EFFECTS OF PLASTIC POLLUTION ON DEEP OCEAN BIOTA AND ECOSYSTEMS

by

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The deep ocean acts as a sink for plastic pollution. What is less known is how the plastics will affect deep ocean biota and ecosystems. Plastics break down due to physical and chemical forces to overcome their initial buoyancy in the water, and are often covered by living matter to help weight them down. Water movement and certain geologic features also help distribute plastic to the deep ocean. Plastic pollution's effects on the deep ocean biota can include ingestion, inhalation, smothering, introduction of toxins, bacteria, viruses, and potentially diseases into organisms, the spread of invasive species to new ecosystems, and much more. Plastics also have the potential to alter the composition of the sea floor from that of a soft-bottom surface to more of a hard-bottom surface with very little oxygen and opportunity for gas exchange, affecting many sessile and infaunal organisms. These factors have the potential to decrease species populations and biodiversity. Additional areas of study that would greatly benefit the knowledge of how plastic pollution affects deep ocean biota and ecosystems include more research on how plastics interacting with hydrothermal vent fluid can affect surrounding organisms, as well as looking into if plastics from the deep ocean can be upwelled and the potential effects on having microplastics mixed in with the nutrient-dense waters. Due to the resilient nature of deep ocean plastics, the fragile nature of deep ocean ecosystems, and the ability of plastics to affect the health, mobility, and habitat of deep ocean biota, it is reasonable to

predict significant negative impacts on deep ocean ecosystems. Mitigations to these issues are most efficiently tackled by reducing the source of these plastics, but effects of deep ocean plastic pollution will likely continue even after plastic production, consumption, and improper waste disposal is reduced.

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I. Introduction

Plastics have become a modern way of life, which has many effects on both the human and natural environment. Due to the disposable culture that is present among both developing and developed nations, a lot of plastic products become litter, waste, and pollution. This plastic waste does not disappear, but rather becomes part of the environment, and of the ecosystems which it resides in. Effects of plastic pollution on land and shallow marine and aquatic environments are relatively easy to measure, as humans can readily access these places. Therefore, stereotypical images of litter along highways, plastic bottle caps in decomposing seabirds, plastic water bottles floating along a coast or river, or a variety of animals with their heads stuck in jugs are common and well known. In addition, plastic's effects on the ocean's ecosystems are somewhat known, especially when it comes to effects with megafauna and with microplastics entering the food webs in the upper part of the ocean, and in streams. However, there is so much more to planet Earth than just the land, rivers, shores, and ocean surface that can be seen fairly readily. The majority of the planet consists of deep ocean.

Figure 1 (above): A plastic bag, one of the most common plastic polluters, floats in the ocean

With an average depth of over 4000 meters ("How deep is the ocean?"), the deep ocean consists of the largest ecosystem on earth. Half of the planet consists of depths that are below the continental shelf, yet this is where human knowledge about planet Earth is lacking the most (Barnes 1990) This lack of knowledge is due to remoteness and inaccessibility, although a lot of efforts are being made to make the oceans more accessible to human intellect. Human's plastic pollution does not stop at the land or near shore, but rather, the deep ocean is also affected by the plastic waste. It has been found that much plastic waste, from a variety of sources, resides within the water column in deep ocean areas, as well as on and beneath the abyssal ocean floor. Therefore, the fragile deep ocean ecosystems are affected by the anthropogenic plastic pollution. This setting for plastics may make for the ultimate example of how waste does not just "disappear", as plastic lasts for hundreds to thousands of years in the deep ocean due to the conditions of the environment (Barnes 1993). Previous studies have shown that plastics have, in fact, reached these depths, as they are found as by-catch from trawling (Schlining 97), seen in video footage ("MBARI research shows where trash accumulates in the deep sea"), and have come up in other forms of fishing and scientific exploration. Due to the prevalence in the ocean, and the already-known problems that plastics create, it is reasonable to explore the impacts of plastic on deep ocean ecosystems and biota. Since the phylums in the deep ocean include species that are affected by plastic pollution on other parts of planet Earth, it is very reasonable to extrapolate that the plastic pollution will take its toll on these deep ocean ecosystems. This paper acts as an introduction to the plastic pollution of the ocean, how the plastic reaches the deep ocean, effects on deep ocean biota, further potential extrapolated effects, and finally a brief summary of what is being done. Plastic pollution has the potential to have a large effect on deep ocean biota due to the fragile nature of the deep ocean ecosystems and the physical resilience of the plastic at such extreme depths.

