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CDS 301- 001

Plastic Pollution in the Ocean

Term Project: Milestone 3 - Research Paper - "Plastic Pollution in the Ocean"

Abstract

The excessive production of cheap plastics in the last few decades has led to an exponential increase in plastic pollution. Public awareness on the negative impacts that plastic consumption brings has slowly started to shift public perception into seeing that the immediate savings and convenience of using cheap (and mostly single use) plastics may not be worth the detrimental toll it can have on our environment. The plastics being released into the oceans have devastating effects not only on water quality but also marine life. Due to the natural water currents, trash in the water has aggregated into vast monstrosities like the Great Pacific Garbage Patch. It is important to note that plastic pollution can be considered a race against time since the longer plastics remain in the ocean, the more they break down into smaller pieces called microplastics. This makes cleanup efforts much harder and can be damaging to wildlife since these microplastics tend to be toxic. In this project, we attempted to illustrate how much plastic pollution has grown in the past decades. The data used were compiled from many different sources, but one of the most used for current research came from water sample data collected by surface manta tows. This set of data contains the categorized types of plastics found in the water, the quantity found, and the coordinates of where they were found. In this research paper we will attempt to present plastic pollution as a problem that has some real world remedies that can be implemented today, in order to help slow the devastating effects that plastic pollution is having on our planet. We used these datasets to develop visualizations to illustrate the seriousness of this problem while also determining examples of how this problem can be collectively addressed.

Introduction/Background

Plastic products are being produced daily at an alarming rate. Most of these plastics end up being released into our environment. The majority of plastics normally take up to 1,000 years to decompose in landfills, while single use plastic bags or bottles can take about 450 years or more to fully decompose. Oftentimes, the plastic that cannot be recycled or sold will end up being dumped into the ocean. These plastics do not easily biodegrade and instead just slowly degrade in size over time due to ultraviolet radiation, external physical forces or through hydrolysis. Once these plastics reach less than 5 mm in size, they become categorized as microplastics and bring forth new sets of problems. Due to their small size, wildlife will at times ingest these microplastic accidently. Since animal digestive systems are unable to break plastics down completely, these microplastics instead physically damage them by blocking or obstructing certain organs inside their bodies, where it can also chemically damage them when toxic pollutants are released from the plastics. The toxic effects that microplastics have on animal life

is not fully understood, but some studies have shown that animals that have had plastic in their systems tend to behave differently and oftentimes are less able to survive or thrive (Lönnstedt).

An important subtopic to consider that is still being researched is the category of the plastics as they continue to degrade into even smaller particles. The term nanoplastic is still under debate, but is used for plastics with the size ranging from 1 nm to 1000 nm. Nanoplastics could potentially be more dangerous since they can cross the cellular membrane and affect cells, and they would be harder to detect as well as get rid of (Gigault). Plastics have been found to enter the ocean mainly through continental sources like industrial and urban effluents, rivers and runoff of beach sediments. Once plastics get into the ocean, marine life will often ingest them. The microplastics tend to be distributed into their circulatory system where it is then taken to different tissues and organs. The presence of microplastics in fish sold for human consumption has been found. Even though the adverse effects that it can have on our bodies is not currently known, the results, if they are at all similar to the adverse effects it has on fish, cannot be advantageous (Barboza).

Global plastic production began to skyrocket 50 years after the production of the first synthetic plastic called Bakelite. As of 2015, we are estimated to have around 381 million tonnes of plastic on our planet (Ritchie). This increase in plastic production has exacerbated plastic pollution, especially due to the use of single use plastics that provide convenient, cheap, lightweight and easy to produce transportable goods. In order to slow the use of single use plastics and phase out their use, we must support development and promotion of sustainable alternatives such as stainable steel, beeswax-coated cloth, wood, ceramic, etc.

Methods

Data found for this research study was put into three distinct types of visualizations, geographical, categorical, and numerical. The geographical visualizations involved the use of an overlay map with data points from the surface Manta Tow sample data. These tows are basically large buoys with nets attached to small to medium sized boats. These boats go out and drag the large nets across different longitude and latitude coordinates and report on the plastics they find. The data is then broken down onto the different categories of plastics found.

Using the coordinates where the plastics are located, along with chosen maps from one of the R, Python and/or Tableau packages, we were able to construct our geographical visualizations. The data points in these visualizations use color and size to demonstrate quantity and size of the plastics found. These geographical visualizations were also used to show different country and continent data. The categorical visualizations included bar charts and pie charts that were illustrated similarly. Numerical visualizations were used to display data as it changed over a period of time. This was important to properly exhibit the increasing and decreasing trends of plastics over time, as well as determine the data projections of where they could be in the future. The data compiled across the different websites came from both government funded groups as well as large privatized groups, both focused solely on the plastic pollution problem.

The data sources often contained more than just their raw data. Some of them contained a bit about the history of how the development of plastic has increased over the years. Others provided ideas about potential practices that we could implement to start combating this problem now. The data sources that contained no raw data were used as references for the main writing on this paper, and the information on them was cross examined using information from other research papers. An important and significant find came from "The Ocean Cleanup Project," which showed how 80% of plastic pollution every year came from only 20 rivers. They collected data annually, making their raw data great for numerical visualizations, showing how the pollution from these 20 rivers has increased over time. Their raw data required less manipulation, for it is simplified and averaged out, albeit still requiring changes. For example, how rivers that flow through different countries get categorized based on the aggregation of plastic pollution continentally. This was solved by moving the numbers from country levels of waste to continental levels of waste. Unfortunately, simplifying data like this can oftentimes create a loss in accuracy.

