Microplastic Pollution in the Chesapeake Bay

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Introduction

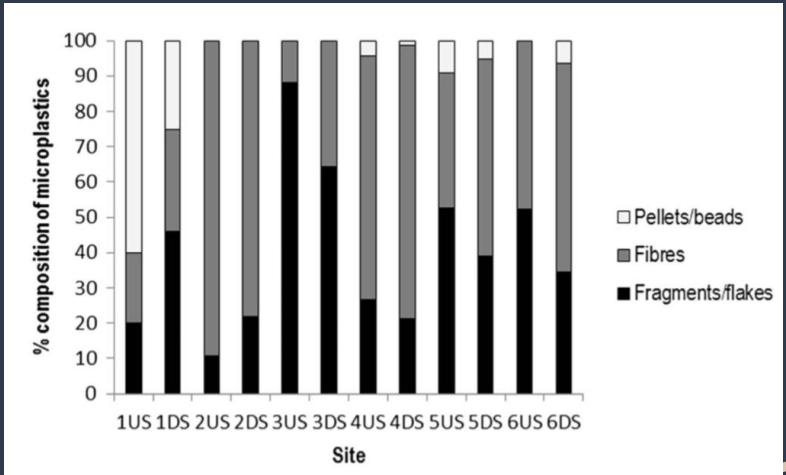

Fig. 2 Mean composition of microplastics in receiving waters up- (US) and downstream (DS) of wastewater treatment plants. $n =$ 3 at site 1 and 5 at all other sites. See Table 1 for details of sampling sites

- Microplastics are defined as small, microscopic pieces of plastic; no bigger than 5 mm (Barboza et al., 2018).
- Most microplastic pollution stems from degradation of larger pieces of plastic in water, such as fishing gear (Barboza et al., 2018). However, there are many sources of microplastics that are already at the microscopic size, including personal care products, cosmetics, packing equipment, etc. (Barboza et al., 2018).
- These products commonly used by humans can be transferred into waterways through wastewater treatment plants (Kay et al., 2018), and urban runoff (Anderson et al., 2018).
- The overall goal of this proposal is to understand the negative effects of microplastics on eastern oyster reproduction, water quality, and human health.
- Our hypothesis for this experiment is that if the Chesapeake Bay is polluted by microplastics, then water quality, eastern oyster reproduction, and human health will be negatively affected.

Introduction

- One of the most vital ecosystems in the United States is the Chesapeake Bay. There are a plethora of problems affecting the Bay, ranging from invasive species to climate change (State of the Bay Report, 2016).
- The most common source of microplastics found in the Chesapeake Bay come from wastewater treatment plants and storm drains (Chesapeake Bay Program, 2018).
- A study done on *Daphnia magna* showed that microplastic ingestion affected the fertility, mobility and overall population of *Daphnia magna* for multiple generations (Martins and Guilhermino, 2018).

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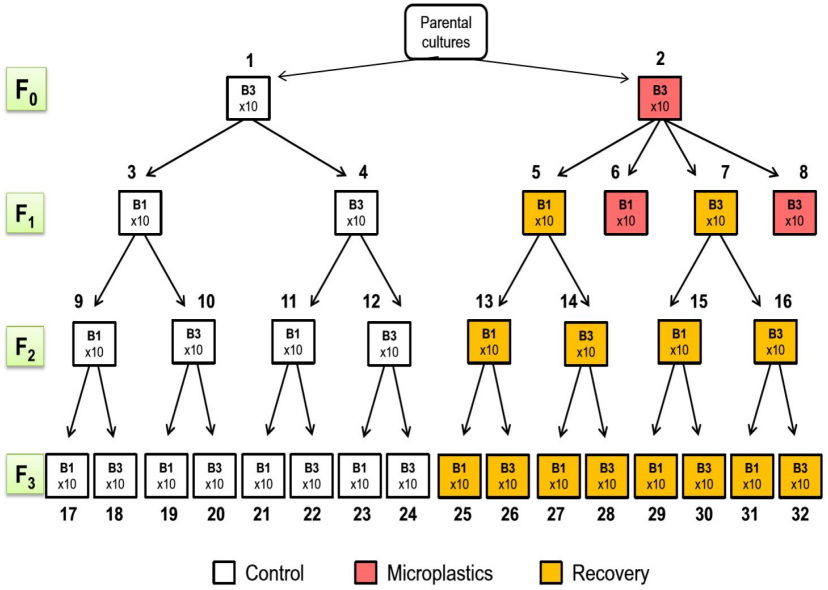


Fig. 1. Experimental design. F_0, F_1, F_2 and F_3 – generations tested. Numbers indicate different groups of females (10 females per group). B1 – females isolated from the first brood. B3 – females isolated from the third brood. Control – females exposed to clean medium. Microplastics – females exposed to 0.1 mg/l of microplastics through test medium. Recovery – females exposed to ASTM and descending from animals exposed to microplastics.

