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# Microplastics in *Lampanyctus crocodilus* (Risso 1810, Myctophidae), a Common Lanternfish Species from the Ibiza Channel (Western Mediterranean)

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**Abstract:** Microplastics' presence in the pelagic environment is still largely unknown due to the difficulty of sampling in this part of the ocean. In this study, we quantify microplastics' exposure in a pelagic lanternfish species from the western Mediterranean, *Lampanyctus crocodilus* (Risso 1810), which occupies an intermediate position in the marine food web. *L. crocodilus* were captured in the Ibiza Channel by a trawling vessel and microplastics were extracted by digestion of their gastrointestinal systems. Almost half of the analysed lanternfish contained microplastics, mostly blue and black fibres (40.9% and 34.66%, respectively). In fishes with at least one microplastic, the median was 3 MPs/fish (CI 95% = 3.46–6.8), similar to other studies performed in other fish species in the area. Biometric parameters of fish, such as total length and body condition, were not correlated with the number of microplastics. Data presented here contribute to quantifying the severity of microplastic pollution in the pelagic environment and in a wild, non-commercial species.

**Keywords:** lanternfish; microplastics; myctophids; pelagic environment; marine pollution; Mediterranean Sea; plastic pollution; anthropogenic impacts; fibres; wildlife



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## 1. Introduction

Microplastics have become a pervasive environmental issue, with their presence documented in all kinds of marine ecosystems. From the surface waters to the seafloor [1,2], and spanning from coastal environments to the open ocean [1,3], microplastics have infiltrated every corner of the Earth. Some studies have calculated that around 2200–4000 t of plastic is released globally into the sea every year [4,5], while other studies have calculated even higher amounts, 200,000 t per year [6], and that by 2040, this quantity could escalate further to 500,000 t per year [6]. It is also estimated that between 21% and 54% of the global microplastic particles that are floating at sea, and that between 5% and 10% of their global mass, are expected to be found in the Mediterranean Sea [7]. The Mediterranean Sea stands out as especially vulnerable to the accumulation of any kind of contaminants due to its limited water exchange with the oceans through the Gibraltar Strait and the particularly narrow Suez Canal. Besides, the Mediterranean Sea is under great anthropogenic pressure. The European coast is highly urbanized and hosts many industries that, together with mass tourism, constitute a very important source of pollution and litter to this sea.

Part of this litter is constituted by microplastics or it is transformed through environmental weathering in microplastics. In spite of the growing knowledge on microplastics in the oceans, information about their occurrence below the water surface and in the food web is limited. Even the positive buoyant microplastics that are floating on the sea surface may eventually sink towards the ocean floor, helped by biofouling and by the creation of biofilms that increase their density until it surpasses that of seawater [8]. Current model projections predict that a mere 1% of these microplastics remain at the sea surface; therefore, the ocean depths could make up a potential reservoir that could not only be formed by sinking microplastics, but also from the fragmentation of the bigger plastic items that are already present on the seafloor [1]. In addition to the seafloor, fish species have been hypothesized as the other big microplastics' reservoir, together with the sea surface [7]. Fish can incorporate microplastics into the food web while drinking contaminated water and when foraging on organisms that had previously ingested microplastics [9–14]. Microplastics might be potentially harmful to marine organisms by leaking adsorbed toxic substances, such as persistent organic pollutants (POPs), plastic additives and other kind of micropollutants, along their transit through their gastrointestinal tracts [15]. At this point, adsorbed contaminants can be incorporated into tissues and, eventually, into the bloodstream, where they might trigger detrimental biochemical reactions. There is evidence that microplastics alter feeding behaviour, decrease growth and compromise immunity in some fish species [16], although there is still a lot of variability across studies and still a lack of studies that use environmentally relevant microplastic amounts and characteristics in laboratory studies [16].

Up to date, several animal species from different parts of the Mediterranean Sea have been studied for microplastic content (some studies are included in the Section 4), most of them of commercial value. Species of by-catch with no commercial value are understudied but provide important information about their ecosystem and marine food webs. In addition, collaborating with fishermen allows one to obtain fish samples from offshore waters, which is often technically and economically not possible for scientists. In this aspect, most studies are conducted near-shore [16], and as a consequence, a gap of knowledge exists about species living far from the coast. Here, we studied microplastic frequency and abundance in a non-commercial, wild lanternfish species present in the western Mediterranean Sea: the jewel lanternfish (*Lampanyctus crocodilus*, Risso, 1810; Myctophidae family). Lanternfish species are great candidates to gather data about microplastics in the Mediterranean bathypelagic environment due to their life history. Myctophids play a key role in organic matter transfer from the seawater surface layer to the sea bottom by vertically migrating on a daily basis [16]. Besides, they contribute to energy transfer from offshore waters to shallower areas at the shelf-slope break as well [17]. Finally, they have been described as important prey species for the striped dolphin (*Stenella coeruleoalba*, Meyen, 1833), the most abundant cetacean species in the western Mediterranean [18,19], and could contribute to pollutant transfer to this and other predator species where microplastics have also been found (see Section 4).

