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RESEARCH ARTICLE

Evidence of a predation event on a tagged Mediterranean spearfish (*Tetrapturus belone*; Pisces, Istiophoridae), inferred from pop-up satellite tagging data

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Abstract – The Strait of Messina is located at the centre of the Mediterranean Sea and is considered a biodiversity hotspot and an obligatory seasonal passage for different pelagic species such as sharks, marine mammals, and billfishes. For the first time, in the Strait of Messina, our research group tagged a Mediterranean spearfish (*Tetrapturus belone*) using a pop-up satellite archival tag (PSAT). The observation of abiotic parameters (depth, light, and temperature) recorded by the PSAT confirmed that the tagged specimen was predated after about nine hours. The tag was then regurgitated 14 days after the tag deployment date. The analysis of collected data seems to indicate that the predator may be an ectothermic shark, most likely the bluntnose sixgill shark (*Hexanchus griseus*).

Keywords: Billfish / behaviour / biologging / tracking / ectothermic shark attack / pop-up satellite archival tag / Mediterranean Sea

1 Introduction

Understanding large vertebrates' movements, ecology, habitat, and behaviour is a challenging task, especially in a marine environment. However, the fast technological advancement of the last few decades has allowed researchers to use biologging, applying electronic tags to study marine pelagic vertebrates (Hays et al., 2016). Biologging is the utilisation of any animal-borne device (biologger) that stores data collected from a single or multiple sensor (Boyd et al., 2004; Hooker et al., 2007). Data stored by a biologger can be retrieved via satellite transmission (satellite telemetry) or acoustic transmission (acoustic telemetry) or can be downloaded after recovering the electronic tag (for an exhaustive review, see Cooke et al., 2004; Ropert-Coudert and Wilson, 2005; Cooke et al., 2012; Hussey et al., 2015; Wilson et al., 2015).

Satellite telemetry devices are generally used to study highly migratory species, especially their movements and behaviour, mainly against time and depth in coastal or open ocean areas. For instance, this technology has been used to study pelagic species belonging to different taxa, such as sharks, rays, tunas, tuna-like fishes, turtles, swordfish (*Xiphias gladius*), other billfishes (Istiophoridae), escolar (*Lepidocybium flavobrunneum*), sablefish (*Anoplopoma fimbria*), Atlantic salmon (*Salmo salar*), and American eels (*Anguilla rostrata*) (Speare, 1995; Sedberry and Loefer, 2001; Canese et al., 2004; Kerstetter et al., 2008; Block et al., 2011; Canese et al., 2011; Dewar et al., 2011; Wilson et al., 2011; Béguer-Pon et al., 2012; Pleizier et al., 2012; Chittenden et al., 2013; Lacroix, 2013; Abascal et al., 2015; Carvalho et al., 2015; Chapple et al., 2015; Echave, 2016; Arostegui et al., 2018; Andrzejaczek et al., 2019; Arostegui et al., 2019). Moreover, pop-up satellite archival transmitters (PSATs) have become the best option to study animals that spend less time at the surface (i.e. billfish, sharks, etc.), allowing one to record the information from sensors (such as depth, temperature, environmental light level, etc.; Hill and Braun, 2001). These

