MICROPLASTICS IN WATER SYSTEMS

Sources, Observations, and Potential Impacts

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CHEMISTS

A BRIEF HISTORY OF PLASTICS

DAWN OF THE "PLASTIC AGE"

- "Bakelite" in 1907, followed by "Styron" and "Lustrex Styrene"
  - "Material of a Thousand Uses"
  - Still demand for a durable, reusable product
- Nylon, polyethylene, and polystyrene were all perfected by late 1940s

Saturday Evening Post, 1/27/1923

Saturday Evening Post, 3/11/1950

DAWN OF THE "PLASTIC AGE"

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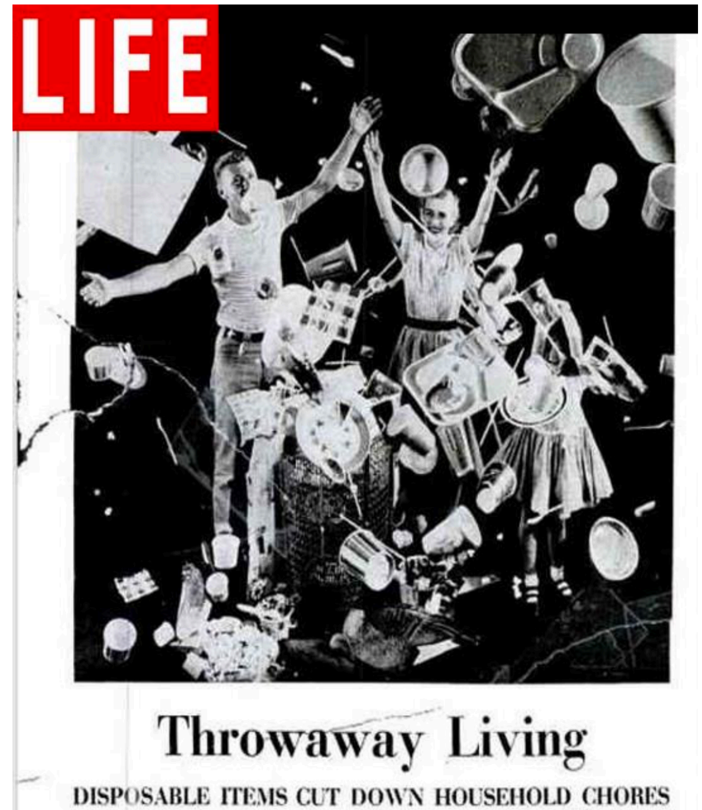
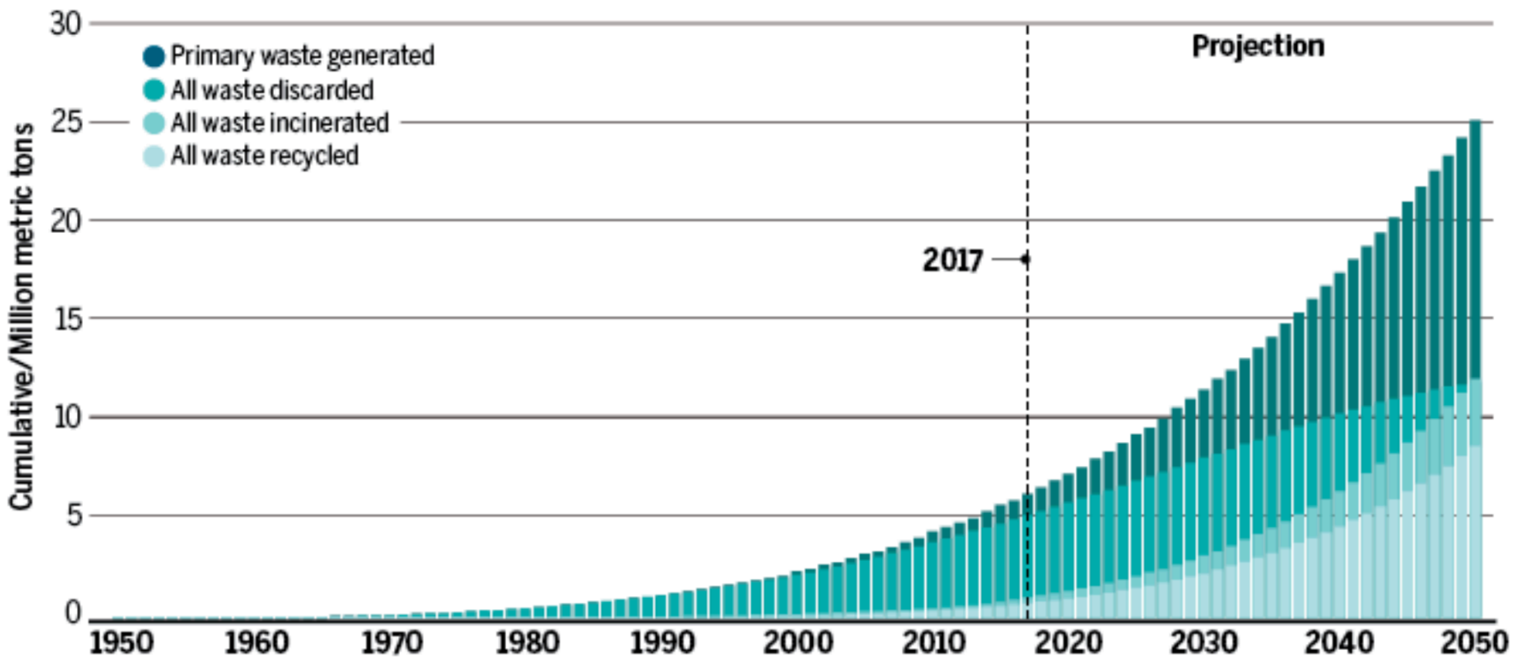
  - Still demand for a durable, reusable product
- Nylon, polyethylene, and polystyrene were all perfected by late 1940s
- Disposable plastics in 1950s
  - Lloyd Stouffer, editor of Modern Plastics, Inc. exclaimed "the future of plastics is in the trash can!"
- 1950 = 2 million tons of plastic produced
- 2020 = 400 million tons



