21 December 2022

Dear sir/madam,

Re: Senate Inquiry into plastic pollution in Australia's oceans and waterways

We communicate our collective support for the Inquiry into plastic pollution in Australia's oceans and waterways by the House Standing Committee on Climate Change, Energy, Environment and Waste. Healthy aquatic ecosystems critically underpin the social, economic and cultural benefits that Australian's enjoy from our aquatic environments, including seafood production, and vibrant fishing and aquaculture.

Growing levels of plastics and other debris in the world's oceans and waterways are causing economic, ecological and social harm. This is a key concern for the fishing and aquaculture community. A recent report to Asia-Pacific Economic Cooperation (APEC) showed marine debris costs economies of countries in the region $15.7 billion in 2015[1]. Social and ecological impacts are not as well understood but are significant.

Addressing the plastics problem will also play a critical part in dealing with changing climate. Without action, greenhouse gas (GHG) emissions from fossil fuel production of chemicals and plastics are projected to double by 2050, with 15% of estimated carbon budget needed to keep global warming below 1.5°C[2]

We acknowledge the coordinating and focussing effect of the UN Sustainable Development Goals (SDGs) in addressing global challenges, and relevance of SDGs 9,12,14&15 to this Inquiry. Targets under SDG 12 have particular relevance, which seek to ensure sustainable consumption and production patterns. Pursuing SDG 12 requires a shift from a linear 'take - make - waste' economy, to a circular economy. For this reason, we support FRDC's research to explore how to integrate circular economy thinking into fishing and aquaculture, and subsequent co-investment in a regional circularity pilot program in southern NSW.

Fishing and aquaculture sectors are already actively pursuing practical opportunities to reduce fishing waste including changes to packaging and materials, fledgling recycling and reuse programs, and coordinated action to remove waste from Australia's waterways. More support is needed to elevate our collective efforts.

Australia's fishing and aquaculture sectors are unified in calling for more systemic investment to accelerate regeneration of healthy oceans and waterways and the need to address plastic waste as a key stressor. Success requires enduring investment and policy that incentivises avoidance of harmful materials and a shift towards renewable resources, increased recycling, improved waste collection and sorting and 'circular' product design.

We support the Fisheries Research and Development Corporation's submission to this Inquiry, and recommendations.

Sincerely,

Russell Conway
Chair, Australian Recreational Fishing Foundation

Veronica Papacosta
CEO Seafood Industry Australia

Chris Calogeras
EO, Indigenous Reference Group

---

[1] https://www.uow.edu.au/media/2020/marine-debris-costs-asia-pacific-economies-us108b-annually-report-.php

[2] Christian Zibunas, Raoul Meys, Arne Kätelhön, André Bardow (2022). Cost-optimal pathways towards net-zero chemicals and plastics based on a circular carbon economy, Computers & Chemical Engineering, Volume 162, 107798, ISSN 0098-1354, https://doi.org/10.1016/j.compchemeng.2022.107798.

Submission to House Standing Committee on Climate Change, Energy, Environment and Waste Inquiry:

Plastic pollution in Australia's oceans and waterways

Submitted to the Committee Secretary
Standing Committee on Climate Change, Energy, Environment and Water
PO Box 6021
Canberra ACT 2600

CCEEW@aph.gov.au

By:
Fisheries Research and Development Corporation (FRDC)
E: frdc@frdc.com.au
T: 02 6122 2110

Table of Contents

Executive Summary

Healthy aquatic ecosystems critically underpin the diverse ways that Australians enjoy benefit from aquatic resources. Both micro and macroplastics have direct and indirect negative impacts on marine organisms, and possibly also human communities, often through pathways that are imperfectly understood. Fishers and aquaculturists acutely feel the impacts of plastics in oceans and waterways, with increased risk to vessel engines and cooling systems, impacted catches due to ecosystem effects, and increased time cleaning gear leading to economic losses and safety risks. Plastic pollution can also deeply affect socially and culturally, impacting experiential recreation, iconic and totemic species, degrading much loved places and sites of significance.

Key points:

- Plastics in oceans and waterways mostly result from poor management of waste on land, and often disproportionately affect regional and remote locations. Plastics in oceans are also a transboundary issue, and Australia must collaborate globally, and in particular with neighbouring countries to share and apply best practices.
- Addressing the impacts of plastics on oceans and waterways will require improvements to the circular economy on land, including phasing out unnecessary plastics, refining plastic recovery processes, transforming waste into commercially viable resources, and adopting life-cycle approaches into product design.
- Australia's fishing and aquaculture sectors, like other parts of Australia's economy, are working towards increased circularity. However, it is important to note that fishing and aquaculture sectors face unique challenges that risk slowing progress if not addressed. Currently, most fishing and aquaculture equipment is difficult to recycle due to design (material types/blends), contamination with biological materials, remoteness of operations, and lack of infrastructure in ports and key points of concentration. There is consequently a need to enable further development of the fishing and aquaculture circular economy through greater support for solution finding, smart design of fishing and aquaculture gear, innovation in fishing and aquaculture techniques that work together to limit waste, make collection operations more viable and increase development of recycling and repair channels.
- There is opportunity to improve connectivity and internal consistency between key elements of Australia's plastics management framework, ensure that targets are sufficiently ambitious, and that investment in action matches that ambition.
- Overall, the plastics management framework presently has a heavy focus on 'plastics-back to-plastics'. This is difficult to apply throughout much of Australia's regional and remote areas, particularly for fishing and aquaculture enterprises in such locations. Consequently, there is a need to also invest into bio-derived compostable alternatives where infrastructure (e.g. Material Recovery Facilities and Advanced Recycling Facilities) are economically unviable.
- Continued monitoring and reporting of investments and policies aligned to the National Plastics Plan is needed to deliver long-term value and inform efficacy and decision-making.
- The Fisheries Research and Development Corporation continues to invest in research, development and extension activities of interest to this Inquiry, including:
  - Minimising plastic use in specific sectors and fisheries
  - Reducing use of polystyrene throughout the supply chain

- Understanding prevalence of microplastics in seafood
- Moving towards a circular economy (aiming to eventually eliminate single-use plastics, and reducing, recycling, and regenerating other types).
- Understanding ecological and food safety impacts.

