Contamination and effects of plastic debris in the marine environment

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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.

Contamination

Macroplastics (>5 mm)

Microplastics (< 5mm)

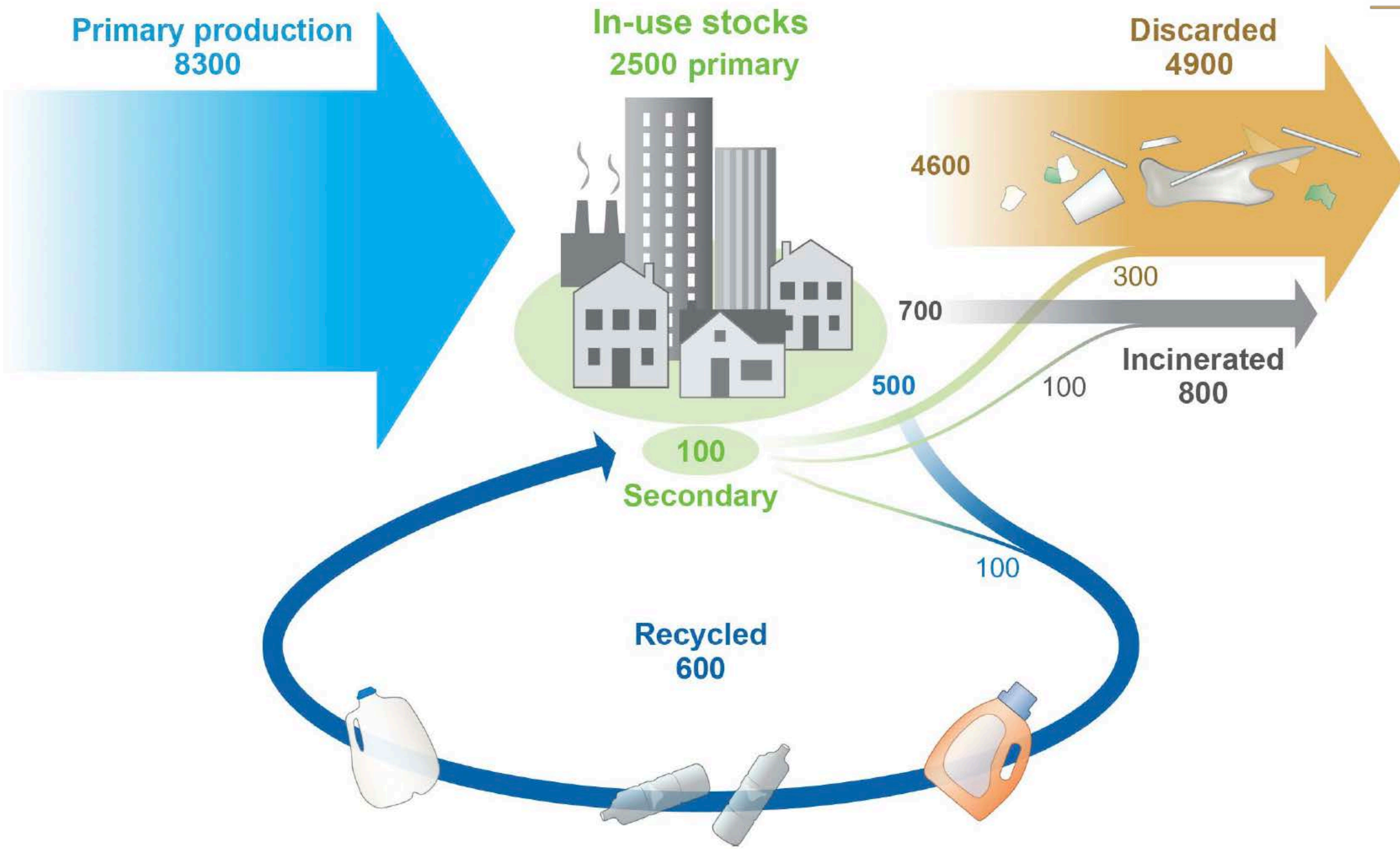
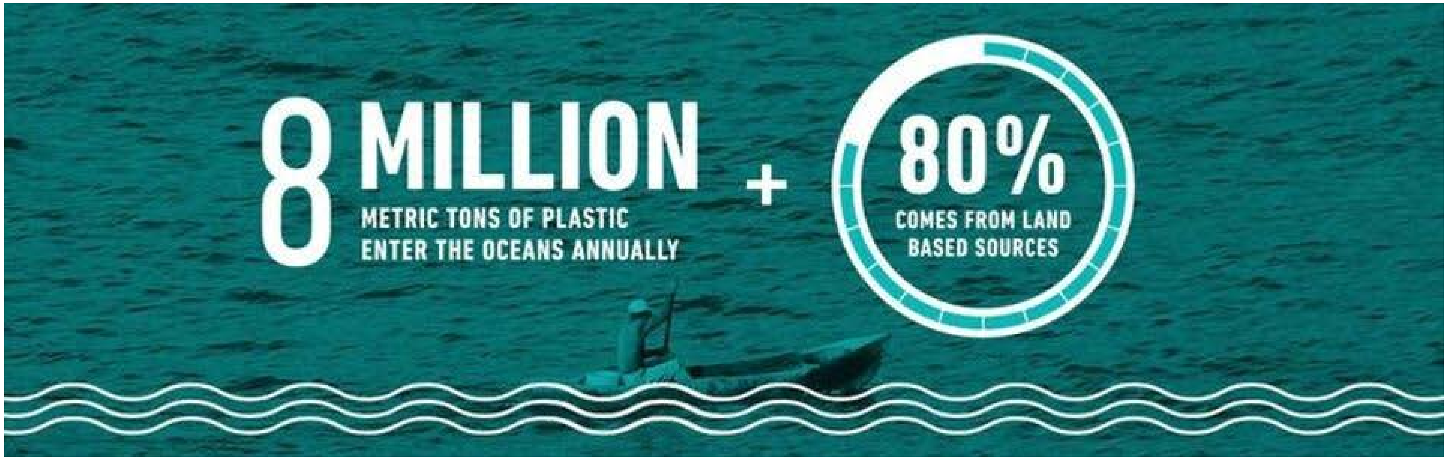


Fig. 2. Global production, use, and fate of polymer resins, synthetic fibers, and additives (1950 to 2015; in million metric tons).

Geyer et al., 2017 *Science Advances*



Jambeck et al., 2015 *Science*

15 to 51 trillion particles weighing 93 – 236 thousand metric tons – van Sebille et al., 2015 *Environmental Research Letters*

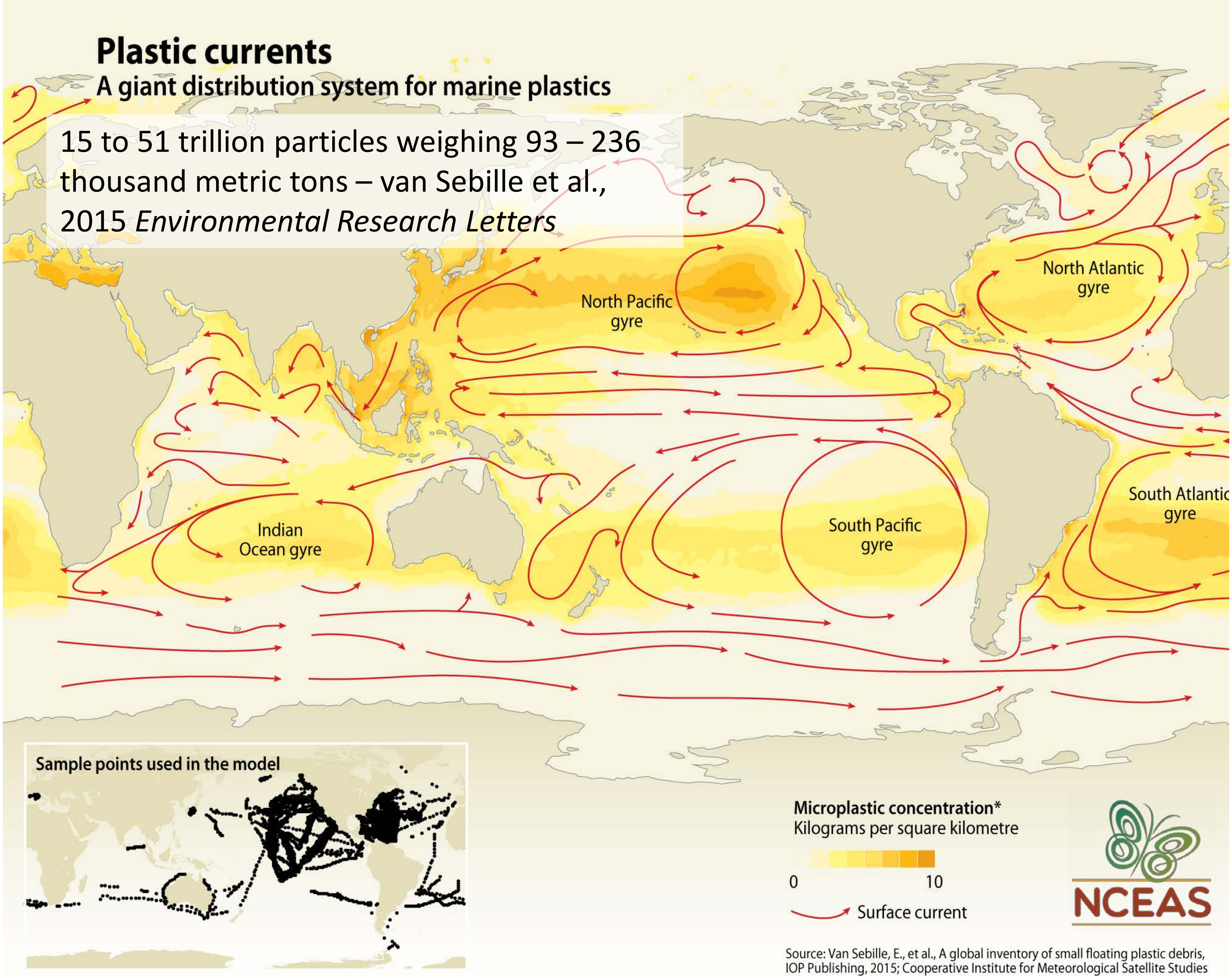



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Photo Credit: Tim Kelly

Photo Credit: earthknight

>800 species

Secretariat of the Convention on Biological Diversity, 2016

>220 species

FAO Report 2017

Similar occurrence of anthropogenic debris in fish from each location

USA

-16 out of 64 fish (25%)

