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First Data on Anthropogenic Microparticles in the Gastrointestinal Tract of Juvenile Scalloped Hammerhead Sharks (*Sphyrna lewini*) in the Gulf of California

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Abstract: Scalloped hammerhead sharks (*Sphyrna lewini*) are critically endangered, according to the International Union for Conservation of Nature Red List, likely due to anthropogenic activities such as intense fishing and pollution. Nowadays, plastic debris contamination is a subject of concern due to its extensive presence in the sea and the digestive tracts of many fish species. The possible effects of plastic debris as a vector of other pollutants are still unknown. We analyzed the digestive tract of 58 hammerhead sharks to investigate the correlation between plastic and other anthropogenic microparticle contamination and their feeding habits in the eastern region of the Gulf of California, revealing a debris contamination occurrence of 79.3%. Out of these, 91.4% corresponded to fibers, and the remaining 8.6% to fragments. The main component of the debris was cellulose (64.4%). According to their diet, these organisms exhibit benthopelagic habits, feeding both in the water column and on the seabed. These results indicate a high level of contamination of anthropogenic cellulosic microfibers in the area. Although cellulosic microfibers are recognized as a biomaterial, they can be harmful to marine species, posing an additional threat to this iconic shark. This changed according to the year, indicating that the anthropogenic microparticle ingestion is related to the discharges of human activities and their seasonality rather than to a selection process by the sharks.

Keywords: marine litter; plastic debris; shark feeding; polymers; cellulose-based fibers; cotton

Key Contribution: This is the first study that relates food ingestion with anthropogenic particles in sharks in the Gulf of California.

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1. Introduction

The flow of anthropogenic particles such as plastics into the ocean is expected to reach 29 million metric tons per year shortly [1]. With the accelerating plastic production, the pressure on ecosystems on land and sea is steadily increasing [2], and plastic debris has been reported in virtually all marine and coastal ecosystems [3–5]. Over time, this debris fragments into smaller pieces, such as microplastics, due to physical, biological, and chemical processes, increasing its availability to a broader range of organisms [6]. Therefore, plastic ingestion has already been reported in various marine trophic groups; even in the studied area, there are reports of a frequency of occurrence of 50.5% in bony fishes and 32.4% in batoids [7,8].

However, despite recent advances in research on plastic ingestion in marine fauna, its consequences in top marine predators remain largely uninvestigated [9–11]. Unlike lower trophic levels, top marine predators face not only the direct ingestion of plastics but also the potential transfer and bioaccumulation of plastics across trophic levels. This could explain the high levels of contaminants found in top predatory fish species [12,13].

Specifically for sharks, there are few studies on plastic ingestion despite the important role these species play in the food web structure [14–16]. Sharks are also considered a sentinel group in marine pollution monitoring because of their position as apex predators and potential exposure to bioaccumulation [17]. While a small number of studies confirm the ingestion of plastics in sharks in various geographic regions [9,11,14,16], no information has been obtained about the scalloped hammerhead shark (*Sphyrna lewini*). As a result, it is challenging to assess the extent of their exposure to these pollutants and the potential impacts on their health and ecosystem dynamics. Given that it is a widely distributed and critically endangered species with declining numbers in many parts of its geographical range [18], there are reports that this species ingests macroplastics, although it is not specified what type [19]. However, studies assessing plastic ingestion in the Gulf of California for this species are nonexistent.

The scalloped hammerhead shark is a circumtropical semi-coastal species [20], with juveniles inhabiting shallow coastal zones where they feed on benthic fish and crustaceans [21,22]. Coastal waters are particularly susceptible to plastic contamination due to the high input of plastic debris from land-based sources [23,24]. This situation can lead to prolonged exposure to contaminants during the maturation of juvenile sharks [25]. Specifically, the feeding strategy of juvenile hammerheads makes them highly susceptible to ingesting dense polymer particles that accumulate on the seafloor. This accumulation forms a significant source of contamination for predators that feed on bottom-dwelling prey [26].

This study evaluated juvenile scalloped hammerhead sharks' ingestion of plastic debris in the southeastern Gulf of California. Previous studies have reported a high presence of plastic debris in coastal sediments in this area [8,27]. Hence, the presence of plastics in the gastrointestinal tract of sharks is expected. We attempted to investigate the quantity and type of plastic ingested, determine differences in feeding habits, and assess the frequency of plastic ingestion.

