# An analysis of Scotia-Fundy vessel users and what this means for the North Atlantic right whale

By

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## ABSTRACT

The North Atlantic right whale is endangered under the *Species at Risk Act* thus, its protection is of the utmost importance. In Canada, there are two ship strike mitigation measures. A voluntary area to be avoided in Roseway Basin and shipping lane amendments in Grand Manan Basin have been implemented; both regions are prime right whale feeding areas. Despite the efforts, non-compliance occurs and right whales still fall victim to ship strikes. MEOPAR (Marine Environmental Observation Prediction and Response), is using passive acoustic monitoring to find whales in real time. The efforts of MEOPAR will lead to a whale alert system for the Scotia-Fundy region; in order to be successfully, the needs of the mariners must be evaluated. A representative sample of the fleet is required to survey them on their needs in the future thus, an analysis of the Scotia-Fundy users must be conducted. This study analyses all vessels using the Scotia-Fundy region. The primary analysis used vessels' MMSI number as their identifier to calculate how many days each vessel was present in the Scotia-Fundy region for the year 2015. The top 20% most frequent vessels were extracted and underwent further analysis. From the analysis, various vessel characteristics were revealed such as average speed, vessel size and vessel type. The result of this study is a list of vessels most frequently present in the Scotia-Fundy region and an idea of how likely they are to impact right whales based on their physical characteristics. The list created is the first step to surveying a representative sample of the fleet thus, ensuring successful implementation of a whale alert system.

Keywords: North Atlantic right whale; conservation; whale alert; Scotia-Fundy fleet; ship strike; vessel compliance; MEOPAR; Scotia-Fundy region.

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**LIST OF IMPORTANT ABBREVIATIONS**

AIS: Automatic Identification System

ATBA: Area To Be Avoided

AtoN: Aide To Navigation

DMA: Dynamic Management Area

ESA: Endangered Species Act

GM: Gulf of Maine

GoSL: Gulf Of Saint Lawrence

GPS: Global Positioning System

GT: Gross Tonnage

HTP: Habitual Traffic Patter

IMO: International Maritime Organization

MEOPAR: Marine Environmental Observation Prediction and Response Network

Navtex: Navigational Telex

PAM: Passive Acoustic Monitoring

SARA: Species At Risk Act

SF: Scotia-Fundy

SMA: Seasonal Management Area

SOLAS: Safety Of Life At Sea

SS: Scotian Shelf

TSS: Traffic Separation Scheme

VHF: Very High Frequency

WHaLE: Whale Habitat and Listening Experiment

# 1. INTRODUCTION

## *1.1 Vessel Activity in the Scotia-Fundy Region*

The Scotia Fundy (SF) region of the Canadian NW Atlantic includes the Scotian Shelf (SS) and the Canadian portion of the Gulf of Maine (GM) that includes the Bay of Fundy. The region is one of very diverse environments, in both a biological and social sense. There are various types of vessels that navigate the SF region, including various kinds and classes (defined by the International Maritime Organization; IMO) of tankers, cargo and passenger vessels, towing and pilot vessels, as well as research/exploration and marine enforcement vessels and fishing and recreational vessels. Of the many classes some include more specific types of vessels than is initially implied. For example, fishing vessels include small scale operations such as lobster and long-line fishing boats, as well as large commercial trawlers. Towing vessels include tugs and barges, cable layers, diving vessels and dredgers, while pilot vessels include research and coastguard vessels and finally passenger vessels can be ferries or cruise ships. All vessel classes in the SF region are engaged in activities that include transportation of resources, commodities and people, the maintenance of security, sovereignty and safety, and fishing.

The *Safety of Life at Sea* (SOLAS) convention recognizes the IMO as the United Nations body responsible for safe and secure shipping as well as preventing marine pollution (Silber et al, 2012). Vessels greater than 100 gross tonnage (GT), or longer than 19.8 m, or towing vessels of 8 m and more than 600 horsepower, or vessels carrying 150+ passengers, or dredging near commercial channels or carrying certain dangerous cargo or flammable or combustible liquid cargo in bulk, are the so-called IMO "rule vessels"; they all require a class-A Automatic

Identification System (AIS) transceiver (US Coastguard, 2016). Many non-rule vessels such as fishing vessels and recreational vessels also carry AIS transceiver.

AIS uses very high frequency (VHF) radio signals to transmit and receive the identification, location and navigational state of all AIS vessels within VHF range. AIS was initially implemented as a response to SOLAS in providing situational awareness of vessels to prevent collisions (Silber et al, 2012). In addition to providing situational awareness, AIS may also incorporate aid to navigation (AtoN) systems (typical stationary) wherein messages are transmitted to the AIS receivers to caution vessels of special hazards, e.g., adverse weather or navigational hazards.

Although originally employed to transmit navigational information amongst vessels, AIS can also be received on shore using coastal bay station receivers that are used for vessel monitoring and are particularly useful for marine traffic services. Most recently, AIS can also be received by satellites then down-linked to bay stations around the world. A network of coastal bay stations can be used to study shipping activity in coastal regions.

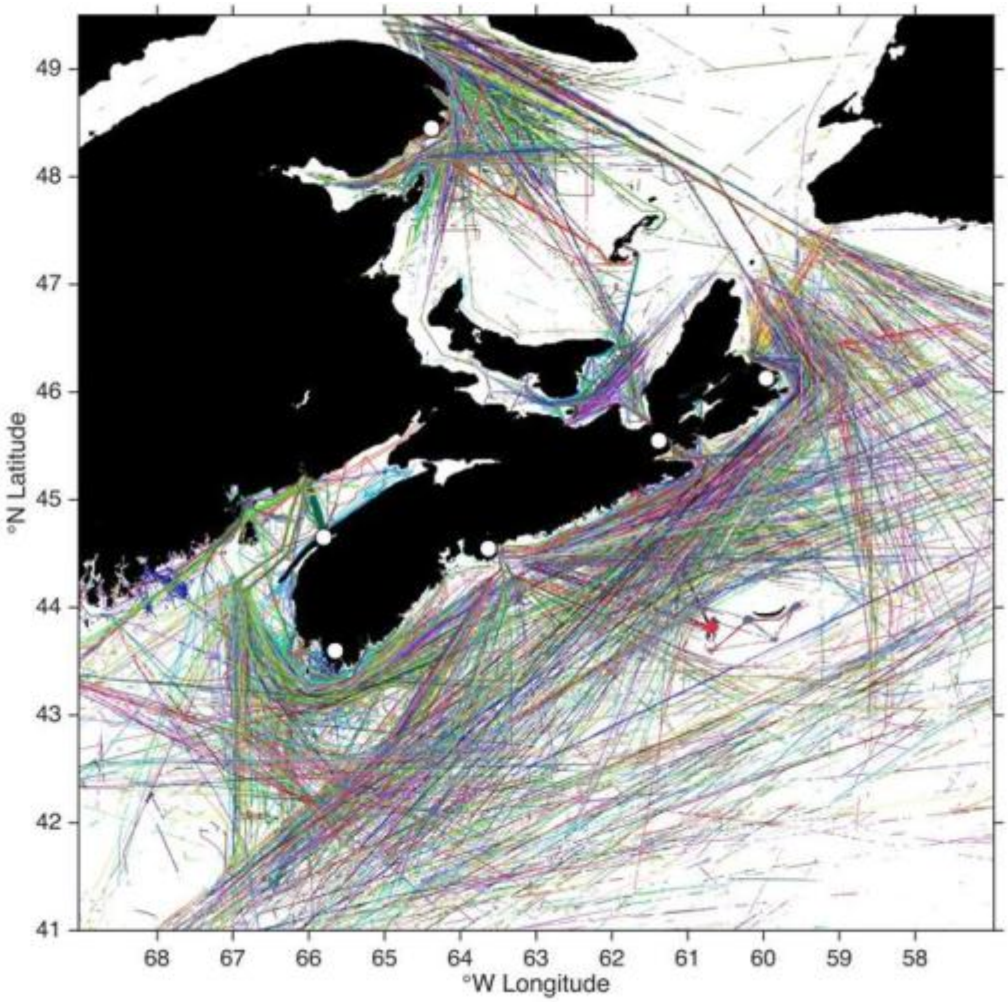


**Figure 1.** An image of coastal traffic courtesy of satellite AIS data. This image draws on Satellite AIS data which are provided by exactEarth Ltd. 2016, and processed by This image draws on Satellite AIS data which are provided by exactEarth Ltd. 2016, and processed by R.C. Hilliard, courtesy of MEOPAR.

Ninety per cent of global trade is carried by sea (IMO) and there are approximately 87,000 ocean-going vessels globally (EMSA, 2015: European Maritime Safety Agency; IMO and Maritime Knowledge Centre, 2012) for which EMSA uses 12 vessel classifications; general, specialized and ro-ro (roll-on, roll-off) cargo vessels, container and bulk carriers; oil, chemical, gas and other tankers; passenger, offshore and service vessels; and tugs. EMSA also uses 4 vessel-size-classifications; small (100 to <500 GT), medium (500 to <25,000 GT), large (25,000 to <60,000 GT) and very large (≥60,000 GT). According to EMSA, in 2015 the world fleet was composed of 37% small, 44% medium, 13% large and 6% very large vessels. Of these, 19% were general cargo, 13% were bulk carriers and 15% oil and chemical tankers, most of which are medium to very large vessels.

Relative to the global fleet, ~5% of the vessels (7.5% of global gross tonnage) navigate eastern North America (Florida to the Arctic, including coastal Greenland), of which ~73% are medium and large vessels.

Most commercial shipping involves port-to-port transits on global and regional scales and results in the emergence of highly concentrated habitual traffic patterns (HTPs). HTPs should not be confused with IMO sanctioned traffic separation schemes (TSSs), or lanes, such as those in the Bay of Fundy. Traffic separation schemes are defined by the IMO and must be used by vessels for safe navigation in constricted high-traffic areas, whereas HTPs occur because they reflect the most efficient routes that over long distances generally follow the great circle (Figure. 2).

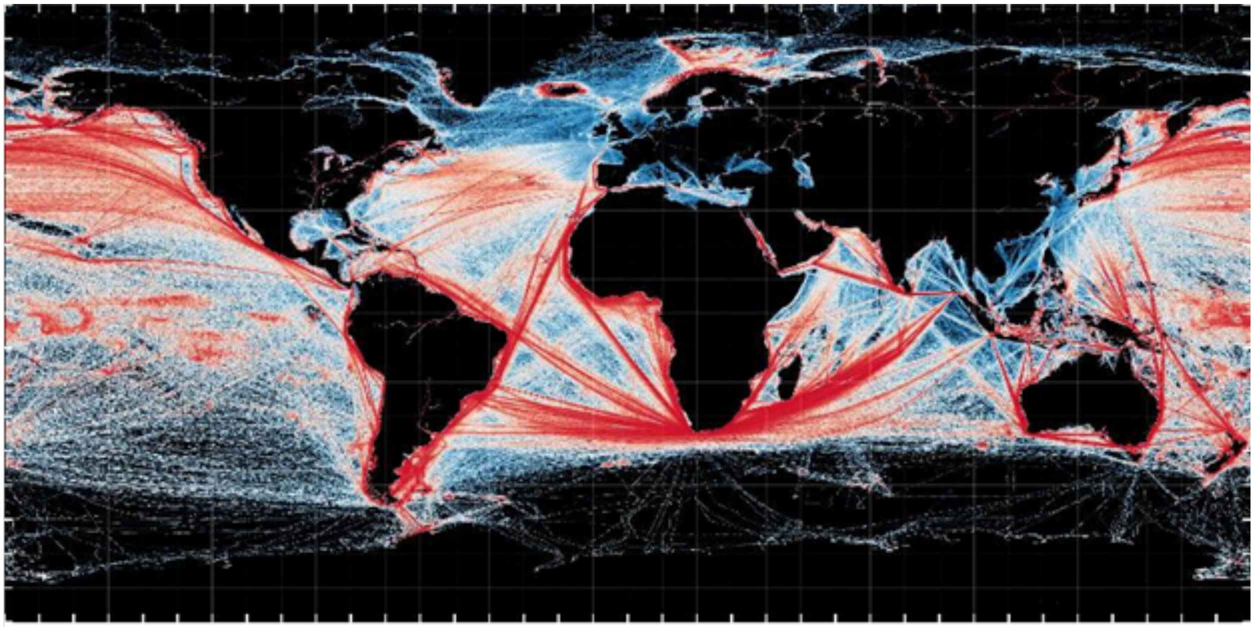

**Figure 2.** Global rendering of satellite AIS vessel receptions for 2015 illustrating the nature of global and regional habitual traffic patterns and the relative concentrations decreasing from red to white to blue. This image draws on Satellite AIS data which are provided by exactEarth Ltd. 2016, and processed by This image draws on Satellite AIS data which are provided by exactEarth Ltd. 2016, and processed by R.C. Hilliard, courtesy of MEOPAR.

The presence of HTPs in the Scotia Fundy Region implies potentially negative impacts on the marine environment and this includes wildlife; i.e., the risk of negative impacts will be elevated where and when wildlife and HTPs intersect. This is especially relevant to cetaceans (whales), pinnipeds (e.g. seals) and sea turtles that are particularly at risk of being struck and injured or killed by a vessel strike because these animals must surface to breathe, and often spend extended periods "logging" at the surface.

*1.2 Biological Diversity in the Scotia-Fundy Region*

The Scotia Fundy region is frequented by large whale species, pinnipeds and sea turtles (MacLean et al, 2013). The large baleen whale species most common in the SF region are the humpback, fin, North Atlantic right, minke, blue and sei whales (MacLean et al, 2013). The baleen whales are differentiated from toothed whales, e.g., sperm whales, orcas and dolphins, in that they are large filter-feeders and do not use echolocation (sonar; sound navigation and ranging) for sensing their environment. The consequence of this differentiation is that baleen whales are prone to vessel strikes and mortality and of the baleen whales the North Atlantic right whale is the most prone to ship strike, especially on a per capita basis (Vanderlaan and Taggart, 2007). For this reason, and its status as an endangered species (below), the right whale has become somewhat of an umbrella species, representative of all baleen whale species. Protection or mitigation of vessel-strike risk to the right whale will also serve the other baleen whales (Fleishman et al, 2001). Therefore, the North Atlantic right whale is, in part, the focus of this study.

A large portion of the right whale population inhabits the SF region for feeding purposes during the summer and autumn months. There are two known feeding habitats in Canada, the Grand Manan Basin in the Bay of Fundy and Roseway Basin on the southwest Scotian Shelf. More recently there is evidence of feeding habitat in the Gulf of Saint Lawrence (GoSL), east of the Gaspé Peninsula. Another large portion (~50%) of the right whale population resides elsewhere during the summer/autumn period in unknown habitats.

Centuries of whaling depleted the right whale to well below the current population size of 522 (Pettis and Hamilton, 2014). The right whale is the most endangered baleen whale species on a global scale. In Canada it is listed as endangered under Canada's *Species at Risk Act* (S.C. 2002, c. 29) and in the USA the right whale is listed as endangered under the *Endangered Species Act* (ESA; 16 U.S.C § 1531 et seq.). In Canada it was assigned endangered status in 1980 when the North Atlantic, Southern and North Pacific right whales were considered one species. Subsequently, the North Atlantic right whale was given endangered status as a distinct species in

2003 (Brown et al, 2009). The right whales are vulnerable and prone to vessel strike and as such, both the USA and Canada have measures in place to help protect them.

*1.3 Anthropogenic Stressors*

The North Atlantic right whale is at risk of extinction (Brown et al, 2009) and currently there are two major factors contributing to that risk; vessel strikes and fishing gear entanglement (Brown et al, 2009). These risks are also faced by all other large baleen species. Vessel strikes have been historically documented; the fin, humpback, North Altantic right, gray and southern right whales are the most prevalent victims of vessel strikes (Vanderlaan & Taggart, 2007). Though many whales suffer from collisions, the North Atlantic right whale is the victim of vessel strike at a rate that is two orders of magnitude greater than other baleen species on a per capita basis (Vanderlaan & Taggart, 2007). Unfortunately, the right whale is in the right place at the right time; i.e., they are an "urban whale" (Kraus and Rolland, 2007) found migrating close to shore where they intersect HTPs. In addition, they may spend extended periods at the surface, are black, and have no dorsal fin which makes them difficult to see (Parks et al, 2011). All of these characteristics make them vulnerable to vessel strike, and this is exacerbated by the fact that there is no compelling evidence that the whales show any behavioural response (e.g., avoidance) to vessel noise (Nowacek et al. 2004).

The second largest anthropogenic stressor for the right whale is fish gear entanglement (Brown et al, 2009). Once a baleen whale becomes entangled, it is a very difficult task to disentangle them. Though gear entanglement is an issue and many countries have regulations in place to prevent it, entanglement is not addressed in this study.

*1.4 Mitigation Strategies*

Both Canada and the USA have strategies in place to protect the North Atlantic right whale species (Silber et al, 2012). In Canada, Roseway Basin and Grand Manan Basin are known feeding grounds for the North Atlantic right whale and have each been designated as “critical habitat” under SARA (S.C. 2002, c.29). From the perspective of vessel-strike mitigation, changes in shipping activities have occurred in each of these habitats. First, the TSS (shipping lanes) in the Grand Manan Basin near the entrance to the Bay of Fundy was amended in 2003 by the IMO and Canada, and this resulted in an ~90% decrease in the likelihood of lethal vessel-strikes to right whales (Vanderlaan et al., 2008). Second, a voluntary Area to be Avoided (ATBA) was implemented by the IMO and Canada in Roseway Basin in 2008 and it is active between 1 June and 31 December annually. Vessels are expected to voluntarily avoid the area by navigating around rather than transiting through (Vanderlaan et al., 2008). ATBA compliance stabilized between 71-82% by the end of October 2008 and those still transiting through reduced their speed significantly (Vanderlaan and Taggart, 2009). In total, the risk of lethal strikes to right whales in Roseway Basin has been reduced by 82% through this strategy.

