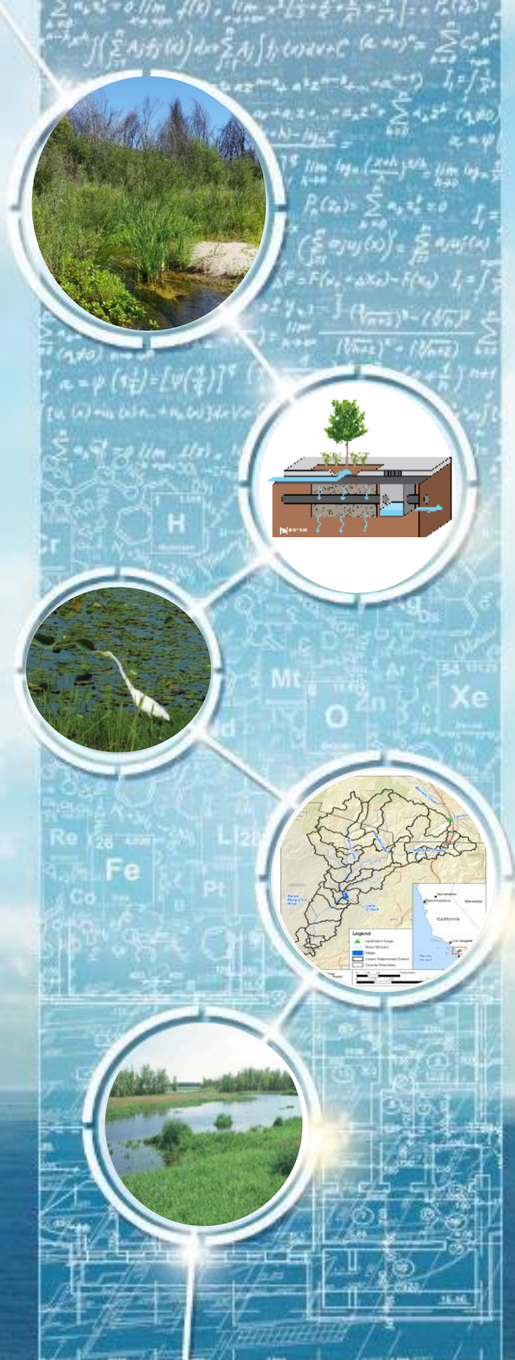

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Determining ecological risks of microplastics: current challenges and paths forward

April 24, 2019

Research and public interest in environmental effects of MPs is very high

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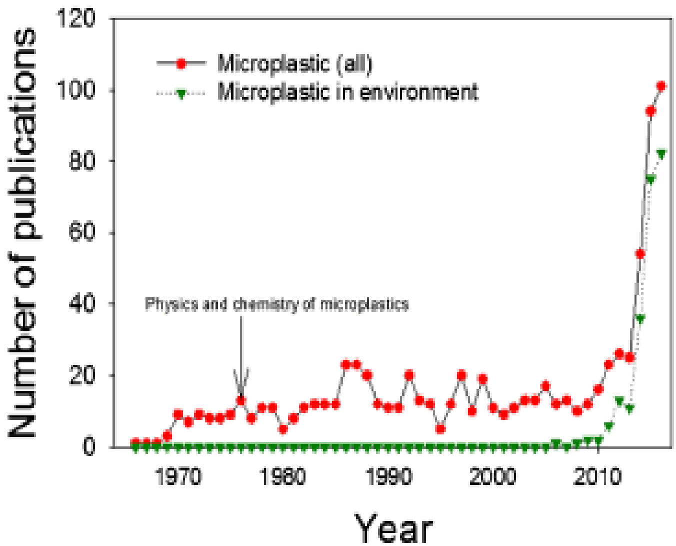
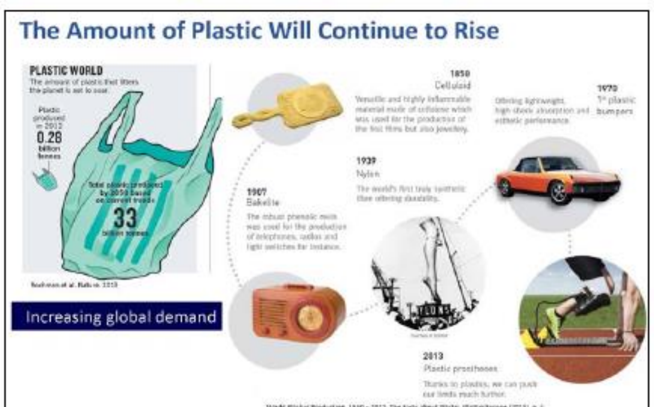


From Connors et al Envir. Tox. Chem. 2017



NATIONAL GEOGRAPHIC

WE MADE PLASTIC. WE DEPEND ON IT. NOW WE'RE DROWNING IN IT.

Some confusion between macro and microplastics?

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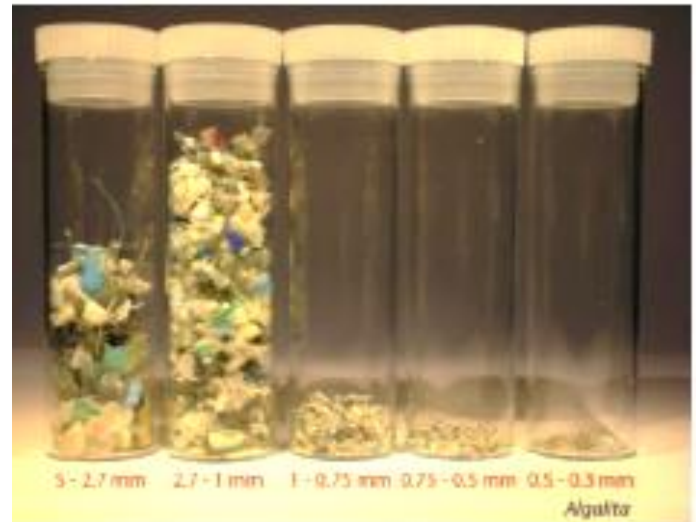
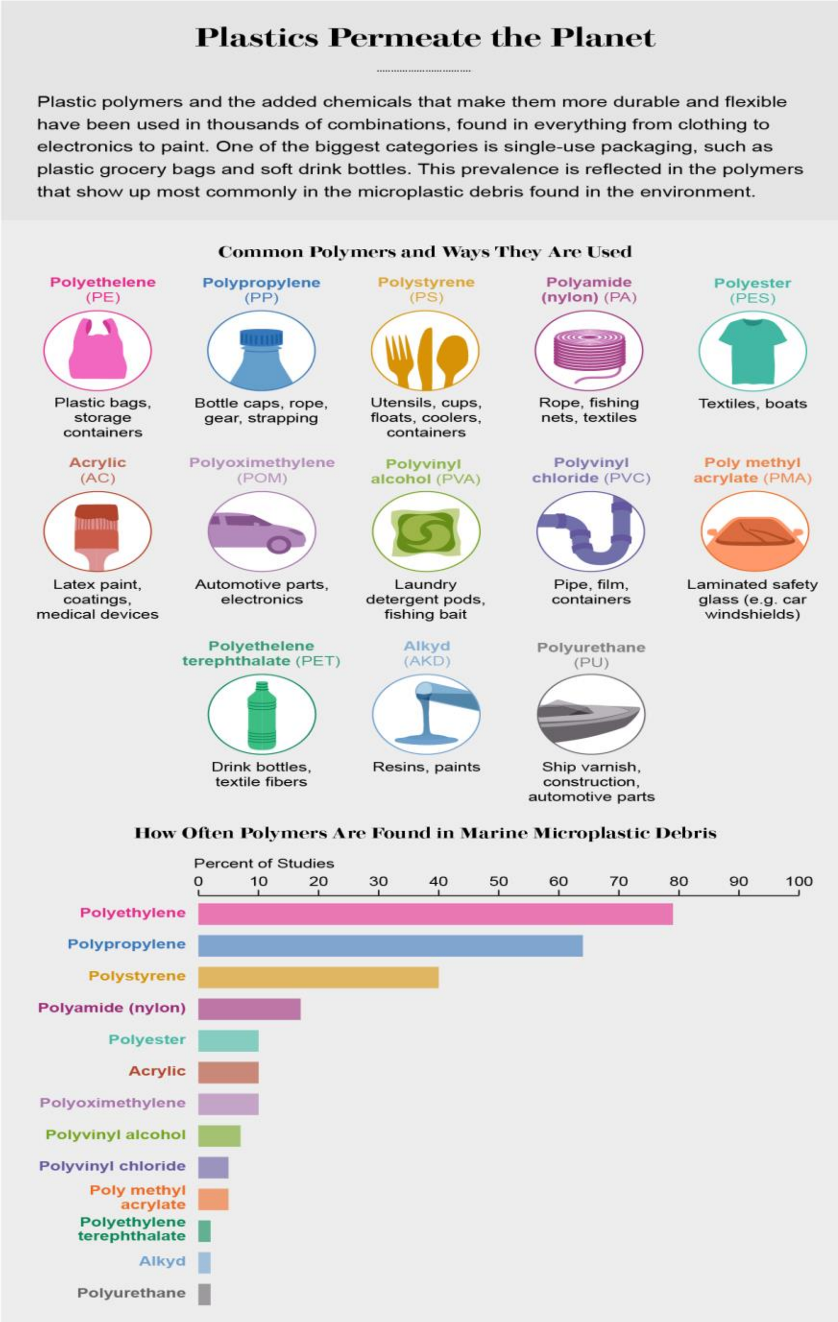
- Macroplastics clearly visible and a cause for concern
- Macroplastics certainly a source of MPs



Is the problem really macro-plastics?
Photo shows size distribution plastics from a typical manta trawl. MPs typically measured 0.5-0.3 mm.

