Microplastic Density and Shore Visitor Abundance at Two Long Island Beaches

by

Samantha Scalice

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Sponsor: Dr. George Kraemer
Second Reader: Dr. Ryan Taylor

Abstract

Degradation of coastal ecosystems due to plastic pollution, particularly on the micro scale, is a topic of growing concern as microplastics are found to be detrimental to wildlife, and carriers of toxins and pollutants. The density and lengths of plastics are reported from two Long Island south shore beaches, one with high patron usage (Jones Beach) and the other with lower patron usage (Lighthouse Beach, Fire Island). At each site, five sand samples of ca. 425 cm^3 collected from the wrack line and five were collected from the backshore (50 m upshore from the wrack line). Plastics were density-separated using a concentrated saltwater solution (1.7 g mL^{-1}), and the supernatant was filtered. After drying, each filter was examined at 25X magnification and the counts and lengths (mm) were scaled up to microplastic quantities and lengths per kg of sand. The results of this study determined there were no significant differences between the two beaches, or between wrackine and backshore locations in either microplastic counts or lengths. There also was no significant relationship between plastic particles <1.0mm and plastic particles ≥ 1.0mm in samples collected. This data did not support a relationship between microplastic density or size and patron usage.

Introduction

The Earth is currently experiencing drastic ecological change, often defined unofficially as the Anthropocene epoch (Laurance, 2019). Human influence has caused global extinctions and extirpation, affecting the overall ecological well-being of the Earth detrimentally (Butler, 2018). Anthropogenic extinctions are a result of human caused environmental degradation including pollution of plastics. Single-use plastic items have been particularly noted as a source of anthropogenic litter. The amount of plastic persistently present in the Earth's ocean has been argued by scholars to be enough to mark the current epoch as the Anthropocene. The presence of plastics in sedimentary rock and in the deep sea further support recognition of this epoch (Fernandino et al., 2020; Cauwenberghe et al., 2013).

Though plastics have been popularly used since about 1950, the use of plastic as disposable packaging and single use items has increased dramatically since (Geyer, 2017). Plastic is now the most abundant litter in oceans today, composing 60-80% of marine litter (Xanthos and Walker, 2017). Studies of plastic distribution are increasing in importance worldwide as the amount of plastic present in oceans increases daily, highlighting the growing need for restoration and further policy intervention. Studies showing large amounts of microplastic presence have been conducted across all 7 continents, even within samples from the Arctic (Auta et al., 2017).

Plastic degradation typically occurs due to environmental conditions causing weak points where fracturing occurs. Many conditions causing fracture of plastics such as weathering from wind, ice, and running water are not impacting the plastics when they are out at sea. However, once the plastics reach the shore, they are especially susceptible to breaking into smaller pieces along fractures due to abrasion from waves or greater oxidation from the sun's UV radiation (Corcoran et al., 2014). These small plastic fragments are often described as microplastics. Scientists predict these microplastics persist in the environment for hundreds to thousands of years (Butler, 2018). These microplastics litter marine ecosystems, causing organisms to suffer including impairments on their feeding, locomotion, and social behaviors (Crump, 2020).

Once microplastics fracture from their origin sources, they are often mistakenly ingested by a wide array of marine organisms from dolphins and shorebirds, to crustaceans, and even zooplankton. Drever et al. (2018) reported 100% of the dead shorebirds they had autopsied had stomachs full of plastic contents in British Columbia, Canada, with little other food present. Drever et al (2018) concluded in times of environmental distress, animals often mistakenly consume plastics as food when other sources of food are unavailable. Due to their strong resistance to decomposition, plastics accumulate within the organisms stomachs after ingestion, causing them to feel constantly full and preventing the consumption of food and resulting in lethal malnutrition (Drever et al., 2018). Crump et al. demonstrated exposure to microplastic presence in quantities representative of a natural marine ecosystem caused hermit crabs to alter their behaviors, failing to select normally optimal new shells (Crump, 2020). Consumption of microplastics in one trophic level affects the rest of the food web drastically. Fecal pellets containing microplastics resulted in a significant decrease in the zooplankton algal feeding (Cole et al., (2013). Other studies such as Zhu et al. 2019 report findings of microplastics in the intestines of *Sousa chinensis*, a type of humpback dolphin, the apex predator in its food web. Both of these studies draw attention to the consequences of accumulation of plastics up the food web due to zooplankton existing in a low trophic level and the humpback dolphin at a high trophic level. Animals such as the humpback dolphin can be considered sentinel in this case because they could give us insight into challenges humans may face due to accumulation of plastics in our food (Zhu et al., 2019).

