FIU Undergraduate Research Journal

Volume 2
Issue 1 *Spring 2024*

Article 1

2024

Implications of Microplastic Pollution for the Conservation of Marine Protected Areas

Estefany D. Carvajal
Florida International University, ecarv018@fiu.edu

Amanda Di Perna
Florida International University, adiperna@fiu.edu

Alain Duran
Department of Biological Sciences, Florida International University, alduran@fiu.edu

Implications of Microplastic Pollution for the Conservation of Marine Protected Areas

Cover Page Footnote

A very special thanks to Dr. Alain Duran for being my mentor in this project. I would also like to thank my close friend Amanda Di Perna for helping conduct the literature reviews and creating the graphs. She was an essential part of this research and I thank her for all her help.

FIUURJ (2024), Volume 2, Article 1, pp. 1–9.
DOI: https://doi.org/10.25148/URJ.020101

FIU Undergraduate Research Journal

Implications of Microplastic Pollution for the Conservation of Marine Protected Areas

Estefany Carvajal, Florida International University, ecarv018@fiu.edu
Amanda Di Perna, Florida International University, adiperna@fiu.edu
Dr. Alain Duran (*Co-Author & Faculty Mentor*), Florida International University, alduran@fiu.edu
Student Editor **Hayley Serpa**, Florida International University, hserp001@fiu.edu

Marine Protected Areas (MPAs) function as a tool for the protection and conservation of marine ecosystems. These designated areas should be free of any environmentally harmful pollutants. Microplastics (MPs) are plastic fragments measuring less than 5 mm (about 0.2 in). These fragments are an emerging threat to our oceans, and we are investigating the effectiveness of MPAs against these pollutants. We analyzed data gathered from research conducted on microplastic concentrations in MPAs and non-MPAs around the world. 53 MPAs and 53 non-MPAs around the world were used and the microplastic concentrations were deemed low, medium, or high by using the classifications established by the researchers. The Marine Protection Atlas (MPATLAS), created by the Marine Conservation Institute, was used to identify the levels of protection of each MPA and confirm the size of the protected area. The population density of cities nearest to an MPA or non-MPA was obtained by dividing the city's population by the total area. Microplastics were found in all 106 sites researched, including waters near Antarctica and the northern waters of Greenland. When compared to non-MPAs, MPAs showed a higher number of areas with a "high" or "medium" concentration of microplastics. This indicates that Marine Protected Areas are an inefficient conservation tool against microplastic pollution. Population density did not appear to have a relationship with microplastic concentrations in MPAs and non-MPAs. The prominence of microplastics in protected marine ecosystems highlights the urgency to uncover their effects and a way to combat these anthropogenic pollutants.

Keywords: *microplastics, marine protected areas, pollutants*

Introduction

Marine debris is a rapidly increasing problem for our world oceans and is a subject that is only beginning to be explored. Based on the *Web of Science,* the number of papers published annually about marine and plastic debris has doubled since 2000. Scientists, along with members of different industries, all agree that marine debris is an environmental concern that damages habitats and the life that lives inside of them (Rochman, 2016). Certain types of debris, such as plastic, become passive tracers whose movement correlates to ocean circulation due to their buoyancy and insolubility. Physical ocean processes, such as surface currents, are responsible for transporting floating marine debris (Kubota, 1994). However, due to their chemical composition and variability in density throughout their breakdown, mapping the transport of microplastics has proven to be a challenge.

The life span of plastic in salt water has not been conclusively determined due to its relatively new appearance in the ocean ecosystem. The mass production of plastics began in the 1930s and 1940s, less than a century ago with the rise of war-era industrialization. Now, according to Plastic Oceans, over 380 million tonnes of plastics are being produced yearly, with China producing 20% of the pollutants (Wang et al., 2019). Different types of plastics rely on different chemicals, such as polyvinyl chloride (PVC) and polyethylene terephthalate. The addition of chemicals can alter the debris' degradation rate (Chamas et al., 2020). The photodegradation of plastic debris is the result of erosion and sun exposure. To more accurately quantify plastic degradation rates, more variables need to be considered. Nevertheless, plastic is not biodegradable. Instead, it will simply break into micro and nanoparticles, remaining in our oceans indefinitely. The increased abundance of marine litter in our oceans has raised concern. On beaches, common plastic items such as bags, cups, straws, fishing gear and containers account for around 80% of debris in our oceans (Galgani et al., 2015). The United Nations Environment Assembly (UNEA) has made sure to highlight the importance of acting to reduce the pollution threatening our oceans and their inhabitants (Chassignet et al., 2021).

