Northland
REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

Macro to Micro

Plastic pathways, deposition, and densities within Te Taitokerau (Northland)



Prepared by
Emmanuelle Martinez
Maunga to Moana Consulting

Corresponding author
Nick Bamford
Email: nickb@nrc.govt.nz
Environmental Monitoring Officer – State of the Environment

Document information
Northland Regional Council, Natural Resources Science Report No: 2024/SRWQ07
Report date: 1 May 2024

Reviewed by: Matt Johnson
Organisation: Northland Regional Council
Position: Media Specialist
Review date: 29 April 2024

Document status: Final.

Citation advice
Martinez, E. and Bamford, N. J. (2024). *Macro to Micro: plastic pathways, deposition, and densities within Te Taitokerau (Northland)*. Northland Regional Council, Whangārei, New Zealand 0110. Science Report No: 2024/SRWQ07

Contents

List of figures

List of tables

List of appendices

Executive summary

Mai I ngā maunga ki ngā moana Mai I uta ki tai Ahakoa ki hea i te taiao He kirihou, He kirihou, He kirihou![1]	From the mountains to the oceans From the land to the sea Everywhere in the environment Plastic can be found!

Plastic is one of the modern world's most revolutionary materials, but its durability has also sowed the seeds of a major environmental concern. Today, plastics are omnipresent in the sea and on land, and pose threats to plants, animals and humans. There has been much scientific and public attention on this problem in recent years, here and overseas, but the issue is only growing. To tackle plastic pollution, we must approach it from all angles – this includes examining its sources, pathways and effects.

This report provides the first insights into plastic pollution in Te Taitokerau (Northland). It summarises available empirical data on macroplastics and microplastics in ecosystems and organisms, as well as the sources of plastic and the pathways it travels.

We hope that by quantifying plastic pollution across the region, this report will help to: a) address knowledge gaps, b) inform policy development, c) better develop scale-appropriate solutions, and d) raise awareness and inspire change to reduce and mitigate plastics in the environment. This report can be used as a tool and a baseline for ongoing environmental monitoring and reporting.

Ultimately, we can only solve such a large problem on a large scale. Te Taitokerau, and indeed Aotearoa (New Zealand), needs a system-wide change in plastic use and disposal across all aspects of society to solve the issue of plastic pollution. It's critical that we act now to preserve our unique natural environment for future generations.

---

[1] PMCSA, Office of the Prime Minister's Chief Science Advisor (2019).

1.0 Introduction

1.1 Plastic

Plastics are synthetic, water-insoluble polymers that are mainly made from petrochemical sources. They're categorised into seven groups, including polyethylene (PE), polypropylene (PP) and polyethylene terephthalate (PET) (Auta et al., 2017; Appendix 1). Their uniqueness lies in properties such as their versatility, lightweight nature, moldability, transparency, and heat and water resistance (Andrady & Neal, 2009; Frias & Nash, 2019). Their durability, utility and affordability have fuelled a significant increase in production worldwide, from 1.5 million metric tons (Mt) in 1950 to 390.7Mt in 2021 (Geyer et al., 2017; Statista, 2023).

Plastics are ubiquitous in daily life, particularly via packaging materials made mostly from PE, PET and PP (Geyer et al., 2017). They are integral to the global economy across various sectors (OECD, 2022). Future projections estimate global plastic use to triple by 2060, reaching 1,231Mt, driven by population and economic growth – this will use up 20% of global oil production and impact 15% of the carbon budget (Wayman & Niemann, 2021; OECD, 2022; Ellen MacArthur Foundation, 2016).

1.2 Plastic waste

Over time, plastics have become a global environmental issue, made worse by excessive consumption (Andrady, 2011) and a 'throw-away' culture (Frias & Nash, 2019). In 2015, for example, 2,600Mt of plastics were in use and 70% of the 302Mt discarded as waste ended up in landfills, while the rest was incinerated (Fig. 1; Greyer et al., 2017). Furthermore, between 1950 and 2015, only 9% of plastic waste was recycled (Greyer et al., 2017). By 2050, it is estimated approximately 12,000Mt of plastic waste will be in landfills or in the environment (Andrady & Neal, 2009; Greyer et al., 2017).

1.3 Plastic litter

Given current levels of production and the quantities of plastic that are already present in the environment, it's inevitable that this abundance of plastics will keep increasing in the foreseeable future (Barnes et al., 2009). What's more, it's considered that due to their durability, all plastics ever introduced into the environment remain there today, either as whole items or as fragments (Thompson et al. 2005).

Rather than decomposing into molecular or further biodegradable compounds, plastic debris fragments into smaller pieces, which spans at least six orders of magnitude in size, from nanometres to metres. These plastic fragments are often referred to as macroplastics (>5mm) and microplastics (<5mm; Table 1). With the increasing attention given to microplastics, researchers have now begun to consider the fragmentation of macroplastics and microplastics down to even smaller sizes, known as nanoplastics (Table 1).

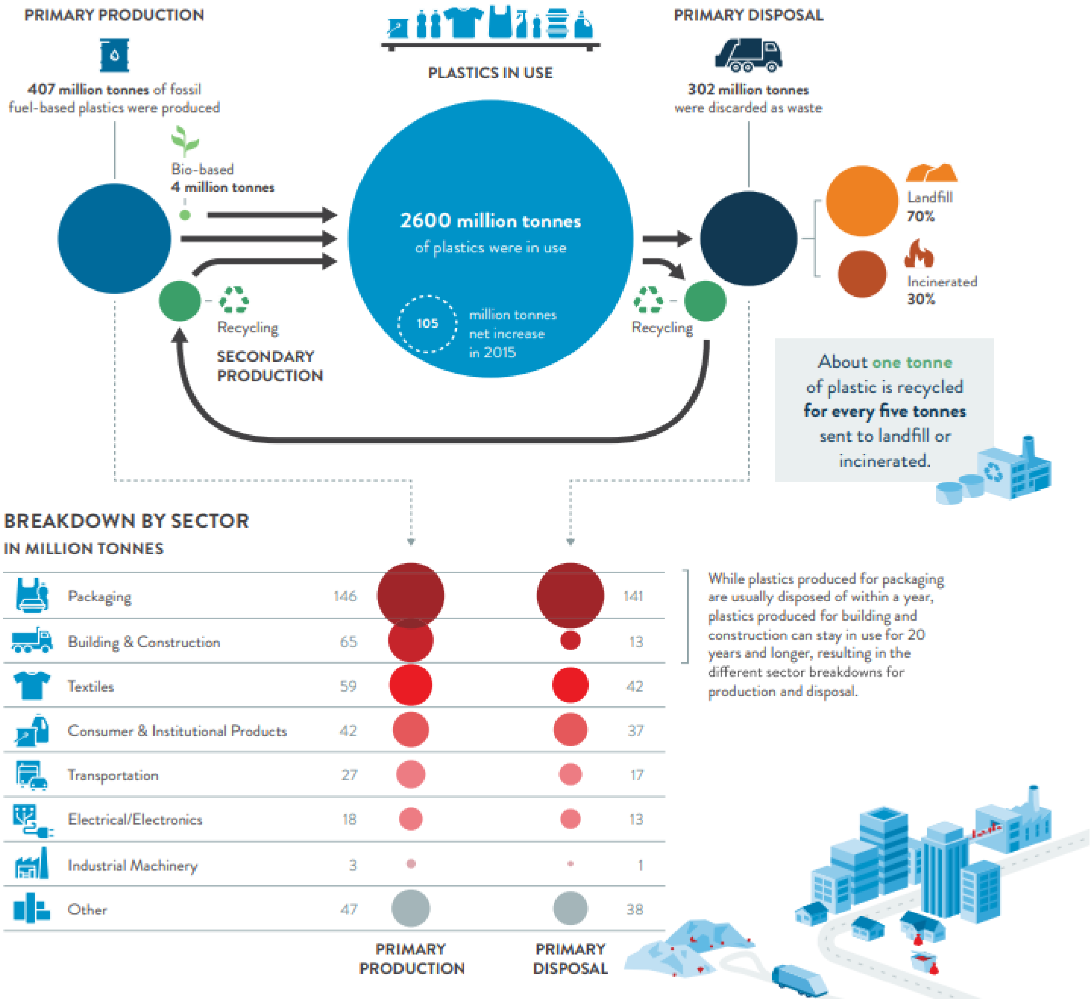
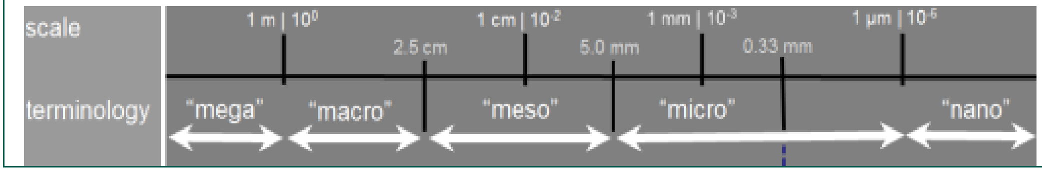


Figure 1: Global plastic production, use and disposal in 2015. (Source: NZ Royal Society, 2019, based on data from Geyer et al., 2017)

Table 1: Classification of plastic litter based on item sizes

	Definition	Reference(s)
Macro-	Plastic debris with regular or irregular shape and with a size of >5mm.	Moore (2008)
Meso- **Macro-** **Mega-**	Macroplastics can also be divided into several categories: • meso: between 5mm and 2.5cm • macro: between 2.5cm and 1m • mega: >1m.	Lippiatt et al. (2013)
Micro-	Any plastic particle with regular or irregular shape and with size ranging between 1µm (1 micron) and 5mm. There is no definition that accurately encompasses all criteria to describe what a microplastic is. Several size classes have been recommended: 1 ≤ 100µm; 100 ≤ 350µm; and 350µm to ≤5mm. Several categories are also defined to help identify the source, including fragment, fibre, fibre bundle film, pellets, sphere (or bead) and foam.	Frias & Nash (2019) Rochman et al. (2019)
Nano-	Any plastic particle with an upper size limit of 1µm or 100nm, depending on the authors.	Cole et al. (2015) Koelmans et al. (2015) Lippiatt et al. (2013)
		Lippiatt et al. (2013)

1.4 Plastic sources and pathways

One of the major challenges in addressing the global issue of plastic pollution is that its sources and transport pathways are many and widespread, and include land, water, and air (Barnes et al., 2009; Royal Society, 2019; Geyer, 2020; Fig. 2). Identifying pollution sources is key to understanding how plastics travel from land to aquatic environments, and ultimately the open oceans (Su et al., 2020).

1.4.1 Land

One of the primary pathways for plastic pollution entering the environment is through a range of land-based activities and practices (Windsor et al., 2019). Plastics can enter the environment at any stage of product manufacturing, use and disposal (Derraik, 2002).

The three main human activities linked to this issue can be identified as:
a) inadequate waste management, and residues generated by any type of activity that can lead to the accidental release of plastics in the environment
b) intentional littering or disposal of waste (domestic, commercial and industrial)
c) unintentional littering. (Royal Society, 2019)

Mismanaged waste (either littered, intentionally or not, or inadequately disposed of) can often find its way into drainage and stormwater systems (Armitage & Roosebom, 2000; Clunies-Ross, 2019). This phenomenon can be exacerbated by wind and rain or surface-runoff water (MfE & Stats NZ, 2019).

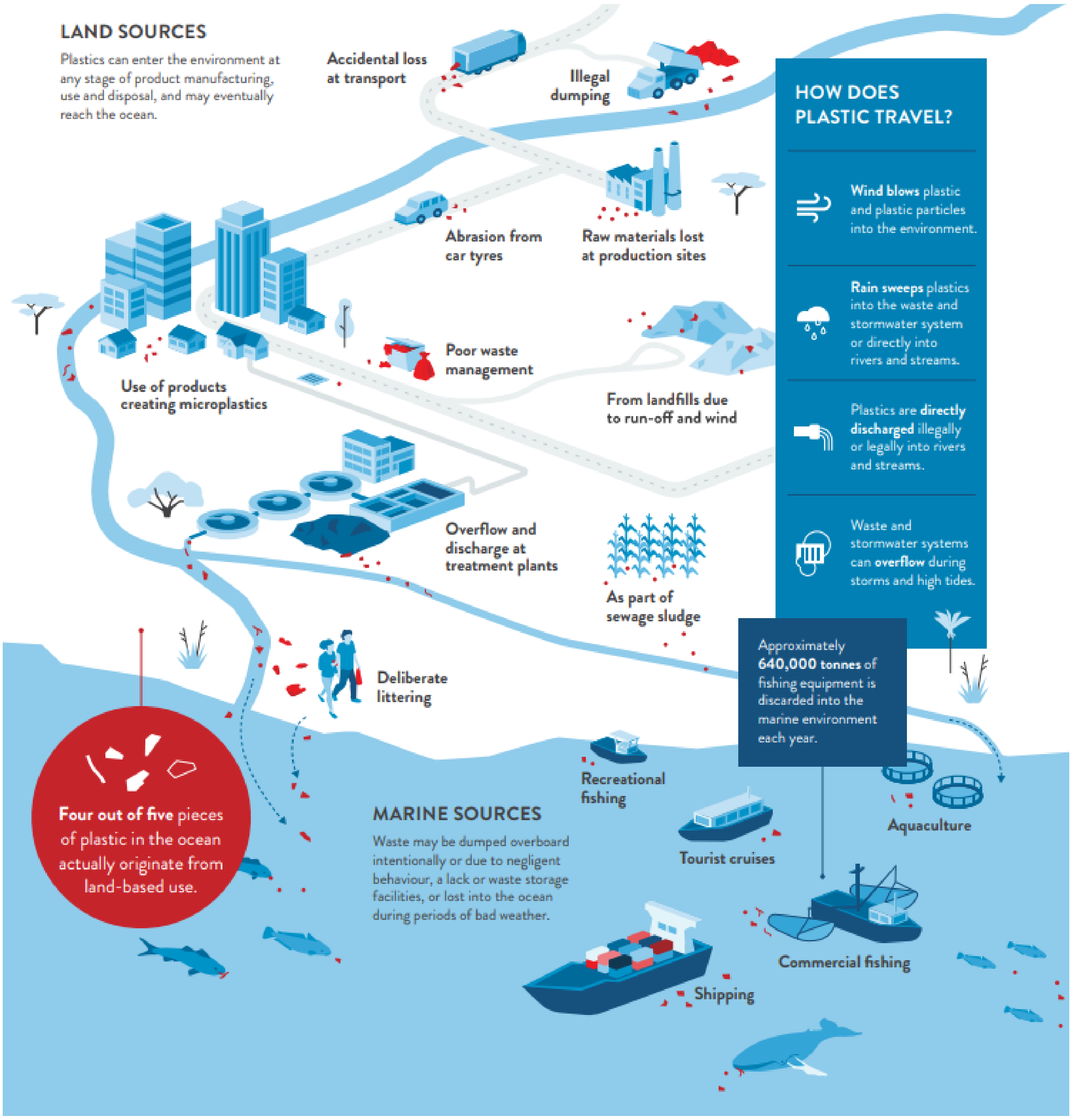
Other important sources of plastic pollution on land include the following:

- agriculture waste and runoff
- industrial spillage
- domestic activities (personal-care products with microbeads, plastic-based textiles worn away during laundry)
- sludge from wastewater treatment plants. (Zubris & Richards, 2005; Siegfried et al., 2017; Windsor et al., 2019; Behrens et al., 2021)

Annually, it is estimated that the amount of plastic released to the terrestrial environment is 4–23-times greater than that released to the marine environment (Horton et al., 2017). Microplastics may then stay in the soil, or wash into rivers and streams when it rains (Horton et al., 2017; Koelmans et al., 2017; Xu et al., 2020).

1.4.2 Freshwater

Another significant pathway for plastic pollution is through water sources, both freshwater (rivers and lakes) and marine. Collectively, river systems, stormwater runoff (Siegfried et al., 2017; Shahul Hamid et al., 2018; Windsor et al., 2019), and wastewater treatment plant discharges (Carr et al., 2016; Dris et al., 2017; Siegfried et al., 2017) are significant sources of plastic pollution, serving as pathways between terrestrial and marine environments (Fig. 2).


LAND SOURCES

Plastics can enter the environment at any stage of product manufacturing, use and disposal, and may eventually reach the ocean.

HOW DOES PLASTIC TRAVEL?

Wind blows plastic and plastic particles into the environment.

Rain sweeps plastics into the waste and stormwater system or directly into rivers and streams.

Plastics are **directly discharged** illegally or legally into rivers and streams.

Waste and stormwater systems can **overflow** during storms and high tides.

Approximately **640,000 tonnes** of fishing equipment is discarded into the marine environment each year.

Four out of five pieces of plastic in the ocean actually originate from land-based use.

MARINE SOURCES

Waste may be dumped overboard intentionally or due to negligent behaviour, a lack or waste storage facilities, or lost into the ocean during periods of bad weather.

Figure 2: Multiple sources of plastic pollution and pathways into the marine environment. (Source: Royal Society, 2019)

1.4.3 Marine

Annually, an estimated 4.8 and 12.7 million tons of plastic enter the marine environment (Jambeck et al., 2015) directly and indirectly from multiple pathways. Under a business-as-usual scenario and in the absence of any interventions, the volume of plastic waste entering aquatic ecosystems annually could double by 2030 (Borrelle et al., 2020) and nearly triple by 2040 (UNEP, 2021).

Maritime activities are also a direct source of plastic pollution and include (Macfadyen et al., 2009; Kershaw & Rochman, 2015; Li et al., 2016; Walker et al., 2019):

- aquaculture
- recreational and commercial fishing
- shipping and offshore operations
- ship-based tourism
- structures.

Once plastic has entered the marine environment, it is influenced by tides, currents, waves and winds. It accumulates in coastal areas (Galgani et al., 2015) and can travel long distances to collect in subtropical gyres (van Sebille et al., 2015). Extreme weather events such as floods, storms and tsunamis transport debris from coasts, riverbanks, estuaries and damaged structures into the oceans (Kershaw et al., 2019).

1.5 Effects and threats of plastic pollution

Plastic contamination extends to various ecosystems, including estuarine areas, coastal regions, Antarctic environments, and even the deepest parts of the Mariana Trench (Chiba et al., 2018; Díaz-Mendoza et al., 2020; Kelly et al., 2020; Lacerda et al., 2019). Unsurprisingly, the number of potentially harmful implications of plastics have escalated over time, including aesthetic issues, hazards, biosecurity risks, and effects on organisms, including humans.

1.5.1 Aesthetics and hazards

Litter is visually and aesthetically unattractive and can spoil public amenities, which in turn can have economic impacts by decreasing tourism (e.g. Phillips & House, 2009; Brouwer et al., 2017). While clean-up operations are one of the solutions to reduce litter, they incur significant costs for local authorities (e.g. Armitage & Rooseboom, 2000; McIlgorm et al., 2011). In addition to becoming an eyesore, plastics also represent a potential hazard and risk of personal injury to humans (Armitage & Rooseboom, 2000; Phillips & House, 2009; Campbell et al., 2016).

1.5.2 Biosecurity risks and invasive species

Floating plastic debris, acting as rafts, poses biosecurity risks by aiding the long-distance colonisation of non-indigenous species (Pace et al., 2007; Maximenko et al., 2015; Casabianca et al. 2019; Audrézet et al., 2021). Microplastics may also transport pathogenic microbes through wastewater treatments, enabling the dispersal of resistant microbes into the environment via treated effluent (Eckert et al., 2018). Recognising these biosecurity implications is vital for comprehending, monitoring and ultimately mitigating the effects of global-scale plastic pollution (Audrézet et al., 2021).

1.5.3 Effects on organisms

Plastic pollution is globally recognised as a major environmental threat to aquatic and terrestrial wildlife, and increasingly attracting worldwide attention (Gall & Thompson, 2015; Wagner & Lambert, 2018; Blettler & Wantzen, 2019; Huang et al., 2021). There are various pathways (both direct and indirect) for plastics to affect organisms depending on their size, via ingestion, entanglement, inhalation, and skin contact or skin absorption (e.g. Laist, 1997; Gall & Thompson, 2015; Kim et al., 2018; Kühn & van Franeker, 2020; Fig. 3).

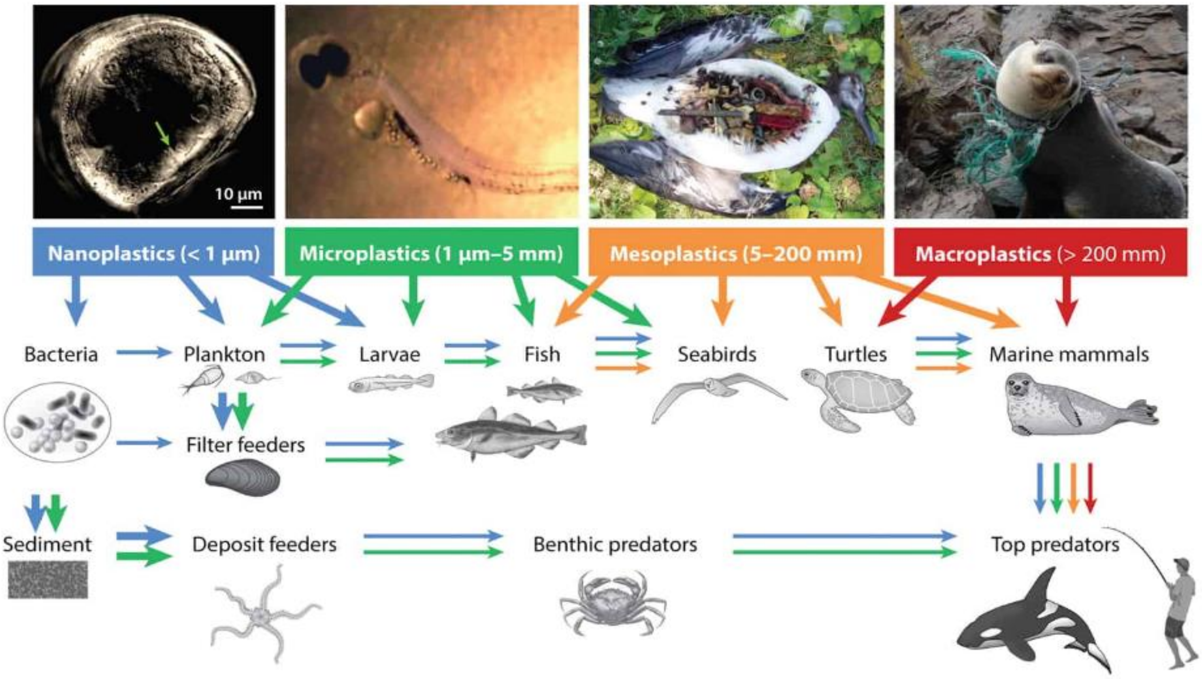


Figure 3: How different sizes of plastic affect marine life, either directly by entanglement or ingestion (thick arrows) or indirectly via food sources that have ingested it (thin arrows). (Source: Worm et al., 2017)

1.5.4 Potential health effects in humans

Like other organisms in the food web, humans are exposed to microplastics primarily via ingestion, as well as inhalation and skin contact. Evidence of plastic contamination in the human food chain is increasing. Microplastics have been detected in:

- beverages, including beer and wine (Shruti et al, 2020; Diaz-Basantes et al., 2022)
- tap or drinking water (Zhang et al., 2020)
- fruits and vegetables (Conti et al., 2020)
- seafood (Huang et al., 2021; Diaz-Basantes et al., 2022; Gündoğdu & Köşker, 2023).

Seafood is considered the primary vector of microplastic pollution in humans (Barboza et al., 2018, although refer to Mohamed Nor et al., 2021), which could put indigenous communities at a higher risk due to a greater consumption of shellfish (Gismondi & Sherman, 1996).

Exposure to microplastics is raising concerns around potential human health issues, especially through eating foods contaminated with microplastics, known as trophic transfer (Barboza et al., 2018; Huang et al., 2021; Meaza et al.,2021). Microplastics could, for example, trigger inflammation, stress, immune dysfunctions, chromosomal modification, and other adverse medical conditions in humans, depending on exposure and susceptibility (refer to Campanale et al., 2020; Prata et al., 2020a; Danopoulos et al., 2022 for reviews).

1.6 Northland monitoring studies

As concern increases over the presence and persistence of plastic pollution in the environment, there are growing efforts to develop a better understanding of plastic pollution and reduce the amount of litter entering the environment (Office of the Prime Minister's Chief Science Advisor, 2019). Such efforts include the monitoring of litter and plastics in various ecosystems (including community litter clean-up events and citizen-science projects), and the assessment of their effects in organisms.

Northland Regional Council, iwi, hapū and non-government organisations have worked together to better understand the extent of this issue in Northland and fill any knowledge and data gaps.

1.6.1 Macroplastic pollution

Clean-up surveys are often used to better understand the scope and current nature of the problem of litter (e.g. Jang et al., 2018), because sites can be easy to access and often do not require specialised equipment (Kershaw et al., 2019). Below is a list of the main projects that deal with macroplastics in Te Taitokerau.

Litter Intelligence

Litter Intelligence was developed in 2018 through collaboration with Sustainable Coastlines, Statistics New Zealand (Stats NZ), the Department of Conservation (DOC), and Ministry for the Environment (MfE) funding, facilitating community data collection and anti-litter initiatives. This platform offers scientifically rigorous litter data, meeting Stats NZ's Tier 1 requirements, from numerous survey sites nationwide. It aligns with United Nations Environment Programme (UNEP) and Intergovernmental Oceanographic Commission (IOC) Guidelines on Survey and Monitoring of Marine Litter (Cheshire et al., 2009), and makes data publicly accessible online.

Northland Regional Council (NRC) adopted Litter Intelligence in 2019. Quarterly surveys are conducted at two sites along the Hātea River and Whangārei Harbour (Fig. 4), with an additional 16 popular recreational beaches across Northland monitored during the summer. The surveys are supported by the community, and 34 sites have been collectively monitored since 2019 (Litter Intelligence, unpublished data). Between 2019 and 2022, 96 beach surveys were conducted across the region (Appendix 3A).

Figure 4: Official Northland Regional Council Litter Intelligence survey sites along the Hātea River (top) and at Onerahi (bottom). (Photos: Bamford, N.)

Te Tai Tokerau Debris Monitoring Project (TTTDMP)

TTTDMP, initiated in 2019 by NRC and Maunga to Moana (M2M) Consulting, involves citizens in collecting litter data. It aligns with Litter Intelligence and UNEP/IOC guidelines (Cheshire et al., 2009). It uses the Marine Debris Tracker (MDT) app (NOAA, University of Georgia, USA) to record GPS locations of litter items. The project encourages data collection, promotes environmental awareness, and offers flexible methodologies. Some data are publicly accessible. The principal investigator also conducts surveys on marine litter and various items in the region (Martinez & Bamford, 2021; Martinez, 2022, 2023). In 2019–2020, TTTDMP conducted 249 surveys at 138 sites using the MDT app.

Stormwater study

To estimate how much plastic and litter is reaching our rivers and estuaries each year, NRC collaborated with NorthTec, Whitebait Connection, Whangarei District Council, Far North District Council, Kaipara District Council and Northland District Health Board to install LittaTraps throughout the region. LittaTraps are inserted into stormwater catch-pits and can capture plastic and litter before they enter the stormwater system.

NRC collaborated with M2M Consulting, examining urban stormwater in Whangārei and five other Northland towns (Martinez & Griffiths, 2023). Supported by various stakeholders, 51 LittaTraps were installed at 16 different land-use types. Quarterly audits from March to December 2021 quantified litter content, identified high-risk land uses, and estimated the annual plastic and litter load discharged into aquatic environments. Data categories align with Litter Intelligence, and results are in their database. In 2022, Northland Regional Council committed to continue monitoring 10 of the original 51 sites (Martinez & Griffiths, 2023).

Keep New Zealand Beautiful

Keep New Zealand Beautiful (KNZB), established in 1967, aims to inspire, educate and empower Kiwis to be tidy through various programmes, including Upstream Battle and Backyard Battle (KNZB, 2023a). In 2019, supported by the New Zealand Government, KNZB initiated a National Litter Audit, collecting data on land-based litter at 413 sites nationwide (16 in Te Taitokerau). Sites were chosen through stratified random sampling to represent diverse environments. As with Litter Intelligence, the audit was developed with input from Stats NZ, DOC and MfE (KNZB, 2021). The audit was repeated in 2022 to track changes over three years (KNZB, 2023b). This report combines cigarette-butt data with plastic data for consistency (Cheshire et al., 2009).

1.6.2 Microplastic pollution

Over the past few years, NRC has initiated and collaborated on several projects relating to microplastic pollution in Te Taitokerau.

Microplastics in sediments

Northland Regional Council collaborated with iwi, hapū and SCION to assess microplastic distribution in beach sediments and across Te Taitokerau, creating baseline data for coastline and freshwater sites (De Lena et al., 2021). Part of the Aotearoa Impacts and Mitigation of Microplastics (AIM^2) initiative is to understand microplastic distribution across Aotearoa environments, identify associated risks to ecosystems, people and animals, and propose solutions, including outreach and education.

NRC collected sand sediment samples from 11 diverse sites, including open coastal, dune lake and estuary locations, between November 2019 and February 2020. These sites were chosen based on geographic factors and recreational use, and samples analysed by SCION. The project received support from multiple iwi and hapū groups.

Microplastics in freshwater

Rivers and effluent are major terrestrial sources of microplastics (Horton et al., 2017). However, freshwater microplastics studies are limited, with fragmented data and lacking standardised protocols (Lambert & Wagner, 2018; Horton et al., 2017). The project GlobAl LAke miCroplasTICs (GALACTIC) was initiated in 2019 to fill this gap, studying microplastics in 38 lakes across 22 countries, including Aotearoa. It provides the first-ever data on microplastics in Aotearoa's freshwater systems. NRC collaborated with NIWA (National Institute of Water and Atmospheric Research) as part of GALACTIC to collect samples from Lake Taharoa, a rare Northland dune-lake ecosystem (NIWA, 2023). This effort was supported by the Taharoa Domain Governance Committee.

Microplastics in seawater

Blue Cradle and researchers from six Aotearoa institutions collaborated to assess microplastic pollution in Aotearoa marine, freshwater and terrestrial environments, investigate impacts on ecosystems and industries, and explore mitigation strategies. Part of the AIM^2 project, funded by the Ministry of Business, Innovation and Employment Endeavour Research Programmes Fund, this initiative conducted a June 2021 expedition in the Hauraki Gulf and along Te Taitokerau's east coast. Seven sites were studied with two manta net trawls at each, primarily in the Bay of Islands and Whangārei Harbour. NRC advised on trawl locations based on the microplastic sediment study and populated areas, and the Institute of Environmental Science and Research (ESR) conducted the analysis.

Microplastics in shellfish

Under the AIM^2 project, NRC collected shellfish samples in 2020 to ascertain: a) if microplastics were present and at what concentration, b) what polymer types were present, and c) the morphotype (shape) and colour of observed microplastics. Three species – pipis (*P. australis*), cockles (*A. stutchburyi*) and wedgeshells (*M. Liliana*) – from three locations within the region were selected. A total of 15–20 individuals per site were sent to ESR for analysis. This project was supported by local hapū and iwi.

1.7 Purpose of this report

Plastic pollution (including microplastics) are in freshwater, seawater, air, soil, sediments, organisms and parts of the human diet. This raises broad concerns about the effects of microplastics and plastics in complex global ecosystems (Trembley et al., 2020). To address the issue of plastic pollution and implement relevant management actions and policies, it is important to know the extent of this issue and address knowledge gaps at national and, where possible, local levels.

