PLASTIC-FREE VENICE:
Quantifying and Mapping Plastic Pollution

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Submitted by
Shanna Bonanno
Alexander Hagedorn
Troy Howlett
Vivian Nguyen

Project Advisors
Dr. William Michalson
Dr. Fabio Carerra

Sponsors
Venice Calls
Wigwam

Date: December 12th, 2019
https://sites.google.com/view/ve19-plast/home
gr-ve19-plast@gmail.com

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Abstract

In this project, we contributed to developing a plan to reducing the build-up of plastic pollution in Venice, Italy. Due to the unique geography, being surrounded by the Lagoon, plastic disposal has been difficult to manage. The high tourist population has increased the importation and distribution of single-use plastic items across the city. These factors have added to the prevalent issue of plastic pollution in Venice. To address the plastic pollution problem, we gathered data to understand the accumulation of waste in the Lagoon. We assessed the effectiveness of the public trash receptacles and waste pick-up locations through research and observations. Finally, we analyzed our data and developed recommendations for the reduction of plastic pollution in Venice.

Executive Summary

Project Overview

Since the 1950's global plastic production has exponentially grown to a cumulative total of 7 billion tons of plastic by 2015 (Ritchie & Roser, 2018). As a result of plastic's unique properties, such as abundance, versatility, and low cost, it can take anywhere from 10 years for a cigarette filter to 200 years for a plastic straw to 600 years for fishing line to biodegrade in the environment. Since the plastic takes hundreds of years to naturally break down, plastic that enters the environment remains unless manually removed. Negative consequences result from this build-up of plastic in the environment. For example, in marine ecosystems, the plastic decreases the water quality as the material releases toxins over time. Wildlife that may consume or become entangled in plastic can develop internal and external complications, potentially leading them to perish. If animals or water contaminated with microplastics and toxins are consumed, human health might also be compromised.

The global plastic pollution problem is amplified due to some of Venice's unique features. Venice has a dense population that consists of 270,000 citizens on the mainland of Venice while about 53,000 residents live in the historical center (Municipality of Venice, 2018). In addition to residents, many people commute to the historical center every day to work, as well as the approximately 36 million tourists who visit Venice each year. With such a diverse population there are many potential contributors to plastic pollution. The distinct geography of the Venice Lagoon also contributes to the plastic pollution in the city and amplifies the visibility of the issue. There are 10 rivers that flow into the Lagoon bringing in plastic waste from surrounding cities. In turn, there are only 3 passages from the Lagoon to the Adriatic Sea trapping much of the waste within the Lagoon. Both natural and man-made salt marshes are present along most of the coastlines of the Lagoon in addition to covering much of the Lagoon's northern region. These salt marshes can become plastic traps as it becomes entangled in the vegetation. Within the historical city itself, Venice has many narrow streets running adjacent to a system of canals. The close proximity of human activity to the marine ecosystem makes it easy for general waste and plastic to enter and move around the environment.

In efforts to reduce the plastic pollution problem the European Union has set forth regulations on some single-use plastics including plastic bags, cutlery, dishes, straws and polystyrene. The regulations aim to ban these items by 2021, because alternatives for the items exist on the market

(Circular economy: New rules on Single-use Plastics, n.d.). Capri for example, has gone farther than just preparing a plan, they have already implemented the bans. Venice has yet to release a statement of how they plan to adhere to the EU regulations besides the regulation of paying a tax for plastic bags.

Local businesses and non-governmental organizations (NGOs) have taken action in Venice to address the plastic pollution problem. Certain small businesses have implemented plastic-free initiatives where they have stopped selling plastic bottles. Some tour companies have implemented programs where they collect plastic as they give their tours. NGOs including Venice Calls (one of our sponsors), Legambiente, and Plastic Free Venice Lagoon all organize community cleanups in the Venice region to remove the plastic from the environment. While these organizations are able to remove much of the plastic that accumulates in and around Venice, they have yet to quantify the scope of the plastic pollution problem, as well as prevent the source of plastic from entering the environment.

Project Objectives

The goal of this project is to contribute to the development of a strategic plan to reduce the build-up of plastic pollution in Venice. To complete this mission, our team focused on the following objectives:

1. To understand the accumulation of plastic pollution in the Venice Lagoon.
2. To assess the effectiveness of public trash receptacles and waste pick-up locations.
3. To develop recommendations for the overall plan to reduce plastic pollution.

Plastic Pollution Accumulation

To understand the accumulation of plastic pollution in Venice we did the following: located places where the plastic was accumulating, collected the accumulated pollutants, sorted what we had collected, quantified what we had sorted and analyzed our results. To locate potential accumulation points we worked with our advisors and sponsors to map out known locations in addition to what we had discovered as we traveled throughout the city. Taking into consideration the time constraints we had, weather, tides and our resources, we selected three locations to cleanup and collect data. These locations included the exposed land adjacent to the S. Alvise boat stop with an area of 310 square meters, the exchange location on Northern Tronchetto with an area of 160

square meters, as well as the area directly behind Monumento alla Partigiana on Giardini with an area of 60 square meters.

We performed two cleanups at each of the three locations. At S. Alvise our collections were 13 days apart on 11/20/19 and 12/03/19. On Northern Tronchetto our collections were 12 days apart on 11/21/19 and 12/03/19. On Giardini (Partigiana) our cleanups were 9 days apart on 11/25/19 and 12/04/19. Once accumulated pollution was collected, we sorted it first into material categories and then into item types. The categories included plastic, glass, metal, rubber and others. The types were individual items branching from the categories. To quantify each of the types we measured the quantity in pieces and then the mass in kilograms to show a comprehensive view of the issue as each type has unique material characteristics and densities.

At S. Alvise we collected 17.5 kg from 713 pieces of plastic on the first cleanup and 13.7 kg from 425 pieces of plastic on the second. At Northern Tronchetto we collected 40.3 kg from 2054 pieces of plastic on the first and 25.2 kg from 820 pieces of plastic on the second collection. At Giardini we collected 10.5 kg from 805 pieces of plastic on the first cleanup and 2.8 kg from 698 pieces of plastic on the second. From the amount collected on the second cleanup and the time elapsed between the first and second we were able to estimate the rate of plastic pollution accumulation at each site. At S. Alvise we approximated 0.65 kg/day and 28 pieces/day, at Northern Tronchetto 1.21 kg/day and 62 pieces/day, and at Giardini 0.22 kg/day and 72 pieces/day. Of the total plastic that was collected at each location we determined that the biggest contributor by number of pieces was polystyrene while the most prevalent by mass was thin plastic sheets.

Trash Receptacle and Waste Pick-Up Effectiveness

To assess the effectiveness of trash receptacles we selected four locations to observe. These receptacles included those in Campo S. Margherita, at S. Lucia Train Station, along Strada Nova and along Salizada San Moise. We observed each location of trash receptacles between a total of 12 and 15 times at four varying times throughout the day: early morning, mid-morning, evening, and late at night. At each observation we ranked the level of fullness of the receptacles from less than half full to overflowing. The data collected from these observations showed us potential sources of plastic and waste entering the environment. In the case of an overflowing trash receptacle, the waste that overflowed onto the ground had the opportunity to be blown into a canal or be picked up and transferred by wildlife. The observations also provided data on the geographical locations and time of day that a receptacle is most prone to overflowing. An example

from our data shows that Campo S. Margherita is prone to overflowing late at night or early in the morning from the previous night, likely due to the increased nightlife in the area.

The waste pick-up locations are available throughout the city along the canals from 06:30 to 08:30 for people who have to leave their homes prior to the door-to-door collection beginning at 08:30. While leaving the trash and recycling out overnight or earlier in the morning is illegal, we observed that it still does occur. The general waste and recycling left at these locations in such close proximity to the canals can easily make its way into the canals again from both wind and wildlife. We observed 5 waste pick-up locations before the 06:30 start time when they bring out the waste carts. The locations included one near S. Lucia Train Station, one in Northern Cannaregio, one along Strada Nova, the one near the Rialto bridge and another by Saint Mark's Square. We visited each of these locations a total of 4 times. From these observations we were able to estimate the frequency that waste bags were left out before the allotted time. One example is the pick-up location closest to S. Lucia Train Station where we recorded that every time we observed this site there was waste left beforehand. The likely reasons for leaving waste outside of the given times are due to a lack of education on the waste collection system or from inconvenient collection times where people have to leave their homes before the drop off times beginning at 06:30.

Conclusions and Recommendations

Based off of the data collected in objective 1, one of the first steps in reducing plastic pollution is to work towards regulating plastic. Plastics to be targeted by these regulations should be polystyrene, single-use plastics (cups, cutlery, straws, etc.), water bottles, and plastic wrappings involved with industrial packaging. While adhering to the EU directive by the 2021 deadline will help with some of these categories, Venice can take it a step further by regulating plastics not included and setting the precedent for the rest of the world. To aid in the removal of plastics from the environment a shared database should be implemented among all of the independent organizations fighting back against the issue in Venice. This database should include maps of all accumulation points, quantities of accumulation collected at each site, the categories and types of accumulation found at each location, as well as schedules for when cleanups were or plan to be conducted. This will aid in the overall monitoring of the plastic pollution problem in Venice as trends in the data over time will be visible and any progress made will be seen. This shared database will also serve as a standardized collection method that will allow for more involvement from community members, businesses, schools, and colleges. This will allow for increased

awareness of the plastic pollution problem, more people to collect more data, and more power for change as people learn more about the issue and become more passionate about it.

From our observations in objective 2 we determined that the city would benefit from additional receptacle emptying shifts in the 20:00 to 23:00 time range due to increased nightlife, tourist foot traffic or commuter traffic depending on the location. In addition, implementing separated public waste and recycling bins would increase the recycling rates as well as save the city money in the separation process. For the waste pick-up locations leaving covered waste carts at the pickup sites either earlier in the morning or overnight would allow for a wider range of time for people to drop off their waste and recycling that could be convenient for people's varying schedules. Waste collection management can also send a survey to the locals to determine the most effective time for the pickup/drop-off locations to be available.

With the implementation of innovative solutions for both removing existing plastic from the environment, as well as preventing plastic from entering the environment in the first place, Venice can set a precedent and show the rest of the world what it means to be plastic-free.

Authorship

The Plastic-Free Venice proposal was written by Shanna Bonanno, Alexander Hagedorn, Troy Howlett, and Vivian Nguyen. The team utilized the collaborative and divided work methods to complete the proposal. After sections were written, the group edited the 1.0 Introduction Chapter together. Shanna Bonanno and Alexander Hagedorn edited the 2.0 Background Chapter. Vivian Nguyen and Troy Howlett edited the 3.0 Methodology Chapter. Finally, the group edited 4.0 Results and 5.0 Recommendations together.

Individual authorships are as follows:

Shanna Bonanno made the Cover Page and wrote the Abstract, and Acknowledgement. Additionally, she wrote the 2.0 Background Introduction, and contributed to 2.3 Regulating Plastic Pollution, and 2.6 Counteracting Plastic Pollution. She wrote 2.8 Background Summary. She contributed to the 3.0 Methodology Introduction and wrote 3.1 Understanding the Accumulation of Plastic Pollution in the Venice Lagoon. She wrote the 4.1 Understanding Accumulation in the Venice Lagoon Introduction. She made Figure 1: Lack of Biodegradability, Appendix A: Biographies of Sponsors, Appendix B: Biographies of Contributing Organizations, Appendix C: Data from Venice Calls, and Appendix D: Data from Legambiente.

Alexander Hagedorn wrote 1.0 Introduction, and contributed to 2.4 Population Around the Venice Lagoon, and 2.6 Counteracting Plastic Pollution. Next, he wrote 3.0 Methodology and 3.2 Assessing the Effectiveness of Public Trash Receptacles and Waste Pick-Up locations. Additionally, he wrote 3.3 Developing Recommendations for the Overall Plan to Reduce Plastic Pollution in Venice. He wrote chapter 5.0 Recommendations. Finally, he created Appendix F: Objective 3 Recommendation Pamphlet.

Troy Howlett wrote the Executive Summary and contributed to sections 2.5 Geography of the Venice Lagoon, 2.5 Geography of Venice Lagoon, and 2.6 Counteracting Plastic Pollution. He wrote section 2.7 Best Practices. He wrote section 4.1 Understanding Accumulation in the Venice Lagoon. He made all the figures shown in section 4.1. He made the map linked in Appendix E: Objective 3 Layered Map. Finally, he made Figure 6: Plastic Pollution Accumulation Location Map, Table 1: Site Location and Collection Information and Table 2: Site Accumulation Information.

Vivian Nguyen wrote 2.1 Production and Characteristics of Plastic Material, 2.2 Harmful Effects of Plastic, 2.3 Regulating Plastic Pollution, and 2.4 Population Around the Venice Lagoon. She contributed to 2.6 Counteracting Plastic Pollution and wrote 2.7 Best Practices. She contributed to section 3.0 Methodology. She also wrote section 4.2 Trash Receptacles and Waste Pick-Up Effectiveness Data. She made all the figures in section 4.2. Finally she made Figure 10: Locations of Selected Trash Receptacle Observations, Figure 15: Locations of Selected Trash Pickup Locations, and Figure 21: Qualitative Scale of Fullness of Trash Receptacles .

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1.0 Introduction

The United Nations Environment Programme (UNEP) estimates that 60% of total plastic produced since 1950 ends up in landfills or the natural environment, leading to the production of 300 million metric tons of plastic waste every year (UNEP, 2018). UNEP warns that if the current rate of plastic production and consumption continues, there will be more plastic than fish in the oceans by 2050. Plastic pollution in the world's oceans is a major concern, however, according to UNEP the biggest concern over plastic build-up is in coastal regions.

With 4,723 miles (7,600 kilometers) of coastline, Italy has the fifth longest coastline in Europe which contributes to higher concentrations of plastic build-up (Sen Nag, 2018). A study by Ocean Cleanup found that only 0.06% of the plastic that gets deposited into the water makes it to the open ocean and the rest of it gets trapped along the coast, which links longer coastlines to higher concentrations of plastic build-up (Simon, 2019). In Venice, a city consisting of 118 islands broken apart by a complex system of canals, there are more places for plastic to get trapped and accumulate (Kiprop, 2018). The beautiful islands and waterfront views also attract tourists, which leads to an increase in single-use plastic products during high influx seasons. In June 2018, it was reported that more than 200 million tourists visit the Mediterranean every summer, leading to a 40 percent increase in plastic pollution (UNEP, 2019). Within this 40% increase, there is an omnipresence of single-use plastic, which confounds the problem that already exists because of the unique geography of the city.

In response to the negative effects that single-use plastics have on the environment, the EU approved a law on March 27th, 2019 that will ban a wide range of single-use plastic by 2021 (Britton, 2019). This legislation has been adopted by Italian communities like the Island of Capri, banning all non-reusable plastic and the region of Puglia banning the sale and use of single-use plastic near beaches. The city of Venice has yet to put any legislation into place to help stem the flow of plastic pollution into the water. Since the Venetian government has not implemented laws against single-use plastic, the community and NGOs have organized beach and canal cleanup days to combat the plastic pollution problem. On one such day, organized by the local Venetian chapter of the United Nations Environmental, Scientific and Cultural Organization (UNESCO), 100 large sized bags of plastic litter were filled and properly recycled (UNESCO, 2018).

Continuing with non-governmental efforts, Venice Calls, a group of young people with visions of improving their community, established themselves in May of 2018 to safeguard the Venetian society and restore the care and protection of the city and its Lagoon. In addition to organizing

beach cleanups, they have done some great work in educating the community about the effects of plastic pollution on their city. However, they lack concrete data and visuals on the scope of the plastic problem in Venice. The sources of plastic entering the canals and Lagoon of Venice have yet to be located, quantified and mapped. To know how to best prevent plastic pollution throughout the city, these sources must be tracked and mapped in relation to trash receptacles and the current waste disposal locations. The analysis of this information will allow for more targeted recommendations for the prevention of plastic pollution.

In completion of the Interactive Qualifying Project (IQP), through Worcester Polytechnic Institute (WPI), Plastic-Free Venice will have provided Venice Calls, Wigwam, and the Venetian community with a valuable foundation for greater work regarding plastic pollution within the city.

2.0 Background

Plastic, a versatile material used today for packaging, transport, construction, electrical, and medical applications was invented in the late 19th century (Plastics Uses, Benefits, and Chemical Safety Facts, 2014). When manufacturers realized its versatility in the 1950s, plastic developed into an omnipresent material, ultimately generating an increased cumulative production rate from only 2 million tons per year in 1950 to 70 million tons per year by 1980 (Richie & Roser, 2018). Producers and consumers were unaware of the staggering effects it would have on the environment due to its lack of biodegradability, a significantly negative characteristic in comparison to other highly used materials (Parker, 2018).

Today, it is estimated that up to 14 million tons of plastic end up in the oceans every year from coastal regions alone (Parker, 2018). Since Venice is a coastal region, plastic waste buildup has become more prevalent, with the addition of high plastic consumption by tourists and residents in combination with poor waste collection systems (Mediterranean Plastic Pollution Hotspots Highlighted in Report, 2019). In the past two years, UNESCO and NGOs have identified plastic pollution as a problem in the city that needs a solution (UNESCO, 2018). The following sections discuss plastic material and its characteristics and production. Furthermore, our background investigates plastic pollution on both a global and local scale, for the purpose of generating a foundation for reducing plastic pollution in the city of Venice.

2.1 Production and Characteristics of Plastic Material

The 20th century ushered in a revolution of plastic material abundance when it was discovered that waste from petroleum manufacturing could be used to create plastic (Parker, 2018). Chemists discovered they could use the gases released by petroleum refinement as monomers, or the building blocks of polymers, to create novel plastic materials, such as polyethylene terephthalate (PET) instead of exclusively working with natural polymers. Chemical synthesis of plastic manufacturing decreased the cost and provided the ability to arrange the monomers in such a way to meet different design specifications, such as flexibility, weight, density, or water resistance.

Because synthetic plastic was cost efficient, scientists started to generate a surplus of plastic products for marketing purposes. In response, plastic was implemented into every industry, such as packaging, construction, textiles, consumer products, healthcare, agriculture, and electrical (UNEP, 2018). Because the negative effects of plastic pollution had not yet surfaced in the 1950s, there was no motive to stop the incorporation of plastic materials into everyday life. Life magazine

celebrated the liberation of the American housewife from drudgery (Parker, 2018). Under the headline “Throwaway Living,” a photograph showed a family flinging plates, cups, and cutlery into the air. The items would take 40 hours to clean, the text noted— “except that no housewife need bother” because instead she could use disposable single-use plasticware. Six decades later, roughly 40% of the now more than 448 million tons of plastic produced every year is single use, much of it used as packaging intended to be discarded within minutes after purchase. Production has grown at such a breakneck pace that virtually half the plastic ever manufactured has been made in the past 15 years. In 2015 alone, 381 million tons of plastic was manufactured globally (Ritchie & Roser, 2018).

2.1.1 Lack of Recyclability

Between 1950 and 2015, only nine percent of plastic was recycled (Ritchie & Roser, 2018). Plastic as a whole is challenging to recycle because some of the most prevalent types are difficult or impossible to break down. Other intricacies like food residue and coloration (preventing the recycling systems from properly sorting the material as plastic), also contribute to the lack of recycling. Low-density polyethylene (LDPE) is one of the most prevalent types of plastic commonly used to create products like plastic bags, trays, and food packaging film, because it is lightweight, low cost, has high flexibility and low tensile strength. Those same characteristics result in its inability to be recyclable as it fails under mechanical and thermal stress.

Polystyrene (PS), more commonly known as Styrofoam is another highly prevalent plastic material (UNEP, 2018). Since it is lightweight and structurally weak, it is beneficial to use this material in single-use plastics, such as takeout containers, packaging, and soft drink cups (Ritchie, 2018). Lesser known, it is used as a transparent solid that is commonly used for medical devices such as test tubes and petri dishes. Being lightweight, polystyrene is not cost-effective to recycle, costing more to transport and process the material, than the profit made from reusing the material (Miller, 2016). Since polystyrene is typically used in the food industry and it is so porous, food residue easily infiltrates into the material, leading to contamination and its inability to be recycled (Miller, 2016). As a result, it has been estimated that 79% of all plastic that is produced ends up in landfills, dumps, or in the environment (UNEP, 2018).

2.1.2 Lifespan of Plastic

Because of the strong bonds between the polymer sequences that make up plastic, it takes much longer for plastic to degrade naturally than other single-use options. Since more than three quarters of plastic produced per year are not recycled, plastic is forced to degrade naturally which causes

the build-up in the environment to be quite evident. Common disposable plastic items can take over 400 years to biodegrade (Kirk, Molloy, Mills, & Wright, 2018). A timeline of the lifespan of commonly used products is shown below in Figure 1.

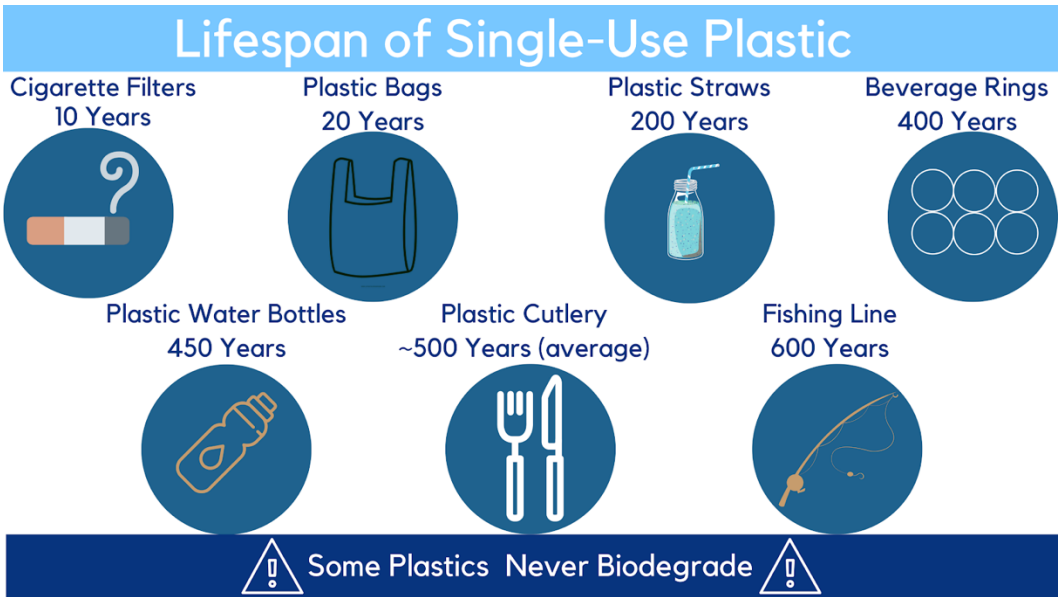

Figure 1: Lack of Biodegradability

2.2 Harmful Effects of Plastic

Plastic negatively affects marine organisms, humans, and the environment. Every year, at least 100,000 marine creatures and approximately 1 million seabirds die solely from entanglement in plastics, due to the buildup of plastics and plastic debris in the oceans (Plastic Statistics, 2012). Marine organisms are negatively affected by plastic in other ways, such as through the ingestion of smaller plastics, directly affecting humans. Researchers conducting studies on plastic particles discovered that approximately 45,000 microplastic particles are consumed by humans every year, risking damage to their immune systems and gut (Gibbens, 2019). Humans tend to dispose of plastic as waste, due to lack of education on proper recycling techniques. A waste treatment method, incineration, burns waste material at high temperatures. Plastic that is disposed of as waste releases harmful toxins into the air and surrounding environment when incinerated (Ritchie & Roser, 2018). Unfortunately, during the 1950s when the increase in plastic production began, manufacturers and environmentalists did not realize the fact that improperly disposed plastic would build up and lead to harmful effects. Now that the plastic pollution problem has received global recognition these harmful effects are coming to light.