In addition to lethal effects of plastic consumption causing blockages and malnutrition, plastics also absorb toxins and pollutants from water, concentrating the toxins and allowing them to persist long term in the ecosystem (Van et al., 2011). Some toxins including POPs, or persistent organic pollutants, cause toxicological effects on wildlife such as zooplankton due to their ability to ingest the contaminated microplastics (Andrady, 2011). Harmful algal blooms (HABs) can also attach to plastics and spread to new areas, further exacerbating eutrophication issues and issues of invasive species spread (Keswani et al., 2016).

Plastics also release chemicals used in their manufacturing called EDCs, or endocrine disrupting chemicals, which affect reproduction and metabolism. A commonly known EDC is bisphenol A, or BPA (Chen et al., 2016). Toxins carried by the plastics are then consumed by marine organisms and become more concentrated as they move up the food chain, starting with micro herbivores. This causes widespread deleterious effects on organisms, even affecting the health of humans consuming marine animals (Devriese, 2017). Other dangers to human health include plastic's ability to carry FIOs, or fecal indicator organisms such as *E.coli*. The plastics provide an ideal surface for biofilm to develop, allowing microbes to be spread from beach and bathing areas and cause low water quality and human health issues (Rodrigues, 2019).

Materials and Methods

The sediment samples were collected from two different beachfronts with varying patron usage (Figure 1). The area of Jones Beach Field 6 sampled is a beach heavily used by tourists and easily accessible to the public by car. Lighthouse Beach at Fire Island is much less accessible and less utilized by the public. This allowed for comparison of plastic contents at the two beaches to determine if areas with higher amounts of human activity resulted in higher amounts of plastic contamination. I also compared plastic quantity and length at the backshore sample locations of the two beaches.

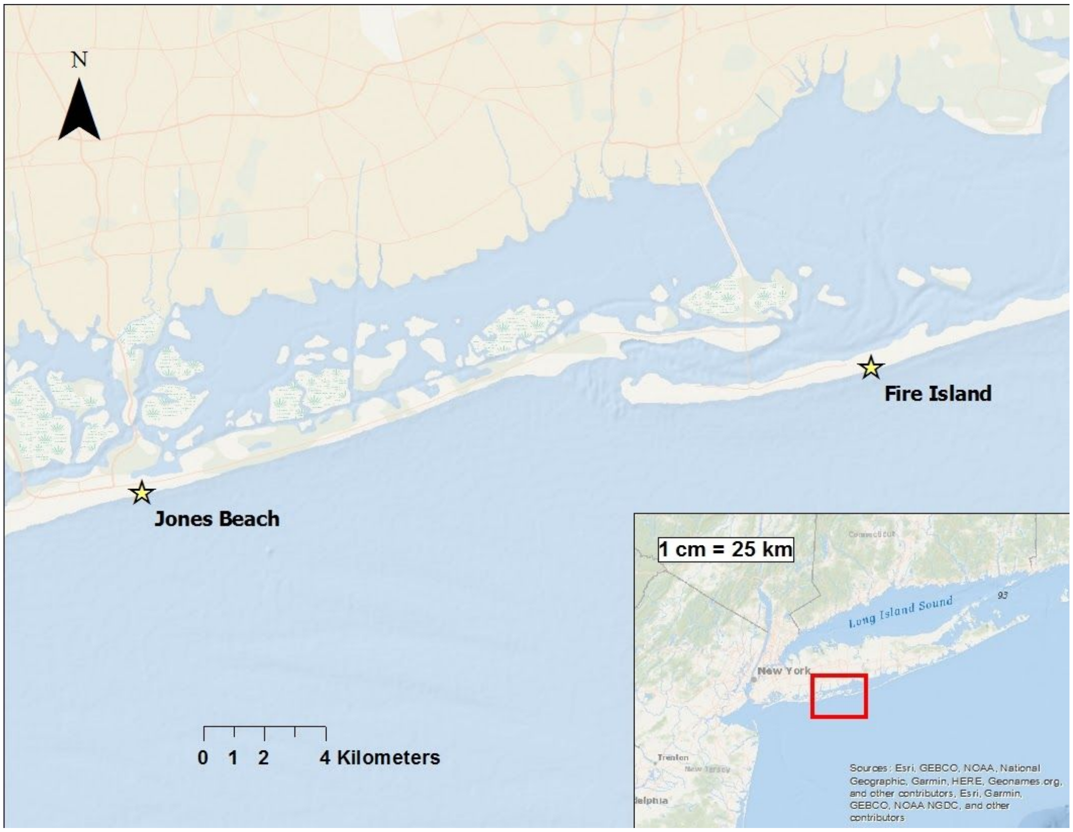

Figure 1 Map of Jones Beach site and Fire Island site on the south shore of Long Island (map courtesy of Daniel Kraemer)

At both sites, a set of five samples were collected both from the wrack line, as well as 50 meters behind the wrack line, in a line parallel with the shore. Each sample was taken 1 meter apart from the last as illustrated in figure 2. The samples were collected by pushing a 6” PVC pipe into the sand to a depth of 15 cm and collecting the sand within the pipe by hand in a collection bag. Each sample had an approximate sand volume of 425 cm^3. The samples were collected at low tide, about two weeks apart, as illustrated in figure 2.

