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Perspective

The WhaleReport Alert System: Mitigating threats to whales with citizen science

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ABSTRACT

Ship strikes are a pervasive threat to cetaceans globally. Real-time observations of cetaceans reported by citizen scientists unlock an opportunity to develop ship strike mitigation tools. The Ocean Wise Sightings Network (OWSN) is an example of a long-running and expansive citizen science program. The OWSN curates sightings data collected by coastal communities, mariners, and tourists into a database that can be utilized to monitor the 23 cetacean species inhabiting British Columbia and Washington State waters. Recently, the OWSN mobilized real-time sightings data into a mitigation tool, the WhaleReport Alert System (WRAS), which alerts professional mariners to the presence of cetaceans within their vicinity, allowing them to take action (e.g., slow down or divert course), to mitigate the risk of ship strike. The success of the WRAS (550 registered users) can be largely attributed to outreach events conducted in coastal communities which recruit new observers who report sightings to the WhaleReport app. Partnering with mariners to develop the WRAS has resulted in its continued support from and use by marine industry. We highlight the critical role of a sightings network for mitigating threats to cetaceans, emphasize the need to collaborate with marine industry, non-governmental, and government bodies to support endorsement of the tool, and stress the importance of metrics to evaluate success of the WRAS. This approach taken by Ocean Wise has resulted in the delivery of >20,000 WRAS alerts and is a framework which could be integrated into existing sightings networks globally to mitigate the risk of ship strikes on cetaceans.

1. Introduction

Marine megafauna, including marine mammals, serve vital roles in ocean ecosystem function and integrity (Pimiento et al., 2020). Cetaceans (whales, dolphins, and porpoises) are considered bioindicators of ocean health (Pimiento et al., 2020) and as large predators play a significant role in structuring marine ecosystems (Roman et al., 2014). Similar to terrestrial and freshwater ecosystems, marine ecosystems are subject to increasing pressure from anthropogenic activities (Halpern et al., 2007). Overfishing, entanglement bycatch, habitat loss and degradation, ocean pollution, underwater noise, ship strikes, and climate change are cumulative impacts which have triggered worldwide cetacean declines (Jewell et al., 2012; Meyer et al., 2017; Pimiento et al., 2020).

In addition to the recognized threats to cetaceans, lack of information on the conservation status of cetacean species is also considered a threat in itself (Parsons et al., 2015). Over 35 % of cetacean species globally are currently classified by the International Union for Conservation of Nature (IUCN) as "data deficient", which presents an obstacle for the development and implementation of conservation strategies (Correia et al., 2021). Data gaps in cetacean distribution and abundance estimates are often interpreted as "no cause for concern" by policy makers, and the lack of known conservation status can also limit the availability of funds for scientific research of data-deficient species (Ashe et al., 2013; Correia et al., 2021; Kaschner et al., 2012; Parsons et al., 2015). Despite large-scale efforts to better establish distribution, abundance, and population trends of cetaceans globally over the last ~50 years (Kaschner et al., 2012), current knowledge remains limited for most species and populations.

Collecting demographic data on long-lived and wide-ranging

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cetaceans is a monumental task, and one that scientists cannot efficiently and cost-effectively tackle alone over large geographic areas. Citizen science, also known as community-based monitoring, has proven vital for generating data on biodiversity within freshwater ecosystems (Robinson et al., 2021). However, marine citizen science initiatives are underrepresented in scientific literature, with marine environments comprising only 14 % of global citizen science projects (Sandahl and Tøttrup, 2020).

There are many benefits of engaging members of the public to collect data on cetaceans. In addition to the large geographic areas that can be covered by citizen scientists, there are also cost benefits involved, especially if you engage people who are already regularly on the water and have existing knowledge of cetaceans (e.g., ecotourism operators) (Mancini and Elsadek, 2019). To date, a range of citizen science-driven short- and long-term initiatives have been established to monitor cetaceans in countries worldwide (Evans and Waggitt, 2020; Garcia-Cegarra et al., 2021; Lodi and Tardin, 2018; Mancini and Elsadek, 2019; Matear et al., 2019; Mwango'mbe et al., 2021; Natoli et al., 2022; Paiu et al., 2021; Pirotta et al., 2020; Rodriguez et al., 2021; Zhang et al., 2021). The overarching goals of these initiatives are to determine cetacean diversity, abundance, and distribution within coastal regions, to inform management strategies, and to mitigate threats to cetaceans.

As technology continues to be integrated into our daily lives, the ubiquity of smartphones and other portable devices (e.g., tablets, laptop computers) provides an opportunity to further improve community monitoring and conservation of cetaceans. Utilizing technology increases the amount of data that can be generated by easing the process of reporting cetacean observations. Additionally, it allows for information to be received in real-time, which enables the use of this data to mitigate imminent threats to cetaceans from large vessels.

