Cruise Report ZDLK3-11-2018

Toothfish Tagging and Underwater Camera

Thomas J. Farrugia
Ludovic Goyot
Amanda Kuepfer

Falkland Islands Government
Directorate of Natural Resources
Fisheries Department
Stanley, Falkland Islands

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Participating Scientific Staff

Dr Thomas J. Farrugia (chief scientist, biological sampling, reporting)
Ludovic Goyot (biological sampling, data entry)
Amanda Kuepfer (seabird officer, vessel data retrieval)

Previous tagging cruises: Dr Haseeb Randhawa, Brendon Lee, Benjamin Keningale

Comments provided by: Dr Haseeb Randhawa, Dr Andreas Winter.

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For citation purposes this publication should be referenced as follows:

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Summary

A research cruise focused on Patagonian toothfish (*Dissostichus eleginoides*) was conducted aboard the *CFL Hunter* between 27 November and 7 December 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. In addition, work was carried out on seabird interaction during setting and hauling operations. The vessel travelled to four areas in the north and north-eastern regions of the Falkland Conservation Zones, where tagging took place on a total of 13 lines. The underwater camera was deployed 8 times on umbrella branch lines of the longline gear.

Overall, 828 conventional tags and 5 mark-recapture satellite tags were deployed on toothfish ranging from 60 to 162 cm TL, with the weight of toothfish tagged and released totalling 9.5 tonnes. On average, 46.2% of the toothfish weight on each line was tagged, with no relationship between tagging percentage and soak time. At the time of writing, a total of 3,314 toothfish have been tagged since the beginning of the toothfish tagging effort, 51 of which have so far been recaptured (2.05% recapture rate before the November cruise, 1.54% recapture rate with the added tagged fish from the November 2018 cruise). No tagged toothfish were recaptured during the November 2018 cruise.

All camera deployments 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 Patagonian toothfish, Bigeye grenadier (*Macrourus holotrachys*), Blue antimora (*Antimora rostrata*), and crabs (*Neolithodes diomedeae*). The performance of the fishing gear was also recorded, indicating that, under normal conditions, 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 on the bottom. Most of the benthos has mud or silt sediment and only rare evidence of long-term damage to the benthic environment (damage to hard corals for example) 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 obliged to address before the next certification period (in 2019). 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 habitats 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 satellite archival transmitting (PSAT) tags. The tagging programme aims to tag 3,000 toothfish in order to: (1) establish linkages between juveniles 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 provides a fishery-independent verification of the movement patterns, and evidence of habitat used by individual fish. Before the November 2018 research cruise, 2,486 conventional tags and fifteen satellite tags had been deployed, and 51 conventional tags had been recovered (2.05% recapture rate).

Benthic habitats in the Falklands Conservation Zones (FICZ/FOCZ) are poorly studied, 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 is only starting to be quantified. To continue gathering data to estimate the proportion of the benthic habitat impacted by the toothfish fishery, which is an important metric in the MSC certification process, underwater cameras were deployed on the longline. During the November 2018 cruise, video footage was successfully obtained from eight camera deployments in the northern area of the FICZ/FOCZ.

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 700 tags in the northern parts of the FICZ/FOCZ, divided equally among 4 areas.
   b. Deploy 5 PSAT tags in the northern 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 the northern parts of the FICZ/FOCZ.
   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.

3) To assess seabird interactions during setting and hauling operations

Methods

Study area

The November 2018 research cruise focused on the northern and north-eastern regions of the FICZ/FOCZ. The cruise was particularly focused on areas where tags had not been deployed in the past (Figure 1).

