The problems of marine debris plastics for coastal resilience

Authors: Lars Bodnar* (primary contact author), Naomi Daniher, Olivia Winters, Matt Wald, Hanna Clary

Team Squidoody

Kodiak High School, 722 Mill Bay Rd, Kodiak, AK 99615 switgard@gci.net, jeismann01@kibsd.org

“This paper was written as part of the Alaska Ocean Sciences Bowl high school competition. The conclusions in this report are solely those of the student authors.”
The problems of marine debris plastics for coastal resilience

Abstract

There are multiple effects of marine debris plastic on coastal resilience. This includes entanglement of marine animals, ghost fishing, micro plastics which can be ingested, and phthalates which leach into the water. Because all these affect the ecosystem, coastal communities that rely on the ocean lose or have diminished ability to rebound from the chronic problems of marine debris. Marine entanglement causes people to lose resources that they use for subsistence or economy. Ghost fishing is a problem for coastal resilience because it wastes marine resources. In Women’s Bay in Kodiak a study was conducted that tracked red king crab, and an estimate for king crab mortality in ghost fishing gear was made. Micro plastics are miniscule plastics created as larger plastics break down from the movement of ocean currents and UV radiation. Micro beads from manufactured cosmetic products also enter the ocean. Filter feeders at the basis of the food web are then affected. Phthalates are an issue to coastal resilience due to their chemical nature. They are hazardous to birds, fishes, and humans through bioaccumulation. There are two main solutions to the marine debris predicament, reactive and proactive. Both are helpful, but one or the other is not enough. In order to turn the tide on plastic marine debris, everyone must help.
Introduction

Resilience is a community’s ability to thrive after a natural or man-made disaster. These disasters could include chemical spills, oil spills, volcanoes, tsunamis, nuclear winters, invasive species, and marine debris. All of these topics are relevant to our community on Kodiak, because as an island community we are dependent on our ocean resources that determine our economy, and transportation from other locations for goods and services. The above disasters could affect our community either through interrupting transportation and delivery or by harming seafood resources. Our team decided to research marine debris because this is a globally growing problem. Marine debris is a disaster, because it persists and affects the ecosystem and life in the oceans thus taking away humans’ seafood resources. Kodiak relies on its oceans for food and economy. Also, the beaches accumulate marine debris that can appear unsightly. People travel from everywhere to see Kodiak’s wilderness and wildlife. When they see marine debris on the beaches or entangled wildlife this can have a negative effect on tourism.

Background and history of the marine debris problem

Plastic debris in the ocean is a relatively new problem. Plastic as we know it was invented in the 1930’s. At the end of World War II, our economy transitioned to one of “consumerism”. We have been conditioned to believe that plastic products are the base of a better standard of life. As the buy-use-and-throw-away life style became more popular, so did plastic. We use plastics because they are inexpensive, and can be easily molded into many shapes. Plastic gets into the ocean through inadequate disposal, for example, littering, carried by the wind from landfills, carried off by birds, through the watershed, through carelessness, and blatant disposal into the ocean.
In the year 2015, the ocean received 5-12 million tons of plastic garbage from land-based sources (Ocean Conservancy, 2014). Estimates like this of how much marine debris enters the ocean annually can be generated through computer modeling. Aerial surveys are useful in sighting plastics on the water surface and on beaches. They have the advantage of covering large areas. A new technology is UAV’s (small unmanned aerial vehicles), which can be used to more accurately survey small areas of beach (White, Fortunato, pers. comm.). There are two main ways to assess the abundance of micro plastics: Neuston net samples can be used to measure how much plastic is present, while stomach samples show the impact on animals and the food chain. We can also estimate the amount of garbage on a beach through a beach clean up survey. By collecting data on how much garbage is in a defined area, it can be extrapolated to the whole beach. In this paper, we compare the worldwide marine debris composition with that on a local beach, discuss marine animal entanglement, ghost nets and pots, micro-plastics and micro beads, phthalates, and solutions to these global problems affecting coastal communities.

