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Plastic Pollution in the Ocean: How Many Animals Die from Pollution?

Ocean Blue PROJECT

This report was written as part of Ocean Blue Project's Microplastics Recovery Program and has been brought to you through volunteer efforts to inform and inspire beach cleanup volunteers, environmental stewards, and ocean lovers everywhere. It is not a full study, and serves as a technical review of relevant scientific literature and studies to connect the general public with science, influence the direction of future scientific studies and inform policy makers on the impacts plastic has on life from sea to shore.

Acknowledgements

Karisa Boyce Arterbury, Director of Operations at Ocean Blue Project, mother, and facilitator of change, continues to remain a powerhouse in effectively rehabilitating and preserving our planet's rivers, waterways and oceans. Continuing the legacy of her grandmother, Karisa has collaborated with schools, agencies and organizations around the nation, providing the educational and technical resources needed to keep waterways clean. In her first year as a director, Ocean Blue increased its revenue by 600%, and has since expanded to include partnerships far and wide. With a background immersed in the awareness that environmental and social justice go hand-in-hand, Karisa harmoniously provides solutions for communities to be engaged and active in the protection of their local waters.

Tonia C. Jorgenson currently resides in Madison, Wisconsin. She is passionate about environmental causes, animals, nature, travel, research science, and endurance sports. Tonia is a former research scientist at the University of Wisconsin-Madison. She would like to acknowledge Ocean Blue Project, Inc. for providing her with an excellent opportunity to be involved in an interesting and important research project and collaborate with like-minded professionals from all across the globe. It has allowed her to expand her research skill set outside of an academic setting within a nonprofit organization. The experience has been positive and Tonia has enjoyed learning and giving back to a cause she feels strongly about supporting.

Surabhi Ram grew up in India and came to California for graduate school where she fell in love with the coastlines of Santa Barbara. She has worked in the private and non-profit sectors, gaining experience in data analysis and project management, while volunteering with grassroots organizations focused on conservation and marine stewardship. Surabhi recently volunteered with Ocean Blue Project, an opportunity she discovered through Patagonia Actions Works. This project was the perfect opportunity to combine her experience and skills with her passion for marine conservation, while working with other like-minded individuals at the organization. She loves all things water and whales, and has through the pandemic spent most of her free time snorkeling, kayaking, learning to surf and watching whales and dolphins off the coast.

Violette is a French national who thrives in New York City. Growing up on a Caribbean island, she understood early on the importance of the ocean and its role in maintaining ecological balance. She is fond of activities linked to the sea: sailing, and scuba diving while actively participating in ocean stewardship. She holds an MBA from Lehigh University, and currently works for an Investment Bank.

Lindsay Hartley-Backhouse is a British scientific researcher based in northern Thailand, who has been working within local and international wildlife NGOs in Asia for the past 12 years. She specializes in wildlife welfare and environmental science, with a particular interest in marine ecosystems and protection policies. Her published work includes reports on marine debris, ghost fishing gear and exploitation of captive cetaceans. She graduated from the University of Edinburgh's Royal (Dick) School of Veterinary Studies with a Masters in International Animal Welfare, Ethics and Law and is currently finishing a Professional Certificate in Environmental Management for Sustainability from the University of Maryland Center for Environmental Science.

Chelsea Good grew up in Indiana, always traveling to Florida every year with her family. This began her love of the ocean and marine life. Visiting the beach, she had a passion to grow up and become a marine biologist. Instead, she graduated with a Business degree from Ball State University. She has turned to writing for ocean conservation organizations in hopes to help educate and promote how important it is to have a better ocean for ourselves and our future. Chelsea enjoys every trip she can get to the ocean. She loves watching dolphins and whales, and has a dream one day to go diving with whale sharks.

Justina Anise is from New Jersey. During her youth, she lived in a coastal town on the Atlantic Ocean and loved nighttimes spent on the beach stargazing. She lives her life by her values which are centered around equity for all people, protecting this planet and all living beings. Justina works in the environmental consulting industry and in her spare time is an avid hiker, climber, biker and yoga practitioner. Justina is honored and privileged to volunteer with Ocean Blue Project, advocating for the health of our Ocean and our ecosystems.

Florian is a multi-media designer from Vienna, Austria. He joined the Ocean Blue Project Borad of Directors in May 2020 after having volunteered to design some infographics for Ocean Blue. Living in a land-locked country, he has been fascinated by the oceans ever since he was a child. As a father of two little boys, he now considers the oceans' protection vitally important. Florian wants to continue supporting Ocean Blue in spreading information by translating it into infographics, a few of which are featured in this report, that are both easy to understand and aesthetically pleasing. He also wants to add a European perspective to Ocean Blue's work.

Nhan Dong is a Graphic Designer. She was born and raised in Vietnam. She graduated with a degree in Visual Communication and wants to use her knowledge in what she deeply cares about: the environment. She believes the ocean is the root of all existence on Earth, and it shouldn't be taken for granted. She solidifies her belief by contributing her graphic skills to make this project possible and accessible to the public.

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Contents

Photo by Ocean Blue Project

What is Ocean Blue Project?

Ocean Blue Project is a grassroots environmental non-profit founded on June 8, 2012 at Nye Beach in Newport, Oregon. Father-and-son tribal members of the Choctaw Nation of Oklahoma, Richard and Fleet Arterbury, hosted a World Oceans Day beach cleanup and have continued in Ocean cleanup efforts ever since. Ocean Blue goals include empowering landowners, communities and local governments by providing them with planning and technical assistance to support local marine ecosystems.

Our main goal is to remove 1 million pounds of debris and microplastic from beaches by 2025. Our mission is to protect our one world ocean, improve urban water quality by using a holistic ecosystem based approach that synergistically reduces pollutants entering the river, prevents erosion, and provides wildlife habitat. Through the process of beach cleanups and urban waterway restoration projects that enhance wildlife habitat, Ocean Blue Project is providing environmental education, connecting people in communities around the United States to their natural environments, and improving biodiversity.

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How Many Animals Die From Plastic Pollution in the Ocean?

While marine life has awed and inspired people for thousands of years, we now have to ask ourselves, how many animals die from plastic pollution in the ocean? Aristotle, who lived between 384-323 BC, recorded what we currently think of as the very first references to a variety of marine species and is noted as the father of zoology and marine biology (Voultsiadou et al., 2017). Now, over 2,300 years later, we are becoming increasingly aware of our connection to marine life and the threats we pose to it.

Human survival depends on the health and balance of a global ocean ecosystem and its inhabitants. We know that over three billion people rely on the ocean for their main source of animal protein, while over 200 million people are directly or indirectly employed in marine fisheries (United Nations, 2015a). From whales to microscopic phytoplankton, the balance of life in the ocean depends on animals; in turn, the balance of the entire planet depends on healthy oceans and the awe-inspiring sea creatures that continue to captivate humans to this day.

Phytoplankton — tiny oceanic organisms — are responsible for producing over half the world's oxygen and capture 37 billion metric tons of CO^2. This is approximately 40% of all CO^2 produced on the planet, or equivalent to the CO^2 amount captured by 1.7 trillion trees or four Amazon forests (Chami et al., 2019).

Whales are intrinsically linked to phytoplankton. Whale waste products contain the nutrients needed for phytoplankton to thrive, while whale movement distributes this 'fertilizer', ensuring increased phytoplankton growth within whale ranges. In addition to aiding oxygen-friendly phytoplankton growth, whales themselves sequester harmful carbon. A single great whale sequesters an average of 33 tons of CO^2 within its body during its lifetime; after death, the sequestered carbon sinks to the ocean floor (Chami et al., 2019).

Whaling takes a toll on whale populations and, subsequently, their overall potential to sequester carbon. However, there is another risk whales and other marine animals are facing, one that we can all actively take a stand against here and now - the plastic pollution crisis.

In 2016 — the most recent year providing global figures — an estimated 11 million metric tons of plastic waste made its way into our one world ocean, adding to the estimated 150 million metric tons of plastic already present (The Pew Charitable Trusts & SYSTEMIQ, 2020). With out-of-control plastic production rates combined with mismanagement of plastic waste, Pew Charitable Trust expects there to be triple that amount of plastic leaked into the ocean by 2040, to 29 million metric tons every year. Current commitments only reduce annual plastic leakage by 7%. In the following pages, you will learn how plastic is specifically impacting a number of wildlife species. We will briefly highlight a combination of solutions that will reduce plastic pollution 80% by 2040 while collectively saving governments $70 billion (The Pew Charitable Trusts & SYSTEMIQ, 2020).

