Written testimony provided by Elise F. Granek, Professor of Environmental Science & Management, Portland State University, Portland Oregon

Committee on Transportation and Infrastructure

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Emerging Contaminants, Forever Chemicals, and More: Challenges to Water Quality, Public Health, and Communities

I would like to thank Chair DeFazio, Chairwoman Napolitano, Ranking Member Rouzer, and Members of the Subcommittee on Water Resources and Environment for this opportunity to present written testimony on *Emerging Contaminants, Forever Chemicals, and More: Challenges to Water Quality, Public Health, and Communities*.

Emerging contaminants, including forever chemicals and other compounds, are ubiquitous in our marine and freshwater ecosystems as well as in our bodies. The drinking water we extract from rivers, the fish and shellfish that are the backbone of the fishing industry, the sea salt, and craft beer we consume, and the freshwater and marine animals that we value for tourism, are exposed to not just a single contaminant, but a cocktail of contaminants as they swim in or attach to the bottom of our streams, rivers, lakes, and oceans. Similarly, we humans are exposed to these same contaminants when we swim in lakes and oceans, eat food harvested from those waters, and even when we breathe the air around us (e.g., Brahney et al. 2021, Zhang et al. 2020). Yet in the United States, our regulatory policy takes a pollutant by pollutant approach, with benchmarks indicating safe levels of exposure for aquatic animals or human consumers for a very limited number of the thousands of contaminants currently in production and use today (https://www.chemicalsafetyfacts.org/chemistry-context/debunking-myth-chemicals-testing-safety/). Aquatic plants, animals and humans are experiencing and consuming many chemicals simultaneously, some of which interact synergistically- more toxic in combination than individually, some interacting antagonistically- in which case the effects of one may counteract the effects of another. As a result, managing a subset of chemicals and doing so on an individual basis is an unrealistic representation of how humans and animals are experiencing chemicals in the environment- and likely under-represents the human health and environmental effects of any individual contaminant or suite of contaminants. Moreover, the effects of some of these chemicals on plants and animals is exacerbated by warming water temperatures (Noyes and Lima, 2015).

These issues are relevant to state and federal agencies tasked with managing species and ecosystems, to federally recognized tribes, many of whom depend on aquatic items as first foods (such as salmon and lamprey here in the Pacific Northwest), as well as industry groups including the aquaculture industry, whose product and livelihood can be affected by chemical contamination.

Professional Background

I am a marine ecologist with 20-years of experience conducting field and laboratory-based research on coastal marine ecosystems and 12 years of experience conducting research on emerging contaminants in coastal marine and freshwater ecosystems and species.

I offer information from studies by my lab group and those of my collaborators and colleagues on emerging contaminants in our fresh and marine waters. My expertise in this sphere is limited to the scientific information on the presence and effects of emerging contaminants, with particular focus on microplastics, pharmaceuticals, and pesticides on fresh- and marine waters, sediment, and animals.

Microplastics

My students, colleagues, collaborators, and I have been studying microplastics in river water, shellfish, and more recently finfish in the Pacific Northwest (Oregon and Washington). Microplastics are small plastics, smaller than the width of a pencil and down to microscopic sizes. They include an array of chemical compositions ranging from the types of plastics used to make synthetic clothing like fleece jackets to other polymers used in chip bags, straws, etc. Our research findings align with studies conducted elsewhere in the US and internationally that have found microplastics to be pervasive in our waterways and aquatic organisms. For example, 99 out of 100 razor clams sampled in the Pacific Northwest have microplastics in their tissue. Similarly, for Pacific oysters, an important shellfish species for aquaculture in our region, 99 out of

100 individuals have microplastics in their tissues (Baechler et al. 2020a, b). In pink shrimp, an economically important fishery in the region, 9 out of 10 contain microplastics. Additionally, all of the Black Rockfish we have examined contain microplastics in their consumable tissue.