II. Input and Transportation of Marine Plastic Debris

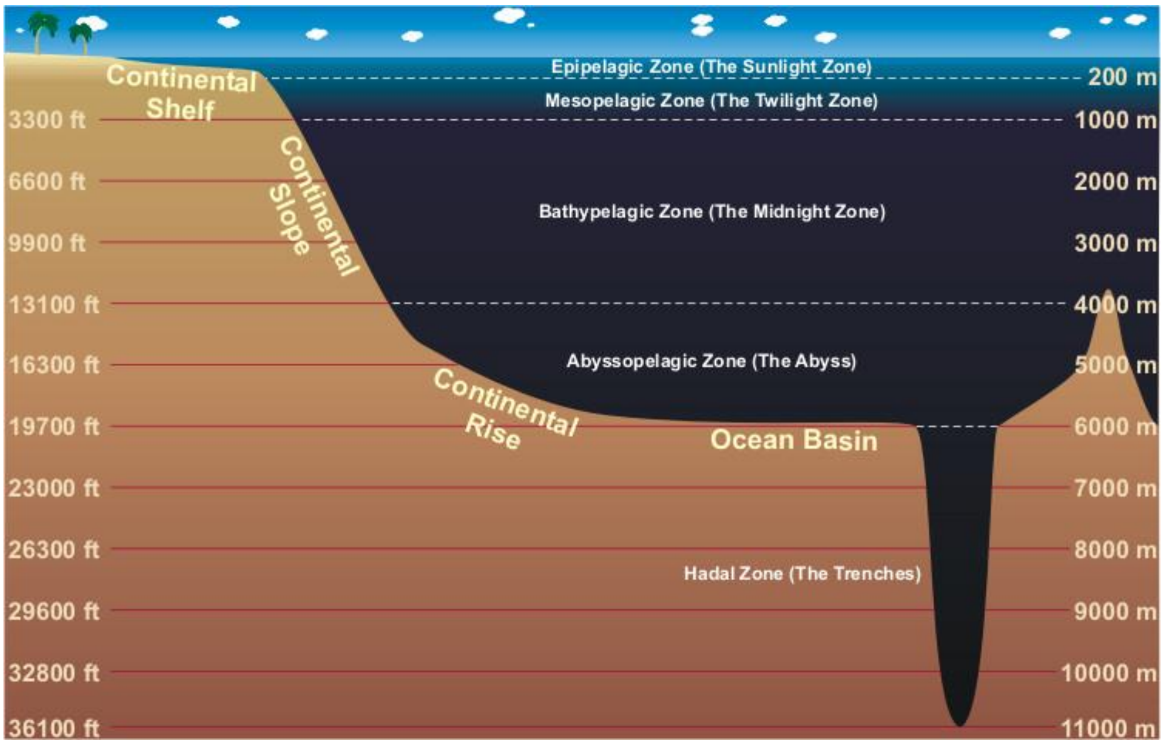

Figure 2 (above): An outline of the different zones of the ocean.

Plastic is not an item that naturally occurs anywhere, but for plastic to get to the ocean, a process must occur. Considering that plastic is a petroleum product, and that all plastic is created on land, all plastic at one point or another originates from the continents. From here, there are a variety of ways that the plastics can end up in the ocean. These sources can be split up into two main groups depending on the source of entry as debris. Plastics can come from land, or they can come from the marine sources. Often, land-based sources can be identified due to material type or plant material that is present with the plastic pollution ("MBARI research shows where trash accumulates in the deep sea"). Some ways in which plastics can reach the ocean from land include litter, purposeful disposal, and river dispersal. Marine-based plastics can come from sources such as fisheries and cruise ships. Although numbers and speculations are constantly fluctuating, it is current thought that up to 80% of marine debris, the majority of which is plastic, is land-based, and about 70% of this ends up at the bottom of the deep ocean ("Good News & Bad News About Ocean Plastics" 2). This means that the plastic pollution that is seen on beaches and at the ocean's surface does not even give the majority of the picture of the plastic pollution problem. To fully understand the full scale of the problem, the distribution of plastics to the deep ocean and their effects must become better known.

At first observation, it may seem odd that plastics are able to sink to the bottom of the ocean. Plastics are generally buoyant in nature, and as seen in Figure 2, the plastics have a long way to travel to reach the bottom of the sea floor. However, there are a variety of actions that can allow them to sink. An accumulation of epibiotic organisms, which attach to the surface of an object, can help weigh down pieces of plastic (Barnes 1988). As discussed later, plastics can act as a habitat for a variety of life forms, some which are visible, and many which are microbial in nature. Physical breakdown can also lead to plastics having more of a tendency to sink, such as with "physical shearing and photodegredation" (Zettler 7138). The action of the water and particles suspended in the water can help break up the plastic. Sunlight, through photodegredation, can also help break the plastic up into smaller parts. The physical characteristics of the ocean's surface are conducive to the break-up of plastics. Ocean currents also play a role in the movement of plastics, and can help plastics migrate to the bottom of the ocean (Fischer 404). Due to both smaller currents and larger currents, such as what composes the great ocean conveyer belt, flows and underwater rivers of water can circulate plastic debris throughout the ocean. Just like the flows of water can bring surface water to the deep ocean, plastic pollution can be distributed to the bottom of the ocean after originating at the surface.

Plastics may then reside at the bottom of the ocean for large periods of time. Some plastics may even be buried further by sediment and debris settlement, as well as landslides ("MBARI research shows where trash accumulates in the deep sea"). The marine snow that falls to create the sediment settlement on the ocean floor helps to create the characteristic soft-bottom abyssal plains that are typical of most places of the deep ocean. Debris that becomes a constituent of the marine snow settles as well, and alters the normal composition of the sea floor. Although the ocean is known as a sink for better known reasons such as carbon sequestration, the bottom of the ocean appears to act as a sink for a variety of marine debris (Gregory 2017). The long periods of time that plastics are theorized to spend at the bottom of the ocean is due to the low levels of oxygen and lack of sunlight. The physical breakup due to shearing from wave action and water movement, as well as the photodegredation and heat that is available at the surface of the ocean is much less available at the bottom of the ocean, and plastics take even longer to degrade. There is also significantly less bacteria to help biodegrade the plastic ("MBARI research shows where trash accumulates in the deep sea"). Each aspect of degradation that naturally occurs becomes less or non-existent. The plastic that makes it to the bottom of the ocean will be given a chance to make an impact on the biota and ecosystems partially because it is given a large amount of time to do so. The effects that the plastics will have at the bottom of the ocean, and are most likely already having, will be long lasting due to plastic's long lasting nature in deep ocean conditions.