Microplastics (MPs) are anthropogenic pollutants caused by the degradation of larger plastic debris. These pollutants are classified as plastic particles smaller than 5 mm in size. In 2014 there was an estimated 5.25 trillion plastic particles in our oceans weighing over 268,000 tons (Eriksen et al., 2014). The origin of microplastics is not just limited to the degradation of larger debris; microplastics can be introduced into the ocean through powders and pellets referred to as nurdles. They can also be introduced via the sewage system through some cosmetic products such as mascaras, lipsticks and face powders (Thompson, 2015). Although their effects are still being investigated, research over the years has highlighted the potential toxicological effects that these pollutants can have on marine organisms. Recently, it has been discovered that MPs were found in tissues of two highly threatened marine species (Nunes et al., 2023) Microplastics expose marine life to a plethora of synthetic chemicals. Among these chemicals are bisphenol A (BPA) and phthalates. These chemicals are referred to as endocrine-disrupting chemicals (EDCs) and have been shown to affect the development of marine species by altering thyroid hormone levels and growth hormone levels and have also been shown to affect reproduction (Mathieu-Denoncourt et al., 2015). Microplastics distribution and their effects are being researched by many international organizations, such as the United Nations, to local universities and national governments.

Marine Protected Areas (MPAs) have been used as a conservation tool to protect marine ecosystems and populations from anthropogenic effects. These designated areas have been shown to increase the connectivity of ecosystems, promote spillover, and increase the protection of critical marine species (Roberts et al., 2001). The first established MPA occurred in the 1970s, around 40 years after the production of plastic products. According to MPAtlas, there is a total of 16, 615 designated marine protected areas covering over 26,000,000 km^2 (about the area of Africa) of our Earth's ocean. Through the review of over 177 articles, researchers determined that 186 marine-protected sites had microplastics present (Nunes et al., 2023). Despite their implementation and record of success against other marine ecosystem threats, not much is known about MPAs success against microplastic pollution.

Methods

Search Strategy

To obtain our primary data we searched for published and peer-reviewed primary sources using *Web of Science*. The keywords used in our search were: "microplastic(s)," "Marine protected area(s)," "MPA(s)," "ocean(s)," "sea(s)," and "marine." Using "WebofScience" to narrow down research papers relevant to our question, we found articles that had measured microplastic concentration in various MPAs and non-MPAs around the globe. To increase the accuracy of our research, we searched for non-protected sites that could be found in the same region as the chosen MPAs. The Marine Protected Areas were verified using the website MPAtlas, an international database of all the established Marine Protected Areas around the globe. Overall, 53 Marine Protected sites and 53 non-protected sites were used in this research for 106 sites. This data collection method was used by multiple sources cited to map the location of microplastics and their relative abundance.

Managing the Data

Primary data collected by researchers varied in units and methods of collection. Some used advanced chemical analysis to identify suspended particles in a water column, others used mesh nets to collect the plastic particles and quantify them. Due to the variability in collecting methods and units, the data collected had to be standardized. To standardize the data, we decided to establish levels of MP concentration. The three categories established were low (1), medium (2), and high (3). Due to the variability in concentration units, an MPA or Non-MPA would have a low MP concentration if the researchers affirmed that in their paper.

Population Density

To determine the population density of the nearest city, the Marine Protected Areas were found on

Google Maps and the nearest city to that MPA was identified. Through a Google search, the total area of the city, along with the population size was found. Then, the population size was divided by the total area to obtain population density. The same steps were completed with the non-protected sites.

