Clean Ocean Action: Microplastic Research Agenda 2014-16

Overview of Current and Planned Research:

In January 2014, Clean Ocean Action (COA) assembled a research team of national and international scientists to establish protocols to document the scope and magnitude of microplastics on shorelines, in waterways, and marine life, as well as to help establish a model for assessing marine microplastics using citizen science principles. Currently, the assessments are being conducted in New Jersey.

Microplastics, or plastic pieces < 5 mm in size, are increasingly common in the marine environment and cause serious ecological concerns. Moreover, in the process of degradation, plastic debris releases toxic chemicals used in their production, such as bisphenol A (BPA) and styrene trimer (a liquid hydrocarbon), which have been linked to endocrine disruption. Plastics in the ocean have also been known to attract persistent, bio-accumulating and toxic substances (PBTs),[1] which include polychlorinated biphenyls (PCBs), dioxins, and petroleum based chemicals. There are two sources of microplastics: 1) the breakdown of larger pieces and 2) manufactured products.[2]

Initial sampling was conducted in the spring of 2014 and engaged specially trained high school students and citizen volunteers. The first phase involved nearly 200 samples (of sand and water) that were collected along the coast of New Jersey and processed and analyzed at the micron level at the National Oceanic and Atmospheric Administration (NOAA) James J. Howard Marine Sciences Laboratory at Sandy Hook in consultation with NOAA scientists. The protocols and techniques have been successful in extracting and identifying microplastics in both media. As of the publication of this document, samples are still being analyzed, but the presence of microplastics measuring less than 5 mm in size has been successfully documented.

In tandem with this first phase of research, COA created a Citizen Manual based on the Environmental Protection Agency's (EPA) Estuaries Monitoring Manual.[3] This Citizen Manual was drafted to guide and standardize citizen participation in the microplastics investigation on beaches and in waterways. This manual is currently under reviewed and is anticipated to be available in Spring 2015.

With its interdisciplinary Research Team and guided by the principles of citizen science, COA will be implementing two additional phases of microplastics investigation. These include assessing plastics visible to the naked eye along with the presence and abundance in the intestinal tract of common marine fishes which will include engaging recreational and commercial fishermen. At each phase of the project, the Citizen Manual will be amended to include such phase to create a model for future endeavors.

Each phase of the research will be linked to the identification of sources and solutions to prevent the release and reduction of microplastics in the marine environment. COA will engage citizens and policy makers to accomplish this through education and advocacy.

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[1] Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C., & Kaminuma, T. (2001). Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. *Environmental Science and Technology, 35*, 318-324.

[2] Hidalgo-Ruz, V., Gutow, L., Thompson, R., Thiel, M. (2012). Microplastics in the Marine Environment: A Review of the Methods Used for Identification and Quantification. *Environmental Science and Technology*, 46, 3060-3075.

[3] Ohrel, R., Register, K. (2006). Volunteer Estuary Monitoring: A Methods Manual, Second Edition. Found at http://water.epa.gov/type/oceb/nep/upload/2007_04_09_estuaries_monitoruments_manual.pdf

Clean Ocean Action – Who are we?

Clean Ocean Action is a nonprofit, ocean advocacy organization comprised of a coalition of 125 groups with a shared mission to improve the degraded water quality of the marine waters off the New Jersey/New York coast. Since 1984, COA has used a combination of science, policy, education, and citizen action to achieve its goal of a cleaner ocean for recreation, fishing, and marine life. From the outset, marine debris problems, sources, and solutions have been priority issues for Clean Ocean Action. In 1985, COA began collecting and documenting litter on beaches twice yearly through the Beach Sweeps program. For over 20 years, COA has published data from these cleanups, which has been cited in various initiatives to reduce sources of marine debris.

Overview of the Issue:

Plastics are synthetic, long-lasting materials derived from petroleum (crude oil). Single use disposable plastics epitomize a society of convenience that unfortunately comes with a cost to the marine environment. Although difficult to quantify, a large amount of plastic ultimately enters the ocean, either via improper management or disposal on land[4] (which accounts for approximately 80% of plastic marine debris)[5] or release from shipping and fisheries activities at sea.[6] As debris, plastics are linked to environmental impacts (discussed below) and economic repercussions, as littered beaches and polluted water may discourage coastal tourism and recreation.