2. Materials and Methods

2.1. Study Area

Juveniles of scalloped hammerhead sharks were caught off the estuarine system of Santa Maria la Reforma (southeastern Gulf of California). Despite the arid and dry climate of the area, significant agricultural and shrimp farming activities take place [28], and intensive small-scale fisheries are also developed there [29]. The system has an area of 53,140 m^2 [30] and is classified as a Type III 5 wave-dominated estuary with a barrier island and two large inlets that have permanent exchange with the sea [31]. Specimens used in this study were caught over two years and five months (from September 2019 to March 2022) at random intervals in two fishing grounds. One location is at 25.035038° N, −108.464851° W, where shark fishing vessels operate, and the other is at 25.099534° N, −108.418764° W, where specimens were selected from the bycatch of the small-scale Pacific Sierra (*Scomberomorus sierra*) fishery. The fishing operations utilized surface gillnets deployed from small-scale boats denominated skiffs or Mexican pangas [32] equipped with 90-hp outboard engines. The individuals were placed on ice and transported to the laboratory, where they were stored in a large freezer at −10 °C.

2.2. Sample Processing

2.2.1. Shark Individuals

The sex, weight (g), and total length (cm) of every specimen were recorded. Gastrointestinal tracts were removed from each shark from the top of the esophagus to the rectum.

Stomach content analysis was conducted to identify prey items and anthropogenic residues, following a methodology with some modifications proposed by Barletta et al. [23]. As well-established and tested protocols for extracting anthropogenic microparticles from the tissue of large marine predators are limited, this study established a methodology based on a selection of protocols [33–35]. Precautions were taken to prevent contamination of samples with plastic or other anthropogenic microparticles from supplementary sources: (1) Access to the laboratory facilities was restricted, and the entrance and windows were fully sealed. (2) The presence of plastic objects near the work area was avoided, 100% cotton lab coats were used, and all glassware, aluminum boats, and Whatman ® filters (Whatman International Ltd., Mainstone, UK) were previously treated under an oven at 400 °C for 4 h; the glassware, weighing dishes, and dissection equipment were rinsed with methanol, acetone, and, finally, with distilled water before use, which was also filtered using a 1.2 µm Whatman® GF/C fiberglass filter. (3) Finally, microscopic observation and filtration were performed inside special plastic cabinets to avoid contamination of the samples, and a clean Petri dish with distilled water was placed inside the working area for each set of samples as a blank, which remained open when the sample was exposed to the environment. The distilled water was filtered and analyzed, allowing for the detection of potential contamination from the laboratory atmosphere [36–38]. The debris found in the blank filters did not correspond in shape or size to those found in the samples.

Gastrointestinal contents from each shark were examined under a stereoscopic microscope (Zeiss Stemi 508) (Carl Zeiss Microscopy GmbH, Jena, Germany), and any ingested particles suspected of being plastic were isolated using tweezers. Prey items were counted, weighed, and grouped into taxonomic categories. After the prey items were digested, the counts were based on identifiable parts, such as otoliths for fish, claws and legs for crustaceans, and beaks for cephalopods [39]. Upon identifying both suspected plastic particles and prey items in the organic tissue, the stomach and intestine lining were scraped with a scalpel and washed with distilled water to collect all potential anthropogenic microparticles attached to the tissue. Scraped-off and washed materials were collected in a Petri dish and placed on a heating plate.

After being left to evaporate excess water for 24 h, the samples were subjected to chemical digestion using a solution of 30% hydrogen peroxide for 12 h at room temperature [35]. Following chemical digestion, the resulting liquid was filtered through 10 µm filters with a 4.7 cm diameter using a suction pump. The filters were then inspected under a stereoscopic microscope fitted with a Zeiss AxioCam ERC 5s digital camera (Carl Zeiss Microscopy GmbH, Jena, Germany) for the presence of plastic particles that could not be identified in the previous steps. Only those particles that met the physical characteristics established in the "Microplastics Identification Guide" [40] were quantified and classified for subsequent analysis by microscope Fourier transform infrared spectroscopy using an attenuated total reflectance accessory (µ-FTIR-ATR). The particles were classified according to their shape (fibers and fragments), color, and size. For each particle that was identified as a potential plastic particle, a single image was captured using the ZEN 2.3 Bue Edition, Zeiss imaging software. This image was then used for subsequent measurements of the particle's length and width.