- Microplastic exposure showed significant impact on Daphnia magna by causing parental mortality, reduced fertility and reduced growth (Martins and Guilhermino, 2018).
- The experiment also found that microplastic exposure caused Daphnia magna to ingest less food as well as experience false food satiation, due to microplastics in the gut (Martins and Guilhermino, 2018).
- Although this study is done on a simple organism, there have been studies that have shown similar results when using oysters.
- The microscopic size of microplastics can be easily filtered through and can lead to the contamination of the oyster, leading to reduced reproductive output and overall individual fitness (Galloway and Lewis, 2016).

Introduction

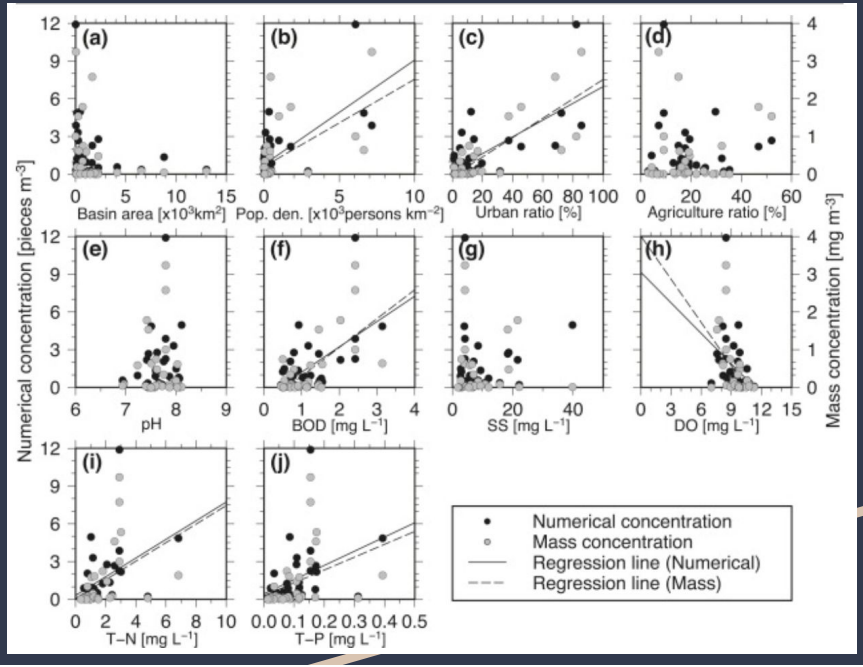


Fig. 3. Correlation of the numerical and mass concentrations with four basin characteristics and six water quality parameters: (a) basin area, (b) population density, (c) urban ratio, (d) agricultural ratio, (e) pH, (f) biochemical oxygen demand (BOD), (g) suspended solids (SS), (h) dissolved oxygen (DO), (i) total nitrogen (T-N) and (j) total phosphorus (T-P). Only significant regression lines are included in this figure, and the statistical significance of the regression lines is shown in Table S3. The legend of the symbols and lines is shown on the right side of panel (j).

- Water quality is something that is affected by microplastic pollution in the Chesapeake Bay. Studies have shown trends between water quality and microplastic pollution (Kataoka et al., 2019).
- Studies have shown that as microplastic pollution increases, so does biochemical oxygen demand (BOD), while dissolved oxygen (DO) decreases as microplastic concentration increases (Kataoka et al., 2019).
- Microplastics commonly contain toxins and chemicals found in plastics that eventually degrade into smaller pieces, whiles still containing these dangerous chemicals which can seep into the water and affect the water quality (Gallo et al., 2018).

Introduction

Table 1
Summary of studies reporting the occurrence of microplastics in shellfish and fish of commercial interest as food.

