PLASTIC POLLUTION FREE GALAPAGOS

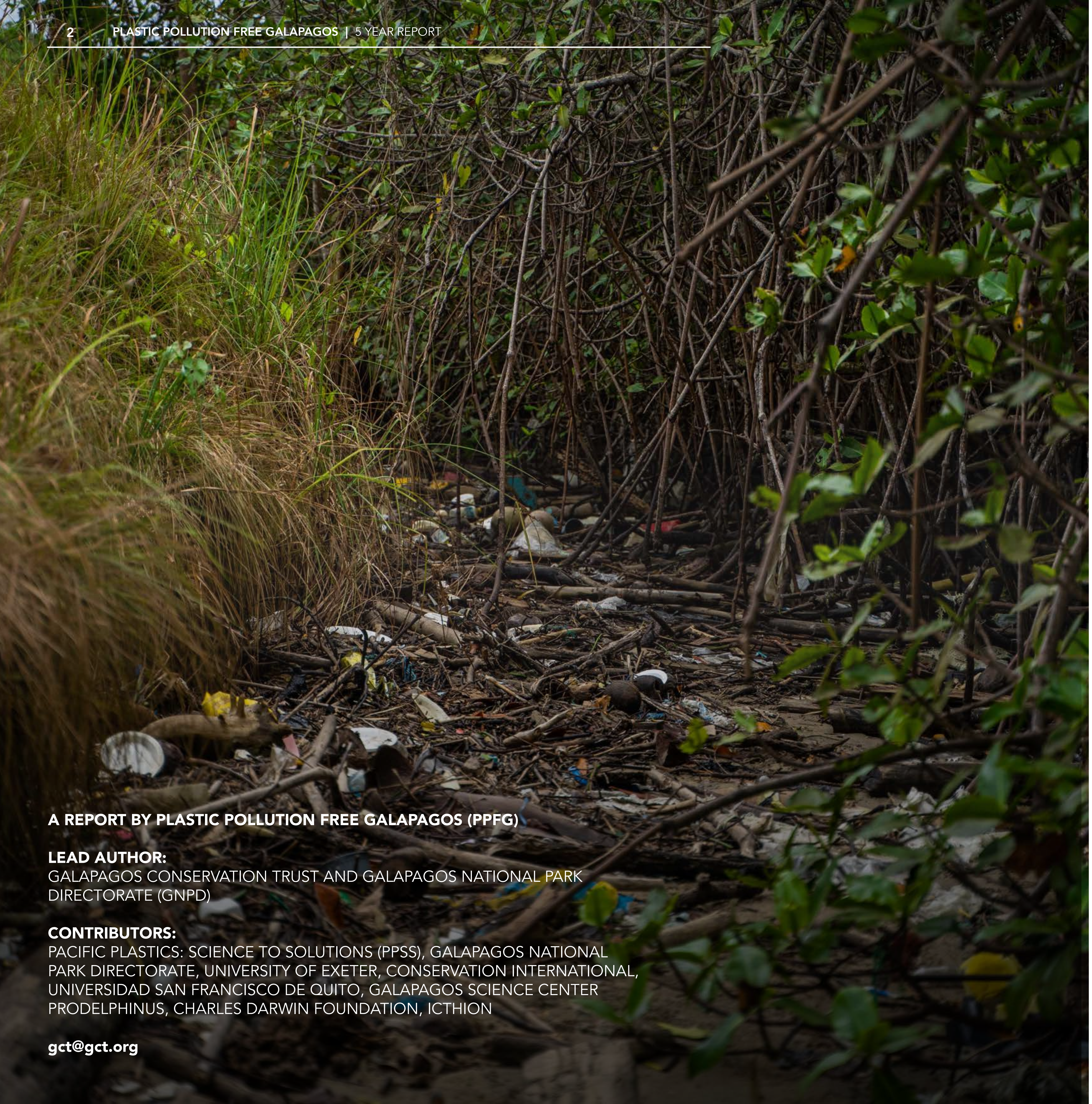
5 YEARS OF SCIENCE TO SOLUTIONS

September 2024

Galapagos Conservation Trust

Parque Nacional GALÁPAGOS Ecuador

PACIFIC PLASTICS SCIENCE TO SOLUTIONS



A REPORT BY PLASTIC POLLUTION FREE GALAPAGOS (PPFG)

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FOREWORD

"I'll never forget the sensation of swimming in a bay where there were so many plastic fragments floating, the water was clicking. I'll never forget seeing fishing lines taking the place of seaweed in the nest of the first ever flightless cormorant I saw. I'll also never forget the feeling of seeing barnacles with all of their feeding appendages bound in polypropylene microfibres likely from ropes. I frequently wonder what historical naturalists would think about the prevalence of this novel material in the environment – plastic. In a place that in some ways, has barely changed since Charles Darwin visited in 1835, the growing rainbow of plastic accumulating on the remote shores of the Galapagos Islands has been disturbing to witness and represents a major call to action for human beings around the globe.

The increase in marine plastic pollution, a tangible side effect of global consumerism, has raised concerns all over the world for ecologically vulnerable ecosystems such as Galapagos. A rising tide of single-use plastics and lost fishing gear is entering the Galapagos Marine Reserve from outside sources, demonstrating that a regional approach is urgently required to tackle the issue.

The Pacific Plastics: Science to Solutions network represents targeted action from grassroots to Government, transforming science to effective solutions. With major input from students and early career researchers, we have developed a wonderfully supportive network that is creating a strong foundation for future solutions. We need multi-disciplinary science, civil society, industry and policy to come together, and here they do. We now need a strong Global Plastics Treaty to revolutionise how plastic is used and to create greater accountability for polluters across the entire supply chain. We are calling for a fair transition to an inclusive circular economy that enhances livelihoods and for better waste management for fisheries and shipping. To increase the power of islander voices, we are building connections across the entire Pacific to share knowledge, experiences and develop aligned goals.

The world needs an example of a marine reserve that is truly protected from plastic pollution. We believe that the Galapagos Marine Reserve can be the first place to achieve this. With the Pacific Plastics: Science to Solutions network, we remain committed to supporting local communities and marine managers achieve their vision of a pollution-free ocean. Please join us in this plight. We need all hands on deck!

Thank you for your interest in this report, summarising findings from the first five years of plastics research. We welcome any feedback and conversations, so please do get in touch.

With best wishes for a protected ocean, free from plastic pollution!"

Jen Jones, Chief Executive Officer, Galapagos Conservation Trust

ABOUT THIS REPORT

This report covers our current knowledge on the international plastic footprint affecting Galapagos, highlighting oceanic inputs and the impacts on wildlife and communities. We anticipate a second volume that will explore local plastic consumption and waste management and celebrate progress towards a circular economy for plastics in Galapagos, highlighting solutions from grassroots to Government that are already underway.

GLOSSARY AND ACRONYMS

Macroplastics
Plastic items larger than 5 mm in size, referred to as 'macroplastics' once they enter the environment.

Microplastics
Very small pieces of plastic, < 5 mm in size.

EPO (Eastern Pacific Ocean)

ETP (Eastern Tropical Pacific)

FADs (Fish Aggregating Devices)
Man-made floating objects used to aggregate open water fish. FADs can be comprised of a combination of natural and non-natural materials, and some have appendages (nets, ropes) hanging beneath the surface.

GMR (Galapagos Marine Reserve)

GNPD (Galapagos National Park Directorate)

IATTC (Inter-American Tropical Tuna Commission)
The regional fisheries management organisation (RFMO) responsible for conservation and management of the tuna fishery in the EPO.

IUU (illegal, unreported, and unregulated) fishing

PPFG (Plastic Pollution Free Galapagos)
GCT's flagship programme, initiated in 2018, to work on how to reduce plastic pollution in Galapagos. We partner with a wide variety of local partners to research the problems caused by plastics and trial locally relevant solutions.

PPSS (Pacific Plastics: Science to Solutions)
International network coordinated by Galapagos Conservation Trust and the University of Exeter, working across the whole South-Eastern Pacific region to reduce plastic pollution.

UNESCO (The United Nations Educational, Scientific and Cultural Organization)

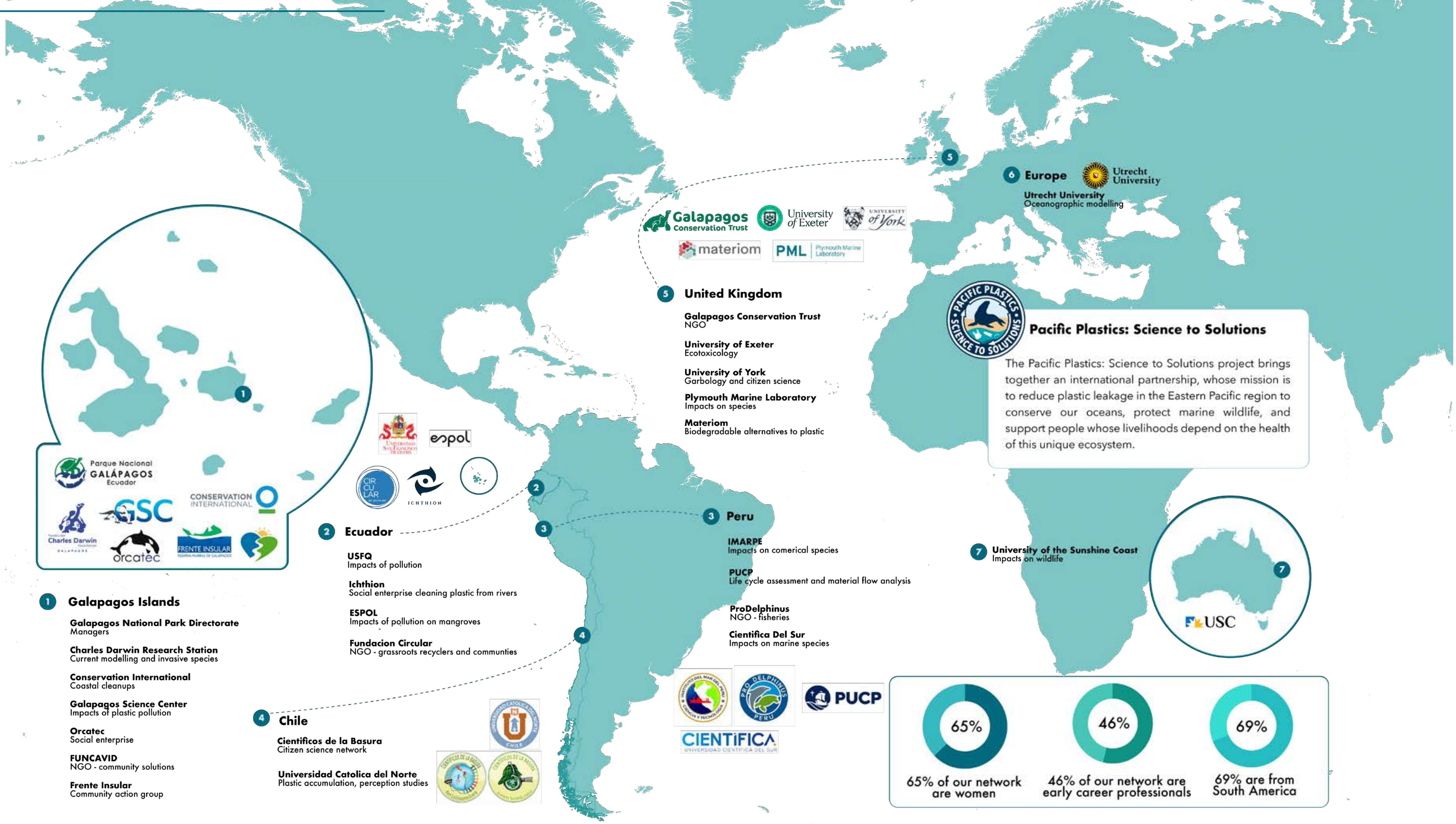
WHO WE ARE

We are an international network of scientists, NGOs, businesses, decision-makers and community members committed to achieving a 'Plastic Pollution Free Galapagos'.

To support the critical work by the Inter-institutional Commission for Responsible Plastics Use in Galapagos launched in 2014, the 'Plastic Pollution Free Galapagos' (PPFG) programme is coordinated by Galapagos Conservation Trust (GCT), the only UK-based NGO focused solely on the conservation of the Galapagos Islands, Ecuador. The PPFG programme is split into three streams:

- **The physical system** (where does plastic pollution come from, how does it get to Galapagos, and what happens to it once it arrives?)
- **The biological system** (which species are most at risk from marine plastic, how does it move through the ecosystem, how might this impact tourism and fisheries and how do we lower those risks?)
- **The human system** (what are the main barriers to plastic alternatives, how effective are policy changes, and what is the most effective form of education and awareness?).

The PPFG programme began in May 2018, when GCT delivered the first 'Science to Solutions' workshop in Galapagos, bringing together key stakeholders across Santa Cruz and San Cristobal islands. This was hosted by local partners, Galapagos Science Center (part of the Universidad San Francisco de Quito (USFQ)), the Charles Darwin Foundation (CDF) and the Galapagos National Park Directorate (GNPD).



Together over the last 5 years, through many workshops, stakeholder consultations and a series of projects, we have accumulated substantial knowledge on the issue of plastic pollution in Galapagos, filling major knowledge gaps identified during this original workshop.

Our impact has been significantly increased by the establishment of the regional Pacific Plastics: Science to Solutions (PPSS) network, co-run with the University of Exeter, which is working to reduce plastic pollution in the South-Eastern Pacific region. The PPSS network is made up of more than 20 organisations, with individuals located in Ecuador, Peru, Chile, Australia, the Netherlands and the UK.

Grateful thanks are extended to many wonderful individuals and organisations that have helped us to achieve the progress presented in this report over the last 5 years.