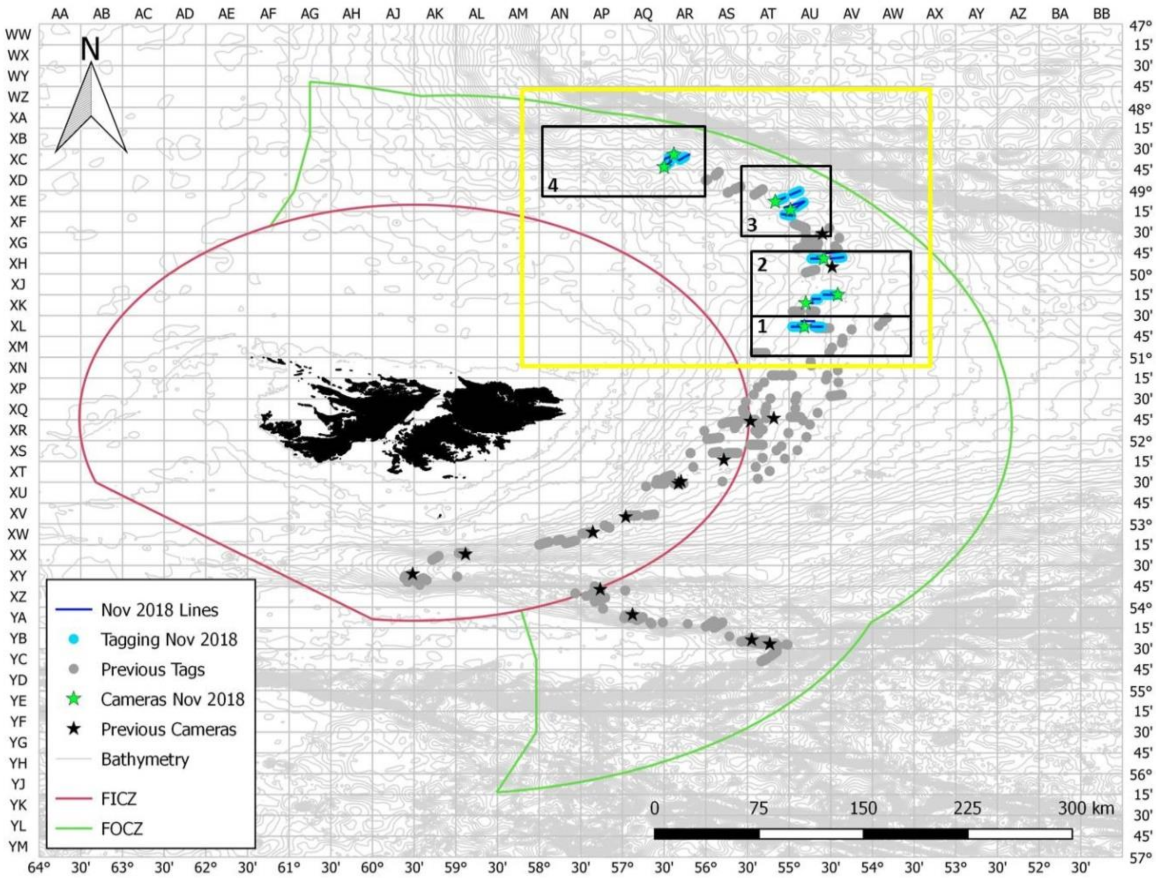

Figure 1. Map of the FICZ/FOCZ showing previous tagging and camera locations. Yellow box shows the region of focus for the November 2018 cruise, with the four areas of focus shown in the black boxes. Circles represent previously deployed conventional tags in 2016-2018 (grey) and tags released during the November 2018 (blue). Stars represent locations of previous camera deployments in 2017-2018 (black) and cameras deployed during the November 2018 cruise (green).

Itinerary

The *CFL Hunter* departed Stanley on 27 November 2018 and steamed northeast to area 1 (Figure 1), where it fished until 29 November. It then moved north to area 2 on 29 and 30 November, then further north to area 3 on 1 and 2 December. The *CFL Hunter* then moved northwest on 3 December to area 4 on 3 and 4 December. This quick progression through the different areas was a decision by the Captain to make sure there was enough time to visit all the areas before potential bad weather moved in. Afterwards, there was one more day of fishing left on 5 December which was spent fishing back in area 2. The *CFL Hunter* then started steaming back to Stanley, arriving on the morning of 7 December.

The research cruise plan assumed that 16 lines total (four in each area) would be necessary to accomplish the goal of deploying a total of 700 tags. However, due to the long steaming times between areas, fewer lines were set, but more fish per line were tagged. In total, tagging took place on two lines in area 1, four lines each in areas 2 and 3, and three lines in area 4. The camera was deployed on one line in area one, three lines in area 2, and two lines each in area 3 and 4 (Figure 1).

Tagging protocol

The station layout was nearly identical to the one used during the February 2018 research cruise (Farrugia and Keningale, 2018), except that a digital spring balance was used instead of the analogue spring balance (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, cutters to remove hooks, the fish sling and the tag board with tags ready to be deployed (Figure 2A). Fish were measured, placed in the fish sling, and tagged with two tags of the same number (one on either side of the dorsal fin to offset the impact of tag loss). 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.

