28	28	104 \pm 14	73 - 133
	28/10/2025	2125	70	36	38	103 \pm 11	81 - 134
	28/10/2025	2126	33	27	12	95 \pm 16	75 - 120
5	31/10/2025	2131	100	30	25	100 \pm 13	72 - 130
	31/10/2025	2132	66	25	25	110 \pm 23	75 - 164
6	01/11/2025	2134	82	28	29	90 \pm 13	68 - 121
	02/11/2025	2136	48	14	10	123 \pm 17	88 - 143
	02/11/2025	2135	48	6	9	104 \pm 17	82 - 133
	03/11/2025	2137	49	16	21	97 \pm 17	72 - 132

At stations 2142 and 2160, tagging was stopped because two sperm whales were sighted near the vessel (Figure 1, Table 4). We did not tag at stations 2138 and 2139 because three sperm whales remained around the vessel for the entire day (Figure 1, Table 4).

A total of 626 toothfish were tagged during the research cruise, weighing a combined total of 6,754 kg. This represents 23.87% of the total toothfish catch during the tagging time by number. The breakdown of tagged toothfish by area was as follows: 107 in area 1, 142 in area 2, 130 in area 3, 50 in the grey area, 78 in area 4, 50 in area 5, and 69 in area 6 (Table 4). The number of tagged toothfish varied from 7 to 70 per day, with an average of 37 ± 20 individuals. The actual numbers tagged matched the expected (allocated) numbers only in areas 3 and 4 (Table 5).

Table 5. Number of tagged toothfish allocated to each area for the tagging survey, and actually realised.

Area	Number of tagged toothfish	
	Allocated	Realised
1	160	107
2	270	142
3	130	130
grey	-	50
4	60	78
5	100	50
6	90	69
Total	810	626

The total length of tagged toothfish during the research cruise ranged from 47 to 167 cm (mean TL \pm sd: 100 ± 16.1 cm) (Table 4, Figure 17a), and the total length of sampled fish in 2025 (i.e. sampled for length-frequency and otoliths) ranged from 59 to 200 cm (mean TL \pm sd: 107 ± 21.5 cm) (Figure 17b). The total length of the toothfish tagged with tag 9814 was recorded as 999 cm in the database because the length was not reported on the scribing board at tagging.

The tag-overlap statistic (CCAMLR, 2022) showed a 91.35% overlap between the length frequencies of toothfish sampled between January and November 2025 and tagged during the research cruise ZDLK3-10-2025. The larger fish, with a total length above 150 cm, were rarely selected for tagging due to the risk of spinal damage when lifted on board without proper support (Figure 17a).

The mean length of toothfish tagged in areas 3, 4, and 5 was larger than in the areas 1 and 2 (north), and 6 (south) (Figures 1, 17). However, the mean length of tagged toothfish was not significantly different between areas (ANOVA, p-value = 0.0732).

