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# PRELIMINARY RESULTS AND PERSPECTIVES FROM BLUEFIN TUNA TAGGING ACTIVITIES WITHIN THE PROMPT AND FISHNCHIP PROJECTS

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*SUMMARY*

*Atlantic bluefin tuna tagging operations were complex during the pandemic. Under the FishNchip and PROMPT projects, substantial tagging activity was resumed, targeting fish from the Mediterranean and the Atlantic. These operations targeted previously uncovered fish and were aimed at investigating in further detail previous hypotheses on size-dependent migrations and transitions between the Atlantic and the Mediterranean. Other preliminary results aiming at diversifying the tagging approach for long-term deployments, initiated in 2023, are also presented herein.*

*RÉSUMÉ*

*Les opérations de marquage de thon rouge de l'Atlantique ont été complexes lors de la pandémie. Dans le cadre des projets FishNchip et PROMPT, une importante activité de marquage a repris, ciblant les poissons de la Méditerranée et de l'Atlantique. Ces opérations ciblaient des poissons qui n'avaient pas été précédemment couverts et visaient à étudier de manière détaillée les hypothèses précédentes sur les transitions et migrations dépendant de la taille entre l'Atlantique et la Méditerranée. Ce document présente également d'autres résultats préliminaires visant à diversifier l'approche de marquage pour des déploiements à long terme lancés en 2023.*

*RESUMEN*

*Las operaciones de marcado del atún rojo del Atlántico fueron complejas durante la pandemia. En el marco de los proyectos FishNchip y PROMPT se reanudó una importante actividad de marcado de peces del Mediterráneo y del Atlántico. Estas operaciones se centraron en peces previamente descubiertos y tenían por objeto investigar con más detalle las hipótesis previas sobre las migraciones y transiciones dependientes del tamaño entre el Atlántico y el Mediterráneo. También se presentan otros resultados preliminares destinados a diversificar el enfoque de marcado para despliegues a largo plazo, iniciados en 2023.*

*KEYWORDS*

*Eastern Atlantic bluefin tuna; electronic tagging; Mediterranean Atlantic migrations*

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## 1. Introduction

Electronic tags (hereafter Etags) are individual observation tools that have been widely used to shed light on many aspects of the ecology of migratory species and large pelagic fish such as Atlantic Bluefin Tuna (hereafter BFT) (Block *et al*., 2011, 2001; Hussey *et al*., 2015). For instance, Etags have recently been key to describe the dynamics of BFT returning to higher latitudes after years of disappearance (Aarestrup *et al*., 2022; Horton *et al*., 2020). For the specific case of BFT, Etags bring further information which is used beyond ecological studies; for instance, tracks obtained from Etags are used in spatially explicit modeling frameworks used for fisheries management; for BFT, the M3 model used by ICCAT for the MSE to evaluate HCR included a spatial component that assimilated Etag data (Aarestrup *et al*., 2022a; Anonymous, 2023a, 2023b, 2021).

The PROMPT project (funded by France Filière Pêche) aims at understanding movements of BFT in the context of a changing environment. This project has a first axis that develops experiments to collect physiological data, such as heart rate and oxygen consumption, to connect the physiology of the animals to their environment (Rouyer *et al*., 2023). A successful first large-scale experiment in Malta was set-up to collect the heart rate of 20 tunas (20kg-200kg) and their high resolution movements in a cage over a whole year (see here). Results are currently being analyzed. A second axis of this project is to collect tagging data to describe the migratory behavior of BFT individuals representative of the exploitation by the French fisheries in the Atlantic and the Mediterranean, while investigating further ecological questions related to the Mediterranean/Atlantic connectivity. Of course, one fundamental objective is also to provide ICCAT with quality long-term tracks from the Mediterranean that are still lacking, even though the Mediterranean represents about 70% of the catch of Eastern BFT. The tagging operations of the PROMPT project are a prolongation of the tagging operations initiated within the FishNchip project (funded by EMFF) that has shown that BFT transitions from the Mediterranean to the Atlantic seemed to be affected by size (Rouyer *et al*., 2022). Specifically, results showed that Mediterranean BFT larger than 200 cm tagged in a spawning aggregation displayed Mediterranean / Atlantic transitions during the spawning period, whereas smaller fish did not. This did not mean that all Mediterranean fish above 200 cm displayed transitions or that all smaller ones did not, but this suggested a change in migratory behavior in relation to the size of the animal. This was further confirmed in a study using a larger dataset that showed that the size for the behavioral change could be between 175 cm and 200 cm (Anonymous, 2023b; Rouyer *et al*., 2023).