Marine Debris composition

Plastic and marine debris is a worldwide problem. Some of the largest percentages of marine debris found are cigarette butts (22%), food wrappers, and plastic lids, which together comprise 50% of the world’s debris (Fig. 1; Ocean Conservancy, 2014).
Fig. 1: Composition of Marine Debris from the Ocean Conservancy International Coastal Clean-up, 2013

Fig. 2: Composition of Marine Debris from a Kodiak beach shoreline survey of 2.82 square kilometers on Nov 20, 2015.
On November 20, 2015 the Kodiak Tsunami Bowl team participated in a NOAA Marine Debris Shoreline Survey to show how much debris is washed up over the duration of two months on a local beach. The survey area was determined by handheld GPS and calculated at 2.82 square kilometer (Pyle, pers. comm.). According to the data we collected, plastic (hard) was the biggest component. The Kodiak beach had no cigarette butts, but large amounts of processed lumber. A component of Kodiak debris is fishing gear, which is not even listed on the worldwide chart. Although, in the shoreline survey only 7% were fishing gear (6% plastic rope, small net pieces plus 1% fishing lure), overall on Alaskan and Kodiak beaches it is the majority of plastic debris on beaches (Decker 2014, Alaska Sea Grant Program 2009, pers. comm. Pogson).

Kodiak has marine debris as does the rest of the world, but the threats and types of debris are different. Figures 1 and 2 show hard plastic to be the world’s largest threat to marine ecosystems, however, local problems may be different as shown by the example of fishing gear on Kodiak.

**Marine debris entanglement**

Marine animals get tangled in large marine debris. This has an effect on coastal resilience because if the animals are affected then the human community could possibly lose one of its major resources. Entanglement is when marine animals become entrapped by marine debris. This can include netting, long line hooks, and other plastics getting wrapped around the animal’s neck, fins, flukes, or other body parts.

Around the world whales, dolphins, turtles, seals, sea lions, swordfish, and many other animals become entangled in marine debris. They get long trailing bits of debris wrapped around their bodies. An animal gets entangled in marine debris when they think it to be food, they swim into it, or are trapped some other way. Plastic six-pack rings can catch fish and other wildlife.
Packing rings can start to choke the animal as it grows. Entanglement makes it difficult for entangled mammals to escape leading to drowning or death from injury, starvation, or weakness (Murray 2009). In Alaska, Steller sea lions and Northern fur seals are often sighted with some sort of entanglement (Fig. 3). Since July 2015 three entangled Steller sea lions were sighted in Kodiak (Savage 2015).

![Number Sighted](image)

Fig. 3: Since July 2010, 102 entangled Steller sea lions and Northern fur seals have been sighted along Alaska’s coasts. All sighted animals were entangled at the neck and all but one were found alive. Twenty-three of the sighted animals were Steller sea lions and 79 were Northern fur seals (Savage, 2015).

**Ghost fishing**

Ghost fishing occurs when fishing gear captures and kills marine life after being lost or abandoned. One piece of ‘ghost gear’ can kill many animals of different species, and dead animals in ghost gear can work as bait to attract predators (Havens et al. 2008). Ghost gear is a
global problem that captures, entangles, and can harm or kill marine organisms. It can continue fishing for a very long time (Matsuoka et al. 2005).

There are many ghost nets in the Pacific Ocean that can entangle and kill marine organisms. Because nets are made sturdy they can float for years and decay very slowly. In 2005, 77,000 lbs. of ghost nets were taken out of Hawaiian reefs and shorelines alone (Brit 2005).

Christopher Long, Peter Cummiskey, and Erik Munk studied the effects of ghost fishing on king crab in Women’s Bay, Kodiak, Alaska, from 1991-2008 (Long et al. 2014). They took active, healthy king crabs that were 42-162 mm CL (carapace length) and epoxied acoustic tags to their carapaces (back of the shell). The king crabs were then released back into the ocean and regularly checked by scuba divers, who located them on the seafloor. During the study scuba divers released 20 tagged crabs and hundreds of aggregated live crabs from ghost pots.