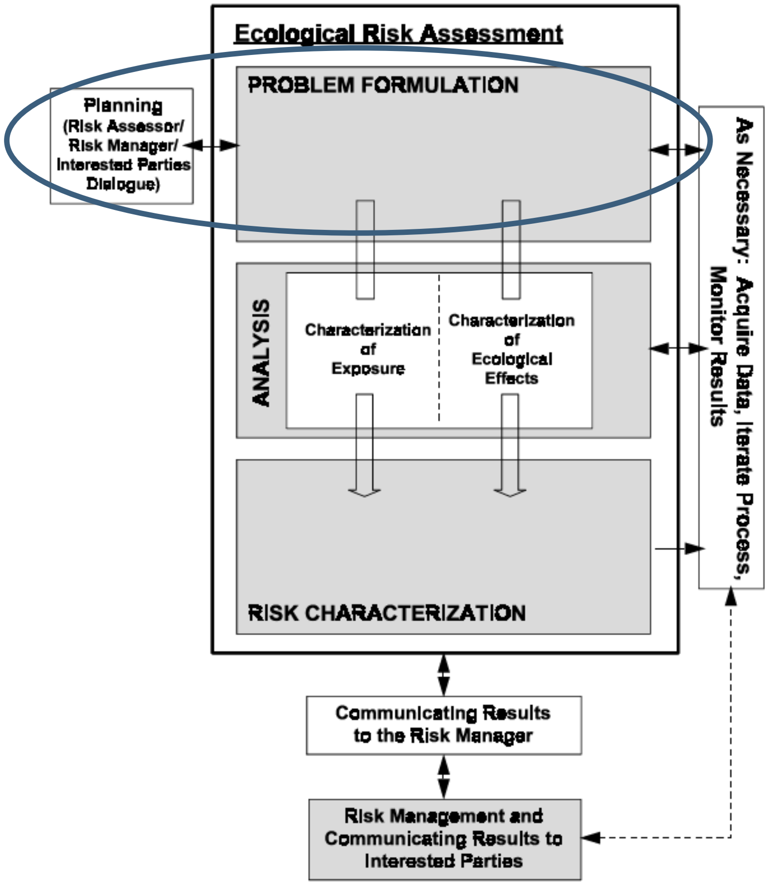


- Many types of MPs
- MPs in many media: personal care products, wastewater, stormwater, etc
- Challenging to determine which type(s) of MPs should be monitored and evaluated from a risk perspective

From: Scientific American: https://www.scientificamerican.com/article/from-fish-to-humans-a-microplastic-invasion-may-be-taking-a-toll/

Can an ecological risk assessment (ERA) framework help evaluate risks of MPs and inform management actions?

How is an ERA structured?



Starts with **Problem formulation**:

- Identify assessment endpoints: valued ecological resources and specific attributes that capture what we want to protect
- Identify measurement endpoints: relevant, measurable characteristics of valued resources and their attributes
- Conceptualize what we know, what we think we know, and what we want to know

Assessment Endpoints

- Valued ecological resource
- Explicitly defined so that it provides a clear focus for the assessment
- Provides a link between measurable endpoints and the steps necessary to achieve the management goal
- Represents a combination of a valued resource and ecologically relevant characteristics
- Selected based on their relevance to management objectives, susceptibility to stressors of concern, and ecological importance

Examples of Assessment Endpoints

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- Abundance and spatial extent of striped bass juveniles
- Abundance and distribution of native oysters
- Diversity and abundance of rare or threatened and endangered species
- More abundant recreational opportunities (e.g., boating, fishing, swimming)

The more explicit the assessment endpoint, the more risk analyses are likely to be useful

e.g., ~~High quality fish community integrity~~

Measurement Endpoints

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- Measurable attribute of the assessment endpoint
- May use a surrogate indicator for the assessment endpoint in order to have a measurable endpoint for risk analyses.

Examples

Assessment Endpoint	Measurement Endpoint
Diverse pelagic fish community	Fish IBI, metrics
Abundant striped bass juveniles	CPUE of striped bass juveniles in surveys
Estuarine benthic macroinvertebrate community abundance and diversity	Diversity of benthic species; proportion of sensitive taxa or species having certain biological traits
Abundant healthy eel grass beds	Aerial coverage of eel grass from satellite images

Conceptual Model

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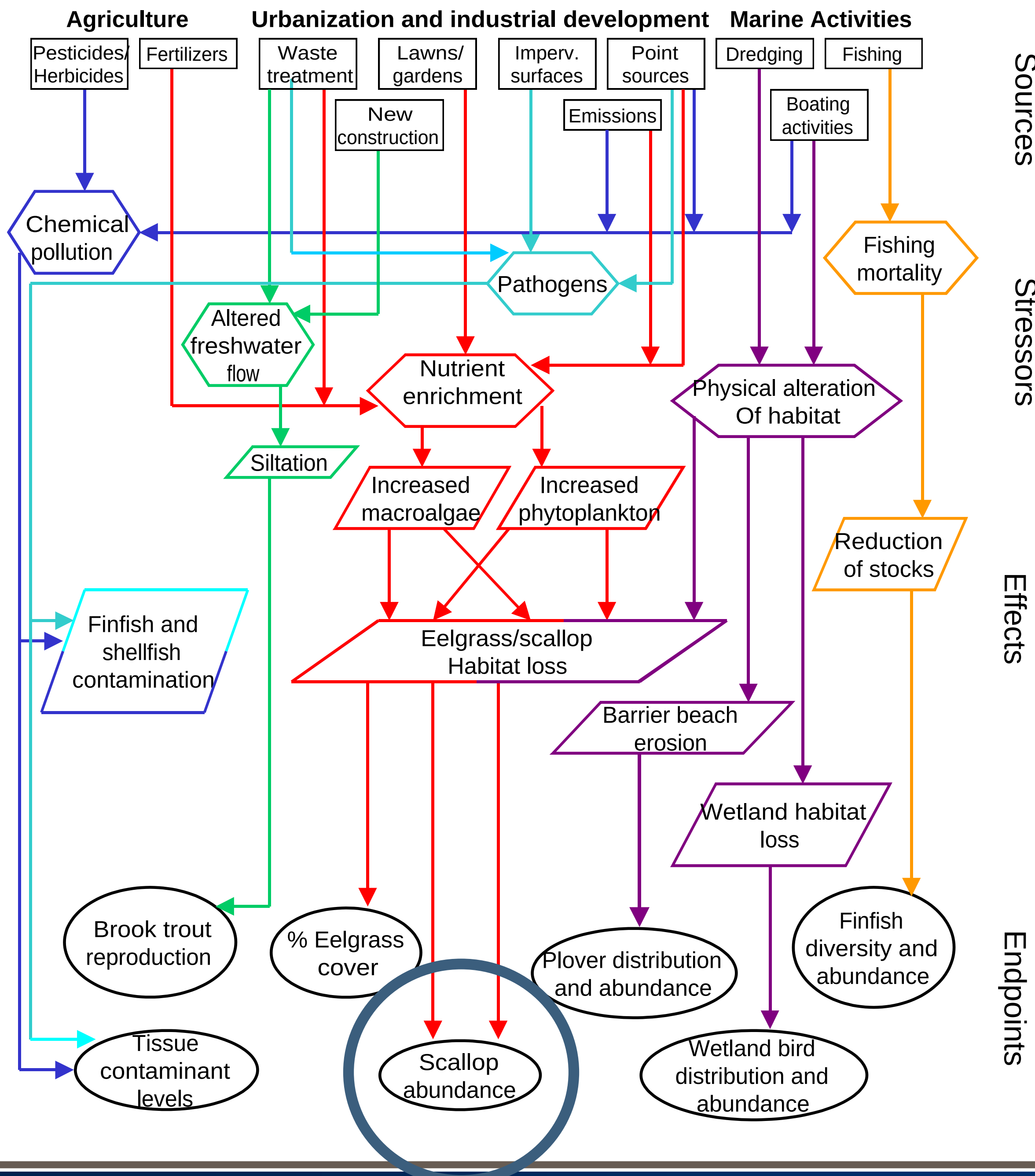
- Describes pathways between:
  - human activities (**sources of stress**)
  - **stressors** (may be physical, chemical, or biological)
  - **assessment endpoints**
- Should yield predictions or risk hypotheses of how human activities affect the valued ecological resources
- Based on ecological experience and best professional judgment

- **May be assessment endpoint – focused [what stressor(s) most responsible for risk to valued resource?] OR**
- **May be stressor-focused [e.g., What is the ecological risk of chemical X at my site or in general? – may have multiple assessment endpoints] OR**
- **May be both stressor and assessment endpoint focused**