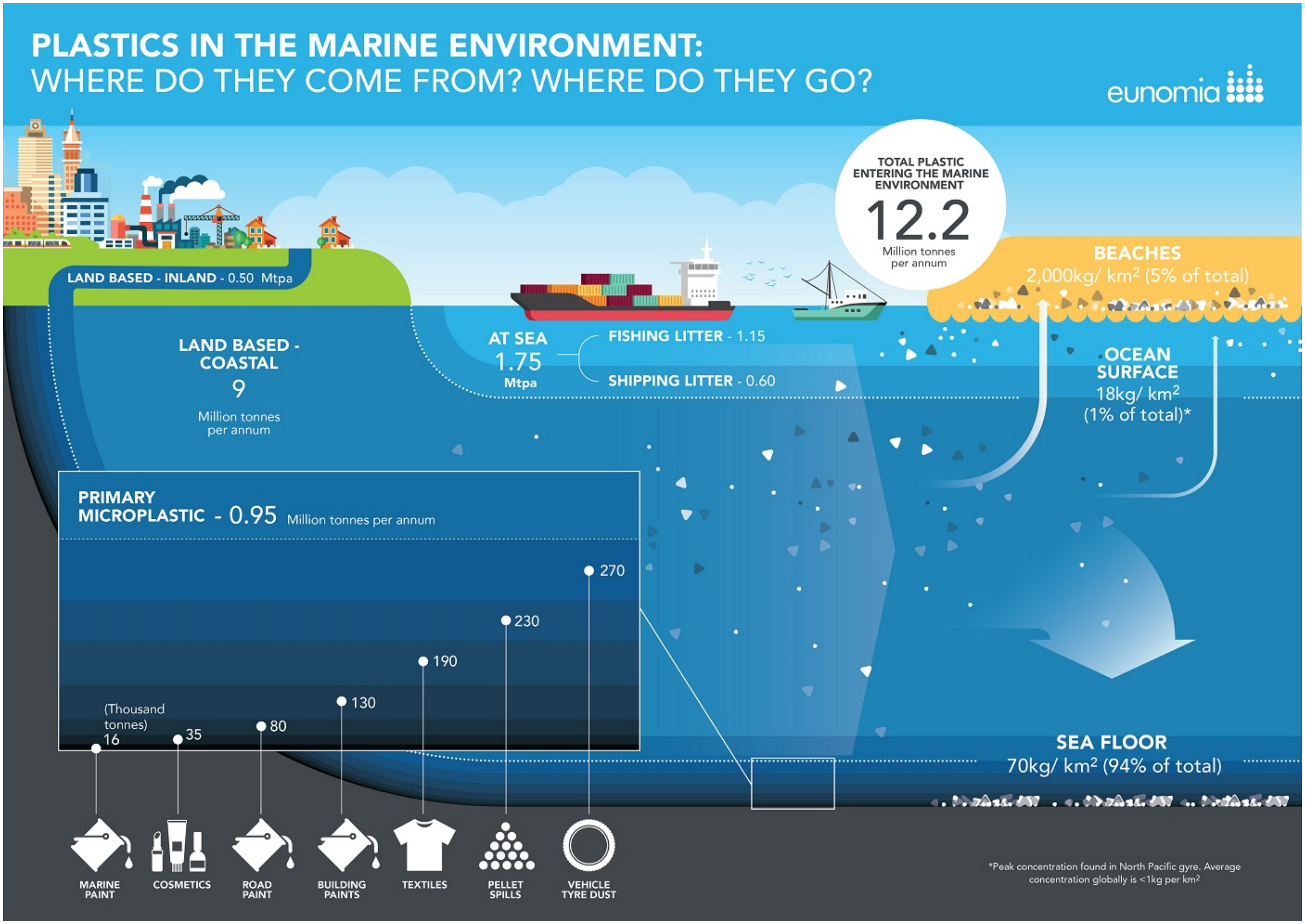
LIFE magazine, 1955

PLASTIC WASTE PRODUCTION & PROJECTIONS



G. Grullón, *Science* (Graphic); Geyer et al. 2017, *Science Advances* (Data)

SOURCES OF MICROPLASTICS



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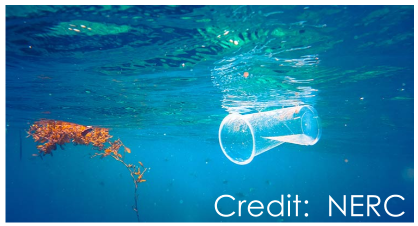
Eunomia, 2016 Report

PLASTICS OF DIFFERENT DENSITIES

<u>Low density (floats)</u>:



Credit: NERC

- Polypropylene (PP)
  - Plastic cups/lids, straws, marine line
- High density polyethylene (HDPE)
  - Trash bags, detergent bottles, milk jugs
- Low Density Polyethylene (LDPE)
  - Food packaging, grocery bags
- Polystyrene (PS) - foam

<u>High density (sinks)</u>:

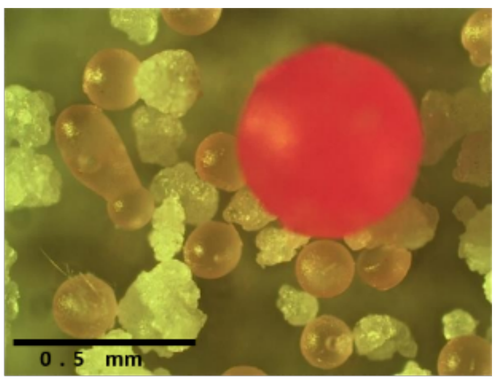
Credit: Sebnem Coskun

- Polystyrene (PS)
  - Disposable cutlery, CD cases
- Polyvinyl chloride (PVC)
  - Packaging around meat or fruit, commercial applications
- Polyethylene Terephthalate (PETE)
  - Water/juice/cooking oil bottles

WHAT ARE MICROPLASTICS?

*Microplastic is plastic < 5mm diameter

Primary:
Manufactured in small sizes



Baker et al. 2015

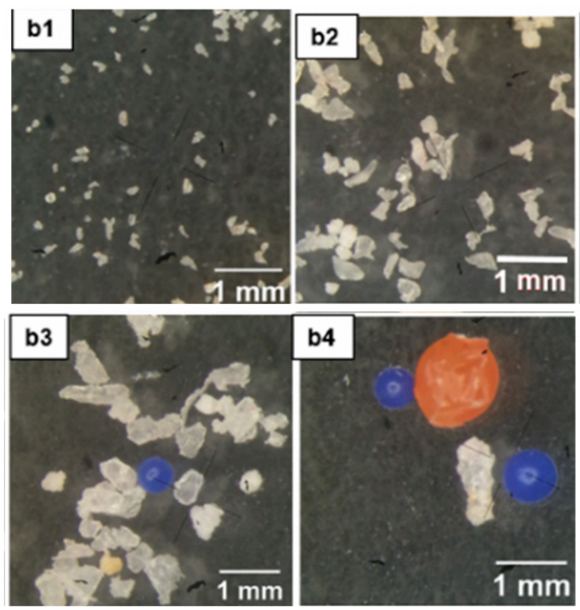
15-31% of MPs in the ocean

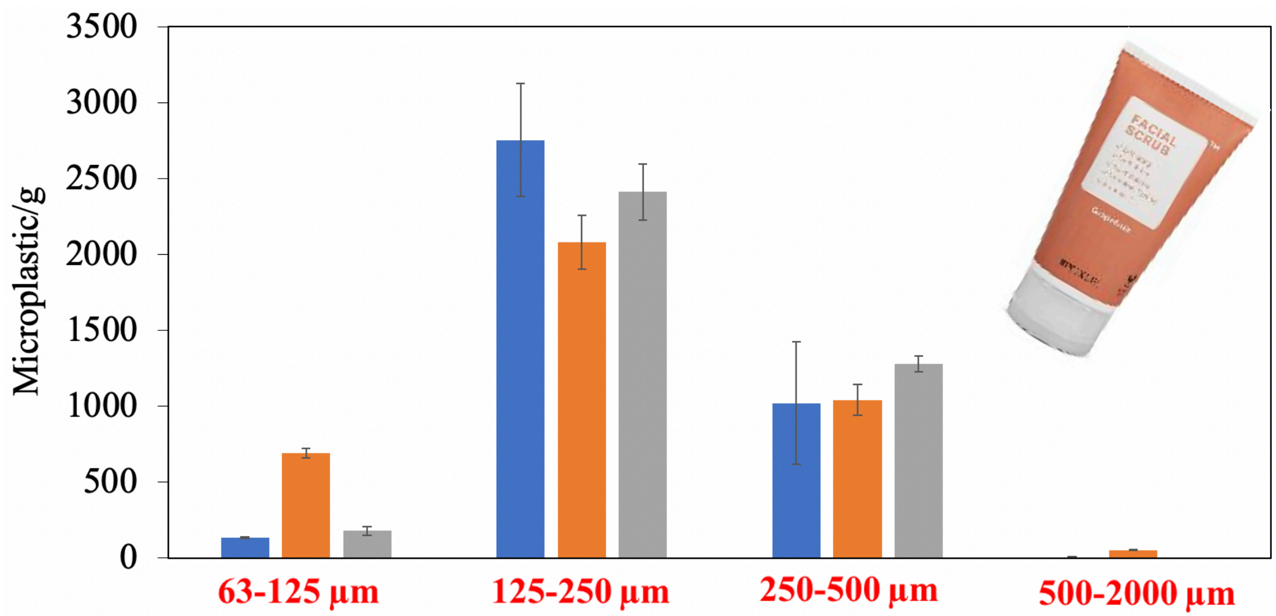
Main sources:

- Synthetic clothes (35% of primary MPs)
- Abrasion of automobile tires (28%)
- MPs added in personal care products (2%)

PRIMARY SOURCES OF MICROPLASTICS

Personal Care Products (about 2% of primary MPs)



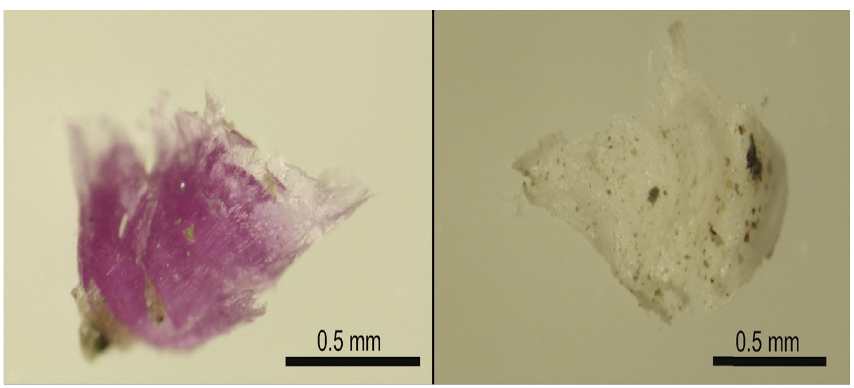


Estahbanati & Fahrenfeld 2016

WHAT ARE MICROPLASTICS?

