POLLUTION

PLASTIC

MARINE

RESEARCH

Schmidt Ocean Institute Planning Workshop – Aug. 2014, Hawaii

Julia Reisser – PhD candidate, University of Western Australia
“Fashions change in all subjects, but in marine pollution, fashions are largely determined by public perceptions which are notoriously capricious.”

R. B. Clark
. Oxygen-demanding Waste
. Oil Pollution
. Metals
. Halogenated Hydrocarbons
. Radioactivity
. Dredgings, solids
. Heat, sound, light

Source: NOAA
Radioactive contamination

“Uncertainty is a key factor in fear of people”

Mitsuyoshi Urashima
**Fukushima**
2011
Levels of radioisotopes measured from March to July 2011 in surface ocean waters off the coast of Japan following the disaster at the Dai-ichi nuclear power plant located on the coast. Radioisotopes entered the ocean from atmospheric fallout and from water used to cool damaged reactors, which flushed into the ocean.

**Chernobyl**
1986
Levels of radioisotopes measured in 1966 in the Baltic Sea and Black Sea from atmospheric fallout following the disaster in the Chernobyl Nuclear Power Plant. The plant was located in Ukraine, hundreds of kilometers inland.

**Weapons Testing**
1960s
Levels of radioisotopes from fallout from atmospheric nuclear weapons tests, measured in the 1960s off Japan. Levels were higher in the immediate areas near Bikini Atoll and others places where weapons were detonated.
“Why make something that is used for minutes out of a material that last forever?”

Jeb Berrier
Global Plastic Production

Plastic is made of petrochemicals

Life Magazine (1955)

PACIA, PlasticsEurope, Industry Canada
Plastic Waste

The “throw away” is usually not recycled

US
8% is recycled
EPA (2010)

Australia
20% is recycled
PACIA (2011)

Japan
26% is recycled
PWMI (2012)
Ocean: the ultimate receiver

Land- and ocean-based sources

- Rivers
- Wind
- Tides
- Sewage Disposal
- Flood Events
- Vessels (fishing)
- Offshore platforms
Ocean sinks for plastic
Vary with biological and physical processes
Plastic fragmentation

Microplastics: the most abundant form of human-made debris

Malaspina Expedition 2010

CMORE

Browne et al 2011

Fendall 2009

Song et al 2014
Why does it matter?

Plastic ingestion

The University of Tasmania

National Geographic
Plastic ingestion
Physical & chemical impacts

Toxic additives (e.g. flame retardants, BPA)
Campioli et al. 2011

POPs from seawater (e.g. PAHs, PCBs, DDTs)
Engler 2012

WHAT GOES IN THE OCEAN GOES IN YOU.
Surfrider Foundation
Surface distribution: modelling
Oceanic plastic hotspots

Maximenko et al. 2011
Surface distribution: net sampling
Lack of data Indian Ocean and Western Pacific

Measured number of plastic items per sq km (in thousands)

- 0
- 0 - 50
- 50 - 150
- 150 - 350
- 350 - 700
- 700 - 3,500

Inner accumulation zone
Outer accumulation zone

National Geographic, Data from: Cozar et al. 2014
SHIPBOARD RESEARCH

“If curiosity killed the cat, curiosity may be the very thing that saves us, the oceans & planet ”

Wendy Schmidt
3D survey: amount and distribution

Wide size ranges; at sea surface, water column, seafloor

Nanometer——-Micrometer———-Millimeter———-Meter-sized

7000 – 35000 tons
3D survey: pollutants loads
~ pollutant, polymer, marine region, weathering level, biofouling
3D survey: metagenomics plastic biofilm

Hydrocarbon-degrading genes?

Plastic waste could be due to a greater abundance of standing stock bacteria in oligotrophic seawater, known to support a high degree of rare taxa, partly due to lower grazing and viral pressures. Additionally, a lower richness is expected in the more selective and metabolically active population of bacteria on the plastic surfaces supported by a relatively higher nutrient microenvironment. The distinctness of microbial communities from PMD was also reflected in the percentage of shared OTUs across the different plastic substrates (Figure 4) and Sargassum (data not shown). Collectively, we found 350 bacterial OTUs shared between the PE and PP samples. Seawater had the largest number of unique OTUs ($n = 1789$), but these were mostly rare. Seawater shared a minor proportion of its OTUs with PE (8.6%) and PP (3.5%), respectively. In contrast, OTUs in common between PP and PE represented a substantial proportion of their overall OTU assemblage with 40% of the OTUs shared between PE and PP and 30% of the OTUs shared between PP and PE. Therefore, Plastisphere communities, despite being quite variable, do appear to have a "core" of taxa that characterize them.

Community Membership.

To further determine the membership of the "core" Plastisphere community, we performed biomarker analyses. Linear discriminant analysis (LDA) effect size (LEfSe) revealed Plastisphere OTUs that characterized PP and PE samples, indicating plastic resins may select for particular microbial community members. Of particular interest were OTUs found on both plastics but not in seawater. These included bacteria documented as capable of degrading hydrocarbons including the filamentous cyanobacterium *Phormidium* sp. known to settle on benthic substrates and *Pseudoalteromonas*, a genus frequently associated with marine algae (Figure 3, SI Figure S1). Additionally, the alphaproteobacterial family Hyphomonadaceae, known for forming long holdfast filaments termed prosthecae (which were common in our SEM micrographs) were unique to PMD and comprised almost 8% of the OTUs on PP (SI Figure S1). Members of the Hyphomonadaceae can be methylotrophic, known to degrade hydrocarbons and present in hydrocarbon enrichments.

Figure 5 summarizes the biomarker results and highlights the differences between each plastic substrate and seawater. LDA scores are shown in SI Figure S3.

Network Analyses.

We can make inferences about organism associations from SEM observations of physical location and community architecture on the plastic surface. Although many bacteria cannot be identified visually, it is possible to infer interactions between members of the Plastisphere indirectly via association networks based on sequence data. We conducted network analyses to further explore co-occurrence patterns between members of the Plastisphere. Reporting all existing networks is beyond the scope of this paper, so we present only networks associated with putative hydrocarbon-degrading bacteria within our overall network. Figure 6 depicts these networks with the cyanobacterium *Phormidium* highlighted as green diamonds, *Hyphomonas* as blue diamonds, members of the *Chloroflexi* as purple hexagons and members of the *Myxococcales* as yellow triangles. The figure only depicts first nearest neighbors in the network with positive correlations having $R > 0.9$. Noteworthy were the co-occurrences of several members of putative hydrocarbon-degrading taxa in close proximity to each other in our network.

Figure 6. Network analysis diagram of putative hydrocarbon-degrading bacterial OTUs. The cyanobacterium *Phormidium* is represented in green diamonds, *Hyphomonas* is depicted in blue diamonds, members of the *Chloroflexi* are shown in purple hexagons and members of the *Myxococcales* are represented as yellow triangles. SI Table S3 includes the full taxonomy for all the OTUs in the network.
Shallow-water drifter deployment

Improve ocean plastic connectivity studies
At-sea feeding experiments

Does size matter? Current assumption: particle smaller than organism

Cole et al. 2013

Michels et al. 2012

Reisser et al. 2014
For discussion

- Efficient 3D survey (sensor for particles?)
- Metagenomics biofilm
- Shallow-water drifters
- At-sea feeding experiments