This report is the first comprehensive summary of the status of plastic prevalence in Te Taitokerau, and the key pathways for plastic to enter the environment. The report also aims to:
- serve as a baseline reference for future projects and research
- identify knowledge gaps
- help better understand the status of plastic pollution in the region
- support policy development to address this ongoing issue in Te Taitokerau and across Aotearoa.

While this report doesn't delve into the management of plastic pollution at local, regional or national levels, it compiles data for future assessment of plastic pollution trends and mitigation effectiveness.

2.0 Macro litter findings

2.1 Illegal dumping, littering, and clean-up events

Macro litter refers to all categories of litter, larger than 5 mm in size. enough to be seen and picked up. Although it is challenging to determine whether all waste during clean-ups was illegally dumped or littered, approximately 8.5 metric tonnes and 527.7 m^3 of litter were removed from the environment annually thanks to clean-up events (Table 2).

Table 2: Estimated annual amount of litter collected by clean-up projects led by some of the charity trusts in Te Taitokerau. Note: Not Available (NA). Volumes were not converted to weight due to the mixed nature of the litter (e.g. plastics mixed with glass, etc.). (Sources: For Our Real Clean Environment Trust, Ocean Spirit Trust, Sea Cleaners Trust)

Location	Charity	Waste collected (kg/year)	Waste collected (m^3/year)	Time period
Te Taitokerau	*Sea Cleaners*	NA	527.7	Aug–Nov 2022
Te Taitokerau	*Litter Intelligence*	127.70	NA	2019–2022
Whangārei district	*F.O.R.C.E.*	8,430	NA	2019–2022
Tutukaka Harbour*	*Ocean Spirit*	3.90	NA	Mid 2020–2022
	Total	**8,561.60**	**527.7**	

** SeaBin installed in the harbour*

The records presented here are, however, an underestimation of the total volume and/or weight of rubbish illegally dumped in the region. This is because: a) not all illegal dumping is reported and dealt with by councils, b) not all councils collect roadside litter, c) if rubbish is collected by councils, the data measuring it are not always recorded, and d) there are many more community-led clean-up events for which there are no data, or data are not publicly available. Furthermore, no data on the categories of waste collected are recorded. As a result, the extent of plastic pollution associated with illegal dumping in Te Taitokerau's environment is unknown.

2.2 Shoreline surveys

2.2.1 Plastic composition

Overall, 12,397 plastic and foamed plastic litter items were collected at NRC's two official Litter Intelligence survey areas (Hātea and Onerahi, Fig. 4) over 30 surveys between 2019 -2023. Plastic items accounted for 68%, while foamed plastic represented 32%, at these sites (Fig. 5).

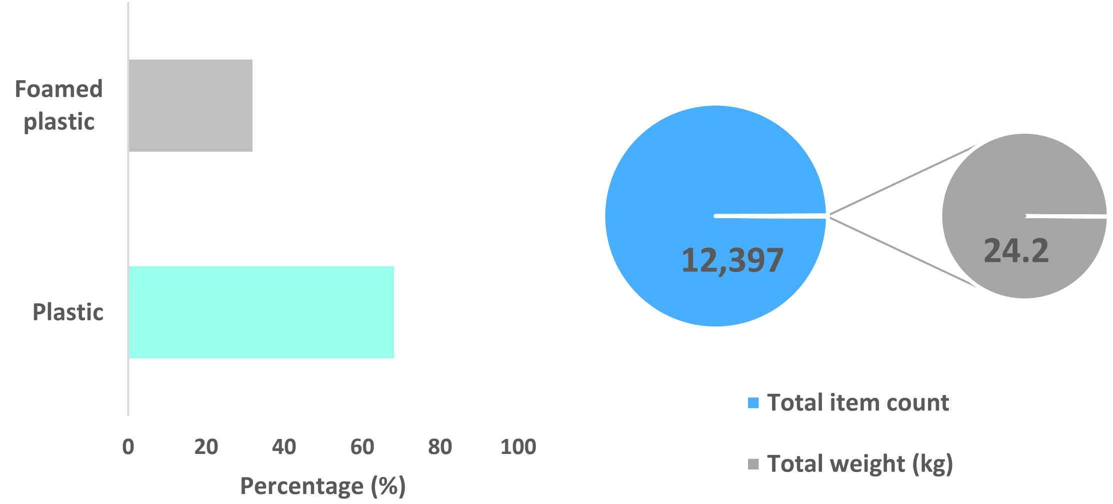


Figure 5: Percentage breakdown of plastic and foamed plastic items (left); total item count and weight (right). Taken over 30 survey events between 2019 and 2023. (Source: Litter Intelligence, insights)

Plastic and foamed plastic items (by percentage) varied between Litter Intelligence surveys across Aotearoa compared to those in Te Taitokerau. For Aotearoa, plastic was 69% and foamed plastic 8%. In Te Taitokerau, plastic was 59% and foamed plastic 21% (Fig. 6). These results were consistent with other surveys conducted in Te Taitokerau, with plastics ranging from 74% (TTTDMP, unpublished data) to 85% (Van Gool, 2021).

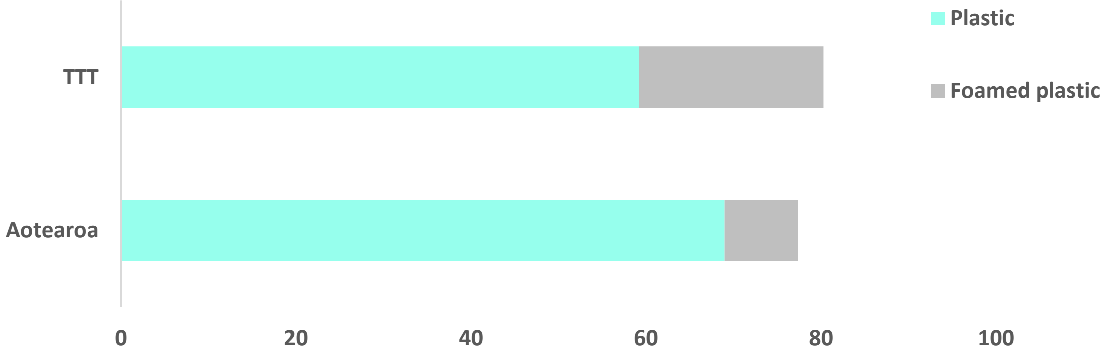


Figure 6: Comparison of plastic and foamed plastic (percentage) collected under the Litter Intelligence programme across Aotearoa and in Te Taitokerau (TTT), between 2019 and 2023. (Source: Litter Intelligence, unpublished data)

2.2.2 Top three plastic items (Litter Intelligence and TTTDMP)

The top three plastic items found differed between NRC's two official Litter Intelligence survey areas (Hātea and Onerahi) over 30 surveys, and TTTDMP from 2019 to 2022. Based on percentage, hard plastic fragments were both the most common item 22% and 36% respectively. Foamed plastic and food wrappers were the next two top items at NRC's survey areas, whereas soft plastic and glass fragments were observed during TTTDMP surveys (Fig. 7).

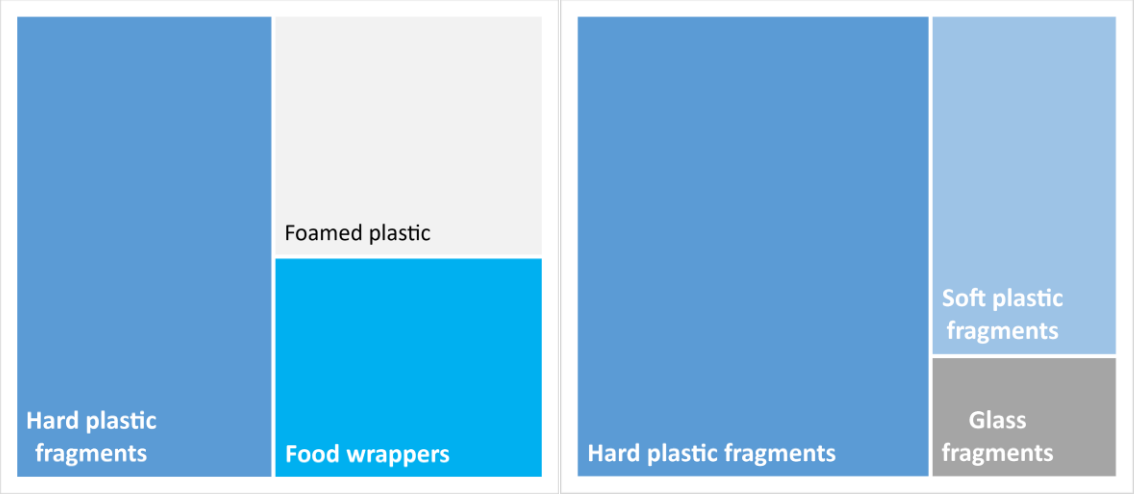


Figure 7: Top three plastic items (based on percentage of all litter items) from NRC's two official Litter Intelligence sites 2019 to 2023 (left), and Te Tai Tokerau Debris Monitoring Project (TTTDMP) between March 2019 and March 2022 (right). (Source: Litter Intelligence, TTTDMP, unpublished data)

2.2.3 District level, including Whangārei Harbour

The proportion of plastic litter differed across the districts in the Litter Intelligence data (Fig. 8), being highest in the Kaipara (88%) and the Far North (82%); these levels were also higher than the regional and national levels. In contrast, the proportion of plastics was 56% in the Whangārei district and 52% in Whangārei Harbour, below both the regional and national levels (Fig. 8). Findings for the Kaipara district were consistent with TTTDMP data. Although TTTDMP data for Whangārei district and Whangārei Harbour had higher proportions of plastics than Litter Intelligence surveys, these were still below the regional level (Fig. 9).

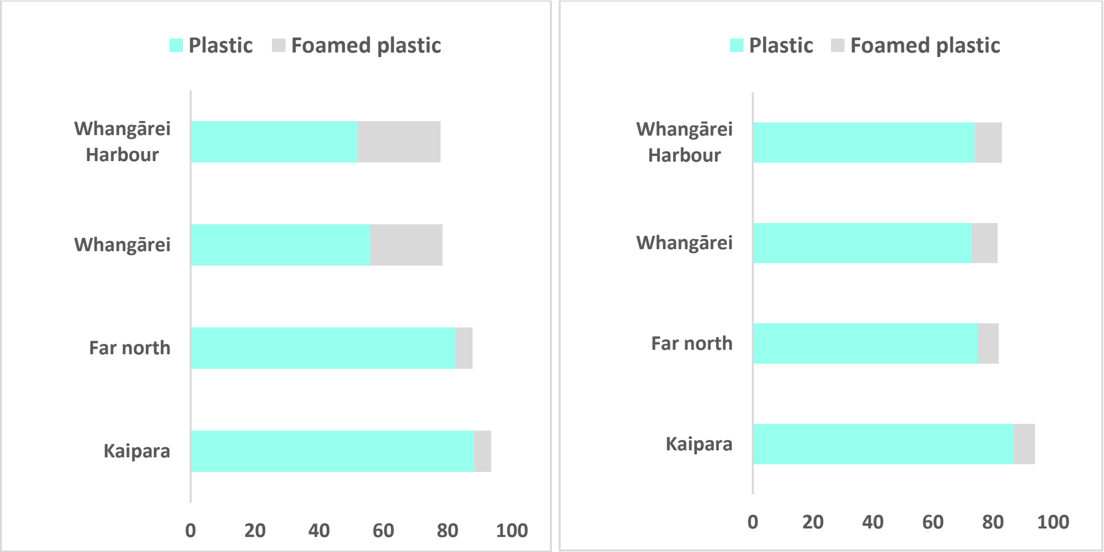


Figure 8: Composition of plastic litter (percentage) collected under the Litter Intelligence programme between 2019 and 2023 (left), and Te Tai Tokerau Debris Monitoring Project (TTTDMP) between March 2019 and March 2021 (right). Measured across Te Taitokerau's three districts, as well as Whangārei Harbour sites. (Source: Litter Intelligence, TTTDMP, unpublished data)

The higher percentage of plastics observed in the Kaipara district is partly explained by the large variation in litter composition between sites across the region. The top three sites from the Litter Intelligence surveys are all located in that district, with more than 97% of litter being plastic items (Fig. 8). The Onerahi (boat ramp) site is a clear outlier (only 5% of items were plastics), decreasing the overall Whangārei district and regional percentage of plastic items. At that site, glass and ceramic items dominated (89%, Litter Intelligence unpublished data).

2.2.4 Litter densities – regional level

It was possible to compare data collected in Te Taitokerau during the KNZB 2019 (KNZB, 2021) and 2022 (KNZB, 2023b) National Litter Audits with Litter Intelligence data collected in the same years. Te Taitokerau consistently had a lower density level of litter than the national level, except in 2019 in Litter Intelligence data (Fig. 9). When comparing trends within projects, however, a difference emerged. While litter densities increased from 2019 to 2022 on land (KNZB) at the regional and national level, litter densities decreased in coastal surveys.

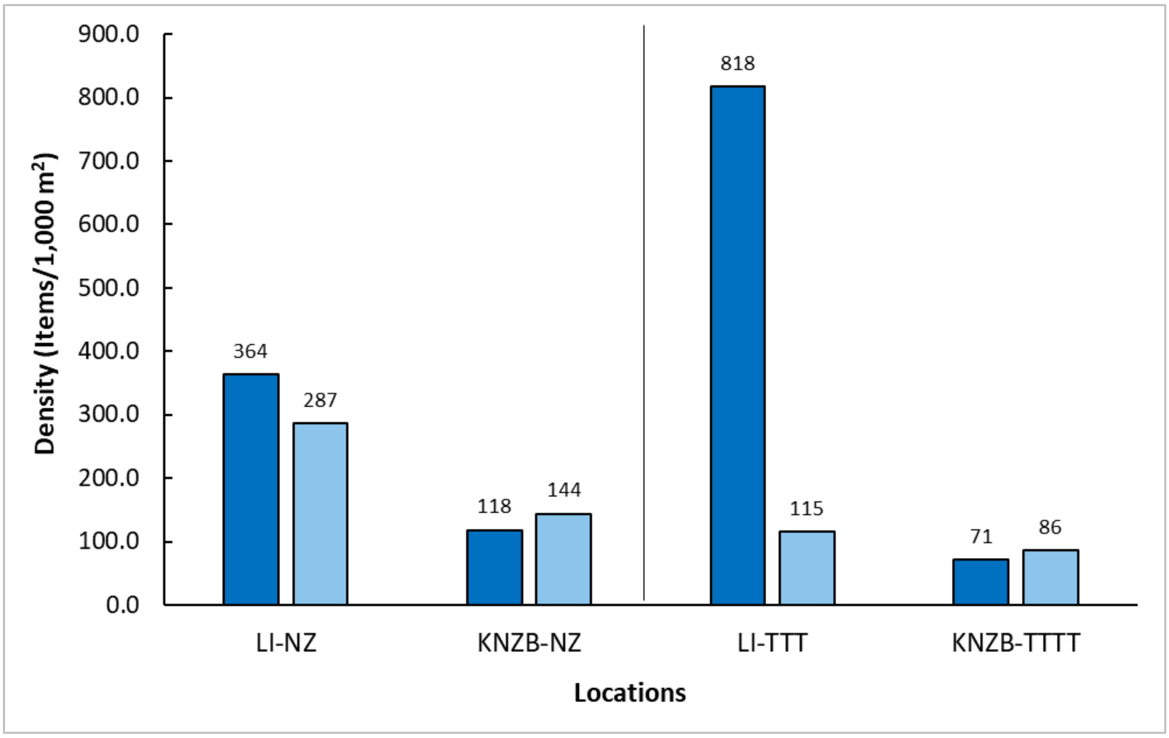


Figure 9: Litter densities per 1,000m^2 in 2019 (dark blue) and 2022 (light blue) across Aotearoa (NZ) and in Te Taitokerau (TTT). Surveys were conducted on beaches by Litter Intelligence (LI), and inland (towns and cities) by Keep New Zealand Beautiful (KNZB). (Sources: KNZB, 2019 and 2023; Litter Intelligence, unpublished data)

Plastic item densities varied among TTTDMP and Litter Intelligence surveys between 2019 and 2022 (Fig. 10). The plastic density in Te Taitokerau was higher for TTTDMP surveys (212 items/1,000m^2) compared to Litter Intelligence surveys (162 items/1,000m^2).

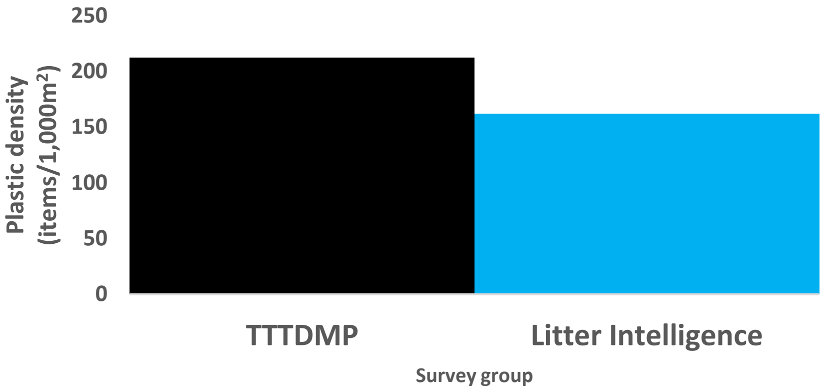


Figure 10: Plastic litter densities per 1,000m^2 collected by TTTDMP (2019-2022) and Litter Intelligence (2019-2023) from coastal surveys in Te Taitokerau. (Source: Litter Intelligence, TTTDMP, unpublished data)

2.2.5 Litter densities – Whangārei Harbour level

Litter Intelligence and TTTDMP surveys indicated the upper Whangārei Harbour had a higher density of litter than the rest of the harbour (Fig. 11). This is likely due to its closer location to the city of Whangārei, which is a source of litter (refer to section 3.0 stormwater studies); the Hātea river acts as a pathway between freshwater and marine environments.

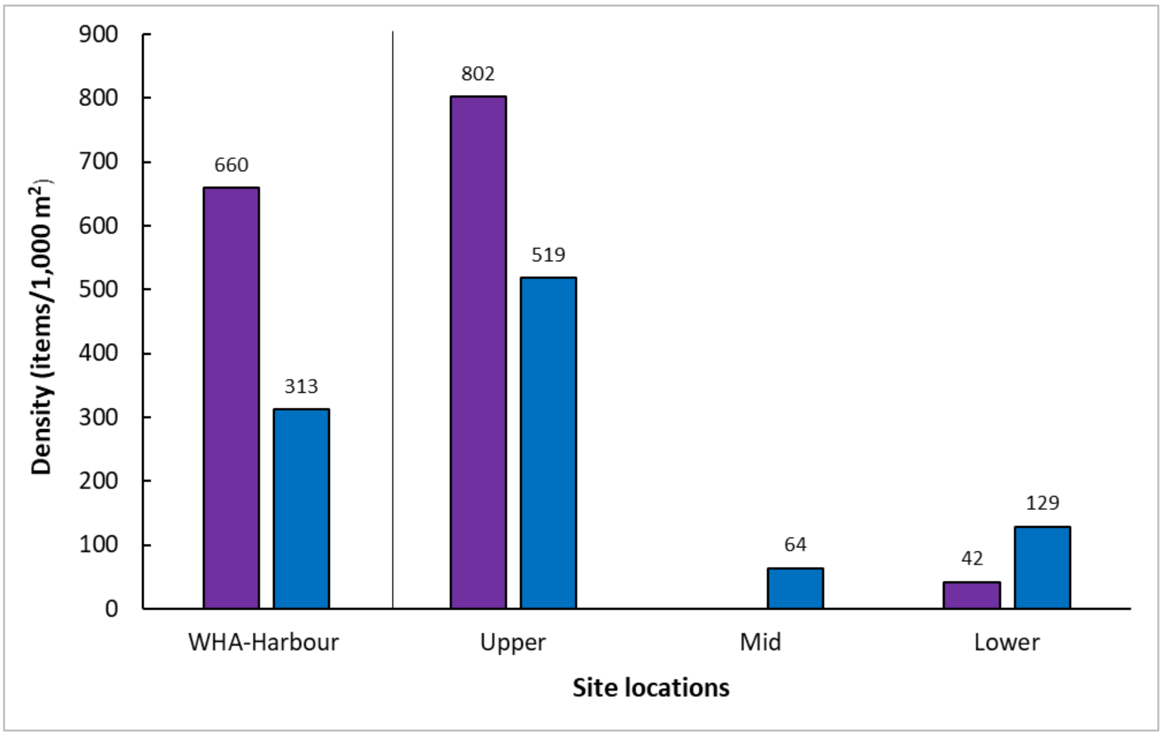


Figure 11: Litter densities per 1,000m^2 across different areas in Whangārei Harbour. Data was collected by Litter Intelligence (LI, purple, 2019–2023) and TTTDMP (blue, 2019–2020). (Sources: Litter Intelligence & TTTDMP, unpublished data)

The differences in litter composition and densities observed between the various projects can be explained by the location of surveys (e.g. KBNZ is land-based vs LI/TTTDMP are coastal-based), the number of surveys conducted (Table 4), the area covered at a particular site, and the protocol used for data collection.

For example, KNZB conducted their surveys at the same sites in 2019 and 2022, while the number of surveys and sites increased over time for the Litter Intelligence programme (e.g. 10 surveys at five regional sites in 2019 vs 43 surveys at 27 sites in 2022; Litter Intelligence, unpublished data). The Van Gool et al. (2021) study had a small sample size and amount of litter collected (20 items in total).

Table 4: Survey effort from various projects on litter in Te Taitokerau (TTT) and across all three districts: Far North (FND), Kaipara (KD) and Whangārei (WD). Effort in Whangārei Harbour (WHA) is also included. Note: not specified (NS). (Sources: KNZB, 2019 and 2022; Van Gool et al., 2021; Litter Intelligence – LI and Te Tai Tokerau Debris Monitoring Project – TTTDMP, unpublished data)

	TTT	FND	KD	WD	WHA
Number of surveys					
LI	96	15	19	62	34
TTTDMP	249	44	22	183	112
KNZB	16	NS	NS	NS	NS
Van Gool	9	6	0	3	0
Number of sites					
LI	34	9	8	17	4
TTTDMP	137	41	22	74	30
KNZB	16	NS	NS	NS	NS
Van Gool	3	2	0	1	0

In terms of protocol, TTTDMP primarily focused on the high-tide mark for random surveys along varying lengths at each site, instead of a wider width of the beach along a 100m transect. When comparing surveys conducted at the same site by Litter Intelligence and TTTDMP (Fig. 12), differences in litter densities were also apparent when a different section of a beach was surveyed (e.g. at Sandy Bay and Ocean Beach), or the whole beach was surveyed rather than a 100m transect (e.g. Onerahi, Pah Road). In contrast, when a survey was conducted in approximately the same area of a beach, results are within the same range (e.g. Langs Beach).

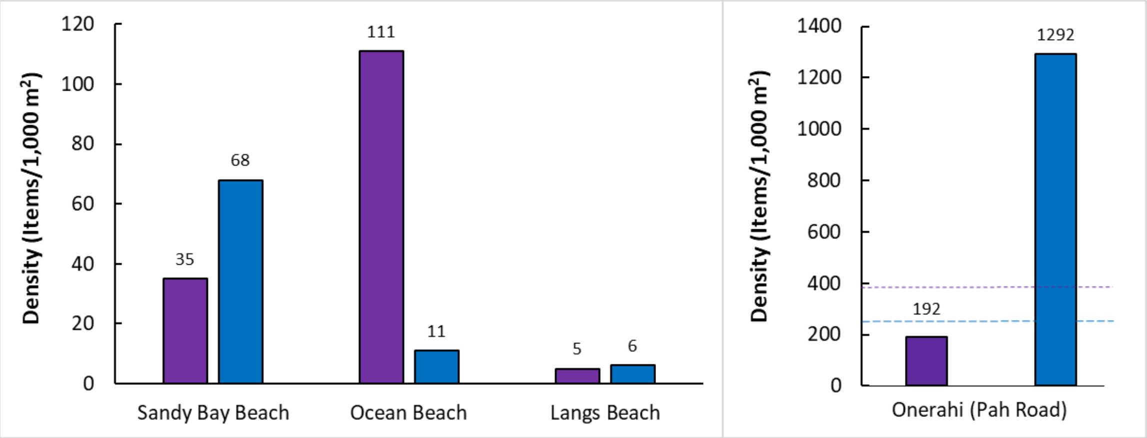


Figure 12: Litter densities per 1,000m² at sites surveyed by Litter Intelligence (purple, 2019–2022) and TTTDMP (blue, 2019–2020) in Whangārei district. Note: the dotted lines represent the litter density estimates at district level from Litter Intelligence (purple) and TTTDMP (blue) surveys. (Sources: Litter Intelligence & TTTDMP, unpublished data)

2.2.6 Flux rates and estimated litter deposition

Flux rates depend on litter accumulation over time: in this instance, 24 hours. A survey at the Hātea Litter Intelligence site by Northland Regional Council in November 2018 found 1,059 items, yielding a 24-hour flux rate of 89 items (density 89 items/1,000m²). Assuming this daily rate, 6,497 items would accumulate over 73 days. However, only 1,315 items were recorded in February 2019, suggesting that 5,182 items (~80%) may have dispersed elsewhere in Whangārei Harbour or the marine environment (Table 3).

Table 3: Estimated flux rate and 'lost' litter items at Hātea river site, Whangārei, Te Taitokerau. (Source: NRC, unpublished data)

Information	Details
Number of litter items (19/11/2018)	1,059
Number of litter items (01/02/2019)	1,315
Number of days between flux survey and first LI survey	73
Litter flux number of items (20/11/2018)	89
Estimated litter loading rate	6,497
Estimated number of 'lost' items	5,182
Estimated percentage of 'lost' litter items	79.8%

3.0 Stormwater studies

3.1 Composition of litter

Between March and December 2021, the 51 LittaTraps installed across Te Taitokerau captured a total of 21,006 litter items, weighing 7.8kg, and consisted primarily of plastic (71.1% by count, 49.4% by mass) across all various land-use categories (Fig. 13).

The proportion of plastic litter captured by LittaTraps fell within the range of Litter Intelligence and TTTDMP surveys (59.2–74.5%) for the region, while being slightly higher than the national level of 68.6% (Litter Intelligence, unpublished data).

Figure 13: Composition of litter (percentage) collected by LittaTraps in Te Taitokerau, in 2021. (Source: Martinez & Griffiths, 2023)

3.2 Litter densities

LittaTraps captured 15.8 litter items/ha/day, equivalent to 0.005kg/ha/day, with significantly higher densities captured in ‘hospital’ and ‘fast food’ land-use areas than in ‘commercial’, ‘residential’ and ‘hotel/motel’ land-use areas (Martinez & Griffiths, 2023; Fig. 14). Capture rate was highest in winter (median = 19 items/ha/day), although no significant seasonal trends were detected. In terms of material type, ‘plastics’ had the highest loading rates by items. There were big differences between the amount of litter captured at different sites. One site captured 2409 items, which was 11% of all litter, while the best site captured just 26 items.

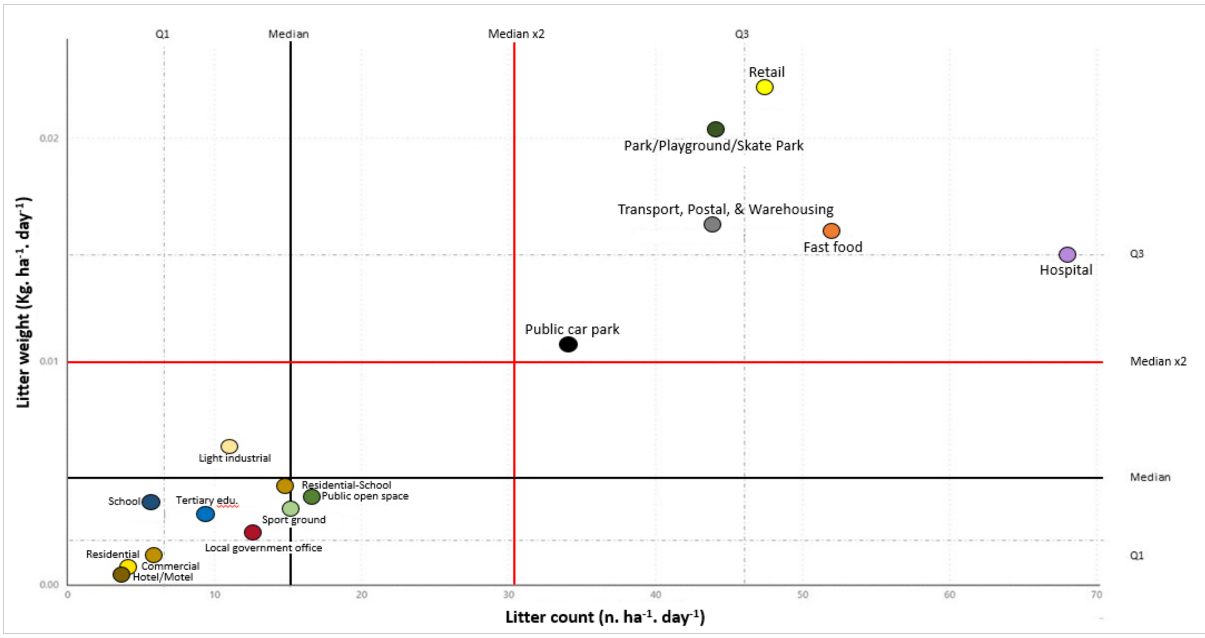


Figure 14: Median loading rates by item (items/ha/day), dry mass (kg/ha/day), and land-use category of litter items captured by LittaTraps in Te Taitokerau in 2021. The median (black line), double median (red line), and Q1 and Q3 (dotted lines) are also included. (Source: Martinez & Griffiths, 2023)

3.3 High loading locations

Several high-risk land uses were identified, such as 'hospital', 'fast food', 'park/playground/skate park', 'retail', 'transport, postal and warehousing' and 'public car parks' (Martinez & Griffiths, 2023). Unsurprisingly, the nine considered 'hot spots' (which caught 50% of the total litter) were all located in those high-risk areas, and the highest load was captured in a city-centre car park (352 items/ha/day; 0.14kg/ha/day). In contrast, 'residential', 'commercial', 'local government' and 'hotel/motel' land uses captured <1% of all litter (Martinez & Griffiths, 2023).

The project estimated that 13.2 million litter items are released annually from the region's stormwater network, including 8.7 million plastic items. If foamed plastics are included, this number increases to 9.4 million items (Martinez & Griffiths, 2023).

3.4 Top three items

The top three types of plastic litter items were like those found in shoreline surveys within Te Taitokerau. Cigarette butts were the largest contributor to litter items (Table 5). Soft and hard plastic fragments were the second- and third-most found items.

The prevalence of hard plastic fragments may be caused by larger hard plastic items degrading due to weathering processes, including photodegradation (Valadez-Gonzalez et al., 1999; Thompson et al., 2004). These can then further degrade into microplastics (e.g. Zhang et al., 2021).

Table 5: Top two litter items captured by LittaTraps in Northland in 2021, according to land use.