The primary objective of our study Is to assess the levels of microplastics present In the gastrointestinal tracts of a bathypelagic lanternfish species, specifically, *Lampanyctus crododilus* (Risso 1810). By focusing on this particular species, we aim to shed light on microplastic occurrence within the bathypelagic environment, which remains relatively understudied. This investigation will contribute valuable insights into the prevalence of microplastics among non-commercial Mediterranean species. Furthermore, we seek to explore the potential role of lanternfish in the distribution of microplastics throughout the marine ecosystem and we hope to enhance our understanding of their impact and influence in the food chain.

## 2. Materials and Methods

### 2.1. Sampling and Study Area

In total, 94 lanternfish (*Lampanyctus crocodilus*, Risso 1810) were analysed for microplastics. The fishes were bycaught on the 20 June 2017, by a commercial trawling fishing vessel, the target species of which were prawns. The by-catch capture was separated from the rest for scientific purposes due to their lack of commercial value and a good on-going relationship with local fishermen. The fishing operation was carried out off the continental shelf, in between the Valencian Community coast (East peninsular Spain) and the Balearic Islands (Spain); starting 39°06′13′′ N 00°24′00′′ E (678 m depth) and ending at 38°51′60′′ N 00°34′52′′ E (671.3 m depth; Figure 1) with a bottom trawling net. Myctophids were brought to the harbour stored with ice. Immediately after, fish were brought to the laboratory, weighed, measured and stored at −20 °C for subsequent analyses.

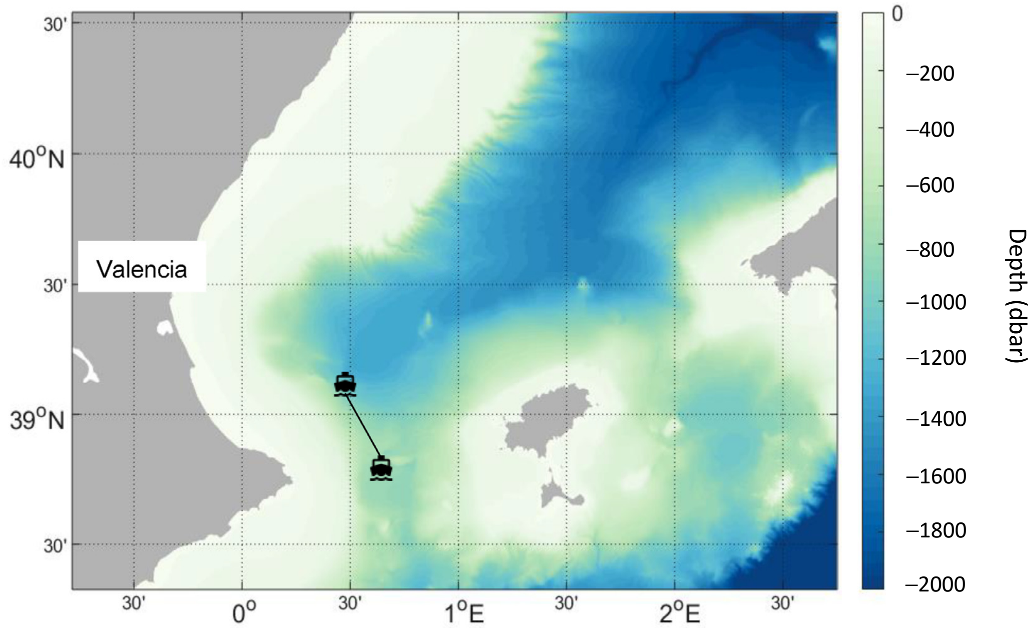



**Figure 1.** Trajectory from start to finish (indicated by the black line) of the fishing vessel used for sampling Myctophids along the Ibiza channel (Western Mediterranean). Exact coordinates are included in the main text. Map created with MatLab by Daniel Fernández Román.

