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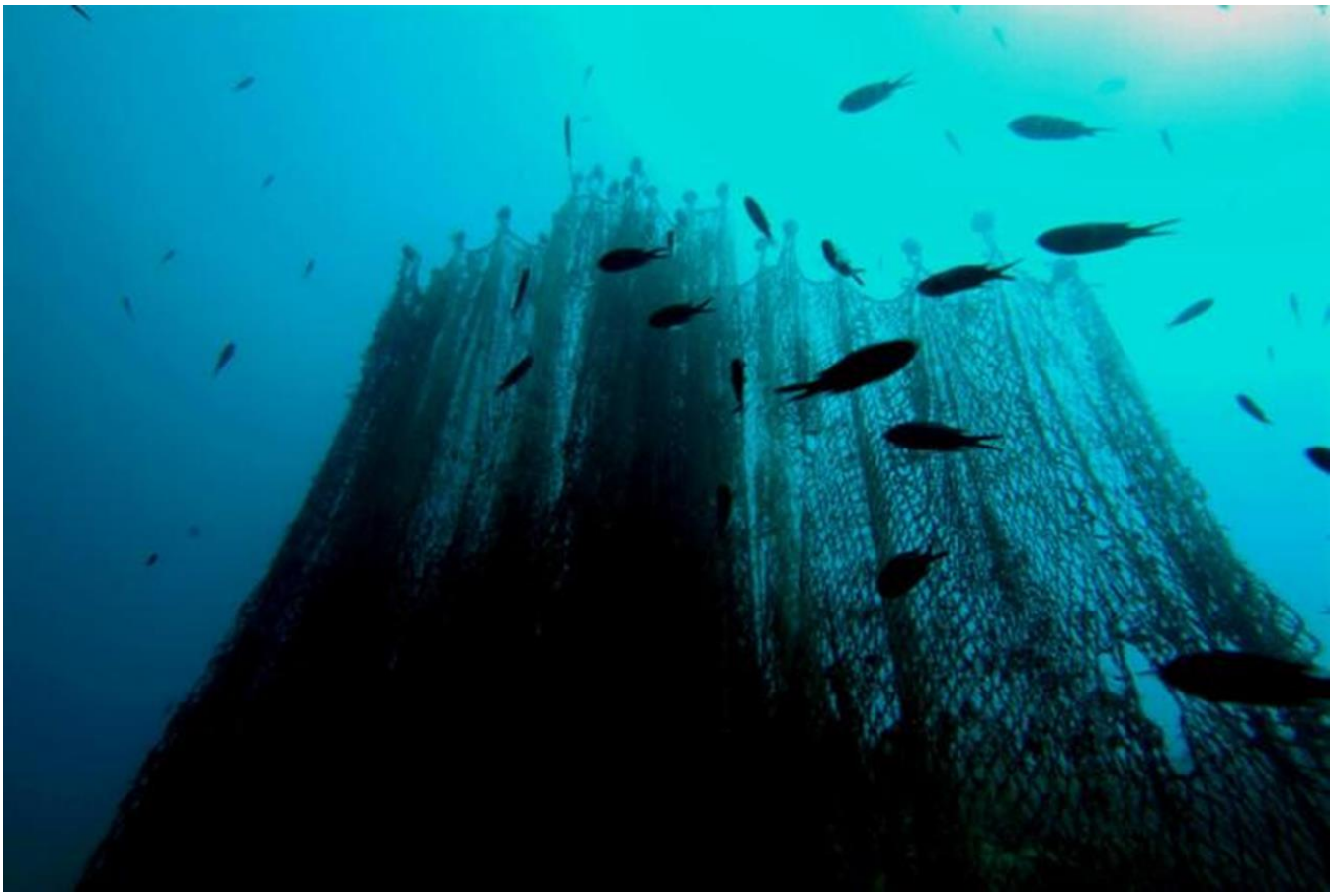
Derelict Fishing Gear in the Northwestern Hawaiian Islands: The Problems of "Ghost Fishing"



