

## **WRITTEN TESTIMONY OF:**

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## **BEFORE THE U.S. HOUSE OF REPRESENTATIVES SUBCOMMITTEE ON WATER, OCEANS, AND WILDLIFE COMMITTEE ON NATURAL RESOURCES**

**HEARING: “Plastic’s Impact on Oceans”**

**October 29, 2017**

### **Key Points**

Based upon my testimony, the top five recommendations for how Congress can best support research, cleanup, or prevention efforts to combat marine debris are:

1. Funding the current agencies and initiatives, as well as new research through other agencies to provide science to further determine human health impacts (e.g., micro and nanoplastics) and mitigate this issue through the entire value chain of plastic (e.g., fate and transport of plastic in the environment, new materials and product design), which can provide economic innovation and growth, and also inform policy. Community-based data collection and citizen science with proper frameworks and structure can contribute to critical data needed to inform circular materials management in communities on the front lines of waste management.
2. To support prevention domestically, Congress could support legislation to reduce waste generation to reduce leakage of especially plastic packaging (and those items found in typical beach cleanups), like deposit-return schemes which show a 40% reduction in beverage containers where in place in the USA, as well as, for example, product stewardship/extended responsibility initiatives to increase the collection and value of waste.
3. To support prevention internationally, we can continue to provide funding through USAID and other bilateral initiatives, which I have seen give NGOs the opportunity to catalyze action, improve infrastructure and the economy, in countries like Vietnam, Philippines and Indonesia. We also need to make sure our exports are not negatively impacting other countries and support development in other countries so they may participate in trade using standards such as the OECD. We can also determine if our trade-agreements can influence other countries improvement of environmental standards, including solid waste management.
4. Show support for global initiatives to assist with the reduction of plastic entering the ocean and improvement of waste management infrastructure development around the world (e.g., with

world development banks, NGOs and industry), along with technology and knowledge transfer to other countries on solid waste management through, for example, the U.S. State Department, US EPA and NOAA. The newest USAID CCBO funding is one aspect of this process.

5. Derelict fishing gear is one of the most dangerous types of debris in the environment. Supporting the development of a program (through an agency) for fisherman to drop off gear that is broken or that they find could help this program (providing collection and disposal in areas where DFG has an impact). NOAA Marine Debris Program “Fishing for Energy” or similar could continue and/or expand.

## **Introduction**

I would like to thank Chairman Huffman, and the rest of the Water, Oceans and Wildlife Subcommittee for the opportunity to testify at this hearing to examine plastic’s impact on the ocean. It is an honor and privilege to be with you today. My name is Jenna Jambeck and I am a Professor of Environmental Engineering at the University of Georgia and a National Geographic Fellow. I have been conducting research on solid waste issues for 23 years with related projects on marine debris since 2001, especially projects regarding location and spatial analysis of debris, debris quantification and characterization, global plastic waste mismanagement and technology/mobile device usage (mapping, etc.). I have also sampled open ocean plastic sailing across the Atlantic and co-developed the mobile app, Marine Debris Tracker, funded by the NOAA Marine Debris Program. I have presented at three Capitol Hill staffer briefings, a Global Ocean Commission meeting, the 2015 Our Ocean Conference, a 2015 G7 workshop, and at the White House Office of Science Technology and Policy (OSTP). I also serve as the U.S. representative on an Advisory Panel for the United Nations Environment Program Global Partnership on Marine Litter. I testified on May 17, 2016 to the Senate Subcommittee on Fisheries, Water and Wildlife on this topic. I have been in the International Informational Speakers Program with the US State Department since 2017 and have been to thirteen different countries/economies working on the issue of marine debris and plastic waste in public environmental diplomacy (Chile, Philippines, Indonesia, Japan, South Africa, Vietnam, Jordan, Israel, South Korea, India, Bulgaria, Taiwan, and China). My testimony today is my opinion, based upon my background and experience in studying marine debris and plastic pollution.

## **Context**

I think it is important to provide context and introduction similar to when I gave testimony to the US Senate in 2016, the US regulatory history is always relevant. I grew up in the 1970s outside a small town (fewer than 3,000 people) in Minnesota. Like many people at the time, we managed our trash by taking it to the landfill and putting it in ourselves. I always found it fascinating to see what people throw away – and I have seen bowling balls to bologna in landfills. In graduate school, my fascination turned into a passion for studying solid waste management as an environmental engineer. Environmental engineers can also design urban drinking water and wastewater facilities, but to me, solid waste management felt like it most closely involved people. Unlike the small effort required to turn off a faucet or flush a toilet

(even a sensor can do this with no human effort), we all have to decide daily what to consume, what materials to use, what *is* and *is not* “solid waste” in our own home, and then whether to give away, discard, compost or recycle unwanted materials. The human component of solid waste management, and the direct interaction with people, is an aspect of my work that continues to be essential to my work.

In 1976 Congress passed the Resource Conservation and Recovery Act (RCRA) that required the U.S. EPA (typically through the states) to regulate solid and hazardous waste.<sup>1</sup> “Open dumping” was prohibited and replaced by engineered and regulated landfills, composting and recovery systems.<sup>2</sup> RCRA also specifically called for research to inform solutions, including demonstrations and special studies on measures to reduce the generation of waste, waste collection practices, and economic incentives to promote recycling and waste reduction (among other things).<sup>3</sup> Because of RCRA, we had outstanding progress in solid waste management, just in my lifetime. When I heard about our trash ending up in the ocean in 2001, I knew we must be contributing to it from the land, and started down the path of my current research. In this testimony, I am going to illustrate the direct connection between the solid waste (trash) we produce on land and the plastic found in our ocean, recalling that the human component goes hand in hand with local, state, regional, national and international initiatives to address this problem.

## Introduction

Marine debris has been recognized as a contamination issue for more than 50 years<sup>4</sup> but the laser-focus on plastic has occurred just in the past 5-7 years. Plastic completely changed our world after it’s expanded use in World War II, and global annual plastic production has increased from 1.7 million metric tons/yr in 1950 to 360 million metric tons/yr (not including polyester fibers) in 2019.<sup>5</sup> Along with a steep increase in production, we have seen a resulting increase in plastic in the waste stream from 0.4% in 1960 to 12.7% in 2012 (by mass) in the U.S. All traditional plastics do not biodegrade, but only fragment into smaller, ultimately microscopic or nanoscopic, pieces. A cumulative 8.3 billion metric tons of plastic has been produced since 1950<sup>6</sup>. Since approximately 40% of plastic is used for packaging and single use items, this means that 6.4 billion metric tons has become waste by 2015 (Figure 1)<sup>6</sup>. Globally, on average, we have recycled only about 9% of plastic, with 12% recycled and 79% ending up in our landfills or in the environment. With cumulative quantities projected to reach 34 billion metric tons of

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<sup>1</sup> Resource Conservation and Recovery Act (RCRA) - Public Law 94-580, October 21, 1976, (42 U.S.C. 6901-6992; 90 Stat. 2795), as amended by P.L. 95-609 (92 Stat. 3081), P.L. 96-463 (94 Stat. 2055), P.L. 96-482 (94 Stat. 2334), P.L. 98-616 (98 Stat. 3224), P.L. 99-339 (100 Stat. 654), P.L. 99-499 (100 Stat. 1696), P.L. 100-556 (102 Stat. 2779)

<sup>2</sup> Code of Federal Regulations (CFR) Title 40, Parts 239 – 282

<sup>3</sup> <https://www.epa.gov/aboutepa/new-law-control-hazardous-wastes-end-open-dumping-promote-conservation-resources>

<sup>4</sup> Ryan, P. (2015). A Brief History of Marine Litter Research, in *Marine Anthropogenic Litter*, Bergmann et al. (eds.), Springer, New York, NY.