*Microplastic is plastic < 5mm diameter

Secondary:
Derived from larger plastic (e.g. photo-, physical, or mechanical degradation)



Corcoran et al. 2015

69-81% of MPs in the ocean

Main sources:

- Plastic bags
- Bottles
- Food containers
- Fishing nets

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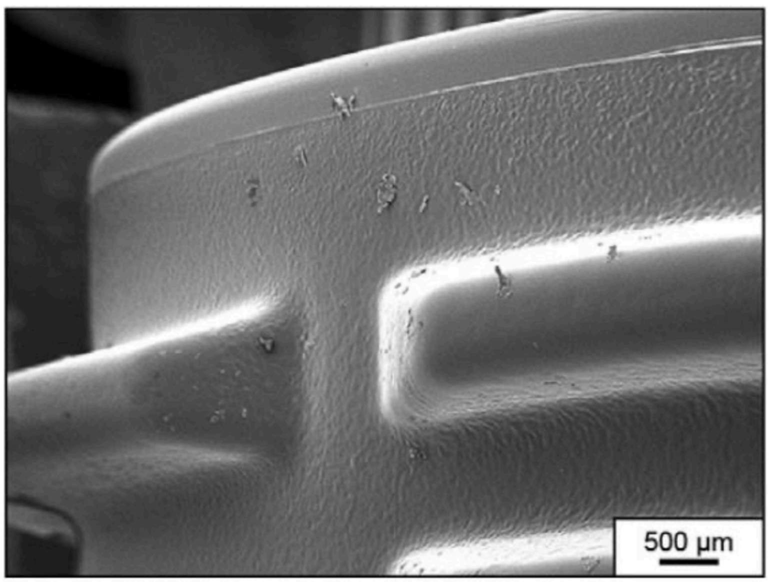
SECONDARY SOURCES OF MICROPLASTICS

Opening a plastic bottle
=14-2,400 MP particles

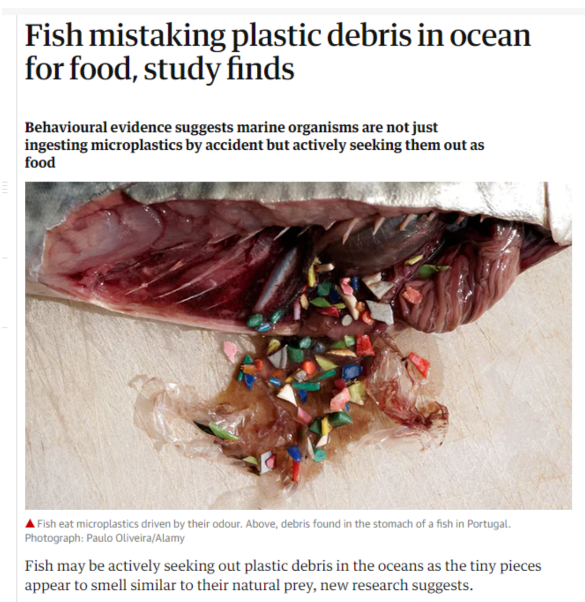


Winkler et al. 2019

Opening a plastic snack bag
=14,000-75,000 MP particles

Sobhani et al. 2020

POLLUTION IN WATER IS A GROWING CONCERN



Fish mistaking plastic debris in ocean for food, study finds

Behavioural evidence suggests marine organisms are not just ingesting microplastics by accident but actively seeking them out as food

▲ Fish eat microplastics driven by their odour. Above, debris found in the stomach of a fish in Portugal. Photograph: Paulo Oliveira/Alamy

Fish may be actively seeking out plastic debris in the oceans as the tiny pieces appear to smell similar to their natural prey, new research suggests.

Plastic production increasing

10% of plastic ends up in the oceans

Plastics are persistent

Plastics can sorb contaminants and be ingested by biota

POLLUTION IN WATER IS A GROWING CONCERN

"Marine debris is one of the most pervasive global threats to the health of the world's coastal areas, oceans, and waterways."

September 2019

Stephen Guertin,
Deputy Director
U.S. Fish and Wildlife Service, Department of the Interior

OBSERVATIONS OF MICROPLASTICS IN WATER SYSTEMS

FIRST OBSERVATIONS

1962

PLASTIC PARTICLE POLLUTION OF THE SURFACE OF THE ATLANTIC OCEAN: EVIDENCE FROM A SEABIRD

STEPHEN I. ROTHSTEIN

Department of Biological Sciences
University of California
Santa Barbara, California 93106

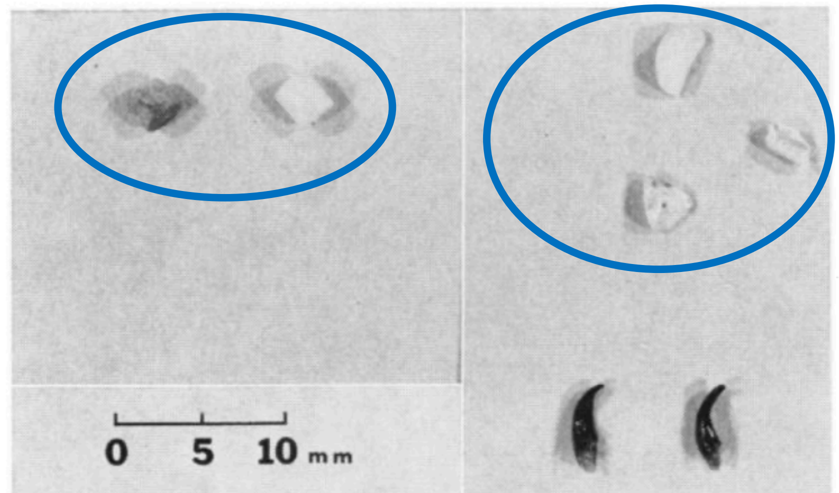
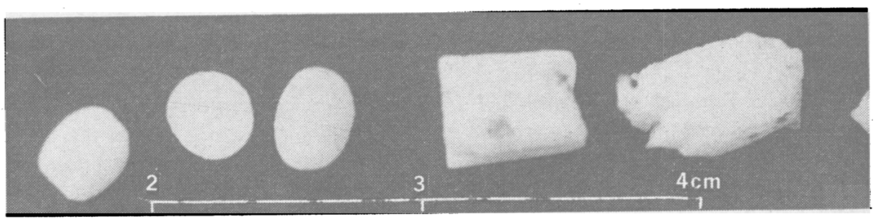


FIGURE 1. Objects found in the stomachs of two Leach's Petrels. The two pieces of plastic in the upper left corner were found in the gizzard of a petrel collected on Gull Island, Newfoundland. The three pieces of plastic as well as the two claw-like structures in the right half of the figure were all found in the gizzard of a petrel collected on Kent Island, New Brunswick. The claw-like structures have been tentatively identified as the pharyngeal teeth of a large polychaete.

