Shorter Research Note

Presence of plastic debris and retained fishing hooks in oceanic sharks

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Abstract

In a context where the problem of plastic pollution is globally increasing, more studies are needed to assess the real impact in oceanic megafauna. Here, we reported on the incidence of plastic and also retained hooks in two species of commercially exploited pelagic sharks in two ocean basins, the North Atlantic and South Pacific. In the South Pacific, 1.18% of caught blue sharks were observed with plastic debris on their body and 4.82% and with retained hooks, while 0.00% of shortfin makos had plastic debris and 1.76% were recorded with retained hooks. In the North Atlantic, 0.21% of blue sharks had plastic debris and 0.37% of blue, and 0.78% of shortfin makos were observed with retained hooks.

Keywords

Plastic debris; marine litter; retained hooks; oceanic sharks

Highlights

– Plastic in the open ocean is a major problem due its durability and persistence;

– Fishing is a widespread human activity in all oceans, producing plastic pollution that can interact with pelagic sharks;

– Oceanic sharks are potential ‘collectors’ for plastic debris floating in the open sea;

– The impact and incidence of retained hooks is important, but poorly studied;

– More quantitative information on the prevalence of plastic/hooks in large commercial species is necessary to accurately assess the impact of the problem.

Introduction

Waste material of anthropogenic origin, in particular plastic, is common in the marine environment (Lavender, 2017). Areas of high plastic concentration have been reported for remote regions of the ocean (Cózar et al., 2014; Lavender, 2017) and levels of plastic accumulation have also been increasing globally, mainly because of plastic high longevity which is estimated to range from hundreds to thousands of years (Barnes et al., 2009; Deudero and Alomar, 2015). Hence, plastic is considered an emerging problem that threatens ecosystems and marine life (Lavender, 2017). In this work we have considered plastic as any material that consists of synthetic or semi-synthetic organic compounds that is malleable into a solid object (Lavander, 2017).

Since the introduction of plastic materials in the 1950s, the global production of plastic has increased rapidly and its likely to continue in the coming decades despite policy changes introduced in several countries (Cózar et al., 2014). As an example, an estimated 4.8 to 12.7 t of plastics entered the oceans in 2010, of which 275 t were generated in 192 coastal countries (Jambeck et al., 2015) and the current plastic load in surface waters of the open ocean was estimated in the order of tens of thousands of tons (10,000–40,000) (Jambeck et al., 2015). Plastic pollution is known to accumulate in certain areas, such as in the South Pacific subtropical gyre, and studies show an increasing abundance of plastic pollution in surface waters there (Eriksen et al., 2013).

Shipping and commercial fishing are the main sea-based plastic sources reaching oceanic waters (Derraik, 2002). Land-based sources such as coastal industries or river outputs, on the other hand, are the main origin of plastics along coastlines (Cliff et al., 2002; Lebreton et al., 2017). Marine organisms interact with plastics in different ways, but the main threats are the result of (1) ingestion, and/or (2) entanglement in plastic debris, synthetic ropes and lines, and strapping bands which can often be fatal (Laist, 1987, 1997; Adams et al., 2015). Although information on entanglement by plastic debris has been recorded for some species of coastal and pelagic sharks (Colmenero et al., 2017), few studies have provided quantitative data for pelagic species.

The presence of retained fishing hooks in wild caught fish is also an important source of information to assess the impact of fisheries and estimate delayed mortality rates (Adams et al., 2015). Although pelagic elasmobranchs are caught with a variety of fishing gears, pelagic longliners targeting tuna and swordfish account for the majority of the catches. Concerns regarding the impact of fisheries on shark populations have led the United Nations' Food and Agriculture Organization (FAO) to adopt the International Plan of Action for the Conservation and Management of Sharks. Because retained hooks are relatively common in pelagic sharks (Bansemer and Bennett, 2010), retention rates can be used as an indirect mechanism to measure the fishing pressure a population is subjected (Clarke et al., 2014).