In the 17-year study a total of 192 crabs were tagged. Out of these 102 were male and 90 were female. The average number tagged per year was 11 king crab. Those crabs were then watched for an average of 147 days. The end results were as follows: 76 crabs molted and lost the tags, 48 had ‘unknown’ conditions, 22 were lost, 16 crabs had traveled where the scuba divers could not and were labeled ‘derelict’, 13 crabs had other mortalities, 13 were killed by ghost gear (12 in ghost pots, and one in a gill net), 3 died shortly after being tagged and were assumed dead because of handling, and 1 crab had a tag failure.

Multiple different types of pots caught the king crab. Over the course of time of the study in Woman’s Bay 143 derelict pots were found. Seventy were dungeness crab pots, 42 were webbed pots, 20 were homemade subsistence fishing pots, 7 were store bought pots, and 4 pots were unknown (not recorded).
The authors calculated that the ghost fishing mortality rate could average from 40% (assuming the crabs the divers released would escape) to 56% (assuming the crabs the divers released would have died).

In an interview with Pete Cummiskey, one of the authors of the research paper “Effects of ghost fishing on the population of red king crab (*paralithodes camtschaticus*) in Womens Bay, Kodiak Island, Alaska” we discussed causes of gear loss. Crab pots are lost many different ways: the propeller of a boat breaking the rope between a buoy and a pot, organisms growing on a rope which then gets weighed down, ice freezing around the buoy and dragging the pot somewhere else, ice cutting a buoy and sinking it to the bottom, and fishermen losing or abandoning their pots. There are laws in place to make sure that crab pots have a biodegradable cotton (“rotten cotton”) holding the opening closed that will break down over time and open the pot so that marine organisms can escape. However, some fishermen don’t abide by this law. In other cases pots will have the biodegradable cotton, however, if pots fall upside down the opening gets blocked. Cummiskey suspects that older pots may not have the biodegradable cotton or that some people will not comply because it is more work to replace the biodegradable cotton.

Cummiskey also mentioned that ghost pots could have an ecological and economical effect on Kodiak. Crabs die before they can get caught and sent to market, and before they can reproduce. This affects both, the catch rates and the potential crab population.

Ghost fishing is a problem for coastal resilience because it affects our ability to access local food resources. In the event that a natural disaster would strike Kodiak that took down transportation, our island community would run out of food. In that situation the king crab’s and other local fisheries resources availability would support our ability to survive and thus our resilience.
Microplastics can affect the marine ecosystem and food web from the bottom up. There are two types of micro plastics: the micro plastics that are broken down in the ocean from larger debris to small bits and micro beads, which are plastics that are manufactured for use in cosmetics and personal hygiene products.

Microplastics in the ocean affect the food web by appearing to be a potential food source for sea life. When plastic garbage such as bags or buckets are in the ocean, they get broken down into smaller bits until the base of the food web is affected through consumption. Surface micro cracking from UV exposure weakens the plastic making it brittle to be broken down by the grinding of the ocean’s movements (Andrandy 2011). These small plastics then look like food for smaller marine life and are ingested, causing internal damage, poisoning, choking, and death. When the base organisms of the food web are affected, the larger species are as well. Ingested chemicals may in turn affect apex predators. When smaller organisms die off the larger predators, if not adaptable could possibly die as well. Humans could be affected as consumers of seafood (Rochman 2015).

Microbeads are small plastic spheres manufactured to add abrasion in face wash and toothpastes (Fendall and Sewell 2009). When using these products the beads are rinsed down the drain, which in turn leads to the ocean. These beads then affect the filter feeders of the ocean. As in the case of microplastics, when these base organisms in the food web are affected by chemicals attached to or absorbed in the bead the higher organisms can be affected as well.

