AIS Whale-alert!
Assessing the fleet preferences for near real-time whale conservation in the Atlantic Canada.

By

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ABSTRACT

North Atlantic Right Whales are an endangered species that face many anthropogenic threats, including vessel strikes. A recent morality event in Atlantic Canada has emphasized the need to implement a flexible method to monitor and protect right whales in real-time. Passive Acoustic Monitoring (PAM) technology is currently used in conjunction with ocean glider technology to detect and identify whales and their location in near real-time based on vocalizations. This novel technology can allow for real-time whale conservation by linking PAM to vessel communication technology, such as the automatic identification system (AIS), to broadcast whale locations directly to vessels in the local fleet. The implementation of the MEOPAR (Marine Environmental Observation, Prediction and Response) AIS Whale Alert is nearing completion, but a paucity of information remains about the fleet's preferences and limitations towards implementing this real-time conservation technology into the bridge protocol. In my study, I surveyed and characterized the fleet and determined the implications for real-time management. The survey results provide insight to fleet receptivity and perceived utility of receiving real-time alerts, as well as their preferred response protocol. AIS analyses determined the Atlantic Canada fleet is dynamic with a high turn over rate. The information gained from this study will inform management plan to implement this novel conservation technology based on stakeholder needs and preferences. The dynamic nature of the ever-changing fleet requires special consideration. By considering fleet preferences towards implementing this technology, it is more likely that the fleet will comply with real-time conservation in Atlantic Canada.

Keywords: real-time management, North Atlantic right whale, MEOPAR, AIS Whale Alert, research survey questionnaire, automatic identification system (AIS), vessel fleet, bridge protocol, Atlantic Canada, vessel-strikes

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LIST OF ABBREVIATIONS

AIS	Automatic Identification System
AOI	Area of Interest
ATBA	Area to be Avoided
AUV	Autonomous Underwater Vehicle
CCG	Canadian Coast Guard
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DFO	Department of Fisheries and Oceans Canada
DMA	Dynamic Management Area
DMON	Digital acoustic monitoring
ESA	Endangered Species Act (USA)
GoSL	Gulf of St. Lawrence
IMO	International Maritime Organization
INMARSAT-C	International Maritime Satellite (phone)
IUCN	International Union for the Conservation of Nature
LFDCS	Low-frequency detection and classification system
MCTS	Marine Communications Traffic Services (Canada)
MEOPAR	Marine Environmental Observation, Prediction, and Response Network
MMPA	Marine Mammal Protection Act (USA)
MSR	Mandatory Ship Reporting System (USA)
NMSF	National Marine Fisheries Services (USA)
NOAA	National Oceanic and Atmospheric Association (USA)
PAM	Passive Acoustic Monitoring
SARA	Species at Risk Act (Canada)
SMA	Seasonal Management Area (USA)
TC	Transport Canada
TSS	Traffic Seperation Scheme
USCG	United States Coast Guard
VACATE	Vessel Avoidance and Conservation Area Transit Experiment
WHaLE	Whales Habitat and Listening Experiment
WHOI	Woods Hole Oceanographic Institution

1. INTRODUCTION

1.1. North Atlantic right whale

North Atlantic right whales, herein referred to as right whales, are vulnerable to negative anthropogenic impacts because they are slow maturing species that produces few offspring over a long lifespan (**Table 1**). These life history characteristics give right whales a slow population growth rate, which gives them low resilience to population declines; thus they are slow to recover (Kraus and Rolland, 2007; COSEWIC, 2013; Kraus et al., 2016).

Table 1 North Atlantic right whale (right whale) life history characteristics. (Kraus and Rolland, 2007; COSEWIC, 2013, Kraus et al., 2016)

Life history characteristic	**Evidence in right whales**
Size	Right whales can grow up to 18 m in length, with females larger than males.
Life span	Right whales routinely live up to 30 years and the oldest known individual lived to be 70 years.
Age at maturity	Females reach sexual maturity at about 10 years and males become sexually mature at about 15 years.
Calving rates	Annual calving rates vary over time. Currently calving rate is estimated at 40% with an average 17 calves born per year.
Gestation period	Right whales have a gestation period of one year.
Reproductive cycle	Female right whales can reproduce every 2-7 years.
Generation time	Right whale generation time is estimated to be 20 years.

Right whales are a migratory species that occur in coastal and shelf waters from Florida to Atlantic Canada and the Gulf of St. Lawrence (GoSL) (DFO, 2014). Their distribution and movements are often correlated with dense concentrations of their food; *Calanus* *finmarchius* stage C5 copepods (Baumgartner et al., 2003; Davies et al., 2015; DFO, 2014). As a result, right whales are often present in areas where zooplankton aggregate due to biophysical and oceanographic processes; i.e., ocean fronts and tidal forcing upwelling zones (Davies et al., 2013, 2014; DFO, 2014). During the spring and summer, right whales migrate along the eastern continental shelf of North America to higher latitudes to feed on zooplankton concentrations and a large proportion of the population inhabits Canadian waters during summer and autumn (Matthews et al., 2014; Brilliant et al., 2015; Davies et al., 2015). During the winter, female right whales often migrate to their southern calving and nursery grounds off the southeast coast of the United States (USA) from Georgia to Florida (Keller et al., 2006, 2012; NOAA, 2017a).

1.2 Population size and conservation status

Right whales are considered one of the most endangered large baleen whale species. Currently, the species population size is estimated at 450 individuals (Pettis and Hamilton, 2016; Pace et al., 2017). Of these individuals, only about 25% are sexually mature females and they represent the true breeding population (NOAA, 2017a; Pace et al., 2017). Historically, right whales were depleted and nearly hunted to extinction by centuries of whaling (Clapham et al., 1999; Reeves et al., 1999). The whales were named 'right' because they were the right whales to hunt by commercial whalers and they were heavily targeted from 1000 to 1949 AD - (Frasier et al. 2007; Reeves et al. 2007; Mullen et al. 2013). It is unknown how many right whales existed historically, but cumulative stock assessments based on catch records estimate a population size of 1100-1200 individuals in 1724 (Reeves et al. 1999). Reports indicate that right whales were already scarce in New England by 1725 due to overhunting (Reeves et al. 1999). Commercial whaling likely reduced the population to 100 individuals or less by 1935 when international protection for right whales came into effect (Reeves et al. 2007; Mullen et al. 2013).

Although they have received total protection from whaling since the 1930's, their population has been slow to recover and remains severely depleted (Clapham et al., 1999; Reeves et al. 1999). The population has been increasing since 1990, but population growth appears to be stabilizing or declining in recent years (Kraus et al., 2016; Pace et al., 2016, 2017; Waring et al., 2016). Two different stock assessment methods and a recent population estimate demonstrate a decline in right whale abundance (Kraus et al. 2016; Pace et al., 2017; Waring et al., 2016). Due to their critically small size, the International Union for the Conservation of Nature (IUCN) Red List, the Canadian Species at Risk Act (SARA), the USA Endangered Species Act (ESA), and the USA Marine Mammal Protection Act (MMPA) have listed North Atlantic right whales as Endangered and depleted throughout its range (DFO, 2014). There are many hypotheses for why the right whale has been slow to recover, including their life history, low genetic diversity, and low reproductive rates (Reeves et al., 1999; Waldick et al., 2002; Fraser et al., 2007; Mullen et al., 2013). External factors include reduced prey availability, a decline in the environmental carrying capacity and human activity (Knowlton and Kraus, 2001; Kenney, 2007; Kraus and Rolland, 2007; van der Hoop et al., 2013). Recovery is feasible, but a reduction in human induced mortalities is absolutely essential (DFO, 2014, 2017a; NOAA, 2017a).

1.3 Anthropogenic threats

As a large coastal species, right whales are exposed to many anthropogenic threats. Currently, the two most significant threats to their population are vessel strikes and fishing gear entanglement (Kraus et al., 2007; Knowlton et al., 2012; DFO 2017a; NOAA, 2017a). Other threats include habitat degradation and the effects climate change and ecosystem change (Kraus and Rolland, 2007; Davies et al., 2013).

Currently, vessel strikes are a global problem and represent a measurable cause of mortality for many large cetacean species (Jensen & Silber, 2003; van der Hoop et al., 2012; Redfern et al., 2013). Although all large whale species are susceptible to vessel strikes, North Atlantic right whales are the most frequent large whale species to be struck by vessels on a per capita basis (Vanderlaan and Taggart, 2007; Nelson et al., 2007; Glass et al., 2009, 2010). Right whales are more susceptible to vessel strikes because of their slow movement, surface feeding and socializing behaviour, and their distribution in shallow coastal waters (Kraus and Rolland, 2007). Until very recently, vessel strikes were the largest source of right whale mortality, representing over half of the determined deaths of necropsied individuals (Moore et al., 2004, 2007; Nelson et al., 2007; Glass et al., 2009, 2010; Henry et al., 2011). The rate of lethal vessel strikes has increased over time as the speed, size and number of vessels has increased (Laist et al., 2001; Vanderlaan and Taggart, 2007). Strikes have been reported for every vessel type, but the risk of lethality is greater with larger and/or faster vessels (Kite-Powell et al., 2007; Vanderlaan and Taggart, 2007; Conn and Silber, 2013; Laist et al., 2014). The reported number of vessel strikes represents an underestimate because it is likely that vessels strikes go unnoticed or unreported (Jensen and Silber, 2003; Moore et al., 2004; Campbell-Malone et al., 2008; Glass et al., 2010; Henry et al., 2011). Additionally, vessel strikes are often only determined through necropsies and these are not performed on every individual or the individual may be too decomposed to determine the cause of death (Moore et al., 2004, 2007; Nelson et al., 2007; Glass et al., 2009, 2010; Henry et al., 2011, 2015). The highest rate of known vessel strikes occurs near ports, in bottleneck areas, or other areas of high co-occurrence between vessels and whales along the continental shelf (Rockwood et al., 2017). Probability estimates indicate as many as ten right whales could be struck and killed per year (Vanderlaan et al., 2009).

The current rate of vessel strike mortality is unsustainable and impedes right whale recovery (DFO, 2014, 2016a; NOAA, 2017a). To make matters worse, mortality records indicate that juveniles, calves, and adult females are at a greater risk of vessel strikes (Kraus 1990; Moore et al., 2007; Browning et al., 2010). This has significant implications on the recovery of the population and preventing only two female mortalities per year could have a measurable influence on growth rate (Fujiwara and Caswell, 2001).

1.4 Existing vessel strike risk reduction measures

There are many management measures in place along the eastern seaboard of Canada and the USA to reduce the vessel strike risk to right whales, including legal protection and changes to conventional vessel operations to either slow vessels or reduce vessel co-occurrence with whales through vessel re-routing.

1.4.1. Legal protection

In Canada, right whales receive legal protections under SARA, the Fisheries Act, and the Canadian Shipping Act. Right whales were first assessed as endangered by Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and listed under SARA by Fisheries and Oceans Canada (DFO) in 2003 and again in 2013 (COSEWIC, 2003, 2013; DFO, 2014). Listing under SARA requires recovery efforts and critical habitat protection (SARA, 2003). Canada's recovery objective for the right whale is to achieve an increasing trend in population abundance over three generations (DFO, 2014, 2016a). Right whales and their habitat also receive protection through the Marine Mammal Regulations under the Fisheries Act (DFO, 2014). The Canada Shipping Act works to address ship source pollution prevention, as well as regulate vessel traffic. Under this Act, the Canadian Coast Guard (CCG) issues notices to mariners/advisories through Marine Communications and Traffic Services (MCTS) to vessels approaching right whale conservation areas (DFO, 2014). In the USA, right whales and their habitat receive similar protection under the MMPA and the ESA (DFO, 2014).

1.4.2. Changes to vessel operations

The Canadian and USA governments have responded to their legal requirements to reduce human-induced mortality to right whales by implementing a number of regulatory and non-regulatory measures. The three primary means of reducing vessel strike risk at the operational level are education of mariners, changing vessel operations, and implementing innovative technological solutions for detecting whales and alerting mariners of their presence. In Canada and the USA, the most common changes in vessel operations include speed reductions or spatially reducing the co-occurrence between vessels and whales through vessel re-routing. These include mandatory and voluntary measures that act to spatially or temporally change vessel operations, such as amendments to Traffic Separation Schemes (TSS), Areas to be Avoided (ATBA), Dynamic Management Areas (DMAs), speed restrictions, ship reporting systems, and designation of Critical Habitat Areas and Conservation Areas.

1.4.3. Traffic Separation Scheme (TSS)

A TSS is a vessel navigational routing system for vessels regulated through the use of mandatory shipping lanes designed to improve the safety of navigation at sea. Amendments to TSS's have been implemented in Canada, the USA and elsewhere in an effort to spatially reduce the co-occurrence of vessels and whales (Silber et al., 2012). In Canada, the Bay of Fundy TSS was amended in 2002 and implemented by the International Maritime Organization (IMO) and Canada in 2003. The outbound lane of the original TSS intersected a Right Whale Conservation Area in the Grand Manan Basin of the Bay of Fundy and represented a significant vessel strike risk in an area where high concentrations of right whales are regularly observed (Vanderlaan et al., 2008). The amended TSS reduced the relative risk of lethal vessel strike by 90% where the original TSS intersected the Conservation Area. The overall risk in the Bay of Fundy region was reduced by 62%. The overall lethal vessel strike rate was reduced from one whale in four years to one whale in twelve years (Vanderlaan et al., 2008).

1.4.4. Area to be Avoided (ATBA)

An ATBA is an IMO vessel routing measure “comprising an area within defined limits in which either navigation is particularly hazardous or it is exceptionally important to avoid casualties and which should be avoided by all ships, or certain classes of ships" (IMO). ATBAs are established by coastal nations after approval by the IMO (Silber et al., 2012; Laist et al., 2014). In Canada, a voluntary ATBA was implemented in Roseway Basin to reduce the risk of vessel strike to right whales on the Scotian Shelf (Silber et al., 2012). This was the first ATBA implemented by the IMO to specifically reduce the risk to an endangered species. The proposal to was brought to the IMO in 2007 and the ATBA was implemented in 2008 and is annually effective from 1 June through 31 December and is recommendatory for all vessels >300 GT. Before the implementation of the ATBA, the probability of lethal vessel strike in the area was one whale every 0.775-2.07 years and following implementation the probability decreased to one whale every 46 years (van der Hoop et al., 2012), but only if vessel operators comply. Compliance with the ATBA is monitored and improved through the Vessel Avoidance and Conservation Area Transit Experiment (VACATE) and Marine Stewardship Recognition Program (Vanderlaan et al., 2009). Through this program, compliance is improved through direct communication with vessel operators navigating the region. Voluntary compliance with the ATBA stabilized at 71% within the first 5 months of implementation, leading to an 82% relative risk reduction to right whales in the area. Recently, compliance with the ATBA appears to have decreased (DFO, 2017; Vanderlaan and Taggart, unpublished data). An ATBA has also been amended in the USA to effectively reduce the vessel strike risk to large whales (Merrick and Cole, 2007).

1.4.5. Dynamic Management Area (DMA)

DMAs are temporary management areas established on short notice based on the presence of a species of concern. DMAs are implemented in Canada and the USA to reduce the risk of vessel strikes to right whales. In Canada, a recent (2017) DMA was implemented by Transport Canada (TC) in the GoSL (**Figure 1**) due to a large number of dead right whales and a high proportion of the population located in the area (CCG: NOTSHIP M1409/17, NOTSHIP M1717/17, Q1189/17). All vessels of 20 meters or more were required limit their speed to 10 knots while transiting the area to reduce the vessel strike risk to whales. The DMA went into effect as a voluntary measure on 12 July 2017, but became mandatory on 11 August 2017 and remains in effect at time of writing this document. TC was willing to move this zone to other areas of the ocean if large numbers of whales were detected. Mariners were notified of the DMA via Notice to Mariners along with other communication platforms. To date, at least 9 non-compliant vessels were fined by TC, including a CCG vessel.

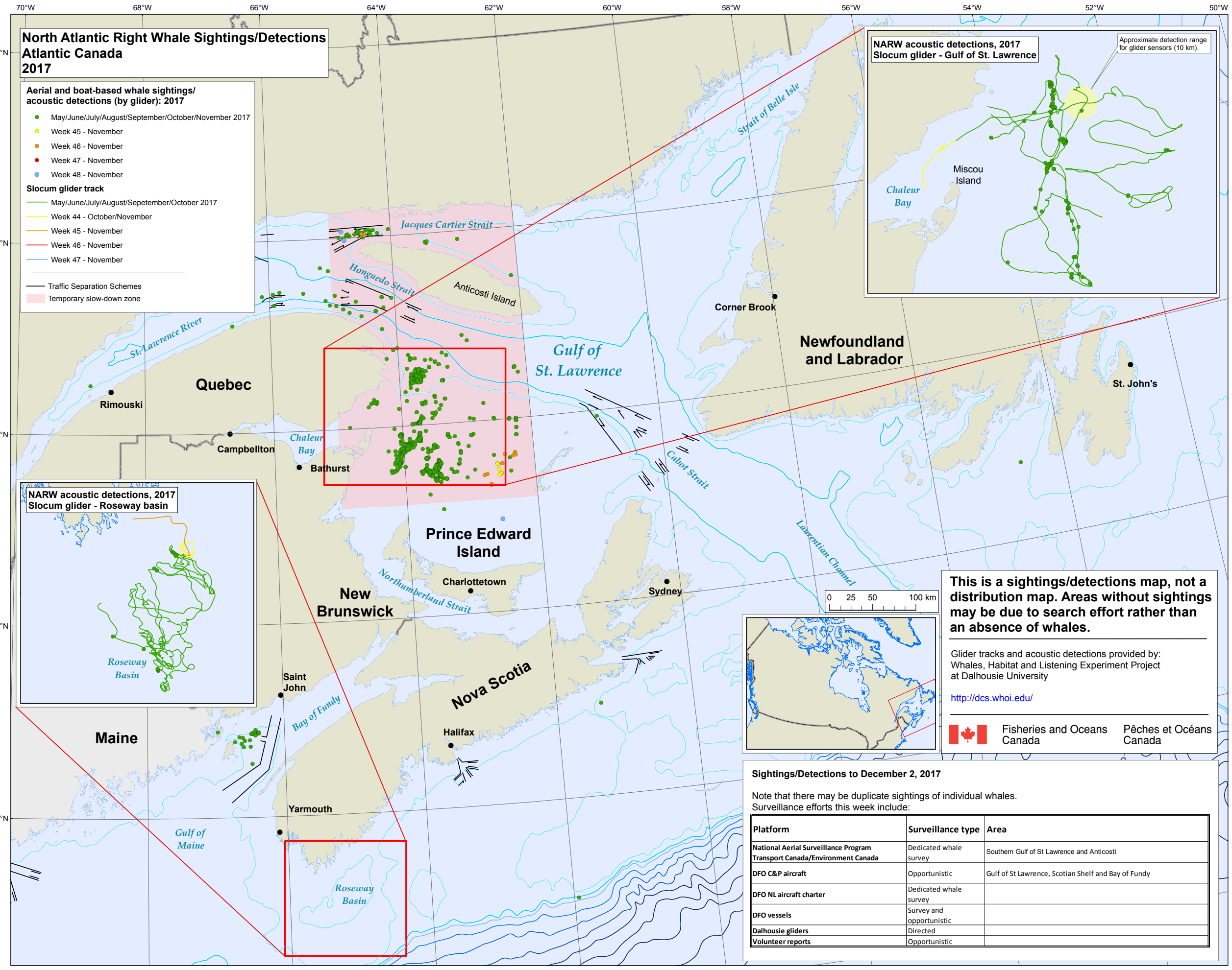


Figure 1. A map illustrating the location of 2017 North Atlantic Right whale sightings in the Gulf of Saint Lawrence (indicated in green) and the location of the Dynamic Management Area (indicated in pink) implemented in 2017 by Transport Canada to reduce the vessel strike risk to right whales. (retrieved from: http://www.dfo-mpo.gc.ca/science/environmental-environnement/narightwhale-baleinenoirean/index-eng.html (DFO 2017)

In the USA, DMAs are temporary (15 day) management areas established to protect aggregations of 3 or more right whales detected outside of their active Seasonal Management Areas (SMAs) (Laist et al. 2014). The DMA boundaries are announced to mariners on short notice through conventional maritime vessels communication technology (i.e., local notices to mariners). Vessels are asked to voluntarily limit their speed to 10 knots within the area or to avoid transiting the areas (Laist et al. 2014; Pettis and Hamilton 2016).

Another form of DMA exists along the eastern seaboard of Canada and the USA through a free mobile application called "Whale Alert" (not to be confused with the AIS Whale Alert) that helps mariners identify whale species and reporting sightings of live, dead or distressed large whales (http://www.whalealert.org). Whale sightings are automatically sent to a central database, which is also used to better understand whale feeding and migration patterns and inform management. The application also provides management information and provides alerts to vessels if they use the app and are in cell-phone range. The mobile Whale Alert application works as a DMA by incorporating the real time passive acoustic monitoring (PAM) network implemented in the United State's National Oceanic and Atmospheric Administration (NOAA) Stellwagen Bank National Marine Sanctuary (SBNMS) and the Boston TSS to reduce the risk of vessel strikes to large whales (Mullen et al. 2013). The system uses PAM to detect and classify right whale calls and automatically relay information to mariners in real time via satellite communication with the mobile phone application to alert mariners to recent whale detections (i.e., within 24 h) in the shipping lanes leading through the SBNMS by whaletail icons on their phone or tablet screen (**Figure 2**). NOAA recommends reducing vessel speed to 10 knots or less through these areas for that duration of time.

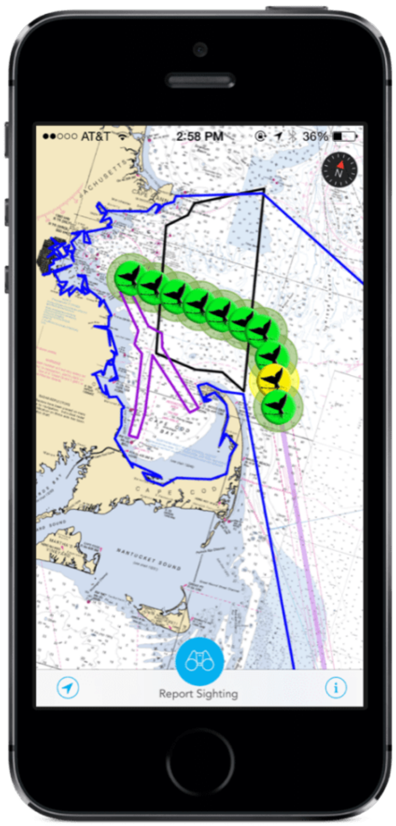


Figure 2. A visual representation of the type of information mariners can receive from the free Whale Alert application (http://www.whalealert.org), which alerts mariners to whale detections that occurred within 24 h in shipping leading through NOAA's Stellwagen Bank National Marine Sanctuary. Mariners are alerted to recent by the yellow whale tails on their phone or tablet screen.

1.4.6. Mandatory Ship Reporting (MSR) systems

One of the first measures to reduce vessels strikes to right whales in the USA were the two MSR systems put into effect for two right whale critical habitats along the USA east coast (summarized as below by Silber et al., 2012; Mullen et al., 2013; Silber et al., 2015). One MSR area operates year round in the feeding grounds off Massachusetts and the other operates seasonally in the calving grounds off Florida and Georgia from 15 November through 15 April. The goal of the MSR system is to provide timely information about right whales and vessel strike avoidance directly to vessels as they enter these areas and to raise awareness about the risk of vessel strikes. The IMO adopted the USA Coast Guard's (USCG's) proposal to implement the MSR systems in 1998 and they came into effect in 1999 and remain in effect to date. All commercial vessels >300 gt are required to report identification, including ship name, course, speed, and destination to shore-based stations upon entering the MSR regions (noted on NOAA nautical charts). All reporting vessels receive an automated reply message with updated information about right whale locations, recommendations on how to reduce vessel strikes, and where to go for additional information (e.g., publications, Sailing Directions, navigational charts, informational placards, CDs, etc.). These reports are typically sent via INMARSAT-C Internet (International Maritime Satellite) at no cost to receiving vessels and affect no other aspect of vessel operation. Reports generated from the MSR system are used to measure compliance. Compliance was slightly lower after the initial onset of the MSR system, but since 2006 compliance has remained generally constant, ranging between 70% and 80% annually. Most ships that are required to report do so and vessels report a decrease in speed following the implementation of speed restrictions in the area. The MSR program was not meant to be punitive and the USCG has not fined non-reporting vessels since 2006. Compliance is encouraged, but not enforced, through outreach and education programs and non-financial civil penalties.

1.4.7. Seasonal Management Area (SMAs)

SMAs are mandatory time-area vessel speed restrictions along the USA east coast (summarized as below, by Silber and Bettridge, 2012; Pace, 2011; Conn and Silber, 2013; Laist et al., 2014). They were implemented by NOAA in 2008 and were in effect for five years with the goal of reducing the risk of vessel strike while minimizing the economic impact of the maritime transport industry. SMAs were designed to correspond with the timing and location of right whale migration in to critical habitats where there is a high co-occurrence with vessel traffic. All vessels over 65 ft in length or >300 gt are required to travel at 10 knots or less (speed over ground) during seasonally implemented periods while transiting an SMA. Sovereign vessels, such as USA military, are exempted from these regulations. After their implementation, the National Marine Fisheries Service (NMFS) evaluated compliance and economic impacts associated with SMAs. Initial compliance was poor, but improved after violation warnings and notices were issued to non-compliant vessels in 2009 and 2010 through various notification programs. Compliance varied by vessel class and non-compliant vessels often reduced their speed by varying degrees, though not necessarily to 10 knots. The biological effectiveness of SMAs was also evaluated based on the rate of whale collisions before and after implementation. The relative vessel strike risk to right whales was reduced by 80-90% for the first two years and by 90% for final 2 years. Furthermore, no ship-struck right whales were found inside or within 45 nm of any active SMA in the first 5 years after the rule became effective; results that suggest SMA's are effective in reducing lethal vessel strikes to right whales.

