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Mitigating vessel strikes: The problem of the peripatetic whales and the peripatetic fleet

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ABSTRACT

A survey questionnaire designed to determine mariner knowledge and awareness of endangered whales, existing conservation measures, and mariner receptivity to near real-time conservation technology on the bridge is herein reported. The survey, distributed by the Shipping Federation of Canada, yielded 43 responses. The majority of respondents were interested in receiving information on endangered whales and conservation measures in eastern Canada and USA Gulf of Maine regions (72% and 79%, respectively). Eighty-four percent of respondents indicated a preference for receiving whale alerts via Navigational telex (NAVTEX) and 79% listed NAVTEX as the most "not disruptive" means of receiving the alerts. A similar 72% also listed Automatic Identification Systems (AIS) as "not disruptive", and 58% identified AIS as the preferred reception format. The results show that the commercial fleet is moderately receptive to near real-time whale alerts on the bridge. It is concluded that to better understand mariner willingness to participate in whale conservation, researchers should consider defining the response required of mariners when receiving such alerts. The results also suggest that future conservation programs should use communication formats that are most familiar to, and favoured by, mariners while being the least disruptive to bridge protocols; i.e., NAVTEX and AIS.

1. Introduction

1.1. Anthropogenic threats to baleen whales

The life histories, ecological requirements, behaviors and spatial distributions of baleen whales result in chronic exposure to various anthropogenic threats. Despite attempts to mitigate the threats, some continue to hinder the recovery of endangered baleen species. The two most prominent threats are entanglement in commercial fishing gear and lethal vessel strikes [1–3]. Some species are more prone to these threats due to habitat requirements and behavior [4]. While each threat represents a considerable impediment to survival and population recovery for endangered species, the latter issue, vessel strikes, is the focus of much research.

Vessel strikes are recognized by the International Whaling Commission as a worldwide threat to large whales and a leading cause of whale mortality [2] that has been studied in the Northern and Southern hemispheres of both the Atlantic and Pacific oceans [5]. In all oceanic regions the risk of vessel strike represents a pressing conservation issue, although the magnitude of the risk depends on the relative distributions of the vessels and the whales, and from a management perspective the whales' conservation status. Vessel strikes, particularly in the NW Atlantic, have been well-documented and addressed relative to the Southern Hemisphere [5]. In the NW Atlantic, where six species of baleen whale are resident at certain times of the year, vessel strikes are a leading cause of mortality and population suppression [4], despite the implementation of several conservation measures.

1.2. Baleen whales of the Northwest Atlantic

The six species of baleen whales in the NW Atlantic that make northward migrations to feed between the months of May and December [1,6] include blue (*Balaenoptera musculus*), minke (*B. acutorostrata*), sei (*B. borealis*), fin (*B. physalus*), humpback (*Megaptera novaeangliae*), and right (*Eubalaena glacialis*) whales. Theses whales are afforded varying levels of protection throughout their migratory range because the population status among

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species differs between Canadian and American waters.

Blue and right whales are listed as 'endangered' in Canada under the Species at Risk Act, SARA; [7], and fin whales are listed as 'special concern'. In the United States of America (USA), blue, fin, sei, humpback, and right whales are listed as 'endangered' under the Endangered Species Act, ESA; [8]. Minke whales are not listed under either Act. Despite the discrepancies, conservation measures instituted by each nation are largely focused on protecting the endangered right whale. Although various measures have been implemented to help protect the right whale, they are assumed to also afford protection of other baleen whales [9,10]. Vessel strikes are a threat to all baleen whales, and strikes involving the above whales are relatively frequent in the NW Atlantic [11,12]. The enhanced focus on the right whale in the NW Atlantic stems from it being the most historically depleted baleen species, and on a world-wide per capita basis, suffers more vessel strikes than the other species [13].

1.3. Existing conservation measures

Over the past decade various agencies collaborated to implement several conservation measures in the NW Atlantic to reduce the lethal risk of vessel strikes to right whales (Appendix A). Canada implemented an amendment to the International Maritime Organization (IMO) adopted Traffic Separation Scheme (TSS) in the Bay of Fundy and a voluntary Area to Be Avoided (ATBA) in Roseway Basin on the Scotian Shelf [10,14] and coincidently identified critical habitat [10] for both regions. Along the east coast of the USA, conservation measures include Mandatory Ship-position Reporting, mandatory vessel-speed restrictions, recommended routes, and Seasonal and (or) Dynamic Management Areas (SMAs and DMAs respectively) [12,14,15]. Many of these measures have been successful in reducing vessel-strike risk to right whales through altering the probability of vessel-whale co-occurrence or by reducing the lethality of strikes through vessel speed restrictions [12,14,16]. However, some of these measures, including speed restrictions, have not been overly successful in achieving compliance amongst vessel operators [17,18]. The degree of success across conservation measures is not equivalent, as each measure relies on an informed, cooperative, and compliant fleet.

Compliance can be determined by several factors including the knowledge of regulations and the severity of consequences for non-compliance that is related to the costs and benefits of compliance [19–21]. The shipping industry can experience considerable costs when complying with regulations prescribed for the protection of whales [22]. Despite costs, some conservation measures in the Northwest Atlantic (NWA) have been effective in reducing strike risk to baleen whales, and right whales in particular, due to a highly compliant fleet and cooperative industry [14]. If conservation information is presented as a collaborative endeavor between industry and conservation agencies, mariners may be more likely to comply with new measures. Moreover, the commercial shipping industry is inherently peripatetic and the effectiveness of existing conservation measures may be hindered by their contrastingly stationary approach to management of whale species that are also inherently peripatetic, and perhaps increasingly so.

