Microplastics: the state of the science in Pacific Northwest

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WA Chemical Policy Forum

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Portland State UNIVERSITY

Sea Grant Oregon

NSF

OSU: Susanne Brander and Stacey Harper
UP: Jordyn Wolfand, CJ Poor and students (UP),
PSU ACE lab

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

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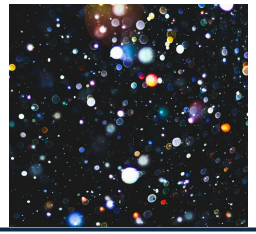
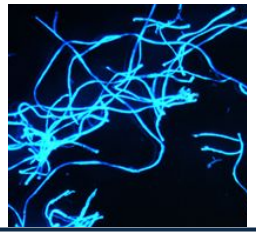
Microplastics: A Brief Primer

- Plastics 1 micron to 5mm in the longest dimension
- Shape, size, chemical composition variable
- Transport vectors for other contaminants
- MPs (microplastics) versus MFs (microfibers)
- Plastic content unregulated

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

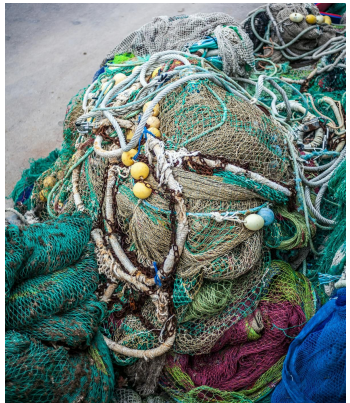
6.3 billion metric tons	Plastic waste generated globally by 2015
9%	of all plastic waste is recycled
~80%	Of all plastic waste enters the environment
170 million metric tons	Total estimated microplastic particles in the upper ocean and sediments.

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

Sources

- Cigarette butts (*#1 litter item globally*)
- Nets and ropes
- Road wear and tire/road
- Laundering and drying of textiles

www.pexels.com



Fiber Sources

If (conservatively)…

- 1 load = 750,000 synthetic MFs
- Portland metro= 2.2 million people
- 1 load/person/2 weeks
- WWTP 99% removal of MPs from gray water

Sudheshna et al. 2022; STotEn

THEN…

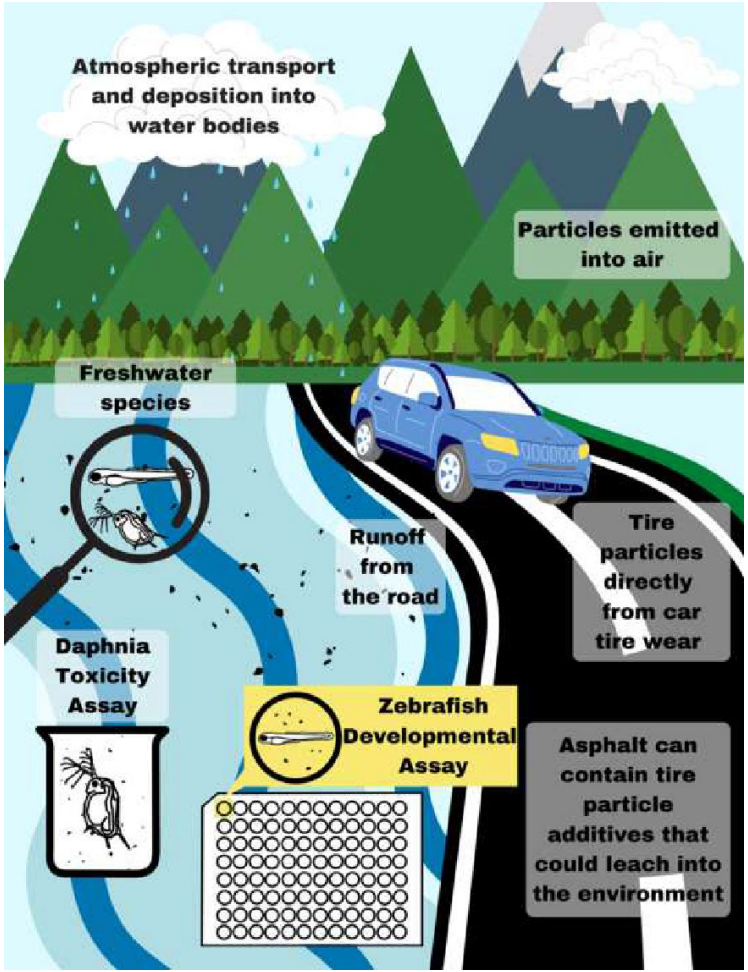
Portland Metro area releases

~429 billion MPs /year

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

Sudheshna et al. 2022; STotEn

Tire Wear Particles (TWPs)



(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) …**

  = 15,000 Boeing 757
- **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

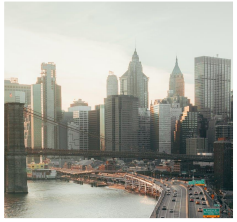
Terrestrial environments

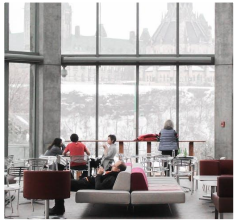
- Includes forests, beaches, urban areas
- Pathways: landfills, agriculture, tire wear

Airborne environments

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



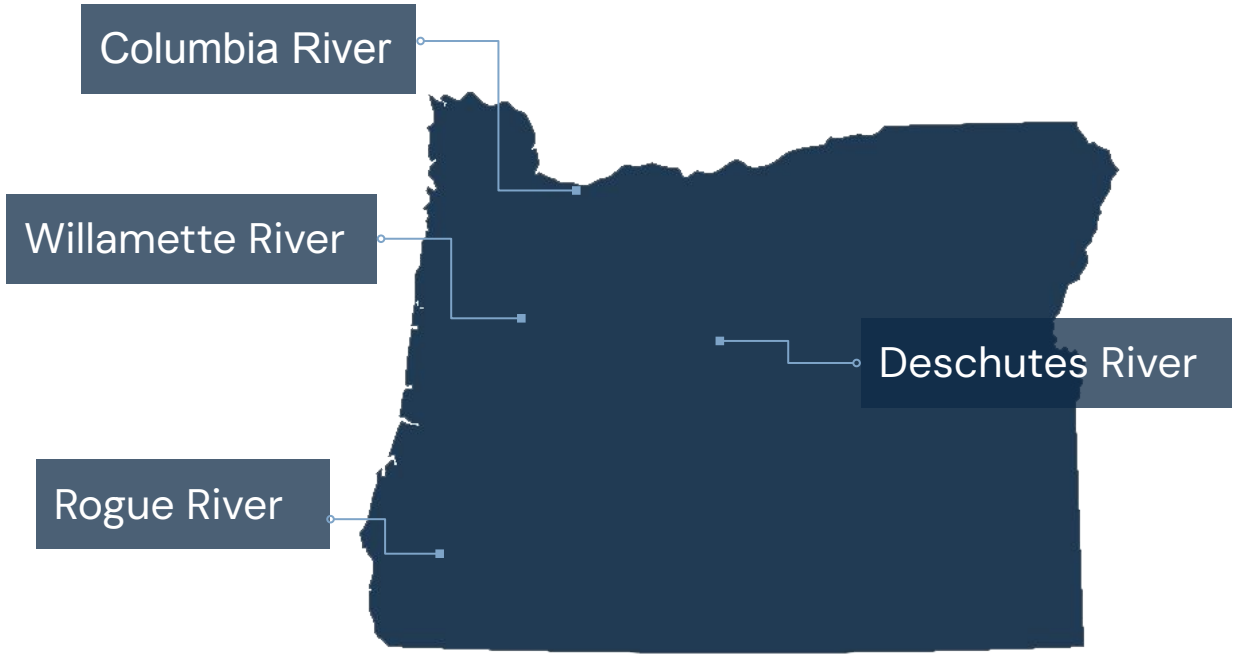


Periyasamy 2023; Geyer et al., 2022

MPs in Oregon

Rivers (Valine et al., 2020)

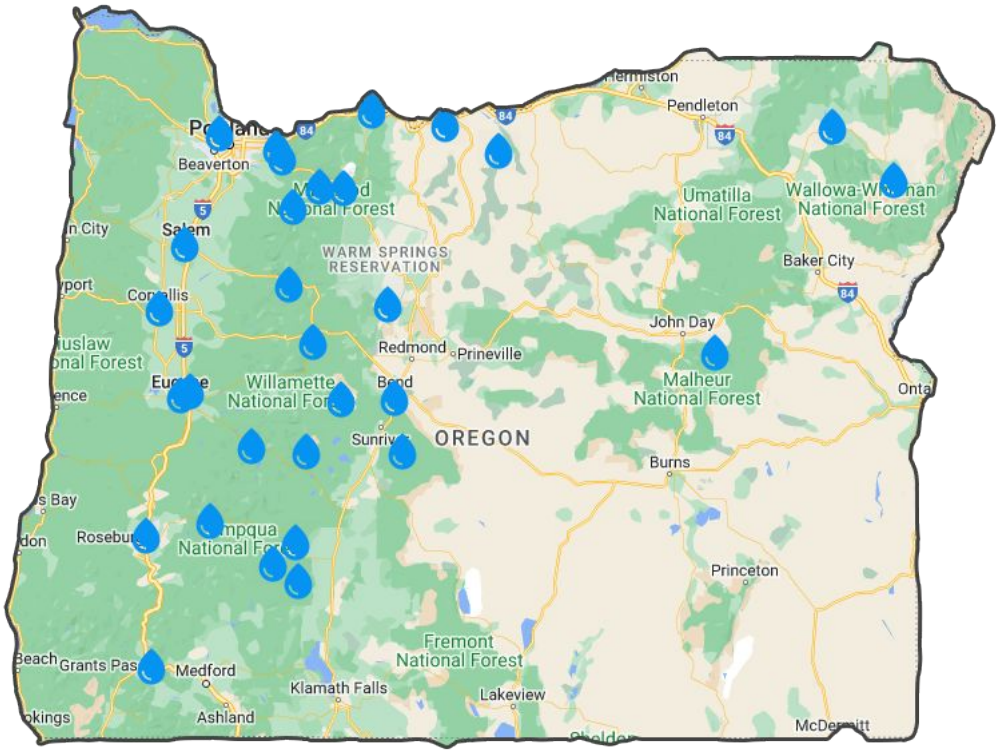
- Measured MPs in 4 Oregon rivers
- All sites were contaminated, including rural sites with pop. = 0
- Projected flow:
  - 144 to 2.9 million microfibers/h
  - 48 to 122,000 microparticles/h



