QUANTITATIVE COMPARISON OF LEVELS OF ORGANIC WASTES FROM FOUR MAJOR SOURCES AT FOUR SCALES ALONG THE NEWFOUNDLAND COASTLINE

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Quantitative comparison of levels of organic wastes from four major sources at four scales along the Newfoundland coastline.

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Abstract

This study compared the levels of organic wastes released along the Newfoundland coastline from four different sources during the period 1992-1996. These sources include offal from fish plants, domestic sewage, aquaculture wastes (wasted feed and faeces), and sawmill wastes (bark, shavings, wood chips, slabs, sawdust). The total amount of organic wastes entering the coastal waters had never been quantified before this study, and hence, comparisons of levels of wastes from different sources had not previously been made. The scattered information on sources of organic wastes was assembled in order to determine and compare the four major sources in Newfoundland. This study also determined whether spatial scale is a factor in determining the greatest and smallest sources of organic wastes released. The levels of wastes released were quantified and compared at four scales along the Newfoundland coastline. Three hypotheses were addressed concerning the relative importance of the sources of wastes: i) The level of organic wastes released from coastal sawmills is lower than that released from the other three sources. ii) At the spatial scale of the entire island the largest levels of organic wastes are from sewage, followed by fish plant offal, and finfish aquaculture. iii) The relative level of organic wastes released from sewage, aquaculture, and offal differs according to spatial scale. As the scale studied becomes smaller (from the entire island, to coastal regions, to fisheries statistical areas, to fisheries statistical sections) either of the three sources could be the major contributor of organic wastes.

At the largest spatial scale examined, the entire island, offal was the largest contributor of organic wastes, followed by sewage and sawmill wastes, with aquaculture as the smallest contributor of wastes. The region of the island with the greatest amount of organic wastes released into the coastal waters was the Avalon Peninsula, while the Northern Peninsula had the least amount of wastes being released. Two interesting trends were found in this investigation. First, aquaculture wastes are increasing at a high, steady rate in Newfoundland at a very localized coastal scale. This was not evident for the other sources of wastes studied. Secondly, although the offal levels for the entire island only increased slightly over the period studied, the form of the released offal changed greatly since the moratorium on Atlantic cod in 1992. Currently, there is a predominance of inorganic shells being released, which are more resistant to degradation than the flesh and viscera of finfish.

The next smallest spatial scale, coastal region (the coastline was divided into five regions), showed the same results as the scale of the entire island. Offal was the largest contributor of organic wastes and aquaculture the smallest contributor. The two smallest spatial scales studied, fisheries statistical area (the coastline was divided into 14 areas) and fisheries statistical section (the areas were divided into 49 sections), showed variation within the two larger coastal scales. The results for the area and section scales corresponded with those for the region scale in that the places with the greatest levels of release (St. John's, Southern Shore,

Conception Bay) were on the Avalon Peninsula, and the places with the lowest levels of release were on, or very near, the Northern Peninsula (Bonne Bay, Gros Morne Park area, Strait of Belle Isle area). Overall, most areas and sections had offal as the greatest contributor and aquaculture as the smallest contributor of wastes. However, the importance of spatial scale was evident from the increased variability in type and level of organic wastes released as the coastal scale examined became smaller. This was due to variation in the population and in level and type of industry between places along the coast.

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Table of Contents

	Page
Abstract	ii
Acknowledgements	iv
Table of Contents	v
List of Tables	vii
List of Figures	ix
List of Abbreviations	xii
Chapter 1: Introduction	1
1.1: Offal	5
1.2: Sewage	9
1.3: Aquaculture	10
1.4: Sawmill wastes	14
1.5: Degradation and assimilation of organic wastes	16
1.6: Hypotheses	17
Chapter 2: Quantitative comparison of sewage, aquaculture wastes, sawmill wastes and offal for the entire Newfoundland coastline	21
2.1: Abstract	21
2.2: Introduction	22
2.3: Methods	23
2.3.1: General methods	23
2.3.2: Finfish aquaculture wastes	27
2.3.3: Domestic Sewage	33
2.3.4: Offal	36
2.3.5: Sawmill wastes	43
2.4: Results	50
2.5: Discussion	53
2.6: Conclusion	61

Table of Contents

Chapter 3: Quantitative comparison of sewage, aquaculture wastes, and offal for 5 coastal regions, 14 fisheries statistical areas, and 49 fisheries statistical sections 70

3.1: Abstract 70
3.2: Introduction 71
3.3: Methods 72
3.4: Results 73
3.4.1: Comparison of amount and type of wastes within and between spatial scales. 82
3.5: Discussion 91
3.6: Conclusion 99

Chapter 4: Predictions and preventative measures for coastal organic waste release in Newfoundland. 119

Literature cited 135

List of personal communications 144

Appendices 146

Appendix A 146
Appendix B 147
Appendix C 156
Appendix D 158
Appendix E 160
Appendix F 162

List of Tables

Page

Table 1.1. Student rankings for the largest contributor of organic wastes in coastal Newfoundland. 19

Table 2.1. Fisheries statistical areas and sections in Newfoundland.......... 26

Table 2.2. The five coastal regions studied and the areas and sections they contain. 27

Table 2.3. Coastal Newfoundland municipalities with partial or total municipal sewage treatment. 36

Table 2.4. Main species processed and their percentage yields, in Newfoundland fish processing plants. 39

Table 2.5. Percent yields for less common species in Newfoundland fish processing plants. 41

Table 2.6. Forestry districts and corresponding fisheries areas and sections. (Note: Inland districts and Labrador were omitted).......... 45

Table 2.7. Percentage of production from the large sawmills (100,001-500,000+ fbm/yr), and the small sawmills (1-50,001 fbm/yr) in 1996-97.......... 49

Table 2.8. Total organic wastes (dry mass in kg) released from 1992-1996 in coastal Newfoundland from offal, sewage, sawmills and aquaculture. 51

Table 2.9. Rank of the four major sources of organic wastes according to amount of waste released. 52

Table 2.10. Number of sawmills per size class, number of small sawmills (class 1 - class 4), and percent of small sawmills per district (excluding class 99) in 1996-97. 55

Table 2.11. Comparison of salmonid aquaculture biomass and wastes, in Newfoundland, as calculated from three different data sources. 59

List of Tables cont'd

Page

Table 3.1. Coastal regions ranked according to level of organic wastes released. 83

Table 3.2. Coastal areas ranked according to level of organic wastes released. 84

List of Figures

	Page
Figure 2.1. Fisheries statistical areas (A-N) and fisheries statistical sections (1-49) for coastal Newfoundland.	62
Figure 2.2. Fisheries statistical sections (1-49) for coastal Newfoundland.	63
Figure 2.3. Total organic wastes (dry mass) released along the Newfoundland coastline from 1992-1996 in the form of offal, sewage, aquaculture wastes and sawmill wastes	64
Figure 2.4. Total offal (dry mass) released from crab and shrimp processing and from finfish processing in Newfoundland from 1992-1996.	65
Figure 2.5. Newfoundland's eighteen forestry districts as defined by the Department of Forestry Resources and Agrifoods	66
Figure 2.6. Maximum level of sawmill wastes (dry mass) released in Districts 1-7 from 1992-1996	67
Figure 2.7. Maximum level of sawmill wastes (dry mass) released in Districts 8-15 from 1992-1996.	68
Figure 2.8. Maximum level of sawmill wastes (dry mass) released in Districts 16-18 from 1992 -1996	69
Figure 3.1. Total organic wastes (dry mass) released from Regions 1-5 from 1992-1996.	101
Figure 3.2. Total organic wastes (dry mass) released in Areas A-E from 1992-1996.	102
Figure 3.3. Total organic wastes (dry mass) released in Areas F-J from 1992-1996	103
Figure 3.4. Total organic wastes (dry mass) released in Areas K-N from 1992-1996.	104

List of Figures cont'd

Page

Figure 3.5. Total organic wastes (dry mass) released in Sections 1-5 (Area A) from 1992-1996. 105

Figure 3.6. Total organic wastes (dry mass) released in Sections 6-9 (Area B) from 1992-1996. 106

Figure 3.7. Total organic wastes (dry mass) released in Sections 10-13 (Area C) from 1992-1996. 107

Figure 3.8. Total organic wastes (dry mass) released in Sections 14-19 (Area D) from 1992-1996. 108

Figure 3.9. Total organic wastes (dry mass) released in Sections 20-23 (Area E) from 1992-1996. 109

Figure 3.10. Total organic wastes (dry mass) released in Sections 24-26 (Area F) from 1992-1996. 110

Figure 3.11. Total organic wastes (dry mass) released in Sections 27-28 (Area G) from 1992-1996. 111

Figure 3.12. Total organic wastes (dry mass) released in Sections 29-32 (Area H) from 1992-1996. 112

Figure 3.13. Total organic wastes (dry mass) released in Sections 33-35 (Area I) from 1992-1996. 113

Figure 3.14. Total organic wastes (dry mass) released in Sections 36-39 (Area J) from 1992-1996. 114

Figure 3.15. Total organic wastes (dry mass) released in Sections 40-41 (Area K) from 1992-1996. 115

Figure 3.16. Total organic wastes (dry mass) released in Sections 42-44 (Area L) from 1992-1996. 116

List of Figures cont'd

	Page
Figure 3.17. Total organic wastes (dry mass) released in Sections 45-47 (Area M) from 1992-1996.	117
Figure 3.18. Total organic wastes (dry mass) released in Sections 48-49 (Area N) from 1992-1996.	118

List of Abbreviations

Abbreviation	Name
BOD	Biochemical oxygen demand
CCFI	Canadian Centre for Fisheries Innovation
DFRA	Department of Forest Resources and Agrifoods
DFA	Department of Fisheries and Aquaculture
DFO	Department of Fisheries and Oceans
fbm	foot board measure (length measurement of logs)
FCR	Feed conversion ratio
FPI	Fishery Products International
g	gram
k	kilogram
Mfbm	1000 foot board measure
MMfbm	1,000,000 foot board measure
N	Nitrogen
NSGA	Newfoundland Salmonid Growers Association.
P	Phosphorus
SI units	International system of units
t	metric tonne (1000 kg)
TBW	total body water

Chapter 1: Introduction

There are two disposal options for the majority of solid wastes, on the land or in the ocean. The release of wastes into the ocean has resulted in widespread coastal marine eutrophication. Human induced organic enrichment is the largest source of pollution on marine sediments (Dunstaffnage 1998). Eighty percent of all global marine pollution originates from land-based sources. Therefore, estuaries and coastal marine regions show the greatest deterioration via human impacts, while the deeper waters are relatively unpolluted (Kennish 1998). The problem of coastal eutrophication is increasing in areas where the human population is increasing (Rosenberg *et al.* 1990). Severe anthropogenic effects are evident in shallow estuarine habitats around large cities and industrial regions world-wide (Root 1990). Stratified coastal waters are particularly susceptible to eutrophication and its effects (Rosenberg *et al.* 1990).

There are five main sources of pollution in the coastal marine environment: degradable wastes, fertilizers, dissipating wastes, particulates, and conservative wastes (Clark 1992). This thesis is focused on degradable wastes, which are composed of organic matter and are subject to bacterial decomposition (Clark 1992). The levels of dry organic wastes released into the coastal waters of Newfoundland from four sources are quantified. These sources include fish plant offal, finfish aquaculture wastes (excess feed and faeces only - fish mortalities were not considered in the study), domestic sewage, and sawmill wastes (bark, shavings, wood chips, slabs and sawdust).

The addition of wastes to any environment will change its physical, biological and chemical properties (Goldberg 1986). The increased input of organic wastes into coastal waters by man may destroy marine habitats and ecosystems. The degradation of nearshore marine habitats by anthropogenic input of wastes can be severe and a number of effects are normally apparent. The most negative effects include reduced water quality and hypoxia or anoxia; fish and shellfish populations with abnormalities and mortalities; marine communities that have changed in abundance, location, and diversity; loss of habitat such as aquatic vegetation; shellfish harvesting closures and beach closures due to contamination; and human contraction of disease from contaminated shellfish or swimming in contaminated water (Kennish 1998). In addition, toxic and harmful algal blooms may occur.

The total annual release of organic wastes into Newfoundland's coastal waters from various sources has never been quantified. Comparisons of levels of wastes from different sources have not been made. Information only exists on release by individual sources, such as sewage and aquaculture. The principal reasons for this study are to assemble the scattered information on sources of organic wastes to compare the level of dry wastes being released by sewage, aquaculture, fish plants and sawmills in Newfoundland, and to determine whether spatial scale is a factor in determining the greatest and smallest sources of organic wastes released. There are several sources of organic wastes that are released into the coastal waters, some of which gain more public attention than others (i.e. sewage into St. John's harbour), and some of which are more visible than others (i.e. barges of offal). This makes it difficult to assess which of the sources of wastes are the largest contributors without gathering all of the available data and making comparisons.

This study also enabled the quantification of the total release of organic wastes to show the cumulative levels of dry organic wastes from four different sources. Environmental impact depends on the release of wastes from all sources. The effects of one project may contribute and interact with the effects of another project, but in Canada this is currently not taken into consideration in an Environmental Assessment (EA). The new Canadian Environmental Assessment Act was supposed to include a guide to cumulative environmental effects of different projects (Canada 1993). However, the CEARC literature does not give any good cumulative impact assessment techniques (Storey 1998). This thesis provides a step towards such techniques by giving a method by which multiple industry waste release may be evaluated. The impact of this release can not be evaluated if the necessary information is scattered, as it is in Newfoundland for organic wastes.

Generally, environmental impact depends on the spatial scale of the area into which wastes are being released. The localized effects of organic wastes are seen in some coastal regions of Newfoundland, for instance in the St. John's harbour. However, at a larger scale, the Canadian marine environment is relatively uncontaminated according to world standards (CEPA 1994), as is Newfoundland's marine environment overall. Inputs that may be negligible on a large scale, for instance the entire Newfoundland coastline, can be very important on a smaller scale, such as in an individual bay. Scale is important when considering ecological variability. Impact on biological and physical factors is dependent on the scale of analysis in the aquatic (Steele 1978) and terrestrial (Urban *et al.* 1987) environments. Each of the wastes quantified in this thesis (except sawmill wastes) are examined at four spatial scales along the Newfoundland coastline.

Traditionally, the coastal waters have been the base of the Newfoundland economy. A very relevant concern regarding the release of organic wastes is the possibility of nearshore habitat degradation which can negatively affect juvenile fish populations, crustaceans, and other marine organisms which are all an important part of a healthy marine community. The inshore fishery, aquaculture, and tourism are important components of the economy and all require unpolluted waters along the coastline. Unpolluted waters are particularly important for a healthy aquaculture operation and for certain facets of the inshore fishery i.e. the lobster fishery, because these bottom dwellers are affected by offal. In addition, the eggs of Atlantic cod, *Gadus morhua*, are endangered when hypoxia or anoxia occurs at eighty to one hundred meter depths where the eggs sink before they develop their buoyancy (Rosenberg *et al.* 1990). The organic wastes discussed in this thesis are generally released in waters, in many regions, shallower than 80-100 m and closer to the coastline. Currently, in the region of Newfoundland, codfish spawning is concentrated in coastal waters (Smedbol and Wroblewski 1997). Quantification of organic input into coastal waters may increase awareness of the potential problem in regions, particularly where cumulative impacts may be observed. This awareness may lead to improved controls on the release of organic wastes and help ensure better management in the future.

Much of the information for this study was gathered through personal communication. Due to the large number of personal communication references a separate List of Personal

Communications is presented after the Literature Cited.

1.1: Offal

Harvesting the ocean's resources has always been an important component of the economy in Canada's coastal provinces. In Newfoundland, it is often accompanied by the disposal of fish wastes (offal) back into the marine environment. Marine disposal of fish waste from shore-based processing plants is not a common practice in the other Maritime Canadian provinces (Tidmarsh *et al.* 1986). In Newfoundland, before the designation of gurry grounds (a marine region where fish waste is disposed), offal was dumped into nearshore waters for tidal dispersal. In the 1980's, however, there was "inconsistent use" of the appointed gurry grounds by the fish plants (Barrie 1985) creating more widespread dumping in Newfoundland than today. Currently, fish processing plants must apply for an ocean dumping permit and release wastes only at a designated site (Appleby and Scarrat 1989). Gurry grounds, which covered an extensive area, are no longer used in Newfoundland. A smaller, more localized marine region is utilized to dump wastes (Wadman 1997 pers. comm. list) and there is no limit on the amount of fish waste dumped by a plant at these sites (Wadman 1998 pers. comm. list). However, Barrie (1985) reports that in Newfoundland, if more than 450,000 kg/yr are dumped in the ocean, an ocean dumping permit is required by the fish plant. In 1983, about 80 marine disposal locations for offal were present in Newfoundland (O.D.C. Scientific Ltd. 1983). There were 47 dumping permits (for 35 locations) issued in Newfoundland in 1998 for fish plant offal. The

Environmental Protection Branch of Environment Canada has a very limited and unreliable record of the amount of offal dumped in Newfoundland at these sites (Wadman 1997 pers. comm. list). The provincial Department of Fisheries and Aquaculture keeps no record (Tucker 1997 pers. comm. list).

A large amount of waste results from fish processing. Offal may consist of the entire fish, only the viscera, or the skin, heads, fins, tails, and backbones that remain after filleting (Hayes *et al.* 1994). During the filleting of groundfish, such as Atlantic cod, 40% to 60% of the fish is discarded. When fish, such as salmon, is cut into steaks or canned 30% of the fish is wasted. When the landed fish is inedible, or when only the roe is wanted, i.e. from lumpfish and herring, 80% or more of the landings may be discarded (Hayes *et al.* 1994). After processing, up to 80% of the landed weight of shellfish such as crab and shrimp is waste (Hayes *et al.* 1994). In Newfoundland, the form of the released offal has changed since the 1992 moratorium on Atlantic cod because the fishing industry is focusing more on crab and shrimp. The hard inorganic shells of crab and shrimp are not degraded as quickly as other forms of offal (i.e. viscera, skin, etc.) and thus may accumulate in coastal waters.

The release of organic wastes in the form of offal varies seasonally and according to changes in the composition of the catch. Different species vary in body composition and within a species there are seasonal differences, both of which affect the composition of offal during processing. Lobster and crab wastes are 7% chitin, 33% protein, calcium carbonate and oil, and 60% water (Tidmarsh *et al.* 1986). Finfish have a high protein content, and shrimp contain carotenoid pigments, chitin, little ash, high levels of calcium, and little protein (Ming-Lesage

1991, Tidmarsh *et al.* 1986). Crab is similar to shrimp except for the very hard mineralized carapace which gives crab a higher ash (mineral) content than shrimp (Ming-Lesage 1991). The carapace also reduces the rate of decomposition.

The marine disposal of offal may create local environmental problems. Some of these problems may include: accumulation of heavy metals from fish flesh at poorly flushed dumping sites used extensively over a long period; an anoxic benthic environment where water circulation is poor; reduction in aesthetic quality of the region; increases in populations of scavengers, and hypernutrification resulting in eutrophication (Barrie 1985). Aesthetic problems include floating solids, surface oil slicks, water discoloration, strong odours and swarms of flies. In addition, the high levels of organic wastes may greatly increase bacterial pathogens and in regions of domestic and industrial effluents may cause fin-rot and possibly tumours in some fish (Menon and Macdonald 1978). During research for this study some local residents said liquid effluent is released from the fish processing plant directly into the surrounding water in their towns. These discharges contain particles of fish, oil, blood, slimes, and bacteria which have caused problems in some regions of Canada, including degradation of water quality, depletion of oxygen levels, and contamination of sediments in harbours and coves (Statistics Canada 1997). The spread of parasites and disease may also occur. Many molluscs become contaminated by fecal bacteria at large distances from the actual fish plant discharge; and many shellfish areas have closed in the Maritimes due to this contamination (Statistics Canada 1997). Bacterial contamination of offal may be occurring via insects, rodents, and seagulls in some plants (Menon and Macdonald 1978). In 1983, 15 of the 80 gurry grounds in Newfoundland had environmental problems such as offal washing up on beaches, fouled fishing nets, and disrupted lobster fisheries (O.D.C. Scientific Ltd. 1983).

The dumping of offal in Newfoundland is not confined to the designated dumping grounds. Fish wastes fall off overloaded barges en route to dumping sites (Williams 1997a, 1997b, pers. comm. list). This creates an oily slick in harbours. Offal is sometimes disposed of in an illegal manner, such as over wharves, when fish meal plants are unable to keep up with the supply (Brown 1998 pers. comm. list). Offshore dumping may not occur when the weather is bad or when there is too much offal to transport (Brown 1998 pers. comm. list). When offal is dumped over the wharf it can cause problems for miles along the coastline. Reports are made to the Newfoundland and Labrador Department of Environment and Labour by residents regarding bad smells, aggregations of flies and unsightly beaches, due to rotting fish in the waters and along the shoreline (Brown 1998 pers. comm. list). Some offal is dumped inland at the local garbage dump, such as in Bay d'Espoir, but the liquid effluent is released into the bay along with small pieces of fish remains. The release of offal into regions of aquaculture activity may have a negative impact on the health of the caged fish.

Fish meal plants also release organic wastes and other substances into the environment. These plants can be a source of three problems: i) Blood and offal spills between the processing plant and the fish meal plant ii) Unpleasant odours iii) Liquid wastes (mainly blood liquor) released with a high biochemical oxygen demand and high levels of suspended solids (Tidmarsh *et al.* 1986). A fourth problem is *Salmonella* infection of the meal. The effluents may contain coliform and *Salmonella* bacteria which may be cycled back to humans via fish and shellfish harvesting in the contaminated local waters (Statistics Canada 1997).

1.2: Sewage

The release of domestic sewage is another major source of pollution in many coastal regions around the world. An expanding population with increasing material usage has resulted in increasing levels of wastes in the domestic sewage systems. In Atlantic Canada, 100 million cubic meters of raw sewage is released each year, and in St. John's alone 38.3 million cubic meters a year is released into the sheltered harbour (Nantel 1996). In Newfoundland, most communities discharge raw sewage directly into the coastal waters. When sewage is treated in Newfoundland, however, the sludge is not released into the coastal waters (Fisher 1997 pers. comm. list). During the research for this thesis local citizens in some rural areas said sewage treatment is not as extensive as the Department of Environment and Labour claim.

Marine organisms and human health are affected by pathogenic microorganisms in sewage. Pathogens per unit volume of sewage are much lower in a healthy population but even in developed countries, such as Canada, some pathogens can be detected (Downing 1986). Bacteria, viruses, and parasites found in stools may harm fish. If the fish are ingested by humans, hepatitis, myocardia, meningitis, diarrhea, and other infections may occur (Nantel 1996). Sewage contamination has caused hepatitis A and cholera outbreaks around the world (CEPA 1994).

Discharged sewage can have a negative impact on the aquaculture industry and on wild marine organisms. In Atlantic Canada the majority of the shellfish closures are caused by bacteria from municipal sewage discharges (CEPA 1994, Nantel 1996). Municipal wastewater is a source of contaminants in more than fifty percent of polluted shellfish area closures, and is the single cause in twenty percent of the shellfish closures (CEPA 1994, Nantel 1996, Statistics Canada 1997). Mussels, clams, and oysters feed by extracting food particles from water which passes through the mantle cavity (Brusca and Brusca 1990). Suspension feeding accumulates bacteria, viruses and chemicals that become concentrated in the tissues of bivalve molluscs at a large distance from the sewage discharge point (Statistics Canada 1997). Finfish experience sublethal effects from sewage as well. The release of sewage into waters near a finfish aquaculture facility could be very harmful to the caged fish, as well as to humans. In addition, sewage can smother and degrade bottom habitats and result in deoxygenation of water via eutrophication. Knowledge on the deposition and final dispersal of toxins and pathogens in raw sewage is limited. Consequently, the potentially harmful effects of released sewage have been hard to fully assess (Pearson 1985).

1.3: Aquaculture

Aquaculture, a food-production ecosystem that is changed into a more efficient one by increasing the yield per unit area (Ackefors and Enell 1990), is often viewed as having no negative repercussions on the aquatic ecosystem. Currently, in comparison to fishing, aquaculture yields 10-10,000 times more product (Ackefors and Enell 1990). This expansion, however, increases the wastes entering the adjacent waters. There are three general groups of wastes which are produced by finfish farms: i) wasted food and faeces, ii) metabolic by-products, and iii) biocides. The major components being introduced to the waters are organic carbon and nitrogen from the wasted food and faeces (Gowen and Bradbury 1987, Iwama 1991).

Finfish aquaculture is more of an environmental concern than shellfish aquaculture. This is because the source of fish culture waste is the addition of feed to the water (De Silva and Anderson 1995). In British Columbia 32,000 tonnes of farmed salmon produce the same amount of sewage as 500,000 people (David Suzuki Foundation 1997). In addition, it takes four pounds of fish protein to produce one pound of netcage salmon in B.C. (David Suzuki Foundation 1997). Folke (1988) estimates that the intensive production of Atlantic salmon, *Salmo salar*, in net pens in Scandinavia utilizes the resources of the marine food web over an area that is 40,000-50,000 times larger than the area of the actual cages. The ecosystem area needed to support intensive aquaculture is quite large.

Finfish aquaculture is a relatively new industry in Newfoundland that predominately occurs in one large bay, Bay d'Espoir. In 1985 it began with a hatchery, and since the mid 1990's, five salmon farms have started in Bay d'Espoir. Four of these grow steelhead trout, *Oncorhynchus mykiss*, (66% of production) and one grows Atlantic salmon, *Salmo salar* (DFA 1998a). In 1998, there were 204 aquaculture licenses issued in Newfoundland. These 204 licenses included incubation facilities, hatcheries, freshwater farms and shellfish farms. In 1999, there were approximately 22 operating marine finfish sites around the island (Appendix

A). Of these 22 sites, nine are in Bay d'Espoir. Marine salmonid aquaculture is restricted to Bay d'Espoir, the other 13 farms in Newfoundland are exclusively Atlantic Cod, *Gadus morhua*, or Greenland Cod, *Gadus ogac*. There are two farms on the Southern Shore, five in Trinity Bay, two in Bonavista Bay, three in Placentia Bay and one in the Burgeo area. However, the number of farms changes from year to year. There is likely to be more wastage from sea-cages, used in the intensive finfish mariculture discussed above, than from tank and freshwater pond farms (Gowen and Bradbury 1987, Folke and Kautsky 1989).