III. Description and Distribution of Deep Ocean Plastics

The range of plastics that are found as plastic pollution in the ocean is quite large, however, there are a variety of patterns that can be found. In many studies, including one near Monterey Bay in California, it was found that the primary plastic polluter was plastic bags ("MBARI research shows where trash accumulates in the deep sea"). In addition, plastics are found at all size scales, from macroplastics (Fischer 402) to microplastics. Microplastics are little pieces of plastic that measure less than 5 mm (Microplastics: scientific evidence). Although microplastics are most commonly thought of as little beads of plastic, partially due to many recent attempts to bring microplastics to public attention, the microplastics in the ocean have been found to mainly consist of plastic fibers (Fischer 399), and have also even been found within the sediment of deep ocean floor (Fischer 402). All sorts of plastics are found in the ocean, so the next step is discovering patterns about their distribution.

Although there are patterns, the best way to describe where plastic pollution can be found in ocean is: everywhere. Plastic pollution can be found in all areas of the ocean and deep ocean, as plastics have been found at all depths (Gregory 2017). Plastic is found throughout the water column and in sediment samples at varying depths. It is becoming a universal pollutant of the ocean. This is important to note, as it shows that anthropogenic effects from plastics have the potential to reach all corners of the globe.

There are a few notable patterns of where accumulation tends to occur. "Hydrography, geomorphology, [and] anthropogenic activity" (Schlining 99) have the biggest say in the characteristics of the plastics that reach the deep ocean. The movement of water can help break down plastics. Certain geomorphologic features can help channel water flows into the deep ocean. Submarine canyons are a prime example of this, and are a place well known place for plastic pollution to occur. These geographic features are typically found starting from the continental shelf, cutting through the continental slope, and depositing sediment on the abyssal plain. Figure 3 illustrates a generalized submarine canyon. Due to these characteristics, the canyons act as a transportation pathway for plastic from shallow waters to the deeper abyss (Schlining 96). In a similar way that sediment is dropped from the water as water movement slows, the plastics are dropped from the water as currents flow down the canyons and decrease in speed (Schlining 97).

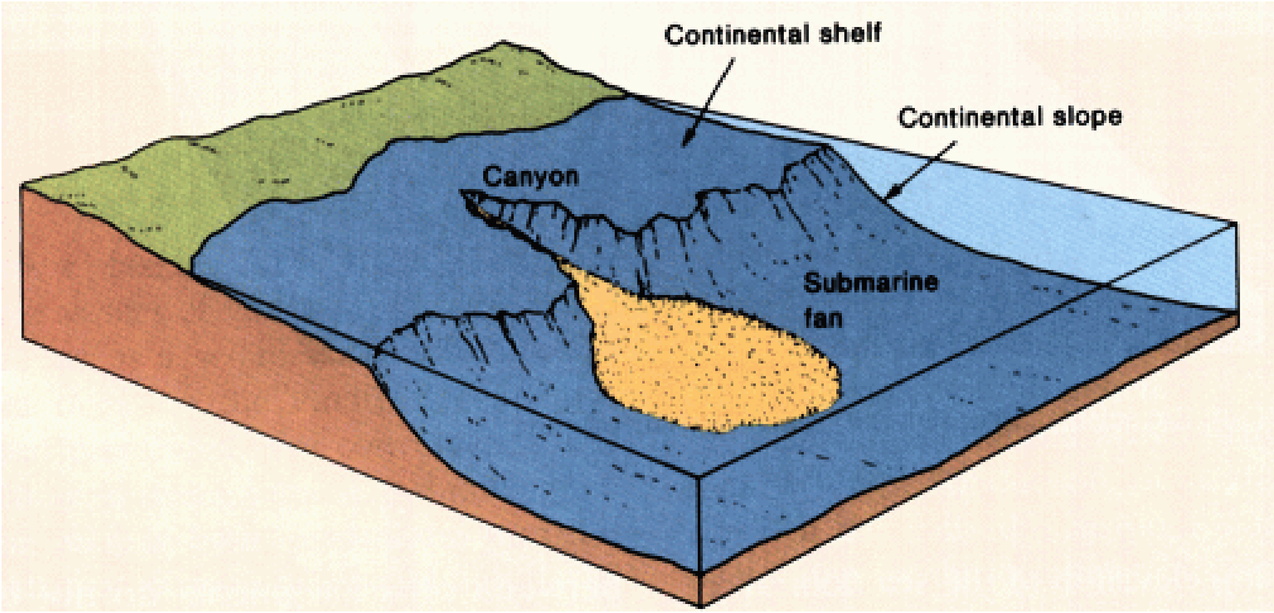

Figure 3 (above): An illustration of a submarine canyon. Just like sediment is brought from shallow to deep waters, plastic can travel down the submarine canyon.

