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PLASTICS DERIVED FROM DERELICT FISHING GEAR IN THE ARCTIC:

Looking at Sustainable Fisheries for a Strategy of Mitigation, Remediation and Prevention in Iceland and Alaska

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In partial fulfillment of a Bachelor of Arts Degree in Environmental Analysis, 2019 – 2020 Academic Year, Pitzer College, Claremont, California

Professor Melinda Herrold-Menzies

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ACKNOWLEDGMENTS

If you would have asked me at the beginning of my college career that I would leave Pitzer College with an unhealthy obsession with trash in the ocean, well I do not know if you would be reading this thesis right now. My journey with litter began during one of the most incredible moments of my life. I had the fortunate opportunity to study in Iceland and Greenland, and met some of the most inspiring, intelligent, and ambitious people. Firstly, I would like to thank Haraldur Einarsson for allowing me to research derelict fishing gear at the Icelandic Marine and Freshwater Research Institute and providing me with endless wisdom on sustainable fisheries. I would also like to give a huge thank you to all of my classmates at SIT who were with me throughout my whole marine trash journey.

Secondly, I would like to thank the entire office at the Alaska Longline Fishermen's Association for providing me with a truly unforgettable opportunity to dive headfirst into the world of fisheries for an entire summer. Next, a massive thank you must be presented to my two thesis readers, Melinda Herrold-Menzies and Masha Prokopenko, for providing me with an incredible amount of help throughout the entire thesis semester, and of course an undeniable thank you to Char Miller for being an environmental analysis lifeline and thesis guru.

Lastly, I would like to thank my friends and family who were there to listen to me when I would not stop talking about plastics in the ocean. I appreciated your sympathetic nods when I would say derelict fishing gear ten times in one sentence.

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ABSTRACT

Marine plastics are not just a problem, they are a silent, sinister epidemic. Marine plastics are the largest economic and ecological threat to our marine ecosystems, particularly marine plastics derived from lost and or discarded fishing gear, which affects sensitive marine communities, the chemical composition of the ocean water, and the physical makeup of the seafloor. With 6.4 million tons of marine debris entering our oceans annually, a third of which is lost fishing gear, it is estimated that, by weight, in 2050 there will be an accumulation of more plastic than fish in the ocean (Heath, 2018; Wilcox, 2015).

Marine litter derived from plastic fishing gear, primarily passive gear, when lost in the ocean causes a series of consequences to the marine ecosystem, that of which increases when there are high concentrations of fishing activity in the geographic area. Arctic countries have some of the most abundant fisheries, that of which is projected to increase due to anthropogenic climate change. In the context of climate change affecting the Arctic ecosystem, in this thesis, we will review the consequences of plastics derived from fishing gear for the Arctic marine ecosystem, estimate the potential influx of derelict gear plastics originating from data obtained in Alaska and Iceland, and then confidently present effective forms of remediation, prevention, and mitigation strategized from models of sustainable fisheries to resolve the ramifications of lost and or discarded gear in Arctic communities.

TERMINOLOGY

In order to prepare the reader for my analysis on lost fishing gear, I am providing a list of key terms and abbreviations that will be used frequently throughout this thesis. The thesis itself will provide additional detail on the terms listed below, but due to complexity of the industry-specific terminology, I find it helpful to start with a preliminary terminology section.

ALDFG: Abandoned, lost, and or discarded fishing gear

Passive gear: Method of fishing where (a sometimes baited) net or trap is left in a certain area for an extended period of time

Active gear: Method of fishing where a net is physically dragged through water via human or engine powers

Gillnet: curtain-like monofilament (plastic) nylon net that is set perpendicular in the water so that fish get trapped in it by their gills

Trammel net: a set-net consisting of three layers of netting, designed so that a fish entering through one of the large-meshed outer sections will push part of the finer-meshed central section through the large meshes on the further side, forming a pocket in which the fish is trapped

Longline: A method of fishing with a long main line anchored to the bottom, and attached vertical lines with baited (or unbaited) hooks

Ghost fishing: Abandoned, lost, and/or discarded fishing gear that continues to induce mortality of marine organisms without the infliction of human control

MFRI: Icelandic Marine and Freshwater Research Institute

ALFA: Alaska Longline Fishermen's Association

AO: Alaskans Own, Alaska's first community supported fishery

CSF: Community Supported Fishery

FCN: Fisheries Conservation Network

Small scale fishing fleet: The small-scale fisheries sector tends to be firmly rooted in local communities, traditions and values. Many small-scale fishers are self-employed and usually provide fish for direct consumption within their households or communities

Large scale fishing fleet: It provides a large quantity of food to many countries around the earth, but those who practice it as an industry must often pursue fish far into the ocean under adverse conditions. Large-scale commercial fishing is also known as industrial fishing

EEZ: Exclusive economic zone

MARPOL: Short for Maritime Pollution 73/78, which was presented at the International Convention for the Prevention of Pollution from Ships

FANTARED and FANTARED II: projects funded by the European Commission to identify, quantify, and ameliorate the impact of static lost fishing gear with the deep-water gill net sector in European shallow and deep waterways

FOREWORD

Thump, crack, splat. These were the motions playing over, and over, and then over again while I was aboard (it felt like against my own will) the Icelandic ferry in Akureyri heading to the Grimsey Island in the Arctic Circle. Winds were howling in excess of eighty miles per hour outside. At about two-minute intervals – out of a total of six hours aboard the ferry – we would climb atop a twenty-five-foot swell, and then crash down on the icy Arctic sea.

The first twenty minutes, I felt as if I was in a National Geographic adventure; my thirteen other classmates and myself were standing on the back deck of the boat, gripping onto the rusted steel handrails, getting mists of cool Arctic Ocean splashed in our faces every time we would ride down the mountainous waves. Minute twenty-one hits and thump; the boat crashes down from the wave. Crack; I hear the water rush onto the deck of the boat, and then timed just as perfectly as the sequential waves of the Arctic, splat; I puked all over the deck of the boat.

For the remaining two hours, thirty-nine minutes, and approximately twenty-four seconds, I was trapped inside the ferry waiting desperately to get to Grimsey. In perfect intervals, I could feel the thump of the boat, the crack of the wave, and then the splat of my puke on the cold railing. When I was not in my own perfectly timed hurling pattern, I could hear other passengers trapped in their own. It was a never-ending sound chamber of thump, crack, and so many splats. Just before I was going to thump my own head on the side of the boat, the thumps came to pats, the cracks faded to soft claps, and the splats turned to sighs. Thinking the worst was finally over, we had finally arrived at Iceland's only island in the Arctic Circle.

I will not go into detail on the rest of the day on Grimsey Island, but let's just say it was followed by a sprint up an Arctic mountain in ninety mile per hour winds and torrential hail only to find the Arctic "monument" that was just a grey, concrete ball, a mad sprint then down the muddy mountain, me nearly fainting on the side of the road, a car driven by the captain of the ferry speeding down the street to pick us up, and then myself and my four other friends scaling up a thirty-foot steel ladder because the ferry had closed its doors and almost left without us.

October 11th, 2018. Grimsey Day. The day I swore I would never set foot on a boat again in my life.

Thump; crack; splat. I was horrified, but also amused, by the similarity in motions while I found myself standing on the deck of the F/V I Gotta in the middle of Alaska's salmon-filled Icy Strait listening to my boss Eric Jordan teach me how to kill a fish. We were at the stern of the longliner where Jordan was acting the thump of the salmon knocking itself against the boat after being caught on the line. Then pulling the line up forcefully, he showed me how to crack the salmon on the top of the head with a club, and then the splat of its cool body against the slippery deck.

Standing on the deck of a boat I swore I would never ride again, I could not stop thinking about how after the Grimsey experience, I actually developed an affinity for the sea. This love for adventure and the ocean lead to me work the Icelandic Marine and Freshwater Research Institute in Reykjavik, I was focusing on plastic derived from derelict fishing gear – a type of marine litter - in the Icelandic Economic Exclusion Zone, and then formulating forms of remediation within the sustainable fisheries industry in order to mitigate the issue. It was while I was doing work in Iceland, however, that I realized growing up in the desert in Arizona did not prepare me for the world of oceanic fishing. To fully immerse myself in my research, I decided the summer after my time in Iceland to work and fish in a much closer Arctic community: Alaska.

Working at the Alaska Longline Fishermen's Association, I dove headfirst into the world of sustainable fisheries. I not only continued my research in marine litter in the Arctic but I was able to work on a variety of different projects involved in Arctic fisheries. One of those projects is how I found myself battling sea sickness for a second time in the middle of the Northern Pacific.

It is hard to reduce my experience aboard the F/V I Gotta in just a few sentences, but when I think back on that June fishing season, I am reminded of one distinct experience with Jordan. It was a beautifully sunny and disturbingly hot day in the Gulf of Alaska, and then all of a sudden, the lines at the front of the ship were vibrating, creating almost a fishermen's siren song indicating that a fish was on the line. Jordan yelled at me to go see what we had caught, and after the thump, crack, and splat Jordan had taught me that morning, I caught my first salmon ever: a pristine white king salmon.

Jordan came from the pit screaming, skipping, and singing; we celebrated in dance until we noticed – together – the quiet and solitude around us. We were looking out to the Gulf of Alaska facing the Bering Sea and all Jordan could do was sigh. Normally a man of many words, he stayed silent for a few moments listening to, what seemed to me, was nothing. I thought I had done something wrong, caught the wrong fish, lost a line, insulted him in some way, but then he said, "You would not believe what these waters used to look like when I first started fishing."

Jordan began fishing when he was six months old with his parents aboard the F/V Salty. Socially, financially, and politically, Jordan lives and breathes the Alaska fishing industry. After staring out into the calm waters and pine studded islands, he explained to me that when he went fishing out here there would be thousands of birds piled high on the island trees, grey whales diving with tails high in the air, and salmon splashing on top of each other in the beautiful Alaskan waters.

I was listening to him and looking out at the sea trying desperately to imagine what it had looked like even ten years earlier. All I could see was grey, soiled water thumping against the F/V I Gotta, the crack of deciduous trees being logged in the Tongass, and continued convulsive splats of the salmon on the plastic deck.

Just as the pattern of thump, cracks, and splats have followed me throughout my journey in the Arctic, there is also a sequential pattern of anthropogenic consequences being witnessed not solely in the Arctic, but all across the globe.

INTRODUCTION

Marine plastics are not just a problem, they are a silent, sinister epidemic. Marine plastics are the largest economic and ecological threat to our marine ecosystems, the most abundant marine plastic deriving from lost and or discarded fishing gear, which affects sensitive marine communities, the chemical composition of the ocean water, and the physical makeup of the seafloor. With 6.4 million tons of marine debris entering our oceans annually, it is estimated that, by weight, in 2050 there will be an accumulation of more plastic than fish in the ocean (Heath, 2018; Wilcox, 2015).

The transition from marine life to oceanic trash can be a disturbing thought considering the cultural, social, and economic significances the ocean has for Arctic communities. The Northern Hemisphere has some of the highest concentration of fishing, exporting large quantities of salmon, cod, pollock, and crab. It is an unsettling reality that this inherently important industry is also a large player in the decline of the marine environment.

Additionally, with the effects of anthropogenic climate change, the Arctic is experiencing mass sea ice loss and sea level rise, which is creating openings in sea passages for commercial use that were previously ice locked. Abandoned, lost, and/or discarded fishing gear (ALDFG) accounts for a third of the total waste in our oceans, and with the opening of additional access to the Arctic, creates the possibility for an increase of fishing activity in previously remote regions (Gilman, 2015). The increase of fishing activity causes the increase of marine litter, thus posing as a threat to the Arctic subpolar gyres and open ocean, particularly through ghost fishing.

Ghost fishing refers to abandoned, lost, and/or discarded fishing gear that continues to induce mortality of marine organisms without the infliction of human control (Matsuoka, 2005). Ghost fishing is a large concern in the Arctic specifically due to the harm it can have to sensitive marine species, such as stellar sea lions, seals, deep sea coral (and thus the species living within the coral community), Arctic sea birds (specifically diving birds who can get caught in ghost gear), grey whales, and sperm whales. Due to the nature of the Arctic in the midst of anthropogenic climate change, in this thesis, we will review the consequences of plastics derived from fishing gear for the Arctic marine ecosystem, estimate the potential influx of derelict gear plastics originating from data obtained in Alaska and Iceland, and then confidently present effective forms of remediation, prevention, and mitigation strategized from models of sustainable fisheries to resolve the ramifications of lost and or discarded gear in Arctic communities.

All types of fishing gear have the possibility of being lost and discarded in the ocean, however, passive gear, such as gillnets, trammel nets, and traps, raise particular concern to the marine environment due to the large concentrations of plastic and sheer size of the nets. For the purpose of this thesis, we will be focusing on the consequences of lost passive gear, particularly the ramifications of lost gillnets, and their particular role in ghost fishing. Gillnets are a curtain-like monofilament (plastic) nylon net that is set perpendicular in the water behind the boat. The net has specific mesh openings designed to be large enough to let certain species of fish to enter, known as target species[1].

When a gillnet is lost in the ocean, however, that target species is then open to the entire marine ecosystem. The loss of gillnets, specifically in the Arctic, has been difficult to monitor and research due to various social and scientific barriers. The reason is that there is a reluctance for fishermen to report when they have lost gear because of financial and political repercussions.

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[1] A variety of regulations and factors determine the mesh size, length, and height of commercial gillnets. It is dependent on the target species, which are usually either benthic (bottom) species, or pelagic species. The variation between benthic and pelagic species is why there are two types of gillnets: set gillnets and drift gillnets. Set gillnets are attached to poles on the gillnetter and anchored, while drift gillnets are kept afloat at certain depths by a system of weights and buoys.