Catchment Type	Top item		Second item	
Fast Food		**Cigarette butts, filters** 49.0% n = 867		**Soft plastic fragments** 18.9% n = 334
Commercial		**Hard plastic fragments** 25.1% n = 148		**Cigarette butts, filters** 16.5% n = 97
Hospital		**Cigarette butts, filters** 72.6% n = 2,371		**Soft plastic fragments** 6.1% n = 200

3.5 Hard plastic fragment colours

Hard plastic fragments dominate Te Taitokerau's coastal litter, ranking third in land and stormwater surveys. Studies on their colours revealed white as the dominant colour, comprising about a third of hard plastics. Blue ranked second, and clear/transparent third highest colour across all districts. McCaulay (2020) assessed 5,409 hard plastic fragments, with consistent colour patterns (Fig. 15).

Northland Regional Council's July 2019 examination at the Hātea River site showed similar results, with white, clear/transparent and blue fragments being the most prevalent, in line with the regional pattern (TTTDMP, NRC, McCaulay, 2020).

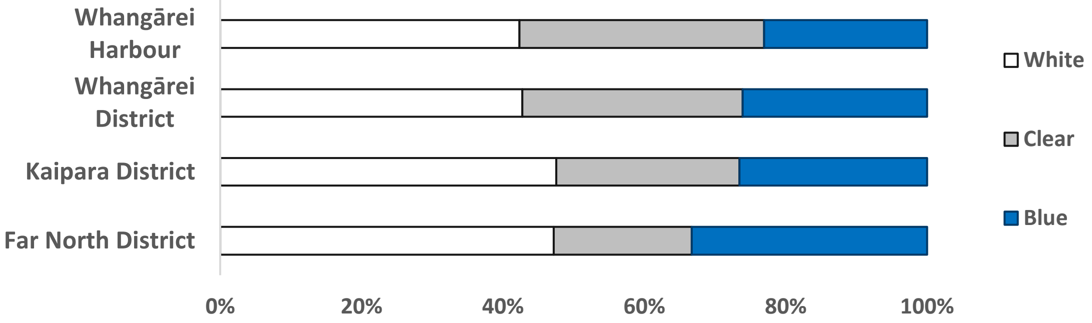


Figure 15: Percentage of the top three predominant colours of hard plastic fragments collected during TTTDMP surveys (2019 and 2020) across Te Taitokerau, Far North, Kaipara and Whangārei districts (2020), and by NRC (July 2019) at the Hātea river site. (Sources: TTTDMP, unpublished data: McCaulay, 2020; NRC, 2019; unpublished data)

3.6 Food packaging

Food packaging, especially when made of plastics, was one of the top three items in Te Taitokerau, which is consistent with the rest of Aotearoa (Fig. 7; Litter Intelligence & TTTDMP, unpublished data; KNZB, 2021 and 2023b).

Out of a total of 470 food wrappers collected at the five sites around Whangārei Harbour, 74% still had the brand name visible. Of those, 57% were considered plastic items (Guilloux, 2020). Of the distinct plastic wrapper items, sweets (16.8%), lollipops (15.7%) and chocolate (13.4%) were the most common (Fig. 16). Chocolate and sweets were also the only two classes of food wrappers present at all sites. Other relatively common plastic food wrapper classes included mints (11.1%), chocolate bars (9.7%) and ice-cream (7.0%). These six item categories represented 73.7% of plastic food wrappers littered.

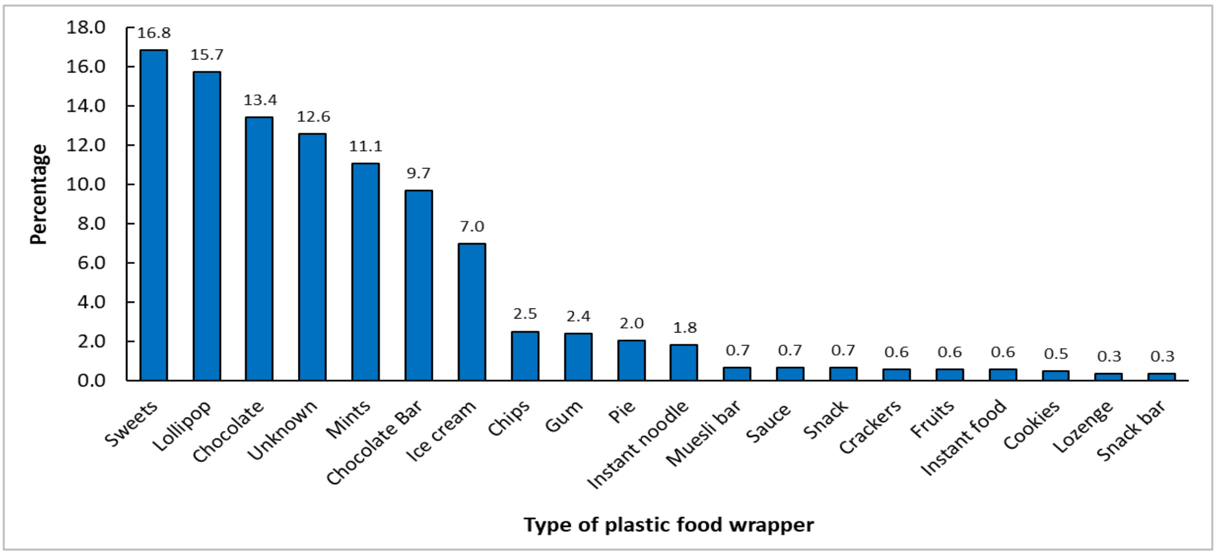


Figure 16: Percentage of different categories of plastic food wrappers collected between 2019 and 2020 at various sites in Whangārei Harbour, Te Taitokerau. (Sources: TTTDMP; Guilloux, 2020)

3.7 Macroplastic pollution hazards

3.7.1 Wildife

There is limited data on the impact of macroplastic pollution on organisms in Te Taitokerau. In Aotearoa, macroplastic entanglement and ingestion have been observed in various megafauna species. Entanglement occurred in New Zealand fur seals (kekeno, *Arctocephalus forsteri*) in the Kaikoura region (Boren et al., 2006). Ingestion of plastic items was documented in immature and sub-adult stranded green turtles (*Chelonia mydas*) (Godoy & Stockin, 2018) and Sooty shearwaters (*Ardenna grisea*) (Hidalgo-Ruz et al., 2021) in Aotearoa.

Plastic debris and fragments were also found in the nests of seabird colonies, including flesh-footed shearwaters (*Puffinus carneipes*) on multiple North Island islands (Buxton et al., 2013), Chatham albatrosses (*Thalassarche eremita*), Northern royal albatrosses (*Diomedea sanfordi*), and Southern royal albatrosses (*Diomedea epomophora*) (Hidalgo-Ruz et al., 2021). Even though plastic was prevalent in Australasian gannet (tākapu, *Morus serrator*) nests at Horuhoru Island, entanglement was infrequent (Adams et al., 2020). Plastic debris poses entanglement, ingestion and health risks to seabirds, and affects conservation efforts (Buxton et al., 2013; Hidalgo-Ruz et al., 2021). This is significant given the predicted high risk of seabirds in the Tasman Sea ingesting plastic (Wilcox et al., 2015).

3.7.2 Biosecurity

A preliminary study along the Coromandel Peninsula indicated marine debris from aquaculture and urban marine structures act as rafts for non-indigenous species, creating biosecurity risks by enhancing their spread and dispersal (Campbell et al., 2017). Several biofouling taxa were documented, with the most common being hydroids, bryozoans, algae and polychaetes. Plastic, especially rope, was the dominant type of marine debris that acted as a raft.

3.7.3 Human health

Using a 10-year dataset (2007–2016) from the Accident Compensation Corporation (ACC), Campbell et al. (2019) demonstrated that marine debris are a pervasive hazard and lead to personal injury, representing an average of 1.6% of all claims across the country. Of these, the majority involved medical treatment (41%), followed by weekly compensation (31%) and hospital treatment (15%). The top five causes of injuries included loss of balance or personal control, punctures, tripping or stumbling, twisting movement, and collision or being knocked over by an object. This study also indicated that injuries affected all ages, especially young children (0–14). Finally, higher claims that exceeded the proportion of their populations were detected in regions considered tourism hubs, including Te Taitokerau (5.1%).

4.0 Microplastics

4.1 Microplastics in freshwater

Northland Regional Council collaborated with NIWA (National Institute of Water and Atmospheric Research). This was part of a global lakes microplastics study (known as the GALATIC (GlobAl LAke miCroplasTICs project) to collect samples from Lake Taharoa, a rare dune lake ecosystem in Te Taitokerau and 37 other lakes across 22 countries.

Lake Taharoa had a microplastic level of 1.4 particles/m^3, slightly lower than Lake Rotorua (1.8 particles/m^3) despite having a much lower population density (17/km^2 vs. 170/km^2). However, it exceeds the median concentration (0.9 particles/m^3) of all study lakes but is below the average (1.9 particles/m^3) (Fig. 17). More than 90% of Lake Taharoa's plastic particles are smaller than 5 mm, consistent with findings in other lakes worldwide (Nava, V., et al, 2023).

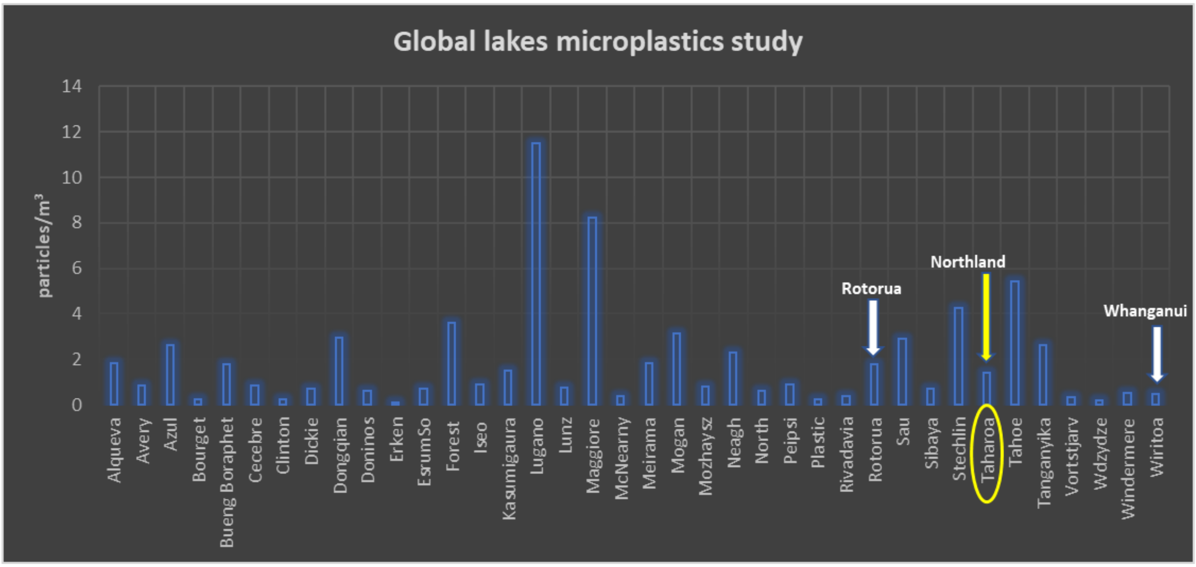


Figure 17: Microplastic particles/m³ trawl results from 38 lakes across the world. Lake Taharoa is circled in yellow and remaining Aotearoa lakes marked with white arrows. (Source: Nava, V., et al, 2023)

4.2 Microplastics in seawater

Preliminary results from seawater manta net trawl samples taken around the Bay of Islands (BOI), Matapōuri (MID) and Whangārei (WHG) (Fig. 18), indicated that the concentration of microplastics varied between and within trawling sites, ranging from 0.02 to 0.17 particles/m^3 (Fig. 19). Microplastic concentrations were the highest in the near-shore area of the Bay of Islands, followed by the waters around Whangārei Heads as well as sites closer to shore, than in offshore waters in the Bay of Islands and Whangārei areas.

Figure 18: Locations of seawater manta net trawls in Te Taitokerau, 2021, during the Blue Cradle Expedition. (Source: ESR/AIM[2], unpublished data)

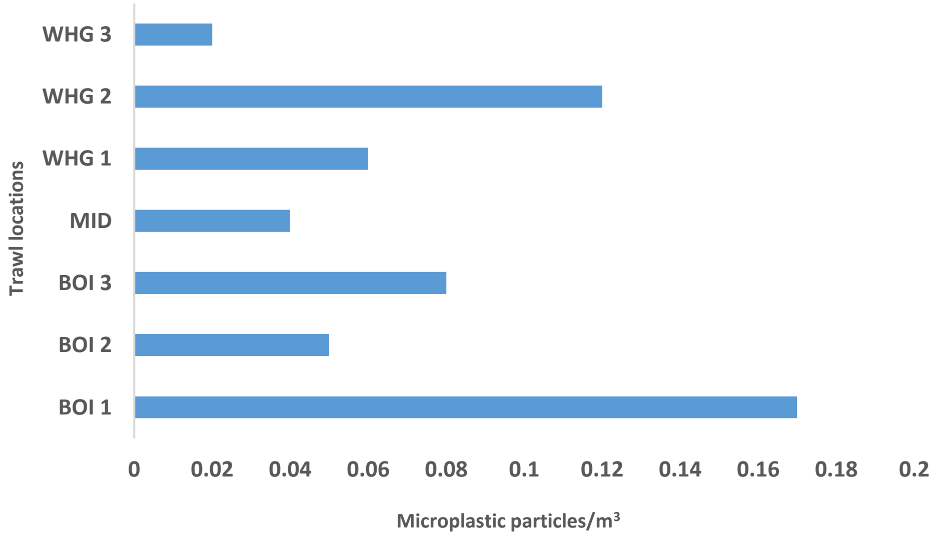


Figure 19: Microplastic concentration (particles/m^3) in seawater samples collected by manta net trawls at different sites in Te Taitokerau, in 2021, during the Blue Cradle Expedition. (Source: ESR/AIM[2], unpublished data)

In Te Taitokerau, microplastics were mainly fibres (60%) and fragments (35%) (Figs. 20 and 22). Among the seven polymer types, polyethylene terephthalate (PET) constituted 41%, followed by polyethylene (PE) at 15% and polypropylene (PP) at 14% (Fig. 21). Of 11 colours identified, black (28%), blue (21%) and clear/transparent (20%) were the most common.

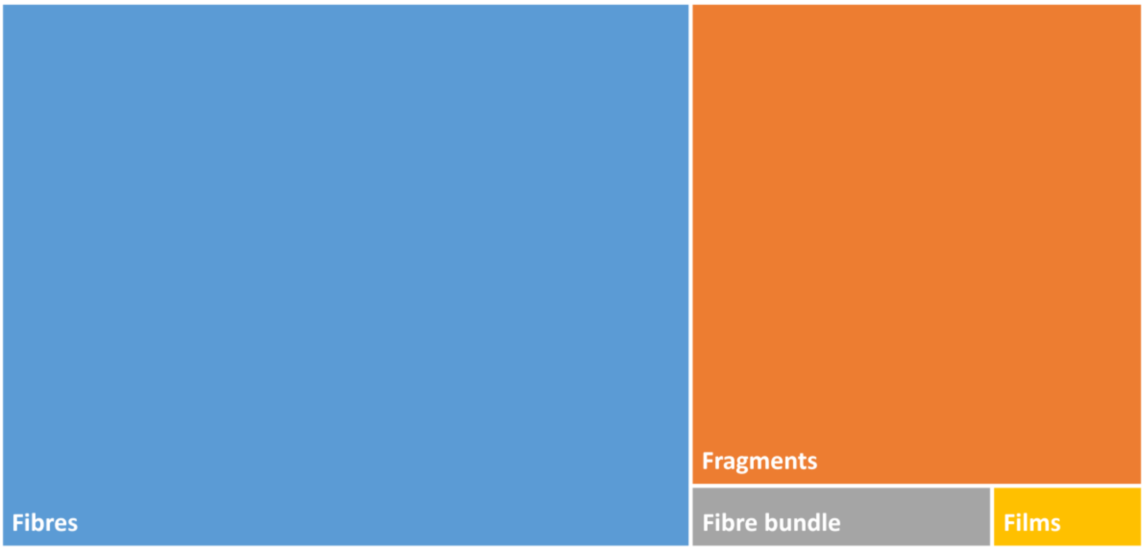


Figure 20: Proportion (percentage) of microplastic morphotypes in seawater samples collected by manta net trawls at different sites in Te Taitokerau, in 2021, during the Blue Cradle Expedition. (Source: ESR/AIM^2*, unpublished data)*

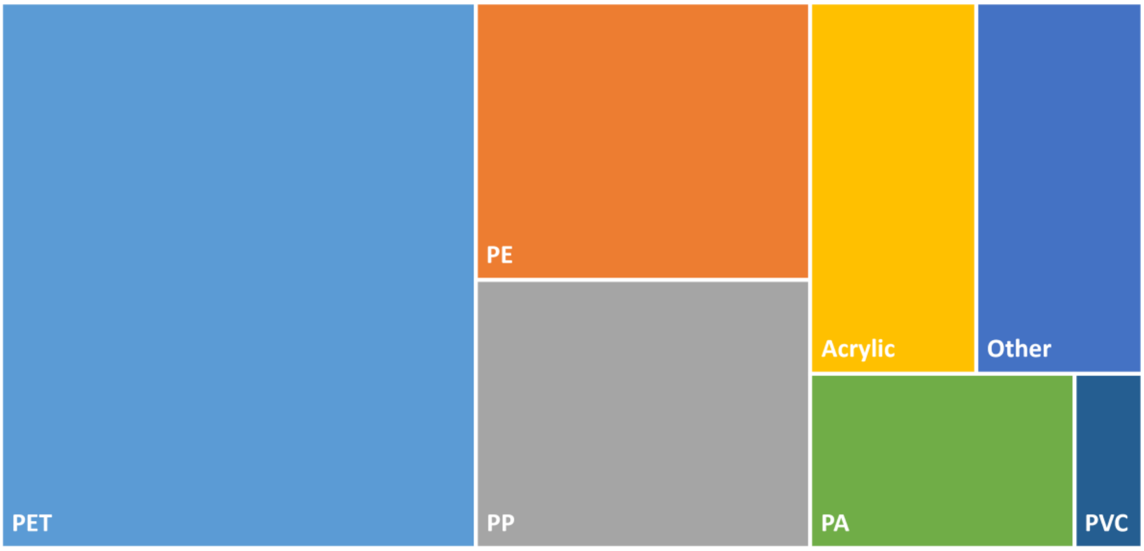


Figure 21: Proportion (percentage) of microplastic polymers in seawater samples collected by manta net trawls at different sites in Te Taitokerau, in 2021, during the Blue Cradle Expedition. (Source: ESR/AIM^2*, unpublished data)*

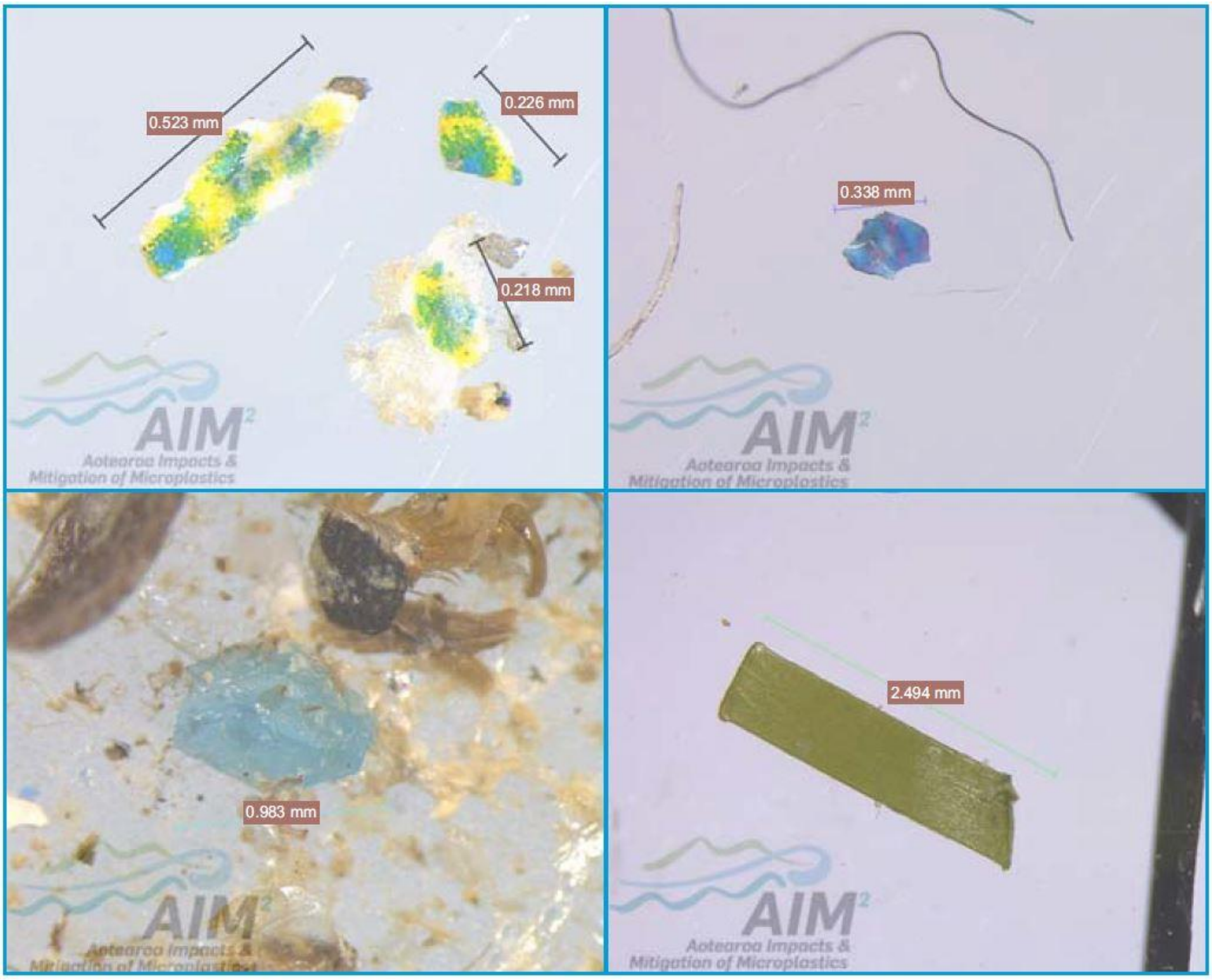


Figure 22: Examples of microplastics collected in manta net trawls during the Blue Cradle Expedition along the east coast of Te Taitokerau, in 2021. Polyethylene terephthalate (PET, top left); acrylic (top right); polyethylene (PE, bottom left); and polypropylene (PP, bottom right). (Photos: ESR/AIM^2)

4.3 Microplastics in sediments

Microplastics were ubiquitous in the coastal sediments of Te Taitokerau and varied significantly between sites, ranging from as high as 6.66 microplastics/kg (MP/kg) of dry weight (DW) in Mangawhai to as low as 0.31 MP/kg in Onerahi (Fig. 23; De Lena et al., 2021; Appendices 6 and 7). No significant differences in mean microplastic concentrations (per kg/DW) were detected between seasons (summer vs winter), coasts (east vs west) or location (north vs south).

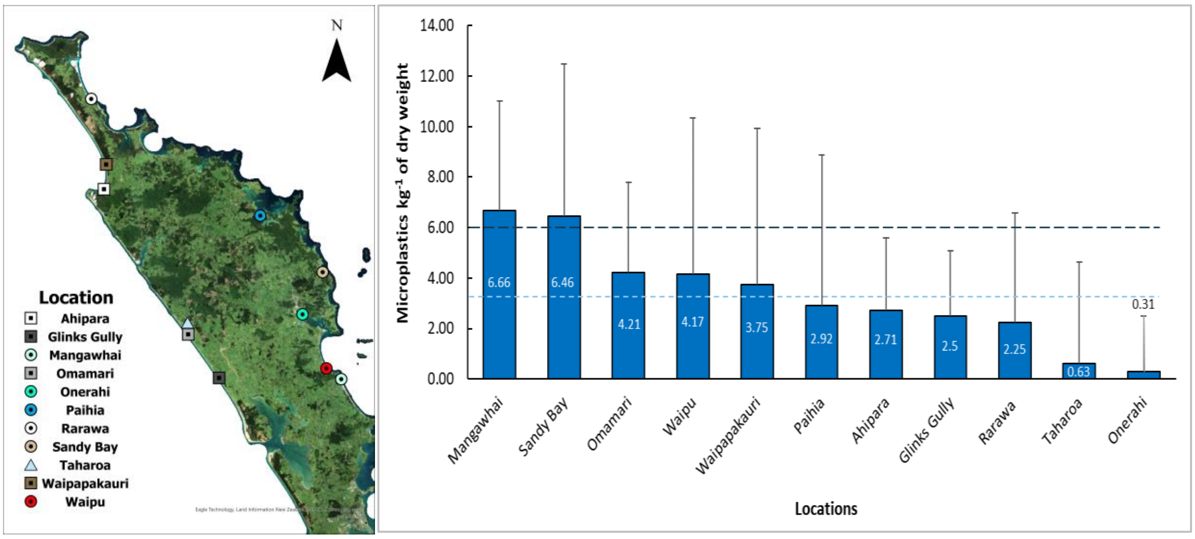


Figure 23: Mean microplastic particles concentrations (per kg/DW) in sediments in Te Taitokerau, 2019–2020. The dashed lines indicate the mean concentration for Northland (light blue) and Auckland (dark blue) for comparative purposes. Error bars = standard deviation. (Source: De Lena et al., 2021)

Mean microplastics concentrations (kg/DW) across Te Taitokerau (3.26 MPs/kg DW ± 4.35 SD; n = 148) were significantly lower than sites in the Auckland region (6.03 MPs/kg DW ± 4.35 SD, n = 55; De Lena et al., 2021) (Fig 24).

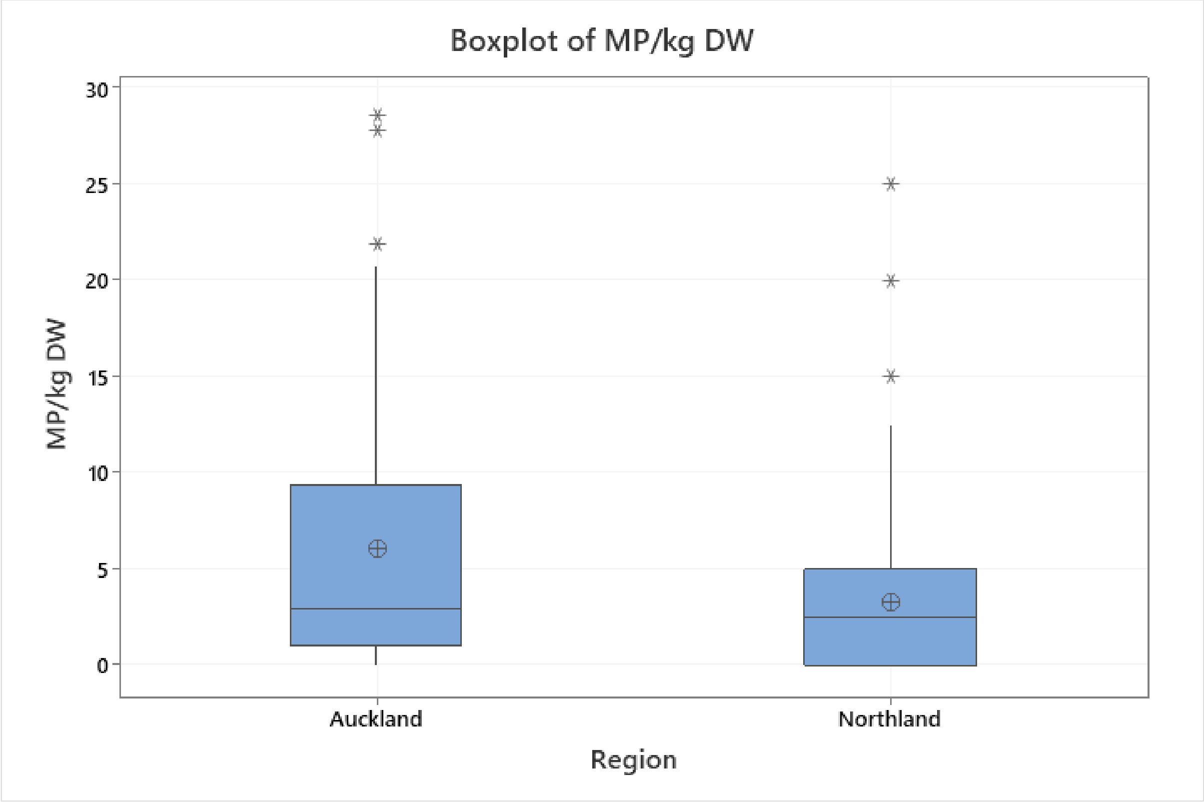


Figure 24: Boxplot of microplastics per kilogram of dry weight in sediments in Northland (Te Taitokerau) and Auckland. (Source: De Lena et al., 2021)

The most common microplastic particles in the sediments of Te Taitokerau were fibres (50%), followed by fragments (36%, Fig. 25), which is consistent with preliminary results from seawater manta net trawls (Fig. 21). Sediments sampled in Auckland also showed fragments and fibres as common microplastic morphotypes. However, there was variation between the Auckland locations.

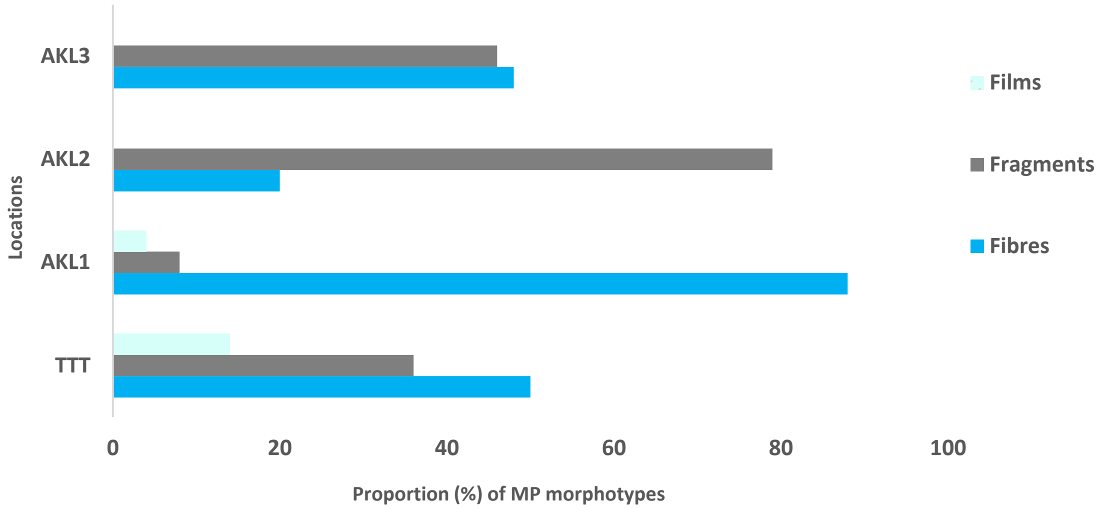


Figure 25: Proportion (percentage) of microplastic morphotypes in sediments in Te Taitokerau (TTT) and Auckland (AKL). (Source: De Lena et al., 2021; Bridson et al., 2020)

The same three most common polymers found in seawater samples were also the most common polymers found in sediment samples (PE, 23%; PP, 18%; PET, 8%), (Figs. 21 and 26). Again, the proportions of polymers varied across sites and regions, with no obvious trends (Fig. 27; Appendices 6 and 7). When data were available, only PP and PE were detected at 83% of the sites. The predominant colours of microplastics in sediments collected in Te Taitokerau were not assessed (De Lena et al., 2021).

