Renewable Energy: Evaluating Campus Opinions on Marine Plastic Waste

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An interactive qualifying project report submitted to the faculty of

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Submitted by

Alex Alonzo, ChE

Ian Camilli, ME

Sarah Doherty, BIO

Project Advisor

Professor Michael Timko

Abstract

By 2050, there will be more plastic by weight than fish in the oceans. As a temporary alternative to regulation policies on plastic manufacturing and waste disposal, energy-from-waste recovery can be implemented in order to remediate the environmental harm caused by marine plastic. The following report supplies an overview of the birth and development of plastic, conveys the political and environmental implications of its source and distribution in the ocean, and lastly, assesses plastic-use habits, awareness, and public stance on the management of plastic waste across a student body to ultimately support a sustainable cleanup solution using a shipboard plastic conversion technology. Overcoming public neglect of marine plastic pollution will be a major driver for the technology's progress.

Acknowledgement

The team would like to thank our WPI faculty advisor, Professors Michael Timko for his guidance, mentorship and support. The team would also like to thank the administrative assistants, Leslie Brodeur, Mary K. Courtemanche, Mileza Gjergo, Jessie Curley, Kristen Bronger, Ina Gjencaj, and Barbara L. Furhman for their much appreciated help in distribution of the surveys to their respective departments. Lastly, we would like to thank all of our surveyees; without you this report would not have been possible.

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1.0 Introduction

Plastic products are implemented in everyone's daily lives, whether it be a plastic container to hold takeout food or the hybrid-plastic exterior of a typical car. Natural alternatives are scarce with population growth, especially on the onset of the industrial revolution, and a fast and easy method of meeting demand has become increasingly required. Although relatively new to the environment, plastic products have facilitated the growth of society and human development like no other material. However with unregulated manufacturing and waste management, there comes a hefty cost towards ecosystems and nature was not ready for such drastic change in environmental equilibrium.

Plastic debris can be observed in seas around the world, from concentrations exceeding 600,000 pieces per km^2 in the accumulation zones to more remote regions such as the waters of the Arctic and the Antarctic where far fewer plastic pieces are observed.[1] An estimated 4.8–12.7 million metric tons of plastic entered the world's oceans from land-based sources in 2010 alone, and the flux of plastics to the oceans is predicted to increase by an order of magnitude within the next decade.[2] It has become clear that humanity's discarded litter is spreading throughout our seas and oceans. Additionally, marine plastic may fragment into small pieces referred to as 'microplastics' (0.1 μm–5 mm), but the vast majority is expected to persist in the environment in some form over geological timescales.[2] In all biological systems, microplastic exposure may cause particle toxicity, with oxidative stress, inflammatory lesions, cancer risk and increased uptake or translocation. The inability of the immune system to remove synthetic particles may lead to chronic inflammation and increase risk of neoplasia. The ubiquitous nature of microplastics in the environment and in consumer products leads to the inevitable human exposure to these harmful particles, as well as damaging the world's vital food supply from the

sea.[3] Management and the political environment on the issue need to be assessed before spending time and effort, if marine plastic pollution is to take priority and attention relative to other global issues.

2.0 Background

Plastic waste pollutes more than just cities with excess overflows from landfills, if any. The majority of plastic pollution enters the ocean at alarming rates that continue to drastically increase with time and population growth. Environmental destruction, food supply disruption, and health effects are ongoing effects of marine plastic pollution, and any efforts should be made to decrease the amount.

2.1 History, Classification and Degradation of Plastics

The history of mankind is often described according to the materials used to make implements and other basic necessities. The most well-known of these periods being the Stone Age, the Bronze Age, and the Iron Age. Currently, it could be argued that we are in the Plastic Age.[4]

Until the nineteenth century, inanimate possessions, homes, tools and furniture were made from varieties of metals, stones, woods, ceramics, glasses, skins, horns, and fibers. During the twentieth and twenty-first centuries, two new closely related classes of materials were introduced and developed, which have not only challenged the older materials for their well-established uses but have also made possible new products which have helped to extend the range of activities of mankind. Without these two groups of materials, namely rubbers and plastics, it is difficult to conceive how everyday features of modern life such as motor vehicles, telephones, and the television sets could ever have been developed.[5]

Mass production of plastics began in earnest at the end of World War II with annual production of around 5 million tonnes in the 1950s. The benefits of plastics quickly became evident due to their lightweight, strong, inexpensive, durable, and corrosion-resistant properties.

Plastics are highly versatile materials which can be used to produce a range of products, from flexible to rigid items, adhesives, foams, and fibers. Consequently, the annual production of plastic increased significantly to 30 million tonnes in 1988 and then 359 million tonnes by 2018.[4]

Practically stated, a plastic is an organic polymer, available in some resin form or some form derived from the basic polymerized resin. These forms can be liquid or pastelike resins for embedding, coating, and adhesive bonding, or they can be molded, laminated, or formed shapes, including sheet, film, or larger-mass bulk shapes.[6]

The number of basic plastic materials is large, and the list is increasing. In addition, the number of variations and modifications to these plastic materials is also quite large. Although there are numerous minor classification schemes for polymers, depending on how one wishes to categorize them, nearly all polymers can be placed in two major classifications: thermosetting materials and thermoplastic materials, or synthetic and semi-synthetic organic polymers.[6] These polymers have a unique molecular structure of long chain-like molecules made up of repeating chemical structural units. The structural units are composed of hydrocarbons which have typically been derived from fossil oil or gas feedstocks. There is a vast variety of different polymers, such as polyethylene, polyvinyl chloride, polystyrene, and polypropylene. Additionally, a wide variety of additives (such as fillers, plasticizers, flame retardants, thermal stabilizers, antimicrobial agents, and colorings) can also be added to enhance their performance and appearance.[4]

The recalcitrance and impermeability of these plastics make them ideal for applications such as food packaging, sterile medical uses, and construction, among others, but also make them particularly long-lived when they are discarded.[7] Fragmentation in the marine environment is dominated by physical mechanisms including weathering due to UV radiation, mechanical

(abrasion, wave action, and turbulence), thermal, and chemical action.[4] Depending on certain environmental conditions, the rate of degradation of plastics is often ambiguous.

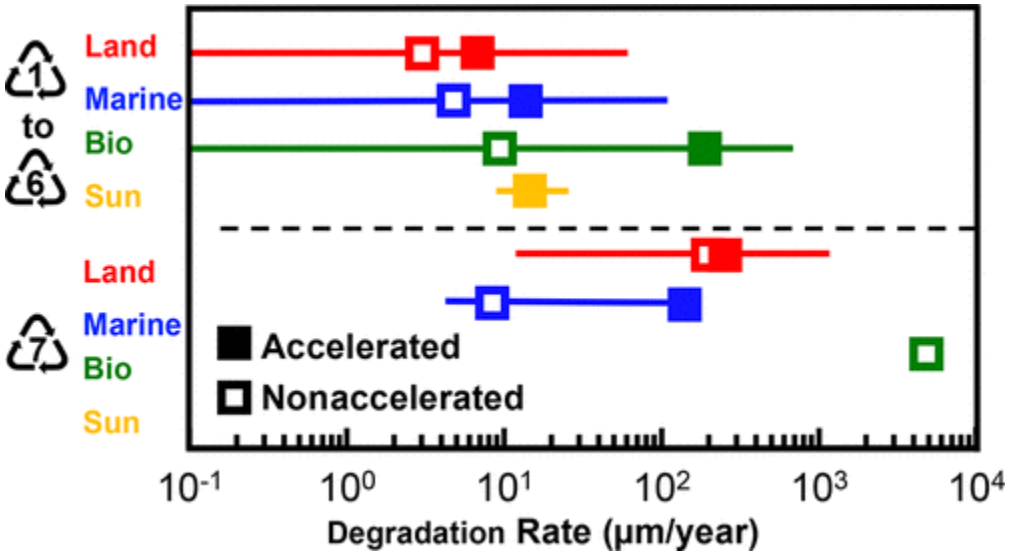


Figure 1. Degradation Rate of Plastic Categories[7]

Media estimates of degradation times for plastic bags tend to fall into one of two ranges: 10–20 years or 500–1000 years, while that for plastic bottles is reported as over 70 up to 450 years, with the types of plastics undefined.[7] Rates of degradation may be reduced in the seawater due to reduced light levels, lower temperatures, and saline conditions. Colonization of microorganisms, plants, algae, and marine life onto floating plastic in the ocean (a process described as fouling) can also inhibit degradation by blocking UV rays and sinking pieces further down causing more irradiance.[4]

2.2 Amount and Distribution of Marine Plastics

There are currently estimated to be five trillion pieces of plastic in the ocean, the majority accumulated into five garbage patches. Garbage patches are large sections of the ocean where litter and marine debris gather due to circular, swirling ocean currents called “gyres”. Gyres act similar to whirlpools by gathering trash and pulling it toward its center. The currents are calmer

in the center of a gyre, allowing the trash to settle and accumulate. A common misconception is that garbage patches are islands of debris. Accumulation often occurs, however, directly at the surface of the water and can extend several centimeters to a meter deep. There are five gyres in the world's oceans: the North Atlantic Gyre, the North Pacific Gyre, the Indian Ocean Gyre, the South Atlantic Gyre, and the South Pacific Gyre. The largest and most famous garbage patch is the Great Pacific Garbage Patch, located in the North Pacific Gyre. The North Pacific Gyre is composed of four clockwise currents, the California, North Equatorial, Kuroshio, and North Pacific currents, that encircle approximately 7.7 million square miles. The garbage patch itself is more of a conglomeration of debris that is constantly being separated and pulled together by the tides, therefore strict boundaries and measurements of the garbage patch are very difficult to attain.[8] Figure 2 shows the four currents that make up the Great Pacific Garbage Patch as well as the two distinct congregations of debris within it, the Western and Eastern patches.