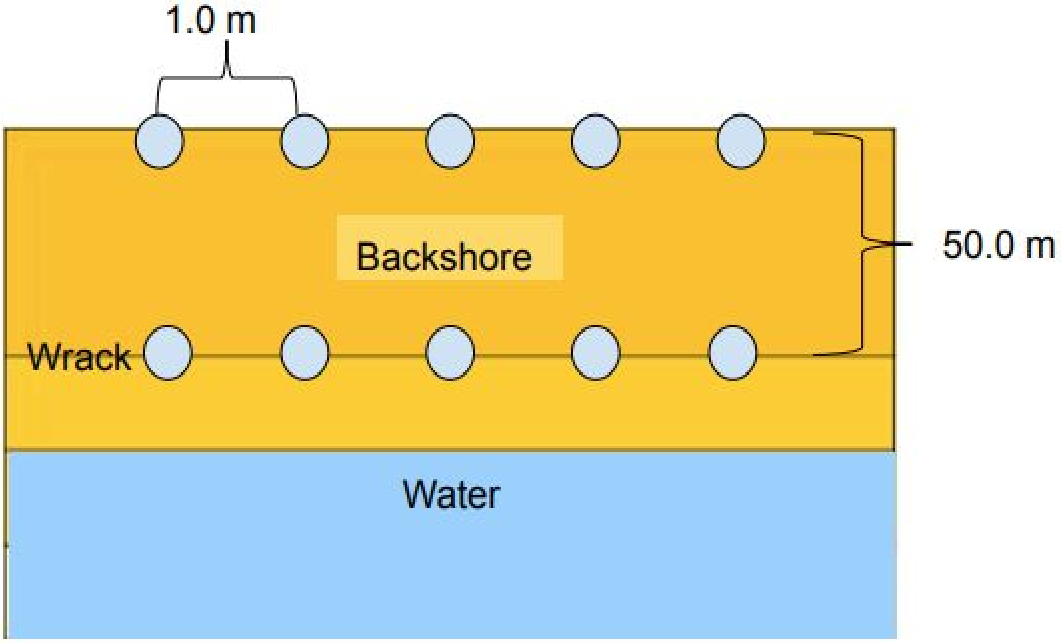

Figure 2 - Diagram of sampling procedure per beach site

The sand samples were sieved through 5mm, 0.5mm, and 250 micron sieves and the sand that was able to pass through the sieves was analyzed for microplastic fibers. Approximately 100 g of sand was mixed with 400 mL of concentrated saltwater (1.7 g of NaCl per 1.0 ml H_2O). In Li et al. 2018, a variety different microplastics were studied, ranging in densities from 0.89 g/cm3 (e.g. PP) to 1.58 g/cm3 (e.g. PVC) (Li et al., 2018). The mixture was stirred using a magnetic stirrer for 30 min. Following mixing, the sand and saltwater solutions were left covered with tin foil for 12+ hours to allow the solution to completely settle. The supernatant was filtered using a Millipore filtration apparatus and 1.2 um filter paper. The filter was rinsed twice with 15ml of H_20 to remove excess salt, and then rinsed with 15 ml of 30% H_20_2 twice to digest remaining organic matter. Filters were given 72 hr to dry completely on a counter before microscope analysis at 25x magnification. Filters were enclosed using tin foil to prevent contamination while drying, with extreme care taken to not allow the foil to touch the top of the filter paper. This was repeated to analyze a total of 200g for each sample.

