ECOCEANOS CORPORATION

ENVIRONMENTAL REGULATION PROGRAM FOR THE REDUCTION OF THE IMPACTS OF MICROPLASTIC PRODUCED BY TOURIST ACTIVITIES ON THE COLOMBIAN CARIBBEAN COAST

ABSTRACT: Microplastics are emerging contaminants with a wide global distribution that represent a risk to biodiversity and the livelihood of human communities. These particles are mainly transported by rivers from the interior to marine-coastal ecosystems, where they accumulate and affect their environmental quality. The objective of this study was to evaluate microplastic pollution in mangroves and beaches of the Cispata marine protected area, Colombian Caribbean coast. In May 2018, three stations in the mangroves and two stations on tourist beaches were selected, where samples of microplastics were taken in surface waters and sediments, in addition to visually identifying them under a stereoscope, counting them to determine their abundance and classifying them according to their shapes. . Microplastics were more abundant in mangroves (13 to 123 elements/m3 of water; 72 to 1,668 elements/m2 or 42 to 1,825 elements/kg of sediment) compared to beaches (0 to 0. 13 elements/m3 of water). ; from 8 to 36 pieces/m2 of sediment). In both ecosystems, films, foams and fragments were the most common forms, relating to the poor management of domestic waste, tourism and fishing in the area. This study contributes to the knowledge of the characteristics, distribution and abundance of microplastics in mangroves and beaches in the region in order to raise environmental awareness about the risks and promote actions to prevent and mitigate negative impacts, especially in marine protected areas.

Keywords: Marine litter, marine pollution, plastic waste, coastal ecosystems, Colombia.

INTRODUCTION

Microplastics (particles <5 mm) are a subcategory of plastic marine litter considered an emerging pollutant, and their environmental risks are an active field of research (Auta et al. 2017). These particles have a wide global distribution, are affecting various species, and are threats to ecosystems and the livelihoods of coastal communities (Wright et al. 2013; Antão-Barboza et al. 2018).

Knowledge of the distribution, abundance and characteristics of microplastics in ecosystems is important to generate environmental awareness about their risks and promote actions that prevent and mitigate their negative impacts in the short, medium and long term (Li et al. 2016 ; Löhr et al 2017 ; Kutralam-Muniasamy et al 2021). In coastal areas, ecosystems that provide environmental services develop that influence the well-being of human communities (Moberg & Rönnbäck, 2003 ; Link & Borchert, 2015). To protect the long-term and sustainably use the natural elements of these ecosystems, geographical spaces have been defined that host outstanding biodiversity features on a regional, national or global scale, or have defined conservation objectives, called marine protected areas (MPAs) (Day et al. 2012).

Despite their protection, MPAs have been contaminated by microplastics that come from human activities in surrounding areas or from marine currents, and different studies have reported abundances of these particles in waters, sediments, and organisms (in the digestive system, organs such as gills, gonads and leaves, and in soft tissues, muscles or exoskeletons) of MPAs around the world (Kutralam-Muniasamy et al. 2021; Garcés-Ordóñez et al. 2022a).

In the Latin American and Caribbean region, studies have been reported in MPAs from Mexico (Rivera-Garibay et al. 2020; Celis-Hernández et al. 2021), Belize (Coc et al. 2021), Guatemala (Mazariegos-Ortíz et al. 2020), Costa Rica (Astorga-Pérez et al. 2022), Panama (Delvalle et al. 2020), Colombia (Garcés-Ordóñez et al. 2019; 2022b), Ecuador (Jones et al. 2022), Brazil (Lorenzi. et al 2021), Chile (Rech et al. 2018) and Argentina (Díaz-Jaramillo et al. 2021), to name some research.

The Cispata integrated management district is an MPA located on the Colombian Caribbean coast (Fig. 1), where the most extensive and best preserved mangroves in this region of the country are located and in its surrounding area are the beaches of greatest tourist importance. . of the department of Córdoba (CVS & INVEMAR, 2010). These ecosystems are the breeding habitat for fishing species; food suppliers; recreational areas; coast protectors and stabilizers; among other ecological functions (Medina-Contreras et al. 2020; 2021), and have been affected by plastic litter (Garcés-Ordóñez et al. 2020a).

The Sinú River is a recipient of domestic and industrial waste and flows into the Cispata protected area, being a transport route for plastics and other pollutants from the interior of the department of Córdoba to the Caribbean coast (Lebreton et al. 2017; Bayona-

Arenas & Garcés-Ordóñez, 2018). Due to coastal dynamics, part of this garbage generally accumulates on beaches and mangroves (Harris et al. 2021), where it fragments due to exposure to solar radiation and other environmental factors, generating microplastics (Garcés-Ordóñez et al. al. 2020b; 2021).