MPs in Oregon

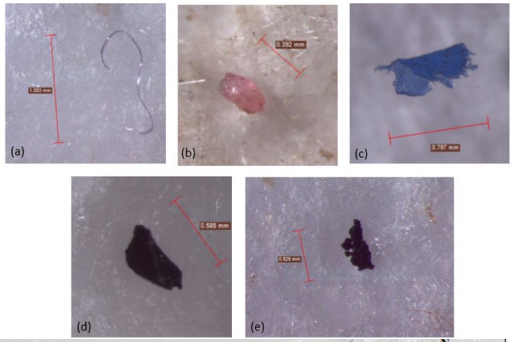
Lakes, Rivers, and Urban Waterways
(EORPC, 2021)

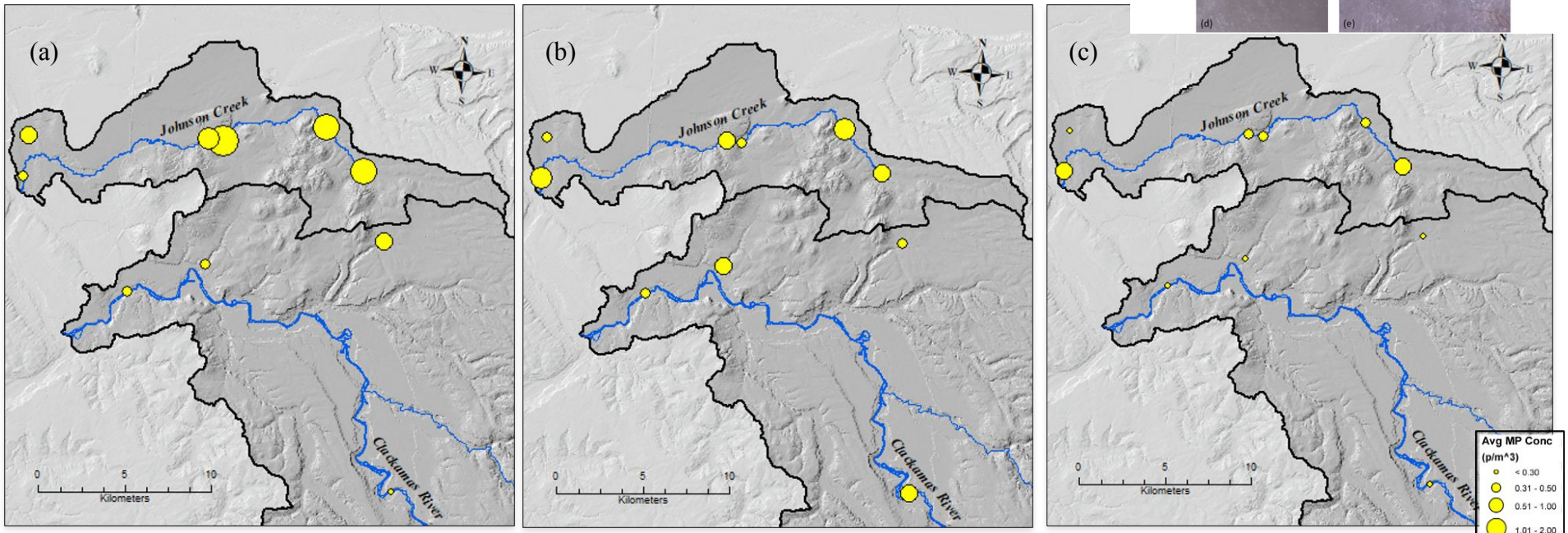
- Measured MPs at 30 sites across Oregon
- 100% of sites contaminated
- Microfibers most prevalent



Spatial and temporal variations of microplastics in Portland's waterways

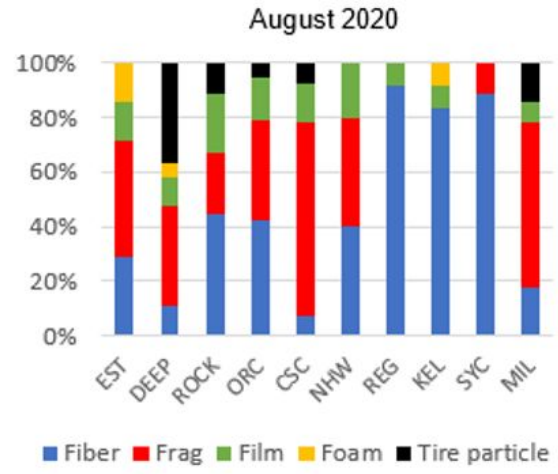
Rebecca Talbot, Elise Granek, Heejun Chang, Rosemary Wood, Susanne Brander (*STotEn* 2022)

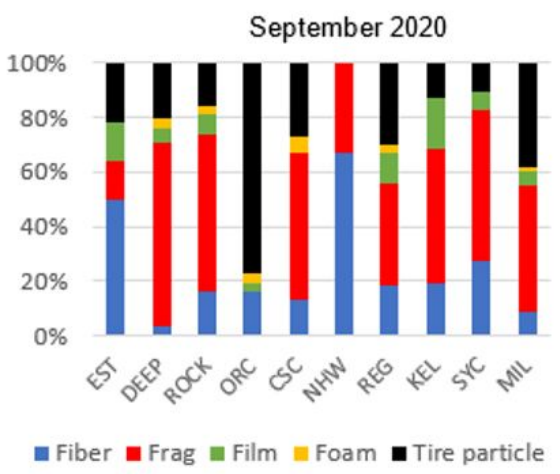


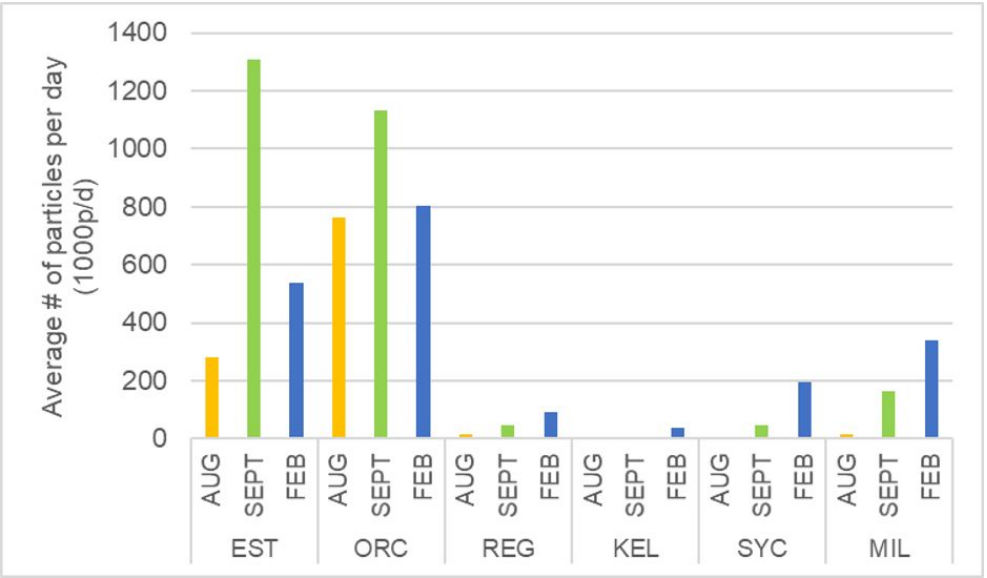


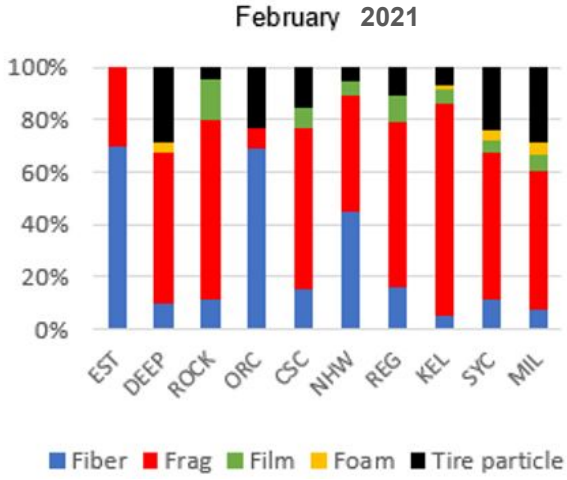
Microplastic concentrations at Johnson Creek and Clackamas River, OR monitoring sites in: (a) August, 2020 (b) September, 2020 and (c) February, 2021.

