Marine transport activity in the vicinity of the St Anns Bank area of interest: potential impact on conservation objectives

By

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The undersigned hereby certify that they have read and recommend to Marine Affairs Program for acceptance a graduate research project titled “Marine transport activity in the vicinity of the St Anns Bank area of interest: potential impact on conservation objectives” by Jana Marie Aker in partial fulfillment of the requirements for the degree of Master of Marine Management.

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Abstract

The St Anns Bank area of interest (AOI) on the Eastern Scotian Shelf was announced in June 2011 and will be designated as the next marine protected in Atlantic Canada. The AOI is intersected by dense commercial vessel traffic that has the potential to negatively impact on some of the conservation objectives associated with a marine protected area. The potential impacts include vessel-sourced pollution, oil spills, vessel strikes to marine organisms, and vessel noise pollution. My study determined that there is a quantitatively measurable relative probability of oil spills occurring from vessels in a defined study area that encompasses the AOI. I also determined that there is a high relative probability of vessel strikes to leatherback turtles within the AOI and this raises vessel management concerns as leatherbacks are listed as an endangered species under the *Species at Risk Act*. In addition, I determined that vessel noise represents a potential and measurable impact to whale species within the AOI, though available data for whales, including abundance, distribution and temporal residency, within AOI is lacking. Though I have identified specific impacts within the area, a more comprehensive and quantitative assessment of the potential impacts is required prior to the consideration of vessel navigation management that could be implemented by the International Maritime Organization that would reduce potential impacts.

Keywords: area of interest, marine protected area, vessel traffic, vessel impacts, International Maritime Organization, leatherback turtles, whales, seabirds

List of abbreviations used

AIS	Automatic Identification System
AOI	Area of Interest
DFO	Fisheries and Oceans Canada
HNS	Hazardous and Noxious Substances
HTP	Habitual traffic patterns
IMO	International Maritime Organization
IUCN	International Union for the Conservation of Nature
MARPOL	Convention for the Prevention of Pollution from Ships
MPA	Marine Protected Area
NASP	National Aerial Surveillance program
PSSA	Particularly Sensitive Sea Area
SARA	Species at Risk Act

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Chapter 1: Introduction

Marine protected areas (MPAs) are being designated on a global scale to conserve and protect specific habitats, species, diversity, and ecologically 'significant' regions of the oceans. Canada is surrounded by three oceans and has one of the largest exclusive economic zones and this implies that there are many areas of the oceans that may warrant protection. The St Anns Bank region on the Eastern Scotian Shelf will likely be the next MPA designated in the Canadian North West Atlantic. This MPA will be different from other MPAs in Atlantic Canada in that the area of interest (AOI) is intersected by relatively dense commercial vessel traffic. Vessel traffic may negatively impact the marine environment associated with the MPA by introducing pollution and oily substances, oils spills caused by accidents or intentional discharge, vessel strikes to large pelagic organisms, and vessel noise pollution.

In this study I assess vessel traffic patterns in and around the St Anns Bank AOI to determine where, when and what kind of negative impacts may occur. Automatic Identification System (AIS) data collected from the Dalhousie University receiving tower in Glace Bay, Nova Scotia will be used to analyze the vessel traffic in the vicinity of the St Anns Bank AOI. As MPAs are designed to offer protection to the marine environment it is essential to determine the nature of risks present within an area and use the insights to inform the management of vessel traffic within the MPA so that protection may be enhanced.

Chapter 2: Marine Protected Areas

2.1 Definition and purpose

Marine protected areas can be defined as "any area of intertidal or subtidal terrain, together with its overlying waters and associated flora, fauna, historical and cultural features, which has been reserved by legislation to protect part or all of the enclosed environment" (Kelleher, 1999). These protected areas have been referred to as marine reserves, closed areas, marine parks and marine sanctuaries (Agardy, 2000). For the purposes of my study, they will be referred to as marine protected areas or MPAs. Marine protected areas represent a regulatory management tool that offers protection for a particular ecosystem that could contain habitat for endangered marine organisms, sensitive habitat, or important commercial fish species habitat (Hoagland, Sumaila & Farrow, 2010). MPAs can be used to help restore populations of exploited commercial fish species and they can also be established to resolve conflicts that exist between parties that make use of a particular area for exploitation or exploration purposes (Agardy, 2000). MPAs follow similar principles used for terrestrial parks and protected areas, but they are substantially more complicated because of the diversity, the temporal and spatial connectivity among organisms and species, and the fluidity of the three-dimensional space that the marine environment encompasses. The boundaries of many terrestrial parks often have few access points, while the boundaries of an MPA are entirely open. Thus it can be much more difficult and expensive to monitor and enforce with respect to the activities that occur within the protected area.

The primary global authority on how marine protected areas are categorized is the International Union for the Conservation of Nature (IUCN); an agency that has developed a series of categories for the conservation status of a protected area (Table 1) (Dudley *et al.,* 2010).

Table 1. A summary description of the IUCN categories for protected areas as adapted from Dudley *et al.* (2010).

Category	Description
Ia – Strict nature reserve	Highest level of protection, minimal human use activities permitted
Ib – Wilderness area	Preservation of the natural condition of an area, limited human activities permitted
II – National park	Protection of a large, ecologically significant area, non-extractive human uses permitted (ex. research, education, recreation, etc.)
III – National monument or feature	Protection of a specific ecological or geological monument, such as a seamount or a submarine cavern.
IV – Habitat / species management area	Protection of a specific habitat or species
V – Protected landscape / seascape	Protection of an area that is ecologically, biologically and/or culturally significant
VI – Protected areas with sustainable use of natural resources	Lowest level of protection. Protection of an area with sustainable human extractive uses allowed.

Marine protected areas are not limited to one specific IUCN management protection category; they can contain multiple use areas with varying categories of protection. MPAs can be established as a category Ia and not allow any human activities but they can also be divided into zones and each zone can offer a different level of protection or an IUCN management category. Zoning allows for the areas of special significance to be protected under the highest category, but also offers protection to other areas while allowing some sustainable uses of the environment that existed prior to the designation of the MPA (Agardy *et al.,* 2003). An example of a zoned MPA would be the Gully MPA located at the shelf break of the Eastern Scotian Shelf. The Gully is divided into three specific zones, each with a different category of protection (Fisheries and Oceans Canada, 2007). Zone 1 encompasses the deep-water canyon and is restricted to all activities with the exception of research (i.e. Category Ia). Zone 2 encompasses the canyon walls, the head and the mouth of the canyon and would be considered a category IV zone as some fishing is allowed as long as there is no habitat damage upon removal of fish species. Zone 3 includes the banks on both sides of the canyon and acts as a buffer zone for the marine protected area and the main focus of this zone is sustainable use and therefore would be considered a category VI zone (Fisheries and Oceans Canada, 2007; VanderZwaag & Macnab, 2009).

Allowing certain activities within the perimeter of an MPA, such as sustainable fisheries, can aid in the acceptance and compliance of stakeholders that had previously relied on that area for their livelihoods. Zoning can also provide a mechanism where particularly sensitive areas can be set aside and declared a category I (i.e. Zone 1 of the Gully) while less sensitive areas within the MPA can be placed in lower categories (i.e. Zones 2 and 3 of the Gully) and allow human uses (Salm, Clark & Siirila, 2000). Multiple use MPAs are an ideal method of providing protection to a certain ecosystem or species while maintaining some sustainable uses within the boundaries of the MPA.

2.2 Oceans Act MPAs

Marine protected areas in Canada are designated through the *Oceans Act* (1996) and are managed and regulated by Fisheries and Oceans Canada (DFO) (Fisheries and Oceans Canada, 2010). The *Act* defines a marine protected area as "an area of the sea that forms part of the internal waters of Canada, the territorial sea of Canada or the exclusive economic zone of Canada and has been designated for special protection under the *Oceans Act* for one or more reasons" (Oceans Act, 1996). The reasons can include the conservation and protection of commercial and non-commercial fish and marine mammal species and their habitats, endangered or threatened species and their habitats, unique habitats, and marine areas of high biodiversity or biological productivity (*Oceans Act*, 1996). The National Framework for Establishing and Managing Marine Protected Areas was developed through the *Oceans Act* and it is through this framework that the establishment process for marine protected areas begins (Government of Canada, 2005).

The Minister of Fisheries and Oceans Canada has the responsibility of overseeing the process for marine protected area establishment. The process begins with the selection of an area of interest that must encompass areas with high biological productivity or biodiversity, commercial or non-commercial fish and marine mammal species, and threatened or endangered species and their required habitats (Government of Canada, 2002). Once selected, AOIs must be evaluated and a candidate AOI is selected for MPA designation. A management plan for the candidate area that includes input from stakeholders then has to be developed. The area is then designated as an MPA and managed by Fisheries and Oceans Canada (Fisheries and Oceans Canada, 2010); the process is detailed further in Chapter 2.

Currently there are eight MPAs and eight AOIs established in Canada (Figure 1).

Figure 1. Map of Canada illustrating the location of eight marine protected areas and eight areas of interest (Fisheries and Oceans Canada, 2011a).

In the Maritimes region there are currently three marine protected areas; the Musquash estuary in New Brunswick, Basin Head in Prince Edward Island, and The Gully located on the Eastern Scotian Shelf and they are part of Canada's MPA network (Fisheries and Oceans Canada, 2011a).

2.3 MPA network

A marine protected area network is defined as "a collection of individual marine protected areas that operate cooperatively and synergistically, at various spatial scales, and with a range of protection levels, in order to fulfill ecological aims more effectively and comprehensively than individual sites could alone" (Fisheries and Oceans Canada, 2011b). When networks are well planned they can act to improve ecosystem functioning through connectivity among MPAs (IUCN-WCPA, 2008). Some of the direct benefits of MPA networks include maintaining natural species ranges, aiding in the protection of endangered species over a fragmented habitat, and they can promote cultural heritage and aid in trans boundary conservation efforts (Fisheries and Oceans Canada, 2011b). Network planning in Canada is currently being conducted with 13 ecologically distinct bioregions that are illustrated in Figure 2.

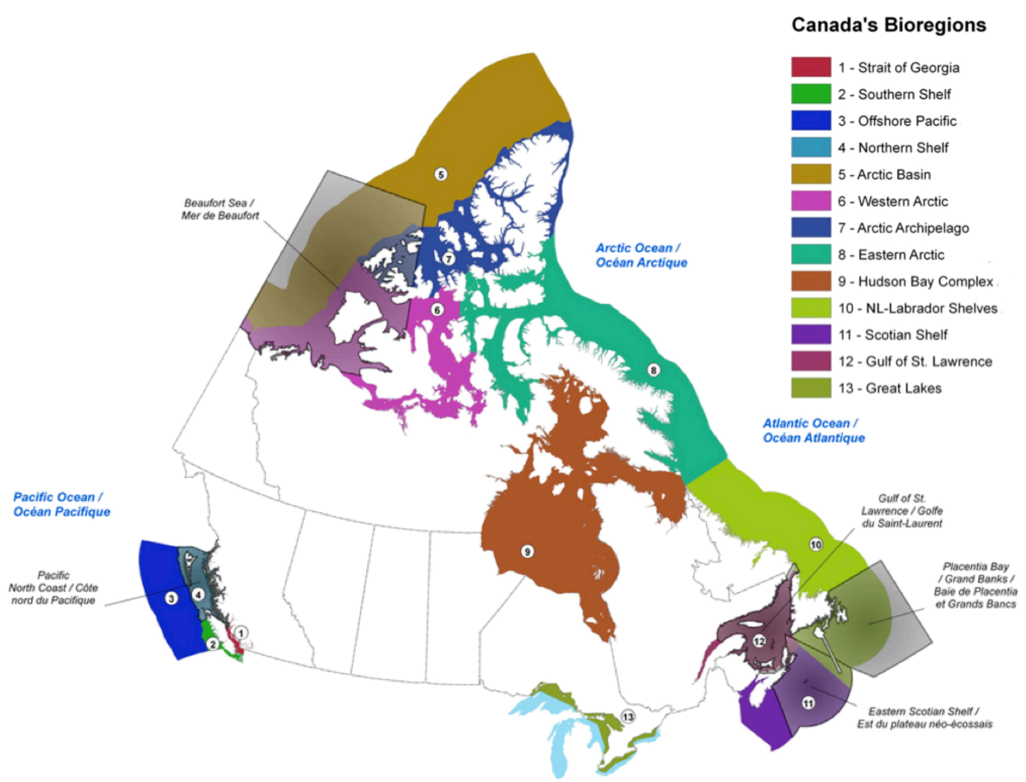

Figure 2. An illustration of Canada's ecologically distinct bioregions for marine protected area network planning (Fisheries and Oceans Canada, 2011b).

MPA network planning in the Maritimes Region is being conducted within bioregion 11 – Scotian Shelf. The Scotian Shelf and the Newfoundland and Labrador Shelves currently contain the highest number MPAs and AOIs in Canada contributing the most to Canada's MPA network and St Anns Bank will be the next MPA added to the network.

Chapter 3: St Anns Bank area of interest

3.1 Area of interest

An area of interest is an area that meets the criteria for consideration as a marine protected area. The AOI is the first of a number of steps towards the establishment of an MPA (Fisheries and Oceans Canada, 2010). AOIs can be selected through ecosystem overviews, fisheries management initiatives or proposals from stakeholders that can be submitted by Fisheries and Oceans Canada and a suite of non-governmental organizations (Fisheries and Oceans Canada, 2010). There are six steps involved in the creation and establishment of an MPA; 1) identify the AOI, 2) initial screening, 3) evaluation and recommendations, 4) management plan development, 5) MPA designation, and finally 6) the ongoing management of the area (Fisheries and Oceans Canada, 2010). The reader may wish to review the details relevant to each step as provided in Table 2.

Table 2. Steps required for an area of interest to become an established marine protected area, adopted from Fisheries and Oceans Canada, 2010.

Step 1	Identification of an AOI through proposal put forward to Fisheries and Oceans Canada. The AOI must encompass areas that are biologically significant, habitat for commercial fish species and marine mammals, habitat for endangered or threatened species, etc.
Step 2	Initial Screening of AOIs. Screening involves determining the location of the AOI and how the AOI meets the requirements for an MPA laid out in Section 35 of the *Oceans Act* and further information is collected from the area including potential management measures and potential stakeholder involvement. Interim protection of the area can be put in place during the MPA establishment process. Protection can come in the form of fisheries closures, activity restrictions, stakeholder notices or wildlife protection measures.
Step 3	AOI evaluation and recommendation. This step involves ecological, technical and socio-economic assessments to determine if the area is ecologically significant and meets the criteria for protection, if the area is feasible in terms of management strategies and to determine what the human uses that are currently occurring within the boundaries of the area, such as fisheries and oil and gas exploration. The costs of establishing an MPA are assessed in this step. Based on these assessments, recommendations will be made to either move forward with the MPA establishment process or stop the process.
Step 4	Development of a management plan. The management plan has to incorporate how the area will be enforced, how the area will be zoned, what category of protection the area will have, where the funding for the area will come from, what types of activities will be permitted within the area and how current activities will be impacted.
Step 5	Designation of MPA. The designation of the MPA is done through Section 35 of the *Oceans Act* and the regulations within the MPA have to be implemented and enforced.
Step 6	Management of the MPA. Regular research, monitoring and enforcement will be ongoing for the MPA as well as carrying out the management plan. The MPA will undergo a periodic review and evaluation to determine the success of the MPA and the management plan.

3.2 St Anns Bank

The St Anns Bank AOI was announced as an MPA candidate on 08 June 2011 by the Minister of Fisheries and Oceans and it is currently at step four of the six-step process toward MPA designation. Fisheries and Oceans Canada selected St Anns Bank as an AOI through a series of analyses that included ecological and environmental factors as well as socio-economic factors. These analyses were used to develop a systematic method of determining marine areas that are best suited for conservation (Fisheries and Oceans Canada, 2010). A Marxan analysis (University of Queensland, 2012) was used to identify ecologically significant areas for potential AOIs on the Eastern Scotian Shelf that could become a part of the MPA network (Horsman, Serdynska, Zwanenburg & Shackell, 2011). Marxan was initially developed for the Great Barrier Reef Marine Planning Authority to aid in the re-zoning process of the Great Barrier Reef MPA (University of Queensland, 2012). The Marxan analysis identified several areas on the Scotian Shelf based on a variety of scenarios and criteria. Areas that were selected in multiple scenarios or from multiple criteria were best suited to meet the goals and objectives of the MPA network (Fisheries and Oceans Canada, 2009). Figure 3 illustrates the results of the Marxan analysis for the Scotian Shelf.