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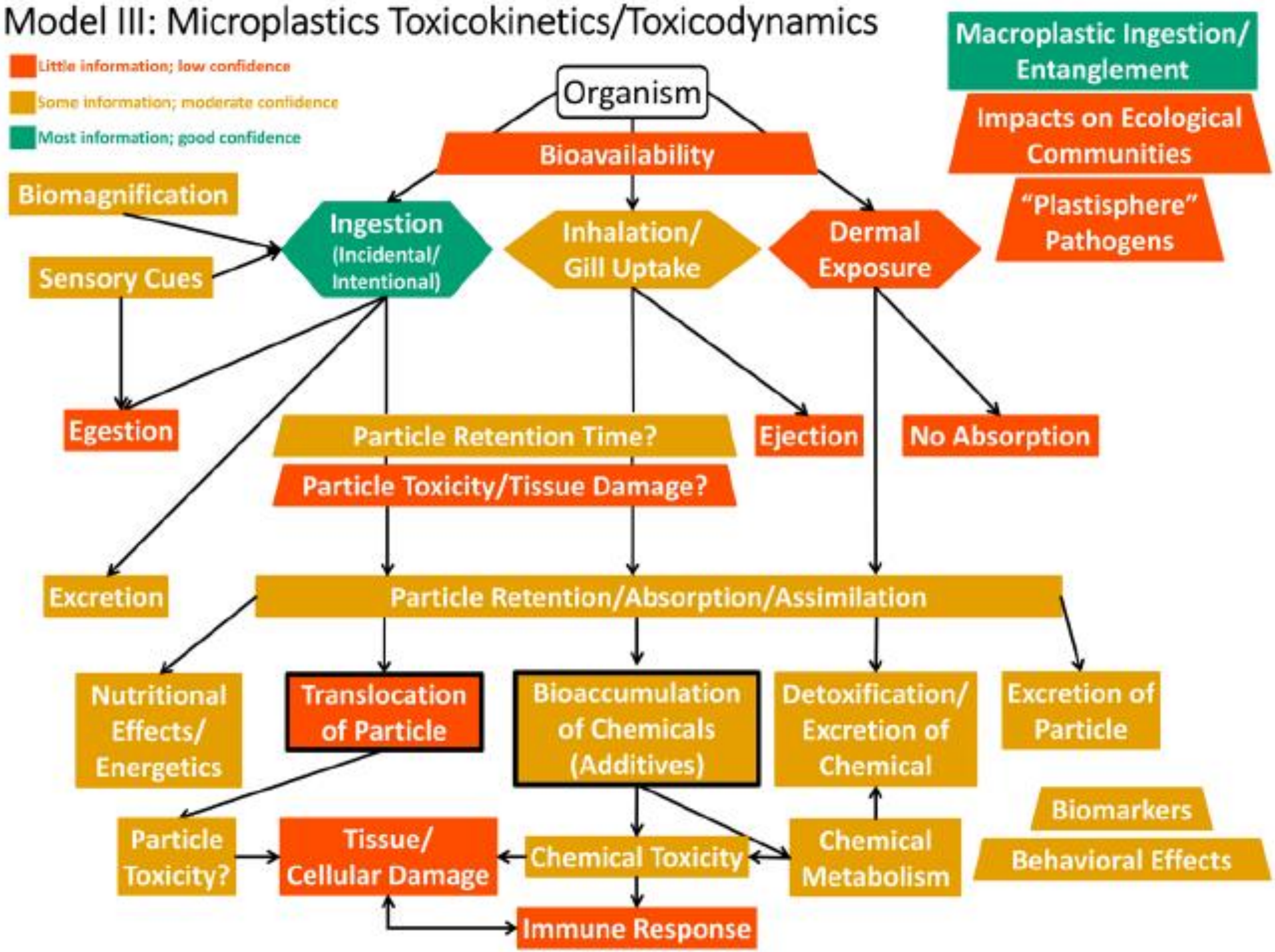
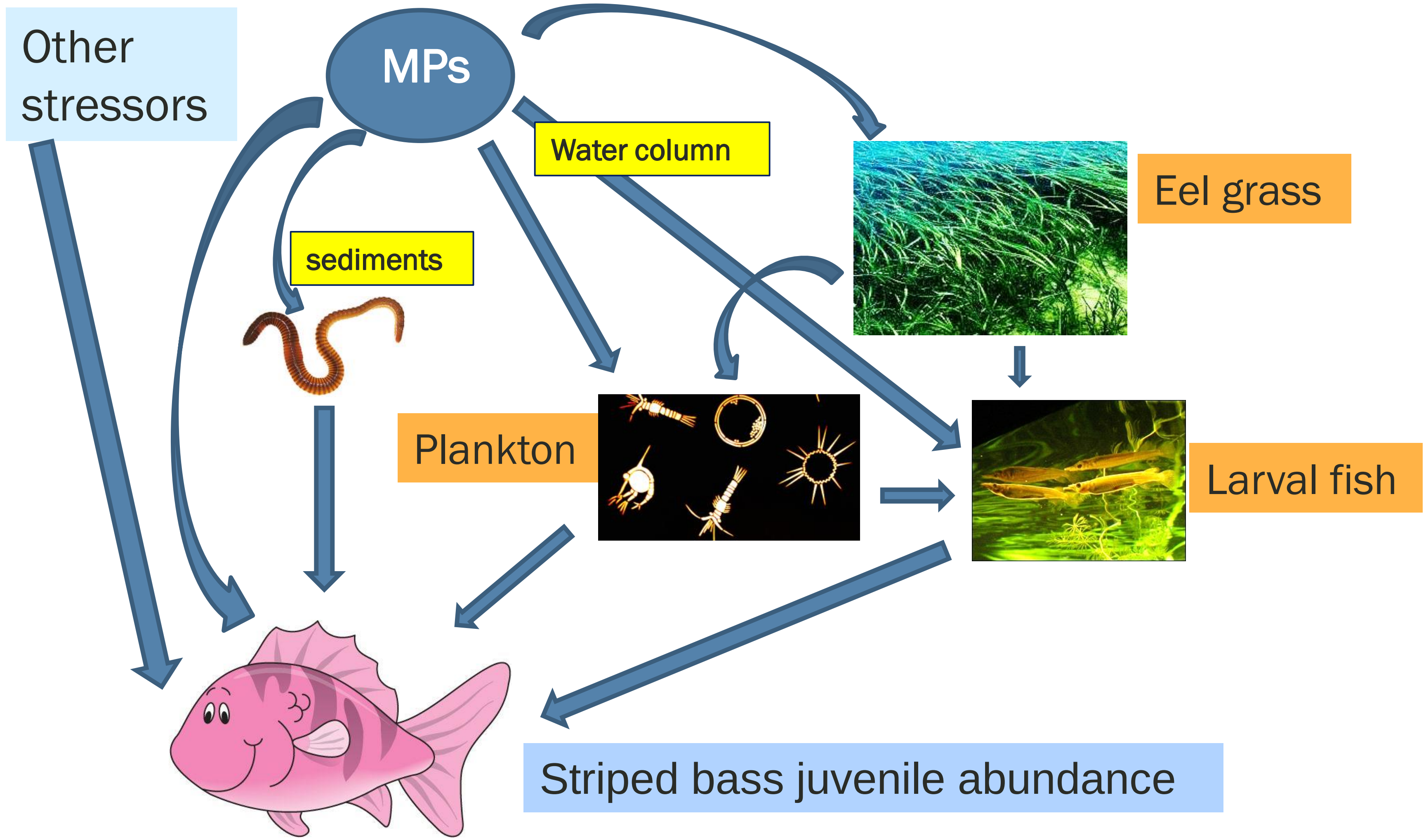
Assessment endpoint-focused:

Scallop abundance
Waquoit Bay, MA



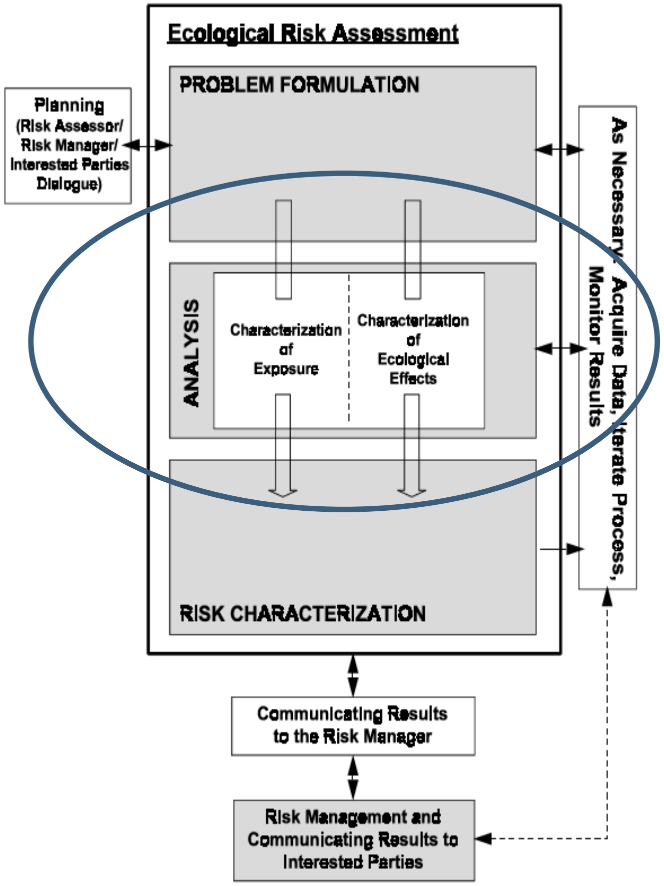
From: EPA microplastics expert workshop June, 2017

Stressor and Assessment Endpoint Focused Conceptual Model



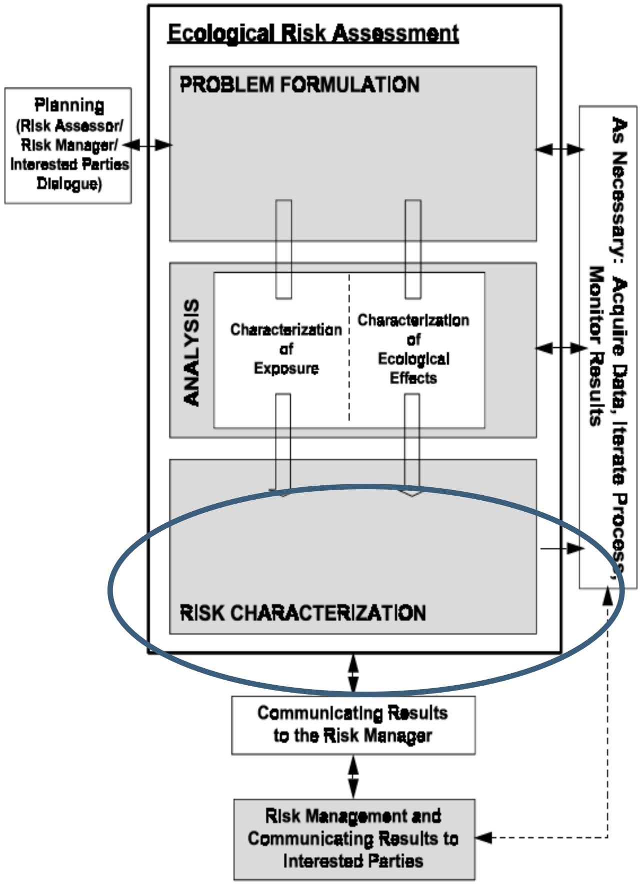
Risk Analyses

- Identify risk hypotheses or testable linkages between sources, stressors and assessment endpoints
- Identify appropriate ways to analyze linkages or hypotheses
- Implement analysis plan and interpret results of analyses
- Often an iterative process as results are obtained; not necessarily linear process



Risk Characterization

- Integrates **exposure and effects**
- Traditionally relies on known effect thresholds (e.g., LC50s, NOECs), species sensitivity distributions, minimum levels for sustained population survival and reproduction
- Identify strength of relationships derived from analyses
- Identify uncertainties, data gaps, confounding factors



How can we apply an ERA framework to the problem of MPs?