FIRST OBSERVATIONS

1972, Edward Carpenter and colleagues

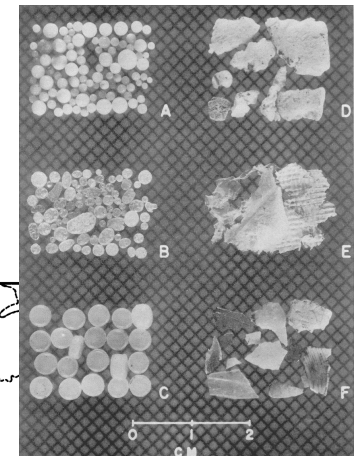


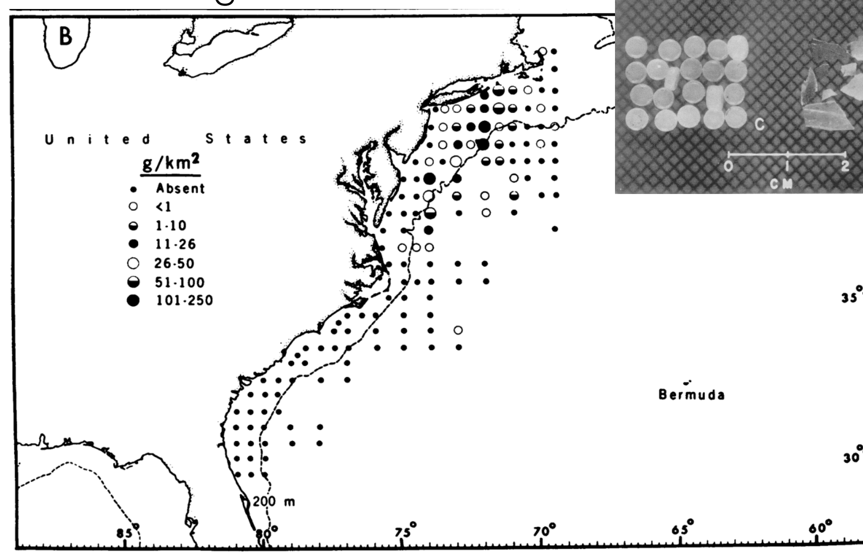
- Found plastics in EVERY net tow in Sargasso Sea
  - ➢ 2.5-5 mm
  - ➢ 3500 particles per km^2
  - ➢ Hydroids and diatoms attached

- Polystyrene spheres observed in Southern New England throughout water column
  - ➢ 0.1-2mm
  - ➢ Up to 14 particles per m^3
  - ➢ PCBs adsorbed to plastic
  - ➢ Evidence of ingestion by fish and chaetognaths

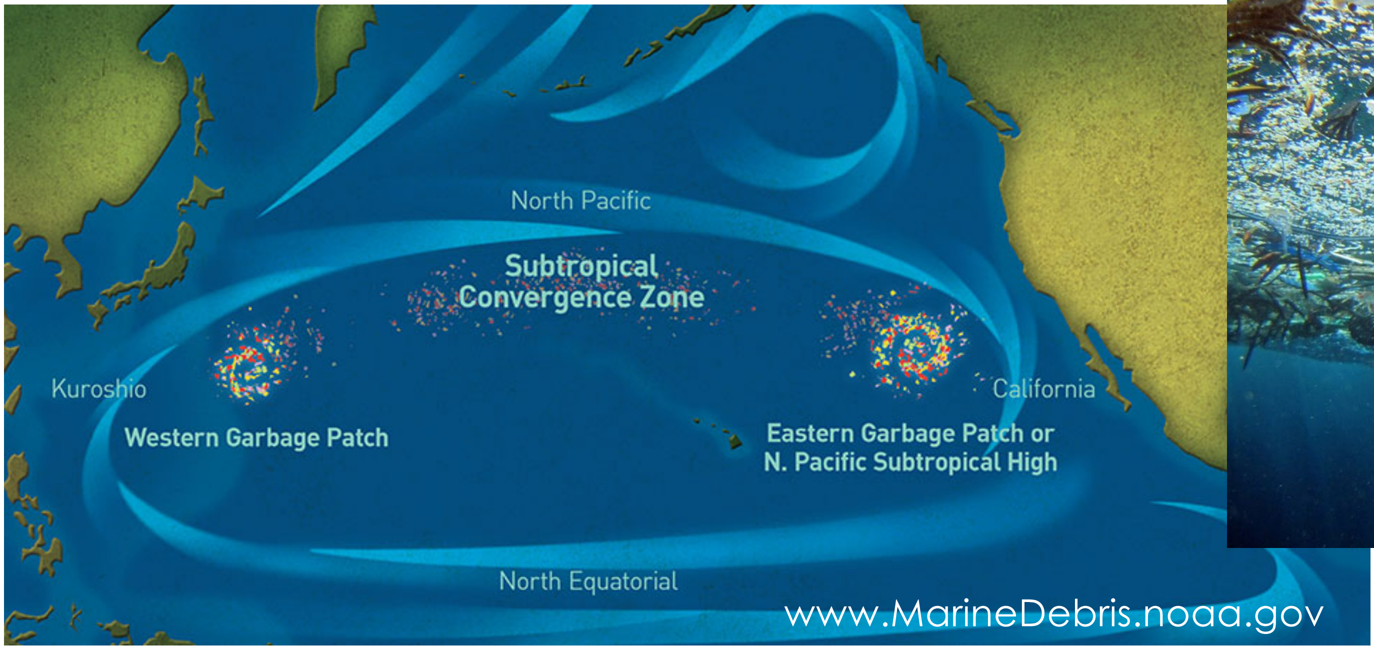
1974, John Colton and colleagues

- Observed plastic particles in surface waters of the Northwestern Atlantic
  - ➢ 1300 -167,000 particles per km^2
  - ➢ First suggestions of mitigation





GREAT PACIFIC GARBAGE PATCH



Accumulation caused by:
Floatable debris from multiple sources + ocean currents conducive to debris concentration

CURRENT WORK: RARITAN BAY

Collaborations with Nicole Fahrenfeld and Robert Chant, Rutgers University

Sea Grant
NJ Sea Grant Consortium
RESEARCH PROJECTS 2018-2019

River plumes as a control on microplastic entry into the food chain

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Plastics are frequently observed marine debris, and there is growing concern about microplastic ecotoxicity. Rivers are considered a major source of plastic marine debris. However, the relative importance of microplastics from different land-based sources is poorly understood. Frontal systems, due to their tendency to concentrate material (i.e. food), are often associated with elevated biological activity and may be in locations where microplastics enter the food chain. The researchers hypothesize that river flow conditions control microplastic abundances, distributions, and uptake in the marine environment.

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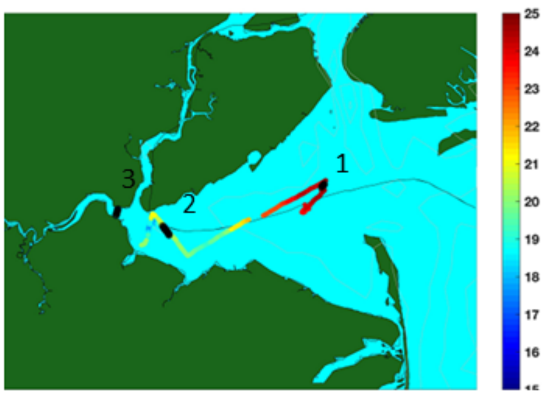
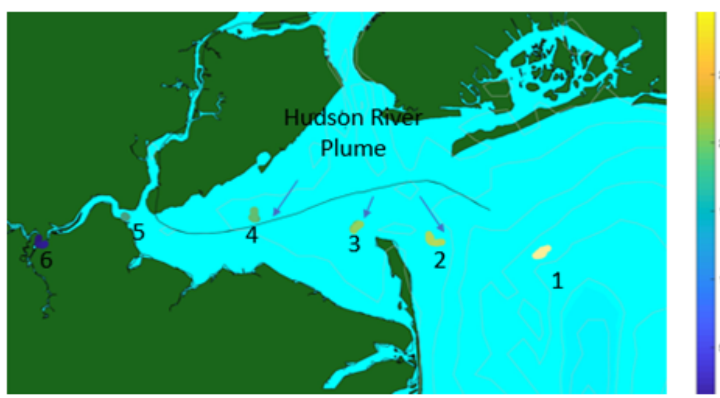
CURRENT WORK: RARITAN BAY