Data Analysis

The Plastic Lifecycle: Production to Use

As mentioned previously, the Plastic's Lifecycle starts at its production. Plastic production started in 1907, but it was not until the 1950's when plastic production started to increase as an industry. In the year 1950, there were 2 million tonnes of plastic produced globally, as seen in Figure 1**.** By 1953, that number had increased to 3 million tonnes, by 1954, there were 4 million tonnes and by 1955, there were 5 million tonnes produced globally. The first larger jump other than a 1 million tonne increase was from the year 1961 to 1962, a jump from 9 million tonnes to 11 million tonnes produced annually on a global scale. From there, the numbers continued to grow exponentially. It was not until 1975 when we started to see a slight drop in the curve. This was mostly due to a large number of plastic production workers being laid off due to a global recession that followed the end of World War II. You can also see another drop in 2008 due to the Great Recession. Global plastic production is expected to continue to increase exponentially in the coming years unless governments begin to set new regulations that will reduce the number of plastics being produced each year.

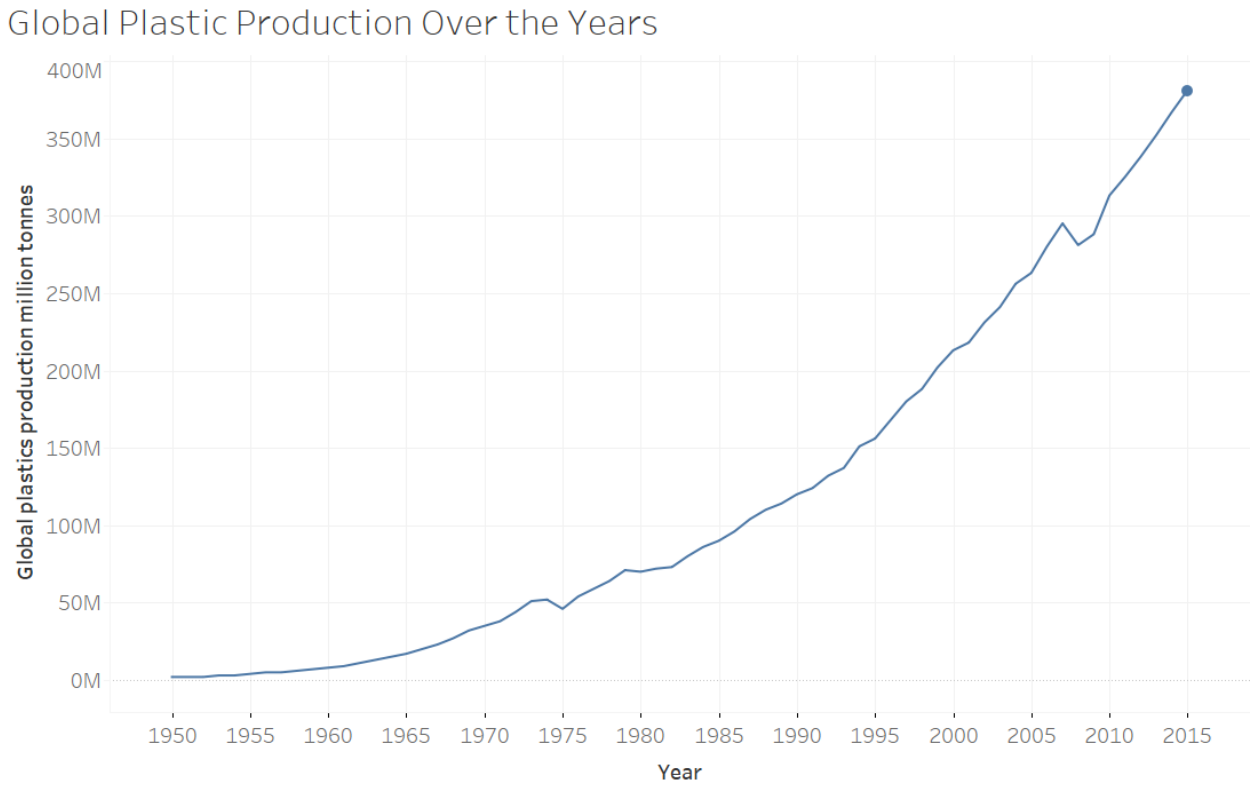

Figure 1: Global Plastic Production Ove the Years

In 2010, the two countries that created the most amount of plastic waste were China and the United States. Their numbers were far higher than those seen from France and Brazil, who are the third and fourth highest plastic waste producing countries. This can be seen in the first world map below (Plastic Waste Created Total in 2010 in tonnes). While the United States may not be directly depositing a large percentage of that waste into the oceans, they are shipping it to smaller countries that may dump it down the line (Mosbergen). Plastic waste reduction would directly lead to less plastic ending up in the oceans, and though it may be hard, it is possible for people to live in the modern world and have little to no plastic waste created. Plastic pollution, in terms of wasteful products ending up in the ocean, is exacerbated due to companies and governments choosing cheaper alternatives instead of non wasteful approaches. The United States should step up and be a leader to this initiative, instead of normalizing the creation of so much waste. Trade that deals with cheap and wasteful plastics should be hindered. In terms of per capita of waste created, the US and Germany are leading. This is shown in the second map below (Plastic Waste Created Per Capita in 2010 in kg). This statistics favors larger countries and makes their impact seem less significant, while smaller countries like Greenland and Dubai come off as worse offenders. There needs to be a global push for recyclable replacements to the current cheap plastics that end up as waste today.

