Feasibility of Repurposing Fishing Gear in Nova Scotia

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Executive Summary

This report provides a characterization of the waste profile of discarded fishing equipment in Nova Scotia, as well as an analysis of fishers' attitudes towards a potential recycling or reuse program for this gear. Additionally, this report analyzes potential solutions to this problem as well as the attitudes of fishing captains in the province towards recycling.

Primary source inquiries in the form of surveys, questionnaires and personal interviews were the main methods used to gather information. The sources contacted to gather this information included Nova Scotia harbour masters, fishing professional associations, public and private waste management experts, relevant government organizations, Nova Scotia small craft captains and fishing gear manufacturers and retailers.

The results of the research indicate that the profile of retired fishing gear in Nova Scotia is not suitable for the approach taken by existing programs, specifically the net recycling program present at Steveston Harbour in British Columbia. Instead of the large fin fish nets found in abundance at Steveston, the most common items being discarded in Nova Scotia are rope and wire framed lobster traps. These are typically disposed of by landfilling, burning or abandonment at sea. Additionally, there is a strong presence of reselling and community level reuse programs. In total, Nova Scotian fishers dispose of over 5,000 tonnes of fishing equipment each year, which is the equivalent of 3,000 cars annually.

Nova Scotia captains do believe that gear should be recycled, but their attitudes and behaviour are not synonymous. The largest barrier to captains recycling their discarded gear is the fact there is currently no system for doing so in the province. Fishers also state that the barriers to participation in any recycling or reuse program would be costs, distance and the time of year when it operated.

We conclude that, due to the large quantity of material being landfilled or illegally discarded, and the apparent willingness of captains in the province, there is sufficient justification as to the need and likely success of a recycling program, if the aforementioned barriers to participation can be addressed.

We find that the current system for measuring the quantity of gear that is disposed is inadequate. Our first recommendation is that a mechanism for captains to report their annual gear disposal quantities be put in place. Additionally, an education program highlighting the negative environmental, economic and health-related impacts of burning, landfilling and abandoning gear at sea should be undertaken. The final recommendation is for the implementation of a pilot program to test the feasibility of the different aspects of a solution, including fisher participation, collection and consolidation methods, and materials processing.

The limitations of the paper are primarily related to limited and possibly unreliable data. Most of the information we based our findings off of were the personal experiences of industry participants. It is possible that respondents misrepresented their experiences to avoid judgement or punitive action, or that respondents did not accurately remember their past practices and actions.

1. Project Goals

The goal of this project is to identify and characterize the social, environmental and economic challenges created by discarded fishing equipment. With a better understanding of the problem, we can then determine the need and feasibility of a program to recycle or reuse these materials. We also explore what the structure of a potential program could look like.

2. Characterization of the Problem

The primary problem with equipment being retired and discarded by the commercial fishing industry in Nova Scotia is that there is no unified program for recycling or reusing this material. Because of this, fishers are forced to discard their fishing equipment by methods that have negative environmental impacts. We have categorized disposal methods into three types: high impact, moderate impact and low impact. High impact includes illegal disposal methods such as abandonment at sea and burning, which pose immediate and serious risks to the environment. Moderate impact refers to landfills, which contain the material, but still don't utilize the material for anything productive. Finally, low impact refers to reuse or recycling efforts, which are preferable. Our research has determined that the three most common high and moderate impact methods of disposal for fishing equipment are landfilling, abandonment and burning. There are numerous small-scale projects and programs that result in these materials being recycled or reused in isolated communities. However, these projects rely on private arrangements between individuals, and do not possess the infrastructure or logistics to handle the capacity generated by the province as a whole.

In addition to there being no unified system for recycling or reusing this material, the tools that would be needed to develop such a system are not present in the province. Currently, there is no method for recording the disposal of retired fishing equipment. Neither the Department of Fisheries and Oceans ("DFO") nor dedicated waste disposal facilities measure how much material is discarded annually, or where this material is discarded.

This report focuses primarily on fishing performed out of small craft harbours because the example of gear recycling that inspired this project was developed at a small craft harbour, and because wild fish harvesting from small craft harbours results in more landed fish than aquaculture (DFO Annual Statistics Report, 2014; DFA Aquaculture Production and Sales Report 2014).

2.1. Current High and Moderate Impact Disposal Methods

2.1.1. Landfilling

There is abundant evidence landfills pose negative impacts to the environment, as well as a loss of resources. They result in landfill gases, leachate, odours, ground water and air pollution and global warming (Environmental Impacts of Solid Waste Landfilling, 1995). From a regulatory perspective, fishing gear should be landfilled in Nova Scotia, despite the fact the province has a waste diversion goal of 300 kg per person per year (Nova Scotia Environment, 2015). Fishing gear such as lobster traps and crab pots can be especially problematic when they end up in landfills as their structure results in a poor mass to volume ratio. Finally, many of the types of gear from the fishing industry have the potential to be recycled, which means, if this gear is landfilled, valuable resources are wasted and not re-circulated into the economy. Despite these

problems, landfilling is still considered a better alternative to burning and abandonment, which is why we consider it a moderate impact disposal method.

2.1.2. Abandonment at Sea

Fishing gear lost or abandoned at sea can pose a number of risks to the environment, the provincial economy and human health, and for these reasons is considered a high impact disposal method. Perhaps the most hidden impact is ghost fishing, which refers to the phenomenon of gear continuing to catch and kill marine species after it is abandoned or lost by a vessel. Species that are killed this way are not limited to commercially targeted species, and can include turtles (Carr, 1987; Meager and Limpus, 2012), seabirds (Good *et al*., 2009; Piatt and Nettleship, 1987), whales (Volgenau, Kraus, and Lien, 1995; Meager, Winter, Biddle, and Limpus, 2012), and seals (Boland and Donohue, 2003; Page *et al.*, 2004). Ghost fishing can also undermine the efficacy of fish stock conservation policies because fish that are caught and killed this way are not accounted for when determining the health of fish populations. This can result in higher than optimal fishing quotas which can lead to notable decreases in local populations (Punt *et al.,* 2016, Coggins *et al*., 2007).

Another phenomenon that contributes to high catch and kill quantities associated with ghost fishing is rebaiting. Rebaiting occurs when a marine animal becomes trapped and is killed by a piece of gear. The decaying animal releases scents into the water and acts as bait that attracts other species to the gear which results in further ghost fishing and further rebaiting (Gilman *et al*., 2013; Personal communication, North Fundy Fishers Association, 2016).

Another way in which gear can be harmful to marine environments is through habitat destruction. Gear that is dragged along the bottom by strong currents can damage marine plant life and reefs which serve as a habitat for numerous marine species (Rose *et al*., 2000; Donohue *et al.* 2001; FAO, 2010).

Abandoned or lost gear can also reduce the population of commercially fishable species, which can impact the success of fishing efforts in the province. It is estimated that nearly 90% of all animals killed by ghost fishing are from commercial species (Al-Masroori, Al-Oufi, McIlwain, and McLean, 2004). This reduces the profit margins of the fishing industry. A study has estimated that approximately 250 million USD worth of commercially viable lobsters are killed annually by ghost fishing (UNEP, 2009). Another study from Japan determined that roughly .3% of the value of the fishery industry in that country was spent on repairing fishing vessels that had become fouled in fishing gear. Gear travelling through bodies of water can also snag on equipment that is still in use. This can cause the in-use gear to become too entangled to retrieve, or cause it to be lost all together (Personal communication, North Fundy Fishers Association, 2016).

Using the .3% value from the Japanese study, the Asian-Pacific Economic Cooperation estimated that the total direct costs incurred by their 21 member countries due to lost or abandoned gear was 1.265 billion USD (Mcilgorn, Campbell and Rule, 2011). This only accounts for costs directly associated with fishing equipment such as damage to boats and in-use gear, and does not account for reduced fish populations from ghost fishing, or reduced tourism levels from unsightly beaches.

Discarded fishing gear can also harm the tourism industry. Tourism is often highly dependent on the visual appeal of destinations. If gear washes up on a beaches and coastlines, it can cause displeasure among tourists who may choose to vacation elsewhere. It is estimated that the state

of New York loses between 950 million and 2 billion USD annually from the tourism industry due to marine waste. The nation of Peru spends 2.5 million USD a year cleaning up marine waste from its shorelines (National Research Council, 2008).

Fishing gear illegally dumped on land can also create high indirect costs. A significant attraction for tourists in Nova Scotia is our harbours, and it is reasonable to believe that if these harbours are littered with discarded fishing equipment that tourists could be less inclined to visit these locations.