### 2.2. Laboratory Procedure

Myctophids were thawed at room temperature and necropsied under a dissecting microscope (Leica MZ APO, 8–80×) with stainless steel scalpels and tweezers. For the extraction of microplastics, we followed the methods used by Lusher et al. [20] and Foekema et al. [21], with few adaptations (see below). Briefly, all the gastrointestinal tracts were removed, opened in a petri dish and observed in order to collect microplastics and other gut contents. Once diet and parasites were separated for further studies, the remains, including the gastrointestinal tissue, were digested in KOH 10% 1:3 $v/v$ (VWR, Epica S. L., Torrent, Spain) for a week at room temperature. After digestion, samples were filtered under vacuum through a Büchner funnel system equipped with Whatman GC/F borosilicate glass microfibre filters (1.2 µm pore size; Epica S.L., Torrent, Spain). These filters were then dried for 24 h at 60 °C and, after that, they were carefully observed under the same dissecting microscope where dissections took place. Microplastics found were separated and classified into categories of size, shape (fibre, fragment, film or pellet) and colour. In order to ensure that we were observing anthropogenic material, microplastic items were mounted on microscope slides and observed under a light optical microscope (Leica DMR, 40×–100×), in which it is possible to observe characteristic surfaces of virgin plastic and cracked plastic, threads, and filaments with great detail [22]. Additionally, the hot needle test was to see if the studied items melted under the heat, which would indicate that the item is made of plastic [23].

### 2.3. Contamination Control

Regarding the ubiquity of microplastics in the environment and in the ambient air, a series of measures were taken in order to minimise potential contamination of the samples in the workplace. Plastic materials were avoided as much as possible in all procedures. All the materials used here were made either of stainless steel or glass; and they were thoroughly cleaned with deionized water and ethanol 70% prior to analysis. The sponges used to clean the benches were always made of the same bright yellow colour, so as to quickly identify potential contamination from the sponges' fibres. The potassium hydroxide solution (KOH 10%) was filtered through Whatman GC/F filters before using it for the digestion of biological material. Additionally, all filtrations were performed under a type I laminar flow cabinet with positive pressure that allows one to prevent the introduction of external contamination through air in the workspace by pushing air out of the cabinet.

Procedural blanks were prepared in order to monitor external contamination. Clean Whatman GC/F filters were exposed to the same environments and for the same amount of time as the real samples, from the start of the necropsy to the final observation. Afterwards, they were also observed under the same dissecting microscope to quantify potential microplastics present in the workspace. Microplastics found were subtracted from the samples accordingly.

In spite of all these measures, contamination control was not possible on-board during fishing operations due to the opportunistic nature of the sampling. This sampling took advantage of already existing fishing campaigns and fishermen could not implement microplastic contamination controls during their work at the vessel. However, fish were immediately frozen at −20 °C, stored in boxes and processed in the lab, which was already clean and where procedural blanks and all the measures explained above were already present.

### *2.4. Statistical Analyses*

All statistical analyses were calculated in R Studio (version 1.2.5033) and data visualization was carried out using the R package ggplot2 [24]. Confidence intervals for the mean and medians of microplastics per lanternfish were calculated in Qpweb (version 1.0.15, [25]) by bootstrapping 10,000 replicates. In order to assess the body condition of the fishes, the Fulton's K condition factor was calculated with the following equation [26]:

$$K = [\text{weight}/(\text{length}^3)] \times 100,$$

where length is the total length of the fish. Both weight and length refer to measures taken before the fish were frozen. The closer to 1, the better body condition the fish has, and vice versa. A Pearson's Correlation test was calculated to check whether microplastic amount in their digestive system was correlated with fish body condition (Fulton's K).

## 3. Results

### *3.1. Biometric Parameters*

Results indicate that a total of 94 individuals of lanternfish, *L. crocodilus*, were examined to assess the presence of microplastics. On average, fish measured 16.83 ± 1.46 cm (mean total length ± SD), which resulted in a normal distribution. All lanternfishes in this study were adult specimens, according to previous literature and based on fish length [16,26,27]. However, sex composition of the fish was strongly biased: 76.92% were females, 7.69% males and 15.38% undetermined, so correlations between microplastics' content and sex were not calculated due to a lack of representativeness. Fulton's K body condition factor was 0.526 ± 0.06.