The Canadian conservation strategy has been to establish policies that result in having vessels avoid those habitats where right whales are known to aggregate; i.e., minimize time-space intersections of whales and vessels. Avoidance reduces the probability of a lethal vessel strike. Conversely, the USA conservation strategy has primarily been to establish policies that result in vessels slowing down to 10 knots or less in those habitats where right whales are known to aggregate; i.e., reduce the probability of a strike being lethal to somewhere near 30% as opposed to near 90% when navigating at speeds of 18 knots or more (Vanderlaan and Taggart 2007). Slowing down a vessel only reduces the probability of a strike being lethal; it has little or no effect on the probability of a strike occurring (Vanderlaan and Taggart 2007).

The USA and IMO have implemented a Mandatory Ship Reporting system as a means of mitigating the risk of vessel strikes to the North Atlantic right whale (Silber et al, 2012). All commercial vessels equal to or greater than 300 GT are required to report to shore based stations when they enter either of the two regions that right whales are known to inhabit (Silber et al, 2012). The first region is off the state of Massachusetts and it operates year round, the second area is off the states of Georgia and Florida but it only operates from November 15th to April 15th annually (Silber et al, 2012). Vessels are required to report their vessel name, call sign, course, speed, location, destination, and route; in return vessels receive near real time information on right whales and guidance to prevent strikes (Silber et al, 2012).

The second USA and IMO mitigation measure was the amendment to the Boston TSS off New England (Silber et al, 2012). The TSS established in 1973 navigated to and from Boston and it intersected areas that were frequently inhabited by high concentrations of right whales (Silber et al 2012). In 2006 the TSS lanes were narrowed and their location modified to reduce the probability of vessel strike by 58% for right whales (Silber et al, 2012). Further alterations to this TSS were proposed in 2008 and adopted by 2009 (Silber et al, 2012).

The third mitigation measure implemented by the USA and IMO is an ATBA in the Great South Channel in the Gulf of Maine; right whales are known to aggregate in this area during the summer and autumn to feed (Silber et al, 2012). This area encompasses one of the existing Mandatory Ship Reporting regions, the Boston TSS, and two other heavily used HTPs (Silber et al, 2012). The ATBA was implemented by 2009 and is active from April 1st to July 21st annually; due to its location, it encourages the use of the amended Boston TSS in addition to mitigating the risk of ship strike to right whales (Silber et al, 2012).

In addition to the IMO and USA joint mitigation strategies, the USA has measures it has implemented individually. The first strategy the USA implemented was based on Seasonal Management Areas (SMA); areas where the whales are found year after year during a specified period of time (Merrick, 2005). SMAs are active between March 1st and July 31st each year (NOAA); during this period two zones are created. The Southeastern zone straddles the states of Florida and Georgia and is active from November 15th to April 15th annually (NOAA). The Mid-Atlantic zone straddles North Carolina, South Carolina and Georgia and is active November 1st through April 30th annually(NOAA). Both SMAs were created to protect critical right whale calving and nursing habitats. The regulations within an SMA include prohibition of lobster pot/traps and gillnet gear (NOAA) and vessels must slow to 10 knots when in the SMA (Russel et al, 2001).

The final strategy the USA implemented is no longer in use; Dynamic Management Areas (DMAs). These were created to mitigate risk to episodic aggregations of right whales (NOAA, 2016). If aggregations of 3+ whales were sighted (0.04 whales/$nm^2$) then the DMA would be implemented (Merrick, 2005). The whales are given a 15 nm protection radius that may increase if whale density increases (Merrick, 2005). The necessity of the DMA was reassessed 15 days post-implementation (NOAA, 2016). The DMA was most often voluntary and vessels were requested to slow to 10 knots when navigating through (NOAA, 2016).

In summary, though Canada and the USA each have strategies for protecting the North Atlantic right whale, they differ in tactics. Canada has adopted vessel avoidance and no directed speed limitations while the USA has adopted primarily speed limitations and some avoidance policies.

### *1.5 Management Problem*

The North Atlantic right whale is the most endangered of the large baleen whale species and it is particularly vulnerable to strikes (Vanderlaan and Taggart, 2007). Though there are some protection measures in place, the whales remain at risk of ship strike in areas outside their known and/or protected habitats and thus additional protection policies are needed. Fortunately, new technologies have begun to emerge that may offer a new approach to reducing vessel strike risk.

### *1.6 Whale Alert Technology*

The Canadian MEOPAR (Marine Environmental Observation, Prediction and Response) research network includes the Whales, Habitat and Listening Experiment (WHaLE) wherein the researchers are addressing whale-vessel risk by generating, exchanging and exploiting new knowledge derived from vessel, airborne and passive acoustic monitoring (PAM) of whales along with oceanographic, and vessel AIS data obtained from fixed and mobile platforms. Passive acoustic monitoring is used to listen for and identify baleen whales and assess the risk present between whales and vessels in the SF region. The WHaLE researchers are in the process of creating an AIS Whale Alert System in Canada to warn mariners of the presence of whales in near real time. An AIS Whale Alert System could add new depth to whale conservation as warning mariners of whale locations provides them the opportunity to avoid the whales. Real time knowledge of whale locations will allow vessels to have an improved awareness of the whales and their vulnerability to strikes. An AIS Whale Alert System could greatly reduce the likelihood of vessels strikes as long as mariners are willing to comply. In consideration of a smooth implementation of an AIS Whale Alert system, a previous study was conducted to gage how willing vessel operators would accept this new technology.

*1.7 Vessel Receptivity to Emerging Technologies*

With the goals of the WHaLE program in mind, Reimer et al (2015) conducted a survey of mariners' receptivity to new conservation measures and their willingness to comply. The Canadian Shipping Federation sent surveys to its membership to obtain information on mariners' knowledge of right whales, conservation measures associated with them, their willingness to comply to whale alerts, and the technology platform they would prefer to receive Whale Alert messages (Reimer et al, 2015). It was found that most mariners would prefer to receive Whale Alerts via NAVTEX or as an AIS message (Reimer et al, 2015). NAVTEX is a navigational aide like AIS; it prints weather forecasts and any other hazards a mariner should be aware of. For those implementing the Whale Alert technology, AIS messaging is the better option as NAVTEX messaging only occurs every few hours while AIS messaging can be achieved in near-real time as an ongoing notification system. In addition to providing their platform preference, most mariners also seemed receptive to learning more about whale conservation and what they could do to help protect whales (Reimer et al., 2015). Therefore, implementing the Whale Alert System using the best platform could make all the difference in whale conservation and user compliance.

Though the Reimer et al. study yielded some important results, it is possible that only a small sample of a larger population of vessel users was captured; this possibility was shown by the fact that many of the vessels were predominantly found in one area and all similar in size (Reimer et al., 2015). Therefore, only certain vessels of similar attributes using the SF region were surveyed. The opinions of the fleet using the SF region are important as increased compliance will occur if new policies and technologies are sensitive to mariner concerns. The sample captured in Reimer et al. allowed a glimpse of the preferences of mariners in relation to conservation, however, it was considered necessary that a representative sample of those vessel using the SF region be obtained. If most vessels agree they prefer AIS to be the mode of communication for the Whale Alert System, then it is more likely to be successfully implemented through AIS.

To obtain a representative survey, with questions similar to those used in the Reimer et al. survey, a characterization of vessels navigating the SF region was required. It was necessary to identify and characterize the vessels that most frequently navigate the SF region. Of the most frequent vessels, the largest and fastest were revealed as they pose the greatest threat to right whales thus, their compliance will matter most when a Whale Alert System is inevitably implemented. Four vessel classes have preemptively been chosen as “focal vessels” due to the pre-existing knowledge of their size, speed and effect on whales; they are tanker, cargo, passenger and military vessels.

**Research Question:**

How will knowing the characteristics of the most frequent Scotia-Fundy vessels aide in implementing a new AIS Whale Alert System?

## 2. METHODOLOGY

This study focused on finding the identity, frequency of presence and class of the vessels navigating the Scotia-Fundy area and the first step was to define the domain for which I would secure vessel data. Knowledge of areas frequently used by right whales contributed to defining the study. Right whales are known to feed in Grand Manan Basin (Gulf of Maine/Bay of Fundy) and Roseway Basin (Scotian Shelf) and elsewhere in the SF region. Thus, polygons were created that encompassed the two basins and a preliminary examination of vessel traffic density in the region provided a secondary aid in the creation of the polygons. Factoring in vessel traffic density and HTPs helped to prevent significant overlap of vessels among polygons.

Therefore, the two primary polygons were used to define the Gulf of Maine including the Bay of Fundy (GM) polygon and the Scotian Shelf (SS) polygon; jointly referred to as the Scotia Fundy (SF) region. In addition to these I created as third polygon for the North Laurentian Channel (NLC) that was used in a secondary analysis for comparison with the SF region.

**Table 1.** Decimal N-latitude and W-longitude coordinates describing the vertices of each of the three polygons in the study domain.

| Gulf of Maine | | Scotian Shelf | | Laurentian Chanel | |
|---|---|---|---|---|---|
| Lat | Lon | Lat | Lon | Lat | Lon |
| 44.87 | 67.00 | 44.83 | 57.38 | 50.3 | 65.72 |
| 42.88 | 67.75 | 45.88 | 58.22 | 50.15 | 67 |
| 40.47 | 65.67 | 46.98 | 60.37 | 48.78 | 67.77 |
| 42.57 | 63.38 | 45.65 | 61.43 | 48.87 | 64.2 |
| 44.28 | 63.28 | 44.72 | 63.68 | 47.88 | 61.07 |
| 45.78 | 64.67 | 44.28 | 63.28 | 46.98 | 60.37 |
| 44.87 | 67.00 | 42.57 | 63.38 | 48.33 | 58.72 |
| | | 44.83 | 57.38 | 50.3 | 65.72 |

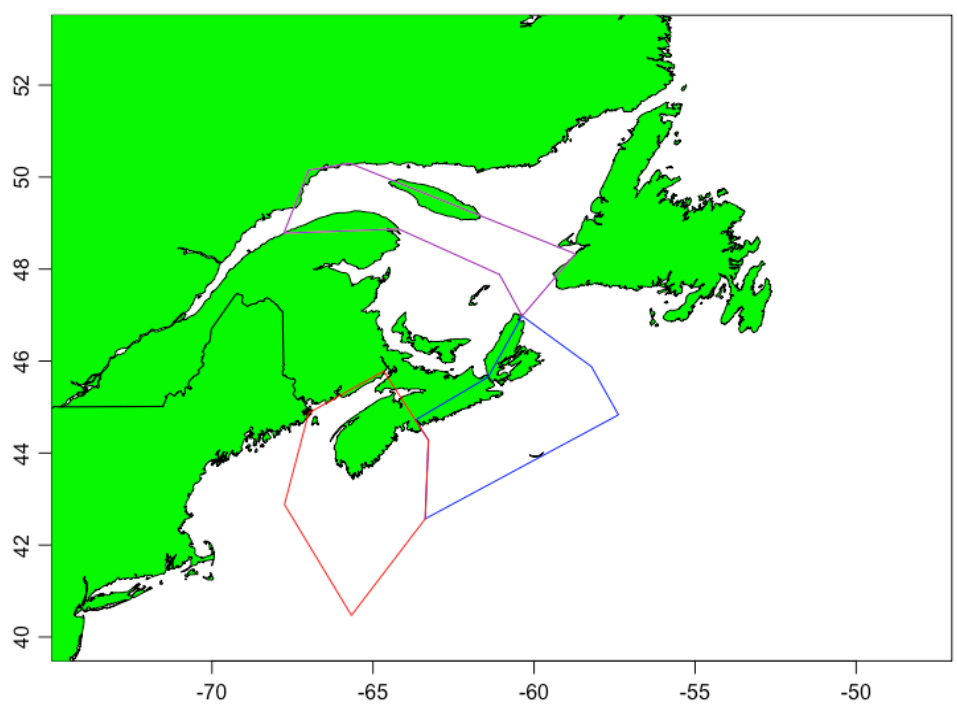


**Figure 3.** The GM (red), SS (blue) and NLC (magenta) polygon used for vessel analyses.

For each polygon, 365 days of satellite AIS data for the year 2015 were used (provided by exactEarth Ltd. 2016, and processed by R.C. Hilliard, courtesy of MEOPAR.). There are two kinds of primary AIS messages; one is a dynamic message transmitted approximately every 3 seconds and the other a static message transmitted approximately every 6 minutes. Satellite AIS data are not necessarily recorded at the same temporal resolution. The only variable common to each message is vessel MMSI number (Maritime Mobile Service Identity). In addition to the MMSI number, the dynamic message includes message date, time, time zone, the vessel navigational status (underway, at anchor etc.), rate of turn (degree), speed over ground (SOG; knots), GPS location accuracy (hi, lo), latitude, longitude, course over ground (COG) and heading (degree true) and UTC time (clock-seconds only) from the vessel GPS at the time of report generation. The dynamic message is generated automatically from the vessel GPS/navigation system and is normally unalterable though some data can be corrupted during VHF transmission. The static message includes the MMSI number, message date, time, time zone, the vessel IMO number, radio call-sign, name, vessel type (class), length, width and draught (m), and destination. The static data are alterable and are input manually by bridge personnel and are known to be error prone and unreliable. (Harati-Mokhtari et al., 2007).

I focused on 13 AIS data fields for the purposes of this study; MMSI, date, time, SOG, latitude, longitude, the IMO number, radio call-sign, name, class, length, width and draught. The above data provided information on vessel identity and characteristics relevant to vessel threat to whales (e.g., speed, size and location). Once secured, I first refined the data to include only those vessels navigating at or above 5 knots because vessels below this speed pose little threat to whales; this refinement also excludes vessels at or near port and/or not underway as their inclusion would bias the time of navigation in the domain (e.g., a vessel in port for several days while transmitting AIS data). All vessels with an MMSI number 0 were excluded as there was virtually no other data to determine vessel identity.

Additional quality control of the data was necessary due to the innumerable errors in the static data either due to human error and/or message corruption during transmission. Quality control began with correcting aliases in the static data by relying on the MMSI number. This number is considered the most accurate vessel identifier and was used to find variations (aliases) in other components of the static messages. In the first case 1) an MMSI-specific vessel may have had all the correct information in the static fields (see below for verification) while at another time at least one static field would be an alias for the same vessel. To correct the problem, a script was created  that compared all records for a given MMSI. When one or more aliases was/were identified, the most correct alias was used to overwrite all others. In the second case 2) only the MMSI was considered reliable (multiple aliases across all other static data fields were lacking information; i.e., there was no "most correct" alias). In either of these two cases, external vessel identification databases were used to verify the most correct alias or to gain data for the lacking static fields based on a given MMSI number. The URL *itu.int* was one such database provided by the International Telecommunication Union (ITU), an agency of the United Nations (UN) that coordinates telecommunication operations and services throughout the world (i.e., correct static data for a given MMSI vessel).

For analytical purposes I simplified the original AIS vessel classes to a condensed vessel class (Table 1) because many of those in the 0 to 99 class/subclass range were not relevant to my needs. In most cases each decadal-class number represents a general vessel class. For example, 50 to 59 represent pilot vessels, but 51 to 59 represent subclasses of "pilot" vessels (e.g., search and rescue). For my purposes it was sufficient to know that vessel type as "pilot". The same held true for other classes (e.g., tanker, cargo, military etc.).

**Table 2.** The original AIS vessel class names and number ranges as assigned for use in an AIS static messages and the newly condensed vessel class number (mostly decadal) used in the analyses. Bold-case vessel classes represent the vessels considered most relevant for the focus of the study.

| AIS Vessel Class Name | AIS Vessel Class (sub-class) Number Range | Condensed Vessel Class Number Used in Analyses |
|---|---|---|
| Unknown | 0-9 | 0 |
| Reserved for Future Use | 10-19 | 10 |
| Wing-in Ground | 20-29 | 20 |
| Fishing | 30 | 30 |
| Towing, Diving, Dredging | 31-34 | 31 |
| **Military** | 35 | 35 |
| Pleasure | 36-37 | 37 |
| Reserved | 38-39 | 38 |
| High Speed Craft | 40-49 | 40 |
| Pilot | 50-59 | 50 |
| **Passenger** | 60-69 | 60 |
| **Cargo** | 70-79 | 70 |
| **Tanker** | 80-89 | 80 |
| Other | 90-99 | 90 |

Additional changes were required for vessel classification. Because the vessel class field is also part of the static AIS message, it too was subject to error, and I thus created a script to identify and overwrite the incorrect vessel class aliases, and gain using various URLs as above. In addition, some vessels were inconsistent in vessel class among the different polygons of vessel data (e.g., a vessel with the same MMSI number could be a ‘tug’ in GM polygon and ‘cargo’ in SS. A similar script was used to rectify these errors and provide the most accurate vessel classification across the entire study domain.

Following vessel data quality control, I created geographic plots of vessel distributions; one representing all unique vessels, one to represent only the top 20% of the vessels by time in a polygon, and one represented by ‘focal’ vessels (military, cargo, tanker and passenger vessels) most relevant my study. Two discovery curves were also created to illustrate the cumulative count of unique vessels appearing in a polygon from the beginning to the end of 2015; first for all unique vessels and then for those vessels representing the top 20%. In addition to the discovery curve, a histogram was created to illustrate day-to-day and season variation in the number of unique vessels navigating a polygon.

