Smithsonian Institution
Written Testimony of
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Plastic Marine Debris Research

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Introduction

Thank you, Chair McCollum, Ranking Member Joyce, and members of the Subcommittee for the opportunity to come before you today to testify on behalf of the Smithsonian Institution. My name is Linsey Haram, and I am a marine ecologist from the Smithsonian Environmental Research Center, where I study how plastic marine debris alters the dispersal and distribution of marine organisms across oceans.

The Smithsonian Environmental Research Center, or SERC, is a world leader in environmental research, especially in coastal marine ecosystems. SERC scientists are based at core laboratories on the Chesapeake Bay and San Francisco Bay, and work with collaborators across a truly global network of sites. Primarily funded by grants and contracts through such agencies as the U.S. Coast Guard, the National Science Foundation, the National Oceanic and Atmospheric Administration, the Department of Defense, and many others; SERC research aims broadly to understand fundamental ecological processes and changes at the land-sea boundary.

One area of focus at our facility is the study of marine invasive species, which is my area of expertise. The Marine Invasions Research Lab at SERC is the largest research program in the nation on biological invasions in coastal marine waters. Biological invasions occur when species are transferred by human activities to new (unoccupied) areas, where they establish new populations and spread, sometimes resulting in unwanted economic and ecological impacts. My colleagues have researched the causes, effects, and dispersal of invasive species within coastal ecosystems for over 3 decades. My research elucidates a missing link in our understanding of these processes - the emerging problem of plastic marine debris as a major source of invasive species spread across oceans.

Plastic Marine Debris

Plastic production has rapidly increased since its industrialization in 1950, having grown from 2 million tons produced in 1950 to 380 million tons in 2015 – half of which was produced within the past 13 years[1]. From 1950 to 2015, a total of 7.8 billion tons has been produced, with 6.3 billion tons discarded; less than 10% of plastic waste in this same period was recycled[1]. A large portion of the waste produced annually occurs in coastal communities because human populations are concentrated on the coasts. In 2010 alone, over 35% of the 275 million tons of global plastic waste generation occurred in coastal communities[2]. In areas with mismanaged waste, plastic pollution can be directly delivered from the land to our oceans, with an estimated 8 million tons of debris entering the oceans from coastal communities each year[2]. Effluent from rivers[3] and fishing gear from offshore fisheries further contribute plastic waste to ocean ecosystems, though resolved estimates for these sources are needed.

We now know that plastic debris is widespread in our oceans and accumulates in high concentrations in gyres, which are areas of current convergence and low flow in the open ocean[4]. One of these areas is the North Pacific Subtropical Gyre (NPSG), commonly called the Great Pacific Garbage Patch, which has the greatest reported concentrations of plastics in the oceans[5]. While much of this plastic debris consists of small microplastics, larger meso- to megaplastics are also common and make up an estimated 75% of the total mass of plastics in the NPSG[5], including:

- Ghost nets (massive conglomerations of derelict fishing nets)
- Associated fishing gear (buoys, fish crates, eel trap cones)
- Bottles, buckets, and jugs
- Miscellaneous household goods
- Plastic fragments

Once at sea, plastics are often buoyant and do not biodegrade, allowing them to persist for long periods of time, accumulate in gyres, and be carried by currents over great distances. This is unlike wood and other natural materials that degrade much more rapidly. The emergence and persistence of large plastics has created a novel and growing ***floating ocean ecosystem***, where

[1] Geyer et al. 2017. Production, use, and fate of all plastics ever made. Science Advances, 3: e1700782.
[2] Jambeck et al. 2015. Plastic waste inputs from land into the ocean. Science, 347 (6223): 768-771.
[3] Lebreton et al. 2017. River plastic emissions to the world's oceans. Nature Communications, 8: 15611
[4] Eriksen et al. 2014. Plastic pollution in the world's oceans: more than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. PLoS ONE, 9(12): e111913.
[5] Lebreton et al. 2018. Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. Scientific Reports, 8:4666.

large plastics are colonized by a wide diversity of organisms and transported across oceans. The magnitude and spatial scale of this species rafting on plastics is unprecedented in history, creating a new mechanism for invasive species introductions to coastal ecosystems of the United States and elsewhere.

