Fisheries and Oceans Canada / Pêches et Océans Canada

Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2024/023

Gulf Region

Survey and Data Considerations to Adopt a Multi-Whale Trigger Density for Protecting the North Atlantic Right Whale in Canadian Waters

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April 2024

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044
ISBN 978-0-660-70726-6 Cat. No. Fs70-5/2024-023E-PDF

Correct citation for this publication:

Ratelle, S.M., Hammill, M.O., Cole, T.V.N., Hardy, M.A., Crowe, L.M., and Elliott, M.S. 2024. Survey and Data Considerations to Adopt a Multi-Whale Trigger Density for Protecting the North Atlantic Right Whale in Canadian Waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2024/023. iv + 32 p.

Aussi disponible en français :

Ratelle, S.M., Hammill, M.O., Cole, T.V.N., Hardy, M.A., Crowe, L.M., et Elliott, M.S. 2024. Considérations relatives aux relevés et aux données en vue de l'adoption d'une densité de déclenchement multi-baleines pour la protection de la baleine noire de l'Atlantique Nord dans les eaux canadiennes. Secr. can. des avis sci. du MPO. Doc. de rech. 2024/023. iv + 36 p.

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ABSTRACT

The role of Canada in protecting the endangered North Atlantic right whale (NARW) and promoting their recovery is crucial as a large proportion of the population spends all or part of the spring, summer, and autumn months in Canadian waters. Starting in 2018, Fisheries and Oceans Canada (DFO) and Transport Canada (TC) used the presence of a single whale to trigger management actions in some areas such as the Gulf of St. Lawrence or NARW Critical Habitat in Canadian waters. Outside of these areas, a trigger applied for dynamic management in the Unites States of American (USA), and based on a minimum density of 0.04 whales/nm^2 or equivalent to three or more whales separated by less than 5.5 nm (10.2 km) from each other, was implemented. This minimal density trigger is rooted in the idea that group size may be a reasonable indicator of whales persisting in a region. Whether this density is adequate for Canadian waters given the observed variability in habitat characteristics and NARW behaviour is, however, unknown.

This paper addresses the information required to reliably locate NARW aggregations, the challenges in identifying and enumerating NARW given the current monitoring framework, the information needed to develop a tailored density trigger in Canada, and short and long-term considerations to enhance NARW protection in Canada.

This advice was developed in a peer review meeting in 2018 and should be interpreted within the context of the situation at that time. It was concluded that there were insufficient information to develop a multi-whale management trigger specific to Canadian waters. An approach using multiple whales to trigger management actions would require methods designed to assess the number of individuals and their persistence in a given area, as well as other operational requirements. Data on NARW over multiple years would also be required to assess the probability of reliably detecting NARW, as well as NARW persistence, habitat use, and behaviours in Canadian waters, and to determine if the approach used in the USA is appropriate for Canada.

INTRODUCTION

The North Atlantic Right Whale (NARW) has a broad geographic range typically extending along the eastern North American Seaboard from Florida to Atlantic Canada. For the last four decades, aerial and shipboard surveys have photographed individuals to track their movements and monitor the species' status (Pace et al. 2017).

From the 1980s through 2009, the majority of NARW in Canadian waters were routinely sighted by surveys in the Bay of Fundy (BoF) and Roseway Basin areas during summer months. A few individuals were photographed opportunistically in the Gulf of St. Lawrence (GSL), but sightings were sporadic, with fewer than 12 individuals reported in most years (DFO 2014; Daoust et al. 2018). However, between 2010 and 2013 there was a notable shift in NARW distribution, with a decline in NARW observations in the BoF (Davies et al. 2019; Davis et al. 2017) and, beginning in 2015, a sharp increase both in NARW acoustic activity (Simard et al. 2019) and in directed survey effort and observations of NARW in the GSL (Cole et al. 2016; DFO 2020). For instance, the number of individually identified whales photographed in the GSL rose from 48 in 2015 to 133 individuals by 2017 (NARWC 2018; Crowe et al. 2021). This apparent shift in NARW distribution is thought to be associated with changes in prey abundance (Sorochan et al. 2019).

The GSL is an important area for commercial fisheries with more than 50 species targeted (e.g., groundfish, pelagic, and shellfish fisheries). In addition, approximately 6,400 commercial vessel annual transits for both domestic and international trade are observed (e.g., petroleum, mining, forestry, fishery and agricultural products, cruise ships, and ferries), calling at more than 40 ports throughout the area (Alexander et al. 2010).

In 2017, 12 NARW mortalities and five live-entanglements were documented in the GSL. Seven of the dead animals were necropsied to determine cause of death; two animals died from entanglement in fishing gear, four animals died from acute trauma consistent with vessel strikes, while cause of death could not be determined for the seventh (Daoust et al. 2018). These mortalities, plus another five in the United States of America (USA), represented the highest annual mortality recorded since the cessation of whaling, and a five-fold increase from the average reported annual mortality from 1970 to 2009 (i.e., 3.1/year) (Meyer-Gutbrod et al. 2018).

Since the spring of 2018, the Canadian government implements multiple protection measures aimed at reducing the threat of collision with vessel traffic and entanglement from fixed-gear fisheries (Fisheries and Ocean Canada (DFO)/Transport Canada (TC) 2018; Davies and Brillant 2019; DFO 2023). A dominant focus of the measures includes designating zones subject to seasonal and/or dynamic restrictions where the detection of NARWs trigger management action(s) (Figure 1). In the GSL and NARW Critical Habitat (CH) in Canadian waters, the presence of a single whale (and subsequently, acoustic detection of NARW [starting in 2020]), has been used as a trigger. Outside of these areas, a density trigger, developed specifically for NARW (Clapham and Pace 2001) and applied for dynamic management in the USA (NOAA 50 CFR Part 224 2008), or the presence of a mother-calf pair triggers management action.

The development of NARW management approaches in the USA was rooted in the assumption that foraging whales are more at risk of entanglement or vessel strike than whales traveling through an area. For that purpose, the analyses of Clapham and Pace (2001) were used to define protection zones in areas with annually predictable occurrences of NARW (e.g., Seasonal Management Areas [SAM]) and where NARW occur randomly (e.g., Dynamic Management Area [DMA]). Clapham and Pace (2001) examined 17 years of sightings data off Massachusetts USA to determine if there was any relationship between the number of NARW in an initial sighting and the likelihood of subsequent sightings in the following 10 days, with the assumption that any persistence of whale sightings within the 10 days was an indication of foraging. Of the 50 initial sightings of one or two whales, 29 were identified in subsequent sightings within 10 days, while all 13 initial sightings involving three or more whales were identified in subsequent sightings during the following 10 days. They identified the minimum initial sighting density of 0.04 whales/nm^2 from these 13 events as a reasonable trigger for a closure, which corresponds to three or more whales separated by less than 5.5 nm (10.2 km) from each other. The average duration of these 13 events, from the initial sighting to the last sighting, was 15 days. In the absence of similar data from Canadian waters, this minimum density approach (or presence of mother-calf pair) was applied to Canadian waters outside of the CHs and GSL starting in 2018.

Overall, the management approaches adopted since 2018 appear to have reduced mortalities compared to 2017 with the exception of 2019. However, the measures and mechanisms used to protect the whales have not been fully effective considering the intended objective *'…preventing* gear entanglements and vessel collisions' *(The Honourable Dominic LeBlanc, Minister of Fisheries, Oceans, and the Canadian Coast Guard [CCG],* 28 March 2018*).* In fact, cases of vessel strikes and entanglements (gear present) or fresh entanglement injuries (no gear present but sighted with fresh entanglement-related injuries within the period of presence in Canadian waters) have been reported, primarily in the GSL (Pettis et al. 2018; Pettis et al. 2020; Bourque et al. 2020; Pettis et al. 2021; Pettis et al. 2022; Pettis et al. 2023).

Many uncertainties need to be addressed to better understand NARW use of Canadian waters and to protect them throughout their occupancy. One consideration is whether the minimum NARW density trigger developed for USA waters is adequate for Canadian waters given the observed variability in habitat characteristics and NARW behaviour. An efficient implementation of such a measure is expected to require high capacity to detect one versus multiple whales in varying sighting conditions while acknowledging differences in NARW behaviours (e.g., dive patterns) over time and space. Here, we examine the challenges and methodologies used in Canada to detect NARW, and determine if/what additional data and/or surveillance would be needed to reliably develop and/or adopt a multiple-whale trigger to implement protection measures in the future. Specifically, this paper addresses the information required to reliably locate NARW aggregations, the challenges in identifying and enumerating NARW given the current monitoring framework, the information needed to develop a tailored density trigger in Canada, and short-term and medium to long-term considerations to enhance NARW protection in Canada.

The information presented follows from a formal scientific assessment and National Marine Mammal Peer-Review Committee (NMMPRC) process conducted during November 2018. It focused on reviewing NARW occurrence as well as risk of entanglements in fishing gear and vessel strikes in Canadian waters. Only data available up to 2018 was analysed as this document informed the Science Advisory Report published in early 2019 (DFO 2019).

CHALLENGES ASSOCIATED WITH NARW OBSERVATIONS

The probability of detecting a whale is a function of the amount of time a whale spends at the surface and an observer's ability to detect it, termed availability bias and perception bias, respectively (Marsh and Sinclair 1989; Hain et al. 1999). At the time of this study in 2018, there were no availability estimates nor associated diving behaviour budgets in contemporary NARW habitat areas in Canada. NARW are difficult to visually detect because they spend the majority of their time beneath the ocean surface in addition to their black colouration, low swimming profile, lack of dorsal fin, low numbers, and generally solitary travelling behaviour (Hain et al. 1999; Brown et al. 2007). Weather conditions, which can be challenging during much of the year, also play a critical role in detection.

In addition to detection challenges, but important to informing protection efforts, ascribing whale behaviour (e.g., feeding, travelling) is inherently problematic without benefit of extensive activity data throughout their range and across seasons (Nowacek et al. 2016; Goldbogen et al. 2013; Ganley et al. 2019). The exception being discernible behaviours observed (or inferred) at the surface, which are currently noted during some surveys (e.g., surface-feeding, Surface Active Group [SAG; group of NARW engaged in mating and social behaviour at the water's surface], 'mud on the body/head' indicating seafloor encounters [Hamilton and Kraus 2019]).

Critical to adopting a multi-whale trigger for management measures, visual survey teams must be able to differentiate and/or identify individual NARW in order to provide reliable numbers of individuals within an area over a given time. This is especially challenging as the recorded number of whales in a group varies when an aircraft passes overhead because not all animals are at the surface at the same time (Cole et al. 2020). Another confounding factor is the ability to enumerate the individuals in a SAG. The ephemeral nature of the SAG (e.g., time in group, individuals joining and leaving the group) as well as the group size, activity level, and/or if animals are submerged for a length of time make it difficult to accurately record the number of individuals (Parks et al. 2007). The work requires experienced observers who can differentiate NARW within a group by their specific markings (e.g., callosities, scars).