Microplastic composition and concentration *in situ* and in zooplankton were measured during low and high flow conditions along a salinity gradient and were compared to the profiles observed in land-based sources

Low Flow: July 26, 2018



Low Flow: April 11, 2019



High Flow: April 16, 2019

MP ANALYSIS

Baker et al. NOAA, 2015

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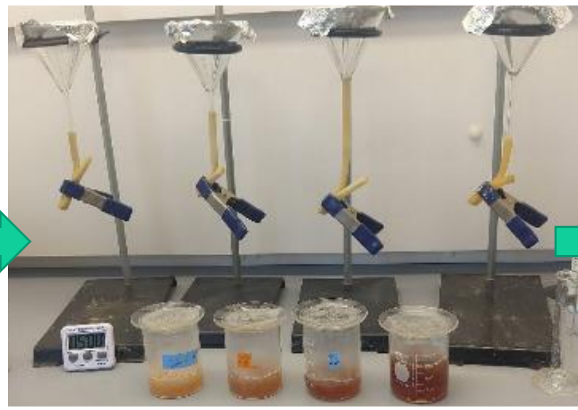
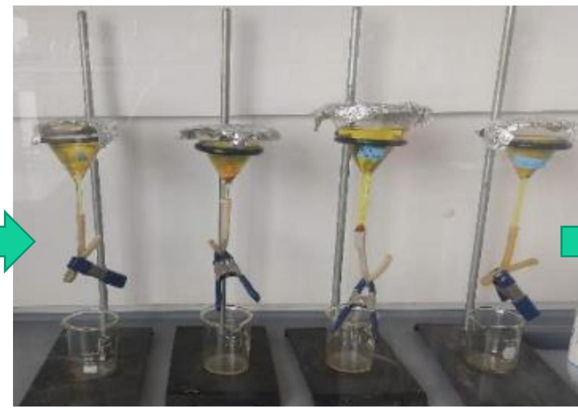
Sieving

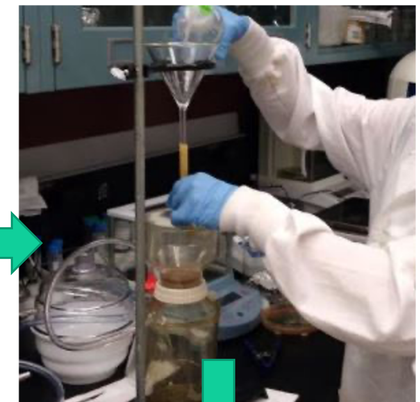
Wet peroxide oxidation

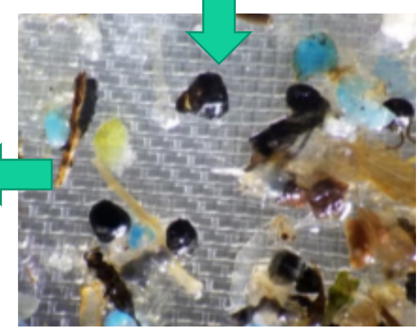


Density Separation

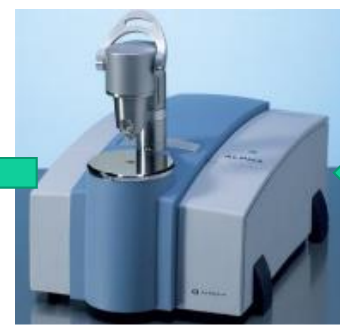


Collection



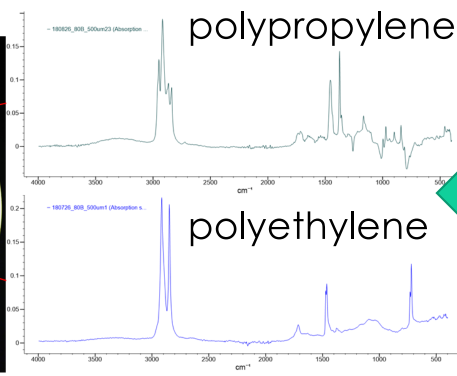


Visual ID of putative plastics

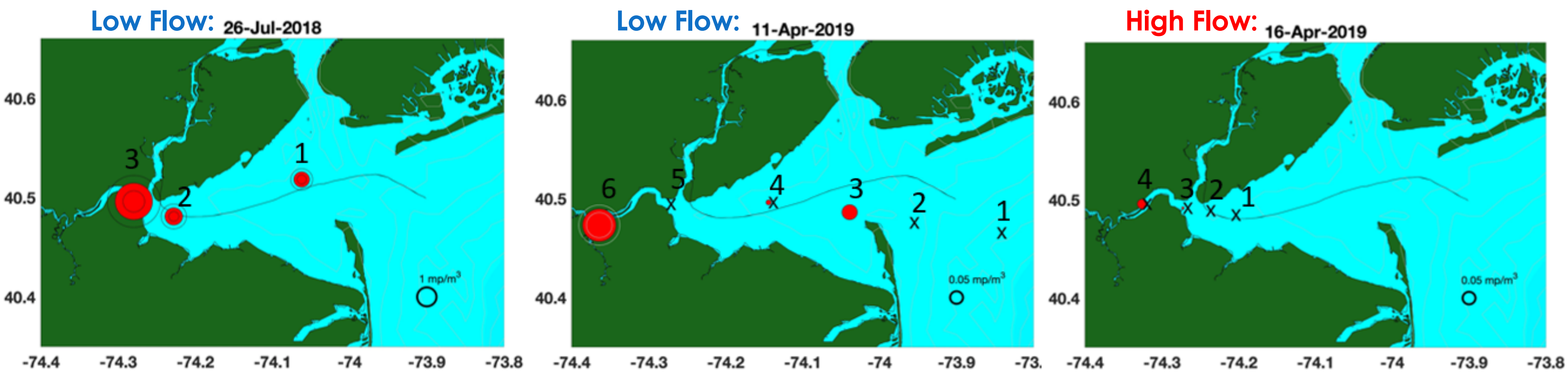


Attenuated total reflectance FTIR

FTIR microscope, refl. or transm.



RARITAN BAY: RESULTS



- Largest MP concentration near river mouth in low flow conditions
- Detectable concentrations in Hudson River plume in low flow conditions
- polyethylene > polypropylene > polystyrene > polyester > other plastics (250-2000 μm)

Bailey, Sipps, et al. (in prep)

ZOOPLANKTON MP ANALYSIS

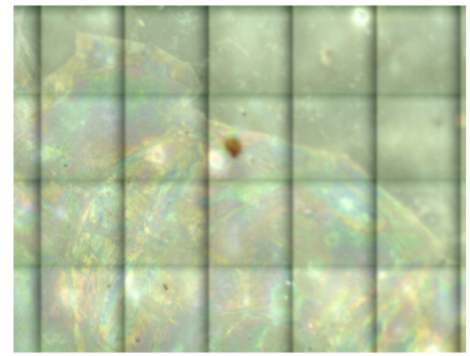
Digestion of zooplankton procedure

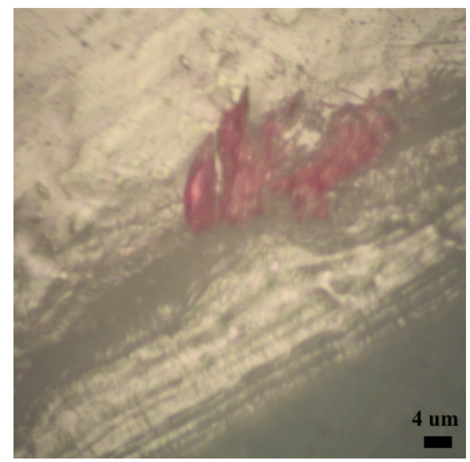
Proteinase – K (enzymatic)
(Cole et al. 2011)

Nitric Acid (chemical)
(Desforges et al. 2015)