Flows of water down a submarine canyon can feed plastics to the deep ocean, but there are other plastic-dispersing properties that underwater river flows can have. Flows of water that bring plastic pollution over rocky areas also tend to collect plastics ("MBARI research shows where trash accumulates in the deep sea"). As plastic-holding water moves over an obstruction, the plastic can get caught up on the obstacle. It has been found that areas expressing slopes between 30 and 40 degrees have the greatest potential to collect plastic pollution (Schlining 97).

To tie this all together, it can be thought that the plastic accumulates in places of the deep ocean where "physical barriers...and depressions" (Schlining 101) are present. Plastic sinking down a submarine canyon or being caught up on a rocky slope seems somewhat logical when thought of this way. In the case of the Monterey Canyon, plastics were most commonly found in deeper areas, especially below 2000 meters (Schlining 96). This is, again, due to flows from the rivers and currents down canyons that move plastics past the shelf areas and to the deeper, abyssal areas (Barnes 1992). Other examples of depression areas where plastic pollution has been seen to accumulate include the Pacific Kruil-Kamchatka Trench (Fischer 399), in areas of the Mediterranean Sea (Ramirez-Llodra 273), and in the Mississippi Canyon (Wei 966). In areas where plastic pollution has accumulated, the mass of the plastic can be higher than the mass of the biomass collected (Ramirez-Llodra 284). Therefore, these features are having a serious impact on the distribution of deep ocean plastic.

Although geomorphology appears to fit the barrier and depression theory fairly well, crustal formations are not the only barriers found in the ocean. In addition to geologic barriers, fronts within the water column have the potential to act as barriers as well (Gregory 2017). Just as when some air fronts meet above land and condense to form rain, fronts in the water column can cause plastic pollution to accumulate. This can also be thought of as similar to when fronts meet at the surface of the ocean and foam forms due to accumulation and breakdown of proteins and various organic material.

The last aspect that highly determines the distribution of deep ocean plastics is the anthropogenic activity. Plastic marine debris is most present in the Northern Hemisphere due to the higher abundance of land mass, and therefore, the higher abundance of people (Barnes 1985). In discussing plastics, especially the effect that plastics can have on ecosystems, it is important to remember that this is an anthropogenic effect, and an anthropogenic problem. Although the plastic may be distributing the negative effect, it is humans that are causing the problem. In studying plastic pollution, it is important to keep the big picture in mind so that solutions can be found and accomplishments be made in the right direction.

IV. Effects on Marine Biota

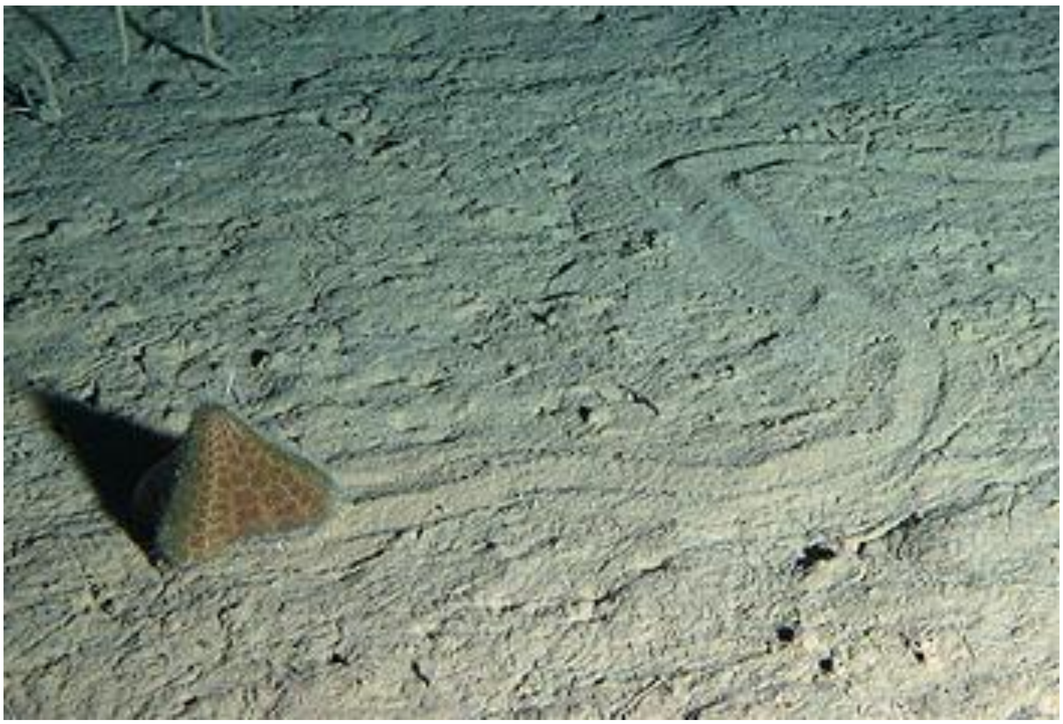

Figure 4 (above): The soft-bottom sediment of the deep ocean can easily be seen as an organism moves above it.

