PERSISTENT INDUSTRIAL MARINE DEBRIS: THE RELATIONSHIP BETWEEN MARINE DEBRIS AND COASTAL INDUSTRIAL ACTIVITIES IN CHARLOTTE COUNTY NEW BRUNSWICK

by

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Submitted in partial fulfillment of the requirements
for the degree of Master of Environmental Studies

at

Dalhousie University
Halifax, Nova Scotia
April 2003

0-612-79594-2

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ABSTRACT

Waste material discarded or abandoned by coastal marine industrial enterprises will accumulate on beaches where it is aesthetically degrading and can pose a threat to wildlife. Accumulated persistent industrial marine debris (PIMD) affects coastal wetlands, marine species, and water quality. The primary objective of this study was to identify the types, amounts, sources, and effects of PIMD in the coastal waters and along the shores of Charlotte County, New Brunswick, and examine any relationship between the amount of debris found in the study area and the types and numbers of industrial operations nearby.

Field studies included an aerial survey of the region followed by preliminary site visits to evaluate the scope of the problem. Definitive site surveys in the spring and summer of 2001 provided data on the types and amounts of PIMD in areas close to coastal industrial activities such as commercial fishing, aquaculture, and marine transport. The debris included plastics (particularly plastic bags and synthetic foams) and chemically treated materials as well as wood and other wastes. Some locations also showed accumulations of wastes from domestic rather than industrial sources.

Accumulations of debris were greatest in areas close to large numbers of industrial sites, particularly where the local topography trapped material carried in by the tides and wind-driven surface currents. Floating debris discharged from coastal industry sites is transported to adjacent shores by wind and wind-driven surface currents. Heavier items such as boats, cage parts, and tires may sink to the bottom. In some locations lightweight materials such as feedbags, salt bags, foam floats, and plastic containers were transported several meters inland by wind. There is a positive statistical correlation between coastal industry operations, and PIMD accumulating above the high water mark in each study area.

Environmental effects include navigational hazards, aesthetic degradation, and release of volatile organic carbons from burning plastic items and treated wood. Literature research also indicates that marine mammals can become entangled in discarded nets, lines, or fishing gear.

The main methods of waste disposal leading to the accumulation of PIMD on the beaches include simple discharge as well as unauthorized burial or incineration along shorelines. In some cases large items such as net frames and old boats appear to be wilfully abandoned on the beach. Appropriate pollution prevention strategies that monitor industrial activities for compliance with waste management regulations and policies are recommended.

KEY TERMS: coastal industry; educational tool; environmental effects; environmental survey; illegal disposal; persistent industrial marine debris (PIMD); pollution prevention; waste management.

Acknowledgements

For the help and advice from my committee in thesis preparation, I am most grateful. Thank you to Professor Raymond Côté, thesis supervisor, and Dr. David Scarratt, committee member for your patience and for pointing me in the right directions while providing diligent input as I developed and wrote my thesis. It was an honour to work with both of you.

I would like to thank Dr. Maria Inez Buzeta, Susan Farquarson, and Wendy Raymond for help and advice during fieldwork. Acknowledgement also to Eastern Charlotte Waterways Incorporated, the Department of Fisheries and Oceans, Shubenacadie Education Department, The Confederacy of Mainland Mi'kmaq, Dalhousie University Research and Development Fund, and Clean Nova Scotia Foundation, for field assistance, materials, information, funding, and support that made thesis study possible. Support was provided by Eastern Charlotte Waterways, the New Brunswick Salmon Growers Association, the Department of Fisheries and Oceans, and Dalhousie University.

Thank you also to Wayne Minor, Captain of the Pandalus II, Danny Loveless, First Mate, Phil Hatt, Aquaculture Manager, Dwaine Richardson, Aquaculture Manager, for providing transport to remote islands and locations as well as information on coastal resource use activities.

It is an honour and a privilege to be a student at the School for Resource and Environmental Studies, Dalhousie University, and I feel fortunate for the opportunity to work with many great people who are as concerned as I am about the environment.

Loving thanks also to my wonderful children who endured my absences from them with remarkable understanding and moral support. To my parents, I am grateful for all the help you gave – especially when things got tough. Finally, for the rest of my family, friends, Our Lady of Perpetual Help parish and others - thank you for the spiritual, moral and other support that inspired thought and action.

CHAPTER I
Overview and Summary

1.1 Introduction

Increasing population, changing technology, and industrial activity in many areas are placing new pressures on natural coastal resources. One inevitable effect of human activity in the coastal zone is the accumulation of persistent industrial marine debris (PIMD) along the shore. Results of 1997 and 1998 beach sweep information for Charlotte County indicated an increase in items such as polystyrene foam, plastic rope, plastic pieces, and strapping bands (ACAP 1997 - 98). PIMD known to accumulate on beaches in the study area included fishing nets, tarpaulin or plastic sheeting, 55-gallon drums, Styrofoam floats, and pallets (ACAP 1998). By 2001 the most common items found on beaches in Charlotte County were identified as beverage bottles, caps, lids, shotgun shells, beverage cans, pieces of glass, rope, plastic, lobster bands, strapping bands, buckets, plastic jugs, Styrofoam, and oil containers (Raymond 2001). The last eight items in this list can be associated with industry operations and identified as PIMD. Many items were of plastic and other synthetic materials that are not readily biodegradable. Sources may be land-based or marine-based industry or activities. According to biologists with the Department of Fisheries and Oceans in St. Andrews, the Charlotte County coastal area represents a portion of the Bay of Fundy that is subject to accumulation of PIMD, which is of concern to local residents and governments. Many areas have not been included in regular beach cleanup programs conducted by not-for-profit organizations, and the material may persist for years.[1] Research indicates that PIMD from aquaculture, commercial fishing, and other coastal industries is a growing problem in the Bay of Fundy, as in other regions of the world (GPAC 2002). The initial step toward a solution is to survey and study the types, amounts, sources, effects, and movement of marine industrial debris, and determine if it can be linked to coastal industries.

[1] The Atlantic Coastal Action Program, Eastern Charlotte Water Ways and the New Brunswick Salmon Growers Association. Eastern Charlotte Water Ways Incorporated (a not-for-profit environmental group) also receives increasing numbers of complaints regarding industrial debris and navigational or environmental hazards along Charlotte County shorelines.

1.2 Statement of Purpose and Study Objective

The purpose of the thesis was to collect and analyze data acquired through a survey of marine industrial debris found in the Passamaquoddy area[2] in order to determine whether there is a relationship between debris and coastal and marine industrial activities. The type, amount, distribution, and sources of industrial debris in the Passamaquoddy study area were determined through field surveys and a review of existing data and published information. Key industrial and coastal operations were identified as fish weirs, lobster pounds, aquaculture sites, fish plants and major marine service areas. The numbers of these types of coastal operations were counted within 2.5km and 1.25 km of each collection site. Since coastal operations may be seasonal, geographical information system data[3] were used to determine the number of industrial sites. The underlying rationale for the study is that there are potential and actual effects of PIMD on the marine or coastal habitat and biota, as well as aesthetic degradation, and possible dangers to people and their amenities in coastal areas. The results may encourage local interest groups such as Atlantic Coastal Action Program and Eastern Charlotte Water Ways to develop preventative strategies. The thesis addresses the following questions. What are the most common types of PIMD? Can they be traced to their sources? Is it all generated locally or does some come from outside the area? Based on averages and rough estimates, how much PIMD is accumulating along shorelines in the study area?

1.3 Thesis Outline

This thesis provides the results of an environmental assessment of persistent industrial marine debris in the coastal areas of Charlotte County, New Brunswick. Research was conducted as part of the requirements for the Master of Environmental Studies degree at Dalhousie University. Nineteen sites were observed during an aerial survey and eighteen

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[2] Maps 1 and 2.

[3] Provided by the Department of Fisheries and Oceans, St. Andrews Biological Station

were visited by boat or car during the preliminary assessments in the spring. Seventeen sites selected for *in situ* data collection are the focus of the analysis.

Chapter I introduces the topic and intent of the thesis and defines persistent industrial marine debris and discusses its environmental, social, and economic implications. Studies on marine debris reported in the literature are also described in Chapter I. The study area is described in Chapter II along with methods and criteria used to determine suitable study and control sites. Chapter II outlines data collection methods, preliminary field visits, and limitations of the research. The results in Chapter III highlight activities most significant to creating PIMD, and focus on the summer field studies that identified the types of debris found at survey sites, and information on industrial activity in the area. In Chapter III, the summary of field results identifies the most common persistent industrial marine debris categories, describes sites with the highest variety of PIMD, highest amounts, largest items, industry presence, waste burning, and land filling.

The statistical assessment in Chapter IV applies scatter plot tests, and correlation analyses to determine the relationships between PIMD, and the presence of industry in the study areas. This compares the number of PIMD items counted at sites close to industrial sources with the numbers counted at control sites (sites farther from industrial operations). The results indicate the strengths or weaknesses of the statistical relationships between PIMD and the amount of local marine industry. Chapter V addresses questions raised in the study objectives. It provides an overview of the potential environmental effects of marine debris, and discusses the means and reasons for the preferential accumulation of PIMD in some locations, while assessing the influence of prevailing winds, and surface currents on the distribution of the material. The data are also discussed in terms of the number of industrial sites, most common activities, types of debris, and main industry sources.

Chapter VI provides a brief evaluation of current pollution prevention initiatives and regulatory framework for solid waste management, and identifies potential solutions through recycling, and pollution prevention options for fish weirs, aquaculture sites, and major marine service areas. The conclusion summarizes the overall meaning of the results and discussion. Recommendations for further research, monitoring, and management of PIMD in Charlotte County conclude this study.

1.4 Literature Review

A variety of literature and other research materials was acquired from libraries, by exploration of Internet sites, e-mail enquiries, and discussion with knowledgeable individuals. Internet sources and resource material from non-profit organizations such as Eastern Charlotte Waterways, the Atlantic Coastal Action Program (ACAP), and Clean Nova Scotia provided most of the published information on marine debris specific to the Passamaquoddy area. The literature reviewed can be categorized as dealing with 1) environmental management of marine pollutants, 2) waste disposal practices, 3) research or studies regarding marine debris from coastal industry, and 4) beach cleanup reports, and related publications. Most of the literature and reference material is from areas of the world that report marine debris, namely North America and Europe.

From a Canadian perspective, Côté (1992) states, "...pollution can be further divided into that which is land-based and that which is the result of activities in the ocean. Many of the pollutants are chemical while others are physical and these include siltation and litter." Côté (1993:394) identifies preventative strategies for: 1) reducing the generation of wastes; 2) recovering and recycling waste materials and 3) reducing the volume of wastes. Appropriate environmental management systems may also serve as an holistic strategy through which non-biodegradable material is prevented from being discharged into the environment. Such management systems or programs developed for industrial sites in coastal waters such as aquaculture operations or fish weirs can increase due diligence, minimize environmental impacts, reduce or eliminate waste, and increase public acceptance (Gavine, 1997).

Marine plastic debris research includes studies on the presence and extent of floating marine debris in locations across Canada. A paper presented by Topping *et al.* (1994) at the 3rd International Conference on Marine Debris in Miami Florida, concluded that:

1. Debris is present on all coasts in Canada.
2. Marine debris types vary with offshore activities.
3. Fishing activity, marine vessels, and recreational boaters are among the known sources of marine debris.
4. Underwater survey of marine debris could provide further understanding of the marine debris problem.
5. Educating volunteers and researchers in consistent and statistically sound data collection methods will provide information on marine debris trends over time.

One strategy for addressing the marine debris problem involves increasing the ability of ports to receive waste materials. This can be achieved by placing dumpsters and waste receptacles at marine service areas and wharves in small craft harbours.

A study on the waste disposal practices of fishing vessels off the Canadian East Coast presented at the same conference provided a specific method of studying and managing PIMD (Topping *et al.* 1994). Data on garbage disposal were collected by fishery observers during a two year study in 1990 and 1991. Three primary methods of disposal were identified: offloading at port, incineration at sea, and discharge into the sea. Combinations of two or more methods were practiced during some voyages. Both domestic and industrial waste items were observed and recorded. Industrial waste items included: bags, polystyrene pieces, packing bands, rope, fishing nets, and other plastic products (broken equipment and damaged fishing buoys). Discharging waste into the sea was the most common disposal method and occurred in 76% of the incidents observed.

Most of the information on marine debris that accumulates on Atlantic Canadian shorelines is the result of beach sweeps such as those conducted by Clean Nova Scotia and ACAP Saint John. Topping *et al.* (1994) point out a major concern regarding the accuracy and uniformity of data since collection and survey methods as well as the types of debris targeted by each organization may vary.

1.4.1 Definition of Persistent Industrial Marine Debris

The Centre for Marine Conservation (1989) identified five categories of marine litter in relation to the following sources: galley wastes, fishing or boating gear, operational wastes, sewage associated wastes and medical waste. By 1997, this same organization identified trends of ocean based marine debris under the following five source categories: recreational fishing and boating, commercial fishing, operational wastes, galley wastes, and debris traceable to passenger ships - effectively connecting the problem to specific sources (MCS, 2000). By defini7tion, PIMD largely falls into the commercial fishing or boating, and operational waste categories.

"...Plastic debris will float on the surface of the sea, or within the water column, where they can harm wildlife, foul fishing gear and cause a hazard to small craft. Floating debris can also be carried substantial distances by ocean currents." (MCS, 2000).

The debris that accumulates on the shores of Charlotte County is entirely different from materials found in the old shell middens[4] of the Passamaquoddy First Nations people. Today, persistent debris is mostly synthetic in nature and may entangle wildlife (i.e. nets and plastic sheeting) or release toxins when incinerated or broken down by natural forces. In the Passamaquoddy area discarded domestic wastes, aquaculture activities, commercial fishing, and other coastal industries are the primary sources.

In comparing each word in the term persistent industrial marine debris to definitions found in Collins Dictionary of the English Language (Hanks *et al.* 1985: 383, 747, 901, & 1093): **persistent** is an adjective that defines something as *incessantly repeated or*

[4] A midden is essentially a common disposal area where waste was discarded. The accumulated material formed mounds that consist mostly of shells, occasional bones, and some artefacts (Smith 2001 Internet).

unrelenting; **industrial** refers to things or actions *derived from industry*; **marine** describes *anything found in or relating to the sea*; and **debris** identifies *fragments or remnants of something destroyed or broken.*

In the current literature there is no specific definition of PIMD, however the following three terms are used to describe debris from human activity in coastal areas: marine litter, marine debris and persistent marine litter. Persistent marine litter can be defined as: "Any material that is lost, discarded, dumped, or discharged into the marine environment, or that is thrown or blows into the sea, or is carried down rivers and ends up in the sea and is resistant to rapid degradation or breakdown in the environment." (Butler *et al* 1989:5)

Marine litter has also been referred to as a solid contaminant that adversely effects birds, fish, mammals, and interferes with aesthetic enjoyment (Côté 1993:387). The International Maritime Organization includes marine debris under categories or activities defined as "garbage from ships" or "dumping of wastes", with no clear distinction between marine debris from industry operations and domestic activity. In a web publication created by GESAMP[5], litter is identified as a threat to marine biodiversity. Here the main sources of marine litter are defined as litter from drainage sources on land, litter left on beaches and litter discarded from ships (Gray 1997 Internet).

This thesis refers to PIMD as discarded materials and items used in industrial activities, that do not readily degrade, persist in the environment, and tend to accumulate over time. The activities include fishing, boating, and aquaculture industries that harvest or use resources in the marine environment and may lose or discharge gear, materials, machinery or solid wastes from industry processes into the water or onto shorelines. This can include anything as large as a fishing boat or as small as a Styrofoam lobster float. It does not include domestic marine debris (DMD), which is waste material from personal use such as coffee cups, magazines, food packages, utensils, articles of clothing or other items that are not directly used in the harvest or use of marine resources.

[5] Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

Biodegradation

By definition PIMD includes materials that due to composition, size and form take a long time to degrade or break down. The following table provides estimates of how long it may take for various types of discarded industrial or domestic material to be degraded.

Table 1.1: Estimation of Marine Debris Biodegradation Times[6]

Biodegradation Time	Item	Debris Type
600 years	Monofilament Fishing Line	Industrial
450 years	Plastic Bottle	Industrial & Domestic
400 years	Plastic Beverage Holder	Domestic
200 years	Aluminium Can	Domestic
80 years	Styrofoam Buoy	Industrial
50 years	Styrofoam Cup	Domestic
50 years	Tin Can	Domestic
13 years	Painted Wooden Stick	Industrial & Domestic
1 - 3 years	Plywood	Industrial & Domestic
6 months	Photo-degradable Beverage Holder	Domestic
3 – 14 months	Cotton Rope	Industrial
2 months	Cardboard Box	Industrial & Domestic

Many types of synthetic material can last for a very long time in the environment (Price 1988). The information in Table 1.1 indicates that monofilament fishing line, plastic bottles, and Styrofoam buoys can have a biodegradation time of 600, 450, and 80 years respectively. As much as 135,000 tons of plastic fishing gear is discharged by commercial fishing fleets around the world each year (Oceans Institute of Canada, 1991). Some manufacturers of fishing gear advertise that products[7] such as plastic navigation or suspension buoys can endure Bay of Fundy conditions for hundreds and possibly thousands of years[8]. This is a significant length of time compared to other items that may serve the same function such as cotton rope and plywood, which may persist in the environment for approximately 14 months and 3 years respectively (MOTE 1993). However, precise data on the length of time it takes for synthetic items to break down in the Bay of Fundy environment is not available (Topping 2002 Pers. Com.). This is due to

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[6] Source: MOTE Marine Laboratory 's Marine Debris Biodegradation time line, 1993.
[7] Referring to items comprised of high molecular weight polyethylene virgin material that is stabilized against the effects of ultraviolet radiation from the sun.
[8] Information gathered from informal interviews, with production and sales representatives for fish gear companies, at the Nova Scotia Aquaculture Association workshop and trade show in January 2002.

regional variations in environmental conditions and the fact that synthetic materials are relatively recent inventions. Since temperature, chemistry, tidal and wave energy dynamics, and other factors influence the rate at which material biodegrades in the environment, the same types of material in the Passamaquoddy environment may not persist for the same amount of time. Another important point is that the material may persist, but not necessarily the item. For example, a foam buoy may last for 80 years. Yet, if left on a high-energy shoreline it may rapidly break apart into smaller and smaller particles. Fragmentation may make it difficult to determine with any certainty how long plastic particles and synthetic fibres will last in coastal environments.

1.4.2 Environmental Effects

Persistence of synthetic materials in the marine environment may be ecologically destructive in that accumulating materials may cover portions of natural ecosystems over time - blocking out or diffusing sunlight, vital nutrients, and oxygen. Persistent debris such as discarded plastic sheeting, may settle over benthic habitats such as coral reefs, and reduce biological activity by limiting sunlight and availability of nutrients (Sea Grant 2001 Internet). Since such material takes longer to degrade, ecosystems may not recover for a very long time.

A more recent study conducted in Antarctic waters by the British Antarctic Survey (Barnes, 2002 Internet) identified a number of small organisms including bryozoans, barnacles, polychaete worms, hydroids and molluscs that encrust boyant debris such as discarded plastic and foam items. The major concern of the researchers was that some types of persistent marine debris were serving as vectors on which species might float to distant habitats and disrupt indigenous ecosystems. Since boyant synthetic items such as foam or plastic bouys are less degradable than many natural items, they float for a longer period of time and are transported farther carrying organisms over greater distances. During *in situ* field studies many boyant items such as foam floats and plastic bouys were found to be encrusted with small marine plants and animals.

Entanglement and Ingestion

Two more environmental effects of persistence include ingestion of small bits of foam or plastic, and entanglement in lines, ropes, nets, or other types of derelict fishing gear (Fisheries and Oceans 1989). It is difficult to determine the extent of these two effects since animals are usually viewed from a distance and may be partially submerged. When animals die in the marine environment they may be washed out to sea or sink to the bottom, or be subject to predation and quickly disappear. Dead animals are also difficult to detect as they may "blend in with debris masses and occur as isolated events over large areas" (Laist 1997).

Laist (1997) compiled a comprehensive list of species known to become entangled in marine debris or known to consume smaller synthetic materials. In the listing it was found that 33% of Mysticete (baleen) whales ingested and became entangled in debris. Laist also determined that polyethelyne bags and plastic sheeting are consumed by minke whales (*Balaenoptera acutorostrata*), and that 77% of Odontocete (toothed) whales ingested debris items such as: trawl net, rope, mylar balloons, buoy line, longlines, plastic bags, plastic straw, plastic bottle caps, and plastic sheeting. In the North Atlantic Ocean both the Loggerhead turtle (*Caretta caretta*) and the Leatherback turtle (*Dermochelys coriacea*) are reported to ingest or become entangled in debris (Laist 1997).

It is presumed that sea turtles approach floating debris as if it were prey (Laist 1997), and may mistake clear plastic bags for jelly fish, their principal food (GPAC 1997). However, such debris items are indigestible and block the esophagus or intestines resulting in death. Turtles as well as seabirds, seals, and cetaceans may die from exhaustion, drowning or starvation when tangled in derelict fishing nets or rope (Price 1988). To seabirds smaller floating plastic or styrofoam particles may look like small sea creatures and they may eat them. It is believed that indigestible material accumulates in the gut providing a false sense of fullness. The result is starvation and eventually death (GPAC 2002).

During field research on Sable Island off the coast of Nova Scotia, Zoe Lucas (1992) observed a dead grey seal (*Halichoerus grypus*) with a rubber trawl roller fitting so tightly around the neck that it caused severe deformation and laceration. She speculated that the persistent material had been on the seal for at least 5 years and was the likely cause of death. A report on a post mortem of an emaciated juvenile harbour porpoise (*Phocoena phocoena*) indicated that a "balled up" piece of plastic found in the animal's esophagus was the likely cause of death. The persistence of such material directly influences what happens to the animals that consume it (Baird *et al.* 2000).

More than 50% of marine litter consists of plastics (Marine Conservation Society, 2000 Internet). The Marine Conservation Society estimated that over one million birds and 100,000 marine mammals and sea turtles die world wide every year from entanglement in, or ingestion of, plastics. Of the 115 species of marine mammals, 47 are known to have become entangled in or to have ingested marine debris. Approximately 30,000 northern fur seals (*Calorhinus ursinus*) die annually due to entanglement, primarily in net fragments. Estimates of marine life endangered by debris include most of the world's turtle species, 25 percent of marine mammal species, and more than 15 percent of seabird species.

Hicklin (1996) describes the Bay of Fundy as "a major migration corridor for millions of coastal shore birds flying southwards from arctic breeding grounds." For example Deer Island and Black's Harbour in Passamaquoddy Bay support a large population of common eider (*Somateria mollissima dresseri*). As many as 2500 pairs of common eider are present during staging season in the spring, or during autumn migration times. Aerial survey photos acquired in the summer of 2001 showed more than 100 sea bird nesting sites on the western side of Tinker Island in the Quoddy West Isles area. Significant amounts of plastic pieces and foamed plastic were found entangled in seaweed along nearby shorelines during field studies. One concern is that eider ducklings that forage the seaweed beds for invertebrates may mistake fragments of foamed plastic for food (GPAC 2002).

The Quoddy Region has a large and diverse population of migrating cetaceans during the spring, summer, and fall. In 1992 the Committee on Status of Endangered Wildlife in Canada COSEWIC listed the harbour porpoise in Eastern Canada as "threatened"[9]. A study of harbour porpoise (*Phocoena phocoena*) in the Gulf of Maine conducted by scientists from Woods Hole, Massachusetts concluded that 37,000 porpoise inhabited the waters of the Passamaquoddy area (Palka, 1995). Persistent materials such as plastic sheets and foam items that are reduced to particles may float among zooplankton at or near the surface. Endangered[10] North Atlantic Right Whales (*Eubalaena glacialis*) visit the Campobello and Grand Manan areas of the Bay of Fundy along with sei whales (*Balaenoptera borealis*) in the summer and fall (Brown, *et al.* 1996). Both whale species are baleen feeders and may consume plastic and foam particles along with zooplankton (Murison 2002 - communications). The implications for such whales are not yet determined. Drifting nets may also pose a threat of entanglement to small and large cetacea including Right, minke, and humpback whales in the Gulf of Maine (Canadian Ocean Habitat Protection Society 2001 Internet).

1.4.3 Conflict of Use

In Atlantic Canada prospective aquaculture developments are subject to a rigorous review process, and local fisheries are stringently regulated. However, disagreement and conflict over marine use continue to exist. Fishers may be worried that areas designated for aquaculture development will encroach upon traditional fishing areas. The main concern is that aquaculture operations could contaminate fish habitat through release of medication, solid waste, and fish wastes into the environment. For example, fishermen in the Bay of Fundy argue that aquaculture gear such as mussel lines and salmon cages are inhibiting access to fishing sites, and altering the environment of lobstering and scallop dragging areas. From the aquaculture operator's perspective there may be a concern that

[9] A species that is likely to become endangered if limiting factors are not reversed (COSEWIC 2002 Internet).

[10] Under the COSEWIC designations, Right Whales are listed as endangered meaning that they are a species facing imminent extirpation or extinction. (COSEWIC 2002 Internet).

the fishers are disrupting their operations through improper waste disposal practices such as bilge flushing near cage sites and discharge of oil cans, styrofoam and other materials into coastal waters.

1.4.4 Social and Economic Impacts

Along with the potential for plastics to cause harm to marine life, and risks to marine transport, broken and jagged rusty metal items pose a human safety hazard, on the seabed and on beaches. Marine debris also detracts from the aesthetic beauty of coastal areas. "Marine debris not only is an aesthetic problem, but has become a serious threat to marine life, a marine transportation hazard, and can threaten human health and safety as well as inflict serious economic loss." (Sea Grant 2001 Internet).

Economic losses include damage to trawler nets; blocked water intake pipes; damage to ships and small craft due to collision with metal drums or wooden pallets; ropes or nets caught in boat propellers; lost fishing opportunity, ghost fishing by free-floating nets; and lost tourism potential due to unsightly beach litter (Butler *et al.* 1989:6). Recreational activities such as swimming, diving and walking along beaches can also result in injury or entanglement in lost or abandoned gear. Burning plastic, vinal, and rubber wastes can result in the release of dioxins[11] (Cleverly *et al* 1997 - internet), and volatile organic carbons[12] from plastic or foam materials (Moroz 1996). Inappropriate waste management practices also hinder the reuse of materials.

[11] Compounds such as dioxin are extremely toxic in concentrated form, cause damage to kidney, liver, and nervous system and may be carcinogenic (Hinke 1996).
[12] VOCs:

CHAPTER II
Methodology

This chapter identifies the study region and the four areas from which data were collected during field studies in the summer of 2001. The methodology and approach to site selection, data collection and treatment are outlined. In addition a distinction between control, and PIMD data collection sites is provided and summarized.

2.1 Study Area Description: Four Topographic Areas

The base for the study was the Biological Station, Saint Andrews, New Brunswick. Located around the 45^{th} northern parallel and between the 65^{th} and 66^{th} meridians west, the study area encompasses the coast of Charlotte County, New Brunswick, extending southward from Oven Head in Passamaquoddy Bay to Deer Island Point, and northeast through the West Iles to L'Etang Harbour, then eastward to Pocologan Harbour in the Bay of Fundy (Map 1). The study area receives discharge from the St. Croix, Digdeguash, and Magaguadavic watersheds, and is a part of the Bay of Fundy / Gulf of Maine system. The western half of the study area includes Passamaquoddy Bay, Western passage, and the West Isles. The Eastern half of the study area includes the L'Etang area and the Southwest New Brunswick coast. Seasonal climatic changes, strong currents, and high tides characterize these waters. Tidal maximum amplitudes of 26ft (7.87 m) occur in Passamaquoddy Bay and of 26.3ft (7.95m) in the L'Etang estuary (ECW, 1997). With many small islands, bays and inlets, there are a variety of locations where PIMD will accumulate.

Dadswell (1996) refers to the Bay of Fundy as a "cul-de-sac for coastal migrating fishes" where large numbers of individuals occur within a small area. He attributed this to the Bay's biophysical characteristics, currents, and nutrient inputs from alluvial processes, and up welling of coastal waters. Approximately 83% of the primary producers such as phytoplankton, seaweeds, and algae, occur in highest abundance in the Outer Bay of

Fundy (Brylinsky 1996). The Quoddy Region is recognized as a "a hotspot" of marine diversity and productivity with a biological importance that surpasses its geographical boundaries (Lotze *et al.* 2002). In the summer of 2001 some of the species noted while conducting field studies included: pollock, mackerel, herring, eider ducks, blue herons, hawks, eagles, cormorants, seagulls, rockweeds, beach grasses, corals, seals, harbour porpoise, crabs, lobster, sea urchins, mussels, scallops, and starfish.

For the purpose of this thesis, I divided the study region into the following distinct topographic areas: 1) Passamaquoddy Bay and Western Passage area, 2) West Isles (Passamaquoddy Archipelago) area, 3) the Southwest New Brunswick shore, and 4) L'Etang Harbour area.

Passamaquoddy Bay is separated from the Bay of Fundy by the West Isles including Deer Island. There are two major passages between Passamaquoddy Bay and the Bay of Fundy through which the tidal flow enters and exits – these are Letete Passage that runs between Letete and MacMasters Island and the Western passage, west of Deer Island. There are also three minor passages north of Deer Island. These include Little Letete, Faux, and Doyles Passages. The St. Croix, Digdeguash, and Magaguadavic Rivers flow into Passamaquoddy Bay, which with its estuaries measures $98.5 km^2$. Residual current direction (Map 4) in the Bay is counter clockwise (Loucks *et al.* 1974). A large whirlpool known as "Old Sow" is located south of Deer Island in Western Passage, and is a feature of the flooding tide. Large volumes of water flowing in and out of passages to Passamaquoddy Bay result in high velocity tidal currents, which profoundly influence temperature and salinity (Loucks *et al.* 1974). Oxygenated by continuous mixing, and rich in nutrients provided by three rivers and up-welling from the Bay of Fundy, Passamaquoddy Bay waters contain an abundant diversity of life.

The West Isles comprise an island chain that runs from the southern side of Letete Passage southward to Campobello. The archipelago includes all the islands between the Wolves[13] and Deer Island.

[13]The West Isles is a group of small islands in the Bay of Fundy sometimes referred to as an archipelago.

The Southwest New Brunswick shore extends from Pea Point to Red Head, including Maces Bay, Seeleys Cove, Beaver Harbour, and Blacks Harbour. To the west of the Southwest New Brunswick shore is the L'Etang Harbour area which includes L'Etang Harbour and the shorelines along the northern side of Letete Passage.

2.2 Procedures and Tasks

Between May 31 and June 8, 2001 a preliminary assessment was conducted to determine the type, location, and amount of PIMD at targeted sites in the study area. This assessment involved field visits to sites by car, DFO vessel (Photo 2.1), and an aerial survey by sea plane. Video footage of sections of the shoreline in the Passamaquoddy Region was recorded on a hand held camcorder during both ground visits and the aerial survey. Approximately 3 hours of videocassette footage was shot and converted to videotape. In addition, 323 photographs were taken at sites in the study region. Most of the items recorded on the data cards appear in the videos and photos of each site. The video footage and photos are useful for reference purposes. Islands and remote areas were accessed by zodiac, DFO research vessel or skiff.

Photo 2.1: Pandalus II and Zodiac

Part of the study methodology was to gather data on accumulated PIMD at selected sites in the study area, identify types of industries close to each site, and determine the relationship between the PIMD amounts and the presence of industrial operations. I identified my tasks as:

- Define PIMD in terms of the thesis research.
- Conduct preliminary site visits and an aerial survey of the study area.

- Develop study site selection criteria.
- Select shoreline sites according to study site criteria.
- Create data record sheets for recording data and site information.
- Identify site size and location by recording GPS start and finish co-ordinates between defined beach features. i.e. - between two points or headlands.
- Visit selected sites and record amount and type of PIMD.
- Record observations with video tape and digital camera along selected shorelines.
- Inspect samples for logos, tags or other markings that might indicate origin.
- If required and where possible take samples such as feed bags, lines, or cage parts.
- Create a brief detailed description of each site that includes coastal geomorphology, fauna/flora, and human interactions.
- Map the distribution, type, and amount of PIMD in the study area.
- Determine the amount of major coastal resource use operations within 1.25km of each site
- Analyze and correlate data. Inspect samples for clues such as labels, tags, company logos that indicate the place of origin or source.

The hypothesis is that the presence of persistent marine debris is due to the presence of industry or other coastal activities located or operating nearby. In order to determine what relationship, if any exists between persistent marine debris and coastal use activities, dependent and independent variables were identified. This provided a way to compare the data collected from each site in the presence or absence of industrial activities. Since the number of PIMD items in an area is assumed to vary with the number of nearby industry sites, the independent variable was defined as coastal industry activities such as fishing, aquaculture, boating, tourism, and fish processing. Debris accumulating on shorelines was the dependent variable, since it is explained by the presence of coastal activities.

2.3 Definition of PIMD

My research provides information on the accumulation and distribution of debris that originates from marine based industries. It does not include waste or debris from land-based industries such as pulp mills, sewage treatment plants, or power generating stations. In terms of materials, PIMD was categorized as follows: 1. plastic and synthetic fibres; 2. foam (including foamed plastic); 3. rubber; 4. metal; and 5. wooden materials. Items or products encountered that were comprised of these materials included:

- Feeder or flotation pipes
- Plastic totes and fish boxes
- Plastic feed and salt bags
- Drums (metal and plastic)
- Aquaculture pens or cages
- Rope or lines longer than 2m
- Nets longer than 1m (fishing, weir, and aquaculture nets)
- Industrial tires
- Foam (floats, packing and sheets)
- Crab or lobster traps (metal and wooden)
- Motors and vessel parts
- 55-gallon drums
- Treated wood (weir poles, aquaculture pens or parts)
- Lobster crates, pallets, industrial beams or planking)
- Plastic sheeting longer than 1m
- Melted plastic from incineration

The PIMD survey also identified illegal landfills and incineration sites where waste material had been deposited or discarded. My PIMD data record card consisted of two pages (Appendix II). Page one recorded information on: site name, date of visit, industries identified, GPS readings, estimated distance inland that debris extended, appearance of the shoreline or beach, items that could be traced to a specific source and dead or entangled animals. Page 2 listed the counted items under five categories as 1) plastics or synthetic fibres, 2) foam or polystyrene, 3) rubber, 4) metal, and 5) wood. Materials that could not be identified with the items listed under each category were counted on the data card as "other".

Data recorded on the PIMD cards were compiled into Excel spread sheets and are in the Appendices. Minimum sizes counted under each category included pieces or scraps of plastic, rubber, metal or wooden items not greater than $0.5m^2$. However, due to the extensive fragmentation of Styrofoam, pieces[14] approximately $5cm^3$ were included in the data. Larger items such as boats or platforms are listed as "other" under the material category that they most closely match. For example abandoned sardine vessels identified during field surveys are included under the category "wood and metal", while old wooden fishing boats are listed under "wood" in the "other" section. Types of wooden items counted included large or treated items that take longer to degrade – such as wharf pilings, weir poles, aquaculture pens, and industrial beams[15].

