ATTEMPTS TO TAG LARGE ATLANTIC BLUEFIN TUNA: DEVELOPMENT OF A METHODOLOGY FOR FUTURE LARGE SCALE DEPLOYMENTS IN THE MEDITERRANEAN

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SUMMARY

*The use of archival tags has greatly improved the knowledge on the biology and ecology of Atlantic bluefin tuna (*Thunnus thynnus*). Ideally tags should be deployed in large numbers, in standardised conditions between individuals and remain attached as long as possible. Large individuals (> 60 kg) are difficult to handle and tagging them outside of the water in suitable conditions for long-term deployments remains complex. In the present manuscript, we describe a protocol applied during two tagging operations carried off Malta in 2018. The first operation was carried out in a farming cage to set-up the protocol, and the second took place onboard a purse seiner. Six large tunas were tagged on-deck in less than 2 minutes. The retention times achieved seem encouraging given that releases occurred due to recapture and failure of the release system of the tag. The number of recaptures, at least 2 over 5 tags, point towards a high fishing mortality in the Mediterranean and suggest that further investigation of the tags deployed so far within the GBYP could lead to interesting insights on that matter.*

RÉSUMÉ

*L'utilisation de marques d'archives a considérablement amélioré les connaissances sur la biologie et l'écologie du thon rouge de l'Atlantique (*Thunnus thynnus*). Idéalement, un grand nombre de marques devrait être apposé, dans des conditions standardisées pour les spécimens et ces marques devraient rester attachées aussi longtemps que possible. Les gros spécimens (> 60 kg) sont difficiles à manipuler et leur marquage en dehors de l'eau dans des conditions appropriées pour des déploiements à long terme reste complexe. Le présent document décrit un protocole appliqué lors de deux opérations de marquage effectuées au large de Malte en 2018. La première opération a été réalisée dans une cage d'élevage pour mettre en place le protocole, et la seconde s'est déroulée à bord d'un senneur. Six grands thons ont été marqués sur le pont en moins de 2 minutes. Les temps de conservation à bord obtenus semblent encourageants étant donné que des remises à l'eau ont eu lieu en raison de la récupération et de la défaillance du système de détachement de la marque. Le nombre de récupérations, au moins deux sur cinq marques apposées, laisse présager une forte mortalité par pêche en Méditerranée et suggère que des recherches plus poussées sur les marques déjà déployées dans le cadre du GBYP pourraient fournir des informations intéressantes à ce sujet.*

RESUMEN

El uso de marcas archivo ha mejorado enormemente los conocimientos sobre la biología y la ecología del atún rojo del Atlántico (Thunnus thynnus). *De forma ideal, debería colocarse una gran cantidad de marcas en condiciones estandarizadas y que permanecieran colocadas el mayor tiempo posible. Los ejemplares grandes (> 60 kg) son difíciles de manejar y marcarlos*

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fuera del agua en condiciones adecuadas para colocaciones de mucho tiempo sigue siendo difícil. En este documento, se describe un protocolo aplicado durante dos operaciones de marcado llevadas a cabo en aguas de Malta en 2018. La primera operación se realizó en la jaula de una granja para establecer el protocolo y la segunda se realizó a bordo de un cerquero. En menos de dos minutos, se marcaron en la cubierta seis atunes grandes. Los tiempos de retención logrados parecen prometedores teniendo en cuenta las liberaciones producidas debidas a la recaptura y al fallo del sistema de liberación de la marca. El número de recapturas, al menos 2 de cada 5 marcas, señala a una elevada mortalidad por pesca en el Mediterráneo y sugiere que una investigación más en profundidad de las marcas colocadas hasta ahora por el GBYP podría conducir a conclusiones interesantes en este sentido.

KEYWORDS

Large Atlantic bluefin tuna, Mediterranean,
Malta, Electronic tagging, Farming cages, Purse seiners

1. Introduction

ABFT is capable of movements across long distances and can move from one stock to another (Rooker *et al.*, 2007). The complexity of these movements, and in particular their relationship to known spawning areas, is far from being resolved (Richardson *et al*., 2016). Therefore, quantifying these movements is currently still an important challenge in order 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 on 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 from 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*., 2013).

