Cruise Report ZDLK3-02-2018

Toothfish Tagging and Underwater Camera

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Summary

A research cruise focused on Patagonian toothfish (*Dissostichus eleginoides*) was conducted aboard the *CFL Hunter* between 10 and 23 February 2018. The two primary goals of this cruise were to: 1) deploy conventional and satellite tags on toothfish in areas where none had been deployed before; and 2) gather video footage of the benthic environment and the behaviour of the longline gear during setting, soaking and hauling. The cruise travelled to five areas in the south-eastern region of the Falkland Conservation Zones, where tagging took place on a total of 21 lines. The underwater camera was deployed 11 times on umbrella branch lines of the longline gear.

Overall, 1,161 conventional tags and 10 mark-recapture satellite tags were deployed on toothfish ranging from 61 to 165 cm TL, with the weight of toothfish tagged and released totalling 10.9 tonnes. On average, 45.1% of the toothfish weight on each line was tagged, with a weak decreasing relationship between tagging percentage and soak time. At the time of writing, a total of 2,285 toothfish have been tagged since the beginning of the toothfish tagging effort, 36 of which have so far been recaptured (3.20% recapture rate before the February cruise, 1.58% recapture rate with the added tagged fish from the February 2018 cruise). No tagged toothfish were recaptured during the February 2018 cruise.

All but one camera deployment were successful and returned useable video footage of the habitat, epibenthic invertebrates (including hard corals, gorgonian corals, and sea pens), and organisms interacting with the baited hooks including toothfish, bigeye grenadier (*Macrourus holotrachys*), blue antimora (*Antimora rostrata*), skates (Rajiformes), hagfish (*Myxine* sp.), and crabs. The behaviour of the fishing gear was also recorded, indicating that only the 6 kg weight at the end of each branch line is contacting the bottom and dragging during hauling. The umbrella does not seem to be regularly making contact with the bottom during normal fishing activity, suggesting that the footprint of the longline fishing is minimal. Most of the benthic habitat seems to be composed of mud or silt and no evidence of permanent damage to the benthic environment was seen.

Background

The initial Marine Stewardship Council (MSC) certification for Patagonian toothfish (*Dissostichus eleginoides*) in the Falkland Islands was awarded in March 2014, and came with four conditions which Consolidated Fisheries Ltd (CFL) were obligated to meet. These conditions were addressed in collaboration with the Falkland Islands Fisheries Department (FIFD) and included enhancing the current knowledge on stock discrimination of toothfish in the Southwest Atlantic, and better understanding the impact of the longline gear on the benthic habitat of the Falkland Islands waters.

The stock discrimination condition was addressed through several methods recommended by an independent review from the National Institute of Water and Atmosphere Research Ltd (NIWA, New Zealand) of stock discrimination tools (Parker, 2015). One of these methods was a tagging project launched in June 2016, which involved a pulsed tag-recapture programme using conventional individually numbered tags (Randhawa and Lee, 2016) and deployment of pop-up archival satellite transmitting (PSAT) tags. The tagging programme aims to tag 3,500 toothfish in order to: (1) establish linkages between juvenile on the shelf and adults in deep waters; and (2) quantify the amount of exchange between adults in the northern and eastern FOCZ and the spawning grounds on Burdwood Bank. The additional deployment of PSAT tags, although expensive, provides a fishery-independent verification of the movement patterns, and evidence of habitat used by individual fish. Before the February 2018 research cruise, 1,124 conventional tags and five satellite tags had been deployed, and 36 conventional tags had been recovered (3.20% recapture rate).

Benthic habitats in the Falklands Conservation Zones (FICZ/FOCZ) are poorly understood, especially in waters deeper than 800 m. This includes the presence and distribution of Vulnerable Marine Ecosystem (VME) species. In addition, the interaction between the longline gear and the benthic habitat has not been quantified. Therefore, it is currently impossible to estimate the proportion of the benthic habitat impacted by the toothfish fishery, which is an important metric in the MSC certification process. To fill this knowledge gap, CFL purchased two underwater cameras to be set on the longline gear during normal fishing deployments. During the June 2017 cruise, video footage was successfully obtained from four camera deployments in the eastern area of the FICZ/FOCZ. This trial period showed that the camera could be used to observe both the benthic habitat and the behaviour of the fishing gear during setting, soaking and hauling operations.

Aims and Objectives

1) To continue the tagging effort on Patagonian toothfish, targeting areas where tags had not been deployed previously, specifically:
    a. Deploy at least 800 tags in the southern parts of the FICZ/FOCZ, divided equally among 5 areas.
    b. Deploy 10 PSAT tags in the southern parts of the FICZ/FOCZ

2) To obtain video footage of the benthic habitat and fishing gear, specifically:
    a. Observe the habitat and VME species present in areas that are predicted to have a high suitability for VME species.
    b. Determine how different parts of the fishing gear (weight, baited hooks, line, umbrella net) interact with the benthic habitat.
    c. Detect evidence of longline gear impact on the seabed and VME species.

Methods

Study area

The February 2018 research cruise focused on the southern and south-eastern regions of the FICZ/FOCZ. The cruise was particularly focused on areas where tags had not been deployed in the past (Figure 1). In addition, the specific grid squares that were chosen for this cruise had a high habitat suitability for two VME species groups, sea pens (Pennatulacea) and sea whips (Gorgonacea) (Figure 2), as predicted by a benthic habitat model (Brewin, 2018).

