Tagging Atlantic bluefin tuna from a Mediterranean spawning ground using a purse seiner

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TAGGING ATLANTIC BLUEFIN TUNA FROM A MEDITERRANEAN SPAWNING GROUND USING A PURSE SEINER

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ABSTRACT

Atlantic bluefin tuna, *Thunnus thynnus*, is as an emblematic and commercially valuable large pelagic species. In the past ten years, the purse seiner fishery in the Mediterranean has been representing more than 50% of the catch and dominates its exploitation. Nowadays, purse seiners target large fish and operate during the spawning season in the spawning grounds. Electronic tagging has shed a considerable amount of light on the ecology and behaviour of bluefin tuna over the past twenty years. However, such technique has hardly been applied on large bluefin tunas caught by the Mediterranean purse seine fishery despite its major importance. The logistical constraints related to this specific

fishery, combined with the timing of migration of the fish and the requirements related to the handling of such large animals to enable tagging in good conditions have made tagging from purse seines complex. Here we detail such an operation, designed to bridge the knowledge gap on the migratory behaviour of tunas targeted by the purse seine fishery. Three large bluefin tunas from the same school were tagged during the fishing operation of a French purse seiner. The fish were tagged onboard in less than 2 min and efficiently, avoiding any subsequent mortality. One fish migrated up to Ireland, one was recaptured in the Alboran sea and the last one remained in Libyan waters. These results contrast with those from tagging operations carried out in the Northwest Mediterranean, which underlies the importance of tagging operations from purse seiners not only for understanding fundamental aspects of the species behaviour, but also for accurately describing the movements of the eastern Atlantic bluefin tuna stock in the context of its management.

Keywords: Large Atlantic Bluefin Tuna; Eastern Atlantic and Mediterranean stock; Electronic Tagging; Purse Seiner; Migrations

1.INTRODUCTION

Atlantic Bluefin Tuna (*Thunnus thynnus*, thereafter referred as BFT) is an emblematic species, whose individuals can migrate across the Atlantic Ocean (Block et al., 2001; Fromentin and Powers, 2005; Rooker et al., 2007). BFT is currently managed as two-stocks, Western and Eastern, by the International Commission for the Conservation of Atlantic Tunas (ICCAT), but the two stocks display a substantial amount of mixing (Puncher et al., 2018). The Eastern stock is much larger than the Western one and Eastern catches represent about 90% of the total catch (ICCAT 2018 - task I). After a complex history of over-exploitation, successive stock assessments since 2008 have shown that the Eastern stock was recovering and increasing quotas were adopted (ICCAT, 2017). In 2017, the TAC for the Eastern stock was set to be 28000 tons in 2018, 32000 tons in 2019 and 36000 tons by 2020.

The Eastern stock is exploited by 25 countries and 11 different types of gears. Most of the catch, 66% in 2017, is made in the Mediterranean and is largely dominated by the purse seiners. Purse seine catches represent more than 90% of the Mediterranean catches and have been representing more than 50% of the overall Eastern stock catches over the past ten years (ICCAT 2018 - task I). They operate during a reduced season in space and time, mostly during June and concentrate on the spawning aggregations in the Balearic Islands, around Sicily and Malta, further south to Tunisia and off Turkey in the East, Libyan waters being now unexploited. This fishery has been managed by strict control measures since the enforcement of the Recovery Plan in the mid 2000s (ICCAT, 2017). The Croatian purse seiners in the Adriatic differ from the other purse seiners as they exploit substantially smaller fish (< 4 year-old). Over the past ten years, the largest purse seiner catch has been France, followed by Tunisia and Spain, representing 25%, 17% and 14% of the purse seine catch, respectively. The BFT caught by the purse seine fishery is predominantly transferred to farms, where the fish are caged and fattened until harvested.