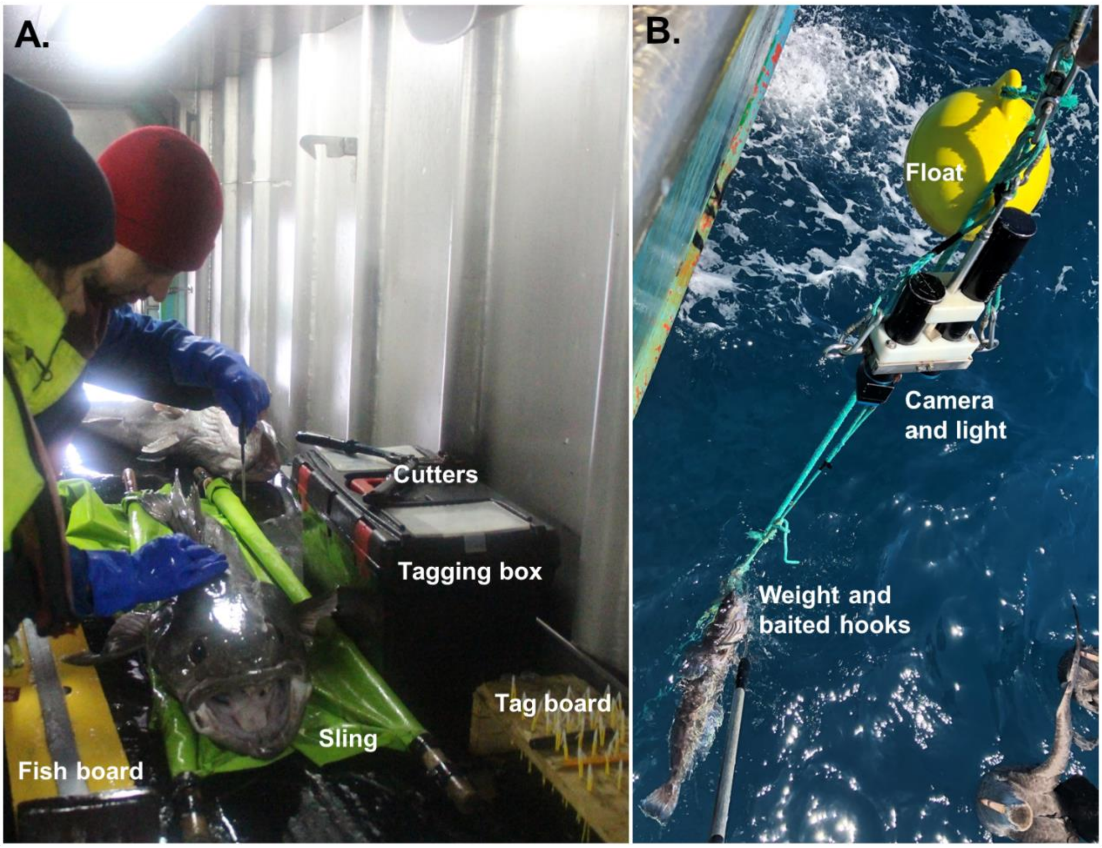

Figure 2. Tagging station and camera set ups. A. Layout of the tagging station showing the location of the fish measuring board, cutters, fish sling, tagging box and tag holding board. B. Set-up for the camera deployment showing the arrangement of the weight, baited hooks, camera, and float. This set-up corresponds to the schematic in Figure 3.

The same tagging process as described in Farrugia and Keningale (2018) was used, except that fish were not injected with oxytetracycline. 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 and then left to dry between fish. 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. 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 five mark-recapture satellite tags (model: mrPAT, manufacturer: Wildlife Computers, Redmond, WA, USA). In addition to two numbered tags, five toothfish larger than 115 cm were also tagged with satellite tags that are scheduled to pop up and send back the location of the toothfish in July/August 2019. 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 during the data entry 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 3). For all deployments during the November 2018 cruise, the camera was attached to a branch line off the mainline of the longline gear. The camera was placed between a weight below it, and a float above it, with the camera pointing down towards the weight and baited hooks. The camera deployments were made without an umbrella on the line (Figure 3). 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.

Because of the limits of battery life, the camera and lights were set on a 40-minutes OFF, 20-minutes ON cycle. This ensured that footage of the end of the line during hauling could be captured. 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.

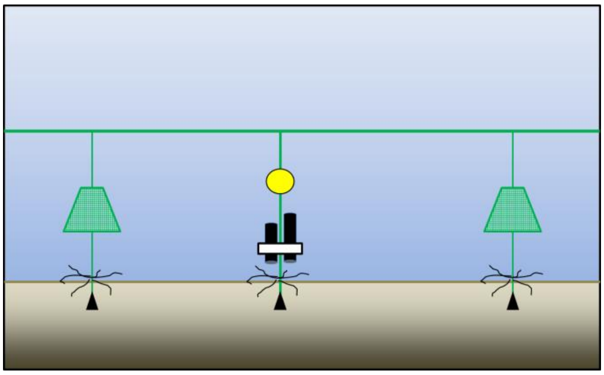

Figure 3. Camera deployment configuration during the November 2018 research cruise. All 8 deployments were be conducted with no umbrellas and the camera pointing down towards the baited hooks and seabed.