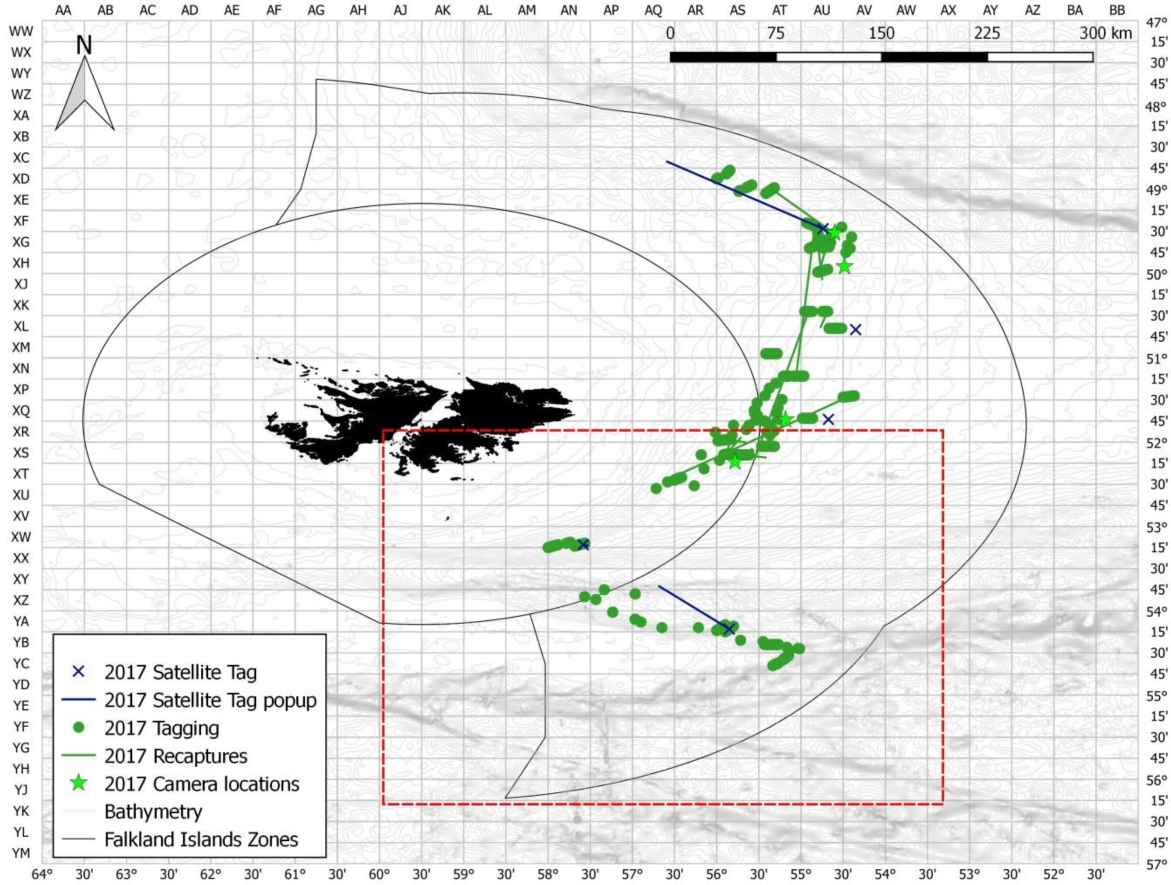

Figure 1. Map of the FICZ/FOCZ showing previous tagging and camera locations. Previously deployed conventional tags in 2016-2017 (green circles) and minimum distance between tagging and recapture locations (green lines) are shown. Deployment locations for PSAT tags are shown for 2017 (blue crosses), including lines to represent the minimum distance between tagging and pop-up locations (blue lines). Green stars represent locations of camera deployments in June 2017. Red box shows the region of focus for the February 2018 cruise.

Itinerary

The *CFL Hunter* departed Stanley on 11 February 2018 and steamed southwest to the Falkland Trough, where it fished until 13 February. It then moved to the north edge of Burdwood Bank on 14 and 15 February, followed by the east edge of Burdwood Bank on 16 and 17 February. The *CFL Hunter* then moved northwest on 18 February to the eastern slope of the Patagonian shelf, and moved north along the slope until 22 February before heading back to Stanley (Figure 2).

The research cruise plan assumed that eight lines would be necessary in each of four areas to accomplish the goal of deploying a total of 800 tags. However, following a suggestion from Captain Chema, the following fishing plan was initiated:

- In each area, three lines were set starting early in the morning.
- The first two lines were then hauled in, during which tagging and a camera deployment was conducted.
- Then, two more lines were set, and the third line was hauled. At this point, the third line would have been soaking for 12 hours or more, therefore this opportunity was taken for the research crew to sleep.
- In the morning, the fourth and fifth lines were hauled and more tagging and another camera deployment was conducted.

In total, Areas 1, 2, 3 and 4 each had five lines set, of which four lines were used for tagging, and two lines for camera deployment. Area 5 was added at the end of the cruise because tagging was happening at a faster rate than anticipated and there was still research cruise time to use. Seven lines were set in Area 5, of which five were used for tagging and three for camera deployments (Figure 2).

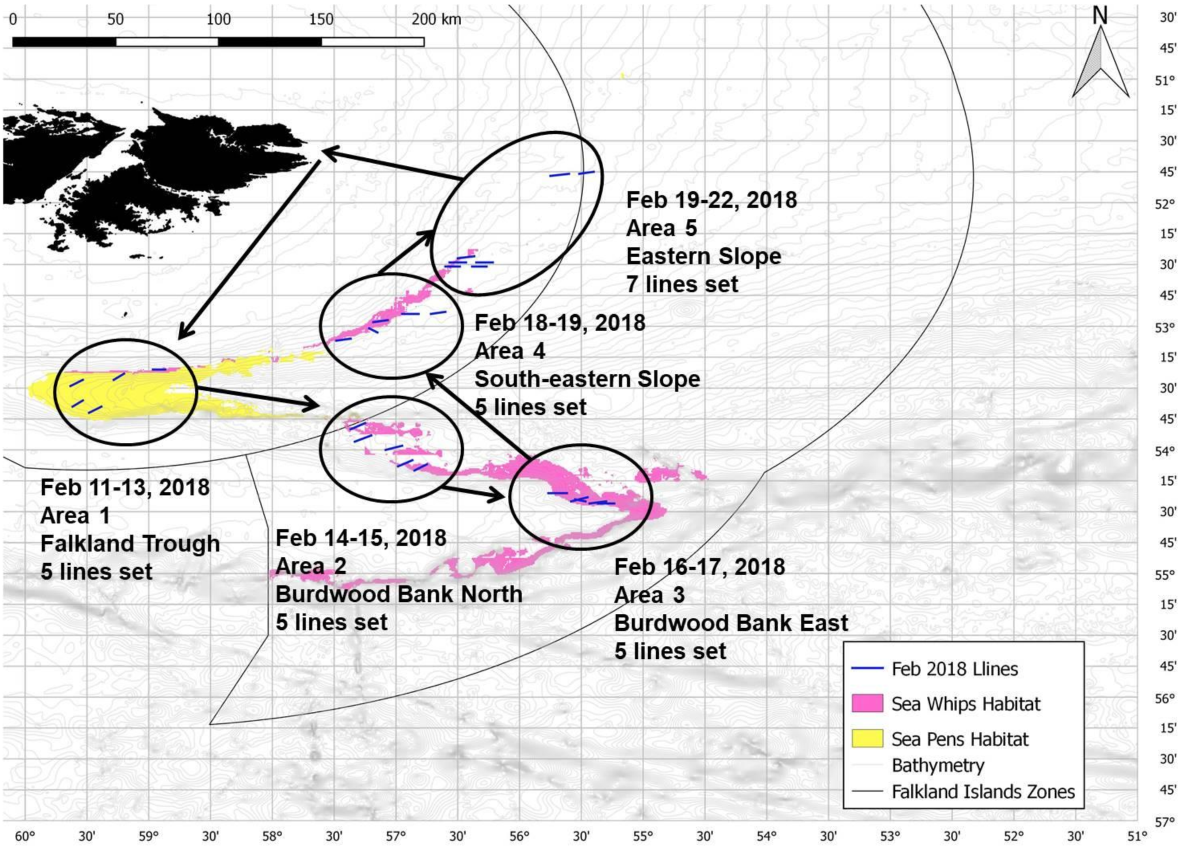

Figure 2. Itinerary of the February 2018 research cruise. Blue lines represent the longline sets deployed during the cruise. Black circles denote the five areas that were sampled. Yellow and pink shading represent the areas of high habitat suitability for sea pens (Pennatulacea) and sea whips (Gorgonacea), respectively.

Tagging protocol

The station layout was nearly identical to the one used during the June 2017 research cruise (Randhawa, 2017), except that a spring balance was used instead of the electronic

Marel marine scale, which was not available for this cruise (see the equipment list in the Appendix). Once a toothfish was brought on board, it was assessed by the research crew for tagging suitability. Fish suitability was identified using the information and figures from Randhawa and Lee (2016; Table 1). If deemed unsuitable, the fish was sent to the factory for processing.

