Microplastics: the state of the science in Oregon

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Portland State University

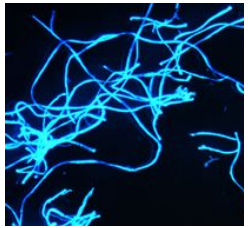
OR Senate Energy and Environment Committee
Wednesday, January 22, 2025

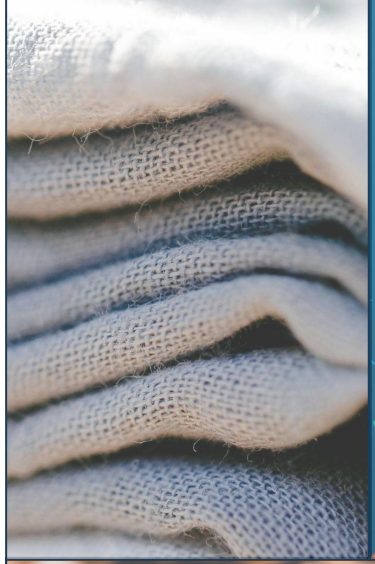
Summer Traylor, Susanne Brander; Stacey Harper, Jordyn Wolfand, CJ Poor and students (UP), ACE lab students: Britta Baechler, Amy Valine, Becky Talbot, Amanda Gannon (PSU)

- What and why
- Sources
- Fate and Effects
- Solutions

Microplastics: A Brief Primer

- Plastics 1 micron to 5mm in the longest dimension
- Shape, size, chemical composition variable
- Transport vectors for other contaminants

Primary MPs: Engineered to be that size (e.g., nurdles)	Secondary MPs: Created from breakdown of larger plastics (tires, clothes, etc.)
 	 



Crawford & Quinn, 2017; García-Gómez et al., 2021; Hartmann et al., 2017

PLASTIC POLLUTION BY THE NUMBERS

6.3 billion metric tons	Plastic waste generated globally by 2015
~80%	of all plastic waste enters the environment
170 million metric tons	Total estimated microplastic particles in the upper ocean and sediments.
9%	Of all plastic waste is recycled.

Geyser et al.

Geyer et al. 2017; Isobe et al. 2021; OECD 2022

Fiber Sources

If (conservatively)…

- 1 load = 750,000 synthetic MFs
- Portland metro= 2.2 million ppl
- 1 load/person/2 weeks
- WWTP 99% removal

  MPs from gray water

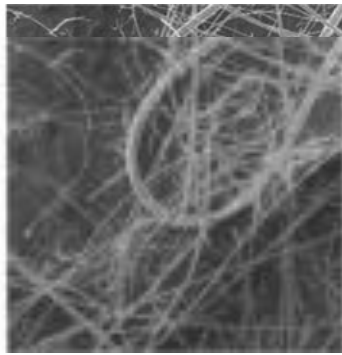
Sudheshna et al. 2022; STotEn

THEN…

Portland Metro area releases

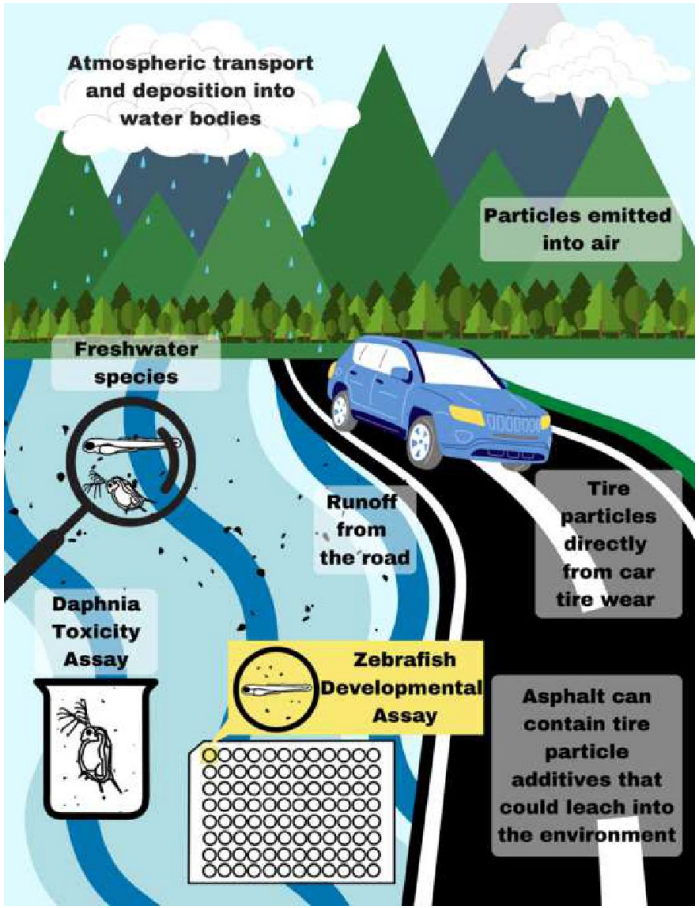
~4.25 billion MPs /year

(…and biosolids would capture ~42 trillion/yr)



Sudheshna et al. 2022; STotEn

Tire Particles (TPs)



(Cunningham et al., 2022)

- Tires are made of plastic!
- Estimated average mass of TWP generated in US is 1,524,740 t/yr (Kole et al. 2017)
- Large concentrations in water samples (Wik and Dave 2009)

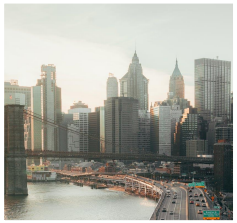
Fate: MPs in the Environment

Aquatic environments

- Includes rivers, lakes, coastal waters
- Pathways: runoff, wastewater effluent, greywater

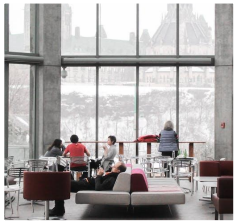
Terrestrial environments

- Includes forests, beaches, urban areas
- Pathways: landfills, agriculture, tire wear



Airborne environments

- Includes indoor air, outdoor air, rain, the atmosphere
- Pathways: manufacturing deposition, blown from land, aerosolization

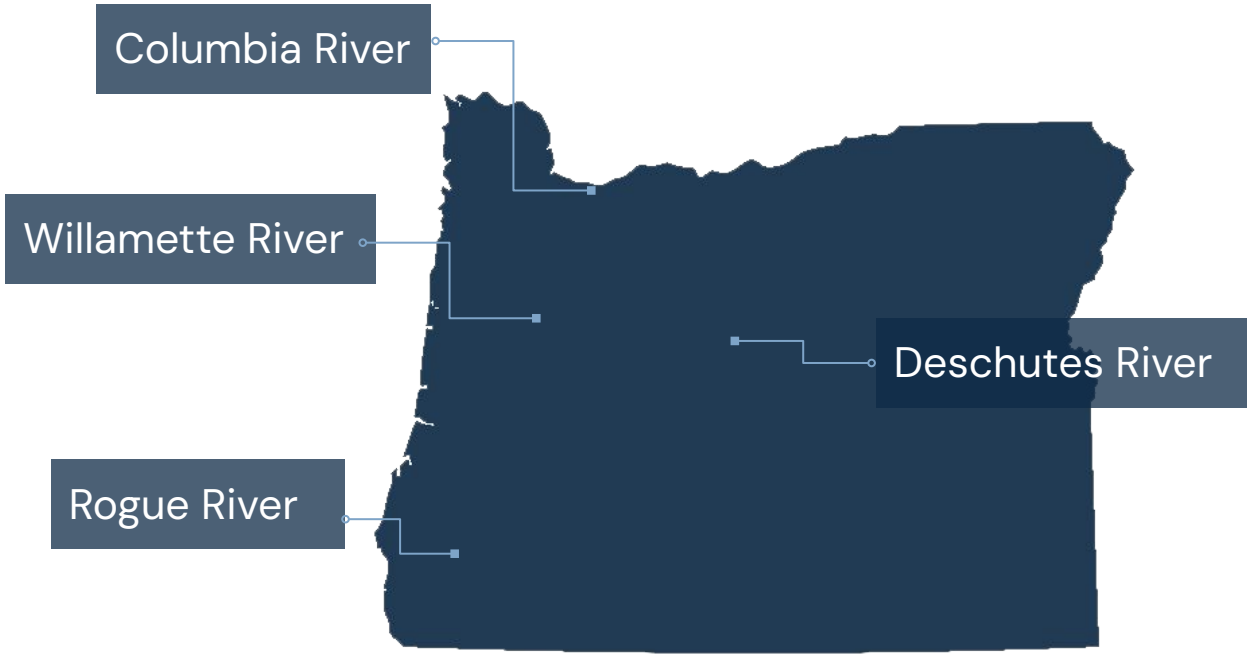


Periyasamy 2023; Geyer et al., 2022

MPs in Oregon

Rivers (Valine et al., 2020)