In addition to microplastics in shellfish and finfish, many studies report microplastics in our drinking water, sea salt, craft beer, and honey (Zhang et al. 2020). So perhaps it isn't surprising that a recent study out of New York State found that all infant and adult stool samples collected contained microplastics (Zhang et al. 2021).

Why does it matter that we find microplastics in waterways, drinking water, salt, and seafood?

A large body of research identifies effects of microplastic exposure in animals ranging from corals, crustaceans (e.g., lobsters) and shellfish, to finfish and humans (see Table 1 below). The deleterious effects range from adverse reproductive outcomes, physical organ damage, and altered growth and development, to behavioral changes, reduced immune response, and inflammation (see Granek et al. *In Press*).

Additionally, other chemicals in waterways, some of which I will discuss below, can stick to the surface of plastic pieces in the environment providing a transport pathway for such chemicals to enter the bodies of animals and humans.

In summary, when microplastics affect the growth and reproductive output of animals (such as those harvested commercially), then organisms grow more slowly and may have fewer offspring. From a human health perspective, microplastics have been found in human tissue ranging from the placentas of newborn babies (Ragusa et al. 2021) to colon tissue of cancer patients (Ibrahim et al. 2020). So these microplastics are making their way into humans with potential effects on human health. Yet no federal regulations currently exist to inform consumers of microplastics in their food, to limit microplastic release into waterways, or to set safe levels of microplastics in human food items.

Pharmaceuticals and Personal care products (PPCPs)

Pharmaceuticals are biologically active chemicals manufactured to induce a response in humans or other animals. Personal care products are personal hygiene products (including toothpastes, soaps and shampoos, sunscreens, etc.) and cosmetics and are identified as contaminants of emerging concern. These compounds are washed down the drain from industry, hospitals, animal care facilities, households, etc. and enter our waterways in part *because there is no regulated disposal process* nationally and current wastewater infrastructure does not remove most of those compounds (Ehrhart et al. 2020). Once washed down the drain, these chemicals enter rivers, estuaries and oceans. Though pharmaceuticals generally do not bioaccumulate, because they are constantly released into waterways from wastewater treatment plants and septic systems, they are considered pseudo-persistent.

In Puget Sound, Washington, juvenile Chinook salmon (federally listed under the Endangered Species Act) accumulated 36 different pharmaceuticals and personal care products (PPCPs) in their tissue, often at concentrations similar to or greater than concentrations of the effluent released from wastewater treatment plants nearby (Figure 1; Meador et al. 2016). Similarly, 18 PPCPs were detected in Olympia oysters, a protected species in Oregon.

Because pharmaceuticals are designed to be biologically active, the effects they have in humans can translate into effects on other animals. For example, as use of prescribed oral antibiotics affects gut microbiota in humans, those same antibiotics alter the gut microbiota in shellfish exposed to antibiotics in their water environment (e.g., Teixeira 2017). Fluoxetine, the active ingredient in the antidepressant Prozac, can reduce inhibition in humans; similarly, shore crabs exposed to fluoxetine have a reduced inhibition around their predators, leading to increased loss of limbs and death (Peters et al. 2017).

Why does it matter that freshwater, estuarine, and marine animals are exposed to pharmaceuticals and personal care products? Some of these chemicals can reduce growth or increase predation in wild populations of animals that are grown commercially, harvested recreationally, of cultural importance to tribes, and that are endangered.