<sup>5</sup> Plastics Europe,

[https://www.plasticseurope.org/application/files/9715/7129/9584/FINAL\\_web\\_version\\_Plastics\\_the\\_facts2019\\_1\\_4102019.pdf](https://www.plasticseurope.org/application/files/9715/7129/9584/FINAL_web_version_Plastics_the_facts2019_1_4102019.pdf)

<sup>6</sup> Geyer, R., Jambeck, J.R., Lavender Law, K. (2017). Production, use, and fate of all plastics ever made, *Science Advances*, 19 Jul 2017, Vol. 3, no. 7

production and 12 billion metric tons of waste, the management of plastic in the waste stream is only continuing to grow.<sup>6</sup>

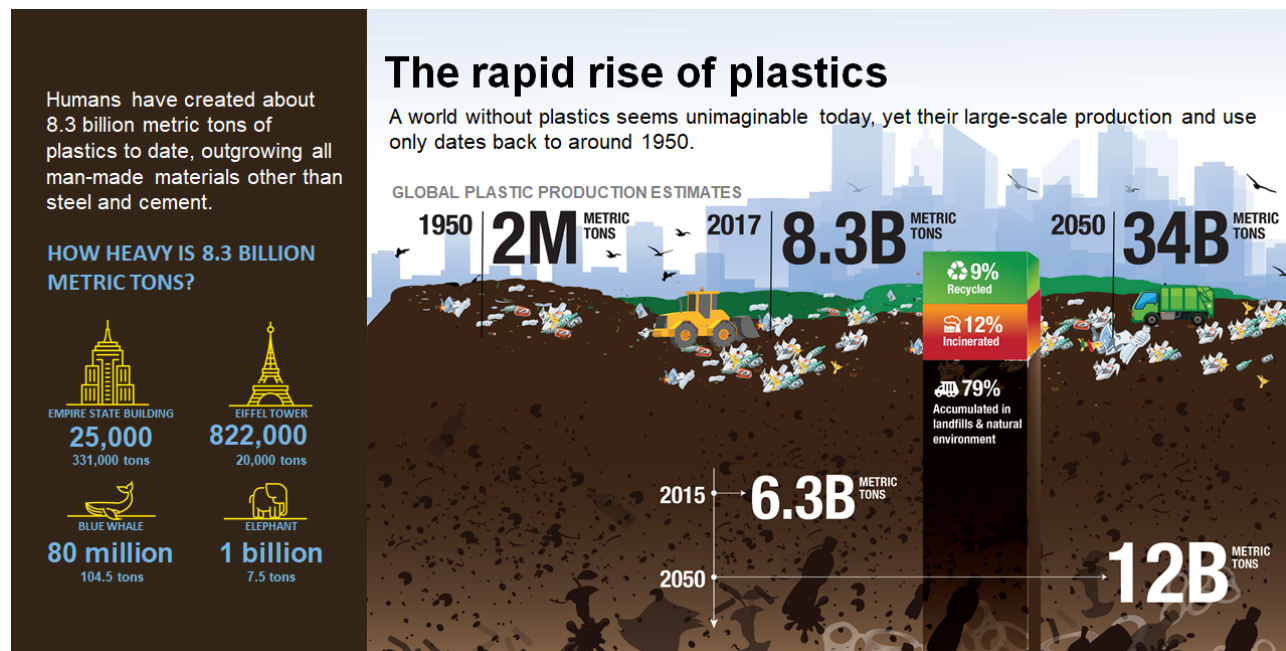


Figure 1. Global Materials Flow of Plastic<sup>6</sup>

Polymers that make up the plastics that we commonly encounter are listed in Table 1. But plastics also contain additives to alter color, texture, shape, form, antimicrobial surfaces, make it flame retardant, and for other properties.<sup>7</sup> The wide variety of available additives results in thousands of different plastic material compounds for particular purposes, creating a diverse array of plastic materials that end up in our trash, which can make recovery and recycling challenging. In the USA, the per person waste generation rate ranges from 4.48 to 6 lbs/person/day (2 to 2.7 kg/person/day), depending on the reference examined<sup>8</sup>. This is 2-6 times the waste generation rates of many countries around the world<sup>9</sup>. The recycling percentage for all plastic in the USA is the same as the global average, with only about 9% of plastic recycled, although rates for individual polymers vary (Table 1)<sup>10</sup>.

Table 1. Common Polymers, Uses and Density related to Seawater

Polymer	Recycling Number	Sink or Float in Seawater	Common Use(s)	USA Recycle Rate
Polyethylene Terephthalate (PET)	1	Sink	Individual beverage bottles, textiles	18.4%
High Density Polyethylene (HDPE)	2	Float	Gallon jugs, some personal care	10.3%

<sup>7</sup> Additives have been mixed into plastic compounds since they have been in the consumer market: Deanin, R.D. (1975). Additives in plastics, *Environmental Health Perspectives*, 11: 35-39.

<sup>8</sup> <https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#Generation>; <https://erefdn.org/national-waste-generation-recovery-and-disposal-assessment/>

<sup>9</sup> <http://datatopics.worldbank.org/what-a-waste/>

<sup>10</sup> [https://www.epa.gov/sites/production/files/2018-07/documents/smm\\_2015\\_tables\\_and\\_figures\\_07252018\\_fnl\\_508\\_0.pdf](https://www.epa.gov/sites/production/files/2018-07/documents/smm_2015_tables_and_figures_07252018_fnl_508_0.pdf)

			product and detergent bottles	
Polyvinyl Chloride (PVC)	3	Sink	Piping, siding (construction)	Negligible
Low Density Polyethylene	4	Float	Retail bags, thin film plastic	6.2%
Polypropylene	5	Float	Bottle caps, yogurt containers, toys	0.9%
Polystyrene	6	Sink (expanded floats)	Foamed/expanded PS in packaging	1.3%
Others	7	Nylon sinks	Fishing nets (nylon), carpet	22.6%

Since plastic “degrades” through fragmentation, the result is microplastic (smaller than 5 mm in size) in the environment. Secondary microplastics are formed by the fragmentation of larger items. Primary microplastics are manufactured in these small sizes. Some sources of primary microplastic are resin pellets and microbeads. Resin pellet loss has been addressed by the industry through their Operation CleanSweep program,<sup>11</sup> and recent federal legislation banned microbeads in personal care products as of 2018.<sup>12</sup> Secondary microplastics are found on our coastlines, in our sediments, and floating in the ocean aggregating in the five oceanic gyres. Using the largest available ocean microplastics dataset, a recent study estimated that 15 to 51 trillion particles, with a mass of 93 to 236 thousand metric tons, are floating on the sea surface globally; this is equivalent to only about 1% of the estimated input of plastic waste to the ocean from land in a single year.<sup>13</sup> Where the remaining plastic debris is in the ocean remains a major unanswered question. The majority of field sampling to date captures only particles larger than approximately one-third of a millimeter in size, but increasing numbers of reports of synthetic fibers (from clothing and woven ropes, for example) in freshwater and marine environments, and even in air, make microfibers now a major concern.<sup>14</sup> And, while many people think of marine debris as being only in the ocean environment, the Great Lakes are governed by NOAA’s Marine Debris Program, and are known to be contaminated with plastic (REF) and not to be overlooked are inland riverine inputs of which there are two global estimates for, but could make up 5% to 50% (likely around 25%) of the global inputs of plastic into the ocean.<sup>15</sup>

