Interactions between marine microbes and microplastics

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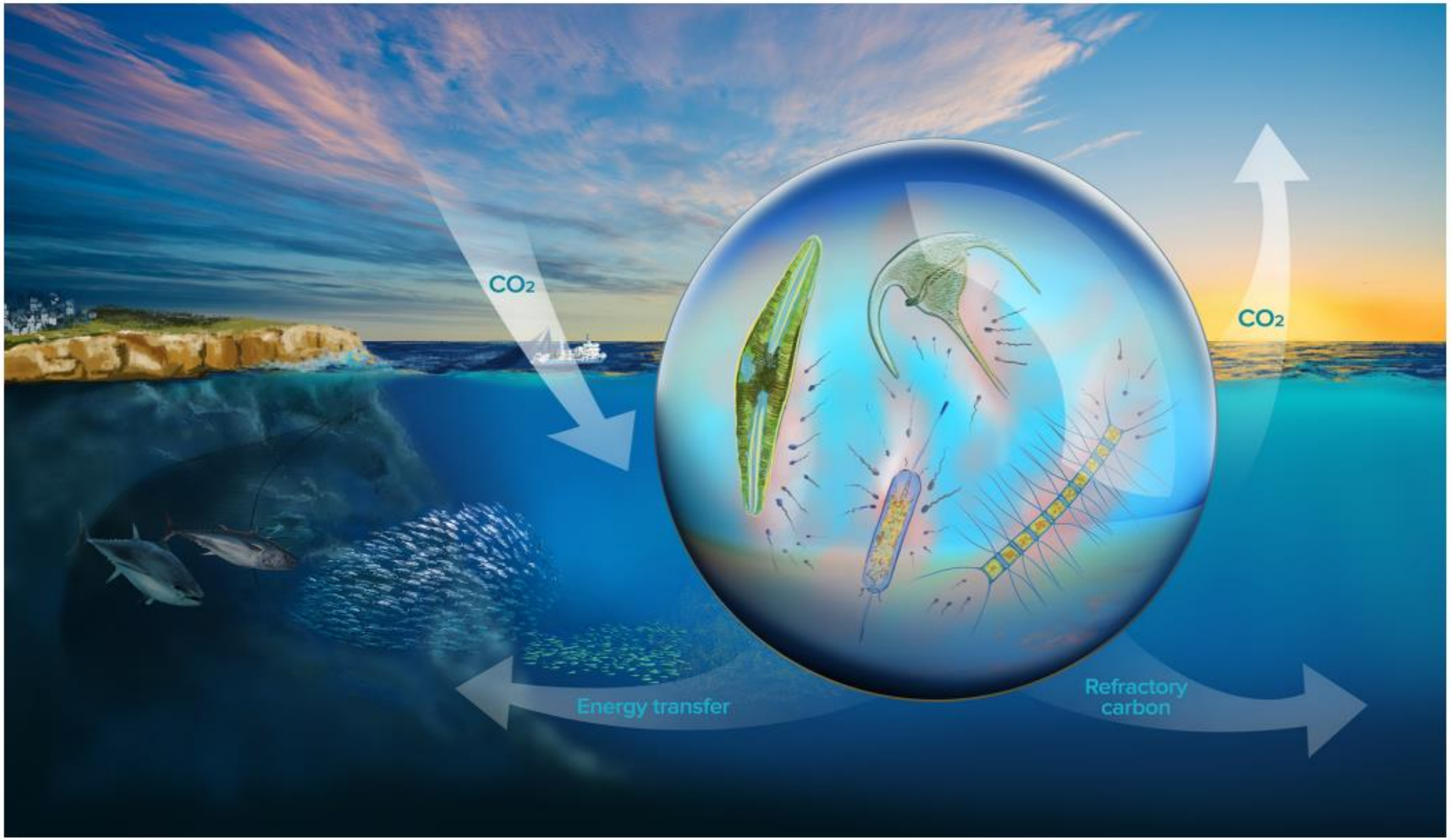
Predicting Pathways for Microplastic Transport in the Ocean, February 24, 2022

Outline:

- ❑ The role of microbes in the fate and transport of organic particles (marine snow) in the ocean.
- ❑ My own path towards microbes and microplastics.
- ❑ Case study I: Interactions between phytoplankton, marine snow and microplastics.
- ❑ Case study 2: Bacterial responses to photooxidation of microplastics.

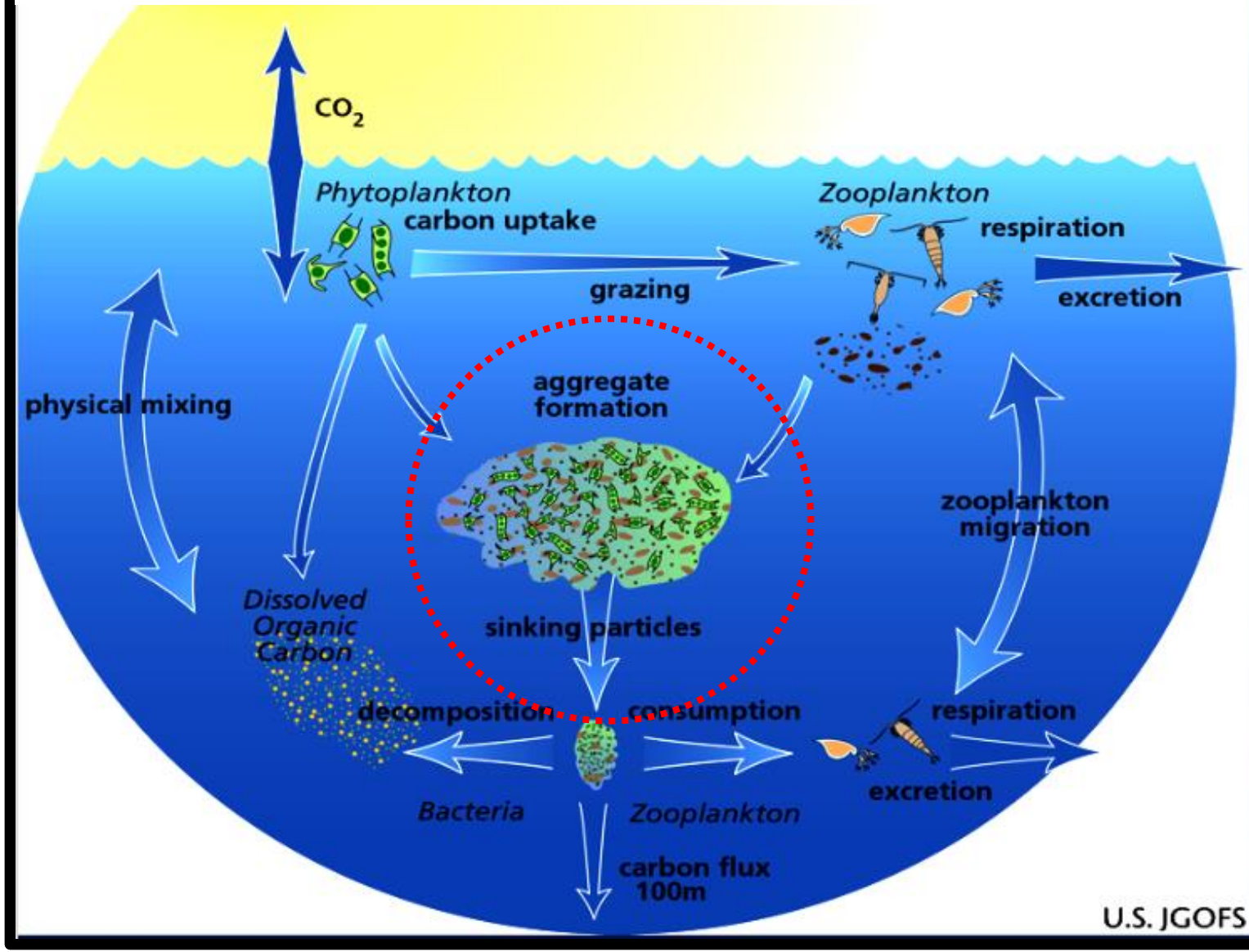
The life aquatic at the microscale (Raina, 2018)



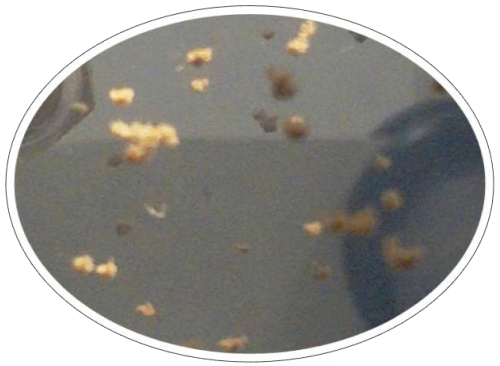
The Biological Pump

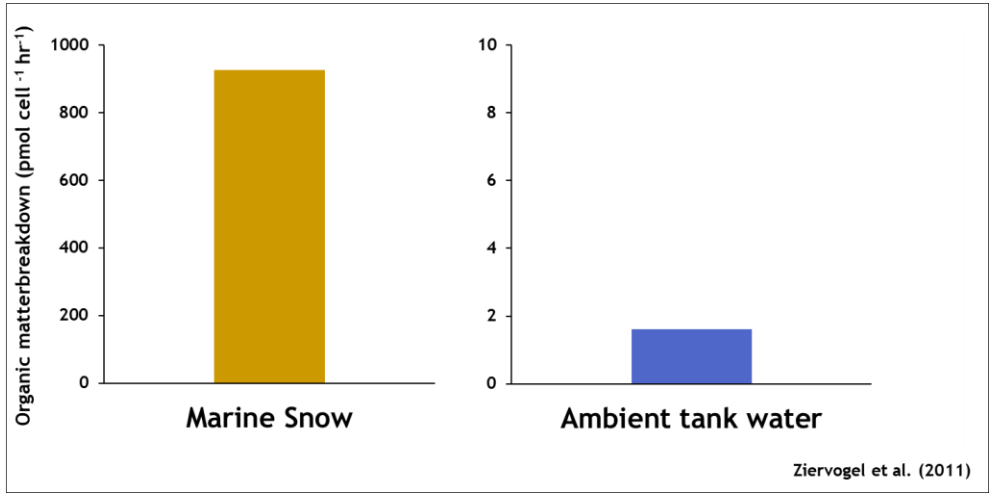
N Atl spring bloom:

→ ~50% of NPP exported out of EZ via sinking marine snow (Buessler and Boyd, 2009)

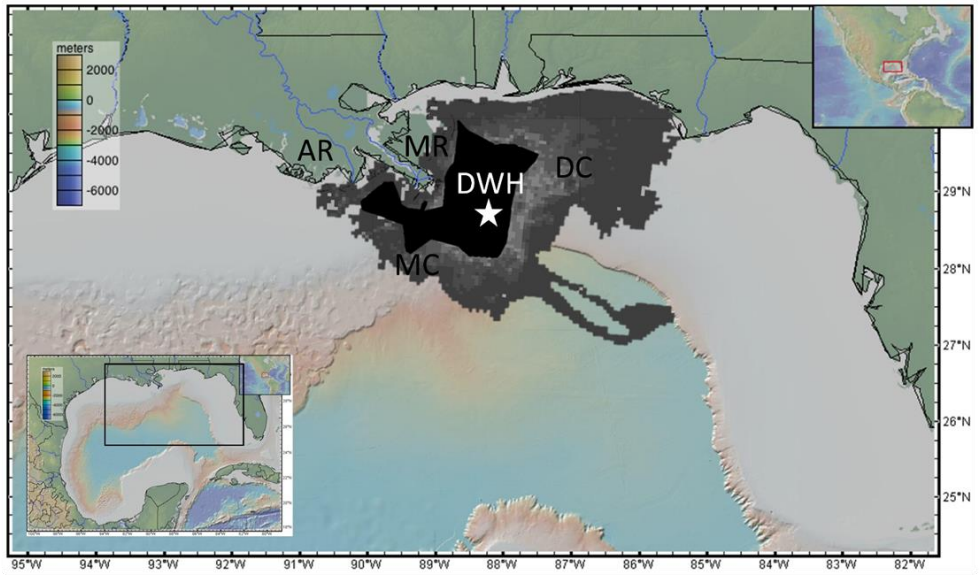


Marine snow: Hotspot for microbial biogeochemical processes

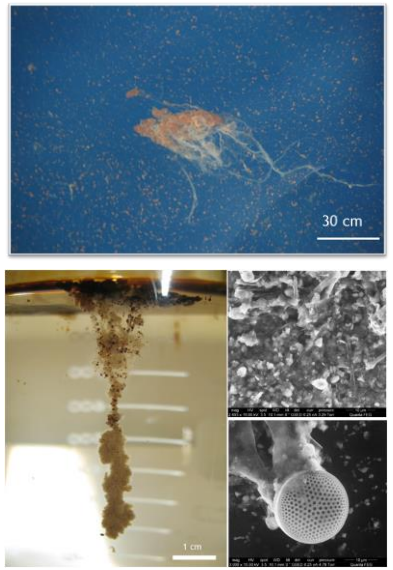




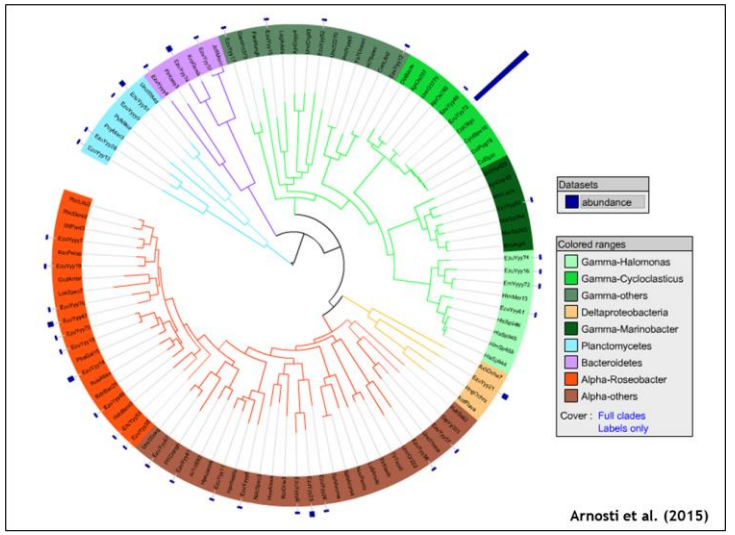
Marine oil snow (MOS): Hotspots for oil-degrading bacteria



Schwing et al. (2020)



Ziervogel et al. (2012)



Marine snow and microplastics

LETTER

2019

Microplastics increase the marine production of particulate forms of organic matter

Luisa Galgani[1,2], Manolis Tsapakis[3], Paraskevi Pitta[3], Anastasia Tsiola[3], Eleni Tzempelikou[4], Ioanna Kalantzi[3], Eleni Dafnomili[8], Steven A Loiselle[1,2]

OPEN ACCESS
RECEIVED 23 July 2019
REVISED 8 November 2019
ACCEPTED FOR PUBLICATION 20 November 2019

Interactions between microplastics and phytoplankton aggregates: Impact on their respective fates

2015

Marc Long, Brivaëla Moriceau *, Morgane Gallinari, Christophe Lambert, Arnaud Huvet,

Role of Marine Snows in Microplastic Fate and Bioavailability

Adam Porter,[†] Brett P. Lyons,[‡] Tamara S. Galloway,[†] and Ceri Lewis*[,†]

2018

[†]College of Life and Environmental Sciences: Biosciences, Geoffrey Pope Building, University of Exeter, Stocker Road, Exeter E
4QD, United Kingdom

lture Science, Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dor

An approach for extraction, characterization and quantitation of microplastic in natural marine snow using Raman microscopy†

2017

Shiye Zhao,[ab] Meghan Danley,[c] J. Evan Ward,[d] Daoji Li[a] and Tracy J. Mincer*[b]

Rapid aggregation of biofilm-covered microplastics with marine biogenic particles

2018

Jan Michels[1,†], Angela Stippkugel[1], Mark Lenz[2], Kai Wirtz[3] and Anja Engel[1]

[1]Biological Oceanography, GEOMAR Helmholtz Centre for Ocean Research Kiel, Düsternbrooker Weg 20, 24105 Kiel, Germany
[2]Benthic Ecology, GEOMAR Helmholtz Centre for Ocean Research Kiel, Hohenbergstraße 2, 24105 Kiel, Germany
[3]Ecosystem Modelling, Institute of Coastal Research, Helmholtz-Zentrum Geesthacht—Centre for Materials and Coastal Research, Max-Planck-Straße 1, 21502 Geesthacht, Germany

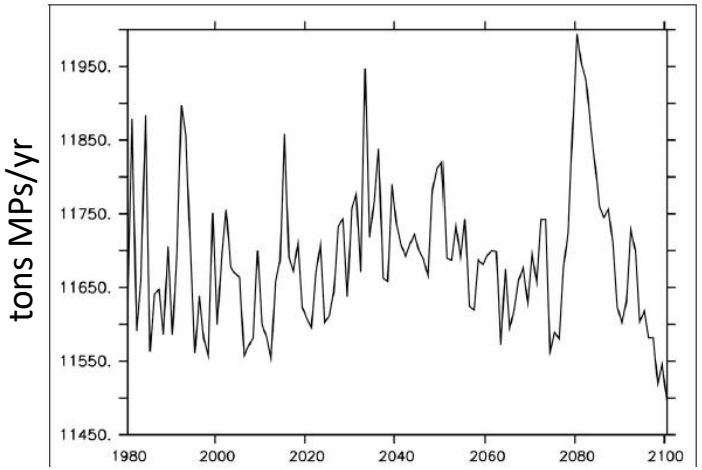
A Critical Examination of the Role of Marine Snow and Zooplankton Fecal Pellets in Removing Ocean Surface Microplastic

Karin F. Kvale, A. E. Friederike Prowe and Andreas Oschlies*

GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany

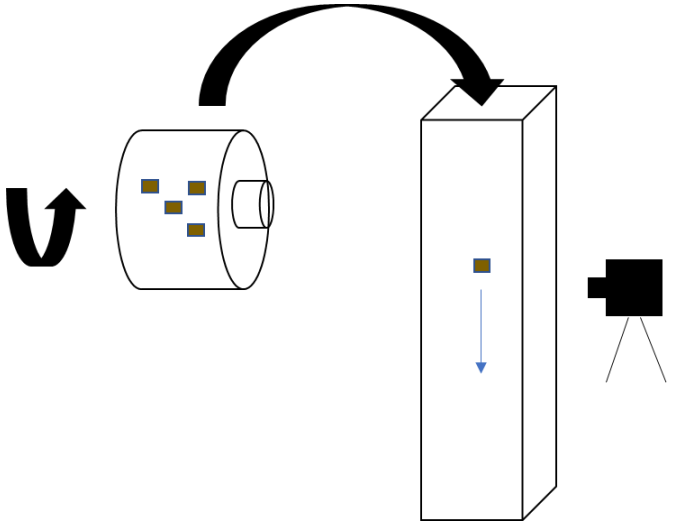
2020

Potential export of MPs in Marine Snow

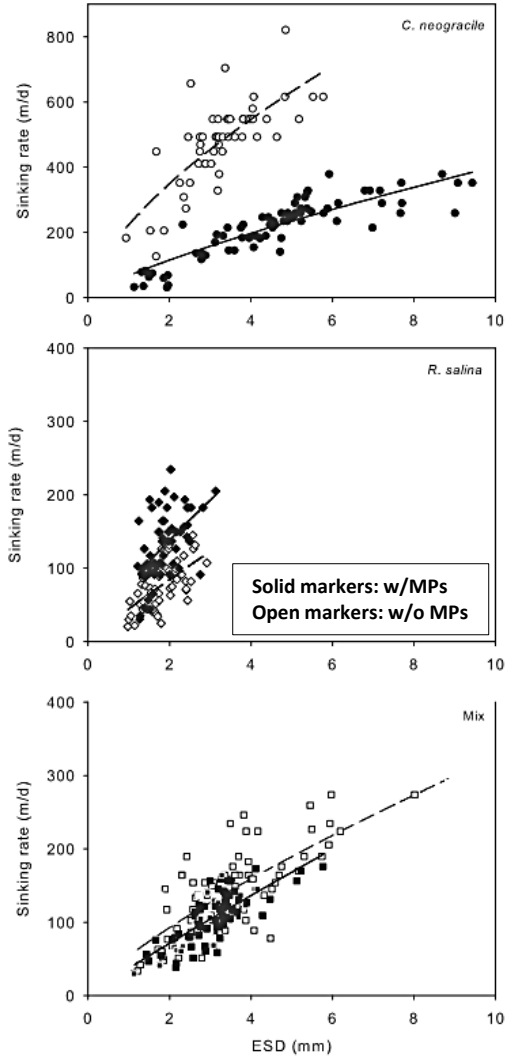


Sinking rates of Marine snow and Microplastics (2-µm PS beads; Long et al., 2015): *Species-specific patterns of aggregate sinking rates*

