NEW YORK STATE
WATER RESOURCES INSTITUTE
Department of Biological and Environmental Engineering

230 Riley-Robb Hall, Cornell University
Ithaca, NY 14853-5701
http://wri.cals.cornell.edu

Tel: (607) 254-7163
Fax: (607) 255-4449
Email: nyswri@cornell.edu

Quantification and Source Identification of Microplastic Pollution

Todd Walter, Biological & Environmental Engineering, Cornell University, mtw5@cornell.edu
Lisa Watkins, MS/PhD Student, Biological and Environmental Engineering, Cornell University
Gray Ryan, BS '18, Cornell University; Susan McGratten, MEng '17, Cornell University

Abstract

Microplastic pollution in freshwater is increasingly studied in the waterways of New York State. Detrimental to organisms, both through physical mechanisms such as false satiation and through chemical mechanisms due to contaminant adsorption and particle leaching, microplastics originate from a variety of yet-to-be-quantified sources. This ongoing study aims to support the quantification and source identification of microplastic pollution in the Hudson River through investigative studies to uncover patterns in microplasic concentrations. The past funding cycle supported four projects. Two found plastic concentrations in rivers vary based on time of sampling and presence of dams. A third found that fish collected from the Hudson River showed signs of preferentially consuming plastic particles. The forth study is still ongoing and looks to compare samples collected using a grab technique to samples collected using a neuston net.

Three Summary Points of Interest

- Riverine microplastic concentrations **vary based on flow condition** and the **presence of dams.**
- When Hudson fish gut contents are compared to zooplankton-microplastic environmental compositions, it appears **fish are actually selecting against microplastics when feeding.**
- Initial findings point toward differences in measured microplastic concentration at a given location based solely on the **sampling technique** used.

Keywords: microplastics, freshwater, sediment, dams, fish, methods, hydrologic conditions

Introduction

Pollution by plastic is observed at concerning levels in waterways across the globe. Of highest concern are particles known as "microplastics", the size fraction made of plastics less than five millimeters in diameter, typically between 0.333-5.0mm. These particles have been detected in waterbodies ranging from oceans and estuaries, to rivers, lakes and streams. Microplastic particles begin as a variety of products: exfoliating agents in facewashes or toothpastes, known as microbeads; larger plastic goods, such as grocery bags, fishing nets, synthetic clothing, dock floats, or milk jugs; or pellets used in manufacturing.

The presence of these particles is of ecological concern because of their negative effects on aquatic organisms. Contaminants such as polychlorinated biphenyls (PCB's) have been found to readily adsorb to plastic particles. Additionally, aquatic organisms such as fish and oysters have been shown to consume microplastics, increasing the risk of physical harm to the organism through false satiation, starvation, or choking, as well as introducing the contaminants into the food chain (Critchell and Hoogenboom, 2018; Foley et al., 2018; Rochman, 2015).

Most research quantifying the amount and the impact of microplastic pollution has focused thus far on ocean gyres, where microplastic concentrations have been measured as high as 20,328 plastic particles per square km of ocean surface (Law, et al. 2010). With an estimated 80% (Andrady 2011) of those marine particles originating in terrestrial sources, studies have increasingly turned to quantifying microplastic abundance in freshwater systems, as well. Only in recent years have any papers been published with surveys of microplastic abundance in lakes, rivers, or streams across the globe, including only a few studies specific to the Hudson River Basin (Smith et al. 2017, Miller et al. 2017). Still little is known about the behavior and distribution of Hudson Valley microplastics and the way they interact with the Hudson's ecosystems.

We have addressed this knowledge gap through four diverse projects this funding cycle:

1. An investigation of how the presence of dams, such as the 1500+ present in the Hudson watershed, may be affecting the transport of microplastics along rivers.
2. A related investigation of how varying flow conditions in general may change the concentrations of microplastics measured at a given riverine sampling site.
3. A study of Hudson fish gut contents to determine whether fish display any selective preferences for or against microplastics as compared to other available food sources.
4. A comparison of river sample collection methods to determine how field methodology may affect measured concentrations, in order to better interpret the existing literature of river microplastic behavior, which utilizes differing methodologies.

Results & Discussion

Dams

Paired sediment and water samples taken upstream, downstream and within the reservoir at six dams revealed two different microplastic concentration patterns. Sediment samples with the highest microplastic concentrations were found in the reservoir behind the dam; whereas surface water microplastic concentrations tended to be highest upstream of the reservoir and lowest within the reservoir. Additionally, in sediment samples, the composition of particles was much more diverse than in surface water samples, though for both samples microfibers were the dominant particle type found. While an average of only 1.8% of water sample particles were fragments, 8.6% of those found in sediment samples were. For both samples, fibers were the predominant type of particle found and most particles found were either blue, black, or red. This is likely evidence that plastics in the sediment exist due to long term inputs from surface water microplastics due to settling.

