Marine Debris in the Ocean & Intertidal

What is Marine Debris?

Marine debris is defined as human-made, solid materials that enters our waterways either directly (such as dumping) or indirectly (such as washing out to sea via river or stream). Marine debris includes both biodegradable items and non-biodegradable items. For thousands of years, marine debris was composed primarily of readily biodegradable items (wooden tools, hemp or linen ropes, cotton or hide clothing). Next, glasses, metals, and paper products were added to the mix. Manufactured glass and metals are not as biodegradable as ancient tools and fibers, but these products are quickly broken down by physical forces and have minimal impacts on the marine environment compared to plastic. Worldwide, about 80% of marine debris is now made up of plastic items. This plastic debris – and other types of marine debris –come from four main sources: land based/personal-use items, marine industries and recreation, container ship spills, and natural disasters.

Non-biodegradable items tend to cause the most problems as marine debris since they persist in the environment. Plastic is more of a problem than glass, not only because it is more prevalent. While glass does not biodegrade, it does break into increasingly smaller pieces and mineralize. Furthermore, it is fairly inert (usually doesn't contain or absorb toxic chemicals), usually sinks, and becomes almost equivalent to a human-made rock in the ocean. On the other hand, plastic photodegrades into smaller pieces when exposed to UV light,but these pieces often contain or absorb toxins and can be easily mistaken by marine animals as food. Long or circular pieces of plastic can also entangle marine animals.

A Brief History of Plastic

Over 100 billion pounds of plastic were produced in 2013, and this figure has been increasing from year to year. The amount of plastic produced annually has grown approximately 40-fold between the 1950s and 2005. Looking at our lives today, it's hard to think of how we could exist without plastic. But plastic is actually a relatively new addition to the world. It was first created by Alexander Parkes in 1856. He showed off this new product to the public, which we later came to know as cellulose, at the Great International Exhibition in London. The term "plastics" was coined by chemist Leo Hendrik Baekland to describe his invention of the first fossil fuel based polymer, which he created in 1907 . After the First World War when manufacturing techniques were refined and petroleum was readily available, plastics started their rise to popularity. However, they did not start to become common until after the Second World War, and there are still people alive who can remember a life without plastic in it. According to the American Chemistry Council, the plastic production process often begins by treating components of crude oil or natural gas in a "cracking process." This process creates hydrocarbon monomers such as ethylene and propylene. The monomers are then chemically bonded together to form chains called polymers.

Simply put, polymers are chemicals made of many repeating units. They can be made by nature or artificially in a lab, some examples include natural polymers such as spider silk, hair, and DNA, and synthetic polymers like silly putty and rubber. Characteristics such as flexibility, heat-resistance, and stable electrical properties can be imparted to plastic polymers by adding different chemicals or "plasticizers." Polymers are often used in both industry and consumer products because they are durable, flexible, and strong.

Transport of Marine Debris

Global winds and currents transport marine debris and other pollution. Wind is the movement of air driven by differences in the density of air masses, which is determined by air temperature. Currents are the continuous and directional movement of water. Surface currents are driven primarily by wind and affect the upper 400 meters of the ocean. Deepwater currents, affecting waters below 400 meters, are driven by differences in the density of water masses, determined by both temperature and salinity (saltiness). Cold air is denser than warm air.

The same is true for water: cold water is denser than warm water. Also, water with a high salinity (saltier) is more dense than fresh water. Differences in the density of water can cause both downwelling and upwelling events. Currents caused by water density due to salinity and temperature are called thermohaline circulation: "thermo" for temperature and "haline" for salinity. This thermohaline circulation creates what is called the "global conveyer belt." In areas of downwelling, warm surface currents (less dense) cool in transit to the poles. As they cool, they become more dense and sink down the water column. In areas of upwelling, winds parallel to coastal land pushes warm surface water offshore. Deep cool water upwells to replace warm surface water. This nutrient-rich cold water can create plankton blooms.

Global wind and current patterns can be generalized as warm equatorial water/air rising and moving north and cool polar air/water flowing along the surface toward the equator. The zones where warm and cold converge are the areas that create the main currents and winds on earth. The currents and winds interact with each other, which changes their direction from what you might predict.