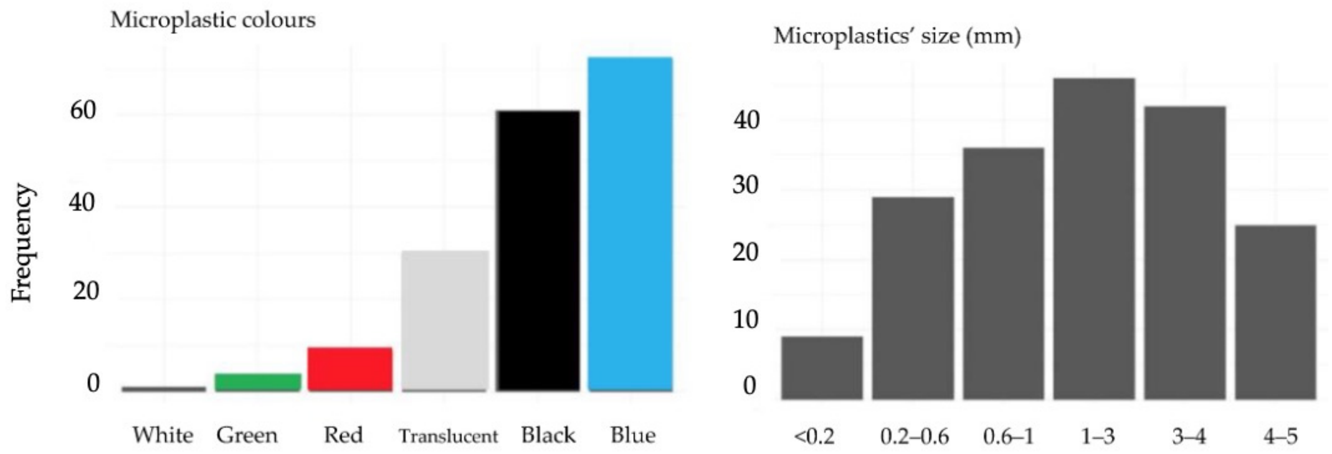
### *3.2. Microplastic Content and Characteristics*

More than the half of *L. crocodilus* (59.79%) did not show microplastics, while 40.21% of myctophids presented at least one microplastic. In total, 185 microplastics items were identified. Nevertheless, even among those which presented microplastics, the number of items was generally close to 1 and, therefore, data showed a strongly right-skewed distribution. In fishes with at least one microplastic, the median was 3 MPs/fish (CI 95% = 3.46–6.8, Table 1), which is, still, relatively low.

**Table 1.** Mean, median, range and confidence intervals of the microplastics found in fishes in this study, together with their mean Fulton's K body condition index.

| | All Myctophids | Myctophids with Microplastics |
|---|---|---|
| Mean (MPs/fish) | 1.907 | 4.744 |
| 95% CI for the mean | 1.26–2.92 | 3.44–6.87 |
| Median (MPs/fish) | 0 | 3 |
| 95% CI for the median | 1.27–2.97 | 3.46–6.8 |
| Range (MPs/fish) | 0–23 | 1–23 |
| Mean Fulton's K | 0.5268 | 0.5097 |

According to our findings, the most prevalent colour of microplastics observed was light blue, accounting for 40.9% of the total, followed by black at 34.66%, translucent at 17.0%, red at 5.11%, green at 1.7% and white items at 0.57% (Figure 2a).




(**a**) (**b**)

**Figure 2.** (**a**) Colour of microplastics found in Mediterranean lanternfish in ascending order of frequency, and (**b**) frequency of microplastics found in each size category.

Figure 2b illustrates that the majority of the measured items fell within the range of 1 and 3 mm, comprising 24.59% of the total, followed by the ranges of 3–4 mm (22.46%), 0.6–1 mm (19.25%), 0.2–0.6 mm (15.5%), 4–5 mm (13.37%) and <0.2 mm (4.81%). Remarkably, almost all microplastics identified were in the form of fibres, accounting for 97.75% of the total, while only 2.25% were fragments. Notably, no industrial pellets or primary microplastics were detected in the analysed fish specimens.

### *3.3. Biometric Parameters and Microplastic Content*

Fish length and the number of microplastics found in them were not correlated ($r = -0.058$, $p > 0.05$), nor when considering only fish that had ingested microplastics ($r = 0.08$, $p > 0.05$). There was no significant correlation between body condition (Fulton's K) and amount of ingested microplastics either (Pearson's correlation product = −0.175); hence, this measure cannot be used as a predictor in this study.