The questions of this research were: which of these beach and mangrove ecosystems in the Cispata area have the greatest abundance of microplastics in their waters and sediments? What are the main types of microplastics in these ecosystems? probable sources?

The objective of this study was to evaluate microplastic contamination in mangroves and beaches of the Cispata MPA, Colombian Caribbean. The information generated represents the baseline of knowledge for the action of environmental authorities and local communities that help conserve these MPA ecosystems in the best possible conditions.

MATERIALS AND METHODS

Sampling stations. Five sampling stations were selected, of which three were located in the mangrove areas (Mestizo, Boca de Corea and Caño Lobo) and two on the tourist beaches (Blanca and Manzanillo) of the study area (Fig. 1). The characteristics of these stations are described in Table 1.

Fig. 1

Location of the microplastic sampling stations on two beaches and three mangrove areas of the marine protected area of Cispata, department of Córdoba, Colombian Caribbean

Table 1

Coordinates and description of the microplastic sampling stations in the mangroves and beaches of the Cispata marine protected area, Colombian Caribbean

To establish the stations in the mangroves, easy access and its location with greater influence of the Sinú River (Boca de Corea) were demonstrated, in the interior area of the forest surrounding the town of San Antero (Caño Lobo) and on the coast (Mestizo).).); and for those on the beach, their tourist importance and distance from the town center were taken into account (Table 1). Field trips to collect microplastic samples in surface waters and sediments in the study area were carried out from May 7 to 10, 2018.

Sampling and isolation of microplastics in mangrove water and sediments. At the Boca de Corea and Caño Lobo stations, 150 L of surface water was collected with a gauged bucket at three points along the edge of the mangrove-water body, and sieved in situ into a 300 µm red. The retained material was transferred into 500 mL glass bottles, 100 mL of 10% NaClO was added to dissolve the organic matter and facilitate its analysis. In the laboratory, the samples were examined directly under the stereoscope.

The sampling of microplastics in mangrove sediments, in the three selected stations, was done with the methodology adapted by Garcés-Ordóñez et al. (2019). At each station, three randomly distributed quadrants of 50 x 50 cm were dimensioned, where the large plant material that covered the soil was carefully removed and samples of surface sediments were collected up to 5 cm deep (~500 g). .

In the laboratory, the samples were dried in an oven at 70 °C for 48-72 h and the dry weight was analyzed. Subsequently, a solution of (NaPO3)6 (2.5 g/L) was added to disaggregate the fine grains, stirring for 10 min and letting it rest for 24 h. Subsequently, the samples were sieved on 5.0 and 1.0 mm sieves and the material retained on the 1.0 mm sieve was examined directly under the stereoscope.

Sampling and isolation of microplastics in water and sediments from tourist beaches.

The sampling of microplastics in the surface water of the Mestizo, Playa Blanca and Playa Manzanillo stations was made considering recommendations from Kovač et al. (2016). A 300 µm plankton net with flow meter and floats was used, towed by a small spear for 15 min. up to 2 knots of speed, in three transects parallel to the coast. The start and end points of the transects were georeferenced with a GPS-Garmin®. The collected samples were transferred into glass bottles with 100 mL of 10% NaClO. In the laboratory, the samples were examined under the stereoscope to separate the microplastics.

The sampling of microplastics in the sand of Banca and Manzanillo beaches was carried out with the methodology adapted by Garcés-Ordóñez et al. (2020c). At each station, three 30 m transects were prepared parallel to the coast, distributed in the low, mid and rear tide areas of the beach. In each transect, three quadrants of 50 x 50 cm were established, separated by 15 m from each other, where surface sediments were collected (first 5 cm). The dried samples were sieved in situ with 5.0 and 1.0 mm sieves; and the wet samples were dried and sieved in the laboratory. The material retained on the 1.0 mm sieve is examined under the stereoscope for isolation of microplastics.

Control measures and characterization of microplastics. During field work, cotton clothing was used and the sample items were washed with filtered distilled water before and after each sample collection. In the laboratory, work areas were cleaned before and after analyses, and metal and glass tools were used. Control containers with filtered distilled water were used that remained next to the sample during the procedure to record possible contamination in the laboratory, which were reviewed at the end of each observation (Ory et al. 2018).

No microplastics were found in the size ranges considered in this study (5-0.3 mm for water and 5-1 mm for sediments). These sizes are easy to identify visually and allow us to reduce the risks due to confusion or overestimation due to contamination in the laboratory, since the particles (mainly fibers) present in indoor air are generally very small, <0.5 mm (Brander et al. al. 2020) or <0.3 mm (Prata et al. 2020).

Microplastics in water and sediment samples are visually identified under a stereoscope considering the absence of visible cellular or organic structures, they were counted and classified according to their shape into fragments, filaments, films, foams, granules and pellets (Kovač et al. 2016). .