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[14] Foam pieces are identified in the pie charts as pieces of foam < $0.25m^2$. The smallest foam pieces recorded on the data sheets are roughly $5cm^2$ in dimensions.

[15] Large wooden items such as pens, wharves or floating docks are potential hazards to navigation when lifted off shore by the tides. In addition, weir poles that are in good condition could be collected and reused instead of cutting down more trees.

Domestic marine debris (DMD) or debris from sources on land includes household or residential items, and solid waste items from land based sources that are discharged in or near the marine environment and accumulate on beaches. Since the study focus was on PIMD the DMD data card (Appendix V) was less detailed and included the following information: site location; estimated distance inland that debris extended; and type and amount of discarded domestic debris. Information on DMD cards falls under 6 material types: plastic, foam, rubber, metal, glass, and fibre (paper, wood, or cloth). Pieces of items roughly larger than $4cm^2$ were also included in the data. DMD data collection took place at all control sites and at one PIMD survey site (Table 2.3). When encountered, PIMD items were recorded on the bottom of DMD data collection cards at control survey sites.

2.4 Most Common Types of Industries

The most common types of industries in the Passamaquoddy Region of the Bay of Fundy are aquaculture and fisheries. Wildish (1996) ranks aquaculture and the commercial fishery as the top 2 human uses of the coastal zone in terms of need for high quality seawater. In the L'Etang Harbour and estuary, aquaculture and the traditional fishery are identified as sources of shoreline degradation that are known to discharge industrial refuse. In the same report, fish processing is also identified as a source of shoreline degradation through industry discharges (ECW 1998).

Map 2 shows the location of three main types of coastal industry in the study area. These are identified as: fish weirs, fish processors, and aquaculture sites. In the summer of 2001, Eastern Charlotte Waterways and DFO conducted a study on the type and amount of PIMD accumulating along shorelines in Charlotte County. Aquaculture, residential dumping, the fishery and related industry, lobster pounds, and recreational boating were the main sources (Smith 2002). Other contributors to persistent debris in the Passamaquoddy region include: shipping & transport, scientific research, and tourism (ECW 1997).

Coastal resource-use activities identified in this thesis as most significant to the accumulation of PIMD in the Passamaquoddy are 1) Aquaculture sites, 2) Line or net fishing, 3) Fish weirs, 4) Lobster pounds, 5) Fish processing and packing plants, and 6) Marine service areas. Lobster pounds and line or net fishing locations are not included on the maps. However, the presence of lobster pounds is noted in the study results.

Table 2.1: Coastal Use Industries, Debris or Derelict Items, and Possible Effects

Industry Type	Related Solid Debris or Derelict Items	Possible Effects of Debris or Derelict Items
Aquaculture sites	Feed bags, salt bags, plastics, nets, lines or ropes, fish boxes, foam buoys, crates, pallets, packing materials, totes, fish boxes, tires, floating docks & wharves, cages, foam sheets, vessels and parts.	Navigational hazard, ghost fishing from free floating nets, destruction of fish habitat, conflict with other users
Line or net fishing	Salt bags, plastics, nets, lines or ropes, fish boxes, plastic cleaner containers, foam buoys, vessels and parts.	Navigational hazard, disruption of fish habitat, ghost fishing from free floating nets, conflict with other users,
Fish weirs	Salt bags, weir poles, plastics, nets, fish boxes, plastic cleaner containers, foam buoys, vessels and parts.	Navigational hazard, disruption of fish habitat, ghost fishing from free floating nets, conflict with other users
Lobster pounds	Nets, floats, lobster crates, pallets, metal drums, plastic cleaner containers, rubber bands	Aesthetic degradation Conflict with other users
Fish processing and packing plants	Crates, metal drums, plastic sheeting, Styrofoam, pallets, plastic cleaner containers, packing materials, totes, fish boxes.	Aesthetic degradation Conflict with other users
Marine service areas	Plastics, salt bags, nets, lines or ropes, fish boxes, foam buoys, pipes, crates, pallets, packing materials, totes, fish boxes, tires, floating docks & wharves, foam sheets, vessels, motors, and boat parts.	Navigational hazard Disruption of fish habitat Aesthetic degradation Conflict with other users

Table 2.1 identifies the types of items that can end up as debris from fishery-related activities. The table also highlights the relevance of PIMD to the coastal environment in terms of hazards, fish habitat, management, and conflict issues. The items associated with aquaculture sites, lobster pounds, fish weirs, and fish processing plants were observed during visits to industry sites, and identified through consultation with aquaculture site

managers, and from catalogues that sell fishing and aquaculture gear. Items listed with line or net fishing were identified through informal discussions with fishers and catalogues that sell fishing gear.

Eastern Charlotte Waterways (1998) identified aquaculture and fish processing as having a high level of impact on the environment in the L'Etang Estuary, and the traditional fishery as having a low impact. In the same report, the traditional fishery and aquaculture are identified as causing shoreline degradation, habitat loss, and degraded water quality through discharge of refuse.

2.5 Preliminary Site Visits

Results of the preliminary site visits conducted between May 31 and June 8, 2001 are included in this section. Each table indicates location name, co-ordinates, items identified, comments, digital photograph number, and which sites were included in the subsequent PIMD summer assessment. GPS co-ordinates were not recorded during the aerial survey. In total 36 sites were surveyed – 13 from the Pandalus on 2 separate days, 19 by air plane in one afternoon, and 4 by car on 3 separate days. All preliminary site visits took place during low tides.

2.5.1 Aerial Survey: June 1, 2001

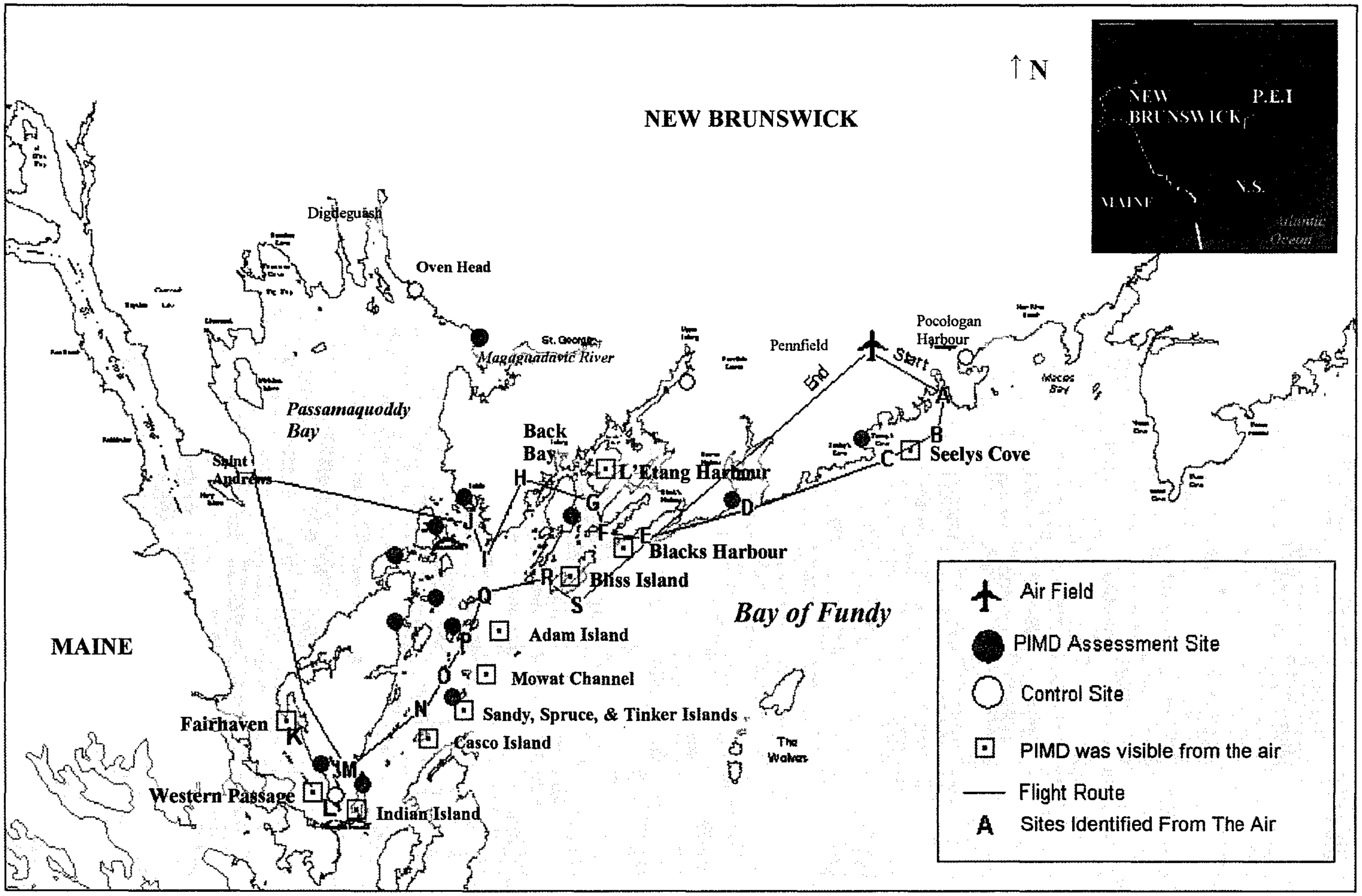
This section provides a more detailed account of the aerial survey including some photos of larger items observed from the air. The aerial survey was conducted on a clear sunny day. During the aerial survey video footage was recorded and photographs were taken. In total 63 photos were taken during the flight. Table 2.2 provides the place names, items identified, comments, and indication of whether or not to return for an on-site visit.

Table 2.2: Aerial Survey - June 1, 2001

Location	Items Identified And Comments	Return
A) Red Head, Pocologan Island	- PIMD could not be detected - No aquaculture sites or herring weirs nearby	No
B) Penn Island, Crow Harbour	Some PIMD may be accumulating	No
C) Seeleys Cove	Piping on beach	No
D) Beaver Harbour	No PIMD noted from air (road to lighthouse),	Yes
E) Deadman's Harbour	Not able to note PIMD during flight	No
F) Blacks Harbour	Piping on beach	No
G) L'Etang Harbour	Beached aquaculture net pen with Styrofoam, old wooden net pen, foam, piping, weir poles, netting (possibly)	Yes
H) Back Bay	Beached aquaculture pen	No
I) Greens Point	PIMD – undetermined On the Western side of the point	No
J) Matthew's Cove	Possibly some PIMD noted Across from Ship Harbour on MacMasters I.	No
K) Fairhaven	Industrial planking - some Styrofoam, plastics (possibly), beached net pens People cleaning nets on the beach.	No
L) Deer Island Point	Beached cage and some other debris Eastern side of the Island	Yes
M) Indian Island	Styrofoam, drums, netting, foam, parts of cages, green nets, weir poles... PIMD noted in the vicinity of 2 sites on the western side of Indian I. - across from Deer I. Point	Yes
N) Casco Island	Planks, foam, aquaculture cage parts- Uncertain	No
O) Sandy, spruce and Tinker Islands	Weir poles, netting (Sandy), melted plastic may be on Tinker Island	Yes (Sandy I)
P) Mowat Channel	Some PIMD noted	No
Q) Adam Island	Foam, weir poles, netting	No
R) Bliss Island	Cages, foam, plastics South of Pea Pt.	No
S) Pea Point area	Positive identification of PIMD could not be noted from air.	No

The flight route covered a path from the airfield in Pennfield along the Southwest New Brunswick coast, from Red Head and into the St. George and L'Etang Region. The flight route proceeded over Greens Point to Mathew's Cove, across Passamaquoddy Bay to St. Andrews. From St. Andrews the flight proceeded south to Fairhaven, Deer Island, and to Deer Island Point. The plane then passed over Indian Island and proceeded east over the West Isles to Pea Point. On Map 1 the upper case letters (A to S) correspond with 19 sites viewed from the plane. PIMD was positively identified and photographed during the flight at 13 of the 19 sites.

Map 1: Aerial Survey: Sites identified from the air, flight route, and data collection sites



Eastern Charlotte Waterways Incorporated and EnviroSmith Atlantic, 2002

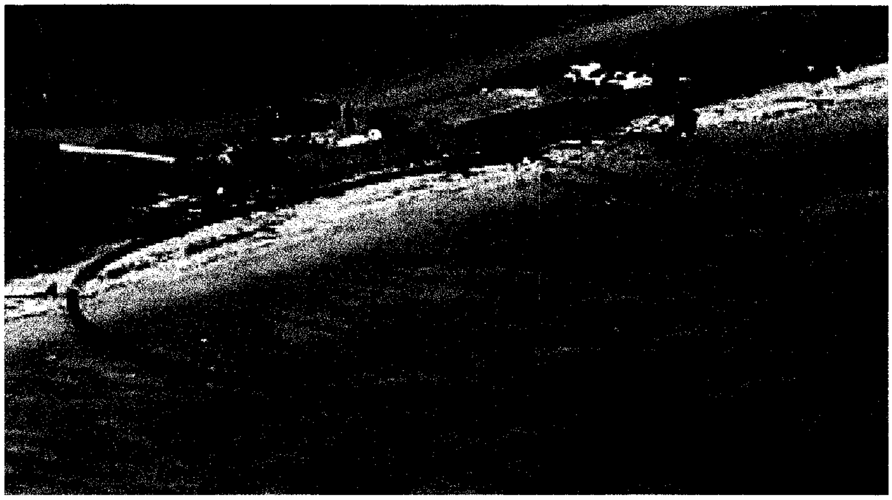


Photo 2.2: Southwest New Brunswick Shore: Piping and other PIMD along the shore

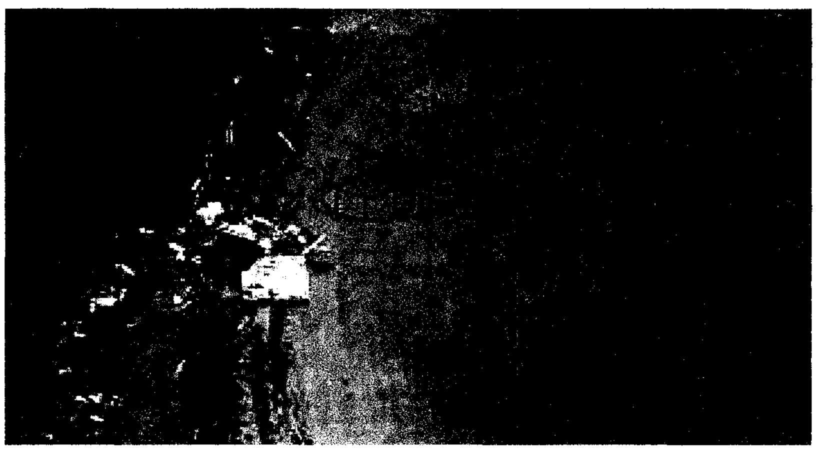


Photo 2.3: Indian Island: Plastic buoys, nets, Styrofoam (selected as a PIMD data collection site)

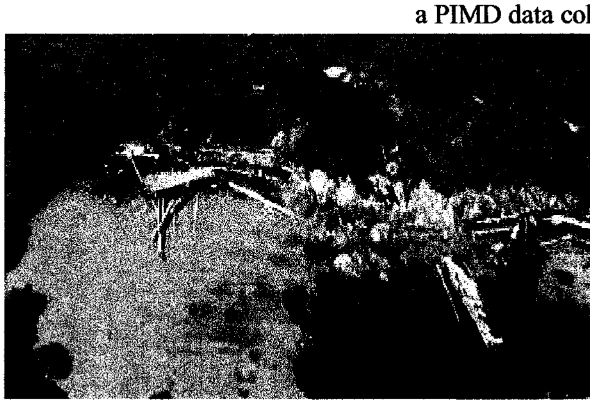


Photo 2.4: Casco Island: Discarded floating docks contain large amounts of

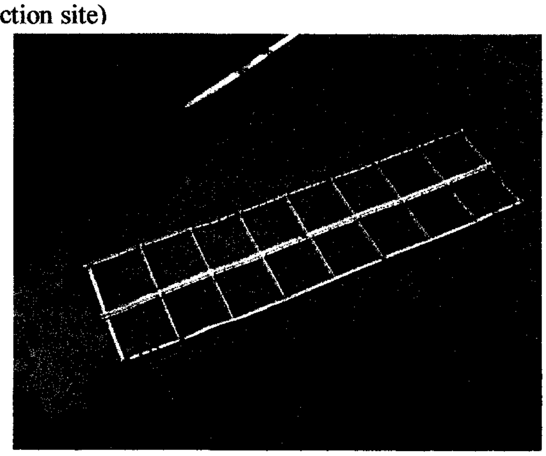
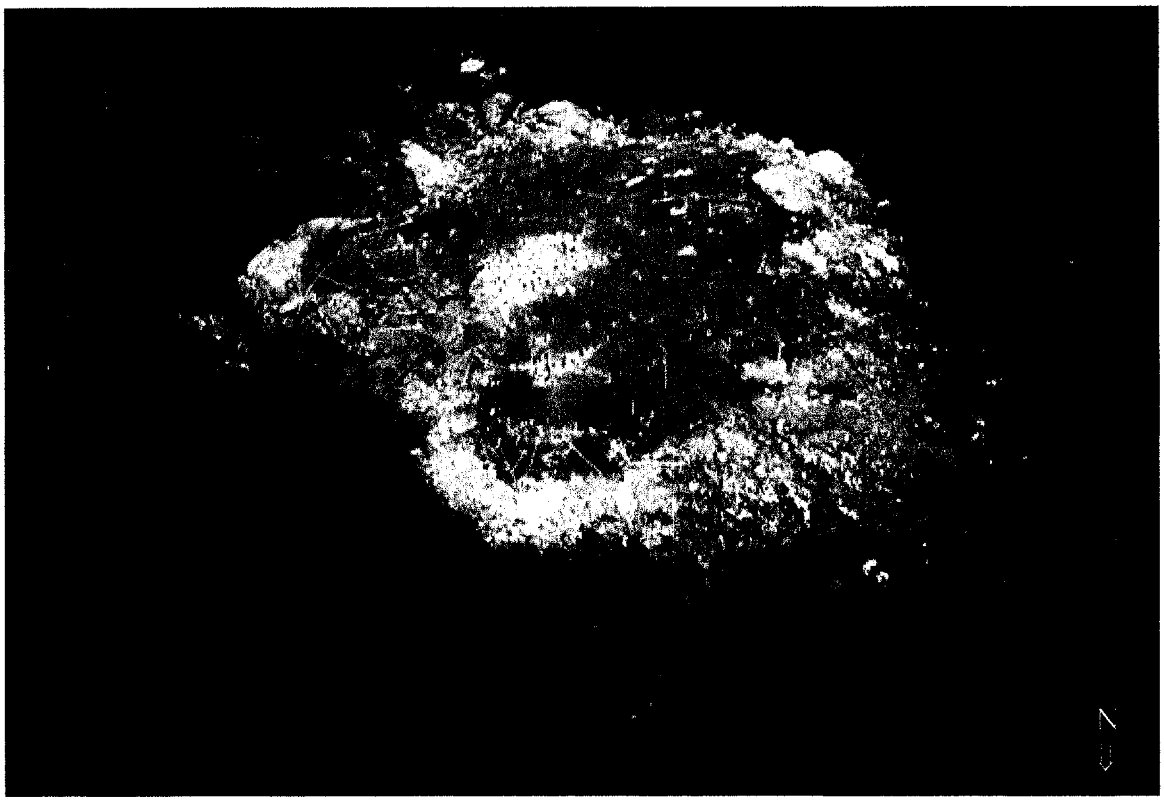


Photo 2.5: L'Etang Harbour: Old Wooden Cage Frame abandoned on a tidal flat.

2.5.2 Tinker Island

Tinker Island (Photo 2.6) is a small rocky islet in the Western Isles. It is mostly covered in rockweed, except for a small grassy area in the centre above the high water mark. This area was included in the aerial survey and subsequently visited twice. Tinker Island supports several species of seabirds including cormorant, eider duck, and herring gull (Photo 2.7) – all of which were noted in abundance during the visits.

Photo 2.6: Tinker Island: Aerial View



From the plane, the scattered pieces of driftwood could be identified. However, no PIMD was seen. Tinker Island was not accessed during the first visit on June 29, 2001 due to high tides - and video footage was shot from the zodiac as we encircled the island. On the second visit, I landed on Tinker Island from the zodiac and walked around the shore looking for evidence of melted PIMD from an illegal incineration site that had been photographed and reported to DFO in the previous year.

Photo 2.7: Cormorant Colony on Tinker Island, June 29, 2001

Surrounded by strong tidal currents, this steep and slippery shore offers no place for PIMD to accumulate. During the brief visit, video footage was recorded and no PIMD was noted.

2.5.3 Preliminary *In Situ* Surveys

Preliminary site visits were conducted in remote areas of the West Isles from the Pandalus on May 31 and June 8. Craig Point and Holts Point, in the northwest side of Passamaquoddy Bay were visited on June 6-7. Back Bay and Greens Cove in the L'Etang were visited on June 4. Detailed results of these preliminary *in situ* surveys are summarized in Appendix I, tables A1 – A4.

May 31 – Sites Accessed By The Pandalus II Research Vessel and Zodiac

Rainy weather, strong winds, and surf conditions prevented landing on all but one of the beaches by zodiac during this survey. Only 12 photographs were taken since storm conditions inhibited use of the digital camera. However, samples were collected from one site on Simpsons Island that was successfully accessed (Table A1).

June 8 – Visits by Pandalus II to the West Isles

Clear weather conditions allowed landing on beaches by zodiac from the research vessel (Pandalus). Samples were collected from Simpsons Island. Fifty-five photographs were taken during site visits on June 8 (Table A2).

Sites Accessed by Car

Four sites in the Passamaquoddy Bay and L'Etang area were accessed by car. No photographs were taken, however, video footage was shot at each site. PIMD was noted at Craig Point and Holts Point. The shoreline in Back Bay in the vicinity of a wharf and lobster pound was covered predominantly with domestic litter. A summary of field visits at these sites is provided tables A3 and A4.

2.6 Site Selection

After considering results of the preliminary visits, site selection criteria, geography, and consultation with ECW and DFO staff, 17 sites were selected for the summer field study assessment (Table 2.4).

2.6.1 PIMD Study Sites

With the exception of the control sites, all selected study sites fit into the following site selection criteria:

1. Sites must be within the study area described in this report with a high concentration of industry activities nearby.
2. Sites must have a shoreline area such as a wave cut terrace or a beach where debris can accumulate.

3. Sites are known to have debris accumulation.
4. Sites are located in one of the four distinct topographic areas described in the thesis.

2.6.2 Control Sites

Control sites provide comparison in the presence or absence of certain aspects or features (Schefler 1980). In this study, coastal industry activity is the independent variable. Since it is impossible to remove the independent variable, sites that are farther away from coastal industry operations were selected as controls. The large amount and diversity of marine based industry throughout the study area made it difficult to select control sites.

Table 2.3 Control Sites: Area use, geomorphic, wave, tidal, and current conditions

#	Control Site	Area use	Geomorphic wave, tidal, and current conditions
7	**Deer Island Point Beach**	Provincial park and ferry terminal	Small coarse grain sand and pebble beach. Extreme tidal currents.
11	**Timber Cove, Oven Head**	Rural – some cottages	Large tidal flat consisting of re-worked glacial tills. Low wave fetch[16] and current conditions.
14	**Treinors Cove**	Rural – residential	Cobble and mud shoreline. Upper reaches of estuary. Low current and wave activity.
17	**Pocologan Harbour, Maces Bay**	Rural – residential	Small fine grain sand beach. Parallel to the highway. Moderate wave fetch and current influence.

The control sites[17] are similar to other sample sites in that they are located along shorelines in the study area. However, they are relatively distant from coastal industries. Thus, the presence and amount of PIMD can be compared to areas close to high concentrations of coastal industries and which may or may not have a regular clean-up

[16] The farthest point up the beach that a wave moves after breaking on the shore.
[17] There is a large amount and diversity of marine based industry throughout the study area, so not many areas in the Quoddy Region can qualify as controls.

program. The locations of control sites are shown in Map 2 and listed in Table 2.3. Control sites are:

1. Within the thesis study area, one along the shoreline of each topograpghic area (Table 2.3).
2. Not close to high concentrations of industrial activity.

Timber Cove, Treinors Cove, and Pocologan Harbour are areas that have no industry close by in the waters off their shores. All three areas are subject to comparable tidal influences and have shorelines that would be susceptible to debris accumulation. The Deer Island control site is located within a provincial park and is subject to a regular beach cleanup program similar to some of the sites where PIMD surveys were conducted. On the east side of the island, approximately 1 km to the north of Deer Island Point Beach is a small ferry terminal. However, there is no industry in the waters directly off Deer Island Point, and no homes or cottages are nearby. These waters are located where the Outer Bay and Western Passage converge, and are subject to strong tidal currents. No weirs, traps, aquaculture sites, or other fisheries activities are found directly off Deer Island Point Beach. DMD data cards were used at control sites to record: site name, GPS readings, discarded material (if any), estimated distance inland that debris extends, date, and time of site visit.

2.7 Topographic Areas and Data Collection Sites

The 13 PIMD collection sites are shown on Map 2 and identified in Table 2.4 along with the 4 control sites. Control sites are remote from urban centres and coastal industries, with relatively low anthropocentric influence[18].

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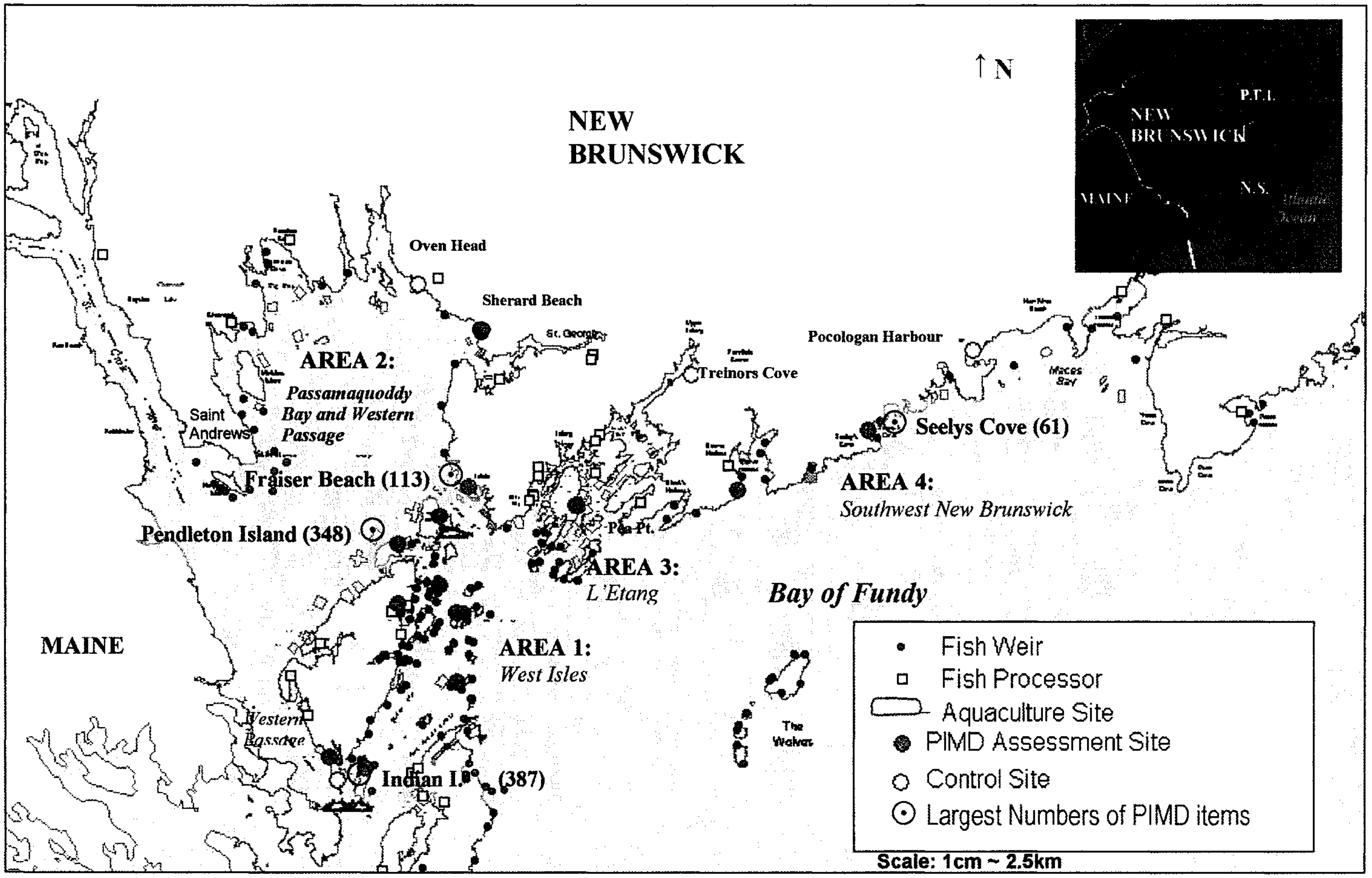
[18] With the exception of Deer Island Point Beach, this is located in a Provincial Park and is 1km away from a small ferry crossing.

MAP 2: Four Study Areas, Data Collection Sites, Weirs, Processors, and Aquaculture Sites



Eastern Charlotte Waterways Incorporated and EnviroSmith Atlantic, 2002

Table 2.4: Topographic Areas: PIMD, DMD and Control Data Collection Sites

Area	#	Site Name	Area use	Data Type
The West (Quoddy) Isles	1	Sandy Island	Weirs, Aquaculture site	PIMD
	2	Simpsons Island	Weirs, Aquaculture site	PIMD
	3	Indian Island	Aquaculture site	PIMD
	4	Ship Harbour, MacMasters Island	Aquaculture site	PIMD
	5	Lords Cove, Deer Island	Lobster pound, Fish Processing Plant	PIMD
	6	Hardwood Island	Aquaculture site	PIMD
	7	Deer Island Point	Provincial Park & ferry to Campobello Island	Control
Passamaquoddy Bay and Western Passage	8	Cummings Cove	Fish Processing Plant, Aquaculture site	PIMD
	9	Pendleton Island Beach	Aquaculture site	PIMD
	10	Sherard Beach	Fish Processing Plant, Aquaculture site, and rural – residential development	Comparison PIMD and DMD
	11	Timber Cove, Oven Head	Rural - some cottages	Control
L'Etang Harbour	12	Fraiser Beach, Mathew's Cove	Aquaculture site	PIMD
	13	Birch Cove, Frye Island, Lime Kiln Bay	Fish Processing Plant, Aquaculture site	PIMD
	14	Treinors Cove	Rural - residential	Control
Southwest New Brunswick Coast	15	Lighthouse Pt., Beaver Harbour	Fish Packing Plant, Weirs, Aquaculture site	PIMD
	16	Seelys Cove	Weirs, Aquaculture site	PIMD
	17	Pocologan Harbour, Maces Bay	Rural - residential	Control

2.8 Data Collection and Treatment Methods

Observations were made and data recorded along a length of shore from the high water mark and moving inland as far as the PIMD extended. The distances between start and end points of each transect were determined by the coastal geomorphology. The approximate lengths of shoreline covered at each site varied from 250m to 750m. The distance inland that the debris extended was governed by topographic and geomorphic features or characteristics and varied between 0m and 100m.

Data collection start and end points were recorded as geographic coordinates taken from a GPS receiver. Site locations were plotted on a map of the study area along with the locations of industrial sites. The amount of area surveyed at each site was defined by geographic features such as areas between 2 headlands reaching inland above the high water mark as far as the debris extended. Data are provided in the results section and in Tables A5 to A12 in the Appendix. Materials that carried company logos, tags, or other identifiers were matched, when possible, to the source industry. However most items could only be identified with a type of industry. For example, the source of a net pen cage, or parts thereof, is the aquaculture industry in general rather than a specific aquaculture site. Some of this material bore the names of manufacturers, or other identifiers, that indicated where the items might have originated, and whether the source was local. Data from each of the 17 survey sites were organized into a series of pie charts that indicate the amount of each PIMD category as a percentage of the total. Average amounts of each debris category were determined for each topographic area. Scatter plots were created to show the relationship between the number of PIMD items counted and the number of fish plants, weirs, aquaculture sites, lobster pounds, or major marine service areas within 1.25km of each site. The product-moment correlation coefficient[19] was derived through a statistical analysis of the data. This measure was applied because it provides a statistical measure of the relationship between the amount of PIMD along shorelines, and the amount of coastal industry in an area.

2.9 Limitations

On-site research took place during the spring and summer. Storm, fog, or unusually high tides inhibited planned visits to sites and data collection on several occasions. In addition, help from local interest groups in accessing remote sites, and variability of weather were unforeseen and increased the time required to complete field studies. To ameliorate such

[19] Correlation coefficient: a statistic measuring the degree of correlation between two variables and obtained by dividing their covariance by the square root of the product of their variances. The resulting value ranges between –1.0 and 1.0, indicating a negative and a positive relationship respectively. A value of zero indicates a complete absence of a relationship between the two variables (Ebdon 1994).

constraints, interest groups[20] were contacted in advance, when possible, to arrange meetings. Field visits were also flexible such that if extreme weather prevented safe use of the zodiac or airtime scheduling, then areas accessible by car were visited.

Differences in shoreline types may also influence the type and amount of accumulated debris in different seasons. This may be due to geomorphologic characteristics that affect the amount and type of debris deposited at each site. For example, a steep shoreline is likely to have less debris than a flat shoreline. Shoreline length and width also vary from site to site. Since it is impossible to find shorelines with identical topographic, biological, and tidal characteristics, various shoreline types were selected throughout the study area. However, it is assumed that persistent debris found above the high water mark and beyond will remain there for a year or longer, regardless of shoreline type.

Statistical limitations relate to any seasonal variations in debris amounts[21]. For example, smolts may be transferred to cages in the spring, and are usually harvested 18 months later before extremely cold weather sets in. Where water temperatures remain above $-0.7^{o}C$ salmon can be successfully over wintered (Saunders, 1995). The size and amount of finfish influences the amount of feed required and therefore the number of feedbags that may be discharged into the water. Nonetheless, salmon culture is a year-round activity, and fish are fed and tended continuously in the Quoddy Region.

A combination of seasonal influences and regulations determines time-of-year activities for line, weir, lobster, and other fisheries. Although fishery and coastal industry operations occur throughout the year, activity tends to be greater in spring and summer.

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[20] Including: New Brunswick Salmon Growers Association, Eastern Charlotte Waterways Incorporated, and the Department of Fisheries and Oceans.