The next step was to identify those vessels representing the top 20% based on the number of days they occupied a given domain in 2015. All vessel classes were included in the top 20% but emphasis was placed on military, cargo, passenger and tanker vessels as they pose more risk to whales. The top 20% was first used to provide a list of the top 10 most frequent vessels in a given domains as well as the top 10 most frequent vessels in joint domains. These top 10 simply provided insight into the differences in vessel class variation within and among domains. The most important deliverable created from the top 20% was an identity list of those for eventual direct contact/survey. The MMSI number was used as the primary identifier that was now correctly linked to the IMO number, vessel name, call sign and additional characteristic relevant to whale-strike risk, including vessel class and size.

The NLC polygon was secondarily analyzed as above to assess, in a preliminary manner, how many unique vessels in the primary domains were also found in the NLC. Once refined, the NLC was compared to the primary domains and the top 10 most frequent vessels overlapping the three domains was determined to provide insight into the those vessels navigating the larger domain.

## 3. RESULTS

*Analyses of All Unique Vessels:*

The two domains (GM and SS) jointly encompassed an area of approximately 230, 839 $km^2$. Within this area 2757 unique vessels navigated the area in 2015. The GM encompassed an area of 133, 174 $km^2$ with 1439 unique vessels of which 288 vessels represented the top 20%. Of these, the most frequently occurring vessel in the GM was present for 345 days (Table. 3) of the year and the least frequent vessel was present for one day of the year. The SS encompassed 97, 665 $km^2$ with 1482 unique vessels present in 2015 of which 296 vessels represented in the top 20%. The most frequently occurring vessel on the SS was present for 323 days (Table. 4) and the least frequent vessel was present for one day.

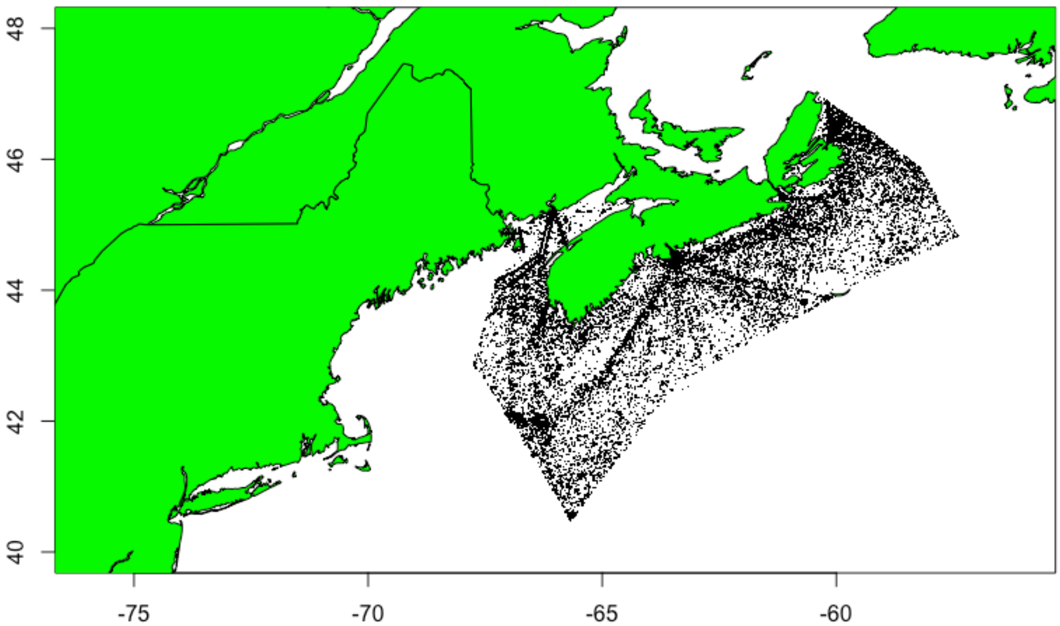


**Figure 4.** Daily positions of each unique vessel navigating the Gulf of Maine and Scotian Shelf in 2015.

Figure 4 illustrates the daily positions of each unique vessel navigating the Gulf of Maine and Scotian Shelf in 2015. There are various patterns are readily apparent within the distribution; the TSS in the Bay of Fundy, HTPs to and from Halifax and along the coast of Nova Scotia and the paucity of vessels southwest of Nova Scotia where the HTPs encompass voluntary ATBA over Roseway Basin.

Various regions of enhanced vessel density appear to represent different vessel activities. For example, fishing vessels are likely responsible for concentrated vessels density near the Haig Line associated with the tip of Georges Bank in the SW region of Figures 4 and 9.

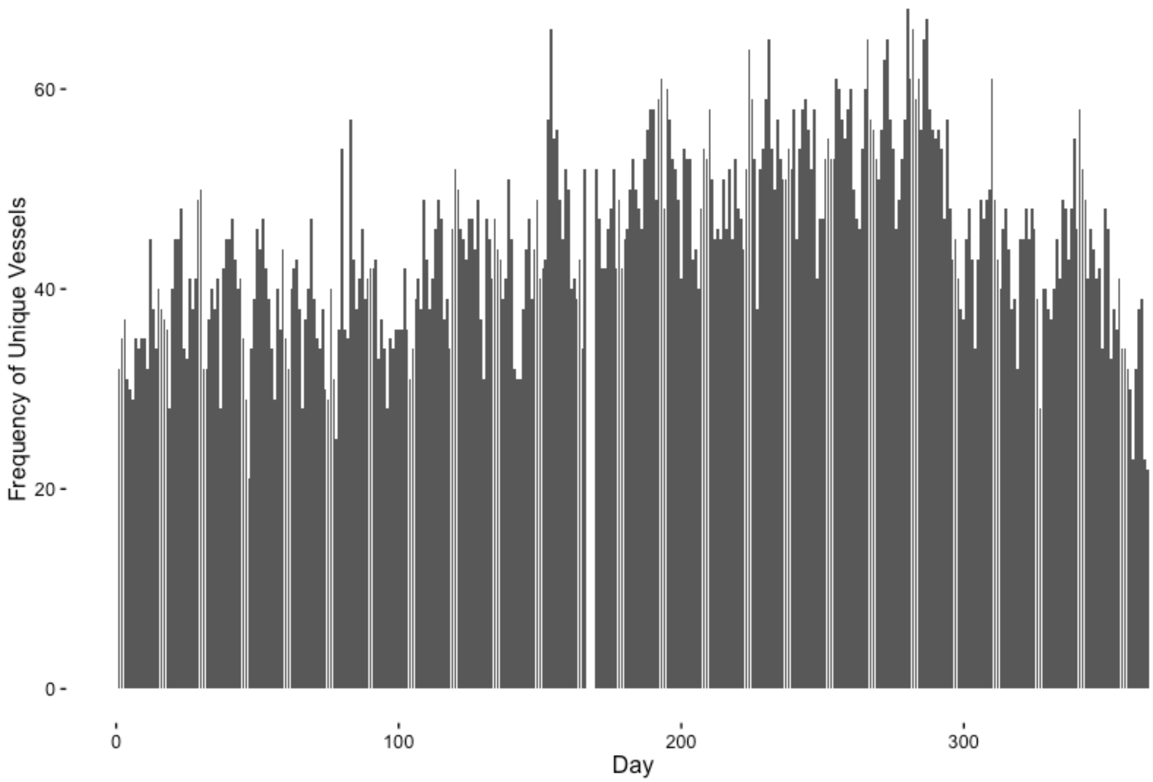


**Figure 5.** The above figure shows how many unique vessels are present each day of the year 2015 in the GM and SS polygon; a vessel is considered unique each day it is present.

Figure 5 illustrates that between 30 and 60 unique vessels are present on any given day in the SS and GM polygons during 2015. There is no clear day-to-day pattern in the number of vessels navigating the region, though some seasonality is clear with more traffic present throughout the summer and autumn months.

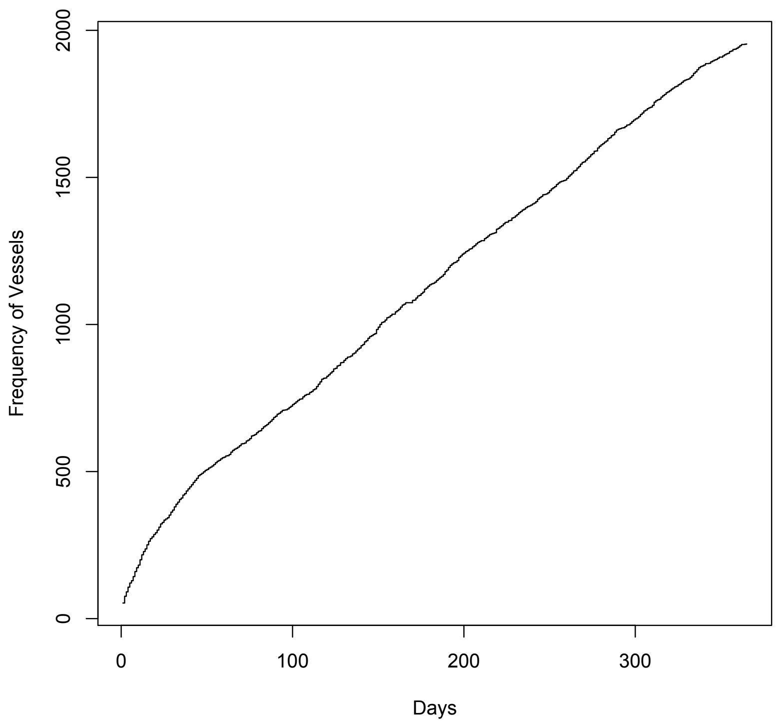


**Figure 6.** The discovery curve for *all* unique vessels found in the GM and SS polygon for the year 2015.

Figure 6 illustrates the discovery curve over 2015 for the vessels in the joint GM and SS polygons. The curve is increasing almost linearly with a near systematic increase in the number of unique vessel navigating the domain with time. In theory, if nearly all the vessels in the 'virtual' fleet associated with the domain had navigated the domain within a year, the curve would reach an asymptote; i.e., discovering a new vessel would become rare. The lack of an asymptote indicates there is no identified fleet associated solely with the study domain. For the first 100 days there is a slightly quicker discovery rate that slows down to a relatively constant rate.

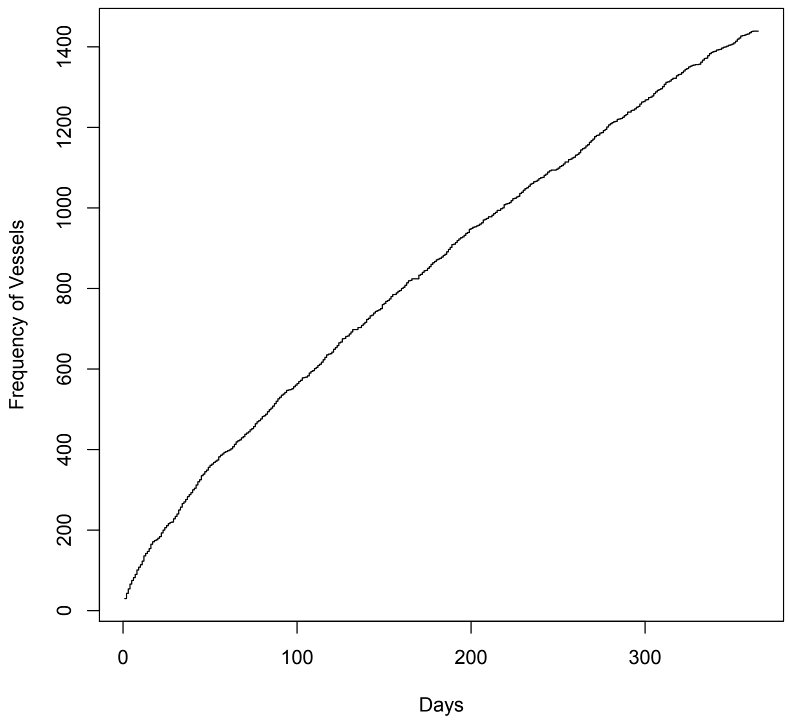


**Figure 7.** Discovery curve for the *all* unique vessels in the GM polygon.

Figure 7 illustrates the discovery of all new unique vessels in the GM polygon over 2015. As in Figure 6, the rate of discovery is nearly constant though at approximately half the rate.

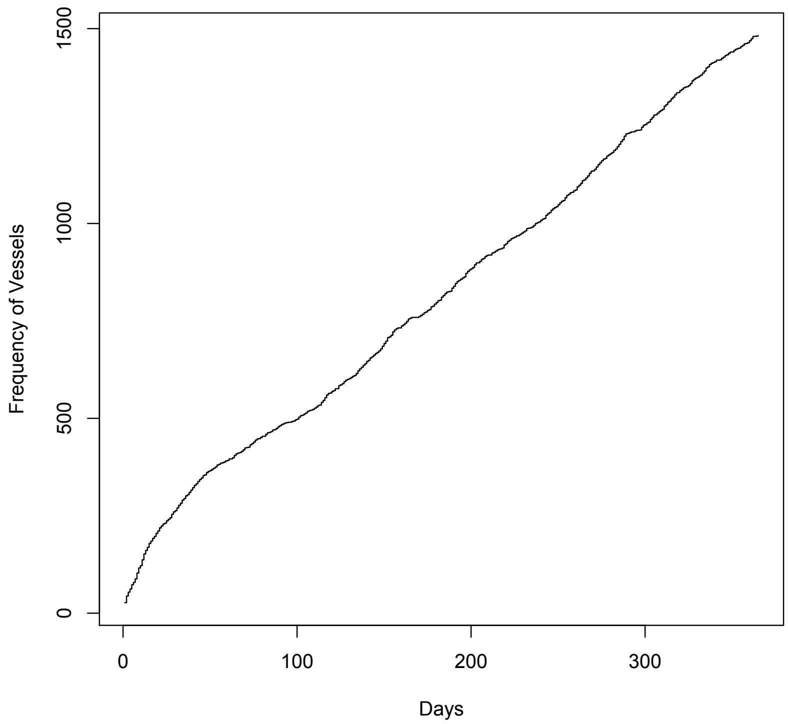


**Figure 8.** A discovery curve of *all* unique vessels found in the SS polygon for the year 2015.

Figure 8 illustrates the rate of discovery of unique vessels navigating the SS polygon in 2015 and has similar characteristics to that of Figure. 6, though the rate is lower than in Figure. 6 and similar to that in Figure. 7. Taken together, the discovery curves indicate a relatively constant arrival of new vessels in the overall domain with no evidence of the rates slowing down.

**Table 3.** The top ten most frequently (days) occurring vessels navigating the GM polygon. Vessels are identified by their MMSI number and name, country of origin, class and length (L) and width (W) and. Information is also given on the registered country of the vessels, their size and vessel class (associated AIS class number is included).

| MMSI | Name | Frequency | Registry | Vessel Class | L x W (m) |
|---|---|---|---|---|---|
| 316004170 | Atlantic Destiny | 345 | Canada | Fishing (30) | 39 x 12 |
| 316013040 | Grand Manan Adventure | 316 | Canada | Passenger (60) | 86 x 16 |
| 316022239 | Chebucto Pilot | 306 | Canada | Pilot (50) | 17 x 7 |
| 316023718 | Captain A.G. Soppitt | 265 | Canada | Pilot (50) | 10 x 4 |
| 316012480 | Atlantic Preserver | 252 | Canada | Fishing (30) | 41 x 11 |
| 316012470 | Atlantic Protector | 214 | Canada | Fishing (30) | 41 x 11 |
| 316001449 | Lady Comeau II | 200 | Canada | Fishing (30) | 40 x 8 |
| 316003563 | M.V. Princess of Acadia | 197 | Canada | Passenger (60) | 146 x 20 |
| 316001451 | Lady Denise II | 187 | Canada | Fishing (30) | 39 x 8 |
| 316013210 | Fundy Rose | 159 | Canada | Passenger (60) | 124 x 19 |

Table 3 lists the major characteristics of the top 10 most frequent vessels navigating the GM polygon. The majority of these vessels are 41m in length or smaller; 5 are fishing vessels, two are pilot and the remaining three all exceed 41 m length and are vehicle/passenger ferries. All 10 vessels have a Canadian registration.

**Table 4.** The top ten most frequently (days) occurring vessels navigating the SS polygon. Vessels are identified by their MMSI number and name, country of origin, class and length (L) and width (W) and. Information is also given on the registered country of the vessels, their size and vessel class (associated AIS class number is included.

| **MMSI** | **Name** | **Frequency** | **Registry** | **Vessel Class** | **L x W (m)** |
|---|---|---|---|---|---|
| 316022239 | Chebucto Pilot | 323 | Canada | Pilot (50) | 17 x 7 |
| 316019125 | M.V. Highlanders | 313 | Canada | Passenger (60) | 186 x 27 |
| 316004240 | Atlantic Oak | 252 | Canada | Tug (31) | 31 x 11 |
| 316014040 | M.V. Blue Puttees | 251 | Canada | Passenger (60) | 200 x 27 |
| 316002800 | Atlantic Willow | 247 | Canada | Tug (31) | 31 x 12 |
| 316008101 | Strait Eagle | 237 | Canada | Pilot (50) | 20 x 6 |
| 316001019 | Atlantic Larch | 229 | Canada | Tug (31) | 31 x 12 |
| 316013940 | Atlantic Condor | 198 | Canada | Tug (31) | 74 x 16 |
| 316278000 | Oceanex Sanderling | 185 | Canada | Cargo (70) | 185 x 27 |
| 316004010 | Panuke Sea | 160 | Canada | Tug (31) | 81 x 16 |

Table 4 lists the top 10 most frequent vessels navigating the SS polygon in 2015 that are dominated by tugs, passenger, pilot, and cargo vessels. All are registered in Canada. There were clear distinctions between the two polygons with more fishing vessels in the GM whereas SS was dominated by tugs. These examples make it clear that the most frequent vessels are not necessarily relevant to this study.

