MARINE DEBRIS ON THE COAST OF SOUTHWEST NOVA SCOTIA: AN ANALYSIS

by
Jacob LeBlanc

A thesis submitted in partial fulfilment of the requirements for the degree of Bachelor of Commerce in Honours Economics

Saint Mary's University, Halifax, Nova Scotia

April 2021

Marine Debris on the Coast of Southwest Nova Scotia: An Analysis

by Jacob LeBlanc

Abstract

This thesis analyzes the levels of marine debris on the coastline of Southwest Nova Scotia and draws possible conclusions for the observed degree of pollution. The plentiful stocks of lobster, scallop, herring, and other marine life in the Atlantic waters surrounding Nova Scotia have led to the creation of multiple commercial fisheries in the Atlantic Canadian region; in addition to the Indigenous fishery that has existed predating Canadian federation. This research sought to identify explanatory variables that could be used to explain the variances in debris levels at different beach sites. It was found that factors relating to the commercial fishing industry may not be as relevant to determining the debris levels as one may think.

Date: April 7, 2021

Acknowledgements

Without the help of multiple individuals, it would not have been possible to complete this research. I would like to start by thanking my supervisor Dr. Mark Raymond, for his support and advice throughout my academic career at Saint Mary's University, and for his belief in this project. Without his guidance and knowledge, I would not have been able to develop this research from the data collection, to the submission of this thesis. I would also like to thank Joshua Watkins & James Blair for the many hours they accompanied me at the data collection sites, and standing in the cold and wind as the counts were conducted. Without their help, the data collection would have been much more difficult. I also give thanks to Dr. Yigit Aydede for his constant support throughout the time that I have known him at Saint Mary's, and for always being willing to lend a hand whenever I needed him. It is because of his excellent teaching, that I was prepared to author this thesis. Finally, I want to give thanks to my parents. Without their love and support throughout my entire academic career, I would not have reached this point.

I also want to acknowledge the Department of Fisheries and Oceans (specifically Jacob MacLeay, Leanne Arsenault, and Colin O'Neil), for their assistance in obtaining the data on the fisheries in the areas that were a part of this research. Without that data, this entire paper would not have been possible.

This research was partially funded by an SSHRC Explore Undergraduate Research Award from the Faculty of Graduate Studies and Research at Saint Mary's University.

Table of Contents

1: Introduction

According to the United States' National Ocean Service, "Marine debris is defined as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes." (US Department of Commerce, 2008). A review written by Murray Gregory on the implications of plastic debris in marine settings noted that prior to the 1950s, most fishing-related textiles such as rope were composed of natural materials that would quickly biodegrade if lost at sea (Gregory, 2009). Over the past ~70 years these materials have been replaced by more durable synthetics including nylon, which will not break down after being left in the ocean for long periods of time. This has implications related to ocean life, as Gregory stated there have been numerous sightings of whales travelling with large entanglements of rope and other debris attached to them (Gregory, 2009).

There has not been much literature published on the subject of marine debris on the coast of Southwest Nova Scotia. However, if one were to seek out similar research that has been conducted, Goodman et al. described a study that took place in the Bay of Fundy where underwater marine debris levels were monitored throughout the bay (Goodman et al., 2020). Goodman et al. holds relevance to this study, as at least two of this study's sites were located on the bay, with the rest of them being positioned directly south of it. This study differs from Goodman et al. in the sense that it was conducted with the purpose of measuring the debris levels on the coast.

The study of marine debris and its effects is important to any area that borders waterways, especially the ocean. As outlined by Marin et al. in *Regional Studies in Marine Science*, while the improper disposal of various types of debris leads to environmental concerns, it can also lead to issues related to social and public health (2019). This includes but is not limited to disease dissemination, transport of chemical toxins, dispersal of invasive species and loss of biodiversity (Marin et al., 2019). These factors can pose threats to fishing industries in any area, as their catches can be threatened by these factors. As postulated by Antonelis et al. debris such as lost or discarded traps were observed to have a 46% mortality rate for crustaceans that became trapped within these remains (2011); in an economic sense, the fishing industry can expect to see greater losses in their catches as the amounts of debris increase in their fishing areas. This can be seen as an important matter for the fishing industry, due to there being just over $700 million in landed catches that were recorded in 2019 by the Department of Fisheries and Oceans in the Southwest region of Nova Scotia alone.

In this thesis we will first take a look at some of the previous literature related to the study of marine debris, and the possible related economic implications. We will then examine the data collection process, as well as the data itself. This will lead into the analysis of the data, and the model that was determined to be the best descriptor of the dependent variables. In examining the data, it will be observed that there is a strong correlation between the average individual income in the survey areas, and the DFO district ID that they are located in. Possible reasons for this will be discussed further in subsequent sections. We will then take a look at the findings and discuss possible reasons for the conclusions that were drawn; we will be sure to note the need for additional work in this area for the results to be more concrete.

2: Literature

Due to the uniqueness of this research question, there is not a plethora of literature to draw ideas from, therefore information was drawn from studies that shared similarities to the work that was being done for this paper. The main concern was to find work that had analyzed the economic impacts of marine debris, as well as the possible adverse effects of pollution that could be observed in the fishing industry.

Antonelis et al.

An article published to the North American Journal of Fisheries Management by Antonelis et al. was able to quantify some of the losses that come as a result of 'ghost fishing' crab traps off the coast of Washington State (2011). The study measured 24 simulated lost traps and found a 46% mortality rate for those crabs that became trapped; this translated to them making an estimate based off the number of traps that were lost every year, which equaled a crab loss of about 4.5% of recent harvests (Antonelis et al., 2011).

Goodman et al.

It is important to mention the Goodman et al. research that was conducted, due to the proximity of their research sites to the ones visited in this study. "Benthic marine debris in the Bay of Fundy, eastern Canada: Spatial distribution and categorization using seafloor video footage" by Goodman et al. was published in 2010 to the Marine Pollution Bulletin.

Goodman et al. recognized that marine debris worldwide is mainly composed of single-use plastics, but in areas with high levels of commercial fishing activity, it is likely that discarded fishing equipment makes up a large portion of the debris levels

(2020). As previously mentioned, these pieces of debris pose entanglement risks to local marine life.

The study measured the levels of marine debris in the benthic zone (the bottom) of the Bay of Fundy, using a camera system that recorded the seafloor in order to count the amount of debris that was present (Goodman et al., 2020). A total of 281 seafloor video stations were observed over the course of the study (Goodman et al., 2020). The mean estimated area of seafloor that was viewed by the stations is $0.342 km^2$ with an estimated density of 137 pieces of debris per km^2 (Goodman et al., 2020). The findings were that 51% of the debris was plastic, while 28% was fishing gear and the other 21% was other human-made objects (Goodman et al., 2020).