Species name	Levels of mp	Size range	Parts
Shellfish			
Alectryonella plicatula	10.78 ± 4.07 particles/individual	5–5000 μm	Soft tissue
Amiantis umbonella	6 particles/individual	10–5000 μm	Soft tissue
Amiantis purpuratus	6 particles/individual	10–5000 μm	Soft tissue
Cerithidea cingulata	12 particles/individual	10–5000 μm	Soft tissue
Crangon crangon	0.68 particles/g individual	200–1000 μm	Whole shrimp and peeled shrimp (abdominal muscle tissue)
Crassostrea gigas	0.6 particles/g individual	> 500 μm	Entire tissue
	0.47 particles/g individual	5–25 μm	Soft tissue
Cyclina sinensis	4.82 ± 2.17 particles/individual	5–5000 μm	Soft tissue
Eriocheir sinensis	13% ind. with MP	Not specified	Stomachs
Meretrix lusoria	9.22 particles/individual	5–5000 μm	Soft tissue
Mytilus edulis	0.36 ± 0.07 particles/g	5–25 μm	Soft tissue
Mytilus galloprovincialis	4.33 ± 2.62 particles/individual	5–5000 μm	Soft tissue
	6.2–7.2 particle/g	760–6000 μm	Valves, hepatopancreas and gills
Mytilus spp.	3.2 ± 0.52 particles/individual	200 – > 2000 μm	Soft tissue
Modiolus modiolus	3.5 ± 1.29 particles/individual	200 – > 2000 μm	Soft tissue
Nephrops norvegicus	83% ind. with MP	Not specified	Stomach
Penaeus semisulcatus	7.8 particles/individual	< 100 – > 1000 μm	Muscle, skin
Patinopecten yessoensis	57.17 ± 17.34 particles/individual	5–5000 μm	Soft tissue
Perna perna	26.7% ind. with MP	Not specified	Digestive tract and entire tissue
Pinctada radiata	11 particles/individual	10–5000 μm	Soft tissue
Ruditapes philippinarum	5.72 ± 2.86 particles/individual	5–5000 μm	Soft tissue
Scapharca subcrenata	45 ± 14.98 particles/individual	5–5000 μm	Soft tissue
Sinonovacula constricta	14.33 ± 2.21 particles/individual	5–5000 μm	Soft tissue
Tegillarca granosa	5.33 ± 2.21 particles/individual	5–5000 μm	Soft tissue
Thais mutabilis	3 particles/individual	10–5000 μm	Soft tissue

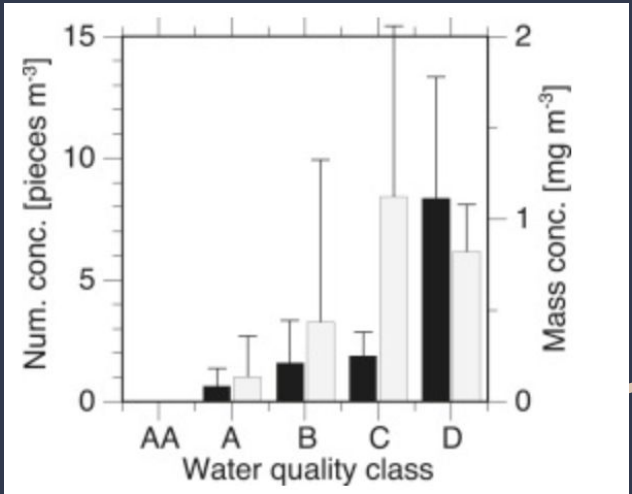
Species of shellfish commonly ingested by humans that contain microplastics (Barboza et al., 2018).

- The impacts of microplastic consumption on humans is limited and there are still many questions about the topic (Barboza et al., 2018).
- Microplastics can flow through the trophic system, with predators ingesting organisms who are already contaminated with microplastics (Barboza et al., 2018).
- There is speculation about the effects of microplastic ingestion in humans, with many scientists claiming that the smaller pieces of microplastics are more dangerous, due to their ability to be absorbed in the human gut (Barboza et al., 2018).
- Other possibilities include the distribution of microplastics to other organs, even placentas in pregnant women, and the possibility of immunotoxicity (Barboza et al., 2018).