Floating Plastics as Vectors for Invasive Species

Invasive species are animals, plants, and microbes that are introduced to a new ecosystem, usually through human activities, subsequently causing harm to their new ecosystems. When new predators, parasites, competitors, or pathogens are introduced, they can impact native biodiversity, fisheries, and water quality, impairing ecosystem services, local economies, and health.

Historically, the main drivers of invasive species introductions in coastal ecosystems are vessels, which deliver marine species from around the world in their ballast water and on their hulls. Within the past decade, however, floating plastic debris has entered as a potential new source of coastal species introductions.

The scientific community became aware of the potential importance of plastics for invasion dynamics following the Eastern Japan Tsunami. On March 11, 2011, a devastating 9.0 magnitude earthquake struck off the coast of the Japan's Honshu region, causing a tsunami over 120 feet high in the hardest hit areas. As the wave receded, it carried millions of tons of debris with it into the Pacific Ocean. One year later, in the spring of 2012, Japanese tsunami debris began washing ashore along the coasts of western North America and Hawaii. In an international effort led by SERC and Williams College, scientists, natural resources managers, and volunteers collected 634 Japanese tsunami debris and surveyed them for the biology attached[6]. Over a 6-year period, 287 marine invertebrate species, 2 fish species, and 49 seaweed species from Japan arrived on North American beaches alive, and in some cases, reproductive; over 5,000 miles from their home shores of Japan[6,7]. This study, published in Science, marked the first time in history that scientists were able to observe the transport of non-native species to distant shores in real-time. The scale and duration of this event was unprecedented, due in part to the presence of highly durable man-made debris, particularly plastics and plastic-compound materials, which effectively acted as rafts for coastal species at sea.

Current Research and Collaborations

[6] Carlton et al. 2017. Tsunami-driven rafting: transoceanic species dispersal and implications for marine biogeography. Science, 357: 1402-1406.
[7] Hansen et al. 2018. Genetic identification of macroalgal species on Japanese tsunami marine debris and genetic comparisons with their wild populations. Marine Pollution Bulletin, 132: 74-81.

Though the tsunami debris research provided essential information about the ability of hundreds of coastal species to raft across the open ocean and successfully land on new shores, many questions remain. In a NASA funded, multi-institutional research project, titled *Floating Ocean Ecosystems* (FloatEco), my colleagues and I build upon the results of the Japanese tsunami debris effort with the purpose of better understanding the movement of large floating plastic marine debris in open ocean gyres and the ecological communities attached.

FloatEco combines expertise from marine ecologists from SERC, Fisheries and Oceans Canada, and Williams College and oceanographers and engineers from University of Hawaii, Scripps Institute of Oceanography and University of Washington – Applied Physics Laboratory. Our interdisciplinary team also includes the ocean health non-profit, Ocean Voyages Institute.

Our research, which takes place in the area of highest plastic accumulation in the NPSG, aims to elucidate the dynamics of this floating ocean ecosystem of marine debris and especially its role in dispersal and distribution of coastal species. We seek to answer the following questions:

- Are coastal species common on floating plastic debris in the open ocean, gyre ecosystems? How many coastal species utilize this new habitat?
- How does the distribution and movement of debris affect survival, reproduction, and fate of coastal organisms in the ocean?
- How does debris type influence community composition and origin of both coastal and open ocean species?
- How do different types of floating plastic debris drift through gyre environments? Can we predict their trajectories based on debris type, size, and oceanographic conditions?

These are large scale questions that can only be answered through the synthesis of effort by multiple stakeholders. Thus, the FloatEco team works closely with external collaborators to maximize our capacity for data collection. Below, we outline our research on floating ocean ecosystems in three primary efforts: **1) Ecological community surveys, 2) Large floating debris movement, and 3) Marine invertebrate colonization.**

1. Ecological Community Surveys

Through collaboration with non-profits and citizen scientists, we collect debris from our target study area in the NPSG. Oceanographers from the University of Hawaii model distributions of floating debris in the region and direct the collaborators to projected areas of highest plastic debris accumulation. During their journeys, our external collaborators either collect debris or they sample the marine invertebrates and seaweeds attached to the large floating debris in the field. All samples are sent to SERC and analyzed by FloatEco biologists.