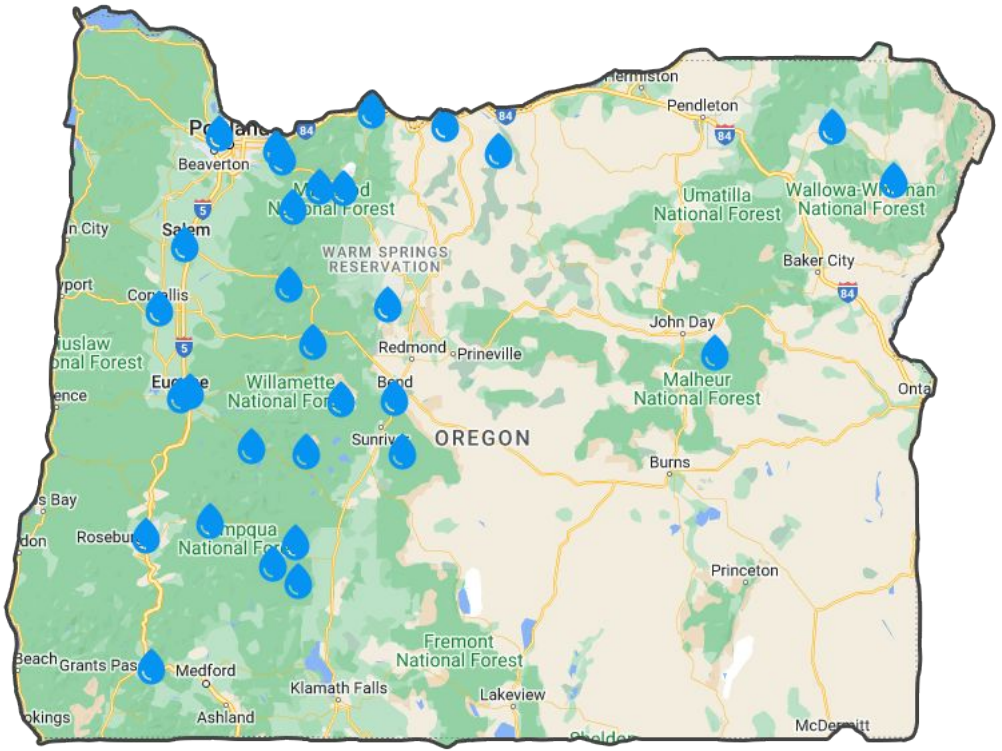
- Measured MPs in 4 Oregon rivers
- All sites were contaminated, including rural sites with pop. = 0
- Projected flow:
  - 144 to 2.9 million microfibers/h
  - 48 to 122,000 microparticles/h



MPs in Oregon

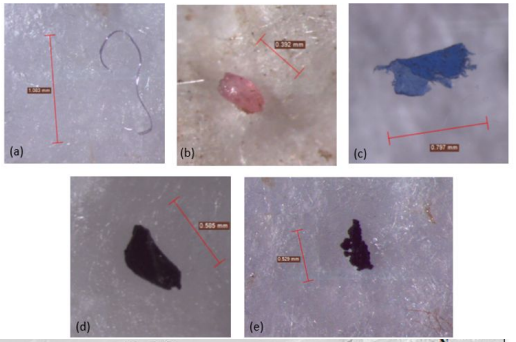
Lakes, Rivers, and Urban Waterways
(EORPC, 2021)

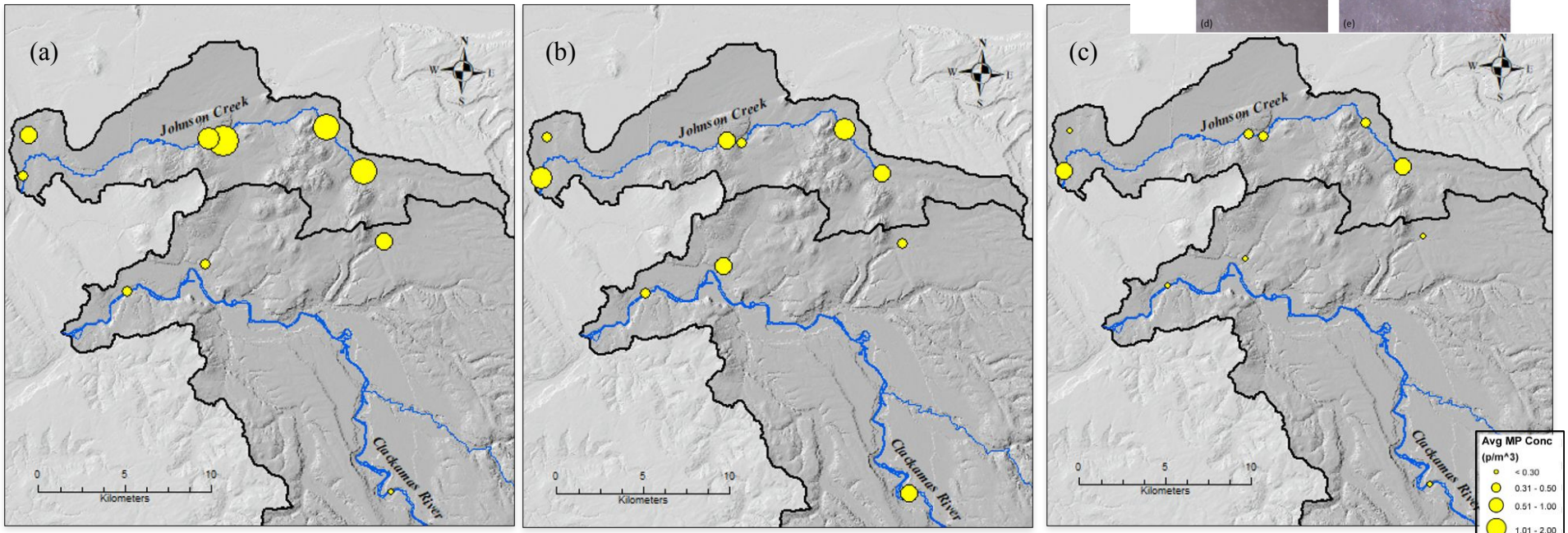
- Measured MPs at 30 sites across Oregon
- 100% of sites contaminated
- Microfibers most prevalent



Spatial and temporal variations of microplastic concentrations in Portland's freshwater ecosystems

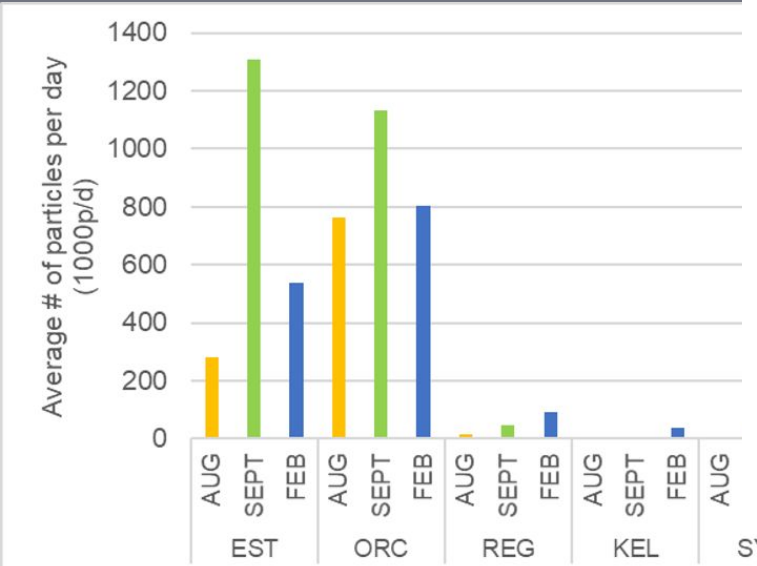
Rebecca Talbot, Elise Granek, Heejun Chang, Rosemary Wood, Susanne Brander (*STotEn* 2022)

