Tagging of Atlantic bluefin tuna (*Thunnus thynnus*) with pop-up satellite archival tags (PSAT) in western Norway during 2018

Keno Ferter[1], Sean Tracey[2], Jan Hinriksson[1], Otte Bjelland[1], Iñigo Onandia[3], Leif Nøttestad[1]

[1] Institute of Marine Research, Bergen, Norway

[2] University of Tasmania, Institute of Marine and Antarctic Studies, Hobart, Tasmania

[3] Azti-Tecnalia, Sukarrieta (Bizkaia), Spain

Corresponding author and project leader: Keno Ferter, Keno@hi.no, phone: +47 94103552

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Executive summary

During the last decade, Atlantic bluefin tuna (ABFT) has been reoccurring in increasing numbers along the coast of Norway. To study behavior, migration and general ecology of ABFT reappearing in Norway, the Institute of Marine Research initiated a tagging program of ABFT along the western coast of Norway between the 24th of August and 30th of September 2018. The aim was to collect genetic samples of 20 ABFT and tag these fish with pop-up satellite archival tags and conventional tags along the coastline outside Bergen. In total, 22 voluntary angling teams were selected through an application process to capture ABFT with rod-and-reel. However, due to technical and logistical issues, only nine angling teams took part in the fishing at the end, with an average of three boats per fishing day. The tagging was coordinated by the Institute of Marine Research and conducted by contracted tagging experts. A total of twelve fishing days were performed, which were substantially fewer days than planned due to unusually long periods with strong winds during September. Two ABFT (FL 240 cm and 235 cm) were landed during the project period. Genetic samples for these two fish were collected and they were tagged prior to release. Sampling and tagging of both fish were done in the water next to the boat, and the handling worked well. While one of the individuals died shortly after the release, the other individual had its PSAT attached for 33 days. The PSAT of the latter individual detached early due to premature tag shedding north-west of Ireland, but the ABFT was alive at the time of tag loss. Within the 33 days of deployment, the ABFT did substantial horizontal and vertical movements. The results of this project contribute to the understanding of the migration and ecology of this species at the northernmost border of its natural distribution range.

Introduction

In the 1950s and 1960s, Norway had one of the largest fisheries for Atlantic bluefin tuna (ABFT) (*Thunnus thynnus*) in the North Eastern Atlantic. Annual landings were up to 15 000 tons, but ABFT disappeared gradually over the following decades, and observations were too rare to maintain a commercial fishery. In summer 2013, however, increasing amounts of ABFT were observed along the coast of Norway and one individual was caught as bycatch by a commercial purse seiner fishing for western horse mackerel. During the following years, observations increased in space and time from year to year, and several catches have been taken by commercial fishing vessels since 2014 (Nøttestad et al., 2017).

In 2008, the International Commission for the Conservation of Atlantic Tunas (ICCAT) implemented an Atlantic-Wide Research Program for ABFT (Grand Bluefin Tuna Year Programme - GBYP). The main objectives of the GBYP are (1) improving basic data collection, (2) improving the understanding of biological and ecological processes, and (3) improving assessment models and providing scientific advice on stock status. Tagging with conventional and electronic tags is one of the main activities of the GBYP program to investigate natural mortality rates, growth and migration patterns (ICCAT, 2018).

Tagging of ABFT with conventional tags and pressure tags was done along the Norwegian coast in the 1950s and 1960s (e.g. Hamre, 1959, Hamre, 1964). These tag-recapture studies investigated the migration routes and ecology of ABFT that appeared in Norwegian waters, and increased our knowledge of the species substantially. During recent decades, electronic tags have been developed which enable researchers to study fish behavior in more detail (Donaldson et al., 2008). While many of these electronic tags rely on recapture (e.g. data storage tags) or signal receivers in the proximity of the tagged fish (e.g. acoustic tags), pop-up archival satellite tags (PSATs) store data during deployment and send those data via a satellite to the researcher (Block et al., 1998). PSATs collect and store data on, amongst others, ambient light, pressure, and temperature and detach after a pre-programmed period from the fish. Once detached from the fish, the tag floats to the surface and sends the stored data via the ARGOS system. PSATs have been used to study ABFT behavior and ecology for many years in the Atlantic Ocean (Block et al., 2005, Tensek et al., 2017). In 2017, the first ABFT were tagged with PSATs in Scandinavian waters (MacKenzie et al., 2017) as part of the ICCAT GBYP – Phase 7. MacKenzie et al. (2017) tagged eighteen ABFT in total during September 2017, of which fourteen were tagged in Sweden and four in Denmark.