Despite these uncertainties, marine debris derived from derelict fishing gear is indeed a known problem. It is known through nets washing up on remote beaches in Alaska and Iceland, or grey whales being found with tons of plastic nets in their stomachs.

In order to quantify the statistical unknowns of ALDFG, in chapter four, we estimate the potential magnitude of fishing gear being lost in the Arctic, through projections created at the Icelandic Marine and Freshwater Research Institute and the Alaska Longline Fishermen's Association. The projections were created utilizing data from FANTARED and FANTARED II, EU funded derelict fishing gear studies, which were then applied to registered gillnets in Iceland and Alaska for the purpose of calculating the potential influx of plastic gillnets entering the Arctic waterways annually (MacMullen, 2001).

After the estimations are presented, in this thesis, I can conclusively present forms of mitigation, prevention, and remediation that can be applied to both the fisheries industry, as well as the market-based industry, in order to diminish the future influx of plastic that is predicted to enter the Arctic, which will be presented in chapter 6.

Fishing for Arctic communities is inherently important culturally and economically, which is why it is important to begin this journey through plastics with the Arctic's connection with its abundant waterways.

CHAPTER ONE: Background of Fishing

Before diving into the consequences of lost gear and the ramifications of plastics derived from the fishing industry, it is necessary to provide a brief explanation of the significance of fishing for both Iceland and Alaska. The following two sections are placed to provide a concise cultural and economic background of the history of fishing for both Iceland and Alaska, and are not to be mistaken for the entire history of fishing for these Arctic communities.

i. FISHING IN ICELAND

From the beginning of Icelandic settlement in the ninth century, Iceland's economy and heritage has rested on fisheries. Iceland has been known as a state of forced isolation, which is why a majority of Icelanders relied on the fishing industry (Wilson, 2016). Icelanders began their fishing on open wooden rowing boats, generally four or eight oars per boat, in family units. The women in the family would be the seafarers, and the men and children would process the day's catch. Fishing was a main economic source for a majority of the Icelandic families, which then became engrained in their cultural livelihoods. Fishing began to stretch past subsistence and marketplace, and started incorporating itself into Icelandic tradition, such as song, poetry, and of course, folklore.

Iceland is a country known for their supernatural folklore and adventure filled stories. The folklore originates from tasks and activities you will find yourself doing in your everyday life, which is why it comes to no surprise that there are many stories and tales about fishing in the Icelandic community. For example, fishing is so heavily ingrained in Icelandic culture that there is even a property created that is believed to help people attract fish, even when there are other fishermen nearby who do not catch anything. Described by Wilson in *Seawomen of Iceland* (2016), this property, known as *fiskin*, is "something special. I can't explain it, but it's there."

Fiskin and other fishing properties can be seen throughout Icelandic folklore and stories, due to its inherent importance in Icelandic culture. Stories of the ocean, fishing, processing, and seafaring are told in Iceland to this day, and the popularity of fishing has only grown since the ninth century *fiskin* years.

Iceland, in the twenty first century, is the largest exporter of fish in the North Atlantic, with its fisheries industry accounting for eleven percent of the country's total gross domestic product (GDP) (Sigfusson, 2012). The increase of economic value occurred in the beginning of the 1900s when the entire industry was completely revolutionized by the transition from the open wooden rowing boats to motorized fishing vessels. A decade after the introduction of the modern, steam-engine fishing fleet, the amount of fishing vessels more than doubled in the Icelandic Exclusive Economic Zone (EEZ) (Sigfusson, 2012).

Fishing has remained one of the pillars of the Icelandic economy in the twenty-first century. Icelandic marine fishery landings account for 2.1 percent of the global catch, making Iceland the twelfth largest fishing nation worldwide (FAO, 2004). Domestically, the industry directly employs around nine thousand people, which is 5.3 percent of the total workforce, and is responsible for a fair share of the nation's total export revenue (Karadottir, 2018).

Gillnetting and trapping, as well as longlining, are among the most popular forms of commercial fishing in Iceland's exclusive fisheries zone, which has an area of 760,000 square kilometers – seven times the area of Iceland (Iceland, 2018). Their preferred catch is primarily cod, Atlantic salmon, Atlantic char, capelin, trout, and pollock. Now, it has been said that saltwater runs through Icelanders veins, and the same is often said, as well, about Alaska's deep relationship with their rich waterways.

ii. FISHING IN ALASKA

The relationship between Alaska and its abundant fishing industry is one that stretches past economic and environmental association: it is rooted in Alaskan culture. Fishing has been a cultural practice for thousands of years, dating back to when the first settlers arrived in Alaska nearly 16,000 years ago (O'Reilly, 2018). These cultural practices have been passed from generation to generation by legends, song, and ceremonies. Nelson Frank, a Haida from Southeast Alaska, in the Alaska Native Review Commission (1998), expressed the deep inter-connectedness between the Alaskan people and their ocean as follows:

> *The relationship between the Native population and the resources of the land and the sea is so close that an entire culture is reflected... Conservation and perpetuation of subsistence resources was part of that life and was mandated by traditional law and custom* (Thornton, 1998)

The relationship between the two is one that almost speaks for itself, and for Alaska Natives, including Aleuts, Athabascans, Alutiiqs, Haidas, Inupiat and Yup'ik Eskimos, Tlingits, Tsimshians and other groups, fishing was and remains a cornerstone of their life and survival. This form of survival transitioned slowly into an economic form of life at the end of the nineteenth century with the first opening of the fishing canneries.

The first two fishing canneries, located in Southeast Alaska, opened in 1878 and profoundly shaped the methods by which fish were caught and processed. This transition allowed for higher yields of fish and more opportunities for state revenue via statewide and transcontinental exportation (Cooley 1963). Quickly, more canneries started opening in Alaska, alongside with additional processers, exporting firms, and more fishermen.

According to a census conducted in 2017, the Alaska fishing industry employs nearly sixty thousand workers, of which nearly half are fishermen (Welch, 2017). Thirty-six percent of those fishermen live in south central and southeast Alaska towns such as Anchorage, Homer, Kenai, Cordova, and Sitka; the latter community being a fishing town where I worked and researched for this thesis (McDowell Group, 2017). In total, the commercial fishing industry contributes $1.8 billion of annual labor income, according to a 2016 Alaska Seafood study, with Sitka ranking in the top five fishing ports for Alaska, netting $121 million annually (McDowell Group, 2017).

Commercially important species of seafood from Alaska include five species of salmon, five species of crab, walleye pollock, Pacific halibut, Pacific cod, sablefish, herring, four species of shrimp, several species of flatfish and rockfish, lingcod, geoducks, sea cucumbers, and sea urchins, all caught primarily with passive gear (Alaska Department of Fish and Game, 2019). The most common fishing vessels for these catches are gillnetters, purse seiners, and longliners/trollers.

These fishing vessels using passive gear cause significant disruptions to the marine ecosystem if the nets are accidentally or intentionally discarded. With Arctic communities primarily using these passive forms of fishing gear, especially gillnets, there is a high risk for loss and subsequently damage caused to the marine ecosystem, both on a level of seawater chemistry and actual marine life. One of the most significant problems associated with lost gear, one that causes disruptions on marine species and the overall health of the ocean, is ghost fishing.

CHAPTER TWO: ENVIRONMENTAL CONSEQUENCES OF FISHING

With commercial fishing industries generating a third of all marine litter, the question is raised on how did the fishing debris get there in the first place (Quin, 2019)? Gear can be lost accidentally, or intentionally, for a variety of reasons. Fishers may lose nets when there is contact with passing vessels or gear conflicts with active gear (e.g., accidentally or intentionally, towed away by trawlers or dredgers, or marker buoy moorings are cut). When a gear is in contact with a marine organism, whether that be snagging, submersion, or damage, the gear will also be abandoned (Gilman, 2015). Gillnets can also be replaced quickly by fishermen due to the inexpensive nature of the plastic material, which is why the design of the net is an additional factor to the frequency of gillnet loss.

Lost gear in the ocean poses as a serious threat to the delicate marine ecosystem, that being animals, plants, and bacteria as well as abiotic factors such as chemical compositions and oxygen levels (Macfayden, 2009). While derelict fishing gear poses a series of detrimental effects to the planet as an entity, a heavy emphasis of research and data collection has been made to the implications on marine life. Marine megafauna, such as seabirds, sea turtles, marine mammals, elasmobranchs, and some bony fishes, are extremely vulnerable to entrapment, entanglement, ingestion, and smothering in ALDFG, a phenomenon known as ghost fishing (Gregory, 2009).

i. GHOST FISHING

Ghost fishing, that being discarded gear that continues to promote targeted mortality on marine organisms without proactive anthropogenic interference, affects marine life from the sub organismal level to the largest marine mammal level. Ghost fishing affects organisms in a variety of different mechanisms. Organisms can be entrapped in the wiring nets of lost fishing gear, and then find themselves entangled in the plastic trap. Marine organisms could also ingest plastic objects, and several laboratory experiments showed the that oxidative stress associated with ingested plastic promotes fatal tumors (Rochman, 2016). Smothering of the seafloor is another fatal aftermath of ghost fishing, which changes chemical and physical compositions of the ocean basin, and lastly, formations of organic toxins from decomposing plastic can change the composition of seawater.

ii. INGESTION

Starting with the initial disposal of a fishing net, while it is floating in the pelagic column, or has even sunk to the benthic zone, it can be mistaken by many marine species for food. By a process known as ingestion, organisms orally consume discarded plastic, which creates a series of health complications. The repercussions include internal and external wounds through the digestive tract and stomach lining, satiation, starvation, impaired reproductive and feeding capabilities, concluding with drowning and eventually death (Gregory, 1978). Individual studies have found evidence of modifications in the gene structure, inflammation of tissues, changes in mental behavior, tumor development and mortality from exposure and/or ingestion of marine plastic (Rochman, 2016).

Furthermore, Gall and Thompson found in their 2016 study on the ingestion of marine plastics, that four percent of the 13,110 organisms who were reported having consumed the plastic litter were either severely injured or found dead (Gall, 2016). A majority of this litter is buoyant, thus affecting organisms in the pelagic and surface oceanic zone. Bony fish, marine mammals, and zooplankton are the most susceptible to ingesting buoyant marine litter. As time persists, however, a majority of the plastic sinks to the bottom of the ocean, affecting the benthic oceanic zone in a phenomenon known as smothering (Gregory, 2009).

iii. SMOTHERING

The sea floor is the ultimate sink for marine debris (Woodal et al, 2014). In Gilman's 2015 report on the status of international monitoring of ghost fishing, he estimated that 70 percent of all marine litter sinks to the seabed, causing detrimental effects on benthic habitats, such as coral colonies, as well as chemical composition of the sediments (Gilman, 2015). Such documentation of a lost gillnet smothering the seafloor can be seen in figure 3 on page 24.

Once the plastic reaches the sea floor, ALDFG can cover fine sediments, thus smothering benthic communities and creating anoxic areas (Gilman, 2015; Levin, 2009; Macfadyen, 2009). A layer of plastic creates these anoxic areas since ALDFG restricts gas exchanges between sedimentary pore water and seawater depriving the benthic infaunal dwellers of needed O_2 (Goldberg, 1997). The inhibition of oxygen exchange affects the entire benthic community, specifically benthic species such as coral colonies, and, in worst case scenarios, lead to mass extinction. Marine litter sitting on the seafloor poses as a serious threat to the benthic communities also through a danger known as entanglement.

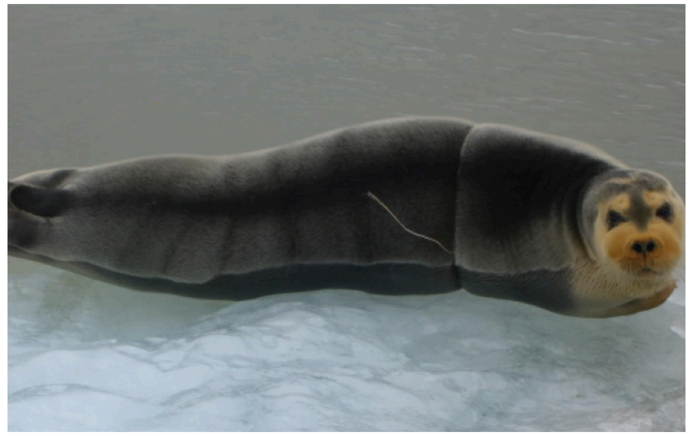
iv. ENTANGLEMENT

Due to the mesh size, mesh openings, and plastic durability of the gillnet, entanglement of marine organisms via ghost fishing leads to injury, stress, fatigue, and ultimately death. Entanglement is the physical entrapment of an organism in derelict fishing gear, without the infliction of direct human activity, which is depicted in figures 1 and 2 on page 24. Thompson found in their 2015 study monitoring marine entanglement and ingestion that of the 30,896 individual marine organisms reported to have been entangled in plastic litter, 79 percent of cases led to injury or mortality (Thompson, 2015).

The specific animals affected globally include marine mammals, sea turtles, seabirds, fish, and invertebrates. Entanglement has been documented to entrap one hundred thirty-six species of marine animals, that including several threatened and endangered species (Laist, 1996). Additionally, 86 percent of all sea turtle populations, as well as 28 percent of the marine mammal species, have been reported and documented entangled in ALDFG (Donahue, 2011).