1.4.8. Right Whale conservation and critical habitat areas

Right Whale 'Conservation Areas' were one of the first right whale recovery initiatives in Canada. Grand Manan Basin in the Bay of Fundy and Roseway Basin on the Scotian Shelf were designated as Right Whale Conservation Areas in 1993; though they were simply areas marked on nautical charts with non-regulatory vessel speed recommendations (DFO 2014). They are areas (**Figure 3**) where there is a greater chance of observing right whales compared to elsewhere in the region (Vanderlaan et al., 2008). However, there is little evidence that vessels voluntarily reduced speed while transiting the areas (Vanderlaan et al. 2008). Regulatory right whale 'Critical Habitat' areas were later designated in each basin and protected under SARA (Canada Gazette, 2017); defined as habitat necessary for survival or recovery of a listed wildlife species (DFO, 2014). These basins have dense copepod concentrations (right whale food) and play a significant role in right whale ecology by supporting important activities, such as feeding, socializing, nursing, and breeding (DFO, 2014; Davies et al., 2015). In the USA, 3 right whale critical habitats are designated and protected under ESA: the Great South Channel, Cape Cod Bay, and Northern Florida and Georgia (DFO, 2014)

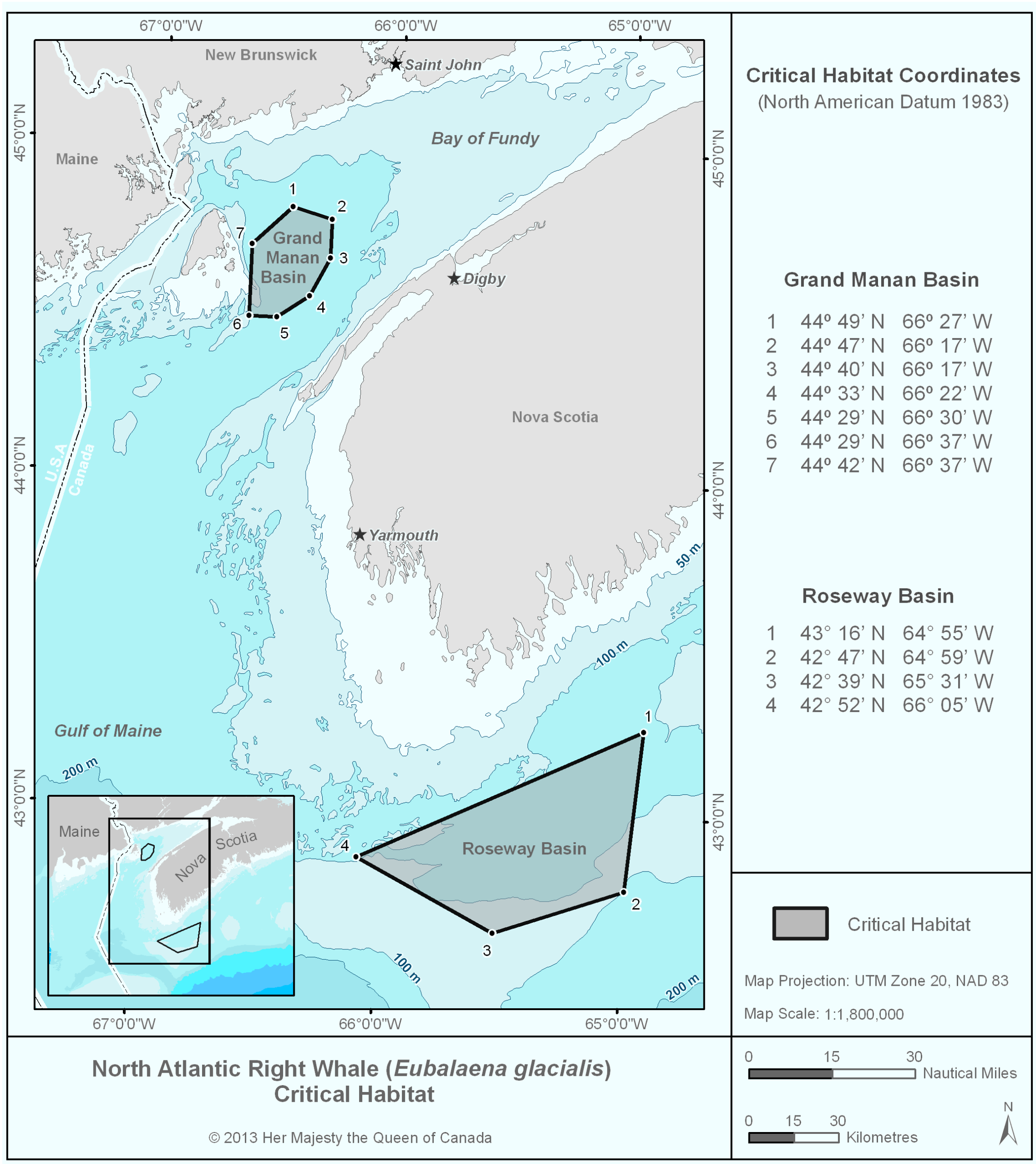


Figure 3. North Atlantic Right Whale 'Conservation Areas' in Canada, later designated as Critical Habitats under the Canadian Species at Risk Act. Retrieved from: http://www.dfo-mpo.gc.ca/species-especes/profiles-profils/rightwhaleNA-baleinenoireAN-eng.html

1.5. Management problem

There is an urgent need to implement a flexible method to monitor and protect whales in real-time in Atlantic Canada. Existing management measures are not enough, as right whales continue to suffer unsustainable mortality rates due to negative anthropogenic impact and an unprecedented 17 dead right whales were found along the Eastern seaboard of North America over the course of June through November 2017 (DFO, 2017b; NOAA, 2017b). Twelve whales were found in Canadian waters and the Gulf of Saint Lawrence (GoSL) specifically, while the remaining whales were found off the USA east coast. Necropsies were performed on seven of the right whales in the GoSL, which indicated that four died from to blunt force trauma, likely due to vessel strike, and two died after being entangled in fishing gear (Daoust et al., 2017). The cause of death for the remaining whale was inconclusive. With only about 450 NA right whales left in the world (Pace et al., 2017), these deaths represent about 4% of their population. This is significant considering their low calving rates and that breeding females represent approximately 25% of their total number (Pace et al., 2017); all illustrating the need for improved monitoring and protection of right whales in Canadian and USA waters.

Extant management measures are mostly static in space and time, focusing on known right whale critical habitats or high use areas. Current understanding of right whale distribution and habitat use is limited and is based on aerial, visual and acoustic survey effort, which covers a small fraction of known right whale range and largely focuses on critical habitat areas where right whales are known to seasonally aggregate. Our understanding of right whale migration patterns, individual movements, and resulting population distribution and aggregation outside known habitats remain unknown (Cole et al., 2013; DFO, 2014; Brilliant et al., 2015; NOAA, 2017a). Right whales are also detected year round in certain areas, such as on the Scotian Shelf and in the Gulf of Maine, which indicates some individuals do not migrate in a typical north-south pattern (Matthews et al., 2014; Roberts et al., 2016; NOAA, 2017a).

Individual right whales exhibit variations in their annual and seasonal patterns of use (Pendleton et al., 2009; Matthews et al., 2014; Davies et al., 2015). Right whales are also known to virtually abandon certain critical habitats depending on the presumed seasonal- or climate-linked suitability of the environment (Hamilton et al., 2007; Pendleton et al., 2009; Davies et al., 2015). In recent years, right whales have shifted their habitat use patterns throughout their range (Pettis and Hamilton, 2016; DFO, 2017a; NOAA, 2017a) and there is considerable evidence that right whales are using other unknown critical habitats where the population receives no protection (Frasier et al., 2005, 2007; Brilliant et al., 2015), and this is especially true now for the GoSL. It is important to further study and understand their movement and migration patterns in space and time to effectively reduce the vessel strike risk to right whales throughout their range. Thus, expanded monitoring/surveys is required to locate, study and protect right whales outside known habitats.

1.6. Implementing real-time conservation

Emerging use of technology has made near real-time conservation possible. Passive Acoustic Monitoring (PAM) is increasingly used to monitor and identify whale species and their location based on the sound repertoire of the whales. This technology can be used on autonomous underwater vehicles (AUVs), such as an ocean glider (**Figure 4**), which moves through the water column and can provide oceanographic data and whale species acoustic detection identification and location information in near real-time. This novel technology can allow for real-time whale conservation by linking the PAM information to vessel communication technology, such as vessel Automatic Identification System (AIS) technology, to inform vessels of the location of whales along the vessel's route (Reimer et al., 2015). To this end the MEOPAR (Marine Environmental Observation, Prediction and Response) WHaLE (Whale Habitat and Listening Experiment) project is developing an AIS Whale Alert System that will use PAM equipped ocean gliders to monitor (detect and locate) and protect right, humpback, sei and fin whales in Atlantic Canada.

Figure 4. A Slocum Ocean Glider fitted with a Passive Acoustic Monitoring system (forward of the glider nose) used for detecting and identifying right, humpback, sei and fin whales in real-time.

1.6.1 Passive Acoustic Monitoring (PAM)

The PAM system being used by MEOPAR-WHaLE uses the Woods Hole Oceanographic Institution (WHOI) digital acoustic monitoring (DMON) hydrophone and a low-frequency detection and classification system (LFDCS) system to detect and identify the four above whale species (Baumgartner et al., 2013). The technology is passive because the hydrophone listens to the surrounding environment without producing sound; a non-invasive tool to study the distribution, behaviour and habitat use of sound-producing species (Baumgartner et al., 2013; Matthews et al., 2014; Ludvigsen & Sorensen, 2016). PAM is useful for highly vocal species, such as right whales whales, but can only detect whales when individuals are vocalizing. Marine mammals produce different voluntary and involuntary sounds that are important for communication or echolocation (André et al., 2011; MMOA, 2017). Numerous methods have been developed to identify a species based on sound (Abbot et al., 2010). Spectrogram correlation is a common method, which involves detecting sounds by using a hydrophone and converting them into a digital record of frequency as a function of time; i.e., the spectrogram (**Figure 5**a). The spectrogram audio can then be analyzed to characterize specific sounds attributed to a specific species (Vanderlaan et al., 2003; André et al., 2011). Using the WHOI LFDCS, the spectrogram is converted to a pitch track (**Figure 5**b) that can be sent in real time from the glider to the lab where it is validated. Then, the whale species identity and location can be forwarded to users. This technique has been proven to work with many baleen whale species such as humpback, fin, North Atlantic right, minke, blue and sei whales with high accuracy (Vanderlaan et al., 2003; Van Parijs et al., 2009; Abbot et al., 2010; Stimpert et al., 2011; Andre et al., 2011; Bingham et al., 2012; Baumgartner et al., 2013). Right whales produce a variety of stereotypical sounds, such as upcalls and gunshots that are easily identifiable (Vanderlaan et al., 2003; Matthews et al., 2014). PAM allows for the acquisition of presence/absence data and species identification, but can also give context based on the type of vocalization produced by the animal and it's possible function (Abbot et al., 2010; Matthews et al., 2014). Conventional PAM devices are not ideal for real time monitoring because they collect and store data from a fixed device mounted to a buoy or to the seafloor and their data are archived and only analyzed when the PAM device is retrieved (Baumgartner et al., 2013). Progress has been made in recent years to develop mobile systems, such as PAM equipped ocean gliders (Baumgartner et al. 2013; Clark et al., 2010; Klinck et al., 2012; Matsumoto et al., 2013; Spaulding et al., 2009; Van Parijs et al., 2009).

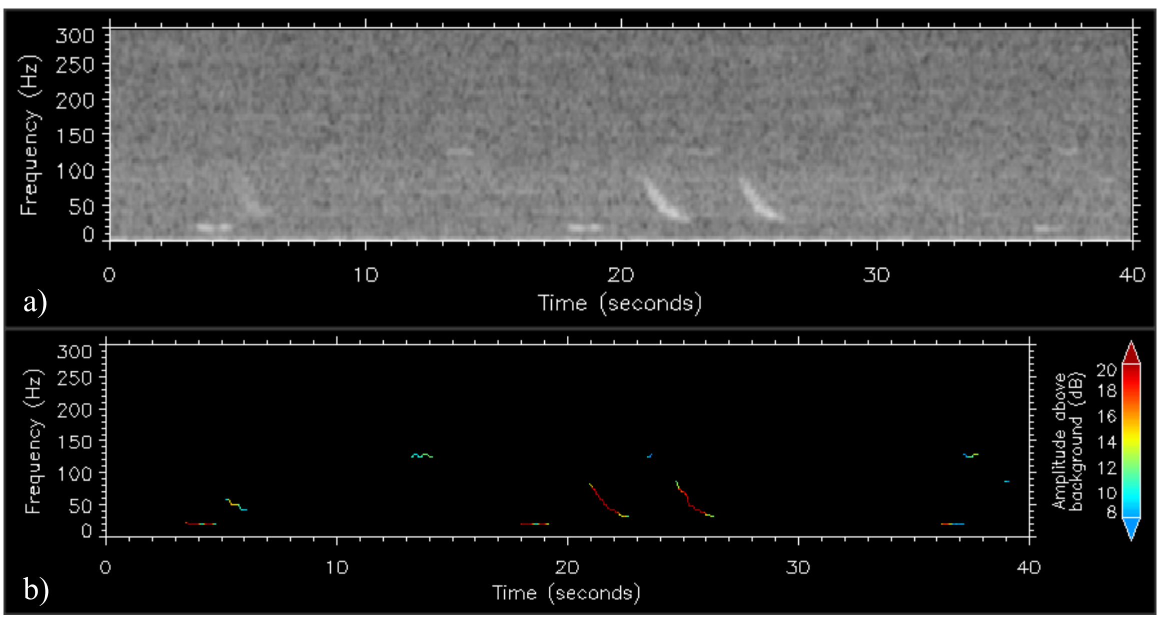


Figure 5. An example a) spectrogram obtained from Passive Acoustic Monitoring and the resulting b) pitch track used to identify whale species in near real time.

1.6.2 Ocean gliders

PAM equipped ocean gliders are a promising technology to monitor marine mammals. Ocean gliders are AUVs that travel through the marine environment on a preprogrammed route (Klinck et al., 2012; Ludvigsen & Sorensen, 2016; Suberg et al., 2014). The absence of an operator allows ocean gliders to operate 24 hr per day for months at a time in remote places, adverse conditions, or other places where it is impractical for people (Suberg et al., 2014; Ludvigsen & Sorensen, 2016). Ocean gliders can operate over wide spatial and temporal scales to collect environmental data without servicing because they expend little energy while they glide through the water by using a battery powered buoyancy changes (Van Parijs et al., 2009; Klinck et al., 2014; Suberg et al., 2014; Ludvigsen & Sorensen, 2016). Ocean gliders are being equipped with multiple sensors to monitor different aspects of the marine environment and they are increasingly being used to detect and accurately identify multiple whale species and characterize their critical habitats (Abbot et al., 2010; Klinck et al., 2012; Baumgartner et al., 2013). Sensors can be used to simultaneously monitor multiple environmental variables and effectively map the seabed and water column characteristics where whales are located (Suberg et al., 2014; Ludvigsen & Sorensen, 2016). Data can be collected and archived over time until the glider is retrieved or data can be received in near real-time each time the glider surfaces to transmit data via satellite (Van Parijs et al., 2009; Andre et al., 2011; Baumgartner et al., 2013; Klinck et al., 2014). An ideal system will operate autonomously in real-time to simultaneously detect and classify different whale species, while providing this information to scientists and managers at a low-cost (André et al., 2011; Baumgartner et al., 2013). This information can then be relayed to vessels via various vessel communication technologies to reduce the vessel strike risk to right whales and other whale species.

1.7 Vessel communication technology

Vessels already receive information and advisory notices through various technologies on the bridge that are compatible with receiving real-time information from oceans gliders, such as vessel AIS technology. A study conducted by Remier et al. (2016) determined that Navigational Telex (NAVTEX) and AIS messages are the least disruptive and most preferred methods by mariners to receive whale alerts. AIS is an onboard navigation system, which transmits dynamic voyage information and static vessel characteristics from ship-to-ship and from ship-to-shore (Silber et al., 2012; Rockwood et al., 2017). All vessels over 300 gross tons are required to carry a functioning AIS system by the International Maritime Organization's (IMO) International Convention for the Safety of Life at Sea (IHO, 1994; IMO, 2017). In USA waters, AIS is also required for most vessels over 65 feet by the USCG (Rockwood et al., 2017). Dynamic and static vessel data are collected by networks of coastal AIS receiving stations and satellites to provide a detailed, near-continuous, and precise record of vessel operations for all AIS carriage vessels (Fonnesback et al., 2008; Silber et al., 2012; Conn and Silber, et al. 2013).

The use of AIS is best for real-time alerts because it is readily and economically accessible, regularly updated and checked by the vessel Bridge team, allows for a visual location area to be used with the Electronic Chart Display and Information System (ECDIS), and can be transmitted to vessels fitted with and AIS system (Silber et al., 2012; Remier et al., 2015; Bouwman 2016). NAVTEX is not ideally suitable for real time alerts because messages are only broadcast every few hours. Initially, AIS was designed to improve the safety of vessel navigation at sea (IMO), but its use is expanding. Currently, AIS is used to characterize vessel traffic patterns over large geographic scales, quantify vessel operator compliance with mandatory and recommendatory vessel strike reduction measures, and enforce compliance with mandatory legislation (Fonnesback et al., 2008; Lagueux et al., 2011; Silber et al., 2012; Campana et al., 2015). Due to its suitability for real-time conservation, the MEOPAR-WHaLE project is planning to use an AIS message to alert vessels of the location of right whales along the vessel's route in an attempt to reduce the vessel strike risk.

1.8 AIS whale alert

A real-time monitoring system is currently being developed in Canada by the MEOPAR-WHaLE project to alert vessels to the presence of whales in near real time (MEOPAR, 2017). PAM equipped ocean gliders are already in operation in Atlantic Canadian waters to monitor and detect whales and upload data to shore-based researchers in near real time via satellite (Reimer et al., 2015; C.T. Taggart, personal communication, 2017). The AIS Whale Alert system will then transmit glider detected whale location information to vessels as an AIS Aide to Navigation (ATON) message in near real time (**Figure 6**). MEOPAR is working with many partners, including Bell-Aliant, Innovation Science and Economic Development Canada, Defense Research and Development Canada, CCG, and DFO to implement the AIS Whale Alert System. The implementation of this real time AIS Whale Alert System is cited in Canada's Ocean Protection Plan: "*Work with* *partners to implement a real-time whale detection system in specific areas of the species' habitat to alert mariners to the presence of whales, which will allow them to better avoid interactions with this and other marine mammal species* (DFO 2016c); a plan to invest $1.5 billion dollars over five years in coastal protections (DFO 2016c; DFO 2017a). The real time AIS Whale Alert System will warn vessels about whale locations and give them an opportunity to slow down and/or avoid the detected whale(s) to help reduce vessel strike risk. An adaptive management plan is needed to integrate this real-time whale alert technology in to the bridge protocol of the fleet and to develop an appropriate response protocol to reduce the vessel strike risk to right whales.

Figure 6. An illustration of the real time AIS whale-alert system being implemented in Canada by the researchers at MEOPAR (Marine Environmental Observation, Prediction and Response) through the Whales, Habitat and Listening Experiment (WHaLE) to alert vessels to the presence of whales in near real time (MEOPAR, 2017)

2. CASE STUDY: VESSEL FLEET IN ATLANTIC CANADA

Assessing the usefulness of the AIS Whale Alert System requires knowledge about the vessel fleet, as well as its interest, receptivity and preferences towards receiving real time whale location alerts. The fleet is highly dynamic in space and time and a large proportion of the fleet is comprised of large commercial vessels that pose a high risk to right whales due to their size and speed. Although the vessel fleet in Atlantic Canada represents a fraction of the global fleet, it is important to understand the needs and preferences of vessel operators when receiving a real time whale alert because the AIS Whale Alert will initially be sent from Halifax, Nova Scotia, Canada.

2.1. Global fleet

The number of vessels and the volume of marine transport have increased over the past few decades (Laist et al., 2001; Corbett, 2004; Vanderlaan et al., 2009; IMO, 2012; ISL, 2016). In 2010, the global fleet of sea-going merchant vessels above 100 gt is registered in over 150 nations and manned by 1.5 million seafarers (IMO, 2012). At the start of 2016, the world merchant fleet (ships of 300 gt and over) consisted of 51,404 vessels (ISL, 2016). Although growth has slowed in recent years, it is expected to continue into the foreseeable future due to the expansion of international trade, shipping, and maritime based travel (Corbett, 2004; Mullen et al., 2013; IMO, 2012; ISL, 2016). The size and speed of vessels has also increased to accommodate more passengers or more cargo (Roberts et al., 2016). Shipping is a vital international industry that plays a role in roughly 90% of global trade and contributes to the global economy (Mullen et al., 2013; IMO, 2012). There is an indication that maritime industries will continue to increase as new ports are developed and new Arctic shipping routes become accessible due to melting sea ice (Corbett, 2004; Roberts et al., 2016). Marine industries are affected by the global economy and economic downturns can result in fewer vessels and shipments globally (Conn and Silber, 2013; Silber et al., 2015; IMO, 2012). These decreases in vessel activity likely have unanticipated benefits in reducing the vessel strike risk to right whales (Silber et al., 2015).

2.2. Atlantic Canada fleet

The vessels transiting eastern North America waters represent a small portion of the global fleet (EMSA, 2015; Bouwman, 2016). The vessel fleet in Atlantic Canada was analyzed in a study conducted by Bouwman (2016) to determine the most frequent vessels transiting the Canadian waters on the Scotian Shelf and in the Gulf of Maine area (Bouwman, 2016). Bouwman (2016) determined that 2757 unique vessels transited the Scotia-Fundy region in 2015 and on average between 30-60 unique vessels were present each day. The vessel fleet was highly dynamic over time and a representative fleet was not discovered. The same study found that 420 unique vessels represented the top 20% of vessels present in the area over time. These vessels were limited to military, passenger, cargo, and tanker classes only, as they pose a greater risk to right whales. Although the Bouwman study yielded important results, the study focused on a single year, which does not accurately represent the dynamic nature of the vessel fleet over time.

2.3. The fleet's receptivity to real time whale conservation

There is evidence that the vessel fleet is willing to comply with new conservation measures to protect endangered whales, including the MEOPAR AIS Whale Alert Program. Remier et al. (2015) conducted a research survey of mariners' knowledge and interest in whale conservation. The survey was sent though the Shipping Federation of Canada to their fleet membership to determine mariner receptivity to new conservation measures, their preferred platform for receiving real time whale alerts, and their willingness to comply. The vessel fleet has also indicated their desire to receive real time information on the location of whales (MEOPAR, 2017).

Most mariners are knowledgeable or interested in learning more about right whale conservation (Remier et al., 2015). Although the Remier et al. (2015) study provided insightful results, the results were limited due to a small sample size that may not represent the larger vessel fleet (Remier et al., 2015; Bouwman, 2016). Additionally, there is little known about mariner receptivity and needs towards implementing the real time whale alert technology into their bridge response protocol (Reimer et al., 2015). It is important to understand stakeholder needs, limitations, and preferences in order to improve compliance and cooperation in conservation (Nkonya, 2005; Silber et al., 2014).

Different sectors of the maritime industry have indicated that if mariners know where whales are located, they will avoid them. Mariners are looking for real-time information and dynamic management measures that have little to no economic consequences to industry (Constantine et al., 2015). The marine industry has undertaken voluntary measures to reduce the risk of vessel strikes to large whales, such as posting a dedicated watch onboard (Koschinski, 2003; Constantine et al., 2015), voluntary speed reduction (Constantine et al., 2015), and participation in panel discussions or research initiatives (Remier et al., 2015).

For the MEOPAR Whale Alert system to be successful, the vessel fleet must both cooperate and comply. Compliance can be improved by several factors, including awareness or knowledge of regulations, their values and beliefs regarding conservation, and the costs and benefits of compliant behaviour (Nkonya, 2005; Silber et al., 2014). Compliance is generally high when the economic implications of conservation measures are negligible, there is a dedicated outreach and education program for mariners, and the regulations are enforced (Wiley et al., 2011; Silber and Bettridge, 2012; Constantine et al., 2015). Including mariners' preferences, values and beliefs in the planning and implementation stage will also foster a compliant fleet (Salz and Loomis, 2005; Weinstein et al., 2007). Thus, gaining more information about the needs, preferences, and operating restrictions of mariners may strengthen relationships between industry and policy makers while allowing for a coordinated and adaptive approach to implement the MEOPAR Whale Alert System.

2.4. Research questions

1. What is the perceived utility of the AIS Whale Alert to mariners and what are their preferences and limitations toward incorporating these alerts in the bridge planning and response protocols?
2. Can the vessel fleet in Atlantic Canada be characterized and defined?

2.5. Management approach

To address the conservation problem, achieve the goals and objectives of this study, and promote the use of the MEOPAR Whale Alert System, this study was completed in two parts: a research survey and an analysis of AIS vessel fleet. Therefore, I first designed and distributed a survey questionnaire to assess mariner receptivity and perceived utility towards receiving near real-time whale alerts and determine mariner needs, preferences and restrictions when incorporating such alerts into bridge protocols and then characterized the fleet using AIS data to determine the nature of the fleet and how the survey sample fleet was representative of the larger fleet.

Research surveys are a common type of quantitative research method in social science that selects a sample of people from a larger population of interest (Bartlett et al., 2001; Kelley et al., 2003; Alderman and Salem, 2010). Surveys allow researchers to collect data from large or small populations during a snapshot in time (Kelley et al., 2003). The survey responses can be used to inform an integrated management plan to incorporate this real time conservation technology into the Bridge planning and response protocols of the fleet. This study builds upon previous work conducted by Remier et al. (2015) and Bouwman (2016) with the specific objectives being to:

1. Determine the perceived utility of the MEOPAR AIS Whale Alert to mariners.
2. Determine mariner needs, preferences, and restrictions when incorporating such real time alerts into the Bridge planning and response protocols.

3. Characterize the vessel fleet to infer the representativeness of the survey sample and the resulting implications for real time management and fleet outreach.
4. Make management recommendations on how to best implement the AIS Whale Alert System in Atlantic Canada.

3. METHODOLOGY

3.1 RESEARCH SURVEY

3.1.1. Development

A research survey questionnaire was developed in collaboration with members of the Canadian Whale Institute (CWI). The purpose of the survey questionnaire was to gain and assess mariner receptivity and perceived utility towards receiving near real-time whale alerts, as well as determine mariner needs and restrictions when incorporating such alerts into bridge planning and response protocols. It is important to note that this survey was developed and distributed before the unprecedented number of dead right whales was found along the Eastern seaboard of North America in summer 2017, many in the GoSL, with some attributed to vessel strike (Daoust et al., 2017) specifically. The survey initially focused on the Scotia-Fundy vessels based on the premise that the first sending of the AIS whale alert would focus on the Scotian Shelf sent from Halifax, Nova Scotia. As I became aware of the 2017 events, the survey was immediately modified to incorporate the GoSL fleet as a part of the target fleet. The GoSL fleet was contacted with help from Green Marine and the Shipping Federation of Canada.

3.1.2. Sample Selection

The survey questionnaire targeted the vessel fleet in Atlantic Canada. The list of target vessels to survey was provided by a previous project (Bouwman, 2016). Bouwman analyzed satellite vessel AIS data for the year 2015 to characterize the vessel fleet representing the top 20% of vessels navigating the Scotia-Fundy region. My use of these data resulted in the determination of a top 20% of 270 vessels. These vessels pose the greatest risk to right whales and are the focal vessels used for this study, which represent only cargo, tanker, passenger, and military class types.

