Spatial and Temporal Distribution and Sources of Marine Microplastics

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Funding provided by the NOAA Marine Debris Program

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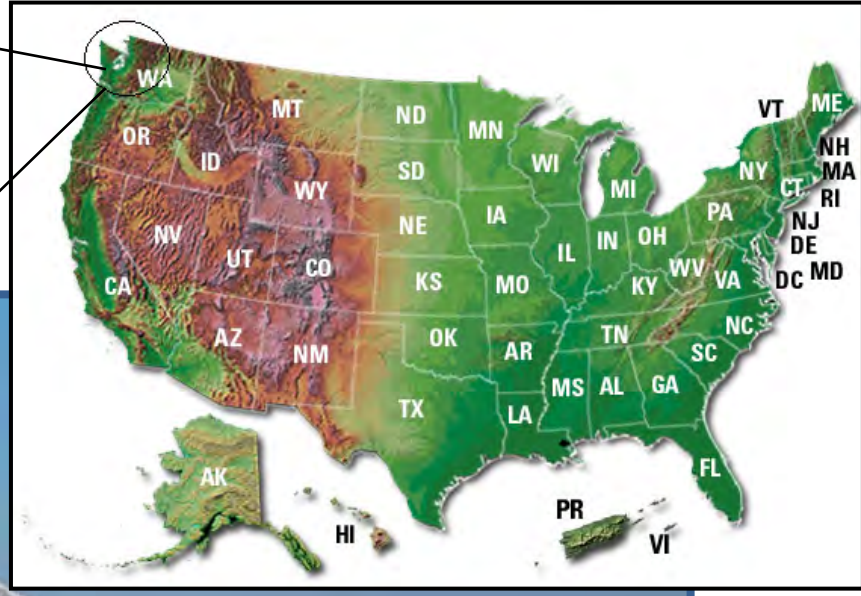
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"Trash Island" discovered in the Pacific Ocean

Pravda 24feb04

Berlin, February 24th. An entire "island" composed of trash has been discovered in the Pacific Ocean. It is as large as the Central Europe.

According to the German magazine "Geo", plastic objects prevail among the trash. The "island" weights approximately three million tons in its entirety. This is six times greater than a number of natural plankton.

Scientists claim that the "island", situated between California and Hawaiian islands, forms circular ocean currents which now accumulate wastes by the shores of Japan and the US and bring it to the center of the Ocean.

Floating, Texas-sized garbage patch threatens Pacific marine sanctuary

By John Timmer | Published: October 23, 2007 - 10:12PM CT

A looming environmental threat the size of Texas should be hard to miss, but when that threat is floating in a rarely-visited section of the Pacific Ocean and composed of a diffuse mass of plastic, it's easy for it to avoid public attention. The recent establishment of a marine preserve north of the Hawaiian Islands has refocused attention on this floating refuse heap, which has picked up the moniker the Great Pacific Garbage Patch.

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Continent-size toxic stew of plastic trash fouling swath of Pacific Ocean

Justin Berton, Chronicle Staff Writer
Friday, October 19, 2007

PRINT E-MAIL SHARE COMMENTS (192) FONT | SIZE: − + TOOLS SPONSOR: verizon wireless

At the start of the Academy Award-winning movie "American Beauty," a character videotapes a plastic grocery bag as it drifts into the air, an event he casts as a symbol of life's unpredictable currents, and declares the romantic moment as a "most beautiful thing."

IMAGES


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To the eyes of an oceanographer, the image is pure catastrophe.

In reality, the rogue bag would float into a sewer, follow the storm drain to the ocean, then make its way to the so-called Great **Pacific** Garbage **Patch** - a heap of debris floating in the **Pacific** that's twice the size of Texas, according to marine

and Hawaiian islands, forms circular ocean currents which now accumulate wastes by the shores of Japan and the US and bring it to the center of the Ocean.

Microplastics in Marine Waters

For today's talk:

1. What are the concentrations of microplastics and how are they distributed spatially?

2. How do levels of marine microplastics vary among studies?

3. What are the consequences of microplastics in the marine environment?

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Plastics in the Marine Environment

The **Oprah Winfrey** Show

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The Great Pacific Garbage Patch

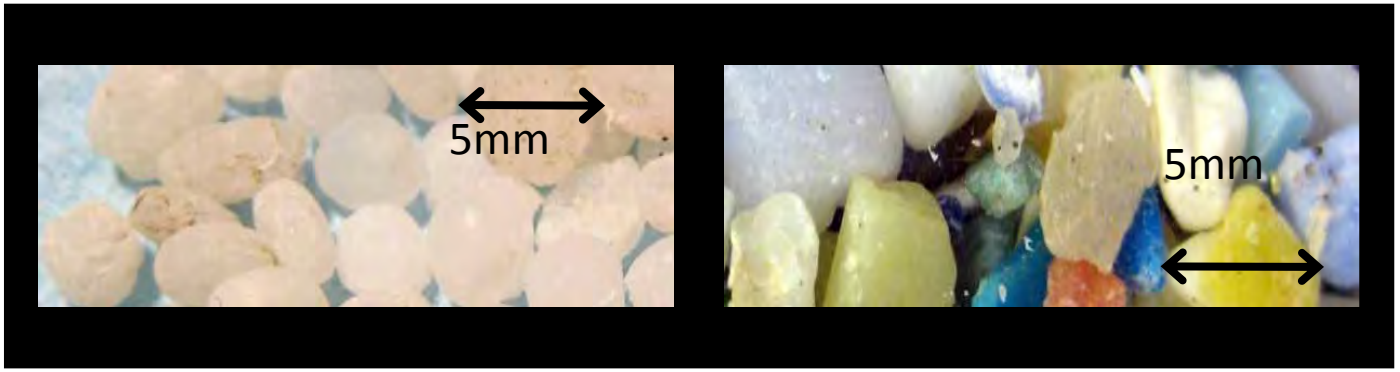
Water covers more than 70 percent of the planet's surface, making our rivers, lakes and oceans the lifeblood of our planet. Many of these bodies of water may be out of sight and out of mind, but our health may depend on their protection.

Currently, scientists believe the world's largest garbage dump isn't on land... it's in the Pacific Ocean. The Great Pacific Garbage Patch stretches from the coast of California to Japan, and it's estimated to be *twice* the size of Texas. "This is the most shocking thing I have seen," Oprah says.

What are microplastics?

WORKING DEFINITION: Any solid material <5 mm that is primarily composed of synthetic polymers.

Practical addendum: '…and larger than 330 μm' for compatibility with icthyoplankton surveys



Where do microplastics come from?

Credit: H. Takada

Primary Microplastics

- Produced intentionally as intermediates or final products.