Here we propose a framework for transforming citizen science data into a comprehensive vessel-based threat mitigation tool for conservation management of cetaceans: 1) Developing networks of dedicated volunteer reporters; 2) Applying smartphone technology to streamline cetacean data collection; 3) Developing a system to deliver alerts to commercial mariners; and 4) Disseminating information back to citizen scientists for facilitating long-term engagement in marine conservation. We introduce the Ocean Wise Sightings Network (OWSN; formerly the 'British Columbia (B.C.) Cetacean Sightings Network), a longstanding citizen science program established in B.C., Canada by Ocean Wise, as a case study to illustrate these framework principles. The OWSN was established in 2000 and is one of Canada's most enduring and successful citizen science programs. >7500 residents of coastal areas of British Columbia and Washington State (USA) have reported cetacean sightings to the OWSN over the past two decades. These reports have been collated into a long-term database covering an area of ~62,000 km^2. This information is used to better understand spatial and temporal occurrence of species.

Within the geographic range of the OWSN, there are eleven species or distinct populations listed under the Canadian Species At-Risk Act (SARA; www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/species-list), including: blue whales (*Balaenoptera musculus*; Endangered), fin whales (*Balaenoptera physalus*; Special Concern), grey whales (*Eschrichtius robustus*; Special Concern), Pacific harbour porpoise (*Phocoena phocoena vomerine*; Special Concern), humpback whales (*Megaptera novaeangliae*; Special Concern), north Pacific right whales (*Eubalaena japonica*; Endangered), sei whale (*Balaenoptera borealis*, Endangered), and four populations of killer whale (*Orcinus orca*): northeast Pacific northern resident (Threatened), northeast Pacific southern resident (Endangered), northeast Pacific transient (also known as Bigg's; Threatened), northeast Pacific offshore (Threatened). Vessel-associated threats, particularly ship strikes, have previously been identified as a priority threat to cetaceans by the International Whaling Commission (IWC) (International Whaling Commission, 2005) and within SARA recovery documents for species mentioned above (Government of Canada, 2006). Large cetacean species found in the North Pacific are at high risk of ship strikes (Schoeman et al., 2020), including humpback whales (Lammers et al., 2013), blue whales (Monnahan et al., 2015), fin whales (Rockwood et al., 2020) and grey whales (Silber et al., 2021). Ship strikes within the North Pacific Ocean make up ~30 % ($n = 139$) of the total global ship strikes as identified by the IWC (Winkler et al., 2020). Of the total globally reported ship strikes in the IWC database, container ships, ferries, general cargo ships and Navy vessels make up 8.2 %, 11.9 %, 5.7 % and 8.2 % of ship strikes respectively (Winkler et al., 2020). In coastal B.C., the classes of vessels mentioned above overlap significantly with cetacean presence (Williams and O'Hara, 2010). To mitigate the ship strike risk presented by this overlap, the OWSN developed the Whale-Report Alert System (WRAS), which uses real-time cetacean sightings submitted by citizen scientists through *WhaleReport* to alert commercial mariners to the presence of whales in their vicinity, allowing them to react appropriately.

2. Establishing a cetacean sightings network: recruiting, retaining, and engaging observers through outreach

Environmental observer networks can take many forms and are often shaped by geographic scale and potential observer types (Earp and Liconti, 2020). For monitoring cetaceans with citizen science, capturing a mix of land-based and boat-based sightings enables collection of spatial and temporal data over a broad geographic area (Embling et al., 2015; Evans and Hammond, 2004). Land-based sightings are non-invasive, and are the main source of data collection for cetacean citizen science projects in the UK (e.g. ShoreWatch, Sea Watch Foundation, and Hebridean Whale and Dolphin Trust (Embling et al., 2015; Evans and Waggitt, 2020; Gutiérrez et al., 2021); however, the extent of coastal access for the public can be a limiting factor. In order to build a network of dedicated cetacean citizen scientists, it is important to identify all potential data collection approaches (e.g. land-based versus boat-based, standardized surveys versus opportunistic approaches) to target outreach and engagement initiatives that encourage long-term data collection (Rotman et al., 2014).

Over the last 20 years, the OWSN has built a diverse and dedicated network of coastal community members who regularly report their cetacean sightings. A vital component to the success of the OWSN is the effective outreach approaches employed to continually engage coastal citizens and provide training and materials to enhance their ability to collect reliable data. One of the long-standing outreach approaches employed are *Dock Talks*, which are targeted outreach events held at marinas throughout coastal B.C. Their purpose is to engage members of the public who are active on or near the water to become observers. In addition to raising awareness of the OWSN and the importance of reporting cetacean sightings, *Dock Talks* equip the public with the knowledge and tools to identify local cetacean species and ensure that boaters are aware of the guidelines and regulations (e.g., Be Whale Wise Guidelines - www.bewhalewise.org) in place to enable safe boating in the vicinity of marine mammals. To date, the OWSN has conducted over 800 *Dock Talks* and engaged a total of 54,000 people through this 'boots on the ground' outreach approach. In addition, the distribution of educational materials (such as brochures, identification guides, and posters), the establishment of a website and social media accounts (Facebook, Instagram), the facilitation of educational community talks and training sessions, and regular media appearances have also been key approaches to engaging people to report sightings.

As a result of ongoing engagement efforts, many observers have become regular reporters to the OWSN, sending sighting reports year-after year. Between 2017 and 2021, ~76 % of observers added to the OWSN database were identified as recreational observers/boaters, which is the largest category of observers to date. In addition to this group of community members, ecotourism providers and other commercial mariners, such as Coast Guard crews and ferry operators, are a key observer group for generating sighting reports. Due to the nature of their occupations, these mariners spend a considerable amount of time on the water, and many have extensive pre-existing knowledge about identifying cetaceans. Reciprocally, commercial mariners also benefit from reporting to the OWSN as they are often incentivized by their employer (e.g., recognition and/or awards) to participate in conservation actions.

