

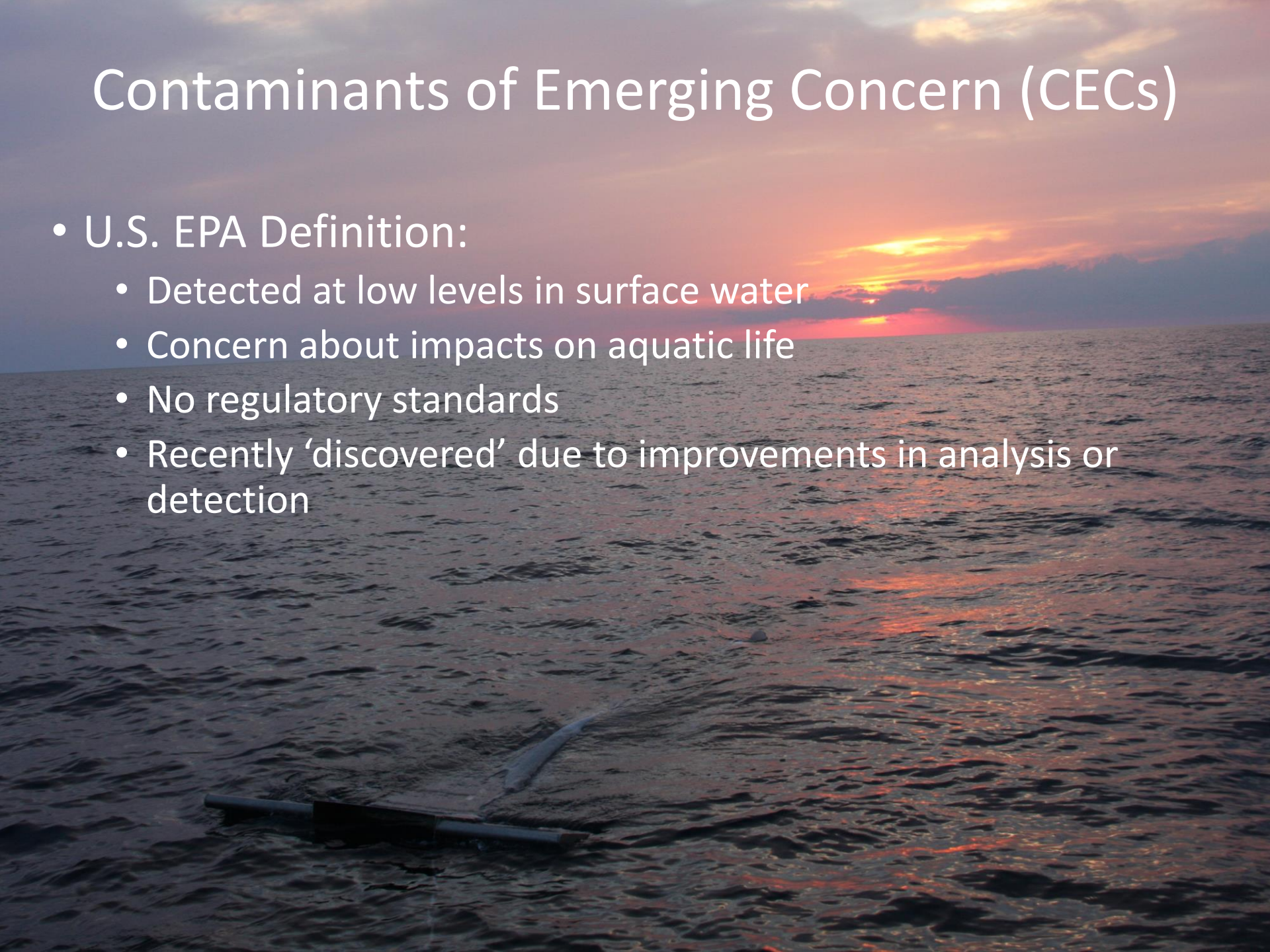
A photograph showing a child's hand holding a pile of colorful plastic debris (shards of plastic) on a sandy beach. The child is wearing a white shirt and yellow shorts. The background is a green gradient.

Aquatic Plastic Pollution: Illinois-Indiana Sea Grant's Role in Research and Outreach

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Contaminants of Emerging Concern (CECs)

A sunset over the ocean with a buoy in the foreground. The sky is filled with soft, colorful clouds in shades of orange, pink, and purple. The sun is low on the horizon, casting a warm glow over the water. In the foreground, a dark buoy with a white top is visible on the water's surface.

- U.S. EPA Definition:
 - Detected at low levels in surface water
 - Concern about impacts on aquatic life
 - No regulatory standards
 - Recently 'discovered' due to improvements in analysis or detection

Contaminants of Emerging Concern (CECs)

- Includes several classes of substances
 - Persistent organic pollutants (POPs)
 - Emerging: Flame retardants (PBDEs), nonstick and stain repellent chemicals (PFASs)
 - Resistant to environmental degradation
 - Bioaccumulate through the food web
 - Demonstrated negative impacts on human and environmental health
 - Pharmaceuticals and personal care products (PPCPs)
 - Endocrine-disruptors (BPA)
 - Nanomaterials (Carbon nanotubes, TiO_2)
 - Microplastics and anthropogenic debris?