In the last decade, scientific research into marine debris, and especially plastic, has increased. In 2011, a scientific working group was convened at the National Center for Ecological Analysis and Synthesis

<sup>11</sup> <https://opcleansweep.org/>

<sup>12</sup> <https://www.congress.gov/114/plaws/publ114/PLAW-114publ114.pdf>

<sup>13</sup> van Sebille E, Wilcox C, Lebreton L, Maximenko N, Hardesty B D, van Franeker J A, Eriksen M, Siegel D, Galgani F and Law K L 2015 A global inventory of small floating plastic debris, *Environmental Research Letters*, 10 124006

<sup>14</sup> Woodall, L. C., Gwinnett, C., Packer, M., Thompson, R.C., Robinson, L.F., Paterson, G.L. (2015). Using a forensic science approach to minimize environmental contamination and to identify microfibrils in marine sediments. *Marine Pollution Bulletin*, 95(1), 40-46; Watts, A.J.R., Urbina, M.A., Corr, S., Lewis, C., Galloway, T.S. (2015). Ingestion of Plastic Microfibers by the Crab *Carcinus maenas* and Its Effect on Food Consumption and Energy Balance, *Environmental Science & Technology*, 49 (24), 14597-14604.

<sup>15</sup> Lebreton, L. C. M. et al. River plastic emissions to the world’s oceans. *Nat. Commun.* 8, 15611 (2017); Schmidt, C., Krauth, T., Wagner, S. *Environ. Sci. Technol.*, 2017, 51, 21, 12246-12253; Lechner, A., Keckeis, H., Lumesberger-Loisl, F., Zens, B., Krusch, R., Tritthart, M., Glas, M., Schludermann, E. (2014). The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe’s second largest river, *Environmental Pollution*, 188, 177-181,

(NCEAS). I was honored to be a part of this working group that spent three and a half years synthesizing data to describe the scale and impact of trash in ocean ecosystems. At least nine scientific articles have been produced from this group describing information to date,<sup>16</sup> advancing the science. The NCEAS work, along with other recent scientific work, has brought attention to the issue of plastic in the oceans further validating action at the global scale by the G7, G20, United Nations, and multinational global funding entities like the World Bank, the Global Environment Fund (GEF). In 2018, the Save Our Seas Act was passed with unanimous bipartisan support. And Save Our Seas 2.0 is in the legislative process now.

Similar to RCRA in the 1970's, sound science should be used when determining policies and solutions. Today, we have sufficient evidence to guide action to reduce inputs of plastic into the ocean. In parallel, new scientific information should be created to help us better understand the sources, sinks and impacts of plastic in our oceans.

### **Impacts from Plastic Marine Debris**

I will cover impacts briefly here, with further detail able to be obtained in my previous testimony to the Senate.<sup>17</sup> In 1966, two U.S. Fish and Wildlife Service employees, Karl W. Kenyon and Eugene Kridler, were among the first scientists to document plastic and wildlife interactions when they discovered plastic was consumed by seabird (Albatross) chicks that had died in the Hawaiian Islands National Wildlife Refuge.<sup>18</sup> Since that time, many individuals of a multitude of different species of wildlife have been found to be impacted by plastic. Like in the Albatross chicks in 1966, ingestion of and entanglement are the most commonly reported interactions. A comprehensive critical review of the literature on marine debris impacts was led by Dr. Chelsea Rochman in the NCEAS group. Of the 296 perceived threats of debris to wildlife that were tested, 83% were demonstrated (proven), and 82% of those were from plastic. There is evidence of impacts to individual animals and to assemblages of organisms suggesting decision-makers should take action in order to avoid risk of “irreversible harm.”<sup>19</sup>

Lost fishing equipment (e.g., nets and traps) can “ghost fish,” or drift while continuing to catch fish and kill wildlife. This can have an impact on the fishing and shellfish industry. One study in Puget Sound alone analyzed 870 recovered “lost” gillnets and found 31,278 invertebrates (76 species), 1036 fishes (22 species), 514 birds (16 species), and 23 mammals (4 species); 56% of invertebrates, 93% of fish, and 100% of birds and mammals were dead when recovered.<sup>20</sup> When experts were asked which marine

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<sup>16</sup> I reference some of them in this document, but the full list is available online here:

<https://www.nceas.ucsb.edu/projects/12645#>

<sup>17</sup> [https://www.epw.senate.gov/public/\\_cache/files/8/0/8074ded1-5986-4a9b-b033-2eb69e66993f/B775115948AB5A3C80BDDDB5B0287E8B3.jambeck-testimony.pdf](https://www.epw.senate.gov/public/_cache/files/8/0/8074ded1-5986-4a9b-b033-2eb69e66993f/B775115948AB5A3C80BDDDB5B0287E8B3.jambeck-testimony.pdf)

<sup>18</sup> Kenyon, K. W., & Kridler, E. (1969). Laysan Albatrosses swallow indigestible matter. *Auk*, 86, 339–343, also referenced in Ryan, P. (2015). A Brief History of Marine Litter Research, in *Marine Anthropogenic Litter*, Bergmann et al. (eds.), Springer, New York, NY.

<sup>19</sup> Rochman, C.M., Browne, M.A., Underwood, A.J., van Franeker, J.A., Thompson, R.C., Amaral-Zettler, L.A. (2016). *Ecology*, 97(2), 302-312.

<sup>20</sup> Good, T.P., June, J.A., Etnier, M.A., Broadhurst, G., (2010). Derelict fishing nets in Puget Sound and the Northwest Straits: Patterns and threats to marine fauna, *Marine Pollution Bulletin*, 60(1), 39-50.

debris item poses the greatest risk to marine life, fishing-related gear ranked first, followed by balloons and plastic bags.<sup>21</sup>

Marine debris can present physical hazards to shipping, boating, fishing and industrial systems by blocking navigation, fouling boat propellers, clogging water intakes or blocking pumping systems. Coastal tourism is also affected by marine debris and other litter. In the 1980s, when medical waste was found on some beaches, communities lost millions of dollars from a decline in tourism and increased costs for beach cleanup maintenance.<sup>22</sup> A 2014 study by the NOAA Marine Debris Program in Orange County, CA found that 1) residents are concerned about marine debris, and it significantly influences their decisions to go to the beach, 2) No marine debris on the beach and good water quality are the two most important beach characteristics to them, and 3) Avoiding littered beaches costs Orange County residents millions of dollars each year. If the debris were reduced by just 25%, it would save residents roughly \$32 million dollars in reduced travel to other beaches.<sup>23</sup> UNEP estimates the financial damage of plastics to marine ecosystems globally is \$13 billion each year.<sup>24</sup> A recent study outlined that there are negative impacts to almost all marine ecosystem services, negative impacts to human wellbeing (fisheries, heritage and recreation) at a cost of \$3300 to \$33,000 per metric ton of marine plastic per year, equaling \$264 billion per year at the mid-input estimate.<sup>25</sup>

Plastic also hosts an entire microbial community termed the “plastisphere.”<sup>26</sup> Plastic can transport non-native species and provide habitat for microbes that might not otherwise thrive, but we don’t yet know the full extent of this microbiome on ocean microbiology or the broader ocean ecosystem. Plastics in the ocean are associated with chemicals. This includes organic compounds like flame retardants, pesticides, and polychlorinated biphenyls (PCBs) that accumulate on the plastic from surrounding water. It also includes the additive ingredients of the plastic that can leach into the surrounding environment. Thus, plastic can transport these compounds around the world and be another potential source of contaminants to wildlife.<sup>27</sup> Some of the additives to plastic have come under question for toxicity<sup>28</sup>, but

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<sup>21</sup> Wilcox, C., Mallos, N., Leonard, G.H., Rodriguez, A., Hardesty, B.D. (2016). Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife, *Marine Policy*, 65 (2016), 107-114.