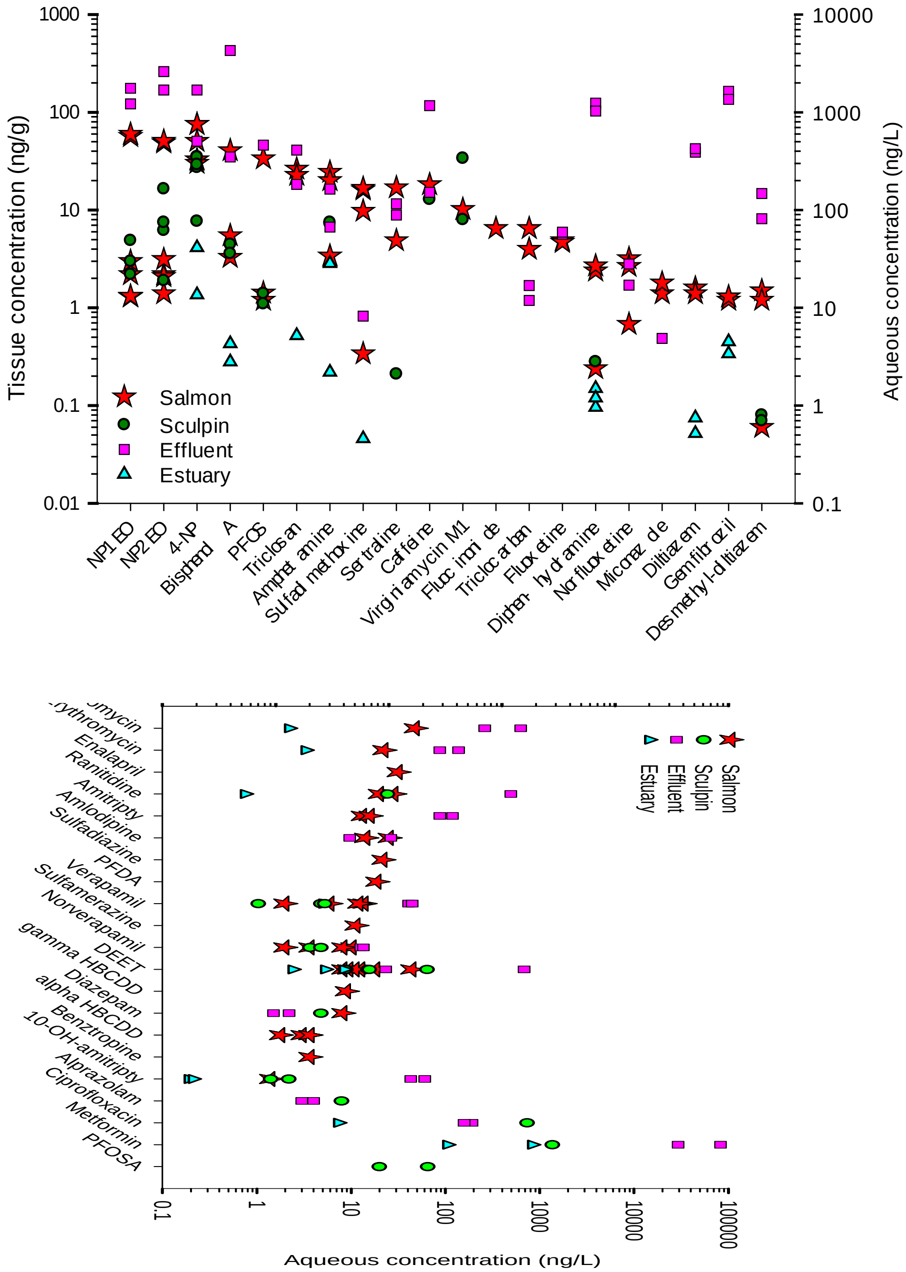

Figure 1. Occurrence of detected analytes in fish (salmon = stars, sculpin =circles), estuarine water, and wastewater effluent. Data are ordered from high to low concentrations in juvenile Chinook salmon. All replicate data shown for each matrix. From Meador et al. 2016.

Pesticides

Pesticide use, including herbicides, insecticides, rodenticides, and fungicides, extends across numerous industries, including agriculture, forestry, and Christmas tree farming as well as by municipalities and homeowners to manage vegetation in public right-of ways and on private property. Herbicide applications are used to reduce competition from unwanted vegetation, decrease wildfire risk, and increase survival and yield of target species (Shepard et al. 2004; Clark et al. 2009). Approximately 1/3 of U.S.-grown crops use pesticides, and while they are generally applied directly to target plants, pesticides enter the environment via spray drift, runoff following rainfall, and groundwater (Tudi et al. 2021).

