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A field-based framework for evaluating sustainable fishing gear in small-scale *Plesionika edwardsii* fisheries

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Introduction: Plastic pollution at sea is a critical global issue, but despite legislative requirements, scant information is available for the ongoing assessment of this threat. Abandoned, lost, or otherwise discarded fishing gear (ALDFG) significantly contributes to marine litter, ghost fishing, and ecosystem degradation.

Methods: A multidisciplinary research effort, carried out in collaboration with small-scale fishers, introduced a new methodological approach implementing sustainable and biodegradable fishing gear. This approach combined experimental field trials with performance monitoring to test pot nets lined with biodegradable and compostable material prototypes, used in artisanal fisheries targeting *Plesionika edwardsii*.

Results: According to our results, these alternative materials deliver artisanal performance comparable to that of traditional plastics, including fishing efficacy, while reducing environmental impact.

Discussion/Conclusion: Early-stage trials indicate that biodegradable pots, while requiring further refinement for effective use in fishing, represent a viable option for reducing ghost fishing and plastic pollution, supporting biodiversity conservation. This work demonstrates a replicable framework for testing and validating sustainable fishing gear under real-world conditions, supporting evidence-based decisions in marine resource management.

KEYWORDS

pot nets, biodegradable materials, artisanal fisheries, plastic pollution, sustainability

1 Introduction

Marine pollution is a transboundary phenomenon recognised as an increasingly global problem (Bergmann et al., 2015). Among all the threats that natural resources and wildlife are facing, plastic pollution has emerged as one of the most pressing issues (Law and Thompson, 2014). All human-related activities, both on land and in marine environments, are constantly contributing to the influx of plastics into oceans. According to Borrelle et al. (2020), global plastic emissions into aquatic ecosystems are projected to increase significantly, with up to 53 million metric tons entering the oceans annually by 2030 under a business-as-usual scenario. The spread of plastics in the ocean is guided by a variety of interconnected factors, including ocean currents, weather patterns, and seasonal changes (Aigars et al., 2021; Lorenz et al., 2019; Wagner et al., 2019), as well as the composition and density of the polymers involved (Erni-Cassola et al., 2019; Hardesty and Wilcox, 2017). As highlighted by the Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment in the European Union, since 1980, 85% of marine waste found on beaches is made of plastic polymers: of these, single-use plastic objects represent 50%. While approximately 80% of marine litter originates from land-based sources, the remaining 20% is attributed to sources at sea, and specifically, fishing-related items and synthetic ropes rank among the top 10 most commonly found objects in the sea (Morales-Caselles et al., 2021). Moreover, it is estimated that approximately 10% of global marine litter by volume entering the oceans is plastic residuals stemming from the fishing sector (UNEP and GRID-Arendal, 2016).

Lost or abandoned fishing gear, referred to as "abandoned, lost, or otherwise discarded fishing gear" (ALDFG), is recognised as the primary source of plastic waste in the fisheries and aquaculture sectors (Lusher et al., 2017). A significant percentage of fishing gear is not successfully retrieved from the seafloor, posing a particularly serious issue in the context of marine litter (Richardson et al., 2019), as it places marine ecosystems, biodiversity, and human health at significant risk (Directive (EU) 2019/904). In fact, ALDFG in a floating state can trap and suffocate already threatened marine organisms, such as cetaceans and turtles (Wilcox et al., 2015; Stelfox et al., 2016), while heavier gear ends up covering large stretches of the seabed, altering the habitat and vital functions of numerous species, in particular the structuring ones (phanerogams, gorgonians, and black corals) (Consoli et al., 2019; Moschino et al., 2019), which play a key role as attractors of biodiversity (Barbier et al., 2011; Godbold et al., 2011). A further problem connected to the presence of abandoned fishing gear is the phenomenon of ghost fishing. Lost nets may remain deployed in an operational configuration, continuing to capture organisms, thereby further compromising fish stocks and endangering vulnerable species (Matsuoka et al., 2005).

Several studies have also highlighted a correlation between the type of resource targeted (e.g., pelagic, demersal, or benthic) and the likelihood or extent of gear loss. Gear used in demersal and benthic fisheries—such as bottom trawls and demersal gillnets—are especially prone to being lost or abandoned due to their direct interaction with the seabed and the complexity of retrieval operations in rough or structurally complex habitats (Gilman et al., 2021; Richardson et al., 2019). Gillnets, for instance, may be lost in high proportions when entangled or damaged during operation and continue ghost fishing for extended periods. Similarly, bottom trawl fisheries, which often target benthic communities, contribute significantly to gear loss and associated habitat degradation. In contrast, pelagic gear such as tuna purse seines with fish aggregating devices (FADs) contribute to ALDFG mainly in absolute quantities due to their large-scale deployment, despite having proportionally lower loss rates (Gilman et al., 2021).

It is estimated that nearly 2% of all fishing gear is lost to the ocean annually, including approximately 2,963 km^2 of gillnets, 75,049 km^2 of purse seine nets, 218 km^2 of trawl nets, 739,583 km of longline mainlines, and over 25 million pots and traps (Richardson et al., 2022; Richardson et al., 2019). The slow disintegration and degradation of the plastic materials used in the manufacture of most fishing gear ensure their prolonged persistence in marine ecosystems when lost or abandoned (Gilman et al., 2021; Macfadyen et al., 2009).