Suitable toothfish were slid from the hauling bay to the tagging station. The tagging station was comprised of a fish measuring board, the tagging toolbox, the fish sling and the tag board with tags ready to be deployed (Figure 3A). Fish were measured, placed in the fish sling, tagged with two tags of the same number (one on either side of the dorsal fin), and injected with oxytetracycline (at 30 mg/kg, McFarlane and Beamish, 1987). The tagged fish were then carried in the sling to the balance scale for weight, and then carried in the sling out to the hauling bay and returned to the water by letting them slide head first out of the sling and into the water. The total time out of the water was typically less than two minutes.

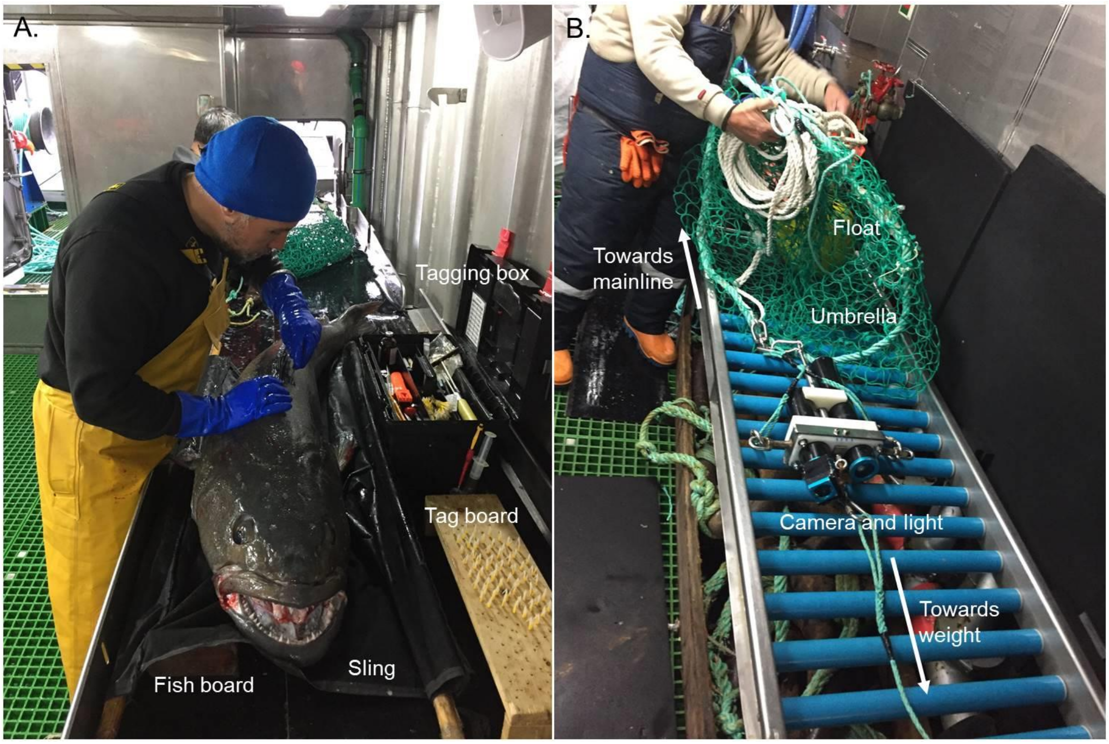

Figure 3. Tagging station and camera set ups. A. Layout of the tagging station showing the location of the fish measuring board, fish sling, tagging box and tag holding board. B. Set-up for the camera deployment showing the arrangement of the weight, camera, umbrella, and float. This set-up corresponds to the schematic in Figure 4C.

Because this research cruise was focused on tagging, a modified two-researcher tagging process was developed. A tag holding board was built, allowing each pair of numbered tags (one large and one small) to be kept together ready to be inserted into the tag applicators. A 50ml tube of 95% ethanol was placed at the end of the fish board, into which the tag and applicators were dipped between fish. A 20ml syringe with oxytetracycline (OTC) was placed in a second 50ml tube of 95% ethanol. For each fish, the tagger would use the first sterilized tag applicator, hand it off to the assistant, then use the second sterilized applicator for the second tag. He would then inject the fish with OTC using the sterilized syringe with an amount of OTC based on the length of the fish, and replace the syringe in the tube of ethanol. The assistant would then remove a pair of tags from the tag board, and place each tag in its applicator and dip them both back into the ethanol, ready for the next fish. The assistant would also write down the tag numbers of the prepared tags, and the tagger would verify this number after tagging the fish. This process allowed fish to be tagged very quickly, minimizing the amount of time each fish was out of the water and with almost no down time between fish.

The same process was used for the deployment of the mark-recapture satellite tags (model: mrPAT, manufacturer: Wildlife Computers, Redmond, WA, USA). In addition to two numbered tags, 10 toothfish were also tagged with satellite tags that are scheduled to pop up and send back the location of the toothfish in July/August 2018. The only modification to the tagging process was that after weighing, the tagged fish was placed in a tank of seawater and allowed to recover for at least 2 minutes. During this time, a magnet was passed over the satellite tag to activate it. The fish were then released as above and observed until they swam down under their own power.

For both conventional and satellite tags, a watch was used to record the time of release at the moment when the fish were returned to the water. This time recording was used for quality control of the data and also to determine the latitude and longitude of the release location. The time and location of the start and end of hauling was extracted from the station data recorded by the *CFL Hunter*. The start time, end time, start hauling latitude and end hauling latitude were used to calculate the degrees of latitude travelled per minute by the *CFL Hunter*. This rate was then used to calculate the latitude position of the *CFL Hunter* at the time of release for each tagged fish. The same calculation was made for longitude, and in the end an individual position for each released tag was obtained.

Camera deployment

The underwater camera and light were harnessed together in a single unit which could be attached to the longline in a variety of ways (Figure 3B). In general, the camera was attached to a branch line off the mainline of the longline gear. The camera is placed between a weight below it, and a float above it, with the camera pointing down towards the weight and baited hooks. Most of the camera deployments during February 2018 were made without an umbrella on the line (Figure 4A). This was because the umbrella poses an additional risk that the line will get snagged on a benthic feature and break off, possibly losing the camera. The first eight deployments were therefore made to examine the benthic habitat and observe the behaviour of the weight and baited hooks. For the last three deployments, an umbrella was added to the branch line, either above the camera for the ninth deployment (Figure 4B), or below the camera for the 10th and 11th deployments (Figure 4C). This allowed us to examine the behaviour of the umbrella during setting, soaking and hauling.

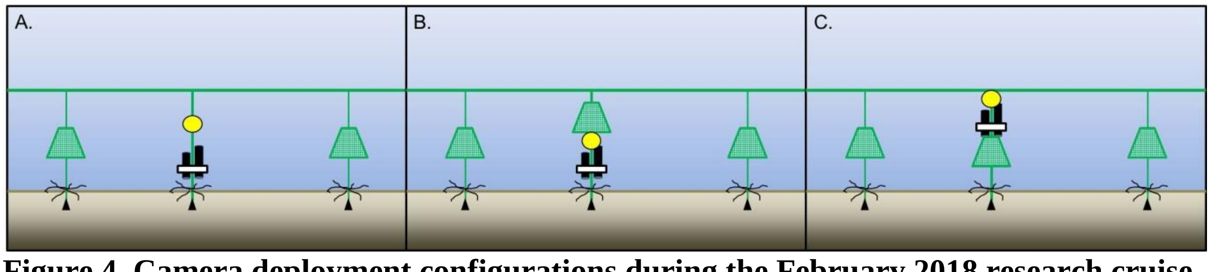

Figure 4. Camera deployment configurations during the February 2018 research cruise. The first 8 deployments were be conducted with no umbrellas (A), the 9th deployment was conducted with the umbrella above the camera (B), and the last two deployments were condcuted with the camera above the umbrella (C).