Traditional ecorisk framework needs to be adjusted to be applicable to MPs

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Traditional Paradigm

- Physical, chemical or biological stressor is readily quantified unambiguously
- Sources of the stressor are typically known or assumed based on BPJ
- Laboratory experiments often used to provide effects information

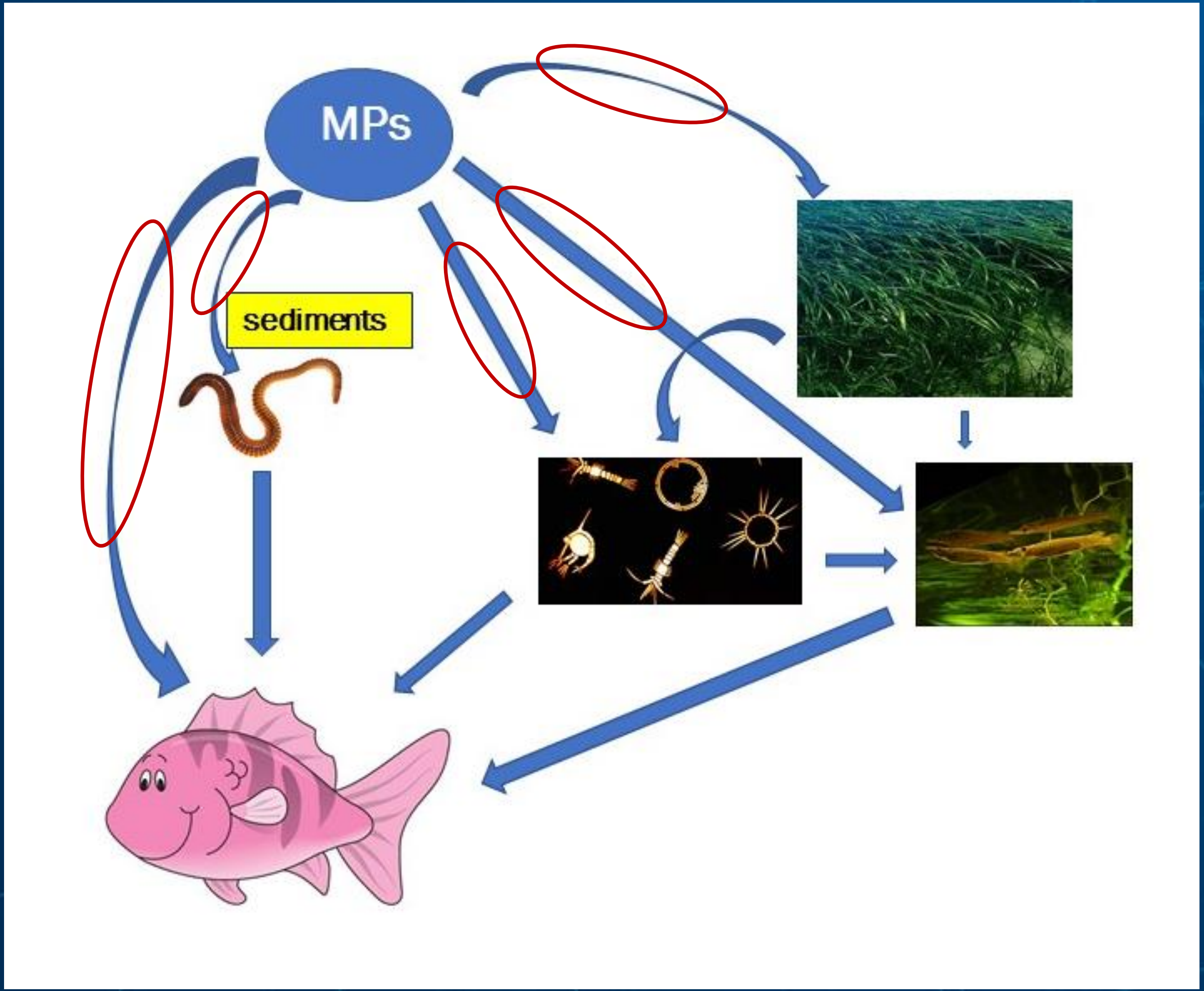
Microplastics

- MPs may encompass many forms, types, sizes; challenging to quantify
- Sources may be diffuse and may influence types of MPs; MPs produced intentionally (e.g., microbeads) and MPs from degradation of macroplastics
- Effects information may be specific to a site, types of MPs, etc

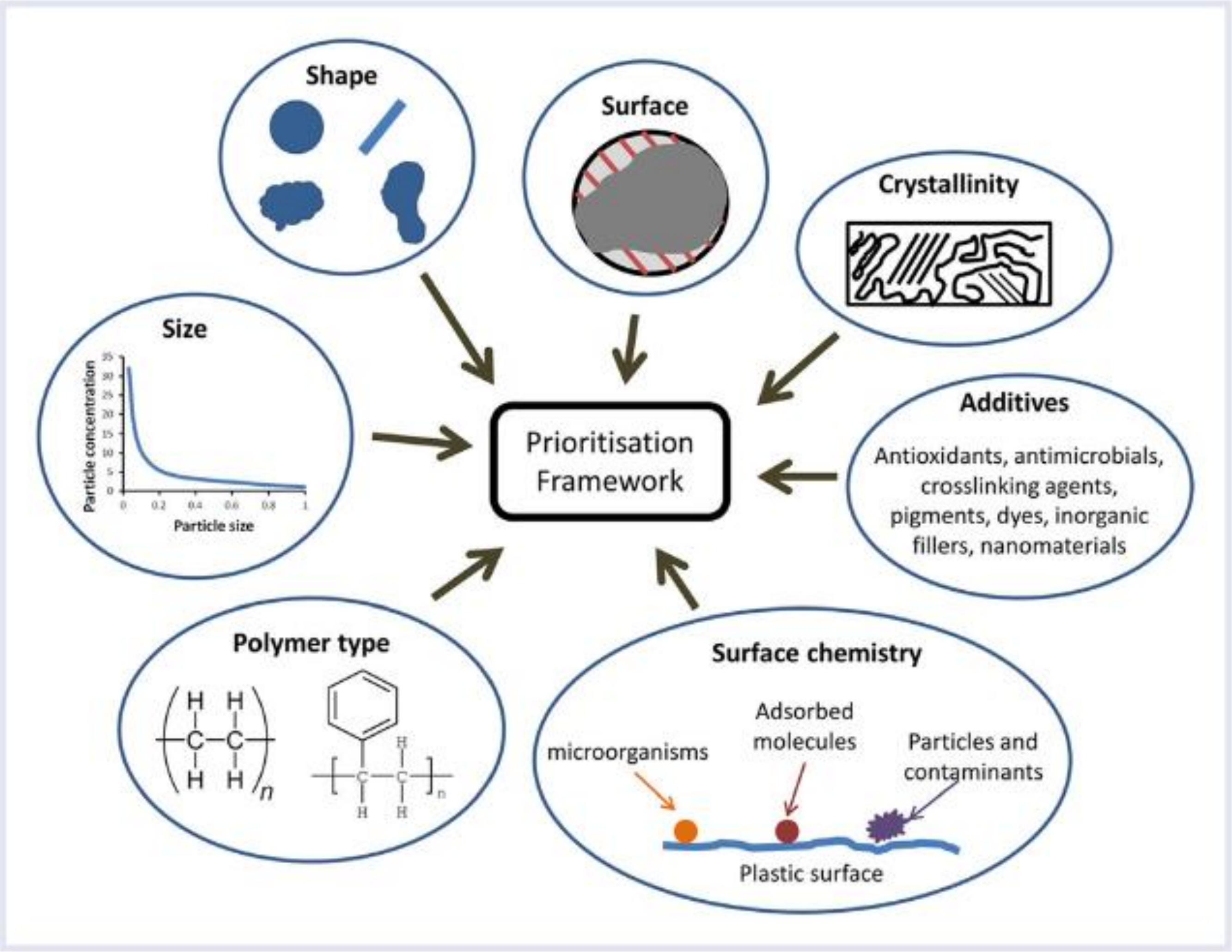
Determine MP Exposure: What factors affect MP exposure to receptors of interest?

Direct exposure: Ingestion of MPs in water column and sediments

Fate of MPs depends on relative density of MP– lighter ones float while heavier ones may accumulate in sediments



Physico-chemical properties of MPs can influence which type of MPs are available for uptake



Lambert et al 2017 IEAM 13: 470-475

What do we know about exposure of MPs to biota?

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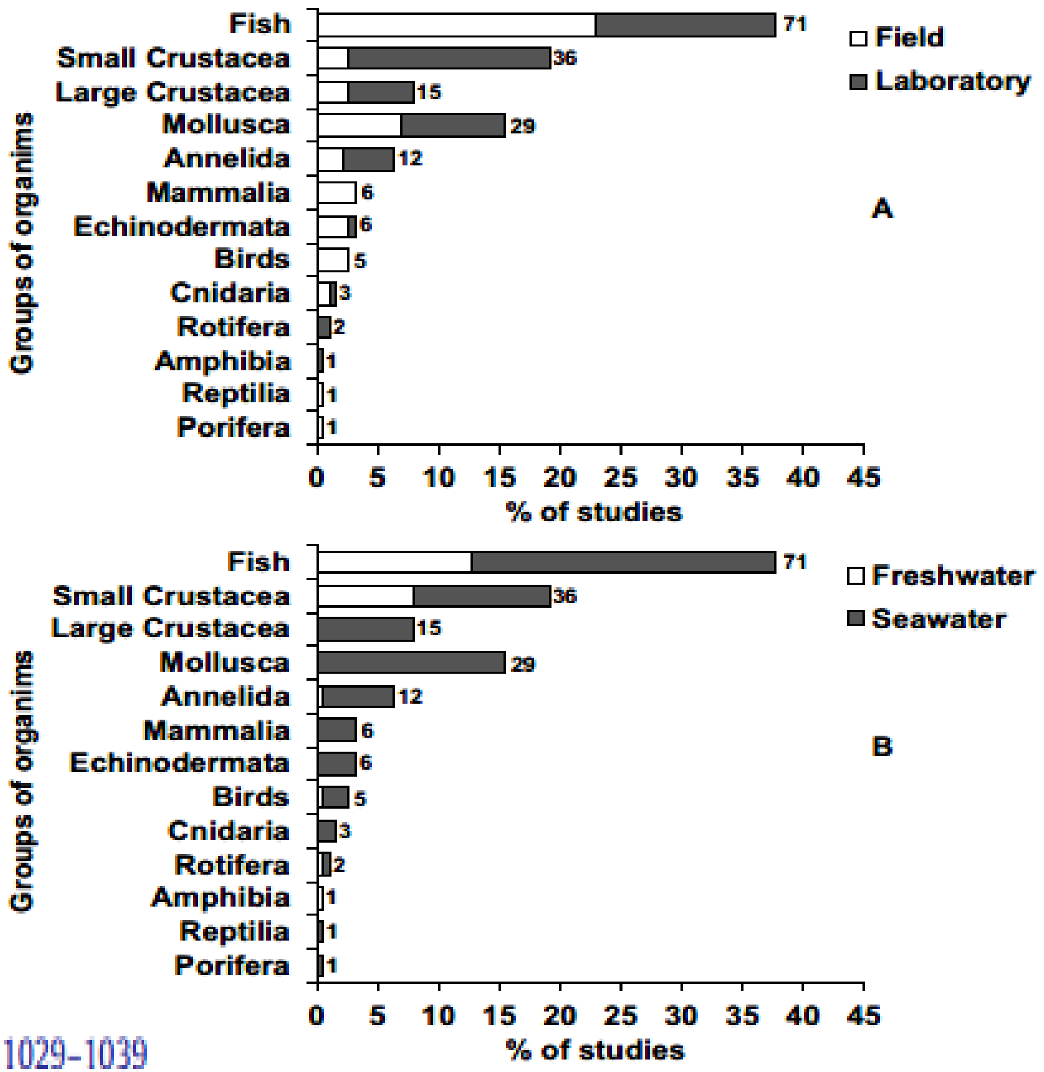
Some types of flora and fauna have been studied more than others; data gaps



de Sa et al

Science of the Total Environment 645 (2018) 1029–1039

Ingestion of microplastics by fish: what's the appropriate size range? Jovanovic IEAM 2017 13:510-515