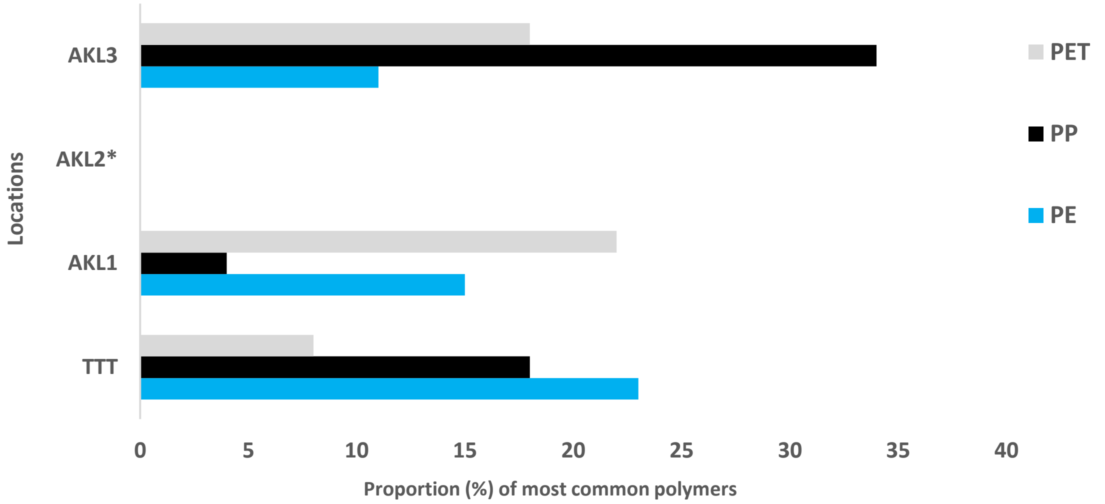


*Figure 26: Proportion (percentage) of top three polymer types in sediment samples collected in Te Taitokerau (TTT) and Auckland (AKL). *No data available. (Source: De Lena et al., 2021; Bridson et al., 2020)*

4.4 Microplastics in shellfish

Microplastics were detected in all three shellfish species and across all sampling sites within Te Taitokerau (ESR, unpublished data). The mean number of microplastic particles per individual varied between species and between sites for the same species (Fig. 27; Appendices 4 and 5). Cockles collected at Mangawhai had the highest concentration of microplastics (2.6 microplastics/individual), while pipis had the lowest (0.6 microplastics/individual).

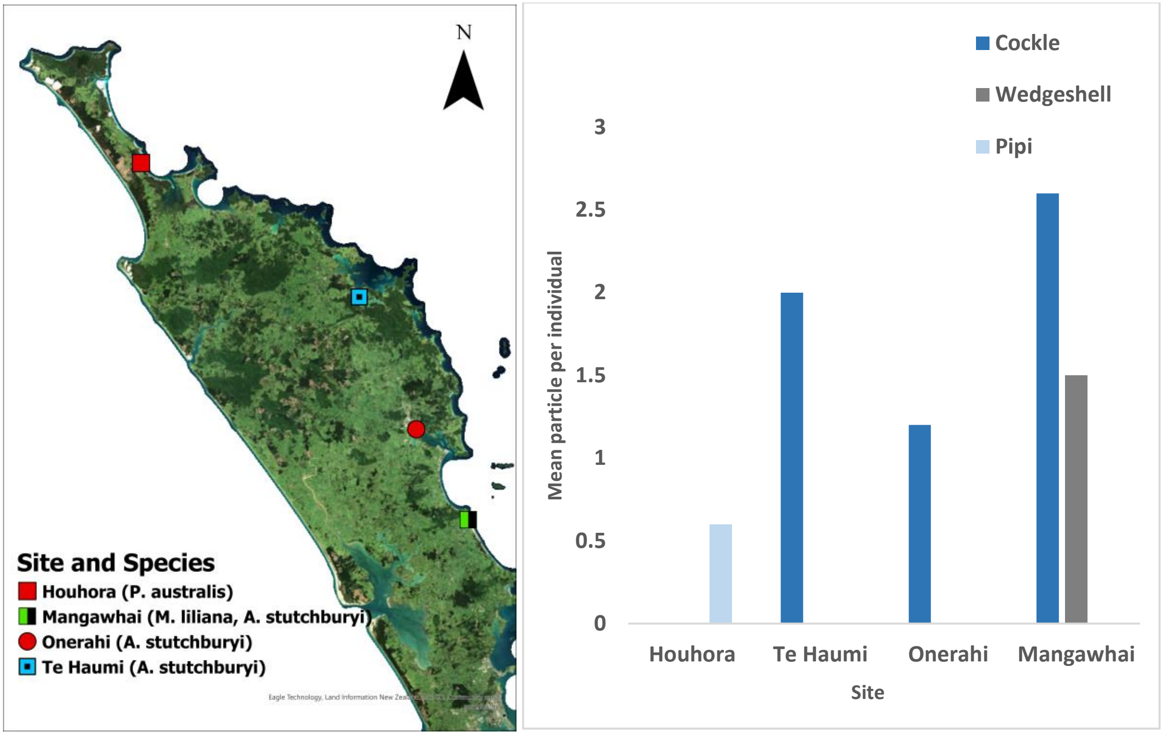


Figure 27: Site, species and mean microplastic particles per individual of different shellfish species collected at four sites in Te Taitokerau in 2020. (Source: ESR, unpublished data)

Fibres (55%) and fragments (45%) dominated microplastic morphotypes in all species and sites in the region (Fig. 28). This was consistent with seawater trawls (Fig. 20; ESR, unpublished data) and sediment samples (Fig. 25; De Lena et al., 2021) in Te Taitokerau.

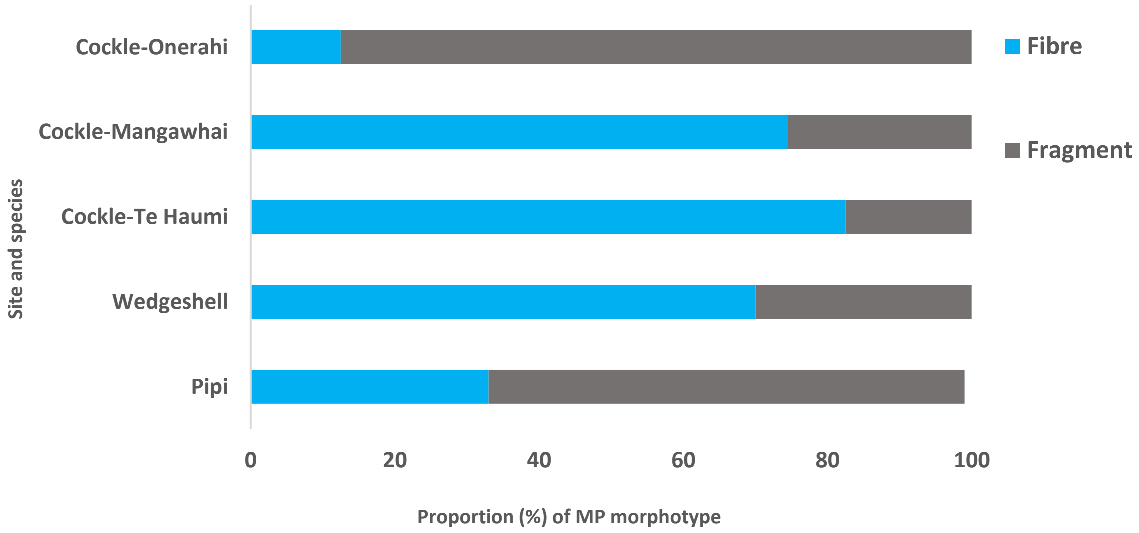


Figure 28: Proportion (percentage) of microplastic morphotypes in different species of shellfish sampled at various sites across Te Taitokerau in 2020. (Source: ESR, unpublished data)

Various polymers were found in shellfish, and PET was consistently present. Other common polymers included PE, PP, PA (polyamide), PS (polystyrene) and ARC (acrylic), with variations among species and sites (Fig. 29). PE, PET and PP were prevalent in seawater and sediment samples regionally (Figs. 21 and 26; ESR, unpublished data; De Lena et al., 2021).

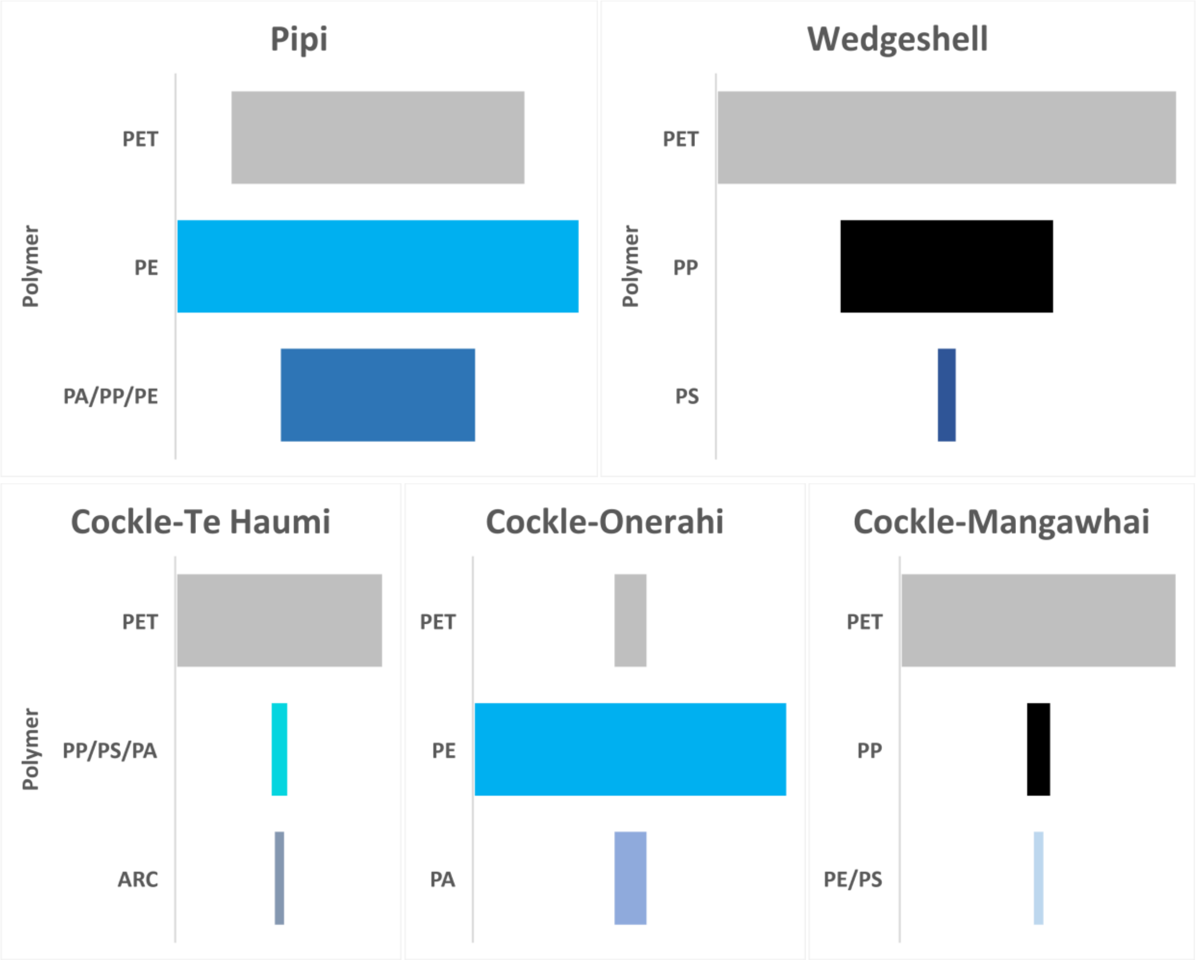
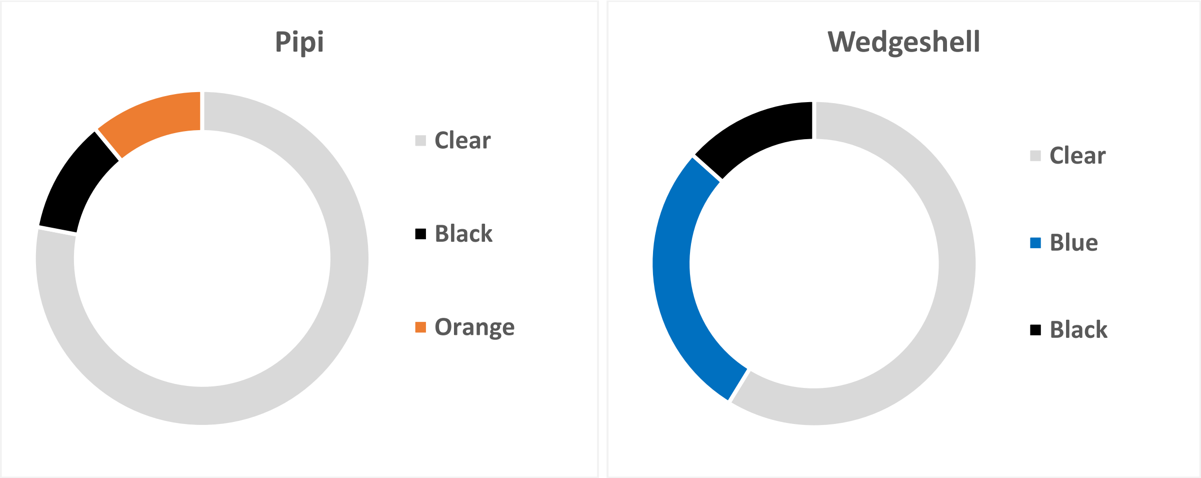


Figure 29: Proportion (percentage) of top three polymer types found in three different shellfish species across four locations in Te Taitokerau. (Source: ESR, unpublished data)

Finally, although the proportions of colours varied between sites and species, clear/transparent microplastics were the most dominant colour in shellfish species in Te Taitokerau (ESR, unpublished data). Blue was the next most common colour, followed by black (Fig. 30). This pattern differed from seawater samples (Fig. 22; ESR, unpublished data).



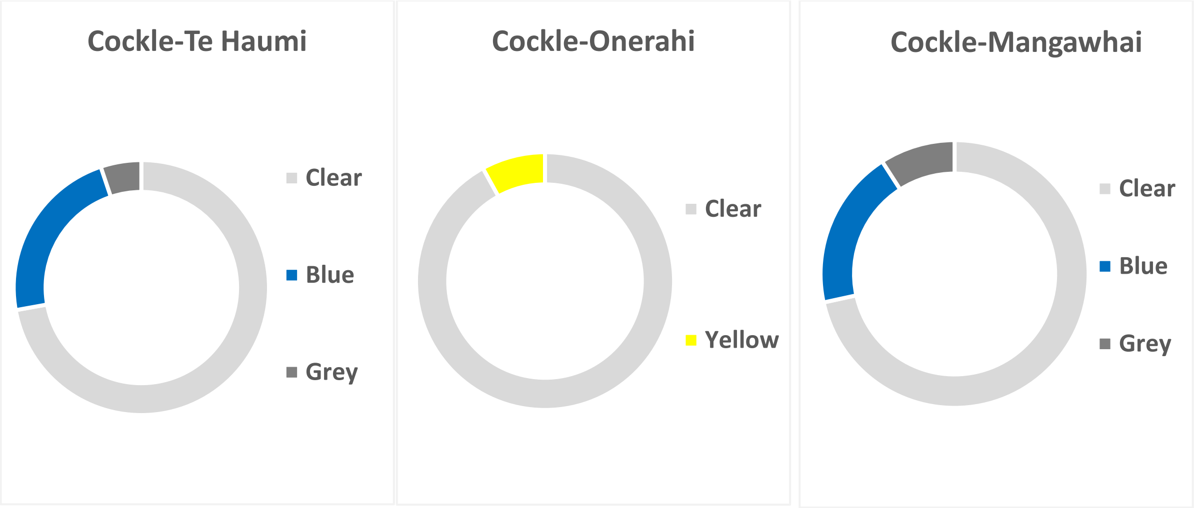


Figure 30: Top three microplastic colours found in three different shellfish species across four locations in Te Taitokerau. (Source: ESR, unpublished data)

5.0 What can we conclude?

5.1 Macroplastic pollution

Plastic pollution is an undeniable issue in Te Taitokerau. Plastics are the predominant type of litter (59–85%) found in the terrestrial and marine environments, despite some variation in proportions between districts. This is consistent with international (e.g. Ocean Conservancy, 2022) and national findings (KNZB, 2021 and 2023b; Van Gool et al., 2021; Litter Intelligence unpublished data). In terms of density, plastics levels in Te Taitokerau were below the national average (KNZB, 2023b; Litter Intelligence, unpublished data).

5.2 Sources and pathways

To date, available data on plastic pollution from various projects from Te Taitokerau have confirmed several sources and pathways. They include:

- Illegal dumping and littering in Te Taitokerau are notable sources of litter and plastic pollution. By weight, Te Taitokerau had the highest rate of illegal dumping and littering in all regions of New Zealand (Litter Intelligence, unpublished data).
- Certain land uses have been identified as high-risk areas for plastic pollution (e.g. commercial, retail, hospital, fast food, transport, postal, warehousing and public car parks).
- Populated areas are also a source of pollution. Sites closer to Whangārei city have higher litter densities than the rest of the harbour (Litter Intelligence & TTTDMP, unpublished data).
- Stormwater systems are an important pathway for litter and plastics to reach aquatic environments, annually releasing an estimated 13.2 million litter items, including 9.4 million plastic items.

Waterways, such as the Hātea River, act as a pathway between freshwater and marine environments. A flux rate estimation at the Hātea river site further implied that a large proportion of litter is remobilised and deposited elsewhere. This might explain the difference in commonly found plastic items collected between land-based and coastal surveys.

5.3 Specific litter items

Cigarette butts are the primary contributors to macroplastic litter on land, at 32.7–42.6% (KNZB, 2019 and 2023; Martinez & Griffiths, 2023), and remain a top-10 coastal litter item (Litter Intelligence & TTTDMP, unpublished data), aligning with global trends (Curtis et al., 2017). Cigarette butts are concerning due to their carcinogenic and toxic content, including polycyclic aromatic hydrocarbons (PAHs), tar, nicotine, arsenic and heavy metals, as well as the release of microplastic fibres (Belzagui et al., 2021).

Coastal beaches primarily feature unidentified hard plastic fragments (22.5–36.3%), predominantly in white, clear/transparent and blue colours (Johns, 2019; NRC & TTTDMP, unpublished data). These colours consistently represent more than 10% of fragments, mirroring global findings (Martí et al., 2020). Long exposure to sunlight likely causes this discoloration (Valadez-Gonzalez et al., 1999; Thompson et al., 2004; Ter Halle et al., 2017), but the weathering of plastics remains incompletely understood due to their varied composition and properties (Ter Halle et al., 2017).

Beaches in the region exhibit a higher prevalence of plastic litter compared to land, partly attributed to plastic's lightweight nature (Andrady & Neal, 2009). Plastic items, especially in fragment form, can easily disperse through rain, runoff, tides, currents and wind (van Sebille et al., 2015; Napper et al., 2020). Soft plastic fragments and plastic food wrappers are commonly found in Aotearoa and globally, reflecting the food industry's reliance on plastic for freshness and cost-efficiency (Ocean

Conservancy, 2022; Law & Narayan, 2022). Once in the environment, soft plastic food packaging, like other plastics, breaks down into fragments through weathering processes (Valadez-Gonzalez et al., 1999; Thompson et al., 2004), contributing to the prevalence of unidentified soft plastic fragments in the region and across the country (Litter Intelligence & TTTDMP, unpublished data).

5.4 Hazards

While data specific to Te Taitokerau is lacking, existing Aotearoa studies suggest plastic pollution poses several risks:

- threats to wildlife through entanglement and ingestion (e.g. Boren et al., 2006; Godoy & Stockin, 2018; Hidalgo-Ruz et al., 2021)
- biosecurity risks by helping non-indigenous species move to new locations (e.g. Campbell et al., 2017)
- health hazards, potentially causing personal injury (e.g. Campbell et al., 2019).

5.5 Microplastic pollution

In addition to the macroplastic pollution issue, the degradation of all these plastics produces microplastics and nanoplastics, which have become another issue of concern (Cole et al., 2011; Koelmans et al., 2015; Auta et al., 2017; Mendoza et al., 2019; Harris, 2020; Xu et al., 2020; Zhang et al., 2021; D'Avignon et al., 2022).

5.6 Microplastic morphotypes

Unsurprisingly, the presence of microplastic fibres, fragments and other microplastic morphotypes have been confirmed in the region's coastal waters, sediments and some organisms (De Lena et al., 2021 and 2022; ESR/AIM^2, unpublished data). Synthetic microfibres often come from textiles shedding or being worn away. They can also be formed when larger items containing fibrous plastic materials, such as cigarette filters (Belzagui et al., 2021) and single-use surgical face masks (Shen et al., 2021), break down.

5.7 Microplastic colours

Microplastic colours in New Zealand's seawater and shellfish samples vary, with distinct patterns. In seawater, black is the most common, followed by blue and clear/transparent, while shellfish samples show the reverse order: clear/transparent leading, followed by blue and black (ESR/AIM^2, unpublished data). These colours are also prevalent in hard microplastic fragments in Northland (Johns, 2019; McCaulay, 2020; TTTDMP & NRC, unpublished data).

The colour of microplastics is useful to identify potential sources of plastics as well as potential contamination (Ren et al., 2020). Dyeing plastics can give them specific properties, such as malleability and tolerance, thus lasting longer in the environment.

In Aotearoa, microplastic colours turn up in varied patterns among marine species. Black and blue are common in fish species (Markič et al., 2018; Clere et al., 2022) and the scat (faeces) of baleen whales (Zantis et al., 2022), while clear/transparent prevails in common dolphins (Stockin et al., 2021). These findings align with seawater sample results from Te Taitokerau.

5.8 Microplastic polymers

Various polymers, including PET, PE and PP, have been detected in seawater, sediment, and shellfish samples in Te Taitokerau, suggesting multiple sources of microplastic pollution (De Lena et al., 2021; AIM^2/ESR, unpublished data).

PE and PP, commonly used for single-use packaging and protective equipment such as face masks, are prevalent polymers in the environment. Additional polymers, such as PET, PA, nylon and acrylic, originate from textiles and the fishing industry (Klein et al., 2022).

PE, PP and PET have been found in various ecosystems in Aotearoa, including freshwater streams, wastewater effluents, the atmosphere and various organisms. This raises concerns about potential health consequences for the organisms and humans who unwittingly consume them (e.g. Campanale et al., 2020; Kwon et al., 2020; Huang et al., 2021).

6.0 Next steps

Aotearoa is at a pivotal point. The country must rethink its relationship with plastic, initiate change and improve its understanding of plastic pollution to mitigate the effects of plastics, while retaining their many benefits (Office of the Prime Minister's Chief Science Advisor (PMCSA), 2019). Differences in findings observed between sites across Te Taitokerau, and other regions of Aotearoa, highlight the need to monitor as many locations and species as possible to better understand microplastic pollution, its sources, pathways, and effects on local organisms.

6.1 Where to from here?

Despite widespread recognition of the harm it causes, plastic pollution is still growing and will persist for decades – if not centuries – even if humans stopped producing and using plastics immediately (Barnes et al., 2009). Furthermore, the implications of plastic pollution, particularly microplastics, are yet to be thoroughly understood (Campanale et al., 2020).

Ultimately, human behavioural patterns are responsible for plastic production and the associated pollution. This is through the use of plastic-enabled products that break down over time and release microplastics, as well as the disposal of plastic items consumed (Tremblay et al., 2020). This is a global issue anchored in systems of production and consumption in a linear economic model, where plastic items are convenient and waste management practices and infrastructures are often absent or inadequate (Burgess et al., 2017).

6.2 Mitigation measures

Measures that can help reduce the amount of litter and plastics generated include (Fig. 31) (e.g. (PMCSA, 2019; MfE, 2021):

- raising consumer and distributor awareness for plastic alternatives
- promoting sustainable production and consumption patterns
- holding plastic producers responsible for disposal of the items they produce
- implementing economic incentives such as plastic-bag charges and Container Return Schemes
- using preventative measures, banning certain single-use plastics, and investing in waste management infrastructure
- focusing on research for product design and process efficiency
- enhancing knowledge about plastic sources, pathways and destinations
- collaborating on research to address knowledge gaps
- strengthening the implementation of existing legislation
- conducting clean-ups in aquatic environments when needed
- applying the precautionary principle in cases of limited evidence, such as nanoplastics.

Examples of solutions implemented in Te Taitokerau include:

- providing detailed information about recycling and waste (NRC, FNDC, KDC, WDC), including plastic waste from agriculture (NRC)
- supporting educational programmes (e.g. Enviroschools, Para Kore) and community clean-up events (e.g. Bay Beach Clean, F.O.R.C.E., Sea Cleaners)
- providing support for businesses to audit and reduce plastic waste (e.g. EcoStar Programme by EcoSolutions and **WDC's** Waste Minimisation Strategy)
- reducing single use-plastics and increasing recycling at events, venues and facilities (e.g. Stone, 2022)
- collaborating with research institutes and citizen science programmes to monitor litter and plastic pollution (e.g. Litter Intelligence, TTTDMP, ESR/AIM^2, Scion).

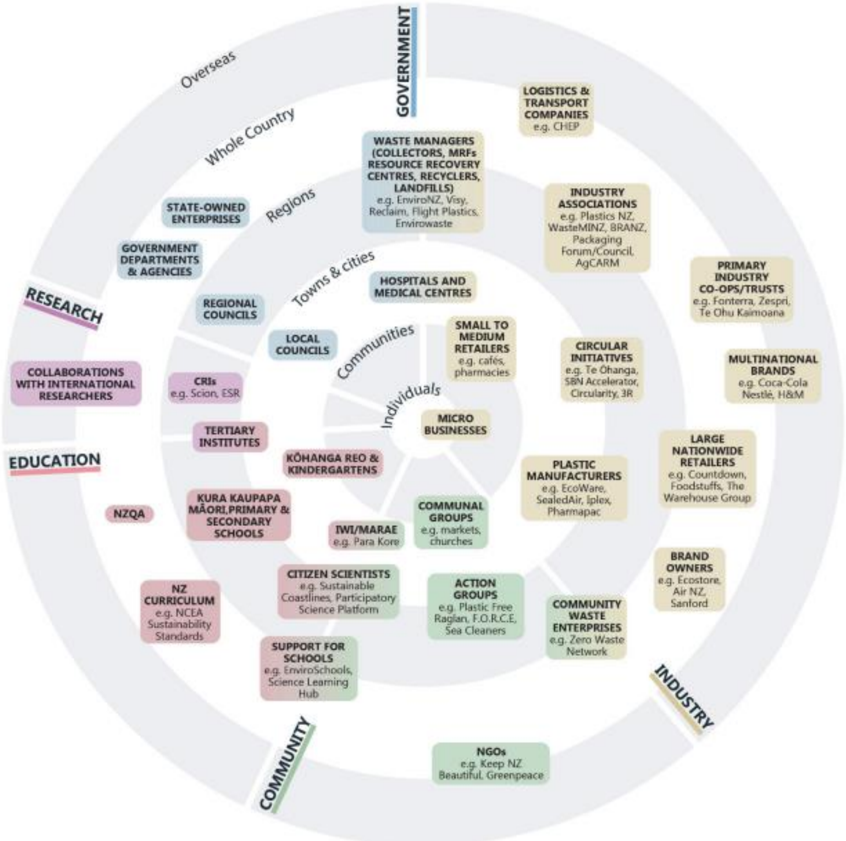


Figure 31: Illustration of the wide variety of groups whose actions can contribute to transformational change in Aotearoa. (Source: PMCSA, 2019)

6.3 Research

It is crucial to address knowledge gaps and build a comprehensive understanding of microplastic pollution's impact on Aotearoa's ecosystems, organisms and potential risks to human health (Tremblay et al., 2020). Plastic pollution, including microplastics, threatens cultural practices of tangata whenua, such as kaimoana gathering (Hikuroa, 2017). Standardised methodologies are lacking, which hinders the ability to compare findings with global and local research (Kühn & van Franeker, 2020).

Methodological standardisation, including measuring plastic use and disposal in Aotearoa, is vital (PMCSA, 2019). Research should encompass smaller streams and diverse sedimentary environments, including pristine locations (Dikareva & Simon, 2019; Harris, 2020). The One Health approach, which considers the interconnection of wildlife, human and ecosystem health, is relevant for plastic pollution assessments (Rabinowitz et al., 2018). Given the knowledge gaps that currently exist, adopting a precautionary approach is advisable (Tremblay et al., 2020).

7.0 Acknowledgments

Thanks to the following iwi and hapū (in alphabetical order): Ngāi Takoto, Ngāpuhi, Ngāti Kurī, Patuharakeke, Te Aupōuri, Te Parawhau, Te Rarawa, Te Roroa, Te Rōpū Whakahau, and Te Uri o Hau. Thanks also to the Taharoa Domain Governance Committee.

Hayley Sharp (NRC)
Erica Cooney (FNDC), Sue Hodge (WDC) and Linda Osborne (KDC)
Anna de Lena (Scion)
Hayden Masterton and Olga Pantos (ESR)
Ella van Gool
Hayden Smith (Sea Cleaners Trust)
Carla Fonseca Paris and Jemma Hovelmeier (Litter Intelligence)
Heather Saunderson and the Keep New Zealand Beautiful team
Karen Lee and Nicholas Connop (F.O.R.C.E. Trust)
Janey Pares Edney (Ocean Spirit Trust)

8.0 References

Abbasi, S., Soltani, N., Keshavarzi, B., Moore, F., Turner, A., & Hassanaghaei, M. (2018). Microplastics in different tissues of fish and prawn from the Musa Estuary, Persian Gulf. *Chemosphere*, *205*, 80-87. https://doi.org/10.1016/j.chemosphere.2018.04.076

Abidli, S., Lahbib, Y., & El Menif, N. T. (2019). Microplastics in commercial molluscs from the lagoon of Bizerte (Northern Tunisia). *Marine Pollution Bulletin*, *142*, 243-252.

