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Incorporation of abandoned and lost fishing gear into the structure of *Dendrophyllia ramea* in the Atlantic coast of Portugal

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ABSTRACT

Plastic pollution poses global and societal concerns, especially from discarded fishing gear, threatening seabed environments like coral reefs. This study examines the incorporation of lost and/or abandoned fishing gear - specifically synthetic lines, and filaments - into the structure of orange tree coral, *Dendrophyllia ramea* along the coast of Portugal, in the North-East Atlantic Ocean. The specimens were inadvertently captured by local fishers (Sines and Cascais), with 6 % showing filaments inside their structure, raising questions about their potential impact on coral health. We discuss the implications of understanding the interactions between plastics, fishing gear, and corals, which is important for developing conservation strategies. We address the need for improved of measures aimed at reducing the impact of fishing gear on corals, emphasizing the importance of endorsing biodegradable fishing materials and supporting lost gear retrieval initiatives. Furthermore, we emphasize the urgent need to communicate these issues to both fishers and stakeholders.

1. Introduction

Plastic pollution has emerged as a worldwide concern due to its extensive prevalence and the potential implications it poses for both the environment and societies. Plastic pollution involves three levels of toxicity: physical, chemical, and biological. Because of this, it is considered a complex pollutant (Leistenschneider et al., 2023). Alongside other widely recognized stressors like climate change and overfishing, plastic pollution is now emerging as a new threat to coral reefs (e.g., Pinheiro et al., 2023).

Over the past decade, there has been increasing recognition to address the adverse ecological effects of particular items of marine litter, in particular, the effects of abandoned, lost and discarded fishing gear (ALDFG), mainly to benthic ecosystems (e.g., Angiolillo et al., 2021; Richardson et al., 2021, 2022).

In today's world, fishing equipment such as gillnets, traps, pots, fish aggregation devices, and various other types of gear represents a substantial sea-based source of global marine pollution. It is estimated that approximately 5.7 % of all fishing nets, 8.6 % of all traps, and a

staggering 29 % of all fishing lines are lost globally each year (Richardson et al., 2019). In addition, recent estimates show that nearly 2 % of all fishing gear, comprising 2963 km² of gillnets, 75,049 km² of purse seine nets, 218 km² of trawl nets, 739,583 km of longline mainlines, and more than 25 million pots and traps are lost to the ocean annually (Richardson et al., 2022).

These ALDFG materials has been demonstrated to produce also navigation hazards (e.g., Hong et al., 2017), and entangle marine wildlife. Nearly 6 % of all fishing nets used globally become lost at sea each year (Richardson et al., 2019), and the negative impacts of these nets are intensified by advancements in the durability and longevity of the plastics used in their production (McElwee et al., 2012). Abandoned fishing gear can have detrimental effects on the marine environment. Several authors have recorded nets and longlines entangled in cold-water coral colonies: e.g., Northwestern Mediterranean Sea (Lastras et al., 2016; Angiolillo et al., 2023), Ligurian Sea (Fanelli et al., 2017; Bo et al., 2023); England (Atlantic) (Sheehan et al., 2017) and Azores (Duncan et al., 2023). In certain locations, such as the Salish Sea (British Columbia, Drinkwin et al., 2023), efforts are being made to implement

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strategies that involve the removal of derelict fishing nets, which in turn safeguards habitats and prevents the mortality of numerous distinct species.

Nevertheless, as mentioned by Pinheiro et al. (2023), plastic accumulation (distribution and effects) in mesophotic reefs (30–150 m) is still unknown. The orange tree coral *Dendrophyllia ramea* (Linnaeus, 1758), is a stony cold-water coral, Azooxanthellate and is found in the Atlantic-Mediterranean region, belonging to the family Dendrophyllidae Gray, 1847. It displays an arborescent morphology, featuring tentacles in a white hue and polyps in a pale orange colour and can form expansive, branched colonies that can exceed heights of 100 cm (Salomidi et al., 2010). Notably, as of December 2017, this coral has been included in Annex II (List of endangered or threatened species) of the Barcelona Convention, which covers all European states within the Mediterranean (UNEP/MAP-SPA/RAC, 2018). Today, this species is considered to be a representative of a vulnerable marine ecosystem (VME). Furthermore, this species is recognized to be susceptible to bycatch and entanglement within lost fishing gear. In the Tyrrhenian Sea, Consoli et al. (2019) demonstrated that the most impacted organisms by line entanglement were corals. In the Ionian Sea, Angiolillo et al. (2022) recorded ROV images and found that in a *D. ramea* population, from the total litter items recorded, 26.6 % were observed to entangle sessile invertebrates and that entanglement affected 44 % of the largest colonies of *D. ramea*. In this last paper, the authors also observed that 10 % of coral colonies recorded were found entangled by longlines.