2.1.3. Burning

Waste burning has been banned in Nova Scotia for two decades for environmental and public health concerns, and we consider it a high impact disposal method. In this context we are specifically speaking about waste burning that is not conducted for the purpose of energy production. Burning used fishing equipment eliminates any possibility of its recycling or reuse for a more productive purpose. Additionally, burning discarded fishing equipment – much of which is plastic – results in emissions that both contribute to greenhouse gas build up in the atmosphere and can be toxic to humans. For example, burning polyethylene, which is a common component in netting and ropes, can lead to the release of benzene which has been proven to be carcinogenic (Saskatchewan Ministry of Environment, n.d.).

2.2. Three Aspects of a Gear Disposal Profile

To characterize the problem of waste fishing gear in the province, we first determined what kind of gear was being used by fishers, and what material this gear was made out of. This would help us better understand what risks the gear would pose in the ocean, and how long those risks might persist. It would also provide insight into the possible methods that might be available to fishers for disposing of this gear. Finally, this initial characterization would help us narrow our search parameters when we began looking for potential solutions for discarded gear. Table 1 summarizes the types of fishing gear used in each of Nova Scotia's seven most significant fisheries.

Table 1. List of primary and secondary gear types used by Nova Scotia's most significant commercial fisheries.

Fishery	Lobster	Herring	Scallops	Crab	Haddock	Hake	Red Fish
Primary Gear Type	Wire Frame Traps	Purse Seines	Off Shore Rakes	Conical Crab Traps	Bottom Trawl Nets	Bottom Trawl Nets	Bottom Trawl Nets
Secondary Gear Type	Wood Frame Traps	Gillnets	In Shore Rakes		Long Line		

Table 2 summarizes the major material components making up each gear type. The gear is a complicated mix of steel, nylon, plastics (polyethylene and polypropylene), wood, cement and rubber.

Table 2. Major material components of Nova Scotian fishing gear.

Equipment	Materials
Wire Lobster Trap	Vinyl covered steel; Nylon webbing; Cement; Rubber (sometimes)
Wooden Lobster Trap	Untreated wood; Polyethylene side netting; Cement; Nylon webbing
In-Shore Scallop Rake	Steel frame; Steel chain
Offshore Scallop Rake	Steel frame; Steel chain; Netting (unknown material)
Purse Seine	Tarred nylon netting; Lead line; Floats; Steel cable
Gill Net	Polyethylene monofilament netting; Floats; Weights; Lead line
Crab Trap	Steel frame; Polyethylene netting; Plastic funnel
Long Line	Polypropylene / monofilament main line; Polypropylene / nylon branch line; Weights; Steel swivels and hooks
Bottom Trawl	Polyethylene netting; Steel doors; Polypropylene line/steel cable; Weights/weighted rollers; Floats

The second aspect of discarded fishing gear we needed to understand was where it was ending up after disposal. This involved determining how and where fishers were discarding their gear after it had outlived its usefulness and then, if it was transported from the original disposal location, either by natural or artificial systems, where it was ultimately being deposited.

Finally, we needed to understand in what quantities these different types of gear were being disposed because some recycling and reuse options have upper and lower limits on what type and quantity of gear they can accept.

2.3. Industry Participant Profile

Any characterization would be incomplete without having some level of understanding of the population most directly connected with the problem, especially since this is the group that a potential reuse or recycling program would have to be designed for. We needed to understand what value fishers place on the health of the ocean environment, and whether they understand or believe that waste fishing gear can have negative repercussions on the environment and their livelihoods. We also needed to identify what barriers might prevent a fisher from participating in a reuse or recycling program.

3. Research Methods

3.1. Gear Type/Material

We gathered information on the type of equipment and its material make-up from several sources. The first source was Clean Foundation staff members who had experience working with the small craft commercial fishing industry from the Ship-to-Shore program. The Ship-to-Shore program works with fishers and harbour masters in small craft harbours to clean up harbours and give captains the tools to bring their waste back to shore and ensure it is disposed of properly. We also consulted with Joel Baziuk, the harbour master of Steveston Harbour,

British Columbia, who is currently operating a recycling program for the nets generated at his harbour.

The next sources we consulted were harbour masters from core fishing harbours in the province. These individuals were interviewed about the types of gear used at their harbours. From these conversations, we were able to create a profile of the type of gear utilized in the Nova Scotia small craft harbour commercial fishing industry.

We also contacted Rainbow Net Rigging, a gear manufacturing company that services harbours across Nova Scotia. Through phone conversations and a facility visit, we determined the prevalence and composition of gear for the most intensely harvested fisheries. We also learned about the benefits of each kind of material, along with its tolerances and life spans.

Finally, we contacted an individual who operated a facility that recycled retired fishing equipment to test our profile. He confirmed what we had heard from our previous sources.

3.2. Gear Disposal Methods

Similar sources were used to determine how retired gear was being disposed of. The first source we used was online resources, including the DFO website, as well as a search for academic publications on the subject. However, we were unable to locate any meaningful information from these sources.

Next we spoke with Clean employees that had worked with the Ship-to-Shore program, who identified a number of potential ways in which gear was disposed. However, these contacts were not able to provide reliable information as to which methods were more common than others.

We also inquired with harbour masters during the previously mentioned interviews. They confirmed the information from the Clean staff, and provided more specific information on how different types of gear were disposed. It is possible that some of these harbour masters did not accurately report illegal methods of disposal out of fear of incriminating their constituents.

Another resource we utilized to find this information was municipal solid waste management representatives. These individuals either provided us with the information personally, or put us in contact with foremen at waste facilities that served their municipalities. From these resources, we gained a more accurate picture of what happened to gear that was disposed of at dedicated waste facilities.

3.3. Quantity of Gear Disposed

The most difficult information to ascertain was the quantities of each type of gear that was being disposed, primarily because the lack of recorded information. The majority of data collected about abandoned or lost equipment focused on the gear once it had already entered ocean. There were plenty of academic sources that provided specific values for how much material was removed from different regions around the globe, and there were projects that detailed ways to measure how much gear was currently in the water in a specific region, but there was no research on gear that was being disposed of on land.

We focused our research on those fisheries that resulted in the highest number of landed fish. DFO data on provincial landings by species indicated that the most intensely harvested species (in descending order) were: lobster, crab, herring, scallops, hake, haddock and red fish. To

ensure that these fisheries combined did in fact make up majority of the fish harvesting effort in the province, we contacted representatives from the Maritime and Gulf Region DFO offices, as well as an employee from the provincial Department of Fisheries and Aquaculture, and representatives from professional associations in the fishing industry.

Below is a description of the methods used to identify how much of each type of gear is disposed of by the fishing industry in the province annually.

3.3.1. Lobster Traps

The current estimate of lobster traps being disposed annually is inferred from information from DFO on the total number of traps permitted in the province. This information was confirmed by speaking with different harvester associations. Harbour masters who currently work, or who have worked as lobster fishers, provided information on the percentage of traps that are typically lost at sea and the percentage that are replaced annually. They also provided information relating to the percentage of wooden traps versus wire traps. From these two values, we inferred the number of wooden and wire framed traps that are typically replaced each year.

3.3.2. Herring Seine Nets

To gather data on the number of seine nets discarded we spoke with Southwest Seiners, the company that repairs seine nets in the province. An affiliate with the Ground Fish Allocation Council gave us information that allowed us to identify the exact number of vessels currently holding seine net licences that were actively fishing, and the approximate number of nets each vessel owned and fished with each season. Southwest Seiners, in turn, provided specific values on the average amount of netting required for each net replacement each year.

3.3.3. Herring Gill Nets

Data from herring harvester associations allowed us to estimate the number of vessels engaged in the herring gill net fishery. We were unable to use license numbers to determine the amount of nets disposed of annually because only a portion of license holders were actively engaged in the fishery at any one time. From details given to us by harvester associations, which were supported by information from harbour masters, we estimated the number of nets that a vessel was likely to possess. From the same sources, we were able to determine the size of these nets.

However, we were not able to identify exactly how many gill nets were discarded annually because, unlike with the seine fishery:

1. gill net fishing vessels possess widely varying net numbers;
2. gill nets are relatively inexpensive, wear out at different rates, and are often discarded rather than repaired, making their rate of replacement hard to predict; and
3. there is no single organization that retains information on the number of gill nets discarded each year.

Instead, the head of the Atlantic Herring Co-op provided an estimate for what he believed was the turnover rate for gill nets in the province. He was also able to provide information about the size of a typical gill net. This information was supported by information from a representative

from the Department of Fisheries and Aquaculture and Jack Mitchel of Rainbow Net Rigging. With these four variables, we were able to infer the quantity of nets lost annually.