Current statistics estimate plastic debris causes the deaths of over one million seabirds and over 100,000 marine mammals annually, though the exact number is unknown and may be much higher (United Nations Educational, Scientific and Cultural Organization, 2021a).

Knowledge of plastic pollution and its harmful effects on the environment, wildlife and the food web is rapidly advancing. While the focus of research on plastic pollution has typically been ocean-based, scientists are now recognizing that terrestrial streams and rivers are common transport paths and origins of plastic pollution (Horton et al., 2017; Eerkes-Medrano et al., 2015). Here, you will find a brief summary of a selection of key research. Further extensive scientific reports and reviews are available online for those wishing to learn more beyond the scope of this report.

What are plastics?

Plastics are used by almost everyone globally, but what are plastics made of? Plastic comes from byproducts of natural, organic materials including crude oil, natural gas, coal, or plant cellulose. However, plastics never fully biodegrade or decompose. Plastic is a synthetic organic polymer that is inexpensive to manufacture, lightweight, strong, and durable, making it ideal for a wide variety of applications. Plastics are typically mass produced from fossil fuels into synthetic polymers for production of various products such as bottles, food containers, balloons, and tires. (GESAMP, 2016). However, more recently the push has been for more biomass-derived natural biopolymers for production of renewable plastics (Motagamwala et al., 2018).

Primary plastics can simply be defined as any polymer fragment or particle composed of polyethylene (PE, high and low density), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS, including expanded EPS), polyurethane (PUR), or polyethylene terephthalate (PET) with or without additives, such as those used as fillers, plasticizers, colorants, stabilizers and fire proofing (GESAMP, 2016). Secondary plastics are typically created from the degradation, fragmentation, or mineralization of the larger and primary plastics due to natural weathering processes. Many clothes are made from fabrics such as polyester, nylon, and acrylic that shed plastic microfibers when washed. Microplastics can be either primary or secondary fragments, with a size less than 5.0 mm. Nanoplastics measure less than 100 nm and are likely to enter membranes and affect how cells function. Plastics measuring more than 5.0 mm are known as macroplastics, while those above 50cm are megaplastics.

Plastic Production and Pollution

Global plastic production and pollution have increased exponentially over the last few decades from 5 million tonnes per year in the 1960s to 368 million tonnes in 2019 (Plastics Europe, 2020). Although plastic is useful for manufacturing, it is a detriment to marine ecosystems, with an estimated 8 million metric tons entering the oceans every year (Jambeck et al., 2015).

According to the Ellen Macarthur Foundation (2016):

- In 2013, the global plastic industry put 78 million tonnes of plastic packaging on the market, totaling in value at USD 260 billion. 98% of that came from brand new, virgin materials. Plastic packaging volumes are expected to continue to steadily rise. The amount will double within 15 years and more than quadruple by 2050, to an estimated 318 million tonnes annually.

- Of the 78 million tonnes of plastic produced, 40% is landfilled and 14% is incinerated, both of which cause environmental problems. 32% is classified as leakage, where the waste plastic goes into the environment outside of landfills and incineration.

- Only 14% of plastics produced are collected for recycling - the majority of which goes into cascaded recycling, where the plastics are recycled for other lower-value uses. 4% of the plastics produced are lost during the recycling process, while the remaining 2% go into close-loop recycling, where it is recycled into the same or similar-quality applications.

- With so much plastic leakage and poor disposal, at the current rate of production and consumption, by 2050 there will be more plastic in the ocean than fish.

Photo by Naja Bertolt Jensen on Unsplash

Plastic debris is alarming because of how much of it is in the natural environment, especially in the water:

There are broadly two non-point sources of marine plastic:

1. Ocean-based plastic, which originates from the fishing industry, nautical activities (such as cruise ships), and aquaculture. This includes abandoned, lost or otherwise discarded fishing gear (ALDFG), which accounts for a minimum of 10% of waste entering the oceans and is recognized as the deadliest threat to marine wildlife according to the UN Food and Agriculture Organization or FAO (2020). Marine mammals such as turtles and seals, plus animals such as seabirds and fish are commonly found dead entangled in fishing equipment (Kühn & van Freneker, 2020).

2. Land-based plastic, which is from urban and storm runoffs, sewage and drainage systems, inadequate waste management, industrial activities, construction, illegal dumping, and litter from recreational activities at the beach.

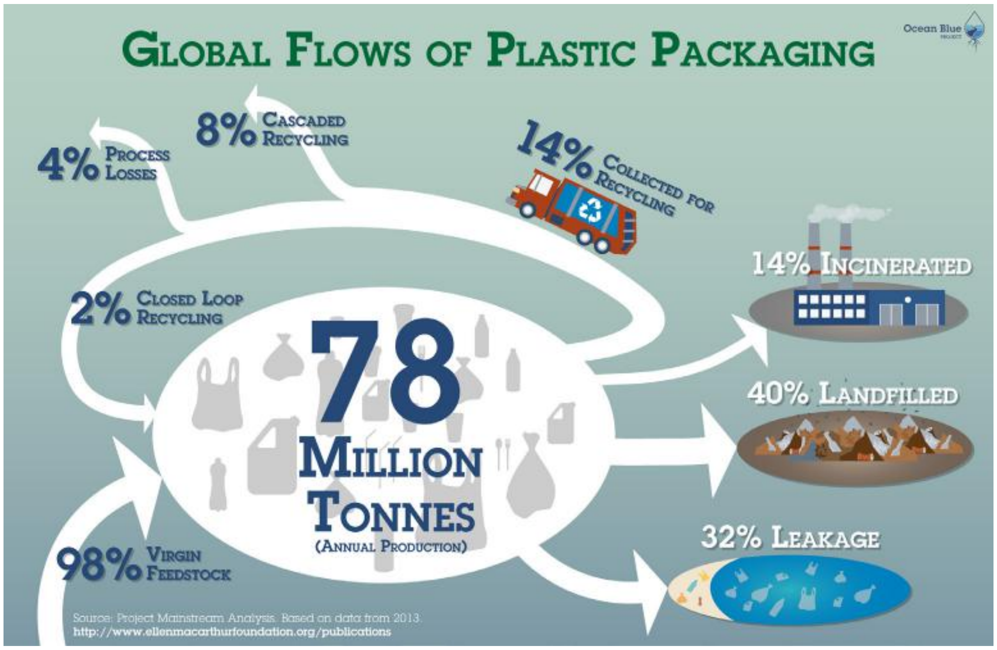
The distribution of plastics in the marine environment is influenced by complex physical and biological interactions of nature and humankind. While knowledge of the terrestrial transport pathways to marine environments is relatively limited, some research on distribution patterns exists. For example, freshwater lakes and rivers tend to be closer to point sources of plastic pollution, but distribute differently or similarly, depending on the specific type of plastic, source (residential vs industrial), size, whether the water source is a lake, river, or estuary, or what speed the water current is moving (Horton et al., 2017; Eerkes-Medrano et al., 2015).

Point Source Pollution is easily tracked because it comes from an identifiable source.

Nonpoint Source Pollution is more challenging to identify and is best described by example.

Runoff or overland flow is usually considered nonpoint source pollution because water picks up toxins and contaminants from places like gardens, farms, parking lots, playgrounds, and construction sites and empties into streams, rivers, or estuaries.

Since there are so many point sources that runoff water flows through, there is not one specific source so we typically consider runoff nonpoint source pollution.



Due to its polymer characteristics and varying density, plastic has been found geographically from the poles to the equator, on shorelines, and throughout the water column, from the ocean surface to the depths of the seabed (Thompson et al., 2009). A recent statistical analysis comparing eight years of land-based and underwater cleanup data analyzed debris buoyancy and the tendency to snag; this information can be used as a method to predict whether an item found on the beach would end up underwater (Roman et al., 2020a). This study reveals that lightweight and buoyant debris – like cigarette butts and plastic water bottle caps – are rarely seen by divers underwater, as they tend to stay on the surface. Items that snag, on the other hand – like plastic bags or netting – are more likely to be caught on the bottom.