-6 of 11 species sampled

30 total pieces

0.5 ± 1.4 SD avg pieces /fish

Indonesia

-21 out of 76 fish (28%)

-8 of 12 species sampled

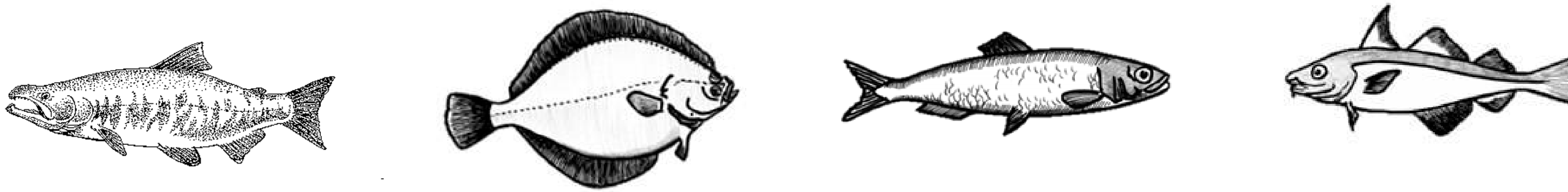
105 total pieces

1.4 ± 3.7 SD avg pieces/fish

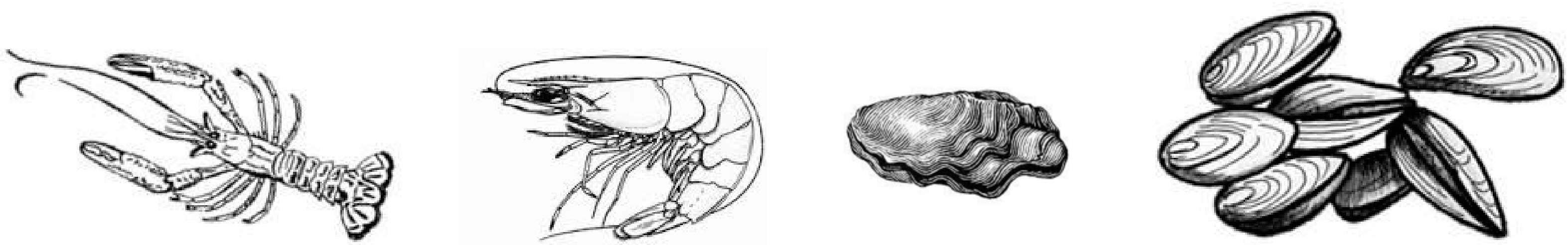
No difference among species

Rochman et al., 2015 *Sci Reports*

49 species commercial fish



Many species of shellfish

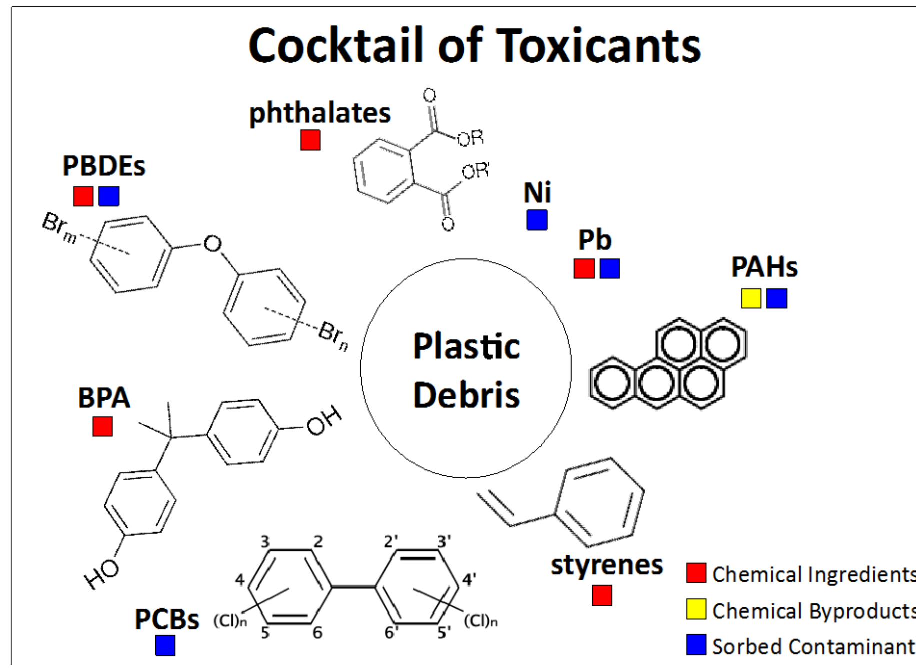


Other commercial products

Rochman et al., 2015; van Cauwenberghe and Janssen, 2014; Li et al., 2015; Yang et al., 2015; Davidson and Dudas, 2016

Impact

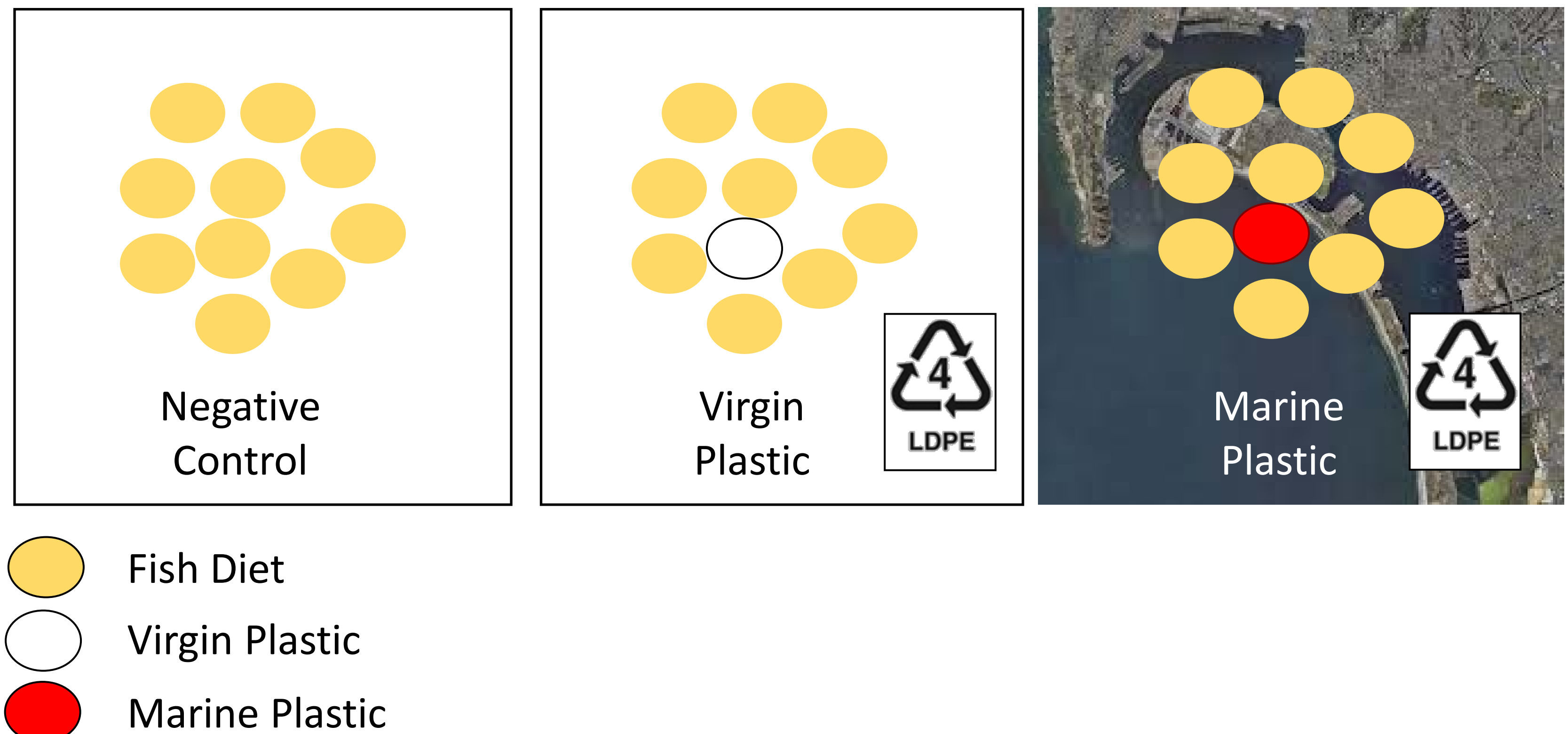
Impacts can be physical or chemical



Rochman 2015 Chapter in *Marine Anthropogenic Litter*

Impacts can be due to the plastic itself or the mixture of plastics and associated chemicals

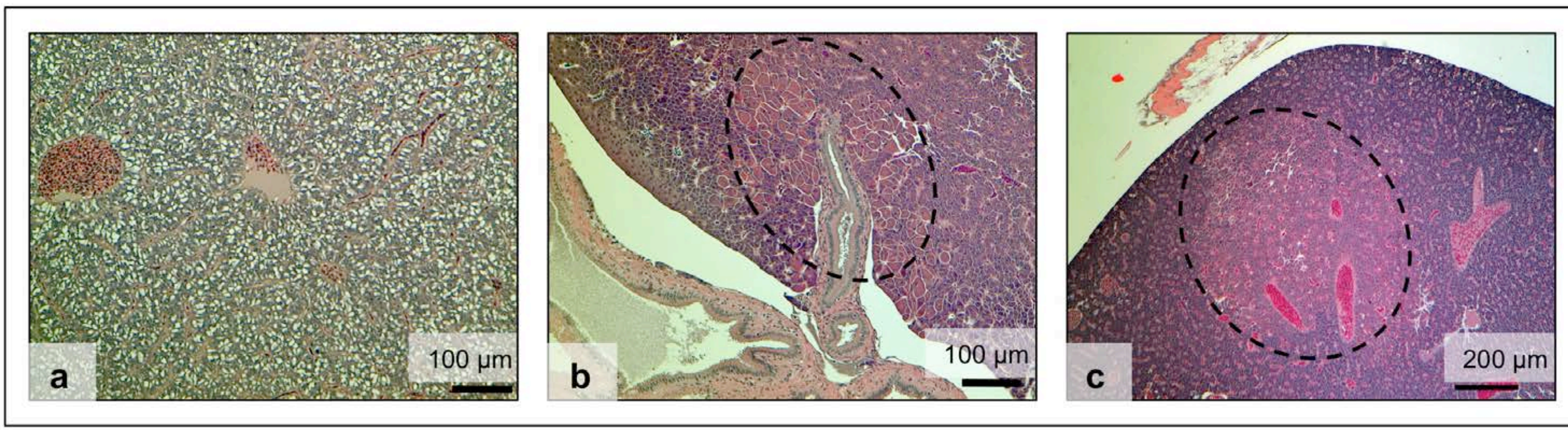
Japanese Medaka (*Oryzias latipes*)