Since the late 1990s, electronic tagging has shed a considerable amount of light on the ecology of BFT (Block et al., 2005; Fromentin and Lopuszanski, 2014; Teo et al., 2007). Electronic tags log temperature, pressure and light and transmit this information via the Argos satellite system after a pre-defined duration before release, often set between a few months and one year. This data allows scientists to reconstruct the trajectory of the tagged fish in time and space. A large number of tags have been deployed on BFT since this technique existed, covering various fleets and parts of the species' life cycle, with the aim of describing as accurately as possible its migratory routes and understanding the variability of these migrations (Abascal et al., 2016; Aranda et al., 2013; Arregui et al., 2018; Cermeño et al., 2015; Fromentin and Lopuszanski, 2014; Galuardi et al., 2010; Galuardi and Lutcavage, 2012). Tagging data are useful for management (Hays et al., 2019) and ICCAT has its own tagging program coordinated by the Atlantic-Wide Research Program for Bluefin Tuna (GBYP). The tracks obtained by tags deployed on BFT are used by the ICCAT Standing Committee on Research and Statistics (SCRS) working group not only to improve the understanding on the ecology of the species, but also to calibrate spatially explicit models, for instance in the context of the Management Strategy Evaluation process (ICCAT MSE). Since the start of the use of this technique, and owing to a larger research effort, substantially more tags have been deployed in the Western Atlantic than in the Eastern Atlantic and Mediterranean. This uneven tagging effort is the opposite to the catch intensity as the Western area only weighs about a tenth of the total catch.

Tagging BFT is not a trivial operation, specifically when the individual is large (e.g. > 70kg), as it requires a skilled crew, suitable boat and material to catch and appropriately handle these animals for tagging purpose (Rouyer et al., 2019). This constraints the ability of scientists to realize large-scale deployments of tags on large BFT and requires specific logistics. Rod and reel (recreative or professionnal) and traps are fishing gears that can provide fruitful opportunities for tagging BFT from the eastern stock. However this still leaves a deficiency of tagging in the main fishing segment, i. e. purse seined fish. Attempts for tagging purse seined BFT were made in the US coast (Wilson et al.,

2005), but tagging large fish from a purse seiner on the Mediterranean spawning grounds, the main and key fishing segment of the eastern stock, has not been covered by tagging activities carried out by the international scientific community.

The migratory behaviour of BFT is at the essence of the purse seine fishery, as it benefits from the spawning behaviour of BFT, which aggregates for spawning in specific areas over a short amount of time, typically mid-May to mid-July. In the northwestern Mediterranean BFT has been shown to display strong residency (Cermeño et al., 2015; Fromentin and Lopuszanski, 2014), whereas Atlantic individuals typically migrate within the Mediterranean in early spring and depart in July-August, often seen as catches by the Morrocan and Portuguese traps (Fromentin and Powers, 2005; Rooker et al., 2007). Catches of purse seiners are composed by fish gathering in the spawning grounds in the Mediterranean. Understanding the migrations routes of the BFT targeted by the purse seiners is therefore of importance for the fishery and the conservation of the species, specifically to assess the relative importance of BFT exiting the Mediterranean after spawning.

Here we describe a tagging operation designed as a first step to address these aspects. After previous work using farming cages to set-up a protocol to efficiently tag BFT (Rouyer et al., 2019), an attempt was made to transfer the protocol to a purse seiner during the 2018 fishing season to assess the feasibility of such an operation on larger fish. The French purse seiners operate in two main fishing grounds, the Balearic Islands and Malta, which are both well documented spawning grounds in the Mediterranean. Two French purse seiner operating off Malta were used for the operation. The tracks obtained from the tagged BFT are then compared to tracks obtained from tagging operations in the Gulf of Lions (french Mediterranean), which target a different component of the population in terms of age and behaviour. As tag data serve as input for connectivity/migration matrices used in spatially explicit models, it is critical to collect information about the migration patterns from large individuals targeted by purse seiners in the Mediterranean Sea.

2.MATERIAL AND RMETHODS

As tagging from a purse seiner involves complex logistics, the protocol has first been set-up in cooperation with a Maltese fattening farm, MFF Ltd and has been described in Rouyer et al., 2019. Tagging from a cage allowed to remove important constraints, such as the variability of the meteorological conditions and the availability of fish, but also allowed to operate on fish with a lower stress level as they are used to be held in a confined space. The following sections describe the transposition of this protocol to a purse seiner.

