Microplastic abundance throughout Puget Sound

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Abstract:

Microplastic pollution in the ocean is caused by the human population, and the way it transports throughout the water can be affected by numerous factors such as wind, tides, and residence times of the water. Microplastic concentrations were determined through sampling in multiple areas throughout Puget Sound: Admiralty Inlet, Hood Canal, Whidbey Basin, and the central basin during December 2017 and January 2018. The microplastic concentrations were compared to the multiple factors that could affect concentration (wind, tides, residence times and human population), and the concentrations were correlated with human population the most, out of all the other factors. This study can be used to help understand how plastic is distributed throughout Puget Sound, to help facilitate more efficient clean-ups in the area.

Introduction:

Microplastics

On a global scale, garbage patches exist worldwide. Garbage patches are large areas of concentrated marine plastic formed by ocean gyres. These patches can obtain a range of plastics, from large sizes to microplastics which are defined to be plastic pieces smaller than 5mm in length by the U.S. National Oceanic and Atmospheric Administration (NOAA). Through the human eye, it's possible to sail through the ocean and not see anything. Globally, plastic marine pollution has been a challenge because plastics are present not only present on the surface, but throughout different levels of the ocean due to the varying densities of the plastic. Plastics are also constantly moving due to winds and currents, creating more of a challenge ("Great Pacific Garbage Patch," 2018).

Once in the ocean, plastics can easily be a problem for marine life. Microplastics can take up to centuries to deteriorate in the ocean and can affect biological communities in the water and on land. (Moore et al, 2005). As marine microplastic concentrations increase from sources from land and at sea, it is becoming more of a growing issue as organisms such as zooplankton are ingesting these particles which contain chemical contaminants (Cole et al, 2013). When organisms from the lower trophic levels consume the chemical contaminants, these chemicals are transferred up the food chain as they are eaten by predators (birds, marine mammals, shellfish, etc.) and can potentially affect humans (Watts et al, 2015). A recent study by the Canadian government and the British Columbia shellfish aquaculture industry collected thousands of clams and oysters and concluded that most shellfish had microplastics in them. Thus, when humans eat shellfish, they're consuming plastic as well (Christensen, 2014). Because plastics are extremely durable, they persist in aquatic environments and threaten the marine community (Lusher, 2015). Microplastics can easily pass through water filtration systems and end up in the ocean, potentially causing a growing issue for life in the ocean (Galloway, 2015).

Sources of microplastics include deteriorated plastic from larger plastic debris, and microbeads which are polyethylene plastic beads between a 5µm and 1µm size that are used in some everyday personal care products such as exfoliating cleansers and toothpastes, and microfibers from everyday clothing after being run through a washing machine (US Department of Commerce, 2016; Christensen, 2014). Another source of microplastic pollution are from scrubbers in paint removal for ships in a process called Plastic Media Blasting (PMB), where tiny pellets of plastics are used to remove paint off ships (WMRC Factsheet: Paint Removal Options," 1998).

Laws and Different Types of Microplastics

Microplastics have been a problem since the 1960s where they first appeared in personal health products. The use of microplastics has been increasing since then, polluting the oceans. Some laws have been passed to counter microplastic pollution, such as the Microbead-Free Waters Act of 2015 signed by President Obama, which banned microbeads in personal care products (US Department of Commerce, 2016). In addition, it is illegal under federal law to dispose of any plastic in the ocean under the Ocean Dumping Ban Act of 1988 amended by the Marine Protection, Research Sanctuaries Act (MPRSA) (Environmental Protection Agency, 2017). However, even with these laws, plastic pollution is still a growing issue and action must be taken to prevent more pollution.

Although microbeads are banned, microfibers are not. Microfibers are another subcategory of microplastics which are polluting the ocean. Microfibers are fine, synthetic strands that can come from washing clothing that contain synthetic materials in the washing machine (Bruce et al, 2016), which still contains harmful chemicals that can be ingested by organisms.