Rochman et al., 2013, *Nature Scientific Reports*

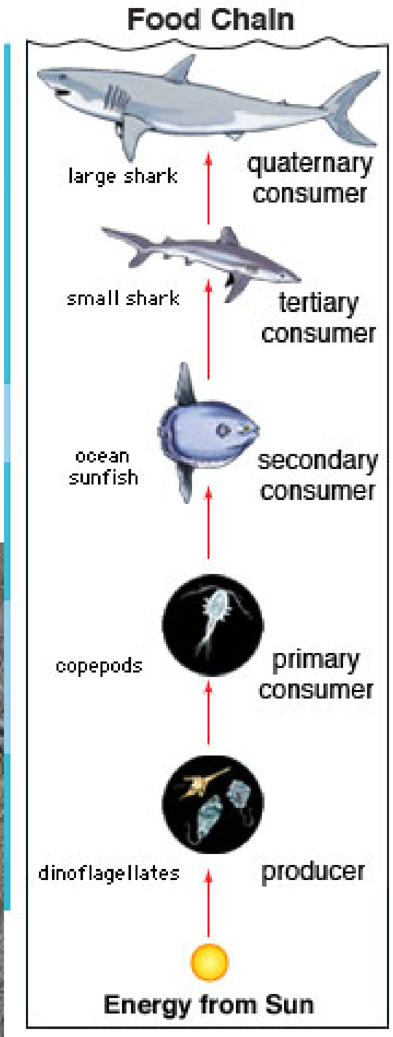
Liver Toxicity

Treatment	# Fish	Severe Glycogen Depletion	Lipidosis	Single Cell Necrosis
Control	24	0%	21%	0%
Virgin-plastic	24	46%	29%	0%
Marine-plastic	19	74%	47%	11%



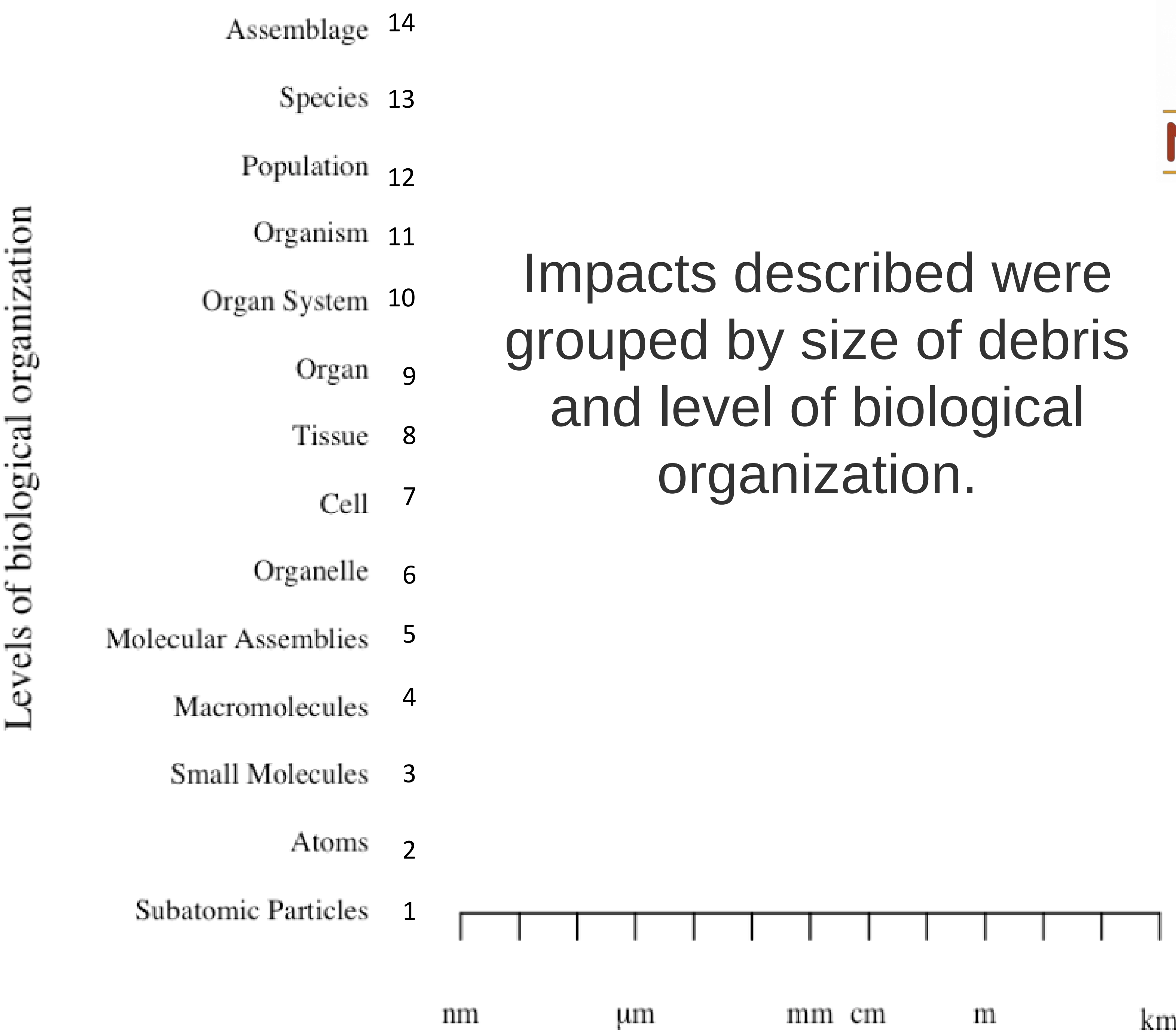
Rochman et al., 2013, *Nature Scientific Reports*

Are there ecological impacts?



NCEAS

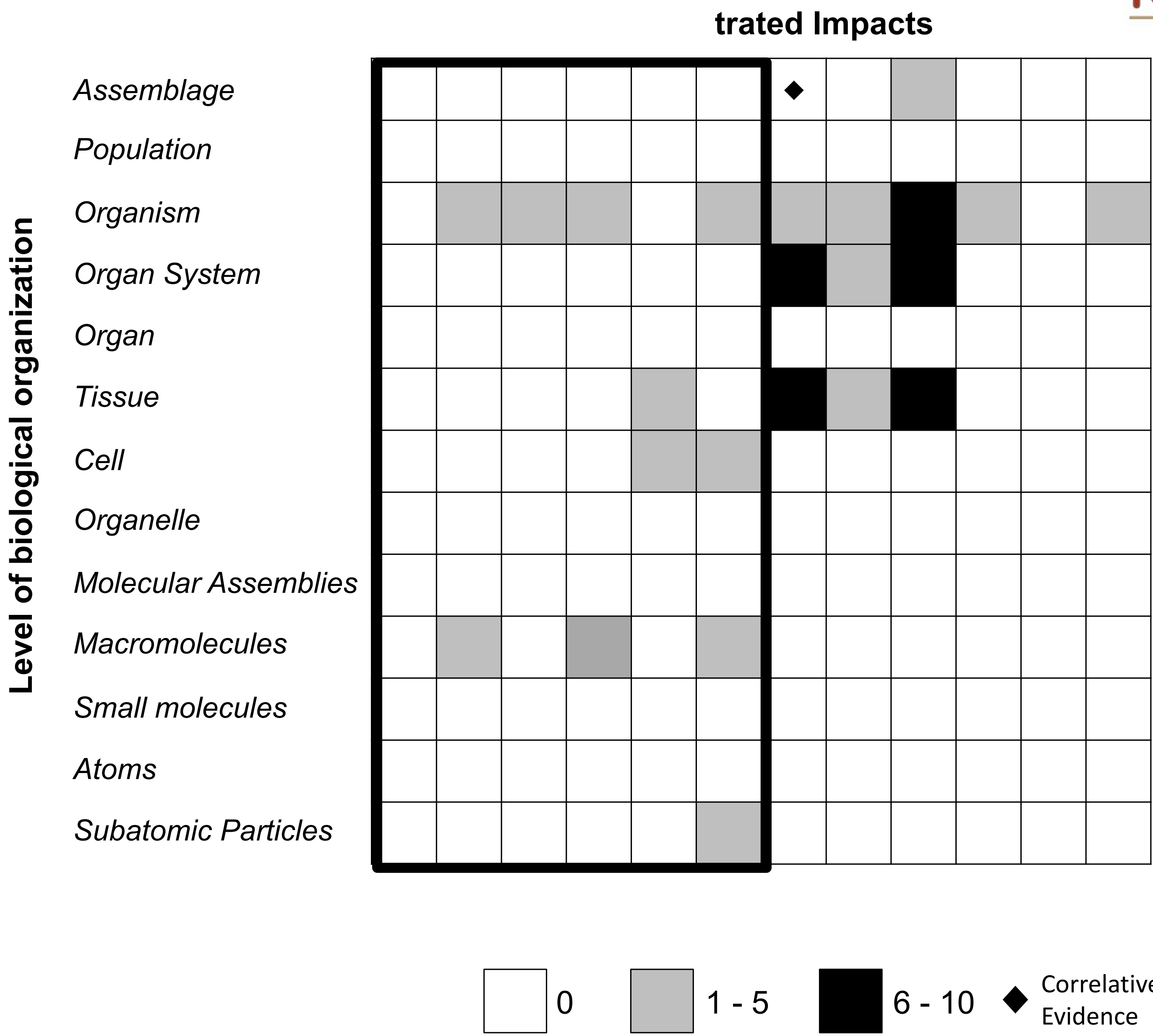
Impacts described were grouped by size of debris and level of biological organization.