[21] Changing weather or climate conditions from season to season influence operational activity in coastal areas.

CHAPTER III

Results

Observations recorded at the seventeen study sites are included in this chapter. This includes site descriptions and summaries of the most common items found. Four tables representing each topographic area show information on the data collected at each site. Pie charts show percentagels of items counted, and photographs taken during field studies are included. Items less than 1% of the total counted are not shown in the pie charts.

3.1 Sites in the West Isles Area

Table 3.1: Data Collection Sites in the West Isles

#	SITE NAME & DATE OF VISIT	LOCATION: GPS – Start & End points	MODE OF ACCESS	Data type, local industry, approximate shoreline length, approximate distance inland that debris extends beyond terrestrial vegetation line.
1	Sandy Island June 29 / 01	Start: N 44^0 58. 366' W 66^0 54. 767' End: N 44^0 58. 338' W 66^0 54. 878'	Pandalus	PIMD, fishery, herring weir, & aquaculture. ~ 500m. ~ 5m.
2	Simpsons Island June 29 / 01	Start: N 45^0 00. 202' W 66^0 54. 740' End: N 45^0 00. 253' W 66^0 54. 738'	Pandalus	PIMD, fishery, herring weir, & aquaculture. ~ 250m. ~20m
3	Indian Island July 11/ 01	Start: N 44^0 56. 094' W 66^0 58. 086' End: N 44^0 56. 186' W 66^0 58. 148'	Pandalus	PIMD, fishery, herring weir, & aquaculture. ~ 250m. ~ 10m.
4	Ship Harbour, MacMasters Island July 11/ 01	Start: N 45 02. 786' W 66^0 55. 434' End: N 45^0 02. 682' W 66^0 55. 319'	Pandalus	PIMD, aquaculture, ~750m. 0m.
5	Lords Cove, Deer Island July 15/ 01	Start: N 45^0 00. 981' W 66^0 56. 245' End: N 45^0 01. 008' W 66^0 56. 168'	Vehicle	PIMD, lobster pound, Fishery, herring weir, & aquaculture. ~500m. ~10m
6	Hardwood Island July 18/ 01	Start: N 45^0 00. 963' W 66^0 55. 397' End: N 45^0 00. 906' W 66^0 55. 443'	NBSGA[22] Dwayne Richardson speed boat	PIMD, fishery, herring weir, transportation, tourism, & aquaculture. ~ 500m. 0m.
7	Deer Island Point July 15/ 01	Start: N 44^0 55. 523' W 66^0 59. 074' End: N 44^0 55. 540' W 66^0 59. 037'	Vehicle	DMD, tourism (Provincial Park), & transportation. ~250m. ~2m.

[22] New Brunswick Salmon Growers Association

3.1.1 Site 1: SANDY ISLAND

Photo 3.1: **Sandy Island beach.** There is a fish weir beside this site (in the water by the beach). Many small plastic items are caught in the rockweed at the high water line.

<u>Site Description</u>

The Sandy Island site is a large sandy beach beside a herring weir on the eastern side of the island facing Spruce Island (Photo 3.1).

Decaying rockweed at and above the high-water mark extends into coastal grasses. Dune-like formations occur along the backshore of the beach, supporting marram grass or other beach vegetation. The beach slopes at a gentle angle to the water, and from the surface, several scallops were noted on the ocean floor. The island was accessed during low tide. A seagull colony occupies the island and a nest with gull eggs (Photo 3.3) was noted among the dry rockweed close to the high water mark, along the backshore.

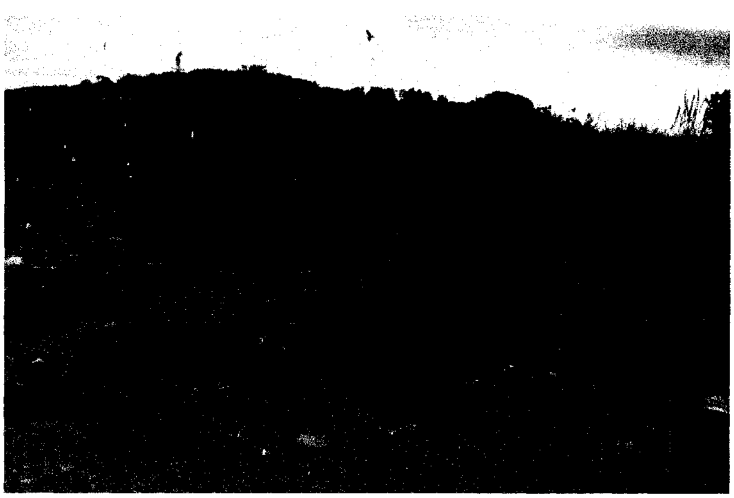


Photo 3.2: Net on Sandy Island Beach – was also photographed by from the plane on June 2, 2001.

Debris extended approximately 5m into the terrestrial vegetation above the high tide line. Nets, plastic, and ropes were integrated into the beach and dune formations (Photo 3.4). Many items could not be identified without excavation.

Most Common Items

Forty-four PIMD items were counted and recorded. Most common items at this site were synthetic rope and lines greater than 2m in length, wooden weir poles, plastic water jugs, and nets. From most to least common the order of each debris category was:

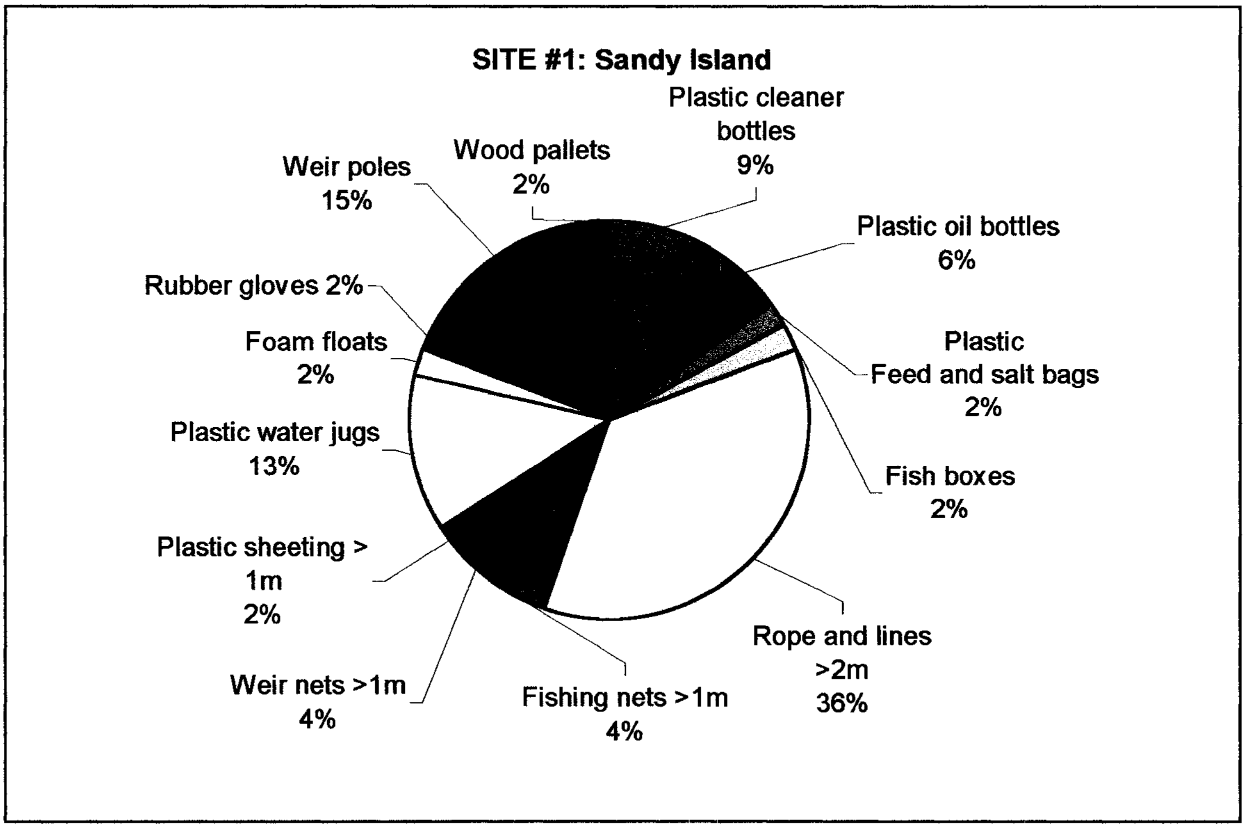
1 Plastics / synthetics
2 Wood
3 Foam
4 Rubber
5 Metal.

Photo 3.3: Seagull nest on Sandy Island – found just beyond the old net in Photo 3.2.

The largest item noted was a net (Photo 3.2) at the point, which was also recorded on video and photographed during the aerial survey. A bulk fish meal feed bag with a 1000kg capacity from Connors feed company was also noted.

Photo 3.4: Sandy Island: Old Net Integrated into Beach Matrix. The net is faded, frayed, and partly buried under sand – beach vegetation and marram grass grow through the mesh.

Pie Chart 1: Sandy Island - Most common PIMD items (%)



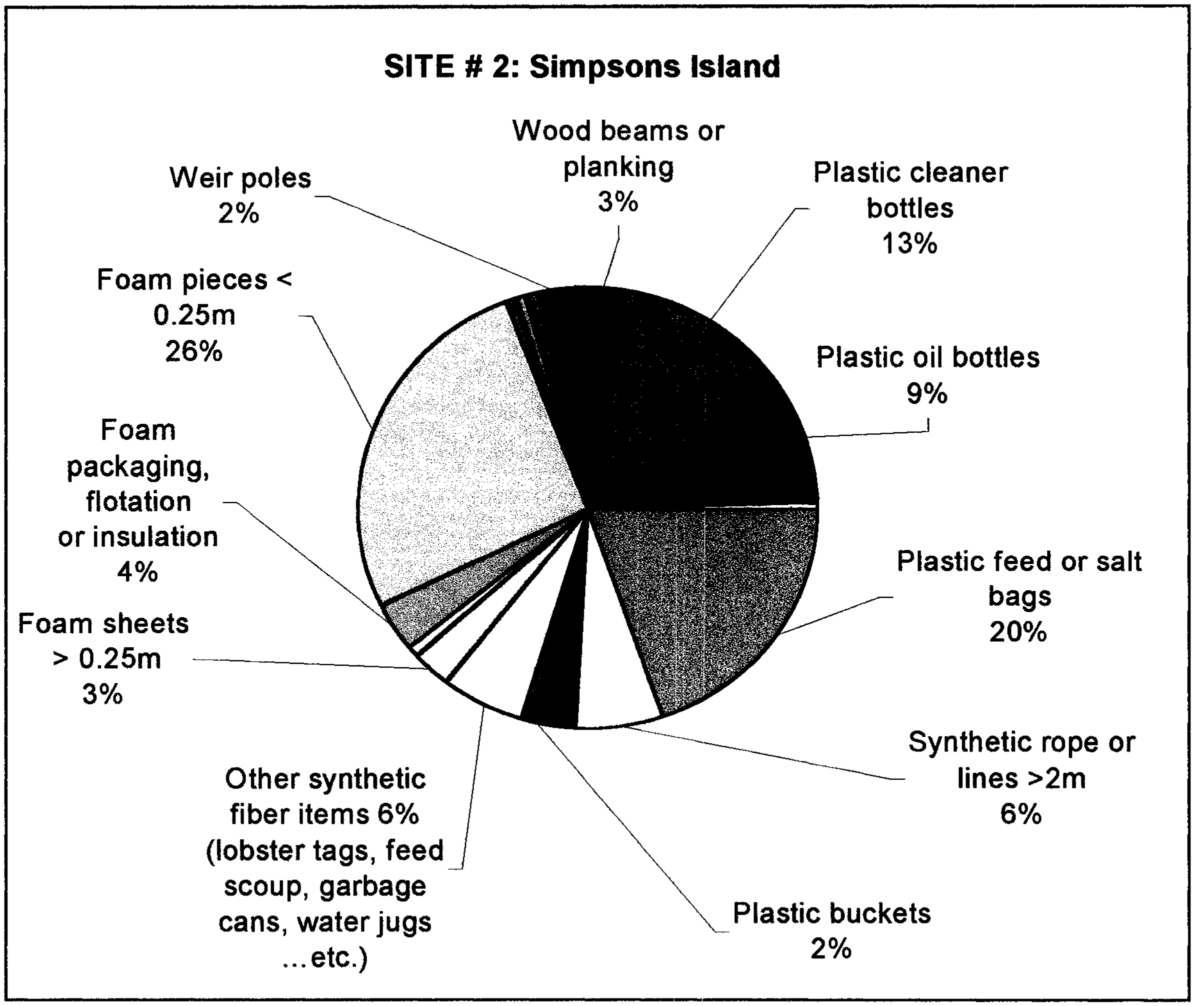
3.1.2 Site 2: SIMPSONS ISLAND

Photo 3.5: Rusty Pontoon on Simpsons Island.

Site Description

Data were collected on a beach that partly covers an exposed rock formation. Pebble and cobble cover the upper foreshore and backshore. Rockweed is cast up on the shore and extends along the high water mark. Terrestrial vegetation consists of a mixed conifer deciduous forest.

Pie Chart 2: Simpsons Island - Most common PIMD items (%)



Debris extended approximately 20m above the terrestrial vegetation line along the backshore. The large metal pontoon noted during the spring visits remained at the high water mark above the beach (Photo 3.5).

Most Common Debris Items

Foam pieces less than ¼ meter in length (65), plastic feedbags (48), and plastic cleaner bottles (31) were the most common items identified respectively. Two hundred and forty five items were counted and recorded: the most common were synthetics with 142 items recorded, followed by foam, wood, metal, and rubber. The largest items noted were the rusty old pontoon (Photo 3.5), and three plastic garbage cans. A dead bird (possibly a cormorant) was found entangled in the trees above the backshore (Photo 3.6). Exact cause of death could not be determined. Evidence of shoreline dumping was noted in a large pit above the shoreline, near the data collection end point (Photo 3.7). Other notable items included a plastic feed scoop, and lobster trap tags.

Photo 3.6: Entangled Bird on Simpsons Island

Photo 3.7: Depression in the earth used as a PIMD Disposal Pit on Simpsons Island

3.1.3 Site 3: INDIAN ISLAND

Photo 3.8: Indian Island

Site Description

The Indian Island shoreline consists of pebbles covering a solid rock formation - similar to Simpsons Island. However, the shoreline below the high water mark is quite green with algae. Aquaculture sites were visible from this shoreline. Beach pea and other shoreline plants grow along the high tide line. Decaying rockweed had accumulated at and above the high water mark. The pattern of vegetation covering the shore in a path from the waters edge toward the back shore was rockweed, algae, rockweed, green coastal plants, rockweed mixed with debris, then grasses, and coniferous forest above the backshore.

Photo 3.9: Waste Incineration Site. Distinguishable items include tires, feed bags, and plastic cleaner (bleach) bottles.

Debris appeared to be transported inland by the wind and extended approximately 10 - 15m into the forest.

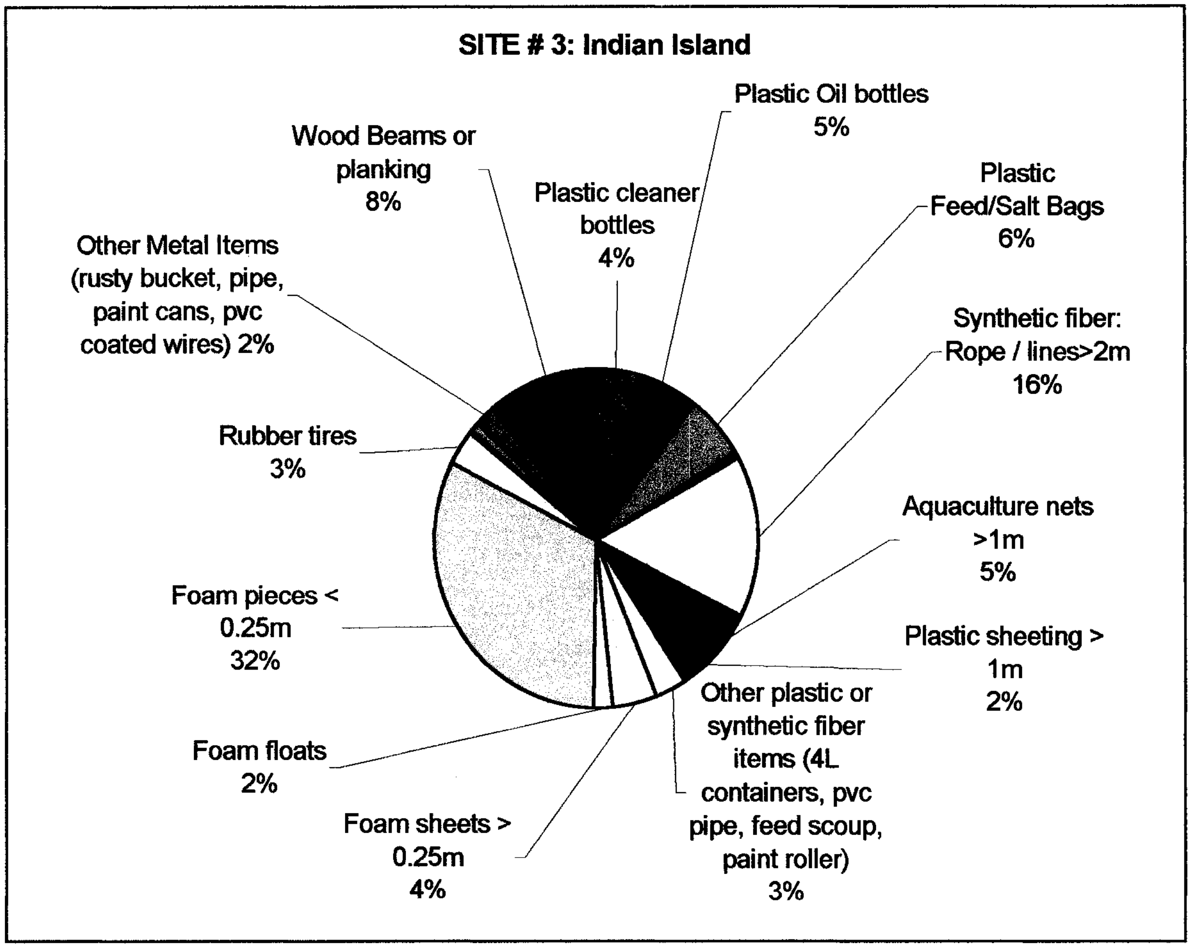
Three separate debris incineration sites were noted between the high water mark and the adjacent forest line (Photo 3.9).

Large damaged and discarded items found at this site included large yellow plastic floats, Styrofoam sheets, large nets, and a broken wooden skiff covered with foam. A large barge was also beached on the shore and covered with empty plastic cleaner bottles, broken floats, pieces of tattered plastic, and old nets tangled together with seaweed and frayed ropes around sheets of foam (Photo 3.8).

Most Common Items

Three hundred and eighty-seven PIMD items were identified at the Indian Island site. The most common items were foam pieces less than 0.25m in length, of which 149 pieces were counted. The second and third most common items were ropes or lines greater than 2m and industrial wood beams. Most common PIMD debris category was plastics (bleach bottles[23], markers, pipes, and floats) and synthetics (170 items), followed by foam, wood, rubber, and metal.

Pie Chart 3: Indian Island - Most common PIMD items (%):



[23] Bleach is used as an anti-fouling agent to remove algae and encrustations from nets and gear.

Photo 3.10: PIMD on Indian Island.
Floats, polystyrene, nets, oil cans, Xactic boxes, ropes and treated wood.

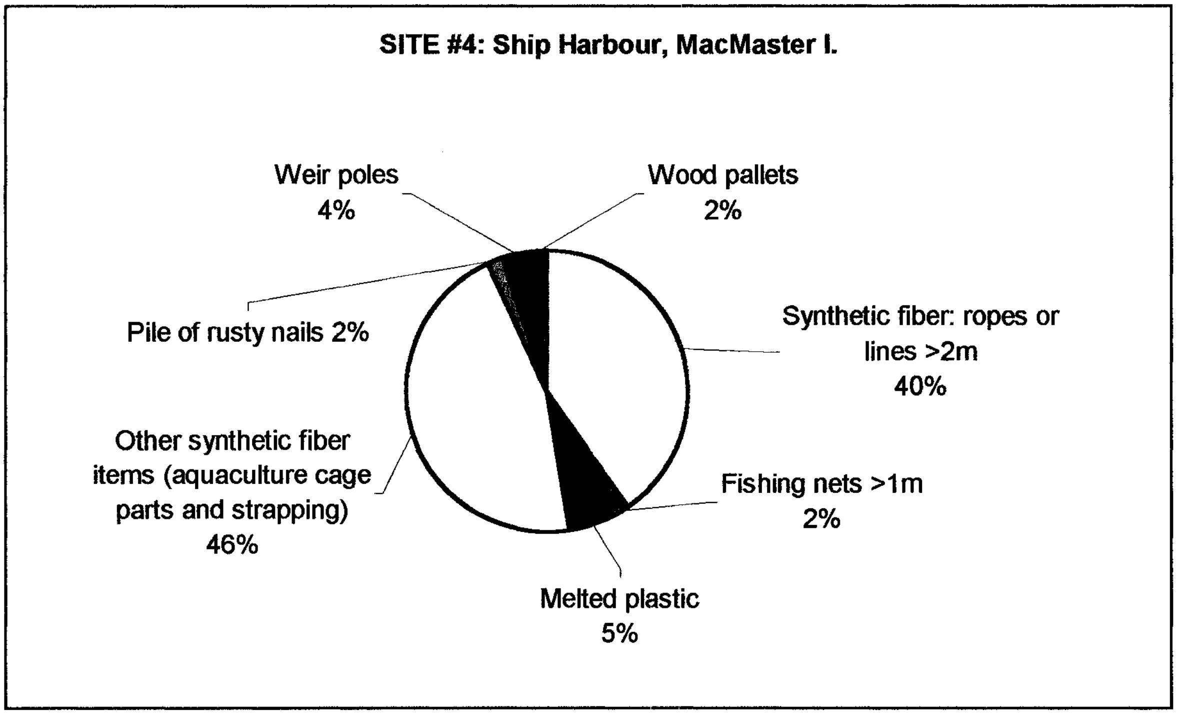
3.1.4 Site 4: SHIP HARBOUR, MACMASTERS ISLAND

The Ship Harbour shoreline consists mostly of gravel and pebble with some coarse sand along the foreshore. A tidal trough extends along the backshore, creating a bar or ridge that separates the foreshore from the backshore – with a steep angle on either side. This is a very large stretch of accessible shoreline. There is a steep slope above the backshore runnel extending up into the forest, which inhibits the movement of debris inland by wind. The forest is a mix of deciduous and coniferous trees. Vegetation along the ridge that separates the foreshore from the backshore trough consists of grasses, wild peas, amaranth, and other wild grains. Data collection began at the western headland and ended half way along the beach – going east. Three old incineration sites were noted within study limits of the site. Compared to other sites the amount of debris was small, and was dispersed over the site.

Most Common Items

Fifty-seven PIMD items were counted at the Ship Harbour study site. Most common items at this site were aquaculture cage parts (26 in total), ropes or lines, and melted plastic. Items in the Plastics category made up 93% of the material at this site. Several picnic tables were located along the ridge between the fore and backshore.

Pie Chart 4: Ship Harbour - Most common items (%)



3.1.5 Site 5: LORDS COVE, DEER ISLAND

Photo 3.11: Lords Cove

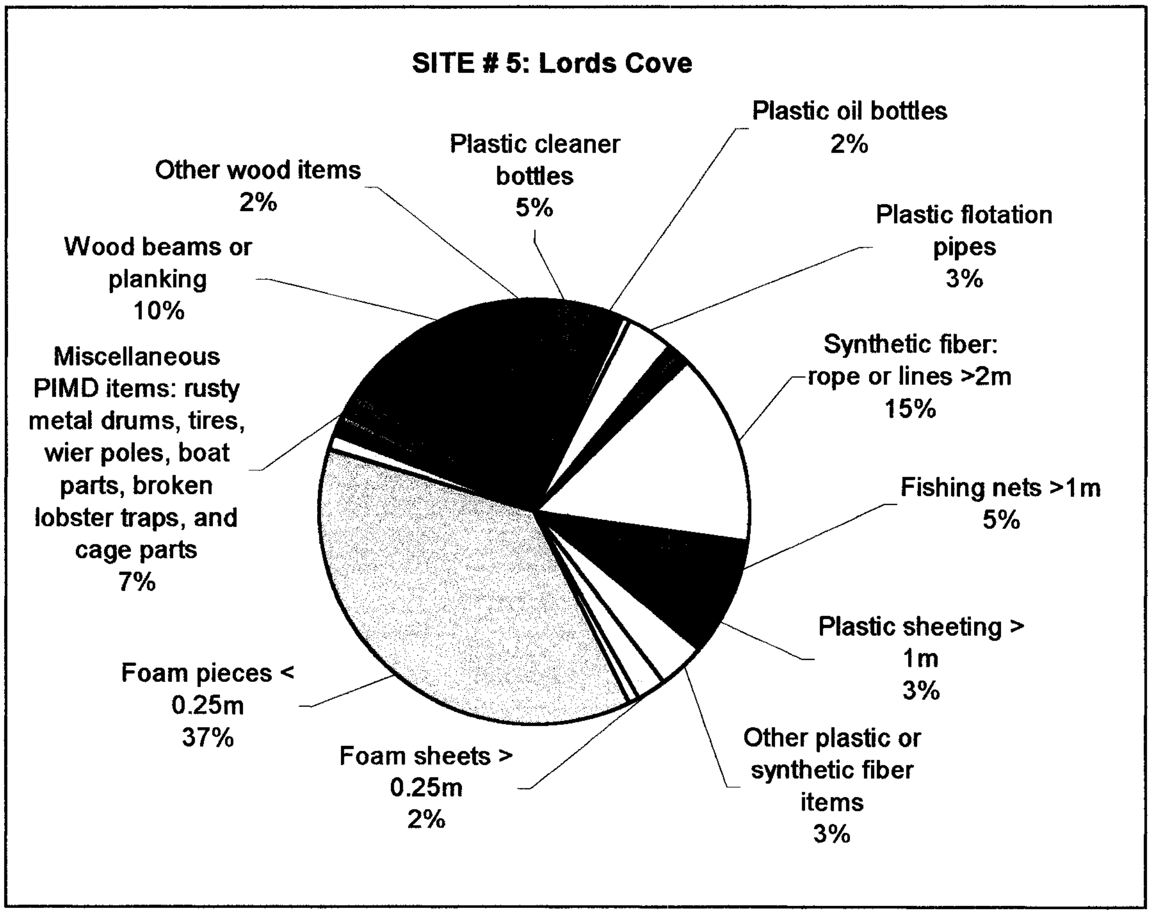
Site Description:

Located on the Northeast side of Deer Island, this stretch of shoreline consists of a pebble beach covered at intervals with detached rockweed.

A rock ridge (possibly man-made) separates foreshore from backshore (Photo 3.12). The backshore lagoon contains a lobster pound. Green leafy coastal vegetation and wild grasses grow up through the rocky ridge.

GPS start readings were taken at the warehouse (red building), and end readings were recorded at the eroding headland in the distance (Photo 3.11). Debris extended inland for approximately 10m toward the end of the study area. Most of the PIMD occurred along the high water line and on the rock ridge. Five or more nets appeared to be anchored among the rocks and driftwood along the mid-shore ridge.

Pie Chart 5: Lords Cove - Most common PIMD items (%)



Most Common Items

Two hundred and eighty eight items were counted between the start and end points in Lords Cove. The most common items were foam pieces followed by industrial wood beams, and rope or lines greater than 2m lengths. Three pieces of melted plastic were found. The most common category was plastic. The largest items recorded include a floating dock (toward the data collection end point), mussel screen (beside the warehouse), tires, and nets. A variety of rubber, metal, and wood items were counted and recorded[24]. Fifty or more dead crabs and several dozen dead lobsters were noted.

Photo 3.12: Nets in Lords Cove

3.1.6 Site 6: HARDWOOD ISLAND

Photo 3.13: PIMD on Hardwood Island

Site Description

The study site on Hardwood Island is located on a small spit (approximately 70m in width) on the eastern side of the Island. A narrow inlet separates this formation from the main part of Hardwood Island. The area toward the isthmus is occupied by a small coastal marsh. The beach is gravel and pebble. Rockweed occurs at intervals along the shore. Flowering vegetation and wild grasses grow along the ridge.

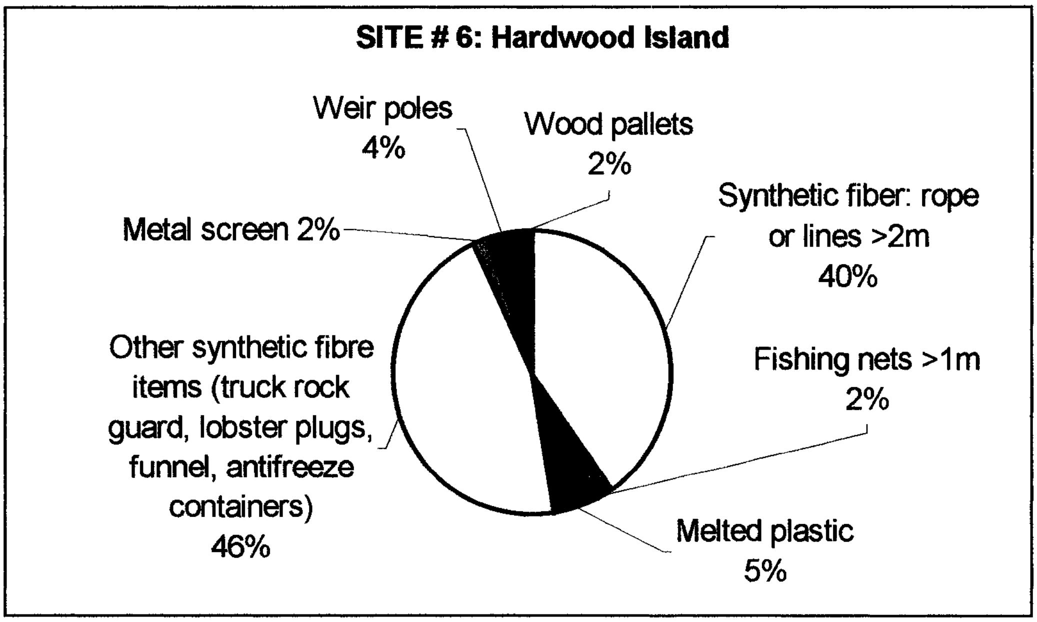
Data were collected between the headlands at the point of the spit and the isthmus in a north to south direction on the open ocean side. PIMD spans the width of the peninsula. Fifty-seven pieces of rope greater than 2m in length were found on and in the beach matrix and 40 plastic containers were counted.

[24] The combined total found in the rubber, metal, and wood categories was ~ 19% and included tires, gloves, traps, vessel parts, metal drums, pipes, screens, PVC coated cable, weir poles, pen parts lobster pound parts, pallets, beams, docks, chains…etc.

Most Common Debris Items

Out of the 202 PIMD items counted and recorded at this site the most common were: plastics, lines, or ropes greater than 2m, and melted plastic. Most common debris category is plastics. The largest items counted include a large part of a barge (Photo 3.13), one Xactic cover, six plastic totes, one oil bucket, five nets, and one lobster crate. Most of these items were noted during preliminary visits to Hardwood Island in the spring of 2001.

Pie Chart 6: Hardwood Island - Most common PIMD items (%)



3.1.7 Site 7: DEER ISLAND POINT – CONTROL SITE

Site Description

Located a few kilometres south of the forty-fifth parallel, the Deer Island Point site rests between two headlands and forms a small fishhook type beach. It overlooks a large tidal whirlpool named “the Old Sow”, that is generated on the flood tide in the Western

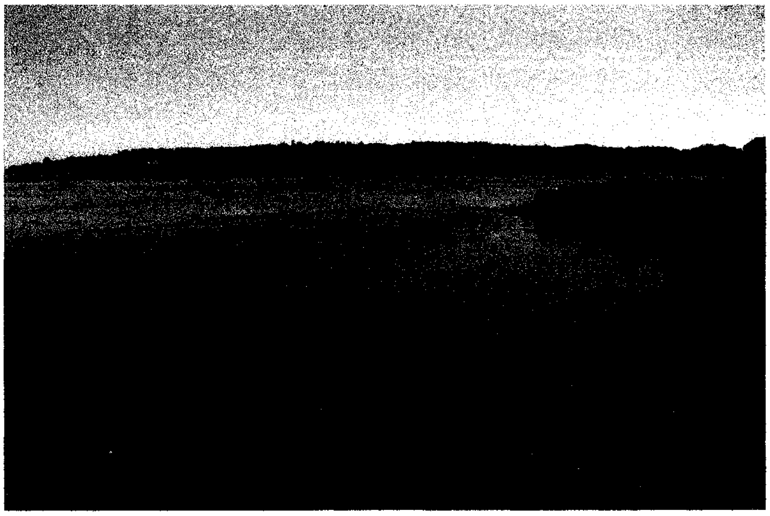


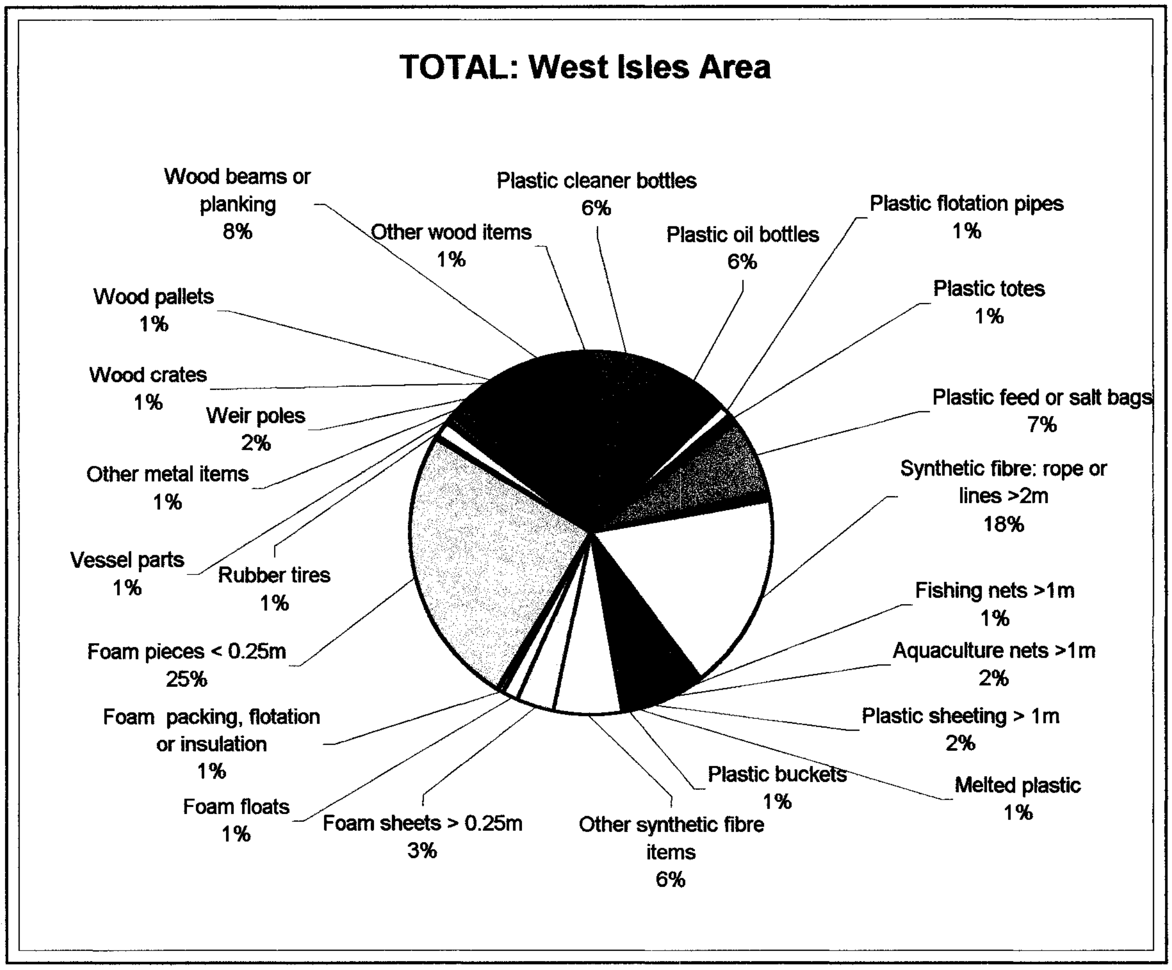
Photo 3.14: Deer Island Point

Passage. Moose Island in the state of Maine is on the opposite shore (Photo 3.14). Sediment type is mostly sand with some pebbly gravel. Three or four harbour porpoises were swimming toward Western Passage just off the Point. Rockweed occurs on the rocks of the small headlands but not on the beach. The strong currents interfere with the anchoring of equipment and vessels, and there are no fishing or aquaculture operations in the vicinity.