We conducted an experiment to see if filter feeders retain micro beads. Toothpaste was fed to a small mussel, large mussel, sea anemone, and limpet (limpets are grazers). The
organisms were each placed in a separate beaker with seawater. The toothpaste was mixed with saltwater to be given to the animals. The next day, the animals were all dead. The cause of death was unknown because other ingredients in the toothpaste could have been poisonous (Matweyou, Schultz pers. comm.). Thus, a second experiment was conducted with isolated small visible beads from a *Softsoap kitchen fresh hands* product. We isolated the beads by filtering the hand soap through a coffee filter in a funnel, then added water to rinse it through. When the beads were isolated we used saltwater to rinse them into a beaker. We placed one mussel in each of four beakers with saltwater, then added equal amounts of saltwater with the micro beads. The beakers were placed in a cold area overnight. Under microscopic examination it was determined that the beads were not plastic but in fact contained oil. After 16 hours we checked the mussels. Many beads floated on the water surface. One mussel was frozen, cut in half, and then checked under a dissecting microscope for ingested beads. We found ruptured beads on the gills. However, the mussels had filtered the beads. This proves that filter feeders will unselectively take in particles the size of micro beads.

**Phthalates**

Phthalates are a group of chemicals used to soften plastics. They make a plastic easier to bend and less brittle. Phthalates are not the only chemicals used to soften plastic but they are the best documented.

Plastic marine debris is the source of phthalates in the ocean. They are not chemically bound to their plastic host so they leach out into the environment. With the large amount of plastic in the ocean phthalates have entered the biosphere in many places. For example, phthalates can be found in the preening gland of see birds far offshore (Hardesty et. al 2015).
When the phthalates leach out of the plastic the plastic can absorb other toxic chemicals and becomes a chemical sponge concentrating various other toxins.

Phthalates enter the food web in a variety of ways such as digestion and through direct contact with plastics. Though this does not put a high concentration of phthalates into any one organism it travels up the food chain and increases in quantity in the higher trophic levels through bioaccumulation. There are continuing studies in Alaska, Norway and Australia on the effects of phthalates on sea birds (Padula pers. comm.). Phthalates in high dosages can cause health problems such as modifying the endocrine and immune systems (Smith 2014). The endocrine system is key to reproduction. Even short duration exposure to phthalates caused immediate effects on the immune system of juvenile salmon (Smith 2014). Phthalates can also cause mental and emotional issues in humans (Factor-Litvak et al. 2014).

This is an issue to coastal resilience because we are putting phthalates into the ecosystem without knowing how or when they will leave the biosphere. There are a lot of things we do not yet understand about phthalates. Coastal resilience is the ability of a coastal community to bounce back after a disaster, but as we put chemicals into the biosphere without knowing their effects we endanger the resilience of our coast and our communities.

Discussion

A large proportion of marine debris in the world ocean are plastics. Plastics cause many problems in the ocean. They harm animals, take over the food chain, and leach harmful chemicals into the water.

There are two kinds of solutions to the marine debris problem: reactive and proactive. Both are important but the reactive solution is less helpful because it tries to take existing plastics
out of the ocean but it is not preventing the plastics from getting there. On the other hand, the proactive solution is preventing the marine debris from entering the water. The proactive solution will make the reactive solution more successful. There are many places around the world where people are applying the reactive solution by picking up the trash on the beaches and recycling it. There are many proactive solutions, for example, banning plastic bags and other one-use plastics. Some plastics such as beverage bottles are recovered through a deposit system and are either recycled or used to make something else.

A large part of the marine debris consists of single use plastics. Single use plastics are everywhere. They are used for food packaging, plastic bottles, and plastic bags. The problem is that the majority of single use plastic does not get recycled. If we have a piece of something that cannot fulfill it’s purpose anymore, then we can put it with others and make it into something new. To address the problem of how to get packaging back into a recycling stream, we need a better system to keep the different materials separated.