To gain more knowledge of the migration and ecology of ABFT in Norwegian waters, the Institute of Marine Research in Norway initiated a tagging program in 2018 as part of the GBYP 2018 – Phase 8. The aim of this project was to collect genetic samples of twenty ABFT and tag these fish with PSATs and conventional tags during their feeding period along the coastline outside Bergen.

Materials and Methods

Study area and period

The study was conducted west of the island Sotra, Hordaland county, in western Norway between the 24th of August and 30th of September 2018 (see figure 1). The area was chosen mainly because it was one of the main historic fishing sites for ABFT, and as many observations and commercial catches were made in this area in 2017. Twelve fishing days were conducted in total which was substantially less than planned, due to unusually bad weather during the project period (table 1). Surface water temperatures ranged between 13° C and 16.5° C (measured with a conventional echosounder). All experimental procedures were approved by the Norwegian Food Safety Authority (FOTS ID 16300) and the Norwegian Directorate of Fisheries.

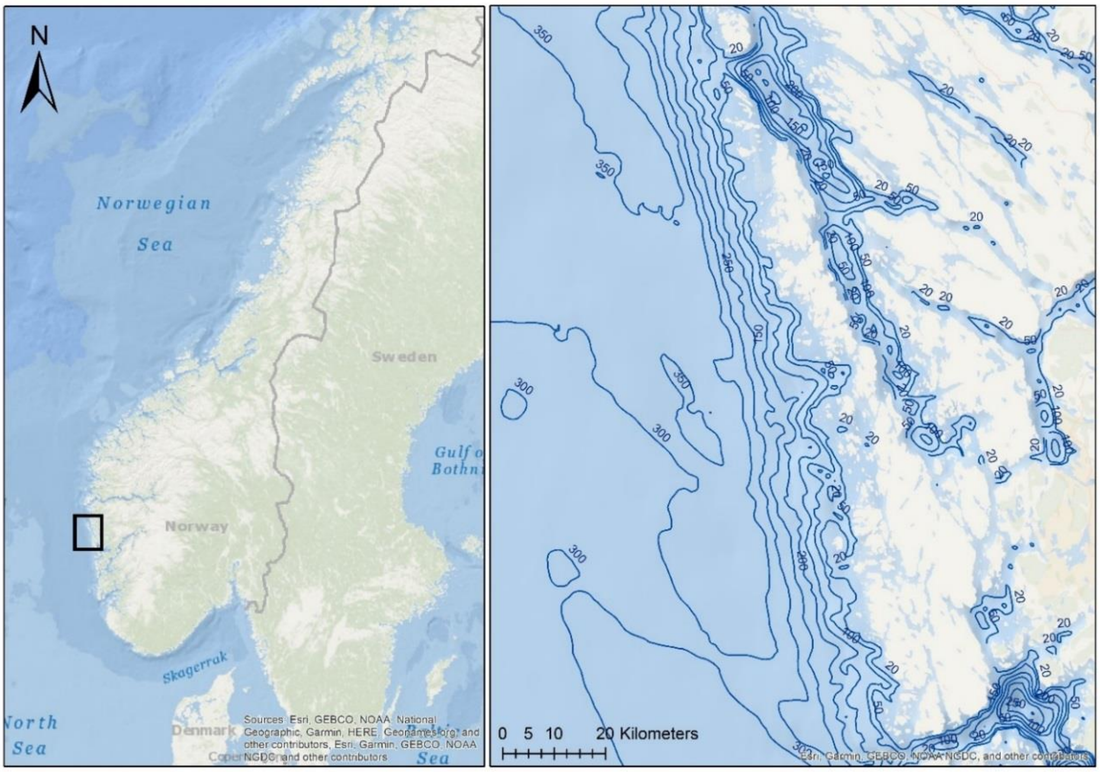

Figure 1: Map of study area

Table 1: Overview of the study period with number of boats fishing each day, duration of the fishing days and the number of ABFT bites, ABFT hooked and ABFT landed.