2.1.Purse seine set

The French purse seine fishery operates mostly south of the Balearic Islands and south of Malta. The purse seiner vessels that participated in this operation were the Saint Sophie François II (SSFII, ICCAT serial number ATEUFRA00064) and the Saint Sophie François III (SSFIII, ICCAT serial number ATEUFRA00065). The tagging team embarked on the purse seiner SSFIII from the harbour of Birzebugga (Malta), on the 19th of June 2018, to rejoin the other vessels scouting the waters south of Malta in search of BFT schools. The period was chosen late enough to avoid the bulk of the fishing season associated with a higher probability of recapture, but early enough so that the post-spawning migration was not at its highest and suitable meteorological conditions could be met. Flat sea and sunny clear sky not only facilitate the operation, but also ensure that the fish remain as calm as possible during the operation and would accept to be fed inside the purse seine for the tagging operation. Such conditions were met the next day, on the 20th of June 2018 (Fig. 1). A school detected in the early morning was captured by SSFII. A transfer cage was organised to transfer the fish the next day, which left the whole day for the tagging trials. Dinghies were deployed around the purse seine to maintain it opened until the transfer cage arrived.

2.2.Personnel and equipment

The purse-seiner SSFIII worked with his sistership SSFII and both crews, 13 people each, are combined during the fishing and subsequent caging operations. Both ships have large decks and are equipped with cranes. A piece of synthetic turf and a thick mattress were laid onto the free deck space, so that the fish could be positioned appropriately for the tagging operation without hurting its lateral line (Fig. 2). The location on the deck was also chosen so that the head of the fish could easily be accessed by a sea water pump to supply the fish with oxygen while being held out of the water. One crane was equipped with a stretcher specifically designed for such an operation, made of smooth material to avoid scraping the fish skin and punctured with holes to let the water through. The stretcher opening was equipped with a chain so that the fish could easily be maneuvered into it, whereas its other end was closed with a rope, so that the fish would be held on the stretcher while being maneuvered in the water and lifted onto the deck. The rope was designed to be easy to remove once the fish needed to be released back into the sea. One crew member was tasked with operating the handline. Two scientists were assigned the task to deploy the tags. One scientist was tasked with covering the eyes and maintaining the water pipe into the mouth of the tuna and another one with measuring the fish (curved forked length). Two crew members were tasked with removing the hook with as much care as possible to avoid injuries. Three divers helped to maneuver the fish into the stretcher placed into the water. One crew member operated the crane with the stretcher to move the fish on the deck and in and out of the water as quickly and smoothly as possible. The ICCAT Regional Observers on each of the fishing boat were present during the whole operation.

2.3.Tagging

Wildlife Computers' minipats were used for the deployments. They were programmed to remain attached on the fish over the course of one year. The tether was 15cm long and equipped with a large Domeier anchor. A second anchor was added to reduce the lateral movements of the tag that could hurt the fish and reduce deployment times (Fromentin and Lopuszanski, 2014). The main anchor of the tags was inserted onto the base of the second dorsal fin. This location enables the anchor to get tangled into hard bones, which increases the probability of long retention times (Cort et al., 2010). The second anchor was directly inserted into the flesh. Chlorhexidine was used to treat all the material before deployments.

The fish caught in the purse seine was fed with frozen sardine in order to induce feeding behaviour. A long handline was prepared with hooks used by maltese longliners. A buoy was attached to the mainline to help keeping the tuna at the surface. The hook was baited with frozen sardine and the line was deployed in the purse seine. The purse seine was deployed to about 500m long and the fishing boat was far from the center of the seine. Thus, the handline was deployed using a small boat placed into the purse seine while baiting with frozen sardine, which concentrated the tunas and induced feeding behaviour. The line was left sinking a few seconds and was towed back towards the purse seiner. Once a tuna took the bait, the fish was towed back by the fishermen as quickly and smoothly as possible to avoid exhaustion of the fish or to break the line. The school caught by the purse seiner was composed of large fish, whose acceleration when taking the bait was so intense that the line often broke. Once the fish was close enough to the purse seiner, the stretcher was deployed and the divers maneuvered the fish into it. The stretcher was then lifted onto the mattress on the deck, where the eyes of the tuna were immediately covered with a wet cloth and the water pipe inserted into its mouth. While the hook was being removed, the tag was deployed onto the fish. The stretcher was then hauled back into the water, outside of the purse seine, the rope of the stretcher opening was undone and the fish was released.