2.2.1 Devastation to the Marine Ecosystems

The longer plastic remains in the water, the more toxins it releases leading to a decrease in water quality. Animals that consume or are caught in plastic experience indigestion, starvation, suffocation, infection, drowning, or entanglement, experiencing the impact of marine plastic pollution including 86% of all sea turtle species, 44% of all seabird species, and 43% of all marine mammal species (NOAA Marine Debris Program, 2014). These effects lead to a shorter lifespan and have resulted in endangered marine species becoming closer to extinction. Plastic can remain in their bodies from the time of ingestion until death. One example is that plastic bags floating throughout the ocean can be mistaken for jellyfish and are ingested by turtles and dolphins who mistake it for food (UNEP, 2018).

2.2.2 Negative Impacts on Human Health

The plastic pollution that enters the marine ecosystems not only affects the animals that live in them, but ultimately humans, who are higher in the food chain. Plastics break down releasing toxins into the environment. Theses toxins include diethylhexyl phthalate (DEHP) and health-bisphenol-A(BPA), which have been linked to cancer, birth defects, immune system problems, childhood developmental issues, and issues with hormonal functions (Andrews, 2018). The toxins enter the marine environment and contaminate animals, when people consume the animals for food, they also ingest the contaminates (Andrews, 2018).

2.2.3 Damage to the Environment

The abundance of plastic fragments, especially microscopic fragments of 330 μm or less, have relatively large surface area to volume ratios, facilitating the transport and release of contaminants into the environment (Thompson, Moore, Vom Saal, & Swan., 2009). Contaminants released include phthalates, alkyl phenols, biphenyl, and polybrominated biphenyl ethers (Bhateria & Jain, 2016). Heat treatment to plastic material, breaks the bonds of the polymer chains, leading to the release of the chemicals that initially synthesized the plastic material. High enough climate temperatures can also begin melting down plastic releasing even more toxic chemicals into the environment. (Pawlowski, 2018).

Plastic waste accumulating in the environment causes an increase in the transmission of diseases. For example, plastic waste can clog sewage systems, providing the ideal environmental conditions for mosquitoes to breed and transmit vector-borne diseases (UNEP, 2018). Plastic accumulation can harm coral reefs, as the rough, spiky coral species provide a platform for the entanglement of plastic. Plastic causes light deprivation, toxin release, and anoxia (lack of oxygen reaching the

tissues of a given species), which is ultimately harming and killing the coral reef. A decrease in the presence of coral reefs due to plastic pollution, directly affects the world's coastlines, as coral reefs protect from coastal erosion, due to the damaging effects of waves or tropical storms (Biodiscovery and the Great Barrier Reef, n.d.).

2.3 Regulating Plastic Pollution

On March 27th, 2019 the EU approved a law banning a wide range of single-use plastics by 2021 with a staggering vote of 360 for and 35 votes against. This law, in addition to banning single-use plastic items like straws, cotton balls, and cutlery, targeted the main plastic polluting industries (Britton, 2019). When this law takes effect, tobacco companies will be required to cover the cost of cigarette butt cleanup. In addition, fishing gear manufacturers will be required to pay for the retrieval of any plastic nets left at sea (Britton, 2019). This will incentivize corporations to manage the impact that their products have on the environment.

In response to this new law, on May 15th, 2019 the island of Capri ratified a law that banned all non-reusable plastic on the island (Speak, 2019). Last summer, the Puglia region of Italy banned sales of single-use plastic near the beaches (Speak, 2019). Even though smaller municipalities in Italy have implemented legislation to combat the plastic pollution problem, Venice legislation has yet to show any effort to comply with the EU's legislation. Due to the differing geographical makeup of mainland Venice and historical city Venice, environmental issues are prioritized differently between these two sectors. Since Venice is led by one government with one mayor, conflicting viewpoints are evident when it comes to voting and ultimately only one view can win the vote. Historical city Venice has a smaller population than mainland Venice, which presents a challenge in convincing the government to see the importance of plastic pollution in the Venice Lagoon and canals.

2.4 Population Around the Venice Lagoon

The Venice Lagoon has a large population of people that interact with it every day. The Municipality of Venice, which is centered around Mestre and the city of Venice has a population of 260,520 people as of December 31st, 2018 (Municipality of Venice, 2018). Mestre is a borough located on the mainland of Italy whereas the city of Venice is an island branching off of the mainland, commonly referred to as the historical city. The historical city of Venice, which is where our project is centered around, has a population of approximately 52,996 people as of December 31st, 2018 (Municipality of Venice, 2018). That number is dwarfed by the fact that there are almost 36 million tourists who pass through the Venice region each year (Fox, 2019). There is a

combination of both overnight tourists and day-trippers that make up the 36 million a year. Because of the large influx of people in the area due to tourism, there is a greater number of people to potentially contribute to the plastic pollution problem. More people using plastic near the Lagoon leads to potentially more plastic getting into the water and causing environmental repercussions.

2.5 Geography of the Venice Lagoon

The Venice Lagoon is the largest lagoon in the Mediterranean at 212 square miles. In it lies a series of islands including the 118 islands that make up the mainland city of Venice (Imboden, n.d). The Lagoon is separated from the Adriatic Sea by two long thin islands, Lido di Venezia and Pellestrina, which result in three small channels separating the Venice Lagoon and the Sea. The Lagoon as a whole is very shallow with an average depth of only two feet (Imboden, n.d). Only 11% of the Lagoon is fully submerged at all times of the year, which is attributable to the twice daily tides from the Adriatic Sea (Venetian Lagoon, n.d). The Lagoon being fed with freshwater from ten different rivers, coming from different directions, and tides from the Sea, resulting in complicated currents. These currents in addition to northeasterly winds bring and trap plastic, which leads to the potential buildup of plastic pollution in the Venice Lagoon.

2.5.1 Features In and Around the Lagoon

In the Lagoon, both naturally existing and man-made salt marshes line the edges of the Lagoon in addition to covering much of its northern region. These salt marshes are habitats for several different species of marine flora and fauna. The salt marshes serve several purposes, such as providing an erosion barrier for the edge of the Lagoon and the islands it encompasses, as well as preventing pollutants from contaminating shorelines, waterways, and fish farms located around the Lagoon. Furthermore, the salt marshes provide a key source of food for those inhabiting the area.

The fish farms that surround the Venice Lagoon have inlets where both fish and water enter the farm. The effects of pollutants, especially plastic, have a detrimental effect on the functionality of the farms, thus fish farmers have to develop methods to filter out or collect the plastic before it enters. One farmer developed a pocket of land where plastic is collected from the winds and currents, reducing the amount of pollutants that enter the protected inlet. The European Route 55 is another feature that connects Villi to Chioggia through means of a land bridge in the southern end of the Lagoon. As many plastic pollutants are pushed south from northeastern winds and currents, the lateral bridge becomes a location prone to plastic accumulation, providing protection to the fish farms farther south.

2.5.2 Acqua Alta

In Venice, acqua alta, translated as high water, is a time of unusually high tidal levels defined as greater than 80 cm (Comune di Venezia, n.d.). Acqua alta normally occurs between October and January and is caused by several environmental factors including the tides caused by the stages of the moon and high winds. Acqua alta, the phenomenon of high water, arises due to "unfavorable weather conditions, typically low pressure and strong {...} winds" coinciding with a "maximum astronomical tide," (Comune di Venezia, n.d.). At 110 cm about 12% of the city is flooded. If the tide reaches 140 cm, approximately 59% of the city is flooded. As the city floods, plastic and other waste left on the ground is lifted up and pulled out into the Lagoon as the tide recedes.

2.6 Counteracting Plastic Pollution in Venice Lagoon

With the distinct geography of Venice and the numerous potential sources of plastic pollution both within and outside of the city, plastic pollution is prominent and has drawn the attention of Venetian groups. Veritas runs the waste management in Venice and continues to develop innovative methods to aid in proper disposal and collection of waste in efforts to keep the city clean with all of the residents and tourists it serves. Non-profit organizations including Venice Calls, Wigwam, Legambiente, the Plastic-Free Venice Lagoon Association, and UNESCO have worked to develop cleanups and other initiatives in the past couple of years in an attempt to preserve the historical city. Some hotels in the city have recognized their ability to reduce plastic pollution in the environment and have introduced plastic-free initiatives beginning in 2019 to start a movement where other Venetian businesses do the same. Another tour company utilizes a cleaner city initiative as their motto to be a part of the environmental change.

2.6.1 Waste Management through Veritas

Due to the surrounding Lagoon, narrow streets, limited transportation, and large flux of tourists, waste removal has been an on-going issue throughout the city. Veritas is the waste management company in Venice that tackles both residential and public disposal of waste and recycling. A year ago, Veritas developed an app called 'Veritas Scoasse,' which caters to both the 930,000 residents and over 40 million tourists that it serves in the Venezia region (Veritas, n.d.). The app includes a map of waste pick-up locations, as well as water refill stations throughout the city.

In years prior to 2016, trash would be put out on the streets and Veritas would visit each street to collect waste. Problems presented with this system include "unpleasant smells, litter, and low-quality separation of waste collection" (C40: New Waste Collection System in Venice, n.d.). It was unclear for residents and tourists on the methodology for separating waste from recycling,

which often led to all trash being put out as waste. Due to the narrow streets of Venice, it was difficult for Veritas to collect trash bags. As a result, the focus was more on picking up all the trash to prevent it from blowing into the canals, rather than ensuring it was properly separated (C40: New waste collection system in Venice, n.d.). Veritas realized that the lack of emphasis on the separation of waste and recycling was an area that they wanted to address.

At the end of 2016, Veritas implemented a new method of waste collection to combat some of the challenges that have persisted for many years. The new method is a system of picking up trash by going door-to-door and bringing the waste to designated waste pick-up locations. The system follows a regimented schedule for weekly collections. On Monday, Wednesday, and Friday they collect paper. On Tuesday, Thursday, and Saturday they collect glass, plastic, and metal. Non-recyclable waste is collected every day except for Sundays (Veritas, n.d.). Veritas collects door-to-door from 08:30-12:00 but allows people to drop off waste at waste pick-up locations from 06:00-08:30AM for those who will not be home during the door collections. Veritas' 55 waste pick-up locations are essentially boats fitted with special compactors. They have individual compactors for each waste type and can hold large amounts of waste to make it easier for transport, ensuring that waste doesn't end up in the water (C40: New waste collection system in Venice, n.d.). With this method in place, Veritas hopes that it will be more efficient in collecting and separating trash from different recycling types. They also hope that it will prevent the prevalence of litter and pollution.

2.6.2 Venice Calls

Venice Calls is a young civil society organization founded by a group of people who share a love for their territory (Venice Calls, n.d.). Initially coming together in May of 2018, as a group of Venetians wanting to commit time and effort to benefit the city, they now "have been active since September 2018. Venice Calls intends to build a platform to promote a new vision of [the] city and [its] citizens" (Venice Calls, n.d.). Their mission is to cooperate with groups that have similar goals working to safeguard the Venetian society in efforts to restore the care and protection of the city and its Lagoon (Venice Calls, n.d.).

The 'Scova E Scoasse' program promotes awareness of the waste system in Venice, and hosts trash clean-up days around the city in collaboration with Veritas (Venice Calls, n.d.). Due to its success, they have been able to host multiple clean-up days, gaining more community awareness. One of their clean-up days was on November 3rd, 2018, where one hundred volunteers participated in collecting 24 cubic meters of waste ("Scova e Scoasse": Raccolti Sabato 24 Metri Cubi di Rifiuti, 2018). Collection locations included the "Sant'Alvise shoal, Tronchetto, Fondamenta Santa

Giustina and the island of the cemetery of San Michele" ("'Scova e Scoasse': Raccolti Sabato 24 Metri Cubi di Rifiuti", 2018) (see Appendix C for Venice Calls clean-up data).

A current challenge that Venice Calls is addressing is in response to the many acqua altas that hit Venice from November 12th-17th, 2019. Specifically, the city experienced three record breaking acqua altas of 187 cm, 154 cm, and 152 cm, which were the second, seventh, and eighth highest tides in Venice acqua alta history, respectively. With these drastically high tides in a short period of time, many businesses and residences experienced unexpected damage. Venice Calls, working in unison with Veritas and approximately 2,000 volunteers, put on their rubber boots and gloves to began performing cleanups in targeted damaged areas. Receiving international recognition for their work, Boston 25 News wrote an article about their determination to help preserve manuscripts in Venice's Music Conservatory (Young Venetians Volunteer after Flood of their Lifetimes, 2019). In an interview with a member of Venice Calls, Vittorio da Mosto, he stated that they "are going to bookshops, to libraries, to shops and restaurants, giving them a hand to try to help out. And when [they] find a lot of trash piling up [they] organize carts to clean it up so it doesn't go in the water" (Young Venetians Volunteer after Flood of their Lifetimes, 2019). Venice Calls truly cares about the image of their city, especially in regard to the environment, sustainability, and plastic pollution. Now people all over the world are beginning to see how Venetian groups are motivated to deal with the problem that is plastic pollution.

2.6.3 Wigwam

Wigwam is a "non-profit association network for the fair, supportive, and sustainable development of local communities," (Tassinato, 2019). It is a worldwide organization, consisting of 21 countries, and was founded in Italy. Their mission is to "promote and realize development in a fair way, through solidarity and sustainable collaboration of the local communities connected in a global network," (World Wigwam Circuit, n.d.). The members of Wigwam when faced with a problem, follow their philosophy that "the limits can (and must) be transformed into opportunities" in which a contribution to the solution is made (World Wigwam Circuit, n.d.).

Giovanni Cecconi is the director of the Venice Resilience Lab of Wigwam Local Community and focuses on building with nature for disaster risk reduction and sustainable development. Through his prior research and experience in these topics, Giovanni had suggested 13 locations in which he has previously observed an issue of plastic pollution. These areas, which can be viewed in Figure 2, enclose plastic pollution due to their unique geography.

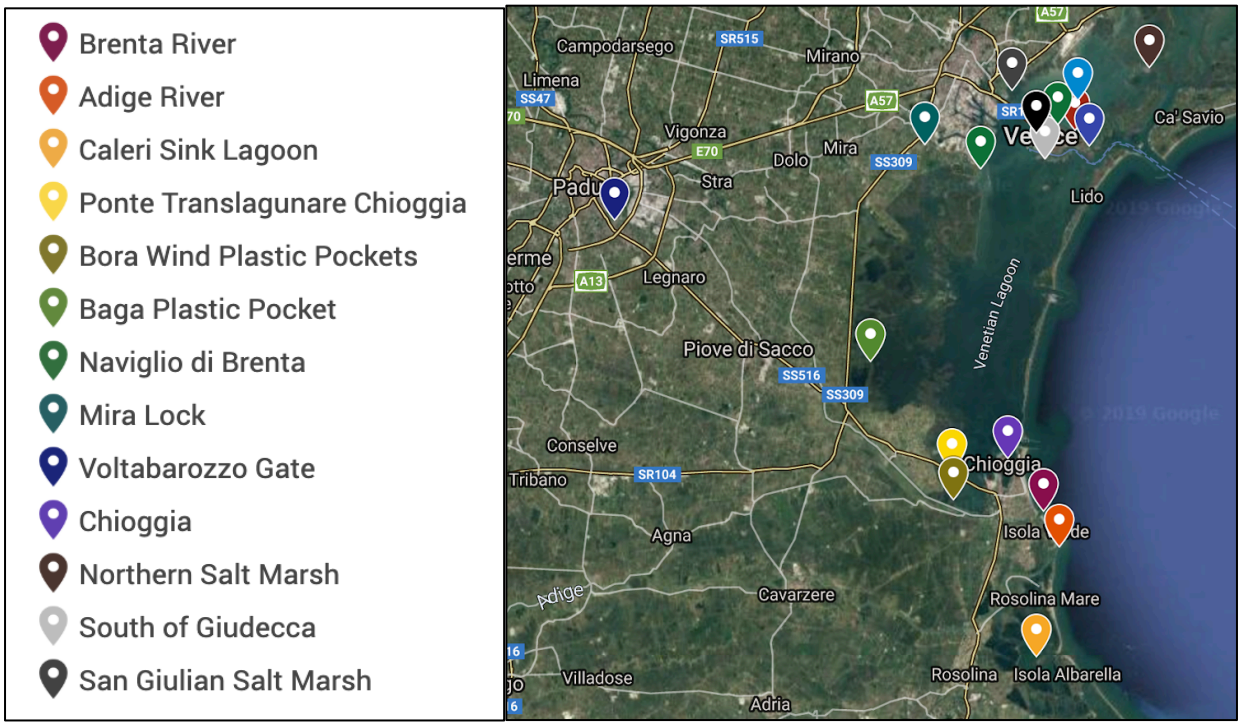

Figure 2: Points of Interest Map

2.6.4 Legambiente

Legambiente is a non-governmental organization with 20 regional sectors throughout Italy, one being Venice (Legambiente Venezia, n.d.). Legambiente is passionate about bridging the gap between nature and man to help instill a more sustainable environment (Legambiente Venezia, n.d.). The local chapter of Legambiente in Venice has three main initiatives: Let's Clean Venice, Countryside Airache, and Don't Waste Venice. In Let's Clean Venice they aim to run cleanups on the beaches, in the salt marshes, and in the canals (Legambiente Venezia, n.d.). Countryside Airache monitors the quality of the air and the pollution in it at a couple locations throughout the historical city (Legambiente Venezia, n.d.). Don't Waste Venice aims to develop a monitoring system for floating solid wastes by quantity and type in the Lagoon in addition to raising awareness in the community of the issue. This final initiative works in coordination with other European countries bordering the Adriatic Sea in an effort to address the issues of waste in the sea.

The current president of Legambiente's Venice chapter is Paolo Franceschetti, who is motivated to rid the city of plastic pollution with the help of the Venetian community. Along with beach cleanups and other initiatives to clean the city, Paolo and the other organization members place focus on data collection to understand the scope of the issue and to determine viable solutions. In the summer of 2016, the Venice Legambiente organization completed beach cleanups and data

collection at the locations outlined in Figure 3 below, which includes Cannaregio (dark green), Dorsaduro (red), Giudecca (light green), Castello (purple), Certosa (white), Santa Croce (yellow), San Polo (pink), and San Marco (blue). After cleaning up these locations, they sorted the items that were collected into overall categories, such as plastic or glass, as well as individual categories, such as bottles or chip bags. They created a database with the counts from each clean-up location and performed a statistical analysis. Figure 4 below shows the percentage of each category of waste with 88.84% of the waste being plastic material. A further analysis of the plastic material in Figure 5 displays the top ten plastic items at these clean-up sites. Cigarette filters were the most common plastic items found in these clean-ups at 30.50%. More data about these cleanups can be found in Appendix D.

Figure 3: Summer 2016 Data Collection Locations
From "percorsi canali.png," Franceschetti, P.

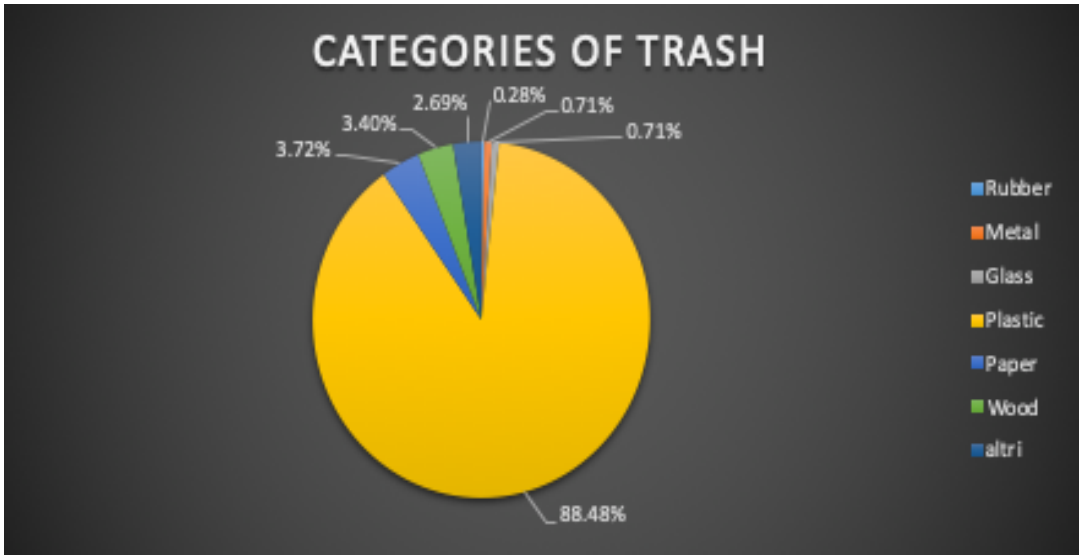

Figure 4: Categories of Trash Collected in Summer 2016
Adapted from "generale città - SI CERTOSA.xlsx," Franceschetti, P.

