Fisheries Research
March 2019, Volume 211 Pages 27-31
https://doi.org/10.1016/j.fishres.2018.10.025
https://archimer.ifremer.fr/doc/00466/57818/

Tagging Atlantic bluefin tuna from a farming cage: An attempt to reduce handling times for large scale deployments

Rouyer Tristan [1, *], Bonhommeau Sylvain [2], Giordano Nicolas [3], Ellul Saviour [4], Ellul Giovanni [4], Deguara Simeon [5], Wendling Bertrand [6], Belhaj Mohamed Moez [7], Kerzerho Vincent [7, 8], Bernard Serge [7, 8]

[1] MARBEC Univ Montpellier, CNRS, Ifremer, IRD, Sète, France
[2] IFREMER DOI, rue Jean Bertho, 97822, Le Port, La Réunion, France
[3] Armement « Saint Sophie François II & III », SARL SSF, 15, Quai d'Alger, 34200, Sète, France
[4] MFF Ltd., Hangar, Triq it – Trunciera, Marsaxlokk, MXK 1522, Malta
[5] AquaBioTech Group, Central Complex Naggar Street – Targa Gap, Mosta, MST 1761, Malta
[6] SATHOAN, 28, promenade J.B. Marty, 34200, Sète, France
[7] LIRMM, 161 Rue Ada, 34095, Montpellier, France

* Corresponding author : Tristan Rouyer, email address : tristan.rouyer@ifremer.fr

Abstract :

Our knowledge on the biology and ecology of marine species have improved greatly through the use of archival tags by enabling the collection on information from individual in the wild. This is specifically true for large pelagic species such as the Atlantic Bluefin tuna (ABFT, *Thunnus thynnus*) where, for the first time, it has been possible to confirm through fisheries-independent data, migration patterns, reproductive and feeding behaviours and habitat use. However, large-scale tagging experiments that would enable researchers to tackle group behaviour are difficult to set up. On the one hand, the impact of the actual tagging operation should be as minimal as possible to avoid any change in behaviour of the fish which could influence tag data analyses. On the other hand, large scale tagging experiments require handling a large number of animals in a relatively short period of time. In the present manuscript, a methodology for tagging several large ABFT with satellite tags was tested with ABFT caught from a cage of a Maltese farm. The total time of the operation, from the moment fish were caught by handline to release back to the sea lasted an average of 10 min for the 3 fish tagged. The handling of the fish on the deck lasted less than 2 min. This methodology proved successful at tagging several large (158–182 cm) fishes in a very short time, while ensuring the best conditions for the fish during tagging and subsequent release. This procedure requires substantial logistical preparation and an experienced crew team but, by reducing the time required for the operation, opens up the possibility of large scale tagging activities of large fish held in cages or caught by purse seiners.

Highlights

► A methodology was tested to allow for large scale tag deployment on bluefin tuna. ► Three large tunas were tagged from a fattening cage in about ten minutes each. ► No mortality was observed as the tagging conditions, on deck, were optimal. ► Using handlines to catch the fish from within the cage proved successful. ► The behaviour of fish held in captivity and released into the wild could be observed.

Keywords : Large Atlantic bluefin tuna, Electronic tagging, Release, Farming cage

1.INTRODUCTION

Tagging using electronic tags is an important tool used to understand the life cycle of many fishes. Since the 1990s, the use of these tags has substantially improved our knowledge of the biology and ecology of numerous marine species (Block *et al.*, 2011; Hussey *et al.*, 2015). This is specially true for large migratory pelagics species such as the Atlantic Bluefin tuna (ABFT, *Thunnus thynnus*), a commercially important top predator (De Metrio *et al.*, 2002; Block *et al.*, 2005; De Metrio *et al.*, 2005; Walli *et al.*, 2009; Fromentin and Lopuszanski, 2014).

This species is managed by the International Commission for the Conservation of Atlantic Tunas (ICCAT) as two stocks (eastern and western stocks), with mixing occurring in foraging areas. The eastern stock groups the East Atlantic and the Mediterranean Sea and is the largest stock. ABFT is capable of movements across long distances and can move from one stock region to another (Rooker *et al.*, 2007). The complexity of these movements, and in particular in relationship to its spawning areas, is far from being resolved (Richardson *et al.*, 2016). Therefore, quantifying these movements is currently still an important challenge to improve the understanding of the species' ecology, but also for its management (*e.g.* implementation of the Management Strategy Evaluation, MSE). However, quantifying these movements is not an easy task. ABFT shows a great amount of inter-individual variation in terms of movements, which also greatly differ from one year to another and even at larger time scales. For example, recent years have seen large individuals of ABFT moving to higher latitudes, to feed on mackerel and herring(MacKenzie *et al.*, 2014), after several decades of disappearance in these areas (Fromentin and Powers, 2005; Fromentin, 2009). ABFT also occurred for a few decades in Brazilian waters before disappearing, the so-called “Brazilian episode” (Fromentin *et al.*, 2014).

