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UNIVERSITY OF TORONTO

Ocean Conservancy

Altered Oceans Part Four: Plague of Plastic Chokes the Seas

This five-part series on the crisis in the world's oceans was published in July and August of 2006. The series — by reporters Kenneth R. Weiss and Usha Lee McFarling and photographer Rick Loomis — won the 2007 Pulitzer Prize for explanatory reporting.

By Kenneth R. Weiss

AUGUST 2, 2006 | REPORTING FROM MIDWAY ATOLL

The albatross chick jumped to its feet, eyes alert and focused. At 5 months, it stood 18 inches tall and was fully feathered except for the fuzz that fringed its head.

All attitude, the chick straightened up and clacked its beak at a visitor, then rocked back and dangled webbed feet in the air to cool them in the afternoon breeze.

Impacts of plastics in the aquatic environment

THEN	NOW
• **90% of floating litter is plastic**	• 90% of debris in seabirds is plastic; 88% of surface water collected has plastic.
• **80% of marine litter comes from land. The rest comes from ships.**	• 80% of plastic debris comes from land. • 8 million MT entering each year. • The sources are diverse.
• **46,000 pieces of plastic litter are floating on every square mile of the oceans. About 70% will eventually sink.**	• On average, ~364,800 pieces of floating plastic per square mile. • We do not know how much sinks. The estimated amount of floating plastic is ~1% of amount predicted to enter oceans/yr.
• **1 million seabirds choke or get entangled by plastic per year.**	• 80 species of seabirds eat plastic, and plastic is ingested by 90% of individuals within each species.
• **Projects 10-fold increase of marine plastic debris every decade.**	• There is no apparent increasing or decreasing trend.
• **in North America, per-capita usage will increase to 326 lbs/yr by 2010.**	• Per-capita usage of plastic in 2015 was 306.4 lbs/year in North America.

See report for references.

http://www.gesamp.org/data/gesamp/files/file_element/0c50c023936f7ffd16506be330b43c56/rs93e.pdf

93

REPORTS AND STUDIES

GESAMP
Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

SOURCES, FATE AND EFFECTS OF MICROPLASTICS IN THE MARINE ENVIRONMENT: PART TWO OF A GLOBAL ASSESSMENT

A report to inform the Second United Nations Environment Assembly

GESAMP Working Group 40
2nd phase

Contributors to the report:

Linda Amaral-Zettler, Anthony Andrady, Sarah Dudas (Chapter 5 lead), Joan Fabres, Francois Galgani (Chapter 7 lead), Denise Hardesty (Chapter 3 lead), Valeria Hidalgo-Ruz, Sunny Hong, Peter Kershaw, Laurent Lebreton (Chapter 2 lead), Amy Lusher, Ramani Narayan, Sabine Pahl, James Potemra, Chelsea Rochman, Sheck A. Sherif, Joni Seager, Won Joon Shim, Paula Sobral, Shige Takada, Patrick ten Brink (Chapter 6 lead), Martin Thiel, Richard Thompson, Alexander Turra, Lisbeth Van Cauwenberghe, Erik van Sebille, Dick Vethaak (Chapter 4 lead), Emma Watkins, Kayleigh Wyles, Chris Wilcox, Erik Zettler and Patrizia Ziveri.

Contamination


GOES 8
1800 UTC
September 1994
Red: Visible
Green: Visible
Blue: Inverted 11um Infrared
NASA Goddard Laboratory for Atmospheres - Hasler, Chesters, Jentoft
University of Hawaii - Nielsen

Photo Credit: Tim Kelly

Photo Credit: earthknight

Macroplastics (>5 mm)

Microplastics (< 5mm)