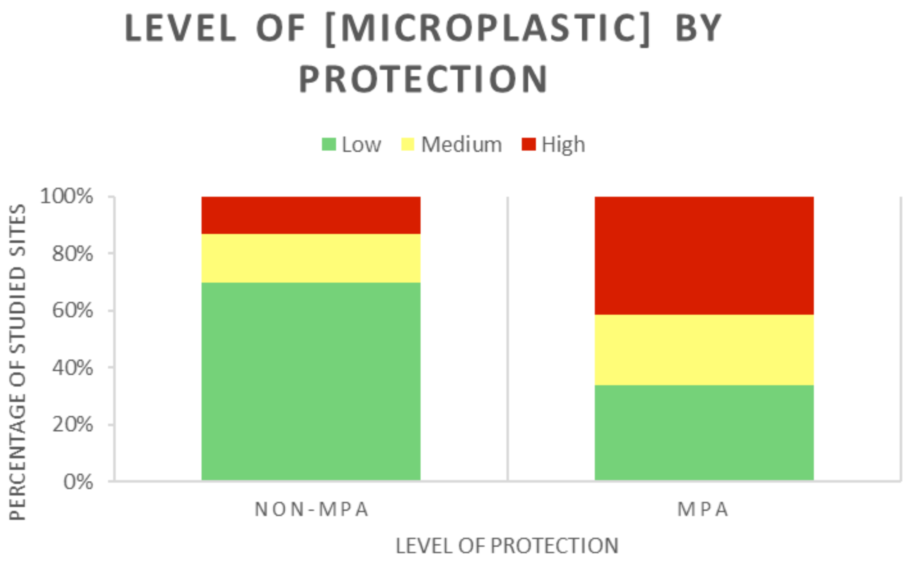
Results

Microplastic Concentrations in MPA and Non-MPAs

Figure 1 shows that 63% of the 53 non-protected sites studied displayed low levels of microplastic concentration. Around 20% of the sites showed a medium level of microplastic concentration. When compared to the marine protected areas, high MP areas had more than 3x the concentration of microplastics when compared to non-MPAs. Only approximately 30% of the protected sites had a low microplastic concentration.

Figure 1

Proportion of studied sites with a low, medium, or high microplastic concentration in both Protected and Non-protected areas



Population Density

A linear regression test (**Figure 2** & **Figure 3**) demonstrated no correlation between population density and microplastic concentration in protected and non-protected sites. The city of Al-Hoceima, Morocco had the largest population density of any of the cities near the studied MPAs. This city's respective MPA is the Al-Hoceima National Park with a microplastic concentration of 519,055 particle/km^2 (high, 3). However, Queen Charlotte Sound (QCS) in Canada also had a high microplastic concentration despite the population density of the nearest city being 0. For non-protected sites, the city of Colon, Panama had the largest population density with 82,717.6163. The microplastic concentration of the site measured near this city was high. The concentration of microplastics was also high in areas with no near cities, or a population density of 0.

Figure 2

Population density of the cities nearest to the non-protected site surveyed

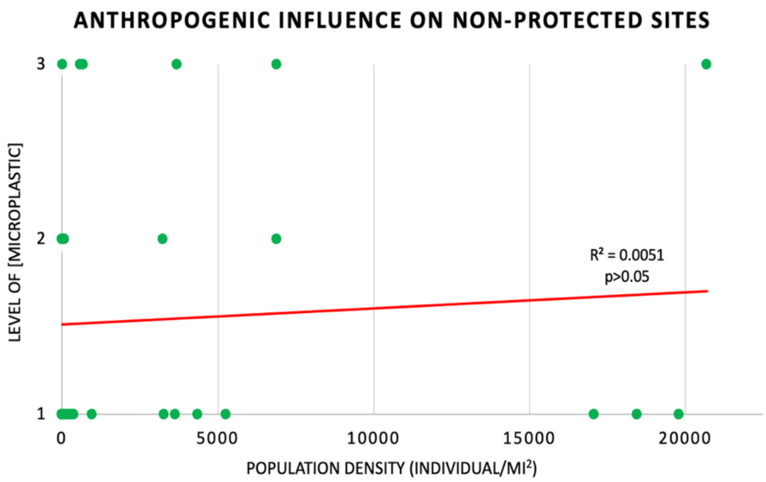
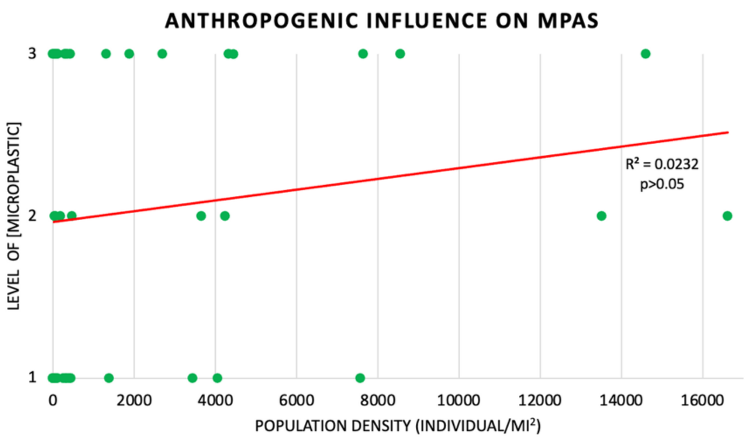