Plastics do not biodegrade – that is, they do not break down into organic constituents that are then re-absorbed naturally into the environment. Existing pieces break down into ever smaller pieces via photodegradation and mechanical abrasion. As such, once plastic is introduced into the environment, it will persist for hundreds of years. The smaller plastics are referred to as microplastics.

Microplastics, or plastic pieces < 5 mm in size, are increasingly common in the marine environment. There are two sources of microplastics: 1) the breakdown of larger pieces and 2) manufactured products. Examples of manufactured products include microbeads, industrial raw pellets ('nurdles'), and synthetic filaments from clothing. Microbeads are increasingly found in cosmetics and toothpaste.[7] The tiny plastic microbeads in personal care products and clothing fragments are often too small for wastewater treatment plant filtration systems to intercept, and end up in waterways and ultimately the ocean. Researchers have documented the accumulation of microplastics in the marine environment for over four decades.[8,9]

Microplastic particles may have serious health implications for a variety of marine species. In the process of degradation, plastic debris releases toxic chemicals used in their production, such as bisphenol A (BPA) and styrene trimer (a liquid

[4] Barnes, D.K.A., Galgani, F., Thompson, R.C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B, 364,* 1985-1998.
[5] Andrady, A.L. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin, 62*¸1596-1605.
[6] GESAMP. (2010). IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection); Bowmer, T. and Kershaw, P.J., 2010 (eds.), *Proceedings of the GESAMP International Workshop on plastic particles as a vector in transporting persistent, bio-accumulating and toxic substances in the oceans.* GESAMP Reports and Studies No. 82.
[7] Fendall, L.S., & Sewell, M.A. (2009). Contributing to marine pollution by washing your face: microplastics in facial cleansers. *Marine Pollution Bulletin, 58,* 1225-1228.
[8] Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W.G., McGonigle, D., & Russell, A.E. (2004). Lost at sea: where is all the plastic? *Science, 304,* 838.
[9] Thompson, R., Moore, C., Andrady, A., Gregory, M., Takada, H., & Weisberg, S. (2005). New directions in plastic debris. *Science, 310*, 1117.

hydrocarbon), which have been linked to endocrine disruption. Plastics in the ocean have also been known to attract persistent, bio-accumulating and toxic substances (PBTs),[10] which include polychlorinated biphenyls (PCBs), dioxins, and petroleum based chemicals. These substances may act as endocrine disruptors, mutagens or carcinogens, causing a range of chronic health impacts. Scientists have documented adsorption of PBTs by plastics of all types and sizes in seawater. Marine life may mistakenly ingest these toxic-tainted plastics.[11,12,13,14,15,16] Once inside an animal's body, plastic pieces may release adsorbed chemicals into the organism, where they can cause serious health impacts or bio-accumulate in tissues[17,18] to be potentially passed up the food chain[19]. More research is needed on the presence, abundance, and effects of microplastics (whether adverse or not) in the marine environment, which is why COA is undertaking this study.

Interest in Microplastics Research and Citizen Science:

Researchers have estimated that globally, plastic comprises 60-80% of marine anthropogenic debris.[20] One of COA's most successful programs, the twice-annual Beach Sweeps, has engaged thousands of volunteers in cleaning up beaches across New Jersey and recording information on the types of trash found, including plastic. Between 2009 - 2013, an average of 71.6% of the marine debris items collected during COA's Beach Sweeps were plastic, much of it in small, unidentifiable pieces. Given the high proportion of collected plastic beach debris, and the propensity for plastic to continuously break down into smaller pieces, COA developed an interest in documenting the presence of microplastics in the New Jersey environment in order to establish a model for similar marine and coastal environments. This research is especially relevant given that microplastic pollution is caused either directly or indirectly by human activity and New Jersey is downstream of the most densely populated area of the United States. Once microplastics presence has been documented, COA will continue its research into the impacts of microplastics to marine life and importantly, to reduce the sources of these pollutants.

Many studies have pointed to the value of collaborations between researchers and volunteers, often termed "citizen

[10] Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C., & Kaminuma, T. (2001). Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. *Environmental Science and Technology, 35*, 318-324.

[11] Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W.G., McGonigle, D., & Russell, E. (2004). Lost at sea: where is all the plastic? *Science, 304*, 838.