Marine snow formation in roller tanks; sinking velocities in graduated cylinder:



Long et al. (2015)

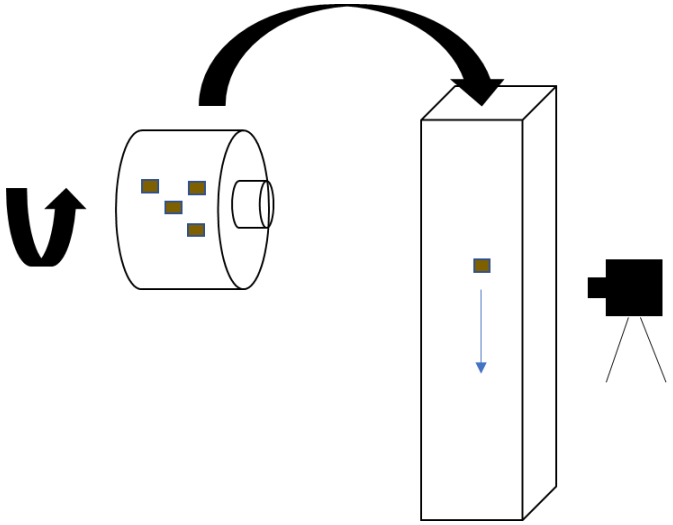


Open questions:

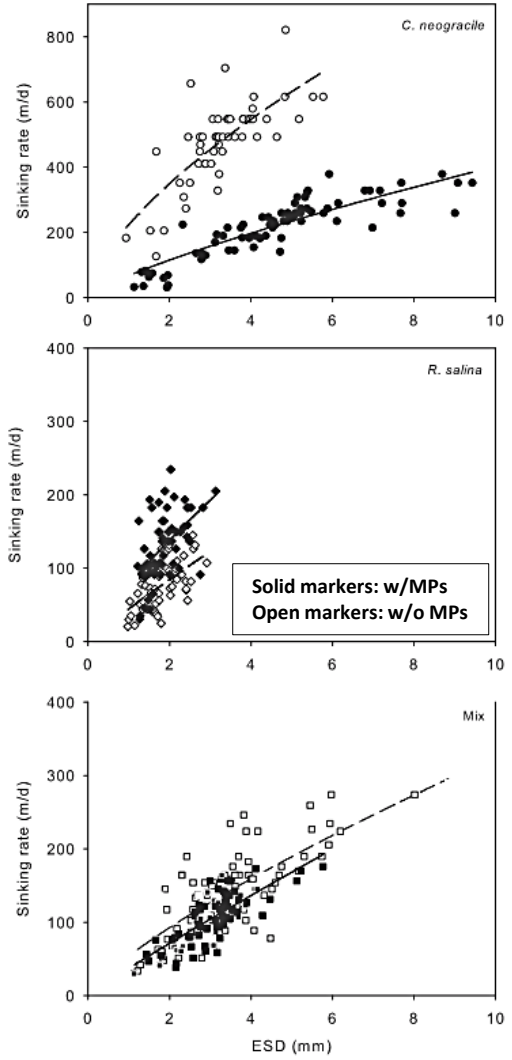
- **Aggregation and sinking behavior of larger MPs (mm-scale);**
- **Sinking rates of MPs vs. MPs-containing marine snow.**

Sinking rates of Marine snow and Microplastics (2-µm PS beads; Long et al., 2015): *Species-specific patterns of aggregate sinking rates*

Marine snow formation in roller tanks; sinking velocities in graduated cylinder:



Long et al. (2015)

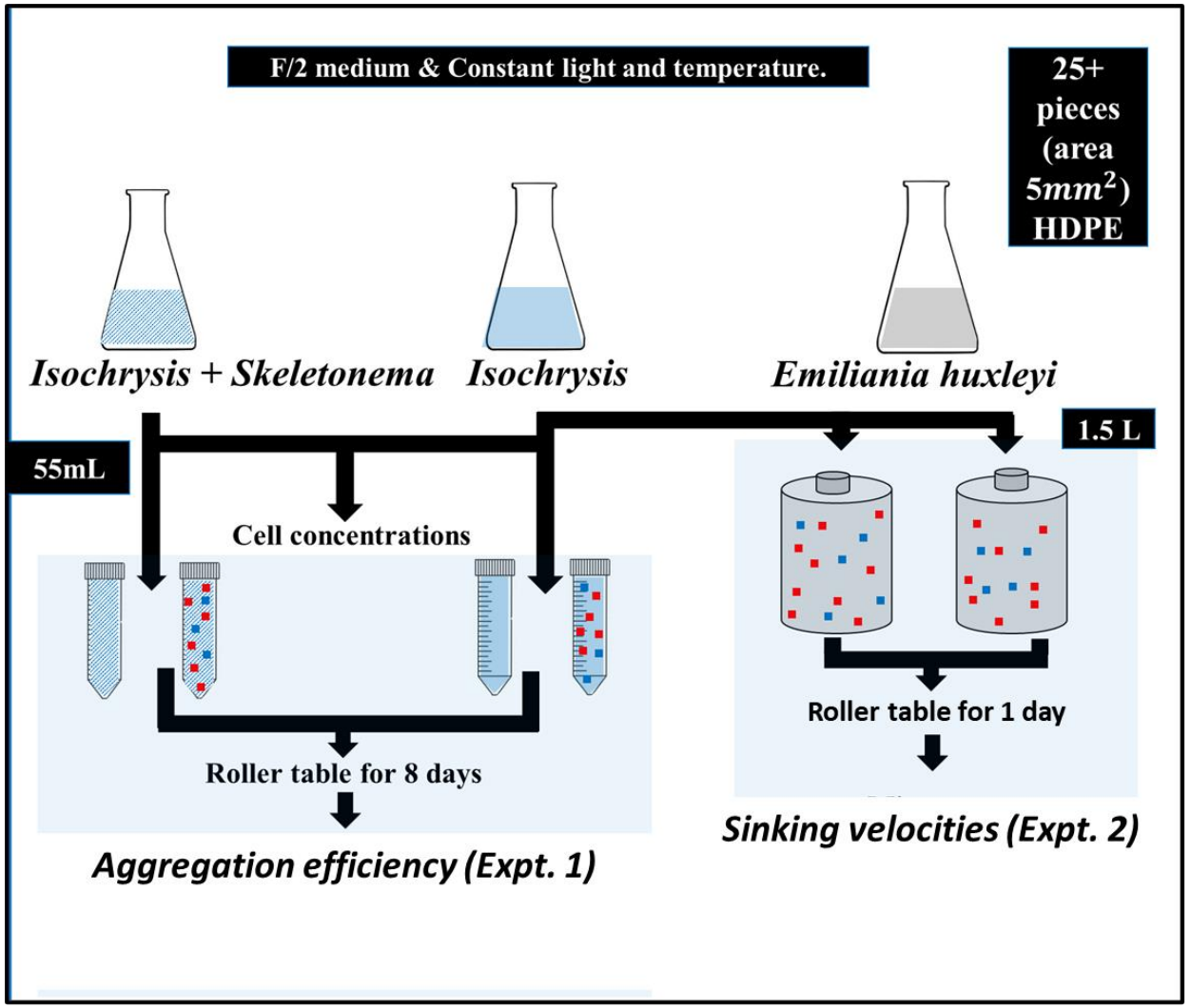


<u>Our hypotheses:</u>

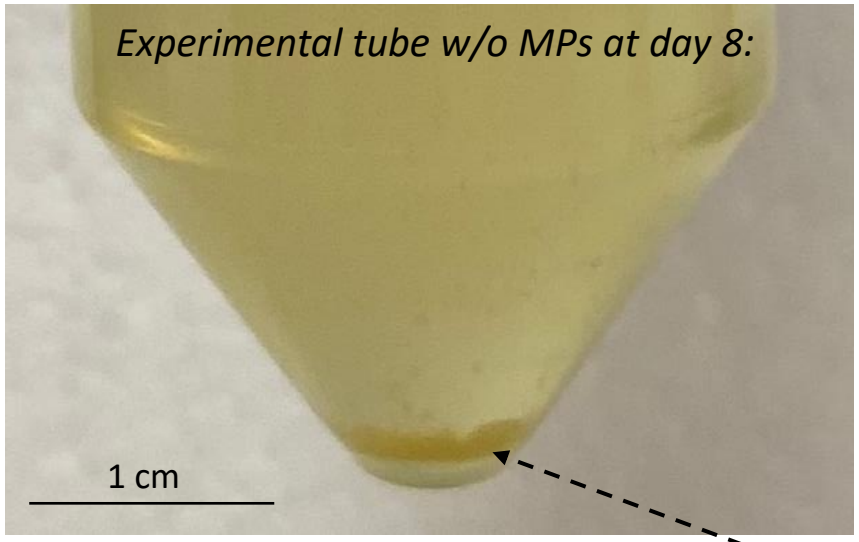
***H1*: MPs act as coagulation kernels for algae, accelerating the formation of plastic-containing marine snow (i.e., marine plastic snow -- MaPS).**

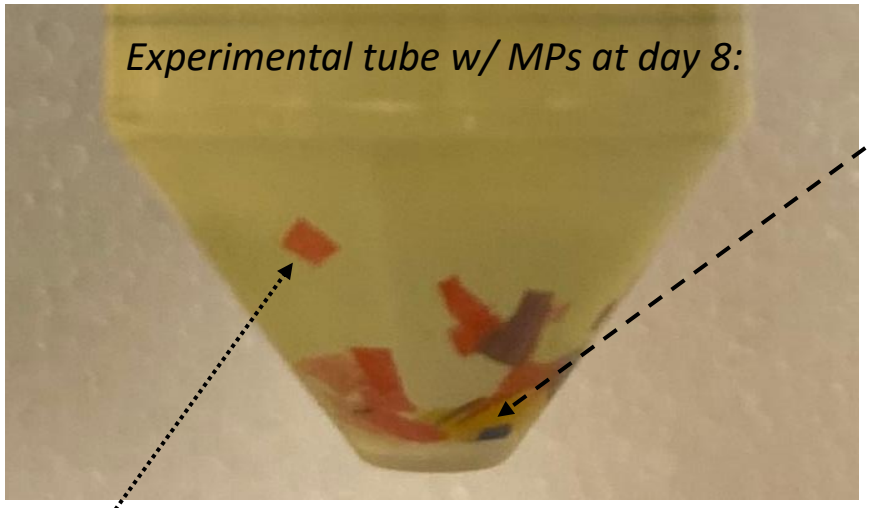
***H2*: Incorporation into marine snow enhances sinking velocities of MPs through the water column.**