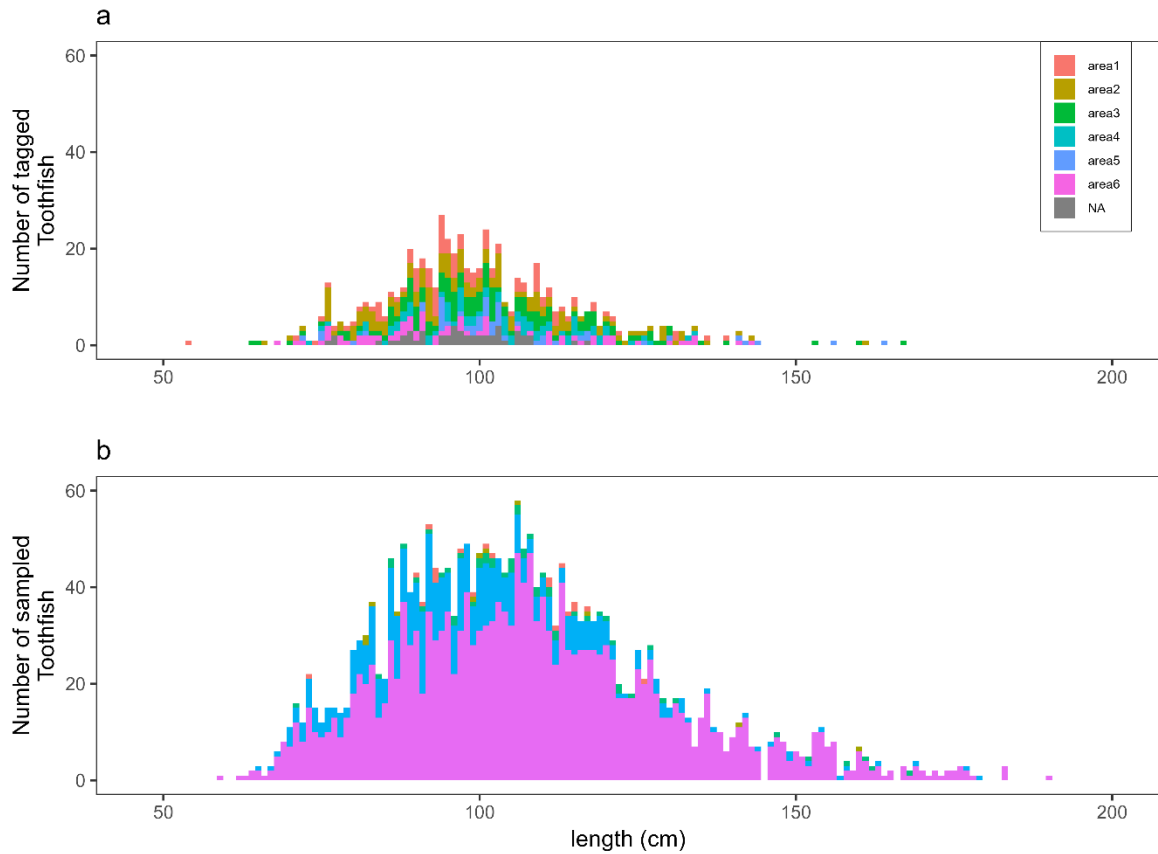


Figure 17. Cumulative length-frequency partitioned by area of (a) tagged during the research cruise ZDLK3-10-2025 and (b) sampled toothfish in 2025 between January and November. Sampled toothfish comprised random and sub-sample toothfish collected for length-frequency and otoliths.

3.4. Sleeper shark

Opportunistic sampling of sleeper sharks occurred whenever one was caught and brought onboard. Among the six sleeper sharks caught during the survey, four were sampled. One female and one male sleeper sharks were caught in area 3, and two males in area 6 (Figure 18). All the individuals were immature. Female total length was 178 cm, and male total lengths were 138, 156, and 198 cm (mean $TL \pm sd$: 164 ± 30.5 cm).