Because of the limits of battery life, the camera and lights were set on a 40-minute OFF, 20-minute ON cycle. This ensured that footage of the end of the line during hauling could be captured. To make sure that the behaviour of the umbrella was captured throughout the fishing process, the cycle was modified to 10-minutes OFF, 10-minutes ON for the last three deployments. After each deployment, the data of the camera were downloaded and the camera and light batteries were recharged. This led to the camera only being able to be deployed every 2-3 lines.

Results

Tagging

A total of 1,161 toothfish were successfully tagged on 21 lines during the February 2018 research cruise. Between 202 and 278 tags were deployed at each of the five areas, with any given line having between 31 and 78 toothfish tagged (Table 1). Their length ranged from 61 to 165 cm (Table 1) and showed a slight left skewed distribution with the median at 93 cm and the mean at 94.5 cm (Figure 5).

There was some variability in the length frequency between the five tagging areas (Figure 6), and in fact the variance of lengths was significantly different between areas (Levene's test, $F_4 = 7.9202$, $p < 0.001$). Therefore, the Welch F test for heteroscedastic data was used, and showed that there was a statistical difference in the tagged toothfish lengths across areas ($F_4 = 18.54$, $p < 0.001$). A post-hoc pairwise comparison with Bonferroni correction showed that the significant differences were between areas 1 and 4 ($p = 0.007$), 1 and 5 ($p < 0.001$), 2 and 5 ($p = 0.002$), 3 and 4 ($p < 0.001$), and 3 and 5 ($p < 0.001$). Area 5 had the largest mean toothfish size (98.8 ±13.6 cm) and area 3 had the smallest (90.2 ± 11.2). Area 2 had the largest variability in tagged toothfish size, with a standard deviation of 15.6 cm, while area 1 had the lowest variability, with a standard deviation of 10.4 cm.

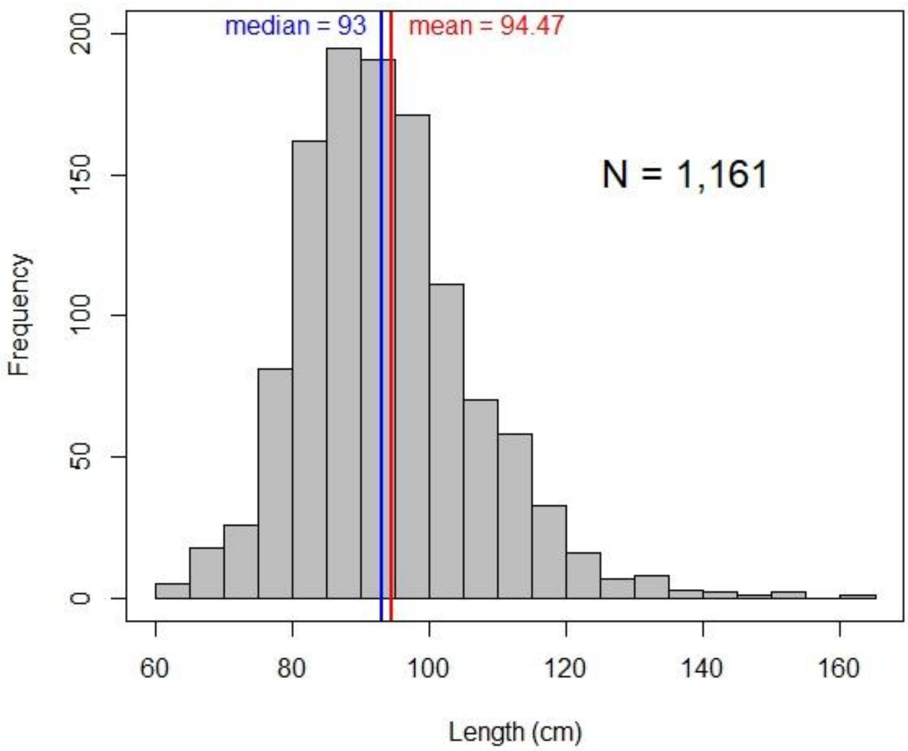

Figure 5. Length frequency of toothfish tagged during the February 2018 cruise. Mean and median length (cm) of all tagged fish are shown in the vertical red and blue lines, respectively.

Table 1. Tagging information by area and station. The average length of the tagged fish (± 1 standard deviation) and the length range are shown. Both the measured weight (using a spring balance) and the calculated weight (based on the length-weight relationship from the observer database) are shown, as well as the weight of toothfish processed and not tagged. The proportion tagged is simply the measured weight divided by the total weight hauled. Soak time was calculated as the difference between the start set time and the end haul time.

Area	Station	# Tags	Avg. length (cm) ± sd	Length range (cm)	Measured weight (kg)	Calculated weight (kg)	Processed weight (kg)	Prop. tagged	Soak time (min)
1	173	41	94.0±11.0	69 - 124	360.3	347.3	487	0.43	861
	174	59	92.6±10.3	72 - 122	497.8	476.2	507	0.50	1,101
	175	75	92.3±10.1	75 - 146	645.4	598.2	1453	0.31	971
	176	60	92.7±10.5	73 - 123	500.0	485.1	1163	0.30	1,225
1 Total		235	92.8±10.4	69 - 146	2,003.5	1,906.8	3,610	0.36	
2	177	37	101.7±16.1	80 - 152	440.4	416.1	576	0.43	768
	178	38	103.2±15.6	74 - 137	468.1	443.1	991	0.32	1,043
	179	60	89.3±14.3	62 - 137	488.4	450.3	744	0.40	931
	180	67	87.5±11.5	67 - 117	517.0	460.8	531	0.49	1,217
2 Total		202	93.6±15.6	62 - 152	1,913.9	1,770.2	2,842	0.40	
3	181	75	93.1±11.8	72 - 134	643.4	623.3	663	0.49	636
	182	52	89.6±9.9	69 - 126	390.2	379.0	609	0.39	1,001
	183	74	89.9±12.5	66 - 133	611.6	557.6	532	0.53	866
	184	43	86.3±7.5	66 - 104	289.8	274.2	681	0.30	1,119
3 Total		244	90.2±11.2	66 - 134	1,935.0	1,834.1	2,485	0.44	
4	185	54	91.4±11.8	67 - 121	455.4	423.5	88	0.84	733
	186	38	98.7±16.0	80 - 165	416.2	393.1	104	0.80	962
	187	50	96.5±10.2	76 - 119	483.0	455.3	239	0.67	870
	188	60	99.8±11.1	70 - 129	633.6	610.0	604	0.51	1,135
4 Total		202	96.5±12.5	67 - 165	1,988.2	1,882.0	1,035	0.66	
5	189	78	94.3±9.3	72 - 115	691.1	658.8	506	0.58	751
	190	61	101.6±16.4	68 - 154	753.5	685.0	713	0.51	1,125
	191	71	97.0±11.8	70 - 124	722.5	664.6	473	0.60	1,188
	192	37	106.9±14.5	83 - 145	525.0	475.1	815	0.39	656
	193	31	99.1±14.7	61 - 119	349.0	316.8	776	0.31	971
5 Total		278	98.8±13.6	61 - 154	3,041.1	2,800.4	3,283	0.48	
Total		**1161**	**94.5±13.1**	**61 - 165**	**10,881.7**	**10,193.5**	**13,255**	**0.45**	