2.2.2. FTIR-ATR Spectroscopy

The samples were analyzed via µ-FTIR-ATR using Nicolet™ iN™ 10 equipment with a diamond crystal (D-SlidIR) and a mercury cadmium telluride detector cooled by liquid nitrogen. The samples were read at a pressure between 15 and 25 psi, with an aperture between 150 × 150 µm and 250 × 250 µm. The spectra were recorded as the average of 16 scans in the spectral range of 650–4000 cm^{-1} at a high resolution of 4 cm^{-1}. At least 60% of the particles were classified as possible MPs from each site, and 100% of the particles found in the blank controls were analyzed via µ-FTIR-ATR.

2.2.3. Data Analysis

To investigate ontogenetic changes in diet, size groups of the scalloped hammerhead shark were identified using length-frequency polygons generated through a Kernel Density Estimate (KDE) [41] using Equation (1):

$$\hat{f}(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right) \tag{1}$$

where h is the bandwidth and $K(x)$ is the Gaussian kernel function. The Sheather–Jones bandwidth selection method for kernel density estimation was utilized [7]. The KDE procedure was performed using the freely distributed software RStudio Version 1.2.1355 (Boston, MA, USA) (RStudio Team, 2020) and Matlab R2021a (Natik, MA, USA) (The MathWorks, 2021). The mean and standard deviation were calculated for each cohort identified.

To determine if the sample size was adequate to describe the diet of each size class of the scalloped hammerhead shark, randomized cumulative prey curves were constructed for each shark to assess the representativeness of the sampling effort. The order in which samples were analyzed was randomized 1000 times for each new cumulative prey item sample using Chao's 2 estimator to determine the absolute number of prey items. It is based on the number of rare species found in a sample [42], and the notation is in Equation (2):

$$S_2 = S_{obs} + \frac{Q_1^2}{2Q_2} \tag{2}$$

where S_2 is the estimated number of prey species, S_{obs} is the observed number of prey species in the stomach, Q_1 is the number of singletons (taxa represented by a single occurrence in the field campaign), and Q_2 is the number of doubletons (two or more occurrences in the field campaign) [43]. When a cumulative prey curve approaches an asymptote, the number of stomachs analyzed is deemed adequate for describing the dietary habits of the predator under study. The asymptote of the curve represents the minimum sample size necessary to adequately describe the diet.

To quantify the significance of prey items and anthropogenic microparticles in the diet of hammerhead sharks, an abundance matrix was constructed, comprising the relative abundance of prey items and polymers. This matrix included every analyzed hammerhead shark as columns and prey and polymer items as rows. As the quantity of prey and anthropogenic microparticles in the gut varies considerably between individual sharks, a multivariate comparison would not be relevant. Therefore, the data were sample-standardized, as the unit of sampling cannot be tightly controlled [44]. After standardizing, the samples were expressed as a percentage composition of each prey and anthropogenic microparticles category, with each column adding to 100. Subsequently, Bray–Curtis similarity matrices were generated from this dataset, considering sex, size, and sampling years as factors. To test the null hypothesis (H0) that the diet and ingestion of anthropogenic microparticles of the analyzed species did not differ according to these factors, PERMANOVA+ was employed [44]. In the event of significant differences, a Canonical Analysis of Principal Coordinates (CAP) [44] was undertaken. This method enables the construction of a constrained ordination based on any distance or dissimilarity measure, which displays a cloud of multivariate points following a specific a priori hypothesis.

Prey items and anthropogenic microparticle polymers were overlaid as vectors on top of the CAP to determine their importance according to the factors in case significant results were found. The trajectory of the vector can be interpreted to indicate the importance of each prey or polymer to the diet of the hammerhead shark according to certain factors. Both axes have a scale from –n to n, in which the point 0, 0 is the centroid—the location where all the points would be located if the null hypothesis was true, or in this case, if a certain prey or polymer item would not differ according to any factor a priori established [44].