Shortfin mako (*Isurus oxyrinchus*) and blue (*Prionace glauca*) sharks are under intensive fishing pressure from commercial longliners in tropical and temperate waters worldwide because of the fin and meat trade (Dulvy et al., 2008, Queiroz et al., 2016). In fact, the last stock assessment for the Atlantic Ocean (ICCAT, 2017) indicated that the shortfin mako population is overfished and has been undergoing overfishing. The IUCN Red List of Threatened Species recently assessed shortfin makos as 'endangered' (Rigby et al., 2019), and blue sharks as 'near threatened' (Stevens et al., 2009) globally. Hence, we aimed to quantify the incidence of plastic debris and retained hooks, and related injuries, in two commercially important oceanic shark species.

Materials and methods

Shortfin mako and blue sharks were sampled during two fishing surveys onboard Spanish commercial longliners; the first in the South Pacific (SP) and the second in the North Atlantic (NA). The first campaign spanned from the 9th of December 2004 to the 9th of March 2005 (austral summer) and the second from the 4th of November to the 9th of December 2005 (boreal winter). All sharks were sexed, measured (fork length) and any plastic and/or hooks registered; stomach contents (396 shortfin makos and 661 blue sharks) were also analysed *in situ* during evisceration. Moreover, during two additionally tagging trips in the North Atlantic in 2015 (13th of August to the 4th October 2015) and 2018 (10th of April to the 10th of June 2018) plastic and/or hooks were opportunistically registered.

Results

During the SP survey, a total of 89 longline sets were deployed (*n* = 172,878 hooks) and 1,082 sharks were caught (Figure 1AB). In the NA survey, 33 longline sets were deployed (*n* = 82,500 hooks) catching 2,409 sharks (267 shortfin makos, and 1,928 blue sharks) (Figure 1CD). During the 2015/2018 opportunistic surveys, a total of 209 shortfin makos (109 in 2015 and 100 in 2018) and 3,775 blue sharks (1,742 in 2015 and 2,033 in 2018) were sampled.

In the Pacific no shortfin makos were caught with plastic debris, while plastic entanglements were observed in eight blue sharks (1.18%; Table 1). In general, plastic consisted of polyolefin packing straps and were usually found around the shark gills (Table 1; but other plastic materials such as ropes were also found (Figure 2AB). In addition, 20 (4.82%) and 12 (1.76%) of shortfin mako and blue sharks, respectively, had at least one retained hook [maximum observed number was five hooks in a shortfin mako; (Table 2A)]. Hooks were most frequently found in the shark mouth (62.8%; Figure 2C) but were also observed in the stomach (9.3%), fins (7%), throat (4.6%), gills (2.3%), and even the liver (2.3%; Figure 2D) (Table 3). Litter was also found in the analised stomachs of five shortfin makos (including one shark with paperboard filling – and seven blue sharks (Table 4).

Similarly, in the North Atlantic survey, no plastic remains were found in shortfin mako sharks, while the presence of plastic was observed in four (0.21%) blue sharks around the gills (Table 1), including one shark with scared tissue around the polyolefin package (Figure 2E). Hooks were found in a total of 16 sharks (one shortfin mako – 0.37% and 15 blue sharks – 0.78%) usually in the mouth (93.7 %) and only one in oesophagus (6.26%), including one shortfin mako shark with a severely damaged oesophagus due to an internal hook.

During the opportunistic surveys (2015/2018), a further three blue sharks were observed with plastic debris, and eight blue shark and one shortfin mako with retained hooks (in the mouth and in the cloacae, respectively). One blue shark was also found with a plastic rope around its body (Figure 2F).