The measured weight of the tagged toothfish ranged from 2 kg to 53 kg, with a mean of 9.4 kg. However, these weight measurements were taken with a spring balance and were therefore somewhat difficult to read. The calculated weight of the tagged toothfish, based on the established length-weight relationship, ranged from 2.1 kg and 46.5 kg, with a mean of 8.8 kg. The total measured weight of toothfish tagged during the research cruise was 10,882 kg, divided relatively equally among the five areas (Table 1). This represented about 45% of all toothfish caught on the tagging lines (range: 30 – 84%). The condition of hooked toothfish can deteriorate over time, therefore it might be expected that the proportion of toothfish suitable for tagging would decrease as soak time of the line increased. Although there was a slight decreasing trend in the proportion of toothfish tagged compared to the soak time of each line, this relationship was not significant (p = 0.29) (Figure 7).

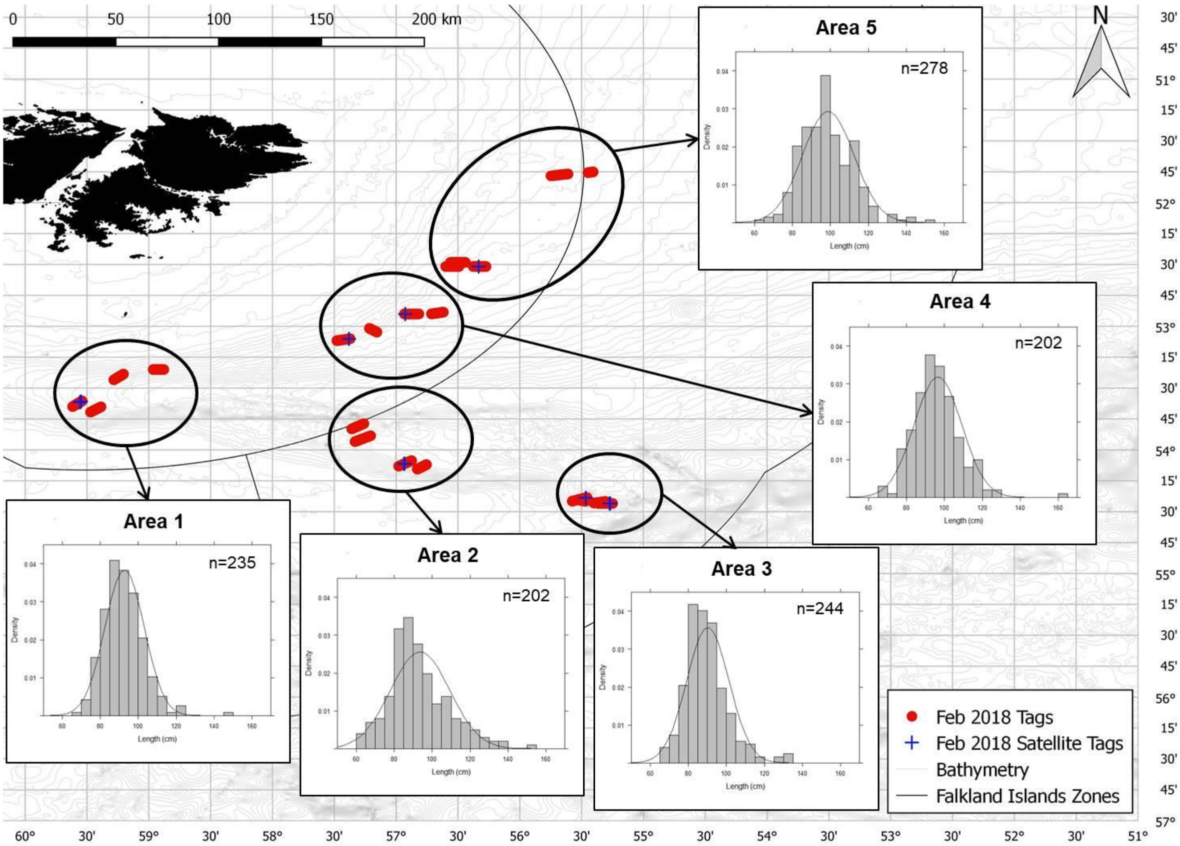

Figure 6. Map of tag release locations with length frequency histograms for each area. Each area has four tagged lines, except area 5 which had five tagged lines. Red dots represent deployed conventional tags, blue crosses represent deployed satellite tags.

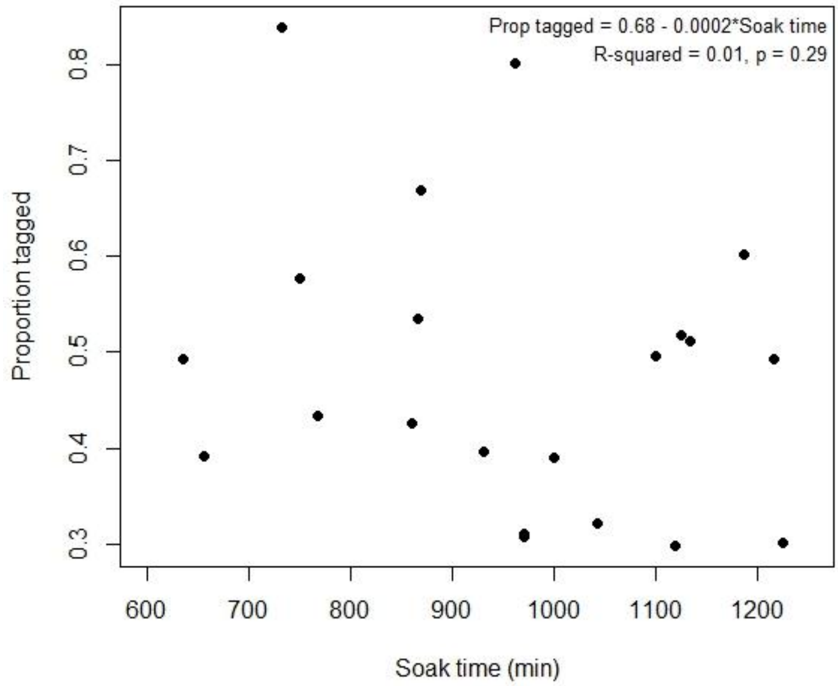

Figure 7. Proportion of tagged toothfish per line compared to the soak time of the line. The equation for the non-significant regression is shown, as is the adjusted r^2 and p-value.

In addition to conventional tags, 10 satellite tags were deployed on larger tagged toothfish, between 106 and 146 cm (14 and 34 kg). Two satellite tags were deployed in each of areas 1, 2, and 4, three satellite tags were deployed in area 3, and one satellite tag was deployed in area 5 (Figure 6).We chose to deploy a third satellite tag in area 3 (Burdwood Bank) as this is the area that is suspected to be a spawning location, and it will be interesting to see the behaviour of fish in this area during the transition from non-spawning to spawning season.