Overall, it was determined that the observed fishing gear was not causing any incidences of ghost fishing (entrapping marine life), but the issue was still a possibility (Goodman et al., 2020). Goodman et al. recognized the mixed perceptions that fishers have on their environmental impacts when gear is discarded or lost, and they noted that perhaps better education on the subject would be a solution to the issue (2020).

Gregory

Murray R. Gregory published his review "Environmental Implications of Plastic Debris in Marine Settings—Entanglement, Ingestion, Smothering, Hangers-On, Hitch-Hiking and Alien Invasions" to the journal Philosophical Transactions: Biological Sciences, in 2009.

In the review, Gregory states "Many marine animals (sea turtles, mammals, seabirds, fish and crustaceans) are either drawn to or accidentally entangled in netting, rope and monofilament lines that have their sources in discards and losses from commercial fishing activities." (2009). Gregory continued on to discuss masses of rope which were seen attached to whales swimming off the coast of New Zealand, which included lobster traps in more than one instance, as well as buoys with marker flags (Gregory, 2009). This is especially relevant for the Lobster Fishing Area 34, due to the high volume of lobster fishing that is conducted throughout the season. It is estimated that 5 to 10 percent of lobster traps are lost annually during the Maine lobster fishing season (Canfield, 2009); assuming similar gear is used in Nova Scotia, one could expect comparable percentages of lost traps.

While the Gregory review focused mainly on the biological significance of these ghost traps, such as the possibility for invasive species to be introduced in areas from debris that 'hitchhiked' along with migrating marine species (Gregory, 2009), it was important to understand the effects that these larger pieces of debris can have on the environment that they are discarded in.

Marin et al.

The Marin et al. study was included in this research partly due to the recognition of economic activities that can be associated with the presence of marine debris in certain areas. "Marine Debris and Pollution Indexes on the Beaches of Santa Catarina State, Brazil" was published to Regional Studies in Marine Science (2019). One of the main goals of the study was to determine the overall effectiveness of various indexes that measure the effects of marine debris and beach cleanliness (Marin et al., 2019).

It was shown in the study that plastic was the most common type of debris, but polystyrene foam was also very regularly being observed at beach sites, the authors attributed these counts to the civil construction sector and the fishing activity, which are both prevalent economic activities in the area (Marin et al., 2019). It was also observed that beaches near ports were shown to accumulate more plastic pellets than those that were further away from ports, depending on the type of beach that was being observed (Marin et al., 2019).

Newman et al.

"The Economics of Marine Litter" by Newman et al., addresses some of the same issues observed in the previous studies but they take a more economic approach in their analysis. They recognize that the fishing industry is commonly viewed as a source of marine debris, but that the industry faces its own economic problems related to the debris (Newman et al., 2015). These costs can include but are not limited to: the need to repair or replace equipment that has been damaged or lost due to contact with marine debris, damage to vessels when debris becomes entangled in propellers or intake pipes, as well as a loss of earnings that is associated with catches that are contaminated due to ingestion of plastics or other debris (Neman et al., 2015).

Newman's study helps outline why it is not only important for those in the fishing industry to realize the impacts of their debris, but also the effects that it may have on their own livelihoods. As previously mentioned, Newman et al. address the problem of ghost fishing and the problem with the increasingly durable materials used in the gear, causing it to remain intact for much longer periods of time than in the past (2015).

Widmer and Hennemann

The goal of Widmer and Hennemann's study (2010) was to test several hypotheses; including currents and wind can affect the levels of debris, plastic would be the most prevalent debris, there would be around 10% biological colonization of the debris, and there would be a negative correlation between the amount of debris found and the number of observed ghost crab burrows.

Data was collected from 5 beaches, from random sites measuring $100m^2$ on the east coast of the island of Santa Catarina in Brazil (Widmer and Hennemann, 2010). It was decided that the supralittoral area (near the sand dunes) of the beaches would be the area surveyed due to the belief that debris is more likely to collect in these zones (Widmer and Hennemann, 2010). The results showed an average of 102 items per $100m^2$, with plastic being the most significant type of debris (Widmer and Hennemann, 2010). It was hypothesized that the absence of many glass objects, such as bottles was due to the value that they hold when returned to recycling plants (Widmer and Hennemann, 2010).

The conclusion recognizes the value of this data for beach management, and the problems associated with the emerging economy in Brazil, where the debris levels will likely continue to increase (Widmer and Hennemann, 2010). The evidence gathered supports the theory that states the supralittoral zones of beaches are a common area for debris to gather. This may contribute to damage of coastal vegetation, which could then lead to increased coastal erosion (Widmer and Hennemann, 2010).

3: Data Collection, Data, and Empirical Methodology

This section outlines the methods used in the data collection, as well as the data itself, and the statistical methods that were used to evaluate the data set.

3.1: Data Collection

The method for data collection was discussed extensively prior to commencing the field work, which began with the selection of research sites. Google Earth was used to select the sites that would be examined (see Figure 2), and the accessibility and safety concerns of each site were discussed before the list was finalized. A total of twenty sites were selected, with each to have subsites 'A' and 'B'. Wanting to work similarly to the Widmer and Hennemann study, it was decided that each subsite would measure 50m in a straight line, with 1m of area on each side. The distance at each subsite was measured using a laser rangefinder to ensure accuracy.

Figure 1. Map showing the research area within the borders of the rectangle.