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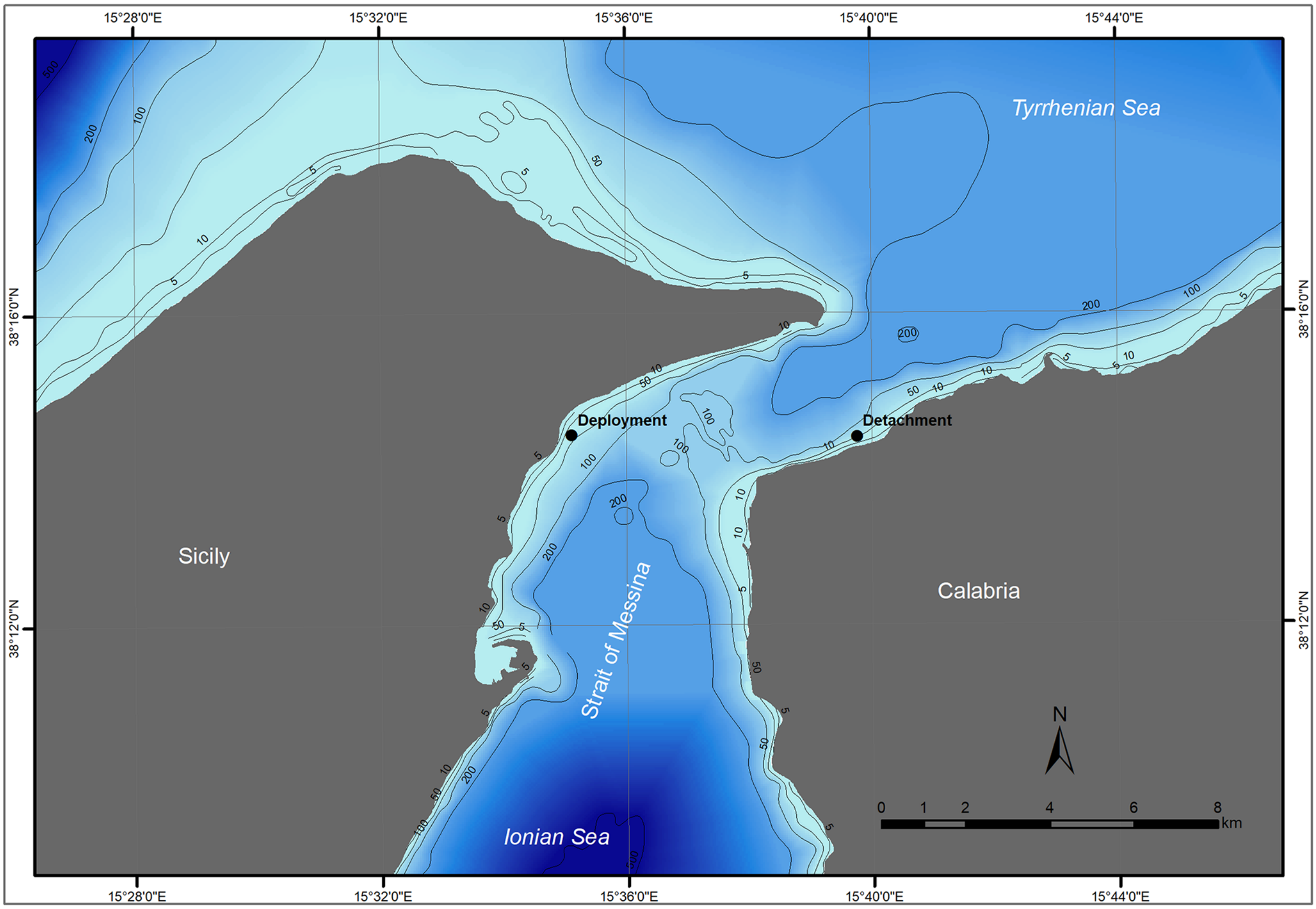

Fig. 1. Study area (Strait of Messina, central Mediterranean), bathymetric information and tag deployment-detachment locations. Image created using ARCGIS v. 10.8.1 while bathymetric data were obtained from digitalised IGM database.

transmitters detach from the animal using a pre-programmed release mechanism (Cooke et al., 2012) or when the animal is dead. In some cases, the tagged specimens are vulnerable to predators because of injuries or stress caused by the tagging. However, the PSATs do not provide any direct information if the tags or the tagged specimens are ingested by predators. Nevertheless, analysing the light sensor data in combination with the depth and temperature profiles (both internal and external) might help to understand whether the tagged specimen has been predated and infer what kind of predator has interacted with it. In the literature, different cases of predation on tagged fishes were reported regarding silver-stage American eels (*A. rostrata*; Béguer-Pon et al., 2012), Atlantic salmon (*S. salar*; Lacroix, 2014; Strøm et al., 2019), opah (*Lampris gattatus*; Kerstetter et al., 2004; Polovina et al., 2008), white marlin (*Tetrapturus albidus*; Kerstetter et al., 2004), sailfish (*Istiophorus platypterus*; Jolley and Irby, 1979), chinook salmon (*Oncorhynchus tshawytscha*; Seitz et al., 2019), albacore (*Thunnus alalunga*; Cosgrove et al., 2015), and southern bluefin tuna (*Thunnus maccoyii*; Tracey et al., 2016). While the predator is often identified at the macro-categories or family level (i.e. marine mammals, endothermic fish, ectothermic fish, lamnid sharks, etc.), one can often infer which predator species interacted with the tagged individual based on ecological knowledge.

The main aim of this study is to report, for the first time, a predation event on a Mediterranean spearfish (*Tetrapturus belone*) after the application of a PSAT in the Strait of Messina (located at the centre of the Mediterranean Sea). Based on the data retrieved from the PSAT, one could infer post-release predation on this billfish, which may be due to an attack by an ectothermic shark.

