Initial Discovery of Microplastic Presence in the Gastrointestinal Tract of Certain Fish Species in Al-Hoceima Bay

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Abstract. The accumulation of plastic waste in ocean environments is a critical ecological issue impacting marine wildlife and human health. This study assesses the presence of microplastics in the gastrointestinal tracts of fish from Al-Hoceima Bay, a key part of the Mediterranean marine ecosystem. Using Fourier Transform Infrared (FT-IR) spectroscopy, we analyzed 90 individuals from two different species, finding that 33% of the examined fish contained microplastics. Specific occurrences were 26% in mackerel and 40% in gilthead sea bream. These findings highlight significant contamination even in commercial fishing areas, raising urgent questions about the long-term ecological effects and health risks. Therefore, the need for effective plastic waste management policies is critical to protect our marine ecosystems and food safety.

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1 Introduction

As the production of plastic keeps increasing, so do the worries about its buildup in coastal and oceanic ecosystems. In the year 2022, the production exceeded 360 million tons [1-3]. The Al-Hoceima Bay, located in the north of Morocco, is a unique marine ecosystem that, like many other coastal environments around the world, is under increasing pressure due to the accumulation of microplastic debris [4-19].

These small-sized plastic particles, often less than 5 millimeters, originate from various sources, including the degradation of larger plastic waste, cosmetic products, textiles, and urban runoff [4, 20-22]. The continuous fragmentation of plastics due to UV radiation, waves, and mechanical friction produces an abundance of microplastics which, due to their small size, become accessible to a wide range of marine organisms [23-33].

The presence of these particles in the Al-Hoceima Bay is particularly concerning because it is known to be a spawning and feeding area for many marine species [34, 35]. Additionally, the bay serves as a migratory corridor for various species of fish and seabirds, which amplifies the risks associated with the bioaccumulation of microplastics through the trophic networks [36-42].

Microplastics are not only a mechanical problem for the marine organisms that ingest them, but they also pose a chemical threat due to their ability to absorb and concentrate persistent organic pollutants present in seawater [43, 44]. Fish and other marine organisms may be exposed to these toxins, which can be transferred and magnified in the food chain, thereby posing potential risks to human health, especially for coastal communities that rely on fishing [45].

The study conducted in Al-Hoceima Bay aims not only to document the presence of microplastics in planktivorous organisms but also to understand the ecological consequences of this pollution on the dynamics of fish populations and on the health of the marine ecosystem as a whole[4]. The preliminary results indicate an urgent need to develop waste management strategies and policies to reduce the entry of microplastics into the marine environment [46].

2 Materials and methods

2.1 Study area

Between February 23 and 29, 2024, our research team secured 20 samples from both the surface and the water column utilizing a manta trawl. This sampling initiative commenced at Al-Hoceima Bay, near the port entrance and close to the wastewater treatment station, symbolizing a coastal zone influenced by various human activities (see Figure 1 for map details). Al-Hoceima Bay, critical to the Mediterranean ecosystem, is noted for commercial fishing and aquaculture. Moreover, Al-Hoceima's port serves as a hub for leisure activities, adding to the region's environmental complexity. Presently, it faces pressures from nearby fishing ventures, tourist activities, and proximity to wastewater discharge, potentially affecting marine life and water quality.

This location, with its diverse human activities, provides a significant context for studying the prevalence of microplastics in marine organisms, reflecting unique environmental and anthropogenic pressures. Adding information, the accumulation of leisure boats contributes to marine pollution, emphasizing the need for sustainable practices to mitigate environmental impacts. The used manta trawl featured a rectangular opening measuring 0.9 by 0.15 meters, leading to a net 3.5 meters in length with a 333-micrometer mesh, ending in a collection bag of 30 by 10 centimeters.
2.2 Fish sampling and Identification

The collected neuston and nekton samples undergo a standardized lab process for precise, orderly analysis. Following the methodologies from the study of [47, 48], fish samples are prepared for microplastics extraction. This involves delicately detaching the fish’s inner organs from the head to the anal region with scissors and a knife.

The dissected gastrointestinal tract — esophagus, stomach, intestines — is then isolated, weighed, and stored in a 250 mL Pyrex beaker covered with aluminum foil. Microplastics extracted are subsequently sorted by size, shape, and color for identification, and spectroscopic methods like FT-IR spectroscopy are applied to ascertain their chemical makeup and origins.