Puget Sound

This study focused on microplastic concentration throughout Puget Sound. Puget Sound is a stratified, fjord-type estuary circulation. Factors that affect the rate of the water flowing out of Puget Sound are the upwelling of the more dense and deep saltwater as well as incoming freshwater from the rivers. The combination of the tidal exchange and bathymetry of the Sound result in a restricted and slow flush rate of water, sediments, and debris where the shallow sills could prevent sediment, organisms, and pollutants from leaving Puget Sound (Ruckelshaus et al, 2007). Puget Sound includes steep sides, deep basins, and sills of a fjord estuary as well as two main rivers that provide freshwater into the Inlet. Factors that affect the circulation in Puget Sound are strong winds, tidal currents, deep water exchange, and the exchange rate of water flowing in from rivers and out at the surface (Baker & Pond, 1995). A previous study in Puget Sound found that microplastics were closely related to residence times than with population density (Mahoney, 2017).

Goals of this Research

The goal of this study is to find data that examines if there is a relationship between the concentrations of microplastics and factors such as wind speed, residence time, and population. If there is a relationship between microplastic concentrations and factors such as wind speed, residence time, and population, we may be one step closer to cleaning up microplastics more efficiently. This study will contribute to the little research available on microplastic marine pollution.

Methods:

Overview

This research focused on five main regions of Puget Sound: the central basin, Whidbey Basin, Admiralty Inlet, Northern Hood Canal, and Southern Hood Canal. Residence times from previous studies were used to compare microplastic concentrations observed in this research (Figure 1, Figure 3). Each main section of Northern Puget Sound had two stations each, except for the Southern Hood Canal which only had one sample, giving a total of nine stations (Figure 1). These stations were chosen to provide a contrast between a well populated region and relatively unpopulated region (Figure 3).

Data was collected on University of Washington's R/V Clifford A. Barnes and R/V Thomas J. Thompson, on January 13-15 and 27-28. A 333µm manta net with an area of 0.717m^2 was towed from 1-2 knots along the surface water at each station for 15 minutes. The net was washed down thoroughly into a 5.6-mm and 0.3-mm mesh sieves, where the surface microplastics were then transferred until lab analysis was conducted. The water volume at each station was calculated using the flowmeter readings on the manta at each station to estimate the volume of water that flowed through the manta net through each deployment, to calculate the microplastic concentrations.

Lab Analysis

Each sample was analyzed following the instructions from National Oceanic and Atmospheric Administration's "Laboratory Methods for the Analysis of Microplastics in the Marine Environment" (National Oceanic and Atmospheric Administration, 2015). Samples were sieved using distilled water and 5.6mm and 0.3mm mesh sieves. The microplastics were placed into a pre-weighed beaker which was then placed into a drying oven for 24-72 hours. After drying was complete, the beakers with the samples were weighed again and the difference in weight determined the weight of the sample. To remove the biological material from the microplastics, underneath the hood, a mixture of 30% hydrogen peroxide solution and aqueous 0.05 M Fe(II) solution was put into the beaker to oxidize the organic material from the microplastics and catalyze the reaction. After five minutes, the beaker was placed on a hotplate at 75°C with a stir bar and removed as soon as bubbles were observed at the surface. When the bubbling died down, the beaker was placed back onto the hotplate at 75°C with a stir bar for 30 minutes. Some samples required more hydrogen peroxide than others, depending on the amount of organic material. After the organic material has been dissolved, NaCl was placed into the beaker to increase the density of the solution causing the plastics to float and create a density gradient. The sample remained on the hotplate until all of the salt was dissolved. The sample was then transferred into a density separator and left overnight or in some cases over two nights. Microplastics were drained through a 0.3mm sieve and air-dried for 24 hours or more. After drying is complete, the solids in each sample were observed under a microscope and categorized as microplastic foams, fiber clumps, fibers, or flat plastic pieces.

Population, Wind, and Residence Times

In order to obtain data, the following resources were used: Washington's Office of Financial Government (for population density), Wundermap (for wind data) and a study done by Puget Sound Institute ("Population by Density Census Block," 2010; Weather Forecast & Reports - Long Range & Local," 2017; Ruchelshaus et al, 2007).

Results:

Concentration

Microplastics were found in the surface samples of all nine stations in Puget Sound. Microplastic concentration varied from 0.006457 pieces/m^3 to 0.05678 pieces/m^3 in the central basin (Figure 3). Overall, from the stations sampled, Whidbey Basin had the most microplastic abundance, 32.2%, out of the other samples stationed from Puget Sound (Admiralty Inlet, Hood Canal, and the central basin) (Figure 4).