The release of finfish aquaculture wastes may result in several negative consequences on the marine environment. The possible consequences include hypernutrification and eutrophication, benthic enrichment, increased biochemical oxygen demand, and bacterial changes (Silvert 1992). These impacts of aquaculture on the environment can cause ecological change, which may then affect the profitability of the aquaculture facility. Poor water quality can contribute to increased disease, slow growth, and poor feed conversion rates. Hypernutrification usually leads to increased primary production and phytoplankton blooms. Rearing salmon in sea-cages in bays can cause phytoplankton blooms that can make the water cloudy, reduce oxygen concentration in the water at night, and cause salmon mortalities (Pridmore and Rutherford 1992). There is evidence that nutrient discharge from coastal farms in Finland has caused eutrophication with resulting increases in phytoplankton biomass (Gowen 1994, Rosenthal *et al.* 1995). Some phytoplankton blooms are of toxic species. On Canada's west coast there have been algal blooms, due to nutrient enrichment of waters near salmon farms, that have killed salmon (Rosenthal *et al.* 1995). In addition, if nutrient enrichment is extremely high, turbidity and decreased light penetrating the water may limit the primary production in the region (Pillay 1992).

The water in the region of a fish farm can have a low oxygen content. The organic enrichment increases the oxygen consumption rate in the water, and if the demand outweighs the supply of oxygen the sediments in the area become anoxic. Water beneath salmon cages can be depleted in oxygen for long periods of time, even in turbulent locations, as the waste level grows (Gowen and Bradbury 1987, Folke and Kautsky 1989). This situation promotes anaerobic processes. Sediment metabolism is drastically higher in fish farm sediments than in natural sediments because organic matter decomposition in fish farm sediments is faster (Holmer 1991). Rosenthal *et al.* (1995) note that in sediments there may be increases in organic carbon, decreased sediment redox potential, and anaerobic activities such as nitrate reduction, sulphate reduction, and methanogenesis. They point out that if a large amount of wastes accumulate, outgassing of methane and hydrogen sulphide may occur with bubbles appearing at the surface. These conditions will kill most macrofauna and may kill the fish. This happened in Dark Harbour, New Brunswick, where a salmon farm had to be closed (Rosenthal *et al.* 1995).

Continuous deposition of wastes onto the bottom sediments of a fish farm can cause azoic patches that have no macrobenthic species present (Kupka Hansen *et al.* 1991, Pillay 1992). Microbenthic species may also be present in reduced numbers and microfauna may largely consist of opportunistic species (Pillay 1992). De Silva and Anderson (1995) observed that the opportunistic species, which are the first signs of ecological change, included the polychaete worms *Capitella* spp., *Scolelepis* spp., and *Polydora* spp. in salmonid farms in Norway.

1.4. Sawmill wastes

Sawmills are another important source of organic wastes into coastal waters of Newfoundland. In 1998 there were approximately 1900 sawmills in the Province, with about 1105 licensed (Blackmore 1998 pers. comm. list). They are mainly located in central and western Newfoundland. There are more sawmills and planing mills licensed to produce lumber in Newfoundland than in any other Canadian province (Trelawny 1994). These sawmills are generally located in coastal areas in the province (Trelawny 1990, Baird 1984). Dumping of sawmill wastes into coastal waters is currently illegal in Newfoundland (Blackmore 1998 pers. comm. list). If sawmill wastes enter the coastal waters it is reported to the Department of Environment and Labour or the Government Service Centres of the provincial Department of Government Services and Lands (Blackmore 1998 pers. comm. list). To date, no legal actions have been taken but legal threats have been made to sawmill managers regarding their dumping practices (Matthews 1998 pers. comm. list). Very few reports of illegal dumping are made, and it is currently not a public concern in Newfoundland (Ledrew 1998 pers. comm. list, Matthews 1998 pers. comm. list, Pyle 1998 pers. comm. list, Brown 1998 pers. comm. list). This may be due to a lack of reporting of the illegal dumping. The reports that are made are not consolidated into one general report and are not available to the public. No lists or statistics of illegal dumping are kept in Newfoundland (Matthews 1998 pers. comm. list).

In Newfoundland, in the past, there was poor management of the marine environment near sawmills. The majority of the sawmills were located along the coast and the logs were generally kept in the water. Thirty-eight to 40% of wood is processed (i.e. made into useable lumber) in Newfoundland, but this percentage varies widely from mill to mill (James 1998 pers. comm. list). When the logs are milled into lumber, by-products such as bark, slabs, edgings, chips from debarking slabs, shavings and sawdust result (Buggie 1993). The majority of the sawmill residue is bulldozed into piles near the mill (Young 1989). These large stockpiles of wastes may be carried by rain and wind to nearby coastal waters (Matthews 1998 pers. comm. list). Sometimes the sawmill wastes are discarded over an embankment into marine waters.

The larger mills, which generally sell their wastes for reuse, do not monopolize lumber production in Newfoundland. In fact, there has been an increase in the number of small sawmills over the past few decades (Trelawny 1994). The smaller mills are not large enough to invest in equipment that will increase the recovery of by-products, in general they do not have buyers for by-products, and many are in remote areas of the island where transportation costs of by-products are higher (Trelawny 1990). In addition, the payment of royalties on timber cut on Crown land does not promote the recovery of by-products by the small mills (Trelawny 1990). Thus, large amounts of sawmill residue (bark, shavings, sawdust, wood chips and slabs) are left to decay on land or in the coastal waters by the smaller mills.

Sawmill wastes may cause problems if left to accumulate in coastal waters. When they enter the water they begin to decay and use the available oxygen, like all organic wastes. Fish and crustacean eggs have no chance of survival in the soft decaying material (Matthews 1998 pers. comm. list). Leachate from wood chips can be a problem in coastal waters (Brown 1998 pers. comm. list). Sawdust and wood shavings are low in nitrogen and phosphorus. During decomposition bioinhibitory phenols, terpenes, and tannins are released from sawdust and wood shavings. Tannins, found in high quantities in bark, inhibit cellulose decomposition and are toxic to many organisms. In addition, the aesthetic value of the coastline is greatly reduced by piles of sawmill wastes.

1.5: Degradation and Assimilation of Organic Wastes.

The extent and rate of biochemical degradation of organic matter in cold oceans is important when considering the impact organic enrichment may have on the marine environment in Newfoundland. The decomposition of organic matter in the oceans is important in controlling the composition of the water and the sediments. In marine ecosystems decomposition is usually via oxic means in which oxygen is the electron acceptor, but anoxic pathways are found where organic matter sedimentation is high, and sulphate becomes the main electron acceptor (Lee 1992). Specific components of organic matter all have different degradation rates in marine waters (Hedges *et al.* 1988, Harvey *et al.* 1995). Different types of biochemical compounds have different structures and vulnerability to biological degradation, thus different decomposition rates (Henrichs and Doyle 1986). In a region of cold ocean waters, such as Newfoundland, the rate of degradation of organic matter is expected to be much slower than in warmer waters. Reduced rates of degradation may create a higher risk of accumulation from the release of organic wastes such as sewage, offal, aquaculture wastes, and sawmill wastes.

Marine environments may be affected differently by organic waste release depending on the hydrodynamic environment. The response to waste disposal depends on properties such as water volume, surface area, rate of water renewal, and vertical stratification (Aure and Stigebrandt 1990). Silvert (1994) notes that the level of impact depends upon the presence of benthic fauna, current speeds and circulation, seasonal storm conditions that cause resuspension, and the type of sediments. Carbon and nutrient inputs generally assimilate rapidly into the marine ecosystem in coastal regions that are open and hydrodynamically active. In coastal regions that are shallow, sheltered, or hydrodynamically inactive, the additional nutrients and carbon may become incorporated into the system much more slowly (Pearson 1985).

1.6: Hypotheses

In Newfoundland, the major contributors of organic wastes into the coastal waters are fish plant offal, raw sewage, finfish aquaculture, and sawmill wastes, leading to excessive quantities of nutrients such as P, N and organic C, in some regions. This thesis addresses three hypotheses concerning the relative importance of these contributors:

1. The level of organic wastes released from coastal sawmills is lower than from the other three sources. This is because it is currently illegal to dump sawmill wastes into marine waters.

2. At the spatial scale of the entire island the largest levels of organic wastes are from sewage, followed by fish plant offal, and finfish aquaculture. This inequality is hypothesized because few towns have sewage treatment and almost all sewage is released directly into the ocean; the majority of the towns on the island do not process fish; aquaculture is a fairly new, thus small and very localized industry in Newfoundland.

3. The relative level of organic wastes released from sewage, aquaculture, and offal differs according to spatial scale. As the scale studied becomes smaller (from the entire island, to coastal regions, to fisheries statistical areas, to fisheries statistical sections) either of the three sources could be the major contributor of organic wastes. This difference in the level of wastes released will depend upon the industry in the region (aquaculture, fish processing plants) and on the population. For instance, in a highly populated region, without sewage treatment, such as St. John's, sewage is expected to be the greatest contributor of organic wastes. In a region with numerous finfish farms, such as Bay d'Espoir, aquaculture is expected to be the greatest contributor of organic wastes.

To determine whether the expected ranking (Hypotheses 1 and 2) developed for this thesis matched the perceptions of the public, an informal survey was conducted. The survey was completed in an environmental science seminar class (October 19, 1998) in which the 11 students present were asked to rank the four major sources of coastal organic wastes (raw sewage, offal, aquaculture wastes, and sawmill residue) from the greatest contributor of organic wastes to the smallest contributor of wastes for the island of Newfoundland (Table 1.1). Three of the 11 students gave the same hypothesis as this thesis (Sewage 1, Offal 2, Aquaculture 3, Sawmill residue 4). The median rank for the entire class placed sewage as the largest source of organic wastes, offal as the second largest source, finfish aquaculture as the second smallest source, and sawmill wastes (bark, sawdust, shavings and slabs) as the smallest source of coastal organic wastes.

Table 1.1. Student rankings for the largest contributor of organic wastes in coastal Newfoundland.

Source of Organic Wastes	Rank	Median
Sewage	11111111111	1
Finfish Aquaculture	22233334424	3
Offal	333222 2243	2.5
Sawmill residue	44444423332	4

The following chapter gives the methodology used in this study. The chapters were organized so that the four spatial scales were examined in order of decreasing size. The entire island (largest spatial scale) was examined first, coastal region second, fisheries statistical area third, and fisheries statistical section last. The final chapter gives predictions about future organic waste release from finfish aquaculture, sewage, fish plants and sawmills, and discusses preventative measures.

Chapter 2: Quantitative comparison of sewage, aquaculture wastes, sawmill wastes and offal for the entire Newfoundland coastline.

2.1: Abstract

The largest spatial scale at which waste releases were quantified was the entire Newfoundland coastline. At the scale of the entire island, offal was the largest source of organic wastes entering the coastal waters of Newfoundland for each of the five years examined. During this period the form of the offal changed from being predominantly finfish wastes to being predominantly crab and shrimp shells. Sewage was the second largest contributor of organic wastes, sawmill wastes were the second smallest contributor and aquaculture was the smallest contributor. Sewage levels increased slightly over the five year period, offal levels were on the rise in 1995 and 1996 (but still had not reached 1992 levels), and sawmill wastes increased slightly over the five years. Excess feed and faeces from finfish aquaculture showed a large, steady, yearly increase from 1992 to 1996, unlike the other sources of wastes. This rise in aquaculture wastes occurred predominately in Bay d'Espoir, on the south coast. If the rate of increase continues it may only be about another 5-6 years before the level of aquaculture waste is similar to the level of offal released.

2.2: Introduction

The largest spatial scale being examined in this thesis is the entire Newfoundland coastline. It is expected that the coastal waters of Newfoundland have relatively low levels of organic waste release in comparison to other coastal regions with higher populations and levels of industry. Existing studies of marine organic waste release have not quantified the total mass of organic wastes released into coastal waters from different sources. These studies have not compared the mass of organic wastes released from various sources in a region. Most studies involved measurement of BOD, P, N, and C in coastal waters. For instance, Strain *et al*. (1995) quantified the tonnes of C, N, P and BOD entering the Letang Inlet in the Bay of Fundy, from salmon aquaculture, fish processing, a pulp mill, a sewage treatment plant, and natural sources. Hargrave *et al*. (1996) also studied organic enrichment of the Letang region by measuring N and BOD levels and comparing inputs (and impacts) from various sources including sewage, a pulp mill, a cannery, a fish plant and aquaculture. Several studies have been completed that quantify nutrients released in the form of carbon, phosphorus and nitrogen from marine salmonid farms (Enell 1995, Aure and Stigebrandt 1990, Ackefors and Enell 1990, Gowen and Bradbury 1987) and benthic organic enrichment (Frogh and Schaanning 1991, Holmer 1991, Lumb 1989). Seymour and Bergheim (1991) measured the dry weight of wasted feed and faeces from marine salmon farming. There were no studies found that could be used in a direct comparison of levels of organic wastes released along coastal Newfoundland.

At the spatial scale of the entire island it is expected that the largest levels of organic wastes are from sewage, followed by fish plant offal, and finfish aquaculture. The level of organic wastes released from sawmills is expected to be lower than from the other three sources.

2.3: Methods

2.3.1: General methods

The general objective of the thesis was to quantify the relative amount of organic wastes released from four major sources at four scales along the Newfoundland coastline. However, sawmill wastes could only be examined at two scales - the scale of the entire island and the scale of forestry district. This is because the data was only available at the scale of forestry district and these districts overlapped with the scales of coastal region, fisheries statistical area and fisheries statistical section. The other three major sources of organic wastes (sewage, aquaculture waste, and offal) were quantified and compared at four different coastal scales in regard to the smallest and largest contributing sources of wastes. The coastal locations with the lowest and greatest levels of organic wastes being released were identified.

The level of organic wastes released was quantified according to the mass of dry organic matter entering the water. In the case of offal both organic and inorganic wastes were considered because of the presence of finfish and shellfish (inorganic shells) wastes. All mass was converted to kilograms. Data were obtained from a number of organizations that initially gathered the data. The sources of data included the provincial Department of Fisheries and Aquaculture, the provincial Department of Municipal and Provincial Affairs, the provincial Department of Forest Resources and Agrifoods, the federal Department of Fisheries and Oceans (DFO), the Newfoundland Environmental Protection Branch of Environment Canada, fish farm owners, the Newfoundland Salmonid Growers Association (NSGA), the provincial Department of Government Services and Lands and their Government Service Centres, and the Canadian Centre for Fisheries Innovation (CCFI) at the Marine Institute of Memorial University of Newfoundland. These data enabled calculation of the amount of organic wastes released from the four sources.

Water samples were not taken for this study for a number of reasons. Sampling would not give the input of organic wastes, only the concentration. It would have been hard to estimate the input from the concentration because concentration depends on mixing rate as well as input. Analyzing water samples would not have enabled differentiation between the four major sources of organic wastes. It would have been impractical to attempt to gather water samples from along the entire Newfoundland coastline. In addition, laboratory analysis would have been very costly for such a large number of water samples. However, if mixing rates are known, a water sampling survey of coastal Newfoundland, for instance the three year survey of the waters of Trinity Bay for specific carbon compounds by Parrish *et al.* 1999, would be useful in conjunction with the results from this thesis. It would help give a better estimate of the fate of organic wastes entering the water.

The level of organic wastes released was quantified for 1992-1996. A longer period of time was initially going to be examined but data were not available for all four sources outside this five year period. The large coastal regions were chosen arbitrarily and consist of the Northern Peninsula, the East Coast and Central Newfoundland, the Avalon Peninsula, the South Coast, and the West Coast. Fisheries statistical areas are defined by the Department of Fisheries and Oceans. There are 14 fisheries areas in Newfoundland listed as A-N (Table 2.1, Figure 2.1). Within the fisheries statistical areas there are 49 fisheries statistical sections. See Figure 2.2 for the fisheries statistical sections and their geographical names (as listed in Table 2.1). The five large coastal regions contain the fisheries areas and sections (Table 2.2). Note that some of the coastal regions may include only parts of certain coastal areas (for instance, the Northern Peninsula, Region 1, contains part of Area M, all of Area N, and part of Area A). Coastal regions do not split the coastal sections.

It is important to take into account the potential level of water circulation in the various coastal locations. This was accomplished through visual observations and maps to determine the level of shelter from the ocean.

Table 2.1. Fisheries Statistical Areas and Sections In Newfoundland.

Area A/ Sections 1-5	**Area G / Sections 27-28**
1. Cape Norman – Cape Bauld	27. Cape Race – Cape Pine
2. Cape Bauld – Lobster Point	28. Cape Pine – Cape St.Mary's
3. Lobster Point – Cape Fox	**Area H / Sections 29-32**
4. Cape Fox – Partridge Point	29. Cape St.Mary's – Bauld Head
5. Partridge Point – Cape St.John	30. Bauld Head – Grandy Point
Area B / Sections 6-9	31. Grandy Point – Jean de Baie Head
6. Cape St.John – New Bay Head	32. Jean de Baie Head – Point Crewe
7. New Bay Head – Farewell Head	**Area I / Sections 33-35**
8. Change Islands – Fogo Island	33. Point Crewe – Point Rosie
9. Farewell Head – Cape Freels	34. Point Rosie – Boxey Point
Area C / Sections 10-13	35. Boxey Point – Pass Island Point
10. Cape Freels – Shoe Cove Point	**Area J / Sections 36-39**
11. Shoe Cove Point – Southern Head	36. Pass Island Point – Cape la Hune
12. Southern Head – Western Head	37. Cape la Hune – Fox Point
13. Western Head – Cape Bonavista	38. Fox Point – Rose Blanche Point
Area D / Sections 14-19	39. Rose Blanche Point – Cape Ray
14. Cape Bonavista – South Head	**Area K / Sections 40-41**
15. South Head – Bonaventure Head	40. Cape Ray – Harbour Point
16. Bonaventure Head – West Random Head	41. Harbour Point – Cape St.George
17. West Random Head – Hopeall Head	**Area L / Sections 42-44**
18. Hopeall Head – Salvage Point	42. Cape St.George – Long Point
19. Salvage Point – Grates Point	43. Long Point – Broad Cove Point
Area E /Sections 20-23	44. Broad Cove Point – Cape St.Gregory
20. Grates Point – Western Bay Head	**Area M / Sections 45-47**
21. Western Bay Head – Feather Point	45. Cape St.Gregory – Martin's Point
22. Feather Point – Topsail Head	46. Martin's Point – Daniel's Harbour
23. Topsail Head – Cape St.Francis	47. Daniel's Harbour – Point Riche
Area F / Sections 24-26	**Area N / Sections 48-49**
24. Cape St.Francis – Cape Spear	48. Point Riche – Ferolle Point
25. Cape Spear – Cape Broyle	49. Ferolle Point - Cape Norman
26. Cape Broyle – Cape Race	

Table 2.2. The five coastal regions studied and the areas and sections they contain.

Region	Sections	Areas
1. Northern Peninsula	46,47,48,49,01,02,03,04	Part of M, N, part of A.
2. East Coast and Central	05,06,07,08,09,10,11,12, 13,14,15,16	Part of A, B, C, part of D.
3. Avalon Peninsula	17,18,19,20,21,22,23,24, 25,26,27,28,29,30	Part of D, E, F, G, part of H.
4. South Coast	31,32,33,34,35,36,37,38,39	Part of H, I, and J.
5. West Coast	40,41,42,43,44,45	K, L, part of M.

2.3.2: Finfish Aquaculture Wastes

Information on aquaculture wastes came from the Newfoundland Salmonid Growers Association (NSGA), SCB Fisheries, four codfish farms in Trinity Bay, Sea Forest, and the Department of Fisheries and Aquaculture (DFA). Feed conversion ratios (FCRs), weight of feed added to cages, and the weight of fish produced were obtained from NSGA for salmonid farms in Bay d'Espoir. However, the majority of the values for salmonids could not be utilized in the calculations because many of the FCRs obtained from NSGA farms were negative values. These were due to a negative change in biomass caused by a loss of fish and a smaller than average weight sample (Tlusty 1998 pers. comm. list). Negative FCRs usually occur during the transition into or out of winter (Tlusty 1998 pers. comm. list). The data were collected by the fish farm owners from their own cages and many of the values seemed incorrect. Thus, results from subsequent calculations would also be incorrect. The FCRs gathered by NSGA were not reliable so production data from DFA and an FCR of 1.5 (from the literature) were utilized to compute waste release from salmonid farms. These data consisted of the mass (kg) of fish produced per year per economic zone.

Aquaculture wastes are commonly calculated with the FCR for the farm, using the calculations below:

- $\text{FCR} = \dfrac{\text{feed (kg/yr)}}{\text{fish biomass (kg/yr)}}$
- $\text{Fish biomass (kg/yr)} = \dfrac{\text{feed (kg/yr)}}{\text{FCR}}$
- Wastes (kg/yr) = feed (kg/yr) - fish biomass (kg/yr)

(Fish biomass is the mass of fish produced for market or, in other words, the mass of fish harvested).

This method does not take into account the metabolism of the fish and the release of faeces. In addition, the FCR is a ratio of dry weight feed to round (or wet) weight fish. Therefore, it does not give an estimate of the amount of wastes entering the water.

Aquaculture wastes were computed using two methods, one for salmonids and one for cod. The method below for salmonids takes metabolism into account:

- FCR = Feed (kg) / Biomass (kg)
- Feed = FCR x Biomass

- Unconsumed feed = Feed x % Unconsumed feed
- Consumed feed = Feed - Unconsumed feed
- Faeces = Consumed feed x % Faeces produced
- Wastes = Unconsumed feed + Faeces

The amount of feed added to the cages was determined using aquaculture production data from the provincial Department of Fisheries and Aquaculture. The mass (kg) of fish produced and FCR for salmon were utilized to get a yearly estimate of feed added to the water. The FCR is the amount of feed an individual fish eats and turns into mass. In a laboratory setting where fish are raised in tanks the amount of feed being consumed by the fish and being lost as waste is readily calculated. However, in a cage or pen it is impossible to determine the exact amount of feed consumed and the weight of uneaten feed. Therefore, a gross FCR is utilized in which the mean weight gain of fish in the cage is estimated and the amount of food added to the cage calculated.

A literature search showed that the FCR for salmonids varies greatly between regions. According to Pepper (1998 pers. comm. list) the salmonids in Bay d'Espoir have a FCR of 1.5-1.7. Tlusty (1997 pers. comm. list) reports a FCR of 1.5 for most farms in Bay d'Espoir. De Silva and Anderson (1995) also base their waste flow computations for typical net pen salmonids on a FCR of 1.5. Thus, a FCR of 1.5 was used to calculate the quantity of wastes from Newfoundland farms. However, lower FCRs are reported for farms in other regions. Ackefors and Enell (1990) give a FCR around 1.2 for Nordic countries, and similarly, Enell

(1995), gives a 1.2–1.3 feed conversion for Nordic farms, with Norway having a FCR of 1.2. Enell (1995) notes that 1.3 has been shown to be too high for Nordic marine farms but was utilized to prevent underestimation of wastes. Rosenthal *et al.* (1995) also report a FCR of around 1.2 for salmonids in New Brunswick, due to a shift to dry feed.

The resulting weight of feed was multiplied by the estimated percentage of unconsumed feed (24%) to give the kg of unconsumed feed. The amount of consumed feed was multiplied by the percentage of faeces (dry weight) per amount of food consumed (20%) to give the kg of faeces produced. These percentages were obtained from a wide range of values in the literature. The percentage of feed added but left unconsumed in net pen or cage culture has a wide range of estimates: 15-20% salmon (Gowen *et al.* 1985), 27% trout (Penczak *et al.* 1982), 20% salmon (Braaten *et al.* 1983), 20% salmon (Gowen and Bradbury 1987), 30% trout (Beveridge 1984), 32% salmon (Stewart 1994) and 30% salmonids (Seymour and Bergheim 1991). The percentage of ingested food that is released as faeces has a narrower range in the literature: 25-30% by salmonids (Iwama 1991), 26% by trout (Butz and Vens-Cappell 1982), 20% by salmon (Rosenthal *et al.* 1995), 20% by salmonids (Seymour and Bergheim 1991), and 20% by carnivorous fish (Brett and Groves 1979). For the calculations faeces was considered to be 20% of the ingested feed. The other percentages in the literature seemed too high for salmonids. Unconsumed feed was considered to be 24% (the median and average % of the literature values given above) of the added feed. Therefore, the estimates of wasted feed and faeces can be considered conservative according to some of the percentages given above.

The following are the calculations used for wastes from salmonid farms, with the estimates of fixed factors:

- FCR = Feed (kg) / Biomass (kg)
- Feed = 1.5 x Biomass
- Unconsumed feed = Feed x 24%
- Consumed feed = Feed - Unconsumed feed
- Faeces = Consumed feed x 20%
- Wastes = Unconsumed feed + Faeces

The Atlantic cod farms in the Province were dealt with differently. The amount of feed given to the fish was not available. In addition, literature values for percentages of unconsumed feed, consumed feed, and faeces were not available. Therefore, an FCR was used to obtain a rough estimate of wastes for the 13 cod farms. For most farms in Newfoundland the FCR for Atlantic cod is about 3.0 (Williams 1997a pers. comm. list, Williams 1997b pers. comm. list, Barrett 1997 pers. comm. list). Percentage of moisture in the feed (raw herring and caplin) and in the cod was accounted for by taking into consideration that the total body water (TBW) of a marine teleost is about 70.8% of the body weight (Hoar *et al.* 1979). Thus, 29.2% of the weight is dry tissue and bone. These percentages enabled waste estimations to be calculated as dry weight.

The following calculations were utilized for wastes from cod farms:

- Feed Weight (kg wet wt/yr) = FCR x Fish harvested (kg wet wt/yr)
- Fish Weight (kg dry wt/yr) = Fish harvested (kg wet wt/yr) x (29.2%)

The feed given to Atlantic cod consists of round weight herring and caplin. These are marine teleosts and therefore have a TBW content of about 70.8% and a dry weight of 29.2%.

- Feed Weight (kg dry wt/yr) = Feed added (kg wet wt/yr) x (29.2%)
- Wastes (kg dry wt/yr) = Feed weight (kg dry wt/yr) – Fish weight (kg dry wt/yr)

All calculations were done on a yearly basis.

The number and location of aquaculture sites for Newfoundland for 1997 and 1998 were obtained from the provincial Department of Fisheries and Aquaculture. Mussel and scallop farms were omitted from the calculations because feed is not added to the water and organic matter is not increased in the water by bivalve molluscs (though sedimentation underneath the farms does increase). Wastes are in the form of pseudofeces produced by these suspension feeding organisms. Water currents carry particulate matter into the mantle cavity, some of the suspended matter is trapped for food and the rest ejected from the mantle cavity as pellets called pseudofeces (Brusca and Brusca 1990). Wastes beneath the mussel farms are thus accumulated from the water, rather than being added to the water.

2.3.3: Domestic sewage

A number of methods were considered to calculate the amount of raw sewage being released into coastal waters. Commonly, quantities of municipal wastewater are determined from water use. Values for the liters per capita per day (Lpcd) for wastewater flow are available in the literature for small, mainly residential municipalities to large industrialized areas. However, this thesis examined levels of dry organic wastes released. Wastewater release could not be used because the composition is unknown and dry mass release could not be computed from levels of wastewater. The second method considered the number of people and the difference between average caloric intake of humans and the assimilative capacity of calories (which is about 75-77% of ingested calories). The third method calculated raw sewage by estimating the annual amount of excretory waste per person, and multiplying this waste level by the population of Newfoundland that utilized coastal disposal of raw sewage. This method was used because it enabled quantification of the dry mass of sewage released. A literature search found one other study, by Folke *et al.* (1997), that considered only the excretory release by humans in its calculation of sewage (they examined N and P releases, not mass of organic wastes as in this study). Like this study, they also underestimated the release of wastes because sources such as food processing, and household wastes were omitted.