The winds and currents are also deflected by the rotation of the Earth. This is called the Coriolis effect, and deflects winds and currents to the right in the northern hemisphere and to the left in the southern hemisphere. For more on the Coriolis effect, see

http://www.youtube.com/watch?v=i2mec3vgeaI
- a short video about the Coriolis Effect from NOVA PBS

http://oceanservice.noaa.gov/education/kits/currents/05currents1.html
- a webpage by NOAA devoted to understanding wind, ocean currents and the Coriolis effect

Because of wind, the Coriolis effect, and thermohaline circulation patterns, global ocean currents tend to follow a predictable pattern, and often move in a circular motion. For example, wind-driven currents off the coast of Southeast Asia and China drive warm water northward. As this water nears Japan, winds shift and begin pushing the water eastward. When the current meets the Western coast of North America, some of the water pushes northward towards Alaska and some moves southward along the coast of California to the equator. Here, prevailing winds push the current back across the Pacific Ocean, where it begins to move northward again near Southeast Asia. Gyres often form in circular currents such as this, accumulating water, plankton, and debris in the center of the circle formed by the current. The North Pacific Gyre is located at the center of currents circling the North Pacific Ocean. "Garbage patches" of small bits of plastic and other marine debris are sometimes found within gyres as the debris concentrates over time. This poses serious threats to organisms living within the gyre ecosystem.

Monitoring Marine Debris

Beach cleanups with recorded items collected are a form of scientific data collection. While a simple beach cleanup does not take the traditional appearance of a scientific study with a laboratory coat and graduated cylinder, recording debris collection actually tells us a lot about what types of trash is entering the ocean and accumulating on shore. The Center for Alaskan Coastal Studies (CACS) has been conducting CoastWalk beach monitoring and cleanups since 1984. The data collected on wildlife, human activity, and marine debris collection along the Kachemak Bay shoreline through this program represents a long-term citizen monitoring project. The CoastWalk program has partnered with the Ocean Conservancy's International Coastal Cleanup (ICC), a worldwide marine debris cleanup and monitoring effort. Therefore, data from Alaskan clean ups that is entered into the CACS database is available locally within Alaska and added to the global ICC database as well.

Marine debris accumulating along Alaskan shorelines originate from one of four sources. These sources include land based/ personal-use items (such as waterbottles, shoes, food wrappers), marine industries (such as buoys, fishing lures, boat parts), container spill items (friendly floatees, nike shoes, items from known spills), and debris resulting from natural disasters (these items can range from gas containers and sports balls to docks and pieces of housing material). Trends in debris accumulating on beaches from each of these sources can be measured from the monitoring and cleanup efforts of Alaskan shoreline cleanups over the past 30 years. The recovery of land based/personal-use items in marine debris clean ups is increasing in the Alaska region. Categories of land based/personal use items include: daily use items by individuals such as toothbrushes and food wrappers, household items such as soap dispensers, dishes, and appliances, and recreational use items like beverage bottles, food wrappers, and sandals.

On the other hand, there is evidence that debris from commercial fisheries and other marine industries may be stabilizing or even decreasing in some areas. Examples of debris from marine industries and recreation include: buoys, boat parts, nets, ropes, fishing line, strapping bands, gloves, and coolers.

Debris from container ship spills is difficult to track because shipping companies are not required to report spills in international waters. However, with ever-increasing amounts of products being shipped across the world's seas, the risk of container ship spills is great and increasing. It is currently estimated that as many as 10,000 containers are lost every year. Other reports estimate the number is in the hundreds. Many freight vessels traveling across the North Pacific do so along the coast of

Southeast Alaska and the Aleutian Islands, crossing the Gulf of Alaska.

Recent container spills include: 1990 – Nike Shoes, 1994 – Hockey Gear, 1997 – Legos, and 2012 – Sport Memorabilia. Container ships also sometimes spill the raw plastic pellets, called nurdles or 'mermaid tears,' that are used in the manufacture of all sorts of products.

One well-known container spill helped oceanographers learn more about global currents. "Friendly Floatees" bath toys were being shipped across the Pacific Ocean to be sold by The First Years, Inc. In early winter, 1992 a container filled with the toys (as well as 11 containers filled with other products) were lost overboard in the middle of the Pacific Ocean. More than 28,000 floating bath toys spilled into the water. They were used by Curtis Ebbesmeyer, an oceanographer to model global ocean currents by keeping track of where the floatees made landfall.