Specific Aims

- **Aim 1: Microplastic pollution will decrease water quality by releasing toxins and decreasing the dissolved oxygen in the Chesapeake Bay.** Due to the chemical components of microplastics many toxins, such as polymers, are released into the water and ingested by organisms.
- **Aim 2: Microplastic ingestion will impact the reproductive rate of the eastern oyster in the Chesapeake Bay.** Oysters are a vital component of the Bay's ecosystem, and microplastic pollution can affect their total population by damaging their reproductive abilities.
- **Aim 3: Human health will be negatively impacted by ingesting organisms contaminated with microplastics.** While there is a lack of research done on microplastics affecting human health, there have been studies that show microplastic contamination in seafood that human eat.

Significance



Microplastic concentration increases as water quality decreases (Kataoka et al., 2019).

- Being one of the most important watersheds to humans in the world, the Chesapeake Bay is in danger of microplastic pollution and the consequences that come with it (Chesapeake Bay Program, 2018).
- The most alarming aspect of microplastic pollution in the Bay is the lack of proper research and studies done on it specifically.
- The toxins in microplastics can be released and decrease the dissolved oxygen in the Bay. Little to no oxygen in water leads to dead zone, which harbor no life and are hard to overcome (Kataoka et al., 2019).
- It is important for water quality in the Chesapeake Bay to be studied in order to understand how low the water quality is due to microplastic pollution, and to also find a solution that could save the environment.

Significance

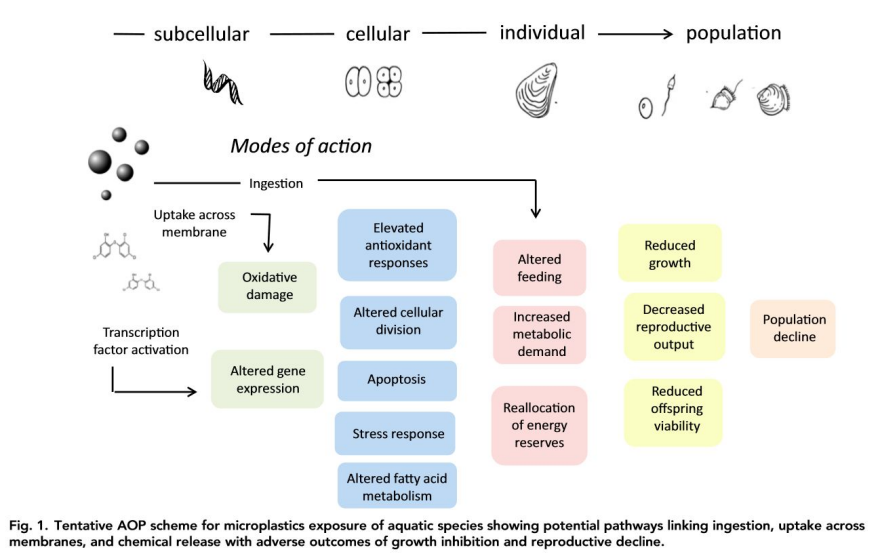


Fig. 1. Tentative AOP scheme for microplastics exposure of aquatic species showing potential pathways linking ingestion, uptake across membranes, and chemical release with adverse outcomes of growth inhibition and reproductive decline.

Effects of microplastic ingestion on oysters from the subcellular level to the entire population (Galloway and Lewis, 2016).

- The significance of oysters in the Chesapeake Bay is huge. They are able to filter debris and improve the water quality.
- Oysters are also a food source for many organisms, including humans.
- With a small oyster population, water quality would decrease, and species who ingest oysters could see their own decline in numbers.
- It is very important for the eastern oysters in the Chesapeake Bay to remain healthy and able to reproduce in order to keep the Bay alive.

Significance

Box 1

Challenges and gaps of knowledge regarding microplastics and implications for human food security, food safety and health.

✓ Since microplastic concentrations are expected to increase in future, it will be increasingly important to regularly assess levels of microplastics in seafood and other food items.

✓ It is important to quantify the presence of microplastics in edible tissues of fish and shellfish. Also, the quantification in edible echinoderms, tunicates and algae also deserves investigation since in several countries they are widely consumed.

✓ Continuous monitoring programs will be required to evaluate the presence of microplastics in environmental compartments and thus avoid the reduction of global fish and shellfish stocks.

✓ Research also should focus on the contributing chemical and microbiological hazards and risks associated with ingested microplastics and in improving methods to evaluate the intake and translocation of these particles in humans.

✓ It is important to adopt food safety risk analysis frameworks to evaluate hazards and risks to consumers of fish, shellfish and food items contaminated with microplastics.