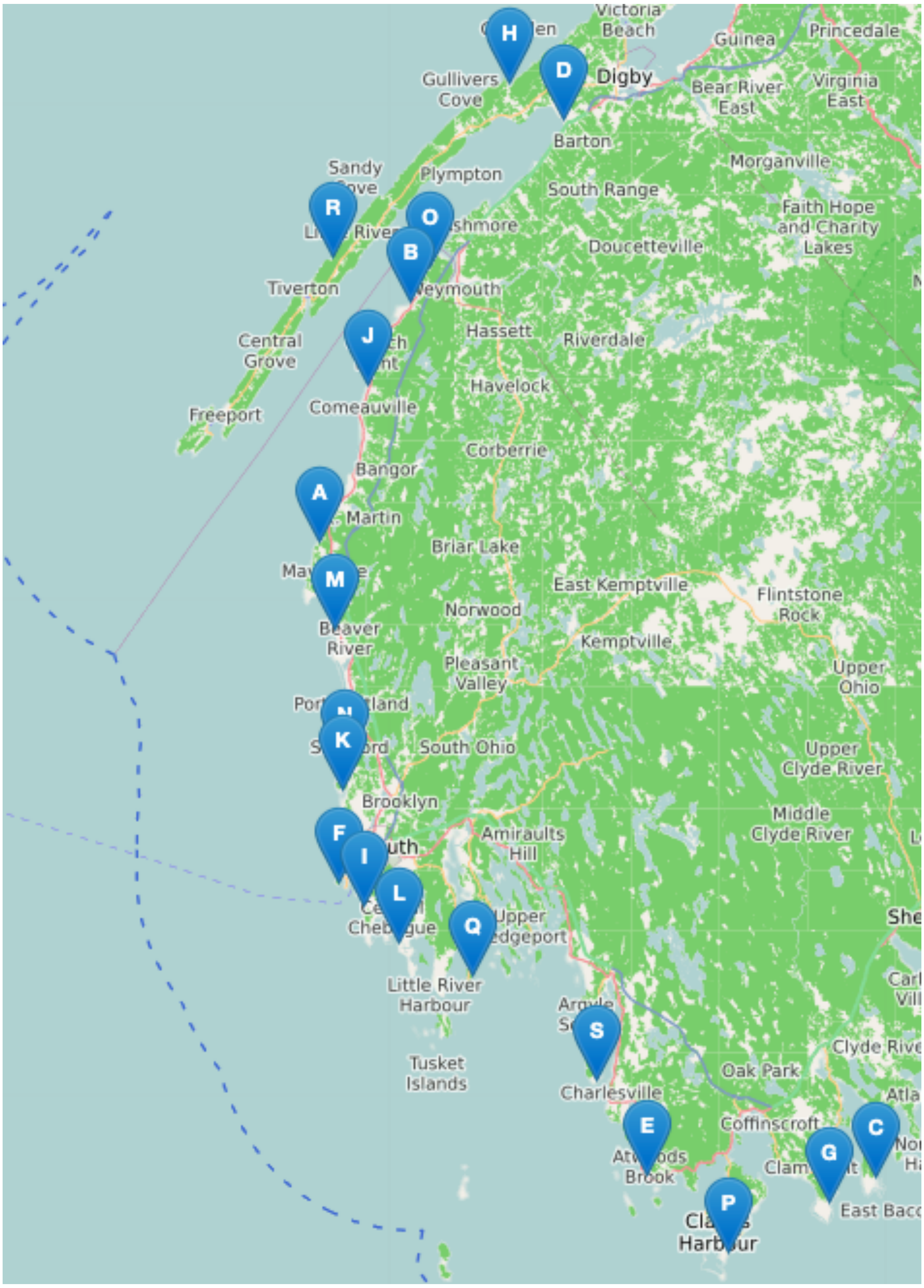

Figure 2. Geolocations of each research site.

Table 1. Legend for Figure 1.

Sites	Label on Map
Bear Cove	A
Belliveau's Cove	B
Blanche Cove	C
Brighton Area	D
Cameron's Cove	E
Cape Forchu	F
Crow Neck	G
Gulliver's Cove	H
Kelleys Cove Area	I
Little Brook	J
Pembroke Cove	K
Pinkney's Point Area	L
Pubnico Windmills	M
Salmon River	N
Sandford	O
Strickland Cove	P
The Hawk	Q
Wedgeport	R
Whale Cove	S

Once the sites were determined, a list for data collection was created that can be seen in Figure 3. It was determined to be important that fishing equipment and fishing-related textiles (ex. rope) would be given their own categories due to the prevalence of the fishing industry in the area. In total, fourteen debris categories were chosen (plastic, metal, glass, timber, paper, cigarette butts, textile, styrofoam, organic debris, marine species, fishing equipment, unknown, rubber, and fishing-related textiles) in order to maintain some similarity with Widmer and Hennemann. Aside from the debris categories, metrics were taken in order to measure the location as well as weather that would be considered relevant to the research. The categories were the coordinates of each site (taken from each end of the site), date, time, wind speed, temperature, direction when facing the ocean, significant weather (whether or not the site experienced wind gusts 60km/h or greater within the previous three days), and the high and low tides for that day.

Site Name:			**Subsite:**		
	Coordinates			**Time**	**Date**
	Coast Direction	**Current Wind**	**Current Temp.**	**Tide**	
Plastic:			Metal:		
Glass:			Timber:		
Paper:			Cigarettes:		
Textile:			Styrofoam:		
Organic:			Marine Species:		
Fishing Equip.			Unknown:		
Rubber:			Fish. Textile:		

Figure 3. Checklist used to record data at each site visit.

Upon arrival at the sites, two subsites were randomly selected near the "supralittoral zones" (Widmer and Hennemann, 2010), which are commonly known as the dunes separating the coast and the mainland. Typically, four sites per week were visited during the summer study period, and all data was recorded on-site. For the winter study period, there was a much stricter time constraint placed on the data collection to ensure ample time would be available to analyze the data; the sites were divided into Northern, Southern, and Western zones, and were counted over a period of three days using the exact same method as the summer study.

Table 2. Sample of descriptive data collected at each site.

Site	**Belliveau's Cove**	**Belliveau's Cove**	**Pembroke Cove**	**Pembroke Cove**
Sub-Site	A	B	A	B
Latitude 1	44º 23' 18"	44º 23' 14"	43º 53' 28"	43º 53' 23"
Longitude 1	66º 03' 46"	66º 03' 49"	66º 09' 38"	66º 09' 37"
Wind	14N	15N	11SW	11SW
Temperature	17º	18º	19º	19º
Coastline	300º	1º	262º	295º
Significant Weather	1	1	0	0

3.2: Data

This section covers a breakdown of the debris counts, as well as the other data used in the analysis. The data used aside from the marine debris counts, was drawn from two sources: The Department of Fisheries and Oceans, and Statistics Canada.

3.2.1 Debris Data

For the breakdown of the debris counts, it is important to note that the summer count included two more locations (four extra sites) due to them being inaccessible during the winter count. Therefore when looking at the charts, place greater emphasis on the percentages rather than the totals.