2.4.Comparison to tracks obtained from the Gulf of Lions

A dataset of 44 tracks obtained from deployments on BFT in the Gulf of Lions by a recreative rod and reel fishery was used to compare to the tracks obtained from the present tagging operation with purse seiners. This dataset was acquired through deployments made between 2007 and 2015 in cooperation with recreational fishermen, off Marseille, after the spawning season, from August through to November (Fig. 1). Full details about the methodology of the deployments are available in (Fromentin and Lopuszanski, 2014). The tracks from the dataset were simply plotted next to the tracks obtained from the present operation to highlight differences in their dynamics.

3.RESULTS

3.1.Tagging operation

About 15 BFT were hooked on the 20th of June 2018. The handlines prepared were just about strong enough to handle the large animals but most of the lines broke, the crimps used to tie the line slipped and/or the hooks were bent open. Three BFT of 226 (BFT1), 189 (BFT2) and 206 cm (BFT3) straight fork length were caught at 11h30, 14h30 and 15h30 respectively. The three fish did not fight more than 15 minutes each time and were towed smoothly towards the divers who could maneuver it into the stretcher. Once a fish was hauled onto the deck, less than 2 minutes were needed to intubate it, cover his eyes with a soft and wet cloth and remove the hook from its mouth as carefully as possible. The fish was then measured and tagged before being released into the water. No tagging-induced mortality was observed.

3.2.Tracks

The retention times were 72 days, 62 days and 32 days for BFT1-3 respectively (Table 1). No premature release was observed. Tags either indicated that the release pin broke or were recaptured. BFT-2 appeared to have been recaptured by a fisherman in the Alboran sea as the tag moved onshore following a straight line after it popped-up (Fig. 3). No tag was physically recovered. The GPE3 state-space model algorithm from Wildlife computers was used to estimate the geolocation of the fish from the tag data. BFT1 and BFT3 showed comparable dynamics as both fish reached the Alboran Sea in about a month. They both went west of Sicily and south of Sardinia and via the Balearic Islands. BFT1 seemed to have passed more northern than BFT3 as it went via the island of Menorca before going

more south passing Majorca and south of Ibiza, whereas BFT3 went more directly south of Ibiza, around where another major fishing ground is located. BFT1 reached the straight of Gilbraltar three to four days before BFT3. Whereas BFT3 was recaptured at this point, BFT1 exited the Mediterranean and followed the continental shelf along the Portuguese and Spanish coasts up to the Bay of Biscay where it stayed for about three weeks from late July to the middle of August 2018. BFT1 then continued its route towards Ireland where the release pin broke. BFT2 contrasted with these two routes. The fish did not attempt any large scale movement, so whilst BFT1 and BFT3 were setting off for the Atlantic, BFT2 went south into Libyan waters where it stayed two months until the tag popped-off in late August.

3.3.Comparison to the Gulf of Lions dataset

The 44 tracks from tagging operations realized in the Gulf of Lions between 2007 and 2015 were plotted next to the tracks obtained from the purse seiner deployment reported here. This dataset spans fish of various sizes (up to 237cm) comparable to the ones tagged from the purse seiner and exhibit times at liberty of up to a year. The fish were tagged after the spawning season, from late July to November off the city of Marseille. Not one single fish from this dataset made its way out of the Mediterranean. The closest attempt was a fish that just crossed the Straits of Gibraltar and immediately after headed back to the Gulf of Lions, close to where it was tagged. This contrasted with the present results that displayed one fish exiting the Mediterranean an another one that seemed to be on its way to do so before it was captured.