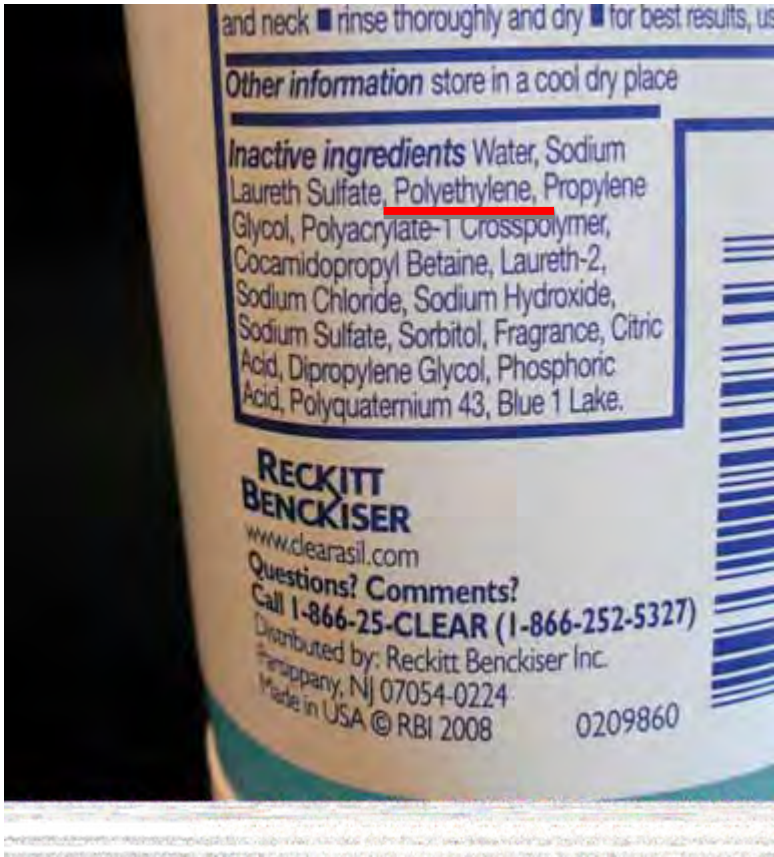
Secondary Microplastics

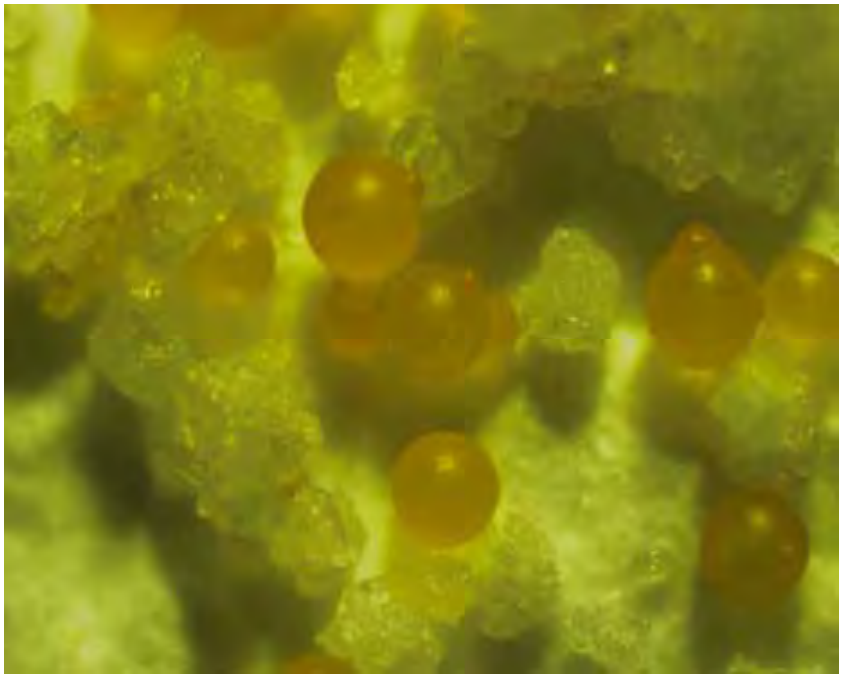
- Generated in the environment by the disintegration of larger plastic materials.

One of many examples of a breakdown product

Credit: NOAA MDP

Microplastics in Consumer Products





Micrographs of particles from Clean and Clear

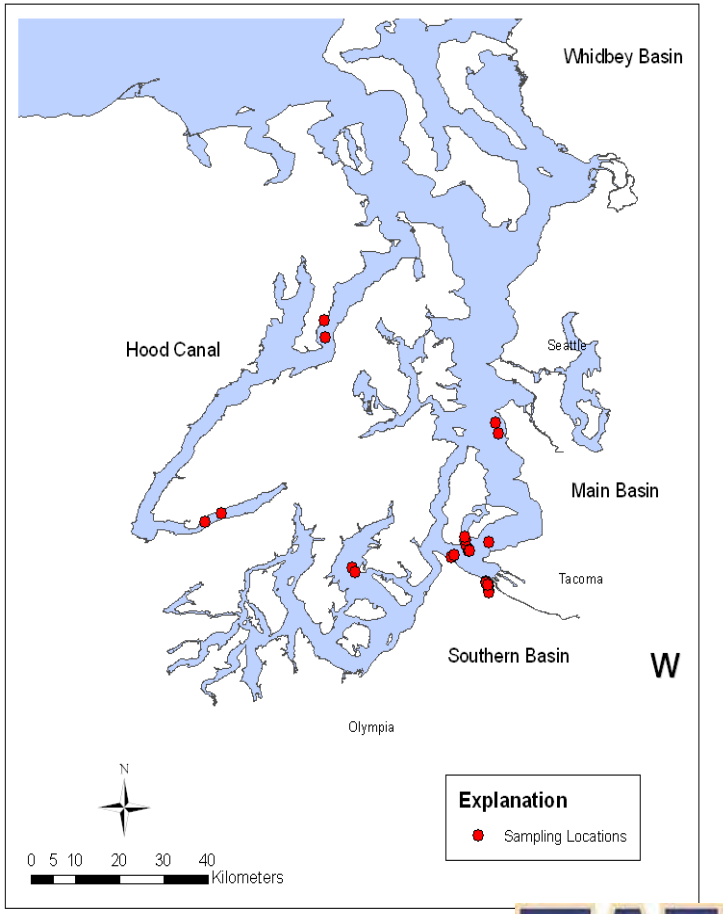
Sample	[Particle] mg/g	Mean Size µm
Clean & Clear (n = 4)	24 ± 4	200
Clearasil (n = 4)	9 ± 2	367
Aveeno (n = 1)	27	402

Sampling Microplastics in Puget Sound

Solids are collected from the upper 0.5 m of the water column using a custom-fabricated manta net equipped with a 0.33 mm plankton net.

The net was towed at 0.7-4.5 m/s for 5-15 minutes for each sample.

The volume of water processed calculated from the measured flow-rate.