Portland Metro area rivers









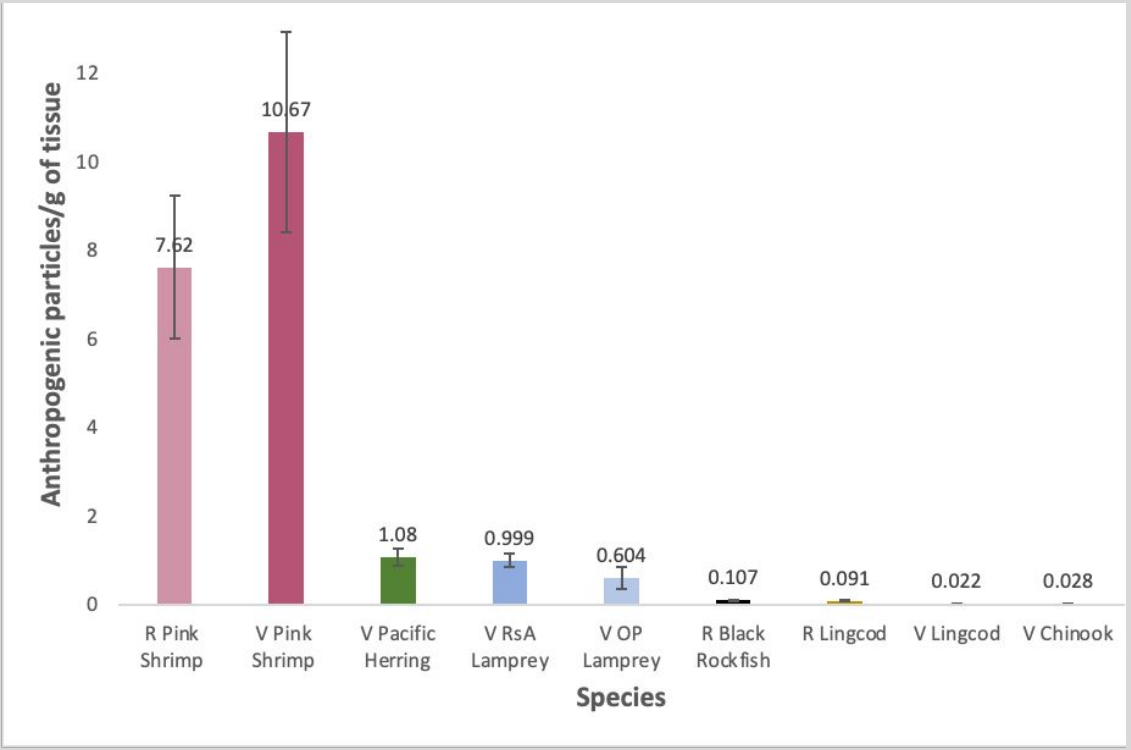
Microparticles from Oregon's ocean to table

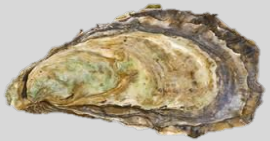
Baechler et al. 2020 L.O. Letters; Traylor et al. 2024 Toxicology

https://newportoregonfishingcharter.com/newport-charter-insight

Pacific oyster, razor clam, pink shrimp, lamprey, Pacific herring, Black rockfish, Lingcod, Chinook salmon

Per gram of Oregon harvested seafood



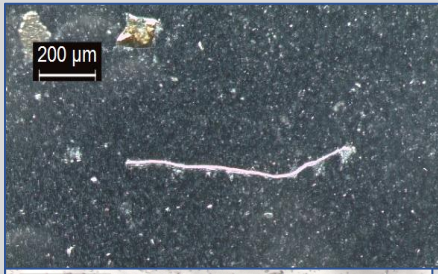


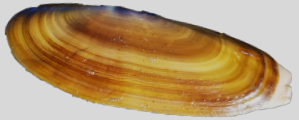
0.35 ± 0.04

MP/g

10.95 ± 0.77

MP/oyster



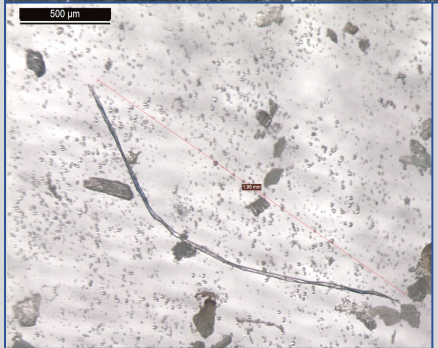


0.16 ± 0.02

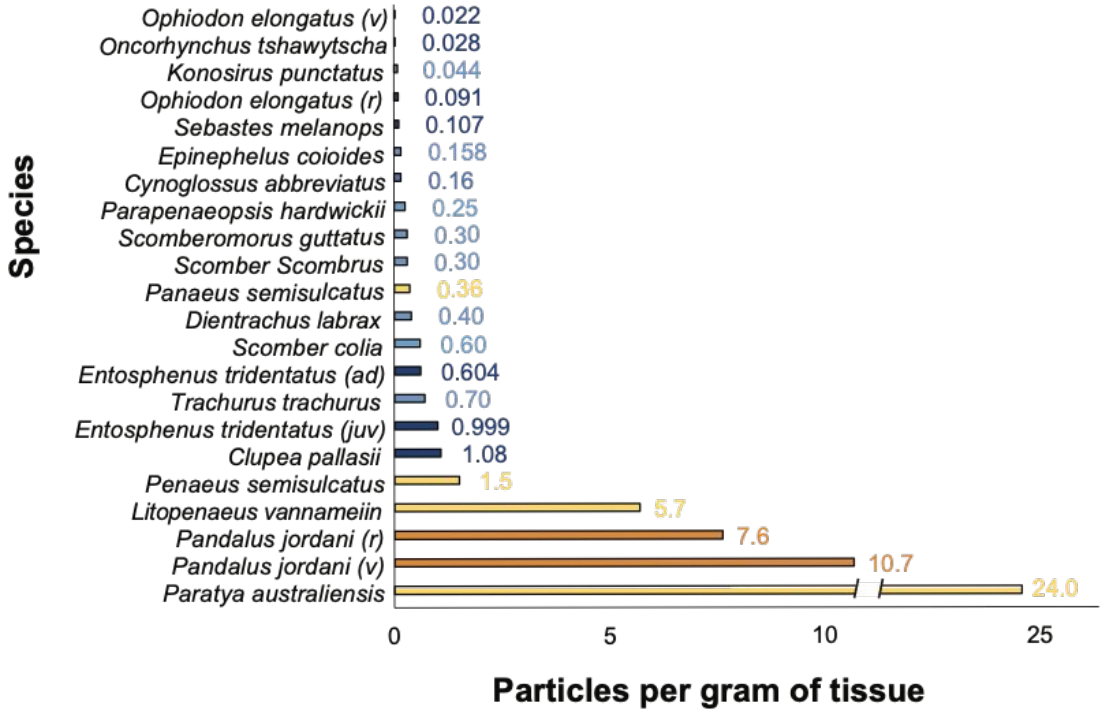
MP/g

8.84 ± 0.45

MP/clam



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:

- **Oregon shrimp (dark orange)**
- **Oregon fish (dark blue) tissue**
- **other shrimp (orange) and fish (blue) globally.**

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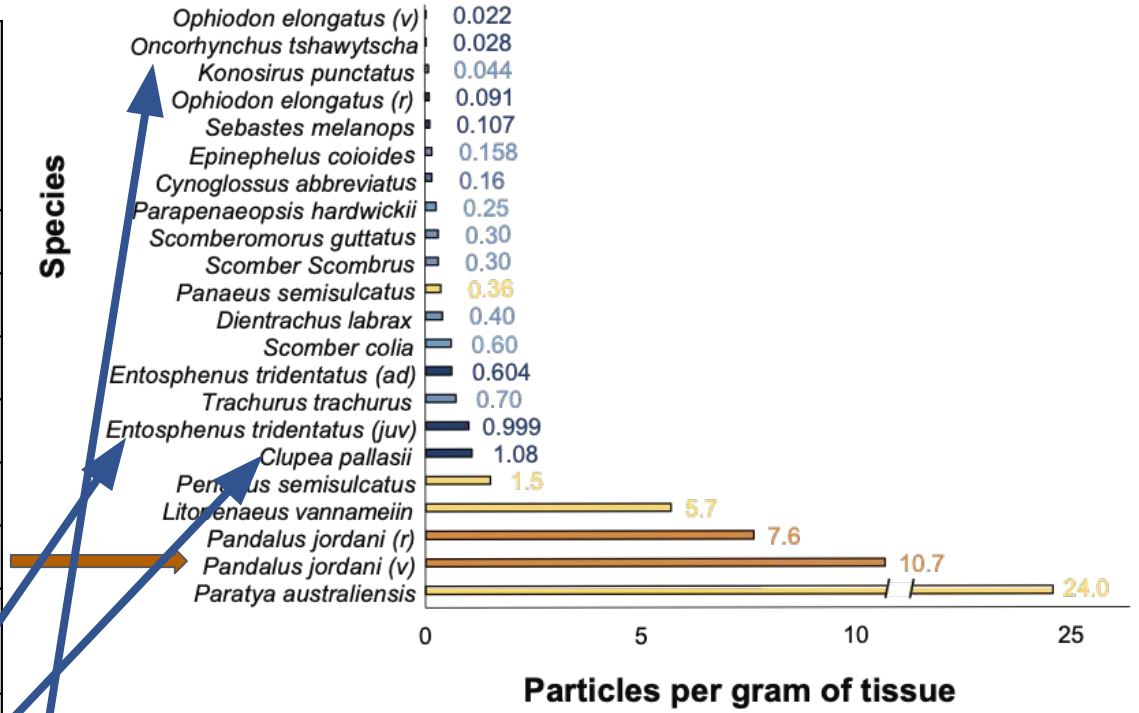