Sampling methods to identify the composition of plastics and microplastics both within the environment and when ingested by wildlife vary. Where methodologies are standardized, for example, in sampling water, sediment, and biota of aquatic environments, this has assisted researchers across varied fields in successfully identifying common problems (Eerkes-Medrano et al., 2015; Horton et al., 2017; Collard et al., 2019; Kühn & van Freneker, 2020). Some of the common problems being identified include the behavior and fate of plastics under various environmental conditions and ecosystems; characteristics that might influence toxicity to humans and wildlife; plastic influence on biodiversity, the food web, and water quality.

The ubiquitous nature of marine debris and its impact are far reaching, not only for wildlife but those who depend on it for their livelihoods and food security. The market value of marine and coastal resources and industries accounts for 5% of global GDP, or an estimated $3 trillion USD (United Nations, 2015a). According to the United Nations Environment Programme (UNEP), the financial damage to the world's marine ecosystems due to plastics is an estimated $13 billion each year (2014). In addition to negative economic impacts, marine debris also contributes to climate change; both the degradation of plastics by natural sunlight and disposal by incineration causes the release of harmful greenhouse gases (Royer et al., 2018).

How Does Plastic Affect Animals in the Ocean?

The foundation of healthy ecosystems and habitats depends on both plant and animal species. Humans depend on healthy ecosystems for our basic survival needs, from food and other physical resources, to general health. For each species that becomes endangered or lost, the ecosystem becomes further out of balance, signs of dysfunction become more apparent, and entire ecosystems begin failing.

Plastic debris affects marine biodiversity across a wide spectrum of habitats. At least 690 marine species have been affected by plastic pollution globally, including cetaceans, pinnipeds, seabirds, turtles, fish, and crustaceans (Gall & Thompson, 2015). Forty-six percent of the species on the IUCN Red List of Threatened Species have been affected by fishing gear pollution (FAO, 2020). While entanglement is the most visible impact of marine debris, the effects of ingestion and chemical toxicity are also disturbing, causing injury and death.

In addition to the risk and likelihood of physical trauma, ingesting plastic debris can also expose the animal to an additional source of toxins. The chemical components can leach into the body following ingestion, with pollutants transferred from prey to predator within food chains (Engler, 2012; Fossi et al., 2012; Eriksson & Burton, 2003). Entanglement can result in severe injuries, or death by drowning, suffocation, or strangulation. The effects of entanglement or ingestion can be lethal or sub-lethal in nature, and lead to a range of issues such as compromised feeding capacity and digestion problems leading to malnutrition, disease, reduced reproductive output, reduced growth rates, and shorter lifespan (Cerim et al., 2008). The severity of the impact of both ingestion and entanglement can vary according to the type of debris, the species, as well as individuals, with some being able to withstand the impact better than others.

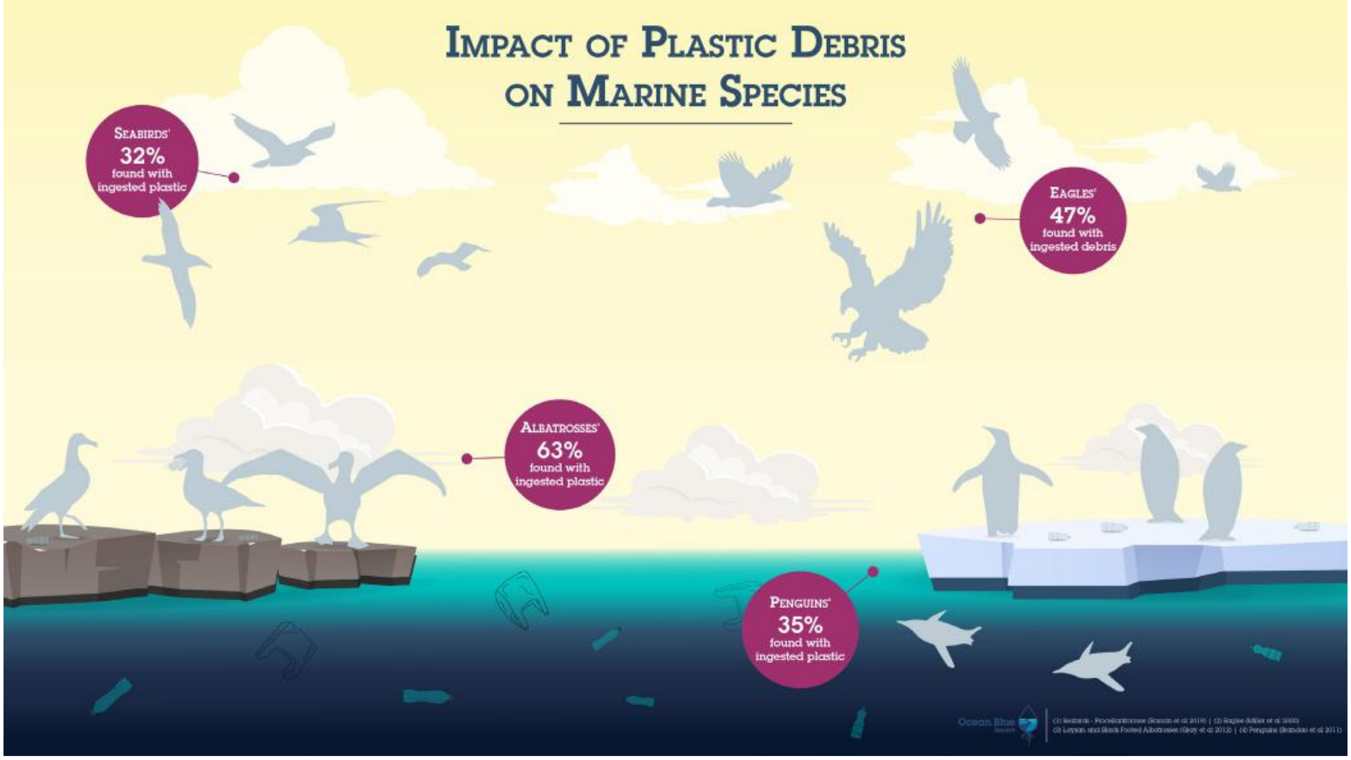
Research scientists have increasingly been analyzing various aspects related to the effects of ingestion, entanglement, and poisoning from plastic pollution on wildlife (Kroon et al., 2018; Collard et al., 2019; Kühn & van Freneker, 2020). Ingested plastic has been well documented during necropsies, including as a cause of death through perforation of internal organs. However, it is often unclear whether the accumulation of plastics and how much plastic in the gut (without a noticeable obstruction) is a direct or indirect cause of death. Wildlife mistake plastic pollution for food, which then accumulates in their gut. A recent study found that certain plastics release a chemical called dimethyl sulfide (DMS), which mimics an olfactory signal that seabirds may use to identify food (Dell'Ariccia et al., 2017).

In the following sections you will find a review of a select set of wildlife species that are highly affected by the ingestion of plastics. These groups and species have been identified through our extensive literature review of articles published over the past 30 years and represent current knowledge. One of the most recently published review articles alone covered 747 studies of over 900 species (Kühn & van Freneker, 2020). Conservation efforts focused on supporting the protection of these species have the potential to help sustain healthy ecosystems, which we all depend on for health.

Species Impacted the Most by Plastic Pollution

The following groups of species were found through a literature review and are some of the most vulnerable to ingestion of plastic pollution caused by humans. Each of the groups of species occupy a unique place in their habitat and impact the overall health of ecosystems.

The research studies represented in this report help us answer the question, how does plastic affect animals in the ocean?



1. Birds

1.1 Seabirds

More than 1 million seabirds are estimated to die due to plastic pollution every year (United Nations Educational, Scientific and Cultural Organization, 2021a), with the group Procellariiformes having the highest frequency of marine debris ingestion (Roman et al., 2019). Procellariiformes consist of four families of birds: albatrosses and mollymawks, petrels and shearwaters, storm petrels, and diving petrels. Although they are found across the world, Procellariiformes predominantly inhabit the southern hemisphere (Hamer et al., 2001).