[12] Browne, M.A., Dissanayake, A., Galloway, T.S., Lowe, D.M., Thompson, R.C. (2008). Ingested microscopic plastic translocates to the circulatory system of the mussel, Mytilus edulis (L.). *Environmental Science and Technology, 42*, 5026-5031.

[13] Ward, J.E., & Kach, D.J. (2009). Marine aggregates facilitate ingestion of nanoparticles by suspension-feeding bivalves. *Marine Environmental Research, 68*, 137-142.

[14] Von Moos, N., Burkhardt-Holm, P., & Köhler, A. (2012). Uptake and effects of microplastics on cells and tissue of the blue mussel *Mytilus edulis L.* after an experimental exposure. *Environmental Science and Technology, 46,* 11327-11335.

[15] Davison, P., & Asch, R.G. (2011). Plastic ingestion by mesopelagic fishes in the North Pacific Subtropical Gyre. *Marine Ecology Progress Series, 432,* 173-180.

[16] Wright, S.L., Thompson, R.C., & Galloway, T.S. (2013). The physical impacts of microplastics on marine organisms: a review. *Environmental Pollution, 178,* 483- 492.

[17] Teuten, E.L., Saquing, J.M., Knappe, D.R.U., Barlaz, M.A., Jonsson, S., Björn, A., Rowland, S.J., Thompson, R.C., Galloway, T.S., Yamashita, R., Ochi, D., Watanuki, Y., Moore, C., Viet, P.H., Tana, T.S., Prudente, M., Boonyatumanond, R., Zakaria, M.P., Akkhavong, K., Ogata, Y., Hirai, H., Iwasa, S., Mizukawa, K., Hagino, Y., Imamura, A., Saha, M., & Takada, H. (2009). Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society B, 364,* 2027-2045.

[18] Engler, R.E. (2012). The complex interaction between marine debris and toxic chemicals in the ocean. *Environmental Science and Technology, 46,* 12302-12315.

[19] Teuten, E.L., Rowland, S.J., Galloway, T.S., & Thompson, R.C. (2007). Potential for plastics to transport hydrophobic contaminants. *Environmental Science & Technology, 41,* 7759-7764.

[20] Derraik, J.G.B. (2002). The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin, 44*, 842–852.

scientists." Citizen science is an especially useful approach for studies requiring the collection of large amounts of data and/or sampling at a wide geographic range of sites, particularly when funding is restricted.[21,22,23] Volunteer involvement has proven to yield successful results in marine debris studies around the world, including in the United States,[24] Australia,[25] Japan,[26] and Chile.[27] This project would employ a citizen science approach to microplastics research in New Jersey, where no similar project has been completed to date. Specifically, COA will continue to engage with high-school students from the Marine Academy of Science and Technology (MAST) and other vocational technical high schools and colleges throughout the state. The students will gain valuable hands-on experience in study design, field sample collection, laboratory processing, and data interpretation as they work to improve our collective understanding of this pressing and ever-growing problem in the New Jersey region. Additionally, COA will engage with 'Beach Captains,' COA representatives that are responsible for the success of the Beach Sweeps program. These captains will assist in field sample collection and analysis which will further the citizen science direction of this project.

The citizen science component will be documented in the Citizen Manual prepared by COA. The Citizen Manual is modeled after the Environmental Protection Agency's (EPA) Estuaries Monitoring Manual and was produced to guide and standardize citizen participation in the microplastics investigation. In addition to providing step-by-step methods for sample collection, processing, and analysis, the Citizen Manual provides readers with information on the issue of microplastic pollution in the marine environment and the importance of their contributions to COA's research. The Citizen Manual is a living document that is regularly updated to reflect subsequent phases in the research project and changes to the project components based on researcher and volunteer experiences.

Microplastic Investigation

Project Summary:

To create scientifically valid model protocols for the collection and assessment of the magnitude and extent of the microplastics in the marine environment and engage principles of citizen science while at the same time establishing a model for similar marine and coastal environments. The purpose is to inform the public about the presence, abundance and impacts of microplastics on shorelines, in waterways of New Jersey, and promote citizen action (i.e., educated purchasing decisions and legislation) while establishing a model for marine ecosystems. COA is implementing the following:

1. **Phase #1:** Establishing a protocol and documenting the presence (and abundance) of microplastics (less than 5mm) on New Jersey beaches, in waterways, and along the coastline. This phase is currently underway.

