Microbial Communities & Plastics: The Marine Environment

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About Me

I'm...

1. A BCHM/CHEM & EBIO major

2. A big fan of almost all animals

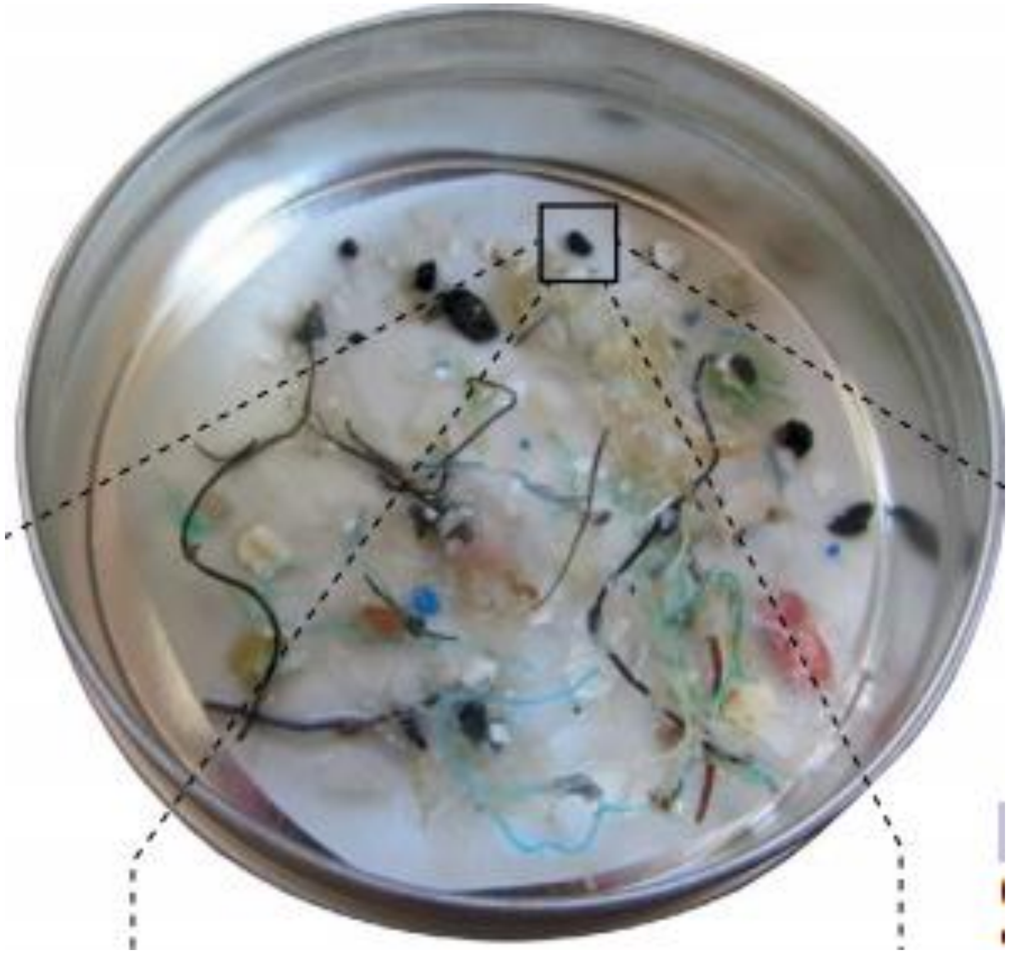
3. Attempting to provide an overview of general industry knowledge regarding plastics and their respective microbial communities in the Marine Environment

General Background

- Global plastic production in the year 2017 was recorded to be about 350 million tones.

- Countries & companies alike around the globe (not all) increased public pressure on the public and themselves to decrease the rate at which plastic waste accumulates in marine environments

Forbes. (2019, May 30). [Garbage stretching for miles]. The Ocean Cleanup.