In the Arctic, the particular animals that are more susceptible to derelict fishing gear are stellar sea lions, seals, Arctic sea birds (specifically diving birds who can get caught in ghost gear) such as the Arctic tern pictured below, grey whales, and sperm whales. All of the animals are considered to be bycatch. In Alaska, bycatch, that being unintended marine species that are accidentally caught on gear, is monitored and recorded by the National Marine Fisheries Service, Alaska Marine Mammal Observer Program.

For Iceland, the Marine and Freshwater Research Institute holds logbooks that contain annual bycatch species and numbers, with additional information and monitoring conducted with the Observers of the Directorate of Fisheries (MFRI, 2015). Close monitoring is typically given to pelagic species, such as sea lions and marine mammals, since they are easier to detect for observers. Entanglement, however, is affecting many vulnerable marine ecosystems (VME's), habituated in benthic communities that are more difficult to monitor. One of these sensitive species that is susceptible to damage from entanglement is deep sea coral.



Figures. 1 + 2*: Top left: Arctic tern entangled in fishing gear (supplied by Governorn of Svalbard); Top right: seal entangled in gillnet (supplied by Stig Onarheim). Both images abstracted from Barker, 2018.*

Figure 3*: Bottom image: Documentation of a gillnet smothering the sedimentation on the seafloor from HAUSGARTEN Observatory (obtained from Tekman (2017)*

v. ENTANGLEMENT ON VULNERABLE MARINE ECOSYSTEMS (VMEs)

ALDFG remains at the surface when initially discarded, affecting target species in various open water depth intervals as mentioned above, however, as time persists, the nets sink to the bottom and either smother the seafloor or entangle vulnerable marine ecosystems (VMEs), such as coral. Coral tends to be associated with tropical white sand beaches and family holidays, however, there are large communities of deep sea coral in the Arctic. Figure 4, obtained from Buhl-Mortensen's 2019 study identifying VME's in the Arctic, depicts the deep-sea coral colonies, known as Lophelia reefs, located near Iceland.

Lophelia reefs are susceptible to the harms of ghost fishing due to the intense fishing activity within that area of the Arctic. Al-Jufaili (1998) in their paper analyzed the repercussions of discarded gear for coral colonies in Oman. The fishing industry in Oman is the second largest natural resource in the country, reigning similar importance to the fishing industry for Nordic countries, such as Iceland (Setlur, 2017). Due to the similarity in both coral populations and fishing activity, for the purpose of this section we will be comparing Al-Jufaili's coral study to the impact on Lophelia reefs in the Arctic.

When a gillnet is first introduced to a coral community, it lays passively on the VME's, creating a breeding ground for invasive algae to colonize at the surface. Invasive algae reduce the sunlight a surface coral uses, however, for Lophelia reefs in the Arctic, algae smother the coral and inhibits water exchange. Different algae then have the ability to spread to adjacent coral colonies and disturb in the same manner.

The physical placement of the nets on the coral also results in tissue loss though abrasion and breakage of entangled coral. Wave action, deep sea currents, and interactions with other marine species cause the nets to move across the coral (Al-Jufaili, 1998). These fragments of coral then drag across the rest of the living reef, resulting in even further damage.

Discarded nets also become a home to pathogens, which are natural stressors that invade damaged reefs. In Oman, over twenty corals were found to be affected by an invasion of pathogens and algae due to exposed skeleton from entanglement and abrasion (Al-Jufaili, 1998). A similar scenario can occur to Lophelia reefs in the Arctic due to discarded gillnets on the seafloor.

Attempts to remove these nets causes additional harm to the coral since the force used to drag the net up through the water column tears and breaks coral communities. The main impact on coral that was documented by Al-Jufaili (1998) was damage from fishing activities in Oman, with abandoned and or lost gillnets being the most detrimental. In the study, a total of 87 abandoned gillnets or fragments of gillnets were found on coral reefs, and 16 percent of the abandoned gillnets contained entangled live or recently dead fish, crustaceans, mollusks, and turtles (Al-Jufaili, 1998). Derelict gillnets advance the ramifications of ghost fishing, specifically with such entanglement and smothering, as well as creating a habitat for pollutants, which is now a concern for remote regions in the Arctic Ocean.

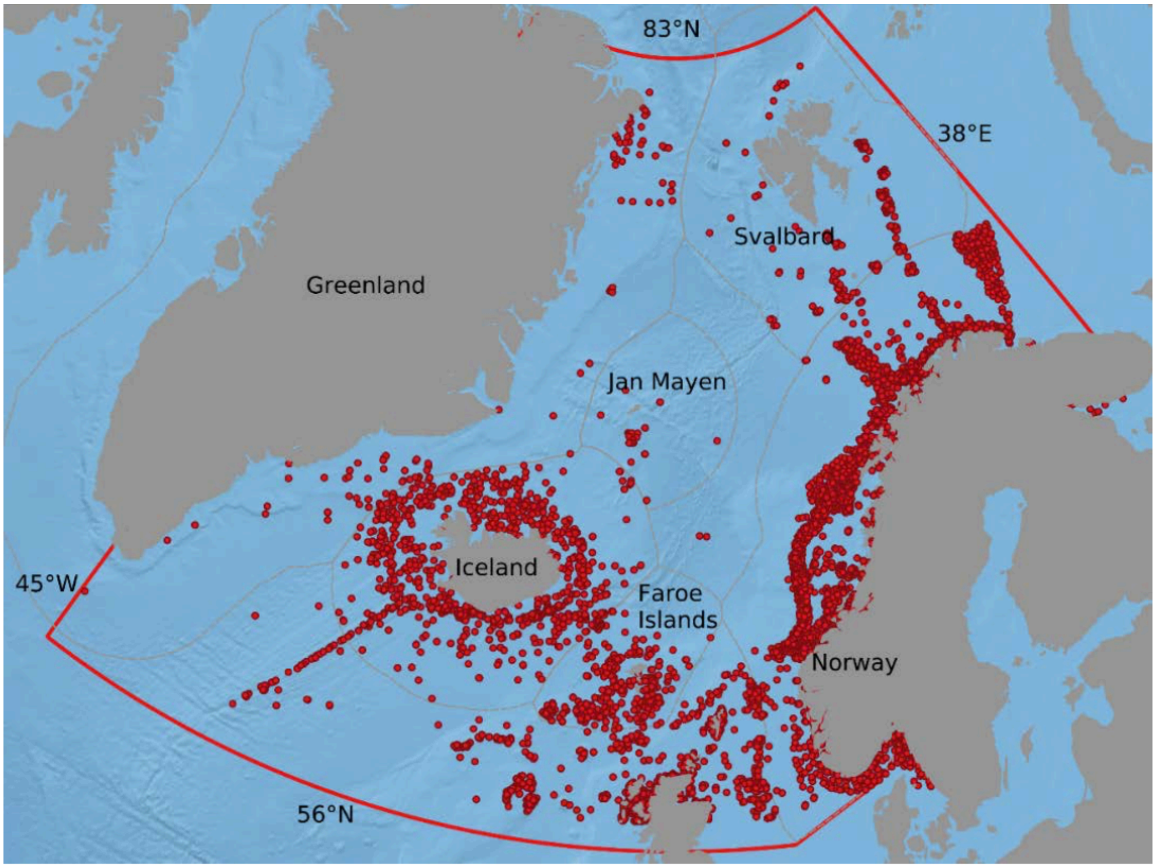


***Figure 4**: Location of tagged VME's in the Arctic (obtained from Buhl-Mortensen, 2019)*

vi. CONCENTRATED POLLUTANTS AND PESTICIDES

Derelict fishing gear has been detected to contain concentrated pollutants and pesticides that are only found outside of the marine water column. Taken from the Rios (2010) paper on pollutants in marine plastics conducted in 2010 from the Northern Pacific Gyre, over 50 percent of the plastic debris contained PCBs, 40 percent contained pesticides, and 80 percent contained Polycyclic aromatic hydrocarbons (PAHs). PAHs are a common carcinogenic formed from the incomplete combustion of organic compounds that have been observed to disrupt endocrine chemicals in organisms and have been found to be persistent organic pollutants (POPs).

A slightly more sinister POP, polychlorinated biphenyls, also known as PCB, was banned from the United States in 1975 due to its high toxicity, but is still being discovered in marine plastics. The compound degrades slower than most organic compounds, has higher mutagenic capacity, and also has a tendency to bioaccumulate within marine organisms. Furthermore, other toxins that are of particular concern to marine health are chlorinated pesticides, and endocrine disrupting chemicals, or EDC, which have the ability to bind and cause disturbances to estrogen and androgen receptors.

All of these toxins have been detected in abandoned plastics found in the North Pacific Ocean gyre (Rios, 2010), The findings from the Rios study, which were abstracted to only contain the data on derelict fishing gear, can be seen attached below in figure five and six, accompanied by photos of ALDFG fragments.

Figure 5*: Rope-line samples found in the North Pacific Ocean Gyre obtained from Rios (2010)*

Figure 6*: Rios study (2010) on PCBs and PAHs found in the North Pacific Ocean Gyre. Pollutants found solely for rope-line abstracted from the study.*

SAMPLE	PLASTIC OBJECT	PLASTIC TYPE	PCBs/ ng g $^{-1}$	PAHs/ng g $^{-1}$
D6	Rope-line	PE	114	14459
D14	Rope-line	PE	nd	15
D17	Rope-line	PE	nd	202
D27	Rope-line	PP	nd	18
D38	Rope-line	PE	8	513
D-38	Rope-line	PE	8	76

nd 1⁄4 not detected at detection limit. Limit of detection for PCBs 0.02–0.15 ng g ^{1}, PAHs 0.05 to 0.8 ng g ^{1}

These organic pollutants, particularly polychlorinated biphenyls, polybrominated diphenyl ethers, and perfluorooctanoic acid, have been detected in remote regions in the Arctic. Concentrations of PCB and polybrominated diphenyl ethers have been found in Northeast Arctic cod, the origination most likely being from ingestion and exposure to plastics (Julshamn, 2013). Transported via derelict fishing gear and ocean currents, such as the Transpolar Drift, Labrador Current, and West Greenlandic Current, these POPs put vulnerable organisms at risk. Over the past decade, more toxic plastics have been found in remote regions of the Arctic, indicating that these pollutants may have gained access to desolate regions through passages in the melting of the Arctic sea ice

vii. THE ARCTIC AND CLIMATE CHANGE

The Arctic is the most susceptible region to climate change, heating twice as fast as the rest of the world and already facing the effects of climate change predicted to occur twenty years in the future (IPCC, 2019). The cryosphere, which refers to the frozen components of Earth, are thawing at a dangerously high rate, according to the 2019 IPCC report on the Ocean and Cryosphere, made specifically for policy makers. Over the last few decades, anthropogenic climate change has led to the consistent shrinking of the cryosphere, resulting in a systematic loss in mass from Arctic ice sheets, glaciers, snow cover, and sea ice extent and thickness (IPCC, 2019).

Between 2006 and 2015, the Greenland Ice Sheet (GrIS) lost ice mass at an average rate of 278 ± 11 Gt yr–1, which is the equivalent of the ocean rising 0.77 ± 0.03 mm yr. Though this might seem subliminal at first glance, it should be noted that the ice melt from 2006 and 2015 was nearly four times the rate of melt from 2003 (Bevis, 2018). Melting was even observed over 90 percent of the island one day during the summer of 2019 (Box, 2019). The melting of the GrIS, one that Bevis even described as "unprecedented," appears to only be increasing through the latest IPCC report and prediction.

The melting of the Greenland Ice Sheet exposes dark colored rock underneath the ice surface. The dark rock absorbs sunlight, and consequently increases in net temperature. The net increase of exposed rock further perpetuates GrIS ice melt, thus increasing the overall rate at which the ice sheet is melting. Cryospheric and associated hydrological changes have consequently impacted both terrestrial and oceanic species in polar regions, which contributes to changes in seasonal activity, migration patterns, abundance of ecologically, culturally, and economically important marine species, ecological disturbances, and ecosystem functions (IPCC, 2019). One of the largest shifts observed in the Northern hemisphere has been these wide scale migration patterns of marine species in response to ocean warming, sea ice change, and biogeochemical changes (anoxia), therefore affecting Arctic fisheries.

The mass movement of marine species in the Arctic consequently means movement in fishing activity. Ocean warming in the twenty first century has resulted in target species moving to the poles, or deeper in the water column, in search for cooler water. Fisheries are gaining access to these remote regions in the Arctic due to sea ice melt, a trend that has steadily increased over the past decade (IPCC, 2019). Additional fishing activity in previously ice locked regions increases the risk of lost gear, posing a variety of risks to Arctic marine ecosystems and coastal communities, such as from invasive pollutants, local pollution, and the harms of ghost fishing, entering the gyres in the Northern Hemisphere.

viii. OCEAN GYRES

The open ocean is bounded by large cyclonic and anticyclonic gyres, including the North and South Atlantic gyre, North and South Pacific Gyres, Indian Ocean Gyre, and the Pacific and Atlantic Subpolar gyre. The Beaufort and Barents Gyres are subpolar gyres located in the Arctic Ocean. Similar to the subtropical gyres, the Beaufort and Barents gyres generate anticyclonic winds, meaning that the net direction of the flow in those gyres is convergent, towards the center of the rotation. The Beaufort and Barents gyre due to this anticyclonic nature would then concentrate plastics to the center.