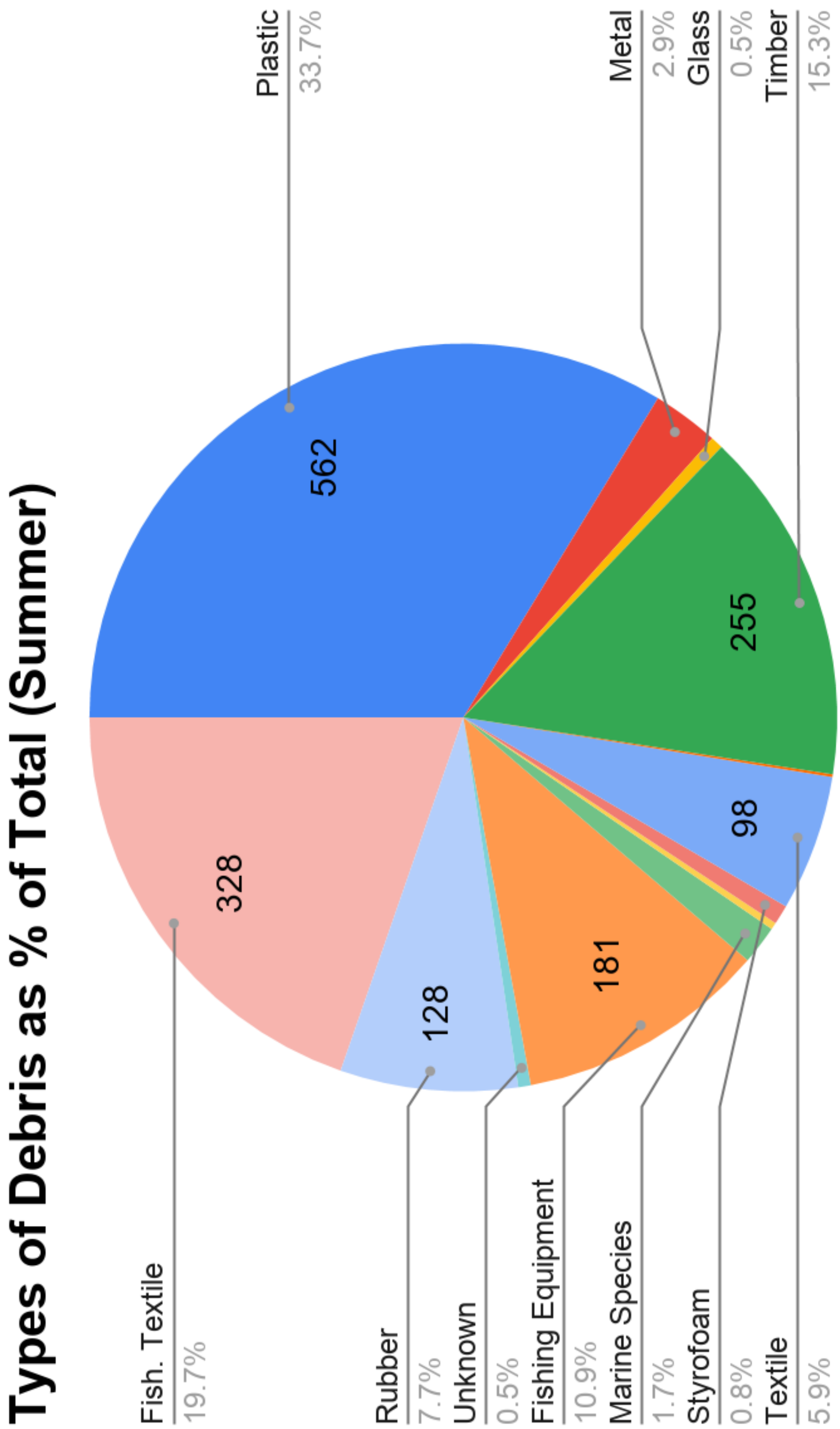

Figure 4. Breakdown of the summer debris totals.

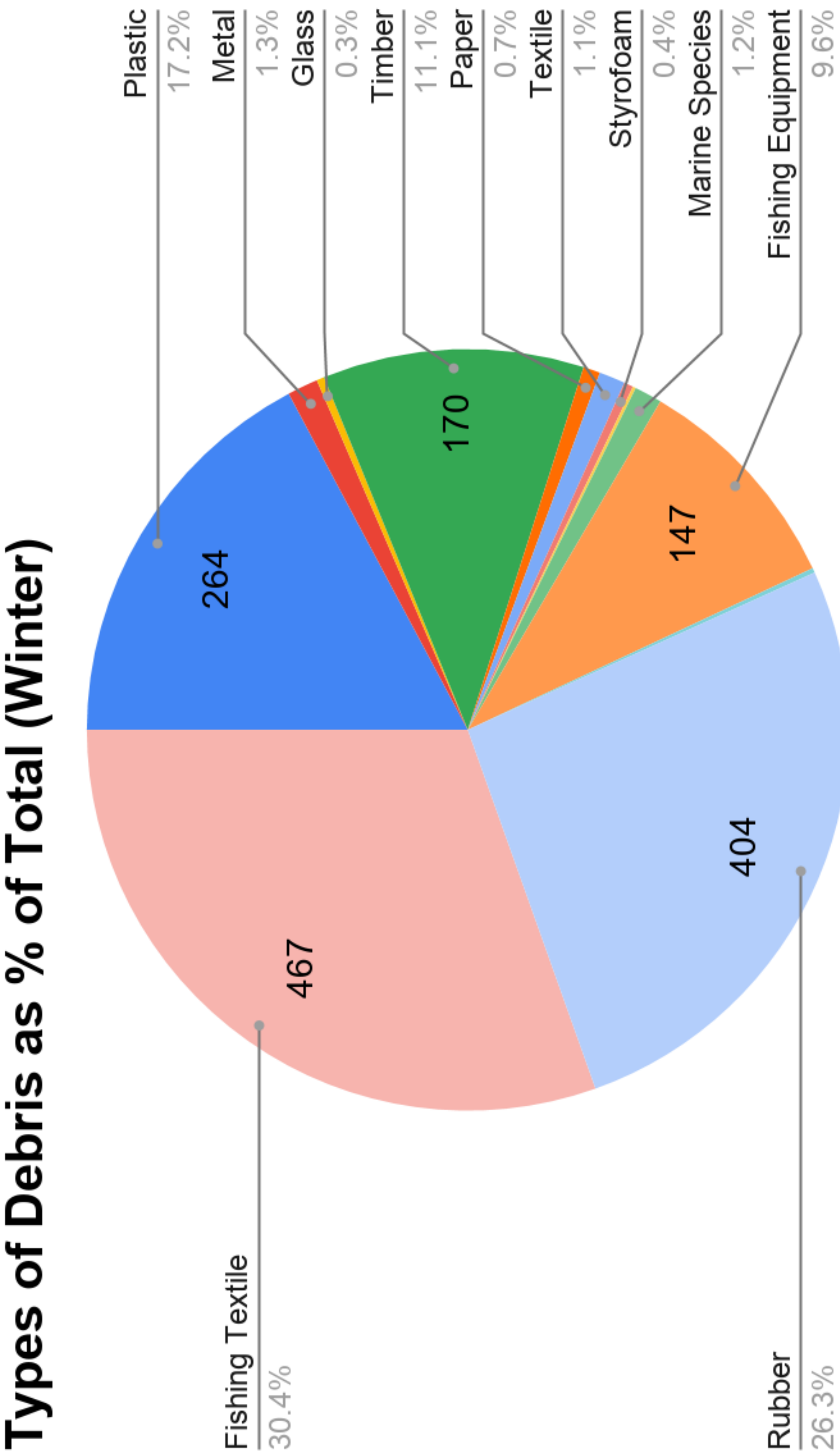

Figure 5. Breakdown of the winter debris totals.