4.DISCUSSION

The operation described here presents a successful tagging attempt of large BFT in one of their Mediterranean spawning ground, during the spawning season. The tags deployed during this operation document the migration of individuals targeted by the largest fishery segment operating on BFT. A past operation using purse seiners in the US coast used harpoons to tag the animals (Wilson et al., 2005). Our results show that tagging large individuals from the spawning grounds on the deck of purse seiners is possible. The tracks obtained from these deployments contrast with the results obtained by tagging operations performed in other areas, periods and gears. This manuscript underlines the importance of such operations to fully grasp the migratory behaviour of BFT in the Mediterranean.

Results obtained from other tagging operations in the northwest Mediterranean have displayed relatively strong fidelity to the Mediterranean (Cermeño et al., 2015; Fromentin and Lopuszanski, 2014). In contrast, the results obtained in the present manuscript tend to suggest migrations outside of the Mediterranean, but this will have to be confirmed by more tracks. These different patterns can be explained by different factors, one being the period of the operation. Post-spawning tagging operations are often favoured as tagging before the purse seine fishing season is increasing the likelihood of early recaptures that reduces the probability of long tracks. In addition, a large number of tagging operations in the Mediterranean are carried out in cooperation with recreative fisheries, which also operate more easily in summer (Cermeño et al., 2015; Fromentin and Lopuszanski, 2014; Stokesbury et al., 2007). This induces a bias on the migratory patterns captured by the tags deployed, as tagging BFT after the spawning season targets fish that did not migrate outside the Mediterranean, such as BFT2. In addition, recreative fisheries operate nearer to shore than professional ones where large schools are less frequent. The group dynamics captured is thus likely to be different compared to the group dynamics of individuals from the spawning grounds, where large aggregation of fish are

commonly encountered. Tags deployed from the spawning grounds and during the spawning season therefore target individuals likely to have a different behaviour than the fish targeted by recreative fisheries. One fish over the three released was recaptured, but not enough tags were deployed to strictly assess whether a larger amount of early recaptures happened than during other periods. Regarding deployment times, a salient aspect was the failure of the release system of the tag ("pin-break") that impaired the retention times achieved by the tags deployed during the operation.

Given the right conditions and the right technique, tagging from a purse seiner can be an advantage in terms of logistics, as purse seiners often catch a very large amount of BFT in less than a day. The first attempt described in the present manuscript show that 3 fish could be tagged in less than an hour of cumulative time, although the technique presented has also a lot of room for improvement, as only three tunas were tagged when about 15 of them had actually been hooked. Compared to the operation carried out in fattening cages (Rouyer et al., 2019), decking the tunas from the purse seine proved to be much more complex. The main problematic aspect was the size and the strength of the individuals captured that broke the handlines deployed. Improving the strength of the material used for the handlines, shock-leader and hooks, should improve this aspect for future operations. Yet, the technique still enabled the decking of a fish estimated to weigh 250kg (BFT1) in less than 15mn. The rate at which the tunas were taking the baits suggested that 15 fish tagged during one day is not an unrealistic target given that the right meteorological conditions are met. Such large scale deployments repeated on different schools would provide a unique source of insights into BFT migratory behaviour.

Besides bridging a gap by describing the migratory behaviour of BFT targeted by the largest fishery and being appropriate for large scale release and group dynamics studies, tagging BFT from the spawning grounds is an opportunity to draw a clearer picture of BFT migrations. Spawning grounds, where the purse seine fishery operates, are areas where BFT from different size classes and potentially different behaviour mix (Fromentin and Powers, 2005; Mather et al., 1995; Rooker et al.,

2007). Tagging from such an area could therefore allow scientists to capture a large range of migratory behaviours, which would draw a clearer picture of the relative importance between resident individuals and individuals migrating outside of the Mediterranean. Our results illustrate this aspect, as it showed that fish from the same school, and whose tagging conditions were as similar as possible, displayed very different migratory patterns. The trajectory of BFT1 was consistent with observations of BFT migrating to northern latitudes during the recent past years, as the fish went straight to Ireland after spending some time in the Bay of Biscay. BFT3 seemed to also exit the Mediterranean, whereas BFT2 displayed a more residential behaviour in Libyan waters.