Given the severity of plastic pollution, European regulations are increasingly aiming, where possible, for the gradual replacement of traditional polymers with biodegradable alternatives (Manfra et al., 2021; European Bioplastics, 2020). According to European Bioplastics, 2020, a bioplastic material is considered as such if it is either biobased or biodegradable or possesses both characteristics. Sustainable alternatives have recently been used to replace traditional plastic in several sectors, such as packaging (Karamanlioglu et al., 2017; Auras et al., 2004), fibres (Satyanarayana et al., 2009), and single-use items (Viera et al., 2020; O'Brine and Thompson, 2010). Although quite recent, the use of bioplastics has also taken place in the fishing industry in several applications, such as mussel nets (Baini et al., 2024), gillnets (Grimaldo et al., 2020, 2019), and pot nets (Kim et al., 2014a, 2014B; Bae et al., 2010). Such materials, if lost, will break down after a specific amount of time at sea and eventually disappear, thus reducing the occurrence of ghost fishing and plastic pollution at sea caused by lost gears (Grimaldo et al., 2020; Brown and Macfadyen, 2007; Large et al., 2009; Macfadyen et al., 2009; Gilman, 2016). Recently, some comparative experiments have not been encouraging (Grimaldo et al., 2018, 2020; Cerbule et al., 2022), reporting a slightly lower catch efficiency of the bio-based gillnets compared to the traditional ones. However, many studies (Bae et al., 2010; Kim et al., 2014a, 2014b; Cerbule et al., 2023) have reported better results for longlines and trap nets. In any case, even in studies where the yield was not comparable, authors (Grimaldo et al., 2020; Cerbule et al., 2022) argue that bio gillnets still show great potential for reducing ghost fishing. Traps, pots, and nets are the main drivers of ghost fishing, with a significant impact on coastal areas (Lively and Good, 2019). To support socioeconomic sustainability, the European Union has allocated funding to promote pot nets as an alternative to gillnets (Petetta et al., 2021). In contrast to gillnets, pot nets offer high selectivity, which can effectively reduce bycatch. Unlike trawl nets or gillnets, which can cause significant damage to the seafloor and marine habitats, pot nets typically rest on the substrate and do not drag along the bottom, thereby reducing habitat destruction (Meintzer et al., 2018; Almeida et al., 2022). Reducing marine litter is a fundamental step to conserve and sustainably use the oceans, seas, and marine resources for sustainable development (Bergmann et al., 2015; Sheavly and Register, 2007).

Considering the advantages of bioplastic in reducing ghost fishing and plastic pollution, it is crucial to explore alternative fishing gear that enhances selectivity and minimises bycatch. In contrast to gillnets, which often show low species selectivity, resulting in significant bycatch levels (Lucchetti et al., 2020; Tsagarakis et al., 2014; Reeves et al., 2013), pot nets are a highly selective tool capable of providing catches exclusively of adult individuals and reducing accidental catches to a minimum (Petetta et al., 2020). Previously, various studies in the Mediterranean Sea have employed pot nets to capture different marine species (Petetta et al., 2020, 2021; Virgili et al., 2024). Specifically, Virgili et al. (2024) examined whether pots can provide a sustainable harvest of mantis shrimp (*Squilla mantis*) in small-scale fisheries in the Adriatic Sea, potentially serving as a replacement for traditional gillnets. Moreover, due to their metal structure, pot nets can be covered with materials of different consistencies than the commonly used plastic nets, offering more options for sustainable fishing practices. Incorporating bioplastics in pot nets could contribute to marine conservation and sustainable development goals (Bergmann et al., 2015; Sheavly and Register, 2007).

In the present research, *Plesionika edwardsii* was selected as the target species. *P. edwardsii* is a cosmopolitan, nektobenthic, and gregarious species distributed between 100 and 650 m, capable of nocturnal vertical migrations for feeding (Relini et al., 1986), with surveys within reproduction season characterised by peaks from March to July (Colloca, 2002). The species is listed in the Food and Agriculture Organization of the United Natio (FAO) catalogue of species relevant to fisheries (Holthuis, 1980; FAO, 2005), with landings primarily coming from traps and trawling (Possenti et al., 2007). Despite being one of the most abundant shrimp species of the Mediterranean Sea (Castriota et al., 2004; Colloca et al., 2002) and likely having the greatest fishing potential, there is currently no commercial fishing targeting *P. edwardsii* in Italy using traps (Possenti et al., 2007).

This study introduces a novel approach by integrating biodegradable and compostable coating materials into pot nets and testing their performance for the first time in targeting *P. edwardsii* in the Western Mediterranean Sea. While previous research has examined biodegradable materials in other fishing gears (e.g., gillnets and longlines; Cerbule et al., 2023; Baini et al., 2024) or has evaluated pot nets for different species (Kim et al., 2014a, 2014b; Bae et al., 2010), no study to date has combined these two strategies to simultaneously address catch efficiency, selectivity, and material durability in deep-water crustacean fisheries.

The main goals of this research were as follows:

i. assess, for the first time, the fishing efficiency of pot nets coated with two prototypes of biodegradable and compostable materials in the context of artisanal deep-water shrimp fisheries;
ii. evaluate the bycatch rate and species selectivity of these innovative gears compared to conventional gears; and
iii. evaluate the durability of the materials in the marine environment.

2 Materials and methods

2.1 Study area

Four fishing surveys were conducted in two distinct macro-areas of north-western Sardinia (Central Tyrrhenian Sea). Operations were carried out using two vessels from the Porto Torres fleet: the M/P *Pierpat* (total length 10.8 m; engine power 205 kW) and the M/P *Polaris II* (total length 13.9 m; engine power 2 × 149 kW). Fishing grounds were selected in collaboration with the participating fishers. The *Pierpat* operated along a coastal transect from Bosa to Asinara, alternating deployments of pots on both shallow and deep seabeds (Figure 1). In contrast, the *Polaris II* consistently operated approximately 5 nautical miles off Isola Piana, deploying pots at the base of steep slopes where depth rapidly increased from 150 to 250 m over short horizontal distances (Figure 1).

2.2 Pot net design, structure, and material innovation

In this study, the pots employed closely resembled those described in previous investigations conducted in the Tyrrhenian Sea (Colloca et al., 1998; Colloca et al., 2002; Sartor et al., 2006). Each pot consisted of a truncated conical frame made of 4-mm-thick galvanised iron, with a cylindrical section diameter of 57 cm and a total height of 56 cm (Figure 2A). The frame was covered with 10-mm mesh netting made of three different materials. The entrance (12-cm diameter) was located at the terminal end of the cylindrical section, while an opening at the apex of the conical section allowed for bait placement and catch retrieval. This opening consisted of a galvanised wire disk (12-cm diameter) covered with the same netting as the rest of the pot, fixed directly to the frame without hinges (Figure 2A). Pots were baited with either *Alosa fallax* or *Scomber scomber*. Lines consisted of 10–12 pots, each connected at 10-m intervals to a weighted groundline (800 g/m) using a quick-release snap hook and an 80-cm segment of 8-mm diameter polypropylene rope (Figure 2B). The groundline was further weighted with a 3-kg dead weight at each end. Each pot was equipped with two 1-L buoyancy floats fixed to the upper rim of the cylindrical section, providing semi-floating capability. The first and last pots of each line were placed 50 m from the start and end of the groundline, respectively. A schematic of the rigging arrangement is shown in Figure 2B. The design of the pots positioned the baited entrance directly in the path of the prevailing current, enhancing the dispersal of olfactory cues and attracting target crustaceans towards the opening.

