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Important Habitats of the North Atlantic Right Whale (*Eubalaena glacialis*) in Eastern Canadian Waters

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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.

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ABSTRACT

Changes in North Atlantic right whale (NARW; *Eubalaena glacialis*) demography, population dynamics, and distribution, beginning in 2010, highlighted the need for an updated assessment of important habitat in Canadian waters to support their recovery and survival. NARWs rely on a variety of eastern Canadian habitats for foraging, rearing, socializing, mating, and migration. NARWs depend on specific habitat features and attributes vital for these functions, and destruction of the habitat can negatively impact their survival and recovery. A key driver of NARW habitat use in Canadian waters is prey availability and the formation of dense prey aggregations, which are influenced by biophysical processes. NARWs also require unimpeded space and connectivity among habitats to move within and between them.

In eastern Canada, NARW sightings occur year-round, with the exception of March, and NARW upcalls are detected through acoustic monitoring efforts in all months, though infrequently from December through March. Directed prey research in the southern Gulf of St. Lawrence indicates persistent and suitable foraging conditions supported by local environmental, oceanographic, and bathymetric conditions. Various data sources including NARW sightings, acoustic detections, persistence of predicted foraging habitat based on prey modeling, and a probability of occurrence model, were used to identify important habitats for NARWs in eastern Canadian waters, as well as to describe their functions, features and attributes. The resulting important habitat for feeding, reproduction, rearing, socializing and socialization is comprised of the southern and northwestern Gulf of St. Lawrence, including the Jacques-Cartier Strait and entrance to Chaleur Bay; the Scotian Shelf, especially Emerald and Roseway Basins; the Bay of Fundy; and the Canadian portions of Georges Bank and the Gulf of Maine. The important habitat also includes corridors for migratory movements and habitat connectivity, namely, the Laurentian Channel, Cabot Strait, and the eastern portion of the Scotian Shelf. Additionally, potential foraging areas were identified in coastal waters of the eastern Scotian Shelf and around Newfoundland, at the southern and eastern edges of the Grand Banks, the Flemish Cap, and in the northeast portion of the Jacques Cartier Strait.

Many threats may impact NARW habitat. Commonly occurring anthropogenic activities that could potentially destroy NARW habitat include fishing activities, vessel traffic in the marine environment, industrial activities, and energy development and production. For each of these activities, the pathways of effects on habitat functions, features, and attributes are described. Disruptions to the environmental features supporting vital functions, whether due to localized circulation changes, anthropogenic activities, or large-scale climate shifts, could lead to the loss or alteration of suitable habitats, potentially impacting NARW distribution, health, and reproduction.

CONTEXT

Once a species is listed under Schedule 1 of the *Species at Risk Act* (SARA) as threatened or endangered, the preparation of a recovery strategy is required. This includes, to the extent possible, the identification of critical habitat which SARA defines as *"the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species"*. The North Atlantic right whale (NARW; *Eubalaena glacialis*; Rosebaum et al. 2000) recovery strategy was finalized and published in 2009 (Brown et al. 2009), and was amended to include a more detailed description of existing critical habitat in 2014 (DFO 2014). Critical habitat in Canadian waters was identified in the Roseway Basin (RB) on the western Scotian Shelf and the Grand Manan Basin (GMB) in the outer Bay of Fundy (Figure 1). These were legally protected from destruction in 2017.

Habitat for aquatic species is defined by SARA as *"… nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where aquatic species formerly occurred and have the potential to be reintroduced."* Recent changes in NARW demography, population dynamics, and distribution led the Species at Risk Program to request an updated Recovery Potential Assessment (RPA; DFO 2007; Terms of Reference). The current paper specifically addresses the habitat-related elements of this RPA, including an update to important habitat for the NARW in Canadian waters. Using the best available information, the Species at Risk Program requested:

1. an evaluation of the recent NARW distribution (RPA Element 2);
2. a description of the habitat properties needed for successful completion of the life cycle processes necessary for the survival and recovery of the NARW (RPA Element 4);
3. a description of the functions, features, and attributes of this habitat (RPA Element 4; see Appendix 1 for definitions);
4. a description of the spatial extent of the areas likely to have these habitat properties (RPA Element 5); and
5. a description of the activities likely to threaten (i.e., damage or destroy) these habitat properties in the areas identified (RPA Element 9).

To address these requests, we also provide a review of the NARW life cycle and habitat features required to support the various NARW biological functions occurring in Canadian waters.

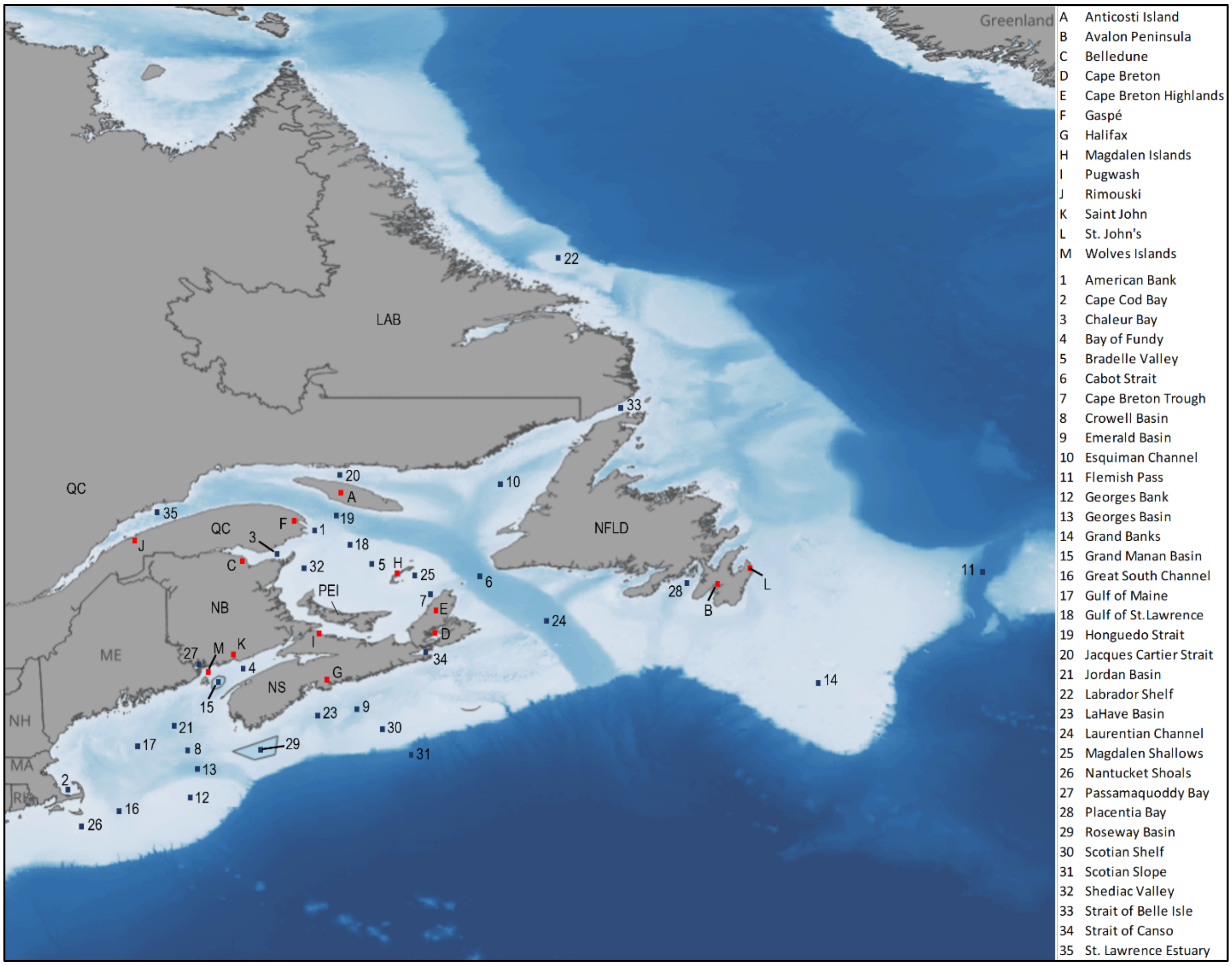

Figure 1: Place names used in the text: bathymetric features (numbered black squares) and terrestrial locations (lettered red squares), the current Canadian North Atlantic right whale critical habitat (grey polygons), and Canadian provinces and American states, including Nova Scotia (NS), Newfoundland (NFLD) and Labrador (LAB), Quebec (QC), New Brunswick (NB), Prince Edward Island (PEI), Maine (ME), New Hampshire (NH), Massachusetts (MA), and Rhode Island (RI).

LIFE CYCLE

North Atlantic right whales are polygynandrous, with both females and males mating with multiple partners within a breeding season. Conception is thought to occur in late autumn and/or winter months, though the exact timing remains uncertain (Brown and Sironi 2023). Kraus and Hatch (2001) estimated conception occurring from October through December whereas Cole et al. (2013) suggested November through February. These dates are based on estimates of a 12- to 13-month gestation period for southern right whales (*Eubalaena australis;* Best 1994), and the timing of NARW neonate sightings off the southeast United States of America (USA; Kraus and Rolland 2007). Alternatively, research on baleen steroid hormones suggests that gestation length could be between 18 and 24 months (N. Lysiak, pers. comm.; Hunt et al. 2016; Lysiak et al. 2023).

The NARW breeding cycle is physiologically constrained. When feeding conditions are good, a female may conceive every three years, whereby year one consists of providing care to a dependent calf for approximately twelve months, year two is a resting year, and year three is when ‘waiting females’ are capable of conceiving again (Kraus et al. 2001; Runge et al. 2023). Prior to the early 1990s, the age of first reproduction in NARWs was described as being 7.5 years on average (Knowlton et al. 1994, Hamilton et al. 1998). Starting in the late 1990s, however, an increase was noted in age of first reproduction to an average of 9.5 years, and the calving interval having increased to 5.3 years, on average (Kraus et al. 2001), compared to the mode of every three years observed between 1980 and 1992 (Knowlton et al. 1994). In recent years, NARWs were also found to be of smaller size at maturity and to have reduced body energy stores, with consequences for reproduction including calves produced per reproductive year (Stewart et al. 2022) and increased inter-birth intervals (> 7 years;Christiansen et al. 2020; Stewart et al. 2022; Pirotta et al. 2024). Changes in body size in cetacean populations, including NARWs, have been linked to changes in prey availability and anthropogenic stressors (e.g., sub-lethal effects; Pirotta et al. 2024). This in turn affects reproductive success as less energy is available, to invest in the calf and to buffer against environmental fluctuations during pregnancy (Miller et al. 2011; Rolland et al. 2016).

Female NARWs give birth to a single calf typically in the southeast USA between December and March, with a peak in January and February (Kraus and Rolland 2007). Importantly, adults and juveniles of both sexes are present on the calving grounds in winter, even if mating is not observed and food resources are locally scarce. This suggests an alternate use of the habitat, such as overwintering (Gowan et al. 2019; Meyer-Gutbrod et al. 2023). For females with calves, the warmer waters of the southern latitudes may reduce calf energy expenditure and exposure to predation risk (Gowan et al. 2019; Meyer-Gutbrod et al. 2023). However, at least three calving events have likely occurred outside of the southeast USA calving grounds, including: female EgNo2360 (‘Derecha’) around the Great South Channel (GSC) in June 2007 (Patrician et al. 2009), female EgNo1140 (‘Wart’) in Cape Cod Bay (CCB) in January 2013 (unpublished data), and female 3232 (‘Lobster’) in the Bay of Fundy (BoF) in May 2021 (North Atlantic right whale Consortium [NARWC] unpublished data).

NARWs can live for at least 70 years (Kraus and Rolland 2007), and possibly to over 100 years (Hamilton et al. 1998; Breed et al. 2024). However, as a result of high mortality rates caused by anthropogenic activities, the current lifespan of this species is thought to be about 45 years for females and 65 years for males (NOAA 2024a). There are very few examined cases of natural mortality documented in the NARW population, with the few documented cases involving newborns and one juvenile (Sharp et al. 2019). NARWs’ natural predators include large shark species and killer whales (*Orcinus orca*), although, they are most vulnerable as young calves (Taylor et al. 2013).

MOVEMENT AND MIGRATION

NARWs are capital breeders, whereby reproduction is a function of stored reserves, a characteristic that allows the separation in time and space of foraging and calving, with seasonal movements between these habitats (Kraus and Rolland 2007; Stephens et al. 2009; Miller et al. 2011). Movements are generally considered to be north-south between productive foraging habitats in northern latitudes during the ice-free period, and southern latitudes for calving during the winter season (Pendleton et al. 2009; Meyer-Gutbrod and Greene 2018; Ganley et al. 2019; Plourde et al. 2019; Hamilton et al. 2021; Pettis et al. 2023; Sorochan et al. 2023). However, this description does not capture the observed variability in NARW migration where the use of habitat-types may differ across demographic groups and years. Instead, NARW migration is more accurately described as condition-dependent partial migrations where, in any given year, individuals move among habitats as a function of the trade-offs among ecological factors (e.g., cost of reproduction and foraging opportunity; Gowan et al. 2019).

Movement patterns, including migratory routes, are thought to be maternally transmitted (Hoelzel 1998; Fortune et al. 2012), although discovery of novel feeding areas in the short-term may be unrelated to maternal learning. Learning via matrilineal socialization and/or level of previous feeding success may allow NARWs to develop a hierarchy of preferred habitats which, in turn, influences their level of site fidelity (Kenney et al. 2001; Crowe et al. 2021).

Information on long-range migration by individual NARWs is limited by the lack of availability of long-term tag technologies with no, or negligible, impacts on the health of this endangered animal (Marine Mammal Commission 2024). While some information can be obtained from resighting individually-photographed whales and predictive modeling tools, these approaches are impaired by the incomplete spatial and temporal survey coverage of the NARW annual range (Firestone et al. 2008; Gowan et al. 2021; Roberts et al. 2024).

Known NARW feeding grounds in the northern portion of their range include: areas off of southern New England (SNE), CCB, GSC, Gulf of Maine (GoM), BoF, Scotian Shelf (SS), and Gulf of St. Lawrence (GSL; Figure 1). Brillant et al. (2015) suggest that NARW movements are generally counter-clockwise north and east along the continental shelf in spring and summer, and south and west along the coast during autumn and winter. While these authors did not identify exact migratory routes, they described relevant and important probabilistic movements within the Canadian extent, including:

- migration from the GSC to the BoF via the northern slope of Georges Bank (GB) in May and June rather than directly across the GoM;
- migration along the shelf break, or possibly east of the SS, entering the GSL via Cabot Strait (CS), and;
- frequent immigration, emigration and seasonal movements into and out of the BoF in summer and autumn.

Kenney et al. (2001) explored migratory mechanisms and provided a synthesis of the literature on a wide range of marine and terrestrial species. Drawing on observations and theories related to other mysticetes, the authors suggested that NARWs may utilize: oceanographic cues such as temperature changes, bathymetric cues such as the continental shelf break, solar cues such as the solar azimuth angle, magnetic field cues, sound cues, and/or ocean current cues. Additional efforts are needed to understand the distribution of NARWs and identify corridors and routes.

FORAGING AND FEEDING

The mechanisms that NARWs use to locate their prey (i.e., foraging) are not well understood (see Movement and Migration section: Kenney et al. 2001). Within the feeding grounds, NARWs do not appear to randomly sample or search to find suitable patches of prey (Watkins and Schevill 1976; Baumgartner and Mate 2003). Rather, they appear to excel at quickly and accurately targeting discrete, concentrated layers of prey (Baumgartner and Mate 2003). Sensory mechanisms proposed for prey detection include vision and mechanoreception via sensory hairs (i.e., vibrissae) on their chin and mandible (Rowntree 1996; Kenney et al. 2001; Baumgartner and Mate 2003; Murphy et al. 2022).

When feeding, NARWs swim through the water column with their mouths open. As water is drawn into the mouth and through the baleen, prey is collected on the fine bristles (i.e., fringe) located inside the baleen plates (Figure 2; Watkins and Schevill 1976; Mayo and Marx 1990; Zhu et al. 2020).

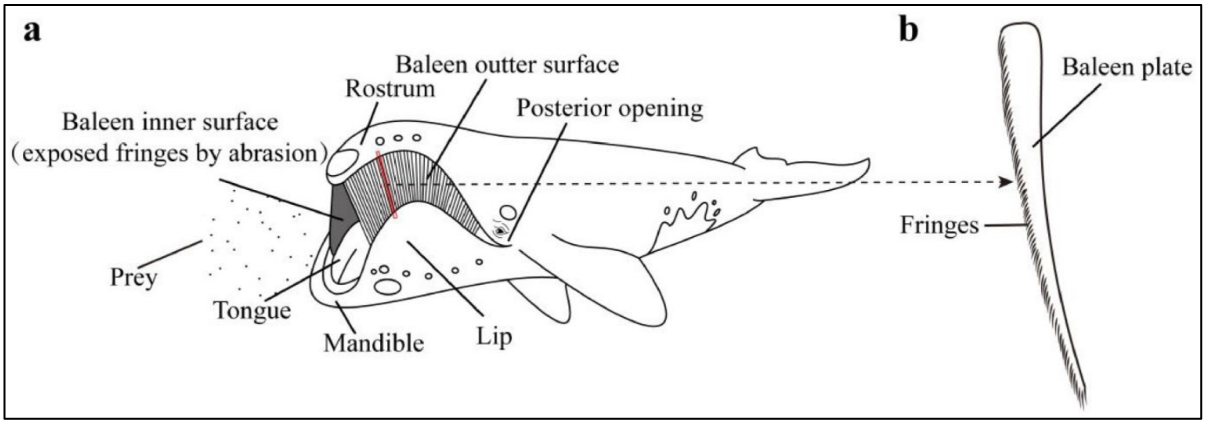

Figure 2: North Atlantic right whales (NARWs) have a very large head (up to 1/3 of body), arching jaws, and up to 270 densely packed, relatively narrow (18 cm), baleen plates with fine hairlike bristles on each side of the mouth measuring up to 2.8 m in length (Baumgartner et al. 2017; COSEWIC 2013). a) Side view of a balaenid depicting the position of the rostrum, mandible, lip, tongue, and baleen; b) one baleen plate depicting fine bristles aka. fringe. From Zhu et al. (2020).

Individuals can make large dynamic movements (e.g., executing 180 degree turns), quickly adjusting their head position, and use a boustrophedon (i.e., right-to-left, left-to-right movement) spatial sampling strategy to adjust to dense prey patches (Nowacek et al. 2001; Nousek-McGregor et al. 2014; van der Hoop et al. 2017). NARWs may feed at the surface or throughout the water column. Surface feeding behaviour, often called "skim feeding", is characterized by the whale swimming slowly at the surface, holding its bonnet (i.e., front of rostrum) and part of the baleen above the water while the rest of the body remains submerged (Watkins and Schevill 1976). NARWs have also been observed sub-surface swimming while skimming the water without breaking the surface (Appendix 4; NARWC). NARWs are also occasionally observed surfacing with mud on their heads, indicating dives to or near the seafloor (Nieukirk 1993; Goodyear 1993; Hamilton and Kraus 2019; Wright et al. 2024).

In Canada, feeding appears to mainly take place in the water column and, therefore, descriptions of NARW feeding behaviour have been primarily informed by tagging efforts. When foraging, NARW optimize their dive time to focus on the range of maximum prey abundance to increase feeding opportunity and maximize net energy acquisition (Baumgartner et al. 2017). To feed on prey patches at depth, NARWs make successive "U-shaped" dives, each characterized by a rapid descent, horizontal swimming within a narrow depth range for up to 15 minutes, and a rapid ascent to the surface (Goodyear 1993; Baumgartner and Mate 2003; Baumgartner et al. 2017; van der Hoop et al. 2017; Wright et al. 2024). The maximum depth limit of foraging dives is uncertain. In the BoF and RB, NARW foraging dives have been observed at average depths of 150 m and seemingly avoid the deep basins (210-250 m depth) with higher *Calanus* spp. abundance, however, previous satellite tagging studies have recorded NARW diving up to 306 m (Baumgartner and Mate 2003, 2005; Baumgartner et al. 2017). NARWs may prefer to conduct shallower foraging dives when possible (Baumgartner et al. 2017). While this theoretically allows for more time within a given dive to feed (e.g., Baumgartner et al. 2003a, b), an analysis of NARW foraging dives has indicated that NARWs do not feed for longer durations at shallower depths (Baumgartner et al. 2017). It has been suggested that NARWs may prefer to avoid long-duration foraging dives to reduce physiological stress associated with extended breath holding (Baumgartner et al. 2017).

Diet

NARWs are stenophagic predators, specializing on copepods (Murison and Gaskin 1989; Mayo and Marx 1990). Zooplankton observations near feeding NARWs in the GMB in the BoF and RB on the SS in summer and autumn have indicated that NARWs primarily feed on discrete and highly concentrated subsurface layers of late-stage *Calanus* spp. (Murison and Gaskin 1989; Baumgartner and Mate 2003; Baumgartner et al. 2017). *Calanus finmarchicus* has been identified in NARW fecal samples, confirming its presence in the NARW diet (Stone et al. 1988). Late stages of *Calanus* spp. are relatively large copepods that are lipid and energy-rich and therefore constitute a high-quality prey source for NARWs (Davies et al. 2012; Helenius et al. 2024). Although *Calanus* spp. are often the primary food source, the NARW diet varies in composition and includes other copepod taxa that are smaller and less energy rich than *Calanus* spp. (e.g., *Pseudocalanus* spp., *Centropages* spp.) and other zooplankton taxa (Watkins and Schevill 1976; Murison and Gaskin 1989; Mayo and Marx 1990; Johnson 2022). In comparison to *Calanus* spp., smaller or more mobile zooplankton may need to occur at extremely high concentrations to be energetically profitable for NARWs due to their lower caloric content or capture efficiency (Mayo et al. 2001; DeLorenzo Costa et al. 2006; Lehoux et al. 2020).

NARWs must consume large quantities of copepods to meet their energy requirements (Kenney et al. 1986; Fortune et al. 2013; Gavrilchuk et al. 2021). Daily energy requirements are believed to be approximately 1500 – 1900 MJ per day (MJ d^{-1}) for adult males and resting adult females, and approximately 4120 – 4233 MJ d^{-1} for lactating females, a value which is approximately double that of pregnant females (i.e., 1855 – 2090 MJ d^{-1}; Fortune et al. 2013; Gavrilchuk et al. 2021). Pregnancy and lactation phases are highly dependent on mature females accruing the energy reserves necessary for carrying the fetus to term, and nursing a rapidly growing calf (e.g., approximately 1.7 cm and 34 kg per day; Fortune et al. 2012). To balance their considerable nutritional requirements with their energy expenditure, a minimum zooplankton density threshold must be met to achieve a net energy gain by feeding in a given location. Given daily energetic requirements, this would translate into an overall *C. finmarchicus* CV threshold density of greater than 1,000 individuals per meter cube (m^{-3}), with > 10,000 individuals m^{-3} required for lactating females (Murison and Gaskin 1989; Mayo and Marx 1990; Woodley and Gaskin 1996; Baumgartner and Mate 2003; Gavrilchuk et al. 2021). The minimum density needed to meet energy demands will change with type of the *Calanus* spp. consumed, as well as with any variations in their energy content or quality (e.g., McKinstry et al. 2013; Helenius et al. 2024; Johnson et al. 2024).

Prey Aggregation

Zooplankton aggregations are a function of the presence of adequate supply, biophysical concentrating mechanisms involving zooplankton movement (i.e., swimming, sinking, floating), and features of the physical environment (Genin 2004). Three zooplankton accumulation mechanisms likely contribute to prey aggregation. First, ontogenetic or higher frequency vertical migration of zooplankton may be physically blocked by the seafloor. The vertical distribution of *Calanus* spp. tends to exhibit a “deep” abundance mode that becomes more compact with decreasing bottom depth, leading to concentrated near-bottom layers on the continental shelf relative to the slope (Krumhansl et al. 2018; Plourde et al. 2019). Second, depth maintenance of zooplankton in the presence of convergent or divergent flow can lead to accumulation of zooplankton in localized zones associated with different physical oceanographic phenomenon such as fronts or internal waves (e.g., Lennert-Cody and Franks 1999; Epstein and Beardsley 2001). Finally, downward zooplankton migration can lead to retention and accumulation of individuals in localized bathymetric depressions on the continental shelf (e.g., Osgood and Checkley Jr 1997; Johnson et al. 2006).

Processes that facilitate the formation of prey aggregations in known NARW foraging areas were reviewed by Sorochan et al. (2021a) and more recently in the southern GSL (sGSL) by Johnson et al. (2024). Both studies emphasize that *Calanus* spp. are re-supplied to NARW foraging areas each year from upstream sources, and that the timing and magnitude of re-supply is dependent on the phenology of *Calanus* spp. (which differs among species), and connectivity between source and sink areas. Furthermore, the biophysical mechanisms that contribute to prey aggregation will vary with the behaviour and vertical distribution of the copepods, which changes over time as the copepods develop. Ultimately, the formation of dense *Calanus* aggregations that NARWs can exploit requires biophysical mechanisms that influence prey supply (e.g., biomass), aggregation (i.e., local accumulation) and availability (i.e., the presence of concentrated prey at depths that NARWs can exploit, given behavioural and physiological limits of NARW foraging dives; Figure 3; reviewed by Sorochan et al. 2021a).

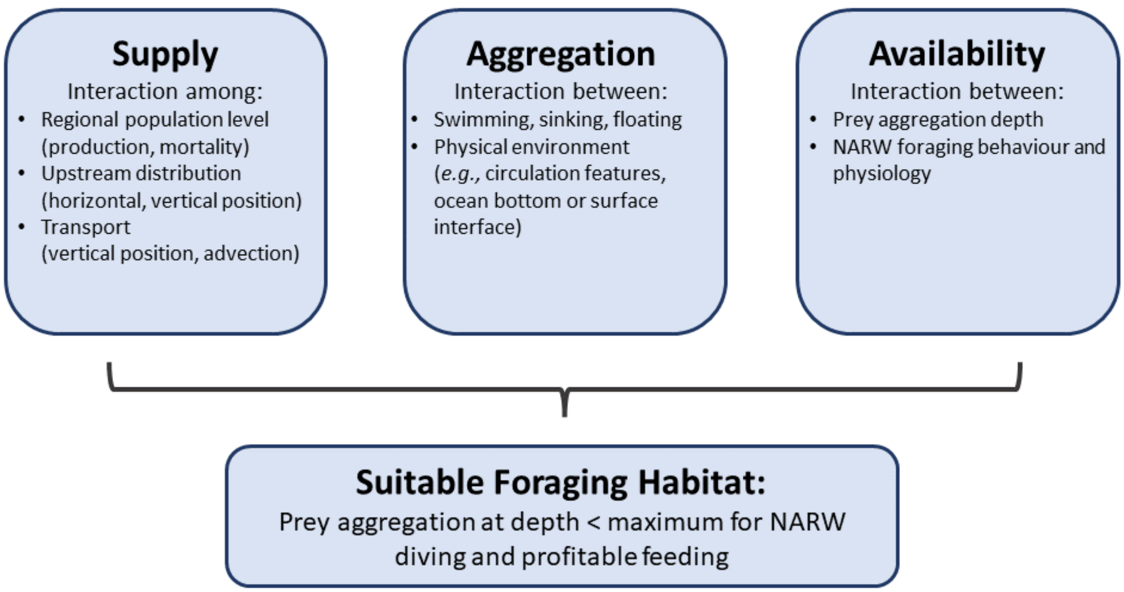

Figure 3: Schematic of the Supply-Aggregation-Availability conceptual model indicating that adequate supply and aggregation processes must align in locations where prey are available at depths less than the maximum for North Atlantic right whale diving and profitable feeding (Sorochan et al. 2021a).

Although zooplankton concentrating mechanisms have been proposed in NARW habitats, in general, these mechanisms are either not well described or rarely observed (Sorochan et al. 2021a). It is important to recognize that NARWs are unlikely to occupy all habitats where prey aggregations occur and that high prey concentrations may not always be associated with certain features due to inadequate prey supply. This likely contributes to inconsistencies in relationships between NARW presence and prey aggregating habitat features.

GESTATION, GROWTH, REARING, NURSING, AND SOCIALIZATION

Pregnant females are regularly detected in Canadian habitats, with some being present for a significant portion of their gestational period (NARWC 2023; Crowe et al. 2021). Mother-calf pairs are also consistently observed in Canadian waters (NARWC 2023) and may be present during a large portion of the nursing period (typically 8 to 12 months) after leaving the calving grounds. In addition to obtaining the energy required for rapid postnatal growth, including baleen growth that optimizes foraging efficiencies once they become weaned juveniles (Fortune et al. 2012; Fortune et al. 2021), accompanying their mother and being nursed for a prolonged period is likely to substantially benefit calves by minimizing the risk of predation by white sharks (*Carcharodon carcharias*) and killer whales (Taylor et al. 2013).