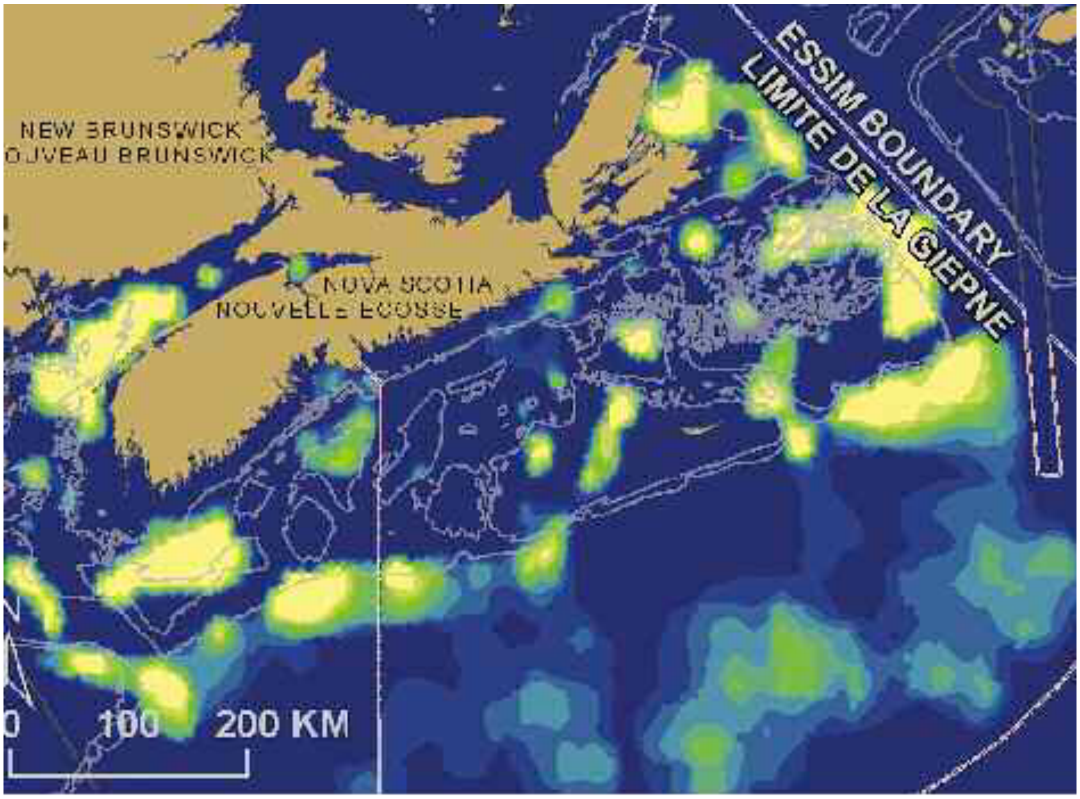

Figure 3. Resulting map from the Marxan analysis that was conducted on the Scotian Shelf. Green areas indicate ecologically important areas where the MPA network planning goals would best be met (Fisheries and Oceans Canada, 2009).

The green areas shown in Figure 3 represent the locations on the Scotian Shelf that are best suited for marine protected areas under the scenarios of the Marxan analysis. This map was used as a template for AOI selection on the Eastern Scotian Shelf. Fisheries and Oceans Canada analyzed each of the areas identified by the Marxan analysis and selected three areas that best met the goals and objectives for the MPA network as candidate AOIs (Figure 4).

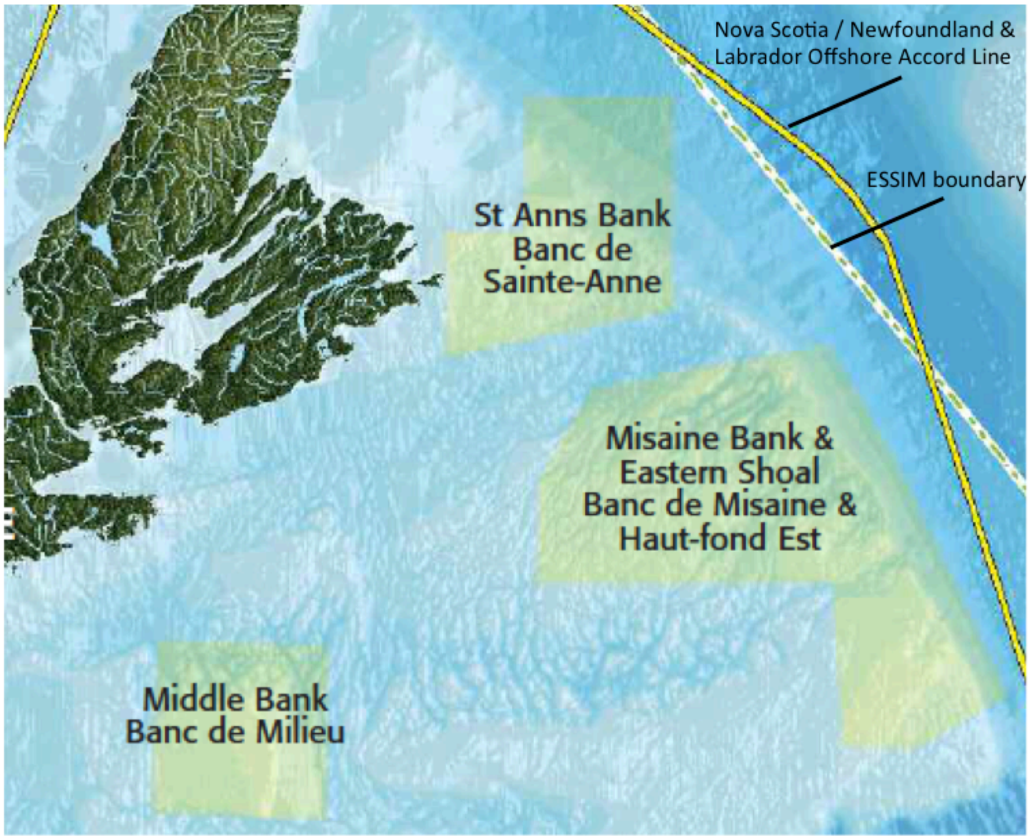

Figure 4. An illustration of the candidate areas of interest that were selected by Fisheries and Oceans Canada from the Marxan analysis (Fisheries and Oceans Canada, 2009).

Public consultations with various stakeholder groups from each of the three areas were held over a period of eight months to determine which of the three areas was best suited ecologically and had the least socio-economic impact on stakeholder groups. Following the consultation period, St Anns Bank was selected to be the area of interest (Fisheries and Oceans Canada, 2011c). Through the remainder of this paper, St Anns Bank is referred to as the AOI and interchangeably as an MPA though the AOI in the process of becoming an MPA and has yet to be established as such.

The St Anns Bank area of interest encompasses an area of 5100 km^2 and is located off of the east coast of Cape Breton Island and will eventually become Atlantic Canada's fourth marine protected area (Fisheries and Oceans Canada, 2011d). St Anns Bank was selected, in part, because it enveloped three bathymetric habitat types, Scatarie Bank, St Anns Bank and a portion of the Laurentian Channel. The area surrounds habitat associated with several commercial fish species including Atlantic cod (*Gadus morhua*) as well as the American plaice (*Hippoglossoides platessoides*), white hake (*Urophycis tenuis*), witch flounder (*Glyptocephalus cynoglossus*) and redfish (*Sebastes* spp.) (Fisheries and Oceans Canada, 2011e). The AOI also encompasses summer feeding ground for the leatherback sea turtle (*Dermochelys coriacea*) and habitat for the Atlantic wolfish (*Anarhichas lupus*); both species are listed as at risk under the Species at Risk Act (SARA) (Government of Canada, 2012). St Anns Bank is also a part of an important corridor for fish and marine mammal migration to and from the Gulf of St. Lawrence (Fisheries and Oceans Canada, 2011e).

The conservation objectives within the AOI are primarily the protection of all habitat types, biodiversity, and productivity. The specific conservation objectives (Table 3) include the three distinct, bottom habitat types as well as sponge and sea pen concentrations. Within the biodiversity category, DFO has identified key species for protection that consist of depleted fish species and the endangered leatherback turtle. Within the productivity category, it is important to recognize that top predators include marine animals such as sharks, whales, and seabirds (Fisheries and Oceans Canada, 2012).

Table 3. Conservation objectives set by Fisheries and Oceans Canada for St Anns Bank marine protected area (Fisheries and Oceans Canada, 2012).

Main Category	Specific Conservation Objective
Habitat	Inshore bank habitats
	Shelf habitats
	Slope/channel habitats
	Sponge concentrations
	Seapen concentrations
Biodiversity	Fish diversity hotspot
	Atlantic cod
	Atlantic wolffish
	Atlantic redfish
	American plaice
	Leatherback turtles
Productivity	Primary producers
	Zooplankton
	Benthic invertebrates
	Planktivorous fish
	Demersal predatory fish
	Top predators

Chapter 4: Marine transportation and potential impacts

The global marine transportation industry is continually increasing and improving as the global population continues to rise and the demand for goods increases. The marine transportation industry is responsible for carrying over 90% of international trade across the world's oceans (International Maritime Organization, 2012). Cargo ships and bulk carriers make up the majority of the vessels in the global fleet, followed by crude-oil tankers (UNCTAD, 2011). Passenger and cruise vessels account for 13% of the fleet, and represent a growing industry worth $32 billion in the United States alone (Copeland, 2010). In the Maritimes Region, the marine shipping sector contributes $0.5 billion to the annual Canadian Gross Domestic Product and employes approximately 10,000 people (CPCS Transcom Limited, 2012).

Vessels have the potential to negatively impact the marine environment through oil spills from accidental or deliberate discharge, input of vessel sourced pollution and garbage, ballast water exchange, vessel strikes to marine animals, and anthropogenic noise pollution. Dense vessel traffic transits the St Anns Bank AOI and thus it is necessary to determine the number, class, and frequency of vessels transiting the area and identify the potential impacts that vessels may present to the conservation objectives associated with the MPA.

4.1 Ballast water

Vessels are built to carry large amounts of cargo and the stability of a vessel is best when fully ballasted; i.e. laden to capacity with cargo. When a vessel travels below cargo capacity a method is needed to add mass to the vessel to maintain optimum stability

(Government of Canada, 2010). Adding water as 'cargo' is the most practical method of adding mass as it is readily available and can be pumped on and off (discharged) of the vessel as needed and at any time, as long as the weather conditions are suitable. However, the use of water as ballast can result in the transfer of organisms, diseases, and sediments from one area of the world to another (Atlantic Bureau of Shipping, 2011). In some cases, species can adapt to the new conditions and become an invasive species. In fact, the majority of known aquatic invasive species have been introduced through ballast water discharge (Buck, 2010). One of the main methods used to minimize species introductions is through ballast water exchange, where a vessel completely discharges and refills the ballast tanks on the open ocean, far from potentially suitable habitat (Government of Canada, 2010). Most ports have a lower salinity content than the open ocean and exposure to high salinity water is meant to kill any organisms that are not tolerant to high salinity environments (Gray *et al.*, 2007). However, as some organisms are able to survive the ballast exchange process, it is not considered the most effective method. Ballast water exchanges could also introduce contaminated water from other ports into the area that could have negative impacts.

In Canada, there are regulations governing where ballast water exchange is permitted to occur: outside of the 200 nautical mile (nmi) limit, in water that is at least 2000 metres deep, with a minimum salinity of 30 parts per thousand. Alternative exchange zones exist within the 200 nmi limit if conditions outside of the 200 nmi limit do not allow for a safe ballast water exchange (Canada Ballast Water Control and Management Regulations, 2012). There is an alternative ballast water exchange zone in the Cabot Strait over the Laurentian Channel that overlaps with the northeast extent of the AOI (Figure 5).

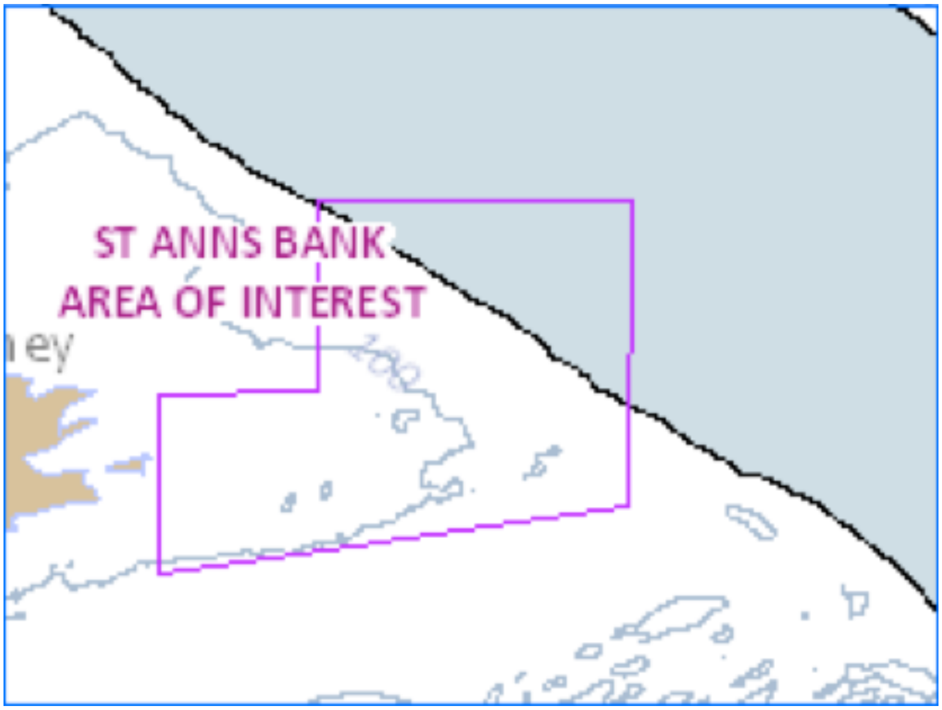

Figure 5. Map illustrating the overlap between the St Anns Bank AOI polygon and the Laurentian Channel alternative ballast water exchange zone (grey area). Note: There are no specific boundaries for the alternative exchange zone. Source: Oceans and Coastal Management Division, Fisheries and Oceans Canada, in consultation with Transport Canada, Atlantic Marine Safety Division.

Although this alternative exchange zone is regulated for use during the period of 01 December to 01 May when the conditions are least favorable for foreign organisms to survive (Ballast Water Management Control and Management Regulations, 2011), there clearly remains the potential for a foreign species introduction. Though survival is unlikely due to salinity levels, the presence of Nova Scotian Coast Current (that has its origin in the region) there remains the potential that a species could become established within the area and subsequently negatively impact native species within the AOI and elsewhere along the coast of Nova Scotia. For example, if an invasive jellyfish species became established in the region, it could outcompete the native species and reduce the amount of available food to leatherback turtles – a species that preferentially feeds on jellyfish. This would be a direct impact on the conservation objective for leatherbacks in the MPA. Though improbable given the current understanding, such an event is not impossible and thus risks associated with ballast water exchanges remain within the vicinity of the MPA and recommendations on how to further decrease such risks are addressed Chapter eight.

4.2 Accidents

Scatarie Island (Figure 6) has historically presented itself as a risk to mariners navigating around Cape Breton Island. An overview of the shipwrecks that have occurred on Scatarie Island since the 1900's is provided in Table 4.