Plastic hydrocarbons can be energy sources. They are carbon-hydrogen compounds, and the simplest hydrocarbon is methane. There are many different combinations of hydrocarbons; branched and unbranched alkanes, aromatics, and polyaromatics. All of these have bonds that contain energy. There is potential to recover this energy from plastic hydrocarbons. For example, in the steal industry plastic is used in super hot furnaces for fuel. In the long term, our marine debris problem could be reduced if we convert our one-way plastic stream to a recycling stream and make good use of the energy. However, profit is made when companies continue to produce and sell one-way plastics, so there is no incentive to stop the flood of single use products. While reactive solutions appear the more direct and simple approach, only proactive solutions will bring a long-term change. Every time any of us buy something, we endorse the production
of the product, so only by our combined decision to avoid single-use plastics can we discourage the production. To make this shift, we need to educate the general public about the magnitude of the problem and its effects. Nothing short of a cultural shift can slow this problem enough to be solvable. The good news is that everyone can help (Fig. 4, 5).

Fig. 4: Team Squidoodly after marine debris beach clean-up. Fig. 5: Everyone can help.

Scientist contacts:

**Cummiskey, Peter.** National Marine Fisheries Service, Alaska Fisheries Science Center (AFSC) Kodiak Laboratory, Kodiak Fisheries Research Center, 301 Research Court, Kodiak AK 99615. Phone: (907) 481-1700. Email: peter.a.cummiskey@noaa.gov

**Fortunato, Ron.** United States McAuliffe Educator & NASA Space Ambassador President, Trillium Learning. 108 Lakeview Court. Pompton Lakes, NJ 07442. Phone: (973) 907-2332. Email: ron@trilliumlearning.com

**Matweyou, Julie.** Marine Advisory Program, Kodiak Seafood and Marine Science Center, 118 Trident Way, Kodiak, AK 99615. Phone: (907) 486-1514. Email: Julie.matweyou@alaska.edu

**Padula, Veronica.** University of Alaska Fairbanks/Anchorage, School of Fisheries and Ocean Sciences website: http://causeylab.uaa.alaska.edu/indexveronica.html

**Pogson, Tom.** Director of Education, Outreach, and Marine Programs. Island Trails Network. P.O. Box 301 Kodiak, AK 99615. Phone: (888) 301-0568 Email: tom@islandtrails.org

**Pyle, Bill.** Supervisory Biologist. U.S. Fish and Wildlife Service, Kodiak Refuge Headquarters, 1390 Buskin River Road, Kodiak AK 99615. Phone: (907) 487-0228 Email: Bill_Pyle@fws.gov

**Schultz, Arthur.** Kodiak fisherman and volunteer in the Kodiak Seafood and Marine Science Lab.

**White, Anthony.** Statewide Virtual Content and STEM Program Coordinator. Phone: (907) 942 0699. Email: awhite01@kibsd.org
Acknowledgments:
We would like to thank all above mentioned scientists for their involvement with members of our team and sharing their expertise. In addition, the following people shall be thanked for talking with us about various fisheries and marine science topics:

**Heimbuch, Hannah.** Community Fisheries Organizer Alaska Marine Conservation Council. P. O. Box 101145, Anchorage AK 99510. Phone: (907) 299-4018. Email: hannah@akmarine.org

**Guo, Lei.** Marine Advisory Program, Kodiak Seafood and Marine Science Center, 118 Trident Way, Kodiak, AK 99615. Phone: (907) 486-1500. Email: lguo2@alaska.edu

For general support and use of the laboratory we thank:

**Foy, Robert.** Director of Kodiak Fisheries Research Center. 301 Research Court, Kodiak AK 99615. Phone: (907) 481-1700. Email: robert.foy@noaa.gov

Thanks are also extended for help in paper editing to:

**Vanek, Victoria.** Crab research biologist, Alaska Department of Fish and Game, 351 Research Court, Kodiak AK 99615. Phone: (907) 486-1890. Email: vicki.vanek@alaska.gov

We further want to acknowledge our fellow students Ostin Webb and Ocean Limchantha for exceptional sportsmanship and participation in discussions and hands-on activities. We would also want to thank our coaches for their amazing patience, support, and guidance (and food).

Literature cited