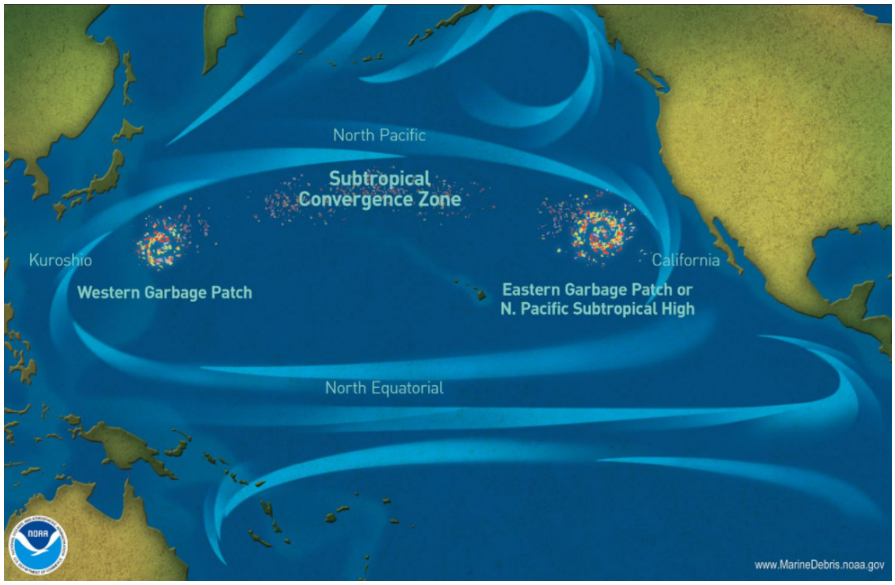


Figure 2. The Great Pacific Garbage Patch.[9]

Plastic comprises between 80 and 85% of marine debris in the garbage patches. The constant pressures of the swirling currents combined with UV light cause plastics to break down over time into microplastics. Microplastics are very small plastic particles less than five

millimeters in size. Two types of microplastics exist in the oceans; primary microplastics, or those that are produced intentionally for industrial and domestic purposes, and secondary microplastics, or those that degrade from larger pieces of plastic due to time and mechanical forces. Primary microplastics can be found in skin cleansers, toothpastes, and synthetic clothing that get rinsed into the oceans.[10] As microplastics degrade via photodegradation, dangerous colorants and chemicals, like bisphenol a (BPA) are released.[11] Microplastics cause the garbage patches to appear as cloudy, soupy water not easily distinguishable by boat or aerial imaging, further contributing to the challenges of estimating the extent of plastic accumulation in the garbage patches.

2.3 Sources of Marine Plastic

Marine plastic pollution enters the ocean either directly from sea-based sources or indirectly through land-based sources. The two major contributors of land-based plastic waste are ordinary litter and materials disposed of in dumps or landfills. These plastics can be blown away by the wind or enter inland waterways such as rivers or wastewater outflows that eventually empty into the ocean. Currently, it is estimated that 8 million tonnes of mismanaged plastic waste enters the oceans every year, with the majority originating from inland sources through waterways transporting 1.15 to 2.41 million tonnes of plastic waste into the ocean per year.[4]

Fishing vessels are a significant source of sea-based pollution as many nets and lines are discarded along with other fishing gear. Sea-based plastic pollutants also come from aquaculture facilities, oil and gas platforms, and cargo ships that drop containers in the sea. Ocean currents can carry these plastics very long distances which makes it difficult to track exactly where plastic waste comes from. Fishing gear and other plastic debris from ships can be carried hundreds or

even thousands of kilometers from where they were last used and find their way into remote areas where no commercial fishing takes place.[12]

Primary microplastics is the term given to plastic pieces less than 5mm in diameter at the time they enter the ocean. Twenty-five percent of annual marine plastic pollution can be attributed to primary microplastics. These microscopic pieces flow into the ocean from drainage systems. The main sources of primary microplastics are consumer goods that are used at an individual level, such as waste water from washing synthetic clothes, the constantly-wearing tread of synthetic rubber tires, and "plastic dust" in city air that accumulates from running shoes and turf. Cleansing components of many types of face wash and toothpaste also contain microplastics that contribute to the runoff of primary microplastics into the ocean.[13]

Secondary microplastics are those which break off from larger plastic parts over time due to UV light or mechanical abrasion.[5] Large plastic pieces are often transported from waste dumps or come directly from sea-based sources such as lost containers from cargo ships and discarded fishing supplies. The lightweight nature of some plastics allow them to travel by ocean currents across great distances, reportedly up to 10,000 kilometers from where they were originally discarded.[12]

There is an uneven distribution of countries that add to the quantity of plastic marine debris. A study from 2010 estimated that 20 out of the 192 coastal countries contributed 83% of the mismanaged plastic waste in our oceans.[14] The countries at the top of this list of 20, including China, Indonesia, Philippines, and Vietnam, all follow the trend of having a rapidly increasing coastal population and poor waste management systems. A lot of urban areas in these countries grow outside of formal planning processes, so they lack services such as solid-waste disposal which would help reduce the percentage of waste that is mismanaged.[12]

There are three major factors to consider when analysing how much a country contributes to land-based marine pollution. The primary consideration is the nation's population density within 50 kilometers from the coast. In Indonesia and the Phillipines the majority of the population live in coastal regions which is a major factor in their placement as the 2nd and 3rd largest contributors to marine plastic debris respectively.[14] The second consideration is how much waste a nation produces per capita. And the third consideration is what percentage of a country's waste is mismanaged. The United States ranks very well on this last factor as only 2% of its waste is mismanaged; however, the United States still produces more waste per capita than almost every other country, and this last factor is how the United States ends up being the twentieth largest contributor to marine plastic debris.

There are a small number of countries that contribute a large percentage of the global marine plastic waste. By focusing efforts to decrease the percentage of mismanaged plastic in a select few countries, a significant impact can be made towards reducing the plastic pollution going into the world's oceans.

2.4 Consequences of Marine Plastic Pollution

Microplastics pose a significant threat to marine ecosystems. The small size of microplastics allow them to be easily ingested by a vast variety of marine life including bivalves, zooplankton, fish, and whales. Plastics are even mistaken for food by some organisms such as turtles, who confuse plastics for jelly due to their gelatinous texture. Microplastics can be physically harmful to those who ingest them in many ways. Plastics can block the intestinal tract, decrease steroid hormone levels, reduce feeding stimuli, and delay ovulation which results in failed reproduction.[15] Ingestion of microplastics can also produce toxic effects in the organism such as reduced growth rate, pathological stress, reduced reproduction, and inhibited enzyme

production.[10] Polychlorinated biphenyls (PCBs) and other pollutants are absorbed from the surrounding seawater by microplastics.[11] The concentration of PCBs in microplastics is one million-fold higher than in the water around it.[16] Most plastic is made from hydrophobic materials, so they are also very capable of carrying airborne toxins such as persistent organic pollutants (POPs). Organisms that ingest microplastics become vehicles that carry pollutants through the food chain. In algae and plankton, both photosynthetic organisms, microplastics prevent adequate sunlight from reaching beneath the layers of plastic. A disturbance in the ecological homeostasis of organisms at the bottom of the food chain, such as these, can shift the balance of organisms that rely on them as food. Plastic debris has also been found in non marine species higher up in the food chain such as seabirds.[15]

Macroplastics are hazardous to marine organisms because animals can become entangled in them, and can also be ingested by larger organisms. In a 2015 review of 340 publications documenting encounters between marine debris and organisms it was found that 92% of encounters were with plastic debris. Other materials considered included glass metal and paper.[17] The effects of entanglement include drowning, suffocation, laceration, and reduced fitness.[15] The notion of "ghost fishing" arose because of the prevalence of discarded fishing nets in the garbage patches. These nets continue to "catch" and suffocate marine animals like seals and turtles.[11] Turtles are especially susceptible to "ghost fishing" as they tend to use floating debris as shelter from predators or as foraging stations. Seals and sea lions are at great risk of becoming entangled particularly when they are younger due to their curiosity and playfulness. Sea lions and seals are most commonly entangled around the neck and due to their long guard hairs the plastics can not slip off easily. Organisms can also directly get wounds, which often lead to infection or necrosis, from materials such as fishing nets or packing bands.[15]

2.5 Marine Plastic Pollution Management

A significant amount of controversy surrounds the debate over whose responsibility it is to reduce marine plastic pollution. Accumulation of plastic in the oceans has become a global danger to the environment and its effects are not limited to one region or population. In general, waste management policies, such as proper disposal and recycling, are to be set at a national level. This is often incongruent with the nature of the problem because of how easily plastic waste travels in the oceans over long distances. National regulations can be negated too easily by the gaps in waste management protocols of countries across the world.[18] International efforts and agreements have improved over time, beginning in the 1970s with the International Convention for the Prevention of Pollution from Ships (MARPOL) and the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. In 2012, the United Nations Environment Program (UNEP) started the Clean Seas Campaign, a program meant to increase awareness, discussion, and research regarding the threat of marine pollution. While these were significant steps, scholars generally agree that international and national policies are too weak and limited to manage the threat on a global scale. The advancements in ocean governance mentioned earlier "have tended to be the exception rather than the rule".[13]

The main reason these international efforts to reduce plastic pollution fail is because there is no international agreement or organization to facilitate the governance of plastic pollution. Organizations such as UNEP can only accelerate research or promote dialogue for plastic pollution. Annex V of the International Convention for the Prevention of Pollution for Ships banned ships from dumping plastic at sea, but since its implementation in 1988 there have been no reductions in plastic pollution as the agreement is rarely enforced. Annex V also doesn't take the plastic that enters the ocean from land into account. Most efforts that mitigate plastic

pollution happen on the local or national level such as bans on microbeads or plastic bags, but the progress made by these bans and local actions is substantially lower than the rate at which plastic pollution is accumulating.[19]

Assuming there are no improvements in waste management infrastructure, the cumulative quantity of plastic waste available to enter the marine environment from land could increase by approximately three times over the decade up to 2025. Microplastics have been detected at very high levels globally in rivers and lakes which could further add to this estimation. Due to the scale of the issue, plastic waste in the marine environment has been identified as a major global issue by the United Nations Environment Assembly and in the G7 Leaders declaration 2015.[4]

Challenges remain in governance of plastic disposal at any level of government. One contributing factor is the nature of plastics themselves. The tendency of plastics to undergo photodegradation into microplastics, their durability and longevity, and the variety of pollution sources can make forming regulations extremely difficult. Additionally, the plastics industry is a booming area for profit due to the diverse applications of plastics in textiles, automobiles, food packaging, retail, and much more. In 2018, total plastic production was approximately 400 million metric tons and could be extrapolated to reach 500 million metric tons by 2025. Profit opportunities have also increased in the past two decades for oil and chemical companies that produce plastics. The result of this can sometimes be business-friendly regulations that do not place adequate responsibility on well-off, larger corporations.[13] With rapidly rising production and consumption of plastics, governance has not been able to maintain the same pace. Fragmentation of governance has been faulted as a critical reason for the lack of effective marine plastic regulation. The pressure of an increasingly powerful plastics industry combined with uncoordinated governance leads to loopholes that allow industries to escape responsibility.[13]

Waste disposal policies and plastics management are therefore vastly uneven across the globe, allowing the negative effects of one region's failings to be felt across the world.

3.0 Methodology

This chapter explains the methods our group will use to assess the opinions and awareness of marine plastic cleanup in the WPI community. The process of improving the cleanliness of the oceans is often controversial because of the sheer size of the problem. The goal of this project is to gauge how the WPI community views the importance of plastic pollution and, more specifically, certain marine plastic cleanup efforts. Our group will look to analyze correlations between opinions and reported behavior involving plastic pollution. The first section outlines the objectives of the project. The second section contains the methods for data collection in the form of surveys. Surveys were forwarded to the chemical engineering, mechanical engineering, computer science, bioinformatics & computational biology, electrical engineering, robotics, mathematical, and biomedical engineering departments; therefore our sample population was limited to those students. Also included is the reasoning for the chosen sample population and methods, as well as the type of data obtained and how it is analyzed.