Debris Observed

Three pieces of rope less than 1m in length were found which may have originated from either recreational boating or industries. No PIMD was identified with any certainty. Items identified on Deer Island Point originate from non-industrial sources. Several DMD items were recorded, including: beverage containers, food bags, lids, cups, toys, pieces of plastic, cigarette butts, broken glass, paper bags, cloth, pieces of newspaper or magazines, and cardboard tubes from flares or fireworks. A dead seagull was on the beach near the data collection start point.

Chart 7: Percentages of PIMD Items Counted at all Sites in The West Isles



The number of PIMD items counted for all sites in the West Isles topographic area excluding the control site on Deer Island was 1223. The most common type of PIMD was foam pieces which accounted for 25% of the total (approximately 306 foam pieces), followed by rope or lines greater than 2m, industrial beams or planking, and plastic feed or salt bags.

3.2 Sites in Passamaquoddy Bay and Western Passage Area

Table 3.2: Passamaquoddy Bay and Western Passage Area Sites

#	SITE NAME & DATE OF VISIT	LOCATION: GPS – Start and End points	MODE OF ACCESS	Data type, local industry, approximate shoreline length, approximate distance inland that debris extends beyond terrestrial vegetation line.
8	Sherard Beach July 8 / 01 & July 10 / 01	Start: N 45^0 08. 101' W 66^0 54.284' End: N 45^0 07. 936' W 66^0 54.148'	Vehicle	PIMD, aquaculture. ~500m. ~3m.
9	Cummings Cove July 14 / 01	Start: N 44^0 56. 646' W 66^0 59. 686' End: N 44^0 56. 560' W 66^0 59. 863'	Vehicle	PIMD, aquaculture. ~ 500m. ~1-6m.
10	Pendleton Island July 18/ 01	Start: N 45^0 02. 018' W 66^0 56.973' End: N 45^0 02. 056' W 66^0 56.885'	NBSGA Dwayne Richardson speed boat	PIMD, weir, & aquaculture. ~750m. 100m.
11	Timber Island, Oven Head July 17/ 01	Start: N 45^0 08. 907' W 66^0 56.278' End: N 45^0 08.949' W 66^0 56.363'	Vehicle	DMD – Control. ~ 750m. 0m.

3.2.1 Site 8: SHERARD BEACH

Photo 3.15: Sherard Beach

Site Description

Sherard Beach is a large pebble and cobble beach with rockweed at intervals between the low and high-water marks. It is located north of where the Magaguadavic River empties into Passamaquoddy Bay. The beach undulates slightly in cusp-like formations perpendicular to the line where the water meets the shore; the steep gradient indicated a high-energy environment. Coastal forest begins abruptly along the backshore and there is no flat grassy area between the beach and the tree line. This very large accessible shoreline forms a crescent between two headlands. Permission to enter through adjacent properties was obtained from the owners.

Debris extended no more than 3m beyond the terrestrial vegetation line and further inland movement was inhibited by the forested backshore slope. Data collection started at the base of a staircase that ascends to an adjacent property, and ended to the west beside a rocky headland.

Pie Chart 8: Sherard Beach - Most common items (%)

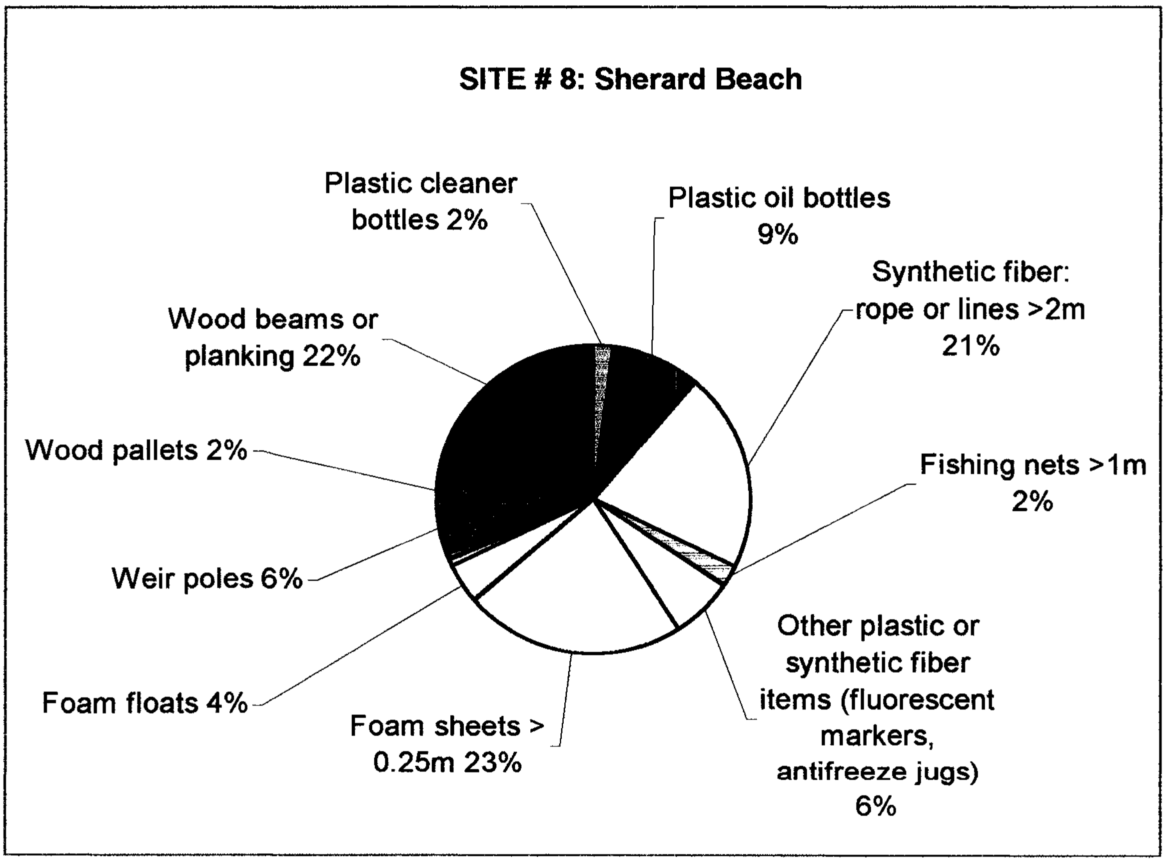


Photo 3.16: Rope integrated into the beach matrix at Sherard Beach

Most Common Items

One hundred and sixty-five items were counted and recorded. Most common were foam sheets, wood beams, and rope or lines in lengths greater than 2m. Most nets, ropes, and lines were integrated into the rockweed, beach gravel, and driftwood. From most to least common, the order of each debris category was plastic and synthetics, wood from industry sources, foam, rubber, and metal. Thirty-seven foam sheets greater than 0.5m in length and thirty-five ropes greater than 2m in length were counted within the site study limits. Other items included fluorescent highway markers and several lengths of PVC coated wire.

Domestic marine debris was also counted and recorded at Sherard Beach. One hundred and twenty DMD items were noted with in the site study limits.

The most common items were plastic and glass beverage bottles of which forty-four were counted. Development in the surrounding areas is mostly rural-residential. This site is close to the mouth of the Magaguadavic River, so many of the DMD items may originate from the town of St. George, carried down by the Magaguadavic River.

3.2.2 Site 9: CUMMINGS COVE

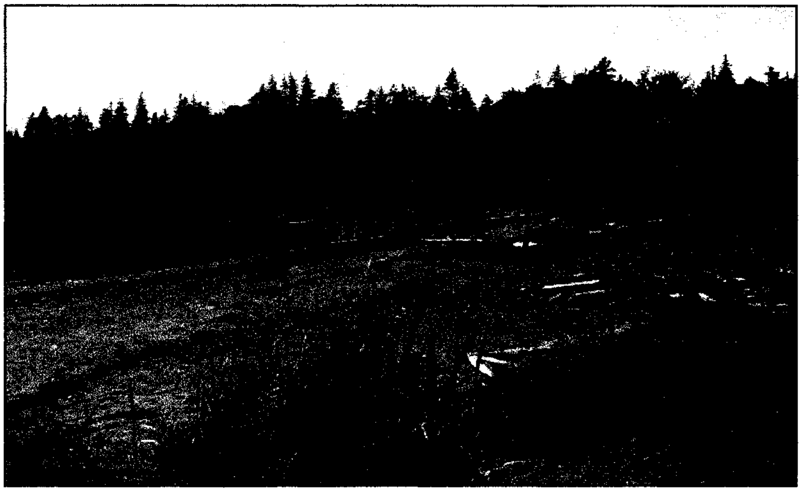


Photo 3.17: Cummings Cove, Deer Island {PIMD items: fishing net – centre right, finfish cage rings – above net, and PIMD burn site – lower-mid right}

Site Description

Cummings Cove faces Western Passage and is located on the west side of Deer Island. This large, very accessible shoreline consists of a sandy "fishhook" pocket beach that extends between two headlands. The slope is steeper at the northern end. Beach grass, wild peas, and wild roses grow along the backshore. Rockweed was cast up along the high watermark. An aquaculture site approximately 500m to the south of the start point was visible (Photo 3.18).

Debris counted and recorded at the Cummings Cove site extended from 1 to 6m above the backshore vegetation line depending on steepness of adjacent inshore area. Data collection commenced on the section of shoreline next to an abandoned homestead. Photo 3.17 was taken at the start point. The end points were recorded beside the northwest headland (upper left in Photo 3.17).

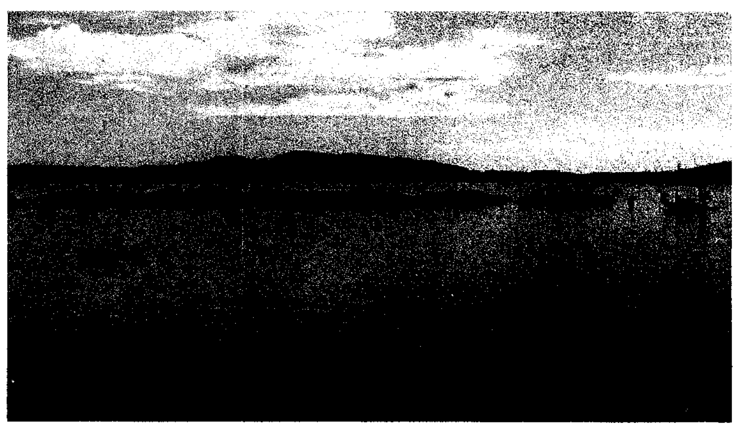
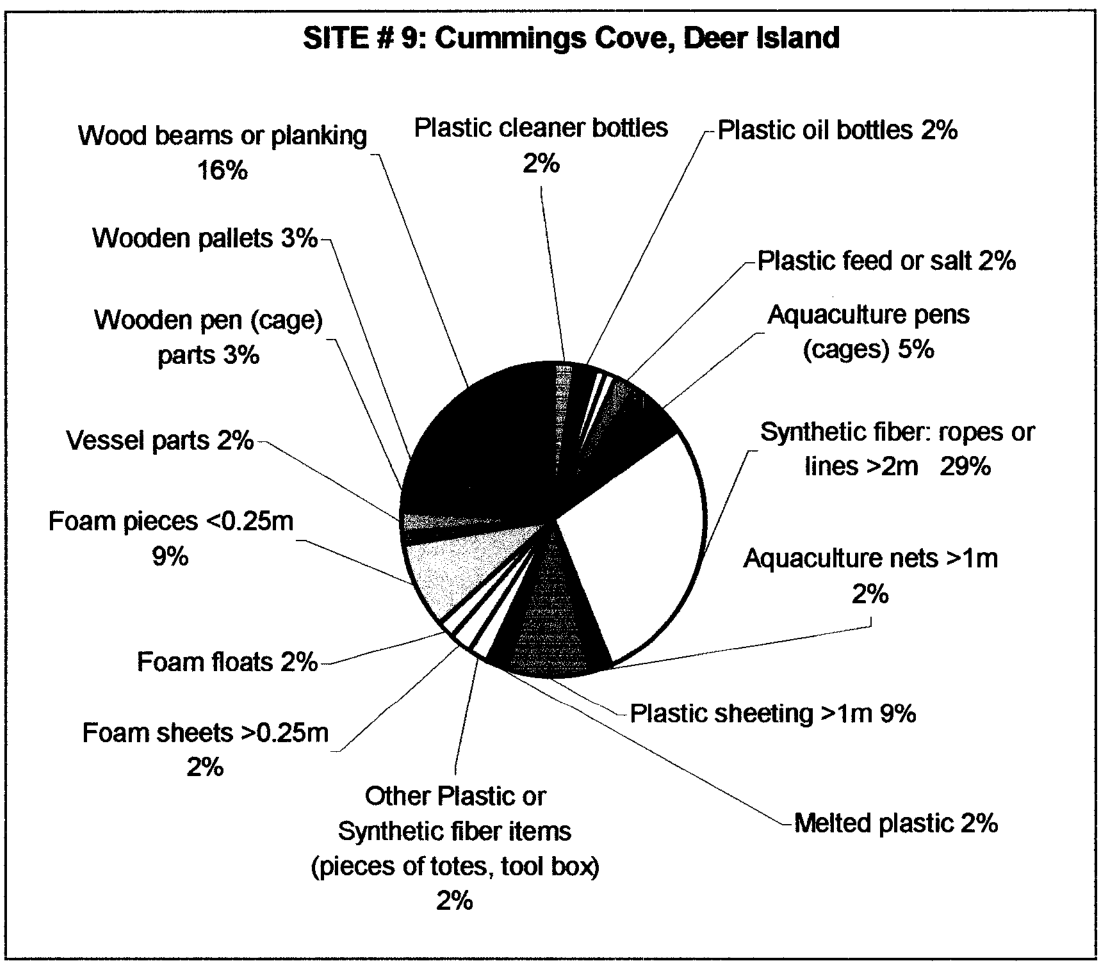


Photo 3.18: Aquaculture Site, Cummings Cove

Most Common Items

Ninety-one PIMD items were recorded. First, second and third most common items at this site were: Rope or line greater than 2 m in length, industrial wood beams or planking, and foam pieces less than 0.25m in length as well as plastic sheeting greater than 1m in length. From most to least common the order of each debris category was: plastic and synthetic materials, wood from industry operations, foam, metal, and rubber. Five large aquaculture cage rings approximately 8 –15m in diameter were anchored to the shore in this area, and three large floating docks (approximately 1 X 8m) were identified on the northwest part of this shoreline. Three large coils of rope were also included in the count. An old Styrofoam float was found. It was encrusted with barnacles, mussels, and algae. Various insects also inhabited this piece of PIMD.

Pie Chart 9: Cummings Cove - Most common PIMD items (%)



3.2.3 Site 10: PENDLETON ISLAND

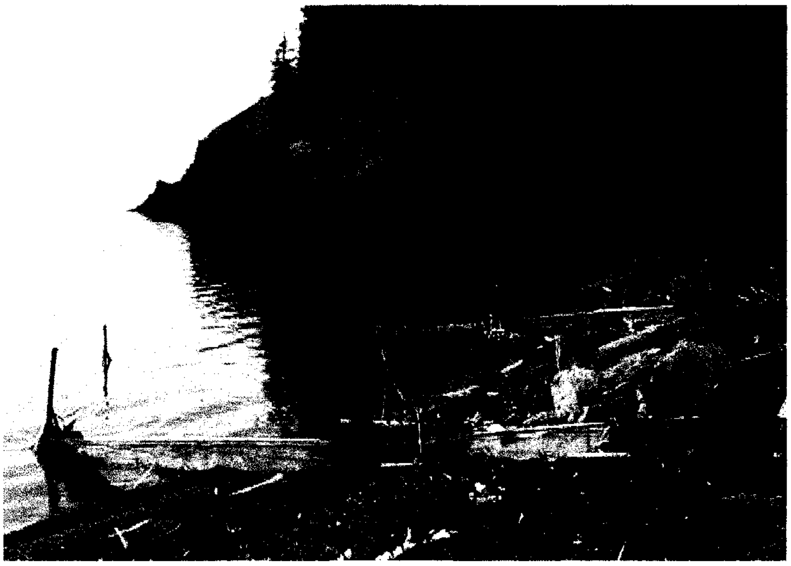


Photo 3.19: Old wooden cage, Pendleton Island Beach.

Site Description

Pendleton Island Beach is a gravel / pebble shoreline with some coarse sand closer to the waters edge. It is similar to the Ship Harbour site in that a tidal trough extends along the backshore, creating a bar or ridge that separates the foreshore from the backshore. Dry rockweed and coastal plants (grasses, beach pea, and wild grains) sparsely populate the ridge. The coastal forest behind the beach consists primarily of coniferous trees. This is a wide beach with large ridges and a very long shoreline.

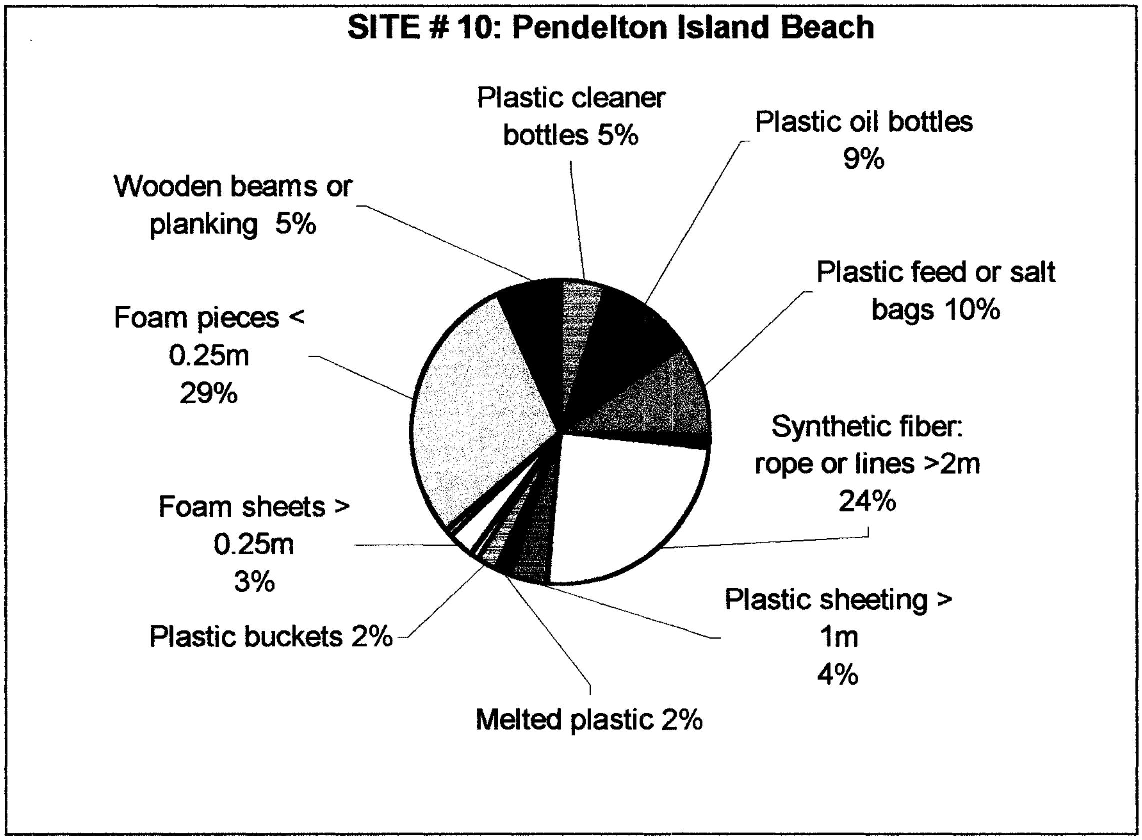
Debris was integrated into the biophysical matrix of the shoreline and extended approximately 100m above the terrestrial vegetation line.

Photo 3.20: PIMD transported by wind into adjacent forest, Pendleton Island

Most Common Items

Three hundred and Forty-eight PIMD items were counted and recorded at Pendleton Island Beach. The most common items were: foam pieces less than 0.25m in length, rope and lines greater than 2m in length, and feed bags. From most to least common the order of each debris category was: plastic and synthetic material, foam, wood from industry, and rubber. Evidence of debris incineration included 6 pieces of melted plastic from 0.25 to 0.5m^2 in size. The old wooden cage frame and remains of a dead seal noted on the eastern end of the beach had also been identified during preliminary site visits in the spring. Other PIMD items include: 50 plastic bottles, 21 Connors feed bags and 14 salt bags, 85 ropes in lengths greater than 2m, 101 pieces of foam, 10 foam sheets greater than 0.25m^2, and a car battery.

Chart 10: Pendleton Island Beach - Most common PIMD items (%)



3.2.4 Site 11: TIMBER COVE, OVEN HEAD – CONTROL SITE

Site Description

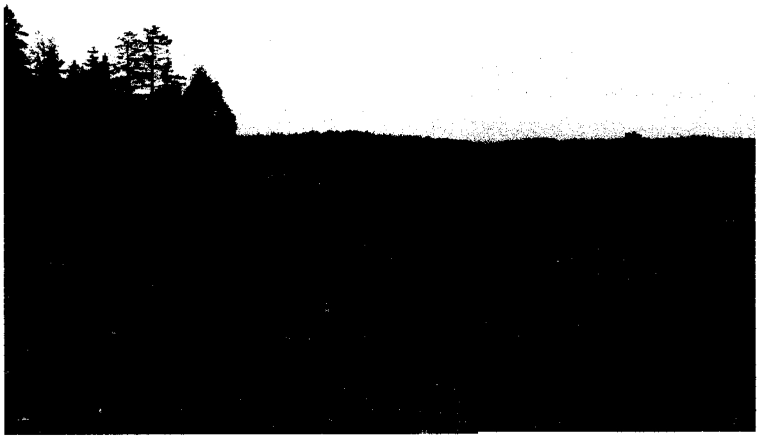


Photo 3.21: Timber Cove, Ovenhead

Timber Cove is located on the northern side of a natural causeway that connects Oven Head to the mainland. The cove itself is shallow and consists of pebble and gravel tidal flats. At the mouth of the cove is a detached beach through which a tidal inlet flows. During low tide, the tidal flats are accessible for walking. Data were collected along the cove side of the detached beach.

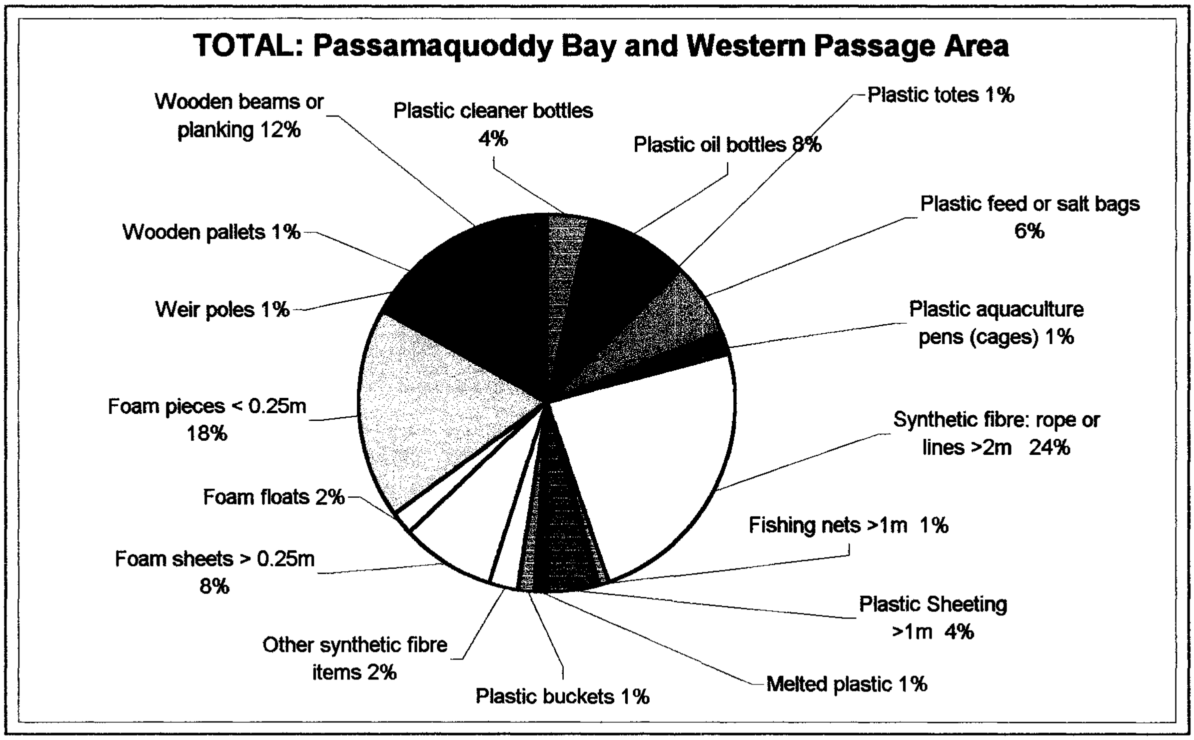
Observations began at the end of the long point extending into the cove and ended at the northern point of Oven Head Island.

Photo 3.22: Detached beach in Timber cove (top of photo)

Comments:

DMD and PIMD items were not detected at this site.

Chart 11: Percentages of PIMD Items Counted at all Sites in Passamaquoddy Bay and Western Passage



The number of PIMD items counted for all sites in the Passamaquoddy Bay and Western Passage area was 348. No debris was found at the control site in Timber Cove, Ovenhead. The percentage totals for all sites indicated that the most common type of PIMD was rope or lines consisting of synthetic material, which accounted for 24% of the total (approximately 145 ropes or lines), followed by foam pieces, wooden beams or planking, plastic oil bottles, foam sheets, and plastic feed or salt bags.

3.3 Saint George & L'Etang Area

Table 3.3: Sites in the Saint George & L'Etang Region

#	SITE NAME & DATE OF VISIT	LOCATION: GPS Start & End points	MODE OF ACCESS	Data type, local industry, approximate shoreline length, approximate distance inland that debris extends beyond terrestrial vegetation line.
12	Fraiser Beach, Catherin Cove July 17/ 01	Start: N 45^0 03. 566' W 66^0 54.329' End: N 45^0 03. 486' W 66^0 54.333'	Vehicle	PIMD, aquaculture. ~500m. ~100m.
13	Birch Cove, Frye Island, Lime Kiln Bay July 17/ 01	Start: N 45^0 03. 088' W 66^0 50.249' End: N 45^0 03. 048' W 66^0 50.265'	NBSGA – Phil Hatt - skiff	PIMD, transportation, tourism, and aquaculture. ~750m. ~1m.
14	Treinors Cove, L'Etang Harbour July 16/ 01	Start: N 45^0 06.564' W 66^0 45.881' End: N 45^0 06.552' W 66^0 45.971'	Vehicle	DMD – Control, ~ 250m. ~3m.

3.3.1 Site 12: FRAISER BEACH, Catherin Cove

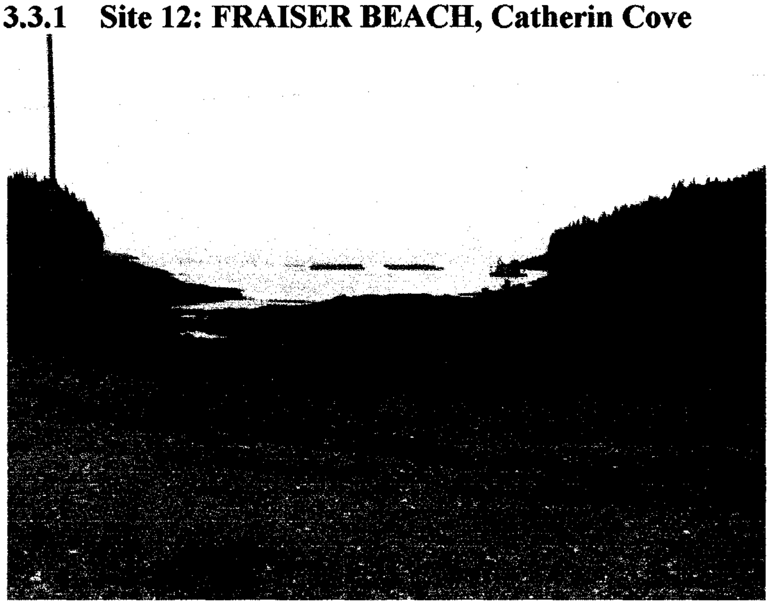


Photo 3.23: Fraiser Beach

Site Description

Fraiser Beach is underlain by a large rock base (the Quoddy formation) and covered with a rock-pebble beach between foreshore and backshore. Rockweed grows in abundance on the exposed rocks below the high tide line. There is a large marsh grass area beyond the backshore. There is a graded road above the high water mark and large tire

Photo 3.24: PVC pipe discarded on Fraiser Beach

marks were noted in the beach gravel between high and low water line. A salmon farm was visible from the shoreline (Photo 3.23).

Estimated distance inland that debris extends is approximately 100m. Data collection commenced at the small cliff face to the right of the road that is used to access the site, and ended at the power pole to the southeast (Photo 3.23).

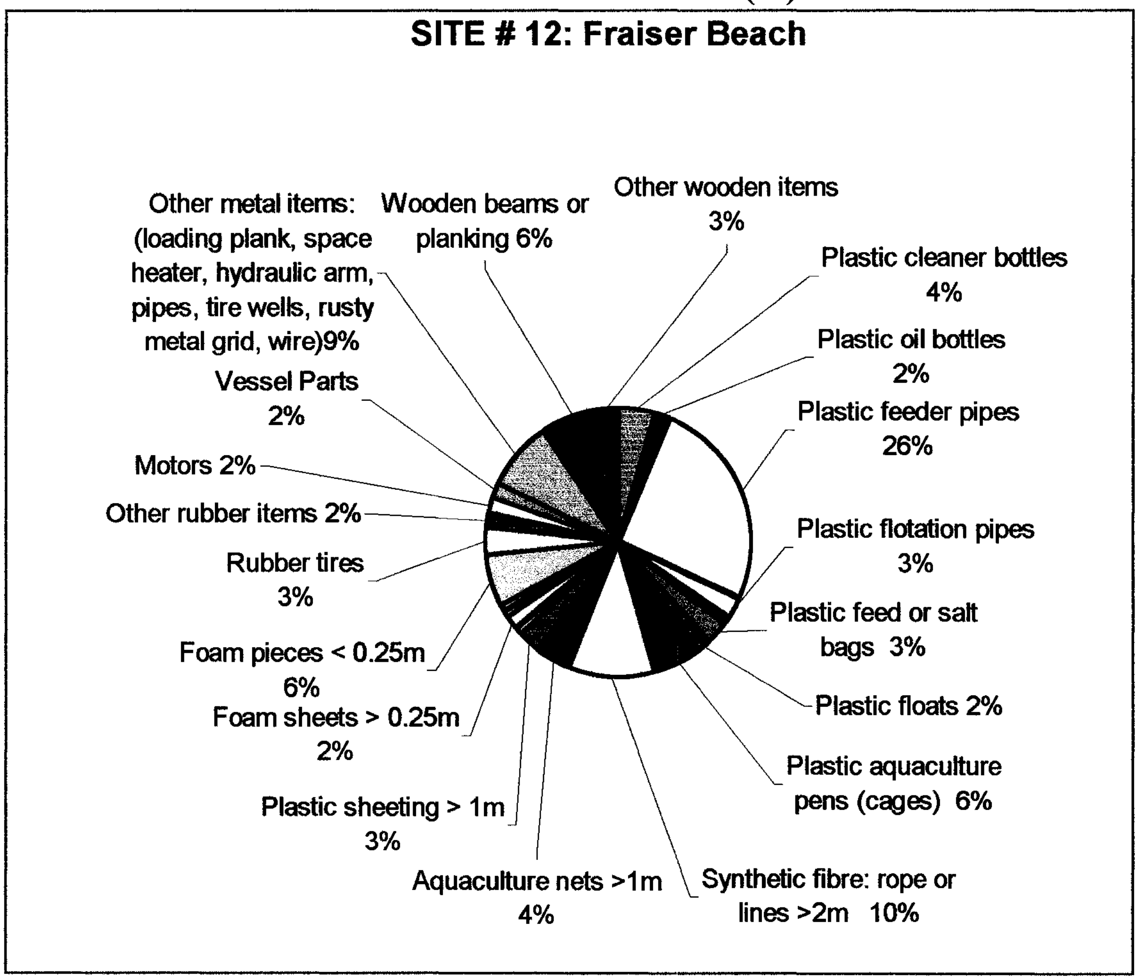
Most Common Items

One hundred and thirteen PIMD items were found at this site and several more items were found below the ground surface by digging into the beach matrix. Most common were: PVC pipes from aquaculture sites (plastic feeder pipes), pieces of rope or line greater than 2m in length and metal items. The most common debris category was plastics and synthetic materials. Thirty different types of PIMD items were identified. Large pieces of debris were buried in the shoreline gravel and their sizes could not be

Photo 3.25: Landfill on Fraiser Beach

identified without excavation (Photo 3.25). This area appears to be used as a dump for fishery and aquaculture operations. Tires, ropes, cage parts, nets, plastic floats, motor parts, and other items were found in piles or buried above the high water line. Data collection was limited since many items were buried. Only items clearly identifiable at the surface were recorded on the data sheet. Melted rubber and metal tire belts found above the high tide mark indicated tire burning at this site. A piece of melted rubber was taken as a sample.