**Table 5.** The top ten most frequently (days) occurring overlapping vessels navigating the GM and SS polygons. Vessels are identified by their MMSI number and name, country of origin, class and length (L) and width (W) and. Information is also given on the registered country of the vessels, their size and vessel class (associated AIS class number is included).

| MMSI | Vessel Name | Frequency | Registry | Vessel Class | L x W (m) |
|---|---|---|---|---|---|
| 316022239 | Chebucto Pilot | 339 | Canada | Pilot (50) | 17 x 7 |
| 316004240 | Atlantic Oak | 253 | Canada | Tug (31) | 31 x 11 |
| 316013940 | Atlantic Condor | 201 | Canada | Tug (31) | 71 x 16 |
| 316268000 | Oceanex Sanderling | 186 | Canada | Cargo (70) | 185 x 27 |
| 316004010 | Panuke Sea | 160 | Canada | Tug (31) | 81 x 16 |
| 316012950 | Acadian | 144 | Canada | Tanker (80) | 187 x 27 |
| 316250000 | Venture Sea | 144 | Canada | Tug (31) | 68 x 16 |
| 316142000 | Atlantic Tern | 141 | Canada | Tug (31) | 63 x 14 |
| 316028329 | Aquaholic | 133 | Canada | Pleasure (37) | 63 x 14 |
| 538002220 | New England | 126 | Marshall Islands | Tanker (80) | 183 x 27 |

Table 5 lists the 10 most frequently occurring vessels found in both the GM and on the SS. The Chebucto Pilot, Atlantic Oak, Atlantic Condor, Oceanex Sanderling and Panuke Sea are all vessels that were found in tables 2 and 3, though now augmented by the Acadian (tanker), Venture Sea (tug), Atlantic Tern (tug), Aquaholic (pleasure craft), and the New England (tanker). The top 10 are dominated by tugs and tankers with only one pleasure craft, one cargo and one pilot vessel present. The days a vessel is present decreases quickly from vessel one to ten, as there are fewer vessels that occur in both SS and GM than in their individual regions. Eight of these ten vessels are longer than 60 m and all but one had a Canadian registry. These eight represent vessels that present the greatest threat to whales in terms of lethal vessel strike.

*Analyses on Unique Vessels in the Top 20%:*

Figure 9 depicts the daily locations of the top 20% of vessels found in the GM and SS polygons. As in Figure 4, similar patterns are apparent within the distribution such as the TSS in the Bay of Fundy, the HTPs to and from Halifax and along the coast of Nova Scotia and the paucity of vessels southwest of Nova Scotia where the HTPs encompass voluntary ATBA over Roseway Basin. In general, the comparison of Figure. 4 with Figure. 9 indicates that the distribution pattern of the top 20% of the vessels well represents the distributional pattern of the entire fleet identified in 2015. These top 20% (GM and SS) were represented by 420 unique vessels of which 164 of these vessels navigated both polygons.

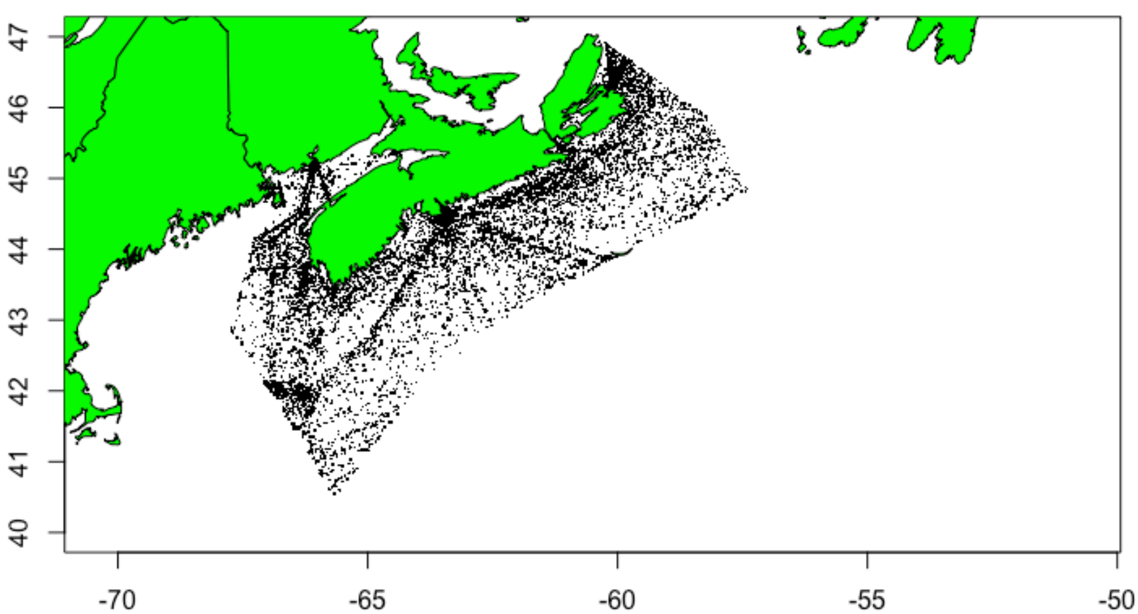


**Figure 9.** Each unique vessel in the top 20% for GM and SS combined are represented by a point for each day they are present throughout the year 2015.

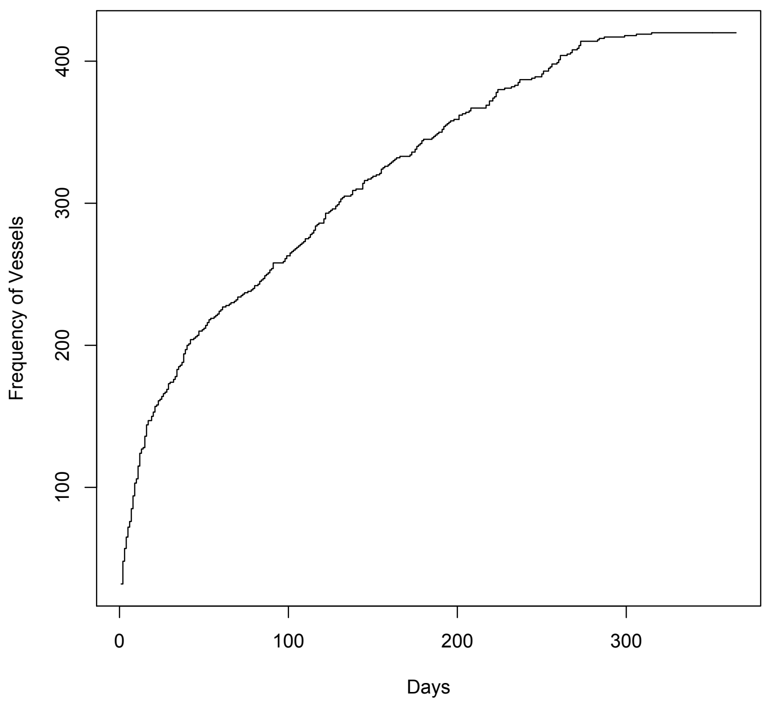


**Figure 10.** The rate of discovery for vessels in the top 20% in GM and SS polygon for the year 2015.

Figure 10 illustrates the discovery curve for the top 20% in the two polygons and it is markedly different from those for the entire fleet (Figure. 6, 7, 8 above). Over the first ~50 days the rate of discovery is steep with 200 vessels. The rate then decreases to a near-constant from day ~50 to 250 after which it becomes asymptotic. This indicates that the top 20% of the fleet was discovered (identified) in just under 300 days; suggesting that the 'representative fleet' was fully identified.

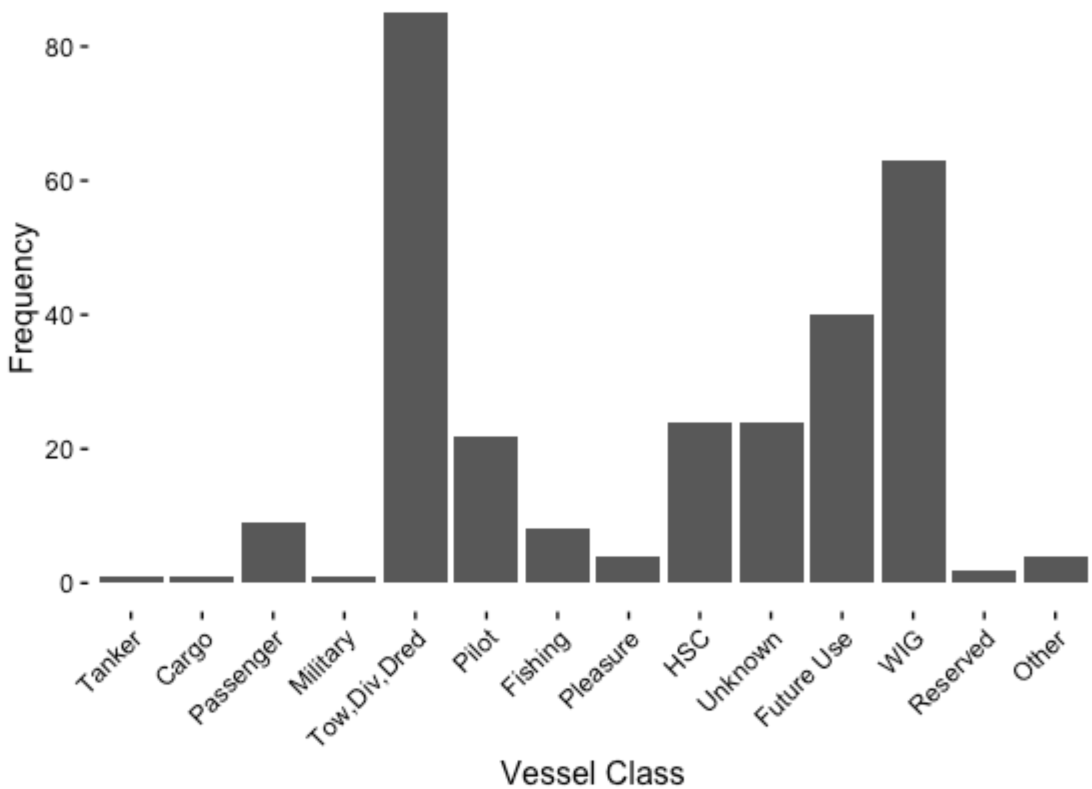


**Figure 11.** The vessel classification of the top 20% in the GM polygon as initially received by the static satellite-AIS message.

According to the static AIS messages from the top 20% of vessels in the GM polygon, by far the majority of vessels were self-classified as towing-diving-dredging, wing-over-ground (WIG) and future-use vessels and virtually no tanker, cargo or military vessels (Figure. 11). Given the known unreliability of static AIS data, these vessel class results were considered highly suspect and required manual inspection with URL look-ups based on MMSI to validate or correct the suspect classifications. This resulted in 13 vessels being reclassified to towing-diving-dredging, 5 to pleasure, 4 to military, 13 to passenger, 41 to cargo, 46 to tanker and 7 to Pilot (Figure. 12). This resulted in. most vessels being classified as towing-diving-dredging; followed by tankers, cargo, pilot, fishing, passenger, pleasure and military vessels.

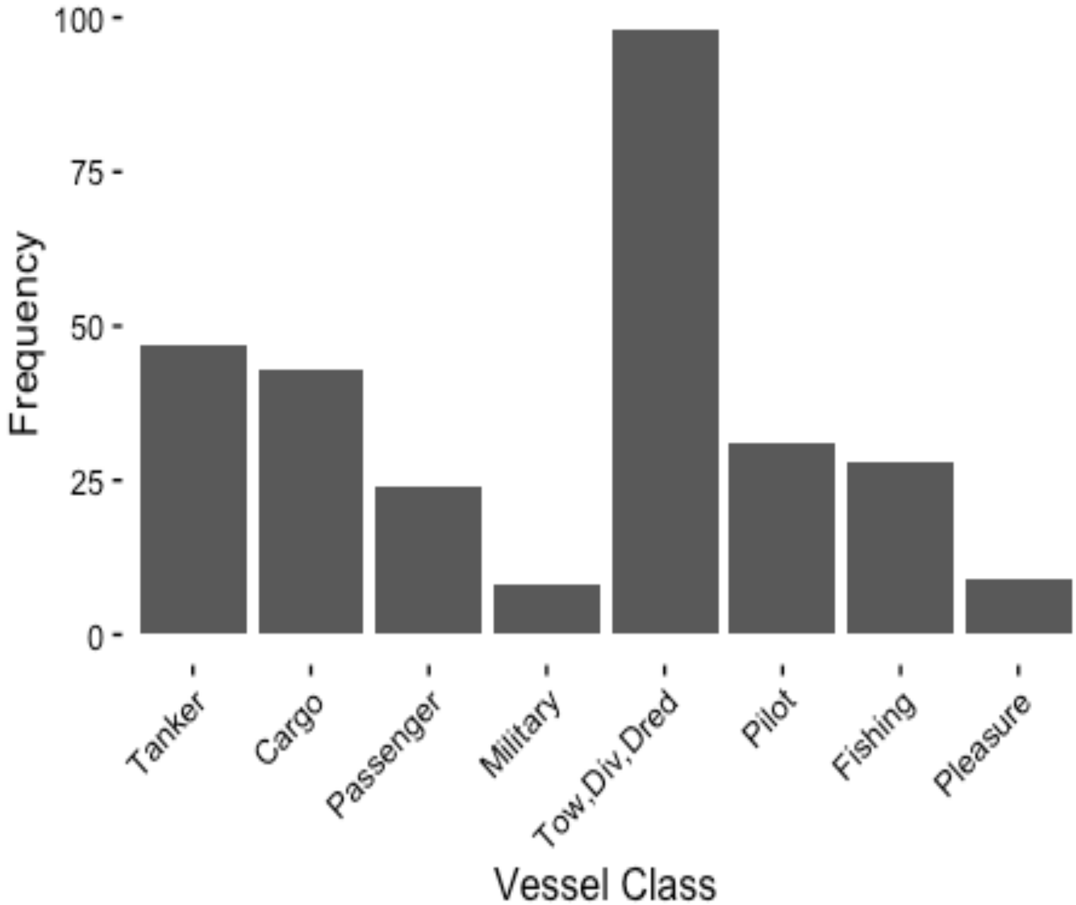


**Figure 12.** The vessel classification of the top 20% in the GM polygon after reclassification based on URL look-ups.

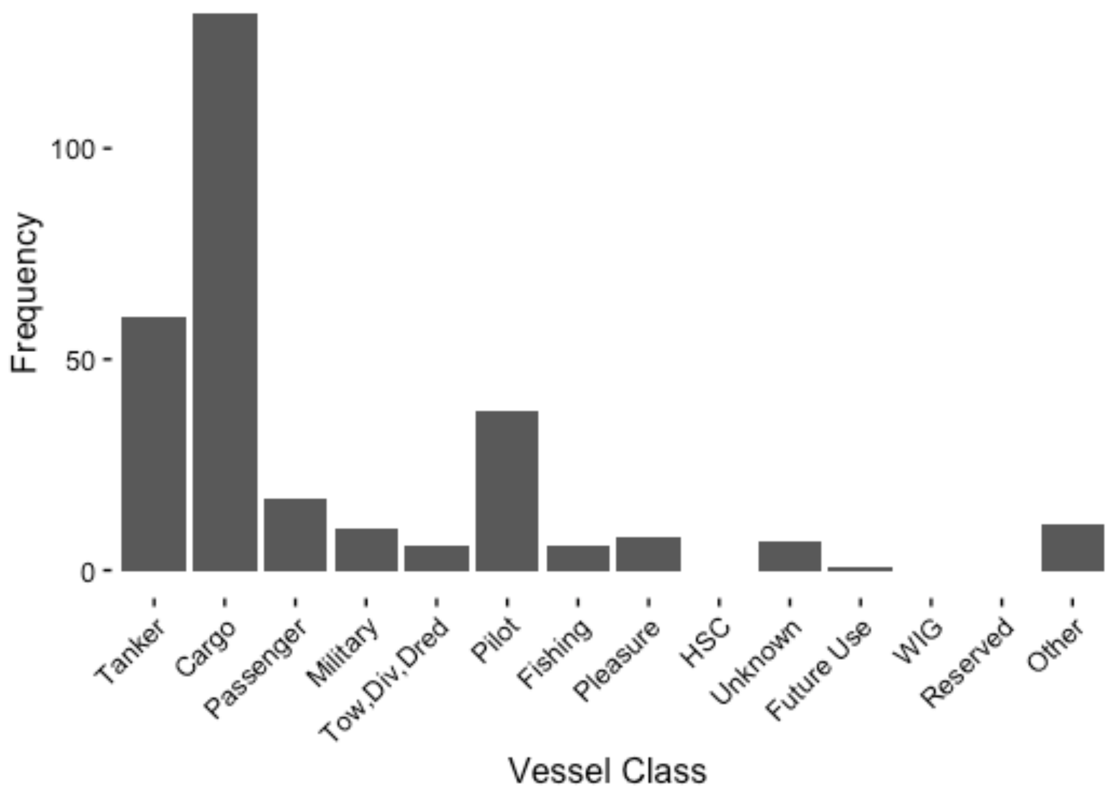


**Figure 13.** The vessel classification of the top 20% present in the SS polygon as initially received by the static satellite-AIS message.