In response to this inquiry the FRDC provide the following recommendations:

- **Integrated and systemic approach -** There is a need to take a more systemic approach towards addressing plastics in oceans and waterways and treat the management of land and waters in a connected way. This includes a need to work globally to address this transglobal issue. There is also a need to take a more integrated approach towards management of natural resources nationally, to facilitate improved coordination between levels of government and enable improvements in the existing legislative framework and better understanding of cumulative pressures.
- **Learning from others -** There is value in exploring international case studies of effective integrated management and policy frameworks that offer insights applicable in an Australian context.
- **Integrating Indigenous Knowledge -** There are valuable opportunities to integrate Indigenous Knowledge, noting that Australia's First People take a more integrative view of natural resource use and management.
- **Scaling up pilot trials -** The FRDC co-funded a regional circularity pilot for fishing and aquaculture in NSW – the first of this kind in Australia. There is a need for additional co-investment to support scaling of fishing and aquaculture's circular economy and accelerate solution finding, smart design of fishing and aquaculture gear, innovation in fishing and aquaculture techniques that work together to limit waste, make collection operations more viable and increase development of recycling and repair channels.
- **Establishing/upgrading infrastructure in ports and centralised locations -** There is a need to establish/upgrade efficient recycling infrastructure at all ports and major collection points to allow for efficient unloading, sorting, processing, treatment and recycling of waste including plastics. This includes a need to upgrade port logistics for end-of-use gear collection. It is important to note the significant proportion of fishing and aquaculture that occurs some distance from major ports, requiring unique solutions for regional and remote areas.
- **Understand and overcome regulatory impediments -** There is a need to understand regulatory factors that may impact or accelerate opportunities for development of circular practices in plastics lifecycles, and where possible, to align policies so that best practice may be adopted quickly, easily and comprehensively.
- **Accelerate investment in non-petroleum alternatives -** In addition to the current heavy focus on closing the loop on production and use of plastics under Australia's plastics management framework, there is value in accelerating investment into bio-derived compostable alternatives. Equally, there is a need to accelerate eco-design of fishing and aquaculture gear that are practical, safe and cost-effective.
- **Inventivise desired behaviours -** Learning from successes in Australia's land-based container disposal schemes, there is a need to create incentives for increased circularity along the entire fishing and aquaculture production chain to support businesses and operators who recycle and re-use gear.

- **Develop harmonised standards -** To accelerate circularity it is necessary to develop harmonised standards for a circular economy that also apply to fishing and aquaculture equipment. Standards can serve as a valuable tool to help develop an agreed common language for effective exchange of information, promote interoperability and remove trade barriers. Standards conversations are already advancing rapidly in other parts of the world, particularly the EU. There is a need for Australia to join these conversations as early as possible so that we can ensure standards are developed with an understanding of the range of risks, obstacles and opportunities at play internationally.
- **Intensify data collection -** Insufficient data limits current understanding of impact caused by micro and macro plastics on ecosystems and fishing and aquaculture sectors. There is consequently a need to intensify R&D investment into impacts on fisheries, aquaculture and ecosystems and propose robust measures to address impacts on fishery resources, ecosystems and human health.

Response to Terms of Reference

1. The environmental impacts of plastic pollution particularly in oceans and waterways

The problem of plastics in oceans and waterways is one of the more pressing environmental challenges of our time. This submission assumes a shared understanding of the scale of the issue and need for action. Additional information on the plastics problem is provided at Attachment 1.

2. the effectiveness of Australia's plastics management framework under the National Plastics Plan and related policies to reduce plastic pollution particularly in oceans and waterways

There is a need for any framework on how plastics will be managed in Australia to be clear, concise, evidence-led, and comprising of the following core elements:

- Agreed, principles-based policy to guide decisions and achieve necessary outcomes, using behavioural insights to elicit desired behavioural change
- Well-resourced programs and projects that are synergistic, necessary and sufficient to allow pursuit of agreed policies
- Targeted and effective education, engagement and capability building initiatives to help stakeholders understand the need for change in their context, feel they can undertake change required, and see that others are changing practices as well.
- Clean up activities to treat symptoms of the plastics problem; and
- Well-resourced and long-term monitoring, evaluation and reporting processes to help clarify what is working, what's not working, and inform adaptive decision-making

We provide the following insights regarding Australia's current plastics management framework:

- Australia's plastics management framework is understood to comprise at least the following key strategic documents including the National Waste Action Plan, National Plastics Plan 2021, Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (2018) and new Global Treaty on Plastics Pollution. Though

each offer value, it is unclear how they relate to each other. Consequently, overall framework efficacy may be impacted by duplication and sub-optimal connectivity and/or internal consistency. For example, linkages between the National Plastics Action Plan (NPAP) and 2018 Threat Abatement Plan (TAP) are not explicit, and the NPAP does not necessarily promote actions under the TAP through the proposed targets. Noting the TAP nears end of life, there is opportunity to update and ensure that components work together.