Chart 12: Fraiser Beach - Most common PIMD items (%)



3.3.2 Site 13: BIRCH COVE, LIME KILN BAY

Photo 3.26: Abandoned boats and wood cage rings, Birch Cove

Located on Frye Island in Lime Kiln Bay, Birch Cove is a small sheltered inlet. Compared to the exposed Passamaquoddy and West Isles shorelines, this cove has much less wave action and is a low energy environment. The southwest parts of the cove are difficult to access on foot due to steep elevations and marsh areas. Most of the data were collected from the skiff. I landed on the southeast part of the cove, where the forest meets the water, and was able to walk for approximately 10 meters along the shore. Wildlife observed on the island includes coyote, deer, and grass snakes. Mackerel were swimming in the water.

Photo 3.27: Abandoned fishing boat, Birch Cove

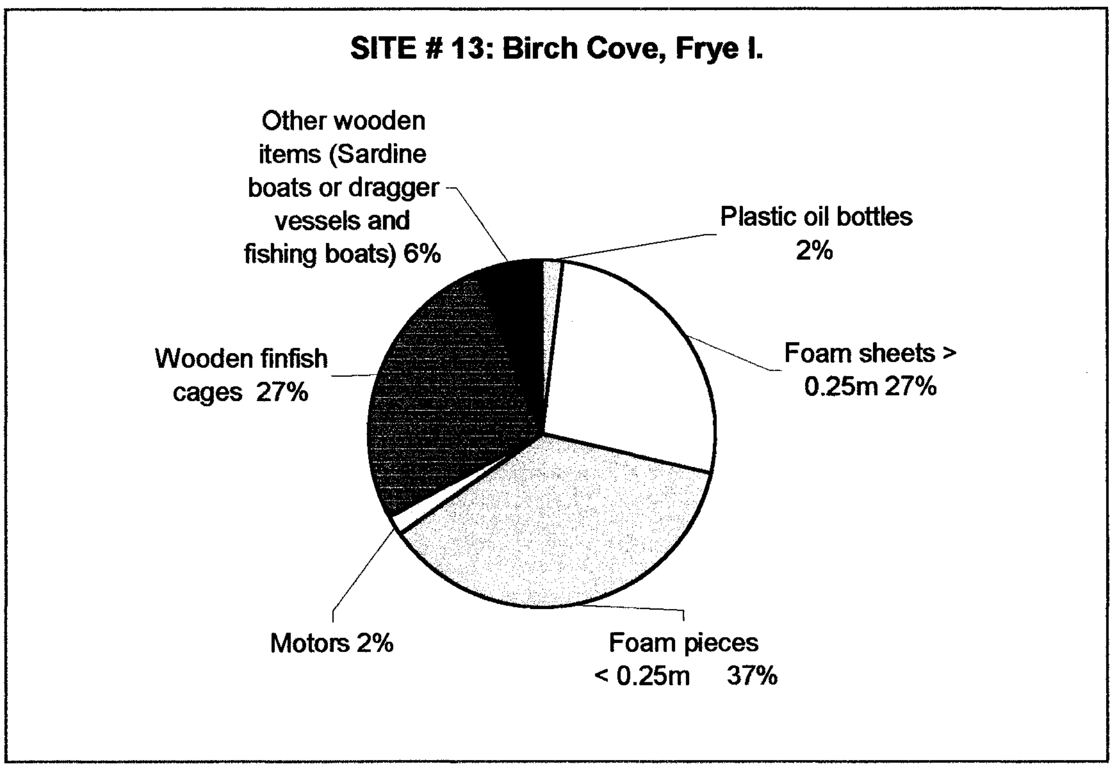
The estimated distance inland that debris extends is 0-1m in steep areas and 2-3m in marshy areas. Data collection began past the point of land on the western side of the cove and ended on the other side before reaching the eastern point. Most of the cove was surveyed from the skiff.

Photo 3.28: Abandoned Dragger Vessel, Birch Cove

Most Common Items

Sixty-two items were counted in Birch Cove. The PIMD in this area is low in variety with only seven types identified. However, of all the sites it had the highest count of very large items including 4 abandoned vessels, and 13 wooden aquaculture cages. Most common items at this site were pieces of foam, wooden aquaculture pens, and abandoned boats. The abandoned vessels (including 2 sardine or dragger vessels and one lobster boat) are located in the western corner of the cove (Photos 3.26 – 3.28). With small trees and grasses growing on the decks, these boats appear to have been there for a very long time. Two foam sheets and five foam pieces were found in the forest on the other side of the cove.

Chart 13: Birch Cove - Most common PIMD items (%)



3.3.3 Site 14: TREINORS COVE, L'ETANG HARBOUR – CONTROL SITE

Photo 3.29: Treinors Cove, Upper L'Etang

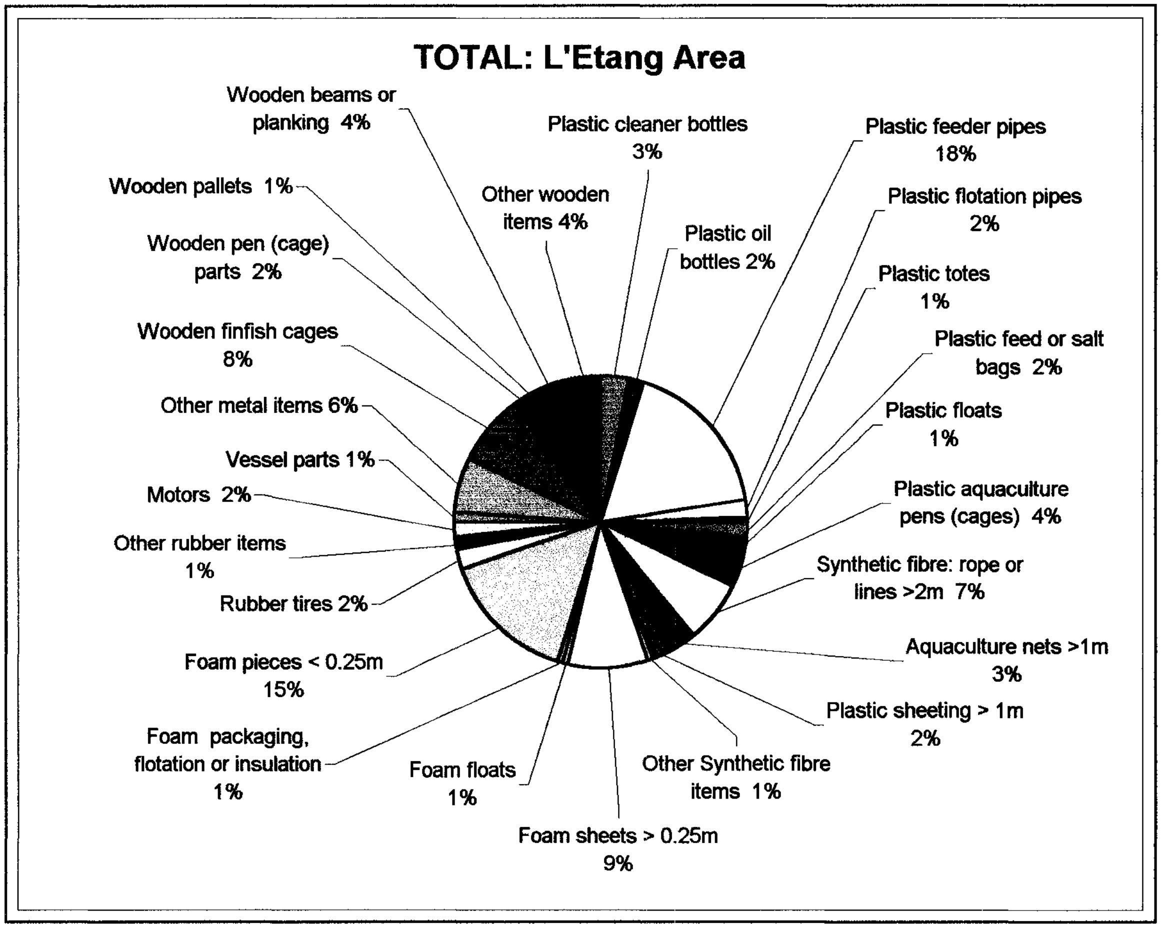
Site Description

Treinors Cove is located in the upper reaches of L'Etang Harbour and has a low energy environment. Development in the area is rural, with some cottages and permanent dwellings. Data collection area access is through woods beside a dirt road. There is no coastal industry close to this site.

Data collection began on the southeast side of the cove and ended at the first point of land to the west. In comparison to other shorelines in this study area, not much domestic or industrial debris was noted.

Ten DMD items (mostly plastic) were counted at this control site. Five pieces of PIMD are indicated on the DMD data collection sheet and include a very degraded feed bag, two foam floats, a metal pipe, and a large rusty spike.

Chart 14: Percentages of PIMD Items Counted at all Sites in the L'Etang Area



The number of PIMD items counted at all sites in the L'Etang area was 175. This excludes the control site at Treinors Cove where five PIMD items were found. The percentages in Chart 14 indicate a very high variety of PIMD. The much wider range of materials and discarded products is likely due to the diversity of coastal industry in and around the islands and estuary of L'Etang Harbour. In addition, the enclosed nature of the area may prevent dispersion of PIMD by tides and currents. The percentage totals for all sites indicated that the most common type of PIMD was plastic feeder pipes, which accounted for 18% of the total (approximately 35 feeder pipes from 1 – 10m in length), followed by foam pieces and foam sheets, wooden salmon cages, and ropes or lines.

3.4 Southwest New Brunswick Shore

Table 3.4: Sites on the Southwest New Brunswick Shore

#	SITE NAME & DATE OF VISIT	LOCATION: GPS – Start & End points	MODE OF ACCESS	Data type, local industry, approximate shoreline length, approximate distance inland that debris extends beyond terrestrial vegetation line.
15	Lighthouse Point, Beaver Harbour July 13/ 01	Start: N 45^0 03. 480' W 66^0 44.188' End: N 45^0 03. 566' W 66^0 44.209	Vehicle	PIMD, fish packing plant, recreational / tourism, aquaculture, and fish weirs. ~250m. ~10m.
16	Seelys Cove July 13/ 01	Start: N 45^0 05. 093' W 66^0 39.267' End: N 45^0 04. 972' W 66^0 39.262'	Vehicle	PIMD, fish weir, & aquaculture. ~250m. ~1m.
17	Pocologan Harbour, Maces Bay July 12/ 01	Start: N 45 07.214' W 66^0 35.324' End: N 45^0 07.222' W 66^0 35.378'	Vehicle	Control, ~250m. ~1m.

3.4.1 Site 15: LIGHTHOUSE POINT, Beaver Harbour

Site Description

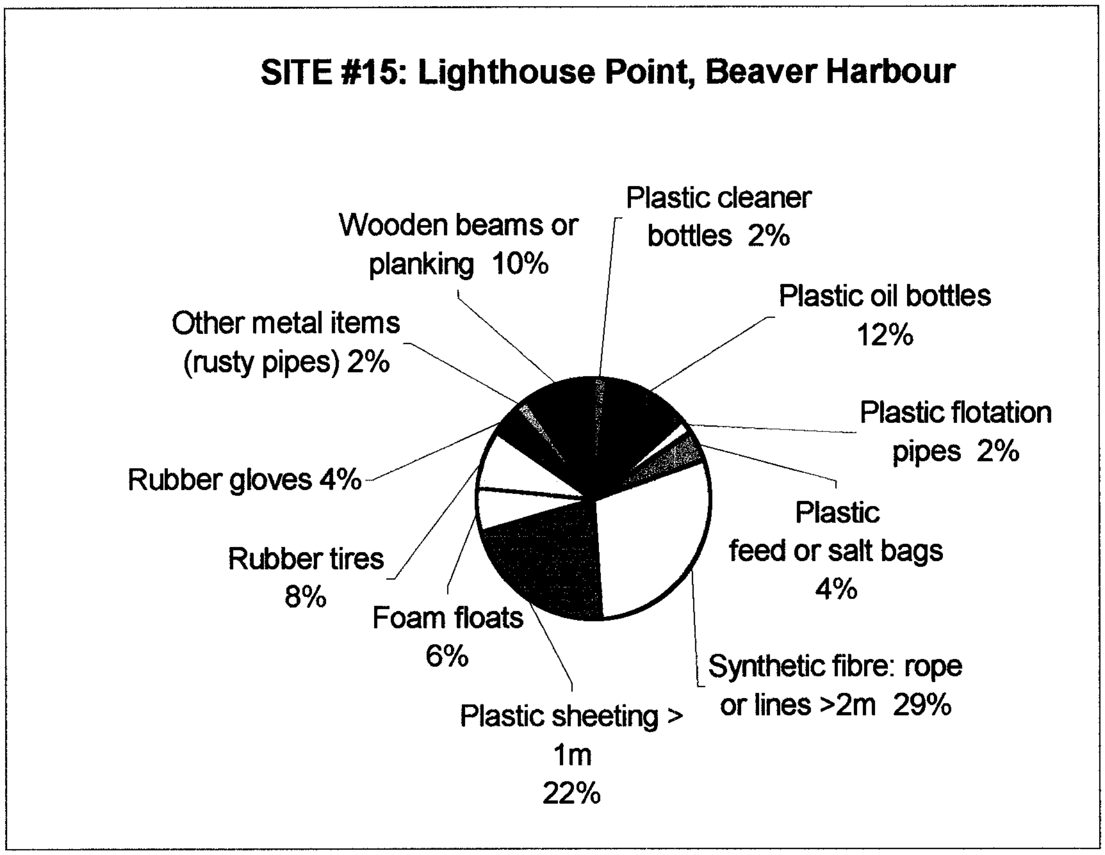
This site is located on Back Beach between Lighthouse Point and West Head. The shoreline consists of cobbles and pebbles, and slopes at a steep angle indicating high-energy wave action. Large tire tracks were noted on the beach and backshore area. Campers or hikers were noted tenting and walking along this shoreline.

The distance inland that PIMD extends is approximately 10m. Items were counted between two headlands on the shore beside an old boarded-up cottage.

Most Common PIMD Items

The total number of items counted was 51. The most common items at this site were: rope or lines longer than 2m, plastic sheeting greater than 1m in length, and plastic oil bottles. Out of 11 PIMD categories, the most common were plastic and synthetic materials. An old fire pit was noted on the beach. It contained remnants of driftwood, beverage containers, and tires. There is no indication that it was an incineration site. It was more likely set by campers and hikers - a few of which were observed in the area during the summer. Sheets of plastic and several lengths of rope were buried in the beach matrix.

Pie Chart 15: Lighthouse Point - Most common PIMD items (%)



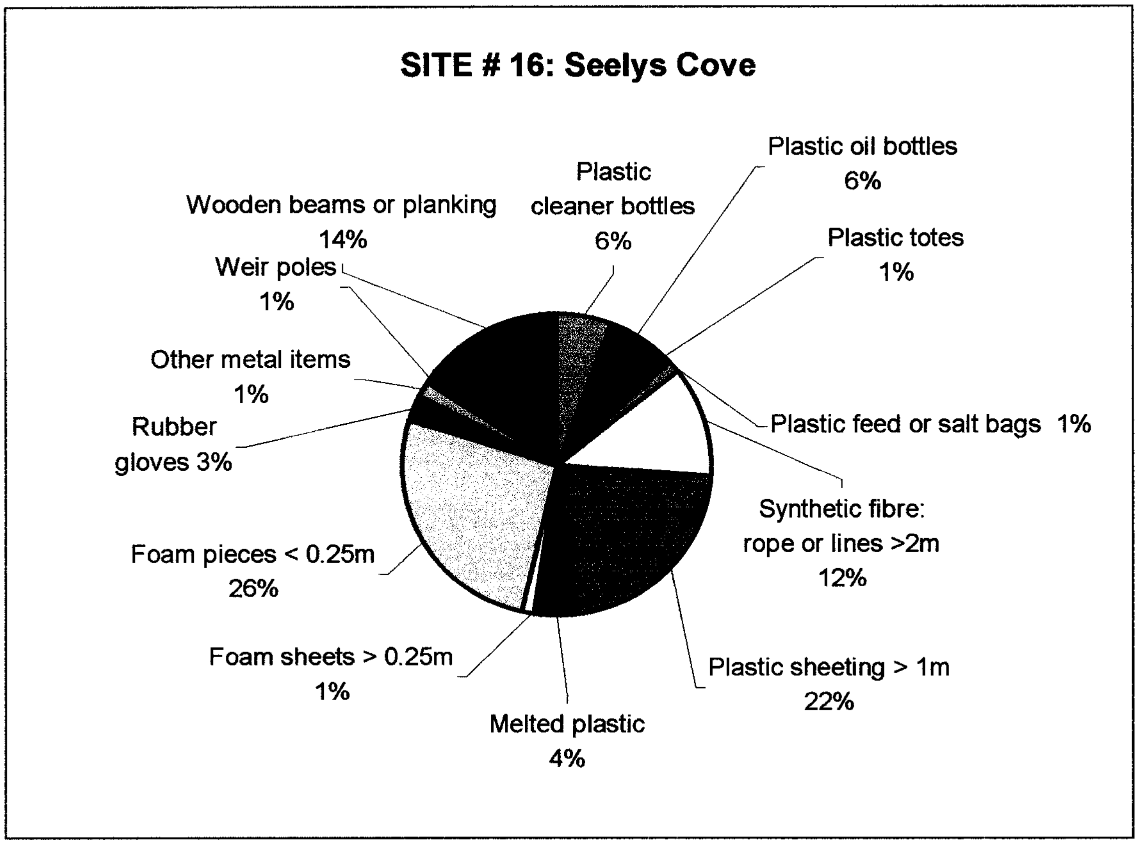
3.4.2 Site 16: SEELYS COVE

<u>Site Description</u>

The Seelys Cove site is along the base of a cliff - the foreshore consists of cobble and the backshore of sand. Several sand dollar shells were noted along the shore. Dry rockweed was found at the high-water mark. The beach slopes at a steep angle down toward the water. Tire tracks were noted along the beach.

The steep slope along the forested backshore inhibits migration of debris inland. Access to the site is by a road that branches off the #1 highway in Pennfield. GPS readings were taken where the steps meet the shore, and mark the point at which data collection began. PIMD items between this point and the headland to the south were identified, counted, and recorded.

Pie Chart 16: Seelys Cove - Most common PIMD items (%)



Most Common PIMD Items

Sixty-one PIMD items were counted in 13 debris categories. The most common items were: foam pieces less than 0.25m in length, plastic sheeting greater than 1m in length and wood beams or planking. From most to least common, the order of each debris category was: plastics and PVC, foam, wood, rubber and metal. Three pieces of melted plastic were noted. Other than this, no evidence of incineration was detected on the beach. Highest amounts of plastic items include sheets in lengths greater than 1m and 8 ropes longer than 2m in length. Five dead fish were found in a tote beside the headland at the study site end point.

3.4.3 Site 17: POCOLOGAN HARBOUR, MACES BAY –CONTROL SITE

Site Description

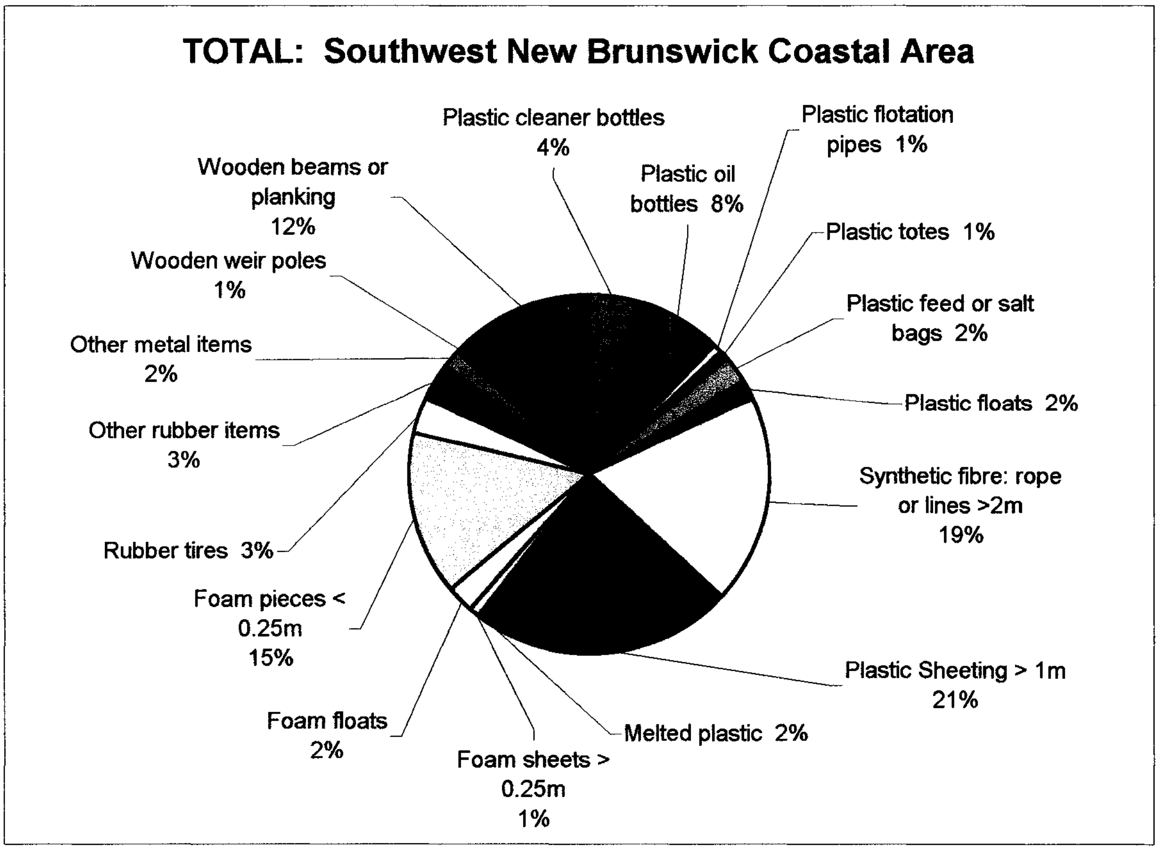
The control site for the New Brunswick Southwest Shore region is a small sandy beach beside the #1 Highway in Pocologan Harbour. An ancient clamshell midden partly buried under the paved access ramp indicates use of this area by First Nations people some time in the past. Rockweed along the high water mark entangles some smaller plastic pieces of undetermined origin. Beach grass and small shrubs were growing along the small backshore, east of the access ramp.

The distance inland that debris extends is approximately 1m. Data were collected between the eastern headland and the end of the beach to the west of the access ramp.

Most Common Items

In total 102 domestic marine debris items were counted and recorded. PIMD items identified at this site include: a spade, some lobster bands, and melted plastic. The largest DMD item identified at this site was a large piece of orange carpet (approximately $10m^2$) partially buried in the sand.

Chart 17: Percentages of PIMD Items Counted at all Sites on the Southwest New Brunswick Coast



In Chart 17, the totals for the Southwest New Brunswick coast indicated the smallest variety of PIMD items at the Lighthouse Point site, which had 51 items in 11 PIMD categories. Seeleys Cove also had a limited variety of PIMD items (13 categories). This is likely due to the low concentration of industry in the area and the nature of the shorelines. Since these shorelines are exposed to the outer Bay of Fundy, tidal currents will have a greater influence on debris movement and relocation. The most common PIMD items were plastic sheeting, synthetic rope or lines, foam pieces, and industrial beams or planking.

3.5 Summary of Field Results

The total number of PIMD items counted at the 13 PIMD data collection sites was 2114. The average for each of these sites was 163. The lowest amount of PIMD was found in Timber Cove where no items were seen. The highest amount of PIMD was found at the Indian Island site where three hundred and eighty seven items were counted. The most common debris category was plastic, and 41.1% to 57.1% of all materials in each area consisted of plastic or PVC. Foam was the second most common PIMD type, and 19.6% to 31.6% of all material was identified as Styrofoam.

3.5.1 Sites With the Highest Variety of PIMD Items

The site with the highest variety of PIMD was Fraiser Beach, at which the following categories were identified: plastic cleaner bottles, motor oil bottles, feeder pipes, flotation pipes, totes, feed or salt bags, aquaculture pens, rope longer than 2m, nets, plastic sheeting, garbage lid, foam sheets, foam floats, foam packing, foam pieces, tires, sparkplugs, melted rubber, tire pad, glove, motors, vessel parts, metal grid, pvc coated wire, space heater, hydraulic arm, metal pipes, tire wells, wood pallets, planking and treated lumber. In total 31 types of PIMD were found at this site.

Sites with the most diverse amounts of accumulated PIMD were: Fraiser Beach (31), Lords Cove (28), Indian Island (27), Simpsons Island (23), Hardwood Island (28), Pendleton Island Beach (22), and Cummings Cove (21). Sites with low varieties and amounts of PIMD were: Beaver Harbour (11), Ship Harbour (7), and Frye Island (7).

3.5.2 Highest Amounts, Largest Items, and Industry Presence

Sites with the highest amounts of PIMD are identified in Table 3.5 along with sites where the largest items were found.

Table 3.5: Sites With the Highest Amounts of PIMD and Largest Items in Each Area

Area	Sites With Highest Amounts of PIMD (number of items)	Largest Items and Sites where Located
West Isles	Indian Island (387)	Pontoon - Simpsons Island Feed barge - Indian Island
Passamaquoddy Bay	Pendleton Island (348)	Wood aquaculture cage - Pendleton Island Floating docks - Cummings Cove
L'Etang	Fraiser Beach (113)	Fishing vessels - Frye Island
Southwest NB coast	Seelys Cove (61)	Furnace oil drum - Seelys Cove

Estimates on the number of fish weirs, aquaculture sites, and fish processing plants within 1.25km (Map 2 and Table 4.2) indicate the amount of industry that is present in each of the study areas. Other coastal resource activities in these areas include net and line fishers, lobster fishing, tourism, research, and transportation.

3.5.3 Waste Incineration and Landfills

From a total of 17 sites visited during the summer eight had evidence of PIMD incineration. This number is high given that open pit burning of waste material is not legal. Partially incinerated PIMD items identified and recorded during field studies included tires, weir poles, plastic toats, feed bags, pieces of rope, and anti-foulant bottles. The long-term effects of waste incineration on local environments are not fully known. PIMD incineration releases carcinogenic compounds such as vinyl chloride from plastic or PVC items into the atmosphere. In addition burning plastics and other items that could be recycled places additional pressure on the environment due to the fact that new materials must be extracted from natural resources.

Table 3.6: Location of PIMD Incineration Sites

Area	Site	Fire Pit Detected?	Melted plastic or rubber?
West Isles	Simpsons Island	No	Yes
	Indian Island	Yes – 3 pits	Yes - plastic and rubber
	Lords Cove	No	Yes
Passamaquoddy Bay	Cummings Cove	Yes – 1 pit	Yes – plastic
	Pendleton Island Site	No	Yes
L'Etang Harbour	Fraiser Beach	Yes ~ 2-3 pits	Yes – melted rubber
Southwest NB coast	Beaver Harbour	Yes	No
	Seelys Cove	No	Yes

Table 3.6 indicates where evidence of incineration was found in the four study areas. Sites highlighted in red are locations where both a fire pit and partly burned PIMD were identified.

Chapter IV
Evaluation of Survey Sites in Relation to Numbers of Industrial Sites

Observations suggest that the amount of debris is greater on shorelines close to municipal centres or with marine industrial sites nearby. In order to test this hypothesis the number of PIMD items counted at the survey sites (Table 4.1) was evaluated in relation to their proximity to numbers of industrial sites (Table 4.2).

Table 4.1 PIMD: Types and Amounts at Each Site

Data collection and control sites	Plastic	Foam	Rubber	Metal	Wood	Total PIMD
1 Sandy Island	34	1	1	0	8	**44**
2 Simpsons Island	142	83	1	3	16	**245**
3 Indian Island	170	149	14	11	43	**387**
4 Ship Harbour	53	0	0	1	3	**57**
5 Lords Cove	117	115	5	11	40	**288**
6 Hardwood Island	130	38	0	2	32	**202**
7 Deer Island Point (West Isles Control site)	3	0	0	0	0	**3**
Total West Isles (average / site)	**649** (~93)[25]	**386** (~55)	**21** (3)	**28** (4)	**142** (~20)	**1223** (204)
8 Sherard Beach	68	45	1	1	50	**165**
9 Cummings Cove	54	12	1	2	22	**91**
10 Pendleton Island Beach	210	114	2	0	22	**348**
11 Timber Cove (Passamaquoddy control site)	0	0	0	0	0	**0**
Total Passamaquoddy and Western Passage (average / site)	**332** (83)	**171** (2)	**4** (~43)	**3** (1)	**94** (~1)	**604** (201)
12 Fraiser Beach	71	11	6	14	11	**113**
13 Birch Cove, Frye Island	1	44	0	1	16	**62**
14 Treinors Cove (L'Etang Control site)	1	2	0	2	0	**5**
Total L'Etang (average / site)	**73** (~24)	**57** (19)	**6** (2)	**17** (~6)	**27** (9)	**175** (~88)
15 Beaver Harbour	36	3	6	1	5	**51**
16 Seelys Cove	28	19	2	1	11	**61**
17 Pocologan Harbour (Southwest N.B. Control site)	3	0	0	0	0	**3**
Total Southwest N.B. (average / site)	**67** (~22)	**22** (~7)	**8** (~6)	**2** (~1)	**16** (~5)	**112** (~56)
Total for all sites Percentage of total (average / site)	**1121** **(52.7%)** **~66**	**636** **(30%)** **~37**	**39** **(1.8%)** **~2**	**50** **(2.27%)** **~3**	**279** **(13.19%)** **~16**	**2125** **(100%)** **125**

[25] The "~" symbol indicates where a value is rounded to the nearest whole number.

The thesis does not address the volume or weight of items recorded during data collection, and areas were assessed in terms of percentage of the total for each debris category and item type (Ribic *et al.* 1997)[26]. The data are also presented as bar graphs, a line graph, and as data points on scatter plots (Figures 4.1- 4.7).

Table 4.2 PIMD Site Totals and the Number of Coastal Operations Within 1.25km of Each Site[27]

PIMD Collection Sites	PIMD Totals	Aquaculture Sites	Fish weirs	Fish Plants	Lobster Pounds	Major Marine service areas	Total Industry close to each site
Indian Island	387	5	6	0	0	2	13
Pendleton Island	348	5	2	0	0	2	9
Lords Cove	288	3	10	3	1	2	19
Simpsons Island	245	3	14	0	0	2	19
Hardwood Island	202	2	11	1	1	2	17
Sherard Beach	165	4	1	0	1	0	2
Fraiser Beach	113	5	1	0	0	2	8
Cummings Cove	91	2	2	0	0	1	5
Birch Cove	62	12	0	0	0	4	4
Seelys Cove	61	1	2	0	0	0	3
Ship Harbour	57	2	1	0	0	0	3
Beaver Harbour	51	1	2	1	0	1	5
Sandy Island	44	1	6	0	0	1	8
Control Sites:							
Treinors Cove	5	0	0	0	0	0	0
Deer Island Point	3	1	1	0	0	1	3
Pocologan Harbour	3	0	0	0	0	0	0
Oven Head	0	0	0	1	0	0	1

Control site data[28] are included in the computer regression analysis, since the purpose is to evaluate the amount of PIMD in the presence or absence of industry operations. Pearson's correlation coefficients[29] for data paired in a variety of sets confirm relationships between PIMD and industry within 1.25km of each site (Table 4.2).