Similar analyses for the top 20% in the SS polygon (Figure. 13) did not appear to show the same classification discrepancies as in the GM polygon (Figure. 11). For example, no vessels were classified as HSC, WIG and reserved etc.  Of the 19 misclassifications, 3 were reclassified as fishing, 8 as towing-diving-dredging, 4 as pilot, two cargo, one tanker, and one passenger vessels (Figure. 14).

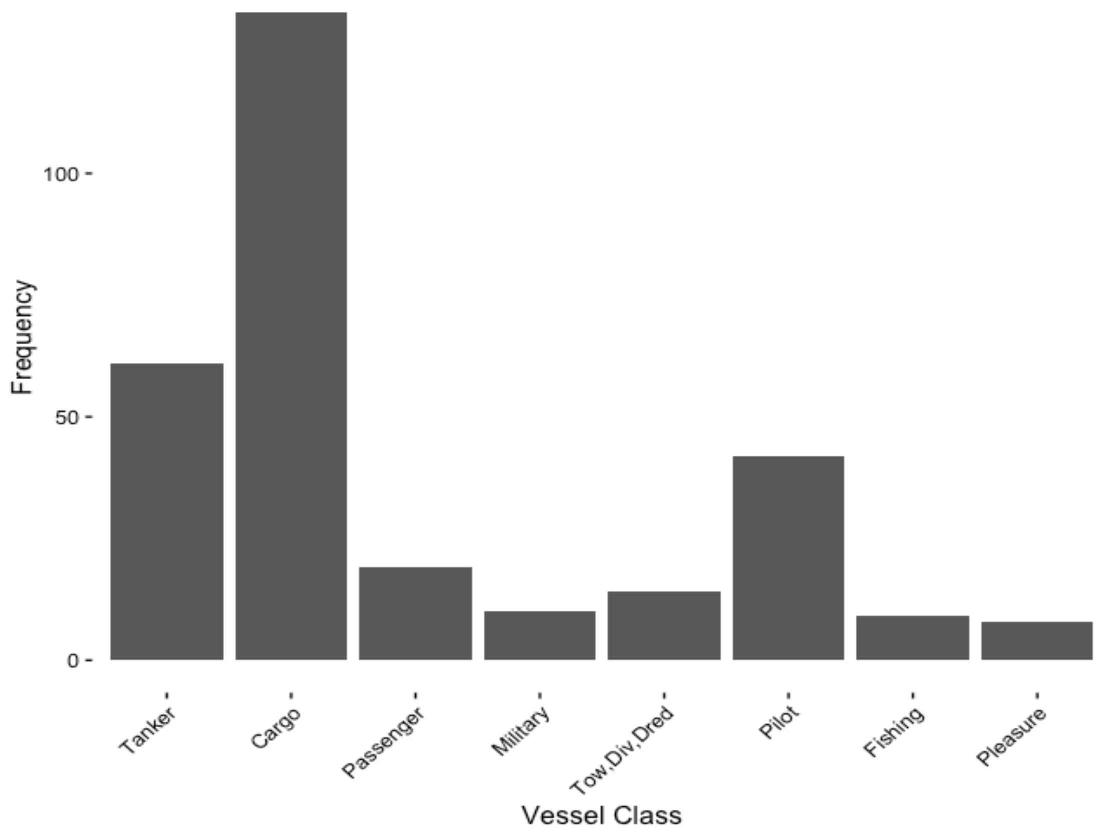


**Figure 14.** The vessel classification of the top 20% in the SS polygon after reclassification based on URL look-ups

A comparison of the reclassified vessels between GM and SS polygons revealed further discrepancies in that some MMSI-specific classifications were different between polygons, again reflecting the unreliability of the static messages. There were 420 unique vessels in the top 20% of vessel navigating both polygons. Of these 73 required further reclassification in addition to those achieved above (Figure. 15, 16, 17)

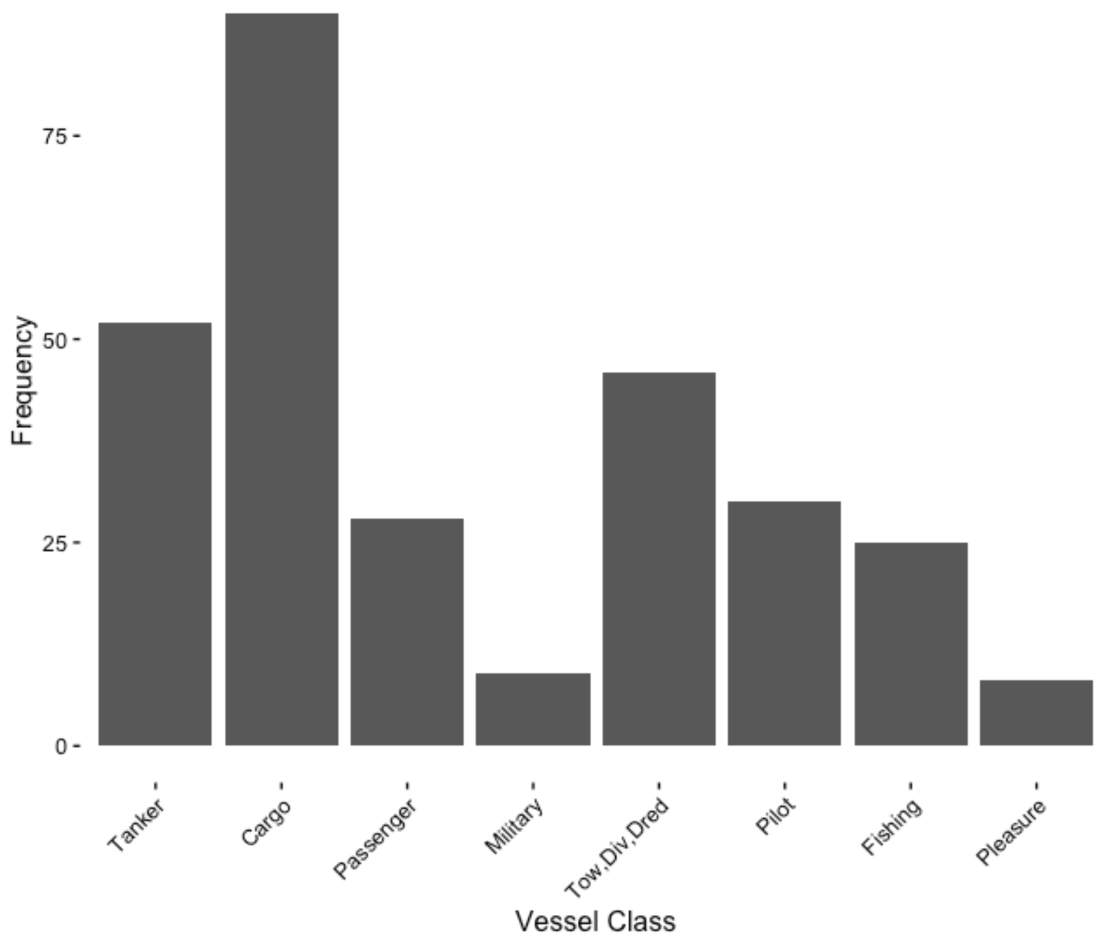


**Figure 15.** The vessel classes present in the GM polygon after completion of all corrections.

Figure 15, 16 and 17 represent the most certain classifications of the top 20% of vessels navigating the GM and SS polygons and navigating both polygons in 2015. In all three cases the fleets are dominated by cargo and tanker vessels.

The focal vessels for this study, in terms of presenting the greatest threat to whales, are the first four classes showing in each of Figure. 15, 16, 17; i.e., tanker, cargo, passenger and military vessels due to their size and speed. These represent focal vessels for eventual survey as they represent the fleet. Their spatial distributions as illustrated in Figure 18, again shows that this subset of the complete fleet is essentially the same as the complete fleet (Figure. 4).

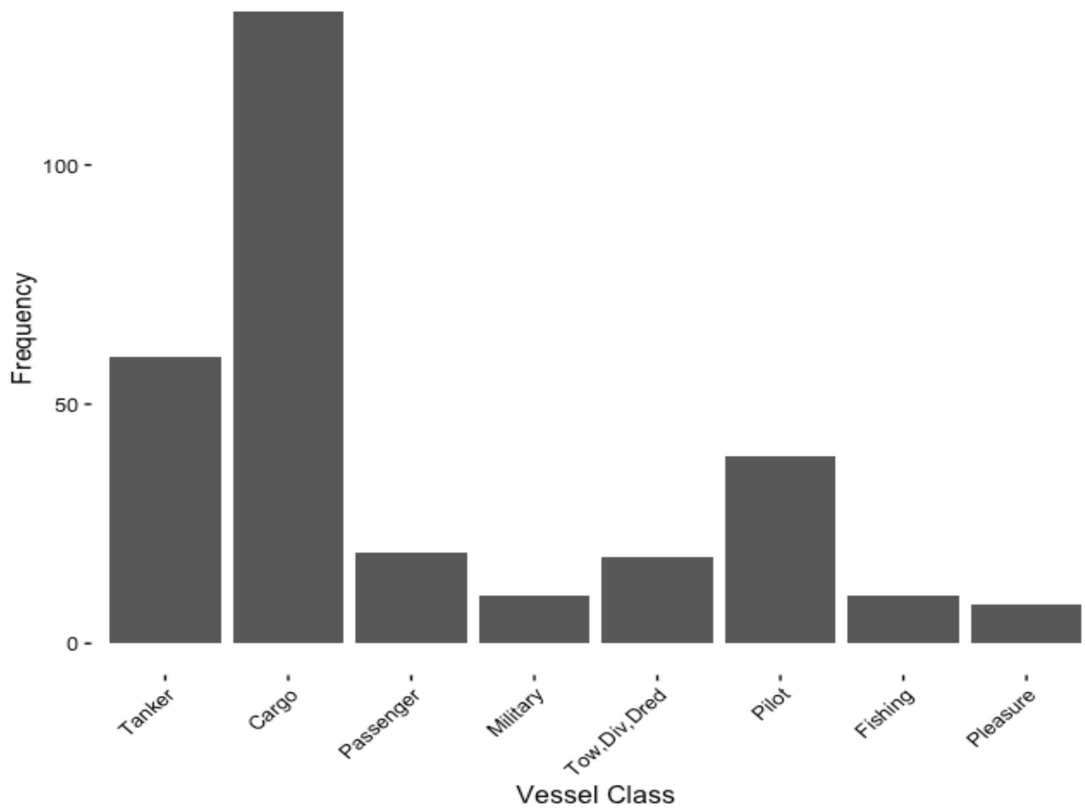


**Figure 16.** The vessel classes present in the SS polygon after completion of all corrections.

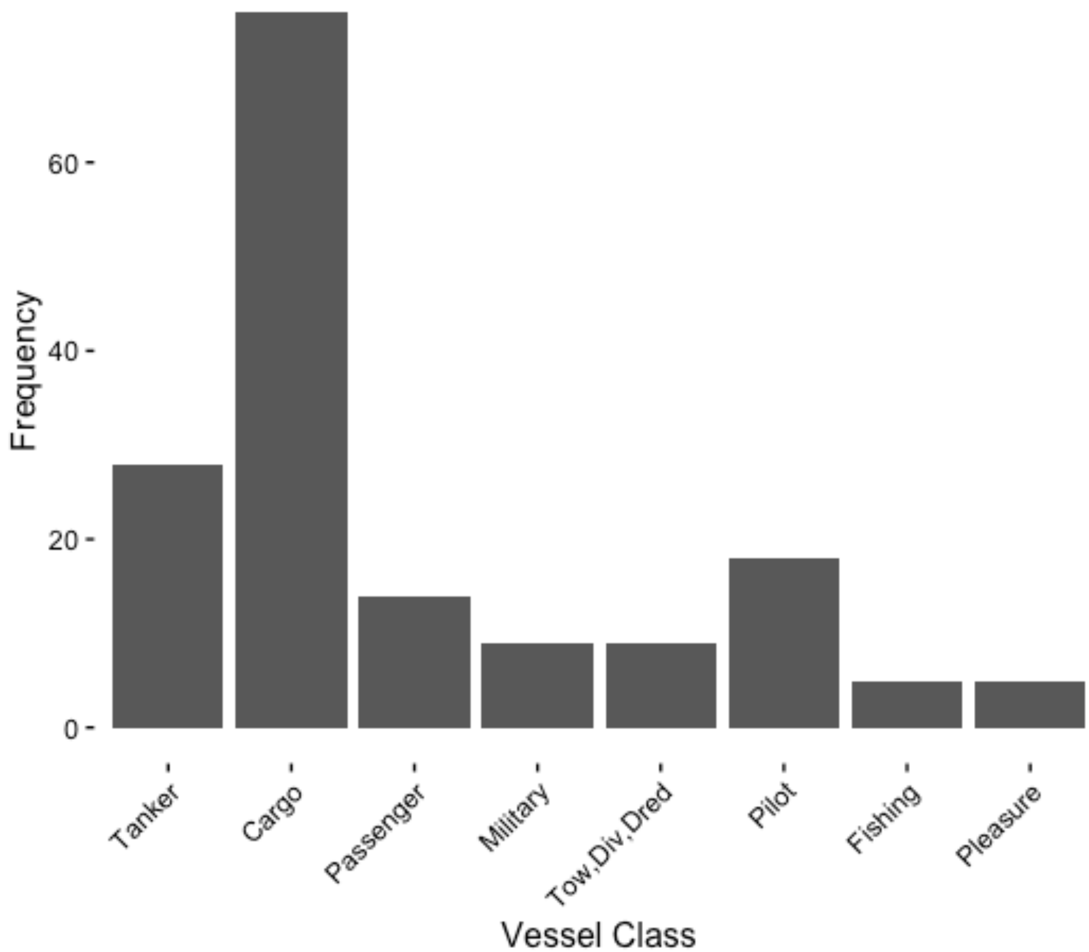


**Figure 17.** The vessel classes present in those 164 vessels present in the top 20% overlapping the SS and GM polygon.

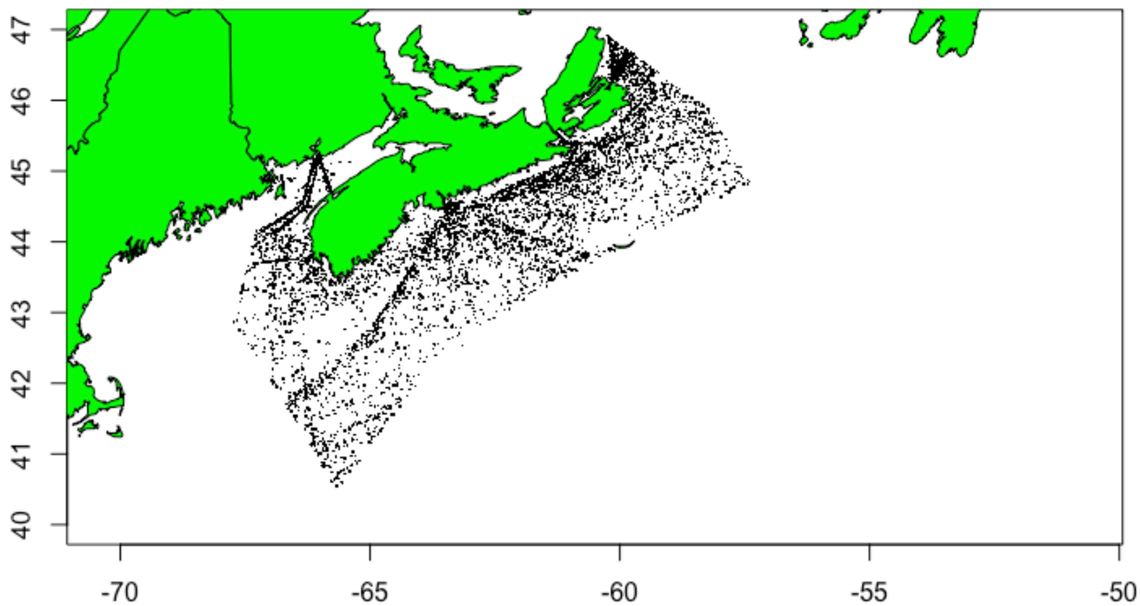


**Figure 18.** The above figure represents the vessels of interest (Military, Cargo, Tanker and Passenger), of the top 20% in the GMBF and SS polygon. Each vessel is represented once for each day it is present throughout 2015.

*Secondary Analysis:*

Vessels navigating the northern Laurentian Channel (NLC) polygon were secondarily analyzed to determine how many vessels in the GM and SS polygons were representative of those navigating to and from the Gulf of St Lawrence. There were 1409 unique vessels identified in the NLC polygon over 2015 and 282 of these vessels represented the top 20%. Of these, 42 (15%) also navigated the GM polygon, 96 (34%) the SS polygons, and 41 (15%) navigated all three polygons. This implies that ~50% of the top 20% of vessel navigating the Gulf of Maine and the Scotian Shelf are also represented by the top 20% of vessels navigating the northern Laurentian Channel. Thus, the fleet characterized in the Gulf of Maine and on the Scotian Shelf is also representative of the fleet in the Laurentian Channel.

Of those top 20% vessels navigating all three polygons, 6 of the most frequent 10 were of Canadian registry, 5 were cargo, three were tanker and one each of passenger and pilot (Table 6). All, except the pilot were 130 m or more in length and all were navigating the various regions for at least 71 days of the year (Table. 6).