CURRENT METHODOLOGIES FOR DETECTING NARW IN CANADA

DFO has emphasized the development, training, and coordination of all available 'eyes on the water' (e.g., observers and officers on aerial and vessel platforms, At-Sea-Observers, general public) to develop an expansive NARW detection and reporting network with information readily available to science, regulatory, industrial sectors, as well as the public (WhaleMap; Johnson 2021; Whale Insight / Baleine-en-Vue).

NARW surveillance involves multiple platforms including DFO Science multi-species surveys (aerial and vessel) and fixed acoustic stations, DFO Conservation and Protection (C&P) enforcement aircraft and vessels, TC aircrafts, USA Government (NOAA) aircraft, DFO / Industry / university autonomous acoustic gliders, NGO research vessels, and opportunistic observations. There are technical challenges associated with each platform. For example, aerial and vessel surveys can only be carried out when sighting conditions are suitable and require trained personnel. Animals can only be detected during the day, if they are at the surface, and are within visibility range. Further, survey protocols and observer experience can vary widely among platforms. However, vessel and aerial surveys collect data that can be used to estimate abundance, and contribute to life history information on individual whales that are important to monitor for births, deaths, and reproduction. Additionally, vessel surveys provide an opportunity to collect biopsy and fecal samples for ongoing genetic and endocrine studies. In comparison, acoustic recorders are able to detect animals nearly continuously provided that they vocalize within the detection range of the instruments. The detection range of a recorder is affected by ambient noise, the instrument specifications (e.g. hydrophone sensitivity), the acoustic properties of the water column, and the characteristics of the signal to be detected (e.g. frequency range, source level). Further, acoustic analysis protocols and analyst experience can vary widely among platforms.

The best tool to survey and monitor the presence of NARW depends on the objective of the defined research, monitoring, and/or management goals which determine the method(s) best suited to address needs. Each research and monitoring method employed has strengths and weaknesses and in most cases, multiple survey and detection platforms will provide the best approach to meet a range of objectives. As mitigation efforts are highly dependent on effective aerial monitoring programmes, and to remain within the scope of this paper, details of all other efforts (e.g., vessel surveys, acoustic platform) are limited and/or not included.

AERIAL MONITORING

Surveys in all regions and by all organizations are typically conducted only on days with good visibility and wind forecasts of 15 knots or less. The decision criteria used by DFO and TC in 2018, as well as in subsequent years, is presented in Appendix 1. These general criteria provided basic sighting condition quality control across regions and surveys that meet national and international standards.

However, surveys varied in their objectives and thus associated methodology and included: assessing species distribution and abundance, management of anthropogenic activity, individual identification and monitoring, and/or exploratory searching to locate whale habitat areas. Additional differences amongst surveys involved: observer experience, observer number, observer configuration (single or double platform), transect width, flight altitude, and/or aircraft speed. These variations in survey methodologies can affect detection rates as well as the scope of the subsequent data analyses (Hain et al 1999; Borchers 2005; Lawson and Gosselin 2009; Thomas et al. 2010; Roberts et al. 2016).

Although survey objectives and design differed, all aerial (and vessel) survey effort collected the basic data and included, but are not restricted to: marine mammal species identification, time of sightings, location of sighting, pod size, and frequently, associated imagery of NARW. Certain surveys also collected sighting conditions, effort metrics, and notable behaviours as part of survey protocols. A description and comparison of the main aerial surveys are presented below and in Table 1.

Canadian Government Surveys in 2018[1]

The Canadian government developed objectives for an aerial surveillance programme to allow the DFO and TC to implement mitigation measures to reduce mortality of NARW, and, for DFO, to update marine mammal information to partially address USA *Marine Mammal Protection Act* (MMPA) requirements. Specifically, programme goals were to:

1. Improve information on the distribution of NARW in the main shipping zones (GSL);
2. Improve information on the distribution of NARW in the main fishing zones (GSL and CHs);
3. Improve information on the distribution and abundance of NARW in eastern Canada;
4. Obtain information on the relative spatial and/or temporal overlap of NARW and these human activities to evaluate mortality risk from shipping and fishing in Canadian waters;
5. Improve information on the abundance and distribution of other marine mammals and other megafauna in eastern Canadian waters.

Although some of the data collected are considered opportunistic rather than obtained through dedicated survey efforts, over 120 DFO officers, Provincial Airlines Limited (PAL) pilots and technicians, TC pilots and National Aerial Surveillance Program (TC NASP) technicians, and dedicated marine mammal observers were instructed by the DFO Science marine mammal

[1] All described aerial survey and surveillance programmes have continued each year as described, have been modified to meet programme objectives, and/or efforts have expanded.

experts in survey methodologies, marine mammal identification, and reporting protocols to augment capacity and complement other survey efforts.

DFO Science Survey

In 2018, the DFO Marine Mammal Science surveys covered much of eastern Canadian waters multiple times (DFO 2020; Whale Insight / Baleine-en-Vue). The DFO Science efforts used a systematic design where data were collected using a line-transect approach with parallel lines spaced 5 nm apart (Table 1; Figures 2 and 3). The survey goals were to:

1. Obtain data on distribution and abundance of all marine megafauna (e.g., marine mammals, turtles and basking sharks) in support of DFO's protection of marine ecosystems and species, requirements under the *Species at Risk Act*, and as part of the response to the USA *Marine Mammal Protection Act* (MMPA) Import rule (MMPA-section 117) requirements (NOAA Fisheries 2019).
2. Increase information on the distribution and abundance of NARW. This platform did not focus solely on the aggregations in the GSL, but when NARW were sighted, the aircraft broke from the transect, circled the NARW for up to 20 minutes to obtain more information on group size then rejoined the transect from the break-off point. Photographs were also taken for individual identification and documenting the condition of the animals.

TC NASP Survey

In 2018, TC dedicated a NASP aircraft (i.e., Dash 8 or Dash 7) to regularly monitor the dynamically-managed shipping lanes in the northern Gulf of St. Lawrence for the presence of NARW. DFO provided marine mammal observers for the TC NASP systematic survey of the Dynamic Shipping Sectors (DSS; aka. Dynamic Shipping Zones; Figure 1) which were patrolled twice within a 7-day period capturing data and imagery (primarily video) of large-whale observations. The TC NASP survey was also conducted using a systematic line-transect approach with parallel lines spaced 5 nm apart covering the entirety of the DSS (Table 1; Whale Insight / Baleine-en-Vue). Only limited information on other marine species was collected although opportunistic sightings of NARW were reported during transit to and from DSS and during other surveillance missions.

DFO Conservation and Protection Surveillance

The primary mandate of DFO's Conservation and Protection (C&P) Air Surveillance program is to monitor fisheries compliance; however, in 2018, emphasis was placed on NARW observation and reporting. DFO C&P assets were tasked with the monitoring of mitigation measure compliances including the cessation of fishing activities in closed areas, gear monitoring, and monitoring for NARW presence in closed areas capturing data and imagery (primarily video) (Table 1).

NOAA Surveys

In 2018, the National Oceanic and Atmospheric Administration- Northeast Fisheries Science Center (NOAA-NEFSC) researchers carried out a NARW Mark-Recapture study to understand the number and movements of whales in Canada. The survey design emphasized photographic identification of individual NARW rather than area coverage as such, efforts were focussed mainly on the southwestern GSL aggregation area (Cole et al. 2020; Whale Insight / Baleine-en-Vue). The NOAA researchers collaborated with Canadian researchers and remained flexible in areas to be examined, targeting locations with systematic and opportunistic sightings, historical sightings, and/or acoustic detections (Table 1; Figure 2) therefore, little effort and few sightings outside of this area were obtained from this platform. The team recorded multiple details for each individual NARW observed, other large baleen whales (excluding minke whales), sperm whales, and other special occurrences such as lost/abandoned fishing gear in the vicinity of NARW as reported by other surveys. A comparison of the typical survey patterns conducted by the NOAA NEFSC team in contrast to the DFO Science team in 2018 is illustrated in Figure 3.

OTHER VERIFIED SIGHTINGS

In 2018, sightings were also submitted from identified trusted sources (i.e., trained marine mammal observers) onboard various platforms and from other sources if accompanied by verifiable imagery. These validated sightings were all considered within the context of the protection management framework and included in the sightings database.

Researchers from the New England Aquarium (NEAq), Dalhousie University (DAL), and the Canadian Whale Institute (CWI) continued their annual surveys of both the Bay of Fundy, concentrating in the Grand Manan Basin, as well as the southwestern GSL, primarily the Shediac Valley and Orphelin Bank area. The Mingan Island Cetacean Study (MICS) research group also continued their long-term large whale surveys along the Quebec North Shore in the Mingan Island / Anticosti region, the Gaspe Peninsula and St. Lawrence Estuary.

DFO marine mammal observers were onboard multiple research vessel surveys throughout the GSL during the spring, summer, and fall, and in the Bay of Fundy and Scotian shelf in July and September. Additionally, several NARW sightings were reported opportunistically from platforms without associated search effort (e.g., DFO C&P officers and Science staff onboard Canadian Coast Guard Ships, At-Sea-Observers).

All Government of Canada (GoC) captured imagery (i.e., photo and video) or submitted to DFO are included in the NARW Catalogue. The NEAq, who curate the NARW Catalogue, finalizes the NARW identification, although the matching process is time consuming and typically not completed until the following year.

PRELIMINARY ASSESSMENT OF A MULTI-WHALE TRIGGER IN CANADIAN WATERS

Clapham and Pace (2001) analysed long-term vessel-based sightings data within a relatively small area to identify a persistence trigger as well as the likely duration of an aggregation event. The analysis found that an initial sighting of three or more whales was associated with whales persisting in the area for an average of 15 days. The authors then established a buffer area that contained the subsequent sightings of the whales for a 15 day period. Although the Clapham and Pace (2001) study was based on observations from a different geographical area, the data represent a respectable time series of observations that could be built upon.

In the absence of analogous data (e.g., long time series, repeated/daily surveys in an area) in Canada at the time of this review, the 2018 NARW sightings data from the NOAA NEFSC surveys and the DFO surveys, both conducted in Twin Otters, were compared. Although the aircraft were nearly identical, the survey design and objectives differed as noted above. The Clapham and Pace (2001) Local Area Density Method (LADM) was used to retroactively evaluate the data to examine the frequencies of closures that would have resulted from using the density trigger as per the USA model (Appendix 2).