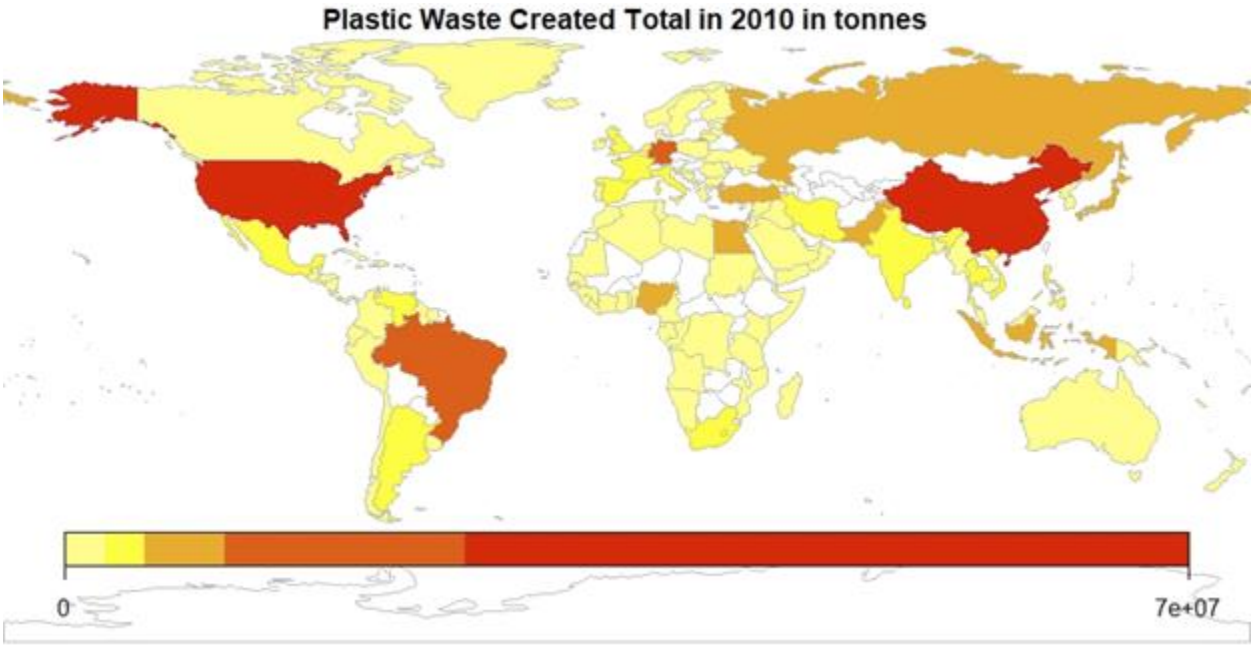

Figure 2: Plastic Waste Created Total in 2010 in Tonnes

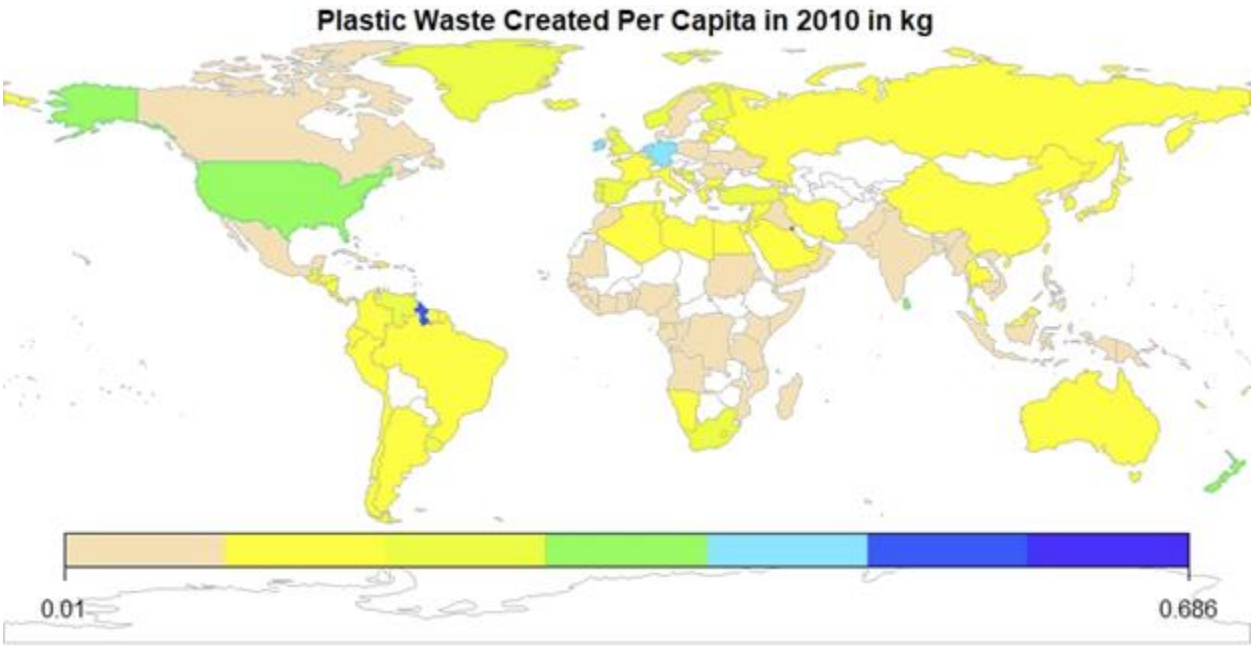

Figure 3: Plastic Waste Create Per Capita in 2010 in kg

The Plastic Lifecycle: Waste in Rivers

The majority of single use plastics that are not recycled end up in our rivers. Plastics littered on the sides of roads or walkways often end up in sewers, which oftentimes, release out onto rivers. The plastics that end up in landfills also find themselves ending up in rivers through