Quantifying such movements would ideally require the deployment of numerous electronic tags each year, so that enough information could be collected to meaningfully assess the number of individuals moving from one area to another while accounting for inter-individual variability. To facilitate the assessment of the true variability of migratory behaviour between individuals, optimally, there should be equal tagging conditions (location, size, day of the year, etc.) yearly. Such conditions could be controlled if several individuals from the same school could be tagged. However, such a large scale operation is not easily arranged because a large number of fish have to be tagged in a short amount of time, and appropriately handling ABFT is not straightforward. Tagging ABFT for long-term deployments is better achieved by placing the fish on the deck, as the tag can then be deployed with enough precision to increase the probability of long retention times that can regularly last more than 4 months (Fromentin and Lopuszanski, 2014). The operation consists of inserting the anchor of the tag through the bones under the second dorsal fin (pterygiophores, Fig. 1), which is easier to achieve onto a deck than under water (Cort *et al.*, 2010; Tensek *et al.*, 2017). However, the large size and weight that ABFT can reach makes hauling up the live fish onto the deck rather difficult, especially since the process has to be as quick as possible to avoid stress and mortality and reduce the impact on the animal inluding injury and subsequent behaviour.

In the Mediterranean Sea, the largest amount of catch is made by the purse seiners fishery during the spawning season (fishing season). The purse seiner fleet has access to a substantial amount of the total allowable catch to the eastern stock fishing fleets. Nowadays the fleet operates in the Balearic Islands, in the Tunisian and Maltese Waters, in the South-East of the Tyrrhenian sea and in the southern coast of Turkey. The vast majority of the catch, consisting of mature fish, is transferred into cages to fatten the fish. These purse seine catches represent a very interesting opportunity for large-scale tagging operations as the fish, usually spawners and hence large (50 to > 500 kg), are caught in the hundreds. However, as a first attempt at tagging several tunas in one go, using fish already housed in a cage is convenient. It allows to have access to a large number of fish that are used to being held in a confined space, without having to deal with the stress and variability inherent to the fishing operations with a restricted time frame and unpredictable meteorological conditions. Tagging fish from a cage also opens up the possibility to study the behaviour of ABFT that are released every year from the cages as part of the over-catch procedures (ICCAT Rec. 17-07).

Nonetheless, getting ABFT out of a cage for large scale tagging purposes requires a quick and efficient methodology so that they can be tagged appropriately and returned to their natural environment in good condition. Techniques employed so far have involved isolating individuals in a confined space and catching them directly through the use of divers, which is not optimal for ABFT as the fish can get easily stressed and exhausted during the operation and lead to higher risks of mortalities. Tagging using harpoons or spearfishing techniques are also used, but they suffer from the major problem of lacking accuracy for inserting the main anchor, which is an important aspect for electronic tags to ensure a greater probability of a long retention times (Chaprales *et al.*, 1998; Aranda *et al.*, 2013).

In the present manuscript, we present an operation carried out on a ABFT farming cage in Malta. The objective of the operation was (i) to show that it is possible to use a handline to fish out relatively large tunas from a confined area and (ii) to show that such a technique allows for quick deployments of tags on fish and release of these fish in good condition.

2.MATERIAL AND METHODS

2.1.Tagging location

Three ABFT were made available by the company Malta Fish Farming (MFF Ltd) for the tagging operation. The fishes had been caught during the 2016 purse-seine fishing season and were housed in a 50m diameter cage, off the harbour of Marsaxlokk. These fish were caught from inside the cage using a handline with large hooks used by local longline fishermen, baited with frozen mackerel and herring. The operation took place in the early morning so that the tunas in the cage would be as calm as possible and to maximize the probability that the fish would take the bait. The day was chosen so that the meteorological conditions were optimal, flat sea and sunny clear sky, to facilitate the operation.