- To some extent, the issue of plastics in oceans and waterways is magnified by the compartmentalised way in which natural resources are managed in Australia. Integrated Ocean Management has emerged internationally as a concept in response to the need for better governance of human activities. Processes such as Integrated Environmental Assessment (IEA) offer opportunity to combine information across diverse knowledge systems to inform improved understanding of cumulative impacts, and decision-making within a more integrated management framework. There is opportunity for increased application of these approaches for governance and assessment in the context of managing human activities in Australia. This would help to address the symptom of plastics in oceans and waterways.
- There is a need to ensure that targets for reduction and re-use are sufficiently ambitious to drive necessary change over acceptable timescales. For example, National Plastics Targets within the National Plastics Plan require new plastics packaging comprise a 20% average of recycled content by 2025. The outstanding 80% plastic component could continue to be of virgin origin - continuing to contribute to total greenhouse gas (GHG) emissions from this fossil fuel production as well as continuing to contribute to the overall waste plastic issue.
- It is important to ensure that investment in action (programs, projects, education and capability building initiatives, and monitoring, evaluation and reporting activities) matches ambition.
- Overall, Australia's plastics management framework is heavily focussed on recycle and re-use, with little attention to bio-derived compostable alternatives. Both are important, particularly when considering remote communities and large distances to urban hubs in Australia. Additional R&D investment is required to allow commercialisation of alternatives to petrochemically-derived plastics. Regional contextualisation of future pilots and modelling will be important, noting that technologies to bring 'plastics back into plastics' (advanced recycling) require sufficient inputs to be viable. Such solutions currently only work in urban areas due to prohibitive transport costs in regional and remote areas and noting that local councils are required to meet waste collection and transport costs. The current CRC-P project led by Plastic Collective to develop waste plastic solutions for remote, regional and Indigenous communities may assist in this regard, however is unlikely to overcome all obstacles to closed-loop circularity within regional and remote areas. Case studies such as those currently underway in Victoria with funding under the National Plastics Recycling Scheme led by the Australian Food and Grocery Council will also help improve understanding of conditions where advanced recycling will be viable. This work could usefully be supplemented by additional research investment and piloting in remote communities where most fishing and aquaculture activity is undertaken.
- The importance of education of community, consumers, and Industries cannot be overstated to support reduction in use of plastics, increased re-use, and recycling. This is particularly the case where inconsistency persists between local government areas in terms of what can be recycled, and how.

National Plastics Plan 2021

The National Plastics Plan outlines actions to reduce the effects of plastics on our environment in five areas:

1. Prevention – Addressing plastics at the source
2. Recycling – Taking responsibility for our plastics
3. Plastics in our daily lives
4. Plastics in our oceans and waterways
5. Research, innovation & data

Input below relates mainly to 4 & 5 above.

Plastics in our oceans and waterways

It is understood that various governments are investing in actions within the National Plastics Plan, including community-led projects, investment to support neighbouring nations to tackle plastics, and investment in removal of ghostnets and marine debris from strategic northern locations. Whilst it is not possible to comment on the efficacy of these initiatives based on their early stage and resultant limited information on progress, these investments appear useful interventions to reduce plastics in oceans and waterways.

Plastics in oceans and waterways mostly result from poor management of waste on land. Plastics in oceans are also a transboundary issue, and Australia must work with neighbouring countries to share and apply best practices. Addressing the impacts of plastics on oceans and waterways will require improvements to the circular economy on land, including phasing out unnecessary plastics, transforming waste into resources, and adopting life-cycle approaches into product design. Australia's fishing and aquaculture sectors, like other parts of Australia's economy, are working towards increased circularity. However, it is important to note that fishing and aquaculture sectors face unique challenges that will impede progress if not addressed. Currently, most fishing and aquaculture equipment is difficult to recycle due to design (material types/blends), contamination with biological materials, remoteness of operations, and lack of infrastructure in ports. There is consequently a need to enable further development of the fishing and aquaculture circular economy through greater support for solution finding, smart design of fishing and aquaculture gear, innovation in fishing and aquaculture techniques that work together to limit waste, make collection operations more viable and increase development of recycling and repair channels.

Research, Innovation & Data

FRDC notes proposed and existing R&D actions under the National Plastics Plan, with examples including CSIROs National Circular Economy Roadmap for Plastics, adoption of Waste impact management as a cross-cutting priority through the National Environmental Science Program (NESP), and establishment of a Waste Data Visualisation Platform. These actions are useful contributions towards achieving the intent of the Plan, however there is a need for additional investment into alternative models for more integrated management of land and water resources, development of bio-based and compostable alternatives to plastics, smart design of renewable and re-usable solutions, and further development of recycling and repair channels.

Many relevant areas of research are being pursued in Australian fisheries R&D, including some enabled through investment from the Fisheries Research and Development Corporation, to improve knowledge and inform action, including:

- Removal and future avoidance of lost fishing gear ("ghost gear")
- Understanding plastic use across fishing and aquaculture
- Minimising plastic use in specific sectors and fisheries
- Reducing use of polystyrene throughout the supply chain
- Measures to ensure that fishing vessels can reduce or eliminate the plastic they take to sea (e.g., finding alternatives to plastic tie-down straps, bait bags etc).
- Understanding prevalence of microplastics in seafood
- Documenting the extent, distribution in different habitat types, quantities, compositions, and sources of marine plastics in Australia (e.g., better understanding the problem's dimensions)
- Moving towards a circular economy (aiming to eventually eliminate single-use plastics, and reducing, recycling, and regenerating other types).
- Understanding ecological and food safety impacts.

