The known and unknowns about the effects of plastic pollution on wildlife






Chelsea M. Rochman
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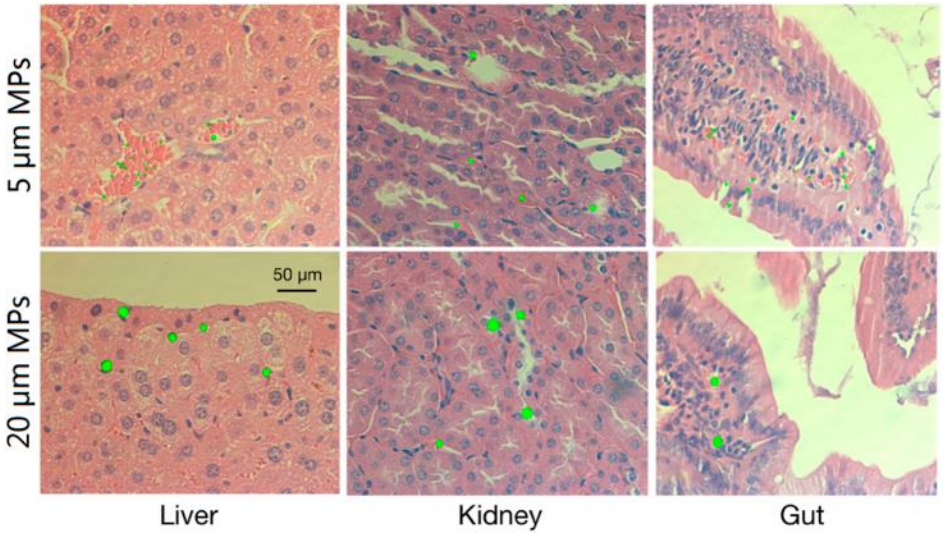
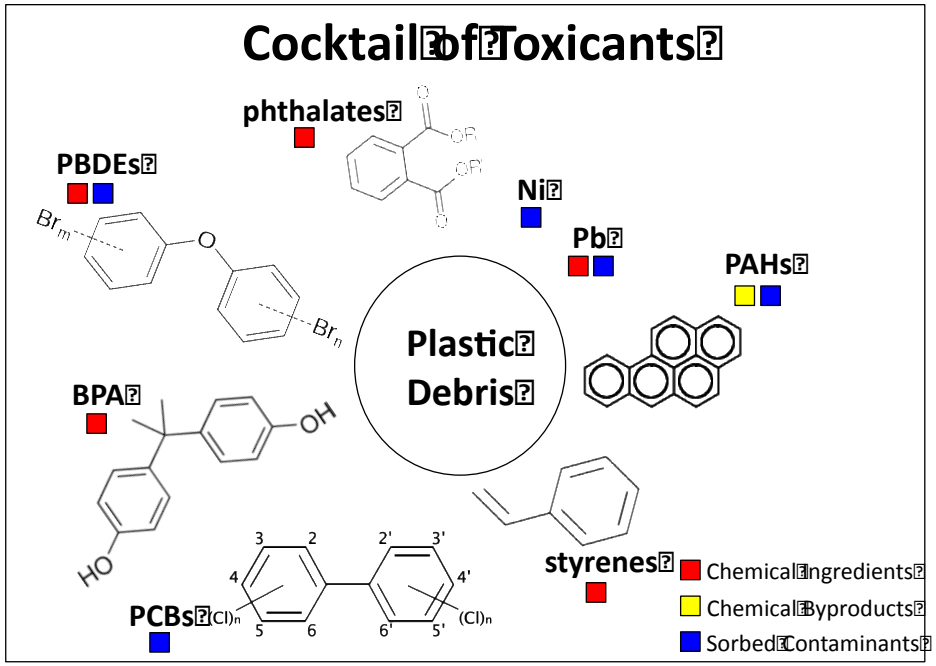
Effects can be physical



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

Effects can be chemical



Rochman 2015 Chapter in *Marine Anthropogenic Litter*

Bucci et al., *Unpublished work*

Contents lists available at ScienceDirect

Environmental Pollution

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

Impact of polyethylene microbeads on the floating freshwater plant duckweed *Lemna minor*☆

Gabriela Kalčíková [a,*], Andreja Žgajnar Gotvajn [a], Aleš Kladnik [b], Anita Jemec [b]

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Effects of microplastics on sessile invertebrates in the eastern coast of Thailand: An approach to coastal zone conservation

Gajahin Gamage Nadeeka Thushari[a,b], Jayan Duminda Mahesh Senevirathna[a], Amararatne Yakupitiyage[b], Suchana Chavanich[c,*]

Contents lists available at ScienceDirect

Fish & Shellfish Immunology

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

Full length article

Effects of dietary polyvinylchloride microparticles on general health, immune status and expression of several genes related to stress in gilthead seabream (*Sparus aurata* L.)

Cristóbal Espinosa, Alberto Cuesta, María Ángeles Esteban*

Contents lists available at ScienceDirect

Marine Pollution Bulletin

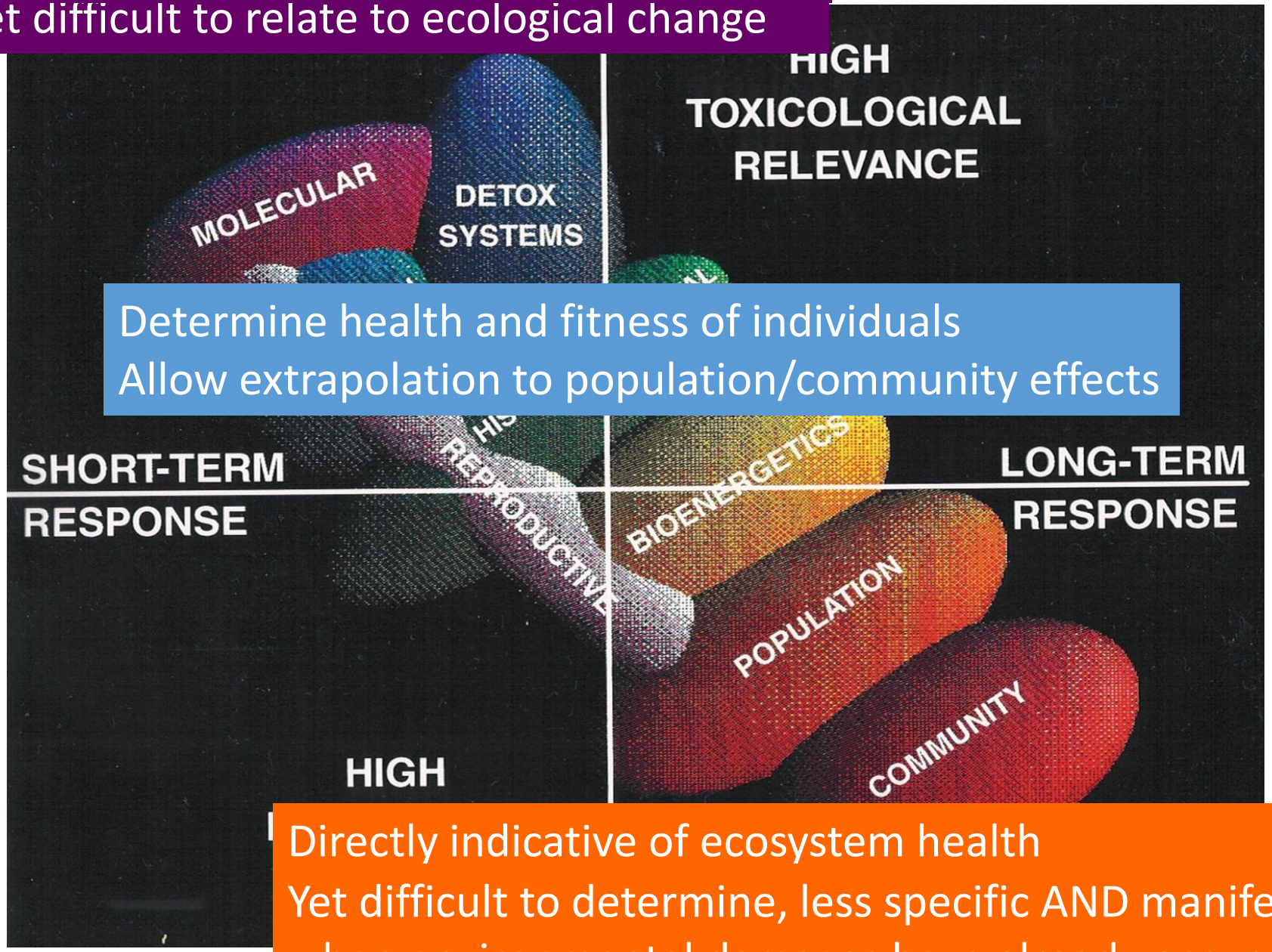
journal homepage: www.elsevier.com/locate/marpolbul

Note

Fatal ingestion of floating net debris by two sperm whales (*Physeter macrocephalus*)

Jeff K. Jacobsen [a,*], Liam Massey [b], Frances Gulland [c]

Specific, sensitive, and reproducible
Yet difficult to relate to ecological change