Types of Microplastics

1° - Production pellets



www.frbiz.com



www.alibaba.com

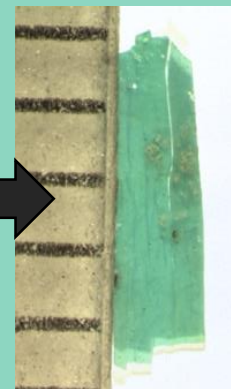
2° - Fragments, foam, film



archipelago.gr



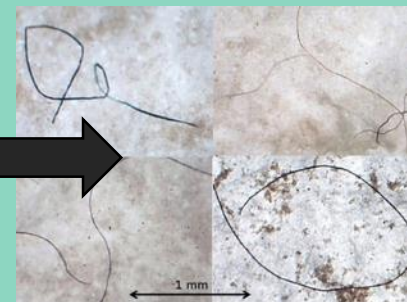
kasitindustry.com



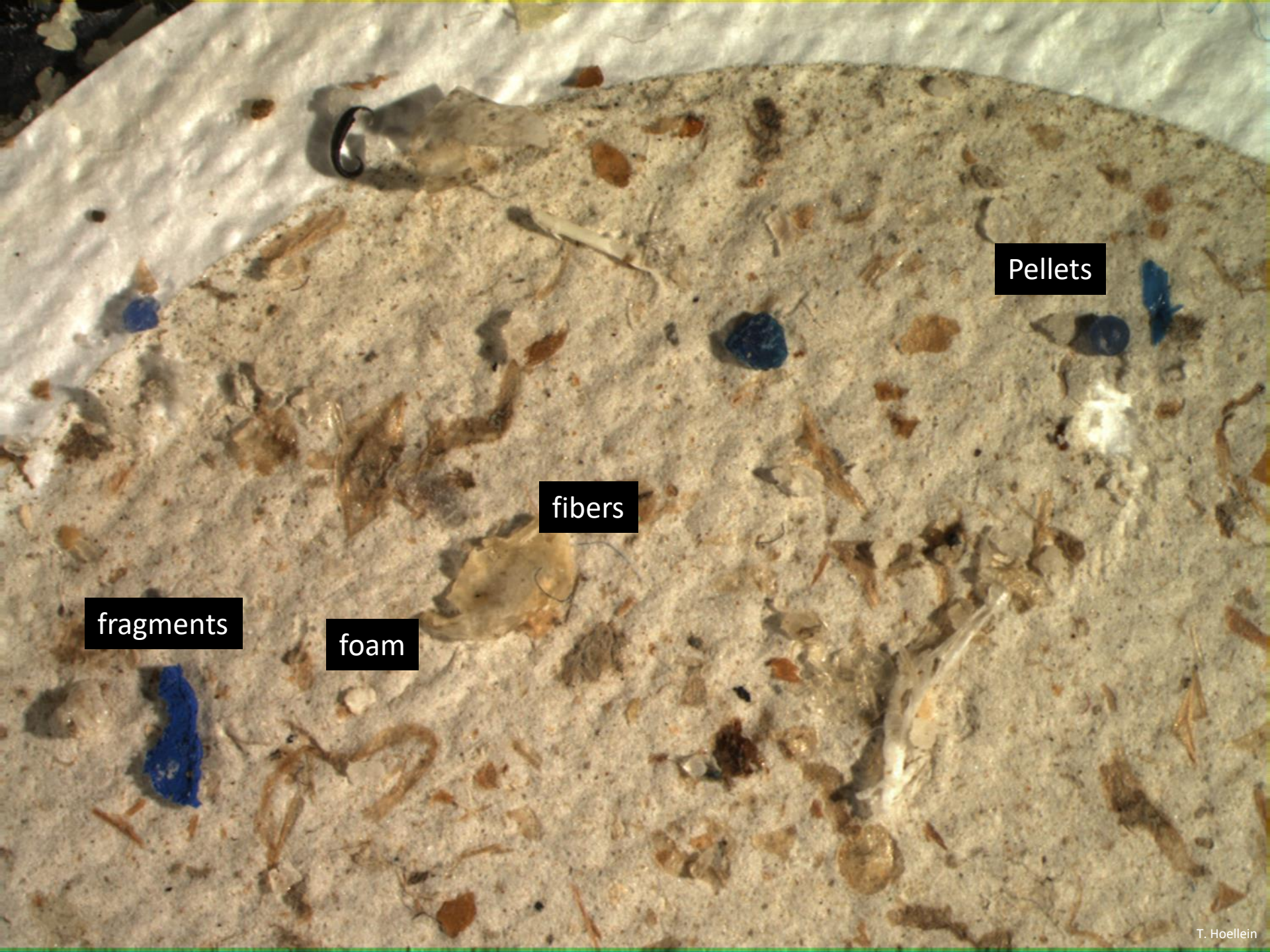
1° - Microbeads



2° - Synthetic fibers



<http://workjournal.archipelago.gr/tag/microplastics/>



Pellets

fibers

fragments

foam

Ecological effects of microplastic

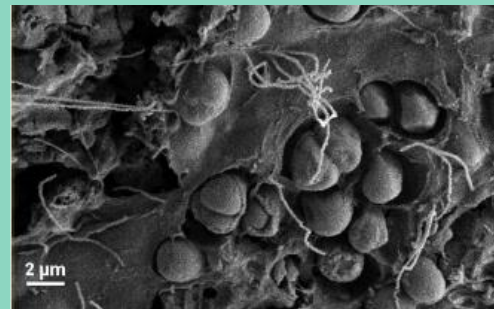
- Ingestion
 - Filter feeders, zooplankton, fish
(Sussarellu et al. 2016, Wright et al. 2013, Rist et al. 2016)
- Prey transfers to predator
(Farrell and Nelson 2013)
- Decreased reproductive success, survival
(Sussarellu et al. 2016, Rist et al. 2016)
- Selects for distinct microbial communities
(Zettler et al. 2013; McCormick et al. 2014)



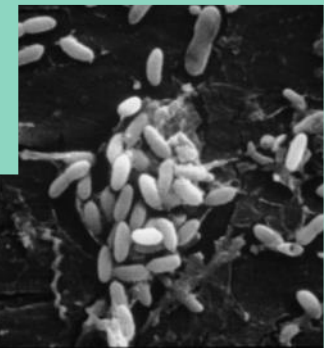
Cole et al. 2013



M. Eriksen, 5 Gyres



Zettler et al. 2013



J. Schlupe, Loyola Univ.

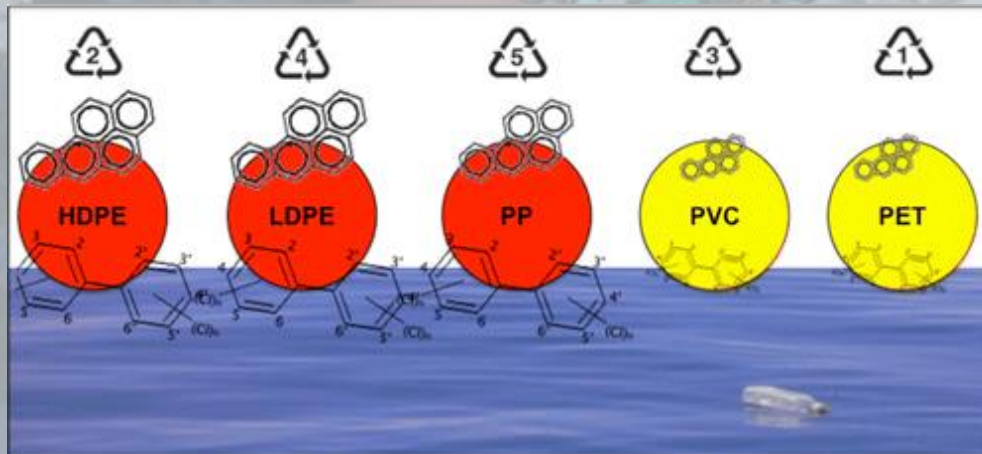
Toxicological effects of microplastic

1. Leach chemicals

- BPA: endocrine disruptor

2. Adsorb chemicals

- Hydrophobic surfaces easily adsorb POPs
- Research on marine plastic has demonstrated that the risk to marine animals *differs by plastic type*