natural causes, such as wind or rain storms(Barboza). Unfortunately, millions of tonnes of Municipal Solid Waste (MSW), more commonly known as trash, is produced by every country each year. As shown in Figure 4**,** the main three countries producing the largest amount of trash each year are the United States, China, and India. These numbers reference all MSW and are not limited solely to plastics. Although the United States produces the largest amount of MSW each year they are not the largest contributor to plastic pollution. This may be due to several reasons. California, along with a few other states have laws against plastic pollution. One of these laws is a ban on single use bags at retail stores. Another reason is a majority of the states make recycling very easy for their residents. Many have recycle trucks that pick up the recyclables as they do with trash. Not all states or counties make it this easy, in Alabama you must take your recyclables to a recycling location instead of having them picked up. Some megacities (cities with a population greater than 10 million) in the United States participate in recycling, such as New York and Los Angeles, which reduces the amount of MSW they produce each year. Not all megacities in the world have recycling regulations like the United States' megacities do.

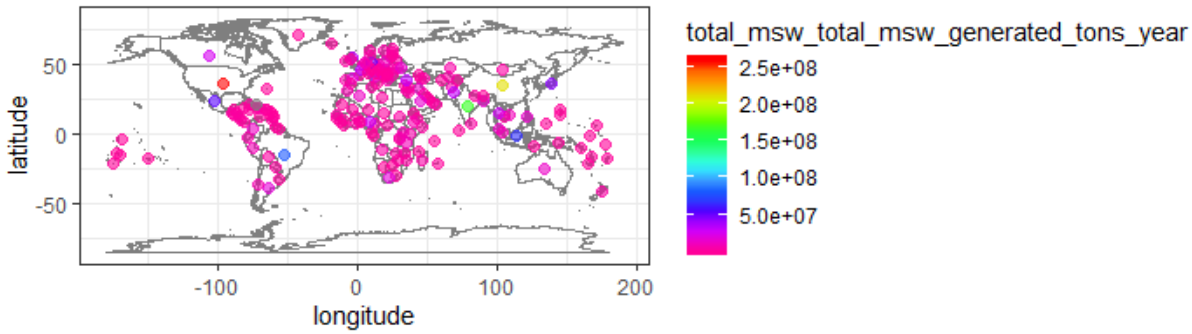

Figure 4: Global MSW Generated in Tonnes per Year

With the fact that most countries do not have recycling initiatives in mind, the top twenty rivers that release the largest amount of plastic pollution are found in the following continents: Africa, Asia, South America and the Philippines. Although some of the countries in each of these continents do not make the top three largest producers of waste, many of them do make the list of most polluted rivers, and China is the second highest on the list for MSW produced each year (Figure 4), these countries contribute the most plastics that end up in rivers Figure 6. One reason why some countries such as Thailand and Cambodia are on this map, Figure 5**,** is because one river may run through several different countries, which does beg the question of if it is really the fault of the minor countries, or the major country that also contains the river, such as China. The Mekong river in Asia runs from China, to Thailand, to Cambodia, and eventually into the ocean. One reason the Philippines contributes so much to waste is due to their land getting hit by typhoons, this then sends the plastic into streams, rivers and then the ocean especially because the majority of their landfills are by major waterways (Vila).