There are a variety of affects that plastics have on marine biota. This is due to differences in plastic composition, size, and constituents, as well as the different creatures that are present to be affected. There are a variety of ways in which the life of the deep ocean feeds. The two most prominent areas are the abyssal floor and hydrothermal vents. The hydrothermal vents rely on chemosynthesis from black smokers, and are able to have a larger amount of individuals and species due to the greater amount of energy available than at abyssal plains. Organisms here can rely on chemosynthetic bacteria to act as an energy source. Abyssal plains contain a variety of species that are either sessile and wait for food to float by or who will eat almost everything and are very opportunistic feeders. Figure 4 depicts a lonely organism on the abyssal plain, where not much else is visible. The very nature and adaptations of organisms that live in the deep sea may lead biotic effects from plastic pollution to be quite large. For example, sessile organisms are would be affected by a variety of factors that have to deal with their immobile nature. First, they may be easily covered by plastic debris, and those that filter feed may end of filter feeding microplastics. Then, those organisms who feed opportunistically, and who generally are characterized by large mouths to accommodate for whatever food comes by, have the ability to ingest large pieces of plastic debris and to feel the effects from that. The potential for biotic effects due to the nature of deep ocean organisms combined with the prevalence and longevity of plastic debris in the deep ocean suggests that the deep ocean ecosystems could be greatly affected.

A. Plastics as a Habitat

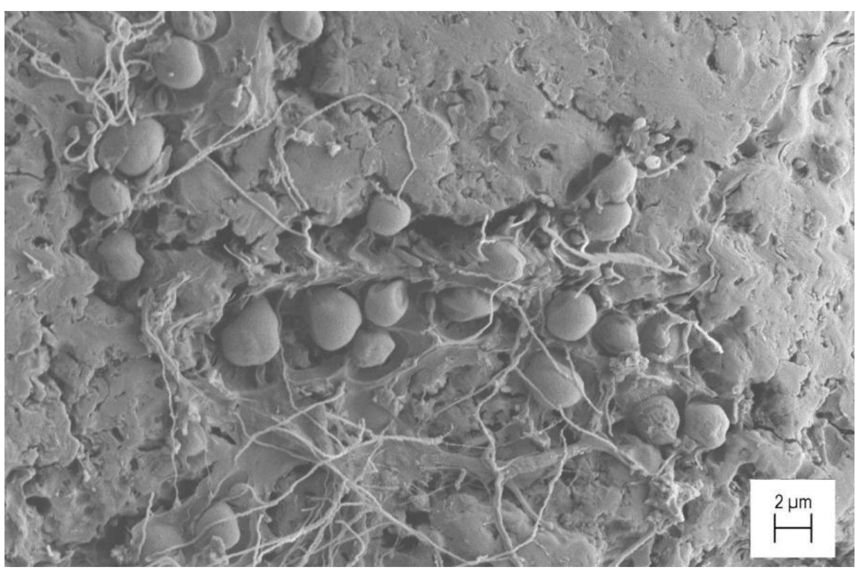

Figure 5 (above): A living community on a piece of plastic

Although the introduction of plastics into the ocean can generally be considered a negative, both macro and microplastics can be places of habitat for biota in the water column and in the deep ocean at the sea floor. A variety of biota, including "hydroids, anemones, asteroids, serpulid worms, crinoids, holothruians, [and] rockfish" (Schlining 98) are commonly found to inhabit plastic debris. In the water column, the plastic debris can act as something to hold onto or hide in, or for microbiota, it can become a place to bury into. Figure 5 depicts a living microbial community on a piece of marine plastic. However, since the plastic tends to travel, the species that inhabit a piece of plastic debris can become invasive species. This can have negatives impacts on biodiversity, as invasive species can often take over an area (Schlining 96). The "plastisphere" (Zettler 7137) has been coined as the term for the ecosystem and habitat created by plastic pollution. This habitat can allow microbes to thrive, and they can even form "pits" (Zettler 7137) in the plastic. This does help the degrading process, but this can also lead to pathogens, diseases (Zettler 7141), and invasives to reside in plastic debris. Both eukaryotes and bacteria have been found as microbial life in plastics (Zettler 7140). If the potentially dangerous microbes make their way to the bottom of the ocean, the fragile ecosystems could be disturbed. In studies, it has been found that the presence of plastic in deep ocean environments doubles the occurrence of invasive species in the area (Ramirez-Llodra 284). Therefore, this threat is very real, and has the potential to make a major impact with native deep ocean biota.

B. Blanketing/Smothering/Entanglement

The process of transporting plastic debris to the bottom of the ocean typically involves the debris slowly settling on the sea floor. There are a variety of difficulties that come along with this. The most common of the plastic debris, the plastic bag, has been known to "smother attached organisms" ("MBARI research shows where trash accumulates in the deep sea"). This is due to a blanketing affect. Many of the sessile creatures that live on the sea floor become smothered and entangled in the plastic debris (Schlining 96). "Cnidarians, sponges, and echinoderms" (Ramirez-Llodra 284), as well as arthropoda (Ramirez-Llodra 284) have been observed entangled and occasionally damaged due to plastic debris. In addition, the blanketing characteristic of the settling plastic debris can cover organisms that are infaunal, or which live below the sea floor within the sediment (Schlining 96). Examples of these organisms can be seen in Figure 6. The blanketing of the ocean floor can then cause issues with gas exchanges, and can create a very low oxygen environment that already has low levels of oxygen as a constricting biotic factor (Gregory 2017). When the plastic debris settles and is covered by more sediment and falling debris, the characteristics of the sea-floor can change, and soft sediment may turn into a hard-bottom area (Gregory 2017). Since many organisms are specially adapted to live their lives in the typical soft sediment of the deep ocean floor, this has the potential to decrease biodiversity and species population sizes.