Our supporters:

Beatrice Ederer-Weber Foundation
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The Woodspring Trust
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Mikael Olufsen
Norwegian Retailers Environment Fund
Open Gate Trust
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EXECUTIVE SUMMARY

PLASTIC POLLUTION IN THE GALAPAGOS ISLANDS

The Galapagos Islands, situated 930 km off the coast of Ecuador in the Eastern Pacific Ocean, are famous for their endemic biodiversity and situation within an important marine corridor for migratory marine species. Both the Galapagos National Park and the surrounding Marine Reserve are UNESCO World Heritage Sites in their own right, since 1978 and 2001 respectively, together making the Galapagos Biosphere Reserve[1]. The Galapagos Marine Reserve now covers a total area of almost 200,000 km^2, including the extension established in 2022 known as the Hermandad Marine Reserve that comprises 30,000 km^2 of no take zone and 30,000 km^2 no long-lining zone to the north-east of the original marine reserve, all together making up 96% of Ecuador's total ocean protection[2]. At the time of writing in early 2024, Ecuador has protections of some category in 18.9% of their national waters.

"Plastic does not respect the boundaries of marine reserves"

Despite this level of protection and its global reputation as a biodiversity hotspot and conservation priority, the Galapagos Islands, like most oceanic islands, are subject to a major influx of plastic pollution; the ocean is often the ultimate fate for mis-managed plastic waste. Many types of plastic float in seawater and can be transported over long distances on ocean currents, eventually beaching on land masses (such as oceanic islands), concentrating in floating 'garbage patches' or sinking to the seafloor. When plastic pollution is concentrated in an area such as a marine reserve, brimming with biodiversity and productivity, this novel pollutant poses substantial ecological and socioeconomic risks.

Isolated island ecosystems tend to be particularly vulnerable to threats such as habitat degradation, over-exploitation (e.g. fishing/hunting), invasive species and pollution, evidenced by the fact that despite only representing 5% of Earth's land mass, islands have seen 61% of known species extinctions[3,4]. The Living Planet Report by the Worldwide Fund for Nature reports a 69% decline in global vertebrate species over the last several decades, with Latin America showing the greatest regional decline in average population abundance at 94%[5]. Research has shown that plastic pollution can exacerbate negative impacts of other threats such as climate change and invasive species, meaning that reducing this additional risk is paramount to improving the survival outlook for vulnerable species and increasing resilience to future shocks.

Oceanic island communities, such as those in Galapagos, are increasingly bearing the brunt of international plastic litter arriving from external sources and accumulating along coastlines. This influx of pollution is constant, and communities are compelled to fund costly clean-ups that add increasing pressure to their over-burdened waste management systems. This problem is continuing to grow – since the launch of PPFG in 2018, global plastic production has increased by about 7%, with an estimated 44% produced for single-use packaging[6]. Plastic pollution entering the ocean and rivers is predicted to triple in the next twenty years if substantial solutions are not implemented quickly, with global ocean plastic pollution predicted to reach 23 – 37 million tons per year by 2040[7].

In this report, we collate the current state of knowledge on the plastic pollution issue in Galapagos, summarising the results of the first 5 years of the Plastic Pollution Free Galapagos programme.

Together with our network, we reiterate the need for a legally binding Global Plastics Treaty to tackle the plastic pollution issue in the long-term at a global scale, whilst maintaining urgent local action to reduce risk to islands and their biodiversity.

"Galapagos is the world's crown jewel, and still the world pollutes it." – **Alberto Andrade,** Frente Insular.

"We go to the beach expecting to find it clean, but instead we find plastic on it. Plastic that has been dragged here by ocean currents. Then, we see sea lions playing with that trash. It's like you're somewhere else, Galapagos shouldn't be this way." – **Joyce Robalino,** Galapagos Hub.

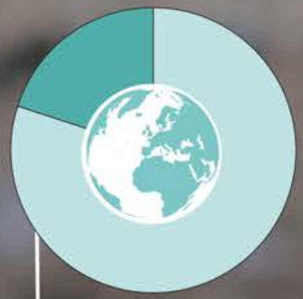
"As Galapagueños, we witness the impacts of pollution daily. In my experience working in coastal clean-ups, I've seen that it's almost impossible to not run into situations where some species are trapped in plastic." – **Salome Castro,** student.

©Tom Shlesinger

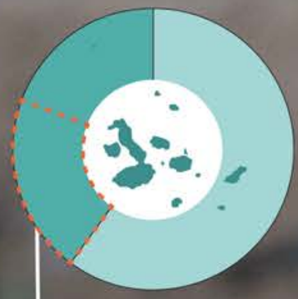
Oceanic islands are being unfairly impacted by plastic pollution

5 years of plastic research in the Galapagos Islands

At least 40% of pollution in Galapagos is from maritime sources, **double the global trend**



Globally
20% plastic pollution is from maritime sources

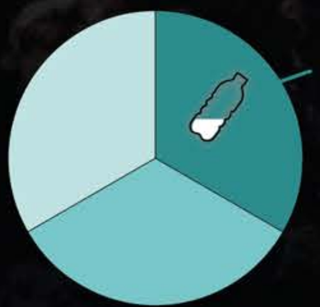


Galapagos
40% plastic pollution is from maritime sources

OVER **2,500**
microplastics found per m² on the most polluted beaches in Galapagos, which are very difficult to clean

69%
of plastic items found on Galapagos Island coastlines are single-use items

>$1.5 million
estimated to clean and monitor Galapagos coastlines each year



1/3
Single-use items found on Galapagos beaches are linked to **drinks**

1/3
of bottles found are **water bottles**

52

52%
Galapagos marine invertebrates sampled contained microplastics

52 species
found either entangled in or ingesting plastic, 20 of which are endemic

TOP 5

the top five species at greatest risk of harm due to entanglement are green sea turtles, marine iguanas, whale sharks, spine-tail mobulas, medium-ground finches

>95%
the majority of coastline plastic is coming from outside the Galapagos Marine Reserve

Accumulation higher on windward shores

SOURCES OF PLASTIC POLLUTION IN GALAPAGOS

OCEANIC POLLUTION

On the coastlines of the Galapagos Islands, most of the plastic pollution (>95%) is coming from outside the Galapagos Marine Reserve (GMR), travelling into the Archipelago on the strong convergence of oceanic currents to the east of the Islands. Plastic pollution originating from outside the GMR comes from two main sources; coastal inputs from continental Central and South America, and at-sea pollution from maritime sources, notably international fishing fleets.

At-sea littering and losses from maritime sources.

It is estimated that globally 20% of ocean plastic pollution is from maritime sources[8]. However, our evidence suggests that this proportion is at least **DOUBLE** in the Galapagos Islands (estimated at least 40%). The dominant fishery in the area is the industrial and semi-industrial tuna fishing fleet made up of >4,450 vessels across 22 Flag States, for which vessels using longlines (46%), trolling (19%), 'multi-purpose' (18%) and purse seine (7%) fishing methods represent the largest groups[9].

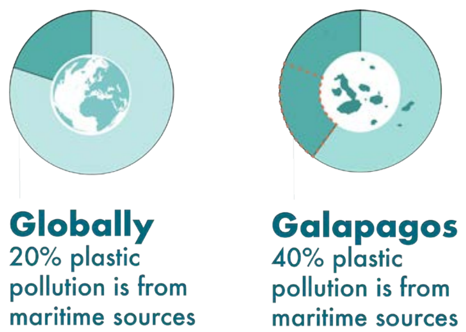


Figure 1. Estimated percentage of coastal plastic pollution from maritime sources globally and in the Galapagos Marine Reserve.

Plastic pollution on the High Seas

Fisheries operating in the Eastern Pacific are a major source of plastic waste, both via littering/loss of gear but also domestic plastics that are dumped after being used onboard, as indicated by plastic bottles with Asian lettering being washed up during the fishing season, and in good condition (little degradation or biofouling) suggesting they haven't been in the marine environment for long. This phenomenon has also been reported in other islands such as the South Atlantic islands[10], suggesting intentional disposal overboard, likely within countries' Exclusive Economic Zones as well as in the High Seas contrary to MARPOL convention[11,12].

Oceanographic modelling confirms that these plastic bottles are entering the ocean surrounding the GMR, as oceanic currents are insufficient to transport plastic from Asia to the Galapagos Marine Reserve. When simulated particles are released in the model, we can observe that this plastic does enter the GMR and accumulates on Eastern-facing shorelines, reflecting the actual findings.

This highlights the urgent need for the enforcement of existing international laws on plastic waste management at sea.

Of the beached plastic found washed up on Galapagos coastlines, preliminary models suggest that the majority of waste generated at-sea enters the ocean in international waters, followed by the Peruvian Economic Exclusion Zone (EEZ), with the predicted flag distribution of plastic waste coming from Chinese fleets, followed by Peruvian fleets.

Models also suggest that the sources of plastic entering the GMR from external sources are likely to originate from a narrow stretch of South American coastline, and fishing fleets near the GMR, as shown in Figure 2[11].

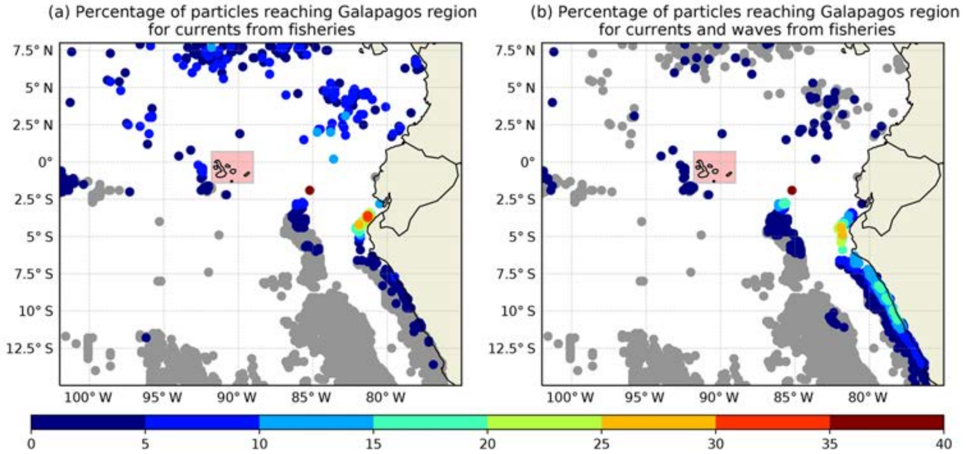


Figure 2. Maps from the "Fate from regional fisheries" scenario, showing the percentage of particles that reach the Galápagos region (red box) from each of the 3885 locations where at least 24 h of fishing was reported in the Global Fishing Watch dataset (Kroodsma et al., 2018). Panel (a) shows percentages for the currents-only simulation and (b) the percentages for the currents+wave simulation. Floating particles from most of these locations have a zero probability of ending up near the Galápagos within 5 years (grey circles), but there are extensive regions of non-zero probabilities (coloured circles) near the Peruvian and Ecuadorian coasts. ©University of Utrecht 2019[11]

Plastic pollution from artisanal fisheries

Within the Galapagos Archipelago, only artisanal small-scale fishing is permitted under management by the Galapagos National Park Directorate. This fishery is a cornerstone of the community, providing livelihoods and food security, and increasing the resilience of the Islands' human inhabitants. There are currently 188 active small-scale fishing vessels (i.e., less than 12.5 metres length) in Galapagos[13], but very little is known about their on-board waste management procedures.

During interviews with 28 artisanal fishers, we identified the most common types of solid waste generated, how waste is segregated on board, and how it's sorted and disposed of on land. Most of the fishers reported that they separate organic and inorganic waste, but the separation of recyclables from non-recyclables appears to be far less frequent. They used many types of products during their fishing activities and applied different ways to dispose of their waste. Only the cylinders for water were reported to be 100% reused (refilled) and all the remaining products ended up in the sea in small percentages.

All fishers mentioned disposing of recyclables and other solid waste using bins placed at the port, however recent observations have shown that the bins at the port are either not present or poorly managed. We identified highly used important items that have a potential risk to the environment, such as plastic sacks and batteries (often used by night divers).

The majority of fishers have observed lost or discarded fishing gear within the GMR, most notably Fish Aggregating Devices (FADs) or longlines, both being attributed to industrial fishing fleets positioned just outside the GMR. While the local input is much less significant in comparison to the much larger industrial fleets, nearly half of the fishers interviewed reported often losing pieces of fishing gear and some admitted to purposefully discarding plastic, tetrapaks and glass directly into the ocean.

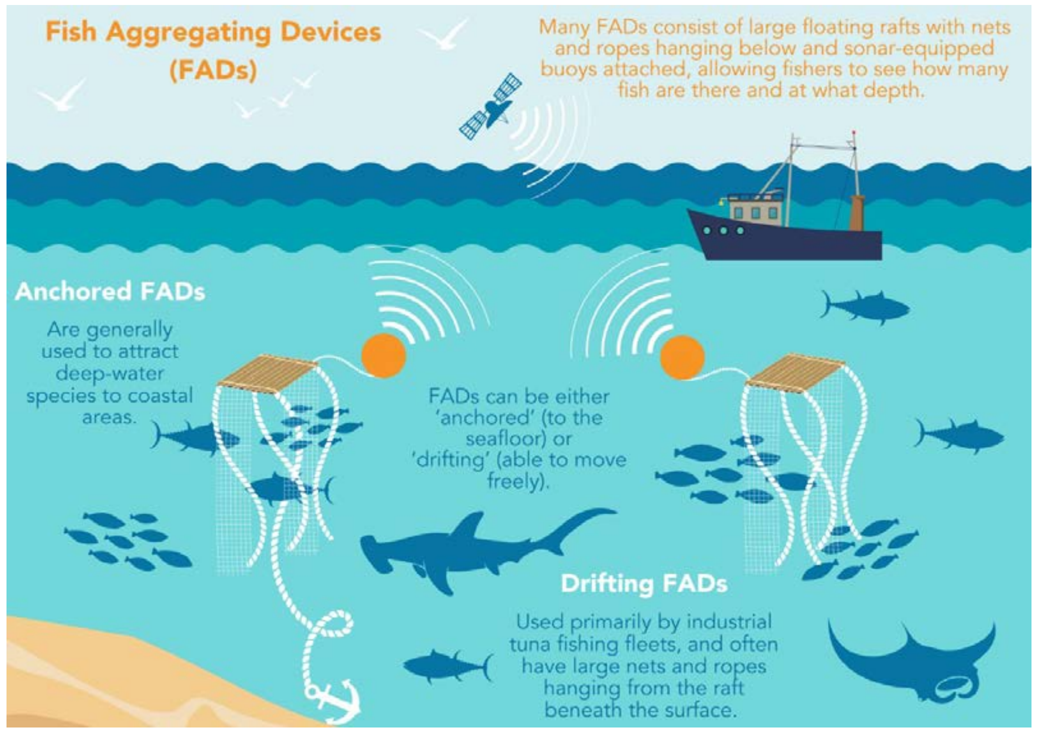
Regarding their perception about marine debris, most of the interviewed identify solid waste as a problem, and plastic as the product with the biggest impact on the environment. However, their perception about whether plastic debris affects their fisheries or not is unclear.