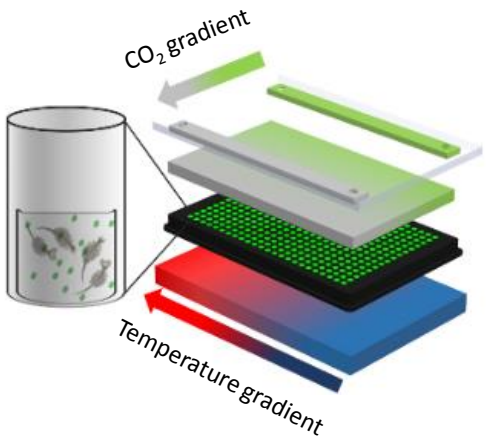


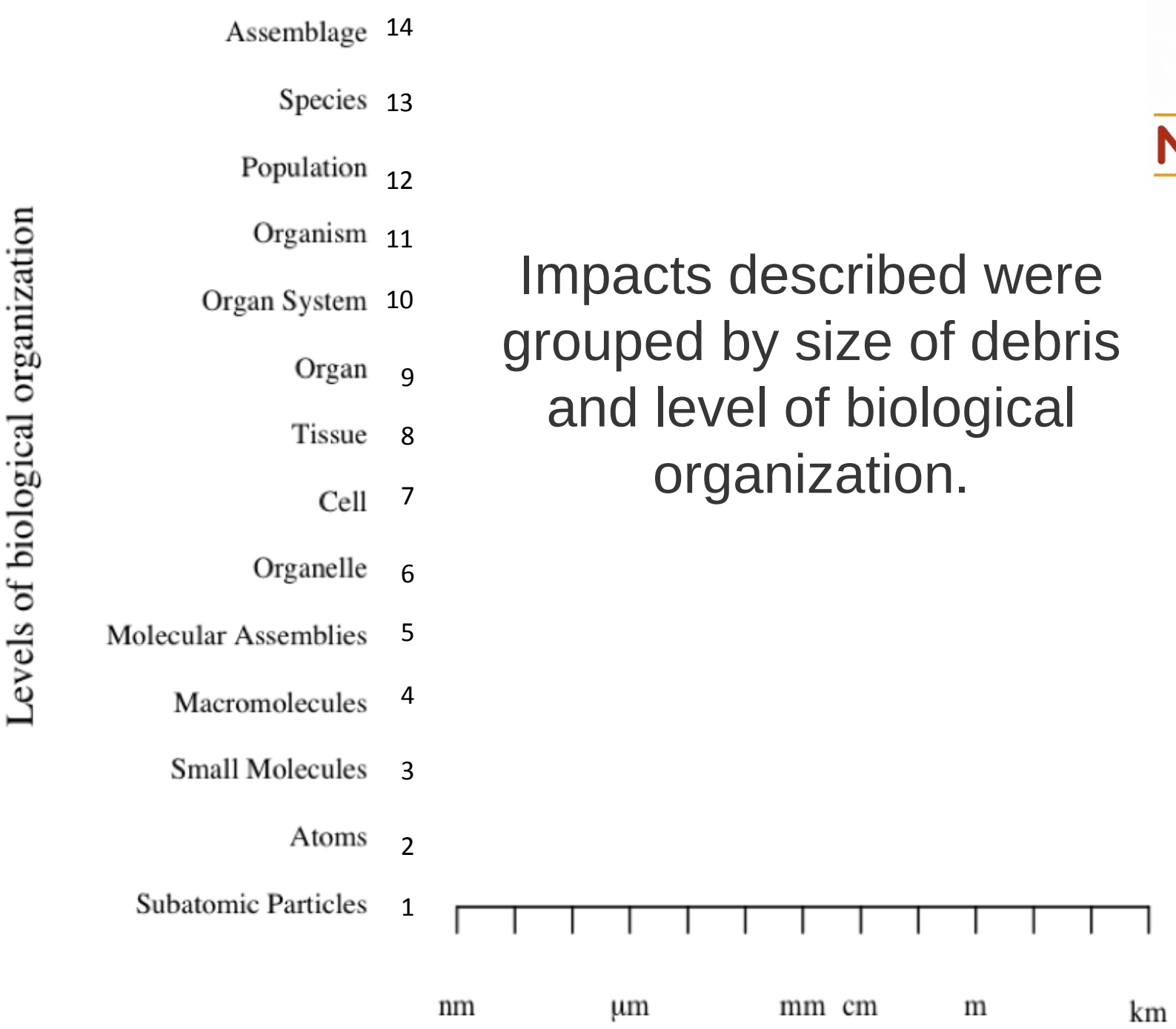
Determine health and fitness of individuals
Allow extrapolation to population/community effects

Directly indicative of ecosystem health
Yet difficult to determine, less specific AND manifest when environmental damages have already occurred

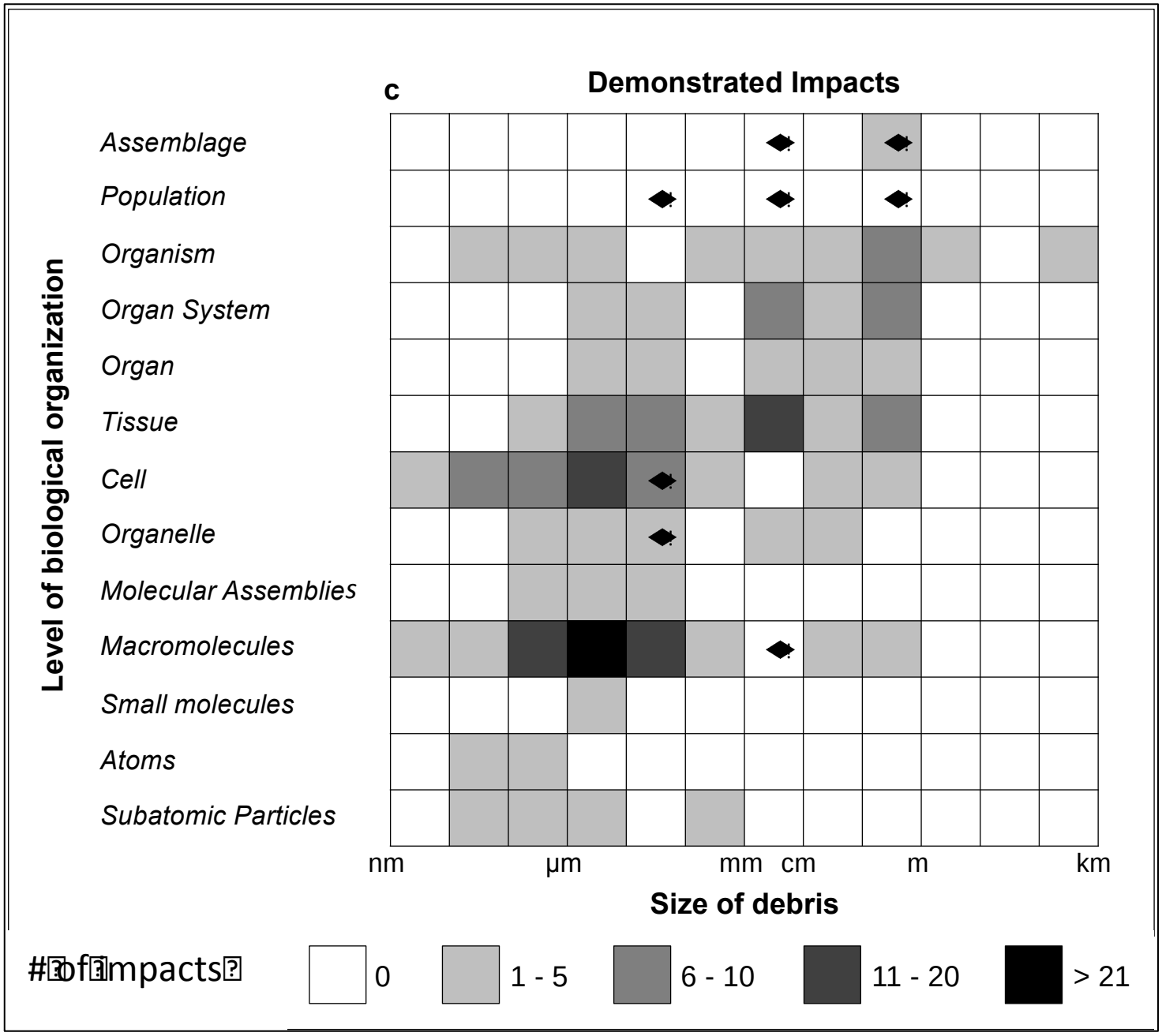
Adams et al. 1989

Multiple Scales

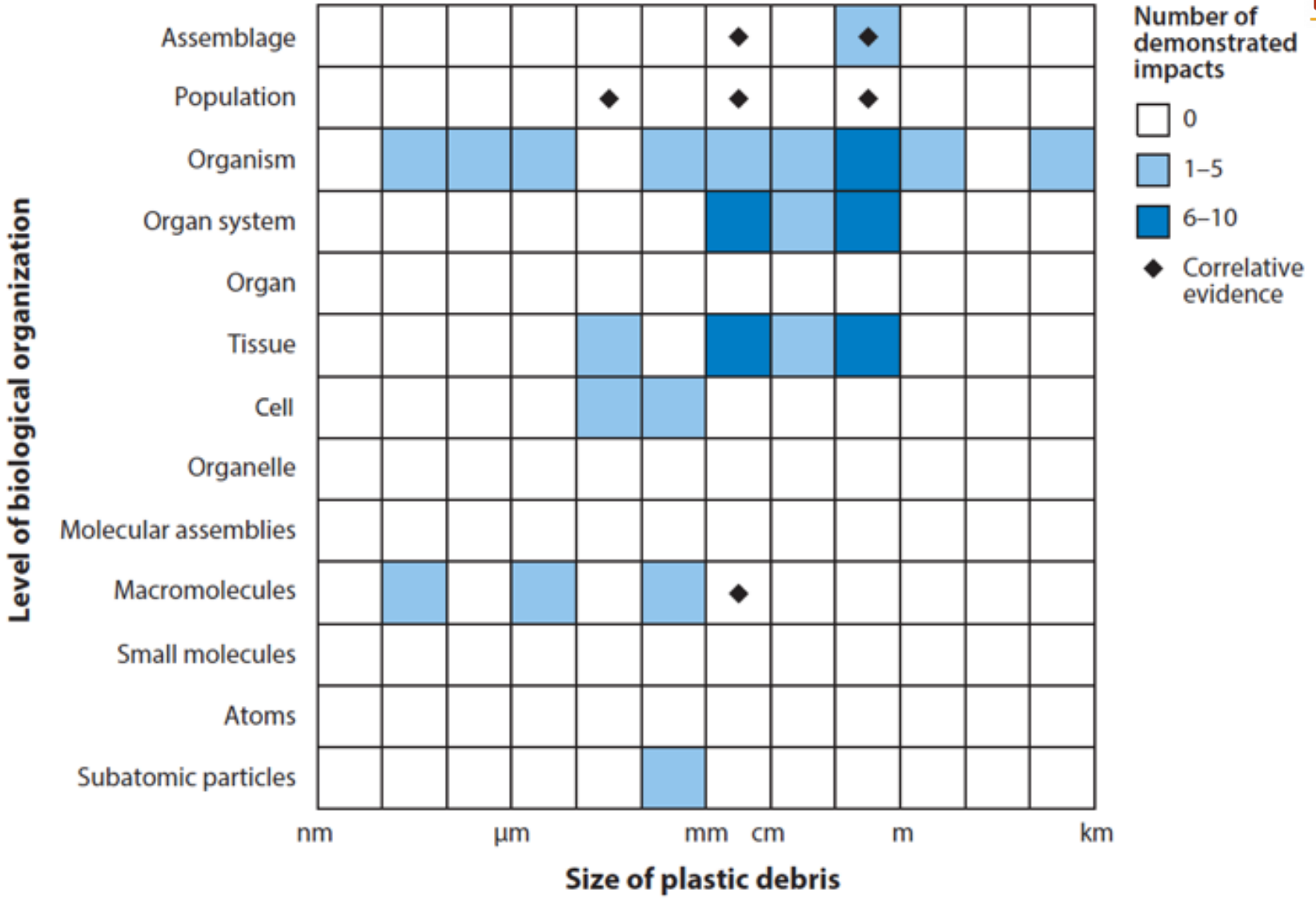




Impacts described were grouped by size of debris and level of biological organization.