In addition to the gyres of interest, there are also subpolar gyres which are cyclonic, meaning that the net direction of the flow is divergent, outwards from the center of rotation. The

Northern Hemisphere has several subpolar gyres, bounded by islands such as Iceland, Greenland, and the Aleutians; and the northern reaches of Scandinavia, Asia, and North America, which can be seen in figure 7 and 8 on page 33. These gyres are important for overall circulation, and rather than moving debris inwards, they redistribute particles outwards, potentially bringing debris in and out of polar regions.

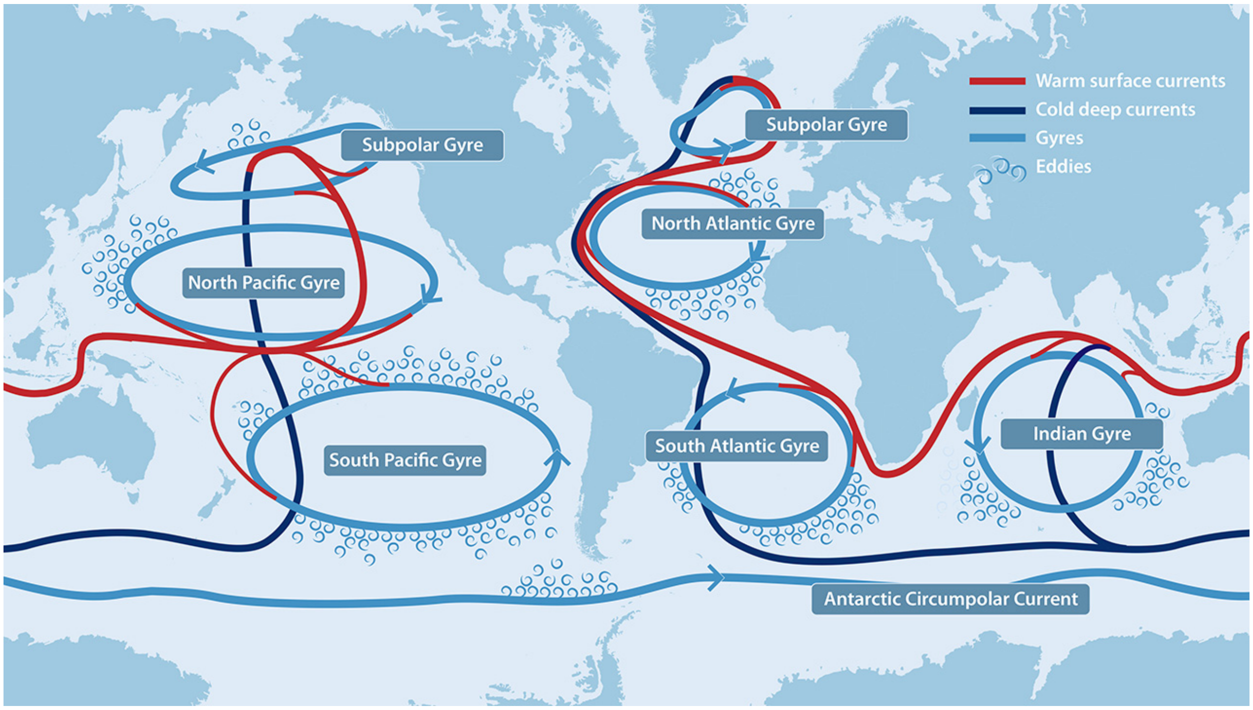


***Figure 7**: Graphic of subpolar, North Pacific, North Atlantic, South Pacific, Indian Gyre, and Antarctic Circumpolar Current gyres (obtained from Levang, 2018)*

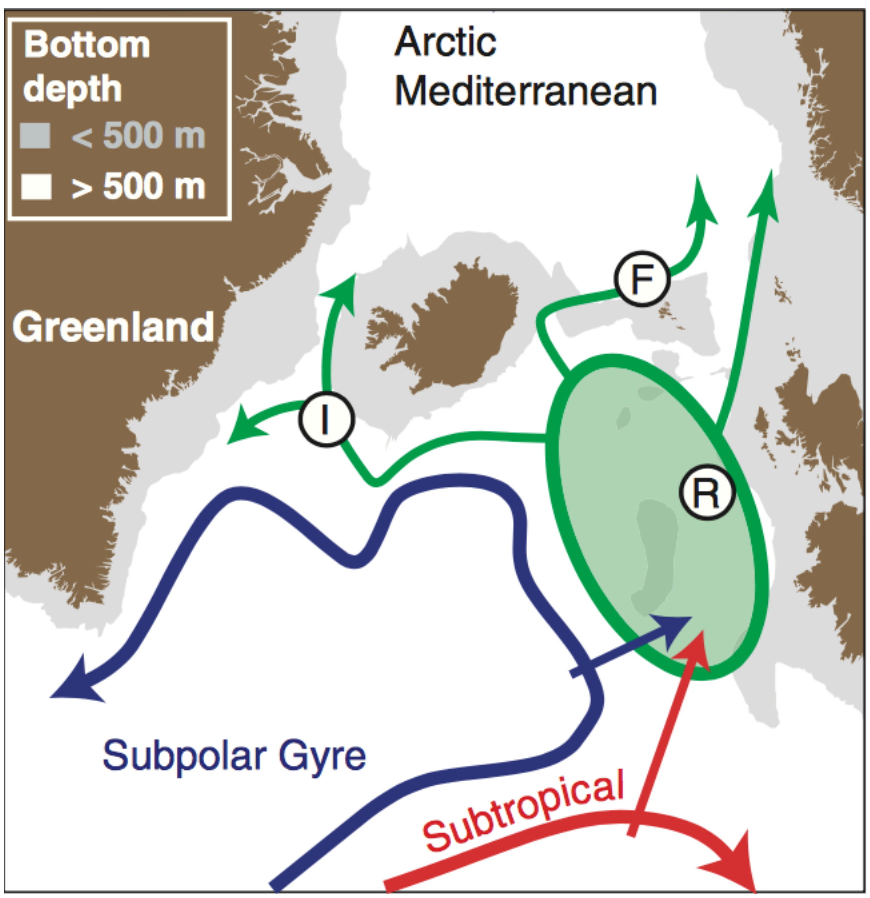


***Figure 8**: Graphic depicting the main features of the surface circulation in the northeastern North Atlantic. The green shaded region shows where the subpolar and the subtropical waters meet, mix, and feed into the Arctic Mediterranean (obtained from Hátún et al., 2005)*

As a brief background on the generation of gyres, winds create friction on the ocean surface, causing the water to move generally in the direction the wind. The Earth's rotation then deflects the movement of the wind via Coriolis effect, which causes Northern hemispheric gyres to move in a clockwise motion and the Southern hemisphere gyres to move in a counter-clockwise motion. Each gyre is then defined by a strong western boundary current and a weaker eastern boundary current which, with all of these factors combined, creates slow moving vortexes of water that derelict fishing gear can enter and remain trapped for long periods of time.

The subpolar gyre of the North Atlantic, in particular, circulates cyclonically between 50° and 65°N and contains strong boundary currents. During the winter, winds move heat at rates of several hundred watts per square meter (Häkkinen et al., 2004). This results in deep sea convection that reaches as far as 2500 m below the surface, forming subpolar waters that provide the origins of the North Atlantic Deep Sea (NADW) (Häkkinen et al., 2004). The creation of cold, deep sea water is important in the process of upwelling.

In contrast with subtropical gyres that have slow moving, downwelling vortexes, the strength of the subpolar ocean gyres forces upwelling and surface water divergence. Areas of upwelling are nutrient rich and abundant with marine organisms, which raises particular concern with the presence of plastics. Areas of upwelling are respectively the best fishing grounds; however, highly active fisheries cause additional accumulations of derelict plastic gear. Plastics in these areas can also be mistaken for food, and with the additional migration of marine organisms in the Arctic entering the subpolar gyres due to climate change, there is an increased risk of organismal exposure to marine plastics.

All of the ocean gyres on the planet have plastic patches detected within them (Bergmann, 2005), but anticyclonic gyres in particular (such as Beaufort Gyre and subtropical gyres) also tend to concentrate plastic in their centers through the convergence. The effects of ALDFG are already being observed in the Arctic (entanglement, ingestion, ghost fishing, fisheries access to previously ice locked regions), however, there is no adequate research that fully identifies and quantifies the accumulations in the Arctic. Identification is difficult due to the unknowns in the fishing industry. Estimates must therefore be conducted to begin to understand the potential magnitude of plastic derived from derelict fishing gear in Alaska and Iceland during anthropogenic climate change.

CHAPTER 3: METHODOLOGY

I have been researching derelict fishing gear since the fall of 2018 in both Iceland and Alaska with the Marine and Freshwater Research Institute (MFRI) and the Alaska Longline Fishermen's Association (ALFA). I will begin my methodology according to place, since my thesis relied heavily on the physical places I conducted my research, as well as the people I worked with.

i. ICELAND (Reykjavik)

My research began in October of 2018 with the Icelandic Marine and Freshwater Research Institute while I was studying climate change in Iceland and Greenland with the School for International Training (SIT). The research was based in Reykjavik where I was working under the supervision of fisheries scientist Haraldur Einarsson. While working at MFRI, I conducted literature reviews, as well as research through MFRI logbooks, presentations, GIS maps, and regional/international databases, in order to write an assessment on derelict fishing gear in the Icelandic EEZ for the organization. In addition to writing a scientific paper with Einarsson for MFRI, I was also researching marine litter in the Arctic for my final research project for SIT.

The Marine and Freshwater Research Institute was interested in researching derelict fishing gear in the Icelandic EEZ due to its potential harm it could have economically and environmentally for Iceland, especially in regard to climate change. MFRI was curious what the potential volume of nets lost per year was in Iceland, which is what I spent October through December researching for the organization.

I began my research through an extensive literature review, where I read through various studies on derelict fishing gear and its potential harm, informally interviewed different fisheries scientists at MFRI, and attended various presentations and conferences in Iceland, such as the Arctic Circle Conference and presentations offered by MFRI. Then utilizing logbooks supplied by MFRI, which had the information of all of the registered gillnets, longline, and lumpfish[2] gillnets in Iceland from 1997-2018, I was able to create a statistical regression model utilizing estimates from FANTARED and FANTARED II to quantify the amount of potentially lost nets in the Icelandic EEZ for MFRI (MacMullen, 2001).

FANTARED and FANTARED II are projects funded by the European Commission to identify, quantify, and ameliorate the impact of static lost fishing gear with the deep-water gill net sector in European shallow and deep waterways (MacMullen, 2001). The research involved partners from six European countries, including Portugal (Algarve Coast, Olhão, Portimão), Spain (Cantabrian Sea to Straights of Gibraltar), France (North Sea to East Channel Bay of Biscay), England (North Sea), Sweden (Baltic Sea), and Norway (Norwegian Sea, North Sea), and included interviews conducted with hundreds of fishermen to identify and quantify net loss.

FANTARED and FANTARED II provided estimates of gear loss that can be applied to Iceland and Alaska, due to the two regional similarities in fishing activity, as well as the similarity in fishing fleets, which is why I used the study for both my time at MFRI in Iceland, as well as my time with ALFA in Alaska.

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[2] Lumpfish are one of the three distinct stocks in Iceland, which deserves additional attention in this thesis due to their unique nature in Icelandic waters (MSC, 2019). Lumpfish gillnets are shallow- water fisheries, which means that they are set on rocky sea beds in low lying areas. Lost nets in these vulnerable areas have significant consequences on marine animals in those habitats. Lumpfish gillnets were assessed and estimated in order to approximate the magnitude of nets being lost in the shallow Icelandic marine regions.

ii. ALASKA (Sitka)

In the summer of 2019, I was accepted as an Alaska Conservation Foundation intern for the Alaska Longline Fishermen's Association (ALFA). At ALFA, I had access to logbooks and databases where I could apply the same estimates used at MFRI from FANTARED and FANTARED II (MacMullen, 2001). It should be noted that the logbooks I used in Alaska were only for the year 2018 and did not have the specific numbers of gillnets of each fishing vessel as the logbooks at MFRI. The estimates that I created for ALFA were the estimations for each registered gillnet boat in Alaska that could potentially lose nets.

In addition to continuing the estimations for my thesis, a majority of my work with ALFA was with Alaskans Own (AO), Alaska's first community supported fishery. Working with AO, I was able to research specific remedial and preventative methods in the fishing industry that could be frameworks for other states and countries to follow in order to diminish plastic entering the oceans. By conducting literature reviews about sustainable fisheries, writing and publishing flyers, press releases, letter to the editors, and newsletters about sustainable fisheries updates, and working within a sector of the sustainable fisheries industry – that being community supported fisheries - I was able to quantify select forms of remediation that could be used to create a more sustainable industry, and lower the plastic entering the ocean.

At Alaskans Own, I was able to gather market-based forms of remediation, such as the positive impacts CSF's have on the environment, and condensed the impacts, as well as fisheries updates, with our shareholders through a monthly newsletter titled "Docklines." I prepared all of the Docklines for the 2019 AO fishing season (May-October), which became an impactful form of remediation. Along with Docklines, I also collected additional forms of plastic mitigation tools through my work with grants and legislation.

At ALFA, I was able to work on the initial writing stage for the National Fish and Wildlife Foundation (NFWF) grant titled Fishing for Energy, which directly funds derelict fishing gear clean up initiatives. Further on specific forms of remediation, I had conducted a literature review and began the initial grant writing stages for ALFA on a National Fish and Wildlife Foundation grant that directly funds derelict fishing gear clean up initiatives.