Figure 3. Image of missing waste disposal at port on San Cristobal Island ©ProDelphinus.

FADs in the Galapagos Marine Reserve

Drifting FADs are a widely used fishing method used by the tropical tuna purse-seine fishery in the Eastern Pacific Ocean (EPO), a globally significant fishery (second largest). Ecuador has the largest number of registered active purse-seine vessels in the region (113, representing 50% of the country's total industrial fleet)[9]. FADs are often comprised of a combination of man-made (e.g. plastic sheeting, floats) and natural materials (e.g. bamboo poles, logs) comprising a raft, and some also have submerged plastic nets and/or ropes – often ranging between 30-80m in length, and can contribute to marine pollution through breakdown into microplastics or heavy metal pollution from electronic components and batteries in satellite buoys[14]. Satellite buoys attached to drifting FADs enable vessels to re-locate them, with more sophisticated buoys also using sonar to assess fish density beneath them.

Figure 4. FADs infographic, ©GCT.



The Inter-American Tropical Tuna Commission's (IATTC, the Regional Fisheries Management Organization for the EPO) Working Group on FADs identified about 60% of catches in 2021 were associated with floating objects, the vast majority of which are FADs, but this also includes natural floating objects[15]. Annual estimates for FAD deployment in the EPO between 2006-2013 ranged between 8,006 and 14,110 per year[16], and current IATTC regulations allow for the largest vessels to have up to 340 FADs active at any one time[17]. However due to the nature of drifting FADs combined with concerns about poor transparency and observer coverage[18], it is difficult to know the true number of FADs in the ocean globally. Moreover, the IATTC recognises that there is a diverging trend between FAD deployment (increasing) and retrieval (decreasing) over time[15], and there is little accountability for the vessels responsible for their deployment.

When FADs are lost or disregarded in the ocean, they become a form of plastic pollution or 'ghost' fishing gear, posing an entanglement risk to threatened marine megafauna, such as highly over-fished silky sharks[19]. They also cause damage to sensitive habitats, with many ending up beached on coastlines and reefs damaging sensitive habitats, as was recently highlighted in the Western and Central Pacific islands[20]. This has also been observed in Galapagos. Drifting FADs can travel great distances on currents, with 96.3% of buoys found beached in French Polynesia traced back to fleets from the IATTC, further highlighting FAD retrieval issues. Moreover, plastics used in the structure of FADs will eventually break down into microplastics, and there is a risk of heavy metal pollution from the electronic parts and batteries of buoys, but this is poorly studied[21].

A gap in data for FAD stranding events in the EPO is recognised[21]. Through anecdotal records and pilot data collected by GCT and our PPFG partners, we estimate (data still under analysis) to have recorded at least 150 FADs in the GMR in the last five years[21] and this is likely a significant underestimate. There are concerns that purse-seine vessels are deliberately releasing FADs on the eastern boundary of the GMR, which then drift through the GMR on the South Equatorial Current and eventually leave the Reserve – taking with them the community of fish they have aggregated to be caught outside the GMR boundary[22]. Using FADs to fish in this way not only increases the risk of FADs beaching on and polluting Galapagos' coastlines, but is a form of illegal, unreported and unregulated (IUU) fishing[18]. The presence of FADs in the GMR also poses a threat to the livelihoods and safety-at-sea of local fishers.

Figure 5. A baited, drifting FAD found just off the coast of Santa Cruz island, Galapagos, 2023. ©GCT.

Concerns are supported by oceanographic modelling of plastic released from high-intensity fishing areas to the east of the GMR, which show that the currents drag items into and throughout the Archipelago, accumulating on east-facing coastlines[11] – also supportive of the theory that much of the plastic found in Galapagos is also discarded from these international fishing vessels. This is reflected in where beached FADs have been observed in Galapagos, including from preliminary analysis of drone footage[23]. However, generally there is a lack of scientific data on FADs in the GMR, and filling knowledge gaps on FAD quantities, sources (including vessels and associated Flag States), pathways and beaching locations will be vital for providing evidence-based recommendations for improved regulations.

Addressing the threat of FADs is a major priority of the GNPD and PPSS network, as echoed during our multi-stakeholder workshops in Lima (PPSS-led, November 2022) and Galapagos (GNPD-led, March 2023), and is a priority research, community engagement and policy focus for GCT moving forward. Building on the data we have collected over the past 5 years through the PPFG programme, in 2024 we are starting a programme that works closely with the GNPD and PPSS partners to produce a case study on FADs in the GMR, aiming to leverage this evidence to strengthen management and regulations for FADs around Galapagos, regionally and internationally.

SOURCES OF PLASTIC POLLUTION IN GALAPAGOS

COASTAL AND CONTINENTAL POLLUTION

Coastal inputs from continental Central and South America.

It is estimated that globally 80% of ocean plastic pollution is from continental sources[8].

Key insights include:

- More than 95% of coastal plastic pollution is traced back to sources located outside the Galapagos Marine Reserve.
- Oceanographic models have pinpointed northern Peru, southern Ecuador, and, during the warm season, Panama, as the primary continental sources of plastic pollution reaching Galapagos[11].
- Plastic waste entering the ocean from continental Ecuador may take ~3 months to reach the shores of the Galapagos Islands[11].
- Many plastic items (e.g. domestic food packaging) could be either from international fishing fleets or could have entered the ocean via rivers.

Oceanographic models

Understanding the sources, movement and fate of plastic pollution entering the Archipelago at broad and fine scale is key to informing effective management. Central to this work are a series of predictive oceanography computer simulations developed by Utrecht University that model the flow of plastics entering the Reserve. Using a continental-scale model, we have concluded that remote sources of plastic pollution to Galapagos are largely from South and Central American coastlines, in particular Northern Peru and Southern Ecuador. It's estimated to take an average of ~3 months for plastic entering the ocean from the continental coast to reach the Galapagos Islands.

By coupling increasingly high-resolution data on ocean surface currents with strategic observational data collected on environmental plastic pollution at a regional scale, numerical model simulations have become important tools to estimate the sources, sinks, and pathways of plastic in the marine environment. To develop a high-resolution Archipelago-scale oceanographic model, we have also released almost 50 drifters (floating sensors) around the Archipelago that are carried by ocean currents as plastic would be. This data is being used to identify nearer sources and predict how pollution moves within the GMR to inform clean up, as well as education and advocacy campaigns, increasing the cost effectiveness and impact of each.
Ecuador and Peru combined generated an estimated 304,000 tons of mismanaged coastal plastic waste in 2010, projected to increase to 558,000 t by 2025[24]. Models suggest that only a small amount of plastic is entering Galapagos from known industrial fishing grounds but this does not reconcile with unpublished coastal clean-up data or archaeological analysis of macroplastic items that suggest maritime sources are likely a significant contributor[11,12].

Figure 6. Oceanic drifter released into GMR to groundtruth oceanographic models. ©Charles Darwin Foundation.

Figure 7. The Azure system, located at the Portoviejo River city of Portoviejo, Ecuador. ©Andrea Osorio Baquero.

Continental river

Within the PPSS network, a set of interventions are being developed and implemented to tackle plastic pollution in the Galapagos Archipelago. One initiative focused on land-based plastics is the Azure system, designed to work as a river monitoring and clean up solution. The Azure was designed by Dr Inty Grønneberg, CEO and co-founder of Ichthion, an Ecuadorian-British start-up company that uses sustainable technologies to protect and restore marine ecosystems, supported by principles of circular economy, innovation, and environmental management. The Azure system consists of a barrier that can capture large, buoyant waste in rivers, which allows both characterisation of this type of contamination but also the collection of this material for repurposing and/or recycling. It is designed to be a commercially feasible solution that can be easily applied to different river systems and across deprived areas in developing economies that suffer with environmental contamination. Ichthion has developed partnerships with different recycling companies that help with the circular aspect of this intervention.

The first barrier has been installed in the Portoviejo River, (Figure 8), and has been active since January 2021. The system is located at 1° 01′ 23.9″ S, 80° 29′ 35.6″ W, downstream from the city of Portoviejo in the province of Manabí, in Ecuador. This river runs northwards until it reaches the Pacific Ocean at the city of La Boca and is likely to be a source of plastic contamination to the ocean and potentially the Galapagos Archipelago.

As of December 2022, tonnes of anthropogenic litter have been recovered from the Portoviejo River using the Azure system (Pinheiro et al., in prep). The types of anthropogenic litter caught by the barrier suggests the lack of an effective waste management system in the city of Portoviejo, which leads to deliberate waste disposal by local communities on the river margin. Having the data generated from the Azure system deployment, we can point to appropriate insights on policies that can embrace circular economy principles to ultimately reduce plastic pollution in the Eastern Pacific region.

TOP POLLUTERS

In Galapagos, just 4 parent companies account for over half (53.22%) of the total number of branded plastic items found polluting coastlines all over the Archipelago.

In a recent analysis of >450 macroplastics collected from Galapagos coastlines, the country of origin, manufacturer and polymer types were analysed to help identify sources and highlight responsible companies. In total, 98 manufacturers were identified, with the most commonly found brands being AjeGroup (20%), the Coca-Cola Company (18.2%), Tingyi Holding Corporation (8.8%) and Pepsico (6.22%)[27].

The international footprint of plastic pollution arriving in Galapagos is also revealed in this analysis, with 14 countries identified as sources from the branding information alone. Of the 14 countries identified, Peru accounted for 46.14%, Ecuador 24.4%, and China 18.32% of the traceable plastic products[27].

Peru and Ecuador contributing to more than 70% of branded plastic items found on Galapagos shorelines may be as expected, since we know that oceanic currents drag floating plastic from the continent out to the Galapagos islands[11]. What may be surprising however, is the high proportion of Chinese-branded items arriving across the Archipelago. The same oceanographic models that predict the arrival of pollution from Peru and Ecuador, indicate that it is highly unlikely that floating plastic could travel from Asia to Galapagos using only ocean currents. What the data doesn't show, is where and how the plastic items enter the ocean. On the high seas surrounding the Galapagos Marine Reserve and Ecuadorian Economic Exclusion Zone, there is significant industrial international fishing activity. Researchers observed that the Chinese labels were clearly legible, lacked biofouling, and had recent expiration dates, suggesting that they had been in the environment for a relatively brief period of time. This supports the theory that such plastics are being consumed on board international fishing vessels before being disposed of at sea, and consequently swept into the nearby GMR.

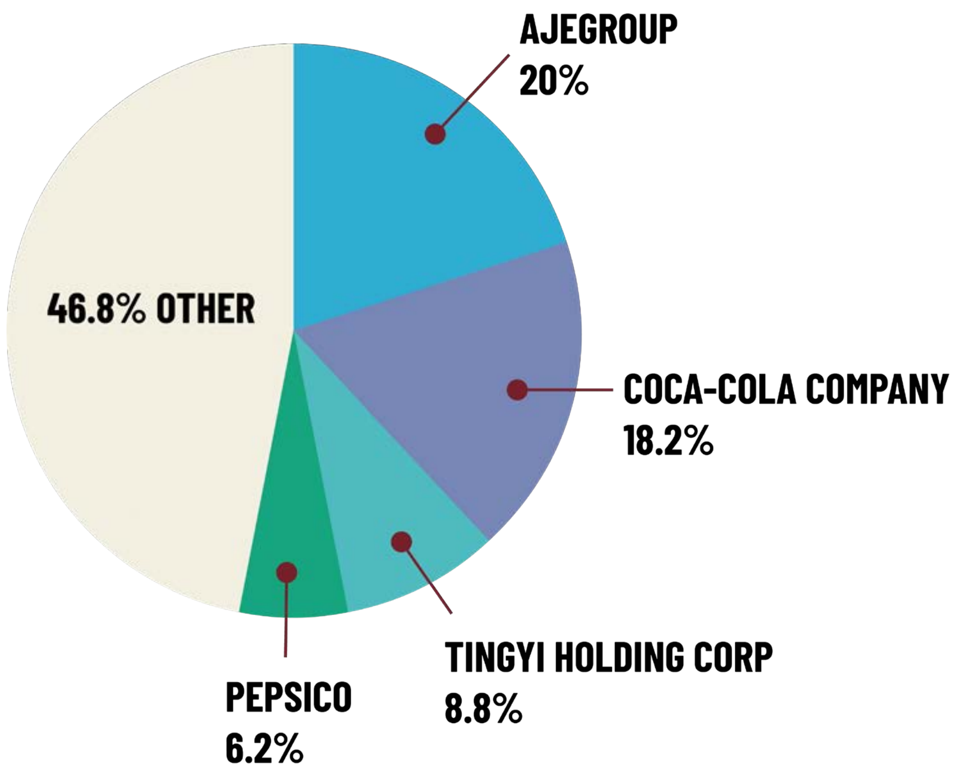


Figure 8: Top 4 polluting brands found on Galapagos coastlines, adapted from Muñoz-Pérez (2023).