No tagged toothfish were recaptured during the February 2018 research cruise.

Underwater camera

The underwater camera was deployed a total of 11 times, twice each in the first four areas, and three times in area 5 (Figure 8). However, one deployment in area 2 failed when the battery connection in the light assembly broke, yielding only black footage for the entire time. As a result, 10 sets of usable videos were obtained from the February 2018 cruise, totally over 2,500 minutes of footage.

The benthic environment differed somewhat throughout the study area. In the Falkland Trough and Burdwood Bank (northern edge) areas, the benthos seems to be relatively fine silt with benthic organisms present (Figure 8A, B). In the Burdwood Bank East, the seafloor seems to be of coarser grain with larger pieces of rocks, shells and corals lying on the bottom (Figure 8C). On the south-eastern slope, the sediment seems like very fine silt with little or no benthic organisms present (Figure 8D). On the eastern slope, the sediment seems to be coarser with rubble and occasional large pieces of coral (Figure 8E, F). In addition to the sediment, the underwater camera captured footage of many organisms, including benthic sessile invertebrates (soft corals, Alcyonacea; stony corals, Scleractinia; sea fans and sea whips, Gorgonacea; sponges, Demospongiae; glass sponges, Hexactinellida; sea pens, Pennatulacea), to mobile invertebrates (*Thymops birsteini*, *Acanthoserolis schythei*, *Neolithodes diomedeae*), to fish (bigeye grenadier, *Macrourus holotrachys*; blue antimora, *Antimora rostrata*; skates, Rajiformes; hagfish, *Myxine* sp.).

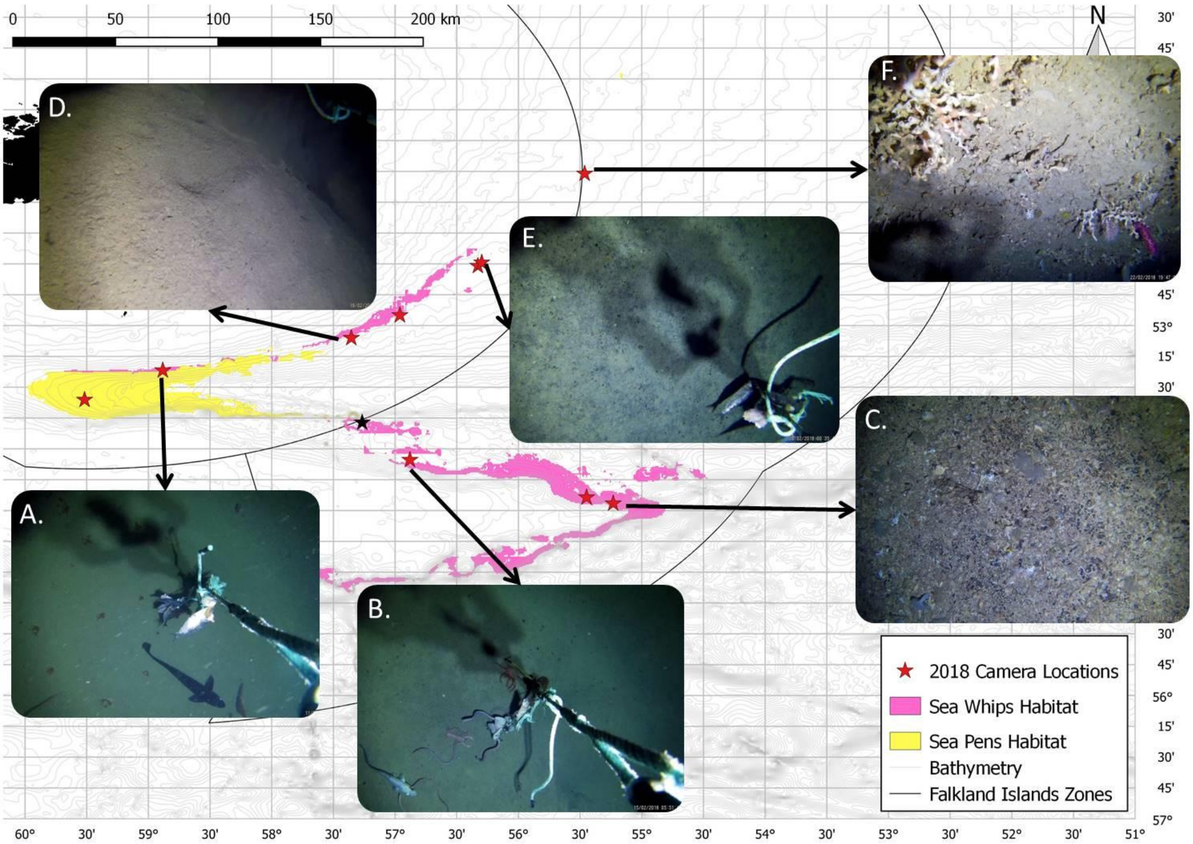

Figure 8. Map of the camera locations deployed during the February 2018 cruise. Camera locations are shown with stars (red stars for the successful deployments, black star for the deployment that failed). Pictures are representative stills from the footage at each of the areas: A. Falkland Trough, B. Burdwood Bank (northern edge), C. Burdwood Bank (eastern edge), D. Eastern slope, E. and F. Eastern slope.

The footage revealed the behaviour of the two main components of the fishing gear: the weight/baited hooks, and the umbrella. During a typical longline set (i.e. one that was not knocked over by strong currents, or where the line did not break) the weight was touching the bottom, and the hooks were lifted just above the seabed (Figure 9A). With not too much current, the weight did not drag at all during soaking and the same view of the benthos was visible until hauling started. Occasionally, the current was strong enough to slacken the longline, which led to the weight or even part of the branch line to sink to the bottom and lay on its side (Figure 9B). This occurred on two of the camera deployments. At other times, the line stayed tight despite the strong current, and this made the weight drag very slowly while soaking (Figure 9C, white arrow shows furrow created by the dragging weight). This happened once during the research cruise.