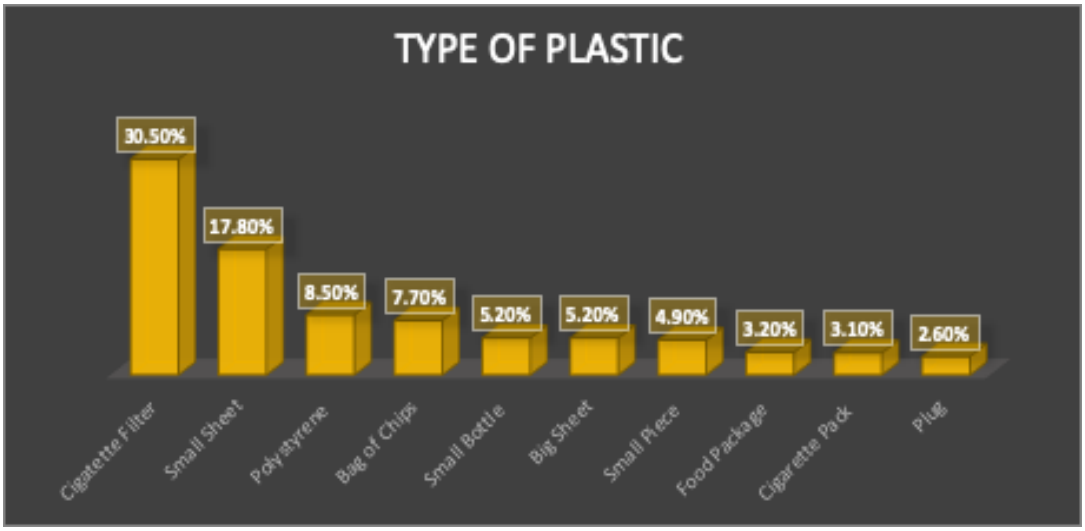

Figure 5: Types of Plastic Collected in Summer 2016
Adapted from "generale città - SI CERTOSA.xlsx," Franceschetti, P.

Through research and data collection they have been able to draw further conclusions that while the tourists do contribute to the plastic pollution problem, they are not the sole contributors and Venetians need to take some responsibility as well. One of the most polluted islands of Venice is Guidecca, which is a densely inhabited Venetian residential area (Franceschetti, 2019).

Through research, Legambiente has found that the historical city of Venice has the lowest rate of recycling in all of Italy. Part of the issue is due to the design of the public trash receptacles

throughout the city. It is observed that while the mainland of Venice has separated public trash receptacles, the historical city of Venice does not. The rate of recycling is reduced, since waste is not separated at initial disposal. It is calculated that only about 25% of the recyclable waste is actually recycled in the historical city, whereas 80% is recycled on the mainland (Franceschetti, 2019).

Legambiente has observed that Veritas cleans the city around 07:00. During acqua alta season, the high tides can come in early enough to occur before Veritas cleans the city. Because Veritas runs by a somewhat rigid schedule (which does not change for weather conditions like acqua altas), waste is not picked up from the streets and public bins before these high tides. As a result, waste is often pulled into the canals and the Lagoon by the high tides. Veritas also has a contract stating that the employees in the entire Veneto region are required to clean up the streets within the cities and municipalities. There is no requirement for Veritas to clean the water. The historical city of Venice in comparison to the rest of the Veneto region is unique in that a good portion of the city is the many waterways running between the islands that comprise the city. In a sense, Veritas in the historical city is able to get around the contract, since once waste reaches the canals or Lagoon it is no longer the responsibility of Veritas to clean it up. Veritas does own two boats that can collect waste in the Lagoon, however, it is noted that they are only put to use twice a year. As a result, there is an overall decrease in the efficiency of waste cleanup in historical Venice (Franceschetti, 2019).

Currently, Legambiente has come up with a couple initiatives based on their research and data collection. One being an education program for hotels and Airbnbs in the historical city to better understand the effects of pollution on the Lagoon. The goal of this initiative is to have education for tourists so they understand the importance of recycling and following the waste system that Veritas has set. Reusable water bottles for Veritas workers is a second initiative that Legambiente hopes to instill with efforts to reduce single-use plastic in the city (Franceschetti, 2019).

2.6.5 Plastic Free Venice Lagoon Association

As a non-profit organization based in Venice, Plastic Free Venice Lagoon “acts as a platform for membership and coordination, between organizations and individuals in order to manage large-scale clean-up operations in the historic center, Lagoon, and eaves territories, including the mainland,” (Plastic Free Venice Lagoon, n.d.). The group raises public awareness of the dangers of plastic pollution by encouraging public debates and discussions in addition to promoting plastic alternatives and best practices.

The Plastic-Free Venice Lagoon Association carries out initiatives aimed at reducing plastic waste in Venice. In August of 2019, Plastic-Free Venice carried out a sampling of the Grand Canal near Sagredo in Venice to test for traces of micropollutants in the Lagoon (Plastica, la Laguna di Venezia è 5 Volte Più Inquinata del Resto del Mare Adriatico, 2019). After testing the samples, they found "packaging, lubricants, elements linked to rubbers, components of polyamides/polyesters and textile compounds" (Plastica, la Laguna di Venezia è 5 Volte Più Inquinata del Resto del Mare Adriatico, 2019). Moreover, the initiative measured that the Venice Lagoon concentration of plastic waste is five times more than the rest of the Adriatic Sea (Plastica, la Laguna di Venezia è 5 Volte Più Inquinata del Resto del Mare Adriatico, 2019). Another initiative of Plastic-Free Venice is 'Puliamo il Mondò,' which was a beach clean-up event put on by Plastic-Free Venice. The event was successful in collecting 200 kilograms of waste in the Lagoon (Plastica, la Laguna di Venezia è 5 Volte Più Inquinata del Resto del Mare Adriatico, 2019).

2.6.6 CNR-ISMAR

CNR-ISMAR is a research institution with the following missions to conduct research in:

- the evolution of the oceans and continental margins to define the activity of submarine volcanoes, faults and landslides, and the impact scenarios on the coasts
- the influence of climate change on oceanic circulation, acidification, bio-geochemical cycles and the productivity of the seas
- habitats and marine ecology, the increasing pollution of coastal and deep areas
- fisheries resources to maintain exploitation within sustainable limits and improve mariculture and aquaculture practices
- the natural and anthropic factors that impact economically and socially on coasts and lagoons from prehistory to the industrial age

  (ISMAR, n.d.)

Currently CNR-ISMAR is studying the bed of the Venice Lagoon to locate and predict areas with high likelihood of marine plastic debris accumulation. With this data they can collect the debris and use it in an experimental new recycling reactor that takes plastic waste and uses it to create marine fuel. They are targeting marine plastic litter because the majority of marine litter is uniform in that it has similar or the same chemical make up. Litter is very prevalent in the Lagoon as it contains about 30% of the plastic waste that is in the world's oceans. Part of their research for finding the locations of marine buildup on the bed of the Lagoon is being conducted using hydrodynamic modeling of the plastic as it enters the Lagoon from different locations throughout the city and rivers. This model is still a work in progress in that it needs a lot of data to be able to tune it so that it can make predictions with higher percentages of accuracy (Ghezzo, 2019).

2.6.7 Francesca Coccon

Francesca Coccon is an independent researcher in Venice focused on monitoring the Yellow-Legged seagull species (also known as Larus Michahellis) and researching the correlation between the population of the seagulls with the presence of waste. The population of the Yellow-Legged seagulls has exponentially increased in Europe, especially around the Venice Lagoon. In the historical city of Venice, alone, the number of breeding pairs increased from 24 pairs in 2005 to 456 pairs in 2017 (Coccon, 2019). Francesca realized that a contributor to the increase in breeding pairs was due to the ease of access to food. Access to food was a result of a poor waste management system (Coccon, 2019). Before 2016, trash was placed out on the streets and Veritas workers would go by and pick it up. Even though there was a rigid block of time where trash could be put out, many Venetians and tourists did not follow this rule, instead putting their trash outside for a much longer period of time (Coccon, 2019). As a result, the Yellow-Legged seagulls had more time to find food in the trash. Furthermore, when seagulls opened the trash bags, the waste was able to be blown across the streets or into the water by the wind. The seagulls could also pick it up and drop it elsewhere. Francesca realized that the seagulls played in active role in the plastic pollution problem and determined that changing the waste management system would stem the problem (Coccon, 2019). The new waste management system has Veritas workers going door-to-door so no trash bags are left outside. This provided less access to food, which decreased the number of breeding pairs in historical Venice. It also decreased the opportunity for waste to blow or move around the city. At the end of her research, she determined that more improvements could still be made including better education on the new waste system (especially for tourists) to further reduce access to food and educating the fishermen not to feed the seagulls (Coccon, 2019).

2.6.8 UNESCO

UNESCO is a specialized agency of the United Nations that attempts to preserve cultural heritage in places all around the world by addressing scientific, environmental and community issues that threatens it ("Plastic Free Venice Initiative", 2017). UNESCO has a local office in Venice where it aims to preserve the historical city by tackling issues that it faces including the plastic pollution problem. The UNESCO Venice office created a "Plastic-Free Venice Initiative" in collaboration with the Consiglio Nazionale delle Ricerche-Istituto di Scienze Marine (National Research Council-Institute of Marine Sciences; CNR-ISMAR), Veritas, and other institutions, where they organized a clean-up day on June 9th, 2018 in response to World Oceans Day, which was on June 8th, 2018. The initiative was "purely civic and educational" to raise public awareness of the plastic pollution problem facing the city ("Plastic Free Venice Initiative", 2017). By the end of this one-

day cleanup, over 100 large sized bags filled with plastic waste were collected and properly recycled (UNESCO, 2018).

2.6.9 Plastic Pollution Reduction- Efforts by Local Businesses

Contributing to the reduction of plastic pollution in their city, some local businesses implement plastic-free policies to minimize the likelihood that the materials enter the environment. Casa Flora, Hotel Flora and Novecento Boutique Hotel are a group of companies in the tourism industry that have implemented these policies (Romanelli, 2019). In each of their guest rooms they have replaced plastic water bottles with glass jars in addition to selling steel water bottles for their guests to use as they travel throughout the city and can refill at the numerous water refill stations as shown on the 'Veritas Scoasse' app. Their reusable alternatives have saved over 3,000 plastic water bottles each month (Romanelli, 2019).

Another company in the tourism industry working to preserve the city and reduce plastic pollution is Real Venetian Kayak. This company is committed to offering 100% eco-friendly kayak tours of Venice through the canals (Real Venetian Kayak, n.d.). Real Venetian Kayak runs the program "Clean Venice for All" with the mission of raising awareness for plastic pollution along with its effects on the environment. To reduce plastic pollution, each tour instructor collects plastic, glass, and organic waste which they record and update the total amount the company has collected by weight. Real Venetian Kayak also supports UNESCO ocean cleaning days, as they both work towards a common goal of a cleaner city to preserve its history (Real Venetian Kayak, n.d.).

Chet Bar, a bar in Campo San Margherita, has implemented a more sustainable way of serving drinks. A customer can order a drink and pay an extra euro to receive a reusable cup. At the end of the night, if the customer does not want to keep the cup, they can return it in exchange for the one euro that they initially used to purchase the cup. Chet bar will then wash the reusable cups for the next night. Otherwise the customers can keep the cup and bring it for refills whenever they visit the bar. Through this initiative, less single-use plastic cups are disposed of by Chet Bar in a given night.

2.7 Best Practices

Best practices for reducing the problem of plastic pollution applicable to Venice are found at geographically similar coastal cities around the world. The best practices target both getting rid of existing plastic pollution in the environment and reducing the amount of plastic that enters the environment at the source.

2.7.1 Best Practices for Addressing Existing Plastic Pollution

To reduce the plastic pollution that is currently existing in the environment, the plastic must be collected and removed. Plastic can be collected naturally, as it washes up on beaches or may become entangled within land pockets or vegetation. Otherwise, it can be collected on artificial land features, such as man-made salt marshes, or using plastic collecting boats or barges.

The plastic can then be removed through community organized cleanups at accumulation locations or by proper maintenance of collection barges. Additional methods consist of a system of incentives to remove plastic pollution. For example, Rome has implemented a program called "+Ricli +Viaggi," meaning more recycling, more travel (Rodari, 2019). This allows travelers to exchange 30 plastic bottles for a standard ticket that is valid for one metro ride or 100 minutes on all buses allowing transfers, costing 1.50 euros. This can be done through the MyCicero app in which users scan their barcode on a special recycling machine, insert the empty plastic bottles inside a compactor, and digitally purchase rides. This program has been placed in 3 metro stations for a 12-month testing phase and has not released data or results.

Another incentive initiative involves fishermen collecting and discarding waste found in the water. Previously, fishermen were not legally authorized to transport waste, causing rubbish that is caught in nets to be returned into the water. The trash being collected by this initiative is being "analyzed and, where possible, recycled in an {...} experiment to try and provide a blueprint for cleaning up the sea," (Onians, 2019). After the collection, fishermen transport the waste back to the port and it is cataloged, sorted, and properly disposed of by volunteers. After a month, statistics were released, consisting of around one tonne of waste collected per week, in which 60% was plastic. Also, "up to a quarter of all the waste retrieved was recyclable," (Onians, 2019). This proves that the initiative was valuable as the plastic collected was able to be recycled after potential degradation from the saltwater. Fishermen reap the benefits of this initiative as plastic is becoming more commonly caught in their nets than fish and are difficult to untangle from the net, preventing their ability to catch fish.

2.7.2 Best Practices for Reducing Plastic Entering the Environment

To prevent plastic from entering the environment, either the amount of plastic used must be reduced or the methods of recycling must be improved. Reducing the amount of plastic that is used can be achieved by passing legislation to ban single-use plastic. A bag thinner than 50 micrometers of plastic film is defined as a lightweight plastic bag. This reform excluded thin plastic bags that

are primarily used in contact with food. After this tax was applied, the use of plastic bags at stores and supermarkets decreased by more than 90 percent.

Another option to reduce the use of plastic is by replacing it with multi-use or biodegradable materials. Some examples are reusable bags, paper or metal straws, reusable plastic or metal water bottles, and wooden cutlery. For insulating and protective materials like polystyrene that are used in product and food packaging, new alternatives like mushroom packaging, cornstarch packing peanuts, and bamboo fiber dishes are eco-friendly and biodegradable options (Allen, 2015). Also, Crai, an Italian supermarket, has "created the 'Eco-Point' initiative in 2005, offering bulk products with minimal packaging for dry food," (Bio Intelligence Service, 2009). This reduced the amount of packaging, preventing the use of an estimated 1 million packages per year between 30 Eco-Points in Italy and Switzerland.

Bringing in an evaluator to assess plastic use within a business and developing specific recommendations would be a major step in reducing the use of plastic. The evaluator would perform an audit-like inspection of the business to determine its compliance with a set of standards for a plastic-free certified business (West, Schneider, McCrea & Grunbeck, 2019). Once the status of the business is determined, a specific plan can be created and implemented to elevate them to a certified plastic-free business.

To improve plastic recycling rates, local separated waste and recycling bins can be implemented. Placing recycling bins directly next to general waste bins forces people to think about what kinds of products they are disposing. Tuscaloosa, Alabama implemented the side-by-side public waste and recycling bins and collected 23 tons of recycling each year since implementation in 2015 and saved thousands of dollars in disposal costs (Karidis, 2018).

Incentives can also be used to reduce the use of plastic. For example, Starbucks is the biggest coffee company in the world, distributing an estimated 600 billion paper and plastic cups globally each year (Starbucks, n.d.). The company has promoted the use of reusable cups and has "conducted a trial of a 5-pence disposable cup fee and a 25-pence reusable cup incentive, which increased reusable cup usage for hot drinks sold in stores nationwide from 2.2 to 5.8 percent" in the United Kingdom (Starbucks, 2019).

Some cities in Japan including Tokyo, Kyoto, and Osaka have removed public trash receptacles and noticed a decrease in the amount of litter in the streets. This is due to their culture, which prompted them to carry an empty plastic bag to bring the waste back home to dispose of properly

(Get Around Japan, 2019). If food or drinks are purchased, it is typically consumed where it was bought. Also, Japan does not have a 'take away" culture in terms of leftovers, leaving them with less of a reason to carry trash with them. Despite the observed improvements, the cities began reinstalling the trash bins to account for the increase in tourism in the cities and the cultural differences they bring.

2.7.3 Citizen Science

"Citizen science is the practice of public participation and collaboration in scientific research to increase scientific knowledge. Through citizen science, people share and contribute to data monitoring and collection programs. Usually this participation is done as an unpaid volunteer," (National Geographic Society, 2012). Citizen science is experiencing major growth around the world as it is effective in engaging the community, as well as increasing the scope of the project that researchers can pursue. A recent citizen science campaign in Venice was organized by one of our sponsors, Wigwam, where they gained engagement from schools throughout the Venice Lagoon. The goal of the project was to measure the tide latency simultaneously throughout the Venice Lagoon. Due to the school engagement, an increased amount of data was collected for the study. Additionally, the study spread education and awareness about the effects of climate change on the tidal aqua altas in the city of Venice. This type of research and engagement could be transferred to the problem of plastic pollution in Venice.

2.8 Summary

Aside from small-scale initiatives over the past two years, there has been a lack of consistent efforts to combat the plastic pollution problem in Venice. Because of the unique characteristics of the Venice Lagoon in combination with the fact that plastic waste lacks biodegradability, plastic will continue to build up. There is a shortcoming on data and models to map the characteristics of plastic waste, which would allow the Venetian community to attack the plastic pollution problem at the forefront. While supporting current initiatives, implementing data studies, and performing statistical analyses, we will provide a foundation and strategic plan so the Venice community can progress in reducing the plastic pollution problem.

3.0 Methodology

The goal of this project is to contribute to the development of a strategic plan to reduce the build-up of plastic pollution in Venice. Our objectives to complete this mission are:

1. To understand the accumulation of plastic pollution in the Venice Lagoon.
2. To assess the effectiveness of public trash receptacles and waste pick up locations.
3. To develop recommendations for the overall plan to reduce plastic pollution in Venice.

While completing this project we operated within the Venice Lagoon. We looked at the individual canals that spread across the city as well as the beaches and inlets on the outside of the city that were recognized to have higher concentrations of plastic build-up, through previously collected data from Venice Calls, Wigwam, and other NGOs. We recognized that a large amount of plastic is possibly entering the Venice Lagoon through the rivers that feed into the Lagoon and the three entryways from the Adriatic Sea. We were not concerned with how this plastic gets into the Venice Lagoon, but it is a part of our study into the location and concentration of plastic accumulation in the Venice Lagoon. We recognized the fact that some plastic accumulation points were only visible during low tide. As a result, we had to be mindful of the tidal schedules and complete data collections at those points before the high tide returns.

In the historical city of Venice, we explored trash receptacle locations that account for commercial, high tourist, and high foot traffic locations. Commercial areas are defined as areas where there is a mix of tourists and locals, such as areas with restaurants and shops. High tourist areas are defined as areas predominantly filled with tourists such as the Santa Lucia Train Station. Finally, high foot traffic areas are defined as major transit streets throughout the city. We scheduled observation times multiple times throughout the day to analyze the times that trash receptacles needed to be emptied by Veritas.

To assess the effectiveness of the waste pick-up locations, we took into consideration commercial, residential, and high tourist populated areas. Furthermore, we understand that within residential areas there is the potential of Airbnb apartments to exist, therefore altering the demographic of the given area. While we understand this could exist, it is not feasible for us to accurately determine the distribution of tourists versus permanent residents. As a result, our main focus with this objective was to observe Veritas' current system for collecting the city's waste to see if the public complies with the waste collection laws. We then used our observations to determine whether the

regimented system is suitable for the public, as well as recommend changes that could be made to make it more effective.

The following sections provide the methods that we have established to complete the objectives listed above.

3.1 Understanding the Accumulation of Plastic Pollution in the Lagoon

To understand the scope of plastic pollution accumulation in the Venice Lagoon, the location and amount of plastic at the build-up sites were determined. Furthermore, a classification of the plastic that accumulated at each site was determined to gain a deeper understanding of the types of plastic that accumulates. To gain an understanding of accumulation rates, we completed data collections at a given build-up site two times, with at least a week time period between the collections. We recorded this information in a database (shown in Table 1 and Table 2) and used the data to create graphs based on quantity and weight.

3.1.1 Selecting Accumulation Sites

To determine the locations of plastic accumulation we began by looking into predicted and observed build-up sites, through research and meetings with NGOs in Venice. Selected locations were on the perimeter of the city where land is exposed during low tide and cleanups by organizations have previously been performed. From there, due to time and accessibility, we chose to collect data at the following three sites: S. Alvise, North Tronchetto, and Giardini (Partigiana). The geographical locations of the sites are shown in the map in Figure 6. Additionally, individual pictures of S. Alvise, North Tronchetto, and Giardini, are shown in Figures 7-9, respectively.

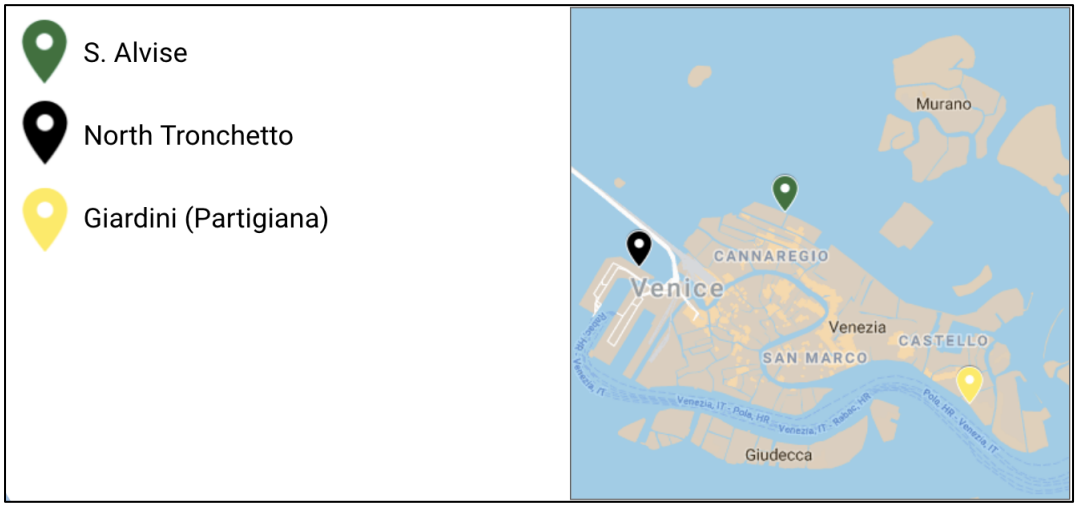

Figure 6: Plastic Pollution Accumulation Locations Map

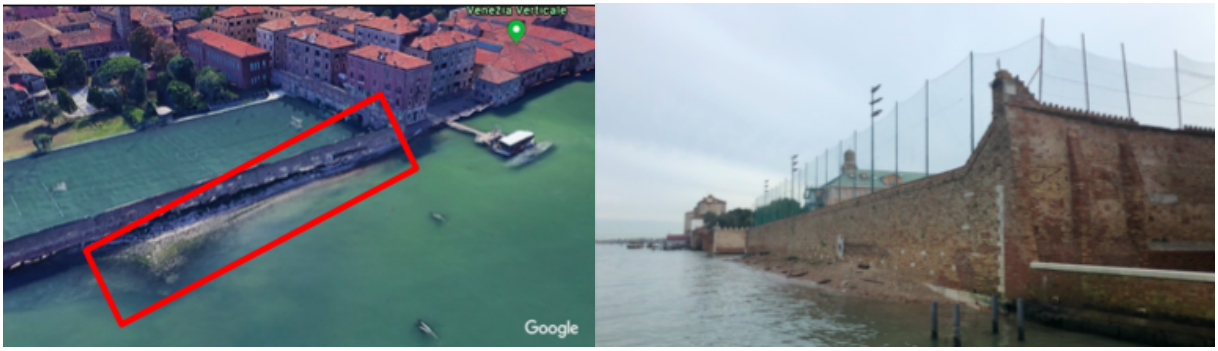

Figure 7: Images of the S. Alvise Site

Figure 8: Images of the North Tronchetto Site

Figure 9: Images of the Giardini (Partigiana) Site

3.1.2 Recording Location and Collection Information at Sites

For each of the three collection sites, we began by recording logistical information in the portion of the database shown in Table 1. The information was split into two sections: location information and collection information. For location information, we determined the latitude, longitude, address, and area of site using google maps. The location notes were determined from our observation of the nearest landmark to the collection site. This information was only recorded once for each of the three sites. We recorded the collection information twice per site for the two data

collections performed. The collection number was filled in with a “1” or “2” referring to the first or second collection at a given location. The date, day of the week, and starting time was recorded when we arrived to the site for data collection. The end time was recorded once we finished bagging all of the waste items.