A recent study analyzing cause of death data from 1,733 seabirds belonging to 51 species, found a significant relationship between ingested debris and a debris-associated cause of death (Roman et al., 2019). Of the 1,733 seabirds examined, 557 (32.1%) had ingested marine debris – ranging from 1 to 40 items, with a maximum weight of 3,340 mg and volume of 3,621 mm3. In total, 2,671 types of known debris were collected. The types of debris were categorized as hard plastic and soft plastic. The hard plastic included fragments and pellets and accounted for 92.4% of all items ingested, while the soft plastic items were packaging (2.1%), balloon fragments (2%), rubbers and foams including polystyrene, expanded polyethylene, and other synthetic foams (1.3%), rope and rope fibers (1%), fishing-related rubbish (0.7%) with other debris types contributing 0.5%. While the cause of death for 1,265 (73%) of the seabirds was not because of the plastic ingested, 13 seabirds died from ingesting marine debris – five fairy prions, four short-tailed shearwaters, one Salvin's prion, one Antarctic prion, one blue petrel, and one light-mantled sooty albatross. For seven of these birds, blockage of the gastrointestinal tract was the leading cause of death, followed by obstruction of the gastrointestinal tract for five of the birds, which subsequently led to infection or other complications, and one perforated gut. The items causing the obstruction and blockage were hard plastics, balloons, and expanded foam. Furthermore, nine birds – four short-tailed shearwaters, two slender-billed prions, one Salvin's prion, one white-faced storm-petrel, and one southern fulmar – were likely to have died from similar circumstances, but could not be confirmed due to decomposition of the bodies (Roman et al., 2019).

Statistical models developed as part of the study showed that the seabirds that died from marine debris had ingested significantly more debris than seabirds with an indeterminate cause of death (446 seabirds). Results of the model concluded that the higher the number of plastic pieces ingested, the higher the likelihood of a Procellariiform dying from debris ingestion (Roman et al., 2019). As with many seabird species, Procellariiform species are also at great risk of entanglement, particularly in ghost fishing gear and other macroplastics (Laist, 1997).

Photo by Bisakha Datta from Pexels

Albatross are another example of seabirds impacted by marine pollution. A study published in 2012 examined 18 Laysan and 29 black-footed albatrosses that were recovered as by-catch from fisheries near the Hawaiian Islands. Thirty out of the 47 albatrosses (63.8%) had ingested plastic debris. Laysan albatrosses were observed to have had a higher frequency of ingested plastic than black-footed albatrosses. The maximum mass of ingested plastic found in one Laysan albatross was 8.1 g, while the maximum for one black-footed albatross was 1.1 g. Five of the 47 specimens had ingested more than 1g of plastic. The maximum number of plastic pieces recovered from a single specimen was 139, found in a black-footed albatross; 135 out of those 139 were fishing line pieces. Additionally, of the four varieties of plastics (fragments, lines, pellets and foam) in this study, the dominance (by mean mass) of fragments indicates that both Laysan and black-footed albatrosses are primarily ingesting plastics composed of a variety of degraded post-consumer products (Gray et al., 2012).

A separate study on albatross found that one to forty plastic items were ingested per bird. The chance of mortality from ingesting a single piece of plastic was 20.4%, while ingesting 93 or more pieces resulted in a 100% mortality rate. Balloons and their fragments were 32 times more likely to cause death than hard plastic pieces (Roman et al., 2020b).

1.2 Penguins

Plastic pollution is one of the main anthropogenic (man-made) risks penguins face, alongside ice-reduction due to global warming and food insecurity by overfishing. The 18 species of penguin, distributed throughout the Southern Hemisphere, have varying vulnerability to plastic ingestion. As penguins feed on fish, krill, and other sea life, bioaccumulation of plastic can occur and move up the food chain. As penguins are hunted, the plastic they contain can then be ingested by predators such as seals, whales and sharks.

Magellanic penguins migrate between colonies on the South American coast, between March and September each year. Plastic and debris have been found in the intestines and stomachs of penguins. Two separate studies indicated that 15% of 175 dead penguins examined and 35.8% of 397 dead birds examined, had debris in their stomach and intestines. Although the specific rate of mortality is not clear, it was found that a plastic straw perforated the stomach of a penguin, and plastic bags and candy wrappers were identified. However, the majority of ingested plastics were small unidentifiable plastic fragments (Brandao et al., 2011).

Penguins are also injured and killed by entanglement in plastic pollution, with individuals from 6 of 19 (38%) of penguin species found entangled (Laist, 1997).

Photo by derek braithwaite on Unsplash

1.3 Eagles

Photo by Marco Bicca on Unsplash

While eagles might not immediately come to mind as victims of plastic pollution — particularly within marine environments — they are undoubtedly affected; due to their long reproductive cycles, any damage to their population is to be taken seriously. Where flagship species such as the bald eagle are concerned, efforts have been made over the years to address threats such as illegal shooting and contamination of food sources, occurring largely as a consequence of Dichlorodiphenyltrichloroethane (DDT) and per- and polyfluoroalkyl substances (PFASs) (Wu et al., 2020; Spears & Isanhart, 2014).

While improvements have been made in this area, eagles are still being harmed by the consumption of plastic pollution and other hazardous materials. Many eagle species rely on fish, particularly those in coastal areas, which carry the risk of plastic bioaccumulation through ingesting fish or marine mammal carcasses contaminated with plastics. As we have mentioned, even eagles eating freshwater fish are at risk of consuming harmful microplastics through their prey.

Several studies are measuring specific toxicities of the contents of various plastics such as polychlorinated biphenyls (PCB's) on bioaccumulation and transfer in tissues of predators and their prey (Rochman, et al., 2019).

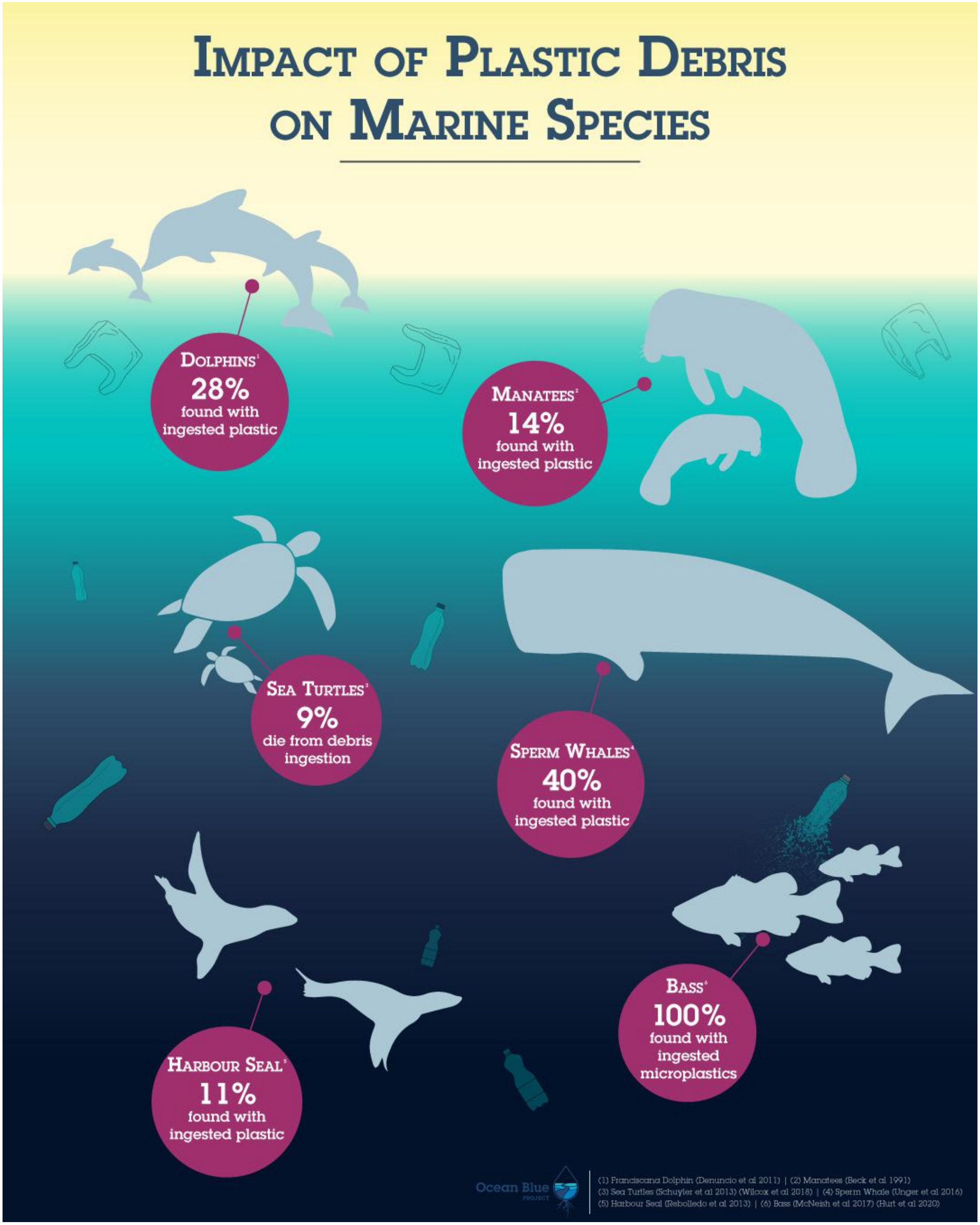
Lead poisoning also presents significant risk to eagles through trophic transfer and bioaccumulation - eagles are especially at risk of lead poisoning from eating shotshell pellet fragments left behind by hunters in animal remains (Russell & Franson, 2014). One study found that each waterfowl bird ingested accounted for an estimated ~3.5 shotshell pellets containing residual lead (Miller et al., 2000). Although mortality due to lead poisoning has often been the focus of bird of prey research, plastic fragments from the ammunition shells have also been documented in their digestive tract. In general, a shotgun shell is made up of low density polyethylene (LDPE) containing a lubricating agent within the raw plastic, commonly referred to as wads, but specifics vary depending on manufacturer. It is filled with shot, which contains little balls made of any number of metals including lead, steel, tin, bismuth and zinc. While metal poisoning is relatively well studied in birds of prey, the effects of plastic ingestion on eagle mortality is unknown. The Center for Coastal Resources Management has developed a wad made of biodegradable polyhydroxyalkanoate (PHA) plastics which outperforms some commercial ammunition, but has not yet replaced standard wads due to price and performance overall (Virginia Institute of Marine Science, 2021). Ocean Blue Project frequently finds plastic shotgun wads washed up on west coast beaches.