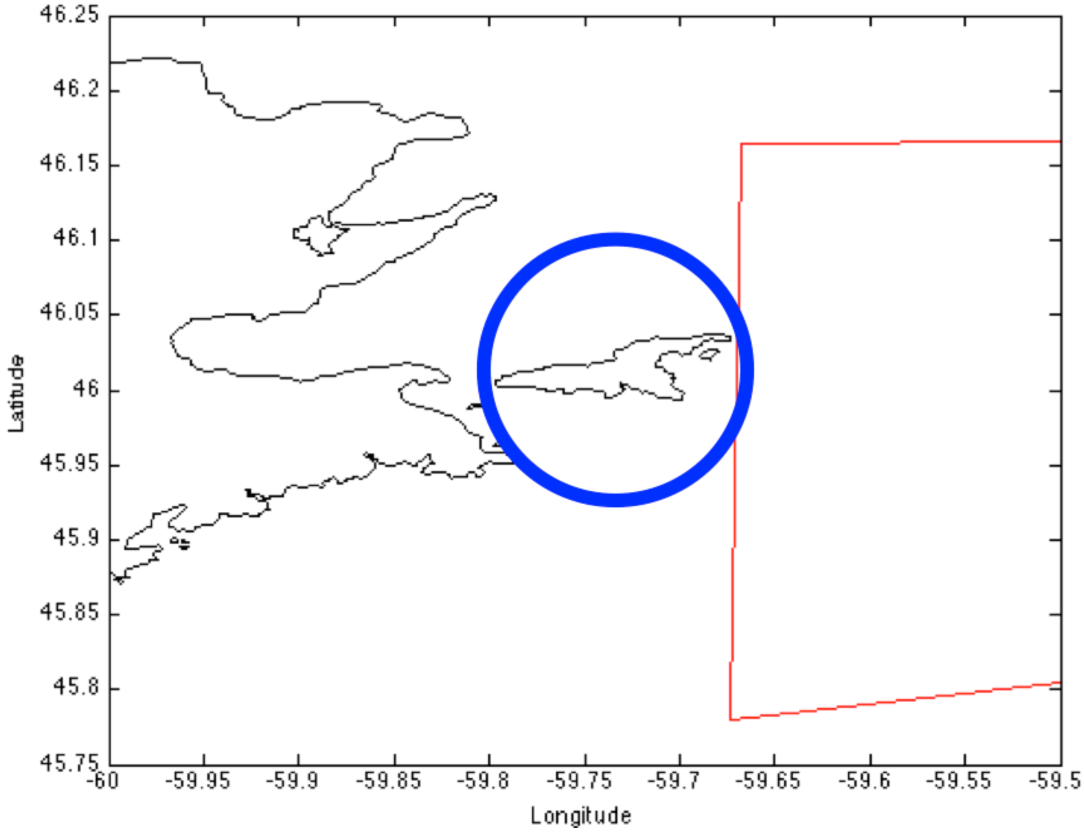

Figure 6. Coastline chart illustrating the location of Scatarie Island (encircled in blue) in relation to the western boundaries (red lines) of the St Anns Bank AOI.

Table 4. List of shipwrecks from Scatarie Island from 1903 to present (Maritime Museum of the Atlantic, 2007; McNeil, 2011).

Vessel Name	Vessel Type	Date	Cause
Amity	Barque	April 1903	Ice
Leone	Schooner	May 1904	Stranded
Samuel Drake	Schooner	September 1905	Foundered
Flora W. Sperry	Schooner	April 1907	Foundered
Jeanie Myrtle	Schooner	September1907	Stranded
Scepter	Schooner	October 1907	Stranded
SS Bruce	Ferry	March 1911	Ice
St. Roch	Schooner	April 1912	Stranded
Cienfuegos	Steam	July 1914	Stranded
Polar Land	Steam	November 1919	Foundered
Cape Breton	Collier	March 1920	Grounded
Yport	unknown	September 1923	Stranded
Curlew	unknown	December 1924	Stranded
Ringhorn	Steam	August 1926	Stranded
Moon	unknown	September 1926	Stranded
Adriatique	unknown	July 1927	Stranded
Admiral Drake	unknown	November 1927	Stranded
Judique	unknown	November 1928	Sank
Carranza	unknown	September 1930	Foundered
Ciss	Freighter	February 1940	Ice
R.B. Bennett	Schooner	May 1942	Stranded
Carolyn A.	unknown	December 1968	Foundered
Tammy Lynn Iv	Fishing	September 1980	Grounded
MV Miner	Bulk carrier	September 2011	Grounded

The proximity of Scatarie Island to the AOI raises concerns for vessel groundings resulting in the input of pollutants into the MPA environment. Between 1902 and 1942, there were an average of 0.57 wrecks on Scatarie per year. This number has significantly decreased with the advent of modern maritime navigational methods and equipment with an average of 0.04 wrecks per year between 1943 and 2011. The two most recent events were the grounding of the fishing vessel Tammy Lynn and the *MV Miner*. The *MV Miner* (a ‘Laker’ vessel) was grounded on Scatarie Island on 20 September 2011 while under tow from the Great Lakes to a breaking yard in Turkey (McNeil, 2011).

Though the likelihood of vessel groundings around Scatarie Island is very low due to modern navigational technology, the recent grounding of the *MV Miner* and the associated minor oil spillage, raised concerns about future events that could occur in the region. With the presence of an MPA in this region, the incident served to highlight the need for reliable measures to respond to such situations in a timely manner.

4.3 Pollution

Commercial shipping has the potential to cause damage to the marine environment depending on the type of navigation, weather and the type of cargo onboard. Vessel sourced pollution in the form of bilge water or overboard dumping can potentially cause harm to the marine environment (Weise, 2002). The bilge, located in the deepest recess of a vessel, acts as a collection area for water from rains or wave splash, runoff oil, and other liquids from the vessel machinery, any accidental spill of machine oil and often solid waste, such as rags, paint, and cleaning solvents etc. (Schmidt, 2000). There are regulations in place that aid in the reduction oily and otherwise contaminated bilge water discharge into the marine environment. Under the International Maritime Organization's (IMO) International Convention for the Prevention of Pollution from Ships (MARPOL) vessel operators are prohibited from discharging bilge water that contain oil levels over 15 parts per million (ppm) unless the discharge is required for safety reasons (Gard, 2011). Under Canadian legislation, vessels are required to have bilge water filtering equipment on board that contains an alarm that signals the cessation of bilge water discharge into the marine environment if the oil concentration reaches a level of 5 ppm or higher (*Vessel Pollution and Dangerous Chemical Regulations*, 2012). Even with these regulations in place, there may still be incidences of illegal dumping of oily bilge water or accidents that result in oily substances entering the marine environment within St Anns Bank AOI. Illegal discharging of oily bilge water has become an environmental problem in the Marmara Sea, where many vessels are not complying with the regulations and the concentrations of oil are significantly higher than the allowable amounts (Doğan & Burak, 2007). Illegal dumping of oil into the marine environment is a problem in the Marmara Sea, but could also be a problem within the AOI. It is difficult to detect and expensive to enforce illegal discharges and therefore even tighter regulations should be implanted in the management plan of the MPA.

Cruise ships also have the potential to introduce many forms of waste into the marine environment. Cruise ships and other passenger vessels create a different type of marine pollution because of the number of passengers that they carry. Cruise ships have the potential to discharge sewage, solid waste, oily discharge, hazardous wastes, greywater, wastewater, and ballast water (Copeland, 2010). Within Canadian waters, cruise ships are advised to follow the Pollution Prevention Guidelines for the Operation of Cruise Ships under Canadian Jurisdiction – TP14202E. Though these guidelines are not regulatory in nature, there are specific pollution categories that fall under ten other legislative documents, including the *Fisheries Act* (1985) and the *Shipping Act* (2001) (Transport Canada, 2009a). These pollution categories include sewage, garbage, air emissions, hazardous and noxious substances, and ballast water (Transport Canada, 2009b).

4.3.1 Sewage and garbage

Sewage is one of the main concerns with cruise vessels because of the large passenger capacity. It is estimated that an average cruise vessel with approximately 3000 passengers and crew can produce over 790,000 liters of sewage during a one-week voyage (Klein, 2009). The regulation for cruise vessel sewage discharge in Canadian waters falls under MARPOL. Cruise vessels with a treatment facility on board are permitted to discharge sewage within 3 nmi of land, while cruise vessels with minimal sewage treatment, such as filtering or dilution, are only permitted to discharge sewage beyond the 3 nmi limit (Transport Canada, 2009b).

In terms of garbage, an average cruise ship with approximately 3500 passengers and crew is capable of producing one ton per day (USEPA, 2008). Dumping garbage from cruise ships in Canadian waters is prohibited within the 200 nautical mile limit and it is required that all vessels have an up-to-date Garbage Management plan (Transport Canada, 2009b). Passengers, as well as crewmembers on other types of vessels also have the ability to throw waste overboard; this would not fall within the Garbage Management plan and therefore goes unreported. Such pollution negatively impacts the marine environment on a small scale, though there could be implications for the St Anns Bank AOI.

4.3.2 Hazardous and noxious substances

Hazardous and noxious substances (HNS) are a class of more critical pollution that has the potential to enter into the marine environment. Hazardous and noxious substances are defined as "any substance other than oil which, if introduced into the marine environment is likely to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea" (Transport Canada, 2011, p.21). Between 2001 through 2010 there have been approximately 100 vessel-sourced HNS spills into Canadian waters, the majority of which were small spills (Transport Canada, 2010). The International Maritime Organization outlines four categories for HNS as listed in Table 5.

Table 5. Description of each of the IMO categories of hazardous and noxious substances (HNS) that are transported via various vessel classes (*MARPOL 73/78*). Note, the categories X, Y, Z and OS were formerly known as A, B, C and D.

Category	Description
X	Noxious liquids that present a major hazard to marine resources or human health, no allowable discharge into the marine environment.
Y	Noxious liquids that present a hazard to marine resources or human health or cause harm to amenities or other legitimate human uses of the sea, limited quantities may be discharged into the marine environment.
Z	Noxious liquids that present a minor hazard to marine resources or human health, restrictions on allowable quantity of discharge into the marine environment
Other substances (OS)	Substances that do not fall under categories X, Y, or Z, present little or no hazard to the marine environment. No regulations under MARPOL for the discharge of these substances into the marine environment.

All categories of HNS can impact the marine environment, though category X is the most dangerous. The primary concern with vessels carrying HNS is damage or accidents that result in a spill of these substances into the marine environment. In Canadian waters, between 2005 and 2009 there were 124 reported incidents with vessels carrying HNS, and 88 involved bulk carriers (Transport Canada, 2011). The majority of these incidents took place in the St. Lawrence Seaway, the Great Lakes and along the Atlantic Coast. Sixty-five of these incidents involved hull or machinery damage, 21 were contacts, nine were collisions, five involved fires or explosions, and 24 incidents were caused by vessels that were wrecked or stranded (Transport Canada, 2011). Vessels report the carriage of

HNS cargo through their AIS transponders, and therefore the AIS data from the receiver tower located in Glace Bay (detailed in Chapter 5) were used to determine the number of vessels carrying hazardous and noxious substances in the vicinity of the St Anns Bank area of interest (Table 6).

Table 6. Number of vessels that transited the St Anns Bank study area between June and December 2011 that were carrying hazardous or noxious substances (HNS). The data were collected using the AIS receiver tower located in Glace Bay.

Vessel type	IMO HNS category	Number of Vessels
Cargo	X	33
	Y	1
	Z	1
	OS	23
	Total	58
Tanker	X	100
	Y	82
	Z	37
	OS	11
	Total	230
	Total	288

There were a total of 288 vessels that were carrying hazardous or noxious substances through the study area between June and December of 2011. HNS category X was the most prominent category within the study area. Since the majority of reported accidents occurred within the Great Lakes, St. Lawrence Seaway and on the Atlantic coast of Canada, there remains measurable risk for the occurrence accidents resulting in HNS spills within the St Anns Bank AOI. According to the records kept within the Marine Pollution Response Information System by Transport Canada, there were no incidents within the AOI between 2010 and present involving vessels carrying hazardous and noxious substances. Though there are no reported incidents involving HNS in the area of interest, it is important that the appropriate response measures are in place to respond immediately if such an accident does occur.

4.3.3 Oil spills

There is always the risk of an oil spill when a vessel enters the marine environment; either from operational discharges or spills from accidents. The global transportation of oil products by sea increased by 30% over the period of 1990 through 2004 and the increase carries with it a higher risk of an oil spill occurring (Eide *et al.,* 2007). Though there is an increase in the amount of oil being transported by vessels, there has also been improvements in navigational and other technologies that have aided in the reduction of the risk of a spill occurrence. Consequently, there has been a large decrease in the number of medium to large sized marine oil spills from tankers as well as the amount of oil being spilled into the marine environment (Figure 7).

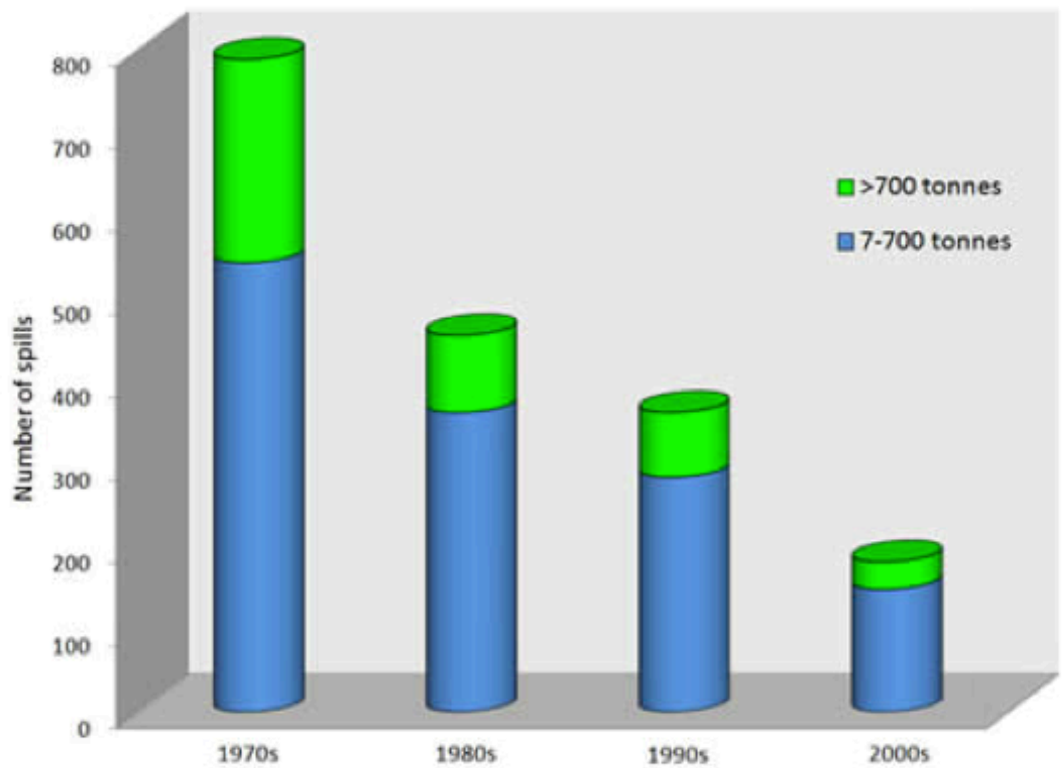

Figure 7. Frequency histogram showing the number and amount of global oil spills from tanker vessels from 1970 through 2009 (International Tanker Owners Pollution Federation, 2012).

Many of the larger spills that continue to occur are a result of the use of substandard oil tankers. Among approximately 50 per cent of major oil spill incidents in the marine environment, 25 per cent were the result of poor quality vessels (Eide *et al.,* 2007). Though the number of large spill events is decreasing over time, there are many smaller spills that happen daily and they too negatively impact the marine environment. The majority of these spills are a result of allowable operational discharges or illegal at-sea discharging of vessel wastes, such as bilge water or oily substances. Transport Canada is responsible for enforcing pollution dumping regulations at sea in Canadian waters (Transport Canada, 2012). This is achieved through the National Aerial Surveillance Program (NASP), which conducts regular flights over Canada's Exclusive Economic

Zone to monitor the input of oil into the marine environment and, in some cases, identifies the source of the pollution (Transport Canada, 2012). NASP records the number of known spills and the amount of oil spilled and I used these data to determine the amount of oil entering the marine environment around St Anns Bank, as presented in Figure 8. NASP has documented two spills within the boundaries of the AOI between 2007 and 2011; a release of approximately 160 liters of oil into the area.