3.3.4. Crab Traps

From association heads and representatives from the Gulf Region DFO office, we were able to identify the number of licenses for the high concentration crab fishing areas. Some of the areas below Cape Breton were not included because the representatives from DFO informed us that there was not a significant quantity of fishing happening in these areas.

From these same sources, we were also able to determine the number of traps permitted per license in each area. For some areas this information is very reliable but in other regions, specifically region 18, there is uncertainty because not all licenses are utilized. The estimated value we utilized was generated from conservative estimates based on actual trap usage provided by Gulf Region DFO representatives. With the number of licenses in each region, as well as the number of traps permitted per license, we were able to calculate the number of traps utilized in each region, and then add these values to arrive at a total value.

Using information from a primary source, the Area 19 Crab Fisherman's Association, the lifespan of crab pots was determined. The pots have two main components: the steel frame, and the polyethylene mesh. The mesh is replaced every seven years, and the frame will be discarded every 20 years on average.

Jack Mitchel of Rainbow Net Rigging provided the weight of each component of the trap. By multiplying these values together, and dividing by the annual replacement rate of each component, we were able to arrive at an annual disposal weight for each type of material.

3.3.5. Bottom Trawls

We gathered the number of licenses in Nova Scotia for bottom trawls from DFO representatives, and confirmed this value with a representative from the Groundfish Enterprises Allocation Council. From this same representative, we determined how many nets each vessel owned per licence, and how many vessels were likely actively utilizing their licenses. This gave us the number of trawls being used in the province.

Next, we contacted a company that repairs and replaces the netting in bottom trawls. From a company representative, we determined an estimate as to how much material was disposed from each net. This value is an estimate because when these nets begin to wear, the holes of the net stretch, and can no longer be used for the specific fishery it was designed for, but they might be used for fishing a larger fish species. Other times, sections will be repaired.

3.3.6. Rope

From various sources, including industry experts, industry participants, and fishing gear suppliers and manufacturers, we received values for their estimate of how much rope is disposed and how much rope was purchased by individual captains. We took an average of these values.

Next, we used DFO data from 2015 to determine how many vessels were actively fishing. We multiplied this value by the estimates for discarded or purchased rope. This gave us a very rough estimate for the quantity of rope discarded.

3.4. Research on Industry Participant Attitudes

While there were no relevant academic sources pertaining to the motivations of fishers regarding recycling, there was a study on the likelihood of farmers in Nova Scotia to participate in a plastics recycling program. This study was conducted by mailing a survey to farmers that asked them questions about the kind of waste they generated, how it was currently being disposed, and what might prevent them participating in a recycling program for this equipment. Farming has much in common with fishing as both farmers and captains are entrepreneurs in harvesting-based industries. Additionally, both fields are predominated by white males (Muise, 2016). We used the conclusions from the farm study to predict the attitudes of captains towards a recycling or reuse program.

4. Results of Gear Characterization

Different fisheries are popular in different regions, and different species are often harvested with different types of equipment. Even within a fishery, there are different techniques and equipment used, often based on the region. Below is a characterization of each fishery, their regions, a summary of the equipment and materials used in each fishery, their quantities, expected lifespan and annual disposal amounts.

4.1. Fisheries

4.1.1. Lobster

Lobster is the largest fishery in Nova Scotia, and the most commercially successful (DFO Annual Statistics Report, 2014). The coast of Nova Scotia is divided into different areas referred to as Lobster Fishing Areas (“LFAs”) and the number of traps per licence and the number of licences permitted varies between each LFA. Because of the high value of lobster and the high cost of a lobster licence, it is unlikely that a lobster licence holder will be inactive during a season.

Lobster fishing is performed exclusively with lobster traps, which come in wire frame and wooden framed varieties. Within each of these types there is a significant amount of design variation, but they typically use the same materials. About 70-75% of traps used in Nova Scotia are wire framed (Figure 1a). These traps are lighter, and typically last longer than wooden traps. They are constructed of vinyl covered steel grating, with nylon mesh funnels inside that allow lobsters to enter but not exit. These will have cement, or sometimes heavy rocks, attached to the bottom that help keep the traps anchored to the seafloor. Sometimes these traps have small rubber components on the edges that protect the joints from the environment and prevent traps from coming apart under water. Some manufacturers sell premade wire framed traps, some sell kits for fishers to hand-make traps themselves, and some individuals have the equipment at their homes to make the traps based on their own design. There are approximately 3,800 lobster licenses given out each year with an average of 275 traps used per license, equalling 1,150,000 traps used each year. If nearly 140,000 traps are discarded annually and 71% of those traps are wire framed, weighing approximately 35 kg, we estimate that 100,000 wire framed traps, or 3,400,000 kg of wire traps are disposed of annually.


Fig. 1a. Typical wire-framed lobster trap (Wade's Wire Traps)
Fig. 1b. Typical wood framed lobster trap (Usedboatsforyou.com)

Wooden frame traps have a mesh component that makes up part of the side walls of the traps and also contain the same nylon mesh funnels as wire frame traps (Figure 1b). The frames are made out of untreated hardwood, and typically only last a maximum of five years before they are eaten away by marine life and/or destroyed by wear and tear on the bottom. Wooden traps are typically used in colder, deeper waters as they are more likely to be destroyed by strong currents and severe weather in shallow waters. Additionally, according to numerous captains we spoke with, in colder waters sea lice will eat the bait out of the bait bags too quickly. However they believe that with wooden traps, the scent of the bait lingers with the wood, which allows them to continue to attract lobsters. Wooden traps are also supplied by a combination of individuals making their own traps and commercial suppliers. We estimate that approximately 40,000 wooden frame traps are disposed of annually with a weight range of 14-23 kg per trap depending on the variety of wood used. This comes to a total of 560,000-920,000 kg.

4.1.2. Herring

Herring are fished with either purse seines nets or gill nets. Herring licences do not stipulate the amount of gear that a fisher is allowed to use in a season. Also, this is a fishery that has experienced a steep decrease in the size of the stock and so only a small fraction – roughly one-third of licence holders – actually fish this species.

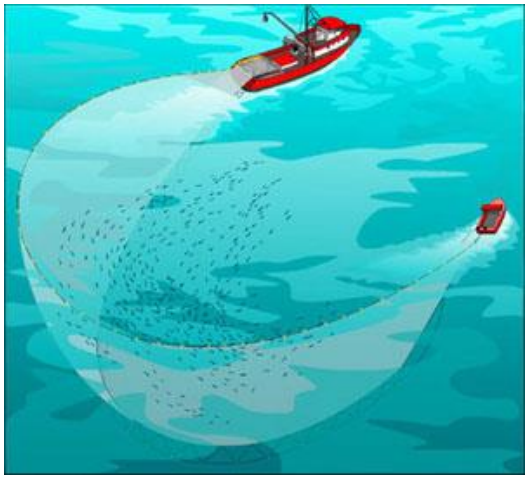

Figure 2. Depiction of the use of a seine net to capture a school of fish (AtlanticHerring.com)

Seines are typically made out of tarred nylon netting with weighted lead line on the bottom to sink the net, and floats on the top of the net to keep it upright in the water (Figure 2). The net is very large, typically 550 meters long by 60 meters deep. Currently there are about 11 boats using seine nets in Nova Scotia, with 49 available licenses. Typically, each boat will only have one net. Instead of being disposed, these nets are often repaired annually and damaged sections are replaced. Seine fishing accounts for approximately 85% of herring caught in the province, and the total weight disposed is roughly 7,500 kg.

Figure 3. Monofilament polyethylene netting used in a gill net (SportsWorld.com).

More than 300 licences are held by Nova Scotia captains for herring gill netting, but only 120 vessels actively fish for this species. Gill nets are comprised of a clear polyethylene monofilament netting, with lead line on the bottom and floats on the top to keep the nets oriented correctly in the water (Figure 3).

Due to the lightness of the materials and predation of trapped fish, these nets are damaged often and see about 50% turn over annually. Best estimates are that each boat engaged in this fishery possesses four to five gill nets that are about 18 meters long by 20 meters deep. The total weight of gill nets disposed annually is estimated to be 900 kg.