Vessel AIS data comprise dynamic and static data. Dynamic data is automatically generated from the vessel, whereas static data is entered manually by the vessel crew and is generally unreliable (See sections: 3.2.4, 3.2.6, and 5.6). Thus, several vetting practices were performed on the list of focal survey vessels to ensure the vessel data were correct. Thus, the most recent vessel information, including the vessel owner-operator and the owner-operator's mailing address was extracted using the online SeaWeb database (http://maritime.ihs.com). From this we were able to determine that 134 owner-operators represented the top 20% list of 270 focal vessels. These operators were then sorted into three groups to distribute the survey: the Royal Canadian Navy (RCN) vessels (1 operator), vessels with information related to the Roseway Basin ATBA (22 operators), and the remaining focal Scotian Shelf vessels (111 operators). Vessel owner-operator mailing information was used to distribute the survey.

3.1.3. Distribution and access

The survey questionnaire was sent directly to vessel owner-operators via mail, who were asked to encourage their vessel Masters to complete the survey online. The survey questionnaires along with a cover letter were distributed by CWI in hand-addressed envelopes on June 29th, 2017. The questionnaires were accompanied by additional information from CWI regarding north Atlantic right whales and their conservation, including a “Caution Mariners placard”, showing the two Right Whale Critical Habitats in eastern Canadian waters (Grand Manan and Roseway Basins), the IMO adopted Bay of Fundy Traffic Separation Scheme and the Roseway Basin ATBA, and a “Whale Alert Postcard”, explaining a free mobile cellular phone app called ‘Whale Alert’ (not to be confused with the AIS whale alert) to increase master and crews awareness, help in identifying species, report sightings of large whales and provide contact information to report whales that are entangled or injured. To make the survey easily accessible by vessel Masters, it was made available online via Google Forms at the web address: www.cwisurvey.ca. Vessel Masters could complete the survey questionnaire online or scan and return the paper copy sent to the owner-operators via mail.

3.1.4. Piloting and testing

The content of the survey questionnaire was jointly developed by researchers at Dalhousie University (A.J McLeod, D.D. Morin, and C.T. Taggart) and members of the CWI (M. Brown and P. Turner) to ensure proper format, language and overall understanding of the content. A preliminary study conducted by Remier *et al.* (2015) distributed a survey questionnaire to the vessel fleet in Atlantic Canada to determine mariner knowledge and awareness of endangered whales, existing conservation measures, as well as their receptivity to near real-time conservation techniques on the bridge. Most respondents were either knowledgeable or interested in whale conservation.

The Remier et al. (2015) study was limited by a small number of 47 respondents, thought to be primarily navigating the GoSL. However, it provided insight and key recommendations to inform the present survey questionnaire, such as defining near real-time response actions and protocols for mariners.

3.1.5. Survey content

Each participant was presented with a standardized one-page survey questionnaire (**Table 2**). The research survey comprised five questions of different format, including multiple choice and open-ended questions. Each question was numbered and the questionnaire was expected to take no more than ten minutes.

Table 2. The Canadian Whale Institute AIS Whale Alert Survey form sent to the vessel fleet in Atlantic Canada

The content of the survey below may be found at: **www.cwisurvey.ca**

CWI Whale-Alert Survey

The Canadian Whale Institute (CWI) invites you to participate in this secure survey. The survey will be used to determine if the information provided to you through an AIS whale-alert is user-friendly and how the information may aid in the safety of navigation while reducing the risk of ship-strikes to endangered large whale species in Canada. The AIS whale-alert will use 'Ocean Glider technology' to detect the location of whales, which is then transmitted to ECDIS receivers on vessels capable of receiving it. The information provided to vessels through the AIS whale-alert will be near real-time and will only give the location of the whales at the time of detection. Ocean Glider technology is in use on the Scotian Shelf and elsewhere in Atlantic Canada, including the Gulf of St. Lawrence. Data obtained from this survey will be used to determine the effectiveness of the AIS whale-alert program and to modify it to accommodate the requirements of the Bridge Team.

1. Please identify the vessel for which you are or were the Master by providing one or more of the following:

   ☐ MMSI #: ______________ ☐ IMO#: ______________☐ Vessel Name: _____________________

2. Is a one-time notice of the location of whales sufficient to alert the Bridge Team of the possibility of a vessel collision with a whale?

   Yes ☐ No ☐

3. What response from the Bridge Team will be caused by the receipt of a whale-alert message noting the location of whales that is near some future location along the vessel's planned route? [Please check all that apply]

☐	Increase awareness on behalf of the watch-keepers.	☐	Immediate alteration of course.
☐	Consideration of a reduction in vessel speed.	☐	Immediate alteration of speed.
☐	Consideration of an alteration in vessel course.	☐	Await further data before taking action.
☐	No action.		

   If "No action", what further information would be useful or required?

4. Would you consider modifying the Safety Management System (ISM Code) and the Bridge Resource Management Documents to reduce the risk of ship strikes to large whales?

   ☐ Yes ☐ No

5. We would appreciate any comment and practical insight that may help us to provide you with additional information that will help you in the protection of the North Atlantic right whale.

Thank you for your participation.

If necessary, please return a hard copy to: CWI, 20 Morning Star Lane, Wilson's Beach, NB, Canada E5E 1S9

or

Email a scanned copy to: ainslie.mcleod@dal.ca

Note: Your participation in this research survey is entirely voluntary and all participant responses will remain confidential. No identifying information about any person, vessel or corporation will be provided with the results of this study. The researchers are happy to discuss with you about any questions or concerns you may have about your participation. Please contact Ainslie McLeod (+1 778-220-3721; ainslie.mcleod@dal.ca) or Dr. Christopher Taggart (+1 902-494-7144; chris.taggart@dal.ca) at any time.

The questionnaire asked the respondent to identify the vessel they represented by providing any one or all of IMO number, MMSI number, and vessel name. This information was later used to validate the survey responses (i.e., ensure all responses were submitted from a legitimate vessel) and to determine the vessel flag of registry. The vessel owner-operator information was also validated using online databases to determine approximately how many owner-operators actually forwarded our survey to their vessel fleet. All vessel identification and owner-operator information was removed once the response was verified and the flag determined.

The questionnaire focused on the utility of the AIS whale-alert for mariners by asking whether or not a one-time notice of the location of whales was sufficient information to alert the Bridge Team of the possibility of a vessel collision with a whale. In particular, the questionnaire asked mariners about possible response protocols upon receipt of the AIS whale-alert. Mariners were also provided the opportunity to comment and/or provide an alternate response option. The questionnaire also asked mariners if they were willing to change their Bridge protocols to reduce the risk of vessel strikes to whales. Lastly, the questionnaire asked for any additional insights and comments.

3.1.6. Survey cover page

The research survey was accompanied by a cover page (**Table 3** & **Table 4**) that included information about the administering organization, the goals and aims of the study, how participants were selected, and the possible outcomes of the study (i.e., the harms and benefits of study). The cover page also provided relevant background information about north Atlantic right whales, ocean gliders, and the proposed AIS whale-alert program. The cover letter instructed the owner-operators to forward the appended survey questionnaire to their vessel masters for completion. Each cover letter was made personal by individually addressing the letter to specific vessel owner-operators and included identifying information about vessels within that operator's fleet. The cover page also included the CWI logo and signatures of M. Brown and P. Turner, who are widely recognizable by many vessel operators in Atlantic Canada.

Table 3. Page one of the primary cover letter used to accompany the research survey questionnaire sent to 122 operators. The cover letter included information about the administering organization, the goals and aims of the study, how participants were selected, the possible outcomes of the study (i.e., the harms and benefits of study), and provided relevant background information about north Atlantic right whales, ocean gliders, and the proposed AIS whale-alert program.

CANADIAN WHALE INSTITUTE

20 Morning Star Lane, Wilson's Beach
New Brunswick E5E 1S9 Canada
506-752-1985 • www.canadianwhaleinstitute.ca

«OPERATOR_»
«ADDRESS_1»
«Address_2»
«Address_3»
«Address_4»

[New date]

Dear Vessel Operator,

The principle aim of the Canadian Whale Institute (CWI) is the protection and conservation of the North Atlantic right whale, listed as endangered in the Canadian Species at Risk Act, which requires that all effort be made to protect the species. Today, only about 525 of these whales exist. Right whales and other large at-risk whales are found on the Scotian Shelf off coastal Nova Scotia, Canada. The major risk of injury and fatality to these whales is vessel strikes. CWI realizes that the presence of these whales is not easily detected by the Bridge Team and we are attempting to assist the Bridge Team avoid whale strikes by providing information about the location of the whales.

Ocean Gliders* are being used on the Scotian Shelf and will, upon detecting the location of large whales, transmit the information to a coastal receiver, which in turn transmits the location as an AIS 'whale-alert' to ECDIS receivers on the vessels in the area. The technology results in a near real-time position locating whales that may be in the vicinity of ships. To assess the value of this program and its use aboard vessels, we have developed a short survey which will aid us in providing the necessary information to vessels for whale strike avoidance. We expect that the information received by the vessel will assist the Bridge Team to determine the best course of action to avoid whale-ship collisions.

Over the past three years the CWI and its partners have identified, using data obtained from AIS transmissions, that the vessel(s) listed below have made one or more passages on the Scotian Shelf. Our information shows that your company is, or was, the Operator of the vessel(s). As such, we are seeking your assistance in assessing the utility of the whale-alert technology. It would be appreciated if you would forward the attached survey information to the Masters of the ship(s) listed below and others taking passage on the East Coast of Canada for which you are the Operator so that they may complete the survey via the following secure online link or the appended survey form.

The secure, semi-anonymous Survey may be found online at: **www.cwisurvey.ca**

IMO	**MMSI**	**NAME**
«IMO__1»	«MMSI__1»	«VESSEL_NAME__1»
«IMO__2»	«MMSI__2»	«VESSEL_NAME__2»
«IMO__3»	«MMSI__3»	«VESSEL_NAME__3»
«IMO__4»	«MMSI__4»	«VESSEL_NAME__4»
«IMO__5»	«MMSI__5»	«VESSEL_NAME__5»
«IMO__6»	«MMSI__6»	«VESSEL_NAME__6»
«IMO__7»	«MMSI__7»	«VESSEL_NAME__7»
«IMO__8»	«MMSI__8»	«VESSEL_NAME__8»
«IMO__9»	«MMSI__9»	«VESSEL_NAME__9»

Thank you for your time and consideration. We appreciate all measures that will assist in reducing the threat of a vessel striking North Atlantic right whales. Please don't hesitate to contact us for additional information.

Table 4. Page two of the primary cover letter used to accompany the research survey questionnaire sent to 122 operators. The cover letter included information about the administering organization, the goals and aims of the study, how participants were selected, the possible outcomes of the study (i.e., the harms and benefits of study), and provided relevant background information about north Atlantic right whales, ocean gliders, and the proposed AIS whale-alert program.

Yours faithfully,

(Signature)	(Signature)
Moira Brown, Ph.D. Senior Scientist, Canadian Whale Institute	Peter Turner Master Mariner Director, Canadian Whale Institute

We have enclosed:

***CWI whale-alert survey* -** that we ask you to send to your fleet Masters for completion using the secure on-line link www.cwisurvey.ca or by using the attached form.

***Caution Mariners placard* –** showing the location of the two Right Whale Critical Habitats in eastern Canadian waters (Grand Manan and Roseway Basins), and the IMO adopted Bay of Fundy Traffic Separation Scheme and the Roseway Basin ATBA.

Whale Alert Postcard – *Whale Alert* is a free mobile app. that will help masters and crews identify species, report sightings of large whales and provide contact information to report whales that are entangled or injured.

***Ocean Gliders –** are remote autonomous vehicles that can be used to survey large bodies of the ocean over long periods of time and when fitted with underwater microphones (hydrophones) they can be used to detect and identify the sounds made by large baleen whales and transmit the location of the whales to shore receiving stations via satellite in near real-time.

There were three different cover letters tailored for specific groups within the survey sample. The first letter was created for the primary group of 111 focal vessels that transit the Scotia-Fundy region (**Table 3** & **Table 4**) and the other two letters were slight variations. The second group of 22 operators not only transits the Scotia-Fundy region, but also the Roseway Basin ATBA. CWI regularly sends letters to such vessels with information related to the ATBA. Therefore, this cover letter was tailored to meet the needs of the CWI, as well as this study. The final letter was tailored for the Royal Canadian Navy.

3.1.7. Survey issues and troubleshooting

Once the survey was distributed, there were some common issues that needed to be addressed. First, ten letters were returned to CWI and were either unopened or were not received by vessel owner-operators; simply "return to sender". Second, two vessel operators sent return letters to indicate they would not be participating in the survey for various reasons, including changes in operation and ownership of vessels. These operators were sent a follow-up encouraging them to nevertheless complete the survey and provide insight. Third, vessel-owner operators responded with questions or concerns that were addressed and answered. Fourth, surveys were submitted via email or mail, which needed to be manually input to the online survey forum. Lastly, as there was a poor response rate for the survey, the vessel owner-operators were sent a follow-up letter to further encourage their vessel Masters to complete the survey in a timely manner. To further promote responses, and with the help of the Shipping Federation of Canada and Green Marine, vessel owner-operators in the GoSL were sent the survey and asked to distribute it to their fleet masters. The survey letter was modified slightly for such vessels in the GoSL.

3.1.8. Survey response analysis

After the research survey response period closed on 2 November 2017, the responses were analyzed to assess mariner perceived utility and receptivity of the AIS Whale Alert. Responses were also analyzed to determine mariner needs, preferences and restrictions when incorporating such alerts into bridge protocols. Each response was verified using the provided identification information (i.e., IMO number, MMSI number or name) to ensure all respondents represent an active vessel. Next the survey responses involving multiple-choice questions were analyzed using proportional response scores. These scores were then analyzed using a Chi-squared test. Lastly, the responses were analyzed to characterize the responders and non-responders within the initial sample size and the entire vessel fleet.

3.2. Vessel fleet characterization

3.2.1. AIS data

Coastal and satellite vessel AIS data – the latter provided by exactEarth Ltd. (2016), and processed by R.C. Hilliard, courtesy of MEOPAR – were analyzed over the years 2011 through 2016 inclusive to characterize the vessel fleet in my area of interest (AOI; **Figure 7**) in Atlantic Canada and to infer the representativeness of the survey sample fleet. Coastal AIS towers receive vessel AIS data via very high frequency (VHF) radio; therefore the towers reception is limited by line-of-sight between vessel and receiver.

Normally, a coastal AIS tower will receive AIS information from vessels within a range of 15-40 nautical miles depending on factors such as antenna elevation on ground and on a vessel, antenna type, obstacles around the antenna, and weather conditions. Currently, there is a network of 6 coastal AIS receivers in Atlantic Canada; 4 of which are relevant to this study (**Figure 7**a). Advancements in satellite AIS receivers provide global coverage of vessel AIS data, with lower temporal resolution relative to coastal receivers (**Figure 7**b).

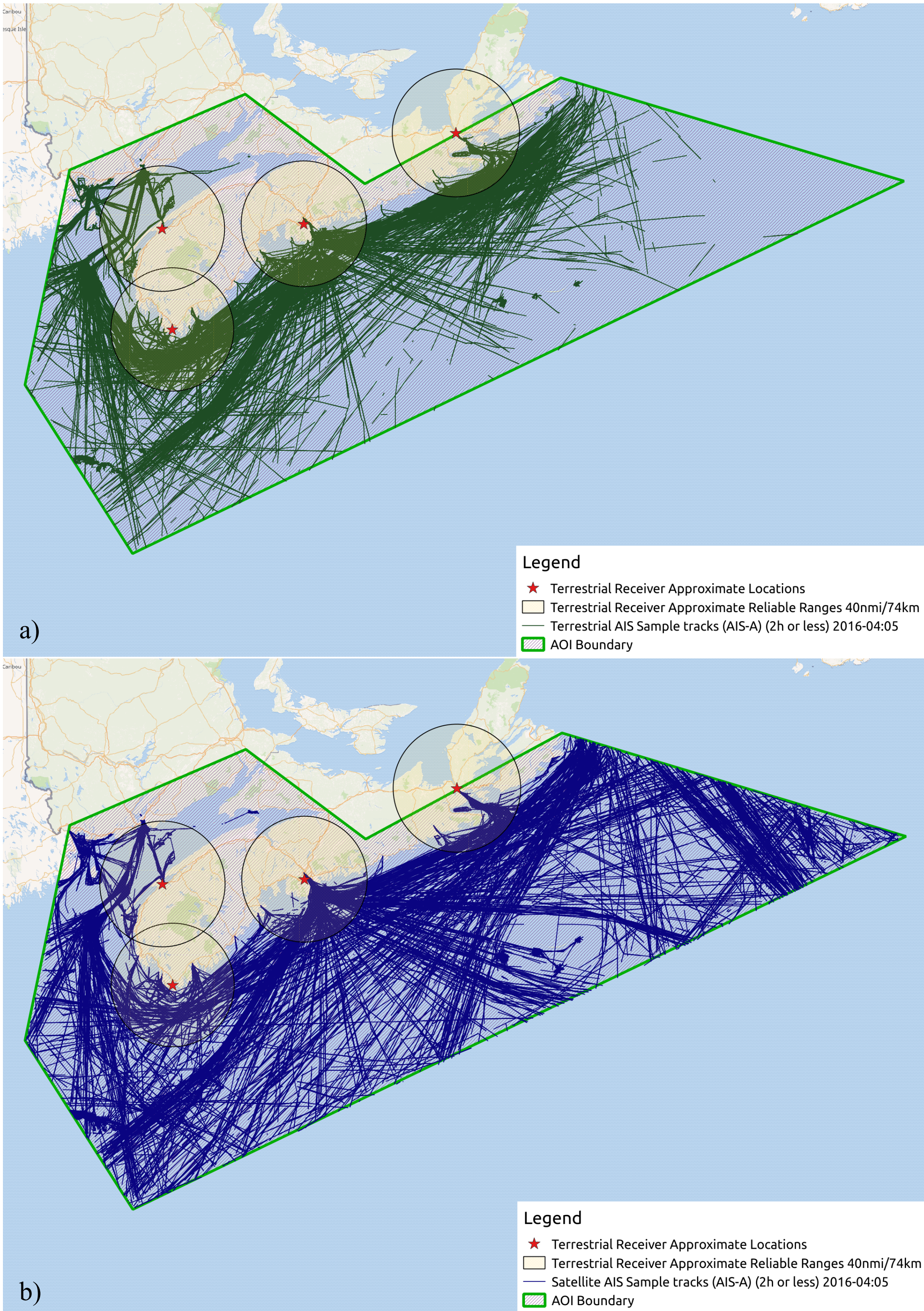


Figure 7. An illustration of the different range of Automatic Identification System (AIS) vessel track data received by a) coastal AIS towers and b) satellite AIS receivers from April though May 2016.

3.2.2. Data retrieval

My AOI was defined to obtain satellite and coastal vessel AIS data and analyze the vessel fleet navigating the Scotian Shelf and the Bay of Fundy based on previous knowledge of areas that are frequented by right whales in Atlantic Canada (**Figure 7**). Once the AOI was chosen, its bounds (**Table 5**) were used to run an extraction query on coastal and satellite AIS data separately on a yearly basis for the years 2011 through 2016 inclusive. Each year had 365 days from 1 January to 31 December, except for 2012, which had 366 days. The December 2016 satellite data were not available at the time of data extraction; thus 335 days of data for analysis.

Table 5. The coordinates (decimal N-latitude and W-longitude) of the area of interest (study domain polygon).

Point	Decimal W-longitude	Decimal N-latitude
1	62° 44' 47.8436" W	45° 4' 35.3913" N
2	64° 31' 46.8432" W	46° 0' 42.9488" N
3	67° 8' 53.5422" W	45° 13' 18.838" N
4	67° 48' 48.8514" W	42° 55' 22.0173" N
5	66° 12' 36.3679" W	41° 3' 19.0903" N
6	54° 42' 29.9481" W	45° 6' 18.9374" N
7	59° 49' 31.5803" W	46° 10' 50.5683" N

There are two primary types of AIS messages – dynamic and static. The dynamic message is generated automatically from the vessel navigational system and includes MMSI number (Maritime Mobile Service Identity), message date-time, time zone, the vessel navigational status (i.e., underway, at anchor, etc.), rate of turn in degrees, speed over ground (SOG) in knots, GPS location accuracy (hi, lo), latitude, longitude, course over ground (COG), true heading in degrees and UTC time (clock-seconds only) at the time of message generation. The static data are manually input by bridge personnel and include the MMSI number, message date-time, time zone, the IMO number, vessel radio call-sign, vessel name, vessel type (class), vessel size (length, width and draught; m), and destination, among others. The MMSI number is common in both the static and dynamic messages; it a seven-digit number used for radios with digital selective calling, as well as AIS transceivers.

The AOI was used to query the dynamic AIS data and extract distinct MMSI numbers on an annual basis. The resultant MMSI numbers were then used to query the static vessel AIS data, with aggregation based on unique MMSI number, IMO number, radio call-sign, vessel name and year combinations. IMO numbers are important because they act as a unique identifier for sea-going merchant vessels. IMO numbers are mandatory for cargo vessels >300 gt and passenger vessels >100 gt, but unlike MMSI numbers, IMO numbers ideally never change for the entire life of the vessel. For each unique combination (MMSI number + IMO number + radio call-sign + vessel name + year), the first instance date and time within the AOI and the location (i.e., the latitude and longitude coordinate from the dynamic data, which corresponds to the static data) were also retrieved.

3.2.3. Data arbitration

Unique data combinations were extracted from both the satellite AIS and coastal tower AIS databases separately and then merged into a single dataset with an indication of the data origin (i.e., satellite or coastal tower). Merging the data made it possible for multiple data points to correspond to a single MMSI record because of multiple receivers: satellite plus 4 coastal. In this case, arbitration was performed on the basis of the satellite or coastal tower unique identifier, which had the effect of an order of preference based on the receivers identity as follows: Satellite (S), Cape Breton Tower (TC), Digby Tower (TD), Gaspe Tower (TG), Halifax Tower (TH), Mulgrave Tower (TM) and Roseway Tower (TR).

3.2.4. Data manipulation

After arbitration, the AIS data were refined to include only mandatory IMO AIS-A carrying vessels and not AIS-B carrying vessels. AIS-B vessels are non-mandatory carriage vessels and can optionally report only radio call-sign information and little else. These vessels are usually fishing vessels or pleasure crafts that do not provide any additional details, thus limiting their use for this study.

Next, the data were refined to eliminate the vessels with MMSI numbers equal to zero, or otherwise clearly invalid. There were other questionable MMSI numbers present in the dataset, which were refined during further data validation (see section 3.2.6.).

3.2.5. Data presentation and access

The refined data were then presented in the following formats as .csv files for further analysis:

File 1: Count per MMSI number, per year, the number of times an MMSI number was counted in the AOI each year.

File 2: First date, coordinate (latitude and longitude), per MMSI number per year as dynamic point data.

File 3: First date, coordinate, per MMSI number, per year as dynamic point data matched to static data records.

File 4: Dynamic point data records with unmatched static data annually.

File 5: a) Dynamic point data matched to static data, and including first occurrence dates attached to distinct combinations of MMSI number, IMO number, radio call-sign and vessel name, as well as including the coordinate.

b) As above, but with leading and trailing space stripped from the vessel name and radio call-sign string to reduce many duplicates in the dataset.

3.2.6. Data validation

Once the data were extracted and manipulated, the AIS data required further validation because vessel AIS static data are highly error prone due to human error and/or message corruption during transmission. A spreadsheet was used for data validation as follows:

1. File 5b was used to obtain unique combinations of vessel MMSI number, IMO number, radio call-sign and vessel name, as well as their first instance date-time and coordinate.
2. The dataset was divided into individual years.

3. Invalid vessel MMSI numbers were flagged. Valid MMSI numbers are 9 digits, beginning in 2 through 7, depending on their country of origin.
4. Invalid IMO numbers were flagged. IMO numbers are 7 digit numbers that are unique to each vessel for its entire lifetime. For the purpose of this study, IMO "0" was not considered invalid because some vessels are not required to have IMO numbers, such as fishing vessels, warships, and wooden ships.
5. A large number of invalid IMO numbers followed the following format: XXXXXXX00; two extra zeros. These invalid IMO numbers were edited to true by removing the extra zeros.
6. Duplicate IMO numbers and MMSI were found and flagged.
7. Records with both MMSI and IMO duplicates were removed, keeping the record with the earliest instance date.
8. The remaining records with MMSI duplicates were edited to true or removed.
    a. Edit to true using other records or online resources
    b. Remove duplicate vessels
    c. Few vessels will have duplicate MMSI numbers because MMSI number changes with vessel flag or can change with vessel ownership.
9. The remaining records with IMO number duplicated were edited to true or removed in the same way.
10. Edit or remove invalid MMSI and IMO numbers
    a. Edit to true using other records or online resources
    b. Remove invalid records if vessel not found
11. Check for invalid characters in dataset, which can occur during a corrupted or interrupted data transmission. Edit the record to true by removing these characters.

This validation and elimination process was carried out for each year individually, as well as all years combined to determine the number of unique vessels with respect to their IMO number, MMSI number, radio call-sign and vessel name.

3.2.7. Data analysis

After the data were validated to get a unique list of vessels per year, as well as a unique list of vessels for all the years combined, the data were then analyzed to create a discovery curve for the fleet. First, for each year unique vessel MMSI numbers were listed based on their first day of appearance within the AOI starting in 01 January and ending on 31 December (i.e., a unique MMSI number appears only once in the list on the year-day in which it first appeared). The cumulative daily count of unique vessels over the year provided the 6 discovery curve for the 6 years. This process was repeated to provide weekly and monthly discovery curves as well as a discovery curve across all 6 years. Discovery curves illustrate vessels joining the fleet over time. In theory, if all vessels within the vessel fleet had navigated the AOI more or less continuously then rate of discovery would decrease over time as new vessels would become increasingly rare (i.e. the discovery curve would approach an asymptote, indicating that the entire fleet had been identified (**Figure 8**a). A lack of asymptotic tendency e.g., linear, indicates a near constant rate of discovery and thus a fleet that has not been fully identified (**Figure 8**b). It is important to note that 1 January vessel counts are not graphically provided (early discovery inflation).