Table 1 Relevant projects funded by the Fisheries Research and Development Corporation

Project Number	Title	Objectives	Status
2021-117	A global review on implications of plastic in seafood	1. Undertake a systematic review, collating, synthesising and analysing global data on the effects and implications of plastic pollution in seafood species and the seafood industry 2. Identify potential sources of plastic in marine environments, including the percentage coming through fishing and aquaculture 3. Highlight key knowledge gaps, opportunities and threats of plastic in the seafood sector 4. Disseminate findings and information on effects and implications of plastic pollution on seafood species to fishers and managers	Current
2020-084	An audit of plastic use in the fishing and aquaculture sectors	1. Undertake an audit of plastic usage and volumes across the Australian seafood industry, inclusive of the production/harvest and post-harvest sectors 2. Identify approaches for industry to adopt cost effective sustainable solutions to plastics usage across the production/harvest and post-harvest areas 3. Identify and document potential future options to address plastic waste and alternatives to plastic across production/harvest/ post-harvest through the entire supply chain to the customer.	Current
2020-078	Circular Economy Opportunities for Fisheries and Aquaculture in Australia	1. Develop increased knowledge for how the circular economy concept relates to fishing and aquaculture, including downstream activities such as post-harvest processing and packaging.	Current

		2. Develop increased knowledge of how circular practices applied in other sectors and industries relate to the fishing and aquaculture sectors and could be adopted by fishing and aquaculture businesses. This includes opportunities for fisheries/aquaculture industries to develop circular linkages with other marine and land-based sectors. 3. Identify opportunities that are available and areas for exploration in the short, medium and longer term to progress a circular economy for fisheries and aquaculture. 4. Identify barriers to adopting circularity within the fisheries/aquaculture sector and known strategies for addressing those barriers.	
2020-062	Minimising plastic in the Western Rock Lobster Industry (Phase 1) – scope and identify	1. Identify where and why plastic is used in the western rock lobster industry. 2. Identify viable environmentally friendly plastic alternatives.	Current
2017-199	A preliminary assessment of the prevalence of marine micro-plastics in Australian fish crustaceans and molluscs	1. Determine how widespread the presence of plastics in Australian seafood sold for human consumption is and how this varies across the country including from metropolitan and non-metropolitan markets 2. Place the presence/absence of plastics in Australian seafood into the international context	Completed
2017-058	Investigation of an environmentally friendly alternative to the ubiquitous polystyrene boxes		Completed
2022-054	Bursary to attend the 2022 Microplastics and Seafood: Human Health Symposium in the United Kingdom		Current
1992-125	Evaluating usable containerised systems for airfreighting live fish using bottled oxygen	1. To monitor changes in water quality when fish are transported in an existing fish transport system 2. To monitor changes in water quality when fish are transported in an existing fish transport system 3. To reduce the amount of bottled oxygen required to meet the respiratory needs of fish without compromising water quality	Completed

4. the effectiveness of community campaigns to reduce plastic pollution particularly in oceans and waterways and encourage the use of alternative materials

It is difficult to evaluate effectiveness of community campaigns to reduce plastic waste impacts on oceans and waterways based on available information. Limited research exists on the intrinsic value of clean up events from a social perspective, improving mood and pro-environmental intentions among participants. However, clean up events can deliver variable results in terms of restoration (Wyles et al. 2016). Other authors (Jorgensen et al, 2021) report that groups who participate in clean up events later branch out their impacts by combining different forms of environmental stewardship targeting plastic pollution and collaborate to scale up their actions in ways that contribute to plastic pollution governance. Community led action is clearly useful but not independently sufficient to manage plastic pollution. FRDC recognises the importance of community-led campaigns delivered under leadership of organisations including OzFish Unlimited and Tangaroa Blue, as part of a broader comprehensive strategy. We will continue to explore opportunities to partner with and support these and other community-led organisations in circumstances that build on our respective core competencies to achieve outcomes that are described within FRDC's R&D Plan 202-25.

Seafood Industry's 'Our Pledge'

Seafood Industry Australia's 'Our Pledge' Program engages the seafood industry in best practice whilst meeting consumer's needs for fresh and nutritious seafood. Among aspects of the pledge, is a commitment to "actively caring for Australia's oceans and environment and work with others to do the same". This has catalysed industry-led actions including:

- Industry-led clean-up events, including Austral's annual Western Australian events, and OceanWatch Australia's annual 'Tide-to-Tip' clean up events which to-date has removed almost 31 tonnes of rubbish from marine and estuarine habitats, and a joint community effort on Tasmania's South-West coast
- Delivery of a plastic-free Seafood Directions Conference in 2019 and 2022
- Installation of seabins in association with new Sydney Fish Market development, allowing removal of over 300,000 pieces of plastic from Sydney harbour
- Recycling of plastic waste from Atlantic salmon aquaculture into civil products
- Installation of Tangler Bins at fishing hotspots
- Removal of foreign ghost nets from the Gulf of Carpentaria by commercial fishers operating in the area
- Tuna Australia, Australian Fisheries Management Authority and OceanWatch Australia are undergoing sea trials on alternative, reusable fishing lights to single use chemical light sticks