The NOAA aerial survey team concentrated in an area approximately 6,300 km^2 (southwest GSL) and reported 941 sightings throughout the 26 survey days between 4 May and 12 August 2018. The range of daily sightings reported was between 10 and 76 NARW (average = 36 NARW; median = 37 NARW). When applying the USA LADM to evaluate if trigger criteria were met, each survey day (n = 26) resulted in up to three different triggers (total = 43 triggers; median = 2 triggers/day) with varying core areas (i.e., the extent of the aggregation). Only 5% (49 of 941) of the total number of sightings did not meet trigger criteria (i.e., likely transient whales). However, it should be noted that the NOAA flights were designed to go where whales were expected to be or had already been observed.

In comparison, the DFO Twin Otter, same visual platform as used by NOAA, surveyed throughout the entire GSL, Bay of Fundy, Scotian Shelf, and southern Newfoundland over 106 survey days from 3 April to 25 November, reporting a total of 98 NARW sightings during 13 of the survey days. The range of daily sightings reported was between one and 17 NARW (average = 8 NARW; median = 6 NARW). When applying the USA LADM to evaluate if trigger criteria were met, seven of the 13 survey days resulted in up to two different triggers (total = 8 triggers; median = 1 trigger/day) with varying core areas, while 22% (22 of 98) of the total number of sightings did not meet USA trigger criteria (i.e., likely transient whales).

DISCUSSION

Right whales are likely to remain in an area where resources important to the whales occur. The whales will adapt accordingly when the resource does not meet their needs, as observed recently, when a large portion of the NARW population shifted their main area of summer distribution from the Bay of Fundy / Gulf of Maine to the GSL (Hayes et al. 2018; Davis et al. 2017). Given the observed shift in NARW distribution, it is important to continue to carry out surveys and collect the prey data required for modelling in order to understand why these shifts occur (for any species) and if they will continue, particularly in a period of changing climate (Record et al. 2019).

To further inform survey efforts, studies to characterize the NARW use of the GSL, including diving behaviour, are critical to increasing the accuracy of availability bias and abundance estimates (Ganley et al. 2019). NARW diving behaviour changes throughout the seasons (e.g., diurnal and/or nocturnal feeding, social activity) within and amongst habitats (e.g., feeding grounds, calving grounds) but is also a function of its activities (e.g., feeding, travelling) and/or its associations (e.g., mother-calf pair, SAG) (Nowacek et al. 2016; Goldbogen et al. 2013; Ganley et al. 2019). For example, Roberts et al. (2016) discuss different availability estimates throughout the NARW range from multiple different dive behaviour studies. They estimated that individual whales spent 33% of the time at the surface in feeding grounds in the northeast USA (CETAP 1982) compared to approximately 22% in Bay of Fundy feeding grounds (Baumgartner and Mate 2003; Nieukirk 1992). In contrast, pairs of whales (likely mother-calf) spent 73% of the time at surface, with this proportion increasing to 86% for groups of three or more (likely SAG) in USA waters (Hain et al. 1999). Long-term implantable satellite tags could fill in data gaps and improve our understanding of NARW habitat use (e.g., identify new foraging areas, seasonal extent of NARW presence in high-risk area, other shifts in distribution, important migration corridors). However, technological (e.g., short-battery life) and logistical constraints (e.g., tagging all individuals), and concerns about their impact on the whale's health renders broadscale tagging unfeasible at this time (Moore et al. 2012; Oleson et al. 2020; Davies and Brillant 2019).

Clapham and Pace (2001) suggested that daily effort over long periods of time in a single area was needed to address the question of how many whales need to be seen to reliably predict that other sightings will occur. The biggest impediment to identifying a trigger for whales is the need for comparable and uninterrupted multi-season NARW sighting records. At the time of this review, the only comparable effort and survey area were from the NOAA surveys from 22 June to July 29 for 2017 and 04 June to 12 August for 2018. The only effort during other months was by Canadian platforms in 2018, which was more varied and systematically covered large areas owing to the multiple objectives of these surveys (Figure 2). The Canadian surveys reported approximately 15% of the total aerial sightings (Table 2), and typically covered the same zones only once or twice a month. This coverage frequency did not allow an evaluation of NARW persistence following the Clapham and Pace (2001) or other methods. Although the NOAA aerial survey team concentrated in the area of the NARW aggregations and provided a large sample of sightings, their limited spatial coverage of the southwest GSL does not provide sufficient information of the spatial extent of potential closure areas (Figures 1 and 2).

Aerial surveys for mitigating anthropogenic impacts in the southeast USA are a special case survey where the objective is to detect all, or nearly all of the NARW present in the area of interest to alert ships of whale presence (Hain et al. 1999). In cases where the whales remain in the surveyed area and the weather is conducive to multiple flights, a large proportion of the whales present are expected to be detected. In contrast, transitory animals are likely to be missed, as are any whales present during poor weather conditions (Hain et al. 1999; Brown et al. 2007). Predictably, the majority of the sightings reported in 2018 were provided by the NOAA aerial survey team as their effort was concentrated in the area of the NARW aggregations, and their objective was to photographically capture as many individuals as possible (Table 2). In contrast, the DFO effort was designed to cover more areas in a systematic manner, and spent less time in the aggregation area resulting in fewer NARW observations. The resulting sightings data from the DFO was therefore not designed to identify ‘events’ of repeated NARW sightings within a short time frame to evaluate a multi-whale trigger.

Additionally, while the observed distribution of NARW in both 2017 and 2018 does coincide with seasonal peak abundance of their prey, *Calanus* spp., in the southern GSL, there are substantial differences in bottom depth, spatial and temporal variability in environmental characteristics as well inter-annual and seasonal variability in NARW prey abundance within and amongst sub-regions (e.g. southern and west-east regions) (Sorochan et al. 2019; Plourde et al. 2019; Gavrilchuk et al. 2021). This spatial and temporal variability in habitat characteristics will inherently affect environmentally-driven NARW behaviours which in turn could impact the effectiveness of protection measures. These seasonal and inter-annual changes, including NARW distribution, should be considered before applying an all-encompassing NARW density measure of persistence throughout the season and for all eastern Canadian waters.

Clapham and Pace (2001) felt that imposing restrictions based on a single animal are unlikely to result in effective management since animals are likely to move out of the affected management zones by the time the restrictions are implemented. However, variability in our ability to detect NARW (e.g., diving, unsuitable weather conditions for surveillance, variable and unclear acoustic vocalization), to ascribe a behaviour (e.g., feeding, travelling), and the challenges with differentiating between a lone NARW versus multiple whales surfacing asynchronously, presents significant challenges to any management approach founded on timely NARW detections and enumeration.

In order to consider a multi-whale trigger, clearly outlined criteria are needed (e.g., numbers of whales or density, area considered) and may require tailored surveys to optimize detections to reliably find and count NARW. A re-evaluation of the timing and distribution of aircraft-based surveys to ensure appropriate coverage of the NARW distribution is maintained may also be needed (Asaro 2012). For example, a series of repeated systematic surveys, possibly with transect spacing less than 5 nm apart and with a limited circling protocol to increase endurance, would be a possible approach. Owing to the large area to be covered in Atlantic Canada and the observations made in 2017 and 2018 (and subsequent years), repeated fine scale surveys of the southwestern GSL and possibly northwestern Anticosti Island would be useful.

Additional considerations for a multi-whale trigger include: the ability to determine if sightings are of the same or different individuals, the development of methods to integrate near-real time data collected from multiple sources if more than a single platform is used, and the ability to promptly analyse and disseminate findings. It is important to note that any approach requiring identification of individual whales also creates data collection and implementation challenges. As emphasis on imagery collection (i.e., circling protocol) reduces survey endurance, imagery are not always prioritized, are only partially collected (i.e., not all individuals photographed), and/or images are not useable for identification. Furthermore, individual identification results are likely not available in near-real time to inform management decisions.

A significant commitment to monitoring NARW distribution and abundance is essential for managing NARW recovery. In 2018, the Canadian government implemented an extensive monitoring effort with multiple detection methodologies to improve knowledge of NARW in our waters, and applied a single or multiple whale trigger depending on area, to initiate management actions and provide expeditious protection for this endangered species. Detection approaches which provide presence information without explicit quantification (e.g., acoustic detections, thermal imaging) do not offer the information needed to implement a density-based trigger but can also be affected by whale behaviour (e.g., variable calling rates, swimming beyond detection ranges) and local conditions (e.g., sound propagation disruption, fog) (Durette-Morin et al. 2019; Zitterbart et al. 2013). Conversely, the benefit of detection methodologies such as acoustics and thermal imaging are not similarly hindered by the same conditions required for aerial and vessel survey (e.g., sea state, daylight). These technologies provide opportunity to identify NARW presence, and possibly, NARW persistence when visual observations are not possible.

The objective of this paper was to examine the methods used for surveillance in 2018 and to determine if/what additional information is needed to use the existing and/or develop a density-based trigger. At the time of this analysis, there were insufficient comparable data to develop a multi-whale trigger applicable to the extent of the NARW distribution and occupancy in eastern Canadian waters. Data on NARW over multiple years will be required to assess the probability of reliably detecting NARW, as well as NARW persistence, habitat use, and behaviours in Canadian waters. These data could then be analysed to determine if the approach used in the USA is appropriate for Canadian management measures or if a novel approach is more suitable. It is important to consider that occurrence and distribution of NARW is linked to changes in their environment. Therefore, there is a need to assess if seasonal and inter-annual changes affect the robustness of the trigger and to periodically revise, and update, analyses to reflect relevant information on habitat use and changes in occurrence and/or distribution (NOAA 2004; Davis et al. 2017).

FURTHER CONSIDERATIONS

To reduce the potential mortalities of NARW, there is a need to expand temporal and spatial distribution data to further develop, improve, and subsequently implement targeted mitigation measures such as vessel slowdown zones and seasonal closures of fisheries. Even if a single whale in a high human-use area is at a non-zero risk (DFO 2014), the application of a single whale versus a whale density trigger for management measures is ultimately based on risk tolerance, which is a policy decision.

All survey and monitoring methods used in 2018 provided relevant scientific and monitoring data and should not be discontinued, although may be modified as objectives change. The way these methods are used may vary depending on management and research objectives, acknowledging that some questions also require the combination of two or more methods to answer. It is essential to identify the key questions that need to be addressed and how these can be prioritized.