1.4. Emerging conservation technologies

Whale conservation initiatives have typically resulted in semi- or permanent spatially-defined coastal regions [20] under the implicit assumption that the whales would continue to aggregate in the defined regions and make use of defined migration corridors. In Canada, no conservation measure seeks to relay near real-time information to mariners regarding the locations of large whales in the NWA. In the USA, near real-time information on right whale presence is available near the port of Boston [21] and in the southeast via the Early Warning System for right whales [23]. However, as whales respond to environmental change, migration patterns and regional residency can become less predictable [24], and thus conventional protection measures (e.g., spatially fixed regions) may fail to provide sufficient protection. Further, the expansion of protection regions throughout the range of the whales is currently an untenable option. Since whale distributions are heavily influenced by the availability of food [25], and prey species are influenced by environmental variability, the distributions of whales may change as prey acclimate to seasonal or climate variations. Therefore, the risk of vessel strike is likely to persist and may worsen as whale movements and aggregations become less predictable while remaining at risk from the fleet. Near real-time measures may improve the effectiveness of mitigating vessels strikes as it is more adaptable than existing spatially fixed measures assuming the fleet can adequately respond to changes in whale distributions. Such measures are technically feasible and may provide improved protection over greater swaths of whale habitat. Near-real time conservation may be achieved by linking passive acoustic monitoring (PAM) technology to vessel communication technology.

In recent years, researchers have been addressing large whale conservation with acoustics [20,26,27]. PAM systems make use of acoustic technology and processing systems to classify some large whale species and their habitats by using identifiable whale sounds. Conventional PAM devices collect and store acoustic data while moored in some fixed location in the ocean and the data cannot be analyzed until such devices are recovered [28]. These data are thus not applicable in near real-time and do not address the disconnect between mobile vessels, mobile whales, and stationary conservation measures. Some fixed PAM moorings are used for near real-time whale detections in the Boston TSS [21,29]. To address the mobile whale issue, Baumgartner et al. [30] proposed the use of autonomous underwater vehicles (AUVs) i.e., ocean gliders, to process, classify, and report acoustic detections of four baleen whales species in real-time. When paired with communication technologies used by the commercial shipping fleet, sending such reports on whale locations to the bridge of a vessel in near real-time can be imagined.

Professional mariners regularly receive information on navigational hazards, weather conditions, and other marine activities through several media that are used variably among mariners (Appendix B). These media include Very High Frequency (VHF) radio, the Automatic Identification System (AIS), and Navigational Telex (NAVTEX). In addition, Canada channels information via various media that include Marine Communications and Traffic Services (MCTS) operated by the Canadian Coast Guard (CCG) through VHF, Notices to Mariners (NOTMAR), bridge placards, and navigational charts. While some of these media are inappropriate for communicating near real-time information, others can feasibly transfer information on whale locations from ocean gliders to the bridge. Two questions arise: (1) are mariners willing to use such near real-time information if/when received on the bridge to help mitigate vessels strikes?, and (2) what media do mariners prefer to receive such information? Knowing these answers may be critical to the implementation of near real-time vessel-strike mitigation because the receptivity of the target group (the fleet), is essential to producing the desired conservation outcome [30].

1.5. Implementing near real-time whale conservation

Bringing near real-time conservation information via whale location alerts to the bridge is dependent on a cooperative fleet that is receptive to an emerging technology and the continued

participation of mariners. A better understanding of the needs, preferences, safety and operational constraints of fleet members may improve conservational relationships among mariners and conservation agencies. Knowledge of conservation problems can be highly related to the support for conservation solutions [30], or linked to the likelihood of individuals acting in favour of the environment [31,32]. Thus, mariners who are more knowledgeable, or are aware of endangered species and their conservation status, may be more likely to help solve conservation problems and may be more receptive to new conservation technologies and programs to do so. Consequently, it may be less important that mariners correctly identify endangered species, but more important that mariners perceive that some species are endangered and conservation measures are, or could be, in place for whales protection. Understanding the relationships among awareness, knowledge, and behavior is critical to ensuring that the desired behaviors of the target groups are obtained strategically.

When conservation programs are being developed, the preferences and values of the target audience must be considered, since that audience is critical for success of the program [33]. In this case, mariners who do not perceive the need for information on whale locations, or who prefer more permanent, print-based media for receiving information, may be less receptive to implementing near real-time conservation technologies. Thus, whale conservation must be designed to appropriately reflect the preferences, needs, and restrictions of the shipping industry to effectively make use of the technologies. To address the above issues we asked the following primary research question:

Are mariners receptive to the implementation of near real-time conservation technologies to reduce lethal vessel-strikes to baleen whales in the NWA?

To better address the question, the following secondary questions addressing (1) mariner knowledge of, and interest in, baleen whale conservation, and (2) mariner receptivity to implementing near real-time conservation technologies on the bridge, were asked:

1. To what extent are mariners aware of the endangered status of baleen whales and existing conservation measures in the study region, and are they interested in learning more?
2. Are mariners able and willing to incorporate near real-time whale alerts into bridge protocols, and if so, what format would mariners prefer, and how disruptive might they be?