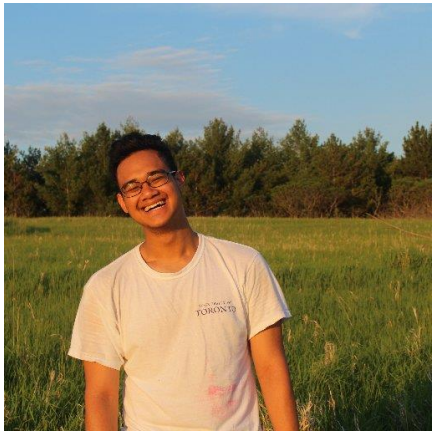
Rochman et al., 2016 *Ecology*



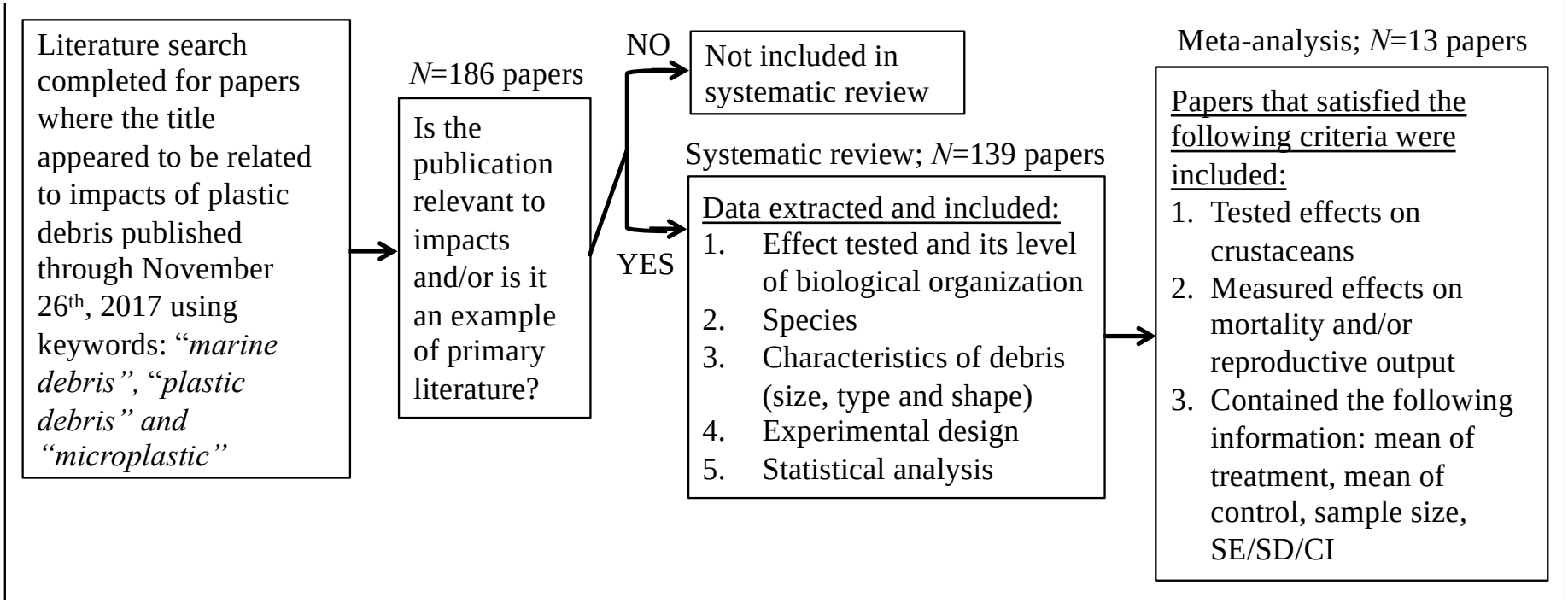
Law, *Ann. Rev. Mar. Sci.* 2017,
adapted from Rochman et al. *Ecology* 2016

Update with the literature through November 26th, 2017

Kennedy Bucci

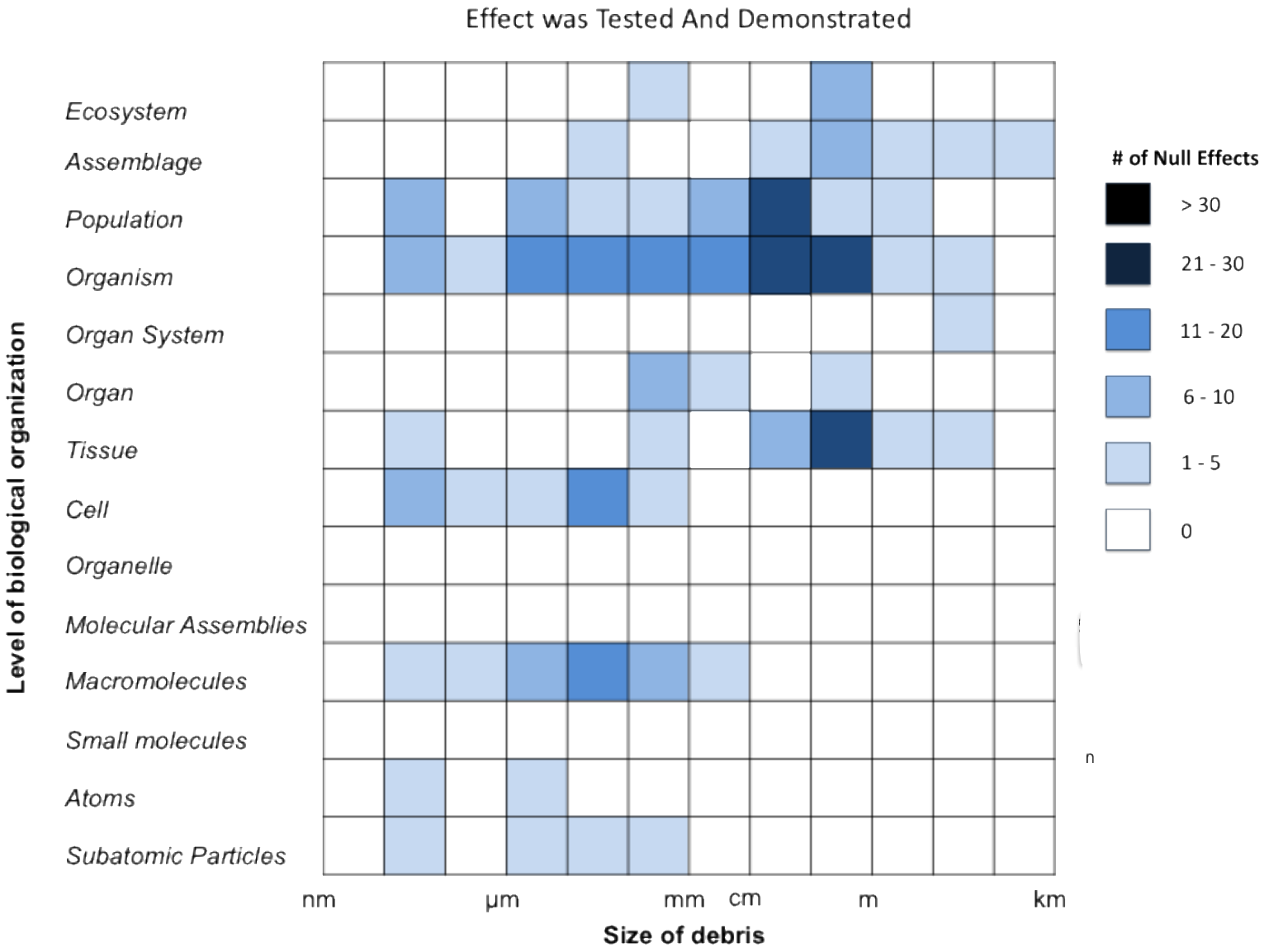


Matthew Tulio



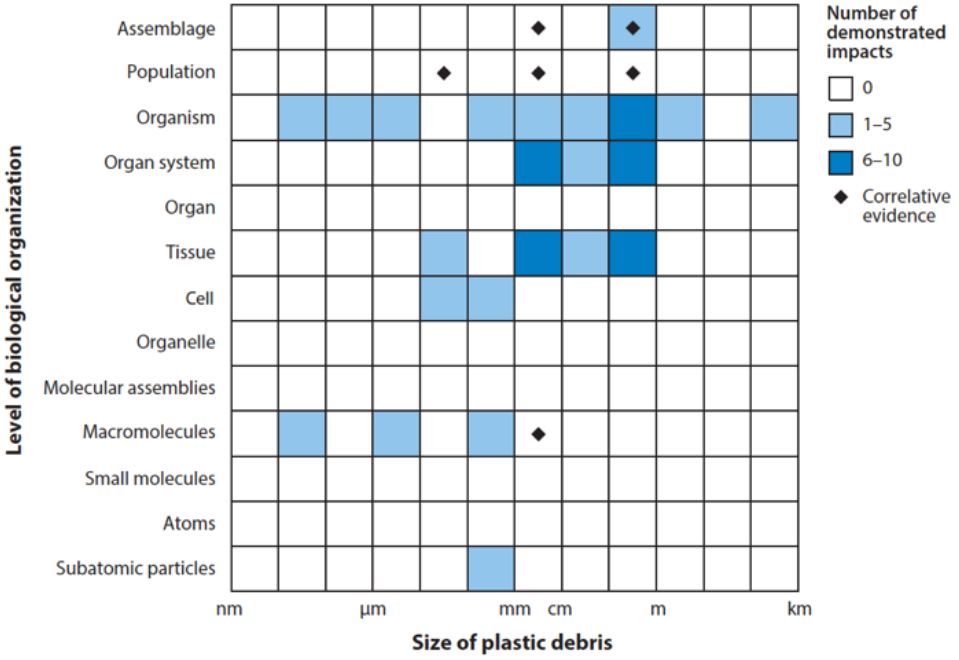
Bucci, Tulio & Rochman, et al. in review *Ecological Applications*