Seabird interaction

In addition to the tagging and camera work, the November 2018 research cruise was taken as an opportunity to conduct some seabird interaction work by Amanda Kuepfer. This work included assessing seabird interactions during setting and hauling operations, and comparing interaction rates with and without the tori-line during setting. For a full description of the methods and results of this work see Kuepfer (2018).

Results

Tagging

A total of 828 toothfish were tagged on 13 lines during the November 2018 research cruise. Between 123 and 297 tags were deployed at each of the four areas, with any given line having between 27 and 83 toothfish tagged (Table 1). Their length ranged from 60 to 162 cm and showed a slight left skewed distribution with the median at 101 cm and the mean at 102.05 cm (Figure 4).

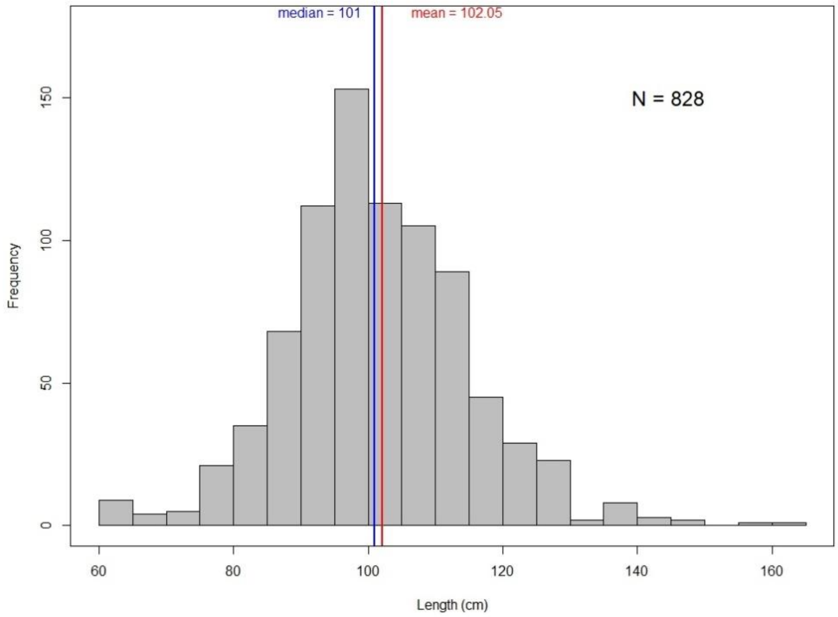

Figure 4. Length frequency of toothfish tagged during the November 2018 cruise. Mean and median lengths (cm) of all tagged fish are shown in the vertical red and blue lines, respectively.

There was some variability in the length frequency between the four tagging areas (Figure 5), and in fact the variance of lengths was significantly different between areas (Levene's test, $F_3 = 4.3395$, $p = 0.005$). 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 ($F_3 = 5.86$, $p < 0.001$). A post-hoc pairwise comparison with Bonferroni correction showed that area 1 is the driver of this difference, with significant differences between areas 1 and 2 ($p = 0.045$), 1 and 3 ($p < 0.001$), and 1 and 4 ($p = 0.005$). Area 1 had the largest mean toothfish size (107.02 ±16.00 cm) and area 3 had the smallest 100.31 ± 12.37 cm). Area 1 had the largest variability in tagged toothfish size, with a standard deviation of 16.00 cm, while area 4 had the lowest variability, with a standard deviation of 11.37 cm.