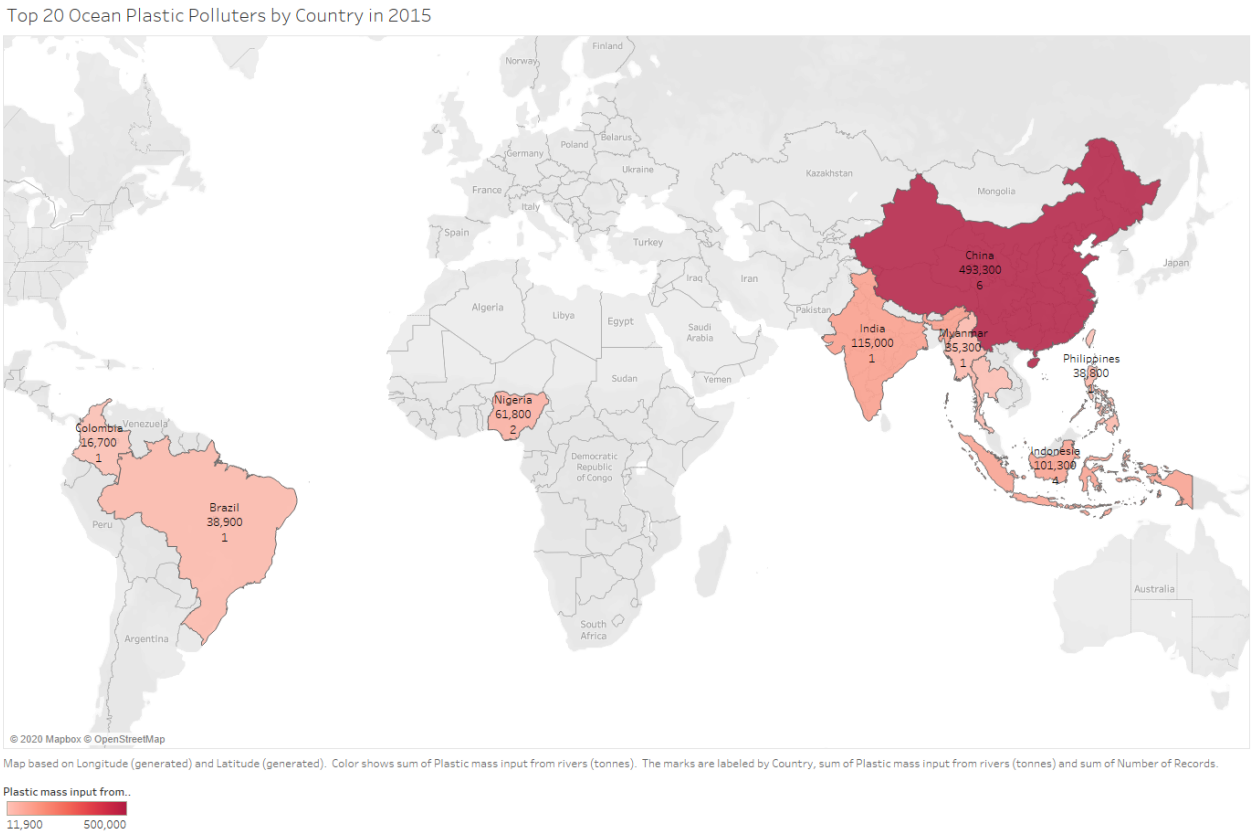

Figure 5: Top 20 Ocean Plastic Polluters by Country in 2015

With this map, we can see that the largest polluters of rivers with plastic waste are considerably higher in Asia, with most of the rivers flowing through China, India, the Philippines, and Indonesia with some more minor world players in Africa and South America in Nigeria making up the Imo river and Brazil and Columbia making up the Amazon river, respectively. It is worth keeping in mind that these countries contain rivers that could be connected through other countries. Some countries may also contain multiple rivers. Six out of the top twenty polluting rivers run throughout China, making it the highest polluting country on this visualization at nearly 500,000 tonnes of plastic waste in 2015. This could be a reason why the Great Pacific Garbage Patch is so large, which we will revisit later.

Asia makes up nearly 87% of the plastic pollution that enters the oceans through rivers; of this, China and India make up the majority. Africa, South America, and Europe/North America make up only about 13% of total plastic entry to the oceans through rivers, making it clear where initiatives must be started in order to curtail the widespread mismanagement of plastic waste. This can be seen in Figure 6. Most of the countries that make this list up do not have initiatives to prevent mismanagement and this has led to accumulations of garbage such as the Great Pacific Garbage Patch; while this is not the only accumulation of garbage in the oceans, it does make up a large majority of ocean waste that could take decades to clean up.

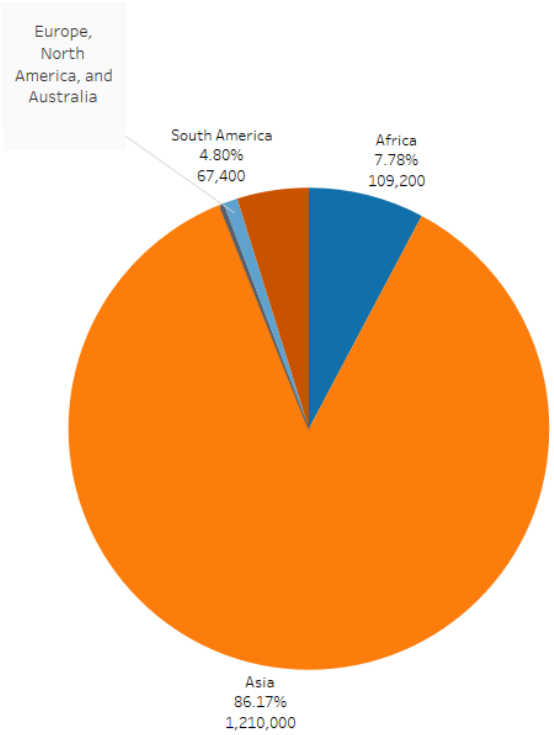

Figure 6: Top Polluters by Continent

China, being the most polluting of the countries through their rivers, contains six of the top twenty rivers that pollute the most in the world, and with the pie chart in Figure 7, that is easily visible. The Yangtze, being the most polluting river in the world, makes up approx. 35% of the entire top twenty polluting rivers, this is likely due to factories that are on the banks of the rivers and little regulation. The Ganges, in India, takes second place, making up approx. 12% of the entire top twenty polluting rivers, is likely also surrounded by factories and waste is unregulated and terribly mismanaged, which is why we see photos of beaches with tons of plastic in both China and India in the news from time to time; however, none of these stories gain enough traction for their to be any regulation done and most likely do not get shown in those countries due to their governments.