An important part of long-term engagement of citizen scientists is continuing to review and diversify outreach approaches (Brouwer and Hessels, 2019). Analysis of OWSN sighting reports in 2015 revealed that over 25 % of submissions came from shore-based hotspots rather than from boat-based observation platforms, despite the OWSN's outreach activities primarily focusing on recreational and commercial boaters. In recognition of this trend, the OWSN partnered with The Whale Trail (www.thewhaletrail.org) to promote land-based whale watching and reporting throughout B.C. and Washington State. This partnership contributed to the establishment of a total of 41 designated *Whale Trail B.C.* sites, marked by interpretive panels or trail markers. Each interpretive panel is designed in collaboration with the local community and highlights the unique features of each site, the marine mammal species one is likely to observe, and how to support conservation initiatives by reporting their sightings and adopting whale-friendly practices (e.g., slowing down in presence of whales).

3. Adapting to observer needs and technological advances

In addition to being active in identifying innovative and effective outreach approaches, it is also important to adapt engagement as well as reporting methods in response to feedback received from observers. This includes being aware of technological advancements which can streamline the reporting process whilst enhancing observer experience (Graham et al., 2011). The development of smartphone applications (hereafter apps) has streamlined citizen science biodiversity reporting (Hann et al., 2018; Luna et al., 2018). At the inception of the OWSN, observers reported sightings via email, hotline, or paper logbook. A webform was implemented in 2008 to further facilitate collection of standardized information with sighting reports. In 2015, the creation of the *WhaleReport* smartphone app enabled reporting of sightings in real-time, and increased submission of cetacean sighting reports by ~1000 sightings per year (Fig. 1). The app contains resources such as a species identification guide, an interactive map displaying marine mammal guidelines and regulations in the user's area, information on how to report dead or distressed animals, and visualization of previous sighting reports submitted by the observer. The reporting interface allows observers to report a variety of information about their sighting in a standardized format, including date, time, species, number of individuals, animal behaviour (e.g., swimming, fluking, breaching etc.), distance of the observer from the animal, exact coordinates of the sighting, sightings platform (land/boat), and extra information such as identification of individual animals from photo-identification catalogues. The app also allows users to attach up to three photos per sighting report, which helps the OWSN to verify the report.

Since its initial launch, reporter feedback has prompted several major updates to the app, including adding the ability to edit reports after they were submitted, the option to save information to submit reports at a later time (such as after re-entering an area with cell phone or internet coverage), the ability to provide more information about the sighting (e.g., killer whale ecotype), and the creation of a web application to ensure reporters can access the app on any device, including their desktop computers. Feedback from observers wishing to view maps of their own, or their organization's, past sightings and use the information for their own reporting or research purposes prompted the creation of the *OWSN Sightings Portal*, a web-based tool that allows visualization and download of sightings and associated data reported using *WhaleReport* by approved users. The user-friendly portal includes summary statistics of species sighted over various time periods and provides an additional tool for observers to see how their efforts and data are being used in conservation initiatives, management decisions and/or policy actions – an important factor in long-term retention of volunteers (Hughes et al., 2014). In addition, subsets of data from the 20-year database can be requested by members of the public, organizations, government, and industry via email, with Ocean Wise providing spreadsheets and/or maps of requested sightings.

To date, >28,000 sightings have been submitted via the *WhaleReport* app, and real-time or near real-time sightings increased 17 % in the first year following its release. These advances have allowed the OWSN to move beyond investigating cetacean occurrence and distribution in