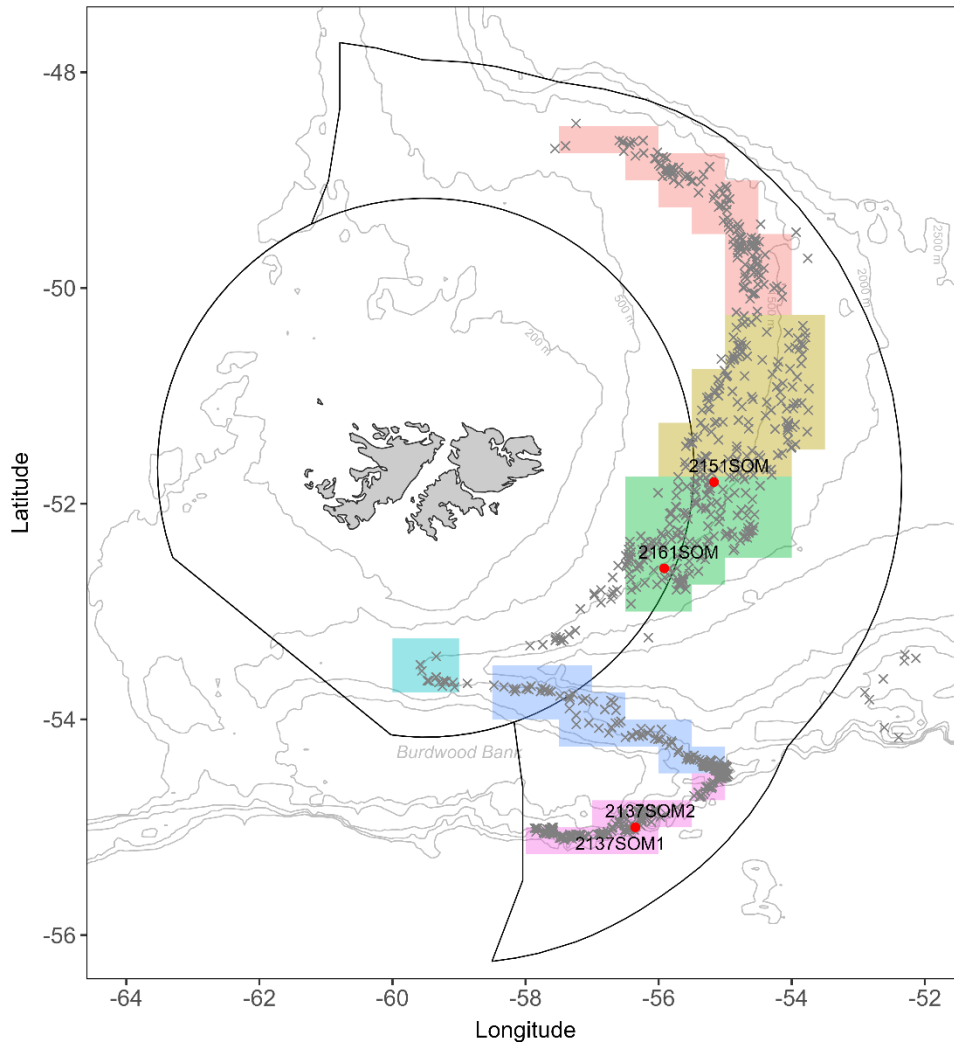


Figure 18. Location of the sleeper sharks caught as bycatch in the toothfish longline fishery since 2008 (grey crosses) and the four sleeper sharks sampled during the research cruise (red dots). Shaded polygons represent the six toothfish tagging areas. Note that two sleeper sharks were caught on the same line at station 2137.

3.5. Grenadier sampling

Grenadiers were sampled at 21 stations during 19 sampling days. The breakdown of grenadiers sampled randomly by area was as follows: 105 in area 1 (104 *M. holotrachys* and 1 *M. carinatus*), 152 in area 2 (151 *M. holotrachys* and 1 *M. carinatus*), 250 in area 3 (249 *M. holotrachys* and 1 *M. carinatus*), 50 in the grey area (50 *M. holotrachys*), 129 in area 4 (127 *M. holotrachys* and 2 *M. carinatus*), 159 in area 5 (150 *M. holotrachys* and 9 *M. carinatus*), and 150 in area 6 (148 *M. holotrachys* and 2 *M. carinatus*) (Table 6, Figure 19).

Table 6. Number of *M. holotrachys* and *M. carinatus* randomly sampled by area to assess the proportion of *M. carinatus* in the catches.

Area	Number of <i>M. holotrachys</i>	Number of <i>M. carinatus</i>	Percentage of <i>M. carinatus</i>
Area 1	104	1	1.0
Area 2	151	1	0.7
Area 3	249	1	0.4
Grey area	50	0	0.0
Area 4	127	2	1.6
Area 5	150	9	5.7
Area 6	148	2	1.3
Total			Average
979		16	1.6