It can be observed that fishing textile is the most observed type of debris in the winter, while plastic is the most observed type of debris in the summer. Fishing textile was mainly rope. It should be noted that the Whale Cove site saw counts nearly four times larger than the next highest total from any of the other sites. Compared to Marin et al., the counts of plastic were proportionally much lower (17% and 34% to Marin et al.'s 69% of total debris counted); this could be due to the increased presence of fishing materials in these counts, although Marin et al. do mention a fishing industry in the area where their counts were conducted in 2019.

3.2.2 Fishery data

DFO was able to provide a statistical map that outlined the different district boundaries in the Maritime Region, as well as spreadsheets that broke down the landed quantities of catches in the different districts, along with their values in Canadian dollars. The spreadsheets also included the vessel counts from each district, and were comprehensive from 2015 to 2019.

Table 3. DFO-provided data.

Year	**District ID**	**Vessel Count**	**Sum of Landed Quantity (kg)**	**Sum of Landed Value (CAD$)**
2015	31	192	23,466,258	108,057,143
	32	390	13,462,369	162,135,665
	33	321	33,813,636	140,903,164
	34	273	39,349,681	102,241,096
	36	136	5,439,683	36,600,964
	37	116	2,668,147	34,537,654
	38	144	13,302,275	57,449,352
2016	31	187	21,324,405	102,547,121
	32	419	12,373,542	150,822,782

	33	317	30,619,804	131,008,670
	34	268	39,585,361	86,132,226
	36	143	6,936,416	41,036,588
	37	129	3,137,619	35,804,234
	38	155	13,288,651	55,639,459
2017	31	199	21,008,335	101,169,733
	32	412	11,167,830	153,374,641
	33	328	32,044,767	140,686,839
	34	261	31,499,845	97,672,386
	36	145	7,529,163	40,225,938
	37	123	2,591,106	33,163,660
	38	144	13,200,751	57,064,715
2018	31	192	21,341,677	116,312,185
	32	420	9,053,886	131,637,702
	33	341	30,605,358	139,367,180
	34	286	31,091,713	106,399,765
	36	140	9,407,045	37,312,034
	37	124	2,287,443	30,473,052
	38	140	12,002,678	56,860,985
2019	31	211	30,888,609	122,930,724
	32	448	9,641,032	156,604,341
	33	375	32,765,959	172,365,936
	34	304	26,623,927	121,243,511
	36	149	5,093,033	38,875,544
	37	142	2,419,359	33,552,387
	38	154	12,510,132	53,047,329

Table 3 lists the data that was provided by DFO, which was used in the analysis. Figures 6 & 7 show two separate charts that illustrate the changes between 2015 and 2019 of the vessel counts and catch quantities by district, respectively. It can be observed in figure 6 that the trend lines for vessel counts in districts 31 & 34 are growing, while that in district 38 is stagnant. When viewing the catch amounts in figure 7, both districts 34 & 38 are seen to be diminishing, while district 31 continues to grow.

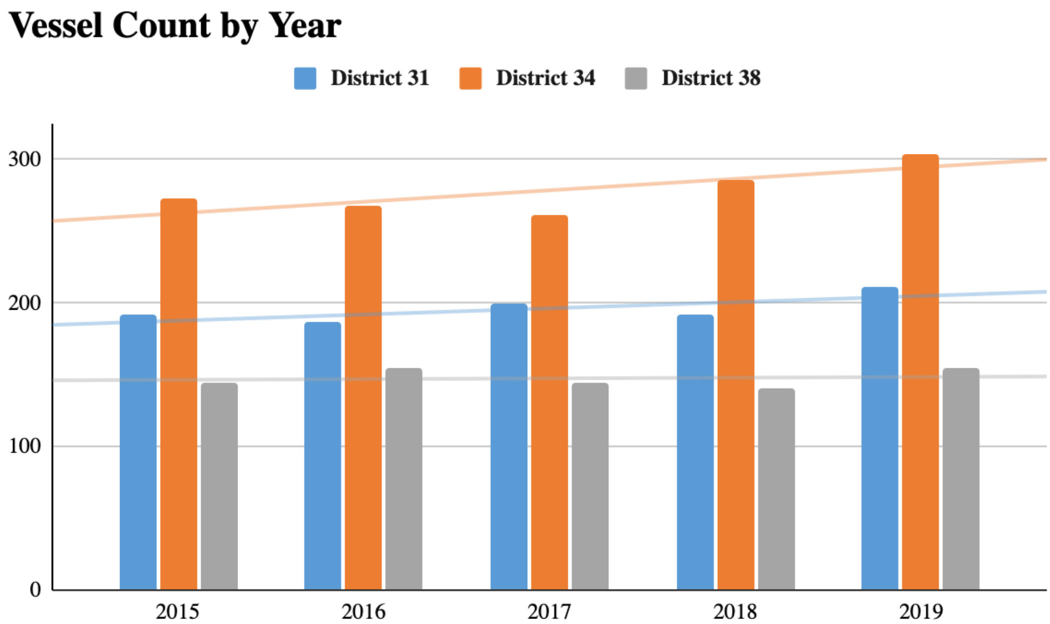

Figure 6. Chart showing the changes over time in the amount of registered vessels in districts 31, 34 & 38.