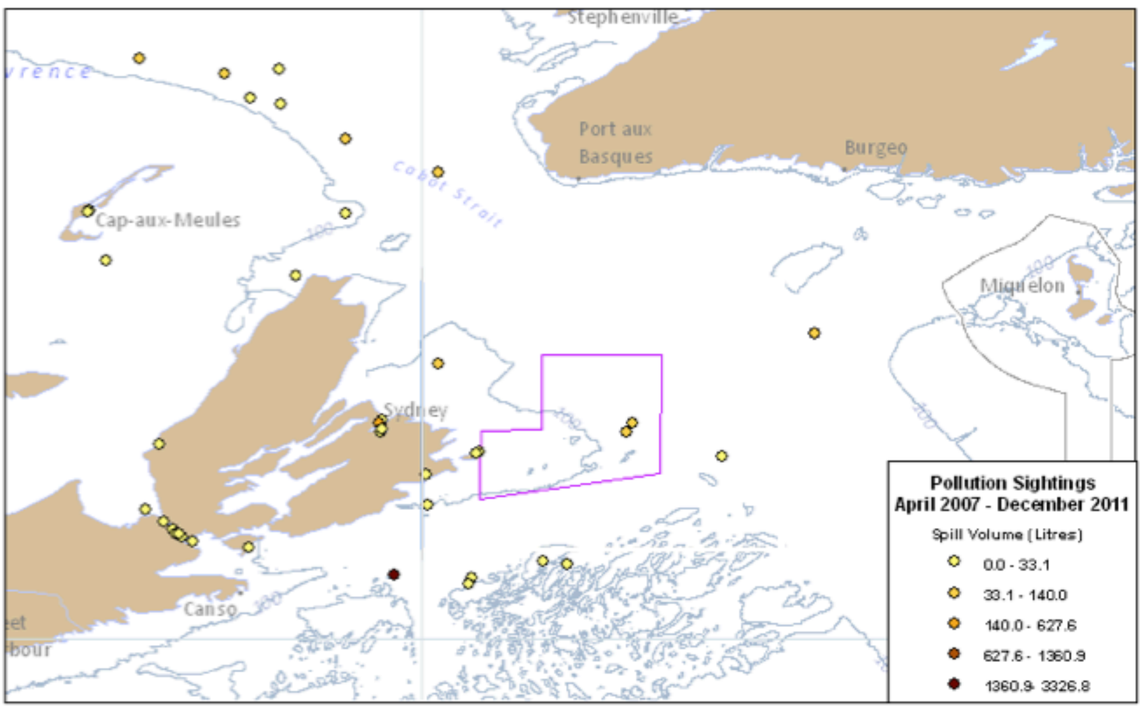

Figure 8. Location of oil spills and the approximate amount of oil spilled that was detected by the National Aerial Surveillance Program (NASP) between 2007 and 2011. The purple polygon represents St Anns Bank AOI.

The data collected by NASP are limited as the agency is only able to document spills that have been detected through the routine monitoring flights and thus additional spills likely go undetected by the NASP flyovers. As detailed above, there are many pollution regulations in place for the release of oily substances from vessels into the ocean, and there are allowable amounts that each vessel can discharge. Many of the spills recorded by the NASP flyovers are small amounts of oil, most likely caused by the discharge of bilge water or oily substances.

When taking into account the allowable amounts and the number of vessels in the global fleet, it is estimated that there are approximately 188,900 tonnes of oil discharged from bilge, vessel operations and fuel oil released into the marine environment each year (GESAMP, 2007). The chronic exposure of organisms to oil can, in some cases, have a greater impact on marine life than an acute impact; i.e. one large oil spill event. Seabirds have become a model for determining the number and amount of oil spill and this is achieved by conducting shore-based surveys for oiled birds (Furness & Camphuysen, 1997). Environment Canada (Wiese, 2002) determined the areas in the Atlantic Region where risk of oil to seabirds occurs. The St Anns Bank AOI falls within a region that has been identified as high to extreme risk for seabirds to come in contact with oil. It is estimated that in a given year in Atlantic Canada, there are approximately 300,000 seabird mortalities caused by legal and illegal oily discharge into the marine environment (Wiese, 2002). This is a large number of seabirds and it raises the concern of what this chronic oil exposure is doing to other marine organisms in the Atlantic Region as well as within the AOI itself. Given that seabirds fall within one of conservation objectives of Fisheries and Oceans Canada for the MPA, there remain concerns about the amount of oil that is within the AOI.

Using the oil spill detection data from the National Aerial Surveillance Program (summarized in Figure 8), I constructed a relative probability map summarizing regions in the vicinity of the St Anns Bank AOI where the probability of an oil spill occurring is most elevated (Figure 9).

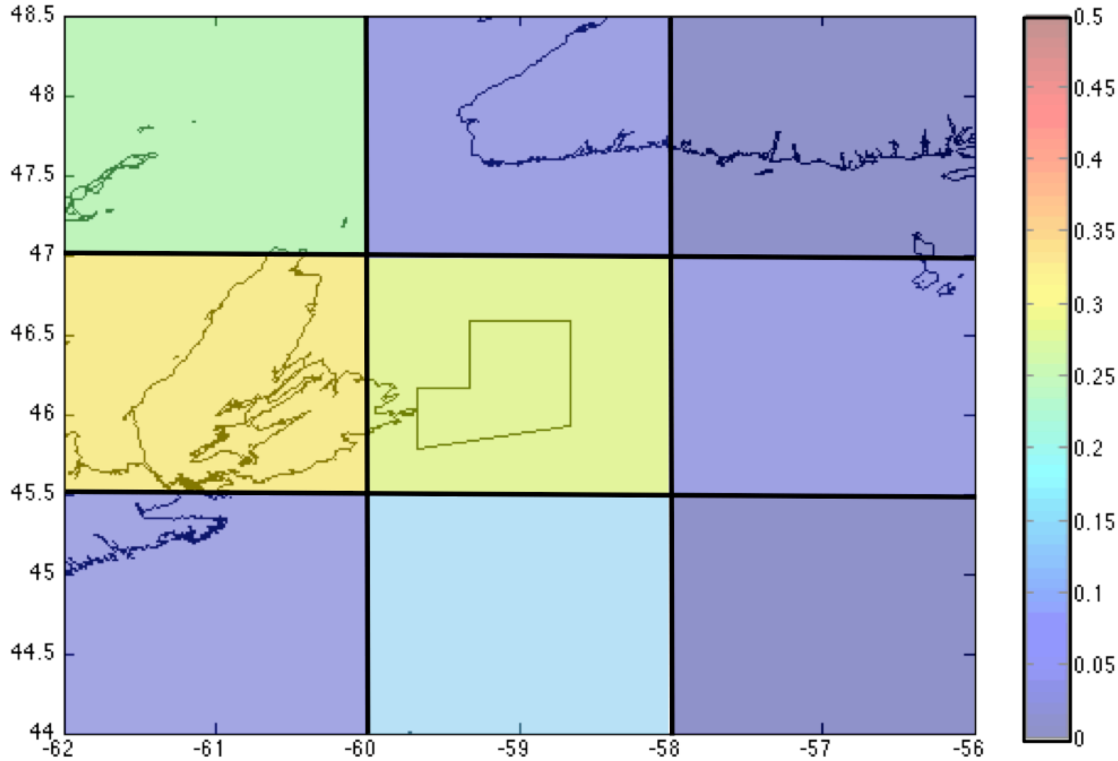

Figure 9. Chart showing the relative probability of an oil spill occurring in the vicinity of the St Anns Bank AOI based on the NASP data from 2007 through 2011.

The grid square encompassing Cape Breton Island has the highest relative probability of a spill occurring, however the majority of the spills detected in this areas were coastal spills. Apart from that, the area with the next highest relative probability of a spill occurrence is the grid square encompassing the St Anns Bank AOI. The majority of the spills that were detected in this area are vessel sourced. It is important to reiterate that NASP only reports detections of oil in the marine environment; it is not necessarily representative of the actual number of oil spills that have occurred in this area. There could potentially be many more spills that occurred and therefore the relative probability may be underestimated. Oil in the MPA will cause negative impacts on the conservation objectives and therefore it is important to reduce the amount of oil entering the environment.

Vessel strikes to marine animals and noise pollution are other risks that are associated with dense vessel traffic and these risks have implications for the conservation objectives of the AOI and the future marine protected area. These risks will be addressed in detail in chapters six and seven, and to do so I first characterize vessel traffic in the region in Chapter five below.

Chapter 5: Vessel characteristics in the St Anns Bank region

The vessel data that I used to characterize traffic in the St Anns Bank region were obtained through an Automatic Identification System receiver tower located in Glace Bay (Figure 11) and monitored by researchers in the Oceanography Department at Dalhousie University. AIS is a system used by the shipping and transportation industry where transponders onboard vessels automatically broadcast vessel position and other information that can be received by transponders on other vessels, land-based receiver stations, and satellite receivers (International Maritime Organization, 2011a). The International Maritime Organization is the global United Nations authority regulating shipping activity in the world's oceans and it requires that all vessels over 300 gross tonnes carry an AIS transponder (Vanderlaan & Taggart, 2009). AIS transponders broadcast two types of information: static and dynamic. Static information is transmitted approximately every six minutes and includes the vessel identification, location, class, dimensions, destination and the nature of the cargo on board. The dynamic information is transmitted approximately every 3 seconds and includes vessel identification, location, speed over ground and heading (Eide *et al.,* 2007).

I used the data received at the Glace Bay tower to characterize the vessels transiting the AOI region and to determine the navigation and traffic density patterns within a defined study area surrounding the AOI. The location of the Glace Bay receiver tower, the AOI, and the study area are illustrated in Figure 10. The larger study area was designed to regionally depict vessels and their activity within and around the AOI.

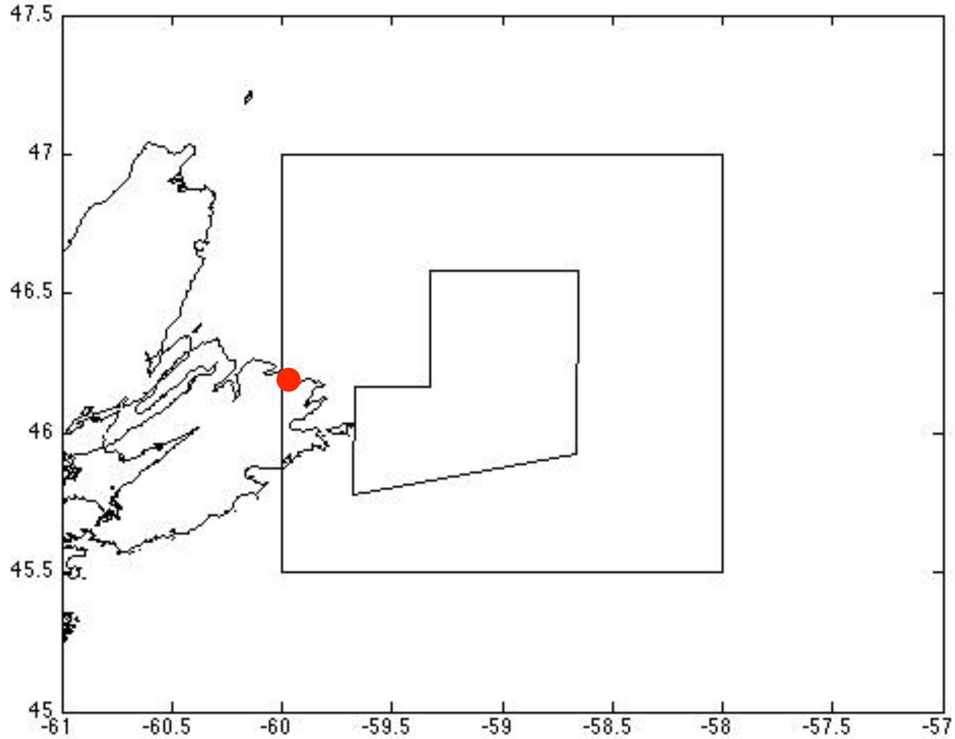

Figure 10. Chart showing the location of the AIS receiving tower in Glace Bay (solid red symbol) and the vessel study area (rectangle) that encompasses the St Anns Bank AOI (polygon).

The Glace Bay AIS receiver has been operational since 2008, but there have been times when the receiver was not functioning. There data used in this study include the periods of March through December of 2008, January through July of 2009, January through July of 2010, May through December of 2011 and January through February of 2012.

Land-based AIS receivers have range detection limitations based on the location, the height of the receiver antenna and weather (Vanderlaan and Taggart, 2009). However, in order to determine the specific range detection accuracy of the Glace Bay AIS receiving tower, I compared the data collected by the tower against AIS data collected by satellite in the same area. The satellite-based AIS data were provided by exactEarth Ltd. (60

Struck Court, Cambridge Ontario, Canada N1R 8L2). The differences in the tower versus the satellite detection are illustrated in Figure 11a and 11b, where it is clear that the full regional coverage is achieved using the satellite data (but has low track-line resolution), while the tower detection decreases with distance (but has high track-line resolution).

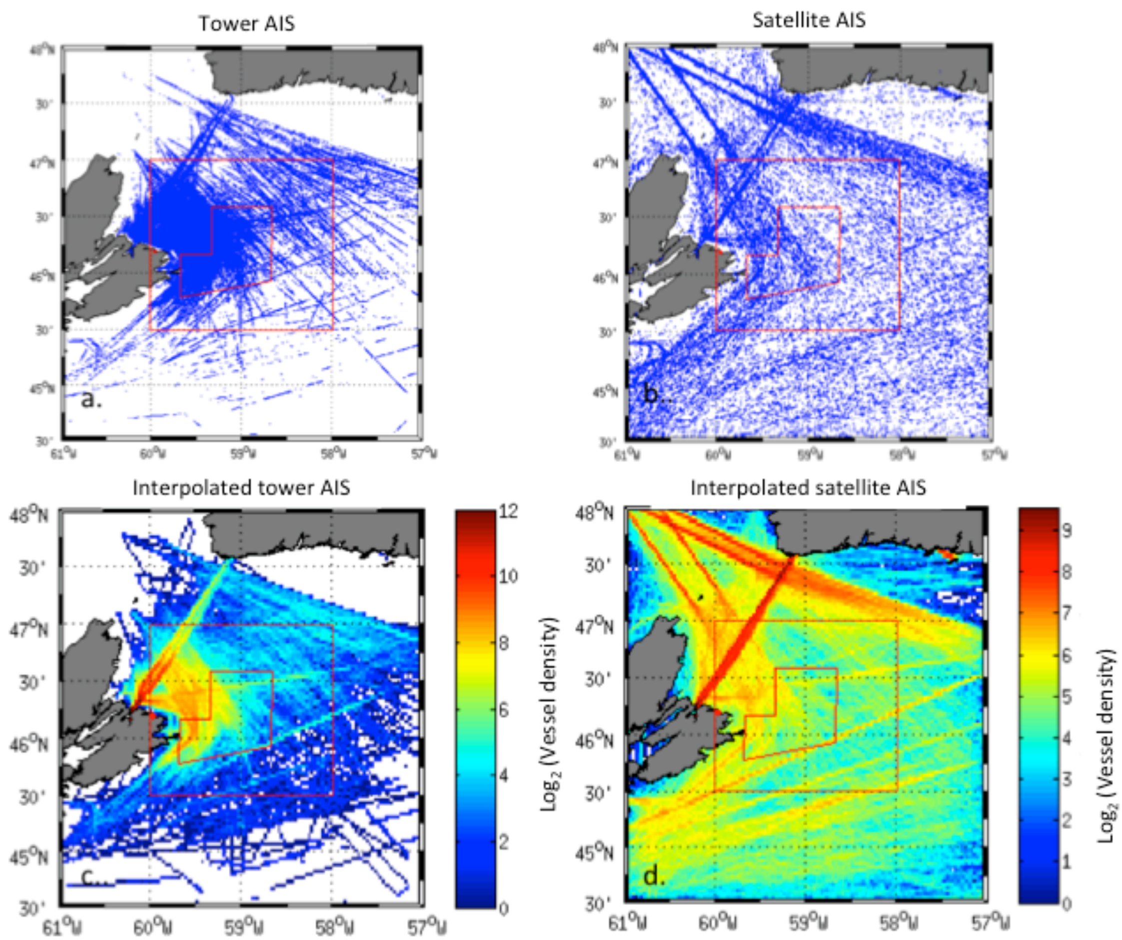

Figure 11. Vessels detection locations logged over the period of 01 May 2011 through 30 April 2012 by a. the Glace Bay receiver tower, and b. by satellite receiver (exactAIS®) and track-line interpolations expressed as a vessel density ($\log_2$ scale) for c. the tower data and d. the satellite (exactAIS®) data.

The interpolated vessel densities were then normalized (0,1) and the satellite-based density was subtracted from the tower-based density to provide residual density estimates for assessing the accuracy of the tower data in providing reliable cover of the AOI. The resulting residuals (Figure 12) clearly intricate zero or better residuals in the AOI and this the tower data are suitable for characterizing the transiting fleet and determining vessel concentrations in the region.