After 2 years of reduced tagging activity (2020-2021) during the COVID 19 pandemic, tagging operations could resume in 2022 and were further developed in 2023. The objectives of these deployments were 1) to describe the migrations for different size classes of BFT in the Mediterranean in order to confirm the size-based transition hypothesis, 2) to describe for the first time the migrations of BFT from the Atlantic off the French coast of the Bay of Biscay and 3) to attempt to obtain year-long data on large individuals of potential Mediterranean residents. These tagging operations took place in different locations to: 1) cover the main exploitation segments, 2) target individuals of different sizes and 3) to describe migrations from locations where tags had not been deployed before.

Satellite tags (Psat) are common tags used for many BFT tagging studies. These tags have key interesting characteristics, the main one being that scientists do not depend on a recapture to retrieve the data since these are transmitted via the Argos network. However, obtaining data over a year long using these tags is uncommon as such durations are getting close to their technical limits. Furthermore, the company that produces the most reliable products (Wildlife Computers with the Minipat model) have recently been plagued with technical issues that reduced the quantity and quality of the data that could be obtained. Alternative tagging approaches enabling these limitations to be overcome are therefore of high interest. Within the PROMPT project, such an alternative tagging approach is being tested.

In that context, we present in this manuscript preliminary results from the deployment of 67 tags on BFT of different sizes and spatial origins, using Psats and alternative tags.

## 2. Materials and method

### *2.1 Tags*

*Psats*

31 Minipats from Wildlife Computers were used, as they have a good tracking record on BFT. However, given the recent transmission issues of the Minipats, one Lotek tag was also tried as a test. The programming of the minipats was adjusted to cater for the transmission issues linked to failing batteries, specifically regarding the

number of transmitted messages. This was done following Wildlife Computer's specifications. As soon as Wildlife Computer communicated the proper protocol to maintain batteries, it was applied to all the tags. Some tags were programmed to last 385 days, because 365 days can be too short to study fidelity to a given area (e.g. spawning ground) in case of delayed migrations. In order to test the limit that could be achieved with minipats, 2 year deployments were also tested with 8 tags. The minipat tags were from two generations, 20P (n=19) and 23P (n=12); according to the manufacturer the latter was supposed to be able to achieve a better transmission rate.

*Multi-year tags*

Although it is possible for Psats to have a life expectancy above a year long, getting 2 years and more is only possible using internal tags. However, internal tags can be difficult to deploy using classical surgery techniques on large fish. We therefore chose to use internal tags fitted externally, in a similar way as a Psat tag. Two anchors were used, the main one was an XL Domeier, whereas the second was a large titanium dart. The tags were Lotek LAT2810, fitted with a buoy so that they could be placed externally on tunas. An extra buoy was added to increase the buoyancy so that a tag that shed with the rigging would have a chance to float ashore. The main buoy was painted with a bright orange color so the tags could be easily retrieved on a beach or on a fish (**Figure 1**). The tagging operation was similar to the deployment of Psats. A first batch of 36 tags was programmed to log temperature, light and pressure every 5s, which corresponds to a life expectancy of approximately 2.5 years. When possible, these tags were mainly used for fish that were smaller than 175 cm, so that we could track a potential change in behavior from Mediterranean resident to being able to make Mediterranean/Atlantic transitions.