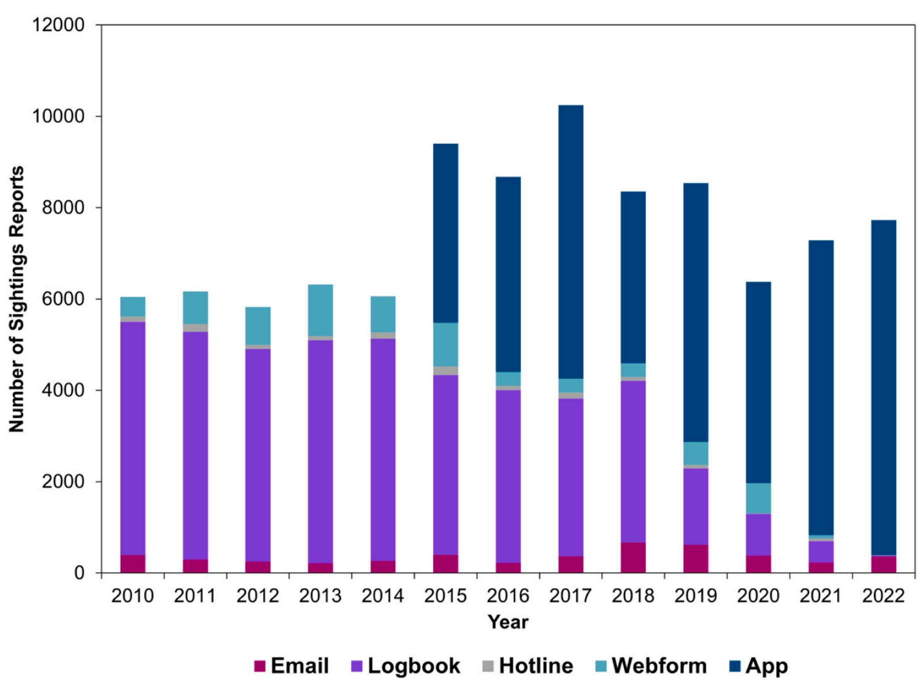

Fig. 1. Number of sightings reports submitted to the Ocean Wise Sightings Network (OWSN) from 2010 to 2022 via email, logbook, hotline, webform and *WhaleReport* app.

retrospect and move towards using these data for real-time threat mitigation.

4. Implementation of a real-time cetacean alert system

Soliciting sightings from members of the public and developing a means of collecting sightings in real-time is an important part of mitigating threats to cetaceans. However, conservation action requires buy-in from industry and government stakeholders to ensure the information is received and acted upon (Christie et al., 2017). This involves setting up a system for delivering alerts of large whales in the proximity of vessels, as well as conducting engagement with mariners to ensure they are aware of the system and how to use it to reduce their vessel's impact.

Ocean Wise’s cetacean alert system is called the WhaleReport Alert System (WRAS). The WRAS was developed in 2018 in partnership with the Vancouver Fraser Port Authority's Enhancing Cetacean Habitat and Observation (ECHO) Program and the Prince Rupert Port Authority in collaboration with a working group comprised of international marine industry professionals. The WRAS is a situational awareness tool that alerts mariners of large commercial vessels to the presence of whales in their vicinity so that they can take mitigation measures to reduce the risk of ship strike and disturbance. WRAS alerts are sent in response to real-time observations reported by mariners and coastal citizens via the *WhaleReport* app. Input from the WRAS working group and species experts during the development of the system guided technical decisions, including platforms for alert delivery and species-specific details of alert availability.

There are two systems of alert delivery in place for mariners to receive WRAS alerts; The first is the WRAS mobile app, available for professional mariners to use on their mobile devices while on the water. When a mariner is within 10 nautical miles of a reported whale, they receive an SMS text message alert. This distance was chosen by the working group based on the reasoning that this alert radius would give a less maneuverable vessel travelling at speed adequate time (~30 min) to respond to alerts with mitigative action. The mariner can then view the location of the reported whales on a map within the WRAS app, along with their current location. Clicking on an alert icon provides pertinent details such as species sighted, time and date of sighting, number of animals in the group, and direction of animal travel (Fig. 2). The second system of alert delivery is the WRAS Desktop Interface. This was designed for vessel operations centre staff to view alerts so that they can relay the information to their fleet in areas with poor cell signal or where operational protocols prevent the use of mobile phones on the bridge. Users can select areas of the coast where their fleet operates and enable audible and visual notifications when a new alert appears in their selected zone(s) of interest. Once mariners receive a WRAS alert, mariners can decide how they respond. They may choose to slow down, alter their course, turn off their sounders, increase vigilance, or dismiss the alert if other navigational hazards take priority (Fig. 2). Vessel slowdowns or avoidance are beneficial to mitigating the impact of vessel disturbance on multiple cetacean species (Burnham et al., 2022; Burnham et al., 2021; Findlay et al., 2023; Lagrois et al., 2022; Laist et al., 2014; Ménard et al., 2022). Slowdowns can reduce the overall time marine ecosystems are exposed to noise, so reducing speed in response to a WRAS alert would benefit the foraging success of whales (Findlay et al., 2023; ZoBell et al., 2021) such as southern resident killer whales (Burnham et al., 2021; Williams et al., 2021) and humpback whales (Blair et al., 2016). Mariners can choose to provide feedback on the courses of action taken in relation to specific alerts when they log out of the app at the end of their shift. This information provides the OWSN with a qualitative way of evaluating the type and frequency of mitigation measures taken in response to WRAS alerts.

Currently, the WRAS sends alerts when certain species are reported with high confidence (self-reported rating via observer), including killer whales (all ecotypes), humpback whales, grey whales, minke whales, fin whales, unidentified cetacean species and rare and rarely sighted whale species (e.g., sperm whale/North Pacific right whale/sei whale/blue whale). WRAS alerts are only generated for these species due to the existing knowledge on the high ship strike risk for these species (International Whaling Commission, 2005) and the identification of vessel strike as a critical threat to recovery (Fisheries and Oceans Canada, 2021; Government of Canada, 2006). For commonly reported species which generate alerts, there have been ~17,000 sightings reported between 2018 and 2021 (Fig. 3). WRAS alerts are delivered to ships