The Evidence Demonstrating Impacts to aquatic biota is Growing

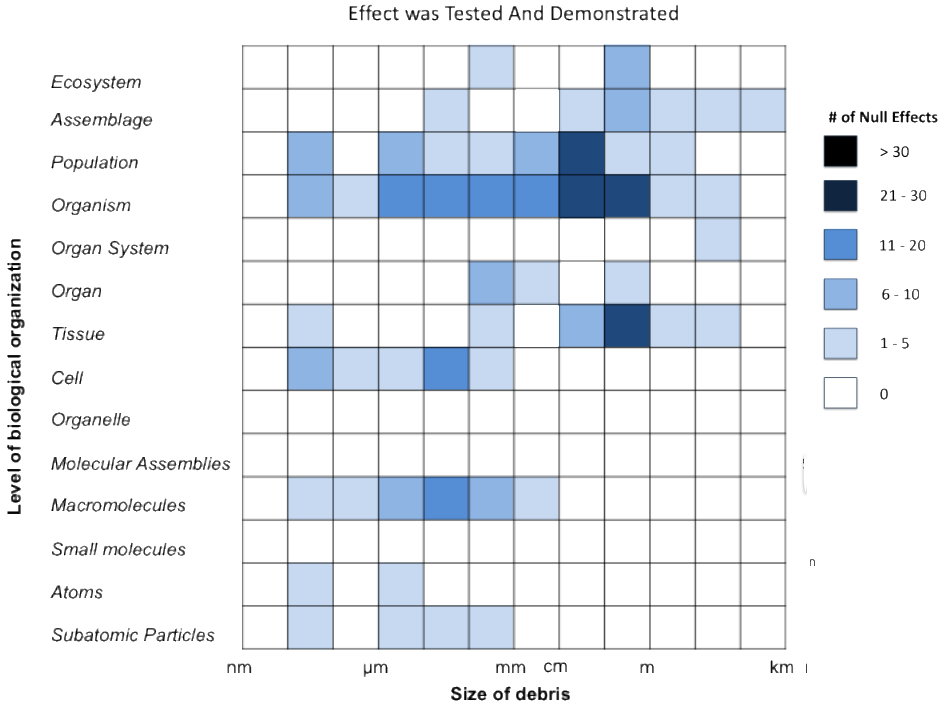


Bucci, Tulio & Rochman, et al. in review *Ecological Applications*

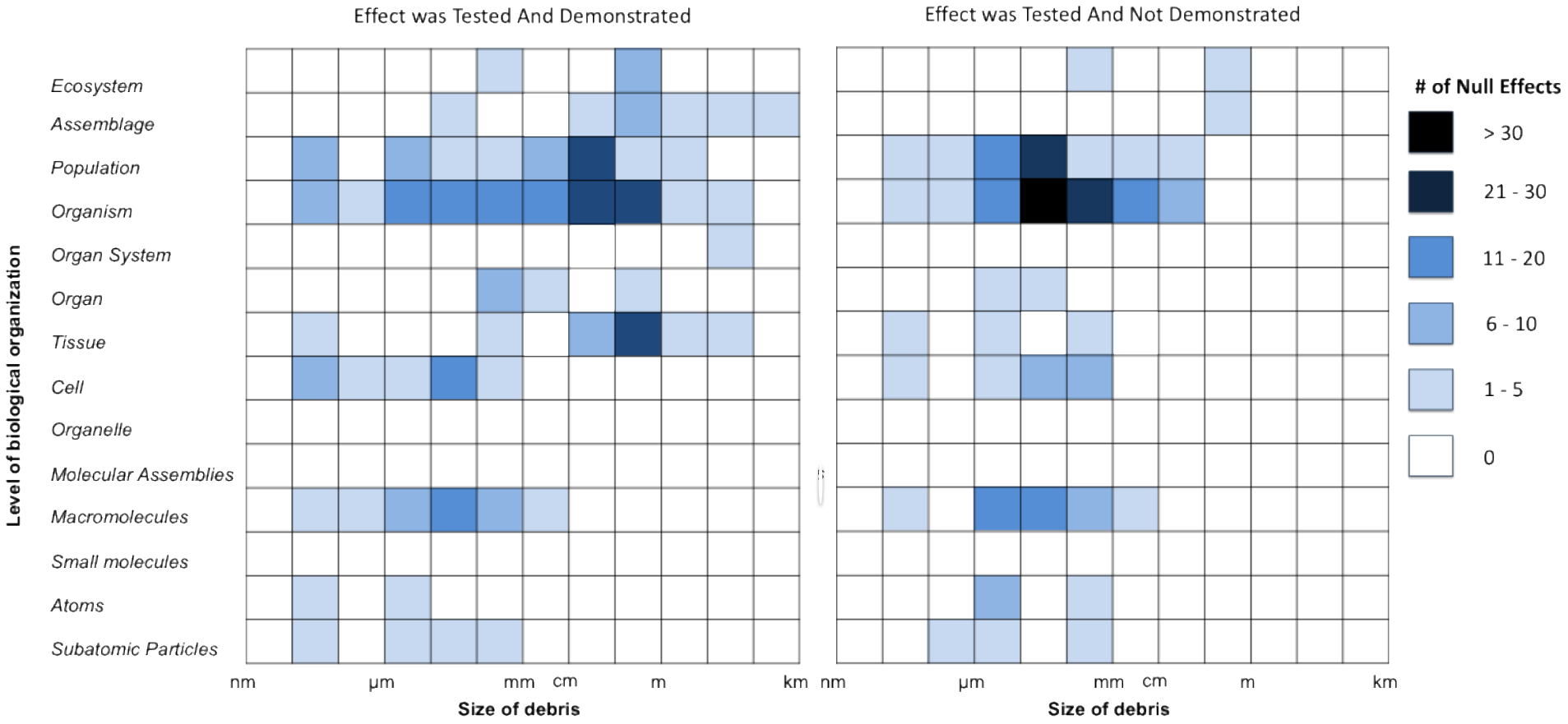
Through 2013



Through 2017



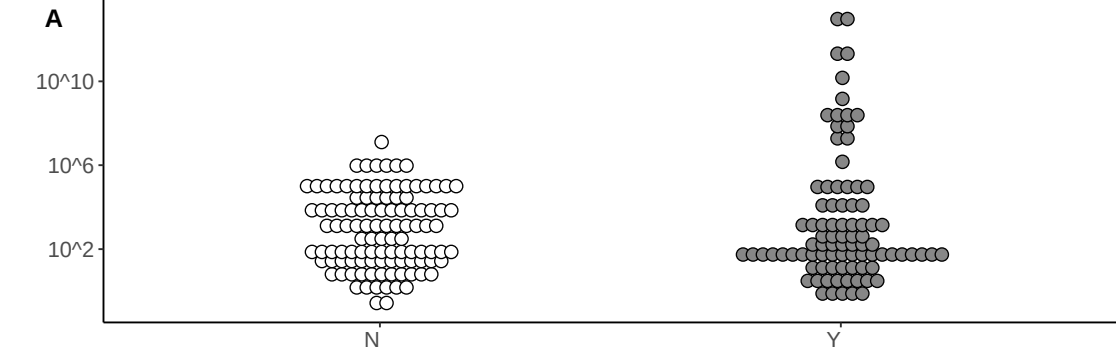
Effect Detected vs Not Detected



Bucci, Tulio & Rochman, et al. in review *Ecological Applications*

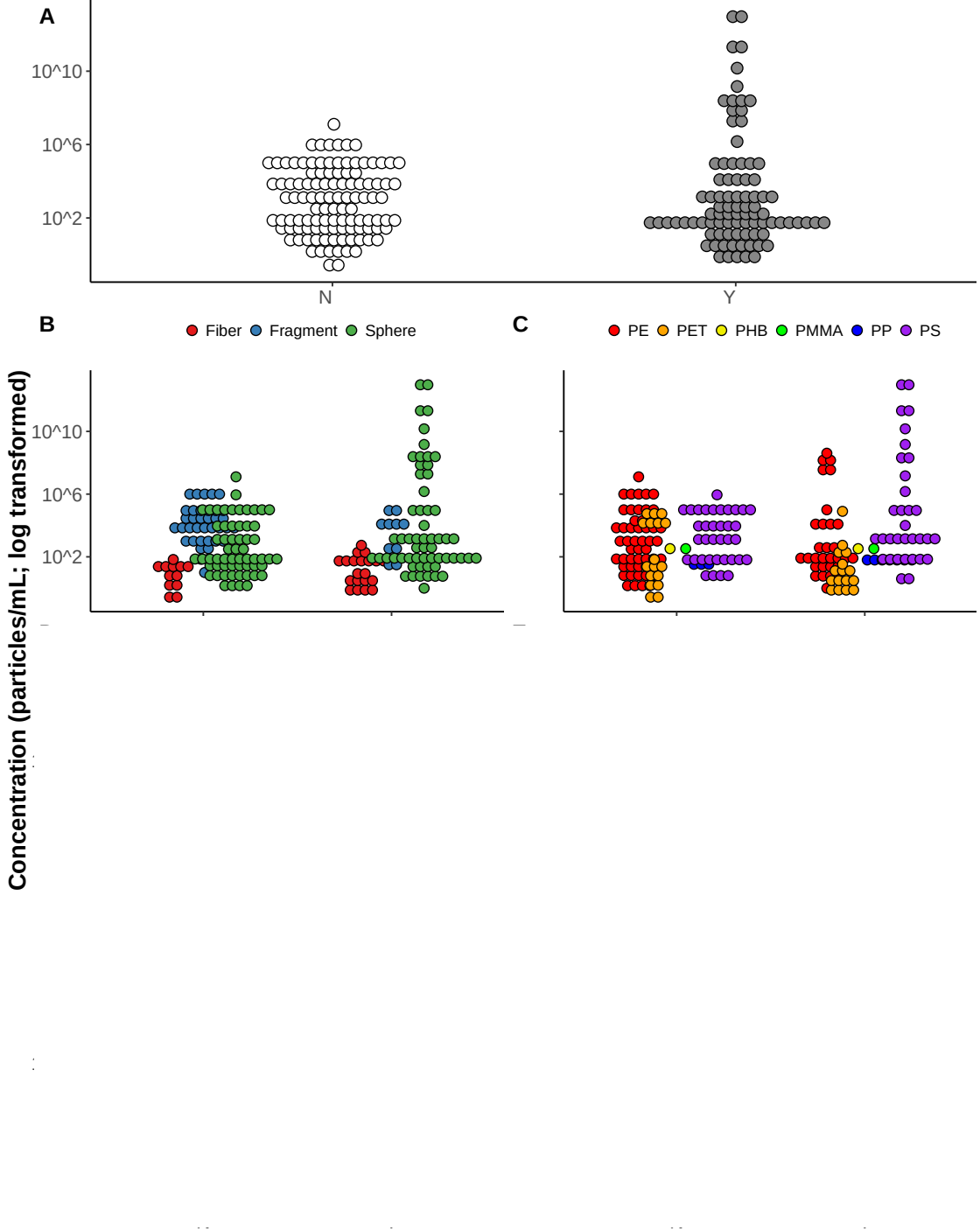
What makes an effect detected vs not detected?