[26] Ribic *et al.* 1997 determined trends in debris abundance, type, and distribution for various debris categories. Transects for her study were located along shorelines in the U.S. and varied between 35m and 100m in length. For each category, the percentage of the total was determined for states along the Atlantic Ocean, Gulf of Mexico, and the Pacific Ocean.
[27] Sites are listed in order of the number of debris items.
[28] Control sites were selected in areas where there are few or no industry operations. Section 2.6.2 provides an outline of control site selection criteria.
[29] Product-moment correlation coefficient or r-value

Table 4.3 PIMD Site Totals and the Number of Coastal Operations Within 2.5km of Each Site

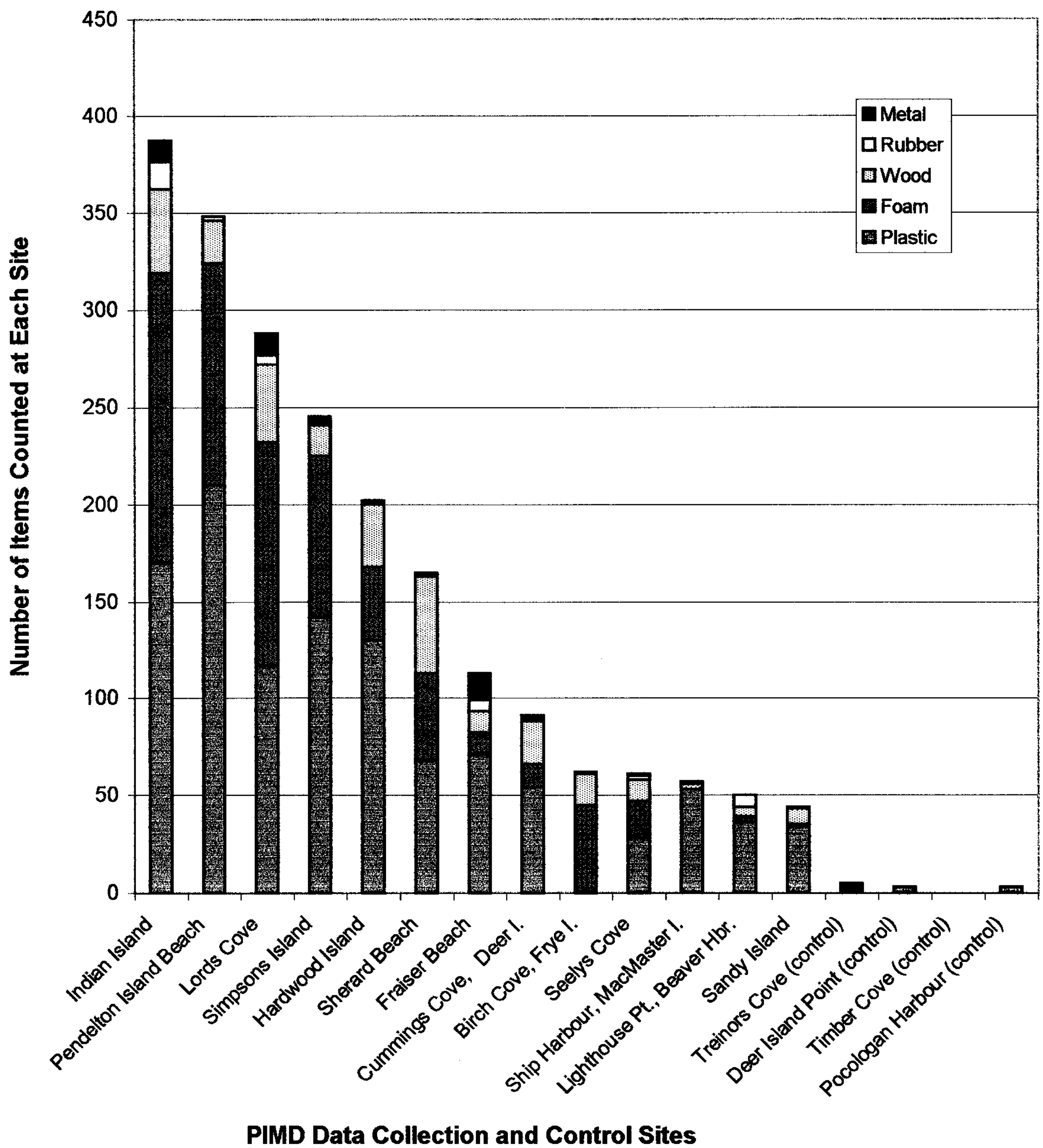
PIMD Collection Sites	PIMD Totals	Aquaculture Sites	Fish weirs	Fish Plants	Lobster Pounds	Major Marine service areas	Total Industry close to each site
Indian Island	387	11	9	3	0	2	25
Pendleton Island	348	13	17	2	0	2	34
Lords Cove	288	13	38	3	1	2	57
Simpsons Island	245	7	40	3	1	2	53
Hardwood Island	202	8	36	3	1	2	50
Sherard Beach	165	6	2	2	0	0	10
Fraiser Beach	113	11	4	6	2	2	25
Cummings Cove	91	10	7	1	1	1	20
Birch Cove	62	32	14	9	3	4	62
Seelys Cove	61	2	3	0	0	0	5
Ship Harbour	57	10	9	0	0	0	19
Beaver Harbour	51	3	6	1	0	1	11
Sandy Island	44	6	35	1	0	1	43
Control Sites:							
Treinors Cove	5	0	0	0	0	0	0
Deer Island Point	3	6	7	0	1	1	15
Pocologan Harbour	3	1	2	0	0	0	3
Oven Head	0	2	2	0	0	0	4

4.1 Analysis of Graphs

Figure 4.1 shows the amount of each type of PIMD counted at the control and survey sites. Figure 4.2 provides a comparison of the total amount of PIMD counted at each site, and the total numbers of industry sites within 1.25km and 25km. Figure 4.3 represents the amount of each type of industry within 1.25km of each site.

Many industrial sites that are within 2.5km of survey sites are located in separate water bodies. Since oceanographic and topographic characteristics are more likely to inhibit or redirect PIMD from industrial sites that are farther away from the data collection sites, only industrial sites within 1.25km are included in the statistical analysis.

Figure 4.1: Number of Plastic, Foam, Wooden, Rubber, and Metal Items Counted At Each Survey Site



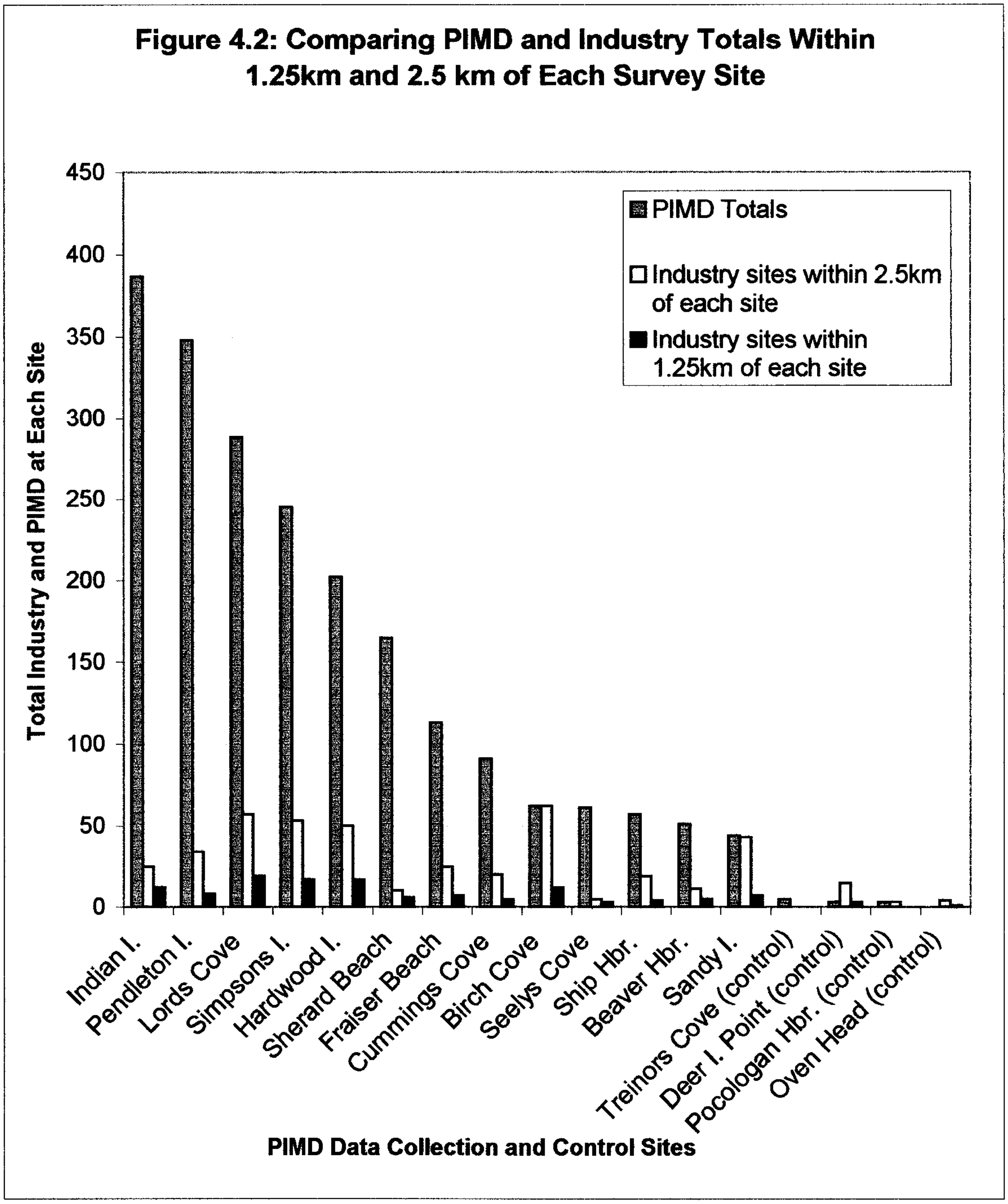
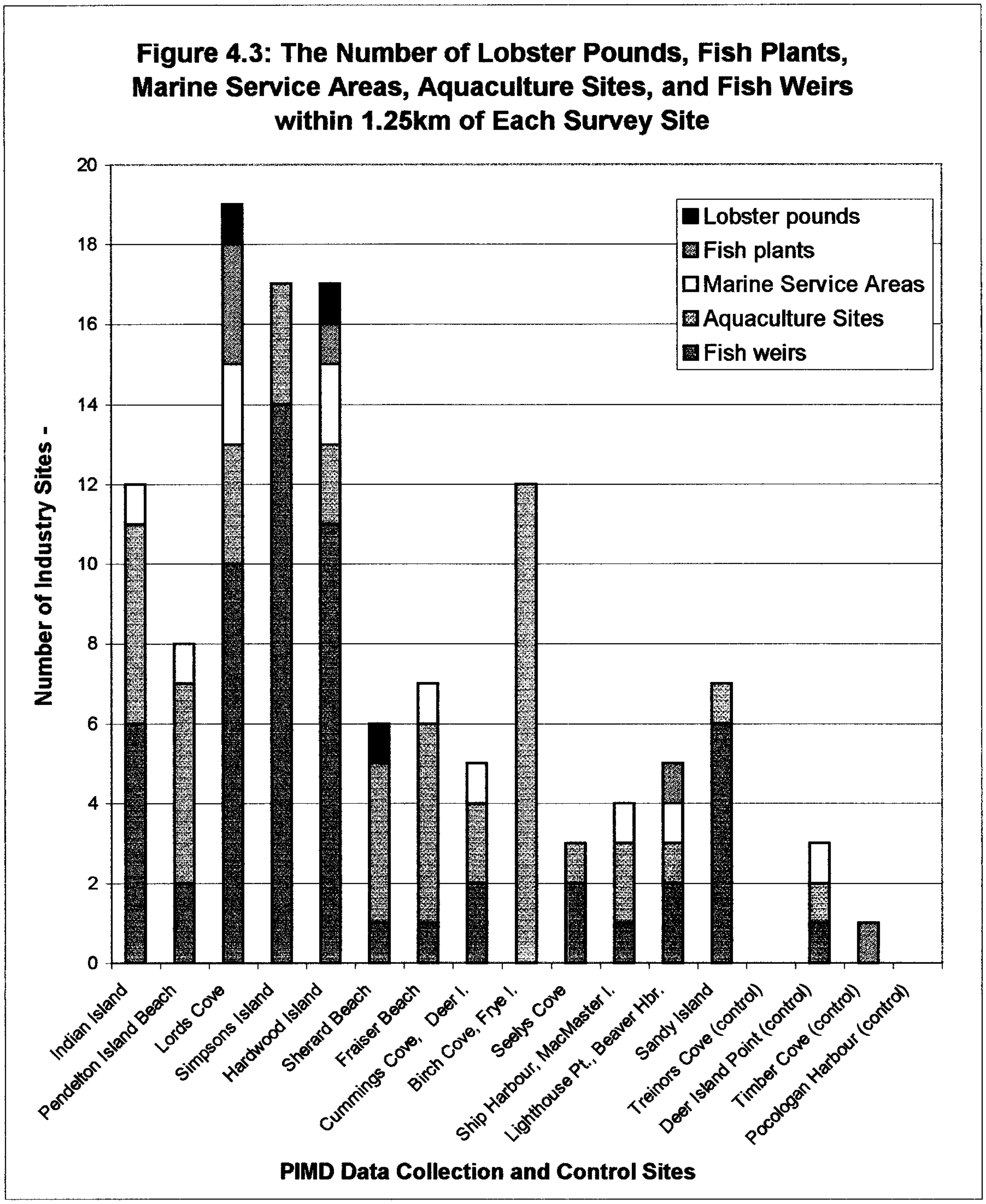


Figure 4.2: Comparing PIMD and Industry Totals Within 1.25km and 2.5 km of Each Survey Site
PIMD Totals
Industry sites within 2.5km of each site
Industry sites within 1.25km of each site
Total Industry and PIMD at Each Site
0
50
100
150
200
250
300
350
400
450
Indian I.
Pendleton I.
Lords Cove
Simpsons I.
Hardwood I.
Sherard Beach
Fraiser Beach
Cummings Cove
Birch Cove
Seelys Cove
Ship Hbr.
Beaver Hbr.
Sandy I.
Treinors Cove (control)
Deer I. Point (control)
Pocologan Hbr. (control)
Oven Head (control)
PIMD Data Collection and Control Sites



Aquaculture sites and fish weirs are the most common activities in all study areas (figure 4.3). Only six fish plants were counted within 1.25km of any survey site, so they are excluded from the regression analyses (Figures 5.1 – 5.3). Although there is a large concentration of aquaculture activities, the correlation analysis excludes the data gathered at Birch Cove on Frye Island since the steep shore and marsh areas impeded shoreline access - the data were gathered by observation from a skiff, and are not comparable to those gathered by walking the beach.

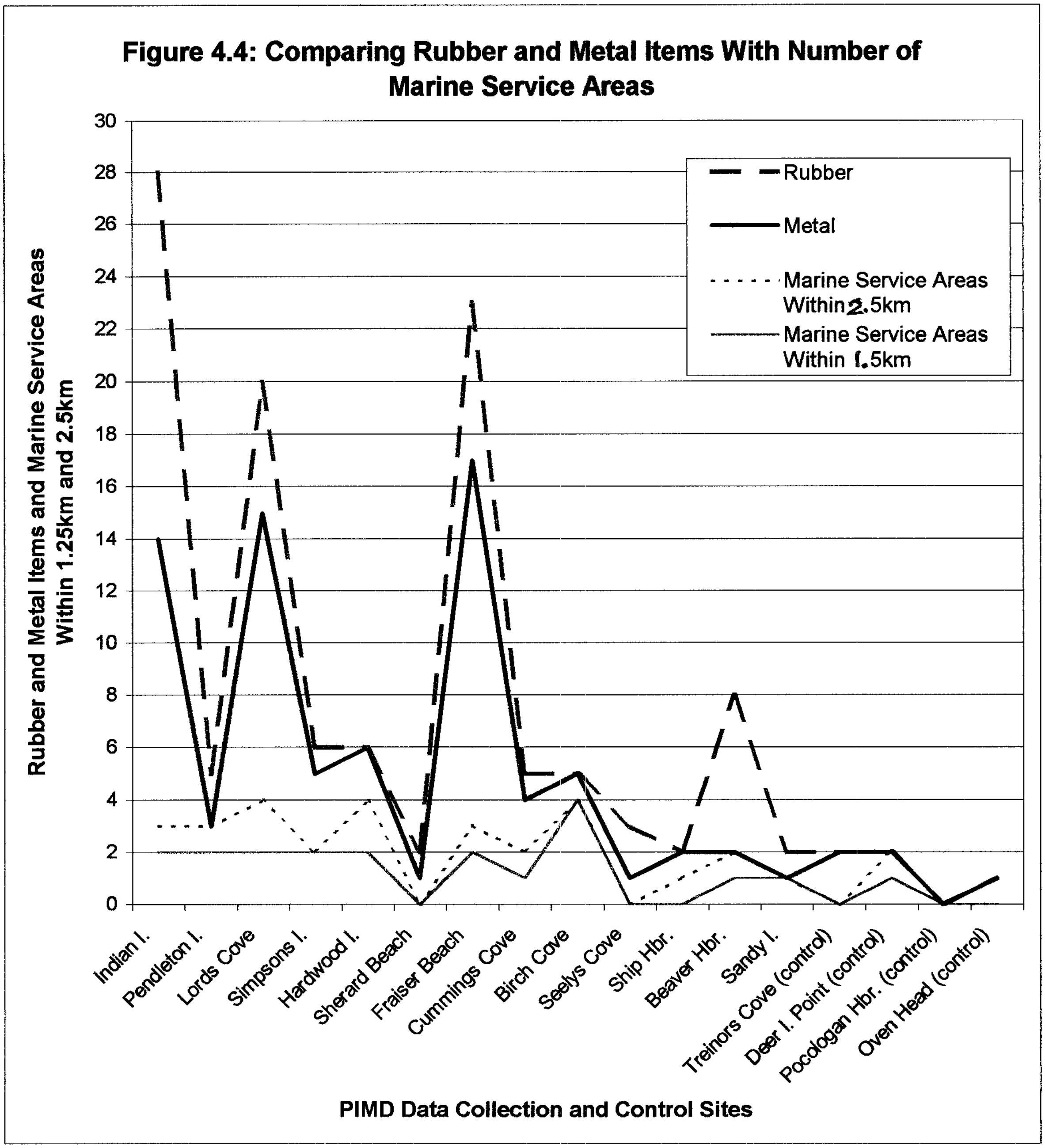


Figure 4.4 shows that peaks representing abundance of metal and rubber items coincide with sites that are close to marine service areas. Metal and rubber items were only found in small quantities.

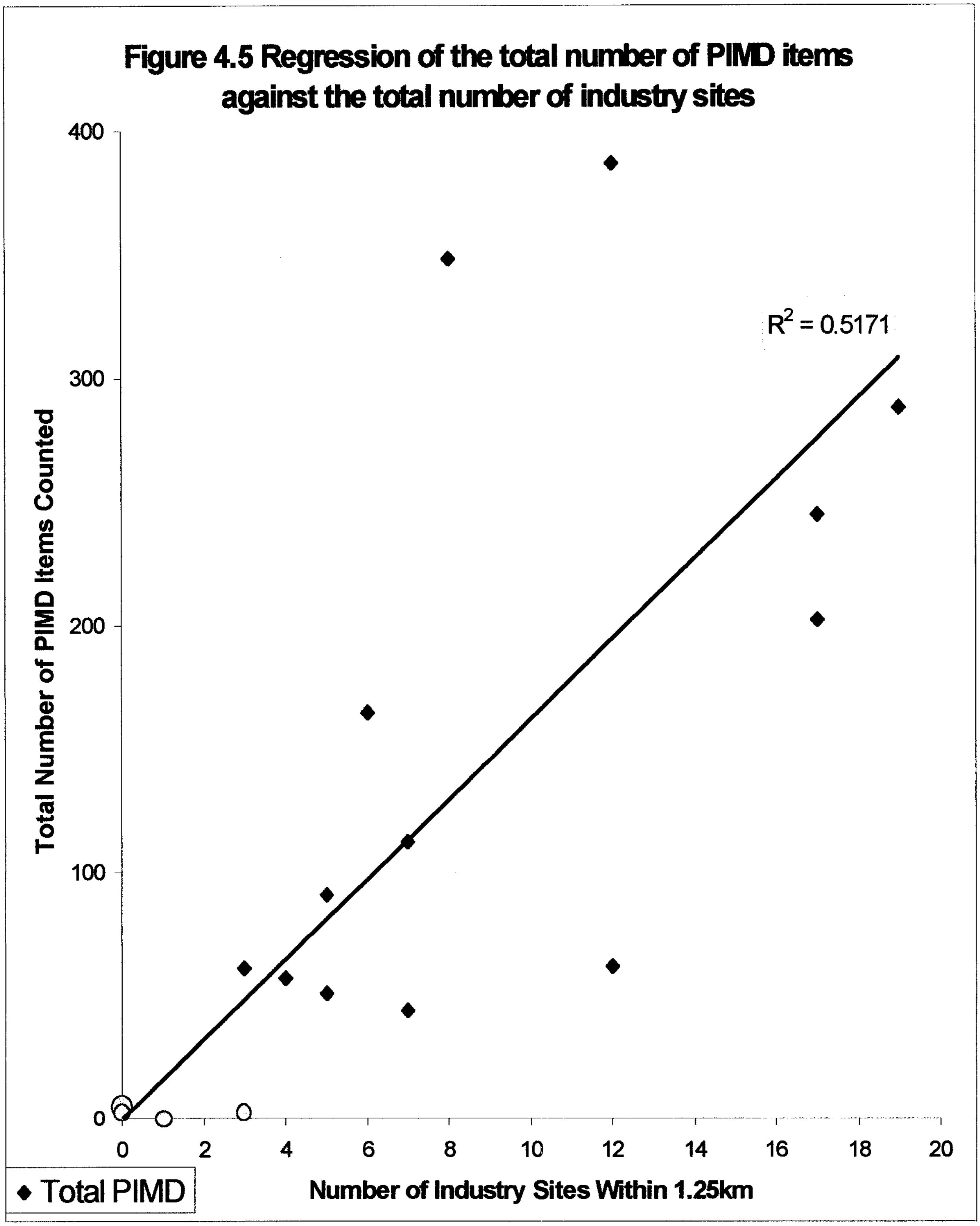
4.2 Correlation Statistics

The PIMD items counted at each study site and the numbers of industry sites nearby are representative of the entire study area. Since it is not possible to count all PIMD items on every shore, the coefficients of determination and correlation coefficients were calculated for these representative samples. Any positive relationship between PIMD amounts and industry presence was indicated by the R^2 values from all variable sets. There was a weak positive relationship between the proximity of industrial sites, and the number of rubber or metal items counted at each site. Since the numbers are small, they were excluded from the correlation analysis, which focuses on the link between plastic, foam, and wooden items and common industrial activities.

Data sets with R^2 values greater than 0.25 were selected for the remaining analysis, and scatter graphs (figures 4.5 – 4.7) were generated for the data sets listed in tables 4.3-4.4. The significance and confidence limits were then calculated using tables for the critical values of t corresponding to various levels of probability, and *r-to-Z* transformations (Schefler, 1980) to estimate 95% and 99% confidence limits (Tables 4.3 - 4.4). An interpretation of the meaning of each scatter plot follows.

The scatter graph in Figure 4.5 shows the regression of the total number of PIMD items against the number of industry sites at study and control sites. Treinors Cove and Pocologan Harbour (both control sites) appear to share the same point on the plot. The number of industry sites within 1.25km of each is zero ($x = 0$), and the number of PIMD items was five ($y = 5$) at Treinors Cove, and three ($y = 3$) at Pocologan.

Trend lines in figures 4.5 – 4.7 show plastic, foam, and wooden items as having the strongest relationship with the numbers of nearby aquaculture sites. Trend lines and R^2 values in figures 4.6 – 4.7 also show a positive correlation between the numbers of foam, and wooden items, and the number of industry sites.



Indicates control site data.

Figures 4.6 and 4.7 provide analyses of the amount of wood, plastic, and foam items against the number of lobster pounds, fish weirs, and aquaculture sites near each survey site.

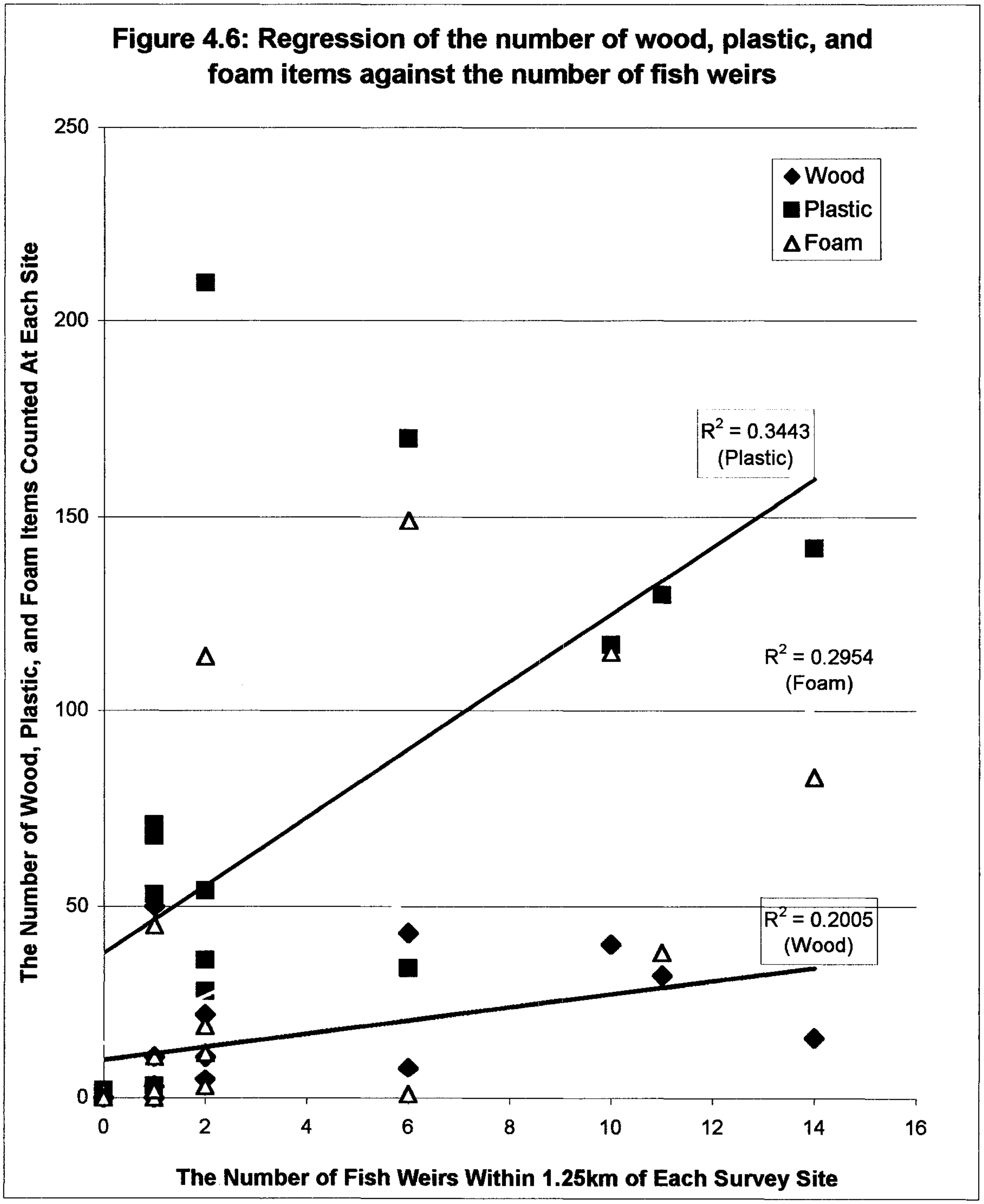
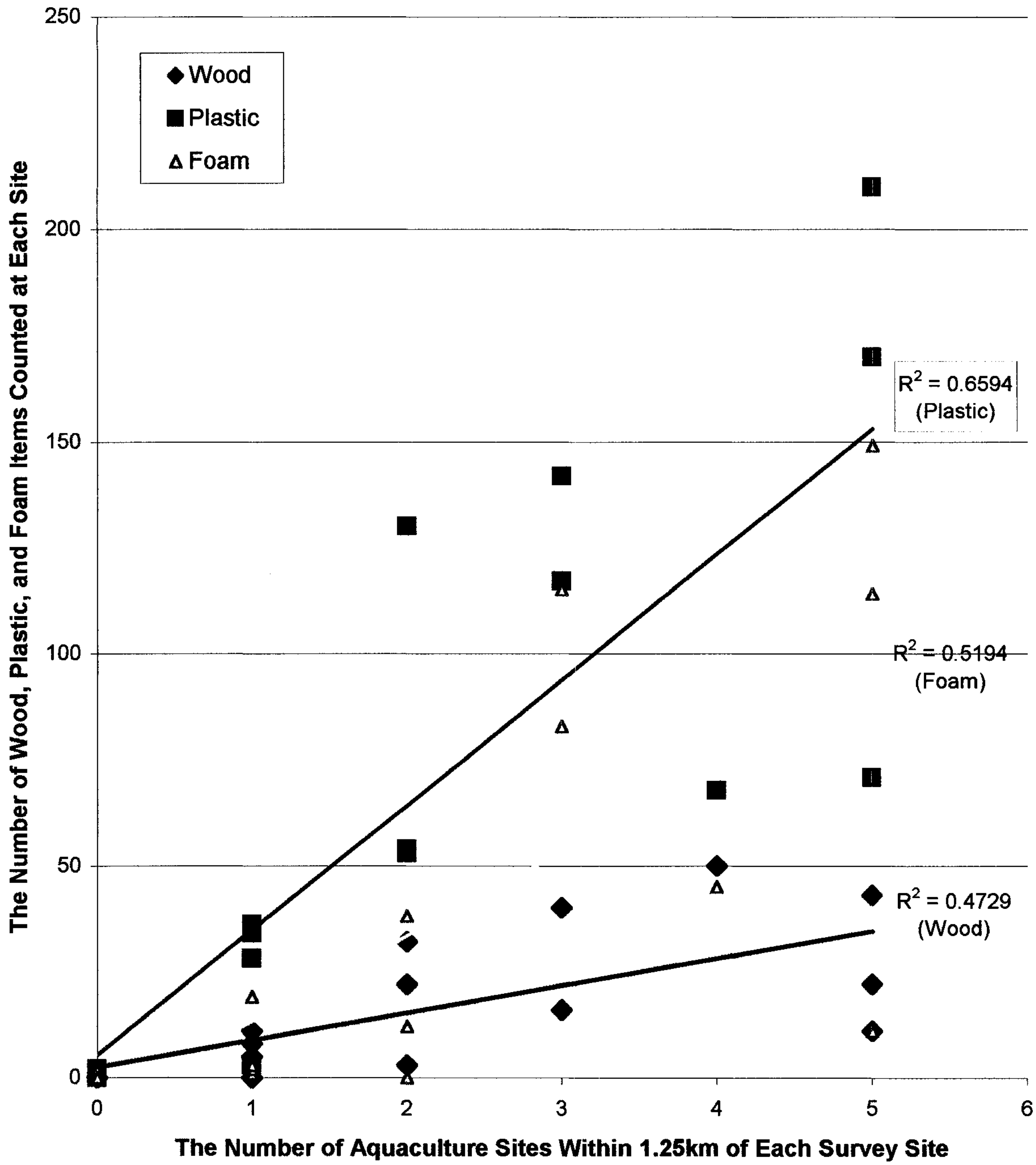


Figure 4.7: Regression of the number of wood, plastic, and foam items against the number of aquaculture sites



4.3 Significance of the Correlations and Estimation of Confidence Limits

The R^2 value or coefficient of determination is used to estimate the intensity of associations between two variables that appear to be correlated (Schefler 1980). For example, the total number of PIMD items (y), against the total number of industry sites (x), yields an R^2 of 0.5171 thus 52% of the variance of PIMD is accounted for by the regression (Ebdon, 1994, Schefler 1980). To estimate the significance of the R^2 values in accounting for the relationship between PIMD items and industry, the r-value and t-value were calculated.

Table 4.4 Significance of the correlation for PIMD items and industry presence

Variable sets: y/x	R^2	r	*t-value*	Is t ≥critical value[30] at the 0.05 level? c.v. = 2.131	Is t ≥critical value at the 0.01 level? c.v. = 2.947
Total # PIMD items/ total # industry sites	0.5171	0.72	4	Yes	Yes
Plastic items / aquaculture sites	0.6594	0.81	5.4	Yes	Yes
Foam items / aquaculture sites	0.5194	0.72	4	Yes	Yes
Wood items / aquaculture sites	0.4729	0.69	3.6	Yes	Yes
Plastic items / Fish weirs	0.3443	0.59	2.81	Yes	No
Foam items / Fish weirs	0.2954	0.54	2.45	Yes	No

Columns 2-6 in Table 4.4 assess the significance of the relationship between the number of PIMD items, and the number of industry sites, for six pairs of variables with R^2 values greater than 0.25. All *t*-values listed in table 4.4 exceed the critical value of 2.131 at the 0.05 level. The Null Hypothesis can also be rejected at the 0.01 significance level for PIMD items against all industry sites; and wood, plastic, and foam items against aquaculture sites. The statistical evidence shows that correlations between representative

[30]The critical values are found in the appendix of Schefler, 1980, Statistics for the Biological Sciences, in Table III: Critical Values of t.

sample values in table 4.4 are significant at the 0.05 level. Although the significance of a relationship between PIMD and industry presence is determined, the meaning of the relationship is not imparted.

Estimation of the upper and lower r-value limits (column 4 in table 4.5) shows where the true population coefficient (ρ) lies with certain degrees of confidence. The true correlation coefficient for the entire population or for all independent and dependent variables in an area is represented by ρ.

Table 4.5 Confidence Limits

Variable sets: y/x	***r-to-Z* value[31] Z**	**$Z \pm S_Z (t_{0.05})$[32] $Z \pm S_Z (t_{0.01})$**	**Estimation of ρ using 95% and 99% confidence limits (r≤ ρ≤ r)**
Total # PIMD items/ total # industry sites	0.908	0.328 -- 1.488 0.108 -- 1.708	@ 95% $0.33 \leq \rho \leq 0.91$ @ 99% $0.11 \leq \rho \leq 0.94$
Plastic items / aquaculture sites	1.127	0.547 -- 1.707 0.327 -- 1.927	@ 95% $0.50 \leq \rho \leq 0.94$ @ 99% $0.32 \leq \rho \leq 0.96$
Foam items / aquaculture sites	0.908	0.328 -- 1.488 0.108 -- 1.708	@ 95% $0.33 \leq \rho \leq 0.91$ @ 99% $0.11 \leq \rho \leq 0.94$
Wood items / aquaculture sites	0.848	0.848 -- 0.58 0.048 -- 1.648	@ 95% $0.27 \leq \rho \leq 0.90$ @ 99% $0.05 \leq \rho \leq 0.93$
Plastic items / Fish weirs	0.678	0.328 -- 1.488 -------	@ 95% $0.10 \leq \rho \leq 0.86$ -------
Foam items / Fish weirs	0.604	0.024 -- 1.184 -------	@ 95% $0.03 \leq \rho \leq 0.83$ -------

For example, the true population coefficient for total number of PIMD against the total number of industry sites falls between 0.33 and 0.91 with 95% confidence, and between 0.11 and 0.94 with 99% confidence.

[31] The *r-to-Z* values are found in the appendix of Schefler, 1980, Statistics for the Biological Sciences, in Table XI: Values for the *r-to-Z* Transformation

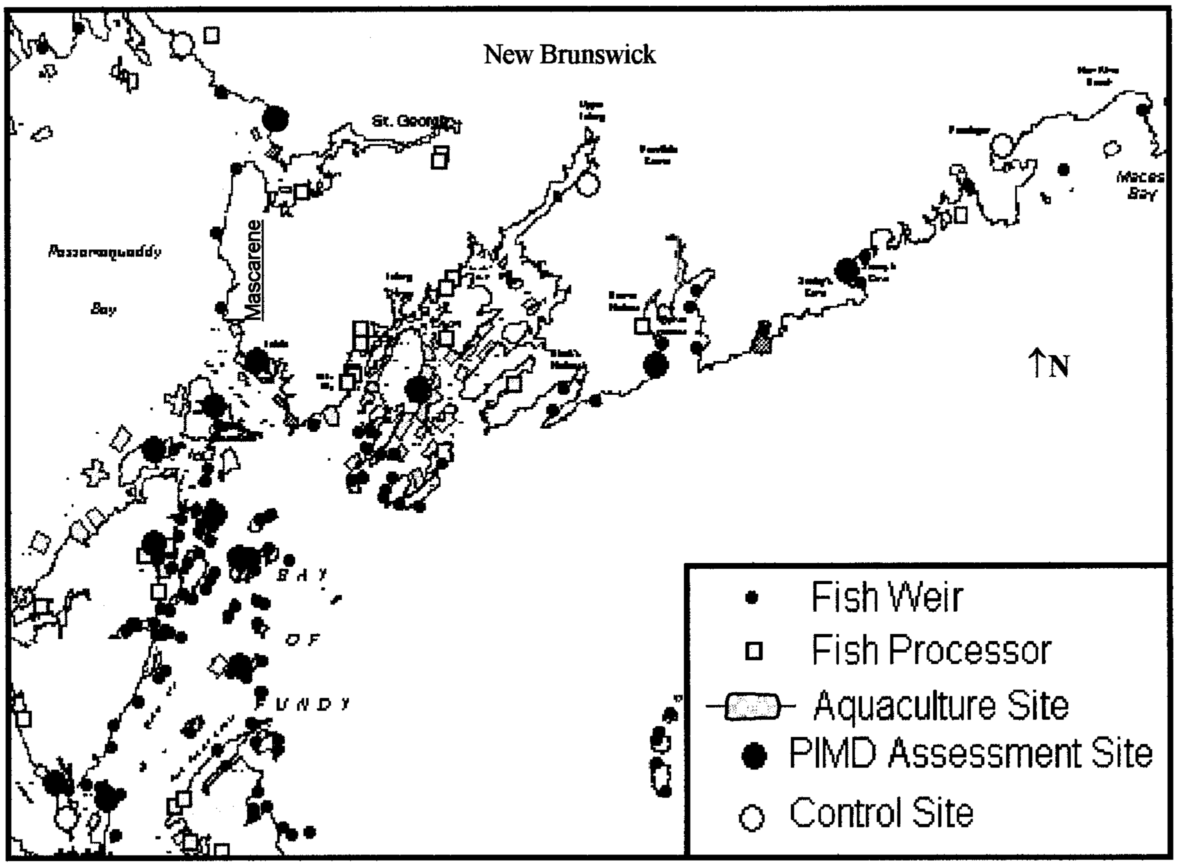
[32] Where: $S_Z = 0.27$

Chapter V

Discussion

This chapter will discuss the most common industrial activities, their relationships to the common types of dibris found at sites in the area and the influence of tides, currents and winds on the movement and dispersion of debris.