2.2.Personnel and equipment

The barge used during the operation was equipped with a crane that was used to haul the fish out of the cage and back into the water after tagging. The tagging team consisted of three scientists to handle the fish and tag it, two fishermen to catch the fish, three divers to move the fish into a stretcher, one crane operator to lift the stretcher from the cage onto the deck and back into the open water, plus the captain of the vessel. The barge had a large open deck on which a 5 cm thick mattress was laid to avoid hurting the lateral line of the fish. The stretcher had specifically been designed for the operation and made of a material used for catamaran trampolines (Fig. 2). This material is smooth and does not remove the mucus of the fish while letting the water flow through. The mouth of the stretcher was kept opened in the water using a chain, whereas the other end of the stretcher was kept closed with a rope that was removed before the fish was released back into the water. The stretcher was attached to the crane at a slight angle so that the entrance of the stretcher would be higher than its exit to prevent the fish from falling while the crane was being operated to haul it out of the cage.

2.3.Tagging

Three pop-up tags (MiniPATs, Wildlife Computers) were set-up to pop-off after 90, 180 and 360 days, respectively. The tags were rigged with metal 12cm long tethers and Domeier anchors. The main anchor was inserted at the base of the second dorsal fin, so that the Domeier anchor would go through the pterygiophores and get tangled in them (Cort *et al.*, 2010). Doing so increases the probability of long-term retention of the tag. In addition, a second anchor was used to limit the lateral movements of the tag on the body of the tagged individuals (Fromentin and Lopuszanski, 2014). This limits the probability of bruises on the sides of the fish. Both anchors and the material used for the tagging were treated with chlorhexidine, a disinfectant and antiseptic.

After throwing some bait into the cage, a handline with a baited hook was thrown into the cage, left sinking a few seconds and towed back to the boat (Fig. 2a). Once a tuna took the bait the fish was manoeuvered towards the surface by the fishermen as quickly as possible to avoid the exhaustion of the fish and consequently a lower probability of survival. However the strength of the fish limited the speed at which the fishermen could get it close to the barge. Once the fish reached the surface, it was placed in the stretcher by the divers that were waiting around the cage (Fig. 2b). The stretcher was then lifted onto the mattress (Fig. 2c,d) on the barge. The rope of the exit of the stretcher was undone, the eyes of the fish were then immediately covered to calm the fish down and a water pipe was inserted into its mouth to ensure a continuous provision of oxygen (Fig. 2e,f). The total fork length of the fish was measured and the fish was tagged, while the hook was removed from its mouth (Fig. 2g,h). The fish was then immediately released into the wild (Fig. 2i-n).

3.RESULTS

3.1.Tagging operation

Three ABFT of 170, 158 and 182 cm straight fork length, were caught successively on May the 4th 2017. The fish were caught with handlines and hauled onto the deck of the barge in less than 10 minutes each. The time on deck including covering the eye, intubation, removal of the hook, measurement, tagging and getting the fish back into the water was less than two minutes for each fish. The total time of the operation from start to finish was less than 40 minutes.

3.2.Retention times and movements

The tags did not remain attached as long as expected. The first fish was caught after only a few weeks by a fisherman on June 1st 2017 (Tag 170333, programmed for 90 days, 27 days at large). The second tag was released on the 10th of June 2017 (Tag 170334, programmed for 180 days, 37 days at large) and the third tag (Tag 170332, programmed for 360 days) was released on June 23rd 2017 (50 days at large). The geolocation of the fish was obtained by using the GPE3 state-space model algorithm from Wildlife Computers. The track of the first fish (Fig. 3) showed movements in the south of Malta, with the fish remaining in the general vicinity of the island. The track of the second fish displayed a comparable track to the first until the fish got caught by a fisherman. The tag then moved to the harbour of Tebulbah in Tunisia. The track of the third fish was quite different from these two tracks. It displayed eastwards movements across the Ionian sea towards the western Greek coast. The three fish spent a large amount of time in the upper layer (0-20m) of the water column, where up to 83% of occurrences were recorded (Table 1). This upper layer was characterized by relatively warm waters, above 20°C during this period (Fig. 3).

4.DISCUSSION

The methodology that was used for the tagging operation allowed to tag three large fish on the deck of the barge, in a relatively short amount of time, about 10 min each, and without suffering any mortality. This methodology could thus allow large scale tag deployments with the fish being tagged onto the deck. Large scale deployments are an important perspective to improve our knowledge on ABFT, for instant about group behaviour, but also to feed the stock assessment with relevant information. For instance, tagging data is used to obtain migration probabilities between different areas for the stock assessment model or for testing management procedures for ABFT (Powers and Porch, 2003; Carruthers, 2016).