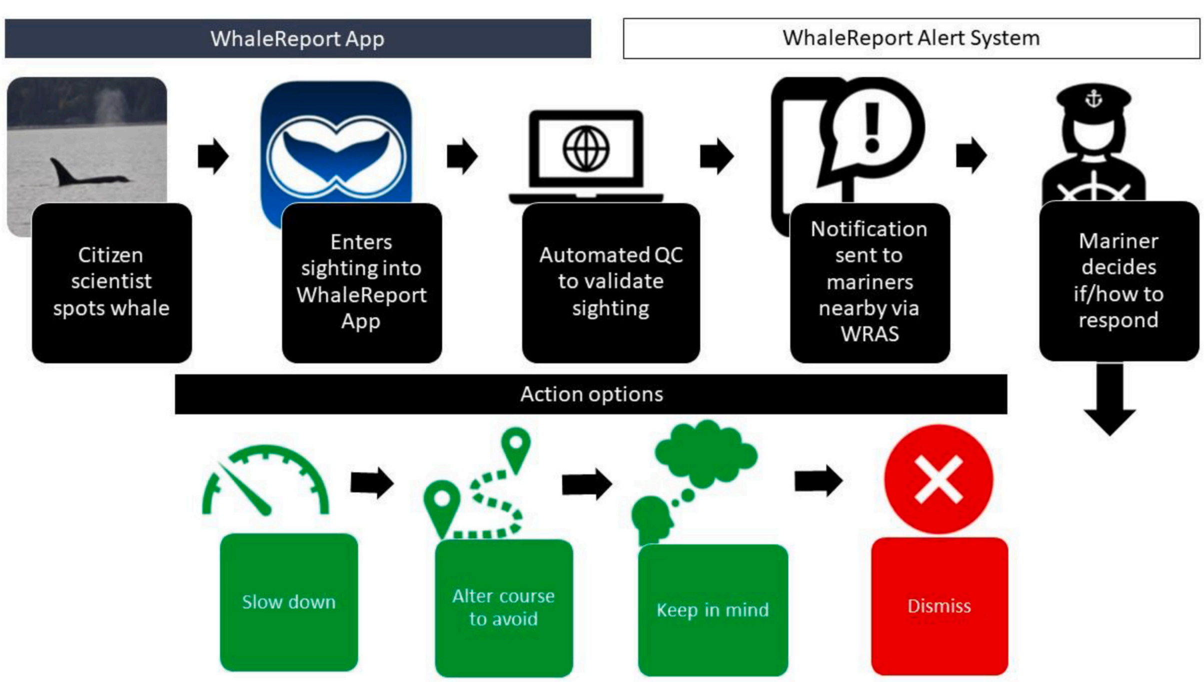

Fig. 2. Infographic of the process of sightings submission via the WhaleReport app, quality control (QC), the sending of alerts via the WhaleReport Alert System (WRAS) and action items which can be taken to mitigate the risk of ship strike.