Date	Number of boats	Start time	End time	Hours fished	Bites	Fish hooked	Fish landed
24.08.2018	5	07:00	19:00	12.00	0	0	0
25.08.2018	5	07:00	19:00	12.00	0	0	0
26.08.2018	5	07:00	19:30	12.50	1	1	0
27.08.2018	4	08:00	19:30	11.50	0	0	0
28.08.2018	3	06:00	18:00	12.00	0	0	0
29.08.2018				Bad weather			
30.08.2018	1	07:00	18:30	11.50	1	1	1
31.08.2018	3	09:00	20:35	11.50	1	0	0
01.09.2018				Bad weather			
02.09.2018				Bad weather			
03.09.2018				Bad weather			
04.09.2018				No fishing boats available			
05.09.2018	1	13:00	19:30	6.50	0	0	0
06.09.2018				No fishing boats available			
07.09.2018	3	07:30	19:00	11.50	3	1	0
08.09.2018	4	07:30	19:20	12.00	2	1	1
09.09.2018				Bad weather			
10.09.2018				Bad weather			
11.09.2018				Bad weather			
12.09.2018				Bad weather			
13.09.2018				Bad weather			
14.09.2018				Bad weather			
15.09.2018				Bad weather			
16.09.2018				Bad weather			
17.09.2018				Bad weather			
18.09.2018				Bad weather			
19.09.2018				Bad weather			
20.09.2018				Bad weather			
21.09.2018				Bad weather			
22.09.2018				Bad weather			
23.09.2018				Bad weather			
24.09.2018				Bad weather			
25.09.2018				Bad weather			
26.09.2018				Bad weather			
27.09.2018	1	07:00	14:00	7.00	0	0	0
28.09.2018	3	14:00	18:30	4.50	0	0	0
29.09.2018				Bad weather			
30.09.2018				Bad weather			

Selection of voluntary anglers

Rod-and-reel angling was chosen as a fishing method to catch ABFT for tagging. The main advantage with this method is that, in contrast to most other fishing methods, no physical contact with the fish is required apart from the hooking during the capture process, which results in very high post-release survival chances if angling duration is kept to a minimum by using heavy fishing tackle (Stokesbury et al., 2011, MacKenzie et al., 2017). As angling for ABFT is forbidden by law in Norway, a list of selection criteria were established based on experience from the project on Sweden and Denmark in 2017, and input from recreational ABFT fishing experts. Anglers were encouraged to apply as teams (minimum 3 persons) with designated team leaders and boat skippers. In total, 36 applications were received, and 22 teams were selected based on their experience, available fishing gear and boats. However, due to technical, logistical and personal issues, only nine angling teams took part in the fishing in the end, with an average of three boats per fishing day

Fishing equipment and fishing methods

The fishing gear used was in the 80-130 lbs or 130 lbs-unlimited range. Anglers were encouraged to install reinforced rod holders on their boats to be able to fight the fish with the rod inside the rod holder. However, if preferred, anglers were also allowed to fight the fish stand-up as long as fighting time was kept as short as possible.

Dead bait and trolling with spreader bars were used as fishing methods by the anglers during the majority of fishing days. Live bait (e.g. alive Northeast Atlantic mackerel (*Scomber scombrus*)) was suggested by experts as the most effective way to catch ABFT on heavy fishing gear. However, the use of live bait is forbidden by law in Norway. Therefore, the Institute of Marine Research applied for an exemption from this regulation which initially was not granted by the Norwegian Food Safety Authority. After a complaint by the Institute of Marine Research, the Norwegian Food Safety Authority granted an exemption to use live bait with several restrictions from the afternoon on the 7th September 2018. However, due to weather conditions, live bait could only be tested on some fishing days in a limited manner.