Not THE garbage patch, but the garbage patcheS

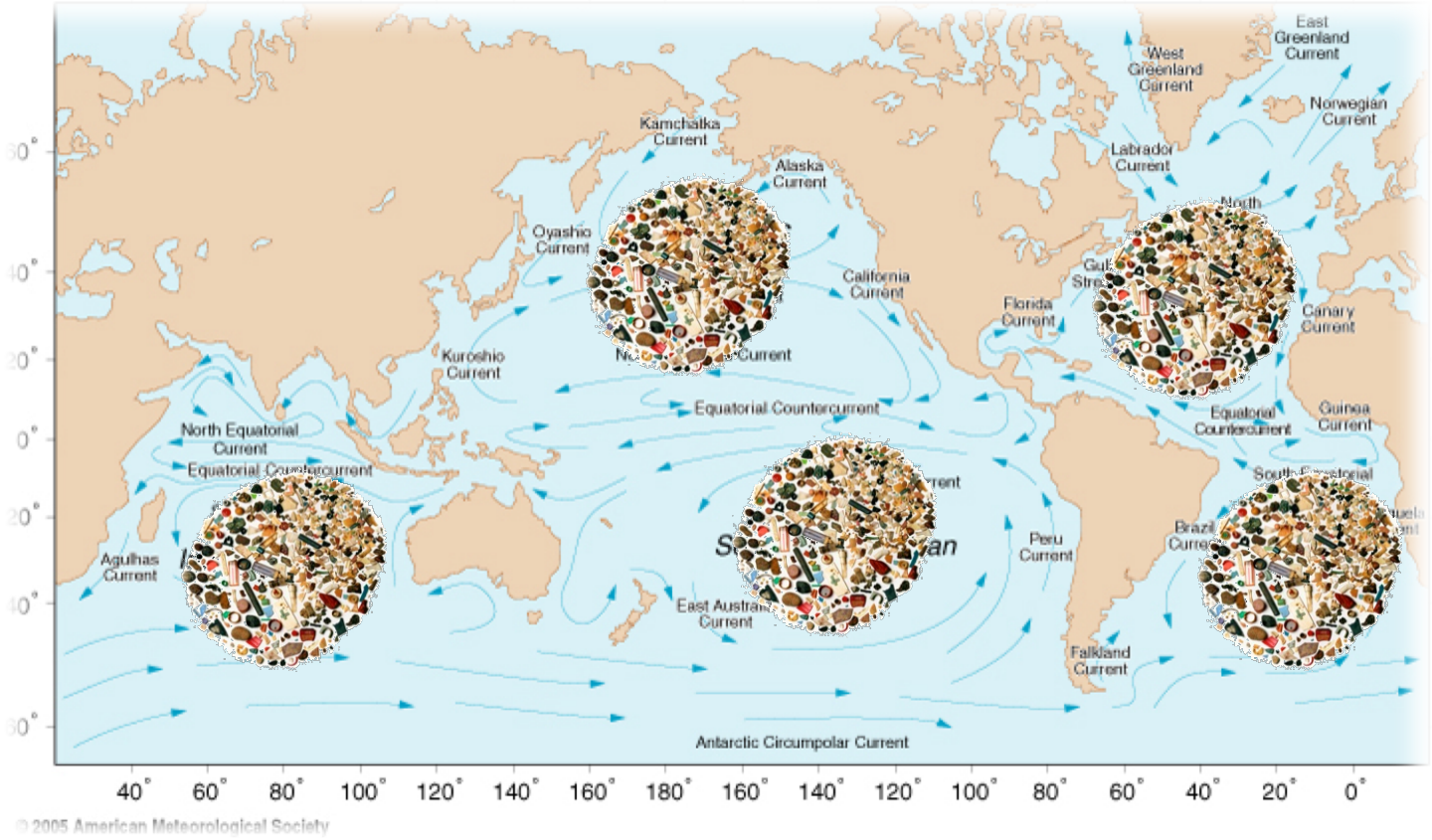


Photo Credit:
NOAA

Photo Credit: Susan Williams


© MBARI

Photo Credit:
NOAA

>690 species

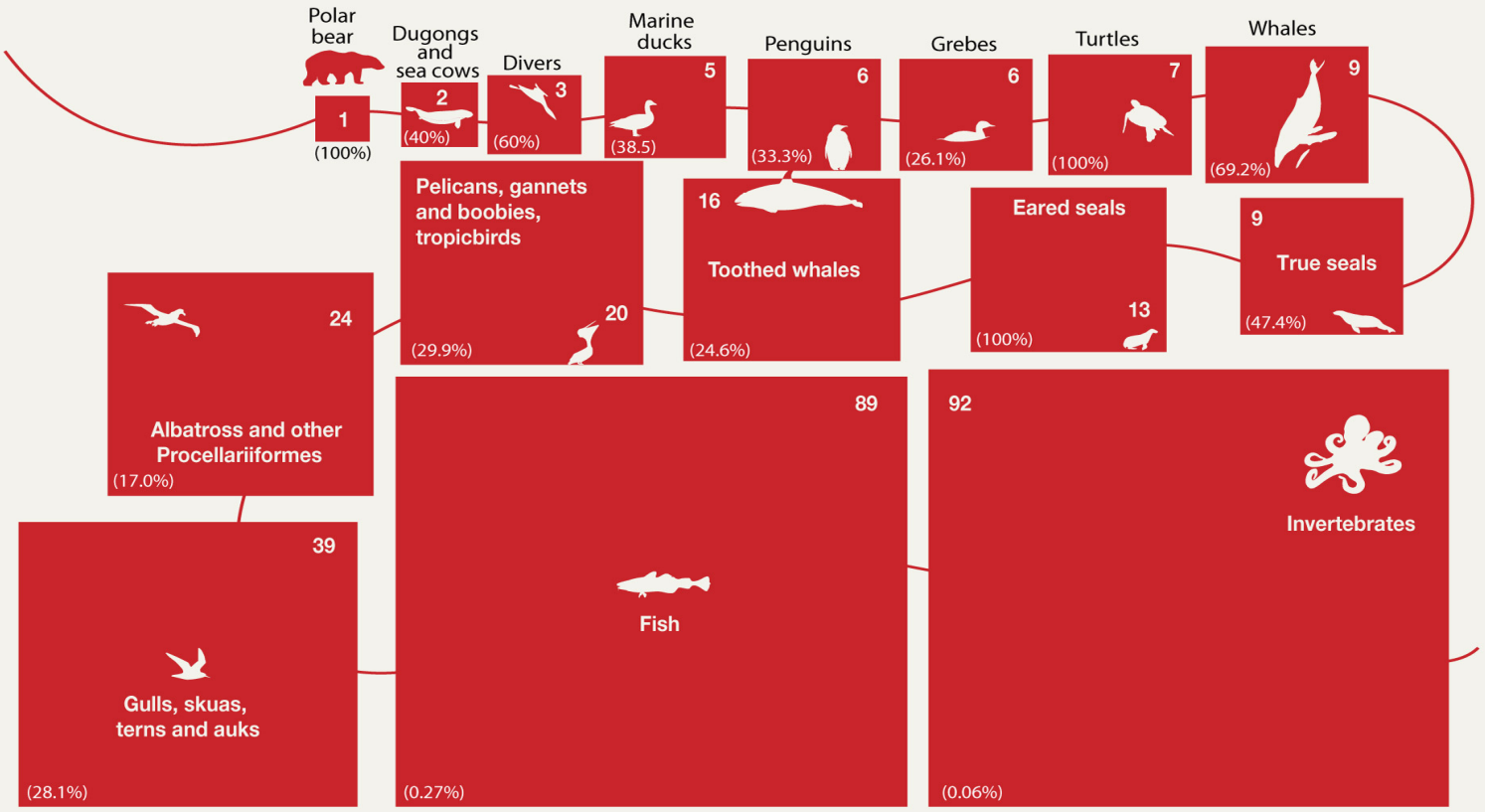
Provencher et al., 2016

>220 species

FAO Report 2017

Plasticized animal species - Entangled

Number of species with documented records of entanglement in marine debris



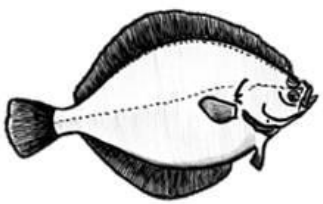
Source: Kühn, S., et al., Deleterious Effects of Litter on Marine Life, in Bergmann, M., et al., Marine Anthropogenic Litter, Springer, 2015

Plasticized animal species - Ingestion

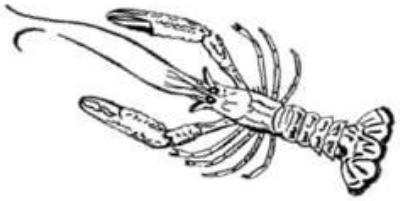
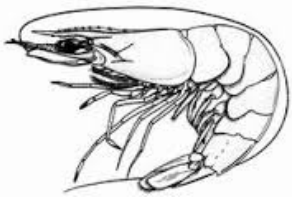
Number of species with documented records of marine debris ingestion

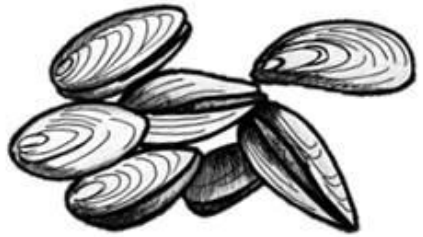
Source: Kühn, S., et al., Deleterious Effects of Litter on Marine Life, in Bergmann, M., et al., Marine Anthropogenic Litter, Springer, 2015

49 species commercial fish



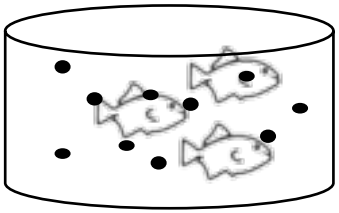
Many species of shellfish



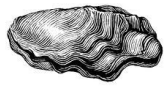
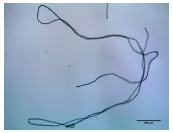
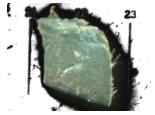
Other commercial products