Abreo, N. A. S., Blatchley, D., & Superio, M. D. (2019). Stranded whale shark (*Rhincodon typus*) reveals vulnerability of filter-feeding elasmobranchs to marine litter in the Philippines. *Marine pollution bulletin*, *141*, 79-83. https://doi.org/10.1016/j.marpolbul.2019.02.030

Adams, N.; Gaskin, C.; Whitehead, E. (2020). Marine debris in the nests of tākapu (Australasian gannets, *Morus serratori)* in the inner Hauraki Gulf, New Zealand. *Notornis, 67*, 558-563. https://hdl.handle.net/10652/5272

Agamuthu, P., Mehran, S. B., Norkhairah, A., & Norkhairiyah, A. (2019). Marine debris: A review of impacts and global initiatives. *Waste Management & Research*, *37*(10), 987-1002. https://doi.org/10.1177/0734242X198450

Allen, S., Allen, D., Phoenix, V. R., Le Roux, G., Durántez Jiménez, P., Simonneau, A., Binet, S., & Galop, D. (2019). Atmospheric transport and deposition of microplastics in a remote mountain catchment. *Nature Geoscience*, *12*(5), 339-344. https://doi.org/10.1038/s41561-019-0335-5

Amato-Lourenço, L. F., Carvalho-Oliveira, R., Júnior, G. R., dos Santos Galvão, L., Ando, R. A., & Mauad, T. (2021). Presence of airborne microplastics in human lung tissue. *Journal of Hazardous Materials*, *416*, 126124. https://doi.org/10.1016/j.jhazmat.2021.126124

Andrady, A. L. (2011). Microplastics in the marine environment. *Marine pollution bulletin*, *62*(8), 1596-1605. https://doi.org/10.1016/j.marpolbul.2011.05.030

Andrady, A. L., & Neal, M. A. (2009). Applications and societal benefits of plastics. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 1977-1984. https://doi.org/10.1098/rstb.2008.0304

Angiolillo, M., Gérigny, O., Valente, T., Fabri, M. C., Tambute, E., Rouanet, E., Claro, F., Tunesi, L., Vissio, A., Daniel, B., & Galgani, F. (2021). Distribution of seafloor litter and its interaction with benthic organisms in deep waters of the Ligurian Sea (Northwestern Mediterranean). *Science of the Total Environment*, *788*, 147745. https://doi.org/10.1016/j.scitotenv.2021.147745

Aragaw, T. A. (2020). Surgical face masks as a potential source for microplastic pollution in the COVID-19 scenario. *Marine Pollution Bulletin*, *159*, 111517. https://doi.org/10.1016/J.MARPOLBUL.2020.111517

Armitage, N. & Rooseboom, A. (2000). The removal of urban litter from stormwater conduits and streams: Paper 1- The quantities involved and catchment litter management options. *Water Sa*, *26*(2), 181-188. https://journals.co.za/doi/pdf/10.10520/AJA03784738_2350

Audrézet, F., Zaiko, A., Lear, G., Wood, S. A., Tremblay, L. A., & Pochon, X. (2021). Biosecurity implications of drifting marine plastic debris: current knowledge and future research. *Marine Pollution Bulletin*, *162*, 111835. https://doi.org/10.1016/j.marpolbul.2020.111835

Auta, H. S., Emenike, C. U., & Fauziah, S. H. (2017). Distribution and importance of microplastics in the marine environment: a review of the sources, fate, effects, and potential solutions. *Environment international*, *102*, 165-176. https://doi.org/10.1016/j.envint.2017.02.013

Azevedo-Santos, V. M., Goncalves, G. R., Manoel, P. S., Andrade, M. C., Lima, F. P., & Pelicice, F. M. (2019). Plastic ingestion by fish: A global assessment. *Environmental pollution (Barking, Essex: 1987)*, *255*(Pt 1), 112994. https://doi.org/10.1016/j.envpol.2019.112994

Barboza, L. G. A., Vethaak, A. D., Lavorante, B. R., Lundebye, A. K., & Guilhermino, L. (2018). Marine microplastic debris: An emerging issue for food security, food safety and human health. *Marine pollution bulletin*, *133*, 336-348. https://doi.org/10.1016/j.marpolbul.2018.05.047

Barnes, D. K., Galgani, F., Thompson, R. C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical transactions of the Royal Society B: biological sciences*, *364*(1526), 1985-1998. https://doi.org/10.1098/rstb.2008.0205

Behrens, E., Wood, B. A., Bowden, D. A., Chin, C. C., & Anderson, O. F. (2021). *Plastics and Marine Debris Across the Ocean Floor in New Zealand Waters*. Ministry for Primary Industries, 2021. https://docs.niwa.co.nz/library/public/NZAEBR-267.pdf

Belzagui, F., Buscio, V., Gutierrez-Bouzan, C., & Vilaseca, M. (2021). Cigarette butts as a microfiber source with a microplastic level of concern. *Science of the Total Environment*, *762*, 144165. https://doi.org/10.1016/j.scitotenv.2020.144165

Bhattacharya, P., Lin, S., Turner, J. P., & Ke, P. C. (2010). Physical adsorption of charged plastic nanoparticles affects algal photosynthesis. *The journal of physical chemistry C*, *114*(39), 16556-16561. https://doi.org/10.1021/jp1054759

Biltcliff-Ward, A., Stead, J. L., & Hudson, M. D. (2022). The estuarine plastics budget: A conceptual model and meta-analysis of microplastic abundance in estuarine systems. *Estuarine, Coastal and Shelf Science*, *275*, 107963. https://doi.org/10.1016/j.ecss.2022.107963

Blettler, M. C., & Wantzen, K. M. (2019). Threats underestimated in freshwater plastic pollution: mini-review. *Water, Air, & Soil Pollution*, *230*(7), 174. https://doi.org/10.1007/s11270-019-4220-z

Boren, L. J., Morrissey, M., Muller, C. G., & Gemmell, N. J. (2006). Entanglement of New Zealand fur seals in man-made debris at Kaikoura, New Zealand. *Marine Pollution Bulletin*, *52*(4), 442-446. https://doi.org/10.1016/j.marpolbul.2005.12.003

Borrelle, S. B., Ringma, J., Law, K. L., Monnahan, C. C., Lebreton, L., McGivern, A., Murphy, E., Jambeck, J., Leonard, G. H., Hilleary, M. A., & Eriksen, M. (2020). Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. *Science*, *369*(6510), 1515-1518. https://doi.org/10.1126/science.aba3656

Botterell, Z. L., Beaumont, N., Dorrington, T., Steinke, M., Thompson, R. C., & Lindeque, P. K. (2019). Bioavailability and effects of microplastics on marine zooplankton: A review. *Environmental Pollution*, *245*, 98-110. https://doi.org/10.1016/j.envpol.2018.10.065

Bridson, J. H., Patel, M., Lewis, A., Gaw, S., & Parker, K. (2020). Microplastic contamination in Auckland (New Zealand) beach sediments. *Marine Pollution Bulletin*, *151*, 110867. https://doi.org/10.1016/j.marpolbul.2019.110867

Brouwer, R., Hadzhiyska, D., Ioakeimidis, C., & Ouderdorp, H. (2017). The social costs of marine litter along European coasts. *Ocean & coastal management*, *138*, 38-49. https://doi.org/10.1016/j.ocecoaman.2017.01.011

Burgess, R. M., Ho, K. T., Mallos, N. J., Leonard, G. H., Hidalgo-Ruz, V., Cook, A. M., & Christman, K. (2017). Microplastics in the aquatic environment – Perspectives on the scope of the problem. *Environmental toxicology and chemistry*, *36*(9), 2259-2265. https://doi.org/10.1002/etc.3867

Buxton, R. T., Currey, C. A., Lyver, P. O. B., & Jones, C. J. (2013). Incidence of plastic fragments among burrow-nesting seabird colonies on offshore islands in northern New Zealand. *Marine Pollution Bulletin*, *74*(1), 420-424. https://doi.org/10.1016/j.marpolbul.2013.07.011

Campanale, C., Massarelli, C., Savino, I., Locaputo, V., & Uricchio, V. F. (2020). A detailed review study on potential effects of microplastics and additives of concern on human health. *International Journal of Environmental Research and Public Health*, *17*(4), 1212. https://doi.org/10.3390/ijerph17041212

Campbell, M. L., Slavin, C., Grage, A., & Kinslow, A. (2016). Human health impacts from litter on beaches and associated perceptions: A case study of ‘clean’ Tasmanian beaches. *Ocean & coastal management*, *126*, 22-30. https://doi.org/10.1016/j.ocecoaman.2016.04.002

Campbell, M. L., King, S., Heppenstall, L. D., van Gool, E., Martin, R., & Hewitt, C. L. (2017). Aquaculture and urban marine structures facilitate native and non-indigenous species transfer through generation and accumulation of marine debris. *Marine pollution bulletin*, *123*(1-2), 304-312. https://doi.org/10.1016/j.marpolbul.2017.08.040

Campbell, M. L., Peters, L., McMains, C., de Campos, M. C. R., Sargisson, R. J., Blackwell, B., & Hewitt, C. L. (2019). Are our beaches safe? Quantifying the human health impact of anthropogenic beach litter on people in New Zealand. *Science of the Total Environment*, *651*, 2400-2409. https://doi.org/10.1016/j.scitotenv.2018.10.137

Carlin, J., Craig, C., Little, S., Donnelly, M., Fox, D., Zhai, L., & Walters, L. (2020). Microplastic accumulation in the gastrointestinal tracts in birds of prey in central Florida, USA. *Environmental Pollution*, *264*, 114633. https://doi.org/10.1016/j.envpol.2020.114633

Carpenter, E.J. & Smith, K.L., (1972). Plastics on the Sargasso Sea surface. Science 175, 1240–1241. https://doi.org/10.1126/science.175.4027.1240

Carr, S. A., Liu, J., & Tesoro, A. G. (2016). Transport and fate of microplastic particles in wastewater treatment plants. *Water Research*, *91*, 174-182. https://doi.org/10.1016/j.watres.2016.01.002

Cartraud, A. E., Le Corre, M., Turquet, J., & Tourmetz, J. (2019). Plastic ingestion in seabirds of the western Indian Ocean. *Marine Pollution Bulletin*, *140*, 308-314. https://doi.org/10.1016/j.marpolbul.2019.01.065

Casabianca, S., Capellacci, S., Giacobbe, M.G., Dell’Aversano, C., Tartaglione, L., Varriale, F., Narizzano, R., Risso, F., Moretto, P., Dagnino, A., & Penna, A. (2019). Plastic-associated harmful microalgal assemblages in marine environment. *Environmental Pollution*, *244*, 617-626. https://doi.org/10.1016/j.envpol.2018.09.110

Catarino, A. I., Macchia, V., Sanderson, W. G., Thompson, R. C., & Henry, T. B. (2018). Low levels of microplastics (MP) in wild mussels indicate that MP ingestion by humans is minimal compared to exposure via household fibres fallout during a meal. *Environmental pollution*, *237*, 675-684. https://doi.org/10.1016/j.envpol.2018.02.069

Chae, Y., & An, Y. J. (2020). Effects of food presence on microplastic ingestion and egestion in *Mytilus galloprovincialis*. *Chemosphere*, *240*, 124855.https://doi.org/10.1016/j.chemosphere.2019.124855

Cheshire, A. C., Adler, E., Barbière, J., Cohen, Y., Evans, S., Jarayabhand, S., Jeftic, L., Jung, R. T., Kinsey, S., Kusui, E. T., Lavine, I., Manyara, P., Oosterbaan, L., Pereira, M. A., Sheavly, S., Tkalin, A., Varadarajan, S., Wenneker, B., Westphalen, G. (2009). *UNEP/IOC Guidelines on Survey and Monitoring of Marine Litte*r. UNEP Regional Seas Reports and Studies, No. 186; IOC Technical Series No. 83: xii + 120 pp. https://www.nrc.govt.nz/media/crzljchg/unepioclittermonitoringguidelines.pdf

Chiba, S., Saito, H., Fletcher, R., Yogi, T., Kayo, M., Miyagi, S., Ogido, M., & Fujikura, K. (2018). Human footprint in the abyss: 30 year records of deep-sea plastic debris. *Marine Policy*, *96*, 204-212. https://doi.org/10.1016/j.marpol.2018.03.022

Clause, A. G., Celestian, A. J., & Pauly, G. B. (2021). Plastic ingestion by freshwater turtles: a review and call to action. *Scientific Reports*, *11*(1), 1-10. https://doi.org/10.1038/s41598-021-84846-x

Clere I. K., Ahmmed, F., Remoto, P. I. J. G., Fraser-Miller, S. J., Gordon, K. C., Komyakova, V., & Allan, B. J. M. (2022). Quantification and characterization of microplastics in commercial fish from southern New Zealand. *Marine Pollution Bulletin 184*, 114121. https://doi.org/10.1016/j.marpolbul.2022.114121

Clunies-Ross, P. (2019). *Plastic pollution in lakes and rivers.* Aotearoa Plastic Pollution Alliance. http://www.nzappa.org/plastics-in-lakes-and-rivers/

Clunies-Ross, P. J., Smith, G. P. S., Gordon, K. C., & Gaw, S. (2016). Synthetic shorelines in New Zealand? Quantification and characterisation of microplastic pollution on Canterbury's coastlines. *New Zealand Journal of Marine and Freshwater Research*, *50*(2), 317-325. https://doi.org/10.1080/00288330.2015.1132747

Cole, M., Lindeque, P., Fileman, E., Halsband, C., & Galloway, T. S. (2015). The impact of polystyrene microplastics on feeding, function and fecundity in the marine copepod *Calanus helgolandicus*. *Environmental Science & Technology*, *49*(2), 1130-1137. https://doi.org/10.1021/es504525u

Conti, G. O., Ferrante, M., Banni, M., Favara, C., Nicolosi, I., Cristaldi, A., Fiore, M. & Zuccarello, P. (2020). Micro-and nano-plastics in edible fruit and vegetables. The first diet risks assessment for the general population. *Environmental Research*, *187*, 109677. https://doi.org/10.1016/j.envres.2020.109677

Cornelius, M., Clayton, T., Lewis, G., Arnold, G., & Craig, J. (1994). Litter associated with stormwater discharge in Auckland city New Zealand. *Island Care New Zealand Trust, Auckland*.

Courtene-Jones, W., Quinn, B., Ewins, C., Gary, S. F., & Narayanaswamy, B. E. (2020). Microplastic accumulation in deep-sea sediments from the Rockall Trough. *Marine Pollution Bulletin*, *154*, 111092. https://doi.org/10.1016/j.marpolbul.2020.111092

Covernton, G. A., Collicutt, B., Gurney-Smith, H. J., Pearce, C. M., Dower, J. F., Ross, P. S., & Dudas, S. E. (2019). Microplastics in bivalves and their habitat in relation to shellfish aquaculture proximity in coastal British Columbia, Canada. *Aquaculture Environment Interactions, 11*, 357–374. https://doi.org/10.3354/aei00316

Critchell, K., & Hoogenboom, M. O. (2018). Effects of microplastic exposure on the body condition and behaviour of planktivorous reef fish (*Acanthochromis polyacanthus*). *PloS one*, *13*(3), e0193308. https://doi.org/10.1371/journal.pone.0193308

Cui, W., Gao, P., Zhang, M., Wang, L., Sun, H., & Liu, C. (2022). Adverse effects of microplastics on earthworms: A critical review. *Science of The Total Environment*, 158041. https://doi.org/10.1016/j.scitotenv.2022.158041

Curtis, C., Novotny, T. E., Lee, K., Freiberg, M., & McLaughlin, I. (2017). Tobacco industry responsibility for butts: a model tobacco waste act. *Tobacco Control*, *26*(1), 113-117. http://dx.doi.org/10.1136/tobaccocontrol-2015-052737

D'Angelo, S., & Meccariello, R. (2021). Microplastics: a threat for male fertility. *International Journal of Environmental Research and Public Health*, *18*(5), 2392. https://doi.org/10.3390/ijerph18052392

D'Avignon, G., Gregory-Eaves, I., & Ricciardi, A. (2022). Microplastics in lakes and rivers: an issue of emerging significance to limnology. *Environmental Reviews*, *30*(2), 228-244. https://doi.org/10.1139/er-2021-0048

Danopoulos, E., Twiddy, M., West, R., & Rotchell, J. M. (2022). A rapid review and meta-regression analyses of the toxicological impacts of microplastic exposure in human cells. *Journal of Hazardous Materials*, *427*, 127861. https://doi.org/10.1016/j.jhazmat.2021.127861

Davidson, K., & Dudas, S. E. (2016). Microplastic ingestion by wild and cultured Manila clams (*Venerupis philippinarum*) from Baynes Sound, British Columbia. *Archives of Environmental Contamination and Toxicology*, *71*, 147-156. https://doi.org/10.1007/s00244-016-0286-4

De Bhowmick, G., Sarmah, A. K., & Dubey, B. (2021). Microplastics in the NZ environment: Current status and future directions. *Case Studies in Chemical and Environmental Engineering, 3*, 100076. https://doi.org/10.1016/j.cscee.2020.100076

De-la-Torre, G. E., Rakib, M. R. J., Pizarro-Ortega, C. I., & Dioses-Salinas, D. C. (2021). Occurrence of personal protective equipment (PPE) associated with the COVID-19 pandemic along the coast of Lima, Peru. *Science of the Total Environment*, *774*. https://doi.org/10.1016/j.scitotenv.2021.145774

de Lena, A., Tanjay, Q., Patel, M., Bridson, J., Pantos, O., Smith, D., & Parker, K. (2021). *Microplastic contamination in Te Tai Tokerau-Northland (Aotearoa-New Zealand) beach sediments*. Report for Northland Regional Council. https://www.nrc.govt.nz/media/akbnnzjn/microplastic-contamination-in-te-tai-tokerau-northland-aotearoa-new-zealand-beach-sediments-2021.pdf

de Lena, A., Tanjay, Q., Parker, K., & Pantos, O. (2022, November 21-24). *Small things add up: Abundance and characteristics of microplastic particles in Aotearoa NZ beach sediments* [Poster presentation] Waitī Waitā: Joint conference of the New Zealand Marine Sciences and New Zealand Freshwater Sciences Society, Auckland, New Zealand.

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin*, *44*(9), 842–852. https://doi.org/10.1016/S0025-326X(02)00220-5

Desforges, J. P. W., Galbraith, M., & Ross, P. S. (2015). Ingestion of microplastics by zooplankton in the Northeast Pacific Ocean. *Archives of Environmental Contamination and Toxicology*, *69*, 320-330. https://doi.org/10.1007/s00244-015-0172-5

Diaz-Basantes, M. F., Nacimba-Aguirre, D., Conesa, J. A., & Fullana, A. (2022). Presence of microplastics in commercial canned tuna. *Food Chemistry*, *385*, 132721. https://doi.org/10.1016/j.foodchem.2022.132721

Díaz-Mendoza, C., Mouthon-Bello, J., Pérez-Herrera, N. L., & Escobar-Díaz, S. M. (2020). Plastics and microplastics, effects on marine coastal areas: a review. *Environmental Science and Pollution Research*, *27*, 39913-39922. https://doi.org/10.1007/s11356-020-10394-y

Dikareva, N., & Simon, K. S. (2019). Microplastic pollution in streams spanning an urbanisation gradient. *Environmental Pollution*, *250*, 292-299. https://doi.org/10.1016/j.envpol.2019.03.105

Donohue, M. J., Masura, J., Gelatt, T., Ream, R., Baker, J. D., Faulhaber, K., & Lerner, D. T. (2019). Evaluating exposure of northern fur seals, *Callorhinus ursinus*, to microplastic pollution through fecal analysis. *Marine Pollution Bulletin*, *138*, 213-221. https://doi.org/10.1016/j.marpolbul.2018.11.036

Dovidat, L. C., Brinkmann, B. W., Vijver, M. G., & Bosker, T. (2020). Plastic particles adsorb to the roots of freshwater vascular plant *Spirodela polyrhiza* but do not impair growth. *Limnology and Oceanography Letters*, *5*(1), 37-45. https://doi.org/10.1002/lol2.10118

Dris, R., Gasperi, J., Saad, M., Mirande, C., & Tassin, B. (2016). Synthetic fibers in atmospheric fallout: a source of microplastics in the environment? *Marine pollution bulletin*, *104*(1-2), 290-293. https://doi.org/10.1016/j.marpolbul.2016.01.006

Dris, R., Gasperi, J., Mirande, C., Mandin, C., Guerrouache, M., Langlois, V., & Tassin, B. (2017). A first overview of textile fibers, including microplastics, in indoor and outdoor environments. *Environmental Pollution*, *221*, 453-458. https://doi.org/10.1016/j.envpol.2016.12.013

Eisfeld-Pierantonio, S. M., Pierantonio, N., & Simmonds, M. P. (2022). The impact of marine debris on cetaceans with consideration of plastics generated by the COVID-19 pandemic. *Environmental Pollution*, 118967. https://doi.org/10.1016/j.envpol.2022.118967

Ekvall, M. T., Gimskog, I., Hua, J., Kelpsiene, E., Lundqvist, M., & Cedervall, T. (2022). Size fractionation of high-density polyethylene breakdown nanoplastics reveals different toxic response in *Daphnia magna*. *Scientific Reports*, *12*(1), 3109. https://doi.org/10.1038/s41598-022-06991-1

Ellen MacArthur Foundation (2016). The new plastics economy: Rethinking the future of plastics https://ellenmacarthurfoundation.org/the-new-plastics-economy-rethinking-the-future-of-plastics

Erni-Cassola, G., Zadjelovic, V., Gibson, M. I., & Christie-Oleza, J. A. (2019). Distribution of plastic polymer types in the marine environment; A meta-analysis. *Journal of hazardous materials*, *369*, 691-698. https://doi.org/10.1016/j.jhazmat.2019.02.067

Faris, J., & Hart, K. (1994). Seas of debris: a summary of the third international conference on marine debris. Conference, Miami, Florida 1994. https://repository.library.noaa.gov/view/noaa/37056/noaa_37056_DS1.pdf

Feng, L. J., Sun, X. D., Zhu, F. P., Feng, Y., Duan, J. L., Xiao, F., Li, X. Y., Shi, Y., Wang, Q., Sun, J. W., & Yuan, X. Z. (2020). Nanoplastics promote microcystin synthesis and release from cyanobacterial *Microcystis aeruginosa*. *Environmental Science & Technology*, *54*(6), 3386-3394. https://doi.org/10.1021/acs.est.9b06085

Ferreira, G. V., Justino, A. K., Eduardo, L. N., Lenoble, V., Fauvelle, V., Schmidt, N., Junior, T. V., Frédou, T., & Lucena-Frédou, F. (2022). Plastic in the inferno: Microplastic contamination in deep-sea cephalopods (*Vampyroteuthis infernalis* and *Abralia veranyi*) from the southwestern Atlantic. *Marine Pollution Bulletin*, *174*, 113309. https://doi.org/10.1016/j.marpolbul.2021.113309

Fischer, V., Elsner, N. O., Brenke, N., Schwabe, E., & Brandt, A. (2015). Plastic pollution of the Kuril–Kamchatka Trench area (NW Pacific). *Deep Sea Research Part II: Topical Studies in Oceanography*, *111*, 399-405. https://doi.org/10.1016/j.dsr2.2014.08.012

Fossi, M. C., Baini, M., & Simmonds, M. P. (2020). Cetaceans as ocean health indicators of marine litter impact at global scale. *Frontiers in Environmental Science*, *8*, 586627. https://doi.org/10.3389/fenvs.2020.586627

Frias, J. P., & Nash, R. (2019). Microplastics: Finding a consensus on the definition. *Marine Pollution Bulletin*, *138*, 145-147. https://doi.org/10.1016/j.marpolbul.2018.11.022

Fukuoka, T., Sakane, F., Kinoshita, C., Sato, K., Mizukawa, K., & Takada, H. (2022). Covid-19-derived plastic debris contaminating marine ecosystem: Alert from a sea turtle. *Marine Pollution Bulletin*, *175*, 113389. https://doi.org/10.1016/J.MARPOLBUL.2022.113389

Furtado, R., Menezes, D., Santos, C. J., & Catry, P. (2016). White-faced storm-petrels *Pelagodroma marina* predated by gulls as biological monitors of plastic pollution in the pelagic subtropical Northeast Atlantic. *Marine Pollution Bulletin*, *112*(1-2), 117-122. https://doi.org/10.1016/j.marpolbul.2016.08.031

Galgani, F., Claro, F., Depledge, M., & Fossi, C. (2014). Monitoring the impact of litter in large vertebrates in the Mediterranean Sea within the European Marine Strategy Framework Directive (MSFD): Constraints, specificities and recommendations. *Marine Environmental Research*, *100*, 3-9. https://doi.org/10.1016/j.marenvres.2014.02.003

Galgani, F., Hanke, G., & Maes, T. (2015). Global distribution, composition and abundance of marine litter. In *Marine Anthropogenic Litter*. Bergman, M., Gutow, L., & Klages, M. (Eds.), 29–56. Springer Nature. https://doi.org/10.1007/978-3-319-16510-3_2

Gall, S. C., & Thompson, R. C. (2015). The impact of debris on marine life. *Marine Pollution Bulletin*, *92*(1-2), 170-179. https://doi.org/10.1016/j.marpolbul.2014.12.041

Gallo Neto, H., Gomes Bantel, C., Browning, J., della Fina, N., Albuquerque Ballabio, T., Teles de Santana, F., de Karam e Britto, M., & Beatriz Barbosa, C. (2021). Mortality of a juvenile Magellanic penguin (*Spheniscus magellanicus*, Spheniscidae) associated with the ingestion of a PFF-2 protective mask during the Covid-19 pandemic. *Marine Pollution Bulletin*, *166*, 112232. https://doi.org/10.1016/J.MARPOLBUL.2021.112232

Galloway, T. S., & Lewis, C. N. (2016). Marine microplastics spell big problems for future generations. *Proceedings of the National Academy of Sciences*, *113*(9), 2331-2333. https://doi.org/10.1073/pnas.1600715113

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, *3*(7), e1700782. https://doi.org/10.1126/sciadv.1700782

Geyer, R. (2020). Production, use and fate of synthetic polymers. In *Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions*. Letcher, T. M. (Ed.), 13-32. Cambridge, MA: Academic Press. https://doi.org/10.1016/B978-0-12-817880-5.00002-5

Gigault, J., Ter Halle, A., Baudrimont, M., Pascal, P. Y., Gauffre, F., Phi, T.L., El Hadri, H., Grassl, B., & Reynaud, S. (2018). Current opinion: what is a nanoplastic? *Environmental pollution*, *235*, 1030-1034. https://doi.org/10.1016/j.envpol.2018.01.024

Gismondi, M., & Sherman, J. (1996). Pulp mills, fish contamination, and fish eaters: A participatory workshop on the politics of expert knowledge. *Capitalism Nature Socialism*, *7*(4), 127-137. https://doi.org/10.1080/10455759609358714

Godoy, D. A., & Stockin, K. A. (2018). Anthropogenic impacts on green turtles Chelonia mydas in New Zealand. *Endangered Species Research*, *37*, 1-9. https://doi.org/10.3354/esr00908

Good, T. P., Samhouri, J. F., Feist, B. E., Wilcox, C., & Jahncke, J. (2020). Plastics in the Pacific: Assessing risk from ocean debris for marine birds in the California Current Large Marine Ecosystem. *Biological Conservation*, *250*, 108743. https://doi.org/10.1016/j.biocon.2020.108743

Goss, H., Jaskiel, J., & Rotjan, R. (2018). *Thalassia testudinum* as a potential vector for incorporating microplastics into benthic marine food webs. *Marine Pollution Bulletin*, *135*, 1085-1089. https://doi.org/10.1016/j.marpolbul.2018.08.024

Goswami, P., Vinithkumar, N. V., & Dharani, G. (2021). Microplastics particles in seafloor sediments along the Arabian Sea and the Andaman Sea continental shelves: First insight on the occurrence, identification, and characterization. *Marine Pollution Bulletin*, *167*, 112311. https://doi.org/10.1016/j.marpolbul.2021.112311

Graham, P., Palazzo, L., de Lucia, G. A., Telfer, T. C., Baroli, M., & Carboni, S. (2019). Microplastics uptake and egestion dynamics in Pacific oysters, *Magallana gigas* (Thunberg, 1793), under controlled conditions. *Environmental Pollution*, *252*, 742-748. https://doi.org/10.1016/j.envpol.2019.06.002

Guilloux, S. (2020). *Food wrapper composition in the northern Whangārei Harbour.* Unpublished report, NorthTec-Tai Tokerau Wānanga & Unitec Institute of Technology, New Zealand.