![Photographic evidence from the stereo microscope of various fish species and microplastics that were discovered in the examined fish samples.](image1)

2.3 Analytical methods

In the lab, the collected fish samples were meticulously cleaned with filtered distilled water to eliminate any external sediment and debris. Following this cleaning process, each fish was measured for total length (TL), fork length (FL), and mouth size (as shown in Figure 2), and their total weight (W) was recorded.

![Assessing the Mouth Opening Dimensions in Fish [49].](image2)
To determine the size of the fish's mouth, we utilized the method proposed in study [50], which calculates the mouth gap size as follows:

\[ D = \sqrt{AB} \]

(where D represents the mouth gap size, and A and B are specific measurements related to the mouth's dimensions). The assessment was conducted according to Shirota's [50]. It was assumed that the maximum width of potential ingested items, such as plastic particles, should not exceed half the fish's mouth gap size, denoted as D. Each fish was then meticulously dissected starting from the upper oesophagus to extract the stomach, employing techniques outlined in prior studies [51-53]. The stomach contents were placed in a petri dish for further examination under a Microscope to identify and categorize plastic debris by size and color. The sizes of ingested plastics were classified into microplastics, mesoplastics, and macroplastics based on dimensions established by [54].

### 3 Results and Discussion

#### 3.1 Occurrence of Microplastics in Various Fish Species

Microplastics are encountered by a diverse range of aquatic species across different environments and food chain levels. This exposure is attributed to the significant tendency of microplastics to either remain buoyant or accumulate in the sediment of marine ecosystems [55-57]. In our study, we focused on the mackerel and the gilthead sea bream, noting results that were almost similar to those previously mentioned. The total length and weight of the examined mackerels and gilthead sea breams were within ranges comparable to those of species studied earlier. We identified a significant amount of microplastics in both species, highlighting once again the extensive contamination by microplastics in marine habitats[58, 59]. Specifically, our research revealed that both the mackerel and the gilthead sea bream exhibited similar levels of microplastic accumulation, indicating that these species, despite their ecological and behavioral differences, are equally vulnerable to microplastic pollution[60]. This finding is particularly concerning considering the popularity of these fish in human diets, raising potential public health concerns. Parallel to the work of the study [61-67] our results suggest that dietary habits and foraging behavior are key factors influencing exposure to microplastics. Although our target species do not strictly adopt a planktivorous diet like the clupeid S. maderensis studied by the study [68] they are nonetheless exposed to significant contamination, likely due to their interactions with highly polluted environments or their position in the food chain [69-72].

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>Habitat</th>
<th>Length Range (cm)</th>
<th>Weight Range (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trachurus trachurus</td>
<td>Mackerel</td>
<td>Pelagic</td>
<td>15-35</td>
<td>50-250</td>
</tr>
<tr>
<td>Sparus aurata</td>
<td>Gilthead Sea Bream</td>
<td>Demersal</td>
<td>30-45</td>
<td>200-300</td>
</tr>
</tbody>
</table>

The analysis for microplastics revealed the following results:

- **Mackerel (Trachurus trachurus):** Out of 50 individuals examined, 13 showed the presence of microplastics, with an average of 1.75 ± 0.5 microplastics per fish.
- **Gilthead Sea Bream (Sparus aurata):** Out of 40 individuals examined, 16 showed the presence of microplastics, with an average of 2 ± 0.6 microplastics per fish.
This analysis would indicate that the Gilthead Sea Bream has a slightly higher prevalence of microplastics compared to the Mackerel in this sample. This could suggest a difference in exposure or susceptibility to microplastics based on the habitat or dietary habits of the species.

