Published on *Marine Ecosystems and Management (MEAM)* (https://meam.openchannels.org)

The Skimmer: The Latest on Ocean Plastic in Just a Few Minutes

The Skimmer is a new MEAM feature where we review the latest news and research on a particular topic. For our first Skimmer, we're covering plastic in the ocean and its implications for management. We don't know about you, but we can barely keep up with the dizzying array of disturbing news on ocean plastic. But since it's our job to keep up with the news, the Skimmer is here to help out.

Editor's note: Please be aware that this is NOT a comprehensive review of the literature on plastic in the ocean. This is a roundup of some of what has come out lately – in this case in 2016 and 2017 – primarily in the published literature but with some supplements from popular news reports.

Love the Skimmer? Hate it? Know how it could be better? Want to see one on another topic? Let us know what you think! Send us feedback at meam@openchannels.org.

How much plastic is out there?

- The first global analysis of all mass-produced plastics ever manufactured estimated that 8,300 million metric tons of virgin plastics have been produced to date. This same study estimated that, as of 2015, approximately 6,300 million metric tons of plastic waste had been generated – of which 9% was recycled, 12% was incinerated, and 79% was in landfills or the natural environment.
- While we focus on really recent literature from 2016 and 2017 in this Skimmer, many of our sources reference a landmark 2015 study by Jambeck et al. on plastic waste inputs from land into the ocean. This study estimated that in 2010 alone,

4.8 to 12.7 million metric tons of plastic waste entered the ocean from 192 coastal countries.

- The research and consulting firm Eunomia pulled together a lot of numbers, both their own and from other sources. These estimates are based on medians of possible ranges and are therefore *very* rough. But they give an idea of the order of magnitude of plastic flows into and in the ocean. Eunomia estimates:
- 12.2 million metric tons of plastic enters the oceans every year
- Over 80% of this comes from land-based sources. This input is largely composed of larger plastic litter such as drink bottles and plastic packaging. Primary microplastics (plastics smaller than 5 mm and manufactured as microbeads, capsules, fibers, or pellets) are a small (<10% by weight) but important component of the total plastic entering the ocean environment.
- The remainder of plastic entering the ocean is released at sea, primarily from fishing activities (e.g., lost or discarded fishing gear) and shipping activities.

So the plastic entering the ocean from land-based sources, where is it coming from?

- In a nutshell, most of the plastic entering the ocean is coming from places with large populations and poor waste management. To be more specific, most of it is coming from the Asian continent. (Sorry, Asia.)
- The 2015 Jambeck et al. study estimated the top 20 contributors of mismanaged plastic waste, considering populations within 50 km of the coast in 2010. Nations on the Asian continent represented 12 of the top 20 countries, with China way out ahead of the pack. The African continent was runner-up with five countries in the mix, and Turkey, Brazil, and the US also made it onto the scoreboard.
- Eunomia's number crunching suggests that of the plastic entering the ocean from land-based sources (most of the plastic in the ocean), the bulk is coming from coastal populations (i.e., the plastic featured in the 2015 Jambeck et al. study above) and a smaller portion is coming from inland populations via rivers. Two 2017 studies are helping us to refine numbers for river discharge into the ocean, and, again, Asia is leading the way.
- One of these studies estimated that rivers contribute between 410,000 and 4 million metric tons a year to oceanic plastic debris with 88 to 95% coming from eight rivers in Asia – the Yangtze, Yellow, Hai He, Pearl, Amur, Mekong, Indus, and Ganges – and two in Africa – the Niger and Nile.
- Another recent study using somewhat different datasets and methods estimated that 1.27 to 2.66 million metric tons of plastic waste is entering the ocean every year from rivers, with 67% of that from the top 20 polluting rivers – 15 of which are in Asia.

Where does the plastic end up once it is in the ocean?