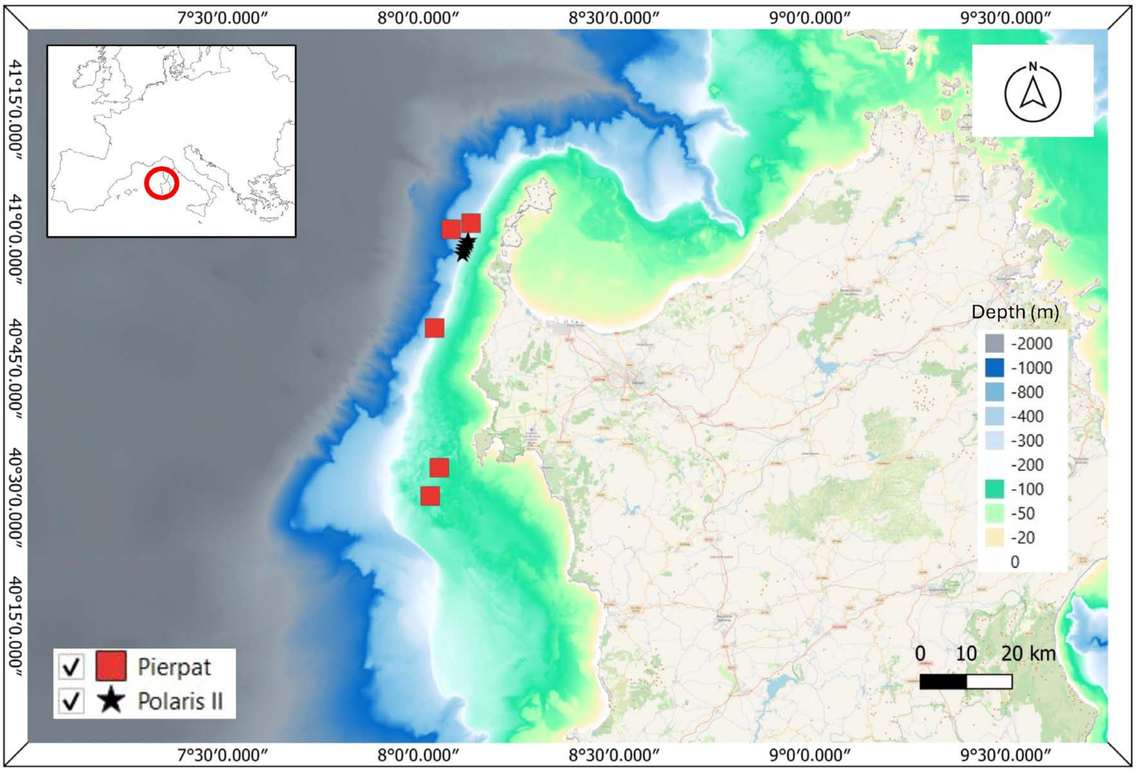

FIGURE 1
Sampling area. The map represents the areas sampled during summer 2022 by the two vessels used in this research in north-western Sardinia, Central Tyrrhenian Sea: *Pierpat* and *Polaris II*. As shown in the legend, the red squares indicate the sampling sites surveyed by *Pierpat* in different areas, while the black stars represent the sites sampled by *Polaris II*, concentrated in the same area.

The pot nets were coated with three types of materials, including two prototypes of biomaterials developed by Novamont (Novara, NO, Italy), specifically for this project. The two biodegradable prototypes were crafted from compostable materials (Prototype A and Prototype B, Figures 3B, C), meeting UNI EN 13432 standards, which define the requirements for packaging recoverable through organic recycling. Prototype A net (Figure 3B) is made of biodegradable polyesters and has a weight of 450 g/m^2, while Prototype B net (Figure 3C) is a combination of biodegradable polyesters, starch, and natural plasticisers, with a weight of 470 g/m^2. The two biodegradable prototypes do not contain the UV additives that are normally added to the conventional plastic nets. The fishing gears were arranged in a repeating sequence along each line, as follows: one high-density polyethylene (HDPE) plastic trap (Figure 3A), followed by a bioplastic pot of Prototype A, then another HDPE trap, followed by a bioplastic pot of Prototype B. This sequence (HDPE→A→HDPE→B) was repeated along each line, ensuring that all three types of gear (HDPE, Prototype A, and Prototype B) were exposed to the same environmental conditions. This pattern continued across the setup, and as a result, the number of bioplastic pots matches the total number of traditional plastic pots.

2.3 Sample collection and analytical methods

The four surveys were initially scheduled monthly from May to September 2022 but were revised due to weather conditions, resulting in the final schedule in Table 1.

The pot nets were set in the early morning and retrieved approximately 24 hours later. Each pot net used in this study was labelled with a unique aluminium tag bearing an individual identification number. The catch from each pot was stored in separate bags, each labelled with the corresponding pot net number. This allowed for a comparison of the capture efficiency of the pots based on the different materials used in their construction. The overall catch from each pot was analysed in terms of species composition, identified to the lowest possible taxonomic level (Falciai, 1992), and biometric parameters, such as length, weight, and sex, were recorded for each species.

Carapace length (CL; ± 0.1 mm) and total weight (TW; ± 0.1 g) of each individual of the target species (*P. edwardsii*) were measured. Every specimen was then examined to determine its sex. During each fishing trip, data concerning the date and time of deployment and retrieval, the geographical coordinates, and the average depth at