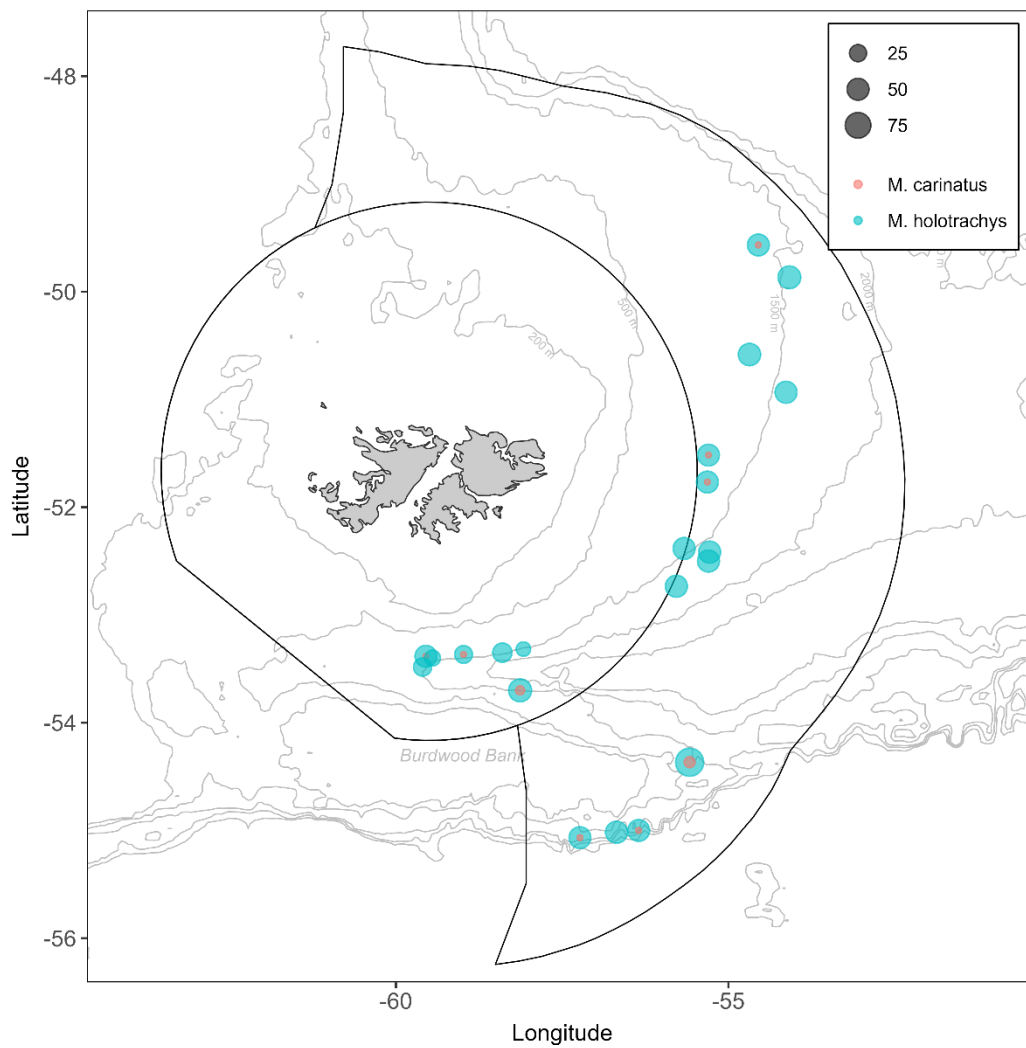


Figure 19. Numbers of *M. holotrachys* and *M. carinatus* randomly sampled at each station during the research cruise.

A total of 242 grenadiers were collected, including 197 *M. holotrachys* and 45 *M. carinatus*, to cover the length distribution of each species in the longline fishery. Anal length ranged from 16 to 33 cm for *M. holotrachys* and from 20 to 31 cm for *M. carinatus*. These grenadiers were frozen onboard to be processed on land by Aina Amukwaya for the project “Improving species identification and bycatch estimation of two morphologically similar grenadier species caught in the Patagonian toothfish longline fishery”. More detailed results based on the grenadiers sampled during this research cruise will be provided in the project report.

4. Discussion

During the ZDLK3-10-2025 research cruise, we successfully achieved the cruise objectives by collecting the data required to estimate VME bycatch rates and whale depredation rates associated with each line configuration (i.e., with and without umbrellas) in key VME habitats of Falkland Islands waters, including sea pen fields in the Falkland Trough and cold-water coral assemblages on the slopes of Burdwood Bank and the Falkland Plateau. We also tagged 626 toothfish with external spaghetti Floy® dart tags, averaging 37 fish tagged per day. Additionally, we sampled four sleeper sharks and 1024 grenadiers, among which 242 were frozen for further analysis on land.