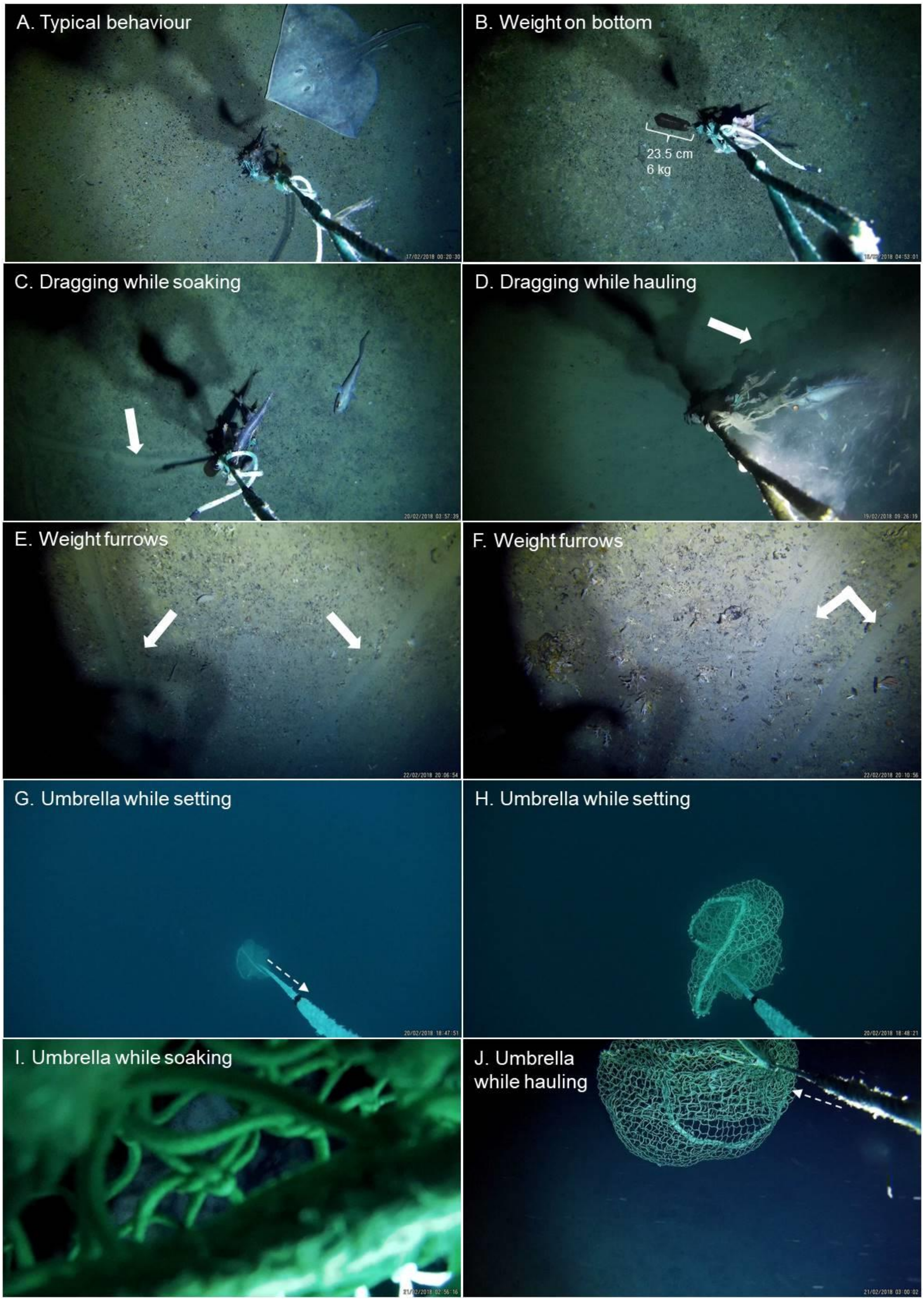

Figure 9. Stills from the camera footage showing behaviour of the fishing gear. The weight and bait behaviours are shown during typical soaking (A), when slightly slack due to current (B), slowly dragging due to current (C), and dragging rapidly while hauling (D). The weight being hauled created furrows in the seabed (E, F, white arrows). The behaviour of the umbrella is shown while setting (G, H), soaking (I), and hauling (J).

Once hauling started, the weight dragged at a rapid rate along the bottom, creating a plume of silt behind it (Figure 9D, white arrow). This is the most intense impact of the fishing gear on the bottom seen during the camera deployments. Furrows from two previous weights on the same line can be seen in Figure 9 (E, F) getting closer to each other as they come up below the fishing vessel before they lift off the bottom.

Furrows from previous weights on the same line also show a very well defined edge, suggesting that only the weight was dragging along the bottom, and not the umbrella. Had the umbrella also been dragging, we would have expected to see a large swath of disturbed sediment on either side of the weight furrow. Furthermore the last three camera deployments were set up so as to see the behaviour of the umbrella (see Figure 4B and C). When the camera was positioned below the umbrella, the umbrella was not visible until hauling. This suggests that the umbrella was floating above the camera, and only came into view when the hauling motion of the line made the umbrella slide over the camera. When the camera was positioned above the umbrella, the umbrella could be seen moving up the branch line during setting, away from the weight and hooks (Figure G and H, sequentially showing the umbrella moving up the branch line). While soaking, the umbrella was floating up into the camera which was positioned 7 m above the weight (Figure 9I). During hauling, the umbrella can be seen sliding down the branch line, away from the camera and towards the weight (Figure 9J).

Therefore, the behaviour of the longline seems to be as expected under typical conditions: the weight makes contact with the bottom, drags while being hauled, and the umbrella remains away from the bottom and the hooks until hauling. When conditions are not typical, the branch line along with the weight and presumably the umbrella may lie down on the bottom and drag during hauling. This could explain the occasional retrieval of benthic organisms (crabs, corals, sea pens) in the umbrella on some of the lines.

Other than the creation of the furrows, no impacts on the seabed were detected in the video footage. In addition, there was no clear evidence of previous impacts from older lines, even in the high historical fishing effort area of Burdwood Bank East. It therefore seems possible that furrows created by the weights are erased on the timescale of a few years. The camera captured a few rare instances of the weight contacting coral directly, but the number and severity of these impacts has not yet been fully examined.

Discussion

Overall, the objectives of the research cruise were achieved. A total of 1,161 conventional tags and 10 satellite tags were deployed across the study area, filling in gaps in the distribution of released tags from previous tagging efforts. In addition, we completed 10 successful underwater camera deployments that obtained footage of the benthic environment, organisms present at depth, and the behaviour of various components of the fishing gear.

On average, 55 toothfish were tagged per line during the February 2018 research cruise, a marked increase from both the 2017 research cruise (37, Randhawa et al., 2017) and 2016 research cruise (23, Randhawa and Lee, 2016). As in 2017, all of the tagged toothfish in 2018 were injected with oxytetracycline. Toothfish tagged in 2018 were smaller than in 2017 (94.5 ± 13.1 cm vs. 101 ± 14.7 cm in 2017), but since both the season and locations differed between the two research cruises, a direct comparison was not very informative.

Much of the success in achieving and surpassing our tagging goals had to do with a new 2-person tagging process (see Methods section). This allowed the tagger to just focus on handling and tagging the fish, who could then work through fish much more quickly. Another advantage was the fishing behaviour that was modified by Captain Chema for this research cruise. By setting only three lines before hauling the first two, and then setting down another two lines later, the soak times of this research cruise were kept quite low, with an average of

959 ± 181 minutes. This is significantly shorter than the soak time during the 2017 research cruise (average 1,181 ± 275 minutes, $t = -2.807$, $p = 0.0096$). Correspondingly, a greater proportion by weight of toothfish were suitable for tagging per line, with 0.48 ± 0.15 in 2018 compared to 0.39 ± 0.16 in 2017 ($t = 3.3344$, $p = 0.002$).

The success of the camera deployments was also due in large part to the efforts of the Captain and crew of the *CFL Hunter*. Captain Chema devised a secure way of attaching the camera to the branch line during the 2017 cruise, and of adding an umbrella to the branch line during the 2018 cruise. This plan was executed diligently by the crew and the camera obtained valuable footage of both the environment and the fishing gear's interaction with it. Along with the videos from the 2017 cruise, there is now a substantial database of footage from around the FICZ/FOCZ. Although a cursory look at the footage has been completed, a full description would be necessary to extract all usable information from this footage. For example, identifying all benthic organisms visible in the footage to the lowest taxonomic level possible, and plotting those onto a map would be very useful in building up the knowledge base of VME species in the Falkland waters.