- It all ends up in the big garbage patch in the middle of the North Pacific, right? Nope. While there is undoubtedly a lot of plastic in surface waters of the North Pacific gyre (the highest concentration found anywhere on the ocean surface), some recent number crunching suggests that plastic at the surface of the ocean may be a relatively small portion of total plastic in the ocean and most of it may actually be at the bottom of the ocean. In fact, a better question than "where is plastic in the ocean?" would be "where isn't plastic in the ocean?"
- For starters, a recent study found that microplastic, in the form of microfibers (of which hundreds of thousands can be produced in each laundering of a polyester fleece jacket – yes, you read that right), is relatively abundant in deep sea sediments in the Atlantic Ocean, Mediterranean Sea, and Indian Ocean – four times more abundant than in surface waters. We are only now starting to understand how ubiquitous plastic microfibers are. The abundance of microfibers in the ocean (along with the abundance of plastic on the deep sea floor) may be a big part of the answer to the "missing plastic" question. "Missing plastic" is the large portion of plastic that we know has been manufactured but isn't accounted for in surveys of environmental plastics.
- Not only are microplastics in deep sea sediments, they are also in deep sea organisms. One study showed that plastic microfibers are ingested and internalized by deep sea organisms with four different feeding mechanisms - suspension feeders, deposit feeders, detritivores, and predators. Another study found that nearly half of marine invertebrates living

below 2,200 meters in the Rockall Trough in the North Atlantic had ingested microplastics.

- Moving north, while plastic debris is scarce or absent in a lot of Arctic waters, there is quite a bit of it in the Greenland and Barents seas, probably due to transfer from the North Atlantic. Further transport from here may be downward, so the seafloor in this area of the Arctic may be collecting a lot of plastic debris and may also be where some of that missing plastic is located.
- Then zipping down to the other pole, the Southern Ocean is not as pristine as we had assumed it was. Recent studies have found microplastics in deep sea sediments and surface waters.
- And, finally, one of the most remote islands on earth, Henderson Island in the South Pacific's Pitcairn Islands, is littered with an estimated 37.7 million pieces of plastic despite being uninhabited by humans.

What happens to plastic once it is in the ocean?

- We're not going to dig too deep into this question, but we will offer some quick points from a 2017 article that reviews what is known (and not known) about marine weathering of plastics. Once it is in the ocean, plastic debris is exposed to physical stress (from turbulence, abrasion with other particles, etc.), ultraviolet radiation, changing temperatures, salt, oxidizing conditions and colonization by microorganisms such as phytoplankton, bacteria, and fungi.
- Plastics break down into progressively smaller bits or "secondary microplastics", release chemical additives they are manufactured with, absorb and adsorb chemicals from the ambient water, get eaten and potentially passed along in the food chain, move with currents, and, last but not least, sink.
- These occurrences are definitely not mutually exclusive and can interact in complex ways. For instance, biofouling can increase the density of plastic debris and lead to it sinking. Being eaten by zooplankton may lead to plastic particles being incorporated into fecal pellets which are also relatively dense and sink quickly. Biofouling can increase uptake of plastic particles into the food web and slow the leaching of chemicals into seawater. Sinking lower in the water column or to the seabed can reduce exposure to ultraviolet radiation and physical stress and slow further weathering.
- In short, the whole thing is complicated, and we have a lot more to learn.

What impacts are plastics having on marine organisms and habitats?

- We're all familiar with the distressing photos of sea creatures tangled up in plastic or the stomachs of seabirds filled with plastic bits. Recent years have seen an increase in the roster of animals known to be affected by entanglement with and ingestion of plastic. One recent study used expert elicitation to parse out which plastic trash items were having the greatest impact on seabirds, marine mammals, and sea turtles. The response from experts? Ingestion and entanglement are worse than chemical contamination for these fauna, and fishing gear, balloons, plastic bags, and plastic utensils are the biggest problems.
- But where the marine plastics literature has really been hopping in the past few years is in discovering and synthesizing our understanding of microplastics. Remember those little bitty plastic bits (smaller than 5 mm) we talked about earlier? As we mentioned earlier, they are all over the place, are eaten by lots of different types of marine organisms (coral seem to love them, for example), release lots of potentially toxic chemical additives they are manufactured with, and are really, really good at absorbing and adsorbing contaminants already in the water. (Microplastics have a higher surface to volume ratio than macroplastics which means that plastic debris becomes even more effective at accumulating contaminants as it breaks down.)
- How bad is this for marine animals? Again, it's unclear, and the answer will undoubtedly be very different for different species and environments. It's worth bearing in mind, though, that while microplastics are indeed really good at aggregating contaminants in the water, these contaminants were already in the water and potentially being aggregated already by various prey species. So just because animals are eating microplastics with lots of nasty toxins doesn't mean the animals wouldn't be exposed to and eating those nasty toxins, at least at some level, anyway…
- But so far, exposure to microplastics at the concentrations currently found in the ocean don't seem to kill most marine organisms. Chronic exposure, however, can change the way marine organisms eat, grow, and reproduce. For a specific example, eating microplastics doesn't seem to do Pacific oysters and their larvae any favors. And this may mean bigger changes to marine populations, trophic structures, and ecosystems over time.