4.1.3. Crab

Crab is exclusively fished with conical crab traps (Figure 5). These traps are comprised of a steel frame with polyethylene netting stretched over the frame to allow crabs to climb into the trap and a hard plastic top that funnels the crabs into the trap and prevents them escaping. The fishery works by a combination of quotas and trap limitations. As with lobsters, the coast is broken up into different crab fishing areas that allow a limited number of licences, and have set numbers of traps permitted per licence. The number of licenses allowed in each region varies greatly and information was not gathered for all CFAs due to low rate of fishing below Cape Breton. Using the numbers from the information collected from four of nine crab fishing areas, there are approximately 2,300 traps used annually, with an estimated disposal rate of 4%, 92 traps are disposed of annually. The total weight of the steel component disposed from crab traps annually is roughly 4,000 kg, whereas the mesh component disposed annually is around 1,300 kg.

Figure 5. Typical crab pot (Winger and Walsh).

4.1.4. Scallops

Scallops are harvested with scallop rakes, which are steel dredges with a chain net that are dragged across the bottom of the sea floor that collect scallops in a mesh netting that has individual bags. Scallop fishing is divided into inshore and offshore harvesting. Inshore harvesting is performed with smaller rakes that do not contain any mesh (Figure 6). Offshore vessels use larger rakes that have a small mesh component (Figure 7). We gathered limited data on specific quantity, sizes and life spans of scallop rakes because the rakes are almost all steel, and the steel, which is repaired more than disposed will already be recycled when dropped off at locations.

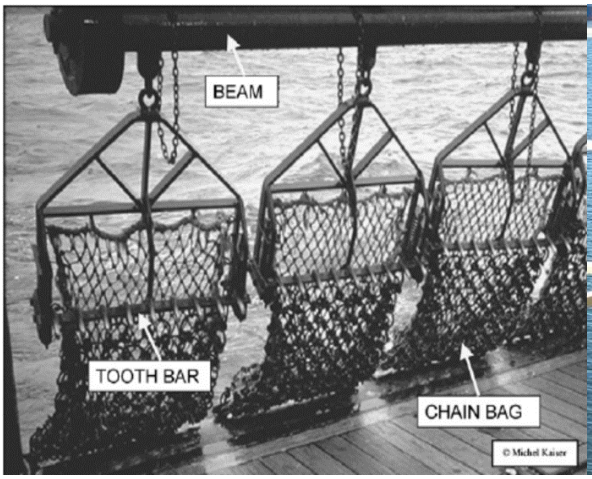

Figure 6a. Inshore scallop rake

6b. Offshore scallop rake (The Daily Catch)

4.1.5. Haddock

The remaining commercially fished species - haddock, hake and red fish – are ground fish, found near the seafloor. The haddock fishery is limited by quotas, so licence numbers alone do not provide us with the quantity of equipment. Haddock in Nova Scotia is fished with a combination of bottom trawls and longline fishing.

Bottom trawls are large nets comprised of polyethylene with steel spreaders that open the net as a boat pulls it across the bottom. These nets have heavy weights on the bottom lip that roll across the seafloor and floats near the top to keep the net open and upright (Figure 8). The best estimate for the total quantity of bottom trawl netting ending up in landfills is approximately 9,000 kg.

Figure 7. Depiction of the use of a bottom trawl net for fishing.

The other type of gear used for catching haddock is baited long line. Long lines are comprised of long main lines made out of polypropylene or monofilament polyethylene with numerous branch lines made out of nylon or polypropylene that hang off the main (Figure 9). These are connected to the main line with steel swivels, and are the branch lines terminate in a baited steel hook. These are sunk to the bottom where haddock swim with weights. Rope is utilized in all forms of fishing, not just longline fishing. It is estimated that the total quantity of rope disposed by the fishing industry annually is approximately 1,200,000 kg.

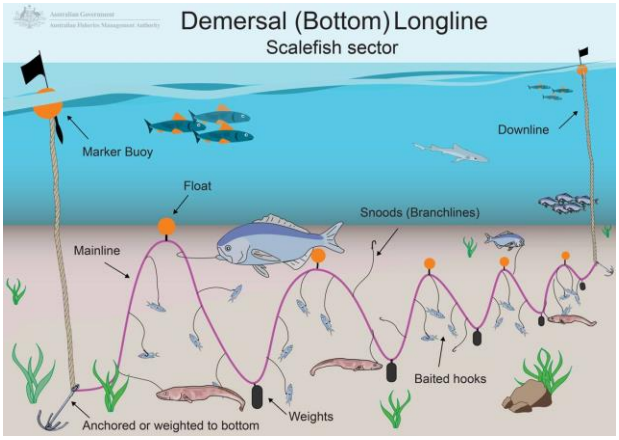

Figure 8. Baited long line being used to catch ground fish (Australian Fisheries Management Authority)

4.1.6. Silver Hake

Silver hake are fished exclusively with bottom trawls in Nova Scotia. These trawls are constructed in the same way as trawls used to catch haddock, and their weight was included in the weight listed for haddock.

4.1.7. Red Fish

Red fish are fished in Nova Scotia exclusively with bottom trawls, similar to haddock. This equipment is constructed out of the same materials as those used for haddock, and their weight was included in the weight listed for haddock.

4.2. Gear Quantity

The quantity of each type of gear is given here in Table 3, and a more detailed breakdown of materials can be found in Table 2.

Table 3. Total weight of each type of gear discarded annually in the province. This only includes the gear types that we considered prevalent enough to measure. Due to the highly infrequent nature of scallop rake disposal, and the fact that they are recycled as scrap metal, they were not counted. Crab traps are broken down into their component parts as the different materials have different lifespans. The weight of wire traps is assumed to be 34 kg, (Wade's Wire Traps), and wooden traps weigh between 14-23 kg depending on the variety of wood used in construction (Sea Coast Fishing Supplies Ltd.). These weights do not include the weight of the ballast.

Table 3. Summary of total weight of gear type

Gear	Estimated Annual Disposal Quantity
Wire Frame Traps	98,0000 Traps, weighing 3,400,000 kg
Wooden Frame Traps	40,000 Traps, weighing 560,000-920,000 kg
Scallop Rakes	Unknown
Crap Traps Steel Component	3,900 kg
Crab Traps Mesh Component	1,300 kg
Herring Seine Netting	7,500 kg
Herring Gillnet	900 kg
Bottom Trawl Netting	8,900 kg
Rope	1,150,000 kg

The total annual estimated weight of discarded fishing gear is therefore between 5,100 and 5,500 tonnes per year. This is equal to the weight of 3,000 cars per year.

4.3 Fisher Attitudes

In a meta-analysis of studies related to the psychology of recycling and the role of effort as a moderator between attitudes and behaviours, Schultz and Oskamp (1996) found that that there is a connection between attitudes related to environmentalism and willingness to participate in a recycling program and that an incentive for participating in a recycling program weakened the negative relationship between effort to recycle and participation. They also found that the link between environmental concern and willingness to participate is weakened if there is less effort required on behalf of the individuals participating in the program.

5. Attitudes and Gear Disposal Practices

In addition to surveying industry experts and individuals from the waste management field on gear characterization, we also interviewed fishing captains, over the phone to determine the attitudes fishers may have toward a recycling program using fishing gear. In order to ensure a high participation rate, we kept the questions brief. The full questionnaire can be found in the appendix.

Because the questionnaire respondents were not randomly sampled and the questions were open ended we cannot make inferences from our results to the larger population of fishers in Nova Scotia. However, the results did reveal several trends.

5.1. Attitudes Do Not Match Behavior in Terms of Disposal Methods

We first asked captains if they believed that recycling/reusing their retired fishing gear was an important objective. There was a strong sentiment that gear should be recycled in an environmentally friendly way. However, reported practice didn't match professed attitudes in that many respondents indicated that gear was disposed of using high and moderate impact methods.

We next asked how captains actually disposed of their retired fishing equipment, and if they were satisfied with that method. The four most common methods of disposal cited by captains were landfilling, resale, disposal in a wharf dumpster and repurposing. We have also included a section on the illegal methods mentioned as it is likely that respondents underreported illegal behaviours. Some captains viewed convenience as the most important factor in determining how they will dispose of their gear, while others are very conscious of the potential environmental damage their gear can cause. Additionally, a number of captains who believed their actions were environmentally responsible were unaware of the true consequences of their actions.

The third question asked if there were any barriers that might prevent the captains from participating in a recycling/reuse program, and the last question asked captains who should be responsible for any costs related to this program.

5.1.1. Landfilling

Ropes and nets ending up at landfills are typically buried with other waste. One landfill we spoke with, the Barrington construction and demolition ("C&D") landfill, set aside fishing nets when they found them and gave them away to trucks as truck bed covers. Lobster traps are more complicated, and from speaking with industry experts in the solid waste field we noted a high degree of variability between the ways different facilities interacted with lobster traps. While the vinyl covered steel can be recycled with relative ease, the non-steel components must be separated from the trap first which can be time and labor intensive.