Tagging protocol

The tagging team was placed on a separate boat (Arronet 23 5 CC), and was called via mobile phone or VHF once an ABFT was hooked by an angling team. Once the ABFT was close to the boat, a large, barbless hook with a rope was placed into the lower jaw of the ABFT (figure 2). The tail of the fish was stabilized with a wide gap crook during tagging (figure 3). The fish were tagged with one PSAT with a Domeier anchor (MiniPat-348, Wildlife Computers, 365 days deployment duration, constant pressure release after three days) and one conventional spaghetti tag following the instructions in the ICCAT-GBYP tagging manual (Cort et al., 2010). Once tagged, the fork length of the fish was measured and a fin clip was taken for genetic analysis. The fin clip was divided into two parts and stored in > 99.0 % ethanol at 4˚C.

This operation was done from the anglers' boat for the first fish, but the second fish was transferred to the tagging boat from which both tagging and sampling were performed (figure 4). After tagging, the fish were restituted for several minutes before they were released.

Data analysis

The recorded PSAT data were accessed via the Wildlife Computers online portal (https://wildlifecomputers.com/). The most likely positions of the second ABFT in this study were modelled using the GPE3 function, where swimming speed was set to 5 m/s.

Figure 2: Illustration picture for hook placement in the lower jaw for holding the fish next to the boat during tagging.

Figure 3: The tail of the ABFT was stabilized using a large gap crook during tagging. This picture was taken during the PSAT tagging of the first fish.