Portion of *Figure 3* from Amaral-Zettler, L.A. et al (2020) paper

The “Plastisphere”

Electron Micrograph of biofilms on plastic substrates revealed the following categories of microbes

1. Saprotrophs
2. Symbionts
3. Predators
4. Heterotrophs
5. Phototrophs

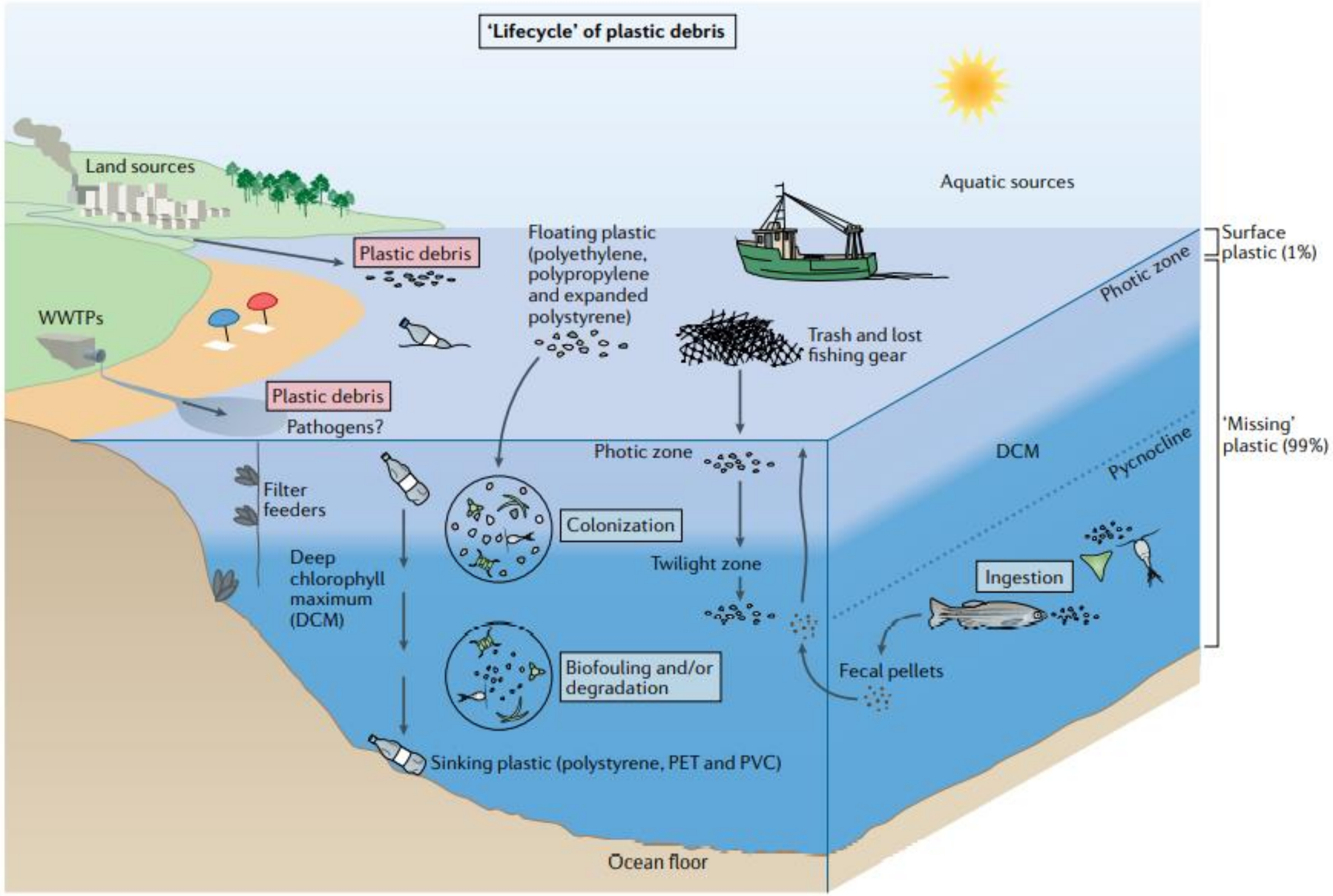


Figure 2 from Amaral-Zettler, L.A. et al (2020) paper

Plastics Lifecycle

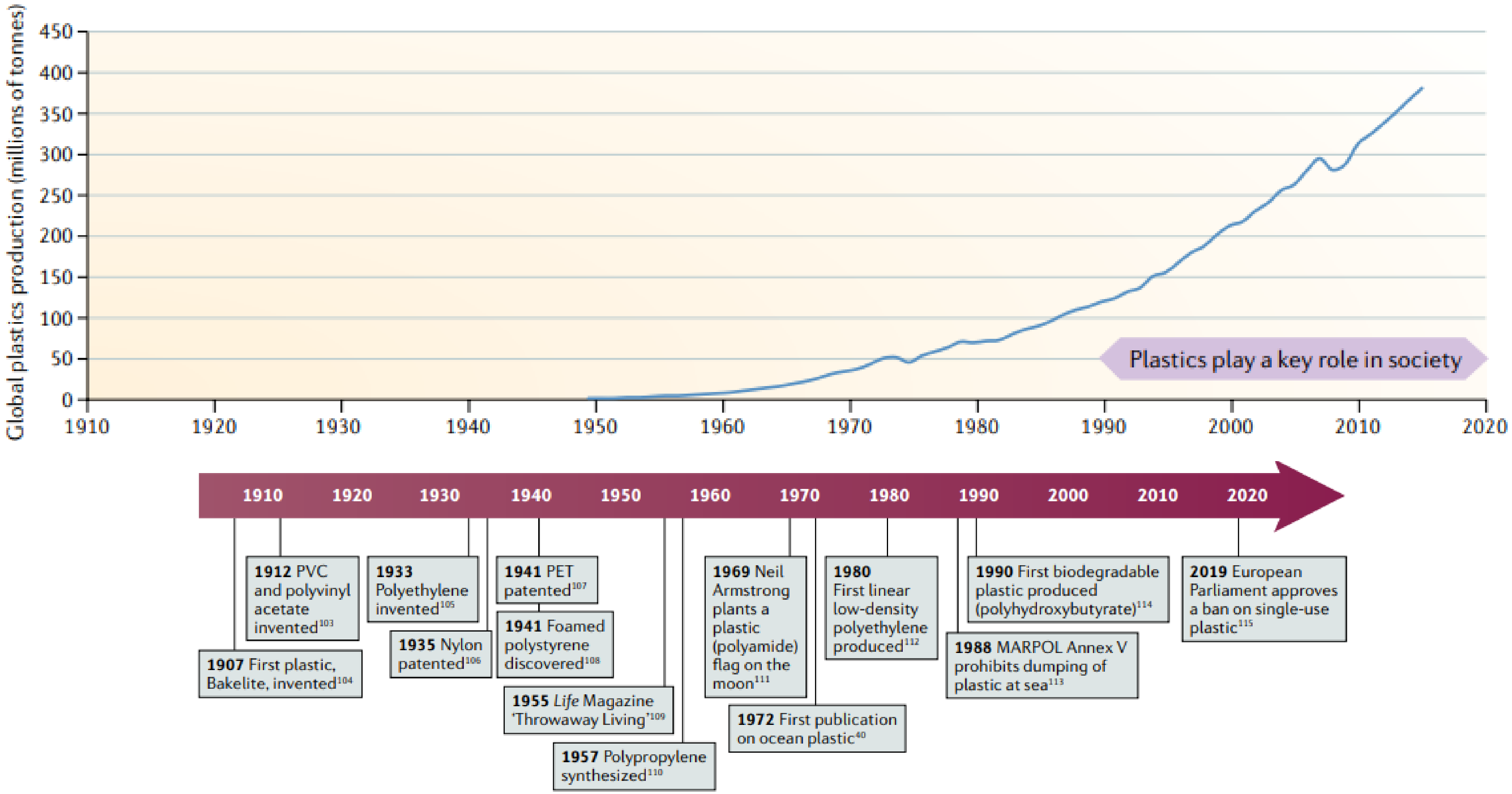


Figure 1 from Amaral-Zettler, L.A. et al (2020) paper

History of Plastics

Microbial Community Composition

Colonization Experiment

- Demonstrating changes in community composition, from a data base known as the Global Assignment of Sequence Taxonomy (GAST).
- To identify and differentiate organisms, microscopy and a small subunit of rRNA marker gene is used (in this case, 16S rRNA gene)