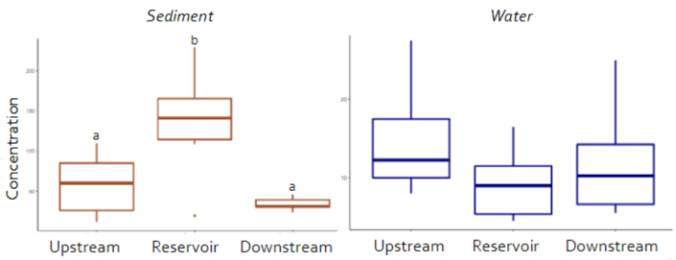

Figure 1. Microplastic concentration measured in plastics/kg for sediment (left) and plastics/L for surface water samples (right). All samples for all dams included in figure to represent general trends (n = 18 for each box). River, not shown here, is found to be a significant predictor of concentration along with location and sample-type (i.e. water or sediment), according to an analysis of variance.

Flow Condition

Samples taken at a designated location in two streams over a 24-hour period in low flow conditions and a second in high flow conditions indicated that while plastic concentrations do not vary significantly over the course of a day, concentrations are significantly different at a given sampling site depending on flow condition (Figure 2). For this study, all sampling occurred at minimum 3 days after the most recent rainfall, meaning that high flow conditions were due to seasonality instead of runoff events. Lowest plastic concentrations were found during high flow conditions. This likely points to a constant source of microplastics to the system emitting independently of season and flow.

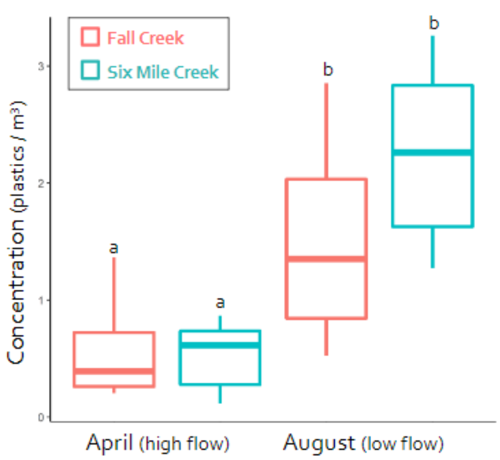

Figure 2. Microplastic concentrations measured over 24-hour sample periods. April 2017 high flow samples (n = 9) were taken at the same locations as samples collected during August 2016 low flow events (n = 8 for Fall Creek and n = 7 for Six Mile Creek). Letters that are different indicate a statistically significant difference, as indicated by an analysis of variance.

Wastewater treatment plants are one common suspect for this kind of point source behavior, so in our study design, we selected two streams with different management strategies: one receiving wastewater treatment plant effluent and the second in a watershed of only septic systems. Interestingly, we detected no difference in the microplastic concentrations between these two sites in either flow condition. This could be an indication that wastewater treatment plants and septic systems perform similarly in terms of their ability to keep microplastics out of streams, but this theory relies on the few observations of microplastics transporting through soil media, which would be necessary to explain how plastics are able to move through septic fields and into nearby streams. Another alternative explanation is that while we were too far downstream and not assessing all relevant size fractions of plastics in order to see a signal from the wastewater treatment effluent, as Magnusson and Norén (2014) suggest is possible, we may be detecting the constant inputs of a microplastic source to the system that has yet to be identified.

Fish Diets

In a sample of 47 Hudson river fish (herring, bass, shad, perch), all of the specimens had at least one microplastic in its intestinal tract. Surface water samples collected from the same reach as the fish contained 20% microplastic particles and 80% organic particles, while the gut contents of the fish contained only 10% microplastic particles and 90% organic particles. This difference is statistically significant and indicates that fish are selectively feeding but in doing so are selecting against microplastic particles, at least in the larger >0.335mm size fraction analyzed for this study.

Additionally, when analyzing fish characteristics with respect to ingestion patterns observed through their gut contents, we found no correlation between the percentage of microplastics consumed and the fish fitness, though we did find a positive correlation between fish size and quantity consumed, irrespective of that food consumption consisting of microplastics or organic particles.