Table 1: Site Location and Collection Information

Location Information			
Latitude, Longitude	Nearest Address	Location Notes	Area of Sample Collection Site

Collection Information			
Collection #	Date	Day of Week	Time

3.1.3 Recording Plastic Accumulation Information at Sites

To collect and record data on plastic accumulation at a given site, we acquired trash bags, gloves, and a hanging digital scale. Using the gloves and trash bags we collected the waste on site. We made sure to dig through the layers of dirt, sand, rocks, and seashells, as the moving tide tends to bury some of the waste. After the waste was collected in trash bags, we brought the bags back to H3, or the complex building in Giudecca owned by SerenDPT for Venetian startups and IQP students to complete projects. There we began filling in the portion of the database shown in Table 2. We counted the number of filled bags and weighed them using the hanging digital scale. The sum of the weights for all of the bags was recorded in total accumulation. We made sure to tare out the weight of the trash bags in that total.

Next we began sorting the collected waste into piles based on type. The general categories, as shown in Table 2, are plastic, glass, metal, rubber, and other (which includes any other items including wood, wire, and fabric). The piles were further split into types, also shown in Table 2, under the column titled “Types”. Once all of the bags were emptied and all items were split into piles, the “Types” column was filled in with names for each of the piles.

To avoid uncertainty and confusion, we must define some of the plastic types. Polystyrene pieces were collected with sizes as small as the tip of a finger and larger. Hard plastic was defined as an opaque and stiff piece of plastic with examples consisting of items such as pens, coffee stirrers, and plastic containers. Hard plastic was separated into two types: small, compromising of pieces similar in size to the tip of a finger, and large, roughly the size of a hand. Lastly, thin sheets of plastic were collected, similar to grocery and trash bags. Small thin sheets were up to the size of

the palm of a hand, medium was up to the size of the forearm, and large was anything larger than the forearm.

Table 2: Site Accumulation Information

Total Accumulation		
Number of Bags	Total Sample Mass (kg)	# Collection Items

Categorized Accumulation				
Overall Category	Item Name	Quantity (#)	Mass (kg)	Mass (w/ bag tared) (kg)
Plastic	Lighters			
	Caps/Covers			
	Polystyrene			
	Large Hard Plastic			
	Small Thin Sheets			
	Medium Thin Sheets			
	Large Thin Sheets			
	Small Hard Plastic			
	Bottles			
	Plastic Crate			
	Wrappers			
	Ribbon			
	Packing Straps			
Glass	Glass			
Metal	Cans			
	Rods			
Rubber	Rubber			
Other	Wire			
	Corks			
	Fabric Pieces			
	Bags of Detergent			
	Rope			
	String			
	Cardboard/Paper			

Next the “Collection Items” could be filled in by summing the number of types. For each type pile, we went through the process of counting the pieces to determine the quantity. We then placed the pieces in a trash bag and used the hanging digital scale to weigh the mass. Once again, we tared out the weight of the bag. This process was repeated until all piles/types have been accounted for and recorded. From there we sorted and properly disposed of the collected waste, as well as summed the masses of all of the types.

3.1.4 Visualizing the Location and Quantity of Accumulation

Once we determined and recorded the location, count, and mass of the waste types, we then constructed graphs to visualize our data. We made graphs of count and mass of waste for both collections at the three different collection sites. We then used the mass collected from the second collection and the time elapsed between the two collections for a given site to determine an estimated accumulation rate for the site. Finally, we compared the data gathered among the three sites to determine overall trends and average accumulation rates.

3.2 Assessing the Effectiveness of Public Trash Receptacles and Waste Pick-Up Locations

To achieve this objective, our team used an observation method to qualitatively classify the effectiveness of trash receptacles and waste pick-up locations that are available throughout the city. For the trash receptacles, we looked at four receptacles at several points in time throughout the day. Classifications of the trash receptacles were made by observing the volume of trash that they contained at each location and time. For the waste pick-up locations, we looked at five locations that are all situated along the canals. The data collected at the nine different locations was then plotted in two different databases, one for the trash receptacles and one for the waste pick-up locations. In addition to our periodic observations of trash receptacle fullness level, we observed one trash can approximately every half hour of the course of an entire day.

3.2.1 Determining Locations and Time of Observations for Trash Receptacles

The four locations, as can be seen in Figure 10 below, were chosen based on the varying demographics of each area.

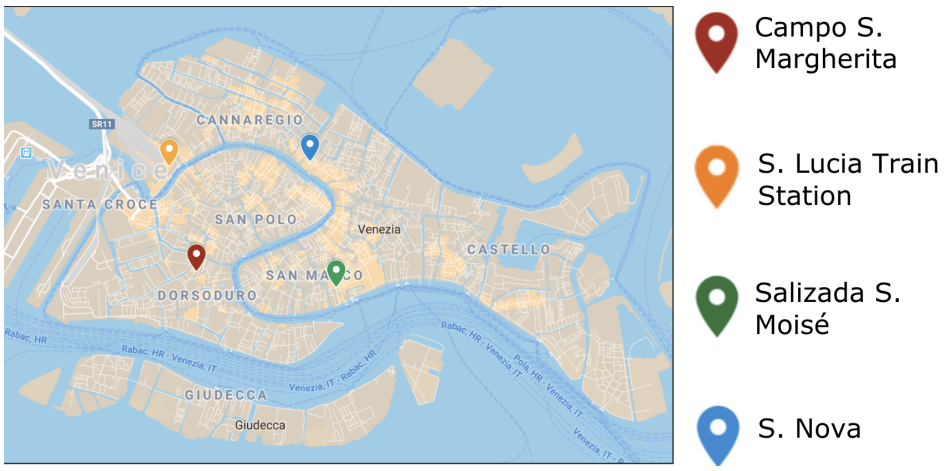

Figure 10: Locations of Selected Trash Receptacle Observations

Campo San Margherita is a commercial area that is surrounded by restaurants and bars. The path and a few examples of the observed trash receptacles are shown below in Figure 11.

Figure 11: Highlighted Path and Examples of Trash Receptacles in Campo San Margherita

Santa Lucia Train Station is a high tourist location as a large portion of tourists enter and leave Venice by train. The path and a few examples of the observed trash receptacles are shown below in Figure 12.

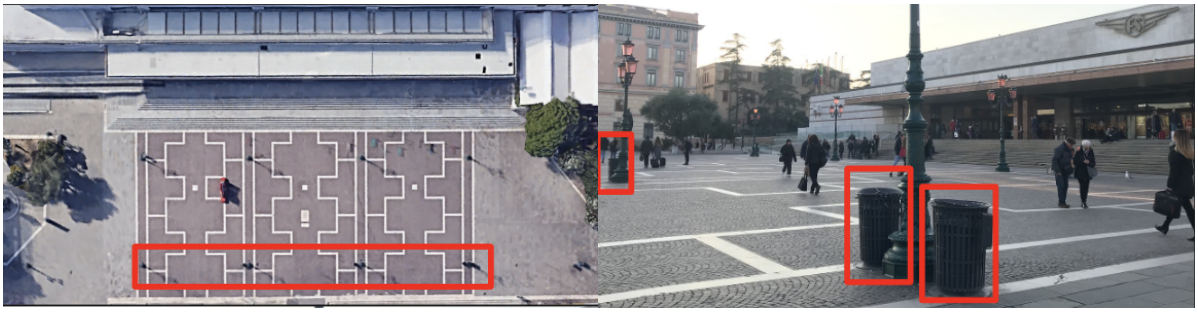

Figure 12: Highlighted Path and Examples of Trash Receptacles at Santa Lucia Train Station

Salizada San Moisé is a commercial area that is filled with high end shopping and hotels. The path and a few examples of the observed trash receptacles are shown below in Figure 13.

Figure 13: Highlighted Path and Examples of Trash Receptacles on Salizada San Moisé

Finally, Strada Nova is a high foot traffic area as it is one of the main streets in the city, with shops ranging from food to clothing. The path and a few examples of the observed trash receptacles are shown below in Figure 14.

Figure 14: Highlighted Path and Examples of Trash Receptacles on Strada Nova

We observed the trash receptacles in these four locations at four time frames: early morning, mid-morning, mid-afternoon, and late night. The early morning was defined as 05:30 to 07:30, while mid-morning was between 07:31 and 12:00. Mid-afternoon was between 12:01 and 20:00 and lastly, late night was between 20:01 and 05:29.

3.2.2 Determining Locations and Time of Observations of Pick-Up Locations

Five locations, as can be seen in Figure 15 below, were chosen based on the varying make-up of each area. Make-up in this context depends on the types of businesses and attractions located in the area.

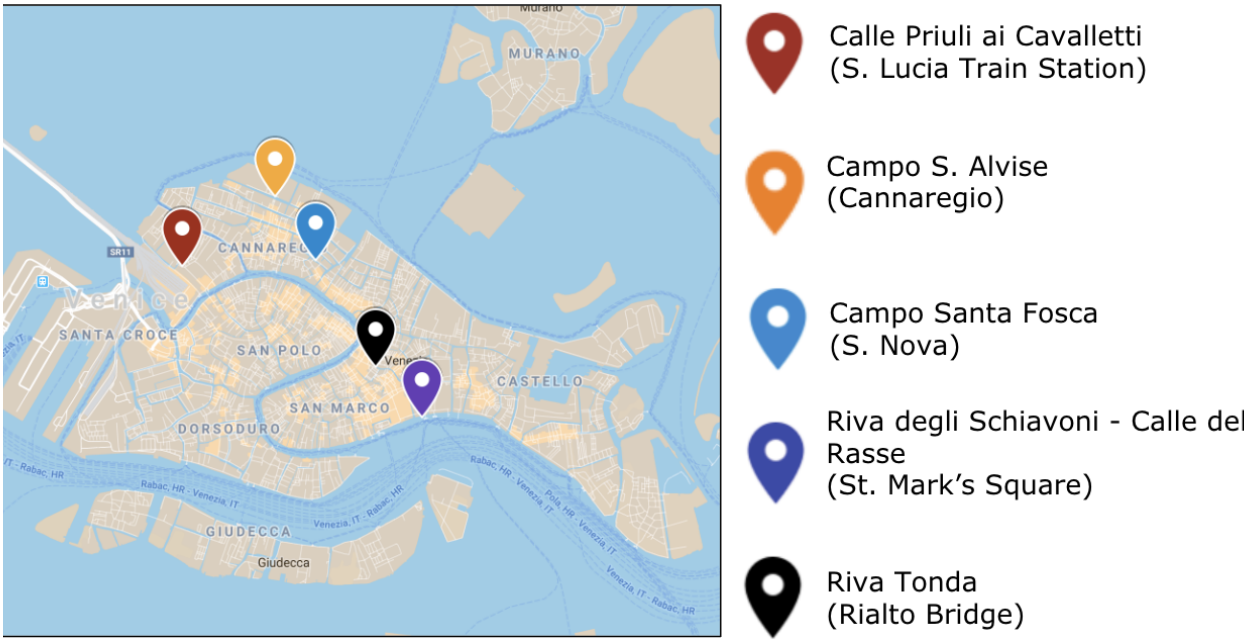

Figure 15: Locations of Selected Trash Pickup Locations

Three of the pick-up locations we visited were close to high tourist traffic areas with shops. These locations included the Rialto Bridge shown in Figure 16, Strada Nova shown in Figure 17, and Saint Mark's Square shown in Figure 18.

Figure 16: Location of Waste Pick-Up Location Closest to Rialto Bridge

Figure 17: Location of Waste Pick-Up Location on Strada Nova

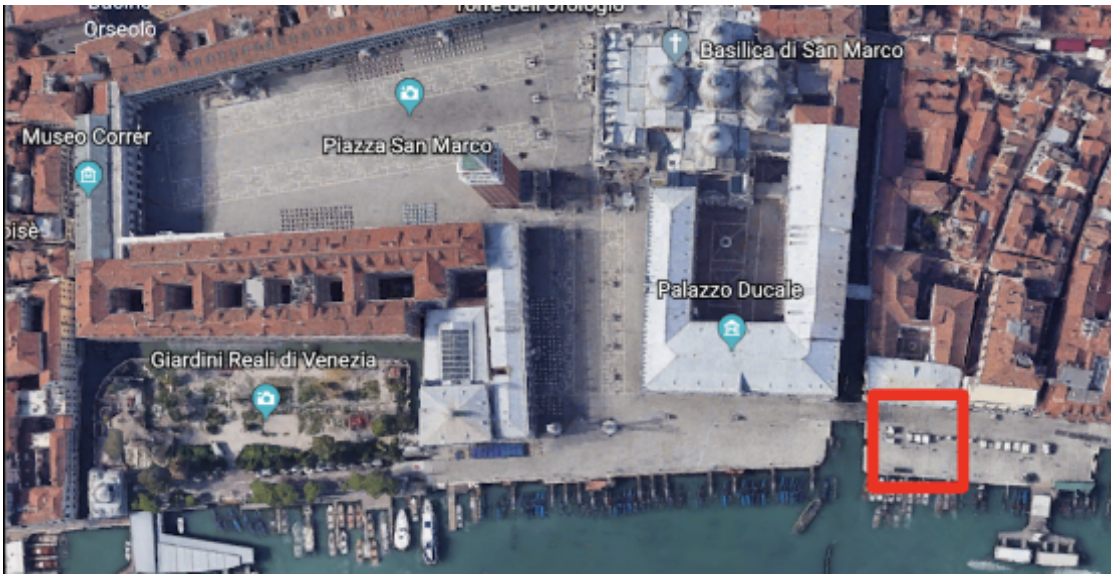

Figure 18: Location of Waste Pick-Up Location Closest to Saint Mark's Square

A high tourist and foot traffic area, due to public transportation availability, was at the Santa Lucia Train Station shown in Figure 19. Finally, a predominantly residential area was on the northernmost section of Cannaregio shown in Figure 20.

Figure 19: Location of Waste Pick-Up Location closest to Santa Lucia Train Station

Figure 20: Location of Waste Pick-Up Location in Northern Cannaregio

The waste pick-up location is active from 06:30 to 08:30 specifically for people to dispose of waste if they are unavailable for door-to-door collection from 08:30 to 10:30. We visited these locations on varying days of the week just before 06:30.

3.2.3 Observing Trash Receptacle Effectiveness

The qualitative scale we developed for measuring trash can effectiveness ranges from less than ½ full, ½ full, ¾ full, full, and overflowing, as can be seen below in Figure 21. A trash receptacle that is less than half full has any amount of trash filled up to just before the halfway point. A ½ full trash receptacle is defined as any receptacle that is filled approximately to the halfway point.

A ¾ full trash receptacle is defined as any receptacle that is over the halfway point, but not filled to the top. A full trash receptacle is defined as a receptacle that is full to the brim. An overflowing receptacle has trash piled ontop or spilling onto the ground nearby. A qualitative analysis through our observations was also taken for these quantitative ranges to thoroughly define the state of the trash receptacle.

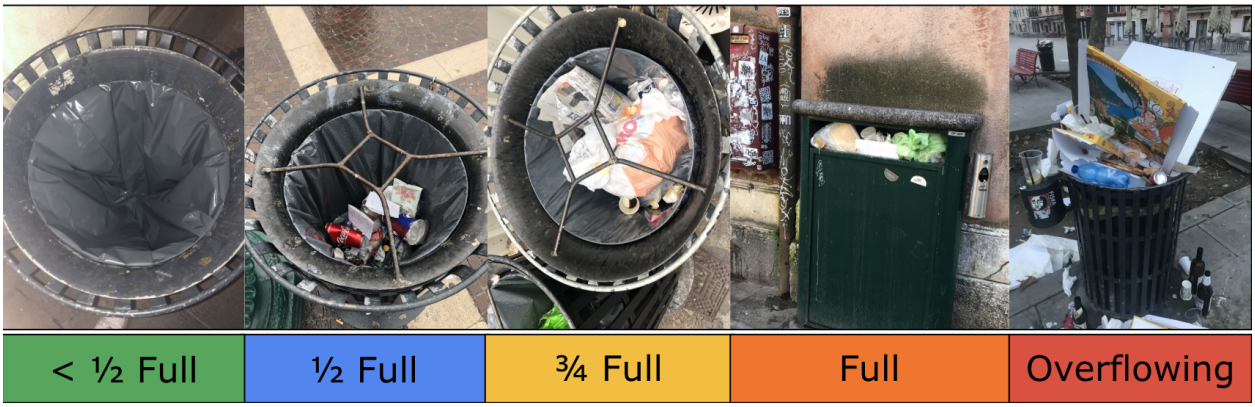

Figure 21: Qualitative Scale of Fullness of Trash Receptacles

3.2.4 Observing Waste Pick-Up Location Effectiveness

Since Veritas begins allowing drop off of trash at their collection points starting at 06:30 every morning except Sunday, we decided to observe the five collection points stated above before 06:30. During the observations, we looked at whether there was trash present prior to the collection time, and, if so, we looked at how much trash was left at the location. Also, we took note of any additional observations about the situation, including the state of the trash bags, wildlife, or recent weather in the area. This information was then recorded along with the date, day of the week, time, and location.

3.3 Developing Recommendations for the Overall Plan to Reduce Plastic Pollution

In objective three, we gathered the data from the first two objectives. The data included quantitative and qualitative information in regard to plastic pollution concentration in the water, and on land. The data was layered on a single map with links to all data and pictures we gathered, which then allowed us to make correlations and find conclusions. We then used this map alongside all of the data and observations we made to provide the best recommendations in rectifying the plastic pollution problem in Venice. Finally, using the recommendations we came up with we

created a pamphlet which outlines the problems Venice is facing in regard to plastic pollution and displays our recommendations in a way that is quick, easy, and simple to understand.

3.3.1 Synthesizing and Compiling Data

The data we gathered was displayed on an electronic map to complete a model that is representative of all the data that we have gathered during our project. Layering the data on an electronic map was important because all of our data has spatial significance, as different sets of data were connected to different parts of Venice. To visualize the data, we used google's 'mymap' application, because it allowed us to easily make different layers for the different types of data we collected. For the first layer, we marked the points of interest for objective one, which included the possible places where plastic is accumulating and where we might want to complete cleanups. The second layer has the three locations that we actually completed cleanups for in objective one. Each of these three places was then linked with the data and pictures from the two cleanups for each site. The third layer consists of the four trash receptacles we completed observations at, and again is linked with our data and pictures for each location. The fourth layer we created contains all of the Veritas waste pick-up locations throughout the city, highlighting the five that we studied in objective two. Finally, for the fifth layer, we only have the five pick-up locations we collected data at with the pictures and data linked. To see the layered map with the linked data and photos, follow the link in Appendix H.

3.3.2 Offering Recommendations and Creating a Pamphlet

Finally, after mapping the data points and analyzing the results we created recommendations for reducing plastic pollution and proposals for continued research and monitoring of the plastic pollution problem in Venice. These recommendations and a brief outline of the plastic pollution problem was then compiled and displayed on a pamphlet to be handed out and used to spread awareness and education. Refer to Appendix I to view the created pamphlet with our recommendations.

4.0 Results

4.1 Understanding Accumulation Data

The following sections discuss the results of the 6 data collections performed among the S. Alvise, North Tronchetto, and Giardini (Partigiana) sites. First, we made graphs for each individual collection based on the count and weight of the types of waste collected. Next we compared the data from the two collections for a given site to determine the accumulation rates for each site. Finally, we graphed and compared data among the three sites to distinguish similarities and differences, as well as determine the plastic type with the highest weight and count overall. As a result, we were able to get a better understanding of the scope of the plastic pollution problem to determine the best recommendations for future improvement.

4.1.1 Accumulation Data for S. Alvise

At the S. Alvise boat stop we conducted cleanups on 11/20/19 and 12/03/19. The area over which we collected accumulation at this location was 310 m^2, the location of which is shown below in Figure 22. The total accumulation collected at the first cleanup was 17.5 kg from 713 pieces of waste. From the total mass collected, plastic accounted for about 41% as shown on the left in Figure 23. From the total pieces collected, plastic accounted for about 82% of the accumulation shown on the right in Figure 23. The concentration of plastic pollution was 0.02 kg/m^2 or 2 $pieces/m^2$.