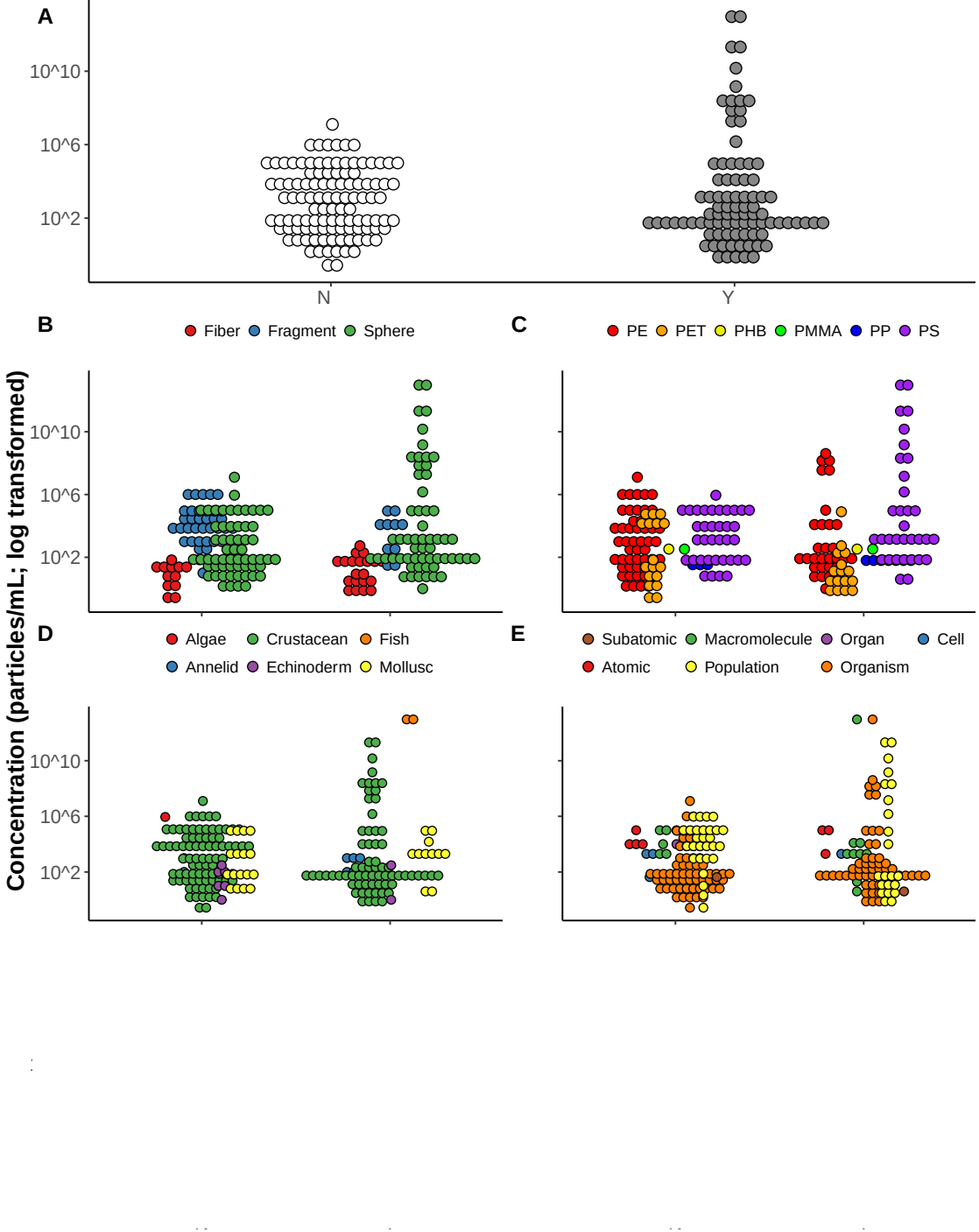
- dose
- shape of microplastic
- type of microplastic
- taxa
- size of microplastic
- experimental design

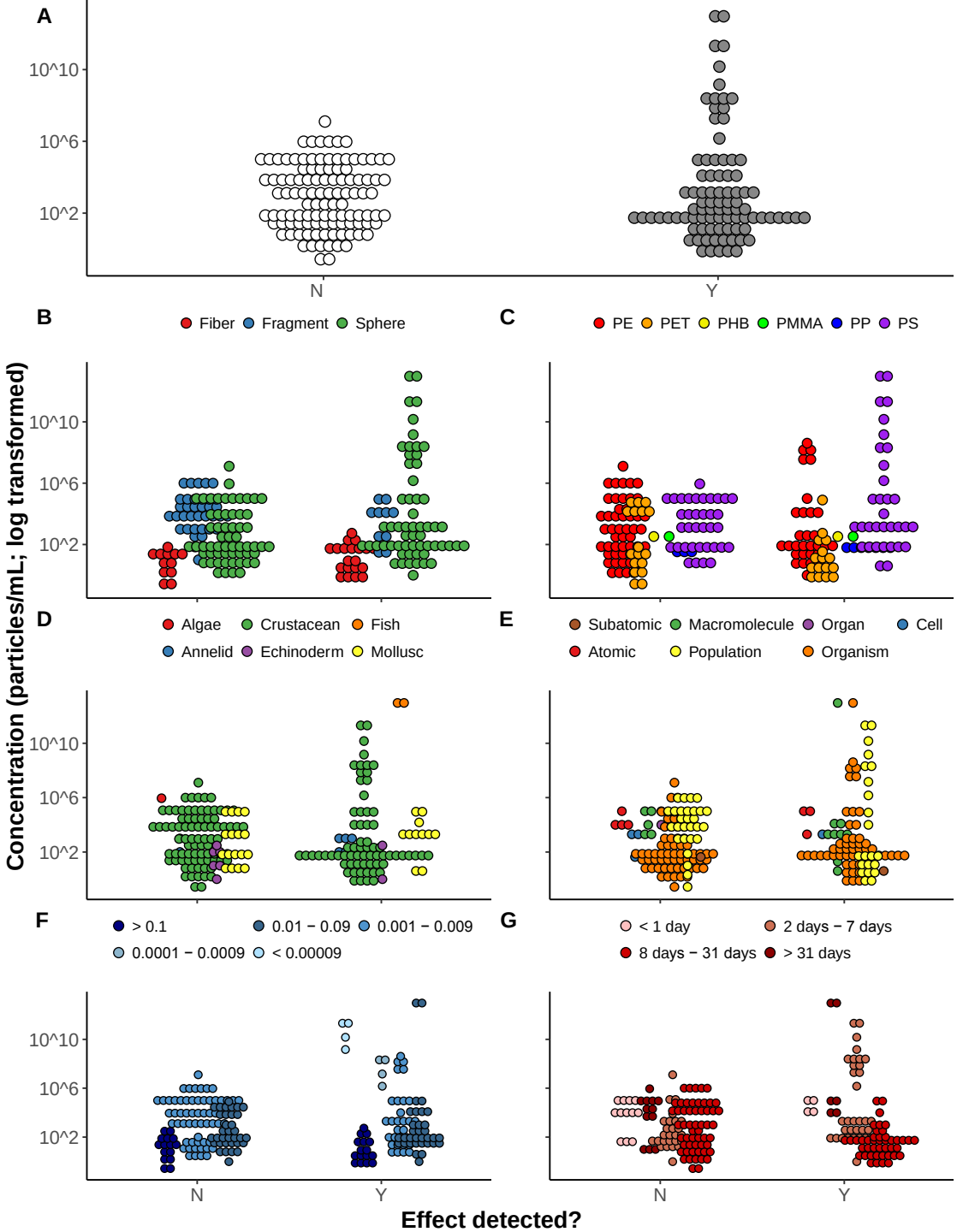


Concentration (particles/mL; log transformed)

Effect detected?