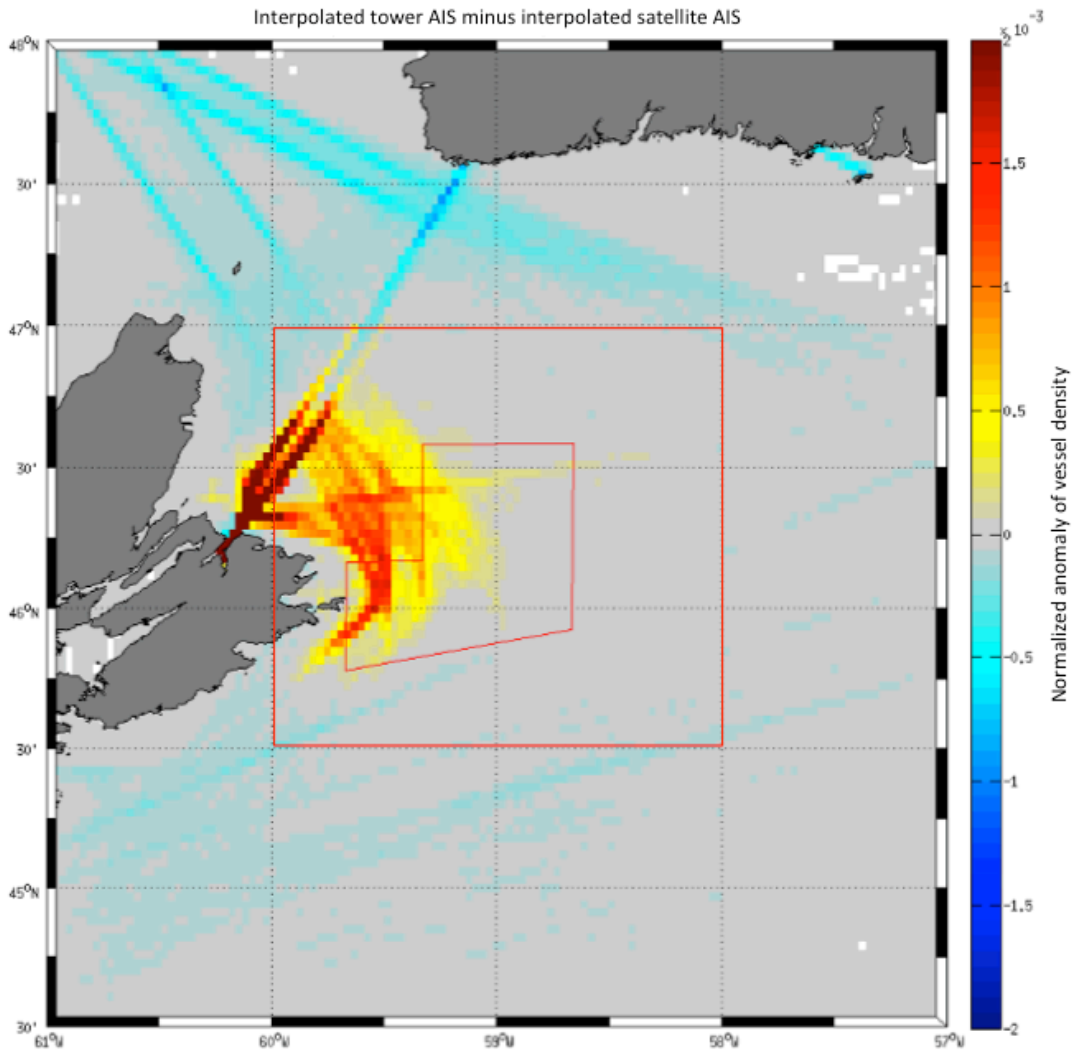

Figure 12. Chart illustrating the difference between the normalized vessel density from the Glace Bay AIS tower and the normalized satellite (exactAIS®) vessel density from satellites. The warmer colors indicate positive residuals (greater vessel density from tower data), cool colors indicate negative residuals (greater density from satellite data) and neutral colors (grey) indicate where both tower and satellite were equivalent in vessel detection. Within the St Anns Bank AOI (red polygon), the tower detected more vessels than the exactAIS® satellites, demonstrating that, in this region, the tower alone is capable of providing accurate estimates of vessel traffic characteristics.

Within most of the study area the AIS tower receiver detected the same density of vessels as the satellite receiver. Vessels in close proximity to the tower and within most of the St Anns Bank study area, the tower detected more vessels than the satellite, implying that the tower is somewhat more reliable for inferring vessel traffic characteristics in the St Anns Banks AOI. However, in the Laurentian channel and other areas further from the AIS tower, the interpolated satellite data are more reliable as tower reception decreases with distance from the vessels. Although some small areas in the periphery of the study area (but not in the AOI) are close to the detection limits of the AIS tower (slightly negative residuals; Figure 11d), the comparison between the tower and satellite data determined that the AIS tower data are suitable for my study and the remaining analyses in this study were conducted using the AIS tower data.

5.1 Vessel densities

Vessel transmissions from the AIS tower in Glace Bay were used to estimate vessel densities. In this study, a vessel transmission refers to a latitude/longitude pair depicting the location of a vessel, and vessel density is defined as the sum of vessel transmissions within a grid cell. Using Matlab®, a vessel density map (Figure 13) was generated by creating a 0.03 degree grid and by summing all the vessel transmissions occurring in each grid cell.

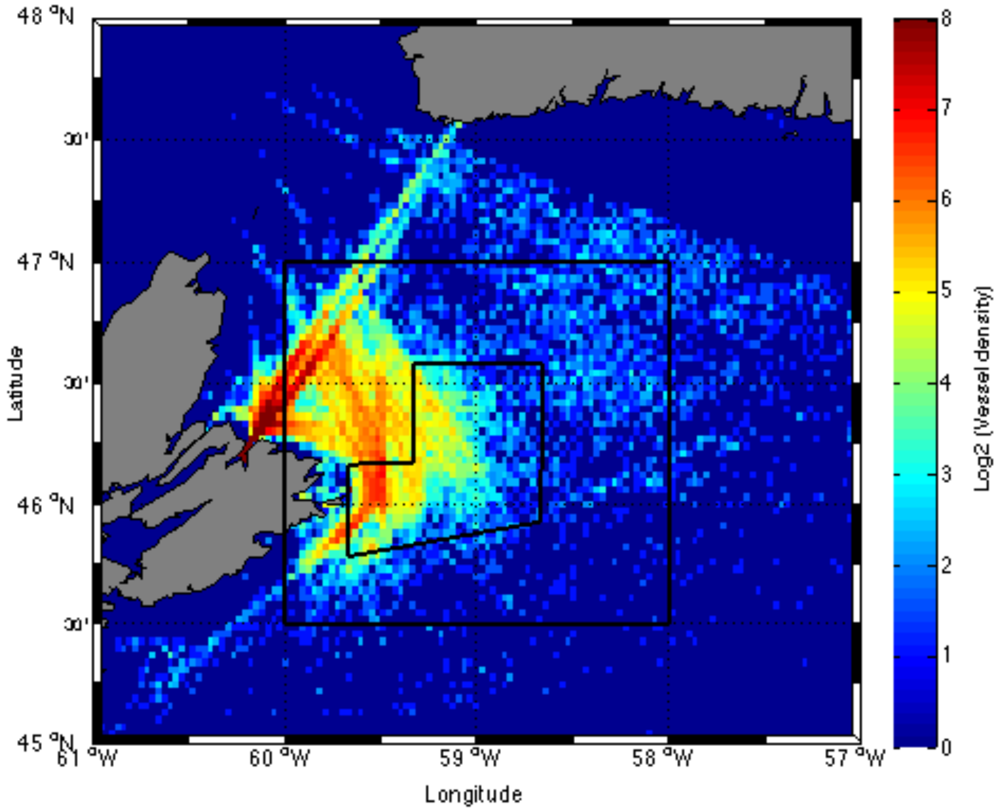

Figure 13. Chart illustrating vessel traffic density (0.03 degree grid cells: log2 scale) created with available Glace Bay AIS tower data over the period 2008 through 2012 where the rectangle represents the study area encompassing the St Anns Bank AOI (polygon).

Vessel density charts provide a graphical representation of which regions within the study area are associated with the highest vessel density. The highest vessel densities occur in the northwestern region of the study area where two self-determined traffic lanes or habitual traffic patterns (HTPs) (Vanderlaan & Taggart, 2009) are apparent. The HTPs reflect the regular navigation of the Marine Atlantic ferries that travel between North Sydney, Cape Breton and Port aux Basque, Newfoundland. The area with the next highest vessel density occurs within the western margins of the area of interest and in the region adjacent to Scatarie Island. Vessels travelling between the Gulf of St. Lawrence and the Eastern Seaboard of North America are forced to navigate around Scatarie Island where the traffic is essentially 'funneled' creating a vessel density region that is higher than elsewhere within the AOI.

5.2 Fleet characterization

The first step in determining the risk of another event like that of the *MV Miner* grounding is to determine the vessel classes transiting the study area, weather conditions, routing, and vessel speed. The fleet characterization was conducted within the study area encompassing the AOI to identify the traffic patterns both in and around the AOI. Individual vessel transits were calculated using a Matlab® script that determined the number of vessels that were within the study area every six hours. Six hour intervals were chosen based on the available data and the fact that most vessels took approximately six hours to transit the study area. In some instances, vessels took longer than six hours to transit the study area and the duplicate records were removed so that each transit was only counted once. The number of transits through the study area, on a monthly basis, using the data available over the period of January 2010 through February 2012 indicate there can be two- to three-fold more vessels navigating the region during the summer months than during the winter months (Figure 14).

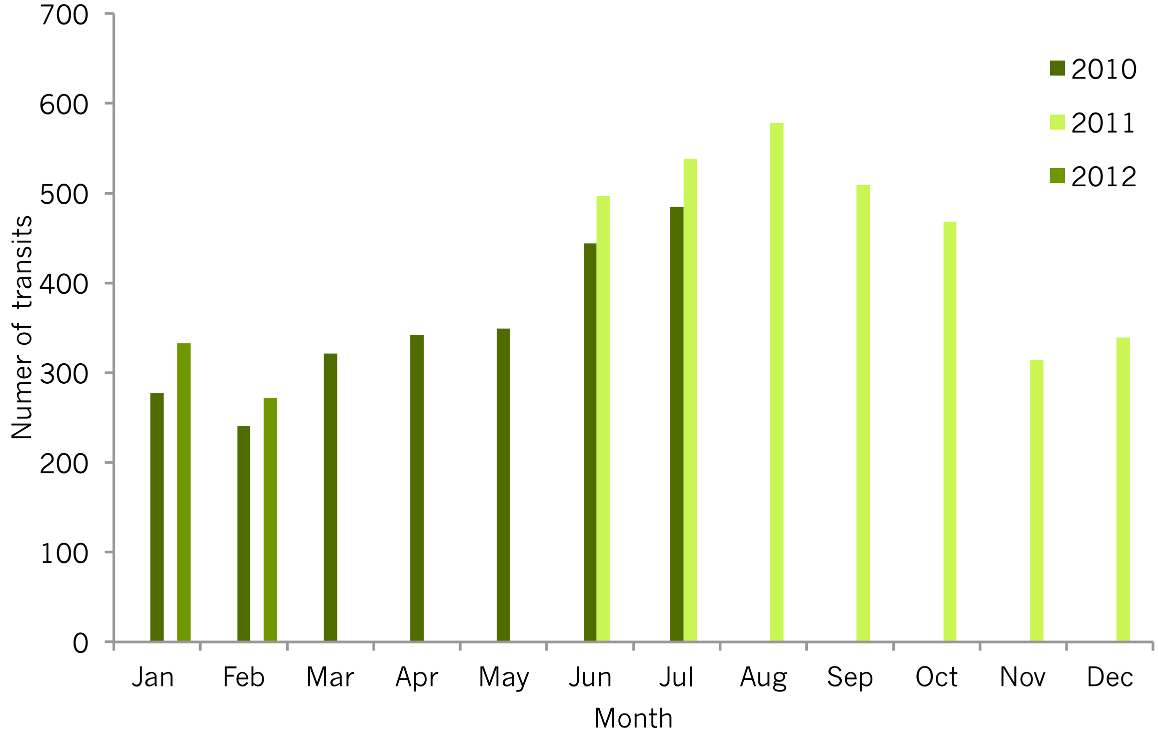

Figure 14. Number of individual vessel transits through the study area per month from 2010-2012. Note: missing data are months when the Glace Bay tower was not functioning.

To estimate the number of transits that occur through the study area on an annual bases I used the same data, compiling the available monthly data, though as the number of vessels carrying AIS transmitters is continually increasing, I used only the most recent data. Figure 15 displays the average number of vessel transits per day in each month for a one-year period that consists of data from March through May of 2010, June 2011 through February 2012.

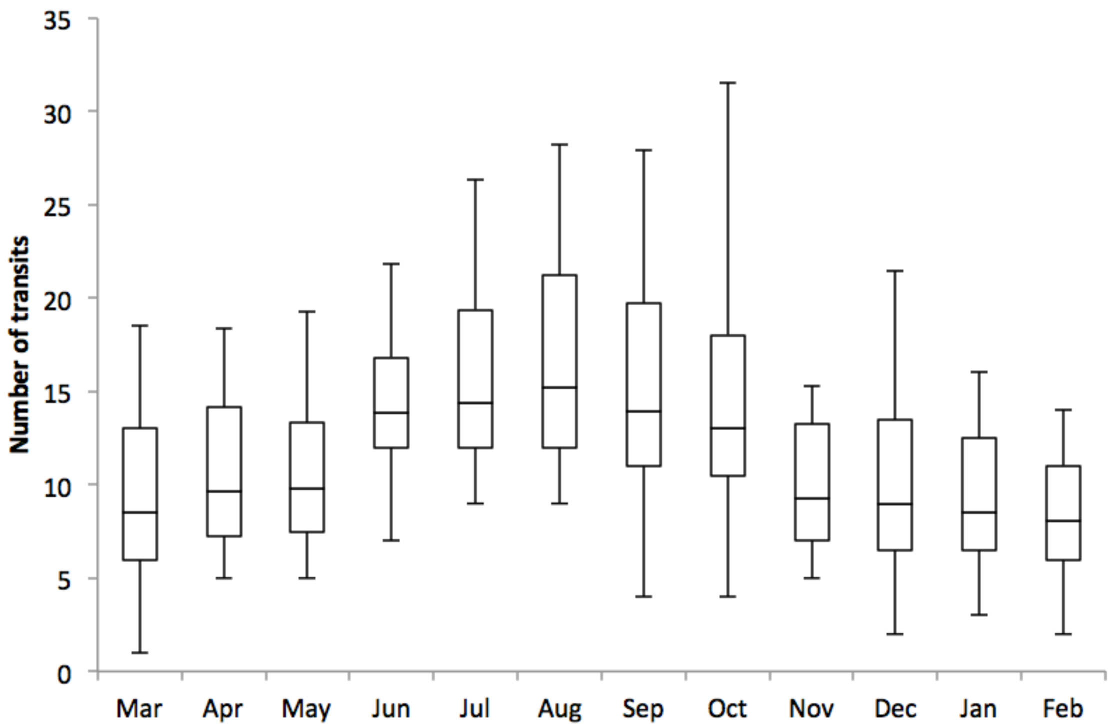

Figure 15. Box and whisker plot showing the number of daily unique vessel transits through the study area for each month based on AIS tower data for the periods of March through May 2010, and June 2011 through February 2012 where the whiskers represent the monthly maximum and minimum number of vessels transiting the study area, the box represents the inter-quartile range and the horizontal line within the box represents the average number of transits per day.

By compiling the data for a one-year period the seasonal patterns in vessel traffic are revealed (Figure 15), with more transits (~15 per day) occurring during the summer months (June through October) and fewer transits (~10 or less) during winter months (November through May), and in each case the day-to-day variation is considerable based on the inter-quartile range. This seasonal pattern can be explained, in part, by the Marine Atlantic ferries operating between North Sydney and Argentia, Newfoundland in the summer months. This route is only operational from mid June to the end of September each year (Marine Atlantic, 2012). The summer increase is also partly explained by the yearly winter closing of the St. Lawrence Seaway. The Seaway is closed between January and March due to ice conditions, so vessels that would normally travel through the Gulf of St. Lawrence to inland ports are not passing through the study area in the winter months (Jenish, 2009).

Knowing the vessel classes that are transiting the area is an important factor in determining the risk associated with a particular vessel transportation activity. Figure 16 displays the percentages of vessel classes that transited the study area in all years of data collection (2008-2012).