However, in the short-term:

1. Given the extent and high cost of monitoring operations, consider establishing protected areas where NARW predictably occur in space and time (i.e., areas of restricted activity) and refine these areas as new data become available.
2. Consider directed surveys dedicated to monitoring NARW, especially during high anthropogenic activity. Density triggers are fundamentally linked to the capacity of survey teams to detect and enumerate the animals, therefore it is necessary to prioritize and/or improve NARW sighting rates and enumeration. The ideal approach would include: chartering effective aircraft, repeated weekly surveys with more closely spaced lines, limiting circling (e.g., 20 minute) to maximize spatial coverage and survey endurance, and employing marine mammal observers experienced in survey methodologies, NARW detection, individual NARW distinction, and reporting.
3. Consider the addition of a presence-based trigger by incorporating acoustic detection or acoustic persistence from various real-time reporting technologies equipped with passive acoustic monitoring (PAM) systems (e.g., autonomous glider equipped, stationary buoys).
4. In order to consider only managing non-transient whales, continue to implement the USA trigger density protocol (0.04 whales/nm^2) in absence of long-term data, as an indicator of persistence. Although this reduces demands on monitoring teams, it would require efficient data dissemination structure as well as increased and coordinated data analysis and reporting capacity. NARW observations will need to be evaluated in near-real time to determine if the trigger threshold is met (e.g., Appendix 2), results expedited to resource managers, and sightings from multiple sources (i.e., possible duplicates) would need to be included to account for unavailable near-real time and/or all-inclusive (i.e., missing NARW imagery) individual NARW identification analyses.

Considering the observed extent of NARW distribution in eastern Canadian waters in recent years, as well as the increase in sighting effort, a comparison of persistence metrics (e.g., density, time, behaviour) amongst areas would be beneficial to evaluate the applicability of a ‘broad brush’ versus a customized approach to NARW protection in Canada. As such, medium and long-term studies could include:

1. Expansion and analysis of temporal and spatial coverage data to identify the extent of NARW occurrence and the areas of predictable annual concentration, to establish dependable season timelines and management areas (Merrick et al. 2001; Parks et al. 2012).
2. Analysis of sighting history and survey effort in main areas of NARW distributions (e.g., southern GSL, northwest GSL, Bay of Fundy, Roseway Basin) to identify the time interval between ‘events’ (e.g., 10 days; Clapham and Pace 2001) and assess the magnitude (i.e., number of whales and radial distances amongst whales) and duration of these ‘events’. The analysis would include the identification of the density of whales (aka. trigger) that would indicate persistence in an area for X days (e.g., 4 whales/100 nm^2 will remain in the area for 15 days [Clapham and Pace 2001]).
3. Analysis of sighting history and survey effort in main areas of NARW distributions (e.g., southern GSL, northwest GSL, Bay of Fundy, Roseway Basin) to assess the area buffer around the aggregation that would include all NARW sightings throughout the duration of an ‘event’. Clapham and Pace (2001) did identify a 15 nm extension of the core aggregation

area boundaries to account for movement of whales during an ‘event’. The protection buffer applied in Canada during the 2018 season included the eight management grids around the core sighting grid for 15 days. The scope of the buffer area will depend on the number and distribution of whales, and the resulting closure area will vary depending on protection protocols applied (Appendix 3).

4. Retrospective evaluation of the management measures applied for NARW protection amongst years while considering the number of whales triggering each management event (e.g., fisheries closures, slow down zone), the average length of implemented measures, survey/resighting history within each area, and the percentage of identified individual NARW within the trigger. The latter analysis could be expanded to individual NARW movement within triggered protection areas.
5. Comparative analysis of the resulting protection scenarios with existing protocols versus different approaches (e.g., one versus three-whale density) to inform the risk to individual whales if moving toward the use of a multi-whale trigger.

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TABLES

Table 1. General comparison of main aerial surveys and surveillance programs in Canadian waters in 2018. Technical details, data collected, and scientific and technical advantages and disadvantages of technologies that are currently being used for detecting and monitoring NARW are presented. New and emerging technologies that may prove to be valuable for supporting research and monitoring in the future are not included but should continue to be tested and developed.

Survey details	DFO Science	NOAA-NFSC	TC NASP	DFO C&P
Main Objective	Multi-species aerial survey and NARW detection	NARW population assessment (individual photo capture)	NARW detection in dynamic shipping lanes	Fisheries surveillance with priority NARW detection
Timeline	Apr 10 to Nov 30	Jun 4 to Aug 12	Apr 28 to Nov 15	Year-round surveillance
Survey details	Single and double platform (systematic)	Single platform (mark-recapture)	Single platform (dedicated to protection zones)	Opportunistic sightings
	Effort based survey	Effort based survey	Effort based survey	Surveillance
	5 nm offset transect survey w/ track break for NARW imagery capture	Survey directed to NARW aggregations	5 nm offset of DSS w/ track break for NARW imagery capture	Active fishery area and transect survey of closed fishing areas.
	100 knot speed	100 knot speed	150 knot speed	variable
	800 ft altitude	1000 ft altitude	1500 ft altitude	500-1000 ft altitude
Near-real time Ind. NARW identification	No	Yes	No	No
Imagery	Max. 20 minute circling for NARW sightings	‘Unlimited’ until each individual captured	Max. 20 minute circling for NARW sightings	Max. 20 minute circling for NARW sightings
	Digital SLR TO: additional fixed automated belly cameras	Digital SLR	Electro-Optical / Infrared (EO/IR) camera, Infrared & Ultra-violet Line scanner (IR/UV), and Side Looking Airborne RADAR (SLAR)	Electro-Optical / Infrared (EO/IR) camera, Infrared & Ultra-violet Line scanner (IR/UV), and Side Looking Airborne RADAR (SLAR)
Aircraft details	Twin Otter (TO) Cessna Skymaster (C) and Partenavia P-68 (P)	Twin Otter	Dash 8 and/or Dash 7	PAL- King Air
	High fixed-winged	High fixed-winged	High fixed-winged	Low fixed-winged
	TO only: Bubble windows with removable window for photos	Bubble windows with removable window for photos	Large viewing windows or bubble window	Standard viewing windows
	TO: 4-6 MMOs C, P: 2-3 MMOs	3-5 MMOs	2-3 MMOs	1 officer and 1 PAL technician, option for 1 MMO
	6-8 hour flight	4-6 hour flight	6-7 hour flight	4-5 hour flight

Survey details	DFO Science	NOAA-NFSC	TC NASP	DFO C&P
Information Collected	Density and abundance Indices;	Identification of individual NARW	Presence of NARW in shipping lanes	Presence of NARW in fishing areas
	Distribution of densities over a large spatial scale	Abundance estimates using counts + mark/ recapture	Photographic identification (post-season ind. ID)	Photographic identification (post-season ind. ID)
	Photographic identification (post-season ind. ID and NARW enumeration)	Residency; Individual movements of NARW;	-	-
	Entanglement documentation and response support possible	Entanglement documentation and response support possible	Entanglement documentation	Entanglement documentation and response support possible
Advantages	Estimates of total abundance of multiple species (NARW and others)	Estimates of NARW abundance, demography, and residency	Support of vessel management needs	Support of fisheries management needs
	Large spatial coverage	Focus monitoring of aggregation	Focus monitoring NARW in areas of high vessel traffic	Focus monitoring NARW in areas of active fishing areas
	Quantified observer effort	Quantified observer effort	Quantified observer effort	Additional detection
	Systematic effort sampling strategy; both line transect and photographic strip transect surveys	Monitoring NARW in southwestern GSL	Targeted surveillance missions. Longer flight time than Twin Otter, shorter than Cessna	Targeted surveillance missions. Large number of flights and aircraft available
	Near real-time information	Near real-time information	Near real-time information	Near real-time information
	Provide data on multiple species	Provide data on all large baleen whale species	Provide NARW and blue whale data and opportunistic sightings of other whales	Provide opportunistic sightings of whales as part of the surveillance of fisheries
	Data on marine mammal incidents, fishing gear presence, debris, vessels	Data on marine mammal incidents and fishing gear presence	Data on marine mammal incidents, pollution, fishing gear presence, debris, vessels	Data on marine mammal incidents, fishing gear presence, debris, vessels
	Photographic capabilities allow for identification of multiple species and data validation; photo-id of individual NARW	Photo identification focus	Multispectral imaging incl. camera system (Identification and photo ID, precise locations)	Multispectral imaging incl. camera system (Identification and photo ID, precise locations)

Survey details	DFO Science	NOAA-NFSC	TC NASP	DFO C&P
Disadvantages	Variance associated with abundance estimates may be high for rare species	NARW estimate negatively biased for total whales in Canada, uncertainty likely underestimated	No abundance indices	Not flown under specific abundance survey design
	Daylight operations	Daylight operations	Daylight operations	Daylight operations (for whale species identification and imagery)
	Weather limited	Weather limited	Weather limited	Weather limited
	Flight time effort temporally and spatially limited relative to acoustics	Flight time effort temporally limited relative to acoustics	Limited ability to fly slow	More limited field of view than other aircraft: Low wing, small windows, exhaust interferes with visibility
	Availability bias likely higher than vessels, although may be similar if circle-back used	Availability bias higher than vessels survey, but may be lower than DFO Science aircraft for NARW	Availability bias higher than vessels	Availability bias higher than vessels or slower aircraft. Limited flight time (although offset by higher airspeed for long distance capability)
	Dependent on a predefined survey design (less flexible to support day-today management operations)	Limited to NARW and other large whales; data on other marine species not collected	Limited data on species other than NARW and blue whales	No dedicated MMOs (NARW observation may require confirmation later by MMO using pictures)
	Visual survey estimates available reasonably soon but photographic surveys take considerable time to analyze.	-	photographic data take considerable time to analyze.	photographic data take considerable time to analyze

Table 2. Source of preliminary sighting (i.e., definite visual detections) numbers separated by platform type. Acoustic detections are not presented. Sightings reported include data from May 13 to Nov 13 2018.