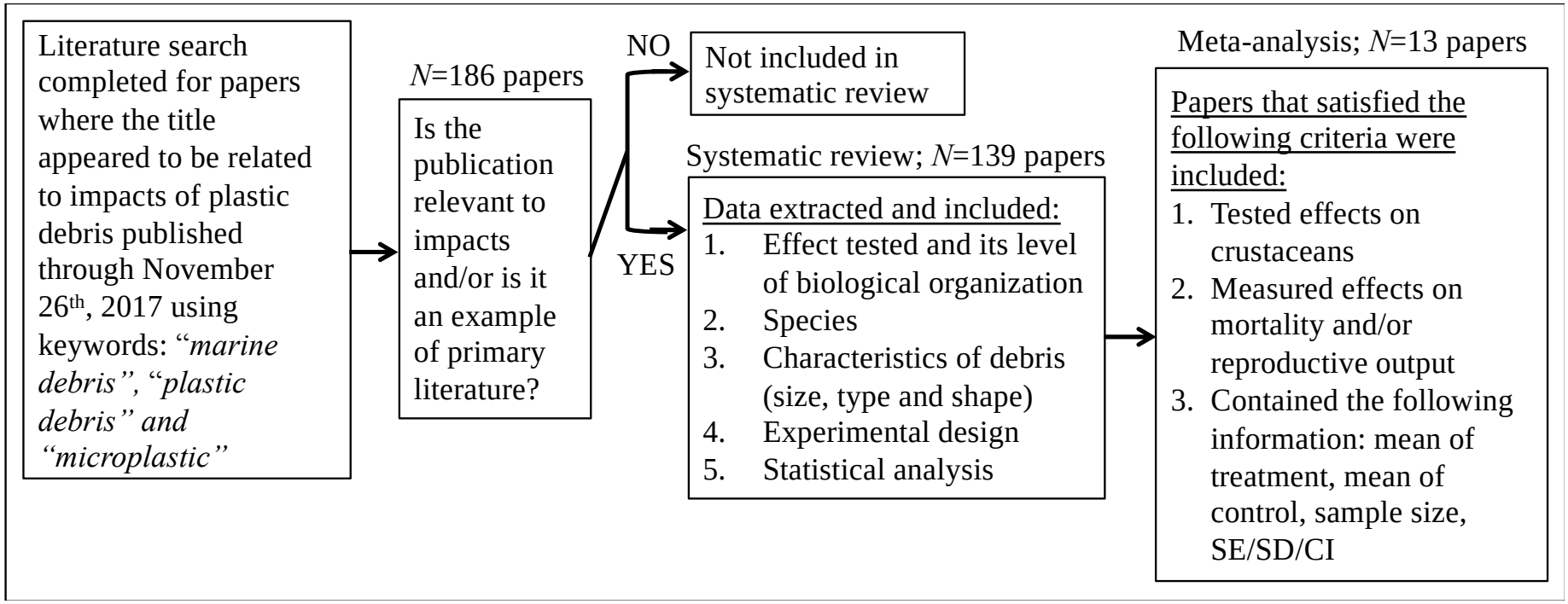

A
10^10
10^6
10^2
N
Y
B
Fiber
Fragment
Sphere
C
PE
PET
PHB
PMMA
PP
PS
Concentration (particles/mL; log transformed)
Effect detected?


A
10^10
10^6
10^2
N
Y
B
Fiber
Fragment
Sphere
C
PE
PET
PHB
PMMA
PP
PS
Concentration (particles/mL; log transformed)
D
Algae
Crustacean
Fish
Annelid
Echinoderm
Mollusc
E
Subatomic
Macromolecule
Organ
Cell
Atomic
Population
Organism
Effect detected?

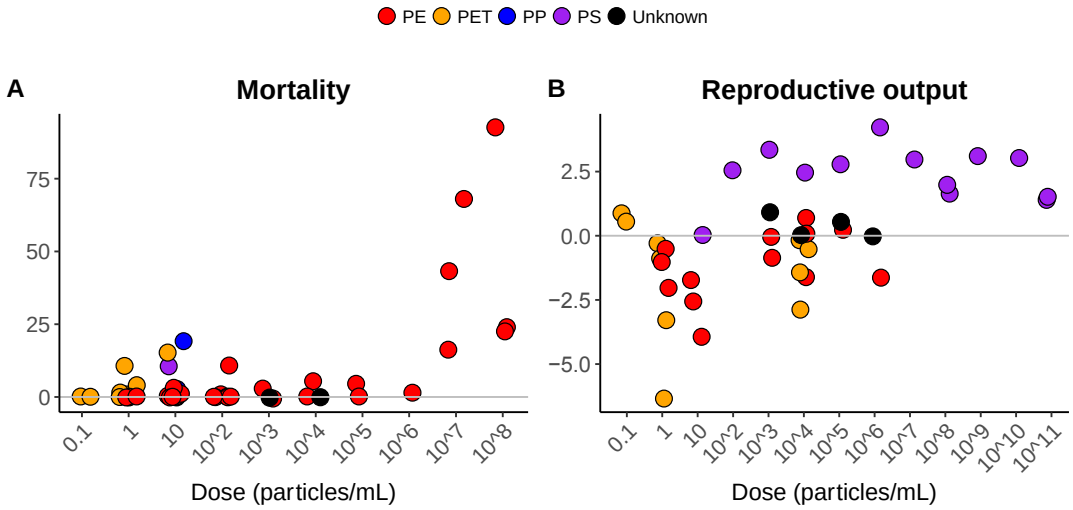

A
10^10
10^6
10^2
N
Y
B
Fiber
Fragment
Sphere
C
PE
PET
PHB
PMMA
PP
PS
Concentration (particles/mL; log transformed)
D
Algae
Crustacean
Fish
Annelid
Echinoderm
Mollusc
E
Subatomic
Macromolecule
Organ
Cell
Atomic
Population
Organism
F
> 0.1
0.01 − 0.09
0.001 − 0.009
0.0001 − 0.0009
< 0.00009
G
< 1 day
2 days − 7 days
8 days − 31 days
> 31 days
Effect detected?

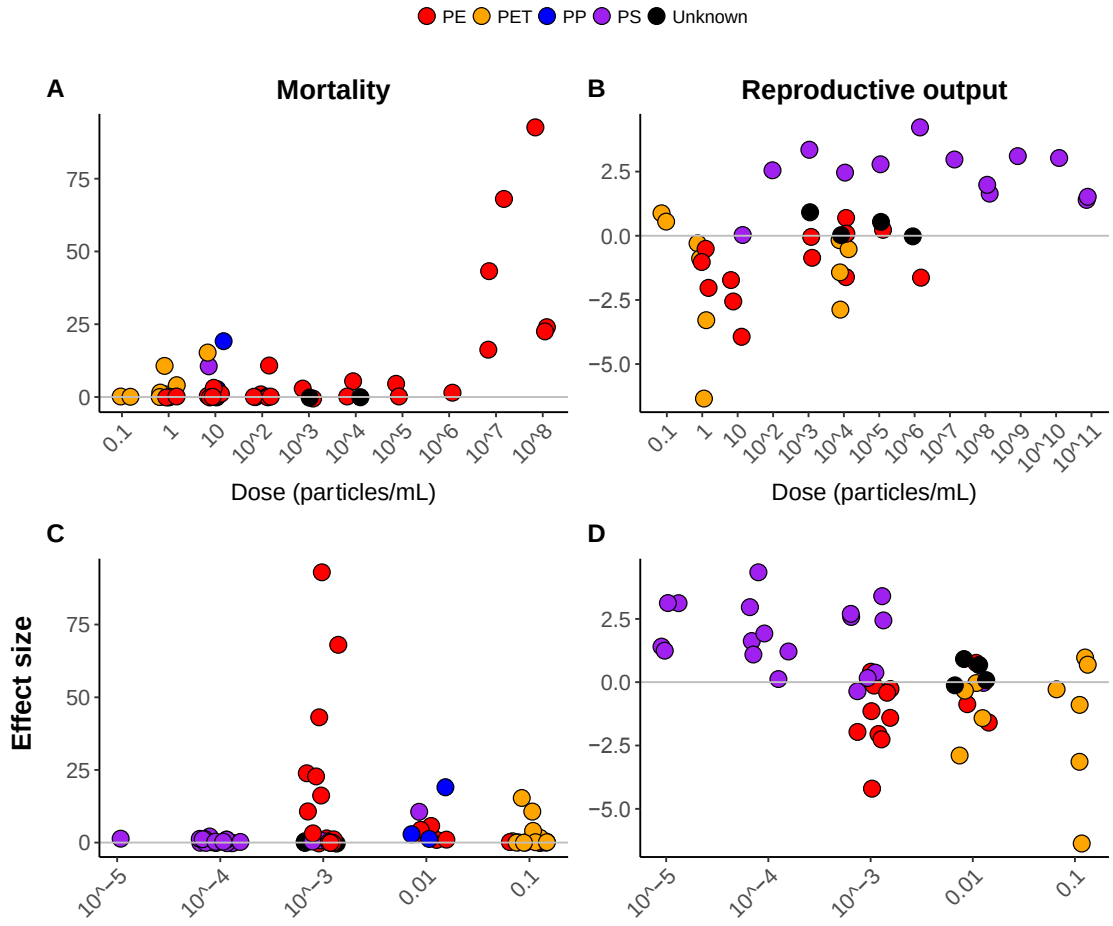
Meta-anlaysis:

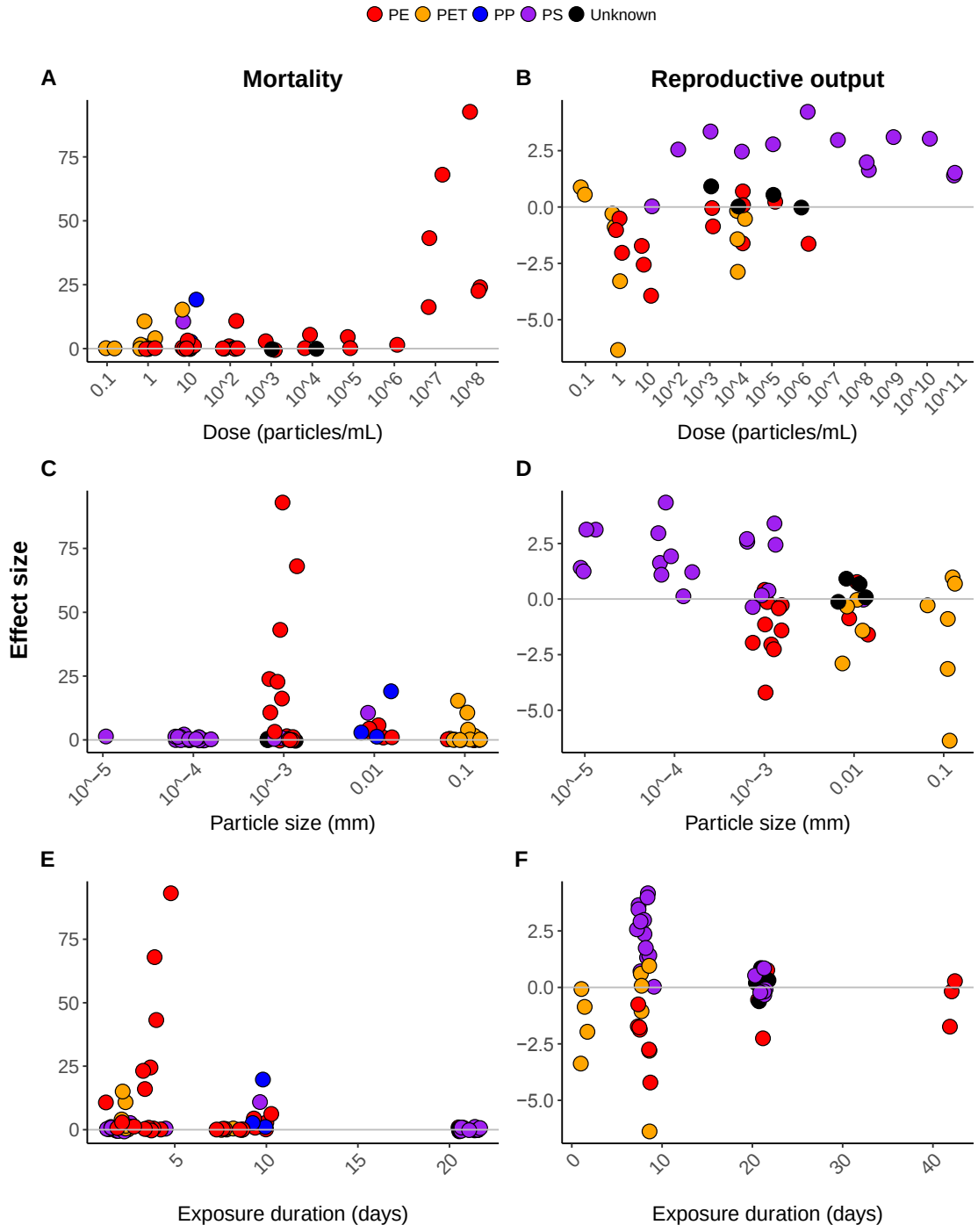
- specific to one taxa
- about one effect
- had to have at least three studies.