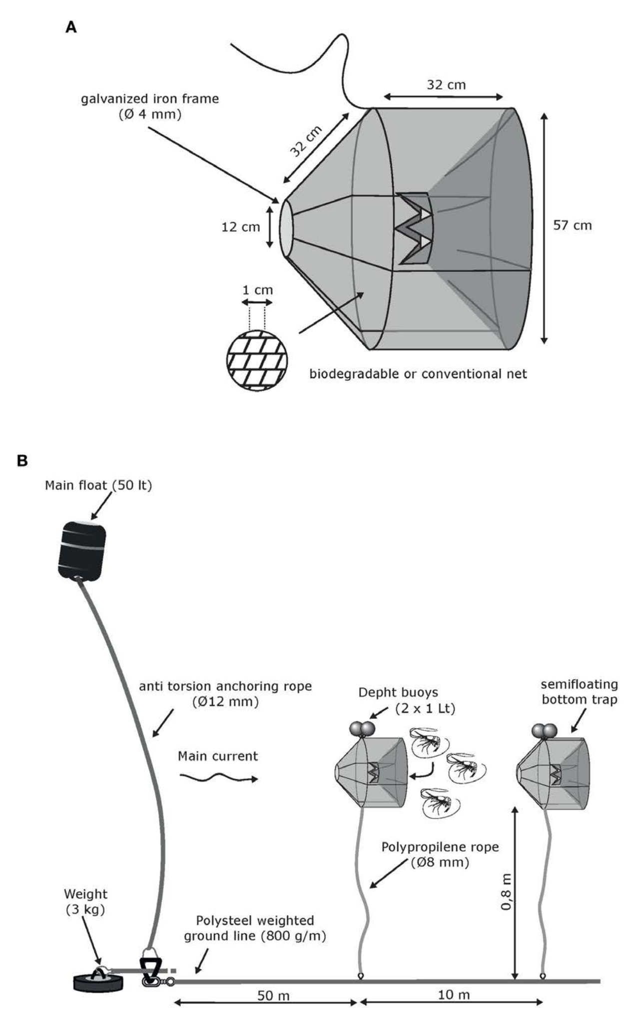

FIGURE 2
Schematic structure of the pots and arrangement of the pots on the lines. Structure of the pots used for sampling *Plesionika edwardsii* **(A)** and schematic of the line rigging **(B)** (adapted from Arrasate-López et al., 2012).

which the pot nets were positioned were recorded. This information was obtained using digital nautical charts for geographic positioning (GPS) and the onboard echo sounder for depth measurement.

Moreover, for an initial assessment of the behaviour of the three types of materials when exposed to marine environmental matrices under mesophilic conditions, a laboratory-scale test was conducted following the ISO 23832:2021 standard, which outlines test methods for determining the degradation rate and disintegration degree of plastic materials exposed to marine environments under laboratory conditions. This method measured the physical degradation of the two prototypes when exposed to marine inocula under aerobic conditions, providing an indication of their potential physical degradation in natural environments, compared to non-biodegradable materials. The three materials (HDPE, Prototype A, and Prototype B) were exposed at the interface between marine sediment and a water column, simulating seabed conditions where most debris sinks. Three reactors were set up, consisting of plastic boxes measuring 30 cm × 20 cm × 20 cm, filled with approximately 2 kg of marine sediment and 3 L of synthetic seawater prepared according to the standard. For each material, samples measuring 5 × 5 cm were prepared and analysed in replicates. Aeration was provided by an air inlet tube into the water column with a constant airflow. The reactors were incubated in the dark at room temperature (23°C ± 3°C). Degradation was assessed by monitoring weight loss at three intervals: 3, 6, and 9 months. At each time point, a reactor was stopped, and the samples were removed, washed with distilled water, and dried at room temperature until they reached a constant weight. Ethical review and approval were not required for this study, in accordance with Italian legislation (D.L. 04/04/2014 No. 26, Article 1, paragraph 1), which states that ethical approval is not necessary for experiments involving invertebrates.

2.4 Statistical analysis

All analyses conducted in this study were performed using Excel (version 2410 build 18129.20116) and the R programming language (R Core Team, 2024). A significance level of p-value < 0.05 was set for all tests performed. Abundance and weight, both absolute and relative percentages, were calculated for each species on the overall catches. Doughnut charts were created to represent the proportional catch composition of different species, categorised according to the material type of the pot nets. Regarding the captures of the target species only, the proportion of empty pots was calculated for each of the three pot net types and represented in a stacked column chart normalised to 100%. The catch per unit effort (CPUE), represented in a bar plot, was computed as the ratio between grams of target species per pot and was split by depth ranges. To better assess whether the different materials exhibited distinct behaviour in terms of catches of the target species, the data collected during the four surveys using the three types of pot nets were analysed using univariate statistical analysis techniques. The CL (mm), the biomass (g), and the number of individuals were compared among different surveys, considering each type of material separately and represented in separate boxplots. Moreover, the Kruskal–Wallis test was applied to verify the existence of significant differences in relation to the factor mentioned above.

Additionally, a non-parametric permutational multivariate analysis of variance (PERMANOVA) was performed to test whether the multivariate catch dataset (number of individuals, carapace length, and weight) differed among pot net types. PERMANOVA partitions variance based on a distance matrix and assesses significance through permutations, without assuming multivariate normality. Regarding statistical evaluation, the fishing surveys were kept separate, as they were found to be heterogeneous in terms of environmental conditions or sampling effort.

3 Results

3.1 Catch results and fishing performance

A total of 11 days of valid fishing surveys were conducted simultaneously from two fishing vessels, reaching a total of 625 pot

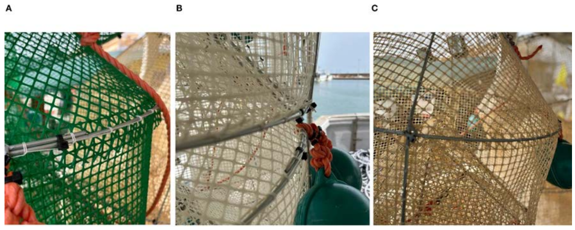

FIGURE 3
Type of nets. Close-up photos of the three types of pot nets targeting *Plesionika edwardsii* in north-western Sardinia, Central Tyrrhenian Sea:
(A) high-density polyethylene pot nets (HDPE), **(B)** Prototype A pot net (Prot. A), and **(C)** Prototype B pot net (Prot. B).

TABLE 1 Sampling survey timeline.

Sampling surveys	Timeframe	Fishing days (both vessels)	Total no. of pots
I	2–6 July	4	108
II	24–29 July	6	143
III	24–28 August	6	182
IV	4–8 October	6	192

List of the four sampling surveys conducted between July and October 2022, including the number of fishing days and the total number of pots used per survey.

nets deployed: 108 in sampling survey I, 143 in sampling survey II, 182 in sampling survey III, and 192 in sampling survey IV.

The complete faunal list of species captured during the four experimental surveys, along with data on their abundance and weight (both total and percentage values), is shown in Table 2. *P. edwardsii*, the target species of this study, accounted for nearly 78% of the total catch by abundance and approximately 24% by weight. The second most abundant species, contributing approximately 12% of the catch in terms of individuals, was another pandalid, *Plesionika narval*. Concerning the bycatch of vertebrate species (a total of eight species), the relationship between abundance and biomass is reversed: although they contributed only 6% of the total catch by number, they comprised almost 73% of the total catch by weight. Noteworthy, among the most frequently encountered species are two chondrichthyans—the small-spotted catshark (*Scyliorhinus canicula*) and the black lanternshark (*Etmopterus spinax*)—as well as the European conger (*Conger conger*). The bycatch consisted primarily of species with low or no commercial value.