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	**survival**
Suborganismal	oxidative stress, changes in gene expression and enzyme activity, tumor promotion and inflammation.

PLASTIC DEBRIS

Rochman et al., 2016 *Ecology*



Li et al., 2016 *ES&T*
Sussarellu et al., 2016 *PNAS*
Ogonowski et al., 2016 *PLOS*
Green, 2015 *ES&T*

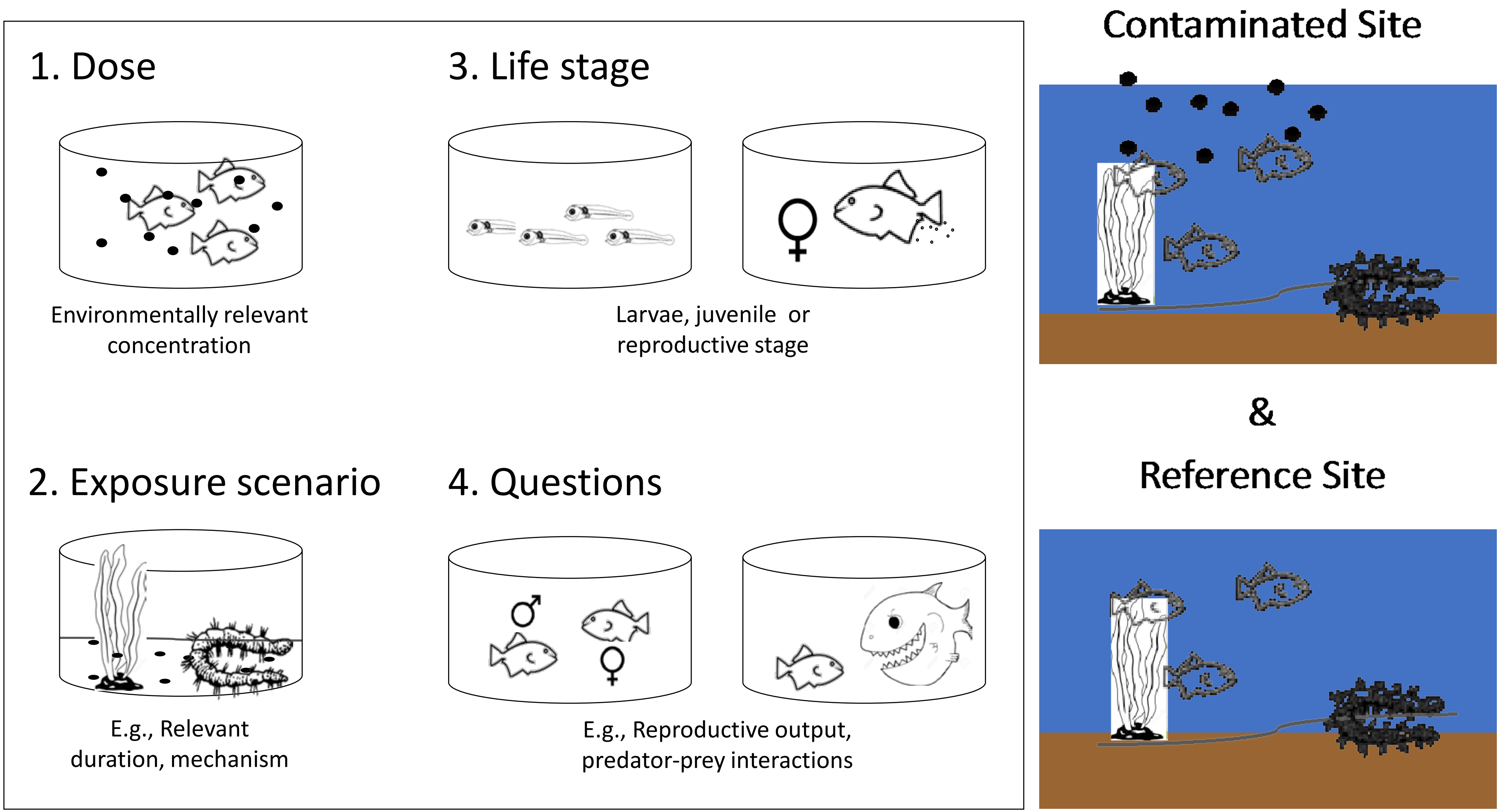
Environmentally relevant concentration of microplastic.

Asked questions about material type.

Asked questions relevant to community and population-level effects:

- settlement
- egg production, viability
- sperm motility
- larval yield
- assemblage change

Ecologically relevant experimental design:



Food and Agriculture Organization of the United Nations

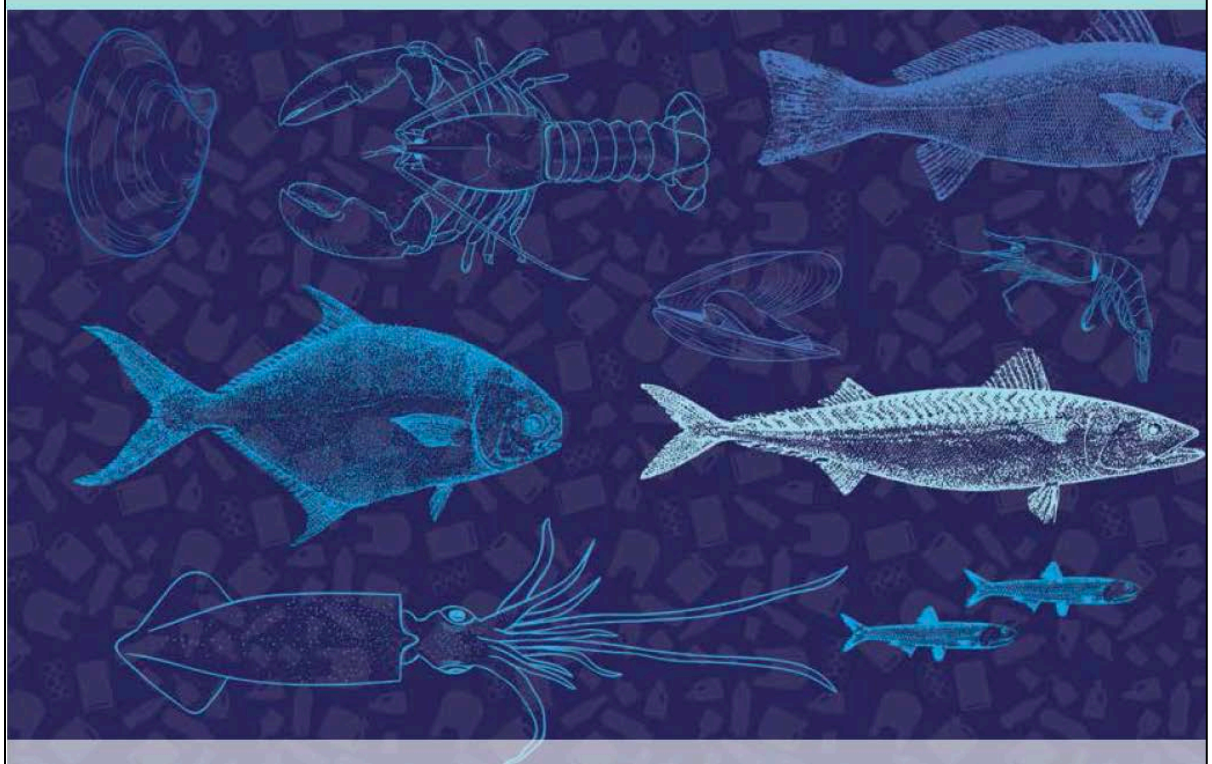
FAO FISHERIES AND AQUACULTURE TECHNICAL PAPER