To begin microscope analysis, the number of photographs needed to accurately represent the entire filter was determined. Each filter has 968 mm^2 total surface area. The field of view covered an area of 16.06 mm^2. By marking a dot at the end of each field of view on a petri dish cover, a grid system was established, ensuring the entire surface area of the filter was captured in a photograph. The purpose of creating the grid was to ensure the same plastic fiber was not photographed twice. One filter was analyzed for plastic counts using a total of 60 photographs. It was determined 10 photos would be representative of the total plastics present, which is ca. 10% of the total filter area. This was done using Figure 3 to determine where the average quantity of plastics per photo began to plateau. Figure 4 displays there is no significant difference in the number of average plastics between 10 and 20 photos, and resulted in a sample size of 10 photos per filter. 10 random points from the original petri dish cover were carefully traced onto a new petri dish cover and was used to randomly sample each of the filters. The points were used as markers for the bottom left corner in each field of view to ensure the photographs did not overlap, preventing the possibility of counting the same fibers twice. The plastic fibers present in each photograph were measured in millimeters using ImageJ and recorded. By dividing the total surface area of each filter (968 mm^2) by the surface area covered by one field of view in each photo (16.06 mm^2), it was determined each plastic length and count could be multiplied by 60.274 to scale up the sample, representing 200g of sand sampled. Counts and lengths were then multiplied by 5 to scale the amount of sand up to 1kg.

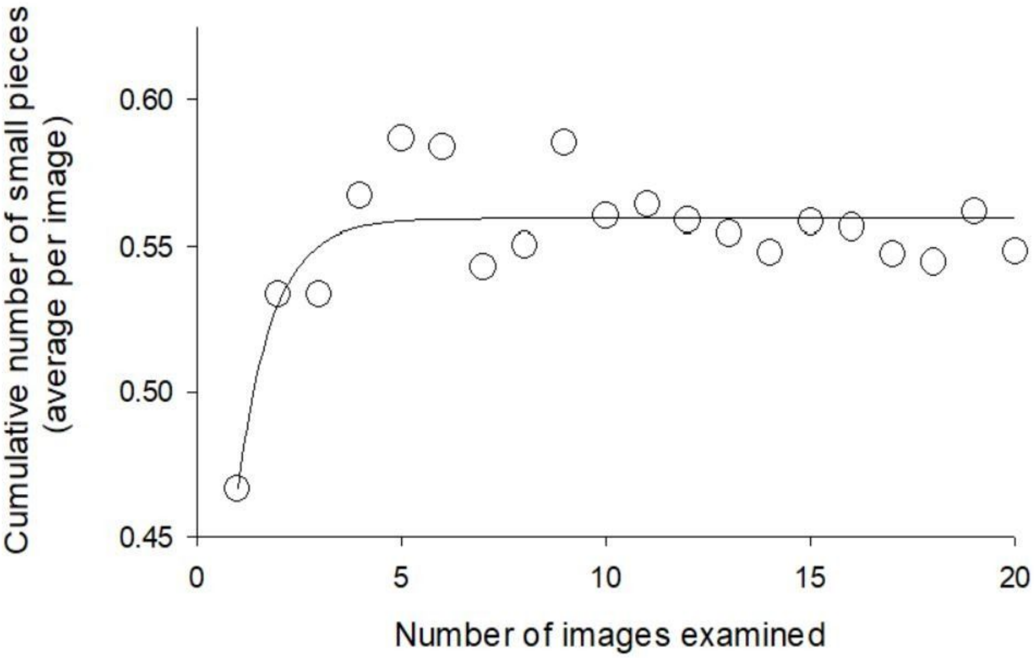

Figure 3- Average plastic count as image quantities increase.

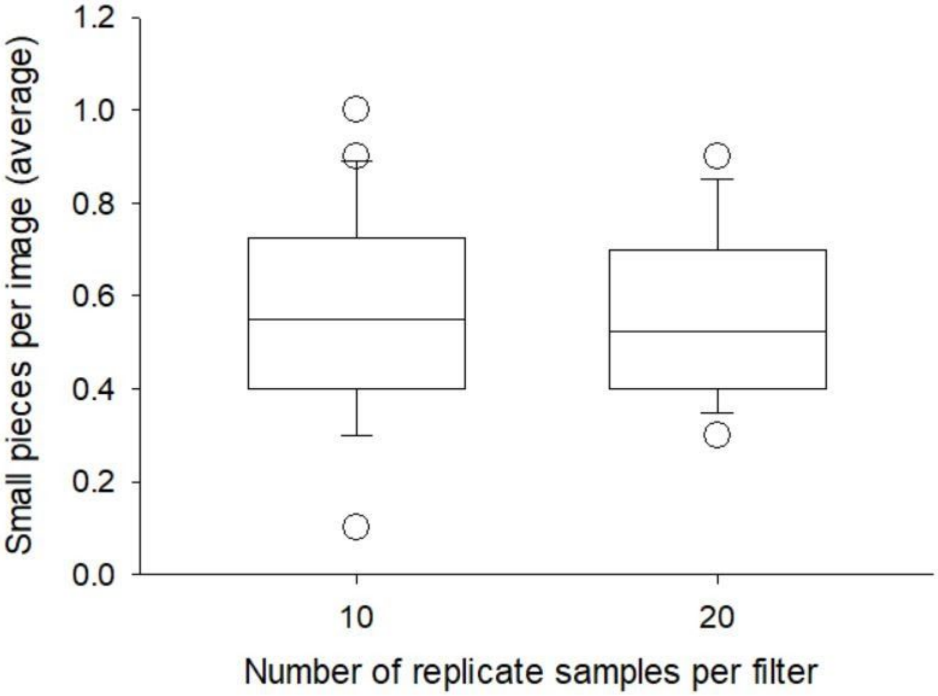

Figure 4- Box and whisker chart representing no significant difference between average plastics per photo between the analysis of 10 photos and 20 photos.