The data were normalized according to the volume of filtered water, sampled area and mass, and were expressed in microplastics m -3 of surface water, in microplastics m -2 of beach sediment, in microplastics m -2 and microplastics kg -1 of sediment of mangrove soil in dry weight (ds).

RESULTS AND DISCUSSION

Microplastics in water and mangrove sediments. In the surface water of the Boca de Corea mangrove, an abundance of 123 microplastics m -3 is sent and in Caño Lobo of 13 microplastics m -3 (Fig. 2A). The Boca de Corea station was located in an area of high influence of the Sinú River, which is the recipient of part of the domestic waste generated by the populations settled on its banks and, therefore, is a source of garbage for the coastal zone (Bayona-Arenas & Garcés-Ordóñez, 2018). Films were the most abundant type of microplastics in water, followed by expanded polystyrene foams (Fig. 2B).

In the mangrove sediment, abundances of 72 to 1,668 microplastics/m 2 or 42 to 1,825 microplastics kg -1 ps were determined (Fig. 2C and D), determining the highest contamination in Mestizo, a coastal area exposed to garbage. that arrives by coastal drift. The most common types of microplastics were: films, filaments and expanded polystyrene foams (Fig. 2E). These are generated by fragmentation of larger plastic items and are known as secondary microplastics (Fig. 3 ; Auta et al. 2017).

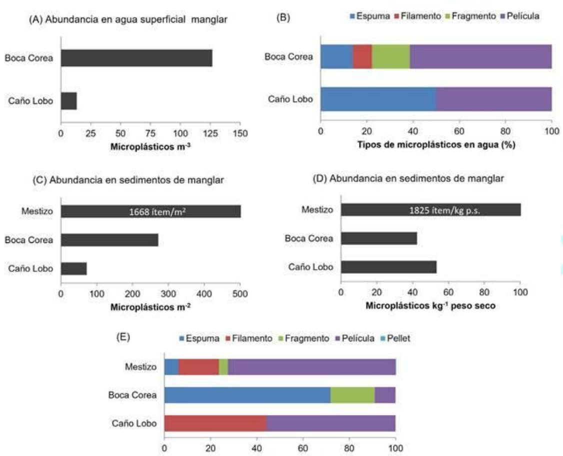

Fig. 2

Abundance and proportion of the types of microplastics in the water (A and B) and sediments (C, D and E) of the mangroves of the marine protected area of Cispata, Colombian Caribbean

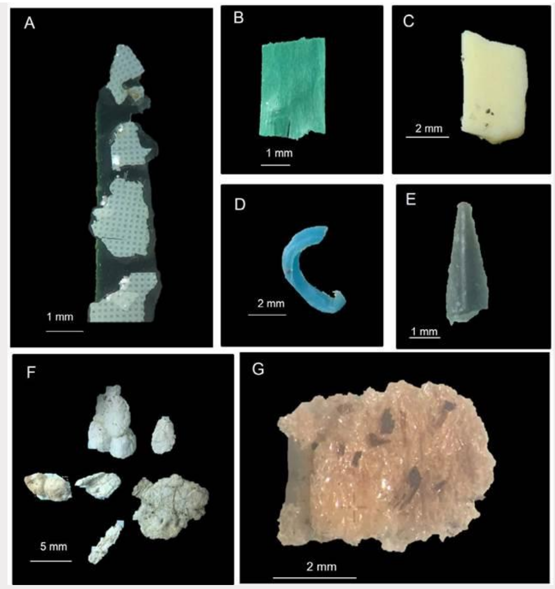

Fig. 3

Micro plastics found at sampling stations in the marine protected area of Cispata, department of Córdoba, Colombian Caribbean. Fragments (A, C, D and E), film (B) and foam (F and G)

Film-type microplastics are usually bag fractions; Expanded polystyrene foams come from the disintegration of disposable utensils for serving food, buoys and refrigerators commonly used in fishing activities; the filaments probably come from fishing ropes and nets and wastewater, and the fragments come from pieces of hard plastics (Li et al. 2016; Wang et al. 2016).

Some pellets were found in the mangroves of Mestizo, which are manufactured in these shapes and sizes to be used as a component in other products, and are considered primary microplastics (Boucher & Friot, 2017). These are probably transported by marine currents from the industrial zone of Cartagena (Rangel-

Buitrago et al. 2018; Garcés-Ordóñez et al. 2021).

Compared to other studies, the abundance of microplastics in the water of the Cispata mangroves was lower than those reported for those from estuaries in Brazil (Deng et al. 2021) and China (Jiao et al. 2022), and exceeded that reported in mangroves of Mexico (Celis-Hernández et al. 2021) and Iran (Deng et al. 2021) (Table 2).