For this grant, as well as for the publications I wrote for ALFA and AO, I informally interviewed members of ALFA and Sitkan fishermen in order to gain more information about fishing and lost fishing gear in Alaska. These interviews were prepared beforehand, but followed more of what a conversation would, since a majority of them took place in the ALFA office, in passing with various community members and friends, or physically on fishing boats. These interviews provided me with information about specific studies, protocols, conventions, and legislations that I was able to use in my literature review for the NFWF grant, and thus background knowledge for my thesis.

Additional background information for this thesis also took place while I was working as a deckhand for skipper Eric Jordan on the F/V I Gotta. Working on his longliner, I was able to fully understand the intricacies of the fishing industry, the impacts on the environment, and specific forms of sustainable measures that are used in various fishing fleets. The measures included gear type, fishing fleet size, technological and gear advancements, as well as economic incentives for fishermen, which are presented as integral forms of prevention, remediation, and mitigation in this thesis.

Through my experience in both Iceland and Alaska, I was able to assess the loss of derelict fishing gear in the Arctic and thus, present forms of prevention, remediation, and mitigation that will be presented in the chapters to follow.

CHAPTER FOUR: ASSESSMENT OF DERELICT FISHING GEAR

To assess the issue of derelict fishing gear in the Arctic, I extrapolated data from countries in the FANTARED and FANTARED II studies that had similarities in fishing fleet and fishing activity as in Iceland and Alaska (MacMullen, 2001). Beginning with Norway, an Arctic country itself, has the closest similarity to Iceland and Alaska, with 75 percent of their fishing fleet being gillnetters, and a majority of their catch being either cod or halibut (MacMullen, 2001). For the Northern Norway gillnetters, approximately 0.1 percent of the gillnets were lost and not retrieved. The loss was due to snagging, interactions with other trawlers, broken lines, and in rare cases, nets lost due to intense storms (MacMullen, 2001). In the Sweden FANTARED case study, a similar pattern of losses was reported in its gillnetting fishing fleet.

Static gear loss poses as a serious problem in the Baltic Sea, which can be connected clearly to one particular métier: bottom gill net fishing fleet fishing in open sea area well off the coast of Sweden. FANTARED investigated this large sample of gillnetters in 1998, and by conducting interviews with all of the skippers, it was deducted that a total estimate of 2.6-2.8 nets per active vessel, with each net being 155-165 km in length, were lost annually in the Baltic Sea. This loss rate can also be translated to approximately 0.1 percent of nets on each Swedish fishing vessel being lost every year. The main reason for losing nets was said to be trawlers – 65.5 percent of the time; then by interactions with others ships or submersed objects – 16.1 percent; and finally, 3.2 percent of the nets being lost in a storm (MacMullen, 2001).

The FANTARED projects also put a heavy emphasis on research in the Mediterranean, due to their extensive use of gillnets in many of their small and large-scale fisheries (Pawson, 2003). Studies on gillnet fisheries indicate that gear is being lost at a consistent rate, with 0.2 percent of the nets being lost annually out of their sixty-five vessel offshore fleet. This translates roughly to between 36 to 73 nets lost per year (MacMullen, 2001). The inconsistency lies when examining other Mediterranean gillnets fisheries, such as red mullet métier and the hake and crawfish industry.

The red mullet métier, using a 0.7 km gillnet, and the hake and crawfish métier, using a slightly larger 1.2 km gillnet, are losing nets at a rate of 0.2-3.2 percent annually per each gillnetting vessel (MacMullen, 2001). The cause for such great losses are again, snagging, interactions with other boats and gear, and in rare cases, intense storms. The data for Spain is much the same.[3]

After the findings and concerns from the FANTARED studies, the DeepNet Project investigated deepwater gillnet fisheries in the northeast Atlantic to estimate the geographic gear loss in that area (Hareide et al., 2005). Before the project began, it was hypothesized that there would be large concentrations of nets in the northeast Atlantic area due to high concentrations of fishing activity, and evidence of illegal gillnet dumping in the deepwater areas – northwest of the United Kingdom and Ireland. The evidence is built off of the notion that the fishing vessels in deepwater gillnet fishing are not capable of carrying the nets back to port, which is why some gillnets are bagged on board, burned, or dumped at sea (Hareide et al., 2005).

The DeepNet Project found that the amount of discarded nets was poorly estimated, due to the difficulty of finding lost nets (Hareide et al., 2005). The project estimated that based on the relationship between water depth and net loss rate, as well as estimates of net loss in the Greenland halibut net fishery, the deep-slope fishery loses approximately 15 gillnets (750 m) per

[3] Spain derelict fishing gear is due to interactions with trawling gears (catching on the bottom of the seafloor) – 29-40 percent of the cases – and uncommonly from losses due to storms – 16 percent.

day (FAO, 2018). It was determined that the main cause of discarded gear was damage to the net, snagging, and weather.

***Figure 9**: Estimates of gillnet loss in selected North Atlantic fisheries from FANTARED and FANTARED II (adapted from table in Brown et. al, 2005)**

COUNTRY	FISHERY	NUMBER OF VESSELS IN FISHERY	km OF NETS LOST	PERCENTAGE OF NETS LOST	NUMBERS OF NETS LOST
Sweden	Mixed (primarily cod)	--------------	156	0.10	1148
Norway	Cod Greenland halibut	--------------	--------------	0.02 0.04	187 5
United Kingdom	Tangle Hake Wreck	18 12 26	24 12 -	--------------	263 62
Mediterranean	Red mullet Crawfish Hake	--------------	0.07 1.2 1.2	0.05 1.6 0.2	--------------
Northwest Atlantic (UK and Ireland)	Deepwater fishery	--------------	1254	--------------	25080

*Summarizing data presented in Chapter Four from extrapolated FANTARED data

Figure 10*: Example of logbook data from FANTARED. Country featured: Sweden. (MacMullen, 2001)**

Date of loss	Position	Depth in fathoms	Seabed	Nets, n	Reason for loss	Fishery
25.06.00	62°26 5°16	350	Clay, corral and boulders	30	Conflict with other gillnets	Greenland halibut.
1993	65°38,50 11°11,50	50		20		Cod
1998	Position reported to the Dir. of Fisheries		Coral	25	Broken Dan line	Saithe
2000	69°47,00 16°34,00	350		21	Conflict with other gillnets	Greenland halibut.
2000	69°57,82 16°39,72	370	Rocks	27	Float and lead line broken due to boulders	Greenland halibut
5.07.00	Position reported to the Dir. of Fisheries	330	Clay	20	Float and lead line broken due to boulders	Greenland halibut

**Placed for the purpose of informing the reader how data was presented and extrapolated in FANTARED*

i. ICELAND RESULTS

At the Marine and Freshwater Research Institute (MFRI) in Reykjavik, the estimates provided by both FANTARED and FANTARED II were then applied to the number of gillnets registered in the Icelandic Exclusive Economic Zone (EEZ). The logbook, ranging from 1997 to 2018, also includes every gillnet registered in the Icelandic EEZ. The registered gillnets in the Icelandic EEZ can be seen through figure 11, a GIS map provided by MFRI. The estimates for the Iceland gillnet fisheries are presented in the next chapter.

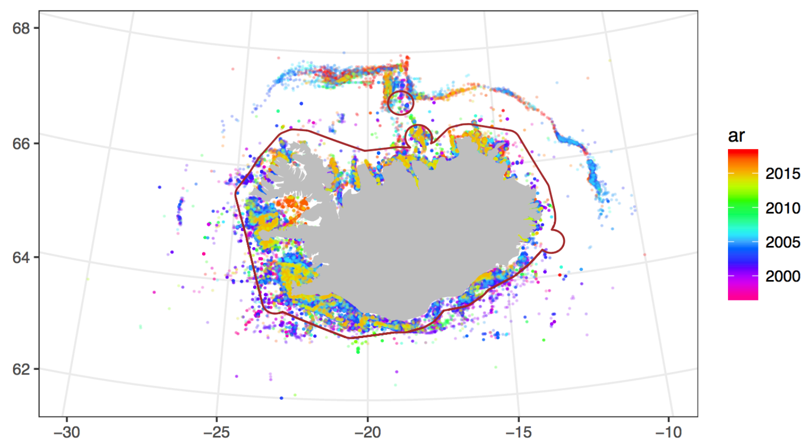

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Figure 11: *Registered gillnets in the Icelandic Exclusive Economic Zone (obtained by MFRI, 2018)*

ii. ALASKA RESULTS

It has been hypothesized that thousands of tons of marine debris exist within three nautical miles of the Alaska coastline, so utilizing data from ALFA, I was able to estimate the approximate number of gillnetters that lose nets annually (Spies, 1996). The results are presented alongside Iceland's results.

CHAPTER 5: RESULTS

The FANTARED and FANTARED II percentages were applied to the registered gillnets and gillnet vessels in both Iceland and Alaska, according to logbook data retrieved at MFRI and ALFA. The numbers derived from the FANTARED and FANTARED II percentages are purely projections in order to understand the potential magnitude of derelict fishing gear, and should not be mistaken as definite gillnets that have been lost in both study sites.

i. SWEDEN

Iceland Gillnets:

From 2007 to 2017, 5,138,733 gillnets used by 1185 fishing vessels in the Icelandic EEZ, coming out to an average of 4322.6 gillnets per vessel. In Sweden, the total estimated loss per year was about 1,500 nets, estimating to about 3.4-3.6 nets per vessel, which is approximately 0.1 percent of nets lost per year per vessel. With this estimate, an average of 4.3 nets are lost per ship annually, creating an estimated 464.4 nets being lost annually.

Iceland Lumpfish Gillnets:

Over the course of the same ten years, 2,247,962 lumpfish gillnets were used by a total of 2806 boats, creating an average of 7948.5 nets per boat. With 0.1% of gillnets lost annually on each Swedish vessel, an average of 0.8 nets are lost annually on each ISL boat coming to 224 lumpfish gillnets lost every year.

Alaska Gillnets:

Following the estimates taken from Sweden, if 0.1 percent of Alaska gillnet fishing vessels lose their nets, approximately 66.53 registered gillnet boats will experience gillnet loss.

ii. MEDITERRANEAN

Iceland Gillnets:

French hake fisheries discovered that their offshore fleets have an estimated loss of 0.2% of nets per year. For Iceland, that would be an estimated 8.6 nets lost per ship, with a total of 920.2 gillnets lost per year.

Iceland Lumpfish Gillnets:

Working with an average of 795 lumpfish gillnets hauled and used by each ship from 2007 to 2017, an estimated 0.8 nets are lost per shipping vessel, for a total of 224 nets per year.

Alaska Gillnets:

Approximately 133.06 Alaskan gillnet fishing vessels will lose their gillnets if they lose the number of gillnets that is predicted in the Mediterranean.

iii. ENGLISH CHANNEL AND NORTH SEA

Iceland Gillnets:

In the English Channel and North Sea, up to 2.11% of gillnets (sea bass) are lost on each vessel (Brown, 2005). With an average of 4322 gillnets on each ship, an average of 91.2 gillnets are lost on every ship annually, coming to a total of 9,758 nets discarded potentially every year.

Iceland Lumpfish Gillnets:

With an average of 794 lumpfish gillnets hauled and used per vessel annually, an estimated 15.9 nets are lost per ship annually, creating a total of 4,461 nets lost annually.

Alaska Gillnets:

With 2.11% of gillnets being lost annually on each fishing vessel in the English Channel and North Sea, approximately 140.38 gillnet fishing vessels in Alaska will experience gillnet loss.

iv. UNITED KINGDOM

Iceland Gillnets:

Focusing further on the English Channel, the United Kingdom has the highest proportional loss rate of gillnets of 3% per year. In the context of Iceland, that would mean an average of 129.7 nets are lost on every vessel, with a potential total of 13,977 nets lost annually.

Iceland Lumpfish Gillnets:

With an average of 794 lumpfish gillnets on every ISL boat, a 3% loss would estimate to an average of 23 nets lost per ship. That would come out to a total of 6,440 nets per year.

Alaska Gillnets:

With an annual 3% loss of gillnets in the U.K., that indicates that approximately 199.5 fishing vessels will experience gillnet loss.

***Figure 12**. DERELICT FISHING GEAR PROJECTED LOSS (Armstrong, 2019)*

FISHERY	**SWEDEN LOSS ESTIMATION** (0.1% nets lost annually per boat)	**MEDITTERANEAN LOSS ESTIMATION** (0.2% nets lost annually per boat)	**ENGLISH CHANNEL AND NORTH SEA LOSS ESTIMATION** (2.11% nets lost annually per boat)	**UNITED KINGDOM LOSS ESTIMATION** (1% nets lost annually per boat)
Iceland Gillnet	4.3 npb	8.6 npb	91.2 npb	129.7 npb
Iceland Lumpfish	0.8 npb	1.6 npb	5.9 npb	22.9 npb
*Alaska Gillnet	*66.52	*133.06	*140.38	*199.5

*an estimated amount of registered gillnet boats that will experience loss
npb: nets per boat

v. SIGNIFICANCE OF ESTIMATIONS

The estimations signify a high concentration of potential gillnets that have been accidentally or intentionally discarded in the Arctic. The typical gillnets measures to be 50 to 200 meters in length composed of plastic nylon material, so if just a single gillnet is lost, that results in a large accumulation of plastic to remain in the ocean (Gilman et al., 2015). With the ramifications of lost gear already being discussed, this raises an alarming concern due to the additional access plastic can have in the Arctic due to melting sea ice and increased fishing in the now accessible regions of the Arctic.