3.1 Objectives

To achieve the project goal, we will evaluate the perceptions of marine plastic cleanup and specific strategies being tested through data collection from WPI students, faculty, and outside experts. We will focus first on current knowledge and perceived importance of marine cleanup of plastics and then address the opinions of the most effective way to clean the oceans. The project's first objective is to evaluate the awareness levels among the WPI community of marine plastic pollution. The focus will be on knowledge of the state of plastic pollution in the ocean, causes and effects of that pollution, and current efforts to clear plastic from the oceans. Our second objective is to assess the perceived importance of the ocean plastics cleanup effort.

This will be done primarily in relation to other global issues around which there is controversy regarding how to tackle the problem. Examples of these kinds of global issues include rising temperatures, air pollution, and management of radioactive waste. The final objective of our project is to evaluate the opinions of WPI students, faculty, and outside experts regarding the most effective way to advance the ocean cleanup effort. This will delve more specifically into the debate over whether sweeping the oceans to pick up plastics is thought to be the best use of resources or whether a more community or individual-based effort would be more productive. Once our team collects survey data, we will analyze the results and make recommendations for where education about marine plastics would be most useful. The survey data will also allow us to compare perceptions of marine plastic cleanup technology across WPI undergraduate students, related faculty, and experts in related fields.

3.2 Surveying Overview

Our team will utilize online surveys deployed via email to gather information from WPI students and faculty about the perceptions of marine plastic pollution and efforts toward plastic reduction. The surveys do not ask socioeconomic questions regarding age, gender, or income. Students have the option at the end of the survey to provide their WPI email to enter a raffle to win a fifty dollar Amazon gift card. An incentive was offered with the hope of increasing student participation.

3.3 WPI Student Demographics

The survey will be sent out to WPI students only. It is important to consider the demographics of WPI and how those demographics could influence survey responses. The WPI

community might not be representative of the larger population, but it is still an important group to analyze for two main reasons. First, WPI is a technical institute with an intrinsic emphasis on technology and offers many classes related to sustainability and environmental engineering. Approximately 90% of students are STEM majors.[8] Students at WPI have the potential to work in fields that directly affect plastic pollution and ocean cleanup efforts. This makes WPI students an interesting population to study because their opinions and behaviors could hint at the possible future directions of efforts to reduce plastic contamination. Second, 71% of WPI students are between the ages of 18 and 24 years old. This sample population is young and could be influential in coming years in terms of advocacy and voting for marine plastic cleanup efforts. WPI is composed of approximately 62% male students and 38% female students. Of the total student population, 59% of students are white with the next largest race or ethnicity being Hispanic/Latino and Asain each making up roughly 8% of WPI's student body.[21] While students all have different backgrounds and experiences, we expect a shared positive bias toward technology at a technical school like WPI. Survey questions that assess the effectiveness of large-scale marine plastic cleanup projects would be expected to obtain a higher positive response than if the survey was given to the general population. We also expect that WPI students might be more knowledgeable about specific, more technical questions such as awareness of the Great Pacific Garbage Patch or of the presence of microplastics in synthetic clothing and dermatology products. Their exposure to science and technology over the course of their education would make them more likely to have come across these facts than someone without a scientific background.

3.4 Strategy for Survey Questions

The survey was designed with the idea in mind that it would provide quantitative data from a large number of people without being tedious or overly complex for participants. The fifty dollar Amazon gift card prize was added as an incentive to complete the survey because of the risk of college students ignoring the survey, forgetting about it, or simply not having adequate free time. When tested by fellow students, the survey on average took between five and ten minutes to complete. This time was seen as ideal in terms of convenience for participants. The survey began with a short introduction explaining the purpose and voluntary participation. 21 questions in total are asked, 7 of which utilize the Likert scale. Survey questions are either multiple choice, mainly using the Likert scale, or rank-in-order style questions. Likert scale questions were designed using a six-point scale to increase precision, going from weakest agreement to strongest agreement with the given statement. Our group therefore gave participants the following options: Strongly Disagree, Disagree, Slightly Disagree, Slightly Agree, Agree, Strongly Agree, Neither Agree nor Disagree, and Prefer Not to Answer. The language of the questions was kept general and nonspecific, designed to be understood across all WPI majors, except in questions that are designed to test the extent of the participant's knowledge of marine plastic pollution (ie. a question asks participants if they know of the Great Pacific Garbage Patch). Rank-in-order questions were employed to compare participants' opinions on the relative importance of world-wide problems and where plastic pollution falls on that spectrum. The survey was designed like a funnel; at the beginning are questions that gauge the participant's common, everyday behavior regarding plastics usage and their awareness of plastic in their daily lives. Questions were incorporated that judged a participant's willingness to change their behavior as well, such as paying extra for products that will contribute to lessening

plastic accumulation. The survey grows more specific as questions focus on plastics specifically in the ocean and the current efforts to reduce ocean plastics. The survey was formatted in this way to provide a smooth, logical flow for participants. General questions act as a warmup to the more detailed questions and can help reduce the dropout rate of participants. One of the objectives specific to survey design was to be able to correlate perception of ocean plastic pollution with individual behavior when doing statistical analysis. This was an important concept when creating the questions and organizing them into a logical flow.

4.0 Results and Discussion

We received 392 survey responses from the WPI student body across the majors mentioned in the methods and all academic standings. The survey was sent out on April 22nd by WPI secretaries of all departments to the WPI student body and was closed on May 5th. Responses were obtained from a relatively even distribution of undergraduate class years at WPI (Figure 3).

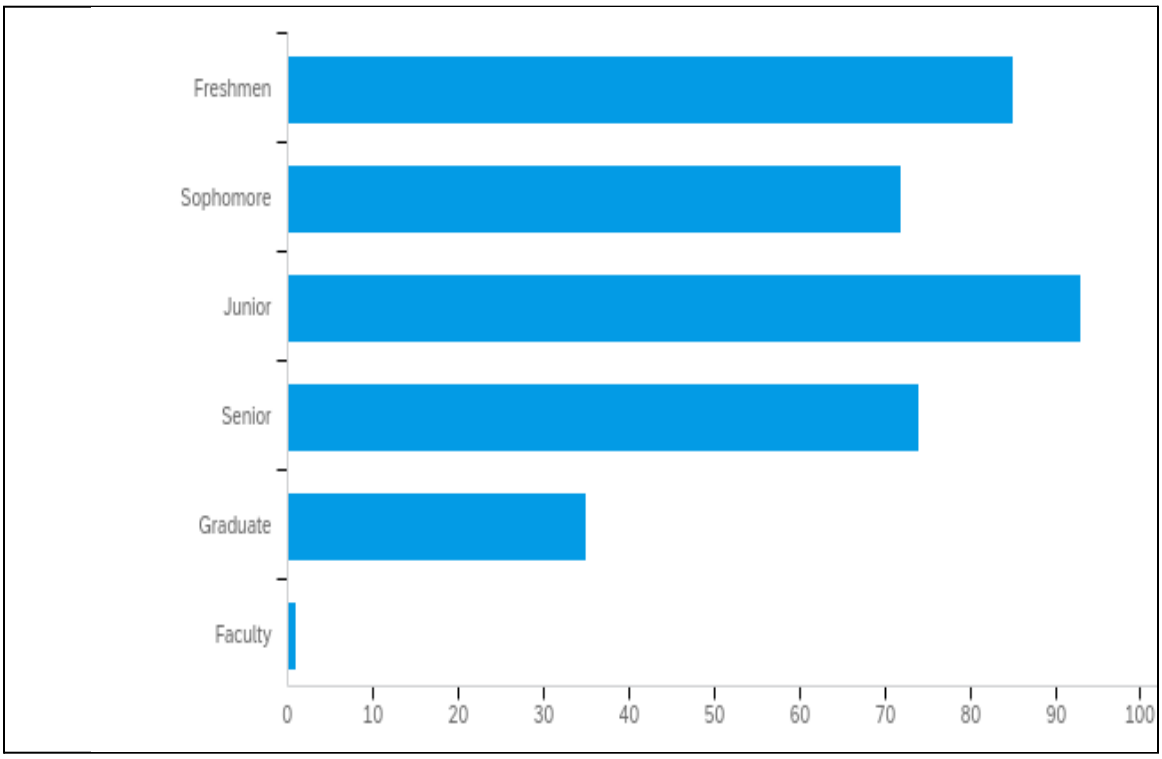
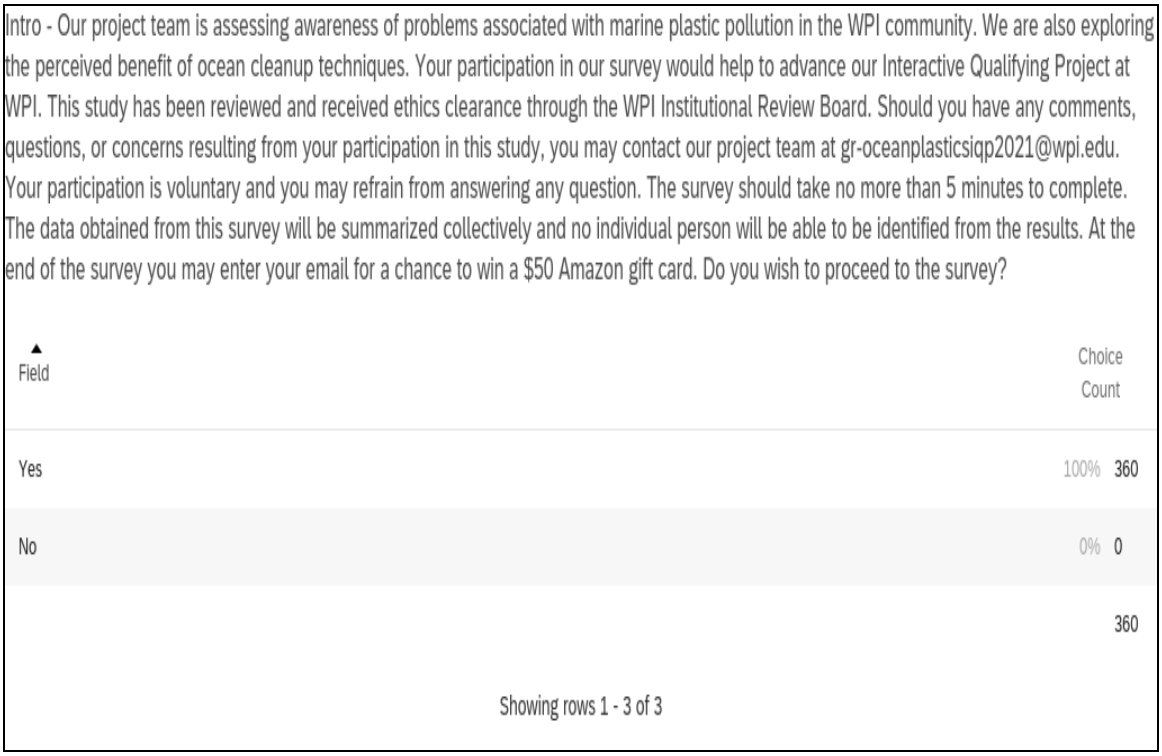


Figure 3. Class distribution of survey results. (Q1)

Fewer responses were received from graduate students. Some of the respondents only answered the survey partially, so certain questions will have a higher count of answers than others. Additionally, there were also respondents that answered none or a couple of the questions and those responses were excluded from our analysis using a filter, resulting in 360 final responses (Figure 4).