MP Analysis & Detection

Focal plane array
FTIR & Raman
spectroscopy for
<100 µm particles

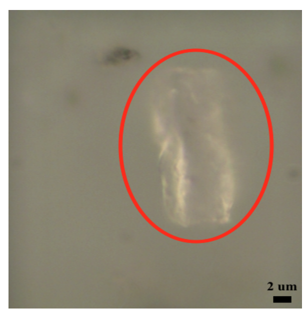


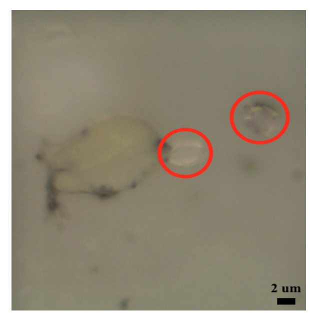


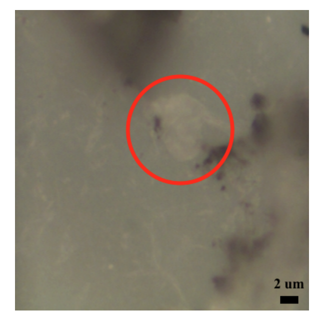
RARITAN BAY: RESULTS

Species	Number Zooplankton in Sub-Sample	Digestion Method	Total MPs Detected	Types of MPs Detected
Acartia tonsa	50	Enzymatic	1	PE
Acartia tonsa	100	Enzymatic	3	PP, PE
Acartia tonsa	100	Chemical	7	PP, PS, PE, polyamide
Acartia tonsa	100	Chemical	6	PE, PS
Acartia tonsa	100	Chemical	5	PE, PP

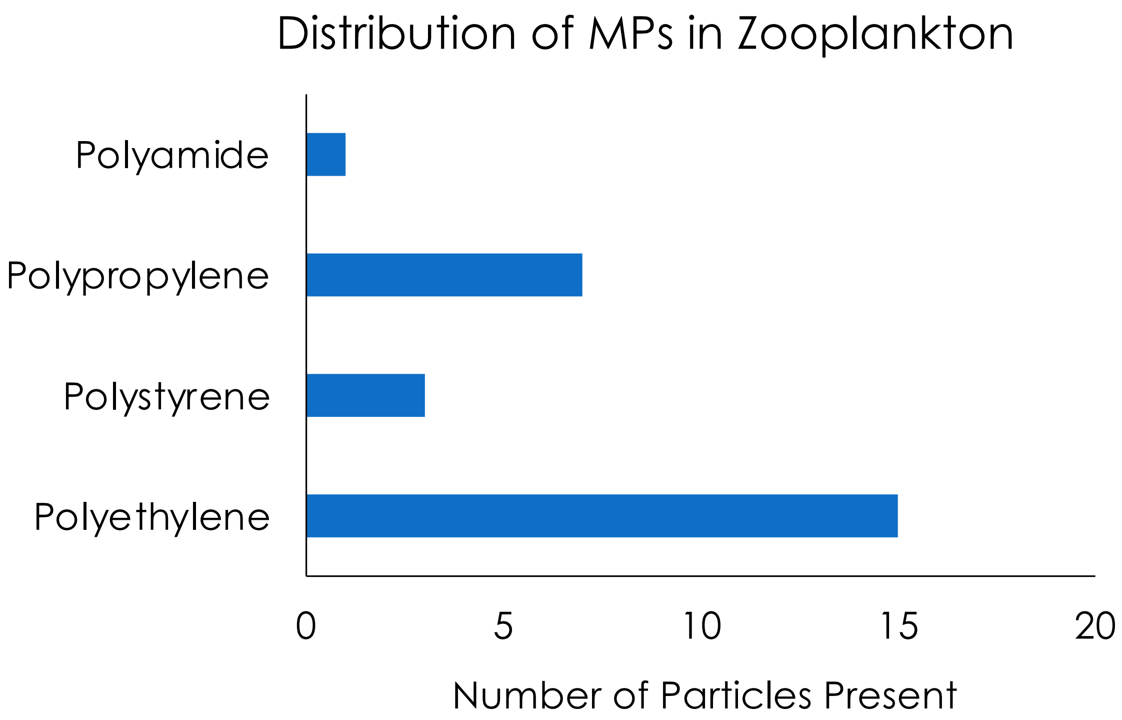
- MPs were detected in every zooplankton sample analyzed so far, averaging 5 MPs per 100 copepods collected in July 2018
- Many MPs detected (circled in red) were colorless and less than 100 µm in size





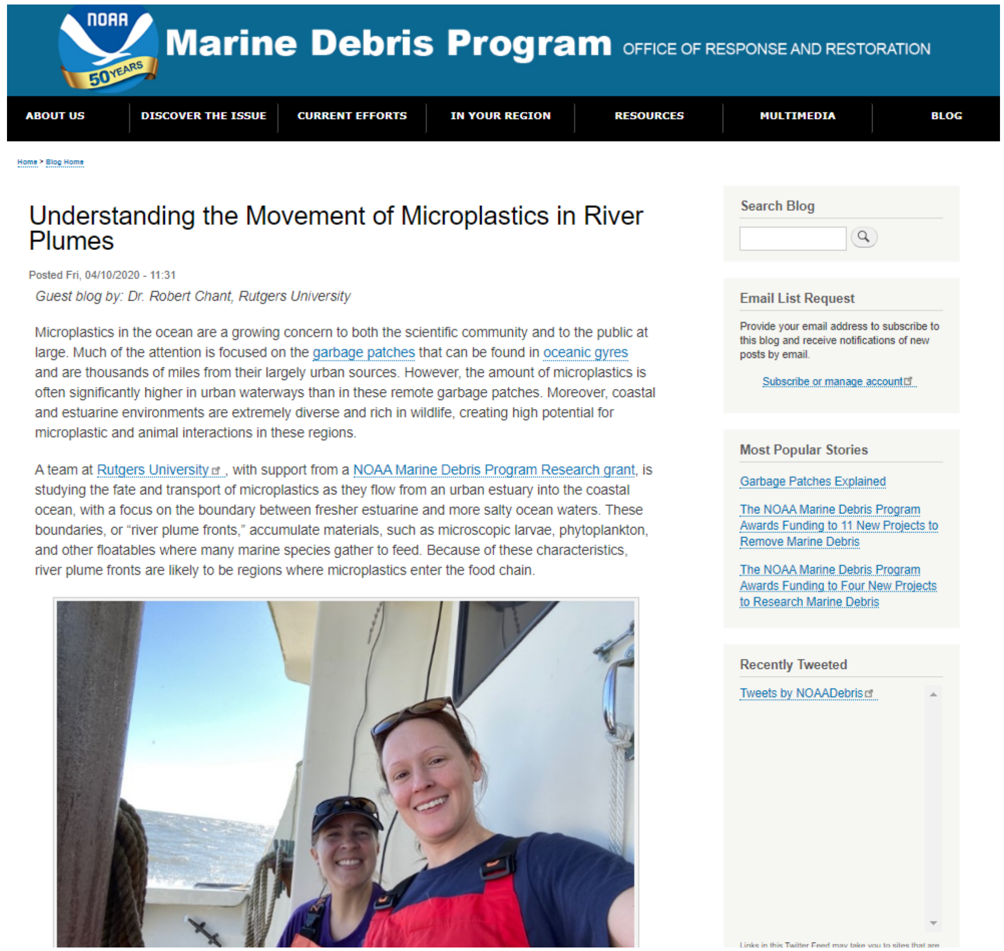


RARITAN BAY: RESULTS



CURRENT WORK: DELAWARE BAY

Collaborations with Nicole Fahrenfeld Georgia Arbuckle-Keil, and Robert Chant, Rutgers University



NOAA 50 YEARS

Marine Debris Program OFFICE OF RESPONSE AND RESTORATION

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Understanding the Movement of Microplastics in River Plumes

Posted Fri, 04/10/2020 - 11:31

Guest blog by: Dr. Robert Chant, Rutgers University

Microplastics in the ocean are a growing concern to both the scientific community and to the public at large. Much of the attention is focused on the garbage patches that can be found in oceanic gyres and are thousands of miles from their largely urban sources. However, the amount of microplastics is often significantly higher in urban waterways than in these remote garbage patches. Moreover, coastal and estuarine environments are extremely diverse and rich in wildlife, creating high potential for microplastic and animal interactions in these regions.