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 green weight of toothfish processed (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)	Green wt (kg)	Prop. tagged	Soak time (min)
1	449	71	104.32±16.29	75 - 162	936.80	862.58	923	0.50	360
	450	52	110.69±14.97	83 - 159	805.10	743.84	982	0.45	781
1 Total		123	107.02±16.00	75 - 162	1,741.90	1,606.42	1,905	0.48	
2	452	73	105.16±14.64	61 - 140	934.30	891.40	591	0.61	360
	453	50	99.74±13.95	60 - 124	528.30	517.21	1,787	0.23	781
	463	55	103.49±16.97	64 - 140	661.40	654.55	519	0.56	360
	464	27	95.93±13.71	70 - 128	247.50	248.54	1,057	0.19	841
2 Total		205	102.18±15.26	60 - 140	2,371.50	2,311.70	3,954	0.37	
3	455	65	97.86±13.73	62 - 130	634.50	635.50	932	0.41	360
	456	83	102.57±11.90	73 - 129	953.60	921.44	400	0.70	781
	458	85	97.51±11.68	60 - 129	826.40	808.54	573	0.59	360
	459	64	103.58±11.23	82 - 128	774.20	728.49	650	0.54	721
3 Total		297	100.31±12.37	60 - 130	3,188.70	3,093.97	2,555	0.56	
4	460	78	99.36±13.09	69 - 130	814.60	793.80	916	0.47	360
	461	60	100.58±10.02	81 - 128	641.00	620.50	1,360	0.32	721
	462	65	104.80±9.61	86 - 129	778.70	759.36	1,053	0.43	360
4 Total		203	101.46±11.37	69 - 130	2,234.30	2,173.67	3,329	0.40	
Total		828	102.05±13.65	60 - 162	9,536.40	9,185.76	11,743	0.45	

The measured weight of the tagged toothfish ranged from 1.3 kg to 51.0 kg, with a mean of 11.5 kg. However, these weight measurements were taken with a digital 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 2.0 kg to 44.0 kg, with a mean of 11.1 kg. The total measured weight of toothfish tagged during the research cruise was 9,536 kg (Table 1). This represented 45% of all toothfish caught on the tagging lines (range: 23 – 70%), with very similar percentages when the comparison was made with numbers of fish (43% of fish tagged overall, range: 21 – 71%). 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 ($p = 0.18$) (Figure 6).

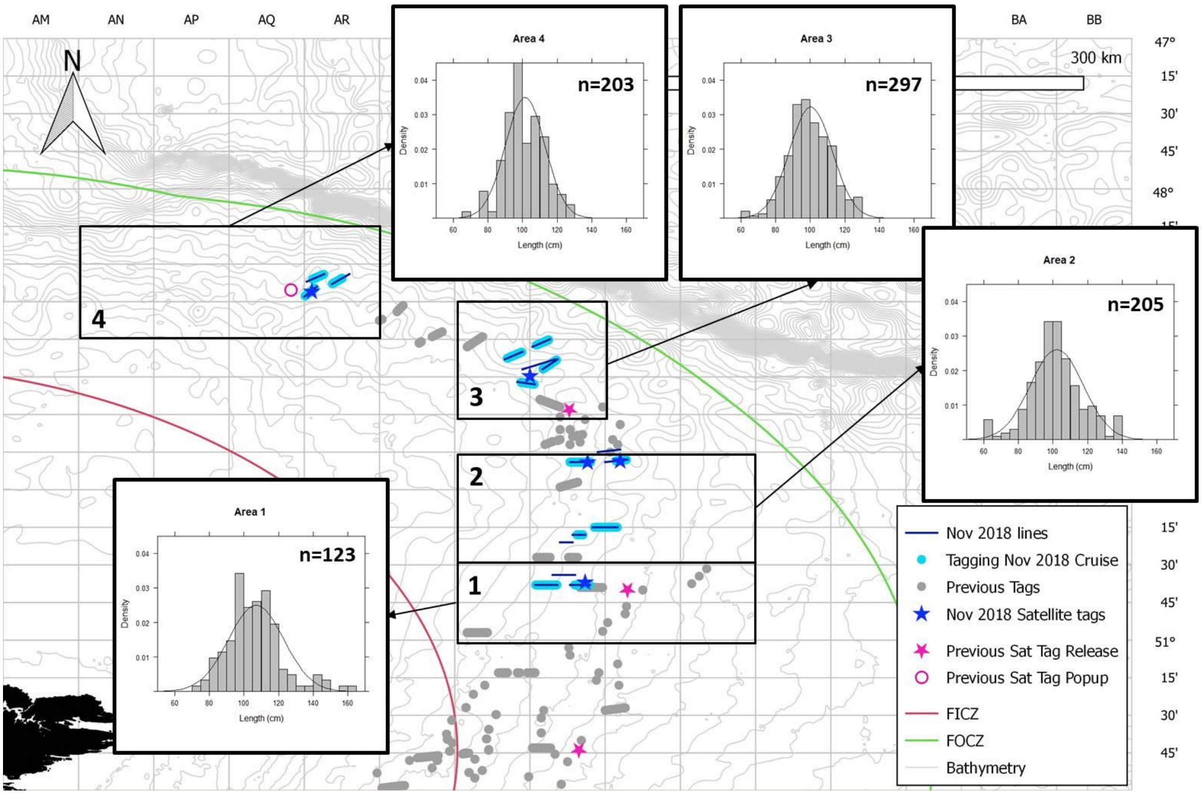

Figure 5. Map of tag release locations with length frequency histograms for each area. Blue dots represent deployed conventional tags; blue stars represent deployed satellite tags.