Intro - Our project team is assessing awareness of problems associated with marine plastic pollution in the WPI community. We are also exploring the perceived benefit of ocean cleanup techniques. Your participation in our survey would help to advance our Interactive Qualifying Project at WPI. This study has been reviewed and received ethics clearance through the WPI Institutional Review Board. Should you have any comments, questions, or concerns resulting from your participation in this study, you may contact our project team at gr-oceanplasticsiqp2021@wpi.edu. Your participation is voluntary and you may refrain from answering any question. The survey should take no more than 5 minutes to complete. The data obtained from this survey will be summarized collectively and no individual person will be able to be identified from the results. At the end of the survey you may enter your email for a chance to win a $50 Amazon gift card. Do you wish to proceed to the survey?

Field		Choice Count
Yes	100%	360
No	0%	0
		360

Showing rows 1 - 3 of 3

Figure 4. Introduction to Survey

The graphs from all Likert-scale survey questions can be found in Appendix A. From these responses we were able to determine their plastic use habits, willingness to change those habits, opinions on how plastic marine pollution should be managed, and perception of the importance of marine plastics.

4.1 Plastic Use Habits

Several survey questions were drafted to assess the daily habits of WPI students regarding plastics use, as well as their willingness to change their behavior. These questions were also analyzed in conjunction with questions that gave insight into perceptions of plastic pollution in order to better understand the connection between everyday behaviors and cognitive perceptions. Of the total number of responders, 130 (36%) stated that they use plastic every day consistently in their life and that this pattern is inevitable. A combined 216 (60%) of students

reported using plastics a few, or several, times per day while only 14 (4%) students reported rarely using plastics in their daily life (Figure 5).

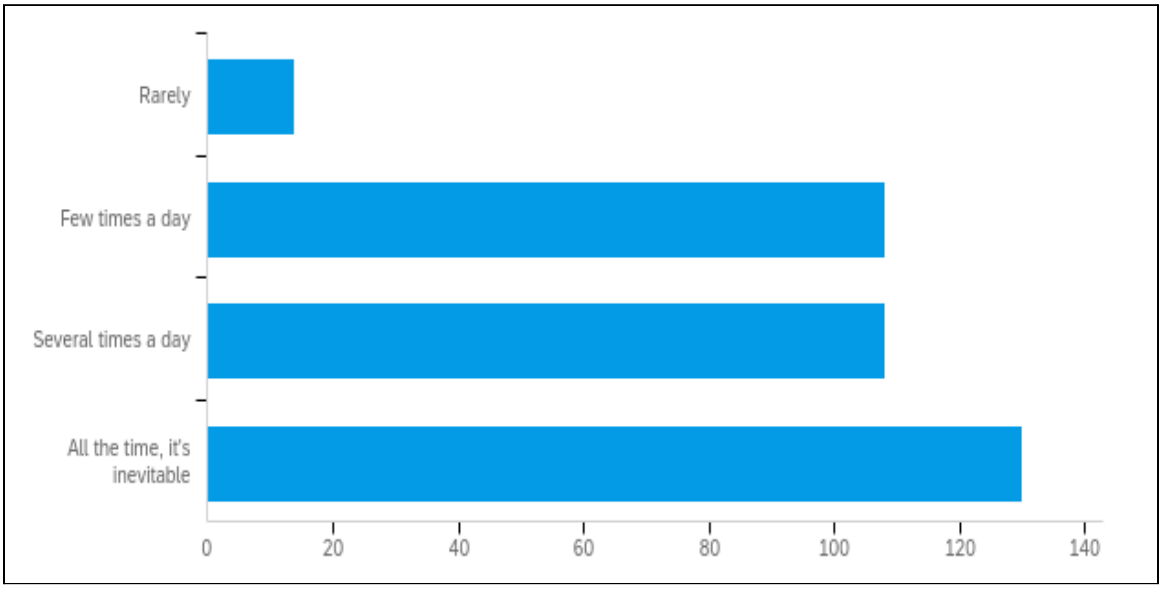


Figure 5. How often do you use plastic in your daily life? (Q4)

An important consideration when analyzing these results is that students could be primarily thinking about their use of large plastic components, such as plastic bags, food packaging, and bottles. As discussed earlier in the background, microplastics found in facial cleansers and other products that get washed down the drain are a significant contributor to marine plastic pollution. If students were more aware of the presence of microplastics in home products the range of answers would shift even more towards the use of plastics being inevitable. Overall, the responders were not concerned enough with the presence of microplastics in food that they ate to cause a change in behavior; 193 (54%) of responders stated that the presence of microplastics in seafood as a result of marine plastic pollution was concerning, but that they would not avoid seafood consumption (Figure 6).

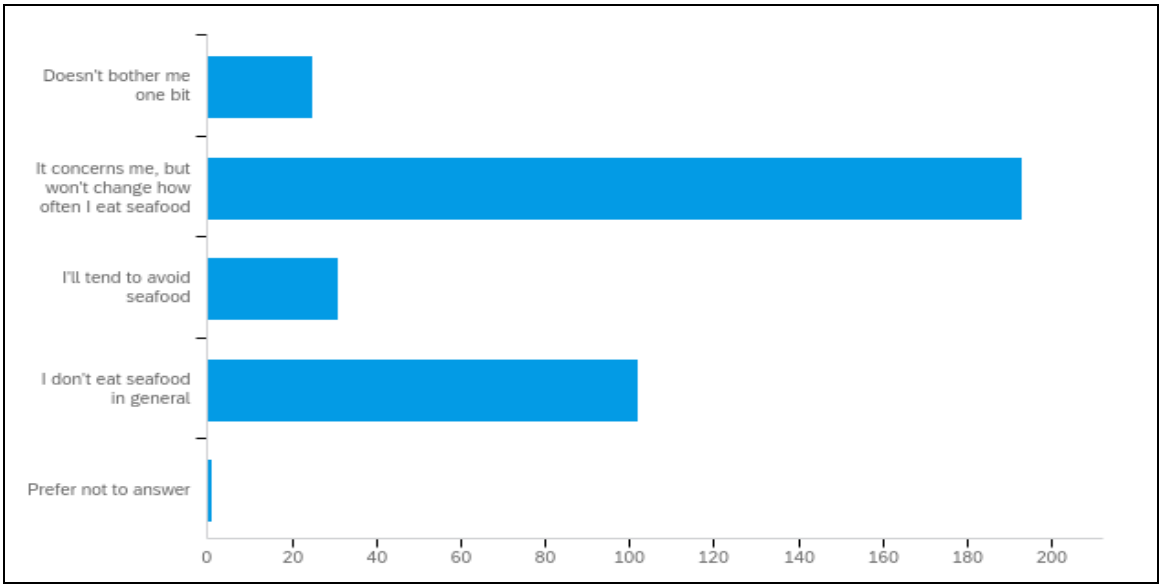


Figure 6. Micro-plastics are commonly present in seafood via the marine life food chain. Because of this, how comfortable are you eating seafood? (Q10)

These results bring into question whether the public has sufficient knowledge of the threat of microplastics in the oceans. As previously mentioned, the majority of plastic pollution in the garbage patches is made up of microplastics. It is interesting to note also that the responders are students at a technological institute, more likely to be knowledgeable on recent, scientific information than the general public. A lack of awareness or concern of microplastics among students of WPI could be an indicator of a much greater gap in the knowledge of the general public. An interesting discrepancy can be seen from the results of questions related to willingness to change behavior with the goal of reducing plastic pollution. When students were asked if they would be willing to pay more for products with recycled packaging, a combined 83% of students reported that they slightly agreed, agreed, or strongly agreed with the affirmative; a combined 91% responded with agree or strongly agree to taking steps in their daily life to reduce individual plastic consumption (Table 1).

Table 1. Likert Scale Responses

count (%)	Q5 - I would be willing to pay an extra dollar for a product that uses recycled packaging as opposed to one with no recycled materials	Q7 - I would be willing to take steps in my daily routine to reduce my own plastic consumption (ie. use refillable water containers or bring bags for groceries)	Q8 - I am concerned about plastic accumulation in the oceans.	Q9 - Would you be willing to support local, state, and federal representatives who make protecting the environment a part of their platform?	Q12 - I am confident marine plastic pollution will be managed accordingly in the future.	Q14 - A stronger effort should be made to clean up plastics from the oceans.	Q15 - People would use less plastic, in sacrifice of convenience, if the consequences of frequent plastic consumption are clear to them
Strongly disagree	7 (2)	1	0	3 (1)	39 (11)	5 (1)	4 (1)
Disagree	10 (3)	2	2	1	118 (34)	0	39 (11)
Slightly disagree	20 (6)	2	4 (1)	3 (1)	74 (21)	1	58 (17)
Slightly agree	75 (21)	25 (7)	34 (10)	37 (11)	44 (13)	31 (9)	118 (34)
Agree	128 (36)	131 (37)	132 (37)	133 (38)	20 (6)	122 (35)	64 (18)
Strongly agree	92 (26)	190 (54)	174 (49)	162 (46)	3 (1)	185 (53)	31 (9)
Neither	23 (6)	2 (1)	7 (2)	13 (4)	52 (15)	6 (2)	34 (10)
Prefer not to answer	1	0	0	0	1	0	0
Total Count	**356**	**353**	**353**	**352**	**351**	**350**	**348**

These results did not correlate strongly with the results from question 16, which assessed willingness to support a large-scale effort to sweep the Great Pacific or North Atlantic Garbage Patch. Only 28% of students stated that they would donate money to a project such as this, while 64% reported that they would publicly support it (Figure 7).