Figure 3

*Population density of the cities nearest to the protected site surveyed and the level of microplastic concentration. *1=low, 2=medium, 3=high*



Discussion

Due to the large proportion of MPAs with high microplastic concentrations compared to the non-MPA sites, MPAs appear to show no protection against microplastic pollution. In fact, the data demonstrates that there is a greater proportion of non-protected sites with lower concentrations of microplastics than the protected areas (**Figure 1**). The population density of the cities closest to the sites also did not appear to be a factor for the unexpected proportion, as shown in **Figures 2** & **3.** Further analysis of water current movement could explain the distribution of microplastics and could identify why certain protected areas accumulate more microplastics than others. Additionally, MPAs have no physical border so they are influenced by oceanographic processes, such as currents. Surface current transport models have been used to accurately predict the movement of plastic debris. Research has demonstrated that these currents are responsible for the transport of microplastics from subtropical to polar regions of the ocean. This can explain the presence of microplastics observed in remote areas such as Antarctica (Wichmann et al., 2019) . Furthermore, understanding the movement of microplastics through deep ocean currents can also help in identifying microplastic hotspots, places of high microplastic concentration.

Finding data to conduct this research tended to be a challenge. The microplastic concentration units varied across different scientific articles. Some measured MP concentration using volume others using area. The lack of standardization of the data leaves room for bias. Because of the inability to standardize the data ourselves, we had to create levels of microplastic pollution. The sites were placed into three levels: low, medium, and high, based on the analysis of the researcher that collected the sample. If the researcher stated that the microplastic concentration they found was considered low, it would also be considered low for the purpose of our research. This can leave room for misinterpretation and the mis-categorization of the protected and nonprotected sites. It is also important to highlight that prior to the establishment of an MPA, there could have been microplastic contamination, so the concentration recorded does not accurately represent the MPA's effectiveness against microplastics. Nevertheless, it cannot be ignored that the presence of microplastics in areas designed for the conservation and protection of flora and fauna is evidence that MPAs are not enough for the proper conservation of marine areas.

Microplastics (MPs) are known to be consumed by a wide variety of marine organisms ranging from filter feeders such as clams to larger aquatic species, like whales and dolphins (Xu et al., 2020). Their presence is pervasive in food chains and can bioaccumulate up trophic levels. The ingestion of these microplastics can cause an accumulation in the digestive tract, liver inflammation, induce oxidative stress in cells, and alter metabolic rates (Lu et al., 2016). From a conservation standpoint, MPs can pose a serious threat to endangered marine species. Most of the research conducted to test the effects of MPs in organisms has been laboratory-based. The lack of in situ research creates knowledge gaps on the topic. These knowledge gaps include the wild effects of microplastics on an organism's behavior, reproduction, morphology, or physiology. The inability to fully and precisely recreate the marine environment also leaves researchers questioning the rate of degradation of plastics. Further research should be conducted on MPs' effects and ways to protect our oceans from them.

Annual fish consumption globally has greatly risen since the 1960s. In 2014, the consumption per capita of seafood exceeded 20 kilograms. This, when compared to the 10 kg per capita consumption in 1960, hints at seafood being a substantial part of the human diet (Guillen et al., 2019). The presence of these pollutants in edible fish gives way to their ingestion by humans. Microplastic particles have been quantified in human blood (Leslie et al., 2022). Although their exact effects are still being investigated, it is predicted that microplastics can disrupt the immune system, cause neurotoxicity, and can be transferred from one tissue to another (Bhuyan, 2022). The pervasiveness of microplastics can be highlighted through the discovery of microplastic particles in the human placenta (Ragusa, 2021). This discovery suggests that microplastics could pose developmental threats to fetuses as these particles could interfere with critical cellular processes. Further research on microplastics and their effects on humans and human development is needed.