Discussion

Plastic debris, such as polyethylene terephthalate (the most common type of plastic found in the present study) can take between 100 and 1000 years to disintegrate (Moore, 2008). During this time plastic interacts with the environment, potentially causing severe lesions in marine animals (Sazima et al., 2002; Haetrakul et al., 2009; Abreu et al., 2019; Wegner and Cartamil, 2012). The presence of plastic and related injuries have been previously reported for a total of 16 shark species worldwide (Colmenero et al., 2017), including both pelagic and coastal species. As an example, in the shark nets off South Africa, 0.18% of caught sharks had polypropylene strapping bands around their body (Cliff et al., 2002). The present study reports similar rates of plastic pollution in pelagic sharks to those recorded by Cliff et al. (2002); but aside from these two studies, there is general lack of quantitative data in the presence of plastic in sharks.

Differences in the presence of plastic debris were observed between shortfin makos and blue sharks, with no plastic found on shortfin makos in both oceanic basins. This difference may be linked to behavioural differences, since blue sharks generally display a more aggressive/exploratory behavior and spend more time around potential prey items (Compagno, 1984). Plastic debris have also been previously found in seven blue sharks in the Atlantic Ocean and one in the Mediterranean Sea (Colmenero et al., 2017) with a recent study showing that 25.26% of analysed blue sharks had ingested plastic debris (Bernardini et al., 2018). Moreover, severe cutting trauma was observed during the growth of three juvenile Brazilian sharpnose sharks, *Rhizoprionodon lalandii*, from plastic gill net collars (Sazima et al., 2002).

The incidence of plastic in the open ocean is, however, wide-ranging. Elsewhere, in the Pacific Ocean, a few studies have reported plastic induced injuries in the gills and stomach of whale sharks, *Rhincodon typus* (Haetrakul et al., 2009; Abreu et al., 2019). Plastic debris have been observed in other pelagic predators, such as, snake mackerel – *Gempylus serpens* and moonfish – *Lampris* spp. (Choy and Drazen, 2013), swordfish – *Xiphias gladius*, and tunas *Thunnus* spp. (Romeo et al., 2015).

Legislation can play an important role in regulation the use of plastic materials, most importantly, in coastal nations; but given the reported scenario, resolving the ultimate pathways and fate of these debris is a matter of urgency. The development and use of biodegradable and photodegradable plastics could be one more way to mitigate the problem (Gorman, 1993). However, recent studies suggest that the rate at which such plastics degrade is not rapid enough to prevent morbidity in aquatic animals (O’Brine and Thompson, 2010; Müller et al., 2012). The presence of plastic debris in pelagic megafauna remains, however, poorly studied with our data showing worrying numbers of plastic pollution found in sharks in the open ocean.

Retained hooks are generally the result of (a) the shark breaking loose from the fishing line or (b) the shark being discarded by fishers due to harvest regulations (by cutting branch lines, the hook from the shark’s mouth – Gilman et al., 2008). A study conducted in South Atlantic reported that bite-offs (i.e. missing hooks) corresponded to ~33% of the shark catch, about 45% of total catch (Afonso et al., 2012). Our results showed some differences in hook incidence rates between the South Pacific and North Atlantic, with higher rates observed in the first. This might be due to methodical and operational differences between the fishing fleets operating in the two regions, with sharks generally being considered as by-catch and discarded (Clarke et al., 2014) in the South Pacific, increasing the likelihood of observing sharks with retained hooks.

Retained hooks can cause a range of serious pathologies, such as oesophagitis, gastritis, hepatitis and proliferative peritonitis or even peritonitis and pericarditis associated with gastric perforation (Borucinska et al., 2002). The histological lesions caused by old hooks generally consist of mucosal ulceration, transmural fibrosing and necrotising oesophagitis (Borucinska et al., 2001). A lesion caused by a circle hook in a longfin mako shark *Isurus paucus* was reported previously, providing evidence of direct mortality due to systemic lesions associated with retained hooks (Adams et al., 2015). A similar case is presented in the current paper wherein a mako shark was observed to have severely damaged oesophagus due to an internal hook confirming the dangers of retained hooks in the Atlantic.