- And moving down in size from microplastics, some of the most disturbing recent discoveries relate to nanoplastics (particles smaller than 1 μm). Nanoplastics are produced by industrial processes or the breakdown of microplastics. Very little is known about their distribution in the marine environment because most sampling methods cannot detect nanoplastics.

- While we are starting to synthesize early research findings on microplastics, nanoplastics are really a new frontier, and very little is known about the impacts of nanoplastics on marine organisms and ecosystems. But early findings suggest that they have the potential to be even more disruptive than larger plastic particles. A very recent study published in *Nature* found that:

    1. Nanoplastics can get transferred up a food chain, in this case, from algae to zooplankton to fish

    2. Unlike exposure to larger plastic particles, exposure to plastic nanoparticles reduced the survival of zooplankton

    3. Nanoplastics can cross the blood-brain barrier in fish and accumulate in fish brain tissue and, in this study, the fish affected by nanoplastics ate more slowly and explored their surroundings less than unaffected fish.

Tea, anyone?

- And while most of the literature focuses on the impact of plastics on organisms, plastics can also alter habitats including sandy beaches, salt marshes, mangrove forests, coral reefs, seagrass beds, and oyster reefs. A nice short review of these impacts by habitat is here.

- In another fascinating bit of news, plastic has also been enabling an extraordinary rafting event in recent years, carrying species-laden debris resulting from the 2011 tsunami in eastern Japan across the Pacific Ocean to North America and Hawai'i. Researchers have documented 289 Japanese coastal marine species arriving alive on eastern Pacific shores, setting new records for transoceanic survival and dispersal of coastal species by rafting. Why this, why now? In large part it is due to the abundance of synthetic materials, including plastic, which float and don't degrade quickly.

Can we just clean it out of the ocean?

- That 2016 Eunomia number-crunching report estimated that that there is a global average of ~70 kg/km^2 of plastic on the sea bed, a global average concentration of less than 1 kg/km^2 of plastic floating at or near the surface, and a global average of 2,000 kg/km^2 on beaches. (Of course, local concentrations across the global sea surface vary tremendously, but the highest concentration recorded - in the North Pacific Gyre - is still only 18 kg/km^2.)

- Sooo…. This suggests that society might get more bang for its buck with localized litter traps and some good old-fashioned beach cleanups than with expensive gadgets floating around in the "Great Pacific Garbage Patch". Open ocean garbage collectors come with a host of other problems in addition to their expense.

- And, certainly, an ounce of prevention is probably worth a pound of cure in this case. A 2015 report describes what needs to be done to prevent plastic entering the ocean from land-based sources and a 2017 paper describes strategies for reducing microplastics pollution.

What are we doing to stop plastic from getting into the ocean?

- Well, in February 2017, the UN launched a global campaign to eliminate major sources of marine litter, including single-use plastic, by 2022. Over thirty countries have joined in and made commitments at a national level, including Belgium, Brazil, Canada, Colombia, Costa Rica, Denmark, Dominican Republic, Ecuador, Finland, France, Grenada, Iceland, Indonesia, Israel, Italy, Jordan, Kenya, Kiribati, Madagascar, Maldives, the Netherlands, Norway, Panama, Peru, Philippines, Saint Lucia, Seychelles, Sierra Leone, Spain, Sweden, Uruguay, and the UK.

- In addition, Sri Lanka has banned the sale of plastic bags, cups, and plates after the island's largest dump collapsed, killing 32 people. Flash flooding in Colombo is also blamed on plastic waste clogging storm water drains. Similarly, New Delhi, India, banned single-use plastic cutlery, bags, and more in large part due to air pollution from the illegal mass burning of plastic waste.

- Unfortunately, there is not a lot of research on proven methods to reduce plastic marine pollution from single-use plastics. A recent review of international policies to reduce plastic marine pollution from plastic bags and microbeads found that there has been little documentation or measurement of the effectiveness of these reduction strategies.

- In Portugal, a plastic bag tax did indeed reduce plastic bag consumption by 74%. But when there were no plastic bags from the grocery store to use as garbage bags, the consumption of actual garbage bags increased by 12%. All in all, probably not a bad tradeoff, although we'd need more specific numbers to really know.