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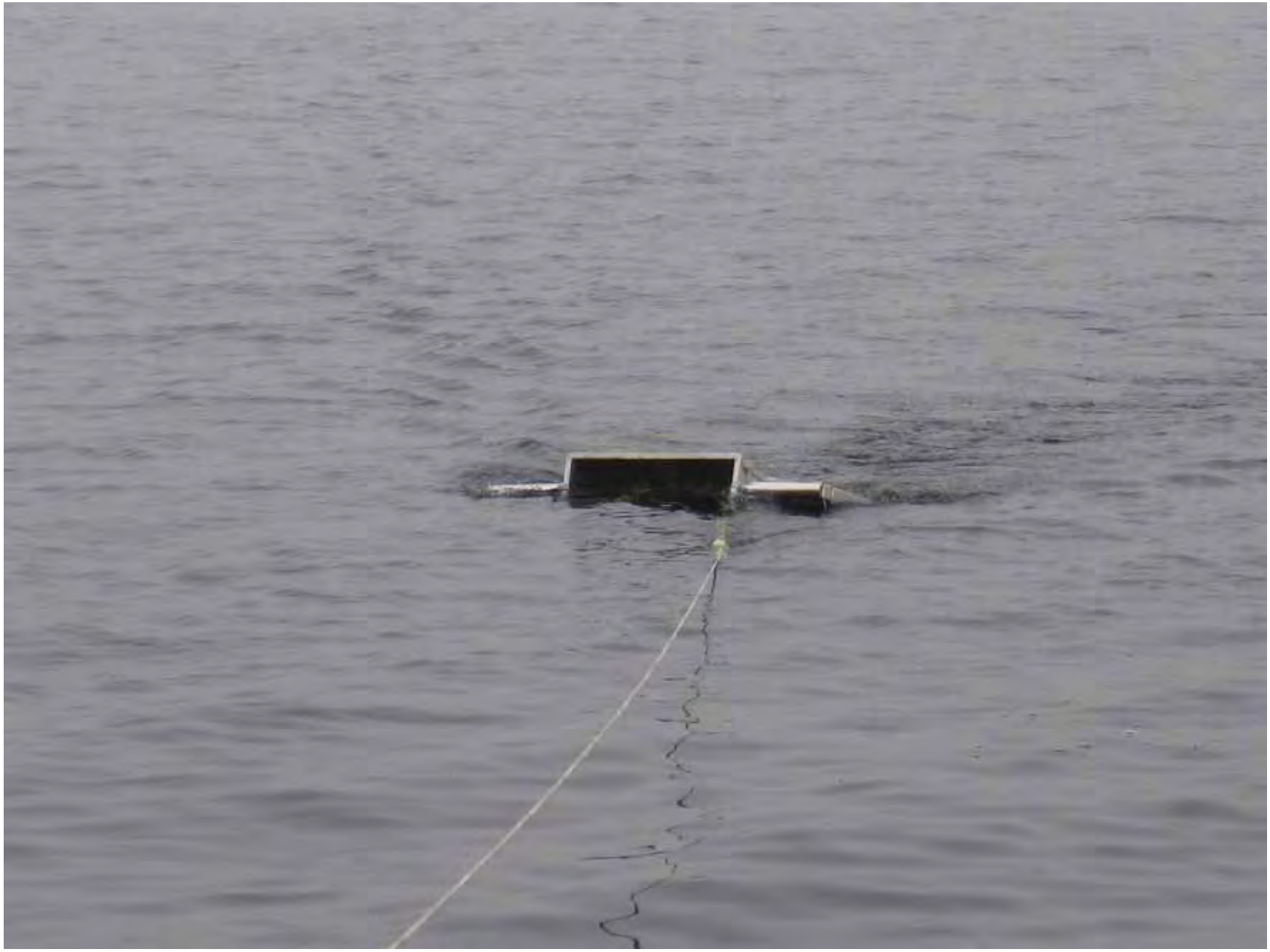
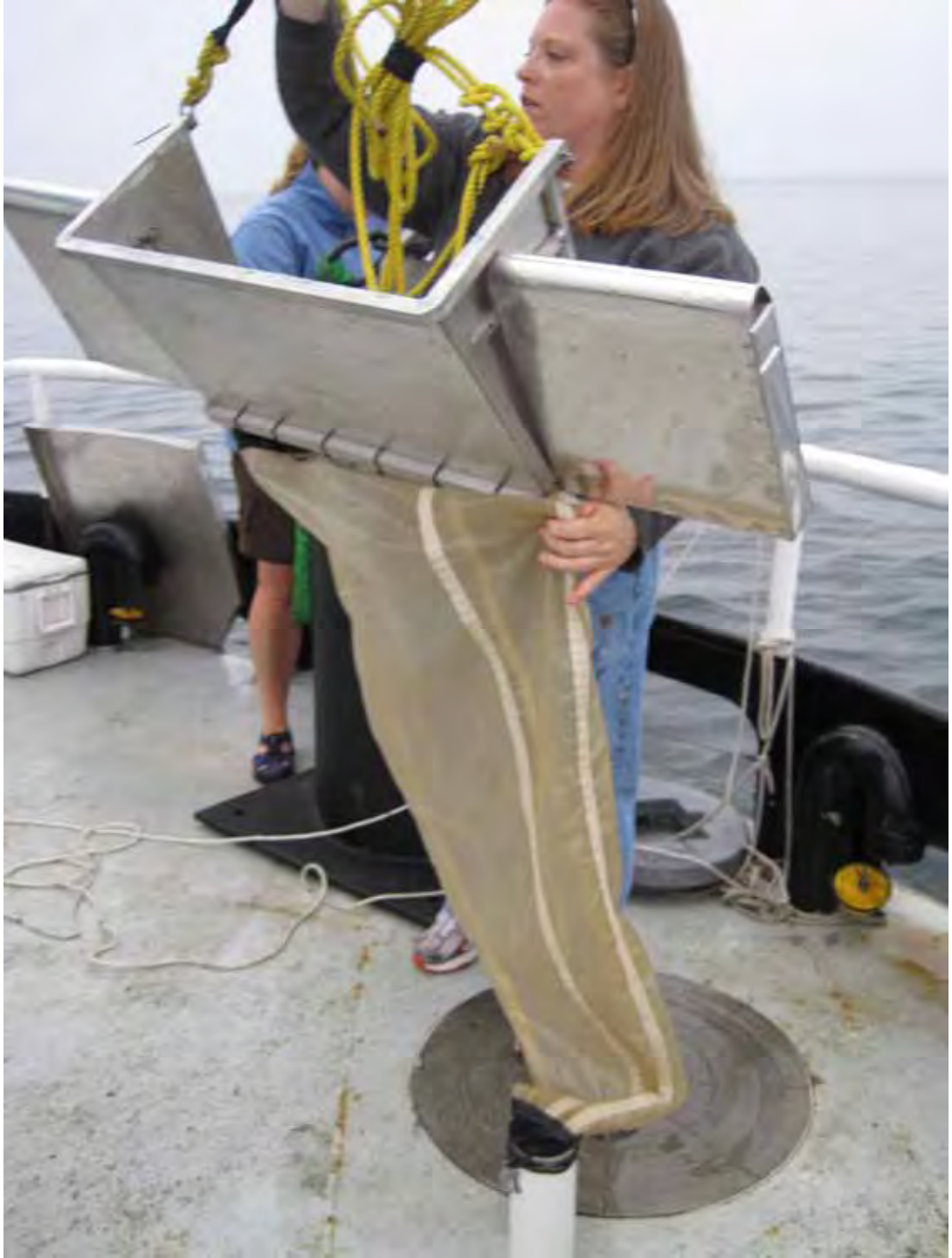
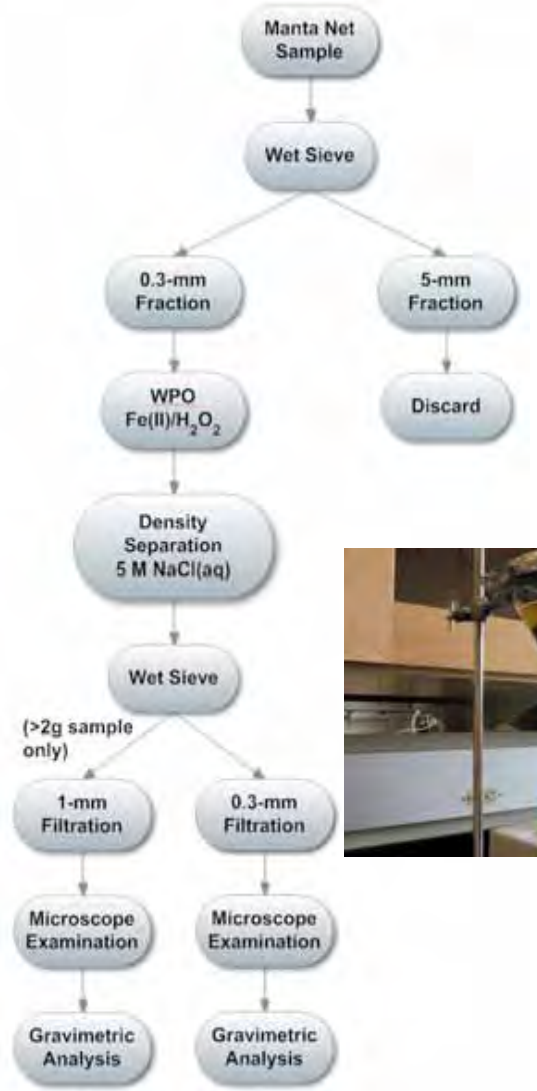




Sampling Microplastics in Puget Sound

- **Wet sieve to remove solids >5 mm**
- **Iron(II)-catalyzed H_2O_2 oxidation of natural organic matter**
- **Density separation to remove dense solids**
- **Microscope evaluation**
- **Gravimetric analysis of remaining 'plastic'**



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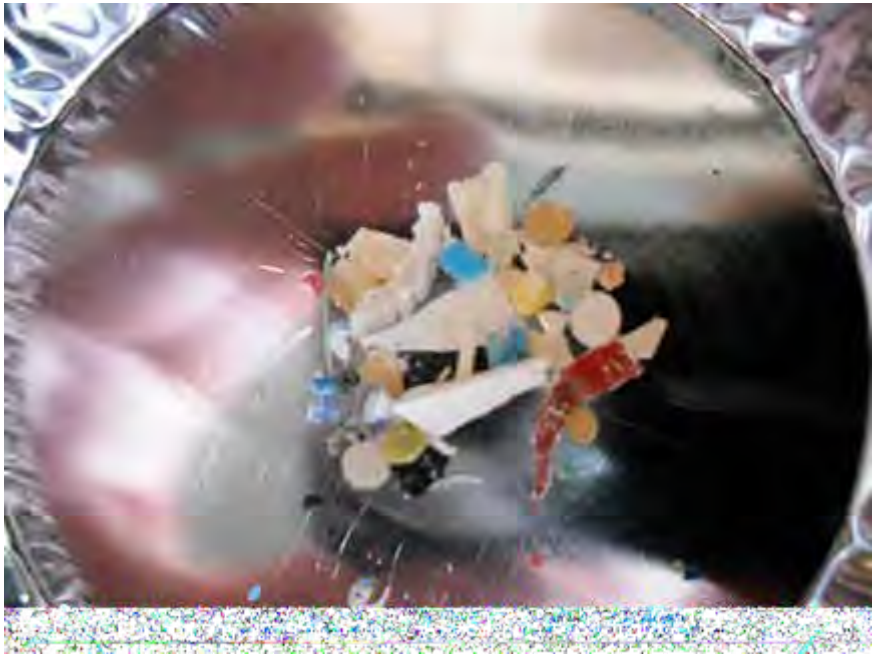