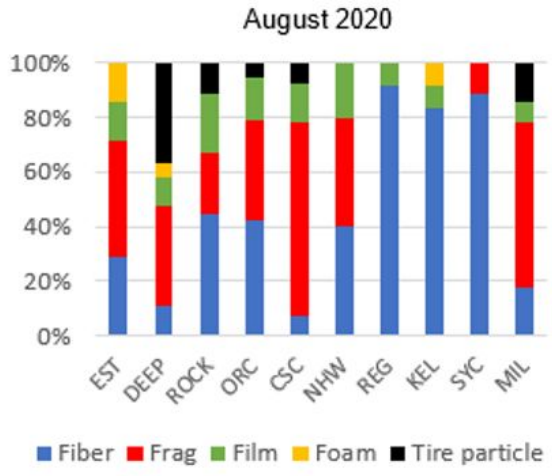


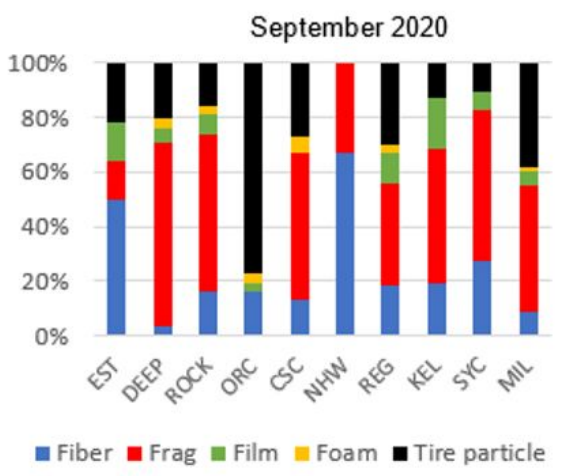


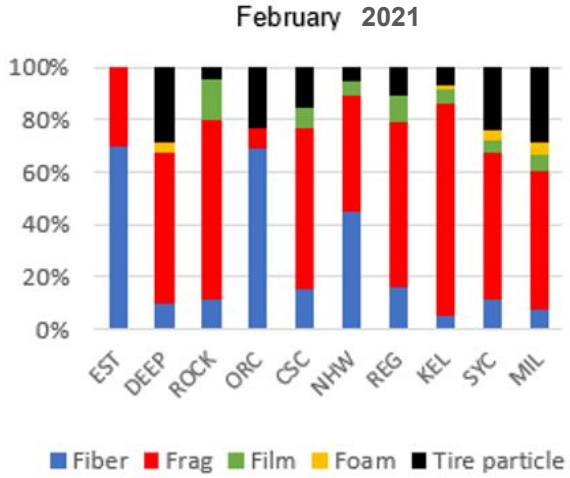
Microplastic concentrations at Johnson Creek and Clackamas River, OR monitoring sites in: (a) August, 2020 (b) September, 2020 and (c) February, 2021.

Portland Metro area rivers



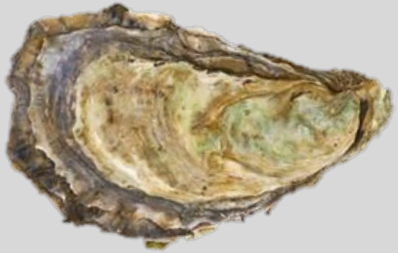


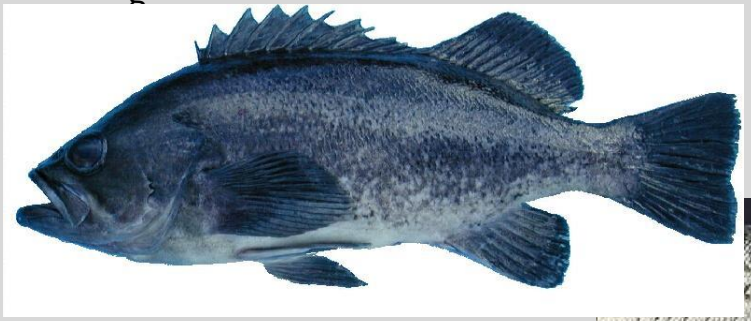




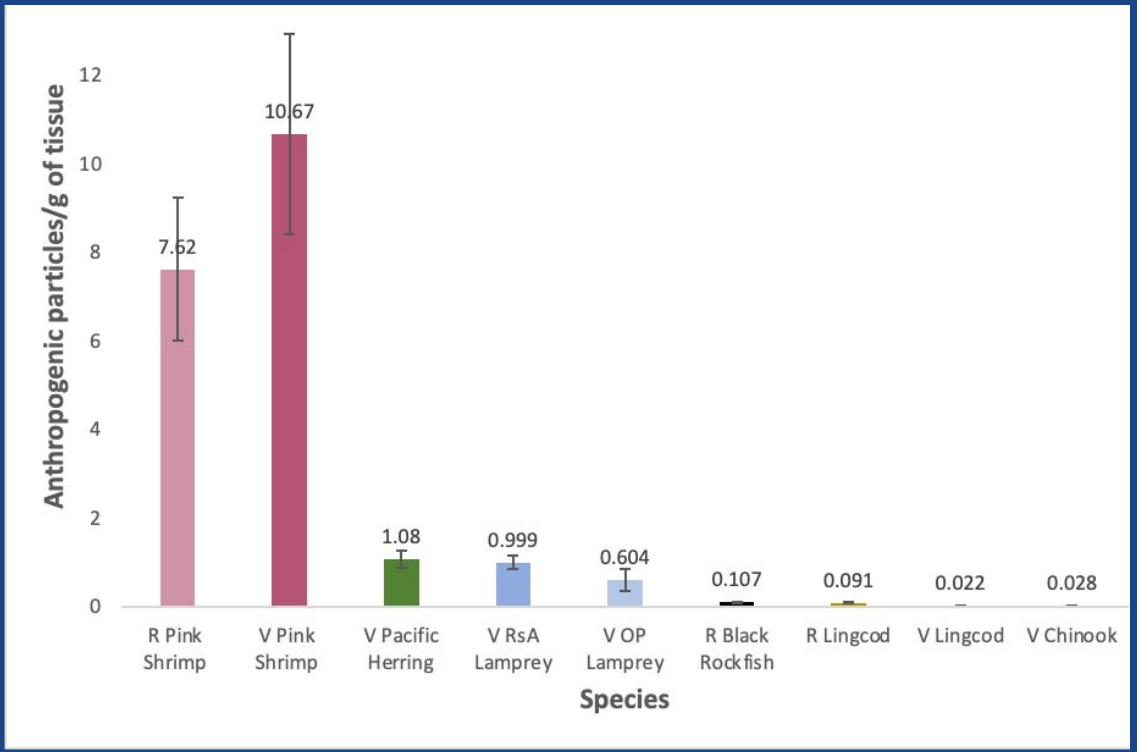
Microparticles from Oregon's ocean to table

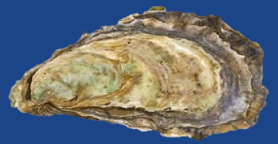
Traylor et al. 2024. Toxicology





Oysters, razor clams, pink shrimp, lamprey, Pacific herring, Black rockfish, Chinook salmon, Lingcod (not pictured),