Platform	Affiliation	Platform Name (as ident. In WhaleMap)	Prelim. Sightings #
Plane			
	NOAA-NFSC	NOAA Twin Otter	941
	DFO Science	DFO Twin Otter	98
	DFO Science	DFO Cessna	19
	TC NASP (ATL)	TC Dash 8	15
	TC NASP (CEN)	TC Dash 7	10
Vessel			
	Canadian Whale Institute	F/V* jdmartin	437
	Mingan Island Cetacean Study	MICS boats	13
	New England Aquarium	Nereid	6
	DFO	DFO Science vessel Cetus	8
Opportunistic			
	DFO C&P	C&P King Air	161
	DFO Science	F/V Jean-Mathieu	21
	DFO/CCG C&P	CCGS* Peddle	15
	DFO/CCG Science	Coriolis II	15
	Dept. of National Defense	DND Aurora	14
	DFO/CCG Science	CCGS Perley	13
	TC- NASP (CEN)	TC Dash7 (off whale mission)	12
	DFO/CCG C&P	CCGS Leblanc	9
	TC	TC RPAS*	4
	DFO/CCG Science	CCGS Teleost	3
	Public (verified)	DFO whale reporting email (XMARwhale)	3
	TC- NASP (ATL)	TC Dash 8 (off whale mission)	3
	DFO/CCG C&P	CCGS Dutka	3
	DFO/CCG C&P	CCGS McLaren	2
	Public (verified)	Grand Manan Ferry	1
	Public (verified)	WhaleAlert	1
Grand Total			**1827**

*F/V = Fishing Vessel
*CCGS = Canadian Coast Guard Ship
*RPAS = Remote Piloted Aircraft System

FIGURES

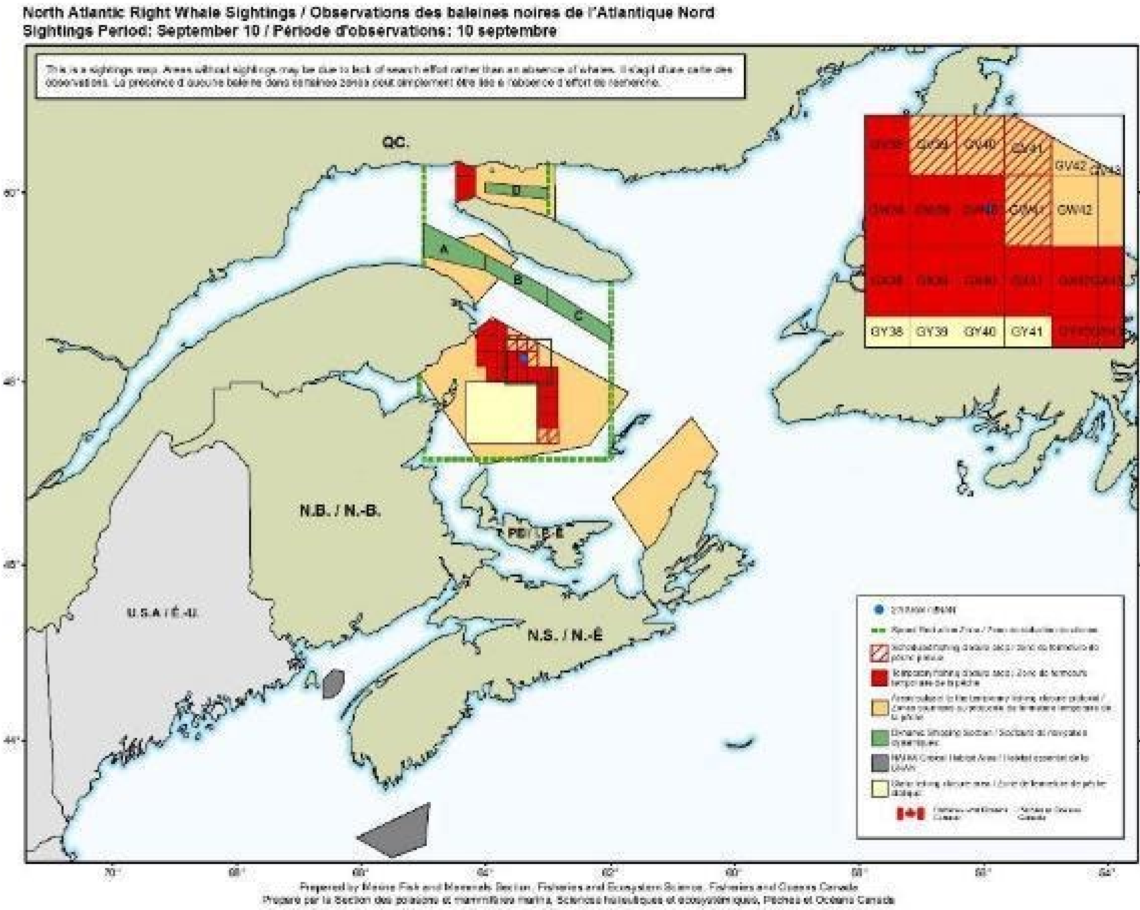


Figure 1. Example of implemented management measures in 2018 to protect the North Atlantic Right Whale based on observations made on 10 September 2018. The measures to address maritime traffic included a large static slow-down zone (stippled green box) and four dynamic shipping sections (DSS A, B, C, and D: green boxes; aka. Dynamic Shipping Zones; DSZs). The DSS were surveyed twice in a 7-day period where vessels greater than 20 m were not restricted to travel less than 10 knots unless a NARW was observed. If NARW were present in any of the DSSs, the specific section would be restricted to the slow-down measures for a period of 2 weeks. The DSSs would also be subject to slow down restrictions if two surveys could not be completed with the week timeline and would reopen once two clear flights were able to be conducted. The measures to address entanglements includes, in the GSL, a 6,513 km^2 static zone (yellow polygon) in the southwest GSL where the area was closed to fixed-gear fishery activity from late-April to mid-November. In addition, a dynamic management protocol was developed where areas subject to temporary closures in the GSL (orange polygons) and the NARW Critical Habitats (grey polygons; BoF nearest NS and Roseway Basin southeast of NS) were divided into 10 x 10 minute grids (on average 230 km^2). If one NARW was detected within a grid, then the grid as well as the adjacent grids (typically 9 grids in total- 2,070 km^2) were closed to fixed fishery activity for 15 days following the removal of the gear from the area (i.e., 48 hours from the issuance of the Notice to Harvesters with deadline extension in poor weather conditions). Aerial surveys were completed twice within the closure period and once it was determined that whales were no longer present in the zone, the closures were lifted or extended for 15 days if whales remained in that closure area.

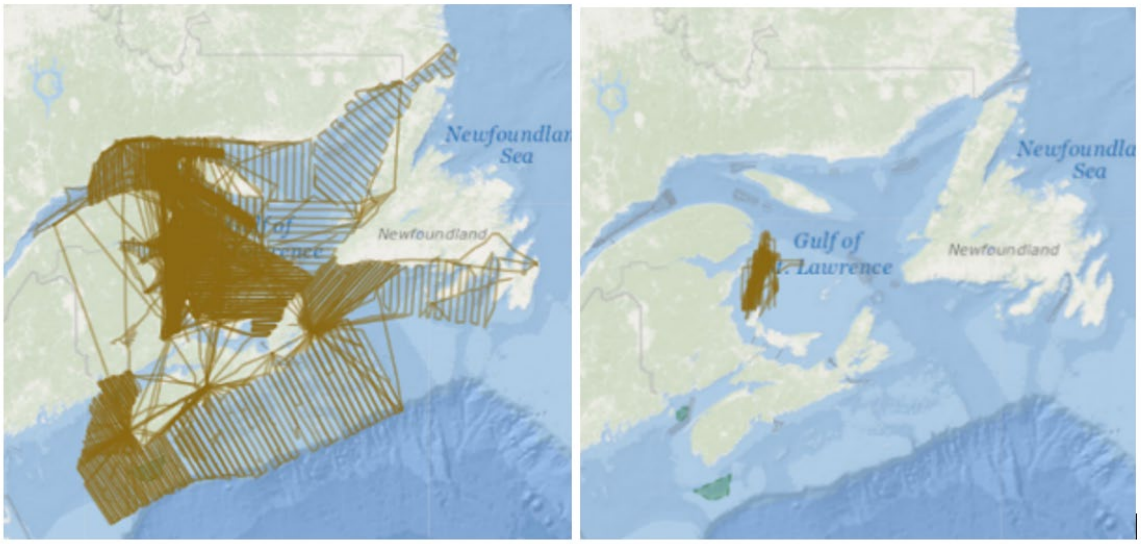


Figure 2. Graphic depiction of the extent of monitoring efforts in eastern Canadian waters in 2018 (left: flight tracks depicting efforts from Canadian Government surveys, right; flight tracks depicting efforts from NOAA-NEFSC survey) as available on Whalemap / Whale Insight / Baleine-en-Vue. In 2018, efforts started in mid-April and continued until late December which included dedicated monitoring of the aggregations observed (NOAA, CWI/NEAq), areas subject to management measures (DFO and TC), and surveys of the majority of eastern Canadian waters to improve knowledge of NARW occupancy and where they likely are not found.

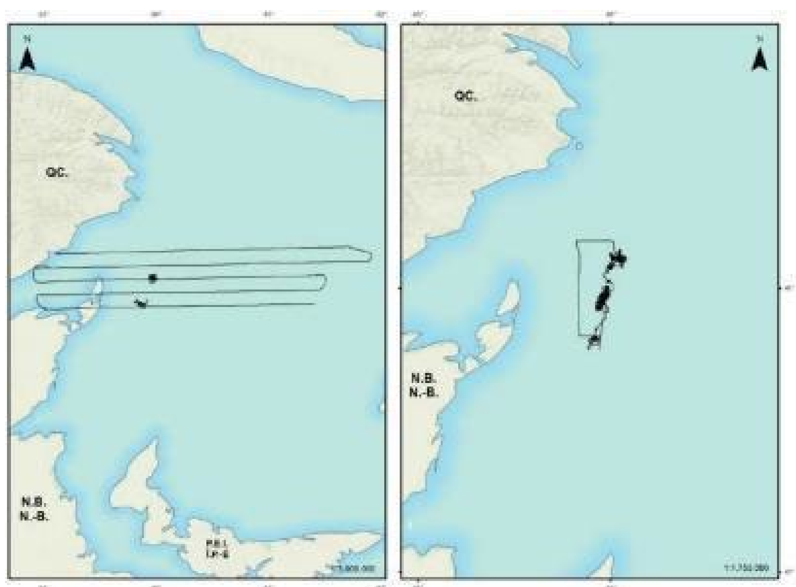


Figure 3. Characteristic type of survey conducted by the DFO Twin Otter team (example from June 1 2018; left pane) and the NOAA Twin Otter team (example from June 4 2018; right pane) in a similar area of the southern Gulf of St. Lawrence (sGSL). The DFO team surveyed prescribed transect lines to complete full area coverage of the sGSL (5 nm offset transects), breaking survey line twice to capture imagery of the NARW observed (n = 14). The NOAA team directed effort towards known NARW aggregations and surveyed a smaller area, breaking survey lines often to capture data on multiple whales (n = 76). Both teams flew roughly for the same length of times but, as a rough comparison, the DFO team survey length was 1,195 km (including circling) and approximately 12,400 km^2 area whereas the NOAA team covered 1,080 km and 3,990 km^2.