SOURCES OF PLASTIC POLLUTION IN GALAPAGOS

LOCAL SOURCES OF POLLUTION

Terrestrial island pollution washed or blown into coastal environments

- Less than 2% of the plastic pollution discovered along the coastlines of the Galapagos is believed to originate from local sources within the Archipelago[35].
- Nevertheless, terrestrial urban and suburban regions are witnessing a growing problem of plastic pollution due to littering and waste management challenges on the islands.

Currently, we are mapping terrestrial plastic flows in the Galapagos Islands, which will allow us to identify potential sources of leakages and interventions to reduce them. During June and July of 2023 leakage of litter in the built environment was quantified through the collection and classification of litter in 40 kerbside transects on Santa Cruz Island. Results showed that the majority of litter that leaks from local sources is plastic[35]. This is reflected in a recent study of giant tortoise faeces in a human-modified area, where plastics were the predominant material found in faeces, followed by cloth, metal, paper, rubber, construction materials and glass[38].
Important measures have been implemented to reduce the impact of plastic pollution on these fragile ecosystems and biodiversity. Nonetheless, the research undertaken to understand the impact of domestic sources reveals the following crucial findings:

Figure 9. Urban litter surveys on San Cristobal island, Galapagos. ©Jen Jones

Littering in situ by beach visitors

In comparison with the mainland, littering is considered to be low on Galapagos beaches[25,26]. Although representing a low percentage of the overall plastic found at an island scale, some beaches did show evidence of probable littering mostly from single-use food and drinks items such as confectionary wrappers, lolly sticks, single-use cups and small plastic bags. Commonly scoring as the highest occurring item on other beaches, cigarette litter was very low on Galapagos beaches, testament to low littering rates and strong enforcement of Galapagos National Park regulations within guided tour groups.

Figure 10. Miguel Andagana's albatross sculpture in cigarette butts from cigarette butts found in the urban areas of Galapagos. ©GCT

MICROPLASTICS IN GALAPAGOS

Figure 11: Common shapes of microplastics found in the marine environment: fragments, fibres, films, nurdles/pellets, foam.

Microplastics that begin as such are known as 'primary microplastics' – including pre-production nurdles or pellets and micro-beads.

Microplastics that are generated as a result of another item degrading or fragmenting are known as 'secondary microplastics'.

Microplastics can be categorised to understand likely sources. We use the categories: fragments, fibres, foams, films and pellets/nurdles.

What do we know about microplastics in Galapagos?

The fragmentation of plastic into microplastic is faster in the beach environment than in seawater. This is because of the increased exposure to sunlight and ultraviolet (UV) radiation on the beach making plastics increasingly brittle, and higher oxygen availability breaking down plastic polymers[28]. Ecuador and the Galapagos Islands are on the equator, the UV Index is very high[29], which means that plastics are likely to fragment on beaches in Galapagos even faster than in other locations.

The longer that plastic items are on the beach, the higher the risk of fragmentation into microplastics. The higher the microplastic concentration, the higher the risk of being eaten by marine organisms.

The most likely scenario (as reported in other islands around the world), is that the main source of microplastic on Galapagos beaches is the fragmentation of larger items that are beached. This is backed up from our research to date that shows >95% of beach microplastics in Galapagos are from secondary sources (i.e., generated by the fragmentation of larger items)[35]. We do not yet know how much is fragmenting in situ or how much has been deposited after fragmenting elsewhere. Microplastics entering the environment nearer the mainland could become biofouled and sink, or be ingested before arriving in Galapagos, suggesting that the local fragmentation could be the most likely source.

This means that continued clean-up effort is vital to stem the generation and resuspension of microplastics locally whilst longer-term solutions manifest to reduce plastic pollution impacting the Islands at source.

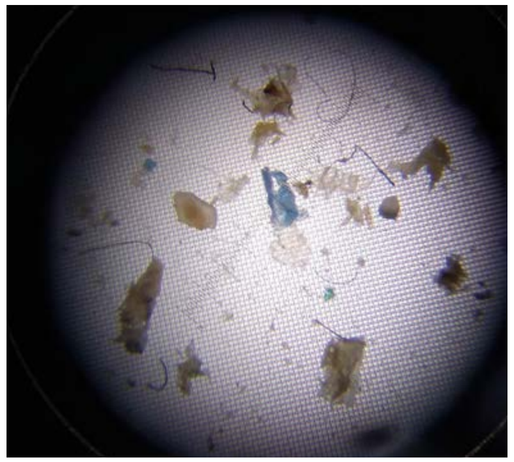


Figure 12: Microscope image of microplastic particles from seawater in the harbour of San Cristobal island. ©Jen Jones

Tortuga Bay (Santa Cruz Island) is the most visited tourist site in the Galapagos National Park. As a result, it receives regular cleaning of microplastic by Park Rangers. Analysis of microplastic surveys on this beach found that pellets make up 24.5% of the microplastic found here[57]. Most pellets were colourless, white or yellowing polyethylene (92%) and were especially common in the turtle nesting zone (location of 95% of all pellets collected)[57], as they are transported up the beach into the nesting zone due to their round shape. Pellets are highly unlikely to enter the system from sources within the Galapagos Marine Reserve, as the closest plastic manufacturing facility is in the city of Guayaquil in mainland Ecuador, >1,000 km to the east. Oceanographic modelling has shown that the arrival of floating microplastics within several months is possible from continental Ecuador[11].

A common source of microplastics to the environment is via wastewater, such as the microplastics produced from laundry or not filtered out of the sewage system.

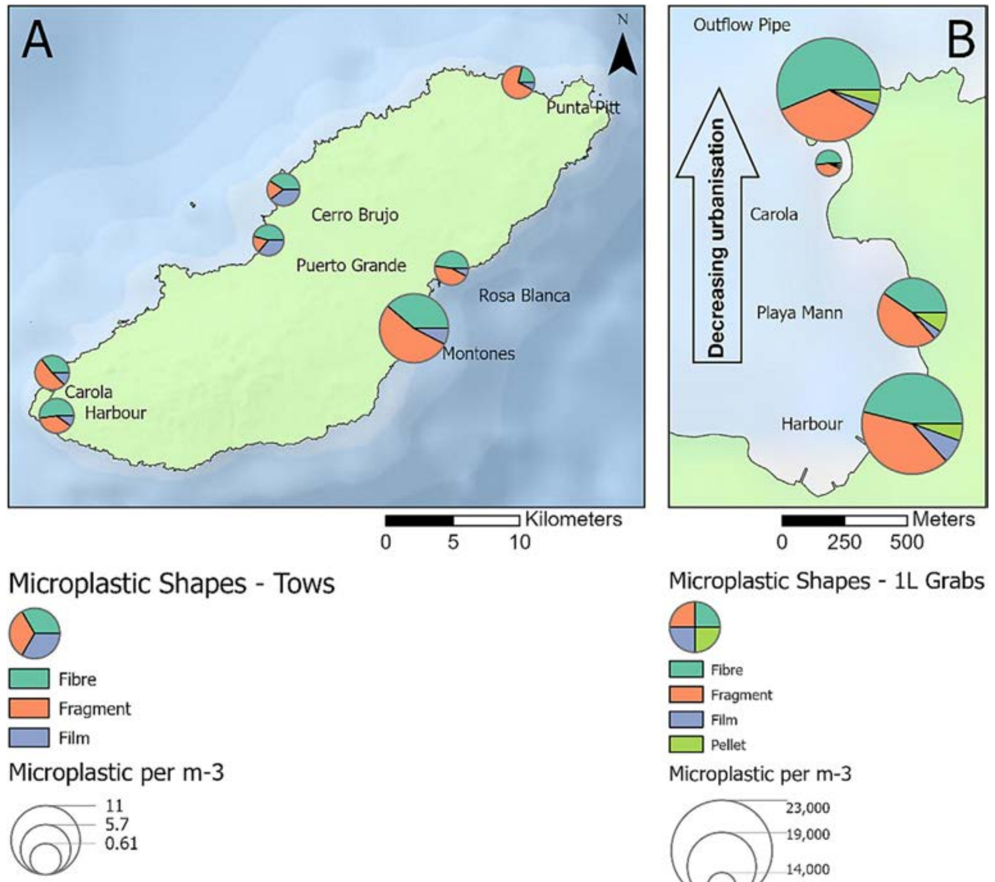


Figure 13: Spatial distribution of microplastic particle shape composition in surface seawater around San Cristobal Island, Galapagos, using tow and grab sampling techniques. Pies indicate the percentage composition of each shape category at the respective site for (A) tow samples and (B) grab samples.
From Deakin et al. (2024)[30].

Seawater samples collected in 2019 from San Cristobal harbour reveals the impact of urbanisation on microplastic and modified cellulosic contamination[30].

Four sites with varying degrees of urbanisation (proximity to the harbour and town) were sampled in triplicate. Focusing on microplastic abundance we found the following:

- High level of microplastic abundance in the harbour, with an average of 11,000 microplastic particles per m^3 across all 4 sites[30].
- Slight decrease of microplastic abundance with decreased urbanisation (away from the town); we found double the abundance of microplastics at the site closest to the urban centre compared with the site furthest from urbanisation, 1,400 ± 3,785.9 particles per m^3 and 7,000 ± 3,214.6 particles per m^3 respectively[30].
- Samples from sites in the port area of Puerto Baquerizo Moreno ranged from 13,667 ± 3180 particles m^{-3} at Carola; a small beach embayment, to 23,333 ± 4667 particles m^{-3}, at the Outflow Pipe[30]. Fibres comprised between 40.5% and 56.3% of all particles collected by the 1l grab samples, greatest at the Outflow Pipe, and of those fibres 70–95% were anthropogenic cellulose, often linked to the washing of clothes[30].

COASTAL CLEAN-UP AND MARINE LITTER MANAGEMENT PROGRAMME IN GALAPAGOS (2017-2023)

The Galapagos Coastal Cleanup and Marine Litter Management Programme, developed by the Ministry of Environment, Water and Ecological Transition through the Galapagos National Park Directorate (DPNG), has been instrumental in the fight against plastic pollution in the Archipelago. Since its inception in 2017, the programme has implemented a series of waste collection, monitoring and scientific collaboration activities to mitigate the adverse effects of plastic on marine and coastal ecosystems.

Activities and Achievements:

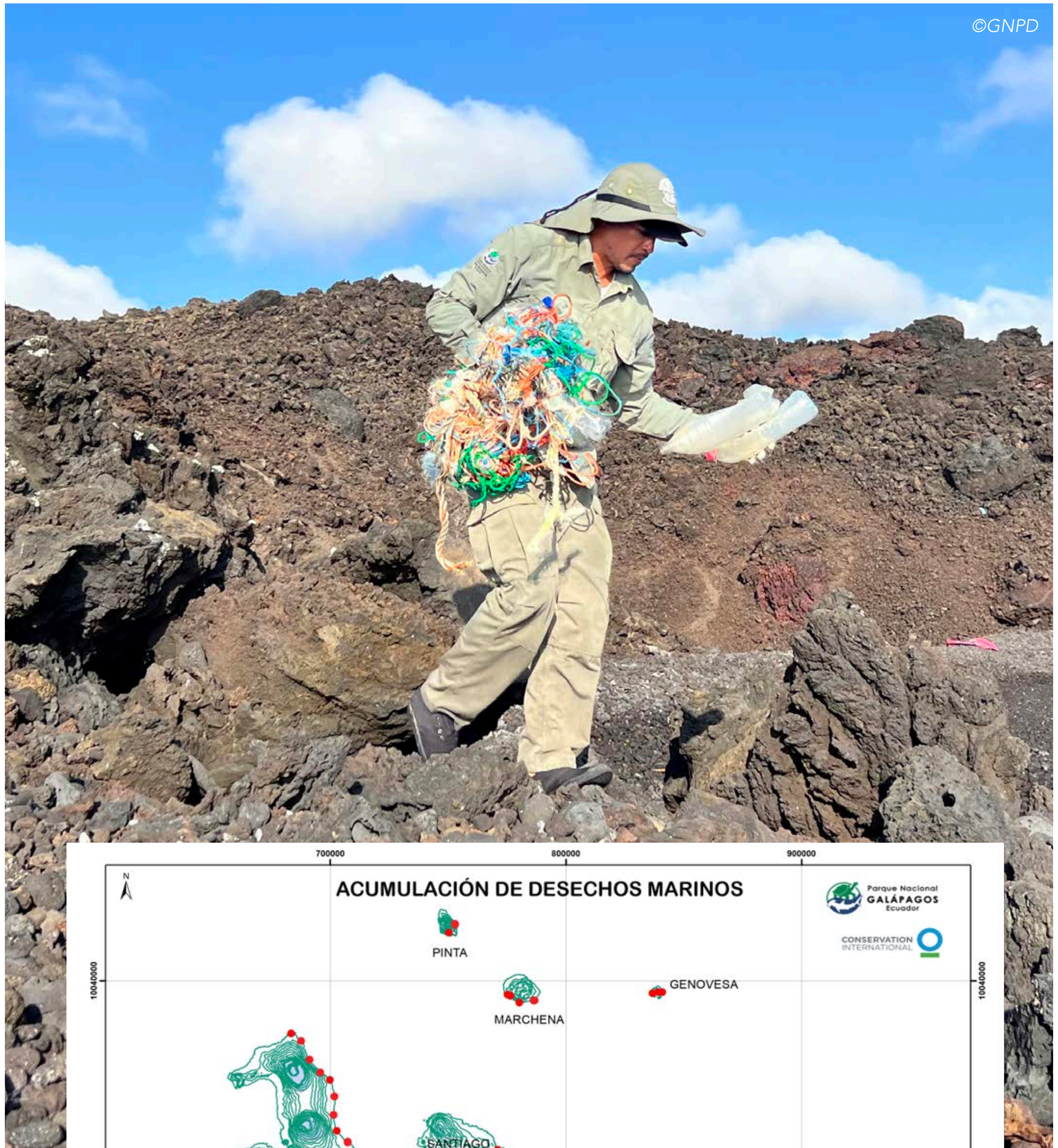
- **Field Trips and Garbage Collection:** 528 interventions have been carried out in different areas of the Archipelago, with the participation of more than 5,637 volunteers, collecting a total of 94 metric tons of ocean rubbish by December 2023.
- **International Cooperation:** The programme has received support from scientific advisors from institutions such as Conservation International and has forged strategic alliances with international organisations, including IAEA, PPSS and Galapagos Conservation Trust (GCT).
- **Local Cooperation:** The programme has established strategic alliances with small organised groups, such as the Island Front and the Youth Advisory Council of Santa Cruz, as well as with local citizen initiatives and private companies, to carry out the activities planned within the framework of this institutional initiative.
- **Training and Workshops:** The programme has actively participated in various workshops, symposiums and talks, disseminating the results obtained from the project. Highlights include participation in an international workshop in Lima, Peru, where the progress achieved up to October 2022 was presented. In 2023, the first workshop was organised in Galapagos for the formulation of the Strategic Plan for Plastics.