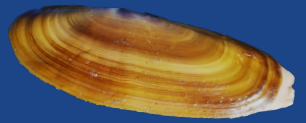


0.35 ± 0.04

MP/g

10.95 ± 0.77

MP/oyster

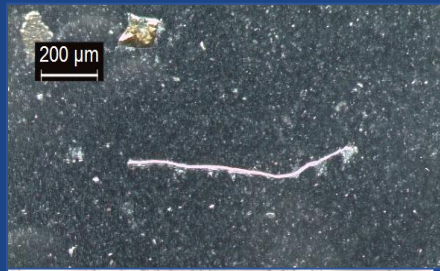


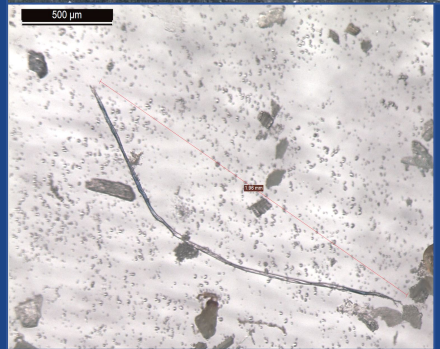
0.16 ± 0.02

MP/g

8.84 ± 0.45

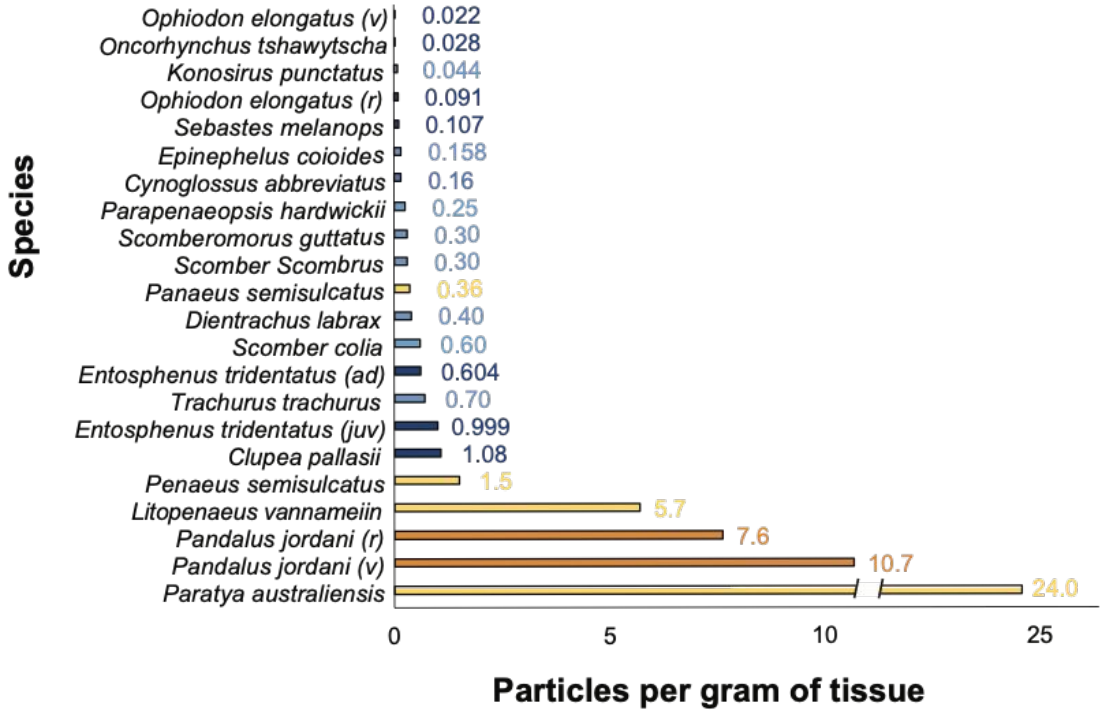
MP/clam





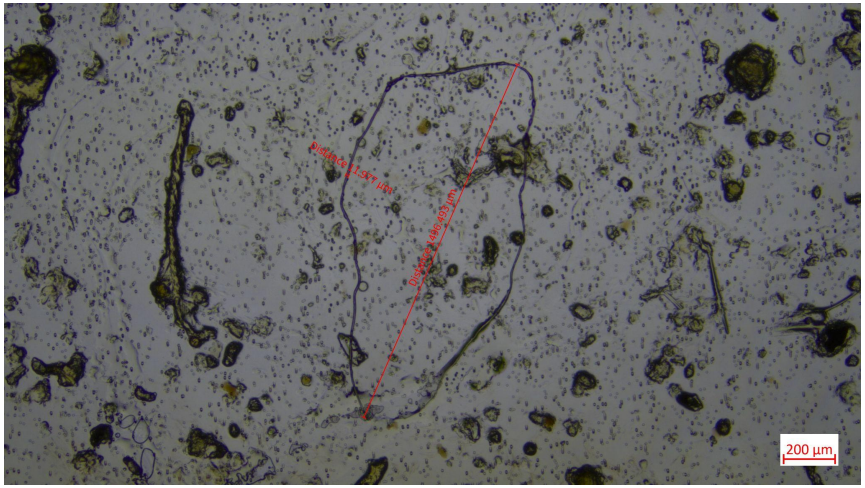
*whole organisms (consumable tissue); ^ ~200 grams of muscle tissue

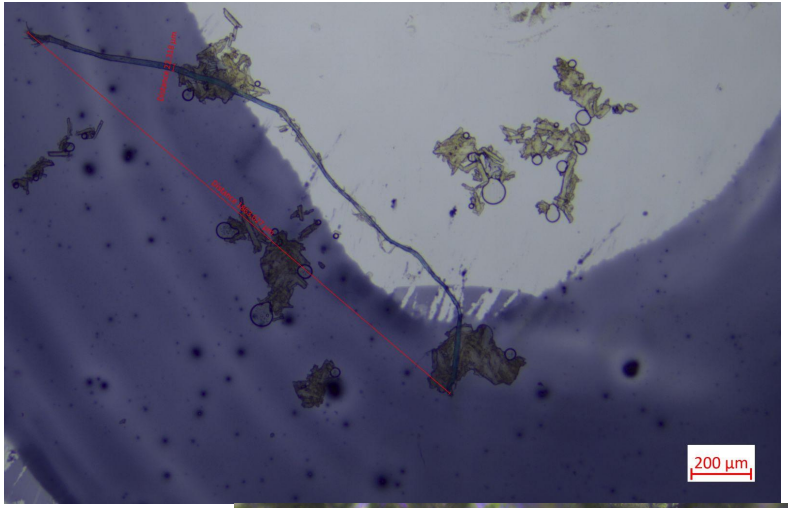
Species	Average particle count/ individual	Average # of particle/gram of tissue (AP/g)(SE)
Retail		
Pink shrimp	12.6	7.6 (1.62)
Black rockfish	10	0.11 (0.02)
Lingcod	7.6	0.09 (0.009)
Vessel		
Pink shrimp	11.9	10.67 (2.26)
Riverine juvenile lamprey	8.13	1 (0.15)
Pacific herring	9.3	1.08 (0.2)
Ocean phase adult lamprey	15.9	0.60 (.25)
Lingcod	3.91	0.02 (0.006)
Chinook salmon	5.3	0.03 (0.008)

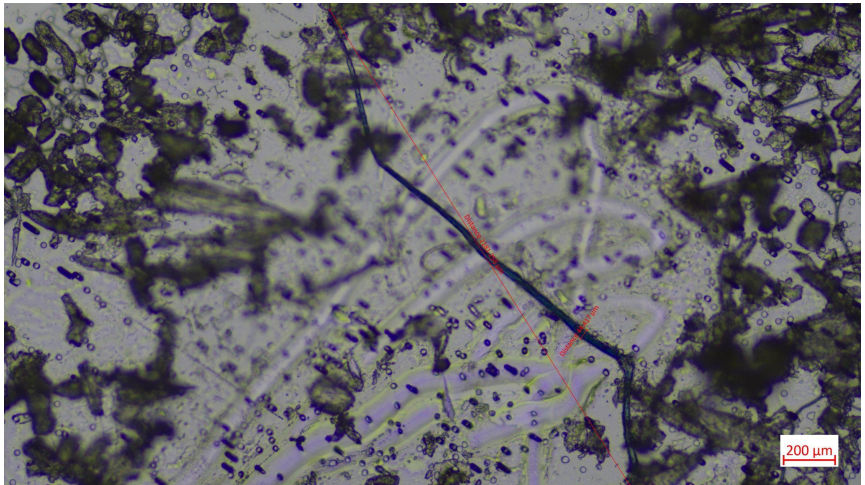


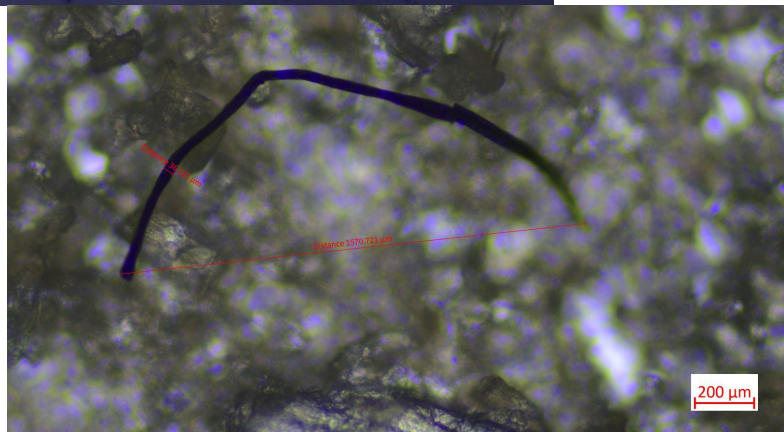
MPs/gram edible shrimp (dark orange) and fish (dark blue) tissue *from Oregon* compared with shrimp (orange) and fish (blue) globally.