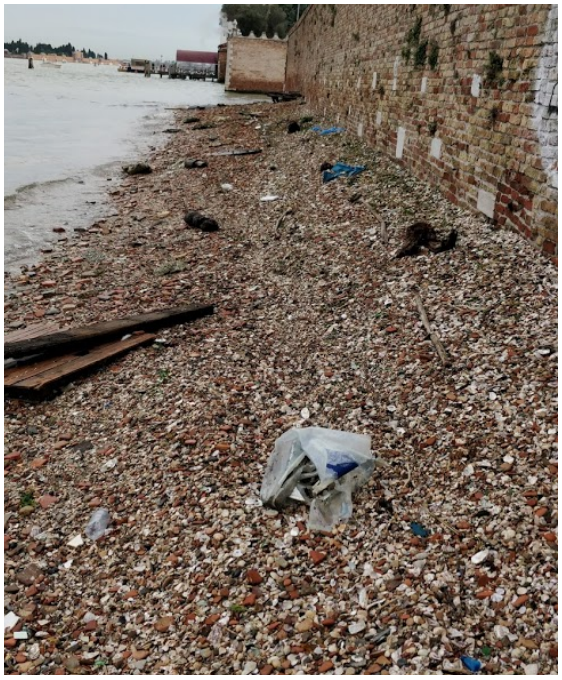

Figure 22: S. Alvise Before Collection

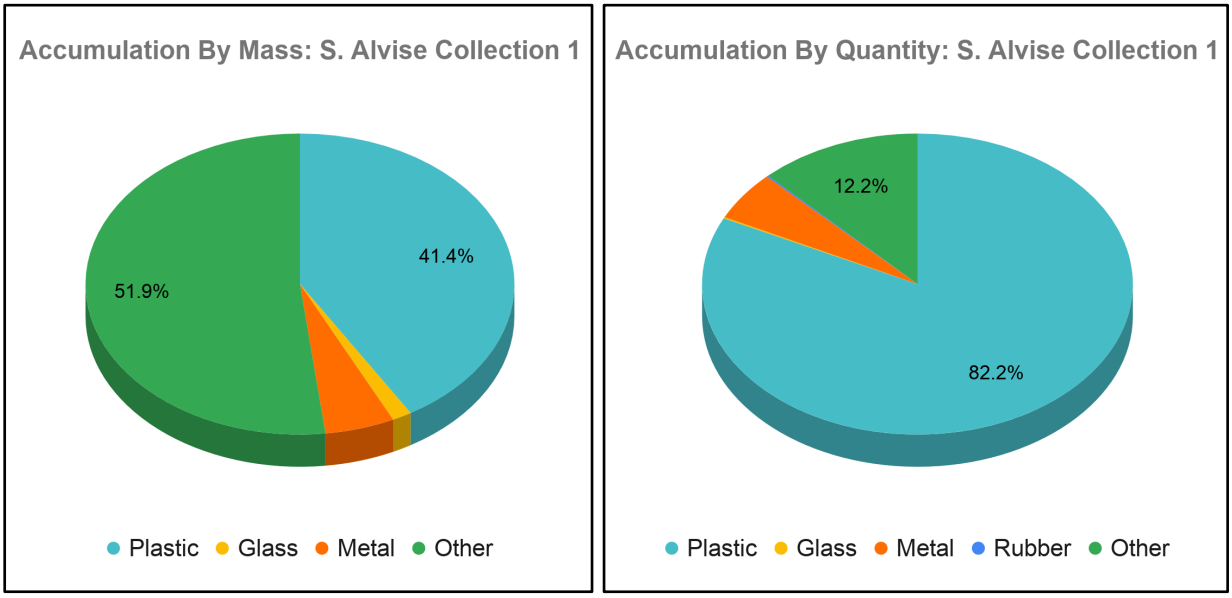

Figure 23: S. Alvise Collection 1 Data by Mass (left) and by Count (right)

The total accumulation from the second cleanup was 13.6 kg from 425 pieces of waste. From the total mass collected, plastic accounted for 66% of the accumulation as shown on the left in Figure 24. From the total pieces collected, plastic accounted for about 86% of the accumulation as shown on the right in Figure 24. The concentration of plastic pollution was 0.03 kg/m^2 or 1 piece/m^2. With 13 days elapsed between the first and second cleanups, the approximated rate of accumulation was 28 pieces of plastic per day or 0.65 kg of plastic per day.

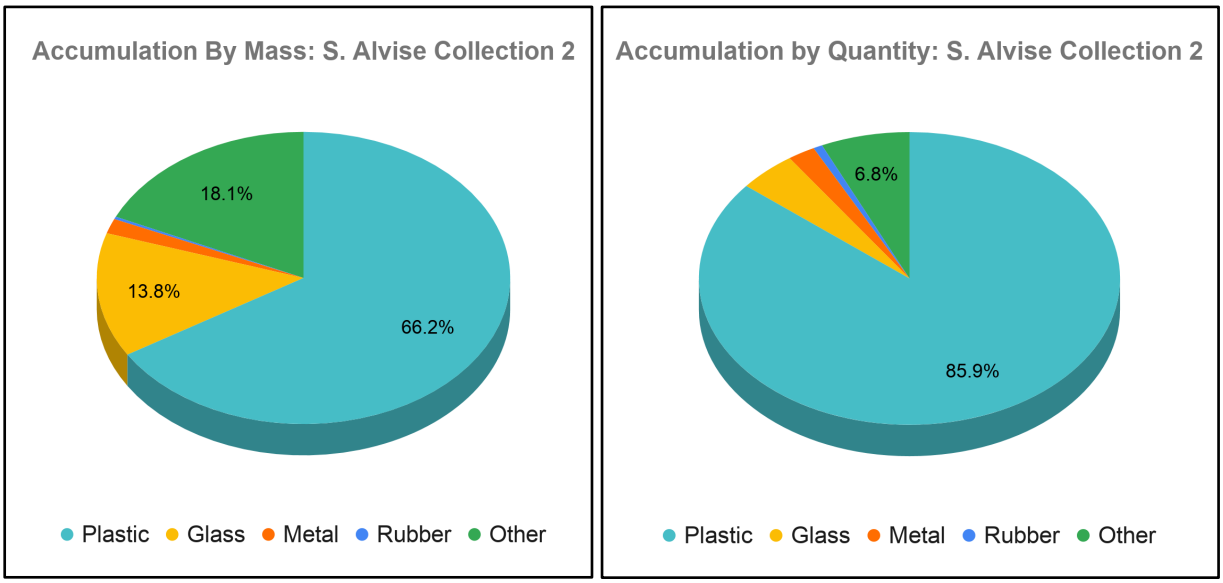

Figure 24: S. Alvise Collection 2 Data by Mass (left) and by Count (right)

Separating the plastic into types, the majority of the first collection's mass consisted of small, medium and large thin sheets, and bottles as shown by the blue in Figure 25. The majority of the first collection's plastic pieces collected were small thin sheets, small hard plastic, and polystyrene as shown in blue in Figure 26. In the second cleanup the majority of the plastic mass collected consisted of large thin sheets, bottles, plastic crates, and large hard plastic denoted by red in Figure 25. The majority of the total plastic pieces collected in the second collection were polystyrene and small hard plastic as shown in red in Figure 26.

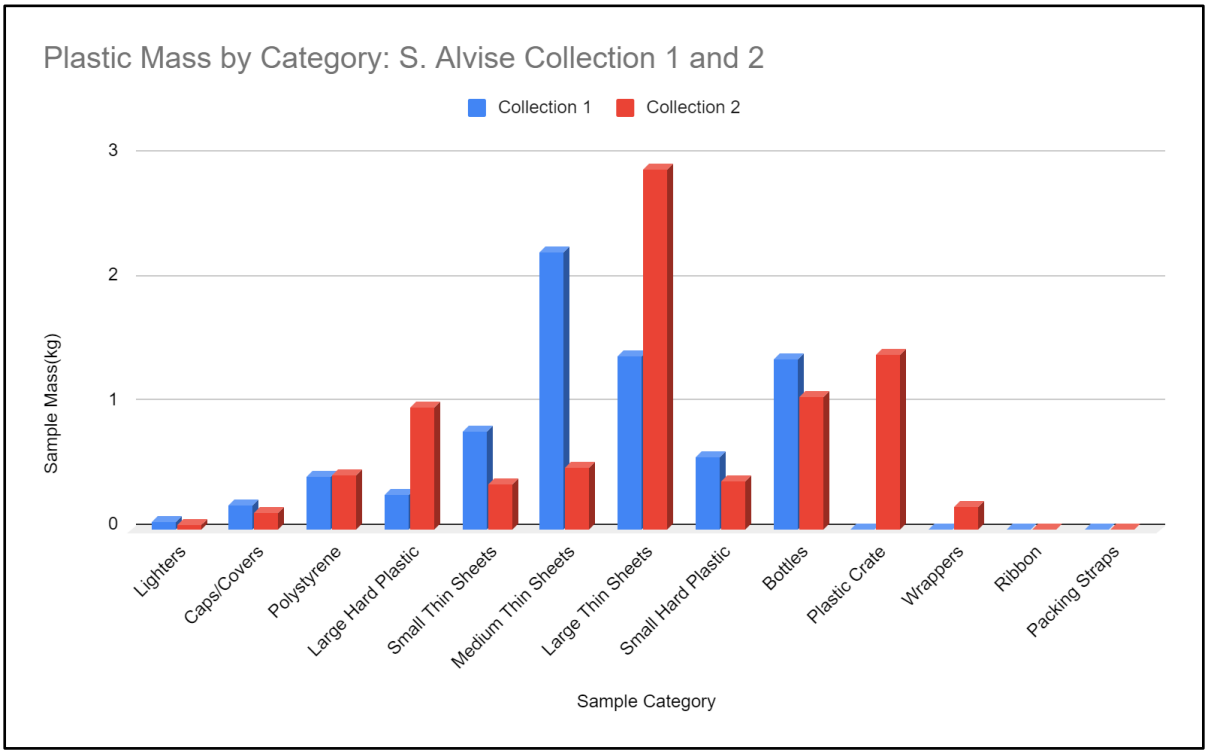

Figure 25: S. Alvise Collection 1 and Collection 2 Comparison by Mass

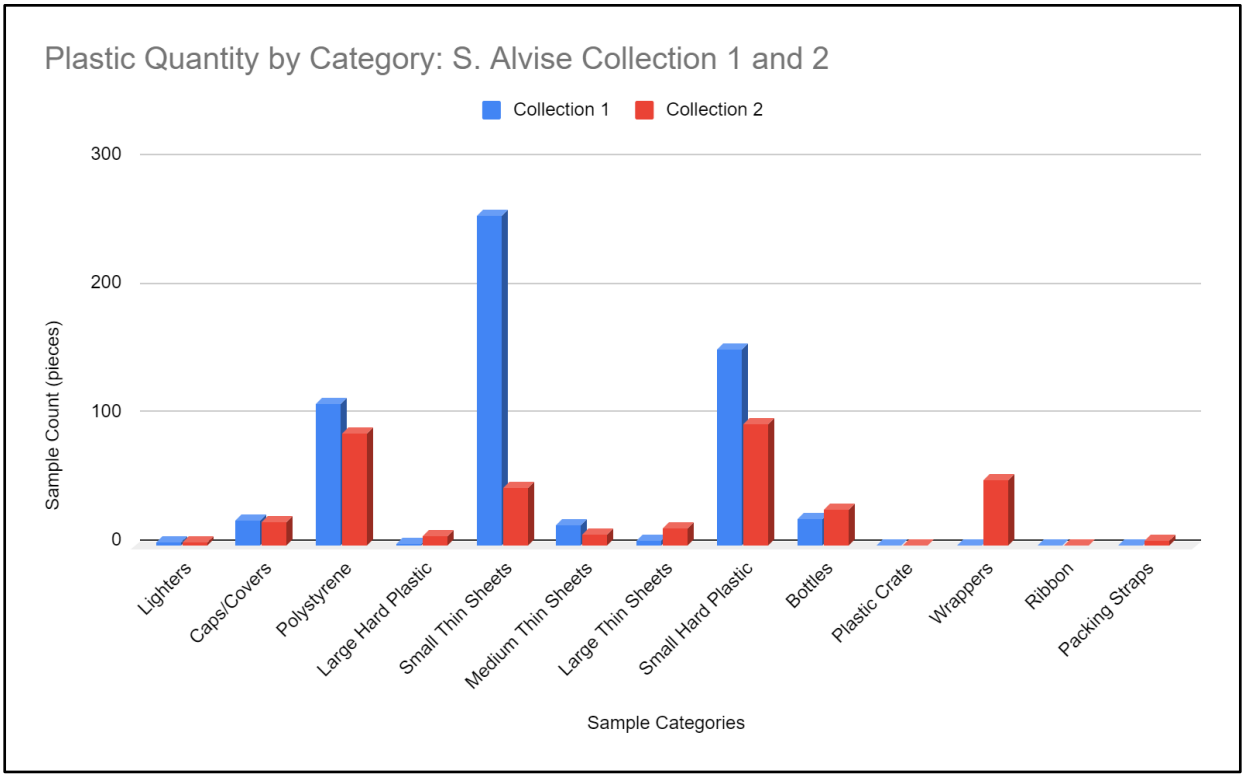

Figure 26: S. Alvise Collection 1 and Collection 2 Comparison by Count

4.1.2 Accumulation Data for Tronchetto

Collections at Northern Tronchetto were conducted on 11/21/19 and 12/03/19. The area over which accumulation was collected at this cleanup site was 160 m^2 the location of which is shown below in Figure 27. At the initial cleanup we collected 40.3 kg from 2,054 pieces of pollution accumulation. From the total mass collected plastic accounted for 79% as shown on the left in Figure 28. From the total pieces collected plastic accounted for 96% as shown on the right in Figure 28. The concentration of plastic pollution was 0.15 kg/m^2 or 11 $pieces/m^2$.

Figure 27: Tronchetto Before Collection

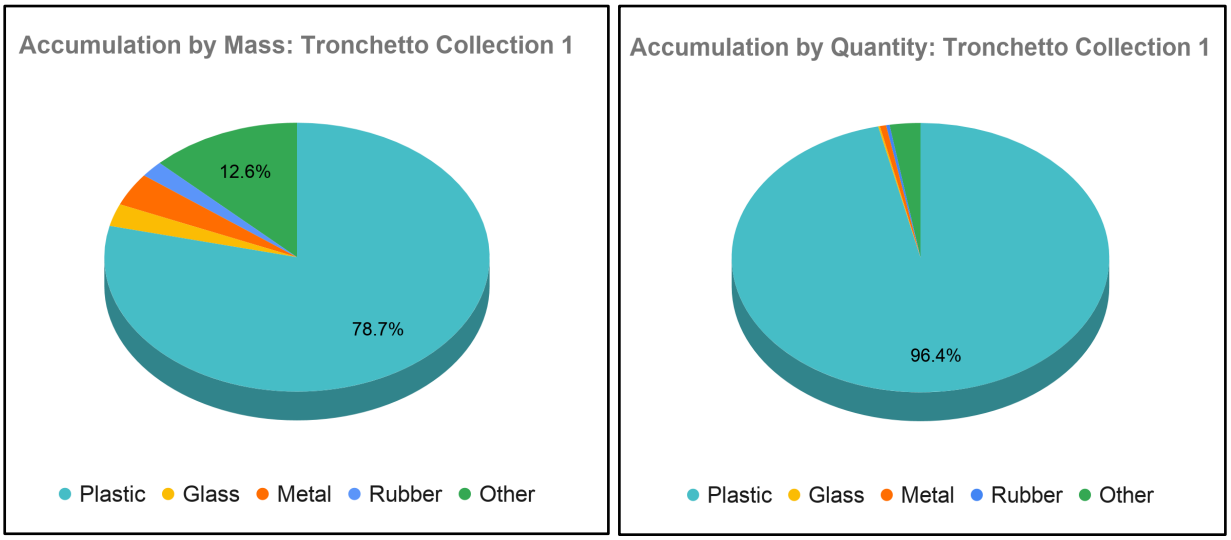

Figure 28: North Tronchetto Collection 1 Data by Mass (left) and by Count (right)

The total accumulation at the second cleanup was 25 kg from 820 pieces of plastic. From the total mass collected plastic accounted for 62% as shown on the left in Figure 29. From the total pieces collected plastic accounted for 91% as shown on the right in Figure 29. The concentration of plastic pollution was 0.08 kg/m^2 or 4 pieces/m^2. With 12 days elapsed between collections 1 and 2 the approximate rate of accumulation was 1.2 kg per day or 62 pieces per day.

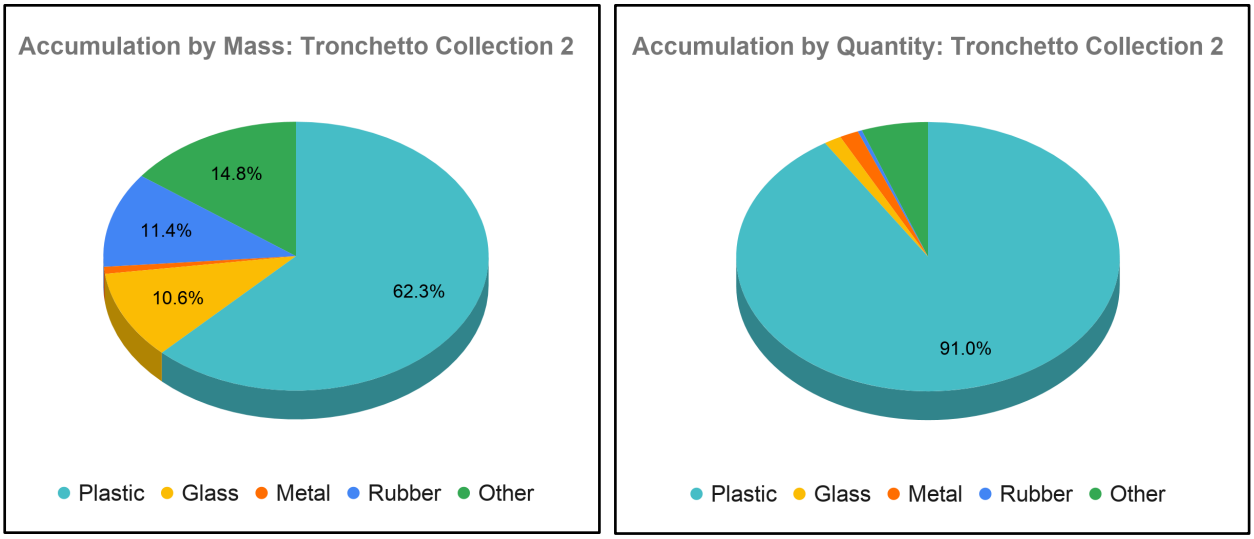

Figure 29: North Tronchetto Collection 2 Data by Mass (left) and by Count (right)

Separating the collected plastic into types the majority of the first collection's mass consisted of polystyrene, bottles, medium thin sheets, and large thin sheets as shown in blue in Figure 30. The most prevalent types of plastic from the total plastic pieces collected in the first collection were polystyrene and small thin sheets shown in blue in Figure 31. From the second cleanup, the majority of the plastic mass collected was polystyrene and large plastic sheets as denoted by red in Figure 30. Of the total plastic pieces collected in the second collection polystyrene and small thin sheets were most prevalent, shown on Figure 31 in red. Both polystyrene and thin plastic sheets are commonly used for packaging. The abundance of these packaging materials at this cleanup location may be connected to the product loading docks directly next to this accumulation point.

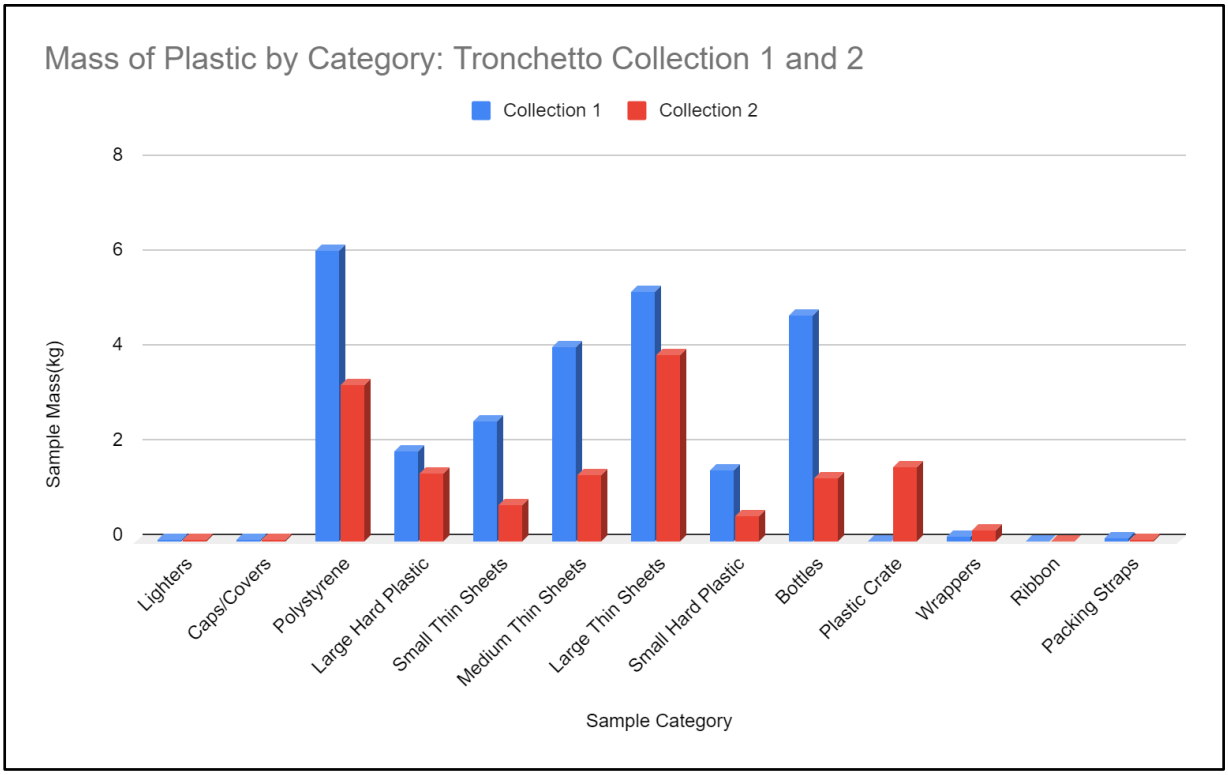

Figure 30: North Tronchetto Collection 1 and Collection 2 Comparison by Mass

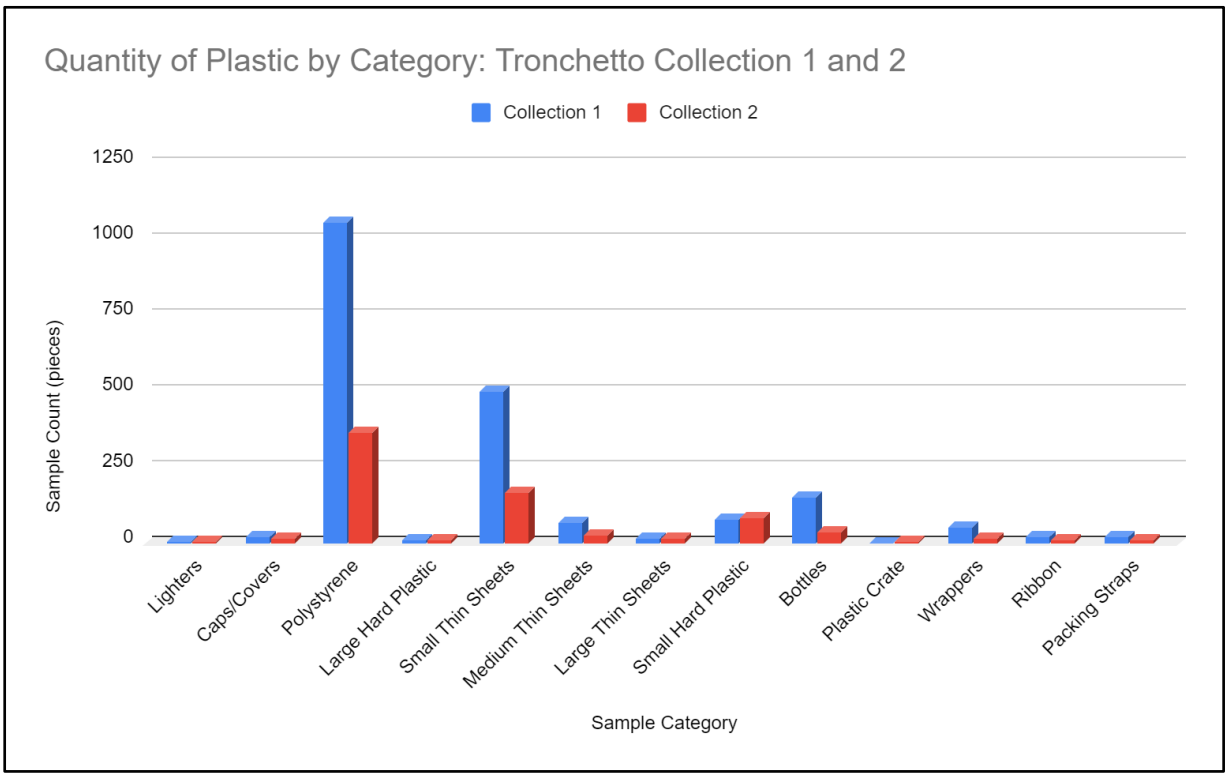

Figure 31: North Tronchetto Collection 1 and Collection 2 Comparison by Count

4.1.3 Accumulation Data for Giardini (Partigiana)

We collected pollution accumulation at the Monumento de Partigiana on Giardini on 11/25/19 and 12/04/19. The area over which pollution was collected at this location was 60 m^2. The location of collection before the initial cleanup is shown below in Figure 32. The total accumulation collected at the initial cleanup was 10.5 kg from 805 pieces of pollution. From the total mass plastic accounted for about 73% as shown on the left in Figure 33. From the total pieces plastic collected accounted for 95% as shown in the right of Figure 33. The concentration of plastic accumulation was 0.12 kg/m^2 or 13 $pieces/m^2$.

