Abundance and Distribution of Plastic within Lake Macatawa Sediments

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Introduction

Plastics are often valued for their weathering resilient qualities, however, this creates a problem in itself. Unlike many materials used in society, plastic does not chemically break down in nature. Plastics undergo only physical weathering, being broken down into smaller and smaller fragments. Due to these processes, plastic litter is often broken into two groups: primary and secondary plastics. Primary plastics remain in their original form (or close to it), whereas secondary plastics are smaller fragments of plastic that have been broken down by physical, or mechanical, weathering (Diedger et al., 2014). This in itself poses a problem since these smaller secondary plastic particles are more easily transported by surface processes. In the case of the Lake Macatawa watershed this would mean that plastics are being transported by currents in tributary waterways and then being deposited within the lake where currents become gentler and suspended loads are able to settle out.

Previous studies on microplastics in the Laurentian Great Lakes and their associated beaches have shown that roughly 80% of anthropogenic litter along shorelines is made up of plastics (Diedger et al., 2014). These plastics on shorelines often come from sediment deposited *within* the lake that is carried onshore by wave deposition. Plastics can be introduced into an aquatic ecosystem in a variety of ways, both directly and indirectly (direct implies point source pollution). Plastic contaminants include larger pieces like wrappers and cigarette filters as well as much finer plastics such as dust produced by construction activity. Indirect sources of plastics can include plastic fluxes into the lake from streams and storm drains carrying plastics in suspension.

Microplastics have been observed in both marine and freshwater systems. (Corcoran, 2015). Three main questions were sought after in the process of this research: Are plastics present in Lake Macatawa sediments? What is the abundance and distribution of (micro)plastics within the sediment in Lake Macatawa?[1] Are these concentrations related to land use (i.e., residential, public park, or harbor, etc.) as opposed to hydrodynamic processes occurring within the lake? Or are the distributions a correlation of both? We hypothesize that there may be a correlation of plastic abundance with direct land use (e.g. residential areas, recreation, fishing, etc.)

Methods

I. Location of Study:

Ten sampling spots were chosen around Lake Macatawa based on location to stream influx (from the Black River) and areas of adjacent high human traffic, for example the Holland Yacht Club and the Boat Marina. Other sites were chosen in order to circumnavigate Lake Macatawa. These sampling sites are marked with yellow arrows and their associated abbreviations on the map below (Figure 1).

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[1] *Microplastics are defined as <5 mm-sized particles. All plastics ≥5 mm were considered macroplastics, but were recorded in results.*