Microfibers in Pacific herring (left) and lingcod (right)

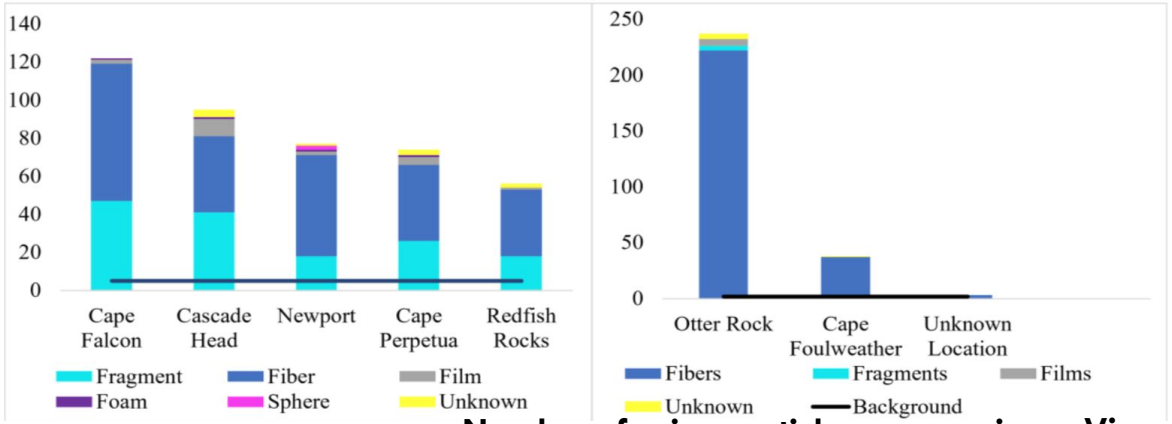








OREGON ROCKFISH



Lasdin et al. 2023

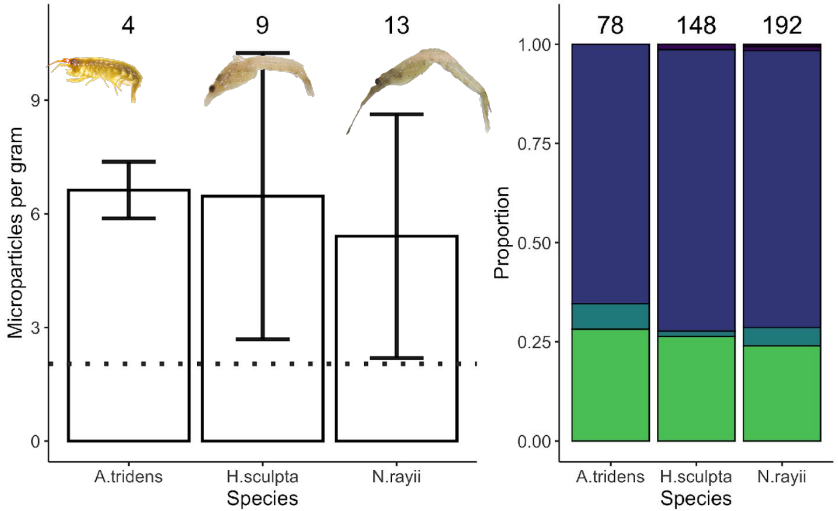
Number of microparticles per species

Visual shape

FTIR result

Lasdin et al. 2023

OREGON ZOOPLANKTON



Torres, Brander, Hildebrand, Henkel, Bernard, et al. 2023, Frontiers Marine Sci

Fate: in Fisheries in Oregon

Black Rockfish	Pink Shrimp	Salmon
High in recreational bottomfish fishery 92% of fish sampled ingested MPs	30 million pounds catch over 30 years Most MPs by body weight-averaged 12/individual	Commercial, recreational, tribal fisheries. Majority sampled Chinook contain MPs

Baechler et al., 2019; Baechler et al., 2020; Lasdin et al., 2023; Traylor et al. 2024

Fate: in First Foods

Salmon	Lamprey	Razor Clams
Central to diet and culture of Columbia Plateau Tribes.	Historically important to tribal diet and ceremonies.	Culturally and economically important to the coastal Quinault, others.

Baechler et al., 2019; Baechler et al., 2020; Lasdin et al., 2023

Effects on Organisms

Reduced Energy and Growth

Ingestion of plastics decreases feeding and lowers energy reserves.

False Satiation

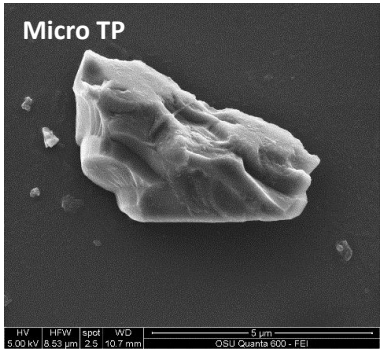
Organisms ingest plastics and stop perceiving hunger, leading to starvation

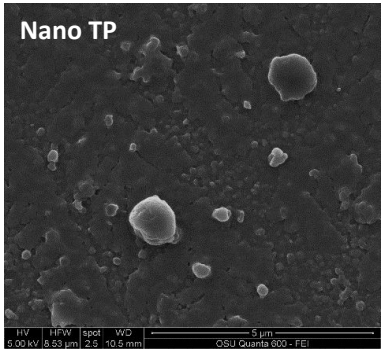
Reproductive Disruptions

Exposure can lead to lower fertility, embryonic maldevelopment, and slower growth.

Doyle et al., 2022; Wright et al., 2013

Zebrafish Assay

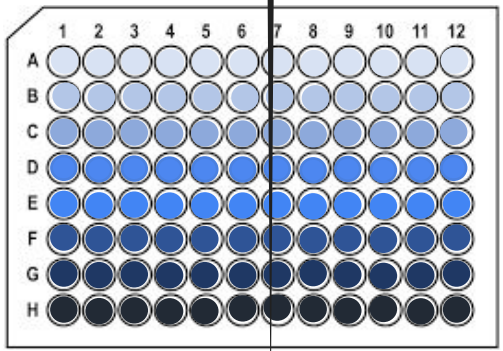




Micro: 1.0E+04 - 1.8E+05 Nano: 5.0E+06 - 9.8E+09 Leachate: 10-100%

García-Cambero et al. 2019

Well loaded with either Micro TP (1-20 µm), Nano TP (<1 µm), or Leachate

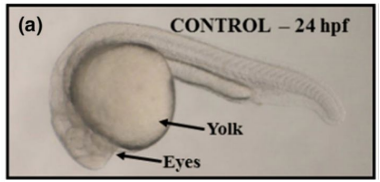


Low Concentration

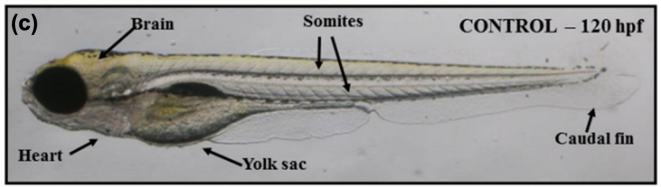
High Concentration

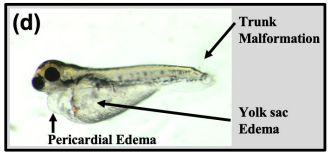
One Zebrafish embryo per well in 200 ul of liquid.
Exposures began at 8 hpf (n=32)