As mentioned before, hooks can be an indirect method of measuring fishing pressure, with the proportion of sharks with attached fishing gear estimated to be increasing (Bansemer and Bennett, 2010). In fisheries management however, the cryptic components of fishing-induced mortality are not routinely accounted for because of a lack of adequate observations. Although live release is a common fisheries management strategy, to better understand its impact, better mortality, post-release survival, sublethal physiological and behavioural estimates are still needed (Donaldson et al., 2008). In a context where the problem of plastic pollution is increasing more studies are needed for assess the impact real impact in oceanic megafauna. We also provided information of the frequency of pelagic sharks with retained hooks which, together with other similar studies, could enable a better quantification of by-catch rates.

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Author contributions

GM conceived the general idea; GM, NQ contributed to data generation; performed data analysis and both authors wrote de paper.

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Figure 1. Locations where plastic debris and retained hooks were observed in the South Pacific (A) and North Atlantic (C) overlaid in bathymetry. Areas highlighted with red rectangles in A and C are enlarged in B (South Pacific) and D (North Atlantic), respectively.

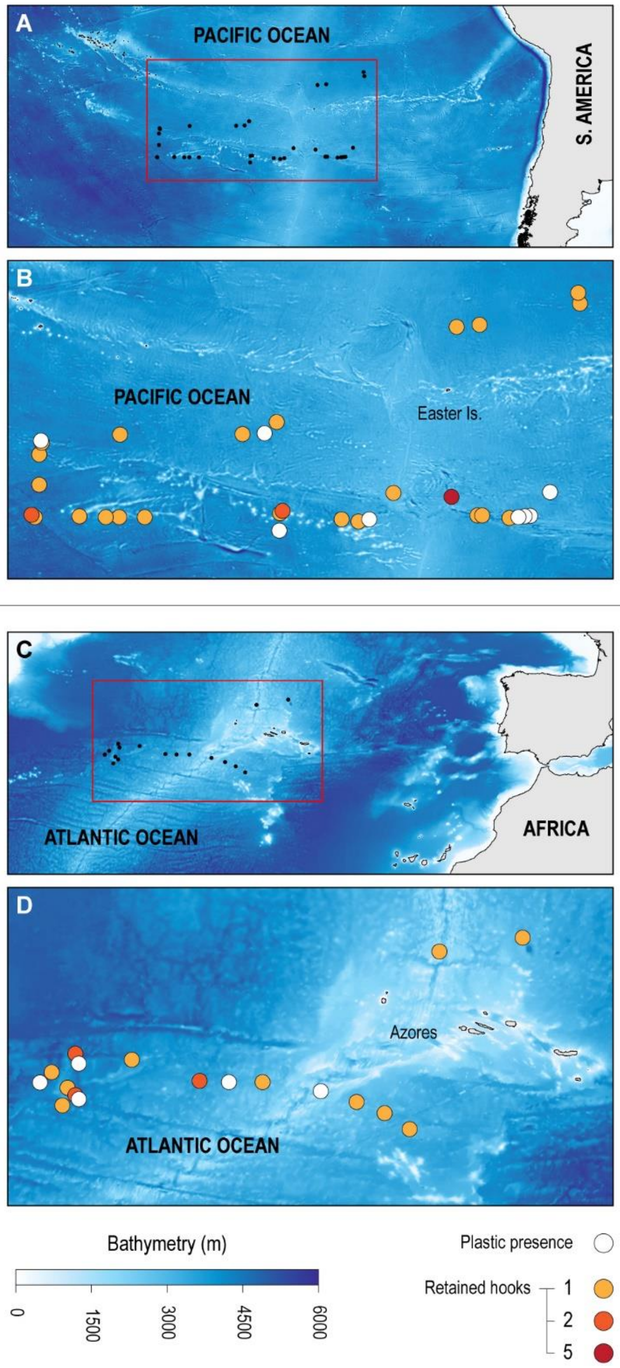

Figure 2. Plastic- and retained hook-related injuries in pelagic sharks. Plastic entangled in the gill area of blue sharks (AB); Retained hooks in the mouth (C) and liver (D) of sampled sharks; scared tissue around a polyolefin package (E) and a plastic rope (F) around a blue shark body.