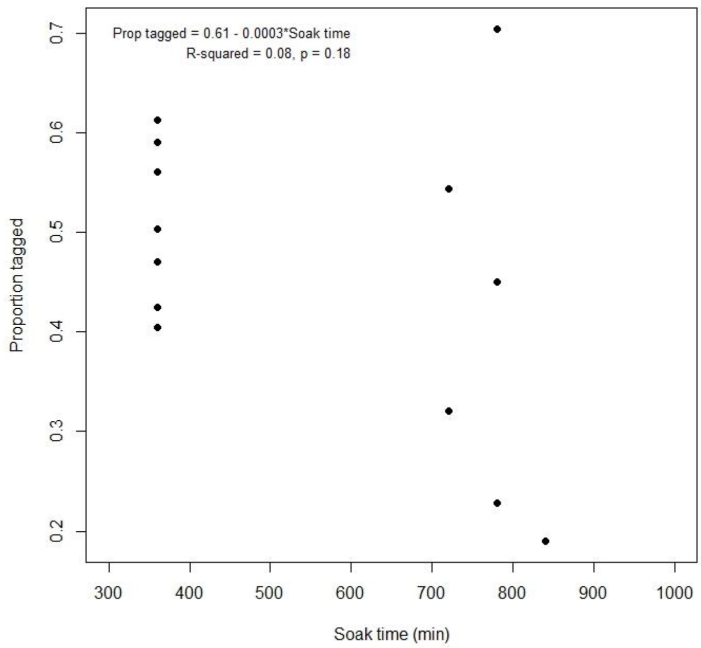

Figure 6. Proportion of tagged toothfish per line compared to the soak time of the line. The equation for the non-significant regression is shown, as is the adjusted r^2 and p-value.

In addition to conventional tags, 5 satellite tags were deployed on tagged toothfish between 119 and 130 cm (17.2 and 26.9 kg). One satellite tag was deployed in each of areas 1, 3 and 4, and two satellite tags were deployed in area 2 (Figure 5).We chose to deploy a second satellite tag in area 2 as this area had had fewer overall tags deployed. No tagged toothfish were recaptured during the February 2018 research cruise.

Underwater camera

The underwater camera was deployed a total of 8 times, once in area 1, three times in area 2 and twice each in areas 3 and 4 (Figure 7). All deployments were successful totalling over 1,200 minutes of footage.

The benthic environment differed somewhat throughout the study area, though most of the underlying sediment seemed to be quite fine (Figure 7). Certain stations seemed to have a higher proportion of some benthic organisms, such as stalked tunicates (Ascidiacea) in station 458 (Figure 7D). Other stations seemed to have more individuals of certain fish species, such as hagfish (*Myxine* sp.) at station 452 (Figure 7B). Some stations also had more hard structures than others, such as stations 463 and 465 (Figure 7G and H), although these structures were not continuously found throughout the seabed but only occasionally encountered by the camera.