615

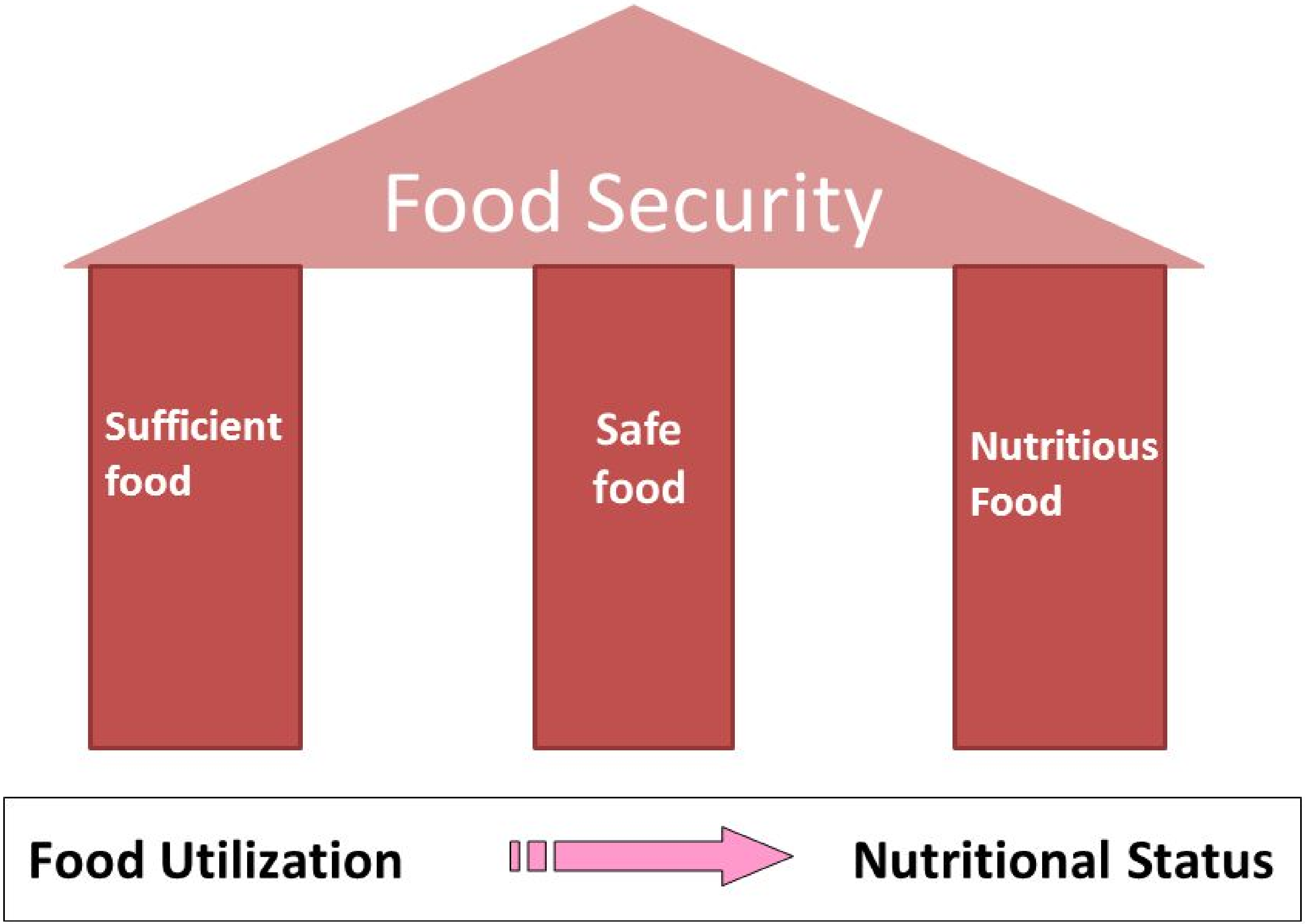
ISSN 2070-7010

Microplastics in fisheries and aquaculture

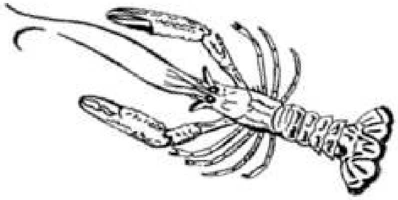
Status of knowledge on their occurrence and implications for aquatic organisms and food safety

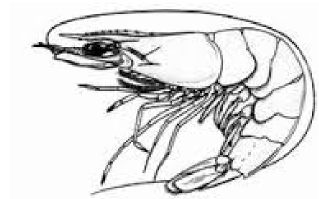


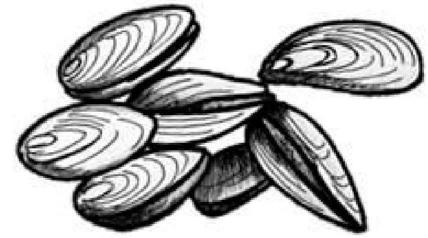
Pillars of Food Security



FAO (Food and Agricultural Organization)





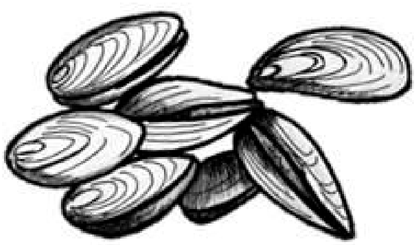


80% of individuals sampled
--Murray and Cowie, 2011

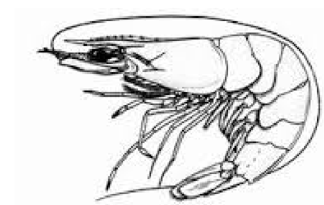
63% of individuals sampled
--Devriese et al., 2015

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

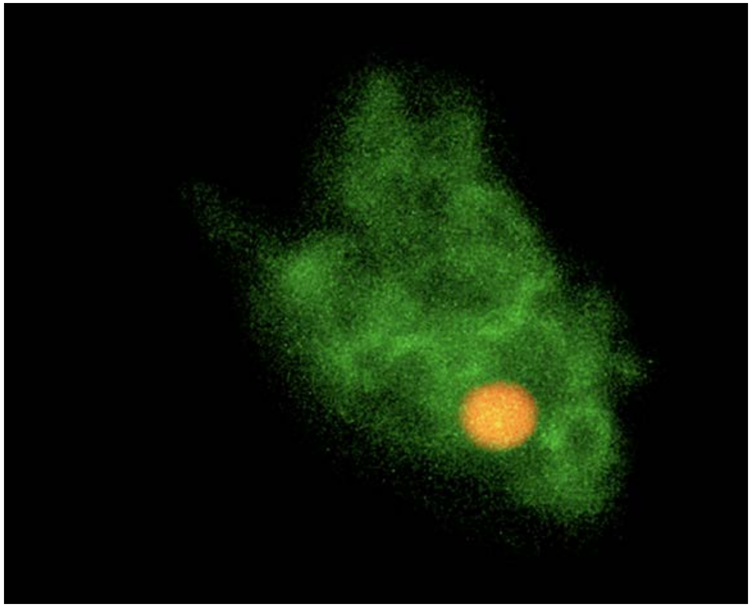
TABLE 6.1

Fate of microplastic and nanoplastics in mammalian bodies as a function of particle size

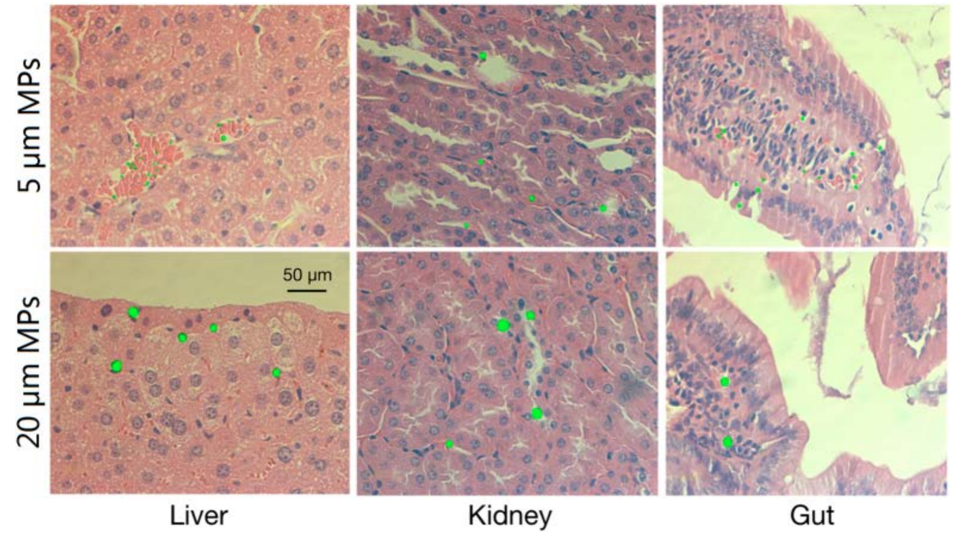
Microplastics (0.1–5000 μm)		**Nanoplastics (1–100 nm)**
> 150 μm	no absorption	
< 150 μm	in lymph absorption ≤ 0.3%	
= 110 μm	in portal vein	
≤ 20 μm (≤20000 nm)	access into organs	
		≤ 100 nm access to all organs, translocation of blood-brain and placental barrier
		Absorption up to 7%

FAO Report 2017

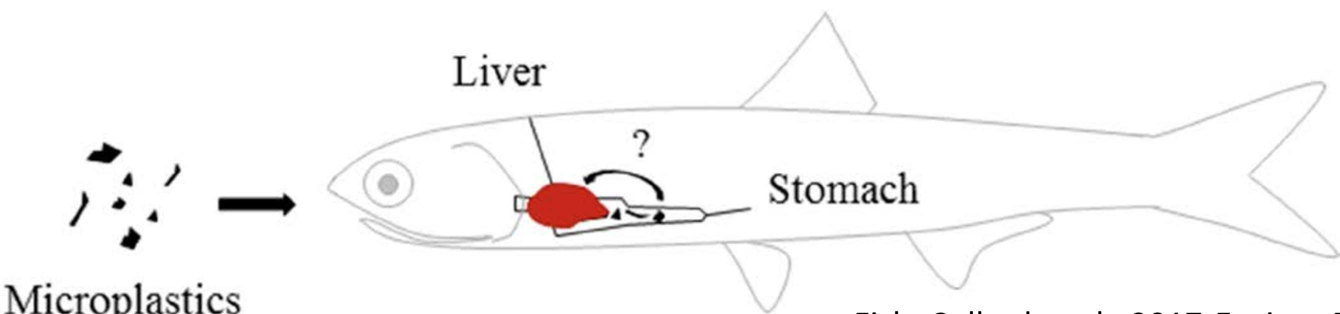
Fate of microplastic and nanoplastics in the body