Introduction

The problem of derelict fishing gear, or 'ghost fishing' is one that has plagued the ocean increasingly as fishing efforts increase, commercial vessels become larger and more numerous, and fishing gear is built with more durable, synthetic materials (Macfadyen and Cappell, 2009). Derelict fishing gear is defined as nets, lines, pots, and other equipment that are abandoned, lost, or otherwise discarded (ALDFG) (Macfadyen and Cappell, 2009). The United Nations Environment Programme estimates about 640,000 tonnes of fishing gear are left in our global oceans annually (Macfadyen and Cappell, 2009). When these fishing nets are lost or abandoned, they drift through the water column or fall to the seafloor where they continue to entangle and kill marine life without discrimination. In a global landscape that demands higher protein from seafood despite the ever growing lack of fish in the sea, the fisheries industry and ocean environments have little resiliency to handle additional mortality of ocean life in this manner. There are a number of additional impacts to the safety and well-being of humans to be addressed as well.

Due to the circulation of ocean currents and other oceanographic conditions, derelict fishing gear is not evenly disbursed in our oceans, but is more commonly found in dense tangled clusters amidst gyres and convergence zones. The Northwestern Hawaiian Islands (NWHI) are one such hot spot, and contain some of the highest global densities of derelict fishing gear-- primarily large trawl and drift nets (Donohue et al., 2001). Much of the gear ends up settling in the protected, calmer and shallow water environments inside barrier reefs of the NWHI. A key physical forcing mechanism that causes this phenomenon is the convergence of surface waters in the North Pacific Subtropical Convergence Zone (STCZ). The STCZ is a result of the interaction of westerly prevailing winds in mid-latitudes with easterly prevailing winds in tropical zones (Kubota, 1994; Brainard et al., 2000).

Much of the public attention and scientific reports around marine debris focuses on land-based sources of pollution, and in particular plastics. While this is a crucial topic to address, there is a lack of understanding and knowledge around maritime-based sources of marine pollution. Derelict fishing gear alone makes up an estimated 10% of marine plastic debris, and contributes proportionally much more damage than other types of debris as they are specifically designed to capture marine life (Macfadyen and Cappell, 2009). Thus, there is a clear need for additional focus on such topics. This paper will attempt to gather known information on a particular sector of ocean-based marine debris-- derelict fishing gear, and make use of the Northwestern Hawaiian Islands as a case study to disseminate the nature of the problem. It will divulge the latest available information on the nature and scope of the problem of derelict fishing gear in the Northwestern Hawaiian Islands, including an overview of the economic, social, and environmental impacts and what has been done to address these impacts.

Nature and Scope of the Problem

The challenging nature of handling derelict fishing gear is that it is a classic tragedy of the commons scenario, only exacerbated by the fact that it is largely invisible to the everyday citizen. Looking at the surface of the ocean, it would appear that the ocean was in fine shape. Most pollution, including this debris, are only visible underneath the surface. This causes most to perceive that there is no problem, and that they are not responsible for the creation of a problem if it did exist, since it is a large, vast, and removed common grounds. The reality is that derelict fishing gear is an expensive and deadly problem that needs a stronger world-wide action plan to be alleviated.

There are no precise estimates as to how much derelict fishing gear exists in the ocean, as it is a daunting and infeasible study to do with the current money and resources available. As mentioned previously, when extrapolating the information that is known, it is expected that about 640,000 tonnes of fishing gear are left in our global oceans annually (Macfadyen and Cappell, 2009). Of this, an estimated 52 tonnes of derelict fishing gear, or 8%, finds its way to the Hawaiian Islands annually (NOAA Marine Debris Program, 2015). This qualifies the Northwestern Hawaiian Islands as a ghost gear hot spot.

In a 1999 Hawaiian island reef removal study, the most common types of nets found off of the Hawaiian Islands were found to be trawl nets, gill nets, and drift nets (Donohue et al., 2001). Trawl nets, large nets dragged behind fishing vessels that scoop up the fish, accounted for approximately 88% of the volume of nets recovered. It is notable that though these types of nets were by far the most common fishing gear collected, very little trawl fishing is conducted off of Hawaii's coast, and all nets were attributable to fisheries from other Pacific Ocean regions. Gill nets are banned in Hawaii, but still often found due to other nets floating on currents and due to lack of enforcement. They can be drift nets, smaller cast nets, or set at the bottom, and have a range of mesh sizes designed to capture fish by their gills as they swim through (Breen, 1989). Though these made up a smaller percentage, they most often were identified as the gear that traveled the longest distance-- many high seas nets from the 1980's and '90s were found and attributed to countries of Asian origin (Donohue et al., 2001). Monofilament driftnets designed for the Russian far east economic zone were also recovered and identified. The remaining fishing gear types were fishing and maritime line, along with pots used to harvest crustaceans.