2 Materials and methods

2.1 Study area

Tagging experiments were carried out in the Strait of Messina, which is a narrow passage of seawater connecting the Ionian and Tyrrhenian seas (Fig. 1). The Strait of Messina is characterised by a peculiar hydrodynamic regime, regulated by tidal currents and producing upwelling phenomena (Vercelli, 1925; Bignami and Salusti, 1990; Mosetti, 1991) that make this area highly productive (Fortier, 1991) and concentrate mesopelagic food resources in upper waters (Berdar et al., 1983; Battaglia et al., 2017). For this reason, the Strait of Messina represents an important feeding area for large pelagic species such as *X. gladius* and *T. belone* (Romeo et al., 2009a) as well as Atlantic bluefin tuna (*Thunnus thynnus*; Battaglia et al., 2013). Therefore, this area holds high importance in the migratory movements of pelagic marine animals between the centre and the western part of the Mediterranean Sea. Here, the periodical abundance of large pelagic fish allowed the development of a peculiar and ancient fishing activity using the harpoon and the *feluca*, a type of boat (Romeo et al., 2009b; Romeo et al., 2015; Battaglia et al., 2018), between April and August. We used these vessels to perform tagging operations.

2.2 Sampling vessel and equipment

Tagging experiments were carried out on board a harpoon fishing vessel commonly used to target swordfish (*X. gladius*) and occasionally Atlantic bluefin tuna (*T. thynnus*) and the Mediterranean spearfish (*T. belone*) in the Strait of Messina (Di Natale et al., 2005; Romeo et al., 2015; Battaglia et al., 2018). The *feluca* is equipped with a long mast (25–40 m) and an elongated plank, having an adjustable length (25–40 m), ending with a pulpit, where the fisherman has the role of harpooning the sighted animals. At the top of the 'must', a maximum of four fishermen spend their time observing the sea surface (such observation can reach up to ~5 m below the sea surface) to sight fishes (Battaglia et al., 2018; Fig. 2a–d).

2.3 Tagging activity

Based on previous tagging activities carried out on board *felucca* boats in the Strait of Messina, targeting swordfish (*X. gladius*; Canese et al., 2004; Canese et al., 2008) and giant devil rays (*Mobula mobular*; Canese et al., 2011), the equipment was adapted and modified to best fit our target, that is, *T. belone*. Indeed, the Mediterranean spearfish has a slimmer body shape compared with the swordfish and the giant devil ray; for this reason, to increase tagging success, the 3.5 m harpoon pole was modified by removing the harpoon tip and inserting a customised short-handle tag pole with the applicator pin, equipped with a stainless steel anchor, connected to the tag via tether, and secured using two elastic bands (Fig. 2e). On 17 August 2019, at about 08:00 (UTC time), the first Mediterranean spearfish was tagged in the position 38°14′26″N, 15°35′06″E, using a MiniPAT PSAT (Wildlife Computers; https://wildlifecomputers.com). The tagged *T. belone* individual swam at the surface in a group of three animals directed towards the northern area of the Strait of Messina and weighed about 12–15 kg. The weight was visually estimated by four different fishermen and researchers and corresponded to approximatively 150 cm of low jaw fork length (LJFL).

The MiniPAT tag was attached to the dorsal musculature of the fish, about 5 cm from the dorsal fin, in the direction of the caudal fin. The tag was in pre-activated mode, which means that the collection of environmental information (depth, temperature, and light level at an interval of 75 s, which were pooled in 6-h bins) started after the animal performed the first dive below 5 m. The tag was also programmed to detach from the specimen via a corrosive burn wire mechanism (emergency release mechanism) and to transmit data either 30 days after activation or if it was floating at the surface or was at a constant depth (variation of 2 m) for more than three days. In addition, the tag was programmed to detach when achieving the threshold depth of 1700 m to avoid reaching its crush depth and

Fig. 2. Harpoon vessel and equipment used for the tagging experiment. '*Feluca*' boat (a), plank (b), 'must' (c) harpooner during fishing operations (d) and modified harpoon consisting in a 3.5 m pole equipped with the pop-up satellite archival tag (e).

becoming inoperable. The tag buoyancy was checked in a bucket full of seawater (~50 L); the tag, equipped with an anchor and tether, showed a slightly negative buoyancy.

2.4 Data analysis

Data from the recovered tag were retrieved using Tag Agent v. 2.2.19.0 (https://wildlifecomputers.com). Time series of temperature, depth, and light level as well as night/day predator time series were constructed using the 'ggplot2' package (v. 3.2.1; Wickham, 2016), while time-at-depth (TAD) histograms were constructed using the RchivalTag package (v. 0.0.7; Bauer, 2018). The depth bins were in 10 m increments from the surface to 50 m and in 50 m increments from 50 to 400 m. The night and day profiles coincided with nautical dusk and dawn times calculated using geographical coordinates at the time of tag deployment as a position reference through the 'suncalc' package (v. 0.5.0; Thieurmel and Elmarhraoui,