Results and Data Collected:

- **Community Participation:** 90% of the interventions were carried out by volunteers, reflecting a strong commitment from the local community.
- **Spatial Coverage:** Clean-up activities covered a total of 1,226 km, including both nearby and remote areas of the Archipelago.
- **Waste Types:** Of the total waste collected, 87.55% corresponded to plastics, which were sorted and managed according to their type and origin.

Importance and Future Needs:

The work carried out by the GNPD underscores the urgent need to implement effective and sustainable measures to manage plastic pollution reaching the Galapagos Islands. These efforts highlight the importance of considering the Galapagos as a critical and unique area within the legally binding Global Plastics Treaty to address this issue in the long term. At the same time, it is essential to continue with immediate local actions to protect biodiversity and strengthen the resilience of marine and coastal ecosystems.



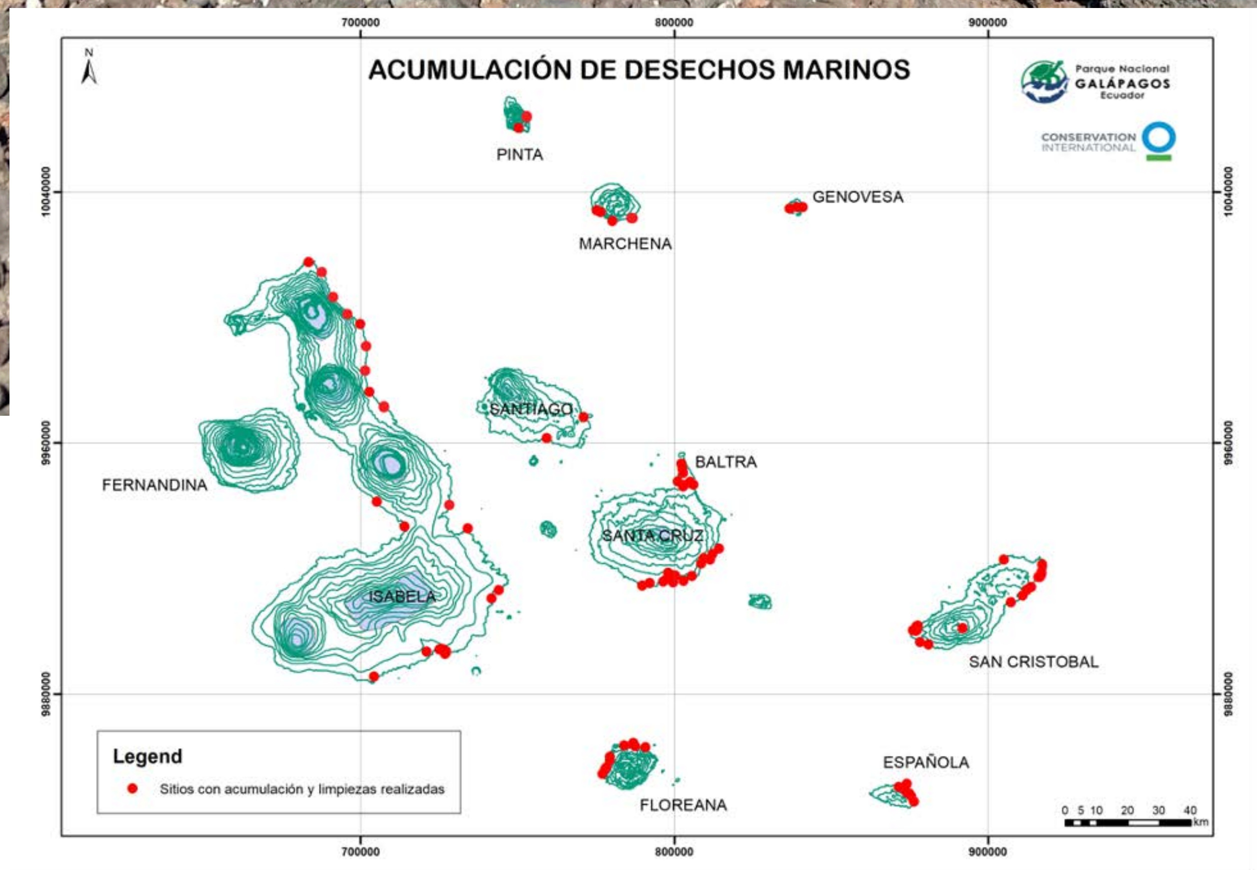


Figure 14: Map with sites identified with accumulation of marine debris, as well as where coastal cleanups have been developed in 7 years of the Programme. DPNG-CI 2023.

DISTRIBUTION OF COASTAL PLASTIC POLLUTION

UNDERSTANDING PLASTIC HOTSPOTS WITHIN THE ARCHIPELAGO

The identification of plastic accumulation zones (or 'hotspots') is essential for establishing risks to species. Knowledge of accumulation zones are also key to focusing clean-up efforts.

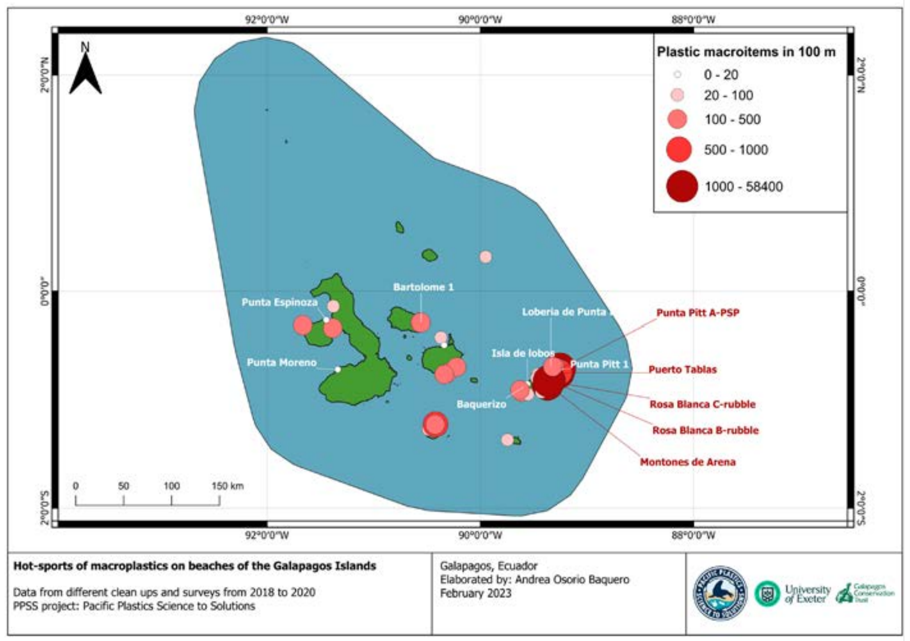
- Plastic accumulating on remote windward shores = likely from continent, fisheries, at-sea disposal
- Leeward shores = likely from fisheries, at-sea disposal and local input (waste management leakage and tourism roles).

Several factors are likely to affect the accumulation rate and distribution of plastic pollution in Galapagos:
Oceanographic factors e.g. Prevailing currents, storm events, tides
Geographic factors e.g. Coastline morphology, beach sediment type
Human factors e.g. Clean up, littering at-sea and locally, waste management leaks

They are all likely to have seasonal changes, including during El Niño and La Niña events, and so long-term monitoring of established sites is key to understanding trends over time and under varied conditions.

In this section, we present findings to date in five key coastal habitats in Galapagos:

1. **Rocky shores**
2. **Mangroves**
3. **Sandy beaches**
4. **Benthic sediments**
5. **Seawater surface**



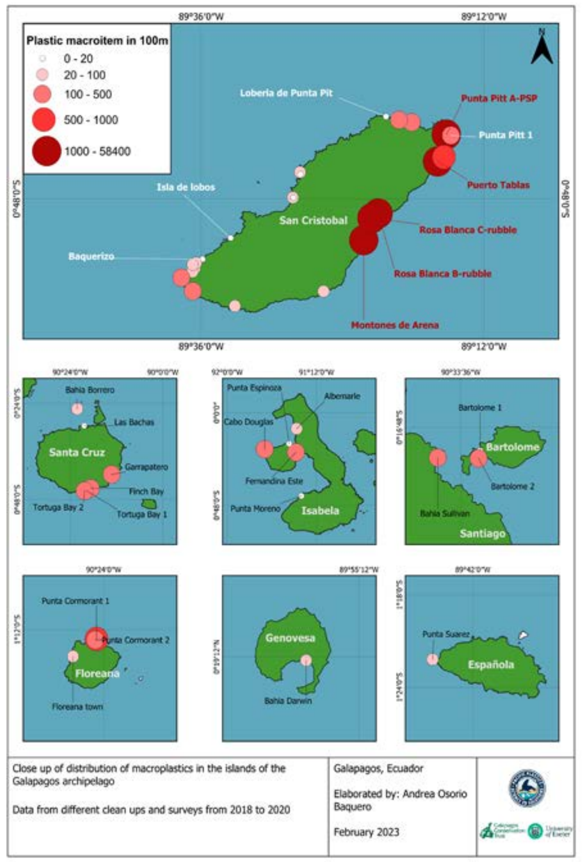


Figure 15: Hot-spot maps of macroplastics on Galapagos coastlines. Above: entire archipelago, right: macroplastic distribution within islands.

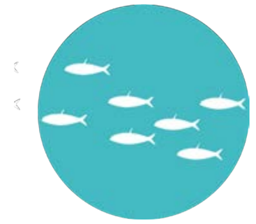
ROCKY SHORES

50%+ of the 1,800 km of Galapagos coastline is exposed lava rocky shore. It is difficult to sample and is often inaccessible to surveyors. Lava rocky shores in Galapagos are often comprised of jagged and cracked lava sheets, boulders and rubble that can trap plastic films/sheets and ropes and larger items. These trapped plastic items are then subjected to high UV radiation and fragment further, making them very difficult to remove. Smaller plastic fragments are less likely to be trapped and therefore are probably washed away from rocky shores and deposited in habitats like sandy beaches or trapped in mangroves. On rocky shores exposed to incoming currents, strong wave action may speed up the fragmentation of plastics as they are thrown against the rocks.

High risk species in this habitat:

Pinnipeds – Galapagos sea lions and Galapagos fur seals are often associated with rocky shores;

Seabirds – flightless cormorants and Galapagos penguins breeding colonies;



Reptiles – marine iguana colonies;

Fish – herbivores linked with rocky reefs;

Invertebrates – filter-feeders such as barnacles and pencil urchins[35];

Plants – green algae may attract microplastics and present ingestion risk.

Figure 16: Drone image of plastic contamination of a rocky shore. ©GCT.

ROCKY SHORES

Known plastic accumulation zones:

The coastlines of the Galápagos Islands are characterised by exposed lava rocky shores interspersed with mangroves and sandy beaches, however little is understood of the accumulation and retention of macro- and micro-plastics in rocky shore habitats. In one instance at Rosa Blanca, 134 plastic bottles were collected within a 30 m transect in 2022 on an exposed section of rocky shore, where bottles were getting trapped in the rocks.

Common items:

- Ropes, buoys and films/sheets of plastic may be more likely to accumulate on rocky shores as they get trapped by rocks.
- Plastic bottles (often clean with labels/lids still on), styrofoam and buoys.
- Smaller items and fragments appear more likely to be deposited on sandy beaches.

Trapped or buried plastics are unlikely to be visible from drone surveys. Although drone surveys generate useful monitoring data, estimates will always be below the true plastic load.

Monitoring protocol status:

- Transect survey methodology – for citizen scientists and management authorities.
- Drone survey methods intended for marine iguana population census (flying at around 20 metres height) work for counting plastic items larger than a bottle in size.
- It is much easier to see brightly coloured items on the drone images and so there is likely to be missed items if colourless, discoloured or similar to the habitat colour.
- Citizen scientists analysing photos through the Zooniverse platform generate useful data (90%+ agreement with trained scientist analysis) presenting opportunities to speed up useful monitoring information.
- Via the current method, 20 citizen scientists check each photo to ensure quality data.

Rapid assessment and monitoring

Drones have great utility in monitoring rocky shores, a landscape that presents difficulty in data collection due to inaccessibility. Drone surveys provide an opportunity to monitor plastic in these isolated locations, facilitating a long-term understanding of trends in plastic accumulation. Citizen science contributions to this analysis prevent bottlenecks in the processing of this data and result in the generation of plastic accumulation zones. This identifies quantities of plastic bottles, fishing gear and other waste items.

Drone training 2023 ©GNPD

Observation: Plastic rocks

During sampling in 2019 on the western coast of Isabela, incidences of plastics melted onto rock surfaces forming 'plasticrusts' were observed, in addition to 'plastiglomerates', where plastics and rock fragments had melded together. This phenomenon has been documented in Hawaii, as well as several other parts of the world, perhaps the lasting evidence of the 'plasticene' era, marking the widespread presence of plastic in the environment.

This suggests that in addition to considering degradation and fragmentation processes in the plastic cycle for volcanic islands such as Galapagos, the impacts of melting plastics and the formation of aggregates should be considered.