Figure 32: Giardini Before Collection

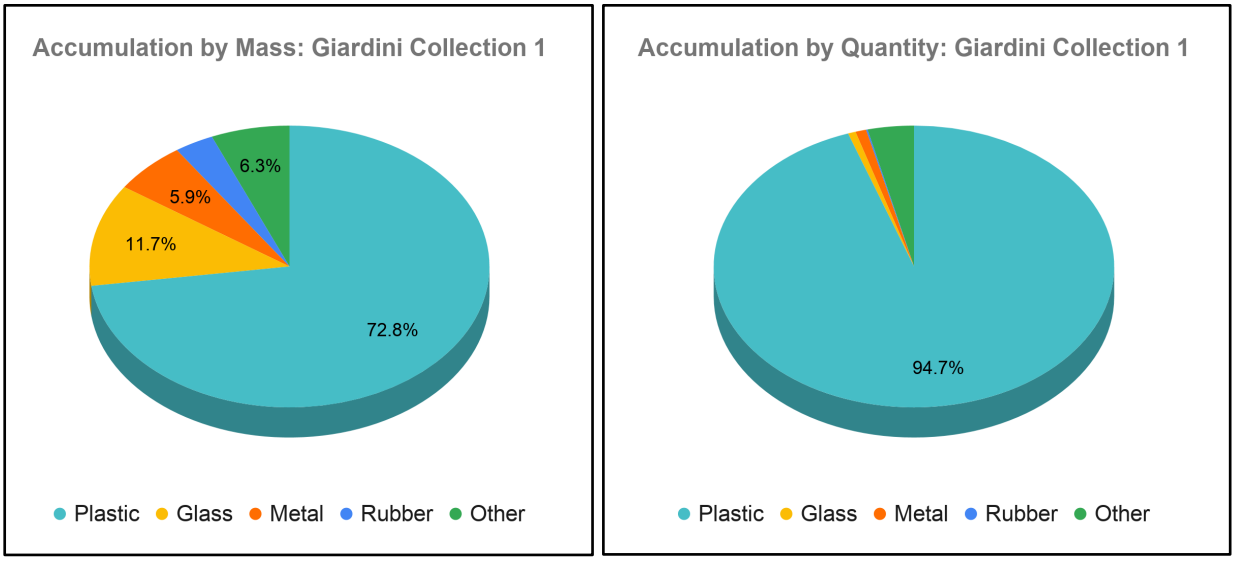

Figure 33: Giardini Collection 1 Data by Mass (left) and by Count (right)

The total accumulation collected at the second cleanup was 2.8 kg from 698 pieces. From the total mass collected, plastic accounted for 80% as shown on the left in Figure 34. From the total pieces collected, plastic accounted for 93% as shown on the right in Figure 34. The concentration of plastic accumulation was 0.03 kg/m^2 or 11 pieces/m^2. With 9 days elapsed between collections 1 and 2 the rate of plastic accumulation was about 0.2 kg per day or 72 pieces per day.

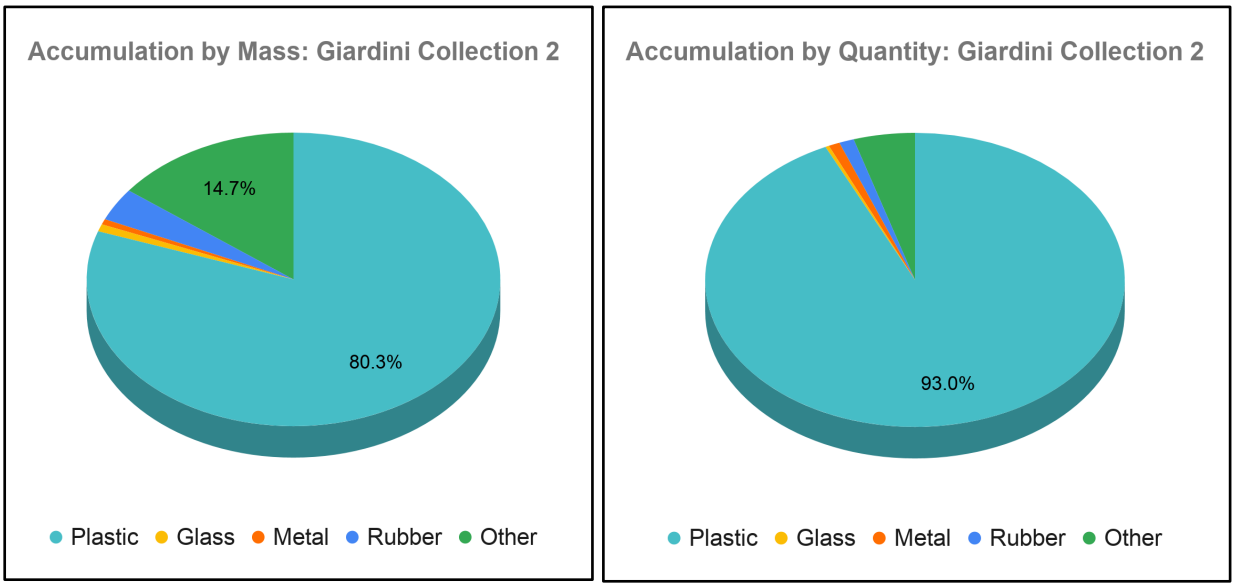

Figure 34: Giardini Collection 2 Data by Mass (left) and by Count (right)

Separating the plastic collected into types, the majority of the initial collection's mass consisted of polystyrene and bottles as shown in blue in Figure 35, while the majority of the pieces was

polystyrene shown in blue in Figure 36. For the second collection the majority of the mass of plastic consisted of polystyrene, large hard plastic, and bottles as shown in red in Figure 35. The majority in terms of pieces collected was polystyrene and small hard plastics as shown in red in Figure 36. Many of the pieces collected at this location were consumer products such as bottles and small hard plastics, which contained coffee stirrers, straws, and fragments of cutlery and cups. The abundance in consumer plastics at this location may be due to the high frequency of tourist foot traffic along this area of Venice. Any plastics used may end up in the water and could be pushed along the edge of the island by boat wakes, until it deposits at the Partigiana monument.

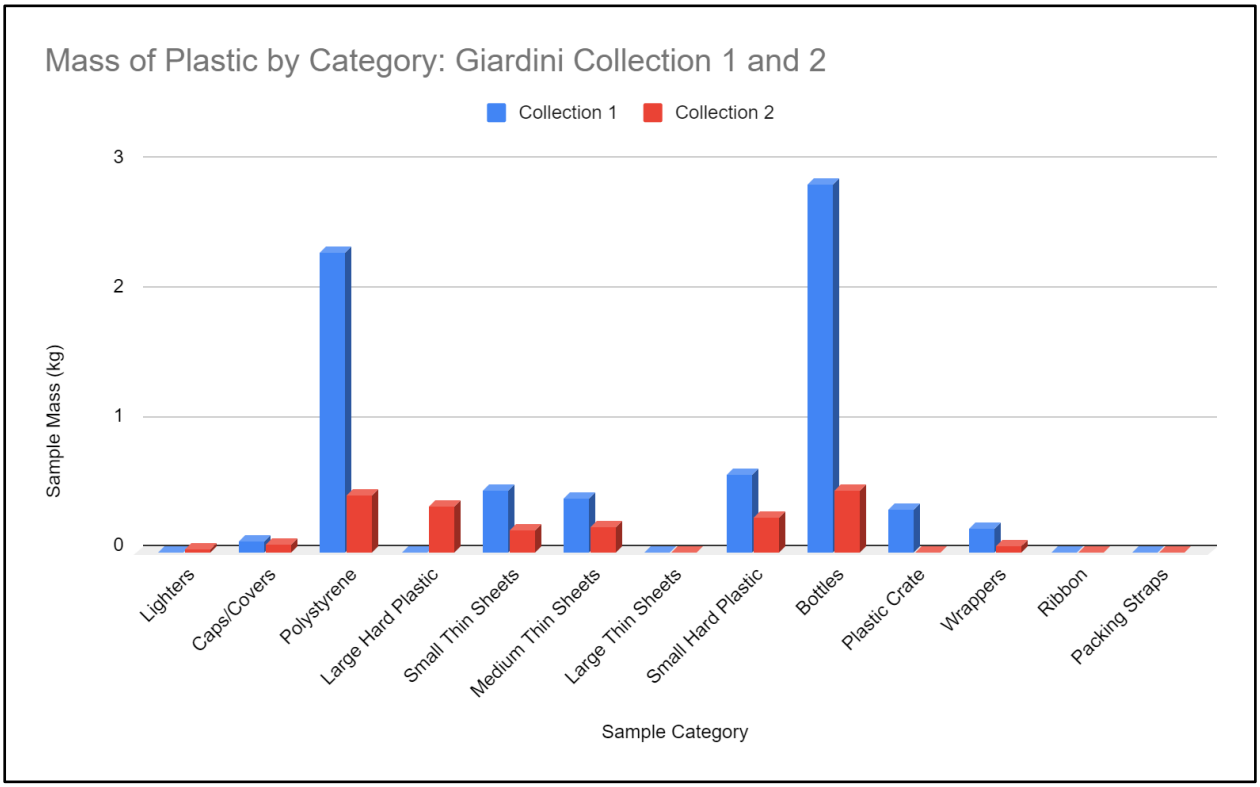

Figure 35: Giardini Collection 1 and Collection 2 Comparison by Mass

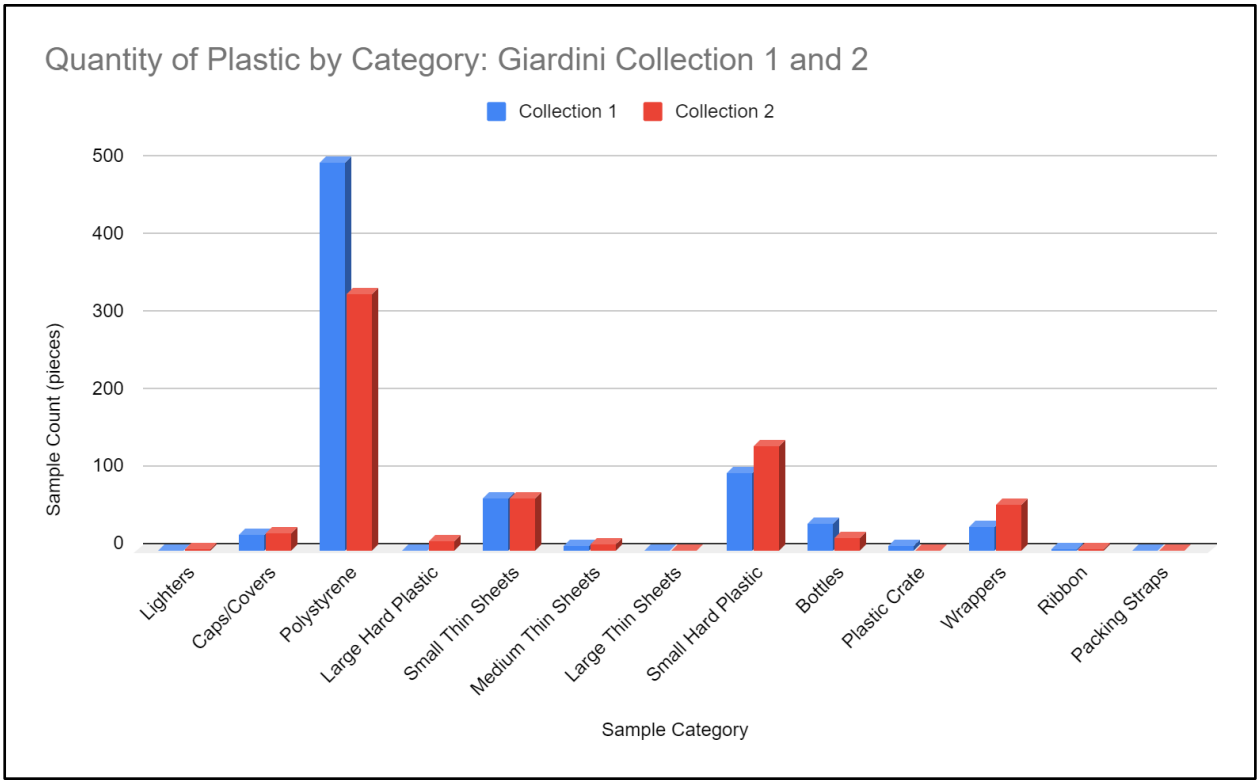

Figure 36: Giardini Collection 1 and Collection 2 Comparison by Count

4.1.4 Comparison of Accumulation Data at All Sites

Based off of the 13 types of plastic found at each of the three locations we simplified them into 4 broad types. Hard plastic includes lighters, packing straps, crates, as well as small and large hard plastics. Thin sheets include wrappers, ribbon, and small, medium, and large thin sheets. Polystyrene remains only polystyrene, while bottles and caps were grouped together. As seen below in Figure 37 of the total plastic collected at each location, thin plastic sheets in blue are the most prevalent type in terms of mass. The thin sheets proved difficult to remove at each of the locations as they could easily become entangled in seaweed and other debris, an example of which can be seen in Figure 38 which was taken at Tronchetto. The sheets can become partially buried and can easily tear into smaller pieces. As seen below in Figure 39 polystyrene in orange accounted for the majority of all of the plastic pieces collected. The polystyrene also proved difficult to remove as it breaks down into small microplastic pieces but does not biodegrade. The small beads of polystyrene become mixed with the dirt making it impossible to completely remove them without digging up as much dirt. An example of this can be seen in Figure 40, which was taken at the Tronchetto cleanup location.

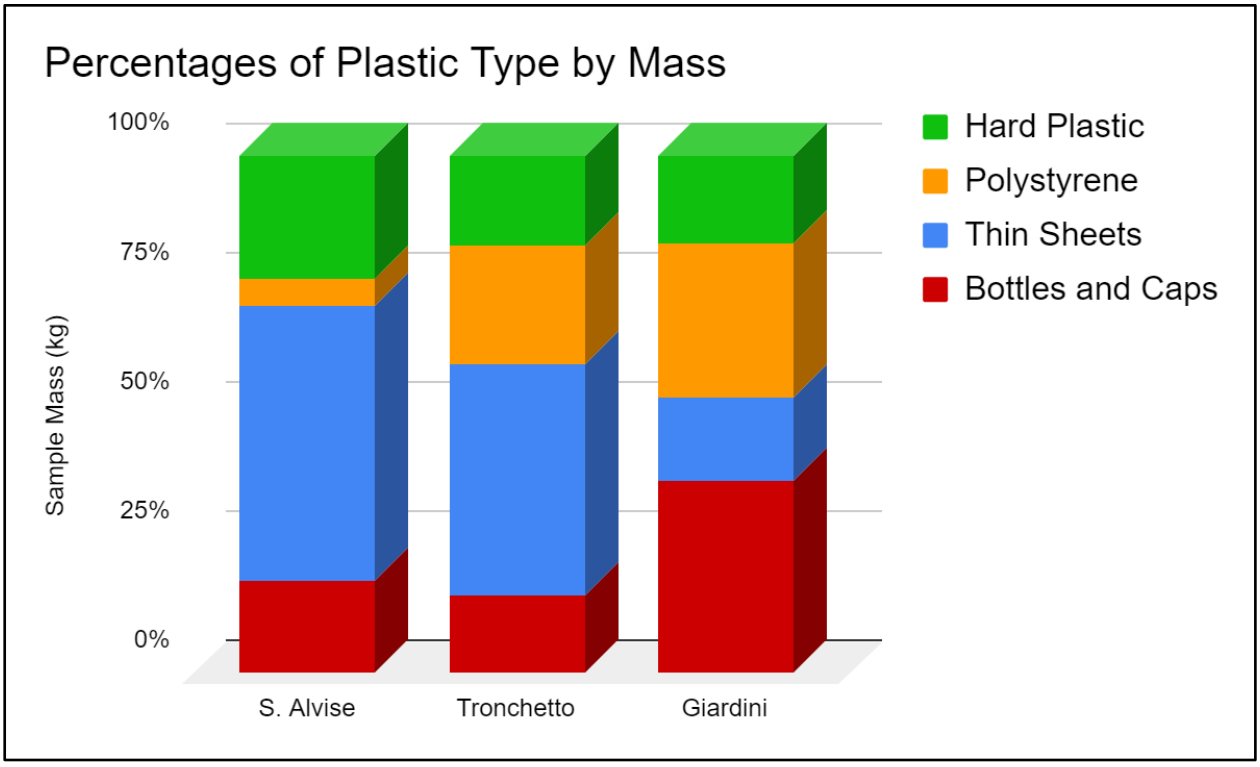

Figure 37: Percentage of Plastic Type by Mass

Figure 38: Entangled Plastic

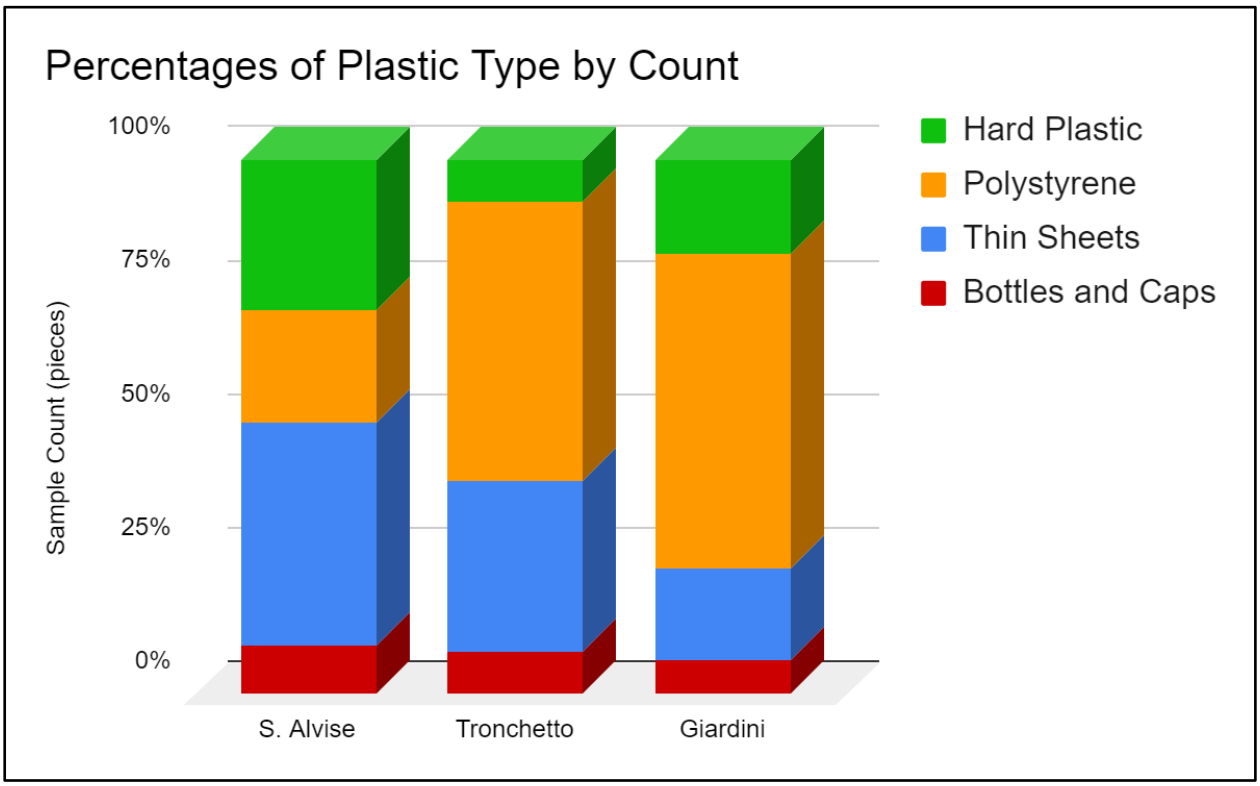

Figure 39: Percentage of Plastic Type by Count

Figure 40: Dirt-Polystyrene Mixture

4.2 Trash Receptacle and Waste Pick-Up Effectiveness Data

Veritas workers arrive at their pick-up locations around 06:30 to leave the carts out for waste collection. They then clean the surrounding streets and sweep the piles of litter towards a nearby trash receptacle, followed by changing the bags in said receptacles. We observed a lack of consistency in the times Veritas workers would check the fullness of the receptacles throughout the day. In addition, the workers would often remove large pieces of waste such as bottles, cartons, and boxes rather than changing the bag.