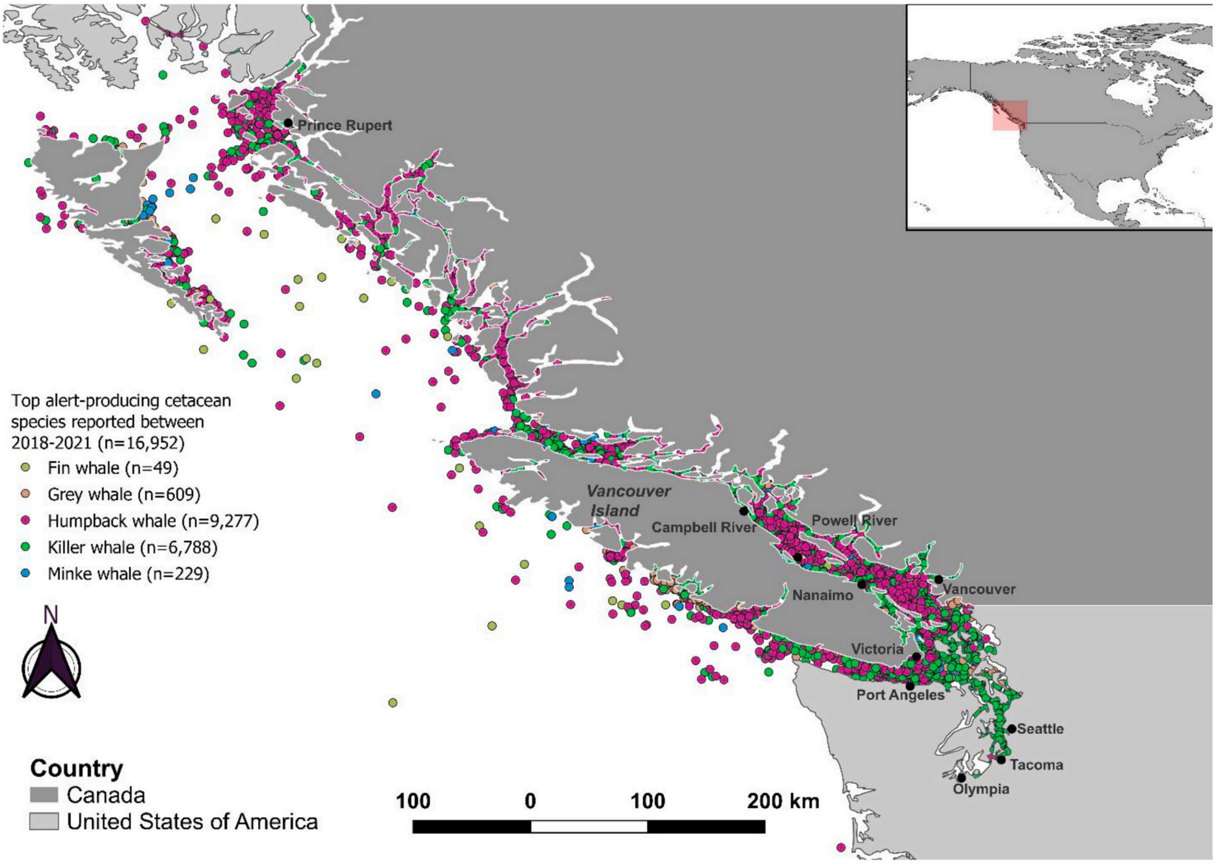

Fig. 3. Sightings reports submitted to Ocean Wise for the most commonly reported species which produce WhaleReport Alert System (WRAS) alerts between 2018 and 2021. Major cities in coastal British Columbia and Washington State are labelled. Inset map (top right) indicates the 62,000 km^2 spatial extent covered by the Ocean Wise Sightings Network (in red) in relation to wider North America. Note: Not all sightings here were reported in real-time and sightings are not corrected for effort. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

passing within a 10 nautical mile radius for species-specific time periods selected by WRAS working group experts in species distribution and behaviour patterns (e.g., foraging longevity, speed of travel, etc.; Table 1). Species such as humpback whales (Goldbogen et al., 2008; McMillan et al., 2019) and minke whales (Christiansen et al., 2013) often are observed within the same area over a prolonged period, especially when foraging, whereas species such as killer whales (Ashe et al., 2010; Dahlheim and White, 2010; Miller, 2002) and grey whales (Nelson et al., 2008; Stelle et al., 2008) are highly mobile even when foraging, and are often not observed in the same area for long time periods. The resulting three-hour alert decay time for humpback and minke whales, and 60–90-min decay time for grey and killer whales are reflective of this. The 12- h decay time for fin whales was decided due to the fact they are often observed travelling in deep, offshore waters, travelling at speeds of between ~2–8 km h^{-1} in an area where they are at high risk of collision with vessels (Nichol et al., 2017). Therefore, this long decay time aims to protect this species for prolonged periods when observed.

Table 1
WhaleReport Alert System (WRAS) species-specific alert decay times.

Species category	WRAS alert longevity
Killer whale	90 min
Humpback whale	3 h
Grey whale	60 min
Minke whale	3 h
Fin whale	12 h
Unidentified cetacean species	3 h
Rare and rarely sighted whale species (sperm whale/North Pacific right whale/sei whale/blue whale)	3 h

The functionality of this tool is similar to other ship strike mitigation tools such as Whale Safe (southwest US coast, www.whalesafe.com) and Whale Alert (US Atlantic coast, www.whalealert.org), but is distinguished from these other systems as it covers a wider geographical scale (62,000 km^2), facilitates the creation of real-time alerts from citizen scientists (no user verification), and is used by both US and Canadian government enforcement officials to monitor vessel activity in transboundary waters.

In addition to establishing apps and mitigation tools for use by observers, it is imperative to provide adequate training for users to facilitate proper usage (Rotman et al., 2014). There have been over 450 training events for coastal citizens and marine professionals for *WhaleReport* and over 120 targeted training sessions for the WRAS, with over 1000 mariners trained. These training sessions have been delivered across a variety of platforms, including face-to-face presentations, virtual training events, and creation of online training platforms, instructional guides, and manuals.

4.1. Metrics for evaluating success of the WRAS

Design and implementation of threat mitigation tools for cetaceans is only the first step in creating shipping practices with reduced disturbance. In conjunction with development and adoption of these tools, there needs to be effective evaluation of tool performance. It is important to identify measurable criteria against which assessment of the efficacy of tool implementation can be determined (McDonald et al., 2016). It is immensely difficult to establish the exact number of cetacean deaths that can be attributed to ship strikes; the current estimates are based on reported strikes and necropsies of recovered dead individuals (Winkler et al., 2020).

For the WRAS, Ocean Wise captures both qualitative and quantitative data to evaluate the relative outcomes of the WRAS alerts sent. Since its inception, over 20,000 WRAS alerts have been sent to mariners from 60 marine organizations in B.C. and Washington State waters. The WRAS has gained momentum over the past two years to become the preeminent whale alert system in the B.C. and Washington State waters and is currently used for marine situational awareness, military exercise planning, emergency response planning, and vessel monitoring and enforcement. 2021 was a record-breaking year for the WRAS, with 10,972 alerts sent (Fig. 4).

Qualitative assessment of responses to WRAS alerts was conducted via an online survey, which was completed by 167 marine professionals. Some questions included "Have you, or the vessel you were on, received a WRAS alert?", "What response have you taken after receiving a WRAS alert?", and "If an alert was received, but no action was taken, why was this?". Survey results determined that 64 % of respondents use the WRAS app >50 % of the time they are on the water and 73 % of respondents received WRAS alerts when on the water. In terms of actions taken in response to alerts, 41 % of mariners increased vigilance, 36 % of mariners decrease speed and 31 % of mariners diverted their course. Feedback form response data provided by mariners at the end of their shift is also important for determining WRAS use rates and which course(s) of action are taken in response to each alert. However, feedback form completion is low, and only a small percentage (6 %) of mariners choose to take this step at the end of their shift.