Different landfills have different policies regarding lobster traps, which makes formulating a unified province-wide program more difficult. Some landfills, such as the Claire C&D facility, charge different tipping fees if the traps have been preprocessed. This facility accepts stripped traps for free but charges tipping fees on unprocessed traps. Also, if the traps are unprocessed, they will eventually be transported to a facility in Liverpool and buried. However, if the traps are already stripped, they will be taken away by a private scrap metal company. The Yarmouth C&D facility takes traps whether or not they have been processed and charges the same tipping fees regardless of the condition of the trap. The Richmond Solid Waste Facility accepts stripped and non-stripped traps, but only if they are dropped off by a resident of Richmond.

Many respondents bring their gear to the nearest solid waste disposal facility, usually a landfill or transfer facility. Most of these respondents noted that there was a tipping fee to leave this material. There was no consensus among this group as to whether they were opposed to paying the tipping fees, with roughly equal numbers claiming satisfaction as those who expressed dissatisfaction.

5.1.2. Gear Reselling

Another trend cited by captains and harbour masters was the reselling of gear, especially wire framed lobster traps. One reason a captain might buy second hand gear is financial limitations. Entering the fishing industry has significant cost barriers; a new lobster trap can cost between $100 and $150, or more if one wants to add in features to increase the life span of the trap. Most licenses permit approximately 300 traps. A new boat and license can cost approximately $500,000. Occasionally, a new captain might not be able to afford to purchase all new equipment in their first year, and so will purchase used gear.

Another reason one captain might judge their gear too worn out where another would judge it usable can be attributed to variable water conditions in different parts of the province. In certain areas, especially shallower waters, traps are more susceptible to damage from bad weather and currents. For captains fishing in this area, the risk in using non-pristine gear is much higher than for a captain fishing in calmer waters. Finally, some captains merely have different risk preferences, some are willing to pay a higher price to avoid risk, whereas others will accept the risk to avoid costs.

5.1.3. Disposal in Dumpster at Wharf

Respondents claimed that the only gear they were allowed to leave in these dumpsters was rope, as any other gear took up too much space. During this project, we identified several pieces of anecdotal evidence that pointed towards a lack of satisfaction, primarily from harbour masters, concerning these dumpsters. The members of the Ship-to-Shore program mentioned that a number of harbour masters had complained about irregular dumpster collection on the part of the waste hauling company that led to the dumpsters overflowing and waste flowing out and spreading around the harbour. Another harbour master claimed that captains would occasionally bring garbage bags from their personal residences and leave them at the harbour, which led to bins filling up faster than planned. Several captains we spoke to mentioned that their harbour masters had banned the depositing of rope in these dumpsters.

5.1.4. Repurposing of Used Gear

Many respondents indicated that they repurposed their gear for other uses as opposed to discarding it, once it was no longer suited for fishing. Old nylon netting from seine nets is used to make bait bags for lobster traps. We were told that this practice accounted for all waste nylon from seine net repair in the province (Personal communication, South West Seiners, 2016). Monofilament netting from gill nets is used to protect gardens from animals and serve as a support for grape vines. Additionally, captains told us that this netting can be used to protect fish in ponds from predatory birds. They also informed us that lobster traps can be filled with stones to be used as anchors and in retaining walls. One company, North Shore Ballast, uses dismantled lobster traps as reinforcement in their cement products. Another Cape Breton business uses discarded fishing gear in art projects and sculptures. Finally, wooden traps are sold as ornaments to tourism sites and tourists. It is important to note that when we inquired as to what happened to this gear when it was no longer usable in its secondary purpose, respondents indicated it was sent to landfill.

5.1.5. Illegal Disposal

Few respondents claimed that they engaged in illegal methods of disposal such as burning and disposal at sea, for obvious reasons. However, information collected from multiple sources within the fishing industry confirms that these methods are prevalent. Some fishers admitted to burning old netting, rope and wooden framed lobster traps. Additional evidence for the presence of this practice comes from the members of the Ship-to-Shore program, who have seen burning pits at numerous harbours (Personal communication, Sonia Smith, 2016).

Both captains and harbour masters admitted that either they themselves, or their constituents at their harbours, intentionally discarded lobster traps at sea. The explanation of this behavior differed between wooden and wire trap owners. Some fishers explained that they used hatchets to smash open these traps prior to disposal to avoid ghost fishing. Gear suppliers informed us that wooden traps are typically made out of untreated hardwood, and are therefore unlikely to release chemicals that could be inimical to fish as they decompose. Individuals who discarded damaged wooden varieties explained that these traps decomposed within three to five years, and so were not a threat to lobster populations. Research in Florida has shown that wooden traps can continue to ghost fish for up to a year and-a-half (Butler & Mathews, 2014). It is unclear from the report whether these traps had their heads and parlours removed before being dumped. It is also possible that different trap construction, tidal intensities and seafloor textures could result in traps within Nova Scotia lingering for more or less time.

Individuals who admitted to discarding wire frame traps in the ocean believed that the traps' escape hatches would prevent ghost fishing. In fact, some fishers believe that the old traps serve as shelters for lobsters. A group that is involved in the retrieval and removal of gear from the waters of the Fundy Bay region, the North Fundy Fisherman's Association, confirms from first-hand experience that if a trap is properly stripped with its head and parlour removed, it does not pose a risk to lobsters in terms of ghost fishing. While they have never found carapaces in a stripped trap, the contact we spoke with did confirm that they had found evidence of lobsters trapped and killed by non-stripped wire traps. This group has no experience with wooden traps as they are not utilized in this region.

While some industry participants confirmed gear disposal at sea occurs, many industry experts claimed that the practice of intentionally discarding fishing equipment in the ocean has decreased considerably in the last two decades. One factor contributing to this change is education about the potential of losing catchable fish through the process of ghost fishing. Another was that industry participants wanted to ensure the viability of the industry for their children. A final factor is that this practice had become socially unacceptable, and that there is considerable pressure from peers to avoid this behaviour. There is academic research that supports the fact that perceived social norms can have a strong impact on behaviour (Schultz, Wesley, Oskamp, Stuart, 1996). The common theme among these factors is the presence of educational outreach.

5.2 Barriers to Low Impact Disposal

The barriers to gear recycling that the respondents identified were similar to those that were identified by the respondents of the agricultural plastic waste survey. Farmers identified cost, time and available space as barriers, whereas the sampled group of captains identified "cost", "distance" and "time of year" as barriers.

5.2.1 Cost

Cost was the most common theme amongst the sampled fishers when identifying barriers. Respondents identified several different potential expenses that might prevent their participation in a recycling program. Some believed that this program would employ a gear pick-up service where the gear is removed from their place of residence, similar to curbside pick-up for garbage, organics and recyclables, and they were concerned about paying for this service. Others expected that they would need to transport their gear to a drop off location and pay a tipping fee similar to traditional waste management facilities such as landfills or transfer stations. Several other respondents did not identify cost as a personal barrier, but when asked later in the survey about who, if anyone, should be financially responsible for such a program, they mentioned that if fishers were made to pay, it would likely reduce participation levels.

Some respondents suggested ways to mitigate the cost barrier. One captain believed fishers would likely fear that they would be forced to pay a fee for this service, without a guarantee that it would be continued. He was concerned that the program might be discontinued after two to three years, but that the fee would persist. To alleviate this fear, he suggested that educational outreach be performed to ensure that fishers were kept well aware of what was happening with the gear their fees would be used to recycle or reuse. Several other respondents suggested that fishing gear recycling be funded by a deposit refund system, similar to the bottle deposit program present in Nova Scotia.

5.2.2 Distance

Distance encompassed any response that indicated a fisher did not want to have to transport their gear to a drop-off location. Some respondents were unwilling to transport their gear any distance, while others were willing to do some travelling. Several individuals who identified distance as a barrier also reported that they currently transported their gear to a landfill without claiming dissatisfaction. This could potentially indicate that these respondents are willing to transport their gear some distance. However, it could also indicate that these fishers did not tell the truth about their disposal habits when they claimed they transported their gear to landfills. A small portion of fishers mentioned that they lived in rural areas, but would be willing to transport their gear as long as the location they had to deposit it at was at a location that they already had to travel to, such as a bottle deposit depot or a waste facility.