The specific objectives of this study were to establish where microplastics are present most abundantly, the backshores of beaches or the wrack lines, and whether high human activity is a main factor in high plastic contamination. This study tests the hypothesis that microplastics will be more abundant at the shore of the Jones Beach site than the shore of the Fire Island beach site because the Jones Beach site is used more heavily by tourists and the general public. Additionally, this study tests the hypothesis that there will be more microplastic presence at the wrack lines for both beaches compared to the backshores, being the wrack line is where material less dense than the seawater is distributed (Pfaff, 2019).

Results

A Kruskal-Wallis One Way ANOVA compared the average quantity of fibers present in all of the treatment groups (Figure 5). The differences in fiber counts were not enough to exclude the possibility that the differences were caused by random sampling, not rejecting the null hypothesis (P= 0.068). The samples taken from Jones Beach resulted in the highest average quantity (2923 fibers kg^{-1} of sand). Interestingly, locations with the lowest average plastic count were the Jones Beach backshore and the Fire Island wrackline (1838 fibers kg^{-1} of sand).

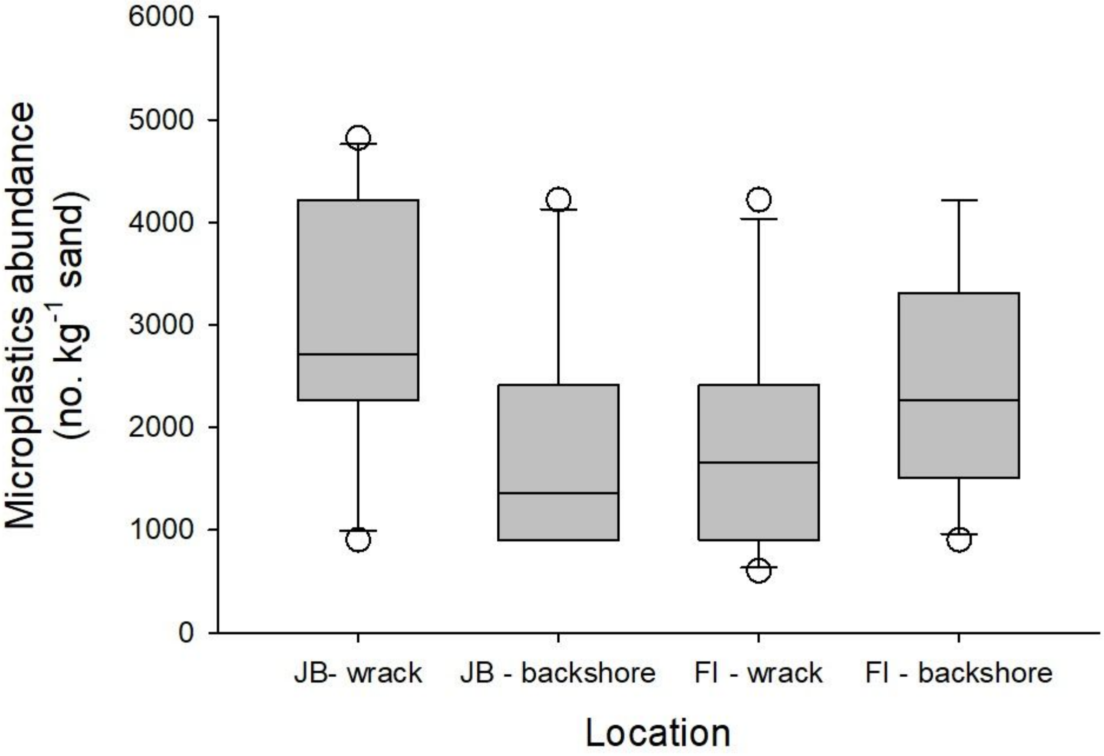

Figure 5 - Comparison of microplastic quantity showing no significant difference in counts. The middle lines represent the samples' median plastic counts, and the box represents the 25th and 75th percentile values of micro plastic counts.