2. Methodology

2.1. Research questionnaire

A survey questionnaire was developed to address the above general question by means of 10 specific questions. The first 4 would give an indication of the respondent demography via their role within the industry and their familiarity with the study region based on how often their vessel(s) navigate(s) the Gulf of St. Lawrence, the Scotian Shelf, the Bay of Fundy, and the Gulf of Maine. These questions (detailed in Appendix C) included:

1. I represent (select one): a fleet or a single vessel.
2. Which of the following regions do you or your vessel(s) navigate annually?
3. If you represent a single vessel, how many trips annually does your vessel make through any or all of the regions identified above?
4. If you represent a fleet, how many of your vessels annually navigate any or all of the regions identified above?

The fifth and sixth questions were designed to estimate the mariner awareness of whale conservation and their interest in learning more about conservation:

5. a) to your knowledge, which of the whales below are considered as endangered?
   b) If you are not aware of endangered whales, would you be interested in receiving such information in the future?
6. Are you aware of any of the following measures on the east coast of canada and or/the USA-gulf of Maine that may help reduce ship strikes to large whales?

The remaining 4 questions were designed to determine the mariner's receptivity to receiving near real-time alerts and their preferences with respect to when and how those alerts should be received:

7. When would you need information on whale locations to help you avoid collisions with whales?
8. If you were provided with near real-time information on whale locations during a voyage, in what format would you prefer to receive the information?
9. How disruptive would near real-time information be to bridge protocols if received in one or more of the following formats?
10. How much would you or your corporation be willing to spend for the technology to enable you to receive near real-time whale location information on the bridge?

Question 9 included options for receiving whale alerts that are currently available, under development, or unavailable to mariners, and included VHF radio, MTCS, AIS, NAVTEX, mobile applications (apps) and web pages. Question 10 was used to gauge how willing the industry might be to fund the implementation of conservation technologies.

The questionnaire was distributed over an eight week period (June through August 2015) by the Shipping Federation of Canada (SFC) to its Members, who operate anywhere in Canadian waters, using their distribution list of 174 contacts. The exact number of individuals who received the questionnaire remains unknown, as an individual contact was able to forward the survey to many more mariners. Therefore, a response rate cannot be estimated. Respondents returned the questionnaire to the SFC via email, fax, or land mail, and these were then forwarded to the research team via email with all identity information redacted (Dalhousie University; ethics requirement). Responses were coded using a simple numbering system that allowed for the quantitative analysis of responses. Qualitative (open) responses to questions were also recorded and, when applicable, sorted into categories of similarity to be analyzed semi-quantitatively.

2.2. Statistical analyses

Survey responses were primarily converted to a percent score to reflect the proportion of responses. Prior to this conversion, response frequencies were compared using a chi-square test (Minitab Ver. 17) to determine whether response proportions for each question were statistically different from the expectation of equal proportions. Where statistical differences were found, Fisher's exact test, appropriate for small sample sizes, was used for pairwise comparisons of proportions within each question as necessary. Responses from participants identified either as a fleet- or vessel-representative were aggregated due to the small sample size.

3. Results

A total of 43 respondents completed the questionnaire. A large proportion (93%, $p=0.000$) identified as representing a single vessel and 86% ($p=0.000$) indicated that they annually navigate the Gulf of St. Lawrence. The Scotian Shelf, Bay of Fundy, and Gulf of Maine regions were identified as annually navigated by 16%, 5%, and 12% of respondents, respectively, and 7% indicated that they did not navigate any of the aforementioned regions annually.

3.1. Knowledge and awareness

Each whale species listed on the questionnaire (Appendix C) was identified by respondents as endangered at least once. The majority of respondents (72%) correctly identified the right whale as an endangered species (Fig. 1). The right whale was correctly identified more often than all other species, except the blue whale ($p=0.000$). Blue, humpback, and fin whales were also frequently identified as endangered species (56%, 33%, 30%, respectively). Forty-two percent of respondents selected at least one incorrect classification when identifying whales considered to be endangered according to Canada's listings. Under the SARA, only right and blue whales are listed as endangered, while fin whales are listed as a species of special concern in this region. It is unknown whether respondents identified endangered species based on SARA or ESA listings. Under ESA, all response options, except the minke and pilot whales, are listed as endangered. When asked whether respondents would be interested in receiving information on endangered whales in the future, had they not been previously aware, 79% ($p=0.000$, $\chi^2=40.7907$, d$f=2$) responded "yes", 7% "no", and 14% offered no response.

Most respondents were aware of whale conservation measures on the east coast of Canada and (or) the Gulf of Maine (Fig. 2). Most were aware of Marine Protected Areas (MPAs; 86%) and this awareness was indicated more often ($p<0.01$) than all other conservation measures with the exception of Areas To Be Avoided (ATBA) that were identified by 84% of respondents and significantly more often ($p<0.02$) than all remaining options. Approximately half the respondents indicated an awareness of Traffic Separation Schemes (TSS) and conservation areas (60% and 51% respectively). The most common means by which mariners became aware of the various conservation measures were bridge placards (79%) and navigational charts (74%). Both media were identified more often ($p=0.001$) than all remaining options with the exception of Notice to Mariners (NOTMAR) at 58%. When asked whether respondents would be interested in receiving advisory information in the future, had they not been previously aware of measures, 72% ($p=0.001$, $\chi^2=29.6279$, d$f=2$) indicated "yes", 9% indicated "no", and 19% did not respond.