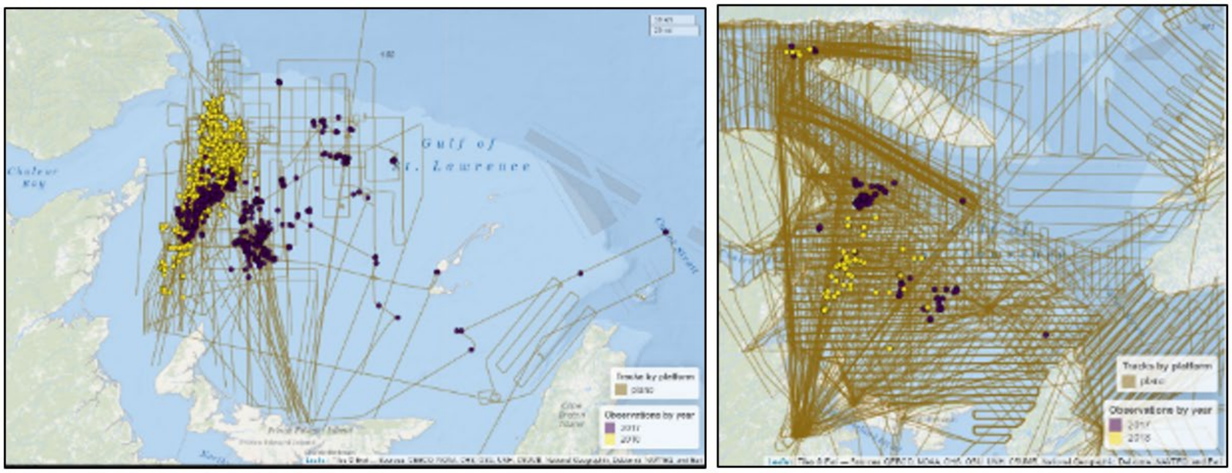


Figure 4. NARW survey and NARW sightings conducted by the NOAA Twin Otter team in 2017 (left panel; 23 June to 29 July; purple) and 2018 (left panel; 4 June to 12 August; yellow) and the DFO Twin Otter, Partenavia, Cessna and TC Dash 8 and TC Dash 7 teams 2017 (right panel; 7 August to 15 December; purple) and 2018 (right panel; 10 April to 30 November; yellow) (Whalemap).

APPENDIX 1

2018 CANADIAN AERIAL SURVEY FEASIBILITY CRITERIA

2018 Marine Mammal Aerial Survey Planning Rationale

The Aerial Survey Teams assess the feasibility of conducting aerial surveys for detecting marine mammals. This document details criterion used to schedule and assess the quality of flights in support of the NARW Management and Atlantic Canada Marine Mammal Survey efforts.

Survey Teams (Marine Mammal Observers [MMO], Partners [e.g., Provincial Airline pilots, TC-National Aerial Surveillance Program], Marine Mammal Program leads) employ multiple data sources and criteria to decide if and when flights can be conducted.

Survey teams make the best informed decisions based on available information pre-flight and reassess and record conditions throughout every flight. The criteria outlined below conform to standards developed by international researchers and presented in scientific literature. Marine mammal surveys need be compatible across a species' range (e.g., NARW surveys in the USA and Canada) to understand and assess population parameters.

2018 Marine Mammal Aerial Survey Feasibility Criteria

Survey Teams plan flights based on multiple predictive weather packages for long- (week), medium- (days), and short-term (24 hours, pre-flight) weather forecasts to schedule each marine mammal aerial survey. *Conditions are verified with the updated weather packages the morning of the planned flight.* Multiple sources are considered as there is not a single source which provides definitive information; in some cases sources provide conflicting forecasts.

Decision criteria are an amalgamation of multiple considerations, and include:

1. Survey objectives - specific to each programme (e.g., marine mammal survey [Science platform], NARW observations [C&P platform]).
2. Beaufort sea state - a measure of sea surface roughness which summarize sea conditions during surveys. Generally, Beaufort conditions ≤ 2 are ideal, whereas conditions > 4 are unsuitable for detecting even large marine mammals.
3. Visibility – a minimum of > 2 nm; a minimum cloud ceiling of > 2,000 feet; no or minimal/sporadic precipitation; no fog banks over area of interest.
4. Other considerations - earlier weather (can affect current conditions), water currents, tide state, storms, temperature at multiple altitudes (e.g., turbulence), sea ice, etc.

MMO leads create a contingency survey area in anticipation of possible weather changes. This is not applicable to the TC Dash platform assigned to the Dynamic Shipping Areas (DSA). The TC Team assess the conditions for each separate DSA to decide if any of the four areas can be surveyed independently based on weather patterns around Anticosti Isl.

MMO leads aboard the platforms will cancel a planned flight or redirect flight survey effort if conditions are not suitable for aerial surveys.

MMO leads can decide to attempt a flight when conditions are at the limit of aforementioned criteria. The flight may be aborted in poor conditions or completed in suitable conditions.

Weather condition criteria will vary amongst the platforms based on programme objectives (i.e., species of interest size [small and large versus just large whale] and behaviour as observing animals [e.g., solitary versus aggregation] will require different conditions).

APPENDIX 2

The USA LADM evaluation procedures outlined in the Federal Registry (NOAA 50 CFR Part 224 2008) were applied to the 2018 NOAA-NEFSC and DFO Twin Otter aerial survey NARW sightings (Crowe et al. 2023). First, a circle (i.e., core buffer) is drawn around each group where the radius would be adjusted for the number of right whales seen such that the trigger density (4 NARW/ 100 nm^2) is maintained. The length of the radius is determined by taking the inverse of the 4 NARW/100 nm^2 density which is 24 nm^2/NARW and using the applicable radius for each sighting (e.g., 2.77 nm for a single NARW sighted, 3.91 nm for 2 NARW, 4.79 nm for 3 NARW, etc.). Secondly, any circle or group of contiguous circles including 3 or more right whales is identified and all the circles delineated to determine the core area (i.e., aggregation). *To note, in the USA, a buffer area (15 nm), to account for NARW movement for 15 days, is added to the edges of the core area which is not applied here. Results presented in series of figures below.*

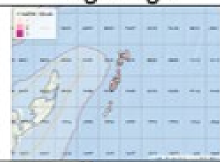
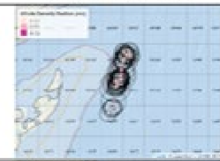
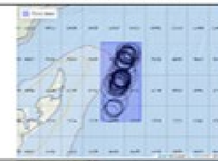
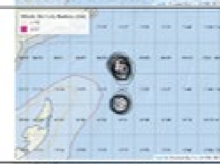
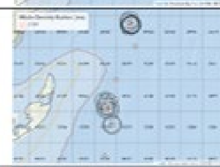
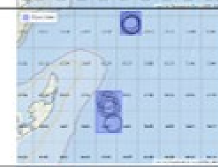
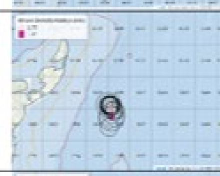
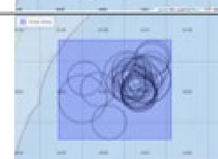
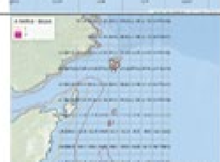
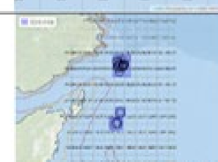
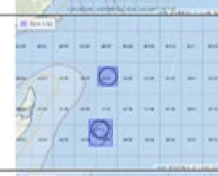
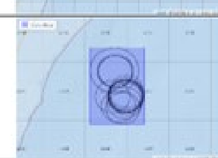
Survey details	Sightings	Core buffer	Core area
NOAA 4-Jun-2018 NARW sighting = 76 Aggregation = 1 NARW not in aggregation = 0			
NOAA 6-Jun-2018 NARW sighting = 41 Aggregation = 2 NARW not in aggregation = 0			
NOAA 7-Jun-2018 NARW sighting = 19 Aggregation = 2 NARW not in aggregation = 3			
NOAA 9-Jun-2018 NARW sighting = 23 Aggregation = 1 NARW not in aggregation = 1			
NOAA 11-Jun-2018 NARW sighting = 50 Aggregation = 1 NARW not in aggregation = 0			
NOAA 15-Jun-2018 NARW sighting = 37 Aggregation = 1 NARW not in aggregation = 0			
NOAA 17-Jun-2018 NARW sighting = 39 Aggregation = 3 NARW not in aggregation = 0			
NOAA 26-Jun-2018 NARW sighting = 10 Aggregation = 2 NARW not in aggregation = 2			
NOAA 29-Jun-2018 NARW sighting = 17 Aggregation = 1 NARW not in aggregation = 0			
NOAA 30-Jun-2018 NARW sighting = 39 Aggregation = 3 NARW not in aggregation = 1			

Figure A2a. USA LADM applied to the 2018 NOAA-NEFSC aerial survey NARW sightings between June 04 to June 30 2018. Survey details and results presented in left column. Visual representation of sightings, core buffer for each sighting, and resulting core area of aggregations meeting criteria.

Survey details
NOAA 05-Jul-2018 NARW sighting = 29 Aggregation = 1 NARW not in aggregation = 4
NOAA 07-Jul-2018 NARW sighting = 48 Aggregation = 2 NARW not in aggregation = 0
NOAA 11-Jul-2018 NARW sighting = 48 Aggregation = 2 NARW not in aggregation = 3
NOAA 13-Jul-2018 NARW sighting = 45 Aggregation = 1 NARW not in aggregation = 2
NOAA 14-Jul-2018 NARW sighting = 30 Aggregation = 2 NARW not in aggregation = 4
NOAA 16-Jul-2018 NARW sighting = 50 Aggregation = 3 NARW not in aggregation = 4
NOAA 19-Jul-2018 NARW sighting = 39 Aggregation = 2 NARW not in aggregation = 2
NOAA 20-Jul-2018 NARW sighting = 32 Aggregation = 1 NARW not in aggregation = 2
NOAA 21-Jul-2018 NARW sighting = 45 Aggregation = 1 NARW not in aggregation = 1
NOAA 27-Jul-2018 NARW sighting = 34 Aggregation = 2 NARW not in aggregation = 0