Case study I: Interactions between phytoplankton, marine snow and microplastics, MPs (post-consumer HDPE, 5 mm^2)



Expt 1: Marine snow formed in all treatments (w/ and w/o MPs)

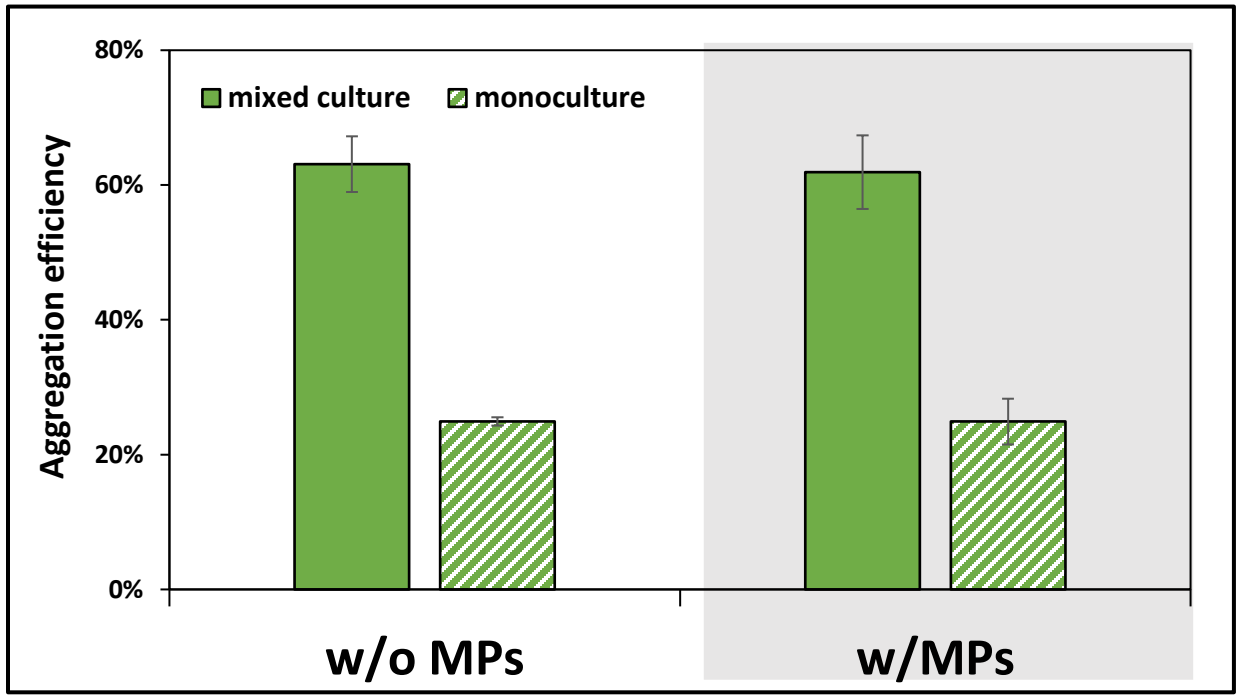




Marine snow

MP

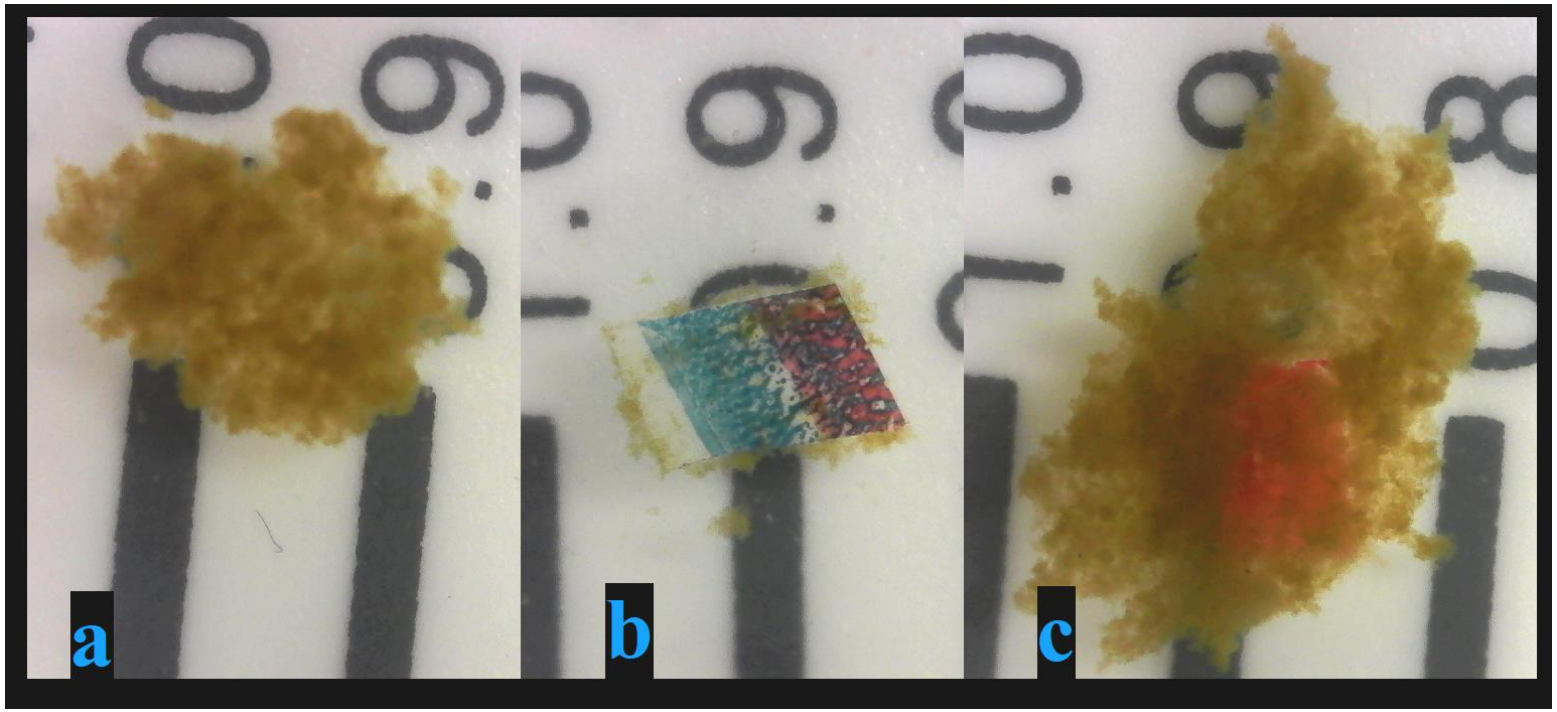
No measurable effects of MPs on aggregation efficiencies



<u>But</u>: Marine snow formation more rapid w/MPs (day 1); w/o MPs (day 8) [H1]!