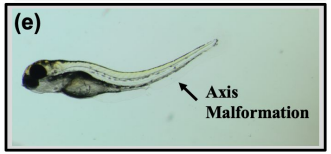
24-hour assessment



120-hour assessment

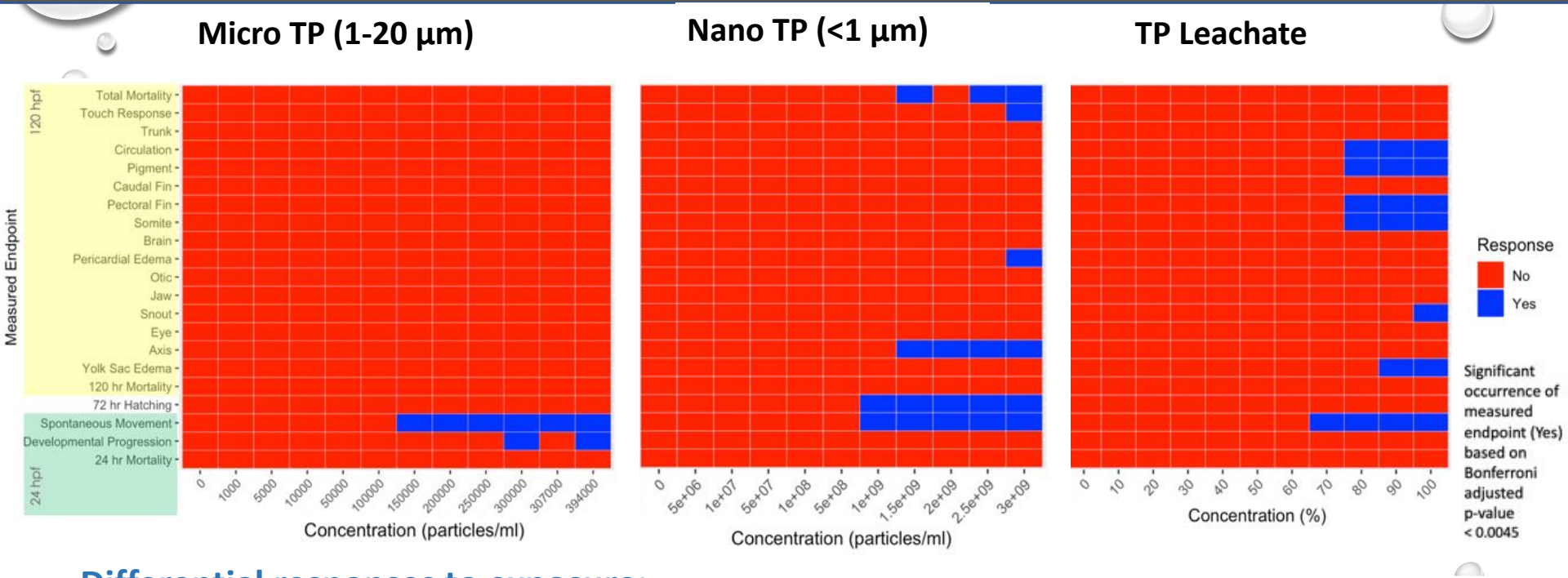






Modified Harper et al. 2015

Zebrafish TP Effects Heatmaps



Differential responses to exposure:

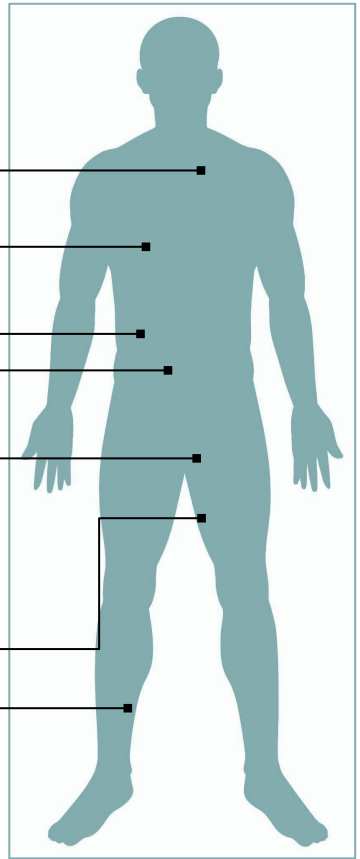
- All exposures led to a decrease in spontaneous movement and some malformations
- Only the micro-fraction had significant developmental delays
- Only the nano-fraction significantly increased mortality and delayed hatching

(Cunningham et al., 2022)

Human health

Microplastics have been found in...

- Heart tissue
- Breast milk
- Liver tissue, Colon tumor tissue
- Placenta, newborns
- Testes
- Waste
- Blood



Microplastics have been linked to...

- Gut inflammation
- Respiratory stress
- Cardiovascular disease (heart attack, stroke)
- Increased cancer risk (e.g., colon)
- Reproductive toxicity and reduced sperm count

Horvatits et al., 2022; Yang et al., 2023; Ragusa et al., 2022; Ragusa et al., 2021; Han et al., 2024; Leslie et al., 2022; Zhang et al., 2021

Hirt & Body-Malapel, 2020; Rubio et al., 2020; Rahman et al., 202, Cetin et al. 2023; Hu et al. 2024; Marfella et al. 20241

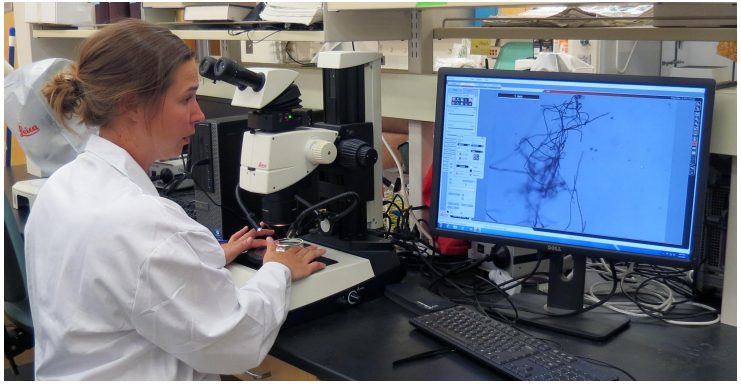
Solutions

- Reduce plastic production
- Regulation and management
  - Upstream interventions - washing machine filters (proposed bill)
  - Bans (single use and foodware)
  - Extended producer responsibility
  - Green infrastructure

- Consumer choice
  - Toothpaste, floss, shampoo
  - Laundry and dish detergent
  - Take out containers

Check out Microplastics Brochure

QUESTIONS?



Research needs

Reduce plastic production

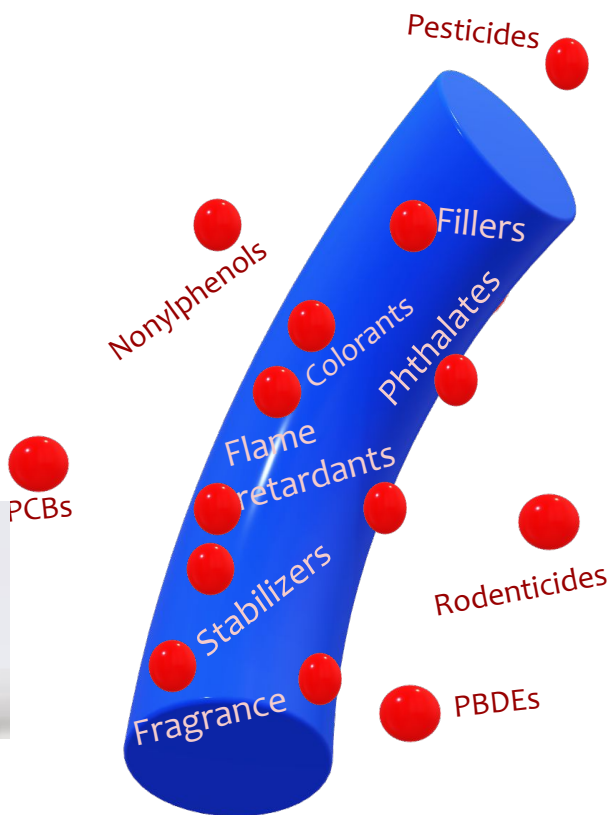
- Multiple stressor effects (plastics + pesticides + pharmaceuticals +...)
- Safe alternatives (avoiding regrettable substitutions)
- **Collaboration and standardization

Regulation and management

- Potential regional regulatory actions
- Baseline data for TMDLs (plastics, microplastics)
- Efficacy of solutions

Consumer choice

- Scaling up existing alternatives
- Developing new alternatives (e.g., 6PPD-q)



https://www.linkedin.com/pulse/empowering-consumers-shifting-burden-navigating-epr-shrivastava-mw1gf/;
https://www.yesihaveablog.com/going-plastic-free-reduce-your-plastic-waste/

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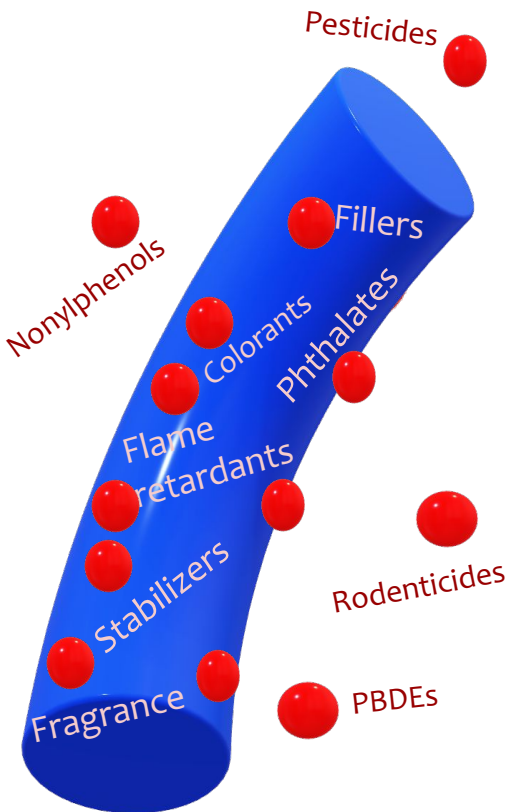
Questions and thoughts?