<sup>22</sup> NRC (National Research Council) Committee on Shipborne Wastes, Clean Ships, Clean Ports, Clean Oceans, National Academy Press, Washington D.C., 1995.

<sup>23</sup> Chris Leggett, Nora Scherer, Mark Curry and Ryan Bailey, Assessing the Economic Benefits of Reductions in Marine Debris: A Pilot Study of Beach Recreation in Orange County, California, Industrial Economics, Inc., for the NOAA Marine Debris Program, 2014.

<sup>24</sup> Raynaud, J. (2014). Valuing Plastic: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry, UNEP, Plastic Disclosure Project, Trucost.

<sup>25</sup> Beaumont, N., Aanesen, M., Austen, M., Börger, T., Clark, J., Cole, M., Hooper, T., Lindeque, P., Pascoe, C., Wyles, K., Global ecological, social and economic impacts of marine plastic, *Marine Pollution Bulletin*, Vol 142, 2019, Pages 189-195.

<sup>26</sup> A recent summary article that references multiple scientific references on this: Samoray, C. (2016). Ocean's plastics offer a floating fortress to a mess of microbes, *Science News Magazine*, February 9, 2016; Zettler, E.R., Mincer, T.J., Amaral-Zettler, L.A., (2013). Life in the “Plastisphere”: Microbial Communities on Plastic Marine Debris, *Environmental Science & Technology*, 47 (13), 7137-7146.

<sup>27</sup> Same as note 6. Plus, a good overview is Rochman, C. (2015). The Complex Mixture, Fate, and Toxicity of Chemicals Associated with Plastic Debris in the Marine Environment, in *Marine Anthropogenic Litter*, Bergmann et al. (eds.), Springer, New York, NY.

we don't yet know the full impact they have on aquatic systems.<sup>29</sup> Still, there has been evidence of the transfer of chemicals from plastic to fish in the lab, causing liver toxicity and impacting functions of the endocrine system and to other organisms in the field.<sup>30</sup> Plastic particles and fibers have also been found in the stomachs of fish, and in shellfish sold for human consumption.<sup>31</sup>

### **Input into the Ocean from Mismanaged Plastic Waste**

In the NCEAS group, as we started compiling information about sources and inputs of plastic into the ocean, we quickly concluded that mismanaged solid waste (trash) made up a large portion of the input. Other inputs include, but are not limited to, commercial fishing gear, shipping, recreational boating and fishing, and catastrophic events. Our first objective was to quantify mismanaged waste from land. To make the estimate of plastics entering the ocean from waste management, we developed a comprehensive framework (Figure 1).

Our methods for this estimate were to look at per person waste generation rates in 2010 from 192 countries with a coastline in the world. Because people's activities nearest the coast are responsible for most of the plastic going into the water, we limited our analysis to a 50km strip of the coastline. From there, we looked at what percent of that waste is plastic, and what percentage of that is mismanaged waste (which means litter or when waste is not captured and dumped on the land). From there we had three scenarios of input into the ocean: low, mid and high.

The results were that in 2010, we estimate that 275 million metric tons (MMT) of plastic waste was generated in 192 countries. Of that, 99.5 MMT of this waste was generated within 50km of the coastline, and 31.9 MMT was mismanaged. We then estimated that between 4.8 and 12.7 MMT (a mid-scenario of 8 MMT) reached the oceans<sup>32</sup> (Figure 2). This annual input of plastic is equal to 5 grocery-size bags filled with plastic going into the ocean along every foot of coastline in the world.

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<sup>28</sup> For example, antimicrobial – Yueh, M. and Tukey, R.H. (2016). Triclosan: A Widespread Environmental Toxicant with Many Biological Effects, *Annual Review of Pharmacology and Toxicology*, 56: 251-272; flame retardants – Agency for Toxic Substances and Disease Registry, Toxic Substances Portal - Public Health Statement for Polybrominated Diphenyl Ethers (PBDEs), September 2004 (accessed May 11, 2016) <http://www.atsdr.cdc.gov/phs/phs.asp?id=899&tid=94>

<sup>29</sup> Teuten, E. L., Saquing, J. M., Knappe, D. R. U., Barlaz, M. A., Jonsson, S., Björn, A., ... Takada, H.. (2009). Transport and Release of Chemicals from Plastics to the Environment and to Wildlife. *Philosophical Transactions: Biological Sciences*, 364(1526), 2027–2045.

<sup>30</sup> Rochman, C.M., Hoh, E., Kurobe, T., The, S.J., (2013). Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress, *Scientific Reports* 3, No. 3263; Rochman, C.M., Kurobe, T., Flores, I., The, S.J., (2014). *Science of the Total Environment*, Vol. 493, 656-661; Jang, M., Shim, W.J., Han, G.M., Rani, M., Song, Y.K., and Hong, S. H. Styrofoam Debris as a Source of Hazardous Additives for Marine Organisms, *Environmental Science & Technology*, Article ASAP, DOI: 10.1021/acs.est.5b05485

<sup>31</sup> Rochman CM, Tahir A, Williams SL, et al. Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. *Scientific Reports*. 2015;5:14340.

<sup>32</sup> Jambeck, J.R., Andrady, A., Geyer, R., Narayan, R., Perryman, M., Siegler, T., Wilcox, C., Lavender Law, K., (2015). Plastic waste inputs from land into the ocean, *Science*, 347, p. 768-771.





Figure 2. Plastic Waste Inputs from Land into the Ocean in 2010

The U.S. is one high income country on the list, and while our waste management systems are well-designed and very effective, and the only mismanaged waste is from litter, we have a large coastal population and a large waste generation rate. If we look to the future, and assume a business as usual projection with growing populations, increasing plastic consumption and increased waste generation, but no increase in capture of waste, by 2025, the 8 million metric tons doubles – with a cumulative input by 2025 of 155 million metric tons.

### Import-Export of Plastic Waste

While recycling and the circular economy have been touted as potential solutions to this issue, one can see from the recycling percentages given in the introduction, we have a long way to go for recycling to be significant. Approximately half of the plastic waste intended for recycling has been exported to hundreds of countries around the world (Figure 3).

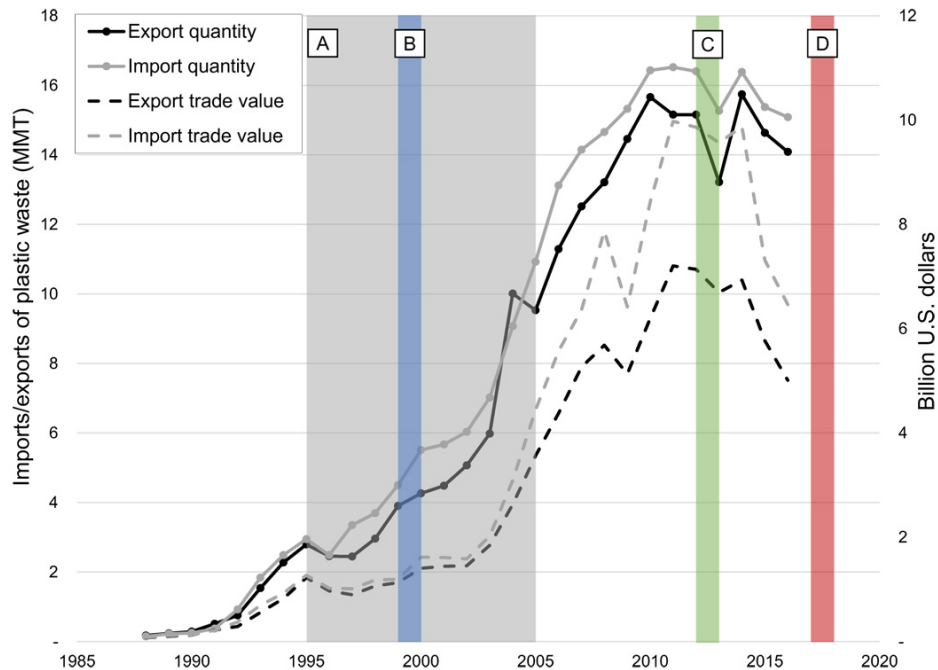


Figure 3. Trade of plastic waste in mass and trade value (UN Comtrade data)<sup>33</sup>