Composition

The microplastics found from the stations fell into four main categories: foam, flat pieces of plastic, fiber clumps, and fiber strings. Fiber strings were the most common microplastic type found, followed by fiber clumps, foam, and flat pieces of plastic. The stations that had the most variation in microplastic composition were Station 1 and 7 (Figure 3), which were both stations in the central basin.

Population

Population data was obtained through the Washington's Office of Financial Management (Figure 2). The most populated stations were in the central basin with over 1,500 persons per square mile, followed by the Whidbey Basin with 250-500 persons per square mile, then Northern Hood Canal with 25-250 persons per square mile, and lastly Southern Hood Canal with 0-5 persons per square mile.

Discussion:

Population

Microplastic concentration trends showed a strong correlation with population (Figure 2). Stations 1, 7, 8, 9 which are locations near highly populated areas such as Seattle and Everett showed relatively higher microplastic concentrations than those near lower populated areas (Figure 3). Although humans are responsible for plastics in the ocean, they are not permanently placed into the ocean in a particular area.

Tides, Circulation and Wind

Plastics are transported to different areas due to the wind, tides, natural estuarine circulation of the Sound. The primary factor of the subtidal circulation of Puget Sound is based on density which is dependent on the difference between the fresh river waters and the salty marine water at the mouth of Puget Sound. Whidbey Basin receives a large inflow of fresh river water which mixes with the saline waters which is then transported to Admiralty Inlet at around

$0.8m^3s^{-1}$, whereas Northern Hood Canal transports $0.25m^3s^{-1}$ of surface water to the Admiralty Inlet. (Babson et al, 2006).

Higher winds are usually in the winter, which was when these samples were collected. Max winds are usually in the afternoons, causing samples to be mixed down into the water column, resulting in under-sampling. A recent study has shown that there are loss of microplastics from the surface, therefore the manta net used in this experiment can result in under-sampling, since this study only focused on samples on the surface (Kukulka et al, 2012).

Residence Times

Microplastic concentrations in Puget Sound are also influenced by the residence time of each area sampled (the central basin, Admiralty Inlet, Northern and Southern Hood Canal and Whidbey basin). From the sample data taken and the data from Babson's study of residence time in Puget Sound, there was no distinct correlation between microplastic concentration and residence time (Figure 3). Although there was no prominent correlation within this data, there was a pattern found in a study done by the University of Washington. This study concluded that microplastic density was influenced more by residence times than population, which this study has shown the opposite (Mahoney, 2017).

Overall

Taking population, wind data, circulation and residence times into account, Station 1 and 7 near Seattle had the highest microplastic concentration as well as population density of 1,500 persons per square mile and residence time of 21.6 days, with one of the highest winds blowing in the SSW and ENE direction, at 8.6km/h and 7.7 km/h, respectively (Figure 2, Figure 3, Table 2). Stations 8 and 9 near Arlington had the second highest microplastic concentration overall of 0.027 pieces/m^3. Although they had the lowest residence time of 4.9 days, there was a higher population near the stations and also a high wind average over the past seven days of 7.8 km/hr and 0.4 km/hr in the SSW and south direction. Station 4 and 5 in the Hood Canal had a residence time of 8.4 days with a lower microplastic concentration than Station 7 and 8 due to their location. There were low wind averages of 0.5km/hr and 1.4km/hr in the SSW and SSE direction, respectively. Station 3 was the furthest station sampled in Hood Canal with a residence tie of 11.7 days, showing an even lower concentration of microplastics of 0.01 pieces/m^3. Station 2 and 6 near Port Townsend had varying levels of microplastic concentrations of 0.035pieces/m^3 and 0.019pieces/m^3, respectively, both with a residence time of 11.7 days.

Conclusion:

Samples were collected in Admiralty inlet, Northern and Southern Hood Canal, Whidbey Basin and the central basin in Puget Sound, WA to examine a relationship between microplastic concentration and other factors such as population, wind speed, and residence times. There was no direct correlation between microplastic concentration and one of these factors in particular, however all factors contributed together to influence microplastic concentrations. Population contributes to the input of microplastics whereas wind and residence time are more responsible for where the microplastics travel from their input site. Overall, this study shows that microplastic concentration are highly related to human population. Looking forward into the future, decreasing the marine microplastic pollution through clean-ups are necessary, as well as finding alternatives to plastics, decreasing plastic-use to avoid placing more pollutants in the ocean.