### *2.2 Tagging operations*

*Atlantic tagging*

Brittany

This operation aimed at tagging fish from Brittany, for which no tag has been deployed yet. The tagging was carried out on board a rod and reel fisherman off La Turballe in August 2022, where both small (115-160 cm) and large fish (> 160 cm) have been found since about 2014, consistently with the return of BFT in higher latitudes. Since no tag has been deployed in this area yet, no specific size was targeted, but younger fish were preferred as numerous tags have already been deployed on larger fish in the neighboring UK waters (Horton *et al*., 2020). This operation followed a classic protocol; once the fish was caught, it was hauled onto the deck using a stretcher (Rouyer *et al*., 2019). Two Psat tags were deployed on BFT of 161 cm and 145 cm. The Psats were programmed to pop-off after 2 years. The fish were tagged during a day in August and at these intermediate sizes, transition in the Mediterranean during the spawning season was not granted.

Vendée

This operation aimed at targeting larger fish in Vendée, south of Brittany, in Talmont Saint-Hilaire, where BFT has been coming back every year since 2014 in late August - early September. As for Brittany, BFT has never been tagged there before. The fish found in that location are often relatively large (>190 cm). The operation took place in September 2023, during a recreational fishing contest. During this operation, no stretcher could be used because the fish were too big to be maneuvered in a stretcher in a boat without a crane. The fish were therefore hooked with a mouth claw and slid onto the dedicated tagging boat. Over two days, 8 tags were deployed on BFT that were 204 cm on average, with 4 Psats (3 minipats and one Psatflex) and 4 long-term tags (Table 1). It was expected that these large fish would display transitions into the Mediterranean during the spawning season.

*Mediterranean tagging*

Purse seiners South of Malta

These operations have been successful in 2018 and 2019 and have already been extensively described (Rouyer *et al*., 2022, 2020). These operations were canceled during the COVID 19 pandemic, but could resume in 2022. However, both attempts made in 2022 and 2023 failed and no tags could be deployed. In 2022, the tagging window was small and technical issues impaired the operation to work as planned. In 2023 the quota was completed very rapidly (about a week) compared to the timing of the planned operation and the flexibility of the logistics at sea such that the scientists did not manage to set foot on the purse seiner in time.

French longliners in the Balearic Islands

A few years ago, a few French longliners operating in the Gulf of Lion started to come to the Balearic Islands in June, after the purse seine season. As since 2012 the quota is quickly completed there, it gave them access to a quantity of large fish, making the completion of their quota much faster. In 2023, 9 boats operated there and caught about 250 tons. This opened a new tagging possibility in the spawning aggregations of the Balearic Islands and a first attempt was made in June 2023. For this operation, a stretcher was used to haul the fish onto the deck of the boat, because the boat was too high to allow for the fish to be slid onto the deck using a mouth claw. During that operation, 6 BFT of about 182 cm were tagged with minipats over a week, each programmed to pop-off after 2 years. Given the size distribution, it was expected that some transitions into the Atlantic at the end of the spawning season would occur, and two years of data could inform about their fidelity to the Balearic spawning ground.

Gulf of Lion

Many tagging opportunities can be found for the young BFT from the Gulf of Lion throughout the year. Many studies report tagging results from this area, but tags rarely hit one year (Cermeño *et al*., 2015; Fromentin and Lopuszanski, 2014). Two Psats were deployed onboard a longliner during a commercial operation and one was deployed on a professional rod and reel boat (Rouyer *et al*., 2023). In these operations, a stretcher was used as the fish is small enough to be manoeuvered by hand (120 cm on average, see Table 1). To study the evolution of movements along the growth of the fish, 14 long-term tags were deployed onboard a professional rod and reel and a recreational boat. BFT from the Gulf of Lion are rather small, 2-4 years old, and seem to move to other locations as they grow past 4-5 years old.

