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Seabirds are threatened by marine plastic debris

Figure 1The Ocean Cleanup Foundation system using a floating boom to concentrate marine debris for removal from our oceans, measuring at length of 600m with a skirt underneath that prevents marine debris from escaping the system. Adapted from The Ocean Cleanup Foundation. Copyright [2018]. https://www.theoceancleanup.com/media-gallery/

Over the expansive oceans that cover the majority of our planet soars majestic seabirds that have evolved to live almost exclusively over the open water. Albatrosses, shearwaters and petrels are only a few examples of seabirds that have managed to adapt to this type of lifestyle that many other organisms cannot endure. Yet, with increasing anthropogenic input of plastic and other waste into our oceans, it raises concern as to how seabirds, amongst many other marine organisms, may be affected.

Marine birds lead an almost-exclusive pelagic lifestyle, meaning they feed only offshore on open water.[1] These organisms demonstrate the fascinating ability to forage away from land in great distances, sometimes spending weeks out over the ocean.[1] Unlike land birds, they only spend sporadic periods of time on land during breeding season to raise their offspring. Because seabirds make use of both land and sea, there are many unique adaptations that allow them to travel between different environments daily.[1] For instance, many have adapted to the landscape with webbed feet for swimming or diving and bills that allow them to capture seafood.[1] The diet of seabirds is diverse, with some feeding on fish while others specialize on krill or crustaceans.[1] Yet, with such an immense area to forage over the ocean and temporal and spatial changes in the landscape, it begs the question of how seabirds successfully forage for food!

Some seabirds have developed an adaptation using their olfactory system to locate food, which come from the order Procellariiformes. This large classification includes four families: Diomedeidae (albatrosses), Procellariidae (petrels and shearwaters), Hydrobatidae (storm petrels) and Pelecanoididae (pelicans).[2] Dependent on the species of bird, their diet can range from fish to squid to krill.[3] Notably, these food sources may be difficult to locate over a vast ocean landscape, but their highly advanced olfactory system enables them to succeed in finding resources.[3]

Past studies have observed that some species of Procellariiform seabirds are capable of sensing the compound dimethyl sulfide (DMS) in the atmosphere as an olfactory cue to find large productive areas.[3–5] The production of DMS begins with phytoplankton, a primary producer in marine food webs that captures energy from the sun in order to photosynthesize and produce organic materials, such as glucose and oxygen (Figure 1).[3] Phytoplankton release DMS as a byproduct of dimethyl sulphoniopropionate decomposition and this process occurs more rapidly when secondary consumers, such as zooplankton, actively graze on phytoplankton blooms.[4] DMS will then diffuse into the surrounding atmosphere. Because this compound can persist in the air for long periods of time, it has been suggested that seabirds can locate these active zones using olfaction to find food in large quantities.[4]

How do plastics affect Procellariiform seabirds?

Plastics in our oceans has been a growing issue for decades, but a more novel concern is ingestion of plastic and other marine debris by seabirds. Marine plastic debris is often introduced into oceans through terrestrial runoff from rivers and sewage systems. Most plastics do not biodegrade so they consistently remain in the oceanic system.[6] Growing human populations worldwide has resulted in an overall increase in plastic demand, with approximately 280 million tonnes of plastic produced in 2011.[6] Plastics may be problematic for marine organisms for two main reasons: ingestion and entanglement.[6] A large-scale review in 2015 on marine debris found that entanglement was a larger issue than ingestion of plastics for organisms such as sea turtles, marine mammals and seabirds.[6] However, there have been studies that found plastic ingestion to be a growing problem, especially for seabirds that forage for prey on surface ocean waters.

In one study, Colabuona et al[7] necropsied 193 birds to look at plastic ingestion by Procellariiform seabirds in Southern Brazil. Of all the birds sampled, nearly 40% were found to have plastic objects within their digestive system. They determined that generally, petrels more frequently consumed plastic than albatrosses. For larger birds like albatrosses, plastic fragments may pass through their digestive system more readily than petrels which are considerably smaller. Long-term exposure to plastics internally can create a whole host of problems including obstructions and internal injuries as well as exposure to pollutants that may have been absorbed in those plastics.[7]