**Table 6.** The top ten most frequently (days) occurring vessels navigating the GM, SS and NLC polygons. Vessels are identified by their MMSI number and name, country of origin, class and length (L) and width (W) and. Information is also given on the registered country of the vessels, their size and vessel class (associated AIS class number is included).

| MMSI | Vessel Name | Frequency (days) | Registry | Vessel Class | L x W (m) |
|---|---|---|---|---|---|
| 316012950 | Acadian | 173 | Canada | Tanker (80) | 182 x 27 |
| 316028326 | East Coast | 166 | Canada | Tanker (80) | 183 x 27 |
| 316013980 | Radcliffe R. Latimer | 114 | Canada | Cargo (70) | 223 x 23 |
| 316014050 | Algoma Mariner | 105 | Canada | Cargo (70) | 226 x 24 |
| 351634000 | MSC Maria Laura | 100 | Panama | Cargo (70) | 229 x 32 |
| 244958000 | Maasdam | 96 | Netherlands | Passenger (60) | 219 x 31 |
| 316053000 | Sir William Alexander | 93 | Canada | Pilot (50) | 83 x 16 |
| 236626000 | Transfighter | 88 | UK | Cargo (70) | 159 x 26 |
| 316013209 | Algonova | 79 | Canada | Tanker (80) | 130 x 20 |
| 244118000 | Maersk Palermo | 71 | Netherlands | Cargo (70) | 210 x 32 |

## 4. DISCUSSION

### *4.1 Vessel Distribution in the Scotia-Fundy Region:*

There was high activity occurring in the SF region for all vessels in general but also for the focal vessels. The vessel distribution figures (Figure. 4, 9, and 18) show that the same patterns exist whether the scope encompasses all vessels or only the focal vessels using the SF region. This means that the focal vessels are a good representation of the whole fleet using the study domain.

On any given day there were 40-60 vessels transiting the study domain; this means that by the end of the year anywhere from 14, 600 to 21, 900 vessels have voyaged through the SF area. Seasonally there were more vessels navigating during the summer and autumn months; this has consequences as during these periods, whales densely populate the area (Brown et al., 2009). The patterns of highest vessel density are the HTPs and TSSs and thus pose the greatest risk to whales.

The primary purpose of this study was to obtain a representative sample of the most frequent SF vessels that are likely to cause harm to whales; i.e., large vessels that can navigate at high speeds in addition to their frequency of navigation in the region. Each of the vessel class histograms displayed the same information about the focal vessels, whether it was the classes for the top 20% in the GM or SS polygons or those vessels most frequently occurring in the two polygons; cargo being the most dominant vessels followed by tanker, passenger and military (Figure 15, 16 and 17). Not only are these vessels large, fast and frequent, this study has shown they are in regions that right whales and other large whale are known to occupy. There are enough of these vessels in the study domain to justify the consideration of new mitigation measures in addition to the amended TSSs and the voluntary ATBA. Though this study has provided insight into frequent vessels and their characteristics, it is possible that the results only accurately depict the vessels' frequencies in relation to their class as opposed to their true identities.

Only ~5% of the global fleet navigates eastern North America and this was displayed by the discovery curves (Figure. 6, 7, and 8) (EMSA, 2015). New vessels are constantly being found in the region; the lack of inflection point reveals this study does not even come close to capturing the entire fleet potentially navigating the region. This may be problematic as the nature of the fleet is likely to change in the future. The study is representative of the types of vessels using the SF region and their frequencies, but it is possible that the identity composition of the fleet could shift. Though there may be a similar number of cargo vessels navigating the study domain in the future, the owners of these cargo ships could change, thus the list of vessel identities compiled in this study would decrease in usefulness.

In addition to the useful information on fleet frequency and characteristics, this study has also provided insight into how mariners use their navigational technologies and what this implies for the health and safety of the right whale.

*4.2 Misuse of the Static AIS Message:*

There were many interesting results that emerged about how mariners use their navigational technology. As previously mentioned, the vessel class, IMO number, radio call sign and vessel name etc. are input manually by crew members as part of the static AIS message. Static message errors were numerous and corrections were time consuming to obtain accurate information on vessels. This type of information is important as it provides modes of identification for the vessel as well as insight into vessel characteristics through its vessel class, average size etc.

Vessels operators often identified their vessel in inactive or inappropriate categories and confusion may be the cause of such actions. For example, the CCGV Hudson is a research vessel (sub-class 59) under the pilot (class 50) but was often self-identified as “other”. Thus, for my analyses the Hudson (and many other vessels) was reclassified accordingly. It is likely that vessel operators are unaware of all the IMO/AIS vessel sub-classes encompassed in the primary list of vessel classes, leading to confusion when proving the self-identified AIS vessel classes.

Other vessels may have experienced confusion if their vessel appeared to apply to more than one category. For example, a High Speed Craft could also be a Pilot vessel. Mistakes caused by confusion were easily rectified. The *Marine Traffic* and/or ITU online databases were very useful in addressing uncertainties surrounding vessel class categories. If such information was readily available to marines the quality of AIS messages could improve.

Other vessel class errors pointed toward apathy among those entering the information, errors that had no clear reasoning. The raw static AIS messages for the GM polygon provided almost no cargo or tanker classification when after data quality control assessment, it was found that over 50 tankers and almost 100 cargo vessels were misclassified; many self-classified as inactive categories such as “Reserved” or “Reserved for Future Use”. Although both vessel types are distinct and have their own AIS primary vessel class (70 cargo, and 80 tanker) it is difficult to understand why they self-identify otherwise, unless it is simply an apathetic attitude toward accurate input of static information.

Targeting vessels by class may be an efficient way for researchers to gain more information, in this case regarding the most threatening vessels (e.g., finding the numbers and/or average speeds of tankers to gauge their risk to whales), but doing so would be unsuccessful without a great deal of quality control of the static AIS message. The vessel class alone can indicate roughly how large a vessel is. For example, tankers are large in comparison to fishing vessels and they are known for partaking in specific activities. A cargo ship can be assumed to be transporting commodities of some kind. Unfortunately, much of this information is unattainable through the raw AIS message. The errors are so numerous that a third party is required to undergo the time consuming task of refining the data into reliable and usable information.

Vessel class was not the only portion of the static message that contained confusion and uncertainty. I encounter many inconsistencies with IMO numbers, vessel names, call signs and most other static identifiers such that a given MMSI number would have multiple aliases of the static identifiers throughout the records, some related to, for example abbreviations; e.g., “Canadian Warship 222” versus “Can Warship 222”.

Improper transmission of the AIS message, or random keyboard entries may provide explanation of variation among records. In many instances, one record contained complete and legible static identifiers but another, associated with the same MMSI number, contained identifiers interrupted by dashes, exclamation points, question marks, etc.

In summary, any research relying on static-AIS vessel information will require a great deal of quality control before any reliable analyses can be undertaken.

*4.3 Implications for Whales:*

There are various factors to consider when mitigating the risk of vessel strike to whales; a vessels’ frequency in the area, vessel class and associated size and activity all contribute to this risk. There are more opportunities for a vessel to strike if it is frequently in regions where whales are known to inhabit; this is especially true for this study as Grand Manan Basin and Roseway Basin are both encompassed within the domain.

Information from this study provides perspective on the three types of risks that vessels pose to whales. The first risk factor is the vessel’s size; vessels longer than 80m are more likely to inflict mortality upon collision (Laist et al, 2001). The second risk factor is speed; large vessels travelling above 12 knots are more likely to cause mortality (Vanderlaan and Taggart, 2007). Vessel class can be used as a proxy to infer the level of risk a vessel poses in both of the first two risk factors as there are common lengths and speeds associated with vessel classes; both contribute to the likelihood of mortality upon collision (Laist et al., 2001; Vanderlaan and Taggart, 2007). For example, because cargo vessels are large (average length 191m) and travel relatively fast for their size (average 12.92 knots), they are more likely to inflict mortality upon collision than a pilot vessel that is relatively small and slow. These two risk factors do not affect the probability of a whale-ship encounter. The final risk factor is the frequency of vessels in areas where whales aggregate. Therefore, knowing the frequency of a vessel in the region provides information on the probability of an encounter and knowing the speed and size of a vessel provides information on the degree of consequence (mortality) if and when an encounter occurs.

### 4.4 *Implications for Future Conservation*

The purpose of this study was to paint a representative portrait of the vessel users to contact them in the future on their receptivity to emerging Whale Alert technologies. The study has displayed useful information on the vessel class proportions in the area and their identities. Table. 6 may be the most useful of all the results when focusing on the goal of contacting the fleet; it displays the top 10 vessels found in the NLC polygon and/or GM and/or SS. These vessels are mostly focal vessels and the least frequent vessel is still present for 71 days of the year (~20%). Table. 6 provides an all-around representation of vessels using the study domain as navigation through one or both of the primary polygons is required (GM and/or SS) to reach NLC; this means they likely used the HTPs and TSSs that have been deemed high risk areas.

### *4.5 Next Steps*

This study has created a list of the most frequent vessels occurring regionally for the year 2015; it will be used to conduct a survey similar to that reported in Reimer et al 2015. Focal vessels will be asked about their receptivity to a Whale Alert System as well as their current knowledge on conservation measures. The list created from this study is a representative sample of those using the SF region. Therefore, with this information a more accurate opinion of the fleet can be obtained.

Once the fleet is surveyed on their opinions regarding whale conservation and the use of real time technologies, there will be a better understanding of how to implement the technologies. Conservation efforts will not be successful if they do not have the compliance of those that are affected by the efforts. Reimer et al, found that most vessel operators surveyed did wish to help conserve whale species so it is hopeful that future studies of the larger fleet operating in the Canadian maritime regions will obtain similar findings. Reimer et al. (2015) found that the preferred method of implementing real time technology was almost unanimously agreed upon to be through technologies already aboard the ship (e.g., AIS or NAVTEX). If future studies yield similar results, then the medium(s) preferred by mariners will most likely be used to implement the Whale Alert Message.

This study has been of particular importance as it has been a stepping stone on the path to implementing a Whale Alert System. The implementation of a Whale Alert System is a goal of the MEOPAR Whale Habitat and Listening Experiment but more recently it has gained even more importance. The Canadian government has now included the implementation of a Whale Alert System as part of their oceans protection plan (Canada's Oceans Protection Plan, 2016).

## 5. CONCLUSION

Much more was revealed in this study than the most frequent vessels. The static AIS message holds useful information such as, IMO number, vessel name, call sign, vessel dimensions, etc; information that could potentially be used to target the most threatening vessel classes and identify them. The problem with the static AIS message is that it is more often than not unreliable. The correction of the static message information takes a considerable amount of time and effort relative to the mere seconds for the mariner initially inputting the information. Increasing the accuracy of the static AIS message would help to increase its potential as a tool to aide in conservation.

Vessel classes and their frequency of occurrence in various ocean regions provided insight into the risk of ship strikes and whale mortality upon collision. This study has revealed the nature of the most frequent vessels using a given region. Those vessels most likely to inflict harm to whales are numerous and cargo and tanker vessels were always in the top three most dominant vessels in the various region studied area. Though military and passenger vessels were less prominent, their presence remains a threat to whales.

Finally, this study will help to implement real-time Whale Alert technology by providing a list of vessels to survey in the future. The most frequently occurring vessels were identified on the Scotian Shelf and Gulf of Maine/Bay of Fundy as these regions are going to be the first to experience the new Whale Alert System. Therefore, the vessels in the region will soon be asked their opinions about conservation issues and future compliance to a Whale Alert System. This will help to build positive relationships with the fleet that will hopefully yield compliance to and success of new conservation strategies. Therefore, this study has revealed the largest, fastest and most frequent vessels occurring in the SF region and this information can now be used to aide future conservation endeavors with the right whale.

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**Appendix 1.** All 420 vessels in the top 20% for both GM and SS polygons. The table provides their MMSI number, IMO number, vessel name and call sign for identification purposes and vessel class and length to provide an idea of their size and activities they may be partaking in. (TDD = Towing, diving or dredging).

| MMSI Number | Vessel Name | IMO Number | Call Sign | Vessel Class | Length (m) |
|---|---|---|---|---|---|
| 316022239 | CHEBUCTO PILOT | 9644964 | NA | Pilot | 17 |
| 316019125 | HIGHLANDERS | 9331189 | VYGT | Passenger | 200 |
| 316004240 | ATLANTIC OAK | 9295672 | CFH8951 | Pilot | 30 |
| 316014040 | BLUE PUTTEES | 9331177 | VXKF | Cargo | 200 |
| 316002800 | ATLANTIC WILLOW | 9192117 | CFH8937 | Pilot | 30 |
| 316008101 | PILOT BOAT S.EAGLE | 821650 | NA | Pilot | 20 |
| 316001019 | ATLANTIC LARCH | 9193745 | CFH8941 | TDD | 29 |
| 316013940 | ATLANTIC CONDOR | 9558335 | CFK9798 | Cargo | 73 |
| 316278000 | OCEANEX SANDERLING | 7603502 | VOLG | Cargo | 188 |
| 316004010 | PANUKE SEA | 8404525 | VOCT | TDD | 81 |
| 316001216 | LEIF ERICSON | 8917388 | VOCJ | Passenger | 154 |
| 316250000 | VENTURE SEA | 9197301 | VCVZ | TDD | 68 |
| 316142000 | ATLANTIC TERN | 7420742 | XJBC | TDD | 64 |
| 316001104 | POINT CHEBUCTO | 9051557 | CFD6314 | Pilot | 20 |
| 316007000 | ATLANTIC VISION | 9211509 | VYPN | Passenger | 203 |
| 316008417 | CANSO PILOT BOAT | 0 | CFD9876 | Pilot | 15 |
| 316005102 | APA20 | 0 | NA | Pilot | 18 |
| 316012760 | SVITZERBEDFORD | 9334090 | XJAG | Pilot | 32 |
| 316007950 | CAPE CORDELL | 8950562 | NA | Fishing | 21 |
| 316012950 | ACADIAN | 9298715 | CFH8964 | Tanker | 183 |
| 377149000 | FUSION | 7528520 | J8B4360 | Cargo | 84 |
| 316005099 | A.P.A.#2 | 0 | NA | Pilot | 0 |
| 311497000 | AMERICAS SPIRIT | 9247443 | C6FW2 | Tanker | 256 |
| 316028326 | EAST COAST | 9298703 | XJBP | Tanker | 181 |
| 316130000 | CANADIAN WARSHIP 339 | 9254381 | CGAJ | Military | 90 |
| 316012656 | SIGMA T | 0 | NA | Pilot | 12 |
| 316011877 | PILOT VESSEL- APA 1 | 368999 | NA | Pilot | 20 |
| 316053000 | SIR WILLIAM ALEXANDE | 8320482 | CGUM | Pilot | 83 |
| 636013275 | NS LOTUS | 9339337 | A8LV2 | Tanker | 249 |
| 316001619 | BICKERTON | 0 | CG3011 | Pilot | 16 |
| 316138000 | CDN WARSHIP 330 | 0 | CGAP | Military | 0 |
| 316009560 | ALGOSCOTIA | 9273222 | VAAP | Tanker | 149 |
| 314190000 | NOLHANAVA | 9208435 | 8PRY | Cargo | 120 |

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|---|---|---|---|---|---|
| 316014090 | BELLE_CARNELL | 9307114 | CFN7208 | Fishing | 73 |
| 316013960 | ALGOMA DARTMOUTH | 9327516 | CFK9211 | Tanker | 91 |
| 538002409 | BARKALD | 9233404 | V7IM6 | Cargo | 189 |
| 255804990 | BERNHARD OLDENDORFF | 8900529 | CQLL | Cargo | 245 |
| 316020000 | EDWARD CORNWALLIS | 8320470 | CGJV | Pilot | 83 |
| 244958000 | MAASDAM | 8919257 | PFRO | Passenger | 220 |
| 236626000 | TRANSFIGHTER | 9216626 | ZDNH3 | Cargo | 178 |
| 255804980 | ALICE OLDENDORFF | 9183776 | CQLK | Cargo | 190 |
| 636015583 | M/V DINKELDIEP | 9518983 | D5BQ5 | Cargo | 106 |
| 308064000 | CSL ACADIAN | 8009571 | C6UZ8 | Cargo | 245 |
| 316024000 | HUDSON | 5405279 | CGDG | Cargo | 91 |
| 351634000 | MSC MARIA LAURA | 8616520 | H3QW | Cargo | 229 |
| 244104000 | MAERSK PENANG | 9168192 | PDHU | Cargo | 210 |
| 266017000 | ATLANTIC CARTIER | 8215481 | SCKB | Cargo | 293 |
| 244118000 | MAERSK PALERMO | 9168207 | PDHW | Cargo | 210 |
| 316024142 | SCOTIAN SEA | 9163025 | XJBF | Pilot | 69 |
| 265101000 | ATLANTIC COMPASS | 8214176 | SKUN | Cargo | 292 |
| 266018000 | ATLANTIC CONVEYOR | 8215534 | SCKM | Cargo | 292 |
| 311057100 | CSL TACOMA | 9640956 | C6ZJ7 | Cargo | 229 |
| 316001017 | ALFRED NEEDLER | 7907104 | CG2683 | Fishing | 50 |
| 316012000 | CAPE ROGER | 7503180 | VCBT | Fishing | 62 |
| 316165000 | LOUIS S ST LAURENT | 6705937 | CGBN | Pilot | 120 |
| 244127000 | MAERSK PEMBROKE | 9168180 | PDHY | Cargo | 210 |
| 316001785 | SPINDRIFT | 0 | CG 2260 | Pilot | 16 |
| 316006910 | EIDSVAAG VINLAND | 9075371 | VYSM | Cargo | 82 |
| 316012280 | LOIS M | 9017616 | CFK5470 | TDD | 30 |
| 265137000 | ATLANTIC CONCERT | 8214164 | SKOZ | Cargo | 292 |
| 316009669 | CHARLEVOIX | 0 | NA | Pilot | 18 |
| 316013209 | ALGONOVA | 9378589 | CFN5191 | Tanker | 130 |
| 316293000 | CANADIAN WARSHIP 701 | 0 | CGAU | Military | 55 |
| 305411000 | SKOGAFOSS | 9375252 | V2EF3 | Cargo | 130 |
| 316014050 | ALGOMA MARINER | 9587893 | CFN5517 | Cargo | 225 |
| 316206000 | ATLANTIC HURON | 8025680 | VCQN | Cargo | 225 |
| 209055000 | SPARTO | 9274800 | P3VW9 | Tanker | 249 |
| 236648000 | REYKJAFOSS | 9202077 | ZDNY3 | Cargo | 127 |
| 316067000 | NORTHERN EAGLE | 9128348 | VCPB | Fishing | 0 |
| 304263000 | SELFOSS | 8914556 | V2RU | Cargo | 127 |
| 316014190 | JONES TIDE | 9697052 | CFN7290 | TDD | 84 |
| 316262000 | RYAN LEET | 7518977 | VOQY | Cargo | 67 |