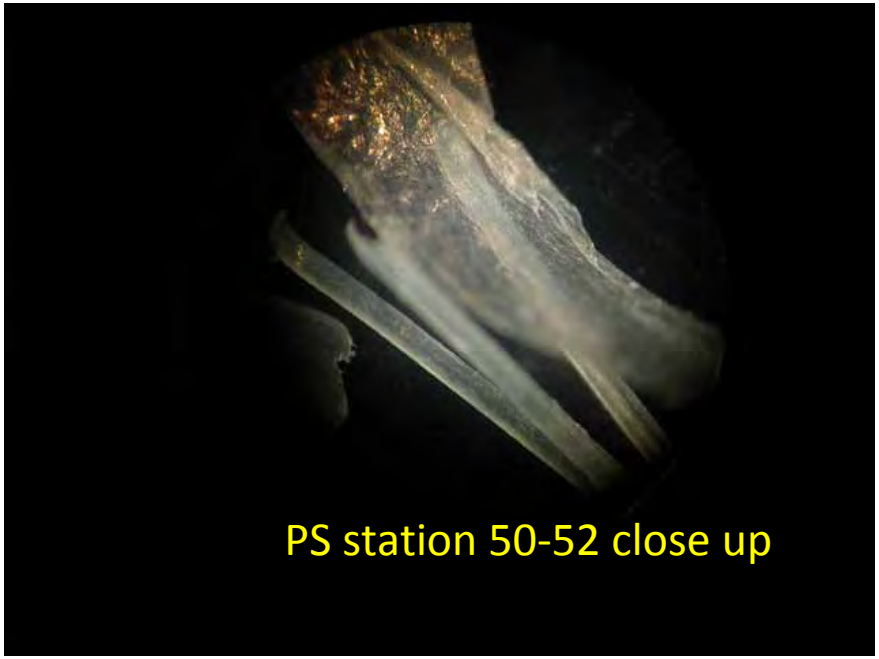

300
200
ML

Balto Harbor

PS station 50-52

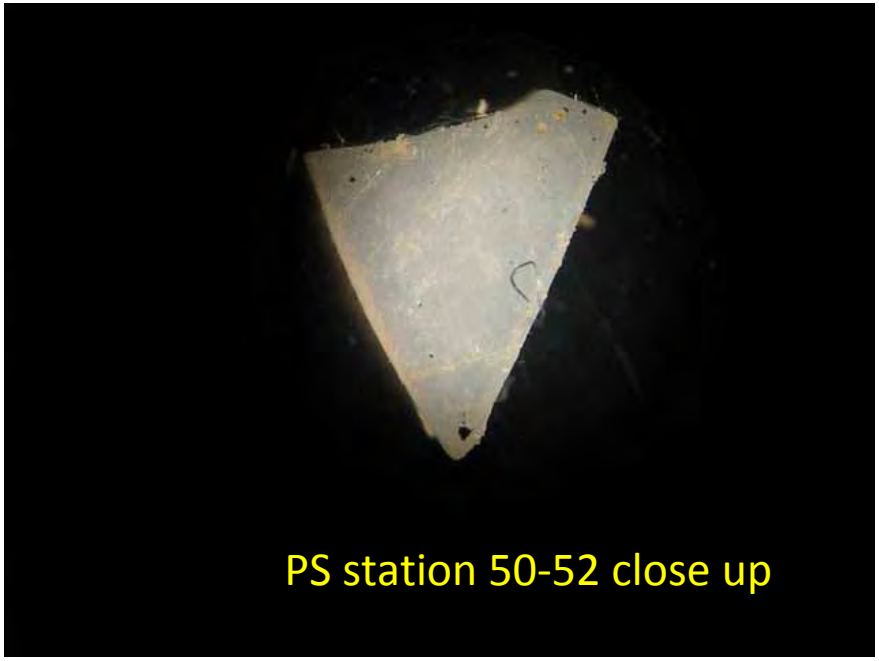
PS Pt Defiance close up

PS Pt Defiance close up

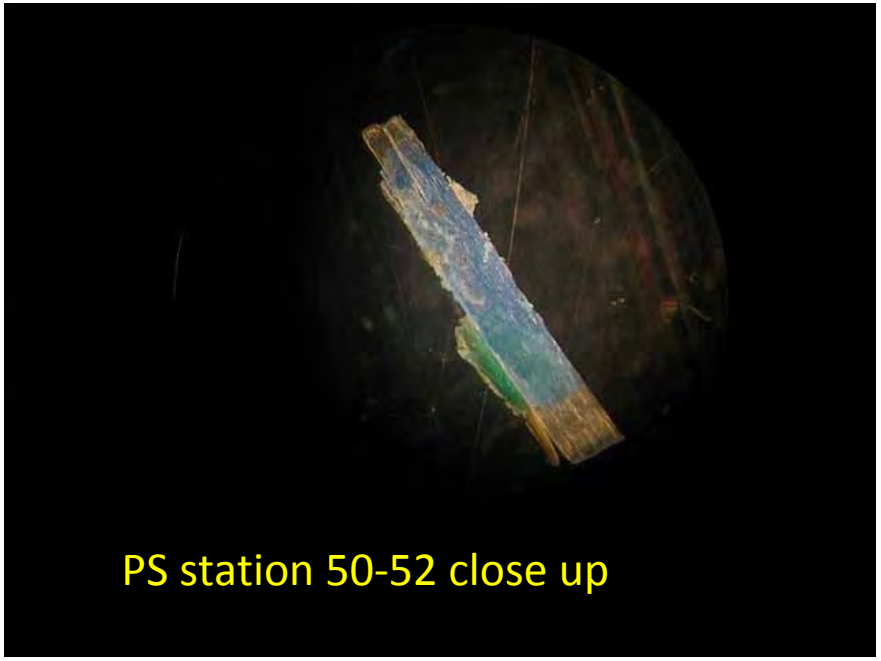


PS station 50-52 close up

PS station 50-51 close up