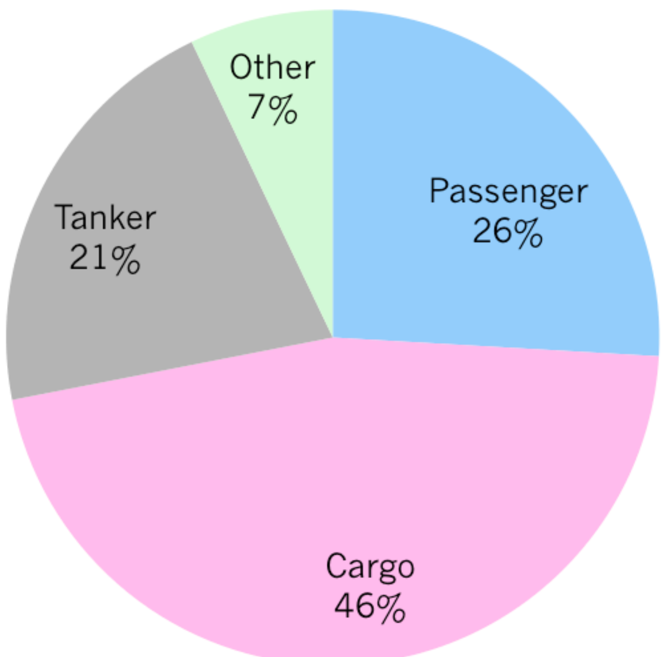

Figure 16. Pie chart illustration of the per cent unique vessels that transited the study area based on the available Glace Bay AIS tower data over the period of 2008 through 2012. The 'other' class includes fishing, towing, dredge, military, sailing, pleasure, pilot, search and rescue, research, ice breakers and coast guard vessels.

Though the AIS receiving tower does pick up signals from vessels smaller than 300 gross tonnes, such as fishing and pleasure craft, it must be noted that these vessels are not required to carry an AIS transponder. Some smaller-vessel operators may choose to carry an AIS transponder for safety reasons, which explains why signals from smaller vessels are received at the tower. Thus, the number of smaller vessels is not accurately represented in this study because not all smaller vessels carry AIS. Therefore, there may be much more smaller vessel activity in the area than what is being displayed from the AIS data. Passenger, tanker, and cargo vessels represent the greatest proportion of vessel classes within the area and the number of transits by vessel class is displayed in Figure 17.

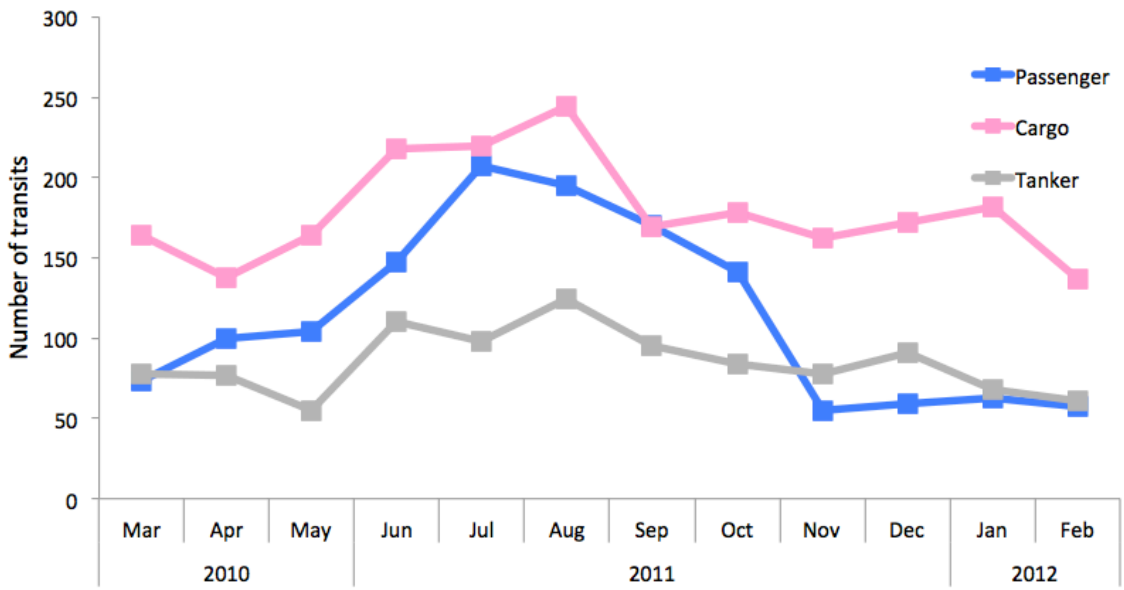

Figure 17. Monthly estimates of the number of unique vessels by class that transited through the study area based on the Glace Bay AIS tower data over 12 month period (March through May 2010 and June 2011 through February 2012).

Cargo vessels were the most prominent class within the study area followed by passenger vessels, except in winter months when the passenger vessels are low and tankers are the next most frequent vessel type. The lowering of the number of passenger vessels in the winter months is because of the reduction in the number of transits that Marine Atlantic ferries provided from North Sydney to Newfoundland (Marine Atlantic, 2012).

Vessel speed can be an important factor in the amount of risk that is associated with shipping activities. The average vessel speed, in nautical miles, by month for each vessel class can be seen in Figure 18.

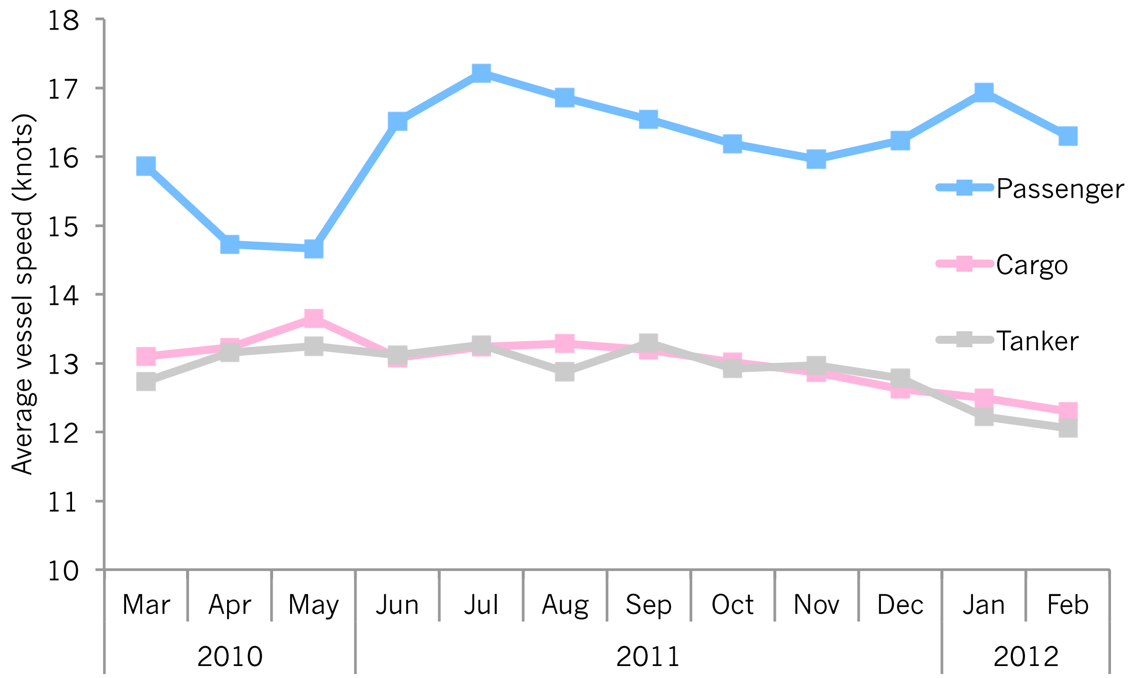

Figure 18. Monthly average-speed estimates for unique vessels by class that transited the study area based on the Glace Bay AIS tower data over a 12-month period (March through May 2010 and June 2011 through February 2012).

Cargo and tanker vessels travel at similar speeds within the study area and passenger vessels travel at the highest speeds. The lower average speeds for passenger vessels in March, April and May can be explained by the replacement of two Marine Atlantic Ferries, the *MV Joseph and Clara Smallwood* and the *MV Caribou*, with two new ferries the *MV Blue Puttees* and the *MV Highlanders* in early 2011 (CBC, 2010). The average service speed that the older ferries could go was 18 knots and the average speed that the newer ferries can travel between ports is 22 knots (Marine Atlantic, 2011). The exchange of the newer, faster vessels on the ferry routes is the most likely cause of the curve in the average speeds for the passenger vessels in the 2010 months.

Speed can play an important part in the lethality of vessel strikes. Within the Bay of

Fundy, vessels traveling faster than 15 knots were more likely to cause a lethal strike on right whales (Vanderlaan *et al.,* 2008). Considering that the average speed of passenger vessels within the study area is between 14 and 18 knots, there are concerns about the risk of lethal strikes on large pelagic species within the St Anns Bank AOI.

Chapter 6: Vessel strikes

6.1 Vessel strikes on whales

Vessel strikes on large, pelagic species are something that has recently been recognized as a problem related to the marine shipping industry. Studies have found that the most common whale species that are struck by vessels are fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter catodon*), gray whales (*Eschrichtius robustus*), and right whales (*Eubalaena* spp.) (Laist *et al.,* 2001). The information regarding whale species within the St Anns Bank AOI is very limited so determining the vessel traffic risk to whales in the area is not possible until more research is conducted. It remains unknown if there is a resident population of whales within in St Anns Bank AOI, but it is thought that pilot whales may use the area throughout the year (Ford & Serdynska, 2012). The most likely scenario, however, is that whale species use the St Anns Bank AOI as a transiting corridor between the Atlantic Ocean and the Gulf of St. Lawrence and that most species simply pass through the area (Ford & Serdynska, 2012).

Through literature review and available sightings data, Fisheries and Oceans Canada has created a list of cetacean species that are most likely to occur in the St Anns Bank AOI. They include the fin whale (*Balaenoptera physalus*), minke whale (*Balaenoptera acutorostrata*), humpback whale (*Megaptera novaeangliae*), pilot whales (*Globicephala* spp.), Atlantic white-sided dolphins (*Lagenorhynchus acutus*), and common dolphins (*Delphinus* spp.). Species that may occur in the area, but are less likely to occur than the previously mentioned species include the sei whale (*Balaenoptera borealis*), blue whale (*Balaenoptera musculus*), northern right whale (*Eubalaena glacialis*), killer whale

(*Orcinus orca*) and the harbor porpoise (*Phocoena phocoena*) (Ford & Serdynska, 2012).

Given that the majority of whale species that are victims of vessel strike incidents include fin and humpback whales, and it is believed that both of these species at least transit though the St Anns Bank AOI as part of a migration route, risk to these species can be assumed. Under the current understanding that whales only use the AOI as a transit corridor between the Atlantic Ocean and the Gulf of St. Lawrence (Ford & Serdynska, 2012) it can be assumed that there is low risk of a vessel strikes on whale species because of the minimal time that would be spent within the AOI. However, it is important that more research be conducted to determine the spatial extent of the whale species that are present in the AOI and develop an accurate risk assessment for whales from vessel strikes.

6.2 Right whale case study

The most prominent examples of vessel strikes in Atlantic Canada are in the Bay of Fundy and the Roseway Basin with the North Atlantic right whale (*Eubalaena glacialis*) (referred to herein after as the right whale). Between 1970 and 2006, 40 right whale necropsies were conducted and in 21 cases the cause of death was determined to be from a vessel strike (Campbell-Malone *et al.*, 2008). In the cases of the Bay of Fundy and the Roseway Basin, shipping lanes were found to overlap with critical feeding habitat of the right whale (Vanderlaan *et al.,* 2008).

The presence of vessels in critical right whale habitat increases the probability that whales will be struck by vessels. One way to reduce this risk is by moving shipping lanes out of areas of the critical whale-feeding habitat. In the case of the Roseway Basin, a voluntary area to be avoided was implemented for the right whale following discussions with the International Maritime Organization (Vanderlaan & Taggart, 2009). The IMO defines an area to be avoided as “an area within defined limits in which either navigation is particularly hazardous or it is exceptionally important to avoid casualties and which should be avoided by all ships, or by certain classes of ships” (International Maritime Organization, 2011b). Areas to be avoided can also be implemented if a certain area is ecologically important and the presence of vessels is causing negative impacts to that area (International Maritime Organization, 2011c).

The Roseway Basin area to be avoided is voluntary for vessel operators and they can choose to avoid that area or continue to transit through it. It has been found through tracking AIS data that there was an approximately 70 per cent compliance rate of vessel operators after five months of the area being designated (Vanderlaan & Taggart, 2009). In the case of the right whales in the Bay of Fundy, the shipping lanes were moved in 2002 to avoid the right whale critical habitat (Silber *et al.,* 2012). Since these vessel traffic changes were made, the right whale population has grown from approximately 350 to 450 individuals (Thomson, 2012), though this may not be a direct result of changes to vessel traffic.

Another way to reduce the risk of fatal vessel strikes is to decrease the speed of the vessels. As technology improves, vessels are being built to travel at faster speeds and speed plays a key role in vessel strikes. Vessels travelling at high speeds increase the risk of a lethal strike occurrence while vessels that reduce their speeds reduce this risk (Vanderlaan *et al.,* 2008). Within the Bay of Fundy it was calculated that implementing a maximum 10 knot speed restriction resulted in a 52 per cent decrease in the risk of lethal vessel strikes occurring (Vanderlaan *et al.,* 2008).

Though changing the shipping lanes within the Bay of Fundy and implementing a voluntary area to be avoided in the Roseway Basin has been shown to reduce the risk of vessel strikes, combining these changes to vessel routing with speed restrictions results in the most reduction of risk for these areas. If it is found that vessel strikes on whales are having an impact within the AOI, some of these options can be applied to reduce the risk.

6.3 Vessel strikes on leatherback turtles

The majority of vessel strike reports are between vessels and whales, but there is also the potential for vessels to strike other large pelagic species. Within St Anns Bank AOI there has been important habitat identified for leatherback turtles. The relative probably of residency of a leatherback turtle is displayed in Figure 19. The probably was determined by tracking 70 turtles for an extended time period (65 turtles were tracked for 11 years) in Atlantic Canada (Fisheries and Oceans Canada, 2011f).

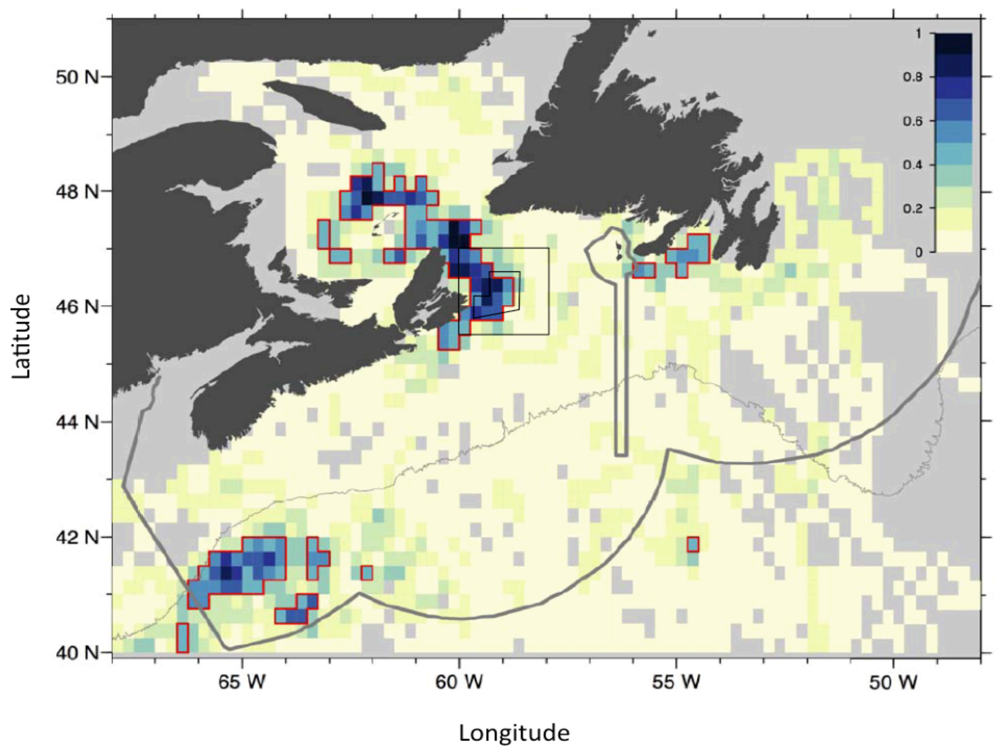

Figure 19. Chart illustrating the relative probability (0,1) distribution of leatherback turtles in Atlantic Canada based on data derived from Fisheries and Oceans Canada (2011f) and the study area (rectangle) encompassing the St Anns Bank AOI (polygon).