In this age, when derelict fishing gear enters the water, it is a relatively permanent addition unless collected through waste removal programs. While cultural and heritage fishing relied on fishing gear made of fibrous and biodegradable materials, today's fishing line is made of plastic. Derelict fishing gear is considered to be a plastic marine debris. These plastics are built to the highest strength and durability standards as technology advances. They are also designed increasingly to be undetectable in the water. The typical fishing net is made of a high tensile strength fiber, the same material used in bulletproof vests, which is 10 times stronger than steel. Long life material that lasts about 600 years in the ocean (World Animal Protection, 2014). And even when they do degrade, they break down to microplastics, which have a whole

range of additional complications. The durability conundrum is only exacerbated by the fact that the amount and size of fishing fleets and fishing gear are accelerating. Seventy-eight percent of ghost nets recovered off the coast of Hawaii had little to no fouling-- meaning they were of a recent make (Donohue et al., 2001).

Drivers Affecting Derelict Fishing Gear

In order to understand which solutions will be most successful, it is first important to understand not only where derelict fishing gear is located, and quantify it, but also to understand the reasons the gear is lost, abandoned, or discarded. As seen in Figure 1, the reasons these occur can be broken down to enforcement pressures, operational and economic pressures, spatial pressures, and environmental conditions. The vast majority of derelict fishing gear are lost because of operational and environmental conflicts (Macfadyen and Cappell, 2009). Though operational procedures and communications can be improved to reduce lost gear, there will always be some percentage of derelict fishing gear that is unavoidable and mainly attributable to weather events combined with environmental conditions. The most frequent environmental condition that causes gear loss is when nets snag on shallow and rough bottom and become unrecoverable.

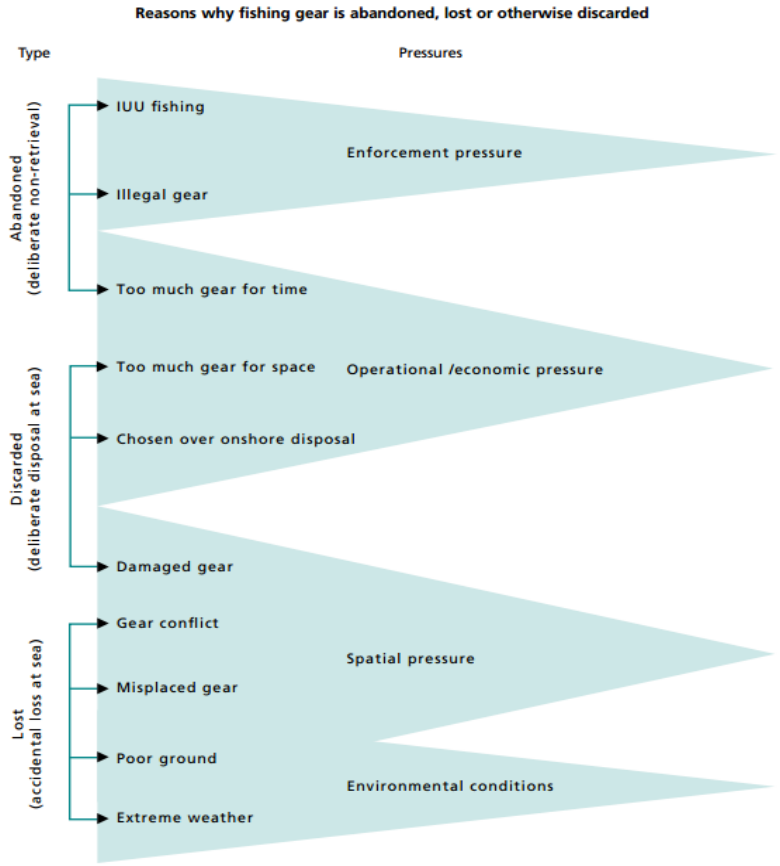


Figure 1- (Macfadyen and Cappell, 2009; Poseiden, 2008)