Post-weaning NARW mother-calf associations are thought to serve a variety of purposes. Observations of these associations have increased since the early 2000s, including weaned calves remaining with mothers during highly energy-demanding ‘non-essential’ return migrations to the calving grounds. These observations support the hypothesized benefits of socialization whereby mothers teach their calves migratory paths, foraging and feeding strategies, and social behaviours (Hamilton et al. 1995; Hamilton and Cooper 2010).

SOCIALIZING AND REPRODUCTION

NARWs participate in surface active groups (SAGs) that are hypothesized to facilitate fertilization, teaching/ learning, courtship, mating practice, as well as the identification of fit mates (Parks et al. 2007; Brown and Sironi 2023). SAGs are described as two, three, or up to 40 or more NARWs interacting at the surface in proximity (i.e., less than one body length apart) with frequent physical contact (Kraus and Hatch 2001; Kraus and Rolland 2007; Brown and Sironi 2023). SAGs can last several hours and composition is variable but generally includes a focal-female with multiple males, wherein the females appear to make calls for males that can be heard for several kilometers (Kraus and Hatch 2001; Parks 2003; Kraus et al. 2007; Lonati et al. 2022; Brown and Sironi 2023; see Communication section).

SAG activity can generally be broken down into non-conceptive and conceptive behaviour types that occur anywhere from April to October, and from September to December, respectively (Kraus and Hatch 2001; Brown and Sironi 2023). However, due to the uncertainty in the gestation length: 12-13 months (Best 1994) versus 18-24 months; (N. Lysiak, pers. comm.; Hunt et al. 2016; Lysiak et al. 2018; Lysiak et al. 2023) it is not possible to separate non-conceptive and conceptive SAG behaviour based on time of year.

COMMUNICATION

Marine mammals, including NARWs, produce sounds to support critical functions such as communication, foraging, and socialization. NARWs produce a variety of sounds including:

- upcalls - a frequency modulated upsweep between 50 and 200 Hz produced by all demographics in all habitats (Parks and Tyack 2005; Parks et al. 2007; Parks et al. 2011a);
- tonal calls including moans, screams, warbles, within frequencies ranging from 50-600 Hz and lasting less than 5 sec (Vanderlaan et al. 2003; Parks et al. 2005; Parks et al. 2012b);
- ‘gunshots’ - broadband impulsive sounds that are much shorter in duration (Parks 2003; Franklin et al. 2022);
- other sounds including baleen rattles, and blows (Watkins and Schevill 1976; Parks et al. 2019; Matthews and Parks 2021).

The vocal behaviour of NARWs varies amongst demographic groups, activities (e.g., SAGs, resting, foraging, travelling), and across seasons and habitat areas. Upcalls are thought be a contact call made by all individuals in the population (Parks and Tyack 2005; Parks and Clark 2007). Gunshots are associated with behavioural displays predominately made by males during the breeding season, and are thought to function as an advertisement to females while being an agonistic signal to other males (Parks 2003; Franklin et al. 2022). Screams are a specific vocalization attributed to the focal-female solely when in a SAG, whereas warbles are specific to calves within SAGs (Parks et al. 2005; Parks et al. 2012a). Other low-amplitude acoustic signals included ‘paired grunts’ recorded from juveniles, pregnant females, and lactating females with calves under three months. It has been hypothesized that these sounds facilitate ‘acoustic crypsis’ to protect vulnerable calves from predators (Parks et al. 2019; Matthews and Parks 2021). The behavioural context of vocalizations not only affects the type of sound produced but also the rate at which sounds are produced. Matthews and Parks (2021) summarized NARW call rates and indicated that in certain areas NARWs called at higher rates in SAGs and while travelling, and at lower rates when foraging and resting. However, there is also extreme variation depending on individual, habitat, time of year, and group size and/or group composition (Matthews and Parks 2021).

Current predictions of NARW hearing capabilities are based on vocalization frequency, anatomical modeling, and behavioural responses, resulting in a predicted hearing range within the 20 Hz to 22 kHz range (Parks et al. 2007; Parks et al. 2011a; Matthews and Parks 2021). Studies on NARW behavioural response and perceptual abilities are very limited, although, in one study, their response to noise varied greatly depending on the noise type transmitted. NARWs responded strongly to playbacks of various alert signals by swimming to and staying at or just below the surface; however, they reacted mildly to conspecific social sounds, and did not respond to vessel noise playbacks at all (Nowacek et al. 2004).

The importance of passive listening for NARW in relation to critical functions is uncertain. However, the acoustic environment must ensure environmental sound levels are below a level that would negatively impact NARW acoustic social communications, navigation, and use of important habitats. Though some work towards developing metrics to quantity underwater noise impacts on NARW has been done (Marotte and Wright et al. 2022); sound level thresholds associated with these various impacts have not been defined.

METHODOLOGY FOR IMPORTANT HABITAT IDENTIFICATION

To identify important habitat, we incorporated information from visual and acoustic detections of NARWs, historical NARW distribution, prey observations, and prey models. This approach allowed us to map locations where NARWs have been detected, are predicted to be detected, and/or where optimal NARW prey abundance is available or anticipated. By synthesizing these data, we enhanced our understanding of NARW distribution and aggregation in Canadian waters while also identifying likely habitats based on foraging energetics where NARWs may currently reside or shift due to ongoing distributional changes.

STUDY AREAS

Previous publications focusing on NARWs in Canadian waters vary in the way they identified study areas (Lehoux et al. 2020; Brennan et al. 2021; Crowe et al. 2021; Durette-Morin et al. 2022; O’Brien et al. 2022; Le Corre et al. 2023; Meyer-Gutbrod et al. 2023; Tao et al. 2023; Moors-Murphy et al. 2025), making comparison among studies challenging. To address this, boundaries herein were defined following the NARWC database methodologies and limitations (see Appendix 2), with adjustments to account for lack of definition north of the eastern SS. The boundaries were also expanded and/or defined by highly-utilized existing area boundaries, oceanographic features, and NARW sightings (Figure 4; see also Figure A2(1)). These could provide a standardized way of referring to Canadian areas in the future.

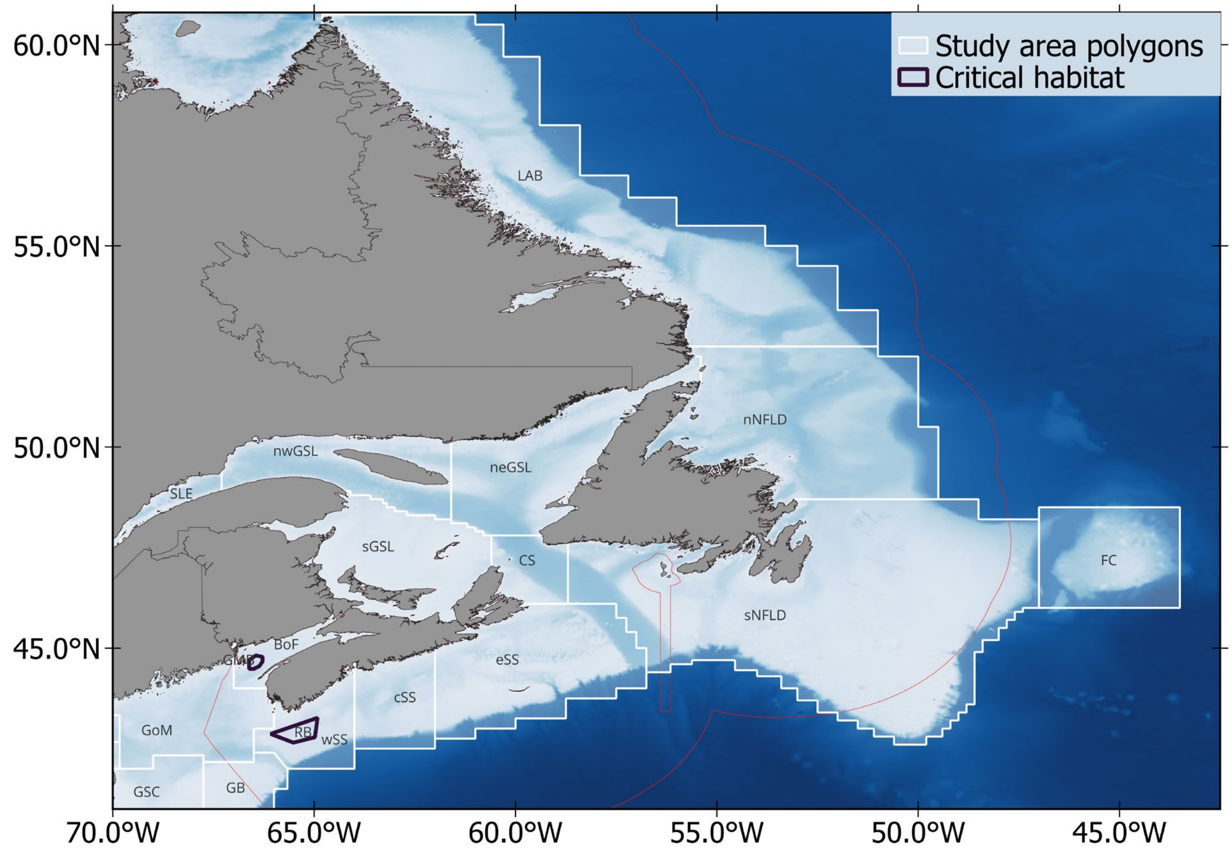

Figure 4: North Atlantic right whale Canadian habitat areas defined in this study that were expanded from the North Atlantic Right Whale Consortium (NARWC) databases (see Appendix 2). The Canadian areas in alphabetical order include: Bay of Fundy (BoF) including the Grand Manan Basin (GMB), Cabot Strait (CS), central Scotian Shelf (cSS), eastern Scotian Shelf (eSS), Flemish Cap (FC), Canadian waters of Georges Bank (GB) and the Gulf of Maine (GoM), Labrador Shelf (LAB), northeastern Gulf of St. Lawrence (neGSL), northwest Gulf of St. Lawrence (nwGSL), northern Newfoundland (nNFLD), southern Gulf of St. Lawrence (sGSL), southern Newfoundland (sNFLD), St. Lawrence Estuary (SLE), and western Scotian Shelf (wSS) including Roseway Basin (RB). Exclusive Economic Zone of Canada boundaries (red lines) are also depicted.

DATA SOURCES

The historical NARW distribution (pre-1990) was described based exclusively on published literature. However, the more contemporary seasonal distribution and densities of NARW were defined using a synthesis of several data sources both from the published literature and from visual and acoustic detection databases. These sources included data from 1990 through 2023. Important habitat was estimated using various approaches that considered NARW distribution and energetic requirements in combination with observed prey densities and habitat modeling when available. Details on data collection and analytical methods for the various data sets are available within the applicable referenced studies.

Sightings Data

Since 2017, unprecedented systematic aerial survey efforts have been undertaken by Fisheries and Oceans Canada (DFO) to increase the knowledge of NARW abundance and distribution in eastern Canada. Efforts began with aerial surveys targeting specific areas in late-2017 and have continued annually thereafter with broadscale, repeated systematic surveys being undertaken between April through November (St-Pierre et al. 2024). Aerial survey efforts covered a substantial portion of eastern Canadian waters, and prioritized known and potential NARW habitat areas subdivided into strata. Each year, surveys were conducted in the GSL and identified critical habitats, while every other summer systematic surveys alternated between the SS and the continental shelf around Newfoundland and southern Labrador (Figure 5). DFO's systematic aerial surveys provided precise locations of NARWs, covered a broad geographic area, and were the bases of habitat modelling efforts for the GSL (Mosnier et al. 2025a; Mosnier et al. 2025b).

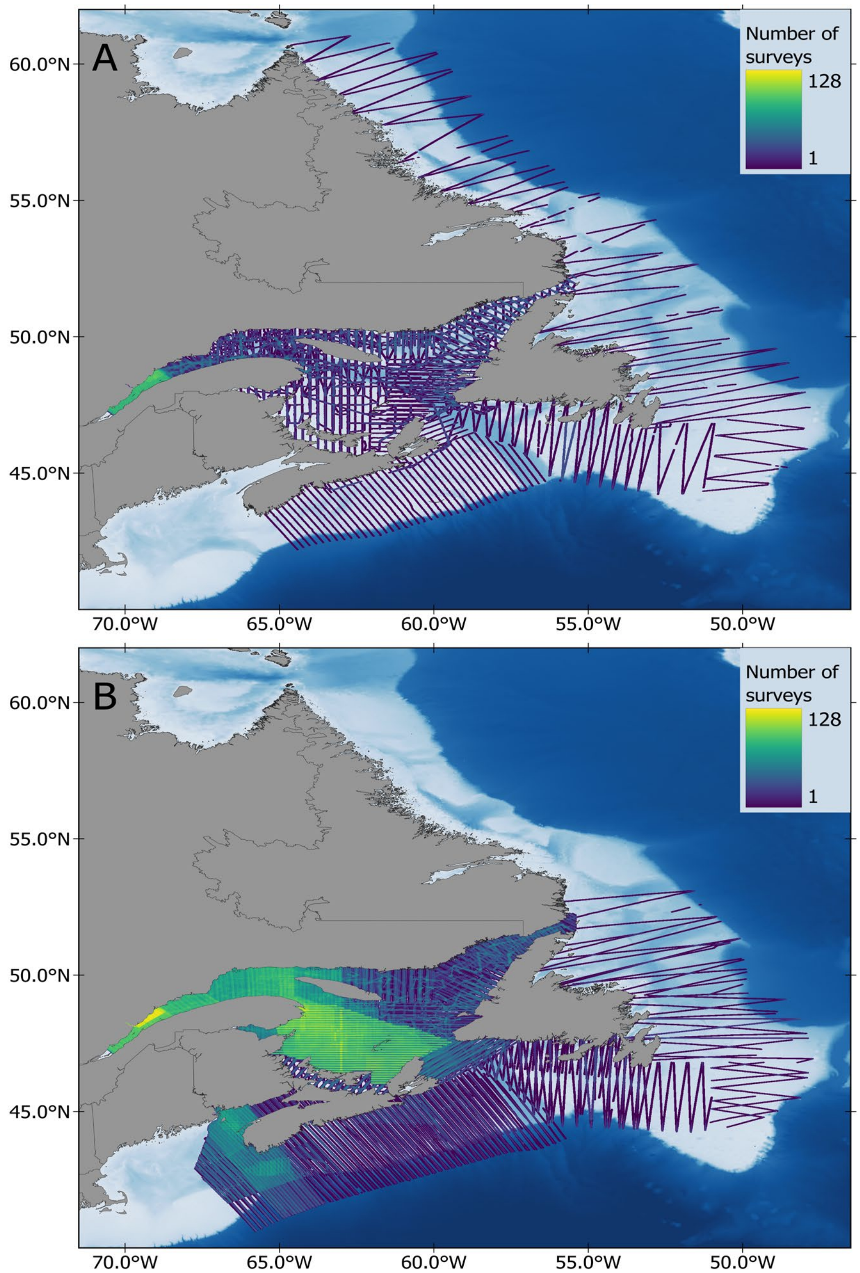

Figure 5: Fisheries and Oceans Canada (DFO) aerial survey coverage from Science's systematic surveys that occurred from April through November in eastern Canadian waters. Effort was measured as the number of systematic line-transect aerial visual surveys and is cumulative for the years 1995-2009 (A) and 2010-2020 (B). The colour scale for the number of surveys flown is on a logarithmic scale (log 10).

Additional NARW sightings, uncorrected for effort, were collected opportunistically or through mark recapture surveys by Government of Canada (GoC) assets or reported to DFO. The source of these data included: dedicated whale surveys, research platforms, whale-watching vessels, oil and gas platforms, fishing vessels, pleasure crafts, and shoreline observers. DFO Science in the eastern regions maintain cetacean sightings databases for storing data collected from various sources including non-DFO marine mammal science programs, consisting of: DFO Conservation and Protection (C&P), Transport Canada (TC) National Aerial Surveillance

Program (NASP), Environment and Climate Change Canada (ECCC) Canadian Wildlife Service (CWS) Eastern Canada Seabirds at Sea (ECSAS) program, and the Whale Research Group at Memorial University, among other organizations/sources.

The NARWC Identification Database (NARWC 2023) contains photographed sightings of NARWs and associated metadata for all individuals identified since 1935. This database includes sightings information on approximately 800 individuals derived from two million images and videos from more than 650 contributors, including the GoC consistently since 2017 (NARWC 2023). These data are curated by the Anderson Cabot Center for Ocean Life experts at the New England Aquarium (NEAq). There is typically a one-to-two-year lag for up-to-date NARW catalog data, therefore, the data obtained from the NARWC Identification Database only includes sighting and information up to 2021. However, some available life history information on mothers and calves up to and including 2023 was included in the dataset (see Appendix 4).

Sighting data for individual NARWs from the NARWC Identification Database were examined to assess connectivity between different areas and identify seasonal movement corridors. Observations of individuals within a given year revealed movement across various habitats; however, these observations should be considered as examples of movement only rather than definitive patterns. This is because sightings are influenced by survey effort, which varies across habitats.

The combined sightings dataset, including a total of 37,426 NARW events spanning the period of 1990 to 2023 from the following sources, was used to characterize the contemporary distribution of NARW in Canadian Atlantic shelf waters (Figure 10):

- NARW sightings from the DFO-Science aerial systematic surveys (2017-2022) as described in St-Pierre et al. (2024) and expanded from data described in Mosnier et al. 2025b;
- NARW sightings from the multi-national Trans North Atlantic Sightings Survey (TNASS) conducted in 2007 (Lawson and Gosselin 2009);
- NARW sightings from the multi-national North Atlantic International Sightings Survey (NAISS) conducted in 2016;
- NARW opportunistic sightings (2002-2023) from Newfoundland and Labrador (NL) waters as described in Lawson et al. (2025);
- NARW sightings, including opportunistic sightings (1990-2023), from eastern Canada available from the DFO Maritimes Region Whale Sightings Database (WSDB; MacDonald et al. 2017);
- NARW sightings, including opportunistic sightings (1990-2023), from eastern Canada available from the Quebec Region and the Ocean Biogeographic Information System (OBIS 2020); and
- NARW individual sightings, including opportunistic sightings (1990-2021), from eastern Canada available through the North Atlantic Right Whale Consortium Identification Database (NARWC 2023).

Duplicate sightings and sightings associated with unrealistic locations (such as on land) were removed from the dataset, as were sightings of whale carcasses. The quality of the opportunistic data varied from high quality sightings submitted by experienced observers with verifiable photos or video, to lower quality (although verifiable) sightings submitted by individuals or organizations of unknown background in marine mammal identification. Some of these sightings datasets include associated survey effort (kilometers surveyed); however, the effort data were not considered in this analysis.

Using a series of Geographic Information System processes, the sightings dataset was transformed to assess the persistence of habitat use by NARWs for two time periods: 1990-2009 and 2010-2023. The two time periods coincide with the start of the shift in distribution circa 2010 (e.g., Grieve et al. 2017; Meyer-Gutbrod and Greene 2018; Brennan et al. 2019; Meyer-Gutbrod et al. 2021; Sorochan et al. 2019). The DFO aerial systematic survey data for the period 2017-2022 were excluded from this analysis to avoid duplication, as they are the basis for the Mosnier et al. 2025b and Mosnier et al. 2025a habitat model. The processes behind this analysis were as follows:

1. the number of whales sighted in a 0.05 degree^2 hexagonal tessellated grid were counted for each year of data. The hexagon grid was used as this shape pattern 'reduces edge effects and sampling bias from lowest perimeter to area ratio of any regular tessellation of the plane', 'all neighbours are identical and the distance between centroids is the same for all neighbours', provides a 'better fit to curved surfaces and along coastlines', and is 'better for connectivity and movement paths' (Koropatnick and Coffen-Smout 2020);
2. the counts of whales observed were then transformed into binary data and summed through time for each period. The percentage of years with sightings was calculated for each hexagonal grid for an estimate of temporal persistence;
3. these temporal persistence measures were then transformed into rasters to represent areas where NARWs had been sighted.

This analysis did not account for survey effort (which was not available for several of the data sources) and thus, the results must be interpreted with caution.

Passive Acoustic Data

Passive acoustic monitoring (PAM) provides additional information on NARW occurrence, and allows for the monitoring of remote locations, during inclement weather, and for long periods of time, regardless of time of day. However, it is important to note that PAM detections are influenced by local topographic features, oceanographic conditions, and ambient noise. Factors such as NARW vocalization rates and calling behaviours, and distance to the instruments will also affect the detectability of NARWs. Notably, the number of acoustic detections does not correspond to the number of whales present (nor does absence of acoustic detections mean an absence of whales), rather the PAM data presented within provides information on minimum presence.

NARW PAM efforts in eastern Canada occurred in all regions likely to be used by NARWs (Figure 6). NARW acoustic data sources came from various systems, including: stationary buoys with PAM packages such as real-time Ocean Observing Stations (OSS; aka., DFO Viking buoys), fixed bottom-mounted PAM systems, and mobile Slocum gliders with PAM packages (Davis et al. 2017; Durette-Morin et al. 2022; Simard et al. 2024; Lawson et al. 2025; Moors-Murphy et al. 2025). Generally, the detection ranges of the PAM systems in this assessment are tens of kilometers (usually up to 30 km for fixed stations), albeit reduced in relatively noisy underwater soundscapes such as in and near the Laurentian Channel shipping lanes (Gervaise et al. 2019a, 2019b; Simard et al. 2019; Johnston and Painter 2024; Simard et al. 2024; Moors-Murphy et al. 2025; Lawson et al. 2025).

NARW acoustic detection data from the following sources, which all focus on detection of NARW upcalls only, were combined to provide a full-Canadian extent layer:

- days with detections of NARW upcalls from PAM systems in eastern Canadian waters (2004-2014) as described in Davis et al. (2017);

- days with detections of NARW upcalls from PAM systems in NL waters (exclusive of GSL; 2010-2023) as described in Lawson et al. (2025);
- monthly average proportion of days with detections of NARW upcalls in the GSL from PAM seafloor stations (2010-2022) and the Viking OOS buoy network (2019-2022) as described in Simard et al. (2019; 2024; Figures 7-9);
- days with detections of NARW upcalls from PAM systems in the CS, SS, BoF and NL waters (2015-2017) as described in Durette-Morin et al. (2022); and
- days with detections of NARW upcalls from PAM systems in the BoF, CS and on the SS (November 2017 to September 2022) as described in Moors-Murphy et al. (2025).

Seasonal presence was examined by first partitioning acoustic detections in Canadian waters by area and period (pre- and post 2010). The proportion of days with detections represents the minimum presence in an area.

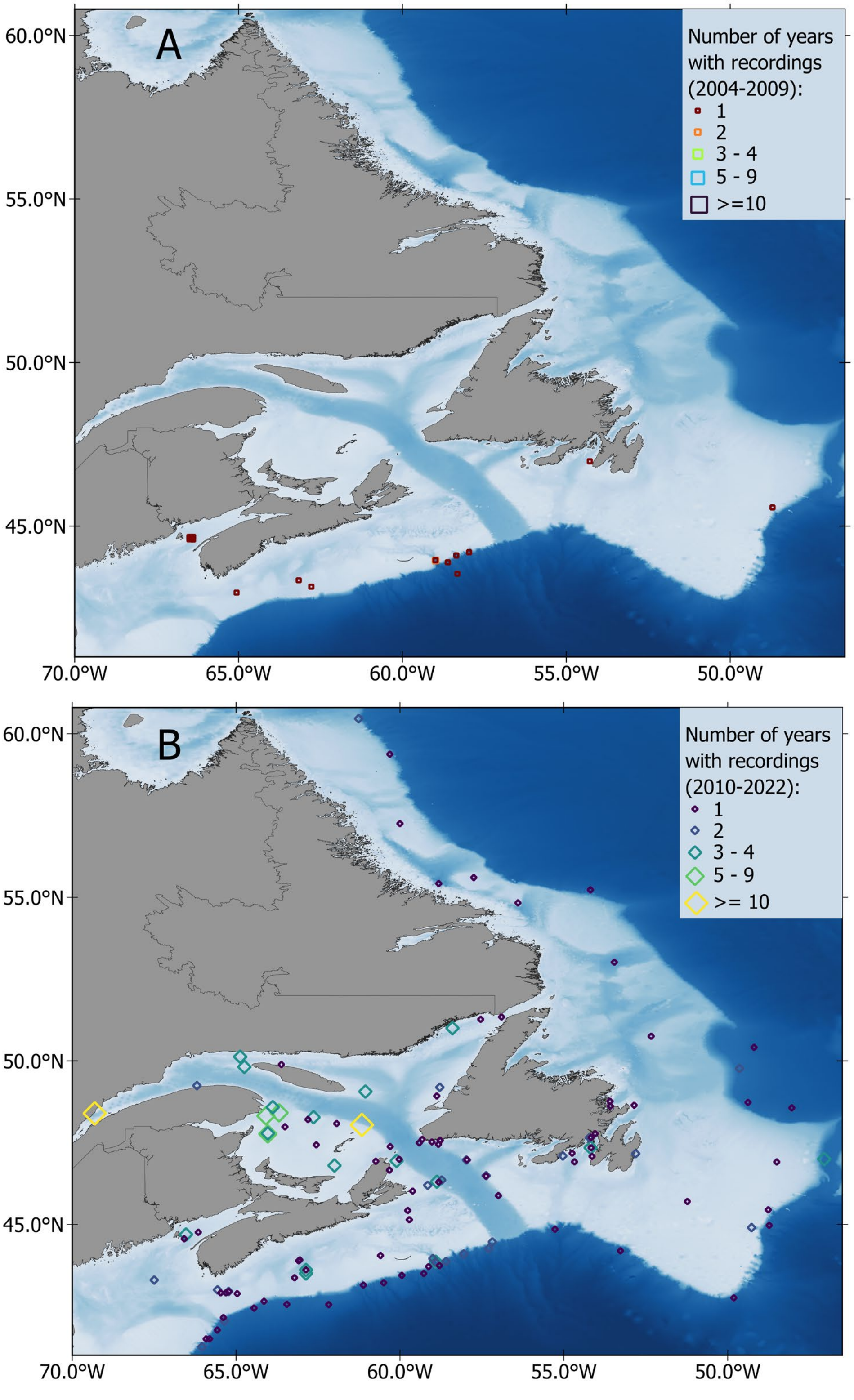

Figure 6: All passive acoustic monitoring (PAM) stations 2004-2022. are depicted and the symbology represent the years of monitoring effort. PAM stations for the period 2004-2009 are depicted as squares whereas PAM stations for 2010-2022 are depicted as diamonds. Data from several studies are combined: Davis et al. (2017); Simard et al. (2019; 2024); Durette-Morin et al. (2022); Lawson et al. (2025); Moors-Murphy et al. (2025).

Prey and Habitat Modelling Data

Several NARW prey and NARW habitat modelling data layers, as described in Plourde et al. (2024), Mosnier et al. 2025a and Mosnier et al. 2025b, were considered for the identification of NARW important habitat. The final data included:

- seasonal persistence (i.e., over one, two, or three months) of predicted foraging habitat (based on prey concentrations that meet the energy requirements of NARWs known as Enet > 90th quantile) in eastern Canada during 1999-2020 for April through September as described in Plourde et al. (2024; Figure 29). Enet is a net energy index that represents the proportion of energy gained or expended relative to energy expended (Gavrilchuk et al. 2021); and
- the relative probability of occurrence (> 90th percentile) of NARW based on the 2017 to 2022 Global Model predictions presented in Mosnier et al. 2025a (Figure 30) and Mosnier et al. 2025b.

Supplemental Data Used for Documenting NARW Habitat Use

NARWs have unique raised patches of tissue on their heads, called callosities, that are used to identify individuals (Kraus et al. 1986). These unique patterns provide a means of monitoring individual NARWs throughout their range (Hamilton et al. 2022). Longitudinal photo-identification data provided by the NARWC was used to identify pregnant females by cross-referencing the annual list of new mothers (Birth Year [Y]) with the females in their pregnancy years (Pregnant Year [Y-1 and Y-2]). For certain analyses, such as pregnancy cross-referenced with mother-calf pairs, the identification data from the 2022 and 2023 catalogue curated by DFO Gulf Region were separately validated by the NEAq experts and added for this analysis only.

NARW identification data can include additional contextual data (e.g., mother-calf pair, SAG) or behavioural information (e.g., nursing, skim-feeding) that are noted while in the field or *a posteriori* when an analyst is reviewing photographs. While these descriptions can be used to confirm some behaviours, they may lead to underrepresentation of other or more cryptic behaviours such as transit or feeding at depth. NARW catalogue experts from NEAq indicate that the most reliable or consistent contextual data noted are: surface/near-surface feeding behaviors, mothers with calves or yearlings, individuals that are entangled or dead, and SAGs (P. Hamilton 2023, pers. comm.).