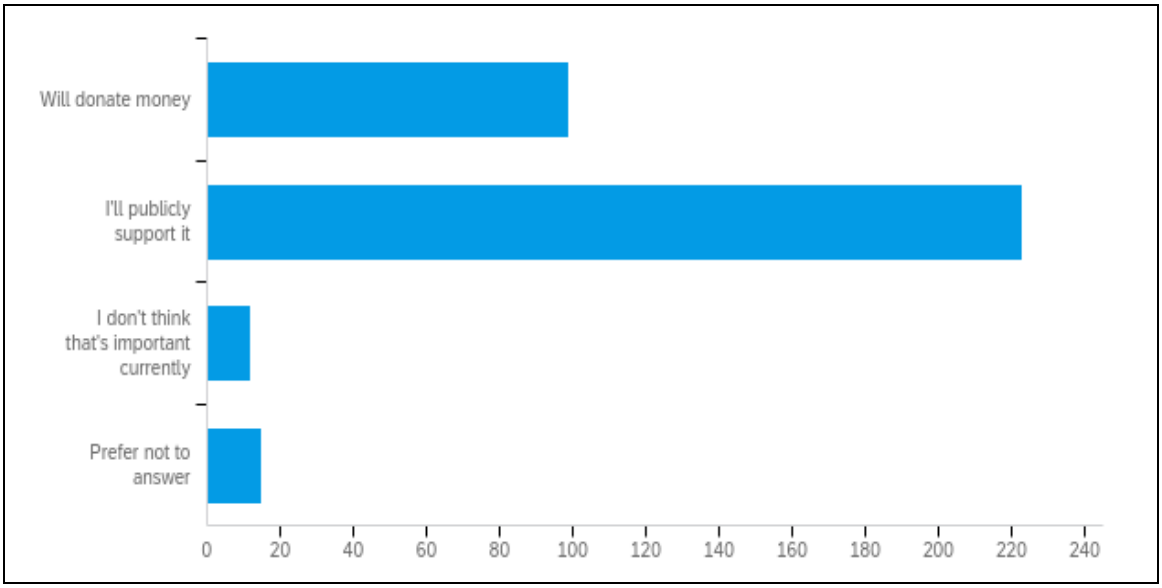


Figure 7. How willing would you be to support a large-scale effort to sweep and dispose of the plastic in the Great Pacific or North Atlantic garbage patch (an area of debris twice the size of Texas)? (Q16)

Students are much less likely to donate money to a large-scale cleanup effort than to spend additional money on products and processes they already use in their daily life. The trend of Figure 7 correlates positively with the results of question 17 that assessed the perceptions of the relative effectiveness of plastic cleanup methods (Figure 8).

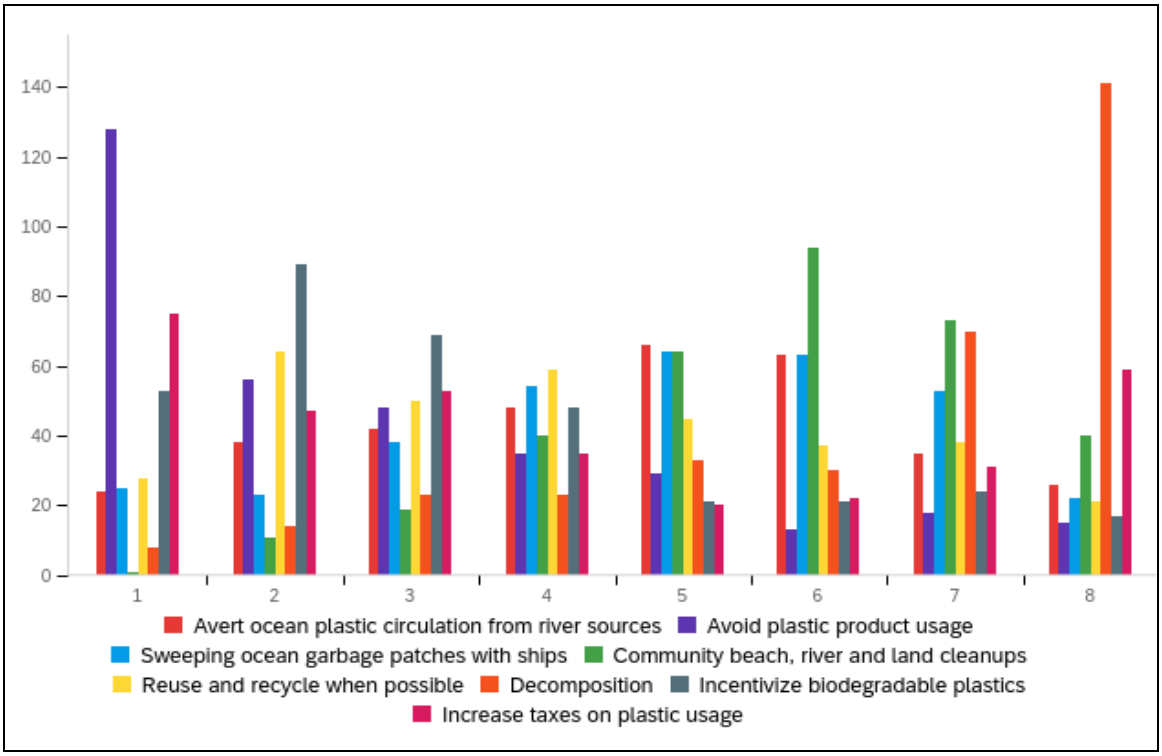


Figure 8. Rank the following in terms of what you believe is most effective at reducing marine plastics. (Q17)

Figure 7 and 8 suggest that students might perceive individual efforts, as opposed to large-scale cleanups, as more worthwhile methods of reducing plastic pollution.

4.2 Opinions on Marine Plastic Pollution Management

Some of our survey questions provided our group with data to analyse the opinions of the WPI student body on how marine plastic pollution should be managed. We asked students who should have the most responsibility regarding plastic pollution. Responders ranked four groups; local communities, companies, government, and individuals, on a numerical scale from 1 to 4 where 1 is the value assigned to the group with the highest responsibility (Figure 9).

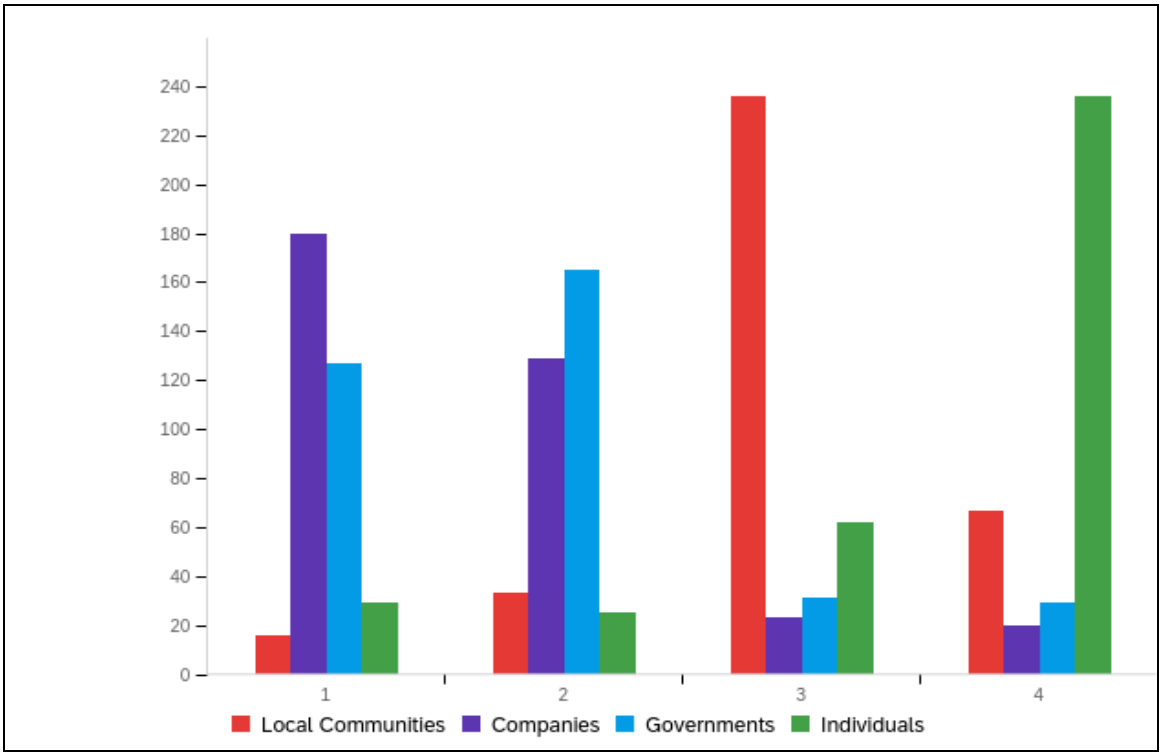


Figure 9. Rank the following in terms of which group should have the most responsibility regarding marine plastic pollution. (Q11)

Responders believed that companies should hold the most responsibility, followed by governments, local communities, and individuals in that order. However, students were not confident that these groups would develop a solution to marine plastics. 66% of students either strongly disagreed, disagreed, or slightly disagreed that marine plastic plastic pollution will be managed accordingly in the future. An additional 15% neither agreed nor disagreed demonstrating that many people are unsure if suitable solutions will be implemented or not (Table 1).

Additionally, survey data showed that the WPI student body wanted more resources put into trying to eliminate marine plastics. 97% of students agreed on some scale that a stronger effort should be made to clean up plastics from the oceans, with 53% of those students strongly agreeing (Table 1). When students were asked how willing they would be to support a large-scale effort to sweep and dispose of the plastic in the Great Pacific or North Atlantic garbage patch, a

combined 92% expressed they would donate money or publicly support it (Figure 7). The remaining 8% of students either preferred not to answer or didn't think this type of clean up effort is important currently. Furthermore, the majority of students (59%) knew about store incentives while the other half were not sure or knew that local stores did not offer incentives (Figure 10).

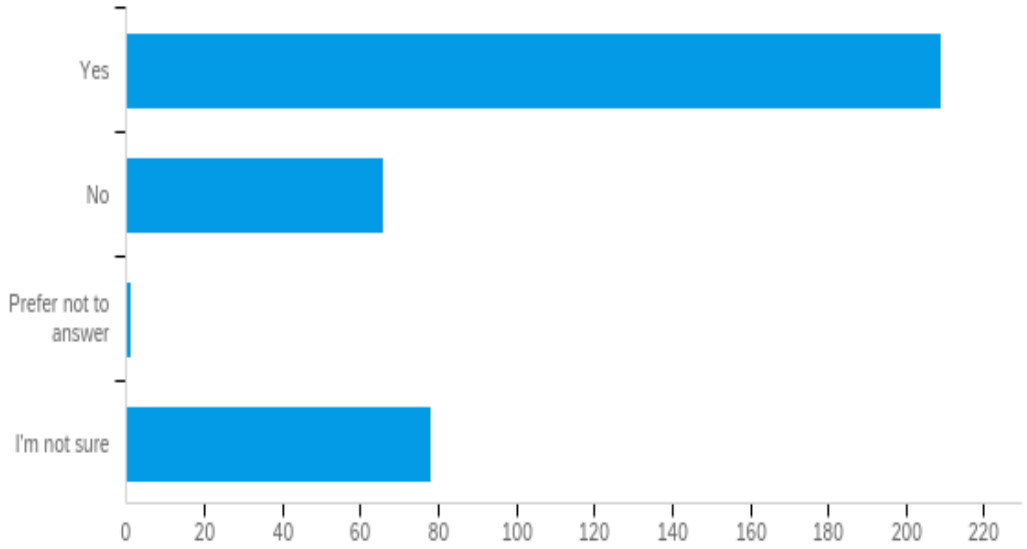


Figure 10. Are local grocery and convenience stores offering incentives to encourage customers to bring their own bags? (Q6)

Data was also collected on which method students believe is the most effective at reducing marine plastics. Each approach was ranked by responders on a numerical scale from 1 to 8 where 1 is assigned to the method that students perceive to be the most effective and 8 is assigned to the perceived least effective method (Figure 8). Responders believed avoiding plastic product usage is the best step towards lowering marine plastic pollution. Even though students believe individuals should have the least responsibility regarding plastic pollution, avoiding plastic product usage was ranked by students as the most practical approach to reduce marine plastic pollution.