The amount of derelict gear attributable to abandoned or discarded actions is much more difficult to estimate, and the quantities of fishing gear associated with each action are unknown. One main reason that gear is dumped or failed to be retrieved is the lack of sufficient onshore receptacles. Many ports do not have facilities for disposing of damaged and used gear, and even ones that do oftentimes will charge a fee and will be more time consuming than dumping nets overboard. Gear that is purposefully dumped in this manner is often dumped on the return journey and not at the fishing grounds and other sites known to be lucrative. A similar economic driver for disposing of gear intentionally at sea is when there is too much gear aboard the ship to carry it home. Nets are worth less than their weight in fish stock, so may be thrown overboard to maximize economic profit. Certainly not all industries or vessels are known to practice this, but it has been observed at times.

Another driver affecting abandoned gear in the ocean is to avoid getting caught or penalized for intentional or unintentional illegal, unregulated, and unreported fishing (IUU). In the case that a fishing vessel has been using nets illegal for the area, such as monofilament gillnets, dumping gear overboard is a way to go undetected when returning with a fishing haul. In addition, unintentional gear loss may increase when participating in IUU fishing because of the tendency to fish without communication to other fishermen, which can result in gear entanglement and conflicts. These fishermen are also more likely to fish in poor weather, at night or other times they are less likely to be seen, resulting in a greater loss of gear (Macfadyen and Cappell, 2009).

Impacts and Effects

Derelict fishing gear is a multi-faceted issue that impacts economic, social, and environmental sectors. Due to the chain effect, not all impacts can be properly discussed in these pages, but below provides an overview of the most pressing impacts and stressors that derelict fishing gear causes.

Environmental

As nets float through the water column or catch along the bottom of the ocean, they entrap and entangle many marine organisms, often true bony fish species of the class Osteichthyes for which the nets were designed to trap (NOAA Marine Debris, 2015). These smaller kills can quickly attract predator species, who come to the nets to feed, and can often get trapped themselves. Even when the entangled species does not die, the gear will often drastically impede its ability to gather food and perform other essential tasks, and the animal will be unable to survive a full life expectancy. Another main cause of species mortality is when fishing gear is mistaken for food and is ingested by predator species. So far, scientific literature has documented that all sea turtle species, about half of marine mammals, and about a fifth of marine birds are affected by ghost nets (Laist, 1997; Donohue et al., 2001). As of a 1997 survey, an estimated 100,000 marine mammals die from entanglement or ingestion of derelict fishing gear (Laist, 1997). These number affected has likely increased within the last fifteen

years. A more recent estimate predicts that 136,000 pinnipeds and whales suffer from entanglement annually (World Animal Protection, 2014). This is particularly worrisome as pertains to threatened and endangered species. In Hawaii, species of particular concern include threatened and endangered species and the highly endangered Hawaiian monk seal. All of the Hawaiian monk seal's breeding grounds are located within the Northwestern Hawaiian Islands, causing it to suffer one of the highest mortality rates from derelict fishing gear of any organism (Donohue et al., 2001).

Another main environmental impact is the damage to habitats. When fishing gear reaches and settles on the bottom of the sea, it can often cause damages to habitat like coral reefs through breakage and smothering. They also degrade fragile habitats through the transport of disease and invasive species. The Northwestern Hawaiian Islands make up 69% of the United States' coral reefs and unfortunately, this is the ecosystem type most vulnerable to smothering and damage by ghost nets that have settled to the bottom (Donohue et al., 2001). Some recovered nets in this area have been found to have about 20% of the weight worth of broken and snagged coral fragments trapped in them (Blumenfeld, 2014).