A Kruskal- Wallis One Way ANOVA was conducted to compare the average lengths of fibers present in all of the treatment groups (Figure 6). The differences in mean fiber lengths were not enough to exclude the possibility that the differences were caused by random sampling, not rejecting the null hypothesis (P= 0.424.) The samples taken from the Jones Beach wrack line again had the highest average fiber length (2923mm kg^{-1} of sand). The location of samples with the lowest average fiber length was the Fire Island wrackline (1847 mm fibers kg^{-1} of sand).

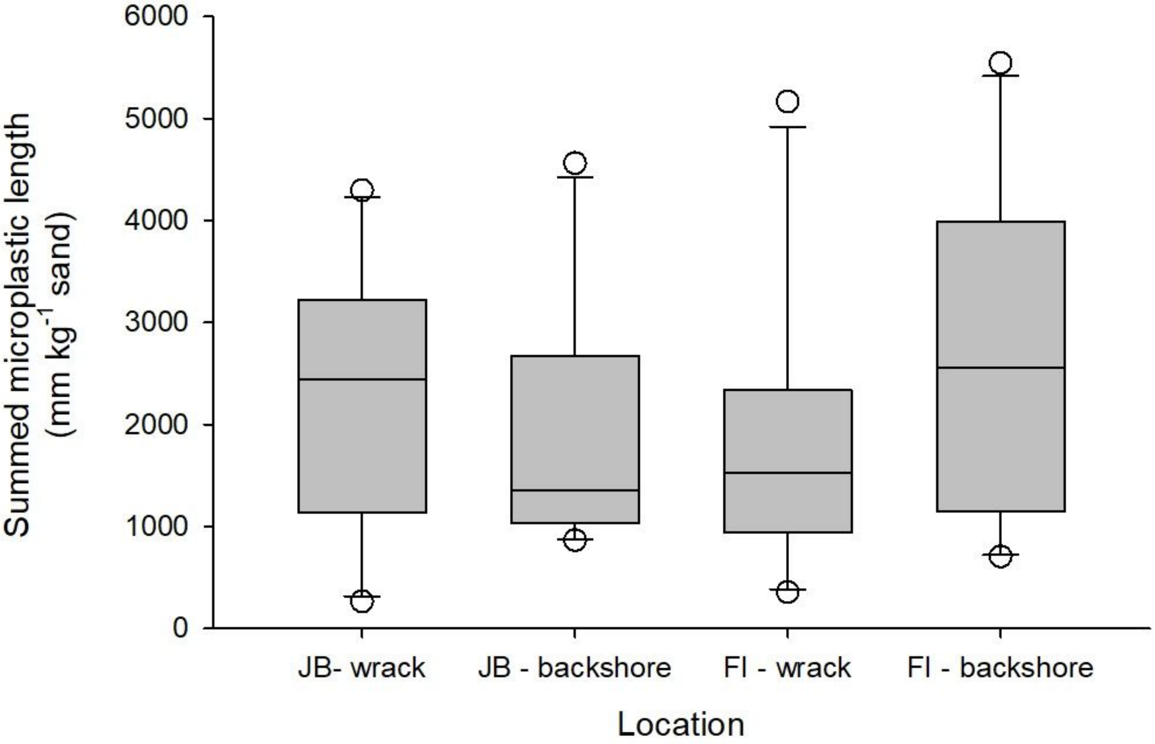

Figure 6 - Comparison of microplastic length (mm) kg^{-1} of sand of sand showing no significant difference in lengths. The middle lines represent the samples' median plastic lengths, and the box represents the 25th and 75th percentile values of micro plastic lengths.

A power of performed test was conducted using an alpha of 0.050 and was below the desired power of 0.800 (0.049). This indicates one would be likely to detect no difference where one actually exists.

The number of plastics < 1.0mm and ≥ 1.0mm were categorized as microplastic or macroplastic as well for each treatment group. In all treatment groups, microplastics and macroplastics were present. However, in all locations, there was a greater amount of microplastics than macroplastics. A regression was done to test the relationship between macroplastic counts and microplastics counts and no relationship was supported (Figure 7).