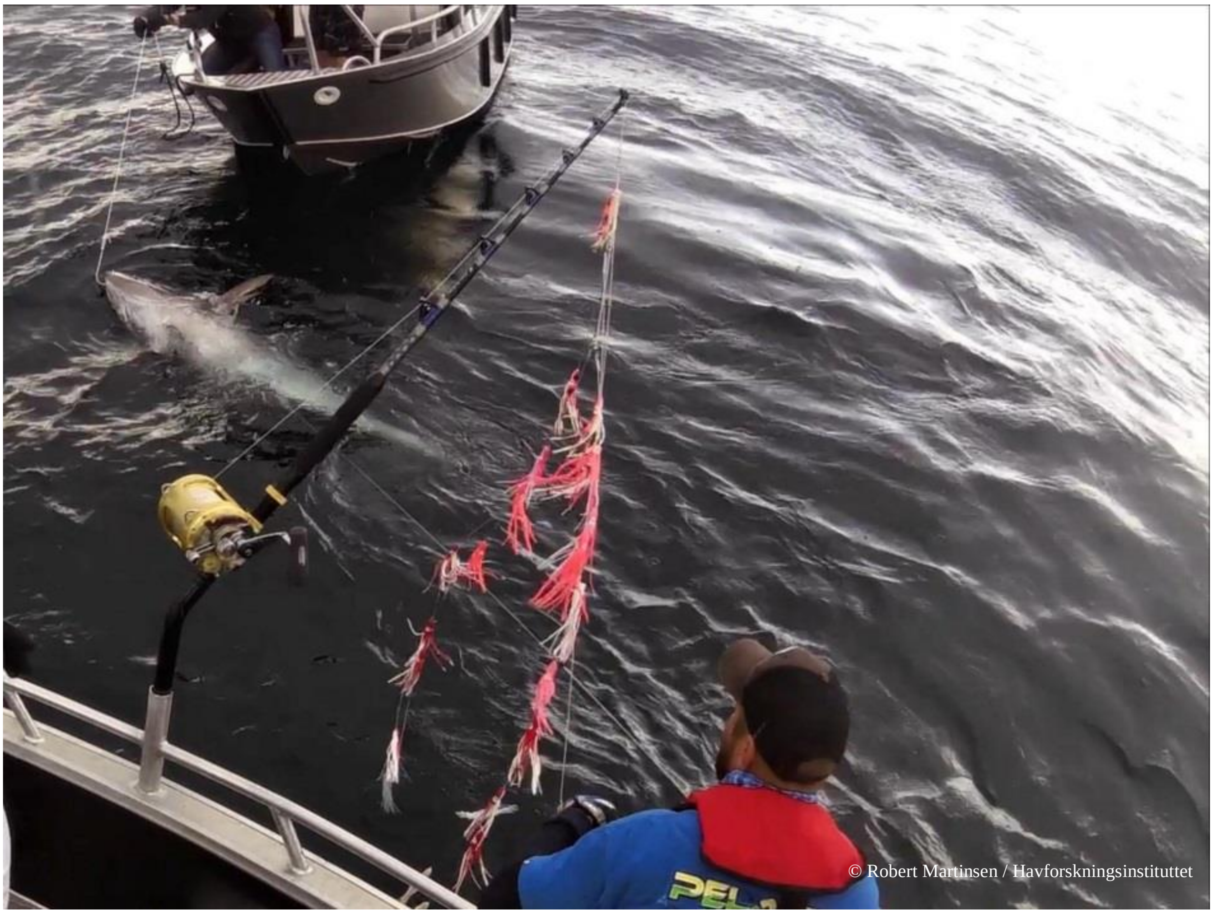

Figure 4: Transfer of the second ABFT in this study from the anglers' boat to the tagging boat from which both the tagging and biological sampling was done.

Results

During the twelve fishing days, the angling teams had eight bites, four hook-ups and two fish were landed successfully (tables 1 and 2). One of the lost fish broke the leader close to the hook, while the other lost fish straightened the hook. All bites, but one, were during active trolling with spreader bars and/or dead bait. One bite was during stationary fishing with a balloon and mackerel as live bait.

Table 2: Overview of the two ABFT tagged along the western coast of Norway in 2018.

Date	ID	Boat ID	Release time	Release position	FL [cm]	Angling duration [min]	PSAT ID	Pop-up date	Conventional
30.08.18	1	Team 14	20:35	N 60.22 E 4.91	240	117	18P0249	03.09.2018	N/A[a]
08.09.18	2	Team 2	17:40	N 60.32 E 4.79	235	45	18P0303	11.10.2018	BYP029426

[a] This fish was only tagged with a PSAT as dart of the conventional tag got damaged during tagging.

The two ABFT landed were 240 cm (ID 1) and 235 cm (ID 2), respectively (table 2). Both fish were caught and tagged in the southern part of the study area (figure 5). The angling duration for the first fish (117 min) was substantially longer than for the second fish (45 min).

None of the fish had any physical damage, but the first fish seemed to be more exhausted than the second fish. The PSAT tag of the first fish surfaced after three days due to constant pressure release, indicating that this fish had died shortly after the release. The PSAT of the second fish surfaced after 33 days of deployment due to premature tag shedding while the fish was alive (pin was intact at release).