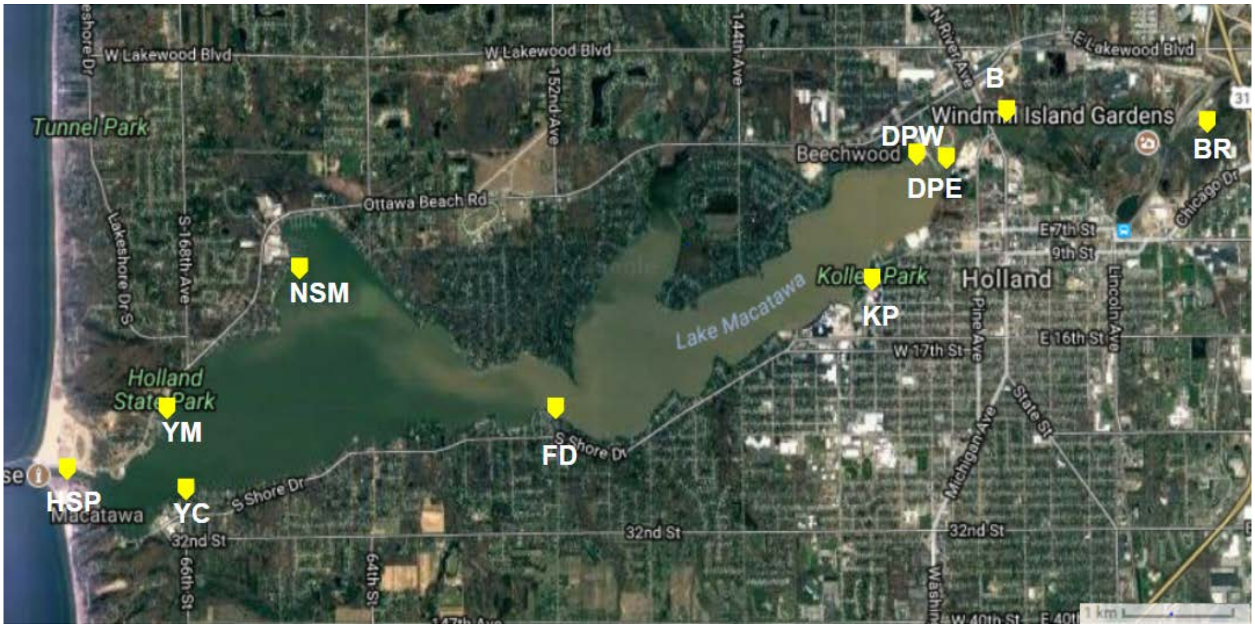

Figure 1. Google Earth image showing Lake Macatawa with initial sampling locations indicated by the yellow arrows. Moving west to east, the abbreviations are as follows: HSP (Holland State Park), YM (Yellow Motel), YC (Yacht Club), NSM (North Side Marina), FD (Fire Dock), KP (Kollen Park), DPW (Dunton Park West), DPE (Dunton Park East), B (Bridge), and BR (Black River).

Each of these sites was sampled with a "WildCo" clam-shell style sediment sampler, placed in metal trays, and covered with aluminum foil to ensure that no plastic contaminants entered the sample during transport. The sample was labeled with date and location to avoid mixed samples.

II. Processing of samples:

The methods used to conduct analyses of sediment samples were based on the methods for bed samples created by the National Oceanic and Atmospheric Administration (NOAA) out lined in Marusa, J., et al. 2015. Hybridization of the NOAA methods was done based in part on the resources available, as well as time constraints requiring data collection to be expedited. The exact methods used are as follows.

Once back in the lab, each sample was dried for ~8 to 12 hours in an oven at roughly 50 to 60 degrees Celsius. After the drying process, each sample was mixed and split into four separate quadrants (Figure 2).