Figure 17: Photographs of plastics on lava rubble beaches. (a) A typical lava rubble beach on western Isabela island, (b) a fragmented blue polypropylene rope, (c) attempting to collect polypropylene microfibres from a quadrat, likely from the same original green polypropylene rope (as verified by FTIR polymer analysis), (d) an example of a 'plasticrust' forming, melted into the crevices of rock and e) an example of either side of a 'plastiglomerate' (plastic/rock compound) that contained traces of both polyethylene and polypropylene.

MANGROVES

35% of the 1,800 km of Galapagos coastline is fringed by mangroves that represent an important 'blue carbon' habitat with major ecological and socioeconomic importance in the Galapagos Islands.

Anecdotal evidence of major plastic accumulations in mangroves, particularly on the east of San Cristobal and Isabela islands has raised concerns of the impact of plastic smothering of mangrove forests, reported in other areas around the world. Like rocky shores, mangroves are very challenging to sample but a study is underway to fill this knowledge gap.

High risk species in this habitat:

Hammerhead shark juveniles, Galapagos sea lions, commercial fishery species. In Galapagos, mangroves represent important nursery sites for many marine vertebrates including threatened elasmobranchs, such as the Critically Endangered scalloped hammerhead shark (*Sphyrna lewini*)[31], with these nursery sites (the 'Galapagos Nursery Complex') recently included as one of the world's first IUCN Important Shark and Ray Areas (ISRAs)[32]. These lagoons also provide shelter for commercially important fishery species and shorebirds such as the lava gull (*Leucophaeus fuliginosus*) that scored highly in the priority analysis.

Known plastics accumulation zones:

East coast of San Cristobal Island (preliminary data is highlighting Montones de Area and Rosa Blanca mangroves as plastic hotspots). A study is underway with the University of Exeter, ESPOL and USFQ to quantify the plastic impact in Galapagos mangroves.

Abundance of macroplastic in the mangroves of San Cristobal Island:

Three sites were sampled, two on the eastern side of the island, and one on the western side.

Preliminary results indicate that the accumulation of macroplastic in mangroves may reflect the trend observed generally in Galapagos, with higher abundance on the eastern coasts of islands.

Common items

Ropes, bags and drinks bottles can be observed polluting mangrove areas, often seen entangled around the mangrove roots, proving difficult to remove.

Monitoring protocol status:

Mangrove survey methodologies were tested in 2022 and their evaluations will be reported to the GNPD. The methodologies tested are below:

Transect surveys - all macroplastic collected within a known distance e.g. 30 m along the mangrove edge.

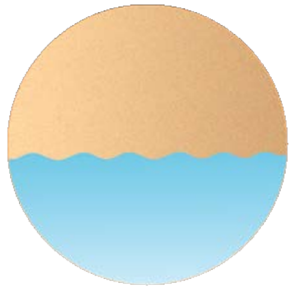
GoPro transect surveys - a known distance e.g., 30 m of mangrove edge was filmed using a GoPro, for subsequent plastic identification. These video transects are being used to help develop a monitoring method based on machine learning techniques, aiming to make the macroplastic identification in mangroves more efficient in future sampling efforts.

Sediment sampling - an aluminium corer was used to collect sediment samples, as it could be manoeuvred around the mangrove roots, unlike traditional sediment grabs.

Quadrat sampling - random quadrat sampling was performed at the back of the mangroves, where large plastic items were accumulating and then fragmenting. All plastic within the quadrats was collected for analysis.

Water sampling - a modified hand held bilge pump with an attached hose was used to sample water within the mangroves, as traditional plankton nets would get caught on the roots. 1L bottle samples were also taken.

SANDY BEACHES



Beaches in Galapagos tend to be small bays with very variable sediments ranging from sea urchin tests and coral rubble to eroded lava[33,34]. Some sandy beaches, particularly on east-facing coastlines, are major accumulation sites for macroplastic and microplastic pollution.

High risk species in this habitat:

Galapagos green sea turtles (important nesting area), Galapagos sea lions, shorebirds including lava gulls.

Known plastics accumulation zones:

Eastern San Cristobal exposed to the incoming Humboldt Current is a major accumulation site of macroplastic and microplastic – including Punta Pitt, Rosa Blanca, Montones. Coastal cleaning by CI and GNPD highlighted Eastern Isabela as another major accumulation zone.

Monitoring at Tortuga Bay by citizen scientists 2019 – 2022 showed ongoing input of plastic pellets, a type of primary microplastic that must have been littered at sea or from factory[57].

Coral rubble beach - plastic concentrations measured here, two orders of magnitude higher than measured on sandy beaches, although the ecological importance of this habitat is not currently known.

- At a beach scale microplastic concentrations were > 300% higher in the south compared to the north of the beach at Punta Pitt (618 ± 104 particles m^{-2} versus 125 ± 40 particles m^{-2}) and > 400% higher at the turtle nesting line compared to the strandline at Tortuga Bay (440 ± 167 particles m^{-2} versus 95 ± 56 particles m^{-2})[57].

Common items:

Hard plastic fragments, bottles, bottle caps/rings, ropes, bags, films

Monitoring protocol status:

Macroplastic and surface microplastic survey methods have been well tested with various citizen science protocols available. More drone surveys on sandy beaches would be valuable to compare to rocky shore images.

Drinks bottles are the most common item consistently recorded on plastic pollution surveys in Galapagos. They consistently make up at least a third of all items found.

28% of bottles found are water bottles meaning that finding a solution to fisheries, tourists and continental populations using single-use plastic water bottles would cut 10% of all plastic pollution. to Galapagos.

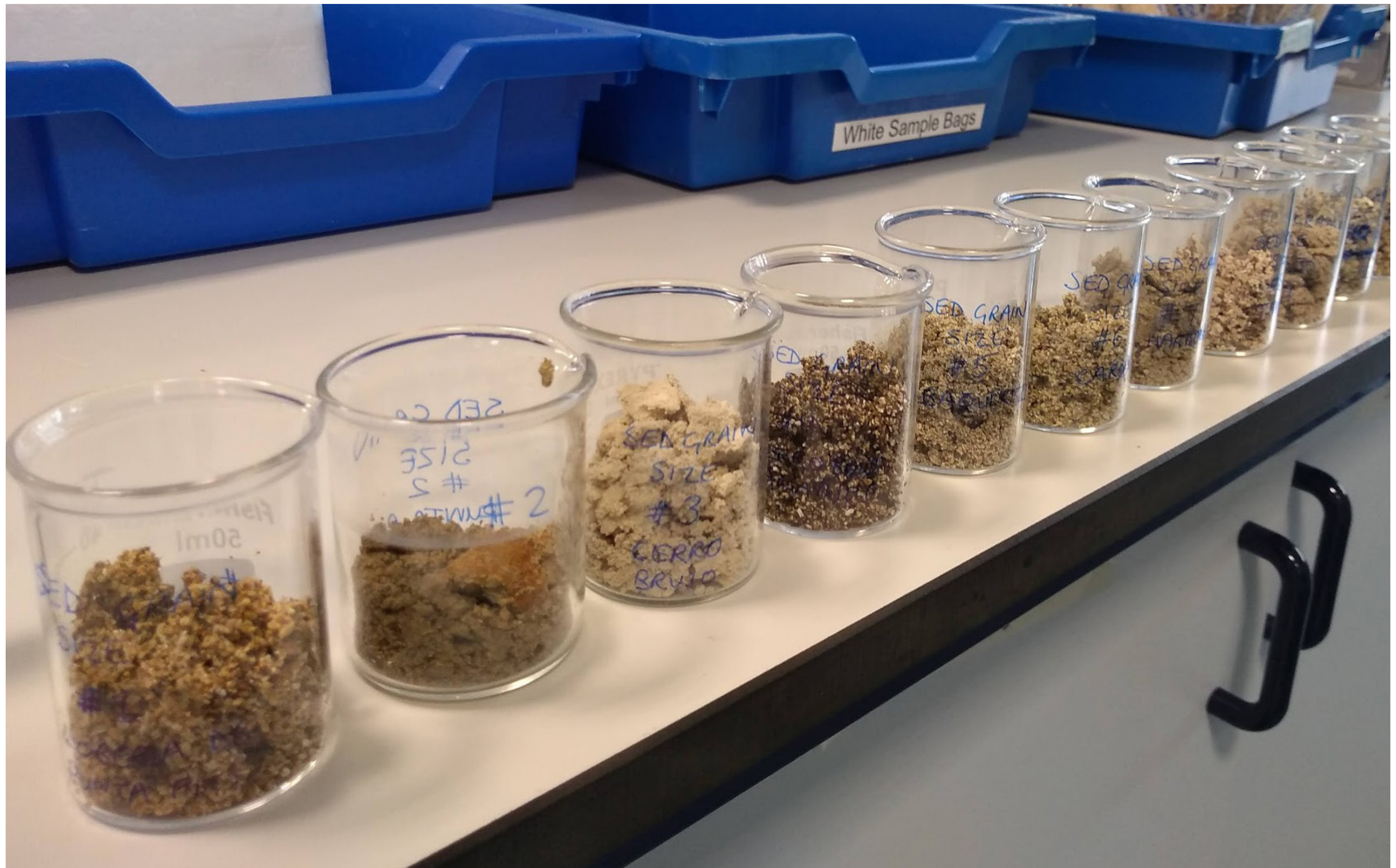
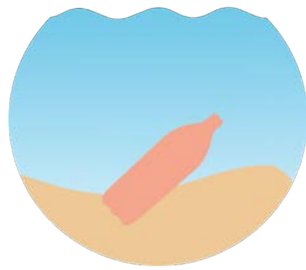


Figure 18: Sediment samples from various sites around San Cristobal island, Galapagos. ©Jen Jones.

BENTHIC SEDIMENT



Shallow seabeds consist of fairly course gravel with patches of muddier sand. Over time, living things start to colonise plastic particles which often causes them to eventually sink (depending on plastic density); < 1% of plastic pollution in the ocean is predicted to be at the sea surface. Benthic sediment is therefore a known accumulation zone for microplastics, suspected to increase with depth as sediment size and wave action decreases.

High risk species in this habitat:

Sea cucumbers, many fish feed on benthic invertebrates, supporting the food web of many endangered species as well as humans.

Known plastics accumulation zones:

Microplastics have been found in shallow benthic sediments (< 10 m) around the Galapagos Archipelago but with low concentrations (6.7 - 86.7 particles.kg^{-1})[35].
Unlike beach plastic that accumulates on the most exposed coastlines, seabed pollution may be more common on sheltered coastlines in deposition environments.

Common items:

Microplastics (mostly fibres) found in sediment grab samples, dive seabed surveys find many macroplastic items close to the harbour. To a lesser extent but highly damaging, sunken FADs and ghost gear.

Monitoring protocol status:

Benthic sediment survey protocols for microplastics have been well tested although confirming microplastic polymer composition is labour intensive and difficult. Less than 50% of suspected microplastics were confirmed by Fourier-transform infrared spectroscopy (FTIR) analysis, meaning visual confirmation is very challenging by microscope alone.

SEAWATER SURFACE

Many common plastic polymers such as polypropylene and polyethylene float easily in seawater. Microplastics at the surface and in the water column present an exposure risk for filter feeders.

High risk species in this habitat: Whale sharks, waved albatrosses, filter feeding invertebrates.

Known plastics accumulation zones:

- High level of microplastic abundance in the harbour of San Cristobal, with an average of 11,000 microplastic particles per m^3 across all 4 sites[30].
- In the Galapagos Marine Reserve, microplastic concentration is 6 – 10 times higher at the seawater surface, in the seabed and in beach sand in the populated South-Central bio-region of the Archipelago compared to the upwelling Western bio-region.
- Floating FADs have been spotted throughout the archipelago, including close to Floreana on several occasions.

Common items: Bottles, bottle caps, large plastic fragments (offshore from exposed, rocky coasts), FADs (with or without satellite buoys).

Monitoring protocol status: Methods for sampling using manta nets, hand pumps and 1 litre Niskin bottle water sampling have been developed and tested. Sample processing and analysis of particles is very time-consuming but results show that more research is needed in this area.

Figure 19 (below). Bottle caps found at various sites around San Cristobal island, Galapagos. ©Jen Jones.
Figure 20 (right). Seawater sampling near San Cristobal island, Galapagos. ©Jen Jones.

IMPACTS OF PLASTIC POLLUTION IN GALAPAGOS

WILDLIFE RISK ASSESSMENTS

Terrestrial wildlife

Terrestrial: Giant tortoises

Plastic exposure risks:
Ingestion of macroplastics[38].

Risk mitigation: Improved local waste management and clean-up of urban and suburban sites

Birds: Finches, Floreana mockingbird

Plastic exposure risks:
Entanglement and ingestion risk.

Risk mitigation: Improved local waste management and clean-up of urban and suburban sites

Oceanic islands can be significant plastic pollution accumulation zones and therefore, coastal biodiversity may be at increased risk of harm. Increasing amounts of waste are now also being observed in terrestrial zones on the human-populated islands in Galapagos, which will have adverse impacts on terrestrial species.

Wildlife impacts of plastic pollution include:

- Entanglement is frequently the most lethal consequence of plastic pollution, causing injury and possible death.
- Ingestion of plastic has been recorded in at least 9 Galapagos marine species since 2019[27, 35, 58]. The harm caused is not currently understood but in other studies, microplastics have been shown to negatively impact species from the scale of DNA damage to mortality/offspring impacts.
- Habitat degradation, such as by the smothering of mangrove shoots or the modification of sediment on beaches.
- Invasive species dispersal; floating plastics represent opportunities for algae and invertebrates such as barnacles to raft around the marine reserve.
- Disease and pollutants effects exacerbated.

A rapid risk assessment of more than 3,000 species identified 27 priority marine vertebrates and 4 priority invertebrates in Galapagos at higher risk of harm from plastic pollution[35].