Attempts to tag several fish from the same school have been made through several programs from the northwest Atlantic (Lutcavage *et al.*, 1999; Block *et al.*, 2001). Attempts in the Mediterranean Sea, mainly through the Atlantic-Wide Research Programme on Bluefin Tuna (GBYP), had a large focus on smaller tunas (Tensek *et al.*, 2017). Large tunas were also tagged from traps, but the technique rarely involved getting the fish on the deck, but rather using poles or underwater spearguns to tag the fish. Using cages has proved successfull for tagging large amount of fish, but mainly involved small fishes (Tičina *et al.*, 2003, 2004).

Apart from the methodological aspects and the perspectives of large scale deployments opened by this operation, tagging fish from cages can bring insights into the behaviour of ABFT held in cages for a period of time and then released into the wild. This is important as the quantity of ABFT that are caught by the purse seine fishery can exceed the quota, which leads to the release of excess fish at the end of the fishing season. Observing the behaviour of the fish released to assess whether they return to the behaviour shown by wild fish is also of interest.

The present case does not precisely fall into this category as the fish that were tagged had been housed in a fattening cage for almost one year. However, it was interesting to note that two of the fishes tagged during the operation remained in the vicinity of Malta during the spawning season in an area known to be visited by ABFT during this period of the year. More surprisingly, the third fish moved quickly towards the western Greek coast in the Ionian sea, which is not part of the areas commonly described through tagging studies at this period of the year.

The retention times were not as long as was expected with this technique and did not allow to go deeper in the analysis of the tracks. A fish was caught in Tunisian waters shortly after having been tagged, which resulted in a short retention time (27 days). The two other tags remained 37 and 50 days at large, which is equivalent to the retention times obtained by 30% of the tags during the GBYP operations and above the retention time obtained by 40% of the tags during the same operations (Tensek *et al.*, 2017). The reason for these premature releases remained unresolved as the tag did not show any sign of failure. Explanations could be related to a bad attachment of the tag to the fish or to a failure of the leader, or even to the fish being caught by a fisherman (Musyl *et al.* 2011). Low reporting rates did not affect the present study, but it has been identified as an important limiting factor for many other studies (Musyl *et al.* 2011). As this was the first time such an operation was conducted, large improvements can be expected for future deployments.

ACKNOWLEDGEMENTS

This research was part of the MERLIN-POPSTAR project funded by Ifremer. We thank our colleagues from Ifremer/REM/RDT and RBE, CNRS, UM and IRD who provided insight and expertise that greatly assisted the research. We thank MFF Ltd for letting us use their facilities and the crew for their great skills and assistance.

REFERENCES

Aranda, G., Abascal, F. J., Varela, J. L., and Medina, A. 2013. Spawning Behaviour and Post-Spawning Migration Patterns of Atlantic Bluefin Tuna (*Thunnus thynnus*) Ascertained from Satellite Archival Tags. PLOS ONE, 8: e76445.

Block, B. A., Dewar, H., Blackwell, S. B., Williams, T. D., Prince, E. D., Farwell, C. J., Boustany, A., *et al.,* 2001. Migratory Movements, Depth Preferences, and Thermal Biology of Atlantic Bluefin Tuna. Science, 293, 1310–1314.

Block, B. A., Teo, S. L. H., Walli, A., Boustany, A., Stokesbury, M. J. W., Farwell, C. J., Weng, K. C., *et al.,* 2005. Electronic tagging and population structure of Atlantic bluefin tuna. Nature, 434, 1121–1127.

Block, B. A., Jonsen, I. D., Jorgensen, S. J., Winship, A. J., Shaffer, S. A., Bograd, S. J., Hazen, E. L., *et al.,* 2011. Tracking apex marine predator movements in a dynamic ocean. Nature, 475, 86–90.

Carruthers, T., 2016. Short-term contract for modelling approaches: support to BFT assessment (GBYP 06/2017) of the Atlantic-Wide Research Programme on Bluefin tuna (ICCAT-GBYP – Phase 7): 13.