Table 1. Details of blue sharks with plastic debris per ocean (all surveys).

Species	Fork length (cm)	Sex	Sampling date	Ocean basin
Prionace glauca	247	male	10/12/2004	South Pacific
Prionace glauca	186	female	14/12/2004	South Pacific
Prionace glauca	198	female	15/12/2004	South Pacific
Prionace glauca	256	male	28/12/2004	South Pacific
Prionace glauca	228	male	06/01/2005	South Pacific
Prionace glauca	243	male	06/01/2005	South Pacific
Prionace glauca	187	male	24/01/2005	South Pacific
Prionace glauca	177	male	06/02/2005	South Pacific
Prionace glauca	142	male	07/11/2005	North Atlantic
Prionace glauca	197	male	11/11/2005	North Atlantic
Prionace glauca	127	male	23/11/2005	North Atlantic
Prionace glauca	241	female	01/12/2005	North Atlantic
Prionace glauca	-	-	21/08/2015	North Atlantic
Prionace glauca	-	-	29/08/2015	North Atlantic
Prionace glauca	-	female	01/09/2015	North Atlantic

Table 2. Number of blue and shortfin mako sharks with plastic and retained hooks per ocean basin and survey.

Table 2A. South Pacific survey (2004/05)

	Number of sharks	Females	Males	Plastic presence	% plastic	Hook presence	% hook
Prionace glauca	680	231	446	8	1.18	12	1.76
Isurus oxyrinchus	415	139	272	0	0.00	20	4.82

Table 2B. North Atlantic survey (2005)

	Number of sharks	Females	Males	Plastic presence	% plastic	Hook presence	% hook
Prionace glauca	1928	660	1268	4	0.21	15	0.78
Isurus oxyrinchus	267	146	121	0	0.00	1	0.37

Table 2C. North Atlantic opportunist survey (2015)

	Number of sharks	Plastic presence	% plastic	Hook presence	% hook
Prionace glauca	1742	3	0.17	7	0.40
Isurus oxyrinchus	109	0	0	1	0.92

Table 3. Details of blue and shortfin mako sharks with retained hooks per ocean (South Pacific and North Atlantic surveys).

Species	Fork length (cm)	Sex	Body position	Date	Number of hooks	Ocean basin
Prionace glauca	247	male	mouth	10/12/2004	1	South Pacific
Prionace glauca	250	male	mouth	16/12/2004	1	South Pacific
Isurus oxyrinchus	216	female	mouth	17/12/2004	1	South Pacific