Fate of plastic: Use, discard, incinerate, recycle

SCIENCE ADVANCES | RESEARCH ARTICLE

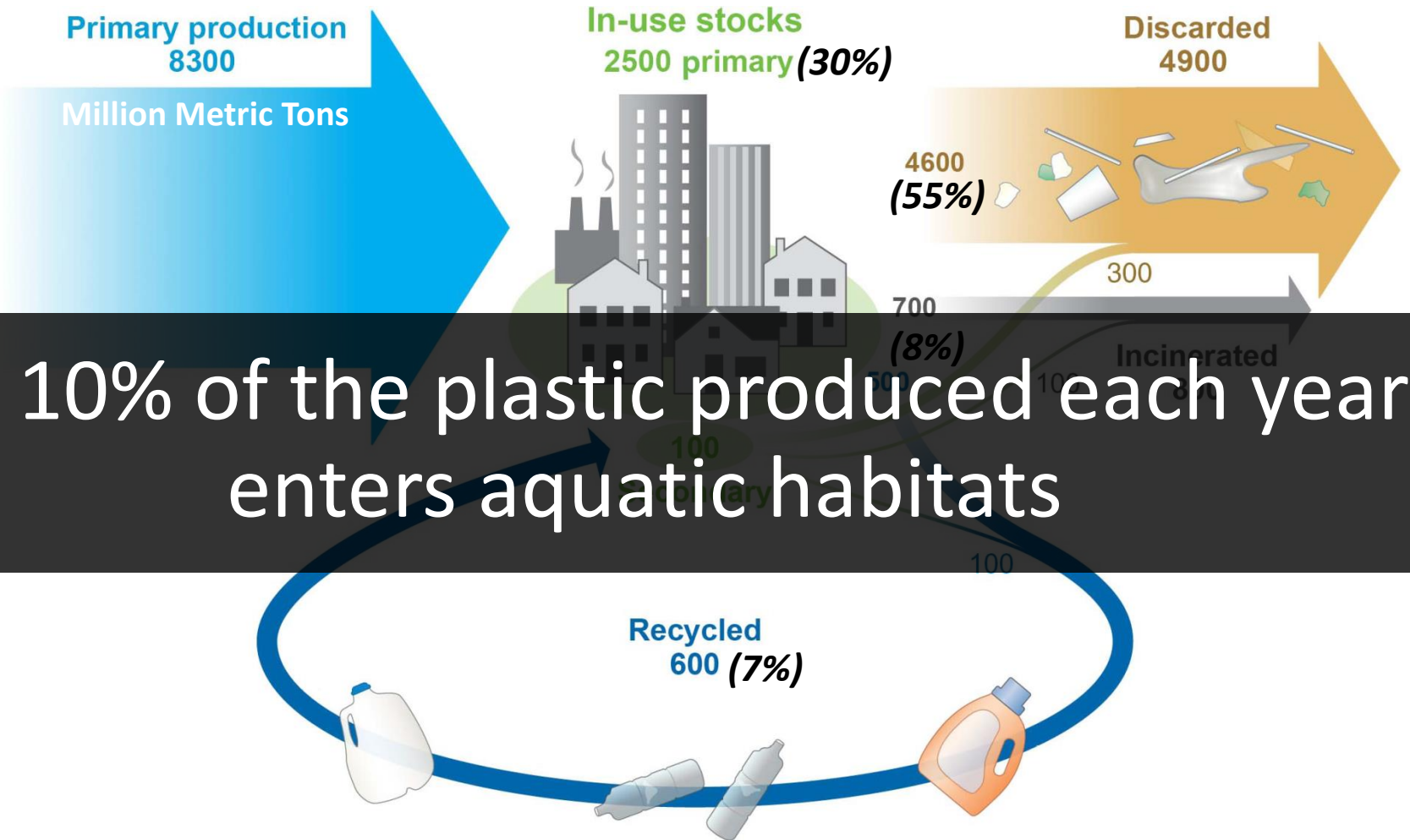
PLASTICS

Production, use, and fate of all plastics ever made

Roland Geyer,^{1*} Jenna R. Jambeck,² Kara Lavender Law³

Plastics have outgrown most man-made materials and have long been under environmental scrutiny. However, robust global information, particularly about their end-of-life fate, is lacking. By identifying and synthesizing dispersed data on production, use, and end-of-life management of polymer resins, synthetic fibers, and additives, we present the first global analysis of all mass-produced plastics ever manufactured. We estimate that 8300 million metric tons (Mt) as of virgin plastics have been produced to date. As of 2015, approximately 6300 Mt of plastic waste had been generated, around 9% of which had been recycled, 12% was incinerated, and 79% was accumulated in landfills or the natural environment. If current production and waste management trends continue, roughly 12,000 Mt of plastic waste will be in landfills or in the natural environment by 2050.

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10% of the plastic produced each year enters aquatic habitats

~92% of the plastic that was ever produced still exists... somewhere, in some form



Accumulation



Litter in aquatic environments has several fates.

Ingestion



Breakdown & Decomposition



Microplastic is pervasive and persistent in marine ecosystems

Ocean Environmental Studies

1855

The Physical Geography of the Sea—first textbook of modern oceanography published

1954

International Convention for the Prevention of Pollution of the Sea by Oil—first international agreement on marine pollution by

1973

Paper: *Pollution of the Oceans: An International Problem?* "More research needs to be done... it is already clear that at least on a local scale marine pollution can cause considerable harm."

Plastic Industry Growth

1930's & 40's

New plastic creations: Polystyrene (1929), Polyester (1930), Polyvinylchloride (PVC) and Polythene (1933), Nylon (1935), Polyethylene Terephthalate (PET) (1941)

In 1940's, war drove growth in the plastic industry, which then turned to consumer goods.

1955

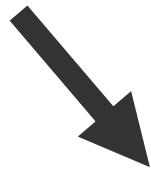


Peter Stackpole—The LIFE Picture Collection/Getty Images

1977

Plastic grocery bags are introduced to supermarkets as paper alternative

1973: Marine pollution found to cause "considerable harm"



1982

Paper: *Oceanic Plastic Particle Pollution: Suspected Effect on Fat Deposition in Red Phalaropes* "A negative correlation between the amount of plastic and fat condition suggests a detrimental effect of a widespread oceanic pollutant on a marine bird."

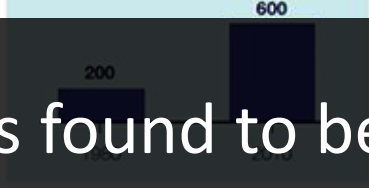
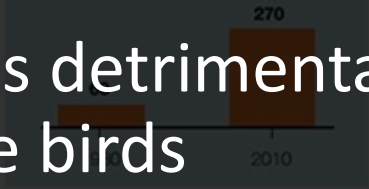
1979

After causing decades of negative health effects in humans and animals, polychlorinated biphenyls (PCBs) are banned from the US.



1987

The *Sixth International Ocean Disposal* paper on the theme of sea disposal of plastics. Major inputs of ocean plastics are from land-based sources in developed and industrialized areas. Ocean plastic debris has negative biological effects: Marine life including seals, birds, and turtles are dying of entanglement with and ingestion of plastics.



Source: Global Ocean Commission 2014 Report

1982: Research first demonstrates detrimental effects of plastic to marine birds

1993

Paper: *A Mechanism for the Accumulation of Floating Marine Debris North of Hawaii* studies inputs to the gyre. The paper explains the persistence of Garbage Patches.

1987: Major inputs to ocean debris found to be land-based

1999

Captain Charles Moore's first expedition to study plastic content of the Pacific Gyre. Finding published in 2001 paper: *A Comparison of Plastic and Plankton in the North Pacific Central Gyre*. The results? Plastic outweighs plankton 6 to 1.



1996

Four of five grocery bags used are plastic

2001

Stockholm Convention on Persistent Organic Pollutants (POP): POP regulation needs to be addressed globally due to potential human and environmental toxicity.