From a management point of view, and in the context of climate change, understanding the migratory behaviour of BFT is of key importance. For instance, within ICCAT, the ongoing Management Strategy Evaluation process uses spatially explicit model that requires migration rates between areas to capture the movement of the stock. ICCAT therefore encourages tagging activities, as accurately depicting migrations and exchange rates between areas from the major fisheries segments is of key importance. The operation described here is thus an important step to enable the international scientific community to move forward in that direction, providing information from the largest BFT fishing segment.

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335 TABLE

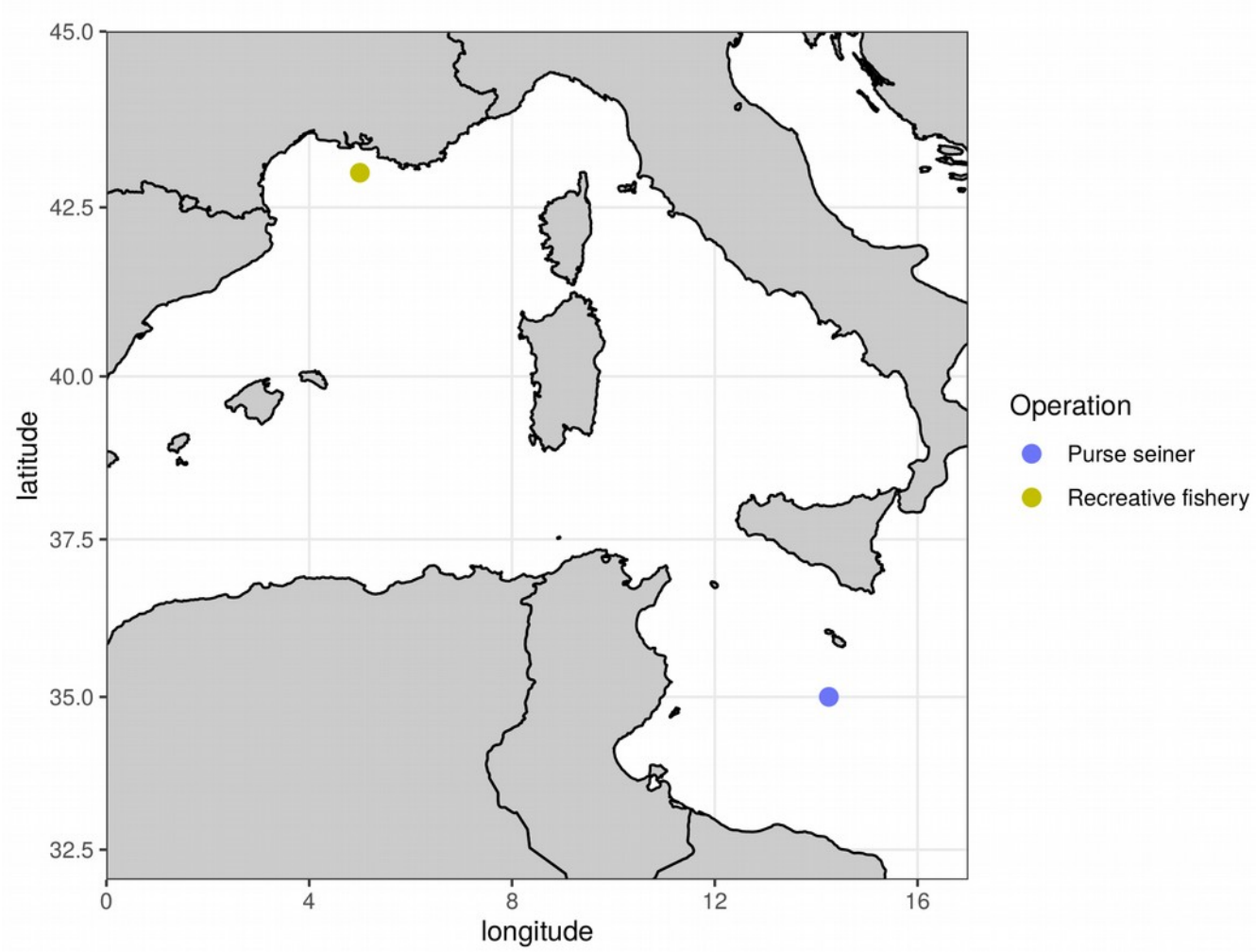
336

337 Table 1: Information about the three tags deployed.

Tag	Straight fork length (cm)	Time of tagging	Time at liberty (days)
BFT1	226	11h30	72
BFT2	189	14h30	62
BFT3	206	15h30	32