Concentration in Environment

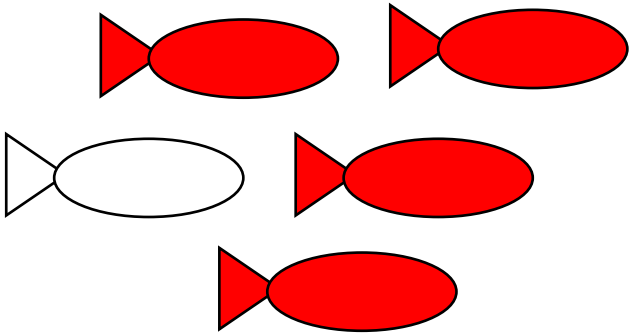


Environmentally relevant concentration

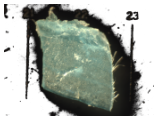
Plastic Type

% Population w/contamination



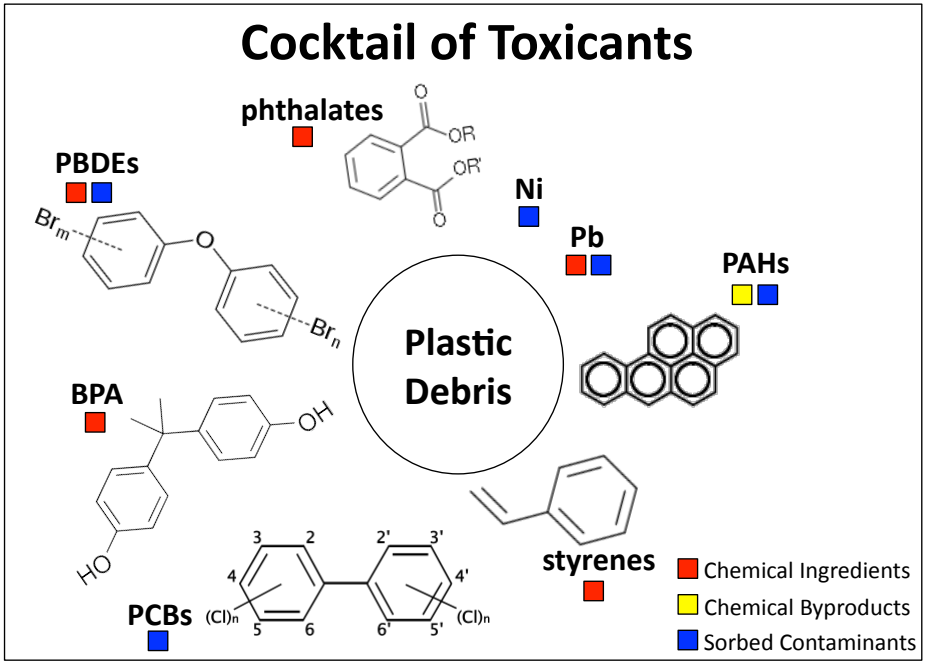


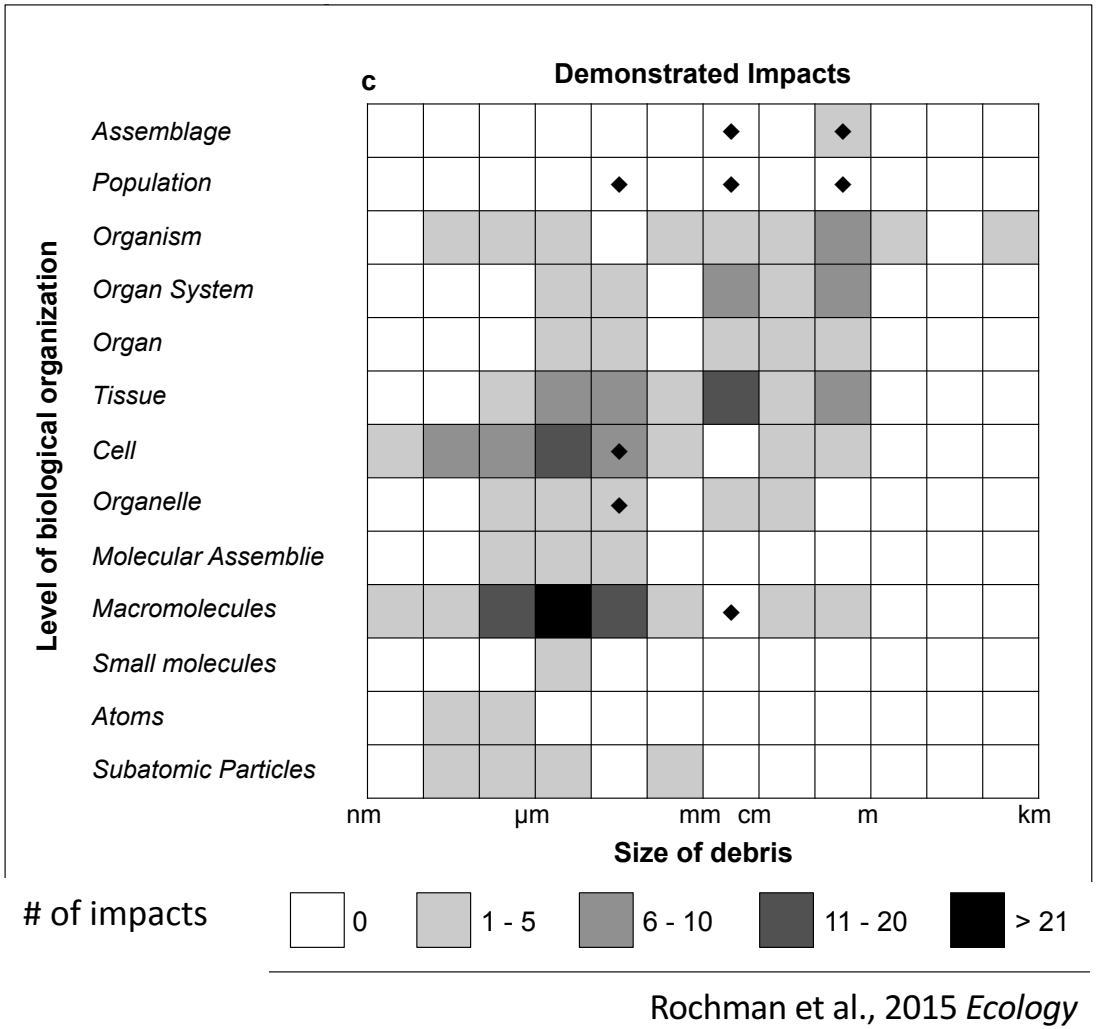


Impact

Impact - Wildlife

Impacts can be physical or chemical





Rochman et al., 2015 *Ecology*

Level of Biological Organization	Impact
Community/Assemblage	Altered species richness and evenness.
Population	Fecundity, % of eggs hatched, inhibition in larval settlement, reduced survival in offspring, change in population size due to increased substrate.
Organism	Altered nesting behavior in turtles, growth, photosynthesis, swimming behavior, survival
Suborganismal	oxidative stress, changes in gene expression and enzyme activity, tumor promotion and inflammation,

Includes studies published since the 2015 paper in Ecology.

Li et al., 2016 *ES&T*

Sussarellu et al., 2016 *PNAS*

Ogonowski et al., 2016 *PLOS*

Environmentally relevant concentration of microplastic.