3.2. Receptivity, needs, and preferences

Regarding the timing of receiving whale alerts on whale locations to aid in avoiding vessel strikes, 53% of respondents indicated before leaving port, and 35% noted within a few hours of arriving at the alert location (Fig. 3). The timing options were not identified with equal frequency ($p=0.001$, $\chi^2=15.453$, d$f=3$). Ten (23%) respondents selected more than one option and seven (16%) selected the need for information both before leaving port and within a few hours of arriving at the alert location, and fewer (28%) stated that they would be able to respond immediately to alerts. Significantly fewer respondents (7%, $p\leq 0.02$) indicated they had no need for such information. This latter response option, and the option for information being required before leaving port, were considered to be less flexible responses, as these options are less viable for the implementation of near real-time conservation. The response options where information was needed within a few hours or where respondents were able to respond immediately, were considered to be flexible responses, as they reflect an ability to better incorporate near real-time information in bridge planning. A cumulative 60% of respondents selected options that indicated a reduced flexibility while 63% of respondents selected the more flexible response options.

The preferred format of receiving near real-time information on whale locations was NAVTEX (84%); an automated direct-printing service used to transmit written alerts to mariners at sea (Fig. 4). NAVTEX was selected significantly more often than all communication options ($p\leq 0.017$). Other notable preferences for reception modality included AIS (58%), VHF radio (51%), and MTCS (40%). AIS, VHF, and MTCS were selected significantly more often than apps, web alerts, and other responses ($p<0.01$), although the differences in these response proportions did not differ from each other. No respondent indicated a preference for receiving alerts through mobile applications (apps), and this difference was significant ($p<0.001$) for all other options with the exception of the web-based alerts ($p=0.055$) that was selected by 12% of

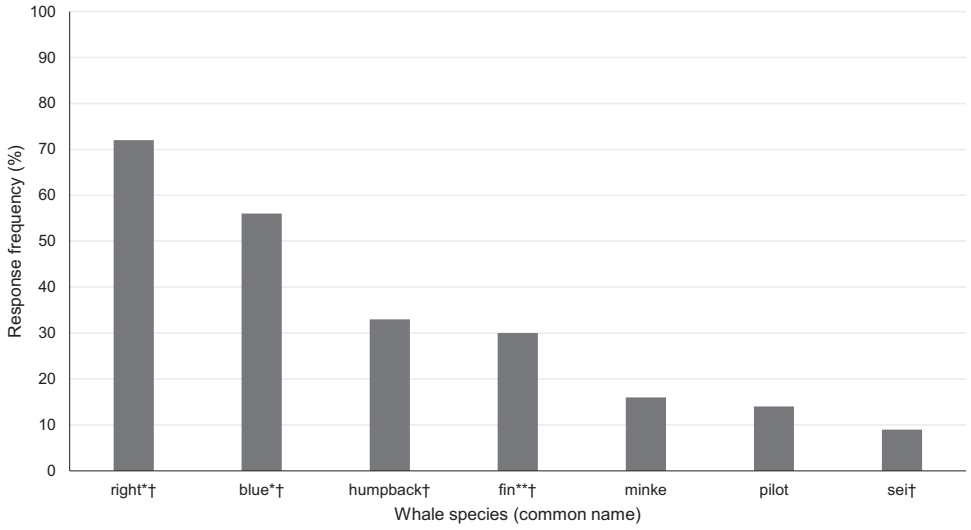

Fig. 1. Bar chart showing the per cent response of mariners identifying whale species that they considered to be endangered. Whale classifications are noted as endangered (*) or special concern (**) in Canada (SARA) and endangered (†) in the USA (ESA).

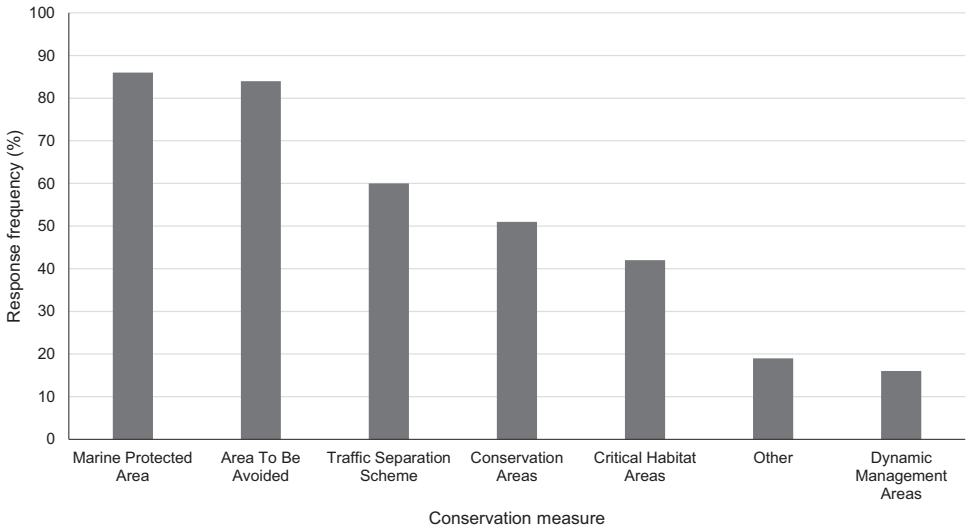

Fig. 2. Bar chart showing the per cent response of mariners identifying their awareness of various whale conservation measures. Note that Dynamic Management Areas are used only in the USA.