Isurus oxyrinchus	206	female	mouth	18/12/2004	1	South Pacific
Isurus oxyrinchus	237	female	dorsal fin	18/12/2004	1	South Pacific
Prionace glauca	197	female	mouth	19/12/2004	1	South Pacific
Isurus oxyrinchus	229	female	mouth	21/12/2004	5	South Pacific
Isurus oxyrinchus	193	male	gills	25/12/2004	1	South Pacific
Isurus oxyrinchus	280	female	stomach	29/12/2004	1	South Pacific
Prionace glauca	208	male	mouth	01/01/2005	1	South Pacific
Prionace glauca	252	male	mouth	04/01/2005	2	South Pacific
Isurus oxyrinchus	246	male	stomach	05/01/2005	1	South Pacific
Isurus oxyrinchus	210	male	mouth	11/01/2005	1	South Pacific
Isurus oxyrinchus	225	male	mouth	12/01/2005	1	South Pacific
Isurus oxyrinchus	192	male	mouth	13/01/2005	1	South Pacific
Isurus oxyrinchus	224	male	mouth	14/01/2005	1	South Pacific
Prionace glauca	226	male	dorsal fin	17/01/2005	1	South Pacific
Isurus oxyrinchus	193	male	mouth	17/01/2005	1	South Pacific
Isurus oxyrinchus	278	female	mouth; pectoral fin	18/01/2005	2	South Pacific
Prionace glauca	238	male	mouth	18/01/2005	1	South Pacific
Isurus oxyrinchus	240	male	mouth	21/01/2005	1	South Pacific
Isurus oxyrinchus	207	male	mouth	22/01/2005	1	South Pacific
Isurus oxyrinchus	232	male	mouth	23/01/2005	1	South Pacific
Isurus oxyrinchus	211	male	stomach	24/01/2005	1	South Pacific
Prionace glauca	249	male	mouth	27/01/2005	1	South Pacific
Isurus oxyrinchus	217	male	mouth	05/02/2005	1	South Pacific
Isurus oxyrinchus	276	female	mouth	06/02/2005	1	South Pacific
Prionace glauca	236	male	liver	07/02/2005	1	South Pacific
Prionace glauca	228	male	mouth	25/02/2005	1	South Pacific
Prionace glauca	239	male	mouth	26/02/2005	1	South Pacific
Prionace glauca	241	male	throat	05/03/2005	1	South Pacific
Isurus oxyrinchus	242	male	mouth	09/03/2005	1	South Pacific
Prionace glauca	154	male	mouth	04/11/2005	1	North Atlantic
Prionace glauca	274	male	mouth	05/11/2005	1	North Atlantic
Prionace glauca	172	male	mouth	06/11/2005	1	North Atlantic
Prionace glauca	139	male	mouth	07/11/2005	1	North Atlantic
Prionace glauca	230	male	mouth	10/11/2005	1	North Atlantic
Prionace glauca	193	male	mouth	13/11/2005	1	North Atlantic
Isurus oxyrinchus	130	female	mouth	13/11/2005	1	North Atlantic
Prionace glauca	145	female	mouth	21/11/2005	1	North Atlantic
Prionace glauca	179	female	mouth	21/11/2005	1	North Atlantic
Prionace glauca	130	female	mouth	24/11/2005	1	North Atlantic
Prionace glauca	209	male	esophagus	27/11/2005	1	North Atlantic
Prionace glauca	157	female	mouth	29/11/2005	1	North Atlantic
Prionace glauca	170	female	mouth	01/12/2005	1	North Atlantic
Prionace glauca	150	male	mouth	01/12/2005	1	North Atlantic
Prionace glauca	175	female	mouth	07/12/2005	1	North Atlantic
Prionace glauca	136	male	mouth	09/12/2005	1	North Atlantic

Table 4. Stomach contents with hooks, guts or garbage (South Pacific survey). Repletion index 1 – 3 (empty, medium, full).

Species	Sex	Fork length (cm)	Repletion	Hook	Gut	Garbage
Prionace glauca	male	222	3	0	0	1
Prionace glauca	male	250	3	0	0	1
Isurus oxyrinchus	female	229	3	0	0	1
Prionace glauca	male	264	2	0	0	1
Prionace glauca	male	222	2	0	0	1
Isurus oxyrinchus	male	237	2	0	0	1
Isurus oxyrinchus	female	200	2	0	0	1
Prionace glauca	male	204	3	0	0	1
Isurus oxyrinchus	male	197	2	0	0	1
Prionace glauca	male	191	2	0	0	1
Isurus oxyrinchus	female	226	2	0	0	1
Prionace glauca	male	220	2	0	0	1
Isurus oxyrinchus	female	196	3	0	1	0
Prionace glauca	male	269	3	0	1	0
Isurus oxyrinchus	male	187	3	0	1	0
Prionace glauca	female	228	3	0	1	0
Prionace glauca	male	208	2	0	1	0
Prionace glauca	female	171	2	0	1	0
Prionace glauca	male	228	2	0	1	0
Prionace glauca	male	194	2	0	1	0
Isurus oxyrinchus	female	280	2	1	0	0
Isurus oxyrinchus	male	246	2	1	0	0