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Marine animal forests as useful indicators of entanglement by marine litter

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A B S T R A C T

Entanglement of marine fauna is one of the principal impacts of marine litter, with an incidence that can vary strongly according to regions, the type and the quantity of marine litter. On the seafloor, areas dominated by sessile suspension feeders, such as tropical coral reefs or deep-sea coral and sponge aggregations, have been termed “animal forests” and have a strong potential to monitor the temporal and spatial trends of entanglement by marine litter, especially fishing gears. Several characteristics of these organisms represent advantages while avoiding constraints and bias. Biological constraints and logistical aspects, including tools, are discussed to better define a strategy for supporting long-term evaluation of accumulation and entanglement of marine litter.

1. Introduction

Entanglement of marine fauna is one of the principal impacts of marine litter. The number of species known to have been affected by either entanglement or ingestion of plastic debris has doubled since 1997, from 267 to 557 species among all groups of wildlife (Laist, 1997; Kühn et al., 2015). Strong increases in records were listed for sea turtles (now 100% of the 7 species), marine mammals (now 66% of the 123 species) and seabirds (now 50% of 406 species). For entanglement only, the proportion of seabirds impacted ranges from 25% (in Kühn et al., 2015) to 36% (Ryan, 2018) and according to UNEP (2016), entanglement incidents in marine debris lead to wounds or death for a large number of other taxa, including 192 species of invertebrate and 89 species of fish. In a more recent review, entanglement was reported in 418 species from reef systems across eight taxa, also evaluating their major conservation implications (Carvalho-Souza et al., 2018).

A reduction in food intake is one of the most frequent consequences of entanglement, as well as, for mobile species, limitations in movements and thus escaping from predators (Kühn et al., 2015). Entanglement also leads to wounds susceptible to secondary infections and sometimes amputation after constriction (NOAA, 2014). Benthic organisms can also be caught in derelict traps or other litter items on the seafloor. For example, crabs, octopus, fishes and many small invertebrates are commonly captured in lost traps and nets, eventually dying because of starvation (June, 1990; Erzini et al., 2008; Good et al., 2010; Cho, 2011).

Although entanglement has been documented in many different types of debris, most records involved fishing gears, especially abandoned, lost, or otherwise discarded fishing gear (ALDFG), with an incidence that can vary strongly according to regions, the type and the quantity of marine litter.

Generally, the factors that may influence the probability of an organism being entangled in – or strangled by litter includes the size and structure of the debris, water turbidity, water depth but also behavioural traits (Kühn et al., 2015). For example, the lack of experience of juvenile or immature individuals can make them more vulnerable of being entangled in mesh nets. In young marine mammals, their “playful” and curious behavior has been suggested to increase the incidence of entanglement (Hanni and Pyle, 2000). In addition, ambient noise can hide or distort the echoes produced by ALDFG thus reducing the ability for cetaceans to detect nets by echolocation (Kühn et al., 2015). ALDFG can have an impact on the environment in many different ways, including the continuing catch of target species, the catching of non-target species or the entanglement of organisms, and the physical impact of gear on the benthic environment (Gregory, 2009), collectively termed “ghost fishing”. In some cases, ALDFG may represent almost 100% of total debris, especially in fishing grounds (Pham et al., 2014; Consoli et al., 2018) with monofilament fishing lines perhaps as the most dangerous kind of litter, as they represent a large part of entanglement records (Consoli et al., 2018). Many studies

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have described entanglement of epibenthic organisms in ALDFG, reaching up to 66% of the entangled or smothered benthic organisms, in particular for habitat-builders such as corals and sponges (Van den Beld et al., 2017; Melli et al., 2017).

2. Monitoring of entanglement

Although monitoring of litter ingestion in marine organisms has been implemented on solid scientific and technical basis (e.g. Van Franeker et al., 2011), entanglement by marine litter demands an in-depth analysis of the existing data (currently inadequate), and requires substantial work before an optimal strategy can be defined. Tracking the changes in the number or proportion of individuals affected at a given zone is the approach to be used to locate areas at risk and, considering trends, evaluate both the increase and the rate of increase in entanglement. It depends not only on the amount and changes of entangling litter in the environment (exposure) but also the rate at which entangling material moves through the studied systems, in relation to both inputs and mitigation measures.

Monitoring entanglement should consider different groups (marine mammals, birds, reptiles, fish, and invertebrates) and be organised by ecosystem compartments. Observations can be recorded at the level of the coastline (via stranding networks), the surface (e.g. during oceanographic campaigns or through observer programmes), and the seabed, through scuba diving for shallow areas, or submersibles/ROVs/AUVs (Remotely Operated Vehicles/Automated Underwater Vehicles) for deeper waters (RAC-SPA, 2017; Claro et al., 2018). To date, few direct and consistent large scale sampling efforts have been undertaken to understand harm caused by marine litter at the population level (RAC-SPA, 2017; Claro et al., 2018). Adequate sampling design is challenging to define since entanglement consists of isolated events, distributed over wide distribution areas, representing an unknown part of the total number of. It is also important to highlight that the dead entangled animals quickly disappear due to degradation of tissues, sinking or predation (Laist, 1997). Furthermore, the item responsible for entanglement is not always identifiable, making it difficult to identify the source, and small items are often not considered. Finally, the most important issues in monitoring the frequency of entanglement in marine organisms lies in our capability of distinguishing between bycatch in fishing gear, and entanglement (Kühn et al., 2015; Ryan, 2018).Certain marine organisms, when caught in active fishing gear, can tear it off, attempting to free themselves, or after being released by fishermen who voluntarily cut the gear; in both cases, these animals may continue to move over long distances with bits of gear entangled around their bodies (Asmutis-Silvia et al., 2017). Moreover, as stated by Ryan (2018), some organisms become entangled in fishing lines after ingestion of baited hooks. Although, detailed information on the entangled material could provide insights on whether the animal was entangled while the fishing gear was still active, it will be very challenging to differentiate between active gear and ghost gear for most entanglements events.