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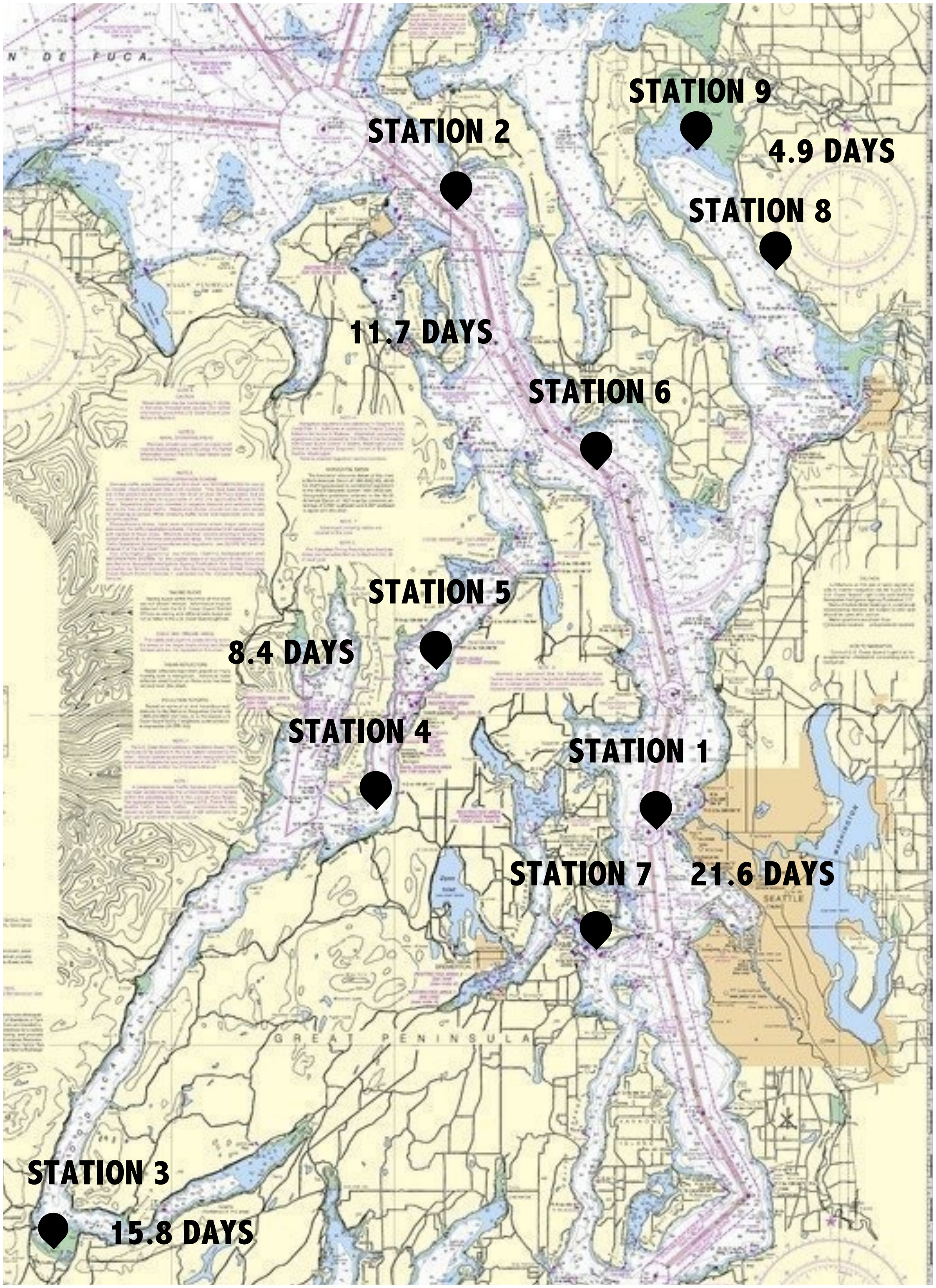


Figure 1: Residence Times (days) of the stations taken throughout Puget Sound displayed on NOAA Chart 18440. This map shows residence times of 4.9 days for Station 8 and 9, 8.4 days for Station 4 and 5, 11.7 days for Station 2 and 6, 15.8 days for station 3, and 21.6 days for Station 1 and 7.