Figure 4 shows the cumulative distribution of total catches, expressed as a percentage, by the types of net used.

These doughnut charts show that for all three types of pots used in this experiment, the target species *P. edwardsii* represents, in terms of abundance, approximately 78.3% of the catches. The second most abundant species across all three material types is a shrimp belonging to the same genus as the target species (*P. narval*), with percentages amounting to 16% (HDPE), 7% (Prot. A), and 12% (Prot. B).

The proportion of empty pots (i.e., those that did not capture any individuals) alongside the proportion of pots that successfully captured individuals is displayed in Figure 5. The percentage of completely empty pots was notably high, consistently exceeding 55% of the total pots deployed.

The most abundant catch per single pot in terms of biomass was carried out during the second survey and was equal to 699 g, corresponding to 91 individuals. Throughout the project, a total of 1,637 individuals of *P. edwardsii* were captured (11,108.1 g), of which 874 corresponded to females (6,555.9 g) and 761 males (4,547.9 g).

The smallest individuals (4–10 mm CL), consisting mostly of female organisms, were all captured during the third survey at the end of August, while the larger ones (26–31 mm CL) were fished in all the surveys carried out for the present research. The females represented the largest individuals captured. The weight and numerical yields of the target species achieved during the four fishing surveys are shown in Table 3.

CPUE (g/pot net) is represented in Figure 6 and divided according to the three bathymetric ranges: 190–249, 250–299, and 300–350 m. As observed, the majority of *P. edwardsii* individuals were captured at the deepest bathymetric range (300–350 m), which also displays a higher CPUE value.

The values of CL (mm), the biomass (g), and the number of individuals (no. of individuals) captured per pot type across surveys I, II, III, and IV, along with the results from the univariate analysis (Kruskal–Wallis test), are shown in Figure 7. For CL, the Kruskal–Wallis test revealed no significant differences among the pots, as they consistently captured individuals of similar sizes across surveys. Throughout the entire experiment, pot nets made of the three different materials showed similar capture efficiency for *P. edwardsii*. However, slight differences in median captures were observed only in survey III, where the Prot. A pot net recorded the lowest number of individuals. Similarly, biomass (g) of the captured individuals did not significantly change depending on the pot material.

PERMANOVA results indicated no significant differences in catch composition (number of individuals, carapace length, and weight) among pot net types ($F = 0.86$, $R^2 = 0.014$, $p = 0.444$), supporting the findings from the univariate analyses.

3.2 Preliminary observations on material behaviour

Concerning the behaviour evaluation of the three tested materials when exposed to marine environmental matrices, the weight loss of each netting type (HDPE, Prototype A, and Prototype B) was monitored over the experimental period (Figure 8).

Despite the relatively short duration of the test, differences among the behaviour of the materials were observed. Both biodegradable prototypes showed a progressive decrease in weight, with Prototype B exhibiting the most pronounced loss (Figure 9). In contrast, HDPE maintained a stable weight

TABLE 2 Catch composition.

Phylum	Class	Family	Species	TN	TW (g)	N%	W%
Arthropoda	Malacostraca	Munididae	*Munida* sp.	1	5	0.05	0.01
		Pandalidae	*Plesionika edwardsii*	1,637	11,108.1	78.51	23.55
			Plesionika heterocarpus	13	15.2	0.62	0.03
			Plesionika narval	258	728.9	12.37	1.55
		Pasipheidae	*Pasiphaea multidentata*	61	471.3	2.93	1.00
Chordata	Elasmobranchii	Etmopteridae	*Etmopterus spinax*	25	4,310	1.20	9.14
		Pentanchidae	*Galeus melastomus*	8	1,500	0.38	3.18
		Scyliorhinidae	*Scyliorhinus canicula*	31	5,790	1.49	12.28
	Teleostei	Congridae	*Conger conger*	14	13,360	0.67	28.33
		Moridae	*Mora moro*	1	300	0.05	0.64
		Muraenidae	*Murena helena*	4	3,000	0.19	6.36
		Phycidae	*Phycis phycis*	1	780	0.05	1.65

Faunal list of species captured during the four experimental surveys. TN indicates the total number of individuals, TW indicates the total weight, and N% and W% represent the percentage contribution of each species to the total number of individuals and total weight, respectively.

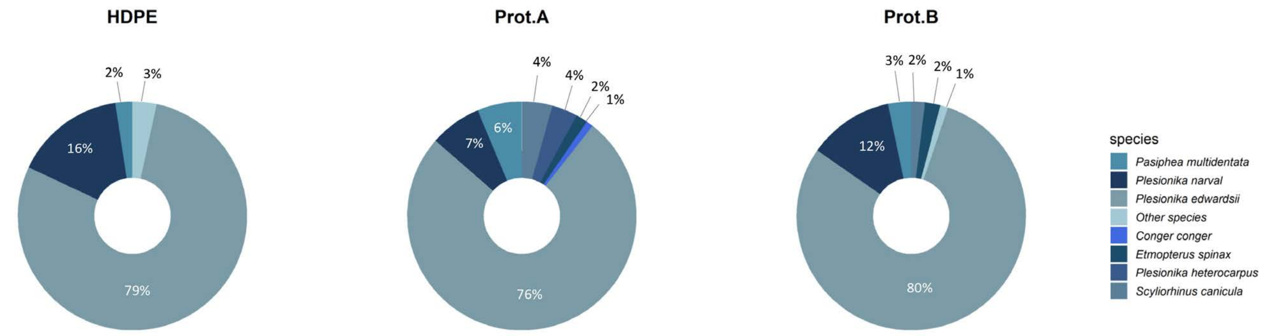

FIGURE 4
Total catches grouped by pot nets' materials. **(A)** HDPE pots, **(B)** Prototype A pots, and **(C)** Prototype B pots. HDPE, high-density polyethylene.

throughout the trial. It was observed that the two biodegradable prototypes exhibited different degradation kinetics. Specifically, Prototype B nets showed clear signs of degradation on the surface, including colour change and cracks, along with increased flexibility and fragility, while for Prototype A nets, changes were limited and mostly noticed after 9 months of exposure. No significant weight loss was observed for the HDPE nets.