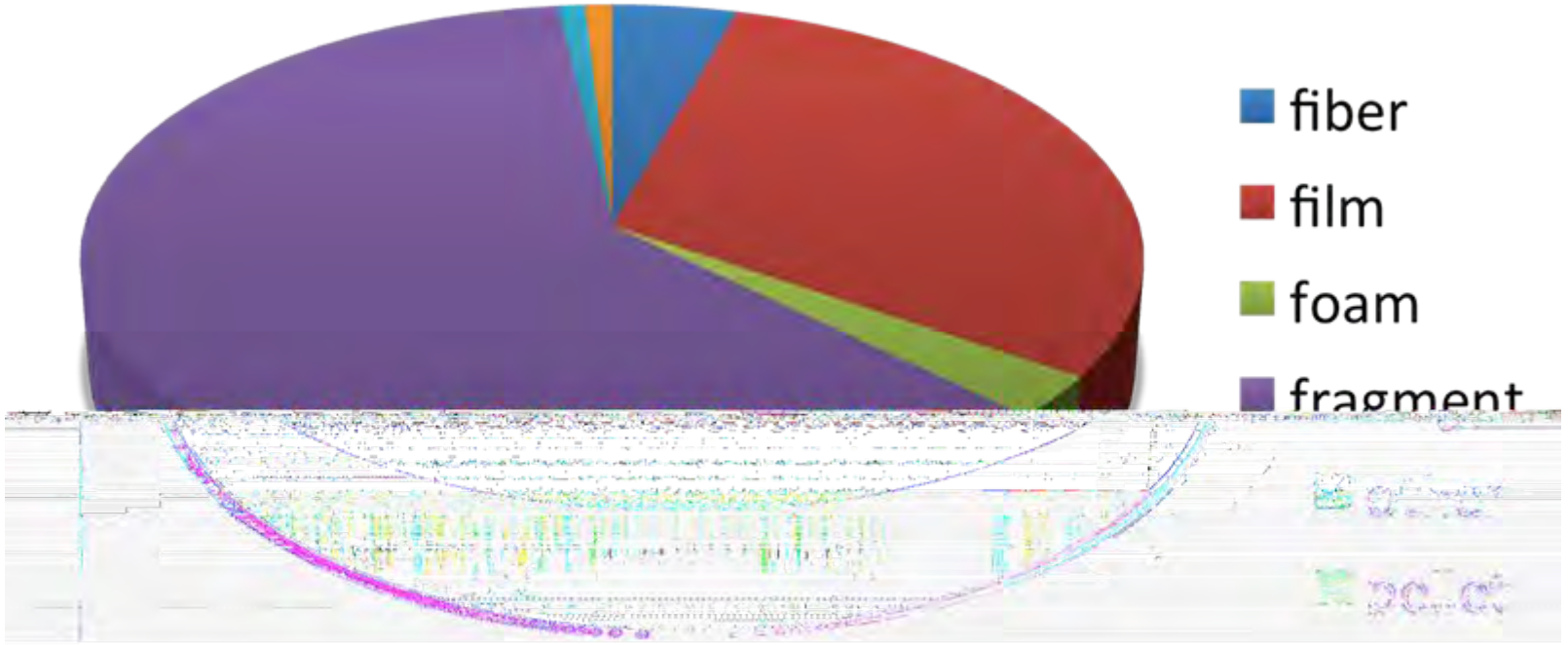


PS station 50-52 close up

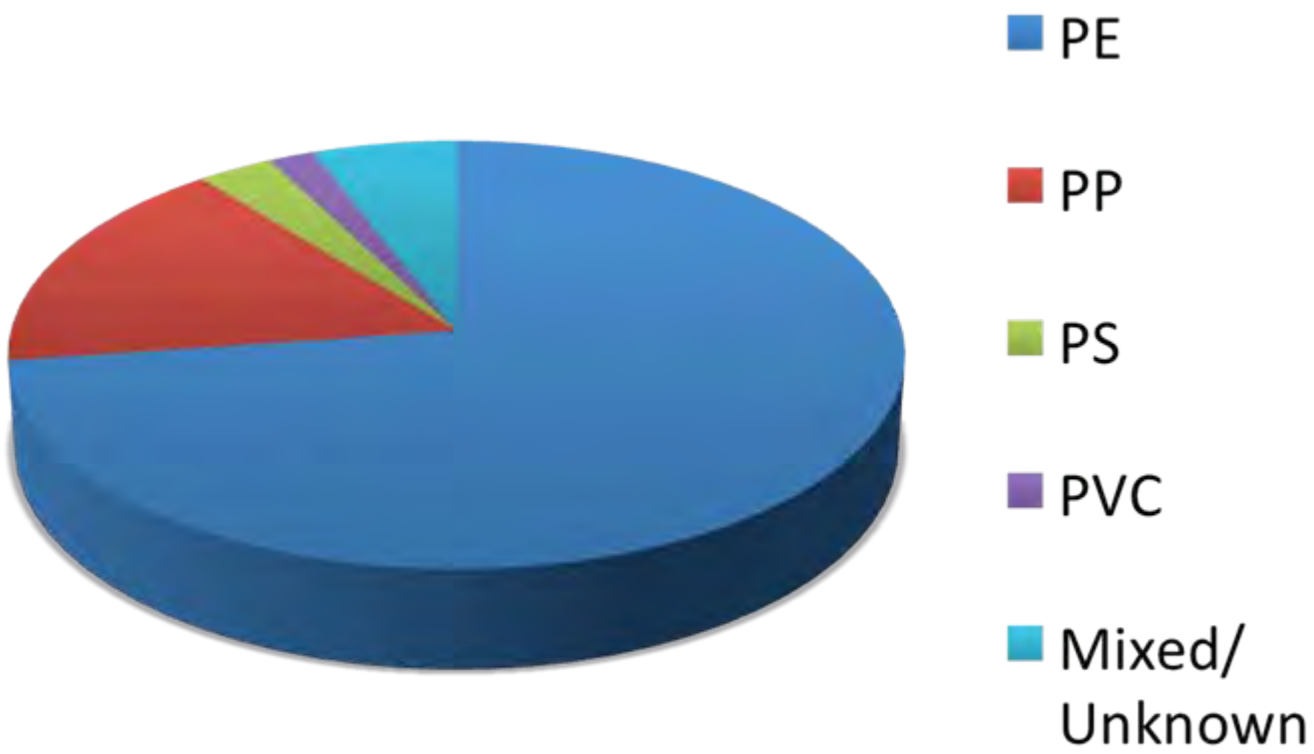


PS station 50-52 close up

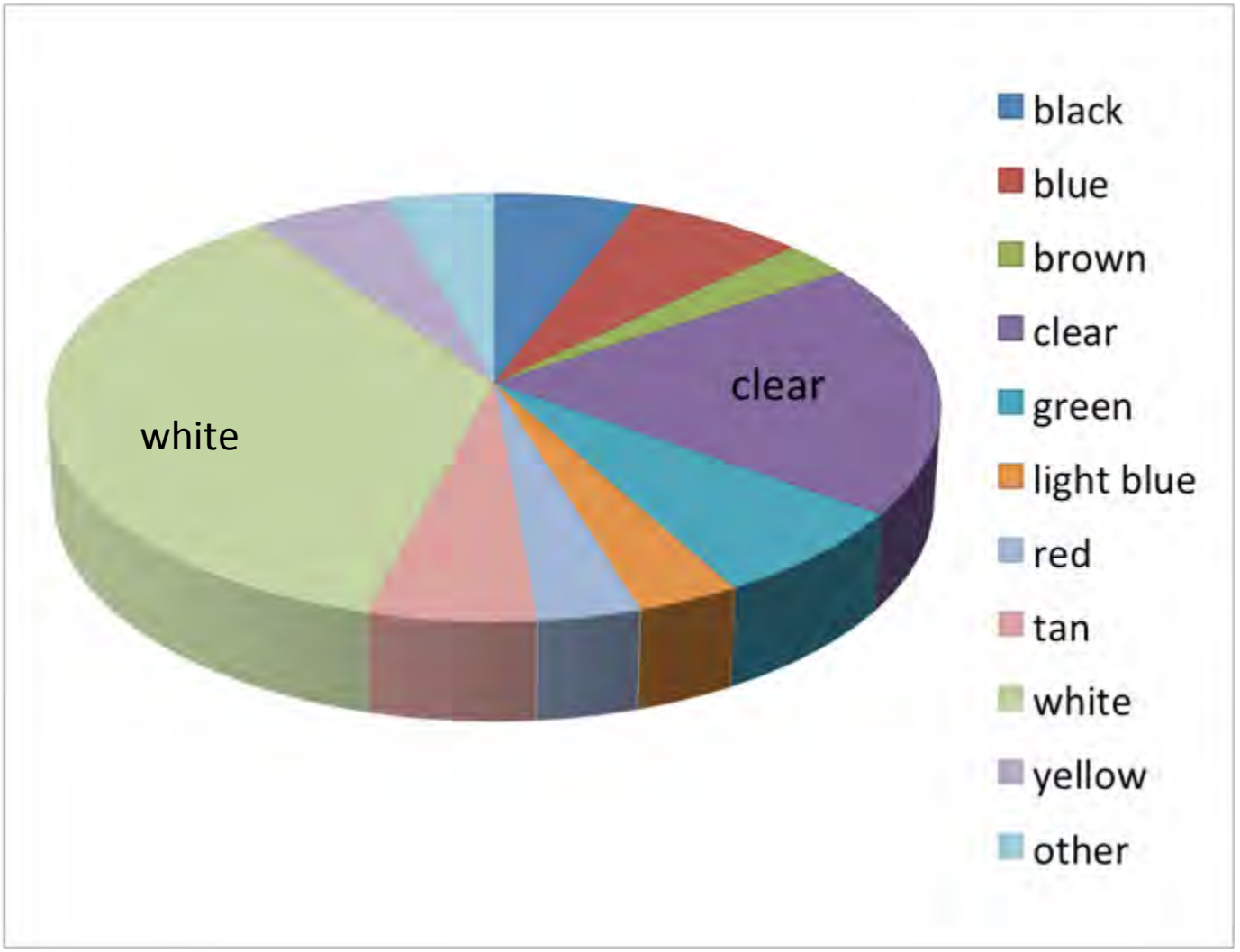
Microplastic Forms



Microplastic Polymers



Microplastic Colors