3. Results

A total of 58 juvenile scalloped hammerhead sharks were captured and subjected to analysis. The mean total length (TL) was 76.4 cm (SD = 15.9), while the mean weight was 2287.2 g (SD = 1545.7). Of these, 33 were females, and 25 were males. Four distinct cohorts were identified with the KDE function: extra small (48.4–57.5 cm), small (57.6–78.7 cm), medium (78.8–108.9 cm), and large (109–121 cm).

3.1. Prey and Plastic Ingestion

Of the 58 stomachs examined, 17 were found empty of prey items (29.3%). In the remaining 41 stomachs (70.7%), three prey groups were found: teleost fish had the highest frequency of occurrence with 64.3%, followed by decapod crustaceans with 28.6%, and cephalopods (squids) with 4.8%. In terms of possible plastic debris, the frequency of occurrence was (79.3%) with 46 individuals. A total of 1924 pieces of debris were found in the gastrointestinal tract of scalloped hammerheads. Of these, 1758 were fibers (91.4%) and 166 were fragments (8.6%). Lengths ranged from 0.024 mm to 7.087 mm. The dominant colors after chemical digestion were blue (43.15%), followed by black (29.04%), red (8.33%), transparent (6.45%), yellow (5.29%), and gray (4.52%), while orange, brown, white, and green accounted for the remaining 3.22% (Table 1) (Figure 1).

Table 1. Mean length (mm) of anthropogenic microparticles for the most abundant colors found in the gastrointestinal tract of the different sizes of juveniles of scalloped hammerhead sharks (SD = standard deviation). ES: Extra small, S = small, M = medium, L = large.

Gray	Yellow	Transparent	Red	Blue	Size
	0.234 (SD ± 0.13)	0.292 (SD ± 0.13)	0.237 (SD ± 0.13)	0.231 (SD ± 0.12)	ES
0.348 (SD ± 0.28)	0.677 (SD ± 0.92)	1.028 (SD ± 1.1)	1.510 (SD ± 1.7)	0.929 (SD ± 1.3)	S
0.238 (SD ± 0.1)	0.716 (SD ± 0.48)	0.435 (SD ± 0.53)	0.908 (SD ± 1.3)	0.327 (SD ± 0.29)	M
0.930 (SD ± 0.66)	0.249 (SD ± 0.3)	2.925 (SD ± 2.3)	0.111 (SD ± 0.09)	0.350 (SD ± 0.34)	L

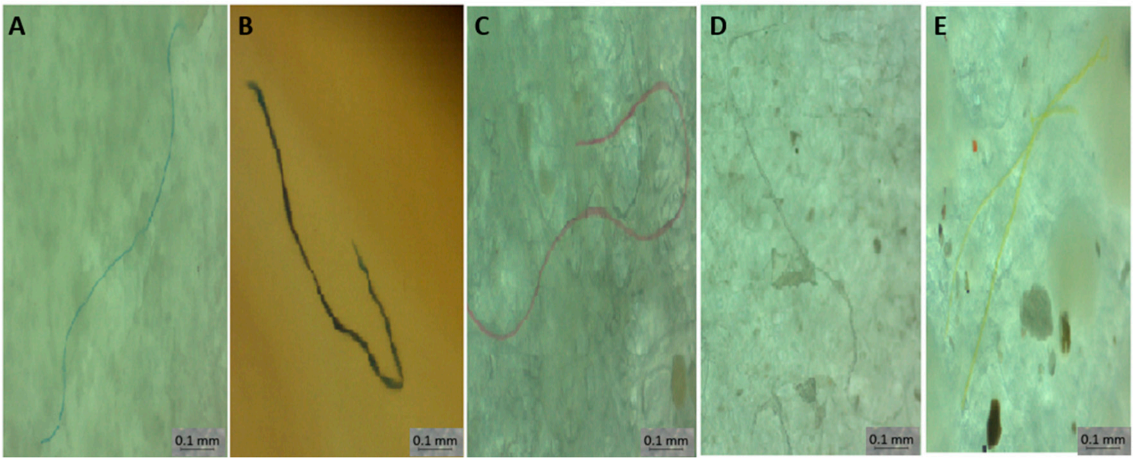

Figure 1. Representative images of the most abundant microfibers found in the gastrointestinal tracts of juveniles of scalloped hammerhead sharks. (**A**) blue fiber (43.15%), (**B**) black fiber (29.04%) observed directly in gastric tissue, (**C**) red (8.33%), (**D**) transparent fiber (6.45%), and (**E**) yellow fiber (5.29%).