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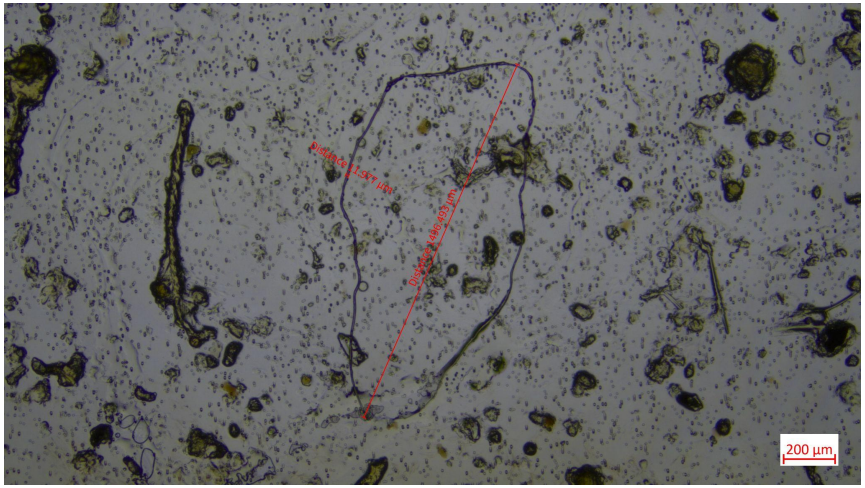
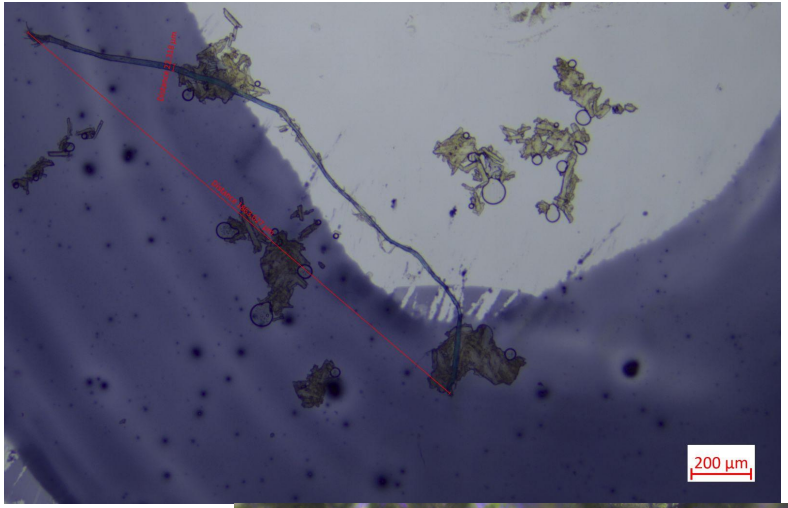
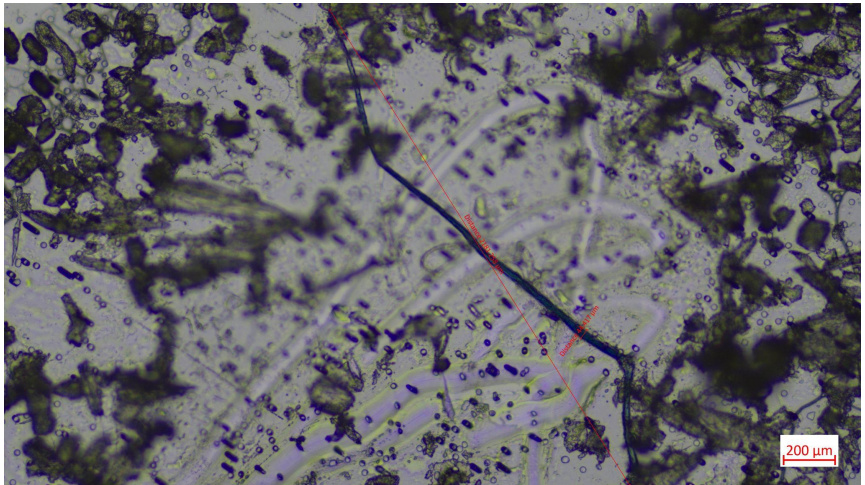
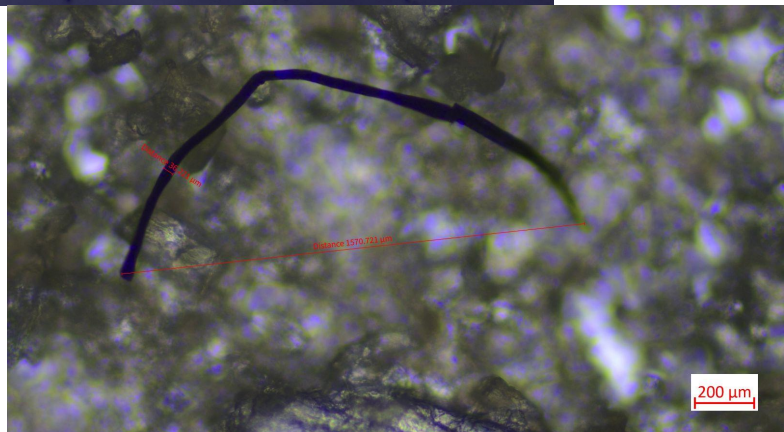
Microfibers in Pacific herring (left) and lingcod (right)









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., 2020; Baechler et al., 2020; Lasdin et al., 2023; Traylor et al. 2025

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

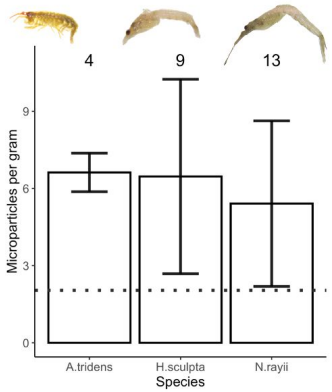
Exposure can lead to lower fertility, embryonic maldevelopment, and slower growth.

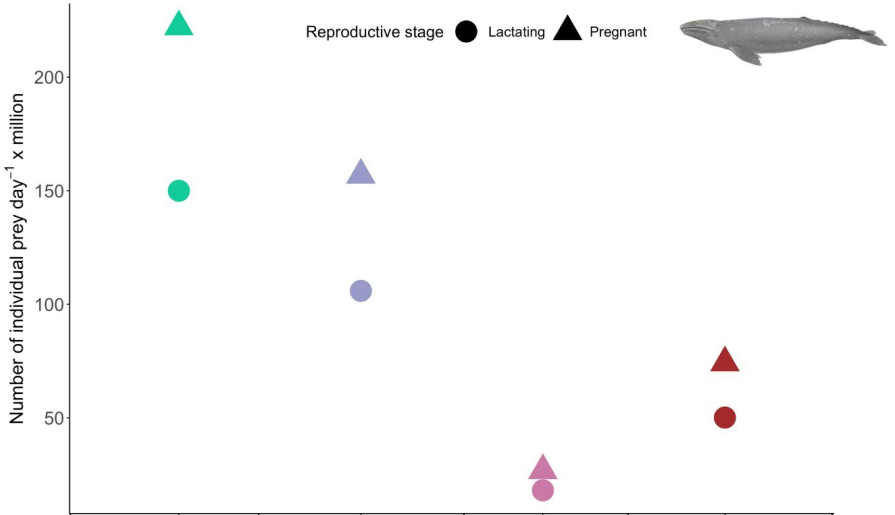
Physical and chemical effects

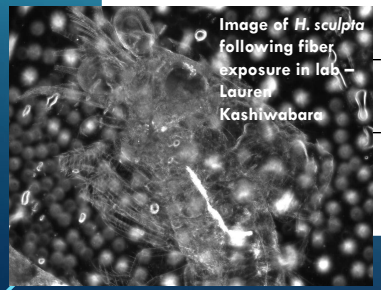
Doyle et al., 2022; Wright et al., 2013

TROPHIC TRANSFER, FOOD WEB IMPACTS

Zoop to poop

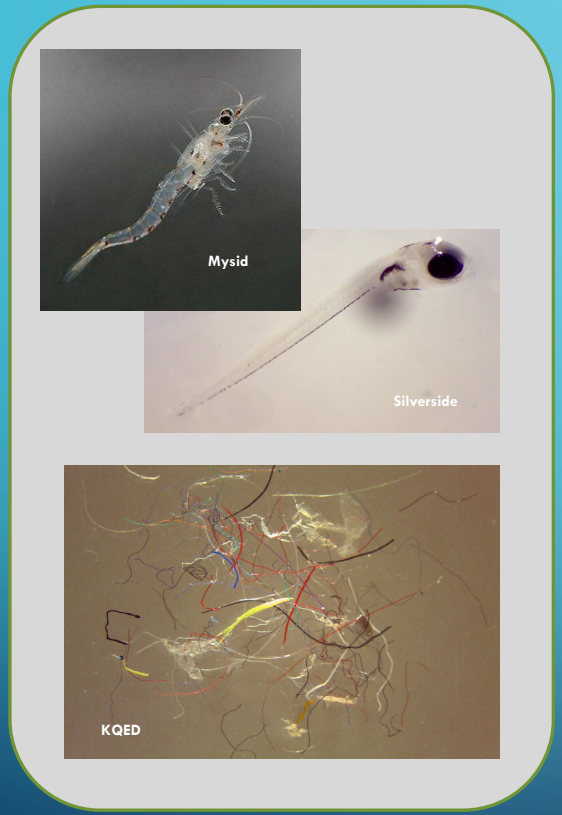






	Atylus tridens	*Holmesimysis sculpta*	*Neomysis rayii*	Composite preyscape
Microparticles per individual prey	0.10	0.09	0.40	0.2
Microparticles ingested by lactating gray whale per day	14.3 million	9.03 million	6.45 million	8.97 million
Microparticles ingested by pregnant gray whale per day	21.2 million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