The contextual data and/or behaviour information in the NARWC Identification database (1990 to 2021/2023) were used to support the documentation of functional behaviours in Canadian waters. These data were categorized into: movement (habitat connectivity), feeding activity, gestation, rearing (nursing), socialization (mother-calf associations), socializing, and reproduction (Appendices 1; 4). Forty-two percent of the observations in Canadian waters from the NARWC Identification database included relevant contextual information. When information could be categorized into multiple behaviours, each were included in the analysis. Contextual data were predominantly (76%) from the period prior to 2010 and thus, may be biased toward certain areas that are less used in recent years. The number of NARW mothers occurring in Canadian waters each year is provided in Appendix 4. While contextual data represent minimum occurrences, they support the designation of the various areas for specific functions. However, seasonal patterns are likely to be more reliable for regions such as the sGSL where survey effort has been consistent across seasons from 2018 - 2023. With the exception of one NARW surface-feeding off eastern Newfoundland and one in the central SS, the available data was restricted to the BoF, GoM, GB, western SS, (wSS) that includes RB, sGSL, and northwestern GSL (nwGSL) as multiple research groups have been collecting these data over multiple years (Figure 7).

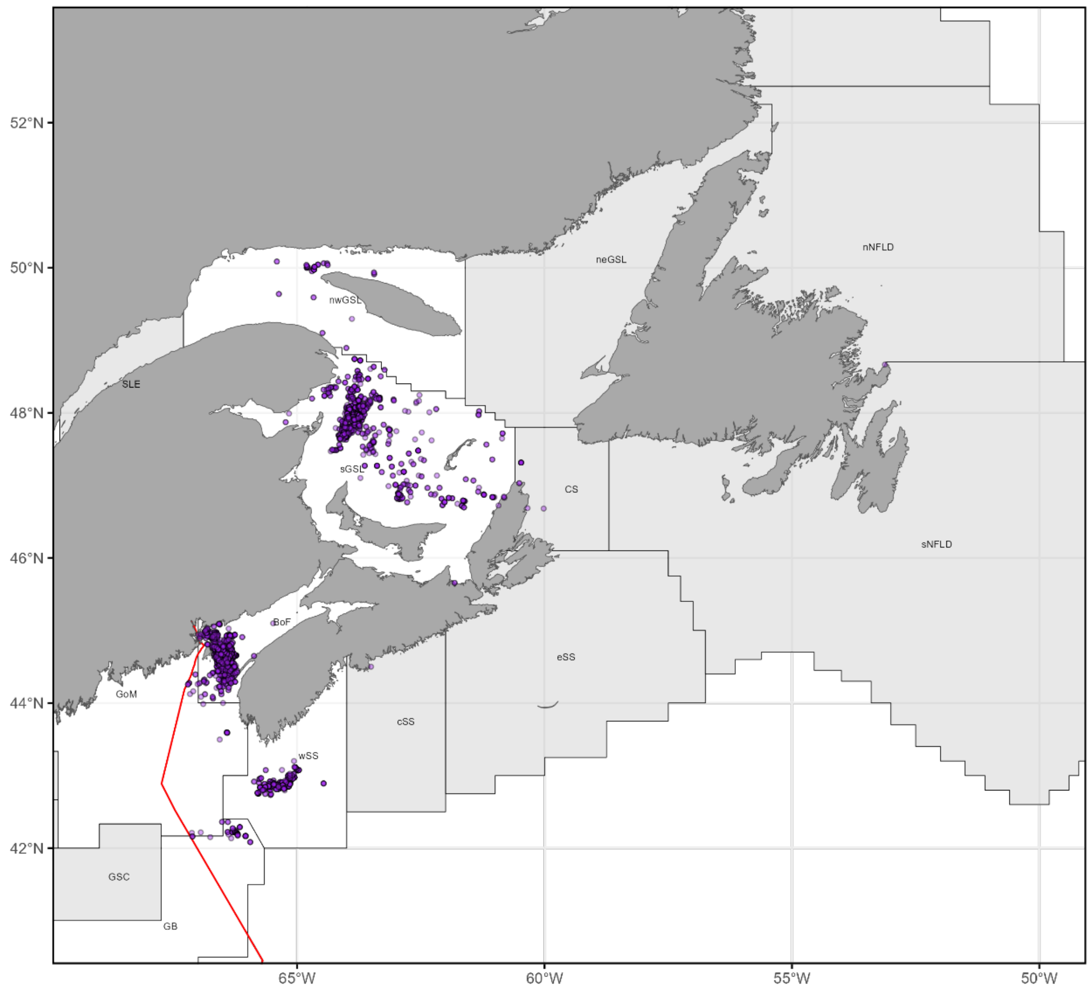

Figure 7: Distribution of North Atlantic right whale observations with associated contextual data or behavioural information in eastern Canadian waters from 1990-2021/2023. Economic Exclusive Zone Canada/United States of America border (red line) is identified. The Canadian areas in alphabetical order include: Bay of Fundy (BoF), Cabot Strait (CS), central Scotian Shelf (cSS), eastern Scotian Shelf (eSS), Flemish Cap (FC), Canadian waters of Georges Bank (GB) and the Gulf of Maine (GoM), Labrador Shelf (LAB), northeastern Gulf of St. Lawrence (neGSL), northwest Gulf of St. Lawrence (nwGSL), northern Newfoundland (nNFLD), southern Gulf of St. Lawrence (sGSL), southern Newfoundland (sNFLD), St. Lawrence Estuary (SLE), and western Scotian Shelf (wSS). White study area polygons represent areas where there were 30 or more sightings with associated contextual data.

NARW DISTRIBUTION

HISTORICAL (PRE-1990)

Historically, NARWs occurred on both sides of the North Atlantic as deduced primarily from whaling records dating back to the Basque fishery in the 11th century in the Bay of Biscay off the coast of France and Spain (Figure 8; Aguilar 1986; Kraus and Rolland 2007). In the northwest Atlantic, NARWs were hunted across the entire eastern seaboard of North America (Figure 8) and in Canada, mainly the coasts of NL, the Strait of Belle Isle, and the GSL (Figure 1;

Aguilar 1986; Brown 1986; Reeves and Mitchell 1986; Lindquist 1994; Reeves 2001; Reeves et al. 2007; Frasier et al. 2022). Basque whaling operations were established in the GSL and surrounding waters as early as the mid-16th century (Allen 1908). Full-scale operations emerged in Newfoundland in the 1530s with the main fishery located in the Strait of Belle Isle (Aguilar 1986). Other areas in eastern Canada were identified in Reeves et al. (2007) where American offshore fisheries in the 18th century successfully hunted NARWs in the BoF, the Strait of Canso (Nova Scotia [NS]), the Cape Breton Banks (NS), off Newfoundland, and east of the Grand Banks (Figure 1). NARWs continued to be hunted sporadically in the 19th and 20th centuries in Canada. Documentation suggests that there were two whales taken in Quebec in 1850 by the Gaspé sailing vessel fishery (Mitchell and Reeves 1983), and two other catches made in Canada, the last of which was in Newfoundland in 1951 (Mitchell and Reeves 1983; Mead 1986). In addition, there was also a record of one live NARW stranding in Pugwash, NS, (i.e., sGSL; Figure 1) in 1954 (Sergeant 1966; Sergeant et al. 1970).

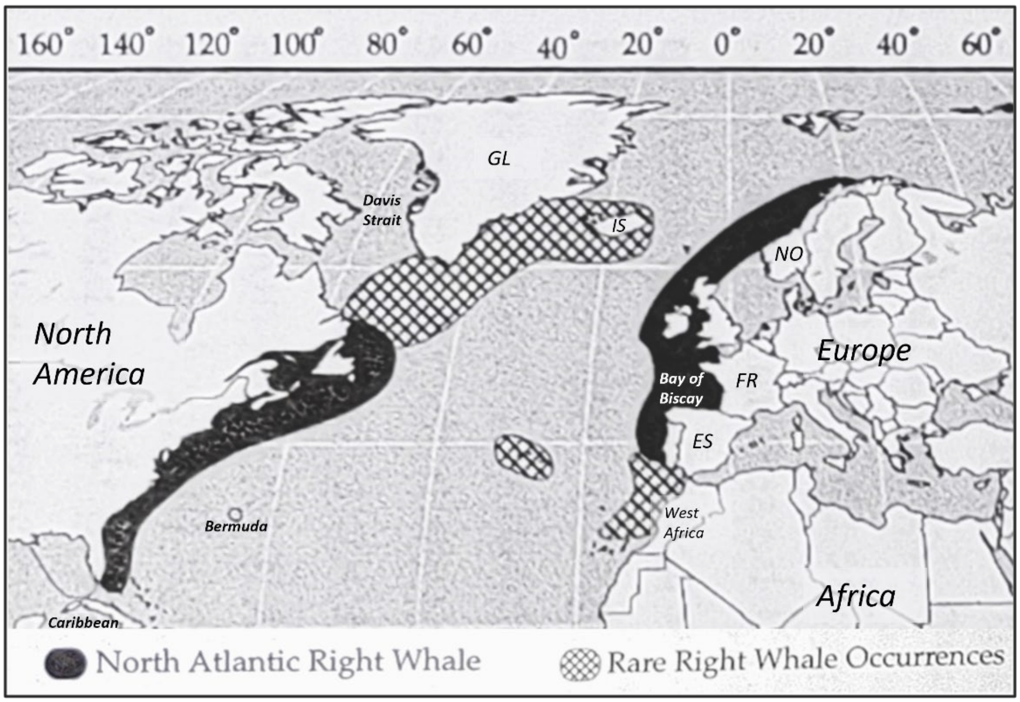

Figure 8: General delineation of the known primary historical range of North Atlantic right whales in the North Atlantic Ocean. Modified from Figure 1.2 presented in Kraus and Rolland (2007). Place names used in the text are identified, including, the Bay of Biscay, Bermuda, Caribbean, Davis Strait, France (FR), Greenland (GL), Iceland (IS), Norway (NO), Spain (ES), and west Africa (including Canary Islands).

In Canada, NARW catch records from some areas have been questioned as a result of unclear descriptions of the species caught, compounded by the overlap in the distribution of bowhead whales (*Balaena mysticetus*) and NARW in the northern Canadian range (Lindquist 1994). Genetic analyses and further scrutiny of sighting records suggests that the size of the pre-exploitation NARW population and the numbers exploited in the western North Atlantic are not as significant as originally described (Rastogi et al. 2004; McLeod et al. 2008; McLeod et al. 2010). However, the extent of the described historical range is considered accurate as a result of validated records combined with consideration of the timing and latitude of the historical records (Sergeant 1966; Sergeant et al. 1970; Reeves 2001; Reeves et al. 2007). For example, based on seasonal distributions of NARW and bowhead whales, records of NARW catches in the Strait of Belle Isle in heavy ice in May are more likely to refer to bowhead whales whereas catches in the GSL in summer and autumn months were likely NARWs as reported (Reeves 2001).

The scarcity of details in the historical records, especially prior to the 1750s, inherently limits the ability to thoroughly describe NARW historical distribution and habitat use (Reeves et al. 2007). However, basic information can be inferred from historical records referencing ‘feeding grounds’ (Allen 1908; Reeves et al. 2007; Frasier et al. 2022). Additionally, from described hunting methods that included chasing and/or striking the calves, NARWs would have been using these habitats to rear their young (Aguilar 1986; Lindqvist 1994; Reeves et al. 2007; Frasier et al. 2022). Monsarrat et al. (2015) used historical catch records of both the NARW and North Pacific right whale and the associated, primarily offshore, oceanographic data to model the historical summer range of NARWs. These efforts suggested that the NARW historical feeding grounds extended across the North Atlantic and were mainly driven by cold temperatures, high productivity, and low mixed layer depth (Figure 9).

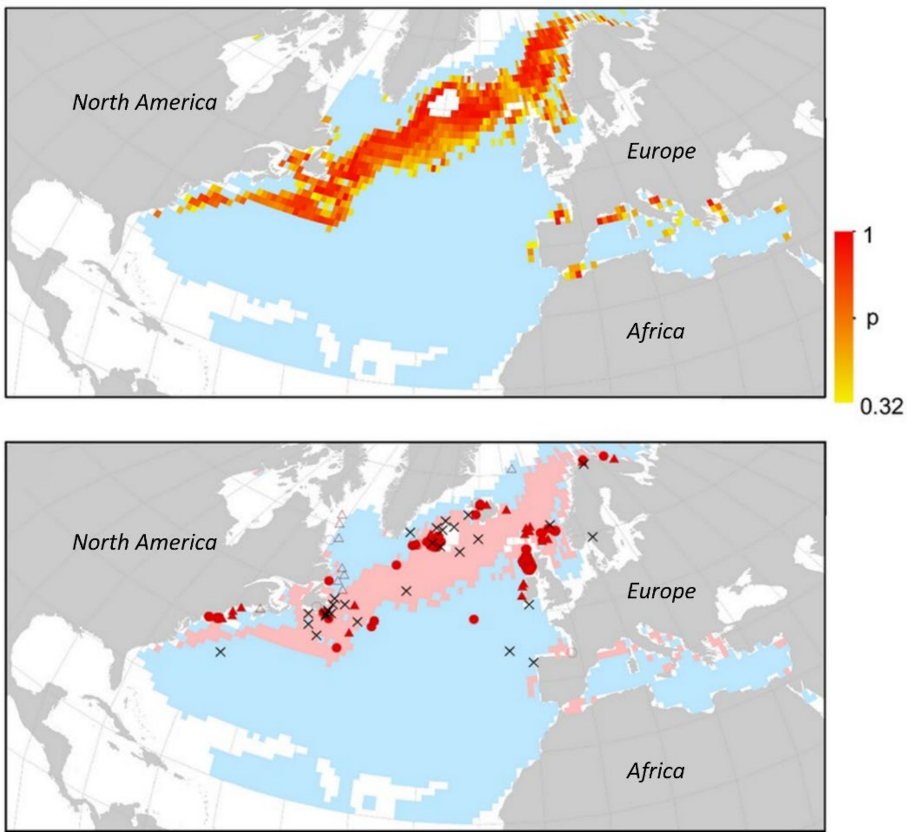

Figure 9: Model predictions and historical data of North Atlantic right whale (NARW) occurrence in the North Atlantic. Upper Panel: Predicted historical distribution of the NARW in the summer months (June–September) based on a species distribution model fitted to whaling records for the North Pacific right whale and extrapolated geographically into the Atlantic. Shades of red indicate progressively higher environmental suitability as predicted by the model; blue cells correspond to areas where the species is predicted to be absent; and white cells are areas for which no reliable predictions can be made. Lower Panel: Historical records, obtained by reviewing the literature for confirmed or likely NARW records from June to September. The area shaded in pink corresponds to the envelope of predicted presence as mapped in the Upper Panel. Symbols correspond to 142 historical (pre-1950) records from 1583 to 1935, distinguishing those for which there is higher (red symbols) or lower (open symbols) confidence in the species’ identity and those for which there is higher (circles) or lower (triangles) precision in location. In addition, the map includes 26 recent (post-1950) records outside the main summer grounds (black crosses). Figures from Monserrat et al. (2015).

CONTEMPORARY (1990-2023)

Contemporary information on NARW distribution has not provided evidence to support the persistence of a trans North Atlantic distribution (Kraus and Rolland 2007; Frasier et al. 2022). In the western Atlantic, NARWs primarily migrate along the eastern seaboard of North America, from Florida to NL. However, occasional extralimital observations or acoustic detections of NARWs have been made outside their contemporary range: to the south in Bermuda and the Caribbean; to the north in the Davis Strait and Iceland, as well as in the eastern North Atlantic, including Norway, Iceland, France, Greenland, and west Africa (Figure 8; Knowlton et al. 1992; Martin and Walker 1997; Jacobsen et al. 2004; Mellinger et al. 2011; Silva et al. 2012; Pettis et al. 2021; Hayes et al. 2023). Frasier et al. (2022) identified some nuclear differentiation between western NARWs and ancient samples from eastern NARWs, suggesting some gene flow within the ocean basin and thus, no genetic impairment of repopulation of the eastern North Atlantic. The importance of site fidelity in this process is however unknown, and remains challenging to estimate (Frasier et al. 2022).

In order to assess the contemporary distribution of NARWs, it is important to highlight the inherent limitations of the current tools available to monitor their presence in habitats. Acoustic data are fundamentally limited by the paucity of information on NARW calling rates and call types produced during migration (Matthews and Parks 2021). NARWs are believed to call infrequently while traveling, making it less likely to acoustically detect individuals briefly passing through large areas. Similarly, NARWs in transit are likely to be missed during visual surveys as NARWs are inherently difficult to observe due to their low profile in the water, dark colour, lack of a dorsal fin, and they may travel independently or in small groups (Hain et al. 1999; Brown et al. 2007; NOAA 2024b). Therefore, areas where a low occurrence of NARWs is indicated based on acoustic detections or visual observations need to be treated with caution as their importance might be underestimated, especially when effort is not taken into consideration. While the following analysis did not account for sightings per unit effort, the distribution and seasonal patterns of sightings per unit effort within Canadian areas described by Meyer-Gutbrod et al. (2023; Supplementary Information) are similar to the patterns observed from the NARW sightings dataset used in this assessment. As a compliment to observational data, the proportion of days with acoustic detections represents the minimum presence in an area; averaging monthly presence through time and across all PAM stations per area provides a measure of consistency. Comprehensive descriptions of the caveats associated with passive acoustic monitoring of NARWs are summarized above and detailed in Simard et al. (2024), Lawson et al. (2025), and Moors-Murphy et al. (2025). Notwithstanding the above caveats, the areas with consistent acoustic presence could indicate foraging, rearing, and/or social areas; functional behaviours typically associated with shorter-range movements (Franklin et al. 2022). Alternatively, areas with minimal or limited acoustic presence could be indicative of transit corridors and longer-range movements through an area.

Seasonal occupancy and migration of NARWs onto the continental shelves of New England and Atlantic Canada occurs in late winter and spring. In general, non-breeding NARWs remain in feeding areas primarily in the northeast USA during winter; areas off of SNE, CCB, GSC, and the GoM (Figure 1; NARWC 2023; WhaleMap - Johnson et al. 2021). In the spring, summer, and autumn, NARWs occur in Canadian habitats in the BoF, on the SS, and in the GSL where they feed (Murison and Gaskin 1989; Nieukirk 1993; Woodley and Gaskin 1996; Baumgartner and Mate 2003; Baumgartner et al. 2003a,b; Patrician and Kenney 2010; Franklin et al. 2022; Meyer-Gutbrod et al. 2023; Wright et al. 2024).

In the 2010s, warming sea surface and deep-water temperatures were linked to changes in the distribution and abundance of *C. finmarchicus* and a shift in the distribution of NARW (Meyer-Gutbrod et al. 2018; Record et al. 2019; Sorochan et al. 2019; Meyer-Gutbrod et al. 2021, 2023). A primary source of variation in northwest Atlantic shelf water column properties is the climate-driven influence of Labrador Current and Gulf Stream dynamics (e.g., Petrie et al. 2007; Peterson et al. 2017). Interaction of these currents, particularly at the tail of the Grand Banks, affects downstream slope and shelf water physical, chemical, and biological composition (Petrie and Drinkwater 1993; Greene et al. 2013; Brickman et al. 2018; Pershing and Stamieszkin 2020; Gonçalves Neto et al. 2021; Lehmann et al. 2023; Garcia-Suarez and Fennel 2024). Temporal variability of subsurface temperature (e.g., > 100 m) on the SS and in the GoM have been characterized by annual and decadal oscillations superimposed on a long-term increasing trend since a cold period in the 1960s (Petrie and Drinkwater 1993; Galbraith et al. 2023; Hebert et al. 2023), and large-scale ocean models predict a continuing warming trend (e.g., Saba et al. 2016; Wang et al. 2024). Ocean temperature rapidly increased in the region starting in the mid- to late 2000s (Brickman et al. 2018; Seidov et al. 2021), and the system entered an extended period of high temperature anomalies in the 2010s due in part to increased influence of Gulf-Stream-derived Warm Slope Water (e.g., Townsend et al. 2023). This temperature increase was linked to declines in population level of *C. finmarchicus* near the southern range limit of this species, and NARWs appear to have subsequently shifted their distribution in pursuit of better feeding conditions (Record et al. 2019; Sorochan et al. 2019; Meyer-Gutbrod et al. 2021; 2023). In Canadian waters, NARWs were observed less frequently, or for shorter periods of time, in GMB and RB. Also, NARWs were detected more frequently in the GSL beginning in 2015 (DFO 2019; Simard et al. 2019; Meyer-Gutbrod et al. 2023).

These significant spatiotemporal changes in NARW detections in Canadian waters, since 2010, prompted the division of the data into two periods for the purpose of this important habitat assessment: pre-distribution shift (1990-2009) and post-distribution shift (2010-2023).

Monthly Distribution (1990 - 2009)

Prior to 2010, the distribution of NARWs was generally maintained with some regional interannual variability (see Movement and Migration section). However, notable differences in distribution were observed in 1992 when NARWs were not seen in their typical spring foraging grounds in the GSC (Kenney 2001), and from 1993 to 1997 when they were not seen in the RB (Patrician and Kenney 2010; Davies et al. 2015). Prior to 2010, NARW were observed in Canadian waters primarily from July through August, and were concentrated in the BoF and SS areas (Figures 10A and C, Figures 17A and C, Figures 18 A and C), mainly in the areas later identified as critical habitat, i.e., RB and GMB (Figure 1). In general, the distribution of NARW also included the northern (Canadian) portion of the GoM and GB, the central SS (cSS; e.g., Emerald Basin), with occasional sightings in the sGSL and nwGSL (Figure 10A). There were infrequent sightings on the NL Shelf, in the CS, and the SLE, and only occasional sightings on the eastern SS (eSS) and off the shelf break. There were NARW sighting records in all months of the year, with the exception of March, with infrequent sightings from December through February (Figure 11A to Figure 22A). There were also acoustic detections of NARWs in RB for the majority of a year, except for the months of January, February, and July (Figure 23). Similarly, the Emerald Basin in the cSS region had acoustic detections in February, March, April, June, and August through November. The BoF had acoustic detections in July and August (Figure 23); however, these were the only two months with PAM effort during the pre-distributional shift period.

Monthly Distribution (2010 - 2023)

Starting in 2010, the distribution of NARWs shifted with a decrease in observations and acoustic detections in the traditional foraging areas in the BoF and RB and increased observations and detections in the sGSL and nwGSL (Figures 10B and D; Figures 24-25). During the 2010 - 2023 period, the distribution of NARWs within Canadian habitats based on the combined sighting and acoustic efforts, included: the BoF, the wSS, the cSS, along the SS edge, CS, the sGSL and the nwGSL (Figures 10B and D). The observed increase in acoustic detections in the sGSL started in 2015 (DFO 2019; Simard et al. 2019, 2024; Meyer-Gutbrod et al. 2023); concurrently, efforts from the existing vessel surveys and the increased aerial survey confirmed the abundance of NARW in the area (Cole et al. 2020; Crowe et al. 2021). NARWs were also occasionally detected off the south and east coasts of Newfoundland, and the north Labrador coast (Figures 10B and D; Lawson et al. 2025).

Ultimately, a distinct early-season pattern of occupancy, starting in southern Canadian waters and extending to the GSL habitats is not clearly discernible due to the simultaneous presence of NARWs in the BoF, RB, cSS, eSS, sGSL, neGSL, and sNFLD during April, although detections are limited in number (Figures 11B and D to Figures 14B and D; Figures 24-25). The simultaneous occupancy of both southern and more northern Canadian habitats highlights the challenges with surveillance, monitoring, and ultimately detecting NARWs throughout this large extent. Sightings data, supported by increased acoustics presence, suggest a notable influx of NARWs in May and June into distinct high-use Canadian habitats in the sGSL and the BoF (Figures 15B and D; Figures 16B and D; Figures 24-25). Moors-Murphy et al. (2025) noted that the general scarcity of NARW upcall detections in April/early-May could indicate that acoustic efforts are missing NARWs while they are migrating across the SS, possibly as a function of little to no vocalization while travelling. It is during this time that multiple PAM stations across several areas show lower daily presence of NARW upcalls.

In general, the average percent of days with acoustic detections in Canadian waters increases in April through to August (Figure 25) and decreases from September through December. However, variation is observed within the Canadian extent, at regional scales. For example, following some detections in April, May, and June in our most southern region, the southern habitats such as the BoF and GoM, NARWs are increasingly detected again both visually and acoustically in these areas later in the year (Figures 24-25; see also Davies et al. 2019). By July and August and markedly so in September, increases in detections are noted in RB, wSS, and BoF, with a peak in detections in October and November (Figure 18D to Figure 21D; Figure 25; Moors-Murphy et al. 2025). Further, in the BoF there are very few (< 10%) days with detections until August and the average days with detections ranges from 7% to 24% for August through November, with a maximum in October (Figure 25).

In the sGSL, NARW observations peaked during July with lower numbers observed in the sGSL during the shoulder seasons (i.e., May/June and September through November; Figure 13B to Figure 16B; Figure 19B to Figure 21B). The timing of these observations nearer the CS, south of the Honguedo Strait, east of the Magdalen Islands or east of Cape Breton (Figure 1; *hereafter* southeastern GSL [seGSL]) may suggest that NARWs were observed while immigrating into the sGSL towards the Shediac Valley (Figure 1; Figure 14B to Figure 16B) or were observed while subsequently emigrating out of the sGSL (Figure 20B to Figure 22B). However, during a few survey years, there were NARW sightings in the sGSL in July and August, primarily west of the Magdalen Islands and in the Bradelle Valley area indicating some summer use of this habitat area (Figure 17B; Figure 18B; St-Pierre et al. 2024). NARW observations and acoustic detections begin to shift from the southwestern GSL (swGSL) to the seGSL starting in September and noticeably in October (Figure 19B; Figure 20B; St-Pierre et al. 2024). Other areas are also frequented in July, August and September, notably the nwGSL, BoF, RB, northern GoM and GB (Figures 17B and D to Figures 19B and D; Figures 24-25). Occasional sightings and acoustic detections occur in the CS, on the eSS, and in waters surrounding Newfoundland (Figures 10B and D; Figures 24-25).

Generally, in the GSL, NARWs are consistently observed or detected from May/June to November (Figures 15B and D to Figures 21B and D). However, acoustic and sightings data show a gradual shift eastward starting in October seemingly signaling the emigration of NARWs from the GSL through the CS to southerly habitats, with a few NARW remaining until December (Figures 20B and D to Figures 22B and D; Simard et al. 2024).

NARW are detected relatively rarely in the waters surrounding NL. Despite sparce visual and acoustical detections, NARWs are found in these waters throughout the year (Figures 11B and D to Figures 22B and D; Lawson et al. 2025). Due to the limited detections in the waters off of NL, seasonal patterns were not examined or presented. However, Lawson et al. (2025) demonstrated that NARWs have occasionally been detected in coastal areas off southern Newfoundland such as Placentia Bay, as well as in offshore areas such as the northern edge of Flemish Pass (Lawson et al. 2025). Interestingly, NARW upcalls have been detected occasionally in the neGSL (i.e., western NL / Strait of Belle Isle) in all three spring (April, May, June) and summer (July, August, September) months, and detections in eastern Newfoundland (north and south) and Labrador, although sparse, occurred primarily in September to November (Figure 19D to Figure 21D). This may indicate the use of the Strait of Belle Isle as a migratory corridor to north and eastern NL waters, primarily in the summer and early-autumn months when NARWs noticeably occupy the nGSL (Simard et al. 2024).