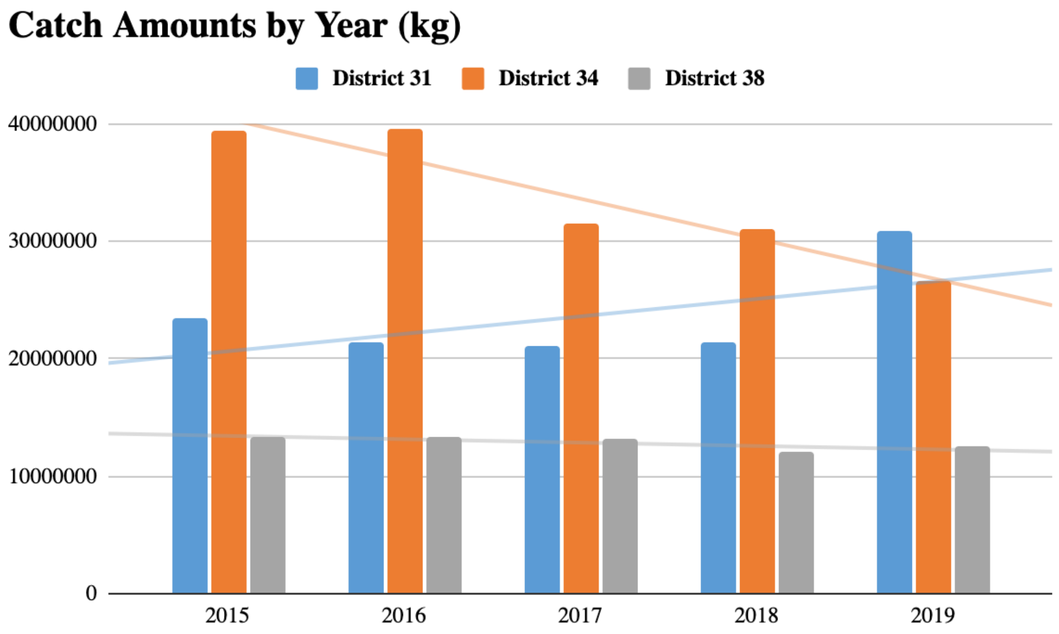

Figure 7. Chart showing the changes over time in the reported catch numbers in districts 31, 34 & 38.

3.2.3 Population Data & Summary Statistics

As for the Statistics Canada data, we drew the population and average individual income data from the 2016 Census for each of the Census subdivisions that had a data collection site in them, as well as the next closest Census subdivision to the site.

Below we can see two tables: one showing the summary statistics for the independent variables, and one showing a correlation matrix between the variables.

The list of variables is as follows:

- **income**: the average individual income from the 2016 Census, for the Census subdivision in which the side is located, in Canadian dollars
- **income2**: the average individual income from the 2016 Census, for the second closest Census subdivision to the site's location, in Canadian dollars

- **catch**: the 2019 quantity of landed catches from the DFO district that the site is located in, in kilograms
- **pop:** the population from the 2016 Census of the Census subdivision that the site is located in
- **prox:** the proximity from the site locations to the nearest wharf in kilometres
- **vessels:** the number of vessels that were registered in each one of the DFO districts
- **ID**: the DFO district ID

Table 4: Summary statistics for the data.

Statistic	N	Mean	Std. Dev.	Min	Max
income	35	37,922	3,011	33,363	42,496
income2	35	35,157	3,620	30,700	42,496
catch	35	19,953,180	10,657,385	5,093,033	32,765,959
pop	35	8,108	1,231	6,646	9,845
prox	35	3.1	2.7	0.1	10.9
vessels	35	270	102	149	448

*note, ID was not included in this table due to the districts being arbitrarily numbered.

Table 5: Correlation matrix for the independent variables.

	income	income2	catch	pop	prox	vessels	ID
income	1.000	0.575	0.382	-0.282	-0.434	0.632	-0.952
income2	0.575	1.000	0.288	-0.373	-0.231	0.497	-0.632
catch	0.382	0.288	1.000	0.313	-0.092	0.384	-0.567
pop	-0.282	-0.373	0.313	1.000	-0.313	0.080	0.147
prox	-0.434	-0.231	-0.092	-0.313	1.000	-0.476	0.477
vessels	0.632	0.497	0.384	0.080	-0.476	1.000	-0.649
ID	-0.952	-0.632	-0.567	0.147	0.477	-0.649	1.000

Take note of the -0.952 correlation between income and district ID. It is hypothesized that this correlation comes from the connection between the decreasing district ID numbers as they move further south, and the various geographic factors that this involves. These factors include closer proximity to more prosperous fishing grounds such as George's Bank as we move further south, as well as greater distance from the abnormally large tidal fluctuations that are observed in the Bay of Fundy.

4: Analysis & Results

Analysis of the data began with plotting the different independent variables against the dependent variables, in single variable regressions. Once variables of interest were identified, their data was included in the multivariate regressions discussed in this section. Initially, a dummy variable was used to create a single set consisting of the summer and winter totals, but it was deemed ineffective due to repeating values for the Census variables.

4.1: Summer Data

In preliminary analysis, the variables of interest that were identified included proximity to wharf, vessel count, and income, which has been found to strongly correlate to district ID. These variables were plotted against the debris totals, and the charts are visible in the following 3 figures (figures 8, 9, & 10). The intuition behind the selection of these 3 variables was that they would be suitable indicators of the amounts of commercial fishing activity that was taking place near the sites.

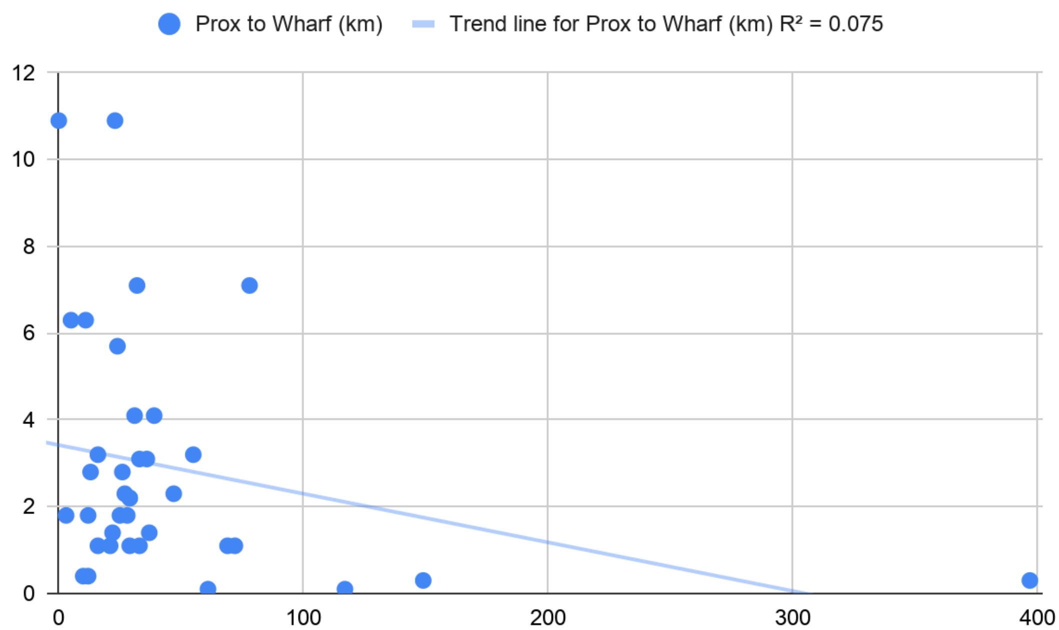

Figure 8. Plotting proximity to the nearest wharf against the summer debris totals.