Once applied, pesticide properties and watershed characteristics affect how they move and where they go in the environment, with some compounds degrading or moving quickly through the watershed and others persisting in the environment and in organisms for long periods of time (Wang et al., 2019). These and other factors influence how organisms are exposed to potentially harmful pollutants which can have detrimental effects on development, reproduction, and behavior in aquatic plants and animals (Luschak et al. 2018).

Of the wide array of pesticides used in each industry, over a hundred have been documented to cause deleterious effects on aquatic plants, animals and/or human development and health (e.g., Bhardwaj et al. 2018; Cimino et al. 2016; Gonzalez-Alzaga 2015; Mnif et al. 2011; Rani et al. 2020). Exposure to atrazine can cause genetic damage and decreased growth, in Pacific oysters (*Crassostrea gigas*) (Bouilly et al. 2004), reproduction and growth in zooplankton, ovarian growth in crabs (Silveyra et al. 2017), and reproduction and behavior in fish (e.g., zebrafish - *Brachydanio rerio* and rainbow trout - *Oncorhynchus mykiss*; Graymore et al. 2001). Moreover, the highest toxicity has been reported in earlier, more fragile aquatic invertebrates life stages (Lindsay et al. 2010) . These negative impacts on reproductive success of some organisms, including humans (Figure 2) have implications for future populations.