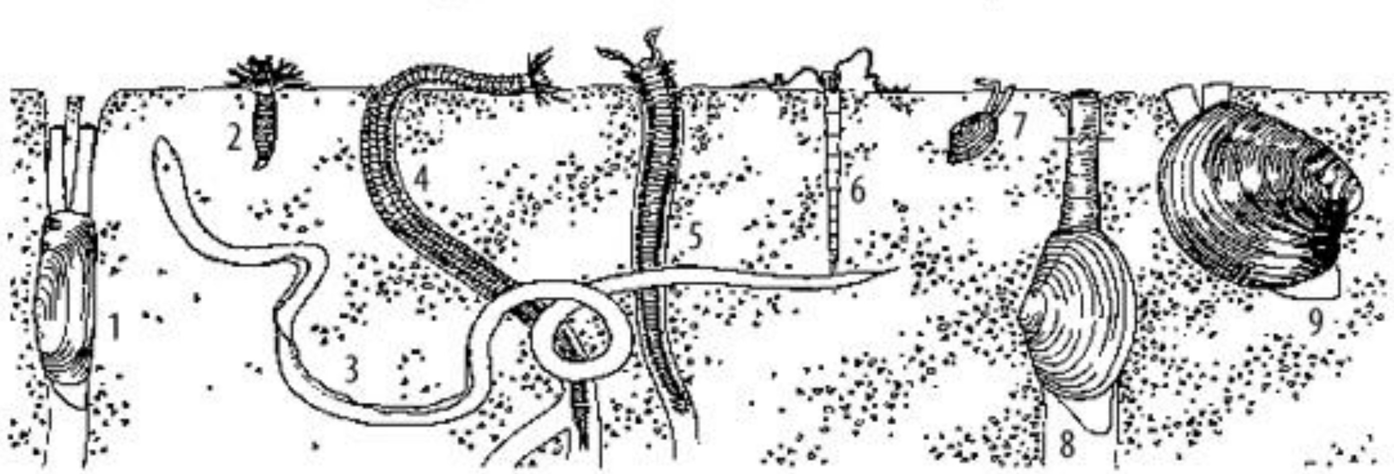

Figure 6 (above): Infaunal organisms below the ocean floor

C. Ingestion

Ingestion is a major issue when it comes to plastic pollution, and is an issue that is already seen in other ecosystems (Schlining 96). "Polychaetes, bivavles, echinoderms, [and] copepods" (Fischer 404) have all been noted to ingest plastic. In Figure 7, a gulper eel with it's very large mouth would easily be able to ingest larger plastics, and may do so since it is an opportunistic feeder. The very prevalent plastic bag can be mistaken as a food source, and can cause disruption in the digestive tract ("MBARI research shows where trash accumulates in the deep sea"). Ingestion of plastics can cause internal damage, as well as further disruptions in the digestive tract, and even starvation and death (Gregory 2015/2016). In addition, "reduction in quality of life and reproductive capacity; drowning and limited predator avoidance; [and] impairment of feeding capacity" (Gregory 2015/2016) can also occur. The physical damage caused by the plastics has the potential to be extreme, and in addition, the potential harmful diseases, bacteria, toxins, chemical constituents, and invasive microbiota that can be on the plastics have the potential to bring much harm to the organisms. Ingestion is by far the primary way that the plastics get inside the organisms and do damage from the inside.

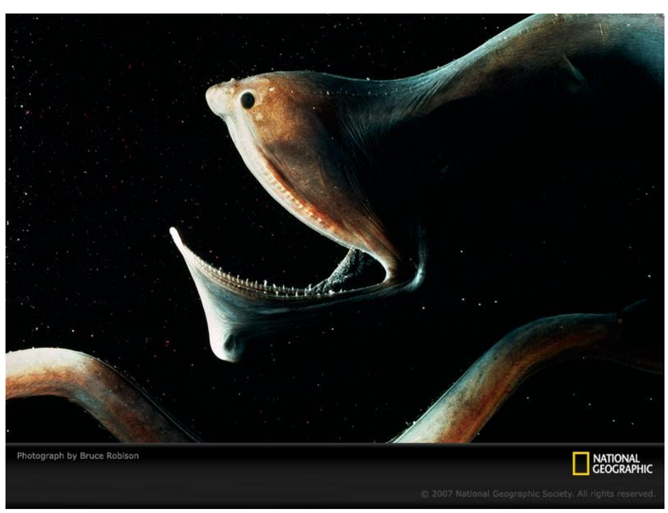

Figure 7 (above): A gulper eel, with its large mouth, is an opportunistic feeder that could accidentally feed on plastic

D. Inhalation

One interesting study found that ingestion is not the only way that plastic pollution finds its way into biota. It has been found that microplastics can be taken in through the gills of crabs, and remain within the body of the crab for a relatively long period of time. Microplastics in these crabs were found to stay in the bodies for 14 days when ingested compared to the normal two days for most food sources (Akpan), but were found to remain within the body for 21 days when taken in through the gills (Watts 8823). This suggests that microplastics could be playing a large part in the respiratory process of deep ocean biota. Since the deep ocean is a place where oxygen and gas levels are typically low, the gas exchange systems of organisms are very vital, and microplastics may have the capacities to disturb the fragile organs that help run them. This may be especially important in places where chemosynthesis is necessary, especially since the chemicals and higher temperatures of the emissions from the hydrothermal vents may interact with the plastic and the attached pollutants in harmful ways. This may become an area of vital research, as ingestion is no longer the only known way for plastics to enter the bodies of living organisms.