Map 3: Location of Weirs and Aquaculture Sites



5.1 Most Common Activities

Fish weirs account for most of the industrial activity close to each study site; followed by aquaculture sites. Map 3 shows the amount and distribution of aquaculture sites and fish weirs in the study area. Point (2, 210) on the graph in Figure 4.6 indicates a high value for plastic at the Pendleton Island site. This site had two fish weirs nearby, and was close to several salmon farms, which may account for the higher amount of plastic observed here. Other sites that show large amounts of plastic are Lords Cove, Hardwood Island, and Simpsons Island. Each of these sites has more than 10 fish weirs nearby. However, each also has 2 – 3 aquaculture sites within 1.25km. Plastic items were more abundant than foam and wooden items at all study sites. Overall, the correlation analysis confirms that sites with high amounts of PIMD tend to have more industry sites nearby than areas with lesser amounts of PIMD on the beaches.

5.2 Common Types of Debris and Source Industries

The most common items at each site were of plastic, foam, or wood. Metal and rubber items were only identified in small quantities at nine sites. Seven of these sites are close to marine service areas. No rubber items were identified at Ship Harbour, Hardwood Island, and Birch Cove, or at any control sites. Sandy Island, Pendleton Island, and Timber Cove showed no signs of metal items (Figure 4.4). Since metal and rubber items tend to sink, and are not readily influenced by oceanographic processes they will not generally be washed ashore.

Figures 4.6 and 4.7 show the strongest relationship between the amount of PIMD and the number of nearby aquaculture sites. The weakest relationship is between wooden items, and the number of fish weirs nearby. The R^2 value of 0.66 indicates a stronger statistical relationship between aquaculture activities and plastic items than with other types of debris. Sites with the highest numbers of plastic items were Indian Island, and Pendleton Island, which also have the highest number of aquaculture sites nearby (except Birch Cove which was not studied due to inaccessibility). The site at Indian Island has five aquaculture sites nearby and 25 out of 170 plastic items (15%) were identified as items used exclusively in aquaculture, including 23 feedbags, a feed scoop, and an old plastic cage ring. Other items found on this beach that may be used at aquaculture sites included 16 anti-foulant (net cleaner) bottles, barges, totes, pallets, and pieces of foam.

On Pendleton Island 22 out of 210 (10.5%) plastic items were identified as exclusive to aquaculture activities. Other plastic items found on this shore such as bleach or cleaner bottles, motor oil bottles, pieces of rope, totes, salt bags (salt is used to keep floating docks and boat decks free of ice in the winter), and plastic feedbags are also items that are commonly associated with aquaculture activities. Bleach or cleaner (referred to as anti-foulant) is used to remove encrustations from aquaculture or fishing nets, as well as boat hulls and equipment. Motor oil is used in boat motors and harvest or maintenance machinery. Salt is used on wharves, floating docks at aquaculture sites, and on boat decks to remove ice during winter.

Not all plastic items can be linked exclusively to aquaculture activities. For example, large quantities of salt are also used to marine service areas free of ice. In addition, many other industry activities use boats or machines with motors that require oil, fluids, or lubricants and may therefore throw away used plastic bottles. Sandy Island and Seelys Cove had the lowest numbers of plastic items counted. Each site has only one aquaculture site within 1.25km. Aquaculture related plastic items found on Sandy Island included one Connors bulk feed bag. At the Seelys Cove site 1 feed bag was identified out of 28 plastic items, so only 3.4% of all plastic items at this site could be directly linked to aquaculture. Other items such as fish totes, bleach or cleaner bottles, motor oil containers, rope, plastic sheeting, rubber gloves, foam pieces, and treated lumber may be attributable to any marine industry activity. Treinors Cove, Timber Cove, and Pocologan Harbour are control sites with no aquaculture sites nearby, and it is interesting to note that only one feedbag was found at Treinors Cove[33].

Waste management practices and clean-up programs at individual sites may also influence the amount of PIMD in an area. The Cummings Cove and Indian Island sites both have an aquaculture operation within 200m of the shore. The PIMD count at Cummings Cove was considerably lower than at Indian Island. This may be attributable to surface currents and winds or it could be an indication that waste management plans

[33] Treinors Cove is found in the upper reaches of the L'Etang estuary. L'Etang Harbour has the highest concentration of aquaculture sites.

are implemented more effectively at Cummings Cove than at Indian Island. The site at Greens Cove visited during preliminary site visits was adjacent to a large aquaculture site (approximately 200m from shore). This shoreline is included in a local beach sweep program and only a few pieces of rope were found along the shoreline. Beach sweeps have also taken place in Seelys Cove and Beaver Harbour, where low PIMD counts were recorded during data collection. However, it is difficult to determine if lower PIMD counts at some sites are due to good waste management practices or oceanographic influences.

Although there are not enough data points to include lobster pounds, fish processing plants, and marine service areas, in the statistical analysis, it was interesting to note a higher number of metal and rubber items at sites closer to marine service areas (Figure 4.4). Vessels are repaired at marine service areas, and parts may be discarded there. Tires filled with foam are used as fenders to protect docks and boats. Storms may destroy wharves and docks, and scatter tires, pilings, and parts down the shore. Sections of docks, boat parts, and tires were found at the Lords Cove site, which has two marine service areas nearby (Stuart Town Wharf, and the Deer Island Ferry). At the Fraiser Beach site, which is also close to the Deer Island Ferry, spark plugs, a hydraulic loading arm, tires, and boat parts were identified. Nine data collection sites were within 1.25km of marine service areas, and only two of them did not have rubber or metal items. Wharf pilings, tires, and an old ferry pontoon were found on Simpsons Island, which is approximately 1.5km from the Deer Island ferry crossing.

5.2 Comparing PIMD and the Numbers of Industrial Sites

Figures 4.2 and 4.3 both show that sites with less industrial activity close by (such as control sites) tend to have the least amount of PIMD. The trend line in Figure 4.5 shows a strong positive relationship between the number of PIMD items counted, and the number of industry sites within 1.25km. The variance in the number of PIMD items (dependent variable) may be explained by variations in number of industrial sites (independent variable). In contrast, control sites have little or no industry in proximity and have less persistent industrial marine debris. Most of the heavily littered sites have a large number of industry operations nearby. Areas with a moderate amount of PIMD are scattered along the trend line, between areas with the highest debris counts, and areas with little or none.

5.4 Influence of Tides and Surface Currents

Tides in the Bay of Fundy flow on a semi diurnal cycle caused by the moon's gravitational pull. Enormous volumes of water move up and down the Bay twice each day (Percy 1996 Internet), and in the upper reaches, the spring tidal range is over 50ft (Greenberg 1979). Currents in the Outer Bay of Fundy and Passamaquoddy Bay are driven by tides, and the residual current direction in both areas is counter clockwise (Percy 1996, Parsons 1986, Loucks *et al.* 1974). Surface currents (Map 4) may disperse material throughout the Quoddy Region.

Tide and current models describe what generally happens to flotsam that is farther from shore. Computer generated models of tides and currents in the Quoddy Region are based on lunar tide cycles. These models show tidal excursions and the movement of water in and out of the region (Mike Dowd, Pers. Com. 2002). The patterns of tide and current models in the Quoddy area are only accurate for shorter tide intervals. Such models may not provide enough detail to entirely explain what happens to debris discharged within 1.25 km of a given beach or shoreline. However, they give a good general representation of how the tides move and how material could disperse in the area if caught in currents and carried farther from shore (Mike Dowd, Pers. Com. 2002).

Chevrier (1959) in Loucks *et al.* (1974) described the results of drift bottle surveys conducted in the Quoddy Region. During these surveys, drift bottle recovery was higher in enclosed areas such as Passamaquoddy Bay. It was also determined that surface waters in the Outer Quoddy Region, east of Deer Island may carry floating debris across the mouth of the Bay of Fundy to Nova Scotia.

Currents and geographic features in the Quoddy Region are such that industrial activities farther away from a shoreline are less likely to contribute to the number of PIMD items that accumulate on the beach. For example, high velocity tidal currents in Letete Passage separate many industrial sites from survey areas. Debris discharged from industrial sites south of MacMasters Island is less likely to disperse into areas along the Mascarene shore. Several larger landmasses such as Frye Island, Indian Island, MacMasters Island, and Beans Island also separate survey areas from industrial sites that are more than 1.25km away. For example, Lords Cove is located in Fish Harbour (on the east side of Deer Island), and 10 of the fifty-seven industrial sites counted within 2.5km are on the other side of Deer Island. These are not likely to contribute to accumulation of PIMD at Lords Cove.

Birch Cove, Frye Island, ((12,62) in figure 4.5) has a very low PIMD count compared with other survey sites with large numbers of industrial sites nearby. This low count is likely due to the sheltered nature of this shoreline, and its location in L'Etang Harbour. PIMD discharged in this area may be carried past Birch Cove to the outer bay on the ebb or to other locations farther up in the estuary during flood tides. Location and orientation of this site also influences the amount of material that may be deposited by water and wind. Birch Cove faces north and is protected from wind driven surface currents. Items that are brought into Birch Cove will probably remain there for a long time. Several vessels and wooden aquaculture cage rings have been abandoned there.[34]

Indian Island has the same number (12) of nearby industrial sites as Birch Cove (Map 3), yet the number of PIMD items counted at Indian Island (387) was much higher. PIMD entrained in predominantly south flowing surface currents may be carried to Indian Island from areas to the north that have a higher concentration of industry sites. However, most of the material appears to originate from a local source.

[34] Birch Cove, Frye Island does not fit all of the site selection criteria outlined in this thesis. In particular, it does not have a shoreline such as a wave cut terrace or a beach that would accumulate debris.

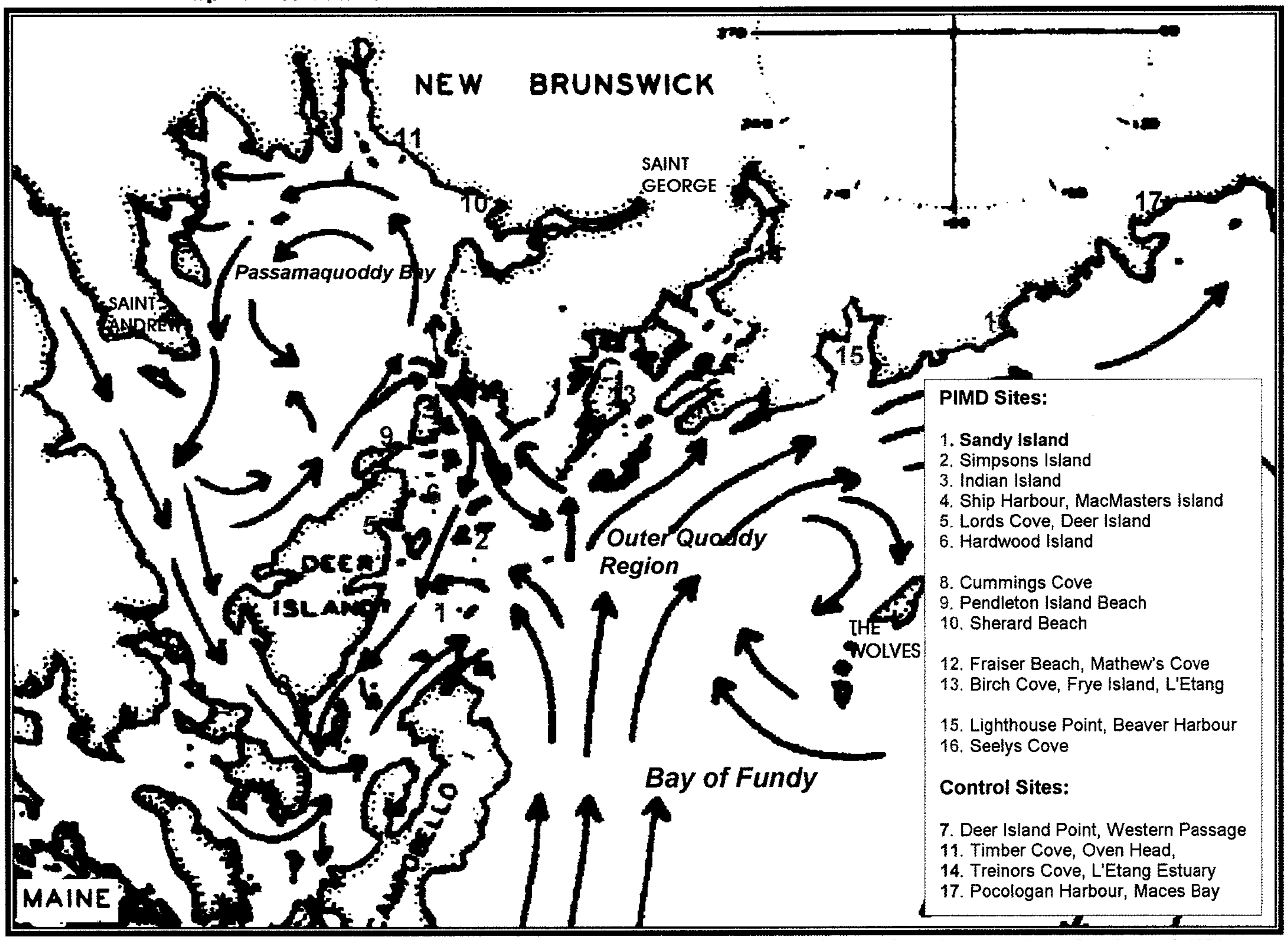
Beaches such as the ones found at Deer Island Point, Sandy Island, and Cummings Cove are directly beside high velocity currents, and deposition characteristics could be similar to those on the banks of a river. This could result in fewer items accumulating from adjacent industry operations since some may be pulled into the currents and swept "down stream" (Mike Dowd Pers.Com. 2002).

Sandy Island is in an area that has a high concentration of coastal resource use activities. The next largest concentration of industry operations is five kilometres to the south along the northwest coast of Campobello Island. Debris also tends to collect in zones where surface waters converge. A convergence zone is an area of sharp delineation between adjacent water masses of dissimilar properties (Parsons 1996). Sandy Island is between two currents – one flowing to the southwest along the west side, and another flowing to the northeast on the east side. The site on Sandy Island had a low debris count, compared to other sites that have a similar amount of nearby industry sites. Dynamic surface currents and tidal characteristics may inhibit deposit and accumulation of marine debris on Sandy Island.

The site on Pendleton Island has the same number of nearby industry operations as Sandy Island, yet has a very high PIMD count. This may be partly due to prevailing winds and residual surface currents (Map 4) along the west coast of Deer Island, which pass through an area to the north that has a high concentration of industrial sites. In addition, materials found above the high water line, on high energy or storm beaches such as at Pendleton Island and Sherard Beach, are likely "episodic". Meaning that such items are most likely stranded above the high waterline and only removed during storms or extreme tidal events (Mike Dowd Pers. Com. 2002).

Simpsons Island, Lords Cove, and Hardwood Island have the largest numbers of industrial sites within 1.25 km. The three survey sites are within 2km of each other and had high PIMD counts (between 202 and 245 items each) compared to other survey sites.

Map 4: Residual Surface Current Direction and Locations of Data Collection Sites



Seasonal pattern of residual surface circulation as indicated by drift bottles, summer, 1958. Source: Chevrier, 1959. From Loucks *et al.* 1974

The site at Simpsons Island is within 2km of the ferry that runs from Letete to Deer Island. In terms of residual surface currents, it is down current from the ferry as well. This may explain the metal ship pontoon; wharf pilings, and the high number of non-industrial debris items on the shore[35].

Sherard Beach, Cummings Cove, and Ship Harbour are located in Passamaquoddy Bay, Western Passage, and Letete Passage respectively. These sites each have 4 industry sites within 1.25 km. Sherard Beach in the northern part of Passamaquoddy Bay has the highest PIMD count of the three (165 PIMD items), and is situated north of where the Magaguadavic River opens into the bay. Currents moving north along the Mascarene Shore may also influence the amount and type of debris deposited on Sherard Beach. The town of St. George is approximately 6km up stream from Sherard Beach. One hundred and twenty non-industrial debris items were counted at this site, including pieces of furniture, beverage and household cleaner containers, toys, clothing, foam coffee cups, plastic plates, cups and utensils, transplant trays, personal hygiene items, party balloons, cups and lids.

The Ship Harbour survey site is in Letete Passage (which connects the northern part of Passamaquoddy Bay with the Bay of Fundy), and only 57 items were counted. This could be attributed to down welling movement of two adjoining water masses in convergence zones that entrain flotsam in Big Letete Passage (Parsons 1986), which flows directly past Ship Harbour. This site also faces east and is sheltered from prevailing westerly winds. However, three fire pits identified at the study site in Ship Harbour contained charred PIMD items including weir poles, steel belts from tires, and melted plastic. The low PIMD count in Ship Harbour may in part be due to the burning of waste as a disposal method.

Cummings Cove faces the Western Passage (which connects the southern part of Passamaquoddy Bay with the Bay of Fundy), and is located directly beside an aquaculture operation. This area is subjected to strong tidal currents in Western Passage

[35] Items noted include beverage bottles, coffee cups, plastic plates, utensils, food packaging, personal hygiene items, and clothing.

and deposition characteristics are similar to those of a river (Mike Dowd, Pers. Com. 2002). This may result in items being swept down current, and away from the beach at Cummings Cove. These currents may also transport debris northward from industry sites along the Deer Island shore on the flood tides, and south toward Campobello Island during ebb tides.

5.5 Influence of Winds and Wind-Driven Surface Currents

Surface currents and winds will have the most influence on debris floating at the surface (Parsons, 1986 and Mike Dowd, Pers. Com. 2002). Parsons (1986), determined that "the ultimate destination of seaweed rafts over short distances were shore fronts close to where they were initially marked", and that the direction of seaweed movement from its point of release was generated by the direction of the wind, and wind driven surface currents. Parsons also determined that the speed of movement was lower for rafts released a few hundred meters from shore, than for rafts released farther from shore. During slack water[36], floating material is dispersed by wind driven surface currents, and may be blown ashore. Transport of lighter PIMD inland is common.

Since most PIMD items found on shore will float, the direction and route flotsam takes at the surface may be similar to Parson's observations of seaweed rafts. Wind direction and speed are also the primary oceanographic characteristic used to track items that float at the surface, such as drift bottles, oil spills and drifting vessels, or for locating people during search and rescue operations. Thus, wind direction and speed are more likely to influence dispersion of flotsam than tidal currents.

[36] Times when currents cease to exist due to changing tidal conditions (Loucks *et al.* 1974).

Prevailing westerly winds create strong surface currents, and waves that perpetually impact the western shores of Deer Island, Pendleton Island, and MacMasters Island. Winds from the west, and surface currents moving from south to north along the Deer Island shore will help to move debris to the northern sections of the Bay (Parsons 1986). Winds also blow debris inland. In the West Isles area, Simpsons Island and Indian Island face west and had large amounts of PIMD driven inland by wind to areas above the terrestrial vegetation line. The distance inland that debris extends along these shorelines is approximately 100 - 150m.

Photo 5.1: Light weight PIMD transported inland by wind on Simpsons Island.

Wind driven PIMD items that accumulate inland include feedbags, salt bags, cleaner bottles, foam sheets, foam pieces, and plastic or foam floats. Photo 5.1 shows a variety of items on the forest floor of Simpson Island among windfall branches, and the arrow indicates prevailing wind direction.

Aquaculture sites need to be in "ideal situations", away from extreme currents, in order to avoid damage to cages and low oxygen levels (David Greenberg Pers. Com. 2002). High water velocities and extreme tides in The Bay of Fundy can pose major problems for aquaculture sites (Percy 1996). Fish weirs and other stationary marine structures are also anchored in areas where tidal and surface currents are not too extreme. Thus, aquaculture sites, weirs, and other operations are seldom located in areas subjected to extreme oceanographic conditions such as the waters off Deer Island Point.

The location of industry sites relative to tidal currents confirms that wind likely has the most influence on where flotsam ends up on shorelines. Removed from areas of extreme currents, PIMD discharged from industrial sites closer to shore is more subject to winds and wind driven surface currents than to tidal currents. My data mirror the situation of Parsons' floating algal rafts, where rafts released not far from shore appeared to take a direct route to the shore due to winds and wind driven surface currents (Parsons 1986). Wind velocity, direction, and duration, along with shoreline features determine where floating and lighter items accumulate on the shore. However, nothing has been found in the literature on PIMD dispersion or movement in the intertidal zone or on open water.

5.6 Potential Effects of PIMD on the Marine Environment

Potential effects to the marine environment in the four study areas include release of toxins from incineration of PIMD, and potential navigational hazards. For example, larger unanchored items such as the pontoon on Simpsons Island, and old floating docks at Cummings Cove could pose navigational hazards if lifted off shore by storm or tidal events. Although no clear evidence of ingestion of PIMD by seabirds or entanglement of wildlife was observed during field studies, several publications show that foam pieces, discarded nets, and plastic fragments or pellets pose a threat to marine species (Laist 1997, GPAC 2000, Baird *et al.* 2000, CMC 1991 & 97, and Lucas 1992). Metabolization of plastic and foam fragments ingested by marine wildlife may also be an ecological concern. Studies conducted by the World Health Organization and the US Environmental

Protection Agency (EPA) indicate that estrogenic compounds released by plastics: "may modify the normal functioning of human and wildlife endocrine systems and cause developmental, behavioral, and reproductive problems." (EPA 2000 - Endocrine Disruptor Screening Program Web Site).

Other adverse environmental effects of inappropriate PIMD disposal include leachate from unauthorized landfill operations along the coast. For example, the site at Fraiser Beach is used as a PIMD burial pit and incineration site as evidenced by the large tire tracks and reports to DFO officers at the St. Andrews Biological Station. The areas where debris is buried exuded a dark slimy substance that had an acrid and pungent odour. A mix of organic and chemical material probably caused this from encrusted nets or gear, and residues in discarded cleaner or machine fluid containers that were identified during the survey. Decomposition of organic material can also produce methane and other flammable gasses that can build up inside landfills, posing a threat to nearby infrastructure (Henry 1996), such as the power line that runs through the Fraiser Beach site. In addition, hikers, aquaculture operators, or boaters may be on the beach.

Chapter VI
Solving the Coastal Debris Problem

Solving this problem is difficult because debris comes from diverse and numerous sources. Simply acknowledging that debris from coastal industries is out there and that there is a large quantity is not enough to address the issues and find practical solutions. Implementing a comprehensive PIMD recycling program could reduce waste disposal, collection, and transportation costs (disposal and tipping fees); generate revenues from the sale of recyclables; and create a few jobs. Materials that are recycled include plastics (bottles, feed bags, and some nets), tires, and lead-acid batteries. Resulting environmental benefits include: reducing the need for landfills, conserving resources, reducing air pollution, and improving aesthetics.

6.1 Regulatory Framework and Solid Waste Management

Federal and provincial Acts and Regulations are designed to mitigate the problem of debris discharged from coastal resource use activities. However, the high concentrations of PIMD observed in this study and local beach sweep information indicate that existing regulations are ineffective. Regulations for managing debris in coastal areas are summarized in Appendix VI. In addition, there has been an increase in aquaculture, boating, and related activities in the Quoddy area over the last few decades.

The different types of sources and the remoteness of industry sites in the study area make it difficult to enforce ocean dumping and solid waste disposal regulations. In addition, policies such as those that require site owners to submit a waste management plan may perpetuate the problem of waste discharge. For example, provisions in the Bay of Fundy Marine Aquaculture Site Allocation Policy and Application Guide (NBAFA 2000) allow operators to use adjacent shores for storing equipment and gear. These areas are also used for storing old material and equipment that would otherwise be discarded encouraging operators to set up unauthorized dumping sites. The apparent ineffectiveness of waste management plans for aquaculture combined with large amounts of debris from other coastal activities indicates that current regulatory mechanisms are deficient in mitigating the problem of persistent debris.

6.2 Potential Solutions

To implement appropriate pollution prevention programs, proper identification, documentation, and tracking of persistent industrial debris in marine areas is required. Educating marine resource users may also assist in mitigating waste disposal problems. Butler *et al.* (1988) perceived education of the people who are responsible as a most important and effective method for solving problems of this type. Lang (1990) also identified education as a tool that can make all people and industries that share coastal resources aware of problems caused by plastics. Solutions that could contribute to solving the PIMD problem include:

- Amend current legislation or create laws that target the companies or industries that are responsible, and ensure that fines for non-compliance exceed the costs of legal disposal of wastes.
- Ensure that waste containers are placed in locations that facilitate access.
- Institute a mandatory take-back program through which the manufacturer is responsible for products and equipment that are no longer useable, or not suitable for a waste exchange program. Through such a program, the onus would be on the user to return the used item, and on the manufacturer to provide accessible collection depots and recycle the items.
- Create a labelling system for such items as; nets, feed bags, cages, floats, and boxes that will track amounts and distribution of items from supplier, to industry user, to disposal (cradle to grave).
- Encourage "adopt-a-beach" programs where each coastal enterprise is responsible for the clean-up of all shorelines next to their operations.
- Create and deliver education programs that assist industry in setting up waste management initiatives.

6.3 Beach Sweeps

Beach sweeps and reports conducted by Eastern Charlotte Waterways Incorporated, and the Atlantic Coastal Action Program (ACAP) indicated that large amounts of domestic, recreational, and industrial debris were collected from 34 beaches in the Charlotte County, Quoddy Area (ACAP 1997, ACAP 1998, and Raymond 2001).

Marine debris accumulates at many other locations throughout the study area, and it was impossible to visit all of them. However, beach sweep reports provided information on debris types and amounts collected from several other sites along shorelines in Charlotte County. Beach sweep results indicated that debris collection areas closer to the PIMD survey sites also had large amounts of debris. For example, the total number of debris items collected on beaches in Lime Kiln Bay (in L'Etang Harbour) and in Beaver Harbour (close to Lighthouse Point) during the 1998 ACAP beach sweep were 1449 and 1129 respectively. This includes items from both domestic and industrial sources.

Approximately 100 different debris categories were included on the ACAP data collection cards, and their numbers counted and recorded at each site (ACAP 1998). Fourteen items out of the 100 ACAP debris categories could be associated with coastal industry activities and identified as PIMD items. The following lists the type and number of these fourteen items identified and counted during the 1998 ACAP Beach Sweep.

Salt bags (10)
Bleach or cleaner bottles (107)
Oil, lube bottles (370)
Fishing line (56)
Fishing nets (109)
Floats and lures (43)
Lobster trap tags (292)
Pipe thread protector (76)
Rope (1691)
Foam buoys (594)
Crab / fish traps (67)
55-gallon drums (26)
Tires (91)
Lobster bands (102)

(ACAP 1998)

There were 3371 PIMD type items counted at all beaches cleaned, which gave an average of 112 items per site. These counts did not include larger items such as floating docks, large parts, abandoned boats, and aquaculture cages or items that could not be moved by the participants, so the actual amount of debris on these shores was likely higher.

Beach sweeps provide short term solutions to PIMD, and involve hundreds of volunteers, who walk along shorelines and pick up litter while recording type and amount on data cards. The focus is on smaller scale debris items (mostly recreational and domestic) and the data provide information on types of discarded material. Although important data are collected and some material is removed, beach clean-ups are an 'end of pipe' approach and do not specifically address prevention.

6.4 Solid Waste Facilities

Solid waste disposal facilities may not be able to handle all waste items, and could be prohibitively costly in time and transport for some marine resource users. Waste handling facilities in the Quoddy Region are under the jurisdiction of the South West Solid Waste Commission (SWSWC), which operates one solid waste landfill in Saint Stephen, and several recycling depots throughout Charlotte County. Through a program supervised by the New Brunswick Tire Stewardship Board, people are encouraged to return tires to retailers. However, this requires that tires are replaced on a vehicle, or that a receipt indicating purchase of tires is provided. Tires found in the marine environment do not qualify for this program.

Rates for bringing solid waste to landfills range from $0.00 to $68.50 per ton. Fees may vary depending on the nature of the waste to be disposed of. For example, the rates for disposal of scrap metal items and untreated wood are $0.00 and $20.00 per ton respectively. There are eleven recycling depots managed under the SWSWC and they only handle corrugated cardboard, box board, newsprint, and mixed office paper. Rates for oversized waste or waste requiring special handling are reviewed on a case-by-case basis and will only be accepted by appointment. However, rope, cable, and fishnets are accepted on the condition that they are cut into lengths no longer than 4 feet.

6.5 Pollution Prevention and Recycling

Pollution Prevention is a waste management concept that considers how products and packaging contribute to the problem of PIMD. It encourages reduction in the volumes of material that potentially enter waste streams at the design, monitoring, and purchasing stage. Table 6.1 outlines Pollution Prevention actions that are applicable to fish weirs, aquaculture, and major marine service areas.

Table 6.1 : Pollution Prevention Actions For Fish Weirs, Aquaculture, and Marine Service Areas

Pollution Prevention Actions	**FISH WEIRS**	**AQUACULTURE**	**MARINE SERVICE AREAS**
Use of equipment and supplies that use less packaging materials	Buy salt in bulk	Buy feed in bulk Buy cleaner in bulk	Buy salt in bulk Buy cleaner in bulk
Delivery of supplies in returnable or recyclable containers	Return, reuse, and repair wooden pallets, totes, xactic boxes, etc. Replace disposable boxes with durable boxes for shipping products Provide employees with re-useable coffee or beverage cups	Return, reuse, and repair wooden pallets, totes, Xactic boxes, etc. Replace disposable boxes with durable boxes for shipping products Provide employees with re-useable coffee or beverage cups	Provide employees with re-useable coffee or beverage cups.
Search for alternative strategies. Use remanufactured equipment and high quality, durable, equipment that is repairable	Create and use local waste exchange. Visit local fisheries related trade shows regularly to determine best available technology Beach comb for weir poles	Create and use local waste exchange. Visit local fisheries related trade shows regularly to determine best available technology	Designate an area for local waste exchange Visit local fisheries boating, and related trade shows regularly to determine best available technology

Recycling facilities and buy-back centres, waste resource processing facilities and local waste exchanges[37], along with waste recycling programs could assist in providing customers with "green" products from "environmentally-friendly" business, improve due diligence and reduce liability associated with illegal waste disposal. Communities that have negative reactions to the accumulation of PIMD may be more accepting of local companies that implement solutions to waste problems. In essence, the company earns its social license. Waste management, recycling, and Pollution Prevention programs show customers and the public that a business is socially and environmentally conscious.

Without regard to cost, time, transport, and company image businesses such as aquaculture facilities, weir fisheries, and marine service areas that depend on the quality of the marine environment should make a better effort to use mechanisms such as recycling depots and dumpsters instead of fouling the waters from which they make a living.

[37] The Eco Efficiency Centre in Burnside Industrial Park, Halifax, Nova Scotia views the business park as an industrial ecosystem with inputs and outputs that can be exchanged with in the community. This helps businesses recover costs through efficient use of waste such as packaging, batteries, old equipment, and thermal energy.

Chapter VII
Conclusion and Recommendations

PIMD is an aesthetic problem, and can harm marine life. It could also damage boats. For example, nets and lines that are caught in propellers may require costly repairs. Items floating just below surface also pose navigational hazards for small craft. Comparison of the PIMD and industry totals suggests that areas with the most industrial activity tend to have the most amount of PIMD, and that areas with less industrial activity (such as the control sites) tend to have the least amount of PIMD.

Of the four areas studied, the West Isles, on average, had the highest amount of marine debris. The average number of items counted at each site in the West Isles study area was 204. This area also has the highest amount of industrial activity within 1.25km of the data collection sites. The Southwest New Brunswick coast had the lowest amount of PIMD with an average of 38 items counted per site, and 8 industrial sites within 1.25km of the data collection sites. This suggests a correlation between amounts of coastal industry in an area and amounts of PIMD washed up on shore. This was confirmed by statistical analyses, which indicated a positive relationship between the amount of PIMD and the number of aquaculture sites, fish weirs, marine service areas, lobster pounds, and fish plants in decending order (i.e. aquaculture sites have the strongest relationship and fish plants have the weakest relationship to PIMD amounts). Evaluation of the research and statistical data showed a direct link between the debris and the local industries.

Since the 17 locations selected for PIMD surveys in this study are representative of the four areas, it is likely that amounts of PIMD at other sites are similar to the average of 163 items per site as calculated in this thesis. In addition, information from beach sweeps conducted in the Charlotte County, Quoddy Area indicated an average of 112 PIMD type items per site. This suggests that there is an enormous amount of PIMD within the study region.

PIMD discharged from industry sites is not transported very far. Data collection sites directly beside aquaculture sites had a higher count of aquaculture related debris, and collection sites beside weirs had a higher weir pole count. Data collection sites directly beside industrial sites tended to have a higher number of marine debris items. Distribution and movement of marine debris can be influenced by location down current from areas that have a high population or concentration of industry sites (Hoagland *et al.* 1997), and areas that were close to tourism and residential areas had the highest amounts of domestic or land based debris (DMD). Remote or sheltered areas that were farther from industrial sites had the lowest number of marine debris items.

Floating debris from marine industrial sites will end up on adjacent shores. However, winds, surface currents, and tides may disperse flotsam from industrial activities to other locations. Depending on the topography and surface geology of a shoreline the lighter PIMD items such as plastic containers, feed bags, and Styrofoam were blown inland.