[21] Cohn, J.P. (2008). Citizen Science: can volunteers do real research? *BioScience, 58*, 192-197.
[22] Silvertown, J. (2009). The new dawn of citizen science. *TREE, 1118,* 1-5.
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Ribic, C.A., Sheavly, S.B., Rugg, D.J., & Erdmann, E.S. (2012). Trends in marine debris along the U.S. Pacific Coast and Hawai'i 1998-2007. *Marine Pollution Bulletin, 64,* 994-1004.
[25] Edyvane, K.S., Dalgetty, A., Hone, P.W., Higham, J.S., & Wace, N.M. (2004). Long-term marine litter monitoring in the remote Great Australian Bight, South Australia. *Marine Pollution Bulletin, 48,* 1060-1075.
[26] Shimizu, T., Nakai, J., Nakajima, K., Kozai, N., Takahashi, G., Matsumoto, M., & Kikui, J. (2008). Seasonal variations in coastal debris on Awaji Island, Japan. *Marine Pollution Bulletin, 57,* 182-186.
[27] Bravo, M., Gallardo, M.A., Luna-Jorquera, G., Núñez, P., Vásquez, N. & Thiel, M., 2009. Anthropogenic debris on beaches in the SE Pacific (Chile): results from a national survey supported by volunteers. *Marine Pollution Bulletin, 58*, 1718-1726.

2. **Phase #2:** Establishing a protocol and documenting the presence (and abundance) of plastic <5mm, visible to the naked eye on New Jersey on shorelines and in waterways.
3. **Phase #3:** Establishing a protocol and documenting the presence (and abundance) of microplastics in the intestinal tract of common ecologically and commercially important marine fishes while working with recreational and commercial fishermen.
4. **On-going:** Engaging the public on the issue via the preparation of written material, presentations, surveys, and other citizen education and advocacy measures.

As mentioned above, the data will be used to identify sources and solutions to reduce and prevent microplastics in the marine environment including citizen education, industry involvement, legislative and regulatory actions that will prevent the widespread distribution of microplastics in the environment. It is imperative to thwart the creation and distribution of microplastics at the source, as significant at-sea cleanup has proved to be technically infeasible, at this time and may come at an ecological cost to marine life.

Project Timeline:

- **Phase #1** began in March of 2014 and is expected to be complete by the fall of 2015.
- **Phase #2** is expected to begin May 2015 and be complete by December 2015.
- **Phase #3** is expected to begin January 2016 and be complete by December 2016.

Each of the outlined projects will follow a similar timeline that involves the following:

- COA meets with potential collaborators and holds telephone conference calls with subject matter experts;
- Research Team finalizes methodology for collecting and analyzing samples;
- COA trains students and volunteers in sample collection and samples are collected under COA supervision;
- COA, along with NOAA scientists, trains and supervises students in sample processing and analysis;
- COA, NOAA scientists, and students collaborate on data interpretation and presentation.

Research Team: Project Collaborators/Technical Advisors:

Name	**Institute**	**Extent of involvement**
Beth Sharack	NOAA James J. Howard Marine Sciences Laboratory, Sandy Hook	Collaboration, technical advising, provision of lab space and equipment
Liza Baskin	Marine Academy of Science and Technology	Collaboration, technical advising, provision of students and lab space
Dr. Jay Kelly	Raritan Valley Community College	Technical advising, possible partnership.
Lisbeth Van Cauwenberghe	Ghent University, Belgium	Technical advising
Tamara Galloway	University of Exeter, United Kingdom	Technical advising

Courtney Arthur, Jason Landrum	NOAA Marine Debris, Silver Spring, MD	Technical advising
Keith Cialino	NOAA Marine Debris, NE Office	Partnership development and coordination
Abby Barrows	Marine Environmental Research Institute (MERI)	Technical advising
Ellen Rubinstein, Jim Nickels	Monmouth University	Technical advising, possible provision of equipment and surface water samples
Anna Cummins	5 Gyres Institute	Technical advising
Steve Fromm	IT Specialist at NOAA Fisheries, retired	Technical advising
Jennifer Samson	NOAA/Pacific Islands Fisheries Science Center, Ecologist	Technical advising

For more information, please contact Catie Tobin, Principal Investigator:

education@cleanoceanaction.org or 732-872-0111.