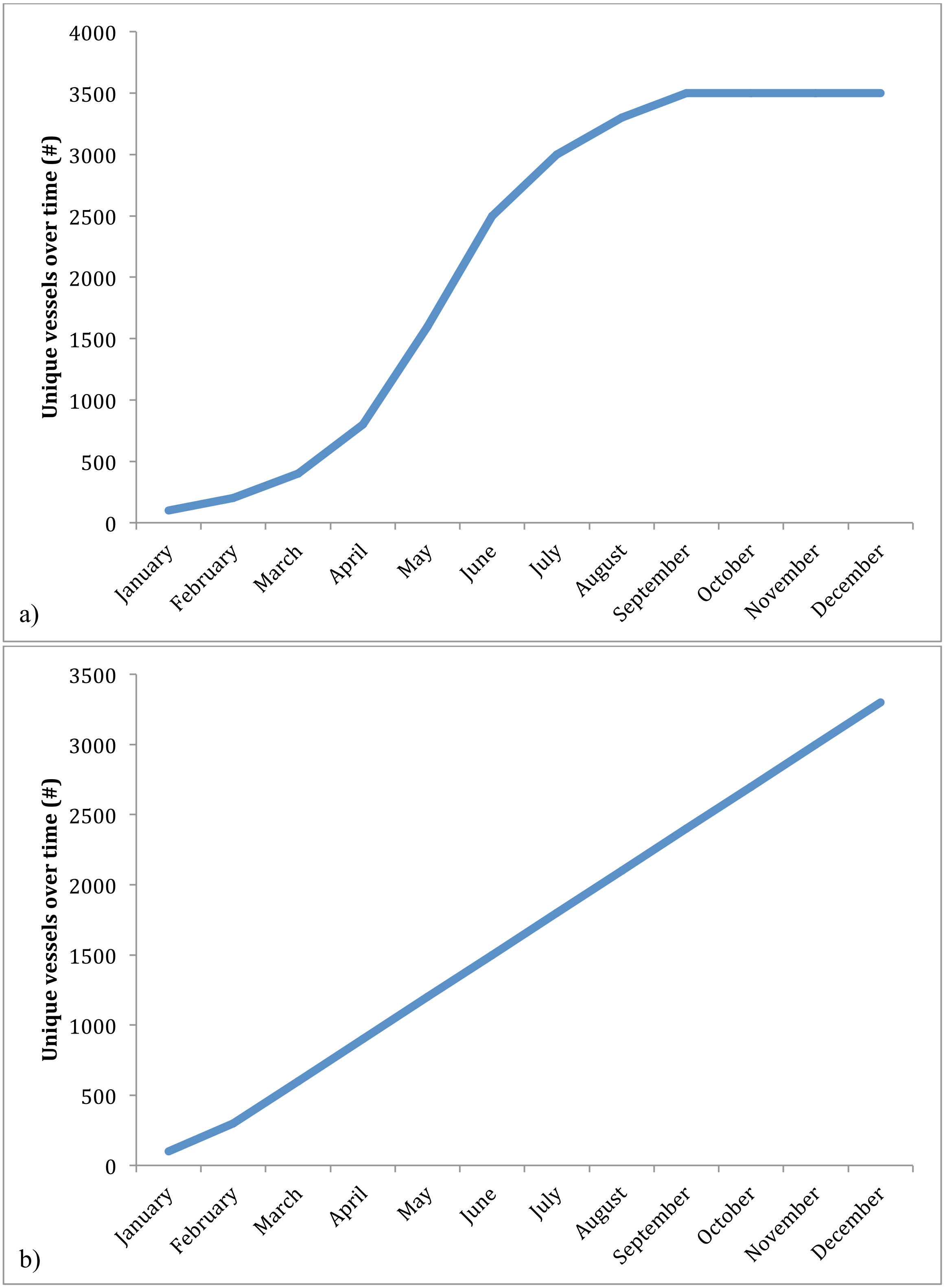


Figure 8. An illustration of a discovery curve and the two resulting extremes where a) the entire population is discovered and the discovery rate drops to zero (indicated by an asymptote) and b) where the fleet continually grows over time and has not been fully identified.

4. RESULTS

4.1. Survey questionnaire responses

A total of 42 completed survey responses were received by CWI (**Table 6**). 19 responses were completed via the online survey form (available at www.cwisurvey.ca) and 23 were received as an email scanned copy of the completed survey form. 38 responses were received from vessel masters and 1 response was received as a generic feedback from the Shipping Federation of Canada and thus is not included in further data analysis. Some duplicate responses received from vessel captains were not included in further data analysis. Thus, a total of 38 unique vessel responses were used for this study.

Table 6. Characteristics of respondents to the Canadian Whale Institute (CWI) Automatic Identification System (AIS) Whale Alert Survey. The respondent characteristics of importance are the AIS vessel class, vessel type, flag the vessel sails under, method of survey response submission (i.e., email or online survey form available at www.cwisurvey.ca), whether the respondent left a comment on the survey, and whether the response was from a duplicate vessel, as three vessels submitted their response online and by email.

#	AIS VESSEL CLASS	VESSEL TYPE	FLAG	EMAIL/ ONLINE	COMMENT LEFT (Y/N)	DUPLICATE RESPONSE (Y/N)	DATE
1	CARGO	BULK CARRIER	Cyprus	EMAIL	N	N	17/10/2017
2	CARGO	BULK CARRIER	Cyprus	EMAIL	Y	N	19/10/2017
3	CARGO	BULK CARRIER	Cyprus	EMAIL	Y	N	19/10/2017
4	CARGO	BULK CARRIER	Cyprus	EMAIL	Y	N	19/10/2017
5	CARGO	BULK CARRIER	Cyprus	EMAIL	Y	N	19/10/2017
6	CARGO	BULK CARRIER	Cyprus	EMAIL	Y	N	27/10/2017
7	CARGO	BULK CARRIER	CYPRUS	EMAIL	Y	N	27/10/2017
8	CARGO	CEMENT CARRIER	SINGAPORE	EMAIL	N	N	17/07/2017
9	CARGO	CONTAINER SHIP	HONG KONG	ONLINE	N	N	11/10/2017
10	CARGO	CONTAINER SHIP	HONG KONG	ONLINE	N	N	12/10/2017
11	CARGO	CONTAINER SHIP	PANAMA	EMAIL	N	N	17/07/2017
12	CARGO	GENERAL CARGO	CANADA	EMAIL	Y	N	11/08/2017
13	CARGO	GENERAL CARGO	CANADA	EMAIL	Y	N	12/08/2017
14	CARGO	GENERAL CARGO	CANADA	ONLINE	Y	Y	13/08/2017
15	CARGO	GENERAL CARGO	CANADA	EMAIL	Y	Y	16/08/2017
16	CARGO	GENERAL CARGO	NETHERLANDS	ONLINE	Y	N	10/10/2017
17	CARGO	GENERAL CARGO	NETHERLANDS	ONLINE	Y	N	10/10/2017
18	CARGO	GENERAL CARGO	NETHERLANDS	ONLINE	Y	N	11/10/2017
19	CARGO	GENERAL CARGO	NETHERLANDS	ONLINE	Y	N	12/10/2017
20	CARGO	GENERAL CARGO	NETHERLANDS	ONLINE	Y	N	20/07/2017
21	CARGO	RO-RO CARGO	CANADA	EMAIL	Y	Y	11/07/2017
22	CARGO	RO-RO CARGO	CANADA	ONLINE	N	N	03/08/2017
23	CARGO	RO-RO CARGO	CANADA	ONLINE	Y	Y	04/08/2017
24	CARGO	SELF DISCHARGING BULK CARRIER	CANADA	ONLINE	Y	N	15/08/2017
25	CARGO	SELF DISCHARGING BULK CARRIER	CANADA	ONLINE	Y	N	16/08/2017
26	CARGO	SELF DISCHARGING BULK CARRIER	CANADA	ONLINE	Y	N	16/08/2017

27	CARGO	SELF DISCHARGING BULK CARRIER	CANADA	ONLINE	N	N	16/08/2017
28	CARGO	SELF DISCHARGING BULK CARRIER	CANADA	ONLINE	Y	Y	25/08/2017
29	CARGO	SELF DISCHARGING BULK CARRIER	CANADA	EMAIL	N	N	13/10/2017
30	CARGO	SELF DISCHARGING BULK CARRIER	CANADA	EMAIL	Y	Y	14/10/2017
31	CARGO	SELF DISCHARGING BULK CARRIER	CANADA	EMAIL	Y	N	13/10/2017
32	CARGO	SELF DISCHARGING BULK CARRIER	CANADA	EMAIL	Y	N	13/10/2017
33	CARGO	SELF DISCHARGING BULK CARRIER	CANADA	EMAIL	N	N	14/10/2017
34	CARGO	SELF DISCHARGING BULK CARRIER	CANADA	EMAIL	N	N	14/10/2017
35	NON-VESSEL	NON-VESSEL*	CANADA	EMAIL	Y	N	23/10/2017
36	PASSENGER	PASSENGERS SHIP	RUSSIA	EMAIL	N	N	3/08/2017
37	PASSENGER	RO-RO CARGO/ PASSENGER	CANADA	EMAIL	Y	N	13/07/2017
38	TANKER	CRUDE OIL TANKER	CANADA	EMAIL	N	N	11/10/2017
39	TANKER	OIL/CHEMICAL TANKER	CANADA	ONLINE	N	N	02/08/2017
40	TANKER	OIL/CHEMICAL TANKER	CANADA	ONLINE	N	N	23/08/2017
41	TANKER	OIL/CHEMICAL TANKER	MARSHAL ISLANDS	ONLINE	Y	N	29/08/2017
42	TANKER	OIL/CHEMICAL TANKER	TURKEY	ONLINE	Y	N	24/07/2017

*One response was submitted by the Shipping Federation of Canada as general feedback on the AIS Whale Alert System and is not considered a vessel response.

The survey responses represented 19 Canadian flag vessels and 19 international vessels, their total representing 16 owner-operators. Most of the responses were received from cargo vessels, followed by tankers and passenger vessels. The one generic response submitted by the Shipping Federation of Canada is considered a “non-vessel” (**Figure 9**).

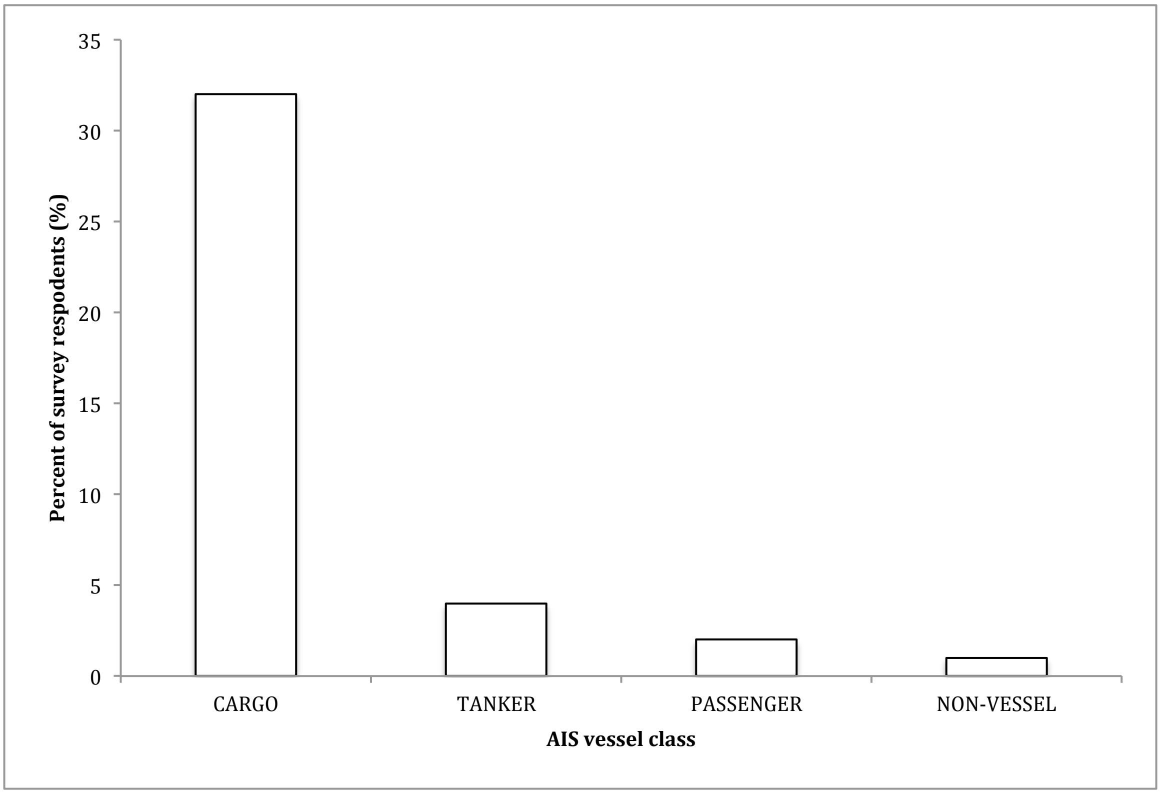


Figure 9. The percent of the 38 survey responses received from respondents among different Automatic Identification System (AIS) vessel classes. One response was submitted from someone other than a vessel captain as general feedback and is considered a "non-vessel".

4.1.1. Perceived utility of the AIS Whale Alert

Participants were asked whether a one-time notice of the location of whales is sufficient to alert the Bridge Team of the possibility of a vessel collision with a whale and 25 of the vessel respondents (66%) answered yes, whereas 13 vessel respondents (34%) answered no. One participant indicated two different responses for this question; they responded "no" online, but hand wrote "maybe" on a survey form submitted via email. This response was considered as "no" for data analysis.

4.1.2. Mariner responses and preferred protocols

Participants were asked how the Bridge Team would respond upon the receipt of an AIS whale-alert message and they all indicated that this would increase awareness on behalf of the vessel watch-keepers (**Figure 10**). Over half the participants indicated that the AIS whale alert would cause a consideration of a reduction in vessel speed (73%) or a consideration of an alteration in vessel course (86%). Fewer participants indicated they would immediately alter the vessel course (22%) or speed (19%) or await further data before taking action (14%). No participants indicated that the Bridge Team would take no action upon receipt of the AIS whale alert. Two participants added comments or suggestions on this question:

1. If a one-time notice of the location of whale through an AIS whale-alert is received on the ship, that will increase awareness of the watchkeeper of the presence of whales in the area. Speed reduction will be considered if needed and a shar[k] lookout with be maintained to visually locate the whales. If a whale is seen, the officer of the watch will determine if a risk of collision exist and take necessary action to avoid a close encounter.

2. Take action is vessel is on the path of a whale according to your message or if a whale is sighted. Will take action when necessary where its applicable instead of modifying ism code.

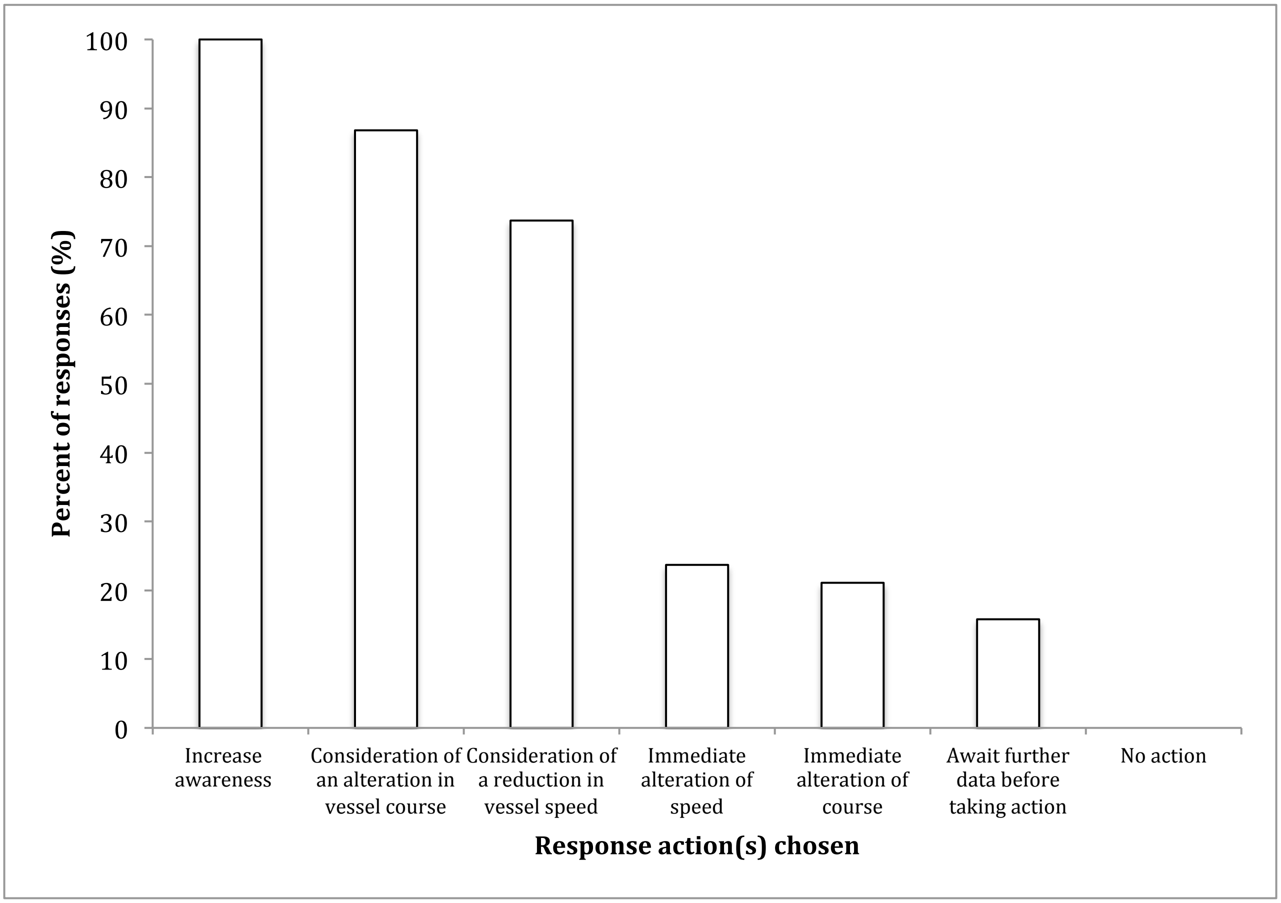


Figure 10. The percent of 38 respondents, who chose each multiple-choice answer when asked what response from the Bridge Team will be caused by the receipt of the Automatic Identification System (AIS) Whale Alert System.

4.1.3. Mariner receptivity to implementing the AIS Whale Alert into Bridge protocols

Participants were asked if they were willing to permanently change their Bridge protocol documents to reduce the risk of vessel strikes to whales and 21 (57%) answered yes, whereas 17 (43%) answered no.

Lastly, participants were asked to leave additional insights or comments and 24 responded with additional information, including the Shipping Federation of Canada (Appendix 1). These comments and insights followed 4 general themes:

1. Recommendations on how to increase the utility of the AIS Whale Alert via different methods of message transmission.
2. Insight to the preferred response protocol of the fleet.
3. Inquiries or concerns about AIS Whale Alert technology.
4. Miscellaneous information regarding mariner knowledge about right whales and current anthropogenic threats.

4.2. Response Rate

Only 38 unique vessel responses, represented by 16 operators, were received by CWI. The initial top 20% list of 270 focal vessels was represented by 134 owner-operators. Responses came from 17 vessels in the top 20%. Responses came from 15 vessel owner-operators in the top 20%, which represent 35 vessels (including the 17 top 20% vessels). The remaining 3 responses were received from a single vessel operator, who was not on the top 20% list. In addition to the survey responses, ten letters were returned to CWI and were either never opened or never received by vessel owner-operators (i.e., returned to sender), two vessel operators sent return letters to indicate they would not be participating in the survey.

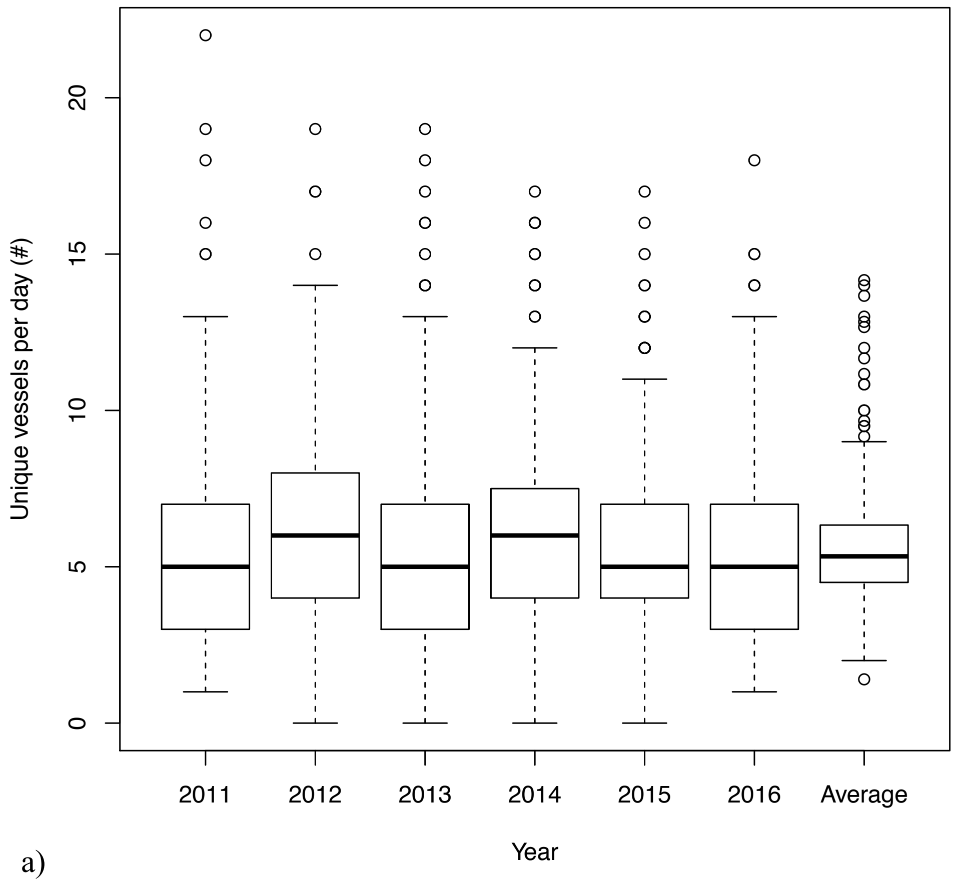
The response rate for the survey can be calculated based on number of vessels that responded or the operators that represented the responding vessels. The response rate is calculated based on the 38 completed survey responses, 3 letters of response, and 10 letters that were returned to sender. It is important to note that it is impossible to determine the exact number of vessels or vessel operators that received the survey. The calculated response rates are likely much smaller because external agencies, such as the Shipping Federation of Canada and Green Marine, distributed the survey in addition to the initial sending by CWI.

In summary, the top 20% vessel response rate was 7% (18/270= 6.6%) and the vessel owner-operator response was somewhat higher at 16% (20/124= 16.1%)

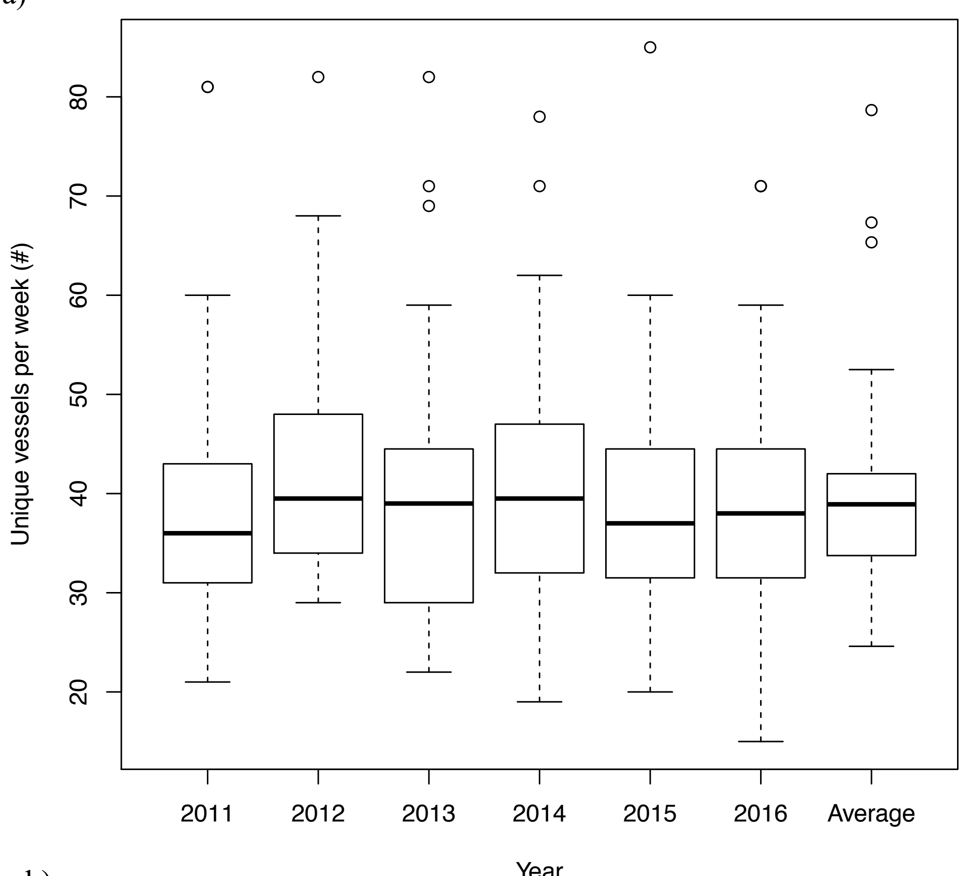
4.3. Characterization of vessel fleet in Atlantic Canada

4.3.1. Annual number of unique vessels (2011-2016)

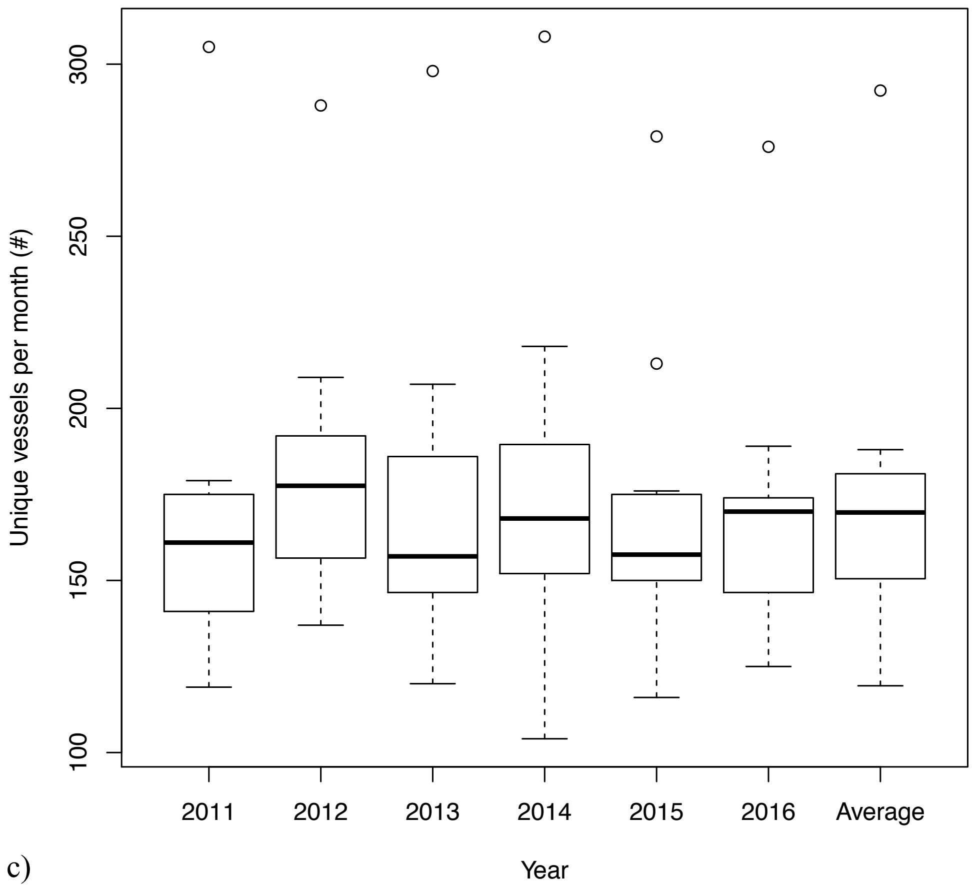
The annual number of unique vessels transiting the AOI ranged from 1867 to 2180 from 2 January 2011 through 30 Nov 2016. On any given day, between 0 and 22 (average=6) unique vessels were present in the study area (**Figure 11**a). There were between 15 and 85 (average=40) unique vessels on a weekly basis (**Figure 11**b) and between 104 and 308 (average=172) vessels monthly (**Figure 11**c). There was high variability in the number of unique vessels within years. The daily, weekly, and monthly number of unique vessels transiting the area was similar for each year throughout the study period, indicating there was no annual trend (**Figure 11** and Appendix 2).