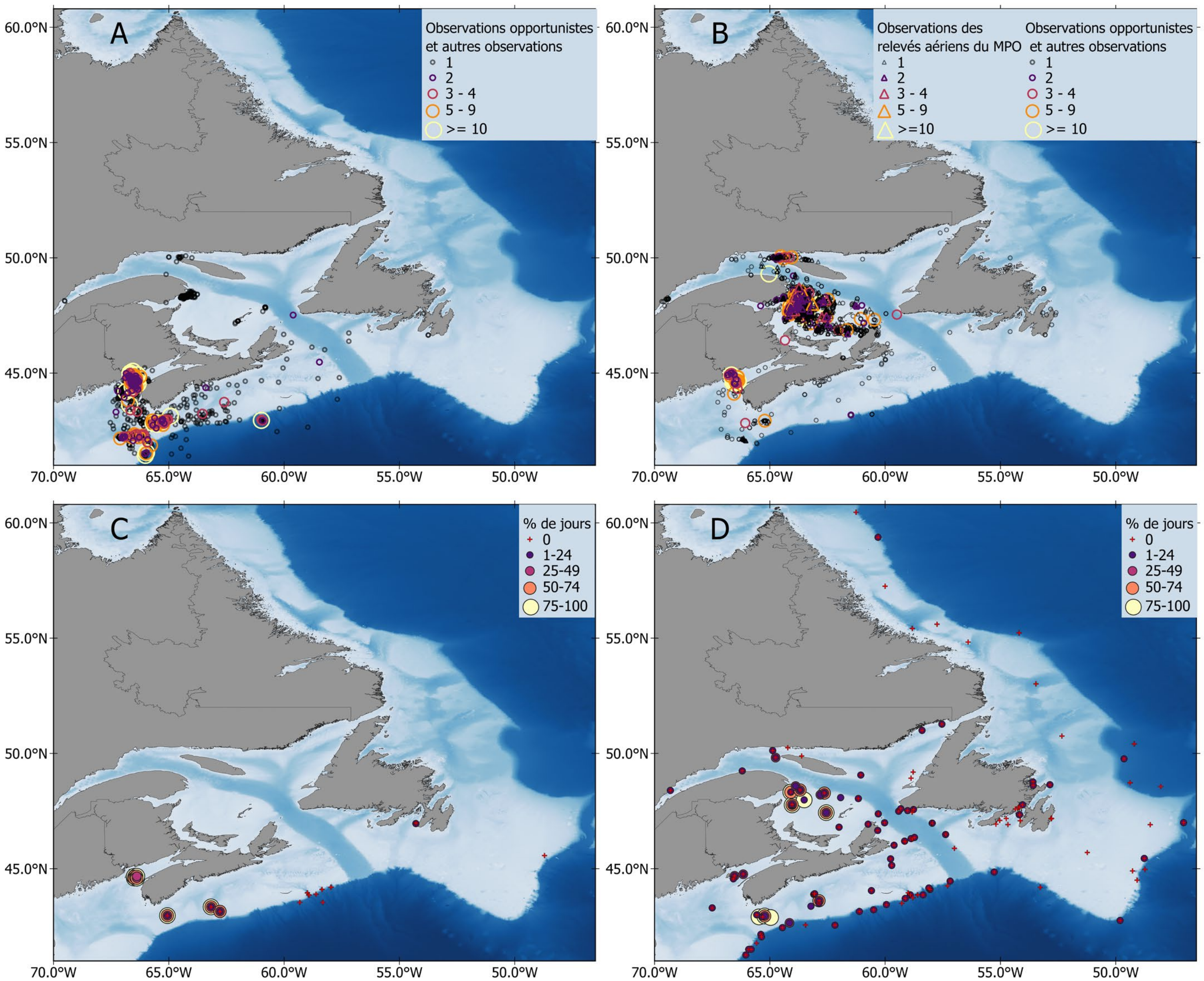

Figure 10: Verified North Atlantic right whale (NARW) sighting events by source for (A) 1990-2009 and (B) 2010-2023, where group sizes are indicated by colour and symbol size. NARW sighting events from DFO aerial survey efforts are depicted by triangles (B). The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for (C) 2004-2009 and (D) 2010-2023.

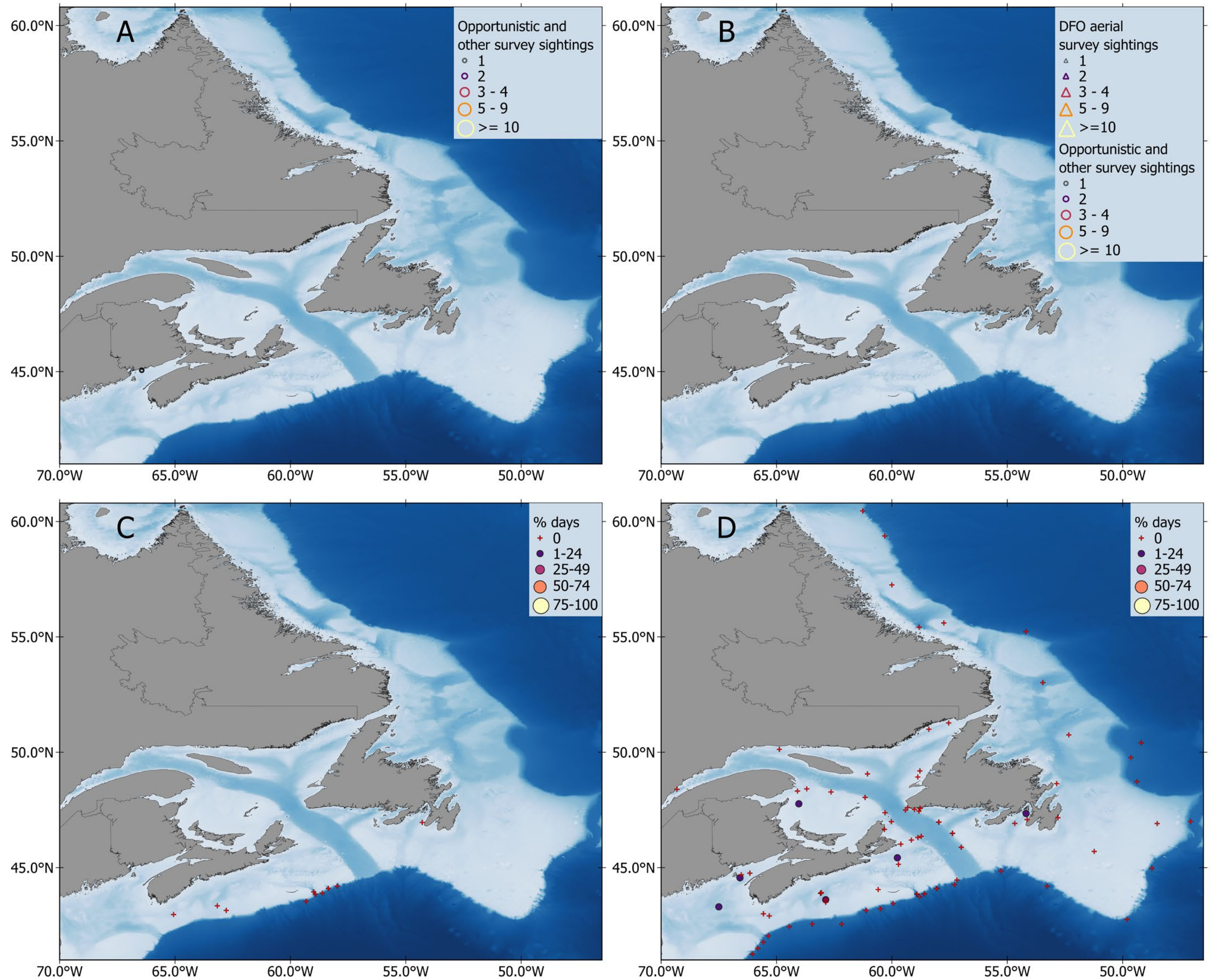

Figure 11: North Atlantic right whale (NARW) sighting events in JANUARY for (A) 1990-2009 and (B) 2010-2023 where group sizes are indicated by colour and symbol sizes. The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for (C) 2004-2009 and (D) 2010-2023.

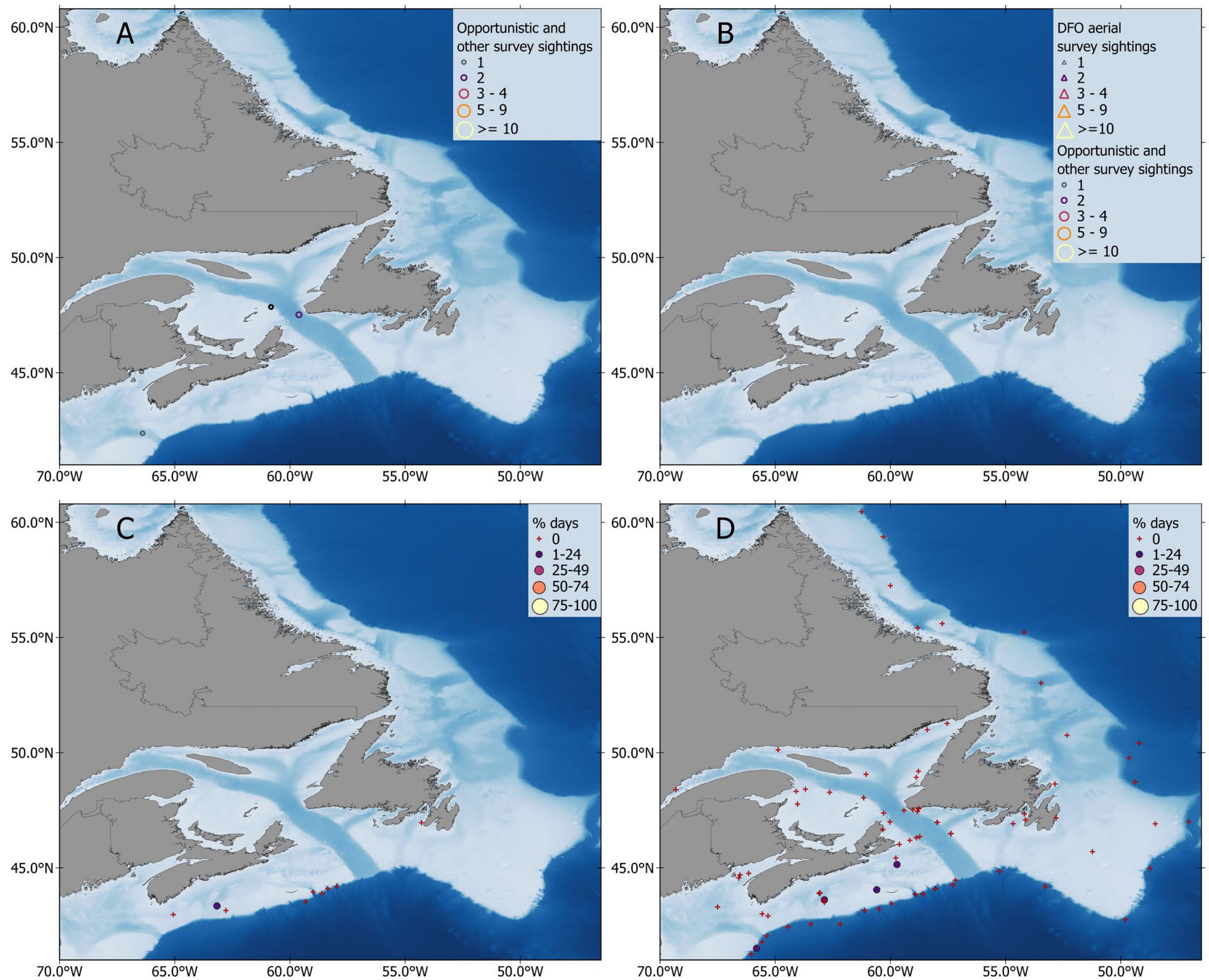

Figure 12: North Atlantic right whale (NARW) sighting events in FEBRUARY for (A) 1990-2009 and (B) 2010-2023 where group sizes are indicated by colour and symbol sizes. The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for (C) 2004-2009 and (D) 2010-2023.

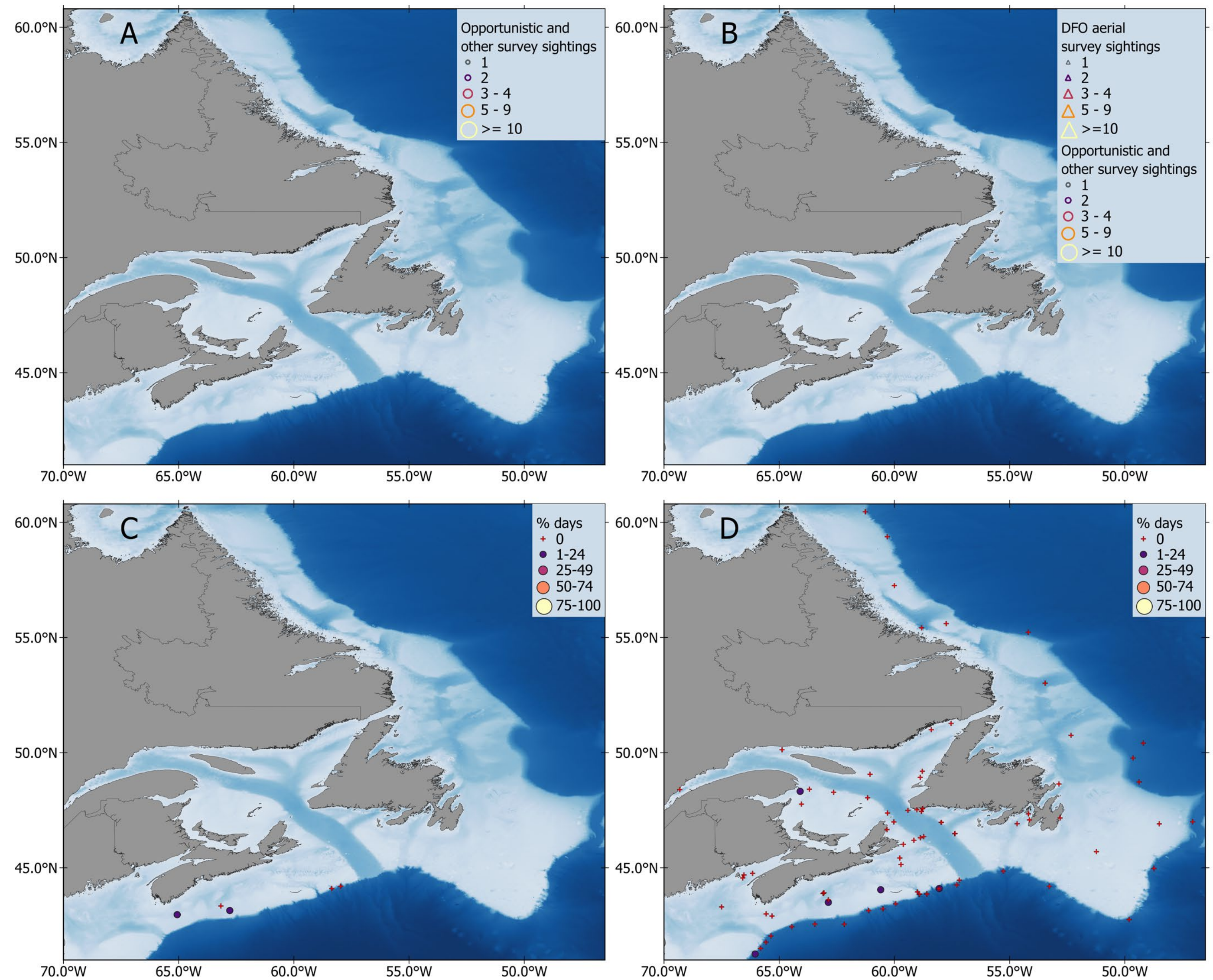

Figure 13: North Atlantic right whale (NARW) sightings events in MARCH for (A) 1990-2009 and (B) 2010-2023 where group sizes are indicated by colour and symbol sizes. The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for (C) 2004-2009 and (D) 2010-2023.

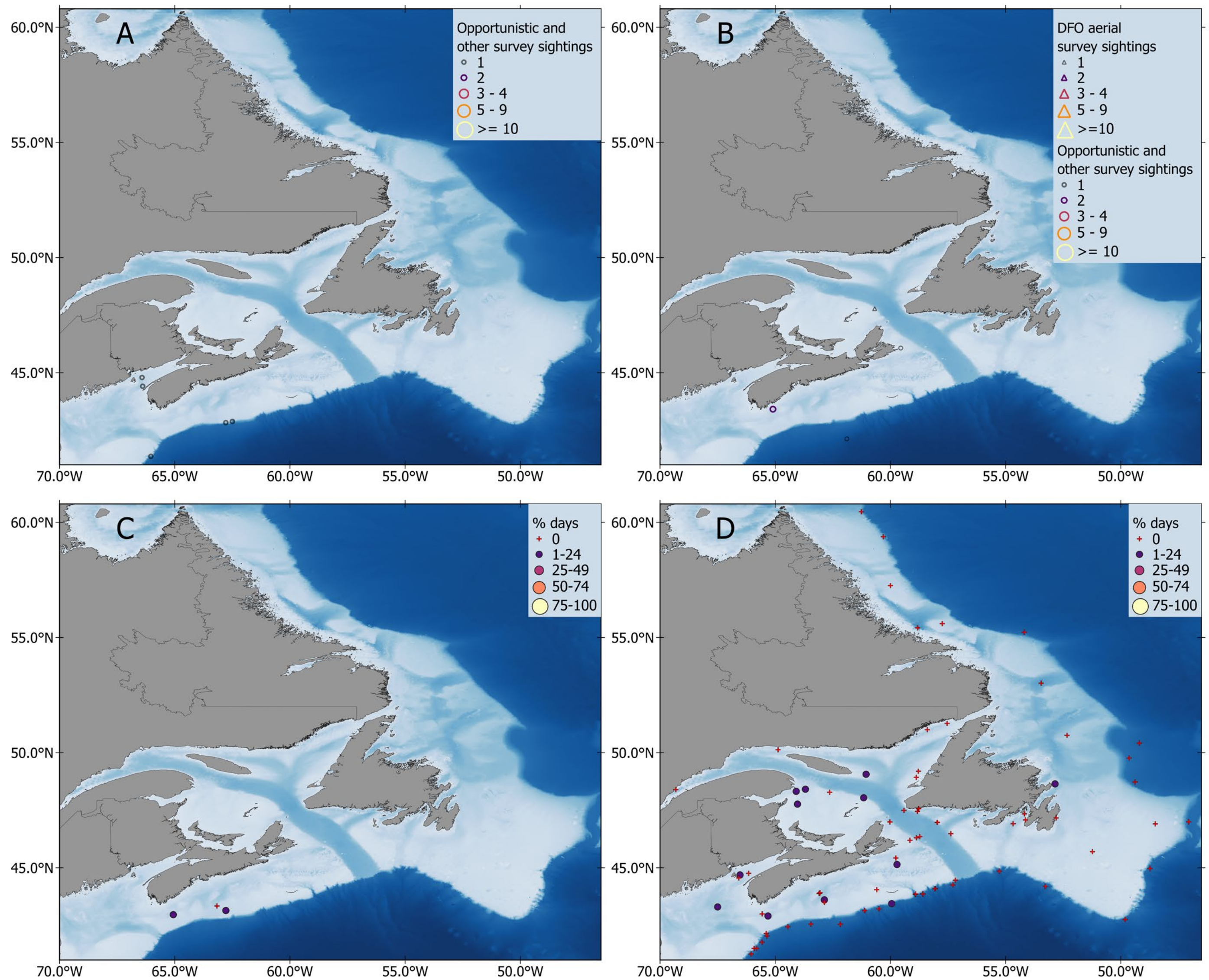

Figure 14: North Atlantic right whale (NARW) sighting events in APRIL for (A) 1990-2009 and (B) 2010-2023 where group sizes are indicated by colour and symbol sizes. The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for (C) 2004-2009 and (D) 2010-2023.

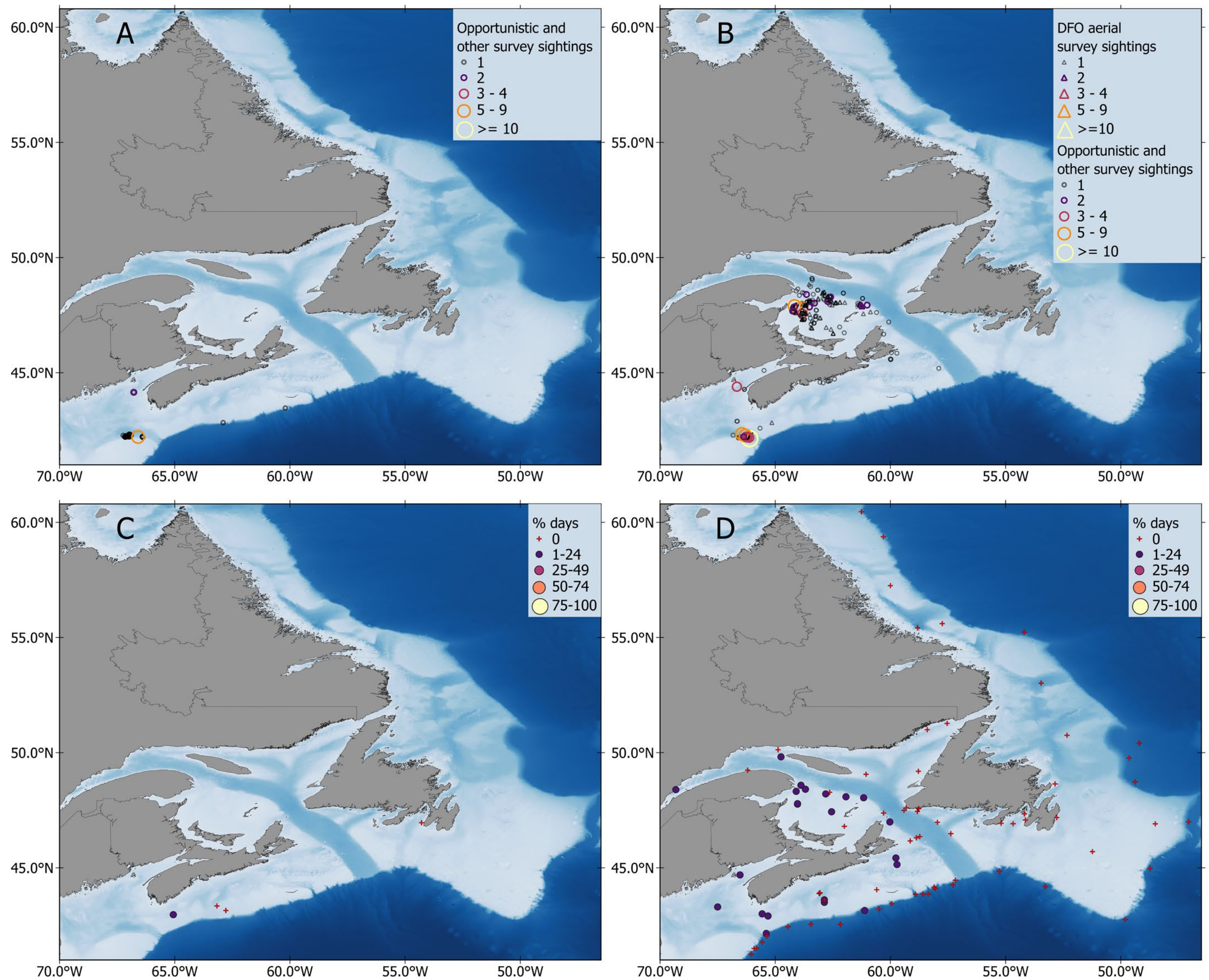

Figure 15: North Atlantic right whale (NARW) sighting events in MAY for (A) 1990-2009 and (B) 2010-2023 where group sizes are indicated by colour and symbol sizes. The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for (C) 2004-2009 and (D) 2010-2023.

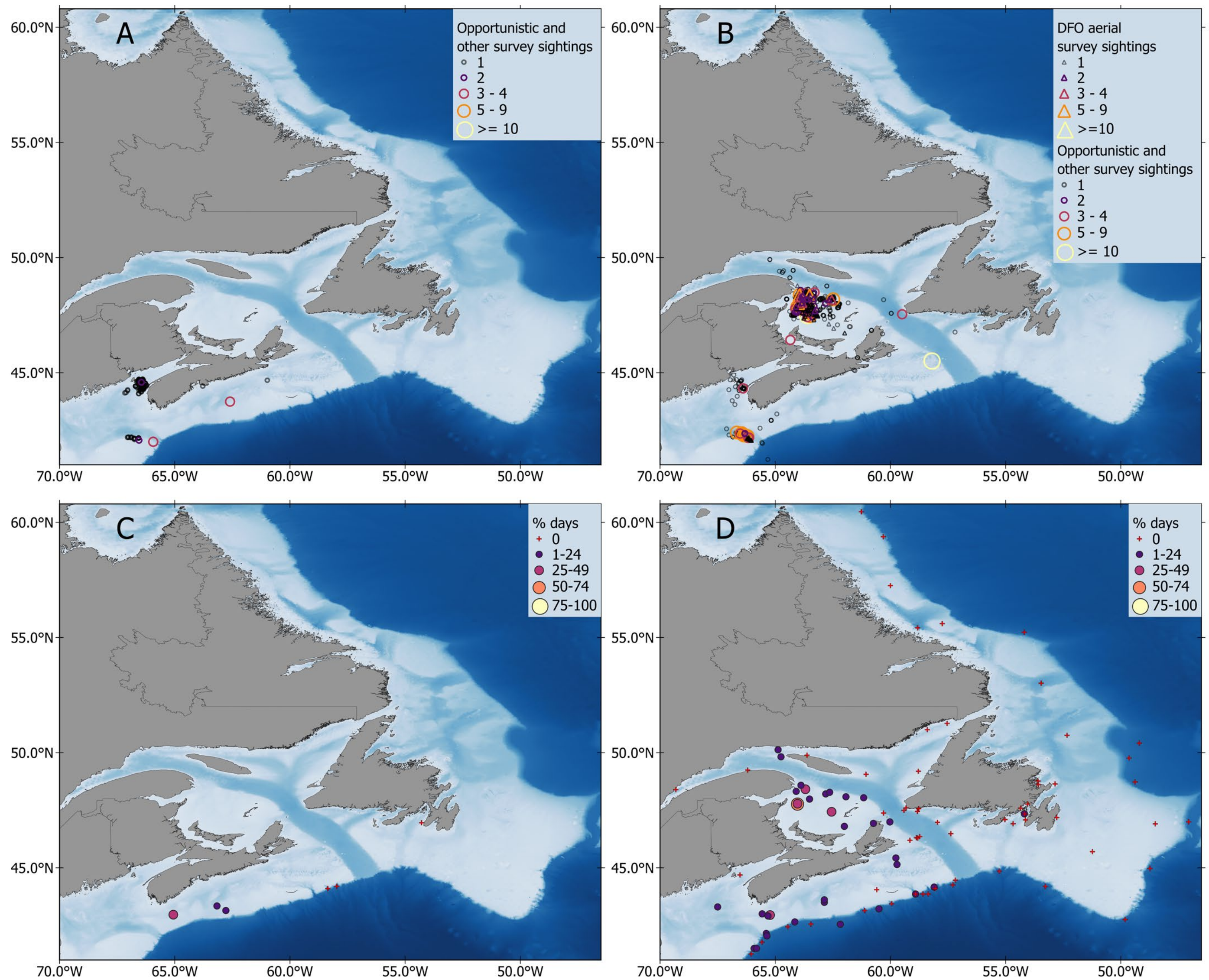

Figure 16: North Atlantic right whale (NARW) sighting events in JUNE for (A) 1990-2009 and (B) 2010-2023 where group sizes are indicated by colour and symbol sizes. The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for the period (C) 2004-2009 and (D) 2010-2023.

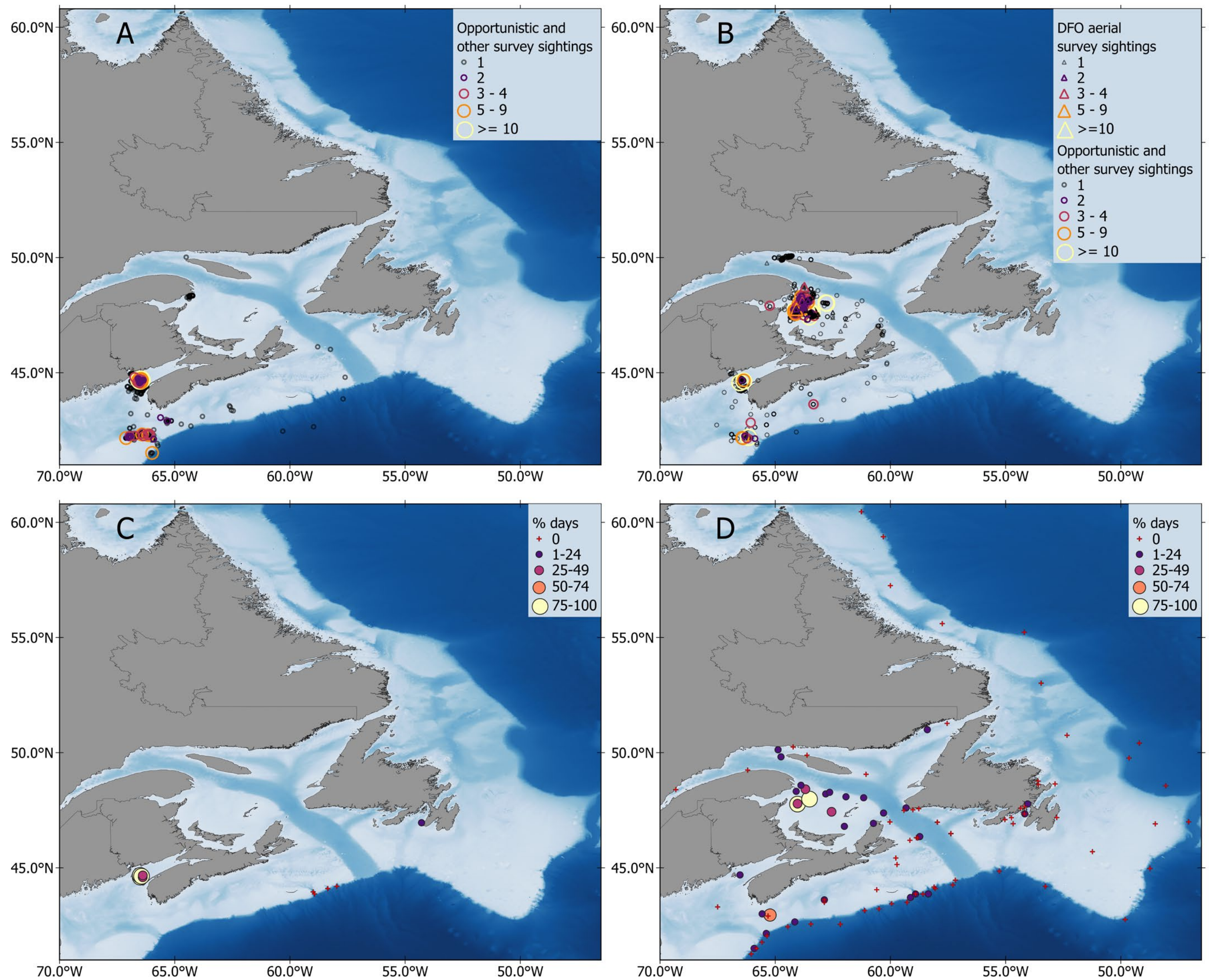

Figure 17: North Atlantic right whale (NARW) sighting events in JULY for (A) 1990-2009 and (B) 2010-2023 where group sizes are indicated by colour and symbol sizes. The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for (C) 2004-2009 and (D) 2010-2023.