Location	Sample size (nr of fish examined)	Fish with microplastics in GI tract (%)	Average nr of particles per fish ± SD	Average nr of particles per fish only fish that ingested microplastics ± SD	Cutoff length of analyzed microplastics
North Pacific Gyre	670	35	2.1 ± 5.78	5.88 ± n.d	N/A
North Pacific Gyre	141	9.2	0.11 ± n.d	1.15 ± n.d	>700 µm
English Channel	504	36.5	0.7 ± n.d	1.9 ± 0.1	N/A
North Sea	1203	2.6	N/A	N/A	200 µm–5 mm
North and Baltic Sea	290	5.5	0.08 ± n.d	1.44 ± n.d	500 µm–5 mm
North and Baltic Sea	406	23	0.24 ± n.d	N/A	100 µm–5 mm
Gulf of Mexico	535	8.2–10.4	N/A	N/A	N/A
Australia and Southern Ocean	342	0.3	0.01 ± n.d	2 ± n.d	>330 µm
South Africa urban harbor	70	73	3.8 ± 4.7	5.1 ± n.d	N/A, measured 200 µm–15 mm
Tokyo Bay	64	77	2.34 ± 2.5	3.06 ± n.d	>200 µm
North Atlantic	761	11	0.13 ± n.d	1.2 ± 0.54	250 µm–5 mm 6% >5 mm
Norwegian coast	302	3	0.05 ± n.d	1.77 ± n.d	N/A, measured 3.2–41.7 mm
Coast of Portugal	263	19.8	0.27 ± 0.63	1.4 ± 0.66	N/A
Adriatic Sea	125	28	0.39 ± n.d	1.39 ± n.d	<5 mm
Balearic Islands, Mediterranean	337	58	2.17 ± n.d	3.75 ± 0.25	???–5 mm
Spain, Atlantic and Mediterranean	212	17.5	0.27 ± n.d	1.56 ± 0.5	N/A measured 0.38–3.1 mm
Italy, Mediterranean	121	18.2	0.24 ± n.d	1.32 ± n.d	N/A measured 0.63–164.50 mm
Turkey, Mediterranean	1337	58	1.36 ± n.d	2.36 ± n.d	26 µm–5 mm

MPs in fish: Function of relative abundance or feeding behavior?

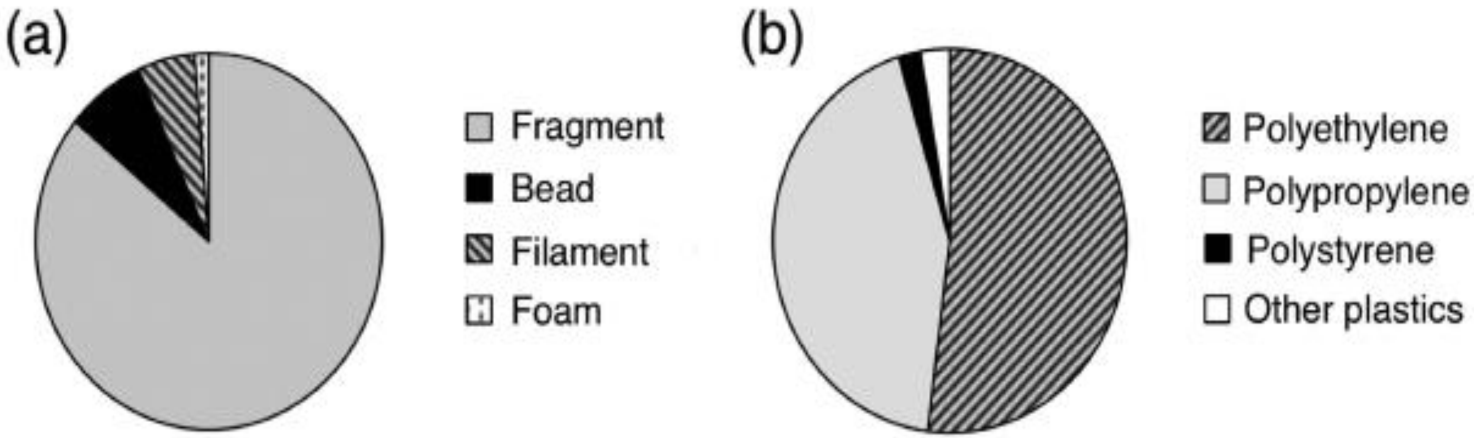


Figure 3. Types of plastics recovered from digestive tracts of Japanese anchovy (*Engraulis japonicus*). (**a**) Percentage by shape. (**b**) Percentage by polymer.

Tanaka and Takada 2016, Scientific RepoRts | 6:34351 | DOI: 10. 1038 / srep34351

MPs a vector of contaminant exposure to aquatic life?

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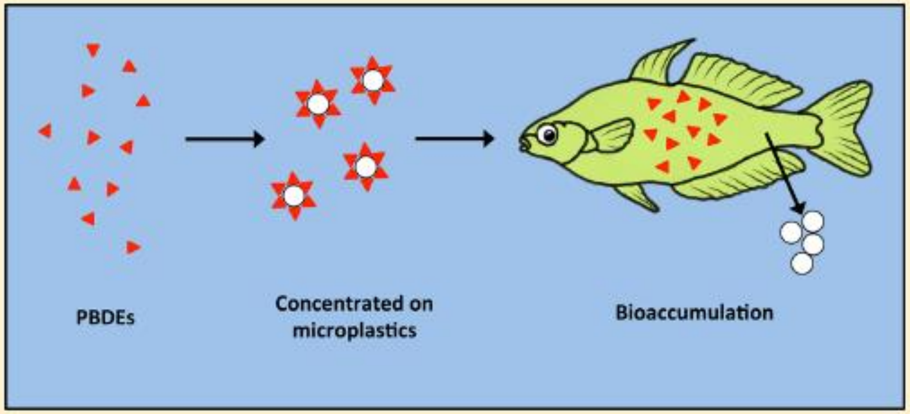
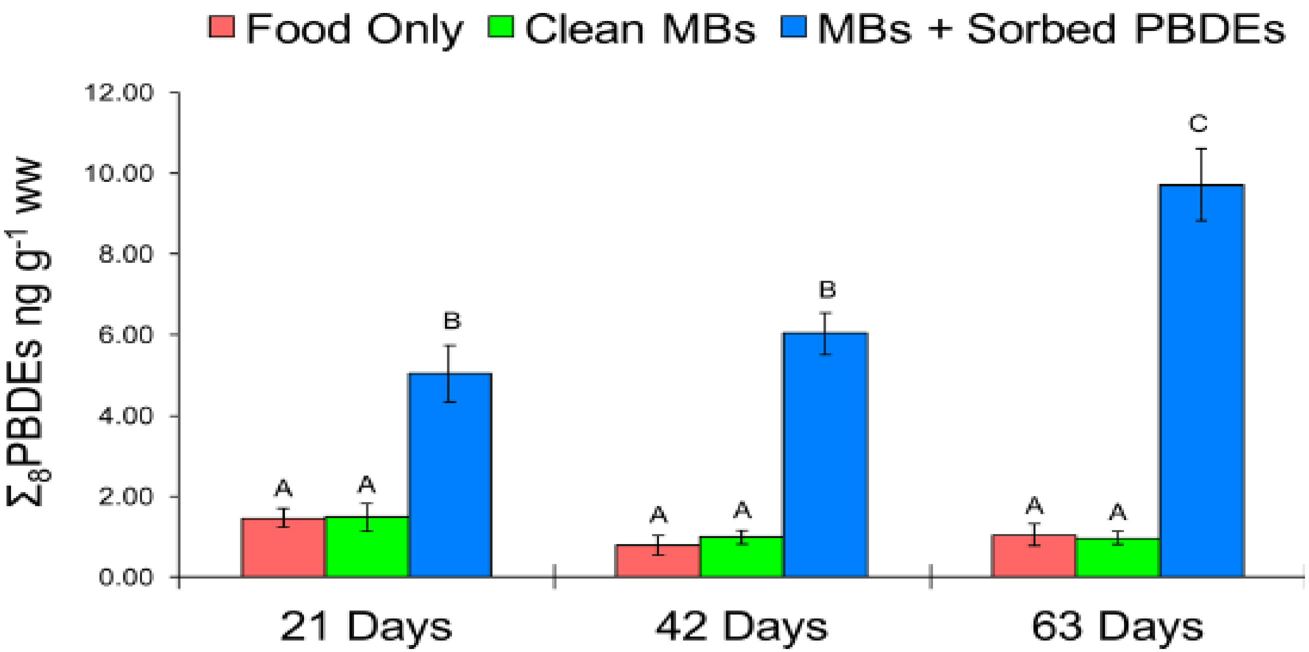