Mussels: Browne et al., 2008 *ES&T*

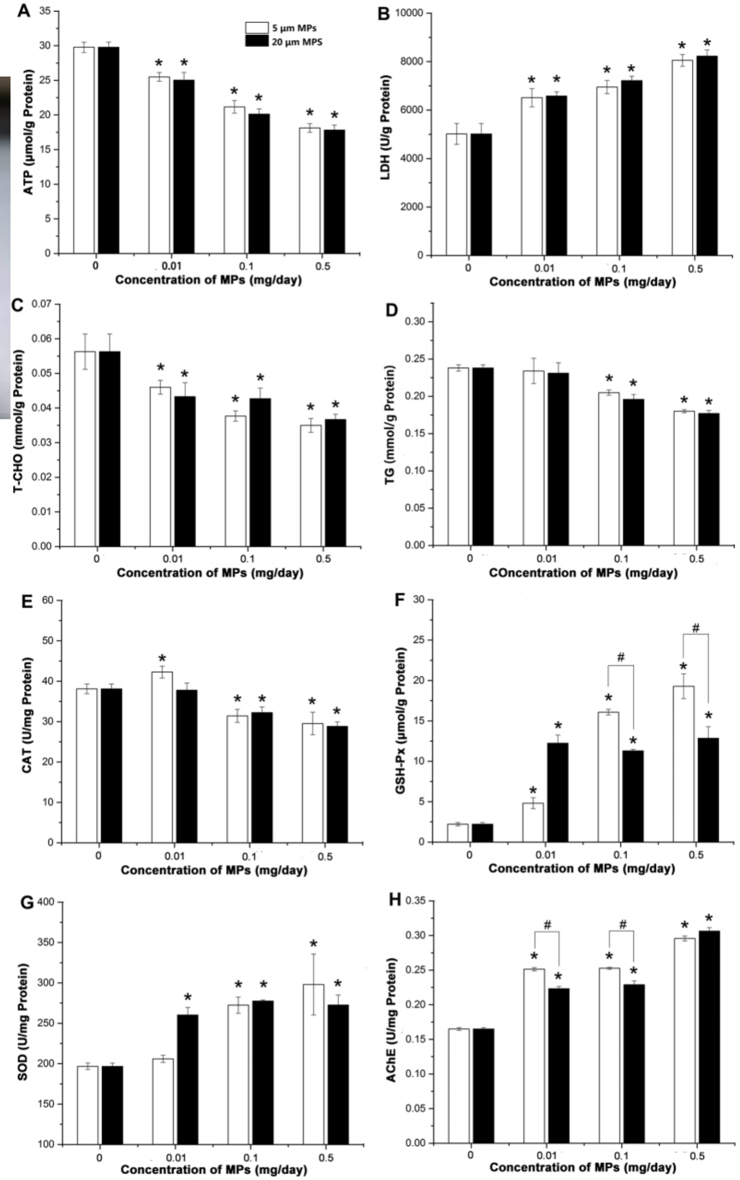


Mice: Deng et al., 2017 *Scientific Reports*



Fish: Collard et al., 2017 *Environ Pollut*

Physical Impact of the Particle

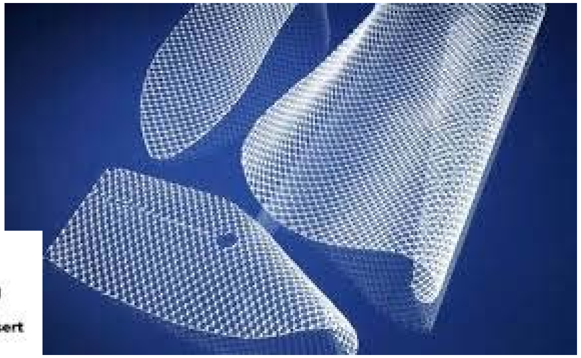


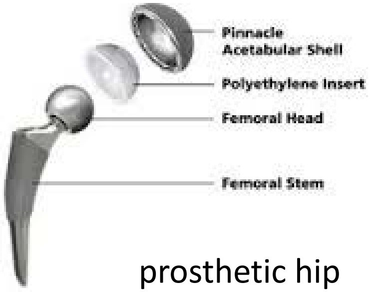
Mice: Deng et al., 2017 *Scientific Reports*

Physical Impact of the Particle

What does the medical literature tell us?

hernia mesh





prosthetic hip

TABLE 6.2

Medical literature on impact of microplastics and nanoplastics originating from inhalation and surgical materials at various levels of biological organization

Level of biological organization	Particle type and size	Effect	Reference
Macromolecules	PE 100 nm–30 µm PS 50 nm–4.7 µm PMMA 1 µm–2 µm PC 1 µm–55 µm	DNA damage, changes in gene and protein expression	Gelb *et al.*, 1994; Brown *et al.*, 2001; DeHeer *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.*, 2012; McGuinness *et al.*, 2011; Samuelsen *et al.*, 2009; Smith and Hallab 2010; Pearl *et al.*, 2011
Organelles*	PMMA 10 µm	more micronuclei	Zhang *et al.*, 2008
Cells	PS 20 nm–4.7 µm PE 300 nm–10 µm PMMA 2 µm–35 µm PS 20 nm–200 nm PS 60 nm–200 nm	cell clotting, necrosis, apoptosis, proliferation and loss of cell viability Oxidative stress Increased Ca ions	Gelb *et al.*, 1994; Brown *et al.*, 2001; Gretzer *et al.*, 2002; Bernard *et al.*, 2007; Fröhlich *et al.*, 2009; Samuelsen *et al.*, 2009; Hallab *et al.*, 2012; McGuinness *et al.*, 2011
Tissues	PE 600 nm–21 µ, PMMA 1 µm–35 µm	inflammation and bone osteolysis	Gelb *et al.*, 1994; Clohisy *et al.*, 2006; Markel *et al.*, 2009; Pearl *et al.*, 2011
Organs	PMMA 1 µm–10 µm	lesions	Zhang *et al.*, 2008; Pearl *et al.*, 2011

*An organelle is a specialized subunit within a cell (e.g. mitochondria) with a specific function.
PE (Polyethylene), PS (Polystyrene), PMMA (Poly(methyl methacrylate)), PC (Polycarbonate).

FAO Report 2017; Data from Rochman et al., 2016 *Ecology*

Chemical Impact

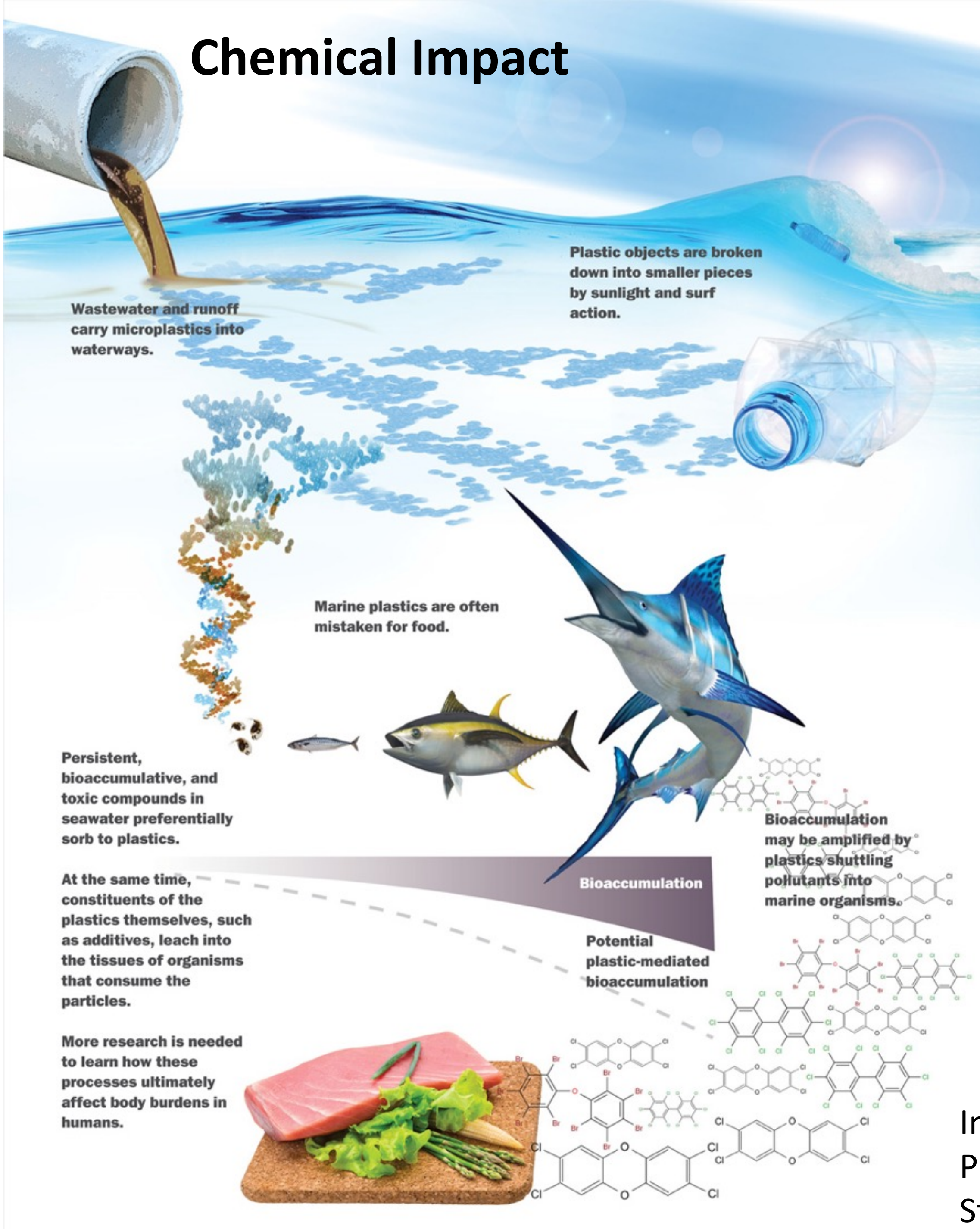
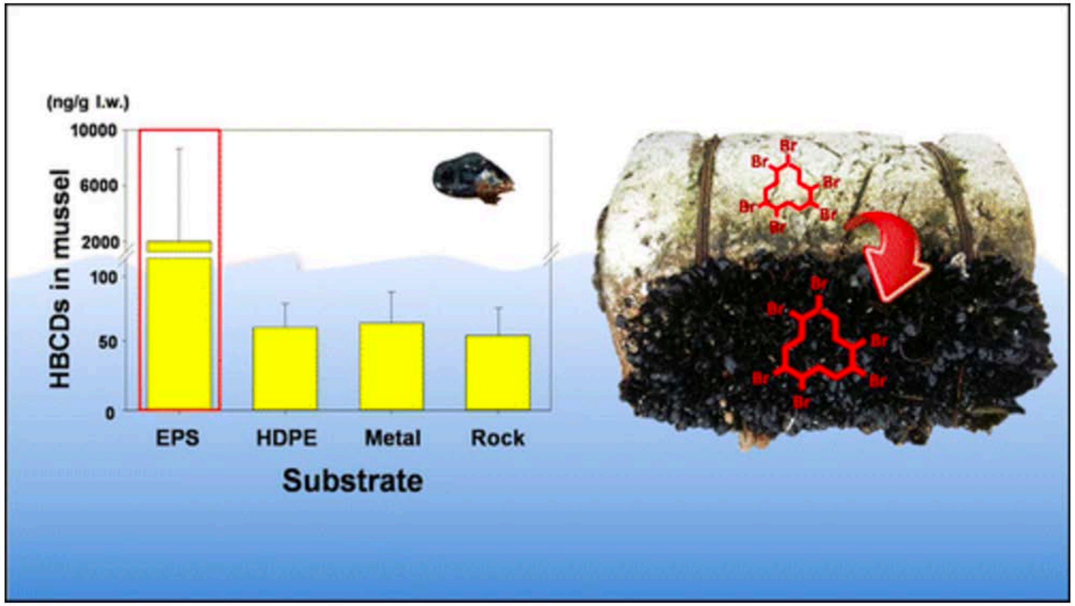
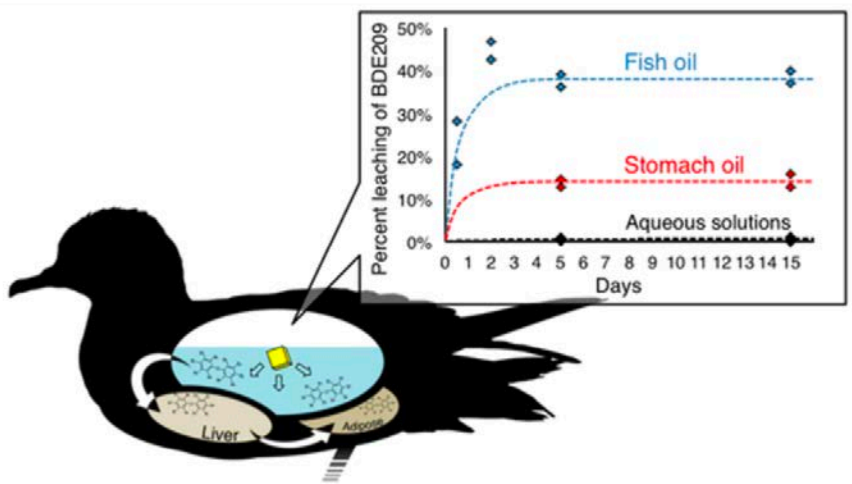