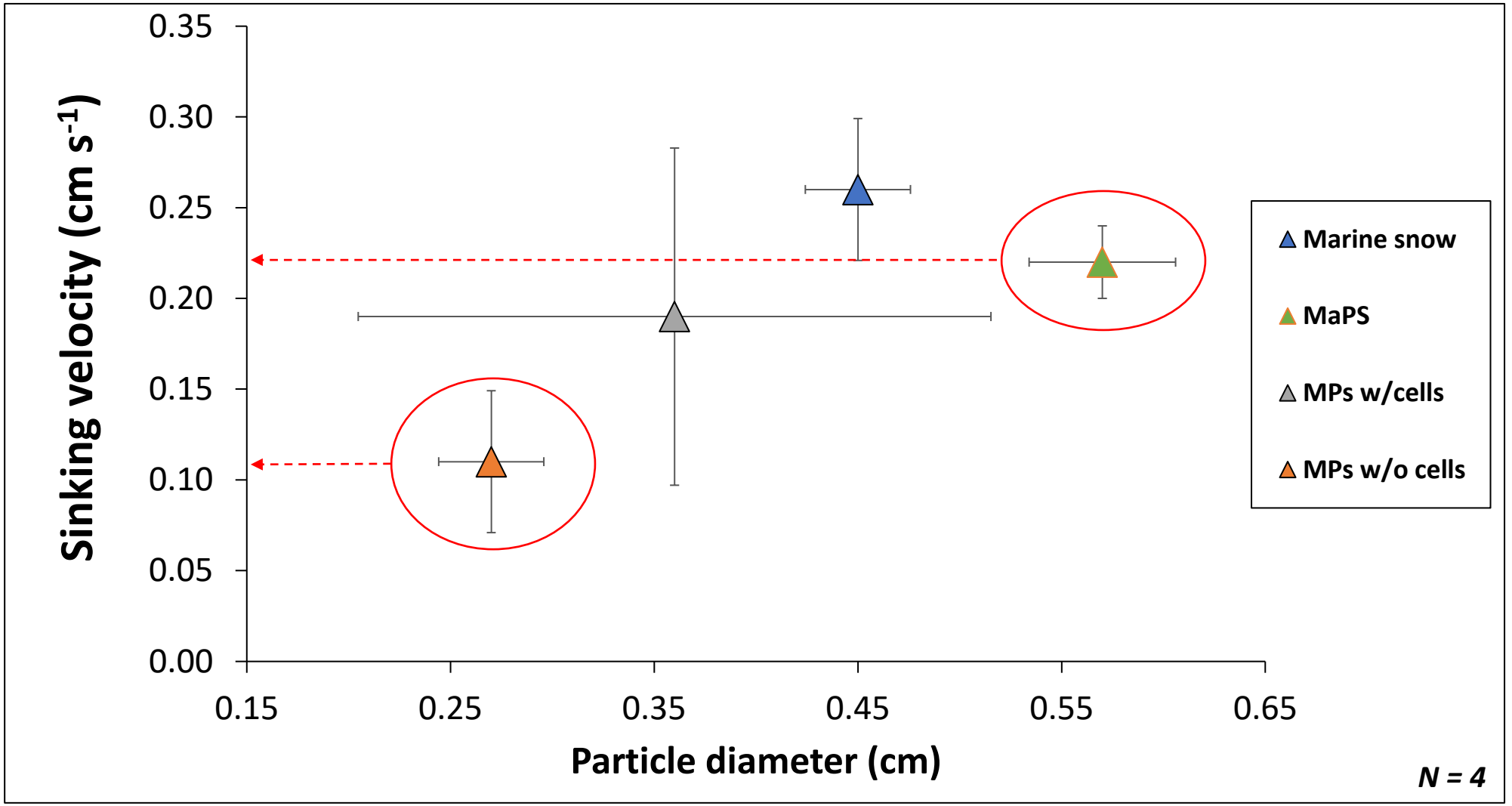
Expt 2: Marine snow sinking velocities

Roller tank (1.5 L) with marine snow

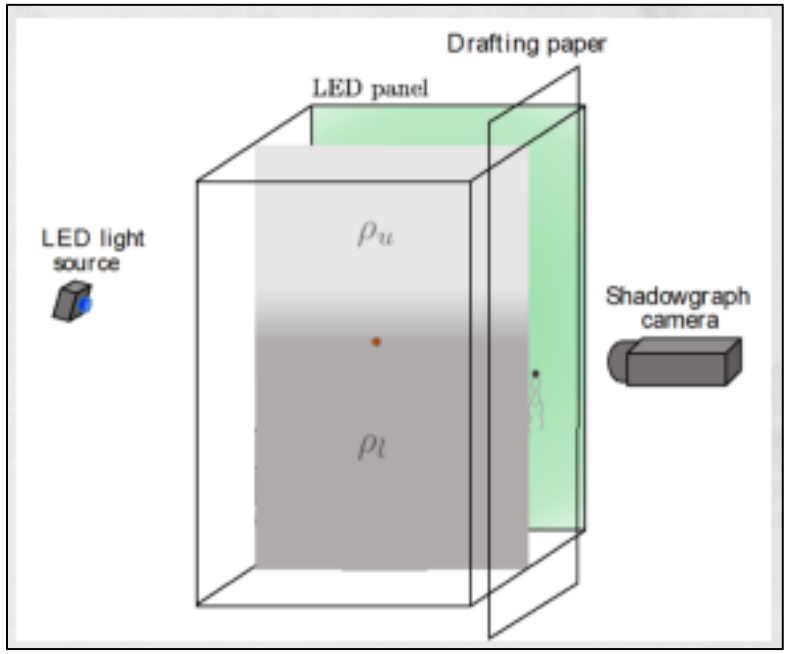


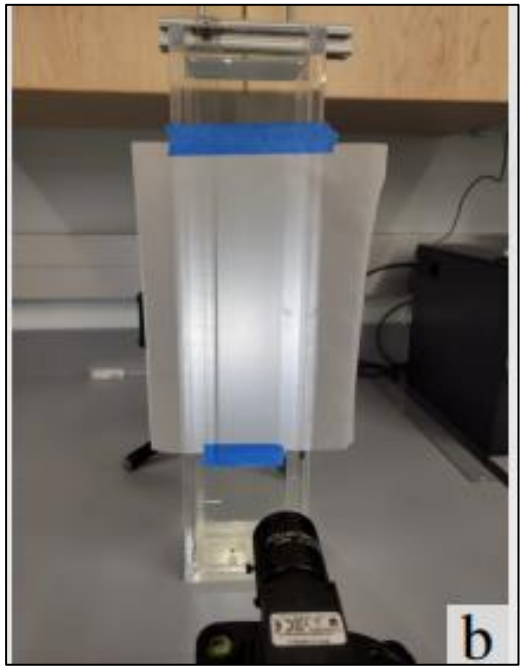
a – Marine snow; b – MP w/cells; c – Marine plastic snow (MaPS)

MaPS are larger and have higher sinking velocities compared with MPs [*H2*]

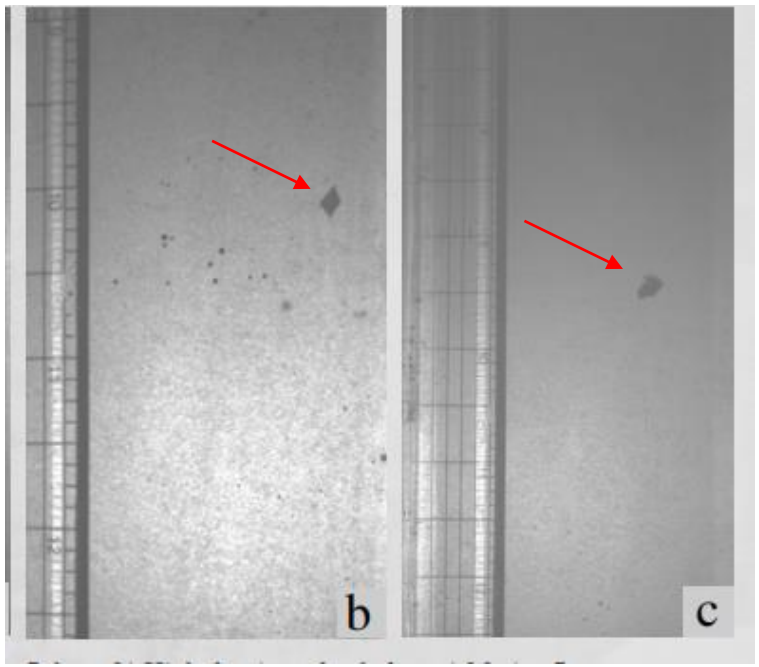


Settling of MPs and marine snow through sharp density layers





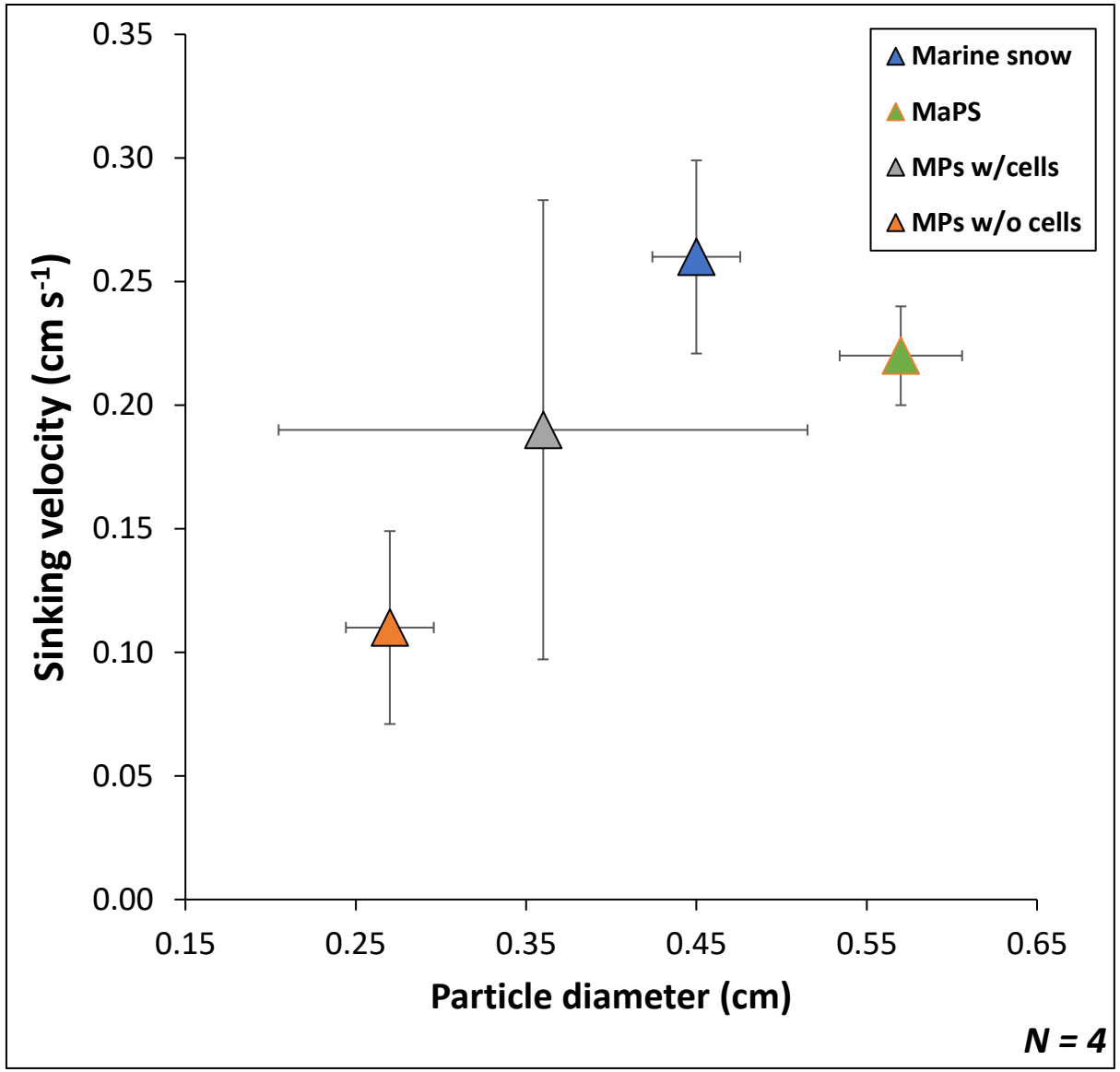
Shadowgraph setup for tracking particle settling, 10 cm x 10 cm x 50 cm (Mandel et al., 2020)