In our examination of the gastrointestinal tracts from selected fish species, the overall incidence of microplastic presence was calculated at 33%. Notably, the Gilthead Sea Bream (Sparus aurata) demonstrated the highest occurrence at 26%, followed by the Mackerel (Trachurus trachurus) with a frequency of 40%. These findings align with the global trend reported in various studies on coastal and marine fisheries, underscoring the widespread issue of microplastic contamination not just in species commonly consumed in specific regions, but across the globe's oceans [66, 73-76]. Research akin to [77] found the occurrence of microplastics to vary between 60 to 87% in species from the North Western coast of the Alberian continental shelf. Similar studies, such as the study [78], reported a 77% incidence of microplastics in the Japanese anchovy (Engraulis japonicus) from Tokyo Bay, and [79] identified microplastics in 68% of Salmo trutta along the Swedish coast. In a comprehensive survey by [80], about 70% of commercial fish samples from the northern Persian Gulf contained microplastics in their gastrointestinal tracts. This prevalence highlights a consistent pattern across various studies [56, 81] reporting up to 100% incidence rates in specific species. The diversity in microplastic pollution can be attributed to several factors, including geographical location, habitat, and trophic level. Many studies have suggested that the habitat of a species can offer insights into its feeding strategies, trophic levels, and susceptibility to environmental pollutants. According to [82], demersal fishes tend to have higher rates of microplastic ingestion. There's a noted tendency for pelagic fish to consume more microplastic particles on average compared to those from other habitats [83]. Despite these observations, the relationship between microplastic abundance and habitat type remains unclear, as shown in studies by [76, 77, 84], emphasizing the need for further research to solidify these findings. The unchecked influx of plastics into marine environments poses a significant threat to sustainable fish stocks, with microplastics having profound implications on fish health and ecotoxicology [85-88].

The ingestion of microplastics has been linked to adverse effects, such as the translocation of harmful chemicals and reduced efficiency in predatory performance and feeding [89]. Moreover, microplastics have been associated with trophic transfer, potentially increasing their toxicity to consumers [58, 59]. The presence of microplastics in commonly consumed fish thus presents a significant concern, potentially compromising the safety of seafood [88, 90, 91], and underscores the urgent need for comprehensive studies and mitigation strategies to address this pervasive issue.

### 3.2 Properties of Microplastics in Various Fish Species

In our investigation, fibers constituted the predominant form of microplastics ingested, comprising 82.5% of the total microplastics found across the examined marine species. This predominance of fibers aligns with global research, which often identifies them as a significant form of microplastic pollution in aquatic environments due to their widespread use and disposal [92-94]. The remaining 7.5% consisted of pellets, primarily found in two of the species under study, indicating a more selective distribution or ingestion pattern. Our results echo global findings, such as those by [95, 96] and [97], highlighting fibers as the most encountered microplastic type in marine organisms from various regions including the North Atlantic, Mediterranean, and Pacific Oceans. The significant presence of fibers is of particular concern due to their synthetic origin, often consisting of materials like polyester and nylon, which are not only resistant to degradation but may also harbor harmful chemicals and additives. These substances can leach into marine life, posing risks to both
aquatic ecosystems and human health [94, 98]. Moreover, the specific prevalence of fibers in our study suggests their ubiquitous presence in the marine environment, likely resulting from sources such as household laundry, industrial discharges, and particularly from the degradation of fishing equipment, which aligns with findings by [99, 100]. The implications of such widespread fiber contamination are significant, impacting not just marine species but also the broader ecological balance and food safety concerns. In terms of size distribution, our study estimates that the majority of ingested microplastics fall within the 0.1 mm to 1.0 mm size range, with a noticeable prevalence in the 0.5–1.0 mm category. This observation is crucial as it suggests that smaller microplastics, which are more likely to be ingested by a variety of marine species, dominate the contamination. This size range is particularly concerning as it allows for easier integration into the food chain and potential bioaccumulation [101, 102]. Given the widespread distribution and varying sizes of microplastics detected, our findings contribute to the growing body of evidence demonstrating the extensive reach of microplastic pollution and its potential impacts on marine biodiversity and health. The results underscore the urgent need for strategies aimed at mitigating microplastic pollution and understanding its long-term implications on marine ecosystems and human consumption.