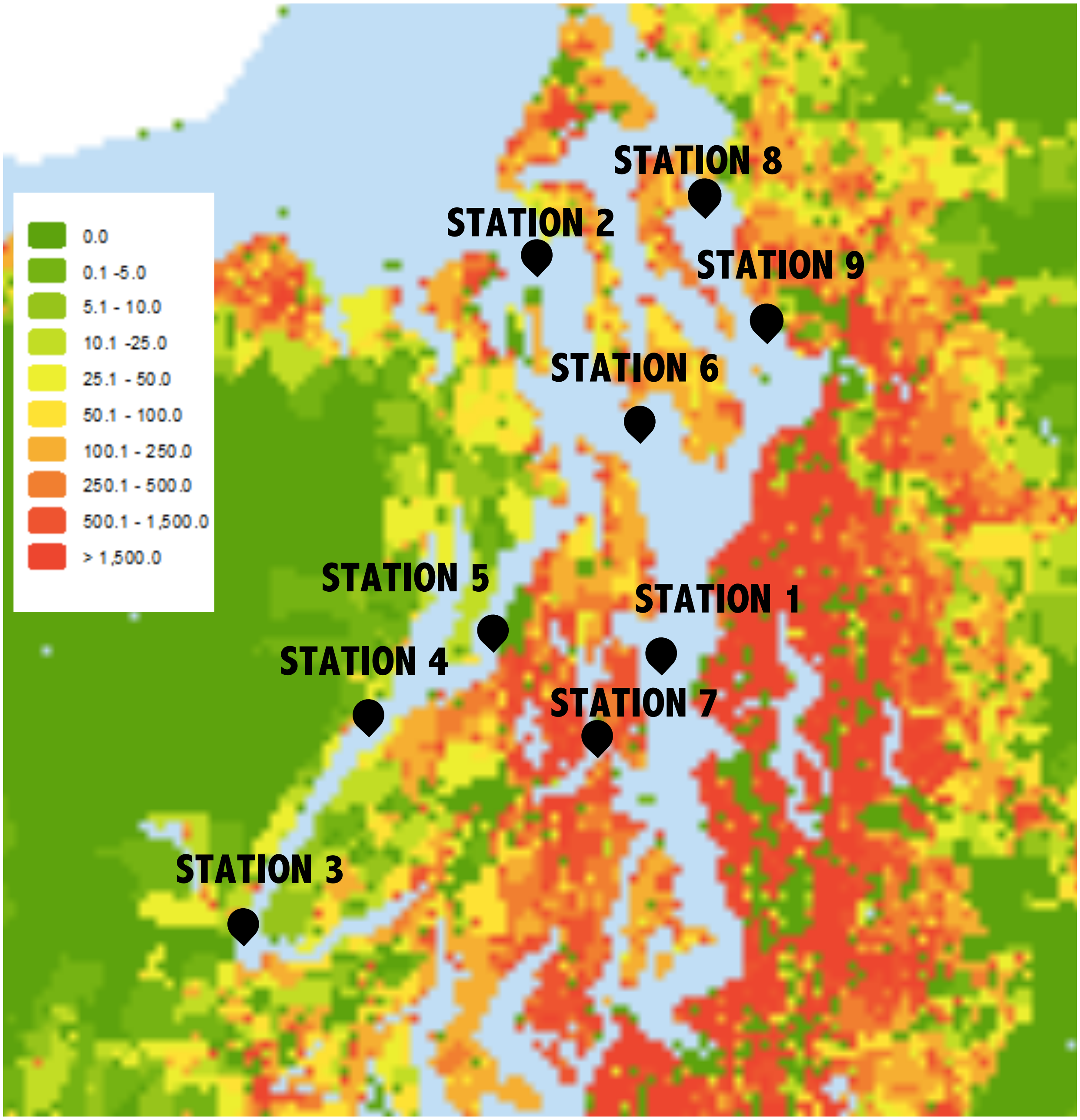