National Recreational Fishing Code of Practice

The National Recreational Fishing Code of Practice describes best practice conduct for recreational fishers. Key requirements include "*Disposal of all waste material, including discarded fishing tackle, plastic bags, bottles, and other packaging appropriately in bins, or take it home and place in your rubbish bin, taking the responsible approach and extra effort to clean up rubbish left by others looking after our favourite fishing spots*". This has catalysed action by recreational fishers in a number of contexts including:

- Investment of over 138,544 volunteer hours through OzFish Unlimited, including delivery of over 130 litter events, and collection of over 5 tonnes of rubbish from Australian waterways.
- Partnership in volunteer clean up events led by Tangaroa Blue, a national charity focused on the health of marine environments with help of volunteers, communities, organisations and agencies. Since their program started in 2004, more than 20 million pieces of marine debris have been removed from the Australian coastline and data on this debris collated and inputted into the Australian Marine Debris Database.
- Installation and maintenance of fishing line recovery facilities in key fishing areas throughout Australia.

Tangaroa Blue - Satlink

Tangaroa Blue have commenced a partnership with international technology company Satlink to launch a world-first program that re-purposes international satellite technology recovered during beach clean-up events to track ghostnets on the Great Barrier Reef until they can be collected and disposed. This innovative project presents a novel circular telemetry solution to support a circular ghostnet recovery solution in a prized World Heritage Area.

Sea Rangers Program

A network of Indigenous Sea Rangers across 31 Indigenous communities work with GhostNets Australia to protect over 3,000 km of saltwater country from marine debris, including ghost nets. Rangers have recorded the removal of 13,000 ghost nets. This has resulted in a number of innovative follow-on investments, including a project funded by Gowings Whale Trust to establish Australia's first Indigenous-run marine plastic recycling enterprise led by MiiMi Aboriginal Corporation, with focus on transforming waste plastic recovered from beaches and waterways into objects of desire.

5. Global initiatives underway to reduce plastic pollution particularly in oceans and waterways, and

We acknowledge and support existing efforts to pursue coordinated global action on marine plastics and recommend that this continues to be prioritised. In particular, we note the new Global Treaty on Plastics Pollution has legally binding provisions and obligations to prevent and remediate plastic pollution and its toxic impacts. It will be critical to support this ambition with investment to aid rapid transition in response to binding targets.

Norway has adopted an approach for managing ecosystems holistically instead of by individual sectors and activities, bringing together research institutes and agencies from various sectors to make ocean management plans that rely on regular, comprehensive, demanding scientific monitoring. This approach was informed by a white paper entitled Protecting Riches of the Sea.

European project BIOGEARS, funded under EMFF-01-2018 Blue Labs: Innovative Solutions for Maritime Challenges by the European Commission's Executive Agency for SMEs (EASME) is developing biobased equipment for use in the aquaculture sector. The €945,000 project will

develop prototypes and trial them in the Atlantic basin using Integrated Multi-Trophic Aquaculture with mussels and seaweed. A 'Blue Lab' will be developed to support replicability, transferability and scale up of the developed biobased ropes into different regions, creating new value chains and more eco-friendly aquaculture.

Development of incentive schemes to convert plastics into value with examples exploring incentivisation of fishers to collect plastic waste from oceans in Indonesia including Government-funded program in Indonesia and European Union

Attachment 1

The plastics problem summarised

Global plastic production has increased exponentially since the 1950s (Geyer et al. 2017). About three percent of global plastic production ends up in the oceans, and plastics are now ubiquitous in the world's oceans, including marine sediments (Ritchie and Roser 2018). In 2018-19, Australia used 3.5 million tonnes of plastic, of which only 13% was ultimately recycled (National Plastics Plan). Ocean plastic can be broadly classified by size as microplastics (very small plastic fragments, including microfibres that separate from clothes during washing, and tiny fragments in cosmetics and shower products) or macroplastics (larger plastic pieces) (Sweet et al. 2019). A schematic representation of how plastics flow through an aquatic environment is provided as Figure 1. Without proper management, plastics can leak to the environment when being transported on land and at sea, via wastewater, and others, ending up in waterways. Both micro and macroplastics have direct and indirect negative impacts on marine organisms, often through pathways that are imperfectly understood (Reisser et al. 2013; Sweet et al. 2019; Alfaro-Núñez et al. 2021). Impacts on human beings (e.g. through seafood consumption) are less obvious, but may exist (SafeFish 2019a,b; Alfaro-Núñez et al. 2021).

Understanding biological and ecological impacts of ocean plastics: macroplastics vs microplastics

The impacts of ocean plastics, both on marine animals and potentially for seafood consumers, are best understood by separating plastics into two broad size categories; microplastics and macroplastics (Sweet et al. 2019). Microplastics are particles of up to 5 mm, while macroplastics are all others (Sweet et al. 2019; NOAA 2021). Distinguishing between these two categories is somewhat arbitrary, as microplastics are continually produced through the breakdown of macroplastics (e.g. through exposure to sunlight) (Sweet et al. 2019). Nonetheless, the distinction is useful in terms of understanding impacts.

Macroplastics harm marine organisms through ingestion or entanglement. Ingesting large pieces of plastic regularly kills seabirds, turtles, whales, and probably other taxa (Sweet et al. 2019). Less obviously, large pieces of plastic can also smother and/or physically damage small marine plants

and animals, such as corals (Sweet et al. 2019). Through mechanisms that remain imperfectly understood, contact with macroplastics also makes corals more susceptible to disease[3].