338

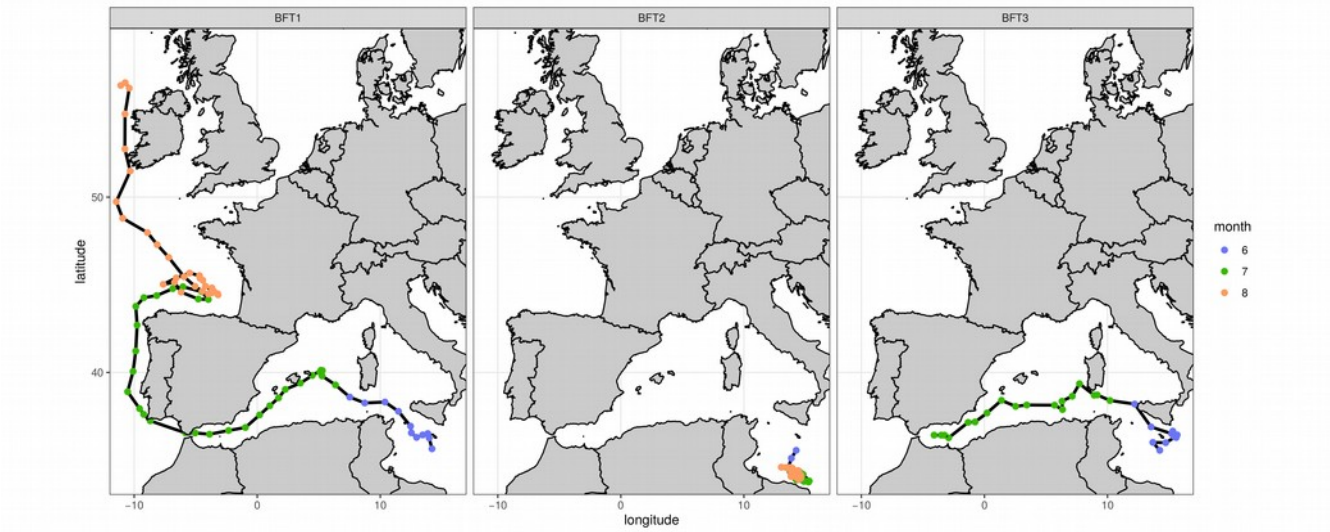
339 FIGURE LEGENDS



341 Figure 1: Location of purse seiner and recreative fishery tagging operations.

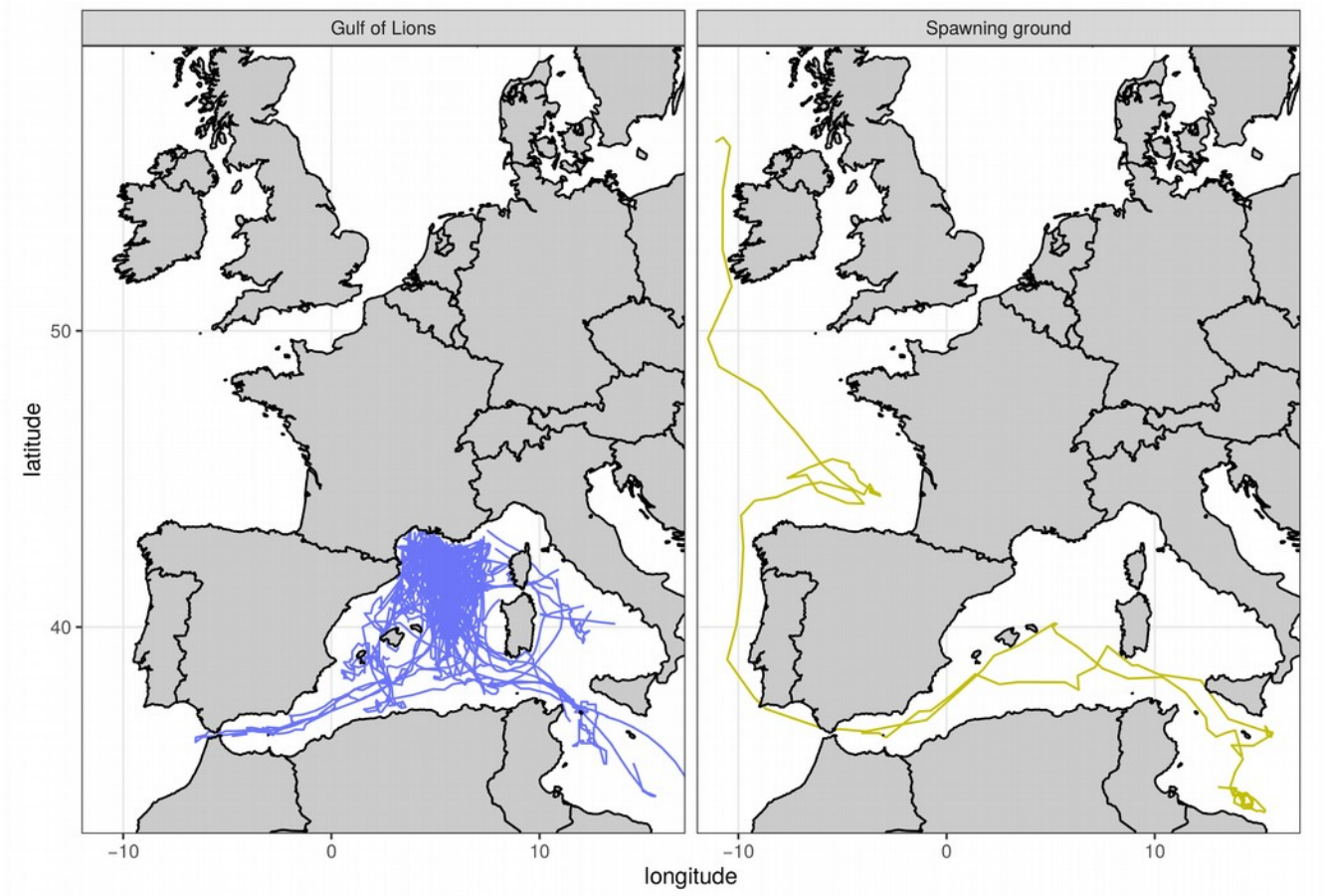
342

Figure 2: Main steps of the tagging operation. From top left to bottom right. A school of tunas was captured by the purse seiner SSFII. The purse seine was maintained open while waiting to transfer the fish into a cage. A dinghy was placed in the purse seine to deploy the baited handline, which was left to sink a few seconds and then slowly towed from the vessel. Once a tuna was hooked, it was towed in as fast and smoothly as possible. A clean space over the deck was prepared with a mattress and a water pipe. Once the tuna was close enough to the boat, three divers manoeuvered the fish inside a stretcher attached to a crane. The fish was then hauled onto the deck and then tagged using a double anchorage. It was immediately released outside of the purse seine.



355 Figure 3: Tracks of the fish tagged during the operation obtained from Wildlife Computer's
356 GPE3 algorithm.

357



359 Figure 4: Comparison of the tracks obtained from the tagging operations in the Gulf of Lions
360 and from the Purse Seiner.