Students were then asked how they would rank the effectiveness of sweeping ocean garbage patches with ships differently if the plastic collected by the ship could be sustainably converted into fuel for the ship, reducing fossil-fuel dependence (Figure 10). Because of the potential of the sustainable energy-to-waste technology, 68% of responders would rank sweeping ocean garbage patches higher than they did, and 10% would rank it as the most effective method out of the 8 methods listed.

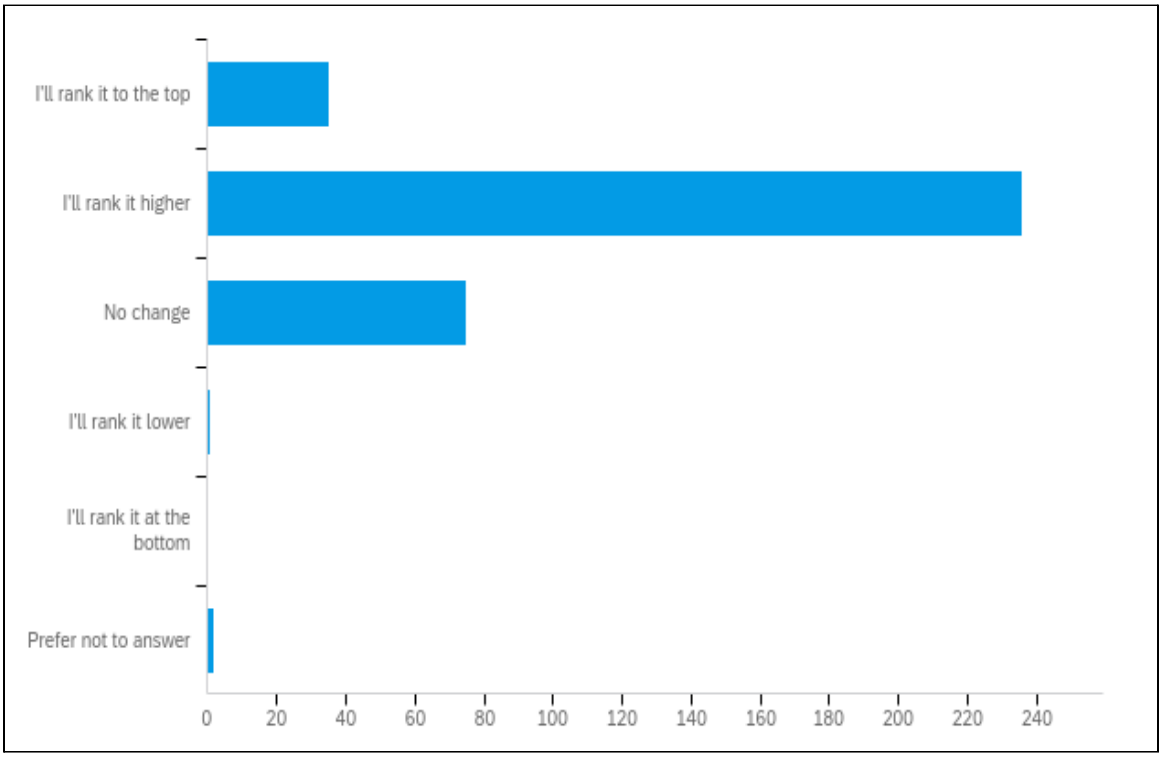


Figure 10. If the plastic collected from the ocean could be converted into fuel for the ship reducing fossil-fuel dependence, how would it change where you ranked the effectiveness of sweeping the ocean's garbage patches (previous question)? (Q18)

4.3 Perceptions on Marine Plastics Importance

Survey questions 3, 8, 9, 13, and 15 assessed the awareness and importance of marine plastic pollution to students. When students were asked to rank the importance of seven global issues in question 3, climate change swept a first place majority with 67% of students, followed by air pollution and ocean plastics in second and third place at 29% and 26%, respectively.

Radioactive waste took last place with the seventh rank behind deforestation, extinction and flooding (Figure 11).

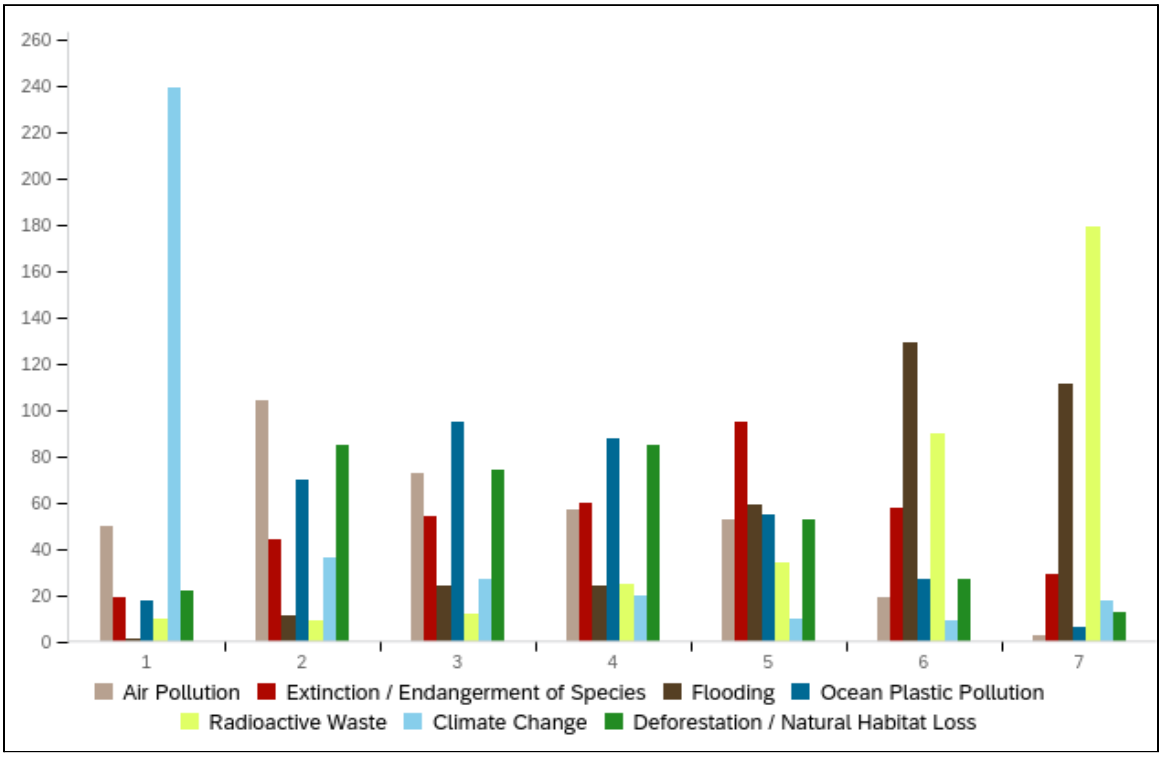


Figure 11. How important do you think the following issues are on a global scale? Rank in order of most important to least important. (Q3)

With climate change frequently reaching headlines of several prominent news outlets, it is reasonable to assume students are more well informed from the effects of climate change and air pollution than ocean plastic pollution. Overlooking the factual importance of a global issue, a trend can be deduced from the level of information on said issue and the corresponding opinion of importance resulting from the excess amount of awareness. Similarly, question 15 in Table 1 determines whether the actions of others will change when better informed of an issue. Students who agreed on any magnitude made up 69% of these responses, highlighting the correlation of information on perceptions on an issue, bias aside. Additionally, question 13 demonstrates whether students are familiar with a major factor in ocean plastic pollution (Figure 12).

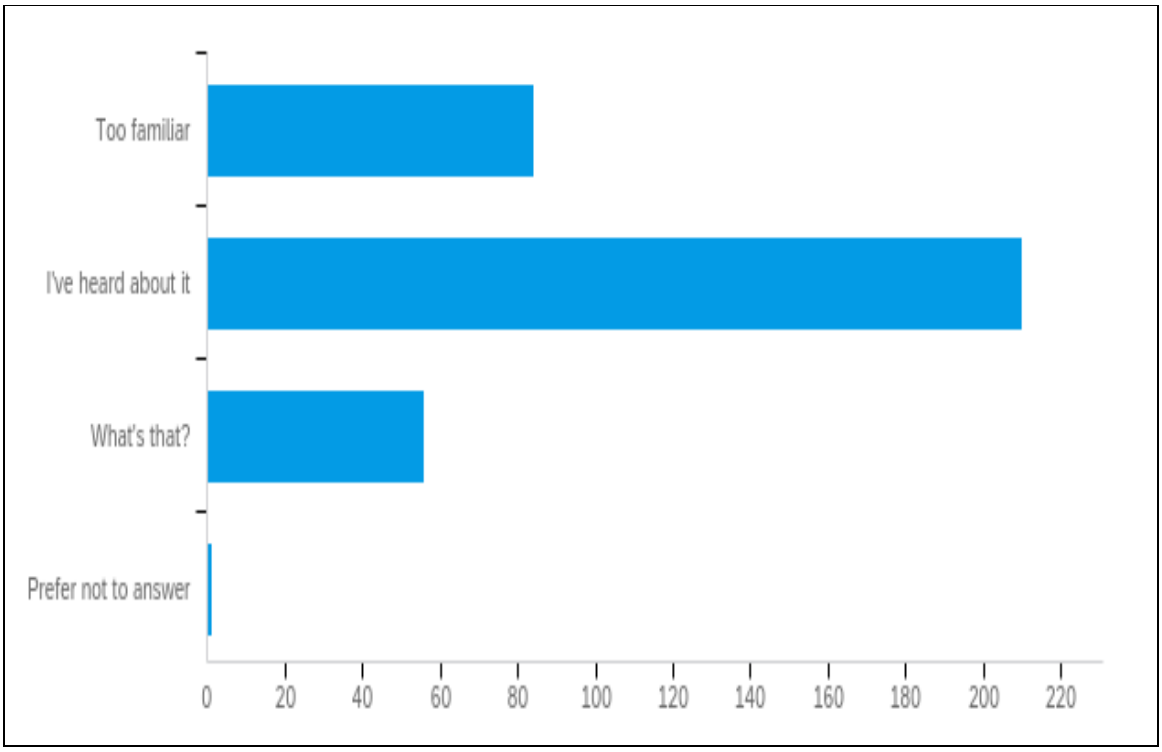


Figure 12. How familiar are you with the Great Pacific or North Atlantic garbage patch? (Q13)

Only 56 students were not aware of the largest garbage patches in the ocean that distribute and maintain plastic pollution. While the students surveyed were somewhat aware of the scale of major garbage patches, the concept of information and importance of an issue is affirmed even further from these results. Conversely, question 8 in Table 1 assesses the relevance and emphasis on ocean pollution. Exactly 85% of students either confirmed or strongly agreed with concerns regarding ocean pollution which establishes a set bias from our surveyants. This set bias helped to determine the scale ocean plastic pollution takes relative to other issues and factors from our surveyants such as climate change or personal plastic-use habits. Question 9 expands this in Table 1 showing a strong trend towards supporting local, state and federal representatives who prioritize environmental protection.