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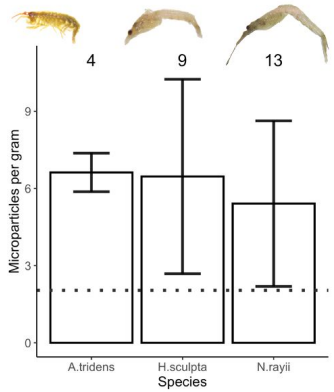
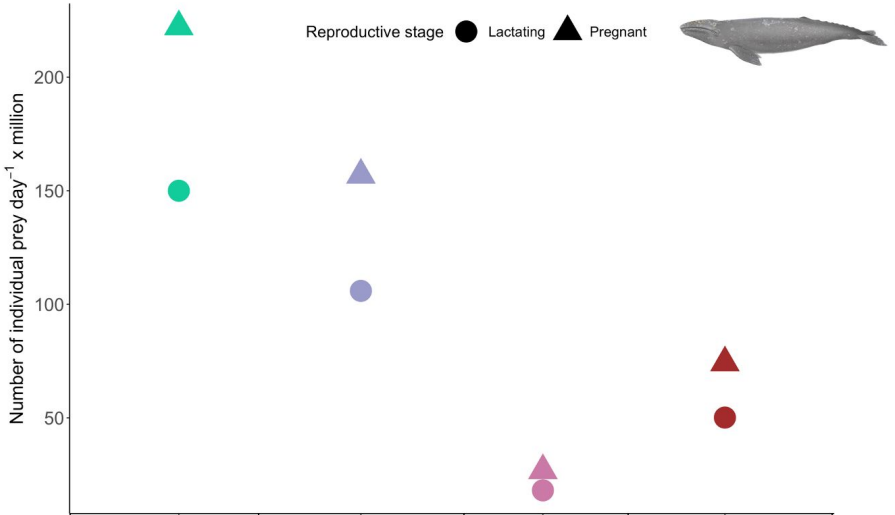
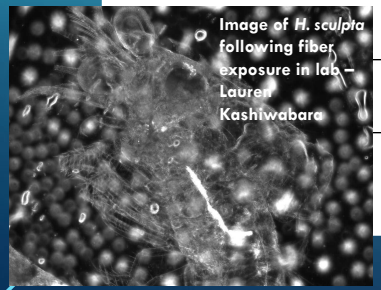
TROPHIC TRANSFER, FOOD WEB IMPACTS

Zoop to poop



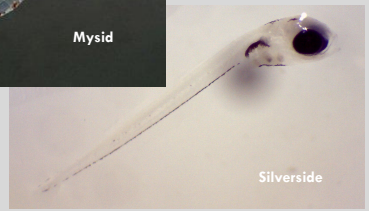


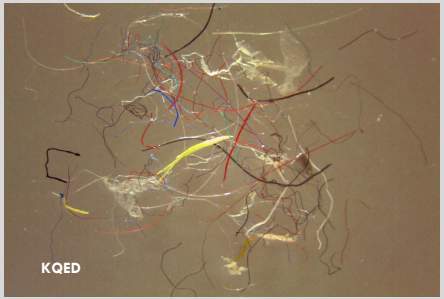


	Atylus tridens	*Holmesimysis sculpta*	*Neomysis rayii*	Composite preyscape
Microparticles per individual prey	0.10	0.09	0.40	0.2
Microparticles ingested by lactating gray whale per day	14.3 million	9.03 million	6.45 million	8.97 million
Microparticles ingested by pregnant gray whale per day	21.2 million	13.4 million	9.55 million	13.3 million

Hildebrand et al. 2021; Torres, Brander et al. 2023

RESPONSES TO MICROPLASTICS – A FOCUS ON FIBERS

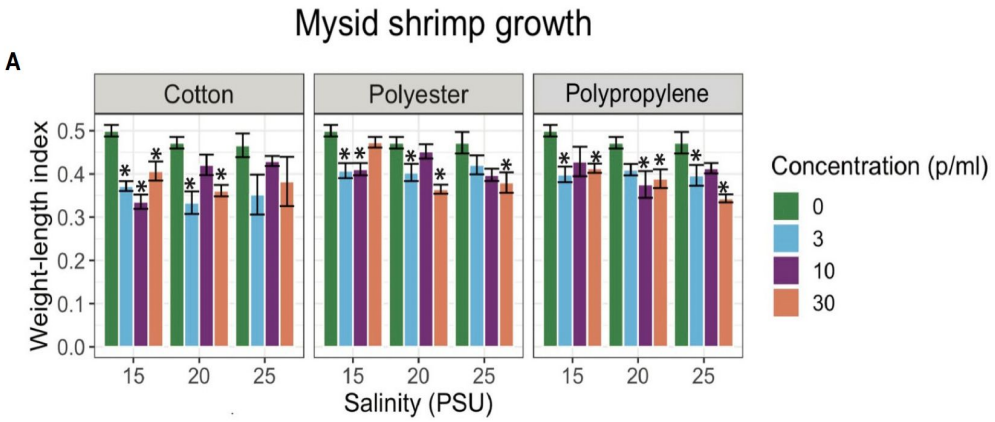




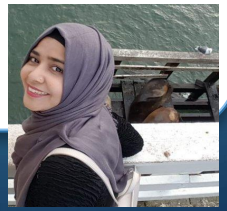
Bucci et al. 2021, Steinbarger et al. 2021, Carney Almroth et al. 2020, Jacob et al. 2020, Bucci et al. 2019, Covernton et al. 2019, Choi et al. 2018, Qiao et al. 2019, Ziajahromi et al 2017, Koelmans et al. 2015, Velzeboer et al. 2014

- Fibers may be more toxic and more easily transported
- Our work uses EPA whole effluent toxicity model species: mysid shrimp and silversides, these are reared in house and spawned to produce embryos and juveniles
- Fish are exposed from 5 days post hatch, and hatch out into exposure solutions, shrimp exposures begin at 7 days of age. Exposure timing follows EPA guidelines.
- Fibers are made to size from a variety of materials (e.g. nylon, polyester, cotton) using a cryostat and confirming material type via FTIR, and properties via scanning electron microscopy.

BOTH SYNTHETIC AND NATURAL TEXTILES CAN LIMIT GROWTH IN SOME SPECIES



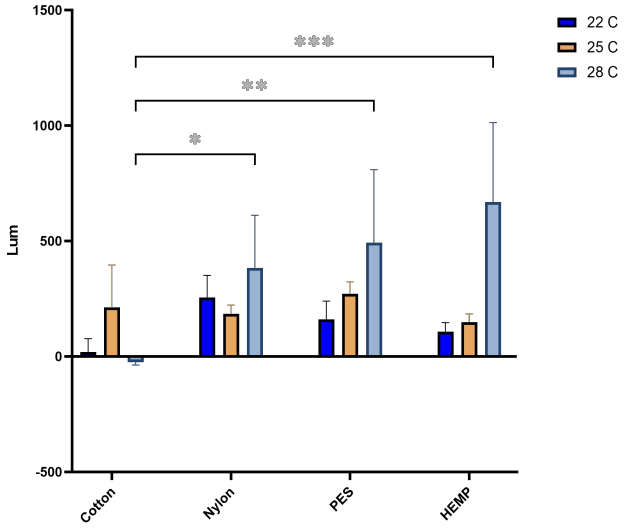
Siddiqui et al. 2023



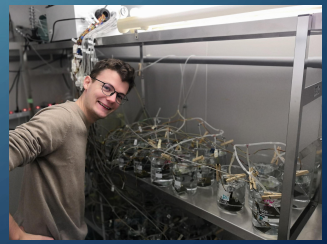
Cotton caused similar decreases in growth for mysid shrimp in comparison to polyester and polypropylene fibers. Silverside growth was not impacted by cotton (data not shown).