Table 2

Comparison of microplastic abundances in Cispata mangrove waters and sediments with other similar studies. No information was reported (nor)

País	Manglar	Microplásticos m-3	Microplásticos kg-1	Fuente
Colombia	AMP Cispata	13 123	42 1 825	Este estudio
	AMP Ciénaga Grande de Santa Marta	n. i.	31 2 863	Garcés-Ordóñez et al. -2019
	Bahía de Tumaco	n. i.	126 413	Preciado & Zapata (2020)
China	Estuario río Bei Lun	22-90	280-890	Jiao et al. 2022
	Estuario río Mai Ling	343 -1 339	600-1 570	Jiao et al. 2022
	Estuario río Qin Jiang	312 648	475-1 030	Jiao et al. 2022
	Estuario río Jiu Zhou	33 170	450-2 110	Jiao et al. 2022
	Reserva de Yunxiao	275	n. i.	Deng et al. (2021)
	Bahía de Qinzhou	n. i.	15-80	Li et al. (2018)
	Isla Hainan	n. i.	65-450	Ding et al. 2022
Singapur	Siete hábitats de manglar	n. i.	dic-63	Mohamed & Obbard (2014)
Irán	Golfo Pérsico, Irán	n. i.	0-125	Naji et al. (2017)
	Bahía Chabahar en Irán	0.14	n. i.	Deng et al. (2021)
México	AMP Laguna Términos	0.02 0.67	4 28	Celis-Hernández et al. 2021
Brasil	Bahía de Todos Santos	n. i.	555 31 087	da Silva et al. 2022
	Estuario de Goiana, Brasil	477	n. i.	Deng et al. (2021)

The abundances of microplastics in sediments from the Cispata mangroves were higher than those reported for Singapore (Mohamed & Obbard, 2014), Iran (Naji et al. 2017), Colombia (Tumaco Bay; Preciado & Zapata, 2020) and China (Qinzhou Bay; Li et al 2018); smaller than those of China (Jiu Zhou River; Jiao et al. 2022) and Brazil (All Saints Bay; da Silva et al. 2022) and similar to that of Ciénaga Grande de Santa Marta, Colombia (Garcés-Ordóñez et al. 2019 ; table 2).

It should be noted that despite the methodological limitations that make comparisons of studies difficult, such as: the sampling instruments, the size of the microplastics analyzed, the reagents and laboratory procedures (digestion, filtration, separation by density) used, and the units of reported concentrations (Hidalgo-Ruz et al. 2012; Weiss et al. 2021), these are required to visualize the state of impact between different sites with similar conditions or with highly intervened areas.

Microplastics in waters and sediments of tourist beaches. In Playa Blanca the abundance was 0.02 microplastics m -3 and in Manzanillo they were not found (Fig. 4A). In the coastal water

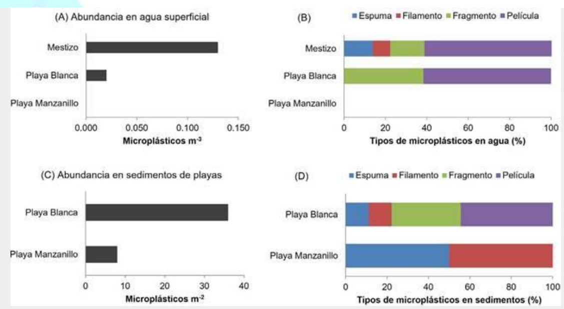

Fig. 4

Abundance and proportion of microplastic types in surface seawater (A and B) and sediments (C and D) of Manzanillo and Blanca beaches in Cispata, department of Córdoba, Colombian Caribbean

From Mestizo, the largest amount was recorded, 0.13 microplastics m -3. Films and fragments were most common in beach surface water (Fig. 4B). In the sand, 8 to 36 microplastics m -2 were determined, Blanca beach was the most contaminated (Fig. 4C); films and fragments dominated in Playa Blanca and filaments and foams in Playa Manzanillo (Fig. 4D).

Microplastic contamination on the beaches evaluated (8-36 microplastics m -2) was similar to what was reported for some AMP beaches in San Andrés and Chocó in Colombia (8-32 microplastics m -2 ; Garcés-Ordóñez et al. 2020b , 2021), and lower than that of Sri Lanka (29-111 microplastics m -2 ; Dharmadasa et al . 2021), Ecuador (74-381 microplastics/m -2 ; Jones et al . 2022) and Guatemala (279 microplastics m -2 ; Mazariegos-Ortíz et al 2020). Microplastic pollution on the beaches was lower than in the Cispata mangroves, because mangroves are more susceptible to accumulating plastic trash, because their roots act as traps (Deng et al. 2021 ; Luo et al. 2021 ; Ding et al. 2021 al. 2022). Cispata's beaches are frequently cleaned by the community. Plastics such as bags, bottles, toys, ropes and disposable utensils were observed in the sand and their probable sources are the inadequate management of domestic waste, tourism and fishing in the area (Garcés-Ordóñez et al. 2020a ; 2020c ; 2021).).