Unique vessels per day (#)
0
5
10
15
20
2011
2012
2013
2014
2015
2016
Average
Year

a)


Unique vessels per week (#)
20
30
40
50
60
70
80
2011
2012
2013
2014
2015
2016
Average
Year

b)

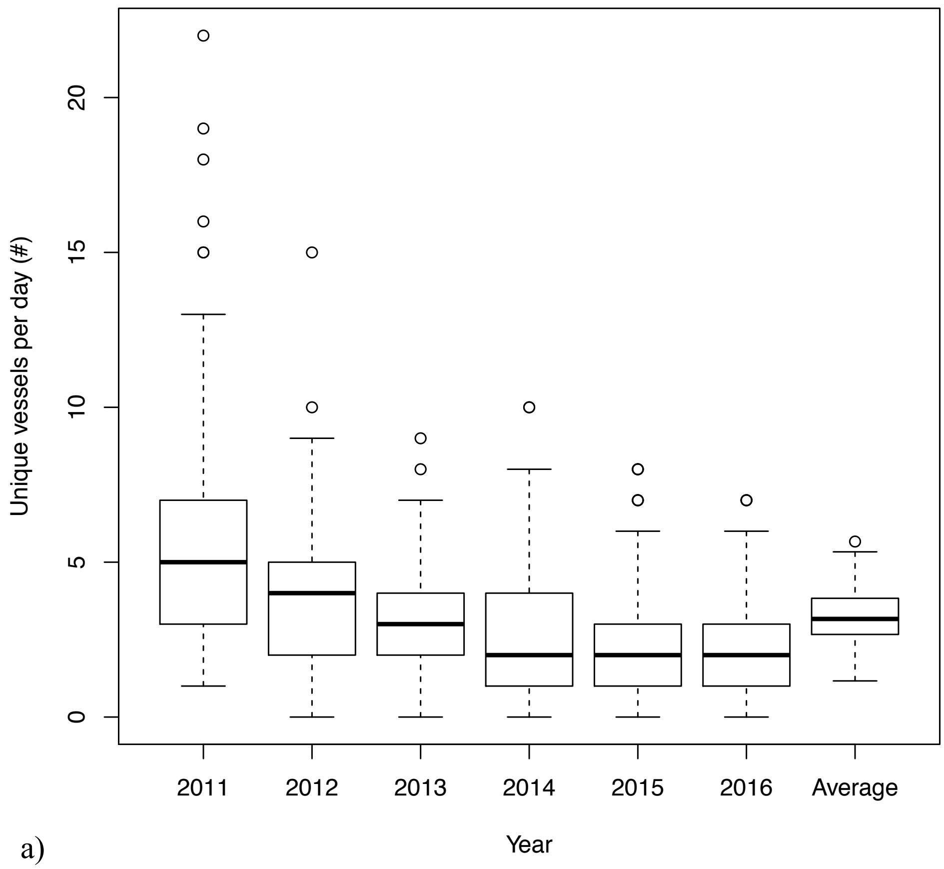


c)

Figure 11. Boxplots indicating the a) daily, b) weekly, and c) monthly unique vessel counts annually from 2011 through 2016. The boxplots provide summary information about the unique number of vessels per year, including the median number (indicated by the horizontal line), the interquartile range (indicated by the box), the maximum and minimum numbers. The number of unique vessels was determined each day annually and then aggregated to get weekly and monthly values.

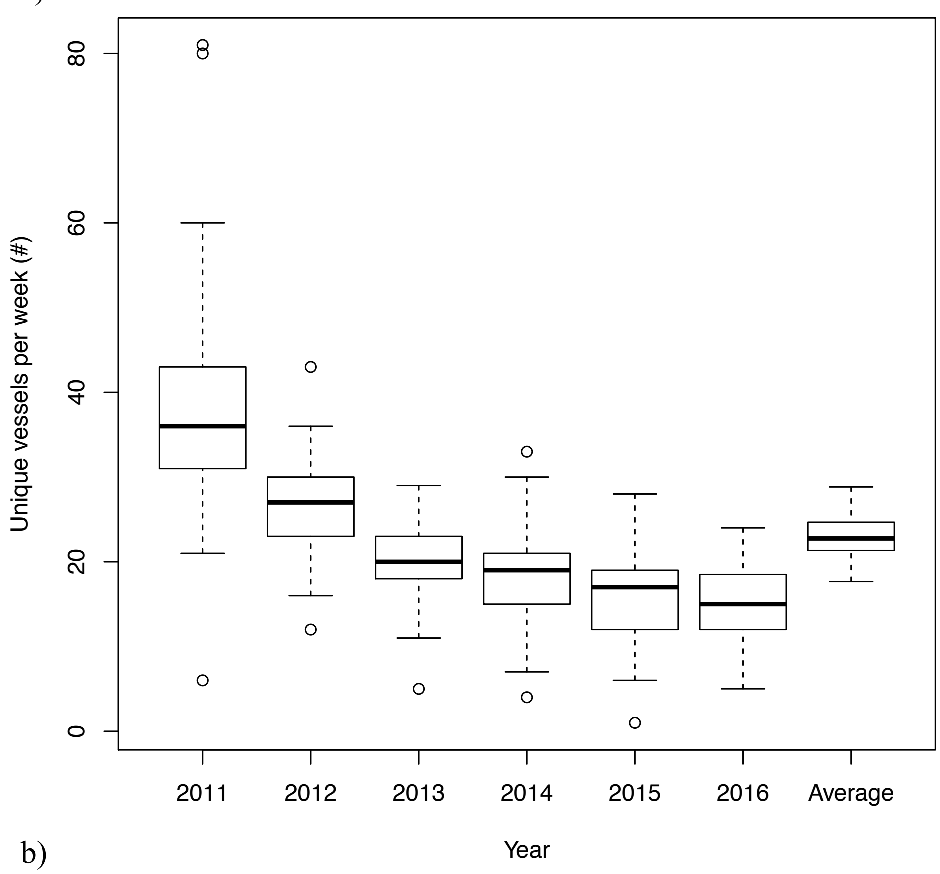
4.3.2. Cumulative number of unique vessels over the study period (2011-2016)

There were 7060 unique vessels transiting the area over the period January 2011 through Nov 2016. Each day, between 0 and 22 (average = 3) unique vessels transited the area. There were between 1 and 81 (average=23) unique vessels on a weekly basis and between 49 and 304 (average=98) vessels monthly. The daily number of unique vessels was highly variable within and among years throughout the study (**Figure 12**a). The daily number of unique vessels was slightly higher during the first three years of the study, but remained relatively stable for the remaining three years. The first two years also contained days with the highest number of unique vessels, indicated by the outliers. These results indicate the rate of discovery remained constant, but decreased slightly during the study period. This trend is more pronounced and less variable when aggregating the data among weeks (**Figure 12**b) and months (**Figure 12**c). Again, it appears that the rate of discovery decreases as more and more vessels are discovered while seemingly moving to toward an asymptote in the latter years with a near constant discovery of ~3 new vessels per day, ~23/week and ~98/month (**Figure 12**; Appendix 3).



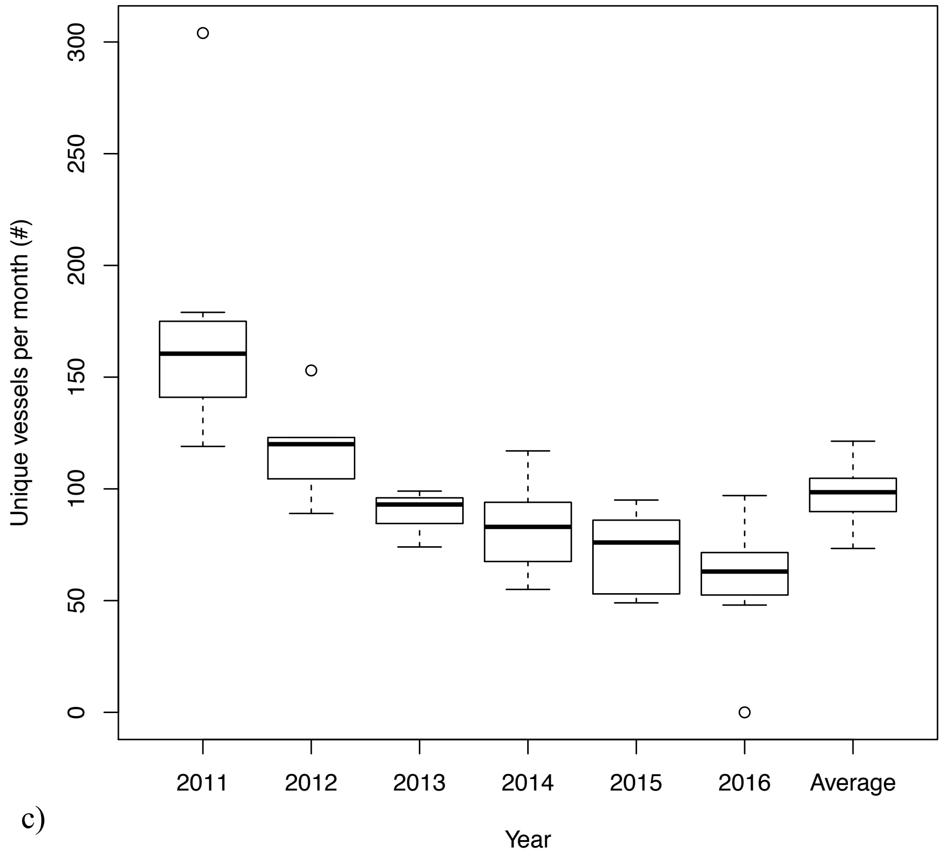
Unique vessels per day (#)
0
5
10
15
20
2011
2012
2013
2014
2015
2016
Average
Year

a)



Unique vessels per week (#)
0
20
40
60
80
2011
2012
2013
2014
2015
2016
Average
Year

b)



c)

Figure 12. The annual average number of unique vessels transiting the AOI on an a) daily, b) weekly, and c) monthly over the entire study period from January 2011 through November 2016. The boxplots provide summary information about the unique number of vessels per year, including the median number (horizontal line), the interquartile range (indicated by the box), the maximum and minimum numbers, and outliers (indicated by the circles).

4.3.3. Annual fleet discovery

The annual discovery curves for the AOI fleet indicated that the growth in unique vessels in the fleet was similar on a daily basis for each year of the study period (**Figure 13**). All discovery curves for the fleet increase almost linearly with no indication of an asymptote (**Figure 13**, **Table 7** and Appendix 4). The rate of discovery increasing somewhat faster during the first few days or weeks and then slowing to a relatively constant rate thereafter at ~5.5 vessels per day (**Table 7**). In theory, if there was a finite number of vessels navigating the AOI within a year, the discovery curve would reach an asymptote, indicating that discovery of new vessels would become rare over time as the entire fleet became identified. The lack of asymptote indicates that the rate of discovery is near constant over time and the vessel fleet has not been fully identified within the study. The data and resulting discovery curves for each individual year is available in Appendix 4.

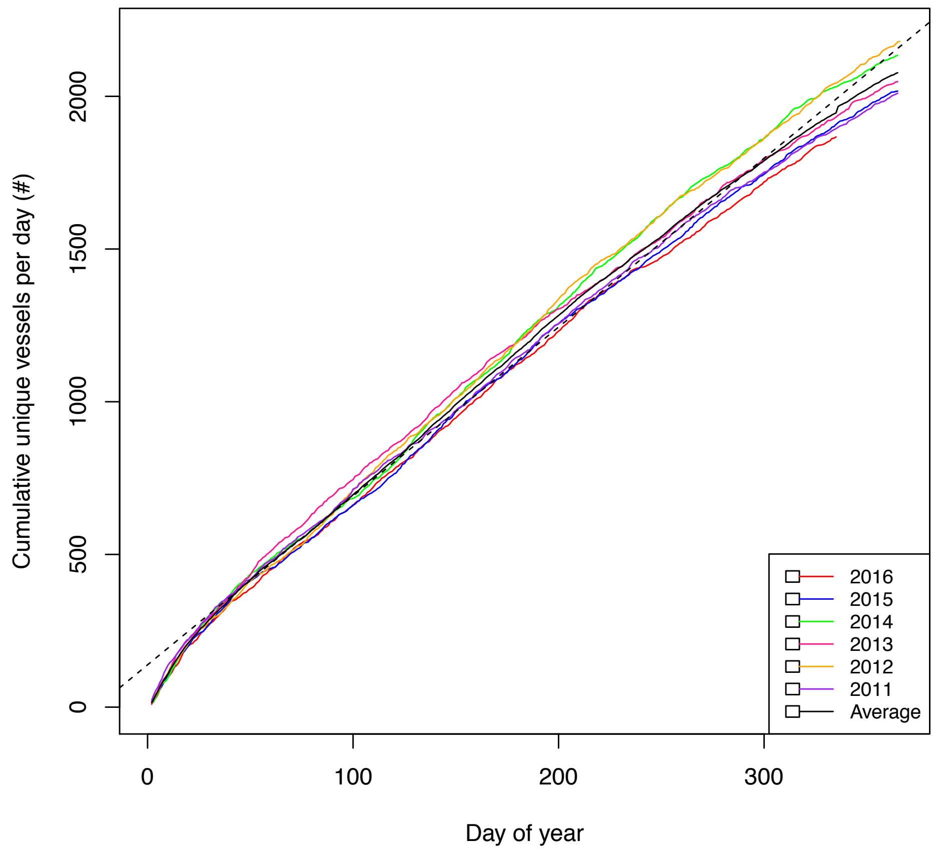


Figure 13. The daily vessel discovery curves, illustrating the cumulative daily count of unique vessels over the year (i.e., the growth of the vessel fleet), for each year from 1 January 2011 through 30 November 2016. The linear trendline (black-dotted line) represents the average annual rate of discovery (i.e., slope).

Table 7. The annual number of unique vessels within the study area and the annual growth rate of the fleet on daily, weekly, and monthly basis.

Year	Total unique vessels (#)	Daily Slope (vessels/day)	Weekly Slope (vessels/week)	Monthly Slope (vessels/month)
2011	2010	5.30655	36.8497	157.759
2012	2180	5.85221	40.7247	175.15
2013	2048	5.37479	37.2580	158.762
2014	2134	5.80986	40.3170	172.619
2015	2017	5.41163	37.5802	161.458
2016	1867	5.41029	37.7363	161.373
AVERAGE	2063.63	5.52984	38.4073	164.533

4.3.4. Overall 6-year fleet discovery

The combined discovery curve for the six-year study period illustrates the daily growth in unique vessels in the vessel fleet from January 2011 through 30 November 2016 (**Figure 14**). The six-year discovery curve for the vessel fleet increased almost linearly with no indication of an asymptote. The rate of discovery was slightly greater during the first year and then slowed to a relatively constant rate (~1170 new vessels per year). Again, the lack of asymptote indicates that new vessels joining the fleet vessel at the above rate. Given that fleet size is more or less constant at around 2000 vessels per year (**Table 7**) and the discovery is ~1000 per year, then the fleet turnover (i.e., losses and gains of unique vessels) must be around 1000 per year, and thus never fully discovered.

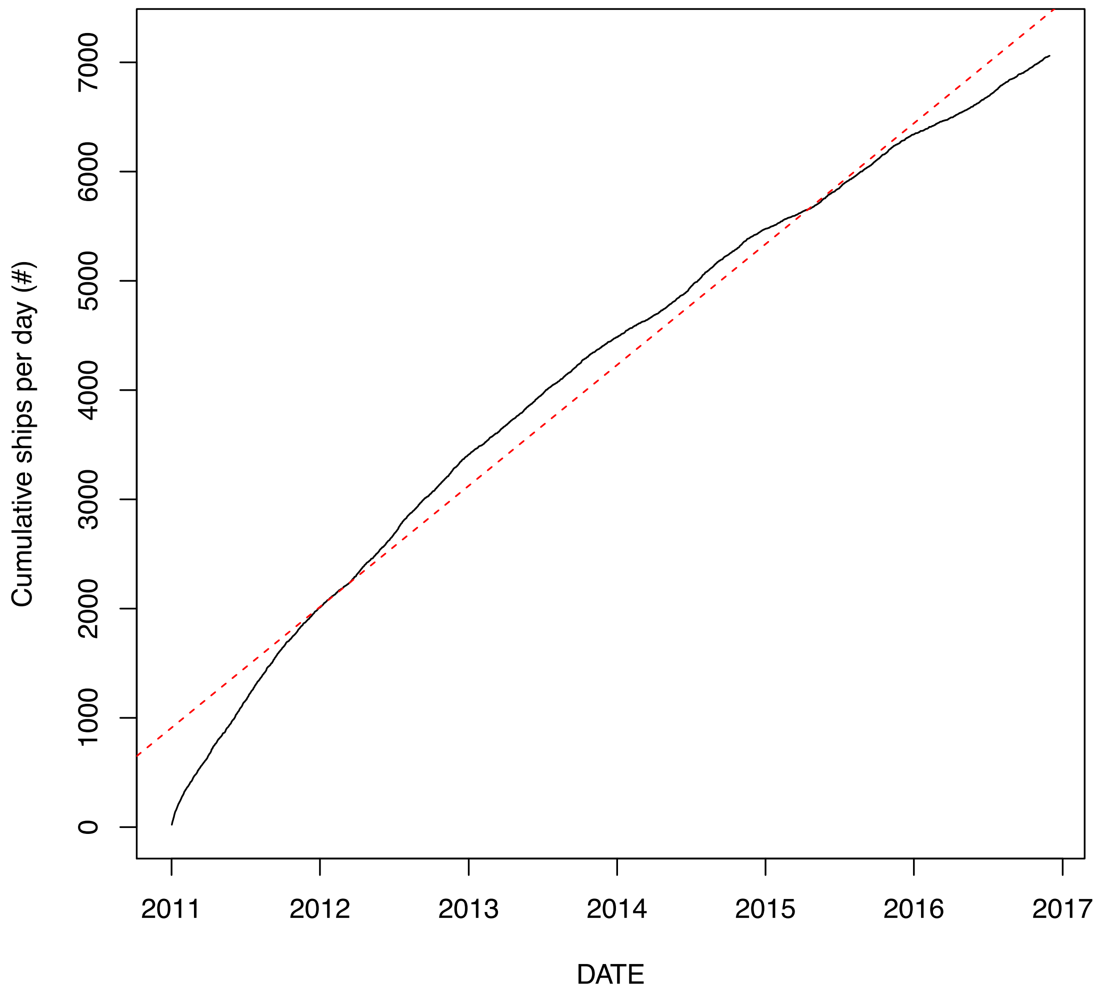


Figure 14. Discovery curve, illustrating the cumulative daily count of unique vessels, for the entire study period from 2 January 2011 through 30 Nov 2016. The linear trendline (red dotted-line) represents the average rate of discovery over the study period.

4.3.5. Vessel Class

Vessel class was analyzed using a randomly selected subset of vessels from 2012 and 2015. The types of vessels present in the study area remained similar throughout the study (**Figure 15**). Cargo vessels were the most abundant followed by tankers in both years analyzed.

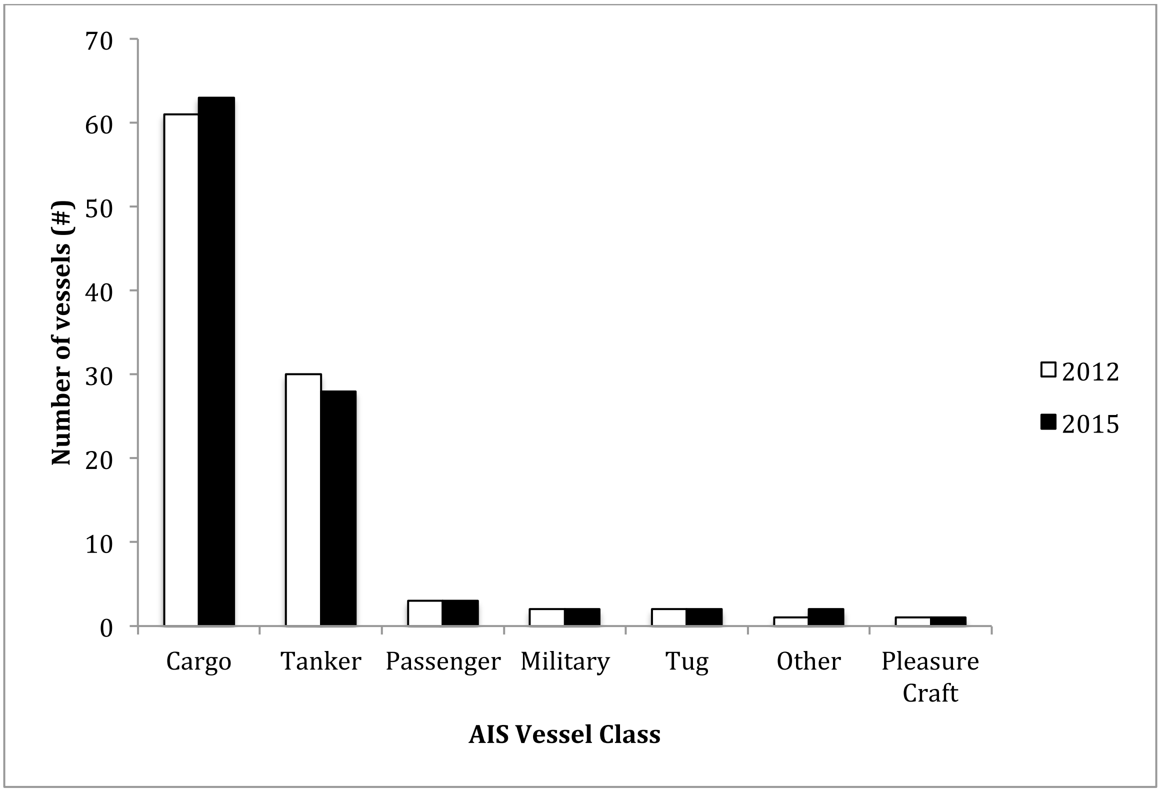


Figure 15. The number of vessels within each class, taken from a random subset of 100 vessels from the unique vessels in 2012 (white) and 2015 (black).

5. DISCUSSION

This study provides novel insights on the vessel fleet in Atlantic Canada through a research survey and analysis of AIS data. The research survey findings highlight mariner receptivity and perceived utility towards receiving near real-time AIS Whale Alert messages to help reduce vessel strike risk to large baleen whales. Most importantly, the survey provides new insights regarding the preferred response protocol upon reception of real time whale location alerts. To supplement the survey results, this study provides novel information about the frequency and characteristics of vessels navigating Atlantic Canada through the analyses of AIS data. Together, these findings can be used to inform a management plan to implement the AIS Whale Alert based on stakeholders needs and preferences towards receiving real time whale location information on the bridge. By including mariner preference, values and beliefs in the planning and implementation stage of the AIS Whale Alert, this study aims to help foster a cooperative and compliant fleet with regards to real time conservation (Nkonya, 2005; Salz and Loomis, 2005; Weinstein et al., 2007; Silber et al., 2014).

5.1. Receptivity of mariners to real-time conservation

Survey responses provide insight to the receptivity of mariners toward receiving real time whale alerts. Responses generally indicate mariners are interested real time conservation, as they responded voluntarily and left additional comments. A study conducted by Remier et al. (2015) also found mariners to be interested in whale conservation. Additionally, various sectors of the maritime industry have indicated their desire to receive real-time information on the location of whales (MEOPAR, 2017). Though there is evidence mariners are interested in whale conservation, the poor survey response rate could be interpreted as most mariners being unwilling to participate in voluntary measures. Mariners that did not respond may have a lack of interest in whale conservation, implementing new conservation technologies, or in the imposition of new management measures. Further, mariners may not view whale conservation as an issue. It is possible that mariners became less receptive to new management measures after the implementation of the DMA in the GoSL in 2017 during the study period. Though responses indicate mariners are receptive to the AIS Whale Alert, they are less receptive to changing their bridge protocol documents to reduce the risk of collision with whales and gave no clear indication of whether they will update their bridge planning protocols to incorporate the AIS Whale Alert System.

5.2. Mariner perceived utility

Mariners indicate the AIS Whale Alert will be useful for increasing awareness on the bridge, but the one-time notice of the location of whales via an AIS message may not be sufficient to alert them to the possibility of a vessel collision with a whale. Survey comments indicate this is in part due to the misuse of the AIS system. The Remier study determined that mariners prefer to receive Whale Alert information via non-disruptive communication technologies already onboard vessels, specifically AIS and Navtex. Mariners in my study expand on these results by providing insights and recommendations on how to better broadcast the AIS Whale Alert to inform mariners of the location of whales. It is essential to consider this insights when implementing the AIS Whale Alert.

5.3. Mariner preferred response protocols

The results of the survey questionnaire provide new insight to a preferred response protocol upon reception of such real-time whale location alerts. Overall, respondents indicate that if a whale is along the path of a vessel, some action will be taken to not damage the vessel or harm the marine environment as a part of good seamanship. No respondents indicated that no action would be taken and at the very least, the AIS Whale Alert will increase awareness for further actions to be considered. Apart from increasing awareness, there is a clear preference for the consideration of two response protocols: an alteration in vessel course or a reduction in vessel speed. This is surprising because speed restrictions were once considered rare and less familiar to mariners, whereas routing actions are more common and accepted by the IMO (Roberts, 2005; Silber et al. 2012). Further, speed reductions are often not readily accepted by maritime industry due to their potential economic impacts (Russel et al., 2001; Kite-Powell and Hoagland, 2002; Silber and Bettridge, 2012). It is possible that mariners are becoming more familiar with vessel speed restrictions through the increased use of DMAs and SMAs along the eastern seaboard of North America.