Once in the lab, these samples are analyzed for the following characteristics:

- Species present (identified to lowest taxonomic level possible)
- Natural species distribution – coastal vs. pelagic

- Signs of reproduction
- Size class structure

All species present are characterized as those with natural distributions in the open ocean or coastal ecosystems. To determine if populations are sustaining at sea, we also analyze the marine invertebrates for evidence of reproduction and presence of multiple generations through age structure.

During the past year, we collected over 150 floating plastic debris items with the help of five external collaborators.

2. Large Floating Debris Movement

Though we know that plastic debris concentrates in gyres, there are gaps in the scientific knowledge regarding how large floating plastics respond to wind and oceanographic dynamics in these unique systems. Additionally, we do not know how differently floating debris responds based on type and size. To address these unknowns, we deploy Langrangian drifters, which measure ocean currents and conditions, and tag debris with GPS tracking buoys within the NPSG.

Lagrangian Drifters. FloatEco oceanographers from the Scripps Institute of Oceanography's Langrangian Drifter Lab and University of Hawaii, construct drifters of different shapes and depths within the water column to better determine how these factors affect the paths of floating debris.

GPS-Tagged Debris. Through our collaboration with Ocean Voyages Institute, we track large floating plastic debris in real-time within the NPSG. To do so, our external collaborators attach specially manufactured GPS tracking buoys to drifting derelict fishing nets (i.e. ghost nets). Once tagged, the locations of the ghost nets are tracked continuously via satellite GPS.

The trajectories of both the Langrangian drifters and the GPS-tracked ghost nets inform oceanographic models created to more accurately predict the seasonal distribution and movement of debris.

3. Marine Invertebrate Colonization of New Debris

In addition to establishing the presence of coastal species on debris in the NPSG, we also need to know if coastal species can colonize new debris when it enters the open ocean. If coastal species do colonize new plastics, coastal species populations may be able to persist and spread within gyres, making these novel floating ecosystems a source of non-native species.

Colonization Arrays. To investigate the colonization of new debris by coastal species, we have adapted methods used by the SERC Marine Invasions Laboratory for monitoring invasive marine invertebrates along coastlines. In our current design, four PVC discs stacked 0.5 inches apart along a central axis create a complex structure meant to mimic plastic debris. The colonization arrays are attached to both drifters and GPS-tagged debris. After several months, the colonization arrays will be recovered, and we will analyze each PVC disc for community composition and abundance. As in our *Ecological Community Surveys*, we will also measure reproductive state and size class structure.

By combining what we learn from our above research efforts, we will better understand how floating plastic debris disperses coastal species and the extent to which it may contribute to the spread of marine invasive species.

Education and Outreach

At SERC, as a complement to our research, we prioritize professional development of the next generation of scientists as well as effective science communication and education for the public.

The issue of plastic marine debris is truly global and one that requires buy-in from all stakeholders involved. Thus, in SERC's tradition, we prioritize outreach and education as a deliverable of our plastic marine debris research. Examples of our efforts include:

- A booth about floating plastic ecosystems at the World's Ocean Day event in the National Museum of Natural History.
- SERC Education department curriculum about plastic ingestion by albatrosses.
- Lectures and presentations at local community centers.
- Coverage in science journalism pieces and other media.
- Creation of a citizen science project for collection of plastic marine debris.
- Inclusion of young scientists in research activities.

From our participation in these activities, it is clear that more education about the societal and environmental context of our plastic pollution issue is needed; and in order to effectively communicate the issue to the public, we need to prioritize more cross-disciplinary research that identifies our current unknowns.

Conclusion

The research presented above highlights an under-investigated aspect of plastic marine debris as a vector of future marine species invasions. Through this work, we aim to clarify the role of plastic marine debris in creating a novel open ocean ecosystem and in transporting species across oceans in historically unprecedented ways. Beyond this research, there are still many unknowns about plastic pollution's sources, sinks, impacts, and solutions. We are in the early stages of understanding the extent of our global plastic pollution issue. Given the scale of the plastic marine debris problem and the scope of the unknowns, greater prioritization and standardization of research is necessary to ensure the future health of our oceans.