Before their import restrictions (resulting really in a ban) in 2017, China had imported a cumulative 45% of plastic waste since 1992<sup>33</sup>. Compiled commodity trade data by Amy Brooks in my research group illustrated that higher-income countries in the Organization for Economic Cooperation (OECD) have been exporting plastic waste (70% in 2016) to lower-income countries in the East Asia and Pacific for decades<sup>33</sup>. An estimated 111 million metric tons of plastic waste is displaced with the new Chinese policy by 2030<sup>33</sup> begging the question of where this plastic goes now and will continue to go – and causing one of the biggest economic disruptions to recycling ever to happen in the USA. With 89% of historical exports consist of polymer groups often used in single-use plastic food packaging (polyethylene, polypropylene, and polyethylene terephthalate), bold global ideas and actions for reducing quantities of nonrecyclable materials, redesigning products, and funding domestic plastic waste management are needed<sup>33</sup>. The USA and others who have exported to countries that lack waste management systems are responsible for some of this mismanagement. In China alone, this added another 11% of plastic mass to their waste stream to manage in 2015<sup>33</sup>. Rethinking trade agreements and the balance of resources to be able to participate in trade for countries (like small island states) that need to, is important. This is also a large global economic system that involves the livelihood of millions of people around the world. Improving their conditions and protecting the environment should be paramount. New amendments to the Basel Convention have put requirements on exporting countries to at least notify and get consent for shipments<sup>34</sup>. The USA could help lead efforts to both improve and develop domestic infrastructure while participating in responsible global trade of recycled materials.

<sup>33</sup> Brooks, A., Wang, S. Jambeck, J. (2018). The Chinese import ban and its impact on global plastic waste trade, *Science Advances*, 20 Jun 2018: Vol. 4, no. 6, DOI: [10.1126/sciadv.aat0131](https://doi.org/10.1126/sciadv.aat0131)

<sup>34</sup> <http://www.basel.int/Implementation/Plasticwastes/Overview/tabid/6068/Default.aspx>

## It's a Global Issue

Once plastic is in our oceans, it becomes a global issue and poses great logistical and economic challenges to get it out. In addition, the plastic is not always visible (although we find it everywhere we look, we have only quantified a fraction in our ocean compared with what is going in), so understanding potential risk to our ecosystems requires two things: 1) understanding the impact and 2) understanding the exposure. Our recent estimate of plastic entering the oceans informs the second part – exposure, just how much plastic is going into the ocean? But it also makes us ask – where is all the plastic going? While we know action will help “turn off the faucet” of plastic input (see potential interventions, below), there are still gaps in the sources, distribution, fate and impacts of plastics in the ocean that need more research if we want to continue to move forward in addressing this issue based upon science.<sup>35</sup>

## Interventions and Mitigation Strategies

I developed the framework below for my 2016 testimony<sup>36</sup> and would like to submit it again with some ideas, further explanation and answers to some of the questions posed by the senators in this hearing. This framework provides intervention points (1 through 5) and then a list of potential (but not all encompassing) interventions that may occur at the various points. In general, this represents a hierarchy of interventions. However, the most “bang for your buck” interventions will depend on the needs of the specific geography addressing the issue, however, in many cases, all geographies have points along the entire framework that will help reduce debris and plastic going into the ocean. Some interventions can be immediate and some will take more time. The framework starts on the left with the most “upstream” interventions and ends with a last chance to capture the material before it enters the ocean. In many cases the interventions offer the opportunity for economic innovation and growth. The USA could be a leader in several of these categories of interventions.

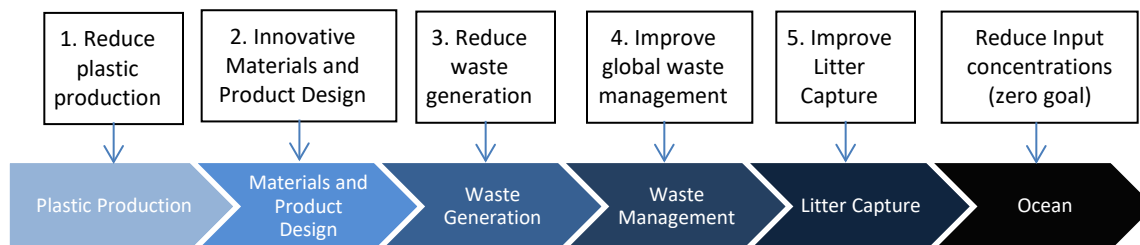


Figure 4. Intervention and Mitigation Strategies along some Points in the Plastic Value Chain

I'll now discuss some potential intervention points identified in Figure 2 in a bit more detail.

<sup>35</sup> A good recent review of why it is important to move forward with science-based solutions is provided in Rochman, C. (2016). Strategies for reducing ocean plastic debris should be diverse and guided by science, *Environmental Research Letters*, 11 014006.

<sup>36</sup> <https://www.epw.senate.gov/public/cache/files/8/0/8074ded1-5986-4a9b-b033-2eb69e66993f/B775115948AB5A3C80BDDDB5B0287E8B3.jambeck-testimony.pdf>

## 1.0 Reducing plastic production

Plastic production is one of the “book ends” of the plastic value chain. Other than a few of the past 65 years, global plastic production has increased annually, and is anticipated to continue to do so into the near future. Although it comes from fossil fuels for the most part, and is produced from monomers that come from the processing of oil and natural gas, these monomers (e.g., ethylene and propylene) are used to make many different compounds, not just polymers. As long as other common chemicals are made, it is likely that polymers will continue to be made as well. And, as economies around the world continue to develop, packaged goods become more prevalent. Unless the industry changes its own course, this stage is mostly influenced if levers in other stages are pushed (e.g., demand is decreased for other reasons along the value chain). Reduction in demand comes primarily from the points given below.