Microplastics, can be produced by the breakdown of macroplastics , or can be manufactured as very small particles (e.g. microbeads in cosmetics, synthetic sandblasting media) (Reisser et al. 2013; Sweet et al. 2019; Alfaro-Núñez et al. 2021; NOAA 2021). According to the OECD, "microplastics originating from tyres are estimated to be one of the largest contributors to microplastics pollution in terms of volumes released to the rivers and oceans.

[3] Chapron, L., Peru, E., Engler, A. *et al.* Macro- and microplastics affect cold-water corals growth, feeding and behaviour. *Sci Rep* **8**, 15299 (2018). https://doi.org/10.1038/s41598-018-33683-6

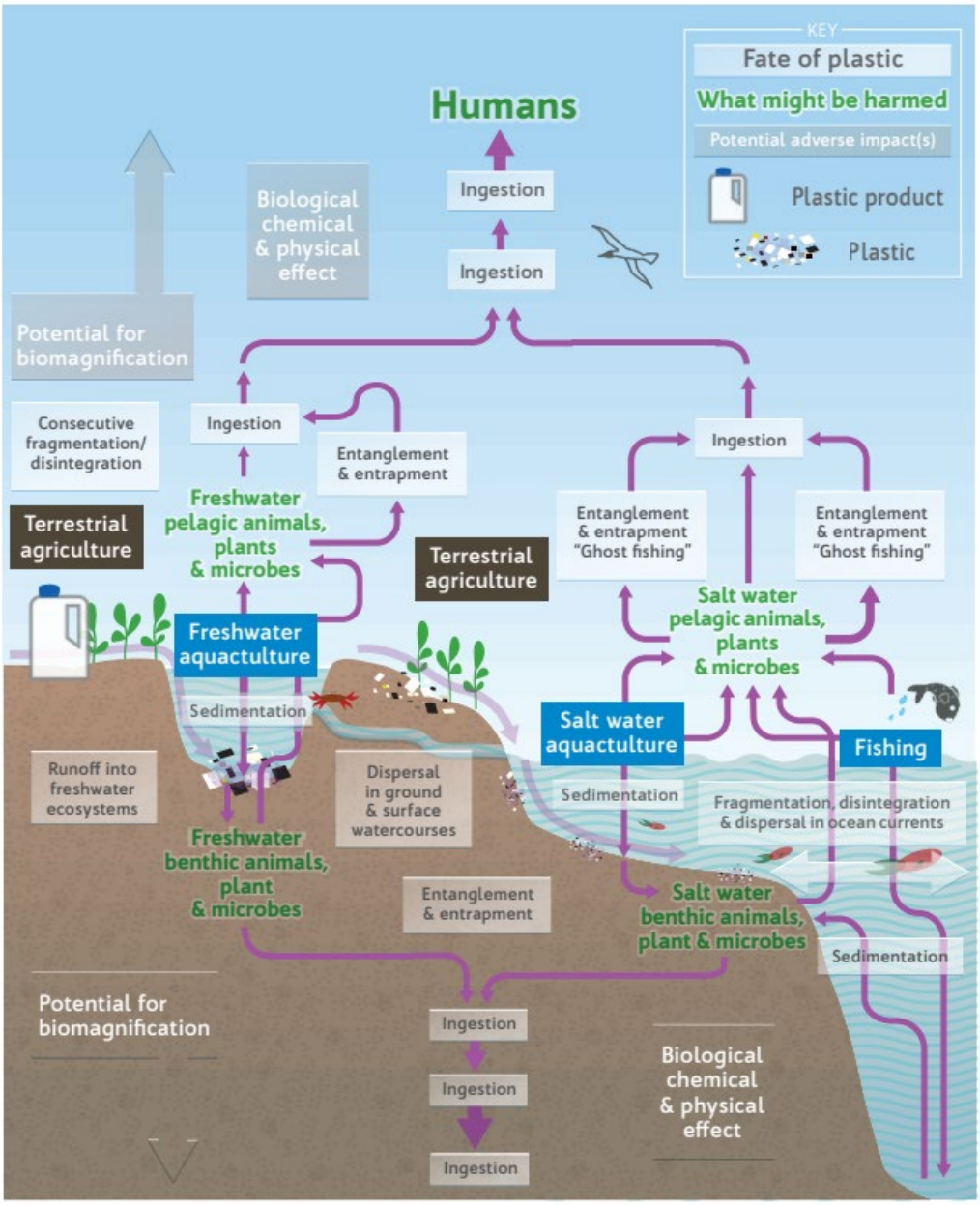

Figure 1 Schematic representation of flow of plastics in an aquatic environment (Source: FAO 2021)

Microplastics are found in all marine environments, including sediments. Microplastic particles smaller than 5mm can be ingested by filter-feeding or planktivorous animals, and propagate in food webs as these animals are in turn eaten by predators (for example, microplastics found in Southern Bluefin Tuna were likely ingested with prey) (Reisser et al. 2013). In this way they can pose an ecotoxilogical risk. The ecological impacts of microplastic ingestion for marine organisms are incompletely understood, as research is new (but increasing rapidly).

Following microplastic ingestion, organisms' gastrointestinal tracts may be blocked or filled by plastic particles, preventing food consumption and/or acting as a physical obstruction.

Leaching of toxic chemicals from ingested microplastics, causing damage to reproductive, digestive, and endocrine systems in marine organisms.