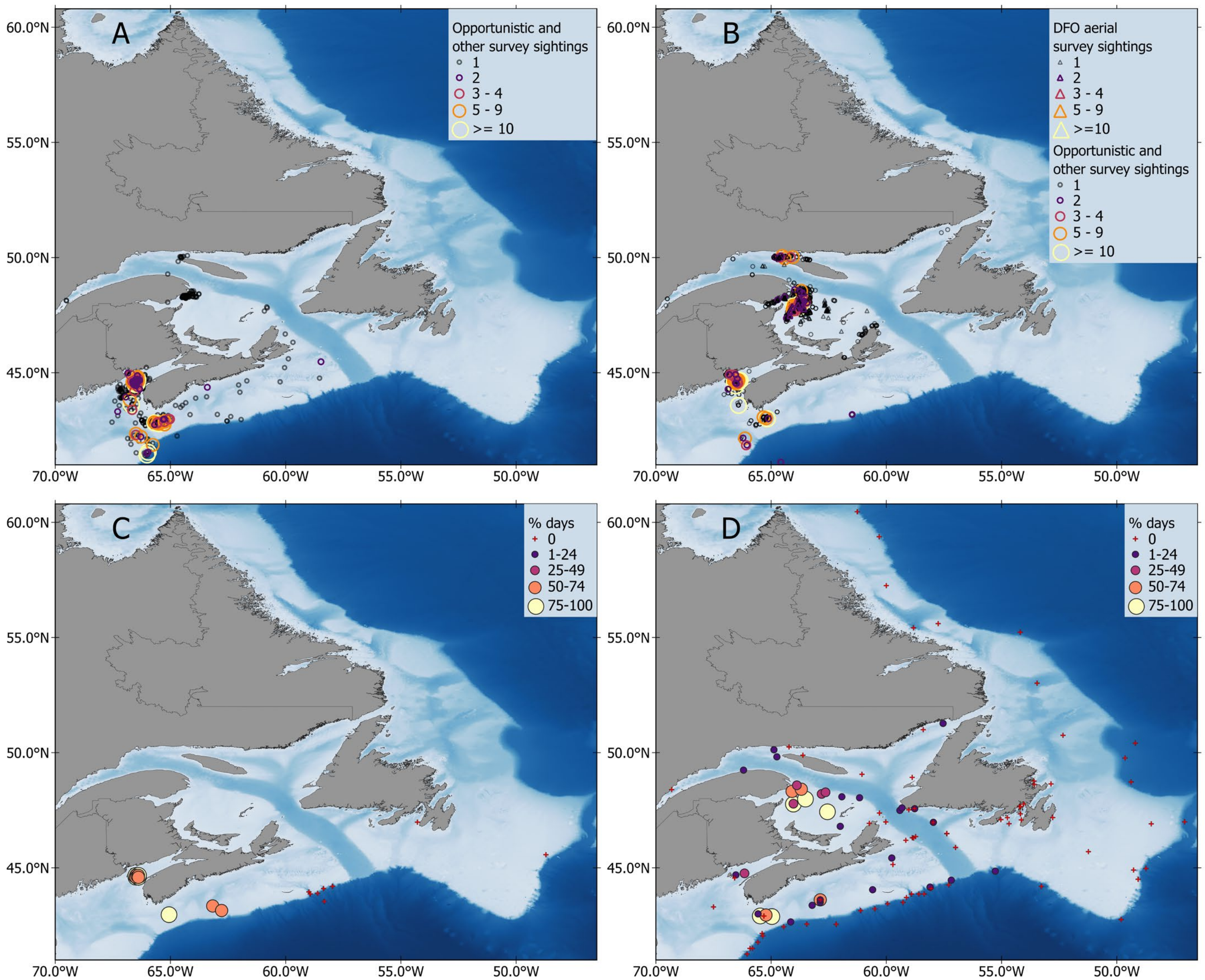

Figure 18: North Atlantic right whale (NARW) sighting events in AUGUST for (A) 1990-2009 and (B) 2010-2023 where group sizes are indicated by colour and symbol sizes. The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for (C) 2004-2009 and (D) 2010-2023.

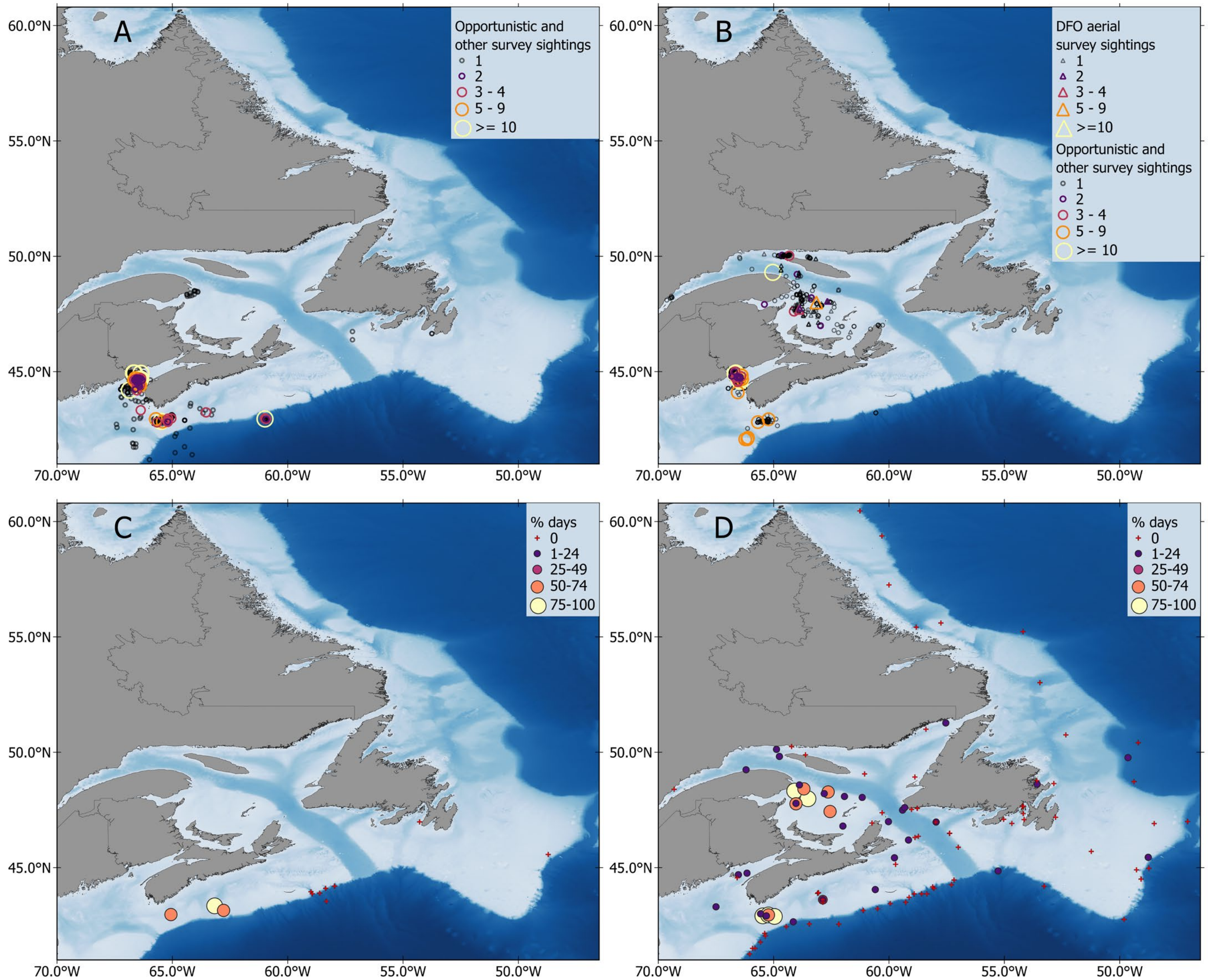

Figure 19: North Atlantic right whale (NARW) sighting events in SEPTEMBER for (A) 1990-2009 and (B) 2010-2023 where group sizes are indicated by colour and symbol sizes. The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for (C) 2004-2009 and (D) 2010-2023.

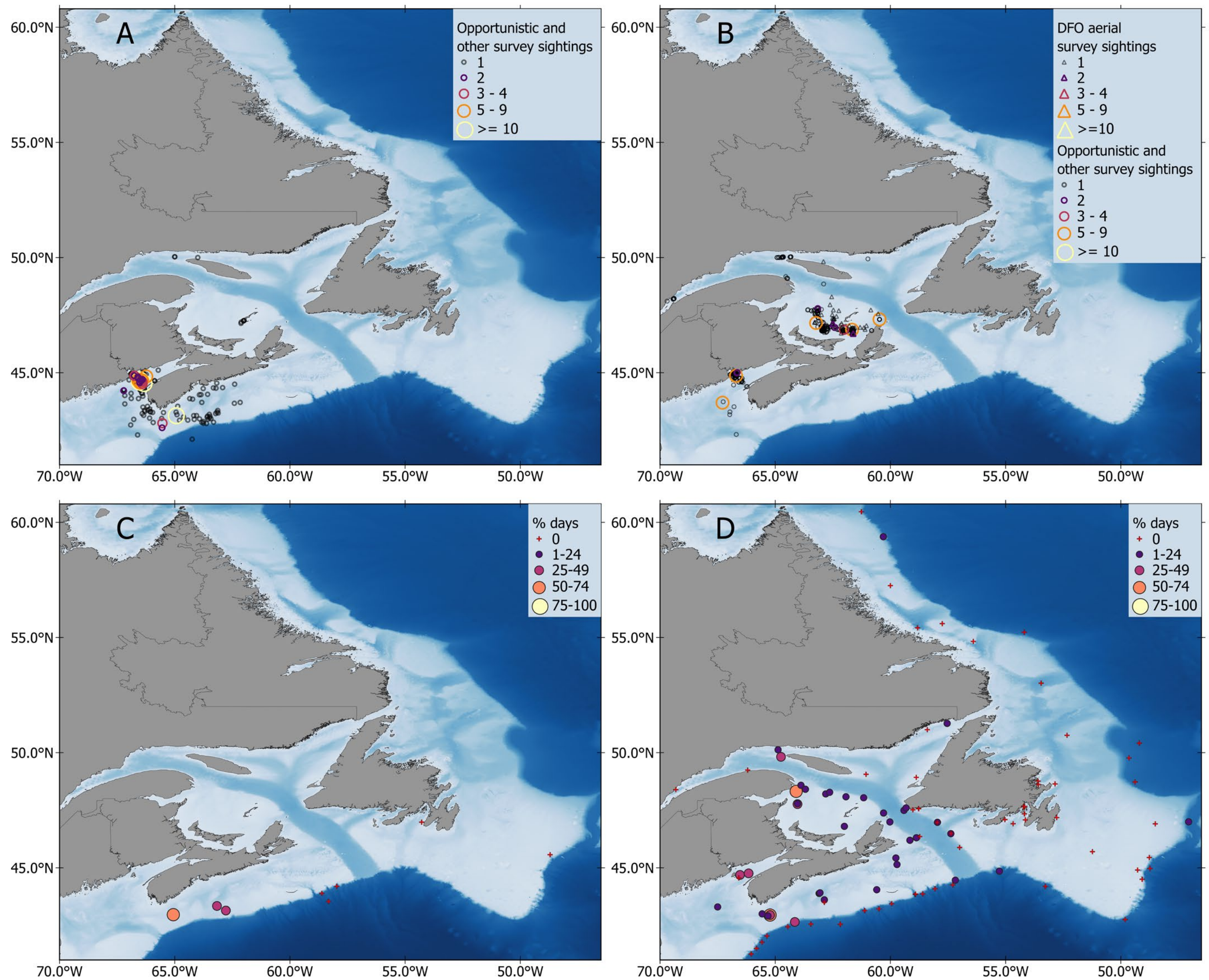

Figure 20: North Atlantic right whale (NARW) sighting events in OCTOBER for (A) 1990-2009 and (B) 2010-2023 where group sizes are indicated by colour and symbol sizes. The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for (C) 2004-2009 and (D) 2010-2023.

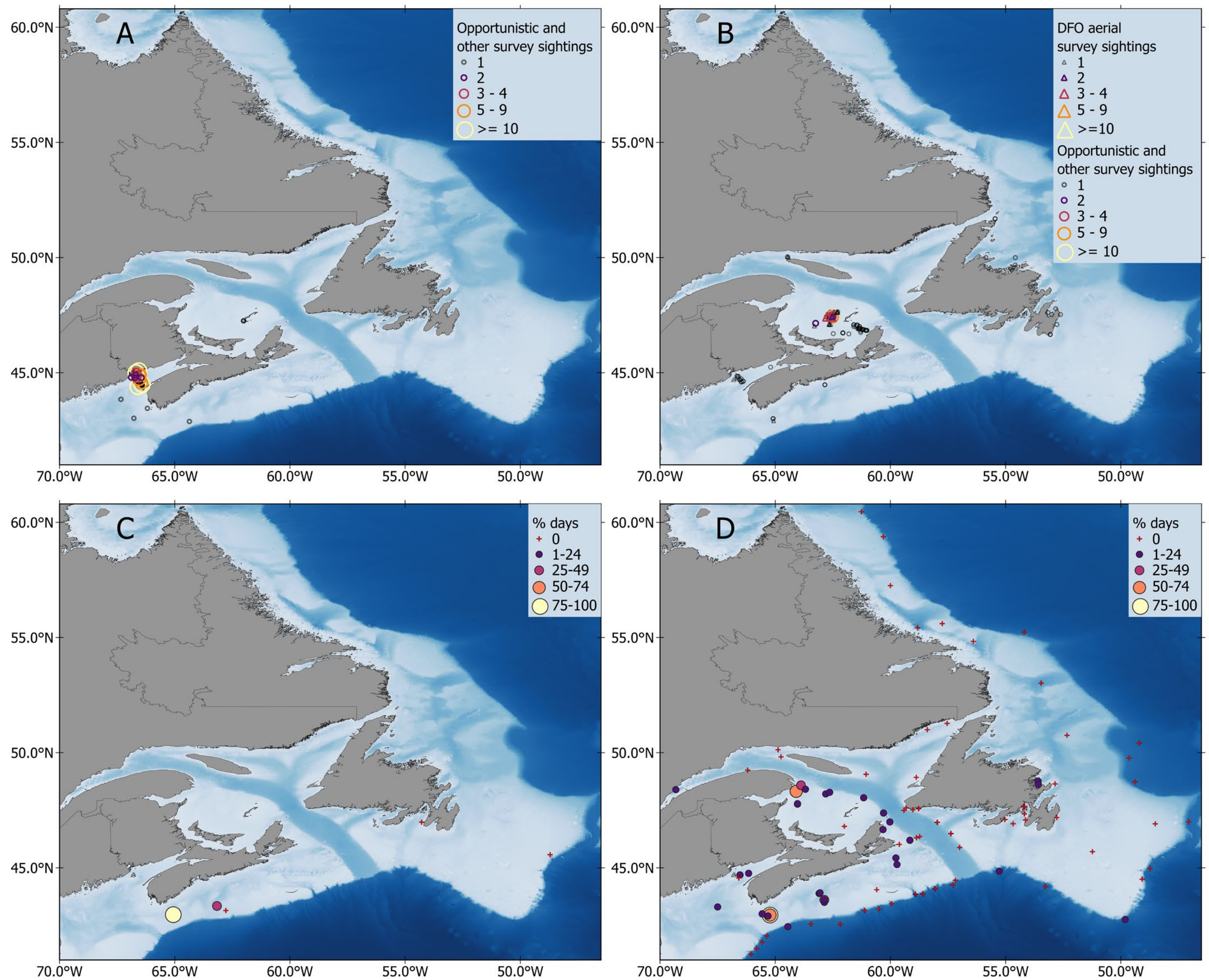

Figure 21: North Atlantic right whale (NARW) sighting events in NOVEMBER for (A) 1990-2009 and (B) 2010-2023 where group sizes are indicated by colour and symbol sizes. The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for (C) 2004-2009 and (D) 2010-2023.

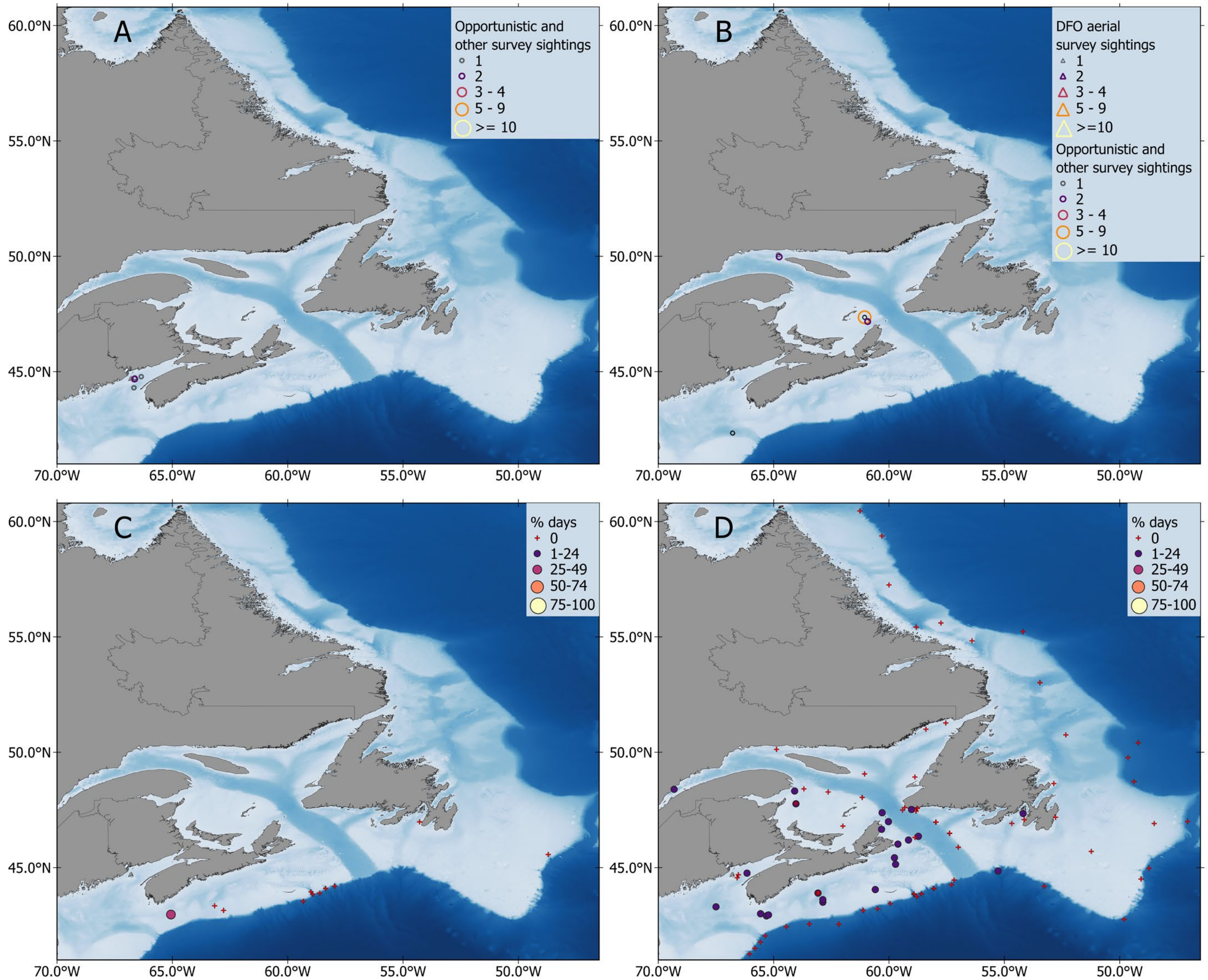

Figure 22: North Atlantic right whale (NARW) sighting events in DECEMBER for (A) 1990-2009 and (B) 2010-2023 where group sizes are indicated by symbol sizes. The percentage of passive acoustic monitoring (PAM) recording days with confirmed NARW upcalls for (C) 2004-2009 and (D) 2010-2023.

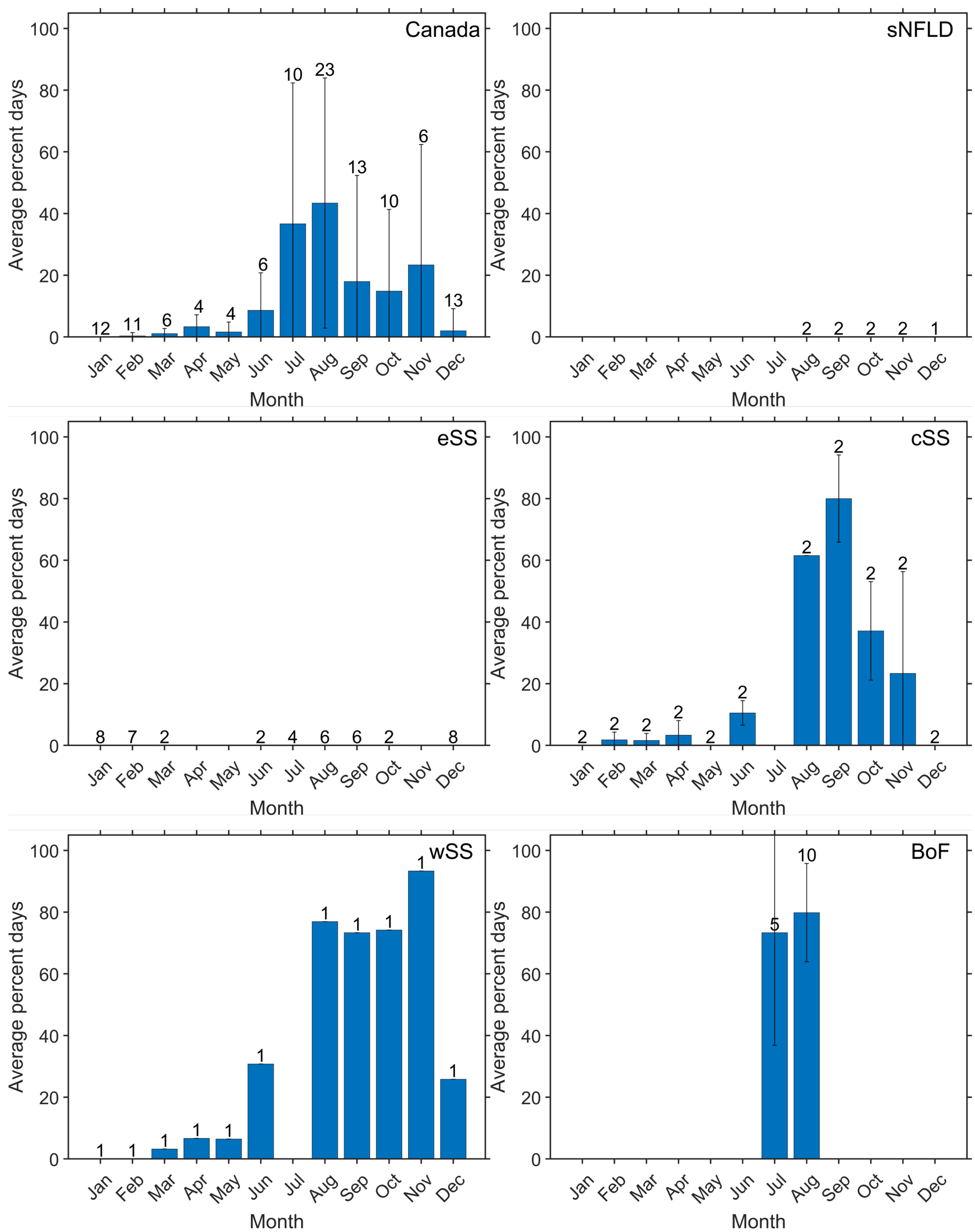

Figure 23: Average percent of passive acoustic monitoring (PAM) recording days (± Std.Dev.) with confirmed North Atlantic right whale (NARW) upcalls for each month, prior to 2010, within six areas: all waters in eastern Canada (Canada); south Newfoundland (sNFLD); eastern Scotian Shelf (eSS), central Scotian Shelf (cSS), western Scotian Shelf (wSS); and the Bay of Fundy (BoF). All PAM sites within an area were combined and, in cases where multiple years of data were collected, the average percentage of recording days with NARW upcalls present was calculated. The numbers above the error bars represent the number of passive acoustic monitoring (PAM) stations used to the average. NOTE - PAM stations prior to 2010 had shorter recording periods (e.g., BoF recordings from July-August).

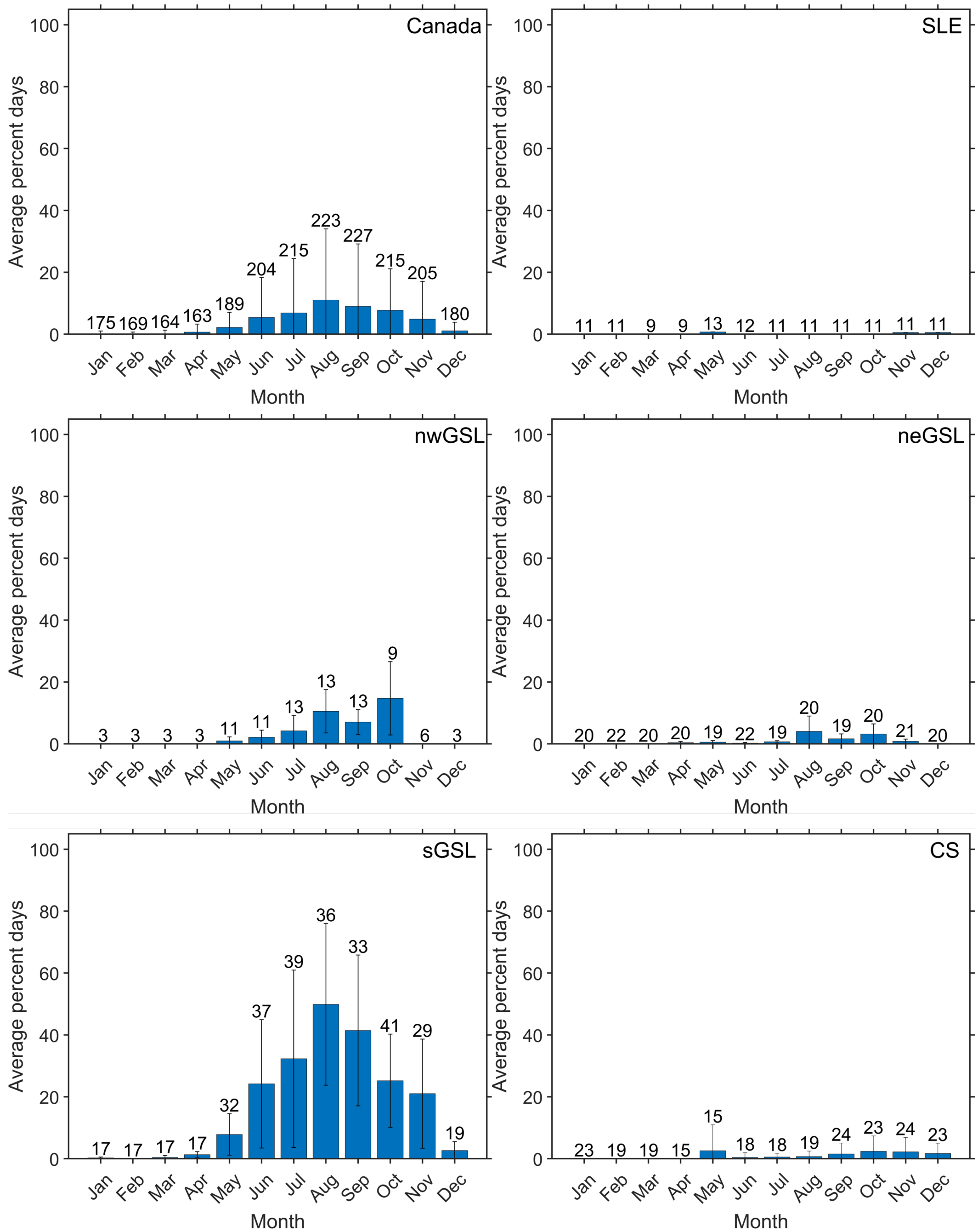

Figure 24: Average percent of passive acoustic monitoring (PAM) recording days (± Std.Dev.) with confirmed North Atlantic right whale (NARW) upcalls for each month, for 2010 through 2022, within six areas: all waters in eastern Canada (Canada); St. Lawrence Estuary (SLE), northwestern Gulf of St. Lawrence (nwGSL), northeastern Gulf of St. Lawrence (neGSL), southern Gulf of St. Lawrence (sGSL) and the Cabot Strait (CS). All sites within an area were combined and, in cases where multiple years of data were collected, the average percentage of recording days with NARW upcalls present was calculated. The numbers above the error bars represent the number of passive acoustic monitoring (PAM) stations contributing to the average.