4 Discussion and conclusion

Finding new materials for use in commercial fisheries should aim to match the performance of traditional, non-biodegradable gear to maintain sector profitability and facilitate acceptance among fishers. Testing these materials on different fishing tools helps identify those offering the best performance. In this research, pot nets constructed with biodegradable and compostable materials were selected due to their reduced environmental impact (UNEP and GRID-Arendal, 2016; Avérous and Pollet, 2012). Non-biodegradable plastics contribute significantly to marine pollution and ghost fishing, making up 85% of the 9–14 million tons of ocean litter annually (UNEP and GRID-Arendal, 2016). Biodegradable fishing gear, designed to decompose into environmentally safe substances, such as carbon dioxide, methane, and water, reduces plastic waste accumulation and minimises entanglement and bycatch risks (Kim et al., 2016, 2023).

Results showed that catch efficiency was comparable between the different materials used, with no substantial differences observed in the biomass of the target organisms captured. The three materials also showed similar catches in terms of the number of individuals and in their sizes (carapace length). The absence of significant differences in the catchability of the target species between HDPE

TABLE 3 Target species abundance.

Sampling surveys	No. of individuals	Weight (g)
I	204	1,141.3
II	860	5,972.3
III	213	1,391.9
IV	358	2,602.5

Target species abundance among the four sampling surveys in terms of number of individuals and weight (g).

pots and biodegradable and compostable pots is a key consideration for introducing alternative materials to plastic in fishing tools, representing an initial step in assessing such alternatives. Similar results were found by Kim et al. (2014a, 2014b) and Bae et al. (2010) for similar fishing tools. Kim et al. reported that the fishing performance was comparable between semi-biodegradable pots and traditional net pots for both *Octopus minor* (Kim et al., 2014a) and *Conger myriaster*, with no significant differences in CPUE (Kim et al., 2014b). The same was observed by Bae et al. (2010) for the red snow crab (*Chionoecetes japonicus*), as well as for several shrimp species (*Pandalus eous*, *Pandalus hypsinotus*, and *Pandalopsis japonica*), both considering catch efficiency and length composition. Additionally, research has shown that even in the case of longlines, biodegradable materials can yield results comparable to those of traditional materials. Indeed, no significant differences were found between the performance of the two materials regarding the hook loss rate, catch efficiency, and catch composition during short-term use in fishing in longlines targeting *Pagellus erythrinus*, *Diplodus vulgaris*, and *Pagellus acarne* (Cerbule et al., 2023).

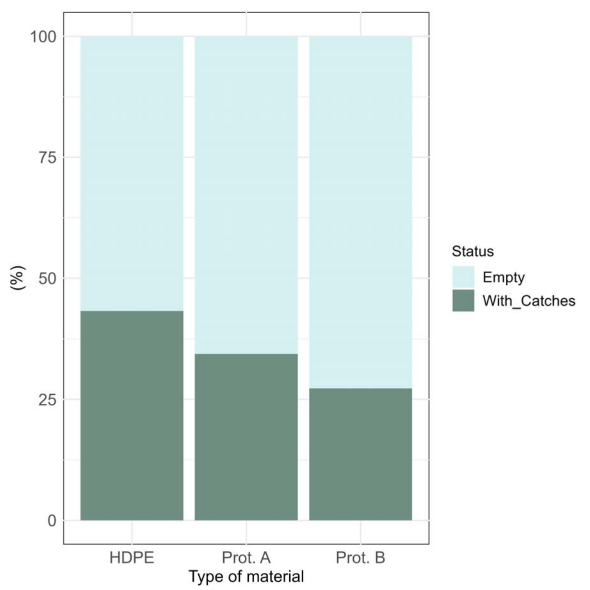

FIGURE 5
Catch efficiency of the three types of pot nets. The proportion of empty pots relative to the three types of materials used, illustrating the patchy distribution and gregarious behaviour of *Plesionika edwardsii*.

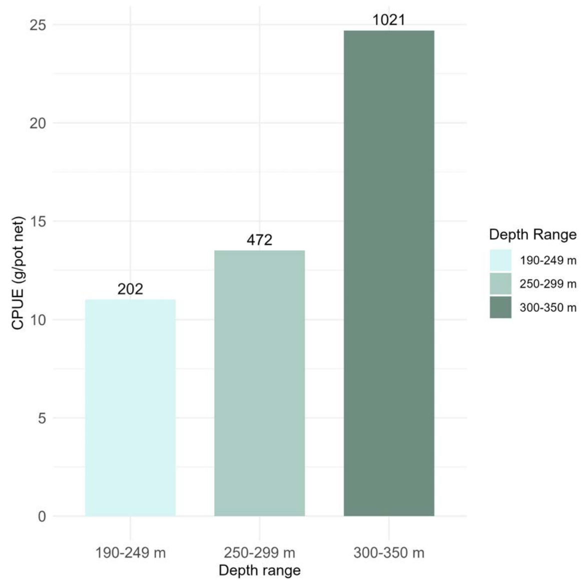

FIGURE 6
Catch per unit effort (CPUE; g/trap) and total individuals caught across three depth ranges: 190–249, 250–299, and 300–350 m. Bars represent the mean PUE for each depth range. Values above each bar denote the total number of individuals captured across four sampling surveys within each depth range.

Another positive finding regarding the use of biodegradable materials comes from mussel nets (Baini et al., 2024): after a testing period of 32 months, several materials were selected as possible substitutes for traditional materials.

However, it is not yet possible to extend this comparability of effectiveness to other types of fishing gear. Although several authors agree that biodegradable materials have promising applications in fishing (Grimaldo et al., 2020, 2019, 2018) as an effective tool for reducing environmental pollution, the results obtained for other types of gear (e.g., gillnets and driftnets) are not as promising as those obtained for pot nets. Particularly, biodegradable gillnets have shown a gradual decrease in catch efficiency over time (Grimaldo et al., 2020, 2019).

In this research, pot nets demonstrated a high level of selectivity, with the target species, *P. edwardsii*, being the most abundant and accounting for 78% of the total catches, followed by the congeneric species *P. narval* (12%). The bycatch consisted primarily of species with low or no commercial value. Furthermore, as no significant damage was observed in the bycatch species, they were safely released back into the environment, emphasising that this is a non-destructive fishing technique that can often provide high-quality catches. This selectivity is largely attributed to the design of the pots, which can be tailored in size, entrance shape, and mesh size to optimise catch efficiency for specific species, reducing bycatch of non-target species and minimising the capture of juveniles or non-commercial species, thus lowering the ecological impact compared to tools like gillnets (Petetta et al., 2020, 2021).