## 4. Discussion

### *4.1. Microplastics in Lanternfish Species*

Frequency of occurrence found in this research is similar to the frequencies found in other studies performed with other species elsewhere in the Mediterranean Sea, including the north-western Mediterranean [28,29], the Ligurian Sea [30], the eastern Mediterranean Sea [31] and the Adriatic and Ionian Seas ([32,33], Table 2). In comparison to a study on

Atlantic mesopelagic fish [34], our frequency of occurrence was lower (40% in contrast to 73%). However, myctophids from the North Atlantic and in the Indian ocean showed lower microplastic content per fish (frequency of occurrence: 0–22% and 2%, respectively) than in our study and, specifically, no microplastics were found in *L. crocodilus* individuals, although the number of sampled fish was lower than in this study (n = 2) [19,34,35]. Previous studies on Mediterranean myctophids, including other species besides *L. crocodilus*, found a far lower frequency of occurrence (0–5.8%, migratory and non-migratory species, respectively), [36,37]. The plastics found in those studies were mainly clear in colour and of the same size of copepods they are known to consume, suggesting that lanternfish could ingest microplastics because they confuse them with prey. By the contrary, we did not find this microplastic-prey similarity in our sample, and results vary depending on the study. Therefore, there are no conclusions about whether lanternfish ingest microplastics accidentally or by confusing them with food. More research is needed in the field of microplastic discrimination in fish behaviour to better understand how microplastics get into their bodies. Concerning microplastics in the water column, studies in our sampling location have not been carried out; however, in research carried out in the Western Mediterranean [38], have found smaller amounts of microplastics. Nevertheless, when searching for microplastics in coastal areas from the Balearic Islands [39], abundance of this contaminant is similar. It is important to gather more data about microplastics in the environment and ingestion rates in fish species in order to study whether microplastic concentrations in the sea could mirror microplastic concentrations in biota.

Colour composition varies widely across studies. Here, the most frequent colours observed were blue and black, as in some studies carried out with other Mediterranean fish species (see Table 2) and in other oceans [40–43]. Although there is variation, blue and black plastics might be the most prevalent colours in some regions due to their frequency of use and possibly due to a higher resistance to colour degradation, which also depends on salinity of the water and intensity of sunlight, among other factors. Lanternfish in our study fed on zooplanktonic species, such as euphausiids and mysids, which agrees with previous studies [44–46]. These zooplanktonic species are not similar to microplastics found in the gastrointestinal tracts of the examined fish, neither in colour nor in shape, so potential selective feeding of microplastics seems unlikely. The question of whether fish selectively feed on these items remains unclear. Besides, microplastics could also be accidentally ingested while swimming, drinking and even through the gills. Interestingly, fish that feed predominantly in a chemosensitive way may be able to avoid foraging on microplastics, while visually oriented fish could eat more of them when microplastics resemble their prey [14]. *L. crocodilus* is known to be mainly a visual predator [47], so microplastic selectivity should be low regarding their dissimilarity to their diet. In addition, when food is not abundant, fish seem to be prone to consume more microplastics, probably driven by an opportunistic feeding strategy developed in an environment with low food availability. Therefore, visually oriented fish in environments with low food availability could be more vulnerable to microplastics' exposure [14].

**Table 2.** Mean microplastics (MPs) per individual ± standard deviation in demersal and pelagic species in different areas of the Mediterranean Sea, along with their main characteristics.