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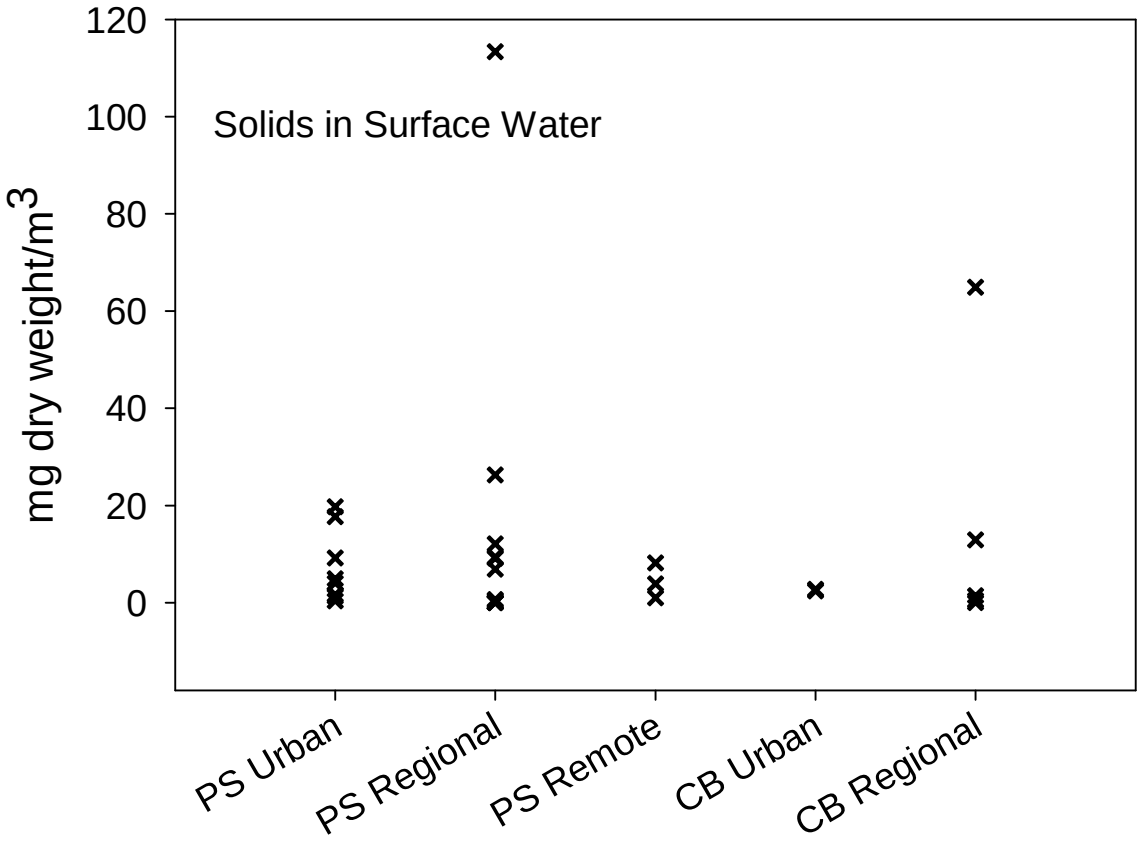
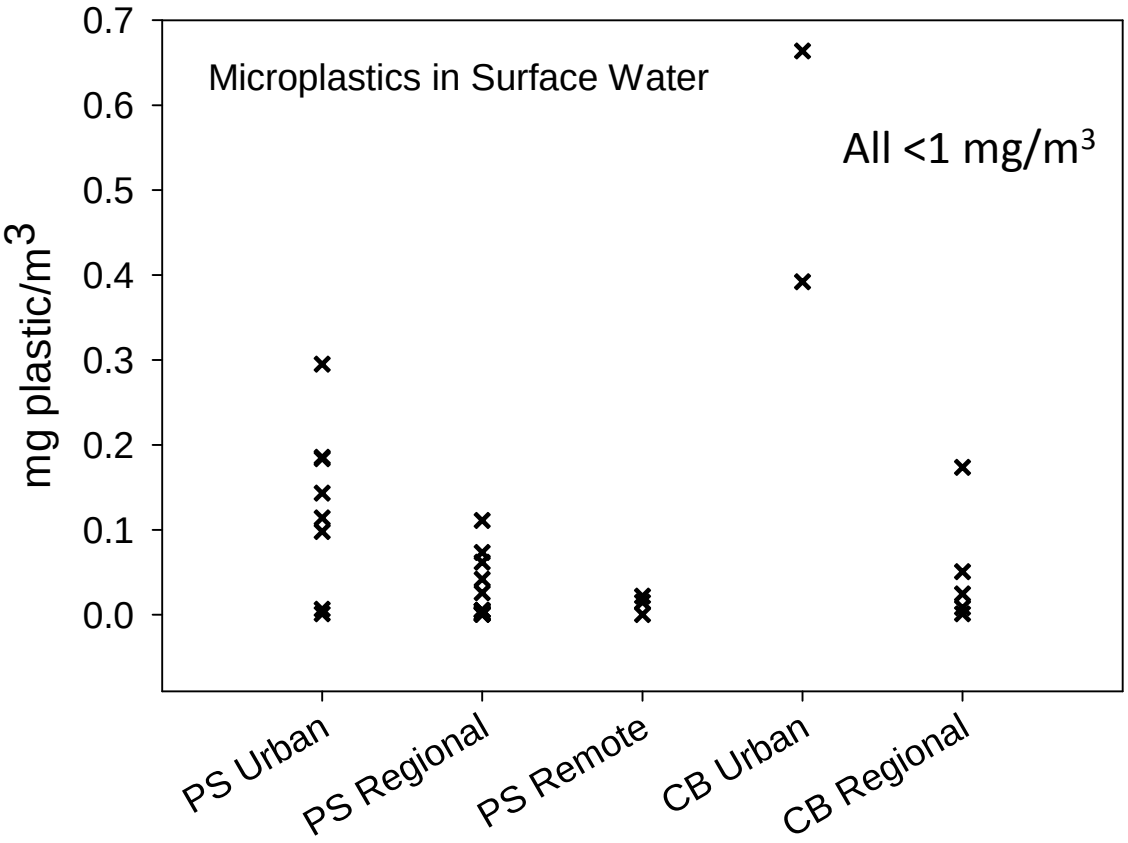
Puget Sound
Chesapeake Bay

Total Solids in Surface Water Tows (dry weight/volume sampled)



Microplastics in Surface Water Tows (dry weight/volume sampled)