Healthy adults in industrialized regions, eating a typical Western diet, have a stool weight with an upper normal limit of 200 g/day (Ammon 1995, Kreja 1996, Andreoli *et al.* 1997) or 73 kg/yr. The total water content of normal stools is 70%-85%, including the water content of bacteria (Ammon 1995). Thus, stools are 15%-30% dry weight. In the calculations, the dry weight of the faeces was considered to be the midpoint of these two percentages, 22.5% of the total weight. The following calculations were utilized.

- Domestic sewage (kg/year) = 73 kg/year x population x (22.5%)

The population of the incorporated towns and communities of Newfoundland from 1951-1996 was obtained from the Municipal Directory of the Department of Municipal and Provincial Affairs. A list of the incorporated coastal towns, and the area and section in which they are located, is in Appendix B. In 1998, there were thirty-six municipalities with sewage treatment in Newfoundland and Labrador, including both treatment by private companies and municipal treatment (Golding 1999 pers. comm. list). Sewage treatment by private companies was not taken into account in this thesis. Many of the treated towns are located inland or in Labrador and were omitted from the calculations because these areas are outside the scope of this thesis. The 14 coastal towns with municipal sewage treatment (Table 2.3) were taken into consideration. Some towns have only a percentage of their sewage treated. When computing the quantities of released sewage the fact that Arnold's Cove has 1/2 to 2/3 of the sewage treated, Baie Verte has about 1/4 treated, Gambo has about 2/3 treated, and Bonavista has 80% or more treated (Fisher 1997 pers. comm. list) was incorporated into the calculations. The raw sewage for the untreated percentage of the population of each town was calculated. If a town had all of its sewage treated it was omitted from the sewage calculations because there was no sewage released into the water.

A Census is taken every five years in Newfoundland. One was taken in 1991 and another in 1996. Thus, the population for the incorporated towns was not available for the period 1992-1995, years which were a part of this study. The amount of sewage released during this period was calculated by finding the difference between the 1991 and the 1996 sewage levels, and dividing it by five. This value was then added on (if sewage levels were rising) or subtracted from (if sewage levels were falling) the yearly sewage levels to find the sewage level for the following year. This method gives values which show a linear yearly increase or decrease in sewage levels (or population) from 1991-1996. This linear change is probably not what actually occurred but it is a reasonable approximation between Census years. The values for 1991 and 1996 were known, and only the four years in between were unknown. Populations did not fluctuate very much in that time period.

Table 2.3. Coastal Newfoundland municipalities with partial or total municipal sewage treatment.

Municipality	% of Population Treated	Year Treatment Began
1. Holyrood	100%	1974
2. CBS, east of Manuals	Partial treatment	1978
3. Arnold's Cove	50% to 66.7%	1976
4. Baie Verte	25%	1974
5. Lumsden	100%	1974
6. Norris Arm	100%	1976
7. Parson's Pond	100%	1993
8. Robert's Arm	100%	1977
9. East Port	100%	1979
10. Victoria	100%	1975
11. Gambo	66.7%	1985, 2nd plant 1984
12. Bonavista	80%+	1972
13. St. Alban's	100%	1976
14. Centreville-Wareham-Trinity	Trinity only	1982
15. Hampden	100% (out of service)	1979

2.3.4: Offal

The level of offal released from fish plants, or the fisheries waste stream, is not regulated in Newfoundland so it was calculated from the landings and production data of the federal Department of Fisheries and Oceans. These data were available for the fisheries statistical areas for the entire Newfoundland coastline. The level of fisheries waste produced depends on the volume of fish processed and the percentage yield (or percentage recovery). Volume of fish processed depends on a number of variables including fish stocks, DFO regulation and quotas, market demands, and political, economic and environmental factors

(Ming-Lesage 1991).

In 1998 there were only two fish meal plants in the province, one in Burgeo and one in Carbonear (Tucker 1999 pers. comm. list). The provincial Department of Fisheries and Aquaculture has not started collecting data from these plants yet, therefore they do not know the percentage of offal being produced at these plants. Data collection was supposed to begin in 1999. Two or three more meal plants may begin operation in 1999 as well (Tucker 1999 pers. comm. list). There was no information available regarding the percentage of offal used, therefore these two plants were not considered in the calculations. Hence, the amount of offal released in the vicinity of the two fish meal plants may be too large of an estimate. Both plants receive offal from the region in which they are located, except for male caplin, which comes from fish plants in other regions as well (Tucker 1999 pers. comm. list). The amount of offal released was calculated using two methods.

I) The first method simply calculated the difference between the mass of fish landed and the mass of fish produced to market in the processing plants. This method enabled calculation of the amount of offal for the entire coastline only. The DFO landings data were not available for the smaller coastal scales analyzed in this thesis.

- Offal (kg/yr) = landed fish (kg/yr) - produced fish (kg/yr)

This calculation was completed on a yearly basis.

In many cases the kg of fish landed for a particular species was less than the kg of fish product produced in the processing plant, according to the values in the DFO production and landings data. Consequently, the results of this method were not used in this thesis.

II) The second method divided the quantity of produced fish by the percentage yield during processing, for each statistical area. If the offal was from shellfish (bivalves, crustaceans, winkles, whelks, cockles, etc.) then the weight of the offal was already a dry weight (only shells are discarded generally). However, if the offal was from finfish, then the dry weight of the offal was calculated, because of the high water content. The majority of the processed fish were marine teleosts with a total body water (TBW) content of 70.8% and a dry weight of 29.2%

- $\text{Landed fish (kg/yr)} = \dfrac{\text{produced fish (kg/yr)}}{\text{\% yield}}$
- $\text{Offal (kg)} = \text{landed fish (kg/yr)} - \text{produced fish (kg/yr)} \times (29.2\%)$

This calculation was completed for each species on a yearly basis. This method was also utilized by Ming-Lesage Development Service Inc. while doing a study of the Canadian Fisheries Waste Stream on the Pacific Coast (See Ming-Lesage 1991, p.4) and by Tidmarsh *et al.* (1986) while studying fish waste disposal practices in eastern New Brunswick.

The percentage yield for various species of fish were obtained from the Productivity Handbooks (Volume I: Fresh, frozen and cured groundfish and Volume II: Shellfish, pelagics, and other) prepared by TAVEL Limited (1997) with the Newfoundland and Labrador Department of Fisheries. The handbooks document the standard yields, throughputs, and product costs for use by the Newfoundland fishing industry. The yield structures in the handbooks gave the expected process losses and overall recoverable yields for each type of product listed. It gave the percent yield for each separate species, for each type of product (i.e. skin on bone in fillets, skinless bone in fillets, skin on boned fillets, skinless boned fillets, etc.), and for each of four processing methods (i.e. hand cut, Baader 184 cut, Baader 185 cut, and Baader 189 cut). However, the production by species data, from DFO, did not include such detailed information. The DFO data only included the weight of product from each species. Therefore, an average percent yield was calculated for each species (Table 2.4) from the detailed percentages given in the report by Tavel. These were utilized in subsequent calculations.

Table 2.4. Main species processed and their percentage yields, in Newfoundland fish processing plants.

Species	Percent Yield	Species	Percent Yield
Cod	32%	Mackerel	49%
Haddock	32%	Smelt	70%
Pollock	36%	Caplin	50%
Redfish	31%	Squid	60%
Turbot	36%	Lumpfish roe	15%
Catfish	30%	Lobster	25%
Hake	32%	Crab	25%
Flounder	29%	Shrimp	25%
Grenadier	21%	Mussels	90%
Herring	46%	Scallop	10%

The percentage yields for species less common in Newfoundland's processing plants were not found in the Productivity handbooks (mentioned above) or anywhere else in the literature. Therefore, the percent yields for the main species processed (Table 2.4) were applied to these less abundant species (Table 2.5). Generally, fish were given a percent yield of 32%, which is the typical percent yield for groundfish. Other species were given a percent yield of a similar species in Table 2.4. For instance, the percent yield of hake was applied to cusk, and the percent yield of herring was applied to alewives. The offal resulting from the processing of seals was not taken into consideration because the percent yields during processing were not available. Considering that only the viscera is discarded generally, (flippers, carcasses, and pelts are sold) seal offal is probably not a significant source of organic wastes in Newfoundland. Fish mortalities on salmon farms were not taken into consideration either, as they are only a minor part of the total fisheries waste stream (Ming-Lesage 1991). In addition, fish wastes are dumped at sea before the vessels reach processing plants and individual fisherman dump wastes off public and private wharves during gutting and filleting. The levels of these released wastes are also unknown. However, they could create significant problems if repeated dumping occurred in areas where the waters are shallow and the currents are slow.

Table 2.5. Percent yields for less common species in Newfoundland fish processing plants.

Species	Percent yield	Species	Percent Yield
Rock cod	32%	Alewives	46%
Cunners	32%	Argentine	32%
Alfonsino	32%	Eels	32%
Cardinal	32%	Salmon	32%
Grouper	32%	Skate	32%
Halibut	29%	Char	32%
Plaice	29%	Dogfish	32%
Yellowtail	29%	Trout	32%
Greysole	29%	Tilapia	32%
Cusk	32%	Whitefish	32%
Monkfish	32%	Porbeagle	32%
Sand eels	32%	Shark	32%
Sculpin	32%	Rainbow trout	32%
Ocean Pout	32%	Hagfish	32%
Chimera	32%	Dollarfish	32%
Groundfish	32%	Clams	10%
Swordfish	32%	Quahaugs	90%
Tuna	32%	Winkles	10%
Billfish	32%	Whelks	10%
Escolar	49%	Cockles	10%
Marlin	32%	Sea Urchin	10%
Mahi Mahi	32%	Cucumber	100%
Miscellaneous	32%	Crustaceans	25%

The Production data from DFO was only available for statistical areas, it was not available for the smaller statistical section. Information was not available from DFO that could identify a particular vessel, processing plant, or bay (Russell 1997 pers. comm. list). Therefore, the list of dumping permits along with the location of each site was obtained from the provincial Department of Fisheries and Aquaculture (Appendix D) to help determine where the offal was released. There are only 47 dumping permits currently allocated for the island, and only 35 dumping locations along the coast (10 towns have two dumping permits each, and one town has three). However, offal is dumped into coastal waters in many areas where dumping permits have not been allocated, according to people who live in some of the fishing outports. In addition, there were more sections with fish processing plants than with dumping sites. Thus, the amount of offal being released was determined according to the location of the processing plants, not the location of the dumping permit from the Province. Instead, the list of licensed processors for Newfoundland for 1997 was obtained from the provincial Department of Fisheries and Aquaculture. The location of the processing plants and the percentage of processing plants in each of the area's sections was determined (Appendix C). The level of offal was calculated for each area, and then calculated for each section by multiplying the area value by the percentage of plants (or estimated percentage of offal) in each section.

For example, consider Area A, Section 1 (see Appendix C). DFO data was available for each fisheries statistical area. The amount of offal produced in each area was calculated using the following equations (as previously stated).

- $\text{Landed fish (kg/yr)} = \dfrac{\text{produced fish (kg/yr)}}{\text{\% yield}}$

- $\text{Offal (kg)} = \text{landed fish (kg/yr)} - \text{produced fish (kg/yr)} \times (29.2\%)$

Area A has a total of eleven fish processing plants. Section one, in area A, has a total of two processing plants. Therefore, section one has 18% of area A's fish processing plants. That is, section one has 18% of the offal production and offal release in area A.

- Section 1 offal (kg) = Area A offal (kg) x 18%

Not all of the processing plants work at the same level of production (which this calculation implies) but there was no way of determining level of production for each individual plant. Even an estimation of production levels for each plant was impossible unless each individual plant was visited, and this was not feasible. Conversations with fishermen and scientists led to the conclusion that even if all of the plants had been visited an accurate value for level of offal released would not have been obtained because plant managers probably would not be forthcoming with such information.

2.3.5: Sawmill wastes

The sawmill wastes were quantified for the entire island and for each Forestry District. The provincial Department of Forest Resources and Agrifoods divided the island into 18 districts (Figure 2.5). The data were going to be examined at the scales of region, fisheries statistical area and fisheries statistical section as well, to be comparable to the results from the other three sources of organic wastes studied. However, the coastal areas and sections overlap different forestry districts. For instance, Area A, Section 4, is found partially in Districts 9, 16, and 17. See Table 2.6 for the areas and sections that correspond to the different forestry districts.

The lack of available data made it difficult to quantify the sawmill wastes (bark, slabs, wood chips, shavings, and sawdust) that are released into Newfoundland's marine waters. The current level of coastal dumping was going to be obtained from reports to the provincial Department of the Environment and to the four Government Service Centres of the Newfoundland and Labrador Department of Government Services and Lands, across the island. However, very few reports of illegal dumping of sawmill wastes have been made to these agencies. This situation made it impossible to quantify these wastes as rigorously or in as much detail as the other three major sources of coastal organic wastes studied. The quantification of sawmill wastes was completed using data received from the Department of Forest Resources and Agrifoods. Sawmill statistics for Newfoundland for the fiscal years 1993-1998 were obtained, as well as a complete list of all mills for 1996-1997 and for 1998.

The method for calculating sawmill residue was taken from Buggie (1993) who also calculated levels of sawmill wastes produced in Newfoundland. However, he looked at levels of green wastes (i.e. wastes containing moisture, not dried wastes) produced from different sized sawmills. Young (1989) also did a sawmill residue study in Newfoundland and found that the simplest way to find an estimate of the level of wastes (in the form of slabs, sawdust, and shavings) was to apply conversion factors to the thousands of foot board measures (Mfbm) of lumber produced. He also studied green tonnes, not dry weight.

Table 2.6. Forestry districts and corresponding fisheries areas and sections. (Note: inland districts and Labrador were omitted.)

Forestry District	Coastal Area	Coastal Section
1	D	17,18,19
	E	20,21,22,23
	F	24,25,26
	G	27,28
	H	29,30
2 and 3	C	12,13
	D	14,15,16,17
	H	30,31,32
	I	33,34
5	B	9
	C	10,11
7	I	34,35
	J	36
8	B	6,7,9
9	A	4,5
	B	6
14	J	37,38,39
	K	40,41
	L	42,43
15	L	44
16	A	4
17	A	4
	M	46,47
	N	48,49
18	A	1,2,3
	N	49

The assumptions of Buggie (1993) were used in this thesis, as follows.

1. There is a 50:50 mix of black spruce and balsam fir in the trees produced.
2. The specific gravity of black spruce is 0.448, and the specific gravity of balsam fir is 0.353 at a moisture content of 0%.
3. Black spruce and balsam fir have a moisture content of 37%.
4. A round log is 13% bark, 17% sawdust, 8% shavings, 27% slabs, and 35% dressed lumber.
5. 43% of a round log is rough lumber.

The provincial Department of Forestry Resources and Agrifoods regional offices (Gander and Corner Brook) and headquarters (St. John's) were contacted to find out the exact ratio of black spruce to balsam fir produced in Newfoundland sawmills at the scale of the entire island and per district. None of these offices could give these ratios. The Corner Brook office supplied a copy of the '20 Year Forestry Development Plan 1996-2015' by the provincial Department of Forestry Resource and Agrifoods (DFRA 1996). However, the ratios were not present in this report either, hence the assumption of 50:50 mix of black spruce to balsam fir was retained.

The following were utilized in this study. See Buggie (1993) for further details.

- Oven dry weight of nominal (rough) lumber per Mfbm = 945 kg/Mfbm
- Total weight of round log per Mfbm = 945/0.43 = 2198 kg/Mfbm
- Bark = 13% x Total Weight = 286 kg/Mfbm
- Sawdust = 17% x Total Weight = 374 kg/Mfbm
- Shavings = 8% x Total Weight = 176 kg/Mfbm
- Slabs = 27% x Total Weight = 593 kg/Mfbm
- Dressed Lumber = 35% x Total Weight = 769 kg/Mfbm

These values were applied to the lumber production data from the Department of Forest Resources and Agrifoods (Appendix E). See calculations below.

Note:

- fbm = foot board measure
- Mfbm = 1000 foot board measure
- MMfbm = 1,000,000 foot board measure

(These units are non SI units but are the forestry industry standard)

Example:

Production = 5,000,000 fbm = 5,000 Mfbm = 5 MMfbm

Total weight of bark = 286 kg/Mfbm x 5,000 Mfbm = 1,430,000 kg

The calculations used to quantify sawmill wastes:

- Bark = Mfbm x 286.
- Sawdust = Mfbm x 374.
- Shavings = Mfbm x 176.
- Slabs = Mfbm x 593.
- Wastes = Bark + Sawdust + Shavings + Slabs.

All data from inland districts were omitted i.e. Districts 4, 6, 10, 11, 12 and 13 (Figure 2.5). The data for the large sawmills (class 05 - 100,001 - 500,000 fbm/yr and class 06 - 500,000 + fbm/yr) (see below) were omitted because many of the larger mills sell the wastes for reuse (James 1998 pers. comm. list). The lumber production data from the provincial Department of Forest Resources and Agrifoods gave the total production for each district per year, but did not give the size of the sawmills and the production per sawmills of given size. These data were available on the 1996-1997 sawmill list however. From this list the percentage of lumber from the large mills, class 05 and class 06, per district was determined (Table 2.7). These percentages were then used to delete large mill production from waste calculations. All residue from small sawmills was assumed to be waste.

- Small sawmill wastes = Wastes x (1 - Percent of large sawmill production).

Note: (sawmill classes according to fbm/yr produced)

Class 01: 1 - 6,000
Class 02: 6,001 - 25,000
Class 03: 25,001 - 50,000
Class 04: 50,001 - 100,000
Class 05: 100,001 - 500,000
Class 06: 500,000 +
Class 99: Did not return (not considered in any calculations)

Table 2.7. Percentage of production from the large sawmills (100,001 - 500,000+ fbm/yr), and the small sawmills (1-50,001 fbm/yr) in 1996-97.

District	Percent production from 500,000+ fbm/yr sawmills	Percent production from 100,001 - 500,000 fbm/yr sawmills	Percent production from small sawmills
1	15%	35%	50%
2 & 3	57%	18%	25%
5	67%	15%	18%
7	0%	43%	57%
8	83%	13%	4%
9	0%	59%	41%
14	0%	0%	100%
15	0%	54%	46%
16	57%	32%	11%
17	0%	30%	70%
18	95%	0%	5%

Although the districts studied border the coastline not all of the sawmills are located directly on the coastline. Attempts were made to find the exact location of each mill (latitude and longitude) to identify the coastal ones. The two regional offices for Forestry Resources and Agrifoods were contacted (Gander and Corner Brook) and the headquarters was contacted

(St. John's) but neither of these offices was able to provide the exact locations of the province's sawmills. All 13 district offices on the island were then contacted but the information was not readily available. The sawmill locations were received from one district office out of 13. Therefore, the sawmill licences listing for 1998 was obtained from the Department of Forestry Resources and Agrifoods, which contained the locations of the licensed mills but not the exact latitude and longitude. The locations from the mill licenses list and a map from Trelawny (1990) showing the distribution of the sawmills, were combined to obtain a rough estimate of the locations of the mills and a maximum percentage of residue that could enter the waters in each forestry district. These estimates were obtained through visual observation of the map. It was estimated that 50% of the small sawmills were located directly on the shoreline, and that 50% of these wastes actually entered the waters. That is, 25% of the small sawmill wastes enters the water. This is a maximum percentage however, and is a very rough estimate.

- Wastes entering water = Small sawmill wastes x 25%.

2.4: Results

At the scale of the entire island, offal was the largest contributor of organic wastes, followed by raw sewage, and sawmill wastes. Excess feed and faeces from aquaculture was the smallest contributor of organic wastes (Table 2.8, Figure 2.3). The amount of offal entering the waters declined from 1992 to 1994, but rose again in 1995 and 1996. The form of the released offal has changed since the 1992 moratorium on Atlantic cod. Finfish offal greatly decreased since 1992, and shellfish offal greatly increased (Figure 2.4). Sewage levels only increased slightly from 1992-1996. The amount of sawmill wastes remained fairly steady over the five years studied, with a slight increase from 1992-1996, but aquaculture wastes showed a large yearly increase.

Table 2.8. Total organic wastes (dry mass in kg) released from 1992-1996 in coastal Newfoundland from offal, sewage, sawmills and aquaculture.

Year	Offal (kg)	Sewage (kg)	Sawmills (kg)	Aquaculture (kg)
1992	159,000,000	5,320,000	3,204,000	49,100
1993	90,500,000	5,640,000	3,659,000	127,000
1994	86,000,000	5,970,000	3,580,000	231,000
1995	112,000,000	6,290,000	4,225,000	340,000
1996	131,000,000	6,620,000	4,446,000	607,000

For further comparison of the four sources of organic wastes see Table 2.9 (Note that the sawmill estimates are less accurate than the estimates for the other three sources of wastes). The sources are given an overall rank (1-4) according to the total waste released in comparison to the other three sources. (i.e. The source releasing the greatest total amount of wastes is ranked as 1, the source releasing the smallest total amount of wastes is ranked as 4). This was done for each year for 1992-1996. The ranking of the four sources was the same for each year so the results were combined in Table 2.9.

Table 2.9. Rank of the four major sources of organic wastes according to amount of waste released.

Scale	Sawmill 1992-1996	Offal 1992-1996	Sewage 1992-1996	Aquaculture 1992-1996
Entire Island	3	1	2	4

Sawmill wastes were also examined at the scale of Forestry district (Methods 2.3.5). None of the other sources of wastes were studied at this scale because the data were not gathered at this scale. District 1, the Avalon Peninsula, was the district releasing the most sawmill wastes (Figure 2.6). District 2 and 3, (northern Trinity Bay, southern Bonavista Bay, western Placentia Bay, and eastern Fortune Bay), were the second highest contributor of sawmill wastes (Figure 2.6). The 1996 levels were the highest for any of the districts in any of the five years studied. District 5, and District 7 had relatively low levels of wastes (Figure 2.6). Relative to the other districts the level of wastes released from District 8, District 9, District 14 and District 15 was not extreme (Figure 2.7). District 16, at the base of the Northern Peninsula, was the second smallest contributor of sawmill wastes on the island (Figure 2.8). Relative to the other districts the level of wastes released in District 17 was not extreme (Figure 2.8). District 18, on the tip of the Northern Peninsula, released the least amount of sawmill wastes (Figure 2.8).

2.5: Discussion

It was hypothesized that at the scale of the entire island raw sewage was the largest source of organic wastes in Newfoundland, followed by offal, then aquaculture, with sawmills contributing the least amount of organic wastes to the coastal waters. The hypothesis was made because of the large number of coastal communities (267 incorporated coastal towns were examined) with an absence of sewage treatment (municipal treatment utilized in 14 coastal municipalities currently). Contrary to expectation, offal releases were higher than sewage in each year that computations were made. Offal release was higher than expected because large amounts of offal are released into the coastal waters all over the island by processing plants. The large amount of offal entering the waters at these locations greatly surpassed sewage levels.

The time scale of release should also be considered when evaluating the levels of organic wastes released. The overall impact of offal and sawmill wastes (if dumped directly into the water) may be greater than that of sewage and aquaculture, when considering the time scale of release and not just the mass of wastes released. Offal, and possibly sawmill residue, is accumulated and large amounts are released at a time at a high concentration. Aquaculture wastes and sewage are released at a frequent, slower, steadier rate. The slower rate allows for better dispersal and assimilation into marine waters. The relatively rapid and episodic release of offal will decrease the possibility of breakdown and the rate of degradation.

The results for sawmill wastes were based on the assumption that 50% of the small sawmills were on the shoreline (estimation from a visual examination of a map of sawmill locations from the Department of Forestry) and 50% of the wastes from these mills entered the water. These percentages were intended to give a rough maximum estimate because the information needed to obtain a more accurate estimate was not available. Sawmill wastes were more difficult to quantify than the others because current regulations prohibit sawmill wastes from being released into marine waters. There are few reports of illegal dumping to the Government Service Centres across the island, resulting in a lack of available information.

The least amount of sawmill wastes were released on the Northern Peninsula, and the most wastes were released on the Avalon Peninsula. This result was due to a large number of small sawmills on the Avalon Peninsula (District 1), with a high percentage of these in the larger production classes (class 2 and class 3; see Methods 2.3.5 for definition of sawmill class). The Northern Peninsula (part of District 16 and all of Districts 17 and 18), however, had many small mills but the majority of these were in class 1, the production class producing the least amount of lumber, hence the low level of wastes released (Table 2.10). Similar results for the Northern Peninsula and Avalon Peninsula, for the other three types of wastes studied, are presented in the following chapter.

Table 2.10. Number of sawmills per size class, number of small sawmills (class 1 - class 4), and percent of small sawmills per district (excluding class 99) in 1996-97.

District	01	02	03	04	05 *	06 *	99 *	Number of small mills	% of small mills
1	89	30	21	9	10	1	13	149	93%
2 & 3	186	88	28	13	11	2	17	315	96%
5	61	15	12	2	3	2	0	90	95%
7	11	6	4	3	3	0	0	24	89%
8	45	27	9	3	16	3	3	84	82%
9	33	18	6	3	5	0	9	60	92%
14	54	11	6	4	0	0	24	75	100%
15	40	11	7	4	5	0	24	62	93%
16	12	9	5	4	8	1	0	30	77%
17	158	3	2	1	2	0	0	164	99%
18	82	16	0	0	0	3	21	98	97%

* - Class 05 and class 06 are large sawmills. Class 99 mills have no data available on them.

The level of offal entering Newfoundland waters is quite high relative to offal production in other Canadian coastal provinces and nation-wide. In eastern New Brunswick an estimated 33,000 metric tonnes (wet) of fish waste is produced annually (Tidmarsh *et al.* 1986), in British Columbia about 100,000 metric tonnes (wet) is produced annually (Aegis 1991) and the amount of offal produced in Canada annually is estimated at 300,000 metric tonnes (wet) (Ming-Lesage 1991). In comparison, Newfoundland's annual levels, between 86,000 and 159,000 metric tonnes of dry offal, are high (Table 2.8). Groundfish processing in Canada creates about 140,000 to 200,000 metric tonnes (wet) of disposable wastes a year (Hayes *et al.* 1994). Newfoundland disposes about 22,000 to 100,000 metric tonnes of dry finfish offal (including groundfish and all other processed species) per year (Figure 2.4), which is about 75,000 to 340,000 metric tonnes of wet finfish offal.