Spanish Operations with Scientific Angler

Scientific Angler designed three operations (see here). A first tagging operation was organized in Barcelona in April 2023 (see here). This operation was set-up to target young fish before the spawning period. There, the tagging took place aboard the boats that had caught the fish, so the tagging had to be improvised on the spot. Because of their relatively small size (125 cm on average see Table 1), the fish were hooked on the lower jaw and hauled onto the deck before being tagged. During that operation, 7 Psats were deployed in a day and programmed to last 385 days. At these sizes, it was not expected that any of the fish would display an Atlantic transition during the spawning season. A second operation was organized in Santa Pola in June 2023 (see here). This operation took place in the Balearic spawning ground during the spawning season and aimed at tagging larger individuals (>175 cm) within spawning aggregations. Similar to the Barcelona operation, the tagging took place aboard the boats that had caught the fish, so the tagging had to be improvised on the spot. The fish were hauled onto the deck of each boat using a mouth claw, before they were tagged. During that operation, 6 fish of about 183 cm (table 1) were tagged over two days. The tags were programmed to last 385 days. Given the size of the fish, similar to the longliner operation in the Balearic islands, it was expected some transitions in the Atlantic after the spawning season would occur. The third operation took place in Ametlla de Mar, next to the Balfegó facilities in November 2023, after the spawning season, so that potential Mediterranean residents could be targeted (see here). This area is interesting because BFT seem to cluster under the cages in large numbers at least during several months, but these individuals are often about 145 cm. To test residency properly, a tag had to be deployed on a fish that would be larger than 175cm during the next spawning season. This operation was a bit technical in terms of fishing, because BFT had to be moved from under the Balfegó farm facilities to be fished outside so that they wouldn't tangle in the anchorage system. The successful technique was to have a boat from Balfegó chumming inside the farm, which clustered BFT under it and could then move out with BFT individuals following it. There BFT could be fished by the recreational boats. In this operation, a boat was dedicated to the tagging and moved nearby each boat that had caught a BFT. The first day 21 BFT were tagged in the space of 5 hours (151 cm on average, table 1), 3 Psats were deployed on the largest fish (187 cm on average) to test the residency and 18 long-term tags were deployed on the smaller individuals (145 cm on average).

### *2.3 Analyses*

The transmission rate (number of messages) were compared between the different generations of minipat tags from Wildlife computers to assess whether newer tags displayed an increased transmission. The movements were obtained from the Psat tags that transmitted data using the GPE3 algorithm provided by Wildlife Computers. The tracks were then simply visualized to assess the general movements.

## 3. Results

### *3.1 Retention times for Psats*

Retention times ranged between 28 and 452 days at large (Table 1). Half the tags displayed a retention time longer than 294 days and, of the tags that popped-off at the time this manuscript was written, 44% of them had a retention time longer than a year. Some variability was observed between operations. The operation in Brittany was also successful, one fish popped-off after 292 days at large whereas the other one popped-off after 452 days and both tags were physically recovered. In Vendée in 2023, two tags detached prematurely after 29 and 268 days, but two tags are currently still at large, among which the Lotek Psatflex, reaching a year. For the operation with the French longliners in the Balearic islands, 3 out of 6 tags popped-off before 2 years and after 322, 361 and 401 days respectively, whereas the other 3 tags are still at large and have now reached more than 430 days at large. The tags deployed in the Gulf of Lion also showed good retention times as 2 over 3 reached 385 days at large (Table 1). In Barcelona, 6 out of the 7 tags displayed a retention time of 385 days, whereas in Santa Pola substantially lower retention times were obtained (114 days) probably mainly due to a rigging problem. All the tags deployed in Ametlla de Mar are still at large, reaching currently about 300 days of retention time.

### *3.2 Transmission from Psats*

Even though all the 23P tags deployed have not yet popped-off, the number of messages transmitted showed a significant variation between the two generations of minipats, 20P and 23P (**Figure 2**). The 20P generation transmitted on average 882 messages (n=19), whereas the 23P generation transmitted on average 2342 messages (n=5), about a threefold increase. Retention time did not seem to influence these results, even though one could expect that tags that spend a longer time at large could have a reduced ability to transmit many messages. These results suggest an improvement of the 23P tags over the 20P generation.