A team at Rutgers University, with support from a NOAA Marine Debris Program Research grant, is studying the fate and transport of microplastics as they flow from an urban estuary into the coastal ocean, with a focus on the boundary between fresher estuarine and more salty ocean waters. These boundaries, or "river plume fronts," accumulate materials, such as microscopic larvae, phytoplankton, and other floatables where many marine species gather to feed. Because of these characteristics, river plume fronts are likely to be regions where microplastics enter the food chain.

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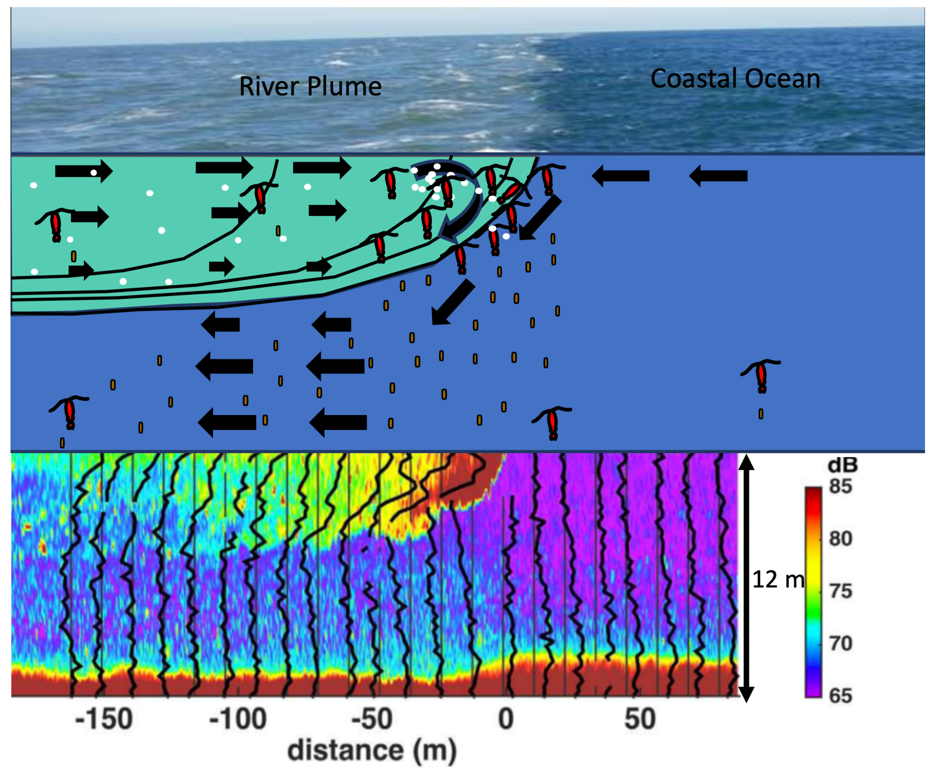
CURRENT WORK: DELAWARE BAY

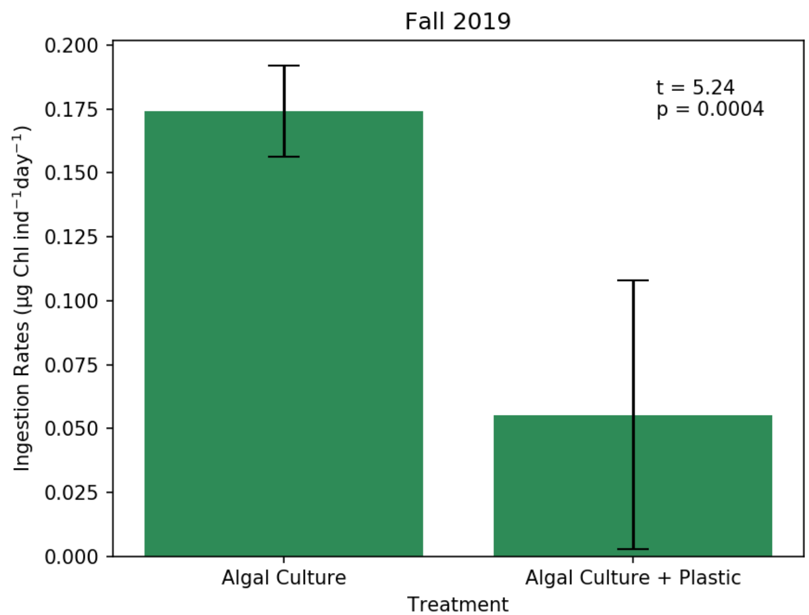
Our project is studying the role that river plume fronts have on two potential loss terms:

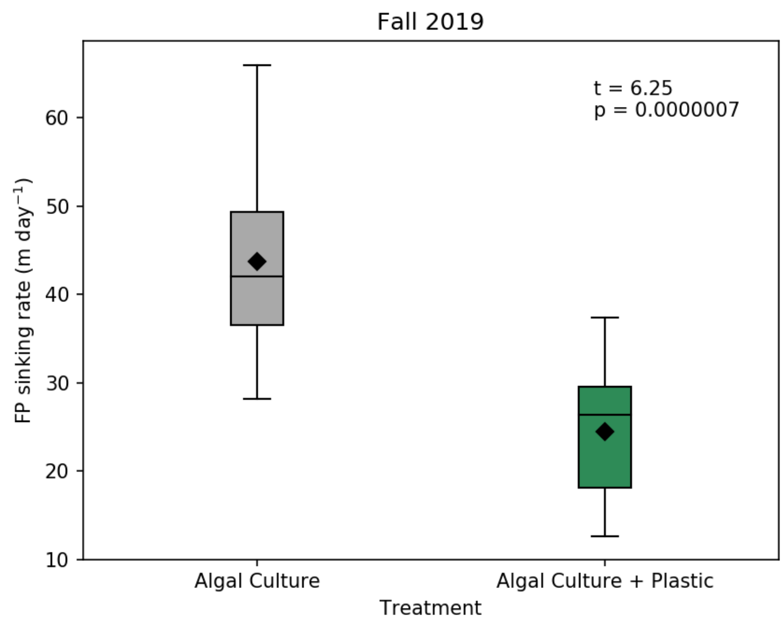
1) the incorporation of microplastics into the food chain

2) the sinking of microplastics as they are incorporated into zooplankton fecal pellets.



DELAWARE BAY: RESULTS





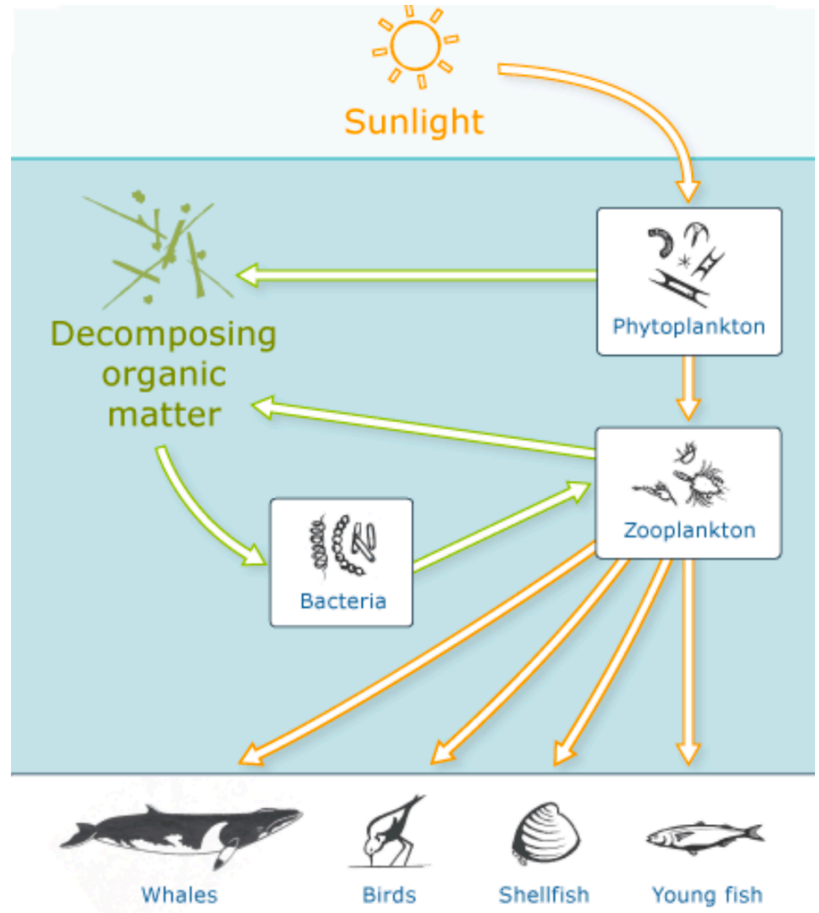
- Presence of microplastics decreased ingestion rates of copepods on algae
- MPs were accumulated into fecal pellets which lowered their vertical sinking rates