The form of the released offal has changed in Newfoundland over this decade, possibly increasing the accumulation and hence organic waste at individual sites. From 1992-1996 there was a steady increase in shellfish offal (including bivalves and crustaceans) and there was a steady decrease in finfish offal from 1992-1995, although an increase occurred in 1996. Shellfish currently dominate the fishing industry in Newfoundland, and the landings of shellfish (mainly crab and shrimp) have more than tripled since 1988 (DFA 1998b). The increase in shellfish offal entering the waters could create greater and longer lasting waste accumulation along the coastline because inorganic shells are not as easily degraded as finfish offal (that is, the flesh and viscera). However, slower degradation may mean a reduced possibility of high levels of microbial activity thus preventing hypoxia or anoxia in coastal areas with large amounts of offal being released. These areas will be subject to piles of discarded shells though.

The collapse of the Atlantic cod stocks and reduction of other groundfish stocks caused some fisherpeople in Newfoundland to turn to finfish aquaculture as a means of making a living from the coastal waters. Aquaculture is a relatively new industry in Newfoundland and as such is still relatively small. In comparison to other nutrient sources salmonid farms typically are a small factor in larger scale marine eutrophication problems, but the contribution of wastes increases with the number of farms present in an area (Folke and Kautsky 1989). The method of marine finfish aquaculture in Newfoundland is intensive aquaculture, which is the usual type of farming used in temperate climates (Iwama 1991). Intensive aquaculture utilizes artificial containers with all of the food being supplied to the fish, although some food may naturally occur in the water supply. The feed being added to the water causes the organic loading at the aquaculture sites. The environmental impacts of intensive aquaculture are similar to that of sewage outlets and industrial wastes (Folke and Kautsky 1992) when the same amount of wastes are released at the same rate. Locally, intensive farms may be the source of a large amount of nutrients and organic wastes into coastal waters. Sites with intensive aquaculture have common characteristics with stressed ecosystems (Folke and Kautsky 1992). Typically, the more intensive and concentrated marine activities need a larger ecosystem to support them (Folke *et al.* 1997). These activities have a flow of resources into them and a flow of wastes out of them. According to Berg *et al.* (1996) the area needed around a fish cage to ensure assimilation of the extra nutrients being added, by the feeding and metabolic processes, is 115 times greater than the actual area of the cage. In addition, the area needed to produce enough oxygen for the fish's consumption and for decay of the organic wastes (excess feed and faeces) is 160 times greater than the area of the fish cages.

Localized problems may occur with the finfish farms, but at the scale of the entire island aquaculture wastes are a small component of the total release. As Table 2.8 and Figure 2.3 show, aquaculture increased in Newfoundland from 1992-1996. In 1996 aquaculture was only present in sections 12 (Southern Head - Western Head), 25 (Cape Spear - Cape Broyle), 32 (Jean de Baie Head - Point Crewe), and 36 (Pass Island Point - Cape la Hune). The increase has continued since then. Each year the biomass of steelhead and Atlantic salmon increased in Bay d'Espoir and more Atlantic cod farms began operation. In 1997 cod farms were in sections 16 (Bonaventure Head - West Random Head), 17 (West Random Head - Hopeall Head), 18

(Hopeall Head - Salvage Point), 19 (Salvage Point - Grates Point), 25 (Cape Spear - Cape Broyle), 30 (Bauld Head - Grandy Point), and 31 (Grandy Point - Jean de Baie Head)), and salmon in 36 (Pass Island Point - Cape la Hune). There are also two more sites on the West Coast according to DFA (1998a). Although this source of wastes is very small in Newfoundland, compared to offal and sewage releases, it is the only form of wastes showing such a large yearly increase (Figure 2.3). If the rate of increase continues it may only be about another 5-6 years before the level of aquaculture wastes is similar to the level of offal released.

In 1996 in Bay d'Espoir, there were about 1620 metric tonnes of salmon produced (Tlusty 1997 pers. comm. list) and 2200 metric tonnes in 1998 (Tlusty 1999 pers. comm. list). To sustain the harvest, however, about 1.5 times the biomass produced needs to be in the water (Tlusty 1999 pers. comm. list), thereby increasing the amount of feed and faeces entering the marine system. The DFA data used in this thesis contained the mass of fish produced, therefore more fish were actually in the water than accounted for by the calculations of waste release. Thus, the waste release was higher than calculated in this thesis. Even if the mass of fish in the water (and not just the mass of fish produced) was used in the calculations it would not increase the level of aquaculture wastes to that above sewage or offal, except maybe within Bay d'Espoir where sewage, fish plant and aquaculture waste releases are closer in total levels than anywhere else on the island (Figure 3.14 for Section 36).

Finding reliable aquaculture data for Newfoundland farms was difficult. The salmonid aquaculture data was initially gathered from three sources. The three data sets gave very different results. Table 2.11 shows the data gathered from SCB Fisheries, NSGA and DFA, and the kg of wastes calculated from these data. Initially only NSGA data were going to be used. However, the biomass, levels of feed and FCRs recorded by the individual farms were sometimes inconsistent or impossible (i.e. negative FCRs). In addition, it was difficult to get data for the five year period being studied. Therefore, only the production data from the provincial Department of Fisheries and Aquaculture were used in this thesis (Methods 2.3.2). These data gave conservative estimates of wastes in comparison with the NSGA and SCB fisheries data (Table 2.11). The Atlantic cod data collected by DFA differed from the data gathered from individual cod farms in Trinity Bay. The production numbers collected from the farms for 1997, during research for this thesis, were much higher than those recorded by DFA. In the end, 1997 aquaculture production was not used in this thesis due to a lack of Census data for sewage calculations and production data from DFO for offal calculations.

Table 2.11. Comparison of salmonid aquaculture biomass and wastes, in Newfoundland, as calculated from three different data sources.

Data Source	1996		1997	
	Fish Biomass (kg)	Wastes (kg) (dry mass)	Fish Biomass (kg)	Wastes (kg) (dry mass)
NSGA	1,930,709	1,135,257 *(247, 738)	5,974,904	3,513,244 *(728,410)
SCB	925,000	668,752	1,280,000	827,904
DFA	1,029,286	605,220	968,264	569,339

* The calculations used the NSGA fish biomass and feed added. A FCR of 1.5 was not used to calculate amount of feed as in the calculations using SCB Fisheries and DFA data.

The raw data from NSGA gave both biomass of fish and feed added. The DFA and SCB data only gave fish biomass and thus a FCR of 1.5 was used to calculate feed added. When considering the biomass of fish and the levels of feed in the original NSGA data set it seemed that the NSGA values must be incorrect, the waste levels calculated above were low for the biomass of fish.

Inferential statistics were not appropriate for analysis of these data. Therefore, other calculations were used to present total levels of organic wastes released. If scientists only examined data that fit well with inferential statistics then many important issues would not be studied. There were two reasons why it was inappropriate to use standard inferential statistics. First, the goal was to make the best estimate of levels of organic wastes released, not to declare a decision. Second, data were not sampled from a larger population, that is, the data were often total estimates, not samples.

This thesis addresses a practical and relevant issue to society as best as possible, while recognizing that the data being analyzed were limited in the level of precision. Often there is an increase in the level of uncertainty when dealing with larger scale issues. It was important to look at the data in this thesis at multiple spatial scales because what is apparent at a large scale may not be what is occurring at a smaller scale. Although large scale studies may not give such precise results they may be more relevant and of more interest to society than some high precision studies. Large scale studies are generally not common and smaller scale studies are preferred, but ecologists and conservation biologists need to deal more with larger spatial scales (May 1993). Commonly, and for various reasons, universities and other institutions have difficulty with research that transcends common disciplinary boundaries or that involves large spatial or temporal scales (May 1993). Some reasons for only studying limited spatial scales are that there are often time constraints and financial constraints on the research, old organizational and departmental boundaries are difficult to change, and hypothesis testing experiments are more easily completed on smaller spatial scales (May 1993). According to May (1993) many ecologists seem to have chosen research that can be done at a convenient small temporal and spatial scale, instead of recognizing the important problems first and working at a spatial scale appropriate for the research.

2.6: Conclusion

At the scale of the entire island offal was the largest source of coastal organic wastes, followed by sewage, then sawmill wastes. Aquaculture was the smallest contributor of organic wastes. However, at the current rate of increase, aquaculture wastes may reach levels similar to that of sewage within the next 5-6 years. Considering that sewage is released along most of the Newfoundland coastline and aquaculture wastes occur in very few places (mainly in Bay d'Espoir) this trend could be a problem in the future for localized coastal organic waste release. The change in the form of the offal since 1992, from finfish to the inorganic shells of crab and shrimp, may also increase accumulation of organic wastes due to the slower rates of degradation and assimilation.

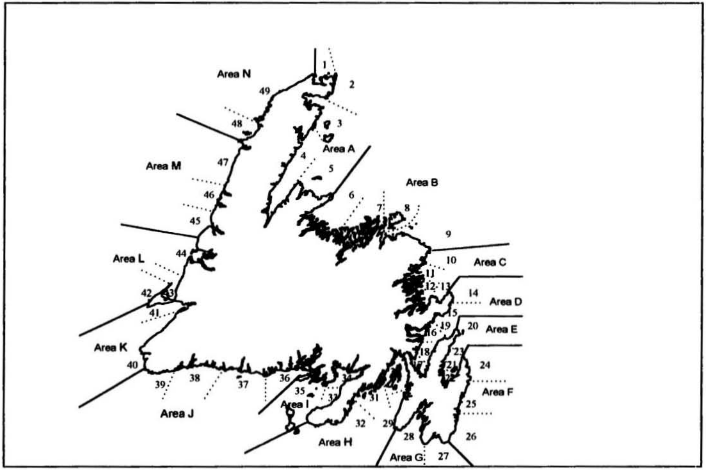

Figure 2.1. Fisheries statistical areas (A-N) and fisheries statistical sections (1-49) for coastal Newfoundland.

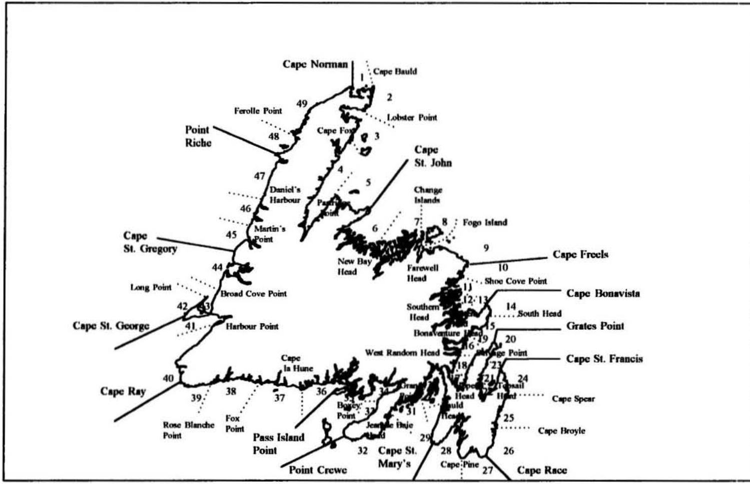

Figure 2.2. Fisheries statistical sections (1-49) for coastal Newfoundland. (Note Sections 17-23. Section 17-West Random Head-Hopeall Head, Section 18-Hopeall Head-Salvage Point, Section 19-Salvage Point-Grates Point, Section 20 - Grates Point-Western Bay Head, Section 21-Western Bay Head-Feather Point, Section 22-Feather Point-Topsail Head, Section 23-Topsail Head- Cape St. Francis).

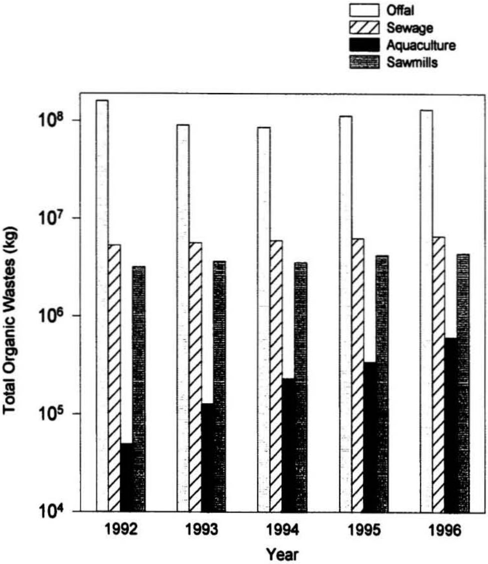

Figure 2.3. Total organic wastes (dry mass) released along the Newfoundland coastline from 1992-1996 in the form of offal, sewage, aquaculture wastes and sawmill wastes.

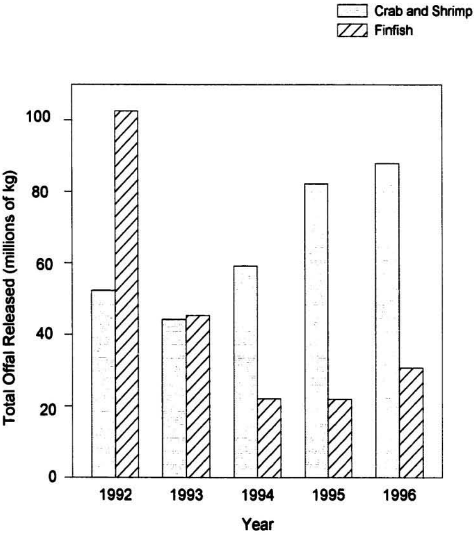

Figure 2.4. Total offal (dry mass) released from crab and shrimp processing and from finfish processing in Newfoundland from1992 - 1996.

Figure 2.5. Newfoundland's eighteen forestry districts as defined by the Department of Forestry Resources and Agrifoods.

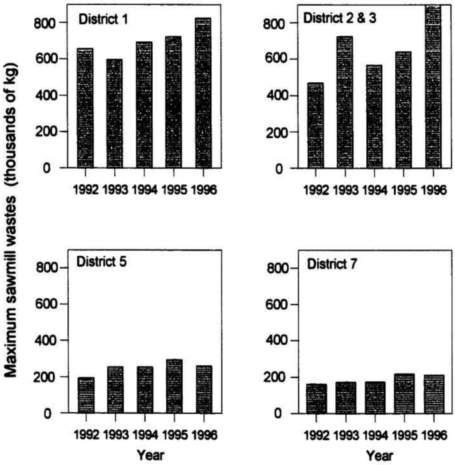

Figure 2.6. Maximum level of sawmill wastes (dry mass) released in Districts 1-7 from 1992-1996.

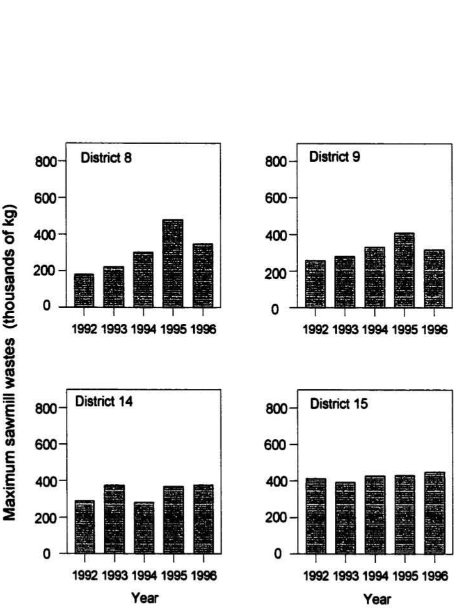

Figure 2.7. Maximum level of sawmill wastes (dry mass) released in Districts 8-15 from 1992-1996.

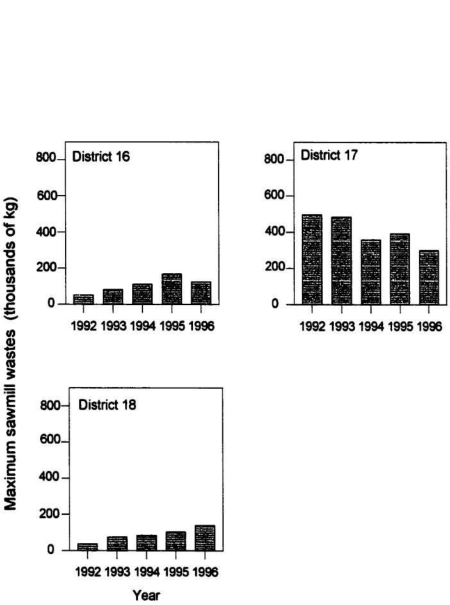

Figure 2.8. Maximum level of sawmill wastes (dry mass) released in Districts16-18 from 1992-1996.

Chapter 3: Quantitative comparison of sewage, aquaculture wastes, and offal for 5 coastal regions, 14 fisheries statistical areas, and 49 fisheries statistical sections.

3.1: Abstract

The second largest spatial scale at which wastes were quantified was coastal region. Five regions were studied and compared for 1992-1996. The Avalon Peninsula (Region 3) was the region that released the most sewage and the most offal in each of the years examined. The South Coast (Region 4) released the most aquaculture wastes in each of the five years. The region that released the least amount of wastes in each of the five years was the Northern Peninsula (Region 1).

The second smallest spatial scale at which wastes were quantified was fisheries statistical area. Fourteen areas were studied and compared. Aquaculture wastes were predominately from Area J, the Bay d'Espoir area. Three other areas (Area C, F, and H) had aquaculture activity (specifically, Atlantic cod farms) but neither area came close to the level of activity in Area J. Offal and sewage levels were highest in Area F (St. John's area and Southern shore). The lowest sewage levels were in Area N (Gulf of St. Lawrence, Strait of Belle Isle area) and the lowest offal levels were in Area M (Bonne Bay, Gros Morne National Park, part of Northern Peninsula).

The smallest spatial scale at which wastes were quantified was the fisheries statistical section. Forty-nine sections were studied (Figure 2.1, Figure 2.2) and the sections with

extreme levels of wastes released (high or low) were compared. This scale showed the greatest variability in level and type of wastes released between different parts of the coastline. It also showed greater variability between years than the larger scales. Section 2 (Cape Bauld - Lobster Point, on the Northern Peninsula) released the smallest amount of offal over the period examined, while Section 22 (Feather Point - Topsail Head, in Conception Bay) released the greatest amount of offal. Section 20 (Grates Point - Western Bay Head, in Conception Bay) had the lowest sewage levels for the entire province, while Section 24 (Cape St. Francis - Cape Spear, on the Avalon Peninsula) released the greatest amount of sewage. Aquaculture wastes were predominately produced in Section 36 (Pass Island Point - Cape la Hune, on the south coast). Generally, the results for each of the spatial scales, in regard to the sources releasing the highest and lowest levels of organic wastes, were similar. There was some variation between different areas and sections.

3.2: Introduction

The second largest spatial scale examined in this thesis is coastal region. The Newfoundland coastline was arbitrarily divided into five coastal regions: Region 1- Northern Peninsula, Region 2 - East Coast and Central, Region 3 - Avalon Peninsula, Region 4 - South Coast, and Region 5 - West Coast (General methods 2.3.1). These regions do not include the same distance of coastline.

The second smallest spatial scale examined is fisheries statistical area. At this scale the spatial variability in level and type of wastes being released from one area of the coastline to the next is more evident than at the regional scale. The Department of Fisheries and Oceans divided the Newfoundland coastline into 14 fisheries areas: Area A - Area N (Table 2.1, Figure 2.1).

The smallest spatial scale examined in this thesis is fisheries statistical section. The 14 fisheries areas are divided into 49 fisheries sections by the Department of Fisheries and Oceans (Figure 2.1, Figure 2.2).

It is expected that as the spatial scale becomes smaller there will be more variability in the type and level of organic wastes released. The smallest scale, fisheries statistical section, is the scale at which the greatest differences in the quantity of wastes from each source are expected between various parts of the coastline.

3.3: Methods

Data were collected from a number of sources and subsequent calculations were completed on these data to quantify the level of organic wastes from offal, sewage, and aquaculture. Data for calculation of levels of offal and related information was received from the federal Department of Fisheries and Oceans (DFO), the Newfoundland Environmental Protection Branch of Environment Canada, the Canadian Centre for Fisheries Innovation (CCFI) at the Marine Institute of Memorial University, and the Department of Government Services and Lands and their Government Service Centres. The data for the calculation of aquaculture wastes was received from the provincial Department of Fisheries and Aquaculture, SCB Fisheries, fish farm owners, and the Newfoundland Salmonid Growers Association (NSGA). The Census data for sewage calculations was received from the provincial Department of Municipal and Provincial Affairs. See Chapter 2 (Methods 2.3) for details of the methods used to calculate the mass of dry organic wastes released from fish plants, aquaculture and sewage outfalls.

3.4: Results

When the coastline was divided into regions, areas, and sections variability was found in the level of organic wastes released within the various scales. This section gives the results for the individual regions, areas, and sections. The next section compares results within and among the four spatial scales studied.

Regions:

- **Region 1** - Northern Peninsula. Offal was the largest contributor of organic wastes, followed by raw sewage. Currently there is no marine aquaculture of finfish on the Northern Peninsula (Figure 3.1).

- **Region 2** - East Coast and Central. Offal was the largest source of organic wastes in the

East Coast and Central region, followed by sewage and aquaculture. Aquaculture was not present here until 1995 and aquaculture wastes decreased in 1996. (Figure 3.1)

- **Region 3** - Avalon Peninsula. Offal was the greatest contributor of organic wastes, followed by sewage and aquaculture. Aquaculture was not present on the Avalon Peninsula in 1992 and 1994 (according to the Department of Fisheries and Aquaculture production data). (Figure 3.1)

- **Region 4** - South Coast. Offal was the largest contributor of organic wastes, followed by sewage and aquaculture. The excess food and faeces released from finfish aquaculture showed a steady increase from 1992-1996. The aquaculture wastes were higher in this region than in any other. Notably, the aquaculture wastes were reaching a level very close to the level of released sewage in 1996. This situation was not seen in any other region. (Figure 3.1)

- **Region 5** - West Coast. Offal was the largest contributor of organic wastes, followed by sewage. There was no (or at least very little) finfish aquaculture in this region of the island. (Figure 3.1)

Areas: (Adjacent areas with similar results were grouped)

- **Area A** – Northern Peninsula, White Bay, Baie Verte Peninsula region. This area is located partially on the Northern Peninsula (Region 1) and partially in central Newfoundland (Region 2). **Area B** – Notre Dame Bay, Fogo Island region (Central). This area is located in Central Newfoundland (Region 2). The largest amount of organic waste released in these two areas was from offal, followed by sewage. There was no aquaculture in these two areas. (Figure 3.2)

- **Area C** – Bonavista Bay. This area is located on the East Coast (Region 2). Offal was the largest contributor of organic wastes, followed by sewage, then aquaculture. Aquaculture was not present in this area from 1992-1994. (Figure 3.2)

- **Area D** – Trinity Bay. This area is located partially on the East Coast (Region 2) and partially on the Avalon Peninsula (Region 3). **Area E** – Conception Bay. This area is located on the Avalon Peninsula (Region 3). Offal was the largest contributor of wastes in these two areas, followed by sewage. There was no aquaculture in these two areas. (Figure 3.2)

- **Area F** – St. John's area and Southern shore. This area is located on the Avalon Peninsula

(Region 3). Offal was the largest contributor of organic wastes in this area, followed by sewage and aquaculture. Aquaculture was not present in this region in 1992 and 1994. (Figure 3.3)

- **Area G** - Trepassey Bay and St. Mary's Bay. This area is located on the Avalon Peninsula (Region 3). Offal was the largest contributor of organic wastes in this area, followed by sewage. (Figure 3.3)

- **Area H** – Placentia Bay. This area is located partially on the Avalon Peninsula (Region 3) and partially on the South Coast (Region 4). Offal was the largest contributor of organic wastes in this area, followed by sewage and aquaculture. There was no aquaculture in this area from 1994-1996. (Figure 3.3)

- **Area I** – Fortune Bay. This area is located on the South Coast (Region 4). Offal was the largest contributor of organic wastes in this area, followed by sewage. (Figure 3.3)

- **Area J** – Bay d'Espoir and South Coast. This area is located on the South Coast (Region 4). Offal was the largest contributor of organic wastes in this area over the five year period. Sewage was the second largest source of wastes in 1992, 1993 and 1994 (by a very small margin in 1994), and aquaculture the second largest source of wastes in 1995 and 1996. (Figure 3.3)

- **Area K** – Codroy Valley region and St. George's Bay. This area is located on the West Coast (Region 5). Sewage was the largest contributor of wastes in this area over the five year period, with sewage levels remaining fairly constant. Offal was only present in this area in 1996 and aquaculture was not present in this area during the period examined. (Figure 3.4)

- **Area L** – Port au Port Peninsula and Bay of Islands. This area is located on the West Coast (Region 5). **Area M** – Bonne Bay, Gros Morne National Park, part of Northern Peninsula. This area is located partially on the West Coast (Region 5) and partially on the Northern Peninsula (Region 1). **Area N** – Gulf of St. Lawrence, Strait of Belle Isle region. This area is located on the Northern Peninsula (Region 1). Offal was the largest contributor of organic wastes in these three areas, followed by sewage. There was no aquaculture in these three areas. (Figure 3.4)

Sections: (Refer to Figure 2.1 and Figure 2.2 for locations)

(Adjacent sections with similar results were grouped)

- **Section 1 - Section 11 (Cape Norman - Southern Head)**

  Offal was the largest contributor of organic wastes in Sections 1-11, followed by sewage. (Figure 3.5, 3.6, 3.7)

- **Section 12** (Southern Head - Western Head)

Offal was the largest contributor of organic wastes in Section 12, followed by sewage, and aquaculture. Aquaculture was not present in this section until 1995. (Figure 3.7)

- **Section 13** (Western Head - Cape Bonavista)

Offal was the largest contributor of organic wastes in Section 13, followed by sewage. (Figure 3.7)

- **Section 14** (Cape Bonavista - South Head)

Sewage was the only form of organic wastes released in this section. (Figure 3.8)

- **Section 15 - Section 24** (South Head - Cape Spear)

Offal was the largest contributor of organic wastes in Sections 15-24, followed by sewage. (Figure 3.8, 3.9, 3.10)

- **Section 25** (Cape Spear - Cape Broyle)

Offal was the largest contributor of organic wastes in Section 25, followed by sewage, and aquaculture. Aquaculture was not present in this section in 1992 and 1994. (Figure 3.10)

- **Section 26 (Cape Broyle - Cape Race)**

Offal was the largest contributor of organic wastes in Section 26, followed by sewage. (Figure 3.10)

- **Section 27 (Cape Race - Cape Pine)**

Sewage was the only form of organic waste released in Section 27. (Figure 3.11)

- **Section 28 - Section 31 (Cape Pine - Jean de Baie Head)**

Offal was the largest contributor of organic wastes in Section 28 - 31, followed by sewage. (Figure 3.11, 3.12)

- **Section 32 (Jean de Baie Head - Point Crewe)**

Offal was the largest contributor of organic wastes in Section 32, followed by sewage, and aquaculture. Aquaculture was not present in this section from 1994-1996. (Figure 3.12)

- **Section 33, Section 35 (Point Crewe - Point Rosie and Boxey Point - Pass Island Point)**

Offal was the largest contributor of organic wastes in Sections 33 and 35, followed by sewage.(Figure 3.13)

- **Section 34 (Point Rosie - Boxey Point)**

Sewage was the only form of organic waste released in Section 34. (Figure 3.13)

• **Section 36** (Pass Island Point - Cape la Hune)

Offal was the largest contributor of organic wastes in Section 36, followed by aquaculture and sewage. This is the only case of aquaculture wastes exceeding sewage for the entire five year period examined. (Figure 3.14)

• **Section 38** (Fox Point - Rose Blanche Point)

The towns in Section 38 were not included in the Newfoundland Census, therefore sewage levels could not be calculated. There are no fish processing plants there and no aquaculture sites.