Ocean and coastal wildlife

Mammals: Galapagos sea lion, Galapagos fur seal

Plastic exposure risks:
Entanglement in fishing gear, Ingestion of plastic items/fragments, Ingestion of microplastics

Risk mitigation: Rapid response veterinary support, Gear/ropes collection incentives, Coastal clean up, Reduce shedding of microplastics from maritime ropes

Seabirds: Waved albatross, Galapagos petrel, Galapagos penguin, flightless cormorant, lava gull

Plastic exposure risks:
Entanglement in fishing gear (potential elevated risk for flightless cormorant due to nesting behaviour) ingestion of bottle caps and fragments, floating plastic exposure, gulls also exposed on shore (scavenging through washed up plastics), ingestion of microplastics via sardines for penguins, evidence of transfer of ingested plastics to offspring in other species of petrels and albatross.

Risk mitigation: Better maritime waste management, including waste-water. It is acknowledged that the risk of long-lining bycatch is a higher risk to these species than plastic pollution entanglement and ingestion but both issues tend to be linked.

Reptiles: Green sea turtle[58], hawksbill turtle, marine iguana

Plastic exposure risks: Ingestion of plastic bags/ films, hard plastic pieces, entanglement in fishing gear, microplastic ingestion likely via algae food, plastic on turtle nesting beaches is a concern for nesting dynamics and reproductive success.

Risk mitigation: Alternative products to petrochemical-based plastic bags. Reduction of single use plastic usage – Ecuador, Peru, China. Stronger accountability for at-sea polluters. Support for fishers to transition to more sustainable gears/ approaches.

Fish: Whale shark, scalloped hammerhead shark, salema spp.

Plastic exposure risks: FADs risk, entanglement in fishing gear, microplastic ingestion likely for whale shark during filter feeding (also larger items), plastic debris including packing straps, food wrappers, a disposable cup and a cigarette butt recovered from gills and gut of stranded whale shark in the Philippines[33].

Risk mitigation: Action to reduce the number of FADs floating and beaching in the Marine Reserve

Marine invertebrates: Brown sea cucumber, three stony corals

Plastic exposure risks: Ingestion of microplastics, elevated risk from diseases and other pollutants, smothering risk of larger plastics on reefs.

Risk mitigation: Dive survey and clean up, stronger accountability for polluters

IMPACTS OF PLASTIC POLLUTION IN GALAPAGOS

TERRESTRIAL POLLUTION

Ainoa Nieto-Claudin[38]

An increasing amount of garbage can be observed on land on all of the five human-populated islands of the Galapagos Archipelago. Yet, its magnitude and potential impact on terrestrial Galapagos species and wildlife health has hardly been documented. In 2021, Harvey et al. reported a mortality of up to 18% in Darwin's finches due to anthropogenic debris including plastic used for nest building and leading to hatchling entanglement and strangulation[39]. Very recently, a comprehensive assessment of Galapagos plastic pollution along the coastline describes microplastic abundance ranging from 0.003 to 2.87 items/m^2 in all five bioregions[27]. Through citizen science, this research documented plastic exposure in 52 Galapagos species and identified Santa Cruz tortoises, green sea turtles, marine iguanas, black-striped salemas, and Galapagos sea lions at the highest risk of harm due to the ingestion of plastics.

On Santa Cruz Island, the Galapagos Tortoise Movement Ecology Programme has observed increased local plastic pollution in the environment and, in recent years, has encountered plastic items in tortoise faeces within anthropic areas[38]. The lack of data on free-living giant tortoises and their exposure to, and potential ingestion of garbage spurred a research project in 2022 to study and characterize the anthropogenic waste in the faeces of *Chelonoidis porteri* within areas of varying levels of human disturbance. Additionally, tortoise abundance and environmental debris available for tortoises to ingest were characterised. More than 6,500 tortoise faeces were collected in National Park and human-modified areas of Santa Cruz, and analysed. Only two fragments of debris were found in tortoise faeces within the National Park transect (0.076 items/kg of faeces). In contrast, 590 pieces of debris were found in tortoise faeces within the human-modified transect (3.8 items/kg of faeces). Plastics were the most predominant garbage category in the human-modified transect (86.3%; n = 511), followed by cloth (8.4%; n = 50), metal (2%; n = 12), paper (1.7%; n = 10), synthetic rubber (0.7%; n = 4), construction materials (0.5%; n = 3), and glass (0.3%; n = 2). The composition of garbage items found in the environment differed to that found within the faeces. Plastics were more frequent in faeces than in the environment, whereas construction materials, rubber, paper, metal, and glass were more abundant in the environment when compared to faeces. This work constitutes the first scientific evidence and quantification of plastics and other garbage in the diet of the Critically Endangered Western Santa Cruz Galapagos tortoise.

Although there is no information on the effect of macro- and microplastics on giant tortoise health, studies in other animals suggest adverse effects. Endocrine disruptors (EDCs) have been described as omnipresent chemicals that can be found within medicines, pesticides, and all types of plastic materials. The impacts of EDCs have been studied in some reptiles and main negative effects include malformation of gonads, altered plasma hormone concentrations and liver function, feminisation of aquatic turtles, and behavioral changes in turtle hatchlings. Moreover, a recent study conducted in Flesh-footed Shearwaters (*Ardenna carneipes*) describes a novel plastic-induced fibrotic disease called plasticosis that induced scar tissue formation within the avian proventriculus[40]. This worrisome finding suggests that other species highly exposed to plastic ingestion can develop gastrointestinal lesions of unknown severity that might compromise their health and survival. The negative effects of plastics on the health and reproductive physiology of reptiles are greatest for Critically Endangered species, such as the Galapagos giant tortoises. Juveniles remain for longer periods in low elevation anthropic areas and near the town of Puerto Ayora, Santa Cruz Island. Therefore, plastics in the diet of immature individuals may create a greater risk for their fitness and consequently for the long-term survival of this species.

Results from this study also showed that tortoises

might be colour-selective when feeding on garbage, with preferences for green, light blue, and white plastic items. In contrast, tortoises avoid dark blues, grey, and transparent items. Preference for green and light blue plastics might be explained by tortoises mistaking them for plants. Because a complete ban of the use of plastics in the Galapagos is unlikely, we recommend that local policy makers restrict the use of green and white plastics in favor of other colours. Comparable data on other species feeding on plastic, which are yet to be documented, would be needed to make more comprehensive recommendations. It should be noted that smell may also play a big role in plastic ingestion, as our team has directly observed tortoises trying to ingest take-away containers/boxes and transparent plastic bags with human food leftovers.

The finding of garbage, especially plastics, in faeces of free-living tortoises highlights the importance of taking actions that minimize human waste within the fragile environments of the Galapagos. As the local population and tourism in the Archipelago increase, so does the amount of garbage generated, and disposed of on the Islands, putting at risk the health and wellbeing of both animals and humans. This study also identifies some of the garbage hotspots near Puerto Ayora town where management actions should be prioritised to protect foraging areas and tortoise health.

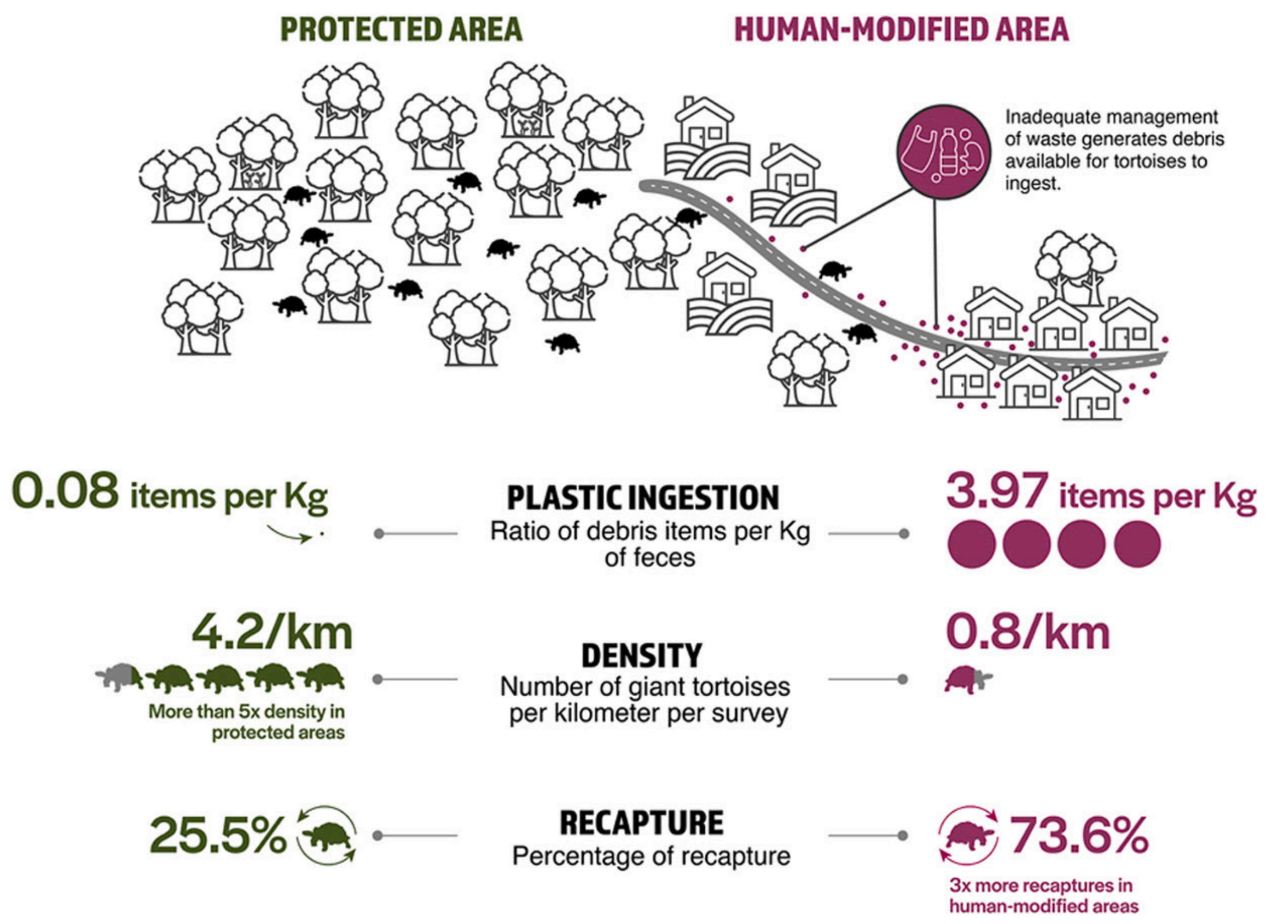


Figure 21. Graphical abstract for recent journal article on plastic ingestion inn Giant Tortoises[38].

IMPACTS OF PLASTIC POLLUTION IN GALAPAGOS

EFFECTS OF MARINE PLASTICS ON LOCAL COMMUNITIES

Marine plastic pollution in Galapagos poses a significant threat to the environment, local economy, and social well-being, while also disempowering local communities from effectively managing their own territories. Throughout the Archipelago, local governments and communities bear an unfair burden as they need to cope with plastic waste originating from distant regions like continental Ecuador and Peru, as well as activities occurring beyond the boundaries of the Archipelago, including industrial and artisanal fisheries. In this section, we present some of the direct consequences of marine plastic pollution across various aspects, including tourism, health, and environmental and waste management costs. Furthermore, we highlight how these issues exacerbate vulnerability and diminish social resilience across the Archipelago while emphasising the key role that the global community can play in protecting Galapagos.

Galapagos attracts thousands of tourists each year - in 2022 alone, 267,688 visitors landed in the Archipelago (GNPD, 2023). They are primarily attracted by its pristine beaches, well-preserved biodiversity, and the opportunity to visit the birthplace of Darwin's groundbreaking theory of evolution. As a result, tourism has emerged as the dominant economic activity, surpassing traditional sectors such as agriculture and fisheries. Moreover, the entrance fees paid by tourists visiting the Archipelago have provided a reliable source of income for funding environmental projects and for empowering local governments to enhance the quality of life for the local population. However, the presence of plastic pollution along the coasts and tourist sites poses a significant threat to the Islands' aesthetic appeal and delicate ecosystem. This issue has the potential to jeopardise the quality of the visitors' experience, which in turn could affect the Archipelago's reputation as a premier destination for nature-based tourism. If the quality of the destination declines, the Archipelago may resort to unsustainable practices to compensate for the reduction of tourist income, such as large-scale tourism. Considering the fragility of the ecosystems, this type of measure can have devastating effects on conservation efforts and the overall social well-being across the Islands.

The presence of marine plastics also poses a significant threat to the health of coastal communities. While there are currently no studies specifically addressing the effects of plastics on the health of people in Galapagos, there is evidence indicating that microplastics may already be entering the food chain and contaminating beaches used by both animals and humans[35]. This issue is particularly worrisome for coastal communities that rely on the ocean not only as a vital source of protein but also for recreational activities, as is the case in Galapagos. As the amount of plastic in the ocean continues to rise, especially in the East Pacific region, so does the risk of marine organisms ingesting microplastics. These tiny particles can then make their way into the human body through the food chain, exposing individuals to the toxic chemicals present in plastics. Such exposure has been associated with various health problems, including disruptions to the endocrine system, reproductive disorders, developmental issues, and an increased susceptibility to certain cancers[41,42]. Furthermore, the inhalation of airborne microplastics near coastal areas or through contaminated air particles can pose respiratory risks[43]. This growing evidence shows that in Galapagos marine plastics could become a silent threat to people's health in the long run, if actions are not taken.

Moreover, marine plastics entering the Archipelago put a heavy burden on local authorities, increasing the management costs of protected areas and local waste systems. In the past six years, the Galapagos National Park authorities, in close collaboration with local NGOs and citizen groups, have made remarkable efforts to collect over 80 tonnes of marine plastics that have washed ashore on Galapagos' coasts. Despite their inspiring dedication, achieving comprehensive coverage across the entire territory remains an ongoing and seemingly impossible challenge. It requires increasingly substantial human and financial resources. Additionally, managing the collected plastic debris from these clean-up activities places extra strain on the already burdened local waste systems, which are now at the verge of collapse. As a result, a significant portion of both public funds and international support is being redirected to address the expenses associated with cleaning and managing the marine plastics that wash ashore on Galapagos' coasts. This redirection reduces the availability of limited funds that could otherwise be allocated towards supporting environmental or social projects, which are very much in need in the Archipelago.