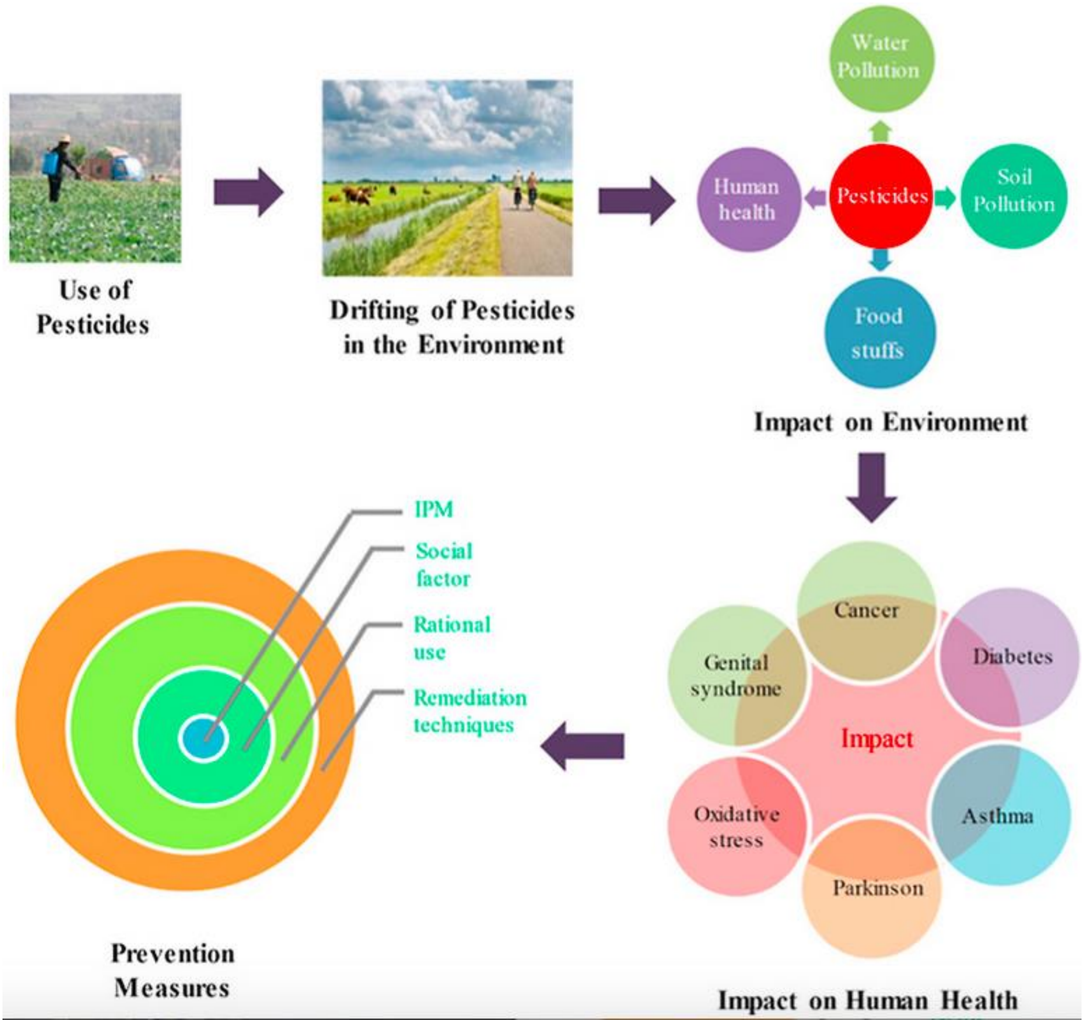

Figure 2. Consequences of chemical pesticides on human health and the environment. From Rani et al. 2020.

Why does it matter that freshwater, estuarine, and marine animals are exposed to pesticides?

Some of these chemicals can affect fitness and survival of animals preyed on by commercial species as well as the commercial species themselves. Some of these compounds can accumulate in shellfish tissue (e.g., Scully-Engelmeyer et al. 2021) that is then consumed by humans. Dozens of studies have identified human health effects of exposure to agricultural pesticides (Bhardwaj et al. 2018; Cimino et al. 2016; Gonzalez-Alzaga 2015; Rani et al. 2020). Ultimately, sublethal levels of pesticide exposure pose a threat to organisms; this threat can be challenging to quantify and monitor, but can have disruptive effects on animal populations (Stark and Banks, 2003)

<u>Other chemicals</u>

<u>*PFAS*</u>

Per- and polyfluoroalkyl substances (PFAS) are found or used in hundreds of consumer products and industrial processes, including but not limited to stain- and oil-resistant coatings on clothing and in food packaging, hydraulic fluids used in aviation, paints, adhesives, and fire-fighting foams (Cousins et al., 2019; Lau et al., 2007). PFAS are a ubiquitous class of industrial contaminants found in waterways nationwide. Ecotoxicity data on newer PFAS are scarce, and to-date just a handful of studies have been conducted with freshwater aquatic organisms (Hoke et al., 2016, 2015) with very little data for effects on marine organisms. Yet a myriad of studies have identified a variety of negative health effects resulting from exposure to PFAS ranging from adverse reproductive and developmental outcomes and cancer to liver disease, lipid and insulin dysregulation, kidney disease, and altered immune and thyroid function (e.g., Fenton et al. 2021).

Tire wear particles and associated chemicals

A complex mixture of chemicals associated with tire wear particles enter the environment primarily through stormwater runoff (Johannessen et al. 2021). As cars drive along our roadways, small tire fragments wear off and end up in roadways or aerosolized. These tire wear particles and associated chemicals have recently been identified as a significant driver of coho salmon mortality in the Pacific Northwest, affecting up to 90% of returning salmon in some streams (Tian et al. 2021). A chemical commonly used in car tire manufacturing interacts with ozone in the environment creating a toxic by-product, 6PPD-quinone, which then enters the environment when it leaches from tire wear particles that are washed off roadways and into our waterways during rain events (Johannessen et al. 2021, Tian et al. 2021). These particles and their associated chemicals are toxic to a number of species in our waterways (Khan et al. 2019, Wik 2008). Other unidentified chemicals have been detected in tire wear particles, as the chemical mixtures used in tire manufacturing are complex, proprietary, and largely unregulated (Tian et al. 2021, Wik & Dave 2009). The formation of a previously unknown chemical, 6PPD-quinone, as an unintended by-product from car tire manufacturing highlights the potential for understudied chemicals to produce unforeseen environmental sequences and the need for regulatory mechanisms to protect species from these effects.