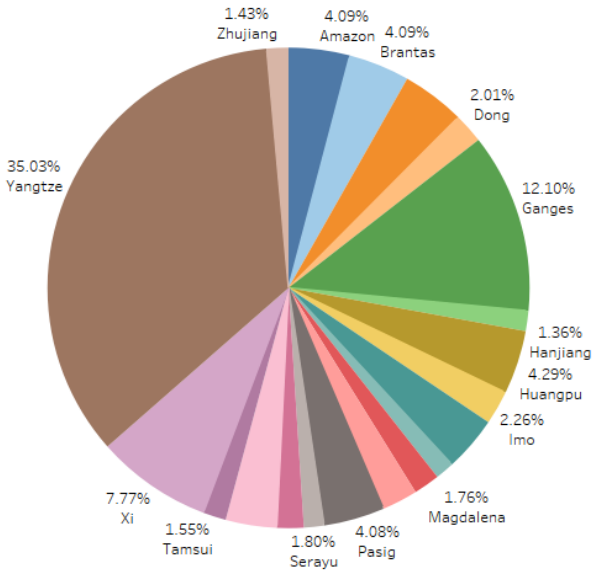

Figure 7: Top 20 Plastic Polluting Rivers

The Plastic Lifecycle: From Rivers to Oceans

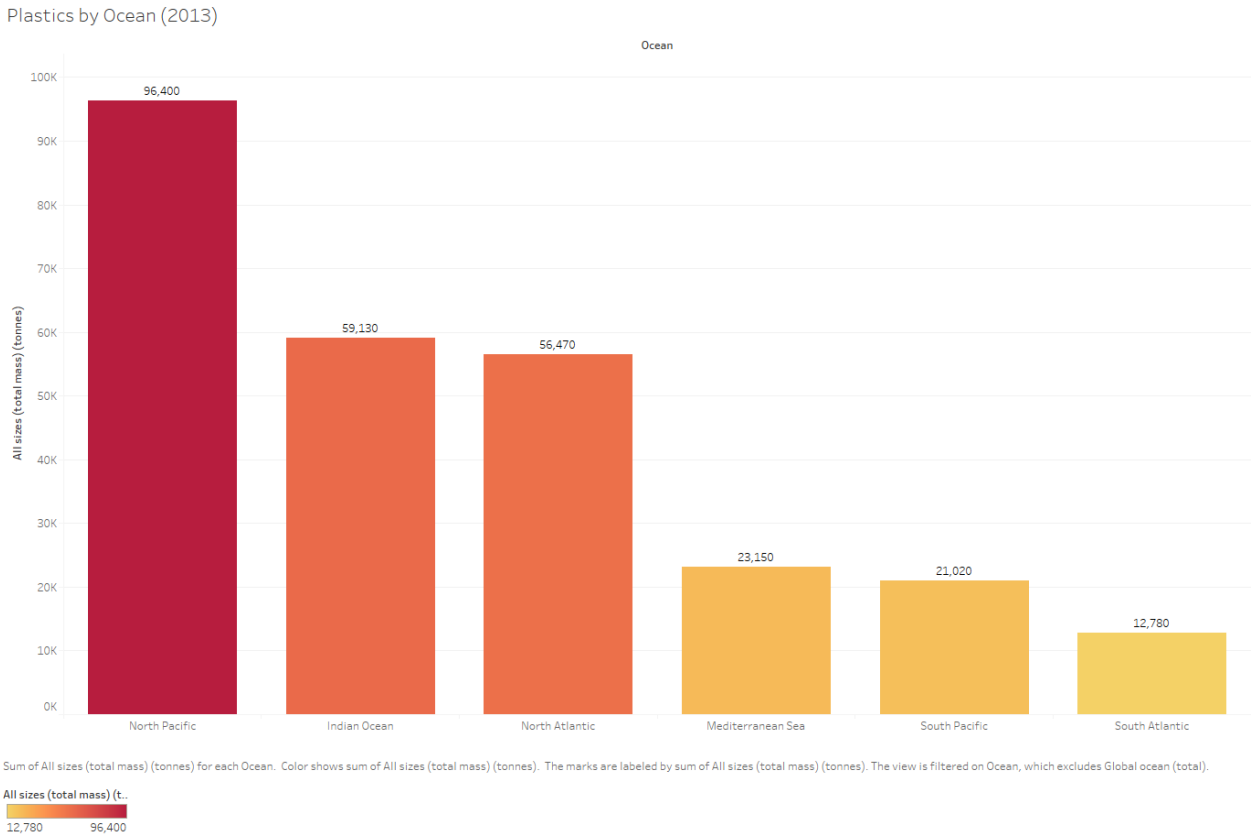

Figure 8: Amount of Plastic in Every Ocean

With most of the top twenty polluting rivers being in Asia, it is unsurprising that the Pacific Ocean contains most of the plastic waste that is polluted in the ocean, creating the Great Pacific Garbage Patch (GPGP). The GPGP is a large mass of plastic waste that has consolidated in the Pacific Ocean. The Pacific Ocean is followed by the Indian Ocean, with a total summed plastic waste tonnage of over 150,000 tonnes, which gives us a better understanding of why the plastic pollution from the top twenty rivers are consolidated mostly in Asia in Figure 5. We can also see from this graph that the amount is directly correlated to the pie chart in Figure 6, showing us that Asia's pollution makes up almost 87% of global plastic waste distributed into the ocean through the top twenty most polluting rivers.

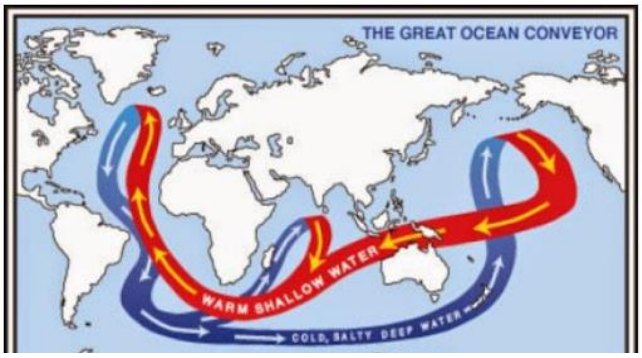

Figure 9: The Great Ocean Conveyor

The Great Pacific Garbage Patch may give us a reason to believe that certain countries contribute more to the heap of garbage and plastics in the ocean. Given the Great Ocean Conveyor, The plastics and garbage move

around the pacific ocean in a cyclical motion, where most of the garbage from Asia would easily move toward the Western United States, contributing to the Great Pacific Garbage Patch. Eventually, it is speculative that the garbage patch will return to Asia through the Pacific Islands. It could also be speculated that the masses that are in the Atlantic could also have come from Asia; more specifically, the Indian Ocean, which will, in time, move directly South along the coast of North and South America. Even though these speculations are probable, we would likely not see it in our lifetimes, as the Great Ocean Conveyor system takes about 1,000 years according to the NOAA; however, it should not deter us from preventing the trash from moving all together, since the breakdown of trashes and plastics into smaller pieces will be faster than the Great Ocean Conveyor's cycle, which could cause even more harm than previously thought.