2007

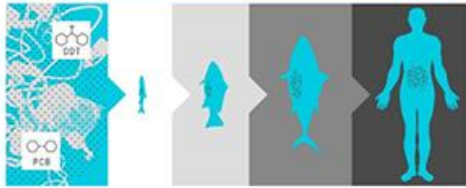
Paper: *Persistent organic pollutants carried by synthetic polymers in the ocean environment* confirms that plastic debris is a trap for POPs.

2009

Paper: *Issues in the Environmental Implications of Plastics for Human Health* addresses implications of human dependency on plastics, in particular the concerns for human health that arise from production, usage, and disposal of plastics.

2010

Paper: *Plastic Ingestion by Planktivorous Fishes in the North Pacific Central Gyre* is the first study to document fish from the gyre eating plastic. **35% of fish examined had ingested plastic.**



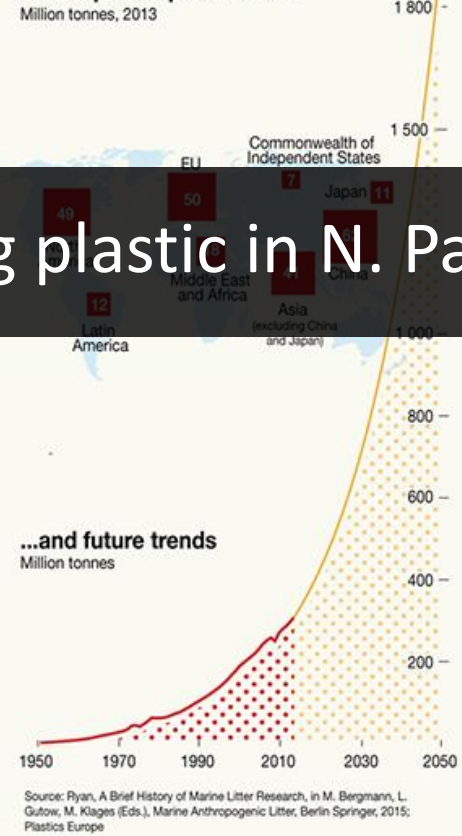
2013

Paper: *Ingested Plastic Transfers Hazardous Chemicals to Fish and Induces Hepatic Stress*. Microplastics naturally sorb chemical pollutants. **Fish eat these plastics and suffer liver toxicity**

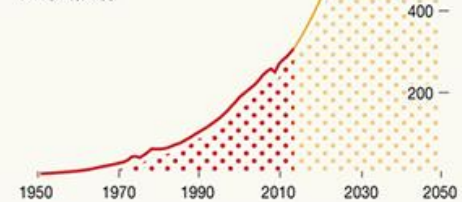
2016

United Nations Environmental Program Report estimates the total number of floating macro and microplastics in the open ocean to be **5.25 trillion pieces**

Global plastic production...



...and future trends



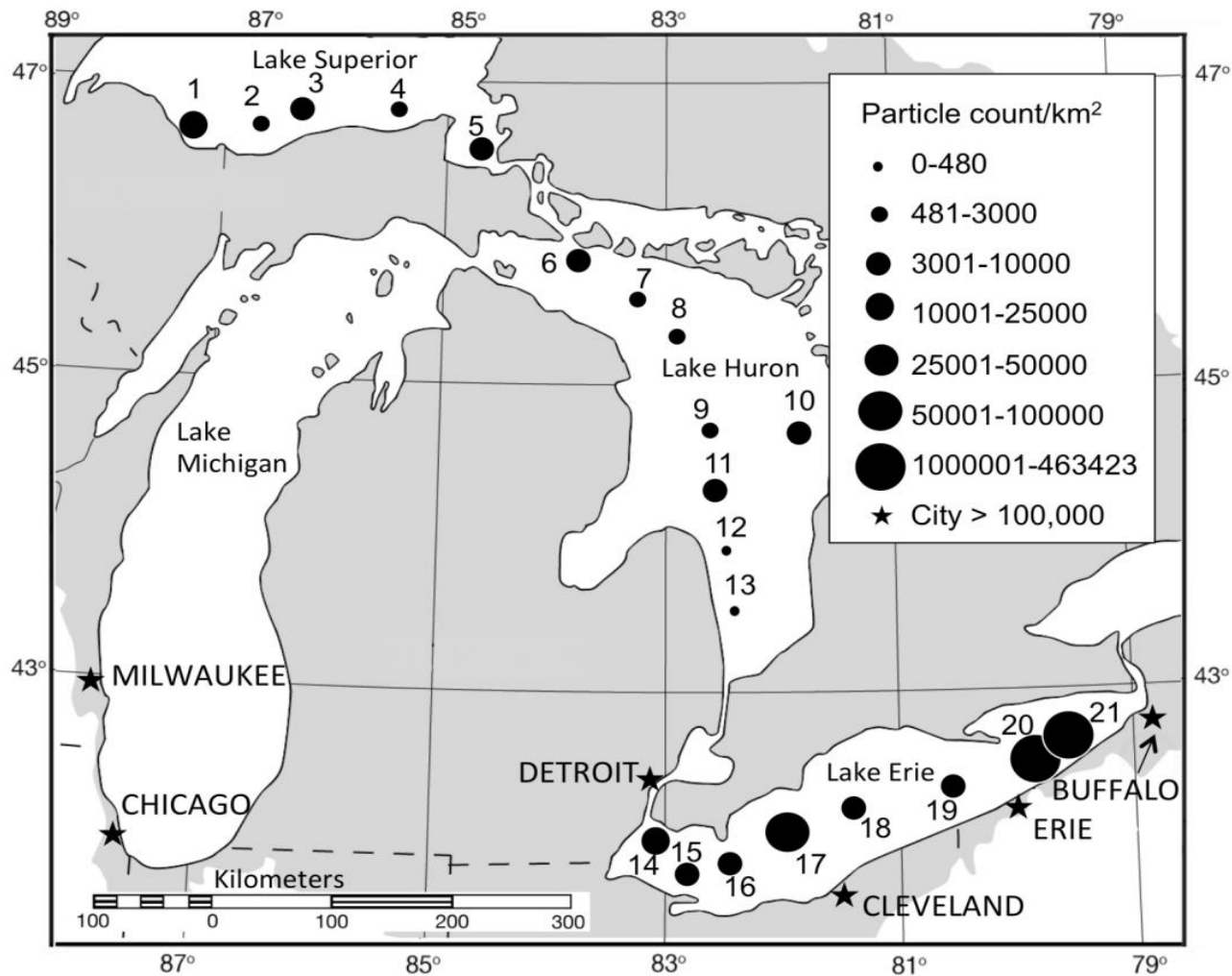
Source: Ryan, A Brief History of Marine Litter Research, in M. Bergmann, L. Gutow, M. Klages (Eds.), *Marine Anthropogenic Litter*, Berlin Springer, 2015; Plastics Europe