ABFT movements have been largely studied using electronic tags, which has led to important improvements in our knowledge of its biology and ecology and also of numerous other marine species (De Metrio *et al.*, 2002; Block *et al.*, 2005, 2011; Arnold *et al.*, 2005; Walli *et al.*, 2009; Fromentin and Lopuszanski, 2013; Hussey *et al.*, 2015). However, data acquisition through electronic tags is still advocated by ICCAT and largely achieved through the GBYP, as data is still lacking to get a full picture of the ABFT's life cycle. Ideally, to capture the complexity of ABFT movements, one would need to deploy several 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 and inter-annual variability. To facilitate the assessment of the true variability of migratory behaviour between individuals, there should ideally be a good control on tagging conditions, location and date, size, etc. 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 period of time, and appropriately handling large ABFT is not straightforward.

Tagging ABFT for long-term deployments is better achieved by handling 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 hit more than 4 months (Fromentin and Lopuszanski, 2013). The operation consists of inserting the anchor of the tag through the rays of the second dorsal fin (pterygiophores, **Figure 1**), which is easier to achieve on 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's wellbeing and subsequent behaviour.

In the Mediterranean Sea, the largest amount of catch is made during the purse seiner fishing season, which takes place during the spawning season. The purse seine fleet represents a very good opportunity for large scale tagging deployments as this fleet has access to a substantial amount of the total allowable catch of the eastern stock. The fish caught, consists of large fish (50 to > 500 kg), which are caught in the hundreds and are transferred into cages to be fattened. However, as a first attempt at tagging several tunas in one go, using fish already housed in a cage is a convenient way 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.

This document describes the results of two operations that aimed to test the feasibility of large scale deployments. An operation carried out in May 2018 was set up at a Maltese farming cage and aimed at setting up the protocol and testing how quick large fish could be tagged and released. The fish in the cages had already spent one year in the cage and were used to manual feeding, a critical aspect for the operation. Subsequently a tagging operation on board two purse seiners was carried out in June 2018 to test whether the protocol could be applied to wild fish not used to manual feeding.

2. Materials and method

2.1 Landing a fish onto the deck from a cage

Due to inappropriate meteorological conditions, the operation took place on 4 May in the afternoon with sea and wind conditions that were not perfect. The optimal conditions are early morning when fish are calmer, with a clear sky, flat sea and no wind; under these conditions the operation can go as smoothly as possible. The licensed farm MFF ltd made available a barge equipped with a crane with operator, a skipper, three divers, a fisherman and 3 other crew members to assist with the operation. These operators were in charge of capturing the fish with longlines, hauling it onboard the barge, removing the hook and getting the fish back into the water after the tagging was completed. Three scientists were in charge of the tagging operation.

Frozen bait fish, usually used to feed the farmed tunas, were used to get the fish into a feeding behaviour (**Figure 1**). Then a handline was thrown into the cage, baited with the same fish. Once the fish took the bait, it was maneuvered towards a specifically designed stretcher fixed on the crane of the barge. This stretcher was made of fabric used to make tarpaulin for catamarans, punctured with holes to let the water go through. Its opening was equipped with a chain so that it remained open in the water, while the exit side had an attachment system that allowed the fish to go through and exit once the tagging was completed. Once the fish was close enough to the stretcher, three divers helped to get the fish into the stretcher, at which point the fish could be then hauled up onto the deck.

2.2 Landing fish onto the deck from a purse seiner

This operation took place during the purse seine fishing season, specifically on 20 June, onboard the purse seiner Saint Sophie François II (SSFII) south of the island of Malta. The boat had 13 crew members and its sistership, the Saint Sophie François III (SSFIII), which also helped with the whole operation, had a similar crew. An ICCAT observer was also present on each boat.

The tuna school was caught early in the morning (**Figure 2**). Skiffs and rubber boats from both SSFII and SSFIII were immediately put into operation to keep the purse seine as widely open as possible while waiting for the transfer cage, which was scheduled for the next day. This left a full day to conduct the tagging attempt. The purse seine is substantially larger than a farm cage, so throwing the bait from the boat would be inefficient. Instead, a rubber boat with three divers and a skipper was deployed into the purse seine so that they could throw some bait and the fishing line not too close from the purse seiner. The handline was equipped with a fender so that the fish would not dive too deep and would also get tired quicker. Similarly as during the cage operation, the fish was maneuvered towards the stretcher attached to a crane, and once the fish was close enough to the stretcher, three divers helped to get the fish into it. The fish could then be hauled up onto the deck.