Despite these successes, the research cruise was not without its challenges too. One of the main issues had to do with weighing of the tagged toothfish. Without a marine balance available, a hanging spring balance was used. Although not inconvenient to use, especially when tagged fish were placed in a stretcher, the readings were difficult to take especially when there was heavy swell. The needle of the scale would at times swing over a 20 kg range, and the best that could be done was to take the mid-point of that swing. We therefore used this as an opportunity to quantify the difference in efficacy between a marine balance and a hanging balance. The average difference between measured and calculated weight was about 7%, much larger than the 0.3% difference during the 2017 research cruise when a marine balance was used (Randhawa et al., 2017). Therefore the measured weights during the February 2018 research cruise should be seen a somewhat unreliable.

Similarly, the camera work was generally successful, but one deployment failed due to an internal electronic component breaking. The issue has to do with the connection between the light battery and the light timer, which is made with relatively small gauged wire. Since the light is pointed down, the battery actually rests on the timer during deployment. It may be possible to construct an internal harness to keep the battery away from the rest of the components, but at this time, if the light gets jostled too much, the battery can knock into and break that connection. This leads the light to not come on, and therefore all the footage is pitch black and unusable. This specific issue is representative of the whole camera/light set-up, which although it can withstand the tremendous pressures at depth, is quite fragile and prone to breaking if not handled with care. It is therefore necessary when the camera is being deployed to have one scientist dedicated to preparing, deploying, retrieving, downloading and recharging the set-up.

Recommendations

We make the following recommendations to the Fisheries Department:

1. With the current tagging numbers at 2,285 toothfish, we are close to achieving our goal of 3,500 tags. However, to make sure we meet this goal by 2019, we recommend that the tagging efforts by the Fisheries Observers continue aboard the *CFL Hunter*. The aim should continue to be 3 – 4 suitable fish per line sampled (sampling target of 50% of lines per trip). Tagging should occur within the first 10 – 15 minutes of hauling so not to disrupt commercial activities and minimize soaking time. If this is difficult to achieve due to other work, the observers should ***aim to tag, on average, 4 fish per day or 100 per 4 week trip.*** The recommendation is for ***tagging to occur***

under normal commercial fishing behaviour (including normal commercial hauling speeds). A protocol was developed by Haseeb Randhawa and Brendon Lee, in consultation with Joost Pompert, and has been in place and communicated to both CFL and Fisheries Observers as of August 15th 2016 (revised on November 8th 2017).

2. We further recommend that another research cruise that includes tagging be conducted aboard the *CFL Hunter* before the end of 2018. This tagging effort should aim to tag at least 800 fish, with the ultimate goal to release all of the remaining tags. During this next research cruise we recommend that the methods and protocols used during the February 2018 research cruise be employed (see #3 below).

3. The following adjustments to the tagging cruise protocols should be employed:
    a. The 2-tagger method described in the methods should be used to allow fish to be tagged and returned to the water as quickly as possible. Each researcher should have a defined role and set of tasks that they stick to, in order to ensure that all the information is correctly and consistently recorded.
    b. A watch should be used to note the time of release of each tagged fish. This helps both for quality control of the data, and to determine the exact release location.
    c. Little plastic pots of ethanol should be set up at the tagging station to dip the tags and applicators between fish. This will further reduce the chances of infection. Once dipped, the tags and applicators should be air dried to ensure sterilization before tagging.
    d. A tag board (Figure 3A) has been built to hold pairs of tags. It is recommended that this board be used on all future tagging cruises.
    e. If possible, and in collaboration with the Captain, the flow of setting and hauling lines should proceed in the following way: 3 lines should be set starting in the morning, then two lines should be hauled during which tagging is taking place. This usually takes a whole day. Overnight, while the researchers are resting, lines 4 and 5 should be set, followed by hauling of line 3, on which no tagging takes place. The following morning, lines 4 and 5 are hauled and toothfish are tagged. The rest of the day can be used to steam to the next set of stations.

4. Assuming funding is available, more PSAT tags should be released on large toothfish in all areas of the FICZ/FOCZ. These tags could be deployed during the spawning season on Burdwood Bank and set to release during the non-spawning season, or deployed during the non-spawning season and set to release during the spawning season.

5. The use of oxytetracycline (OTC) should be revisited. The benefits (antibiotic properties and age validation) need to be reassessed and weighed against the disadvantages (extra tagging time, possible loss of product if flushing rates are slow). The age validation may no longer be necessary as over 1,700 tagged toothfish have already been injected with OTC. Furthermore, the antiseptic properties of OTC are not conclusive, and it could be replaced by ethanol during tagging.

We make the following recommendations to CFL:

1. We would recommend that a marine balance dedicated to research should be installed on the *CFL Hunter*. However, this recommendation was made in the last cruise report

(Randhawa et al., 2017) and acted upon by CFL. A marine balance has now been purchased and will be installed on the *CFL Hunter* in the coming months. This marine balance should be placed either next to the observer bench in the wet factory, or next to the tagging station in the dry factory. Ideally, it could be moved from one of these locations to the other depending on the need.

2. A lot of very valuable data has already been collected with the underwater camera, and more data are likely to come in the future. This amount of data is too much for somebody to do as a side project, and a dedicated person should be assigned to using the video footage. We therefore recommend that CFL either hire a technician, or sponsor a graduate student, to analyse the footage as part of a project on the benthic habitat and gear interaction of the toothfish fishery. We suggest that FIFD, CFL and the South Atlantic Environmental Research Institute (SAERI) write a proposal for an iCASE studentship to fund such a project. An attempt at this studentship has already been made by SAERI, and this should be revisited in close collaboration with FIFD and CFL.

3. It is recommended that CFL continue their education campaign about the rationale and merits of tagging toothfish aimed at its officers and crew. It should be clearly outlined that this is a CFL initiative supported by the Fisheries Dept.

4. Finally, we suggest determining if there's a way of recording and downloading a track of the *CFL Hunter* during the research cruise. Ideally this would take the form of an excel sheet or text file with a GPS location at fixed intervals, such as every minute. This would be very useful for plotting the exact location of the vessel and determining the precise release location of every tagged toothfish.

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Appendix

Equipment used during the February 2018 research cruise

Reusable equipment

- Small and large tag applicators
- Satellite tag applicator
- Measuring board and extra ruler
- Hanging scale (50 kg round)
- Scribing board
- Fish stretchers (one large and one small)
- Tag holder board
- Tagging box
- Camera and light setup (with harness)
- Back-up light and electronic components
- Battery chargers
- Extra SD cards
- Knives, forceps
- Tagging and recapture forms
- OTC dosing sheet
- Protocols
- Pencils
- Permanent marker
- Clipboard
- Watch

Disposable equipment

- Rubber gloves: 3 pairs
- OTC: 16.5 bottles (1.65 L)
- Syringes: 1 x 20mL
- Needles: 13
- Tags: 1161
- Satellite tags: 10
- Scalpel blades: 10
- Eppendorfs: 10
- Large plastic tubes: 4
- Otolith envelopes: 15
- Genetic vials: 1
- Ethanol: 500 mL
- Label paper