• **Section 37, Section 39** (Cape la Hune - Fox Point and Rose Blanche Point - Cape Ray)

Offal was the largest contributor of organic wastes in Sections 37 and 39, followed by sewage. (Figure 3.14)

• **Section 40** (Cape Ray - Harbour Point)

The towns in Section 40 were not included in the Newfoundland Census, therefore sewage levels could not be calculated. Offal was only present in this section in 1996 and there was no aquaculture. (Figure 3.15)

• **Section 41 - Section 43** (Harbour Point - Broad Cove Point)

Sewage was the only form of organic wastes released. There was no offal released and there was no aquaculture in these sections during the period examined. (Figure 3.15, Figure 3.16)

- **Section 44, Section 45 (Broad Cove Point - Martin's Point)**

Offal was the largest contributor of organic wastes in Sections 44 and 45, followed by sewage. (Figure 3.16, Figure 3.17)

- **Section 46 (Martin's Point - Daniel's Harbour)**

Overall, offal was the largest contributor of organic wastes in Section 46, followed by sewage. However, in 1994 sewage levels exceeded offal levels. This was the only case in the study where this result was found. (Figure 3.17)

- **Section 47 (Daniel's Harbour - Point Riche)**

Sewage was the only form of organic waste released in Section 47, and levels were fairly constant throughout the five year period. (Figure 3.17)

- **Section 48, Section 49 (Point Riche - Cape Norman)**

Offal was the largest contributor of organic wastes in Sections 48 and 49, followed by sewage. In 1992, section 49 had the highest level of offal in any of the sections for any of the five years. (Figure 3.18)

3.4.1: Comparison of amount and type of wastes within and between spatial scales.

Comparison of amount and type of wastes between Regions 1-5:

The Avalon Peninsula, Region 3, had sewage and offal levels that surpassed the levels in any other region. The South Coast, the region in which Bay d'Espoir is located, had much higher levels of aquaculture wastes than any other region. Only two other regions had finfish aquaculture, the East Coast and Central, Region 2, and the Avalon Peninsula, Region 3. Both of these regions had finfish farms in 1995 and 1996, but the Avalon Peninsula also had farms in 1993. The amount of wastes released was much greater on the Avalon Peninsula than in East Coast and Central, for all three years. The Northern Peninsula, Region 1, released the least amount of organic wastes from each of the three sources over the five year period. Overall, all five regions were similar in levels of offal and sewage wastes released, but greatly differed in levels of aquaculture wastes. See Table 3.1 for further comparison of the five regions.

To describe the general trends the regions were given an overall rank (1-5) according to how much waste was released in comparison to the other regions (i.e. 1 – the largest contributor of these wastes, 5 - the smallest contributor of these wastes). Each year was initially ranked separately, but for each region the rank was the same for an individual source over the five years studied. Therefore, the years are grouped 1992-1996.

Table 3.1. Coastal regions ranked according to level of organic wastes released.

Scale	Offal 1992-1996	Sewage 1992-1996	Aquaculture 1992-1996
Region 1- Northern Peninsula	5	5	NA
Region 2- East Coast and Central	2	2	3
Region 3- Avalon Peninsula	1	1	2
Region 4- South Coast	3	4	1
Region 5- West Coast	4	3	NA

(See Appendix F, Table F1 for regions data)

Comparison of amount and type of wastes between Areas A-N:

The areas were ranked according to the level of wastes released (Table 3.2). An overall rank (1-14) was assigned for each year according to how much waste was released in comparison to the other areas (i.e. 1 – the largest contributor of these wastes, 14 - the smallest contributor of these wastes).

Table 3.2. Coastal areas ranked according to level of organic wastes released.

Scale	Year	Offal Rank	Sewage Rank	Aquaculture Rank
Area A	1992	12	8	NA
	1993	10	8	NA
	1994	12	8	NA
	1995	11	8	NA
	1996	11	8	NA
Area B	1992	7	3	NA
	1993	3	3	NA
	1994	2	3	NA
	1995	3	3	NA
	1996	4	3	NA
Area C	1992	11	7	NA
	1993	5	7	NA
	1994	5	7	NA
	1995	5	7	3
	1996	5	7	3
Area D	1992	8	6	NA
	1993	6	6	NA
	1994	4	6	NA
	1995	4	6	NA
	1996	3	6	NA
Area E	1992	5	2	NA
	1993	4	2	NA
	1994	3	2	NA
	1995	1	2	NA
	1996	2	2	NA
Area F	1992	3	1	NA
	1993	1	1	3
	1994	1	1	NA
	1995	2	1	2
	1996	1	1	2
Area G	1992	13	13	NA
	1993	12	13	NA
	1994	10	13	NA
	1995	10	13	NA
	1996	9	13	NA

Table 3.2. cont'd . Coastal areas ranked according to level of organic wastes released.

Scale	Year	Offal Rank	Sewage Rank	Aquaculture Rank
Area H	1992	4	5	2
	1993	2	5	2
	1994	7	5	NA
	1995	6	5	NA
	1996	7	5	NA
Area I	1992	6	11	NA
	1993	9	11	NA
	1994	6	11	NA
	1995	9	11	NA
	1996	6	11	NA
Area J	1992	2	10	1
	1993	7	10	1
	1994	9	10	1
	1995	8	10	1
	1996	12	10	1
Area K	1992	NA	9	NA
	1993	NA	9	NA
	1994	NA	9	NA
	1995	NA	9	NA
	1996	14	9	NA
Area L	1992	10	4	NA
	1993	11	4	NA
	1994	11	4	NA
	1995	12	4	NA
	1996	10	4	NA
Area M	1992	9	12	NA
	1993	13	12	NA
	1994	13	12	NA
	1995	13	12	NA
	1996	13	12	NA
Area N	1992	1	14	NA
	1993	8	14	NA
	1994	8	14	NA
	1995	7	14	NA
	1996	8	14	NA

(See Appendix F, Table F2 for Area data)

The differences in rank (Table 3.2) enable easy comparison of the 14 areas. Aquaculture was only present in Areas C, F, H, and J. Area J (Bay d'Espoir and South Coast), was the only area with aquaculture activity in each of the five years studied, and had the highest level of aquaculture wastes for each of those years. Area F (St. John's area and Southern shore), was the next largest contributor of aquaculture wastes, with farms in operation in 1993, 1995 and 1996. Both the 1995 and 1996 waste levels for Area F exceeded the waste levels for Area C (Bonavista Bay). These were the only two years farms operated in Area C. Area H (Placentia Bay), had finfish aquaculture in 1992 and 1993 and was the second largest contributor of aquaculture wastes at that time.

Area F (St. John's area and Southern shore), released the greatest amount of offal over the five year period. Area E (Conception Bay), was the second largest contributor of offal and Area B (Notre Dame Bay and Fogo Island region - Central), released the third largest amount of offal. The lowest offal levels were in Area M (Bonne Bay, Gros Morne National Park, part of Northern Peninsula), followed by Area A (Northern Peninsula, White Bay, Baie Verte Peninsula region), Area L (Port au Port Peninsula and Bay of Islands), and Area G (Trepassey Bay and St. Mary's Bay).

Area F (St. John's area and Southern shore), had the highest sewage levels for each of the five years examined. Area E (Conception Bay), was the second largest contributor of sewage in that time period and Area B (Notre Dame Bay and Fogo Island region - Central), released the third largest amount of sewage. The lowest sewage levels were in Area N (Gulf of St. Lawrence and Strait of Belle Isle area), followed by Area G (Trepassey Bay and St. Mary's

Bay), Area M (Bonne Bay, Gros Morne National Park, part of Northern Peninsula) and Area I (Fortune Bay).

Overall, Area F (St. John's area and Southern shore), was the greatest contributor of organic wastes and Area M (Bonne Bay, Gros Morne National Park, part of Northern Peninsula) the smallest contributor of wastes.

Comparison of amount and type of wastes between Sections 1-49:

Aquaculture wastes were predominately produced in Section 36 (Pass Island Point - Cape la Hune, on the south coast). In fact, this was the only section in which aquaculture wastes exceeded sewage levels, and this occurred in each of the five years examined. This was also the only section in which fish processing occurred and the offal levels were surpassed by another form of organic waste (Figure 3.14). In this case aquaculture wastes exceeded offal levels in 1996 (by 10,600 kg, Appendix F, Table F3). The three other sections with aquaculture activity were Sections 12 (Southern Head - Western Head), 25 (Cape Spear - Cape Broyle), and 32 (Jean de Baie Head - Point Crewe). These sections predominately raised Atlantic Cod, but one raised Greenland Cod. In 1992-1993 Section 32 was the largest contributor of organic wastes from aquaculture of these three sections, and in 1995-1996 Section 25 was.

There was considerable variation in the level of offal production between sections. There were some sections with no offal production for the entire period studied. These included Sections 14 (Cape Bonavista - South Head), 27 (Cape Race - Cape Pine), 34 (Point

Rosie - Boxey Point), 38 (Fox Point - Rose Blanche Point), 41 (Harbour Point - Cape St. George), 42 (Cape St. George - Long Point), 43 (Long Point - Broad Cove Point), and 47 (Daniel's Harbour - Point Riche). These sections will not be considered in the following comparisons. Section 40 (Cape Ray - Harbour Point) will also not be considered because there was no fish processing there until 1996. The 1996 offal levels there were below the levels in other sections. Section 22 (Feather Point - Topsail Head, in Conception Bay) released the greatest amount of offal over the five years studied. Section 49 (Ferolle Point - Cape Norman, on the Northern Peninsula) was the second largest contributor (however in 1992 the offal levels in section 49 largely surpassed the levels in any other section in any of the five years examined). Section 25 (Cape Spear - Cape Broyle, on the east coast) and Section 26 (Cape Broyle - Cape Race, on the east coast) were the third largest contributors of offal (they had the same levels of offal because they both contained 36% of Area F's fish processing plants, Appendix C). Section 2 (Cape Bauld - Lobster Point, on the Northern Peninsula) released the smallest amount of offal over the period examined. Sections 1 (Cape Norman - Cape Bauld), 3 (Lobster Point - Cape Fox), and 5 (Partridge Point - Cape St. John) released the same amount of offal (each section contains 18% of Area A's processing plants, Appendix C) and were the second smallest contributors of offal. Section 20 (Grates Point - Western Bay Head) was the third smallest contributor of offal. The sections with no processing plants (Sections 14 (Cape Bonavista - South Head), 27 (Cape Race - Cape Pine), 34 (Point Rosie - Boxey Point), 38 (Fox Point - Rose Blanche Point), 41 (Harbour Point - Cape St. George), 42 (Cape St. George - Long Point), 43 (Long Point - Broad Cove Point), and 47 (Daniel's Harbour - Point Riche)) could not release any offal into the marine environment. These same sections generally tended to have low populations and no aquaculture activity as well, which makes them the lowest contributors of organic wastes in the province.

The greatest amount of sewage was released into the waters of Section 24 (Cape St. Francis - Cape Spear, on the east coast). The second largest contributor of raw sewage was Section 44 (Broad Cove Point - Cape St. Gregory, on the west coast), and the third greatest contributor was Section 22 (Hopeall Head - Topsail Head, in Conception Bay). Section 20 (Grates Point - Western Bay Head, in Conception Bay) had the lowest sewage levels for the entire province. The second lowest levels were in Section 43 (Long Point - Broad Cove Point), and the third lowest levels in Section 19 (Salvage point - Grates Point). Note that Figure 3.15 indicates that Section 40 (Cape Ray - Harbour Point, on the west coast) released no sewage. This is because the towns in Section 40 were not included in the Census. There was no way to calculate sewage levels for this section. This was also the case for Section 38 (Fox Point - Rose Blanche Point, on the south coast). This section had no processing plants or aquaculture either. Therefore, there was no data available for Section 38.

Comparison of amount and type of wastes between spatial scales:

The results for all five coastal regions corresponded with those of the entire island: Offal was the greatest contributor of organic wastes, sewage was the second largest contributor, and aquaculture was the smallest contributor. Almost all of the results for the fisheries statistical areas corresponded with the results for the scale of the entire island and for the regional scale, while the results for one area did not. Sewage was the largest source of organic wastes and offal the second largest source in area K, but offal was only produced in 1996. All of the other areas had the same results as the entire island and the five coastal regions.

Some of the results for the scale of fisheries statistical section corresponded with the results for the scale of fisheries statistical area. However, other results for the scale of fisheries statistical section did not. For instance, some of the sections with no offal production were in areas that have fairly high offal levels over all. Section 14 in Area D (Trinity Bay), Section 34 in Area I (Fortune Bay), and Section 38 in Area J (Bay d'Espoir and South Coast), are examples of this situation. Some of the sections that actually produced offal but at relatively small levels (Sections 1, 2, 3, and 5) are in Area A (Northern Peninsula, White Bay, Baie Verte Peninsula area), the area which produced the second lowest levels of offal in the province. Section 22 was the greatest contributor of offal and is in Area E (Conception Bay), the area which produced the second largest levels of offal in the province. Section 49 produced the second largest amount of offal but is in Area N (Gulf of St. Lawrence, Strait of Belle Isle region), an area that did not release a large amount of offal relative to some other areas.

The lowest sewage levels for the Province were in Section 20, which is in Area E (Conception Bay), the area which contributed the second largest amount of sewage in the province. Section 43, with the second lowest levels is in Area L (Port au Port Peninsula/Bay and Bay of Islands), which did not have a very low relative sewage output. The highest sewage levels were in Section 24 (which was expected), in Area F (St. John's area and Southern shore), the area which was the highest contributor of sewage in the province. The second largest contributor was Section 44 (which was also expected), in Area L (Port au Port Peninsula and Bay of Islands), an area that was not a very high contributor of sewage overall.

Aquaculture wastes were predominately found in Section 36, an expected result since this is in Area J, the Bay d'Espoir and South Coast area.

3.5: Discussion

The results for the five coastal regions, 14 fisheries statistical areas, and 49 fisheries statistical sections supported the hypothesis that the relative level of organic wastes released from the three sources in Newfoundland would differ according to spatial scale. As the scale became smaller, from the entire island to fisheries statistical section, the ranking of the three sources of organic wastes was expected to change depending upon the industry in the region (aquaculture, fish plants) and on the population. This was apparent in the results for coastal area and section.

The Northern Peninsula was the region with the lowest level of organic wastes being released into coastal waters. It had the lowest population and thus the lowest amount of raw sewage being released, even though this region had no municipal sewage treatment in any of its towns. This region had no marine finfish aquaculture activity because the ocean freezes and the pack ice piles up on the coast (DFA 1998a). In addition, less fish were landed at the processing plants there than in other regions. Towns and processing plants are spread out along the Northern Peninsula, a region that extends over a large tract of the coastline. This prevented an accumulation of sources of organic wastes in one place. Most towns in this region are not sheltered from the open ocean and are subject to wave action and strong currents. Thus any organic wastes being released were generally dispersed rapidly into the marine environment.

The East Coast and Central region had the second highest population in Newfoundland, next to the Avalon Peninsula. However, this region is spread out along a greater expanse of coastline. It also included seven of the fourteen municipalities with sewage treatment (Table 2.3). Therefore, even though this region had the second highest levels of sewage released it had less potential for accumulation of sewage along the coast. The processing plants were concentrated into specific parts of the coastline in this region, for instance, Fogo Island, New World Island, and a few regions in Bonavista Bay. The release of offal was a potentially greater problem in this region than sewage because of the localized nature of offal dumping. In addition, unlike sewage, tonnes of offal were released in one spot at a time making dispersal and assimilation more difficult. The aquaculture activity was also localized, in Bonavista Bay and the northern part of Trinity Bay, but these operations were not a major concern due to their small size.

The Avalon Peninsula was the region with the greatest potential for increased organic waste release. In Newfoundland, there are very few municipalities with sewage treatment, therefore the greatest amount of sewage released was in regions where the coastal population was the highest. The Avalon Peninsula had the highest population of people on the island concentrated into a relatively small area. However, only four of the 14 municipalities with sewage treatment (Holyrood, CBS east of Manuals, Arnold's Cove, and Victoria) were located there (Table 2.3). Many of the towns on the Avalon Peninsula are found in bays, most notably Conception Bay, and are not exposed to the open ocean. This decreases the flushing effect of currents and waves from the open ocean. The Avalon Peninsula had the largest number of processing plants (Appendix C) and the highest production of fish products, therefore the greatest amount of offal. This region also contained a large number of the aquaculture operations (Appendix A).

The South Coast did not release large amounts of organic wastes generally. The release of excess feed and faeces from aquaculture was greater in this region than in others (Figure 3.1). However, salmonid aquaculture is exclusively in Bay d'Espoir, thus making it a more localized situation than on the regional scale (Figure 3.14, for Section 36, in Region 4). Ninety to 95% of Newfoundland's aquaculture revenue comes from Bay d'Espoir (Moyse 1998 pers. comm. list), thus this result was expected.

The West Coast has towns concentrated in the Port au Port, Corner Brook and Bonne Bay areas. The highest sewage levels were concentrated into these three regions. The highest levels were in the Corner Brook region. This area has the Humber Arm extending far into the land area, thus decreasing wind and wave action from the open ocean. Overall, apart from Corner Brook, sewage was probably not a concern on the West Coast due to the exposed nature of the coastline. Offal was probably a larger concern than sewage, as in the other regions, due to the regionalized nature and high concentrations when released. The level of offal being released was also on the rise in 1996 on the West Coast. This could be of potential concern since offal now consists of more inorganic shells which may create increased accumulation of wastes.

Variation in levels of organic wastes released became more apparent at the scale of areas than at the larger scale of regions. Each of the 14 areas showed variation in the level and type of wastes released. Area J (Bay d'Espoir and South Coast) was the area with the highest levels of aquaculture wastes due to the high concentration of fish farms in this area. Area F (St. John's area and Southern shore) had the highest population and the highest production levels at processing plants, thus had the greatest releases of sewage and offal. Area N (Gulf of St. Lawrence, Strait of Belle Isle area) had the lowest sewage levels because of the low relative population. Area M (Bonne Bay, Gros Morne National Park, part of Northern Peninsula) had the lowest offal levels because of the low level of fish production in that area.

At the scale of areas, Area F was the largest contributor of wastes overall. This was not an unexpected result considering the St. John's and Southern Shore area had a high relative population, a large number of processing plants, and the second highest level of aquaculture activity (behind Bay d'Espoir) in the province. Area M (Bonne Bay, Gros Morne National Park, part of Northern Peninsula) was the smallest contributor of organic wastes. Area N (Gulf of St. Lawrence and Strait of Belle Isle region) had a lower population, thus less sewage being released, and both areas had no aquaculture activity. However, Area M released less offal than Area N. The amount of offal produced by fish plants was much greater than the sewage levels in the same vicinity, another unexpected result.

Variation within fisheries statistical areas was apparent from the sectional breakdown of results within the areas. Some of the fisheries statistical section results corresponded with the area results, whereas other sectional results did not. At the scale of sections, environmental effects were much more evident than at the larger scales examined in this thesis. Numerous examples of localized (small scale) environmental effects of organic wastes can be found in the literature. For instance, when sediments from the St. Johns' harbour were tested near a sewage outlet there was an organic content of about 44% (McDermott 1998). In both Aquaforte and Fogo Harbour the decomposing gurry in offal dumping grounds formed an anoxic ooze which generally prevented macrofauna and macroflora from inhabiting the gurry ground (Barrie 1985). In Fogo Harbour, estimated one year old offal could be identified and decomposed offal which was several years old was still present (Barrie 1985). The benthic environment appeared anoxic which probably slowed down the decomposition of the gurry and limited the number of scavengers. Barrie (1985) noted that lighter portions of the fish wastes remained in the water column moving with the currents, thus spreading the organic wastes. In Fogo Harbour, two years after cessation of dumping there were no signs of wastes present (Barrie 1985, Fudge and Associates Ltd. 1989). At that time the majority of the offal was from groundfish, in contrast to today with the increasing levels of crab and shrimp offal.

Studies completed at small coastal scales in other parts of Atlantic Canada show negative impacts from the liquid effluents emitted from processing plants. At Louisbourg, Nova Scotia, the effluent may have increased the primary productivity and disrupted benthic organisms locally (Environmental Protection 1977). The coliform bacteria in the effluent from one fish meal plant were at a level comparable to that of sanitary sewage (Environmental Protection 1977). However, most of the effluents from the processing plants tested were not lethal to fish such as rainbow trout, *Oncorhynchus mykiss*, and mummichogs, *Fundulus heteroclitus*, and were considered to create only temporary, localized effects (Environmental Protection 1977). In Louisbourg harbour and Lockeport, the study revealed a build-up of decomposing organic wastes on the bottom due to the released plant effluent. Chlorophyll-a levels were higher near the fish plants than at controls and both regions showed other signs of organic waste release such as reduced abundance and variable diversity of benthic communities (Environmental Protection 1977). This study was completed over 20 years ago so conditions may have improved since that time. There may also be positive impacts from the release of fish processing plant effluents. Field observations have shown that fish of various species consume the effluent at discharges. Thus, the effluent may be increasing the productivity of the fish population in the area (Brodersen 1973).

Bay d'Espoir, Newfoundland's predominant aquaculture region, is a complex estuarine fjord, which could increase the possibility of environmental problems. It is stratified by a year round halocline into an upper fresh water layer, a middle tidal layer, and a basin. The aquaculture occurs in the fresh water layer, with the net containing the salmon sometimes entering the tidal layer. The wastes sink to the bottom basin. According to Baden *et al.* (1990) such regions are at risk for increased primary production due to eutrophication, leading to sedimentation of the phytoplankton and reduction of oxygen in bottom waters. This occurs because of the halocline, which greatly decreases mixing of surface waters and bottom waters.

Problems due to low oxygen concentrations have occurred in regions such as the SE North Sea, the coast of Brittany, the Adriatic Sea, the coast of Alabama, the New York Bight, and the SE Kattegat, which all have a salinity stratification created by freshwater outflow (Baden *et al.* 1990).

Localized impacts from aquaculture have been reported in Bay d'Espoir. An aquaculture survey completed by the Ocean Mapping Group at the University of New Brunswick found some interesting results with their seabed topography images of current aquaculture sites in Bay d'Espoir. The bathymetric resolution showed that some of the most protected sites had a 10-50 cm positive depth anomaly under salmon cages (i.e. a build-up of wastes). The backscatter resolution showed that Man of War Cove, Muddy Hole, Hardy Cove and Southeast Cove in Roti Bay, had a 10 m diameter circular anomaly beneath salmon pens or sites just recently vacated (Clarke *et al.* 1997).

A four year Carrying Capacity Project is being carried out by the NSGA in Bay d'Espoir to help determine the capacity of the region to raise fish while maintaining a healthy environment (DFA 1998a). According to Tlusty (1998 pers. comm. list) there is build up under some cages but when the cages are moved the current quickly dissipates it. All locations are healthy and water nutrient samples show that they are well within the safe BOD (biochemical oxygen demand) zone. This is due to the high volumes of water in the bay. Field sampling completed during the winter of 1996/1997 in Bay d'Espoir indicated that, generally, variables measured were within environmental norms for sustainable aquaculture. Only two problem areas were discovered. One area, Roti Bay, had a low dissolved oxygen level 1 m from the bottom in the inside basin of the bay, compared to the outside basin. The other concern was in Roti Bay and Northwest Cove, where areas next to operating farms had higher nutrient levels and lower oxygen levels than areas 50 m or more from the farms. This situation may be due to low flushing and circulation (Anderson *et al.* 1997). The results of this thesis show that this part of the island is the only one where sewage levels were surpassed by aquaculture wastes.

Numerous other examples of aquaculture problems occurring on a small scale are cited in the literature. On the west coast of Canada there have been occurrences of salmon-killing blooms due to nutrient enrichment of waters near salmon farms (Rosenthal *et al.* 1995). A fatal bloom occurred in Big Glory Bay, New Zealand in 1989 where about 600 t of Chinook salmon died as result of a phytoplankton bloom partly caused by hypernutrification from farms (Pridmore and Rutherford 1992). Many salmon farms in Scottish sea lochs showed an accumulation of wastes underneath the cages (Lumb 1989). Fish farm sediment consisting of excess food and faeces were found beneath salmon cages in Norwegian fjords (Aure and Stigebrandt 1990). A 40 t marine cage farm on the Swedish coast had a sedimentation rate 20 times higher than in untouched regions (Folke and Kautsky 1989). In Dark Harbour, N.B., a salmon farm had to be closed due to accumulation of wastes that created outgassing of methane and hydrogen sulphide that could harm or even kill the fish above. (Rosenthal *et al.* 1995). Wildish *et al.* (1993) also report conditions under salmon cages in New Brunswick, in which the faeces and uneaten food accumulated on the bottom and caused deoxygenation of the sediments due to an increase in aerobic bacteria.

There are examples of localized sewage impacts in the literature as well. In St. John's harbour, winter flounder have fluid retention in their gills, more than half of the flounder studied had eroded fins, and liver lesions were apparent in fish caught in and around the harbour (Nantel 1996). In California, black abalones at a sewage outfall had high mortality rates and slow growth rates, in comparison to those from a clean area. They also had eroded shells and were starving (Nantel 1996). In Caraquet Bay, New Brunswick and the Annapolis Basin, Nova Scotia, fecal pollution prevents almost 50% of the potential shellfish harvesting. In the Halifax harbour, there is a low diversity of species, and surface sediments near sewage outfalls are anoxic in some cases. These characteristics are at least partly attributable to sewage discharges (Nantel 1996). In addition, mussels from the outer Halifax harbour are healthier than those in the inner harbour, in 1965 bacteriological contamination permanently closed the harvesting of clams and mussels in that area, lobsters have experienced subtle increases in contamination levels, and odours and floating debris cause a large decrease in aesthetics in the Halifax harbour, where one third of the shoreline litter comes from sewage discharges (Nantel 1996).