This report was prepared for the New York State Water Resources Institute (WRI) and the Hudson River Estuary program of the New York State Department of Environmental Conservation, with support from the NYS Environmental Protection Fund

Methods Comparison

Though analysis for this project is still ongoing, preliminary results indicate that there are measurable differences between microplastic concentrations derived from the same sampling site depending on whether a 2-liter grab sample or a 10 minute neuston net sample is used for collection. Whether this difference is consistently higher or lower for one sampling method will become clear after analysis has been completed in the coming months. The variability found will likely provide clues as to what steps can be taken to reduce sample loss or environmental contamination during specific stages of sampling and processing. It will ideally provide a tool to use when comparing previously published studies that use differing sampling collection methods.

Policy Implications

Currently there stands a microbead ban nation-wide. Through our research we have consistently collected samples containing far more microplastic fibers than microbeads, even in collections predating the ban. For this reason, of the plastic particles to focus on, in New York waters, it appears that microplastic fibers are actually the more numerous category.

Through our research we have focused on improving our ability to interpret and utilize existing literature. The findings included in this report indicate a few key things about how we understand existing findings and can use them to properly inform policy.

First of all, through our study of fish diet we find two key points. One is that we find plastics in every fish we analyze. This fact is also true for all sediment and water samples we have collected thus far. Mismanaged waste streams and insufficient filtration of wastewater streams are two known sources of plastic pollution to waterways, so in addressing the ubiquity of microplastics in aquatic environments, these would be two avenues to focus on, as talks of plastic bag and disposable drinking straw bans attempt to do.

The second key finding from our fish study, however, is that we find no evidence to suggest that consumption of microplastics is correlated with fish size or fitness. In fact, we found that in the presence of microplastics, at least for the larger sizes measured in our study, fish selected against microplastic particles when feeding. This should serve as a caution for policy-makers: we don’t yet have sufficient evidence to know whether, at least at current levels, the plastics we are finding are causing harm to the systems we’re studying.

Our research also has interesting implications for dam removal decisions. We found clear evidence that shows that plastics are in highest concentration in the sediment behind dams. Like contaminants such as metals and pesticides, microplastics may be an additional contaminant to consider before releasing the sediment during dam removal projects. Until additional research provides the concentrations of these particles are harmful in river environments and what the effects are of exposure, however, proper accounting and prevention cannot be done.

Methods

Surface water samples were collected using a 0.335mm mesh-size neuston net from the thalweg of the stream. Grab samples for the methods comparison study were collected in liter bottles at the same location as net samples. Sediment samples were collected in areas of deposition using a scoop, attached to a long conduit as needed. These samples were then transferred into glass jars for safe transport and storage back to the laboratory. Fish samples were collected with a 4.8 mm (3/16”) heavy delta beach seine, euthanized following IACUC-approved methods and preserved in a 4% formalin solution followed by an 80% ethanol solution.

In the laboratory, all samples were sieved to ensure all analyzed particles were between 5mm and 335mm in size. All samples were then processed in the lab following a wet peroxide oxidation method outlined by NOAA, which includes a density separation following the oxidation step (Masura et al. 2015). The entirety of each sample was then analyzed under a dissecting microscope and plastic particles were counted visually and assessed based on plastic category (i.e. bead, fiber, fragment, film, foam) and color.

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During processing to reduce and standardize any potential contamination, white lab coats and nitrile gloves were used at all times during sample processing. Additionally samples were kept covered when not being actively processed or counted and were only introduced to containers that had first been thoroughly rinsed. Clean filter paper was left exposed to laboratory air to measure the number of deposited airborne microplastic particles over 24 hours. This number was then subtracted from all counts before data analysis.

Outreach Comments

During this funding cycle, we

- Appeared in Pacific Standard magazine article about microfibers in US waterways (Baskin 2018).
- Provided support for a one-day Earth Day booth about microplastic pollution at the Museum of the Earth.
- Presented this research to a general scientific audience at the Cornell Biological and Environmental Engineering Research Seminar, in addition to the field-specific poster presentation given this year to ASABE (Watkins & Walter 2017).

Student Training

Over the course of this funding cycle, one graduate student, two MEng students, and one undergraduate student served in leadership roles for one or more of the projects within this grant. Additionally, under these student leaders, three additional undergraduates served as lab helpers to process and analyze samples and one undergraduate student used our resources and expertise to complete a video essay class project for a communications class on microplastic pollution research. Each of these students gained experience in the field, as well as in the laboratory through their involvement with these projects.

Publications/Presentations

Further information on the study of fish plastic ingestion is available in the Undergraduate Honors Thesis (May 2018) of Molly Ryan. This work, as well as the study of sedimentation near dams and temporal concentration changes are currently being formatted for submission to academic journals.

Results from the study on temporal changes in concentration were presented at the American Society of Agricultural and Biological Engineers (ASABE) Annual meeting (Watkins & Walter 2017).

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