There is very limited information regarding these cold-water corals in Portugal and their interactions with plastic materials are not well known. For instance, a baseline quantitative assessment of coral bycatch was conducted for the southern coast of Portugal, specifically in the Algarve region (Dias et al., 2020). The study focused on the impact of bottom-set gillnets used by artisanal fisheries. The results revealed that approximately 85 % of the gillnet deployments captured corals of various species, which corresponds to around 13 % of the total coral species known along the Portuguese mainland coast, in Algarve (Dias et al., 2020).

Here, we conduct the first evaluation of the interactions between lost and abandoned fishing gear and the cold-water coral *D. ramea* from the Atlantic coast of Portugal.

2. Material and methods

2.1. Study area

This study comprises two main areas in the central coast of Portugal (Sines and Cascais, Fig. 1). The Cascais coastal area situated near Lisbon, on the western coast of Portugal, is a region of high ecological significance with diverse marine ecosystems (e.g., Ferreira et al., 2015). Located in the vicinity of Tagus Estuary, this area benefits from nutrient-rich waters due to the discharge of the Tagus River into the Atlantic Ocean (Fig. 1). Cascais exhibits favourable environmental conditions, such as clean and relatively warm waters, fostering the development of diverse marine life (Ferreira et al., 2015). In Cascais, there are currently around 30 fishing vessels with lengths between 6 and 14 m, operating in the local and coastal areas of Cascais. The vessels operated with nets, pots, traps, and hooks.

In Sines located around 150 km south of the Tagus River on the southwest coast of Portugal (Fig. 1), there are currently around 15 vessels operating, with lengths between 5.5 and 11.5 m. At this location, local vessels predominantly use traps to capture lobsters. In neither of the localizations were there any trawls.

Nowadays, fishermen in Portugal no longer discard their fishing gear into the sea as they did in the past, due to national restrictions. However, despite these regulations, accidents still occur, leading to the loss and abandonment of fishing gear.

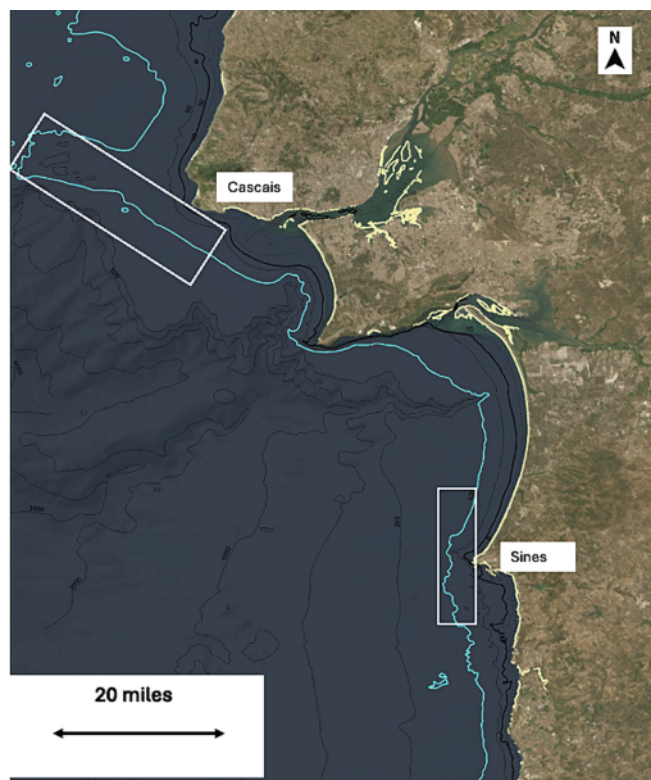


Fig. 1. Location where cold-water corals (*D. ramea*) were collected as bycatch from local fishers on the Atlantic coast of Portugal. Blue lines indicate the isobaths of 100 m. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2.2. Coral bycatch data

We contacted around 20 vessels in Cascais, and 14 in Sines, explaining our intention to study the coral communities and asking them to provide us with the specimens inadvertently captured in their fishing gear. The vessels in each locality are engaged in fishing activities in the areas surrounding the two ports and operate all year. Several fishermen from 5 vessels reported and provided the corals fragments or branches for assessing the interaction between fishing gear and corals.