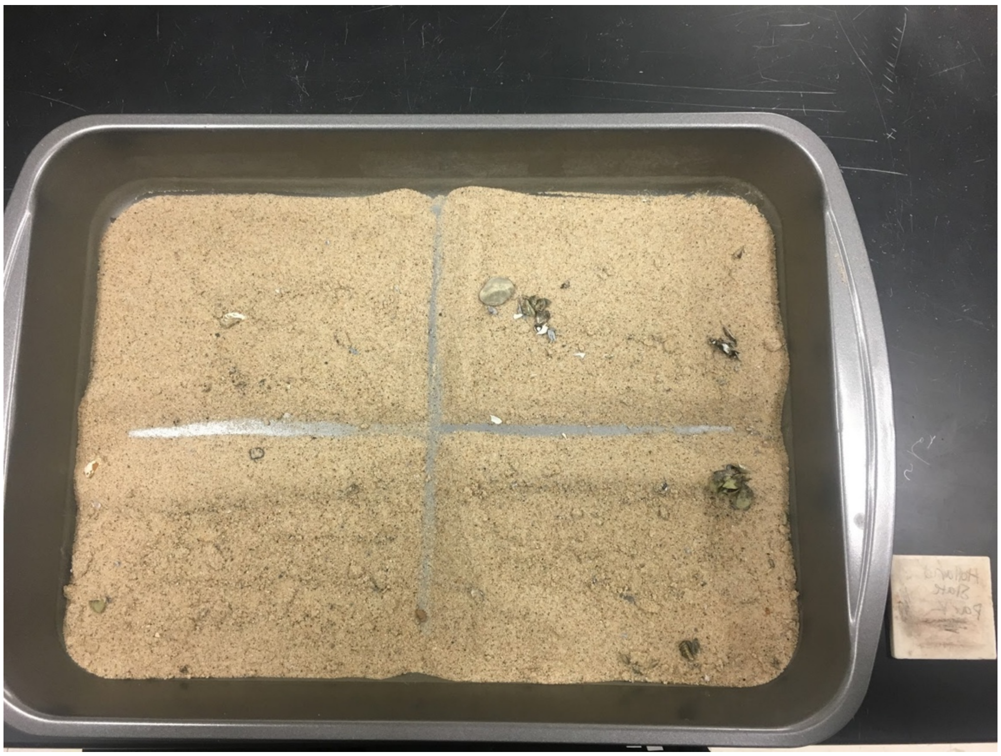

Figure 2. The Technique Used to Randomize and Decrease our Sample Size.

The top left and bottom right quarters of each sample were removed (to halve the sample), and the process was repeated until a volume of 150 mL was reached. This splitting process was done to systematically decrease sample volume, as well as to combat sample biases possibly created by the way each sample was taken using the “WildCo” sampler. In other words, it allowed us to randomize our sample to avoid looking specifically at one sediment strata of the lake bed. These separation experiments are loosely based on laboratory methods of isolating plastics outlined by Julie Masura, Joel Baker, Gregory Foster, and Courtney Arthur (Masura et al., 2015).

Once split, each sample was then wet sieved through 5.6mm, 1.18mm, and 250μm mesh sized U.S.A. standard test sieves. Each sample was transferred into the stacked sieves, making sure to rinse the beaker several times before continuing. The samples were then sieved with a constant flow of water, until sample was well washed, drained, and sorted (Marusa, J., et al. 2015). The samples were then allowed a minimum of 12 hours to dry before sieves were emptied into beakers for storage. All beakers were covered with aluminum foil to limit exposure and subsequent contamination. *Note: if large easily identifiable plastic particles were present, they were removed and cataloged.*

Following sieving, the contents of the 1.18mm and 250μm sieves were subjected to a 20 mL, 3% hydrogen peroxide bath in order to remove organic material from the samples. Samples were allowed approximately 30 to 60 minutes in the hydrogen peroxide bath. If organics were still visible the process was repeated once more. The sample was then rinsed with a fine sieve to remove any fine, partially dissolved organic matter. These sieves were covered and allowed to air dry on a closed shelf.

Following the removal of organic matter, density separation techniques were used to further separate plastic particulates from each sample. The density separation apparatus was composed of a unit consisting of a glass funnel, a tube and a pinch clamp. A salt solution containing 50g NaCl per 1000 mL of water, in other words, a density of ~1.05 g/cm^3 was used as the density separation solution. This meant that plastics with a density less than 1.05 g/cm^3 would float in the solution.

Once set up, 150 mL of this salt solution was poured into the density separation apparatus along with the sample to separate. The sample was stirred to ensure that particles were not trapped among heavier sediment that had settled out. The sample then sat about 10 minutes (dependent on nature of the sample/how quickly it settled). After the sample had settled, the particles floating on the surface were scooped out onto a glass watch glass using a metal spoon. These particulates, and the excess water that was removed with them, were transferred to a vacuum station lined with a Whatman filter pad to filter out the excess water. This prepared the sample to be visually sorted underneath a microscope.

Under a binocular microscope, we were able to visually sort plastic from other particulates. The plastics found were grouped into three categories: fibers, films, and pellets. Fibers were identified as elongated in one direction along one line. Films were considered an elongated plane. Finally, pellets were considered more or less spherical. All plastics found were recorded within one of these categories and attempted to be collected by forceps. If the plastic was too small to be retrieved, a photograph was taken to further record the plastic found.