4.2.1 Trash Receptacle Data at Strada Nova

After 15 observations of 16 receptacles along Strada Nova, it was observed that the trash receptacles needed to be emptied more frequently during the mid-afternoon, which could have led to the overflowing state observed during the late night as shown in Figure 41. This was predicted to be due to the high foot traffic and shoppers present on this street comprised of clothing stores, restaurants, cafes, and more.

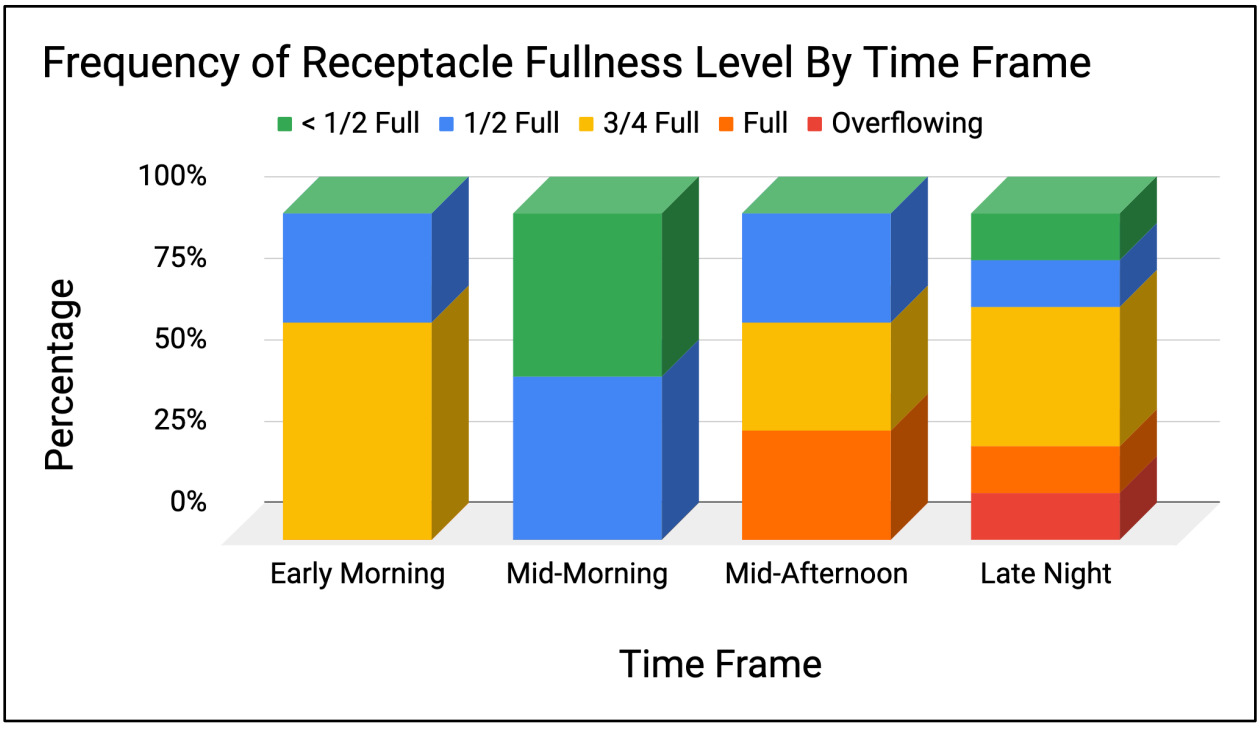

Figure 41: Frequency of Receptacle Fullness Level by Time Frame at Strada Nova

4.2.2 Trash Receptacle Data at Salizada San Moisé

After 12 observations of 8 receptacles along Salizada San Moisé, it was determined that this area was not of concern as shown in Figure 42. As the majority of the observations were less than half

full or half full, we did not find high end shopping or the hotels near by to be an issue and do not recommend any changes to the current Veritas schedule for this area in particular.

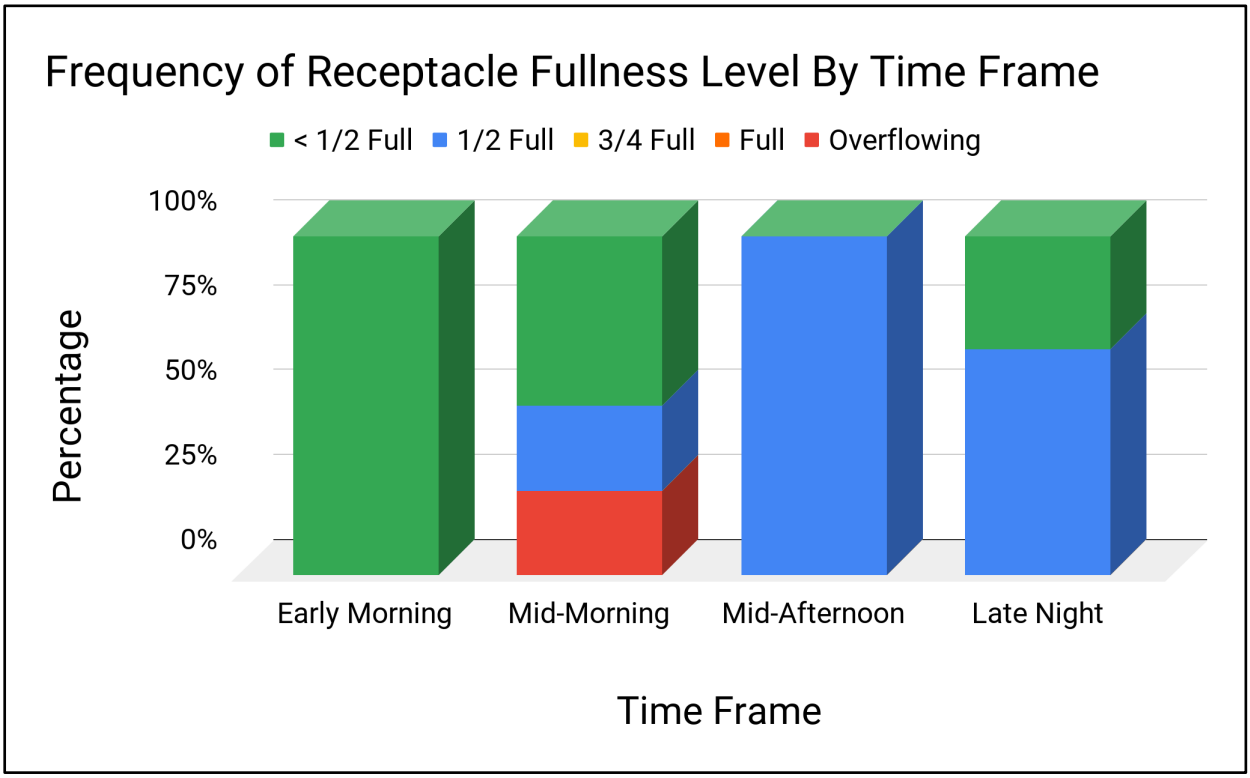

Figure 42: Frequency of Receptacle Fullness Level by Time Frame at Salizada San Moisé

4.2.3 Trash Receptacle Data at Campo San Margherita

Over 14 observations of 7 trash receptacles within Campo San Margherita, we saw that receptacles were beginning to become full in the mid-afternoon, but likely was not changed by Veritas until the next morning as shown in Figure 43. Thus, the fullness in the mid-afternoon led to overflowing receptacles between late night and early morning. It is also predicted that the nightlife in the area has a significant impact on the fullness of receptacles. We recommend Veritas to change the bags at an additional time between the mid-afternoon and late night.

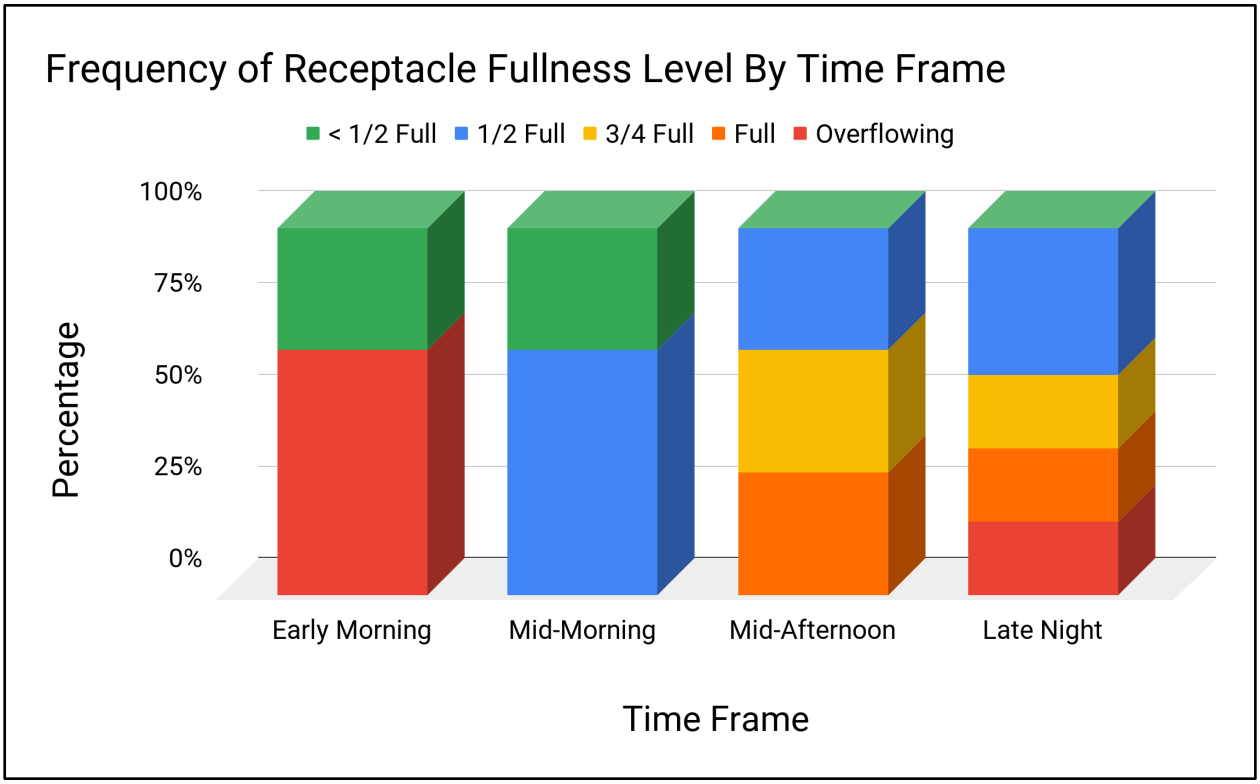

Figure 43: Frequency of Receptacle Fullness Level by Time Frame at Campo San Margherita

4.2.4 Trash Receptacle Data at Santa Lucia Train Station

Over 14 observations of the 5 receptacles at Santa Lucia Train Station, we saw receptacles full or overflowing only during the late night and early morning as shown in Figure 44. This is predicted to be due to commuters and tourists entering and exiting the city at the beginning and end of the day. We recommend receptacles to be changed out additionally during the late night time frame.

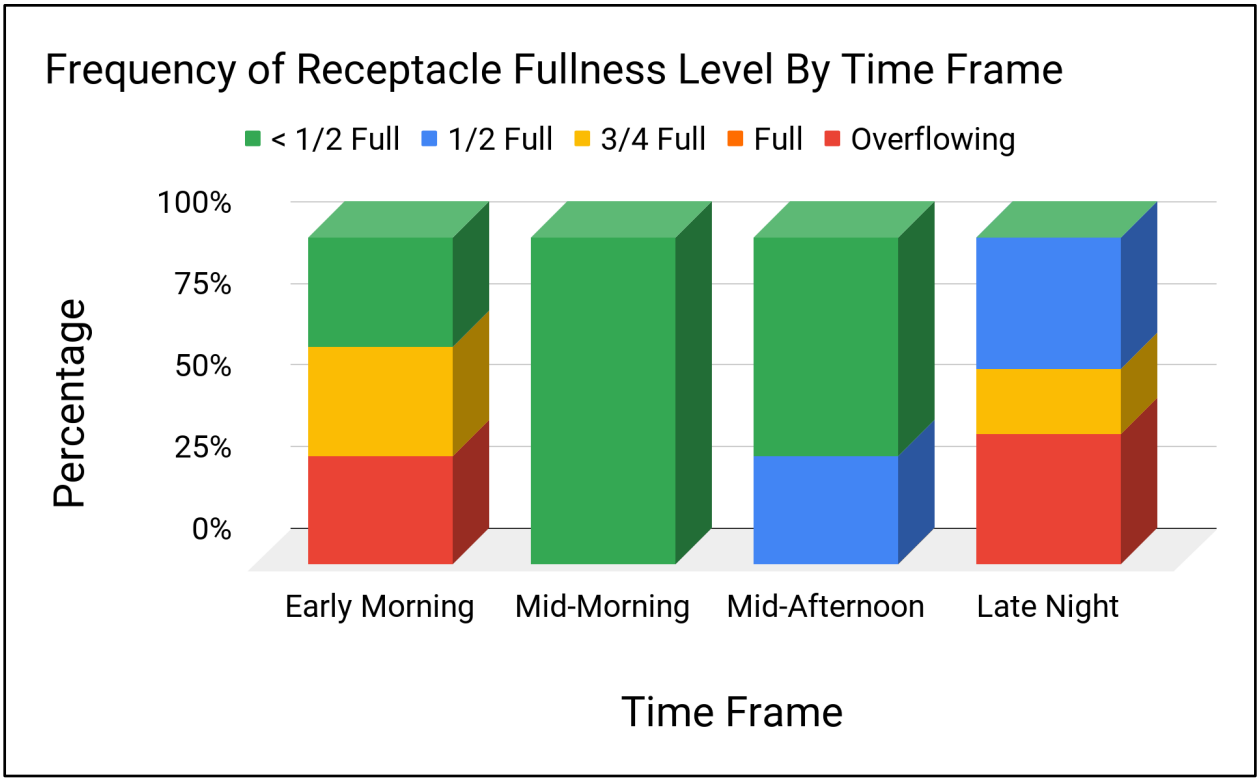

Figure 44: Frequency of Receptacle Fullness Level by Time Frame at S. Lucia Train Station

4.2.5 Waste Pick-Up Data at Rialto Bridge

At the waste pick-up location closest to the Rialto Bridge, we observed a lack of the two carts for the public to properly dispose of their residential waste. This forced people to leave their bags of trash on the ground, which could easily fall into the canal due to weather or allow birds to rip open the bag and expose the waste as shown in Figure 45. The birds may carry the trash, attempt to fly away with it, and drop it in the water or again, weather may cause it to enter the water.

Figure 45: Waste Pick-Up Location Closest to Rialto Bridge at 07:00

4.2.6 Waste Pick-Up Data at Saint Mark's Square

Although there was a cart for paper products this day when observing the waste pick-up location closest to Saint Mark's Square, there was not one present for general waste as shown in Figure 46. Again, this forced people to leave their bags of waste in a pile on the ground near the cart for paper products. This presents the potential for the waste to enter the water through weather or wildlife.

Figure 46: Waste Pick-Up Location Closest to Saint Mark's Square at 06:32

4.2.7 Waste Pick-Up Data at Northern Cannaregio

We found the waste pick-up location in Northern Cannaregio to be a successful model for other locations as two carts were present and bags of waste were never left on the ground as shown in Figure 47.

Figure 47: Waste Pick-Up Location in Northern Cannaregio at 06:50

4.2.8 Waste Pick-Up Data at Santa Lucia Train Station

A cart for general waste was present this day when observing the waste pick-up location closest to the Santa Lucia Train Station. However, there was not one present for recycling as shown in Figure 48. This forced people to leave their recycling bags in a pile on the ground closer to the canal. Again, weather and wildlife are potential contributors to plastic pollution in the water.

Figure 48: Waste Pick-Up Location Closest to Santa Lucia Train Station at 06:26

4.2.9 Waste Pick-Up Data at Strada Nova

It was observed that people were leaving their bags of waste and recycling in a pile on the ground at 05:58, prior to the time carts were left out between 06:30 and 08:30 as shown in Figure 49. Not

only is this illegal, but it also presents the potential of plastic pollution in water due to weather and wildlife.

Figure 49: Waste Pick-Up Location on Strada Nova at 05:58

4.2.10 Comparison of Waste Pick-Up at All Locations

After a total of 20 observations, we saw that the waste pick-up location closest to the Santa Lucia Train Station consistently had trash present prior to the pick-up time of 06:30 to 08:30 as shown in Figure 50. The majority of the observations at Saint Mark's Square and Strada Nova had trash present prior to the pick-up time. Cannaregio and Rialto Bridge had a much lower frequency, but still saw trash before the allotted time. We predict that this issue is due to a lack of education to both residents and tourists. Residents may not be aware of the potential contribution to the ever-growing plastic pollution problem in Venice when leaving waste out beforehand. Tourists may be trying to do the right thing when removing residential waste but are unaware that it is illegal to leave out waste prior to the allotted time, although it is not strictly enforced. In addition, it is possible that the times carts are available is inconvenient for residents, especially those who may have to be present at work by 06:30. Hence, we recommend researching the option of covered waste carts to be left out for longer periods of time, but are protected by weather and wildlife to prevent additional plastic pollution in the water. The covered cart may be left out at the end of the work day and allot a larger period of time for people to properly dispose of waste at a more convenient time. Lastly, we recommend exploring the option of administering a survey in which residents can provide their input on the best time of day for waste disposal.

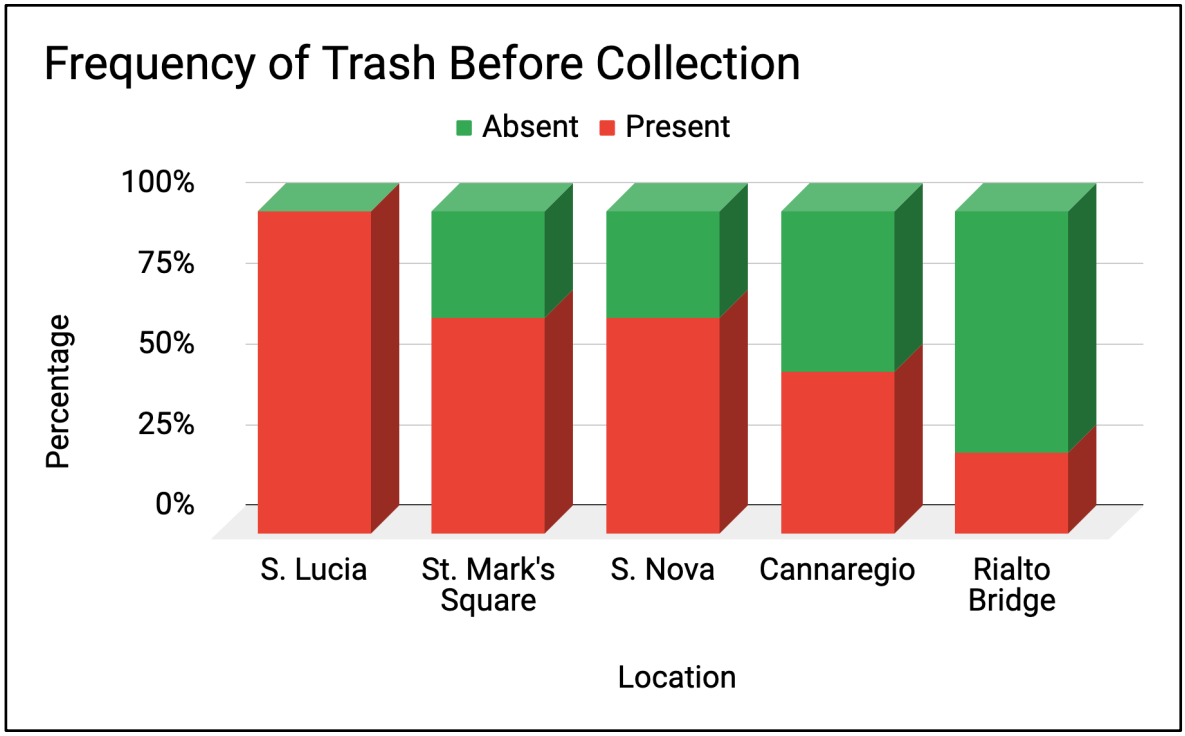

Figure 50: Frequency of Trash Before Collection Between All Locations

5.0 Recommendations

The plastic pollution problem in Venice is very dynamic because of the many influencing variables. Because of these variables, there is no one way to stem the flow of plastic pollution into the Venice Lagoon. Additionally, there is no efficient standard way to remove all of the plastic that is currently polluting the Lagoon. As a result, we have established recommendations that lead to improving the current situation of plastic pollution. We have also recommended building a framework for cleanups to allow more groups within the community to be involved in removing the waste from the Lagoon.

Our recommendations follow two major themes. The first being the action of reducing existing plastic pollution and the second being the action of preventing plastic pollution from continuing to enter the marine environment. A pamphlet displaying our recommendations, which can be used to publicize the plastic pollution problem in Venice to spur actions, can be seen in Appendix E. Because of the time restraints of our project and limited resources, there were many areas where we were not able to conduct as much research as we would have wanted. Furthermore, when conducting our research, it became clear to us that there were other parts of the problem that we would have liked to study if we were to do the project again. As a result, we have established a series of suggestions and guidelines for continued research in the field of plastic pollution in the Venice Lagoon.

5.1 Preventing Plastic from Entering the Marine Environment

Ultimately, the only way that the plastic pollution problem in Venice will improve is if we stem the flow of plastic that is entering the marine environment. The only way for this to happen is if we reduce the amount of plastic used in our day to day lives, especially in single-use plastic and polystyrene. To reduce the excessive use of plastic, Venice should first conform to the EU legislation that is targeting a large quantity of single-use plastic by 2021. We expect that the presence of single-use plastic like bottles, wrappers, and some polystyrene, would decrease in the Lagoon and environment, if Venice applies EU regulations. However, a large majority of the polystyrene we collected and many of the thin sheets from the different locations are not covered in the EU legislation on plastic. With continued research about the most effective ways to limit the use of those two types of plastic, Venice could set an example on how to deal with these two major categories.