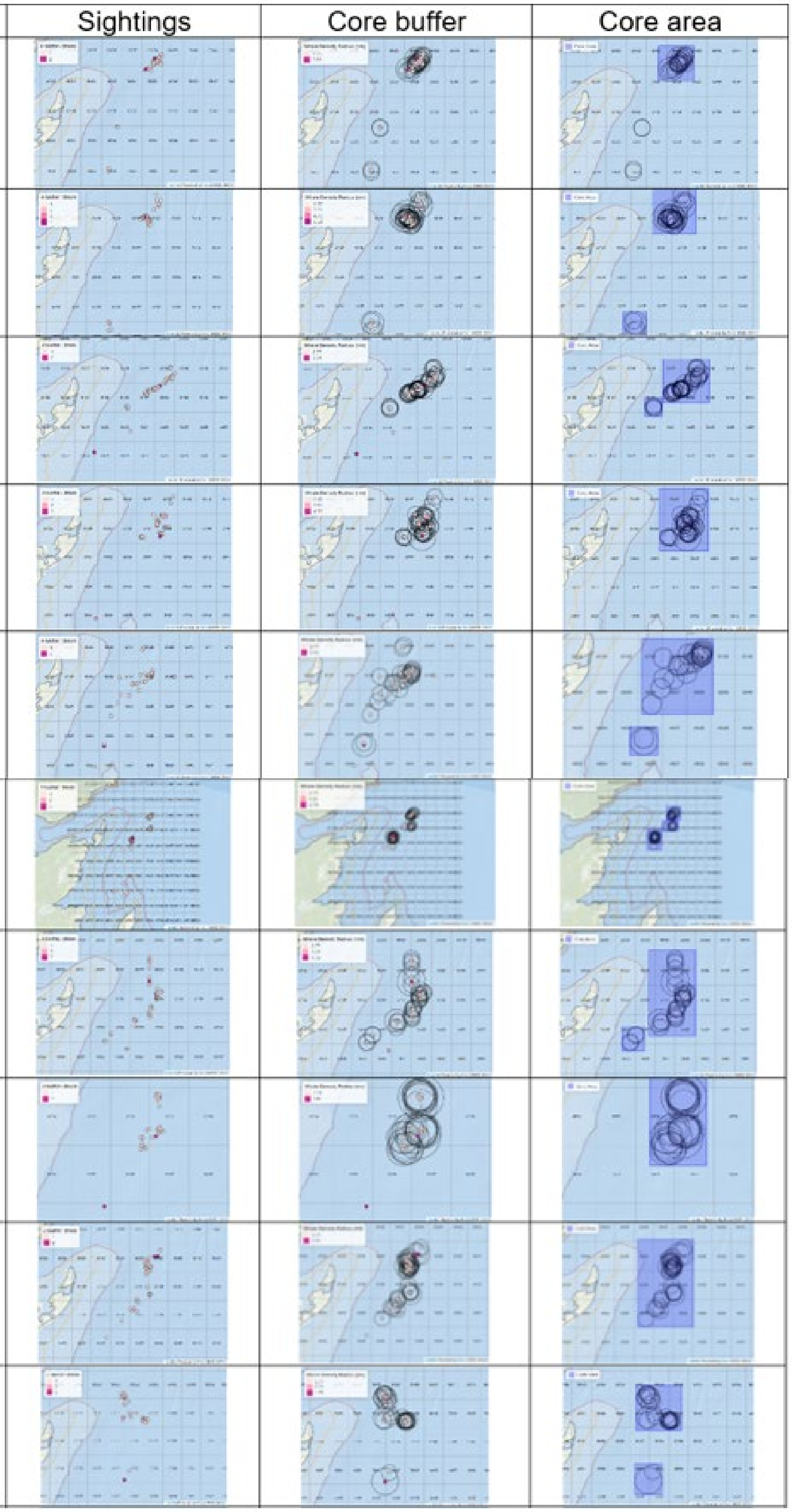


Figure A2b. USA LADM applied to the 2018 NOAA-NEFSC aerial survey NARW sightings between July 05 to July 27 2018. Survey details and results presented in left column. Visual representation of sightings, core buffer for each sighting, and resulting core area of aggregations meeting criteria.

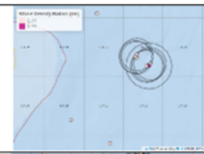
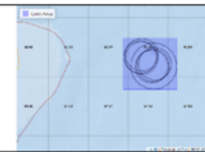
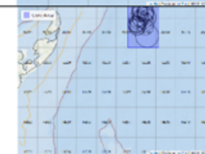
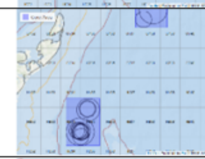
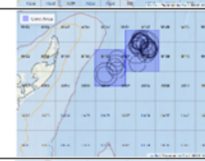
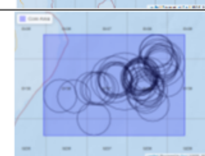
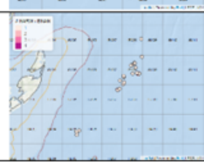
Survey details	Sightings	Core buffer	Core area
NOAA 29-Jul-2018 NARW sighting = 11 Aggregation = 1 NARW not in aggregation = 3			
NOAA 31-Jul-2018 NARW sighting = 28 Aggregation = 1 NARW not in aggregation = 4			
NOAA 01-Aug-2018 NARW sighting = 20 Aggregation = 2 NARW not in aggregation = 1			
NOAA 03-Aug-2018 NARW sighting = 38 Aggregation = 2 NARW not in aggregation = 2			
NOAA 06-Aug-2018 NARW sighting = 56 Aggregation = 1 NARW not in aggregation = 0			
NOAA 12-Aug-2018 NARW sighting = 37 Aggregation = 2 NARW not in aggregation = 1			

Figure A2c. USA LADM applied to the 2018 NOAA-NEFSC aerial survey NARW sightings between July 29 to August 12 2018. Survey details and results presented in left column. Visual representation of sightings, core buffer for each sighting, and resulting core area of aggregations meeting criteria.

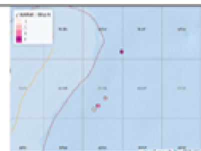
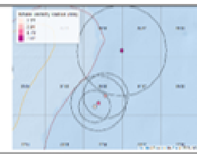
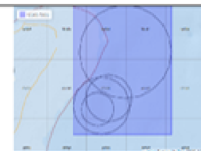
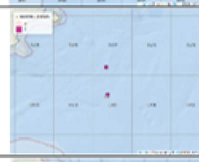
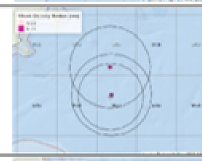
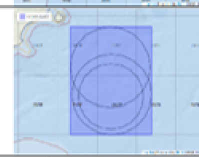
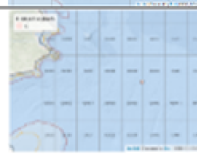
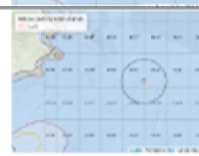
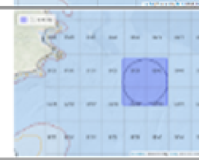
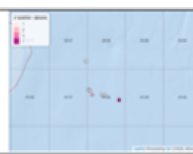
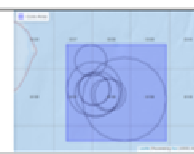
Survey details	Sightings	Core buffer	Core area
DFO Twin Otter 31-May-2018 NARW sighting = 1 Aggregation = 0 NARW not in aggregation = 1	No Aggregation		
DFO Twin Otter 01-Jun-2018 NARW sighting = 14 Aggregation = 1 NARW not in aggregation = 0			
DFO Twin Otter 17-Jun-2018 NARW sighting = 16 Aggregation = 1 NARW not in aggregation = 0			
DFO Twin Otter 26-Jun-2018 NARW sighting = 6 Aggregation = 1 NARW not in aggregation = 0			
DFO Twin Otter 3-Aug-2018 NARW sighting = 2 Aggregation = 0 NARW not in aggregation = 2	No Aggregation		
DFO Twin Otter 4-Aug-2018 NARW sighting = 2 Aggregation = 0 NARW not in aggregation = 2	No Aggregation		
DFO Twin Otter 6-Aug-2018 NARW sighting = 3 Aggregation = 0 NARW not in aggregation = 3	No Aggregation		
DFO Twin Otter 12-Aug-2018 NARW sighting = 17 Aggregation = 1 NARW not in aggregation = 0			
DFO Twin Otter 07-Sept-2018 NARW sighting = 6 Aggregation = 0 NARW not in aggregation = 6	No Aggregation		

Figure A2d. USA LADM applied to the 2018 DFO aerial survey NARW sightings between May 31 to September 07 2018. Survey details and results presented in left column. Visual representation of sightings, core buffer for each sighting, and resulting core area of aggregations meeting criteria.

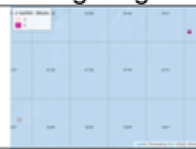
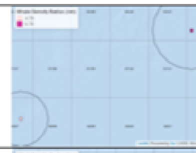
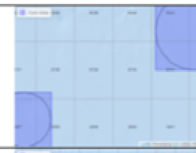
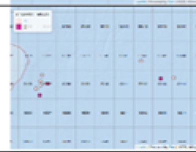
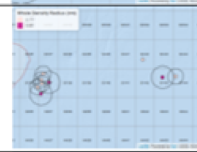
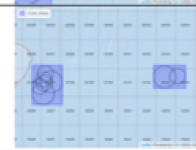
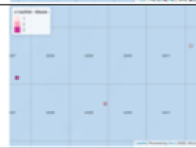
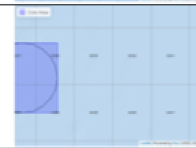
Survey details	Sightings	Core buffer	Core area
DFO Twin Otter 13-Sept-2018 NARW sighting = 9 Aggregation = 2 NARW not in aggregation = 0			
DFO Twin Otter 14-Sept-2018 NARW sighting = 12 Aggregation = 2 NARW not in aggregation = 1			
DFO Twin Otter 25-Sept-2018 NARW sighting = 8 Aggregation = 1 NARW not in aggregation = 3			
DFO Twin Otter 5-Nov-2018 NARW sighting = 2 Aggregation = 0 NARW not in aggregation = 2	No Aggregation		

Figure A2e. USA LADM applied to the 2018 DFO aerial survey NARW sightings between September 13 to November 05 2018. Survey details and results presented in left column. Visual representation of sightings, core buffer for each sighting, and resulting core area of aggregations meeting criteria.

APPENDIX 3

The following examples (Figures A3a to A3c) compare resulting protection areas using the 2018 one-whale trigger within management grids versus the USA LADM and 15 nm buffer area (NOAA 50 CFR Part 224 2008).