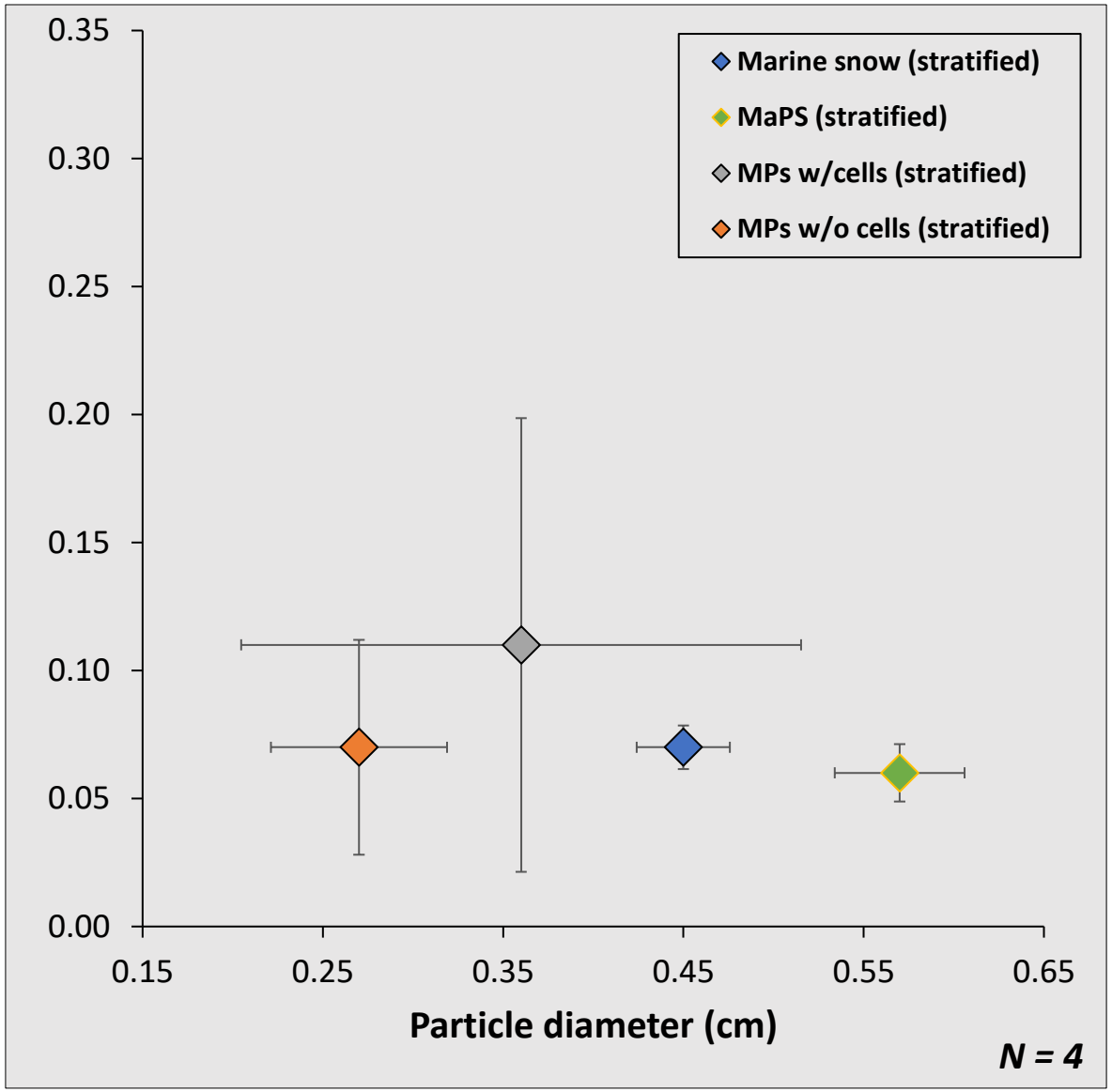
HDPE particle (b) and marine snow (c) during sinking through the tank.

What are the effects on water column stratification on vertical transport of MPs and marine snow?

Sinking velocities in unstratified water column (31 PSU)



Weighted average sinking velocities in stratified water column (31 PSU – 37 PSU)



Case study I – summary and conclusions

H1: MPs act as coagulation kernels for algae, accelerating the formation of marine plastic snow (MaPS).

- ***Algal cells aggregated more rapidly in the presence of MPs compared with the non-MPs control.***
- ***Aggregation efficiencies w/ and w/o MPs were comparable among the same algal treatments.***

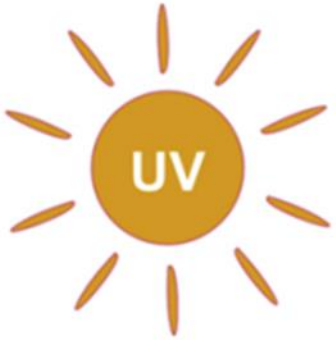
H2: Incorporation into marine snow enhances sinking velocities of MPs through the water column.

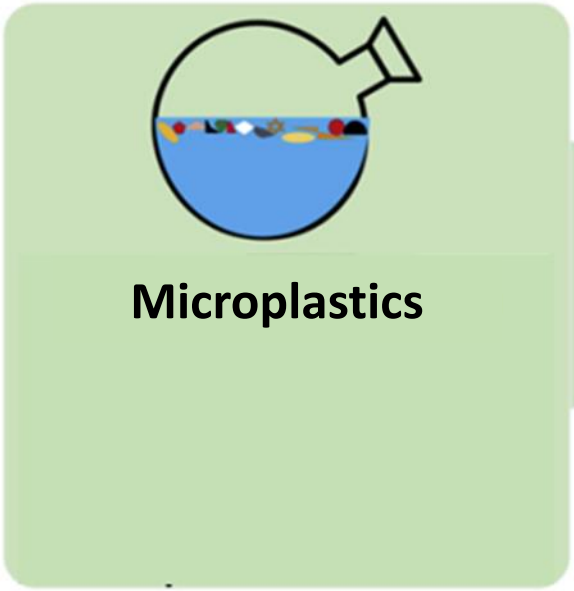
- ***MaPS were double the size and had two times higher average sinking velocities compared with MPs.***
- ***MaPS and MPs sinking through a stratified water column showed comparable sinking patterns.***

<u>Conclusions</u>:

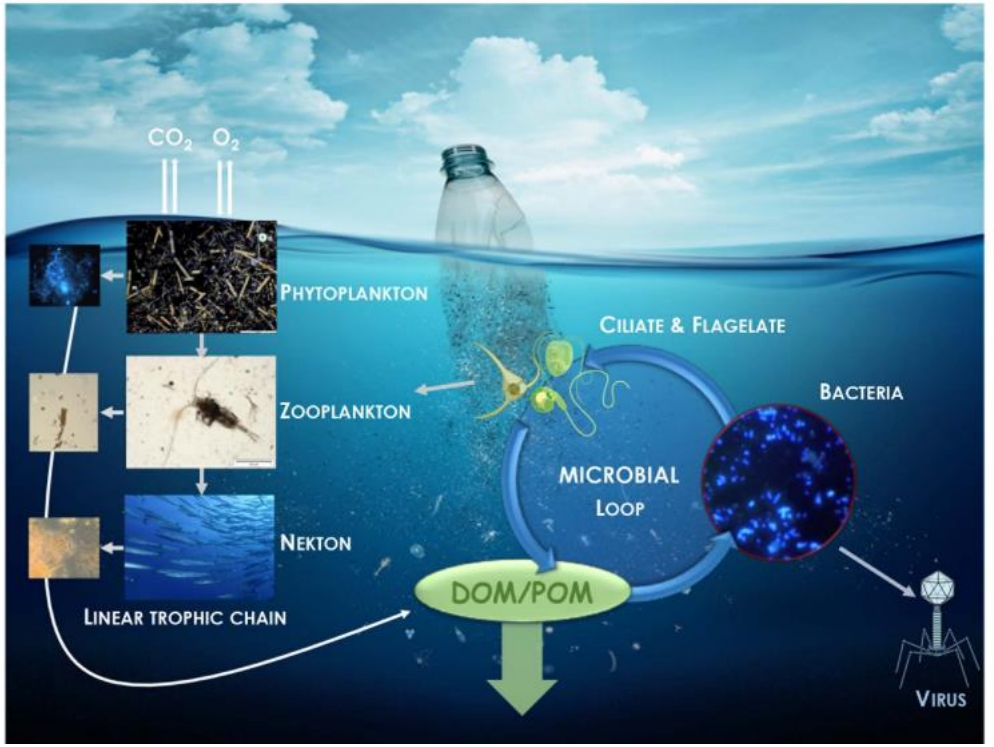
- **Marine snow may accelerate the downward flux of MPs under certain conditions (unstratified vs. stratified);**
- **MaPS formation and sinking → pathway of MPs into food webs in ocean's interior.**

Case study II: Microbial responses photooxidized MPs





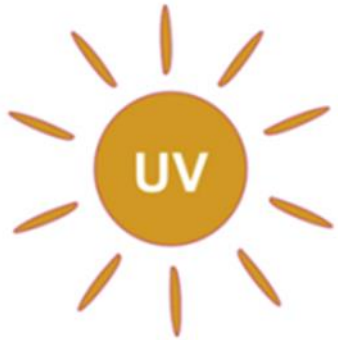
DOC

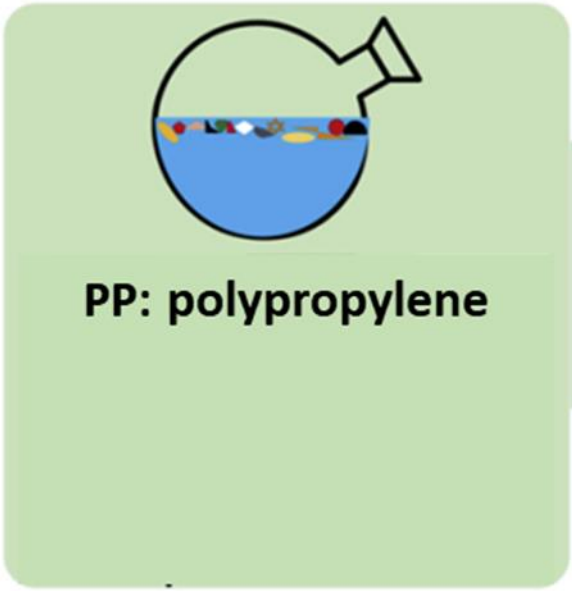


Ward et al. (2019); Zhou et al. (2019); […]

Jacquin et al. (2019)

Photochemical dissolution of microplastics to DOC





Ward et al. (2019); Zhou et al. (2019); […]