Even with legislation that targets polystyrene and thin sheets, it will take time to slowly phase them out of use in Venice. Until that point Venice needs to and can do a better job at preventing

the amount of plastic that is entering the Lagoon. The first step in this process is creating a more effective way of dealing with public waste disposal, which can be broken down into two parts: public trash receptacles and Veritas waste pick-up locations.

5.1.1 Recommendations for the Trash Receptacles

For trash receptacles we suggest switching to separated waste and recycling receptacles. Currently, Mestre has separated receptacles installed, but the historical city of Venice does not. Studies have shown that separated trash receptacles make people think before they throw their waste away. Since more thought is being put into the disposal of waste, recycling rates have been seen to increase. As a result, the city would save money and show that Venice cares about fighting the plastic problem. Second, a majority of the trash receptacles that we studied were overflowing in the afternoon to late nighttime range. The reasons are different for each location, but it is clear that in most places across the city there needs to be an additional time where Veritas empties the trash receptacles in the city between the times of 20:00 and 23:00. This will decrease the amount of time the trash receptacles are overflowing, which will lead to a decrease in the amount of waste and plastic that is entering the canals and eventually the Lagoon after it falls out of the trash receptacle.

5.1.2 Recommendations for Waste Pick-Up Locations

In regard to the waste pick-up locations, our observations found that from the five locations we studied there was waste left at the site before the prescribed time of 06:30 at least 50% of the time. This meant that the waste was left on the edge of the canal because there was not yet a waste bin placed out by Veritas. This leads to the waste being affected by weather, animals, and an assorted number of other factors that can contribute to the waste falling into the canal and finding its way to the rest of the Lagoon. This shows that there are clearly flaws with the current system, either through a lack of education for tourists who are staying the night in Venice, or from the system not being effective for all of Venice's residents. To counteract this, we recommend a change to Veritas bins so that they are covered, which would allow them to be left out for longer times without being affected in the same ways by animals or weather. These bins could then be left out earlier in the morning or late the night before so that residents who have to leave for work before the prescribed 06:30 start time would be able to drop their waste off at a time that was convenient for them. Additionally, there should be education on waste drop-off procedure for all tourists staying the night in the historic city. Finally, a survey should be released for the residents of Venice to gain an understanding of how to make the Veritas waste pick-up system more efficient for the general public.

5.2 Reducing Existing Plastic Pollution

By performing our own clean-ups, we were able to understand the extent of the plastic pollution problem in the Venice Lagoon. Additionally, it emphasized the importance of proper removal of existing plastic, as well as plastic that continues to be added until the flow of plastic into the water is ultimately stopped. From our cleanups we found an average of 0.69 kg or 54 pieces of plastic accumulated per day, indicating the great presence of plastic within the Lagoon.

Our sponsor, Venice Calls, and the other organizations we worked with have completed at least twenty cleanups at ten locations in the past two years. Each time they return to a location, there is more plastic that has accumulated and will continue to occur until the flow of plastic into the Lagoon has stopped. Until that point, it is necessary to actively work on removing the plastic from the Lagoon to decrease the negative effects it has on the health of the ecosystem. To do this most effectively, Venetians cannot rely solely on the non-profit organizations to continue conducting clean-ups, as they are not able to complete the number of clean-ups that are required to make a difference. Therefore, there needs to be a standardized way for other community members and potentially tourists to become involved and organize their own cleanups. As a group of four students, we were able to complete each of our cleanups in less than four hours. This indicates that it is obtainable for a family or group of friends to clean a site. One issue we encountered was the restriction of access to the collection locations around the Lagoon. Many locations were only accessible by boat and as a group of students, we found it difficult to determine locations accessible by foot. As it is more common for Venetians to own a boat, we predict that this would not be a prevalent issue for them.

As an increase of people are conducting their own clean-ups and gathering data, we suggest a development of a user-friendly online database which would allow for anyone to post their results. Additionally, this could be used to compare data between independent and non-profit organized clean-ups. This database could indicate which locations have been recently cleaned as well as areas that need to be cleaned. This would prevent groups and individuals from mistakenly going to a location that does not need to be cleaned. As the central location for storing and analyzing data, it would increase efficiency in comparing and drawing conclusions, as well as an insight on the improvement or worsening about the plastic pollution problem. This would allow non-profit organizations to further education locals and tourists on the severity of the plastic pollution problem in Venice.

5.3 Future Research

This project was the beginning of the effort to understand and eventually stop the plastic pollution problem in Venice. Our project laid the groundwork for understanding the problem, but our limitations in time and resources prevented us from completing everything we had hoped.

As a group we were able to complete clean-ups at three different locations on the historic city of Venice. To get a more comprehensive understanding of the problem in the entire Lagoon, conducting cleanups at a larger variety of locations would be needed. These cleanups would be conducted using the same methodology at the following sites: Chioggia, Bora, Brenta Canal, South Giudecca, San Pietro di Castello, North End of Murano, San Giulian Salt Marsh, Southern Corner of San Michele, along the Lido in addition to any other accumulation points discovered. Each of these locations are labeled as "points of interest" on our layered map which is linked in Appendix F. The data collected from locations all over the Lagoon could reveal trends which can lead to a better understanding of how to target the problem in different areas of the Lagoon. In addition, it would be valuable to collect data at different times of the year to determine the effects of changing weather as well as a fluctuating tourist population.

There is further research that can be done into the waste management system and how the city of Venice uses plastic through its shops and businesses. Looking further into the effectiveness of trash receptacles around the city would help to determine other locations where the current system is insufficient. With additional time it would be interesting to watch individual trash receptacles throughout an entire day on multiple different days. These day-long observations would show the rate that the trash receptacles fill up as well as the frequency that they are emptied by Veritas. Another approach would be to look at the shops and other local businesses that are surrounding each of the receptacles. This would allow us to determine any trends between the types of business and the rate that the receptacle fills. This could lead to more specific recommendations on how individual business could limit their contribution to the plastic problem. This would also give the local government more information to develop bans or regulation for specific types of plastic.

6.0 The Vision of a Plastic-Free Venice

As Venice is a global center of culture and history, it has the ability to influence the world. With a global focus on plastic pollution in the water, Venice could set an example for the rest of the world by taking a stand in fighting plastic pollution. In result, this could create an opportunity for the citizens and local government to initiate a solution through additional regulations of plastic, as well as targeting polystyrene and thin plastic sheets from industry. Secondly, Venice could be an example by encouraging citizen science, community engagement, and education. This city has implemented a framework for success as multiple non-profit organizations have made major contributions in removing plastic pollution from the Lagoon. Additionally, they have raised awareness and assisted the city of Venice on the topic repeatedly. The future goal should allow for people to come together and work alongside these non-profit organizations in addition to the local government making changes. This will lead to meaningful and long-lasting effects that can be used as a guideline for cities all over the world.

We would like to thank Venice and our collaborators for our worthwhile experience here. We hope that the work we conducted had a meaningful effect and is the beginning of many more research projects to come in supporting this beautiful, historic, and unique city.

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Appendix

Appendix A: Biographies of Sponsors

(1) Venice Calls

Venice Calls is a non-profit association born during the summer of 2018. It started as a shared sense of responsibility for the city and as a solution for the lack of innovative active citizenship within the community. Their main themes of action revolve around sustainability and subsequently divides into three large areas, which are: Territory, Environment and Community.

Their first public event was held on the 9th of September as a Clean-up of the whole city. They did not only intend to actively clean the shores and canals of Venice from plastic, metal, and polystyrene waste, but they wanted to send out a message of hope and action for the city to become a platform of opportunities for the community of Venice. Through cleanups, conferences, workshops, hackathons and much more, they wish to bring more value into the community and the city of Venice, to foresee a better, cleaner, and more sustainable future for the island and future generations.

With this act, they wish to be part of the waves of change of this world that we are currently living in. They wish to build bridges and make new connections to be able to reinforce a strong and long-lasting network of people interested in actively work together with team spirit.

(2) Wigwam

Wigwam is a non-profit association network that promotes and supports the fair, supportive, and sustainable development of local communities. It was founded in Italy on December 3, 1972 and represents one of the first environmental associations born in the world. It is a National Association of Environmental Protection recognized pursuant to art. 13 of the law n. 394/1986 with Decree of the Ministry of the Environment n. 347 of 15 December 2017.

Giovanni Cecconi is the founder of the Venice Resilience Lab, a co-exploration platform for glo-cal science, resilience and social literacy for better living, a project of the NGO: Wigwam Local Community. Benefitting from a 30-year experience at Consorzio Venezia Nuova as the director of the study, design, and operation of the Venice storm-surge barriers, he is now promoting sustainable solutions for coastal cities in times of climate change, aiming at the conservation and cultivation of socio-ecological resources. He is interested in the study of complex systems, to be

explored as COOS: Confined Ontic Open System. He is also an experienced hydro-morphologist, with skills on sediment management for improving soil/water-quantity/quality by learning and building with nature integrated solutions for: navigation, fishing, aquaculture, ecotourism, conservation of local cultural identities from the impacts of migrations and climate change.

Appendix B: Biographies of Contributing Organizations

(1) Legambiente

Legambiente is a non-profit organization in Italy with 20 regional branches and over 115,000 members. The association operates in favor of a society with a balanced relationship between man and nature. Legambiente strives for the protection and enhancement of nature and environment, of collective health, of historical and cultural heritage, and of the territory and landscape. Finally, Legambiente operates in favor of lifestyles, production and consumption, and education based on sustainable development and consumer protection. The Legambiente Circle of Venice is one of the various associative bases of Legambiente Onlus, of which it shares the aim and focuses it on the territory of the Municipality of Venice, understood in all facets of its characteristics: towns, lagoons, and coasts. Legambiente pursues exclusively environmental and social solidarity purposes, acting both on the level of reporting, evaluating, and resolution of problems; that on an educational and popular level, organizing in the territory: summer camps for children, film clubs, conferences, campaigns for monitoring air and water quality, and following national campaigns such as Clean the World and Mal'Aria (Legambiente Venezia, n.d.).

(2) Plastic Free Venice Lagoon Association

Venice Lagoon Plastic Free is a non-profit organization based in Venice, functioning as a platform for action, connecting other organizations along with single individuals to operate large scale cleanups in the city of Venice, its Lagoon, including nearby mainland towns and cities. It also promotes public debates and discussion with different stakeholders to raise awareness of the danger of plastic pollution, encouraging the uptake of good practices along with individual and collective actions. Finally, Venice Lagoon Plastic Free intends to propose alternatives and viable solutions along with the promotion of good practices and the launching of independent environmental monitoring initiatives in the waters of Venice, in cooperation with research institutes and centers and students groups at the national and international level. Their infield activities are complementary and set in cooperation with the local/national environmental/waste management authorities and related departments.

Marie Curie, a fellow at the University of Keele in UK, holds a European doctorate in Sustainable Development Governance Affairs from the University Ca' Foscari. He combines in his work a robust background in international scientific project management in a multidisciplinary fashion. He has been collaborating with various national and international institutions and organizations, serving UNESCO for more than 10 years as program/project Office and is author/coauthor of a

number of scientific publications. He is the co-founder and currently deputy president of the newly established non-profit organization Venice Lagoon Plastic Free and he works as an international consultant in the field of sustainable development governance in UNESCO designated sites, with particular focus on sustainable energy, disaster risk management being also an activist against marine litter.

(3) CNR-ISMAR

CNR-ISMAR conducts research in Mediterranean oceanic and polar areas to study the evolution of the oceans and continental margins to define the activity of submarine volcanoes, faults and landslides and the impact scenarios on the coasts. They look into the influence of climate change on oceanic circulation, acidification, bio-geochemical cycles and the productivity of the seas. They study how habitats and marine ecology increase pollution of coastal and deep areas. They utilize fisheries resources to maintain exploitation within sustainable limits and improve mariculture and aquaculture practices. Finally, they research the natural and anthropic factors that impact economically and socially on coasts and lagoons from prehistory to the industrial age.

Michol Ghezzo has dealt with numerical hydrodynamic and ecological models applied in lagoons and coastal areas. Currently at ISMAR (Venice), she collaborates with the SHYFEM modeling group. She is interested in the use of dispersion models in issues related to fishing and the management of biological resources. Another aspect of her research is the use of numerical models to support investigations in the field of sedimentology (Dr. Guerzoni), study of benthos (Dott Tagliapietra) and plankton (Dr. Pugnetti). She also carries out activities related to the application of web-GIS tools (ISMAR, n.d.).

(4) Francesca Coccon (Researcher)

Francesca Coccon was born on January 25th, 1984, in Venice, Italy. She went to the Classical Lyceum of Marco Foscarini (Venice, Italy) obtaining the High School Diploma in 2002. After the completion of her high school education, she enrolled in the Faculty of Natural Science, at the University of Padova, Italy, obtaining her bachelor's degree in 2007. For her thesis, she focused on the xylophage organisms present in the Lagoon of Venice and conducted the study in the Benthonic and Ecology Laboratory of the Centre for National Research (CNR), in Venice. Afterwards, she undertook a two years Master Degree in Conservation and Management of Natural, Environmental and Cultural matters at the University of Ferrara, Italy, where she completed a thesis on the courtship behaviour of *Manacus vitellinus*, a neotropical passerine living in the secondary tropical forest between Panama and Colombia. For the field work, she went to Gamboa, in the Republic of Panama, working under the supervision of Prof. Leonida Fusani and in collaboration with the Smithsonian Tropical Research Institute (STRI). In September 2009 she

obtained a master's degree with a final result of 110/110 *cum Laude*. The experience in the tropical rainforest greatly enhanced her innate interest in birds and animals' behavior so that in September 2010 she started her PhD at the Ca' Foscari University of Venice. For her research project she focused on the development of new methodologies for preventing and reducing the risk of wildlife strike at airports, obtaining a PhD in December 2013. After that she continued with her interest in the interaction among birds and humans, being involved in a project, carried on since 2005 by CORILA, Consortium for coordination of research activities concerning the Venice lagoon system, aimed at studying the effects produced by the MOSE constructions in the Venice lagoon on birds. Since January 2016 she is a freelance in the field of ornithology and environmental science and from March 2017 to December 2018 she has conducted, as scientific director, a monitoring project of the yellow-legged gulls, *Larus michahellis*, in the historic center of the city of Venice with the aim of studying the effects of a new waste collection system on the population dynamics of the species. From March 2019 she is involved as project manager in a project with the aim of improving the biodiversity and conservation, as well as promoting sustainable tourism, in a wood in Meolo (in the Province of Venice).

Appendix C: Data from Venice Calls

Venice Calls Clean-Up Data by Location					
Location	**Date**	**Plastic (kg)**	**Plastic Bag (#)**	**Other Waste (kg)**	**Other Waste Bag (#)**
Murano Sacca S. Mattia	9/21/18	97.52	24	560.3	72
S. Alvise	3/23/18	n/a	n/a	n/a	n/a
S. Alvise	5/25/18	n/a	n/a	n/a	n/a
S. Alvise	9/9/18	n/a	n/a	n/a	n/a
S. Alvise	9/21/18	63.6	11	14.5	3
S. Alvise	11/3/18	160.4	n/a	177.4	n/a
Castello	9/21/18	22.3	9	53.7	9
Dorsoduro/ S. Croce	9/21/18	21.6	5	19	4
Tronchetto	3/23/18	n/a	n/a	n/a	n/a
Tronchetto	9/9/18	n/a	n/a	n/a	n/a
Tronchetto	11/3/18	194.3	n/a	68.5	n/a
Cimitero	11/3/18	153.6	n/a	14.3	n/a
S. Michele	3/23/18	n/a	n/a	n/a	n/a
S. Michele	9/9/18	n/a	n/a	n/a	n/a
Sant' Erasmo	5/22/18	n/a	n/a	n/a	n/a
Tocello	3/16/18	n/a	n/a	n/a	n/a
Murazzi	3/9/18	n/a	n/a	n/a	n/a

Adapted from “cleanup data.pdf,” Cognolato, S.

Venice Calls Clean-Up Totals by Date						
Date	Plastic (kg)	Plastic Bag (#)	Other Waste (kg)	Other Waste Bag (#)	Total Waste (kg)	Total Bag (#)
9/21/18	205.02	49	647.5	88	852.52	137

Adapted from “cleanup data.pdf,” Cognolato, S.

Appendix D: Data from Legambiente

Quantity of Items from Summer 2016 Cleanups		
RUBBER	Balloon	15
	Condom	1
	Gasket	2
	Glove	1
METAL	Sheet	28
	Tin Can	20
GLASS	Small Bottle	32
	Big Bottle	16
PLASTIC	Lighter	14
	Tap Ring	35
	Tampon	21
	Pen	103
	Small Bottle	313
	Big Bottle	47
	Drinking Straw	63
	Chupa	11
	Food Package	190
	Cosmedic Package	40
	Soap Package	12
	Cotton Swab	13
	Bag of Chips	459
	Ice Cream	29
	Toy	13
	Gloves	23
	Labels of Bottle	60
	Small Sheet	1062
	Big Sheet	311
	Polystyrene	507
	Foam Rubber	36
	Cigarette Filter	1821
	Cigarette Pack	185
	Small Piece	290
	Dog Poop Bag	20
	Full Bag	7
	Empty Bag	135
	Plug	158
PAPER	Cigarette Pack	77
	Fragments	130
	Tetrapak	44

WOOD	Small Piece	87
	Big Piece	44
	Cork	99
OTHER	Buiione	2
	Piece of Metal	3
	Cotton Net	1
	Big Glass	2
	Ceramic	4
	Big Piece of Rubber	39
	Big Metal	3
	Building Waste	15
	Net	6
	Scotch Tape	20
	Medium Tap	3
	Cable	2
	Platic Net	8
	Phone Protection	2
	Big Polystyrene	14
	Medicinal Plastic Package	1
	Ice Cream Wooden Stick	4
	Plastic Shoes	2
	Plastic Pen	13
	Plastic Stick	1
	Plastic Patch	0
	Cotton Hat	1
	Newspaper	2
	Rubber Mat	1
	Light Bulb	1
	Plastic Clothes Pins	7
	Umbrella Bag	1
	Syringe	1
	Paraffin	2
	Paper Glass	7
	Glass	1
	Fabric Ribbon	6
	Nylon Thread Role	1
	Small Wood	2
	Big Wood	1
	Polyurethane Foam	3

Adapted from “generale città - SI CERTOSA.xlsx,” Franceschetti, P.

Total Counts by Type and Location								
	Cannaregio	Giudecca	San Marco	Dorsoduro	Castello	Santacroce/Sanpolo	Certosa	Total
Rubber	3	11	2	0	0	3	0	19
Metal	11	21	2	7	4	2	1	48
Glass	6	24	3	6	3	4	2	48
Plastic	1979	1704	690	529	513	369	194	5978
Paper	82	96	9	26	17	5	16	251
Wood	73	59	39	21	16	14	8	230
Other	20	52	28	8	0	34	40	182
Total	2174	1967	773	597	553	431	261	6756

Total Percentages by Type and Location								
	Cannaregio	Giudecca	San Marco	Dorsoduro	Castello	Santacroce/Sanpolo	Certosa	Total
Rubber	0%	0%	1%	0%	0%	1%	0%	0%
Metal	1%	1%	1%	1%	0%	0%	0%	1%
Glass	0%	1%	1%	1%	1%	1%	0%	1%
Plastic	91%	89%	87%	93%	74%	86%	89%	88%
Paper	4%	4%	5%	3%	6%	1%	1%	4%
Wood	3%	4%	3%	3%	3%	3%	5%	3%
Other	1%	1%	3%	0%	15%	8%	4%	3%
Total	32%	9%	29%	8%	4%	6%	11%	100%

Adapted from “generale città - SI CERTOSA.xlsx,” Franceschetti, P.

Appendix E: Objective 3 Recommendation Pamphlet

WHO WE ARE

We are a group of undergraduate students completing a project on plastic pollution in the city of Venice through the Venice Project Center for the Interdisciplinary Qualifying Project (IQP) for Worcester Polytechnic Institute (WPI). The goal of our project was to develop a plan to eliminate the build-up of plastic pollution in Venice, Italy. Due to the unique geography of Venice, being surrounded by the Lagoon, plastic disposal has been challenging to manage. The high tourist population has increased the importation and use of single-use plastic items across the city. These factors have contributed to the prevalent issue of plastic pollution in Venice. To address and help the plastic pollution problem, we gathered data to understand the accumulation of waste in the Venice Lagoon. We assessed the effectiveness of the public trash receptacles and waste pick-up locations through research and observations. Finally, we analyzed our data, determined trends, and developed recommendations for reducing and eventually eliminating plastic pollution in the city of Venice.

OUR FINDINGS

We conducted two pick-ups at each of S. Alvise, North Tronchetto, and Giardini (Partigiana). From our pick-ups we found that plastic is accumulating on the historical city of Venice at an average rate of 0.69 kg from 54 pieces/day per accumulation location. By quantity of plastic pieces, polystyrene was the most prevalent and by mass plastic sheets is the most prevalent.

We also observed the effectiveness of the trash receptacles and Veritas waste pick-up locations throughout Venice. For the trash receptacles we found that at least 20% of the time that we observed the receptacles they were full or overflowing, especially in the afternoon to late night time period. This leads to plastic and waste falling out of the trash receptacles and falling into the canals. For waste pick-up locations we found that over 50% of the time waste was left before Veritas carts were deposited at 06:30. Because the waste bags were left on the street next to the canal there were similar problems as with the overflowing trash receptacles where the waste bags were susceptible to getting knocked over by wind or animals disrupting and depositing the contents into the canals.

RECOMMENDATIONS

Our recommendations follow two major themes. The first being the action of eliminating existing plastic pollution and the second being the action of preventing plastic pollution from continuing to enter the marine environment.

Venice should first conform to the EU legislation that is targeting a large quantity of single-use plastic by 2021, as well as going beyond the EU regulation to regulate polystyrene and thin plastic sheets in industry. Next, we recommend that a standardized way for other community members and tourists to become involved and organize their own cleanups. This would allow comparisons with other groups to get a better understanding of the progress of the plastic problem.

For trash receptacles we suggest switching to separated waste and recycling cans which leads to increased recycling and, in turn, save money for the local government. An additional shift to empty trash receptacles between 20:00 and 23:00, would also prevent waste pollution. For waste pick-up locations we suggest covered waste bins that are left out earlier so that more Venetians are able to leave their waste in a bin instead of on the street next to the canal.

Appendix F: Objective 3 Layered Google MyMap

To view our map with linked data and images follow the link below:
https://drive.google.com/open?id=1DukXZ0KYGAZMA1k2UXhBWLMeKm0c4sz&usp=sharing