Summary

In our collaborative research with colleagues across multiple universities, state and federal institutions, federally recognized tribes in the Pacific Northwest, Industry groups, and non-governmental organizations, there is concern about the threats emerging contaminants pose to freshwater and marine animals as well as human consumers.

Though more multiple-stressor studies are needed to understand the full scope of how these contaminants, paired with environmental stressors resulting from climate change- such as ocean acidification and increasing sea surface temperature - are affecting freshwater and marine plants and animals, ***there is ample scientific evidence that these contaminants affect freshwater and marine organisms, with potential implications for human consumers***.

More active engagement between policy makers and scientists is needed to determine appropriate benchmarks for these chemicals, both individually and in combination with other chemicals, to safeguard environmental and public health. Such ***benchmarks need to consider how simultaneous exposure to multiple contaminants affects animals, including commercially important and endangered species, as well as public health***.

Thank you for the opportunity to speak with you.

Table 1. Ecological and biological effects of microplastic fibers on organisms by species and material type (modified from Granek et al. *In Press*)

Level	Type of Effect	Organism Clade	Genus species	Plastic Material Type	In Text Citation
Sub/Cellular	**Adverse Immune Response**	Bivalves	*Mytilus spp.*	Polyamide Nylon	(Cole et al., 2020)
		Coral	*Acropora sp.*	n/a	(Mendrik et al., 2021)
		Coral	*Seriatopora hystrix*	n/a	(Mendrik et al., 2021)
	Cellular Response	Annelid Worms	*Lumbricus terrestris*	Polyester	(Prendergast-Miller et al., 2019)
		Bivalves	*Mytilus galloprovincialis*	composite household lint	(Alnajar, Jha and Turner, 2021)
		Coral	*Acropora sp.*	n/a	(Mendrik et al., 2021)
		Coral	*Seriatopora hystrix*	n/a	(Mendrik et al., 2021)
		Crustaceans	*Nephrops norvegicus*	Polypropylene	(Welden and Cowie, 2016)
		Humans	*Homo sapiens*	nylon, polyester	(Dijk et al., 2020)
		Nematodes	*Caenorhabditis elegans*	polyethylene terephthalate	(Liu et al., 2021)
		Nematodes	*Caenorhabditis elegans*	polyethylene terephthalate	(Liu et al., 2021)
		Nematodes	*Caenorhabditis elegans*	polyethylene terephthalate	(Liu et al., 2021)
		Rodents	*Mus musculus*	nylon, polyester	(Dijk et al., 2020)
	Oxidative Stress	Annelid Worms	*Lumbricus terrestris*	Polyester	(Prendergast-Miller et al., 2019)
		Bivalves	*Mytilus spp.*	Polyamide Nylon	(Cole et al., 2020)

		Bivalves	*Mytilus spp.*	Polyamide Nylon	(Cole et al., 2020)
		Coral	*Acropora sp.*	n/a	(Mendrik et al., 2021)
		Coral	*Seriatopora hystrix*	n/a	(Mendrik et al., 2021)
		Echinoderms	*Apostichopus japonicus*	n/a	(Mohsen et al., 2021)
		Fish	*Dicentrachus labrax*	polyethylene (80%); polyester (19%); rayon (1%)	(Barboza et al., 2020)
		Fish	*Trachurus trachurus*	polyethylene (80%); polyester (19%); rayon (1%)	(Barboza et al., 2020)
		Fish	*Scomber colias*	polyethylene (80%); polyester (19%); rayon (1%)	(Barboza et al., 2020)
		Fish	*Danio rerio*	polypropylene	(Qiao et al., 2019)
		Nematodes	*Caenorhabditis elegans*	polyethylene terephthalate	(Liu et al., 2021)
		Terrestrial Snails	*Achatina fulica*	polyethylene terephthalate (PET)	(Song et al., 2019)
Organ	**Growth Development**	Bivalves	*Mytilus galloprovincialis*	composite household lint	(Alnajar, Jha and Turner, 2021)
		Crustaceans	*Emerita analoga*	polypropylene	(Horn, Granek and Steele, 2020)
		Crustaceans	*Artemia franciscana*	polypropylene, polyethylene terephthalate	(Kim et al., 2021)
		Fish	*Carassius auratus*	ethylene vinyl acetate (EVA)	(Jabeen et al., 2018)