The proportion of pots without any catches was quite high (approximately 55% of the total pots deployed). This finding aligns

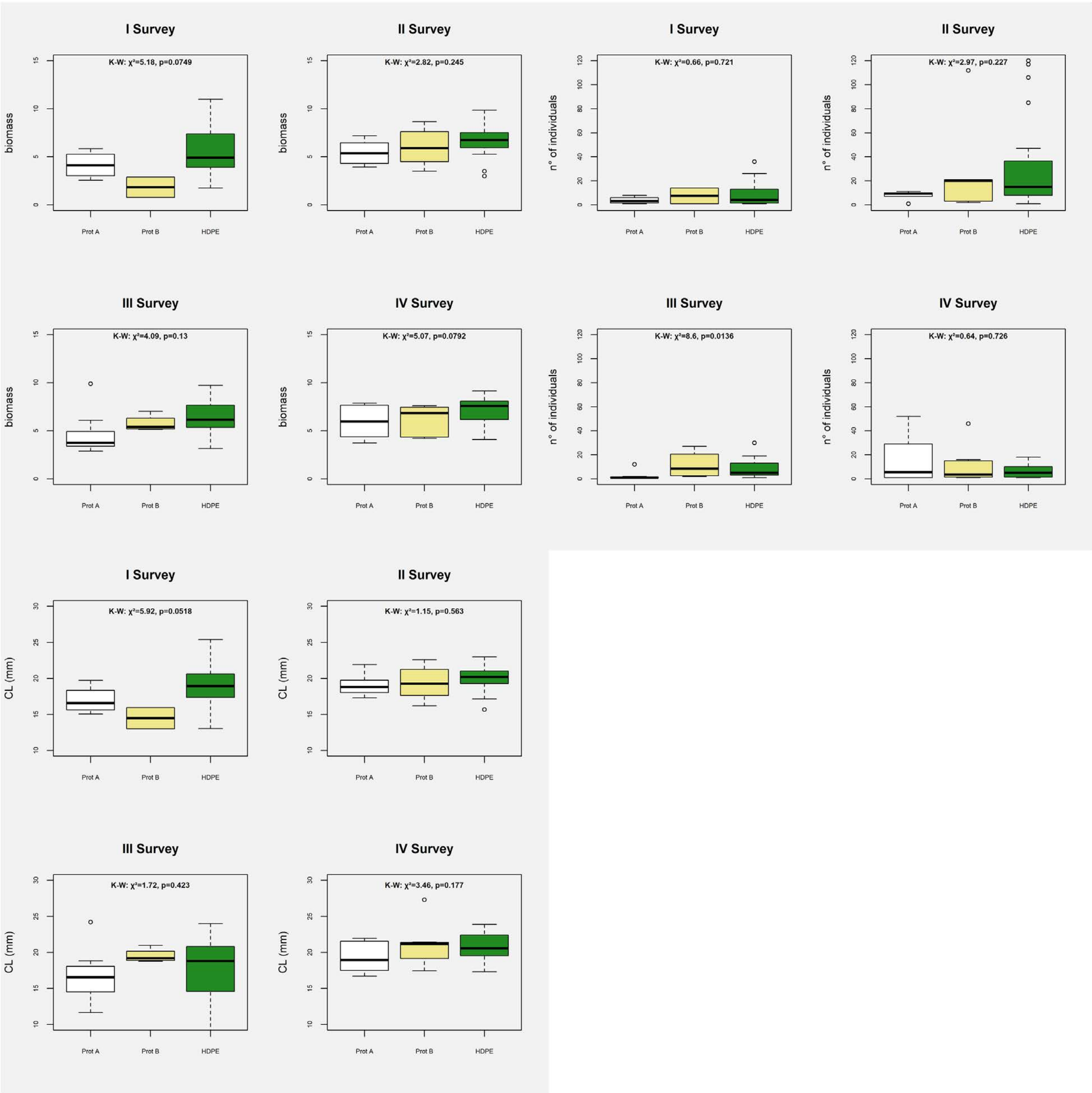

FIGURE 7
Trend in carapace length (CL; mm), biomass (g), and number of individuals among the three types of materials and sampling surveys. Boxplots of the four sampling surveys comparing the three different types of materials (Prot. A; Prot. B; HDPE). HDPE, high-density polyethylene.

with previous studies using pots targeting *P. edwardsii* (Colloca, 2002; Sartor et al., 2006), which similarly reported that the catches of the target species were rarely distributed evenly across the pots in each line. Instead, the catches were often concentrated in a subset of pots. Therefore, the presence of many empty pots reflects the "patchy" spatial distribution and gregarious behaviour, which are typical traits observed across multiple species within the genus *Plesionika*, including *P. edwardsii* (Vasilakopoulos et al., 2019; Fanelli et al., 2004).

The highest number of catches and CPUE were recorded at the deepest bathymetric range investigated (300–350 m). The observed abundance pattern may also be influenced by the life cycle of *P. edwardsii*, as its depth range across the Mediterranean spans from 150 to 500 m (Relini et al., 1986; Fanelli et al., 2007) and leads to migrations to shallower or deeper waters depending on its developmental stages (Colloca et al., 2002).

PERMANOVA result suggests that the type of pot net did not substantially influence the overall catch composition, in terms of abundance, size distribution, or biomass. The consistency between multivariate (PERMANOVA) and univariate (Kruskal–Wallis tests) analyses strengthens the reliability of this finding, indicating that differences among pot designs are unlikely to bias catch structure.

The study on biodegradable net degradation in the marine environment revealed that the two biodegradable prototypes,

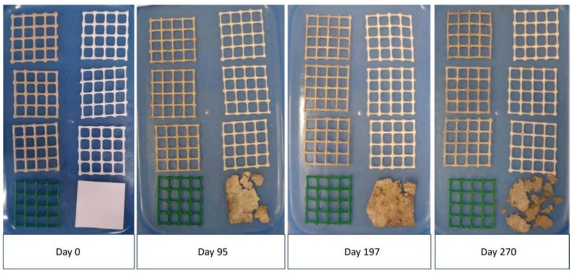

FIGURE 8
Visual comparison of the netting materials used in the experiment (HDPE, Prototype A, and Prototype B) together with a paper square used as a control—at the start of the trial (Day 0) and after 95, 197, and 270 days of immersion. Images show the progressive degradation of the biodegradable prototypes and the paper control, in contrast with the stability of the HDPE netting. HDPE, high-density polyethylene.