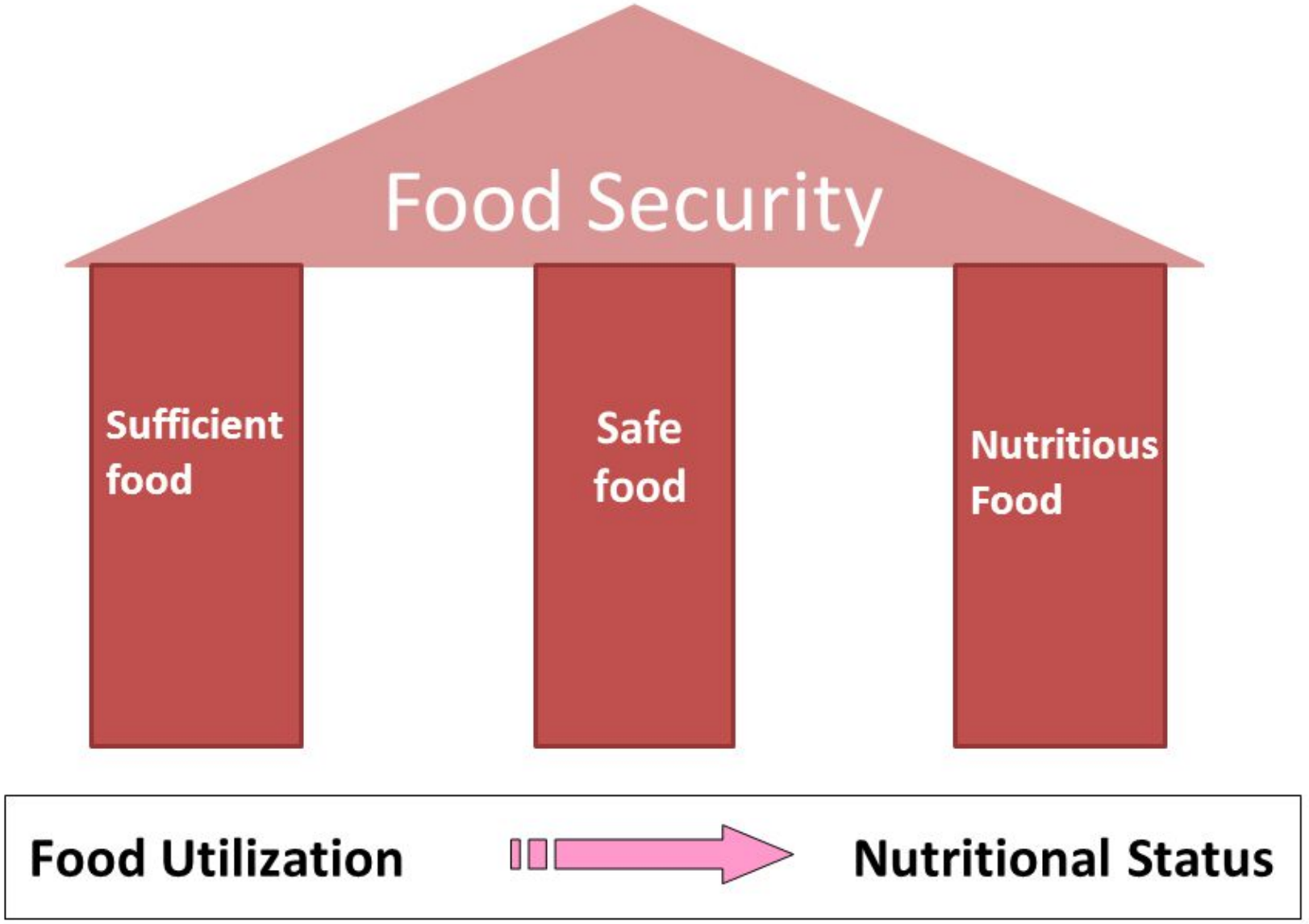
Asked questions about material type.

Asked questions relevant to population-level effects:

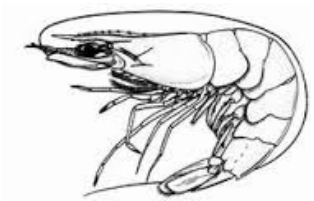
- settlement
- egg production, viability
- sperm motility
- larval yield
- predator/prey interactions

Impact – Human Health

Pillars of Food Security



FAO (Food and Agricultural Organization)



80% of individuals sampled

--Murray and Cowie, 2011

63% of individuals sampled

--Devriese et al., 2015

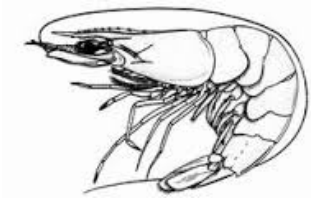
75% of individuals sampled

--Santana et al., 2016

Estimated Human Exposure

11,000 and 100,000 particles/yr

--Van Cauwenberghe and Jansen 2014, GESAMP 2016



175 particles/year

--Devriese et al. 2015

Fate of microplastic and nanoplastics in the body based on particle size

Microplastics (0.1 – 5000 µm)		**Nanoplastics (1 – 100 nm)**
> 150 µm	no absorption	
< 150 µm	in lymph absorption ≤ 0.3%	
= 110 µm	in portal vein	
< 1.5 µm (< 1500 nm)	access into organs	
		≤ 100 nm access to all organs, translocation of blood-brain and placental barrier

Table by Peter Hollman

Level of Biological Organization	Particle Types and Size	Effects	Studies
Subatomic	PS 20nm – 200nm	oxidative stress	Brown et al., 2001; Frohlich et al., 2009
Atomic	PS 60nm – 200nm	Increased Ca ions	Brown et al., 2001
Macromolecules	PE 100nm – 30μm, PS 50nm – 4.7μm, PMMA 1μm - 2μm, PC 1μm - 55μm	DNA damage, changes in gene and protein expression	Gelb et al., 1994; Brown et al., 2001; de Heer et al., 2001; Gretzer et al., 2002; Petit et al., 2002; Ingram et al., 2004; Clohisy et al., 2006; Kaufman et al., 2008; Markel et al., 2009; Huang et al., 2010; Hallab et al., 2011; McGuinness et al., 2011; Samuelsen et al., 2009; Smith and Hallab 2010; Pearl et al., 2011
Organelles	PMMA 10μm	more micronuclei	Zhang et al., 2008
Cells	PS 20nm - 4.65μm, PE 300nm - 10μm, PMMA 2μm - 35μm	cell clotting, necrosis, apoptosis, proliferation and loss of cell viability	Gelb et al., 1994; Brown et al., 2001; Gretzer et al., 2002; Bernard et al., 2007; Frohlich et al., 2009; Samuelsen et al., 2009; Hallab et al., 2011; McGuinness et al., 2011
Tissues	PE 600nm - 21μm, PMMA 1μm - 35μm	inflammation and oestolysis	Gelb et al., 1994; Clohisy et al., 2006; Markel et al., 2009; Pearl et al., 2011
Organs	PMMA 1μm - 10μm	lesions	Zhang et al., 2008; Pearl et al., 2011