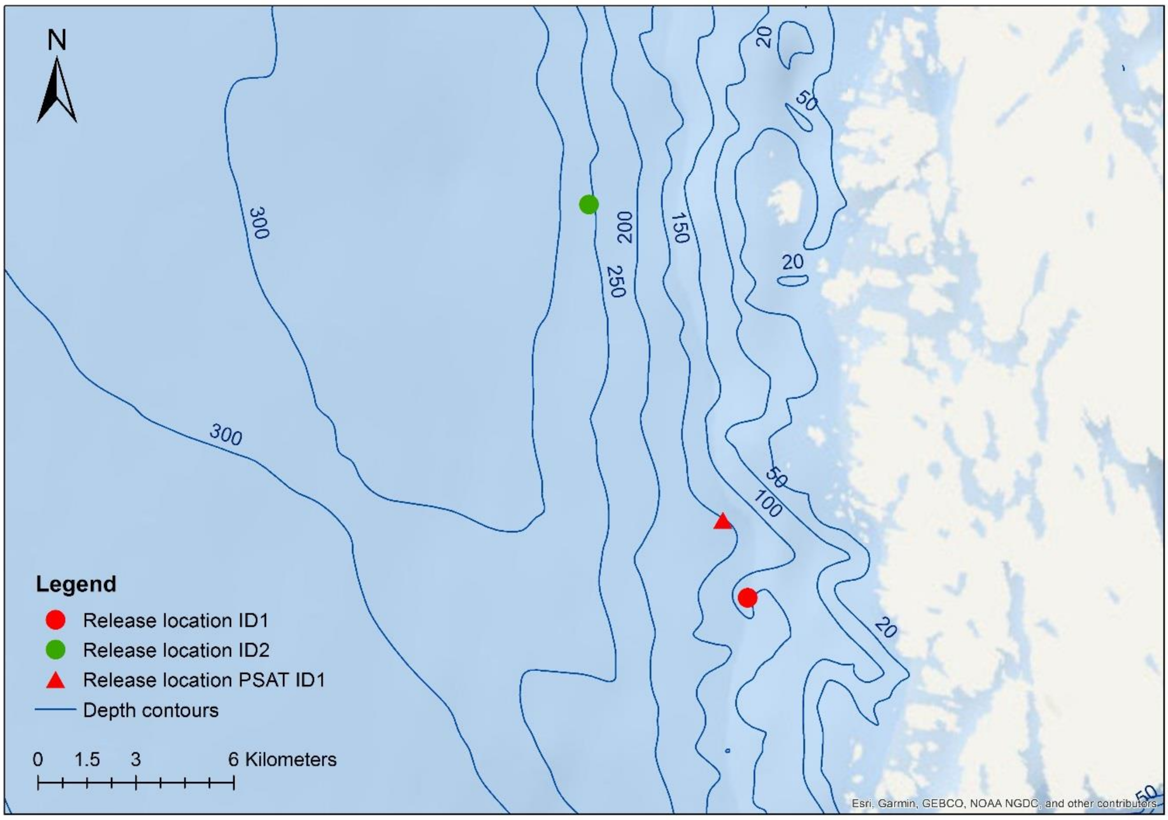

Figure 5: Map showing the capture and tagging locations for the two ABFT landed in this study, and the tag release location for the first fish tagged.

The data recorded by the PSAT of the second ABFT tagged in this study showed substantial vertical and horizontal movements during the 33 days of deployment. The recorded vertical movements ranged from 0.5 m to 487 m depth, and recorded water temperatures ranged from 3.5 °C to 17.2 °C. The maximum likelihood track indicates that the ABFT first swam southwards, before moving back to the Norwegian coast. Afterwards, the fish swam westwards and crossed the Norwegian Sea north of Shetland, before it turned southwards heading towards waters west of Ireland (Figure 6).

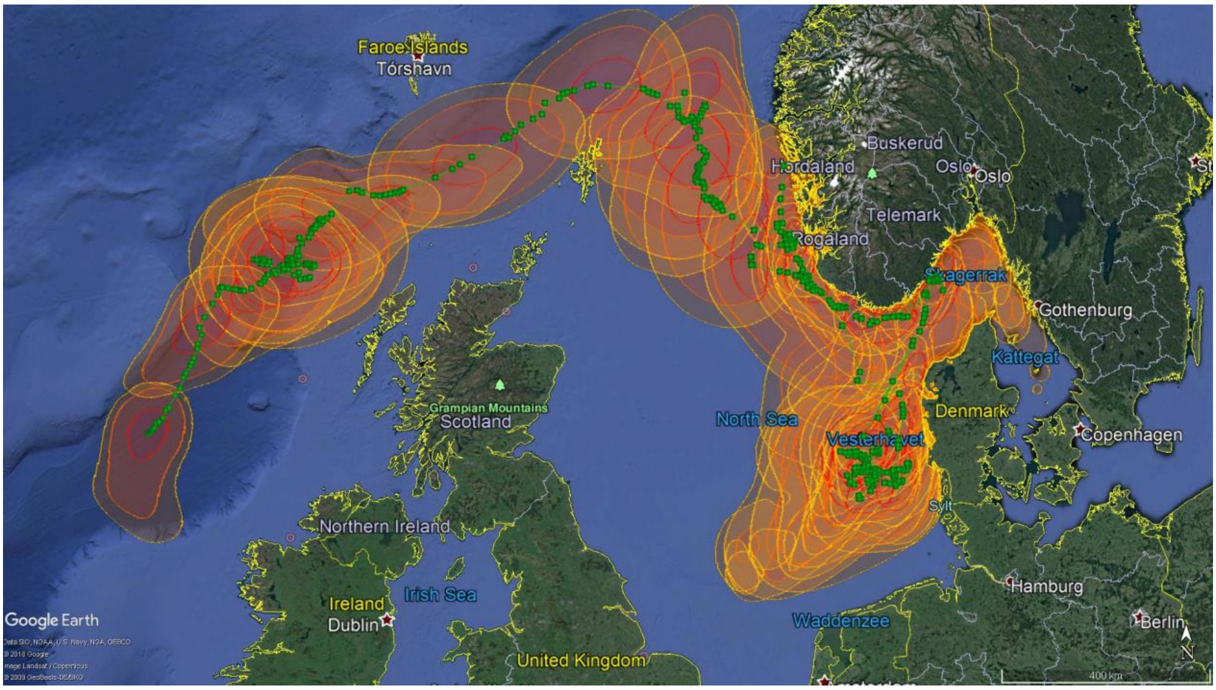

Figure 6: Maximum likelihood locations and track for the second ABFT (ID 2) based on 33 days of tag deployment and an assumed animal speed of 5 m/s.