Gündoğdu, S., & Köşker, A. R. (2023). Microplastic contamination in canned fish sold in Türkiye. *PeerJ*, *11*, e14627. https://doi.org/10.7717/peerj.14627

Halsband, C. (2021). Effects of Biofouling on the Sinking Behavior of Microplastics in Aquatic Environments. In *Handbook of Microplastics in the Environment* (pp. 1-13). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-10618-8_12-1

Hardesty, B. D., Lawson, T. J., van der Velde, T., Lansdell, M., & Wilcox, C. (2017). Estimating quantities and sources of marine debris at a continental scale. *Frontiers in Ecology and the Environment*, *15*(1), 18-25. https://doi.org/10.1002/fee.1447

Harris, P. T. (2020). The fate of microplastic in marine sedimentary environments: A review and synthesis. *Marine Pollution Bulletin*, *158*, 111398. https://doi.org/10.1016/j.marpolbul.2020.111398

Hayward, B. W. (1984). Rubbish Trends—Beach Litter Surveys at Kawerua, 1974-1982. *Tane*, *30*, 209-217. https://www.researchgate.net/profile/Bruce-Hayward/publication/256456434_Rubbish_trends_-_beach_litter_surveys_at_Kawerua_1974-1982/links/5b3c81caaca27207850aa5c1/Rubbish-trends-beach-litter-surveys-at-Kawerua-1974-1982.pdf

Hayward, B. W. (1999). A Load of Old Rubbish—Kawerua Beach Litter Surveys, 1974-1997. *Tane.*, *37*(15), 13. https://www.thebookshelf.auckland.ac.nz/docs/Tane/Tane-37/3%20A%20load%20of%20old%20rubbish.pdf

He, M., Yan, M., Chen, X., Wang, X., Gong, H., Wang, W., & Wang, J. (2022). Bioavailability and toxicity of microplastics to zooplankton. *Gondwana Research*, *108*, 120-126. https://doi.org/10.1016/j.gr.2021.07.021

Hidalgo-Ruz, V., Luna-Jorquera, G., Eriksen, M., Frick, H., Miranda-Urbina, D., Portflitt-Toro, M.,Thiel, M. (2021). Factors (type, colour, density, and shape) determining the removal of marine plastic debris by seabirds from the South Pacific Ocean: Is there a pattern? *Aquatic Conservation: Marine and Freshwater Ecosystems*, *31*(2), 389-407. https://doi.org/10.1002/aqc.3453

Hikuroa, D. (2017). Mātauranga Māori–The ūkaipō of knowledge in New Zealand. *Journal of the Royal Society of New Zealand, 47*(1), 5–10. https://doi.org/10.1080/03036758.2016.1252407

Holland, E. R., Mallory, M. L., & Shutler, D. (2016). Plastics and other anthropogenic debris in freshwater birds from Canada. *Science of the Total Environment*, *571*, 251-258. https://doi.org/10.1016/j.scitotenv.2016.07.158

Hope, J. A., Coco, G., Ladewig, S. M., & Thrush, S. F. (2021). The distribution and ecological effects of microplastics in an estuarine ecosystem. *Environmental Pollution*, *288*, 117731. https://doi.org/10.1016/j.envpol.2021.117731

Horton, A. A., Walton, A., Spurgeon, D. J., Lahive, E., & Svendsen, C. (2017). Microplastics in freshwater and terrestrial environments: Evaluating the current understanding to identify the knowledge gaps and future research priorities. *Science of the Total Environment, 586*, 127–141. https://doi.org/doi:10.1016/j.scitotenv.2017.01.190

Huang, W., Song, B., Liang, J., Niu, Q., Zeng, G., Shen, M., Deng, J., Luo, Y., Wen, X., & Zhang, Y. (2021). Microplastics and associated contaminants in the aquatic environment: A review on their ecotoxicological effects, trophic transfer, and potential impacts to human health. *Journal of Hazardous Materials*, *405*, 124187. https://doi.org/10.1016/j.jhazmat.2020.124187

Ibrahim, Y. S., Tuan Anuar, S., Azmi, A. A., Wan Mohd Khalik, W. M. A., Lehata, S., Hamzah, S. R., Ismail, D., Ma, Z. F., Dzulkarnaen, A., Zakaria, Z., Mustaffa, N., Tuan Sharif, S. E., & Lee, Y. Y. (2021). Detection of microplastics in human colectomy specimens. *JGH Open 5 (1),* 116–121. https://doi.org/10.1002/jgh3.12457

Jacob, H., Besson, M., Swarzenski, P. W., Lecchini, D., & Metian, M. (2020). Effects of virgin micro- and nanoplastics on fish: trends, meta-analysis, and perspectives. *Environmental science & technology*, *54*(8), 4733-4745. https://doi.org/10.1021/acs.est.9b05995

Jambeck, J. R, Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., & Law K. L. (2015). Plastic waste inputs from land into the ocean. *Science* 347 (6223): 768–771. https://doi.org/10.1126/science.1260352

Jang, Y. C., Ranatunga, R. R. M. K. P., Mok, J. Y., Kim, K. S., Hong, S. Y., Choi, Y. R., & Gunasekara, A. J. M. (2018). Composition and abundance of marine debris stranded on the beaches of Sri Lanka: Results from the first island-wide survey. *Marine Pollution Bulletin*, *128*, 126-131. https://doi.org/10.1016/j.marpolbul.2018.01.018

Jawad, L. A., Adams, N. J., & Nieuwoudt, M. K. (2021). Ingestion of microplastics and mesoplastics by *Trachurus declivis* (Jenyns, 1841) retrieved from the food of the Australasian gannet *Morus serrator*: First documented report from New Zealand. *Marine Pollution Bulletin*, *170*, 112652. https://doi.org/10.1016/j.marpolbul.2021.112652

Johns, G. (2019). Assessment of Far North New Zealand Coastal Marine Debris, Using the Sustainable Coastlines' Citizen Science, Beach Survey Protocol. DOC Summer Science Scholarship Report. https://www.nrc.govt.nz/media/gjtjlitu/summer-scholarship-marine-litter-report_gabrielle-johns-2019-doc-5937820.pdf

Kalčíková, G. (2020). Aquatic vascular plants–A forgotten piece of nature in microplastic research. *Environmental Pollution*, 262, 114354. https://doi.org/10.1016/j.envpol.2020.114354

Karami, A., Golieskardi, A., Keong Choo, C., Larat, V., Galloway, T. S., & Salamatinia, B. (2017). The presence of microplastics in commercial salts from different countries. *Scientific Reports*, *7*(1), 46173. https://doi.org/10.1038/srep46173

Keep New Zealand Beautiful, KNZB (2021). The National Litter Audit September 2019. Auckland: Keep New Zealand Beautiful. https://www.knzb.org.nz/download/national-litter-audit-2019/

Keep New Zealand Beautiful, KNZB (2023a). Citizen Science. https://www.knzb.org.nz/programmes/citizen-science/

Keep New Zealand Beautiful, KNZB (2023b). The National Litter Audit November 2022. Auckland: Keep New Zealand Beautiful. https://www.knzb.org.nz/download/national-litter-audit-2022/

Kelly, A., Lannuzel, D., Rodemann, T., Meiners, K. M., & Auman, H. J. (2020). Microplastic contamination in east Antarctic sea ice. *Marine Pollution Bulletin*, *154*, 111130. https://doi.org/10.1016/j.marpolbul.2020.111130

Kershaw, P. J., & Rochman, C. M. (2015). *Sources, fate and effects of microplastics in the marine environment: part 2 of a global assessment.* Reports and Studies – IMO/FAO/UNESCO-IOC/WMO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) Eng No. 93. https://unesdoc.unesco.org/ark:/48223/pf0000247517

Kershaw, P. J., Turra, A., & Galgani, F. (2019). *Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean* (No. 99; GESAMP Reports and Studies). IMO/FAO/UNESCO-IOC/UNDIO/WMO/IAEA/UN/UNEP/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. https://www.researchgate.net/publication/332014608_GESAMP_2019_Guidelines_for_the_monitoring_assessment_of_plastic_litter_in_the_ocean_Reports_Studies_99_editors_Kershaw_PJ_Turra_A_and_Galgani_F

Khoo, K. S., Ho, L. Y., Lim, H. R., Leong, H. Y., & Chew, K. W. (2021). Plastic waste associated with the COVID-19 pandemic: Crisis or opportunity? *Journal of Hazardous Materials*, *417*, 126108. https://doi.org/10.1016/j.jhazmat.2021.126108

Kim, J. S., Lee, H. J., Kim, S. K., & Kim, H. J. (2018). Global pattern of microplastics (MPs) in commercial food-grade salts: sea salt as an indicator of seawater MP pollution. *Environmental science & technology*, *52*(21), 12819-12828. https://doi.org/10.1021/acs.est.8b04180

Klein, J. R., Beaman, J., Kirkbride, K. P., Patten, C., & Da Silva, K. B. (2022). Microplastics in intertidal water of South Australia and the mussel *Mytilus spp*.; the contrasting effect of population on concentration. *Science of The Total Environment*, *831*, 154875. https://doi.org/10.1016/j.scitotenv.2022.154875

Koelmans, A. A., Besseling, E., & Shim, W. J. (2015). Nanoplastics in the aquatic environment. Critical review. In *Marine Anthropogenic Litter*. Bergmann, M., Gutow, L., & Klages, M. (Eds.), 325-340. Springer Open. https://doi.org/10.1007/978-3-319-16510-3_12

Koelmans, A. A., Besseling, E., Foekema, E., Kooi, M., Mintenig, S., Ossendorp, B. C., Redondo-Hasselerharm, P. E., Verschoor, A., Van Wezel, A. P., & Scheffer, M. (2017). Risks of plastic debris: unravelling fact, opinion, perception, and belief. *Environmental Science and Technology, 51*, 11513–11519. https://doi.org/10.1021/acs.est.7b02219

Kolandhasamy, P., Su, L., Li, J., Qu, X., Jabeen, K., & Shi, H. (2018). Adherence of microplastics to soft tissue of mussels: a novel way to uptake microplastics beyond ingestion. *Science of the Total Environment*, *610*, 635-640. https://doi.org/10.1016/j.scitotenv.2017.08.053

Kowalski, N., Reichardt, A. M., & Waniek, J. J. (2016). Sinking rates of microplastics and potential implications of their alteration by physical, biological, and chemical factors. *Marine Pollution Bulletin*, *109*(1), 310-319. https://doi.org/10.1016/j.marpolbul.2016.05.064

Kühn, S., & Van Franeker, J. A. (2020). Quantitative overview of marine debris ingested by marine megafauna. *Marine Pollution Bulletin*, *151*, 110858. https://doi.org/10.1016/j.marpolbul.2019.110858

Kwak, J. I., & An, Y. J. (2021). Post COVID-19 pandemic: Biofragmentation and soil ecotoxicological effects of microplastics derived from face masks. *Journal of Hazardous Materials*, *416*, 126169. https://doi.org/10.1016/j.jhazmat.2021.126169

Kwon, J. H., Kim, J. W., Pham, T. D., Tarafdar, A., Hong, S., Chun, S. H., Lee, S. H., Kang, D. Y., Kim, J. Y., Kim, S. B., & Jung, J. (2020). Microplastics in food: a review on analytical methods and challenges. *International Journal of Environmental Research and Public Health*, *17*(18), 6710. https://doi.org/10.3390/ijerph17186710

Lacerda, A. L. D. F., Rodrigues, L. D. S., Van Sebille, E., Rodrigues, F. L., Ribeiro, L., Secchi, E. R., Kessler, F., & Proietti, M. C. (2019). Plastics in sea surface waters around the Antarctic Peninsula. *Scientific Reports, 9*, 1–12. https://doi.org/10.1038/s41598-019-40311-4

Laist, D. W. (1997). Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In *Marine debris: sources, impacts, and solutions*. Coe, J. M., & Rogers, D. B. (Eds.), 99-139. Springer New York. https://doi.org/10.1007/978-1-4613-8486-1_10

Lambert, S., & Wagner, M. (2018). Microplastics are contaminants of emerging concern in freshwater environments: an overview. In *Freshwater Microplastics. Emerging Environmental Contaminants*. Wagner, M., & Lambert, S. (Eds.), 1-23. Springer International Publishing. https://library.oapen.org/bitstream/handle/20.500.12657/42902/1/2018_Book_FreshwaterMicroplastics.pdf#page=14

Lavers, J. L., Bond, A. L., & Hutton, I. (2014). Plastic ingestion by flesh-footed shearwaters (*Puffinus carneipes*): implications for fledgling body condition and the accumulation of plastic-derived chemicals. *Environmental Pollution, 187*, 124–129. https://doi:10.1016/j.envpol. 2013.12.020

Lavers, J. L., Hutton, I., & Bond, A. L. (2019). Clinical pathology of plastic ingestion in marine birds and relationships with blood chemistry. *Environmental Science & Technology*, *53*(15), 9224-9231. https://doi.org/10.1021/acs.est.9b02098

Law, K. L., & Narayan, R. (2022). Reducing environmental plastic pollution by designing polymer materials for managed end-of-life. *Nature Reviews Materials*, *7*(2), 104-116. https://doi.org/10.1038/s41578-021-00382-0

Law, K. L., Starr, N., Siegler, T. R., Jambeck, J. R., Mallos, N. J., & Leonard, G. H. (2020). The United States' contribution of plastic waste to land and ocean. *Science Advances*, *6*(44), eabd0288.

Le Guen, C., Suaria, G., Sherley, R. B., Ryan, P. G., Aliani, S., Boehme, L., & Brierley, A. S. (2020). Microplastic study reveals the presence of natural and synthetic fibres in the diet of King Penguins (*Aptenodytes patagonicus*) foraging from South Georgia. *Environment International*, *134*, 105303. https://doi.org/10.1016/j.envint.2019.105303

Lee, K. W., Shim, W. J., Kwon, O. Y., & Kang, J. H. (2013). Size-dependent effects of micro polystyrene particles in the marine copepod *Tigriopus japonicus*. *Environmental Science & Technology*, *47*(19), 11278-11283. https://doi.org/10.1021/es401932b

Leslie, H. A., Van Velzen, M. J., Brandsma, S. H., Vethaak, A. D., Garcia-Vallejo, J. J., & Lamoree, M. H. (2022). Discovery and quantification of plastic particle pollution in human blood. *Environment International*, *163*, 107199. https://doi.org/10.1016/j.envint.2022.107199

Lewis, A. (2021). *Microplastics in the marine environment: Sediment contaminant and bioaccumulation rates in bivalves within the Bay of Plenty*. Unpublished Master dissertation, The University of Waikato, New Zealand. https://researchcommons.waikato.ac.nz/handle/10289/14609

Li, L., Zhao, X., Li, Z., & Song, K. (2021). COVID-19: Performance study of microplastic inhalation risk posed by wearing masks. *Journal of hazardous materials*, *411*, 124955. https://doi.org/10.1016/j.jhazmat.2020.124955

Li, W. C., Tse, H. F., & Fok, L. (2016). Plastic waste in the marine environment: A review of sources, occurrence and effects. *Science of The Total Environment*, *566*, 333-349. https://doi.org/10.1016/j.scitotenv.2016.05.084

Lippiatt, S., Opfer, S., & Arthur, C. (2013). *Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment*. NOAA Technical Memorandum NOS-OR&R-46. NOAA Tech. Memo. NOS-OR&R-46 82. https://repository.library.noaa.gov/view/noaa/2681

Liu, K., Wu, T., Wang, X., Song, Z., Zong, C., Wei, N., & Li, D. (2019a). Consistent transport of terrestrial microplastics to the ocean through atmosphere. *Environmental Science & Technology*, *53*(18), 10612-10619. https://doi.org/10.1021/acs.est.9b03427

Liu, G., Jiang, R., You, J., Muir, D. C., & Zeng, E. Y. (2019b). Microplastic impacts on microalgae growth: effects of size and humic acid. *Environmental Science & Technology*, *54*(3), 1782-1789. https://doi.org/10.1021/acs.est.9b06187

Liu, S., Guo, J., Liu, X., Yang, R., Wang, H., Sun, Y., Chen, B., & Dong, R. (2023). Detection of various microplastics in placentas, meconium, infant feces, breastmilk and infant formula: A pilot prospective study. *Science of The Total Environment*, *854*, 158699. https://doi.org/10.1016/j.scitotenv.2022.158699

Ma, J., Chen, F., Xu, H., Jiang, H., Liu, J., Li, P., Chen, C.C., & Pan, K. (2021). Face masks as a source of nanoplastics and microplastics in the environment: quantification, characterization, and potential for bioaccumulation. *Environmental Pollution*, *288*, 117748. https://doi.org/10.1016/j.envpol.2021.117748

Macfadyen, G., Huntington, T., & Cappell, R. (2009). *Abandoned, lost or otherwise discarded fishing gear*. Food and Agriculture Organization of the United Nations (FAO) Technical Report No 523. https://www.fao.org/3/i0620e/i0620e00.htm

MacLeod, M., Arp, H. P. H., Tekman, M. B., & Jahnke, A. (2021). The global threat from plastic pollution. *Science*, *373*(6550), 61-65. https://www.science.org/doi/abs/10.1126/science.abg5433

Maes, T., van Diemen de Jel, J., Vethaak, A. D., Desender, M., Bendall, V. A., Van Velzen, M., & Leslie, H. A. (2020). You are what you eat, microplastics in porbeagle sharks from the North East Atlantic: method development and analysis in spiral valve content and tissue. *Frontiers in Marine Science*, *7*, 273. https://doi.org/10.3389/fmars.2020.00273

Maghsodian, Z., Sanati, A. M., Tahmasebi, S., Shahriari, M. H., & Ramavandi, B. (2022). Study of microplastics pollution in sediments and organisms in mangrove forests: A review. *Environmental Research*, *208*, 112725. https://doi.org/10.1016/j.envres.2022.112725

Markic, A., Niemand, C., Bridson, J. H., Mazouni-Gaertner, N., Gaertner, J. C., Eriksen, M., & Bowen, M. (2018). Double trouble in the South Pacific subtropical gyre: Increased plastic ingestion by fish in the oceanic accumulation zone. *Marine Pollution Bulletin*, *136*, 547-564. https://doi.org/10.1016/j.marpolbul.2018.09.031

Markič, A., Gaertner, J. C., Gaertner-Mazouni, N., & Koelmans, A. A. (2020). Plastic ingestion by marine fish in the wild. *Critical Reviews in Environmental Science and Technology*, *50*(7), 657-697. https://doi.org/10.1080/10643389.2019.1631990

Martí, E., Martin, C., Galli, M., Echevarría, F., Duarte, C. M., & Cózar, A. (2020). The colors of the ocean plastics. *Environmental Science & Technology*, *54*(11), 6594-6601. https://doi.org/10.1021/acs.est.9b06400

Martinez, E. (2022). ***Plastic fireworks as marine debris in Te Tai Tokerau/Northland, Aotearoa New Zealand. Do we need a "pyrodigm" shift on their public sale?*** [Oral presentation] 7th International Marine Debris Conference, September 18-23, Busan, Republic of Korea. https://www.unep.org/events/unep-event/7th-international-marine-debris-conference-7imdc

Martinez, E. (2023). ***Estimation of plastic pollution from littered single-use facemasks during the Covid-19 pandemic***. [Poster presentation]. Conference of the New Zealand Marine Sciences, June 26-28, Wellington, New Zealand. http://nzmssconference2023.nz/

Martinez, E. and Bamford, N. (2021). ***Using citizen science to improve our understanding of marine macro-litter in Northland***. [Poster presentation] Conference of the New Zealand Marine Sciences, July 5-8, Tauranga, New Zealand. https://nzmss.org/conference/

Martinez, E. & Griffiths, R. (2023). *Assessing gross pollutant/litter loads and composition from urban stormwater run-offs in Northland.* Northland Regional Council report. https://www.nrc.govt.nz/media/k5pphj50/assessing-litter-loads-and-composition-from-urban-stormwater-discharges-in-northland.pdf

Mason, S. A., Garneau, D., Sutton, R., Chu, Y., Ehmann, K., Barnes, J., Fink, P., Papazissimos, D. & Rogers, D. L. (2016). Microplastic pollution is widely detected in US municipal wastewater treatment plant effluent. *Environmental Pollution*, *218*, 1045-1054. https://doi.org/10.1016/j.envpol.2016.08.056

Maximenko, N., MacFadyen, A., & Kamachi, M. (2015). Modeling the drift of marine debris generated by the 2011 tsunami in Japan. *PICES Press*, *23*(2), 32-36. https://www.pices.int/publications/other/2015-MOE-PICES-Press-summer.pdf

Mazlan, N. A., Lin, L., & Park, H. E. (2022). Microplastics in the New Zealand Environment. *Processes*, *10*(2), 265. https://doi.org/10.3390/pr10020265

McCaulay, S. (2020). *Marine Debris and Hard Plastic Fragments Along Northland Coastlines.* Unpublished report, NorthTec-Tai Tokerau Wānanga & Unitec Institute of Technology, New Zealand.

McIlgorm, A., Campbell, H. F., & Rule, M. J. (2011). The economic cost and control of marine debris damage in the Asia-Pacific region. *Ocean & Coastal Management*, *54*(9), 643-651. https://doi.org/10.1016/j.ocecoaman.2011.05.007

Meaza, I., Toyoda, J. H., & Wise Sr, J. P. (2021). Microplastics in sea turtles, marine mammals and humans: a one environmental health perspective. *Frontiers in environmental science*, 298. https://doi.org/10.3389/fenvs.2020.575614

Mendoza, L. M. R., & Balcer, M. (2019). Microplastics in freshwater environments: a review of quantification assessment. *TrAC Trends in Analytical Chemistry*, *113*, 402-408. https://doi.org/10.1016/j.trac.2018.10.020

Ministry for the Environment (2021). *National Plastics Action Plan for Aotearoa New Zealand*. Wellington: Ministry for the Environment. https://environment.govt.nz/assets/publications/National-Plastics-Action-Plan.pdf

Ministry for the Environment & Stats NZ (2019). *New Zealand's Environmental Reporting Series: Our marine environment*. Wellington: Ministry for the Environment. https://environment.govt.nz/publications/our-marine-environment-2019/

Mitrano, D. M., Wick, P., & Nowack, B. (2021). Placing nanoplastics in the context of global plastic pollution. *Nature Nanotechnology*, *16*(5), 491-500. https://doi.org/10.1038/s41565-021-00888-2

Mohamed Nor, N. H., Kooi, M., Diepens, N. J., & Koelmans, A. A. (2021). Lifetime accumulation of microplastic in children and adults. *Environmental Science & Technology*, *55*(8), 5084-5096. https://doi.org/10.1021/acs.est.0c07384

Monteiro, R. C., do Sul, J. A. I., & Costa, M. F. (2018). Plastic pollution in islands of the Atlantic Ocean. *Environmental Pollution*, *238*, 103–110. https://doi.org/10.1016/j.envpol.2018.01.096

Moore, C. J. (2008). Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. *Environmental Research*, 108, 131–139. https://doi.org/10.1016/j.envres.2008.07.025

Mora-Teddy, A. K., & Matthaei, C. D. (2020). Microplastic pollution in urban streams across New Zealand: concentrations, composition and implications. *New Zealand Journal of Marine and Freshwater Research*, *54*(2), 233-250. https://doi.org/10.1080/00288330.2019.1703015

Murray, F., & Cowie, P. R. (2011). Plastic contamination in the decapod crustacean *Nephrops norvegicus* (Linnaeus, 1758). *Marine Pollution Bulletin*, *62*(6), 1207-1217. https://doi.org/10.1016/j.marpolbul.2011.03.032

Napper, I. E., Davies, B. F., Clifford, H., Elvin, S., Koldewey, H. J., Mayewski, P. A., Miner, K. R., Potocki, M., Elmore, A. C., Gajurel, A. P., & Thompson, R. C. (2020). Reaching new heights in plastic pollution—preliminary findings of microplastics on Mount Everest. *One Earth*, *3*(5), 621-630. https://doi.org/10.1016/j.oneear.2020.10.020

Nava, V., Chandra, S., Aherne, J. et al. Plastic debris in lakes and reservoirs. *Nature* 619, 317–322 (2023). https://doi.org/10.1038/s41586-023-06168-4

Ngata, T., & Liboiron, M. (2020). *Māori plastic pollution expertise in Aotearoa*. CLEAR. https://civiclaboratory.nl/2020/07/13/maori-plastic-pollution-expertise-and-action-in-aotearoa/

Nelms, S. E., Duncan, E. M., Broderick, A. C., Galloway, T. S., Godfrey, M. H., Hamann, M., Lindeque, P. K., & Godley, B. J. (2016). Plastic and marine turtles: a review and call for research. *ICES Journal of Marine Science*, *73*(2), 165-181. https://doi.org/10.1093/icesjms/fsv165

Nelms, S. E., Galloway, T. S., Godley, B. J., Jarvis, D. S., & Lindeque, P. K. (2018). Investigating microplastic trophic transfer in marine top predators. *Environmental Pollution*, *238*, 999-1007. https://doi.org/10.1016/j.envpol.2018.02.016

Nelms, S. E., Clark, B. L., Duncan, E. M., Germanov, E., Godley, B. J., Parton, K. J., Pham, C. K., & Rodríguez, Y. (2023). Plastic Pollution and Marine Megafauna: Recent Advances and Future Directions. In *Plastic Pollution In The Global Ocean,* Norton, A. A. (Ed), 97-138. World Scientific Publishing. https://doi.org/10.1142/9789811259111_0005

Nzediegwu, C., & Chang, S. X. (2020). Improper solid waste management increases potential for COVID-19 spread in developing countries. *Resources, conservation, and recycling*, *161*, 104947. https://doi.org/10.1016/j.resconrec.2020.104947

Ocean Conservancy, OC (2022). *Connect + Collect. 2022 Report.* https://oceanconservancy.org/wp-content/uploads/2022/09/Annual-Report_FINALWebVersion.pdf

OECD (2022). *Global Plastics Outlook. Policy Scenarios to 2060*. Organisation For Economic Co-Operation and Development Publishing. https://doi.org/10.1787/aa1edf33-en.

Ory, N. C., Sobral, P., Ferreira, J. L., & Thiel, M. (2017). Amberstripe scad *Decapterus muroadsi* (Carangidae) fish ingest blue microplastics resembling their copepod prey along the coast of Rapa Nui (Easter Island) in the South Pacific subtropical gyre. *Science of the Total Environment*, *586*, 430-437. https://doi.org/10.1016/j.scitotenv.2017.01.175

Pace, R., Dimech, M., Camilleri, M., & Schembri, P. J. (2007). *Litter as a source of habitat islands on deepwater muddy bottoms*. Rapport du Congrès de la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée, 38, 567. https://www.um.edu.mt/library/oar//handle/123456789/21502

Padha, S., Kumar, R., Dhar, A., & Sharma, P. (2022). Microplastic pollution in mountain terrains and foothills: A review on source, extraction, and distribution of microplastics in remote areas. *Environmental Research*, *207*, 112232. https://doi.org/10.1016/j.envres.2021.112232

Pauly, J. L., Stegmeier, S. J., Allaart, H. A., Cheney, R. T., Zhang, P. J., Mayer, A. G., & Streck, R. J. (1998). Inhaled cellulosic and plastic fibers found in human lung tissue. *Cancer epidemiology, biomarkers & prevention: a publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology*, *7*(5), 419-428. https://aacrjournals.org/cebp/article/7/5/419/108754/Inhaled-cellulosic-and-plastic-fibers-found-in

Peryman, M. (2023). *Why plastics can never be 'circular': a Māori perspective on the Global Plastics Treaty*. Greenpeace. https://www.greenpeace.org/aotearoa/story/why-plastics-can-never-be-circular/

Phillips, M. R., & House, C. (2009). An evaluation of priorities for beach tourism: Case studies from South Wales, UK. *Tourism Management*, *30*(2), 176-183. https://doi.org/10.1016/j.tourman.2008.05.012

Pierce, K. E., Harris, R. J., Larned, L. S., & Pokras, M. A. (2004). Obstruction and starvation associated with plastic ingestion in a Northern Gannet *Morus bassanus* and a Greater Shearwater *Puffinus gravis*. *Marine Ornithology*, *32*, 187-189. http://www.marineornithology.org/PDF/32_2/32_2_187-189.pdf

PMCSA, Office of the Prime Minister's Chief Science Advisor. (2019). *Rethinking plastics in Aotearoa New Zealand*. https://www.pmcsa.ac.nz/topics/rethinking-plastics/

Prata, J. C., da Costa, J. P., Lopes, I., Duarte, A. C., & Rocha-Santos, T. (2020a). Environmental exposure to microplastics: An overview on possible human health effects. *Science of The Total Environment, 702*, 134455. https://doi.org/10.1016/j.scitotenv.2019.134455

Prata, J. C., Silva, A. L. P., Walker, T. R., Duarte, A. C., & Rocha-Santos, T. (2020b). COVID-19 Pandemic Repercussions on the Use and Management of Plastics. *Environmental Science and Technology*, *54*(13), 7760–7765. https://doi.org/10.1021/acs.est.0c02178

Provencher, J. F., Vermaire, J. C., Avery-Gomm, S., Braune, B. M., & Mallory, M. L. (2018). Garbage in guano? Microplastic debris found in faecal precursors of seabirds known to ingest plastics. *Science of the Total Environment*, *644*, 1477-1484. https://doi.org/10.1016/j.scitotenv.2018.07.101

Rabinowitz, P. M., Pappaioanou, M., Bardosh, K. L., & Conti, L. (2018). A planetary vision for one health. *BMJ Global Health*, *3*(5), e001137. https://doi.org/10.1136/bmjgh-2018-001137

Ragusa, A., Svelato, A., Santacroce, C., Catalano, P., Notarstefano, V., Carnevali, O., Papa, F., Rongioletti, M. C. A., Baiocco, F., Draghi, S., D'Amore, E., Rinaldo, D., Matta, M., & Giorgini, E. (2021). Plasticenta: First evidence of microplastics in human placenta. *Environment International*, *146*, 106274. https://doi.org/10.1016/j.envint.2020.106274

Rathinamoorthy, R., & Raja Balasaraswathi, S. (2022). Impact of coronavirus pandemic litters on microfiber pollution—effect of personal protective equipment and disposable face masks. *International Journal of Environmental Science and Technology*, 1-20. https://doi.org/10.1007/s13762-022-04462-8

Ren, X., Sun, Y., Wang, Z., Barceló, D., Wang, Q., Zhang, Zhang, Y. (2020). Abundance and characteristics of microplastic in sewage sludge: A case study of Yangling, Shaanxi province, China. *Case Studies in Chemical and Environmental Engineering 2 (2020) 100050.* https://www.researchgate.net/publication/344726685_Abundance_and_characteristics_of_microplastic_in_sewage_sludge_A_case_study_of_Yangling_Shaanxi_province_China

Reynolds, C., & Ryan, P. G. (2018). Micro-plastic ingestion by waterbirds from contaminated wetlands in South Africa. *Marine pollution bulletin*, *126*, 330-333. https://doi.org/10.1016/j.marpolbul.2017.11.021

Ribó, M., Watson, S., & Strachan, L. (2021). *Microplastics contamination in Queen Charlotte Sound/Tōtaranui marine sediments*. Report for the Marlborough District Council, New Zealand. https://www.marlborough.govt.nz/repository/libraries/id:1w1mps0ir17q9sgxanf9/hierarchy/Documents/Your%20Council/Meetings/2021/Environment%202021%20list/Item_5-26082021-Envirolink_University_of_Auckland_Microplastics_FINAL%20Report.pdf

Richardson, C. (2021). *The impact of microplastics on larvae of the sea urchin* Pseudechinus huttoni*.* Unpublished Master dissertation, University of Otago, New Zealand. https://ourarchive.otago.ac.nz/handle/10523/10868

Rochman, C. M., Tahir, A., Williams, S. L., Baxa, D. V., Lam, R., Miller, J. T., Teh, F. C., Werorilangi, S. & Teh, S. J. (2015). Anthropogenic debris in seafood: Plastic debris and fibres from textiles in fish and bivalves sold for human consumption. *Scientific Reports, 5*(1), 14340. https://doi.org/10.1038/ srep14340

Rochman, C. M., Brookson, C., Bikker, J., Djuric, N., Earn, A., Bucci, K., Athey, S., Huntington, A., McIlwraith, H., Munno, K. & De Frond, H. (2019). Rethinking microplastics as a diverse contaminant suite. *Environmental Toxicology and Chemistry*, *38*(4), 703-711. https://doi.org/10.1002/etc.4371

Rosas-Luis, R. (2016). Description of plastic remains found in the stomach contents of the jumbo squid *Dosidicus gigas* landed in Ecuador during 2014. *Marine Pollution Bulletin*, *113*(1-2), 302-305. https://doi.org/10.1016/j.marpolbul.2016.09.060

Royal Society Te Apārangi (2019). Plastic in the environment. Te Ao Hurihuri – The Changing World. https://issuu.com/royalsocietynz/docs/plastics-in-the-environment/48

Ruffell, H., Pantos, O., Northcott, G., & Gaw, S. (2021). Wastewater treatment plant effluents in New Zealand are a significant source of microplastics to the environment. *New Zealand Journal of Marine and Freshwater Research*, 1-17. https://doi.org/10.1080/00288330.2021.1988647

SAM (2019). *Environmental and Health Risks of Microplastic Pollution.* Scientific Advice Mechanism. Group of Chief Scientifc Advisors. European Commission, Luxembourg. https://www.plasticheal.eu/sites/default/files/content/file/2021/09/20/1/download_0.pdf

Saliu, F., Veronelli, M., Raguso, C., Barana, D., Galli, P., & Lasagni, M. (2021). The release process of microfibers: from surgical face masks into the marine environment. *Environmental Advances*, *4*, 100042. https://doi.org/10.1016/J.ENVADV.2021.100042

Schwabl, P., Köppel, S., Königshofer, P., Bucsics, T., Trauner, M., Reiberger, T., & Liebmann, B. (2019). Detection of various microplastics in human stool: a prospective case series. *Annals of Internal Medicine*, *171*(7), 453-457. https://doi.org/10.7326/M19-0618

Senko, J. F., Nelms, S. E., Reavis, J. L., Witherington, B., Godley, B. J., & Wallace, B. P. (2020). Understanding individual and population-level effects of plastic pollution on marine megafauna. *Endangered Species Research*, *43*, 234-252. https://doi.org/10.3354/esr01064

Sequeira, I. F., Prata, J. C., da Costa, J. P., Duarte, A. C., & Rocha-Santos, T. (2020). Worldwide contamination of fish with microplastics: A brief global overview. *Marine Pollution Bulletin*, *160*, 111681. https://doi.org/10.1016/j.marpolbul.2020.111681

Shahul Hamid, F., Bhatti, M. S., Anuar, N., Anuar, N., Mohan, P., & Periathamby, A. (2018). Worldwide distribution and abundance of microplastic: how dire is the situation? *Waste Management & Research*, *36*(10), 873-897. https://doi.org/10.1177/0734242X18785730