E. Microplastics

Microplastics are small pieces of plastics that could either have originated as microplastics or could have degraded from larger pieces of plastic.

Figure 8 (above): Microplastics places next to a ruler to show scale

Microplastics are a primary source for how chemicals associated with plastics are introduced into the food web (Schlining 102). Figure 8 shows how small they are, and it is easy to imagine them being accidentally ingested. Microplastics can easily sorb pollutants from the water, and can transfer these pollutants, as well as chemicals in the plastic, into marine biota (Fischer 404). Due to their size, microplastics are just the size of food that would be expected for filter feeders, such as plankton (Jackson 3770). Therefore, filter feeders may be impacted tremendously from microplastics. Many deep ocean creatures use filter feeding as a passive way of feeding, and collect particles from the water that float by. This is energy efficient, which is good for such a remote area, but this also means that the microplastics that float by become a food source as well. The filter feeders at the bottom of the ocean would be primary consumers, and are vital to higher levels of the food chain. If they become disturbed by the microplastics, either due to clogging of filter feeding abilities or due to toxic effects from chemicals or pollutants in the plastics, then the deep ocean ecosystem balance and biodiversity could be thrown off.

F. Toxins

Plastics are found to be toxic to living organisms in a variety of ways (Schlining 96). Leaching of chemicals associated with the plastics can have negative effects on deep ocean biota (Jackson 3770). In addition, plastics can tend to act as a sponge for the water around them. The plastics are hydrophobic, but attract pollutants and chemicals in the water that can be toxic to living systems (Gregory 2015/2016). It is even thought that PCBs may primarily be entering food webs due to ingestion of plastics that contain them by marine life (Lang 733). Components of the plastics, including styrene and bisphenol-A, are known to disrupt the endocrine system

(Rochman 2014 656). Other chemicals commonly found in plastics can act as synthetic hormones, and often disrupt processes involving female and male hormones (Rochman 2014 656). Even pesticides, metals, and hydrocarbons originating from petroleum have been found attached to plastics in the marine setting and affecting certain fish species (Rochman 2014 657). Reproductive systems have been shown to be hit relatively hard by toxins associated with plastics, as this is shown with many species by the thinning of eggshells and decreases in fitness (Lang 732). However, not all plastics sorb the same types and amount of chemicals. Of the five main types of plastics, it has been found that high-density polyethylene, low density polyethylene, and polypropylene sorb more polychlorinate biphenyls and polycyclic aromatic hydrocarbons (Rochman 2013 1647). Therefore, the types of plastics that get to a certain area due to location, hydromorphology, and geomorphology may affect the plastic-pollution impact on a deep ocean community.

G. Overall Effect on Biodiversity

Due to the difficult environments and bodily harm that the plastic pollution can create, it is reasonable to predict that plastic pollution can have a negative effect on the deep ocean biota and ecosystems. The plastics have the potential to decrease population sizes and the overall biodiversity of an area. It can be predicted that largest impacts will occur with filter feeders and opportunistic feeders, and especially areas with keystone species (such as the hydrothermal vents with tube worms). Additionally, sessile creatures may be very affected due to the blanketing and smothering factor, as larger pieces of plastic would take long amounts of time to break down, and may alter the sea floor surface too greatly and cause difficulty with gas exchanges. It is also important to consider that plastics are going to be continually inputted into the deep ocean for many years to come, and that this is not just a one-time event that species need to survive through. Those species which can utilize the plastics as a habitat and avoid the negative consequences, and adapt to slightly new bottoms surfaces, will be the most likely to survive.

H. Further Research

Although there is not currently much research on the topic, it would not be wild to assume that plastics, and especially microplastics given their similar size to plankton and small nutrient particles, may become of a part of upwelling. This is an aspect that emphasizes how everything is linked together, and when considering how important upwelling zones are to surface level marine biodiversity and food webs, if there is plastic contamination in the nutrient rich waters, this could be a place where a lot of plastics and associated chemicals get into the food chain. Further research and analysis should be conducted on this idea.