Despite being a relatively recent population, Galapagos' communities have actively advocated for biodiversity protection, organising coastal clean-ups, and demanding enhanced regulations against industrial fishing[44]. However, their efforts are limited in addressing the plastic pollution issue due to most plastic originating from outside the Islands. Consequently, despite bearing a disproportionate burden of marine plastic pollution, their ability to effectively manage and protect their territories is constrained without the necessary resources and regulatory support properly channelled and implemented to increase their levels of resilience to deal with this external threat. Without comprehensive backing from national, regional, and global regulations, local communities find themselves with limited capacity to safeguard their livelihoods and overall well-being.

IMPACTS OF PLASTIC POLLUTION IN GALAPAGOS

INTERRELATIONSHIPS AND SOCIOECONOMIC RAMIFICATIONS OF MARINE PLASTIC DEBRIS WITHIN THE GALAPAGOS FISHERIES SECTOR

Susana Cardenas, Carlos Mena, Pablo Llerena, Maria Virginia Gabela, Samantha Garrard and Nicola Beaumont.

In recent decades, marine litter has become a major global environmental challenge. The environmental damage to marine ecosystems caused by plastic debris is estimated to be USD 13 billion per year, which includes the financial losses caused to fisheries and tourism[45].

The impact of marine litter on the fishing sector has caused damage to boats and fishing equipment, as well as reduced potential catches. Floating objects have the greatest impact, causing engine damage once their propellers become entangled in them[45,46].

To find out the impact that plastic waste has on the artisanal fishing sector of the Galapagos Islands, 123 surveys were carried out on fishermen. They were asked if in the last 5 years (since 2017) they have experienced any incidents with marine plastic waste during their fishing trips. To which, 25.2% (n=27) of the interviewees reported having had an incident.

The largest number of incidents corresponded to entanglements (56%), predominantly with plastic bags and nylon, followed by collisions with FADs (30%). Finally, the less common incidents were the accumulation of plastic in the boat's water pump (11%) and the presence of plastic in fishing gear (4%).

For the incidents corresponding to entanglements, 20% of them caused damage to the engine, generating an average repair cost of USD 533.33. While in the case of collisions with FADs, 88% of them represented an average cost of USD 4,107.14, where the most prominent case was that of a fisherman who had the complete loss of one engine and damage to the other engine, causing an economic loss of around USD 24,000.

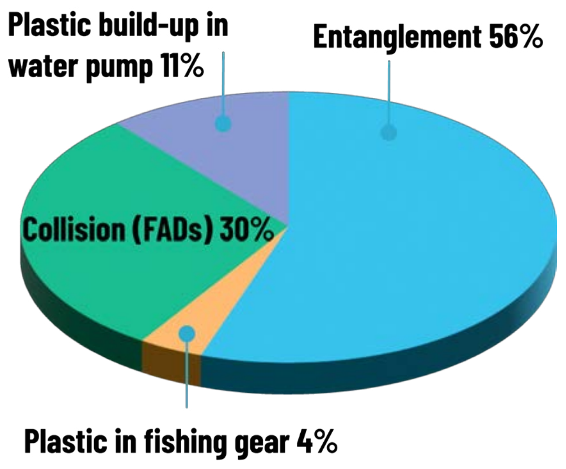


Figure 22. Reported incidents with marine plastic pollution from fishers survey.

Among the total plastic waste entering the oceans, Abandoned, Lost or Discarded Fishing Gears (ALDFG) represents a particularly troublesome percentage, which may continue to cause incidents to marine animals for decades after release[47–49].

To have a critical understanding of marine debris in general, it is important to incorporate the subjective experience-based perceptions of fishermen[50]. Thus, fishermen's perception of the ecological risk posed by discarded objects derived from the fishing sector can provide an important context for marine plastic mitigation.

In this way, when fishermen were asked, "what is their perception of the level of ecological risk of objects discarded into the ocean voluntarily or involuntarily?", FADs were the objects that fishermen considered to have the highest ecological risk (29% very high risk and 34% high risk) followed by plastic packaging (24% very high risk and 34% high risk) and fishing nets (11% very high risk and 40% high risk). On the other hand, buoys are considered to have the lowest ecological risk (45% very low risk and 28% low risk) followed by fishhooks (33% very high risk and 32% high risk).

Fishermen were also asked, 'where do they think the plastic waste they see in the ocean comes from?'. The majority (94.3%) think that it comes from fishing vessels that operate outside the GMR, which dump their waste into the sea. In addition, 44.7% believe that the waste comes from mainland Ecuador or other countries, through tidal currents, and 43.1% from tourist boats.

"Multi-stressor" Effects

As with any marine ecosystem, plastic pollution is being experienced by organisms against a background of other stressors including sea surface warming, acidification, severe overexploitation of natural capital and chronic pollution. Due to the small human population and strong environmental protection, the Galapagos Marine Reserve is assumed to have low local pollutant inputs, nonetheless, there are several local contamination sources of concern including from agriculture run-of (especially pesticides and insecticides), sewage and wastewater run-off, human activities in harbour and touristic areas, maritime and fishing activity (oil spills, hydrocarbon emissions and ballast water) and solid waste including the incineration of plastics and organic waste presenting a potential source of dioxins and furans[33]. For many pollutants, no robust baselines exist and therefore, the risk profile is unknown[51].

We have a new project with the University of Exeter that hopes to map pollutant levels around the Archipelago using novel, accessible, passive sampling devices. These findings, along with training and knowledge exchange on the passive sampling devices will be delivered to the GNPD. We also plan to also develop a rapid assessment toolkit using simple and quick to perform, low-cost tools to monitor pollutant exposure and biological impacts on the wildlife.

PLASTIC POLICIES IN GALAPAGOS

POLITICAL ACTION FROM GRASSROOTS TO GOVERNMENTS

There are laws in Ecuador that regulate plastic production and plastic waste. According to the Organic Code on Territorial Organisation, Autonomy and Decentralisation (COOTAD), the Municipal Decentralised Autonomous Governments (GADMs - by its acronym in Spanish) are directly responsible for the provision of public services, including solid waste, solid waste management and environmental sanitation activities[52].

Furthermore, in 2012 the Ministry of Environment promoted the Extended Producer Responsibility (REP) principle which establishes that whoever places a product on the market is responsible for it until the end of its useful life. In other words, they must be accountable for its recovery through reverse logistics mechanisms, which consists of the recovery of the waste generated in the distribution and commercialisation of the product. The Ministerial Agreements No. 21, No. 98, and No. 191 confirmed that the companies responsible for trading tyres, agrochemicals in plastic containers, mobile phones, and PET plastic bottles are responsible for recovering them after their service life. Importers or manufacturers of these products must have a plan to promote the reduction, recycling and other forms of recovery[53].

In 2020, the National Assembly approved the Organic Law for the Rationalisation, Reuse and Reduction of Single-Use Plastics, 2020, the objective of this law is to rationalise, reuse and reduce single-use plastics through promoting responsible use and consumption, reuse and recycling of single-use plastic waste, replacing the plastic products with products that use a percentage of recycled material or that are biodegradable. This percentage is gradual and will phase in over 18, 36 and 48 months. In the fourth year, bags must have 60% recycled material; Styrofoam containers, 18%; cups, 30%; cutlery, 30%; and PET bottles, 30%. Moreover, this law prohibits single-use plastics in Protected Areas and coastal communities or cities and the use of any component that degrades the plastic into microplastics such as oxo-biodegradables. It also bans the imports of plastic waste for recycling purposes unless there is proof that there is a lack of plastic waste material at the national level. It also establishes that the Ministry of Environment, Water and Ecological Transition (MAATE) will design the "National Plan of Plastic Waste", implementing this law. Finally, it demands that the GADMs promote solid waste recovery centres' installation and operation to encourage recycling and industrialisation[54].

In 2021, The National Assembly approved the Organic Law on Inclusive Circular Economy. In theory, it aims to shift from a linear economy to an "Inclusive Circular Economy". The latter is a model that proposes the regeneration and restoration of ecosystems through a strategic change of production and consumption that avoids waste generation by eco-design, sustainable production and consumption, and promoting integrated and inclusive waste management. This law also bans oxo-biodegradable plastic or any other additive turning plastic into microplastic. Yet plastic bags, flex foam, plastic packaging, and single-use cutlery will still be available but must include recycled material in its components or be reusable.

In addition, the province of Galapagos has pioneered regulations addressing plastic pollution. Indeed, in 2014 the Galapagos Governing Council (CGREG) approved a resolution to prohibit the sale and use of T-shirt-type plastic bags and disposable polystyrene containers. In 2015 the CGREG passed a resolution to promote responsible consumption by regulating the marketing and distribution of disposable plastic products and disposable packaging. This regulation was updated in 2018 so that it also prohibited the use and sale of plastic straws, disposable plastic containers, plastic cutlery, high and low density polyethylene bags, disposable plastic PET and PEAD containers, and disposable beverage bottles. The implementation of these regulations in Galapagos is promoted by the Interinstitutional Commission to reduce plastic pollution. This commission is coordinated by the Galapagos Governing Council, and restarted working in March 2023 with the aim to evaluate the effectiveness of the regulations, to promote adjustment of regulations to the national legislation, and to improve their implementation.

- Ocean plastic pollution traverses jurisdictions and geographic boundaries requiring regional if not global cooperation across multiple disciplines to tackle the challenge[55].
- Due to its inherent nature as a stressor to biodiversity and the difficulty of tracing its source, there are calls for plastic pollution legislation to be integrated with the treaty on the protection of biodiversity in areas beyond natural jurisdiction (BBNJ) to ensure that action is taken unanimously and at the geographic scale required[56].
- The issues of climate change and plastic pollution are inherently connected, not least due to the vast carbon footprint of plastic production, still primarily manufactured from fossil fuels.
- Technological improvements and better modelling data can support more effective capture and clean-up of leaked plastics but ultimately, the move away from the traditionally linear economy to one that is more circular with products designed with end-of-life in mind will not only contribute to the reduction of plastic pollution, it will also contribute to many of the other United Nations Sustainable Development Goals (SDGs) including the provision of sustainable livelihoods.
- To achieve this, we need a multi-stakeholder consortia of researchers, industry, government bodies, NGOs and the media. We are asking for regions/countries to establish alliances with scientific networks to connect different forms of evidence with policymaking. For additional benefits, these networks should be supported to engage early career researchers and practitioners into Treaty design, implementation and monitoring to strengthen capacity around the world and support the measurement of the Treaty's impact. This could also inform improved enforcement.

CONCLUSIONS AND RECOMMENDATIONS

The Galapagos Archipelago remains one of the most pristine ecosystems in the world, a hope spot for biodiversity, with 97% of the Archipelago's land area protected as a National Park, surrounded by a 198,000 km² marine reserve.

But even here we can see the devastating effects of plastic pollution. The increasing contamination of the natural world with plastic waste is a global crisis. Plastic particles have been found everywhere we've looked for them, from our highest mountains to the deepest ocean trenches, and even the air we breathe. Plastics can disrupt biology on every level, from cells to species, communities, and entire ecosystems.

Mitigating the impacts of plastic pollution on the health of people, animals, and ecosystems requires an approach that considers the complexity of these issues. The One Health approach recognises the interconnectedness of people, animals, and plants, and how their individual health is itself dependent on the health of their shared environment. The One Health perspective calls for a multi-sectoral, transdisciplinary, and collaborative approach to solving health issues at local, national, and global levels.

- In the last five years, Galapagos National Park rangers have removed 80 tonnes of plastic waste from the Archipelago's beaches, most of it originating outside the Galapagos Marine Reserve. These clean-ups come at a considerable economic cost, diverting funds away from local communities that desperately need them.
- At least 52 different species, both on land and in the sea, have been found to be entangled in plastic, living in affected habitats or having ingested plastic after mistaking it for food. This includes iconic endemic species such as the Galapagos giant tortoise, the marine iguana and the waved albatross.
- Plastic pollution accumulating in the environment is a serious threat to the future of tourism and fisheries - key industries for oceanic islands such as Galapagos - and it also poses a growing threat to human health.
- Nowhere is more emblematic of what we stand to lose if we don't act now. Stop the rising tide of plastic for people, animals and our environment.

Recommendations for 2024 – 2030

1. Co-design and implement a Strategic Plan for the Management of Ocean Plastics in the Galapagos Marine Reserve to 2030 with the Galapagos National Park Directorate with input from research, civil society and industry and collaborate with regional plastic pollution monitoring efforts.
2. Support a fair transition to a circular economy, improving waste management with maximum benefits to local communities.
3. Target research at urgent knowledge prioritising support for early career researchers and students, to sustainably grow capacity and capability.
4. Engage the fishing sector in waste management and clean up solution pilots, calling for improved waste management at sea.
5. Generate evidence on the impact of ghost gear and fish aggregating devices (FADs) in Marine Reserves in the Eastern Pacific for strengthening policy.
6. Champion community leadership in improving waste management and transitioning to a circular economy, ensuring meaningful engagement at all stages of decision making and solutions design.
7. Convene a special Pacific Islands plastics working group to present a joint voice for a strong, legally binding Global Plastics Treaty that considers the entire plastics supply chain, eliminating harmful chemicals, reducing threats to the ocean and maximising livelihood benefits for local communities.
8. Embrace and maintain multi-disciplinary collaborations supported by networks such as the Pacific Plastics: Science to Solutions (PPSS) network.
9. Support partners to secure sustainable financing, prioritising actions best aligned with ocean protection initiatives and 2030 targets including the UN Ocean Decade Challenges, the SDGs, the High Seas Treaty and the BBNJ.

Figure 23. Graphical representation of recommendations for future plastics work in Galapagos. ©GCT.

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