1 -- DOC$_{PP}$ amended (~5x background)	2 -- unamended	control 1	control 2
			

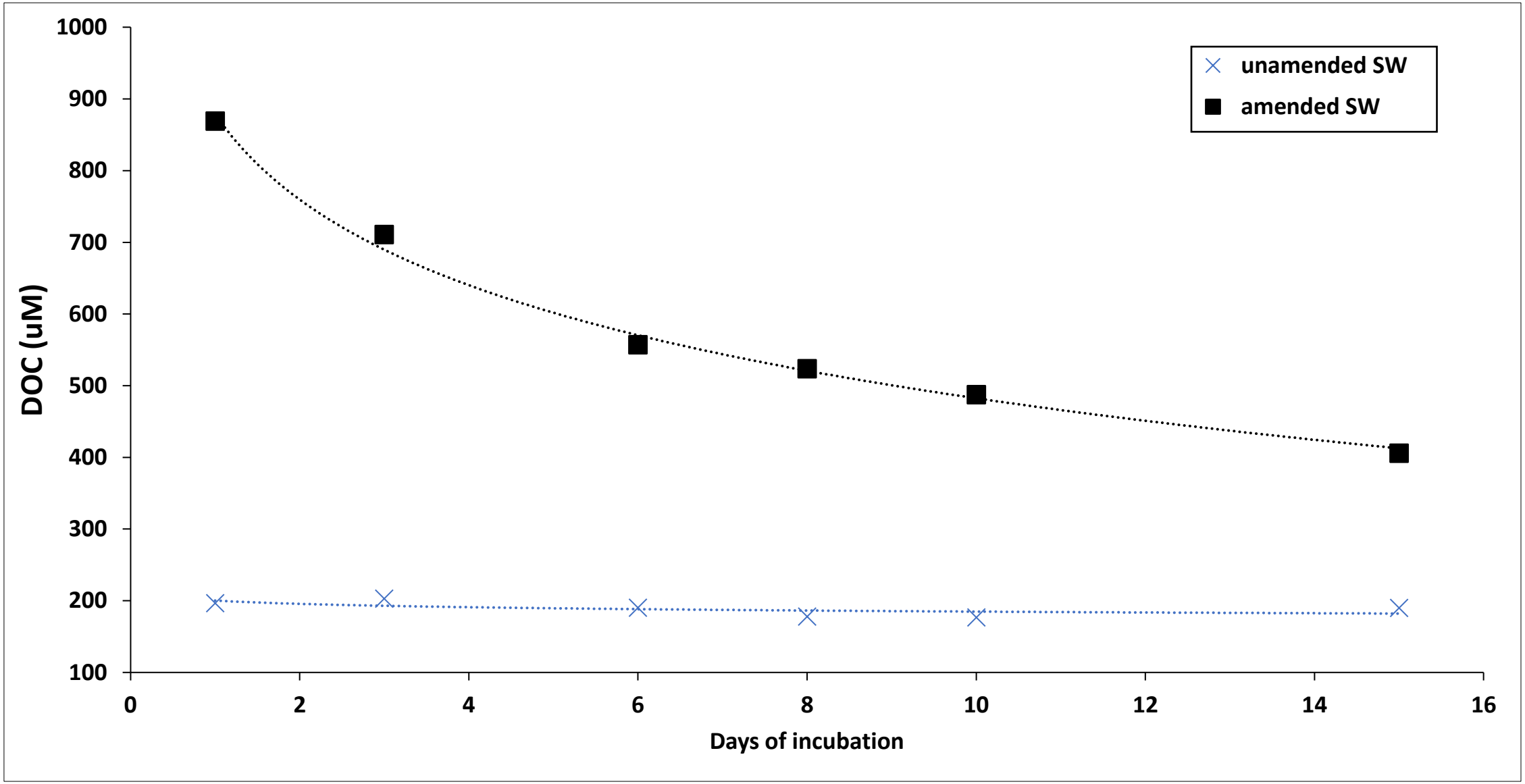
System comparison: offshore, coastal, river

Parameters: DOC, DOM, bacterial cell abundance, community composition, enzyme activities (lipases, glucosidases, peptidases).

Hypothesis: Biodegradation rates of DOC$_{PP}$ will differ among the systems (bacterial community structure and functions).

Coastal water experiment

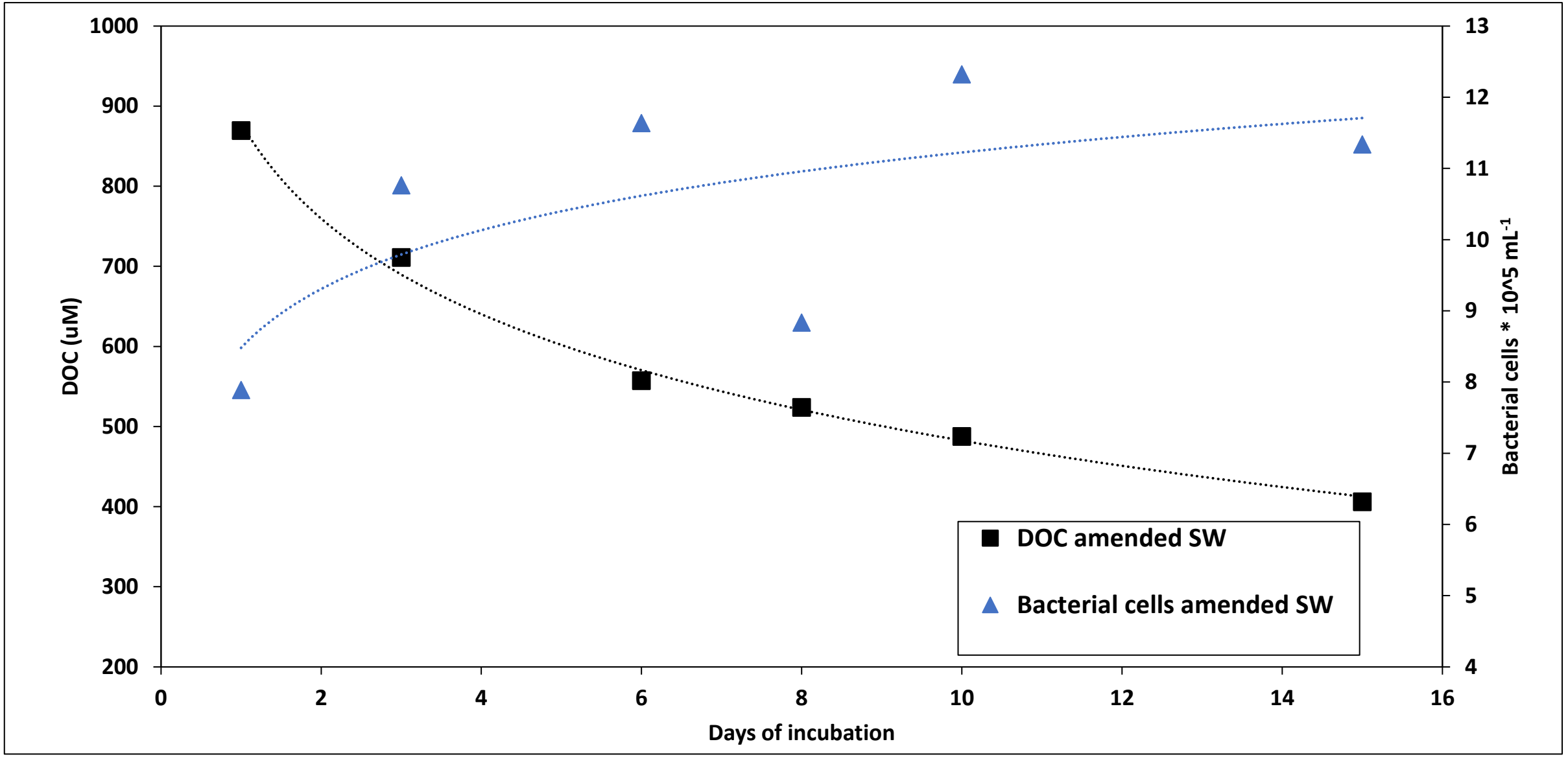
Dissolved organic carbon (DOC)



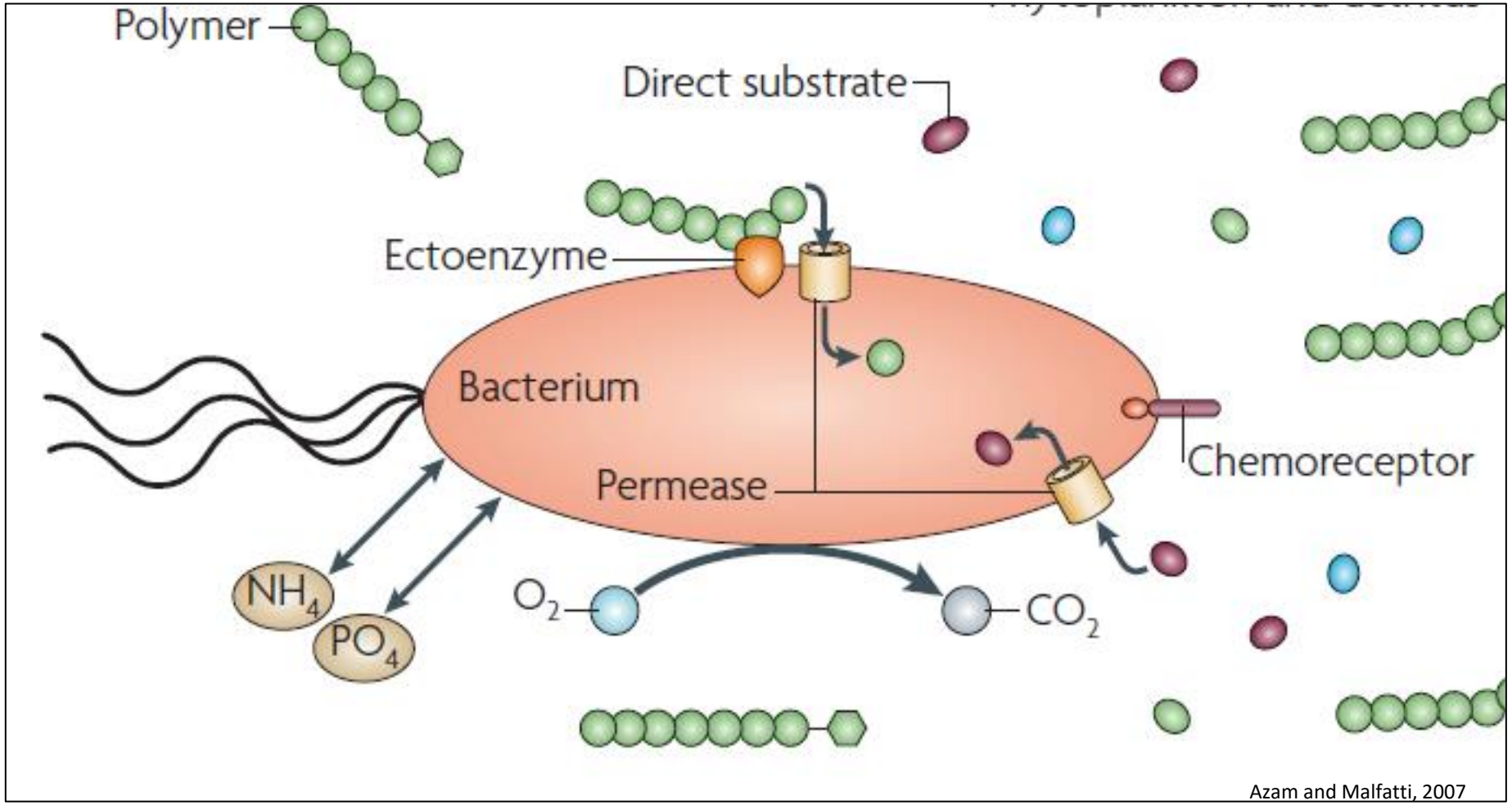
Mineralization rate of DOC_{pp}: ~60 uMd^{-1} (week 1), ~16 uMd^{-1} (week 2)