To effectively evaluate the impact of the WRAS on prompting mitigation measures in response to cetacean presence, more in-depth efficacy testing is necessary. We intend to evaluate changes in vessel speed and bearing in response to the receipt of WRAS alerts using the Canadian Coast Guard's Automatic Identification System (AIS) data. This approach has been successful at monitoring compliance of vessels with voluntary and mandatory slow downs (Burnham et al., 2021; Ebdon et al., 2020; Guzman et al., 2020; Lagueux et al., 2011; Vanderlaan and Taggart, 2009). This will enable quantitative assessment of mitigation measures taken by large vessels in response to WRAS alerts.

5. Limitations and caveats

As is often the case with other citizen science initiatives (Tang et al., 2021), there is a spatial bias in sampling effort for the OWSN, despite the fact that observers are spread throughout coastal B.C. and Washington State. For OWSN data, the majority of cetacean sightings are reported throughout the south coast of B.C. (from Powell River in the north to Capital in the south; Fig. 2), which, based on AIS data, is also the area in B.C. waters with the most vessel traffic. This overlap between high observer effort and vessel traffic can in fact bolster the application of citizen science data for mitigation tools, through observing overlaps between cetacean presence and vessel activity. The caveat to this unequal distribution of effort is the difficulty in distinguishing lack of cetacean presence versus lack of observer effort in particular areas. Species distribution models (SDMs) and effort models can be applied to reduce spatial bias of citizen science data to gain a better understanding of accurate species distributions (Sicacha-Parada et al., 2021; Tang et al., 2021). OWSN is in the process of producing SDMs to inform conservation and species management across B.C. and Washington State.

In terms of data quality, data collected by citizen scientists is

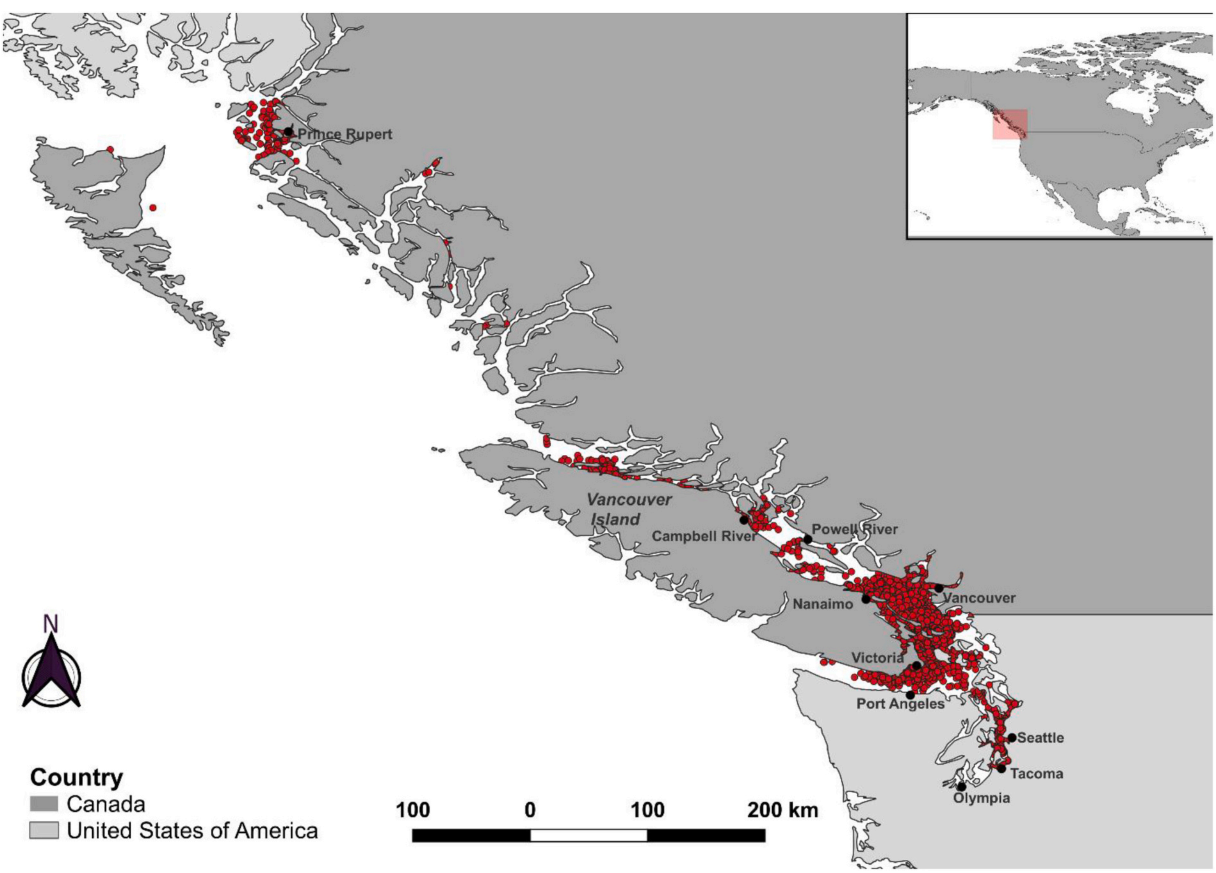

Fig. 4. WhaleReport Alert System (WRAS) alerts delivered to British Columbia & Washington State mariners in 2021. Major cities in coastal British Columbia and Washington State are labelled. Inset map (top right) indicates the 62,000 km^2 spatial extent covered by the WRAS (in red) in relation to wider North America. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