3.2. FTIR-ATR Analysis

The potential presence of anthropogenic microparticles was investigated using Fourier transform infrared spectroscopy with attenuated total reflection (FTIR-ATR). This analytical technique enables the identification of the functional groups present in a given compound that shows the molecular composition of materials [44]. A total of 457 particles (23.8%) were examined. Due to budget restrictions, not all particles could be analyzed. These results were extrapolated to all the obtained particles. Of the total of the particles analyzed, 24.9% did not match with any polymer and were reported as not identified (NI). When leaving these particles out, the remaining particles indicate the presence of eight distinct polymer types. Cellulose was identified as the most abundant polymer, occurring with a frequency of 64.4%. This compound is commonly used in the textile industry and is an important component of cigarette butts, which are a common source of pollution. This was followed by PET, which constituted 12.8%, a polymer that is abundant in the environment due to its use in water or soda bottles prevalent in the environment due to its widespread use and slow degradation rate. Cotton and polyester were detected in 12.5% and 3.8%, respectively; these polymers are widely used in the textile industry, and both persist in the environment, contributing to pollution. Cellophane is a polymer commonly manufactured for bags used to store food and constitutes 3.2% of the total. While cellophane is derived from cellulose, improper disposal can result in environmental contamination. The remaining materials were polypropylene at 1.2%, which is used for ropes in fishing gear and a component of face masks where its durability and resistance to degradation make it a common pollutant in marine environments; acrylic at 1.2%, which is a polymer widely used in fishing gear for many fisheries globally, and in the region, the material is employed in the manufacture of fishing rods used to catch tuna; rayon at 0.9%, a compound used mainly in fabrics for the textile industry. Although rayon is a semi-synthetic material, it can contribute to marine pollution when it breaks down into smaller fibers (for further details, please refer to Figure 2 and Table 2).