Results:

Our first question we needed to answer was “are plastics present in Lake Macatawa sediments?” Within our first sample processed we learned that there are indeed plastics found within the sediments of the lake. Plastics were found in all of the ten sampling sites. The total plastics found within the ten sites were compiled to look at the composition of the different categories of plastics we found within the sediments, as seen in figure 3. Our results show that fibers were largely the most common type of fiber found.

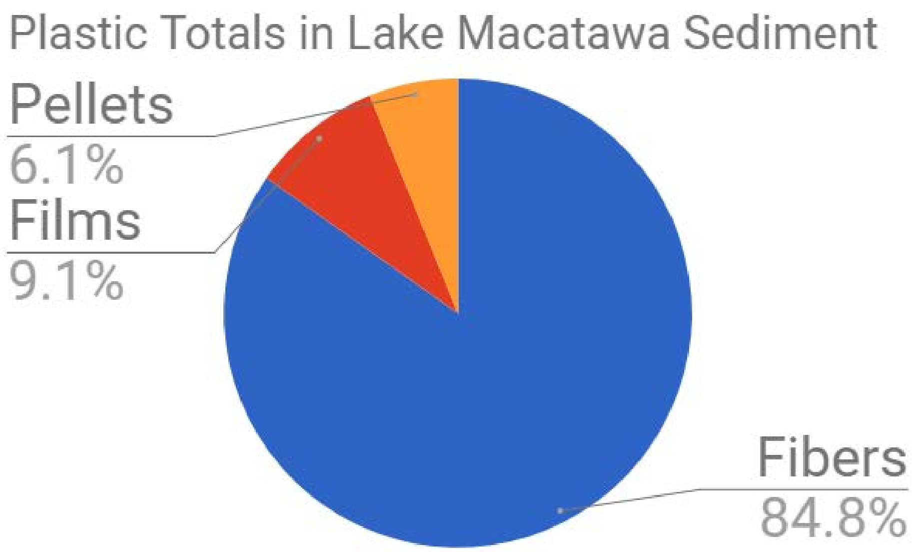

Figure 3. Plastic Totals Found within Lake Macatawa Sediments. The total plastic found at our ten sites categorized into three categories, fibers, films, and pellets. Fibers were the most abundant type of microplastic found at 84.8% of all the microplastics found, films comprised 9.1%, and pellets were the least common type of microplastics found at 6.1%.

Once we knew that plastics were present, we wanted to address our second and third questions, "What are the abundances or distribution patterns of plastics within the sediments of Lake Macatawa?" and "Are these concentrations related to land use of the sampling site?" To accomplish this we looked at our data in order of sampling site location from our most western site, Holland State Park (HSP), to the most eastern site, Black River (BR). Figure 4 made it easier to see the trends and abundances at the sites around the lake. We could see that there were increases as you enter the river seen near the bridge site (B). This increase differs from the much smaller abundance found up river at the Black River site (BR). There are noticeable increases in recreational locations such as Dunton Park, Kollen Park, and Holland State Park.