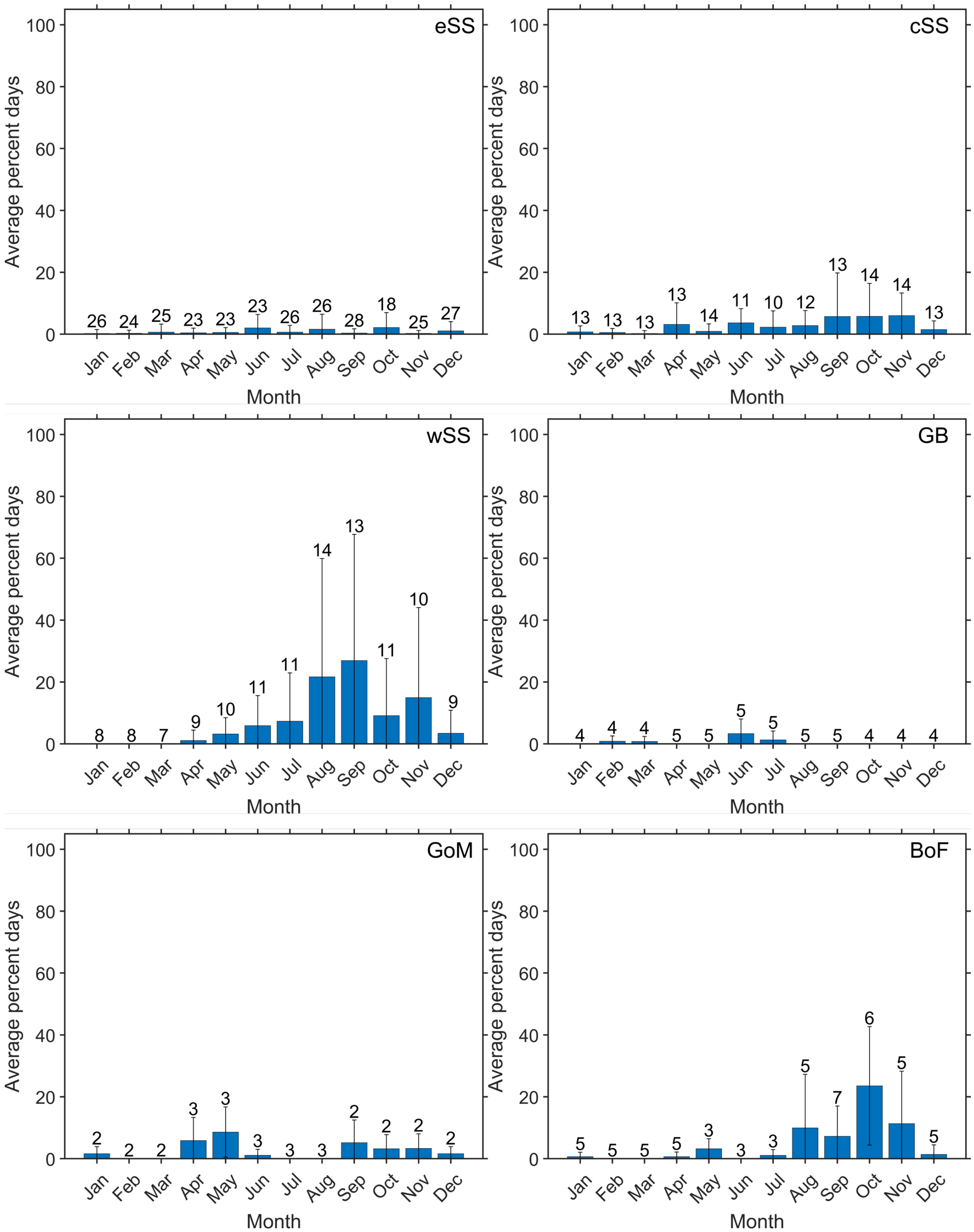

Figure 25: Average percent of passive acoustic m onitoring (PAM) recording days (± Std.Dev.) with confirmed North Atlantic right whale (NARW) upcalls for each month, for 2010-2022, within six areas: eastern Scotian Shelf (eSS), central Scotian Shelf (cSS), western Scotian Shelf (wSS),Gulf of Maine (GoM), and the Bay of Fundy (BoF). All sites within an area were combined and, in cases where multiple years of data were collected, the average percentage of recording days with NARW upcalls were calculated. The numbers above the error bars represent the number of passive acoustic monitoring (PAM) stations contributing to the average.

The acoustic data reveals what appears to be a notable difference in average percentage of days with acoustic detections between pre- and post-2010 periods (Figures 23 to 25). However, this apparent difference should be treated with caution. There was a four-fold increase in number of stations in eastern Canada post-2010. During this period, the recorders in eSS and sNFLD areas did not detect NARW upcalls, contributing to a low average percent of days with detections post-2010. Consequently, zero-inflation has influenced the post-2010 acoustic detection averages for eastern Canada waters. Furthermore, some of the pre-2010 PAM stations had shorter recording periods. For instance, stations in the BoF had recordings restricted to July and August that failed to capture the true temporal distribution of NARW upcalls in this area. In RB, only a single PAM station was deployed, providing no insight into interannual or spatial variation in the area. These factors could lead to very different temporal (monthly) distribution when compared to the period of 2010 to 2022.

Temporal Persistence Based on Sightings Data

The temporal persistence of NARW sightings was examined for both pre- and post-2010 periods to further investigate habitat use. Between 1990 and 2009, NARW sightings were recorded annually in the GMB Critical Habitat (Figure 26). In contrast, the RB Critical Habitat had sightings in less than 30% of the years. However, since the temporal persistence data was not corrected for survey effort, it is possible that some years without sightings correspond to periods when the RB was not surveyed. Additionally, an area off the Gaspé Peninsula indicates NARW sightings in five percent to 15% of the years within the historical period, revealing NARW presence in the sGSL prior to their distributional shift and the large aggregation area observed in the contemporary period. The temporal persistence of NARWs for 2010-2023 (Figure 26) differed from the pre-2010 period with a notable increase in the sGSL. The percentage of repeated sightings in the critical habitats declined post-2010, with sightings being much more diffuse (Figures 26-27). An approximate two-fold increase in temporal persistence was observed around the Wolves Archipelago in the BoF (Figure 1). The aggregation areas in the BoF, sGSL, and north and northwest of Anticosti (Figure 1), all had similar temporal persistence for 2010 through 2023. Although the number of sightings between the two time periods is very different, this measure of temporal persistence demonstrates the areas of consistent aggregation before and after the distributional shift of NARWs in Canadian waters.

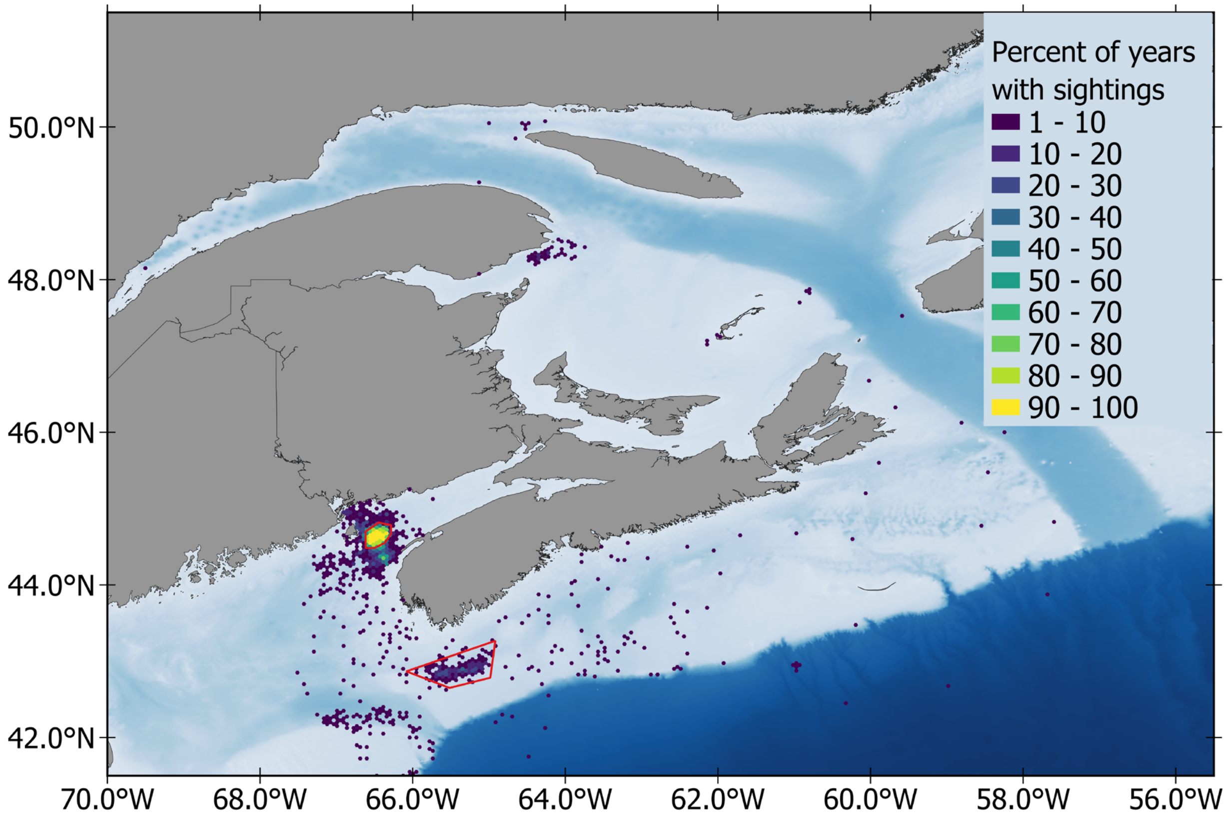

Figure 26: The temporal persistence of North Atlantic right whales (NARWs) for 1990 -2009. Persistence is based on the percentage of years NARW sightings occurred, regardless of the number of sightings and the amount of effort, in each hexagonal grid across eastern Canadian waters. The NARWcritical habitats in Grand Manan Basin and Roseway Basin are also depicted (red polygons).

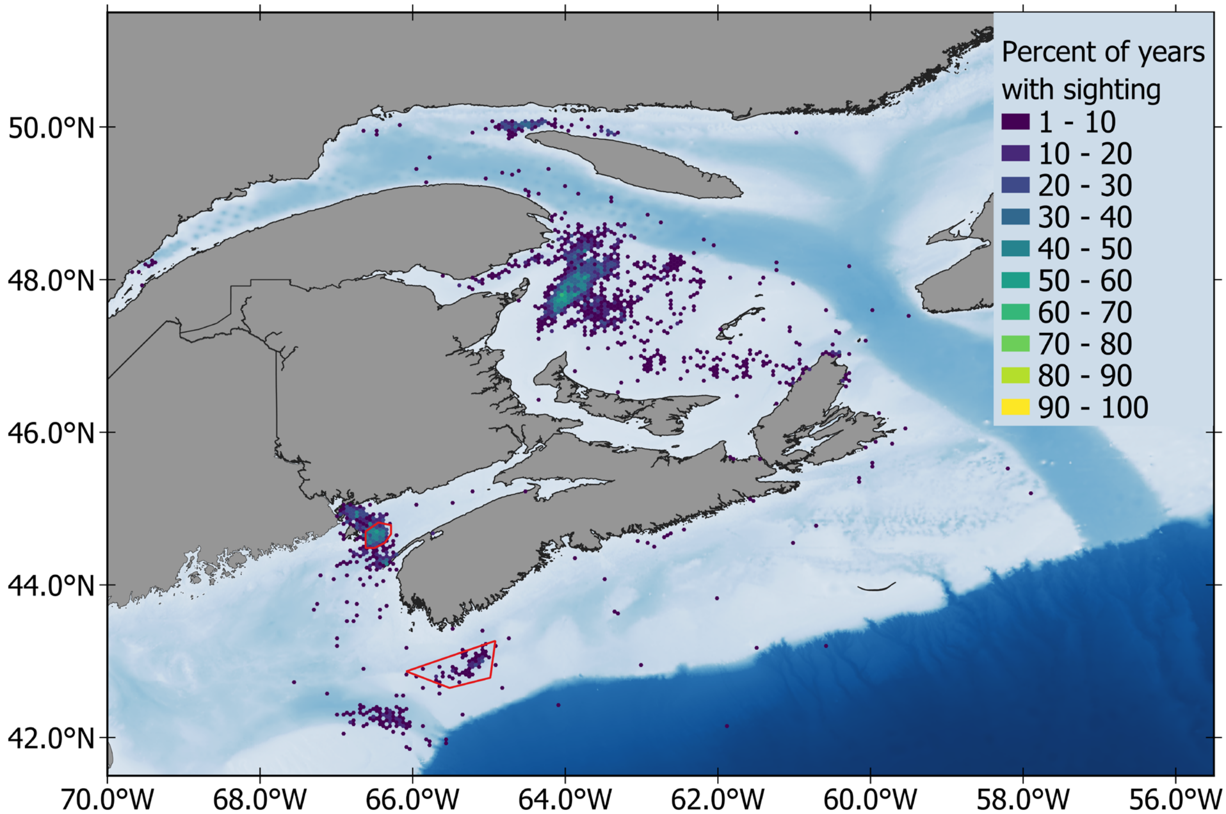

Figure 27: The temporal persistence of North Atlantic right whales (NARWs) for 2010-2023. Persistence is based on the percentage of years NARW sightings occurred, regardless of the number of sightings and the amount of effort, in each hexagonal grid across eastern Canadian waters. The NARWcritical habitats in Grand Manan Basin and Roseway Basin are also depicted (red polygons).

HABITAT REQUIREMENTS

CONNECTIVITY AMONG AREAS AND MIGRATORY CORRIDORS

Seasonal movements between areas in the southern range of Canadian habitats (e.g., BoF to and from RB) have been well described and linked to adaptive exploitation of optimal feeding opportunities (Mate et al. 1997; Baumgartner and Mate 2005; Vanderlaan 2010).

Based on results from acoustic monitoring efforts off NS, Moors-Murphy et al. (2025) suggested that NARWs utilize the Scotian Shelf (rather than the Scotian Slope) and Cabot Strait as migratory corridors when travelling to and from the GSL. The CS is likely the main entry and exit route to the GSL with consistent, although limited, acoustic detections from May through December. There are relatively few acoustic or visual detections of NARWs in the Strait of Belle Isle suggesting this area is not a primary migratory corridor in and out the GSL.

Movements of individuals inferred from visual identification have been documented between the sGSL and nwGSL (e.g., Crowe et al. 2021), between nNFLD and the sGSL (Lawson et al. 2025), and between several other areas (Figure 28; Vanderlaan 2010, Brillant et al. 2015). Based on these analyses, areas that provide habitat connectivity broadly include: the shelf waters between the GoM, BoF, and wSS (including the RB), SS shelf waters, the CS, the Honguedo Strait, the Jacques Cartier Strait, the neGSL/ Strait of Belle Isle to Labrador shelf waters, and the shelf waters to the south, east, and north of NL.

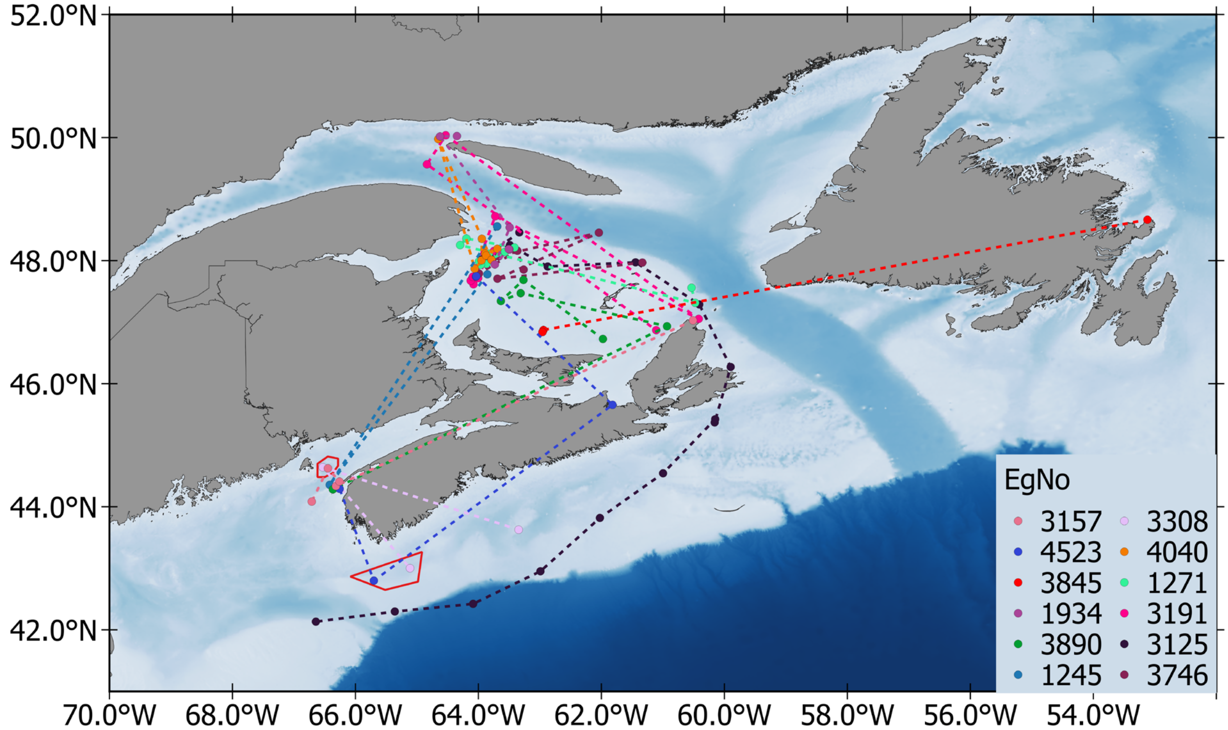

Figure 28: Representation of examples of individual North Atlantic right whale (NARW) movements amongst Canadian habitats within a year. Individual sighting history included (see Appendix 5) and visualization of the extent of movements (colored lines by individual). The lines join individual sighting records chronologically. The actual path of travel can not be determined from these data as the individual sighting histories are not comprehensive, especially for animals in transit, thus lines that cross over land do not accurately represent the actual movement track of the animal. EgNo 3125 (black) is the only example of coarse movement as it was entangled (4 July 2022) and fitted with a telemetry buoy on the trailing gear (19 July 2022). EgNo 3125's location data was provided once per day at mid-day (end of track is incomplete within this paper as sighting data are limited to the southern edge of Canadian waters).

HABITAT SELECTION AND SUITABILITY

Suitable feeding habitat is characterized a positive Enet value that represents the proportion of energy gained relative to energy expended by NARWs (Gavrilchuk et al. 2020, 2021; Lehoux et al. 2020). Habitat suitability for NARWs can be inferred from NARW occurrence and densities alone (e.g., Roberts et al. 2024; St-Pierre et al. 2024; Mosnier et al. 2025a; Mosnier et al. 2025b), or from the prey concentrations that meet the energy requirements of NARWs (referred to as Enet in this report; e.g., Gavrilchuk et al. 2021; Lehoux et al. 2024; Plourde et al. 2024). Plourde et al. (2024) recommended that the identification of potentially important foraging areas consider results from April to September to account for evident seasonality in predicted Enet throughout the study domain (Figure 29) as well as increased uncertainty associated with the northern extent of the domain. The authors also acknowledged uncertainty in *Calanus* spp. aggregation mechanisms, vertical distribution, and emphasized that suitable NARW feeding areas that were identified do not fully predict the areas where NARWs will occur as the distribution of NARW is not solely driven by food (Davies et al. 2015).

As such, potentially suitable feeding areas were identified using Enet for the months April through September to account for known seasonality in prey availability (Plourde et al. 2024). Enet is a measure of NARW energy balance and, in the current analysis, was based on pregnant females, which are intermediate in their energy requirements compared to lactating or resting females or adult males (Lehoux et al. 2020; Gavrilchuk et al. 2021). Enet is relative to the scale of eastern Canadian waters, and was used to identify areas during which foraging conditions are likely to be the most suitable based on the > 90th quantile (Plourde et al. 2024).

Persistent suitable (Enet > 90th quantile) foraging conditions were found in the following areas: the northeast channel of GB, the wSS including the RB Critical Habitat, the cSS, the western-slope of the CS and the coast of Cape Breton, the sGSL, the head of Esquiman Channel in the wGSL, the inner shelf near the coast of eastern NL (eNL) and offshore eNL, the waters off the southern tip of the Grand Banks (eNL), off south NL, along the northeast slope of the Grand Banks, and on the Flemish Cap (Figure 29; Plourde et al. 2024).

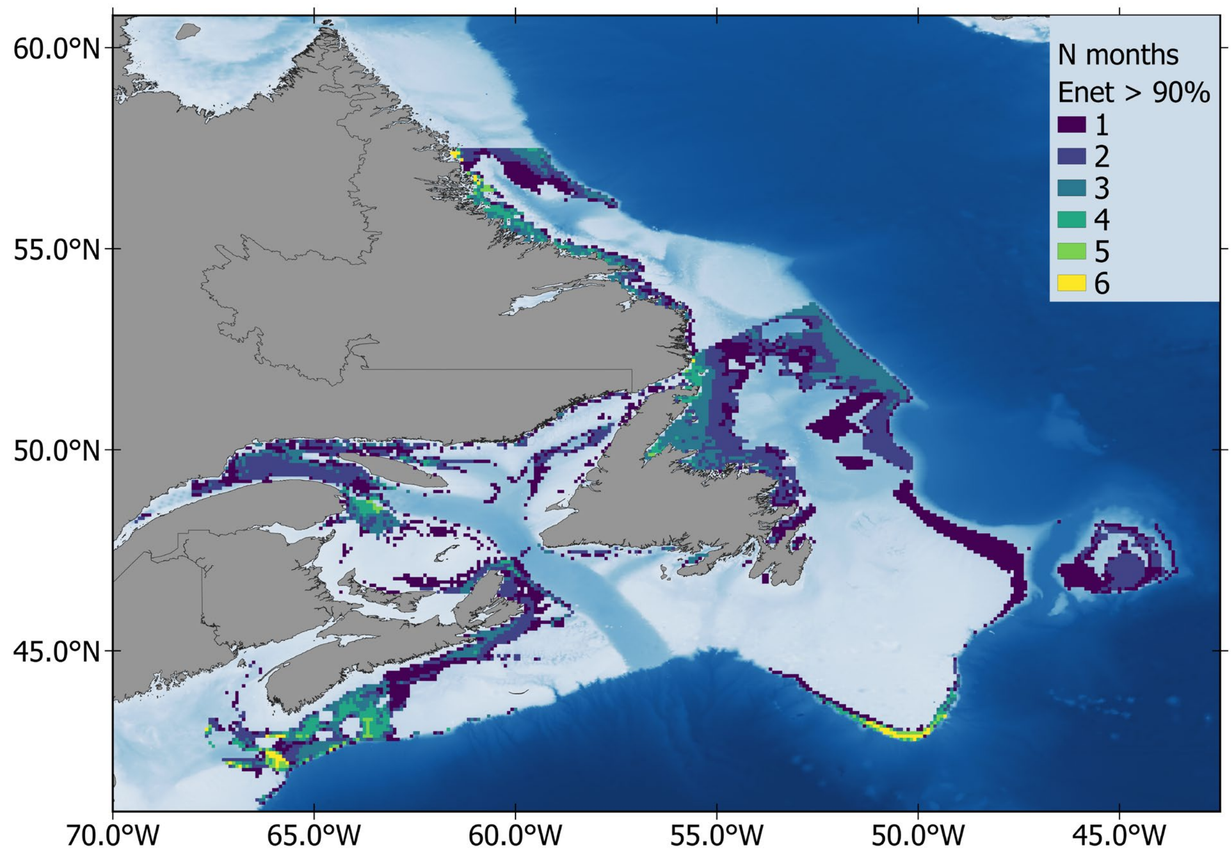

Figure 29: Monthly persistence of predicted foraging habitat suitability, Enet values > 90th quantile, from April to September for eastern Canada 1999-2020. Color scale reflects the number of months with Enet values > 90th quantile.

Directed research on NARW prey in the sGSL has indicated that the habitat can support high concentrations of prey for NARWs (Sorochan et al. 2023; Johnson et al. 2024). While there is uncertainty in upstream population level and spatiotemporal variability in prey concentration, the quality of the sGSL foraging habitat appears to benefit from a more diverse composition of Calanus spp. are and higher prey quality (i.e., larger size and higher energy content per individual copepod) in comparison to the GoM and wSS (Johnson et al. 2024).

Species distribution modelling in the GSL has indicated that the relative probability of NARW occurrence is positively influenced by sea surface temperatures (SST) between 7 °C and 14 °C, and negatively influenced by temperatures between 0 °C and 7 °C and 14 °C to 20 °C (Mosnier et al. 2025b). In addition, these models predicted an occasional use of deep areas (i.e., 280 to

420 m) within the GSL, and avoidance of the deepest waters in the Laurentian Channel. Other physical and biological variables also appear to be influencing the probability of NARW occurrence including possible prey aggregation mechanisms (Table 1 and Appendix C in Mosnier et al. 2025b). Notably, the probability of NARW occurrence increases with the frequency of thermal fronts, dynamic ocean processes, and in areas with low current speed. Mosnier et al. 2025a and Mosnier et al. 2025b hypothesized that NARWs may occur at fronts as they are a possible mechanism for concentrating prey. Using the highest (> 90th quantile) relative predictions (2017-2022) from the Mosnier et al. 2025a and Mosnier et al. 2025b Global Model, NARWs are predicted to mostly persist along the southern slope of the Laurentian Channel in the swGSL, and in several valleys of the sGSL (i.e., Bradelle and Shediac valleys, including Chaleur Bay and north of Prince Edward Island), to the north and west of Anticosti Island, western and northern Cape Breton (Figure 1; Figure 30D). NARWs were also predicted to occur in the SLE, the Honguedo Strait and the Jacques Cartier Strait, and all along the northern coast of the GSL to the Strait of Belle Isle though with lower relative probabilities.