Nets and ropes that become entangled in rockweed and the shoreline matrix tend to remain at or above the high water mark. However, high tides can lift heavy and entangled items off shorelines and redistribute them into other areas. Some PIMD items will sink if discharged from sites or operations on the water. So not all debris generated from coastal industry sites ends up on adjacent shores. Most of the sites where rubber and metal items were identified are close to marine service areas. Heavier items such as boat parts, pipes, and tires that are discarded along the shore remain there for a long time.

Some of the debris generated by coastal marine industries is brought to shore and disposed of at waste management facilities. However, large amounts of PIMD counted at sites throughout the study area indicate that waste management regulations and procedures are generally ineffective. Beach monitoring and cleanup events are not the complete answer since material continues to be discarded and continues to wash up on shore. If laws were properly enforced the amount of PIMD accumulating on shorelines might be reduced. However, some marine debris could still be transported into Quoddy waters from other areas by oceanographic influences.

7.1 Recommendations

The design, construction, anchoring, operation, and maintenance of marine industrial sites influences the amount of PIMD discharged into the environment. With some care, much of the problem is preventable. Implementation of monitoring and maintenance programs for materials and equipment used by marine resource industries, and education on waste disposal methods offer some solutions to the problem of PIMD along the coast of Charlotte County New Brunswick. The following is a list of recommendations for further research, monitoring, and management of PIMD in Charlotte County.

- Study the effectiveness of the infrastructure that handles PIMD in each of the four study areas, and determine appropriate pollution prevention alternatives through consultation with community and industry representatives.
- Educate coastal resource users on the adverse impacts of PIMD, and how to develop and implement pollution prevention strategies.
- Promote voluntary adoption of environmental management systems for coastal industries that are monitored or audited by community representatives for compliance and performance regarding waste management and pollution prevention procedures[38].
- Determine wether synthetic materials are being ingested and metabolized by marine organisms that inhabit plastic and foam debris on shorelines.
- If it is determined that plastic, foam, and other items are metabolized by microorgaanisms then identify the types of chemicals that may build up, and research the effects on the food chain. For example determine if it is assimilative, bioaccumulative and what the effects are on living systems.

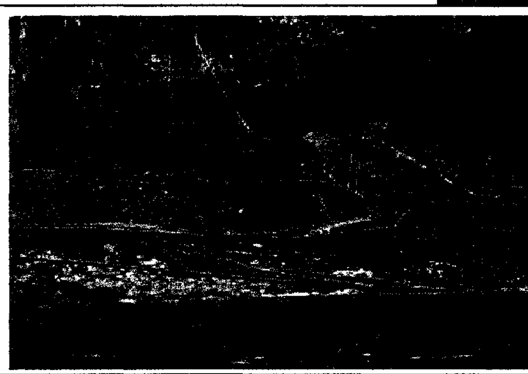
Proper waste management is more than knowing what to do once waste is generated. It requires an understanding of the material composition of tools, equipment, and packaging

[38] With consensus between other stakeholders and industry representatives, audit findings ensure compliance with regulations and encourage the development and implementation of solutions for correcting or preventing activities that pollute the environment. This is based on the ISO 14000 Environmental Management System improvement process, which requires continual review of the Environmental Policy, Objectives, Targets, and environmental performance (Smith 2000).

that are likely to end up as PIMD. It also requires evaluation and survey of current waste resource collection methods and handling operations as well as locating local markets for PIMD. If there are no appropriate management programs and facilities then regulations and waste management programs will be ineffective.

Appendix I: Preliminary Site Visits: Description of Sites

Table A1: Pandalus: May 31, 2001

Name Coordinates	Items Identified Comments	Photo #
* Pendleton Island 45^{0} 05. $111^{\prime}$ 67^{0} 04. $505^{\prime}$	Large pieces of Styrofoam	00070
* Pendleton I. Beach 45^{0} 02. $089^{\prime}$ 66^{0} 56. $957^{\prime}$	 Old wooden aquaculture pen, fishing net, plastic containers, Styrofoam. Attempted landing with the zodiac. Compact and powerful breakers filled it with water. Had to stand in hip deep water to prevent zodiac from beaching. Left gear on shore and got people back to boat. Emptied water and retrieved gear from shore.	00071 00072
MacMasters Island, Northwest side. 45^{0} 02. $423^{\prime}$ 66^{0} 56. $260^{\prime}$	Plastic and foam floats, possibly melted plastic, plastic containers, nets and rope. Also known as Macs Island 	00073 00074 00075
Ship Harbour, MacMasters Island 45^{0} 02. $852^{\prime}$ 66^{0} 55. $245^{\prime}$	 Black flexible pipe (PVC) ~4-5 cm in diameter & ~ 100m in length. -Believed to have been there for at least 2 years.	00076 00077 00078
* Simpsons Island 45^{0} 00. $239^{\prime}$ 66^{0} 54. $797^{\prime}$	Large old rusting ferry pontoon attached to wooden pilings. Foam, floats, plastic oil or bleach containers, nets, industrial planking, rope. – Amount of litter was uncountable. Collected samples: feed bag, rope, piece of foam, and plastic oil cans ... Able to land on this beach with the zodiac. Ferry pontoon is possibly from the Abenaki or MacLean Ferries - out of commission for 20 yrs. Compared to length of time on Island. Old copper mines. PIMD blown into the woods as far as the eye can see. Dead bird suspended from tree – possibly caught in lines. An eagle was flying overhead.	00079 00080

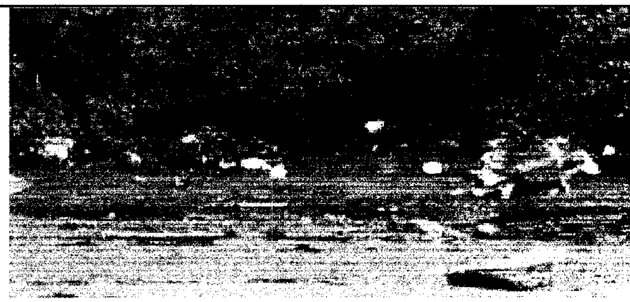
Name Coordinates	Items Identified Comments	Photo #
Mowat Hbr. $45^{0}\ 00.096'$ $66^{0}\ 54.593'$	Beached cages on both Mowat and Simpsons Islands. Foam, rope, and plastic containers. Immature Eagle flying overhead. 	00081
Beans Island $44^{0}\ 59.771'$ $66^{0}\ 55.763'$	Plastic oil containers, Styrofoam, pieces of net pens, black PVC pipes, Styrofoam cylinders... Adjacent herring weirs. Adult eagle sitting on rock.	
Hardwood Island $45^{0}\ 00.893'$ $66^{0}\ 55.316'$	Cage (possibly wooden), Float, Styrofoam, blue tote	

Table A2: West Isles: East of Deer Island, June 8, 2001

Name Coordinates	Items Identified & Comments
*Pendleton Island Beach N $45^{0}\ 02.089'$ W $66^{0}\ 56.957'$	 Old wooden net pen, large nets, Styrofoam, feed and salt bags, totes, a lot of plastic debris integrated into the rock weed, weir poles, lobster crate, planking. 2 Riverdale coffee cups. Bermed beach, privately owned by the Pendleton family who own the adjacent aquaculture sites. It is reported that the owners have a bonfire every year to burn accumulated PIMD. Shoreline debris extends in land- beyond the limits of the beach into the adjacent shoreline woods. Dead seal found among debris inside old wooden cage frame. A dead blue heron was also found along the beach. Cause of death for both animals is undetermined.
* Hardwood Island N $45^{0}\ 00.893'$ W $66^{0}\ 55.316'$	Industrial planking, plastic containers (oil and cleaning solutions) Styrofoam, floats, rusting drums, weir nets, aquaculture nets, xactic box cover (in photo) totes, pieces of plastic, approx. 8 Riverdale coffee cups. Old herring weir on the other side of the spit. Samples taken: lobster door, floats. 

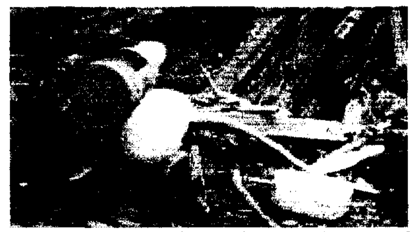
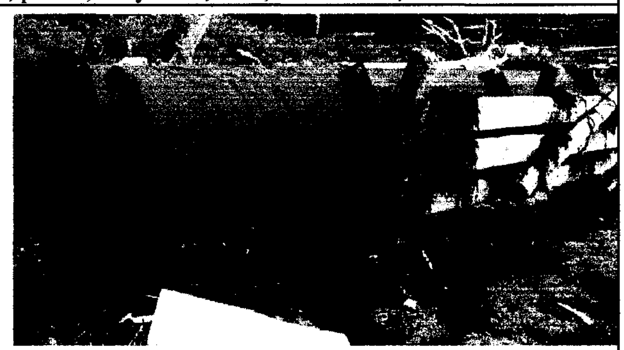
Name Coordinates	Items Identified & Comments
* Beans Island beaches East of Lords Cove, Deer Island. Landed on the Eastern side of Beans Island	 Melted plastics, floats, weir poles, wood pallets, discarded netting, rope, wood beams with spikes, partially burned wharf piece - approx. 2.5m in length, burned plastic on pallet, hot water tank, plastic tarp, 1 Riverdale coffee cup Samples of nets taken for identification from second beach visited. Samples: melted plastic, nets, coffee cup.
* Barnes Island East of Simpsons Island	  Weir poles, several tires, large pieces of Styrofoam, plastics, industrial planking, floats, rope, pilings or barge parts, rusty cans, plastic containers, oil cans, herring weir nets, metal drums pipes, feeder pipe, crates, pallets, rusty drum, totes, lobster crate, treated lumber
* Simpsons Island (eastern side) N 45^0 00. 239$'$ W 66^0 54. 797$'$	Old rusty pontoon, oil cans, weir poles, tires, floats, pilings or barge parts, crates, pallets, cage parts, cylindrical pieces of Styrofoam - from aquaculture operations, totes, feeder pipes, floats, large pieces of Styrofoam, wooden pallets, salt and feed bags, plastic cleaner bottles, nets, ropes, 5 Riverdale coffee cups. Considerable amount of plastics and foams carried by  wind into adjacent coastal forest - extending approximately 100m. Including plastic containers (oil, cleaners), feedbags, salt bags, plastic sheets, large pieces of Styrofoam.

Table A3: Back Bay and Greens Cove - St. George / L'Etang - June 4

Name	Items Identified	Comments
Back Bay	Weir poles, several tires, netting, car wreck, oil cans, motor, boat and vehicle parts, lobster crates, several large pieces of Styrofoam, metal railing, cage parts, totes, plastic sheeting, feed bags, moving cart, fish boxes, rope, large pile of rusting nails	The area also included domestic wastes. Foul odors along the shore - especially by the pier indicate release of untreated sewage.
Greens Cove	A few small pieces of rope or nets. Small amount of little plastic pieces caught-up in the rockweed.	Other than a few pieces of small scale litter, this area is clear of PIMD. It is reported that the adjacent aquaculture operators monitor waste residuals and conduct beach cleanups.

Table A4: Craig Point and Holts Point - June 6-7, 2001

Name	Coordinates	Items Identified	Comments
Craig Point area, June 6	N 45° 06. 877′ W067° 03.619′	Rubble from old sardine factory, floats, Styrofoam, corrugated plastic (3 pieces < 1m in length),	Point at the end of Harkness Road across from Ministers I. in Chamcook Harbour. Relatively low in PIMD. Video close-ups revealed no PIMD on the northern point and low tide causeway of Minister Island
Holts Point, June 7	N 45° 08.830 W066° 59.087′	Some pieces of Styrofoam, a car battery, 3 floats, a few weir poles, 2 tires, a few rusting metal objects under 1m in length	Walked from entrance around the point and down into Mill Cove between the high and low water marks. Return route- above the high water mark. Approximately 0.75 km. Compared to other sites (Pendleton I, Simpsons I, and Back Bay), and considering the amount of area covered, this beach does not have a lot of PIMD.

APPENDIX II: Persistent Industrial Marine Debris: Amounts Recorded on Data Cards for the 17 Sites

Table A5: PIMD: Plastic and Synthetic Items

	Plastic cleaner bottles	Plastic Oil bottles	Plastic FEEDER PIPES	Plastic FLOTATION PIPES	Plastic TOTES	Plastic FEED/SALT BAGS	Plastic FLOATS	FISH BOXES	PLASTIC DRUMS	Plastic PENS (cages)	Synthetic fibre: ROPE / LINES> 2m	Fishing NETS >1m	Weir NETS >1m	Aquaculture NETS >1m	Plastic Sheeting > 1m	MELTED PLASTIC	BUCKETS	OTHER Plastic or Synthetic fibre items
Birch Cove, Frye I.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sandy Island	4	3	0	0	0	1	0	1	0	0	17	2	2	0	1	0	0	6
Simpsons Island	31	22	0	2	0	48	0	0	0	0	15	0	2	1	1	1	5	14
Indian Island	16	19	1	0	4	23	0	1	0	2	60	0	0	19	7	4	2	12
Ship Harbour, MacMaster I.	0	0	0	0	0	0	0	0	0	0	23	1	0	0	0	3	0	26
Lords Cove	13	6	2	10	2	1	0	1	0	1	42	14	0	0	10	2	0	10
Hardwood Island	13	24	0	1	6	7	3	1	0	0	57	1	0	4	5	0	1	7
TOTAL: West Isles Sites	77	74	3	13	12	80	3	4	0	3	214	18	4	24	24	10	8	75
Sherard Beach	3	14	0	0	0	1	0	0	0	0	34	4	0	0	2	0	0	10
Cummings Cove, Deer I.	2	2	1	1	0	2	1	0	0	5	26	0	0	2	8	2	0	2
Pendelton Island Beach	17	31	0	1	4	35	2	0	3	0	85	1	0	0	14	6	7	3
TOTAL: Pass. Bay & Western Passage	22	47	1	2	4	38	3	0	3	5	145	5	0	2	24	8	7	15
Fraiser Beach	5	2	30	3	1	3	2	0	0	7	12	0	0	5	3	0	0	1
Birch Cove, Frye I.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL: L'Etang Harbour	5	3	30	3	1	3	2	0	0	7	12	0	0	5	3	0	0	1
Lighthouse Pt., Beaver Hbr.	1	6	0	1	0	2	0	0	0	0	15	0	0	0	11	0	0	0
Seelys Cove	4	4	0	0	1	1	0	0	0	0	8	0	0	0	15	3	0	0
TOTAL: Southwest NB Shore	5	10	0	1	1	3	2	0	0	0	23	0	0	0	26	3	0	0

Table A6: PIMD: Foam and Rubber Items

	FOAM Sheets > 0.25m	Foam Floats	Foam Packing: flotation or insulation	Foam Pieces < 0.25m	OTHER Foam items	RUBBER tires	OTHER RUBBER ITEMS	METAL Crab or lobster traps
Birch Cove, Frye I.	13	0	0	18	0	0	0	0
Sandy Island	0	1	0	0	0	0	1	0
Simpsons Island	7	2	9	65	1	1	0	0
Indian Island	17	8	0	124	0	13	1	0
Ship Harbour, MacMaster I.	0	0	0	0	0	0	0	0
Lords Cove	6	3	0	106	0	3	2	1
Hardwood Island	12	1	0	18	0	0	0	0
TOTAL: West Isles Sites	42	15	9	303	1	17	4	1
Sherard Beach	37	7	0	0	1	1	0	0
Cummings Cove, Deer I.	2	2	0	8	0	0	1	0
Pendelton Island Beach	10	3	0	101	0	0	2	0
TOTAL: Pass. Bay & Western Passage	49	12	0	109	1	1	3	0
Fraiser Beach	2	1	1	7	0	4	2	0
Birch Cove, Frye I.	13	0	0	18	0	0	0	0
TOTAL: L'Etang Harbour	15	1	1	25	0	4	2	0
Lighthouse Pt., Beaver Hbr.	0	3	0	0	0	4	2	0
Seelys Cove	1	0	0	18	0	0	2	0
TOTAL: Southwest NB Shore	1	3	0	18	0	4	4	0

Table A7: PIMD: Metal and Wood Items

	METAL Crab or lobster traps	Metal Pens (cages)	Motors	Vessel Parts	Rusty METAL Drums	New METAL Drums	OTHER METAL ITEMS	WOOD Weir poles	WOOD finfish cages	WOOD Pen (cage) parts	WOOD Crates	WOOD pallets	WOOD Beams or planking	OTHER WOOD ITEMS
Birch Cove, Frye I.	0	0	1	0	0	0	0	0	13	0	0	0	0	3
Sandy Island	0	0	0	0	0	0	0	7	0	0	0	1	0	0
Simpsons Island	0	0	0	1	1	0	1	6	0	0	2	0	8	0
Indian Island	0	0	0	4	1	0	6	3	0	0	2	3	32	3
Ship Harbour, MacMaster I.	0	0	0	0	0	0	1	2	0	0	0	1	0	0
Lords Cove	1	0	0	2	2	0	3	2	0	3	2	3	29	6
Hardwood Island	0	0	0	0	1	0	1	3	3	0	1	1	27	0
TOTAL: West Isles Sites	1	0	0	7	5	0	12	23	3	3	7	9	96	9
Sherard Beach	0	0	0	0	0	0	1	9	0	0	0	4	36	1
Cummings Cove, Deer I.	0	0	0	2	0	0	0	0	0	3	0	3	15	1
Pendelton Island Beach	0	0	0	0	0	0	0	0	1	0	0	2	19	0
TOTAL: Pass. Bay & Western Passage	0	0	0	2	0	0	1	9	1	3	0	9	70	2
Fraiser Beach	0	0	2	2	0	0	10	0	0	0	0	1	7	3
Birch Cove, Frye I.	0	0	1	0	0	0	0	0	13	0	0	0	0	3
TOTAL: L'Etang Harbour	0	0	3	2	0	0	10	0	13	3	0	1	7	6
Lighthouse Pt., Beaver Hbr.	0	0	0	0	0	0	1	0	0	0	0	0	5	0
Seelys Cove	0	0	0	0	0	0	1	1	0	0	0	0	10	0
TOTAL: Southwest NB Shore	0	0	0	0	0	0	2	1	0	0	0	0	15	0

APPENDIX III: Domestic Marine Debris: Amounts Recorded on Data Cards for Five Study Sites

Table A8: Domestic Marine Debris: Plastic Items

DMD Data Collection Site Name	PIMD ITEMS	PLASTIC Bottles (beverage)	Plastic cleaner bottles	food bags	trash bags	Plastic buckets, containers	Plastic caps/ lids	Plastic cigarette lighters	Plastic Cups, utensils	Diapers (disposable)	Plastic 6-pack holders	Plastic strapping bands	Plastic straws	Syringes	Tampon applicators	Plastic toys	Plastic Sheeting >1m lengths	Other PLASTICS
Deer Island Point West Isles	**3**	4	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	23
Oven Head, Timber Cove, Passamaquoddy Bay	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sherard Beach, (PIMD collection site) Passamaquoddy Bay	165	**38**	5	1	0	3	12	2	3	0	1	1	0	0	1	4	1	8
Treinors Cove, L'Etang Harbour	**5**	2	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	2
Pocologan Hbr, Maces Bay, Southwest New Brunswick Coast	**3**	1	2	1	1	0	3	0	0	0	0	8	4	0	0	0	9	11

Table A9: Domestic Marine Debris: Foam and Glass Items

DMD Data Collection Site Name	FOAM Cigarette butts	Foam cups	Foam egg cartons	fast food containers	meat trays	Foam packaging	Foam Pieces	Foam plates	Other FOAM items	GLASS beverage bottles	glass food jars	florescent light tubes	Light bulbs	glass pieces	Other GLASS items	RUBBER balloons	Rubber gloves	Other RUBBER items
Deer Island Point, West Isles	8	0	0	0	0	0	4	0	0	0	0	0	0	11	1	0	0	0
Oven Head, Timber Cove, Passamaquoddy Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sherard Beach, (PIMD collection site) Passamaquoddy Bay	2	7	0	0	0	0	6	0	0	6	1	0	0	0	0	2	0	2
Treinors Cove, L'Etang Harbour	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0
Pocologan Hbr, Maces Bay, Southwest New Brunswick Coast	9	1	0	0	0	1	2	0	0	0	0	0	0	0	0	0	2	17

Table A10: Domestic Marine Debris: Metal and Paper Items

DMD Data Collection Site Name	METAL aerosol cans	beverage cans	bottle caps, pull tabs	Food cans	Metal pieces	Other METAL items	PAPER, WOOD, CLOTH bags	Boxes, cartons	Clothing, cloth	Paper cups	Furniture	Newspaper, magazines	paper, wood, cloth pieces	paper plates	Other PAPER, WOOD, CLOTH items	DMD TOTALS FOR EACH SITE
Deer Island Point, West Isles	0	0	1	0	0	0	2	0	1	1	0	0	47	0	3	223
Oven Head, Timber Cove, Passamaquoddy Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sherard Beach, (PIMD collection site) Passamaquoddy Bay	0	2	4	3	0	3	0	0	1	0	0	0	0	0	1	120
Treinors Cove, L'Etang Harbour	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	15
Pocologan Hbr, Maces Bay, Southwest New Brunswick Coast	0	1	2	0	0	4	0	3	8	4	0	0	9	0	2	105

Appendix IV: PIMD DATA RECORD SHEET

Date: Site Name: Time start: Time stop:

Industries Identified On Site:

GPS start: N W GPS finish: N W

Estimated distance inland that debris extends:

Appearance of the beach:

Items that can be traced to a specific source

Type of Item

Labels, Markings, Indicators

Source

Dead Animals (or entangled animals)

Animal/Species (if possible)	Entangling Debris	Comments

PAGE 2: PIMD Card **Site Name:** ____________________

Plastic, PVC, and fiber: Total

Bottles:

- bleach, cleaner ____________________ ( )
- oil, lube ____________________ ( )
- other ____________________ ( )

Feeder Pipes ____________________ ( )

Flotation Pipes ____________________ ( )

Totes ____________________ ( )

Feed /salt Bags ____________________ ( )

Floats ____________________ ( )

Fish boxes ____________________ ( )

Drums ____________________ ( )

Total

Net pens ____________________ ( )

Rope or Lines longer than 2m. ____________________ ( )

Nets longer than 1 m.

- Fishing ____________________ ( )
- Weir ____________________ ( )
- Aquaculture ____________________ ( )
- Other ____________________ ( )

Sheeting longer than 1 m. ____________________ ( )

Melted Plastic ____________________ ( )

Buckets ____________________ ( )

Other (specify) ____________________ ( )

Foam: Total

Sheets ____________________ ( )

Floats ____________________ ( )

Total

Packaging ____________________ ( )

Pieces ____________________ ( )

Other (specify) ____________________ ( )

Rubber: Total

Industrial tires ____________________ ( )

Total

Other (specify) ____________________ ( )

Metal: Total

Crab/lobster traps ____________________ ( )

Net pens ____________________ ( )

Motors ____________________ ( )

Vessel parts (specify) ____________________ ( )

Total

55-gallon drums

- rusty ____________________ ( )
- new ____________________ ( )

Other (specify) ____________________ ( )

Wood: Total

Weir Poles ____________________ ( )

Aquaculture pens ____________________ ( )

Pen parts ____________________ ( )

Lobster crates ____________________ ( )

Total

Pallets ____________________ ( )

Industrial Beams or planking ____________________ ( )

Other (specify) ____________________ ( )

Appendix V: DMD Data Record Card

Date: ____ **Site Name:** ____ **Time start:** ____ **Time stop:** ____

Estimated distance inland that debris extends: ____ **Comments:** ____

Plastic, PVC, and fiber:	Total		Total
Bottles:		Diapers ____	( )
Beverage ____	( )	6 - pack holders ____	( )
Household cleaner ____	( )	Strapping bands ____	( )
Food bags ____	( )	Straws ____	( )
Trash bags ____	( )	Syringes ____	( )
Buckets, containers ____	( )	Tampon applicators ____	( )
Caps, lids ____	( )	Toys ____	( )
Cigarette lighters ____	( )	Sheets > than 1 m. ____	
Cups, utensils ____	( )	____	( )
		Other (specify) ____	( )

Foam:	Total		Total
Cigarette butts ____	( )	Packaging ____	( )
Cups ____	( )	Pieces ____	( )
Egg cartons ____	( )	Plates ____	( )
Fast food containers ____	( )	Other (specify)	
Meat trays ____	( )	____	( )

Glass:	Total		Total
Beverage bottles ____	( )	Light Bulbs ____	( )
Food jars ____	( )	Pieces ____	( )
Florescent light tubes ____	( )	Other (specify) ____	( )

Rubber:	Total		Total
Balloons ____	( )	Other (specify) ____	
Gloves ____	( )	____	( )

Metal:	Total		Total
Aerosol cans ____	( )	Food cans ____	( )
Beverage cans ____	( )	Pieces ____	( )
Bottle caps pull tabs ____	( )	Other (specify) ____	( )

Paper, Wood, Cloth:	Total		Total
Bags (paper) ____	( )	Newspaper,	
Boxes, cartons ____	( )	magazines ____	( )
Clothing, cloth ____	( )	Pieces ____	
Cups ____	( )	____	( )
Plates ____	( )	Other (specify) ____	( )
Furniture ____	( )		

Appendix VI: Relevant Legislation

Canadian Acts and Regulations

Fisheries Act (1985) & Maritime Provincial Fisheries Regulations (SOR/93-55) & R.S., c.F-14, s.1.

The Fsheries Act is administered by the Department of Fisheries and Oceans. One of the purposes of the Fisheries Act is to protect fish and marine organisms and habitat from the discharge of harmful or deleterious substances. Particular sections of the Act address the deposit of deleterious substances. Under the Fishery Act a "deleterious substance" is identified as:

- Any substance that, if added to any water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water, or
- Any water that contains a substance in such quantity or concentration, or that has been so treated, processed or changed, by heat or other means, from a natural state that it would, if added to any other water, degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water.

In terms of coastal resource use activities related to the accumulation of PIMD, the following sections of the Fisheries Act are relevant.

Section 35:	Authorization for habitat destruction.
Section 36:	Disposal of deleterious substances in water frequented by fish.
Section 37:	Allows Minister to request plans, documentation etc... relating to activities that may pollute waters frequented by fish.
Section 42 (3):	Where not authorized under Section 36 - owners of the deleterious substance must compensate for loss of income to licensed commercial fishers.

The Fisheries Act has very direct relevance to coastal resource use activities of significe to PIMD issues. Sections 35, 36, and 37 are directly relevant to the aquaculture, lobster, and fish processing industries. However, all the Fisheries Act sections mentioned above are directly relevant to aquaculture, and section 42 is directly relevant to net or line fishing. In addition, the Minister can require submission of plans and specifications related to new or modified structures and facilities such as processing plants, pounds, and aquaculture sites. However, with regard to the disposal of materials, the Canada Shipping Act covers ship source marine pollution. (VanderZwaag 1992).

The Oceans Act
Oceans Act, Chapter 1996, C- 31

The purpose of this Act is to facilitate and promote the protection, understanding, and study of the oceans of Canada and their resources. Under the Oceans Act, the Canada Wildlife Act is also amended to protect the marine environment by establishing protected areas in any part of the internal waters and territorial seas of Canada. The three mechanisms that facilitate management and preservation of resources under the Act are: 1. the Oceans Management Strategy, 2. Integrated Management Plans, and 3. Marine Protected Areas.

The Ocean Management Strategy (OMS) is a national strategy for Canadian marine ecosystems. It promotes principles of sustainable development, integrated management, and the precautionary approach. Integrated Management Plans (IMPs) may be developed under the OMS and implemented through consultations with other federal, provincial and territorial government agencies. In addition aboriginal groups, coastal communities, and other interested groups are included in consultations on developing and implementing IMPs.

Through these processes marine environmental quality guidelines, objectives and criteria are established with respect to estuarine, coastal, and marine waters. Through the IMP Marine Protected Areas (MPAs) may be designated in order to conserve and protect fisheries, endangered or threatened marine species, areas of high biodiversity or biological productivity, and related habitats, as well as unique habitats or other areas important to the Minister's mandate.

Relevance of Fishery Regulations to PIMD

All fisheries activities are relevant to the three main elements of the Oceans act. This is most obviously due to the fact that PIMD is not static in the dynamic coastal environment - it will be carried by tides, currents, or wind into areas that are considered under IMPs or may be designated as MPAs. Proposals for IMAs and MPAs in the Passamaquoddy may include sites of fish farming aquaculture, weirs, or lobster pounds.

Canadian Environmental Assessment Act, S.C. 1992, C.37 (CEAA)[39]

The Canadian Environmental Assessment Act sets out the responsibilities and procedures for the environmental assessment of projects involving the federal government. The Act was passed in 1992 and proclaimed in 1995. It replaced the Federal Environmental

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[39] CEAA Regulations: Comprehensive Study List Regulations, SOR/94-638, Exclusion List Regulations, SOR/94-639, Federal Authorities Regulations, SOR/96-280, Law List Regulations, SOR/94-636, Inclusion List Regulations, SOR/94-637, Projects Outside Canada Environmental Assessment Regulations, SOR/96-491, Regulations Respecting the Coordination by Federal Authorities of Environmental Assessment Procedures & Requirements, SOR/97-181, Canada Port Authority Environmental Assessment Regulations, SOR/99-318

Review Office (FEARO). The Act is used to assess new or significantly modified projects that have a potential to affect the environment above a particular threshold. A project must be assessed under the CEAA if the federal government is involved. Federal involvement in a project includes: Project proposal by a federal department of agency; a grant of financial support to the project; grant, sell, lease or transfer of a land interest to a proposed project; permit or license issuance defined in the Law List Regulations.

The CEAA is applicable when there is a project, a trigger, or a responsible agency and it must not be excluded under the Act's exemption clauses. This act applies to aquaculture and fish processing facilities. It indirectly relates to fish weirs, lobster pounds, and line or net fishing in that the locations of such operations must be identified when located in areas in and around proposed activites that are the subject of an environmental assessment under the CEAA. Several provisions (i.e. re-licensing) may reduce the applicability of the Act to disposal of PIMD at existing facilities through procedures approved under CEAA requirements. PIMD related issues that could trigger the Act, at least at the screening stage may include:

- Construction of new solid waste management facilities.
- Reconstruction or relocation of facilities such as incinerators or recycling plants.
- Significant changes to operation procedures potentially affecting habitat.
- Decommissioning of waste management sites.

Two sections of legislation that are most likely to trigger this Act are Section 35(2) of the Fisheries Act (dealing with habitat destruction) and section 5 of the Navigable Waters Protection Act (loss of debris in navigable waters).

Canadian Environmental Protection Act

Through this Act the federal government promotes the protection of the environment as essential to the well being of Canadian people. All activities on federal lands that are of potential harm to the environment require licences, permits, or Ministerial approval. The description of "federal land" in the Act includes all internal waters and territorial seas of Canada.

The CEPA is directly related to PIMD management since the Ocean Dumping Control Act has been subsumed under its authority. Where an individual or company has no federal consent or approval and perpetrates serious harm to the environment on federal land appropriate measures such as fines or incarceration may be enforced under the CEPA. However most issues related to marine debris are usually met through other federal legislation (i.e. Fisheries Act).

Navigable Waters Protection Act and Navigable Waters Works Regulations (CRC c, 1232)

The Navigable Waters Protection Act ensures the protection of navigable waters in Canada by forbidding works on or near navigable waters - unless the Department of Fisheries and Oceans approve such works. The term "works" includes any:

- Bridge, boom, dam, wharf, dock, pier, tunnel or pipe and the approaches or other works necessary;
- Dumping of fill or excavation of materials from the bed of a navigable water;
- Telegraph or power cable or wire; or
- Structure, device or thing that may interfere with navigation

This act is most relevant to aquaculture, lobster pounds, and herring weirs, since these activities and associated equipment and structures are most likely to interfere with navigation. Each of these activities could release a "structure, device, or thing that may interfere with navigation." Most environmental issues related to such loss or releases are addressed under the Federal Fisheries Act or the Provincial Environment Act. The Navigable Waters Protection Act approval relates more to the actual obstruction to navigation by a permanent structure or alteration of a structure.

<u>Province of New Brunswick Requirements</u>

Provincial acts significant to PIMD issues include the New Brunswick Aquaculture Act and the New Brunswick Clean Environment Act.

New Brunswick Aquaculture Act

In 1998, the Province of New Brunswick signed a Memorandum of Understanding for aquaculture development, which calls for the establishment of an Aquaculture Management Committee and Subcommittees of other bodies (Coffen *et al* 1992). The New Brunswick Department of Fisheries and Aquaculture administers the Aquaculture Act. Application for aquaculture or related operations are made under the following categories:

- Lease or Occupation Permit and License;
- License for a sub occupancy arrangement;
- Boundary amendment to lease;
- Production increase license;
- Species amendment to license;
- License for a lobster pound for species other than lobster;
- Transfer of lease or license.

All aquaculture applications submitted under this act must first be reviewed by the Aquaculture Site Evaluation Committee (ASEC). This committee is comprised of representatives from Fisheries and Oceans Canada, Environment Canada, the Canadian Wildlife Service, the Canadian Coast Guard, the Atlantic Canada Opportunities Agency, as well as the New Brunswick departments of Environment & Local Government, Natural Resources & Energy; and Agriculture, Fisheries & Aquaculture. Through the N.B. Aquaculture Act activities relevant to aquaculture and lobster pounds that are no longer used for lobster are regulated. Regulations under this act require an environmental operational plan upon site application and must include a waste management component.

The waste management component must identifie how the operator plans to deal with common garbage and obsolete materials and includes a schedule for clean-up of any beach debris originating from site operations. However, only the items and material that make it to shore are dealt with. Shoreline adjacent to marine aquaculture sites are also granted as anchoring and storage areas through licences issued under this act. This may perpetuate PIMD in that some areas are used as landfill and incineration sites. Improperly anchored materials could be carried away by the tide and deposited some where else. This creates a PIMD problem in other areas of the bay. In addition, these plans are implemented by people employed at the site so the results of monitoring may be biased.

New Brunswick Clean Environment Act

This Act deals with waste, solid waste and the danger of pollution, and describes industrial waste as "any liquid, solid or other waste, or any combination thereof, resulting from any process of industry or manufacture or the exploration for, or development of, a natural resource and includes ... useful or waste material from a danger of pollution that becomes a contaminant".

The focus of the Act is on the responsibility of the polluter to clean up or remediate the problem, or reimburse the government for so doing (Section 5). In addition, section 15(1) allows agreements to be made with the federal and provincial governments, state governments (U.S.), as well as at the municipal and individual level. Under this Act, the minister may also assist in the operation and management of solid waste collection and disposal facilities (Section 15.1. (1))..

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