Finally, tragic natural disasters like the 2011 Tohoku Earthquake and Tsunami in Japan and the 2013 Haiyan Typhoon in the Philippines have created influxes of marine debris worldwide and along Alaska coasts specifically. An astounding amount of land-based debris washed into the ocean along with debris dislodged from fishing, aquaculture, and marine recreation following the 2011 Tohoku earthquake and tsunami. Much of this debris drifted back to Japanese shores, but a large portion was swept by large-scale Pacific currents. Two researchers from the Washington Sea Grant, Miller and Brennan, predicted where the current-driven tsunami debris is likely to wash up. Relying on data from past debris studies and surface drifters, they concluded that "the coast of Alaska is the epicenter of drifter groundings in the northeast Pacific." After the tsunami devastated Japan, the Gulf of Alaska Keeper and Center for Alaskan Coastal Studies have observed a significant increase in the amount of plastic foam pieces (including polystyrene/Styrofoam and polyurethane) on Montague Island and Gore Point, much of which is likely connected to the 2011 Tsunami.

On a more local scale, minor weather events cause damage to docks, boats, and shoreline development and scatter debris into the water every year, and more extreme events can cause upticks in the local occurrence of debris.

Effects of Marine Debris

A large amount of plastic marine debris is transported throughout the ocean by winds and currents. Much of this plastic accumulates in ocean gyres such as the North Pacific and North Atlantic. This plastic poses many threats to marine ecosystems when they entangle, smother, or are ingested by living organisms. As the plastic photodegrades into smaller and smaller pieces, the pieces are easily mistaken for plankton and often ingested by forage fish. These forage fish are in turn consumed by predators, some of which are then caught and eaten by people. Furthermore, plastics in the marine environment can block sunlight from penetrating into the water column, preventing phytoplankton from absorbing the sunlight needed to photosynthesize and obscuring the light small fish and zooplankton use to find food.

Three major effects of marine debris in the ocean ecosystem are entanglement, ingestion, and water pollution. Entanglement refers to what happens when animals get caught in pieces of debris such as fishing line, nets, rope, soda rings, and plastic bags. The mobility of these animals is threatened by entanglement, hindering their ability to acquire food, evade predators, and, in the case of marine mammals, sea turtles, and birds, reach the surface for oxygen. Entanglement can also cause physical injuries and sores as the animals struggle against the debris they are caught in and grow larger than they were when they were originally entangled.

Ingestion refers to what happens when animals consume marine debris. Photodegraded plastic often breaks into smaller and smaller pieces until it is about the size of plankton. These tiny plastic pieces (< 1 mm) are called microplastics. Microplastics are often ingested by small fish, baleen whales, filter feeders such as mussels, and other marine organisms. In some parts of the ocean, the small bits of photodegraded plastic outweigh plankton, the base of the ocean food chain. In 2001, the scientists from 5 gyres found that plastic nodules outweighed plankton 6:1 in the Pacific Gyre. In 2011, they tested again and found the nodules outweighed plankton 40:1. Larger pieces are sometimes targeted by predators such as albatross and sea turtles because they look like prey items, namely squid and sea jellies.

The ingestion of marine debris can cause both direct and indirect problems. The animals consuming the plastic can starve because their stomachs are filled with plastic rather than food. Dwindling populations of sea birds, sea turtles, and especially forage fish can disrupt entire food webs because low populations decrease availability of prey to predators up the food chain. When forage fish or benthic invertebrates consume microplastics, the plastic is stored in the digestive system or absorbed into the animal's circulatory system, and accumulates there. When these forage fish with microplastics in their bodies are in turn eaten by larger fish, marine mammals, and birds, the microplastics make their way up the food chain. A large top predator can accumulate quite a lot of plastic in its system. This process is called bioaccumulation.

Bioaccumulation contributes greatly to the severity of the third major effect of marine debris: water pollution. As these pieces of plastic float throughout the ocean column they begin to provide unnatural habitat for tiny microbes. These microbes are attracted to plastics because the rough surface of the plastic provides an excellent surface for the microbes to cling to. As these plastics become home for microbes, they also begin to absorb Persistent Organic Pollutants (POPs) from surrounding seawater. These POPs are trace insecticides, pesticides, and industrial chemicals. When these plastics are ingested by animals, the microbes are digested and POPs subsequently absorbed into the animal's fatty tissue. Then the animal's predator eats its prey, digesting that fatty tissue and accumulating the POPs into the predator's fatty tissue. Records of bioaccumulation of toxic POPs through eating plastics have been recorded in sea birds and top predator marine mammals such as Orcas. Plastics that contain POPs can also leach them into the surrounding water, so areas with large amounts of marine debris can have high level of toxic pollutants in the water column. These pollutants can be absorbed from the water into adult marine animals as well as their egg and larval stages.