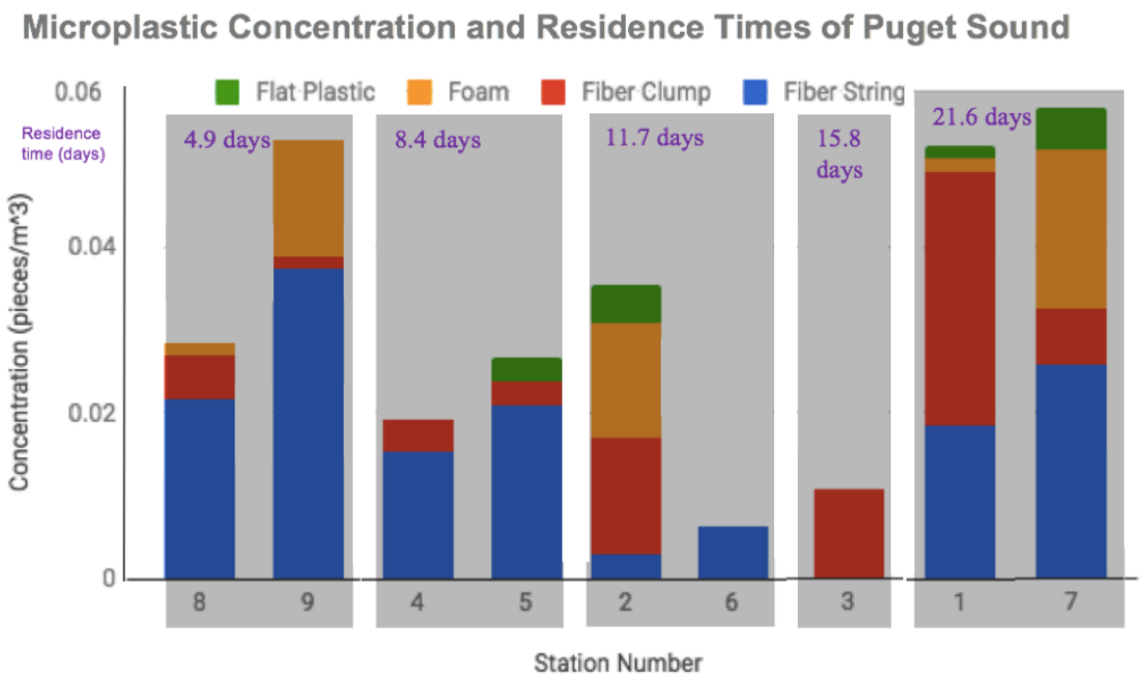


