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The effect of hook type and trailing gear on hook shedding and fate of pelagic stingray (*Pteroplatytrygon violacea*): New insights to develop effective mitigation approaches

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ABSTRACT

The pelagic stingray (*Pteroplatytrygon violacea*) in the French Atlantic bluefin tuna makes up almost half of the catch in numbers, ranking first of the five major species caught. Given the high levels of catches, more attention was given to the impact of this fishery in order to avoid future conservation issues. The effects of the hook shape (circle versus J-type hooks) and trailing gear on hook retention has been investigated on 10 individuals kept in captivity during 125 days. Experiments showed that the J-type hook used commonly by fishers had a fast self-shedding rate which will allow for a quick resumption of feeding and minimal injury which means quicker wound healing and better chance for survival. J-type hooks were all expelled within 6 days while circle hook shedding rates were much longer, taking 44.5 ± 54.4 days (mean ± SD). The mechanism of expulsion of the hook has been clearly described and the impact of the trailing line assessed. Appropriate handling practices maximizing the crew safety and the post-release survival were identified. Other effective mitigation approaches for the fishery are proposed and discussed.

1. Introduction

Pelagic stingray (*Pteroplatytrygon violacea)* occurs in tropical and subtropical waters of all the Oceans, including the Mediterranean. It is the only species from the family Dasyatidae to be encountered in pelagic ecosystems [1,2] and one of the most productive oceanic elasmobranchs that, in captivity, can produce two litters of 1–13 pups per year, giving a potential annual rate of population increase of 31% [3]. Pelagic stingray can be caught in shelf seas and open oceans, mainly by pelagic longlines and, to a lesser extent trawls and nets [4–6].

Of limited commercial value, pelagic stingrays are not usually retained and catch data from commercial fisheries are incomplete. Their at-vessel mortality (AVM) in pelagic longline fisheries is generally low, in the range of 1–18.5% [7–9] possibly because they are not obligate ram ventilators and so can survive longer when hooked. Furthermore, regardless of hook shape, pelagic stingrays are almost always hooked in the mouth or body, and not deep-hooked in the esophagus or stomach [10,11]. Common practices to remove the hook consist of swinging the animal against the rail, cutting the jaws with a knife, or pulling strongly on the trace until either the jaw breaks or the line parts. As pelagic stingray can inflict serious injuries to the crew [12], the tail may sometimes be cut off before being discarded. Consequently the post-release mortality (PRM) rate could be high [13], and highly dependent on fisher behavior and discarding practices [14,15]. Moreover, in response to the increased fish welfare concerns [16,17], higher standards of care of captured fish should be considered [18,19] and implemented onboard fishing vessels.

In the Mediterranean, different longline types are traditionally used to target swordfish, albacore or bluefin tuna. Each type is characterized by differences in the gear's components (e.g. mainline material, hook shape and size, bait type and size, etc.) which affect the selectivity and the impact on potential bycatch species [20,21]. After the ban of Atlantic bluefin tuna (ABFT) driftnet fishery, French fishers switch steadily to longline fishing. The number of permits has doubled in one decade. Around 100 hundred small-scale vessels were operating in 2018. This surface longline fishery operates mainly in the Gulf of Lions (France) and around Corsica Island between April and December. The number of hook deployed range from 400 to 900 hooks per set and the soaking time very short (less than 5 h). The quota for this fleet has been increasing in the last years from 225 mt in 2014 to 389 mt in 2018. A recent study showed that pelagic stingray accounted around 50% of the catch in numbers, ranking first of the five major species caught [22].

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Table 1
Information on eight pelagic stingrays (six females (F) and two males (M)) caught during commercial longline fishing operations, and monitored in captivity for 125 days.

Specimen	Weight (kg)	Disc width (cm)	First feeding (date)	First feeding (days)	Date of hook shedding	Days until hook shed
F1	4	47	2016-10-10	12	2016-10-28	6
F2	4.2	43	2016-09-29	1	2016-10-28	6
F3	2.9	36	2016-10-15	17	2016-10-21	28
F4	4.3	43	2016-10-01	3	2016-10-28	125
F5	3.5	44	2016-10-10	12	2017-01-26	19
F6	4.8	46	2016-10-15	17	2016-10-12	6
M1	2.65	40	2016-09-29	1	2016-10-28	6
M2	1.6	36	2016-10-10	12	2016-10-28	6

Studies conducted mainly on recreationally-caught freshwater fish showed that hooks lodged in fish jaws, or even deeply internally, can be evacuated naturally over time [23–27]. The influence of hook type, size and shape on hook retention, injuries and mortality, and the ability to ingest food has been also investigated on bonefish [24,26] but never to our knowledge on pelagic fish.