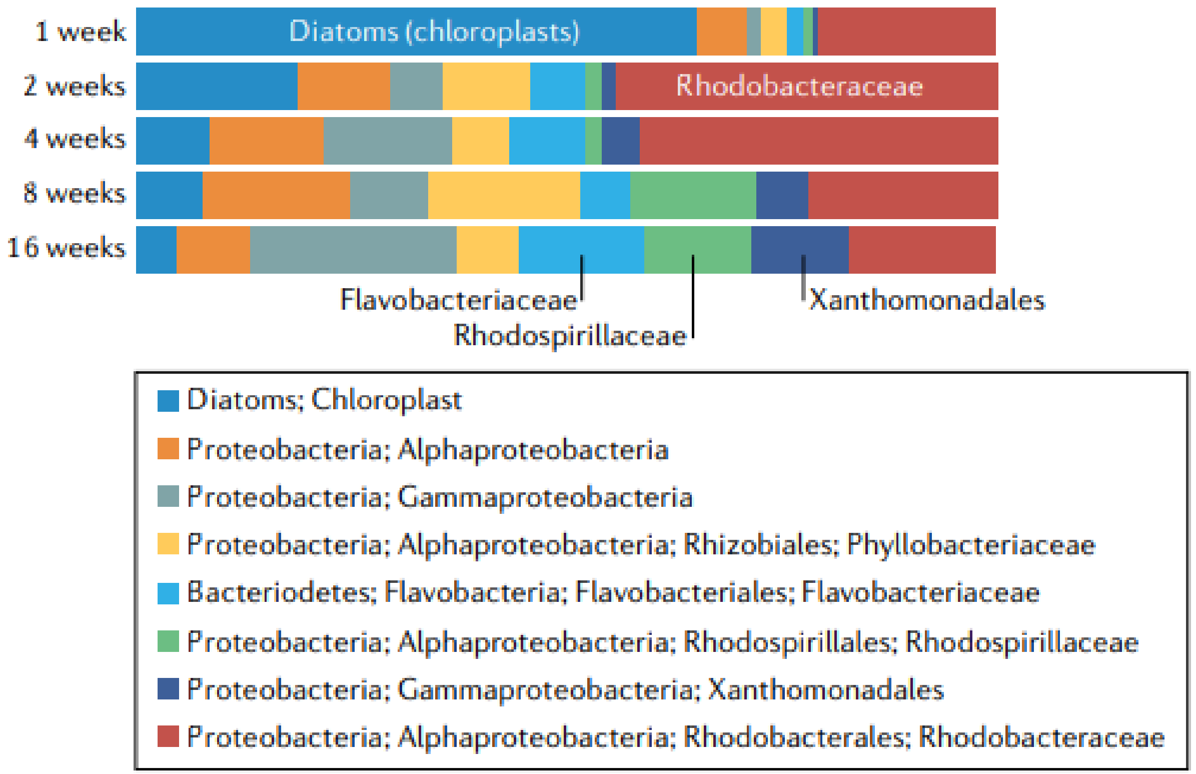


Figure 4 from Amaral-Zettler, L.A. et al (2020) paper

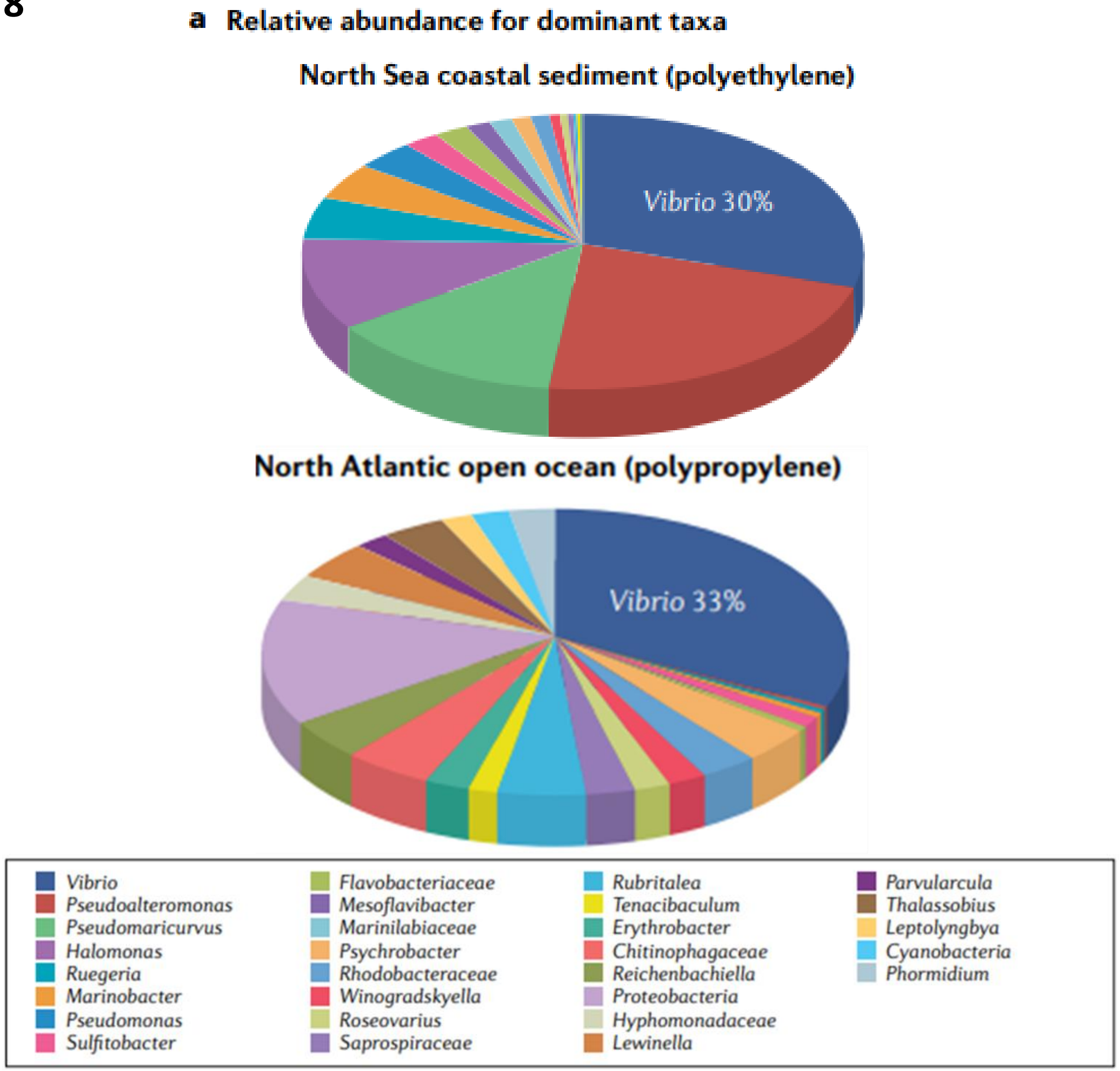


Figure 5-a from Amaral-Zettler, L.A. et al (2020) paper

Relative Abundance

The figure demonstrates abundance of identifiable taxa with respect to one another.

In other words, the figures shown do not represent the actual amounts of each microbial species present, only their amounts relative to one another.