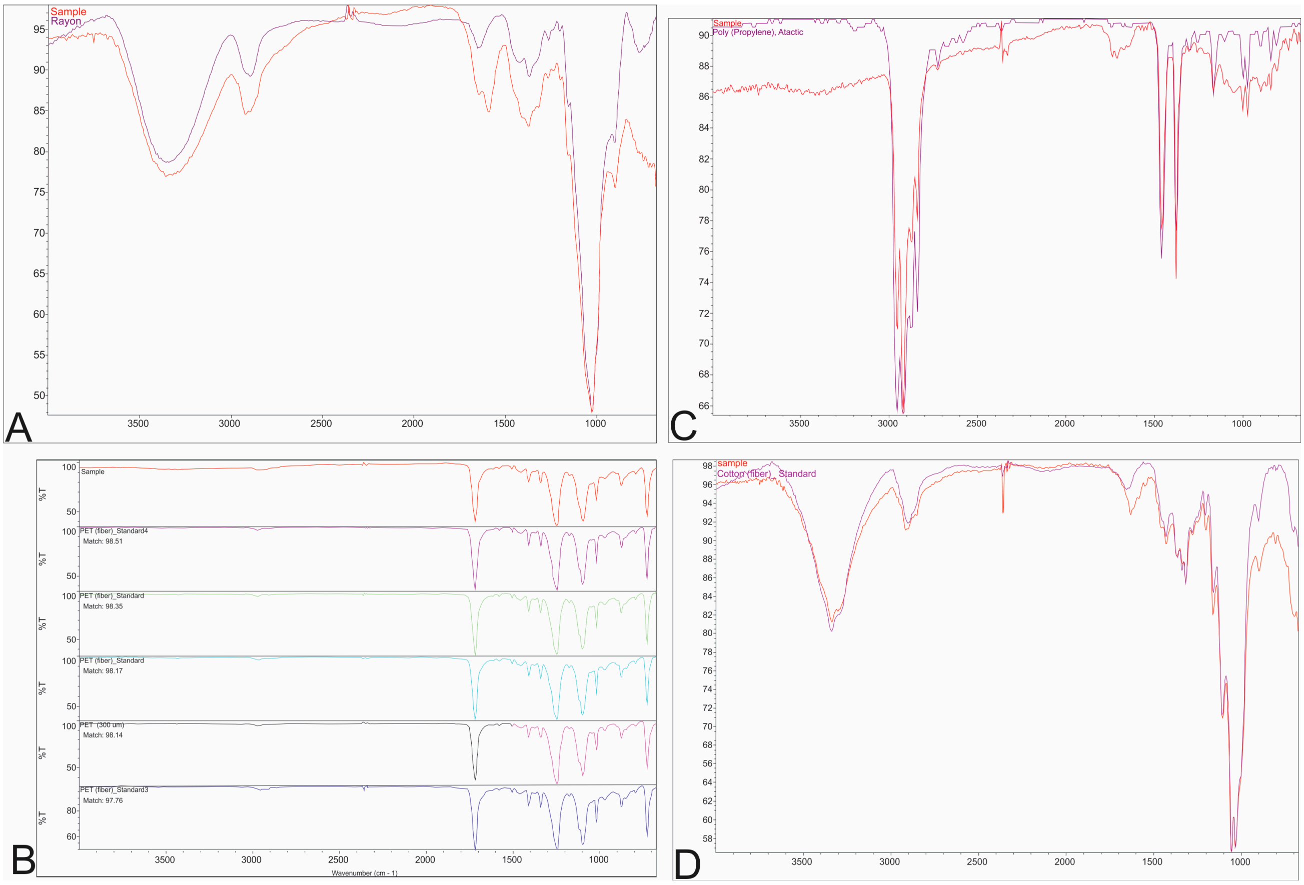

Figure 2. ATR-FTIR spectra of the anthropogenic particles found in the gastrointestinal tract of juveniles of scalloped hammerhead sharks: The red line represents the sample analyzed and the other color lines represents the polymer that matched (**A**) rayon, (**B**) polyethylene terephthalate, (**C**) polyethylene, (**D**) cotton.

Table 2. Summary of analyzed polymer found in the gastrointestinal tract of juvenile scalloped hammerhead sharks.

Frequency (%)	Min–Max and Mean Length (mm)	Number of Particles	Polymer
64.4	0.050–7.041 and 1.216	221	Cellulose
12.5	0.176–2.473 and 1.158	43	Cotton
3.8	0.531–0.226 and 0.350	13	Polyester
12.8	0.131–4.301 and 1.283	44	PET
3.2	1.931–0.426 and 1.174	11	Cellophane
1.2	0.202–1.679 and 0.946	4	Polypropylene
0.9	0.221–1.948 and 0.997	3	Rayon
1.2	0.601–1.932 and 1.222	4	Acrylic

3.3. Data Analysis

Chao's estimator indicated that the number of stomachs analyzed was representative of a meaningful statistical analysis of diet. The diet and anthropogenic ingestion of this species were not found to be significantly related to sex (Pseudo-F1,71 = 0.67243, $p < 0.05$), size (Pseudo-F2,71 = 1.1862, $p < 0.05$), or any of the interactions (size–sex Pseudo-F2,71 = 1.002, $p < 0.05$; size–year Pseudo-F1,71 = 1.52, $p < 0.05$; sex–year Pseudo-F2,71 = 0.61, $p < 0.05$; size–sex–year Pseudo-F3,71 = 1.31, $p < 0.05$). However, differences were found according to year (Pseudo-F2,71 = 2.01, $p > 0.05$). Pairwise comparisons revealed that the years 2019 and 2020 were not statistically different from one another. However, all other combinations were statistically distinct (see Supplementary Materials Table S1).

These results were confirmed by CAP, as no distinct groups were formed based on the factors of size and sex, but clear groups were formed according to year (Figure 3). In terms of prey, decapod crustaceans were eaten mainly during the years 2019–2020 and 2022, whilst squid was eaten during the year 2021. Fish were eaten in all years, according to the vectors. In terms of polymers, the vectors of cotton, cellophane, rayon, and acrylic were close to the centroid, indicating that they were consumed similarly in different years. Cellulose was more present during the years 2019–2020, PET had a higher presence during the years 2021–2022, polypropylene had a higher presence during the year 2022, and polyester had a higher presence from 2019 to 2021.