There are at least three types of hooks commonly used in the domestic ABFT longline fisheries: circle hook, J-hook and tuna hook. The point of the circle hook directed inwards and perpendicular to the shank prevents the deep engagement in the esophagus and the stomach [28] while the sharp point of J-hook (or jabbing) oriented parallel to the shank [29,30] can penetrate the flesh and stay embedded thanks of the reversed barb. However, the anatomical location of hooking is directly correlated with the potential for lethal injuries and mortality. Retained deep hooks in blue shark (*Prionace glauca)* can have long-term pathological consequences [31,32].

The main objectives of this study were to (1) examine the effects of hook shape (circle versus J-type hooks) and trailing gear on hook retention, feeding behavior, fate of pelagic stingray and recovery from injuries, (2) monitor any delayed mortality in captive-held specimens (3) propose potential and effective mitigation approaches for the fishery.

2. Material and methods

2.1. Field collection

Fieldwork was conducted by researchers aboard longliners operating in the ABFT fishery in the Gulf of Lions. Longlines were rigged with two hook types commonly used by the fleet (Circle hook: VMC ref. 9788PS, size n°7 and J-type hook, size 5/0 ARG. Ref 1.20*10 MTRS). Hooks were baited with sardine (*Sardina pilchardus)*. Ten pelagic stingrays were caught under normal commercial operations, of which six were caught with J-type hooks and four with circle hooks. All ten specimens retained had hooks embedded in the lower jaw, but otherwise appeared in good condition, based on visual observations of their vigor (active and no external injuries). The rays' barbed spines were cut off at the base after capture, in order to avoid self-mutilation during their transport. The monofilament fishing line was cut close to the hook's eye, except for one specimen on which a 10 cm length of fishing line was left. Each specimen was placed individually in a 50 L tank. At land, the stingrays were placed in a large circular tank (ca. 50 m^3 volume). They were kept under quarantine for six days before being transferred to the Marineland aquarium in Antibes, where they were placed in a recirculating system (50 m^3). The experiment was initiated as soon as the animal arrived at the aquarium with monitoring taking place from the following day (September 29, 2016) to January 26, 2017, when the last hook had been shed. During the transfer, each ray was identified using external features, sexed and the disc width (DW) measured to the nearest centimeter.

2.2. Study design

The stingrays were fed *ad libitum* (fish supplemented with vitamins) twice daily and the tank was cleaned every day. The occurrence of shed hooks on the bottom of the tank was recorded daily and the individual which expelled it identified. Quick inspection of each stingray (< 5 min) was conducted weekly, several pictures of the ventral face were taken.

2.3. Data analysis

A Kaplan–Meier survival analysis (using a logrank test) was used to compare the time to hook shedding by hook type. Statistical significance for the delayed time for feeding was tested with a two-sample-t-test. For both tests, significance was evaluated at alpha = 0.05.

3. Results

3.1. Hook shedding and healing

During the 6 day quarantine, the ten stingrays were left unattended to reduce stress, some food was provided but no inspection of the fish was implemented. Therefore, it was not possible to identify the specific day when any hooks were shed. At the completion of the quarantine period, seven hooks (one circle and six J-type hooks) were found on the bottom of the tank. The number of hooks shed was conservatively assigned to the sixth day after the capture event. For the remainder of the experiment, eight stingrays (six females and two males) were transferred to another facility at the Marineland aquarium (the other two specimens, both free of hooks, were kept in the same tank and excluded from further study). The mean (± SD) DW were 43.2 ± 3.5 cm (females) and 38.0 ± 2.0 cm (males) (Table 1; Fig. 1).

Analysis of the two survival curves showed that the factor “hook shape” significantly affected the shedding time for pelagic stingrays. J-type hooks were all expelled within 6 days, while circle hooks were expelled over 6–125 days (mean = 44.5 ± 54.4 days; Fig. 1). The difference between the two survival functions was significant (Chi-square = 5.786, df = 1, p = 0.0162).