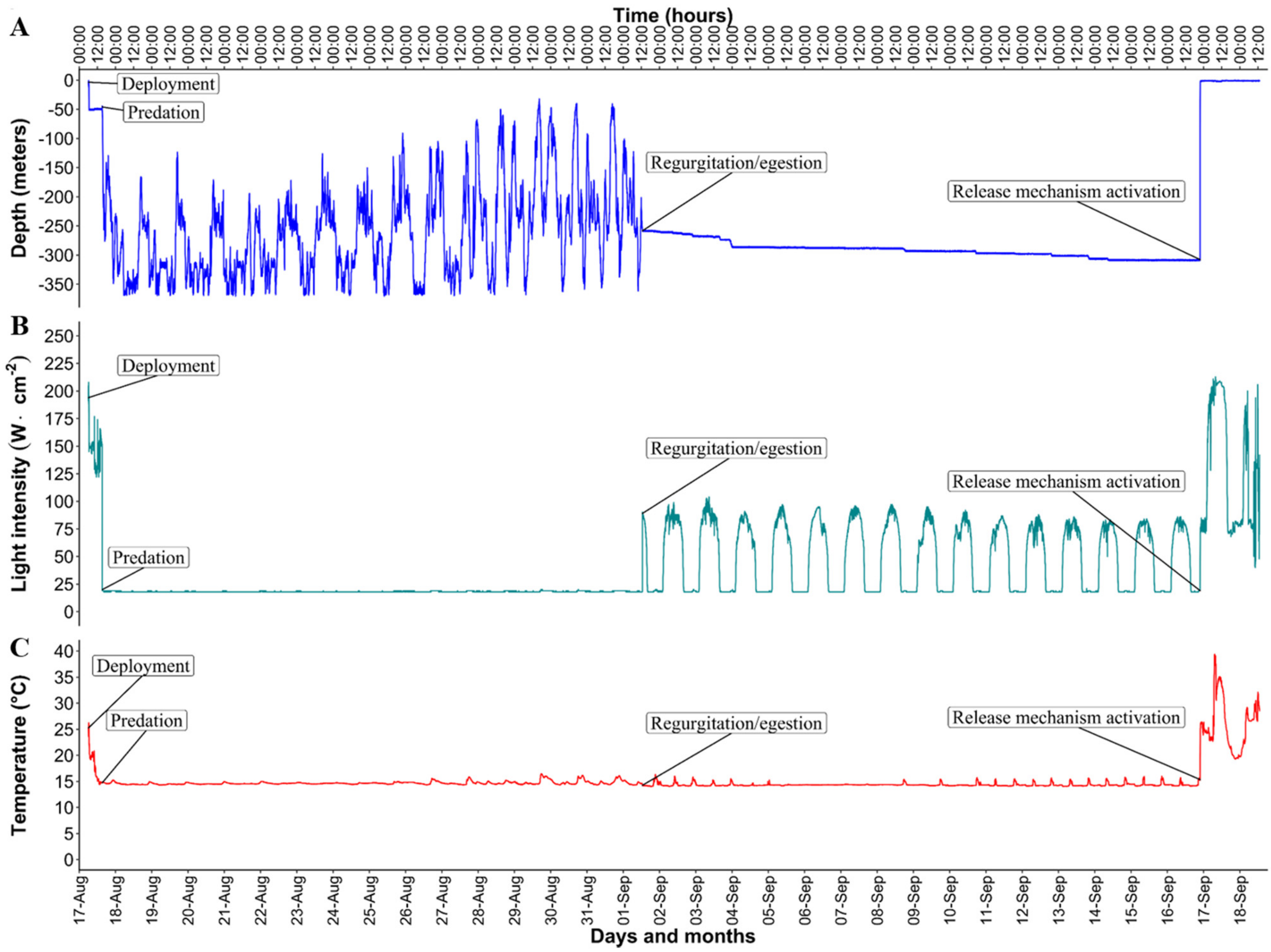

Fig. 3. Depth (a), light intensity (b) and temperature profile (c) retrieved from PSAT. The time of the deployment, predation, regurgitation/egestion and pin burn activation for each profile is also shown.

2019). Data analysis were performed using R v. 3.5.2 and R-studio v. 1.2.5033 (2020-01-17; R Core Team, 2015; R Studio Team, 2015), while the cartography was created using ARCGIS v 10.8.1.

Since an anomaly on the light, depth, and temperature profiles was evident, the data were re-analysed and compared with information in the literature to confirm the hypothesis of a predation event on the tagged fish. Therefore, to avoid making wrong assumptions, we differentiated the following: (i) data belonging to the Mediterranean spearfish; (ii) data recorded from the predation event to tag regurgitation/egestion; and (iii) data recorded after tag regurgitation/egestion. Finally, to analyse the predator's behaviour, only the TAD and night/daytime series at the depth data belonging to point (ii) were considered.