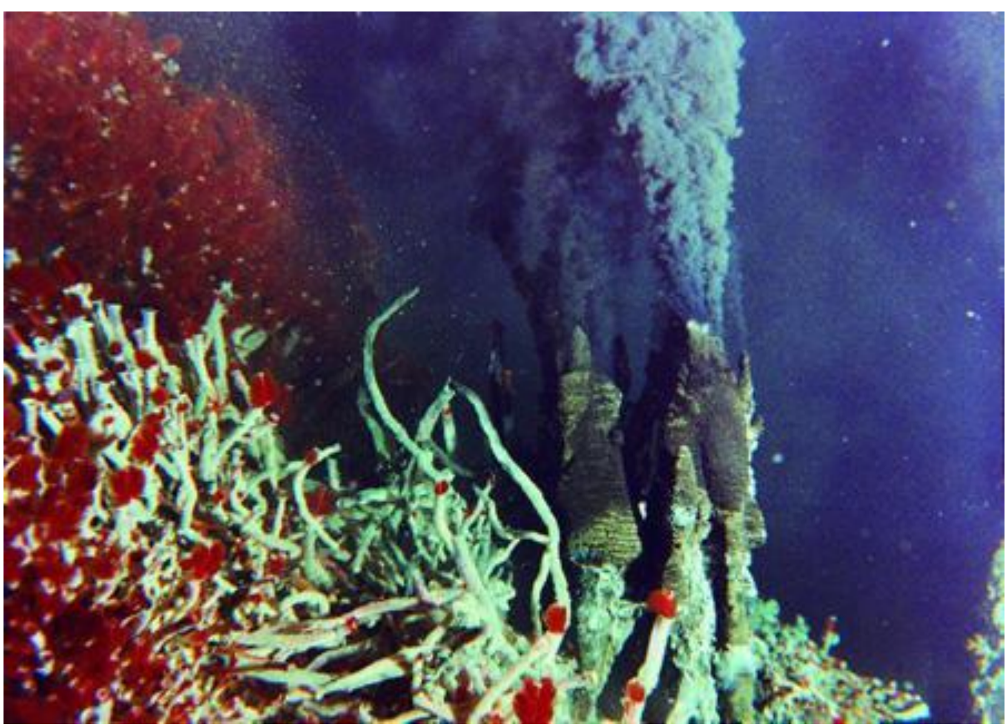

Figure 9 (above): A hydrothermal vent system, tube worms can be seen on the left side of the picture.

Additionally, further research should be conducted on the effect of hydrothermal vents with plastic pollution. Examples of hydrothermal vents and the hydrothermal fluids that come out of them can be seen in Figure 9. If a water bottle is left in a hot car for a day or two, the water inside of the bottle often starts to taste like plastic. Although this would be due to a combination of heat and photodegredation, the effect of the heat from hydrothermal vents may have the ability to produce a similar effect. Although this may help break down the plastics, this may also release dangerous chemicals and toxins into water that is near very fragile organisms that depend on the hydrothermal vents as an energy source. Hydrothermal vents occur at spreading ridges, and since plastics are most likely to accumulate in depressions and at obstacles, it may be common for hydrothermal vent areas to collect plastics. Therefore, studying the potential of the vents to degrade the plastics, release chemicals and toxins into the water, and the ability for the surrounding organisms to absorb those toxins would help predict potential impacts on the deep ocean ecosystems.

V. Preventative Measures

It is vital to stop marine plastic pollution at the source. Since this involves a combination of both land-based and marine-based sources, combined efforts in and between countries must be made. The majority of the materials that are causing harm to the marine ecosystems are materials that can be recycled, and emphasis should be placed on the decrease of disposables consumption and on the increase on reusables and recycling ("MBARI research shows where trash accumulates in the deep sea"). There are some efforts at cleaning up the plastic in the ocean, such as the Ocean Cleanup Array which passively collects plastic debris from the ocean's surface

("Good News & Bad News About Ocean Plastics" 2), but there is no way to efficiently clean up the deep ocean ecosystems that reside on the sea floor. Once the plastic debris is in the ocean, it is often too expensive to clean up. Efforts to do so can also cause further harm on already fragile deep ocean ecosystems ("MBARI research shows where trash accumulates in the deep sea"). Therefore, reducing plastic pollution at the source is the most viable action to reduce further impacts on deep ocean environments.

VI. Conclusion

The deep ocean is an ecosystem that relies on nutrient deposition from the above water column as well as chemosynthetic inputs. The ecosystems found in this area are very fragile, with a complex biodiversity and important keystone species. Anthropogenic plastic pollution is found in all parts of the ocean, and may have a large impact on the deep ocean biota due to their susceptibility. To preserve the biodiversity of the deep ocean, it will become increasingly important to try to reduce the amount of trash from the sources of the plastic. Further research should be done on the effect of the chemicals, toxins, and invasives that can be a part of the plastic pollution and their affect on deep ocean biota, how these same constituents interact with hydrothermal vent communities, and whether or not plastic pollution may also become a part of upwelling. The organisms which have a sessile nature and which feed opportunistically or through filter feeding have the biggest chance of being negatively affected by the plastic pollution. There are far too many points of large potential impacts towards deep ocean biota caused by plastic pollution for this topic to go unnoticed. Further research is vital to discover even more about the effects of plastics on deep ocean biota, and to discover ways to mitigate certain harmful effects.

VII. Acknowledgements

A big thank you to my faculty advisor, Karyn Kaplan, for the support in scientific and academic endeavors as well as in personal awareness about sustainability and the environment. In addition, thank you to Peg Boulay for overseeing the Environmental Science department at the University of Oregon, and to all of the teachers and professors who have inspired me pursue my interests in the natural sciences and sustainability.

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