Inflammation	Fish	*Carassius auratus*	ethylene vinyl acetate (EVA)	(Jabeen et al., 2018)
	Fish	*Danio rerio*	polypropylene	(Qiao et al., 2019)
	Rodents	*Cavia porcellus*	polyester	(Pimentel et al., 1975)
	Zooplankton	*Artemia franciscana*	polyethylene terephthalate (PET)	(Kokalj, Kunej and Skalar, 2018)
Oxidative Stress	Crustaceans	*Homarus americanus*	polyethylene terephthalate (PET)	(Woods et al., 2020)
	Fish	*Danio rerio*	polypropylene	(Qiao et al., 2019)
Physical Organ Damage	Bivalves	*Mytilus galloprovincialis*	composite household lint	(Alnajar, Jha and Turner, 2021)
	Crustaceans	*Artemia franciscana*	polypropylene, polyethylene terephthalate	(Kim et al., 2021)
	Crustaceans	*Nephrops norvegicus*	Polypropylene	(Welden and Cowie, 2016)
	Fish	*Dicentrachus labrax*	polyethylene (80%); polyester (19%); rayon (1%)	(Barboza et al., 2020)
	Fish	*Trachurus trachurus*	polyethylene (80%); polyester (19%); rayon (1%)	(Barboza et al., 2020)
	Fish	*Scomber colias*	polyethylene (80%); polyester (19%); rayon (1%)	(Barboza et al., 2020)
	Fish	*Carassius auratus*	ethylene vinyl acetate (EVA)	(Jabeen et al., 2018)
	Fish	*Danio rerio*	polypropylene	(Qiao et al., 2019)

		Humans	*Homo sapiens*	polycarbonate, polyamide, polypropylene	(Ibrahim et al., 2021)
		Humans	*Homo sapiens*	polyester	(Pimentel et al., 1975)
		Rodents	*Cavia porcellus*	polyester	(Pimentel et al., 1975)
		Terrestrial Snails	*Achatina fulica*	polyethylene terephthalate (PET)	(Song et al., 2019)
		Zooplankton	*Artemia franciscana*	polyethylene terephthalate (PET)	(Kokalj, Kunej and Skalar, 2018)
Organism	**Adverse Reproductive Response**	Crustaceans	*Emerita analoga*	polypropylene	(Horn, Granek and Steele, 2020)
		Nematodes	*Caenorhabditis elegans*	polyethylene terephthalate	(Liu et al., 2021)
		Nematodes	*Caenorhabditis elegans*	polyethylene terephthalate	(Liu et al., 2021)
		Terrestrial Veg	*Lolium perenne*	high-density polyethylene (HDPE); polylactic acid (PLA)	(Boots et al., 2019)
		Worm	*Aporrectodea rosea*	high-density polyethylene (HDPE); polylactic acid (PLA)	(Boots et al., 2019)
		Zooplankton	*Ceriodaphnia dubia*	polyethylene terephthalate (PET)	(Ziajahromi et al., 2017)
	Behavioral Change	Annelid Worms	*Lumbricus terrestris*	Polyester	(Prendergast-Miller et al., 2019)
		Bivalves	*Mytilus galloprovincialis*	composite household lint	(Alnajar, Jha and Turner, 2021)
		Bivalves	*Mytilus edulis*	Nylon	(Christoforou et al., 2020)