Bald eagles have become a sentinel species for biomonitoring environmental contaminants. This is due to their top position in the trophic level, which makes them a good candidate to study bioaccumulative potential effects of chemicals such as polyfluoroalkyl substances (PFAS) and polybrominated diphenyl ethers (PBDE) among several others. Organo-halogenated contaminants - chemicals known to have toxic effects on several biological systems - are being monitored in the plasma of eagle nestlings; (Loseth, et al., 2019). Used as flame retardants, lubricants or pesticides, many of these chemicals have been banned, although they can still be found in high concentrations in drinking water, living organisms and plastic pollution.

2. Fish

Fish species in general are one of the most studied when it comes to plastic ingestion, such as the nine species of marine and freshwater bass. Bass are considered keystone species, hunting other fish and amphibians as apex predators in their habitats. Large- and smallmouth bass are the most popular freshwater game fish for anglers in North America, while seabass are popular for marine fishing in the Pacific Ocean. Population levels have been increasing along the Pacific Northwest Coast since the 1980s, when efforts to stem overfishing were made. Both freshwater and marine bass species are affected by plastic pollution (Bennett, 2017).

A study examining bass and gizzard shad in two reservoirs in Illinois found a high prevalence and abundance of microplastics, with 100% of the fish having ingested them. As a predatory fish, bass had a higher concentration of ingested microplastics, suggesting trophic transfer from their prey (Hurt et al., 2020). Another study focusing on many species of fish caught in river watershed locations near Lake Michigan found 85% of individual fish caught contained microplastic particles, with an average of 13 particles per fish. Plastic fibers were found to be the dominant microplastic type (McNeish, et al., 2018).


Impact of Plastic Debris on Marine Species
Dolphins[1]
28%
found with ingested plastic
Manatees[2]
14%
found with ingested plastic
Sea Turtles[3]
9%
die from debris ingestion
Sperm Whales[4]
40%
found with ingested plastic
Harbour Seal[5]
11%
found with ingested plastic
Bass[6]
100%
found with ingested microplastics
Ocean Blue
PROJECT
(1) Franciscana Dolphin (Denuncio et al 2011) | (2) Manatees (Beck et al 1991)
(3) Sea Turtles (Schuyler et al 2013) (Wilcox et al 2018) | (4) Sperm Whale (Unger et al 2016)
(5) Harbour Seal (Rebolledo et al 2013) | (6) Bass (McNeish et al 2017) (Hurt et al 2020)

Although we don't know the number of fish killed by ingesting plastic pollution, we do know that, for some species, two-third of fish stocks have ingested plastic (Cheung et al., 2018), which is concerning for fish and all who consume them. Nanosized plastic particles have been found in fish brains and have created behavioral disorders - those with nanoplastic brain damage were found to eat slower and explore their surroundings less than those without plastic contamination of the brain (Mattsson et al., 2017). For the species higher up the food chain — including humans — who are even more prone to the trophic transfer of plastics, the long-term consequences of eating fish and other plastic contaminated food is unknown.

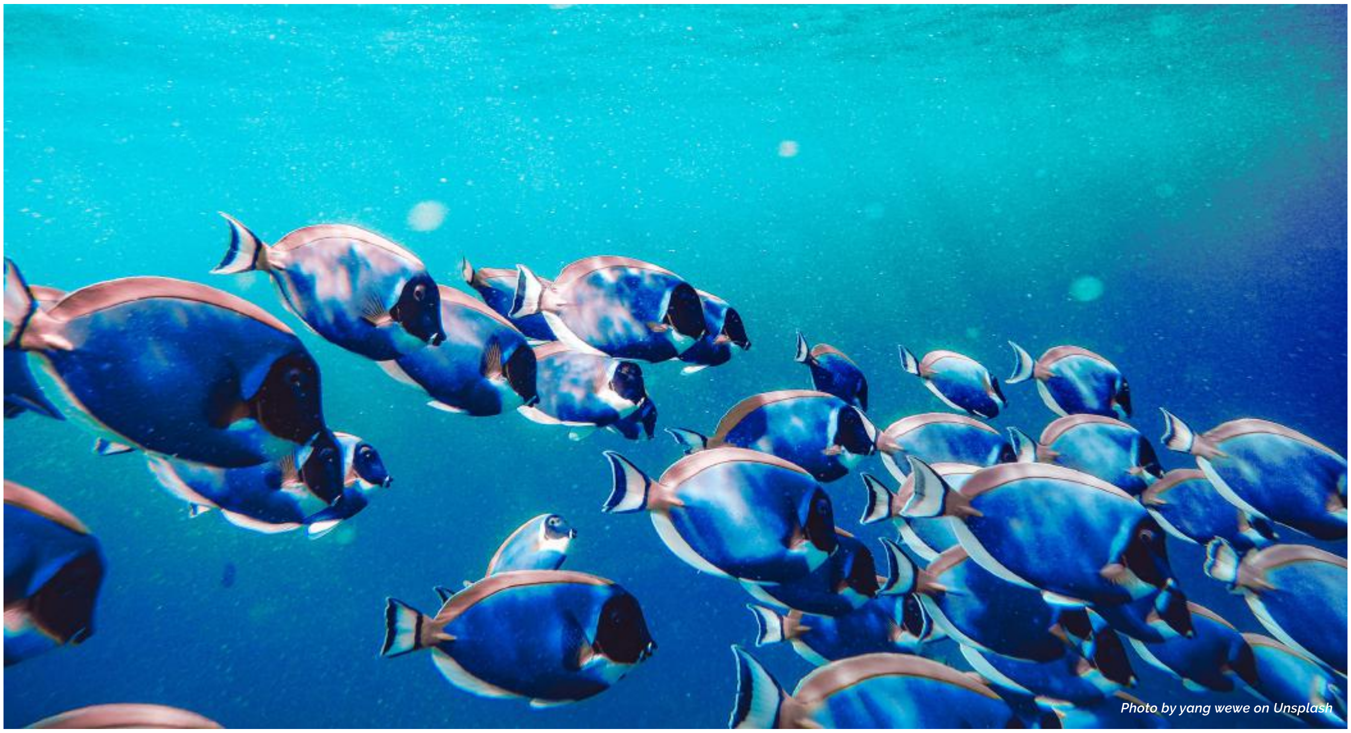


Photo by yang wewe on Unsplash

3. Cetaceans

3.1 Dolphins

Dolphin species are found in every ocean globally, as well as in a few rivers in South Asia and the Amazon. Dolphins range from critically endangered to commonly seen species and, just like whales, have been hunted for centuries for their meat and blubber. More recently, their main anthropogenic threat is marine debris, including derelict fishing gear, such as abandoned gillnets. While there is more research and reports relating to incidents of entanglement than those relating to ingested plastic debris, cases and occurrences of the latter have been documented and show just how ubiquitous marine debris is in the ocean.