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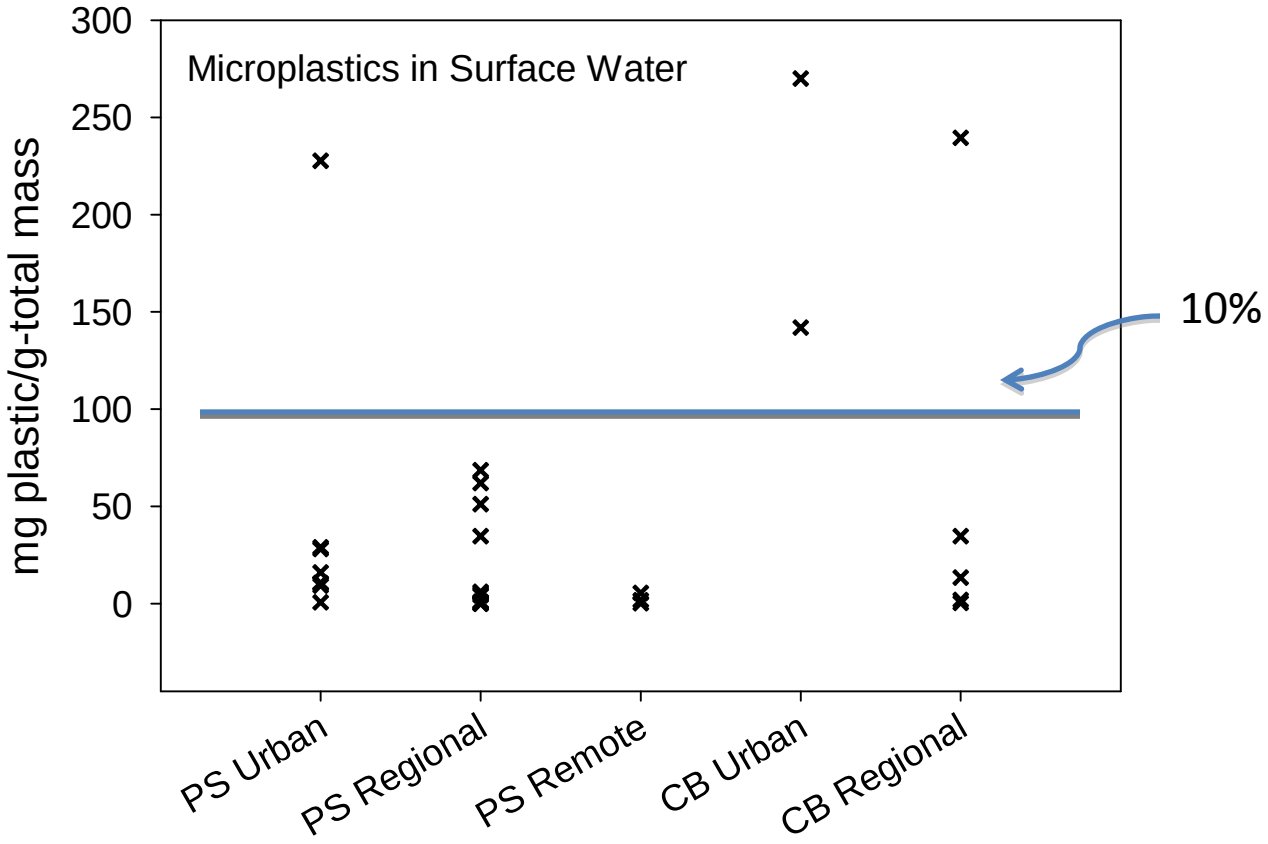
Microplastics in Surface Water Tows
(dry weight of plastic/dry weight of total solids)



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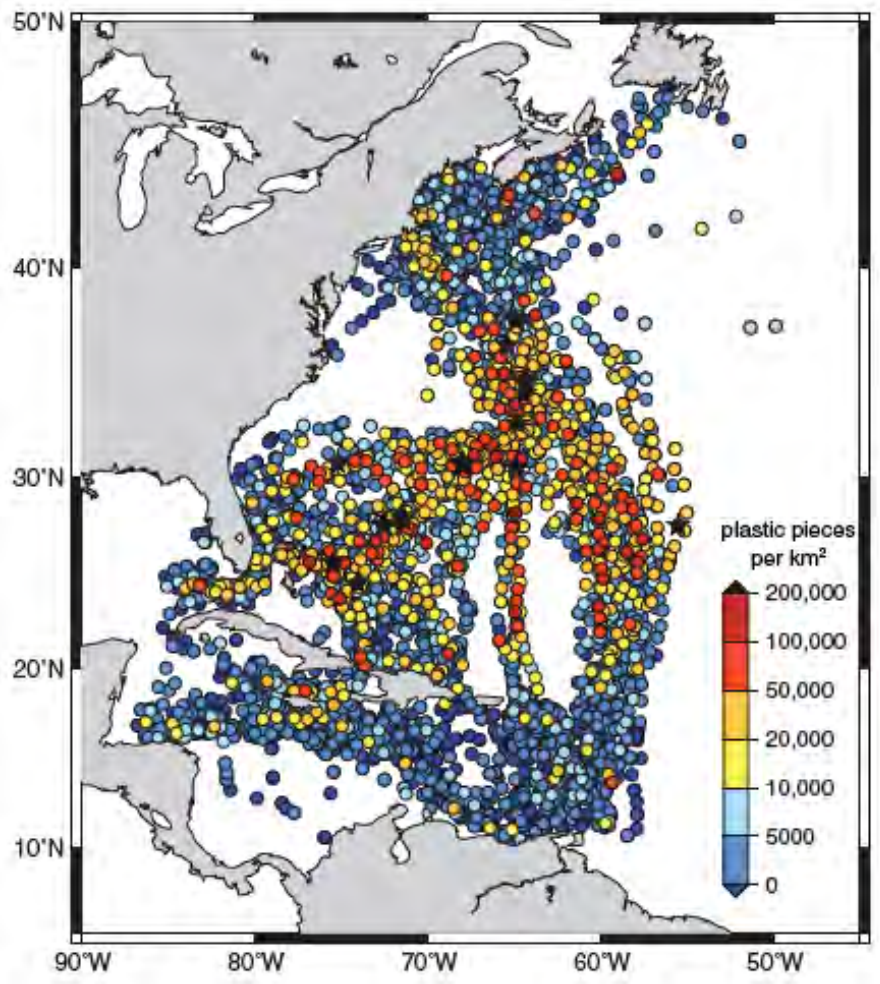
Comparing Across Studies…

- Assume surface water trawls sample upper 0.25 meter.
- Assume weight of individual plastic particle averages 13.6 mg
- 250,000/km^2 = 1/m^3
  = 13.6 mg/m^3
- Compare to <1 mg/m^3 in Puget Sound and Chesapeake Bay



(Law *et al.*, 2010)

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Plastic particles in coastal pelagic ecosystems of the Northeast Pacific ocean

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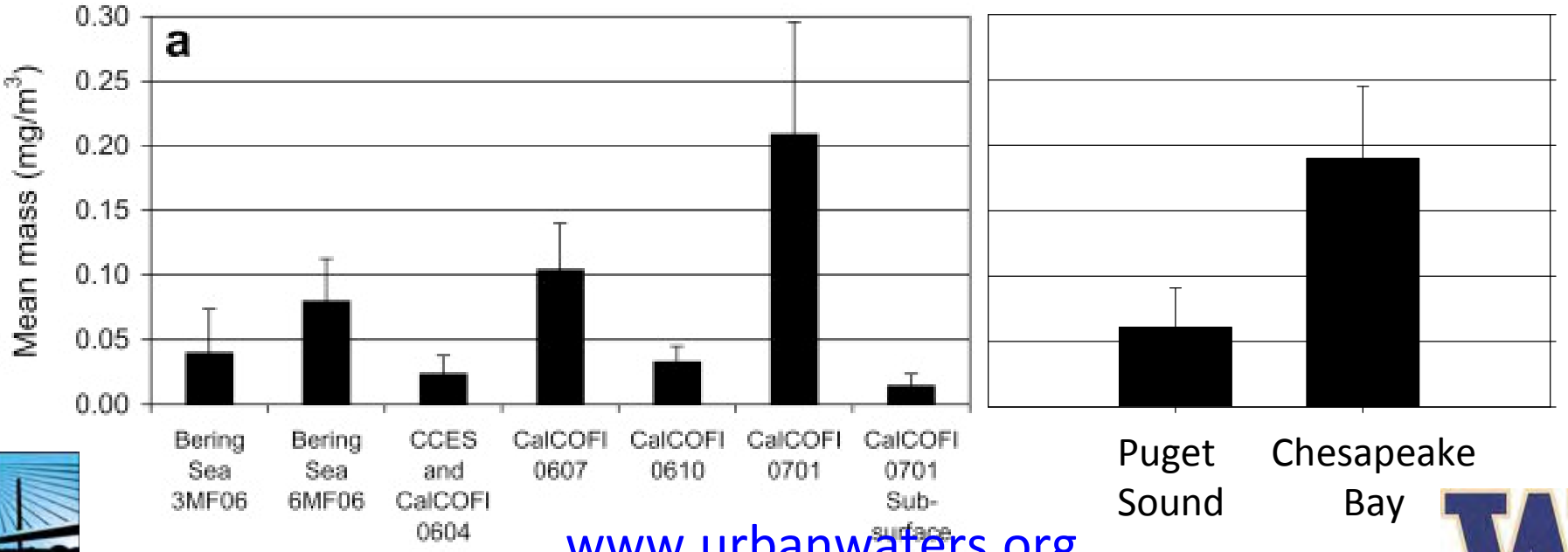