Chaprales, W., Lutcavage, M., Brill, R., Chase, B., and Skomal, G. 1998. Harpoon Method for Attaching Ultrasonic and ‘Popup’ Satellite Tags to Giant Bluefin Tuna and Large Palegic Fishes. Marine Technology Society. Marine Technology Society Journal; Washington, 32: 104.

Cort, J. L., Abascal, F., Belda, E., Bello, G., Deflorio, M., Estruch, V., Godoy, D., *et al.,* 2010. Tagging manual for the Atlantic-Wide Research Programme for Bluefin Tuna (ICCAT-GBYP). Introduction: 42pp.

De Metrio, G., P. Arnold, G., Block, B., M. de la Serna, J., Deflorio, M., Cataldo, M., Yannopoulos, C., *et al.,* 2002. Behaviour of post-spawning Atlantic bluefin tuna tagged with pop-up satellite tags in the Mediterranean and Eastern Atlantic. Collective Volumes of Scientific Papers ICCAT, 54, 415–424.

De Metrio, G., Arnold, G.P., de la Serna, J.M., B.A. Block, Megalofonou, P., Lutcavage, M., Oray, I., and Deflorio, M., 2005. Movements of bluefin tuna (*Thunnus thynnus L.*) tagged in the Mediterranean Sea with pop-up satellite tags. Collective Volumes of Scientific Papers ICCAT, 58(4), 1337-1340.

Fromentin, J. M., and Powers, J. E., 2005. Atlantic bluefin tuna: population dynamics, ecology, fisheries and management. Fish and Fisheries, 6, 281–306.

Fromentin, J.-M., 2009. Lessons from the past: investigating historical data from bluefin tuna fisheries. Fish and Fisheries, 10, 197–216.

Fromentin, J.-M., Reygondeau, G., Bonhommeau, S., and Beaugrand, G., 2014. Oceanographic changes and exploitation drive the spatio-temporal dynamics of Atlantic bluefin tuna (*Thunnus thynnus*). Fisheries Oceanography, 23(2), 147–156.

Fromentin, J.-M., and Lopuszanski, D., 2014. Migration, residency, and homing of bluefin tuna in the western Mediterranean Sea. ICES Journal of Marine Science, 71(3), 510-518.

Hussey, N. E., Kessel, S. T., Aarestrup, K., Cooke, S. J., Cowley, P. D., Fisk, A. T., Harcourt, R. G., *et al.,* 2015. Aquatic animal telemetry: A panoramic window into the underwater world. Science, 348, 1255642.

Lutcavage, M. E., Brill, R. W., Skomal, G. B., Chase, B. C., and Howey, P. W., 1999. Results of pop-up satellite tagging of spawning size class fish in the Gulf of Maine: do North Atlantic bluefin tuna spawn in the mid-Atlantic? Canadian Journal of Fisheries and Aquatic Sciences, 56, 173–177.

MacKenzie, B. R., Payne, M. R., Boje, J., Høyer, J. L., and Siegstad, H., 2014. A cascade of warming impacts brings bluefin tuna to Greenland waters. Global Change Biology, 20, 2484–2491.

Musyl, M. K., Domeier, M. L., Nasby-Lucas, N., Brill, R. W., McNaughton, L. M., Swimmer, J. Y., Lutcavage, M. S., et al. 2011. Performance of pop-up satellite archival tags. Marine Ecology Progress Series, 433: 1-28.

Powers, J. E., and Porch, C. E., 2003. Approaches to incorporating mixing and movement of Atlantic bluefin tuna into management and assessment. ICES CM2003/V:25.

Richardson, D. E., Marancik, K. E., Guyon, J. R., Lutcavage, M. E., Galuardi, B., Lam, C. H., Walsh, H. J., *et al.,* 2016. Discovery of a spawning ground reveals diverse migration strategies in Atlantic bluefin tuna (Thunnus thynnus). Proceedings of the National Academy of Sciences, 113(12), 3299–3304.

Rooker, J. R., Bremer, J. R. A., Block, B. A., Dewar, H., Metrio, G. de, Corriero, A., Kraus, R. T., *et al.,* 2007. Life History and Stock Structure of Atlantic Bluefin Tuna (*Thunnus thynnus*). Reviews in Fisheries Science, 15, 265–310.

Tensek, S., Natale, A. D., and García, A. P., 2017. ICCAT GBYP PSAT tagging: the first five years. Collective Volumes of Scientific Papers ICCAT, 73(6), 2058-2073.