| Area | Species | Environment | MPs/Individual (Mean ± SD) | % Fish with MPs | Prevalent Shape | Prevalent Colour | Reference |
|---|---|---|---|---|---|---|---|
| W Med. (E Spain) | *Mullus barbatus* (Linnaeus, 1758) | Demersal | 1.9 ± 1.29 | 10–33% | Fibers (71%) | Black | [28] |
| W Med. (Spain) | *Boops boops, Engraulis encrasicolus, Sardina pilchardus* and *Trachurus mediterraneus* | Pelagic | 0 ± 0–1.22 ± 2.08 | 28% | Fibers | Blue | [29] |
| Ligurian Sea | *Engraulis encrasicolus* | Pelagic | 0.34 ± 0.29 fibres ind−1 and 0.12 ± 0.12 fragments ind−1 | 30–40% | Fibers | Blue and black | [30] |
| E Med. (Turkey) | 28 species | Demersal and pelagic | 2.36 (only fish with MPs, 58%) | 41% | Fibers (70%) | Blue | [31] |
| NE Ionian, N Adriatic | *Chelon auratus* (Risso, 1810), *Mullus barbatus, Mullus surmuletus, Pagellus erythrinus, Sparus aurata, Sardina pilchardus, Solea solea* (Linnaeus, 1758). | Demersal and pelagic | 6.7 ± 3.5; 2.5 ± 0.2; 1.7 ± 0.2 | 40–87% | – | – | [32] |
| N Ionian | *Sardina pilchardus, Pagellus erythrinus* and *Mullus barbatus* | Pelagic | 0.8 ± 0.2, 0.8 ± 0.2, 0.5 ± 0.2, respectively. | 47.2%, 42.1%, 32%, respectively. | Fragments (80%) | Blue | [33] |
| Central Med. | *Electrona risso* (Cocco 1829), *Hygophum benoiti* (Cocco, 1838), *Myctophum punctatum* (Rafinesque, 1810), *Diaphus metopoclampus* (Cocco, 1829) | Pelagic | 1.09 ± 0.30, 4.10 ± 3.08, 1.91 ± 0.55, respectively. | 2.7% | Small microplastics | Hyaline | [36] |
| E Med. (Lebanon) | *Engraulis encrasicolus* | Pelagic | 2.9 ± 1.9 | 83.4% | Fragments | Blue | [48] |
| Spanish Med. | *Sardina pilchardus* and *Engraulis encrasicolus* | Pelagic | 0.18 ± 0.20 | 14.8% | Fibers (83%) | Blue | [49] |
| Thyrrenian Sea | *Pagellus* spp. | Demersal | MPs in the stomach of 4 specimens. Amount not specified. | 10.25% | Fibers (100%, Nylon 66) | Black | [50] |
| Balearic Sea | *Mullus surmuletus* (Linnaeus, 1758) | Demersal | 0.42 ± 0.04 | 27.3% | Filament (97%) | Blue | [51] |
| Balearic Sea | *Galeus melastomus* (Rafinesque, 1810) | Demersal | 0.34 ± 0.07 | 16.8% | Filament (86.36%) | Transparent | [52] |
| W Med. (Spain) | *Boops boops* (Linnaeus, 1758). | Pelagic | 1.68 ± 0.31<br>0.50 ± 0.14<br>0.53 ± 0.14 | 46% | Fragments | Blue | [53] |
| Adriatic, Thyrrenian and Ionian Seas | *Mullus barbatus* and *Merluccius merluccius* (Linnaeus, 1758). | Demersal | 0–1.75 | 23.3% | Fibers | Blue | [54] |
| SE Med. (Egypt) | *Caranx crysos* (Mitchill, 1815), *Liza aurata* (Risso, 1810), *Signus rivulatus* (Forsskål & Niebuhr, 1775) and *Epinephelus caninus (Valenciennes, 1843)* | Demersal | 8.6 ± 1.52–2 ± 2.64 | – | Fibers (70%) | Blue | [55] * |
| Central Med. (Italy) | *Trachurus trachurus* | Pelagic | 112.86 ± 38.93 | 90.6% | Filament (84.9%) | Blue | [56] |
| SW Med. (Mar Menor) | *Sparus aurata* (Linnaeus, 1758) | Demersal | 20.11 ± 2.94 MP/kg | 100% | Fibers (71.68%) | White | [57] |
| W Med. (E Spain) | *Lampanyctus crocodilus* (Risso, 1810) | Pelagic | 1.907 ± 4.023 | 40.21% | Fibers (97.75%) | Blue | This study |

* When the reference included specimens from other seas and ocean basins, only specimens from the Mediterranean were taken into account. Med. = Mediterranean; N = North; S = South; W = West; E = East.

Most of the microplastics found here were fibres (Figure 3), similarly as in most studies about microplastics in the Mediterranean Sea (Table 2). Ríos-Fuster et al. [29] also found mostly fibres in four fish species (*Trachurus mediterraneus*, Steindachner, 1868; *Sardina pilchardus*, Walbaum, 1792; *Engraulis encrasicolus*, Linnaeus, 1758 and *B. boops*, Table 2) and showed that species closer to the East Spain's coastline tended to present higher amounts of microplastics than those sampled close to the Balearic Islands. This ubiquity of fibres and filaments is maybe due to inefficient waste-water treatment, an intensive use of washing machines [29,58] and to the use and improper disposal of fishing gear [59]. Moreover, species examined by Ríos-Fuster et al. [28] belong to a similar trophic level [60] and have similar amounts of plastic than lanternfish in our study, suggesting that differences in microplastic content among species could be caused mostly by abiotic factors, such as sea currents, distance to point sources and wind regime, rather than by feeding ecology [7,48,61,62]. Finally, the method by which fish are captured might be of influence as well and it is worth studying in future analyses. In our study, fish were captured by trawling nets. This method might expose fish to fibres leaked from the fishing nets that capture them from long periods of time.