Despite the low R^2 observed in Figure 8, proximity to wharf is the only variable from these 3 figures that makes it into the adjusted model. This is due to the value that was identified in the variable being used as a proxy for the distance from the Bay of Fundy, reinforcing the previous findings in this thesis.

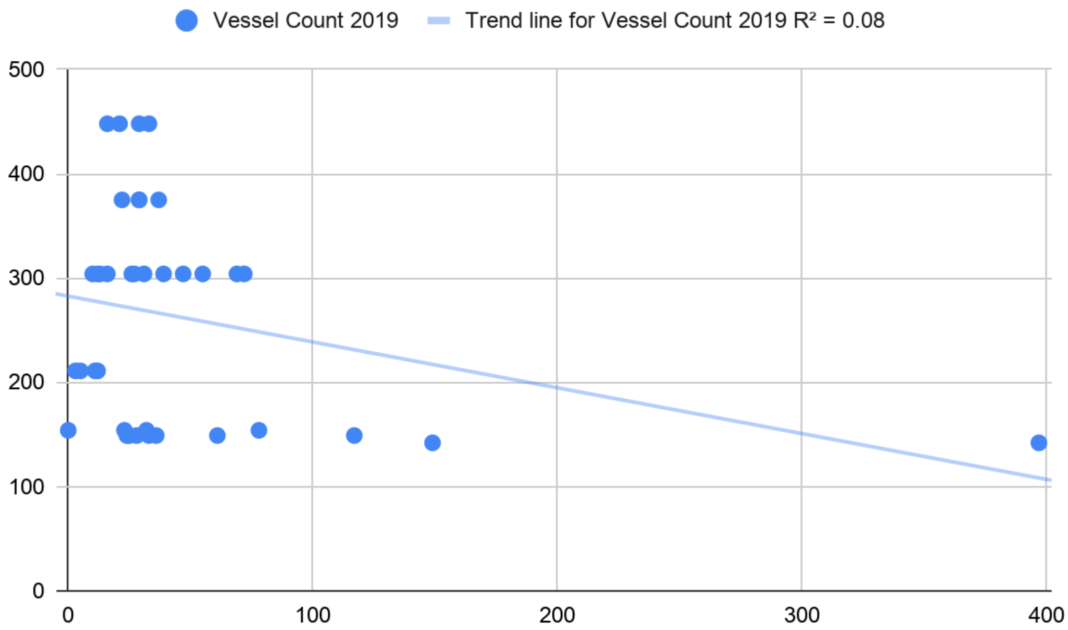

Figure 9. Plotting the vessel count against the summer debris totals.

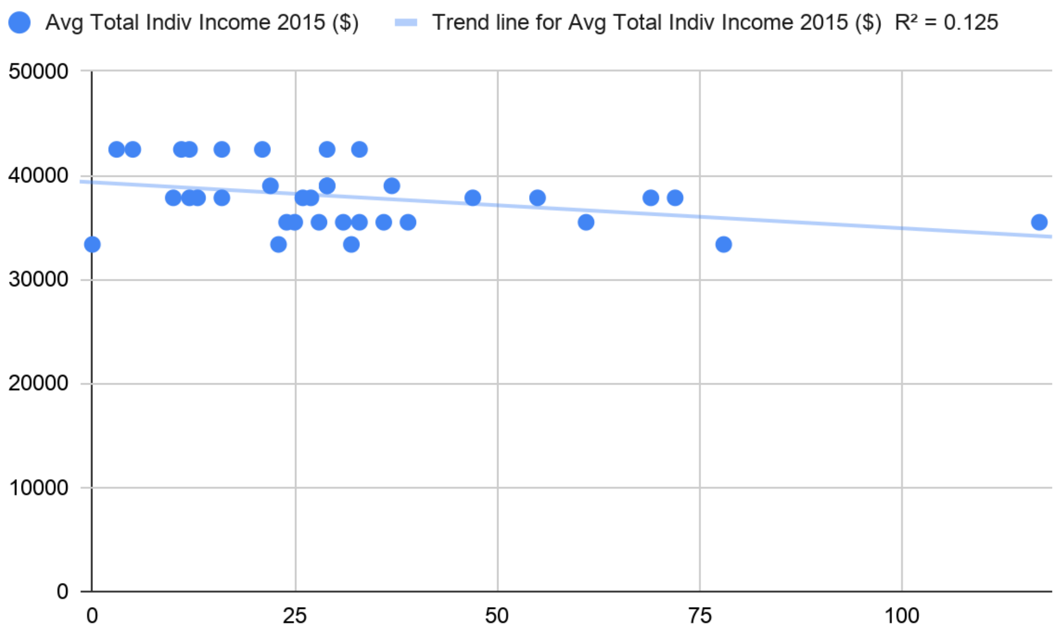

Figure 10. Plotting average individual income against the summer debris totals.

When viewing the previous figures, it is important to note that the low R^2 values can be associated with the small size of the data set. If the population were larger, it may have been easier for these variables to explain the variances observed in the debris totals from the coastal sites.

The data was analyzed using R Software (Version 4.0.3), where a model was constructed with the six variables that seemed to be of the greatest importance based on the single variable plots, and the main hypothesis of this paper. The model was then refined to find the two variables with the greatest statistical significance. Only the adjusted models will be shown, as it was deemed unnecessary to display the six-variable models due to them being overfitted for such a small data set.

Before looking at the results of the regressions it should be mentioned that while the model was able to describe the summer data set to an extent, it was not nearly as effective when examining the winter data. These results will be shown after the results of the summer regressions, and possible conclusions will be discussed in Section 5.

Table 6. The adjusted summer model.

Adjusted Model	**Dependent Variable: Summer Total Constants:**
prox	-4.5747***
ID	6.8215***
Constant	-187.0456***
N	35
R^2	0.3253
Adjusted R^2	0.2831
Residual Std. Error	20.3858 (df = 32)
F Statistic	7.7125*** (df = 2; 32)
Note: *p<0.1; **p<0.05; ***p<0.01	

It was observed that district ID and proximity to the nearest wharf were the two variables with the greatest statistical significance (p-values less than 0.01). It is shown that as the sites become closer to a wharf the debris totals increase, and as the district ID lowers (moves further south) the debris count decreases.