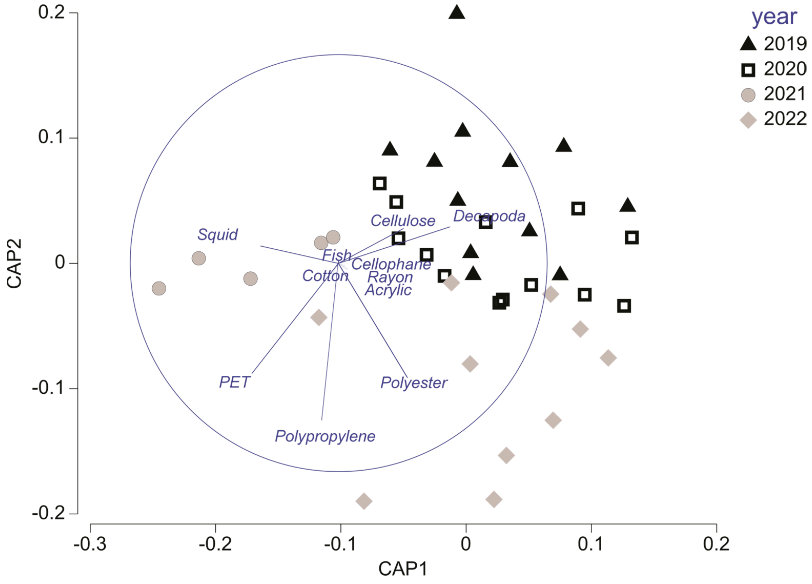

Figure 3. Canonical analysis of principal coordinates (CAP) describing the feeding behavior and debris ingestion of juveniles of scalloped hammerhead sharks in the different analyzed years. The vectors indicate the importance of each prey item and polymer found in the gastrointestinal tract of this species.

4. Discussion

This study is the first to assess anthropogenic debris contamination in the gastrointestinal tract of juvenile scalloped hammerhead sharks in the Gulf of California. It also provides the first data on the presence of microplastics and other anthropogenic debris in this species, which confirmed the presence of plastic debris in the Gulf of California. A region where plastic pollution in coastal sediments and fish has already been reported [8,27].

The extensive use and improper disposal of anthropogenic products as litter have led to their presence in estuarine and marine habitats [45]. This has resulted in the ingestion of these products by marine organisms becoming a common phenomenon that can cause bioaccumulation through the food chain. Growth retardation, hormone disruption, metabolic dysfunction, oxidative stress, immunological, neurological malfunction, and behavioral changes have been the potential effects of exposure to these pollutants [46].

Juvenile hammerhead sharks remain in coastal environments for extended periods to feed and seek refuge from other predators [25], making them vulnerable to ingesting debris particles resulting from anthropogenic activities in these areas. The diet observed in this and other studies for hammerhead sharks, which includes fish, benthic crustaceans, and coastal cephalopods [21,47], confirms that juvenile sharks are generalist benthopelagic feeders. This means that hammerhead sharks feed both in the water column and at the bottom; this makes them vulnerable to consuming debris found on the seafloor and in the water column. The high frequency of occurrence of microplastics and other anthropogenic particles (79.3%) corroborates this observation. Plastic debris and anthropogenic particles with high-density sinks accumulate on the seabed [48]. The present study found a higher frequency of occurrence than in Haller's round ray for the same area [8]. This suggests that the hammerhead shark's predation in the neritic area also contributes to a higher occurrence of anthropogenic particles. This is because this species feeds in the water column [49]. Although there are not many reports of debris contamination in juvenile sharks, a recent study made by Stilinger [50] with juveniles of Atlantic sharpnose sharks along northwestern Atlantic Ocean coastlines showed a similar frequency of occurrence of anthropogenic debris.

The majority of the debris found in the gastrointestinal tract of the hammerhead shark consisted of fibers, as reported in previous studies [51–54]. This may be because fibers are widely used in various human activities, including clothing (textiles), fisheries, civil engineering (geotextiles), and agriculture. As a result, their production has increased by approximately 2% per year, and they are now found in aquatic and terrestrial environments [55]. These microfibers are transported through wastewater systems to treatment plants and through the atmosphere into aquatic systems, where they accumulate in the oceans and shorelines [56]. This can pose a significant risk of environmental contamination and organisms.