Leatherback turtles are the largest living, marine turtle growing up to 2.4 metres long and up to 3.6 metres wide and can weigh up to 725 kg. They are also listed as endangered under the *Species at Risk Act* (SARA) (Government of Canada, 2012). Leatherbacks nest on beaches in tropical and sub-tropical climates, and the turtles spend minimal time on land, only when they hatch and when they return to nesting beaches (Doyle *et al.*, 2008). Leatherbacks spend the rest of their lives transiting through the oceans in search of food, mainly in temperate waters (Government of Canada, 2012). The main food source of the leatherback turtle is jellyfish and in Atlantic Canada it has been found feeding mainly on the lion's mane jellyfish (*Cyanea capillata*) and the moon jelly (*Aurelia aurita*) (James, Myers & Ottensmeyer, 2005). Leatherbacks have to consume up to 200 kg of jellyfish per day in order to meet their metabolic requirements (Houghton *et al.,* 2006).

The behavior of leatherback turtles while they are foraging can increase the risk of a vessel strike. Jellyfish usually have a diurnal migration pattern where they are deeper in the water column during the day and come to the surface at night (Hays *et al.,* 2006). In some instances the jellyfish can dive too deep for the turtles to feed on them, so the leatherbacks remain at the surface during the day and then feed in surface waters at night (Hays *et al.,* 2006). The turtles also spend time at the surface during the day to absorb solar radiation, a behavior known as basking, which helps to maintain their body temperature in the cold northern waters (James *et al.,* 2005). When leatherbacks are migrating they tend to take long, deep dives, but in northern waters the pattern changes to short, shallow dives (Hays *et al.,* 2006). In the waters off of Nova Scotia, leatherbacks are known to spend approximately 50 per cent of the daylight and evening hours in surface waters at a depth of no more than six metres (James *et al.*, 2006). The increase in the amount of time that leatherbacks spend in surface waters in northern regions, such as in the St Anns Bank AOI, makes them more vulnerable to vessel strikes.

There have been many records of marine turtles getting struck by vessels in Australia, with 14 per cent of the turtles that wash ashore showing evidence of a vessel strike (Dobbs, 2001). Between 1990 and 2003 in Queensland, vessel strikes were the cause of death for 0.7 leatherback turtles per year (Hamann *et al.,* 2006). In 2008, there were approximately 30 leatherback turtle mortalities off of the coast of Massachusetts, the majority of which were caused by a vessel strike (Shields, 2011). In many of these cases the strikes were caused by smaller recreational vessels and fishing boats as opposed to large, commercial shipping vessels. As of 2006 there were no reported incidents of vessel strikes on a leatherback turtle in Atlantic Canadian waters (Fisheries and Oceans Canada, 2006), but considering the reports of vessel collision mortalities in other places in the north western Atlantic, it is important to have an understanding of the probability of a vessel striking a leatherback turtle within the St Anns Bank AOI.

6.4 Relative probability of a vessel strike on a leatherback

In order to determine the probability of a vessel strike occurring on leatherback turtles within the St Anns Bank study area, the probability of turtle presence was extracted from the chart in Figure 19 (Fisheries and Oceans Canada, 2011f). Once the probability of turtle residence was extracted from the chart, the numbers were normalized (0,1) to represent the relative probability of turtle residency within the St Anns Bank study area. Using the AIS data obtained from the Glace Bay tower, the relative probability of a vessel occurring within the study area in the 0.25 degree grid squares (the same grid squares used in the turtle probability analysis) was calculated for the months of June through October 2011. These months were selected for vessel data because those are the relevant months where turtles are present within the area (Fisheries and Oceans Canada, 2011f). The relative probabilities for a vessel strike occurring in each of the 0.25 degree grid cells were calculated using the following equation:

$$P_{rel}(\text{Encounter})_i = \frac{P_{rel}(\text{Turtle})_i \text{ x } P_{rel}(\text{Vessel})_i}{\sum_i (P_{rel}(\text{Turtle})_i \text{ x } P_{rel}(\text{Vessel})_i)}$$

The equation was modified from Vanderlaan *et al.* (2008) and the results were normalized so that the sum of all of the grid squares adds up to one. Figure 20 illustrates the relative probability of a vessel strike occurring on a leather back turtle within the study area.

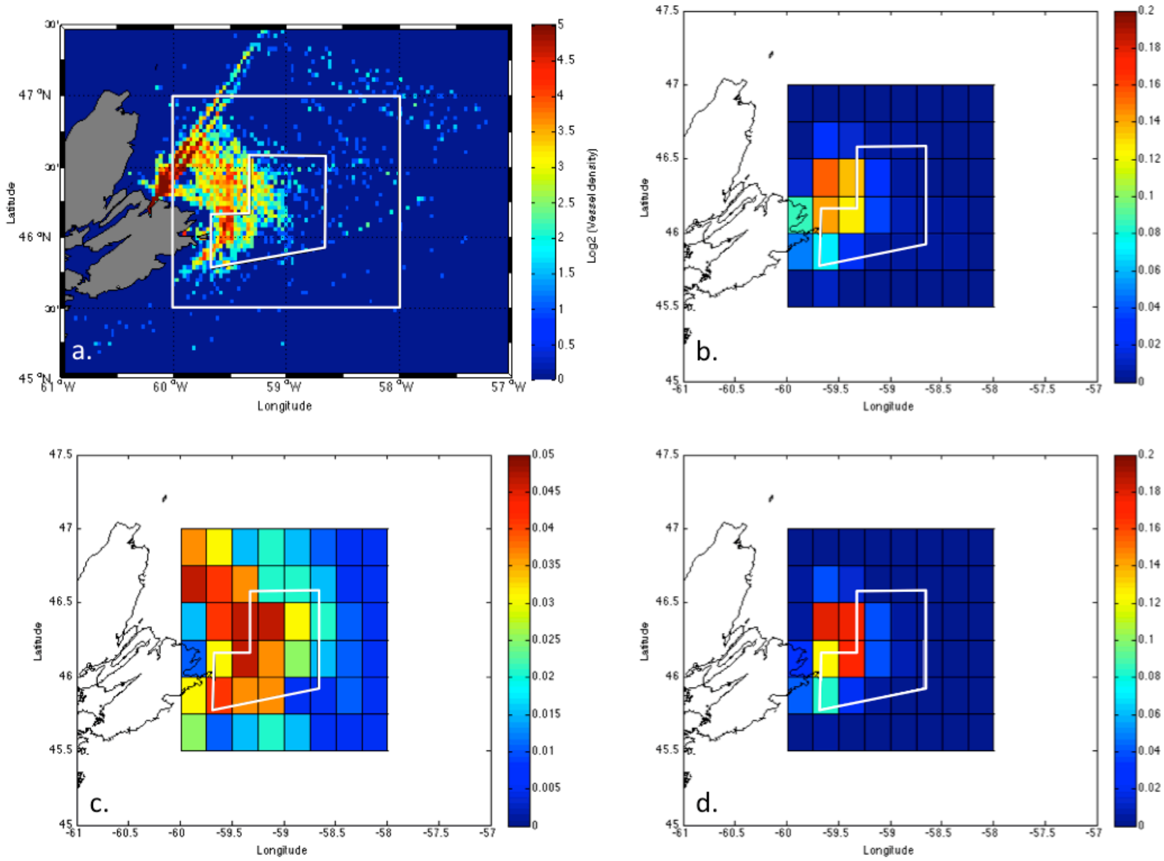

Figure 20. Chart illustrating a. the vessel density for the months of July through October of 2011 within the St Anns Bank study area, b. the relative probability of a vessel occurring in 0.25 degree grid squares for the months of July through October 2011, c. the relative probability (0,1) of the summer and autumn distribution of leatherback turtles in the St Anns Bank study area derived from Fisheries and Oceans Canada (2011f), and d. the resultant relative probability of a vessel and turtle encounter occurring at a 0.25 degree resolution within the St Anns Bank study area.

The relative probability of a vessel striking a leatherback turtle within the St Anns Bank AOI is mostly low, but there are some grid squares with a higher relative probability of a strike occurring. Two of the three highest relative probability grid squares overlap with the boundaries of the AOI and this could potentially work against the conservation objectives of the marine protected area for leatherback turtles.

The analysis only took into account the probability of turtles and vessels being present within a grid square at a specific time. It did not take into account the behavior of the animals when they are within the study area. The turtles are at the surface foraging for the greater part of each day, but they also spend time diving. When the turtles dive to depths greater than the reach of the draft of the vessels in the area the likelihood of a strike occurring would be reduced. Further analysis, including turtle behavior, could produce differing results in terms of relative strike probability.

Chapter 7: Vessel noise

Anthropogenic noise has been recently identified as an impact within the marine environment. Much of the noise that is considered dangerous to the marine organisms includes things like sonar and seismic testing, but the low frequency, consistent noise that is produced from dense vessel traffic can also be harmful to marine organisms (Merchant *et al.,* 2012). There is a natural range in variation of the sound frequencies in the marine environment from wind and waves (approximately 20 Hz), but the introduction of commercial shipping over the last century has increased the level of ambient noise that can be found in the marine environment today (between 20-200 Hz) (Tyack, 2008).

Vessel traffic noise has been found to cause short and long-term behavioral changes in marine mammals and it can mask biologically important sounds, such as mating calls (Merchant *et al.,* 2012). Sound masking is placed into two categories, energetic and informational masking, but they are not mutually exclusive (Clark *et al.,* 2009). Energetic masking occurs when two sounds of the same frequency are produced therefore making the two sounds indiscernible. Informational masking occurs when a sound is audible but other background noise makes it impossible to decipher the information that is being transmitted with the sound (Clark *et al.,* 2009).

Whale species use sound to communicate with others, find mates, locate food, and for navigation, making them particularly sensitive to anthropogenic noise (Hatch *et al.,* 2008). Baleen whales are capable of communicating across hundreds of kilometers of ocean by producing low frequency sounds that are able to travel longer distances through water than high frequency sounds (Tyack, 2008). Blue whales produce sounds between 12 and 200 Hz and up to 188 dB at source (Cummings & Thompson, 1971). In the presence of high densities of vessel traffic, that is also producing low frequencies (<300 Hz), sound masking can occur and have implications for whales (Merchant *et al.,* 2012).

Along with sound masking, anthropogenic noise can also result in a reduction of communication space within the marine environment. Communication space is the area surrounding an individual whale that it uses to communicate with other individuals (Clark *et al.,* 2009). It was determined that within the Stellwagen Bank National Marine Sanctuary during a period of approximately 13 hours within one day, an individual whales communication space was reduced by 84 per cent (Clark *et al.,* 2009).

In some cases, whales have actually changed the behavior of communication in order to make their calls heard over other anthropogenic noise (Williams, Trites & Bain, 2002). Fin whales have been found to change their vocalization patterns to compensate for anthropogenic noise interferences when ambient sound reaches 120 dB or more (Castellote, Clark & Lammers, 2010). Within the Bay of Fundy, it has been found that right whales change the frequency and amplitude of their calls in order to compensate for vessel noise disturbances (Rolland *et al.*, 2012). High levels of anthropogenic noise in the marine environment can also lead to whale strandings (Weilgart, 2007).

Though there is very little known about the whale species in the St Anns Bank AOI and the current understanding is that the area is used as a migration corridor into the Gulf of St. Lawrence, it is important to determine what regions of the protected area will be influenced by vessel noise and how much of an impact it could potentially have on whales. The identification of areas of high anthropogenic noise levels coupled with further research on the whale species in the area can help to inform management so that the appropriate steps can be taken if there is a need to mitigate the input of anthropogenic sound in the MPA.

7.1 Vessel noise in the AOI

Determining the sound that a vessel can produce in the marine environment is difficult. The best way to determine sound is to use hydrophone (an underwater recording device) and analyze sound recordings in a specific area, however there is currently no hydrophone placed in the St Anns Bank AOI. A study conducted in California used a hydrophone paired with AIS data to determine the sound fields that specific vessels were creating (McKenna, 2011). For the purposes of St Anns Bank, the information from McKenna (2011) was used to create a general picture of the sound environment within the AOI. A container vessel, a products tanker and a bulk carrier were assessed in detail over a one-hour period and it was found that a bulk carrier travelling at 14.4 knots could produce a sound of approximately 180 dB at a frequency of 800 Hz at source (McKenna, 2011). The majority of the vessel traffic in the AOI consists of cargo vessels and the total average speed of all vessels within the study area is approximately 14 knots, therefore the bulk carrier was used as a model to analyze the sound within the area of interest. Three points within the AOI were selected to approximate the sound that occurs within high, medium and low traffic density spots within the AOI, see Figure 21a. Every minute within the time frame of 01 April 2008 through 01 March 2009 was analyzed to determine the number and location of vessels relative to each of the three selected points. I used an exponentially decreasing function to determine the amount of noise (in dB) a vessel would be producing as a function of distance from each of the three points. From this, I created three plots that show the approximate sound intensity for each of the three points within the AOI (Figure 21).

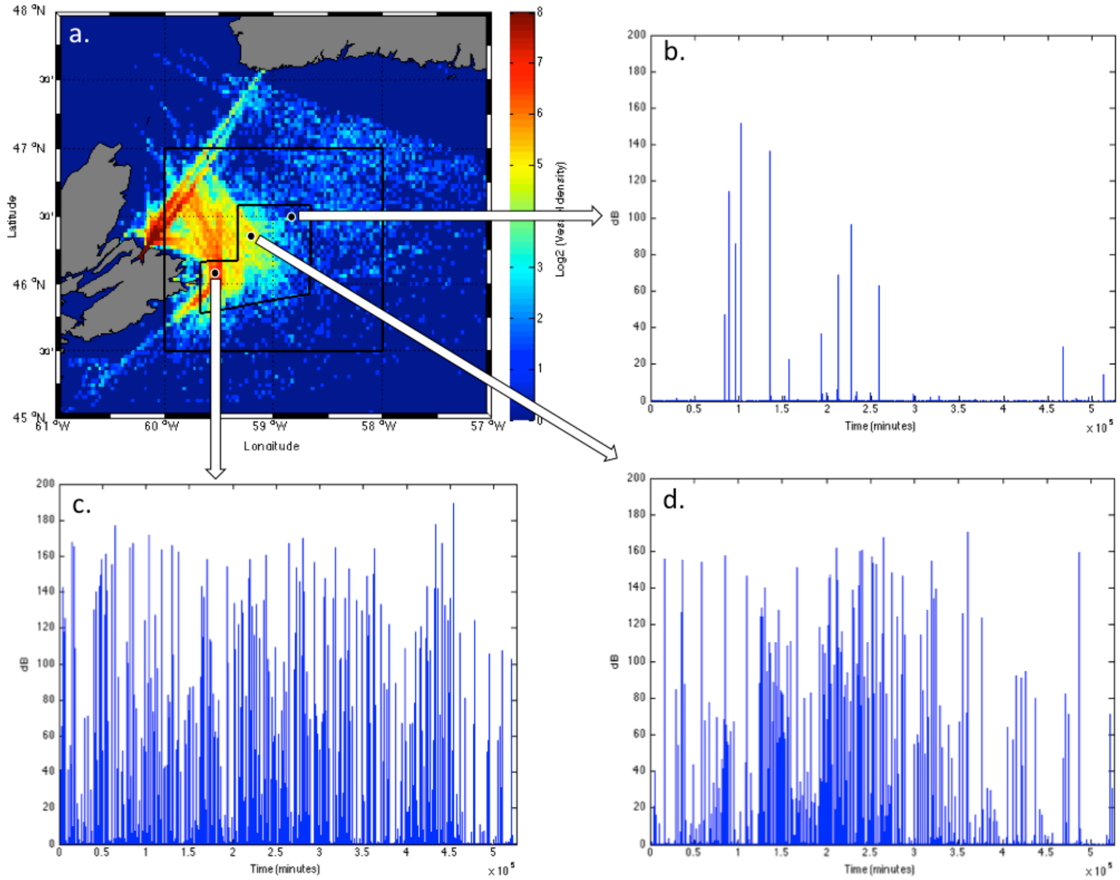

Figure 21. a. Chart illustrating the vessel density patterns for the St Anns Bank study area with three points identified as high, medium and low-density areas within the area of interest. b. Estimate of vessel-produced noise in an area of low vessel density within the AOI. c. Estimate of vessel-produced noise in an area of high vessel density within the AOI. d. Estimate of vessel-produced noise in an area of medium vessel density within the AOI. All sound estimates were made for the time period of 01 April 2008 through 01 March 2009.

The sound intensity is highest in the area with high vessel density and lowest in the area with low vessel density. The descriptive statistics for each of the plots in Figure 21 are in Table 7.

Table 7. Descriptive statistics for the estimated sound profile within high, medium and low vessel density areas in the St Anns Bank AOI.