Coastal water experiment

Dissolved organic carbon (DOC) and bacterial abundance



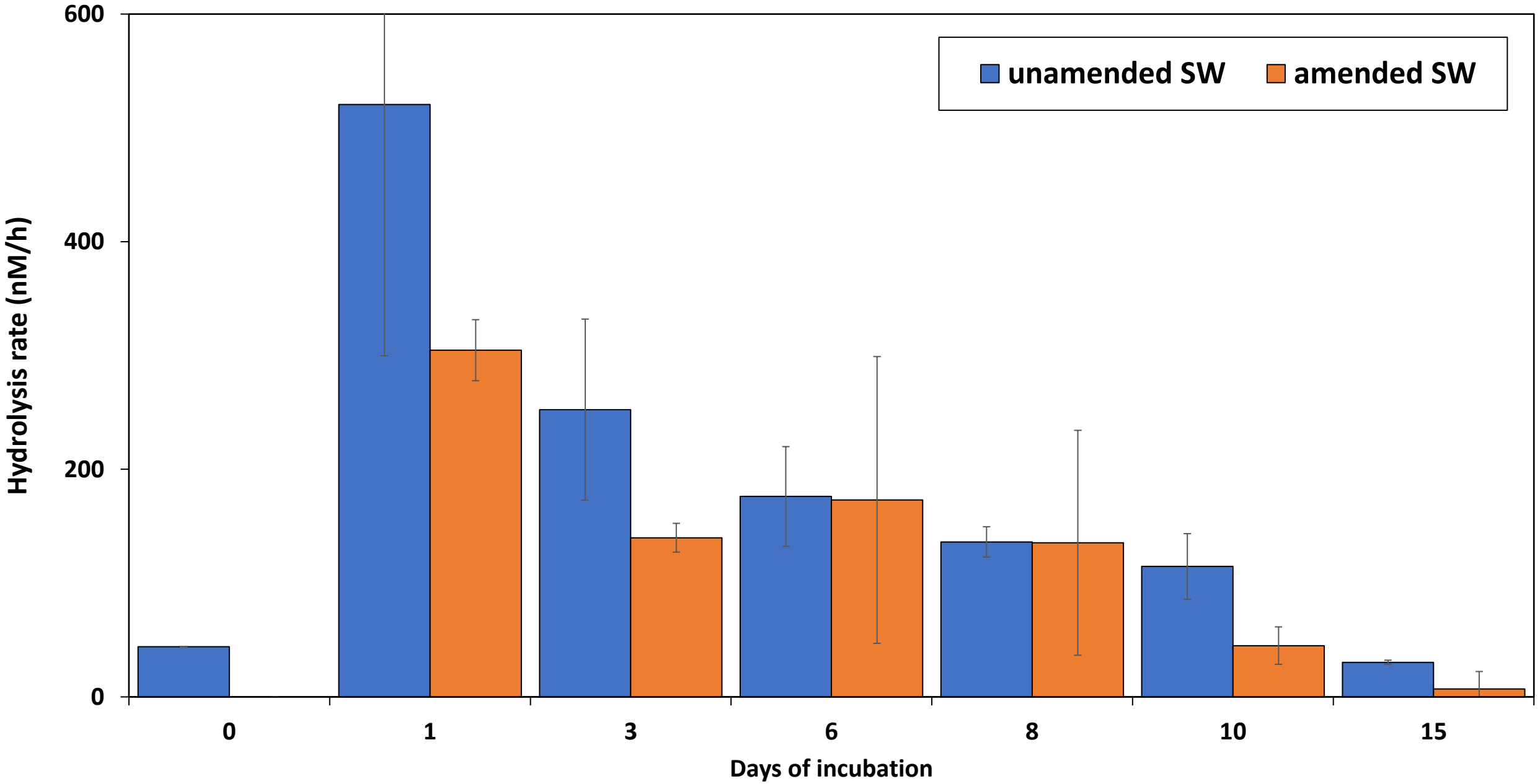
DOC_{PP} : Carboxylic acids ≤ 700 Da (Gewert et al., 2018)



Enzyme activities (lipases) as indicator for DOC_{PP} degradation?

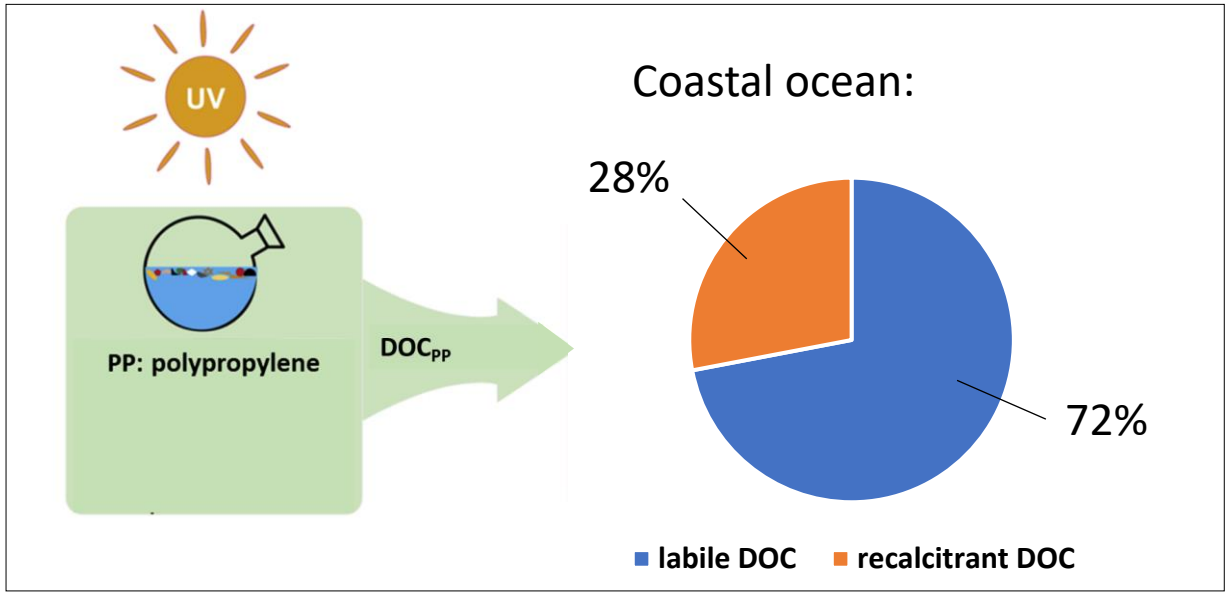
Coastal water experiment

Lipase activities (MUF-Oleate, $C_{28}H_{40}O_4$)



Correlation coefficients (*p*-value):

DOC_{PP}-amended SW	Cell#s	Lipase	Esterase	Glucosidase	Peptidase
DOC	-0.66 (0.15)	**0.90** **(0.01)**	0.02 (0.002)	-0.76 (0.08)	0.18 (0.13)

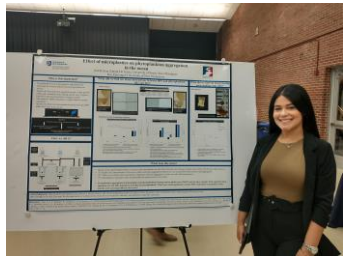


<u>Open questions</u>:

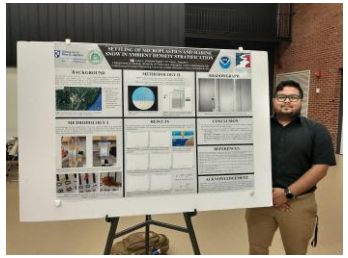
- **System comparison?**
- **Elevated respiration of DOC_{PP}: consequences for elemental cycling (nutrients, oxygen, …).**

Acknowledgments

Case study I:



Astrid Joan Zapata-De Jesus (University of Puerto Rica, Mayaguez)



Jobel Y Villafane Pagan (University of Puerto Rica, Mayaguez)

Tracy Mandel (UNH)

Case study II:

Aron Stubbins, Ariana Petterson, Lixin Zhu (all Northeastern University)

Funding:

Collaborative Research Excellence (CoRE) Initiative

School of Marine Science and Ocean Engineering (SMSOE)

Postdoc position in the Ziervogel lab

Postdoc position in marine microbial biogeochemistry at UNH

The Ziervogel lab at the University of New Hampshire (UNH) is seeking a highly motivated postdoc to conduct research in the field of marine microbial biogeochemistry related to a multi-institutional project funded by NSF's Established Program to Stimulate Competitive Research (EPSCoR). This ongoing project aims to further our understanding in microbially-mediated cycling of organic matter in the ocean, combining biogeochemical tools with single cell genomics. The work is a collaboration with Bigelow Laboratory for Ocean Sciences, ME, the Desert Research Institute, NV, and the University of Nevada, Las Vegas. More information about the project can be found here: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1826734&HistoricalAwards=false.

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