1. Consumers demanding less packaging or no packaging (some markets)
  - a. Not everyone has access to clean water, for example, so can't always make the choice of a reusable bottle, but these choices taken collectively where possible do make a difference
2. Local initiatives (e.g., bans, taxes)
  - a. These are often very local-specific, but are also becoming more common
  - b. Mass of items removed may be relatively small, but numbers of items are also important – there is more than one way to measure debris (e.g., mass, count, etc.)
3. Voluntary industry actions
  - a. Industry has become more engaged on this issue – I wonder if they will volunteer some changes to help in the future as well?
  - b. The reality is that all signs point to further growth in waste generation, as well as plastic use, especially where economic development is occurring or predicted to occur in the future

## 2.0 Innovative Materials and Product Design

New materials development and product design take time to advance, so these activities need to be happening now – and they are, but even more time and resource investment is needed. Overall, I think Green Engineering principles,<sup>37</sup> if followed during material development and product design, would help to avoid many of the externalities of plastic that we are dealing with currently. In addition, circular economy concepts, emerging all over the world now, will be important to also apply to plastic materials. Both of these guiding principles promote non-toxic materials, ultimately with the capability of biodegrading and/or being recycled. Materials and products made with more homogenous compounds would make recycling more efficient and effective. Materials and products can be designed to retain their value, for collection, recovery and recycling. Several of these concepts are outlined in Ellen MacArthur Foundation's report on the “The New Plastic Economy: Rethinking the future of plastics,” which focuses specifically on packaging.<sup>38</sup> The University of Georgia has combed environmental

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<sup>37</sup> <http://www.acs.org/content/acs/en/greenchemistry/what-is-green-chemistry/principles/12-principles-of-green-engineering.html>

<sup>38</sup> <https://www.ellenmacarthurfoundation.org/publications/the-new-plastics-economy-rethinking-the-future-of-plastics>

engineering and polymer chemistry in a successful and rapidly expanding New Materials Institute with centers on biodegradable polymers and circular materials management to develop and test materials to reduce the flow of plastic into the ocean. NMI has become part of a National Science Foundation (NSF) Industry–University Cooperative Research Centers (IUCRC) that has over 30 corporate partners interested in more sustainable and biodegradable polymer products. These industry-research groups participate in pre-competitive research and development as new materials need to scale to be economical for all to use. There is no doubt that developing alternative materials without the unintended consequences of traditional plastics will spark innovation and economic growth in the USA where truly biodegradable polymer production facilities (e.g., Polyhydroxyalkanoates (PHA)), like the ones in Georgia owned by Danimer Scientific and RWDC are creating jobs. There are many current corporate commitments to change materials, use more recycled materials, and be more circular with materials – many of these commitments have been made at the Our Ocean meeting that just occurred for the sixth time in Oslo Oct 23-24. \$652 million was committed by governments, corporations and NGOs to reduce ocean pollution, including plastics. Commitments to move to redesign were made by Unilever and PepsiCo, for example, moving to reduction in virgin plastic use and increases in recycled content<sup>39</sup>. Specific points are given for redesign and material substitution below:

1. Sustainable packaging associations (pre-competitive collaborations)
  - a. E.g., UGA’s New Materials Institute IUCRC, Sustainable packaging coalition, Green-Blue: These pre-competitive environments could help develop alternatives, standardize packaging and help packaging retain value so that it is easier to recycle and less leakage will occur if it has value.
2. Truly biodegradable alternatives (e.g., PHA)
  - a. PHA is expanding in the market in the USA and is creating economic value (new facility opening in Kentucky – several open in Georgia already). While it may biodegrade if littered in the environment, it should still be managed in the solid waste system, and be thoughtful about where used (in currently non-recyclable items, for example). But it has the possibility of being home-composted as well. The USA is currently a leader in the development of this material.
  - b. An important distinction should be made with polylactic acid (PLA), a popular corn-based polymer is bio-based and industrial compostable (avoids using fossil fuels as feedstock), but it will not biodegrade in home composting or in the ocean. It will not biodegrade if littered on land. It has to reach a high temperature (reached in industrial composting) to be able to biodegrade.
3. Packaging with more value (e.g., single, homogenous materials, design for recycling/end-of-life)
  - a. This can be helped by collaborations between industry, brands and waste managers/experts
4. Design out problematic items/materials (e.g., caps/lids)
  - a. Similar to how aluminum can “pop-top” opening was changed to a tab that stayed on (so the pull tabs did not get littered), we can innovate design for items that leak into the environment (if data is collected – see intervention point 5, last chance capture).

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<sup>39</sup> <https://ourocean2019.no/wp-content/uploads/2019/10/20191025-Commitments-1616.pdf>

### 3.0 Reduce Waste Generation

In places like the U.S., where we already have high per person waste generation rates, we can examine methods of waste reduction. For example, some of us have the luxury of being able to make choices about single use items we use daily. The majority of us have access to clean drinking water infrastructure so we can use a reusable water bottle, reusable coffee mug, bring a reusable bag to the grocery store, and say “no” to straws (or get reusable ones). These seem like small and mundane things, but what our research on plastic input showed is that since population density is such a big driver of these inputs, just one small choice, taken collectively, can make a big difference. There is a bit of a “chicken and egg” scenario here though, consumers can make choices, but they also need availability and access to those choices. For example, it might be hard to not buy bottled water if you don’t have access to a drinking fountain or water filling station. But this is also where policies regarding specific items of concern can provide motivation. Waste reduction can also occur from participation in new collaborative and sharing economies. These new paradigms are emerging and technology and social media are helping to move them forward. People are choosing to own less and “share” more. It started with car and bike shares, but has expanded to tools, and even clothing. As people become more aware of the issue of plastic in our environment, they are demanding companies reduce waste themselves, and help provide the right choices and infrastructure for people to reduce their own waste generation. Specific points on waste reduction below – and asking the question, *can we decouple waste generation from economic growth?* I get very excited to see what my students and young innovators will create in this category daily.

1. Using reusable items (e.g., bottles, mugs, bags, etc.) and if this is challenging for citizens, I ask them to think about why and what change is needed so it is possible at the government or corporate level? Then advocate for that change.
2. Sharing, Collaborative Economy concepts
  - a. Bike shares, car shares, tool shares, clothing rental, etc. these all reduce the need to purchase and create waste (facilitated by technology), but still meet people’s needs and can still create revenue for the companies providing the services.
  - b. How can these concepts be related to packaging? (see 2.b)
3. Decouple waste generation with economic growth (facilitated by technology)
  - a. Reuse programs (using mobile phones, which many people have globally, especially where rapid economic growth is occurring)
  - b. RFID, mobile phones, smart-labels, etc. (e.g., RFID water refill stations exist for both Coca-Cola and PepsiCo products, but are not yet widely distributed yet)

### 4.0 Improve Waste Management Globally

Improving waste management globally could go a long way to keeping a large mass of plastic out of the ocean (realizing mass is not the only meaningful metric for plastic – volume, count, shape, or impact to wildlife are other metrics). For example, in our *Science* paper the top 20 countries’ mismanaged plastic waste encompassed 83% of the total input in 2010. But with a combined strategy, in which total waste

management is achieved in the 10 top-ranked countries and plastic waste generation is capped, a 77% reduction could be realized by 2025. That sounds simple. We know how to design waste management systems, but in light of the context I gave at the beginning, waste management is much more than just a design challenge, it also has deep social and cultural dimensions. So we need to work together at a combination of local and global initiatives, and we need global participation from various stakeholders along the entire value chain of plastic (see following section on Circularity Assessment Protocol). Per person waste generation is coupled with economic development and, in many cases, the waste stream has fairly quickly changed characteristics to include more plastic. There are still many people in both the U.S. and globally that are unaware of the consequences of plastic in our aquatic environment.