	Low density	Medium density	High density
Mean	0.0101	0.2462	0.5600
Median	$5.1618e^{-29}$	$1.9360e^{-17}$	$1.8958e^{-13}$
Maximum	151.5821	170.2041	189.0161
Minimum	0	0	0
Standard deviation	0.7296	3.5137	5.2668

Given that most fin whales change their communication behavior when anthropogenic noise levels are higher than 120 dB and the estimation for the three areas of vessel traffic intensity all contained levels above 120 dB (Table 7) raises concerns for fin and other whales within the AOI. It is important to note that this is an approximation of the anthropogenic sound produced by vessels within the St Anns Bank AOI and is not an accurate representation of the actual amount of sound that is in that environment as a result of marine transportation activity.

In this study, I have identified several vessel related impacts that have the potential to work against the conservation objectives for the St Anns Bank marine protected area. The management plan for the MPA is in the process of being written and there are several ways to reduce the risk to the conservation objectives of the MPA from vessel traffic. In the next chapter, I put forward several recommendations to Fisheries and Oceans Canada that can be implemented into the management plan for the MPA to reduce the impacts of marine vessel traffic on conservation objectives.

Chapter 8: Discussion and recommendations

Marine transportation activity within the St Anns Bank marine protected area could potentially interfere with some of the conservation objectives of the MPA. There are still many unknowns regarding the impacts of shipping activity in the area and more research is needed in order to fully understand these impacts. My study provides a starting point outlining the issues that need to be addressed and the areas that should receive more research initiatives. In general some of the threats that the MPA would be exposed to from the shipping activity include the introduction of pollutants (in many forms), strikes to large pelagic species, and the noise input that is associated with vessels.

In terms of the traffic patterns in the study area, there are no discernable shipping lanes, with the exception of the Marine Atlantic ferries. This means that vessels are able to transit through any portion of the AOI and this results in a greater spatial reach of some of the impacts that marine transportation activity can cause. Designating specific shipping lanes will reduce the spatial extent of shipping impacts by condensing the vessel traffic into two distinct lanes (one entering and one exiting the Gulf of St. Lawrence). Designated lanes within the Bay of Fundy and Roseway Basin were directly overlapping with right whale habitat and causing strikes on that species. Designating lanes within the St Anns Bank AOI could have a greater impact on conservation objectives if lanes are placed in regions of important whale habitat. Prior to any changes in traffic patterns, I recommend that more research be conducted on whale abundance, distribution, and seasonality in the area to determine the most suitable location for lanes based on all conservation objectives as well as mariner safety.

8.1 Pollution

The introduction of pollution into the St Anns Bank AOI can be in the form of operational discharges of oily water (intentional or accidental), hazardous and noxious substances, and sewage. Section 35(3) of the *Oceans Act* (1996) states 'that the Governor in Council may make regulations prescribing measures that may include the prohibition of classes of activities within marine protected areas'. I recommend that Fisheries and Oceans Canada place restrictions on the operational discharges of vessels that are travelling within the St Anns Bank marine protected area. Though there are currently regulations in place for vessel sourced discharges in the marine environment, they could be further restricted within the MPA. In the United States, there are some marine areas that are designated as "no discharge zones" where all vessel sourced operational discharges are prohibited (World Shipping Council, 2012). I recommend that the St Anns Bank MPA be regulated as a "no discharge zone". This would reduce the amount of oil entering the environment and as a result reduce the risk of exposure to the animals within the MPA. I also recommend that no ballast water exchanges be conducted within the boundaries of the MPA. Though the likelihood of a species introduction is low, ballast water can also carry pollutants that could be harmful to the conservation objectives of the MPA.

There are also many unknowns when it comes to oil and leatherback turtles. Turtles dive frequently while feeding, and if they do this in an area that has been oiled they repeatedly expose themselves to oil (NOAA, 2010). Turtles have also been found to consume oil, which can remain within their systems for extended periods of time and the toxins get absorbed into the tissues of the turtles (NOAA, 2010). Oil may also cause turtles to become disoriented, it can influence the olfactory senses of the turtles and they rely heavily on these senses for navigation and orientation (NOAA, 2010). With so many uncertainties regarding oil and leatherbacks it is important to move forward with the St Anns Bank regulations with precaution and reduce the amount of oil that enters the MPA.

Though reducing the operational discharge of oily substances into the marine protected area would reduce the amount of oil that enters into it, there is still a chance major accidents could happen that result in the spilling of large volumes of oil. Accidents can still happen and oil could still enter into the MPA and for this reason I strongly recommended that there is an oil spill response plan within the management plan for the MPA so that if an accident occurs it can be responded to quickly and properly before significant impacts occur on the MPA conservation objectives. These plans should also reflect the seasonality of the MPA. Many of the species that the MPA is working to protect are seasonal species (i.e. summer residents) and therefore a response plan for an oil spill occurring in the summer months should be more thorough and the response times should be faster.

8.2 Vessel strikes

Vessel strikes on large pelagic species can be very common depending on the concentration of vessel traffic, the concentration of certain pelagic species and the spatial overlap between the two. In the case of whales in the St Anns Bank AOI, more research needs be conducted to determine whale presence and activity. In areas where whale strikes are a prominent issue, an area to be avoided or changes to vessel traffic lanes would work to reduce the risk of vessel strikes on whales. Before these actions can be put in place, whale species need to be identified along with their abundance and distribution. Monitoring should also be implemented for the detection of strike events.

In terms of vessel strikes on leatherback turtles, there is a high relative probability that turtles will get hit within the AOI boundaries as a result of the spatial overlap between vessel and turtles. Since 2006, there have been no reports of turtle fatalities as a result of vessel strikes off of Nova Scotia (Fisheries and Oceans Canada, 2006). This could be a result of no strikes occurring or it could be that there have been no strike event detections. They could be occurring in the AOI, given the higher relative probability, and simply going undetected. I recommend that Fisheries and Oceans Canada incorporate regular surveys of the marine protected area during the summer months when turtles and whales are present in order to aid in the detection of strike victims.

Another option to reduce the probability of a vessel strike on leatherback turtles is to concentrate the vessel traffic to an area where there is a lower probability of residency of the leatherbacks. The vessels could be routed in designated lanes that avoid critical areas for the turtles; one option is illustrated in Figure 22.

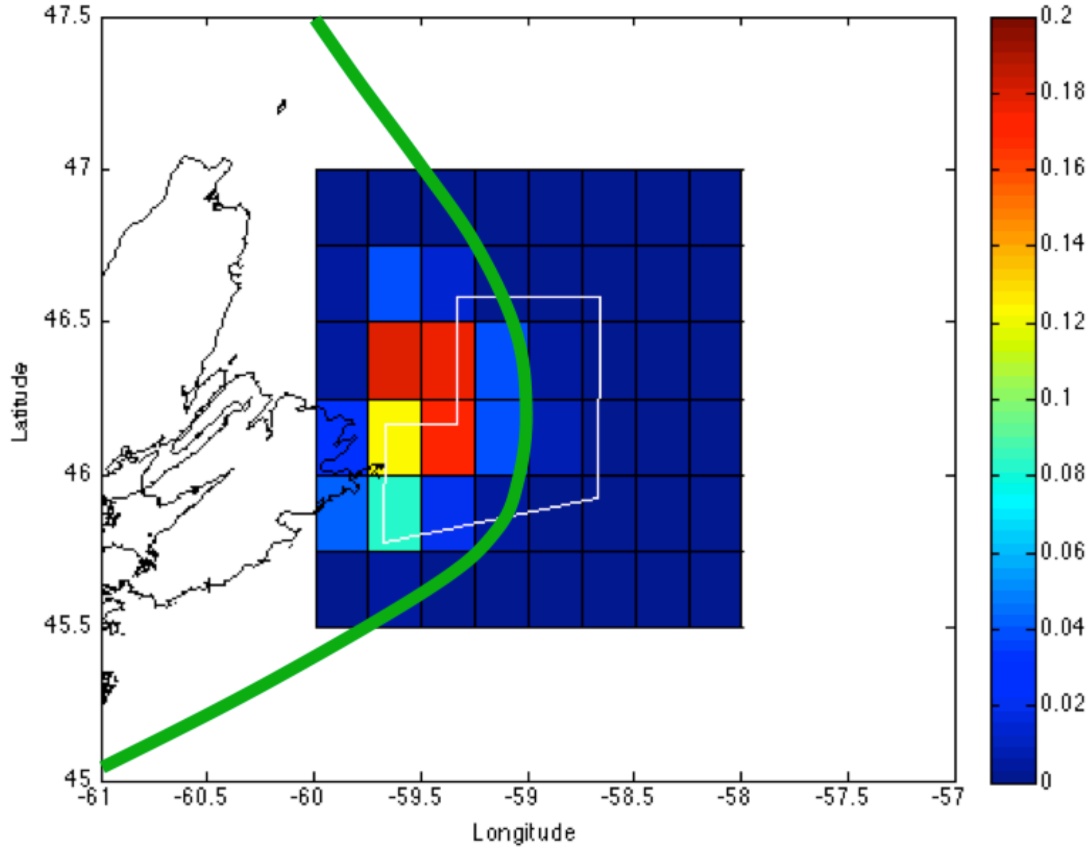

Figure 22. Chart illustrating a vessel routing option that could reduce the relative probability of a vessel strike occurring with a leatherback turtle. Note: the routing options are based on relative turtle strike probability do not take into account potential routing hazards or other species.

Figure 22 represents the best scenario based on relative vessel strike probabilities on turtles for vessel traffic lanes. Vessels could also transit closer to Cape Breton Island to avoid the high relative probability areas, however I recommend the route proposed in Figure 22 as to avoid moving vessels closer to inshore environments, which has the potential to increase the risk of a grounding event. In relation to this, the lane suggestion does move vessels further from shore reducing any current risk of groundings in the vicinity of the AOI; therefore the lane change serves a dual purpose. Leatherbacks are only present in the area between the months of June and October and any traffic lane designations could be reduced to seasonal lane changes. Fisheries and Oceans Canada could also implement a summer speed restriction for vessels travelling through the marine protected area in the summer months. Reducing the speed of the vessels does not reduce the probability of a strike occurring, but it could reduce the lethality of a strike event on whales and turtles. As mentioned previously, more research needs to be conducted before vessel routes are designated within the AOI. Re-routing vessel traffic to avoid areas of high probability of residence for leatherbacks could potentially create issues for whale species.

8.3 Vessel noise

Though this study did not measure the actual amount of anthropogenic sound produced by vessels within the St Anns Bank area of interest, the estimates that have been made are a step towards determining the impacts of vessel noise in the area. If the approximations made in this study are somewhat representative of the actual anthropogenic noise input, there are levels of noise occurring that would disturb the whale species (e.g. fin whales) that are thought to use the area of interest.

In order to get an accurate depiction of the sound that is being produced in the AOI, I recommend that a hydrophone be deployed in the area in order to record the ambient sound that is within the AOI and determine the levels that are being produced by the vessel traffic in the area. A sound recording device can also be used to identify whale species in the area, thus providing a dual purpose. It is of utmost importance that the whale species and presence be identified for the area in order to determine what the potential impacts of marine transportation activity are on the conservation objectives of the MPA. Weilgart (2007) recommended that for marine protected areas that encompass cetacean ‘hot spots’ have a buffer surrounding them. That way the MPA would also work to protect the cetacean species from anthropogenic sound as well as from other human impacts. If it is determined that St Anns Bank is a ‘hot spot’ for a particular whale species, routing changes may have to be put into place to either divert vessels into an area that is far enough from the whales’ main habitat or be completely routed around the MPA.

I mentioned earlier the potential for creating designated vessel traffic lanes within the AOI in order to avoid the areas of high probability of leatherback turtle residency, but shifting all of the vessels to a concentrated area within the AOI could have implications to the sound profile of the area. Concentrating the vessel traffic would also concentrate the sound being produced by vessels and could potentially increase the noise intensity in the shipping lanes. If there are normally several vessels in the AOI at one time, but they are spatially spread apart, the sound of each vessel would have minimal overlap. However, if several vessels travel through the AOI in designated lanes at the same time it would cause an additive effect of the sound in the area and create regions within the AOI with higher noise levels, potentially having negative impacts on whale species. However, while noise within the shipping lanes would increase, noise elsewhere in the AOI would decrease. Again, more research needs to be conducted on whale species in order to place the lanes in regions where sound will have minimal impact on whales. This research could be conducted with a hydrophone or with observer vessels in the area. One option is to create a partnership with Marine Atlantic. The ferry travelling from North Sydney to Argentia passes though the AOI from June through October. Fisheries and Oceans

Canada can work with the Marine Atlantic staff to train them on the identification of whale species and sightings can be reported to DFO.

8.4 Making changes to vessel traffic

In the examples of the Bay of Fundy and the Roseway Basin, the probability of vessel strikes on right whales was lowered by moving shipping lanes and creating a voluntary area to be avoided, respectively (Silber *et al.*, 2012). Making changes to vessel traffic patterns or routing cannot be done at a federal level. All changes to vessel traffic have to be made by the International Maritime Organization. In terms of protecting specific areas of the marine environment, a country or state can put in a request for the IMO to create a specific area of the ocean to be designated as a Particularly Sensitive Sea Area (PSSA) (International Maritime Organization, 2011c). A PSSA is defined by the IMO as "an area that needs special protection through action by IMO because of its significance for recognized ecological or socio-economic or scientific reasons and which may be vulnerable to damage by international maritime activities" (International Maritime Organization, 2011c). The types of impacts that can be reduced by the designation of a PSSA include operational discharges, accidental or intentional pollution, and any physical damage that may occur on marine habitats or organisms (International Maritime Organization, 2006).

Once more research is conducted within the St Anns Bank AOI, it could qualify for designation as a PSSA. If marine transportation activities are having negative impacts on the conservation objectives of the MPA, the Government of Canada can submit an application for the designation of St Anns Bank as a PSSA. In order to apply for the designation of a PSSA, the area must meet at least one of the criteria that are outlined in Table 8.

Table 8. Criteria for the establishment of a PSSA (International Maritime Organization, 2006)

Category	Criteria
Ecological criteria	Uniqueness or rarity
	Critical habitat
	Dependency
	Representativeness
	Diversity
	Productivity
	Spawning or breeding grounds
	Naturalness
	Integrity
	Fragility
	Bio-geographic importance
Social, cultural and economic criteria	Social or economic dependency
	Human dependency
	Cultural heritage
Scientific and educational criteria	Research
	Baseline for monitoring studies
	Education

St Anns Bank marine protected area could potentially meet some of the criteria for the application for the designation of a PSSA. The AOI does encompass important habitat for leatherback turtles and also provides important habitat for depleted commercial fish species (i.e. cod). Further research could determine that marine transportation activity is negatively impacting the conservation objectives of the MPA and this, combined with the criteria in Table 8 could make St Anns Bank a candidate for PSSA designation.

If an area is designated as a particularly sensitive sea area, routing options, such as areas to be avoided, can be implemented (International Maritime Organization, 2011c), similar to the Roseway Basin. Other routing options include a traffic separation scheme (as used in the Bay of Fundy), traffic lanes, separation zones or lines, roundabouts, inshore traffic zones, recommended routes, deep-water routes, and precautionary areas (International Maritime Organization, 2011b). Though these are options for the St Anns Bank marine protected area, it is critical that more research be conducted and more information collected in the area before any changes are suggested or applications put forward to the International Maritime Organization.

Chapter 9: Conclusion

Marine transportation activity can have implications for the conservation objectives of marine protected areas. There are potential issues in St Anns Bank AOI in relation to vessel traffic, including oily discharges of vessels, vessel noise, and vessel strikes. In summary, I recommend that Fisheries and Oceans Canada

- Conduct more research on whale species including spatial and temporal information
- Regulate St Anns Bank MPA as a 'no-discharge zone' and exclude ballast water exchanges
- Create a oil spill response plan that is unique for spills occurring within the MPA
- Conduct regular surveys of the area to detect strike mortalities
- Consider changes to vessel traffic routing (dependent on whale information)
- Consider speed restrictions within the MPA boundaries
- Deploy a hydrophone to determine the extent of vessel traffic noise and detect whale species presence
- Consider designating the St Anns Bank MPA as a PSSA through IMO, pending more research

In this study, I was able to identify the relative probability of vessel strikes occurring on leatherback turtles as well as create an estimate of the anthropogenic noise that is being produced in the area from vessel traffic. These impacts have the potential to work against the conservation objectives of the marine protected area, but more research is needed.

This study also identifies the areas of information that are lacking and the need for more research to be conducted on the whale species presence in the area. Fisheries and Oceans Canada will be able to use the information presented in my study to inform the management plan of the future St Anns Bank marine protected area in terms of marine transportation activity.

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