### *3.4 Preliminary analysis of movements*

The movements obtained are preliminary, because the geolocation was not tested in depth and also because some tags did not report a lot of data. However, their preliminary analysis reveals some interesting aspects. The two fish tagged in Brittany displayed contrasting movements (**Figure 3**). The smaller fish popped off in late May in the South of the Bay of Biscay, suggesting it did not enter the Mediterranean for the spawning season. However, the larger one moved into the Mediterranean in June, and went to the Tyrrhenian Sea before returning around Brittany. Whereas one of the tags deployed in Vendée had too short a retention time to be analyzed in detail, the other one displayed small-scale movements in a reduced area of the French coast of the Bay of Biscay, not far from the tagging location until the spawning period, when the fish entered the Mediterranean and went South of Malta, where the Psat popped-off (**Figure 3**). The young fish tagged in the Gulf of Lion remained in the Mediterranean and displayed small scale movements in front of the Gulf of Lion, between the Balearic islands, Corsica and Sardinia, sometimes visiting the Gulf of Genoa (**Figure 3**). Two out of the three tags that popped-off from the French longliner tagging operation displayed very clear transitions in the Atlantic (180 and 189 cm, respectively). One of them went out and stayed in the French coast of the Bay of Biscay, whereas the second one moved to higher latitudes, into Brittany, UK waters and west of Ireland and then went North-West of the Azores. This individual did not visit the Mediterranean for the 2024 spawning season. The third fish tagged was smaller and preliminary results show that it did not leave the Mediterranean after the spawning season, although moving several times close to the Gibraltar straits. The fish tagged in Barcelona remained in the Mediterranean, but displayed larger movements in the Western Mediterranean than the fish tagged in the Gulf of Lion. The fish tagged in Santa Pola showed different patterns depending on their sizes. The two individuals that were 170 cm and 155 cm remained in the Mediterranean. One 181 cm individual did not exit the Mediterranean, whereas a 180 cm fish left the Mediterranean and remained on the Cantabric sea. The two larger fish, 201 cm and 214 cm respectively, exited the Mediterranean, one remained on the continental shelf off the Brittany and Vendée coasts, the other one was caught just outside the Gibraltar strait. These results showed contrasting migratory dynamics between fish whose size was smaller than 170 cm and larger individuals. No transition between the Atlantic and the Mediterranean was found for fish smaller than 170 cm in June (n=11), whereas 80% of the fish between 170 cm and 200 cm displayed a transition between the Atlantic and the Mediterranean (n=5) and 100% of the fish larger than 200 cm (n=3) as well.

### *3.5 Recoveries of long-term tags*

Over the 36 long-term tags deployed, 2 were recovered after 5 and 6 months, respectively, representing 5.5% of the tags deployed. One of them was recovered on a beach near Sète, the other one was recovered still attached onto a tuna in Algeria. The high resolution data extracted showed high frequency dives (**Figure 4**).

## 4. Discussion

Our preliminary results show that tracks longer than a year can be obtained with a decent probability using Psats, providing long-term tracks for the Mediterranean and the Atlantic. However, a small amount of data transmitted for these long retention times is all the more problematic as it impairs the capacity of the geolocation model to produce reliable tracks. Even though the sample size is still reduced, the analysis of the amount of messages transmitted showed that the newer Psat generation seems to perform much better than the older ones. The Psat tags that are still to pop-off are likely to provide more insights on this aspect.

Overall, our preliminary results seem to confirm that fish below 175 cm did not display any transition between the Mediterranean and the Atlantic during the spawning season (**Figure 3**). The hypothesis seemed to hold for the opposite migration, from the Atlantic to the Mediterranean, with the smallest fish to enter the Mediterranean being 174 cm at entry. Several tags are yet to pop-off and should provide more insights into this aspect. In particular, all tags from Ametlla de Mar are still at large as well as three tags from the French longliner tagging operation and will likely provide interesting data on that respect. In 2024, 12 Psat tags were deployed in the Balearic spawning ground and more tags are planned to be deployed in the Atlantic.