2.3 Tagging protocol

For both deployments, a 5cm thick mattress was placed onto the deck to avoid hurting its lateral line. The eyes of the fish were covered with a cloth and a flowing pipe was inserted into its mouth to ensure a continuous provision of oxygen over the gills. The fish was measured (CFL) and then tagged. Pop-up tags (MiniPATs, Wildlife Computers) were set to pop-off after 360 days. The tags were rigged with 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 entangled 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, 2013); 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.

3. Results

3.1 Fish from farm cage

During the cage operation, three fish of 186, 160 and 150cm were caught and tagged. The fish took the bait almost immediately after it was thrown into the cage. Each fish was then hauled up onto the deck, tagged and released in about 10minutes each, including the fishing operation. 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 operation lasted about 45mn. No mortality was suffered by the fish.

Two tags prematurely popped-off after 71 and 95 days (**Figure 3**). Both tags indicated "broken pin", which indicates that the release system broke. The first tag (150 cm fish) popped-off off Malta and the track of the fish and its diving behaviour presented movements that suggested that the fish could have been caught by a purse seiner and transferred into a cage. On the 9th of June, the dives of this fish started to be limited to 28.5 m maximum compared to the 433 m before that date (**Figure 4**). The track also presents straight movement over rather long distances, difficult to attribute to a wild free-swimming tuna. The second fish (160 cm) was caught in Greece after 95 days at large. This was easily assessed as the tag moved onto the land quickly after it popped-off. The GPE3 algorithm from Wildlife computers did not converge for this tag. The third fish (186 cm) is still at large after more than 135 days.

3.2 Fish from farm cage

Three fish of 206 cm, 189 cm and 226 cm were caught during the operation on the purse seiner. The fish easily took the bait, but the fish within the purse seine were generally too big for our fishing material. More than 12 fishing lines were immediately broken, or the hook bent, after the fish took the bait. The three fishes that were caught were probably at the lower range of the size distribution within the purse seine. Each of these 3 fish was hauled up onto the deck, tagged and released in 15 to 20 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. Because of the numerous broken fishing lines, the total operation lasted about 6 hours. No mortality was observed.

The three tags prematurely popped-off after 32, 62 and 72 days (**Figure 3**). As had been observed for the cage deployments, they all indicated "broken pin", which meant that the release system broke. The first tag (206 cm fish) popped-off just beyond the Strait of Gibraltar. The tag movement on land while transmitting its data indicated that the fish had been caught by a fisherman. The track of the fish obtained through Wildlife's GPE3 algorithm indicated that the fish went northeast of Malta where it spent some time and then went almost directly to the Strait of Gibraltar, with a small detour near the Balearic Islands. The second tag (189 cm fish) popped-off in Libyan waters, quite close to the deployment point. For this tag, it seems unlikely that the fish was caught by a fisherman. Its track consists of erratic movements south of Malta with no clear direction. The third tag (226 cm fish) popped-off west of Ireland. At first sight, it does not seem that it has been caught by a fisherman; the tag is still transmitting as this manuscript is being written and the data cannot be interpreted yet.

4. Discussion

The two operations described here were successful as they showed that large scale deployments are feasible within a reasonable time frame. In particular, the operation onboard the purse seiner showed that several individuals from the same school could be tagged and released at the same time. This would enable scientists to study group behaviour and to obtain good statistics on the amount of fish that exit the Mediterranean after spawning. In our case, two out of the three fish from the same school that were tagged on the same day at the same location exited the Mediterranean, whereas the third one remained in the Libyan waters, nearby its release location. However, for deploying a larger amount of tags, say 50, the technique needs to be improved or the school transferred into a cage to allow more time to achieve the tagging. In our case, one easy way to substantially improve the speed of the operation will be to use much stronger fishing material to avoid broken lines.