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

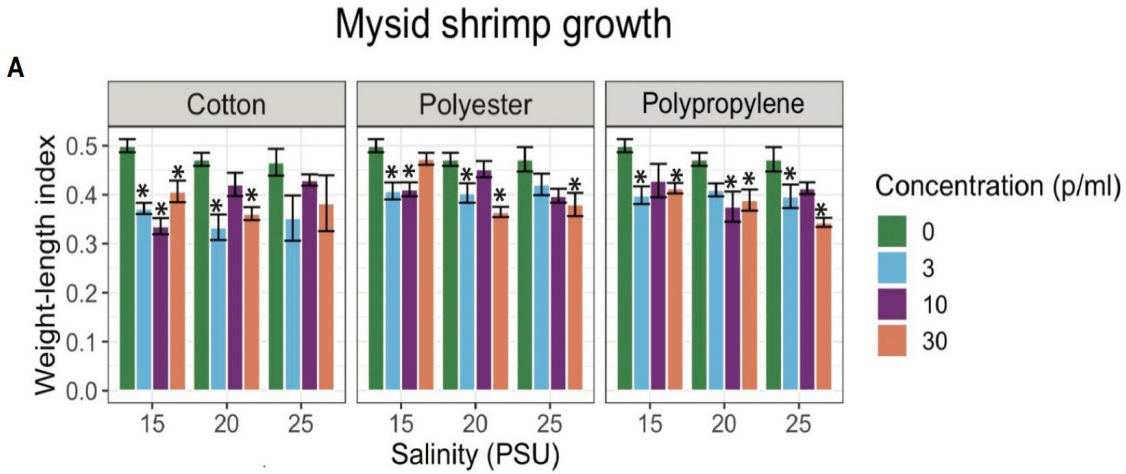


Bucci et al. 2021, Steinbarger et al. 2021, Carney Almroth et al. 2020, Jacob et al. 2020, Bucci et al. 2019, Caverntton et al. 2019, Choi et al. 2018, Qiao et al. 2019, Ziajahromi et al 2017, Koelmans et al. 2015, Velzeboer et al. 2014

RESPONSES TO MICROPLASTICS – A FOCUS ON FIBERS

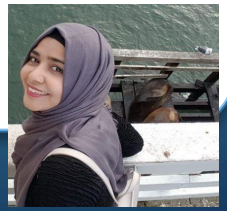
- Fibers may be more toxic and more easily transported
- Our work uses EPA whole effluent toxicity model species: mysid shrimp and silversides, these are reared in house and spawned to produce embryos and juveniles
- Fish are exposed from 5 days post hatch, and hatch out into exposure solutions, shrimp 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



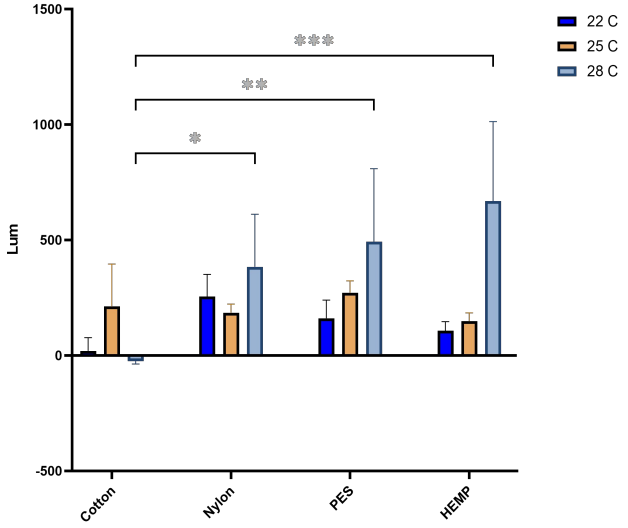
Siddiqui et al. 2023

- Cotton, polyester and polypropylene fibers decreases mysid shrimp growth.
- Silverside growth not impacted by cotton (data not shown).

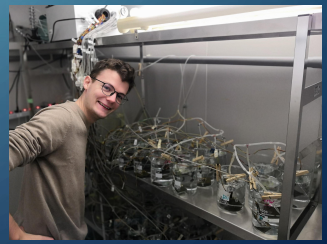


FIBERS

Reactive Oxygen Species

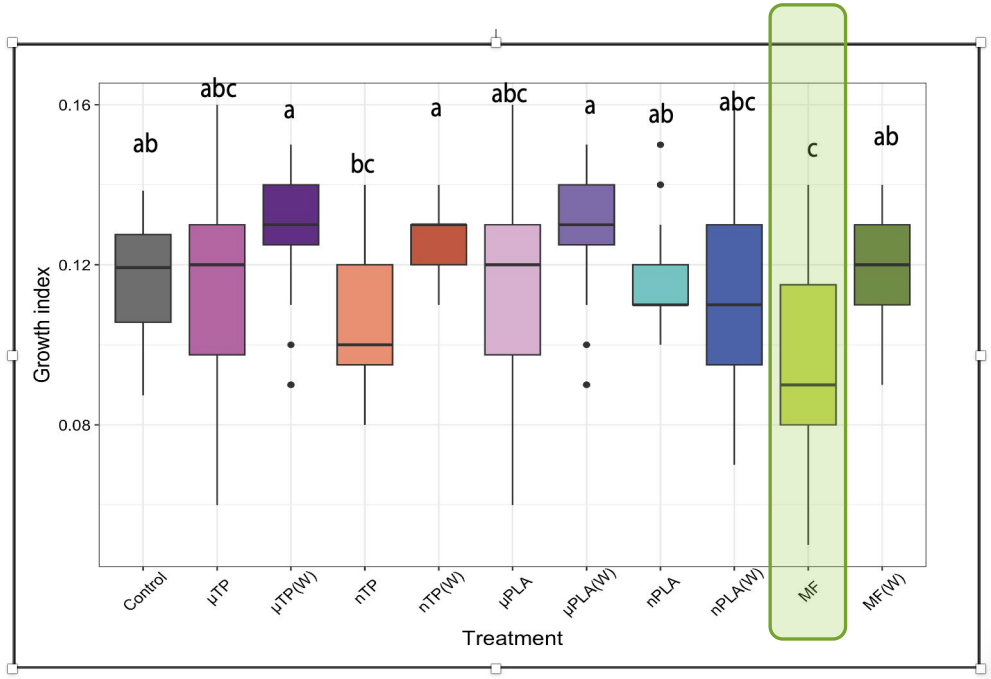


NATURAL IS USUALLY BETTER, BUT TEXTURE AND TEMP MATTER TOO FOR REACTIVE OXYGEN SPECIES PRODUCTION.