5.2.3 Time of Year

The “time of year” barrier relates to the timing of program operation. Many fishers assumed that collection would not be done regularly, and instead carried out at specific times during the year. They were concerned that if the gear collection dates occurred during fishing season that they would not be able to participate. We had several suggestions as to what times of the year would be best to hold a program, but because season opening and closing dates vary from harbour to harbour, these dates are only relevant to a specific geographic area and so are not of use to an analysis of the province as a whole.

5.2.4 Failure to Recognize High and Moderate Impact Disposal Methods as Problematic

This barrier was not specifically identified by captains, but instead was inferred by other remarks made during the questionnaire. In several instances, captains claimed that due to rising

awareness of the environmental risks posed by high impact disposal methods, they had switched to what they called an environmental approach, which they identified as landfilling. Additionally, a number of captains mentioned that they sent gear to the landfill where they believed it would be recycled. However, this gear included ropes and nets, which right now cannot be recycled from landfills. Additionally, a number of captains claimed that they were making shelters for lobsters by stripping their traps and disposing of them in the water. These responses indicate that captains believe their behaviours are environmentally conscientious. If this is true, it will be difficult to convince them to change their routines and utilize a low impact solution unless a proper educational campaign can convince them of the risks of their current behaviours.

5.3 Financial Responsibility

The most common opinion on who should be financially responsible for paying for a recycling or reuse program was the fishers who generated this gear. The next most common belief was that the provincial government should be financially responsible and the third most common reply was that the organization recycling the material should be the one to pay. It is possible that some of the respondents who gave this answer believed that the company recycling this material would be making a profit from it. Some respondents believed that the costs should be shared. The most common cost sharing suggestion we received was that the costs should be shared between fishers and the provincial government.

6. Potential Low Impact Solutions to Discarded Fishing Gear

The inspiration for this project was the net recycling program that is being operated out of Steveston Harbour. Steveston Harbour has an arrangement with Aquafil, a Slovenian company that processes nets into plastic fibres. These fibres are transported to Interface, a company that uses them in carpet tiles.

Unfortunately, as we characterized the fishing equipment profile in Nova Scotia, it became apparent that this would not be a viable solution. Aquafil only accepts a specific type of material, the polymer nylon 6. They pay to ship the netting to their facility in Slovenia, and reimburse two individuals from Steveston Harbour who pre-process the nets, but only pay for full containers to be shipped, which equates to roughly 40 tonnes of nylon 6 netting. While Steveston Harbour generates enough netting to send a container annually, Nova Scotia only generates a fraction of that amount – about 7.5 tonnes – meaning it would take approximately five years to collect enough nets to fill a container. And, as previously mentioned, all nylon 6 generated in province is already being re-used by lobster fishers for bait bags. We decided at the outset that we did not want to target materials that are reused in community projects for collection, and instead would focus on gear for which there are no solutions. Finally, there is a high degree of preprocessing involved in preparing the nets that requires specialized equipment and skilled labor.

Once we realized that Steveston Harbour's solution was not feasible in Nova Scotia, we started looking for alternative recycling and reuse options. The criteria we used to identify these are listed below. The unifying factor in all of these solutions was the need for a collection and consolidation mechanism. Unlike in Steveston Harbour where all the gear is stored in a single location, fishing equipment in Nova Scotia is dispersed across a large number of small harbours, many of which are located in rural areas that are not easily accessed by conventional transportation methods.

While we have determined that the Aquafil model is not a feasible solution for Nova Scotia, it does have several positive attributes that are worth mentioning. It ranks well on the waste hierarchy, fully recycling nets into a new high value product and financially self-sustaining.

6.1. What Would a Low Impact Solution Look Like?

For the first phase of the solution identification process, we aimed to generate as many potential options as possible, so the criteria were kept broad. Any potential solution had to:

1. be able to handle at least one type of material generated by the fishing industry;
2. be able to accept a reasonable quantity of material; and
3. result in the gear being diverted from landfill.

The first criterion is straightforward; we were only looking for facilities that could reuse or recycle the materials found in discarded fishing equipment. The second criterion was utilized to rule out solutions that only worked on a very small scale, such as an individual that sold lobster traps to tourists in his yard, or a community group that made art out of discarded rope. The third criterion was used as a precaution to ensure we were keeping in mind the mission statement of any potential program, which was to divert waste from landfills either by reuse or recycling.

6.2. Relevant Factors

Once we had gathered an initial list of potential solutions, we analysed the attributes of each option to assess their suitability as solutions for Nova Scotia's waste fishing gear. We identified the following factors that were important for each facility to have.

6.2.1. Transportation Costs

For any potential program to work, the waste material will somehow have to be transported to the facility where it will be recycled or reused. For the facilities within Nova Scotia, transportation costs were not a significant factor. Some transportation costs, such as the costs involved in consolidating gear to a single location, would apply to every solution we considered and so are not considered in this section.

6.2.2. The Waste Hierarchy

Not all forms of landfill diversion are considered equal, and it is important that we consider the differing level of merit associated with each form of recycling or reuse, as depicted in the waste management hierarchy (Figure 10). Reducing waste is not implausible, but any method likely to achieve a reduction in waste quantity disposed of would likely involve changes in available technology and or behaviours which are beyond the scope of this paper. Therefore, we focused on reuse and recycling, though we will also make a note of waste "reclamation", or the process of exploiting potential energy stored within waste material. Reclamation is considered to be the least valuable form of diversion, while still being considered a positive alternative to landfilling.

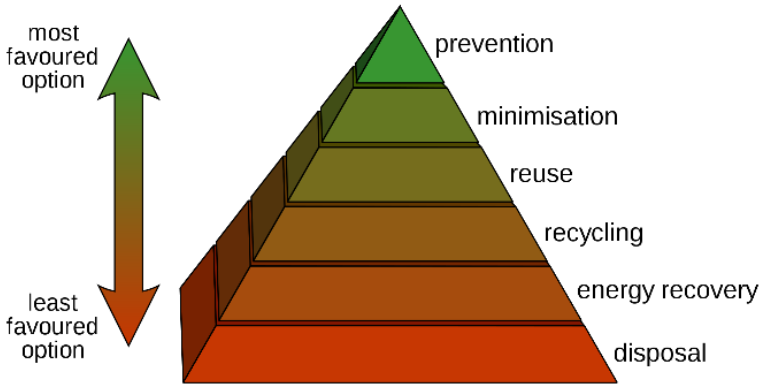

Figure 9. Depiction of the waste diversion hierarchy (Romero Waste Consulting)

6.2.3. Relevant Materials Handled

Different potential solutions process and work with different types of materials. Our characterization of Nova Scotia's waste fishing gear revealed that materials are generated in vastly differing quantities, and so the waste processing capabilities of the facility must match the waste generation realities of the province.

6.2.4. Reliability

An additional factor used to determine the merit of each solution is reliability or, in other words, whether it could be reasonably expected to be a viable solution in years to come. One method of determining reliability is to determine how long a company has been in business. A long-standing company is evidence that their business model is sound, and that they understand the way the market works. Another aspect of these businesses we looked at was if they were financially self-sustaining. From an economic perspective, a business that recycles or reuses materials while generating a profit, or at the very least covering its own costs, is more likely to stay in business because the owner/operators have a financial incentive to maintain it. On the other hand, a volunteer-based solution relies on the good will and generosity of individuals, and if these individuals are incapacitated then there is no economic incentive for someone else to take their place.

6.2.5. Preference for Local

The final factor used in determining the viability of a solution is whether it is local or not. The benefits of a solution within Atlantic Canada is that the positive economic impacts, such as job creation and the revenue stream from the facility, will be retained. Additionally, it is possible that the facility would be able to accept materials from other industries which could lead to diversion for other industries.

6.3. Low Impact Solution Analysis

6.3.1. Plastix Global

Plastix Global is an environmental initiative based in Denmark. Their mission is to find innovative methods for recycling retired fishing equipment. To date, they have primarily partnered with harbours in England, are looking to partner with North American harbours in the

future. Plastix Global has not yet developed a way to economically recycle all of this material, but is conducting research on potential methods. Like Aquafil, this organization will pay for the overseas shipping (Personal Communication Joel Baziuk, 2016).

The primary strengths of Plastix Global are that they will take all materials commonly generated in Nova Scotia. Additionally, they do not require that any of this material be processed in any way before it is sent to them. The major challenge with Plastix Global as a solution is that we do not have an assurance that the material we send will be recycled or reused, as any material they cannot recycle or reuse will be landfilled. Additionally, while Plastix Global does not have a set structure for how gear collection would work, Mr. Baziuk advised that at least 20% of the material we send per load would have to be nylon 6, which again could prove difficult to do in Nova Scotia.