Contributions of each taxon for each sample location

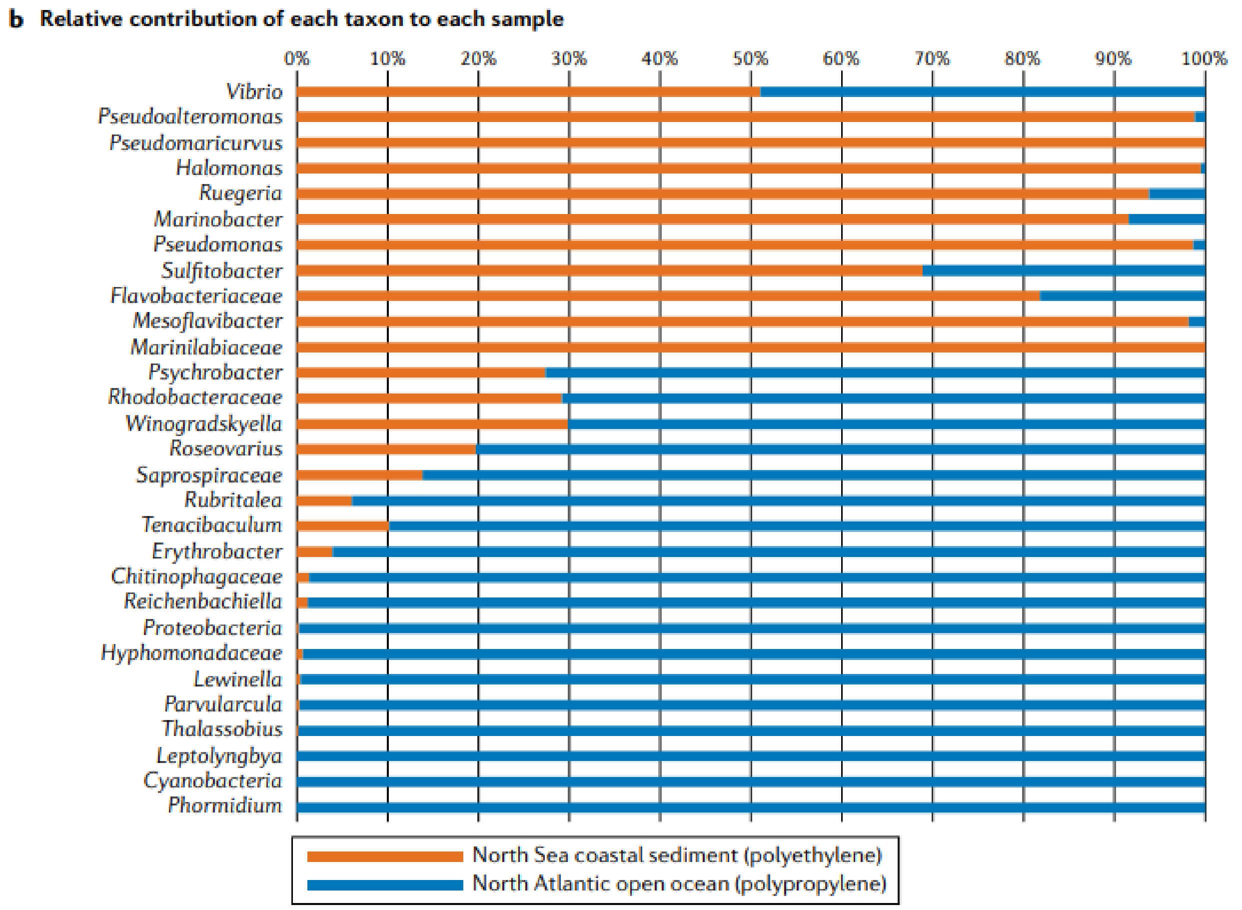


Figure 5-b from Amaral-Zettler, L.A. et al (2020) paper

Demonstrates the differences of relative abundance from each sample (from coastal sediment & one from the open ocean, BOTH using PET as the substrate)

Microbes Relevant to Plastics Bio-deterioration & fragmentation

Classification & Scientific Name/Genus

*Gamma-proteobacteria
-Pseudomonas (Gram negative)

*Actinobacteria
-Arthrobacter (Gram positive)

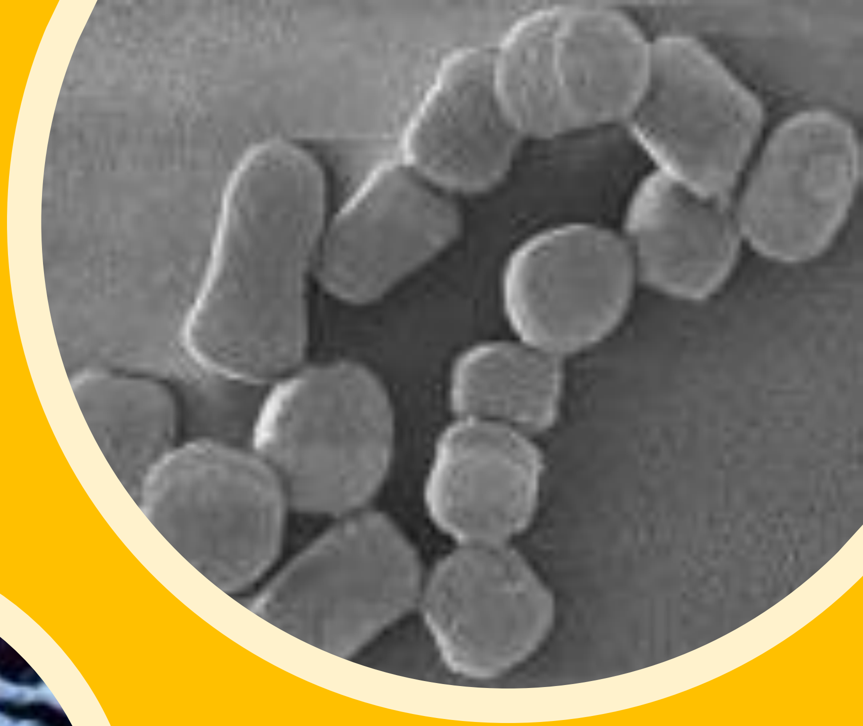
*Corynebacteriaceae
-Corynebacterium (Gram positive)

*Nocardiaceae
-Rhodococcus (Gram positive)