Economic

Derelict fishing gear causes a range of economic impacts that prove to be much greater than the cost of operating programs to prevent and remove the gear. When gear is lost, there is a cost associated with the fishermen to get new gear. This cost is but a fraction of the cost in ecosystem services lost by damage from the derelict fishing gear. Another more significant cost to the fishing industry is the decrease in stock of economically valuable species that can be caught by fishermen. An estimated 90% of marine animals caught and killed in these nets are economically significant (commercial) species. This is about 5% of all global fishing efforts (Macfadyen and Cappell, 2009). A study off the coast of Washington state calculated that some derelict fishing gear can kill approximately $20,000 worth of commercial fish stock per net within a 10 year span (World Animal Protection, 2014). The cost to remove one net from the water is, on average, $2,000.

In a 2007 report by the United States National Marine Debris Monitoring Program, it was found that 17.7% of beach litter originates from the ocean. Approximately 12% of this waste is represented by fishing nets, lines, baskets, and pots (Sheavly, 2007). When beaches are filled with marine debris, it degrades the beauty of shorelines, which is turn can decrease the amount of tourism revenue retained by the state. It also represents a maintenance cost to clear fishing gear and other marine debris from the beach if tourism is to remain high. The loss of habitats additionally reduce the value of the area to tourists, since coral reefs are a main driver for tourism within the Hawaiian Islands.

Social

The safety and navigational hazards of derelict fishing gear are a concern, as they can result in injury or loss of human life. In more than one instance, derelict fishing gear has wrapped around a boat's propeller and navigational systems, putting crew and passengers at risk. In one extreme example in 1993, a Korean passenger ferry became entangled in a long fishing line offshore, eventually causing the boat to sink. This incident resulted in the loss of 292 people that were aboard (Cho, 2004). A Pacific-wide survey conducted by the United States Coast Guard in 1992 revealed that derelict fishing nets were considered one of the most hazardous drifting objects for boat navigation (Macfadyen and Cappell, 2009).

There is a potential, though undocumented risk for divers and swimmers when derelict fishing gear is located near coasts in shallow habitats, including coral reefs. There is, additionally, a social existence value of marine habitat that is lost when derelict fishing gear smothers habitat. The intrinsic and emotional value of healthy marine ecosystems is a well-documented benefit to humans. Derelict fishing gear can negatively impact these intrinsic benefits.

Current Actions

The negative impacts of derelict fishing gear were first formally recognized in the 1980's, when the Food and Agriculture Organization (FAO) addressed concerns with ghost fishing in the 16th Session of the FAO Committee on Fisheries in April 1985 (Smith, 2005). Since then, several updated issue reports have been release by the FAO, and the issue has garnered global recognition through the United National General Assembly and national recognition through NOAA's Marine Debris Program. In a 2004 resolution, The United Nations General Assembly called member states to action to collect data on and develop solutions for derelict fishing gear, with particular action requirements for the FAO, the International Maritime Organization (IMO), the United Nations Environment Programme (UNEP), and UNEP's Regional Seas Programme (RSP) (Macfadyen and Cappell, 2009).

A number of other international resolutions have been implement that touch upon or relate to ghost fishing. These resolutions or annexes to treaties are summarized in Table 1 below:

Table 1

Resolution / Annex	Organizer	Relevance
The IMO Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter	International Maritime Organization, 1972	Requires preventative action when evidence suggests that materials introduced into the ocean will cause harm, even when there is no conclusive proof of the impacts.

Annex V- International Convention for the Prevention of Pollution from Ships (MARPOL), Regulations for the Prevention of Pollution by Garbage from Ships	International Maritime Organization, 1973; amended 2013	Prohibits the throwing overboard of certain types of garbage from ships, outline the procedures and places. Call for fisheries managers to use fishing gear identification systems and encourages governments to consider developing technology for more effective fishing gear identification.
Article 18, Duties of the Flag State of the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea	United Nations, 1982	Requires the identification of fishing gear by marking them
The FAO Code of Conduct for Responsible Fisheries	Food and Agriculture Organization, 1995	Promotes that measures should be taken to minimize waste, discards, and catch by lost or abandoned gear, particularly when endangered species are involved
Resolution A/RES/59/25	United Nations General Assembly, 2004	Calls on stakeholders and relevant parties to take action to address the issue of lost or abandoned fishing gear and related marine debris, including through the collection of data on gear loss, economic costs to fisheries and other sectors, and the impact on marine ecosystems
Resolution A/RES/60/30 and 31	United Nations, 2006	Notes the lack of information and data on marine debris and invites the International Maritime Organization (IMO) to review annex V to the International Convention for the Prevention of Pollution from Ships of 1973 to assess its effectiveness in addressing sea-based sources of marine debris
Report from 57th Session of IMO's Marine Environment Protection Committee (MEPC)	International Maritime Organization, 2008	Discusses the need to apply record-keeping and gear-marking requirements for Annex V in association with fishing gear. Discusses the inadequacy of port fishing gear receptacles.