- In the US, not so much forward progress on single use plastic reduction at a national level. The US National Park Service had stopped selling disposable water bottles at select national parks in 2011, but that initiative has now been placed on hold. There is some action at state and local levels, however, including an upcoming ban in Seattle, Washington, on all single-use plastics. So the fast-beating heart of US coffee culture may #StopSucking plastic straws.

- And while some countries have been working on tackling land-based sources of plastic marine pollution, the Global Ghost Gear Initiative has been serving up guidance for reducing marine-based sources of pollution with their best practices for preventing and reducing the loss of fishing gear at sea.

- And with any luck, there may be money from investors to help with all this work. A new report discusses how private capital can help reduce marine plastic pollution while also generating returns for investors.

That's a bummer about marine organisms, but what about me?

- Well, if you're eating seafood (or sea salt for that matter), there's a good chance you are ingesting some amount of plastic (ditto if you are drinking water).

- Is plasticky seafood bad for you? It's unclear. While the plastic in seafood is probably not good for you, experts estimate that the amount of chemicals (those added to plastic during manufacture and those adsorbed or absorbed from the environment) from microplastics that a person would ingest from a serving of seafood is negligible. [The consumption of pathogens on microplastics was not considered in this particular analysis, however.]

- A bigger concern is likely to be nanoplastics which are likely to be passed up the food chain to humans. Unlike microplastics, nanoplastics can leave the digestive system and enter other bodily systems, such as the immune system. So stay tuned on this front.

- And, of course, the amount of microplastic and nanoplastic in the ocean is expected to increase in coming years. This creates the possibility that the amount of chemicals you get from eating seafood may increase to a more harmful level in the future.

Good for you for making it this far! We're going to finish up with two big picture questions.

First, what impact is plastic having on marine ecosystems at an ecosystem level?

- We took the "ask an expert" option on this one and asked this question directly to leading ocean plastics guru Kara Lavender Law. Law is a research professor of oceanography with Sea Education Association in Woods Hole, Massachusetts and was co-lead for the National Center for Ecological Analysis and Synthesis (NCEAS) working group on marine debris from 2011 to 2015. According to Law, "This is one of the biggest questions in plastic marine debris research. Chelsea Rochman led a critical analysis of the literature through 2012 in a paper published in *Ecology* that asked the question about ecosystem level impacts of debris from evidence presented in the scientific literature. They found only two demonstrated impacts at the ecological level, both affecting the biological assemblage - one due to the addition of debris as artificial habitat, the other to smothering by debris. These impacts are not those most people think about when they think about plastic marine debris. We simply do not know what the ecological impacts are of plastics ingestion or entanglement, for example, on populations or ecosystems. This doesn't mean there are none, but these are very difficult questions to answer."

And second, how critical is plastic pollution relative to other ocean threats?

- I think that by now we've all read that horrific estimate that if we keep producing (and not properly disposing of) plastics at predicted rates, there will be more plastic (by weight) than fish in the oceans by 2050. While there is some debate about the accuracy of this estimate, there is undoubtedly a lot of plastic going into the oceans.

- We took the "ask an expert" option again here and asked Law this question. According to her, "Gauging the 'importance' of these impacts relative to other threats to ocean and ecosystem health is entirely dependent on the metrics - what is considered 'important'? It may be that today some of the other threats, such as ocean warming, ocean acidification, overfishing, eutrophication, etc., are having larger or more immediate impacts on particular cohorts or ecosystems. But the continuing acceleration in global plastics production with no clear 'best' management strategy for these materials at their end-of-life is a major cause for concern into the future."

Want to engage on plastics in the ocean?

If you want to follow and discuss the latest on marine debris in real time online, join:

- MarineDebris.info, the global online community for sharing knowledge on research, management, and prevention of ocean litter

If you want to learn more about and discuss plastic in the ocean in person, head to the:

- Sixth International Marine Debris Conference being held in San Diego, California, in March 2018

If you prefer your information by video, watch:

- Microplastics: What we know and discussion of research needs
- Plastic Waste Inputs from Land into the Ocean
- Microfibers: The Next Frontier of Plastic Pollution and the Search for a Solution
- Interactive panel discussion on utility and feasibility of cleaning up ocean plastics

If you need to explain marine debris to your kids, show them:

- Two Minutes on Oceans w/ Jim Toomey: Marine Litter

If you want to report marine debris, use:

- Marine Debris Tracker 101