An international microplastic monitoring system would prove to be a useful tool in recording microplastic concentrations throughout the world's oceans into one standardized system. This can allow researchers to compare microplastic concentrations throughout time and location, possibly helping to identify areas at greater risk for contamination. An example of this is the Integrated Marine Debris Observing System (IMDOS). The goal of this system is to monitor plastic debris concentration, pathway, origin, and composition (Maximenko et al., 2019). Supporting and implementing programs like these will help facilitate the fight against these anthropogenic pollutants.

On a positive note, the danger of microplastics to our oceans and their persistent threat to humans have become a popular topic of concern throughout the years, with more research being published regarding the topic. International organizations such as the United Nations, in conjunction with nations interested in protecting our environment, have passed laws and treaties to decrease plastic pollution. According to the United Nations, 175 nations are creating an agreement to decrease the amount of plastic waste. It is important that we understand the consequences of microplastics, their degradation rates, how to remove them from our environment, and how to prevent more plastics from entering our oceans.

References

Chamas, Ali, et al. "Degradation Rates of Plastics in the Environment." *ACS Sustainable Chemistry & Engineering*, vol. 8, no. 9, 2020, pp. 3494–3511, doi:10.1021/acssuschemeng.9b06635.

Cruz-Salas, Arely Areanely, et al. "Solid Waste and Microplastics on the Beaches of Holbox Island, Mexico." *Regional Studies in Marine Science*, vol. 53, June 2022, p. 102423, doi:10.1016/j.rsma.2022.102423.

Delvalle de Borrero, Denise, et al. "Distribution of Plastic Debris in the Pacific and Caribbean Beaches of Panama." *Air, Soil and Water Research*, vol. 13, 2020, p. 117862212092026, doi:10.1177/1178622120920268.

Desforges, Jean-Pierre W., et al. "Widespread Distribution of Microplastics in Subsurface Seawater in the NE Pacific Ocean." *Marine Pollution Bulletin*, vol. 79, no. 1–2, 2014, pp. 94–99, doi:10.1016/j.marpolbul.2013.12.035.

Eriksen, Marcus, et al. "Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea." *PLoS ONE*, vol. 9, no. 12, 2014, doi:10.1371/journal.pone.0111913.

García Rellán, Adriana, et al. "Sources, Sinks and Transformations of Plastics in Our Oceans: Review, Management Strategies and Modelling." *Science of The Total Environment*, vol. 854, 2023, p. 158745, doi:10.1016/j.scitotenv.2022.158745.

Germanov, Elitza S., et al. "Microplastics: No Small Problem for Filter-Feeding Megafauna." *Trends in*

Ecology & Evolution, vol. 33, no. 4, Apr. 2018, pp. 227–232, doi:10.1016/j.tree.2018.01.005.

Guillen, Jordi, et al. "Global Seafood Consumption Footprint." *Ambio*, vol. 48, no. 2, 2018, pp. 111–122, doi:10.1007/s13280-018-1060-9.

Hatzonikolakis, Yannis, et al. "Quantifying Transboundary Plastic Pollution in Marine Protected Areas across the Mediterranean Sea." *Frontiers in Marine Science*, vol. 8, 2022, doi:10.3389/fmars.2021.762235.

Jambeck, Jenna R., et al. "Plastic Waste Inputs from Land into the Ocean." Science, vol. 347, no. 6223, Feb. 2015, pp. 768–71. DOI.org (Crossref), https://doi.org/10.1126/science.1260352.

Kibria, Md. Golam, et al. "Plastic Waste: Challenges and Opportunities to Mitigate Pollution and Effective Management." *International Journal of Environmental Research*, vol. 17, no. 1, 2023, doi:10.1007/s41742-023-00507-z.

Kubota, M. "A Mechanism for the Accumulation of Floating Marine Debris North of Hawaii." *Journal of Physical Oceanography*, vol. 24, no. 5, 1994, pp. 1059–1064, doi:10.1175/1520-0485(1994)024<1059:amftao>2.0.co;2.

Lorenzi, Luciano, et al. "Spatio-Seasonal Microplastics Distribution along a Shallow Coastal Lagoon Ecocline within a Marine Conservation Unit." *Marine Pollution Bulletin*, vol. 170, 2021, p. 112644, doi:10.1016/j.marpolbul.2021.112644.

Lu, Yifeng, et al. "Uptake and Accumulation of Polystyrene Microplastics in Zebrafish (Danio Rerio) and Toxic Effects in Liver." *Environmental Science & Technology*, vol. 50, no. 7, Apr. 2016, pp. 4054–60. *PubMed*, https://doi.org/10.1021/acs.est.6b00183.