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|---|---|---|---|---|---|
| 231839000 | NORDANHAV | 8914130 | OZ2125 | Cargo | 128 |
| 316014180 | SKANDI FLORA | 9372896 | CFN7285 | TDD | 95 |
| 316021599 | G. PEDDLE S.C. | 9586071 | CGGP | Pilot | 42 |
| 316129000 | CANADIAN WARSHIP 336 | 0 | CGAG | Military | 0 |
| 316294000 | CANADIAN WARSHIP 708 | 0 | CGJC | Military | 55 |
| 309822000 | HON HENRY JACKMAN | 7926174 | C6VQ9 | Cargo | 245 |
| 316013870 | BREAUX TIDE | 9697064 | CFN7289 | TDD | 84 |
| 246506000 | VEENDAM | 9102992 | PHEO | Passenger | 220 |
| 311498000 | AUSTRALIAN SPIRIT | 9247455 | C6FW3 | Tanker | 255 |
| 316001601 | SAMBRO | 0 | CG 2613 | Pilot | 16 |
| 316065000 | MERSEY VENTURE | 871435800 | CFD2073 | Fishing | 63 |
| 316196000 | CAN WARSHIP 340 | 0 | CGAK | Military | 2 |
| 566758000 | ANTIGUA | 9512587 | 9V7733 | Cargo | 130 |
| 316001486 | RJ BALLOTT | 5118814 | VC3024 | TDD | 29 |
| 240145000 | CAP PIERRE | 9274446 | SYCU | Tanker | 274 |
| 316001453 | LADY MELISSA | 7927829 | VY2506 | Fishing | 28 |
| 316012308 | SARAH DESGAGNES | 9352171 | XJAB | Tanker | 148 |
| 316020186 | STRAIT HUNTER | 7208455 | XJAW | Pilot | 60 |
| 316021601 | CORPORAL MCLAREN M.M | 9586083 | CGMM | Pilot | 42 |
| 351607000 | MSC MONICA | 9060649 | 3FSU7 | Cargo | 242 |
| 316200000 | CANADIAN WARSHIP 707 | 0 | CGBV | Military | 55 |
| 308299000 | CSL ARGOSY | 7915412 | C6UZ9 | Cargo | 244 |
| 316013860 | TIM MCKEIL | 901760400 | CFN6731 | TDD | 34 |
| 538003366 | BALDOCK | 7926148 | V7QH6 | Cargo | 244 |
| 269628000 | SCT MATTERHORN | 9298351 | HBHA | Tanker | 164 |
| 316001738 | MERSEY PHOENIX | 9247089 | VOGB | Fishing | 71 |
| 316001890 | SAMUEL RISLEY | 805575 | CG2960 | Pilot | 70 |
| 240124000 | CAP LEON | 9274434 | SVGP | Tanker | 274 |
| 258276000 | MARIT | 9235464 | LAQV7 | Tanker | 153 |
| 311057300 | RT HON PAUL E MARTIN | 9600970 | C6ZJ9 | Cargo | 228 |
| 316002282 | MISTER JOE | 0 | NA | TDD | 0 |
| 316013980 | RADCLIFFE R LATIMER | 7711725 | VCPK | Cargo | 225 |
| 316043000 | SALARIUM | 7902233 | VCQL | Cargo | 222 |
| 357814000 | MSC MIRELLA | 8709640 | 3FTW9 | Cargo | 177 |
| 316002179 | SANDRA MARY | 0 | NA | Pilot | 29 |
| 316295000 | CANADIAN WARSHIP 711 | 0 | CGJJ | Military | 55 |
| 319060200 | GRACE OF TIDES | 745201 | ZGDR7 | Pleasure | 21 |

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|---|---|---|---|---|---|
| 538001647 | DECISIVE | 9242364 | V7DI7 | TDD | 137 |
| 636015646 | EM KEA | 9334351 | A8NN6 | Cargo | 219 |
| 205567000 | LOWLANDS OPAL | 9317559 | ONGH | Cargo | 190 |
| 239416000 | CAP JEAN | 9158147 | S Z W V | Tanker | 274 |
| 316005971 | BEVERLY M I | 9084047 | CFP2004 | TDD | 34 |
| 246865000 | AVONBORG | 9466362 | PCOF | Cargo | 143 |
| 249276000 | SICHEM DUBAI | 9376933 | 9HOJ9 | Tanker | 127 |
| 314002000 | ESPADA DESGAGNES | 9334698 | 8PLE | Tanker | 229 |
| 316022125 | M. PERLEY | 9656151 | CGMP | Pilot | 22 |
| 538002220 | NEW ENGLAND | 9298727 | V7HF3 | Tanker | 183 |
| 212450000 | ANDEAN | 9413925 | 5BNN2 | Cargo | 185 |
| 229782000 | MSC NORA | 9163207 | 9HA3604 | Cargo | 195 |
| 265142000 | ATLANTIC COMPANION | 8214152 | SKPE | Cargo | 292 |
| 316001617 | SPRAY | 0 | CG 2248 | Pilot | 16 |
| 316006713 | CAPE_EDENSAW | 827458 | CFN4210 | Pilot | 0 |
| 538070916 | TIME FOR US | 0 | V7AP9 | Pleasure | 37 |
| 238265000 | VERIGE | 9401128 | 9AA6988 | Tanker | 195 |
| 255805611 | MACAO STRAIT | 9362724 | CQFJ | Cargo | 180 |
| 316001640 | EARL GREY | 8412340 | CG3029 | Pilot | 70 |
| 316285000 | MARIA DESGAGNES | 9163752 | VCWL | Tanker | 120 |
| 356100000 | SICHEM MUMBAI | 9322085 | 3EHA7 | Tanker | 129 |
| 356579000 | MSC DON GIOVANNI | 9102746 | 3FIV6 | Cargo | 203 |
| 371443000 | MSC JAPAN | 9110975 | 3ECR5 | Cargo | 243 |
| 236501000 | STEN BERGEN | 9407988 | ZDIY8 | Tanker | 144 |
| 239574000 | CAP ROMUALD | 9160229 | SVGN | Tanker | 274 |
| 247276500 | CENITO | 9423736 | IBQC | Tanker | 183 |
| 311046700 | GOTLAND CAROLINA | 9328132 | C6YV6 | Tanker | 183 |
| 311579000 | ASIAN SPIRIT | 9247431 | C6FW6 | Tanker | 269 |
| 367667560 | SEA CRESCENT | 8984563 | WDH9391 | Pilot | 29 |
| 538001583 | RELIANCE | 9236494 | V7CZ2 | Pilot | 137 |
| 538002992 | NYK CONSTELLATION | 9337626 | V7NP4 | Cargo | 294 |
| 566878000 | NORD QUEBEC | 9612296 | 9V9368 | Cargo | 178 |
| 636091081 | FRITZ REUTER | 9357872 | A8JE9 | Cargo | 178 |
| 211262460 | KOBE EXPRESS | 9143544 | DGSE | Cargo | 294 |
| 211362460 | DALIAN EXPRESS | 9229829 | DGXS | Cargo | 320 |
| 245347000 | AZORESBORG | 9466051 | PBPU | Cargo | 142 |
| 246265000 | ORANJEBORG | 9232797 | PIAG | Cargo | 158 |
| 249830000 | ZIM LUANDA | 9403229 | 9HA2029 | Cargo | 260 |
| 255805390 | NA | 9138109 | NA | Passenger | 0 |
| 259890000 | SUSANA S | 9406714 | LACF7 | Tanker | 164 |

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|---|---|---|---|---|---|
| 271042976 | ELEVIT | 9466609 | TCSI4 | Tanker | 144 |
| 316002900 | ATLANTIC ELM | 7910230 | VC9942 | TDD | 30 |
| 316013946 | VICTORIOUS | 9473262 | CFN5313 | TDD | 151 |
| 316296000 | CANADIAN WARSHIP 704 | 0 | CGAX | Military | 55 |
| 352270000 | MSC ERMINIA | 9043756 | 3FGH3 | Cargo | 277 |
| 353025000 | NYK DEMETER | 9337664 | 3ENV5 | Cargo | 294 |
| 367524560 | TITAN | 906149 | WDG3294 | Fishing | 0 |
| 367628510 | WEATHER GAUGE | 671784 | WDH5498 | Pleasure | 13 |
| 538003543 | PEARL MIST | 9412701 | V7RM9 | Passenger | 99 |
| 564004000 | EAGLE BOSTON | 9111620 | 9VHI | Tanker | 254 |
| 566550000 | NORD MONTREAL | 9612284 | 9V9367 | Cargo | 177 |
| 636008252 | PATHFINDER II | 801359600 | ELHZ5 | Cargo | 209 |
| 211331640 | SEOUL EXPRESS | 9193305 | DHBN | Cargo | 294 |
| 240840000 | CAP THEODORA | 9380740 | SVAM5 | Tanker | 274 |
| 249047000 | CELEBRITY SUMMIT | 9192387 | 9HJC9 | Passenger | 294 |
| 273413400 | AKADEMIK IOFFE | 8507731 | UAUN | Passenger | 117 |
| 310702000 | SICHEM EDINBURGH | 9352066 | ZCEP3 | Tanker | 129 |
| 311037700 | GOTLAND MARIEANN | 9375575 | C6YL8 | Tanker | 183 |
| 314066000 | M V FEDERAL SAGUENAY | 9110913 | 8PNQ | Cargo | 200 |
| 372319000 | NYK DIANA | 9337688 | 3EOS4 | Cargo | 294 |
| 477133700 | HALIFAX EXPRESS | 9200823 | VRMW7 | Cargo | 294 |
| 538002559 | SICHEM DEFIANCE | 9244374 | V7JQ3 | Tanker | 136 |
| 538002773 | PILTENE | 9323376 | V7LN6 | Tanker | 195 |
| 538005166 | NAVE EQUINOX | 9351634 | V7BM2 | Tanker | 184 |
| 636092099 | ANETTE | 9279094 | A8WY8 | Cargo | 180 |
| 211327410 | TOKYO EXPRESS | 9193290 | DGTX | Cargo | 294 |
| 229326000 | LOWLANDS BOREAS | 9609665 | 9HA3235 | Cargo | 180 |
| 235075024 | TOSCANA | 9398333 | 2CQX6 | Cargo | 200 |
| 244673000 | HOLLANDIA | 9374973 | PHKV | Cargo | 143 |
| 249509000 | ZIM MONACO | 9389708 | 9HTY9 | Cargo | 257 |
| 255805553 | VERA D | 9290177 | CQID | Cargo | 178 |
| 305852000 | SLOMAN HERMES | 9466738 | V2FY5 | Tanker | 145 |
| 310703000 | SICHEM HONG KONG | 9397054 | ZCEO8 | Tanker | 129 |
| 311492000 | SERENADE OF THE SEAS | 9228344 | C6FV8 | Passenger | 294 |
| 311578000 | AFRICAN_SPIRIT | 9250737 | C6FW5 | Tanker | 269 |
| 311927000 | ARIADNE | 9292967 | C6UI5 | Tanker | 185 |
| 316001327 | SALVOR | 5427019 | NA | TDD | 0 |
| 316006000 | MAERSK CHIGNECTO | 8204937 | VCJC | Pilot | 72 |
| 367389710 | ALIZANN | 0 | WDE7152 | Pleasure | 15 |

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|---|---|---|---|---|---|
| 367592930 | SEAHORSE | 916889 | NA | Pilot | 20 |
| 428041000 | ZIM TARRAGONA | 9471214 | 4XFA | Cargo | 261 |
| 477904300 | OAKLAND EXPRESS | 9200811 | VRMU9 | Cargo | 294 |
| 538003515 | FEDERAL MACKINAC | 9299460 | V7RI8 | Cargo | 183 |
| 538004099 | ZIM TEXAS | 9471238 | V7VE3 | Cargo | 261 |
| 538004749 | FEDERAL TWEED | 9658898 | V7YW4 | Cargo | 190 |
| 636091083 | HERMA P | 9317925 | A8JF4 | Cargo | 294 |
| 235010980 | BRITISH ENSIGN | 9312913 | MMER9 | Tanker | 184 |
| 235070707 | TORINO | 9398321 | 2BZH7 | Cargo | 198 |
| 239529000 | CAP GEORGES | 9128283 | SZGS | Tanker | 274 |
| 246435000 | HELGA | 9456719 | PBRT | Cargo | 143 |
| 271043022 | DUZGIT ENDEAVOUR | 9581007 | TCTW2 | Tanker | 152 |
| 310627000 | QUEEN MARY 2 | 9241061 | ZCEF6 | Passenger | 345 |
| 311038900 | SEABOURN QUEST | 9483126 | C6YZ5 | Passenger | 198 |
| 316001096 | MOLLY M 1 | 0 | NA | Pilot | 28 |
| 316013840 | NANNY | 9051399 | CFN5289 | Tanker | 116 |
| 316055000 | ALSTERSTERN | 9053220 | XJAZ | Tanker | 161 |
| 316143000 | CDN WARSHIP 337 | 0 | CGAN | Military | 0 |
| 319043700 | A2 | 1008035 | ZGBH4 | Pleasure | 46 |
| 354212000 | NYK METEOR | 933763800 | 3ENA9 | Cargo | 294 |
| 357191000 | MSC NILGUN | 9051492 | H8MU | Cargo | 202 |
| 477300800 | M.V.GOLDEN RUBY | 9470399 | VRNF5 | Cargo | 225 |
| 538004245 | FEDERAL YOSHINO | 9218416 | V7VY9 | Cargo | 190 |
| 538006172 | SICHEM MELBOURNE | 9376921 | V7KL8 | Tanker | 127 |
| 636091079 | ALLISE P | 9320685 | A8JE7 | Cargo | 294 |
| 211367460 | YANTIAN EXPRESS | 9229831 | DPCK | Cargo | 321 |
| 211387390 | BERLIN EXPRESS | 9229855 | DGHX | Cargo | 321 |
| 212177000 | ICE BASE | 9346433 | 5BCE2 | Tanker | 229 |
| 218350000 | NAGOYA EXPRESS | 9450428 | DGWD2 | Cargo | 335 |
| 220465000 | NORDPOL | 9253193 | OVSF2 | Cargo | 225 |
| 229734000 | SEAMUSE | 9382700 | 9HA3561 | Tanker | 180 |
| 235070715 | JANET C | 9430129 | 2BZI7 | Cargo | 138 |
| 244730000 | SCHELDEGRACHT | 9202510 | PFAQ | Cargo | 172 |
| 246263000 | AMURBORG | 9466336 | PBRO | Cargo | 142 |
| 246596000 | BEAUFORCE | 9526095 | PCHK | Cargo | 118 |
| 246719000 | ARUBABORG | 9466295 | PCCY | Cargo | 142 |
| 247080200 | GRANDE NAPOLI | 9247924 | IBZE | Cargo | 197 |
| 247187700 | AIDADIVA | 9334856 | ICDH | Passenger | 251 |
| 255805380 | CAROLINE OLDENDORFF | 8900517 | CQLW | Cargo | 245 |