Tičina, V., Grubišić, L., Katavic, I., Jeftimijades, I., and Franicevic, V., 2003. Tagging of small bluefin tuna in the growth-out floating cage. Report of the research activities on tuna farming in the adriatic sea during 2002.

Tičina, V., Grubišić, L., and Katavić, I., 2004. Sampling and tagging of live bluefin tuna in growth-out floating cages. Aquaculture Research, 35, 307–310.

Walli, A., Teo, S. L. H., Boustany, A., Farwell, C. J., Williams, T., Dewar, H., Prince, E., *et al.,* 2009. Seasonal Movements, Aggregations and Diving Behavior of Atlantic Bluefin Tuna (*Thunnus thynnus*) Revealed with Archival Tags. PLOS ONE, 4, e6151.

TABLE

Table 1: Percentage of occurences at different depth bins for each tag

Depth Range	MiniPAT 170332	MiniPAT 170333	MiniPAT 170334
5-0	25.9	25.6	51.1
10-5	27.4	6.2	21.3
20-10	20.3	18.8	11.2
30-20	8.9	11	2.9
40-30	1.6	8.1	1.8
50-40	1.2	6.7	1.6
100-50	6.4	17.1	6
200-100	5.7	5.4	3.2
500-200	2.5	1	0.9
800-500	0	0	0.1

FIGURE LEGENDS

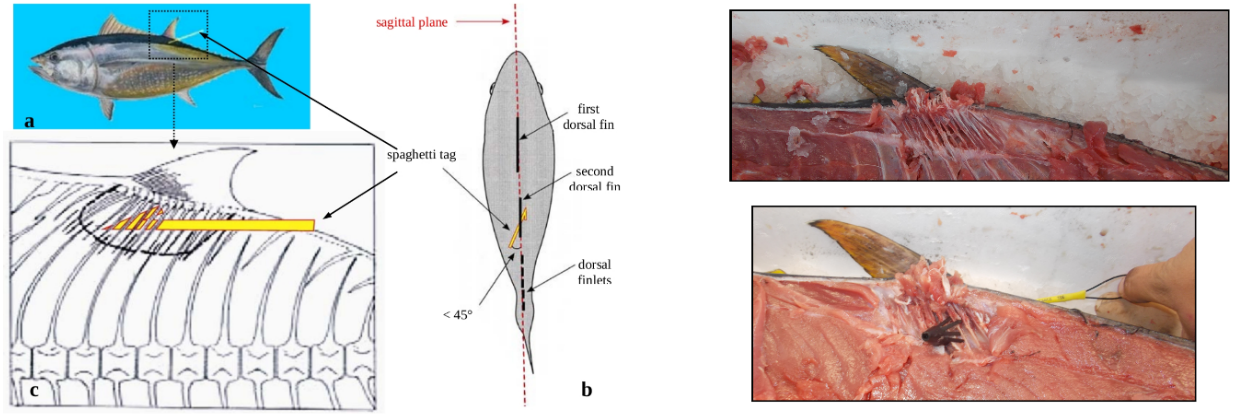


Figure 1: Implantation of the tag. The left panels (adapted from Cort *et al.*, 2010) show the insertion of the tags within the pterygiophores of the second dorsal fin. The top right panel shows the pterygiophores of the second dorsal fin from an ABFT. The bottom right panel shows a domeier anchor tangled within the pterygiophores.