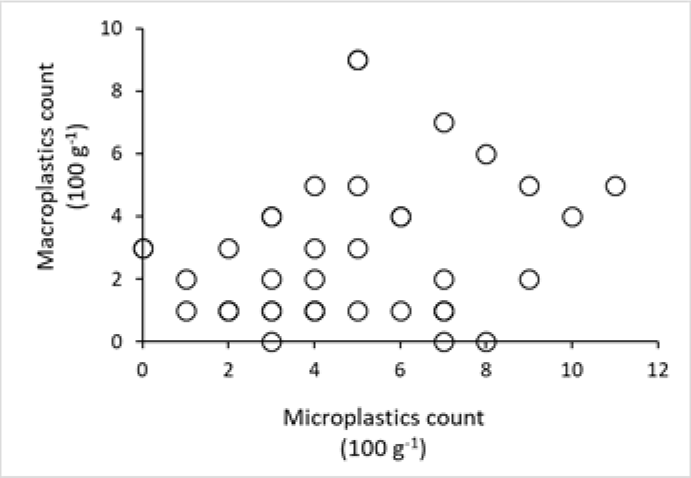

Figure 7- Linear regression showing microplastic count (<1.0mm) has no notable effect on macroplastic count (≥ 1.0mm).

Discussion

Microplastic fibers were found at both field locations, with no significant difference between plastic fibers found at Jones Beach Field 6 and Fire Island Lighthouse Beach. From this data, one could conclude that patron density does not have a significant effect on the amount of microplastic fibers present in sand samples. It is important however, that in both locations there were microplastic fibers present in the sand samples.

In the study conducted by Chiba et al. (2018), pieces of one-time use plastics were photographed in the deepest parts of the oceans, 1000 km from the mainland. Chiba et al. (2018) found the buoyancy of microplastics enabled them to be carried large distances by ocean current, allowing for the spread of microplastics to areas otherwise untouched by humans (e.g., the deep sea). The results of Chiba et al (2018) demonstrates the ability for plastics to move far distances, even without human interaction, thus supporting the findings of this study. Other studies have found microplastic fibers, such as those found in this study, in places as remote and untouched as freshwater lakes in the arctic (González-Pleiter et al., 2020). The ability of microplastics to travel great distances is likely a factor in why microplastics densities were similar at both beach locations.

Plastic's ability to spread over far distances should also be noted when considering effects on wildlife. Studies of wildlife plastic ingestion are widespread geographically and among various subject species (Zhu et al., 2019) (Drever et al., 2018) (Crump et al., 2019). Wildlife from all trophic levels are exposed to plastics, with particular concern for those of low trophic levels, as plastic has been proven to amplify up the food chain (Cole et al., 2013). The inability of animals' to break down and digest plastic results in animals feeling a false sense of being full due the plastic's presence in their stomach, when actually they become malnourished and die

(Drever et al., 2018). Plastic ingested and not passed remain in the bodies of wildlife for the duration of their lives (Butler, 2018).

Though efforts have been made to minimize plastic use and improve the efficiency of its disposal through legislation, this progress is being threatened by the current global health crisis caused by COVID-19. One must consider the environmental implications of this outbreak. A major consequence of the influx of disposable personal protective equipment is the dire need to come up with a system capable of safely processing the waste, some of which being hazardous waste (Klemeš et al. 2020). There has been an influx of protective equipment in urban environments, many of which are plastic and other synthetic materials, carried by wind and water across many ecosystems and geographic areas. Additionally, requirements for beach patrons to wear a mask when entering the beachfront has resulted in masks, many of which are composed partially of plastic such as elastic, being abandoned in the sand and faced with reluctance from staff to pick them up and dispose of them due to their own precautions against the virus. Furthermore, the ability of plastics to spread to areas never touched by humans, such as the deep sea, suggests the need for further research on plastic fragments and their ability to be used as vectors, potentially resulting in widespread, or even global, outbreaks (Cauwenberghe et al., 2013).

There is a critical need for the reduction of plastic use in our world today. Represented in this study and studies from all over the world, widespread plastic is yet another indicator that we, as humans, need to change how we treat the natural world (Auta et al., 2017). Without modification to currently normal practices, such as ending the use and production of single use plastics, the degradation of these ecosystems will continue to cause detrimental effects to populations, ranges, and overall viability of organisms in ways proving to be irreversible. Just as plastic has become more abundant in our everyday lives, we can expect the same fate for our beaches.

In future studies, one should consider taking sand samples very early in the Spring season in hopes of allowance of using a shore protected from the public all together such as a wildlife sanctuary. For the timeline of this project, it was not feasible to sample in such a place due to the endangered shorebird breeding season on the Northeast coast where this study was conducted. Fire Island Lighthouse beach has significantly lower patron usage, but ideally a private beach could be sampled in the future. Furthermore, the size of plastics samples were limited in this study. Further research should be done on these areas with larger plastics such as the study of Long Island and Connecticut shores conducted by Doherty (2019) showing plastics of < 5mm present at various beaches, some of which are similarly located on the south shore of Long Island.