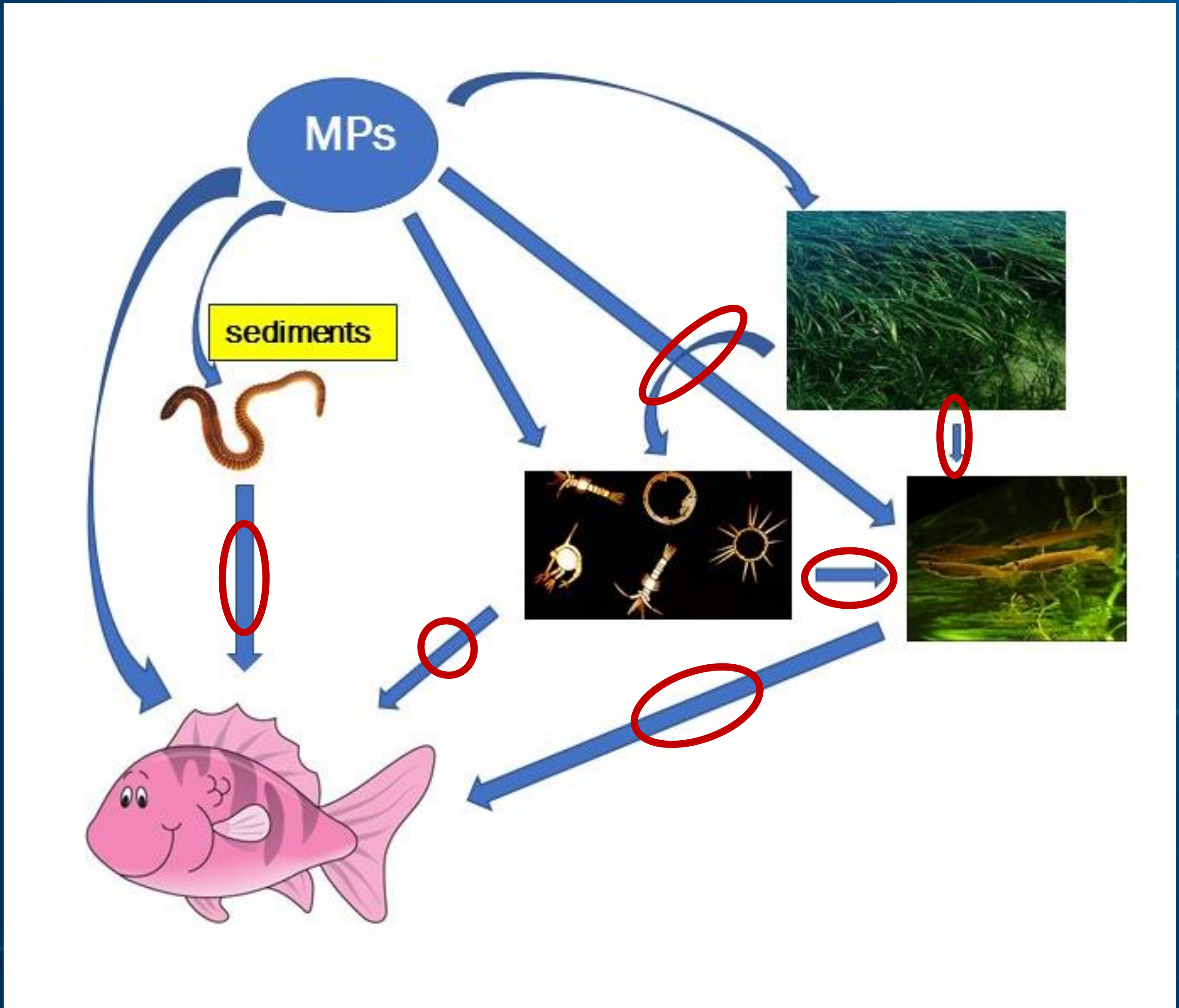
Wardrop et al 2016. ES&T 50: 4037−4044

Rainbow fish PBDE concentration after exposure to food only, clean microbeads (MBs), MBs spiked with PBDEs, and PBDE concentration on sorbed MBs



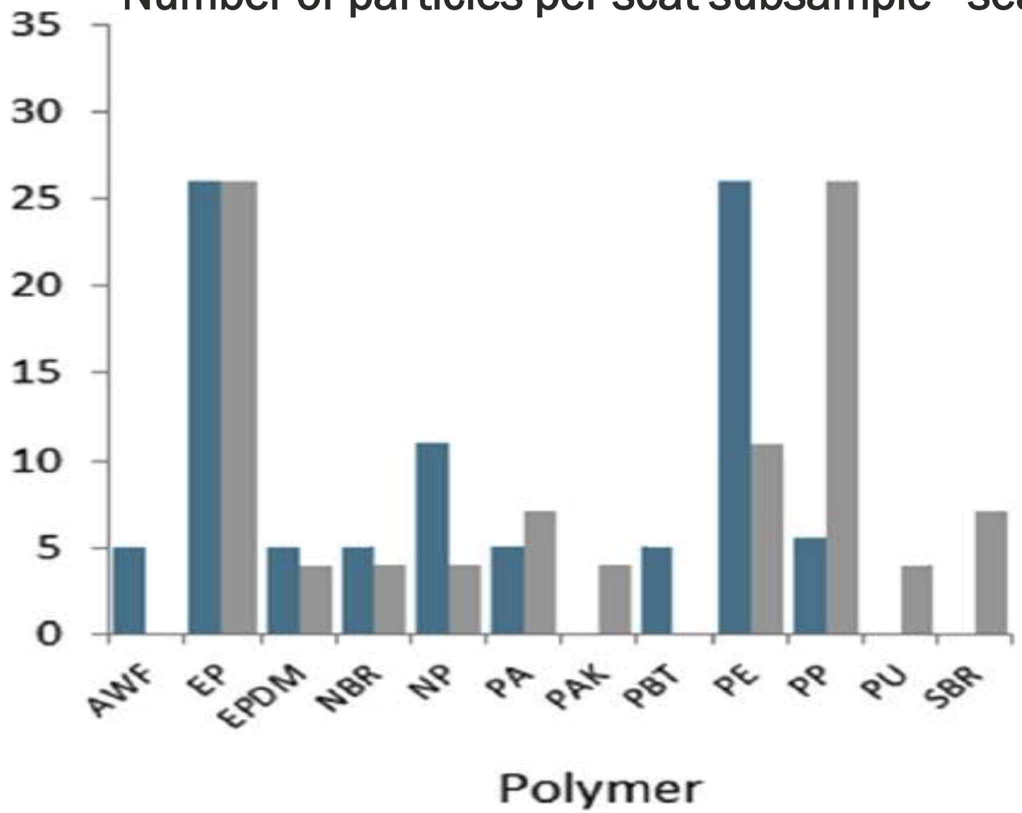
How important is indirect exposure of MPs?

Uptake of MPs from food items; trophic transfer



Trophic transfer of MPs a critical pathway?

Number of particles per scat subsample - seals

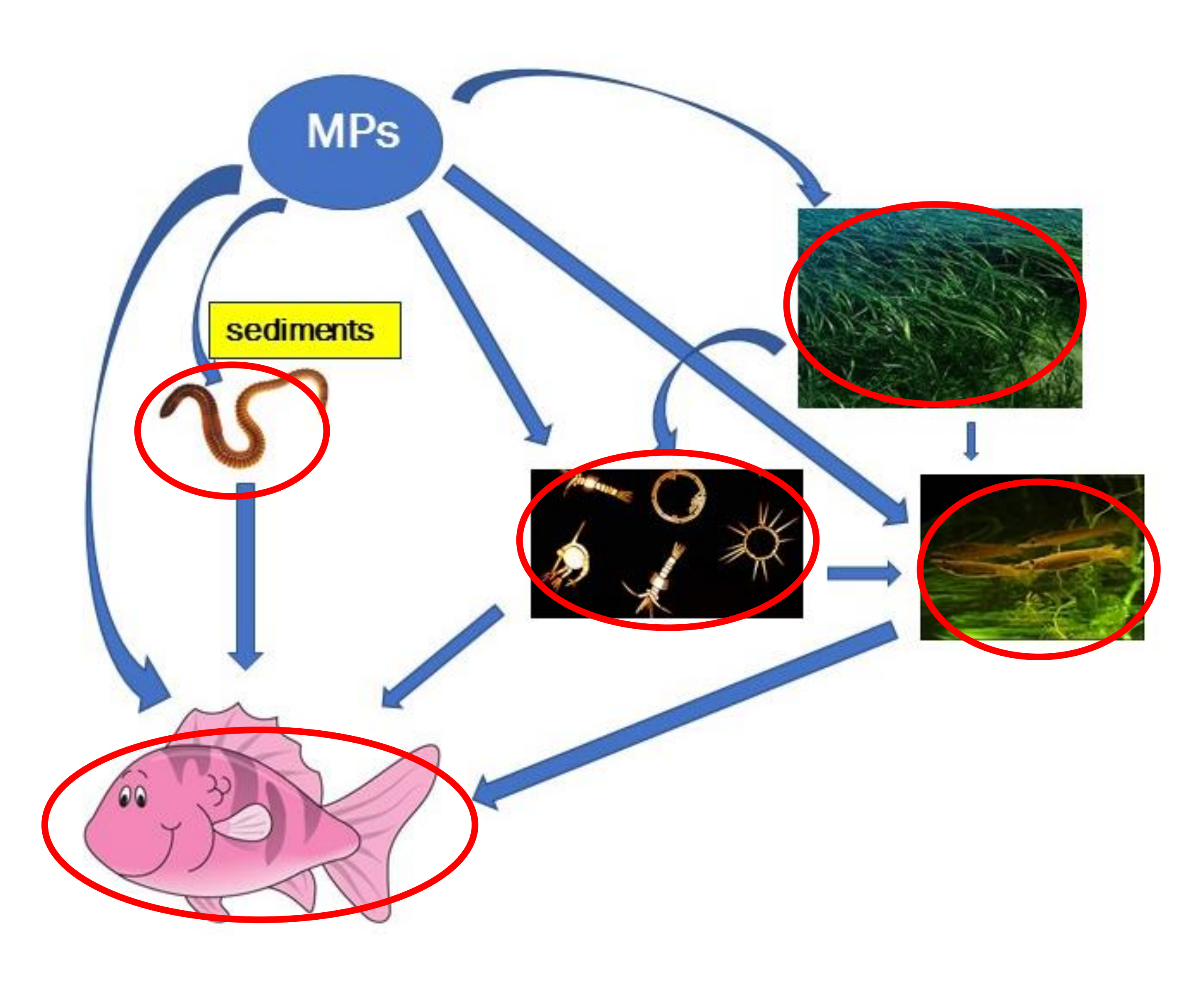


Evidence that seals obtained MPs from ingesting fish that had accumulated MPs

Nelms et al 2018

Environmental Pollution 238 (2018) 999–1007

What Do We Know About MP Effects on Biota?