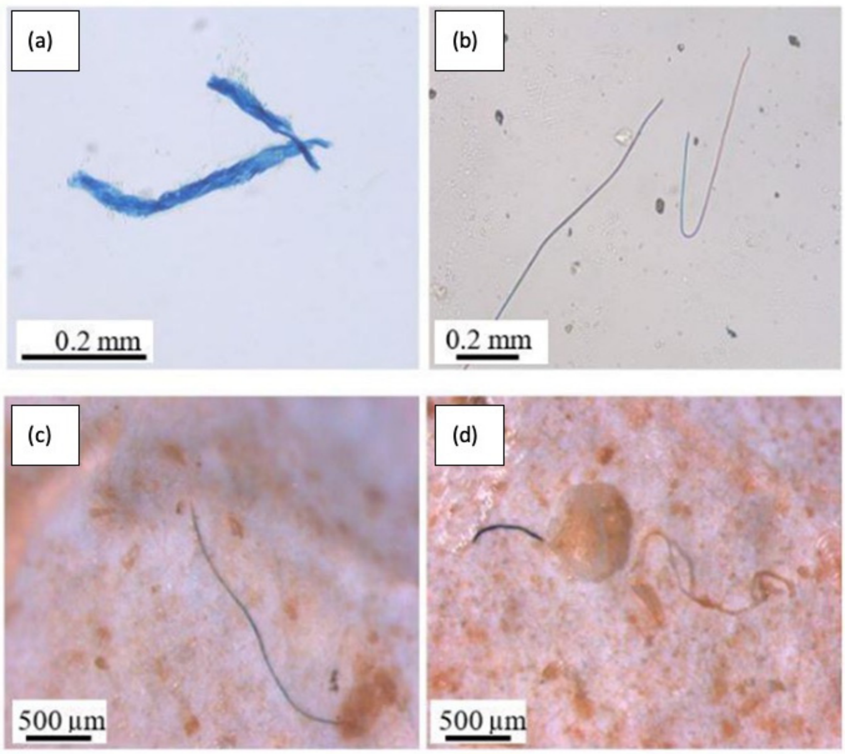



**Figure 3.** Microplastic fibres and filaments found in myctophid's gastrointestinal tracts (**a**–**d**). Leica MZ APO.

### *4.2. Microplastics and Fish Fitness*

In our study, the number of microplastic items per individual was not related either to body condition nor to total length of the fish, so these variables could not be used as a predictor of microplastic ingestion risk. The Fulton's K condition factor was not very close to 1 (which would indicate the best possible condition); it was 0.526 ± 0.06. However, this measure has to be interpreted taking into account that lanternfish are fairly long fishes, while this measure was originally thought for more rounded fish, so even if Fulton's K is not very high in this case, fish were in good body condition. Specifically, in our case, weaker, smaller fish do not seem more prone to microplastic ingestion than bigger, fitter fish, as has been shown in other studies [49,63]. When looking at fish size, we find cases of both bigger fish having more microplastics [64], or bigger fish having less microplastics [65]; and cases in which fish weight and length are not related at all with microplastic content ([44], present study). In either case, it is important to gather more evidence about how environmentally relevant concentrations of microplastics could be affecting fish development and survival. Overall fitness in wild fish will depend on environmental quality of their surroundings, predator pressure and exposure to infections, among other factors.

Potential transfer of other contaminants from microplastics to the organism is of concern as well. Exposure to these persistent organic pollutants could increase their bioaccumulation capacity and induce negative physiological effects in the fish. For instance, Rochman et al. [66] found a positive correlation between polybrominated flame retardants (PBDEs) and plastic amount in the water where myctophids inhabited, although this relationship did not exist for other pollutants such as polychlorinated biphenyls (PCBs) and alkylphenols. However, to date, some studies suggest that transfer of these contaminants to biota is scarce and can be neglected [15,67–69]. In fact, in some experimental setups, microplastic pollution did not affect fish fitness and survival significantly [70]. It is hypothesized that natural particulate matter plays a more important role in hydrophobic contaminant transport and desorption due to its higher relative abundance [71]. Information is, therefore, not conclusive yet and further toxicity studies as well as a better understanding of sorption and desorption of contaminants in the natural environment would be of benefit.