Manta Tows data is given and organized as the number of plastics found in a surface tow of a given size in either length or mass. The lifecycle of a plastic in the ocean is to continually break down over time, turning into smaller and smaller pieces that become harder to remove from the water. Manta tow data allows researchers to understand where plastics are and how far along that lifecycle they are. The world map below (Counts of Plastics of Size 4.75 - 200mm found in Manta Tows) shows a collection of multiple manta tows by different research groups into one large set. The specific figure shows the largest plastic size category, meaning this plastic is newer and less broken down. Areas of mass gathering of the plastics are places like the Great Pacific Garbage Patch, which makes sense from data above as it is right between the two biggest producers of plastic pollution, China and the US. Currents of plastics leaving countries are seen specifically coming from South America and India, where there is little regulation and huge dumping of trash seen in rivers. Places like Europe also still have behaviors to fix, as even developed countries like Spain and Italy still have large counts of trash right off their coast. They may not be directly depositing the trash here, but an effort needs to be made by these countries to keep their waters clean and punish those who intentionally pollute their coast. Mass collections of trash are also developing in the Atlantic Ocean as well as the Indian Ocean, while small amounts of trash are continually found closer to Antarctica over time. Places like Australia which had a lot of regulation and little trash dumping are suffering as a result of other countries dumping their plastic in the oceans that end up on Oceania's shores. Figure 10 demonstrates how this is a global issue, even if only a small subset of countries are doing the majority of the trash dumping every country ends up affected by this with more toxic water that sustains less habitats and growing ecosystems.

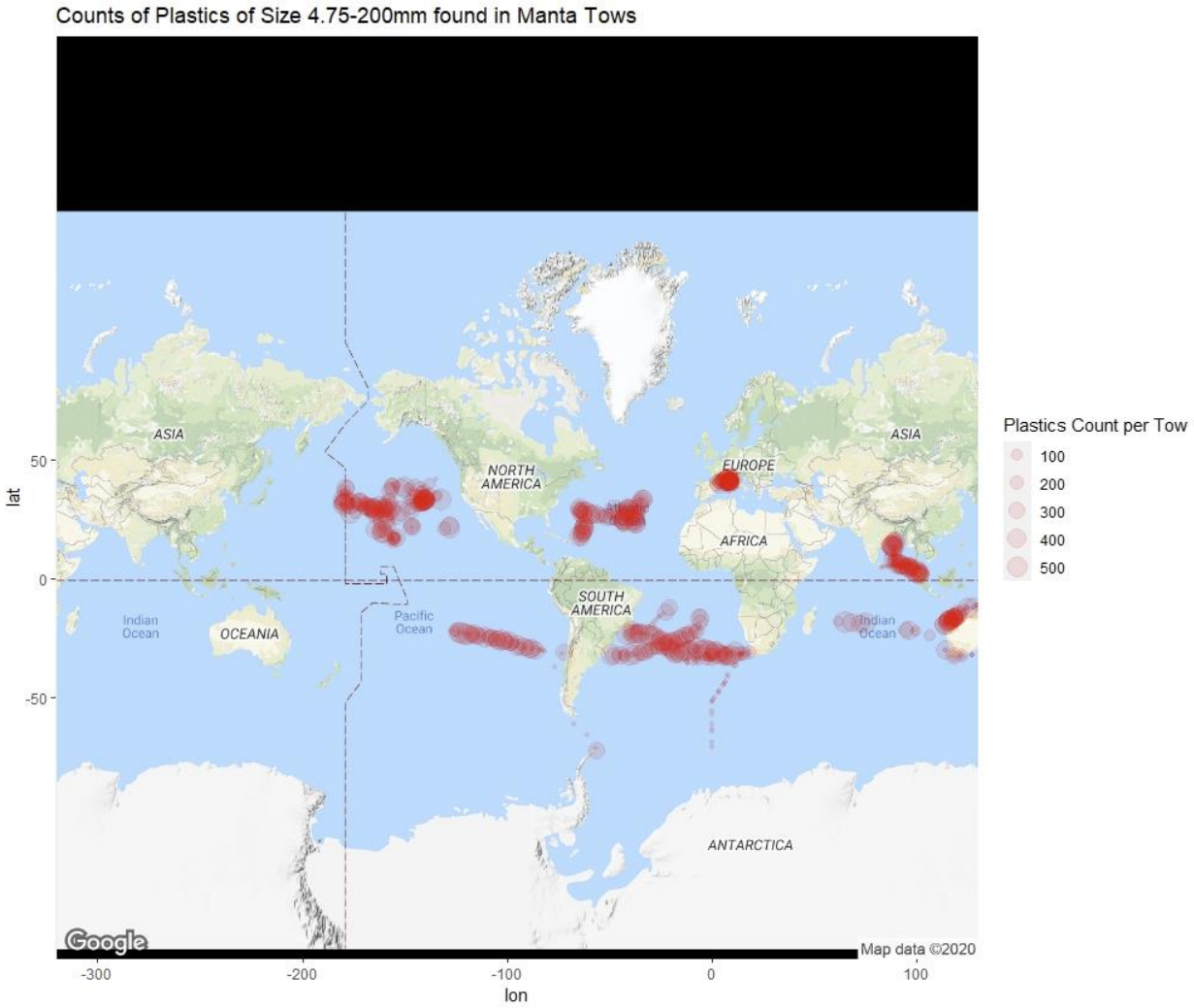

Figure 10: Counts of Plastics found in Manta Tows

Summary/Conclusion

The excessive production of plastic that is leading to an increase in plastic pollution is a problem that we cannot ignore and hope that it will go away on its own. As of right now, we have no feasible way to biodegrade the plastics being made and most of the plastics that have ever been produced are still somewhere on this planet. The small amount that is no longer with us and was burnt away and is now in the form of numerous toxic pollutants. Public perception has finally begun to shift into seeing that the immediate savings and convenience of using cheap plastics may not be worth the devastating toll it has on us and the planet. If we are unable to at least slow down production or find ways to decrease the plastic pollution, then our oceans will only get worse and monstrosities like the Great Pacific Garbage Patch will only get worse or

become more common. Marine life will continue to suffer and it could have devastating effects on the human population, since a good percentage of our population depends on marine life for food and survival.