typically considered less accurate compared to data collected by scientific professionals (Kosmala et al., 2016). For sightings reports submitted to the OWSN, there is a standardized and rigorous process of ensuring the retention of high-quality data on cetacean distribution. In addition to the review of submitted photos, each sighting submission includes an observer-rated confidence of species identification (Certain, Probable, Possible, and Uncertain), to enable review of observer accuracy for each report. New observers, as well as known observers who report anything besides 'Certain', are contacted directly via email within ~2 weeks of submitting a sighting with additional questions in an attempt to verify the accuracy of their species identification. Similarly, observers that report a sighting with terrestrial coordinates or report a species in an unusual location despite a confidence ranking of 'Certain' (e.g., a blue whale in inland waters) are also contacted to obtain more accurate coordinates and to challenge species identified. After conducting these data verification steps, each sighting report is then assigned an additional confidence rating based on the information within the sighting report as a whole. These verification steps boost the accuracy of the resulting database and also provide a data quality value for researchers who request access to OWSN data for conservation projects. OWSN is in the process of automating parts of this system to improve the speed of data input into the database.

6. Future of the WhaleReport Alert System

Since implementation, the WRAS has gained widespread support of marine industry and government agencies in B.C. and Washington State, and there is appetite for the WRAS to transform from a pilot project into a tool that is fully integrated into the operational practices of ferries and other large vessels. Despite the existence of the Canada Shipping Act (2001), which details regulations for minimum-approach distance for cetaceans, and a reporting line to Fisheries and Oceans Canada for reporting ship strikes, there is no regulatory framework for shipping or vessel transiting speed in existence in B.C. Pending results of AIS efficacy testing, there is the potential to implement frameworks to reduce ship strike risk for whale species in B.C., similar to those that exist for reducing vessel strike for North Atlantic right whales. However, to achieve this and to also expand the WRAS across additional operating platforms and beyond the west coast of Canada and the US, there first must be actions implemented to improve WRAS functionality, particularly in remote areas with limited cell phone coverage. As a potential solution, the Canadian and US Coast Guard are currently examining the feasibility of incorporating WRAS alerts as Area-Specific Messages into AIS. To increase the number of WRAS alerts being sent in areas of poor observer coverage or a times of poor visibility, Ocean Wise is incorporating other methods of cetacean detection, such as other reporting apps and acoustic (Mouy et al., 2009; Sanguineti et al., 2021; Spaulding et al., 2009) and infrared detection (Richter et al., 2023; Zitterbart et al., 2020). Ocean Wise is undertaking a pilot project, in partnership with JASCO Applied Sciences and the Vancouver Fraser Port Authority, to incorporate automatic acoustic detections of killer whales from the Boundary Pass underwater listening station (Boundary Pass Underwater Listening Station | JASCO Applied Sciences).

7. Conclusions

Through meaningful engagement and collaboration with commercial, non-governmental, governmental, and community partners, Ocean Wise demonstrates how it is possible to effectively achieve the colossal task of generating distribution data on cetaceans from a long (25,725 km) but relatively unpopulated coastline. The roadmap highlighted in this study demonstrates how citizen science generated data can be verified and transformed into real-time mitigation actions that have implications for conserving cetaceans throughout B.C. and Washington State.

By amalgamating feedback directly from users, Ocean Wise has demonstrated how app and tool upgrades can enhance usability. The success of the WRAS throughout B.C. and Washington State is evidence that the WRAS could be scaled-up and implemented in other locations globally, so long as an existing sighting network is in place and observers have access to a tool that facilitates real-time reporting. Ocean Wise's systematic approach to community outreach, user training, sighting data amalgamation, maintenance of the WRAS mitigation tool, and data feedback to observers via the Sightings Portal facilitates long-term engagement of observers and mariners with *WhaleReport* and the WRAS, which in turn fosters greater temporal coverage of cetacean data collection and threat mitigation.

Overall, the WRAS serves as an important tool to significantly reduce vessel-based disturbance on cetaceans. Through the amalgamation of specific elements, including a dedicated sightings network, an effective and accessible smartphone reporting app, and a community of trained and informed mariners, observer data can be mobilized into a much-needed tool for cetacean conservation and management. Going forward, further partnership and decision-making endorsement of the WRAS within other parts of Canada, U.S. and beyond is essential to increase the spatial footprint covered by these mitigation measures.

CRediT authorship contribution statement

JLS and CVR conceived the paper, JLS, CB and CVR wrote the manuscript with input from other co-authors.

Declaration of competing interest

The authors report no declarations of interest.

Data availability

Data used for Figure 3 can be requested by contacting sightings@ocean.org and completing a data request form. More information on accessing WhaleReport and the WhaleReport Alert System can be found at www.ocean.org.

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