FIBERS

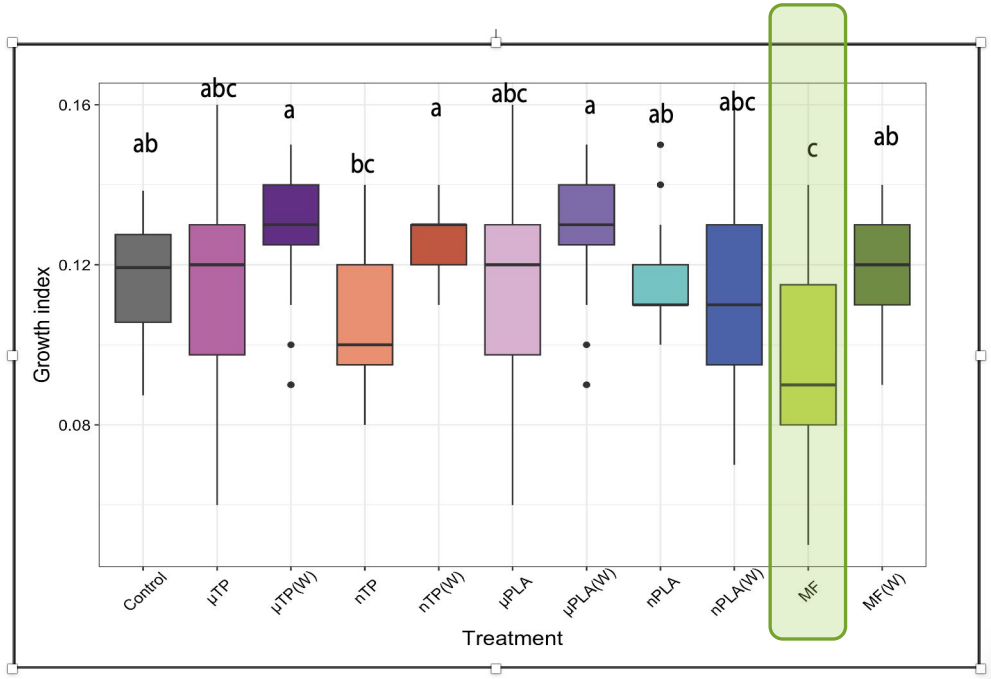
Biefel et al. in 2024



NATURAL IS USUALLY BETTER, BUT TEXTURE AND TEMP MATTER TOO FOR REACTIVE OXYGEN SPECIES PRODUCTION.



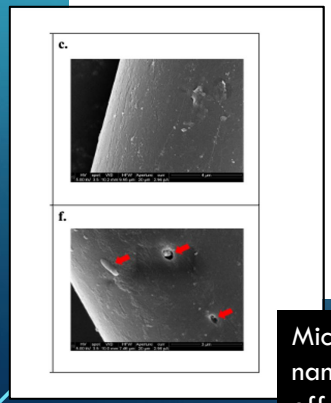
ACROSS PARTICLE TYPES



Hutton et al. 2024

New microfibers significantly reduce growth over 21 days in larval fish, some polylactic acid treatments overlap with microfibers and tire particles.

Weathered microfiber activated gene pathways similar weathered nano polylactic acid (bio-based)



Microscope image showing nano-sized particles breaking off from polyester fibers (Kashiwabara)

Top 15 upregulated pathways

Hutton et al. 2024

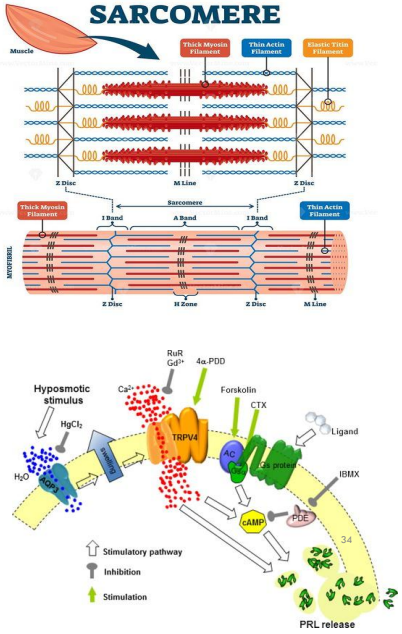
GENES RELATED TO MUSCLE FUNCTION, CELL SIGNALING, AND OSMOREGULATION WERE ENRICHED,

BUT ONLY FOR NANO-SIZED PLASTICS

CHANGES IN MUSCLE RELATED GENE PATHWAYS HAVE ALSO BEEN SEEN IN MAMMALIAN MODELS FOLLOWING MNP EXPOSURE

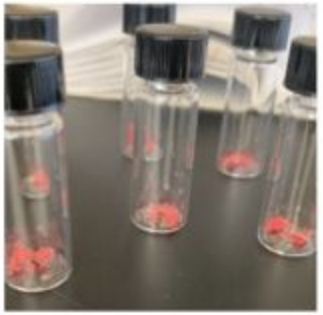
- Muscle function – Z disk, M band, sarcomerogenesis and organization, filament assembly, actin binding
- Calcium ion homeostasis
- Negative regulation of signal transduction
- HIF-1 signal transduction KEGG pathway was enriched in all MNP exposures

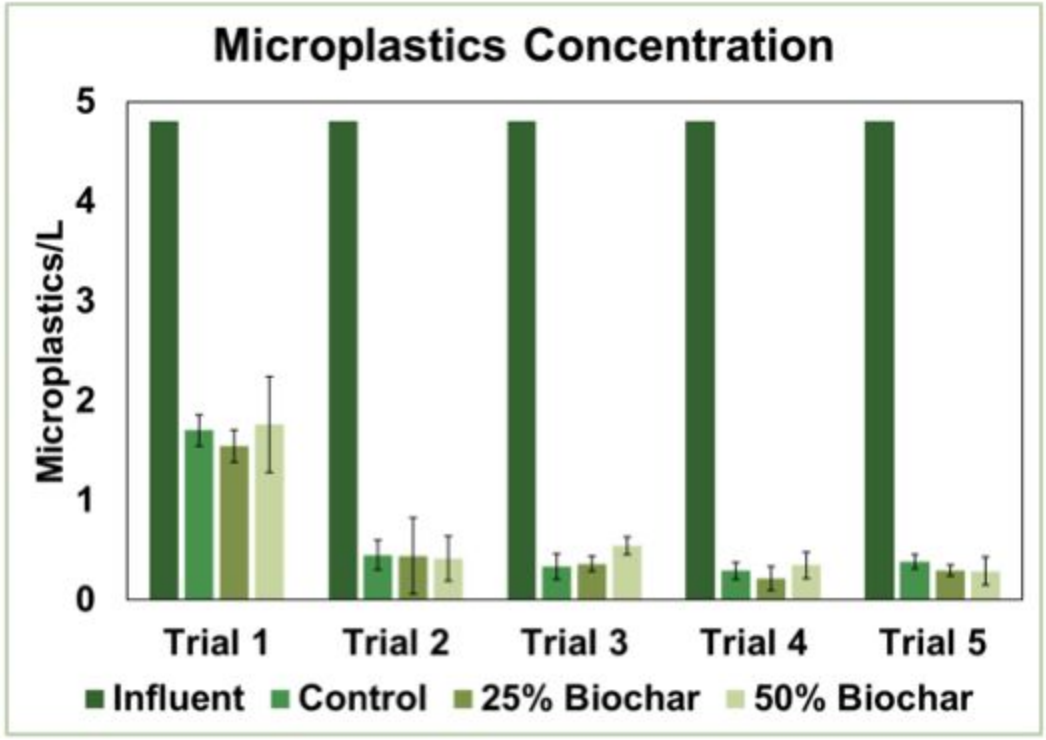
- Signal transduction events are critical to euryhaline species and osmoregulation



Persiani et al. 2023, Evan et al. 2021, Seale et al. 2012

Column studies – consistent MP removal





- High removal rates (99.8–100%)
- Particles found in top 4 in of media
- Mobilization from previous tests during wet/dry cycles
- Soil mixtures appear to contain microplastics; source of contamination

Struzak, Poor, and Wolfand. 2024. *Journal of Environmental Engineering.*