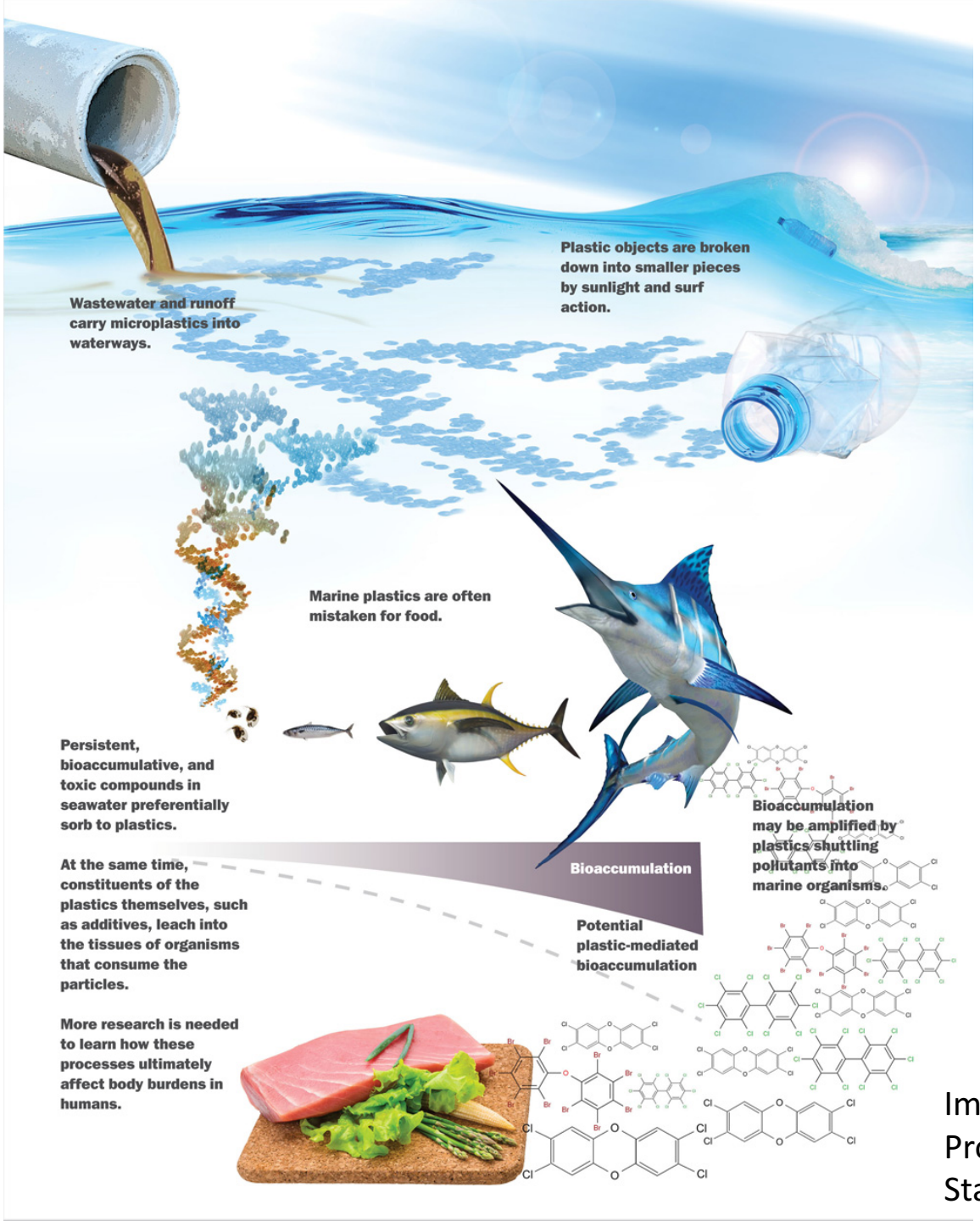
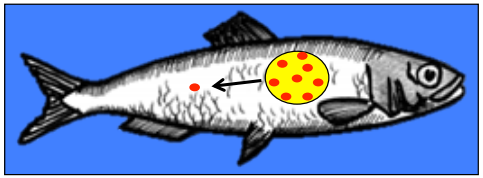
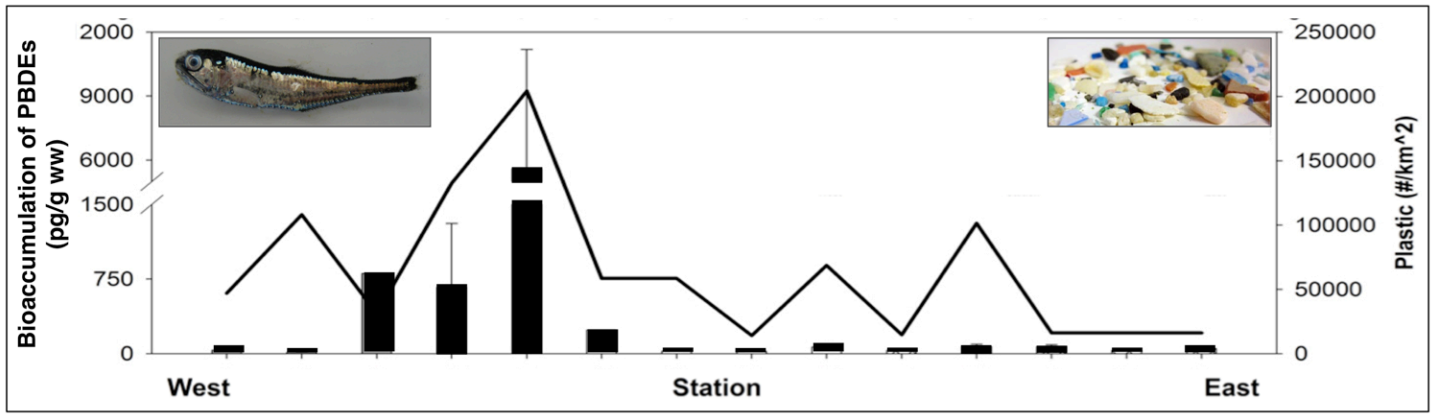


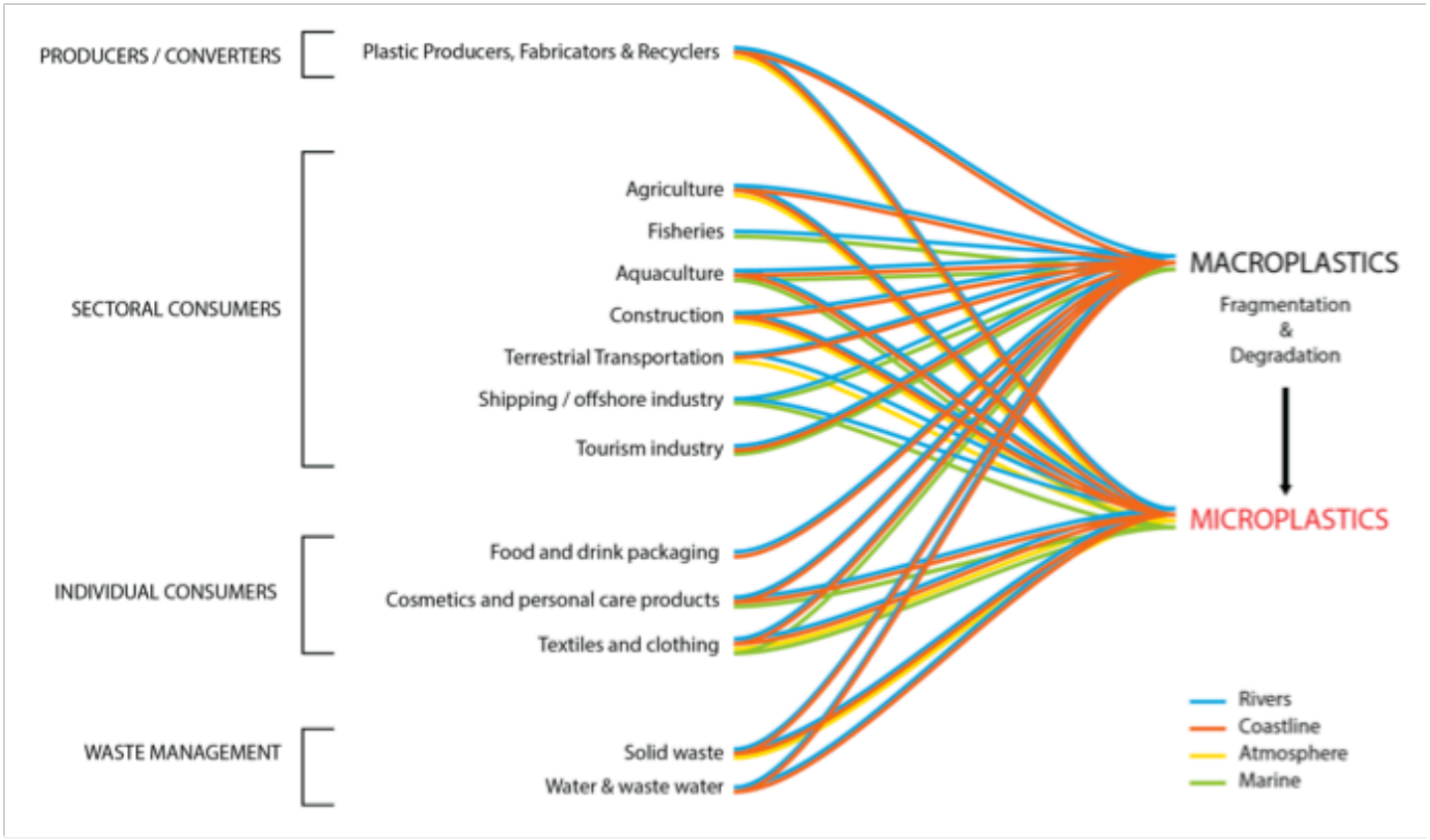
Image by Rolf Halden, Professor at Arizona State University