Finally, the threat that microplastic contamination represents for the ecosystems evaluated is highlighted, mainly due to the transfer of toxic contents in plastics or adsorbed from the surrounding environment to the organisms that ingest it, generating a risk for food safety and the environment. livelihood of local communities (Antão-Barboza et al. 2018 ; Garcés-Ordóñez & Bayona-Arenas, 2019), since in the Cispata MPA it has been reported that fish with high local consumption have ingested microplastics (Garcés-Ordóñez et al. . 2020a).

Therefore, it is necessary to generate environmental awareness in the local community, authorities and other interested actors about the state of contamination of the AMP, to promote actions to prevent and mitigate the impacts of microplastics, and contribute to effective management of the AMP. . (Pomeroy et al. 2005; Garcés-Ordóñez et al. 2020a).

Among the actions required are: (i) environmental education days and garbage cleaning on beaches and mangroves with the communities; (ii) improvement in domestic waste management; (iii) reduce the production and consumption of disposable plastics; (iv) formulation of public policies related to marine litter and (v) research on the ecological, economic and social impacts of microplastic pollution in the MPA (Garcés-Ordóñez et al. 2020b; Rivera-Garibay et al. 2020).

CONCLUSIONS

The Cispata MPA is threatened by microplastic contamination, which comes from inadequate management of domestic waste, tourism and fishing activities in the area. Mangroves have a greater abundance of microplastics in their waters and sediments compared to the nearby tourist beaches evaluated. Secondary microplastics such as films, fragments, foams and filaments dominated in the two ecosystems, which are generated by fragmentation of larger plastics.

It is necessary to continue researching this problem by analyzing the types of polymers, impacts and effects of microplastics in these ecosystems. Likewise, it is recommended to carry out education and awareness campaigns to increase environmental awareness and generate positive changes that contribute to the reduction of plastic pollution.

REFERENCES

Antão-Barboza, L.; Vethaak, A.; Lavorante, B.; Lundebye, Alaska; & Guilhermino, L. (2018). Marine microplastic debris: an emerging problem for food security, food safety and human health. March survey. Bull. , 133 , 336-348. https://doi. org/10.1016/j.marpolbul.2018.05.047

Astorga-Pérez, A.; Ulate-Naranjo, K.; & Abarca-Guerrero, L. (2022). Presence of microplastics in marine species from the Las Baulas National Marine Park. Rev. Technol. March, 35 (2), 27-38. https://doi.org/10.18845/tm.v35i2.5466

Auta, H.; Emenike, C.; and Fauziah, S. (2017). Distribution and importance of microplastics in the marine environment: a review of sources, fate, effects and possible solutions. about In t. , 102 , 165-176. https://doi.org/10.1016/j.envint.2017.02.013

Bayona-Arenas, M. & Garcés-Ordóñez, O. (Eds). (2018). Diagnosis and evaluation of the quality of marine and coastal waters in the Colombian Caribbean and Pacific. REDCAM 2017 technical report. Periodical publication series No. 4 of INVEMAR, Colombia. INVEMAR. http://www.invemar.org.co/inf-redcam

Boucher, J. and Friot, D. (2017). Primary microplastics in the oceans: a global assessment of sources. Swiss. IUCN, https://doi.org/10.2305/IUCN.CH.2017.01.en

Brander, S.M.; Renick, V.C.; Foley, M.M.; Steele, C.; Woo, M.; Lusher, A.; and Rochman, C. M. (2020). Sampling, assurance and quality control: a guide for scientists investigating the occurrence of microplastics in matrices. Apply. Spectrosc. , 74 (9), 1099-1125. https://doi. org/10.1177/0003702820945713

Celis-Hernández, O.; Ávila, E.; Ward, R.D.; Rodríguez-Santiago, MA; & Aguirre-Téllez, JA (2021). Distribution of microplastics in urban versus pristine mangroves: use of marine sponges as bioindicators of environmental pollution. about Survey. , 284 , 117391. https://doi.org/10.1016/j.envpol.2021.117391

Coc, C.; Rogers, A.; Barrientos, E.; & Sánchez, H. (2021). Analysis of micro and macroplastics in the digestive tract of a sea cucumber (Holothuriidae, Holothuria floridana) from the Placencia lagoon, Belize. Caribbean. J. Sciences. , 51 (2), 166-174. https://doi.org/10.18475/cjos.v51i2.a2

CVS & INVEMAR. (2010). Comprehensive management plan for the Integrated Management District (IMD) of Cispata Bay La Balsa Tinajones and surrounding sectors of the estuarine delta of the Sinú River, department of Córdoba. Colombia. INVEMAR. http://www.invemar.org.co/redcostera1/invemar/docs/11028PIM_Cispata.pdf

da Silva, E.; Gloaguen, TV; dos Anjos, H.; Santos, T.; de Almeida, M.; Vinhas, O.; Rebouças, M.; & Gonzaga, J. (2022). Widespread contamination by microplastics in mangrove soils of Todos os Santos Bay, northern Brazil. on Res., 210, 112952.