3.6: Conclusion

The results for the five regions corresponded with those of the entire island - offal was the greatest contributor of organic wastes and aquaculture the smallest. The region with the highest levels of coastal organic wastes being released was the Avalon Peninsula, and the region with the least organic wastes was the Northern Peninsula. However, when smaller spatial scales were examined variation was found within the larger coastal scales. It is at these smaller scales that evidence of accumulation of wastes and negative ecological effects may be apparent. The results for the area and section scales corresponded with those for the region scale in that the places with the highest release rates (St. John's, Southern Shore, Conception Bay) were on the Avalon Peninsula, and the places with the lowest release rates (Bonne Bay, Gros Morne Park area, Strait of Belle Isle area) were on (or very near) the Northern Peninsula. At the two smallest scales, most areas and sections had offal as the greatest contributor and aquaculture as the smallest contributor of wastes.

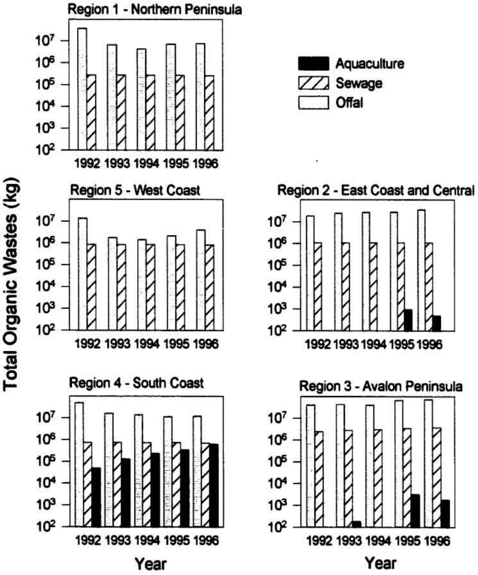

Figure 3.1. Total organic wastes (dry mass) released from Regions 1-5 from 1992-1996. Graphs are arranged according to the Region's geographic position on the island.

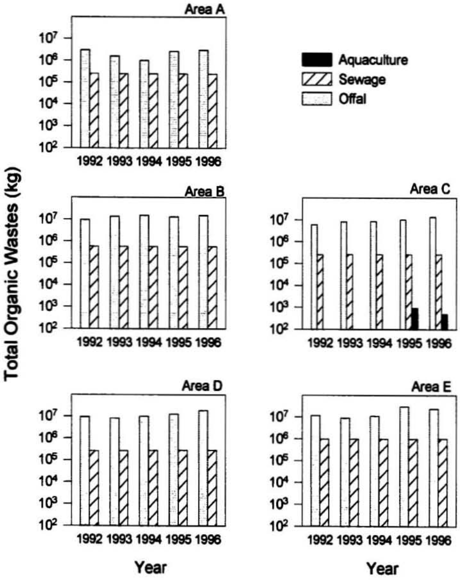

Figure 3.2. Total organic wastes (dry mass) released in Areas A-E from 1992-1996.

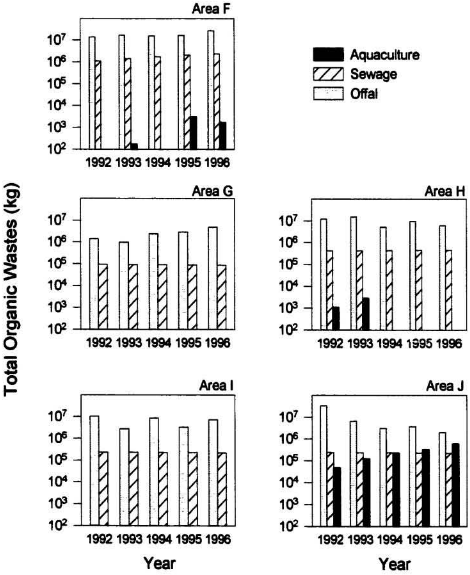

Figure 3.3. Total organic wastes (dry mass) released in Areas F- J from 1992-1996.

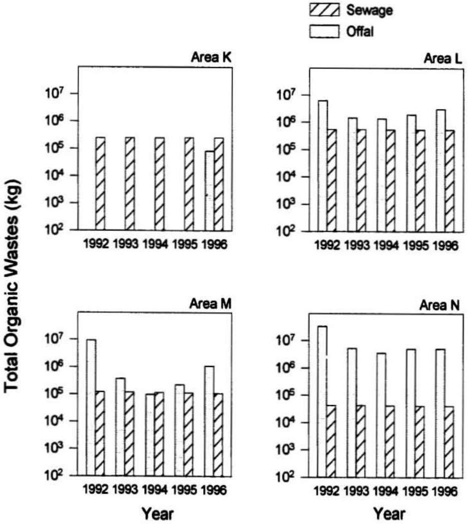

Figure 3.4. Total organic wastes (dry mass) released in Areas K-N from 1992-1996.

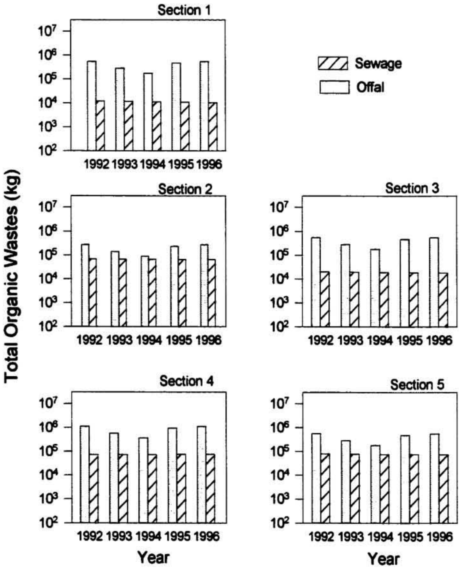

Figure 3.5. Total organic wastes (dry mass) released in Sections 1-5 (Area A) from 1992-1996.

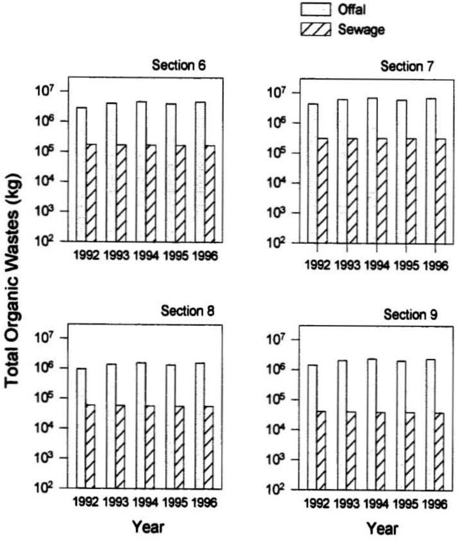

Figure 3.6. Total organic wastes (dry mass) released in Sections 6-9 (Area B) from 1992-1996.

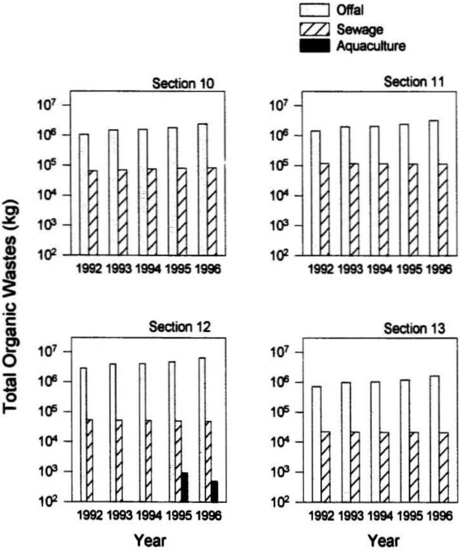

Figure 3.7. Total organic wastes (dry mass) released in Sections 10-13 (Area C) from 1992-1996.

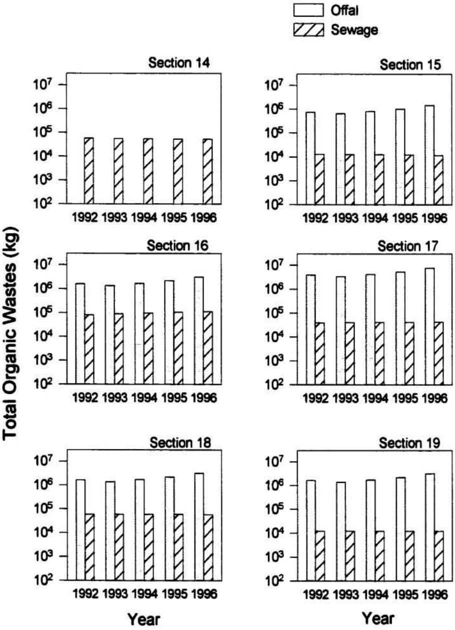

Figure 3.8. Total organic wastes (dry mass) released in Sections 14-19 (Area D) from 1992-1996.

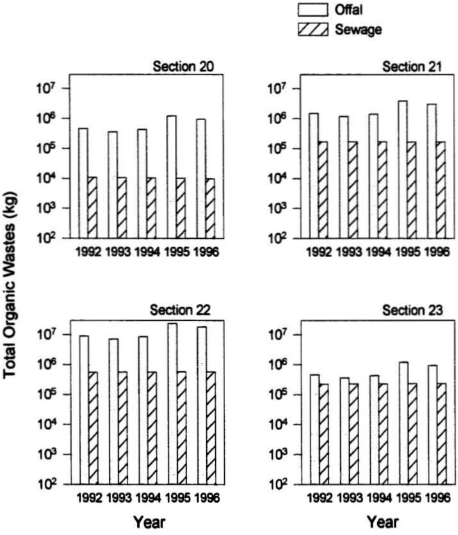

Figure 3.9. Total organic wastes (dry mass) released in Sections 20-23 (Area E) from 1992-1996.

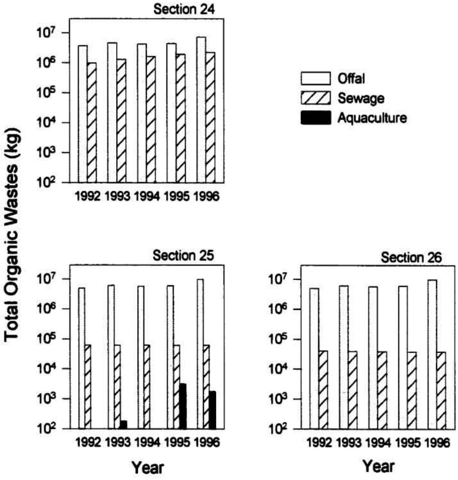

Figure 3.10. Total organic wastes (dry mass) released in Sections 24-26 (Area F) from 1992-1996.

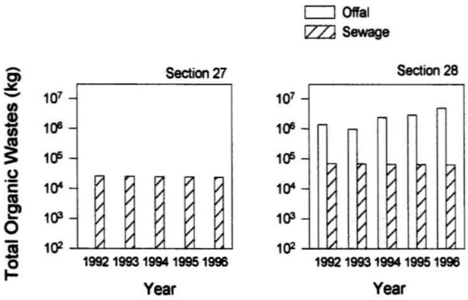

Figure 3.11. Total organic wastes (dry mass) released in Sections 27-28 (Area G) from 1992-1996.

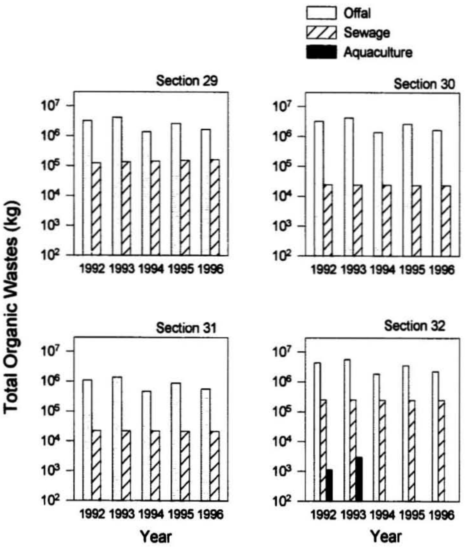

Figure 3.12. Total organic wastes (dry mass) released in Sections 29-32 (Area H) from 1992-1996.

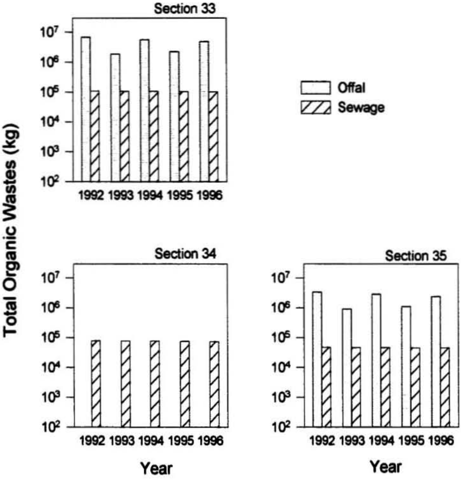

Figure 3.13. Total organic wastes (dry mass) released in Sections 33-35 (Area I) from 1992-1996.

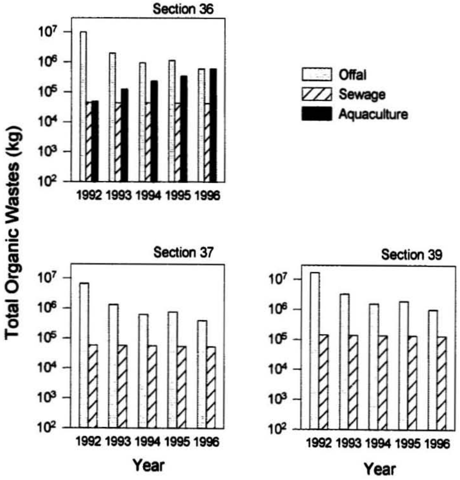

Figure 3.14. Total organic wastes (dry mass) released in Sections 36-39 (Area J) from 1992-1996.

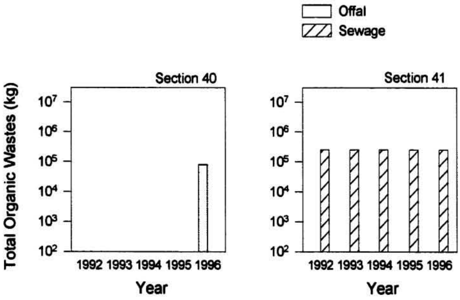

Figure 3.15. Total organic wastes (dry mass) released in Sections 40-41 (Area K) from 1992-1996.

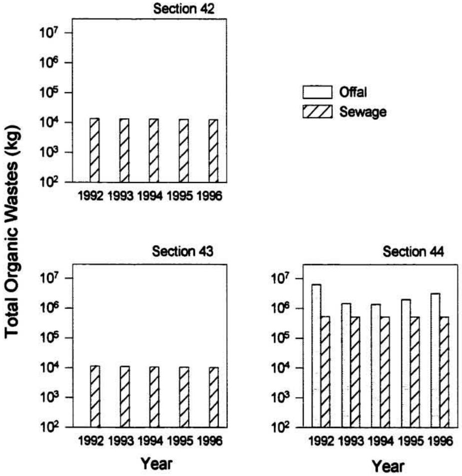

Figure 3.16. Total organic wastes (dry mass) released in Sections 42-44 (Area L) from 1992-1996.

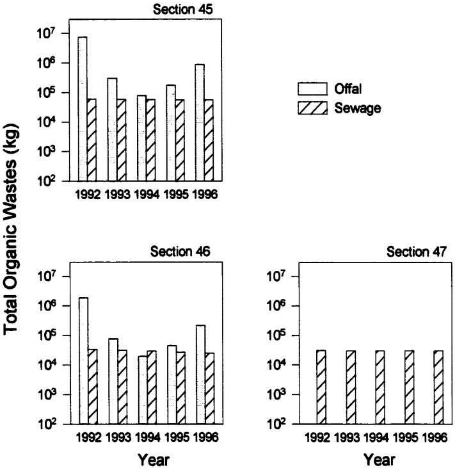

Figure 3.17. Total organic wastes (dry mass) released in Sections 45-47 (Area M) from 1992-1996.

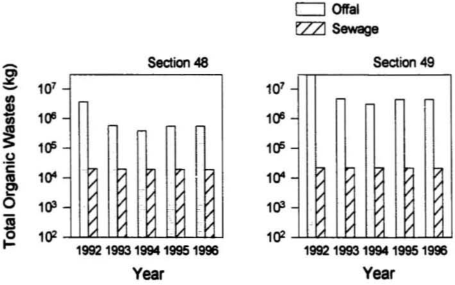

Figure 3.18. Total organic wastes (dry mass) released in Sections 48-49 (Area N) from 1992-1996.

Chapter 4: Predictions and preventative measures for coastal organic waste release in Newfoundland.

Although the waters around Newfoundland are relatively uncontaminated in comparison to more industrialized and highly populated regions, there are many organic wastes being released into coastal waters. Total levels of organic wastes released in other areas were not available for direct comparison with Newfoundland. The quantities of organic wastes presented in this thesis were generally difficult to compute. In some cases information which may have helped generate more accurate estimates was not available, and in other cases the data gathered were not reliable. Hence, alternative methods were used. The lack of data regarding organic waste disposal in Newfoundland was surprising. Although the quantities presented are simply estimates they give an idea of the level of wastes entering the coastal waters and enable a comparison between the various sources of organic wastes released.

Offal is a source of wastes that may have a large environmental impact in the future in Newfoundland. This is because of the current high levels of offal produced (Figure 2.3) and the increase in inorganic shellfish offal which may cause greater accumulation of wastes over time (Figure 2.4). There are a large number of fish plants (Appendix C) in Newfoundland but only two fish meal plants to process the offal. Although the number of fish meal plants may soon increase, there will not be enough plants to reduce all of the offal into fish meal. Offal levels in individual fisheries statistical areas and fisheries statistical sections were actually increasing in many places, thus localized problems may ensue.

The release of offal into coastal waters can be reduced through a number of methods. Instead of dumping tonnes of offal as waste it can be produced into animal or fish feed. This production will not only decrease the release of environmentally damaging materials but will be a source of revenue for Newfoundland. Fishery by-products have increased the economic value of landed catches in Canada. Canadian produced fish meal is used nationally in agriculture and aquaculture and is exported to numerous other countries. Originally many fish meal plants were solely for waste reduction, but for many decades, fish meal has been an important product on the world market for animal feed (Ming-Lesage 1991). In British Columbia, in 1991, over 100,000 metric tonnes of offal was produced, and one third to one half of this offal was made into fish meal and fish oil. This type of production is a fairly large Canadian industry (Ming-Lesage 1991, Aegis 1991). New Brunswick also has a fish waste processing industry. Sixty percent of the 33,000 metric tonnes of waste is made into fish meal and fish oil. Only a very small, but unknown, amount is dumped at sea there (Tidmarsh *et al.* 1986). In 1992 in Newfoundland, about one hundred and fifty-nine thousand tonnes of offal was produced (Figure 2.3, Table 2.8), apparently enough to support a viable fish meal industry.

In addition to fish meal, there are many processing alternatives for offal. These include fish silage, fish protein hydrolysate, fish protein concentrate, aquaculture feeds, agriculture feeds, zoo and pet food, glue and gelatin, insulin and other biochemical and pharmaceutical products, pearl essence, marine animal leather, chitin and chitosan, non-edible uses of fish oils, fertilizer, and bait (Tidmarsh *et al.* 1986). According to Ming-Lesage (1991) by-products such as low temperature fish meals, fish silage, fishery based protein concentrates and fish hydrolysates would be the most commercially viable in Canada and in the United States.

Another method to reduce organic loading from offal is to implement stricter control measures to ensure utilization of designated dumping grounds. Many marine regions have not been assigned a dumping permit, yet are used to release fish waste. At marine disposal sites for herring offal in Nova Scotia a limit of 2,000 metric tonnes was implemented for two permits (Tidmarsh *et al.* 1986). Similar action would be beneficial for the Newfoundland dumping sites, since there are currently no regulations regarding the level of offal dumped. In addition, large amounts of offal should not be accumulated and released periodically at a high concentration. Instead, smaller amounts of offal could be released more frequently to enable easier dispersal and assimilation of wastes into the marine waters.

Currently, there are attempts to reduce the amount of offal entering the coastal waters in Newfoundland. In Harbour Breton, the FPI plant processes fish offal into fish food, fertilizers, and cattle food. However, the waste water is released into the ocean. The fish processing plant in Winterton sells male caplin to Sea World and Marine Land, and their damaged caplin are sold for the processing of dog and cat food. A no dumping policy will be considered for crab and shrimp shells if a company will come to Newfoundland to process these wastes into a product (Efford 1998). In addition, the provincial Department of Fisheries and Aquaculture is trying to develop new products from male caplin, crab and shrimp offal. These products include pet treats made from male caplin offal, feed for local fish farms, as well as pharmaceutical, health industry products and waste water treatment from chitin and chitosan from crab shells (DFA 1998b).

Sewage is a source of organic wastes that may increase in some areas of Newfoundland in the future and cause localized problems. The population of Newfoundland is currently decreasing, but more people are moving into the larger centres. These areas are the ones with the greatest levels of organic wastes and they are going to experience an increase in sewage over time (such as the St. John's area, Area F, Figure 3.3; Section 24, Figure 3.10, and Corner Brook, Section 44, Figure 3.16). In addition, further problems may stem from the current decrease in sewage treatment in many of the smaller towns. Many of the treatment facilities are old (from the 1970's generally), are not maintained, and are in a state of disrepair (Golding 1999 pers. comm. list). There are places on the island where the effluent leaving the facility is more harmful than the sewage entering (Golding 1999 pers. comm. list). In the seventies, generally, areas heavily involved with the fishery had sewage treatment. There is less money to maintain these systems now and in many cases a lot of rain or snow may wash out the whole system. Currently, there are fewer treatment plants than in the 1970's. For instance, Hampden's system is out of service and Bonavista's is going out of service to be replaced by a marine outfall (Golding 1999 pers. comm. list). This trend is inconsistent with the general global concern regarding the pollution of the environment.

The release of sewage into coastal waters can be reduced. Increased use of sewage treatment should be a priority in Newfoundland today considering the importance of the coastal waters for tourism and aquaculture. Newfoundland should follow the example of Prince Edward Island, where almost all of the municipal sewage is treated to prevent groundwater contamination and to protect the coastal-oriented tourism industry and shellfish aquaculture.

Many benefits are accrued by increasing sewage treatment, including a decrease in chlorophyll-A concentrations and phytoplankton biomass, an increase in the Secchi-depth (Brattberg 1986), and regrowth of lost macrophyte communities (Viitasalo 1988). In addition, less contamination of shellfish areas and less disease in fish populations will result.

Aquaculture is a source of organic wastes that is currently increasing each year, and therefore has the potential to become a problem in the future. Being a relatively new industry to Newfoundland, and generally confined to a few restricted areas, it is currently not a large concern even on a localized scale. The amount of fish being produced has not risen to levels high enough to create problems of hypernutrification, eutrophication, or large amounts of sediment build up. Any finfish aquaculture problems in Newfoundland will probably occur first in the Bay d'Espoir area, due to the high number of cages present and the stratified water column. Other aquaculture activity in Newfoundland is currently on a small scale and is in fairly open areas that are well flushed. It is not currently expected that Bay d'Espoir will develop problems from organic wastes, due to the high volumes of water present. In addition, attention is being paid to sedimentation and water nutrification in the bay by the Newfoundland Salmonid Growers Association and the provincial Department of Fisheries and Aquaculture. People in the Bay d'Espoir region also seem very aware of the aquaculture activity in the bay and it seems they will hold the companies accountable for their activities and waste production (Whiffen 1998).

Expansion of intensive aquaculture activity does not necessitate a continued increase in organic wastes in local waters. The amount of aquaculture wastes released can be reduced in a number of ways. The monoculture of salmonids can be integrated with the culture of other species that will utilize organic wastes from the salmon cages. For instance, a polyculture system of salmon, blue mussels and macrophytes, that is similar to a naturally functioning ecosystem can be utilized (Folke and Kautsky 1992). Bivalve suspension feeders can reduce some eutrophication effects. Aquatic plants are very good at assimilating nutrients and creating an environment suitable for bacterial decomposition of organic matter. Aquatic macrophytes may be used to help control organic pollution of many types and to treat municipal wastewater, especially from small contributors (Brix and Scheirup 1989), like many of the organic waste sources in Newfoundland. Integrated systems will be similar to unstressed ecosystems in that they do not generate harmful wastes, and the by-products are utilized by the surrounding ecosystem (Folke and Kautsky 1992). The Japanese have systems in which various species from different trophic levels are cultured together so that the wastes and available nutrients from one level are utilized by the next lower level. The Japanese use various fish species which have different feeding habits inside and outside of cages to utilize all the available feed to prevent pollution (Tacon *et al.* 1995).

There are many other measures which are currently being implemented which can significantly reduce the release of aquaculture wastes into the coastal waters. The reduction is mainly due to the advances in feeding technology. However, bioengineering and biotechnical techniques, such as automated feeding devices and recombinant DNA technologies, which allow for feed supplements such as microbial phytases, are extremely important (Mayer and Mclean 1995). In order to regulate faecal output and food wastage in a fish farm, the feeding regime and the diet formulation must be modified and controlled. If the fish could control the amount of food available to them and feed to satiation, there would be much less wastage (Thorpe and Young Cho 1995). The manipulation of feed formulations is the best way to reduce the wastage from the fish farms, however. Good predictions of the fish growth and the relationship between feeding, growth, and feed conversion must be well understood. Future fish feed needs to have greater digestibility to reduce wastes. Lower N and P content of the feed is paramount to the reduction of nutrients released from fish farms (Kolsäter 1995). Some countries have reduced the digestible protein/digestible energy ratio and the P in feed, and as a result the fish better utilize and retain N and P. This has effectively reduced the nutrients released into the waters (Lanari *et al.* 1995). High nutrient density feeds (HND feeds) allow for better feed conversion and therefore less production of faeces (De Silva and Anderson 1995). These diets are being used in Denmark and have reduced the feed coefficient to 1.0 (Enell 1995). Moisture content of the feed is another important factor in reducing wastes. There is increased wastage with a higher water content feed (Gowen and Bradbury 1987). Thus, many farmers are turning to drier pellets. The salmonid industry in Norway now uses extruded pellets, instead of pressed pellets, because they have a smaller surface area in contact with the water and thus disintegrate more slowly (De Silva and Anderson 1995, Lanari *et al.* 1995).

The location of the farm is another important factor in the impact on the environment. The occasional movement of cages to different locations may allow the sediment to recover (Gowen and Bradbury 1987). The sites for fish cages should be in locations which are well flushed to reduce the chance of hypernutrification (Gowen and Bradbury 1987, Iwama 1991).

A strong tidal current will disperse particulate matter over a larger area. This dispersal will favour aerobic degradation, not anaerobic, and result in a faster turnover of waste from farms (Frogh and Schaanning 1991). Cages should be in deep waters to prevent negative effects, and fallowing grounds and dredging may be used to prolong the productivity of a site (Iwama 1991).

Of the four sources of organic wastes studied in this thesis the sawmill industry in Newfoundland will probably release the lowest levels of organic wastes in the future. The release of sawmill wastes is not expected to rise in the future. This is due to the current awareness of problems created by dumping sawmill residue into coastal waters, and the resulting legislation to prevent such actions. The estimates made in this thesis were maximum ones. They were made because releases (by a few small sawmills) still occur.