Chart from New Plastics Economy Report

2010: Fish found to be eating plastic in N. Pacific Gyre

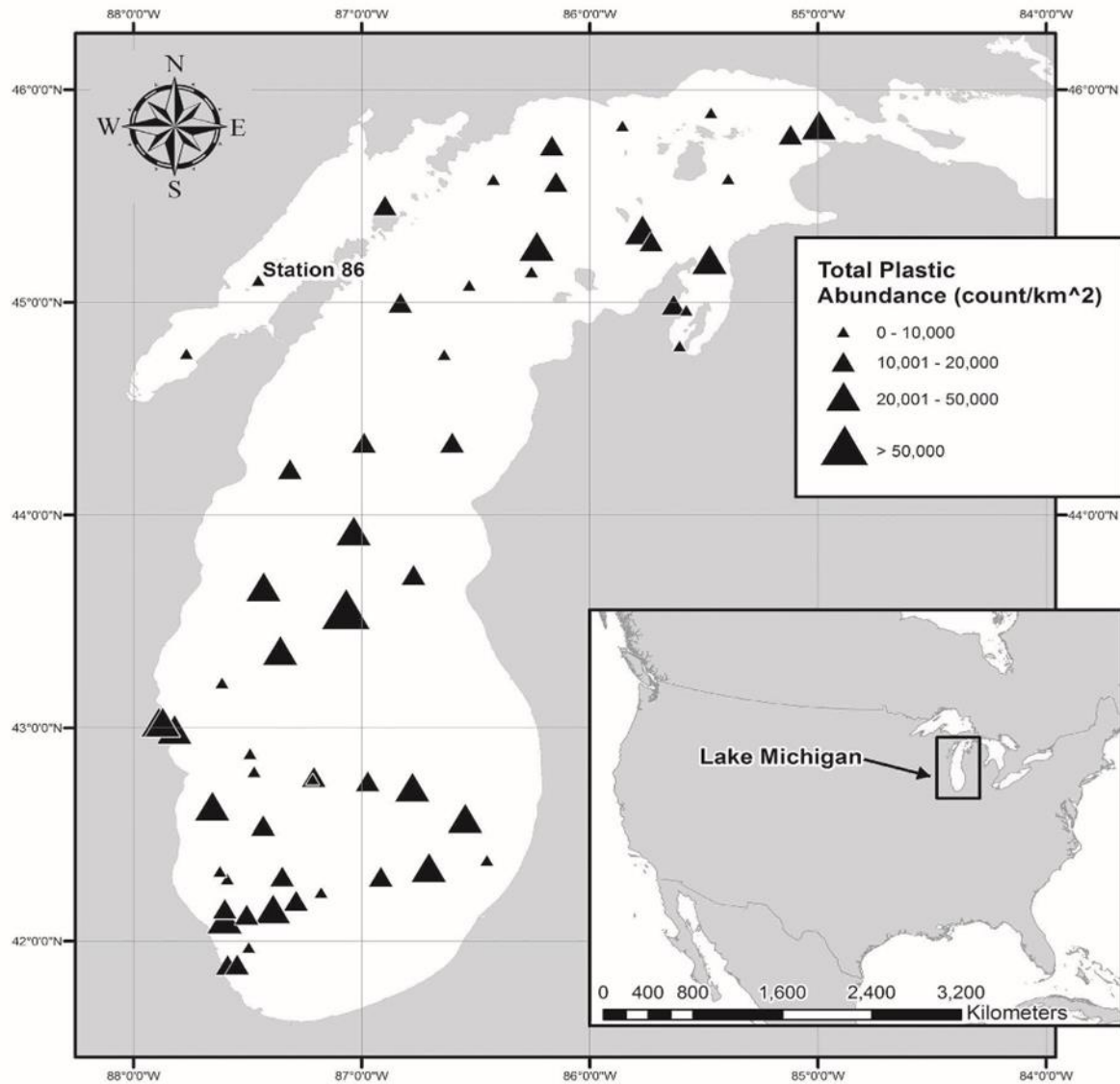
2016: U.N. estimates there to be 5.25 trillion pieces of oceanic macro and microplastics



Microplastic is pervasive and persistent in ecosystems *worldwide*

2013 Lake Michigan Survey

Mason et al. 2016, Journal of Great Lakes Research

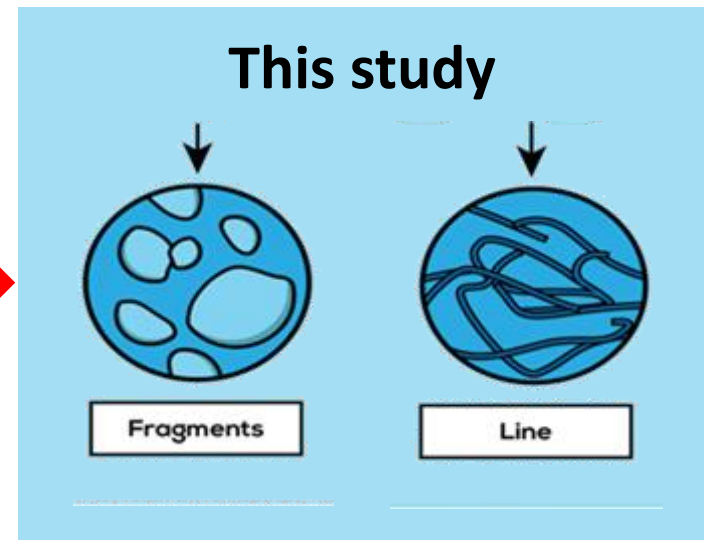
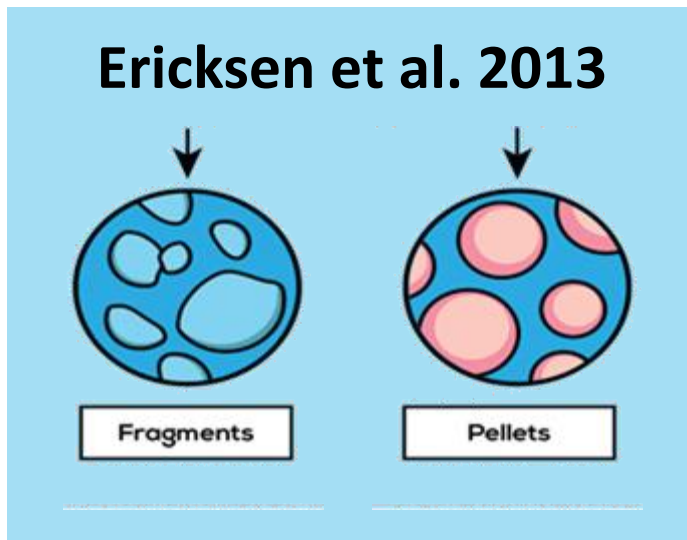


In search of microbeads...