https://doi.org/10.1016/j.envres.2022.112952

Day, J.; Dudley, N.; Hockings, M.; Holmes, G.; Laffoley, D.; Stolton, S. and Wells, S. (2012). Guidelines for the application of IUCN protected area management categories in marine protected areas. Switzerland: IUCN. https://portals.iucn.org/library/sites/library/files/documents/PAG-019-Es.pdf

Delvalle, D.; Fábrega, J.; Olmos, J.; Garcés-Ordóñez, O.; Amaral, S.; Vezzone, M.; & Anjos, R. (2020). Distribution of plastic waste on the Pacific and Caribbean beaches of Panama. Air, Soil Water Res., 13, 1-8. https://doi. org/10.1177/1178622120920268

Deng, H.; The J.; Feng, D.; Zhao, Y.; Sol, W.; Yu, H.; and Ge, C. (2021). Microplastic pollution in mangrove ecosystems: a critical review of current knowledge and future directions. Science. Total environment. , 753 , 142041. https://doi.org/10.1016/j.scitotenv.2020.142041

Dharmadasa, W.S.; Andrady, AL; Kumara, PTP; Maes, T. and Gangabadage, C.S. (2021). Microplastic pollution in marine protected areas of southern Sri Lanka. March survey. Bull. , 168 , 112462. https://doi.org/10.1016/j.marpolbul.2021.112462

Díaz-Jaramillo, M.; Islands, MS; & González, M. (2021). Spatial distribution patterns and identification of microplastics in intertidal sediments of urban and semi-natural estuaries urban and semi-natural areas of the southwest Atlantic. Reign. Survey. , 273 , 116398. https://doi. org/10.1016/j.envpol.2020.116398

Ding, C.; Jiao, M.; Wang, Y.; Yao, Z.; Illuminated.; Wang, W.; and Wang, Y. (2022). Distribution and retention of microplastics in plantation mangrove forest sediments. Chemosphere, 307 (Part 4), 136137. https://doi.org/10.1016/j.chemosphere.2022.136137

Garcés-Ordóñez, O. & Bayona-Arenas, MR (2019). Impacts of pollution by marine litter on the mangrove ecosystem of the Ciénaga Grande de Santa Marta, Colombian Caribbean. Rev. Hundred. Mar. Cost. , 11 (2), 145-165. https://doi. org/10.15359/revmar.11-2.8

Garcés-Ordóñez, O.; Saldarriaga-Vélez, J.; Espinosa-Díaz, L.; Canales, M.; Sánchez-Vidal, A. & Thiel M. (2022a). A systematic review on microplastic pollution in water, sediments and organisms 1 of 50 coastal lagoons around the world. Reign. Survey., 315, 120366. https://doi.org/10.1016/j.envpol.2022.120366

Garcés-Ordóñez, O.; Saldarriaga-Vélez, J.; Espinosa-Díaz, L.; Patiño, AD; Cusba, J.; Canales, M.; and Thiel, M. (2022b). Contamination by microplastics in water, sediments and commercial fish species of the Ciénaga Grande de Santa Marta lagoon complex, Colombian Caribbean. Science. Total environment. , 829 , 154643. https://doi. org/10.1016/j.scitotenv.2022.154643

Garcés-Ordóñez, O.; Espinosa, L.; Costa, M.; Salles, L.; and Meigikos, R. (2021).

Abundance, distribution and characteristics of microplastics in coastal surface waters of the Colombian Caribbean and Pacific. Reign. Science. Survey. Res., 28, 43431-43442. https://doi.org/10.1007/s11356-021-13723-x

Garcés-Ordóñez, O.; Mejía-Esquivia, K.; Sierra-Labastidas, T.; Patiño, A.; Blandón, L.; & Espinosa, L. (2020a). Prevalence of microplastic contamination in the digestive tract of fish from the Cispata mangrove ecosystem, Colombian Caribbean. March survey. Bull. , 154 , 111085. https://doi.org/10.1016/j.marpolbul.2020.111085

Garcés-Ordóñez, O.; Espinosa, L.; Pereira, R.; Issa, B.; and Meigikos, R. (2020b). Pollution by plastic garbage along sandy beaches on the Caribbean and Pacific coast of Colombia. Reign. Survey. , 267 , 115495. https://doi.org/10.1016/j.envpol.2020.115495

Garcés-Ordóñez, O.; Espinosa, L.; Pereira, R.; & Muñiz, M. (2020c). The impact of tourist activity on marine litter pollution on the beaches of Santa Marta, Colombian Caribbean. March survey. Bull. , 160 , 111558. https://doi.org/10.1016/j.marpolbul.2020.111558