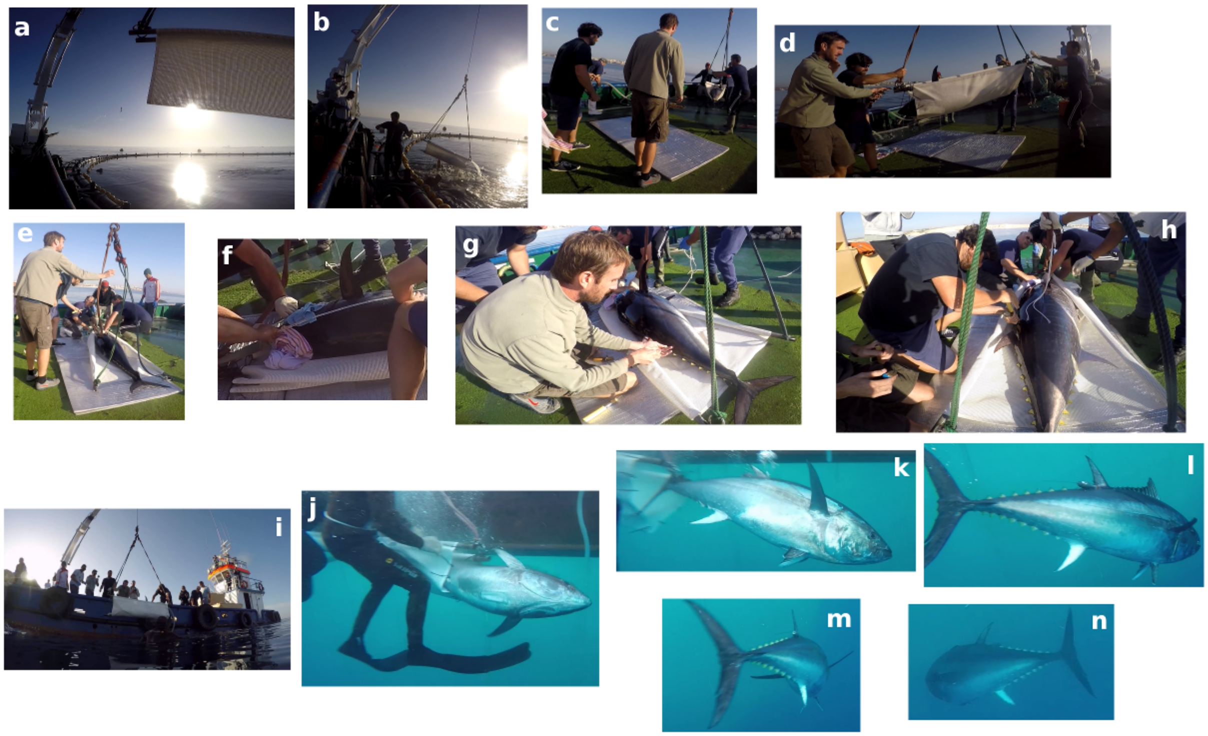
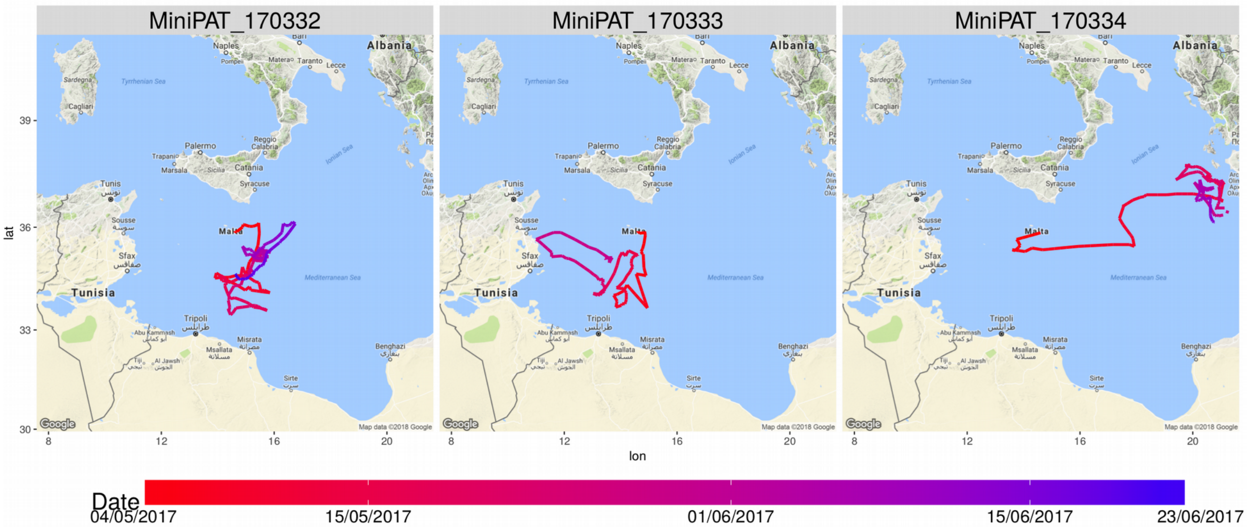
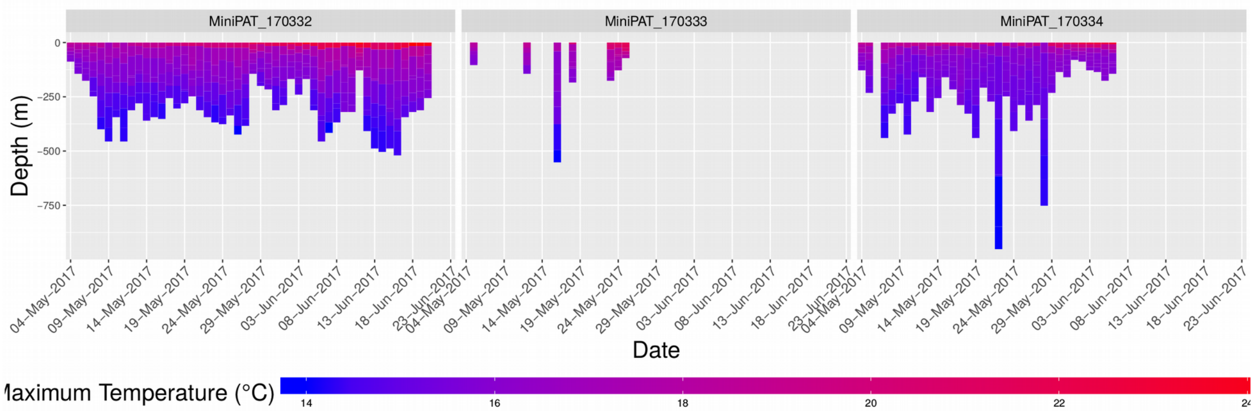