In June 2001, an adult male rough-toothed dolphin was stranded at Poço da Draga Beach, located in the northeastern coast of Brazil. The dolphin was visibly emaciated, unable to swim and later died while being transported to a local rescue center. A necropsy revealed debris occupying 2/3rds of the fore-stomach and blocking the passage to the main stomach, where most of the digestion takes place. This consisted of two plastic bags with a combined weight of 14.12g plus four pieces of sea sponge weighing 17g. The three stomach chambers were completely free of food, indicating the animal had not been feeding for at least a few days. Further examination revealed the presence of multiple ulcers, likely to have been caused by the ingested debris and subsequent excessive production of gastric acids. Researchers were able to determine that the debilitation and death of the animal were caused by the ingested plastic.

The ingestion of plastic could have caused the animal to feel a false sensation of satiation, which in turn could have reduced its appetite (De Meirelles & Barros, 2007).

The Franciscana, also known as La Plata, is a small dolphin that lives only in the shallow, coastal waters of the Atlantic ocean and saltwater estuaries of the southwestern coast of Brazil, Uruguay, and Argentina. As with their relatives, the Amazon river dolphins, the Franciscana dolphins are endangered (Cunha et al., 2014). Because the species ranges in waters only up to 30 meters in depth, the Franciscana dolphins are more vulnerable to anthropogenic activities.

A total of 106 Franciscana dolphins were recovered entangled in gillnet fisheries between 2007 and 2010, in both estuaries and coastal waters. Examination of the gastrointestinal tracts during necropsies showed 28% of the dolphins had plastic debris present in their stomachs. The dolphins were found to have ingested at least one piece of plastic debris, with the 5 pieces of plastic being the most found in one individual. Two main sources of debris were identified : fishing-related items and plastic packaging debris. The plastic debris was further identified as plastic rubber bands, cellophane bands, and plastic bags. The size of the plastic debris found was between 0.2 to 11.4 cm, with cellophane bands of cigarette packages being the longest (Denuncio et al., 2011).

Furthermore, a statistical model from the study, indicated that the proportion of dolphins with plastic debris rapidly increased with body length. In other words, the occurrence of plastic debris was significantly more for animals with a body length between 110 and 130cm, which is the typical length of juveniles, with less debris found in adults (whose body length was more than 130cm). This finding coincided with changes in feeding regimes. Franciscana dolphins have a gradual weaning process between two to seven months of age, where they are typically 80 to 100cm in body length. The drastic increase in the presence of plastic debris could be attributed to the process of juveniles learning to catch prey by themselves, and accidentally misidentifying and ingesting the debris (Denuncio et al., 2011).

3.2 Whales

Photo by Todd Cravens on Unsplash

Whales are the largest animals on Earth and live in every ocean. These mammals can range from 600 pounds (dwarf sperm whales) to more than 200 tons and up to 100 feet long (blue whales). There are two types of whales: toothed whales – such as sperm whales and orcas – and baleen whales – such as humpbacks, right, blue and gray whales. Both types of whales are at the top of the food chain and play an important role in reflecting the overall health of the marine environment. Recent studies show that whales play a significant role in capturing carbon from the atmosphere. Each whale is said to sequester an estimated 33 tons of CO^2 on average during its lifetime (Randow, 2019).

Unfortunately, several species of whales are classified as threatened, endangered, or vulnerable, even after decades of protection. Though the stark population declines from whale hunting have largely stopped, whales continue to be threatened by a wide range of manmade factors such as marine debris, ship strikes and climate change.

Studies associated with marine debris occurrence and impact in sperm whales have been documented worldwide since 1895. Between January and February 2016, 30 sperm whales were found stranded in different locations along the North Sea coast in Germany, the Netherlands, the United Kingdom, France, and Denmark. Necropsies were performed on 22 of these whales. An examination of their gastrointestinal tracts revealed that nine individuals had ingested a significant amount of debris. Debris findings were categorized into two groups, fishing-related and general debris. The latter category included two chocolate/cereal bar packaging, a coffee capsule, foils (thin pieces of plastic that were mostly transparent), duct tape, parts of plastic bags, strapping tapes, a screw-cap, parts of two different blue plastic buckets and a plastic part of a car engine cover. The amount and weight of ingested debris varied greatly between individuals, with the highest weight in one individual sperm whale being 24.8 kg. While the necropsies performed as part of this study determined the cause of death was not directly caused by the debris ingested, the significance of the amount and types of debris found cannot be ignored. It is likely that it would have been an eventual cause of death (Unger et al., 2016).

In March 2019, a young Cuvier beaked whale was found stranded, and later died, in the Davao Gulf of the Philippines. While performing the necropsy, researchers pulled out more than 88 pounds of plastic waste from its stomach. This shocking amount of debris included 16 bags of rice sacks, numerous plastic bags, snack bags and big tangles of nylon rope. The young whale likely died of starvation and dehydration from the plastic stuffing its stomach. Whales absorb water from the food they eat, and the necropsy further showed that there was no sign that any food made it into the whale's intestine for many days prior to its death. Researchers said that the stomach acids, unable to break down the plastic waste, had worn holes through the stomach lining instead (Borunda, 2019).

Although the exact numbers of cetaceans killed by plastic pollution - including discarded fishing gear - is unknown, we do know that 300,000 dolphins, whales and porpoises are entangled and die from fishing gear annually (Read et al., 2006). Given this figure only represents known bycatch from manned fisheries, the amount is likely much higher.

4. Other Marine Mammals

4.1 Pinnipeds

Pinnipeds are commonly known mammals that include all seal, sea lion and walrus species. Studies have shown that these marine mammals are prone to get entangled in marine debris. As well as injuries and fatalities caused to pinnipeds by entanglement, research has also documented plastic ingestion (Laist, 1997).

In 2002, an epidemic disease – Phocine Distemper Virus (PDV) – caused the mortality of 30,000 harbor seals in the North Sea by the Netherlands. Where possible, bodies were collected and necropsies were performed. One-hundred and seven of these seals had intact stomachs and 100 of them had intestines that were suitable for further examination. Twelve out of 107 seal stomachs (11.2%) contained plastic with a


Photo by Sevak on Unsplash

maximum of eight items and maximum weight of 1.4g per stomach. In total, 28 plastic items with a total weight of 2.6g were found. According to the study and results of the necropsy, almost all of the plastic identified were in young harbour seals (up to 3 years in age) (Bravo Reballedo et al., 2013).

Another case involved plastic ingested by a harp seal pup in the Gulf of Saint Lawrence, located in eastern Canada. Necropsy results showed that a flimsy 2 inch square piece of plastic was found crumpled up in the seal's stomach. The presence of mild ulcers indicated that the plastic had been stuck in the seal's stomach for a significant amount of time. Researchers believe that the plastic debris could have blocked the pyloric sphincter, the part of the stomach that empties into the intestine, which in turn could have prevented the seal's stomach from emptying. The intestine also showed signs of being inflamed. While researchers determined that the plastic was unlikely to have directly caused the death of the pup, the seal was severely dehydrated and emaciated, showing that it had not eaten recently (Zachos, 2020).

While the exact number of pinnipeds killed by plastic pollution is unknown due to the low percentage of corpse recovered, we know that 67% of seals (22 of 33 species) have known entanglement reports (Kühn et al., 2015). For pinnipeds that do become entangled, mortality rates range between 16 and 80% globally (Butterworth et al., 2012).