Compared to the fish tagged from the purse seiner, the fish tagged from the cage did not exit the Mediterranean. They remained within the vicinity of Malta or went to Greece. Even though the sample size is small and the size range of the fish is smaller than for the purse seiner deployment, the results suggest that the behaviour of fish that spent one year within a cage could be substantially different from the behaviour of wild-tagged fish. In our

case the fish had spent one year in the cage, but this is an interesting aspect as fish caught over the quota are often released sometime after the fishing season has closed. How this affects their natural behaviour is therefore a question of interest and merits further study.

The premature releases due to the “pin-broken” issue is a problem that is well-known by the manufacturer, but it seemed to have impaired part of the deployments as all the tags reported that issue. However, at least two tags from 5 were caught by fishermen. Even though the sample size was small and the impact, if any, on the behaviour of the fish following handling and tagging is unknown, this suggests that the fishing pressure in the Mediterranean remains quite high. Investigating the GBYP database of electronic tags in that perspective would probably yield interesting insights into this aspect.

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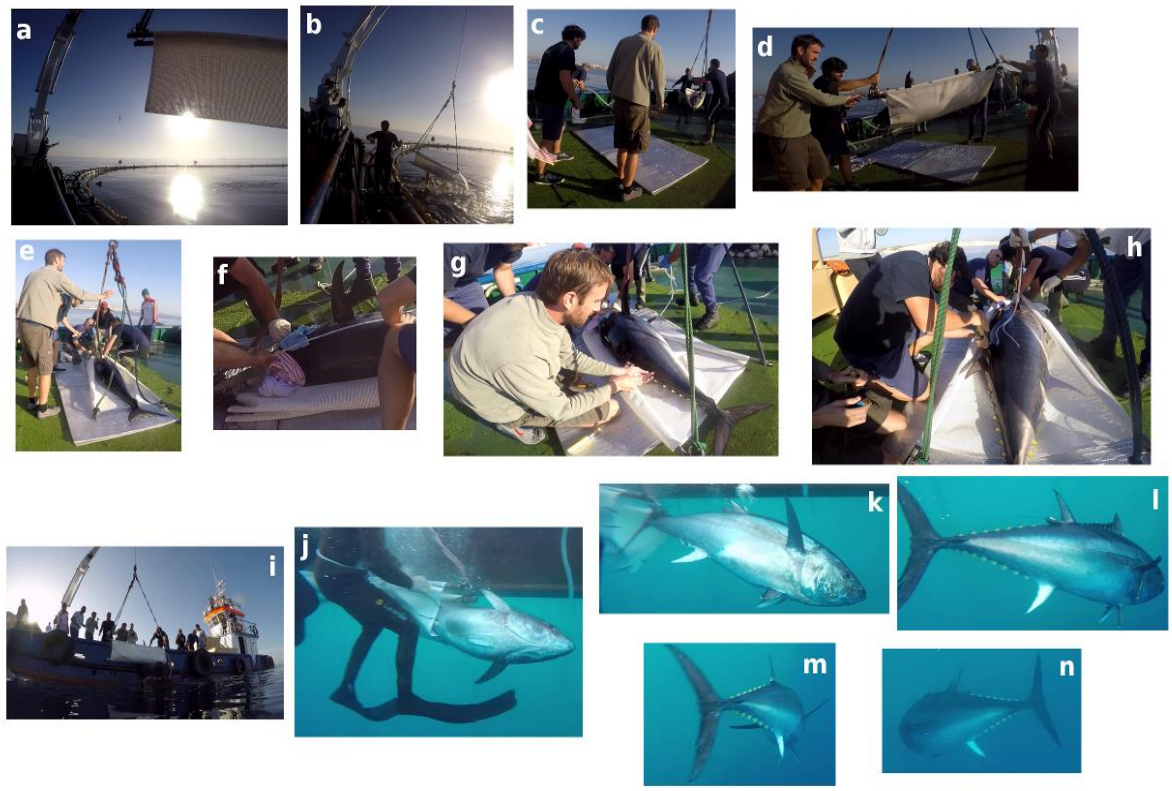

Figure 1. Tagging operation from a cage of MFF ltd. The pictures from the top left through to the bottom right, describe the steps of the operation. The fish were caught using a handline and the fisherman manoeuvered the tuna towards a stretcher set up on a crane from the boat. Divers steered the tuna into the stretcher, which was hauled up onto the deck. The fish was layed onto a mattress, his eyes covered and his mouth intubed with a continuous influx of seawater. The fish was tagged and the hook removed, before being released at sea. The pictures were taken during the 2017 operation, but the 2018 operation was completely similar.