Mathieu-Denoncourt, Justine, et al. "Plasticizer Endocrine Disruption: Highlighting Developmental and Reproductive Effects in Mammals and Non-Mammalian Aquatic Species." *General and Comparative Endocrinology*, vol. 219, Aug. 2015, pp. 74–88. ScienceDirect, https://doi.org/10.1016/j.ygcen.2014.11.003.

Maximenko, Nikolai, et al. "Toward the Integrated Marine Debris Observing System." *Frontiers in Marine Science*, vol. 6, 2019. Frontiers, https://www.frontiersin.org/articles/10.3389/fmars.2019.00447.

Mayr, Floyd B., et al. *Marine Protected Areas*. Nova Science Publishers, 2010.

Nunes, Beatriz Zachello, et al. "Microplastic Contamination in Seawater across Global Marine Protected Areas Boundaries." *Environmental Pollution*, vol. 316, 2023, p. 120692, doi:10.1016/j.envpol.2022.120692.

Ragusa, Antonio, et al. "Plasticenta: First Evidence of Microplastics in Human Placenta." *Environment International*, vol. 146, 2021, p. 106274, doi:10.1016/j.envint.2020.106274.

Roberts, Callum M., et al. "Effects of Marine Reserves on Adjacent Fisheries." *Science*, vol. 294, no. 5548, Nov. 2001, pp. 1920–23. *DOI.org (Crossref)*, https://doi.org/10.1126/science.294.5548.1920.

Rochman, Chelsea M., et al. "The Ecological Impacts of Marine Debris: Unraveling the Demonstrated Evidence from What Is Perceived." *Ecology*, vol. 97, no. 2, 2016, pp. 302–312, doi:10.1890/14-

2070.1.

Saley, A.M., et al. “Microplastic Accumulation and Biomagnification in a Coastal Marine Reserve Situated in a Sparsely Populated Area.” *Marine Pollution Bulletin*, vol. 146, 2019, pp. 54–59, doi:10.1016/j.marpolbul.2019.05.065.

Sevwandi Dharmadasa, W.L.S., et al. “Microplastic Pollution in Marine Protected Areas of Southern Sri Lanka.” *Marine Pollution Bulletin*, vol. 168, 2021, p. 112462, doi:10.1016/j.marpolbul.2021.112462.

Sharma, Shivika, and Subhankar Chatterjee. “Microplastic Pollution, a Threat to Marine Ecosystem and Human Health: A Short Review.” *Environmental Science and Pollution Research*, vol. 24, no. 27, 2017, pp. 21530–21547, doi:10.1007/s11356-017-9910-8.

Tanhua, Toste, et al. “A Near-Synoptic Survey of Ocean Microplastic Concentration along an around-the-World Sailing Race.” *PLOS ONE*, vol. 15, no. 12, 2020, doi:10.1371/journal.pone.0243203.

Thompson, Richard C. “Microplastics in the Marine Environment: Sources, Consequences and Solutions.” *Marine Anthropogenic Litter*, June 2015, pp. 185–200, https://doi.org/10.1007/978-3-319-16510-3_7.

Wang, Sumin, et al. “Microplastic Abundance, Distribution and Composition in the Mid-West Pacific Ocean.” *Environmental Pollution*, vol. 264, 2020, p. 114125, doi:10.1016/j.envpol.2020.114125.

Wang, Wanli, et al. “Current Influence of China’s Ban on Plastic Waste Imports.” *Waste Disposal & Sustainable Energy*, vol. 1, no. 1, May 2019, pp. 67–78. DOI.org (Crossref), https://doi.org/10.1007/s42768-019-00005-z.

Wichmann, David, et al. “Influence of Near-Surface Currents on the Global Dispersal of Marine Microplastic.” *Journal of Geophysical Research: Oceans*, vol. 124, no. 8, Aug. 2019, pp. 6086–96. DOI.org (Crossref), https://doi.org/10.1029/2019JC015328.

Xu, Shen, et al. “Microplastics in Aquatic Environments: Occurrence, Accumulation, and Biological Effects.” *The Science of the Total Environment*, vol. 703, Feb. 2020, p. 134699. PubMed, https://doi.org/10.1016/j.scitotenv.2019.134699.