Rochman et al., 2014 *Science of the Total Environment*

Sources


PRODUCERS / CONVERTERS
Plastic Producers, Fabricators & Recyclers
SECTORAL CONSUMERS
Agriculture
Fisheries
Aquaculture
Construction
Terrestrial Transportation
Shipping / offshore industry
Tourism industry
INDIVIDUAL CONSUMERS
Food and drink packaging
Cosmetics and personal care products
Textiles and clothing
WASTE MANAGEMENT
Solid waste
Water & waste water
MACROPLASTICS
Fragmentation
&
Degradation
MICROPLASTICS
Rivers
Coastline
Atmosphere
Marine

GESAMP, 2016

80%

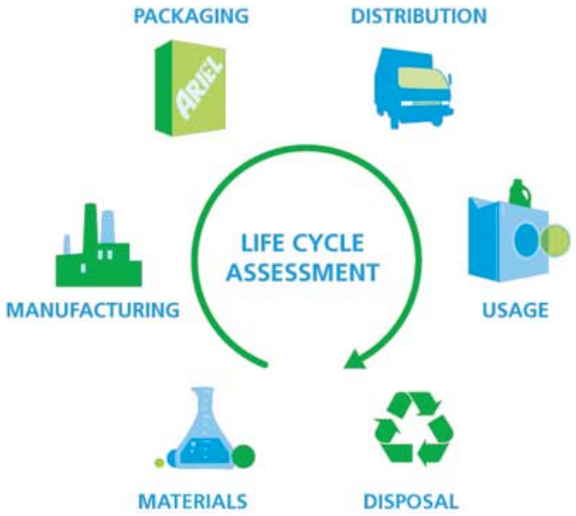
Jambeck et al., 2015 *Science*

What's next for research?

- Sources of emissions
- Fate of plastics and associated chemicals
- Ecologically-relevant Impacts
- Impacts to food safety

Complex Problems...

Need Complex Solutions...



Not a one-size-fits-all solution

Science to Solutions

Observation	Scientific Evidence	Policy Reform
Widespread Contamination of Plastic Debris in Oceanic Gyres	Law et al., 2010; Goldstein et al., 2012; Eriksen et al., 2014	Amendment to MARPOL Annex V
Pre-production pellets littered in aquatic habitats globally	Ogata et al., 2009; van Franeker & Law, 2015	International Clean Sweep, California Nurdle Law (AB258)
Plastic entering coastal habitats via urban runoff	Browne et al., 2011	TMDLs, trash collecting technologies in storm drains
Microbeads in Aquatic Habitats	Magnussen & Wahlberg, 2014; Eriksen et al., 2013; Castaneda et al., 2014; Rochman et al., 2015a	Legislation to ban microbeads from personal care products.

The *microbead* free waters act is not the *microplastic* free waters act.

One Hundred Fourteenth Congress
of the
United States of America

AT THE FIRST SESSION

Begun and held at the City of Washington on Tuesday, the sixth day of January, two thousand and fifteen

An Act

To amend the Federal Food, Drug, and Cosmetic Act to prohibit the manufacture and introduction or delivery for introduction into interstate commerce of rinse-off cosmetics containing intentionally-added plastic microbeads.

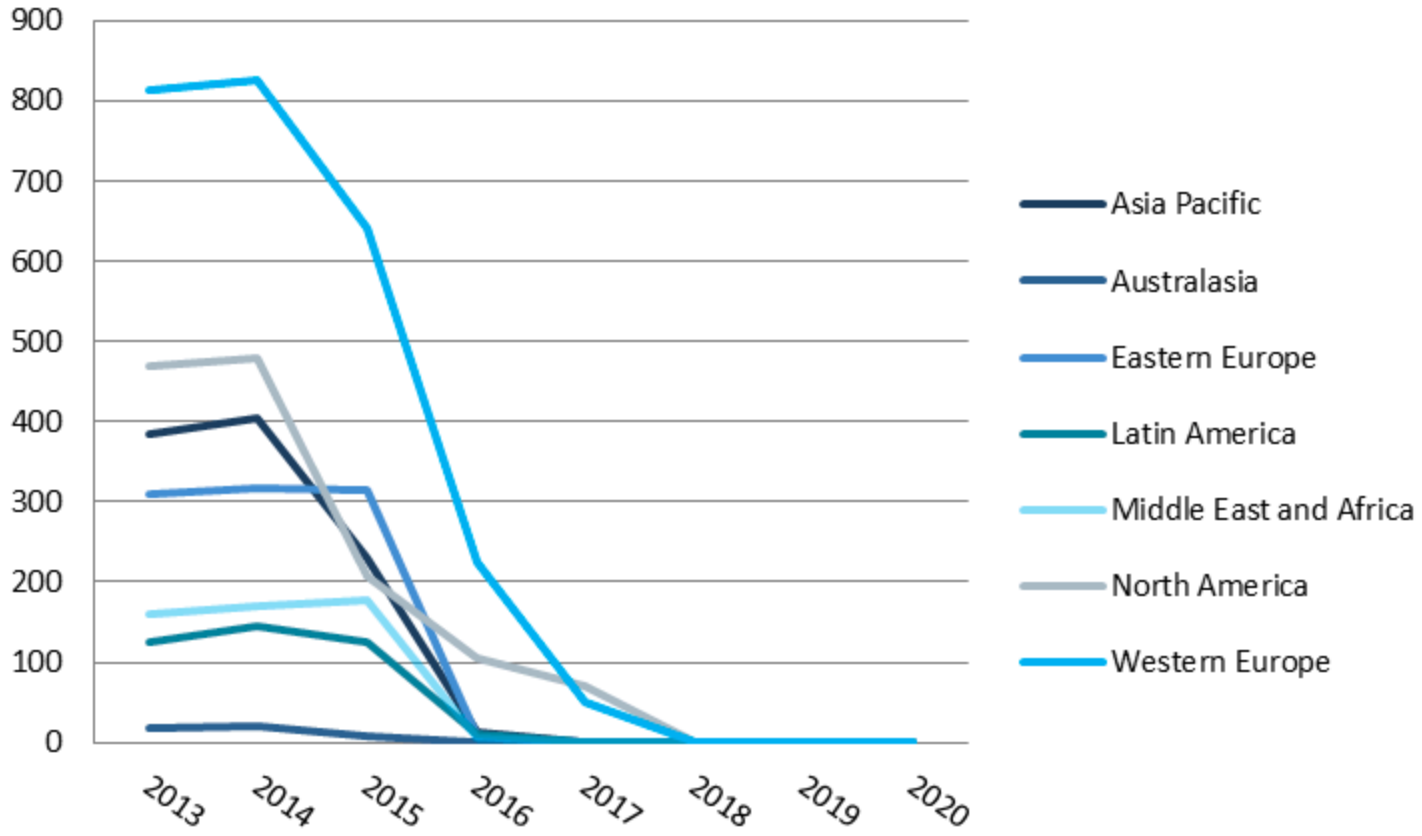
"(ddd) (1) The manufacture or the introduction or delivery for introduction into interstate commerce of a rinse-off cosmetic that contains intentionally-added plastic microbeads.