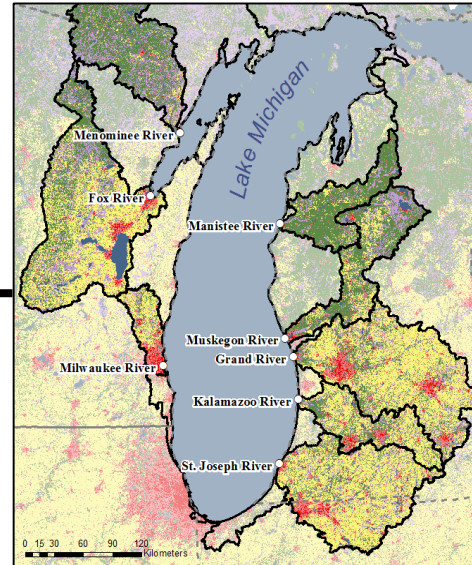
2013 Lake Michigan Survey

	Size Classification			Particle Type				
	0.355— 0.999mm	1.000— 4.749mm	> 4.75mm	Fragment	Pellet	Fiber/ Line	Film	Foam
	Eriksen et al. 2013	81%	17%	2%	42%	48%	0%	1%

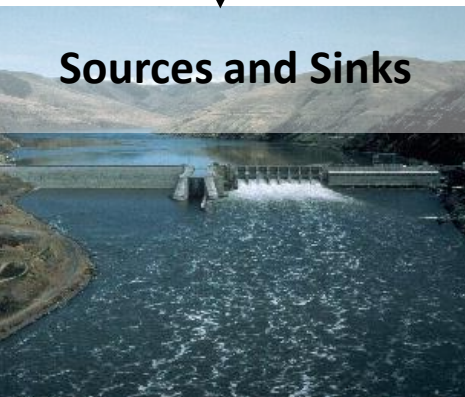


Microplastic Inputs to the Great Lakes

IISG-funded research funded at Loyola University Chicago



Sources and Sinks



Landscape Features



Annual Microplastic Budget



Aquatic Biota



Q: Are microplastic abundances higher in certain seasons?

Seasonal Microplastic Abundance Patterns

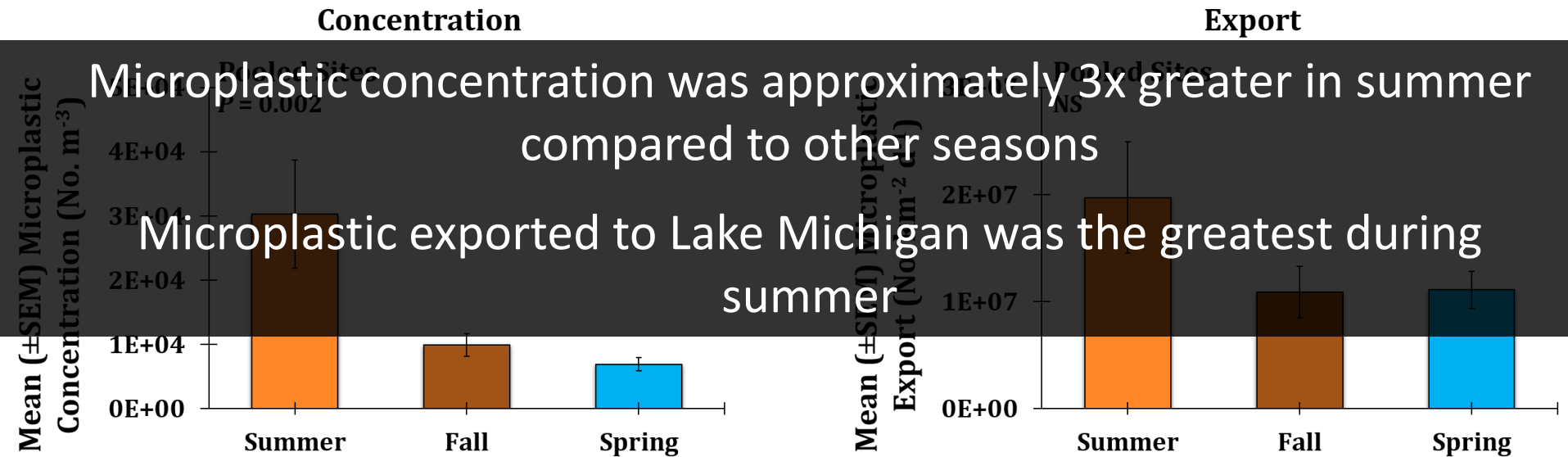


Figure 2: Mean microplastic concentration in river surface water (left panel) and export to Lake Michigan (right panel) between seasons from eight major Lake Michigan tributaries.

Q: Does land use affect seasonal microplastic abundances?

Microplastic Abundance and Change in Land-use

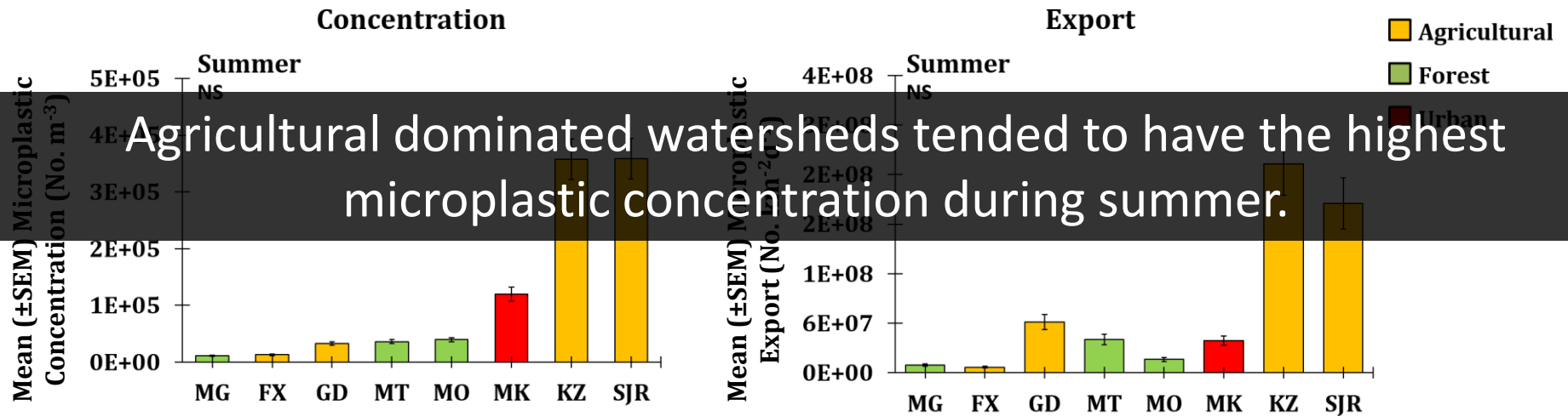
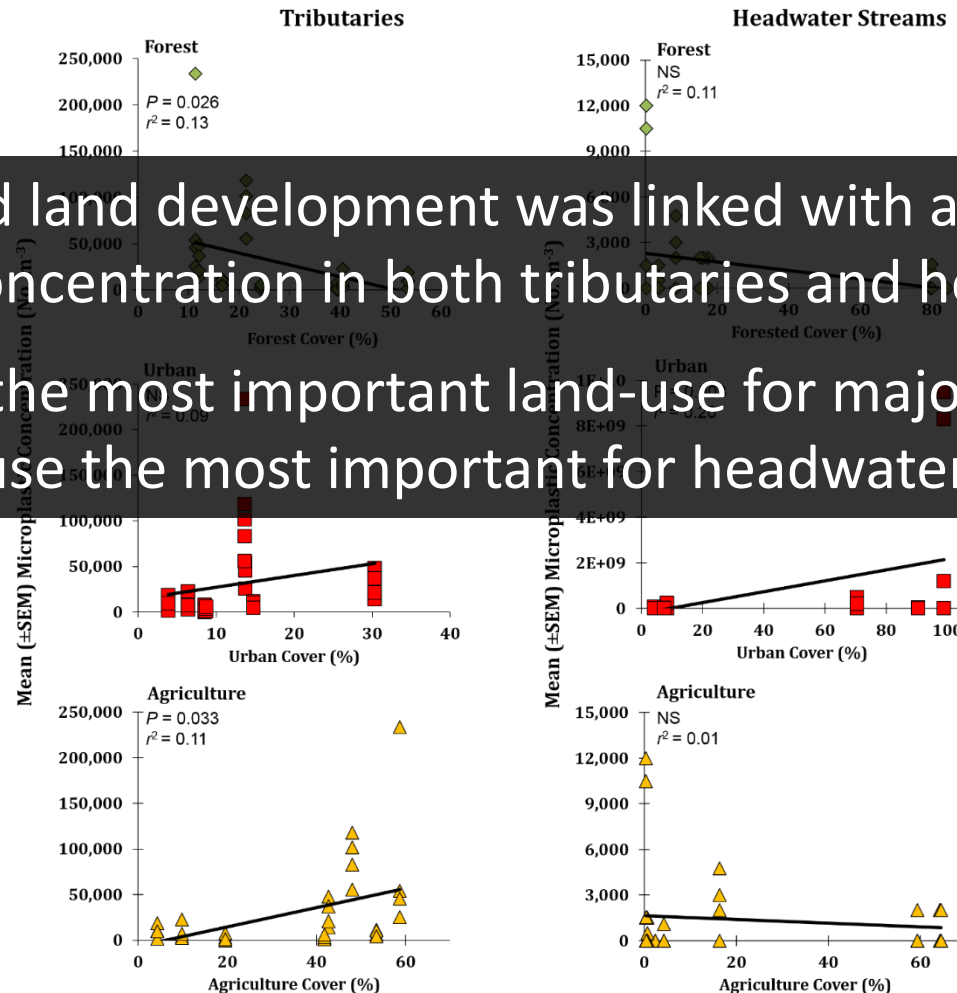