Adapted from information gathered in Macfadyen and Cappell, 2009

The United States has programs that tackle the derelict fishing gear problem on a national scale. During the period between 1996 and 2006, a multi-agency debris program was in force in the Northwestern Hawaiian Islands, led mostly by NOAA. All in all, the NOAA Pacific Islands Fisheries Science Center removed 511 metric tons of derelict fishing gear from the region, mostly in shallow water (NOAA Pacific Islands Fisheries Science Center, 2012). That is about the same weight as 3 adult blue whales. Since 2006, there have continued to be waste removal expeditions on an annual basis, but they are only executed at a rate that prevents new build-up. This means that the projects only prevent the worsening of derelict fishing gear impacts, not contribute to the betterment of gear that currently exists around the Hawaiian Islands. Expeditions are usually taken on NOAA's debris removal vessel, the *Oscar Elton Sette* with a crew that are mostly trained scientific divers (NOAA Pacific Islands Fisheries Science Center, 2012). It is a large and costly program to operate. Both the Regional Seas Programme and NOAA's Marine Debris Program have additional action plans under way, as called for by the UNGA. Appropriate outreach, research, and data collection are under way for marine debris as a broad topic, often with derelict fishing gear as a highlighted focus area. There is an effort to increase collaboration efforts and dissemination of best practices and data databases to begin to increase success towards tackling this problem.

Additionally, NOAA created a program in Hawaii called Nets to Energy in 2002 that has seen some measurable success. Nets to Energy provides receptacles at ports to make the disposal of gear easier for fishermen. The goal is to reduce the amount of nets at sea that are abandoned intentionally as a cost and time saving mechanism. The program is also intended to decrease net build-up in landfills. These nets then are transported to a facility that breaks down the nets and burns them, using the heat to create steam that drives turbines to create electricity for homes. It is a multi-agency program that was used as inspiration for a national program, Fishing for Energy, funded mostly by NOAA and the National Fish and Wildlife Administration (NFWA, 2014). Since 2008, 41 ports in 10 states have participated in a fishing gear collection initiative that then is processed in similar energy facilities. Together, these two programs have collected approximately 2,200 tonnes of unwanted fishing gear (NFWA, 2014). It is uncertain, however, the impact that such programs have on preventing derelict fishing gear from the ocean, or rather simply divert a waste stream that was going to the landfill.

Since derelict fishing gear pollution has garnered more attention, numerous non-profit organizations have been created that center around the issue. Ghost Fishing, Global Ghost Gear Initiative, Healthy Seas, and Bureo Skateboards are some of a few organizations whose mission focuses on the prevention or reduction of ghost nets in global oceans. They work primarily on solutions involving raising awareness, recovering tangled nets near shore, and building additional recycling programs. Other design ideas focus around marketing products using ghost nets, attempting to turn what is seen as trash now into a commodity.

Gaps and Recommendations

As seen in the previous section, a range of public and private initiatives exist at a range of local and international scales. These programs serve as a key step to reducing the impacts that ghost nets can have, especially in the Northwestern Hawaiian Islands. However, it is remarkable how little reliable, accurate, or comprehensive information that exists on this topic. In addition, no truly robust programs exist that have adequate strategic plans and resources to develop and initiate a coordinated and effective response (Macfadyen and Cappell, 2009). The best way to quantify gear lost is to design individual experiments and observer programs, but since this has not been a topic stressed in fisheries management, few reporting programs exist. Those that do often suffer from nonstandardized procedures, nonuniform use of units and terms, and poor experimental design (Macfadyen and Cappell, 2009). There is no clear information on volume of gear, location of gear, predicted movements, animal mortalities, economic costs, or the implications and extent of impacts. Small localized studies have been shown within this report, but even such numbers usually represent broad estimates and are not to be taken as precise and specific information (NOAA Marine Debris Program, 2015). Though there is a severe deficit of information, one key recommendation is that actions should not be put on hold until after clear information is disseminated. This is a time sensitive and pressing issue, and it is more important to begin acting now in conjunction with plans for additional impact assessments. Actions should then be revised to reflect updated information and data collection.