Following the size-dependent migration hypothesis, since 50% of BFT are mature at 115 cm, the individuals between 115 cm and 170 cm are likely mature and do not enter the Mediterranean. The smallest fish tagged in Brittany met these conditions and were found to be in the Basque country at the end of May. In the past few years, French professionals operating in that same area have been reporting substantial catches of fish that size during the spawning period in June, sometimes even larger. A first gonad sample was taken in early June this year on a fish of about 60 kg (~145 cm) caught in the area, and a quick inspection showed gonads in development (**Figure 5**). BFT larvae have already been found in the Cantabric sea, but more samples from the Basque country could provide more insights into this aspect in the future (Rodriguez *et al*., 2021). In 2024, fish up to 200 kg have been reported in the area.

The alternative tagging approach with long-term tags yielded 2 recoveries over 36 tags deployed, which makes a 5.5% recovery rate after less than 1 year. Given the retention times achieved for the Psats and the fact that one of the tags was found washed ashore and another was found still attached on a fish, this strongly suggests that this general approach works in principle. If the tag detaches prematurely, it can float to the coast and otherwise, when a fish is recaptured, the tag can be easily spotted. Another positive aspect is that the battery life is long, so that the tags that are recovered prematurely can be redeployed. These tags are also 5 times cheaper than a Psat and generally smaller, which suggests that greater retention times could be achieved. 35 long-term tags are planned to be deployed in 2024. To ensure long-term retention, a perspective could be to use a tagging technique developed for deploying heart rate tags (T. Rouyer *et al*., 2023). With this technique, the tag is inserted under the jawline of the fish and it has been shown to have a very high retention time for heart rate tags, with excellent healing (**Figure 6**). Given that archival tags are smaller than the heart rate tags used, this technique could be used to deploy them. This could permit the deployment of archival tags on a large range of fish sizes without any surgery. The first deployments of 25 archival tags using this technique are planned in 2024.

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**Table 1.** Number of Psats and long-term tags deployed, retention times for the fish tagged with Psat tags and average fish size for each operation.

| *Operation* | *nPsat* | *nTag LT* | *Retention time for Psats (days)* | *Average fish size (SFL cm)* |
|---|---|---|---|---|
| Brittany | 2 | 0 | 292, 452 | 153 |
| Vendée | 4 | 4 | 29, 268, 2 tags at large (currently 350 days) | 204 |
| Longliners in Balearic | 6 | 0 | 322, 361, 401, 3 tags at large (currently 430 days) | 182 |
| Gulf of Lion | 3 | 14 | 246, 385, 385 | 120 |
| Barcelona | 7 | 0 | 212, 385, 385, 385, 385, 385, 385 | 125 |
| Santa Pola | 6 | 0 | 74, 28, 225, 33, 176, 146 | 183 |
| Ametlla | 3 | 18 | All tags at large (currently 300 days) | 151 |


**Figure 1.** Electronic tag used for long-term deployments. The orange buoy and the white custom-made buoy ensure that the tag can float with all the rigging still attached.