Figure 1: Seasonal microplastic concentration in river surface water (left panels) and export to Lake Michigan (right panel) between eight major Lake Michigan tributaries across a land-use gradient.

Q: Does increased land development contribute to more microplastic abundance in tributaries and headwater streams?

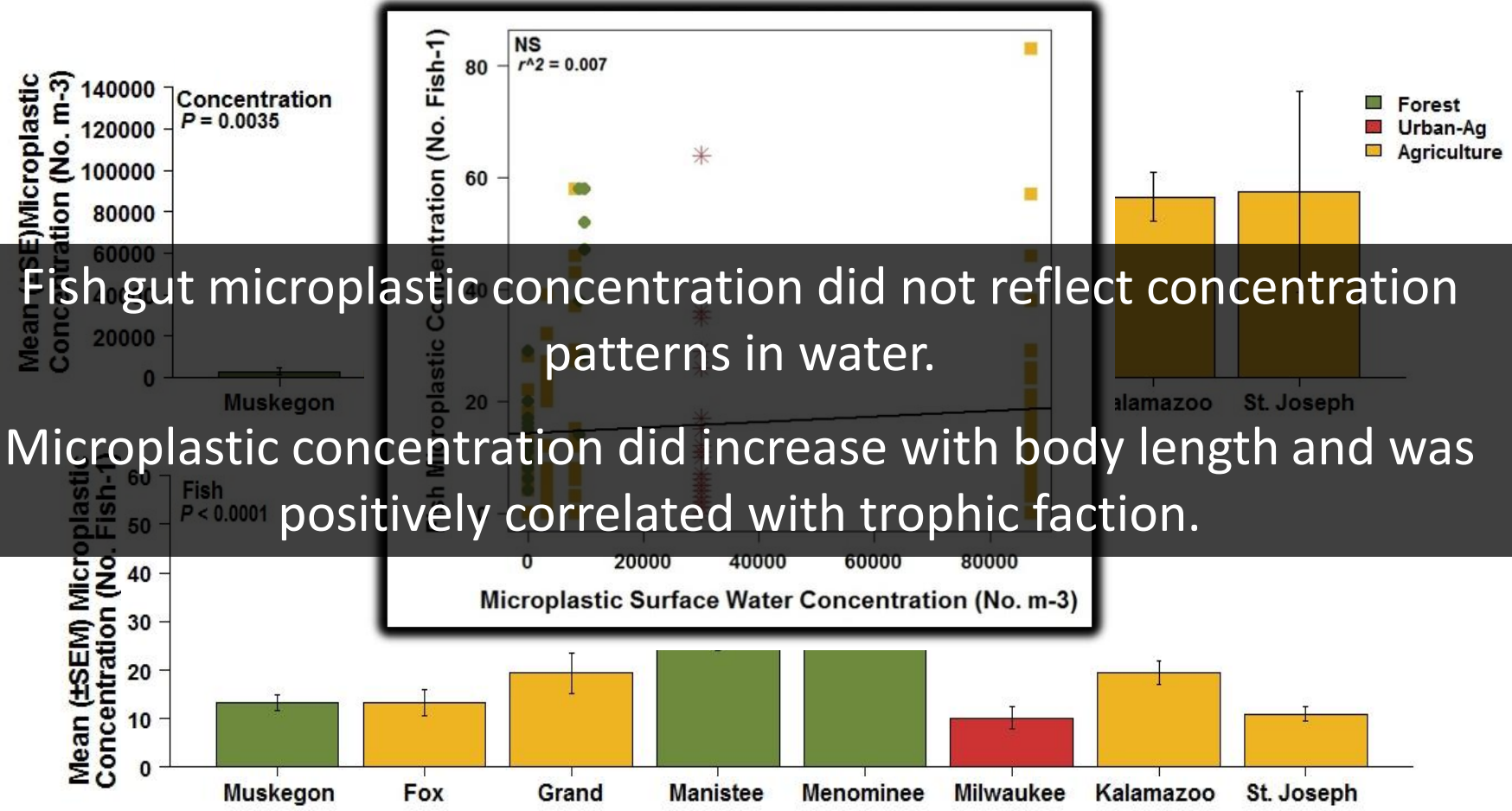
Land-use Effects on Microplastic Abundance



Increased land development was linked with an increase in microplastic concentration in both tributaries and headwater streams. Agriculture is the most important land-use for major rivers and urban land-use the most important for headwater streams.

Figure 1: Mean microplastic concentration in Lake Michigan tributaries and headwater streams across a land-use gradient summer 2016.

Q: Does microplastic concentration predict what's in the fish?



Fish gut microplastic concentration did not reflect concentration patterns in water.

Microplastic concentration did increase with body length and was positively correlated with trophic fraction.

Research Gaps: What don't we know?

- Method standardization
- What are the effects of microplastics?
 - Long-term?
 - On ecosystem and organism health?