		Bivalves	*Macomona liliana*	Polyethylene terephthalate (PET)	(Hope et al., 2020)
		Cnidarians	*Aiptasia pallida*	nylon, polyester, polypropylene	(Romanó de Orte et al., 2019)
		Crustaceans	*Hyalella azteca*	Polypropylene	(Au et al., 2015)
		Crustaceans	*Nephrops norvegicus*	Polypropylene	(Welden and Cowie, 2016)
		Nematodes	*Caenorhabditis elegans*	polyethylene terephthalate	(Liu et al., 2021)
		Terrestrial Snails	*Achatina fulica*	polyethylene terephthalate (PET)	(Song et al., 2019)
		Zooplankton	*Daphnia magna*	Nylon, Polyethylene terephthalate	(Hernandez et al., 2019)
		Zooplankton	*Tigriopus japonicus*	Polyester	(Kang et al., 2020)
	Growth Development	Bivalves	*Macomona liliana*	Polyethylene terephthalate (PET)	(Hope et al., 2020)
		Crustaceans	*Hyalella azteca*	Polypropylene	(Au et al., 2015)
		Crustaceans	*Emerita analoga*	polypropylene	(Horn, Granek and Steele, 2020)
		Crustaceans	*Carcinus maenas*	polypropylene	(Watts et al., 2015)
		Crustaceans	*Nephrops norvegicus*	Polypropylene	(Welden and Cowie, 2016)
		Crustaceans	*Homarus americanus*	polyethylene terephthalate (PET)	(Woods et al., 2020)
		Microphytobenthos	*Cyanobacteria*	Polyethylene terephthalate (PET)	(Hope et al., 2020)
		Nematodes	*Caenorhabditis elegans*	polyethylene terephthalate	(Liu et al., 2021)

		Nematodes	*Caenorhabditis elegans*	polyethylene terephthalate	(Liu et al., 2021)
		Terrestrial Veg	*Lolium perenne*	high-density polyethylene (HDPE); polylactic acid (PLA)	(Boots et al., 2019)
		Worm	*Aporrectodea rosea*	high-density polyethylene (HDPE); polylactic acid (PLA)	(Boots et al., 2019)
		Zooplankton	*Daphnia magna*	Nylon, Polyethylene terephthalate	(Hernandez et al., 2019)
		Zooplankton	*Artemia franciscana*	polyethylene terephthalate (PET)	(Kokalj, Kunej and Skalar, 2018)
		Zooplankton	*Ceriodaphnia dubia*	polyethylene terephthalate (PET)	(Ziajahromi et al., 2017)
	Neurological	Fish	*Dicentrachus labrax*	polyethylene (80%); polyester (19%); rayon (1%)	(Barboza et al., 2020)
		Fish	*Trachurus trachurus*	polyethylene (80%); polyester (19%); rayon (1%)	(Barboza et al., 2020)
		Fish	*Scomber colias*	polyethylene (80%); polyester (19%); rayon (1%)	(Barboza et al., 2020)
	Survivorship or Mortality	Crustaceans	*Hyalella azteca*	Polypropylene	(Au et al., 2015)
		Crustaceans	*Emerita analoga*	polypropylene	(Horn, Granek and Steele, 2020)

		Crustaceans	*Emerita analoga*	polypropylene	(Horn, Granek and Steele, 2020)
		Crustaceans	*Artemia franciscana*	polypropylene, polyethylene terephthalate	(Kim et al., 2021)
		Crustaceans	*Nephrops norvegicus*	Polypropylene	(Welden and Cowie, 2016)
		Crustaceans	*Homarus americanus*	polyethylene terephthalate (PET)	(Woods et al., 2020)
		Zooplankton	*Daphnia magna*	polyethylene terephthalate	(Jemec et al., 2016)
		Zooplankton	*Ceriodaphnia dubia*	polyethylene terephthalate (PET)	(Ziajahromi et al., 2017)
Population	**Adverse Reproductive Response**	Crustaceans	*Emerita analoga*	polypropylene	(Horn, Granek and Steele, 2020)
		Nematodes	*Caenorhabditis elegans*	polyethylene terephthalate	(Liu et al., 2021)

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