3. Results and discussion

A total of 115 coral fragments and branches from *D. ramea* were recovered by fishers from both areas, at depths of around 100 m, during the years 2022 and 2023.

The collected samples of *D. ramea* showed that colonies were entangled in fishing lines and had plastic filaments incorporated in the coral branches (Figs. 2 and 3). A total of 6 % of corals had plastic incorporated into their structure in their branches. Specifically, six

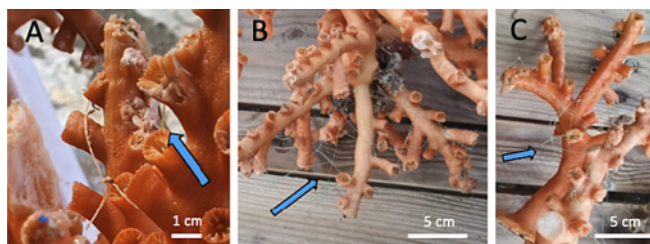


Fig. 2. *D. ramea* coral branches at their arrival in the fishing port of Sines (Portugal). In A, the coral is still alive. Blue arrows serve as indicators for the fishing gear entangled or incorporated. Photos Joaquim Parrinha.

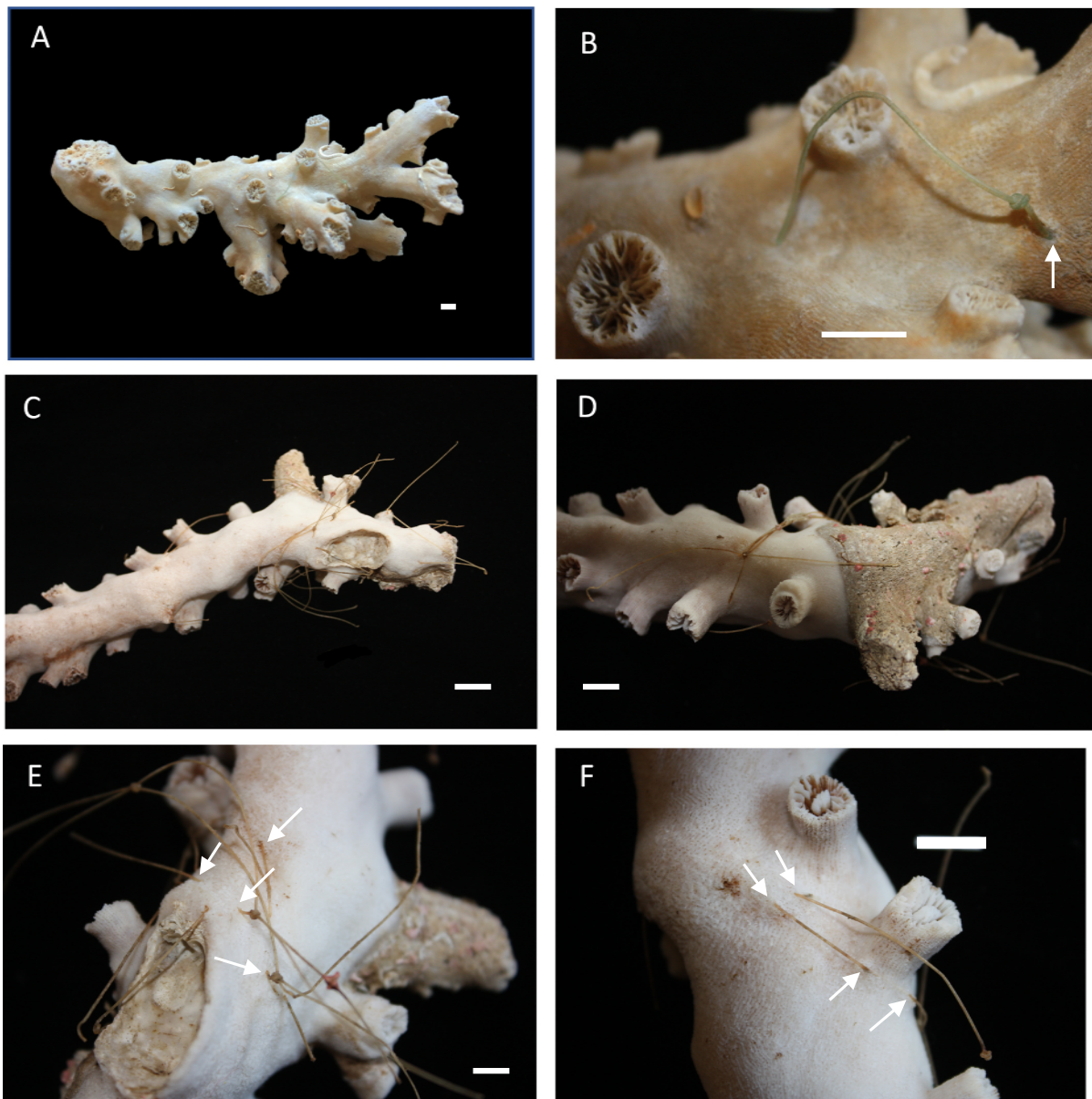


Fig. 3. A) and B) *D. ramea* with incorporation of fishing lines collected from Cascais, C) to F) corals collected from Sines, Atlantic coast (Portugal). Scale bar = 1 cm. The arrows indicate some locations where fishing lines enter and exit the coral structure. Photos: Filipa Bessa.

corals with plastic were collected from the Sines area, while only one was found in Cascais. Corals from Figs. 2 and 3 (E and F) showed white filaments, possibly resulting from fishing nets (the size is challenging to determine due to entanglement and incorporation into the structure of the coral). However, the maximum size of an external filament observed was 10 cm (Fig. 3E). In Fig. 3 (A and B), the filament observed was green (nylon elastic filament) and measured 4 cm in length.

The photos in Fig. 3 show that after the initial interaction with the fishing filaments, the coral tends to continue their growth, and effectively integrates the filaments into their structure, a phenomenon that was recorded and observed in specimens from both study locations. In specific instances, the filaments extend from one side of the coral to the opposing side (with marked scars, as illustrated in the detailed photographs with the white arrows). Some filaments exhibit a harmonious alignment as they enter and exit the coral structure (Fig. 3E and F). Further studies are needed to investigate these processes and the way *D. ramea* undergoes growth and incorporates intricate network-like filaments into its structure. This process raises questions about the

potential impact of these interlinked filaments on the overall health and well-being of the coral. As the coral is sessile and expands, it appears to actively assimilate these filaments from its surroundings, thus creating an intricate and interconnected structure within its skeleton structure. However, the implications of these incorporated filaments remain uncertain. There is a need to investigate and determine whether these filaments have a positive, neutral, or adverse effect on the health and development of the corals. For example, in zooxanthellate corals, plastic provides