✓ There is a great need to study the assimilation of a range of microplastic sizes and compositions into human tissues and in the development of techniques capable of identifying the presence of microplastics in the human body (e.g. biopsies and tissue banks).

✓ Another area that deserves urgent attention is the presence of nano-sized plastics in seafood on which there is even less data in the literature.

✓ Research on analytical methods, toxicokinetics, and toxicity of micro- and nano-sized plastics is needed to improve the understanding of their potential impacts on seafood safety and human health.

Gaps of knowledge on microplastic effects on human health (Barboza et al., 2018

- There is barely any research on microplastic ingestion affecting human health, which is why it is important for more research to be done on this topic.
- The possible toxins and chemicals that would impact human health and also affect unborn children in pregnant women are rarely discussed.
- More research on how microplastics affect humans could lead to new discoveries in human health and could find a possible solution to reduce microplastic ingestion.

Significance

- The Chesapeake Bay is an important way of life for humans and animals alike.
- Microplastic pollution can kill, and this danger can go up the food-chain to us.
- The main goal of this research is to develop a better and more in-depth understanding of microplastic pollution on the Chesapeake Bay, and learn more about the detrimental effects microplastics have on water quality, eastern oysters, and humans.

Aim 1: Experimental Design

The goal of aim 1 was to determine if microplastic pollution in the Chesapeake Bay affected the DO or other chemical components of the water.

Samples would be taken from three locations in the Bay

One should be shallow or near the shore, one in deep water, and one in an area with a lot of pollution and debris

In order to do this five samples would be taken at varying depths from the surface and going down .5 meters each time at each location

These samples will be tested for pH, dissolved oxygen concentration, and nutrient content

The microplastic content of each location will be measured by collecting samples with nets

The chemical components of each location will then be compared based on the level of microplastics at each location

Aim 2: Experimental Design

100 oysters will be kept in controlled environments in groups of 25

There will be a control group, a group exposed to low levels of microplastics, a group exposed to moderate levels, and a group exposed to high levels of microplastic pollution

The study will be conducted for 60 days during which the reproduction abilities of the oysters will be observed

Variables studied will include the number of eggs they produce and the swimming speed of their sperm

Aim 3: Experimental Design

The objective of this experiment was to determine if the ingestion of microplastics by humans would have adverse effects on their health

100 people were given a diet that including seafood from the Chesapeake Bay for 60 days and a control group, of 100 people, was given a similar diet without the seafood

Their health, blood pressure, heart rate, and reproductive health will be monitored and compared to the control group of people throughout the experimental period

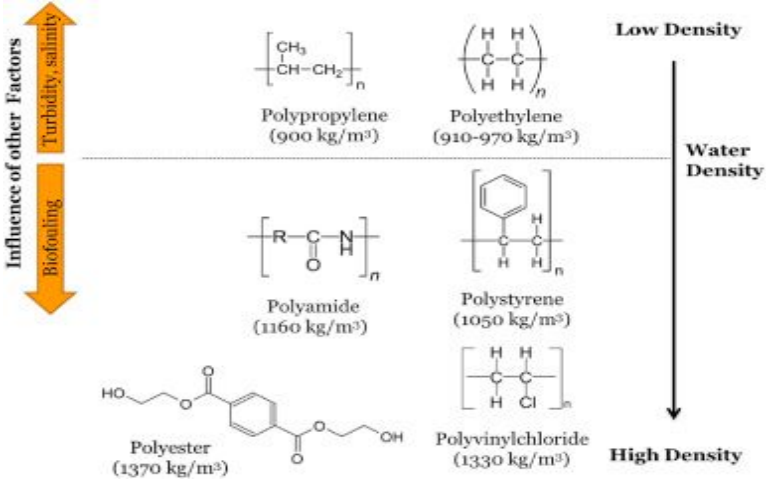
Pitfalls

Aim 1: A potential problems that could affect the outcomes of the experiment could be the fact that microplastics were not the only reason that dissolved oxygen levels decreased in certain areas. Areas in the Bay that experience high levels of algae growth could also face decreased dissolved oxygen levels.

Aim 2: Potential problems that arise from this experiment could be the fact that the eastern oysters collected were already exposed to some sort of contaminant.

Aim 3: A huge factor that could affect results is the fact that most health problems seen in the people from the experiment could not be just from microplastic ingestion. There are many other factors that could affect a person's health such as their environment and genetics.