The picture series of the ventral surfaces of the pelagic stingrays allowed a better understanding of how the circle hooks were expelled (Fig. 2). On 6 October 2016, the first day of the observation (Female F3), the hook was fully swallowed, with the point of the hook was visible and the fishing line emerging from the mouth (Fig. 2A). Fourteen days later, the hook had rotated around its central axis, the hook's eye was visible and the point of the hook was inside the mouth (Fig. 2B). Noticeable skin healing occurred after the hook was shed six days before (and 21 days after the first picture was taken; Fig. 2C), with further healing evident 28 days after the first observation (Fig. 2D).

The hooking and trailing gear injuries are clearly noticeable on the pictures. Necrosis appeared on the ventral surface of the ray, one caused by the hook's point which punctured the skin below the jaw, while the fishing line created a large notch perpendicularly to the

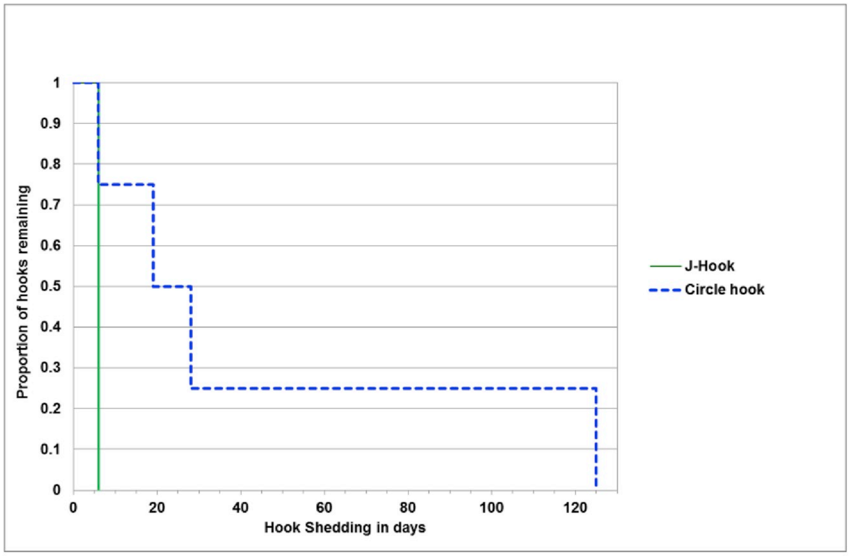

Fig. 1. Kaplan–Meier survival function for pelagic stingrays based on weekly observations for hook presence/absence recorded over a 125-day monitoring period. The graph compare hook retention probabilities for Circle and J types hooks located in the jaw.

mouth axis. The injuries healed over time and the scars vanished from the ventral surface after about one month.

3.2. Feeding

The hook lodged in the jaw affected the feeding performance, with pelagic stingrays free of hooks feeding significantly sooner than the ones with a retained hook (*t*-test, $p < 0.05$; 5.8 versus 15.3 days). Female F6 started to feed three days after expelling the hook, while female F5 started feeding six days before the hook was expelled. Female F5, the last to expel the hook, started feeding on day 12.

3.3. Discarding practices and observations

During informal discussions at landing sites or at sea trips, longline skippers engaged in our research project (around 25% of the fleet) reported different discarding practices they developed gradually to retrieve their hooks, these procedures part of their routine work during line hauling. For example, one used a short-nosed plier and, after bringing the ray tight to the rail, ventral face against the vessel, would grasp the hook with the pliers and, with a quick twist of his wrist, to extract the hook. Another used a de-hooking gear. Others would just cut the trace close to the hook's eye, as they consider this procedure quicker, leaving the hook in the mouth of the ray.

Most of the fishers observed attempted to release the stingrays in

Fig. 2. Time series of photographs of the ventral face of female F3 (pelagic stingray) showing the different phases of the expulsion of the hook along with the wounds healing.

good condition, but their motivation depended upon the number of pelagic stingrays caught and on the success of the fishing operation. Generally, fishers assume that mortality arising from their release technique would be negligible and did not consider survivorship as an important issue.