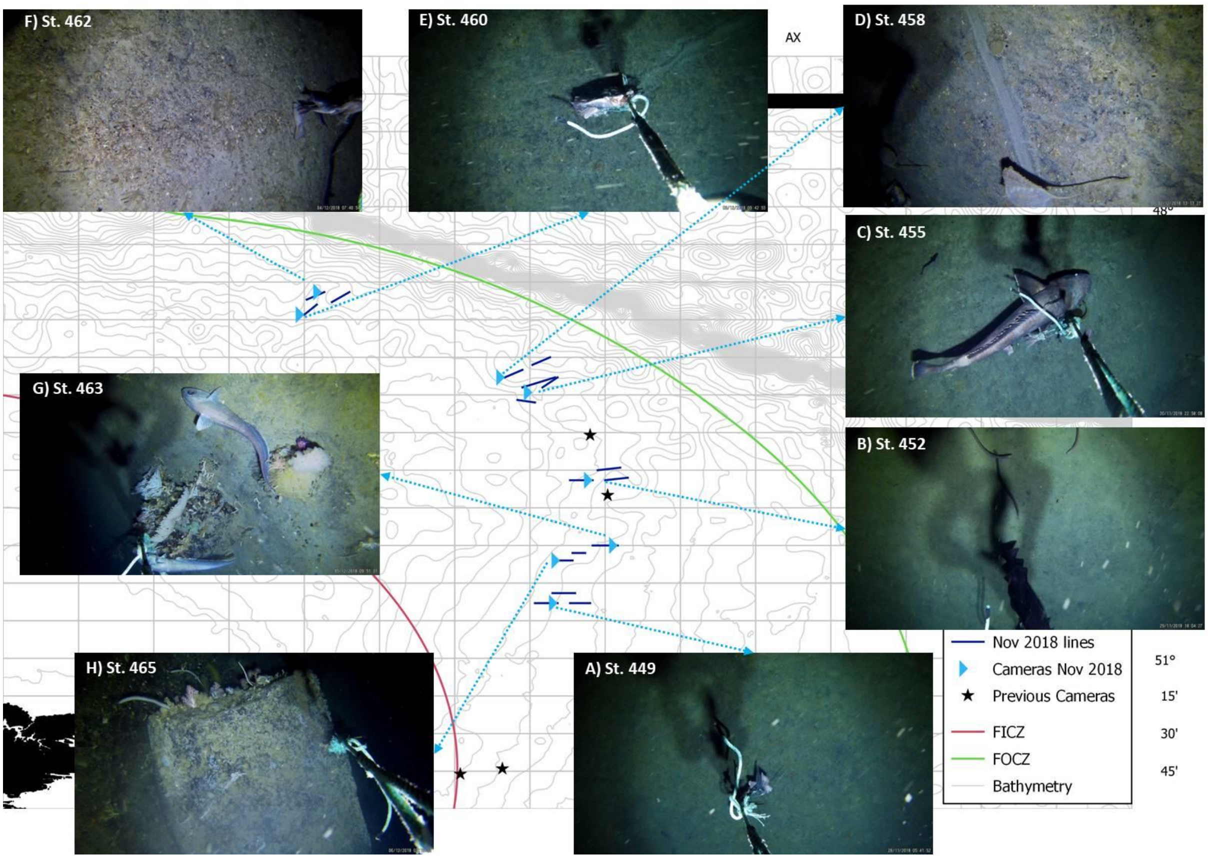

Figure 7. Map of the camera locations deployed during the February 2018 cruise. Camera locations are shown with triangles. Pictures are representative stills from the footage at each station.

The underwater camera captured footage of many organisms, including benthic sessile invertebrates (soft corals, Alcyonacea; stony corals, Scleractinia; sponges, Demospongiae; glass sponges, Hexactinellida; sea pens, Pennatulacea; sea squirts, Ascidiacea), to mobile invertebrates (*Thymops birsteini*, *Acanthoserolis schythei*, *Neolithodes diomedeae*, *astrotoma* *agassizii*), to fish (toothfish; bigeye grenadier, *Macrourus holotrachys*; blue antimora, *Antimora rostrata*; hagfish, *Myxine* sp.).

The footage also revealed some behaviour of the weight/baited hooks. 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 7E). 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 make the weight drag very slowly while soaking (Figure 7E). This happened twice during the research cruise. Once hauling started, the weight dragged at a rapid rate along the bottom, creating a furrow (Figure 7D) and occasionally impacting on benthic organisms (Figure 7G). This was the most intense impact of the fishing gear on the bottom seen during the camera deployments. However, there was no evidence of previous impacts from older lines, even in areas of high historical fishing effort. It therefore seems possible that furrows created by the weights are erased on the timescale of a few years.

Discussion

Overall, the objectives of the research cruise were achieved. A total of 828 conventional tags and 5 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 8 successful underwater camera deployments that obtained footage of the benthic environment, organisms present at depth, and the behaviour of the fishing gear.

On average, 63 toothfish were tagged per line during the November 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), and a slight increase from the February 2018 research cruise (55, Farrugia and Keningale, 2018). Toothfish tagged in November 2018 were larger than in February 2018 (102 ± 13.7 cm vs. 94.5 ± 13.1 cm), 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. The soak times of this research cruise were also kept quite low, with an average of 550 ± 215 minutes. This is significantly shorter than the soak time during the 2017 research cruise (average 1,181 ± 275 minutes, $t = -6.94$, $p < 0.001$). Correspondingly, a greater proportion by weight of toothfish were suitable for tagging per line, with 0.46 ± 0.15 in November 2018 compared to 0.30 ± 0.16 in 2017 ($t = 2.69$, $p = 0.012$). However, the tagging proportion in November 2018 was comparable to the proportion in February 2018 (0.48 ± 0.15, $t = -0.36$, $p = 0.72$), likely due to the similarity in tagging procedure and fishing behaviour.