### 4.3. Influence of the Environment in Microplastic Concentration in Lanternfishes

Myctophids perform extensive vertical nychthemereal migrations; however, information about them is only collected from fishing grounds of limited depth [17,21]. According to observations and modelling approaches, microplastics tend to accumulate in subsurface waters and on the sea bottom [5,7,61,70], especially between 200 and 600 m [70] where lantern fish feed [45]. The vertical diel migration performed by these fish could be mimicking the biological whale pump [50,72]. That is, besides cycling nutrients, they would contribute to the vertical circulation of microplastics throughout the water column and could introduce these items in the marine food web, making them bioavailable for longer periods of time than would have been expected. For instance, microplastics have also been found in striped dolphins in the area [73]. Striped dolphins in the western Mediterranean often prey on *L. crocodilus* [19] and, therefore, fish that had previously ingested microplastic might be contributing to microplastic transfer to these dolphins, and to other predators. However, this potential transfer still lacks evidence and it does not appear as an important circulation pathway, as can be seen in a study performed by Alava et al. (2020). Alava et al. [48] predicted a low biomagnification capacity of microplastics in cetacean food webs. By contrast, biomagnification in lower trophic levels could actually be taking place and could negatively affect benthic populations and coastal fish more than species in open waters [48]. Another important species in this food web would be the European hake (*Merluccius merluccius*), which also preys on myctophids and, in turn, is preyed upon by striped dolphins [19]. In another study carried out by Ríos-Fuster et al. [29], it was found that species high in the food web showed more microplastics that species lower in the food web; therefore, in this case, it would be worth it to test the biomagnification hypothesis. Potential biomagnification from wild fish (Atlantic mackerel, *Scomber scombrus*) to a top predator (captive grey seal, *Halichoerus grypus*) has been previously studied [11]. Unfortunately, both our study and the aforementioned studies lack data about ingestion patterns, retention time of the particles in the gastrointestinal tracts, and egestion rate, which would be of much interest to build robust biomagnification and bioaccumulation models [48].

On the other hand, microplastic concentration may vary among seasons [5,51,74], and therefore, studies performed at different times of the year or with different oceanic conditions (up-welling, down-welling, fronts, winds, currents, etc.) would be of big interest to understand microplastic concentration, distribution and circulation at sea. Litter tends to accumulate during the summer months in the study area, due to more locals going to the beach and due to the characteristic mass tourism in the area [52]. In consequence, an increase in sinking microplastics across the pelagic environment in this season could also be expected. However, in the western Mediterranean, microplastic concentrations are expected to be lower than in the eastern Mediterranean due to differences in water circulation, topography and coastal management. The area covered in this study is connected to the Atlantic Ocean through the Gibraltar Strait, and it is located in a wide gulf, so there is significant water exchange and flow if compared with the oriental part of this sea, especially at surface level. In addition, there is a north-east surface current that could hinder potential accumulation. This current, together with the lack of physical barriers until it reaches the African continent, pushes microplastics circulation southwardly. These geographical characteristics could be a contributing factor to explain the low value of microplastic content per fish found in this study.

## 5. Conclusions

In conclusion, lanternfish species play a vital role in the pelagic biomass and are key in the transfer of carbon from the deep sea to the epipelagic environment. However, our understanding of their interaction with microplastics and the potential impact on their survival remains limited. In this study, we found that *Lampanyctus crocodilus* (Risso, 1810) had relatively low levels of microplastics per individual fish. However, the frequency of occurrence was relatively high compared to other studies on myctophids. It is noteworthy that the majority of the microplastics detected were in the form of fibres, consistent with previous findings in marine fish studies. The presence of microplastics in organisms undergoing diel vertical migrations from the benthic and pelagic zones to the photic zone suggests that microplastics in the ocean can persist and remain bioavailable for longer periods than anticipated within the water column. These findings underscore the potential ecological implications of microplastic contamination and the need for further research to understand the broader impacts on marine ecosystems.

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**Institutional Review Board Statement:** While our research involved fish, these animals were by-catch from a commercial trawling fishing operation, and we did not experiment with them. Hence, we did not need any ethical approval, as fishes' carcasses were going to be discarded by the vessel due to lack of commercial value. Details explaining the methodology of this study can be found in Section 2.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author.

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