Garcés-Ordóñez, O.; Castillo-Olaya, V.; Granados-Briseño, A.; Blandón, L. & Espinosa, L. (2019). Marine litter and microplastic contamination in mangrove soils of the Ciénaga Grande de Santa Marta, Colombian Caribbean. March survey. Bull. , 145, 455-462. https://doi.org/10.1016/j.marpolbul.2019.06.058

Harris, P.; Westerveld, L.; Nyberg, B.; Maes, T.; Macmillan-Lawler, M.; & Appelquist, L. (2021). Exposure of coastal environments to plastic pollution of river origin. Science. Total environment. , 769 , 145222. https://doi.org/10.1016/j.scitotenv.2021.145222

Hidalgo-Ruz, V.; Gutow, L.; Thompson, R.; and Thiel, M. (2012). Microplastics in the marine environment: a review of the methods used for their identification and quantification. Reign. Science. Technology. , 46 (6), 3060-3075. https://doi.org/dx.doi.org/10.1021/es2031505

Jiao, M.; Ren, L.; Wang, Y.; Ding, C.; Illuminated.; Chaos.; and Wang, Y. (2022). Mangrove forest: an important coastal ecosystem for intercepting riverine microplastics. Reign. Res., 210, 112939. https://doi.org/10.1016/j.envres.2022.112939

Jones, J.S. Guézou, A.; Medor, S.; Nickson, C.; Savage, G.; Alarcón-Ruales, D.; and Lewis, C. (2022). Distribution and composition of microplastics on two beaches of the Galapagos Islands, Ecuador: Verification of the use of data derived from citizen science in long-term monitoring. Reign. Survey. , 311 , 120011. https://doi. org/10.1016/j.envpol.2022.120011

Kovac, M.; Palatino, A.; Koren, Š.; Peterlin, M.; Horvat, P.; and Kržan, A. (2016). Sampling protocol for microplastics on the sea surface and sample analysis. J. Vis. Exp., 118, e55161. https://doi. org/10.3791/55161

Kutralam-Muniasamy, G.; Pérez-Guevara, F.; Elizalde-Martínez, I.; and Shruti, V. C. (2021). How well protected are protected areas from anthropogenic microplastic pollution? Review of analytical methods, current trends and perspectives. Trend environment. Anal. Chemistry. , 32 , e00147. https://doi.org/10.1016/j.teac.2021.e00147

Lebretón, LCM; van der Zwet, J.; Damsteeg, J.W.; Liston, B.; Andrady, A.; and Reisser, J. (2017). Plastic emissions from rivers to the world's oceans. Community Nat. , 8, 15611. https://doi.org/10.1038/ncomms15611

Li, J.; Zhang, H.; Zhang, K.; Yang, R.; Li, R.; and Li, Y. (2018). Characterization, origin and retention of microplastics on sandy beaches and mang wetlands of Qinzhou Bay, China. March survey. Bull. , 136, 401-406. https://doi. org/10.1016/j.marpolbul.2018.09.025

Li, W.; Tse, H.; and Fok, L. (2016). Plastic waste in the marine environment: a review of its source, occurrence and effects. Science. Total environment. , 566-567, 333-349. https://doi.org/10.1016/j.scitotenv.2016.05.084

Enlace, P. and Borchert, L. (2015). Ecosystem services in coastal and marine zones - State of the scientific art and research needs. In PM Link & L. Borchert (Eds.), Blickpunkt Küste: Aktuelle Forschungsansätze in der Meeresund Küstengeographie (pp. 6785). Germany, Coastline Reports 24. http://eucc-d-inline.databases.eucc-d.de/files/documents/00001195_CR24_AMK_2013.pdf

Lohr, A.; Savelli, H.; Beunen, R.; Kalz, M.; Ragas, A.; and Van F. (2017). Solutions for global marine litter pollution. current. Opinion. Reign. Sustainability, 28, 90-99. https://doi.org/10.1016/j.cosust.2017.08.009

Lorenzi, L.; Reginatus, before Christ; Mayer, CEO; Gentle, E.; Pezzin, A.; Silveira, V.; & Dantas, D. (2021). Spatial-seasonal distribution of microplastics along a shallow coastal lagoon ecocline within a marine conservation unit. Sea. Pollution. Bull. , 170 , 112644. https://doi.org/10.1016/j.marpolbul.2021.112644

Luo, Y.Y.; Not c.; and Cannicci, S. (2021). Mangroves as unique but understudied traps for anthropogenic marine debris: a review of current information and the way forward. Reign. Survey. , 271 , 116291. https://doi.org/10.1016/j.envpol.2020.116291

Mazariegos-Ortíz, C.; Rosales, M.; Carrillo-Ovalle, L.; Pereira, R.; Costa, M.; and Meigikos, R. (2020). First evidence of microplastic contamination on the sandy El Quetzalito beach in the Guatemalan Caribbean. March survey. Bull. , 156 , 111220. https://doi.org/10.1016/j.marpolbul.2020.111220