Shannon, C. (2020). *Spatial & Temporal Patterns of Microplastic Pollution in Wellington, New Zealand, and the Southern Ocean* (Doctoral dissertation, Open Access Te Herenga Waka-Victoria University of Wellington). https://openaccess.wgtn.ac.nz/articles/thesis/Spatial_Temporal_Patterns_of_Microplastic_Pollution_in_Wellington_New_Zealand_and_the_Southern_Ocean/17148608

Shen, M., Zeng, Z., Song, B., Yi, H., Hu, T., Zhang, Y., Zeng G. & Xiao, R. (2021). Neglected microplastics pollution in global COVID-19: disposable surgical masks. *Science of the Total Environment*, *790*, 148130. https://doi.org/10.1016/j.scitotenv.2021.148130

Shruti, V. C., Pérez-Guevara, F., Elizalde-Martínez, I., & Kutralam-Muniasamy, G. (2020). First study of its kind on the microplastic contamination of soft drinks, cold tea and energy drinks – Future research and environmental considerations. *Science of the Total Environment*, *726*, 138580. https://doi.org/10.1016/j.scitotenv.2020.138580

Siegfried, M., Koelmans, A. A., Besseling, E., & Kroeze, C. (2017). Export of microplastics from land to sea. A modelling approach. *Water Research*, *127*, 249-257. https://doi.org/10.1016/j.watres.2017.10.011

Singh, T. (2021). Generation of microplastics from the opening and closing of disposable plastic water bottles. *Journal of Water and Health*, *19*(3), 488-498. https://doi.org/10.2166/wh.2021.025

Statista, 2023. *Annual production of plastics worldwide from 1950 to 2021*. https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/

Stockin, K. A., Pantos, O., Betty, E. L., Pawley, M. D., Doake, F., Masterton, H., Palmer, E. I., Perrott, M. R., Nelms, S. E., & Machovsky-Capuska, G. E. (2021). Fourier transform infrared (FTIR) analysis identifies microplastics in stranded common dolphins (*Delphinus delphis*) from New Zealand waters. *Marine Pollution Bulletin*, *173*, 113084. 10.1016/j.marpolbul.2021.113084

Stone, B. (2022, November 18). Northland market and event organisers on a mission to reduce waste and educate public. *The Northern Advocate.* https://www.nzherald.co.nz/northern-advocate/news/northland-market-and-event-organisers-on-a-mission-to-reduce-waste-and-educate-public/G2EVHMAE55E5T2URX4HZKLCF2U/

Su, L., Nan, B., Craig, N. J., & Pettigrove, V. (2020). Temporal and spatial variations of microplastics in roadside dust from rural and urban Victoria, Australia: implications for diffuse pollution. *Chemosphere*, *252*, 126567. https://doi.org/10.1016/j.chemosphere.2020.126567

Tagorti, G., & Kaya, B. (2022). Genotoxic effect of microplastics and COVID-19: The hidden threat. *Chemosphere*, *286*, 131898. https://doi.org/10.1016/j.chemosphere.2021.131898

Talvitie, J., Mikola, A., Setälä, O., Heinonen, M., & Koistinen, A. (2017). How well is microlitter purified from wastewater? A detailed study on the stepwise removal of microlitter in a tertiary level wastewater treatment plant. *Water Research*, *109*, 164-172. https://doi.org/10.1016/j.watres.2016.11.046

Tanaka, K., Watanuki, Y., Takada, H., Ishizuka, M., Yamashita, R., Kazama, M., Hiki, N., Kashiwada, F., Mizukawa, K., Mizukawa, H., & Nakayama, S. M. (2020). In vivo accumulation of plastic-derived chemicals into seabird tissues. *Current Biology*, *30*(4), 723-728. https://doi.org/10.1016/j.cub.2019.12.037

Tekman, M. B., Gutow, L., Macario, A., Haas, A., Walter, A., Bergmann, M.: Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (n.d.). *LitterBase. Interactions between aquatic life and marine litter*. Accessed on 10 April 2023. https://litterbase.awi.de/interaction_detail

Ter Halle, A., Ladirat, L., Martignac, M., Mingotaud, A. F., Boyron, O., & Perez, E. (2017). To what extent are microplastics from the open ocean weathered? *Environmental Pollution*, *227*, 167-174. https://doi.org/10.1016/j.envpol.2017.04.051

Tesfaldet, Y. T., & Ndeh, N. T. (2022). Assessing face masks in the environment by means of the DPSIR framework. *Science of The Total Environment*, *814*, 152859. https://doi.org/10.1016/J.SCITOTENV.2021.152859

Thompson, R., Moore, C., Andrady, A., Gregory, M., Takada, H., & Weisberg, S. (2005). New directions in plastic debris. *Science*, *310*(5751), 1117-1117. https://doi.org/10.1126/science.310.5751.1117b

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W., McGonigle, D., & Russell, A. E. (2004). Lost at sea: where is all the plastic? *Science*, *304*(5672), 838-838. https://doi.org/10.1126/science.1094559

Tremblay, L. A., Pochon, X., Champeau, O., Baker, V., & Northcott, G. L. (2020). The Current Status of Plastics: A New Zealand Perspective. In *Particulate Plastics in Terrestrial and Aquatic Environments*, Bolan, N. S, Kirkham, M. B., Halsband, C., Nugegoda, D., & Ok, Y. S. (Eds), 363-376. CRC Press. https://doi.org/10.1201/9781003053071

Trestrail, C., Nugegoda, D., & Shimeta, J. (2020). Invertebrate responses to microplastic ingestion: Reviewing the role of the antioxidant system. *Science of The Total Environment*, *734*, 138559. https://doi.org/10.1016/j.scitotenv.2020.138559

United Nations Environment Programme, UNEP. (2021). *From Pollution to Solution: A global assessment of marine litter and plastic pollution*. Synthesis. Nairobi https://wedocs.unep.org/bitstream/handle/20.500.11822/36965/POLSOLSum.pdf

Valadez-Gonzalez, A., Cervantes-Uc, J. M., & Veleva, L. (1999). Mineral filler influence on the photo-oxidation of high density polyethylene: I. Accelerated UV chamber exposure test. *Polymer degradation and stability*, *63*(2), 253-260. https://doi.org/10.1016/S0141-3910(98)00102-5

van Calcar, C. V., & van Emmerik, T. V. (2019). Abundance of plastic debris across European and Asian rivers. *Environmental Research Letters*, *14*(12), 124051. https://doi.org/10.1088/1748-9326/ab5468

Van Cauwenberghe, L., Claessens, M., Vandegehuchte, M. B., & Janssen, C. R. (2015). Microplastics are taken up by mussels (Mytilus edulis) and lugworms (Arenicola marina) living in natural habitats. *Environmental pollution*, *199*, 10-17. https://doi.org/10.1016/j.envpol.2015.01.008

van Gool, E., Campbell, M., Wallace, P., & Hewitt, C. L. (2021). Marine debris on New Zealand beaches – Baseline data to evaluate regional variances. *Frontiers in Environmental Science*, *9*, 700415. https://doi.org/10.3389/fenvs.2021.700415

van Sebille, E., Wilcox, C., Lebreton, L., Maximenko, N., Hardesty, B. D., van Franeker, J. A., Eriksen, M., Siegel, D., Galgani, F., & Law, K.L. (2015). A global inventory of small floating plastic debris. *Environmental Research Letters*, *10(12)*, 124006. https://doi.org/10.1088/1748-9326/10/12/124006

van Weert, S., Redondo-Hasselerharm, P. E., Diepens, N. J., & Koelmans, A. A. (2019). Effects of nanoplastics and microplastics on the growth of sediment-rooted macrophytes. *Science of the Total Environment*, *654*, 1040-1047. https://doi.org/10.1016/j.scitotenv.2018.11.183

Wagner, M., & Lambert, S. (2018). *Freshwater microplastics: emerging environmental contaminants?* (p. 303). Springer Nature. https://link.springer.com/book/10.1007/978-3-319-61615-5

Walker, T. R., Adebambo, O., Feijoo, M. C. D. A., Elhaimer, E., Hossain, T., Edwards, S. J., Morrison, C. E., Romo, J., Sharma, N., Taylor, S., & Zomorodi, S. (2019). Environmental effects of marine transportation. In *World seas: an environmental evaluation* (pp. 505-530). Academic Press. https://doi.org/10.1016/B978-0-12-805052-1.00030-9

Wang, L., Nabi, G., Yin, L., Wang, Y., Li, S., Hao, Z., & Li, D. (2021). Birds and plastic pollution: recent advances. *Avian Research*, *12*, 1-9. https://doi.org/10.1186/s40657-021-00293-2

Wang, W., Ge, J., & Yu, X. (2020). Bioavailability and toxicity of microplastics to fish species: A review. *Ecotoxicology and environmental safety*, *189*, 109913. https://doi.org/10.1016/j.ecoenv.2019.109913

Wayman, C., & Niemann, H. (2021). The fate of plastic in the ocean environment – a minireview. *Environmental Science: Processes & Impacts*, *23*(2), 198-212. https://doi.org/10.1039/D0EM00446D

Webb, S., Ruffell, H., Marsden, I., Pantos, O., & Gaw, S. (2019). Microplastics in the New Zealand green lipped mussel Perna canaliculus. *Marine Pollution Bulletin*, *149*, 110641. https://doi.org/10.1016/j.marpolbul.2019.110641

Webb, S., Gaw, S., Marsden, I. D., & McRae, N. K. (2020). Biomarker responses in New Zealand green-lipped mussels *Perna canaliculus* exposed to microplastics and triclosan. *Ecotoxicology and Environmental Safety*, *201*, 110871. https://doi.org/10.1016/j.ecoenv.2020.110871

Weber, A., Scherer, C., Brennholt, N., Reifferscheid, G., & Wagner, M. (2018). PET microplastics do not negatively affect the survival, development, metabolism and feeding activity of the freshwater invertebrate Gammarus pulex. *Environmental Pollution*, *234*, 181-189. https://doi.org/10.1016/j.envpol.2017.11.014

Weinstein, J. E., Crocker, B. K., & Gray, A. D. (2016). From macroplastic to microplastic: Degradation of high-density polyethylene, polypropylene, and polystyrene in a salt marsh habitat. *Environmental Toxicology and Chemistry*, *35*(7), 1632-1640. https://doi.org/10.1002/etc.3432

Wilcox, C., Van Sebille, E., & Hardesty, B. D. (2015). Threat of plastic pollution to seabirds is global, pervasive, and increasing. *Proceedings of the national academy of sciences*, *112*(38), 11899-11904. https://doi.org/10.1073/pnas.1502108112

Windsor, F. M., Durance, I., Horton, A. A., Thompson, R. C., Tyler, C. R., & Ormerod, S. J. (2019). A catchment-scale perspective of plastic pollution. *Global Change Biology*, *25*(4), 1207-1221. https://doi.org/10.1111/gcb.14572

Worm, B., Lotze, H. K., Jubinville, I., Wilcox, C., & Jambeck, J. (2017). Plastic as a persistent marine pollutant. *Annual Review of Environment and Resources*, *42*, 1-26. https://doi.org/10.1146/annurev-environ-102016-060700

Wright, S. L., Ulke, J., Font, A., Chan, K. L. A., & Kelly, F. J. (2020). Atmospheric microplastic deposition in an urban environment and an evaluation of transport. *Environment International*, *136*, 105411. https://doi.org/10.1016/j.envint.2019.105411

Xu, B., Liu, F., Cryder, Z., Huang, D., Lu, Z., He, Y., Wang, H., Lu, Z., Brookes, P. C., Tang, C., & Gan, J. (2020). Microplastics in the soil environment: occurrence, risks, interactions and fate – a review. *Critical Reviews in Environmental Science and Technology*, *50*(21), 2175-2222. https://doi.org/10.1080/10643389.2019.1694822

Zantis, L. J., Bosker, T., Lawler, F., Nelms, S. E., O'Rorke, R., Constantine, R., Sewell, M., & Carroll, E. L. (2022). Assessing microplastic exposure of large marine filter-feeders. *Science of The Total Environment*, *818*, 151815. https://doi.org/10.1016/j.scitotenv.2021.151815vb

Zettler, E. R., Mincer, T. J., & Amaral-Zettler, L. A. (2013). Life in the “plastisphere”: microbial communities on plastic marine debris. *Environmental science & technology*, *47*(13), 7137-7146. https://doi.org/10.1021/es401288x

Zhang, K., Hamidian, A. H., Tubić, A., Zhang, Y., Fang, J. K., Wu, C., & Lam, P. K. (2021). Understanding plastic degradation and microplastic formation in the environment: A review. *Environmental Pollution*, *274*, 116554. https://doi.org/10.1016/j.envpol.2021.116554

Zhang, M., Li, J., Ding, H., Ding, J., Jiang, F., Ding, N. X., & Sun, C. (2020). Distribution characteristics and influencing factors of microplastics in urban tap water and water sources in Qingdao, China. *Analytical Letters*, *53*(8), 1312-1327. https://doi.org/10.1080/00032719.2019.1705476

Zhao, S., Zhu, L., & Li, D. (2016). Microscopic anthropogenic litter in terrestrial birds from Shanghai, China: Not only plastics but also natural fibers. *Science of the Total Environment*, *550*, 1110-1115. https://doi.org/10.1016/j.scitotenv.2016.01.112

Zubris, K. A. V., & Richards, B. K. (2005). Synthetic fibers as an indicator of land application of sludge. *Environmental Pollution*, *138*(2), 201-211. https://doi.org/10.1016/j.envpol.2005.04.013

9.0 Appendices

Appendix 1: The seven types of plastics, including their properties, common use, recyclability, and toxicity.

Appendix 2: Various polymer morphotypes that either sink or float in seawater.

Appendix 3: Locations of litter survey conducted in Te Taitokerau, Northland.

Appendix 4: Characteristics of microplastics (type, size, polymer morphotype, and colours) documented in various species of New Zealand fauna across different locations.

Appendix 5: Amount of microplastics detected in various species of New Zealand fauna across different locations.

Appendix 6: Characteristics of microplastics (type, size, polymer morphotype, and colours) documented in various New Zealand ecosystems across different locations.

Appendix 7: Mean abundance of microplastics (by volume or weight) documented in various New Zealand ecosystems across different locations.

Appendix 8: Number of particles, type, and polymer morphotype of microplastics found in various foods available in New Zealand.

APPENDIX *1*

The seven types of plastics, including their properties, common use, recyclability and toxicity. ***Note: The triangle symbols on plastic products do not imply that a product is always recyclable****. The number inside each chasing-arrow triangle represents the resin identification code, which indicates the type of plastic the product is made of.*

Polymer name	Polyethylene terephthalate	High-density polyethylene	Polyvinyl chloride	Low-density polyethylene	Polypropylene	Polystyrene	All other plastics
Resin Identification Code and abbreviation	1 PET	2 HDPE	3 PVC	4 LDPE	5 PP	6 PS	7 OTHER
Clarity	Clear	Translucent	Clear	Translucent	Translucent	Clear	Catch-all for other plastic resins not previously described or a combination of these plastics (e.g. nylon, acrylic, polylactic acid). #7 PLA plastics are compostable plastics made of bio-based polymers.
Rigidity Stiffness	Moderate to high	Moderate	Moderate to high	Low	Moderate to high	Moderate to high	
Resistance to impact	Good to excellent	Good to excellent	Fair to good	Excellent	Poor to good	Poor to good	
Resistance to heat	Poor to fair **or** high	Good	Poor to fair	Fair	Good	Fair	
Resistance to cold	Good	Excellent	Fair	Excellent	Poor to fair	Poor	
Resistance to sunlight	Good **or** poor	Fair	Poor to good	Fair or poor	Fair	Poor to fair	
Moisture barrier	Fair to good	Good to excellent	Fair	Good	Good to excellent	Poor to fair	
Other properties	▪ Good microwave transparency ▪ Solvent-resistant	▪ Soft waxy surface ▪ Permeable to gas ▪ Pigmented bottles are stress-resistant	▪ Good chemical resistance ▪ Low gas permeability ▪ Stable electrical properties	▪ Waxy surface ▪ Low melting point ▪ Stable electrical properties	▪ Waxy surface ▪ High melting point ▪ Excellent chemical resistance	▪ Glassy surface ▪ Affected by fats and solvents	

Polymer name	Polyethylene terephthalate	High-density polyethylene	Polyvinyl chloride	Low-density polyethylene	Polypropylene	Polystyrene	All other plastics
Commonly used for	▪ Water and soft drink bottles ▪ Sport drink bottles ▪ Other beverage bottles ▪ Some condiment bottles ▪ Some shampoo and mouthwash bottles ▪ Food jars ▪ Medicine jars ▪ Cups ▪ Rope ▪ Combs ▪ Tote bags ▪ Clothing and carpet fibres ▪ Prepared food trays and roasting bags	▪ Milk jugs ▪ Non-carbonated drink bottles ▪ Cosmetic bottles ▪ Household cleaner bottles ▪ Some plastic bags ▪ Motor oil containers ▪ Snack food boxes ▪ Cereal box liners ▪ Toys ▪ Buckets ▪ Some pipes ▪ Crates ▪ Plant pots ▪ Garden furniture ▪ Playground equipment ▪ Refuse bins and compost containers ▪ Park benches ▪ Truck bed liners	▪ Pipes and fittings ▪ Plumbing pipes ▪ Wire and cable sheeting ▪ Credit cards ▪ Carpet backing ▪ Floor covering ▪ Window and door frames ▪ Rain gutters ▪ Synthetic leather products ▪ Clear plastic food wrapping ▪ Cooking oil bottles ▪ Teething rings ▪ Pool liners ▪ Auto products ▪ Shower curtains ▪ Child and pet toys ▪ Garden hoses	▪ Plastic wraps ▪ Sandwich bags ▪ Bread bags ▪ Newspaper bags ▪ Produce bags ▪ Squeezable bottles ▪ Hot and cold beverage cups ▪ Plastic shopping bags ▪ Thick shopping bags ▪ Food storage containers and lids ▪ Bubble wraps ▪ Trays and containers ▪ Irrigation pipes ▪ Wire and cable covering ▪ Coating for paper milk cartons	▪ Most bottle tops ▪ Juice bottles ▪ Drinking straws ▪ Prescription bottles ▪ Some condiment bottles ▪ Yoghurt and margarine containers ▪ Hot food containers ▪ Potato chip bags ▪ Heavy-duty bags ▪ Kitchenware ▪ Disposable plates, cups, cutlery ▪ Packing tape ▪ Hangers ▪ Hinged lunch boxes ▪ Disposable diapers ▪ Sanitary pad liners ▪ Thermal vests ▪ Auto parts ▪ Fabric/carpet fibres	▪ Disposable foam cups ▪ Hot cups ▪ Foam packaging ▪ Takeaway food containers ▪ Plastic cutlery ▪ Egg cartons ▪ Fast-food trays ▪ Rigid foam insulation ▪ Video cases ▪ Coat hangers ▪ Low-cost, brittle toys ▪ Underlay sheeting for laminate flooring	▪ Baby bottles ▪ Sippy cups ▪ Large, multi-litre water containers ▪ Medical storage containers ▪ Safety glasses ▪ Exterior lighting features ▪ Metal linings of food cans ▪ CDs and DVDs ▪ Dental sealants ▪ Headlight lenses ▪ Nylon
Decomposition under ideal conditions	5–10 years	100 years	Never	500–1,000 years	20–30 years	50 years	Varies Majority: never Polylactic acid: 6 months

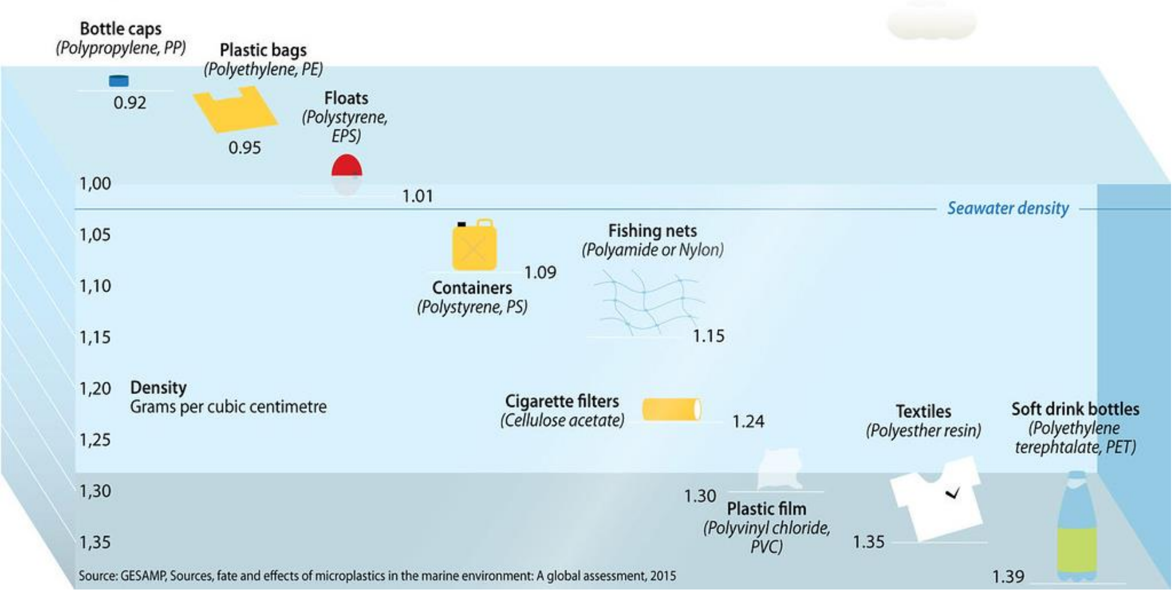
Polymer name	Polyethylene terephthalate	High-density polyethylene	Polyvinyl chloride	Low-density polyethylene	Polypropylene	Polystyrene	All other plastics
Recyclability (kerbside)	Kerbside recycling in Northland	Kerbside recycling in Northland	No kerbside recycling in Northland	No kerbside recycling in Northland	Kerbside recycling in most places in Northland	No kerbside recycling in Northland	Difficult to recycle. No kerbside recycling in Northland
Can be recycled into	▪ Plastic bottles ▪ Storage containers ▪ Fleece garments ▪ Carpets ▪ Rope ▪ Stuffing for pillows, jackets and sleeping bags ▪ Bean bags ▪ Car bumpers ▪ Tennis-ball felt ▪ Combs ▪ Sails for boats ▪ Furniture	▪ Plastic bottles and jugs ▪ Detergent bottles ▪ Plastic lumber ▪ Playground equipment ▪ Fencing ▪ Rope ▪ Toys ▪ Plant pots ▪ Crates ▪ Decking	▪ Pipes ▪ Panelling ▪ Flooring ▪ Carpet backing ▪ Roadside gutters ▪ Traffic cones ▪ Credit cards ▪ Wall siding ▪ Binders	▪ Compost bins ▪ Rubbish bins and bags ▪ Plastic lumber ▪ Floor tiles ▪ Furniture ▪ Shipping envelopes	▪ Storage bins ▪ Food containers ▪ Paint cans ▪ Cutting boards ▪ Hangers ▪ Mixing bowls ▪ Watering cans ▪ Shovels ▪ Brooms ▪ Ice scrapers ▪ Auto parts ▪ Shipping pallets ▪ Speed bumps ▪ Plant pots	▪ Rigid foam insulation ▪ Foam protective packaging ▪ Egg cartons ▪ Picture frames ▪ Moldings ▪ Rulers ▪ Cassette tapes ▪ Home décor products ▪ Hangers ▪ Plant pots ▪ Toys ▪ Tape dispensers	▪ Electronic housings ▪ Auto parts ▪ PLA compostable plastics are NOT recyclable
Toxicity level	**High** ♳ 1 PET ⚠ use with caution	**Low** ♴ 2 HDPE ✓ safe	**High** ♵ 3 PVC ⊘ avoid	**Low** ♶ 4 LDPE ✓ safe	**Low** ♷ 5 PP ✓ safe	**High** ♸ 6 PS ⊘ avoid	**High** ♹ 7 PC ⚠ use with caution
Most commonly leached toxin(s)	▪ Antimony oxide ▪ Bromine ▪ Diaszomethane ▪ Lead oxide ▪ Nickel ethylene oxide ▪ Benzene	▪ Chromium oxide ▪ Benzoyl peroxide ▪ Hexane ▪ Cyclohexane	▪ Benzene ▪ Carbon tetrachloride ▪ 1,2-Dicholroethane ▪ Phthalates ▪ Ethylene oxide ▪ Lead chromate ▪ Methyl acrylate ▪ Methanol	▪ Benzene ▪ Chromium oxide ▪ Cumene hydroperoxide ▪ Tert-butyl hydroperoxide	▪ Methanol ▪ 2,6-di-ter-butyl-4methyl phenol ▪ Nickel dibutyl dithiocarbonate	▪ Styrene ▪ Ethylbenzene ▪ Benzene ▪ Ethylene ▪ Carbon tetrachloride ▪ Polyvinyl alcohol ▪ Antimony oxide ▪ Tert-butyl hydroperoxide	▪ Bisphenol A (BPA) ▪ Bisphenol S (BPS) ▪ Other toxins mentioned

Polymer name	Polyethylene terephthalate	High-density polyethylene	Polyvinyl chloride	Low-density polyethylene	Polypropylene	Polystyrene	All other plastics
			▪ Phthalic anhydride ▪ Tetrahydrofuran ▪ Tribasic lead sulfate ▪ Mercury ▪ Cadmium ▪ Bisphenol A (BPA)			▪ Benzoquinone	
Health risks	▪ Can leach toxic metal antimony (carcinogen) especially when shelved for a long time or exposed to high temperatures ▪ Can also leach bromine, which acts as a central nervous system depressant and can trigger psychological symptoms ▪ Never heat PET plastics and only use once to reduce risks of leaching	▪ Considered one of the safest forms of plastic ▪ Safer option for food and drinks ▪ **But** never safe to reuse HDPE plastic for food/drink if it did not originally contain either ▪ HDPE can leach oestrogen-mimicking chemicals that can disrupt hormones and even alter structure of human cells	▪ Most hazardous plastic and contains many toxins ▪ Toxins can leach throughout its entire life cycle ▪ Chemicals can cause cancer and disrupt the hormonal system ▪ Linked to chronic conditions (e.g. allergies, asthma and autism) ▪ Toxic when heated. **Never** use for cooking or storing food	▪ Less toxic than other plastics and relatively safe to use ▪ **But** could leach oestrogen-mimicking chemicals (similar to those in HDPE) ▪ Chemicals can disrupt hormones and potentially alter the structure of human cells	▪ A safer plastic option for food and drink use as can withstand high temperatures and is less likely to leach chemicals ▪ Although microwave-safe, these plastics could still leach some chemicals that could lead to asthma and hormone disruption	▪ A highly toxic form of plastic ▪ Leaches many toxins, including styrene, which can cause cancer and damage to the nervous system ▪ Styrene could also affect genes, lungs, liver and immune system ▪ More styrene is leached with heat	▪ Difficult to know exactly which toxins can be found in this type of plastic ▪ Good chance these plastics could leach BPA and BPS ▪ BPA and BPS are endocrine disruptors, which can affect hormones and cause issues with growth and development, tissue function, obesity, sexual function and reproduction, brain and neurological functions, etc.

References:
Chia et al. (2013). *OMG Chemistry.* https://omg-chemistryyyy.blogspot.com/2013/03/welcome-to-world-of-plastics-look.html
EcoWatch (2016). *7 Types of Plastic Wreaking Havoc on Our Health.* https://www.ecowatch.com/7-types-of-plastic-wreaking-havoc-on-our-health-1882198584.htmlSmall Pocket Library (2020). *Infographic: The Seven Types of Plastics.* https://www.smallpocketlibrary.com/2020/11/infographic-seven-types-of-plastic.html
Rethink Waste (2019). *The hard facts about plastics.* https://rethinkwaste.org/2019/10/18/the-hard-facts-about-plastic/
Seaman, G. (2020). *Plastics by the Numbers.* Eartheasy. https://learn.eartheasy.com/articles/plastics-by-the-numbers/
YesStraws (2020). *Types of plastic – A complete plastic numbers guide.* https://yesstraws.com/blogs/news/types-of-plastic-plastic-numbers-guide

APPENDIX *2*

Various polymer morphotypes that either sink or float in seawater (Source: Kershaw & Rochman, 2015; Maphoto/Riccardo Parvettoni, 2016)



APPENDIX 3

Locations of litter survey conducted in Te Taitokerau, Northland.

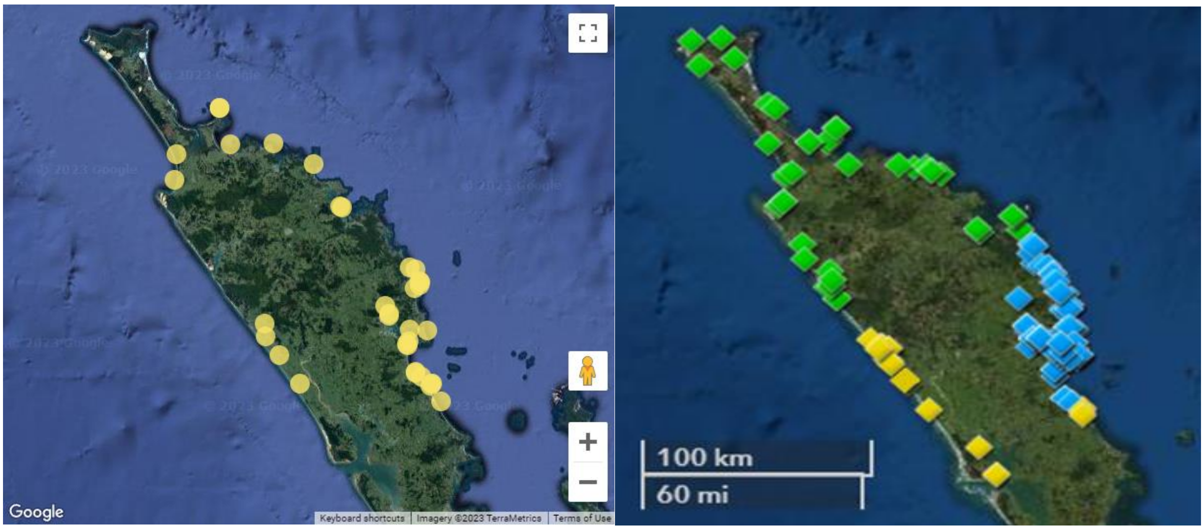


Figure A: Locations of beach surveys conducted in Te Taitokerau, Northland under the Litter Intelligence programme between 2019 and 2022 (left), and Te Tai Tokerau Debris Monitoring Programme (TTTDMP) between March 2019 and March 2021 (right). (Source: Litter Intelligence, Sustainable Coastlines)

Figure B: Area of Whangārei city centre, Te Taitokerau, Northland, systematically surveyed for parking tickets (June 2021–November 2022) and face masks (September 2021–November 2022) by Te Tai Tokerau Debris Monitoring Project (TTTDMP). (Source: TTTDMP, unpublished data)

APPENDIX *3*

Characteristics of microplastics (percentage of type, size, polymer morphotype, and colours) documented in various species of New Zealand fauna across different locations.
Note: Percentage of polymer type, morphotype, and colour shown in brackets. Abbreviations: acrylonitrile butadiene styrene (ABS); cellulose and regenerated cellulose (cotton, rayon or cellophane) (C & CR); polyamide/nylon (PA); polyacrylonitrile (PAN); polybutadiene acrylonitrile (PBAN); polyethylene (PE); polyethylene glycol (PEG); poly(ethylene terephthalate) (PET); poly(methyl methacrylate) (PMMA); polystyrene (PS); polyurethane (PU); polyvinyl alcohol (PVA); polyvinylchloride (PVC); not assessed or not publicly available (NA).