POTENTIAL ECOLOGICAL IMPACTS OF MICROPLASTICS

IMPACTS ON FOOD WEBS

- Microplastics are eaten directly by organisms and transferred to and accumulated in larger organisms through predation

- Fecal material containing microplastics can be produced by animals and sink to bottom where it is ingested by benthic organisms like shellfish



IMPACTS ON SEABIRDS

PNAS

Threat of plastic pollution to seabirds is global, pervasive, and increasing

Chris Wilcox[a,1], Erik Van Sebille[b,c], and Britta Denise Hardesty[a]

[a]Oceans and Atmosphere Business Unit, Commonwealth Scientific and Industrial Research Organisation, Hobart, TAS 7001, Australia; [b]Grantham Institute & Department of Physics, Imperial College London, London SW7 2AZ, United Kingdom; and [c]Australian Research Council Centre of Excellence for Climate System Science, University of New South Wales, Sydney, NSW 2052, Australia

Edited by James A. Estes, University of California, Santa Cruz, CA, and approved July 2, 2015 (received for review January 31, 2015)

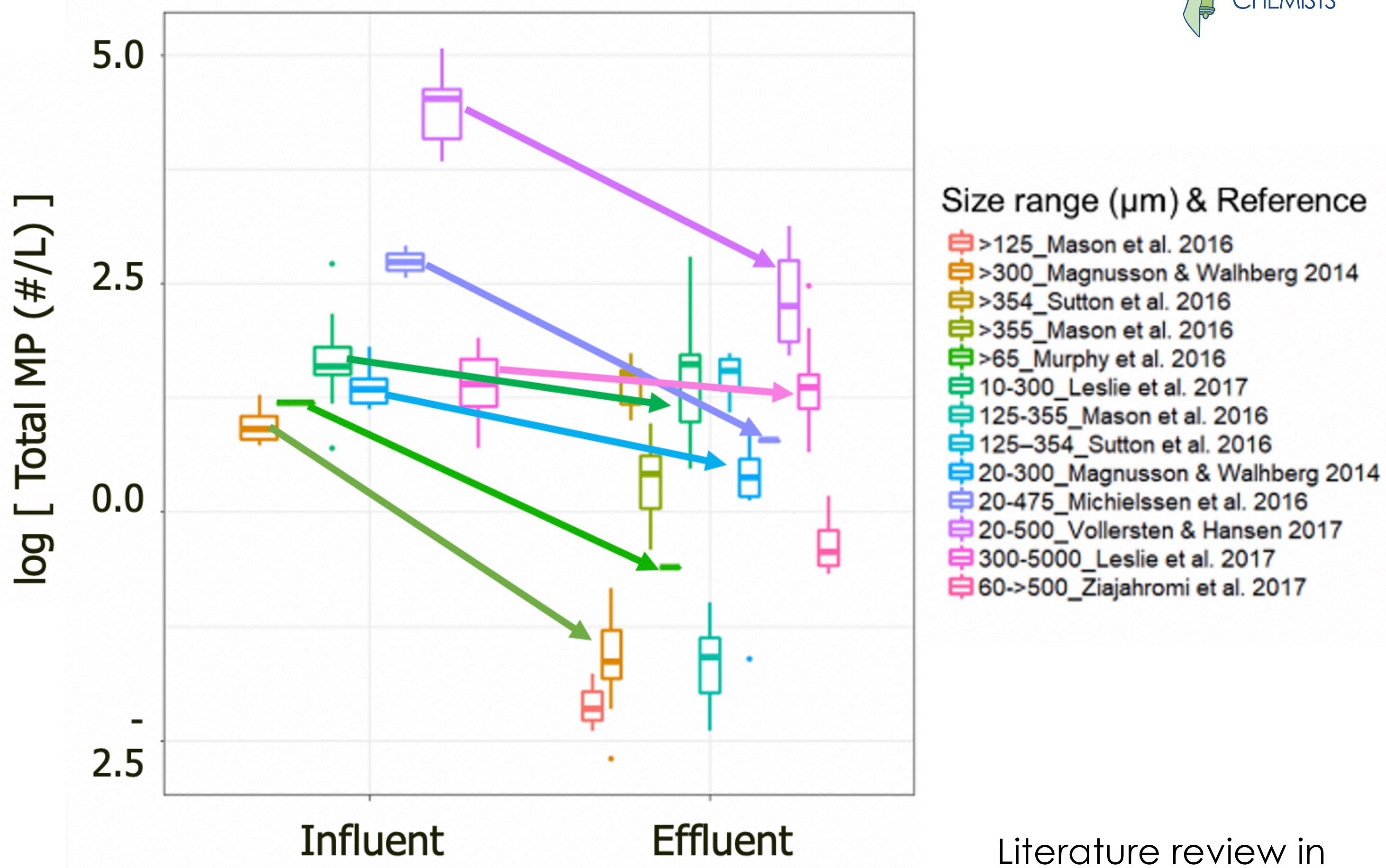
- 90% of seabirds have ingested plastic. By 2050, virtually all seabirds will have ingested it.

OTHER IMPACTS ON THE ECOSYSTEM

- Injure, harm, or kill marine and coastal wildlife
- Damage and degrade habitats
- Cause economic loss to fishing and maritime industries
- Threaten human health and safety

MITIGATION STRATEGIES

WASTEWATER TREATMENT PLANTS ARE EFFECTIVE AT REMOVAL



Literature review in Fahrenfeld et al. 2019

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SURFACE WATER CLEAN-UP EFFORTS UNDERWAY

THE OCEAN CLEANUP

OCEANS RIVERS PRODUCTS UPDATES CAREERS ABOUT PRESS SUPPORT US

ENGINEERING, GENERAL 2 October 2019

THE OCEAN CLEANUP SUCCESSFULLY CATCHES PLASTIC IN THE GREAT PACIFIC GARBAGE PATCH

DEEP OCEAN CLEAN-UP IS THE PROBLEM TO SOLVE

Over 90% of plastics are not in surface waters, but are thought to be fated to the deep sea

Here, clean up is logistically difficult, if not impossible

Marine Policy 96 (2018) 204–212

Contents lists available at ScienceDirect

Marine Policy

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

ELSEVIER

Human footprint in the abyss: 30 year records of deep-sea plastic debris

Sanae Chiba[a,b,*], Hideaki Saito[c], Ruth Fletcher[b], Takayuki Yogi[d], Makino Kayo[d], Shin Miyagi[d], Moritaka Ogido[d], Katsunori Fujikura[e]

Photo credits: JAMSTEC

LONG-TERM SOLUTIONS

Use less!

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Recent bans on single-use plastic and microbeads in personal care products

ONGOING CHALLENGES IN THE FIELD

- Accurately identifying plastics (including nanoplastics) and polymers (multiple methods needed)
- Lack of data for several terrestrial sources
- Difficulty in isolating, identifying, and quantifying small (< 100μm) microplastic particles digested from organic-rich samples
- Poor understanding of fate/transport/weathering processes for MP
- Need more information about biodegradation potential

THANK YOU

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NOAA Marine Debris Program (NA19NOS9990083)

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