*Microccaceae
-Micrococcus (Gram positive)

*Streptomycetaceae
-Streptomyces (Gram positive)

Pseudomonas



Arthrobacter

Rhodococcus

Streptomyces

Indicators of Successful Biodegradation

Three measurements to determine success

1. More than 60 – 70% of ambient CO2 concentrations are due productions by microbes

2. Biological Oxygen Demand (BOD): Negative control should not exceed the upper limit of experimental parameters

3. Observable loss in mass and visual verification/evidence of degradation

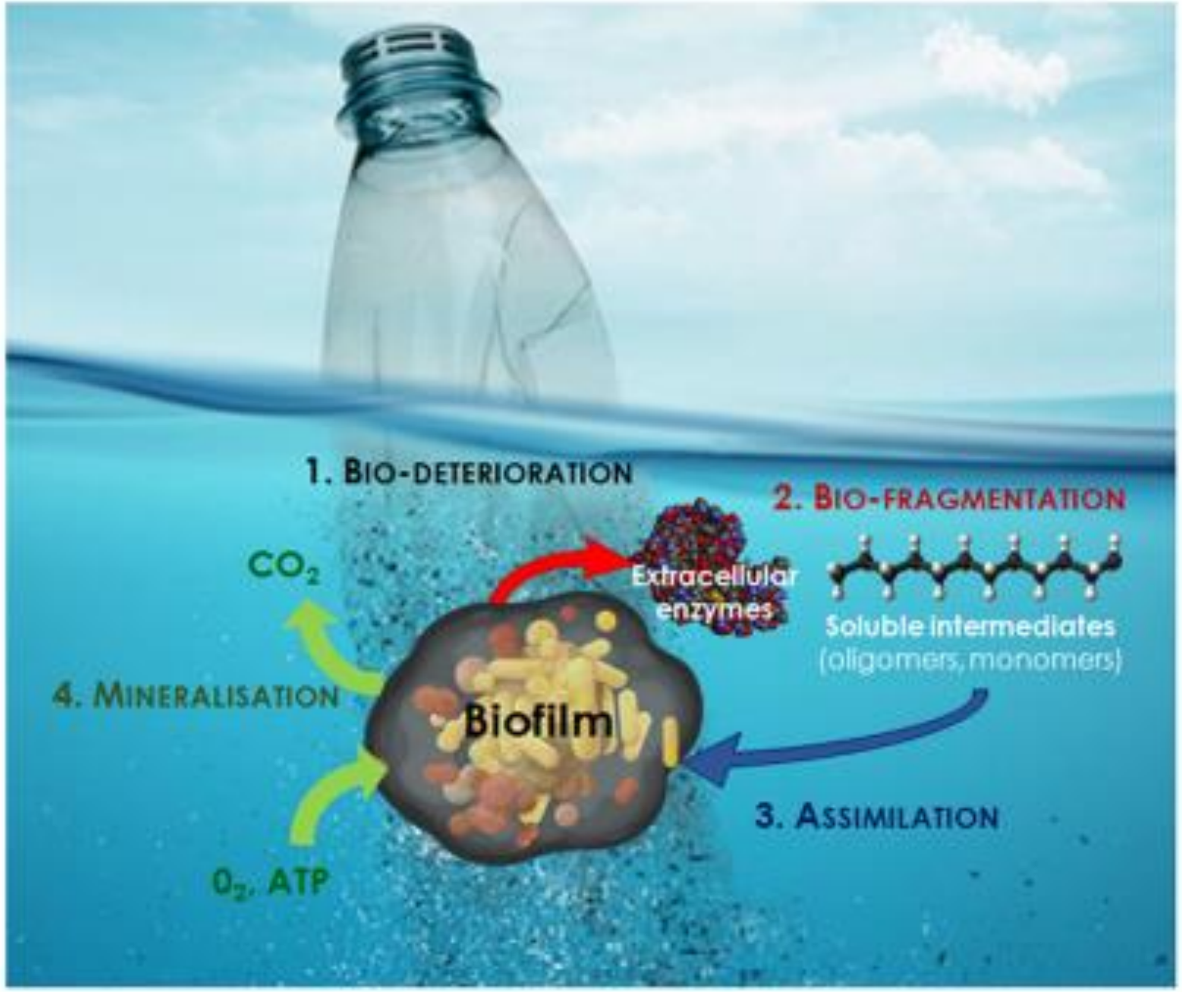


Figure 2 from Jacquin et al. (2020) paper

In Conclusion

- Microbe community composition are dependent on BOTH time and location (based on Amaral-Zettler, L.A. et al (2020) paper).