Conclusion

As time goes on, the problem of plastic disposal is going to be more critical, affecting local and global ecosystems drastically. Ingestion by wildlife is one of the most notable issues due to amplification that can spread across many species and territories. Ongoing research such as this study continues to prove the widespread gravity of microplastic contamination of ecosystems. Current research supports that due to factors such as buoyancy and very slow decomposition, plastics are becoming abundant in areas that are untouched by humans, proving more importance than ever in establishing a standardized practice of microplastic extraction to create a baseline of information for future conservationists and policy makers. This is information that could influence decisions regarding plastic disposal globally and allow us to create a plan for disposal. If we hope to preserve our shores and the complex biodiversity they support, change must occur now.

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Literature Cited

Andrady, A. L. Microplastics in the marine environment. 2011. Marine Pollution Bulletin 62:1596–1605.

Auta, H. S., C. U. Emenike, and S. H. Fauzian. 2017. Distribution and importance of microplastics in the marine environment: A review of the sources, fate, effects, and potential solutions. Environment International 102:165–176.

Butler, D. R. 2018. Zoogeomorphology in the Anthropocene. Geomorphology 303:146–154.

Cauwenberghe, V. L., A. Vanreusel, J. Mees, and C. R. Janssen. 2013. Microplastic pollution in deep-sea sediments. Environment Pollution 60: 1-5.

Chen, Q., A. Allegien, D. Yin, and H. Holler. 2019. Leaching of endocrine disrupting chemicals from marine microplastics and mesoplastics under common life stress conditions.

Environment International 130:104938.

Chiba, S., H. Saito, R. Fletcher, T. Yogi, M. Kayo, S. Miyagi, M. Ogido, and K. Fujikura. 2018. Human footprint in the abyss: 30 year records of deep-sea plastic debris. Marine Policy 96:204–212.

Cole, M., P. Lindeque, E. Fileman, C. Halsband, R. Goodhead, J. Moger, and T. S. Galloway. 2013. Microplastic Ingestion by Zooplankton. Environmental Science Technology 47, 12: 6646-6655.

Corcoran, P. L., C. J. Moore, and K. Jazvac. 2014. An anthropogenic marker horizon in the future rock record. GSA Today:4–8.

Crump, A., C. Mullens, E. J. Bethell, E. M. Cunningham, and G. Arnott. 2020. Microplastics disrupt hermit crab shell selection. Biology Letters 16:20200030.

Doherty B. 2019. Quantification of micro- and macroplastics from beaches of Long Island and Connecticut. Senior thesis, Purchase College.

Drever, M. C., J. F. Provencher., P.D. O'Hara, L. Wilson, V. Bowes, and C. M. Bergman. 2018. Are ocean conditions and plastic debris resulting in a “double whammy” for marine birds? Marine Pollution Bulletin 133, 684–692.

Fernandino, G., C. I. Elliff, H. Francischini, and P. Dentzien-Dias. 2020. Anthropoquinas: First description of plastics and other man-made materials in recently formed coastal sedimentary rocks in the southern hemisphere. Marine Pollution Bulletin 154:111044.

Geyer, R., J. R. Jambeck, and K. L. Law. 2017. Production, use, and fate of all plastics ever made. Science Advances 3:e1700782.

Laurance, W. F. The Anthropocene. 2019. Current Biology 29:R953–R954.

Keswani, A., D. M. Oliver, T. Gutierrez, and R. S. Quilliam. 2016. Microbial hitchhikers on marine plastic debris: Human exposure risks at bathing waters and beach environments. . Marine Environmental Research 118:10–19.

Klemes, J.J., Y. VanFan, R. R. Tan, and P. Jiang. 2020. Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19. Renewable and Sustainable Energy Reviews 127:109883.

Pfaff, M. C., and R. Nel. 2019. Intertidal Zonation. Encyclopedia of Ecology (Second Edition)1:97–107.

Rodrigues, A., D. Oliver, A. McCarron, and R. Quilliam. 2019. Colonisation of plastic pellets (nurdles) by E. coli at public bathing beaches. Marine Pollution Bulletin 139:376–380.

Van, A., C. M. Rochman, E. M. Flores., K.L. Hill, E. Vargas, S. A. Vargas, and E. Hoh. 2012. Persistent organic pollutants in plastic marine debris found on beaches in San Diego, California. Chemosphere 86(3): 258-263.

Xanthos, D., and T. R. Walker. 2017. International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): A review. Marine Pollution Bulletin 118:17–26.

Zhu, J., X. Yu, Q. Zhang, T. Li, S. Tan, D. L, Z. Yang, and J. Wang. 201Z9. Cetaceans and microplastics: First report of microplastic ingestion by a coastal delphinid, Sousa chinensis.Science of The Total Environment 659:649–654.