Now more than ever, we must push our governments into regulating the amount and types of plastics that are being produced. If we ever hope to slow down the problem before us, we must be open to decreasing our use of cheap and convenient single use plastics and slowly phase out their use and production. Alternatives such as, stainless steel, beeswax-coated cloths, wood, ceramics must become more mainstream. Only this, or new breakthroughs in plastic biodegradation can really make a difference on the problem we have at hand.

Bibliography

- Lönnstedt, Oona M., and Peter Eklöv. "Environmentally relevant concentrations of microplastic particles influence larval fish ecology." Science 352.6290 (2016): 1213-1216.
- Gigault, Julien, et al. "Current opinion: What is a nanoplastic?." *Environmental pollution* 235 (2018): 1030-1034.
- Barboza, Luís Gabriel Antão, et al. "Marine microplastic debris: An emerging issue for food security, food safety and human health." *Marine pollution bulletin* 133 (2018): 336-348.
- Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., ... & Law, K. L. (2015). Plastic waste inputs from land into the ocean. Science, 347(6223), 768-771.
- Mosbergen, Dominique, and Huffington Post. "China no longer wants your trash. Here's why that's potentially disastrous." *Huffingtonpost. com* (2018).
- Ritchie, Hannah, and Max Roser. "Plastic pollution." *Our World in Data* (2018). https://ourworldindata.org/plastic-pollution
- US Department of Commerce, and National Oceanic and Atmospheric Administration. "NOAA's National Ocean Service Education: Currents: The Global Conveyor Belt." *NOAA's National Ocean Service Education: Currents: The Global Conveyor Belt*, USDC, 19 Dec. 2004, oceanservice.noaa.gov/education/kits/currents/06conveyor2.html
- Vila, Alixandra. "This Is Why Philippines Is World's Third-Largest Ocean Plastic Polluter." South China Morning Post, 18 Oct. 2018, www.scmp.com/lifestyle/health/article/2168819/philippines-plastic-pollution-why-so-much-waste-ends-oceans.

Data Sources

- Ritchie, Hannah, and Max Roser. "Plastic pollution." *Our World in Data* (2018). https://ourworldindata.org/plastic-pollution

- Geyer, R., Jambeck, J. R., & Law, K. L. "Global Plastic Production, 1950 to 2015." *Our World in Data* (2017). https://ourworldindata.org/grapher/global-plastics-production
- "What a Waste Global Database". *World Bank* (2018) https://datacatalog.worldbank.org/dataset/what-waste-global-database/resource/de74cc68-e796-4e42-9793-f140719c91ac#{view-graph:{graphOptions:{hooks:{processOffset:{},bindEvents:{}}}},graphOptions:{hooks:{processOffset:{},bindEvents:{}}}}
- "NESDIS News & Articles." *NOAA National Environmental Satellite, Data, and Information Service (NESDIS)*, 5 June 2018, https://www.nesdis.noaa.gov/content/volvo-ocean-race-collects-valuable-new-ocean-data-insights-microplastic-pollution
- Boulissière, Stéphane. "The Countries Polluting the Oceans the Most with Plastic Waste." *Plastic Ethics*, Plastic Ethics, 17 Mar. 2019, https://www.plasticethics.com/home/2019/3/17/the-countries-polluting-the-oceans-the-most-with-plastic-waste
- "Why Plastics Can Be Garbage for the Climate." *Yale Climate Connections*, 23 Aug. 2019, https://www.yaleclimateconnections.org/2019/08/how-plastics-contribute-to-climate-change/
- "Plastic Ocean Input from Top 20 Rivers." *Our World in Data*, 2017, https://ourworldindata.org/grapher/plastic-top-20-rivers
- "River Plastic Pollution Sources." *The Ocean Cleanup*, https://theoceancleanup.com/sources/
- "River Research Projects." *The Ocean Cleanup*, https://theoceancleanup.com/milestones/river-research-projects/
- Sebille, Erik van, Paul van Vriend, et. al "Scientific Publications." *The Ocean Cleanup*, https://theoceancleanup.com/scientific-publications/
- Franklin, Pat. "Plastic Water Bottles Should No Longer Be a Wasted Resource." *Down the Drain*, http://www.container-recycling.org/index.php/issues/.../275-down-the-drain
- "THE SEAS OF PLASTIC." *The Seas of Plastic Interactive*, http://dumpark.com/seas-of-plastic-infographic/
- "Ocean - Data Catalog." *Data.gov*, https://catalog.data.gov/dataset?groups=ocean9585
- Reisser, Julia. "Supplementary Data for 'Evidence That the Great Pacific Garbage Patch Is Rapidly Accumulating Plastic'." *Figshare*, 10 Apr. 2018, https://figshare.com/articles/Supplementary_data_for_Evidence_that_the_Great_Pacific_Garbage_Patch_is_rapidly_accumulating_plastic_/5873142
- Erikson, Marcus. (2014) Plastic Marine Pollution Global Dataset. https://figshare.com/articles/Plastic_Marine_Pollution_Global_Dataset/1015289