Debate over plastics derived from derelict fishing gear is not new; it has been discussed in numerous agreements and conventions since the 1970s. However, additional forms of remediation, prevention, and mitigation must be presented to ensure that the estimations provided decrease in the future. Some of the forms that will be discussed are already being implemented in Alaska and Iceland, which can be utilized and frameworks for other Arctic countries who will be facing the repercussions of plastic accumulations in remote parts of the Northern hemisphere.

Before we enter forms of mitigation, we must begin with when the initial conversations of derelict fishing gear first globally took place. Beginning in the 1980's, ALDFG was brought to global attention when it was discussed in a series of agreements and conventions due to its threat on marine life.

vi. ON NATIONAL AGREEMENTS

Marine debris, for its biotic and abiotic harms, has been recognized as a global epidemic and is listed as the major perceived threat to marine biodiversity for over a decade. Agreements, such as the 11th Conference of the Parties to the Convention on Biological Diversity (CBD COP 11 Decision XI/18), the 10th Conference of the Parties to the Convention on the Conservation of Migratory Species of Wild Animals (CMS Resolution 10.4), the International Convention for the Prevention of Pollution From Ships Annex V, which presented Maritime Pollution 73/78 (MARPOL), and the EU Marine Strategy Framework Directive (MSFD), have discussed the impacts of plastics, and even referred to the litter as hazardous waste (Rochman et al., 2013).

The US Environmental Protection Agency (EPA) is also interested in the toxicity of plastic debris due to its relationship to existing legislation that regulates hazardous environmental chemicals. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Pollution Prevention Act, and the Clean Water Act, policy is being created in order to identify and determine what legislation is warranted to control the toxicity of plastic debris. Initially, the programs must lay the groundwork to perform risk assessments and marine research, so currently there is no legislation that is directly cleaning the ocean.

The issue facing these agreements is that there is a lack of direct enforcement, which could partially be an explanation as to why there is still an influx of plastic entering our oceans (Gray, 1997, STAP, 2011, Sutherland et al., 2010). Since the time of these agreements, and even after the MARPOL agreement, which banned the disposal of ship waste, the seafloor has actually accumulated more plastic litter from illegal dumping, coastal waste, riverine discharge, and loss of fishing gear (Ramirez-Llodra et al., 2011). According to Bergmann and Klages (2017), there has even been an increase in marine litter discovered at the HAUSGARTEN observatory in the Arctic from 2002 to 2014 (Tekman, 2017).

The agreements and conventions lack a unified form of enforcement, which has been raised as an alarming problem with the MARPOL agreement, specifically.

vii. ON MARITIME POLLUTION 73/78

On December 31, 1988 Annex V of the International Convention for the Prevention of Pollution from Ships, presented Maritime Pollution 73/78, also known as MARPOL, which was enacted to prevent plastics and other litter from ships to enter the oceans. In addition to banning the disposal of plastics and ship litter in the marine environment, ships signed to MARPOL are also obliged to keep a garbage record book that should be presented at every dock. These books should include the date, time, and position of the ship, as well as a description of the garbage and the estimated amount that must be incinerated or discharged.

All MARPOL signed ships, ranging from merchant ships to fixed or floating platforms to non-commercial ships like pleasure crafts and yachts, must follow the specific guidelines and rules of conduct. Despite MARPOL being an optional provision, many influential fishing groups have pledged to abide by its guidelines to keep the waterways clear.

Over 150 countries have signed the MARPOL and pledged to prohibit waste from entering marine waters. The four main Regional Fisheries Management Organizations (RFMOs) that are signed to the pledge include The Intern-American Tropical Tuna Commission (IATTC), the Western and Central Pacific Fisheries Commission (WCPFC), the International Commission for the Conservation of Atlantic Tunas (ICCAT), and the Indian Ocean Tuna Commission (IOTC). These influential fishing groups have considerable political and legislative power over global fishing policy, yet despite this influential agreement, little is being seen to aid the ALDFG epidemic.

Plastic pollution in the ocean has only increased since MARPOL was enacted in 1988. Though legislation, agreements, and policy are motivating forms of remediation, in the chapters to follow, we will examine more active forms of remediation and prevention that have had positive results in small case studies. These forms of remediation can consequently aid Arctic countries and communities in order to effectively and efficiently diminish the influx of plastic entering the oceans.

CHAPTER SIX: Presenting Forms of Remediation, Mitigation, and Prevention

Forms of remediation, mitigation, and prevention are critical when examining the consequences derelict fishing gear has on marine ecosystems. These three forms have the capability of proactively and progressively cleaning up the Arctic waters, as well as global waters, if applied correctly in Arctic states and countries. The preventative measures presented are proposed to initially stop ALDFG from entering the waterways in general, while forms of remediation and mitigation are presented in order to alleviate the ramifications of lost gear, and treat gear that has been intentionally or unintentionally lost.

Beginning with Iceland, the country over the past decade, has addressed plastics as being a national problem, and has begun implementing forms of remediation themselves. The forms of remediation can be built upon and expanded, however, in order to further diminish the consequences, we have estimated for ALDFG in the Icelandic EEZ.

i. DETECTION AND REMOVAL OF GEAR IN ICELAND

The remedial methods designed to counteract and correct derelict fishing gear tend to be costly and time intensive, yet the outcome can be incredibly effective for beach and water cleanup and lowering marine mortality. Detection and removal are the initial steps in order to clear our waterways. In 2016, upwards of 20 metric tons of trash were collected by volunteers from beaches in Iceland, mainly from a volunteer group named the “blue army” located in many of the major coastal cities in Iceland (White, 2018).

In addition to physical beach clean-up initiatives, onboard equipment to retrieve lost gear and regulating frameworks are essential for detection of derelict gear. Many of these frameworks are currently in place, but are not utilized for financial disincentives that compel those not to report lost gear (Gilman, 2015). There must be a total elimination of monetary penalties for losing gear, so that there are better logbooks and maps that detect and define lost fishing gear locations.

With fishers utilizing databases to log when the have lost gear with no economic penalization, programs that survey the sea floor of commercial fishing zones and/or vulnerable marine habitats should be implemented in order to locate and detect ALDFG. It has been mandatory for some decades in Iceland to mark buoy's and gillnets anchor's in cod fishery with ship name and number, which assists with detection and remediation; however, technology to detect and remove former fishing gear, rather than just identify, would be a crucial remedial strategy in order to remediate ALDFG. Along with identifying gear, advancements in gear design would also be an advantageous addition to Iceland fisheries in order to decrease the impacts long lasting nets have on the marine ecosystem.

Figure 13*: The Blue Army of Iceland derelict fishing gear clean up (obtained from Project AWARE)*

ii. FISHERIES INNOVATIONS IN ICELAND

Iceland fisheries have undergone a fisheries revolution over the recent years, but primarily in processing technologies. Icelandic processers have abided by a zero-waste policy, where they have designed technology that uses as much of the fish as possible. Being a global leader in those technological advancements, there should also be improvements in gear innovation. Transitioning back to biodegradable material such as hemp, manila, sisal, and cotton-based gear, rather than plastic monofilament gillnets would diminish marine mortality and plastic accumulations in the ocean.

Applying an emphasis on bycatch innovations for passive gear would also significantly lower the devastating effects ghost fishing can have on the ocean. Focusing on mesh size, and target species in gillnets, would lower bycatch numbers and create a safer, more localized net. For other passive gear, such as traps and pots, the same methodology applies for additional innovations in the crabbing industry, and gear innovation that will diminish the gears long life after it is lost in the ocean.

Though innovations will help with remediation efforts, forms of mitigation and prevention are crucial in ensuring the epidemic will decrease over time, which is why in Iceland there has been a growing emphasis on derelict fishing gear education.

iii. EDUCATION AS PREVENTION

Community education and outreach is a powerful method in preventing marine litter from further entering our Arctic waterways. MARine Pollution in the Arctic, also known as MARP3 is a project affiliated solely for Arctic marine debris prevention. The project delivers research through workshops on marine waste in order to enhance the knowledge base for more sustainable outreach and community education. MARP3 puts a heavy emphasis on outreach and communication, under the assumption that the most important tool for combating ALDFG is education itself.

Education is an all-encompassing form of prevention, remediation, and mitigation since fishermen, policy members, and overall community members become aware of the epidemic and efficient forms of prevention. Rather than targeting certain forms of global remediation, such as cross-national legislation or the creation of private recycling centers, educating the entire public pulls ideas and effective forms of mitigation that can be organized and applied locally in order to moderate marine litter. Additional forms of education, like MARP3, through workshops, lecture series, and discussion groups organized in Iceland would be advantageous for the prevention of Arctic ALDFG.

iv. FURTHER ON PREVENTION IN ICELAND

Prevention can halt causation and initiate remediation within marine ecosystems that have been or will potentially be vulnerable to the effects of ALDFG. Prevention, in addition to education, is believed to be the most cost efficient and cost-effective way when it comes to remediating derelict fishing gear, and can solve not just solely lost gear, but the broader management of fisheries (Gilman, 2015). There are various ways to prevent gear entering the ocean, the first being gear marking to identify ownership and increase surface visibility. Marking will allow for vessels to mark and distinguish which gear is theirs and where it is. This method goes hand in hand with technology, like GPS, to pinpoint and position the location of fishers' gear.

Observation is critical in prevention and can be achieved through limiting the amount of soak time of the gear through input control, and periodic surveillance of passive gear. Illegal, unreported, and/or unregulated (IUU) fishing must also be observed and regulated in order to deter the actions from taking place. In 2011, a case study of the Icelandic integrated system for monitoring, control, and surveillance was released and reported the effect preventative monitoring can have on the amount of derelict fishing gear that enters Icelandic waterways (FAO, 2011).

The 2011 FAO Fisheries and Aquaculture Circular report covered the dramatic difference monitoring, control, and surveillance (MCS) had on combatting IUU in the Icelandic EEZ (FAO, 2011). The integrated system has proved to be effective in combating and eliminating IUU fishing operations in the Icelandic EEZ and in the North Atlantic, an approach that identifies vessels, movement, IUU lists, notifications, reports, fishing licenses, permits, reports, and other crucial data. It was discovered that monitoring not only decreased the amount of fishing nets being discarded in the waters, but also served as efficient tools in combating organized crimes that seem to have little to do with fish and marine activity. MCS proved in Iceland to control the trafficking of humans and drugs in the Icelandic EEZ, as well as halting the pollution of the waterways. With surveillance taking place in the waters, it has been proposed that another form of prevention is enforced consequences for discarding gear.

Banning the discarding of fishing gear in the ocean would potentially be an effective form of prevention, but only if there is compliance between fishers and governmental enforcement. Ways to ensure there is an efficient decrease in the intentional discarding of nets would be economic incentives, such as deposits on new gear when old gear is returned to ports and recycled. Such recycling stations are currently in place in Iceland, and have been working for over ten years in cleaning up the oceans, ports, and beaches of Iceland.

v. RECYCLING AS REMEDIATION IN ICELAND

In August of 2005, the National Association of Icelandic Vessel Owners established an agreement with the Board of the Icelandic Recycling Fund for implementing recycling stations and ports for fishers to drop off and distribute derelict fishing gear made of synthetic materials. Under Art. 8, of Act No. 162/2002 of Recycling Fees, to ensure the adequate and sustainable recycling of fishing gear the agreement was built off of stationary authorization of undertakings and sectors.

If the protocol is followed correctly, Icelandic vessels can discard synthetic waste at the recycling port stations without a fine. The agreement was passed that year and officially was enacted on January 1, 2006. After the agreement was passed, Iceland witnessed a radical change with their relationship between fisheries and recycling – the largest one being the implementation of recycling stations at every port.

The Iceland Environmental Agency established an agreement with the ports and third parties to design and designate receiving stations for recycling gear of synthetic material that would then be directed to various recycling stations. It is at the recycling stations where the synthetic material will be processed down into raw material that can then be reused in various products. About 90 percent of this material is recycled, which can be seen in 2016 where 1,297,331 kg of discarded gear were received, resulting in 1,165,051 kg of the gear being sent to recycling stations and just 132,280 kg ending up in landfills (Fisheries Iceland, 2017). From the beginning of the agreement in 2006 to the most recent data collected in 2016, in total 8,400 tons of discarded gear has been dropped off at the port stations and recycled (Fisheries Iceland, 2017). One of the largest reuses of this raw material can actually be found in the automobile industry in Germany.

The discarded gear is sent to recycling stations in Lithuania, where a majority of the production is used in the electricity and automobile industry. The raw product is used in plastic automobile components, like dashboards and floor mats, which creates this completely "circular car," that being a car that does not utilize any new raw, unsustainable products (Lacy, 2016). Creating this circular economy – of sorts – that incentivizes fishermen, organizations, companies, and community members to recycle and find an economic purpose with the raw material will lower the loss of fishing gear lost at sea.

vi. HESITANCY WITH RECYCLING

Though recycling is a form of remediation that directly solves the problem of waste in our oceans, and already has a system implemented in Iceland, I do not believe it is the most economic or ecologically advantageous solution for the plastic epidemic, nor one that we should fall back on. Presenting recycling as a form of remediation tends to halt other forms of prevention and mitigation, and not fully solve the overall problem of marine plastics. Recycling almost draws the curtain over the larger problem at hand; the problem that plastic does not go away. Ninety percent of plastic that is labeled recyclable is not even recycled, and for lost fishing gear, there are structural issues with the plastic that makes it incredible difficult to repurpose (U.N., 2018).