Biefel et al. in 2024

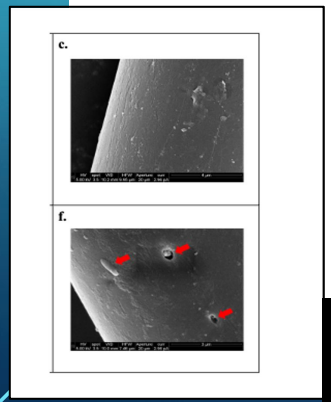
ACROSS PARTICLE TYPES



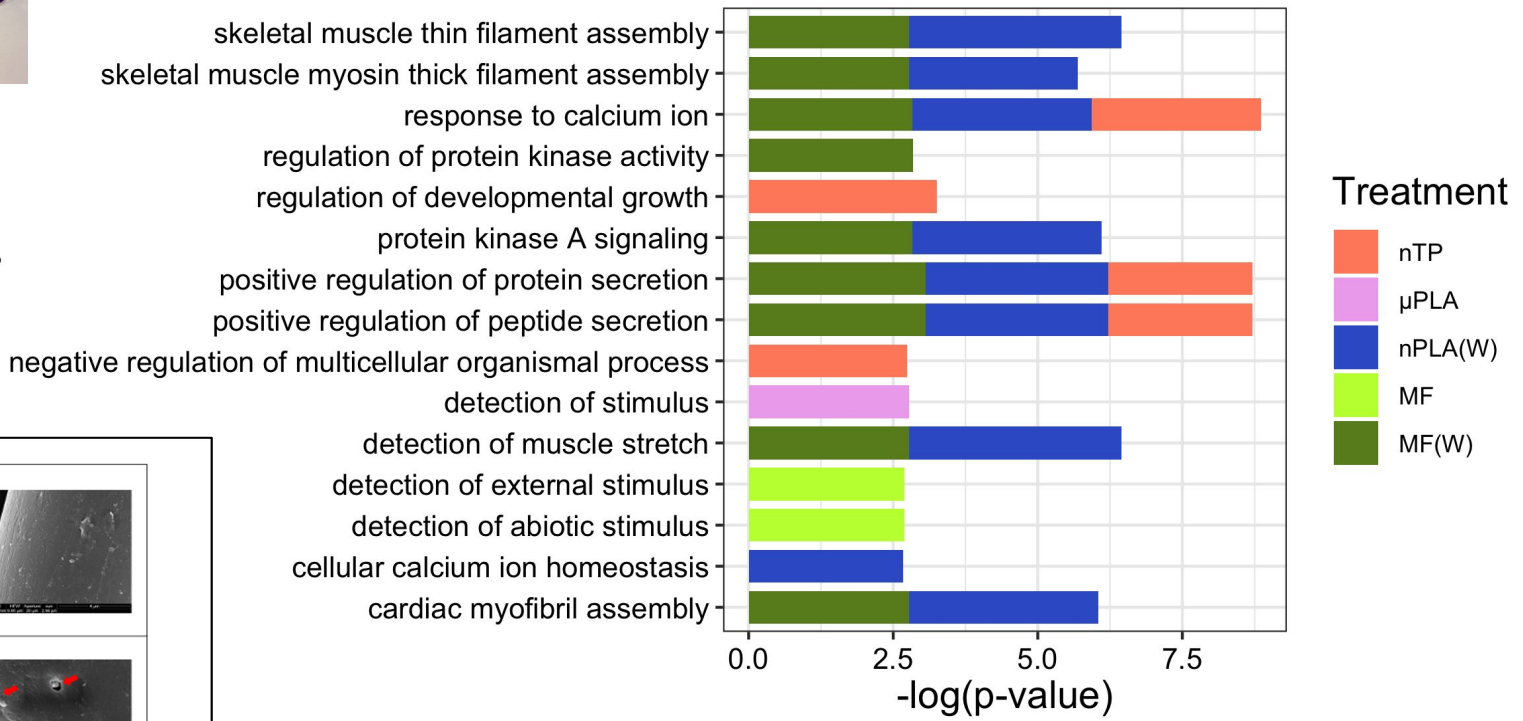
Hutton et al. 2024

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

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



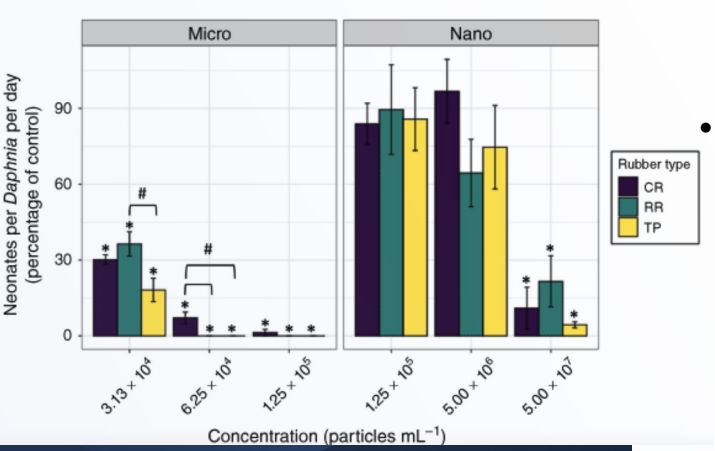
Microscope image showing nano-sized particles breaking off from polyester fibers (Kashiwabara)



Top 15 upregulated pathways

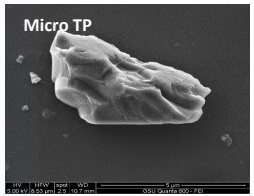
Hutton et al. 2024, Frontiers in Tox

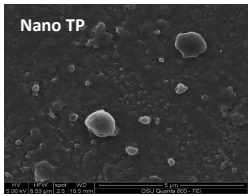
IMPACTS FROM TIRES, RECYCLED RUBBER, CRUMB RUBBER



- Sublethal concentrations of 3 rubber types reduced reproduction.
  (# of neonates produced/*Daphnia*/day + time to reproduction).

- All concentrations of micro- rubber particles (TPs, RR and CR) decreased neonate production compared to controls.
  (Daphnia from parents exposed to nano-TPs took significantly longer to reproduce)





Cunningham et al., 2024, *Env Chemistry*

Tire wear mixture weathered

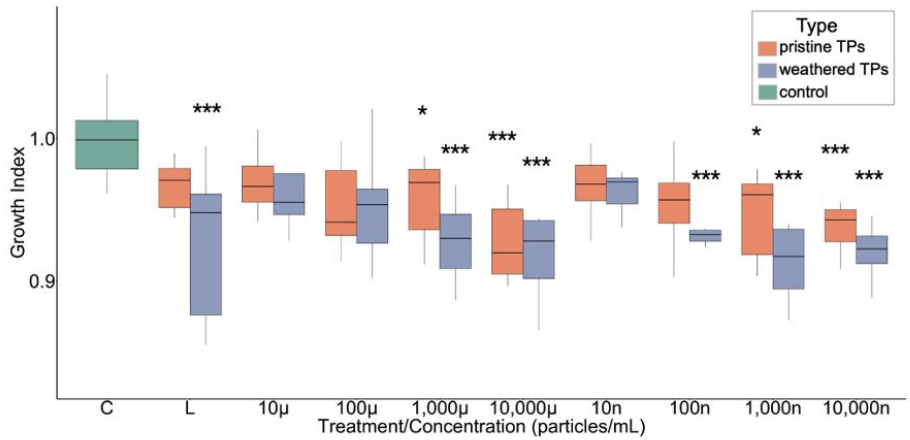
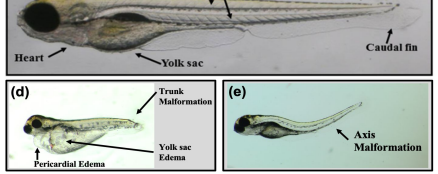


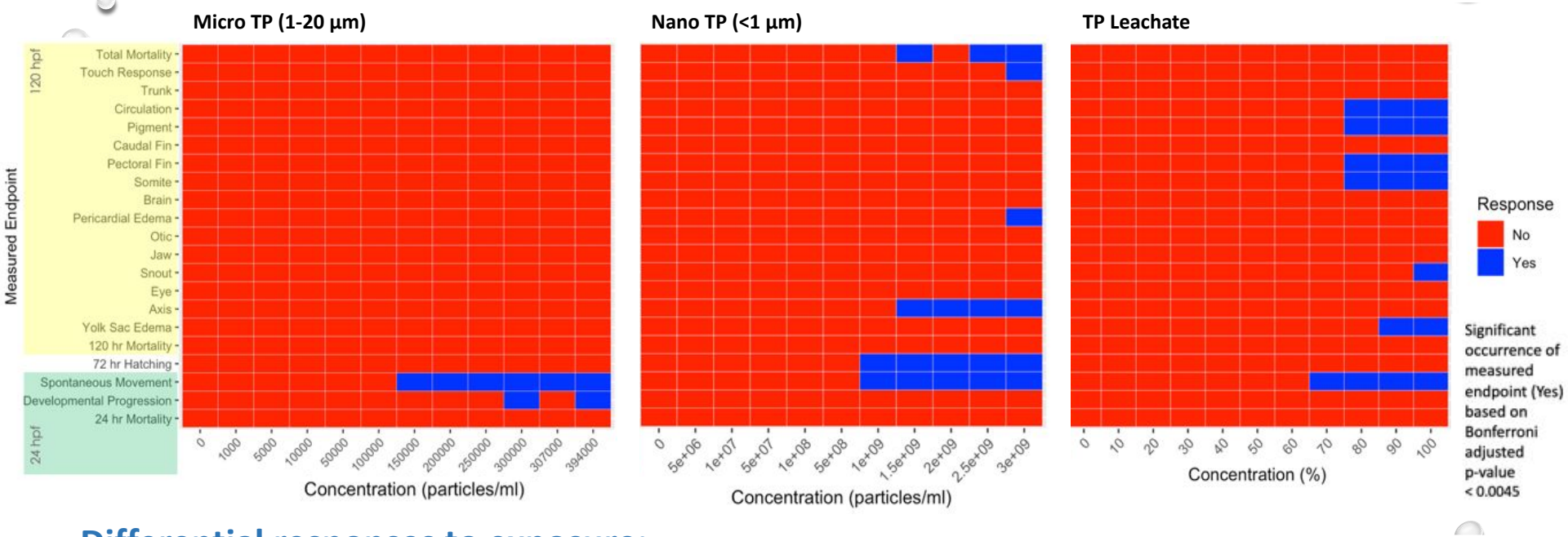
Figure 2: Growth index of *A. bahia* across varying concentrations of pristine and weathered micro- and nano-TPs and leachates. Concentrations ranged from 10 to 10,000 particles/mL. Asterisks indicate significant differences compared to the control group (*$p < 0.05$, ***$p < 0.001$). Abbreviations: L = leachate, C = control, µ = micro, n = nano.

- Animals exposed to weathered tire particles,
- New versus weathered particles
- Weathered particles more readily ingested and greater impact on growth.