3 Results

The MiniPAT tag release happened, as scheduled, on 16 September 2019 (30 days after tagging); the signal was located within 6 km east of the tagging area (latitude = 38°14′16.8″N; longitude = 15°39′46.8″E; Fig. 1). Considering that the location signal was not in real time, it was necessary to monitor the location signal until it stabilised before starting a tag recovery expedition. Therefore, after monitoring the tag for a few days, we observed a steady signal of location class (LC) 3 pointing to the Calabrian coast near the village of Villa S. Giovanni (Italy). On 19 September, the tag was recovered through an inspection on the beach around the LC 3 signal, and the data were downloaded.

The time series dataset (light, depth, and temperature profiles) showed an unusual vertical movement behaviour of the *T. belone* individual tagged with the PSAT. Indeed, the time and depth data series (Fig. 3) show that immediately after tagging on 17 August 2019, at about 08:00 (UTC time), the *T. belone* individual remained at a depth of 50 m for about nine hours. Then on the same day at 17:17, the tag started recording an abrupt pressure change and showed short upward movement, followed by movement to an approximate depth of 270 m. From this moment on, the tag recorded diel vertical movements, with permanence in shallow waters at night (about 40–270 m) and deeper waters during the day (about 200–370 m). Simultaneous with the quick change in depth profile on 17 August, the light intensity profile returned a minimum value. This value had been recorded for several days without significant changes until 16 September; the tag may have remained in a dark environment for the entire period, even when the depth profile showed that the tag had remained periodically in shallow waters (Fig. 3b). Similarly, the temperature profile changed from about 26 to 15 °C after 17 August. Figure 3c shows that the temperature values remained almost constant (15–17 °C) until 16 September. Given the absence of natural light, we could not estimate any horizontal movement; indeed, geolocations (latitude and longitude) are generally obtained using light intensity level measurements and calculated from twilight events (Hill and Braun, 2001). On 1 September, the tag had begun to record an almost constant depth; however, the pre-programmed emergency release system (the software programmed to release the tag after 3 days of inactivity) was not activated. The tag remained on the bottom until 16 September (the programmed tag release date), when the pin burn release system was activated, releasing the tag from the anchor and tether, resulting in tag surfacing (Fig. 3a).

4 Discussion

The analysis of these data allowed us to formulate the hypothesis of a predation event on the tagged fish. Reconstructing the dynamics of the events, at about 05:00 on 17 August 2019, the Mediterranean spearfish was likely dead ~50 m below the sea surface; we assume that it was eaten by another large animal, along with the tag. Although the tagging was apparently successful and the tagged fish seemed vital soon after, the animal may have been stressed from the recent tag application; the penetration of the applicator pin with the anchor (about 8 cm) may have also caused serious injuries and the death of the animal.

From this moment until 1 September, the tag remained in the gastro-intestinal tract (GIT) of the predator, and after this time, it was regurgitated/egested (Fig. 3). However, since the PSAT is relatively big, it cannot have passed through the entire GIT because of the presence of the spiral valve in the elasmobranch GIT. Indeed, the valve lumen is too narrow to allow the PSAT passage without causing damage to the animal or obstruction in the digestive tract. Consequently, the tag was likely regurgitated, as reported in some cases regarding the regurgitation of ultrasonic tags in *P. glauca* (Hazin et al., 1994) and *Carcharhinus amblyrhynchos* (Economakis and Lobel, 1998). Indeed, sharks have the capacity to maintain a healthy alimentary tract by adopting a voluntary stomach eversion manoeuvre to remove indigestible food items or objects (Brunnschweiler et al., 2005).

After regurgitation, the tag remained at an almost constant depth for 17 days given the negative buoyancy of the whole tag assemblage (PSAT, tether, and stainless steel anchor). This period of inactivity at a constant depth should have activated the emergency release mechanism (programmed to release the tag after 3 days), which failed. However, the release mechanism was activated, as programmed, 30 days after tag deployment.

This hypothesis is confirmed by the following data:

- In our research, the MiniPAT tag showed that in the first nine hours, the tagged *T. belone* remained at a depth between 40 and 60 m. The bathymetric profile near the deployment location was close to 50 m in depth (Fig. 1). These results most likely demonstrate that the animal was dead or immobilised soon after tagging, lying motionlessly near or at the bottom, and its light movements were probably current induced. Indeed, swimming for nine hours without changing depth is highly unusual for *T. belone*, as demonstrated by the data collected by Arostegui et al. (2019), which show that such a pattern was observed only sometimes at night, when the *T. belone* spends hours at the sea surface. Such a pattern is unknown for this species while it swims in deeper waters. Considering the absence of vertical movements for 9 h, we hypothesise that the tagged specimen was dead soon after tagging.
- After this time (about 17:00, UTC time), we found evidence that the animal had been eaten by a large predator. The rapid vertical movement from 50 m towards the surface at about 17:00 on 17 August 2019 (Fig. 3a) was likely due to the predator seizing the Mediterranean spearfish together with the tag. Then we observed a deep dive of up to 270 m (Fig. 3a), along with a drop in light level and temperature (Fig. 3b and c). After a successful attack, the predator spent most of the recorded time (>80%) in deep layers between 100 and 400 m (Fig. 4b) below the surface. This diving behaviour seems unusual for *T. belone*, supporting our hypothesis of a predator attack. This species prefers epipelagic layers between the sea surface and 30 m, remaining above the thermocline, with rare excursions below 84 m in depth (Arostegui et al., 2018; ICCAT, 2006–2016).
- Between 17 August and 1 September, the tag recorded a particular depth profile, indicating a diel vertical migration pattern, with rises in shallow waters to 50–250 m in depth at night, remaining in these layers throughout the evening. The animal migrated back into deeper layers (250–370 m) in the morning, staying there during the day (Fig. 4a). Such a pattern of vertical habitat utilisation contrasts with current knowledge on the behaviour and ecology of *T. belone*, confirming our hypothesis of a predation event. The minimum depth reached by the predator became constantly shallower during the monitored period, reaching 50 m at night, in correspondence with the less luminous lunar phase (new moon). This behaviour may demonstrate a relationship between the predator's vertical migration pattern and the lunar cycle.
- While the tag remained inside the predator, it recorded a constant light level (18 W/cm^2), corresponding to a dark environment (i.e. the stomach of the predator). Indeed, a recent study (Comfort, 2012) demonstrated that MiniPAT tags anchored at about 400 and 200 m recorded light levels between ~30 and ~130 W/cm^2 and that only tags attached to sharks that dived below 600 m (i.e. deeper than the maximum depth recorded in this study) reported values of light intensity <30 W/cm^2.

Starting from 14:35 on 1 September 2019, the light sensor data indicated normal environmental light levels based on the alternation of daylight and night periods. The temperature was almost constant, with frequent peaks after the tag was considered expulsed and deposited at an almost constant depth (Fig. 3). While the tag remained in the predator's stomach, the temperature was almost constant (15–17 °C), similar to the external water temperature in the study area