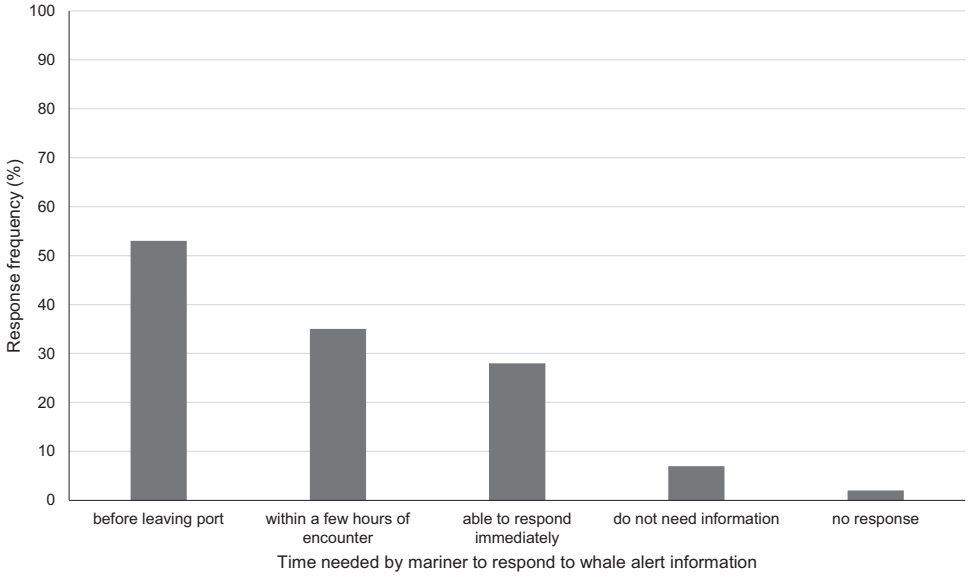

Fig. 3. Bar chart showing the per cent response of mariners identifying their need for whale alert information and their ability to initiate a response to the information.

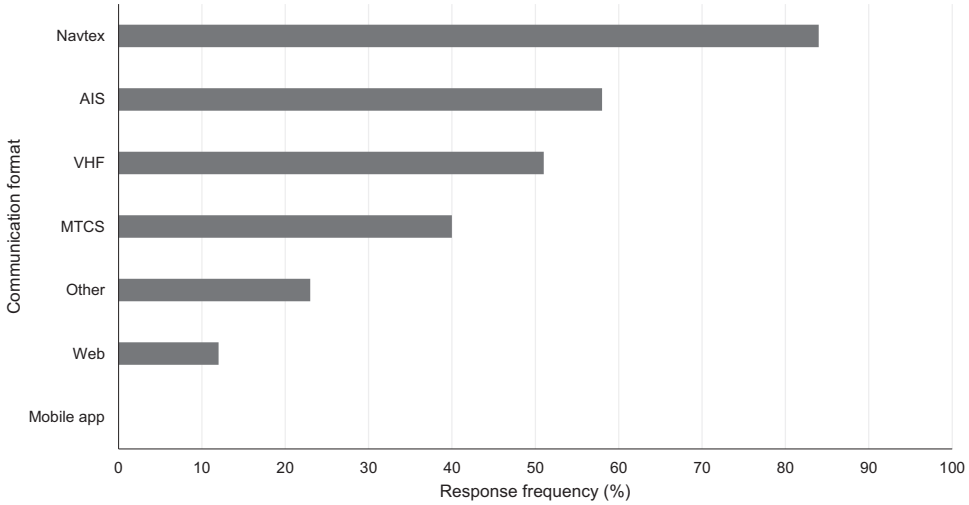

Fig. 4. Bar chart showing the per cent response of mariners when identifying their preferred communication format for receiving near real-time whale alert information.

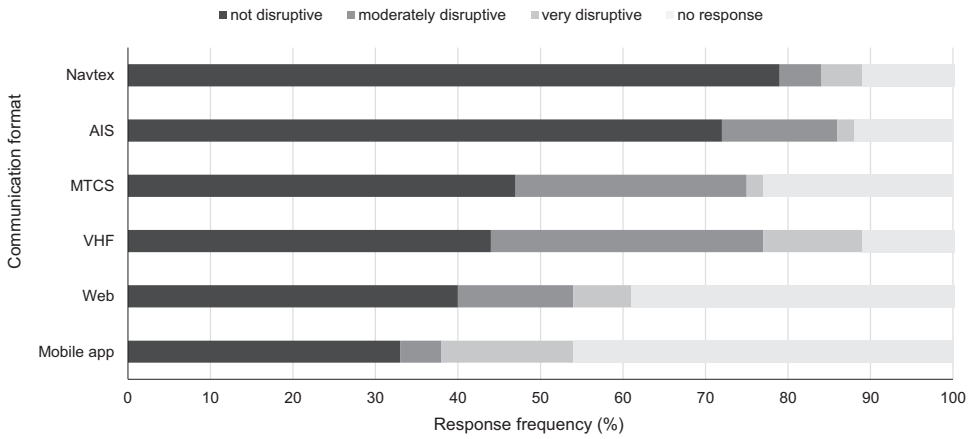

Fig. 5. Bar chart showing the per cent response of mariners ranking their perceived disruptiveness of various whale alert communication methods to bridge protocols if used to transmit near real-time whale alerts.

respondents. Ten respondents (23%), however, noted a preference for e-mail.