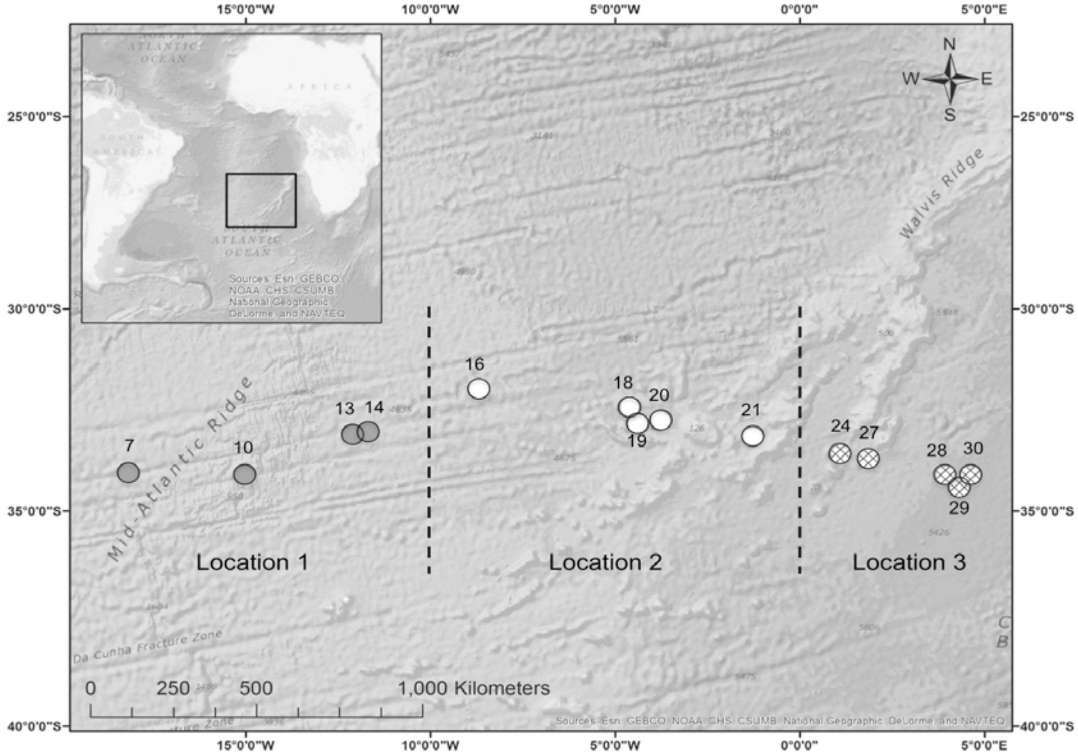
Image by Rolf Halden, Professor at Arizona State University

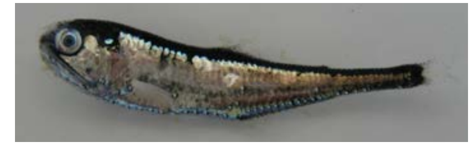


Jang et al., 2016 *ES&T*



Tanaka et al., 2015 *ES&T*;
Tanaka et al., 2013 *Mar Pollut Bull*





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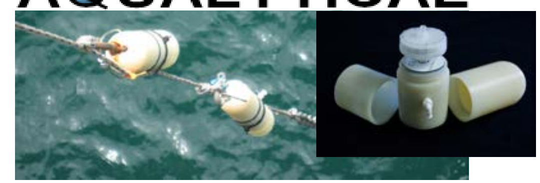
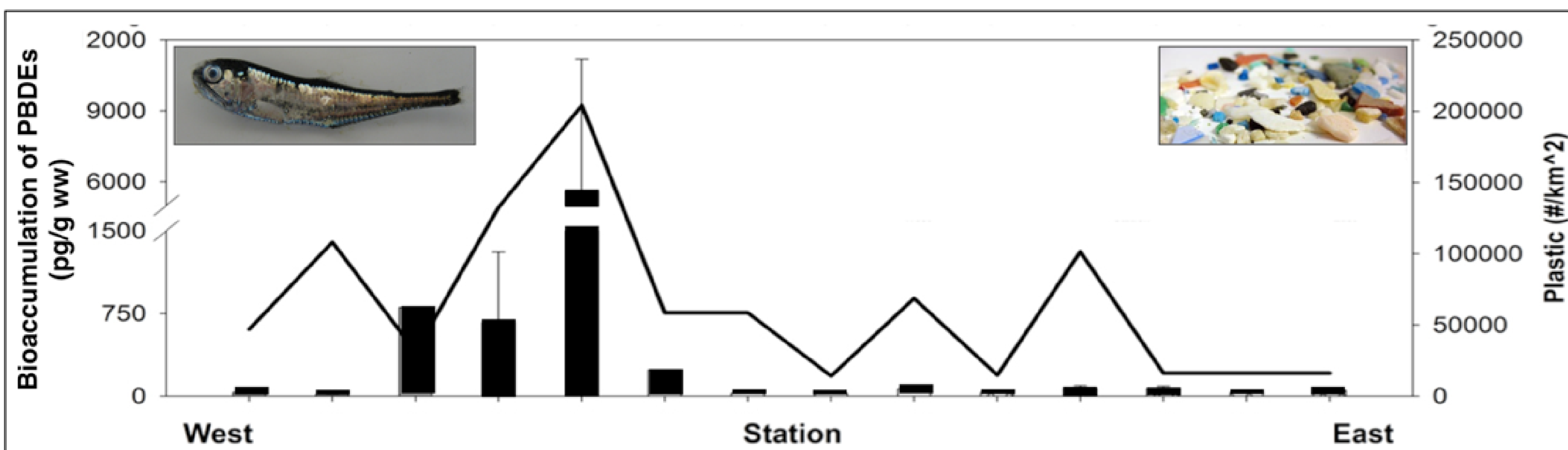
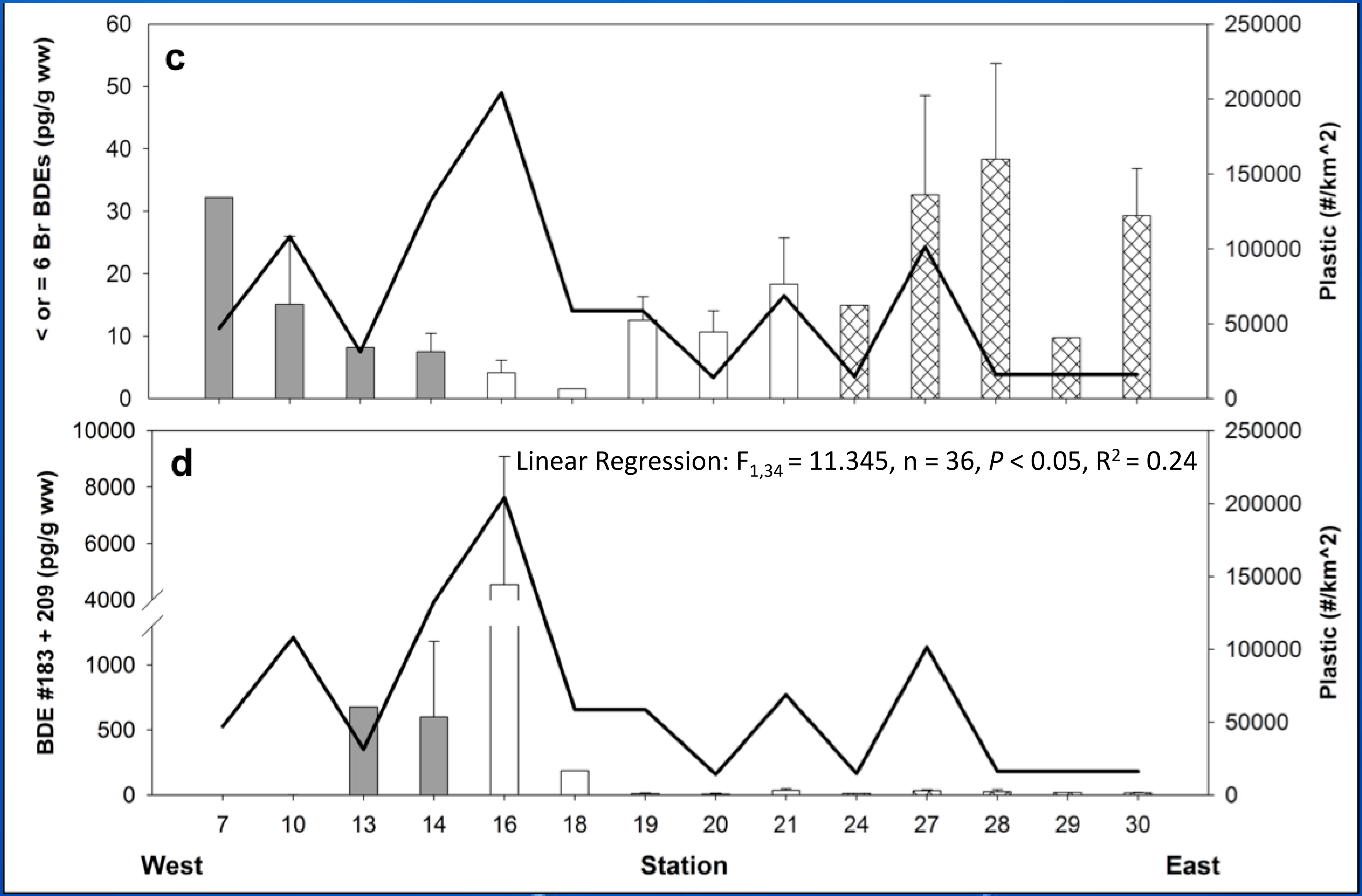