"(2) In this paragraph—

"(A) the term 'plastic microbead' means any solid plastic particle that is less than five millimeters in size and is intended to be used to exfoliate or cleanse the human body or any part thereof; and

"(B) the term 'rinse-off cosmetic' includes toothpaste.".

VOLUMES OF POLYETHYLENE MICROBEADS IN BEAUTY AND PERSONAL CARE APPLICATIONS IN THE PERIOD (2013-2020)

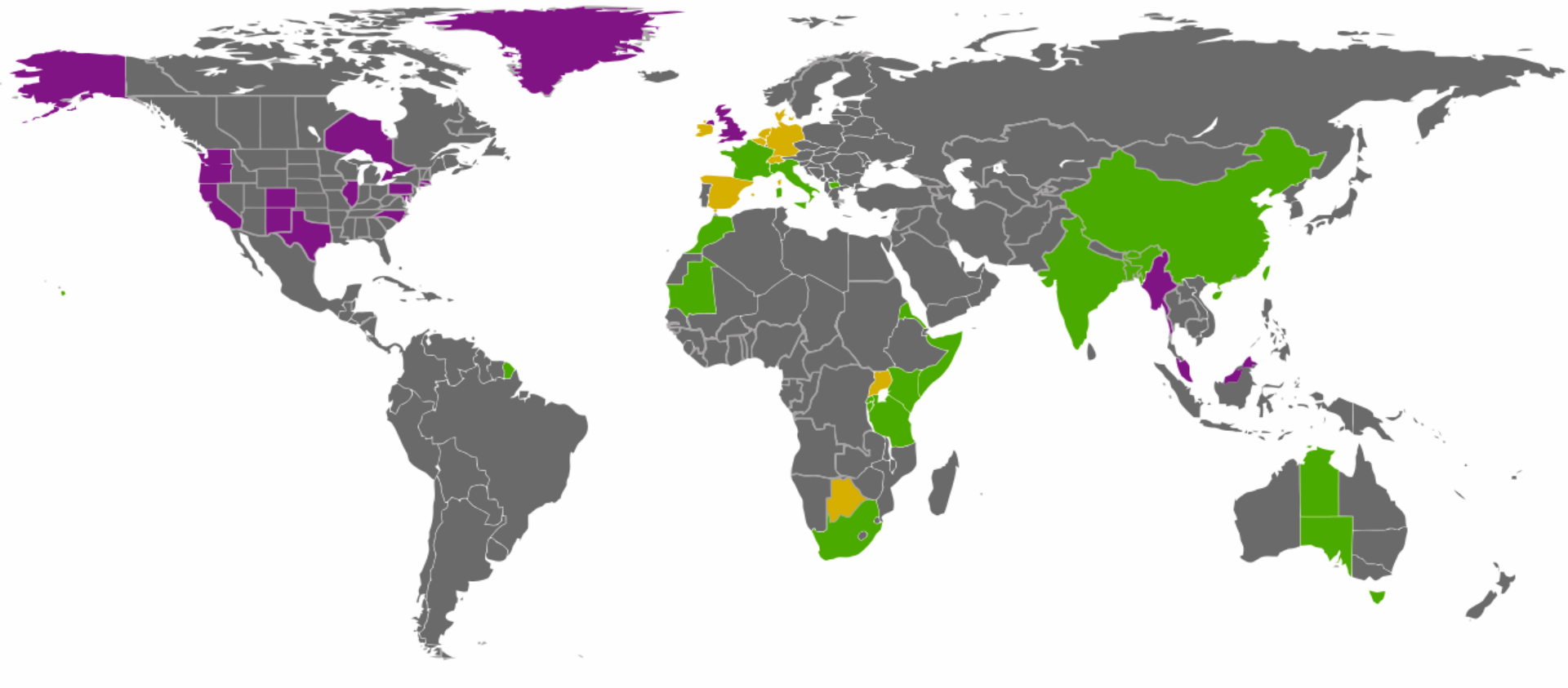


Related Legislation around the World

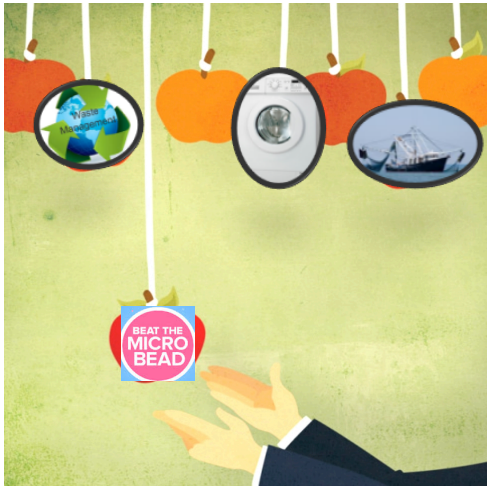
- France to ban disposable plastic cutlery.
- Plastic bag bans all over the world.
- Bans on expanded polystyrene (styrofoam as you likely know it) take-out containers.
- Governments are adding microplastics to their “lists of lists” and creating monitoring programs for microplastics and soliciting proposals for research measuring the sources, fate and impacts.

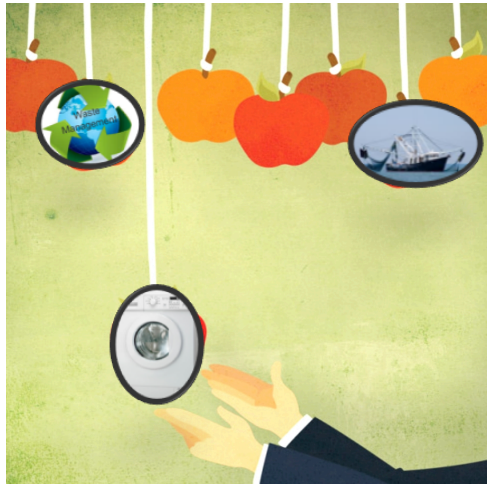
FOAM FREE DC

Bag Regulations around the World



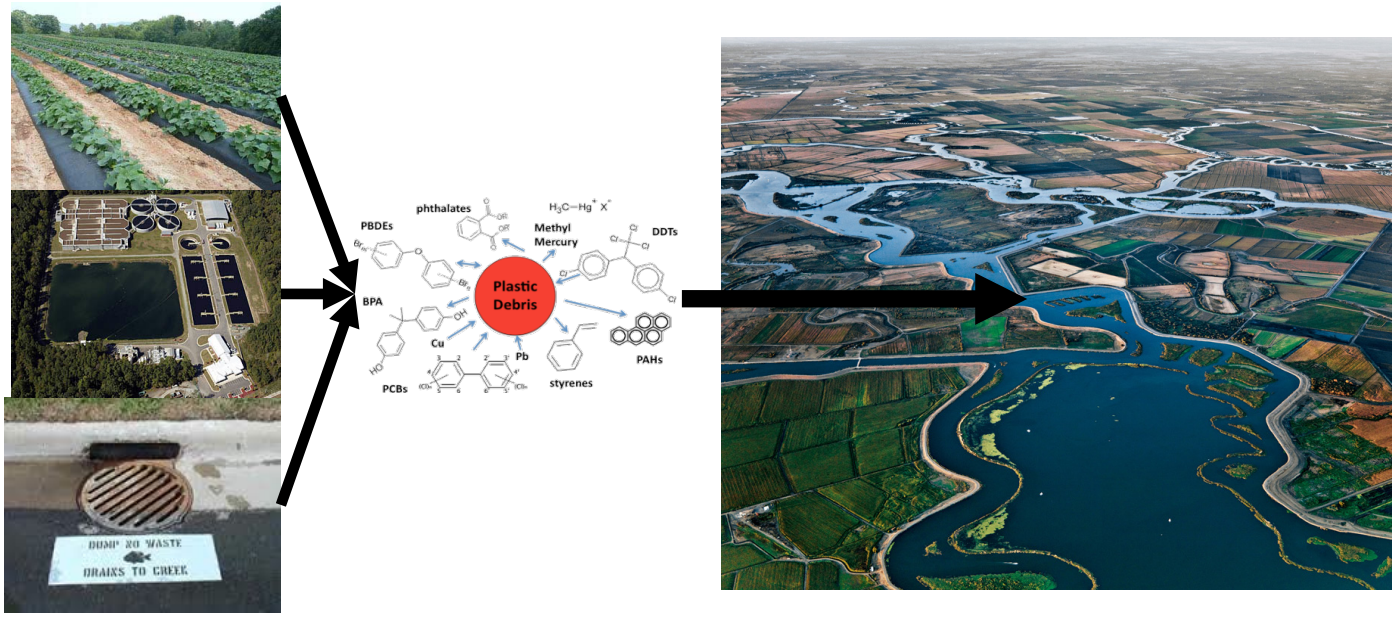
Phase out of lightweight plastic bags around the world.
■ Plastic bags banned; ■ A tax on some plastic bags; ■ Partial tax or ban (municipal or regional levels)