5.0 Conclusion

This project focused on assessing the perceptions and behaviors of the WPI student body regarding marine plastic pollution. This was done by distributing a survey to a sample population at WPI to analyze trends in opinions compared to behaviors. The sample population was limited to WPI students because it was hypothesized that their background in science and technology would suggest a greater awareness and emphasis on activism than the general public.

The main findings of this project show incongruences between perceptions and behaviors and even among perceptions surrounding different areas of marine plastic pollution. Considering attendance at a technological institute, WPI students were less aware of microplastics, a main contributor to ocean pollution, and emerging techniques for large-scale ocean cleanup projects than originally predicted, indicating the general public could also lack the knowledge to understand potential benefits of these large-scale projects. Based on the survey, students seem willing to take action on an individual level to reduce plastic pollution, but believe that responsibility falls more heavily on companies and corporations.

A useful addition to this project would have been a comparison survey with the general public in order to gauge how WPI students understand if an education in a technological field has a significant effect on perception and behavior. Another idea could be to assess public opinion before and after learning new information about large-scale cleanup projects. The majority of students believed individual efforts were the most efficient way to reduce waste, but once they were provided with information about new technologies the perceived effectiveness of large-scale projects increased. It would be an interesting way to assess how education and the type of information that people hear could change public opinion.

Appendix A

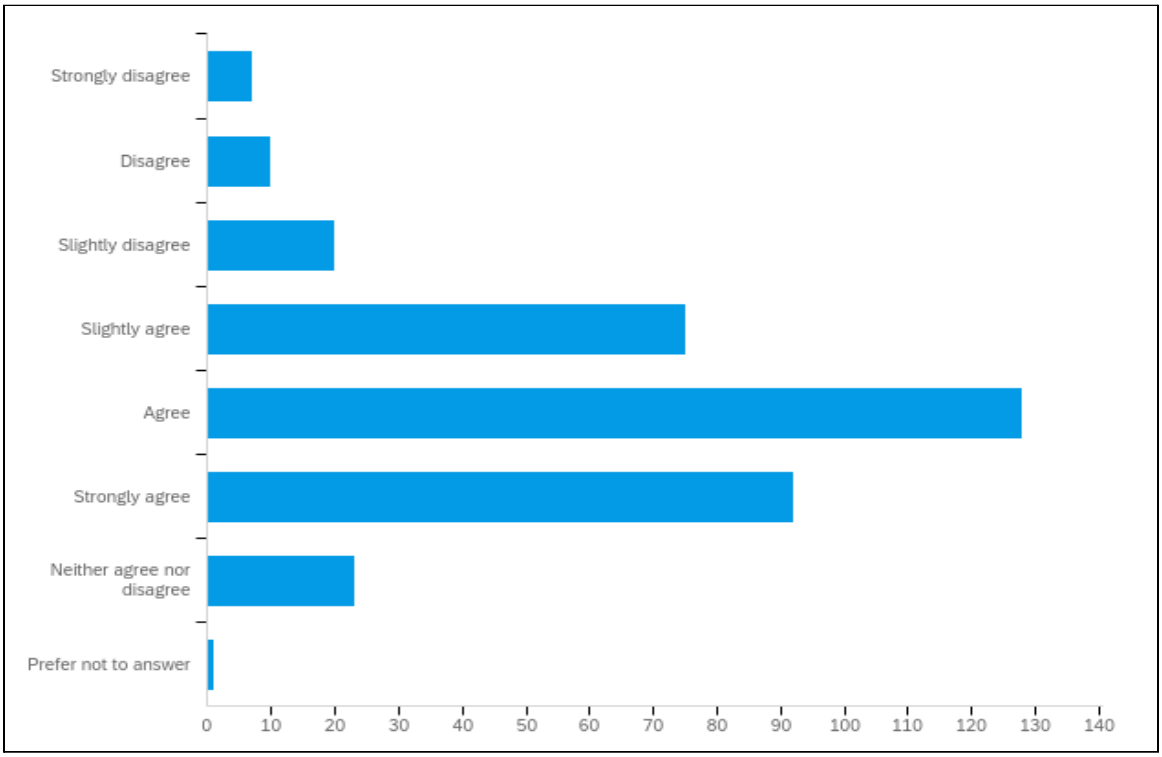


Figure 13. I would be willing to pay an extra dollar for a product that uses recycled packaging as opposed to one with no recycled materials. (Q5)

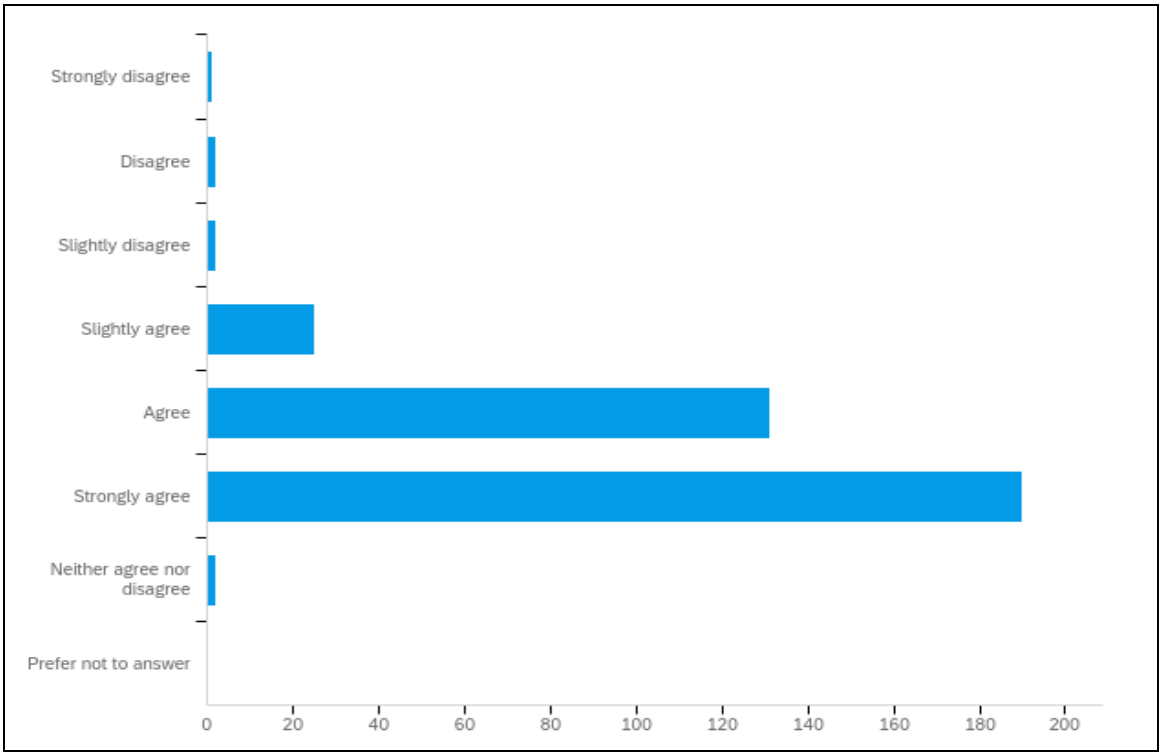


Figure 14. I would be willing to take steps in my daily routine to reduce my own plastic consumption (ie. use refillable water containers or bring bags for groceries). (Q7)

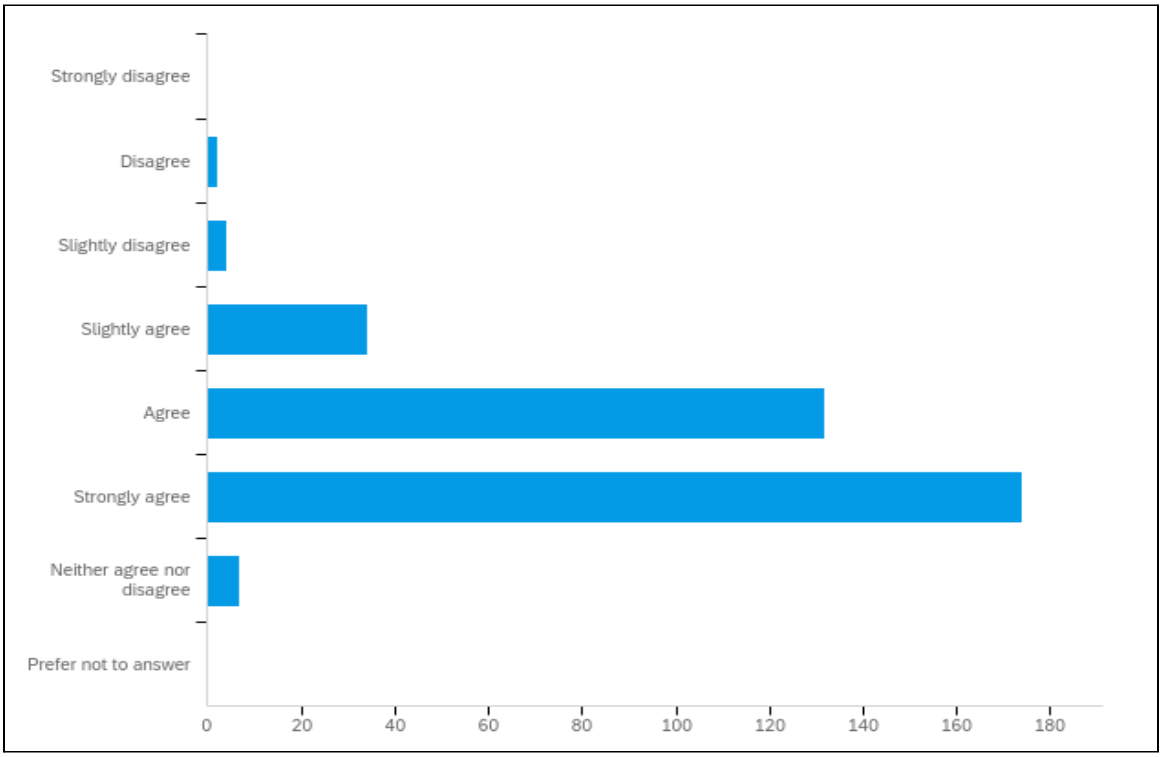


Figure 15. I am concerned about plastic accumulation in the oceans. (Q8)