Research Gaps: Effect Data

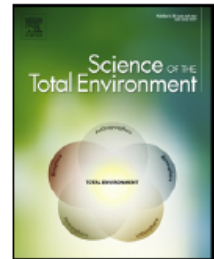
Science of the Total Environment 631–632 (2018) 550–559



Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv



Review

A meta-analysis of the effects of exposure to microplastics on fish and aquatic invertebrates



Carolyn J. Foley^{a,b,*}, Zachary S. Feiner^a, Timothy D. Malinich^a, Tomas O. Höök^{a,b}

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^b Illinois-Indiana Sea Grant College Program, 195 Marsteller St., West Lafayette, Indiana 47907, USA

IISG Meta-Analysis

- Question:

What is the impact of exposure to microplastics on 1) consumption and feeding, 2) growth, 3) reproduction, and/or 4) survival rates in aquatic organisms?
- Examined 43 published studies
 - In order to be included, study must have:
 - Measured at least one effect of direct exposure to an organism
 - Been an experiment
 - Included a 'no microplastics' control
 - Reported mean, sample size, and variance measures
 - Also looked at publication bias

IISG Meta-Analysis

- Question:

What is the impact of exposure to microplastics on 1) consumption and feeding, 2) growth, 3) reproduction, and/or 4) survival rates in aquatic organisms?

	Significant Negative effect?	Evidence of publication bias?
Consumption	YES	YES
Growth	YES	YES
Reproduction	YES*	YES
Survival	YES	YES

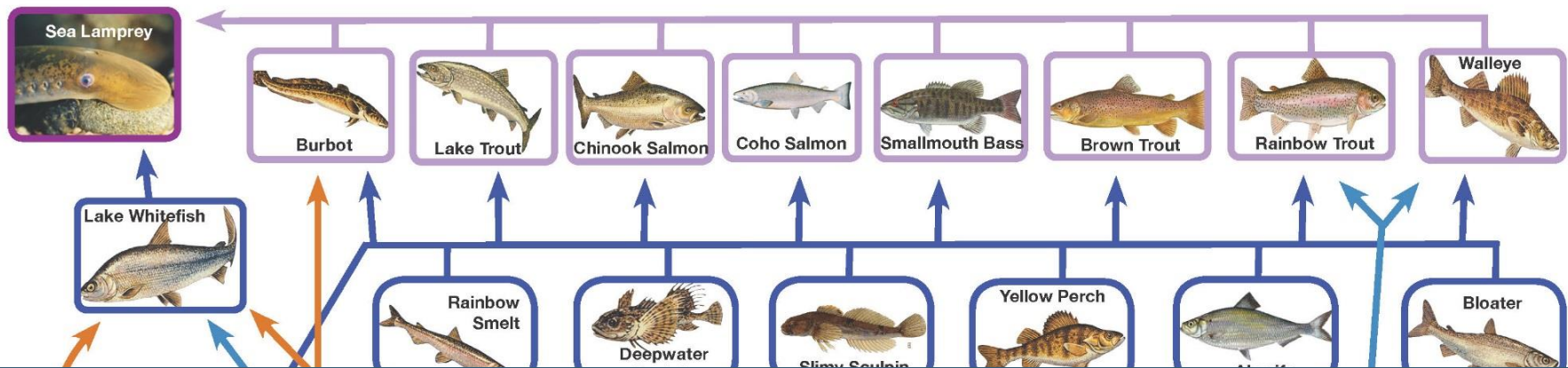
IISG Meta-Analysis

- Determined that effect varied with taxonomic group

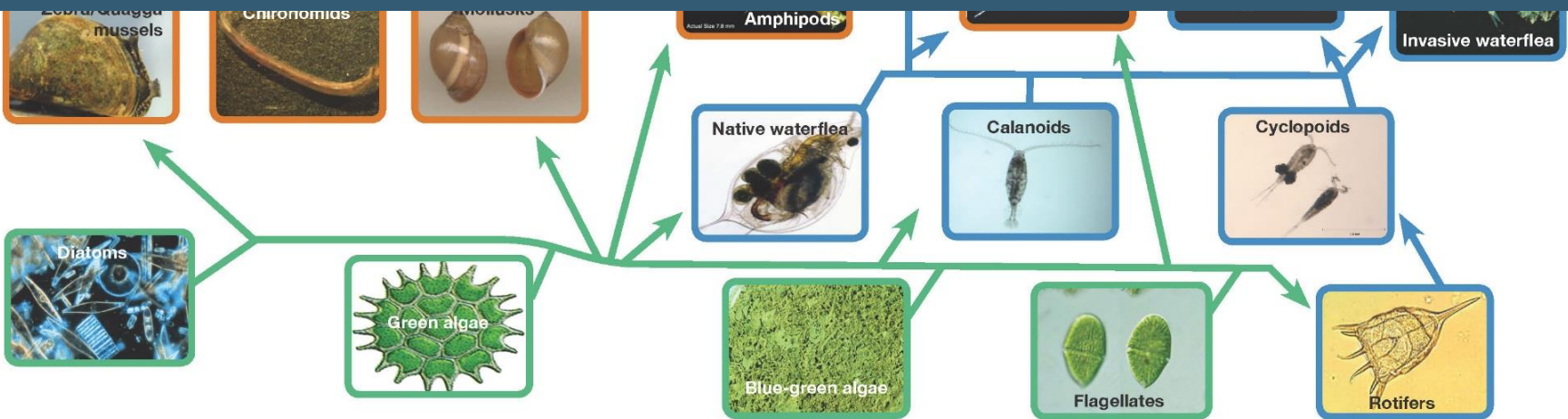
	Consumption	Growth	Reproduction	Survival
Zooplankton		*	*	*
Echinodermata			+	
Molluscs	+	+		
Macroinvertebrates		+		
Larval & Juvenile Fish	*			+
Adult Fish				

* = significant negative effects

+ = possible negative effects



- What do these results mean?
 - Many aquatic biota may be affected, but no real trends
 - Zooplankton most susceptible to microplastics exposure



How do we solve a problem like microplastics?

Legislative Solutions: Microbead-Free Waters Act

- Rinse-off Cosmetics
 - 12/31/17: Stop manufacturing
 - 12/31/18: Stop introduction & delivery into marketplace
- OTC Drug Rinse-off Cosmetics
 - 12/31/18: Stop manufacturing
 - 12/31/19: Stop introduction & delivery into marketplace



How do we solve a problem like microplastics?

Engineering Solutions: Consumer-Driven



Upcoming Conference: Emerging Contaminants in the Environment

May 21-22, 2019

More information at:

<https://www.istc.illinois.edu/events/conferences/ECEC19>



Acknowledgments

Tributary Inputs Data (Loyola University)

- Principal Investigators: Drs. John Kelly and Tim Hoellein
- Post Doc: Dr. Rachel McNeish
- Undergraduate Students: Homira Wardak, Deeb Omari, Hamza Asim, Rachel Meyer, Stuti Desai, Naiha Sharma, Rick Tijerina

Microplastics Meta-Analysis Data (IISG)

- Principal Investigator: Carolyn Foley



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ILLINOIS-INDIANA SEA GRANT

POLLUTION PREVENTION PROGRAM

Thank you! Questions?

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