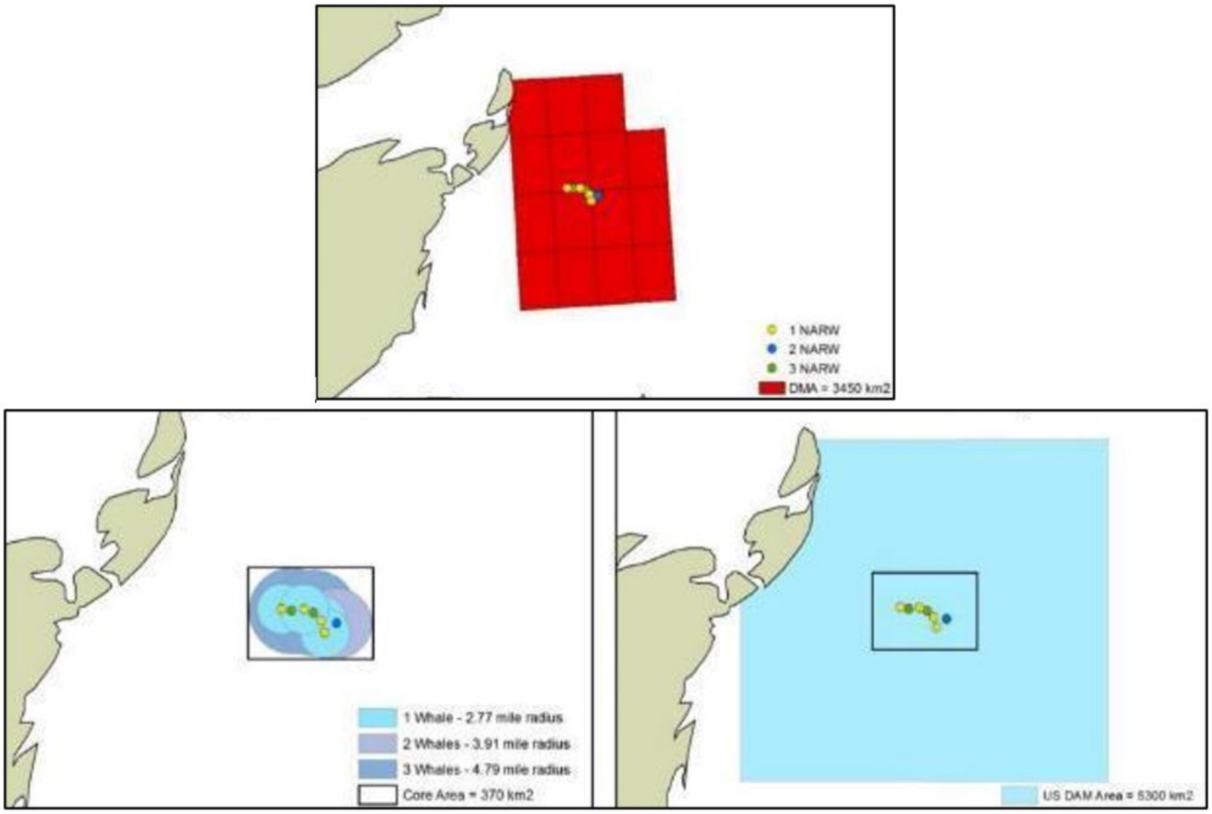


Figure A3a, Example 1 (May 24 2018 sightings data from Canadian Platforms). The top panel shows an example of the resulting protected area using the existing 1-whale trigger and associated grid closures (including buffer grids). In contrast, the American Model protocol uses overlapping core buffers (bottom left- blue circles around sighting, radius depends on number of whales per sighting) to determine the number of whales in the aggregation (≥ three whales needed) and define the extent of each aggregation (bottom left panel- black outline around circles). The resulting core area is subsequently extended by 15 nm from each edge to define the protection buffer around the aggregation (a.k.a., DAM; bottom right panel- outer blue area around core area). The total area protected when applying each protocol is: 3,450 km^2 (1-whale), and 5,300 km^2 (USA DAM model). The USA model would be a 53.6% increase in area protection. (Note: protection areas are not carried over into subsequent daily analyses and the 2018 Static Management Area is not included).

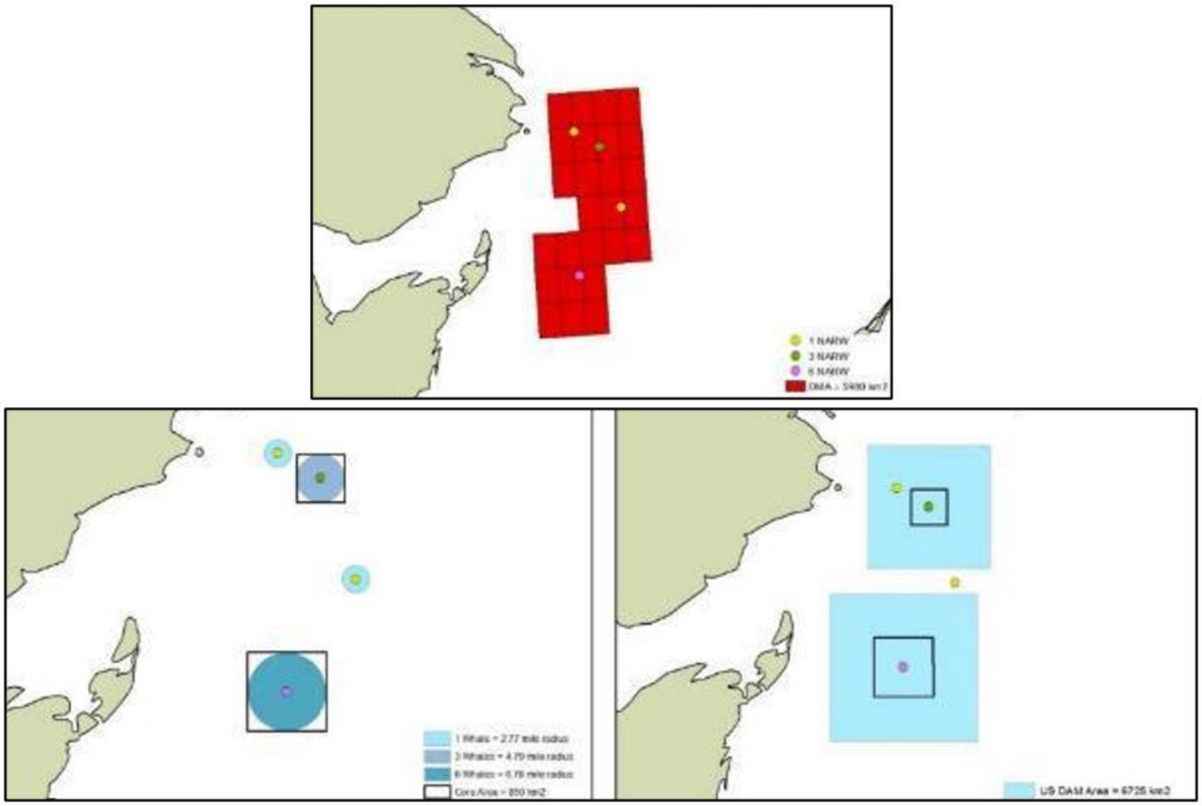


Figure A3b, Example 2 (May 26 2018 sightings data from Canadian Platforms). The top panel shows an example of the resulting protected area using the existing 1-whale trigger and associated grid closures (including buffer grids). In contrast, the American Model protocol uses overlapping core buffers (bottom left- blue circles around sighting, radius depends on number of whales per sighting) to determine the number of whales in the aggregation (≥ three whales needed) and define the extent of each aggregation (bottom left panel- black outline around circles). The resulting core area is subsequently extended by 15 nm from each edge to define the protection buffer around the aggregation (a.k.a., DAM; bottom right panel- outer blue area around core area). Note that in this situation, 2 of the sightings were non-aggregated whales and therefore not included in the protection calculation although one of the whales is afforded a measure of protection as it is within an aggregations' protection buffer (right panel- northern most sighting [yellow]). The total area protected when applying each protocol is: 5,980 km^2 (1-whale) and 6,725 km^2 (USA DAM model). The USA model would be a 12.5% increase in area protection.

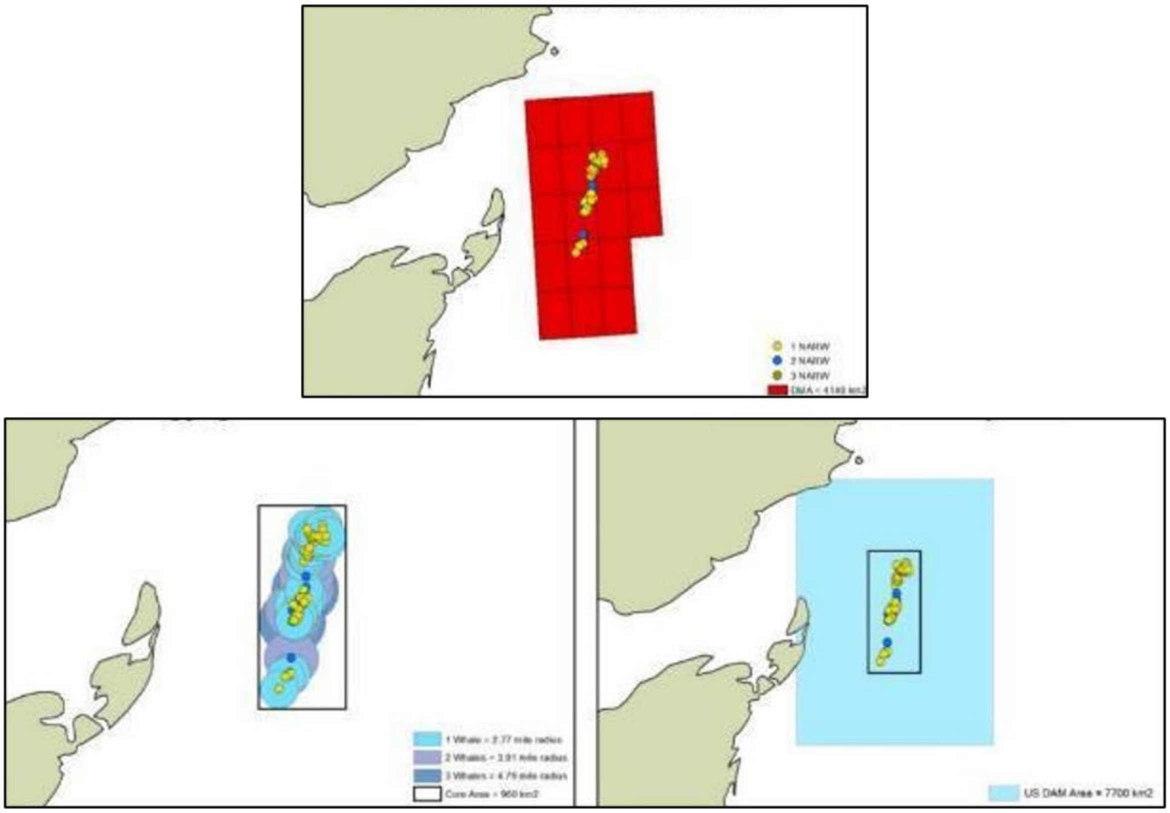


Figure A3c, Example 3 (June 4 2018 sightings data from the NOAA platform). The top panel shows an example of the resulting protected area using the existing 1-whale trigger and associated grid closures (including buffer grids). In contrast, the American Model protocol uses overlapping core buffers (bottom left panel- blue circles around sighting, radius depends on number of whales per sighting) to determine the number of whales in the aggregation (≥ three whales needed) and define the extent of each aggregation (bottom left panel- black outline around circles). The resulting core area is subsequently extended by 15 nm from each edge to define the protection buffer around the aggregation (a.k.a., DAM; bottom right panel- outer blue area around core area).The total area protected when applying each protocol is: 4,140 km^2 (1-whale) and 7,700 km^2 (US DAM model). The US model would be a 46% increase.