Figure 2. Tagging operation on the purse seiner SSFII. The pictures from the top left through to the bottom right, describe the steps of the operation. The school was caught and the net was kept open by support vessels. Divers went into the net with a vessel to bait the fish and throw the handline. A fisherman manoeuvered the handline to get the tuna towards a stretcher set up on a crane from the boat. Divers steered the tuna into the stretcher, which was hauled up onto the deck. The fish was layed onto a mattress, his eyes covered and his mouth intubed with a continuous influx of seawater. The fish was tagged and the hook removed, before being released.

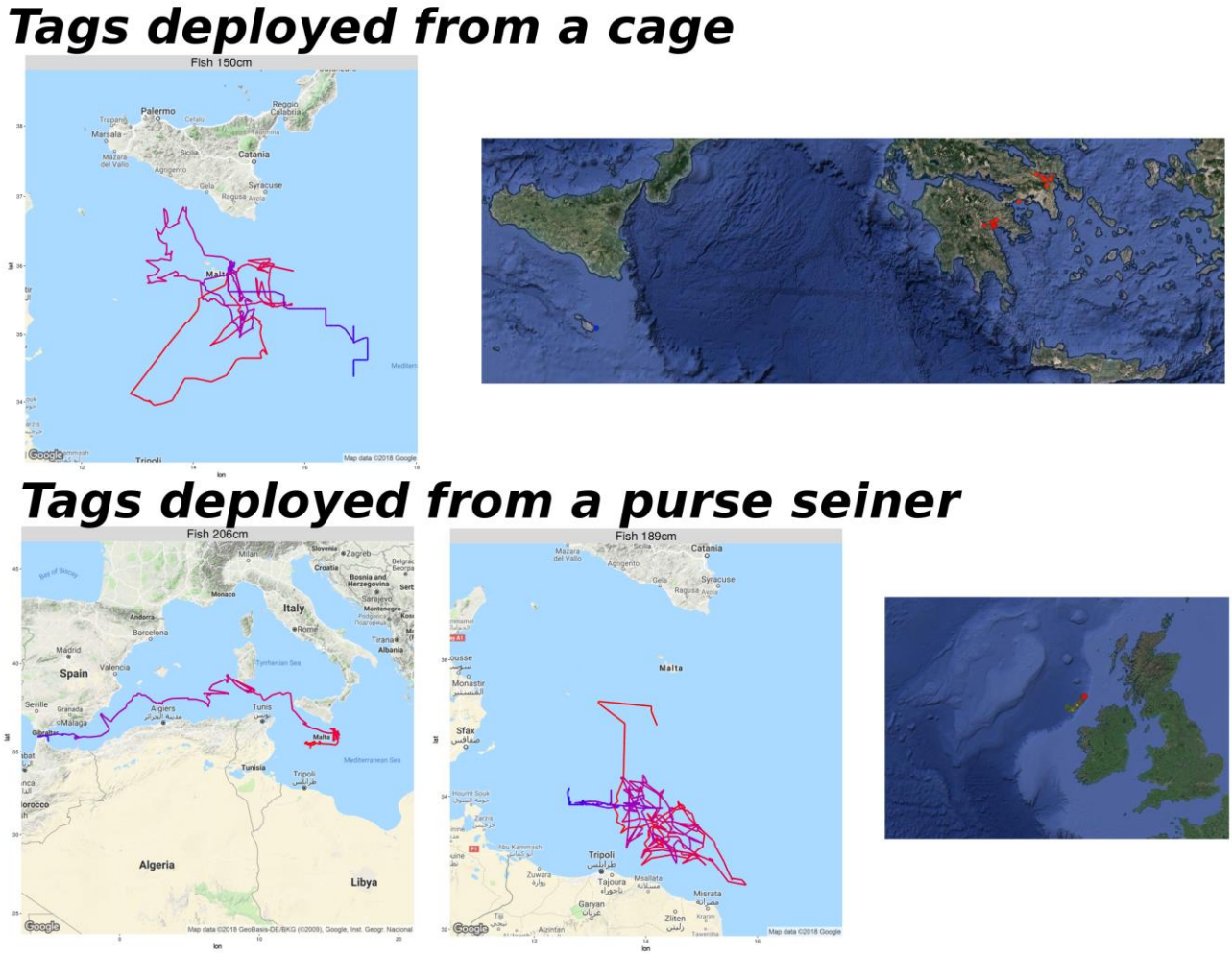

Figure 3. Tracks and pop-off locations of the tags deployed during the operation on the cage (top panels) and onboard the purse seiner SSFII (bottom panel). The colors on the tracks indicate the early (red) to late (blue) days.

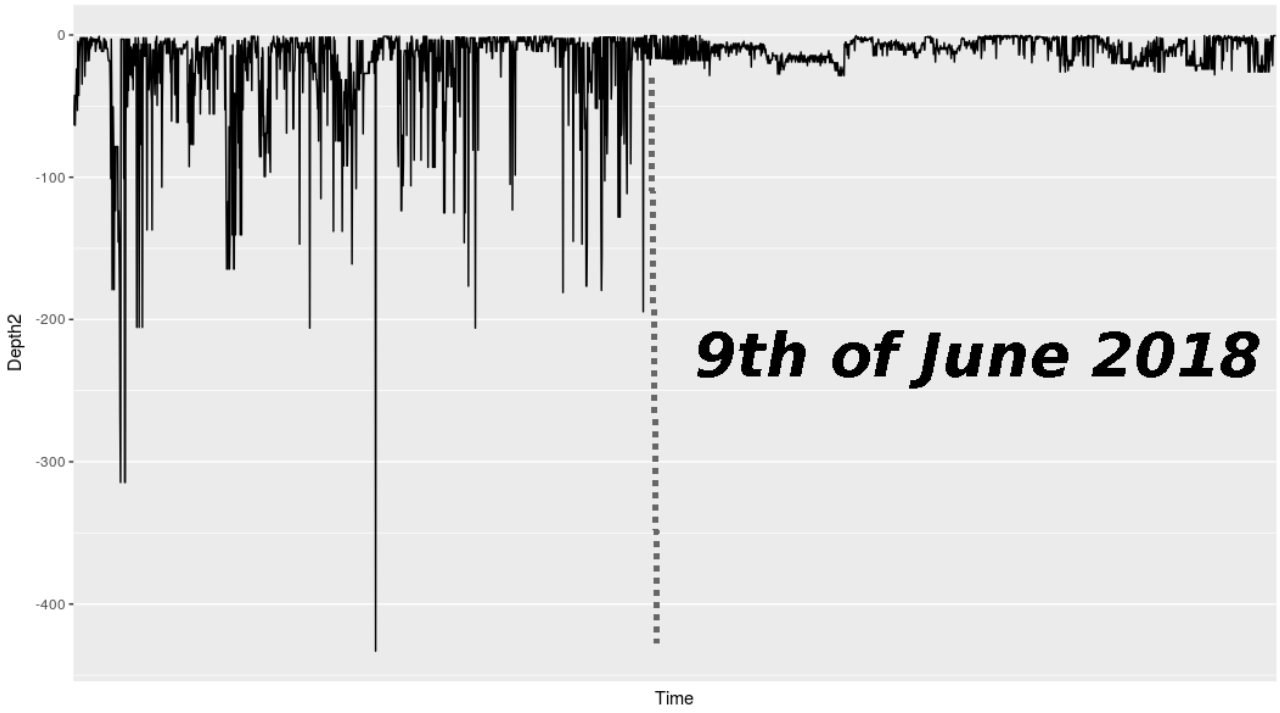

Figure 4. Vertical behaviour of the 150 cm fish released from a Maltese cage. The 9th of June marks a change in behaviour associated with a change in tracks as well. It suggests that the fish was caught by a purse seiner.