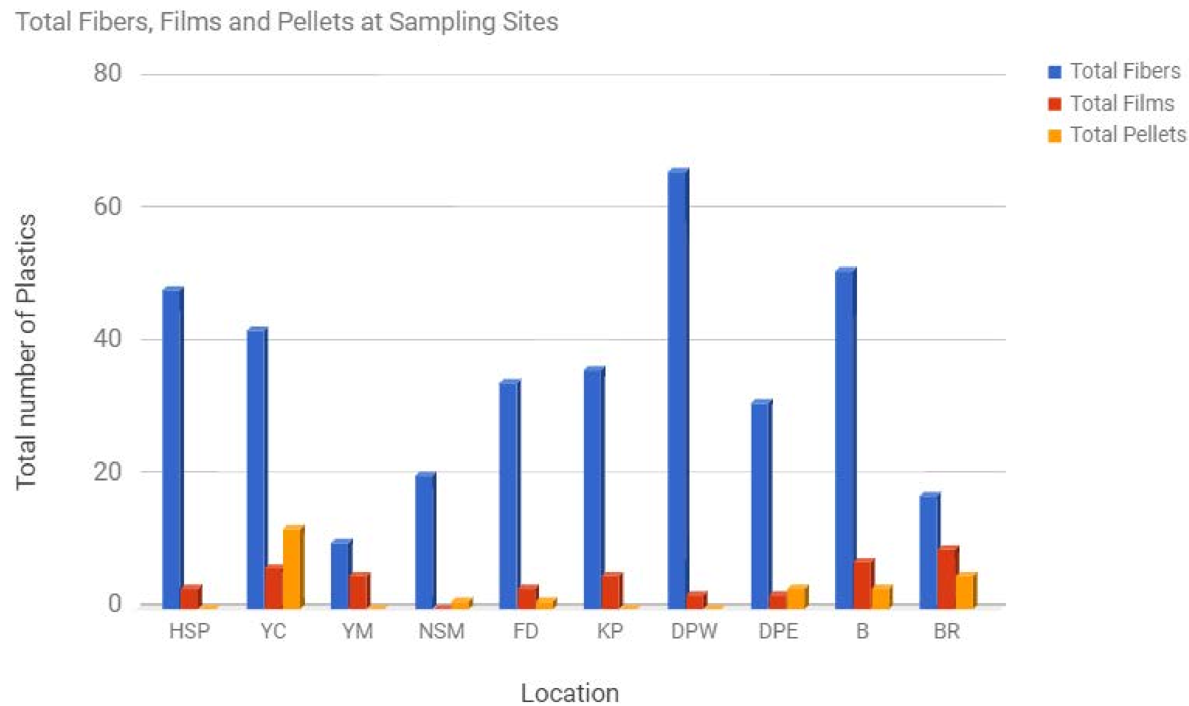

Figure 4. Total fibers, films, and pellets found at sampling sites. The total amount of microplastics found at each site categorized into fibers, films, and pellets. Sites were listed in order of location from most Western site, Holland State Park, to the most Eastern site, Black River.

Discussion:

Impact of Land Use:

We were interested in looking at the ways that land use could influence the abundance of plastics found at site locations. We found that in areas of recreational land use, plastics were found in higher abundances than those in residential locations. The only type of plastic we were able to confidently identify directly was fishing line. Fishing line was commonly found as a macroplastic as well as in microplastic size range, at sites where it is a common fishing destination for local fisherman such as Dunton Park, Kollen Park, and Holland State Park.

Much of the fibers that were found within our samples were colored leading us to suspect that it was originally from fabrics. Because we noticed that there was a large increase in the number of fibers found as the river enters the lake, we explored the idea that these fibers could be from the local water-treatment plant located close the bridge. We hypothesized that the outwash from this plant may not be filtered for items as small as microplastics. Thus all the water from the laundry processed in Holland which would contain microfibers from our synthetic clothing, is entering Lake Macatawa from this site. Other potential sources for microplastics within the lake could be the storm drain outwashes, contributing plastic pollutants from litter on the streets into the lake during times of high rainfall. In order to gain confidence in our hypotheses of how land use could contribute to the microplastics found within the sediments, further testing would need to be conducted. This research could obtain replicable samples at the recreational sites as well as further up river to see if the pattern found in our research would persist. It would be important for future studies to monitor the storm drain outwashes as well as the outwash location from the water treatment plant in order to conclude any contributions they may be making to the microplastics found within the sediments of Lake Macatawa.