Prototype A and Prototype B, exhibited different degradation rates. Prototype B showed noticeable surface degradation, while Prototype A displayed limited changes, with significant alterations appearing mainly after 9 months of exposure. However, the short duration of the experiment did not allow the three types of nets to be tested during a longer period, which could have led to higher degradation rates, as seen in similar studies. Other research (Brakstad et al., 2022; Grimaldo et al., 2020) suggests that over longer exposure periods or with different methodologies, the degradation rates of biodegradable nets increase, facilitating the breakdown of the gear in the marine environment (Samalens et al., 2022).

While Drakeford et al. (2023) emphasised that the adoption of biodegradable fishing gear is primarily hindered by technical inefficiencies (see also Grimaldo et al., 2020; 2019), recent findings suggest that economic barriers may also play a significant role. According to Loizidou et al. (2024), the high cost of biodegradable nets remains prohibitive for many fishers; however, targeted financial incentives could facilitate their wider adoption. Addressing both technical and economic challenges is therefore essential to unlock the full potential of biodegradable gear as a sustainable alternative to conventional equipment.

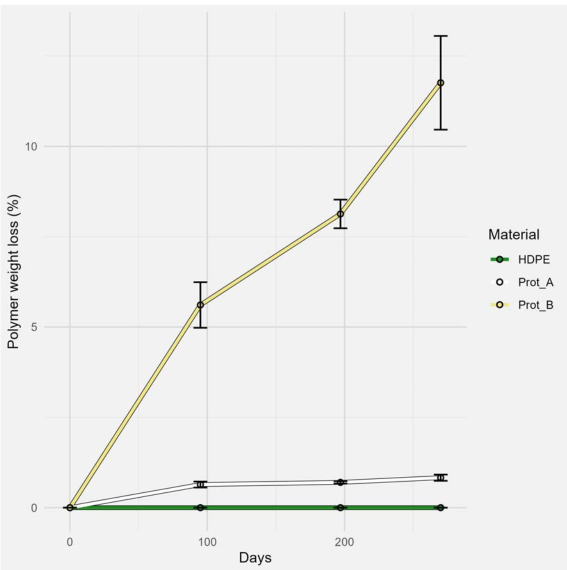

FIGURE 9
Behaviour of the three types of materials exposed to marine environmental matrices. Weight loss percent of the three types of nets exposed at the sediment/marine water interface under laboratory conditions over a period of 270 days.

This study was based on data collected during a few months, which may limit the generalisability of the findings. Environmental conditions, fishing practices, and species behaviour can vary significantly across seasons and years, potentially influencing the effectiveness and degradation rates of biodegradable and compostable materials. Therefore, long-term studies spanning multiple years and different environmental contexts are essential to validate these preliminary results and to better understand temporal variations. Nevertheless, this work provides a valuable preliminary assessment of the performance of biodegradable fishing gear in the Western Mediterranean Sea, contributing novel insights into an emerging field. While similar studies have been conducted on related gear types or targeting other species (Kim et al., 2014a, 2014b; Bae et al., 2010; Cerbule et al., 2023; Baini et al., 2024), applications of biodegradable and compostable materials in north-western Sardinia (Central Tyrrhenian Sea), specifically targeting *P. edwardsii*, remain limited. No previous study in the area has addressed this topic, representing a novel contribution in this field. Our findings, therefore, represent an important step forward, offering a new sustainable alternative in fisheries that balances environmental benefits with functional effectiveness.

In summary, biodegradable pot nets, with their selectivity and non-destructive characteristics, present a valuable tool in sustainable fisheries management. Their ability to target specific species while minimising bycatch and habitat damage positions them as an effective alternative to more invasive fishing methods. However, there is a trade-off between the durability of traditional plastics, which ensures longevity and resistance to degradation but contributes to pollution and ghost fishing in marine ecosystems, and biodegradable plastics, which reduce environmental risks by breaking down over time but may compromise gear durability and require more frequent replacements. This concept highlights the challenge of balancing material longevity with the need to reduce plastic pollution. Before the widespread use of plastics, a major limitation in fishing tools was the wear and tear of materials, with their lifespan directly impacting the pressure on fish stocks.

The shift towards biodegradable plastics represents a necessary compromise, where the natural degradation of materials must be carefully balanced with the need for durability. Improving the strength, reducing the cost, and maintaining the biodegradability of fishing gear is essential in this transition, ensuring that the materials used are both effective and environmentally responsible over time. The choice to explore more sustainable alternatives is vital for both the conservation of biodiversity and the evolution of fishing practices that support environmental protection. As biodegradable pot nets become more efficient and widely adopted, they could gradually replace traditional plastic pots, particularly in fisheries where sustainability is prioritised.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The manuscript presents research on animals that do not require ethical approval for their study.

Author contributions

EM: Writing – review & editing, Software, Conceptualization, Writing – original draft, Resources, Investigation, Project administration, Formal analysis, Validation, Methodology, Supervision, Data curation, Visualization. LC: Resources, Software, Formal analysis, Project administration, Data curation, Visualization, Writing – original draft, Writing – review & editing, Investigation, Conceptualization, Validation, Methodology, Supervision. BC: Investigation, Validation, Writing – review & editing, Conceptualization, Supervision, Methodology, Writing – original draft, Formal analysis, Software, Project administration, Visualization, Data curation, Resources. GF: Validation, Data curation, Supervision, Conceptualization, Investigation, Methodology, Project administration, Writing – review & editing, Software, Resources, Visualization, Writing – original draft, Formal analysis. CA: Visualization, Data curation, Methodology, Supervision, Investigation, Validation, Resources, Writing – review & editing, Software, Formal analysis, Project administration. BT: Data curation, Software, Writing – original draft, Writing – review & editing, Conceptualization, Resources, Investigation, Project administration, Visualization, Methodology, Validation, Formal analysis, Supervision. BL: Software, Formal analysis, Data curation, Writing – review & editing, Methodology. MF: Writing – review & editing, Software, Data curation, Formal analysis, Methodology. ON: Conceptualization, Validation, Data curation, Supervision, Project administration, Methodology, Writing – review & editing, Investigation, Writing – original draft, Resources, Funding acquisition, Visualization, Software, Formal analysis.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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