Fishers mentioned that they noticed that a lot of blue sharks caught could already have one or more hooks embedded in the jaws, due to previous interactions with longline gears. Such cases appear to be rarer for pelagic stingray. According to fishers, instances of deep hooking in stingrays were rare for both circle and J-hooks.

4. Discussion

4.1. Effects of the hook type and the hook size

Circle hooks have been considered as one of the more promising mitigation options for reducing deep hooking of hard-shelled turtles and lethal injuries associated [33]. They increase jaw-hooking, facilitating life release of unwanted or protected species but usually do not reduce catch rate. Indeed, the use of circle hooks is already mandatory in certain areas in the world [34,35]. In the case of sharks species, they can increase catch rate on monofilament gears reducing bite-offs due to jaw-hooking [36]. Nevertheless, the performance of the circle hook varies between species and fisheries [15,37,38]. Catch rate reduction is usually associated with hook size. A study conducted in collaboration with commercial and artisanal swordfish longliners in the Strait of Sicily showed that the larger the J-type hook, the lower the capture rate of pelagic stingray, and that 16/0 circle hooks could reduce significantly the catch rates of pelagic stingray in comparison to narrower circle hooks [39]. This mitigation approach should an appropriate solution to be tested in the domestic fishery.

4.2. Feeding, healing and mortality

Our study revealed that the presence of the hook in the buccal cavity and the injuries associated could prevent the animals from feeding normally. While there is evidence that indicates injuries caused by ingested hooks can induce morbidity and mortality of sharks [31,32], the impact of trailing gear embedded in the jaws of released or escaped sharks has been also investigated. Though tissues necrosis, abscesses, jaw dislocation and permanent deformities have been observed on grey nurse sharks (*Carcharias taurus*) [40].

In this study, fishing line seemed to cause damages to the ray, it is assumed that over time the impact of the trailing gear could have been more serious injuries leading to a continuous necrosis without expulsion of the hook. After hook shedding, injuries healed in about one month. These statements are based on a single case of observation of trailing gear, more information must be collected to confirm these observations.

One of the ten pelagic stingrays kept in captivity died after 45 days of holding (M2). This stingray lost its hook early during its quarantine but was very slow in acclimatization as it started eating after 12 days following the transfer. Therefore, we assumed that this mortality could be attributed to the original capture process. The PRM rate estimation derived from this experiment (10%) should be confirmed with a larger sample size of animals. A control group (stingrays relieved from hooks when retrieved onboard the fishing boat) of experimental stingrays could be used to clarify this issue. The results are representative of animals caught with small sized hooks and bait and released in relatively good condition. The mortality rates reported in this study are within the range reported in earlier studies [15,41].

4.3. Safe handling and release practices

Fishers are generally supportive of simple measures incurring limited expenses, therefore “safe handling and release” guidelines seemed to be more easily accepted as fisheries management tool and conservation strategy [8,41]. The approach during this study was to document and to observe the current practices, and to identify scientific based best handling practices in order to increase chances of survival of unwanted animals and to avoid injuries to the crew. A dedicated manual has been developed for the fishery [42].

Fishers must be encouraged to use pliers or de-hookers for removing hooks, in the case they want to keep the hooks. If not, cutting the line as close as possible to the eye of the hook should be recommended, in order to reduce the amount of trailing line. Finally, cutting the line instead of removing the hook, in the case of deep hooking, seems to be the best practice. Studies conducted on brook trout (*Salvelinus fontinalis)* and bluegill sunfish (*Lepomis macrochirus*) have shown that survival was higher when gut hooks were left, rather than removing from the internal tissues [25].

5. Conclusions

The use of circle hooks is widely promoted to reduce deep hooking and lethal injuries associated regardless the species. The current study shows that for the stingray J-type hook had a faster self-shedding rate than circle hook (for a similar size), highlighting the fact that it is crucial when implementing mitigation methods to consider all possible conflicting effects on other vulnerable taxa. The adoption of good practices to handle and release the stingrays identified could reduce drastically their mortality. Nevertheless, estimates of the PRM rates are needed to confirm the full efficiency of the methods. Tests of larger hooks and larger bait should be undertaken to assess the profitability and to confirm the reduction of the impact on the bycatch species. Research interest in fish welfare in capture fisheries has increased over time and this issue should be considered as a crucial research area in the coming years.

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