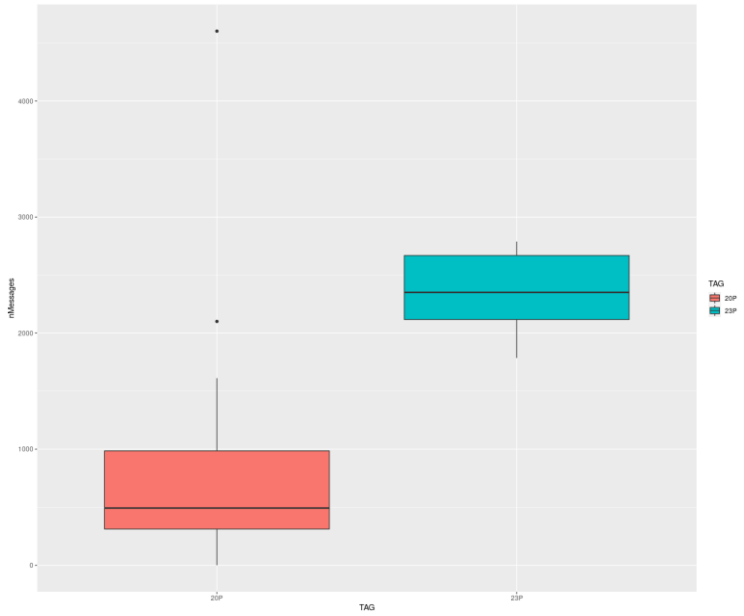


**Figure 2**. Number of messages received from minipat tags of generation 20P (in red, n=18) and 23P (in blue, n=5).

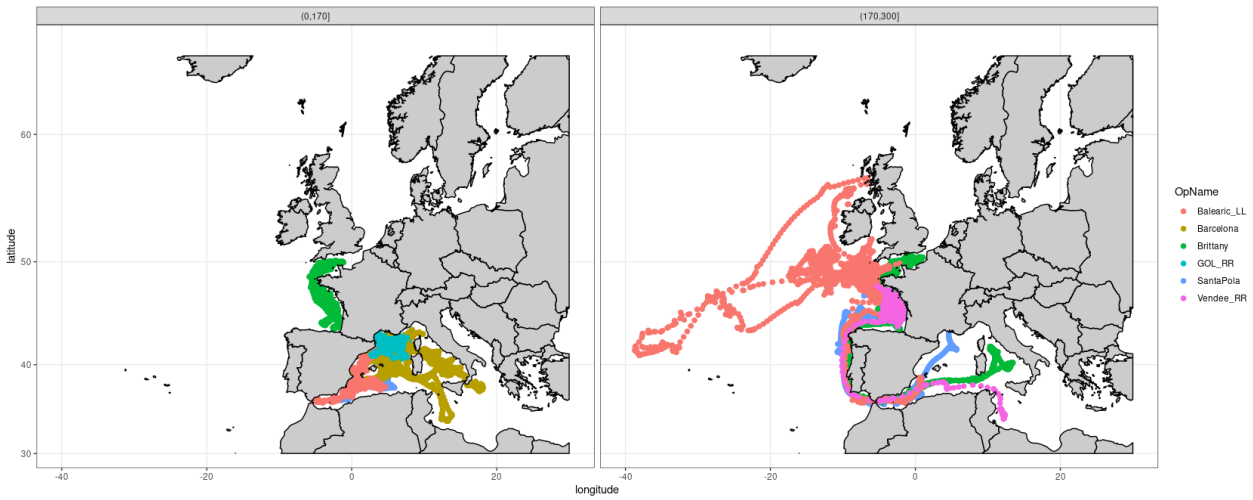


**Figure 3**. Tracks obtained by the GPE3 algorithm for fish smaller than 170 cm in June (left panel) and fish larger than 170 cm in June (right panel). The colors represent the different operations, the Brittany operation (green), the Vendée operation (pink), the Gulf of Lion (light green), the French longliners in the Balearic (red), Barcelona (brown) and Santa Pola (blue).

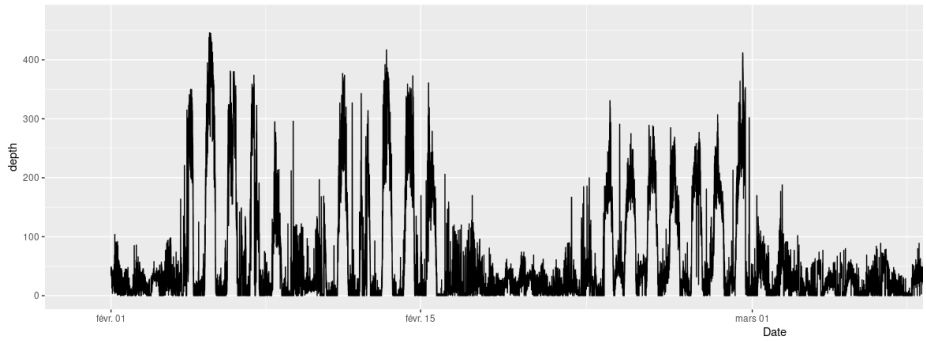


**Figure 4.** Example of depth data over the month of February, extracted from the first recovered long-term tag.

**Figure 5**. Picture of the gonads sampled from a fish of about 60 kg caught in early June in the Basque Country.

**Figure 6**. Deployment of a heart rate tag in a BFT in Malta.