Few respondents indicate that they would undertake an immediate response action upon the reception of the AIS Whale Alert. Mariners may be restricted in their capacity to respond immediately depending on vessel type, vessel location, surrounding vessel traffic, sea state, weather conditions, time of day (i.e., day or night), and company requirements with respect to operational safety and efficiency. This assumption is consistent with survey comments. Similarly, Remier et al. (2015) found it was unclear whether mariners felt that bridge protocols were flexible enough to respond to real time whale location information. The capacity for mariners to respond will depend on the location of the whale relative to the vessel and whether the vessel has adequate time to respond in a way that does not compromise the safety of navigation at sea. An immediate response is ideal for real time management.

5.4. Vessel fleet characterization

To compliment the findings of the research survey, this study provides novel insights regarding the frequency and characteristics of vessels navigating Atlantic Canada though analyses of AIS data. The results demonstrate that the Maritime fleet is highly dynamic and cannot be easily defined; i.e., the lack of inflection point or asymptote on the discovery curves means the fleet was infinitely increasing at annual and six-year scales. These results are similar to a study conducted by Bouwman (2016), who characterized the Maritime fleet for 2015 to determine the top 20% of vessels transiting the Scotian Shelf, the focal survey vessels in my study. My study expands on the Bouwan (2016) study by analyzing multiple years of AIS data to define and characterize the fleet over time.

Though the annual discovery curves for the fleet very similar, they are composed of different vessels. This is consistent with the comparison of the summed total number of unique vessels for the annual discovery curves and the six-year discovery curve. This comparison demonstrates that although the size of the fleet is very similar from year to year it is highly dynamic with a high turnover rate of vessels entering and leaving the fleet. These results have significant implications on right whale conservation, as a huge part of management involves educating the mariners and soliciting their adoption of the whale alert. If the fleet is constantly changing over time, it will be nearly impossible to contact every vessel without an extensive communication and outreach effort.

AIS data also provide information about the nature of the Maritime fleet and the threat to whales though vessel class. The analysis of vessel class revealed that while the Maritime region represents only a faction of the global fleet, the Maritime fleet has similar vessel-class proportions as the global fleet. The top three vessel classes for the global fleet are cargo, tanker, and passenger vessels (IMO, 2016; ISL, 2016), which are mirrored over time in my study. These results also reveal the Maritime fleet is comprised of large and fast shipping vessels, which pose a greater risk to whales. The frequency, size, and speed of vessels all play a role in the degree of lethal strike-risk to whales (Kite-Powell et al., 2007; Vanderlaan and Taggart, 2007; Silber et al., 2010; Conn and Silber, 2013; Laist et al., 2014).

5.5. Representativeness of the survey sample

While the survey findings provide useful insight to inform the implementation of the AIS Whale Alert in Atlantic Canada, it is important to acknowledge that the results reflect a small sample size of 38 mariners, who voluntarily participated in the survey. Thus, these results may only reflect a small proportion of mariners who are interested in taking conservation action and may not be representative of the entire fleet. Furthermore, multiple respondents represent vessels within a single owner-operator fleet, which has potential to bias the findings. The extent to this bias, however, is unknown. The low response rate is considered inadequate when compared to the literature (Alderman and Salem, 2010; Bennet et al., 2011; Kelly et al., 2003). Remier et al. (2015), experienced similar limitations due to a poor response rate. My study aimed at expanding the Remier study by targeting a more global set of mariners with a more concise survey, yet received fewer responses from a much larger and directly contacted fleet.

There are multiple explainations for a poor response rate, including the administration technique, mariner interest in whale conservation, a misunderstanding of the AIS Whale Alert, and the administering authority. There is indication that mariners did not understand the AIS Whale Alert technology in my study, as some left comments or inquiries about its operation. The survey itself was developed using published guidelines for survey design to increase the quality and number of responses (Edwards et al., 2002, 2007; Iglesias et al., 2002; Kelly et al., 2003; Alderman and Salem, 2010; Bennett et al., 2011; Hardigan et al., 2016) and administered via mail, email and easily accessible and secure on-line survey. Postal surveys are often considered impersonal and achieve lower response rates (Edwards et al. 2002, 2007; Kelly et al., 2003; Alderman and Salem, 2010; Hardigan et al., 2016). Furthermore, respondents were contacted indirectly through their vessel owner-operator, who may or may not have passed along the questionnaire to their fleet. Although the questionnaire was sent via mail, respondents could also access the questionnaire online, which may have influenced the response rate. Fortunately, mariner responses increased after follow-ups were sent to the fleet from external shipping agencies, which volunteered to collaborate on this project. Thus, it is apparent that external shipping agencies, such as the Shipping Federation of Canada and Green Marine, are interested and willing to cooperate with real-time conservation initiatives. It is possible that mariners are more familiar with the authority of these agencies compared to the CWI, which may affect their likelihood to respond. It may be that the implementation of the AIS Whale Alert might in itself be the vector by which the fleet becomes increasingly aware.

Analysis of AIS data further highlights the poor response rate for the survey due to a high frequency of vessels within the area and their high turn over rate. Though there was a small response rate, the analysis of the AIS vessel classes revealed that the respondents were representative of the entire Maritime AIS vessel classes. The class proportions were not only similar to the survey sample but also the to the global fleet. Thus, the limited survey sample is a least representative of the Maritime fleet in Atlantic Canada and the global fleet with respect to vessel class proportions. Despite a poor response rate, the survey yielded insightful and high quality responses that can be used to inform the implementation of the AIS Whale Alert in Atlantic Canada based on the needs and preferences of the fleet.

5.6. Misuse of AIS systems

Though AIS data is being increasingly used in conservation, it is important to remember that conservation is not its intended purpose, which leads to challenges and limitations in usage. Common limitations recognized in this system are restricted transmission range (unless sent via satellite), saturation of the receivers in areas of high vessel density, and the inability to detect small vessels (Langeux et al., 2011; Campana et al., 2015;

Shelmerdine et al., 2015; Roberts et al., 2016). Further, static AIS data are entered manually by the bridge personnel and results in human error so that in a study such as mine, the use of the AIS data requires special care to ensure its reliability and usefulness for conservation through quality control (Shelmerdine et al., 2015; Bouwman, 2016; Roberts et al., 2016). My study provides further insight to the common misuse of AIS systems by mariners. As previously mentioned, static data, such as the vessel class, MMSI number, IMO number, radio call sign, and vessel name, are input manually by bridge personnel. This information is important to managers, as it provides a mode of vessel identification, as well as insight into the characteristics of the fleet. Unfortunately, the erroneous nature of static AIS message makes this information not easily attainable without undertaking the costly task of quality control to correct and refine the data and produce reliable and usable information. Common issues with static AIS data observed in this study include aliased vessel names (i.e., abbreviations such as "CANADIAN WARSHIP 700" versus "WARSHIP 700" or "CDN WARSHIP 700"), invalid MMSI or IMO numbers, and duplicate MMSI or IMO numbers. Some of these errors are caused by a change in vessel name and/or flag, which can result in a change in MMSI number. However, the majority of the errors are due to mariner input error and interrupted AIS message transmissions. In many instances, interrupted AIS transmissions resulted in the presence of invalid characters within the message. Bouwman (2016) found similar issues. In summary, while AIS data is useful to characterize the vessel fleet and inform management, any research relying on raw static AIS vessel information will require a great deal of quality control time before any insightful information can be retrieved.

6. CONCLUSIONS & RECOMMENDATIONS

Despite existing management measures, right whales have shown limited recovery over the past decade (Kraus et. al., 2016; Rolland et al., 2016; Pace, 2017). Further, the unprecedented right whale mortality event in in the GoSL in 2017 has significant implications on population recovery. Thus, implementing new management measures is essential for the survival of the population (DFO, 2017). This study represents an integrated approach to right whale conservation by first considering the preferences and limitations of vessel operators. The results of this study can be used to inform the implementation of the AIS Whale Alert based on stakeholder needs and preferences. By considering the vessel fleet's needs and preferences towards implementing this technology, there is a greater chance mariners will find this novel conservation method legitimate and will be willing to use it (Nkonya, 2005; Salz and Loomis, 2005; Weinstein et al., 2007; Silber et al., 2014).

To increase the utility of the AIS Whale Alert, whale location information should be broadcast to mariners using multiple communication platforms. Vessels are becoming more technologically sophisticated (IMO) and mariners already receive navigation and whale conservation information through various platforms, which are compatible real time whale conservation i.e., website, LISTSERV, mobile phone app, AIS whale-alert, NAVTEX, NOTMAR, and NOTSHIP. By taking advantage of multiple communication platforms, the AIS Whale Alert will likely be received by a wider range of mariners.

This work indicates either a change in vessel course or reductions in vessel speed are preferred and suitable response actions to the reception of real time whale location information. The ideal response for conservation is area avoidance to reduce the vessel strike occurring by separating vessels from whales in space and time. Unfortunately, area avoidance is not always possible due to location, operational constraints, and the safety of navigation (Vanderlaan and Taggart, 2007; Silber et al., 2012; Conn and Silber, 2013), and therefor speed restrictions become the only reasonable alternative. The effectiveness of area avoidance measures in reducing the vessel strike risk to whales has been demonstrated, as long as mariners are willing to comply (Vanderlaan and Taggart 2009; Vanderlaan et al., 2008, 2009; Lagueux et al. 2011; Silber et al., 2012; Conn and Silber, 2013); however, the effectiveness of speed restrictions is less clear (Hazel et al. 2007; Kite-Powell et al., 2007; Fonnesback et al., 2008; Laist et al., 2014).

Slower vessels have three potential benefits for reducing the vessel strike risk to whales: 1) reducing mortality on impact, 2) providing the vessel crew a greater chance to spot and avoid the whale, and 3) providing the whale a greater chance to avoid the vessel (Kite-Powell et al. 2007). The relationship between speed reduction and reducing vessel strike mortality has been demonstrated (Pace and Silber, 2005; Vanderlaan and Taggart, 2007; Silber et al., 2010; Conn and Silber, 2013), but the other potential benefits are less reliable. Slowing vessels could increase mariner ability to detect a whale, and then maneuver to avoid collision; however, this depends on both mariner and vessel ability to do so (Laist et al., 2001; Hazel et al., 2007; Kite-Powell et al., 2007; Vanderlaan and Taggart, 2007). This is difficult for larger vessels travelling at slower speeds because they have limited maneuverability (Vanderlaan and Taggart, 2007). Further, whale detection is often limited by time of day (i.e., day or night), meteorological conditions, or sea state that limits visibility (Laist et al., 2001; Koschinski, 2003; Mullen et al., 2013). Right whales are particularly difficult to detect due to their low dorsal profile and sometimes surface feeding behaviour where they swim just below the surface for extended periods (Mullen et al., 2013) Thus, mariners are unable to consistently detect and avoid marine mammals (Laist et al., 2001; Laist and Shaw, 2006; Vanderlaan and Taggart, 2007; Mullen et al., 2013; Wiley et al., 2016). Speed restrictions may also give right whales a greater ability to avoid vessels; however there is little evidence that baleen whales react to approaching vessels. It appears that right whales have either a negligible ability to respond or they respond in a way that makes them more vulnerable to vessel strike i.e., a delayed response or moving in the path of a vessel (Laist et al., 2001; Nowacek et al., 2003; Mullen et al., 2013; DFO, 2014). Thus, we cannot rely on right whales to avoid an approaching vessel, even with speed restrictions in place. Though the reason behind their effectiveness is unclear, multiple studies have quantified the biological and operational effectiveness of speed reduction measures and concluded that vessel speed limits are a useful tool for reducing anthropogenic mortality risk of right whales (Vanderlaan and Taggart, 2007; Kite-Powell et al., 2007; Vanderlaan and Taggart, 2007; Silber et al., 2012; Conn and Silber, 2013; Constantine et al., 2015). Thus, the best management plan is to implement a combination of voluntary area avoidance and speed reduction measures.

To ensure the use of the AIS Whale Alert, extensive mariner outreach and communication programs are absolutely essential for engaging the highly dynamic

Maritime fleet. Compliance is generally high when there is a dedicated outreach and education program for mariners, and conservations measures are enforced (Silber and Bettridge, 2012; Wiley et al., 2011; Constantine et al., 2015). This will also help to foster ongoing communication with mariners, build respect and trust, and facilitate an integrated approach to conservation initiatives.

In conclusion, this work provides novel insight to the implementation of the real time AIS Whale Alert in Atlantic Canada. Near real time whale conservation provides a solution to reducing the vessel strike risk to right whales, but the effectiveness of real time conservation will depend entirely on compliant behaviour. There is promise that mariners will respond to the AIS Whale Alert. Thus, an integrated management approach is important to ensure the needs and limitations of the fleet are considered while conservation objectives are met. This study represent an important step toward real time whale conservation by communicating with mariners to determine their preferred response protocol to receiving real time whale location alerts. Overall, this study can help lead to the successful implement the AIS Whale Alert, a goal of the MEOPAR WHaLE Project (MEOPAR, 2017) and Canada's OPP (DFO, 2016c).

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APPENDIX 1 – Additional survey comments

1. A website we could access in real time showing the latest known positions

2. AIS alert might not be recognized by bridge teams. As per SOLAS primary means of AIS is to exchange vessel information and shore data, but not alerts. It is not mandatory that the bridge team monitors AIS messages frequently, especially as there is plenty of unimportant information/messages transmitted and the whale alert could not be recognized at all or recognized to late.

   In addition the ECDIS implementation of AIS data is not standard, but an additional/optional package for which ship owners have to pay additionally during installation. Although our vessels have it, there could be a vast amount of companies not having this option.

   To transmit the whale position as any type of AIS target would be more suited, unknown if same is allowed from regulation side. But transmitting whale positions as AIS target would make them visible on RADARS and ECDIS, where this function is fitted.
   Anyway, the approach is honorable.

   Ships crews will avoid to hit any obstruction in the water in order not to damage the vessel or harm the marine environment as part of good seamanship.

3. AIS Messages around the world are 90% junk messages. It is therefore very Well possible that your message is ignored if sent by Ais only.

4. AIS target will give some heads up that there are whales. As they are animals it is impossible to predict witch way they will move definitely they don't comply with COLREG rules. AIS target would help a lot during night time, as visually it's almost impossible to see them.

5. AIS virtual areas and positions of whales' location on electronic charts will be great help and support for plan passages and finally will reduce any ship-strikes to minimum

6. Already included in SMS

7. Any additional information in electronic printed format like posters in the publication "a mariners guide to whales in the nw atlantic" will be considered a valuable tool for the bridge team

8. Any updates to the "mariners guide to whales in the northwest atlantic" will be useful information for all officers in watch, as sane is being consulted

ecert time our vessel approach whale area

9. By experience, vessel making their ways below 18-20 knots are less likely to collide with marine mammals as these creatures are highly intelligent and know by the ship's noises where we are. Most of the seamen know that the main cause of artificial death tor marine mammals are the oil industries use of submerged powerful air cannons for seismic surveys. It is dangerous to them and more than likely, lethal as it may damage the internal organs. The whale, tor example, may die weeks or months later in a geographical position much different than where the accident was. For the seriousness of your studies, I sincerely think you should have a look at oil industries seismic surveys, other research party in foreign countries currently do. By the way, please make sure your ocean glider do not pose a threat of collision with a ship.

10. Commercial traffic operating at 10 kts or 13 kts, the maneuverability of the ships and likelihood of making contact with a whale is slim to none; Faster vessels like cruise ship and container vessels operating at 18 + kts are a much more serious threat, especially with the large blind spot over the bow on container vessels.
I believe the biggest threats to any whales are the tourist vessels that chase them all day long and disrupt them from their routines.

11. During night time number of notifications of whales' location can be increased

12. I don't feel it is necessary to reduce speed in daylight hours in clear visibility. There is a greater risk of hitting a whale in hours of darkness. The present area is 135 miles which means at a speed of 10 knots a vessel will be in the zone for 13.5 hours which increases the probability of being in the zone in hours of darkness. Where as if a ship could maintain full speed in daylight hours with clear visibility when whales are visible there would be less probability of transiting the area in hours of darkness. They could be in and out of the zone before darkness sets in. In fact I feel by having vessels reducing speed in daylight hours you are putting the whales at a greater risk because they are increasing the time a ship is in the area in hours of darkness where there is a greater risk of striking a whale.

13. A whale-alert site that we can access would be more useful than a one time AIS triggered location system.

    I think a real time site that we could access would be more effective. Action by the ship regarding course alteration or speed changes would depend on location of ship, i.e. if we are close to shore, in a traffic separation scheme and weather.
    Curious to know if the ocean glider relies on visual or tagged whales.

Seems we are in the fog most of the spring and summer in this area.
Wishing you well in this initiative.

14. If a one-time notice of the location of whale through an AIS whale-alert is received on the ship, that will increase awareness of the watchkeeper of the presence of whales in the area. Speed reduction will be consider if needed and a sharp lookout will be maintain to visually located the whales. If a whale is seen, the officer of the watch will determine if a risk of collision exist and take necessary action to avoid a close encounter. Presently, vessel are receiving area where whales is more likely to be encounter via notice to shipping. We are reducing speed and maintaining a sharp lookout in these area in the same manner that if we would receive a AIS whale alert. If a one-time notice of the location of whale through an AIS whale-alert is received on the ship, that will increase awareness of the watchkeeper of the presence of whales in the area. Speed reduction will be considered if needed and a shark lookout with be maintained to visually locate the whales. If a whale is seen, the officer of the watch will determine if a risk of collision exist and take necessary action to avoid a close encounter. Presently, vessels are receiving area where whales is more likely to be encountered via notice to shipping. We are reducing speed and maintaining a shark lookout in these area in the same manner that if we would receive a AIS whale alert.

15. If Right Whales are tagged with transponders, it would be very beneficial to the mariner if a secure website would be available, so that we can detect or be alerted within an appropriate range. Maybe even alerted via TRANSAS.

16. Information concerning right whale areas is also received via Notice to Mariners, CG, Navtex. Herewith the is already more sharp for a whale alert.

17. Keep speed 10 knt. "Marines Guide To Whales in the NW Atlantic" is always taken into consideration from Bridge Team.

18. MAYBE - is the one time whale alert sufficient. Please note that the AIS is not a proper mean of collision avoidance with either ships or objects. Radar and visual sight are. However, AIS is helpful as a supplementary mean of getting information and approximate estimation of position, course and speed.

19. More frequent broadcasts of whale-alert messages on VHF. Vessels to also broadcast whale alert messages on appropriate VHF channel if any sightings of whales in immediate area noticed.

20. Proper watchkeeping,sharp lookout,awareness raised in due time and ready

for manoeuvre at anytime.Running by safe(adviced) speed.Navigational warnings to be broadcasted by all means available.

21. Suggestion: one time notice of whales is scanty information. on the contrary, it should comprise of multiple observations with adequate data to enable vessels such that most effective avoiding action is taken

22. Take action is vessel is on the path of a whale according to your message or if a whale is sighted. Will take action when necessary where its applicable instead of modifying ism code

23. The avoiding areas will be added as appendix in the bridge managemet manual.

24. The FLIR camera is installed on my vessel. it helps in night look-out greatly

25. The publication, a mariners guide to whales in the northwest atlantic is a part of passage plan and it is being pursued by bridge team

26. Updates via e-mail might helpful

27. Warning beforehand and reduction of speed could be suffiecient actions

28. We only operate between Digby NS and Saint John NB. We did go to refit, One Off. Whale sightings in the upper Bay of Fundy are scarce. Mostly Minks and Fins.

APPENDIX 2 – Annual discovery curve (2011-2016 individually) statistics

Table 1. Descriptive Statistics for the daily number of unique vessels annually from 2 January 2011 to 30 November 2016.

Stat test	X2011	X2012	X2013	X2014	X2015	X2016	Average
nbr.val	364	365	364	364	364	334	365
ndr.null	0	1	5	2	3	0	0
nbr.na	1	0	1	1	1	31	0
min	1	0	0	0	0	1	1.4
max	22	19	19	17	17	18	14.17
range	21	19	19	17	17	17	12.77
sum	2010	2180	2048	2134	2017	1867	2063.63
median	5	6	5	6	5	5	5.33
mean	5.52	5.97	5.63	5.86	5.54	5.59	5.65
SE.mean	0.16	0.15	0.16	0.15	0.15	0.15	0.10
CI.mean.0.95	0.31	0.30	0.32	0.30	0.29	0.30	0.19
var	8.94	8.62	9.50	8.55	7.97	7.94	3.39
std.dev	2.99	2.94	3.08	2.92	2.82	2.82	1.84
coef.var	0.54	0.49	0.55	0.50	0.51	0.50	0.33

Table 2. Descriptive Statistics for the weekly number of unique vessels annually from 2 January 2011 to 30 November 2016.

Stat test	2011	X2012	X2013	X2014	X2015	X2016	Average
nbr.val	52	52	52	52	52	48	52
ndr.null	0	0	0	0	0	0	0
nbr.na	0	0	0	0	0	4	0
min	21	29	22	19	20	15	24.6
max	81	82	82	78	85	71	78.67
range	60	53	60	59	65	56	54.07
sum	2004	2164	2042	2127	2014	1867	2054.43
median	36	39.5	39	39.5	37	38	38.92
mean	38.54	41.62	39.27	40.90	38.73	38.90	39.51
SE.mean	1.68	1.43	1.75	1.71	1.55	1.52	1.37
CI.mean.0.95	3.38	2.88	3.52	3.44	3.11	3.05	2.74
var	147.16	106.79	159.73	152.79	124.48	110.18	96.94
std.dev	12.13	10.33	12.64	12.36	11.16	10.50	9.85
coef.var	0.31	0.25	0.32	0.30	0.29	0.27	0.25

Table 3. Descriptive Statistics for the monthly number of unique vessels annually from 2 January 2011 to 30 November 2016.

Stat test	X2011	X2012	X2013	X2014	X2015	X2016	Average
nbr.val	12	12	12	12	12	11	12
ndr.null	0	0	0	0	0	0	0
nbr.na	0	0	0	0	0	1	0
min	119	137	120	104	116	125	119.40
max	305	288	298	308	279	276	292.33
range	186	151	178	204	163	151	172.93
sum	2010	2180	2048	2134	2017	1867	2062.57
median	161	177.5	157	168	157.5	170	169.75
mean	167.50	181.67	170.67	177.83	168.08	169.73	171.88
SE.mean	13.82	11.33	13.72	14.39	12.21	12.23	12.45
CI.mean.0.95	30.42	24.93	30.19	31.68	26.87	27.25	27.41
var	2293.00	1539.70	2258.06	2485.42	1788.81	1645.02	1860.86
std.dev	47.89	39.24	47.52	49.85	42.29	40.56	43.14
coef.var	0.29	0.22	0.28	0.28	0.25	0.24	0.25

APPENDIX 3 – Cummulative discovery curve (2011-2016 inclusive) statistics

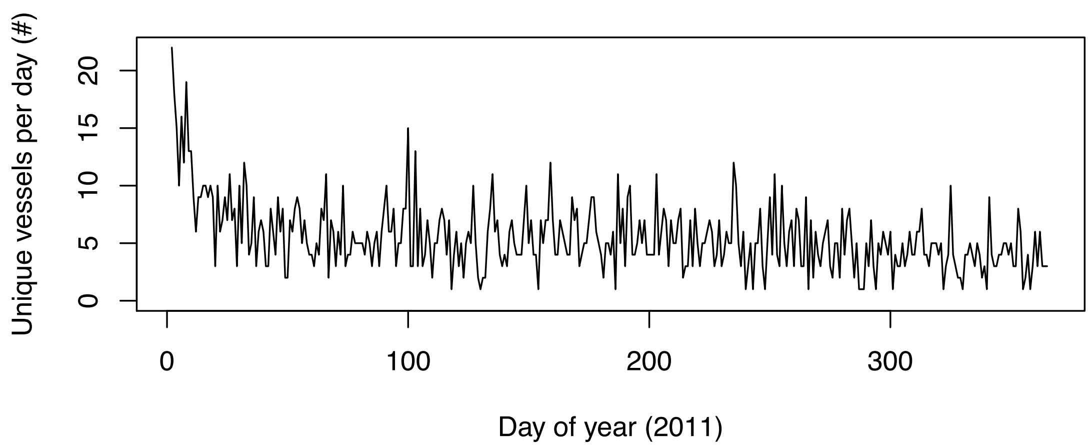
Table 1. Descriptive statistics for the daily number of unique vessels over the entire study period from 2 January 2011 to 30 November 2016 on an annual basis.