For example, after a net is used for a number of years, the synthetic material is oxidized and cracked due to being immersed in seawater and exposed to sunlight. With the structural intensity weakened, as well as dirt, trash, shells, and organic matter tending to be caught within them after being lost at sea, nets are difficult to be recycled. While recycling should be encouraged for retrieved nets, and can easily be implemented in other Arctic countries/states, it must be coupled with forms of prevention, such as gear advancement and education, in order to systematically combat plastic pollution in our waterways.

vii. DETECTION AND REMOVAL IN ALASKA

In Alaska, there are similar forms of prevention, remediation, and mitigation that are being discussed and frame worked, as well as other unique approaches that can be utilized by other Arctic countries. Alaska marine debris removal efforts are currently scattered regionally and often opportunistic. Government agencies, environmental organizations, landowners, and tribes attempt to identify and solve these natural resource issues with no centralized organization.

As a result, regional marine debris removal programs often operate in isolation, modestly funded and using a combination of volunteer and paid staff. Furthermore, difficult access to Alaska coasts, safety and weather considerations, and limited landfill sites and recycling options result in high removal costs. The National Fish and Wildlife Foundation (NFWF), however, has partnered with Fishing for Energy to create a no-cost solution for fishermen to dispose of ALDFG.

NFWF, an American government-backed agency for sustainable fish, wildlife, plants, and habitats, created the Fishing for Energy grant to reduce the impacts of derelict fishing gear on the delicate marine environment, and provide opportunities for fishermen and coastal community members. The grant follows four main guidelines for derelict fishing gear prevention, remediation, and mitigation.

Fishing for Energy provides organizations opportunities for direct derelict gear disposal, such as collection and recycling bins. Organizations partnering with NFWF also collaborate with government agencies and city planners in order to address and resolve legal impediments that impair the removal of derelict fishing gear, such as financial burdens, city legislation, etc. The grant also works to identify technological advancements in order to detect unwanted gear from entering the marine environment, as well as, lastly, working on community education and outreach in order to inform the public on the impacts of ALDFG.

Currently, Fishing for Energy had provided disposal bins in 58 different ports and in 13 states. These receptacles have collected 4 million pounds of derelict fishing gear. The gear is then sorted and recycled at Schnitzer Steel industries, located in central California, while the non-recyclable material is converted into energy at a Covanta Energy-from-Waste facility in California. In total, Fishing for Energy has awarded $3.77 million in grants to more than 40 projects in 19 U.S. states and Puerto Rico, including the Sitka Science Center in Alaska.

The Sitka Sound Science Center (SSC) has been involved in Marine Debris research, cleanup, and outreach since 2008, when the NFWF grant was awarded to them. SSC has partnered with fishermen, community partners, and schools in order to physically remove debris from Southeast Alaska marine waters. Additional initiatives have been enacted ever since the derelict gear epidemic was detected in the 1980s, including the National Oceanic and Atmospheric Administration (NOAA) Marine Debris program.

In 2006, The National Oceanic and Atmospheric Administration noticed the ever-growing problem of marine litter and initiated the NOAA Marine Debris Program to combat the issue. Focused on marine debris prevention and removal, the program partners with organizations to conduct litter research and removal. Currently, the program has funded over 20 projects in Alaska that have collectively removed 450 metric tons of debris from the shorelines.

Many of the debris clean ups are accompanied by beach surveys to determine the origin of the debris, accumulation rates, and patterns in the types of debris that are coming on shore. This act of prevention NOAA believes is “the key to solving the marine debris problem overtime. If you think about an overflowing sink, the first step before cleaning up the water is to turn the tap off" (NOAA, 2019). Though turning off the sink is metaphorical, in actuality we must track the patterns of debris, and incorporate innovative solutions that directly, and indirectly, tackle the epidemic. Transitioning to local seafood, though it may seem like an indirect solution, has been found to directly diminish the amount of lost passive gear in the Artic.

viii. COMMUNITY SUPPORTED FISHERIES AS A PREVENTATIVE SOLUTION

Local food movements, also known as "locavore" movements, have emerged across the globe as a means of reducing environmental and ecological impacts, increasing economic profit for small-scale food producers, fostering community collaboration, and improving the quality of food. One of the most popular forms of this farm to table movement is the community supported agriculture (CSA) model, where consumers pay in advance for a share, and then pick up their order of produce every week at a vendor site.

The CSA model has been emulated closely in many coastal regions, with the community supported fishery model (CSF). With this model, a shareholder will purchase an order of fish in advance, commonly following that of the May-to-October fishing season, and pick up their fish share biweekly, or monthly, at their vendor site. CSFs decrease the financial risk to fishers, since the share is paid in advance, and provides consumers with a transparent supply chain where they can track exactly what day, by whom, and where their fish was caught.

Additionally, seafood that is distributed locally reduces fisheries carbon footprint compared to industrialized fisheries for global markets by shortening the distance from boat to plate, and encourages the use of less destructive fishing gear, such as longlines, which diminishes plastic in highly trafficked waterways. Finally, CSFs motivates fishers to be actively involved in fisheries management by developing local rules or protocols rooted in sustainability and safe fishing practice that improve on those imposed by state or federal managers (McClenachan, 2014).

The first successful CSF began out of Port Clyde, Maine when the Mid-Coast Fishermen's Cooperative teamed up with the First Universalist Church in Rockland, Maine in creating a shrimp CSF. The success of the Maine CSF encouraged other coastal fishermen to start their own operations, such as Alaskans Own based in Sitka, Alaska.

Figure 14*: Graphic comparing a large fishing fleet supply chain to a CSF supply chain (permission granted by McClenachan, 2014)*

ix. ALASKANS OWN

Alaskans Own (AO) is Alaska's first community supported fishery, which began in 2009 as a pilot project for the Alaska Longline Fishermen's Association. Alaskans Own works almost as a fishermen collective; the organization collaborates with the local Sitkan fleet, and sells their locally caught fish at their marketplace once a month in their five locations of Sitka, Fairbanks, Anchorage, Juneau, and Seattle.

Alaskans Own operates from May until October in tandem with the natural fishing season, and offers 5lb, 10lb, and 20lb shares of locally caught seafood. Quite similarly to the key components of a successful community supported fishery, AO emphasizes supporting coastal communities, collaborating with fishermen, promoting sustainable fishing practices, and providing high-quality seafood. Alaskans Own, however, runs differently than other community supported organizations.

All of the proceeds for Alaskans Own is distributed to sustainable research initiatives and projects that are run by the Fisheries Conservation Network. ALFA's Fishery Conservation Network (FCN) facilitates cooperative research between local Alaska fishermen and scientists to address research challenges and issues of common concern. FCN is currently conducting research on bathymetry and bycatch reduction, sperm whale avoidance, electronic monitoring, and fuel efficiency.

Community supported fisheries both reduce the amount of bycatch that is normally caught in industrialized fishing vessels, and also encourage markets to utilize accidentally caught species. The most common bycatch in Alaska is rockfish, an abundant benthic Pacific fish species, which Alaskans Own sells to their shareholders. The fish is often caught, then discarded in large fishing fleets; however, local fishermen with AO have utilized this specific fish, and provided a local food outlet for the species. The CSF model creates a new market for these stocks, and also encourages electronic innovations to further prevent bycatch from being caught, as well as monitoring the health of the fishing stocks.

Community supported fisheries incentivize small fishing vessels to utilize advanced gear that reduces harmful environmental impacts. The use of line and gear, such as longlines, individually have hooks attached every three meters that catches singular fish. Longlines reduce high quantities of bycatch, which can be compared to gillnets that catch everything in one net, use less material than other fishing gears (purse sein, gillnet, etc), and eliminate benthic disturbance, since it is solely floating in the pelagic zone. Longlining is referred to as a low impact fishery, and many CSF's, including Alaskans Own, supply their seafood from longline fishermen.

Longlines pose some threats to marine mammal species, however FCN has found an innovative way to detect and deter boats from sperm whales. FCN implemented bathymetric systems on their fishermen's boats to detect sperm whales, monitor fish stocks, and avoid bycatch species. A bathymetric map is the submerged, marine equivalent to a terrestrial topographic map. The maps are designed to present detail presentations of the sea floor, and an accurate depiction of any sizeable masses on or above the submerged terrain. Bathymetric maps can show, for example, where sperm whales are swimming and accumulating.

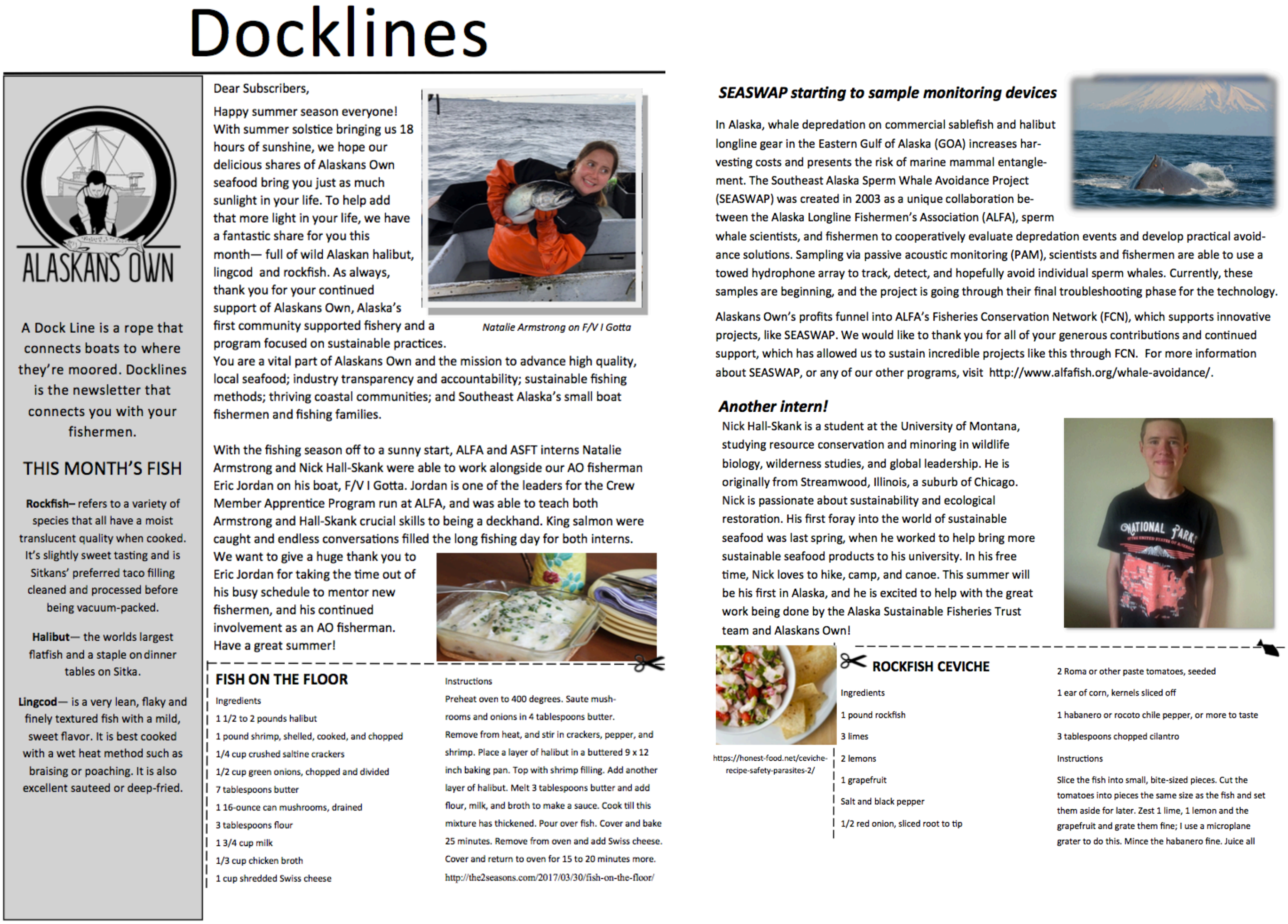
In Alaska, whale depredation on commercial sablefish and halibut longline gear in the Eastern Gulf of Alaska (GOA) increases harvesting costs and eliminates the risk of entanglement. The Southeast Alaska Sperm Whale Avoidance Project (SEASWAP) was created in 2003 as a unique collaboration between the Alaska Longline Fishermen's Association (ALFA), sperm whale scientists, and fishermen to cooperatively evaluate depredation events and develop practical avoidance solutions. Sampling via passive acoustic monitoring (PAM), scientists and fishermen are able to use a towed hydrophone array to track, detect, and hopefully avoid individual sperm whales. Fishermen are then taking these sustainable practices and applying them within their communities through education and outreach.

x. EDUCATION THROUGH COMMUNITY SUPPORTED FISHERIES

Community supported fisheries (CSF's) aid in the efforts to promote community collaboration through fisheries education and consumer awareness. To create community between shareholders, several CSF's construct educational initiatives, such as pamphlets, interviews, lectures, etc., to share information about local fisheries stocks, sustainability efforts, local fishing news, fishermen updates, processing, recipes, and events (McClenachan, 2014). Alaskans Own does this through a monthly newsletter titled Docklines.

A dockline is a rope that connects boats to where they are moored, and the purpose of Alaskans Own's Docklines newsletter is that it connects "you with your fishermen" (AO, 2019). Every month, a digital version of the newsletter is released, which includes recipes from fishermen or shareholders, updates with Southeast Alaska fishing news, innovations in the fisheries industry, and any other information that aims to bridge the gap between ocean to table.