Expected Results



This graph shows the density, structures, and expected distributions of different plastic polymers in the water column. Factors affecting buoyancy, and the direction of the change, are indicated with the arrows on the left (Anderson, Julie C., et al., 2016).

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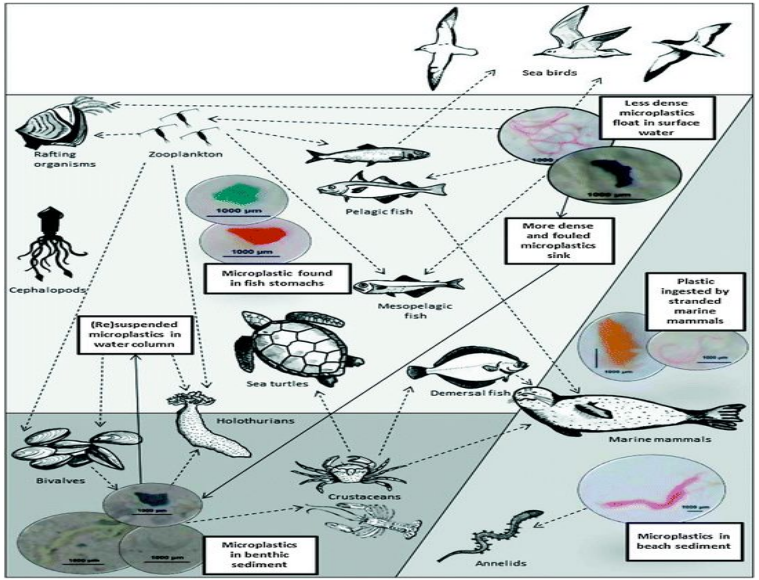
- The microplastics will some consume and spread the Chesapeake Bay's water quality becoming polluted due from high concentrated density of the microplastics.
- The microplastics density appearance can have a significant effect on the Chesapeake Bay current depending on the composition, shape, and density in each individual polymers within the microplastics (Anderson, Julie C., et al., 2016).
- As the density of microplastics grows enough to sink deep of the Chesapeake Bay, the microplastics pollution will spread within the Bay as time pass (Johnson, Harold.16 Aug. 2012).

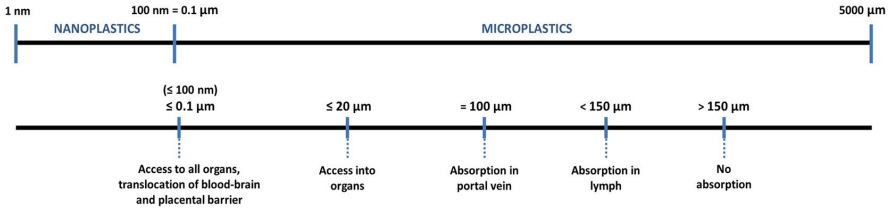
Expected Results



Microplastic interactions in the marine environment including environmental links (*solid arrows*) and biological links (*broken arrows*), which highlights potential trophic transfer (Lusher, Amy 2015)

- The oyster population will soon decrease as they ingested a large number of microplastics.
- When microplastics appearance in a marine environment that can cause behavior, abundance, and toxic effects on the marine food chain (Lusher, Amy 2015).
- During the ingestion, microplastics will go into the trophic transfer then it persists in the tissues which lead to the toxic potential inside the oysters (Lusher, Amy 2015).

Expected Results



This graph shows the fate of nano- and microplastics in humans bodies *Barboza, L. et al. (2018)*.

- The people in the experiment will be unable to breathe and dies from suffers hyperactive heart rate once devouring microplastics that are inside the seafood.
- The microplastics particles may be toxic to a person's internal organs due to the physical damage caused by small particles absorbing into a person's cell membrane.(Barboza, L. et al. 336-348).
- This effect will increase the risk of toxic chemicals to people by consuming seafood that was contaminated with microplastics after ingesting them (Barboza, L. et al. 336-348).

Conclusion

Hypothesis: If the microplastics polluted the Chesapeake, it will have adverse effects on the water quality, people health, and reproduce oyster within the Bay.

Significance important: Determine the microplastics' negative effect towards the Chesapeake Bay's marine environment.

Take Home Message: Make sure that do not leave any plastic waste such as empty bottles of trash or non-renewable resources into the Bay which produced microplastics throughout the Bay.

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