6.3.2. Fundy Plastics

Fundy Plastics is a private waste management facility in Pennfield, New Brunswick that processes mainly retired fishing gear. Currently, this facility provides service to harbours in New Brunswick but the owner has expressed interest in receiving material from Nova Scotia. This facility does not charge tipping fees to drop off material.

The strengths of this facility are reliability, waste hierarchy precedence, and the types of material it can accept. The owner-operator has a background in solid waste management and this facility is for-profit, which suggests reliability. Fundy Plastics accepts all materials related to the fishing industry, including Styrofoam™. Material is either sold to local scrap metal dealers, or shredded into plastic fibres and shipped to China for recycling.

The challenges associated with Fundy Plastics relate to its pre-processing requirements and shipping costs. Before this company can accept netting, the nets must be dried out for four to six months to kill off any attached plants and shellfish. This requires a large, secure area that can be kept dry, and which must be located in a place where no one will object to the odor of rotting sea life. Additionally, this company does not pay for shipping or collection, so gear would have to be shipped to Pennfield from Nova Scotia. The cheapest way to do so would be via truck, and would cost approximately $1,190 per full truck load, which would amount to 17.5 tonnes of material (Personal communication, Sonia Smith, 2016). As previously mentioned, this does not account for costs related to collection or consolidation, only for transporting gear from Dartmouth, Nova Scotia to Pennfield New Brunswick.

6.3.3. Pubnico Plastics

Pubnico Plastics is a new organization based in Pubnico, Nova Scotia, that can process ropes of various materials used in the fishing industry. This facility is not yet operational; however, it has received permission to install a rope shredding device. The strengths of this facility as a solution are that it is local and has a high precedence on the waste hierarchy. Pubnico is located close to many of the largest harbours and most prolific fishing areas in Nova Scotia, which would reduce collection and consolidation costs. The material this facility processes is converted to plastic fibres that are used in the production of new materials overseas.

The challenges with Pubnico Plastics are that they have not yet devised a tipping fee structure, they cannot currently accept all types of material generated, and they cannot necessarily accept the quantity of material generated. As of now, the owner has stated that he is only interested in

rope; however, he was open to the idea of accepting new materials such as nets in the future. The estimate he gave for how much rope he could process in a year was significantly lower than our estimates of how much rope is generated in the province as a whole, but our estimates for rope generation in southwest Nova Scotia are close to his estimated capacity. This implies that his facility will be able to handle the material load from his region. Because this business is in its infancy, there is also a potential concern of reliability.

6.3.4. Halifax C&D/Lafarge Brookfield Cement Plant

The Lafarge cement plant in Brookfield, Nova Scotia has been given permission to use non-chlorinated shredded plastic waste from Halifax C&D in place of coal to fuel their furnace. From discussions with our contact at the rope manufacturer, Polysteel, we understand that there is no chlorine used in the production of polyethylene, polypropylene or mixed fibre ropes.

The major strength of this solution is that it is local. All aspects of this solution can be conducted in the province without the need for international shipping. Even the other solutions that involve local processing, typically ship their output material to other countries for final production.

The challenges with the Lafarge/Halifax C&D solution are related to the low position on the waste hierarchy, the fact that the facilities necessary do not yet exist, and that they cannot accept some of the most common fishing related materials generated in the province. While reclamation of energy from material is considered more productive than landfilling, it is still low in the waste hierarchy. Additionally, Halifax C&D does not currently have a machine that is capable of shredding nets and ropes into a material that the cement plant can utilize. While Lafarge can likely accept the majority of lines and nets if they were to be shredded at the plant itself, there would need to be a high degree of front-end processing to ensure that no lead core or cork core line was put in loads. As previously mentioned, the single most commonly generated type of waste gear is the lobster trap, and these cannot be accepted by Lafarge. Finally, Halifax C&D charges tipping fees on material they accept.

6.4 Collection and Consolidation

Regardless of which solution is selected, if a program is to exist there will need to be a method for consolidating and collecting discarded fishing gear. There are several complicating factors that may be relevant for this collection service. There are close to 200 harbours spread across the province, all of which generate this material. The two most prolific areas for fishing are around Cape Breton and in southwest Nova Scotia. Many of these harbours are located in rural areas. Also, at these locations waste is not discarded evenly throughout the year, but is tied to fishing seasons. Typically, gear is replaced at the tail-end of the season. This is further complicated because different fisheries have different season end dates and, even within the same fishery, the season end date can vary with each region. Finally, waste disposal habits, protocols, and enforcement levels can vary drastically. Some harbours have contracts with waste hauling companies to collect and empty dumpsters at wharfs. Others require that individuals take their waste home with them. The time intervals between collections of these dumpsters can vary wildly.

Given the nature of this waste profile, the method that seems most appropriate and feasible for collecting this waste to a central location is a blitz model. This model would involve identifying “rally point harbours”, which would be the largest harbours in each region. On designated days, the program administrator would arrange to have trucks sent to these harbours. Smaller

peripheral harbours would transport their retired gear to these larger “rally point” harbours, where they would be loaded onto trucks. From here, these trucks would drive towards the most appropriate location. This location will vary depending on the facility to which the gear is being transported. The location might simply be the solution facility, or, if processing is required, a different space that meets the needs of the processing requirements. The blitz would likely occur once or twice a year.

The logic behind this system is based on our research of behavior regarding recycling, and the barriers to participation. By strategically selecting the “rally point” harbours, it is possible to limit the distance any captain would have to travel from their harbour to the location where they would drop off their material. This also prevents the need for a truck to visit each and every harbour around the province, which may only have small quantities of material to contribute individually. There are alternative sites that could be used in place of large harbours, including transfer stations and larger Enviro Depots, the logic behind using harbours is that we felt that fishers at smaller harbours are likely to know the nearby large harbours.

7. Conclusions and Recommendations

7.1 Conclusions

Through our research efforts, we learned that there is little to no data being gathered by any single group or organization on the quantity of gear being disposed or the method in which it is being disposed. Neither DFO, the Nova Scotia Department of Fisheries and Aquaculture, provincial landfills keep track of this information. However, from speaking with numerous industry participants, we know that captains typically remember how much gear they dispose of in a single season. Also, gear suppliers in the province should not be considered a reliable source for this information, as captains purchase some portion of their gear from out of province suppliers, some of which are based in foreign countries. It is unclear whether it will be possible to contact these companies, or whether they will keep records on the specific quantity of gear they sell to Nova Scotia fishers.

There is need for a recycling or a reuse program for used fishing equipment in Nova Scotia. There is a huge quantity of material generated between different types of traps nets and ropes, especially considering there are types of equipment that this study did not account for, and the fact that other industries are contributing materials that could be diverted as part of the same solution such as rope from other industry sectors such as the commercial marinas. Currently there is no province wide, low impact disposal method for gear in the province. There are numerous community level reuse initiatives, but gear repurposed in this manner often still ultimately ends up in landfills.

The solution utilized by Steveston Harbour was not appropriate for Nova Scotia, because we do not generate enough gear to fill a container annually. Also, all the material that Aquafil accepts is already being reused by captains for lobster bait bags. Finally, whereas all the material generated at Steveston Harbour is in one central location near a major shipping port, gear in Nova Scotia is dispersed around the province in small, often hard-to-access ports.

Nova Scotia fishing vessel captains do care about the environment and want to limit their negative impacts on it; however, there are misconceptions about what harms certain types of gear can cause. Some captains believe that moderate impact disposal methods such as landfilling are actually low impact. With high impact disposal methods such as abandonment at

sea, some captains believe they can eliminate the impacts of ghost fishing by partially dismantling gear before throwing overboard. If so, they do not account for other potentially harmful impacts such as damage to marine ecosystems and the potential to entangle in-use gear.

There are multiple potential solutions to the problem of waste fishing gear of varying merit and feasibility, and a recycling program is deemed ideal by Clean. This study identified several organizations that could serve as a final destination in a low impact gear recycling program.

The largest barriers to participation in a reuse or recycling program are cost, distance, time of year, and perceptions about what a low impact solution truly is. In order for a solution to be successful, it will need to lower these barriers in order for fishers to participate.

There are already numerous community-level solutions already operating in the province. Certain organizations and individuals have proprietary arrangements with harbours and captains that result in gear being resold, reused and repurposed. These are often self-sustaining, either because of volunteer labor or because of economic viability. While material repurposed in this method often does end up in landfills, this is still preferable to gear going straight from the fishing industry to landfills at the present time. While these solutions have gaps, given the abundance of waste gear that is not being reused or recycled in any manner, we believe the first focus should be on gear for which there is no existing low impact alternative.