Species	Location	Microplastic types and size	Polymer morphotype	Colours	References
Invertebrates					
Sponges 6 species (45)	Wellington Harbour • Evans Bay • Shark Bay • Māhanga Bay	*Type* Fragments > fibres *Size* > 100µm more abundant	NA	NA	Parry et al. (2023)
Pipi (*Paphies australis*)	Northland 3 locations	*Type* Fragments (67%) Fibres (33%) *Size (NA)*	PE (45%) PET (33%) PA (11%) PE.PP (11%)	Clear (78%) Black (11%) Orange (11%)	ESR & NRC (unpublished data)
Wedge shell (*Macomona liliana*)		*Type* Fibres (70%) Fragments (30%) *Size* (NA)	PET (64%) PP (30%) PS (3%) ABS (3%)	Clear (57%) Blue (27%) Black (13%) Red (3%)	
Cockle (*Austrovenus stutchburyi*) • Mangawhai		*Type* Fibres (74.5%) Fragments (25.5%) *Size* (NA)	PET (82%) PP (8%) PS (2%) PE (2%) Other (6%)	Clear (63%) Blue (17%) Grey (8%) Yellow (2%) Orange (2%) White (2%) Green (2%) Black (2%) Pink (2%)	
Cockle (*Austrovenus stutchburyi*) • Te Haumi		*Type* Fibres (82.5%) Fragments (17.5%) *Size* (NA)	PET (80%) PE (7.5%) Acrylic (5%) PA (2.5%) PP (2.5%) PS (2.5%)	Clear (70%) Blue (22.5%) Grey (5%) Yellow (2.5%)	

Species	Location	Microplastic types and size	Polymer morphotype	Colours	References
Cockle (*Austrovenus stutchburyi*) - Onerahi		*Type* Fragments (87.5%) Fibres (12.5%) *Size* (NA)	PE (75%) PA (8.5%) PET (8.5%) PS (4%) Other (4%)	Clear (92%) Yellow (8%)	
Cockle (*Austrovenus stutchburyi*)	Bay of Plenty 29 locations - Tauranga - Ōhiwa Harbour - Eastern coastline	*Type* Fibres (50%) Fragments (45%) Films (5%) *Size* 10–20mm prevalent	PET (34%) PA (27%) PE (25%) PVC (9%) Inorganics (5%)	NA	Lewis (2021)
Wedge shell (*Macomona liliana*)		*Type* Fragments (80%) Fibres (17%) Films (3%) *Size* 20–30mm prevalent			
Tuatua *(Paphies subtriangulata*)		*Type* Fibres (52%) Fragments (48%) Films (0%) *Size* 40–50mm prevalent			
Mediterranean mussel *(Mytilus galloprovincialis*)	Wellington Harbour - Oriental Bay - Kau Point - Scorching Bay	*Type* Fibres (96%) Fragments (4%) *Size* 1–2mm (40%) 2–5mm (36%) < 1mm (24%)	NA	Blue (52%) Black (26%) Colourless (14%) Red (5%) Green (1%) Orange (1%) White (<1%) Purple (<1%) Yellow (<1%)	Shannon (2020)

Species	Location	Microplastic types and size	Polymer morphotype	Colours	References
Green-lipped mussels (*Perna canaliculus*)	North Island South Island 9 locations, 16 sites	*Type* Fragments (71%) Beads (19%) Fibres (10%) *Size* 100–200µm (52%) 50–100µm (28%) > 300µm (19%)	PE (38%) Polyamide-imide (28%) Acrylic (19%) Nylon (5%) Rayon (5%) PVA (5%)	Blue (38%) Red (33%) Transparent (14%) Orange (10%) Green (5%)	Webb et al. (2019)
Green-lipped mussels (*Perna canaliculus*)	NZ supermarkets	Fragments (93%) Fibres (7%)	Predominantly PP	NA	Mazlan et al. (2022)
Vertebrates (Fish)					
Marine species Parore (*Girella tricuspidata*) (20) Leatherjacket (*Meuschenia scaber*) (19) Yellowtail kingfish (*Seriola lalandi*) (15) Grey mullet (*Mugil cephalus*) (22) Tarakihi (*Nemadactylus macropterus*) (23) Australasian snapper (*Pagrus auratus*) (22) Blue fin gurnard (*Chelidonichthys kumu*) (27) Y.t. jack mackerel (*Trachurus novaezelandiae*) (31) Garfish (*Hyporhamphus ihi*)	NZ Auckland Fish Market	*Type* Fibres (45%) Fragments (34%) Film (21%) *Size* 1–5mm (40%) 0.5–1mm (29%) 0.1–0.5mm (24%) > 5mm (7%)	(Rayon) (50%) PE (20%) PES (15%) PP (15%)	Black White Blue Green	Markic et al. (2018)
Hoki (*Macruronus novaezelandiae*)	West Coast Cook Strait	*Type* Fibres (90.9%) *Size* NA	NA	NA	Rotman (2020)
Coastal inshore species (6), including: Y.b. flounder (*Rhombosolea leporina*)	Auckland, Hauraki Gulf 11 locations	NA	NA	NA	Shetty (2020)

Species	Location	Microplastic types and size	Polymer morphotype	Colours	References
Red gurnard (*Chelidonichthys kumu*) Pilchard (*Sardinops sagax*)					
Greenback horse mackerel (*Trachurus declivis*) (25)	Auckland Hauraki Gulf	*Type* Fragments (100%) *Size* 4.5–10mm	PE (43%) PP (14%) PA (14%) PAN + PBAN (14%) PMMA (14%)	Transparent (43%) Green (14%) Black (14%) Red (14%) Blue (14%)	Jawab et al. (2021)
Benthic and pelagic marine fish 10 species (155)	Otago Southland	*Type* Fibres (86.7% pelagic, 82.3% benthic) Film *Size* < 5 mm (99%)	PE (68%) Viscose (14%) PE + pumbophyllite (12%) PP + TiO_2 (2%) PP + PO_4 (2%)	Blue (33.3% pelagic, 38% benthic) Black Red White	Clere et al. (2022)
Tarakihi (*Nemadactylus macropterus*)	NZ supermarkets	Fragments (59%) Fibres (26%) Beads (15%)	PEG	NA	Mazlan et al. (2022)
Vertebrates (marine mammals)					
Bryde's whales *(Balaenoptera brydei)* (18 scat samples) Sei whales (*Balaenoptera borealis*) (3 scat samples)	Auckland coastal waters	*Type* Fibres (99%) Fragments or films (1%) *Size* Mean 1085µm ± 1395 (SE) Range: 152–26,290µm	Regenerated cellulose (84%) PE (4%)	Blue or black (83%) Red (9%) Clear/transparent (3%) Green (2%) Brown (2%) Purple (1%)	Zantis et al. (2022)
Common dolphins (*Delphinus delphis*) (15)	Northland Auckland Wairarapa Wellington Marlborough Sounds	*Type* Fragments (77%) Fibres (23%) *Size* Fragments Mean: 584 ± 925µm Range: 44–4361µm Fibres Mean: 1567 ± 1969µm Range: 198–10,032µm	*Fragments* PE (31%) ABS (20%) PET (15%) *Fibres* PET (65%) PP (13%)	Translucent/clear (46%) Black (10%) Orange (10%) Multi-coloured (10%) Blue (7%)	Stockin et al. (2021)

APPENDIX *4*

Amount of microplastics detected in various species of New Zealand fauna across different locations.

Depending on the study, data are provided as particle per dry weight (unless specified). PIR = plastic ingestion rate (% of individual fish of the same species containing one or more plastic items); AP = average plastic (the average number of microplastics per individual for the total sample size or total microplastic/total sample size); PL = plastic load (the average number of microplastics per individual, only for those that had ingested microplastics or total microplastic/sample size of ingested). Abbreviations: Bay of Plenty (BOP); not assessed or not publicly available (NA); not detected (ND); standard deviation (SD); standard error (SE).

Species	Location	Particles (dry weight)	PIR (%)	AP	PL	References
Invertebrates						
Sponges, 6 species (45) • *Suberites australiensis* • *Crella incrustans* • *Halichondira knowltoni* • *Crella affinis*	Wellington Harbour • Evans Bay • Shark Bay • Māhanga Bay	208g^{-1} ± 131 (SE) 625g^{-1} ± 149 (SE) 1001g^{-1} ± 73 (SE) 1894g^{-1} ± 397 (SE)	NA	NA	NA	Parry et al. (2023)
Pipi (*Paphies australis*)	Northland 3 locations	NA	NA	0.6 ± 0.35 (SD)	NA	ESR & NRC (unpublished data)
Wedge shell (*Macomona liliana*)				1.5 ± 1.70 (SD)	2.3 ± 1.60 (SD)	
Cockle (*Austrovenus stutchburyi*)						
• Mangawhai				2.6 ± 2.37 (SD)	3.2 ± 2.23 (SD)	
• Te Haumi				2.0 ± 1.49 (SD)	2.4 ± 1.32 (SD)	
• Onerahi				1.2 ± 1.74 (SD)	2.4 ± 1.78 (SD)	
Bivalves	BOP: 29 locations	Wet weight	NA	NA	NA	Lewis (2021)
Cockle (*Austrovenus stutchburyi*)	• Tauranga Harbour	Range: 0.07–1.2g^{-1}				
Wedge shell (*M. liliana*)	• Ōhiwa Harbour	Range: 0.1–1g^{-1}				
Tuatua (*Paphies subtriangulata*)	• Eastern coastline	Range: 0.03–0.23g^{-1}				
Mediterranean mussel *(Mytilus galloprovincialis)*	Wellington Harbour 3 sites	Wet weight 0.30g^{-1} ± 0.04 (SE)	NA	NA	NA	Shannon (2020)
Green-lipped mussels (*Perna canaliculus*)	NZ: 9 locations		NA		NA	Webb et al. (2019)
	• Bay of Islands	0		ND		
	• Mt Maunganui	0.03g^{-1}		0.3		
	• New Plymouth	0.06g^{-1}		0.3		
	• Napier	ND		ND		
	• Wellington Harbour	0.01g^{-1}		0.2		
	• Port Underwood	ND		ND		
	• Westport	0.01g^{-1}		0.2		
	• Avon-Heathcote	0.16g^{-1}		0.5		
	• Dunedin	0.04g^{-1}		0.7		

Species	Location	Particles (dry weight)	PIR (%)	AP	PL	References
Green-lipped mussels (*Perna canaliculus*)	NZ: local supermarkets	14 x $100g^{-1}$	NA	NA	NA	Mazlan et al. (2022)
Vertebrates (fish)						
Marine species	NZ Auckland fish market	NA	15.8%	NA	3.6 ± 0.7 (SE)	Markic et al. (2018)
Parore (*Girella tricuspidata*) (20)			70%		5.9 ± 1.3 (SE)	
Leatherjacket (*Meuschenia scaber*) (19)			36.8%		2.0 ± 0.5 (SE)	
Yellowtail kingfish (*Seriola lalandi*) (15)			20%		1.0 ± 0.0 (SE)	
Grey mullet (*Mugil cephalus*) (22)			13.6%		2.0 ± 0.6 (SE)	
Tarakihi (*Nemadactylus macropterus*) (23)			8.7%		3.5 ± 0.5 (SE)	
Australasian snapper (*Pagrus auratus*) (22)			4.5%		1.0 ± 0.0 (SE)	
Blue fin gurnard (*Chelidonichthys kumu*) (27)			3.7%		2.0 ± 0.0 (SE)	
Y.t. jack mackerel (*Trachurus novaezelandiae*) (31)			3.2%		1.0 ± 0.0 (SE)	
Marine species (6 species) Yellowbelly flounder (*Rhombosolea leporine)* Red gurnard (*Chelidonichthys kumu*) Pilchard (*Sardinops sagax*)	Hauraki Gulf 11 locations	NA	23%	1.73	0.397	Shetty (2020)
Hoki (*Macruronus navaezelandiae*)	West Coast Cook Strait	NA	NA	4.25 6.9	NA	Rotman (2020)
Greenback horse mackerel (*Trachurus declivis*) (25)	Auckland Hauraki Gulf	NA	4%	0.4	Only 1 individual had plastics in stomach	Jawab et al. (2021)
Benthic and pelagic marine fish (155)	Otago Southland	NA				Clere et al. (2022)
Benthic (7 species)			78.2%	2.7 ± 0.3 (SE)	3.4 ± 0.3 (SE)	
Pelagic (3 species)			72.2%	2.1 ± 2.9 (SE)	2.9 ± 0.4 (SE)	
Marine migratory species	New Zealand Exclusive Economic Zone	NA	All litter material	NA	NA	Horn et al. (2013 and 2021)
Mako shark (*Isurus oxyrinchus)* (993)			0.4%			
Porbeagle shark (*Lamna nasus*) (1,489)			0.2%			
Blue shark (*Prionace glauca*) (8584)			0.3%			
Lgs. lancetfish (*Alepisaurus ferox*) (849)			1.2%			
Shs. lancetfish (*A. brevirostris*) (381)			0.3%			
Moonfish (*Lampris guttatus*) (1,565)			18.4%			
Kingfish (*Seriola lalandi*) (5)			20%			
Ray's bream (*Brama sp.*) (1,560)			0.3%			
Butterfly tuna (*G. melampus*) (949)			0.5%			
Albacore (*Thunnus alalunga*) (694)			0.1%			

Species	Location	Particles (dry weight)	PIR (%)	AP	PL	References
Yellowfin tuna (*T. albacares*) (967) Sth. bluefin tuna (*T. maccoyii*) (9,966) Bigeye tuna (*T. obesus*) (1169) Pac. bluefin tuna (*T. orientalis*) (47) Swordfish (*Xiphias gladius*) (3,494) Striped marlin (*Kajikia audax*) (20)			0.3% 0.6% 0.2% 2.1% 0.1% 5.0%			
Tarakihi (*Nemadactylus macropterus*) (3)	NZ Local supermarkets	20 x 100g^{-1}	NA	NA	NA	Mazlan et al. (2022)
Vertebrates (marine mammals)						
Bryde's whales (*Balaenoptera brydei*) (18 scat samples) Sei whales (*Balaenoptera borealis*) (3 scat samples)	Auckland coastal waters	5g–1	NA	Exposure: 24,028 MPs (>150µm) per mouthful when feeding	NA	Zantis et al. (2022)
Common dolphins (*Delphinus delphis*) (15)	Northland Auckland Wairarapa Wellington Marlborough Sounds	NA	NA	7.8 MP ± 1.4 (SE)	7.8 MP ± 1.4 (SE)	Stockin et al. (2021)

APPENDIX *5*

Characteristics of microplastics (percentage of type, size, polymer morphotype, and colours) documented in various New Zealand ecosystems across different locations.

*Note: * = not provided. Abbreviations: acrylonitrile butadiene styrene (ABS); cellulose and regenerated cellulose (cotton, rayon or cellophane) (C & CR); polyamide/nylon (PA); polyacrylonitrile (PAN); polybutadiene acrylonitrile (PBAN); polyethylene (PE); polyethylene glycol (PEG); poly(ethylene terephthalate) (PET); poly(methyl methacrylate) (PMMA); polystyrene (PS); polyurethane (PU); polyvinyl alcohol (PVA); polyvinylchloride (PVC); not assessed or not publicly available (NA).*

Location	Microplastic types and size	Polymer morphotype	Colour(s)	References
Sediments				
Northland 11 locations, 22 sites • Rarawa • Waipapakauri • Ahipara • Taharoa • Ōmāmari • Glinks Gully • Paihia • Sandy Bay • Onerahi • Waipu Cove • Mangawhai	*Type* Fibres (50%) Fragments (36%) Films (14%) *Size* < 25µm 50–100µm	C&CR (44%) PE (23%) PP (18%) PET (8%) PS (1%) Other (6%)	NA	De Lena et al. (2021)
Auckland 39 sites • Waitematā • Hauraki • Tamaki • Manukau • Tasman	*Type* Fibres (88%) Fragments (8%) Films (4%) *Size* 300–500µm (39%) 500–1,000µm (35%) 1,000–5,000µm (21%) < 300µm (4%)	CR (34%) PET (22%) PE (15%) PP (4%) PU (4%)	Colourless White Black	Bridson et al. (2020)
Auckland 18 locations, 21 sites	*Type* Fragments (79%) Fibres (20%) *Size* 63–500µm 500–1,000µm 1,000–5,000µm	NA	NA	Dikareva & Simon (2019)
Auckland 22 sites • Waitematā Harbour	*Type* Fibres (48%) Fragments (46%) *Size* 1–5mm (30%) 201–400µm (25%)	PP (34%) PET (18%) PE (11%)	Blue (15%) Green (12%) Black (9%)	Hope et al. (2021)
Bay of Plenty 29 locations • Tauranga Harbour • Ōhiwa Harbour • Eastern coastline	*Type* Fibres (75%) Fragments (23%) Films (2%) *Size* (NA)	C & CR (40%) PVC (13%) PA (10%) Inorganic (37%)	NA	Lewis (2021)
Wellington Harbour 3 sites	*Type* Fibres (90%) Fragments (9%)	NA	Black (47%) Blue (40%) Colourless (4%)	Shannon (2020)

	Size 1–2mm (45%) < 1mm (30%) 2–5mm (25%)		White (3%) Red (3%) Green (1%) Orange (1%) Yellow (1%) Purple (1%)	
Canterbury 10 sites	*Type* Fragments (86%) Pellets (11%) *Size* 2–5mm (59%) 1–2mm (25%) < 1mm (16%)	PS (55%) PE (21%) PP (11%)	White (67%) Clear (10%) Blue (8%) Red (5.5%) Green (5.5%) Yellow/orange (3%) Brown (1%)	Clunie-Ross et al. (2016)
Canterbury 30 sites • Avon/Ōtākaro River • Upper reach • Middle reach • Lower reach	*Type* Fragments (47%) Fibres (35%) Foams (10%) Pellets (8%) *Size* 100–300µm (43%) 500–1000µm (30%) 30–100µm (18%) 300–500µm (8%)	PET (21%) PP (17%) PS (16%) PE (7%) Nylon (7%)	Red (27%) Blue (26%) White (21%) Black (19%) Green (2%) Orange (2%) Yellow (2%)	Phillips (2020)
Marlborough Queen Charlotte Sound 2 sites • Marine reserve	*Type* Fibres Fragments Filaments *Size* NA	NA	Red (56%) Transparent (>15%) Blue (~11%) Black (~10%)	Ribó et al. (2021)
• Anchorage	*Type* Fragments Fibres Filaments *Size* NA		Blue (~45%) Red (~30%) Black (15%)	
Stormwater drain sediments				
Canterbury Avon/Ōtākaro River • Upper reach • Middle reach • Lower reach	*Type* Fragments (66%) Fibres (26%) Pellets (8%) *Size* 500–1000µm (34%) 30–100µm (24%) 1000–5000µm (18%) 300–500µm (14%) 100–300µm (10%)	Nylon (16%) Rubber (12%) PP (12%) PE (10%) PC (8%) PET (6%)	White (20%) Green (18%) Black (14%) Blue (12%) Yellow (12%) Red (10%) Orange (10%)	Phillips (2020)
Wastewater treatment effluents				
Canterbury • Christchurch • Kaiapoi • Lyttelton	*Type* Fragments (58%) Fibres (35%) Films (7%) *Size* > 300–1000µm (61%) 0–300µm (23%) 1000–5000µm (16%)	PET (26%) PE (22%) PP (15%)	NA	Ruffell et al. (2021)

Freshwater streams				
Auckland 18 locations, 21 sites	*Type* Fragments (39%) Fibres (34%) *Size* 63–500µm 500–1,000µm 1,000–5,000µm	NA	Transparent/white Yellow Black Blue Green	Dikareva & Simon (2019)
Auckland **Hamilton** **Wellington** **Christchurch** **Dunedin** 52 sites	*Type* Polystyrene (51%) Fibres (33%) Fragments (15%) Beads (< 1%) *Size* 250–500µm (43%) 500–1,000µm (35%) 1,000–5,000µm (22%)	NA	NA	Mora-Teddy et al. (2019)
Marine waters				
Northland 7 sites	*Type* Fibre (60%) Fragment (35%) Fibre bundle (3%) Film (1%) *Size* NA	PET (42%) PE (15%) PP (14%) Acrylic (10%) PA (7%) PVC (2%) Other (10%)	Black (28%) Blue (21%) Clear (20%) Green (7%) Orange (6%) White (5%) Grey (3%) Multicoloured (3%) Yellow (3%) Red (2%) Purple (1%)	AIM^2/Blue Cradle/ESR (Unpublished data)
Wellington Harbour 3 sites	*Type* Fibres (94%) Fragments (5%) *Size* 1–2mm (42%) 2–5mm (31%) < 1mm (27%)	NA	Black (48%) Blue (27%) Colourless (8%) Red (7%) Green (3%) Orange (3%) White (2%) Yellow (2%) Purple (1%)	Shannon (2020)

APPENDIX *6*

Mean abundance of microplastics (by volume or weight) documented in various New Zealand ecosystems across different locations.

*Note: In bracket (site number, n). WW: Wet weight, otherwise data are provided as dry weight; (*) A range is given from the different sites as low, mid and high concentrations for comparative purposes; ** Data for north sites during summer only. For a list of all sites, please refer to the reference.*

Abbreviations: acrylonitrile butadiene styrene (ABS); cellulose and regenerated cellulose (cotton, rayon or cellophane) (C & CR); polyamide/nylon (PA); polyacrylonitrile (PAN); polybutadiene acrylonitrile (PBAN); polyethylene (PE); polyethylene glycol (PEG); poly(ethylene terephthalate) (PET); poly(methyl methacrylate) (PMMA); polystyrene (PS); polyurethane (PU); polyvinyl alcohol (PVA); polyvinylchloride (PVC); not assessed or not publicly available (NA); not detected (ND); standard deviation (SD); standard error (SE).

Region	Location	Mean abundance (MPs m^{-2}; cm^{-3}; L^{-1})	Mean abundance (MPs g^{-1}; kg^{-1})	Reference
Sediments				
Northland 11 locations 22 sites	• Ahipara (12) • Glinks Gully (16) • Mangawhai (12) • Ōmāmari (16) • Onerahi (16) • Paihia (12) • Rarawa (12) • Sandy Bay (12) • Taharoa (12) • Waipapakauri (16) • Waipu (12)	56m^{-2} ± 98 (SD) ** 107m^{-2} ± 98 (SD) ** 486m^{-2} ± 275 (SD) ** 217m^{-2} ± 82 (SD) ** ND 88m^{-2} ± 150 (SD) ** 182m^{-2} ± 178 (SD) ** 629m^{-2} ± 762 (SD)** 68m^{-2} ± 118 (SD) ** 256m^{-2} ± 205 (SD) ** 56m^{-2} ± 98 (SD) **	2.71kg^{-1} ± 4.32 (SD) 2.50kg^{-1} ± 4.00 (SD) 6.66kg^{-1} ± 3.59 (SD) 4.21kg^{-1} ± 6.17 (SD) 0.31kg^{-1} ± 0.85 (SD) 2.92kg^{-1} ± 2.57 (SD) 2.25kg^{-1} ± 2.20 (SD) 6.46kg^{-1} ± 6.16 (SD) 0.63kg^{-1} ± 1.13 (SD) 3.75kg^{-1} ± 2.89 (SD) 4.17kg^{-1} ± 5.96 (SD)	De Lena et al. (2021)
Auckland	18 locations 21 sites	ND	Range: 9-80kg^{-1}	Dikareva & Simon (2019)
Auckland	East coast	245m^{-2} ± 251 (SD)	NA	Bridson et al. (2020)
Auckland	West coast	900m^{-2} ± 820 (SD)	NA	Bridson et al. (2020)
Auckland (east)	Waitematā Harbour (19*) • Hobson Bay • Kotukutuku Inlet • Stanley Bay • Timothy Place • Point Chevalier Beach	312m^{-2} ± 295 (SD) ND 75m^{-2} ± 107 (SD) 21m^{-2} ± 175 (SD) 411m^{-2} ± 175 (SD) 873m^{-2} ± 374 (SD)	NA	Bridson et al. (2020)
Auckland (east)	Hauraki Gulf (14*) • Surfdale Beach • Ōrewa Beach • Takapuna Beach • Saint Heliers Bay • Ōmana Beach	177m^{-2} ± 194 (SD) ND 81m^{-2} ± 114 (SD) 292m^{-2} ± 127 (SD) 369m^{-2} ± 161 (SD) 671m^{-2} ± 183 (SD)	NA	Bridson et al. (2020)
Auckland (east)	Tāmaki Estuary (4*) • Tiraumea Drive • Bucklands Beach	162m^{-2} ± 108 (SD) 205m^{-2} ± 167 (SD) 230m^{-2} ± 163 (SD)	NA	Bridson et al. (2020)
Auckland (west)	Manukau Harbour (11*) • Green Bay • Kauritutahi Beach • Clarks Beach • Māngere WWTP • Cornwallis Beach	896m^{-2} ± 886 (SD) 51m^{-2} ± 72 (SD) 275m^{-2} ± 227 (SD) 720m^{-2} ± 353 (SD) 1645m^{-2} ± 366 (SD) 2615m^{-2} ± 1129 (SD)	NA	Bridson et al. (2020)
Auckland (west)	Tasman Ocean (7*) • Hamiltons Gap • Piha Beach • Karioitahi Beach	907m^{-2} ± 773 (SD) 197m^{-2} ± 279 (SD) 1204m^{-2} ± 178 (SD) 1753m^{-2} ± 824 (SD)	NA	Bridson et al. (2020)

Region	Location	Mean abundance (MPs m^{-2}; cm^{-3}; L^{-1})	Mean abundance (MPs g^{-1}; kg^{-1})	Reference
Bay of Plenty	- Eastern coastline	$2066.9m^{-2}$	NA	Lewis (2021)
	- Tauranga Harbour	$571.2m^{-2}$	NA	
	- Ōhiwa Harbour	$477.7m^{-2}$	NA	
	- Karewa Parade	$11087m^{-2}$	$157.1kg^{-1}$	
	- Papamoa Domain	$3343.9m^{-2}$	$49.1kg^{-1}$	
	- Omanu Sewage Outfall	$2800.2m^{-2}$	$44.7kg^{-1}$	
	- Ohope Beach	$2487.3m^{-2}$	$28.2kg^{-1}$	
	- Matakana Island	$63.5m^{-2}$	$1kg^{-1}$	
Wellington	Wellington Harbour 3 sites	NA	$124.9kg^{-1}$ ± 35.7 (SE) (WW)	Shannon (2020)
Canterbury	Exposed beach area (5*)		NA	Clunies-Ross et al. (2016)
	- Clifton Beach	$175m^{-2}$ ± 151 (SD)		
	- South New Brighton	$1552m^{-2}$ ± 695 (SD)		
	- New Brighton	$1748m^{-2}$ ± 609 (SD)		
Canterbury	Harbour area (3)		NA	Clunies-Ross et al. (2016)
	- Governors Bay	ND		
	- Corsair Bay	$265m^{-2}$ ± 3 (SD)		
	- Akaroa Harbour	$353m^{-2}$ ± 407 (SD)		
Canterbury	Estuarine area (2)		NA	Clunies-Ross et al. (2016)
	- Avon River mouth	ND		
	- Heathcote River mouth	$178m^{-2}$ ± 154 (SD)		
Canterbury	Avon/Ōtākaro River (6) - Upper reach - Middle reach - Lower reach	NA	$5.2 \times 100g^{-1}$ Range: $0–35 \times 100g^{-1}$	Phillips (2020)
Marlborough Queen Charlotte Sound	Marine reserve (11 depths)	(Depth range inside brackets)	NA	Ribó et al. (2021)
	- Lowest	$2cm^{-3}$ (2.5–5cm)		
	- Highest	$26cm^{-3}$ (30–35cm)		
	Anchorage (10 depths)			
	- Lowest	$3cm^{-3}$ (15–25cm, 30–35cm)		
	- Highest	$22cm^{-3}$ (0–2.5cm)		
Stormwater drain sediments				
Canterbury	Avon/Ōtākaro River (6)	NA	$3.3 \times 100g^{-1}$ Range: $0–8 \times 100g^{-1}$	Phillips (2020)
	- Upper reach		$3.8 \times 100g^{-1}$	
	- Middle reach		$5 \times 100g^{-1}$	
	- Lower reach		$1.2 \times 100g^{-1}$	
Wastewater effluents				
Canterbury	Region	$1.3\ L^{-1}$ ± 0.6	NA	Ruffell et al. (2021)
	- Christchurch	$1.2\ L^{-1}$ ± 0.5		
	- Kaiapoi	$0.8\ L^{-1}$ ± 0.4		
	- Lyttelton	$1.8\ L^{-1}$ ± 0.4		
Freshwater streams				
Auckland	18 locations 21 sites	Range: $17–303m^{-3}$	NA	Dikareva & Simon (2019)
Across NZ 52 sites	NZ Auckland (*) - Papakura Stream - Waimahia Stream Waikato(*) - Tuhikaramea Stream - Waitawhiriwhiri Stream	Range: < $1–44.8m^{-3}$ $7.3m^{-3}$ $2.1m^{-3}$ $44.8m^{-3}$ $5.1m^{-3}$ $8.3m^{-3}$	NA	Mora-Teddy et al. (2019)

Region	Location	Mean abundance (MPs m^{-2} ; cm^{-3}; L^{-1})	Mean abundance (MPs g^{-1}; kg^{-1})	Reference
	Wellington (*)	1.8m^{-3}		
	• Waiwhetu Stream			
	• Porirua Stream			
	Christchurch (*)	2.7m^{-3}		
	• Heathcote River			
	Dunedin (*)	NA		
	• No site in top 16			
Marine waters				
Northland 3 main locations 7 sites	Bay of Islands area (3)		NA	AIM^{2}/Blue Cradle/ESR (Unpublished data)
	• Inner	0.17m^{-3}		
	• Outer	0.05m^{-3}		
	• Offshore	0.08m^{-3}		
	Matapōuri Bay (1)			
	• Mid	0.04m^{-3}		
	Whangārei area (3)			
	• Inner	0.06m^{-3}		
	• Outside heads	0.12m^{-3}		
	• Offshore	0.02m^{-3}		
Wellington	Wellington Harbour (3)	59.5 x 200m^{-1}± 23.8 (SE)	NA	Shannon (2020)

APPENDIX *7*

Number of particles, type, and polymer morphotype of microplastics found in various foods (other than animals) available in New Zealand.

Food item	Location	Number of particles	Type Polymer morphotype	References
Sea salt	NZ Local supermarkets	10 x 100g^{-1}	Fragments (67%) Fibres (16.5%) Beads (16.5%) PP	Mazlan et al. (2022)
Tap water	NZ	1 x 100g^{-1}	Fragments (50%) Fibres (50%) PET	Mazlan et al. (2022)
Bottled water	NZ Local supermarkets	4 x 100g^{-1}	Fibres (56%) Fragments (33%) Beads (11%) PE PP	Mazlan et al. (2022)

Northland Regional Council

P 0800 002 004

E info@nrc.govt.nz

W www.nrc.govt.nz