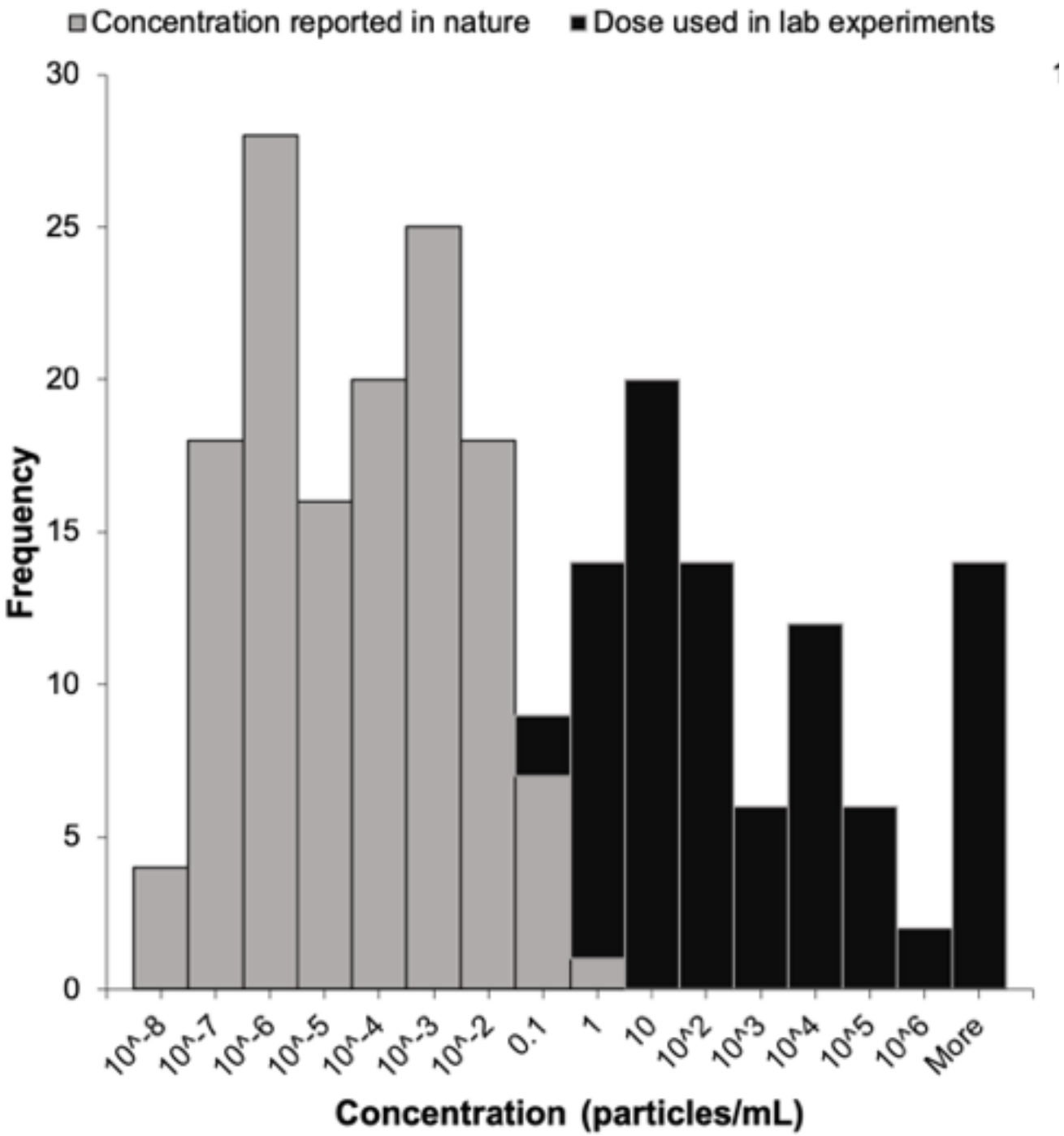
$$g = \frac{Mean_T - Mean_C}{\sqrt{\frac{(n_T - 1) * SD_T^2 + (n_C - 1) * SD_C^2}{n_T + n_C - 2}}} * \left(1 - \frac{3}{4 * (n_T + n_C - 9)}\right)$$

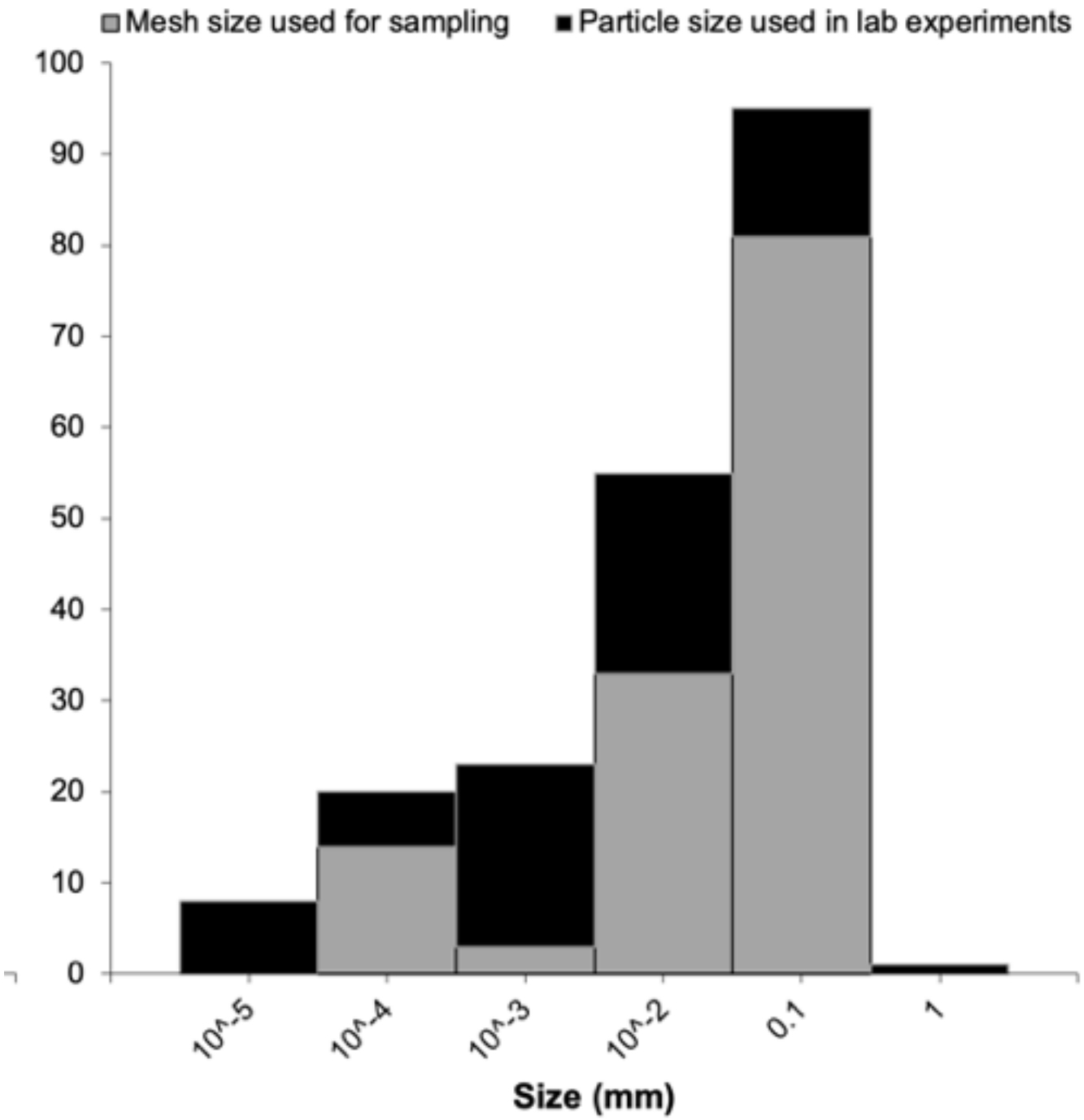

PE
PET
PP
PS
Unknown
A
Mortality
75
50
25
0
0.1
1
10
10^2
10^3
10^4
10^5
10^6
10^7
10^8
Dose (particles/mL)
B
Reproductive output
2.5
0.0
−2.5
−5.0
0.1
1
10
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9
10^10
10^11
Dose (particles/mL)