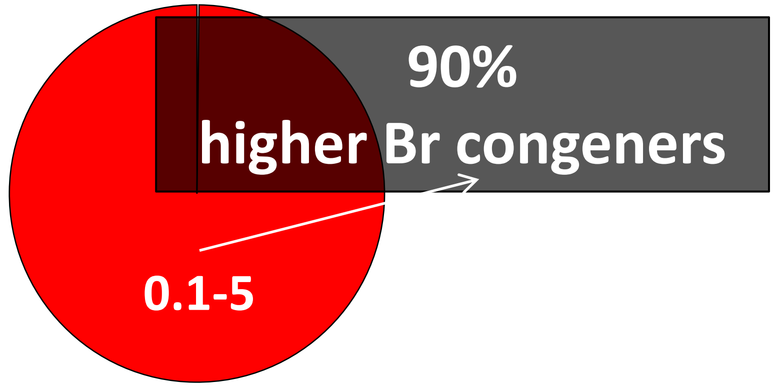


Rochman et al., 2014 *Science of the Total Environment*

Concentration of BDE-183 + BDE-209 at each station

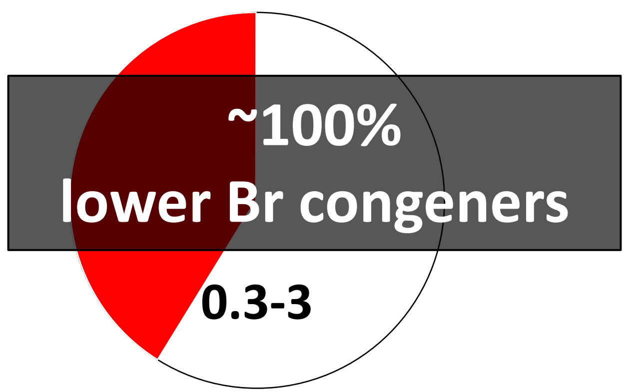


Chemicals associated with the plastic debris



PBDEs (ng/g)

Chemicals detected in water samples



PBDEs (pg/L)

What’s next for research?

- Fate of plastics and associated chemicals in marine ecosystems and seafood products

- Ecologically-relevant studies to assess impacts to wildlife and fish stocks

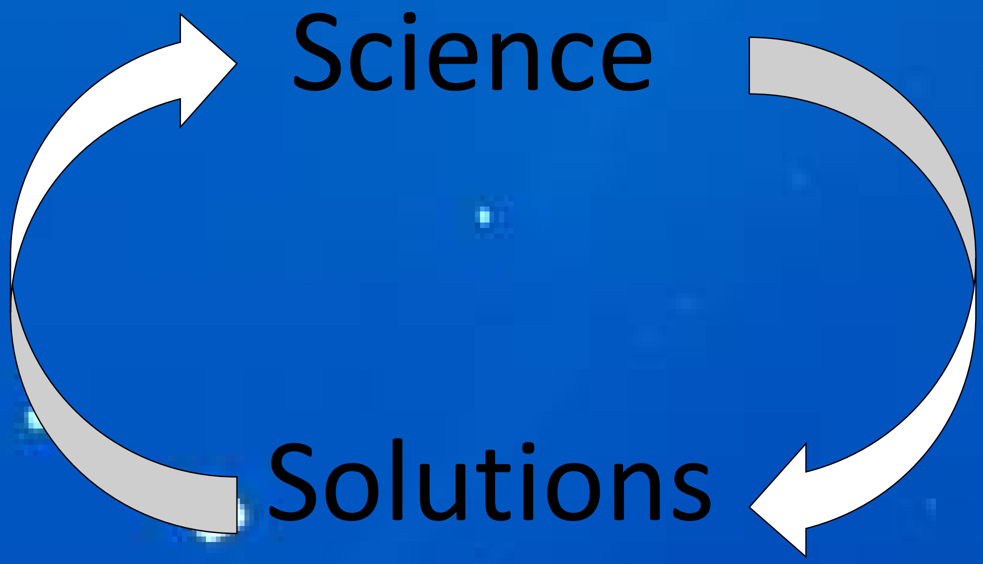
- Impacts to food safety and nutritional value

Widespread Contamination in habitats and animals – including seafood.

Evidence of effects to wildlife – particularly macroplastics – including to populations and communities.

Evidence of effects of microplastics in lab animals, populations and communities.

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



In the meantime, we have enough science to begin to mitigate now and prevent future sources of plastic pollution.

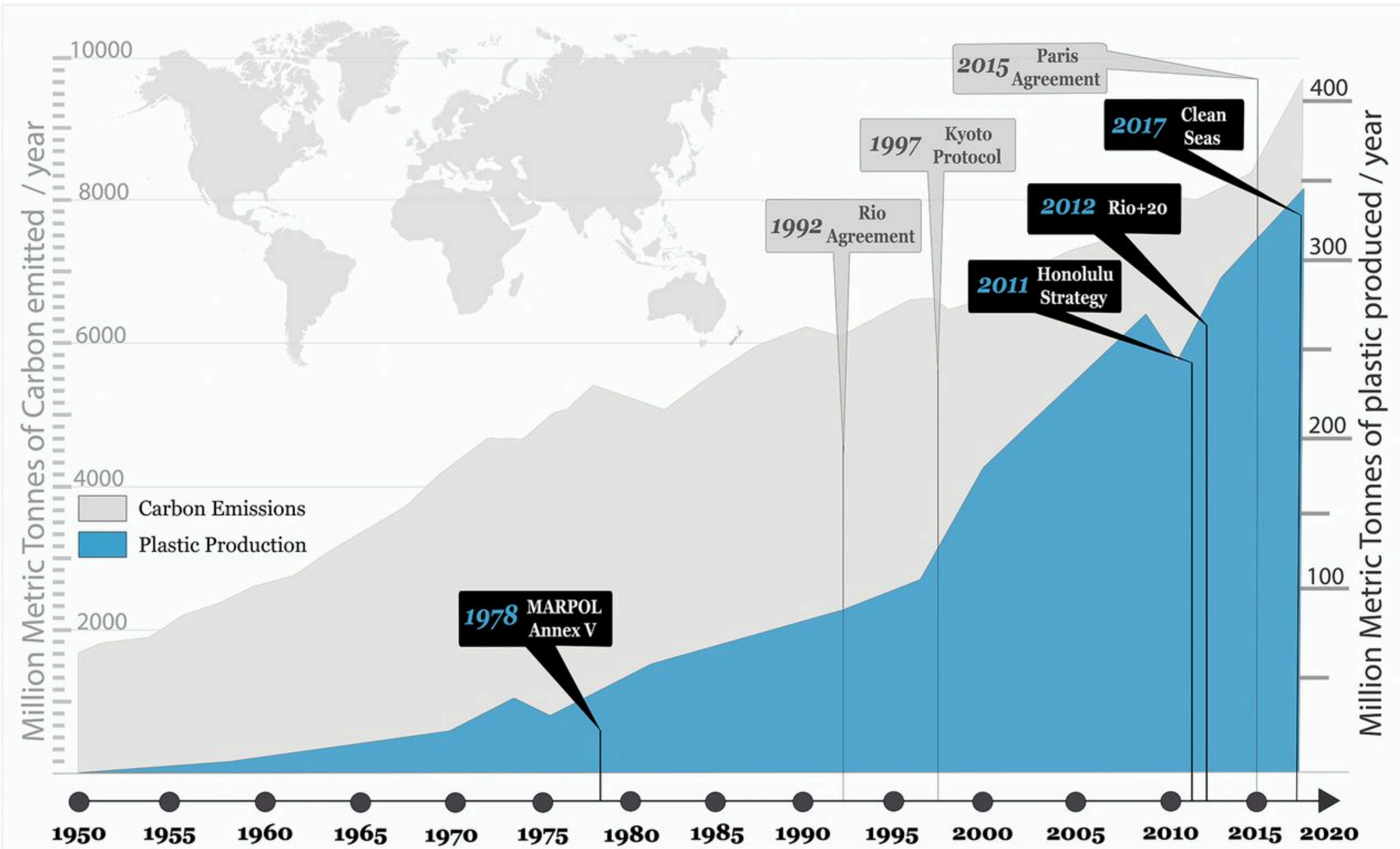
What's next for policy?

- 8 million metric tons of plastic enters the ocean each year (Jambeck et al., 2015 *Science*)

- Most policies occur on a very local scale, but plastic pollution does not observe borders, so why should policy?

- Policy is needed that scales with the magnitude of the problem.

What can we learn from other issues?



Stephanie B. Borrelle, Chelsea M. Rochman et al. PNAS 2017;114:9994-9997

Why we need an international agreement on marine plastic pollution

Stephanie B. Borrelle[a,1], Chelsea M. Rochman[b,1,2], Max Liboiron[c], Alexander L. Bond[d], Amy Lusher[e], Hillary Bradshaw[c], and Jennifer F. Provencher[f]

- Reduction targets for plastic pollution

- Signatories from member states

- Annual reporting on success

- Global fund to support infrastructure and innovation

Thank you!

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