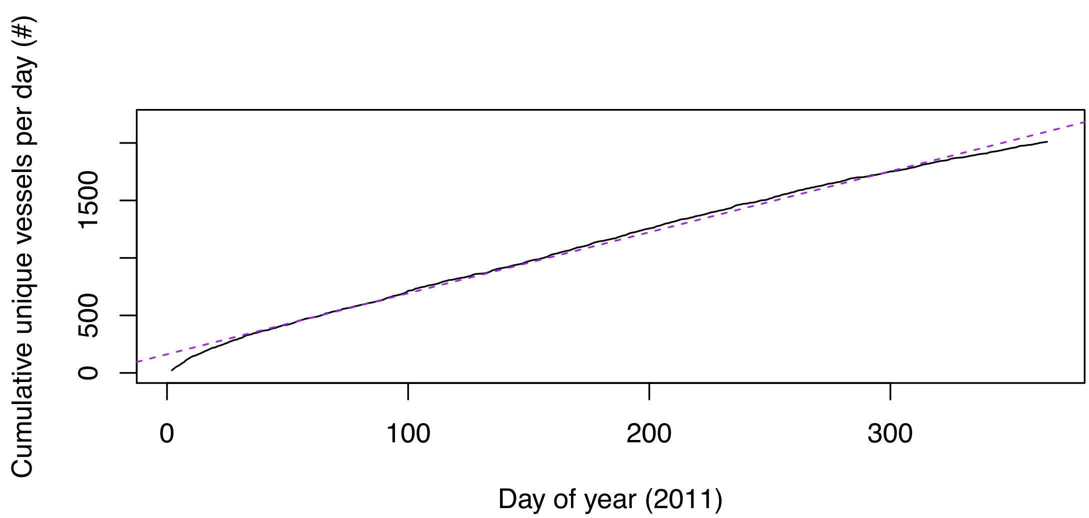
Stat test	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**AVERAGE**
nbr.val	364	366	365	365	365	335	366
ndr.null	0	12	29	30	45	55	0
nbr.na	2	0	1	1	1	31	0
min	1	0	0	0	0	0	1.17
max	22	15	9	10	8	7	5.67
range	21	15	9	10	8	7	4.5
sum	2008	1398	1078	990	864	722	1192.93
median	5	4	3	2	2	2	3.17
mean	5.52	3.82	2.95	2.71	2.37	2.16	3.26
SE.mean	0.16	0.11	0.09	0.09	0.09	0.09	0.04
CI.mean.0.95	0.31	0.21	0.18	0.18	0.17	0.17	0.09
var	8.92	4.27	3.17	3.09	2.78	2.47	0.69
std.dev	2.99	2.07	1.78	1.76	1.67	1.57	0.83
coef.var	0.54	0.54	0.60	0.65	0.70	0.73	0.26

ADDENDIX 4 – Daily unique vessel counts and annual discovery curves for each year individually