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 José Manuel Sánchez Lema devised a secure way of attaching the camera to the branch line during the 2017 cruise. This same plan was executed diligently by the crew during the November 2018 cruise and the camera obtained valuable footage of both the environment and the fishing gear's interaction with it. Along with the previous videos, there is now a substantial database of footage from around the FICZ/FOCZ. Although a cursory look at all 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. One of the main issues had to do with weighing of the tagged toothfish. Without a marine balance available, a hanging electronic 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 display 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 7.5%, much larger than the 0.3% difference during the 2017 research cruise when a marine balance was used (Randhawa et al., 2017), but similar to the 7% difference during the February 2018 research cruise when a hanging analogue scale was used. Therefore the measured weights during the November 2018 research cruise should be seen as somewhat unreliable.

The tagging and survival of the fish seemed to be overall very successful as well. However, two situations arose during the November 2018 cruise that are important to keep in mind for future toothfish tagging efforts. First, some toothfish seemed to have swallowed some air during hauling, and although this did not directly impact their immediate survival, it may make it more difficult for them to swim back down to depth once released. This phenomenon was first observed after one satellite-tagged toothfish seemed unable to swim down immediately upon release. We suggest that future satellite tagging of toothfish avoid fish that have a bloated stomach, which can be seen and felt during the assessment period.

Secondly, the release of tagged toothfish during a few stations was impacted by seabirds and sperm whales. During one station in particular, seabirds (specifically giant petrels, *Macronectes giganteus* and *Macronectes halli*) were coming within the confines of the Brickle curtain and attacking tagged toothfish as soon as they were released. Often this only lasted a few seconds before the fish swam down beyond the reach of the birds, but occasionally, it lasted longer and the seabirds were potentially causing serious damage to the eyes and gills of the fish. In addition, sperm whales were occasionally seen near the vessel during hauling, potentially removing fish from the line. In one instance however, the Captain noticed a sperm whale moving behind the boat as one tagged fish was released, possibly eating the fish. If either of these situations arises again in the future, we suggest suspending the tagging efforts until the seabirds or sperm whales are no longer in the close vicinity of the vessel.

Finally, although the camera work was successful, there is still an issue with the ease of operating the camera and light system. The connection between the light battery and the light timer is made with relatively small gauged wire and can easily be broken during set-up and deployment, rendering the camera useless. 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. Ideally, there would also be a way of turning the system on and off, and downloading the footage without having to open up the watertight compartments. The manufacturer of this system is currently working on this.

Recommendations

We make the following recommendations to the Fisheries Department:

1. With the current tagging numbers at 3,314 toothfish, we have achieved our initial goal of tagging 3,000 toothfish by June 2019. However, since the strength of a tagging program is in its sample size, we recommend that the tagging effort continue. This can

be done both by observers deployed on the CFL *Hunter*, and during research cruises. The aim for observers 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 regular commercial fishing behaviour*** (normal commercial hauling speeds, in areas and at times when commercial fishing would take place). 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 2019. The aim should be to tag more than 500 toothfish if possible. During this next research cruise we recommend that the methods and protocols used during the November 2018 research cruise be employed (see #3 below).

3. The following adjustments to the tagging cruise protocols should be employed:
    a. An additional criterion during the assessment of tagging suitability should be employed: fish should not be selected for tagging if there is evidence of air in the stomach. This can be seen and felt externally by the bloating of the body of the toothfish, ventrally and anterior to the anal fin. When pressed, the area feels taut and bounces back immediately.
    b. Tagging should be suspended if birds are seen continuously entering the Brickle curtain and attacking released fish. Similarly, tagging should be suspended if marine mammals are seen positioning themselves directly behind the boat as they may be feeding on released fish.
    c. 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.

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*. This recommendation was made in the last cruise report (Farrugia and Keningale, 2018) and 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 FIFD.

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 November 2018 research cruise

Reusable equipment

- Small and large tag applicators
- Satellite tag applicator
- Measuring board and extra ruler
- Hanging scale (50 kg electronic)
- 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
- Plug adaptor (to European style)
- Extra SD cards
- Knives, forceps
- Tagging and recapture forms
- Protocols
- Pencils
- Permanent marker
- Clipboard
- Watch

Disposable equipment

- Rubber gloves: 3 pairs
- Tags: 828
- Satellite tags: 5
- Scalpel blades: 5
- Large plastic tubes: 3
- Otolith envelopes: 0
- Genetic vials: 3
- Ethanol: 750 mL
- Label paper