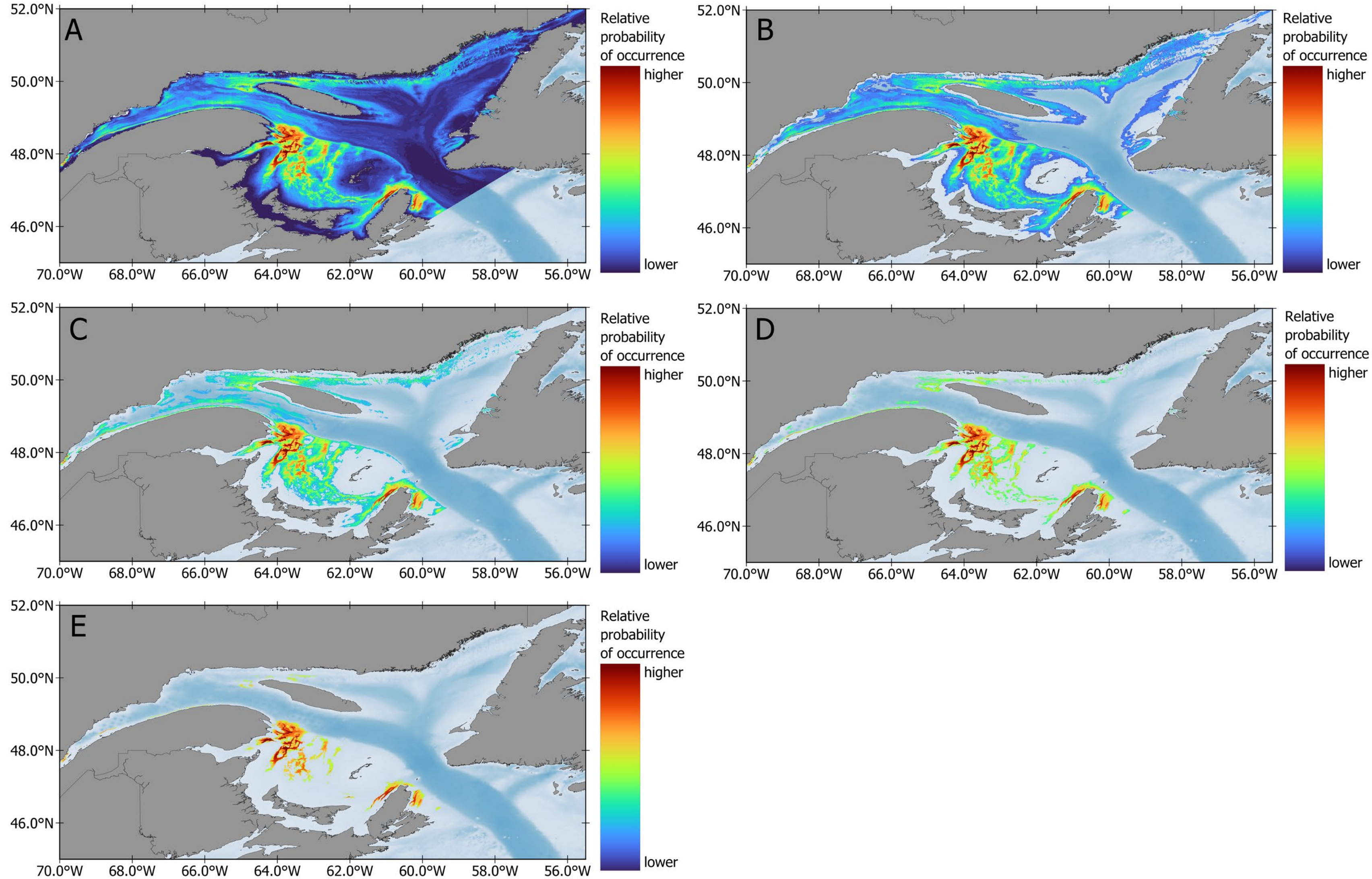

Figure 30: Results from the Global model predictions (April to November; 2017 to 2022) of the relative probability of occurrence of North Atlantic right whales (NARWs) in the GSL (Mosnier et al. 2025a; Mosnier et al. 2025b). Full model (A); 50th percentile (B); 75th percentile (C); ***90th percentile (used in this analysis) (D)****; and 95th percentile (E).*

IDENTIFICATION OF IMPORTANT NARW HABITAT

Although the datasets presented above originate from vastly different methodologies spanning three decades, there was sufficient information to identify important NARW habitat in eastern Canadian waters.

Overall, the distribution of NARWs within Canadian habitats based on pre- and post-2010 sightings and acoustics include: the BoF, the Canadian portions of the GoM and GB, the wSS (e.g., RB), the cSS (e.g., Emerald Basin), the sGSL and the nwGSL (Figure 10). There are infrequent sightings and acoustic detections off northern, eastern, and southern NL, in the CS, and the SLE, as well as occasional sightings and detections on the eastern SS and off the shelf break (Figure 10).

In eastern Canada, there have been NARW sightings recorded in all months of the year (Figure 11 to Figure 22), with the exception of March (Figure 13). Sightings were infrequent from December through February (Figure 22; Figures 11-12). Based on the extent of acoustic monitoring in eastern Canada, NARW upcalls have been detected in all months of the year although infrequently from December through March (Figure 22; Figures 11 to 13).

Important habitat for NARWs was identified within Canadian waters using a combination of four datasets:

1. predicted persistence of high (>90th quantile) Enet from Calanus spp. consumption (Plourde et al. 2024);
2. predicted high suitability of habitat (highest 10% of values of the relative probability of occurrence) based on sightings data from DFO systematic aerial surveys (Mosnier et al. 2025a; Mosnier et al. 2025b) collected from April through September;
3. sightings and derived temporal persistence for the periods: 1990-2009 and 2010-2023;
4. minimum acoustic presence of NARWs based on upcall detections from 1990-2023.

Figure 31 shows the spatial overlap among the first four datasets above, supporting the designation of these areas as important habitat for NARWs. Acoustic presence of NARWs also contributed to the identification of important habitat, highlight the need to capture certain areas, such as the cSS, where sightings were limited, although NARWs were consistently detected acoustically. Acoustic detections were used to inform general spatiotemporal patterns without the identifying specific areas around each mooring location. By aggregating the various datasets and spatiotemporal patterns of NARW presence, both the interannual variability and the historical presence of NARWs was captured and used to identify important habitat.

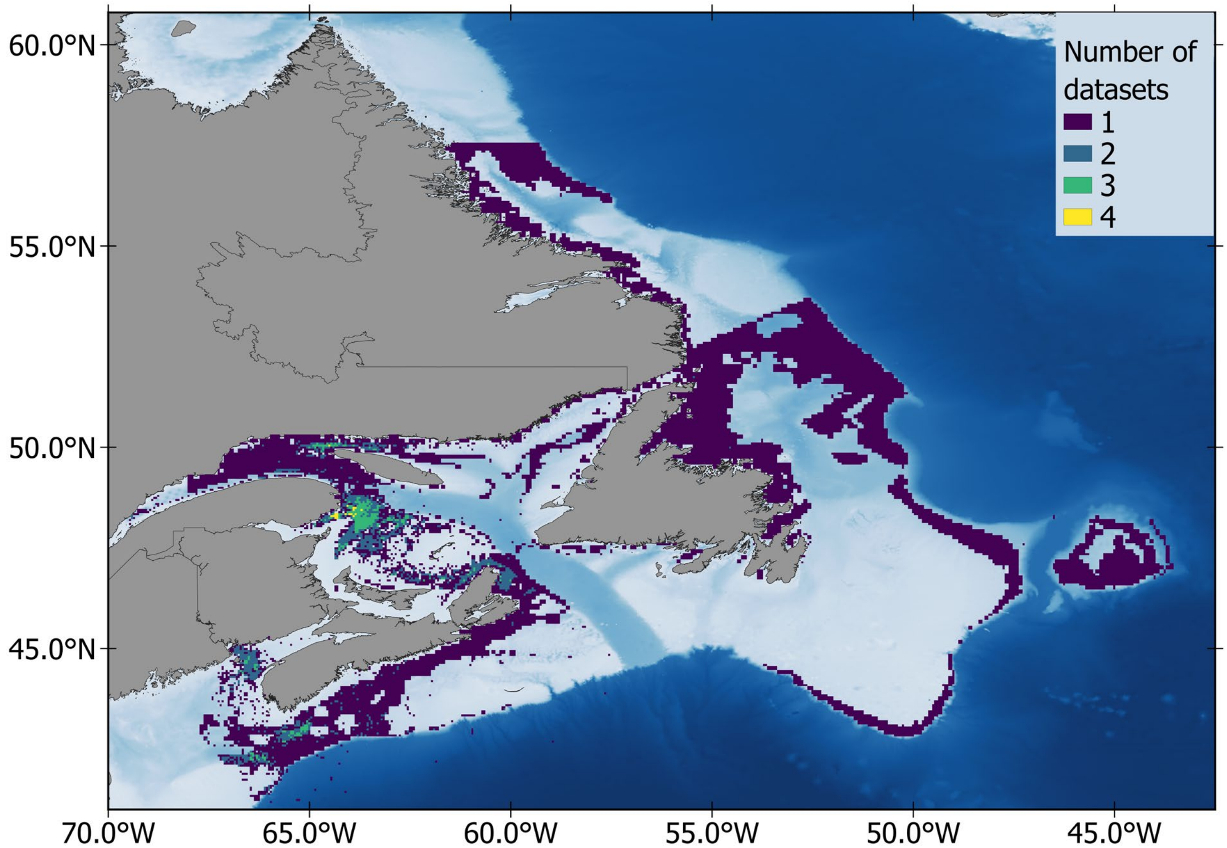

Figure 31: Spatial overlap among four datasets: sightings pre- and post-2010, probability of occurrence model (Mosnier et al. 2025a; Mosnier et al. 2025b), and persistence of predicted foraging habitat (Plourde et al. 2024) used in conjunction with minimum presence based on passive acoustic monitoring to inform the designation of important habitat.

IMPORTANT HABITAT

Based on all the information provided above, and in order to ensure habitat connectivity, a large contiguous area was identified as important habitat for the recovery and survival of NARWs. The NARW important habitat includes: the sGSL, the nwGSL, the SS and BoF, including the RB and Emerald Basin on the cSS, as well as the Canadian portions of the GoM and GB. The eSS, CS, and Laurentian Channel were all identified as important transit corridors that connect important feeding habitats (Figure 32).

The coastal extent of important habitat was limited to the 40 m isobath as a broadbrush approach, and is based on the average value of the relative probability of NARW occurrence estimated across depths in the SLE and GSL (Mosnier et al. 2025b). Options discussed included extending the habitats to shore or using a standard distance from shore. The latter was not retained as coastal topography is highly variable among habitats in eastern Canada. For example, the coastlines of eastern Canada include subdued seabed relief, relatively shallow-waters in the swGSL, steep and rocky relief, and relatively deep waters in coastal waters in southern NL (Eamer et al. 2020). Although waters less than 40 m have been described as migratory routes for NARWs (Knowlton et al. 2002) and NARWs have been occasionally detected in shallow-waters (< 40 m; St-Pierre et al. 2024; Lawson et al. 2025), described feeding habitats (see Foraging and Feeding section) and the majority of NARW sightings data are generally in depths > 40 m (> 99% of the sighting events in Figures 10 A and B). The outer limit of the important habitat on the Scotian Shelf and through the Laurentian Channel was based on the 350 m isobath as NARWs recorded diving depths have not exceeded 350 m (max dive depth = 306 m; Baumgartner and Mate 2003, 2005; Baumgartner et al. 2017). This also allows the inclusion of the entire Scotian Shelf to the shelf break, however it excludes NARW acoustic detections on the Scotia Slope. NARWs are rarely detected at the deep-water locations of PAM moorings suggesting they are not regularly using these areas (Davis et al. 2017; Durette-Morin et al. 2022; Moors-Murphy et al. 2025).

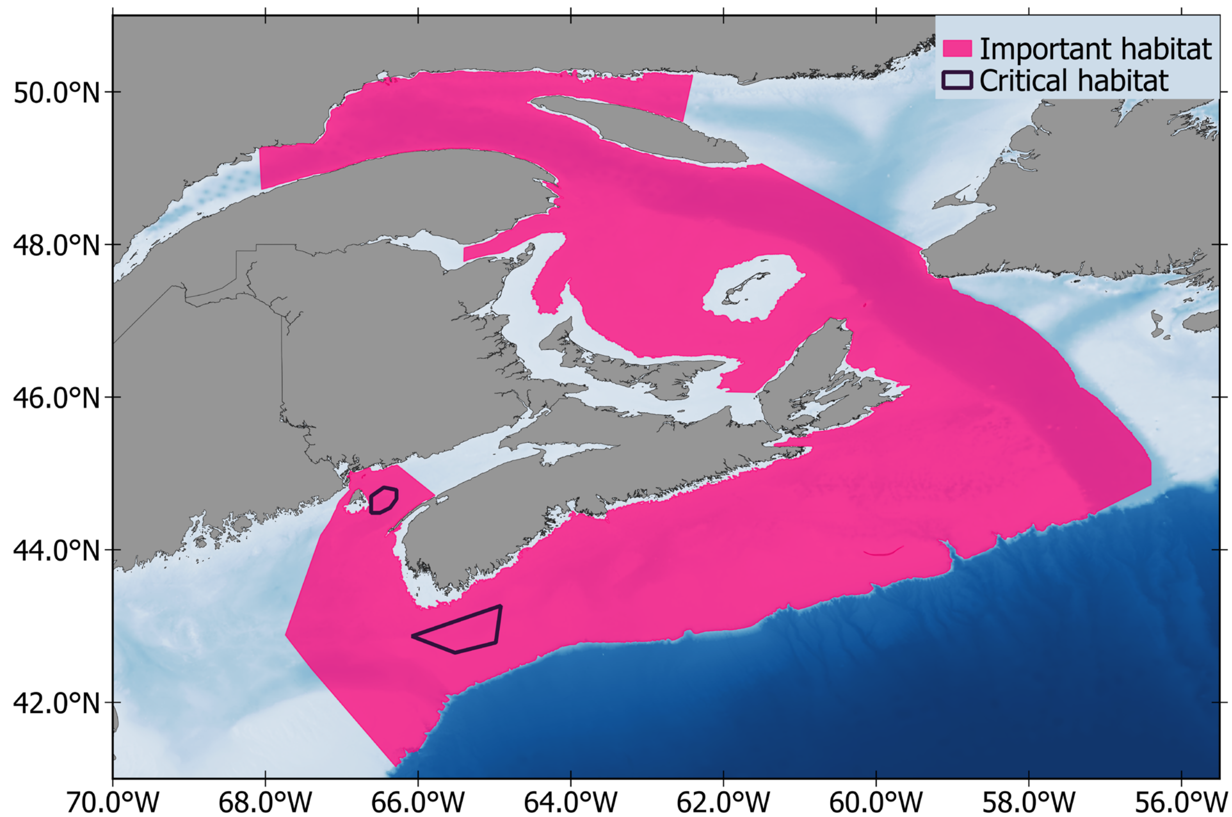

Figure 32: North Atlantic right whale (NARW) important habitat polygon categorized by the synthesis of NARW data considered within this analysis (pink polygon). The coastal margin of the polygon is defined by the 40 m isobath and does not extend to shore, while the outer boundary follows the 350 m isobath and the southeastern boundary follows the exclusive economic zone of Canada. The black polygons depict the NARW critical habitat in Grand Manan Basin (GMB) and Roseway Basin (RB) identified in the NARW recovery strategy in 2014 (DFO 2014).

The Bay of Fundy, Gulf of Maine, Georges Bank, Roseway Basin, and the Scotian Shelf

The multispecies 3-D prey models and resulting estimates of Enet from Plourde et al. (2024) indicate potential foraging habitat areas for NARWs on the SS and into the GoM and the northeast tip of GB. Combined with the sightings data, and considering the recurrent acoustic detections of NARWs, we have identified the cSS, RB, the Canadian portion of the GoM and GB, and the BoF as important habitat. This area includes the Canadian NARW critical habitats in the GMB and RB (DFO 2014). This area is characterized by several basins, e.g. GMB, Jordan Basin (JB), Crowell Basin, Georges Basin, RB, LaHave Basin (LB), and EB that may serve to aggregate NARW prey in concentrations suitable for NARWs.

Notably during the post-distributional shift period, the data from the array of PAM stations on the SS showed that NARWs occur year-round in waters off NS (Davis et al. 2017; Durette-Morin et al. 2022; Moors-Murphy et al. 2025). Specifically, acoustic detections were particularly consistent on the cSS, primarily the Emerald Basin area throughout the year, peaking in the autumn (Figure 25; Davis et al. 2017; Durette-Morin et al. 2022; Moors-Murphy et al. 2025). In addition, there were repeated monthly acoustic detections in the GMB and RB from April to December (Figure 25), clearly indicating that these areas (i.e., critical habitat) have not been abandoned as has sometimes been described in the literature (e.g., Record et al. 2019; Crowe et al. 2021; O'Brien et al. 2022; Meyer-Gutbrod et al. 2023; Helenius et al. 2024).

The expansion of NARW critical habitat was previously proposed by Davies et al. (2014) based on prey field distribution and oceanographic and bathymetric processes that aggregate prey in the RB. RB has been shown to have considerable interannual variation (order of magnitude) in the deep copepod layer among years (Davies et al. 2015), which might explain variability in visual and acoustic detections there; yet NARW are still acoustically detected each year in this region (Davis et al. 2017; Durette-Morin et al. 2021; Moors-Murphy et al. 2025). Limited visual detections of NARW in RB in recent years may be a factor of limited survey effort in the area. In the BoF, there have been fewer whales observed in the GMB, although in the early 2020s, NARWs have been observed regularly to the west of this Basin near the Wolves Islands, as well as further northwest in the BoF, at the head of the Passamaquoddy Bay (Figure 1). Notably, multiple sightings occurred in the early 1980s in this same general area (Gaskin 1987; DFO 2018; NARWC, unpublished data).

The eSS was also identified as NARW important habitat despite there being few sightings and limited acoustic detections in this area. The eSS is a potential feeding habitat and also connects known and potential feeding habitat via the Cabot Strait and has been defined as an important migration area for NARWs, which are considered a nearshore species (Rice et al. 2014) likely migrating along the SS (Moors-Murphy et al. 2025). Brillant et al. (2015) estimated a migration pattern along the continental shelf in the spring and summer and along the NS coast during the autumn and winter. Furthermore Mate et al. (1997) estimated that 80% of the locations of NARWs tagged in the BoF were in waters less than 182 m deep, implying that NARWs were migrating along the continental shelf and not in deeper water past the shelf break.

Cabot Strait

The Cabot Strait is a migratory corridor into the GSL, and analyses of acoustic data indicate that, at a minimum, NARWs transit through this area from May through December with a peak in upcall detections in autumn (Durette-Morin et al. 2021; Moors-Murphy et al. 2025). Although there are low numbers of acoustic detections in the area, major shipping lanes pass through the Cabot Strait (Simard et al. 2014; Veinot et al. 2023) rendering it a noisy environment that could be masking NARW upcalls and limiting detection ranges of PAM systems. Data on NARW occurrence in the GSL and Cabot Strait since 2015 provide evidence that NARWs use the area throughout the spring, summer, and autumn. Although the northern migration route through the Strait of Belle Isle cannot be discounted, migration into and out of the GSL via the Cabot Strait is likely the primary route as it represents the shortest path from southerly aggregation areas and is thus less energetically demanding. Furthermore, it is not as impacted by sea ice in late-winter/early-spring as the northern route (Galbraith et al. 2023) which could impede movements or trap transiting whales.

Southern Gulf of St. Lawrence

There has been considerable effort undertaken in the GSL to monitor and study NARWs and their prey. Johnson et al. (2024) reviewed empirical and model-based research undertaken by

DFO to assess the sGSL as an important foraging habitat for NARWs, and indicated that the environmental, oceanographic, and bathymetric features of the sGSL can support and aggregate high concentrations of prey. This was further confirmed in the prey modelling of Plourde et al. (2024) where relative Enet values in the sGSL were approximately double the values of other regions in the prey model extent. Furthermore, the acoustics data demonstrates the highest average proportion of days for each month with NARW upcall detections in the sGSL from 2015 through 2022 compared to any other Canadian area. The systematic aerial surveys between 2017 through 2022 also identified large aggregations of whales observed annually in the Shediac Valley of the sGSL, although the specific locations of aggregations varied among years (St-Pierre et al. 2024).

The sightings were highly concentrated in the Shediac Valley (Figure 1; Figure 10D; Figure 27). The sGSL could be separated into seGSL and swGSL as in St-Pierre et al. (2024), however with other features indicating the importance of both the east and west sides of the GSL, we kept the sGSL area whole. Both the prey modelling (Plourde et al. 2024) and the modelling of relative probability of occurrence of NARWs (Mosnier et al. 2025a; Mosnier et al. 2025b) identified the coastal waters around the Cape Breton Highlands and in the Cape Breton Trough (Figure 1; Figure 30), leading to the incorporation of these areas into the important habitat area.

Approximately 140 individual NARWs have been documented annually in the sGSL since 2017 and there is a high rate of inter-annual return (Crowe et al. 2021). Whaling records and previous habitat modelling identified the sGSL as potential habitat for NARWs (Moses and Finn 1997) and predicted elevated and sometimes persistent relative probabilities of occurrence in a small area off of the Gaspé coast (Figure 1; Brillant et al. 2015). The NARW Recovery Strategy also identified the Gaspé area in the GSL as an area for future study for the presence of critical habitat (DFO 2014). Driven by the shift in prey species' distribution and abundance in the 2010s (e.g., Meyer-Gutbrod and Greene 2018; Record et al. 2019; Sorochan et al. 2019; Meyer-Gutbrod et al. 2021, 2023), the sGSL has become an important habitat that supports large number of NARWs.

Northern Gulf of St. Lawrence

The northern portion of important habitat includes the SLE, areas north and northwest of Anticosti Island as well as the Honguedo Strait, where acoustic detections, contemporary sightings, prey, and probability of occurrence modelling all indicate this is an important habitat for the NARW. The SLE may represent a potential upstream food source that supplies the sGSL (Johnson et al. 2024). The Honguedo Strait also serves as a transit corridor between the nGSL and sGSL. Although relatively lower numbers of NARWs are detected in the northern GSL, NARWs regularly use this area in late summer and fall to feed, and for movements between the nwGSL and the sGSL as documented (Figure 28; Crowe et al. 2021; Lesage unpublished data; Whale Insight).

POTENTIAL FORAGING AREAS

The northeast GSL, the edges of the Grand Banks, Flemish Cap, and areas on the Newfoundland Shelf were all identified as potential foraging areas by the multispecies 3-D prey model and resulting estimates of Enet from Plourde et al. (2024; Figure 33). These areas represent estimates of prey fields present in quantities that are energetically relevant to NARWs (>90th quantile of Enet). Although there were large areas identified off the coast of Labrador as having high Enet values in Plourde et al. (2024), there was considerable variance and uncertainty in model predictions. Therefore, this northern end of the model domain was not used to identify potential feeding habitats in this analysis. The areas in the Esquiman Channel and coastally along southern Newfoundland where Enet values were greater than the 90th quantile

(Figure 29; Plourde et al. 2024) were not identified as potential feeding habitat due to their small size and patchiness.

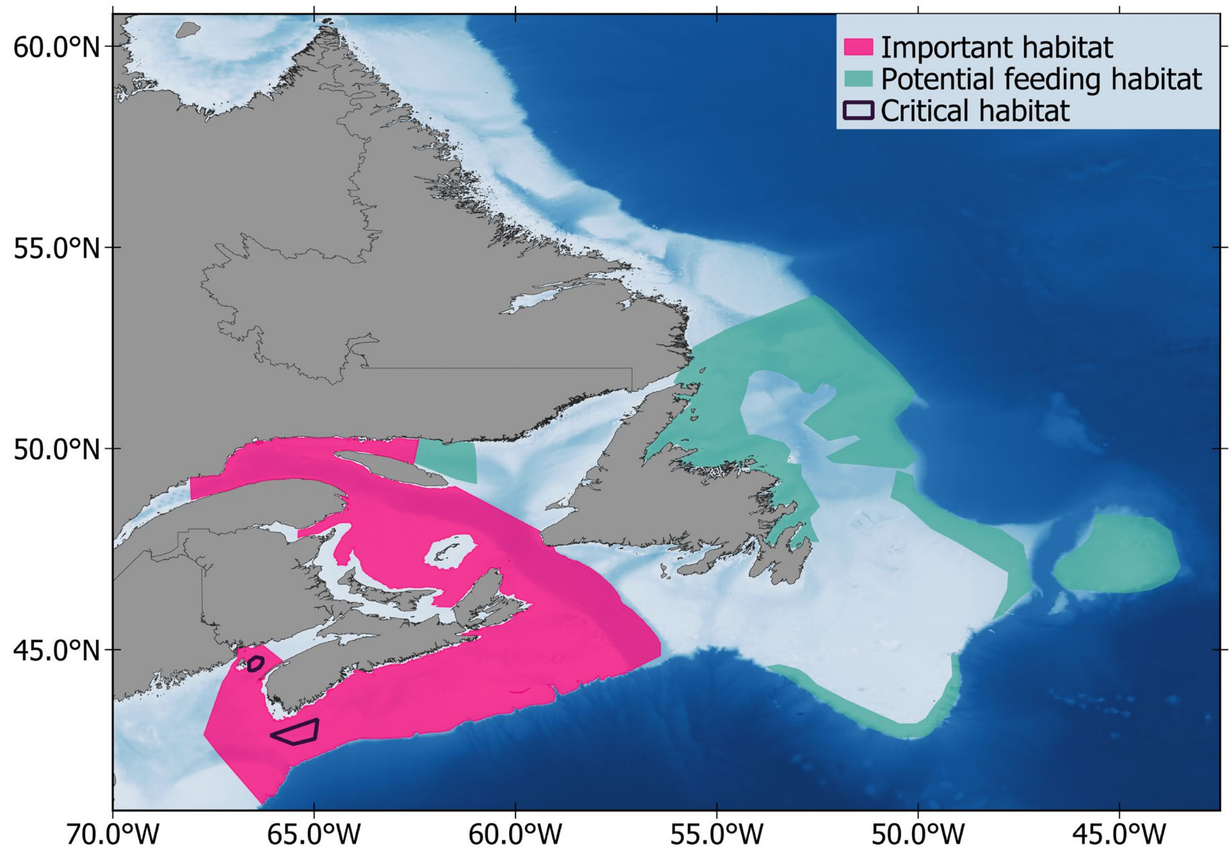

Figure 33: North Atlantic right whale (NARW) important habitat (pink polygon) and potential foraging habitats based on prey availability predictions (green polygons). The coastal margins of the polygons are defined by the 40 m isobath and do not extend to shore, while the outer boundary follows the 350 m isobath and the southeastern boundary follows the exclusive economic zone of Canada. The black polygons depict the NARW critical habitat in Grand Manan Basin (GMB) and Roseway Basin (RB) which were identified in the NARW recovery strategy in 2014 (DFO 2014).

FUNCTIONS, FEATURES, AND ATTRIBUTES OF IMPORTANT HABITAT

In accordance with the Directive on identifying critical habitat for aquatic species at risk, a *function* is a life-cycle process of the species taking place in critical habitat (Appendix 1). Each life-cycle function is sustained by one or more features, which are fundamental biophysical components of the critical habitat. These features consist of one or several attributes, which are measurable traits that offer the most detailed information about the critical habitat. Detailed attributes important to NARW have been described in previously published literature for specific habitats during specific time periods (see Appendix 3). For example, in the BoF, in the summer and autumn, NARWs were found to associate with surface temperatures that range between 10 – 16 °C and depths between 80 – 240 m (Murison and Gaskin 1989; Gaskin 1991; Baumgartner and Mate 2003; Baumgartner et al. 2017). However, identifying specific attributes linked to these biophysical features remains challenging due to a lack of sufficient data to define quantitative attributes for the features essential to NARWs while in Canada (DFO *In prep.*[1]).

FUNCTIONS

The NARW lifecycle functions identified included movement (habitat connectivity), feeding activity, gestation, rearing (nursing), socialization (mother-calf associations), socializing, and reproduction (Appendices 1, 4) and were document in Canadian waters using the contextual data and/or behaviour information from the NARWC Identification database (NARWC 2023).

'Movement (active and passive)' includes: exploration, migration, and resting however capturing the breadth of NARW movement is inherently complex and difficult due to limited sub-surface activity budgets. As such, to inform NARW use of habitats, movement and migration in Canadian waters is only discussed within the context of foraging and feeding, socializing and reproduction, gestation, and functions associated with rearing including nursing, growth, and socialization of the calves (Appendices 1, 4).

Foraging and Feeding

Foraging is presumed to occur in all of the identified important habitat areas, given the timing of use during the species' annual cycle, phenology and spatial distribution of Calanus spp. (Plourde et al. 2019), and observations of whales feeding (skim-feeding, near-surface feeding) or with mud on their head or body, documented from May through November. Such observations were primarily made in the sGSL, RB, BoF, GoM, GB, and a few in nwGSL (Figures 34, 35). As well, limited observations of NARWs skim-feeding in Cabot Strait (i.e., one observation) and coastal shallow waters in Newfoundland have been reported (Lawson et al. 2025). Observations of feeding behaviours are limited as not all are visible to survey teams, especially those performed at depth (Nowacek et al. 2001; van der Hoop et al. 2019; Wright et al. 2024). However, tagging studies in the sGSL and the BoF support feeding dives to depth in these areas (Baumgartner and Mate 2003; Baumgartner and Mate 2005; van der Hoop et al. 2019; Wright et al. 2024).

[1] DFO. Important Habitat of Northern Bottlenose Whales, Scotian Shelf Population. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. In preparation.