Most respondents (79%) ranked NAVTEX as a non-disruptive form of receiving whale alerts (Fig. 5). A similar number (72%) gave AIS this ranking. and these two were ranked non-disruptive more often than any other media ($p \leq 0.003$ and $p \leq 0.028$, respectively). The disruptiveness of mobile apps was not ranked by 47% of respondents and this was more than all other options, except web-based alerts ($p \leq 0.041$). Communications media did not differ significantly in the ranking categories of moderately disruptive ($p=0.132$, $\chi^2=5.619$, d$f=5$) and very disruptive ($p=0.293$, $\chi^2=4.497$, d$f=4$). The modalities that were most preferred (above) were also found to be least disruptive to bridge protocols. The proportion of respondents who selected NAVTEX as their preferred alert media did not differ from the proportion who indicated that NAVTEX would non-disruptive ($p=0.782$). This was also true for AIS ($p=0.258$) and VHF ($p=0.666$) communications. Significantly more respondents did not respond to the final question regarding willingness to pay for alerting technology (53%, $p \leq 0.001$). Of those respondents who did answer this question, 40% were not willing to pay for the technology.

4. Discussion

The above results provide new insights on the preferences, needs, and constraints of mariners concerning the implementation of near real-time whale alert technologies that could help mitigate vessel strikes to whales. Although mariners may be knowledgeable of endangered whales and various conservation measures, especially those implemented for the protection of the right whale, there was no clear consensus as to when information would be needed to safely initiate a response to near real-time whale alerts. Further, the flexibility of mariners to implement these alerts into bridge planning was dichotomous; approximately half the respondents chose less flexible options to whale alerts and another half chose more flexible options. Conversely, the same sample population reached some consensus in their preference for the whale-alert communication format, particularly NAVTEX and AIS, and these formats were considered the least disruptive. Thus, if mariners are to receive such information in near real time, it must be achieved in the least disruptive manner. This knowledge, and the apparent awareness of whale conservation problems, along with the attendant possible and preferred solutions regarding vessel-strike mitigation, may be a precursor to actions that favour conservation, thereby easing the adoption of near real-time conservation by mariners.

4.1. Knowledge and awareness

Since the mid 1990s, mariners transiting the eastern coast of Canada and the USA-Gulf of Maine regions have been receiving information on the conservation of endangered right whales. Given the temporal awareness of right whale threat issues (20+ years), and the implementation of several protective solutions (12+ years), it was expected in this study, that mariners would have a basic understanding and awareness of the endangered status of, at minimum, right whales, as well as the measures protecting the species. The high percentage of respondents correctly identifying the right whale as an endangered species indicates considerable success among the various conservation initiatives and their attendant communication strategies.

The species that were most often identified as endangered – right, blue, humpback, and fin whales – were also those species which have some form of endangered or threatened status through the International Union for Conservation of Nature, SARA, or ESA. These responses may reflect a general awareness amongst mariners that baleen whales are threatened, and such awareness may ease the implementation of new conservation technologies by highlighting the need for adaptive management as the threat persists. Since the majority of respondents indicated a desire to receive more information on endangered whales, new conservation programs could enhance an engagement with the fleet based on a shared understanding that some species and populations remain threatened. This desire by the fleet to learn more may also reflect a lack of access to such information or a lack of time to become adequately informed, and may indicate a desire to actively participate in conservation. While 14% of respondents did not indicate whether they were interested in receiving information on endangered whales, it may reflect a group of respondents who felt they were already knowledgeable; though there was no indication they had no interest in such information in the future. Most importantly, the results indicate mariners have not become deaf to the issue.

The efficacy of existing conservation initiatives in reaching target audiences is positively reflected by this study. Mariners were aware of large-scale spatial conservation measures, including MPAs and ATBAs, and this may indicate mariners are disproportionately receptive to spatial information and may better understand the role of spatial restrictions in conservation. At the same time, the results indicate that mariners were less aware of dynamic or seasonal management areas, and this may indicate a future challenge in implementing near real-time conservation technology. However, DMAs are exclusively located in USA waters of the NW Atlantic, and few respondents indicated regular

navigation of the Gulf of Maine. Dynamic conservation measures may not allow mariners to develop a sense of familiarity with, and understanding of, the measures as they are not permanent, are voluntary, are short term in duration, and are temporally difficult to track as they come and go into effect. This may be ameliorated by informing mariners of new conservation programs through communication media with which mariners are most familiar and already use.

Mariners indicated that bridge placards and navigational charts were the most common means through which the awareness of conservation measures was gained. This is a finding that conservation practitioners should not ignore; i.e., mariners may be looking to these media in the future to gain information on new programs and available technologies. However, using these media alone to share information may not compel mariners to comply with conservation requirements or opportunities, as these are a passive means of communication. Despite this, the high proportion of respondents who indicated a desire to learn more indicates a fleet that is receptive to seeing a greater prevalence of conservation information in the industry.