Medina-Contreras, D.; Cantera-Kintz, J.; & Sánchez, A. (2021). Trophic structure of fish communities in mangrove systems subject to different levels of anthropogenic intervention, Eastern Tropical Pacific, Colombia. Reign. Science. Survey. Res., 29, 61608-61622.

https://doi.org/10.1007/s11356-021-16814-x

Medina-Contreras, D.; Arenas-González, F.; Cantera-Kintz, J.; Sánchez-González, A.; & Giraldo, A. (2020). Food web structure and isotopic niche in a marginal macrotidal mangrove system, tropical eastern Pacific. Hydrobiology, 847(15), 3185-3199. https://doi. org/10.1007/s10750-020-04295-x

Moberg, F. and Rönnbäck, P. (2003). Tropical seascape ecosystem services: interactions, substitutions and restoration. Ocean Coast. Manage. , 46 (12), 27-46. https://doi.org/10.1016/S0964-5691(02)00119-9

Mohamed, N.H., & Obbard, J.P. (2014). Microplastics in Singapore coastal mangrove ecosystems. March survey. Bull. , 79 (1-2), 278-283. https://doi.org/10.1016/j.marpolbul.2013.11.025

Naji, A.; Esmaili, Z.; Mason, SA; and Vethaak, A.D. (2017). The emergence of microplastic pollution in the coastal sediments of the Persian Gulf of Iran. Reign. Science. Survey. Res., 24 (25), 20459-20468. https://doi.org/10.1007/s11356-017-9587-z

Ory, N.; Chagnon, C.; Felix, F.; Fernández, C.; Ferreira, JL; Gallardo, C.; and Thiel M. (2018). Low prevalence of microplastic pollution in planktivorous fish species from the southeastern Pacific Ocean. March survey. Bull. , 127, 211-216. https://doi.org/10.1016/j.marpolbul.2017.12.016

Pomeroy, RS; Watson, L.M.; Parks, JE; and Cid, GA (2005). How is your AMP doing? A methodology to evaluate the effectiveness of the management of marine protected areas. Coastal ocean management. , 48 (7-8), 485-502. https://doi.org/10.1016/j.ocecoaman.2005.05.004

Prata, JC; Castro, JL; da Costa, JP; Duarte, AC; Rocha-Santos, T.; & Cerqueira, M. (2020). The importance of pollution control in sampling airborne fibers and microplastics: indoor and outdoor air sampling experiences in Aveiro, Portugal. March survey. Bull. , 159 , 111522. https://doi.org/10.1016/j.marpolbul.2020.111522

Preciado, D. & Zapata, A. (2020). Pollution by marine litter and microplastic in prioritized points of mangrove soils in the municipality of San Andrés de Tumaco Nariño. (Unpublished undergraduate work). University Corporation of Cauca, Colombia.

Rangel-Buitrago, N.; Williams, A.; & Anfuso, G. (2018). Killing the goose that lays the golden eggs: Effects of garbage on the scenic quality of the Caribbean coast of Colombia. March survey. Bull. , 127 , 22-38. https://doi.org/10.1016/j.marpolbul.2017.11.023

Rech, S.; Thiel, M.; Borrell Pichs, YJ; & García-Vázquez, E. (2018). Travel light: contamination of biota by macroplastics washing up on the beaches of remote Rapa Nui (Easter Island) in the subtropical gyre of the South Pacific. March survey. Bull., 137, 119-128. https://doi.org/10.1016/j.marpolbul.2018.10.01

Rivera-Garibay, O., Álvarez-Filip, L., Rivas, M., Garelli-Ríos, O., Pérez-Cervantes, E. & Estrada-Saldívar, N. (2020). Impact of plastic pollution in Mexican protected natural areas. Mexico. Green Peace. https://www.greenpeace.org/static/planet4-mexico-stateless/2020/08/0ead5354-impacto-de-la-contaminacion-por-plastico-resumen.pdf

Wang, J.; Tan, Z.; Peng, J.; Qiu, Q.; and Li, M. (2016). The behaviors of microplastics in the marine environment. Sea. Environment. Res., 113, 7-17. https://doi.org/10.1016/j.marenvres.2015.10.014

Weiss, L.; Luis, W.; Heussner, S.; Canales, M.; Ghiglione, JF; Estournel, C.; & Kerhervé, P. (2021). The missing ocean plastic sink: the rivers took it away. Science, 373(6550), 107-111.
https://doi.org/10.1126/science.abe0290

Wright, SL; Thompson, R. C.; and Galloway, T. S. (2013). The physical impacts of microplastics on marine organisms: a review. Reign. Survey. , 178, 483-492.
https://doi.org/10.1016/j.envpol.2013.02.031