Although it is clear that the effects of derelict fishing gear are a known international transboundary concern, and that there have been numerous international resolutions touching upon fishing gear, no global coordination framework yet exists for monitoring and collaborating on ghost net solutions. There is a call for a robust global initiative and framework that would share intelligence, data, and best practices, agree on shared cross-boundary commitments and hold each other responsible, as well as direct attention and resources to global ghost net hotspots in a more effective way (NOAA Marine Debris Program, 2015). It is equally as important in developing new measures to incorporate a broad spectrum of stakeholders and engage in the best known practices for stakeholder engagement and management. Fisheries managers, states in hot spot zones, tourism sectors, and other pertinent players should be included more in the dialogue of collaborative measures.

Beyond the creation of a strong global action plan and coalition, recommendations fall under three broad categories: Prevention, Removal, and Education and Outreach. In order to prevent the buildup of more derelict fishing gear, there is a need for stronger fisherman accountability through increased measures of enforcement and more stringent systems of clearly marking gear. Economic incentive programs to make it worth fishermen while to collect gear and return or recycle it instead of abandoning it should be put in place (Macfadyen and Cappell, 2009). There should also be efforts at the supply chain level to create alternate types of gear with reduced environmental impact. Focus should not be on increasing strength and invisibility of nets, but rather turned to creating nets that are biodegradable. Additional innovations could reduce snags to prevent loss of gear. Measures will need to be taken to

ensure eco-efficient nets are widely used and competitive in a market environment. Continuing to increase the amount of port receptacles to throw away old gear will also play an important role in the prevention stage. Lastly, improvement of severe weather warning systems would decrease the amount of unintentionally lost gear by giving fishermen more time to prepare for incoming storms.

The R~~r~~emoval category in the recommendations is about continuing to remove derelict fishing gear that is already present in marine environments. Currently, databases are being built that aid in disseminating where ghost nets are located, so that removal projects can be planned. There is a need for additional sources of funding to make such projects a reality, however. There is also a need for the development and execution of stronger systems for locating, reporting, and mapping ghost nets. Utilizing more advanced spatial modeling and remote systems programs will enhance these initiatives. Finally, existing organizations have been successful at Outreach and Education about derelict fishing gear; however, there is a need to redouble efforts to raise awareness of such issues in order to increase public participation and potential funding sources through donations. Involving fisheries more in this process, and increasing messaging that stresses the economic and social impacts alongside environmental impacts should help to craft a more effective message.

Conclusion

All in all, derelict fishing gear pollution is a form of ocean pollution that is creating negative impacts at a global scale. Some research and recognition have been established within the last thirty years, but to truly eradicate the most harmful environmental, economic, and social impacts, efforts on an international and regional level need to be increased. Little exact estimates are known about the volume and impacts that derelict fishing gear has, but enough is known to see tangible evidence of species mortality, habitat destruction, economic hardships, decrease of fish stocks and more. Gear concentrates within ocean convergence zones, especially in the North Pacific Subtropical Convergence Zone at the Northwestern Hawaiian Islands. In the Northwestern Hawaiian Islands, derelict fishing gear snags and breaks species-rich coral reef habitats, and increases mortality of endangered species such as sea turtles and monk seals. The United Nations, Food and Agriculture Organization, International Maritime Organization, and National Oceanic and Atmospheric Administration all have recognized these impacts, and have put limited programs in place to handle the problem. However, additional measures in the prevention, removal, education, and outreach of derelict fishing gear is needed that stress the importance to act now. These measures should be implemented at multiple levels and should support an increase in international coordination.

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