Overall, there are many difficulties associated with data interpretation. Although stranding networks may present a good way to obtain entanglement data and relevant information at a relatively low cost (Camphuysen, 2008), largescale risk assessments are constrained because of the rarity of stranding, mainly for large organisms. Therefore, the use of stranding can only be useful to particular groups of organisms that can be very locally affected, particularly in areas of intense fishing activity, high density of litter, or high abundance of vulnerable species (Galgani et al., 2013).

In the present stage of development, identifying the constraints inherent to a possible monitoring programme of entanglement is a priority. The constraints, related to the life cycle of the target organisms, integrate several items such as the choice of the species to monitor, their behaviour, their development stages, possible migration features and behavioural traits that will influence the probability of encounters between species and litter, a knowledge of the prevalence of entanglement in each species, and a knowledge of pathologies for an accurate diagnosis of the impact after entanglement.

With respect to the methods used, a certain number of elements are needed to set up a monitoring programme. Data collection scheme, standardized protocols, and a knowledge of the seasonal variations in the abundance of litter and target species are critical points that need to be taken into account when designing a programme. Finally, logistical aspects linked to the cost of monitoring and the accessibility of samples and data, including opportunistic approaches (e.g. fisheries observer programme, stranding networks or habitat mapping campaigns), are essential aspects that needs to be considered (RAC-SPA, 2017).

3. Entanglement in marine animal forests

On the seafloor, areas dominated by sessile suspension feeders (e.g. corals, hydrozoans and sponges) have been called “marine animal forests” because they form three-dimensional structures, increasing biodiversity similar to terrestrial forests (Rossi et al., 2017). We believe that such epibenthic communities (both found in shallow and deep waters) have a strong potential to monitor the temporal and spatial trends of entanglement by marine litter. Several characteristics of these organisms represent advantages while avoiding constraints and bias: Their increased vulnerability to damage due to their slow growth rate (Sheehan et al., 2017), their large distribution in shallow tropical water and in the deep sea (Rossi et al., 2017), their exposure to marine litter, occurring in both fishing areas, locally (e.g. Chiappone et al., 2005; Pham et al., 2013), or in remote areas after long distance litter drifting (miss a reference), their immobility allowing a precise location of the entanglement event as opposed to migrating or mobile organisms. In addition, the sessile characteristic reduces the risk of misinterpretation due to possible interaction with active fishing gears, since these organisms will not actively move e towards active fishing gear or attracted by any prey already captured. However, it is important to note that entanglement of epibenthic organisms can still occur when the gear is active, especially when longlines are lost when being retrieved. Therefore, we suggest that areas closed to fishing (e.g. MPA) are the most relevant sites to monitor entanglement, avoiding misinterpretation between active and ghost gear.

Subsurface reefs, coral heads and deep-sea coral and sponge aggregations (also known as reefs or gardens), as well as associated organisms are exposed to water circulation and currents, a “way of life” that may expose them more to marine litter, with an abundance of litter significantly higher in the crest zone (Figueroa-Pico et al., 2016) and, for the deep sea, higher over rocky bottoms than that on soft substrates (Melli et al., 2017).

Coral bleaching and damage from active fishing activities appears as the most important threats to coral. Evaluating the impacts of marine litter on animal forests started in the 1990s with authors studying damage resulting from fishing activities (mainly netting and lining), revealing it to be the most commonly recorded direct human impact on coral reefs worldwide (Breen, 1990; Al-Jufaila et al., 1996; Haines, 1997, Bavestrello et al., 1997). The threat posed by both plastic items and fishing gear on benthic communities was further confirmed by many other studies in shallow waters (Asoh et al., 2004; Yoshikawa and Asoh, 2004; Chiappone et al., 2005; Sheehan et al., 2017) and in the deep sea (e.g. Schlining et al., 2013; Pham et al., 2013; Cau et al., 2017), also showing entanglement for reef-associated organisms including crabs and teleost fish (Donohue et al., 2001) but most importantly that the likelihood of diseases increased 20-fold once a coral is smothered or entangled in plastic (Lamb et al., 2018). In the Marshall Islands, marine debris was shown to act as a significant stressor for coral reefs, causing suffocation, shading, tissue abrasion and mortality of corals, resulting in a significant negative correlation between the level of hard coral cover and coverage by marine debris (Richards and Berger, 2011).