7.2 Recommendations

1. We recommend that a pilot low impact gear collection and recycling program be delivered with a small number of harbours to assess the viability of such an initiative. We recommend that a pilot program be implemented at Meteghan Harbour because it is one of the largest harbours in Nova Scotia with several smaller harbours nearby. Additionally, a disproportionately high number of questionnaire respondents were from Meteghan which means the information in this report regarding barriers and attitudes is likely more accurate for this harbour than for any other harbour. Also, many of the respondents from this harbour indicated a strong desire for a recycling or reuse program, and some volunteered to help consult if their harbour was selected.

   For the pilot program we recommend that materials be sent to Pubnico Plastics and Fundy Plastics for recycling. Of the organizations we considered, these two are best positioned to meet the needs of a province-wide frame work for gear recycling that this pilot is designed to test. We believe a solution that utilizes both of these solutions will be the most feasible and efficient.

   a. Short term: As a feasibility test for a province wide solution, Clean should approach Meteghan Harbour as to the possibility of hosting a pilot program for the proposed gear collection and recycling solution. This program should be geared around testing that the program can collect the gear, process the gear and transport it to its final destinations at Pubnico Plastics and Fundy Plastics. Because of this, the level of participation is only significant in that there must be enough gear to test the infrastructure of the solution. If the pilot proves successful, Clean should advertise the program across the province and identify new harbours to participate in this program. We recommend that Clean partner with Miller Waste and Eastern Sanitation ltd. to determine the most efficient way

to do this. These are waste hauling companies that have expressed interest in participating in a recycling or reuse program for fishing gear.

b. Long term: When, and if, the program spreads and becomes available to all commercial fishing harbours and sees wide spread participation, provincial legislation could be used to support this program. If all captains in Nova Scotia have relatively easy access to a recycling initiative, a landfill ban on recyclable fishing equipment could encourage full participation in this program and lead to additional landfill diversion. Obviously it would be important to ensure that the barriers captains faced to participation would be low enough that they did not resort to illegal high impact disposal methods such as burning or abandonment at sea.

2. There is a clear need for more accurate and complete data collection concerning fishing gear disposal. In addition to assisting in our understanding of the scope of this problem, such information will make determining an efficient collection schedule and route for gear from harbours much easier. Additionally, the owners of Pubnico Plastics and Fundy Plastics both stated that the number one barrier to their opening up satellite facilities in Nova Scotia was a lack of guaranteed material inputs.

    a. Short/medium term: Fishing equipment, specifically ropes, traps and nets should be added to the landfill audits performed by DivertNS. Additionally, a unified metric should be adopted to measure different varieties of gear. Right now different sources measure gear quantities in different ways. For instance, some groups measure rope by length, whereas others measure it by weight. We recommend weight be used as a metric for all gear types, as that is the most relevant value for transportation and processing concerns. Additionally, metrics like length and area can involve different weights depending on the specific materials.
    b. Short/medium term: Venues such as derbies and professional fishing association events provide excellent opportunities to gather information concerning the amount of gear fishers are using and disposing. While this will not reach 100% of captains, if information is gathered from captains across the province in large enough numbers, it will be possible to draw statistical inferences about the disposal habits of all captains.
    c. Long term: It would be ideal if there were a province-wide program that compels captains to self-report their gear disposal numbers from the previous year. This should be done through a medium that reaches all captains, preferably by an organization with ties to the fishing industry, such as the coast guard or DFO Small Craft Harbours.

3. Our next recommendation involves providing education to fishers to correct misconceptions regarding the impacts of gear disposal habits. The belief that some fishers hold that their gear disposal choices are low impact, or even beneficial for their target species, may be a barrier to participation in a low impact diversion program. Education must be done in a careful manner, however, as a message that comes across as accusatory can also discourage individuals from participating. The initial focus of this education should be on the harms associated with gear abandonment at sea and burning. This will hopefully influence the behavior of captains away from high impact

disposal methods. In the longer run, when and if there is an effective solution for recycling gear available across the province, this education will seek to educate captains of the benefits of diverting their gear from landfills, moving to a low impact disposal method.

4. Another problem we noticed during our study was the abundance of difficult to recycle materials utilized in modern fishing gear, specifically plastics, and the fact that modern fishing gear is not designed for efficient disposal. Because of its low cost and high durability relative to alternative materials such as cotton, plastics have become common in the fishing industry. The majority of rope used in the fishing industry is made of different types of plastics as well as many different kinds of nets. These polymers take much longer to decompose if lost in the ocean environment, or if discarded in landfills than organic materials.

   Many pieces of fishing equipment are composed of multiple materials that are difficult to separate. Some examples include wire frame lobster traps with integrated ballasts, nets with floats and weights attached, and rope with a lead or cork core. The integrated nature of these pieces of equipment make them difficult to recycle, as they require more processing to separate them to their component parts. These two issues can be solved by better designs for fishing gear. Additionally, if better gear design can result in longer-lasting equipment, it could result in a reduction of the total quantity of material disposed of in the province, which according the waste hierarchy is the best option for waste management.

   a. Short/medium term: Evaluate the potential for creating incentives for better gear design for end-of-life disposal, and for further developing existing innovations. The goal of this research should be gear that either lasts longer than contemporary equivalents, is designed to be easier to recycle or reuse, utilizes less materials, or utilizes materials that are less harmful if lost in the ocean environment. It is important to note that this gear must be cost-competitive with current designs, and must be at least as effective at fish harvesting. There are already designs that meet some of these criteria, such a trap that utilizes steel grating in place of a cement ballast which can be recycled along with the whole trap. However, use of this design innovation has not become wide spread because it does not increase the traps effectiveness at catching lobsters, but it does increase the cost.
   b. In the medium run, once innovations become more available to the public, incentives should be given for captains to utilize these lower impact pieces of equipment. This could come in the form of a licensing rebate for each piece of low impact gear used, for example. This will be most effective in the lobster and crab fisheries, where the licenses specifically limit the amount of equipment used. There could also be tax credits provided to fishers who have purchased lower impact gear.
   c. In the long run, once low impact gear has been made available in all parts of the province, measures should be taken to discourage high impact gear use, by either adding a tax to these gear types or banning them completely.

APPENDIX

Gear	Fishery	# of Licenses	Life Span/Replacement Rate	Kg's disposed
Seine Net	Herring	11/49	Repaired, avg of 1500 lbs replaced	7484
Gill Net	Herring/Other	120/300	50% turn-over rate annually	919
Lobster Traps (Wire)	Lobster	Appendix X.1	Varies, between 20-60 traps annually	97976 Traps
Lobster Traps (Wooden)	Lobster	Appendix X.1	Varies, between 20-60 traps annually	40018 Traps
Crab Traps Frame	Snow Crab	Appendix X.2	20 years	Mesh 1315
Crab Traps Mesh	Snow Crab	Appendix X.2	7 years	Frame 3875
Scallop Rake	Scallop	NA	NA	NA
Bottom Trawl	Groundfish	65/89	1.5 per year	8845
Rope	All	NA	Varies	1151881

The values given in this table represent the values we reached using the data we were able to gather. While these numbers appear more accurate than the numbers used in the report above, they are generated from estimates, and are therefore no more accurate. They are presented here only to display the original calculations.

Lobster Fishing Areas's

LFA	# of Licenses	Traps per License	Total Traps
26A	766	300	229800
26B	253	300	75900
27	543	275	149325
28	18	250	4500
29	74	250	18500
30	20	250	5000
31A	73	250	18250
31B	71	250	17750
32	161	250	40250
33	720	250	180000
34	985	388	382180
35	95	300	28500

Crab Fishing Areas's

CFA	# of Licenses	Traps per License	# of Traps
12	2	150	300
12F	6	1*75//5*50	325
18	30	65/75	>1950
19	156	3-26	1699
Mesh	4.75 lbs		
Frame	40 lbs		

Questionnaire Script

"Hello, my name is Emory Ackman with the Clean Foundation, we are trying to determine the level of interest in a recycling or reuse program for used fishing equipment. Do you have time for five quick questions?

Any answers you give are anonymous and your contact information will not be attached to your responses.

1. What is your home harbour?
2. Do you think it is important that used fishing gear, specifically ropes, traps and nets are disposed of in an environmentally friendly way?
3. How are you currently disposing of your retired fishing gear, and are you satisfied with this method? Why or why not?
4. What might stop you from participating in a project that involved you recycling/re-using your fishing gear?
5. If there were costs involved, who should have to pay for a recycling or reuse program?"

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