When analyzing the forms of plastic consumed, Colabuona et al[7] concluded that it was mostly fragments with low densities, meaning plastics would float on the ocean surface. Roman et al[2] confirmed that marine debris on surface waters would pose a threat to seabirds that forage along the ocean surface. They used a model that predicted what ecological factors would increase marine debris ingestion and found that foraging behaviour was one of the most prominent drivers for this issue. In analyzing case studies, they observed a species of diving shearwater had a significantly lower amount of debris ingested than surface feeding fairy prions within the same geographic location.[2]

A novel concept that could also explain plastic ingestion by Procellariiform seabirds arose in 2016 by Savoca et al[8], using the term biofouling in relation to DMS. Biofouling occurs when plastics in the ocean take up chemical compounds produced by biota, such as phytoplankton producing DMS. Their study experimentally tested how likely different types of plastic would take up DMS in an oceanic setting. Using common forms of plastic, they placed three varieties of plastic samples during upwelling season onto buoys in the California current in the Pacific ocean.[8] In upwelling season, surface currents are replaced by deep water currents which are rich in nutrients, thus fueling large phytoplankton production and subsequent DMS production. Researchers found that "[the] three common varieties of plastic acquire a DMS signature after less than a month of marine exposure at concentrations that Procellariiform seabirds can detect".[8] This result suggests that seabirds may be detecting DMS signals from plastic debris, subsequently ingesting plastic as a mistake for food.

Though researchers showed plastic can take up DMS signatures, very few studies have experimentally shown the link between olfactory cues and plastic ingestion for these species of birds. Savoca et al[8] conducted a large-scale review on past studies of Procellariiform seabirds to understand whether using DMS as an olfactory cue increased frequency of plastic consumption. They concluded that species that were responsive to DMS were five times more likely to ingest plastic than those that did not rely on the compound. They, therefore, suggest that Procellariiform seabirds may be more reliant on olfaction than vision when foraging for prey, leading to plastic ingestion by mistake.[8] However, their methodology and conclusions have been recently questioned by other scientists, suggesting Savoca et al misclassified some species as DMS-responsive in their analyses which could ultimately change their statistical results.[9] Therefore, more experimental research is required to confirm this new finding.

Finally, an important, and almost obvious, ecological driver of marine debris ingestion is simply *exposure* to plastics and other pollutants. Researchers observed that along more heavily polluted areas such as the Hawaiian Islands, there was a significantly higher rate of marine debris ingestion in some species within Procellariiformes.[2] Thus, it is our responsibility as part of the human population to mitigate and control the exposure of plastics to organisms, such as seabirds, that suffer from polluted oceans as a result of anthropogenic activity.

Working solutions to reduce plastic in our oceans

A solution to our plastic problem is not a simple one given the magnitude of the issue globally. Inarguably, a major issue is developing methods to remove plastic from our oceans as it is nonbiodegradable and poses constant threats to all marine organisms. To achieve this, it is important to understand and quantify the amount of plastic and marine debris in the ocean, leading then to large-scale removal of plastics. The Ocean Cleanup Foundation (TOC Foundation), a not-for-profit organization founded by a young engineering student Boyan Slat, has developed many forms of technology for plastic removal from oceans and has published scientific papers on methods for quantifying plastic debris in our oceans.[10–12]

TOC Foundation developed a method to sense plastics in oceans using an airborne shortwave infrared imager, which in simple terms uses optical sensors on an aircraft to detect plastic fragments in the ocean.[11] Recording information such as position and type of plastic provides useful information to detect and quantify the amount of debris in the oceans. Researchers tested this new technology along the Great Pacific Garbage Patch, a large area in the Pacific Ocean of accumulated marine debris as a result of seasonal currents and wind patterns. Their sensors were able to capture position, size, colour and type of the plastic identified in the ocean, which allowed them to locate and quantify the abundance of debris.[11] However, there were limitations as they were only able to use certain known properties of plastics for their sensors to detect the fragments. Over time, plastic can alter their size, shape and colour based on the environment and sensors may not be able to capture all debris in the environment. Thus, this area of research is still ongoing to improve technology.

Nevertheless, knowledge gained from these research studies has enabled TOC Foundation to advance their technology towards plastic clean-up in our oceans. A simple, yet seemingly powerful, design using floating booms to clean up the Great Pacific Garbage Patch has generated hope that our oceans can be rid of debris (Figure 2). Floating booms are more commonly used to contain oil spills in the ocean, but TOC Foundation suggested that it can be used to concentrate marine debris into one centre point autonomously, where it can then be extracted by vessels to be properly recycled.[13] Though this technology has yet to be employed and scientifically reviewed, research has focused on addressing environmental conditions, such as wind, seasonal changes and ocean currents, that may affect their ability to collect plastic debris.[13] They intend on setting out to clean the Pacific Ocean in 2020.