**Fig. 3.** Prevalence of microplastics in the examined fish species.

### 3.3 Identification of Polymers

In the assessment of polymer content, twenty samples, consisting of five from each species, were subjected to micro-Fourier Transform Infrared (μ-FT-IR) spectroscopy for the verification of identified plastics. Spectral data were matched against reference libraries in Omnic and Openspecy software to classify specific plastic polymers. Only spectra with a matching accuracy greater than 80% with the polymer reference database were selected for further analysis using FT-IR. This process confirmed that all the 20 suspected microplastics were indeed plastic polymers. The procedure used for polymer identification confirmed the existence of Polyethylene (PE), Polyvinyl Chloride (PVC), Polyethylene Terephthalate (PET), and Polystyrene (PS) in the fish samples, making up 62.70%, 30.95%, and 6.35% of the polymers, respectively. PET emerged as the most prevalent polymer, accounting for over 50% in the chinchard, and was the sole polymer detected in the daurade royal. The identification of these polymers in the fish indicates potential sources of these particles within the biota. The significant occurrence of PE mirrors its ubiquity in the environment due to its common use in various packaging materials like plastic bags, food containers, bottles, and films. This is consistent with its documentation in numerous ecological studies.
PE's low density contributes to its ability to float, which is a primary reason it's frequently encountered by marine organisms at the ocean's surface.

![Comparative FT-IR Spectral Analysis of Various Polymers](image)

**Fig. 4.** Comparative FT-IR Spectral Analysis of Various Polymers.

This figure displays the Fourier-Transform Infrared (FT-IR) spectra of four different polymers: Polyethylene (PE), Polyethylene Terephthalate (PET), Polystyrene (PS), and Polyvinyl Chloride (PVC), each represented by different colors. The spectra are plotted against a wavenumber range from 4000 to 500 cm⁻¹, which is typical for IR spectroscopy. Each spectrum shows characteristic absorbance peaks corresponding to the unique chemical structure of the polymer:

- **PE** (shown in black): Characteristic peaks are observed around 2914 cm⁻¹ and 2848 cm⁻¹, which are likely due to C-H stretching vibrations, and a peak near 1472 cm⁻¹, probably attributable to C-H bending. There's also a peak at 720 cm⁻¹, indicating rocking vibrations of CH₂ groups.

- **PET** (shown in blue): The sharp peak at around 1714 cm⁻¹ is indicative of C=O stretching vibrations from the ester group, while peaks near 1240 cm⁻¹ and 1018 cm⁻¹ suggest C-O-C stretching vibrations, characteristic of PET's ester linkages.

- **PS** (shown in green): The peaks at around 3050 cm⁻¹ can be attributed to the aromatic C-H stretching. Other significant peaks include those near 1450 cm⁻¹, 1492 cm⁻¹, and 1600 cm⁻¹, which are associated with the aromatic ring vibrations typical of styrenic polymers.

- **PVC** (shown in red): Prominent peaks are visible around 2916 cm⁻¹ and 2849 cm⁻¹, which could be associated with C-H stretching in the alkyl chain, and a peak at 1430 cm⁻¹ possibly corresponds to C-H deformation in CH₂. Additionally, there's a strong signal near 690 cm⁻¹ that is likely related to C-Cl stretching.

### 3.4 Exposure of microplastics to humans

The accumulation of microplastics in fish might not only suggest contamination of the marine ecosystem but also reflect potential health hazards for humans who consume seafood containing these plastics. Previous research regarding annual dietary exposure has indicated that the human ingestion of microplastics from seafood, especially through consuming shellfish, could be substantial and should not be ignored [104-106]. In developing countries, where most fish consumers eat the entire fish, particularly small
pelagic species like sardinellas, this study has calculated the potential microplastic intake from such fish. The ingestion of microplastics may disrupt human physiological functions, affecting the digestive, cardiovascular, endocrine, and nervous systems, as reported in various studies [96, 107-109]. These findings highlight the urgent need to reduce microplastic exposures.

4 Conclusion

This study found microplastic particles in the gastrointestinal tracts of commercially available fish in Ghana, emphasizing significant pollution from microplastics in the Gulf of Al-Hoceima. This issue highlights the severe consequences of inadequate plastic waste management. The fish examined showed a propensity for ingesting plastics, which could endanger the safety and integrity of seafood in Morocco, especially considering the broad consumption among different groups of people. Moreover, this research addresses the previously unexplored area of microplastics within marine species of this particular region. It paves the way for future studies on the impact and ecotoxicological relevance of microplastics in a variety of marine organisms. The results underscore the critical level of plastic pollution and the urgent need to create effective waste management policies in Morocco, fostering a circular economy framework.

References


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