Attraction and accumulation (adsorption) of other toxins onto microplastics, magnifying their harmful effects when ingested by marine animals—through adsorption, microplastics become "vehicles" for transporting other toxins into the bodies of marine animals (Reisser et al. 2013; SafeFish 2019a; Sweet et al. 2019; Alfaro-Núñez et al. 2021; NOAA 2021).

Large accumulations of both micro- and macroplastics in oceanic convergence zones or gyres ("marine garbage dumps") (Reisser et al. 2013) have caused considerable recent commentary and drawn public attention, including through the Netflix program "Seaspiracy". Ongoing media interest in this and other aspects of marine plastics will drive growing public focus.

The following graphical summaries illustrating the dimensions of the ocean plastics issue.

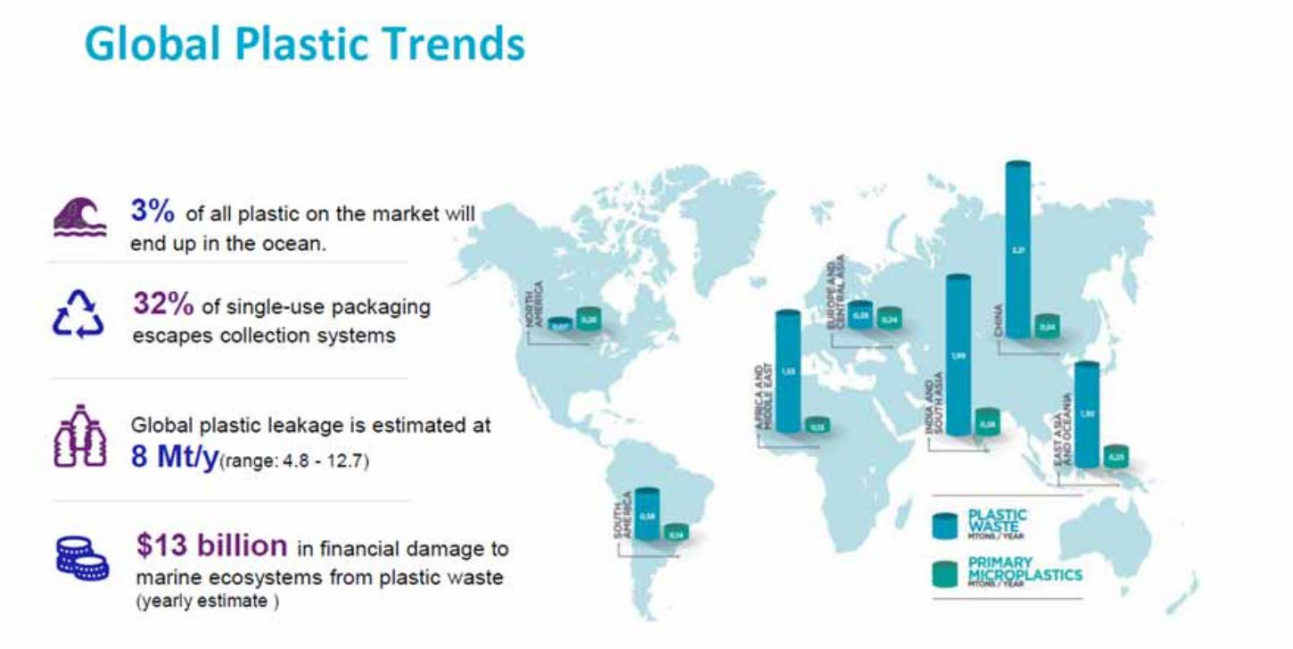

Figure 2 Global releases of primary microplastics and plastic waste into the World's oceans (Sources WEF, 2016, UN Environment 2018, The Challenges of measuring plastic pollution 2019, Ellen Macarthur Foundation NPEC 2017)