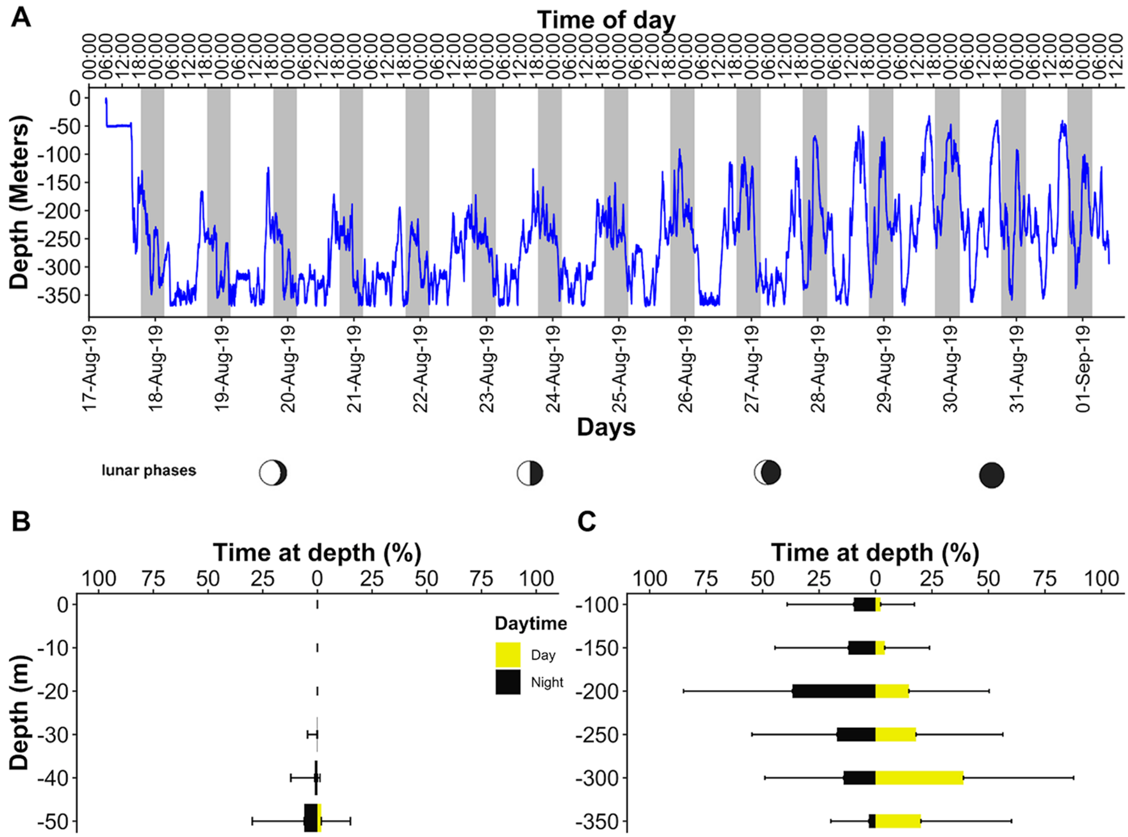

Fig. 4. Graphic representation of predator vertical movement. (A) Predator diving behaviour by date (days), time (h) and lunar phases between 17th of August 2019 and 1st of September 2019. Blue line = dive profile, grey area = nautical twilight night event (time between dusk and dawn) and white area = nautical twilight day event (time between dawn and dusk) (bB) percentage of Time at Depth (TAD) bar plot. Depth bins = 0 (thresholds 0–9 m), 10 (thresholds 10–19 m), 20 (thresholds 20–29 m), 30 (thresholds 30–39 m), 40 (thresholds 40–49 m), 50 (thresholds 50–99 m). (C) percentage of Time at Depth (TAD) bar plot between 100 and 350 m with 50 m resolution Depth bins = 100 (thresholds 100–149 m), 150 (thresholds 150–199 m), 200 (thresholds 200–249 m), 250 (thresholds 250–299 m), 300 (thresholds 300–349 m), 350 (thresholds 350–399 m). Yellow colour = daytime, black colour = night-time, error bars = standard deviation (SD).

(De Domenico, 1987). For this reason, we hypothesise that the predator was an ectothermic species (cold-blooded).

Increases in temperature, light level, and depth after the activation of the pin release mechanism were observed and followed by tag emergence. The hypothesis of the light sensor malfunctioning was rejected as the light intensity had increased since 1 September 2019 (Fig. 3b), that is, after tag regurgitation.

Based on these considerations, all the data recorded from 17 August to 1 September (Fig. 4b) can be attributed to the presence of the tag in the predator's stomach.

The predation of tagged animals is not a rare event, as shown in Table 1. Cases of predation on tagged eels (*A. rostrata*; Béguer-Pon et al., 2012) and Atlantic salmon (*Salmo salar*; Lacroix, 2014; Strøm et al., 2019) were observed and attributed to the porbeagle shark (*Lamna nasus*). In another study, Cosgrove et al. (2015) described that lamnid sharks such as shortfin mako (*Isurus oxyrinchus*) and porbeagle (*L. nasus*) were possibly responsible for the predation of tagged albacore tuna (*T. alalunga*). Furthermore, Jolley and Irby (1979) reported that one specimen of sailfish (*I. platypterus*), tagged with an acoustic tag, was predated by an unidentified shark. Kerstetter et al. (2004) demonstrated that two white marlins (*T. albidus*) and one opah (*L. gattatus*), equipped with PSATs, were eaten by a blue shark and an unidentified endothermic shark, respectively. Additionally, Hoffmayer (2009) described the attack of another endothermic shark (shortfin mako) on a PSAT-tagged silk shark (*C. falciformis*), while Polovina et al. (2008) hypothesised that a shortfin mako (*I. oxyrinchus*) or a great white shark (*Carcharodon carcharias*) was responsible for the death of a satellite-equipped opah (*L. gattatus*).

In our case, as discussed above, the temperature values remained constant (15–17 °C) while the tag was in the predator's stomach. For this reason, we hypothesise that the predator was an ectothermic species (cold-blooded), thus excluding any endothermic predator species (hot-blooded) such as marine mammals, bluefin tuna, and Alopiidae and Lamnidae sharks. Indeed, marine mammals have a body temperature range of 36–38 °C (Whittow et al., 1974); bluefin

Table 1. Reported cases in which tagged animals were predated by marine predators. Common names of the species are provided according to Froese and Pauly (2019).