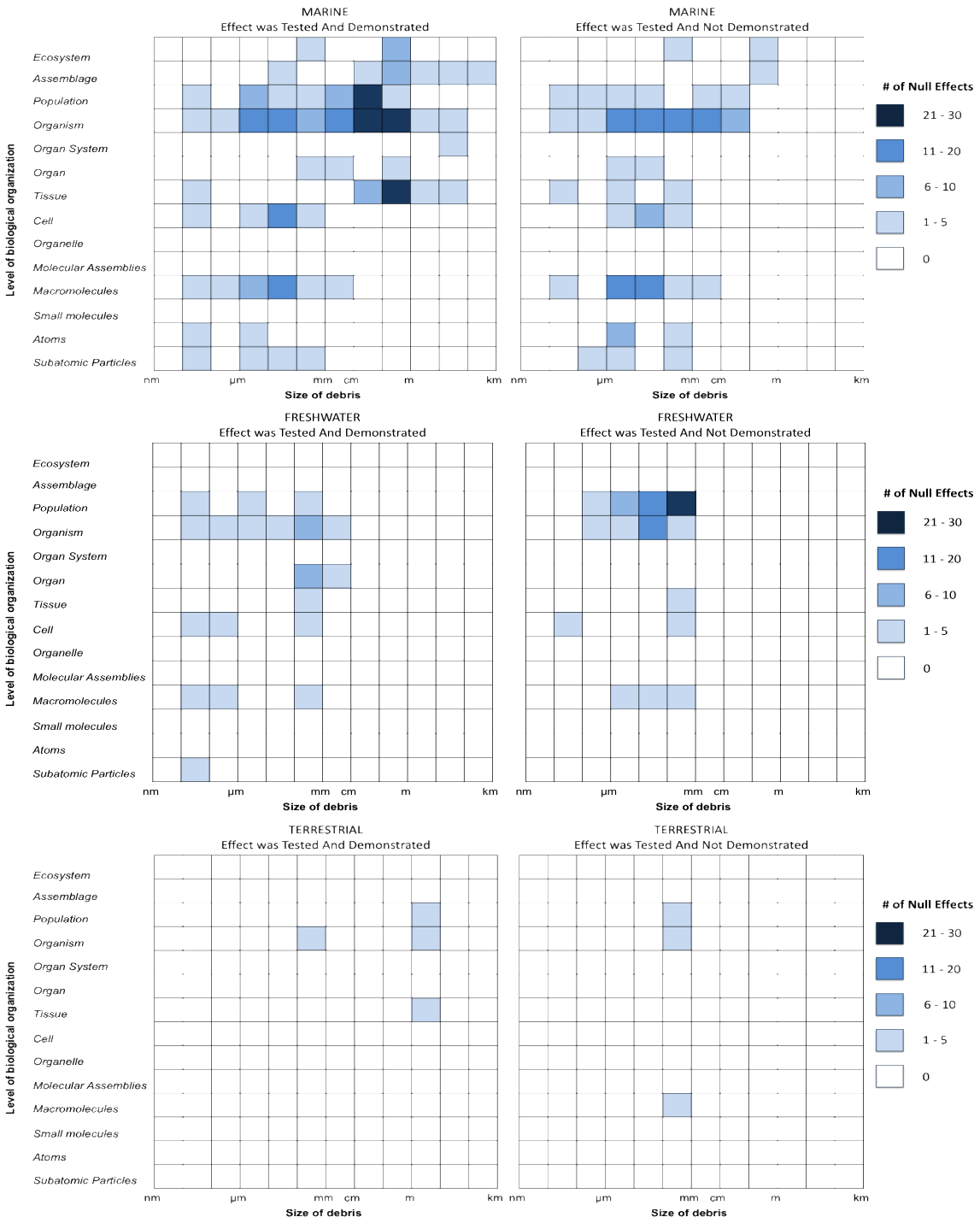

PE
PET
PP
PS
Unknown
A
Mortality
B
Reproductive output
Dose (particles/mL)
Dose (particles/mL)
C
D
Effect size


PE
PET
PP
PS
Unknown
A
Mortality
B
Reproductive output
Effect size
Dose (particles/mL)
Dose (particles/mL)
C
D
Particle size (mm)
Particle size (mm)
E
F
Exposure duration (days)
Exposure duration (days)

The known and unknowns about the effects of plastic pollution on wildlife


Concentration reported in nature
Dose used in lab experiments
Frequency
30
25
20
15
10
5
0
10^-8
10^-7
10^-6
10^-5
10^-4
10^-3
10^-2
0.1
1
10
10^2
10^3
10^4
10^5
10^6
More
Concentration (particles/mL)


Mesh size used for sampling
Particle size used in lab experiments
100
90
80
70
60
50
40
30
20
10
0
10^-5
10^-4
10^-3
10^-2
0.1
1
Size (mm)

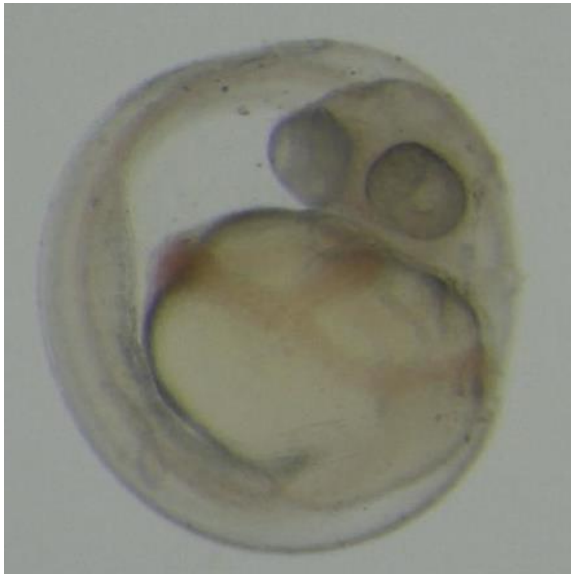
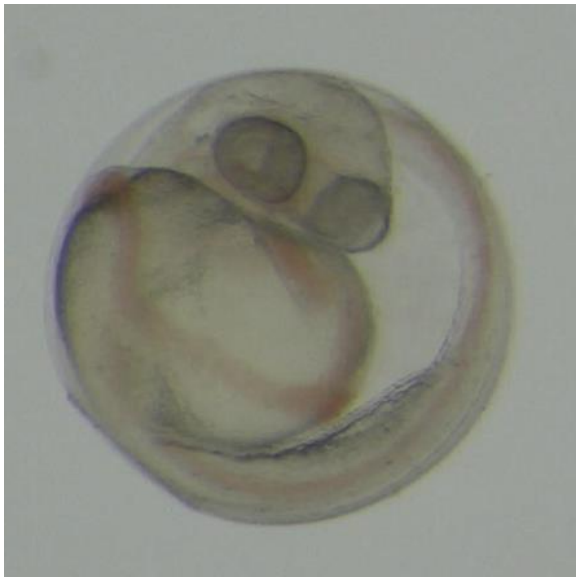

MARINE
Effect was Tested And Demonstrated
MARINE
Effect was Tested And Not Demonstrated
FRESHWATER
Effect was Tested And Demonstrated
FRESHWATER
Effect was Tested And Not Demonstrated
TERRESTRIAL
Effect was Tested And Demonstrated
TERRESTRIAL
Effect was Tested And Not Demonstrated
Level of biological organization
Ecosystem
Assemblage
Population
Organism
Organ System
Organ
Tissue
Cell
Organelle
Molecular Assemblies
Macromolecules
Small molecules
Atoms
Subatomic Particles
nm
µm
mm
cm
m
km
Size of debris
# of Null Effects
21 - 30
11 - 20
6 - 10
1 - 5
0

Study	Organism	Effect	Plastic Type	Size	Length of Exposure	Shape	LC50 Concentration
Ogonowski et al., 2016	*Daphnia Magna*	Death	Unknown (from Cospheric)	4 µm	14 d	Sphere	1 M particles/mL
Au et al., 2015	*Hyalella azteca*	Death	PP	20-74µm	10 d	Fiber	46,400 particles/mL
	Hyalella azteca	Death	PE	10-27µm	10 d	Fragment	71.43 particle/mL
Frydkejar et al., 2017	*Daphnia magna*	Immobilization	PE	10-75µm	48 h	Fragment	65 mg/L
Ziajahromi et al., 2017	*Ceriodaphnia dubia*	Death	PE	1-4µm	48 h	Sphere	2.2 mg/L
	Ceriodaphnia dubia	Death	PE	1-4µm	48 h	Fiber	1.5 mg/L
Rehse et al., 2016	*Daphnia magna*	Immobilization	PE	1µm	96 h	Sphere	57.42 mg/L
Kim et al., 2017	*Daphnia magna*	Immobilization	PS	200nm	48 h	Sphere	0.04 mg/L

In Summary:

- There are a lot more studies testing hypotheses about the effects of plastics on organisms.
  - This includes studies testing effects at higher levels of organization.
- For large plastic debris, there is no doubt that plastic harms wildlife. For microplastics, there is evidence that it can cause harm, but when and how is complicated and further work is needed to understand this.
- We need more studies testing hypotheses about microplastics:
  - That recognize their complexity
  - In freshwater and terrestrial environments
  - That help us understand the environmentally relevant effects: more field studies, using relevant concentrations and sizes (includes better measurement in nature)

Thank you!


UNIVERSITY OF TORONTO

Ontario
Ministry of the Environment and Climate Change

Ocean Conservancy

Detected and non-detected impacts due to debris				
Type of study	Effect Detected		Effect Not Detected	
No. of cases	341		236	
Size of debris	Micro	Macro	Micro	Macro
Size (mm)	(<5)	(>5)	(<5)	(>5)
%	58	42	94	6
No. of cases	199	142	222	14
No. of cases at each level of biological organization				
Suborganismal				
Subatomic (e.g., oxidative stress)	8	0	6	0
Atomic (e.g., greater concentrations of intracellular Calcium)	3	0	7	0
Small Molecules (e.g., toxic metabolites)	0	0	0	0
Macromolecules (e.g., protein, DNA damage)	36	0	38	0
Molecular assemblies (e.g., formation of protein-chains)	0	0	0	0
Organelles (e.g., more micronuclei)	0	0	0	0
Cells (e.g., necrosis, less viable cells)	29	0	17	0
Tissues (e.g., inflammation, laceration)	3	32	6	0
Organs (e.g., change in size, lesions)	10	4	5	0
Organ System (e.g., poorly functioning digestive system)	0	1	0	0
Organismal				
Organism (e.g., reduced growth, death to an individual)	75	59	96	8
Ecological				
Populations (e.g., increase or decrease in size of population)	28	24	44	1
Assemblages (e.g., change in abundance or diversity of biota)	4	14	0	3
Ecosystem (e.g., change in ecosystem function)	3	8	3	2

>800 species

Secretariat of the Convention on Biological Diversity, 2016

>220 species

FAO Report 2017

What are the effects?