Raguso et al. in review, *Jr. Haz. Mat.*

Zebrafish TP Effects Heatmaps





Differential responses to exposure:

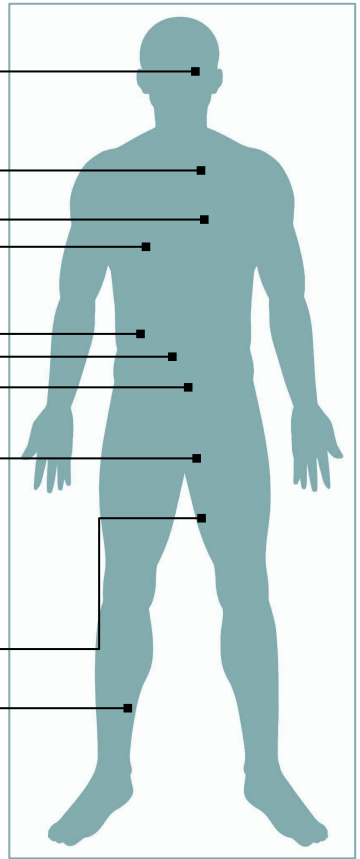
- All exposures led to a decrease in spontaneous movement and some malformations
- Only the micro-fraction had significant developmental delays
- Only the nano-fraction significantly increased mortality and delayed hatching

Cunningham et al., 2022, *Jrnl Haz Materials*

Human health

Microplastics found in…

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



Microplastics linked to…

- Dementia
- Cardiovascular disease (heart attack, stroke)
- Respiratory stress
- Gut inflammation
- Increased cancer risk (e.g., colon)
- Premature births
- 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

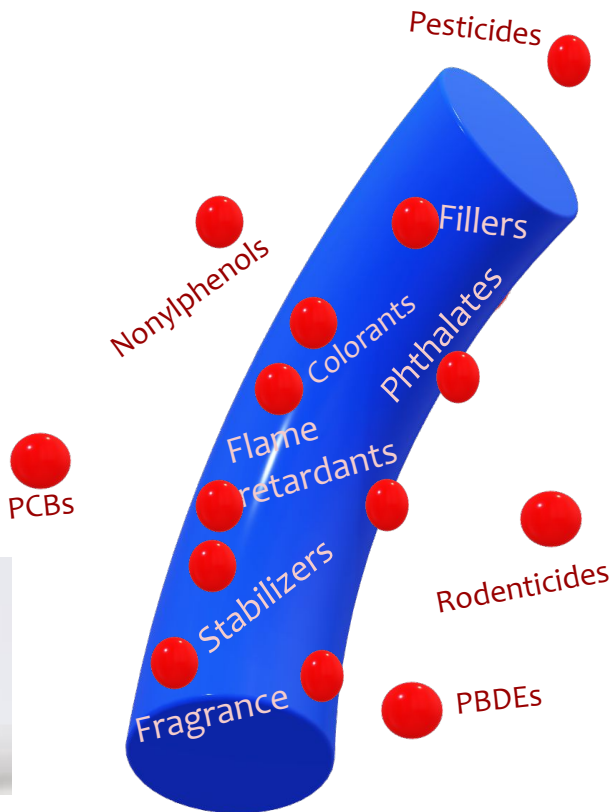
Research, Regulations, Management

Research

- Multiple stressor effects (plastics + pesticides + pharmaceuticals +...)
- Safe alternatives (avoiding regrettable substitutions)
- **Collaboration and standardization
- Baseline data for TMDLs (plastics, microplastics)
- **Efficacy of solutions**
- Developing new alternatives (e.g., 6PPD-q)

Regulations and Management

- Reduce plastic production
- Regional regulatory actions
- Increase accessibility of consumer alternatives
- **Scaling up existing alternatives**



https://www.linkedin.com/pulse/empowering-consumers-shifting-burden-navigating-epr-shrivastava-mw1gf/

https://www.yesihaveablog.com/going-plastic-free-reduce-your-plastic-waste/

Solutions

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

Check out microplastics brochure:

SCAN ME

Solutions

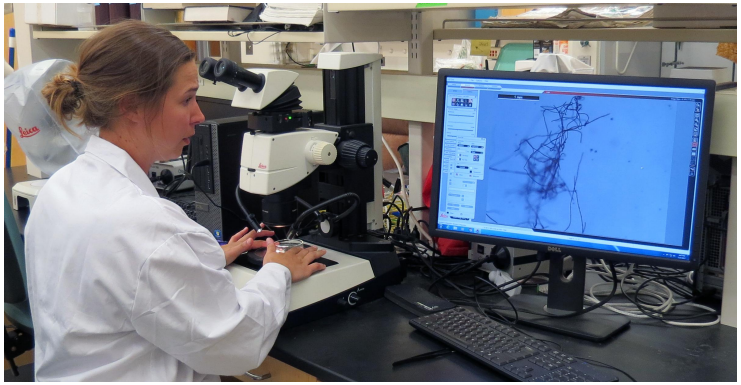
- Reduce plastic production
- Consumer choice
  - Toothpaste, floss, shampoo
  - Laundry and dish detergent
  - Co-ops, refilleries, farmer's markets
  - Take out containers
  - Avoiding fast fashion - longer
  - Launder less
  - Avoid laundry pods

Check out brochure:

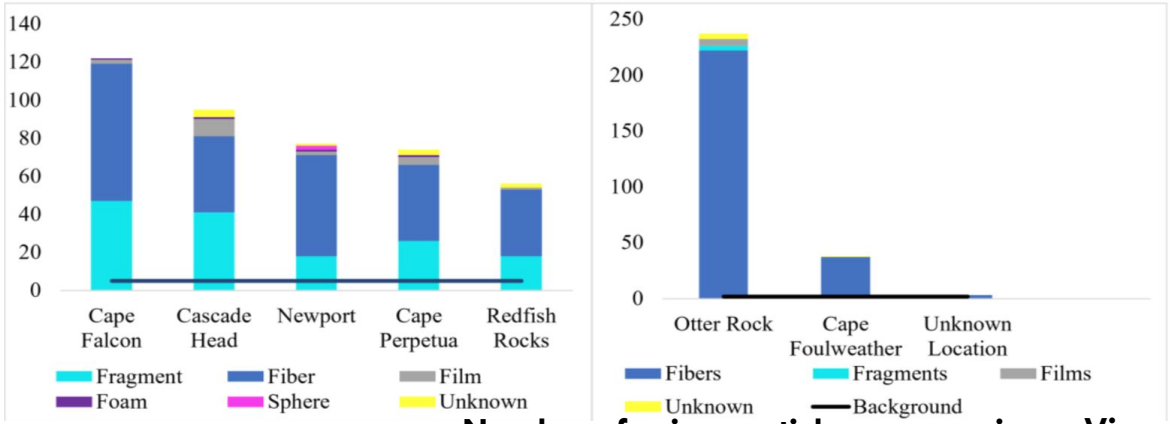
SCAN ME

SCAN ME

QUESTIONS?



OREGON ROCKFISH



Lasdin et al. 2023

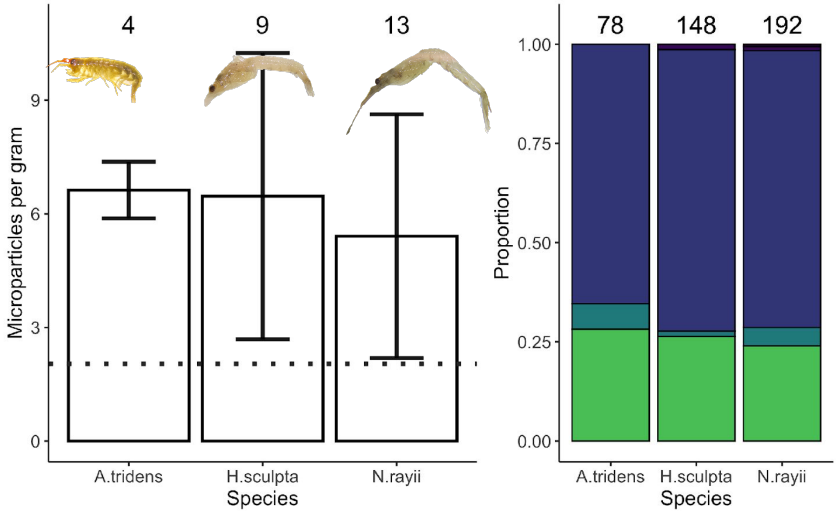
Number of microparticles per species

Visual shape

FTIR result

Lasdin et al. 2023

OREGON ZOOPLANKTON



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

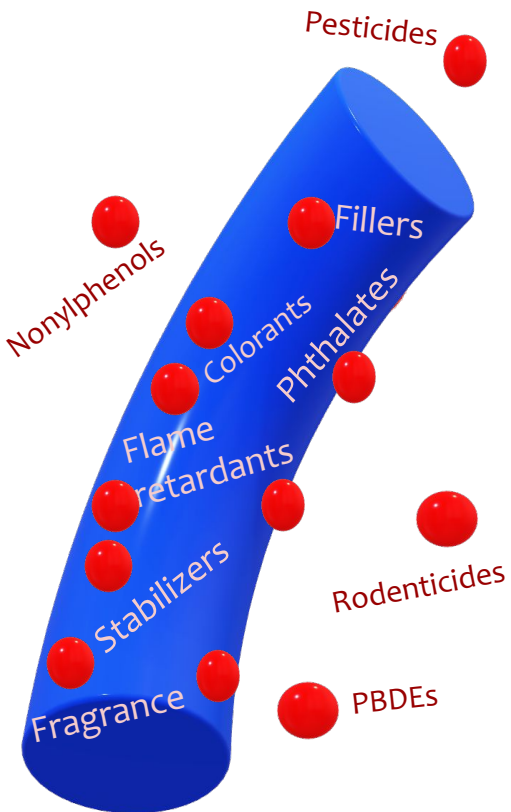
Research needs

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)

Questions and thoughts?



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Tire wear mixture weathered

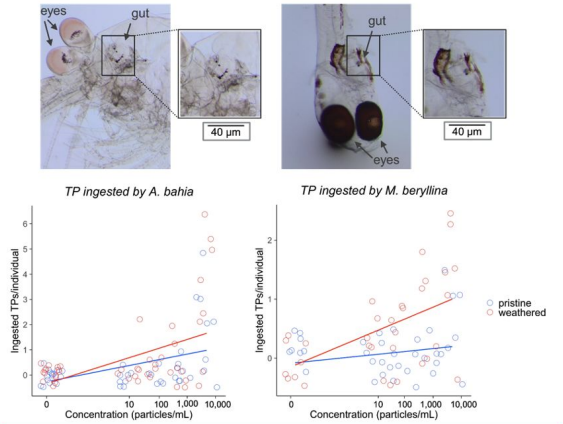


Figure 1: Top images show the gut contents of *A. bahia* (left) and *M. beryllina* (right), highlighting ingested TPs, captured using an Olympus SX10 microscope. The bottom panel presents the results of a Generalized Linear Model analysis, illustrating the relationship between TP concentration (pristine and weathered) and ingestion rates across treatment groups for both species.