Studies have examined effects of different MP types, locations, and type of species

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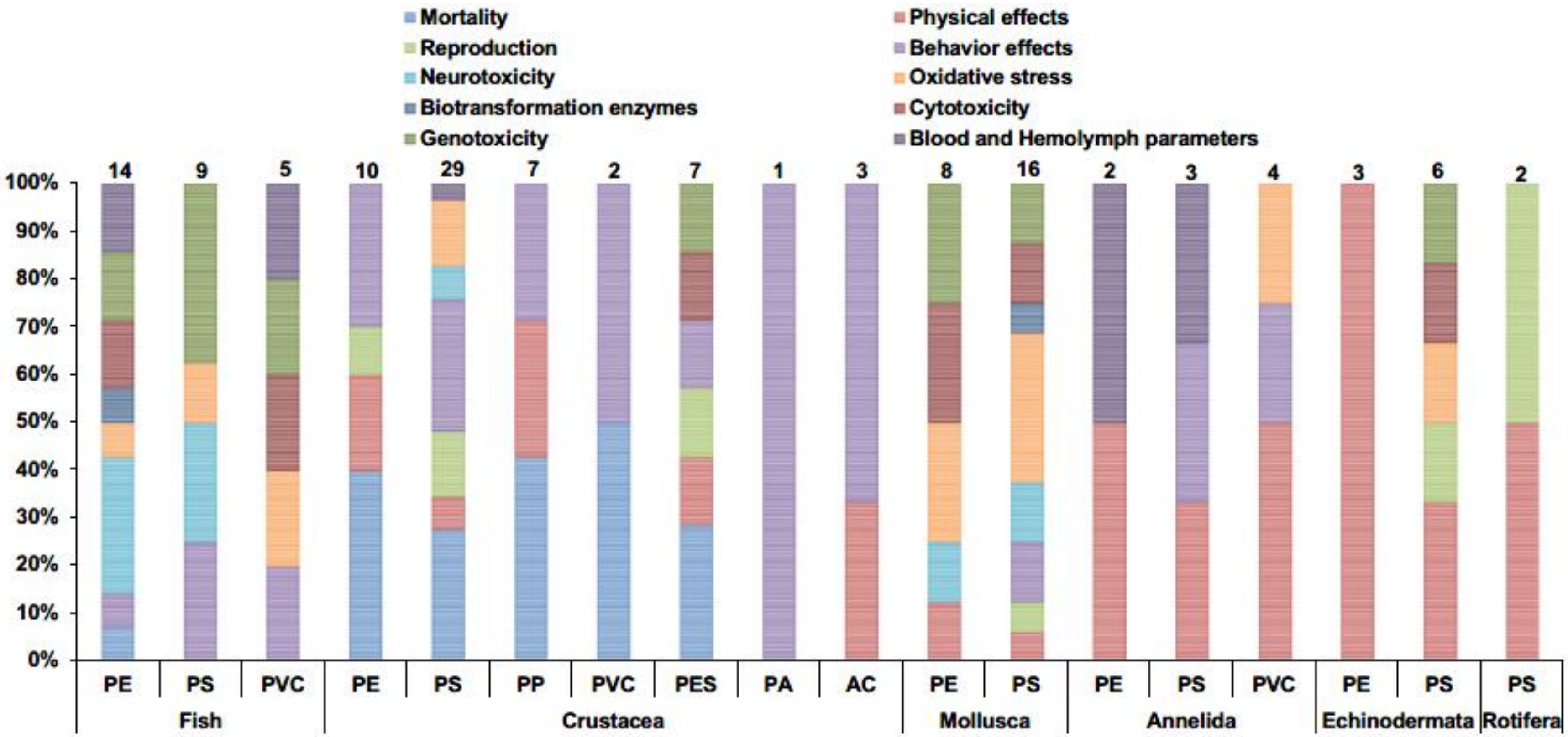


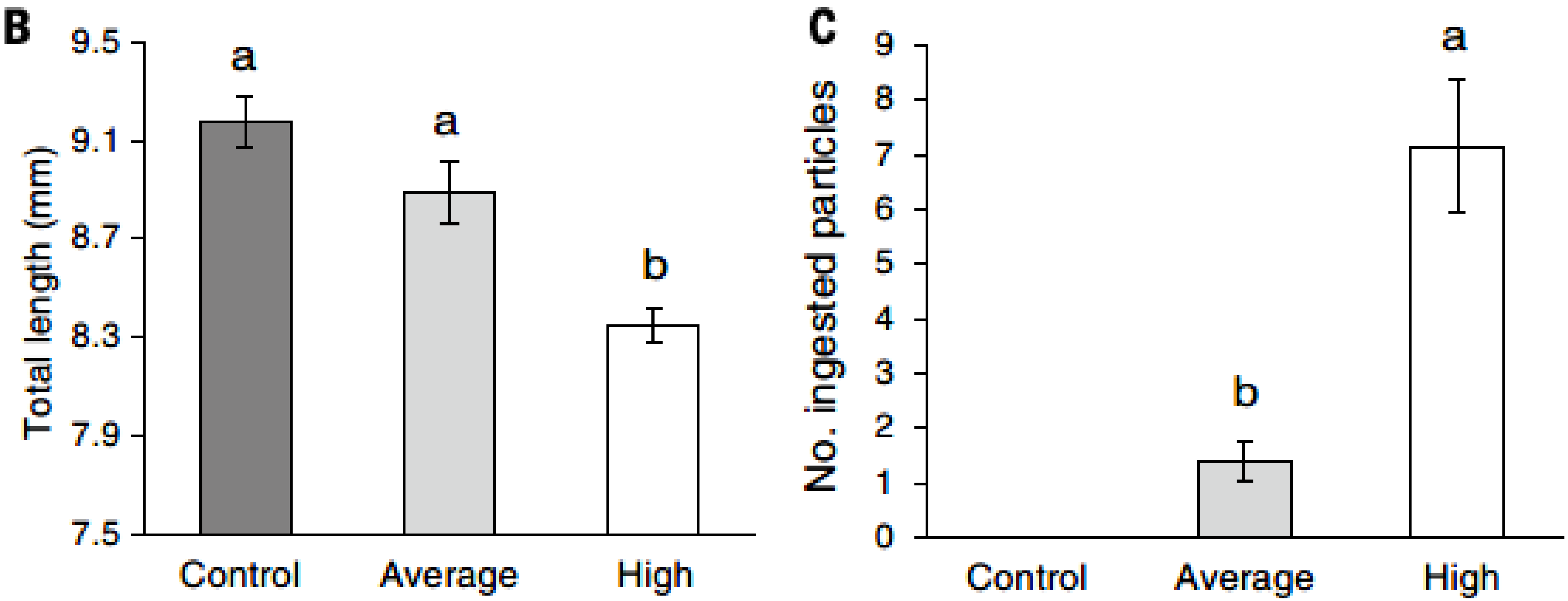
de Sa et al

Science of the Total Environment 645 (2018) 1029–1039

Physical effects well described for some fish species – particularly larval stages, icthyoplankton

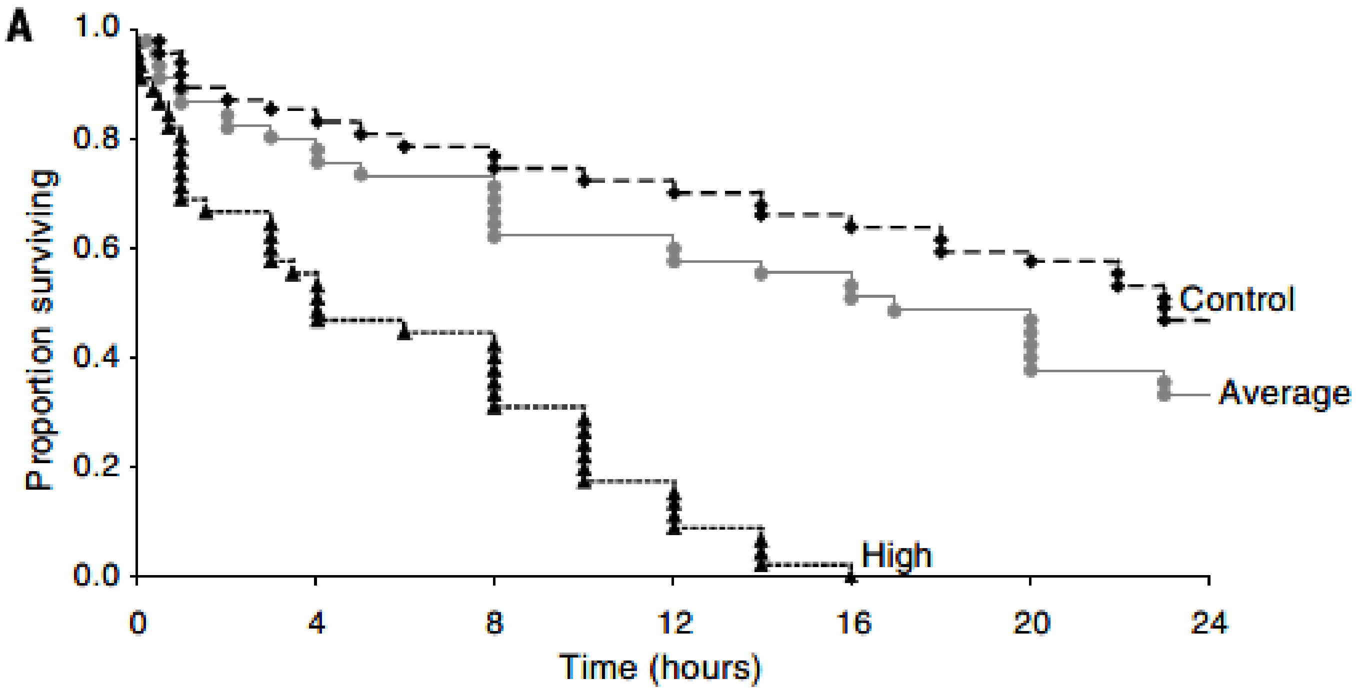
- Starvation due to MP blockages in gut
- Mobility effects – reduced predator avoidance
- Consumption of MPs over actual prey, reduction in feeding performance
- Apparent satiation from ingestion of MPs but lack of nutrition – poor growth, eventual death
- Intestinal perforations, ulcerations, and other mechanical injuries from sharp MP objects