Globally, innovation and creativity is needed in this space and people are heeding the call. Large, global NGOs are partnering with local groups in areas of concern to try to implement culturally appropriate mitigation strategies. Infrastructure is being integrated into existing informal waste management sectors in the hopes of continuing and improving people's livelihoods. U.S.-based groups can help in efforts for this global problem by connecting with groups who are trying to address these issues in their own countries, and there is a lot of work to be done. Some concepts that can be drivers in this area: zero waste (reduce disposal or destruction of waste to as close to zero as possible) and product stewardship/extended producer responsibility (waste management responsibility is shared or is the entire responsibility of product manufacturers). Plastic reuse and recycling can grow if the right economic structure is in place to motivate the collection of plastic waste and its reprocessing. Many local groups in global communities need some added support to elevate and expand what they are already doing to bring it to scale. Policies like deposit-return schemes reduce the quantity of plastic that reaches the environment. In US states that have these schemes, a 40% reduction of beverage containers is observed.<sup>40</sup>

Solid waste collection can be a hyper-local activity and can look different in each country, city and even neighborhood. Plastic has made it a more complicated and created a rapid change in the waste stream that we were ill prepared for. It creates a waste stream that is more varied and dynamic than we have ever experienced before. It has proved to be quite a challenge for waste operators and municipalities to manage. I have developed a "Five C" approach for this intervention point.

1. **Collect:** May be traditional, on-demand, or decentralized waste collection
  - a. Collection innovation is needed – reverse logistics may play a role
2. **Capture:** Material Recovery Facilities, waste depots, waste banks, community centers (e.g., "punto limpio" in Chile)
3. **Contain:** Recycling or engineered disposal
4. **Context and 5. Culture** – these can "make or break" the success of a potential intervention. The local community and stakeholders absolutely need to be engaged and involved from the start through the end of any project and not just led through it, but their local and indigenous knowledge is critical

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<sup>40</sup> Schuyler, Q., Hardesty, B.D., Lawson, T.J., Opie, K., Wilcox, C., Economic incentives reduce plastic inputs to the ocean, *Marine Policy*, Volume 96, 2018, Pages 250-255.

## 5.0 Litter Capture

Litter capture and collection is the last point to keep materials from entering the ocean. It is reserved for mostly the litter that occurs from inadvertent littering, lack of awareness and behavior issues. After outreach and education to prevent litter in the first place, there are street sweeping, municipal litter clean-up programs and stormwater catchment systems, all which will only be conducted in their respective jurisdictions. An innovative example of a final catchment device is the Baltimore Water Wheel.<sup>41</sup> Operated off of mechanical and solar energy in Baltimore Harbor, “Mr. Trash Wheel” has booms that skim the surface of the harbor and direct the floating trash to the conveyer system that removes it from the water and places it into a dumpster to be managed properly.

Non-governmental organization and volunteer cleanups to remove litter have been occurring for years. These events certainly help to keep litter from entering the ocean, and they are also a source of data. The Ocean Conservancy’s International Coastal Cleanup is now in its 33<sup>rd</sup> year and it not only helped to remove Over 10,500 metric tons of debris from beaches in 2018, but it has spread awareness and education as well. For the first time in 2017 and also in 2018, the top ten items found on beaches for the ICC were all plastic. In 2011, my colleague Dr. Kyle Johnsen and I co-developed a mobile app called Marine Debris Tracker at the University of Georgia funded by the NOAA Marine Debris Program. The Marine Debris Tracker mobile app and citizen science program allow for the collection of global standardized data at a scale, speed, and efficiency that wasn't previously possible <sup>42</sup> It also spreads awareness and education about this issue wherever it is used. Individuals all over the world have helped to clean-up or document over **2 million** items – by simply hitting a few buttons on their mobile phone to tell us what they found. User metrics provide a ranking and our largest group user is the Georgia Sea Turtle Center protecting and caring for Sea Turtles on Jekyll Island, GA and one of our largest individual user is in Omaha, NE (not far from the Missouri River) where he has collected over 87,000 pieces of litter alone, over the past 7.5 years. We, along with our app users, have fostered an online community through social networks – everyone is supportive of each other’s efforts and individuals know that they are a part of a large global effort. There is now enough (opportunistic) data in the database to start to examine characteristics and trends based upon the spatial and temporal data provided by our extremely dedicated users. Data is critical to informing upstream solutions and can really empower communities and decision-makers to be able to take actions driven by data. Last-chance cleanup points are summarized below.

1. Engineered, mechanical systems
  - a. Mr. Trash Wheel or other engineered devices
2. Manual (by hand)
  - a. Cleanups (e.g., ICC by Ocean Conservancy)
  - b. Use of ocean-bound plastic can catalyze the development of infrastructure since the material now has value – often a much higher value than it did previously (e.g., Parley, Dell, NextWave plastics)

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<sup>41</sup> <http://baltimorewaterfront.com/healthy-harbor/water-wheel/>

<sup>42</sup> Jambeck, J.R., Johnsen, K. (2015). Marine Debris Tracker: Citizen-based Litter and Marine Debris Data Collection and Mapping, *Computing in Science and Engineering*, 17(4), 20-26; <http://www.marinedebris.engr.uga.edu/>



3. Data to feed back to Interventions 1 through 4 in the Framework
  - a. E.g., Marine Debris Tracker developed by UGA (or other apps) to collect data
  - b. Could make upstream choices/changes based upon what is leaking into the environment

### **Community-Based Data Collection and Assessment**

Communities are at the front lines of this issue. They are where solid waste is managed and many decisions and development of waste management systems are made. They also experience the direct impacts of plastic pollution in their local environment. It is important we work with communities in the decision-making process to be able to come together on realistic and viable solutions. After I began traveling for the US State Department for the International Informational Speakers Program in 2017 (that has now brought me to 13 countries), I often find myself in the same situation over and over again. Speaking with governments and communities about this issue, they would say to me, “Well now that we know more about this issue, what can we do?” and I would pause (since I had not often been there very long typically), and tell them that they have the local and indigenous knowledge for solutions to this issue – they know their own context and culture. But I could also look around and take note of what I saw to contribute data for them to use... from what stores and cafes were selling in packing, from waste and recycle bins I saw, to litter on the ground. I also thought more about the concept of the circular economy – being touted as a solution to this issue, what does it really mean at the community level? How does a community move closer, or even see where they are at, related to the circular economy? In addition the community systems are an inherently complex, sociotechnical system, which is difficult to define with traditional metrics. There was a need for a methodology and a framework that provides a baseline understanding, illustrates the impacts of changes in the system, and facilitates useful knowledge exchange between cities, while allowing for flexible adaptation to local knowledge and expertise.

This is the context for how our Circularity Assessment Protocol (CAP) was developed in our Center for Circular Materials Management (the only center of its kind in the USA), in our New Materials Institute at the University of Georgia. Conducted in collaboration with a community and eventually by the community itself, the CAP characterizes seven community components: 1) inputs, 2) consumers, 3) product design, 4) use, 5) collection, 6) end-of-cycle management (e.g., waste management), and 7) plastic leakage into the environment. Various influencing factors drive this system including governance, economics, policy and legislation (e.g., bans, taxes, extended producer responsibility). Furthermore, multiple stakeholders exist at every level of the CAP influencing the complex system and these include citizens, government, industry, NGOs and academia. While the hub and spoke model illustrates the CAP (Figure 4), it is a complex system with components inherently interconnected to each other and to life-cycle impacts beyond each component.



Figure 5. The Hub and Spoke model of the Circularity Assessment Protocol (CAP)

While the CAP is a framework approach to addressing marine litter originating from land-based sources, it can also include data collection for marine or water-based sources through parallel research questions, and the quantity of leakage from this sector can be characterized during litter assessments (e.g., if fishing gear is an issue, it is typically evident on litter surveys on land as well). The framework supports points of intervention and actions, including guidance on effective impact (in terms of environmental and economic) to improve circularity. The CAP can help to inform a community by giving them a baseline assessment to work from and direct potential actions to take to improve the areas that most need it, and to answer specific questions they have about their own community. The CAP can inform and support the government to define policies and good practices related to solid waste management and infrastructure, including facilitating an understanding of solid waste and plastic management through a social lens. This can provide an understanding of people’s actions (both local and transient) which will inform policy and interventions.