4.2 Manatees

Manatees, sometimes called sea cows, are aquatic mammals weighing an average of 1,000 pounds and are mostly herbivorous. There are three main species of manatees, which are distinguished by where they live – West Indian manatees that occupy the coastal waters from Florida to Brazil; the Amazonian manatee that lives in the Amazon River; and the Africa manatee that lives along the west coast and rivers of Africa (Beck & Barros, 1991).

The Florida manatee, a subspecies of the West Indian manatee, inhabits the coastal waters and rivers of the southeastern United States. These habitats have incrementally accumulated debris from wave and tidal action. As manatees feed on a variety of seagrass, algae and other vegetation, debris trapped by mats of vegetation may be ingested, further endangering a species already listed as "vulnerable" under the International Union of Conservation of Nature's (IUCN) Red List of Threatened Species.

A study published in 1991 examined the extent of debris ingested by the Florida manatees (Beck & Barros, 1991). From 1978 through 1986, 439 manatees were examined to determine causes of death. Complete examination of the gastrointestinal tracts revealed that 63 (14.4%) manatees had ingested debris. These manatees were observed to be part of all age classes (three calves, 30 juveniles and 30 adults). While the weight and volume of debris were not assessed in the study, results showed that more than one type of debris was seen in 13 (3.0%) of the manatees. In 14 (3.2%) of the manatees, debris was found in multiple locations of the gastrointestinal tract, including the esophagus, stomach, colon and small intestine.

Furthermore, plastic bags or packaging were the second most common type of debris found. While ingestion of debris was determined to be the cause of death for 4 manatees, some plastic debris appeared small enough to pass through the gastrointestinal tract without apparent complications. Given the subtle, sub-lethal effects of debris ingestion, however, even plastic particles small enough to pass through animals could negatively affect manatee health through the release of toxic compounds (Beck & Barros, 1991).

As well as the clear threats to manatees from plastic pollution, the impact of humans on the water quality in key manatee habitats is indirectly killing them in large numbers. In Florida, nitrogen and phosphorous levels are increasing due to runoff from sources such as fertilized lawns and poor sewage treatment, resulting in the loss of seagrass (Tribou, 2021). Without the seagrass to feed on, manatees are starving. More Florida manatees have died in the first half of 2021 than ever before, with 841 manatees dying between 1st January and 2nd July 2021, compared to 830 deaths in the whole of 2020 (Florida Fish and Wildlife Commission, 2021).

Photo by San Diego Zoo Wildlife Alliance Animals & Plants

5. Sea Turtles

The seven species of sea turtle are widely distributed, with species to be found in each of the world's oceans. Globally, all species are classified as between 'vulnerable' and 'critically endangered' according to the IUCN Red List of Threatened Species (2021). Sea turtles' wide distribution means their lives vary greatly; while some species prefer shallow, tropical coastal environments, others live in the open ocean; some are carnivores, some herbivores, while several species are omnivores.

Turtle entanglement in megaplastics, particularly 'ghost' fishing gear which keeps snaring animals even when lost or discarded, has been documented across all species, all life stages, and all oceans, causing life-threatening injuries and death (Duncan et al. 2017).

Six of the seven sea turtle species have been documented as ingesting marine plastics, and the diet of various sea turtle species plays a strong part in their vulnerability to plastic pollution. Several research studies have been published on sea turtle ingestion of marine debris (Schuyler et al., 2013). The probability of debris ingestion for the green and leatherback turtles has increased significantly over time.Omnivorous and herbivorous turtles (hawksbill and green) were reported to have the highest amount of ingested plastic, while the lowest amount of plastics were ingested by carnivorous turtles (loggerhead and Kemp's ridley). Out of 454 turtles reported to have ingested debris, 42 or 9% of sea turtles died as a result (Schuyler et al., 2013).

A quantitative analysis for sea turtle mortality was performed across causes of death. Cause of death categories included unknown causes, indeterminate between non-plastic and plastic causes or a direct cause of death by ingestion of plastic. One data set was based on necropsies of 246 sea turtles. Another data set analyzed 706 recorded deaths from a national database. The quantitative analysis found a 50% probability of death once a sea turtle had 14 pieces of plastic in its gut (Wilcox et al., 2018).

In addition to direct harm to sea turtles by plastic ingestion and debris entanglement, plastic pollution also affects sea turtle reproduction. Greenhouse gases are associated with both plastic production and its degradation in the environment, contributing to global warming and temperature increases. As the sex of sea turtle eggs is determined by temperature — with warmer incubation temperatures producing female hatchlings — the balance of males and females is already being disrupted, affecting future population trends. One study showed that at one of the largest green turtle populations in the world, the sex ratio is now 99% female, with the potential complete feminization of the population happening in the near future (Jensen et al. 2018). As sea levels rise, the availability of beaches suitable for laying eggs is also decreasing, threatening already endangered animals.

Photo by Amanda Phung on Unsplash

Collecting Pieces of Plastics Can Save… how were these numbers determined for the above infographic?

The infographic on page 19 was developed in order to help engage the general public and raise interest in the plastic pollution problem and for joining efforts in beach and river cleanups. It can be used as a learning tool for all ages about the potential negative effects of ingestion of plastic fragments on wildlife, and how wemight be able to help save wildlife from the fate of death by removing fragments from the environment.

The specific numbers are based on a subset of the research studies available for your review in the table titled, "Average amount and types of plastic found to cause mortality in wildlife." The studies present specific data on the average number of plastic particles, pieces, or fragments likely to cause the death of a particular animal. Those numbers likely to cause death were then rephrased in order to reflect the animals potentially saved by removing that specific number of fragments from wildlife habitat. This can be misleading scientifically due to several reasons, which are discussed in the context of the entire report. For more information and additional references for each species, please see the above sections of this report.

Species	This amount of plastic is likely enough to cause the death - # of fragments	Type of Plastics
Penguins	~ 5 particles per bird	Pieces of plastic bags, candy wrappers, several unidentified plastic fragments, some fishing related items, and other garbage such as gum.
Eagles	~ 3.5 per waterfall bird ingested. Trophic transfer.	Shotshell pellets and castings with residual lead.
Albatross	1-40 plastic items ingested - chance of mortality from ingested in single piece of plastic = 20.4% and 100% of mortality from ingesting 93 or more pieces; Balloon and ballon fragments 32 times more likely to cause death than hard plastic pieces. The average density for hard plastic was 0.95g per cm^3, 0.91g per cm^3 for balloons and 7.7g per cm^3 for fishing hooks.	Hard plastic – pellets and fragments were the most common. Soft plastic – packaging, balloon and its fragments, rubbers and foams, rope and rope fibers, fishing related rubbish.
	Mean weight of plastic in the chicks were 76.6g and mean volume was 85.0cc	Bottle caps, toys, plastic fragments and cigarette lighters
All Turtles	50% probability of mortality once an animal had 14 pieces of plastic in its gut. "Our analyses suggest that a turtle has a 22% chance of dying if it eats just one piece of plastic."	All sizes and types of plastics included visible to naked eye.
All Whales	59 items were of plastic items, weighing total of 18kg and a total surface area of 37.5m^2.	Dishwasher plastic pot, hanger, ice cream tub, small plastic items (<4cm^2), plastic bags, plastic carafe.
All Dolphins	Average size of plastic debris = 7.45 ± 5.54 cm; Average surface area = 2.01 ± 3.46 cm^2; The hard plastic fragments were less than 0.6cm in length and 0.2 cm^2 in surface.	Packaging related – cellophane bands, plastic bags and plastic rubber bands. Fishing related – fragments of ropes, monofilament lines and nets.
All Bass	~ 25 particles per fish	All sizes and types of plastics included following tissue digestion protocol.

Table: Average amount and types of plastic found to cause mortality in wildlife

Table References:
Penguins: (Brandao et al., 2011)
Eagles: (Miller et al., 2000)
Albatross: (Roman, et al., 2020b; Fry et al., 1987)
Turtles: (Wilcox et al., 2018)
Bass: (Hurt et al., 2020)
Whales: (de Stephanis et al., 2013)
Dolphins: (Denuncio, et al., 2011)

Data Gaps Due to Environmental Factors

The presence of marine debris and its impact on a wide range of species, from plankton, shellfish and fish to marine mammals, is undeniable. With an increasing number of studies, documentation and reports, there is now a better understanding of marine debris interaction within the marine food web. However, population-level impact remains poorly understood (Baulch & Simmonds, 2015).