a potential entry point for pathogens to invade, as demonstrated by Lamb et al. (2018). The same phenomenon requires investigation in the context of cold-water corals. In the coral *Desmophyllum pertusum* (Linnaeus, 1758), experiments have shown that macroplastics had a significant inhibitory effect on skeletal growth rates. Macroplastics are known also to induce increased polyp activity while causing a decrease in prey capture rates, acting as physical barriers that can impede the food supply (Chapron et al., 2018).

To understand when these fishing gears begin to be incorporated, we must consider also the growth rate of these corals. Cold-water corals

exhibit an exceptionally slow growth rate compared to tropical corals (Jantzen et al., 2013). Knowledge regarding the growth patterns of this species is still very limited. For instance, in an aquarium experiment spanning 18 months, an average daily growth rate of 0.021 % was recorded, while the calcification rate reached 0.07 % per day, as reported by Reynaud and Ferrier-Pages (2019). This leads us to hypothesize that the interactions between fishing gear and corals highlighted in the present study likely originate from the durability and prolonged presence of these synthetic materials that have been lost, abandoned and/or discarded in the sea.

4. Final remarks

Efforts to mitigate the impact of fishing gear on corals in this Atlantic coastal stretch are strongly recommended. Coral colonies are inadequately described and mapped along the Atlantic coast in Portugal, especially in the areas where these specimens were captured. Additional efforts are also needed to promote the adoption of biodegradable fishing gear and supporting initiatives for mapping and retrieving lost fishing gear are essential steps for more sustainable fishery activities. Furthermore, educational and outreach programs can play a pivotal role in increasing awareness among fishers and other marine stakeholders regarding the significance of safeguarding coral habitats and the detrimental impact posed by fishing gear and other plastic materials. In Portuguese waters, cold-water corals are widespread (e.g., Dias et al., 2020) despite the limited information regarding their distribution along the coast remains largely unknown. It is crucial to prioritize the safeguarding and conservation of these habitats to ensure the continued existence of these corals and their ongoing contribution to the well-being of marine ecosystems.

CRedit authorship contribution statement

Sónia Seixas: Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Joaquim Parrinha:** Writing – original draft, Methodology, Investigation, Funding acquisition, Conceptualization. **Pedro Gomes:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Data curation. **Filipa Bessa:** Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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