A Variance Inflation Factor test was run, which did not detect multicollinearity due to VIF values below 5. White's Test for heteroskedasticity did not detect signs of heteroskedasticity due to the calculated p-value being greater than 0.05, which led to the rejection of the null hypothesis that heteroskedasticity exists within the model. It is important to remember that these tests are not to be taken with absolute certainty, due to the small population size.

4.2: Winter Data

As previously mentioned, the independent variables were far less capable of describing the variances in the winter totals. Therefore, this section will be much shorter than the section on the summer data.

Table 6. The adjusted winter model.

Adjusted Model	**Dependent Variable: Summer Total Constants:**
prox	-2.6036
ID	8.7898**
Constant	-253.8428**
N	31
R^2	0.1674
Adjusted R^2	0.1079
Residual Std. Error	37.0243 (df = 28)
F Statistic	2.8151* (df = 2; 28)
Note: *p<0.1; **p<0.05; ***p<0.01	

Taking a look at the table above, we can see that proximity remained statistically insignificant, and income is only significant at the p-value less than 0.1 level. Taking a look at the R^2 and the adjusted R^2 values, we see that this model is not a good fit. It was unnecessary to run the tests for multicollinearity and heteroskedasticity in this case, as we already conclude that the model is ineffective at describing the winter data.

The main hypotheses behind proximity and district ID being the two most statistically significant variables are as follows; for proximity, it is believed that the proximity to wharves plays a larger role in the summer due to the increase in leisure boating activity that is associated with the season. While there is obviously fishing-related activity taking place at these wharves year-round, there is an increase in activity during the summer of these wharves being used for recreational purposes. As for the district ID, it is believed that this variable acts as a proxy for open ocean compared to the more enclosed areas near, or within the Bay of Fundy, where they are subject to large tidal fluctuations. These areas within the Bay are also further away from fishing areas that are generally seen as more desirable, such as George's Bank which is further south.

5: Conclusions and Future Possibilities

This thesis sought to find an explanation for the variances observed in the amounts of debris that were found on the shores of Lobster Fishing Area 34 in Southwest Nova Scotia; keeping this goal in mind, we examined data from two different time periods in order to determine whether or not we could find explanatory power stemming from data that was collected from various sources including DFO and Statistics Canada. An attempt was made to unify the data from the two different seasons using a dummy variable, but it was found to be less effective than keeping the two sets separate; this perhaps could have been due to the poor explanatory power that the independent variables have over the winter set, or it could stem from the values repeating in the Census data when the dummy is integrated.

One of the reasons that was hypothesized for why the summer counts could be explained by proximity is due to the increase in boating activity and general beach activity that is associated with the season, however this is simply anecdotal. Further data such as a list of boating associations and registered pleasure crafts in the area would be needed to perform such an analysis.

Unexpectedly, the DFO-provided data such as the vessel counts and landed quantities did not prove to be strong predictors of the debris counts. One important relationship that was noted in the data, was the strong negative correlation between district ID and income. This means that as we move further south (district ID numbers decreasing), the income increases. It is also worth mentioning that this comes with increasing vessel counts as we move closer to more prosperous fishing grounds (such as George's Bank), and further away from the abnormally large tides that are observed in the Bay of Fundy. It is our belief that the district ID variable from the regressions acts as a proxy for the aforementioned theories.

Due to the hypothesis of this thesis regarding the fishing industry, some data that was collected at the sites was not used in the regressions due to it being unrelated. This opens up the possibility for future studies to take a closer look at some of these variables for which data was collected. It was discussed that the tides, direction of the coastline, wind speed and direction, and significant weather within the days preceding the data collection could all be significant factors in explaining the observed amounts of debris.

Dr. Raymond and I have discussed our desire to continue this study in the future, in order to collect a more comprehensive set of data that can be used to further our understanding in this area. This thesis will be shared with the Department of Fisheries and Oceans in hopes of receiving further support in our endeavours.

6: Appendix

Image 1. Lobster traps observed at one of the data collection sites.

Image 2. Various debris types including plastic, rope, and timber.

Image 3. An entanglement of fishing gear, rope and other types of debris.

7: References

Antonelis, K., Huppert, D., Velasquez, D., & June, J. (2011, October). Dungeness Crab Mortality Due to Lost Traps and a Cost–Benefit Analysis of Trap Removal in Washington State Waters of the Salish Sea. Retrieved December 02, 2020, from https://www.researchgate.net/publication/254311405_Dungeness_Crab_Mortality_Due_to_Lost_Traps_and_a_Cost-Benefit_Analysis_of_Trap_Removal_in_Washington_State_Waters_of_the_Salish_Sea

Goodman et al. (2019). Benthic marine debris in the Bay of Fundy, eastern Canada: Spatial distribution and categorization using seafloor video footage. *Marine Pollution Bulletin*, *150*. Retrieved August 5, 2020, from https://www-sciencedirect-com.library.smu.ca/science/article/pii/S0025326X19308781

Gregory, M. (2009). Environmental Implications of Plastic Debris in Marine Settings—Entanglement, Ingestion, Smothering, Hangers-On, Hitch-Hiking and Alien Invasions. *Philosophical Transactions: Biological Sciences, 364*(1526), 2013-2025. Retrieved August 5, 2020, from www.jstor.org/stable/40485979

Marin, Camila Burigo, Niero, Henrique, Zinnke, Isadora, Pellizzetti, Maria Amélia, Santos, Paulo Henrique, Rudolf, Adriana Cestari, . . . Polette, Marcus. (2019). Marine debris and pollution indexes on the beaches of Santa Catarina State, Brazil. Regional Studies in Marine Science, 31, 100771.

Newman S., Watkins E., Farmer A., Brink P.., Schweitzer JP. (2015) The Economics of Marine Litter. In: Bergmann M., Gutow L., Klages M. (eds) Marine Anthropogenic Litter. Springer, Cham. https://doi-org.library.smu.ca/10.1007/978-3-319-16510-3_14

US Department of Commerce, N. (2008, November 14). What is marine debris? Retrieved August 05, 2020, from https://oceanservice.noaa.gov/facts/marinedebris.html

Widmer, W., & Hennemann, M. (2010). Marine Debris in the Island of Santa Catarina, South Brazil: Spatial Patterns, Composition, and Biological Aspects.

Journal of Coastal Research, 26(6), 993-1000. Retrieved August 9, 2020, from www.jstor.org/stable/40928838