BEAT THE
MICRO
BEAD




filtrol 160

Microplastics added to “lists of lists”



Microplastics added to “lists of lists”

ROYAL SOCIETY OF CHEMISTRY

Analytical Methods

Microplastics in the environment

A compilation of papers that we hope will facilitate discussions leading toward harmonized methods for microplastics that are informed by hypotheses, and ultimately produce data that can be synthesized and used to inform effective local and global policies that prevent and mitigate microplastics.

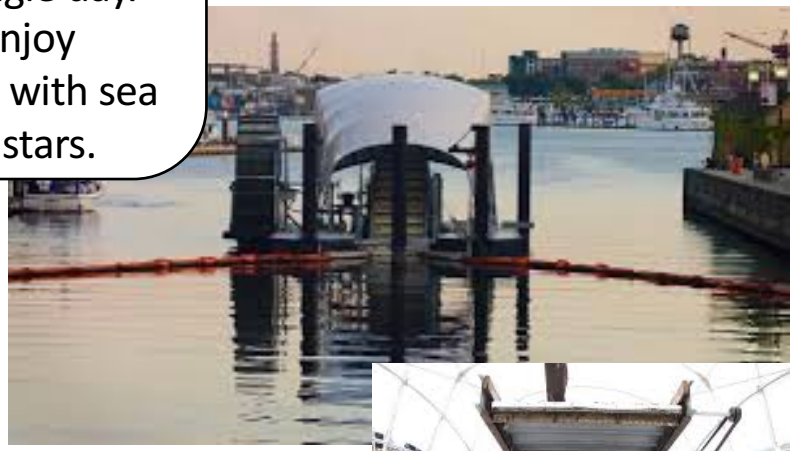
Fiona Regan

Richard Thompson

Chelsea Rochman

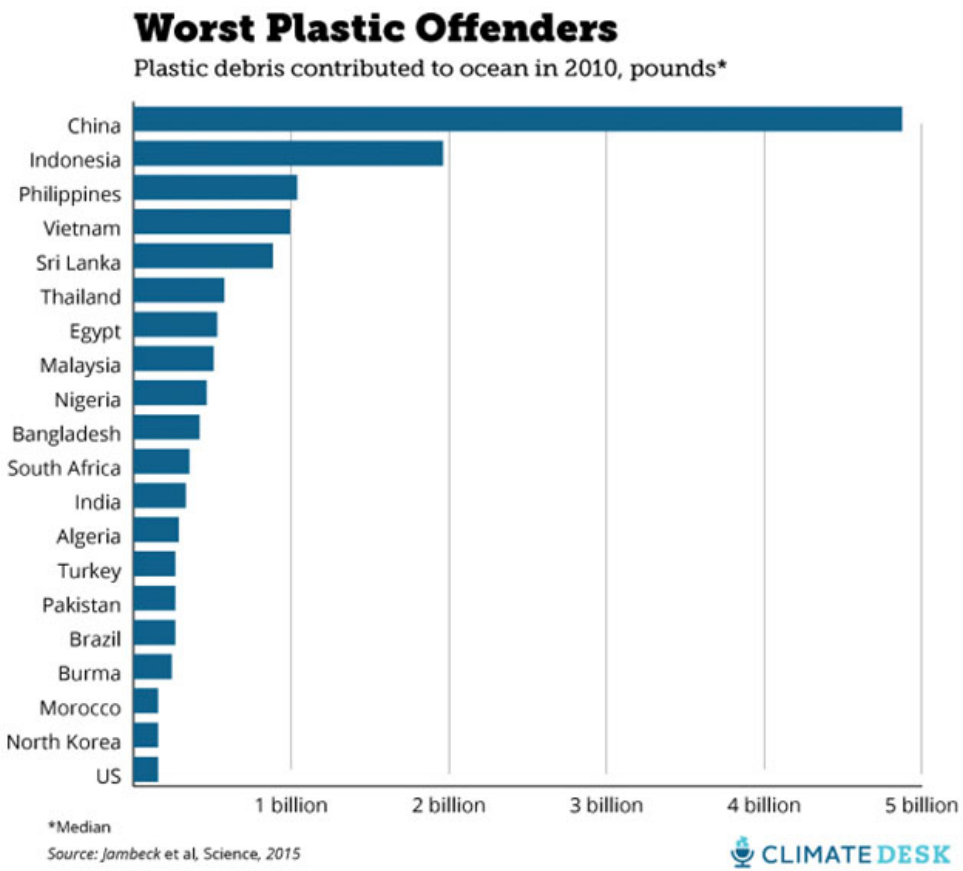
Investment in Local Waste Management Infrastructure

I'm Mr. Trash Wheel, the first of its kind situated in Baltimore's Inner Harbor. Since May 9, 2014, I've removed 331 tons of trash, collecting as much as 38,000 lbs in a single day. When I'm not eating trash I enjoy making new friends, partying with sea creatures, and looking at the stars.

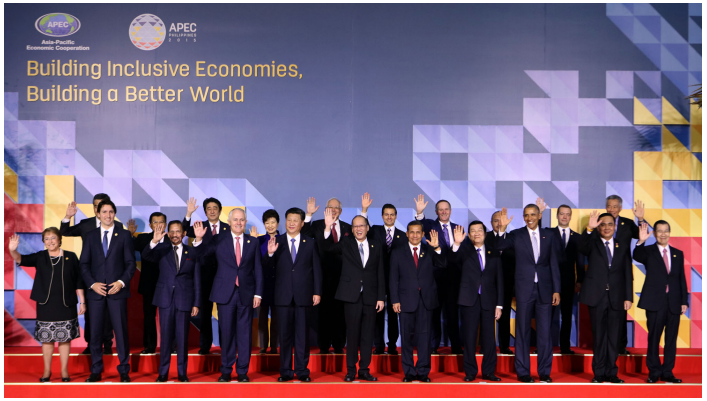


OVER 9000 followers on TWITTER

Investment in Global Waste Management Infrastructure



Asia-Pacific Economic Cooperation



Ocean Conservancy

Widespread Contamination in habitats and animals – including seafood.

Evidence of effect in laboratory animals, populations and communities.

Working toward a better understanding of sources, fate and impacts to humans and wildlife populations.

But we have enough science to begin to mitigate now and prevent future sources of plastic pollution.

Thank you!

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www.rochmanlab.com