4.2. Receptivity, needs, and preferences

Mariners appear to be restricted in their capacity to respond to whale alerts, and that may be dependent on their voyage, weather, and corporate requirements with respect to operational efficiency. Additionally, such alerts, depending on format, may be quite disruptive to bridge planning and protocols and may have perceived implications for navigational safety. In attempting to understand the minimum time restriction for when whale location information must be received to initiate a risk reducing response, the results indicated a clear dichotomy among mariners with respect to the flexibility of navigation since 60% and 63% of respondents selected inflexible and flexible response options, respectively. This dichotomy potentially indicates an inability to commit to near real-time conservation without receiving more information on the conditions associated with using such technology. Further, since 16% of respondents selected both types of response options, mariners may need more information on the actions required to reduce vessel strike risk. The communication media by which location information is received may alter the timeliness of information delivery since some mariners appear to prefer formats that infer greater delays in information sharing.

Eight out of ten mariners indicated a preference for receiving near real-time whale location information through NAVTEX. Slightly fewer indicated a preference for AIS, and even less so for VHF radio. These latter communication media, unlike NAVTEX, can be updated immediately upon receiving information with a limited delay in transmission, though VHF, presumably through MCTS, is uncertain and likely has limited coverage. Since NAVTEX, AIS and VHF are widely accepted by the industry, it is not surprising that mariners are particularly uninterested in receiving information via mobile apps or web pages. These latter media may be unfamiliar or restricted (corporate policy) to mariners, and may represent an unwelcome or unavailable form of technology on the bridge. Further, in most cases mobile phone coverage is expensive and becomes poor or non-existent with increasing distance from the coast (except satellite phone). These media also received the fewest responses when mariners were asked to rank the disruptiveness of each communication media to bridge protocols.

Since many respondents did not address the disruptiveness of web pages and mobile apps to bridge protocols, mariners may not consider these media as options worthy of consideration for receiving information mid-voyage. It is clear that near real-time conservation should focus first on communication media that are most likely to be used, are most preferred, and are least disruptive. NAVTEX was the most preferred and it was also the least disruptive. Second to NAVTEX was AIS in both preference and disruptiveness. AIS may prove to be a more valuable medium for near-real time conservation, as this technology enables communication of AIS messages that are regularly updated and can be checked by mariners. While NAVTEX is most preferred, the four hour delay between messages may be insufficient for timely response for reducing vessel strikes to whales. Further, the AIS system, through the use of an aid to navigation (ATON) transceiver, can send whale alerts as AIS messages that can appear in association with a vessel's electronic chart display and information system (ECDIS). Such messages would allow mariners to accordingly adjust their navigation. Regardless, the high portion of respondents who indicated that both NAVTEX and AIS would not be disruptive to bridge protocols points to a greater receptivity to near real-time conservation or, at minimum, a means by which the adoption of such conservation information may be improved.

Despite the positive implications arising from the questionnaire, more than half those surveyed did not respond to an inquiry regarding their willingness to provide funds to acquire the technology needed for near real-time conservation. An unwillingness to pay for conservation measures can be indicative of a belief that this is the responsibility of more senior personnel in the attendant agency [33]. This may represent a barrier to implementation, as mariners are effectively not responsible for the acquisition of such technology. This barrier is not expected to be significant in the implementation of near real-time conservation though the process of achieving it may be difficult and time-consuming unless achieved under the auspices of some other agency such as the IMO. Implementing near real-time conservation cannot progress without a 'buy-in' from the shipping industry and cooperative action with shore-based stakeholders.

4.3. Limitations and restrictions

While this study has provided valuable information to marine conservation practitioners, and may be used to expedite the implementation of near real-time conservation technologies, it is important to recognize that the results reflect 43 mariners who chose to volunteer their responses to the questionnaire. These responses may reflect only a small portion of mariners who are knowledgeable and supportive of conservation. Further, mariners who chose not to respond to this survey may not view conservation as an industry issue and may not be receptive to the implementation of new conservation technologies.

Since 93% of respondents identified as representing a single vessel and 86% of respondents indicated that they annually navigate the Gulf of St. Lawrence, it is possible that the survey was completed by multiple representatives of a fleet operating primarily in the Gulf. This bias may significantly alter the research findings, as the needs, preferences, and restrictions captured by this study may only reflect a sub-population of mariners transiting a small portion of the Northwest Atlantic. It is therefore critical to acknowledge that this study represents a first step toward understanding the commercial fleet as a social group, and could be improved and expanded in the future to capture the interests of a more global set of mariners who may be otherwise variably interested in conservation.

5. Recommendations and conclusions

As technologies in passive acoustic monitoring advance and the reception of the derived information approaches near real-time, alerting mariners to whale locations in near real-time may be realized on the bridge in the near future. It is therefore imperative

that conservation agencies begin to consider the challenges of implementing these technologies such that mariners can make the best use of whale alerts while underway. Those proposing new measures must be wary of overstepping the limitations of the shipping industry, as it may compromise otherwise healthy relationships amongst conservationists and the shipping industry.