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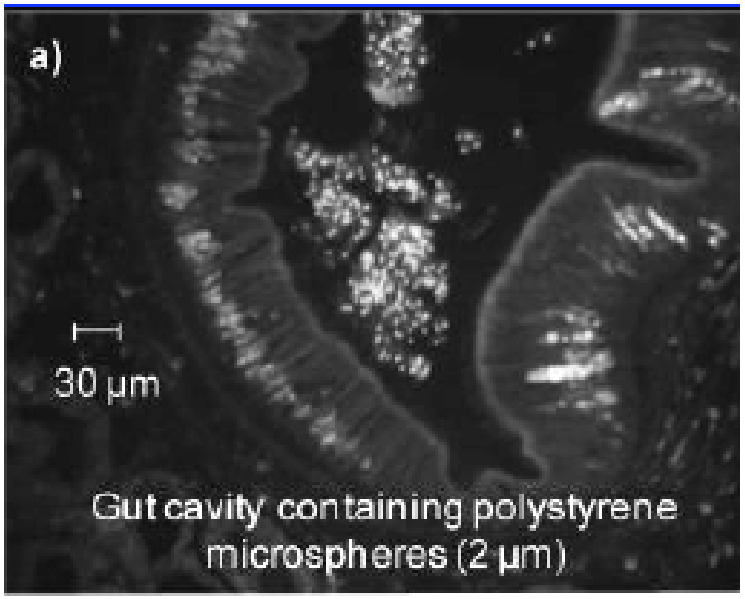
Possible Effects of Marine Microplastics

- Ingestion hazards?
  - Physical blockage
  - Altered nutritional value
  - Exposure to chemical constituents of plastic
  - Exposure to adsorbed pollutants

Possible Effects of Marine Microplastics

- Incorporation into higher trophic levels?
  - Passage across membranes



Browne et al.

- Rafting of organisms?
- Source of chemical constituents to global oceans?

Microplastic concentrations in perspective

	North Atlantic (Law *et al.*, 2010)	Puget Sound (this study)
chlorophyll-a (ug/L)	0.5	2.1
phytoplankton (mg/m^3)	30	130
microzooplankton (mg/m^3)	0.3	---
mesozooplankton (mg/m^3)	1.7	---
DOM (mg/m^3)	850	2000
Microplastics (mg/m^3)	0.008 - 1.1	0.0002 – 0.29

Also Horner *et al.* (2005), Calbet *et al.*, (2008), PSAMP (2010), Goldbert *et al.*, (2010)

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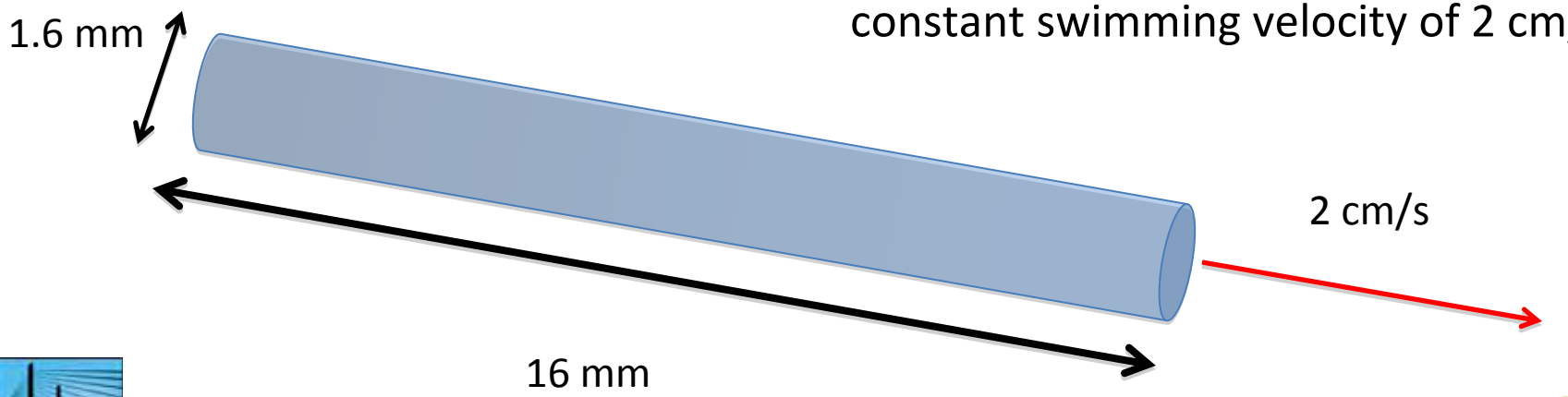
Implications: Potential Exposure of Microplastics to Krill

Mean length = 16 mm (West et al., 2011)

Mean swimming speed = 1.8 cm/s (day)
= 2.2 – 3.5 cm/s (night)
(DeRobertis et al., 2003)

Assumptions:

10:1 L:d morphology
constant swimming velocity of 2 cm/s



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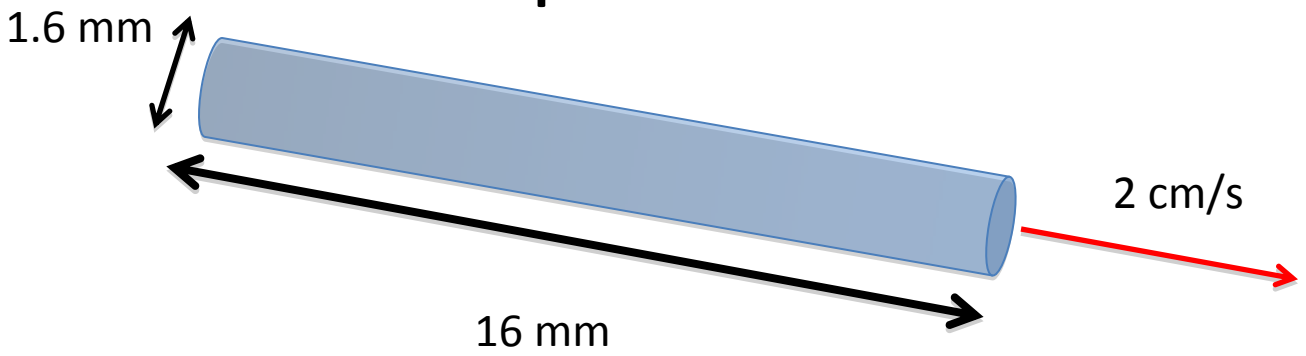

Volumetric Encounter Rate per Krill = 3.5×10^{-3} m^3/day (1.3 m^3/year)

Microplastic concentration = 0.004 – 0.19 pieces/m^3 (Doyle et al., 2011)

Mean encounter rate = between 1.4×10^{-5} and 70×10^{-5} particles/day

In a day, between 99.9 and 99.99% of krill do <u>not</u> encounter a microplastic

In a year, between 75% and 99.5% of drill do <u>not</u> encounter a microplastic

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Microplastics are Easy
What about Nanomaterials?

- Substantial production of synthetic nanomaterials
- Complex aquatic behavior: do they exist in ocean water?
- Cross membranes and likely are persistent
- Effects at ambient concentrations largely unknown
- Remediation options unknown

Conclusions

1. Microplastics are ubiquitous in coastal waters.

2. Microplastic concentrations in the Puget Sound estuary are:

    - Highly variable in space and time
    - Appear not to be correlated to putative source locations
    - Are similar to levels in the open North Atlantic and Eastern Pacific

1. Microplastic levels are an insignificant reservoir of marine carbon.

2. Simple modeling suggests ingestion of microplastics by marine krill happens very rarely.

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Conclusions

5. Role of microplastics as a source of micropollutants is largely unknown

6. Pelagic fish do ingest millimeter sized plastic debris

7. Preliminary source work in coastal waters suggests physical disintegration is an important source of microplastics.

8. Microplastic abrasives have not yet been detected in the environment (metric tonnes/year release).

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