- There are currently 4 biodegradation pathways for plastics (based on *Figure 2* from Jacquin et al. (2020) paper).
    - One for each type of plastic PE, PET, and PS (polyethylene, polyethylene terephthalate, and polystyrene respectively).

    - One for a biodegradable plastic known as polyhydroxybutyrate (PHB)

Current Challenges: With respect to plastic as a substrate in the Marine Environment

- Carrying capacity of microbial communities on plastic debris is unknown/not agreed upon
- Majority of research have approached the topic from a colonization perspective
- Working with microplastic samples yields extremely low biomass for DNA extraction
- Knowledge of microbial communities in sediments are less common
- Most studies on plastics have been done on bacterial and archaeal composition

Literature Cited

1. Amaral-Zettler, L.A. et al. Ecology of the plastisphere. *Nat Rev Microbiol* 18, 139–151 (2020). https://doi.org/10.1038/s41579-019-0308-0

2. Amaral-Zettler, L. A. et al. (2015). The biogeography of the Plastisphere: implications for policy. *Frontiers in Ecology and the Environment*, *13*(10), 541–546. https://doi.org/10.1890/150017

3. Delacuvellerie, A. et al. (2019). The plastisphere in marine ecosystem hosts potential specific microbial degraders including Alcanivorax borkumensis as a key player for the low-density polyethylene degradation. *Journal of Hazardous Materials*, *380*, 120899. https://doi.org/10.1016/j.jhazmat.2019.120899

4. Erik R. Zettler, et al. *Environmental Science & Technology* 2013 *47* (13), 7137-7146 DOI: 10.1021/es401288x

5. Jacquin, J. et al. (2019). Microbial Ecotoxicology of Marine Plastic Debris: A Review on Colonization and Biodegradation by the "Plastisphere." *Frontiers in Microbiology*, *10*, 1–11. https://doi.org/10.3389/fmicb.2019.00865

Ecology of the plastisphere

Linda A. Amaral-Zettler[1,2], Erik R. Zettler[1] and Tracy J. Mincer[3]*

Abstract | The plastisphere, which comprises the microbial community on plastic debris, rivals that of the built environment in spanning multiple biomes on Earth. Although human-derived debris has been entering the ocean for thousands of years, microplastics now numerically dominate marine debris and are primarily colonized by microbial and other microscopic life. The realization that this novel substrate in the marine environment can facilitate microbial dispersal and affect all aquatic ecosystems has intensified interest in the microbial ecology and evolution of this biotope. Whether a 'core' plastisphere community exists that is specific to plastic is currently a topic of intense investigation. This Review provides an overview of the microbial ecology of the plastisphere in the context of its diversity and function, as well as suggesting areas for further research.

Microplastics
Generally, plastic particles smaller than 5 mm in size.

Fragmentation
Physically breaking an item into smaller pieces.

As global plastics production, which approached 350 million tonnes in 2017 (REF.[1]), has continued to rise[2] (FIG. 1), public awareness of plastic pollution in our environment has increased. With the United States and Canada recently placing restrictions on the use of microbeads in cosmetics and the European Commission's decision to ban some single-use plastics (which will come into effect in 2021), there is an increase in public pressure and legislation to dampen the input of plastic debris into our ocean and into the environment overall. In 2010, approximately 5–13 million tonnes of plastic entered the ocean[3], contributing to 15–51 trillion floating plastic particles circulating in the marine environment[4]. This increasing stream of contamination threatens to double by 2030 if the present rate of release continues[5]. studies confirm that we can only account for about 1% of the plastic litter that is released into the marine environment[4], the plastisphere biomass in the global ocean is likely to be substantial. Where is the missing plastic, and what are the ecological effects of plastic debris in the marine environment? Fragmentation results in many particles that are too small to quantify, due to limitations in sampling and analysis techniques, and even much of the floating plastic (polyethylene, polypropylene and expanded polystyrene; Supplementary Table S1) is hypothesized to ultimately end up below the ocean surface in different oceanic compartments, such as marine sediments via biofouling and the marine food web via ingestion[11,12].

Elucidating the role of plastic debris in the microbial loop, especially in the oceanic gyres or accumulation