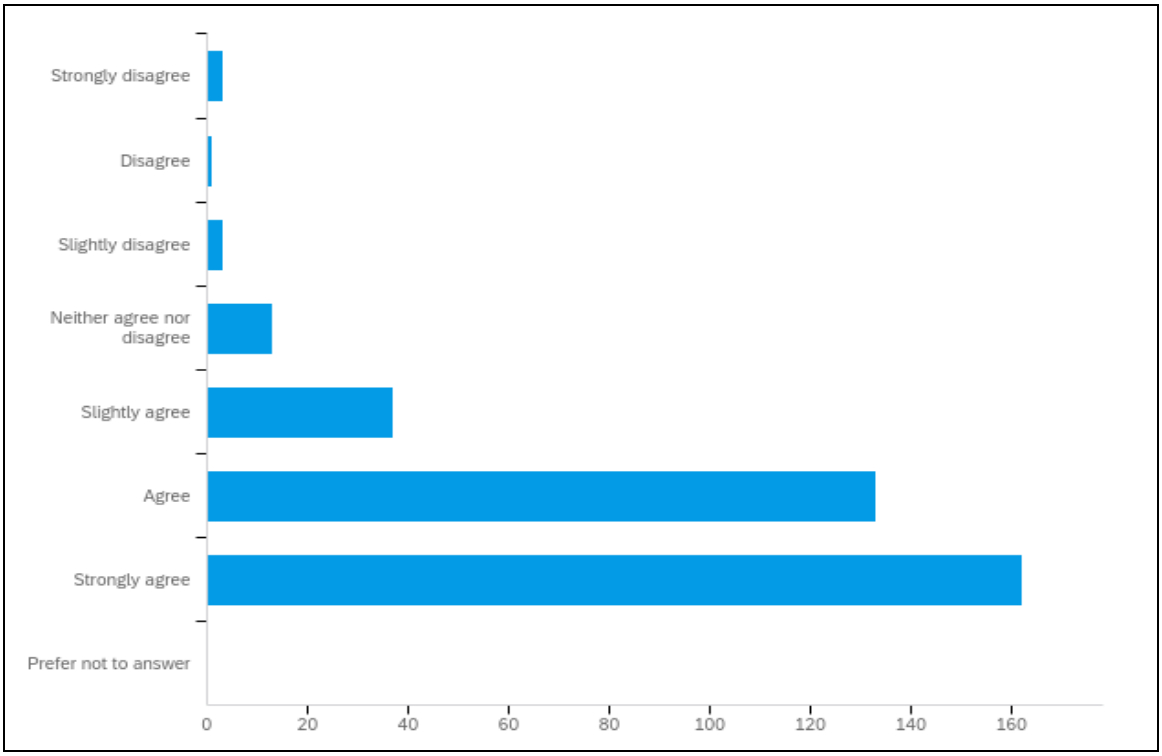


Figure 16. Would you be willing to support local, state, and federal representatives who make protecting the environment a part of their platform? (Q9)

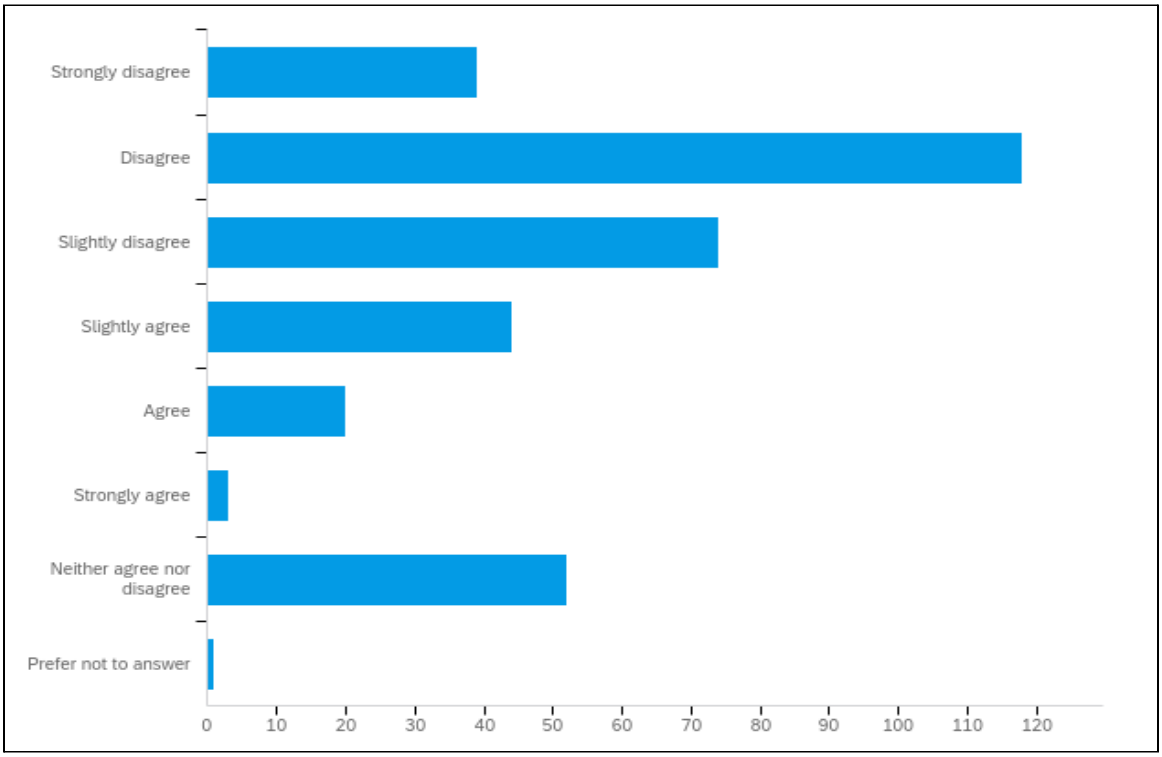


Figure 17. I am confident marine plastic pollution will be managed accordingly in the future. (Q12)

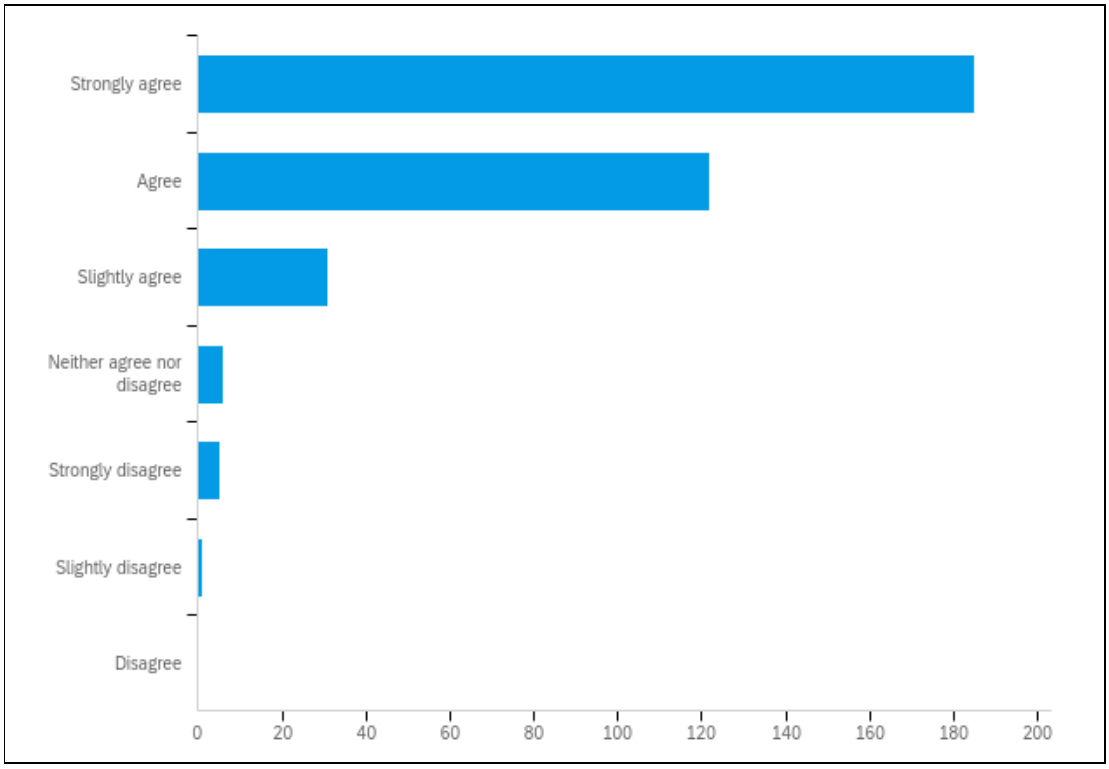


Figure 18. A stronger effort should be made to clean up plastics from the oceans. (Q14)

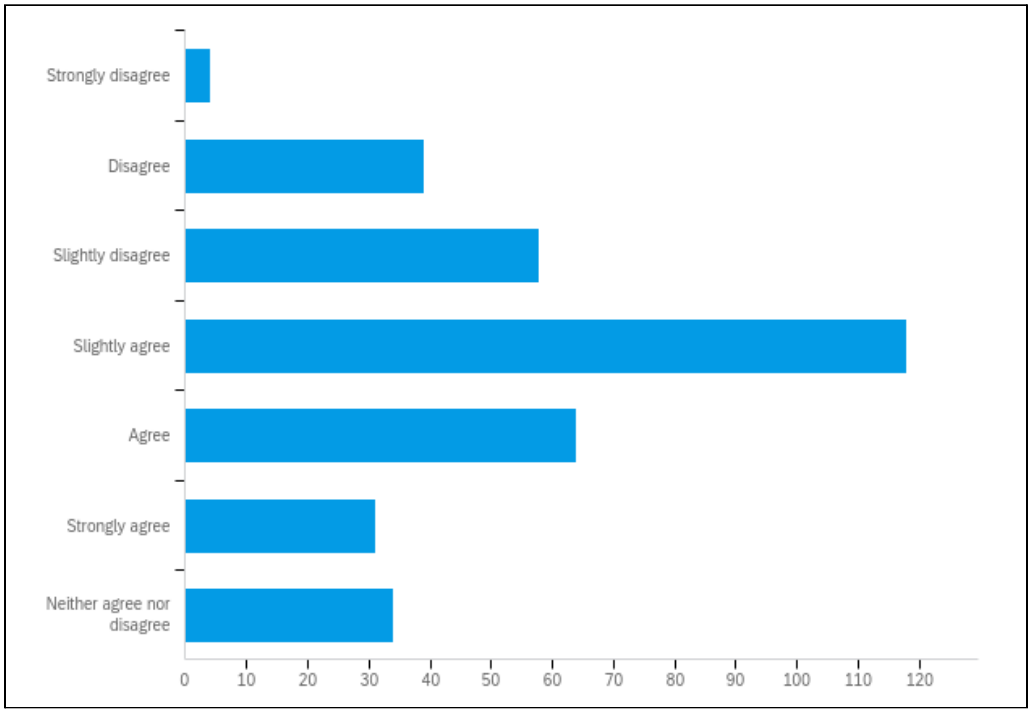


Figure 19. People would use less plastic, in sacrifice of convenience, if the consequences of frequent plastic consumption are clear to them. (Q15)

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