The release of sawmill wastes into coastal waters can be reduced. There are economic opportunities for some of the sawmills if they sell the wastes instead of dumping them. Many of the larger sawmills in the Province sell their wastes to other businesses. Currently, the sale of by-products increases with lumber production, with by-product sales accounting for 6% of the large sawmills revenue in 1987 (Trelawny 1990). Sawmill residues from large mills are used to provide furnish for the pulp and paper industry, and for heating (industrial, thermal electricity generation and domestic firewood) (Trelawny 1990). For instance, companies such as the Kruger pulp and paper mill in Corner Brook (Pyle 1998 pers. comm. list), and Abitibi Price in central Newfoundland (Blackmore 1998 pers. comm. list), use sawmill wastes in their furnaces and boilers. Blackmore (1998 pers. comm. list) also noted that, at one time, hospitals in central

Newfoundland burned hog fuel (a mixture which includes bark, wood chips, and sawdust) as well. In addition, Newfoundland farmers use sawdust as bedding for animals (Matthews 1998 pers. comm. list).

There are other measures which may help reduce the release of wastes from the Newfoundland sawmills. These sawmills recover much less by-product than other Canadian provinces, and produce much larger amounts of wastes from a given volume of logs when producing lumber (Trelawny 1990). It should be made easier for smaller sawmills to sell their by-products in Newfoundland. The consolidation of some of the smaller mills may help reduce wastes by making it possible to purchase better equipment (debarkers and chippers) and making the recovery of by-products more affordable. Consolidation will also make it more affordable to transport wastes to the larger centres for reuse (Buggie 1993).

The population of Newfoundland is relatively low and it is not a highly industrialized province, yet the level of wastes released into the coastal waters are fairly high in some cases. For instance, total offal releases are comparable to those of other Canadian provinces (Discussion 2.5). At the scale of the entire island offal was found to be the highest contributor of wastes, followed by sewage, sawmills, and aquaculture. Currently, aquaculture is the smallest contributor of coastal organic wastes in Newfoundland. However, this situation may change in the future as aquaculture levels steadily increase. In fact, the level of organic wastes released from each source will probably change over time in Newfoundland. A dissimilar level of wastes from the three sources compared (sewage, offal, and aquaculture) will probably become more similar in the future, at the scale of the entire island. This change will be due to an expanding aquaculture industry, and increased production of fish meal, reducing offal levels.

One might question the use of the kind of information available for this study but it is currently recognized that many environmental studies have to be completed by assembling the best data available. In many cases, such as this one, the ideal data is not available, but this does not mean that the issue of interest should not be examined. The type of analysis done in this thesis would never be completed if we waited for a perfect data set. Standard statistical procedures add to the problem by focusing on Type I error (the rejection of a true hypothesis), rather than Type II error (accepting a false hypothesis, or failure to detect real change). To remedy this problem it is important to initially address environmental issues with a first approximation, enabling identification of sources of uncertainty. Then the sources of uncertainty can be reduced in subsequent approximations (or estimates). This thesis is a first approximation of the levels of organic wastes being released into the coastal waters of Newfoundland. The estimates were based on a thorough evaluation of all available data in the province. The results of this thesis are reproducible (data are available from the sources listed and the methods are clearly stated) and the conclusions do not go beyond the stated impression of the results. Based on this study recommendations can be made to improve subsequent estimates of coastal organic waste release in Newfoundland.

The following gives the sources of uncertainty in the calculation of the level of organic wastes from the four sources. The importance of each of the sources of uncertainty was considered, based on personal judgement, and the two highest sources of uncertainty were identified. Reducing these two sources of uncertainty could help improve this study, thus ways to address them are given.

Overall, there was uncertainty in the lack of standardization in gathering the data. Data were obtained from a number of local sources. However, there was no extrapolation from the sample (there was no sample used to estimate to a larger population).

Aquaculture Calculations

i) A number of estimates used in the calculations were taken from the literature. These estimates include the FCR, percentage of faeces, percentage of unconsumed feed, and percentage of moisture in the cod feed (raw herring and caplin) and in the cod.

ii) Many of the values seemed incorrect in the data collected by the fish farm owners in Bay d'Espoir. Many of the FCRs obtained from NSGA farms were negative values. Therefore, the production data from the Department of Fisheries and Aquaculture were utilized instead.

iii) The methods for aquaculture waste calculations were not the same for salmonids and cod. The method for salmonids took metabolism into account; the method for cod did not. In addition, the amount of feed given to the cod was not available and literature values for percentages of unconsumed feed, consumed feed, and faeces were not available. Therefore, an FCR of 3.0 was used to obtain an estimate of wastes for the 13 cod farms.

<u>Sewage Calculations</u>

i) Estimates used in the calculation of sewage levels were taken from the literature. These estimates include normal stool weight and the total water content of normal stools.

ii) Sewage treatment by private companies and the use of septic tanks were not taken into consideration in this thesis. Better estimates of septic tank usage and private treatment could help improve the study as these forms of waste disposal help reduce organic waste release into the ocean.

iii) A linear yearly increase or decrease in sewage levels (or population) from 1991-1996 was assumed. This is because a Census was taken in 1991 and in 1996 and the populations of the incorporated towns and communities were not available for the period 1992-1995.

<u>Offal calculations</u>

i) An estimate of the average percent yield for each species of fish processed in Newfoundland fish processing plants was taken from the literature.

ii) In 1998 there were two fish meal plants in the province and these two plants were not considered in the calculations. The provincial Department of Fisheries and Aquaculture does not know the percentage of offal being produced at these plants.

iii) The offal resulting from the processing of seals was not taken into consideration because the percent yields during processing were not available and only the viscera is discarded generally. Fish mortalities on salmon farms were not taken into consideration either.

iv) Some fish wastes are dumped at sea before the vessels reach processing plants and individual fisherman dump wastes off wharves during gutting and filleting. The levels of these released wastes are unknown.

v) The amount of offal being released was determined according to the location of the processing plants, not the location of the dumping permits from the Province. The location of the processing plants and the percentage of processing plants in each of the area's sections were determined (Appendix C). The level of offal was calculated for each area, and then calculated for each section by multiplying the area value by the percentage of plants (or estimated percentage of offal) in each section. In addition, not all of the processing plants work at the same level of production (which the offal calculation utilized implies), but level of production for each individual plant could not be determined. The uncertainty is considered high at the smallest scale (fisheries statistical section) examined because only a few plants (or less) may be located in each section and some of the plants could be working at a much higher level of production than others. The uncertainty might be reduced by visiting the individual fish plants and obtaining the level of production for each plant, as well as the exact location where the individual plants dump their wastes.

Sawmill Calculations

i) A number of estimates used in the calculations were taken from the literature. The method for calculating sawmill residue was taken from Buggie (1993) who also calculated levels of sawmill wastes produced in Newfoundland.

ii) The data for the large sawmills were omitted because many of the larger mills sell the wastes for reuse. All residue from small sawmills was assumed to be waste.

iii) It was assumed that 50% of the small sawmills are located directly on the shoreline, and that 50% of the wastes actually enter the water. That is, 25% of the small sawmill wastes enter the water. The uncertainty is considered high because these estimates were made by visual observations of maps showing the locations of Newfoundland's coastal mills, rather than by quantification. The uncertainty can be reduced by visiting individual mills and ascertaining their level of waste production and exactly where the waste disposal areas are. Also, many of the Department of Forestry's district offices had the exact location of the coastal mills (latitude and longitude) plotted on a map but not in a format that could be forwarded. Others simply did not send the information requested. Each of the 13 district offices could be visited and the exact location of the district's mills collected.

In addition, this study could have been improved with corroboration on the personal communications. However, there was generally only one person in a department or organization who had the particular information needed, which limits the amount of corroboration possible.

Two of the three hypotheses for this thesis were proven wrong. Sewage was not the largest source of wastes at the scale of the entire island, and sawmill wastes were not the smallest source of wastes. An informal survey of environmental science students (Hypotheses 1.6) showed that the level and types of wastes being emitted into the coastal waters of Newfoundland are easily misjudged. Their impression was that sewage would be the greatest source of organic wastes and sawmills the smallest source. This perception shows the importance of a study such as this one, because people are generally unaware of the level of organic wastes being released into coastal waters; and the amount of wastes released in Newfoundland had never been quantified before.

This study revealed the general lack of basic data in Newfoundland which would enable more accurate quantification of organic waste release. This shows the need for data collection by agencies to enable environmental risk assessment of various coastal activities. Studies examining coastal water quality and release of organic wastes are necessary due to the importance of Newfoundland's coastline to the tourism industry, inshore fishery and aquaculture. Nearshore habitat degradation could have a negative impact on juvenile fish populations and on other organisms. The importance of Atlantic cod to the traditional Newfoundland fishery, and the present reduction of the Atlantic cod stocks, make the effects of eutrophication on cod eggs and juvenile cod an important consideration. Measures of total organic waste release tell us less about environmental impact than flux and concentration. Therefore the necessary studies should include water sampling surveys, with water mixing rates, that can be coupled with theoretical estimates of organic waste release such as derived in this thesis. Field studies should be conducted that examine the impacts and effects of releasing various quantities of organic wastes into the cold ocean environment and the function of rate of release of these wastes. These studies will help in obtaining more accurate estimates of the amount of organic wastes being released along the Province's coastline. Quantification of organic input into coastal waters may increase awareness of the environmental impacts and potential problems in some coastal locations. This awareness may lead to increased regulation of the release of organic wastes into coastal waters and help ensure better management in the future. Improved management could be critical for the future success of industries in Newfoundland that depend on high water quality.

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Appendix A:

Table A1. Licensed sites where marine finfish aquaculture occurs in Newfoundland. This table excludes all shellfish aquaculture, freshwater farms, tanks, hatcheries, incubation facilities, sites utilized solely for overwintering, and sites used solely for fingerlings or smolt. (Note: NU = never used)

Location	Species
Old Perlican Cove, Trinity Bay	Atlantic cod
Ship Cove, Trinity Bay	Atlantic cod
New Hbr., Trinity Bay	Atlantic cod
New Hbr., Trinity Bay	Atlantic cod
Heart's Content Hbr., Trinity Bay	Atlantic cod
Bay Bulls Hbr., Southern Shore	Atlantic cod
Maddox cove, Motion Bay, Southern Shore	Atlantic cod
Fox Cove, Placentia Bay	Atlantic cod
St. Lawrence, Placentia Bay	Atlantic cod
Gaultion's Cove, Placentia Bay	Atlantic cod
Princeton, Bonavista Bay	Atlantic cod
Southern Bay, Bonavista Bay	Greenland cod
Venils Island (near Burgeo), South Coast	Atlantic Cod
Lee Cove, Bay d'Espoir (Zone 1)	NU
Lou Cove, Bay d'Espoir (Zone 1)	Steelhead
Snook's Cove, Bay d'Espoir (Zone 1)	Steelhead
Jersey Cove, Bay d'Espoir (Zone 2)	Steelhead
Muddy Hole, Bay d'Espoir (Zone 2)	Atlantic salmon
Burnt Woods, Bay d'Espoir (Zone 2)	Steelhead
Northwest Cove, Bay d'Espoir (Zone 4)	Steelhead
May Cove, Bay d'Espoir (Zone 5)	Steelhead
Arran's Back Cove, Bay d'Espoir (Zone 5)	NU
Blackfish Cove, Bay d'Espoir (Zone 6)	NU
Seal Nest Cove, Bay d'Espoir (Zone 6)	Atlantic salmon
Strickland's Cove, Bay d'Espoir (Zone 6)	Steelhead
Wild Cove, Bay d'Espoir (Zone 9)	NU

Appendix B.

Table B1. Incorporated coastal towns in the Newfoundland census 1951-1996. Sewage levels were calculated for these towns. Towns in bold have total or partial sewage treatment. (Incorporated towns located inland and in Labrador were omitted from this list).

Town	Area	Section
ADMIRAL'S BEACH	G	28
ANCHOR POINT	N	49
AQUAFORT	F	26
ARNOLD'S COVE	**H**	**30**
AVONDALE	E	22
BADGER'S QUAY-VALLEYFIELD-POOL'S ISLAND	C	10
BAIE VERTE	**A**	**05**
BAINE HARBOUR	H	31
BAULINE	E	23
BAY BULLS	F	25
BAY DE VERDE	E	20
BAY L'ARGENT	I	34
BAY ROBERTS	E	22
BAYTONA	B	07
BAYVIEW	B	07
BEACHSIDE	B	06
BELLBURNS	M	47
BELLORAM	I	34
BERRY HEAD	K	41
BIDE ARM	A	04
BIRCHY BAY	B	07
BIRD COVE	N	49
BISCAY BAY	G	27
BISHOP'S COVE	E	22
BONAVISTA	**C**	**13**
BOTWOOD	B	07
BRANCH	G	28
BRENT'S COVE	A	05
BRIGHTON	B	06
BRIGUS	E	22
BRYANT'S COVE	E	22
BURGEO	J	37
BURIN	H	32

Table B1 cont'd. Incorporated coastal towns in the Newfoundland census 1951-1996. Sewage levels were calculated for these towns. Towns in bold have total or partial sewage treatment. (Incorporated towns located inland and in Labrador were omitted from this list).

Town	Area	Section
BURLINGTON	B	06
BURNT ISLANDS	J	39
CAMPBELLTON	B	07
CAPE BROYLE	F	25
CAPE ST.GEORGE-PETIT JARDIN-GRAND JARDIN-DE GRAU-MARCHES POINT-LORETTO	K	41
CARBONEAR	E	21
CARMANVILLE	B	09
CATALINA	D	14
CENTREVILLE - WAREHAM - TRINITY	**C**	**11**
CHANCE COVE	F	26
CHANGE ISLANDS	B	08
CHANNEL-PORT AUX BASQUES	J	39
CHAPEL ARM	D	17
CHARLOTTETOWN	C	12
CLARENVILLE	D	16
CLARKE'S BEACH	E	22
COACHMAN'S COVE	A	05
COLINET	G	28
COLLIERS	E	22
COME-BY-CHANCE	H	30
COMFORT COVE-NEWSTEAD	B	07
CONCEPTION BAY SOUTH	**E**	**22**
CONCEPTION HARBOUR	E	22
CONCHE	A	03
CONNE RIVER	J	36
COOK'S HARBOUR	A	01
CORNER BROOK	L	44
COTTLESVILLE	B	07
COW HEAD	M	46
COX'S COVE	L	44
CROW HEAD	B	07
CUPIDS	E	22
DANIEL'S HARBOUR	M	46
DOVER	C	11

Table B1 cont'd. Incorporated coastal towns in the Newfoundland census 1951-1996. Sewage levels were calculated for these towns. Towns in bold have total or partial sewage treatment. (Incorporated towns located inland and in Labrador were omitted from this list).

Town	Area	Section
DUNTARA	C	13
DUNVILLE	H	29
DURRELL	B	07
EASTPORT	**C**	**11**
ELLISTON	D	14
EMBREE	B	07
ENGLEE	A	04
ENGLISH HARBOUR EAST	I	34
FERMEUSE	F	26
FERRYLAND	F	26
FLATROCK	F	24
FLEUR DE LYS	A	05
FLOWERS COVE	N	49
FOGO	B	08
FORTUNE	I	33
FOX COVE-MORTIER	H	32
FOX HARBOUR	H	29
FRENCHMAN'S COVE, FORTUNE BAY	I	33
FRESHWATER, PLACENTIA BAY	H	29
GAMBO	**C**	**11**
GARNISH	I	33
GASKIERS-POINT LA HUNE	G	28
GAULTOIS	J	36
GILLAMS	L	44
GLENBURNIE-BIRCHY HEAD-SHOAL BROOK	M	45
GLOVERTOWN	C	11
GOOSE COVE EAST	A	03
GRAND BANK	I	33
GRAND LA PIERRE	I	34
GREAT HARBOUR DEEP	A	04
GREENSPOND	C	10
JOHN'S BEACH-FRENCHMAN'S COVE	L	44
HAMPDEN	**A**	**04**
HANT'S HARBOUR	D	18
HAPPY ADVENTURE	C	12

Table B1 cont'd. Incorporated coastal towns in the Newfoundland census 1951-1996. Sewage levels were calculated for these towns. Towns in bold have total or partial sewage treatment. (Incorporated towns located inland and in Labrador were omitted from this list).

Town	Area	Section
HARBOUR BRETON	I	35
HARBOUR GRACE	E	21
HARBOUR MAIN-CHAPEL COVE-LAKEVIEW	E	22
HARE BAY, BONAVISTA BAY	C	11
HAWKE'S BAY	M	47
HEART'S CONTENT	D	18
HEART'S DELIGHT-ISLINGTON	D	18
HEART'S DESIRE	D	18
HERMITAGE	J	36
HODGE'S COVE	D	17
HOGAN'S POND	E	23
HOLYROOD	**E**	**22**
HUGHES BROOK	L	44
INDIAN BAY (PARSON'S POINT)	C	11
IRISHTOWN-SUMMERSIDE	L	44
ISLE AUX MORTS	J	39
JACKSON'S ARM	A	04
JACQUES FONTAINE	I	34
JERSEYSIDE	H	29
JOE BATT'S ARM-BARR'D ISLANDS-SHOAL BAY	B	08
KEELS	C	13
KING'S COVE	C	13
KING'S POINT	B	06
KIPPENS	K	41
LA SCIE	A	05
LAMALINE	H	32
LARK HARBOUR	L	44
LAWN	H	32
LEADING TICKLES	B	06
LEWIN'S COVE	H	32
LEWISPORTE	B	07
LITTLE BAY, NOTRE DAME BAY	B	06
LITTLE BAY EAST, FORTUNE BAY	I	34
LITTLE BAY ISLANDS	B	06
LITTLE BURNT BAY	B	07

Table B1 cont'd. Incorporated coastal towns in the Newfoundland census 1951-1996. Sewage levels were calculated for these towns. Towns in bold have total or partial sewage treatment. (Incorporated towns located inland and in Labrador were omitted from this list).

Town	Area	Section
LITTLE CATALINA	C	14
LOGY BAY-MIDDLE COVE-OUTER COVE	F	24
LONG HARBOUR-ARLINGTON HEIGHTS	H	29
LORD'S COVE	H	32
LOURDES	L	42
LUMSDEN	**B**	**09**
LUSHES BIGHT-BEAUMONT-BEAUMONT NORTH	B	06
MAIN BROOK	A	03
MARYSTOWN	H	32
MASSEY DRIVE	L	44
MELVERS	L	44
MEADOWS	L	44
MELROSE	D	14
MERASHEEN	H	30
MIDDLE ARM, GREEN BAY	B	06
MILES COVE	B	06
MILLTOWN - HEAD OF BAY D'ESPOIR	J	36
MING'S BIGHT	A	05
MORRISVILLE	J	36
ST. CATHERINE'S	G	28
MOUNT MORIAH	L	44
MOUNT PEARL	F	24
MUSGRAVE HARBOUR	B	09
MUSGRAVETOWN	C	12
NEW PERLICAN	D	18
NEWTOWN, BONAVISTA BAY	C	10
NIPPERS HARBOUR	B	06
NORMAN'S COVE-LONG COVE	D	17
NORRIS ARM	**B**	**07**
NORRIS POINT	M	45
NORTH RIVER	E	22
NORTHERN ARM, NOTRE DAME BAY	B	07
OLD PERLICAN	D	19
PACQUET	A	05

Table B1 cont'd. Incorporated coastal towns in the Newfoundland census 1951-1996. Sewage levels were calculated for these towns. Towns in bold have total or partial sewage treatment. (Incorporated towns located inland and in Labrador were omitted from this list).

Town	Area	Section
PARADISE	E	23
PARKER'S COVE	H	31
PARSON'S POND	**M**	**46**
PASADENA	**L**	**44**
PETERVIEW	B	07
PETTY HARBOUR-MADDOX COVE	F	25
PILLEY'S ISLAND	B	06
PLACENTIA	H	29
PLATE COVE EAST	B	12
PLATE COVE WEST	B	12
POINT AU GAUL	H	32
POINT LANCE	G	28
POINT LEMINGTON	B	07
POINT MARY	H	32
POINT OF BAY	B	07
POOL'S COVE	I	34
PORT ANSON	B	06
PORT AU BRAS	H	32
PORT AUX CHOIX	N	48
PORT AU PORT WEST-AGUATHUNA-FELIX COVE	L	43
PORT BLANDFORD	C	12
PORT ELIZABETH	H	31
PORT KIRWAN	F	26
PORT REXTON	D	15
PORT SAUNDERS	M	47
PORT UNION	D	14
PORTUGAL COVE	E	23
PORTUGAL COVE SOUTH	G	27
POUCH COVE	F	24
RALEIGH	A	01
RAMEA	J	37
RED HARBOUR, PLACENTIA BAY	H	31
RENCONTRE EAST	I	34
RENEWS-CAPPAHAYDEN	F	26

Table B1 cont'd. Incorporated coastal towns in the Newfoundland census 1951-1996. Sewage levels were calculated for these towns. Towns in bold have total or partial sewage treatment. (Incorporated towns located inland and in Labrador were omitted from this list).

Town	Area	Section
RIVERHEAD, ST. MARY'S BAY	G	28
RIVER OF PONDS	M	47
ROBERT'S ARM	**B**	**06**
ROCKY HARBOUR	M	45
RODDICKTON	A	04
ROSE BLANCHE-HARBOUR LA COU	J	39
RUSHOON	H	31
SALLY'S COVE	M	45
SALMON COVE	E	21
SALVAGE	C	12
SANDRINGHAM	C	11
SANDY COVE, BONAVISA BAY	C	12
SANDY COVE, ST. BARBE NORTH	N	49
SEAL COVE, FORTUNE BAY	I	35
SEAL COVE, WHITE BAY	A	04
SELDOM-LITTLE SELDOM	B	08
SHOAL HARBOUR	D	16
SMALL POINT-BROAD COVE-BLACKHEAD-ADAMS COVE	E	21
SOUTH BROOK, HALL'S BAY	B	06
SOUTH RIVER	E	22
SOUTHERN HARBOUR	H	30
SPANIARD'S BAY	E	22
SPRINGDALE	B	06
ST. ALBAN'S	**J**	**36**
ST. ANTHONY	A	02
ST. BERNARD'S	I	34
ST. BRENDAN'S	C	11
ST. BRIDE'S	H	29
ST. GEORGE'S	M	41
ST. JACQUES-COOMB'S COVE	I	34
ST. JOHN'S	F	24
ST. JOSEPH'S, ST. MARY'S BAY	G	28
ST. JOSEPH'S, PLACENTIA BAY	H	31
ST. LAWRENCE	H	32

Table B1 cont'd. Incorporated coastal towns in the Newfoundland census 1951-1996. Sewage levels were calculated for these towns. Towns in bold have total or partial sewage treatment. (Incorporated towns located inland and in Labrador were omitted from this list).

Town	Area	Section
ST. LUNAIRE-GRIQUET	A	02
ST. MARY'S	G	28
ST. PAUL'S	M	46
ST. PHILLIPS	E	23
ST. SHOTT'S	G	28
ST. THOMAS	E	23
ST. VINCENT'S-ST. STEVENS-PETER'S RIVER	G	28
STEVENVILLE	M	41
STEVENVILLE CROSSING	M	41
SUMMERFORD	B	07
SUNNYSIDE	D	17
TERRENCEVILLE	I	34
TILT COVE	B	06
TILTING	B	08
TILTON	E	22
TORBAY	F	24
TRAYTOWN	C	11
TREPASSEY	G	27
TRINTY, BONAVISTA BAY	C	11
TRITON	B	06
TROUT RIVER	M	45
TWILLINGATE	B	07
UPPER ISLAND COVE	E	22
VICTORIA	**E**	**21**
WABANA	E	23
WEDGEWOOD PARK	F	24
WESLEYVILLE	C	10
WESTPORT	A	04
WHITEWAY	D	18
WINTERTON	D	18
WITLESS BAY	F	25
WOOD'S ISLAND	L	44
WOODSTOCK	A	05
WOODY ISLAND	H	30
WOODY POINT	M	45

Table B1 cont'd. Incorporated coastal towns in the Newfoundland census 1951-1996. Sewage levels were calculated for these towns. Towns in bold have total or partial sewage treatment. (Incorporated towns located inland and in Labrador were omitted from this list).

Town	Area	Section
YORK HARBOUR	B	44
MARGAREE	J	39
NEW HARBOUR	D	17
SHIP COVE	K	41
CODROY	K	40

Appendix C:

Table C1. Location of Licensed Processors in Newfoundland for 1997 and the Percentage of the Area's Plants per Section.

Area	Sections with Processing Plants.	Number of Processing Plants per Section	Percentage of processing plants per section. (or percentage of area's offal per section)
A	01	2	18%
	02	1	9%
	03	2	18%
	04	4	36%
	05	2	18%
Total		11	
B	06	6	30%
	07	9	45%
	08	2	10%
	09	3	15%
Total		20	
C	10	3	18%
	11	4	24%
	12	8	47%
	13	2	12%
Total		17	
D	15	1	8%
	16	2	17%
	17	5	42%
	18	2	17%
	19	2	17%
Total		12	
E	20	1	4%
	21	3	13%
	22	18	78%
	23	1	4%
Total		23	
F	24	3	27%
	25	4	36%
	26	4	36%
Total		11	
G	28	4	100%
Total		4	

Table C1 cont'd. Location of Licensed Processors in Newfoundland for 1997 and the Percentage of the Area's Plants per Section.