European perch growth with polystyrene MP exposure



Lönnstedt* and Eklöv, 2016, Science: 352

Effects of polystyrene MP on European perch survival



Lönnstedt* and Eklöv, 2016, Science: 352

Behavioral effects

European perch activity and movement in response to polystyrene MP exposure

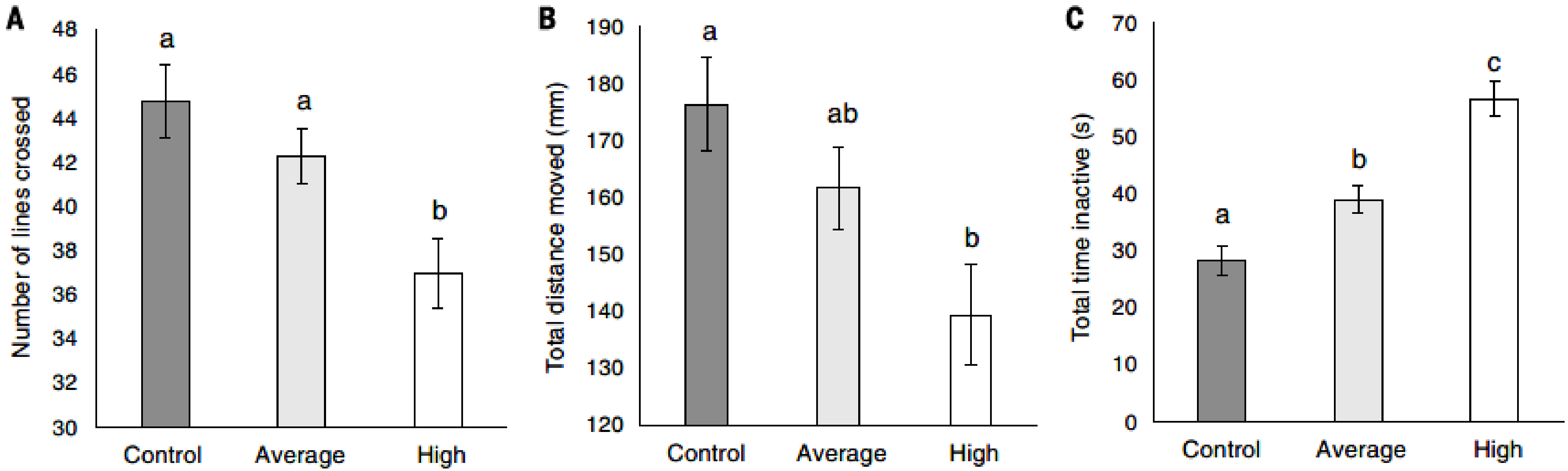
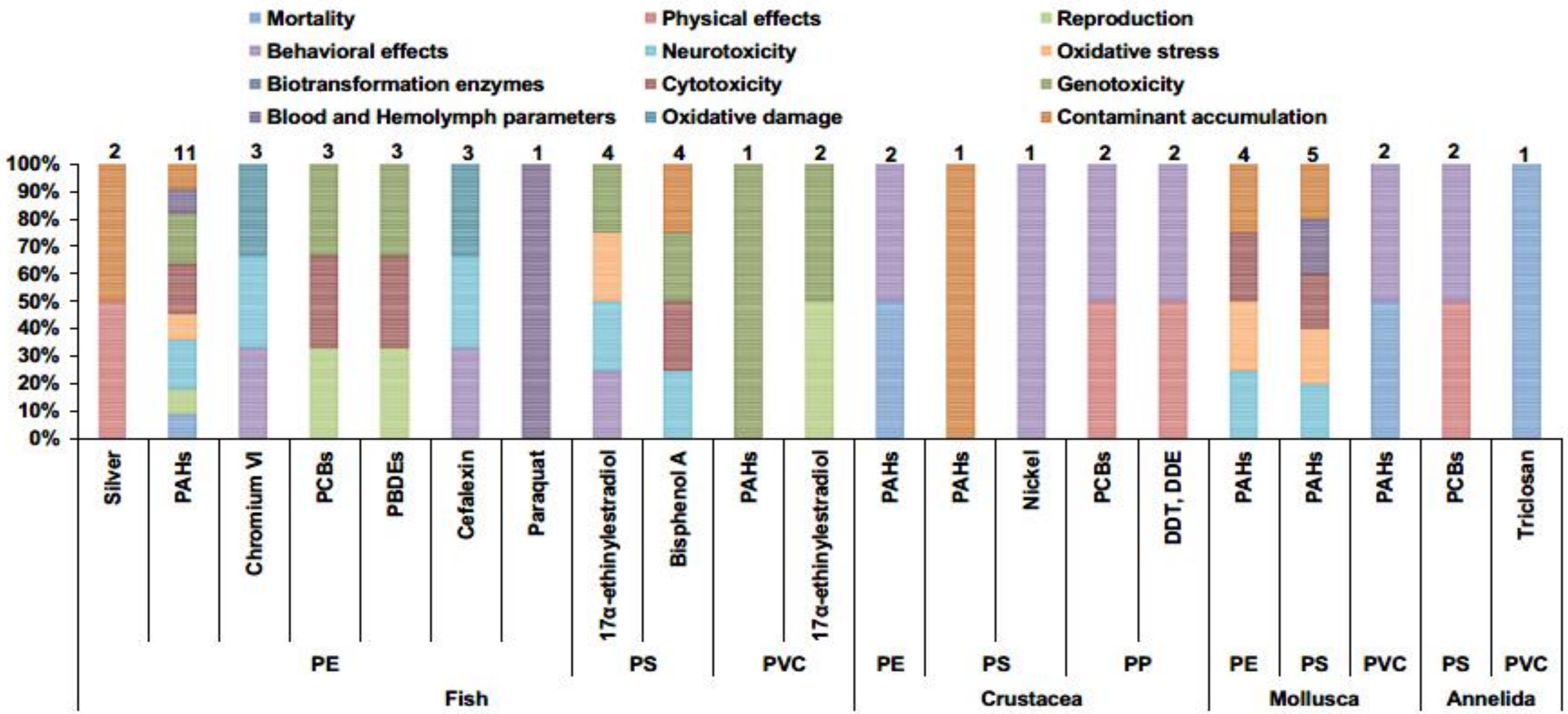


Fig. 1. Fish behavior when exposed to polystyrene microplastic particles. Mean (±SE) number of (**A**) lines crossed (a measure of activity), (**B**) total distance moved (mm), and (**C**) total time spent inactive (s) for 10-day-old *P. fluviatilis* were affected by microplastic concentration (control, average, or high).

Lönnstedt* and Eklöv, 2016, Science: 352

Toxicological effects of MPs?



Studies suggest effects of different MPs with adsorbed metals, PCBs, pharmaceuticals, pesticides, endocrine disrupting compounds;

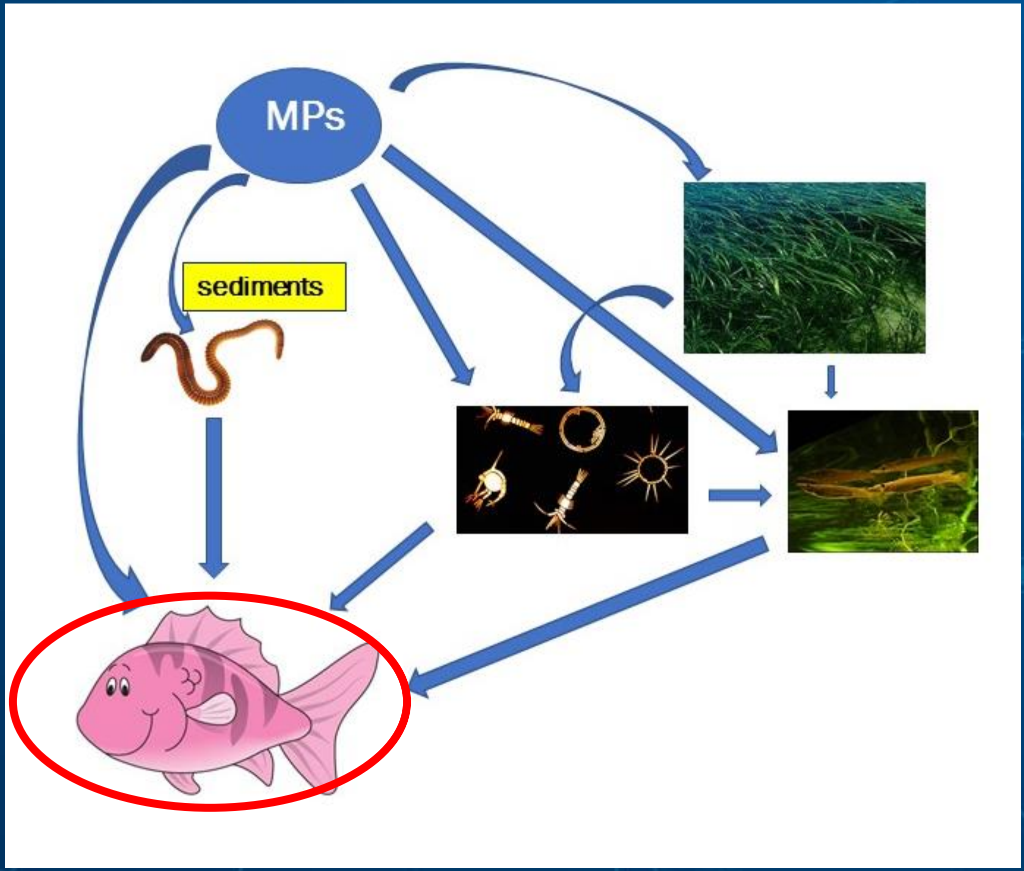
But jury still out

de Sa et al
Science of the Total Environment 645 (2018) 1029–1039

Risk Characterization: Integrating Exposure and Effects

Challenging to characterize risks without clear effects thresholds of MPs

May be more tractable if focus on effects of particular types and size range of MPs using controlled lab and field studies



Path forward using ERA framework

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- Set spatial/geographic boundaries for the ERA
  - Chesapeake Bay?
  - Potomac estuary?

- Identify assessment endpoints
  - Striped bass population characteristics?
  - Blue crab populations?
  - Oyster populations?
  - Others?

Path forward using ERA framework

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- Which measures of MP exposure and effect can be compiled and analyzed fairly readily based on existing monitoring information for desired assessment endpoints?

- How well do the data and measures reflect the assessment endpoint?

- What resources are needed (new studies, funding) to obtain desired measures of exposure and effect?

Critical Data Gaps and Uncertainties from an ERA Perspective

What are some of the critical questions/unknowns?

- What is the true exposure of aquatic organisms to MPs?
- Are the size fractions of MPs usually being sampled appropriate from an ecological exposure and effects view? What is the occurrence and potential effects of MPs smaller than 300 microns?
- Are adverse effects on aquatic biota possible at concentrations found in worst-case scenarios?
- Can metals and trace organic compounds adsorbed to MPs be a risk concern, given their concentrations in nature and chemical uptake rates?

From G.A. Burton WERF White Paper 2017

Challenges ahead

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- No standard methods exist for sampling and quantifying MPs, making it difficult to compare studies or reliably predict exposure, effects, hazards, or risks.
- Improved MP exposure models for effluent discharges and other sources into receiving waters are needed to predict whether MPs may be a stressor of concern.
- Measurement methods for MPs vary significantly and there is no universal protocol for sample preparation, which can make results difficult to compare.
- Much of the effects information for MPs stems from direct exposure studies; indirect effects due to trophic transfer have been less explored.
- Need more infromation relating organismal effects of MPs to population level consequences

Thank You!

Jerry.diamond@tetratech.com