Figure 2: Population Density (persons/sq mile) of Puget Sound. Out of the stations sampled, the area near station 1 and 7 contain a largest population of at least 250 persons per square mile to over 1,500 persons per square mile.



R^2 values:

Flat Plastic R^2 = -0.075
Foam R^2 = -0.055
Fiber Clump R^2 = -0.085
Fiber Sting R^2 = 0.392

Figure 3: Concentration (pieces m^3) of microplastics found at each station with residence times of each station, separated by grey blocks with residence times of 4.9 days for Station 8 and 9, 8.4 days for Station 4 and 5, 11.7 days for Station 2 and 6, 15.8 days for station 3, and 21.6 days for Station 1 and 7. Each bar contains the distribution of different types of plastic found in the samples: flat plastic, foam, fiber clump, and fiber string. R^2 values for flat plastic, foam, fiber clump, and fiber string were -0.075, -0.055, -0.085, and 0.392 consecutively.

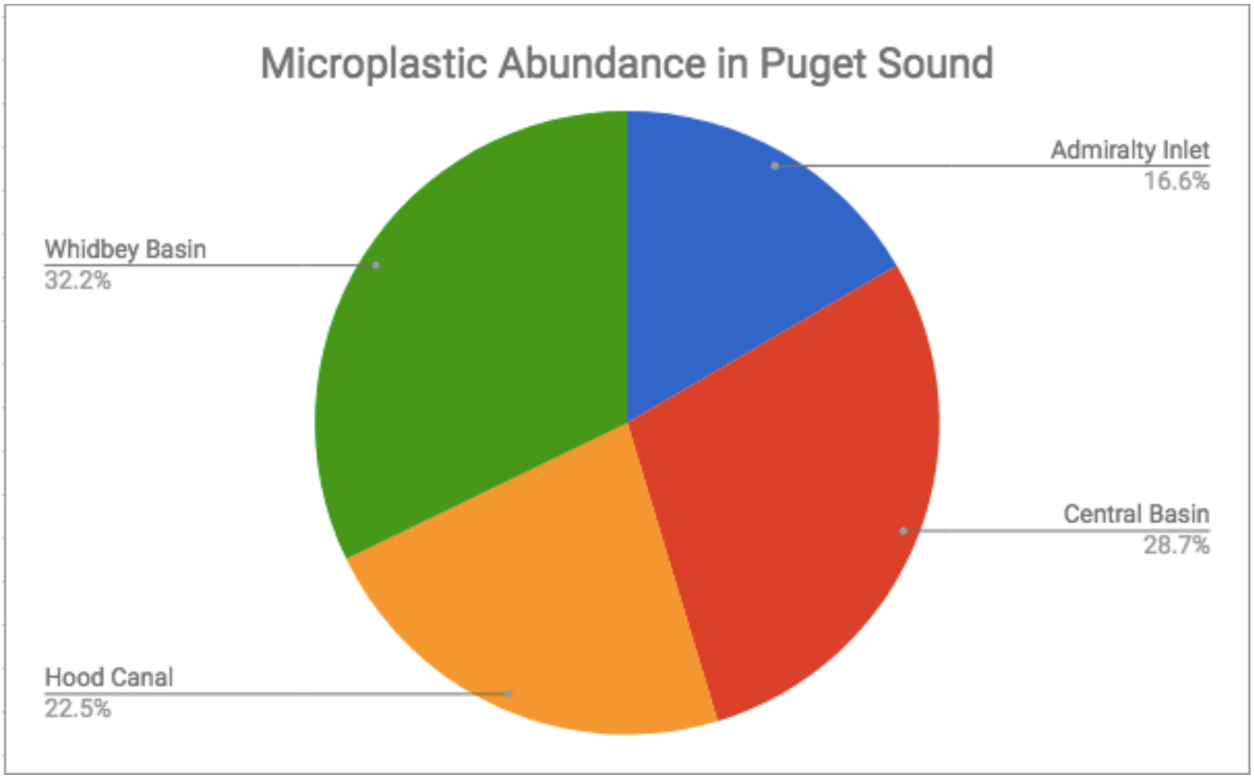


Figure 4: Microplastic Abundance in Puget Sound, based on concentration, separated by areas in Puget Sound. Admiralty Inlet, Whidbey Basin, the central basin, and Hood Canal had an abundance of 16.6%, 32.2%, 28.7%, and 22.5%, respectively.

Table 1. Coordinates of station numbers throughout Puget Sound.

Station Number		Latitude	Longitude
		Puget Sound	
1	Main Basin	47.6218° N	122.4079° W
2	Admiralty Inlet	48.1194° N	122.6720° W
3	Hood Canal (South)	47.3711° N	122.1300° W
4	Hood Canal (North)	47.6080° N	122.9394° W
5	Hood Canal (North)	47.7363° N	122.7523° W
6	Admiralty Inlet	47.9383° N	122.5258° W
7	Main Basin	47.5917° N	122.5407° W
8	Whidbey Basin	48.1604° N	122.4022° W
9	Whidbey Basin	48.0660° N	122.3322° W

Table 2: Wind data of each samples stationed, displaying the wind speed average (km/h) over previous 7 days before sampling. Wind data was taken from Weather Underground, from www.wunderground.com.

Station Number		Wind Speed avg over previous 7 days (km/h)	Wind Direction
		Puget Sound	
1	Main Basin	8.6	SSW
2	Admiralty Inlet	1.6	ESE
3	Hood Canal (South)	1.5	SSW
4	Hood Canal (North)	0.5	SSW
5	Hood Canal (North)	1.4	SSE
6	Admiralty Inlet	9.4	SOUTH
7	Main Basin	7.7	ENE
8	Whidbey Basin	7.8	SSW
9	Whidbey Basin	0.4	SOUTH