Area	Sections with Processing Plants.	Number of Processing Plants per Section	Percentage of processing plants per section. (or percentage of area's offal per section)
H	29	3	27%
	30	3	27%
	31	1	9%
	32	4	36%
Total		11	
I	33	4	67%
	35	2	33%
Total		6	
J	36	3	30%
	37	2	20%
	39	5	50%
Total		10	
K	40	1	100%
Total		1	
L	44	4	100%
Total		4	
M	45	4	80%
	46	1	20%
Total		5	
N	48	1	11%
	49	8	89%
Total		9	

Appendix D:

Table D1. The locations where permits are allocated for the dumping of offal. (A place name is present for each individual permit given).

location	town	area	section	dump long	dump lat
Fogo	0097	2001	1008	54.26667	49.73333
Fogo	0097	2001	1008	54.26667	49.73333
Fogo	0097	2001	1008	54.26667	49.73333
Cottlesville	0072	2001	1007	54.9	49.51667
Cottlesville	0072	2001	1007	54.9	49.51667
Englee	0090	2000	1004	56.11667	50.73333
Englee	0090	2000	1004	56.11667	50.73333
Hant's Harbour	0124	2003	1018	53.31667	48.03333
Hant's Harbour	0124	2003	1018	53.31667	48.03333
Salvage	0660	2002	1012	53.65	48.71667
Salvage	0660	2002	1012	53.65	48.71667
Jackson's Arm	0148	2000	1004	56.73333	49.86667
Jackson's Arm	0148	2000	1004	56.73333	49.86667
La Scie	0158	2000	1005	55.61667	49.98333
La Scie	0158	2000	1005	55.61667	49.98333
Margaree	1035	2009	1039	59.08333	47.56667
Portugal Cove	0339	2004	1023	52.88333	47.61667
Sandy Cove	0663	2013	1049	56.66667	51.35
Harbour Main	0131	2004	1022	53.15	47.43333
Foxtrap (CBS)	0062	2004	1022	53.00	47.53333
Joe Batt's Arm	0151	2001	1008	54.16667	49.73333
Joe Batt's Arm	0151	2001	1008	54.16667	49.73333
Long Cove	0203	2003	1017	53.65	47.6
Long Cove	0203	2003	1017	53.65	47.6
Witless Bay	1029	2005	1025	52.78333	47.26667
Valleyfield	0008	2002	1010	53.6	49.1
Cox's Cove	0074	2011	1044	58.06667	49.13333
Cox's Cove	0074	2011	1044	58.06667	49.13333
Dover	0083	2002	1011	53.95	48.85
Dover	0083	2002	1011	53.95	48.85
Happy Adventure	0125	2002	1012	53.73333	48.61667
St. Joseph's	0884	2006	1028	53.61667	47.1
Bonavista	0029	2002	1013	53.23333	48.68333
Winterton	1028	2003	1018	53.36667	47.96667
Conche	0064	2000	1003	55.96667	50.86667
St. Anthony	0776	2000	1002	55.55	51.36667
Rose Blanche	0556	2009	1039	58.7	47.6
New Harbour	1036	2003	1017	53.6	47.61667
St. Lawrence	0886	2007	1032	55.35	46.9

Table D1 cont'd. The locations where permits are allocated for the dumping of offal. (A place name is present for each individual permit given).

location	town	area	section	dump long	dump lat
Southern Harbour	0772	2007	1030	53.96667	47.71667
Anchor Point	0002	2013	1049	56.83333	51.23333
Fleur De Lys	0095	2000	1005	56.13333	50.11667
Lttl Bay Islands	0169	2001	1006	55.76667	49.65
Ship Cove	1037	2010	1041	53.18333	47.58333
Codroy	1038	2010	1040	59.43333	47.86667
Bay de Verde	0013	2004	1020	52.9	48.06667
Triton	1011	2001	1006	55.56667	49.55

Appendix E:

Table E1. Sawmill production data for 1992-1996 for each Forestry District in Newfoundland.

YEAR	DISTRICT	PRODUCT (fbm)	MFBM
1992	1	3671643	3671.64
1993	1	3340268	3340.27
1994	1	3876131	3876.13
1995	1	4045918	4045.92
1996	1	4615325	4615.33
1992	2	5235201	5235.20
1993	2	8111813	8111.81
1994	2	6349115	6349.12
1995	2	7169981	7169.98
1996	2	12239923	12239.92
1992	5	3008194	3008.19
1993	5	3963717	3963.72
1994	5	3943837	3943.84
1995	5	4561422	4561.42
1996	5	4053196	4053.20
1992	7	792894	792.89
1993	7	842786	842.79
1994	7	850567	850.57
1995	7	1065541	1065.54
1996	7	1029809	1029.81
1992	8	12603254	12603.25
1993	8	15449469	15449.47
1994	8	21130151	21130.15
1995	8	33663628	33663.63
1996	8	24368089	24368.09
1992	9	1758558	1758.56
1993	9	1919221	1919.22
1994	9	2259090	2259.09
1995	9	2790670	2790.67
1996	9	2167288	2167.29
1992	14	809506	809.51
1993	14	1048763	1048.76
1994	14	786597	786.60
1995	14	1029822	1029.82
1996	14	1054658	1054.66

Table E1 cont'd. Sawmill production data for 1992-1996 for each Forestry District in Newfoundland.

YEAR	DISTRICT	PRODUCT (fbm)	MFBM
1992	15	2509234	2509.23
1993	15	2394604	2394.60
1994	15	2604680	2604.68
1995	15	2619247	2619.25
1996	15	2735658	2735.66
1992	16	1329758	1329.76
1993	16	2099816	2099.82
1994	16	2824413	2824.41
1995	16	4286863	4286.86
1996	16	3193986	3193.99
1992	17	1990905	1990.91
1993	17	1939838	1939.84
1994	17	1433504	1433.50
1995	17	1566124	1566.12
1996	17	1199417	1199.42
1992	18	2006991	2006.99
1993	18	4118979	4118.98
1994	18	4635211	4635.21
1995	18	5761491	5761.49
1996	18	7856616	7856.62

Appendix F:

Table F1. Total Organic Wastes (dry mass in kg) for Region 1-5.

Scale	Year	Offal	Sewage	Aquaculture
Region 1	1992	37668163.4000	277336.1320	0.0000
	1993	6630504.7100	273097.4840	0.0000
	1994	4358101.7600	268860.8360	0.0000
	1995	7169525.2300	264623.1880	0.0000
	1996	7757464.9200	260385.5400	0.0000
Region 2	1992	18436929.1300	1065375.1680	0.0000
	1993	24345977.5900	1071221.6760	0.0000
	1994	25202613.8300	1077068.1840	0.0000
	1995	27095642.1800	1082914.6920	912.7900
	1996	34375731.2100	1088761.2000	488.2200
Region 3	1992	40082332.5200	2379516.3640	0.0000
	1993	41270421.8700	2716015.4680	176.3700
	1994	39237592.7600	2990441.2120	0.0000
	1995	63980105.7100	3389014.1760	3087.0000
	1996	72147114.0800	3725512.7800	1752.0000
Region 4	1992	48679823.9100	745882.2560	49066.2600
	1993	16206176.6500	735886.0020	126677.2900
	1994	13940208.6800	725889.7480	230722.1500
	1995	11404766.6000	715893.4940	336199.1700
	1996	12043321.8700	705897.2400	605220.1700
Region 5	1992	13681947.0100	850700.1900	0.0000
	1993	1760494.0500	847053.8100	0.0000
	1994	1439451.0000	843407.4300	0.0000
	1995	2137700.2900	839761.0200	0.0000
	1996	3989405.9400	836114.6400	0.0000

Table F2. Total Organic Wastes (dry mass in kg) for Areas A-N.

Area	Year	Offal	Sewage	Aquaculture
	1992	3058485.5500	250343.2800	0.0000
A	1993	1574590.5200	247351.4700	0.0000
	1994	1001679.8600	244359.6600	0.0000
	1995	2586787.0800	241367.8500	0.0000
	1996	3022850.5600	238376.0300	0.0000
	1992	9488765.1500	578205.3700	0.0000
B	1993	13681952.5300	577676.6400	0.0000
	1994	15528129.8800	577147.9100	0.0000
	1995	13269948.6700	576619.1800	0.0000
	1996	15537805.1700	576090.4500	0.0000
	1992	5982620.7100	257744.7500	0.0000
C	1993	8271700.9900	259894.8200	0.0000
	1994	8604958.5000	262044.8900	0.0000
	1995	10059279.3800	264194.9600	912.7900
	1996	13574956.5700	266345.0100	488.2200
	1992	9420758.5900	260487.3600	0.0000
D	1993	8104723.0600	266896.3900	0.0000
	1994	10014631.0900	273305.4200	0.0000
	1995	12800798.6600	279714.4500	0.0000
	1996	18332427.1500	286123.5000	0.0000
	1992	11467964.3900	952126.8700	0.0000
E	1993	9027360.3600	959913.1400	0.0000
	1994	10899843.2500	967699.4100	0.0000
	1995	30031683.3100	975485.6800	0.0000
	1996	23460062.1700	983271.9500	0.0000
	1992	13828869.5900	1073991.3500	0.0000
F	1993	17065128.6300	1395077.1000	176.3700
	1994	15796447.8900	1716162.8500	0.0000
	1995	16591212.7500	2037248.6000	3087.0000
	1996	27018670.9900	2358334.3500	1752.0000
	1992	1400563.7300	95695.3400	0.0000
G	1993	981485.0600	93514.1000	0.0000
	1994	2416534.7700	91332.8600	0.0000
	1995	2893653.5200	89151.6200	0.0000
	1996	4874594.3400	86970.3800	0.0000

Table F2 cont'd. Total Organic Wastes (dry mass in kg) for Areas A-N.

Area	Year	Offal	Sewage	Aquaculture
H	1992	11996530.7600	417409.7700	1114.8600
	1993	15366265.1600	424645.9000	2920.0000
	1994	5149277.9900	431882.0300	0.0000
	1995	9631811.3400	439118.1600	0.0000
	1996	6233202.3500	446354.3000	0.0000
I	1992	10183168.7300	232712.6900	0.0000
	1993	2746946.0900	229513.1000	0.0000
	1994	8511058.5200	226313.5100	0.0000
	1995	3332870.5300	223113.9200	0.0000
	1996	7256221.3700	219914.3300	0.0000
J	1992	33098216.3300	243319.9500	47951.4000
	1993	6544411.2300	238655.2500	123757.2900
	1994	3111975.0600	233990.5500	230722.1500
	1995	3737580.9700	229325.8500	336199.1700
	1996	1982159.4400	224661.1500	605220.1700
K	1992	0.0000	249032.5700	0.0000
	1993	0.0000	249177.1100	0.0000
	1994	0.0000	249321.6500	0.0000
	1995	0.0000	249466.1900	0.0000
	1996	81358.5000	249610.7300	0.0000
L	1992	6230543.7400	542649.1700	0.0000
	1993	1460325.4100	539741.9400	0.0000
	1994	1361433.4600	536834.7100	0.0000
	1995	1958485.5300	533927.4800	0.0000
	1996	3116149.7600	531020.2500	0.0000
M	1992	9314254.0900	122441.8100	0.0000
	1993	375210.8000	119215.9400	0.0000
	1994	97521.9200	115990.0700	0.0000
	1995	224018.4500	112764.2000	0.0000
	1996	1091570.2300	109538.3300	0.0000
N	1992	33327939.2800	42649.1400	0.0000
	1993	5280044.2300	42002.0000	0.0000
	1994	3527236.7000	41354.8600	0.0000
	1995	5029424.0100	40707.7200	0.0000
	1996	5090641.9200	40060.5800	0.0000

Table F3. Total Organic Wastes (dry mass in kg) for Sections 1-49.

Year	Area	Section	Sewage	Offal	Aquaculture
92.0000	A	01	11885.1300	550527.4000	0.0000
93.0000	A	01	11484.3600	283426.2900	0.0000
94.0000	A	01	11083.5900	180302.3700	0.0000
95.0000	A	01	10682.8200	465621.6700	0.0000
96.0000	A	01	10282.0500	544113.1000	0.0000
92.0000	A	02	67871.3860	275263.7000	0.0000
93.0000	A	02	67020.5720	141713.1500	0.0000
94.0000	A	02	66169.7580	90151.1900	0.0000
95.0000	A	02	65318.9440	232810.8400	0.0000
96.0000	A	02	64468.1300	272056.5500	0.0000
92.0000	A	03	19959.6600	550527.4000	0.0000
93.0000	A	03	19420.9200	283426.2900	0.0000
94.0000	A	03	18882.1800	180302.3700	0.0000
95.0000	A	03	18343.4400	465621.6700	0.0000
96.0000	A	03	17804.7000	544113.1000	0.0000
92.0000	A	04	71547.3040	1101054.8000	0.0000
93.0000	A	04	72089.3280	566852.5900	0.0000
94.0000	A	04	72631.3520	360604.7500	0.0000
95.0000	A	04	73173.3760	931243.3500	0.0000
96.0000	A	04	73715.4000	1088226.2000	0.0000
92.0000	A	05	79079.8060	550527.4000	0.0000
93.0000	A	05	77336.2920	283426.2900	0.0000
94.0000	A	05	75592.7780	180302.3700	0.0000
95.0000	A	05	73849.2640	465621.6700	0.0000
96.0000	A	05	72105.7500	544113.1000	0.0000
92.0000	B	06	172107.7240	2846629.5500	0.0000
93.0000	B	06	170192.5680	4104585.7600	0.0000
94.0000	B	06	168277.4120	4658438.9600	0.0000
95.0000	B	06	166362.2560	3980984.6000	0.0000
96.0000	B	06	164447.1000	4661341.5500	0.0000
92.0000	B	07	306664.6100	4269944.3200	0.0000
93.0000	B	07	309745.9400	6156878.6400	0.0000
94.0000	B	07	312827.2700	6987658.4500	0.0000
95.0000	B	07	315908.6000	5971476.9000	0.0000
96.0000	B	07	318989.9300	6992012.3300	0.0000
92.0000	B	08	59425.6540	948876.5200	0.0000
93.0000	B	08	58292.3280	1368195.2500	0.0000
94.0000	B	08	57159.0020	1552812.9900	0.0000

Table F3 cont'd. Total Organic Wastes (dry mass in kg) for Sections 1-49.

Year	Area	Section	Sewage	Offal	Aquaculture
95.0000	B	08	56025.6760	1326994.8700	0.0000
96.0000	B	08	54892.3500	1553780.5200	0.0000
92.0000	B	09	40008.0160	1423314.7700	0.0000
93.0000	B	09	39446.2820	2052292.8800	0.0000
94.0000	B	09	38884.5480	2329219.4800	0.0000
95.0000	B	09	38322.8140	1990492.3000	0.0000
96.0000	B	09	37761.0800	2330670.7800	0.0000
92.0000	C	10	65010.1540	1076871.7300	0.0000
93.0000	C	10	69822.6780	1488906.1800	0.0000
94.0000	C	10	74635.2020	1548892.5300	0.0000
95.0000	C	10	79447.7260	1810670.2900	0.0000
96.0000	C	10	84260.2500	2443492.1800	0.0000
92.0000	C	11	117758.4120	1435828.9700	0.0000
93.0000	C	11	116354.7640	1985208.2400	0.0000
94.0000	C	11	114951.1160	2065190.0400	0.0000
95.0000	C	11	113547.4680	2414227.0500	0.0000
96.0000	C	11	112143.8200	3257989.5800	0.0000
92.0000	C	12	52901.6400	2811831.7300	0.0000
93.0000	C	12	51962.1300	3887699.4700	0.0000
94.0000	C	12	51022.6200	4044330.5000	0.0000
95.0000	C	12	50083.1100	4727861.3100	912.7900
96.0000	C	12	49143.6000	6380229.5900	488.2200
92.0000	C	13	22074.5480	717914.4900	0.0000
93.0000	C	13	21755.2460	992604.1200	0.0000
94.0000	C	13	21435.9440	1032595.0200	0.0000
95.0000	C	13	21116.6420	1207113.5300	0.0000
96.0000	C	13	20797.3400	1628994.7900	0.0000
92.0000	D	14	56469.1540	0.0000	0.0000
93.0000	D	14	55302.9780	0.0000	0.0000
94.0000	D	14	54136.8020	0.0000	0.0000
95.0000	D	14	52970.6260	0.0000	0.0000
96.0000	D	14	51804.4500	0.0000	0.0000
92.0000	D	15	12969.1800	753660.6900	0.0000
93.0000	D	15	12666.9600	648377.8400	0.0000
94.0000	D	15	12364.7400	801170.4900	0.0000
95.0000	D	15	12062.5200	1024063.8900	0.0000
96.0000	D	15	11760.3000	1466594.1700	0.0000
92.0000	D	16	80906.2700	1601528.9600	0.0000

Table F3 cont'd. Total Organic Wastes (dry mass in kg) for Sections 1-49.

Year	Area	Section	Sewage	Offal	Aquaculture
93.0000	D	16	88343.5100	1377802.9200	0.0000
94.0000	D	16	95780.7500	1702487.2900	0.0000
95.0000	D	16	103217.9900	2176135.7700	0.0000
96.0000	D	16	110655.2300	3116512.6200	0.0000
92.0000	D	17	38930.5360	3956718.6100	0.0000
93.0000	D	17	39853.6220	3403983.6900	0.0000
94.0000	D	17	40776.7080	4206145.0600	0.0000
95.0000	D	17	41699.7940	5376335.4400	0.0000
96.0000	D	17	42622.8800	7699619.4000	0.0000
92.0000	D	18	58969.0360	1601528.9600	0.0000
93.0000	D	18	58479.5720	1377802.9200	0.0000
94.0000	D	18	57990.1080	1702487.2900	0.0000
95.0000	D	18	57500.6440	2176135.7700	0.0000
96.0000	D	18	57011.1800	3116512.6200	0.0000
92.0000	D	19	12243.0800	1601528.9600	0.0000
93.0000	D	19	12249.6800	1377802.9200	0.0000
94.0000	D	19	12256.2800	1702487.2900	0.0000
95.0000	D	19	12262.8800	2176135.7700	0.0000
96.0000	D	19	12269.4800	3116512.6200	0.0000
92.0000	E	20	10873.3540	458718.5800	0.0000
93.0000	E	20	10594.1280	361094.4100	0.0000
94.0000	E	20	10314.9020	435993.7300	0.0000
95.0000	E	20	10035.6760	1201267.3300	0.0000
96.0000	E	20	9756.4500	938402.4900	0.0000
92.0000	E	21	169341.7540	1490835.3700	0.0000
93.0000	E	21	168832.5780	1173556.8500	0.0000
94.0000	E	21	168323.4020	1416979.6200	0.0000
95.0000	E	21	167814.2260	3904118.8300	0.0000
96.0000	E	21	167305.0500	3049808.0800	0.0000
92.0000	E	22	548590.8920	8945012.2200	0.0000
93.0000	E	22	554629.5440	7041341.0800	0.0000
94.0000	E	22	560668.1960	8501877.7400	0.0000
95.0000	E	22	566706.8480	23424712.9800	0.0000
96.0000	E	22	572745.5000	18298848.4900	0.0000
92.0000	E	23	223320.8700	458718.5800	0.0000
93.0000	E	23	225856.8900	361094.4100	0.0000
94.0000	E	23	228392.9100	435993.7300	0.0000
95.0000	E	23	230928.9300	1201267.3300	0.0000

Table F3 cont'd. Total Organic Wastes (dry mass in kg) for Sections 1-49.

Year	Area	Section	Sewage	Offal	Aquaculture
96.0000	E	23	233464.9500	938402.4900	0.0000
92.0000	F	24	971197.1140	3733794.7900	0.0000
93.0000	F	24	1293163.2480	4607584.7300	0.0000
94.0000	F	24	1615129.3820	4265040.9300	0.0000
95.0000	F	24	1937095.5160	4479627.4400	0.0000
96.0000	F	24	2259061.6500	7295041.1700	0.0000
92.0000	F	25	62257.3200	4978393.0500	0.0000
93.0000	F	25	62165.3400	6143446.3100	176.3700
94.0000	F	25	62073.3600	5686721.2400	0.0000
95.0000	F	25	61981.8800	5972836.5900	3087.0000
96.0000	F	25	61889.4000	9726721.5600	1752.0000
92.0000	F	26	40536.9000	4978393.0500	0.0000
93.0000	F	26	39748.5000	6143446.3100	0.0000
94.0000	F	26	38960.1000	5686721.2400	0.0000
95.0000	F	26	38171.7000	5972836.5900	0.0000
96.0000	F	26	37383.3000	9726721.5600	0.0000
92.0000	G	27	26332.5600	0.0000	0.0000
93.0000	G	27	25793.8200	0.0000	0.0000
94.0000	G	27	25255.0800	0.0000	0.0000
95.0000	G	27	24716.3400	0.0000	0.0000
96.0000	G	27	24177.6000	0.0000	0.0000
92.0000	G	28	69362.7800	1400563.7300	0.0000
93.0000	G	28	67720.2800	981485.0600	0.0000
94.0000	G	28	66077.7800	2416534.7700	0.0000
95.0000	G	28	64435.2800	2893653.5200	0.0000
96.0000	G	28	62792.7800	4874594.3400	0.0000
92.0000	H	29	123532.4260	3239063.3100	0.0000
93.0000	H	29	133141.0520	4148891.5900	0.0000
94.0000	H	29	142749.6780	1390305.0600	0.0000
95.0000	H	29	152358.3040	2600589.0600	0.0000
96.0000	H	29	161966.9300	1682964.6300	0.0000
92.0000	H	30	24027.7420	3239063.3100	0.0000
93.0000	H	30	23787.2140	4148891.5900	0.0000
94.0000	H	30	23546.6860	1390305.0600	0.0000
95.0000	H	30	23306.1580	2600589.0600	0.0000
96.0000	H	30	23065.6300	1682964.6300	0.0000
92.0000	H	31	22150.7560	1079687.7700	0.0000
93.0000	H	31	21897.8120	1382963.8600	0.0000

Table F3 cont'd. Total Organic Wastes (dry mass in kg) for Sections 1-49.

Year	Area	Section	Sewage	Offal	Aquaculture
94.0000	H	31	21644.8680	463435.0200	0.0000
95.0000	H	31	21391.9240	866863.0200	0.0000
96.0000	H	31	21138.9800	560988.2100	0.0000
92.0000	H	32	247698.8600	4318751.0700	1114.8600
93.0000	H	32	245819.8400	5531855.4600	2920.0000
94.0000	H	32	243940.8200	1853740.0800	0.0000
95.0000	H	32	242061.80003	467452.0800	0.0000
96.0000	H	32	240182.7800	2243952.8500	0.0000
92.0000	I	33	107774.2800	6822723.0500	0.0000
93.0000	I	33	106322.3100	1840453.8800	0.0000
94.0000	I	33	104870.3400	5702409.2100	0.0000
95.0000	I	33	103418.3700	2233023.2600	0.0000
96.0000	I	33	101966.4000	4861668.3200	0.0000
92.0000	I	34	78130.4400	0.0000	0.0000
93.0000	I	34	76960.9800	0.0000	0.0000
94.0000	I	34	75791.5200	0.0000	0.0000
95.0000	I	34	74622.0600	0.0000	0.0000
96.0000	I	34	73452.6000	0.0000	0.0000
92.0000	I	35	46807.9700	3360445.6800	0.0000
93.0000	I	35	46229.8100	906492.2100	0.0000
94.0000	I	35	45651.6500	2808649.3100	0.0000
95.0000	I	35	45073.4900	1099847.2700	0.0000
96.0000	I	35	44495.3300	2394553.0500	0.0000
92.0000	J	36	44360.6400	9929464.9000	47951.4000
93.0000	J	36	43683.9300	1963323.3700	123757.2900
94.0000	J	36	43007.2200	933592.5200	230722.1500
95.0000	J	36	42330.5100	1121274.2900	336199.1700
96.0000	J	36	41653.8000	594647.8300	605220.1700
92.0000	J	37	58059.0900	6619643.2700	0.0000
93.0000	J	37	56593.9800	1308882.2500	0.0000
94.0000	J	37	55128.8700	622395.0100	0.0000
95.0000	J	37	53663.7600	747516.1900	0.0000
96.0000	J	37	52198.6500	396431.8900	0.0000
92.0000	J	38	0.0000	0.0000	0.0000
93.0000	J	38	0.0000	0.0000	0.0000
94.0000	J	38	0.0000	0.0000	0.0000
95.0000	J	38	0.0000	0.0000	0.0000
96.0000	J	38	0.0000	0.0000	0.0000

Table F3 cont'd. Total Organic Wastes (dry mass in kg) for Sections 1-49.

Year	Area	Section	Sewage	Offal	Aquaculture
92.0000	J	39	140900.2200	16549108.1700	0.0000
93.0000	J	39	138377.3400	3272205.6200	0.0000
94.0000	J	39	135854.4600	1555987.5300	0.0000
95.0000	J	39	133331.5800	1868790.4900	0.0000
96.0000	J	39	130808.7000	991079.7200	0.0000
92.0000	K	40	0.0000	0.0000	0.0000
93.0000	K	40	0.0000	0.0000	0.0000
94.0000	K	40	0.0000	0.0000	0.0000
95.0000	K	40	0.0000	0.0000	0.0000
96.0000	K	40	0.0000	81358.5000	0.0000
92.0000	K	41	249032.6000	0.0000	0.0000
93.0000	K	41	249177.1400	0.0000	0.0000
94.0000	K	41	249321.6800	0.0000	0.0000
95.0000	K	41	249466.1900	0.0000	0.0000
96.0000	K	41	249610.7300	0.0000	0.0000
92.0000	L	42	13764.2700	0.0000	0.0000
93.0000	L	42	13435.7400	0.0000	0.0000
94.0000	L	42	13107.2100	0.0000	0.0000
95.0000	L	42	12778.6800	0.0000	0.0000
96.0000	L	42	12450.1500	0.0000	0.0000
92.0000	L	43	11467.9360	0.0000	0.0000
93.0000	L	43	11142.7220	0.0000	0.0000
94.0000	L	43	10817.5080	0.0000	0.0000
95.0000	L	43	10492.2940	0.0000	0.0000
96.0000	L	43	10167.0800	0.0000	0.0000
92.0000	L	44	517417.0700	6230543.7400	0.0000
93.0000	L	44	515163.5600	1460325.4100	0.0000
94.0000	L	44	512910.0500	1361433.4600	0.0000
95.0000	L	44	510656.5400	1958485.5300	0.0000
96.0000	L	44	508403.0300	3116149.7600	0.0000
92.0000	M	45	59018.3140	7451403.2700	0.0000
93.0000	M	45	58134.6480	300168.6400	0.0000
94.0000	M	45	57250.9820	78017.5400	0.0000
95.0000	M	45	56367.3160	179214.7600	0.0000
96.0000	M	45	55483.6500	873256.1800	0.0000
92.0000	M	46	33162.0760	1862850.8200	0.0000
93.0000	M	46	30944.7020	75042.1600	0.0000
94.0000	M	46	28727.3280	19504.3800	0.0000

Table F3 cont'd. Total Organic Wastes (dry mass in kg) for Sections 1-49.

Year	Area	Section	Sewage	Offal	Aquaculture
95.0000	M	46	26509.9540	44803.6900	0.0000
96.0000	M	46	24292.5800	218314.0500	0.0000
92.0000	M	47	30261.4200	0.0000	0.0000
93.0000	M	47	30135.5900	0.0000	0.0000
94.0000	M	47	30011.7600	0.0000	0.0000
95.0000	M	47	29886.9300	0.0000	0.0000
96.0000	M	47	29762.1000	0.0000	0.0000
92.0000	N	48	20321.0100	3666073.3200	0.0000
93.0000	N	48	19946.5200	580804.8700	0.0000
94.0000	N	48	19572.0300	387996.0400	0.0000
95.0000	N	48	19197.5400	553236.6400	0.0000
96.0000	N	48	18823.0500	559970.6100	0.0000
92.0000	N	49	22328.1460	29661865.9600	0.0000
93.0000	N	49	22055.4920	4699239.3600	0.0000
94.0000	N	49	21782.8380	3139240.6600	0.0000
95.0000	N	49	21510.1840	4476187.3700	0.0000
96.0000	N	49	21237.5300	4530671.3100	0.0000