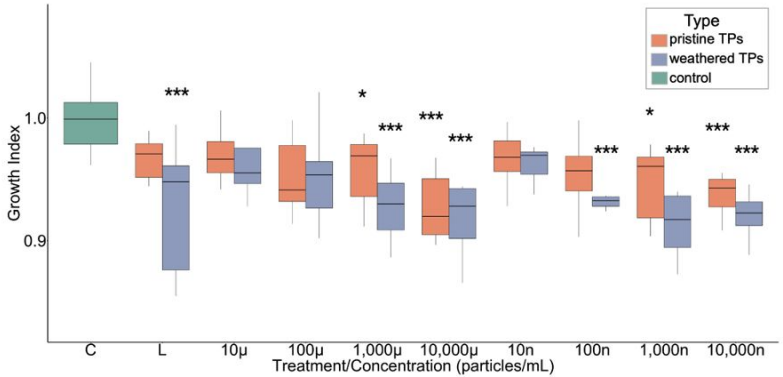
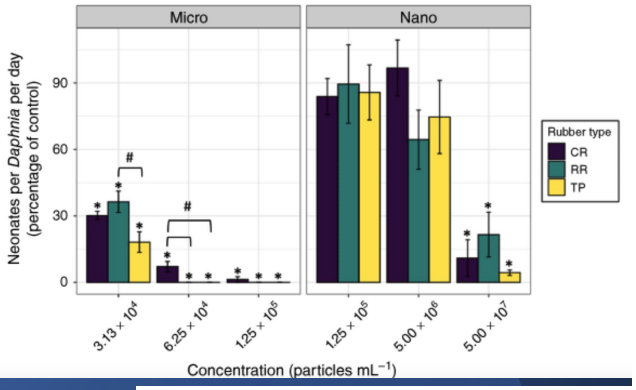


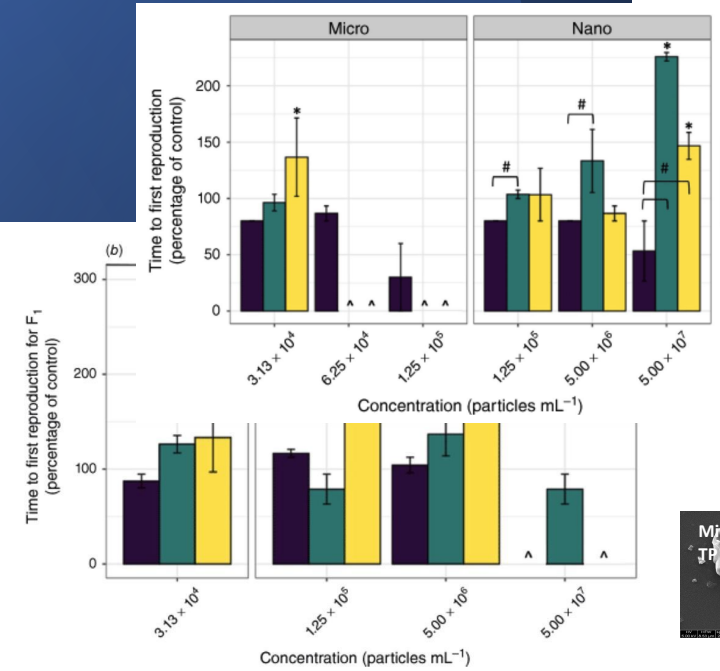
Figure 2: Growth index of *A. bahia* across varying concentrations of pristine and weathered micro- and nano-TPs and leachates. Concentrations ranged from 10 to 10,000 particles/mL. Asterisks indicate significant differences compared to the control group (*$p < 0.05$, ***$p < 0.001$). Abbreviations: L = leachate, C = control, µ = micro, n = nano.

- By the time organisms are exposed to tire particles, they are likely highly weathered, here we compared new to weathered particles from the same CMTT mixture.
- Weathered particles were more readily ingested and had a greater impact on growth.

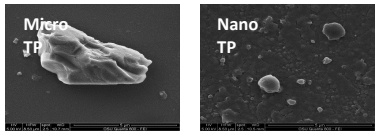
Raguso et al. in review, *Jr. Haz. Mat.*

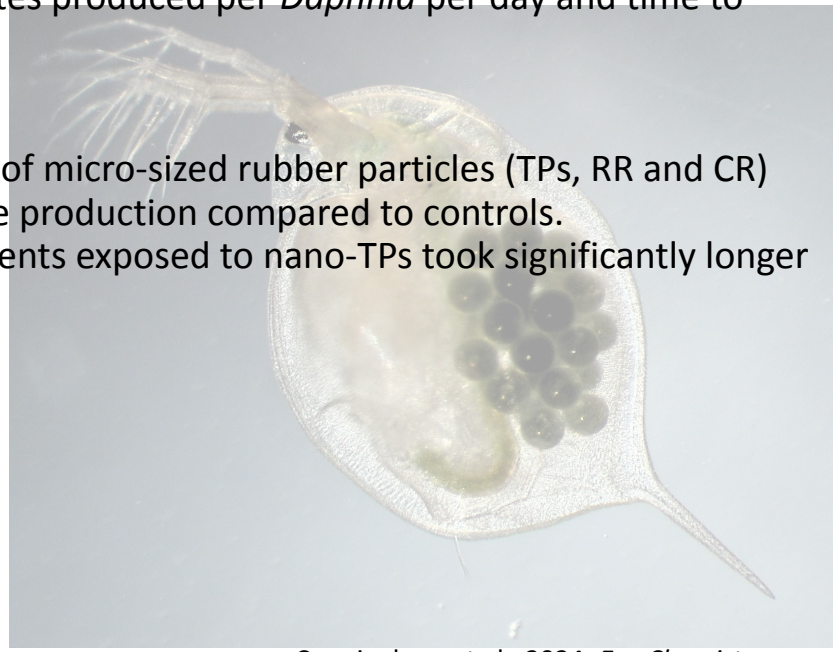
IMPACTS FROM TIRES, RECYCLED RUBBER, CRUMB RUBBER





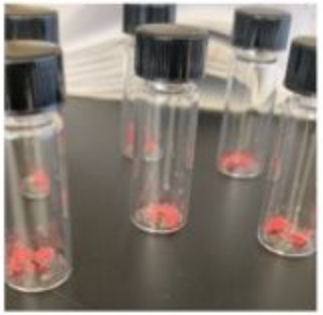
- Reproduction affected by sublethal concentrations of 3 rubber types. (number of neonates produced per *Daphnia* per day and time to reproduction).
- All concentrations of micro-sized rubber particles (TPs, RR and CR) decreased neonate production compared to controls. (Daphnia from parents exposed to nano-TPs took significantly longer to reproduce)

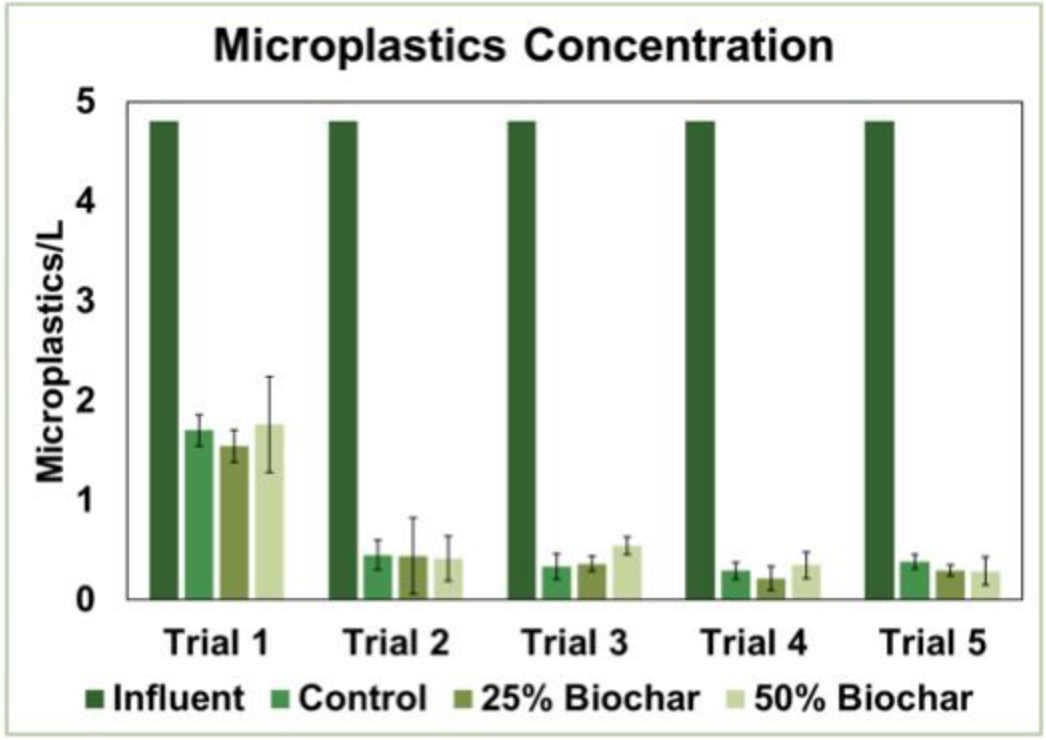




Cunningham et al., 2024, *Env Chemistry*

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.*