While working at ALFA, I collaborated with and interviewed fishermen, Sitkan community members, and ALFA members in order to write the Docklines for the 2019 fishing season. The Docklines covered an array of topics occurring in Southeast Alaska, all with the purpose of increasing consumer awareness of sustainable seafood and providing a transparent supply chain that could be traced from exact boat to your table. All of the articles written had to the sole purpose of shifting the local demand of seafood towards a more sustainable practice and informing the community about the benefits of a CSF, which can be seen through the June 2019 Dockline featured in figure 15. Community supported fisheries provides economic, ecological, and educational advantages to the fishing industry.



Docklines

ALASKANS OWN

A Dock Line is a rope that connects boats to where they're moored. Docklines is the newsletter that connects you with your fishermen.

THIS MONTH'S FISH

Rockfish– refers to a variety of species that all have a moist translucent quality when cooked. It's slightly sweet tasting and is Sitkans' preferred taco filling cleaned and processed before being vacuum-packed.

Halibut— the worlds largest flatfish and a staple on dinner tables on Sitka.

Lingcod— is a very lean, flaky and finely textured fish with a mild, sweet flavor. It is best cooked with a wet heat method such as braising or poaching. It is also excellent sauteed or deep-fried.

Dear Subscribers,

Happy summer season everyone! With summer solstice bringing us 18 hours of sunshine, we hope our delicious shares of Alaskans Own seafood bring you just as much sunlight in your life. To help add that more light in your life, we have a fantastic share for you this month— full of wild Alaskan halibut, lingcod and rockfish. As always, thank you for your continued support of Alaskans Own, Alaska's first community supported fishery and a program focused on sustainable practices. You are a vital part of Alaskans Own and the mission to advance high quality, local seafood; industry transparency and accountability; sustainable fishing methods; thriving coastal communities; and Southeast Alaska's small boat fishermen and fishing families.

Natalie Armstrong on F/V I Gotta

With the fishing season off to a sunny start, ALFA and ASFT interns Natalie Armstrong and Nick Hall-Skank were able to work alongside our AO fisherman Eric Jordan on his boat, F/V I Gotta. Jordan is one of the leaders for the Crew Member Apprentice Program run at ALFA, and was able to teach both Armstrong and Hall-Skank crucial skills to being a deckhand. King salmon were caught and endless conversations filled the long fishing day for both interns. We want to give a huge thank you to Eric Jordan for taking the time out of his busy schedule to mentor new fishermen, and his continued involvement as an AO fisherman. Have a great summer!

FISH ON THE FLOOR

Ingredients

1 1/2 to 2 pounds halibut
1 pound shrimp, shelled, cooked, and chopped
1/4 cup crushed saltine crackers
1/2 cup green onions, chopped and divided
7 tablespoons butter
1 16-ounce can mushrooms, drained
3 tablespoons flour
1 3/4 cup milk
1/3 cup chicken broth
1 cup shredded Swiss cheese

Instructions

Preheat oven to 400 degrees. Saute mushrooms and onions in 4 tablespoons butter. Remove from heat, and stir in crackers, pepper, and shrimp. Place a layer of halibut in a buttered 9 x 12 inch baking pan. Top with shrimp filling. Add another layer of halibut. Melt 3 tablespoons butter and add flour, milk, and broth to make a sauce. Cook till this mixture has thickened. Pour over fish. Cover and bake 25 minutes. Remove from oven and add Swiss cheese. Cover and return to oven for 15 to 20 minutes more.

http://the2seasons.com/2017/03/30/fish-on-the-floor/

SEASWAP starting to sample monitoring devices

In Alaska, whale depredation on commercial sablefish and halibut longline gear in the Eastern Gulf of Alaska (GOA) increases harvesting costs and presents the risk of marine mammal entanglement. The Southeast Alaska Sperm Whale Avoidance Project (SEASWAP) was created in 2003 as a unique collaboration between the Alaska Longline Fishermen's Association (ALFA), sperm whale scientists, and fishermen to cooperatively evaluate depredation events and develop practical avoidance solutions. Sampling via passive acoustic monitoring (PAM), scientists and fishermen are able to use a towed hydrophone array to track, detect, and hopefully avoid individual sperm whales. Currently, these samples are beginning, and the project is going through their final troubleshooting phase for the technology.

Alaskans Own's profits funnel into ALFA's Fisheries Conservation Network (FCN), which supports innovative projects, like SEASWAP. We would like to thank you for all of your generous contributions and continued support, which has allowed us to sustain incredible projects like this through FCN. For more information about SEASWAP, or any of our other programs, visit http://www.alfafish.org/whale-avoidance/.

Another intern!

Nick Hall-Skank is a student at the University of Montana, studying resource conservation and minoring in wildlife biology, wilderness studies, and global leadership. He is originally from Streamwood, Illinois, a suburb of Chicago. Nick is passionate about sustainability and ecological restoration. His first foray into the world of sustainable seafood was last spring, when he worked to help bring more sustainable seafood products to his university. In his free time, Nick loves to hike, camp, and canoe. This summer will be his first in Alaska, and he is excited to help with the great work being done by the Alaska Sustainable Fisheries Trust team and Alaskans Own!

https://honest-food.net/ceviche-recipe-safety-parasites-2/

ROCKFISH CEVICHE

Ingredients

1 pound rockfish
3 limes
2 lemons
1 grapefruit
Salt and black pepper
1/2 red onion, sliced root to tip
2 Roma or other paste tomatoes, seeded
1 ear of corn, kernels sliced off
1 habanero or rocoto chile pepper, or more to taste
3 tablespoons chopped cilantro

Instructions

Slice the fish into small, bite-sized pieces. Cut the tomatoes into pieces the same size as the fish and set them aside for later. Zest 1 lime, 1 lemon and the grapefruit and grate them fine; I use a microplane grater to do this. Mince the habanero fine. Juice all

***Figure 15**: June, 2019 Docklines (obtained from Armstrong)*

CSF's create opportunities for new markets of fish, such as bycatch, to be sold at market days, and encourages small fishing vessels to adopt and practice sustainable fishing methods, such as line and hook trolling. CSFs lastly provide a platform for cross community engagement and awareness through newsletters that highlight sustainable initiatives and environmental awareness.

Community supported fisheries are an indirect system that incorporates forms of derelict gear prevention, mitigation, and remediation. By using less invasive, low impact gear, such as longlines, it prevents mass accumulations of monofilament nets that potentially could be lost at sea. Longlines, statistically, are not lost as frequently as gillnets, which eliminates the danger of ghost fishing. The gear and technology utilized by AO is also highly advanced; monitoring bycatch, bathymetric data, and fuel levels which lowers the harmful impacts on the environment and diminishes the potential for lines being lost in the ocean.

Furthermore, community supported fisheries put an emphasis on education and outreach, an effective form of ALDFG mitigation. Community awareness encourages those to invest in more sustainable seafood, purchase locally from small fleets, and become aware of the environmental dangers posed by large fishing fleets. In situations where there is no access to community supported fisheries, another method of plastic prevention is a unique market based solution of labeling.

xi. ADDITIONAL MARKET BASED SOLUTIONS

Seafood traceability through environmentally sustainable eco-labels allows customers to become aware of where their seafood is coming from, and motivates consumers to purchase environmentally sustainable fish. FishWise Advisory has provided a market-based incentive for purchasing ecologically sustainable seafood through an innovative, color-coded labeling system (FishWise, 2019).

FishWise, located across the West Coast of the United States, has created a color-coded system of red, yellow, and green that informs purchasers on the sustainability of their fish. Under the FishWise traffic light system, the pin tag label contains whether the seafood was farmed or caught in the wild, the country where it was caught, catch method (gillnet, longline, trawl, etc.), and price. The hierarchical green, yellow, and red system are then created to motivate a consumer to purchase sustainably.

Seafood labelled in green signifies that the specific species is abundant and/or from a well-managed fishery, and was caught in an environmentally safe fashion. Yellow, the second-best option, means that the species comes from a stock that has normal quantities, however, there are still environmental reservations due to either the catching method or specific fishery. Lastly, red indicates that the species is unsustainable, and was caught in a way that causes substantial harm to the environment (Hallstein, 2013).

The color-coded system can allow consumers to target fisheries and catch methods that are less invasive and utilize sustainable catching models, such as longlines. For example, a green eco-label would identify a King Salmon sold at a market as being wildly caught in Alaska on a longliner for $20 a pound. A red label would be a species caught by a bottom trawler in a sensitive marine ecosystem, such as an area in the Southern Pacific with an abundance of coral communities.

Seafood traceability through eco-labels, especially when there is no access to local seafood markets, is a market based solution for diminishing plastic in our ocean, since consumers can purchase a specific species that is caught by a sustainable, low impact catch method (longline). Longlining, as one of the most sustainable fishing practices, reduces plastic that can be potentially disposed in the ocean, since the physical line is not made entirely of plastic, like gillnets and other forms of passive gear.

Both Alaska and Iceland can incorporate this further into marketplaces where mass quantities of seafood are being sold to lessen the pressure for large fleets to use unsafe and harmful fishing methods, and economically support the sustainable practice of small-scale fishing boats.

CONCLUSION

There is always this inherent “so what?” or “why does it matter?” question when assessing the ramifications of pollution in our world’s largest landfill: the ocean. Since only a small portion of us are working and living on the water every day, we fail to recognize the magnitude of this epidemic, especially during a time of anthropogenic climate change. The crux of plastic in the ocean is that, even though it feels distant, it is inherently personal to all of our lives.

I could not answer this “so what?” question until my summer in Alaska when I was standing on a boat in Redbout Bay with the Sitka Conservation Society. We were on this boat in order to raise public awareness for the devastations that are occurring in the Tongass Forest, and that is when I saw a stellar sea lion sitting coyly on top of a buoy. Normally a performative species, I supposed the sea lion was simply posing for the boat, until I looked closer and saw a gillnet wrapped around its neck.

The gillnet was wrapped so tightly around the sea lion’s neck, that it was carving into the flesh, seemingly choking the sea lion. We called the coast guard for help, but it was in that moment that the research that I had been conducting for a year at that point became real.

I understand that not everyone has the ability to see, first-hand, the repercussions of derelict fishing gear, however, it should be understood that everyone on this planet indirectly or directly depends on the health of the ocean and cryosphere. These two systems dictate weather, carbon storage, water and energy exchange, transportation, migration, and life itself. The Arctic in particular is facing the largest environmental ramifications, due to anthropogenic climate change, which is being seen through mass sea ice melt, sea level rise, changes in marine migration patterns, and the opening of sea passages to previously ice locked spaces.

Additional access to areas in the Arctic, along with target species migrating further to the poles, will increase fishing and aquatic activity in the area, thus exacerbating the risk of derelict fishing gear. Increased fishing activity in the Arctic raises particular concern due to the location of the subpolar gyres. When a plastic material enters the anticyclonic and cyclonic subpolar gyres, the plastic particles converge and diverge within the gyre. In areas of convergence, as seen with the Beaufort and Barents gyre, the plastic material concentrates within the center of the gyre, and with cyclonic subpolar gyres, the particular currents carry it outwards, increasing the area at which ghost fishing can have to the physical, chemical, and biological marine ecosystem.

Ghost fishing effects the marine environment through entanglement, smothering, ingestion, and exposure to concentrated pollutants and pesticides. The ramifications of ghost fishing target particularly vulnerable Arctic species, such as stellar sea lions, grey and sperm whales, and vulnerable marine ecosystems, such as Lophelia coral. The consequences of ghost fishing are already being documented in the Arctic, however, the net input of lost plastic gillnets entering the marine ecosystem is unknown.

In order to quantify the unidentified loss of gillnets in the Arctic, projections were created at the Marine and Freshwater Research Institute, as well as at the Alaska Longline Fishermen's Association, to provide an estimated number for the amount of plastic that is potentially entering the waterways. The percentages applied to the registered gillnet fleet in both Alaska and Iceland were adapted from the FANTARED and FANTARED II studies, which determined the percentages of gillnets being lost in active fishing European countries.

The projections indicated a large accumulation of gillnets potentially entering the Arctic. The steps then moving forward from the projected plastic landfill is proactive and progressive change. Looking at sustainable fisheries as a model, forms of prevention, remediation, and mitigation were presented in order to combat the ramifications of derelict fishing gear.

Methods of mitigation are most commonly seen in one of two ways: through both a fishery based and market based plastics solution, however, all working towards the same goal of creating more sustainable fisheries. Some of these forms of remediation and prevention are already being implemented in both Alaska and Iceland, which can be adopted by other Arctic communities in order to diminish the influx of plastic from further entering the waterways.

From a fisheries perspective, advancements in gear technology, net design, and technological initiatives implemented on boats can ensure that passive gear will not be lost in the ocean. In the instance when a net is lost, transitioning the material from plastic back to a biodegradable hemp based material will decrease the half-life of the gillnet, and halt the ramifications of ghost fishing.

We, as consumers, also have the ability to remediate ALDFG through market-based personal actions. Simply knowing where your fish is coming from, where it was caught, how it was caught, are just a few examples of ways that communities can personally inhibit plastic from entering the Arctic. Purchasing from a community supported fishery, or reading the eco-label of your fish at a local grocery store, are market-based forms of remediation and prevention that not only solve the marine plastic epidemic, but give back to the community. Further community engagement and remediation can also be seen through outreach and education initiatives, whose main purpose is to inform the community about derelict fishing gear in order to mitigate the issue.

Plastics are a material that we have created in order to last forever, but we treat it as something that can easily be disposed. Out of sight, out of mind, however, the ramifications are unfolding before our very eyes. Direct forms of action in order to transition to sustainable fisheries must be implemented to diminish the influx of derelict fishing gear from entering the ocean, and provide a healthy marine ecosystem not just in the Arctic, but for the entire globe in the years to come.

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