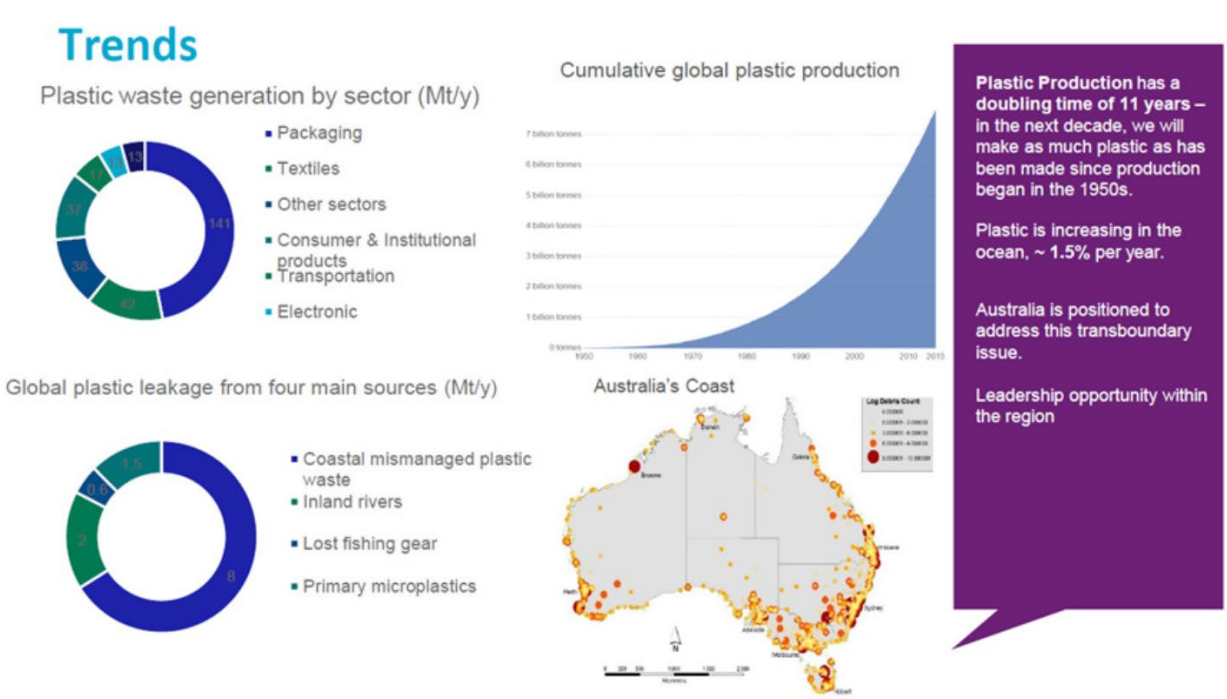

Figure 3 Plastic waste generation by sector (Mt/y) Source: Geyer et al. 2017, WEF 2016, UN Environment 2018, The Challenges of measuring plastic pollution 2019)

Risks posed by microplastics for seafood consumers

The risks posed by microplastics to seafood consumers in Australia and New Zealand have been summarised in [two factsheets produced by the SafeFish program] (primarily funded by FRDC). Briefly, assessing the risks to seafood consumers requires considering (i) the likelihood that microplastics will be ingested by people while eating seafood, and (ii) the potential harms that could result following ingestion.

The risk that Australian and New Zealand seafood consumers would ingest microplastics while eating seafood is generally low. This is for a number of reasons. First, Australian seafood species have low abundances of microplastic compared to globally (Wootton et al., 2021; Wootton et al. 2022). Additionally, removal of the gastro-intestinal tract before consumption (which is common practice for many seafood species in Australia) further reduces risk. In spite of what is sometimes portrayed in the media, the likelihood of consuming microplastic from the surrounding environment (e.g. shedding from clothes, carpets and cooking equipment) is much higher than consuming plastic via seafood. For seafood that is eaten whole (e.g. shellfish), the risk is slightly higher. Of microplastics that are ingested, 90% or more are likely to be excreted with faeces. However, it is important to note that further research is required to understand potential human health impacts from microplastics and any adsorbed toxins.

Notwithstanding, the human health impacts of plastic consumption are largely unknown, with very limited literature indicating that there are negative consequences of consuming plastics. There would be value in delivery of additional research designated to confirm health impacts, if any, of micro and nano-plastics in human diets.

References

Alfaro-Núñez, A., Astorga, D., Cáceres-Farías, L., Bastidas, L., Villegas, C.S., Macay, K. & Christensen, J.H. (2021). Microplastic pollution in seawater and marine organisms across the tropical Eastern Pacific and Galápagos. *Scientific Reports* 11, https://www.nature.com/articles/s41598-021-85939-3.

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

Jorgensen, B., Krasny, M. & Baztan, J. Volunteer beach cleanups: civic environmental stewardship combating global plastic pollution. Sustain Sci 16, 153–167 (2021). https://doi.org/10.1007/s11625-020-00841-7

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, 643–651. doi:10.1016/j.ocecoaman.2011.05.007

NOAA (2021). *What are microplastics?* https://oceanservice.noaa.gov/facts/microplastics.html accessed 7/07/2021

Reisser, J., Shaw, J., Wilcox, C., Hardesty, B.D., Proietti, M., Thums, M. & Pattiaratchi, C. (2013). Marine plastic pollution in waters around Australia: characteristics, concentrations, and pathways. *PLoS One* 8, e80466. https://doi.org/10.1371/journal.pone.0080466

Ritchie, H. & Roser, M. (2018). *Plastic Pollution*. Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/plastic-pollution' [Online Resource], on 7/07/2021.

SafeFish (2019a). *SafeFish Overview: Micro Plastics in Seafood*. SafeFish fact sheet accessed at https://www.safefish.com.au/reports/food-safety-fact-sheets/microplastics-in-seafood on 7/07/2021.

SafeFish (2019b). Microplastic research in Australia and New Zealand August 2019. SafeFish fast sheet accessed at https://www.safefish.com.au/reports/food-safety-fact-sheets/microplastics-research-australia-new-zealand on 7/07/2021.

Sweet, M., Stelfox, M. & Lamb, J. (2019). *Plastics and shallow water coral reefs*. *Synthesis of the science for policy makers.* United Nations Environment Program. https://wedocs.unep.org/bitstream/handle/20.500.11822/27646/plastic_corals.pdf?sequence=1&isAllowed=y

Wootton, N., Reis-Santos, P., Dowsett, N., Turnbull, A., Gillanders, B.M., 2021. Low abundance of microplastics in commercially caught fish across southern Australia. Environmental Pollution 290, 118030.

Wootton, N., Sarakinis, K., Varea, R., Reis-Santos , P., Gillanders, B.M., 2022. Microplastic in oysters: A review of global trends and comparison to southern Australia. Chemosphere 307, 136065.

Wyles, K. J., Pahl, S., Holland, M., & Thompson, R. C. (2017). Can Beach Cleans Do More Than Clean-Up Litter? Comparing Beach Cleans to Other Coastal Activities. *Environment and Behavior*, *49*(5), 509–535. https://doi.org/10.1177/0013916516649412