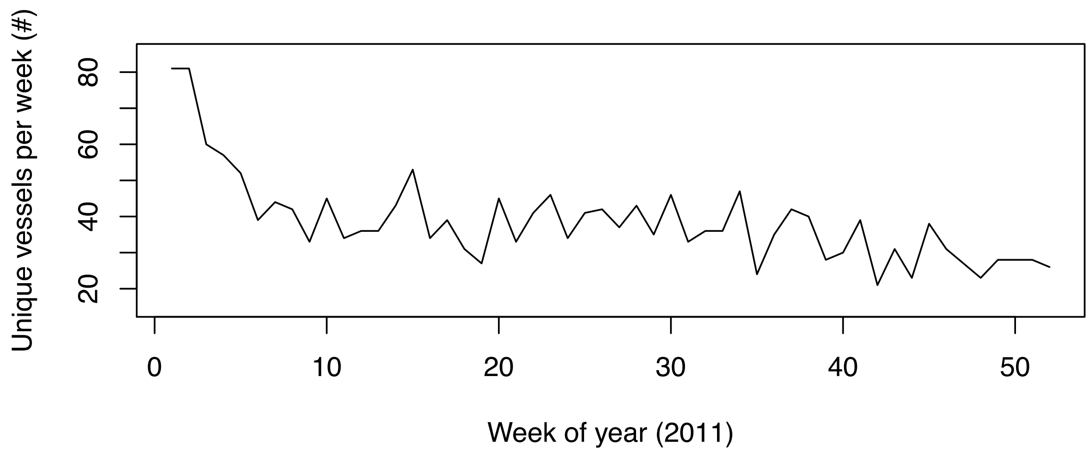
<u>2011</u>

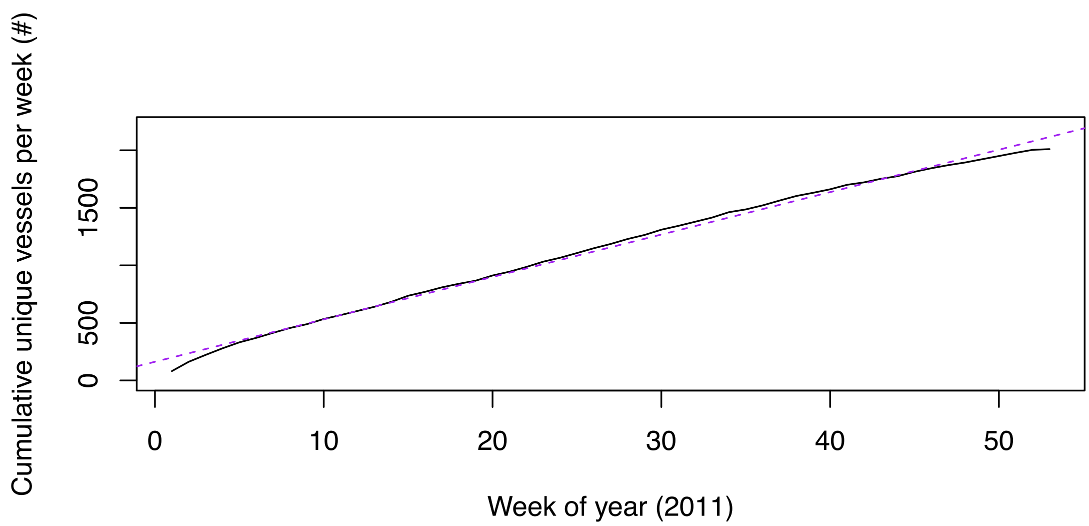
2011 daily unique vessels



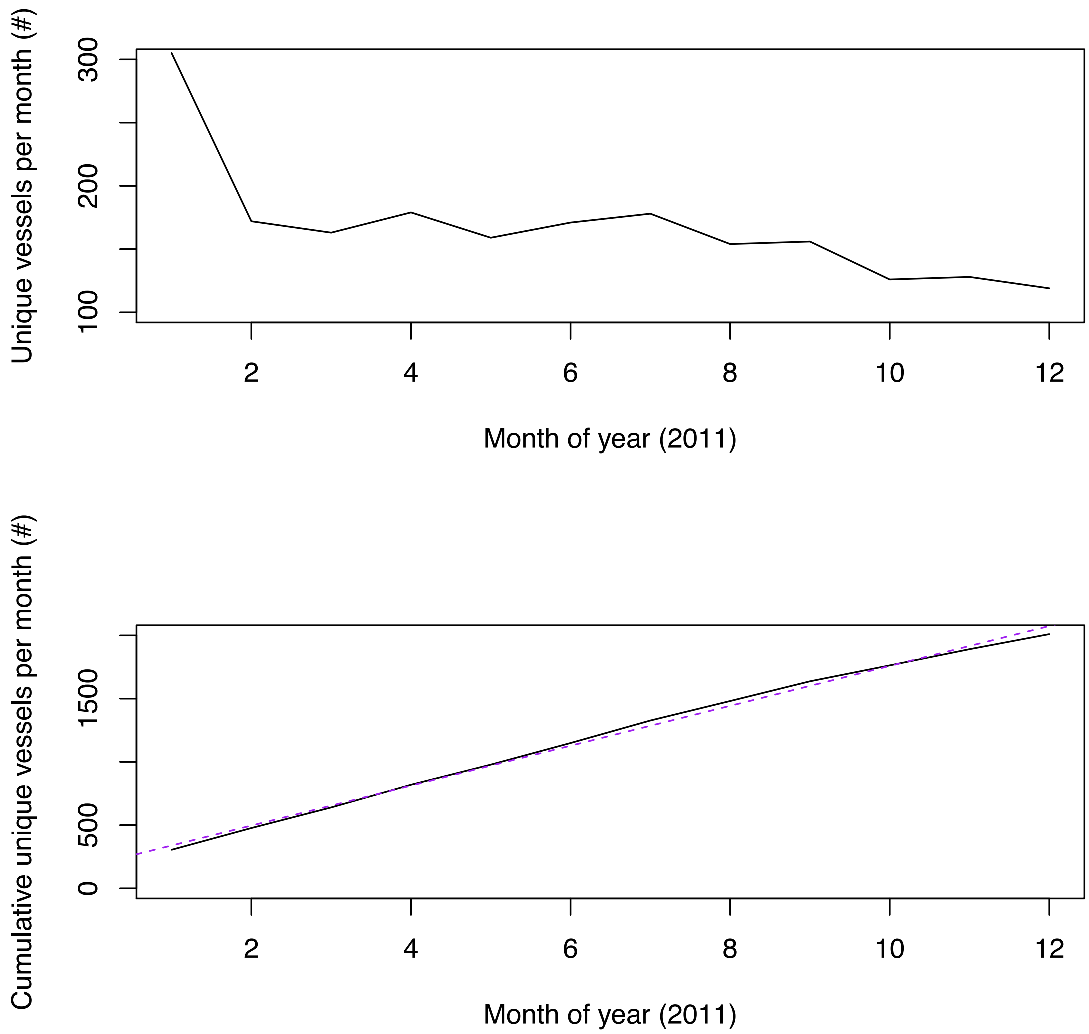


2011 weekly unique vessels



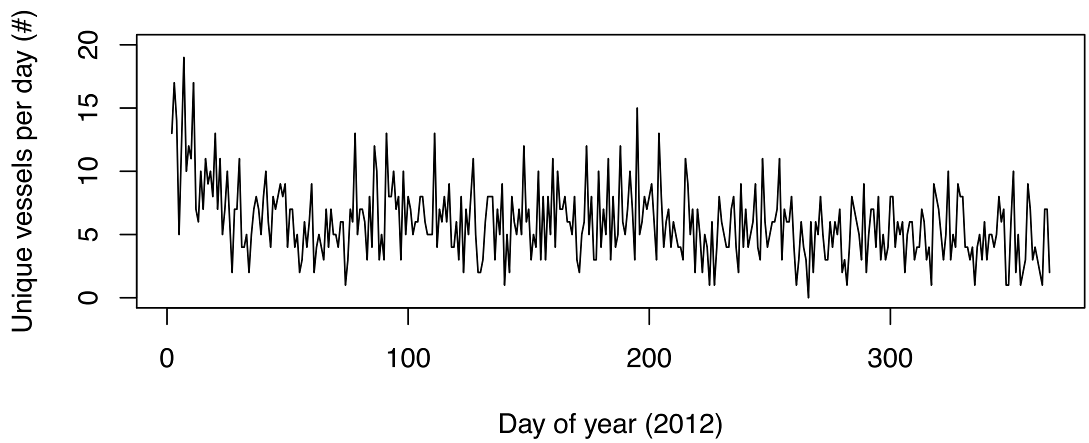


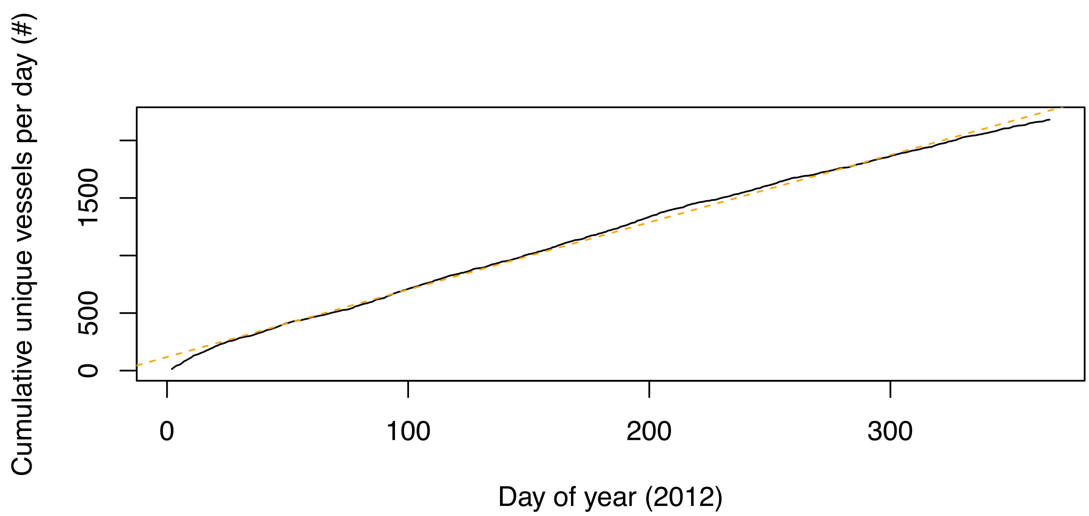
2011 monthly unique vessels



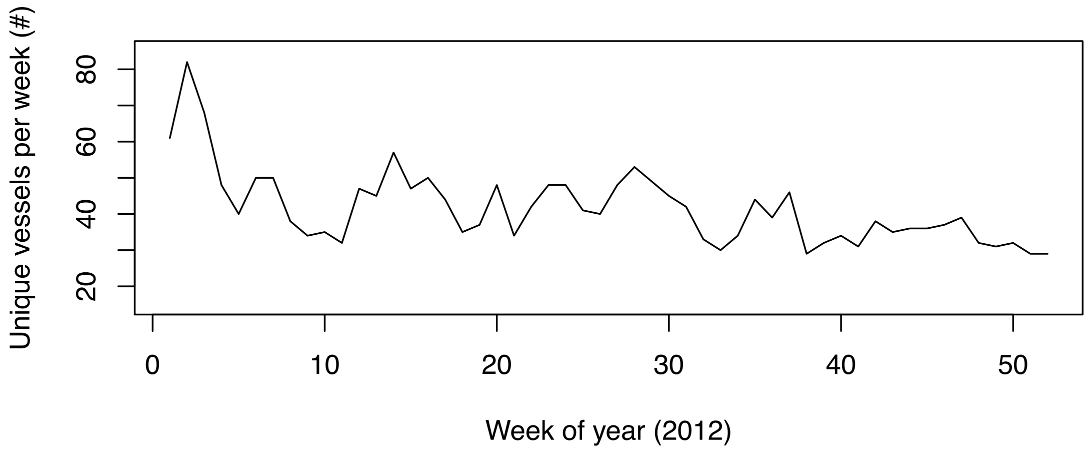
2012

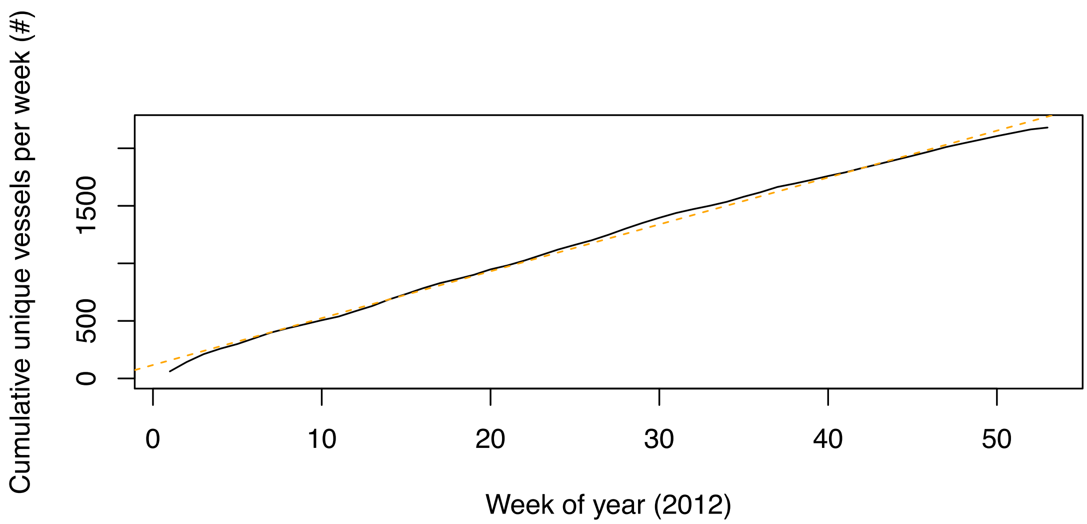
2012 daily unique vessels



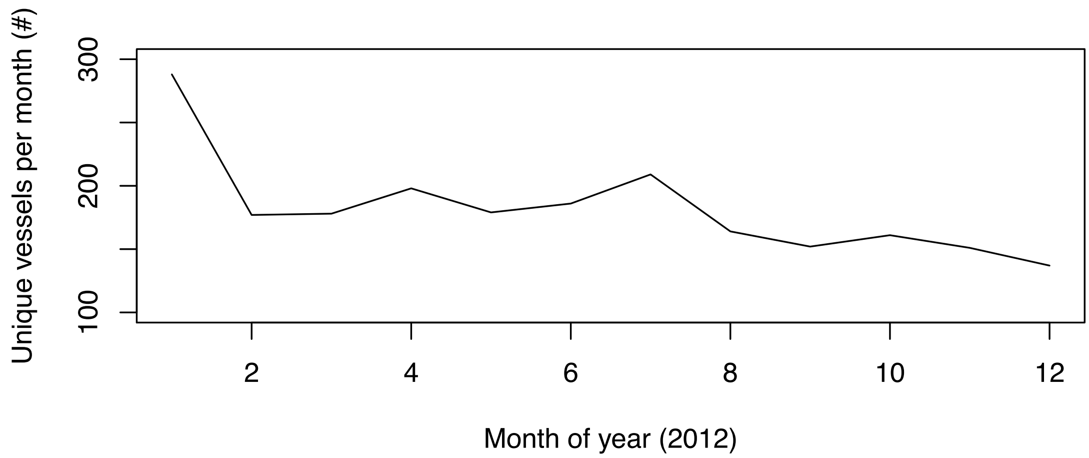


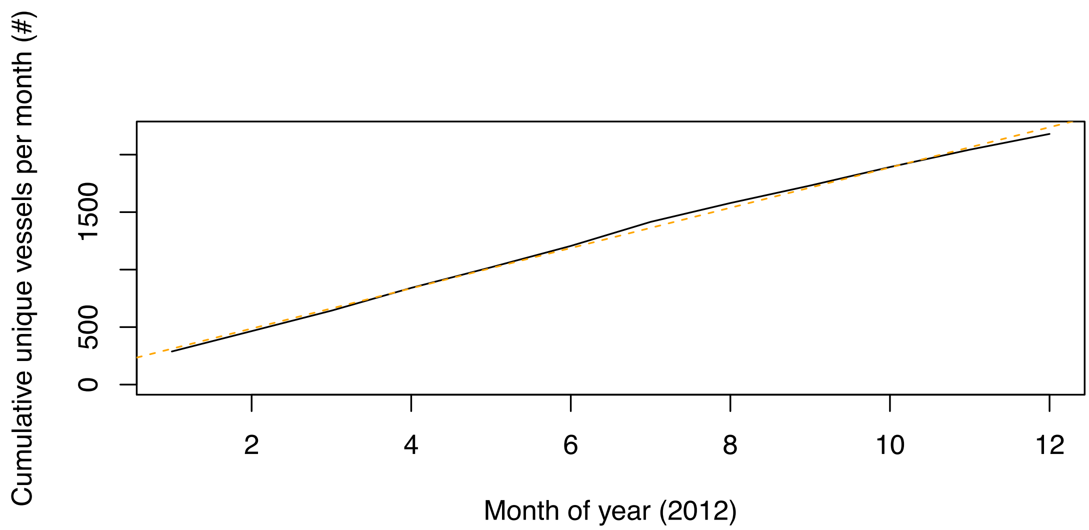
2012 weekly unique vessels





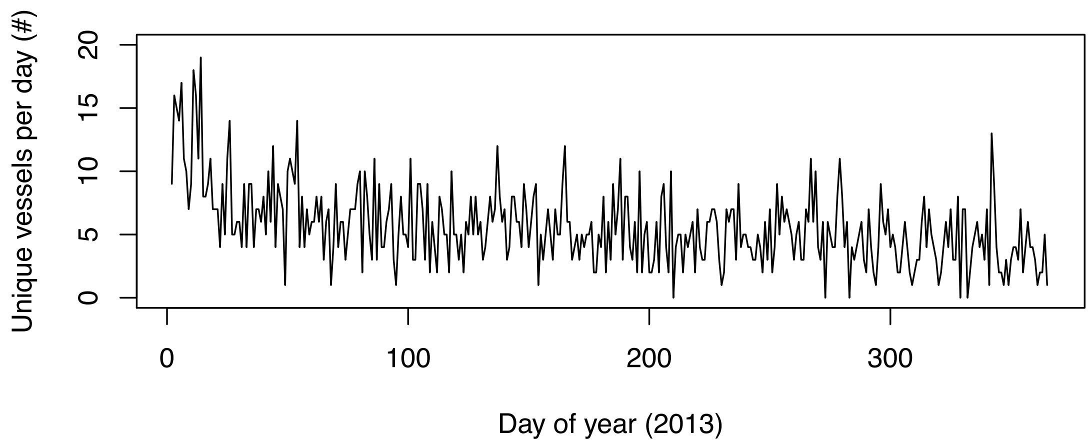
2012 monthly unique vessels

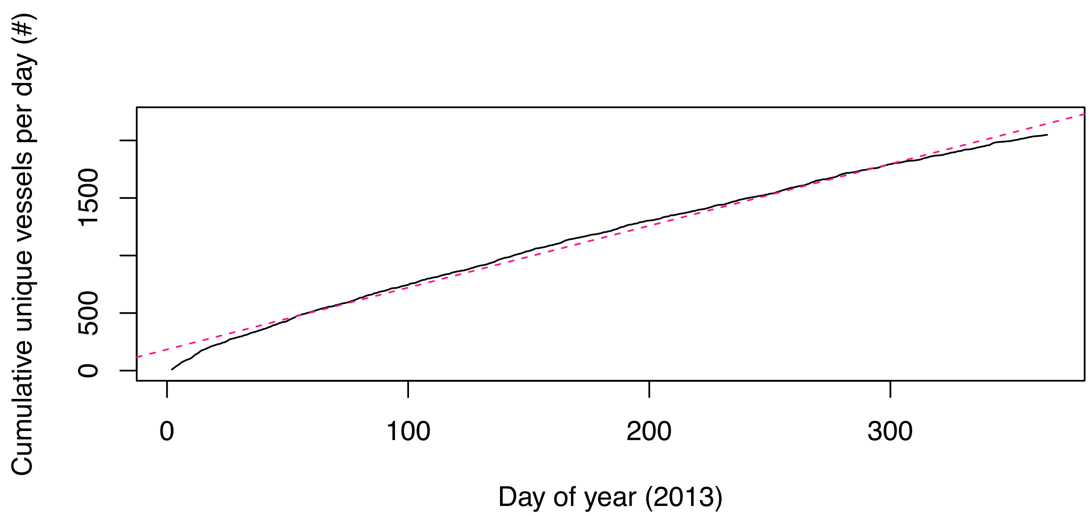




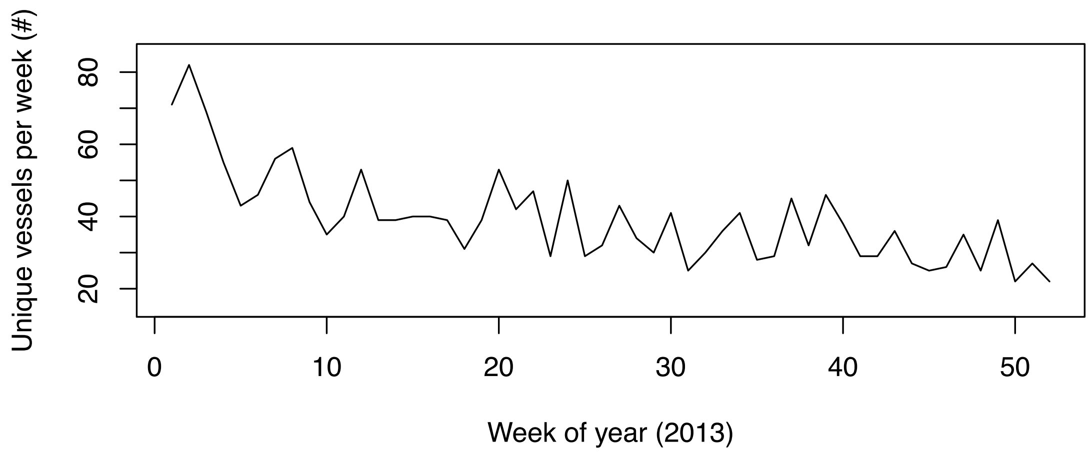
2013

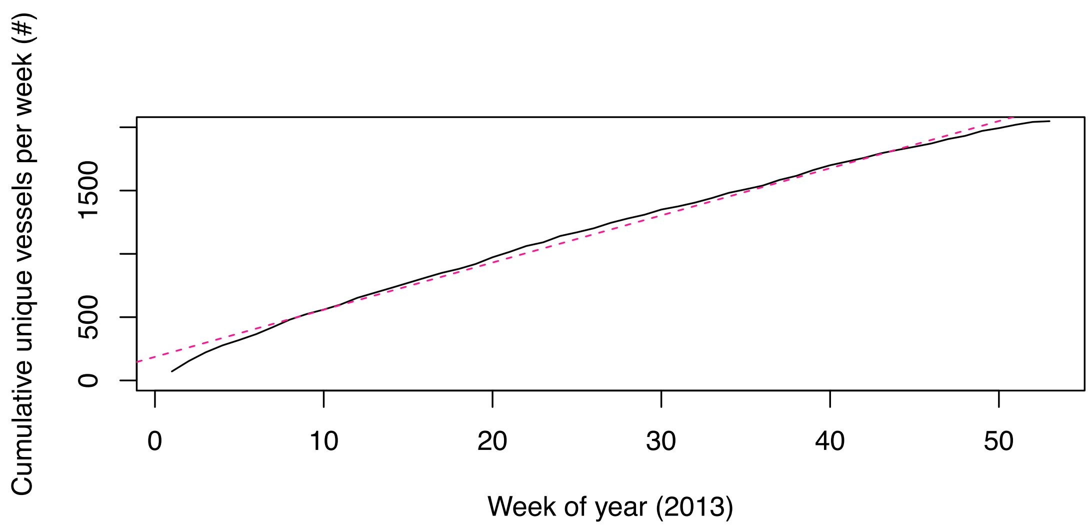
2013 daily unique vessels



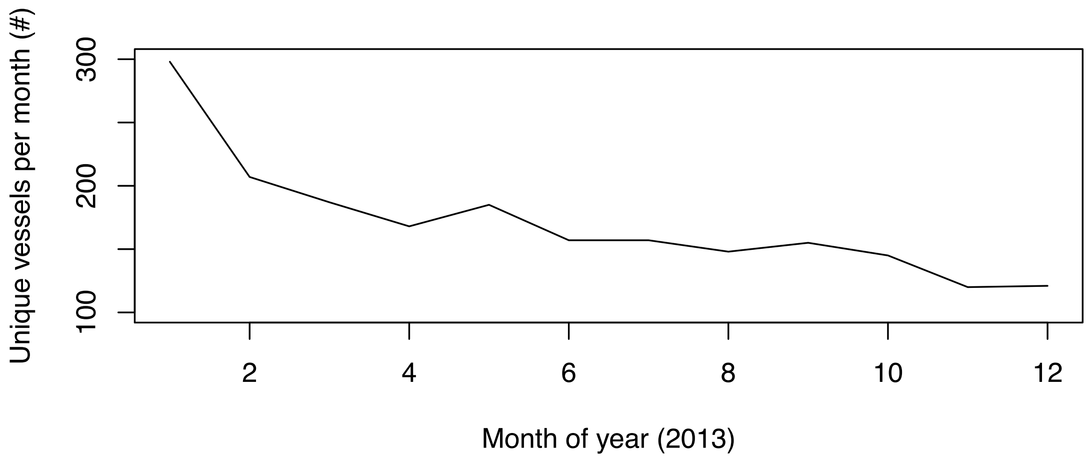


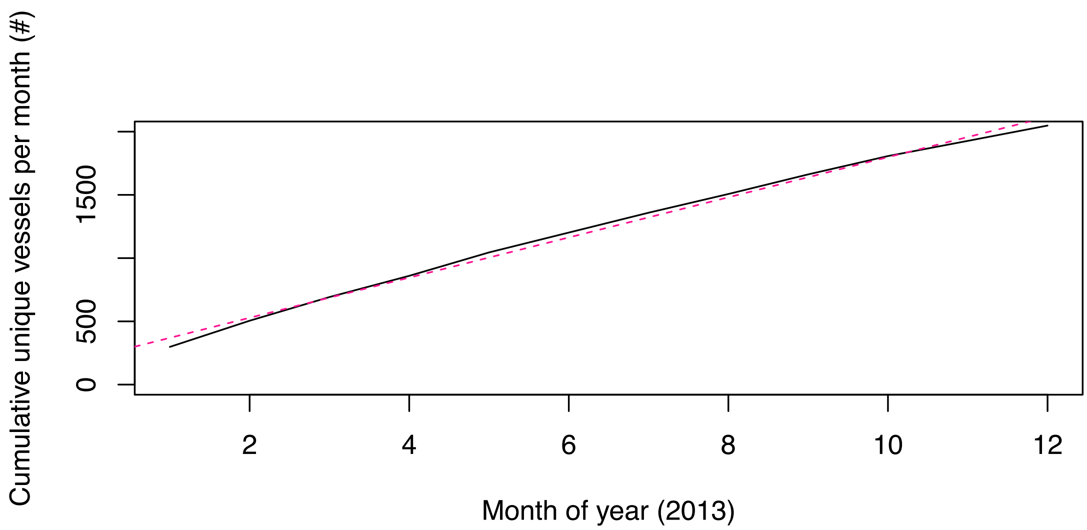
2013 weekly unique vessels





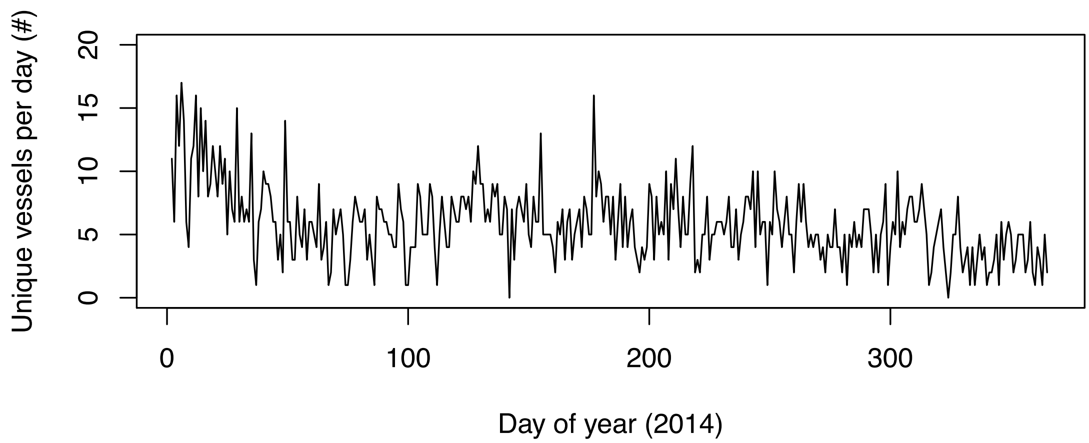
2013 monthly unique vessels

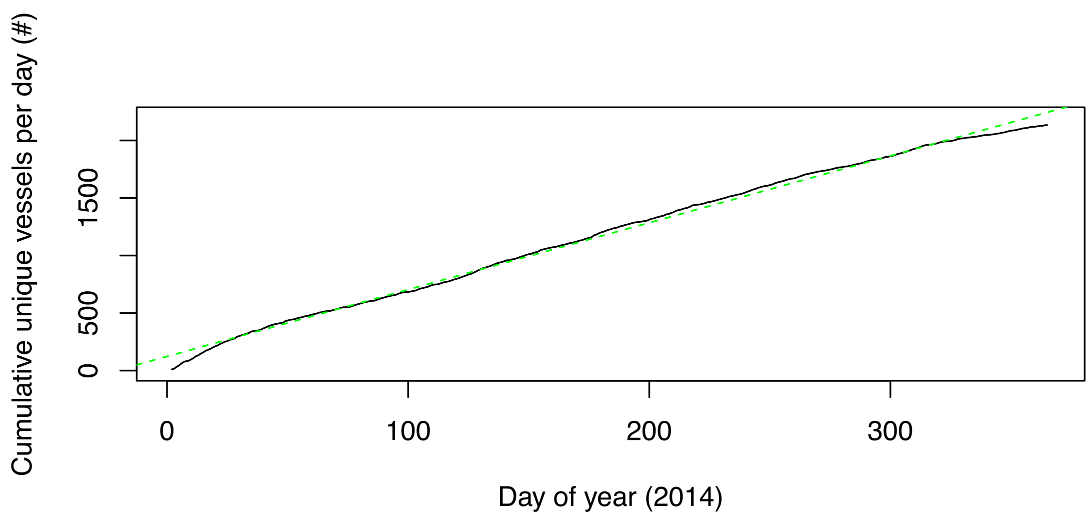




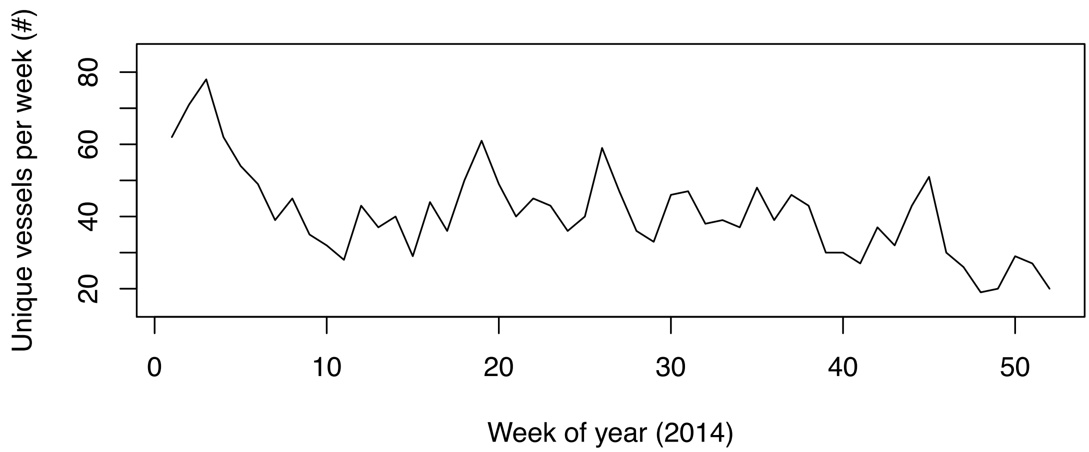
2014

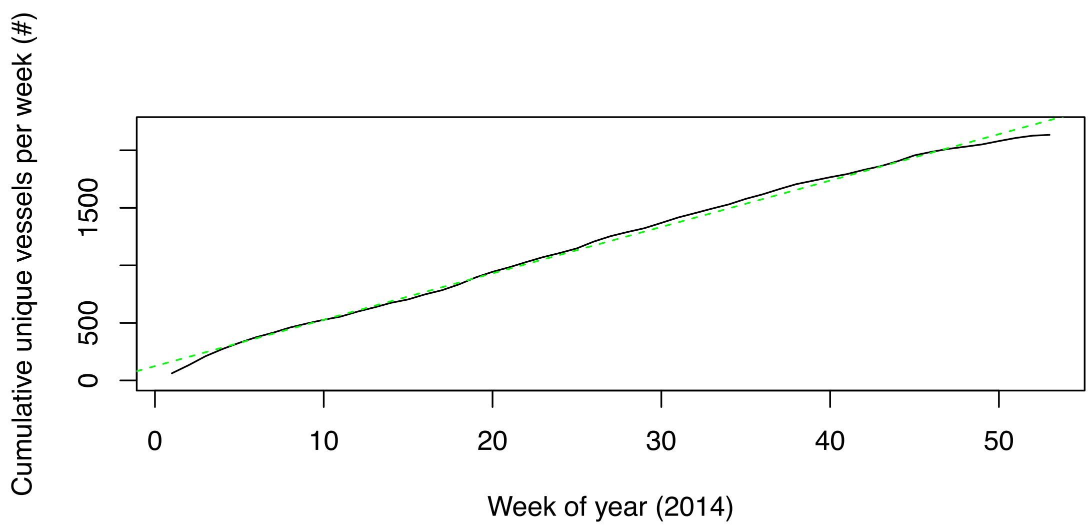
2014 daily unique vessels



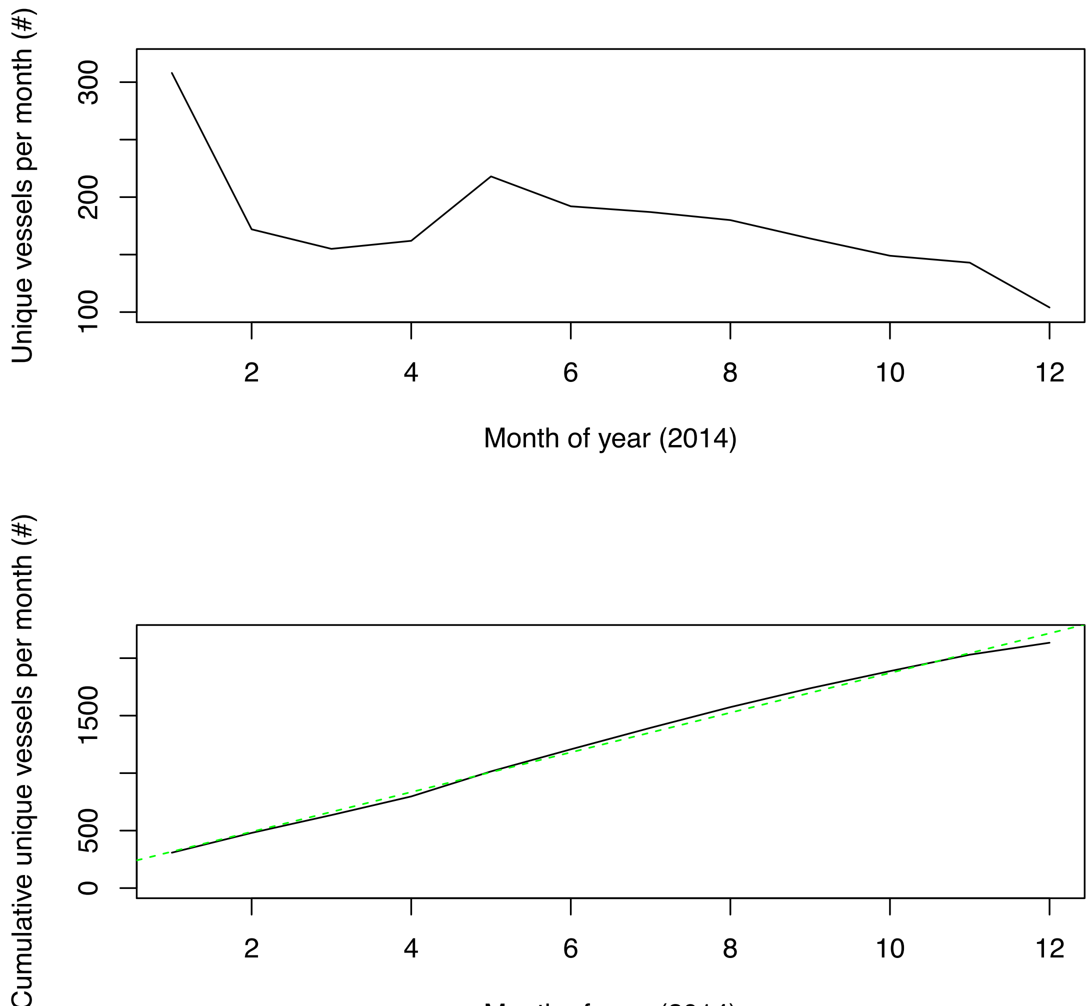


2014 weekly unique vessels



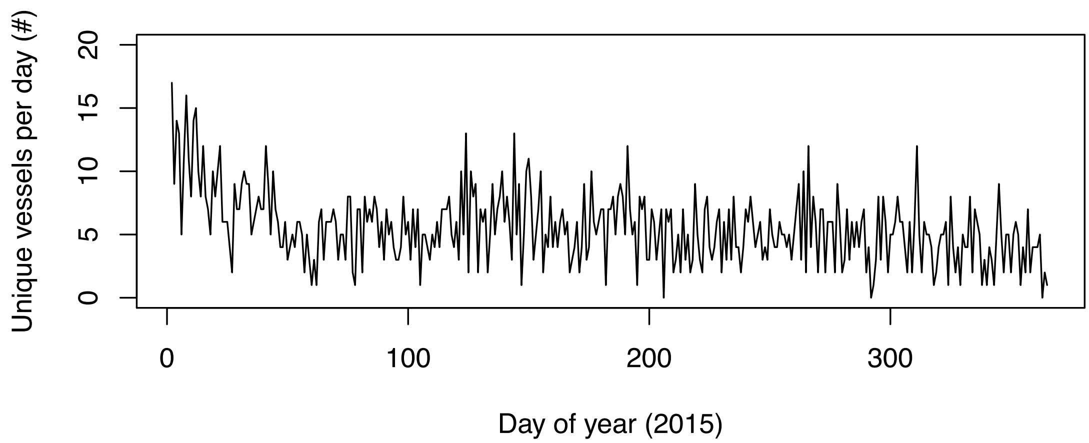


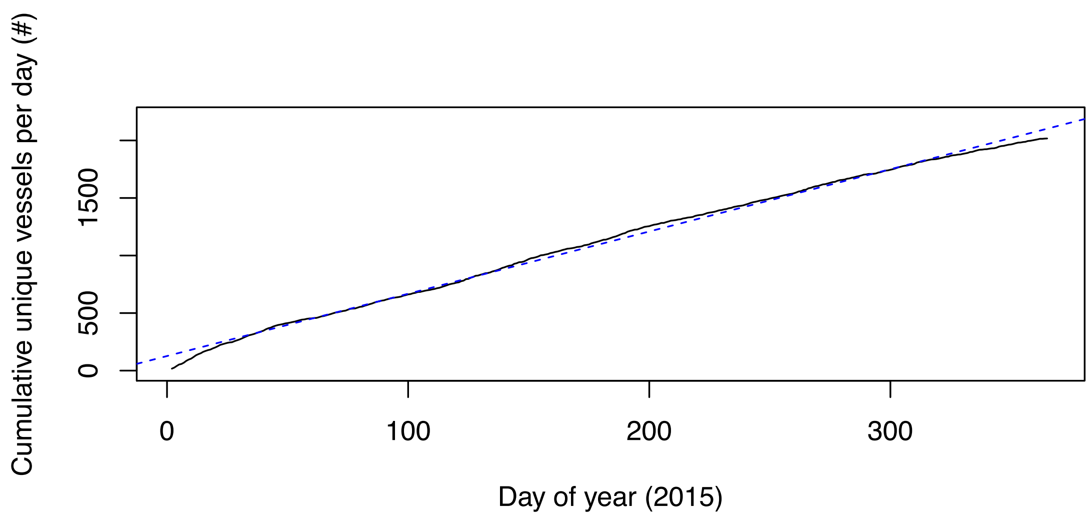
2014 monthly unique vessels



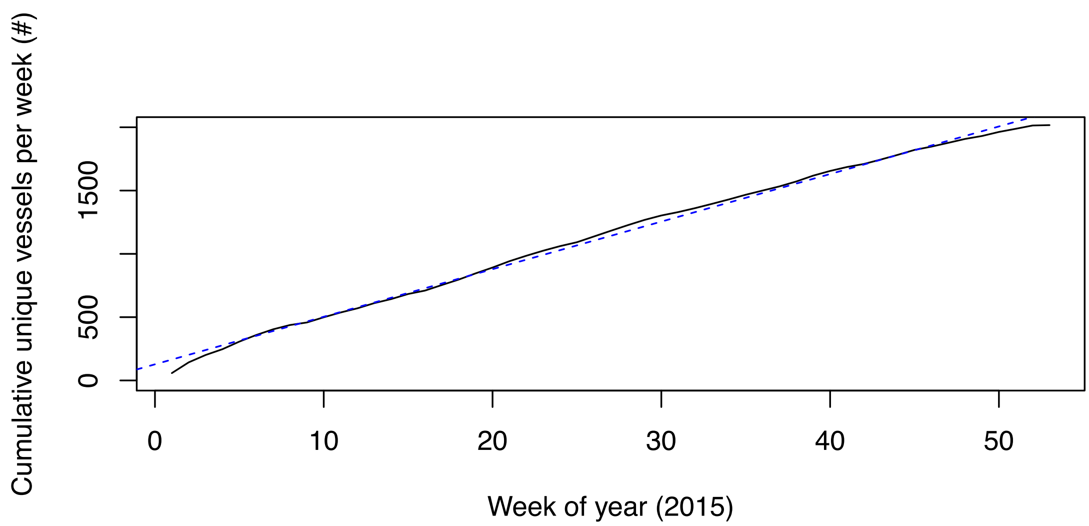
2015

2015 daily unique vessels

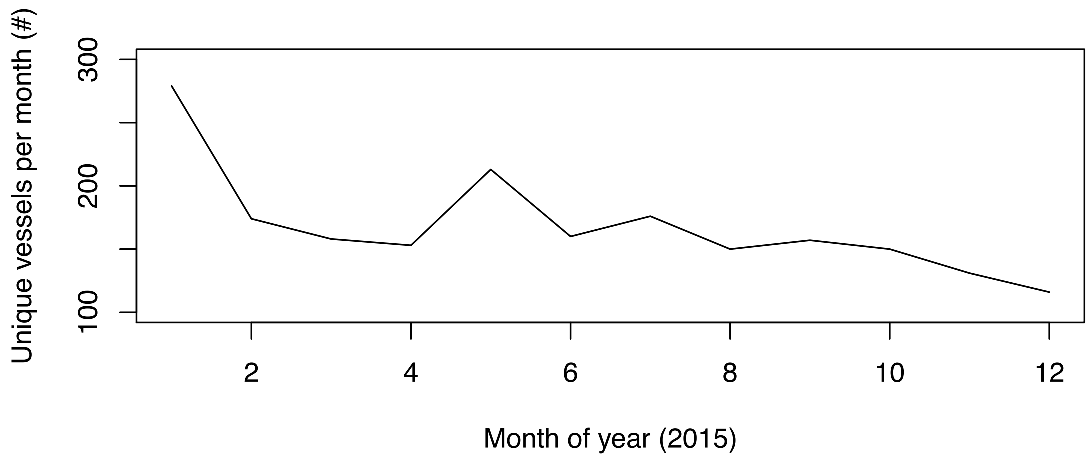


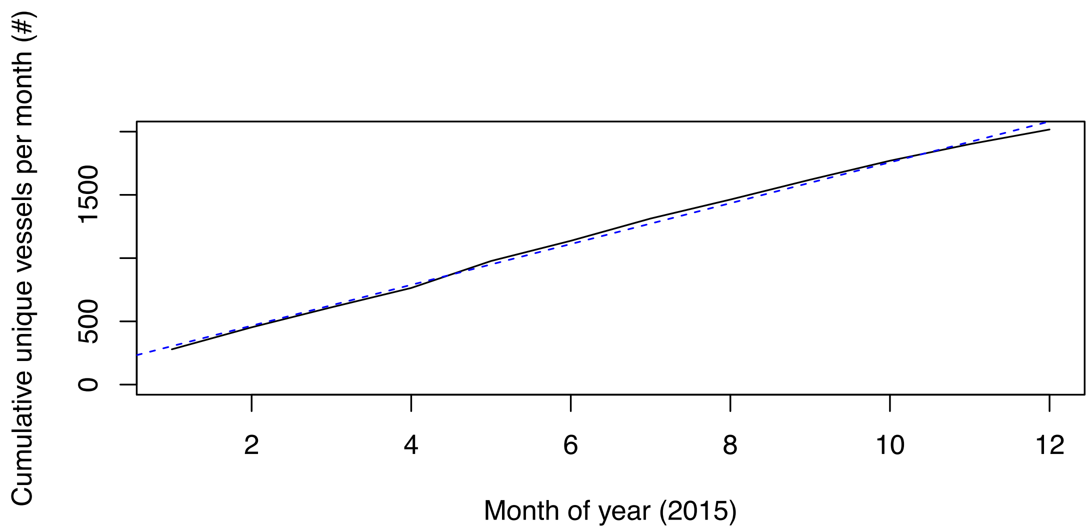


2015 weekly unique vessels



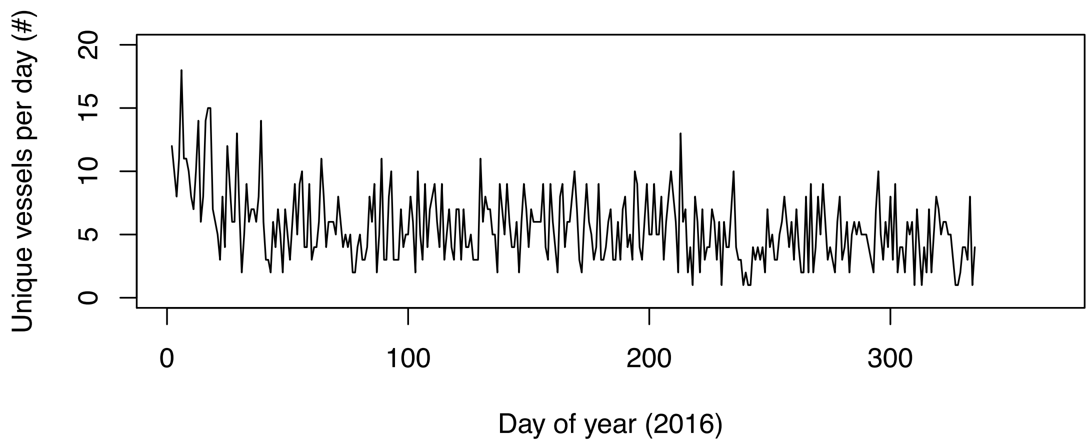
2015 monthly unique vessels

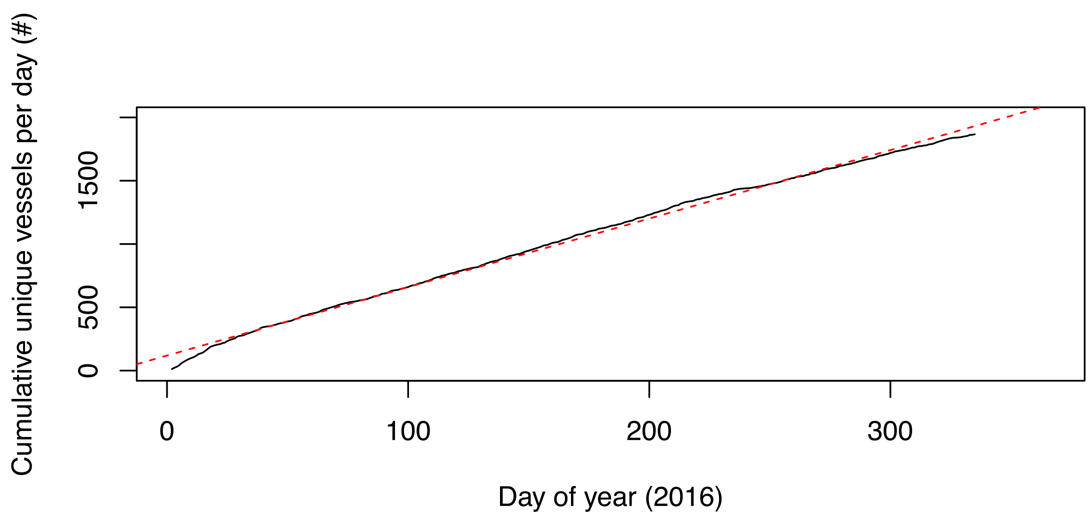




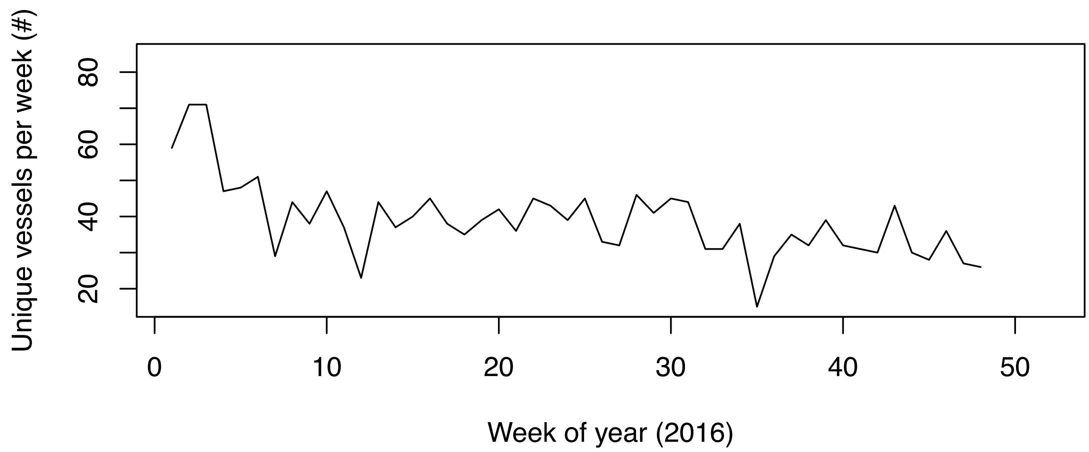
2016

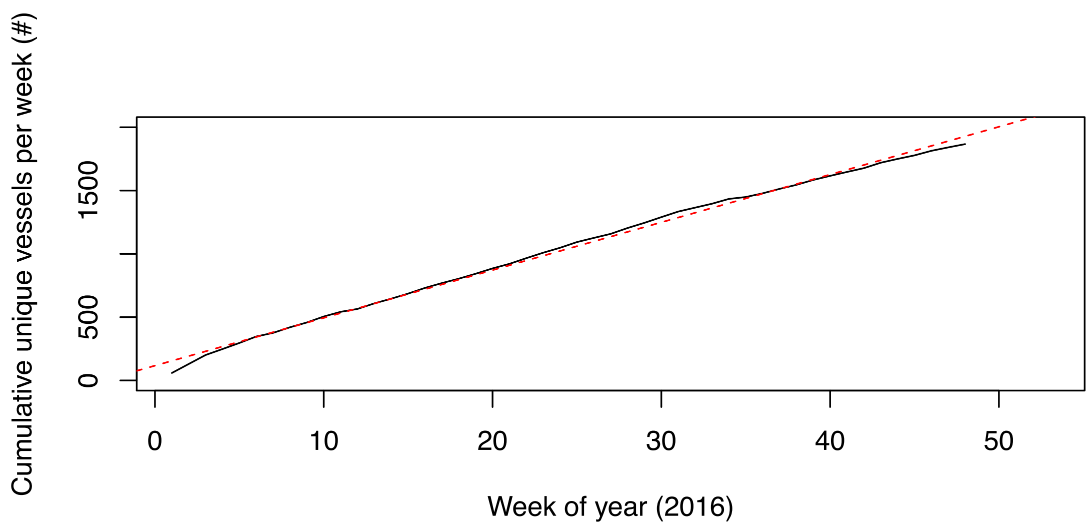
2016 daily unique vessels





2016 weekly unique vessels





2016 monthly unique vessels