Hydrodynamic Influences:

It can be seen that the influence of the hydrodynamic processes within Lake Macatawa could be responsible for some of the trends seen within the findings of this study. The Black River, located at the eastern end of Lake Macatawa, serves as the main tributary in this system. The material transported by a body of water is directly related to the velocity at which it is moving. Thus, areas of increased velocity will be able to transport a larger amount of material whereas areas of lower velocity will transport less material. This shift from high to low velocity will result in the deposition of the material carried in suspension. When looking at our system we observed that the Black River was a zone of higher velocity and Lake Macatawa was a zone of lower velocity. The junction of these two bodies results in the deposition of sediment carried in the Black River into Lake Macatawa. This would mean that more plastic should be found in the eastern segment of the lake at the mouth of the Black River.

When looking at the results we can see that in fact there is a spike in plastic abundance at locations nearest the mouth of the Black River and much lower numbers of plastic present within the river itself. So it is possible than much of the plastic present on the eastern segment of Lake Macatawa is being deposited from the Black River. This could be tested with sampling the water column of both the lake and the river were the results would be hypothesized to be opposite with higher plastic abundance within the water column of the river than in the eastern segment of the lake.

Research Continuation:

To fully understand the abundance and distribution of microplastics in the Lake Macatawa watershed further work must be conducted. This work should include expanding the range of plastic densities that are recordable, repeated sampling and increasing the number of sampling localities, and the determination of plastic presence and abundance with the water column itself. By utilizing a denser solution to serve as a floatation medium, it may be possible to quantify a larger range of plastics. In this study a relatively narrow range of densities were examined (1.0 g/cm3 to 1.05 g/cm3). In addition, by completing a series of density separations with varying solutions it may be possible to gain an increased understanding as to the type of plastic most predominant in Lake Macatawa. By obtaining replicable samples from a larger number of sampling localities the confidence of the findings could be statistically increased, thus eliminating outliers. In order to examine how plastics influence Lake Macatawa as a whole, sampling may be extended to physical sampling of the water column via trolling as performed in many studies for larger bodies of water.

Sampling could finally be extended further by examining whether or not plastic has been introduced into the food web through consumption by aquatic life (i.e., bottom dwellers). Researchers are concerned with the effects that plastics may have on the surrounding ecosystem, particularly in the food chain. (Sanchez, Bender, and Porcher, 2013).When researching plastics in the sediment of Lake Macatawa we are concerned that bottom feeders could be ingesting plastic particles. By analyzing the digestive contents of bottom feeders of Lake Macatawa future researchers could establish a clear connection that plastic is entering the food web of this ecosystem.

By extending this project to include these additional finding a better picture of the overall abundance and distribution of plastic within the lake can be assessed. This project could easily be undertaken as a summer research project for a Hope College student. The continuation of this project would allow both for more statistically confident results as well as long term monitoring of the plastic abundance and distribution. This study could be viewed as a small piece in assessing the impact of plastics within the Great Lakes.

Conclusion:

In conclusion, plastics are pervasively used in every aspect of our lives, including but not limited to, one-use plastic bags and packaging, polyester clothing, bottles, cutlery, plastic cups, the list is endless. These plastics eventually degrade into finer and finer pieces which are becoming a problem in the environment. These pieces of plastic start to accumulate in sinks, such as beaches, and have even presented themselves in the food web (Sanchez, Bender, and

Porcher, 2013). As they travel through ecosystems, they break down into finer and finer plastic pieces, leaving us with the plastic category: *microplastics*.

Our study shows that microplastics (in this study, defined as anything larger than 0.25 mm and smaller than 5.6 mm), are present within Lake Macatawa bottom sediments. The dominant *type,* or *shape*, of these microplastics is fibers - which could be due to a lot of different reasons. In order to make any further claims, we need to continue this research to become more confident in the pervasiveness of these microplastics in the lake bed. What can be said about plastic in general, is that the modern society is a plastic society. We cannot go a day without using something made out of plastic, which will prove to be a larger and larger problem as more plastic is created and "thrown away." This plastic will continue to pile up in our natural environments over time, so we must limit the amount of plastics we use in our everyday lives. This starts with reducing its use, reusing the plastics we may have in our possession, and recycling plastics as well as better control over how plastics are being used and how they might pass through the waste stream

References

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