Figure 2: Tagging operation. The fish is hooked (a) and placed into a stretcher attached to a crane (b). The tuna is placed onto a mattress with care (c-e). The stretcher is opened, the eyes of the tuna are covered and a water pipe is placed in its mouth, while the hook is removed (f). The tag is deployed on the fish (g and h). The stretcher is hauled back into the water (i) and the fish returns in open waters (j – n).

271


MiniPAT_170332
MiniPAT_170333
MiniPAT_170334
lat
lon
Date
04/05/2017
15/05/2017
01/06/2017
15/06/2017
23/06/2017


MiniPAT_170332
MiniPAT_170333
MiniPAT_170334
Depth (m)
Date
Maximum Temperature (°C)

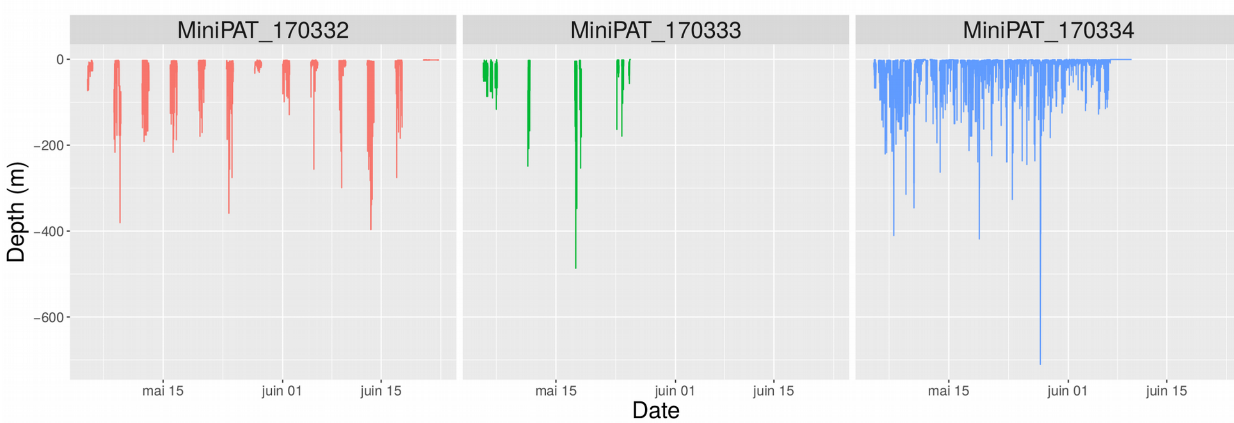

MiniPAT_170332
MiniPAT_170333
MiniPAT_170334
Depth (m)
mai 15
juin 01
juin 15
Date

Figure 3: Data collected from the three tags deployed and geolocation processing results. The top panel depicts the tracks of the fish obtained using the GPE3 state-space model algorithm from Wildlife Computers, the second panel represents the temperature profile along the deepest dive for each day and the third panel represents the diving pattern. For tag 170332 and 170333, depth data were not collected every day.