Discussion and concluding remarks

This study was the first to tag ABFT with PSATs in Norwegian waters with the aim to study the migration and ecology of this species at the northernmost border of its distribution range (Nøttestad et al., 2017). Moreover, this project yielded substantial and valuable knowledge of ABFT angling with rod-and-reel along the west coast of Norway, and the involvement of voluntary anglers in research projects.

Rod-and-reel angling has been proven to be a suitable method for catching ABFT for tagging purposes along the coast of Norway, but some lessons were learned in this year's project. The first fish died shortly after the release, even though post-release survival of ABFT has been shown to be very high in other studies (Stokesbury et al., 2011). One possible explanation could be that the angling duration was stretched longer than necessary for this particular fish, because the tagging boat took longer than planned to reach the angling boat due to increasing winds. Even though an angling duration of two hours may be acceptable, this individual may have been too exhausted to recover from the capture and tagging event (Bartholomew and Bohnsack, 2005). In addition, restitution of the fish was difficult due to the increasing wind and higher waves. While these are possible explanations for the mortality of this fish, other factors could have played a role and a definite cause of mortality could not be determined. However, as a direct consequence of this mortality event, the tagging boat made sure to be within short distance from all angling boats throughout the remaining project period.

While the first fish was tagged from the anglers' boat, the second fish was tagged from the tagging boat. To do this, the fish was transferred from the anglers' boat to the tagging boat using a rope which was attached to the large hook in the lower jaw of the fish. As there is variation in experience of anglers, space on the anglers' boat and general boat design, transferring the fish to the tagging boat is the preferred method for the future. However, in some cases, it may be easier to transfer the researcher to the angler's boat which works, if the anglers' boat is well suited and the anglers are experienced in handling large pelagic fish. Yet, tagging the ABFT from the tagging boat ensures that all fish handling and tagging can be performed by trained research personal from a suitable vessel and in a standardized manner. The distance from the gunwale to the water surface of the tagging boat used in this project was low, making it easy to handle the fish inside the water, and to place the tag properly. On-board tagging has been discussed as an option and has been used in other studies (Block et al., 2005, MacKenzie et al., 2017), as it potentially leads to lower premature tag loss. The downside with on-board tagging is that a specially designed vessel is required to minimize potential negative impacts on the fish, which may have animal welfare implications and potentially reduce post-release survival. In this study, the in-water tagging worked well and it was possible to place both PSATs as described in the GBYP tagging manual (Cort et al., 2010). However, the PSAT of the second ABFT got shed prematurely 33 days after tagging, so some adjustments to the tagging method are recommended, e.g. the use of a different anchor. Captive observation experiments comparing on-board tagging versus in-water tagging are recommended to estimate tag shedding rates.

There were ABFT observations in the fishing area both at the surface and on the echosounder on almost every fishing day, indicating that ABFT were around from the beginning to the end of the project period. Even though most fish contacts were on spreader bars or dead bait during trolling, live bait may still have a higher catch efficiency. However, this could not be tested thoroughly in this study, as the use of live bait was only allowed on a small fraction of all possible fishing days. The final permission to use live bait came unexpectedly on the 7th of September, and most angling teams were rigged and prepared to do trolling at this point. Moreover, the weather and sea conditions on the last two days of the project period did not allow for testing of live bait with stationary balloon fishing. Angling effort was lower than expected due to technical, logistical and personal issues, as only nine out of the 22 selected angling teams fished in this project. In the future, it is thus important to confirm angling team availability before the project starts and consider incentives to make sure that most teams have the possibility to take part in the fishing. Moreover, the project period should be expanded (e.g. from mid-August to the end of October), as strong winds over several weeks made fishing impossible during most part of September.

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