The most fundamental limitation in assessing marine debris ingestion is the difficulty of detecting animals that ingested the debris. Most animals, including seabirds, sea turtles and marine mammals, that are vulnerable to marine plastic ingestion are migratory and plastic debris is scattered throughout the ocean, across the water column and from the surface to the seabed. Detection of the interactions between the scattered plastic debris and the animal depends on the data collected from the small sample size provided by stranded animals, which only presents a snapshot of the animal species (Baulch & Simmonds, 2015). Information on plastic ingestion, especially in cetaceans (whales, dolphins or porpoises) can typically be obtained only through necropsies (Unger et al., 2016). In order for the marine debris interaction to be detectable after plastic is ingested, the animal must be stranded on shore, be found and then reported to the appropriate authorities for analysis.

Studies in the Gulf of Mexico, a region rich in biodiversity, found that carcasses recovered from the sea accounted for an average of just 2% of total cetacean deaths (Williams et al., 2011). Even when carcasses are recovered, only a fraction are subjected to a full necropsy and even fewer have a cause of death directly linked to the debris that was originally ingested. The cause of death, even if linked to ingested plastic debris, can vary depending on the case and the animal. The plastic could have sub-lethal effects where it accumulates over time, eventually blocking the intestine causing starvation, or it could be more lethal, where a sharp object can perforate internal organs. Decomposure of carcasses often makes establishing a cause of death difficult. The true frequency and the severity of debris interactions in marine mammals remains unclear.

The impact of plastic ingestion by seabirds is better studied, though the severity of ingestion in birds can depend on species' feeding habits. For instance, seabirds that feed on hard, sharp, types of prey are better able to tolerate hard plastic debris than those which feed on softer prey. Furthermore, some seabird species regurgitate the food they have already ingested, including any possible debris. This can therefore result in reduced impact when compared to seabirds that either do not regurgitate or who have debris accumulate in their gut (Gall & Thompson, 2015).

Data Gaps Due to Research Methodology and Protocols

Limitations have also been related to current data and research analysis available and can usually be attributed to three main factors: biases in sampling and reporting, differing objectives of studies and lack of standardized protocol to follow.

A vast number of publications document a single stranding event, without expressing it as a proportion of all strandings recorded for that particular species or creating context around the carcass recovery rates and population size. Sample size has a significant influence on the prevalence of debris ingestion. In situations where the sample size is small, rare events are less likely to be detected, and so, even if the ingestion rates were 20%, it would go undetected if, for instance, only five individuals of the species have ever been recovered or documented in a particular region (Baulch & Simmonds, 2015).

The scientific studies and reports included in this review are based on the objective and hypothesis of the researcher. Differing aims of studies result in different information being collected and provided. Hence, not all reports provide a detailed account of the findings. For instance, in studies where the main objective is not to capture the effects of marine debris ingested, it is likely that specifics on the presence of plastic is overlooked. Such studies are less likely to provide details of the size or number of plastic items ingested, the number of individuals affected, the impact of the presence of debris, or whether debris ingestion contributed to the harm that was caused. Such factors can also cause the presence of microplastics to be grossly underestimated or entirely overlooked (O'Hanlon et al., 2017).

Lack of standardization in sampling methodologies when gathering data represents another limitation in assessing the impact of marine debris, specifically microplastics. Quantifying and characterizing plastic in the marine environment is not standardized, so understanding the magnitude of the problem is difficult. For instance, some studies minimize the size threshold of plastic detected, or fail to recognize size as a category. Other inconsistencies relate to how the debris found is characterized – some studies record the number of items, some record the mass and some do both. This makes it difficult to compare across studies and findings, which then affects the overall understanding of how plastic impacts marine species.

What Can Be Done

There is no single solution to combat plastic pollution and save the lives of sea animals. Systemic governmental, institutional, commercial and societal changes need to be made in order to stand a chance of successfully halting additional leakage of plastic into marine environments, restoring already damaged ecosystems and creating clean, healthy oceans.

Individual proposals within these objectives include enacting protective and restorative measures to improve existing habits. Other proposals include working with locals in small island developing states to identify their vulnerabilities to pollution and fishery issues, and to create Green Economies, where the needs of the ecosystems and the people reliant on them are in balance One important proposal is to have the United Nations (UN) review any urgent issues and promptly provide a solution as soon as possible. This will help with already urgent issues that have been ignored or pushed to the back burner.

Created in 2015, the UN Sustainable Development Goals (SDGs) are goals designed to lead the way towards a better, more sustainable future for all. Goal 14 - Life Below Water - is concerned with the conservation and sustainable use of the ocean, seas and marine resources for development (United Nations, 2015b). Goals, many of which were due to be met in 2020, include increasing the amount of protected and restored marine and coastal ecosystems. This specific goal has seen progress, with global key marine biodiversity areas covered by protected areas increasing from 30.5% in 2000 to 46% in 2019 (United Nations, 2015c).

Successfully implementing all the goals and proposals mentioned above will help slow, stop and ideally reverse the damage already done, with the aim of regenerating the ocean to healthy levels and saving the lives of the wildlife currently dying from plastic pollution.

Congress' Save Our Seas Act 2.0 (2020) includes a range of strategies to combat marine debris, including the promotion of circular economies, where industries and economic activities are, by design, restorative, regenerative and aim to eliminate waste of materials, products, and systems. Other strategies include the Genius Prize for Save Our Seas Innovations, a competition to encourage technological innovation with the aim of reducing plastic waste, pollution, and marine debris.

The varied and complex proposals and goals set out by the institutions above emphasize there is no simple solution to creating plastic-free oceans. Modeling by The Pew Charitable Trusts & SYSTEMIQ (2020), found that no single-solution strategy can reduce the leakage of plastic into our oceans to pre-2016 levels, or stop it entirely. Single 'upstream' solutions such as switching from plastic to eco-friendly packaging, or 'downstream' solutions such as improved waste management will not work alone. All solutions need to be implemented together to have maximum impact.

While it will take significant systemic change to reduce plastic pollution and regenerate marine ecosystems, individuals too can have an impact. On a local and regional scale, we can organize gatherings for beach or river cleanups. Beach and river cleanups are vital to ecosystem protection because they remove plastic debris before they fragment into dangerous microplastics, enter aquatic environments and harm further wildlife.

Ocean Blue Project organizes volunteer beach cleanups and uses ocean cleanup technology that make vital contributions to healthy oceans. We know plastic is more likely to biodegrade on a warm sandy beach than in cooler water temperatures in the Pacific Ocean (National Oceanic and Atmospheric Administration, 2015), so beach cleanups are a vital part of tackling plastic pollution.

What can we do in order to reduce the amount of plastics on the beach outside of beach cleanups?

Here is a list of small impactful actions you can take:

- Support organizations that are focused on sustainable practices and conservation efforts. You can help financially by donating, or by volunteering your time.
- Support environmentally-friendly businesses with strong sustainability policies. Don't purchase products from companies you know are harming the environment and be on the lookout for greenwashing.
- Write to government and corporate leaders to express your concern over plastic pollution and suggest initiatives like cleanups to tackle the problem locally.
- Use a reusable cup, water bottle, bag, take out containers, a non-plastic straw, cutlery, etc. instead of using single-use plastics.
- Be a mindful consumer - when buying products think of the packaging used. Avoid items wrapped in plastic and purchase unpackaged options instead, such as solid shampoo bars.
- Incorporate recycling into your daily routine if using single-use plastics and know what types of plastic are accepted by your local recycling facility. For biodegradable plastics, check the packaging information for disposal recommendations.
- Make your home wildlife friendly by planting native species for food and shelter, securing garbage, and minimizing use of pesticides that can run off into local ocean-bound streams and rivers.
- Talk to your friends, family members and co-workers about plastic pollution. Encourage them to start recycling and reduce their use of single-use plastics. Lead by example.

Being mindful of our actions and our own impacts on the planet can make a significant difference to the number of animals dying from marine plastic pollution.

By working to combat plastic pollution, we can be leaders not only to our own generation, but also to future ones. As the brilliant Sylvia Earle has said,

"We need to respect the oceans and take care of them as if our lives depended on it. Because they do."

Photo by David Troeger on Unsplash

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