Tagged animal			Location	Possible predator	Reference
Scientific name	Common name	Family			
Anguilla rostrata	Silver-stage American eels	Anguillidae	Gulf of St. Lawrence	Porbeagle shark (*Lamna nasus*)	Béguer-Pon et al. (2012)
Carcharhinus falciformis	Silk shark	Carcharhinidae	Northern Gulf of Mexico	Shortfin mako (*Isurus oxyrinchus*)	Hoffmayer (2009)
Istiophorus platypterus	Sailfish	Istiophoridae	Southest Florida	Unidentified shark	Jolley and Irby (1979)
Lampris gattatus	Opah	Lampridae	Georges Bank	Endothermic shark	Kerstetter et al. (2004)
			Central North Pacific	Shortfin mako (*I. oxyrinchus*) or great white shark (*Carcharodon carcharias*)	Polovina et al. (2008)
Oncorhynchus tshawytscha	Chinook salmon	Salmonidae	North Pacific Ocean	Marine mammals	Seitz et al. (2019)
			North Pacific Ocean	Ectothermic fishes	Seitz et al. (2019)
			North Pacific Ocean	Salmon shark (*Lamna ditropis*)	Seitz et al. (2019)
Salmo salar	Atlantic salmon	Salmonidae	North Atlantic Ocean	Marine mammals	Strøm et al. (2019)
			North Atlantic Ocean	Ectothermic fish	Lacroix (2014); Strøm et al. (2019)
			North Atlantic Ocean	Endothermic fish	Strøm et al. (2019)
			North Atlantic Ocean	Lamnid shark	Lacroix (2014)
			North Atlantic Ocean	Bluefin tuna (*Thunnus thynnus*)	Lacroix (2014)
			North Atlantic Ocean	Porbeagle shark (*L. nasus*)	Lacroix (2014)
Thunnus maccoyii	Southern Bluefin Tuna	Scombridae	Southeast of Tasmania, southwest Victoria and the south coast of NSW	Lamnid sharks	Tracey et al. (2016)
Thunnus alalunga	Albacore	Scombridae	Bay of Biscay (northeast Atlantic)	Shortfin mako (*I. oxyrinchus*)	Cosgrove et al. (2015)
			Bay of Biscay (northeast Atlantic)	Porbeagle shark	Cosgrove et al. (2015)
Tetrapturus albidus	White marlin	Istiophoridae	Georges Bank	Blue shark (*Prionace glauca*)	Kerstetter et al. (2004)
Tetrapturus belone	Mediterranean spearfish	Istiophoridae	Central Mediterranean Sea – Strait of Messina	Ectothermic shark, bluntnose sixgill shark (*Hexanchus griseus*)	Present paper

tuna is an endothermic species (Carey and Lawson, 1973; Shiels et al., 2015), while the abovementioned sharks generally have a body temperature of about 8–14 °C above the water temperature (Carey et al., 1981; McCosker, 1987; Goldman, 1997; Bernal and Sepulveda, 2005). Furthermore, it is highly unlikely that some other large billfish, such as swordfish, ate an entire 12–15 kg Mediterranean spearfish. Therefore, the predator may be an opportunistic shark species. Several sharks are considered asynchronous opportunistic feeders (scavengers; Compagno, 1984; Cortés et al., 2008) and are usually attracted by the chemical cues, fish distress stimuli, and/or body fluids (i.e. blood released after tag anchor application; Hobson, 1963; Tester, 1963) generated by an animal in danger or in distress (Hogstedt, 1983), such as a recently tagged animal. Potential bathypelagic/bathydemersal species that should be excluded because of their relatively small size (<200 cm; Compagno, 1984) compared with their prey include the sharpnose sevengill shark (*Heptranchias perlo*), the bigeyed sixgill shark (*Hexanchus nakamurai*), and the picked dogfish (*Squalus acanthias*). On the contrary, the predator is highly unlikely to be the bramble shark (*Echinorhinus brucus*) despite its maximum length of 300 cm (Compagno, 1984) since the most recent report of this species in the Strait of Messina was in 1937 (Cipria, 1937) and it is considered a highly rare species in the Mediterranean Sea (De Maddalena and Zuffa, 2003; Kabasakal and Bilecenoglu, 2014). Similarly, the smalltooth sand tiger shark (*Odontaspis ferox*) has been occasionally reported near the study area (Fergusson et al., 2008) and observed only once during fishing surveys conducted in the Calabrian region between 2000 and 2009 (Sperone et al., 2012). According to current knowledge, the study area has a stable population of *Hexanchus griseus* (Celona et al., 2005; Potoschi et al., 2010), an ectothermic shark that, in the Mediterranean Sea, reaches up to more than 650 cm in total length (Kabasakal, 2013) and prefers deep waters of up to 2500 m (Jones et al., 2002, 2003) as well as temperatures below 19°C (Comfort, 2012; Comfort and Weng, 2015). The diel vertical migration patterns of this shark match with the predator's behaviour observed in our study. Indeed, *H. griseus* usually stays in deep waters during the day (Comfort, 2012; Comfort and Weng, 2015) and moves towards shallow waters at night (up to about 40 m; Dunbrack and Zielinski, 2003; Andrews et al., 2009; Comfort, 2012; Comfort and Weng, 2015).

To sum up the outcomes presented in this study, we demonstrated the post-release mortality of a large pelagic fish (*T. belone*) tagged with a PSAT. The interpretation of the biologging data demonstrated predation or scavenging on the tagged Mediterranean spearfish by an ectothermic shark. The day/night behaviour observed resembled the pattern of the bluntnose sixgill shark (*H. griseus*), which, based on the current knowledge of the megafauna in this region, is highly abundant in the Strait of Messina.

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