Exploratory data analysis showed that differences in VME bycatch with and without umbrellas were more subtle than previously assumed and varied across habitats and taxonomic groups. These findings, together with the high depredation rates and the likely occurrence of cryptic depredation on line sections without umbrellas in the presence of sperm whales, suggest that removing umbrellas may not be a practical measure for reducing VME bycatch in the toothfish longline fishery. However, statistical analyses that account for relevant covariates and spatiotemporal autocorrelation are required before any firm conclusions can be drawn. It is also worth noting that sperm whales remained around the vessel during hauling for only two lines. Therefore, more data should be collected to provide robust estimates of depredation rates and cryptic mortality when lines are set without umbrellas.

Following recommendations from the tagging Cruise Report ZDLK3-10-2023 (Le Luherne and Peruzzo, 2023), the allocated percentage of tagged toothfish per area reflected the distribution of fishing effort of the last 5 years. However, the actual numbers tagged matched the allocated numbers only in areas 3 and 4, and the total number of tagged toothfish was lower than expected. The discrepancy between expected and realised numbers of tagged toothfish was mainly due to the sampling schedule, which was implemented to examine the impact of umbrellas on VME habitats. Tagging did not drive the choice of fishing locations and was thus conducted opportunistically, while still aiming to meet the tagging

objectives. Furthermore, tagged toothfish accounted for 23.87% of the total toothfish caught, lower than the 32.63% recorded during the 2024 tagging survey. This reduction may reflect differences in line-setting practices or other operational or environmental factors. Further analysis is required to identify the key parameters influencing toothfish suitability for tagging.

The average soak time of the lines set during the survey (736 ± 213 min, excluding commercial lines) was lower than last year (773 ± 240 min; Le Luherne and Desmet, 2025) but still higher than during previous tagging surveys (705 ± 125 min during the ZDLK3-10-2023 cruise (Le Luherne and Peruzzo, 2023), 550 ± 215 min during the ZDLK3-02-2018 cruise (Farrugia and Keningale, 2018), and 622 min during the ZDLK3-10-2022 cruise (Nicholls and Raczynski, 2023)). As the proportion of tagged toothfish per line appears to decrease with increasing soak time (Le Luherne and Desmet, 2025), we recommend shorter soak times during tagging surveys to ensure toothfish are in better condition for tagging, ideally between 420 and 720 min (i.e., 7 to 12 h). Additionally, we advise following the recommendations of Captain Fernando Garcia Portas, particularly avoiding long soak times in areas with scavengers (e.g., myxine and invertebrates), as this can further impact the condition of the toothfish and their suitability for tagging.

The overlap in length distribution of toothfish tagged and toothfish sampled between January and November 2025 was 91.35%, aligning with the objectives of the research cruise program. The mean total length of tagged toothfish (100 ± 16.1 cm) was comparable to the lengths recorded in the previous tagging surveys (2024: 99.1 ± 17 cm, 2023: 101 ± 17.1 cm and 2022: 98.4 ± 16.2 cm) and in Farrugia et al. (2018) (102.1 ± 13.7 cm).

The outcomes for tagged fish appeared generally favourable, as toothfish were observed swimming downwards shortly after release. Tagging was either paused or not initiated when sperm whales were sighted in the vicinity of the vessel to prevent the released tagged toothfish from being consumed. This precaution was also taken to avoid encouraging any associated depredation behaviour.

In conclusion, the ZDLK3-10-2025 research cruise met the objectives outlined in the scientific proposal and followed the recommendations from previous reports (Le Luherne and Peruzzo, 2023; Le Luherne and Desmet, 2025). To keep improving the tagging survey and its outcomes, we recommend implementing the actions listed below.

Recommended actions from the chief scientist for the next (2026) tagging survey

- Record daily weather conditions (wave height and wind speed) and fishing practices to assess any influence of these factors on toothfish suitability for tagging and on the resulting tagging percentage per line.
- Continue to write a survey logbook that includes the following key information: date, station and line numbers, area, number of toothfish tagged at each station, presence of toothfish predators, and weather conditions. A logbook has been maintained by the chief scientist since 2024 and has proven valuable for writing the tagging report.

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