To our knowledge, this research is the first to highlight the receptivity of mariners to near real-time conservation measures through an analysis of knowledge, needs, and preferences with respect to existing and emerging conservation measures. The research findings indicate that Members of the SFC and their affiliates – mariners who regularly transit regions of the Northwest Atlantic – are receptive to near real-time conservation. Mariners who responded to the questionnaire were aware of endangered whales and existing conservation measures, particularly with respect to the endangered right whale. Most importantly, mariners were interested in receiving more information on both endangered whales and conservation measures. Respondents indicated that bridge placards and navigational charts were the most common means by which they became aware of conservation measures. As such, it is recommended that these media be employed for future communications with mariners when developing new conservation programs, as mariners absorb the information provided in such documents.

With respect to receiving near real-time whale location information on the bridge, it was unclear whether mariners felt that bridge protocols were flexible enough to accommodate responses to such information. This may be due to a lack of information on how location alerts would be received and what a response would entail. It is therefore recommended that near real-time conservation programs clearly define "response" for mariners, and establish a protocol for safely initiating a response upon receiving whale location alerts mid-voyage, whether that be avoidance or reduced speed. This protocol must consider the communication media used to transmit whale location alerts, and should not ignore the preferences identified by mariners in this study.

While NAVTEX was the most preferred means of receiving near real-time location information, NAVTEX is not the most dynamic communication media available to mariners. Since NAVTEX messages are broadcasted to mariners once every four hours, AIS may be a more appropriate technology for communicating whale alerts in near real-time. Both NAVTEX and AIS were significantly different from all other media options in terms of their disruptiveness to bridge protocols. Given this, the greater flexibility of AIS messaging, and the option to passively inform mariners of whale locations, it is recommended that near real-time conservation programs consider AIS as a primary option for communicating whale locations to mariners. It is essential that whatever media is used to bring whale location alerts to the bridge appropriately balances the preference for non-disruptive formats with a system that is regularly updated and monitored.

This work provides initial insights into some unknown sub-set of the commercial shipping fleet on the east coast of Canada, and speaks to the effectiveness of past conservation programs in reaching mariners through education and awareness campaigns. Conservation can only be effective when coupled with measurable change in the behavior of the target audience. Despite the successes of conservation in the Northwest Atlantic, baleen whales remain threatened by commercial activities; and shipping in particular. Near real-time conservation may be an added solution to reducing the risk of vessel strikes to whales by bringing current and updated information on whale locations to mariners who are arguably at the frontline of large whale conservation. Like all conservation measures in the Northwest Atlantic, however, near real-time conservation will entirely depend on a compliant fleet, with mariners who are receptive to the implementation of new technologies. This work represents a novel approach to solving large whale conservation issues by first considering the needs, preferences, and restrictions of vessel operators in the effort to reduce risk to whales without compromising vessel operations or navigational safety.

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Appendix A. Whale conservation measures used in eastern Canada and USA

ATBA – Area to Be Avoided: an area of the ocean adopted by the IMO where it is recommended that all vessels avoid.

Critical Habitat: a habitat area in the ocean identified by Canada as being necessary for the survival or recovery of a species listed as endangered under the SARA.

DMA – Dynamic Management Areas: areas in the USA where vessels voluntarily reroute or reduce speed (≤ 10 knots) when right whales have been detected.

MPA – Marine Protected Areas: delineated regions of the ocean wherein human activities are managed primarily for the conservation of resident biodiversity.

MSR – Mandatory Ship-position Reporting: applicable in the USA for vessels to report identification, course, speed, and destination when entering two regions of the east coast.

Mandatory speed restrictions: applicable in right whale habitat in the USA wherein vessels are required to slow down to reduce the lethality of vessel strikes (≤ 10 knots).

SMA – Seasonal Management Areas: areas along the USA east coast where vessels must seasonally operate under speed restrictions (≤ 10 knots).

TSS – Traffic Separation Scheme: mandatory IMO vessel-traffic-management and routing scheme used for safety of navigation in and around constricted or congested vessel traffic regions.

Appendix B. Marine communication media

AIS – Automatic Identification Systems: an automatic vessel tracking system (VHF transceiver and GPS) used by vessels for identifying, locating and tracking each other.

ATON – Aid To Navigation: a special AIS transceiver designed for installation on maritime infrastructure for effective and efficient transmission of maritime awareness information as AIS messages.

Bridge Placards-printed informational materials intended to be posted on the bridge of a vessel.

ECDIS – Electronic Chart Display and Information System: a computer-based navigation information system used on vessels that complies with International Maritime Organization (IMO) regulations and is used as an alternative to paper nautical charts.

MCTS – Marine Communications and Traffic Services: an entity of the Canadian Coast Guard responsible for the delivery of information and advice regulating the safety and efficiency of vessel

movements in Canadian waters.

Navigational Charts-nautical charts showing ocean properties, topographic features, aids to navigation, and navigational hazards.

NAVTEX – Navigational Telex: an automated direct-printing (FAX) service used to transmit printed alerts to mariners at sea. NAVTEX alerts are prepared and distributed by the Canadian Coast Guard.

NOTMAR – Notice to Mariners: communications prepared and distributed by the Canadian Coast Guard, including information on chart updates, nautical publications, initiatives, services, and announcements.

VHF – Very High Frequency radio: an internationally recognized means of voice communication between vessels and land stations.

Appendix C. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.marpol.2016.02.017.

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