In the meantime, efforts on a smaller scale has generated research data on plastics that could aid in future policy changes and campaigns to reduce plastic usage. The Great Canadian Shoreline Cleanup is a conservation group encouraging volunteers nationally to clean their local shorelines from litter. A recent paper was published in 2018 by Konecny et al[14], summarizing the trends observed in litter collected along shorelines in British Columbia, Canada. Over forty categories, researchers found that the majority of the trash was composed of plastics along all shorelines, providing important information to policy makers and waste management employers in order to change current policies to improve our plastic situation.[14]

To conclude, there is not one clear and concise solution that will protect seabirds from ingesting plastic debris as the problem is complicated on many levels. Changes in policies, waste management strategies and public awareness is equally as important as developing advanced technology that will clean the existing plastic debris in our oceans. Simply volunteering with local groups is an act that could reduce litter from reaching oceans and affecting seabirds and other marine organisms. Therefore, efforts on a small and large scale are essential in order to preserve the diversity of organisms on our planet and within our oceans.

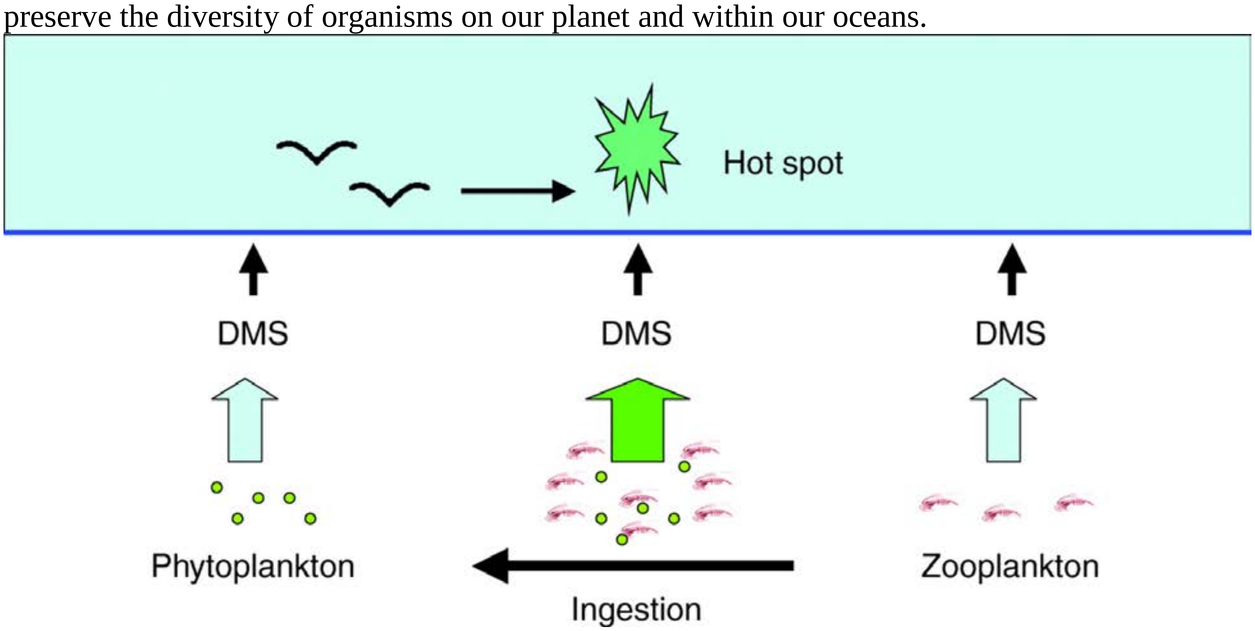

Figure 2. Proposed mechanism of DMS production in which primary producers, phytoplankton, release DMS more rapidly when consumed by secondary consumers, such as zooplankton. DMS

diffuses into the surrounding atmosphere and seabirds, such as those in the order Procellariiformes, may use it as an olfactory cue to locate highly active zones in the ocean. Adapted from "Sensory ecology on the high seas: the odor world of the procellariiform seabirds," by G.A. Nevitt. 2008, *J Exp Biol*, 211,1706-1713. Copyright [2008]. doi: 10.1242/jeb.015412.

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