In terms of the components of the debris found, the most common material was cellulose. Cellulose is not a microplastic; it is a natural polymer that can be considered an anthropogenic particle found in the environment. The current focus of marine research is on the issue of plastic pollution [57–60]. It has been discovered that synthetic cellulose fibers are also prevalent [61]. In the past, these fibers were often confused with petroleum-based plastic fibers because it was assumed that all fibers are plastics. However, recent studies have begun to distinguish between fibers of cellulosic polymers and synthetic textile fibers [62]. They are harvested from natural resources and manufactured from cellulosic materials. For example, rayon is manufactured using viscose from cellulose, a natural component found in plants; it undergoes several chemical processes to transform into its final form, making it a semisynthetic fiber [52]. These fibers from natural polymers are anthropogenic particles with unknown environmental issues; additives or dyes associated with them could potentially be harmful to marine organisms [62]. The data on the impact of synthetic organic dyes on marine fauna remains limited due to the wide range of dyes available; the effects can be diversified in terms of aquatic toxicity even within the same chemical class. Therefore, it is crucial not to underestimate their impact as a pollutant [63].

Another source of cellulose that is often overlooked is cigarette butts. These constitute one of the most common types of litter in urban areas, with an estimated 4.5 trillion discarded annually, representing 22–46% of visible litter [64]. Once discarded, they are transported by rain or rivers to coastal areas [65]. Cigarette butts are composed of nearly 95% microscopic-sized fibrous cellulose acetate. Although it is a photodegradable polymer, it does not degrade easily and may persist in the environment for more than ten years [64]. Currently, there is still no sustainable disposal method or recycling technology established for this waste.

Polyester, which accounted for over 3.8%, is also used in textiles. This indicates that over 80% of textile particles were found in the gastrointestinal tract of hammerhead sharks. As previously stated, debris originating from textiles is transported from households to rivers and eventually to the ocean through the wastewater systems of cities. Unfortunately, water treatment plants typically lack filters designed to capture these particles. The influx of plastic debris from textiles is a significant concern in terms of contaminating coastal environments with airborne particulates.

The other fibers found were consistent with plastics commonly used by fishers, such as plastic bottles for water, sodas, and other beverages, plastic bags, and fishing gear. These anthropogenic factors contribute to the presence of plastic and other anthropogenic particles in the region. From these particles, it is interesting that the results indicate that the highest presence of polypropylene, one of the main components of face masks, was in the year 2022, two years after the start of the COVID-19 pandemic. During this global health crisis, the use of personal protection equipment (PPE) to safeguard the human population was very prominent, which resulted in vast plastic pollution to the marine environment [66–68]. Face masks were effective and cheap protective equipment widely used, with polypropylene as their major component [69]. It has been studied that face masks can release fibers if they are discarded into the environment, and with their gradual aging and decomposition, the whole mask would completely become microplastics [70]. Although these results are not conclusive, likely, the increase of this polymer in the digestive tracts of the analyzed hammerhead sharks is a consequence of the pollution derived from the COVID-19 pandemic.

The studied area is considered the largest estuarine system in northwest Mexico and a very important fishing ground in the Gulf of California. It is highly productive in terms of fishing and the economic activities derived from it. However, fisheries can be considered an anthropogenic activity with a significant effect on microplastic pollution due to the materials used in their fishing gears and other associated contamination, along with the wastewater from nearby cities [71]. Furthermore, given the importance of the industry to the local economy, the estuarine system is situated close to human settlements, increasing the risk of contamination.

5. Conclusions

Juveniles of scalloped hammerhead sharks spend extended periods in coastal environments, making them vulnerable to accidentally ingesting microfibers due to their presence in the water column and on the seafloor. Especially for anthropogenic cellulose fibers, this polymer has become a major component of this type of microplastic pollution. Although they are considered natural fibers, the additives or dyes attached to them may affect the organisms inhabiting aquatic environments. Additionally, in the case of polypropylene fibers, we cannot conclude with certainty that this is a post-COVID-19 pandemic consequence, but their appearance suggests a potential correlation.

For this reason, it is necessary to expand our understanding of these (MPs and anthropogenic fibers) emerging pollutants to comprehend their potential impact on marine organisms. Further analysis of other marine species in the area during this period is needed to indicate if these findings are a consequence of the wide use of face masks at the time.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fishes9080310/s1, Table S1: Pairwise *t*-test of the PERMANOVA looking for differences between the diet and anthropic debris ingestion of juvenile hammerhead sharks according to the factor Year.

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