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|---|---|---|---|---|---|
| 257745000 | BOA ODIN | 9557927 | LCXI | TDD | 36 |
| 266260000 | FAUST | 9332925 | SLKQ | Cargo | 228 |
| 304798000 | FEDERAL MIRAMICHI | 9315549 | V2BN9 | Cargo | 185 |
| 309168000 | CRYSTAL SYMPHONY | 9066667 | C6MY5 | Passenger | 238 |
| 310423000 | CARIBBEAN PRINCESS | 9215490 | ZCDG8 | Passenger | 290 |
| 310711000 | SICHEM NEW YORK | 9337834 | ZCEO5 | Tanker | 127 |
| 316001413 | ATLANTIC BEECH | 6912437 | VC6440 | Pilot | 0 |
| 316002535 | KALIUTIK | 0 | KALIUTI | TDD | 19 |
| 316018751 | RONJA | 9165475 | CFN5530 | Fishing | 0 |
| 316025601 | OCEAN ARCTIQUE | 9261607 | CFN6674 | Pilot | 33 |
| 316029762 | MAERSK CUTTER | 9649938 | XJBW | Pilot | 80 |
| 316254000 | STRAIT EXPLORER | 8023096 | VOFG | Cargo | 40 |
| 319563000 | SOLAIA | 1006910 | ZCFQ7 | Pleasure | 40 |
| 353153000 | STELLAR SUNRISE | 9566631 | 3FUB5 | Cargo | 210 |
| 356251000 | HECTOR N | 9384100 | 3FEL3 | Tanker | 183 |
| 373667000 | UNITED BREEZE | 9574236 | 3EZG7 | Cargo | 292 |
| 428042000 | ZIM CONSTANZA | 9471202 | 4XFB | Cargo | 261 |
| 477617600 | OOCL WASHINGTON | 9417256 | VRFU9 | Cargo | 323 |
| 477734000 | FEDERAL RIDEAU | 9200445 | VRWG7 | Cargo | 200 |
| 538001582 | RESPONDER | 9236509 | V7CY9 | Pilot | 140 |
| 538001664 | REGATTA | 9156474 | V7DM3 | Passenger | 180 |
| 538004094 | ZIM ALABAMA | 9471226 | V7VD5 | Cargo | 261 |
| 538005597 | LION | 9183635 | V7FG8 | Tanker | 0 |
| 538006177 | BERYL | 9681168 | V7KN4 | Tanker | 183 |
| 538006419 | FEDERAL BARENTS | 9697820 | V7FY7 | Cargo | 200 |
| 563079000 | NYK ROMULUS | 9416989 | 9V7644 | Cargo | 294 |
| 563758000 | NYK RUMINA | 9416991 | 9V7645 | Cargo | 294 |
| 566351000 | MAERSK KATALIN | 9431317 | 9V8528 | Tanker | 183 |
| 636091346 | NORTHERN DEBONAIR | 9353228 | A8MH2 | Cargo | 231 |
| 211311970 | DALLAS EXPRESS | 9193288 | DGAF | Cargo | 294 |
| 229325000 | LOWLANDS SAGUENAY | 9609653 | 9HA3234 | Cargo | 180 |
| 244584000 | STATENGRACHT | 9288045 | PHAQ | Cargo | 172 |
| 245789000 | SPIEGELGRACHT | 9197911 | PCEO | Cargo | 168 |
| 245816000 | SNOEKGRACHT | 9202546 | PCHF | Cargo | 168 |
| 257661000 | STAR KVARVEN | 9396153 | LAJK7 | Cargo | 208 |
| 266338000 | FIGARO | 9505041 | SMIO | Cargo | 228 |
| 269817000 | MCT STOCKHORN | 9298387 | HBHD | Tanker | 164 |
| 304261000 | HELENE J | 9138238 | V2JA7 | Cargo | 178 |
| 308322000 | SILVER WHISPER | 9192179 | C6FN7 | Passenger | 186 |
| 311000368 | CSL SPIRIT | 9138111 | C6BU6 | Cargo | 225 |

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|---|---|---|---|---|---|
| 311050600 | SEVEN SEAS NAVIGATOR | 9064126 | C6ZI9 | Passenger | 172 |
| 311307000 | NORWEGIAN DAWN | 9195169 | C6FT7 | Passenger | 294 |
| 314001000 | LAURENTIA DESGAGNES | 9334703 | 8PLD | Tanker | 225 |
| 316013000 | HENRY LARSEN | 8409329 | CGHL | Pilot | 100 |
| 316013550 | JASMINE KNUTSEN | 9273557 | VGYJ | Tanker | 277 |
| 367318000 | INDEPENDENCE 2 | 9070448 | WGAX | Cargo | 200 |
| 367592780 | SPRING DAY | 1012768 | WDG9942 | Pleasure | 26 |
| 369156000 | KITTIWAKE | 8974477 | WDA8782 | Cargo | 23 |
| 403533001 | BAHRI JAZAN | 9620970 | HZFI | Cargo | 225 |
| 477250100 | M.V.GOLDEN BRILLIANT | 9438638 | VRLR9 | Cargo | 225 |
| 477284000 | FEDERAL KUMANO | 9244257 | VRYL4 | Cargo | 200 |
| 477300500 | SINGAPORE EXPRESS | 9200809 | VRNE9 | Cargo | 294 |
| 477640200 | REDHEAD | 9285940 | VRAK4 | Cargo | 199 |
| 538001923 | RESOLUTE | 9242340 | V7FF3 | Pilot | 139 |
| 538004926 | BALTO | 9600982 | V7ZV8 | Cargo | 220 |
| 538005611 | FEDERAL LEDA | 9229996 | V7FL3 | Cargo | 199 |
| 538005681 | PRINCIMAR EQUINOX | 9486245 | V7GA4 | Tanker | 162 |
| 538006066 | CMA CGM MONTREAL | 9232761 | V7JL2 | Cargo | 211 |
| 538006222 | KIRSTIN | 9428372 | V7AI3 | Tanker | 183 |
| 563619000 | BW LYNX | 9635808 | 9V2340 | Tanker | 183 |
| 566087000 | TOSCA | 9605798 | 9V9459 | Cargo | 200 |
| 576532000 | BAHAMA_SPIRIT | 9083263 | YJRE4 | Cargo | 187 |
| 636012904 | ZIM QINGDAO | 9318163 | A8IZ2 | Cargo | 261 |
| 209996000 | GREENWING | 9230921 | P3GG9 | Cargo | 186 |
| 212093000 | BARNACLE | 9409742 | 5BNK2 | Cargo | 185 |
| 215193000 | GOLD POINT | 9506693 | 9HA2669 | Tanker | 183 |
| 218352000 | BUDAPEST EXPRESS | 9450430 | DGWE2 | Cargo | 335 |
| 232205000 | LADY GEORGINA | 1002275 | GCSF | Pleasure | 45 |
| 238295000 | VELEBIT | 9455741 | 9AA7659 | Tanker | 194 |
| 316004170 | ATLANTIC DESTINY | 9246669 | VODZ | Fishing | 43 |
| 316013040 | GRANDMANAN ADVENTURE | 9558103 | XJAV | Passenger | 86 |
| 316023718 | CAPTAIN AG SOPPITT | 9644976 | NA | Pilot | 10 |
| 316012480 | ATLANTIC PRESERVER | 9137480 | VABF | Fishing | 40 |
| 316012470 | ATLANTIC PROTECTOR | 9137507 | VABG | Fishing | 13 |
| 316001449 | LADY COMEAU II | 5418719 | CFD7756 | Fishing | 40 |
| 316003563 | PRINCESS OF ACADIA | 7039567 | VGDT | Passenger | 157 |
| 316001451 | LADY DENISEII | 5423788 | CFD8101 | Fishing | 39 |
| 316013210 | FUNDY ROSE | 9203916 | CFK5493 | Passenger | 124 |

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|---|---|---|---|---|---|
| 316002518 | OCEANPROVIDER1 | 9046552 | CFD4700 | Fishing | 81 |
| 316002592 | SWELL MASTER | 186491 | VC 8102 | TDD | 34 |
| 538002783 | IVER PROGRESS | 9350642 | V7LP7 | Tanker | 184 |
| 316001454 | LADY.YVETTE II | 262159 | CFD9864 | Fishing | 39 |
| 316003143 | IRVING HAZELNUT | 362177 | CFD6945 | Cargo | 19 |
| 311000199 | NOVA STAR | 9462067 | C6AZ4 | Passenger | 126 |
| 316003015 | MV-GRAND MANAN V | 8902591 | CFD3491 | Passenger | 72 |
| 316003110 | FREEDOM 99 | 431600321 | CFD3098 | Fishing | 48 |
| 538002221 | GREAT EASTERN | 9298739 | V7HF4 | Tanker | 183 |
| 316002801 | CHOCKLE CAP | 806087000 | VO3551 | Fishing | 282 |
| 367370780 | COHO | 9536662 | WDE5724 | TDD | 152 |
| 316027036 | DUAL VENTURE | 7727164 | NA | Fishing | 32 |
| 316006025 | ATLANTIC CEDAR | 9324928 | CFH8959 | TDD | 30 |
| 316002591 | ATLANTIC TAMARACK | 331561 | VC6732 | Pilot | 12 |
| 316001070 | ATLANTIC SPRUCE | 9174555 | CFD7836 | Pilot | 30 |
| 316163000 | ATLANTIC HEMLOCK | 9127588 | CFD8488 | TDD | 30 |
| 564212000 | ASIATIC WIND | 9366495 | 9V8791 | Cargo | 148 |
| 305249000 | AHS HAMBURG | 9406934 | V2DL4 | Cargo | 148 |
| 316001892 | WESTPORT | 0 | CG 2388 | Pilot | 16 |
| 316007483 | FUNDY PILOT | 0 | NA | Pilot | 14 |
| 538004988 | ASPHALT SAILOR | 9263954 | V7AG3 | Tanker | 109 |
| 316001616 | CLARK'S HARBOUR | 0 | CG 2612 | Pilot | 16 |
| 311929000 | AFRODITE | 9292620 | C6UI7 | TDD | 186 |
| 316029374 | TREVOR AND JESSICA | 0 | VHF 105 | Passenger | 16 |
| 316001514 | FUNDY LEGAND | 9046978 | CG 3187 | Fishing | 20 |
| 316016472 | VIOLA M. DAVIDSON | 834342 | CGEC | Pilot | 18 |
| 316001828 | RONJA CARRIER | 9282845 | CFK9573 | Fishing | 41 |
| 316001621 | COURTENAY BAY | 816537 | CG 2240 | Pilot | 16 |
| 316111000 | KINGUK | 880046800 | VOLZ | Fishing | 50 |
| 372808000 | CARNIVAL SPLENDOR | 9333163 | 3EUS | Passenger | 290 |
| 316013808 | ATLANIC BEAR | 9451147 | CFH8990 | Pilot | 30 |
| 538002073 | BALTIC | 9253258 | V7GC9 | Tanker | 182 |
| 316013660 | COLBY PERCE | 9296169 | VOMT | Fishing | 40 |
| 538002408 | BALDER | 9233416 | V7IM5 | TDD | 190 |
| 316009640 | ATLANTIC FIR | 9324916 | CFH8958 | Pilot | 30 |
| 316245000 | BLUENOSE II | 5419086 | CYJZ | Pleasure | 55 |
| 369991000 | NOAA HENRY BIGELOW | 9349057 | WTDF | Fishing | 64 |
| 316009284 | COURTNEY & KIARA | 0 | NA | Fishing | 11 |
| 311361000 | BRILLIANCE OFTHESEAS | 9195200 | C6SJ5 | TDD | 294 |

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|---|---|---|---|---|---|
| 316001415 | ATLANTIC TEAK | 742732400 | VC9924 | TDD | 31 |
| 235060249 | CPO RUSSIA | 9353125 | 2AJP8 | Tanker | 184 |
| 309951000 | NORWEGIAN GEM | 9355733 | C6VG8 | TDD | 294 |
| 316013045 | SPITFIRE III | 9451135 | CFH8987 | Pilot | 30 |
| 247069800 | FAVOLA | 9246786 | IBFH | TDD | 180 |
| 310674000 | REGAL PRINCESS | 9584724 | ZCEK6 | Passenger | 330 |
| 538004769 | ALGA | 9636632 | V7YZ3 | Tanker | 184 |
| 309436000 | LIBERTY OF THE SEAS | 9330032 | C6VQ8 | Passenger | 339 |
| 316007519 | JESSICA AND TREVOR | 0 | VHF 105 | Passenger | 16 |
| 316016449 | PENINSULA PRINCESS | 816086 | CFD4889 | Passenger | 46 |
| 563393000 | EAGLE TRENTON | 9250907 | S6NK4 | Tanker | 247 |
| 247088500 | CIELO DI ROMA | 9241803 | IBCK | Fishing | 175 |
| 247095800 | CIELO DI MILANO | 9241815 | IBDS | Fishing | 175 |
| 316012539 | ATLANTIC BEAVER | 9451123 | CFH8981 | Pilot | 30 |
| 642122013 | MAETIGA | 9386861 | 5AWX | TDD | 183 |
| 235630000 | BRITISH INNOVATOR | 9238040 | VQHO7 | Tanker | 279 |
| 248299000 | SEAVICTORY | 9315783 | 9HA2305 | TDD | 183 |
| 256472000 | STAR I | 9376945 | 9HVF8 | Tanker | 185 |
| 428002000 | ZIM VIRGINIA | 9231808 | 4XFV | TDD | 293 |
| 477634600 | ZIM SHANGHAI | 9231822 | VRGA6 | TDD | 294 |
| 477634800 | ZIM PIRAEUS | 9280847 | VRGA5 | TDD | 294 |
| 538003945 | STI HIGHLANDER | 9334789 | V7UG4 | Tanker | 183 |
| 636091632 | CONTI GUINEA | 9391402 | A8QQ4 | Tanker | 185 |
| 636092234 | MV FENELLA | 8501581 | A8YX7 | Cargo | 159 |
| 239380000 | SERIFOPOULO | 9081825 | SYNC | TDD | 183 |
| 239939000 | ASPHALT STAR | 9127693 | SVVF | TDD | 181 |
| 311315000 | GRANDEUR OF THE SEAS | 9102978 | C6SE3 | Passenger | 280 |
| 353467000 | DOLPHIN II | 9318125 | 3EZI3 | TDD | 300 |
| 367138530 | MICHAEL&KRISTEN | 0 | WBA4573 | Fishing | 23 |
| 372682000 | BALSA 93 | 9616072 | 3FGU7 | Cargo | 106 |
| 477634700 | ZIM NEW YORK | 9231810 | VRGA7 | TDD | 294 |
| 428011000 | ZIM HAIFA | 9288904 | 4XIM | TDD | 294 |
| 477201100 | ATLANTIC MUSE | 9374301 | VREZ4 | TDD | 183 |
| 229769000 | ZIM SAN FRANCISCO | 9400112 | 9HA3591 | TDD | 274 |
| 229882000 | BALTIC MARINER I | 9314820 | 9HA3691 | Tanker | 182 |
| 311050400 | SAINT LAURENT | 9213129 | C6YZ9 | Passenger | 91 |
| 357431000 | BALSA 82 | 9580235 | 3FHN3 | Cargo | 106 |
| 563553000 | EAGLE TUCSON | 9253064 | S6NK5 | Tanker | 247 |
| 232366000 | BRITISH INTEGRITY | 9288758 | MGGF9 | TDD | 183 |

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|---|---|---|---|---|---|
| 235076272 | PARAMOUNT HANOVER | 9398723 | 2CWA7 | Tanker | 250 |
| 235081745 | EDITH KIRK | 9302657 | 2DST9 | Tanker | 183 |
| 357488000 | BALSA84 | 9580259 | 3EXE5 | Cargo | 106 |
| 369023000 | GRANDE CARIBE | 8978631 | WCX4495 | Passenger | 55 |
| 370350000 | BALSA 92 | 9616060 | 3FPM3 | Cargo | 106 |
| 477216000 | GENCO PIONEER | 9197935 | VRYI4 | Cargo | 170 |
| 538004222 | AGENA | 9587831 | V7VV4 | Tanker | 184 |
| 636010736 | TEXAS STAR | 9256860 | ELUP9 | Tanker | 249 |
| 636016432 | MSC ARUSHI R. | 9244881 | A8RL3 | TDD | 281 |
| 636091524 | NORTHERN DELEGATION | 9346005 | A8PA7 | TDD | 231 |
| 220530000 | KIRSTEN MAERSK | 9431264 | OYDH2 | Tanker | 183 |
| 224152000 | MADRID SPIRIT | 9259276 | ECFM | Tanker | 285 |
| 256122000 | ACACIA NOIR | 9287883 | 9HA3828 | Tanker | 105 |
| 256123000 | CROWN II | 9236640 | 9HA3829 | TDD | 183 |
| 259025000 | HOEGH XIAMEN | 9431848 | LAJM7 | TDD | 183 |
| 303913000 | GORDON GUNTER | 8835255 | WTEO | Fishing | 59 |
| 304578000 | SINA | 9262003 | V2BG4 | Cargo | 100 |
| 353274000 | NYK DAEDALUS | 9337614 | 3EMS | TDD | 294 |
| 367167850 | ENDLESS SUMMER | 0 | WDD6067 | Pleasure | 30 |
| 367469290 | MAKO | 9579896 | WDG9743 | TDD | 39 |
| 367491360 | LUCKY SEVEN | 1232560 | V7KN4 | Pleasure | 40 |
| 371819000 | UNITED HARMONY | 9755672 | 3FXX9 | TDD | 179 |
| 466243000 | MESAIEED | 9299745 | A7NA | Tanker | 244 |
| 477829700 | OOCL SOUTHAMPTON | 9310240 | VRCU7 | Cargo | 323 |
| 538090149 | OCTAVIA | 9290452 | V7HB6 | TDD | 294 |
| 538090189 | CAPE BRINDISI | 9293143 | V7IV5 | Tanker | 274 |
| 636011466 | M/T ELKA ANGELIQUE | 9216913 | ELZK3 | TDD | 184 |
| 636012626 | PRINCIMAR CONFIDENCE | 9296389 | A8GQ6 | Tanker | 274 |
| 636013214 | ZIM VANCOUVER | 9322334 | A8LK5 | TDD | 260 |
| 212160000 | MSC JEANNE | 9135638 | P3BA7 | TDD | 195 |
| 215958000 | HISTRIA PERLA | 9301287 | 9HGL8 | Tanker | 180 |
| 218292000 | SEAPIKE | 9423449 | DEHR | TDD | 199 |
| 229335000 | URANIA | 9177480 | 9HA3244 | Cargo | 154 |
| 245546000 | SINGELGRACHT | 9197375 | PCGM | Cargo | 169 |
| 255805660 | TASMAN STRAIT | 9351218 | CQGK | Cargo | 175 |
| 256909000 | IRON POINT | 9388209 | 9HA2959 | TDD | 182 |
| 257350000 | STAR KILIMANJARO | 9396139 | LAIG7 | TDD | 208 |