The CAP is being used for projects funded by the World Bank, National Geographic, the Asia-Pacific Economic Cooperation (APEC) through the Ocean Conservancy, and USAID. Projects are completed or active in the Seychelles, Philippines (metro Manila), Chile, India, Bangladesh and at least two places in the USA, one small island community and a large metropolitan coastal city. A scaled-down version of CAP is being conducted in 30 small island and coastal community stopovers around the world with eXXpedition, and further development of the CAP for communities to conduct the process themselves within the framework is underway.

**The U.S. can be a Global Leader in Addressing this Issue**

Once plastic enters the ocean, it quickly becomes a global problem. The United Nations Environment Program has been addressing this issue through the Global Partnership for Marine Litter, with resolutions anticipated out of a meeting later this month. There is also the discussion of a global agreement with the potential for flexibility of countries to be able to reach reduction goals as they see fit. But the U.S. should be a leader in addressing this global issue, and it has in some ways. The U.S. Department of State has worked on this issue through the G7, G20 and Our Oceans conference. The NOAA Marine Debris Program started in 2006 with the Marine Debris Reduction Act (reauthorized in the Save Our Seas Act) and is one of the few agencies to provide grant assistance to community groups and research. The U.S. EPA has a Trash Free Waters Program that has expanded recently in bringing in partners and pilot sites around the U.S. NOAA and the U.S. EPA (chair and vice chair, respectively) lead the Interagency Marine Debris Coordinating Committee (IMDCC), a multi-agency body responsible for streamlining the federal government's efforts to address marine debris. Representatives meet to coordinate a comprehensive program of marine debris activities and make recommendations for research priorities, monitoring techniques, educational programs, and regulatory action. The IMDCC participants are the U.S. Army Corps of Engineers, U.S. Navy, U.S. Coast Guard, U.S. Fish and Wildlife Service, Bureau of Safety and Environmental Enforcement, Department of Justice, Environmental and Natural Resources Division, Department of State, Office of Marine Conservation, and the Marine Mammal Commission. Another group that has worked on U.S.-based marine debris issues is the National Fish and Wildlife Foundation. While U.S. scientists, universities, and research groups are at the forefront of the science of marine debris, there have only been a few research grants funded through the National Science Foundation and NOAA. Even while a multitude of domestic agencies and research groups have been working on this issue, resources are limited for addressing this issue and meeting our goals in being global leaders. Multi-agency cooperative programs could further advance the science of plastic contamination and pollution while also providing future economic benefits through startup companies and whole new industries. Community-based and citizen science programs to collect badly needed data, like our CAP using the Marine Debris Tracker mobile app can be used in the USA, as well as around the world.

## **Summary**

Based upon my testimony, the top five recommendations for how Congress can best support research, cleanup, or prevention efforts to combat marine debris are:

1. Funding the current agencies and initiatives, as well as new research through other agencies to provide science to further determine human health impacts (e.g., micro and nanoplastics) and mitigate this issue through the entire value chain of plastic (e.g., fate and transport of plastic in the environment, new materials and product design), which can provide economic innovation and growth, and also inform policy. Community-based data collection and citizen science with proper frameworks and structure can contribute to critical data needed to inform circular materials management in communities on the front lines of waste management.
2. To support prevention domestically, Congress could support legislation to reduce waste generation to reduce leakage of especially plastic packaging (and those items found in typical

beach cleanups), like deposit-return schemes which show a 40% reduction in beverage containers where in place in the USA, as well as, for example, product stewardship/extended responsibility initiatives to increase the collection and value of waste.

3. To support prevention internationally, we can continue to provide funding through USAID and other bilateral initiatives, which I have seen give NGOs the opportunity to catalyze action, improve infrastructure and the economy, in countries like Vietnam, Philippines and Indonesia. We also need to make sure our exports are not negatively impacting other countries and support development in other countries so they may participate in trade using standards such as the OECD. We can also determine if our trade-agreements can influence other countries improvement of environmental standards, including solid waste management.
4. Show support for global initiatives to assist with the reduction of plastic entering the ocean and improvement of waste management infrastructure development around the world (e.g., with world development banks, NGOs and industry), along with technology and knowledge transfer to other countries on solid waste management through, for example, the U.S. State Department, US EPA and NOAA. The newest USAID CCBO funding is one aspect of this process.
5. Derelict fishing gear is one of the most dangerous types of debris in the environment. Supporting the development of a program (through an agency) for fisherman to drop off gear that is broken or that they find could help this program (providing collection and disposal in areas where DFG has an impact). NOAA Marine Debris Program “Fishing for Energy” or similar could continue and/or expand.

As environmental engineers, we manage all solid waste that comes our way. But by connecting our activities on land with what ends up in our oceans, and through that awareness, realizing that we should be thinking about end-of-life in materials development and product design stages, we can shift the paradigm of “waste” to materials management. Also, the worldwide interest on this topic has put the spotlight on global solid waste management infrastructure needs, and so we need to collectively come up with creative, socially and culturally-appropriate mitigation strategies. Collectively, we hold the key to this problem. By changing the way we think about waste, reducing at source, designing products for their end-of-life management, valuing secondary materials, collecting, capturing and containing our waste, we can open up new jobs and opportunities for economic innovation, and in addition, improve the living conditions and health for millions of people around the world while protecting our oceans.

Previous questions from Congress:

*1. What are some of the most promising innovations?*

In my opinion some of the most interesting and promising innovations are the ones that decouple waste generation from economic growth. How can we meet people's needs and increase livelihood without creating more waste to manage? Sharing and collaborative economy concepts, RFID cups, using technology to connect people and facilitate sharing and reuse programs all lead to potential interventions. Reduce waste generation in the first place. See page X, above.

*2. What is role of PLA and other bio-based plastics?*

I think there is a role for material and product innovation and bio-based and biodegradable (truly) polymers will be a part of the solution. However, these materials are being produced at relatively low quantities right now, so they are not going to be a big market share for some time. And thought needs to go into what they replace as well as life-cycle tradeoffs. And an understanding of situational biodegradability is critical. See page X, above.

*3. Fisherman incentives*

I think incentives for fisherman to collect or bring back gear would be a way to get some of the most deadly gear out of the ocean and marine environment. I think also supplying a place for fisherman to put used gear is important (e.g., dumpster or recycle bin at the port). Tracking and transparency of nets – and really all plastic (as much as feasible) could help keep the material out of the ocean because we would have a better inventory of it.

*4. What are some of the root causes?*

Responsibility – while not particularly popular in the USA, product stewardship is an important concept to discuss here. From an engineering standpoint, when a company wants to build a development/civil engineering project, there often is a partnership with the community. One example, I live near an above ground storage tank farm, and trucks come and go from it regularly. There were likely road improvements needed to be able to build the tank farm and the company who constructed it may have contributed to that infrastructure since they were building at this site. In some ways, this can be analogous to selling products in a country or location that does not have infrastructure to manage the waste created from those products. I don't think companies knew the issues this would bring. And I think they want to help based upon new awareness, but we are certainly playing "catchup" with the issue now. Besides policies in other countries, some companies are doing this individually, but many still don't know how to help with infrastructure. I think that facilitating this in some way could be significant – maybe it will all be individual public-private partnerships, but some thought could go into how to facilitate companies engaging in shared responsibility. Ultimately it will take shared actions by industry, municipalities, and citizens to make significant positive change on this issue.

As often said, there is no one solution to this issue, but an integrated approach is needed to reduce and eliminate plastic entering and impacting our ocean.