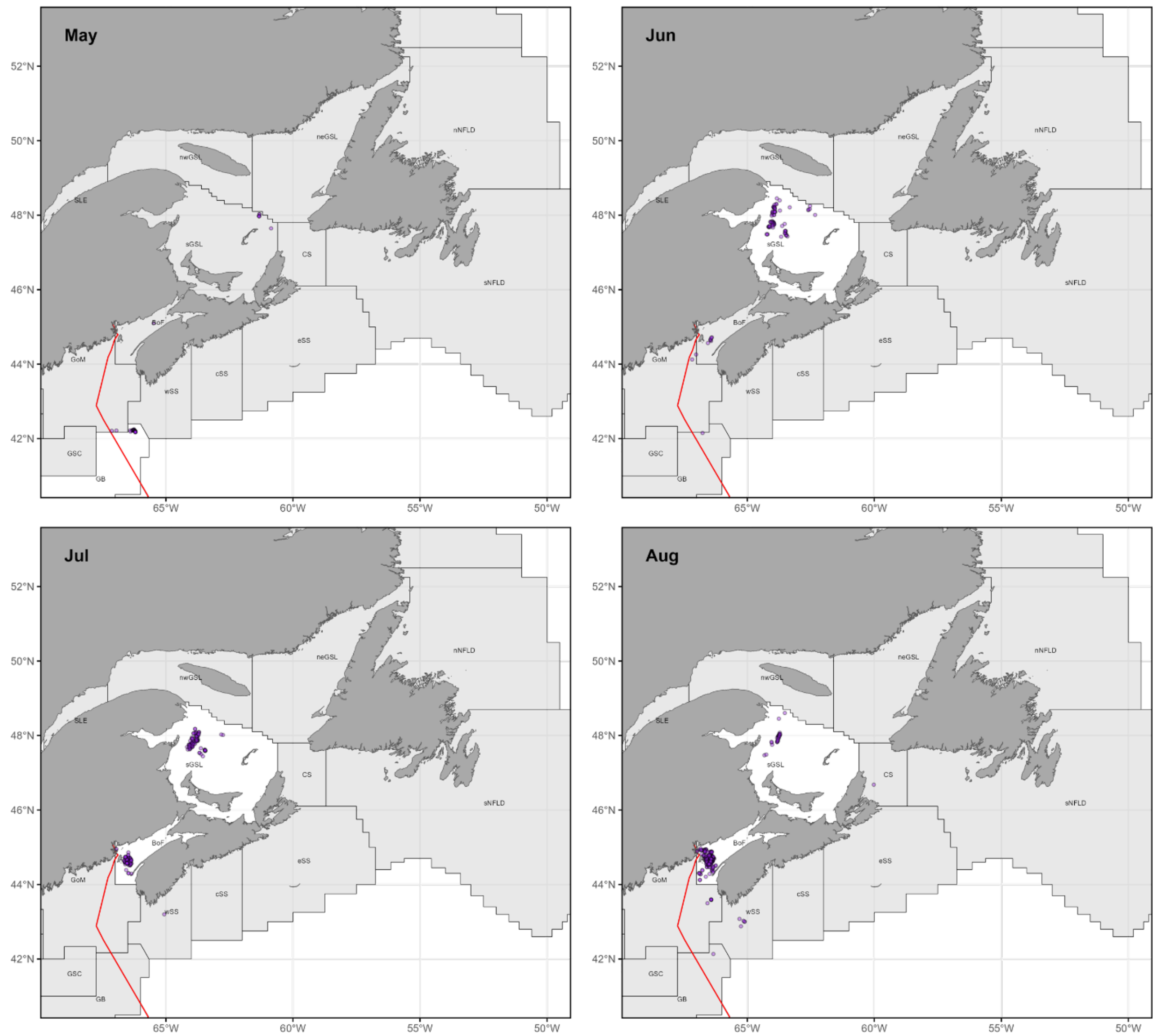

*Figure 34: Distribution of monthly occurrence of individual North Atlantic right whale observed behaviours indicating **feeding behaviour** (described in Appendix 4) for 1990-2021; May, June, July, and August. Canadian areas and the Exclusive Economic Zone Canada/United States of America border (red line) identified. NOTE 1: White study area polygons represent areas where there were 30 or more sightings with associated contextual data. The number of observations within and across areas reflects the **minimum** occurrence, due to areas and/or months without survey effort and/or disparity in survey effort amongst areas and months, and the natural limitations in observing 'interpretable' behaviors. NOTE 2: The extent of the map is reduced to better visualize the data, no occurrences were recorded off Labrador or in the Flemish Cap.*

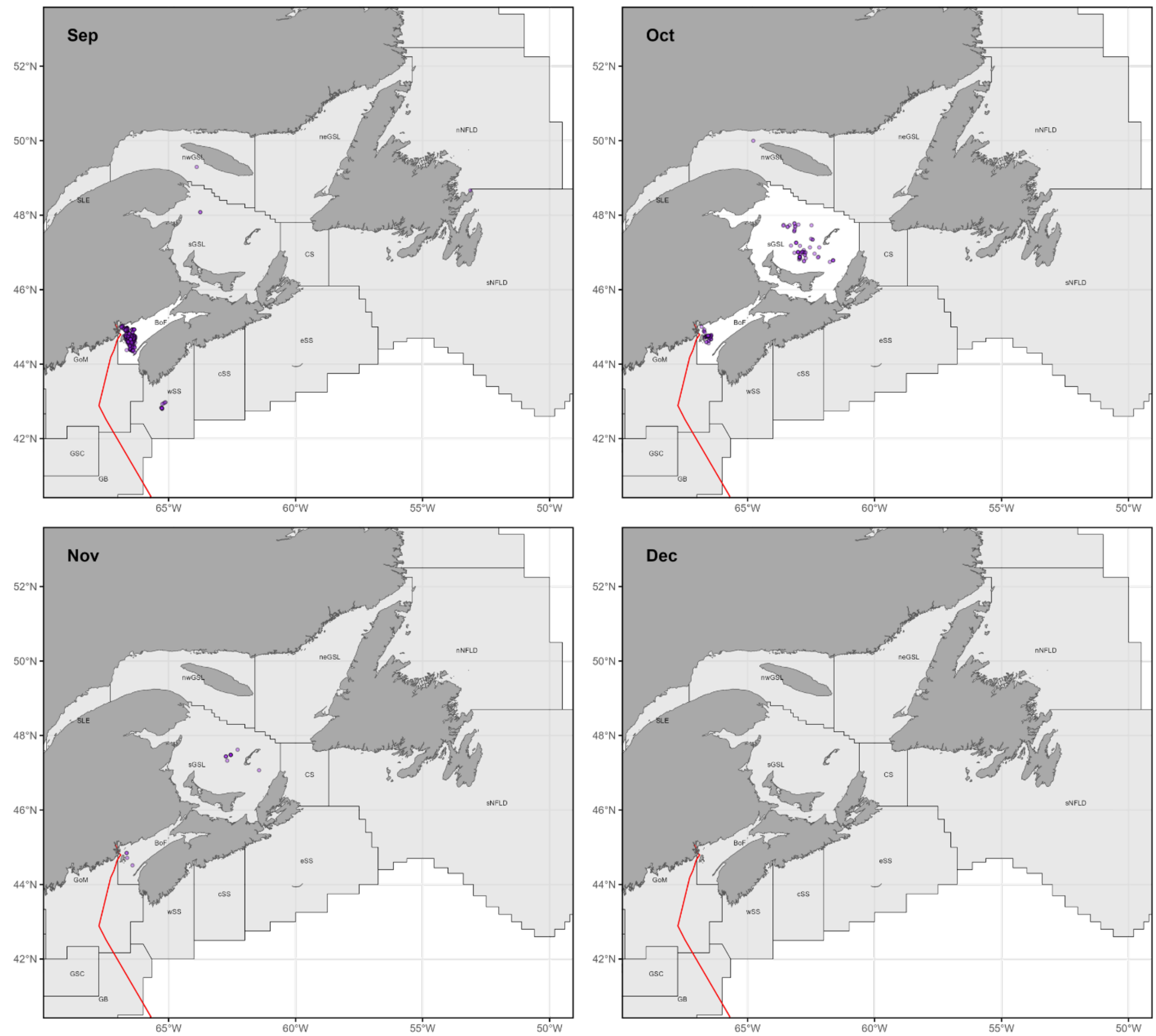

Figure 35: Distribution of monthly occurrence of individual North Atlantic right whale observed behaviours indicating ***feeding behaviour*** *(described in Appendix 4); September, October, November, and December from 1990-2021. Canadian areas and the Exclusive Economic Zone Canada/United States of America border (red line) identified NOTE 1: White study area polygons represent areas where there were 30 or more sightings with associated contextual data. The number of observations within and across areas reflects the* ***minimum*** *occurrence, due to areas and/or months without survey effort and/or disparity in survey effort amongst areas and months, and the natural limitations in observing 'interpretable' behaviors. NOTE 2: The extent of the map is reduced to better visualize the data, no occurrences were recorded off Labrador or in the Flemish Cap.*

In the following subsections, we summarize features and attributes of the BoF, RB, and sGSL foraging areas that contribute to prey aggregation and availability. Alignment of biophysical mechanisms that influence prey supply, aggregation and availability (Figure 3) facilitate suitable foraging conditions for NARW (i.e., high prey concentration at depths that NARW can readily access). In their syntheses, Sorochan et al. (2021a) highlighted that *Calanus* spp. are annually re-supplied to NARW foraging areas from upstream sources. The timing and magnitude of this re-supply are influenced by the phenology of *Calanus* spp. and the connectivity between source and sink regions. Additionally, the biophysical mechanisms driving prey aggregation are dynamic, as they are influenced by the behavior and vertical distribution of the copepods, which changes over time as the copepods develop. In a given foraging area, NARWs may feed on both active and diapausing *Calanus* spp. copepods and can change their foraging strategies throughout the season to exploit different stage compositions and species of prey.

Bay of Fundy

Proximate sources of *Calanus* spp. to the lower BoF include the NS Coastal Current, GoM, and slope water that enters the GoM from the North East Channel (Corey and Milne 1987; Johnson et al. 2006; Record et al. 2019). The BoF is characterized by very strong tidal currents that interact with coastline and bottom topography to produce a highly dynamic environment (Johnston et al. 2005; Ingram et al. 2007; Aretxebaleta et al. 2008). NARWs have been observed within the BoF in a variety of environmental conditions including: stratified waters, well-mixed waters with frequent upwelling, along fronts, and in transition zones between mixed and stratified waters (Gaskin 1987; Murison and Gaskin 1989; Gaskin 1991; Woodley and Gaskin 1996). Woodley and Gaskin (1996) found that SST was significantly higher in areas where NARWs were sighted; however, Baumgartner et al. (2003a) found no evidence for these associations. The presence of strong gradients in flow and water properties likely indicate convergence and divergence zones where zooplankton could potentially become concentrated.

NARW foraging ecology has been studied in the GMB (maximum bottom depth ~220 m) in summer, where individuals have been observed targeting concentrated layers of late-stage *C. finmarchicus* (Baumgartner and Mate 2003). Baumgartner and Mate (2003) reported an average foraging dive depth of 121 m from 32 tag deployments (including two deployments from RB on the SS). van der Hoop et al. (2019) reported an average dive depth of 138 m based on 132 “U-shaped” dives from 10 tag deployments. Baumgartner and Mate (2003) found that prey aggregations occurred just above a thick (10s of metres in width) bottom mixed layer (BML). If copepods avoid this BML and aggregate above it, the BML would contribute to the availability of the prey layer to NARWs by reducing the time required to reach the layer during foraging dives (Baumgartner et al. 2003a); however, Michaud and Taggart (2011) did not observe this relationship with the BML, and reported maximum densities of *C. finmarchicus* at depths > ~120 m. Tidal currents appear to transport subsurface (> 100 m depth) patches of stage CV of *C. finmarchicus* and contribute to their spatio-temporal variation in GMB (Baumgartner et al. 2003b; Michaud and Taggart 2011). Michaud and Taggart (2011) hypothesized that sloshing of relatively deep warm salty water in the basin contributes to excursions of *C. finmarchicus* up and down the basin walls. Such upward excursions enhance availability to NARWs and potentially further concentrate the copepods (see Davies et al. 2013).

Scotian Shelf

Sources of *Calanus* spp. to the SS include the GSL outflow and slope water (e.g., Labrador Slope Water and Warm Slope Water; Gatien 1976) via equatorward currents that flow along the coast and shelf break (e.g., Loder et al. 1998). Instability or change in position of the shelf break front (McLellan et al. 1953) and subsurface intrusions of slope water (Petrie and Smith 1977) influence hydrographic variability on the SS and represent potential sources of *Calanus* spp. (e.g., Head et al. 1999; Davies et al. 2014). In addition, relatively deep basins on the central SS (cSS; e.g., Emerald Basin, maximum depth ~290 m) may provide adequate overwintering habitat for *C. finmarchicus* and are thus potential local sources (Herman et al. 1991). High concentrations of *Calanus* spp. have been reported in relatively deep water (e.g., > 100 m) in SS basins (e.g., Sameoto and Herman 1990; Herman et al. 1991; Davies et al. 2014) potentially due to accumulation of individuals that are retained at depth (e.g., Herman et al. 1991).

NARWs have been observed feeding on *Calanus* copepods in RB (maximum bottom depth ~170 m) with an average foraging dive depth of 102 m in summer (Baumgartner et al. 2017). Baumgartner et al. (2003b) found that NARW occurrence was associated with gradients in sea surface temperature. Tides in the RB area are not as energetic as in the BoF, but still have a strong impact on ocean currents and hydrography (Hannah et al. 2001; Wang et al. 2020). Davies et al. (2013) found evidence for the same tidally driven mechanism proposed by Michaud and Taggart (2011) in GMB, which can enhance availability of relatively deep aggregations of *Calanus* spp. (primarily stage CV of *C. finmarchicus*) to NARWs on basin margins. Davies et al. (2014; 2015) found that spatial and temporal variability of *C. finmarchicus* CV was associated with subsurface water mass variability in RB, which is influenced by both coastal and slope water sources that can vary in their significance over time (e.g., Davies et al. 2015; Ruckdeschel et al. 2020). Davies et al. (2014) proposed that concentrations of *C. finmarchicus* could be modulated by the proximity of the 1026 kg m^{-3} isopycnal to the seafloor, meaning that copepods are concentrated as this isopycnal approaches the bottom.

Southern GSL

The GSL is a productive semi-enclosed marginal sea that supports high densities of overwintering populations of *C. finmarchicus* and *C. hyperboreus* in the Laurentian Channel and its branches (e.g., Plourde et al. 2001, 2003, 2019; Maps et al. 2011). The GSL receives inflow from the western North Atlantic on the northern side of the CS and the Labrador Shelf from the Strait of Belle Isle in the neGSL (Loder et al. 1998). Plourde and Runge (1993) hypothesized that near-surface residual flow in the SLE results in export of *Calanus* spp. production in the Gaspé Current, effectively acting as a ”Calanus pump”. The Gaspé Current is itself a biologically productive environment with potential to facilitate zooplankton growth and reproduction (e.g., Benkort et al. 2020) and subsequently amplify zooplankton abundance (Sorochan et al. 2021a). The Gaspé Current penetrates the sGSL on its western side at the mouths of the Chaleur and Shediac troughs (Koutitonsky and Bugden 1991), and is an important source of zooplankton to the sGSL (e.g., Brennan et al. 2019). However, zooplankton can also immigrate to the sGSL from the greater GSL via other pathways (e.g., Le Corre et al. 2023).

NARWs have been observed throughout much of the sGSL, and aggregations of NARWs have been frequently observed on the western side of the sGSL, in the vicinity of the Shediac Trough (i.e., Shediac Valley; Crowe et al. 2021). The Shediac Trough (as depicted by Loring and Nota 1973; their Figure 17) is one of five troughs that cut into the sGSL from the shelf break. The long axis of the Shediac Trough is characterized by bottom depths ranging from ~180 – 50 m. NARWs have been observed foraging within metres of the bottom in this trough in summer (dive depths ranging from 77 – 121 m, n = 3; Wright et al. 2024). Zooplankton sampling within 24 h of two NARW tag deployments indicated the presence of highly concentrated near-bottom layers of *Calanus* spp. with mixed water column-integrated composition of *C. finmarchicus*, *C. hyperboreus*, and *C. glacialis* (Sorochan et al. 2023; Wright et al. 2024). The highest concentrations of *Calanus* spp. have typically been observed between 70 m and 90 m, usually near the bottom and in close proximity to the Cold Intermediate Layer (Johnson et al. 2022; Sorochan et al. 2023; Johnson et al. 2024).

Since the troughs of the sGSL are relatively shallow (mostly < 100 m depth), they are probably less effective at accumulating copepods that descend to the near bottom in comparison to deeper basins (e.g., GMB). However, particle tracking has indicated that the troughs may play a role in retention and distribution of copepods that reside relatively close to the bottom (Le Corre et al. 2023). Throughout the sGSL, the shallow bottom depth appears to obstruct diel and ontogenetic vertical migrations of NARW prey, contributing to their aggregation near the sea floor (Plourde et al. 2019; Sorochan et al. 2023). In certain areas, the shallow bathymetry may also impede the persistence of high concentrations of *Calanus* spp. by reducing retention. In autumn and winter, mixing to the near-bottom and horizontal advection likely facilitate losses from the system (Sorochan et al. 2021b; Johnson et al. 2024).

Aerial observations of NARWs in the GSL have indicated less frequent near-surface feeding behaviour per individual in August relative to June and July (Franklin et al. 2022). This may reflect increased scarcity in near-surface prey aggregations and increased foraging activity on near-bottom prey aggregations in late-summer (Johnson et al. 2024). The composition of prey-layers that NARWs target in the upper water column has not been studied in the sGSL; however, an analysis of the vertical distribution of *Calanus* spp. biomass in the GSL indicates a shift from a bimodal distribution (upper and lower water column peaks) in spring to a unimodal near-bottom peak in summer and fall (Plourde et al. 2019). Temporal variability in the vertical distribution of *Calanus* spp. biomass is influenced by differences in the life-cycle of the three *Calanus* species and their associated phenology in the sGSL (see Johnson et al. 2024). The biomass dominance of *C. hyperboreus* relative to the other *Calanus* spp. in spring and early summer, and transition to biomass dominance of *C. finmarchicus* later in summer (e.g., Lehoux et al. 2020), is a key feature of the sGSL NARW foraging habitat (Johnson et al. 2024).

Essentially, for NARWs to successfully forage and feed, key characteristics are needed in the marine environment such as water and topographic characteristics to supply and aggregate prey at depths accessible to NARW feeding, unimpeded space to successfully find and consume prey, water and air quality to not cause adverse effects on the prey and NARWs as well as an acoustic environment that will not impede use of the habitat.

Gestation, Growth, Rearing, Nursing, Socialization

While NARWs occurrence in Canadian waters is mainly for feeding, other functions are fulfilled while present on their feeding grounds, including gestation, growth, calf rearing (including nursing), and socialization (Figures 36 to 39; Appendix 4). Retrospective analysis of sightings of females with calves indicate that pregnant females were present in important habitats in the BoF, GoM, GB, wSS, CS, nwGSL, and the sGSL (Figures 36 to 39, left panels). Pre-2010, reproductive females that demonstrated site fidelity to the BoF ("Fundy mothers") represented two thirds of the females in the population (Schaeff et al. 1993). These mothers were brought to the BoF by their mothers, and it has been suggested there was a strong maternally directed site fidelity in NARW (Malik et al. 1999). With the distributional shift to the GSL, it is not yet known whether the mothers seen with calves are distinctly mothers that previously regularly visited the BoF (i.e., "Fundy mothers"), the other reproductive females ("non-Fundy mothers"), or some combination of the two.

Mother-calf pairs have primarily been observed in the BoF and GSL, and to a lesser extent in the GoM, GB, and wSS (Figures 36 to 39, right panels). The presence of mother-calf pairs from May through November suggests that the important habitat is a crucial growth, rearing and socialization area for young of the year. This is further supported by direct observations of nursing in the sGSL and BoF during the same period (May through October; Appendix 4). Although no mother-calf pairs were sighted in the nwGSL within the time frame of this analysis, a few pairs have since been detected persisting northwest of Anticosti Island (Whale Insight).

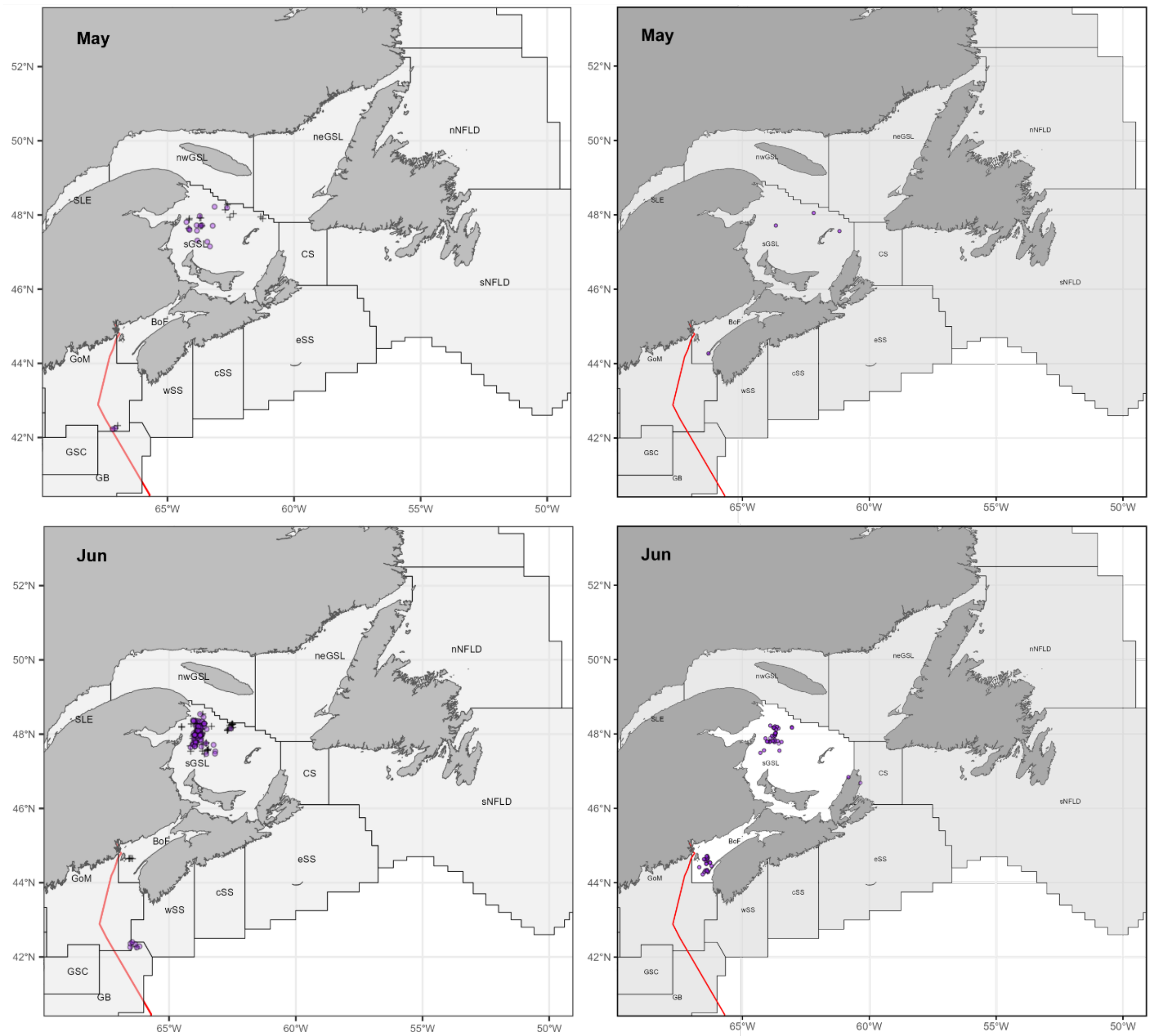

*Figure 36: Distribution of monthly (May and June) occurrence of individual North Atlantic right whale observations of pregnant females (i.e., **gestation**; left column; see Appendix 4) and mother-calf pair associations (i.e., **rearing, socialization, visible nursing** behaviour; right column; see Appendix 4) from 1990-2022. The location of pregnant females is represented by circles for Birth Year-1 and grey plus signs for Birth Year-2 to account for pregnant (Y-1) and possibly pregnant (Y-2). Canadian areas and Exclusive Economic Zone Canada/United States of America border (red line) identified. NOTE 1: White study area polygons in the mother-calf pair associations represent areas where there were 30 or more sightings with associated contextual data. The number of observations within and across areas reflects the **minimum** occurrence, due to areas and/or months without survey effort and/or disparity in survey effort amongst areas and months, and the natural limitations in observing 'interpretable' behaviors. NOTE 2: The extent of the map is reduced to better visualize the data, no occurrences were recorded off Labrador or in the Flemish Cap.*

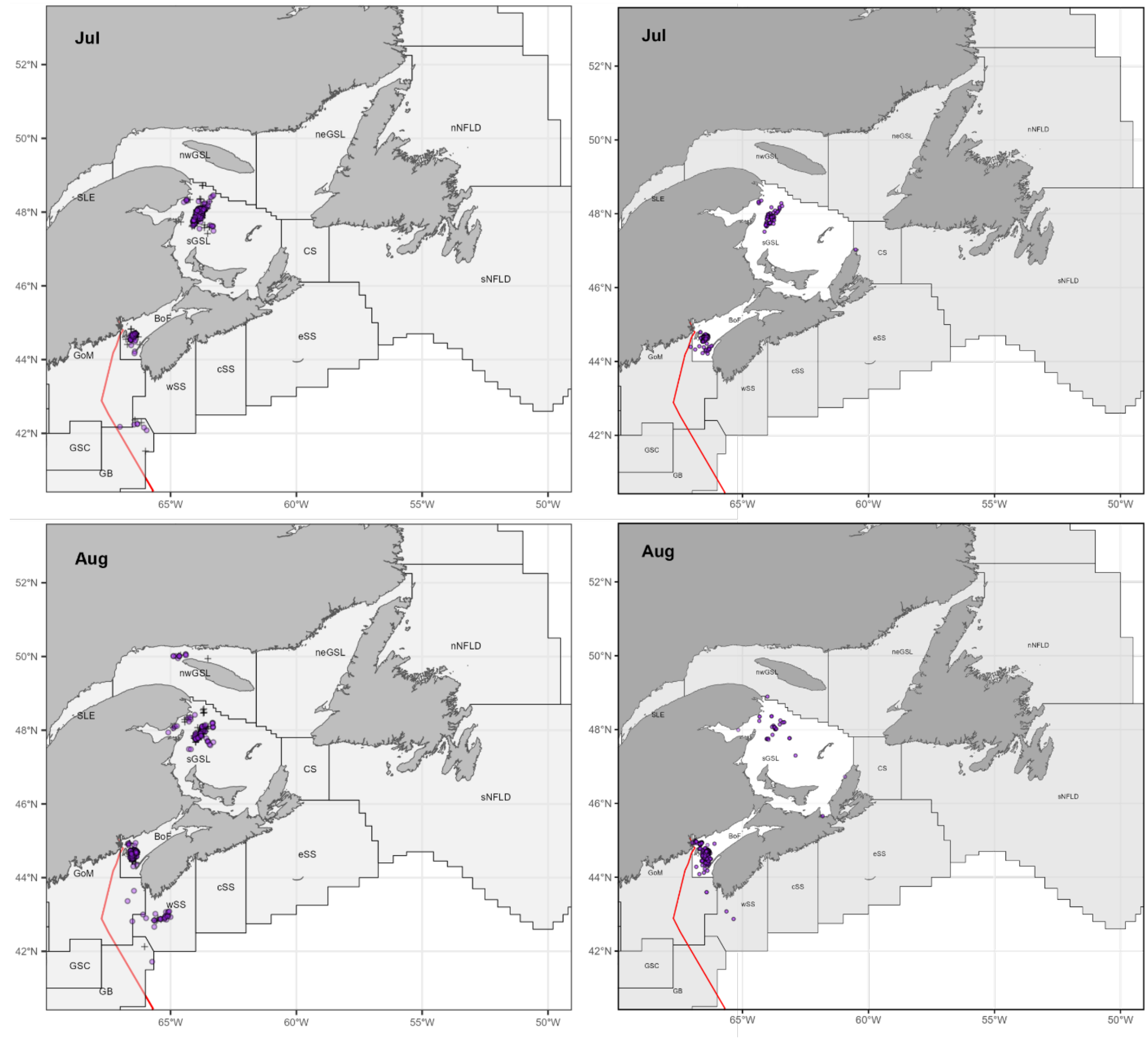

*Figure 37: Distribution of monthly (July and August) occurrence of individual North Atlantic right whale observations of pregnant females (i.e., **gestation**; left column; see Appendix 4) and mother-calf pair associations (i.e., **rearing, socialization, visible nursing** behaviour; right column; see Appendix 4) from 1990-2022. The location of pregnant females is represented by circles for Birth Year-1 and grey plus signs for Birth Year-2 to account for pregnant (Y-1) and possibly pregnant (Y-2). Canadian areas and Exclusive Economic Zone Canada/United States of America border (red line) identified. NOTE 1: White study area polygons in the mother-calf pair associations represent areas where there were 30 or more sightings with associated contextual data. The number of observations within and across areas reflects the **minimum** occurrence, due to areas and/or months without survey effort and/or disparity in survey effort amongst areas and months, and the natural limitations in observing 'interpretable' behaviors. NOTE 2: The extent of the map is reduced to better visualize the data, no occurrences were recorded off Labrador or in the Flemish Cap.*

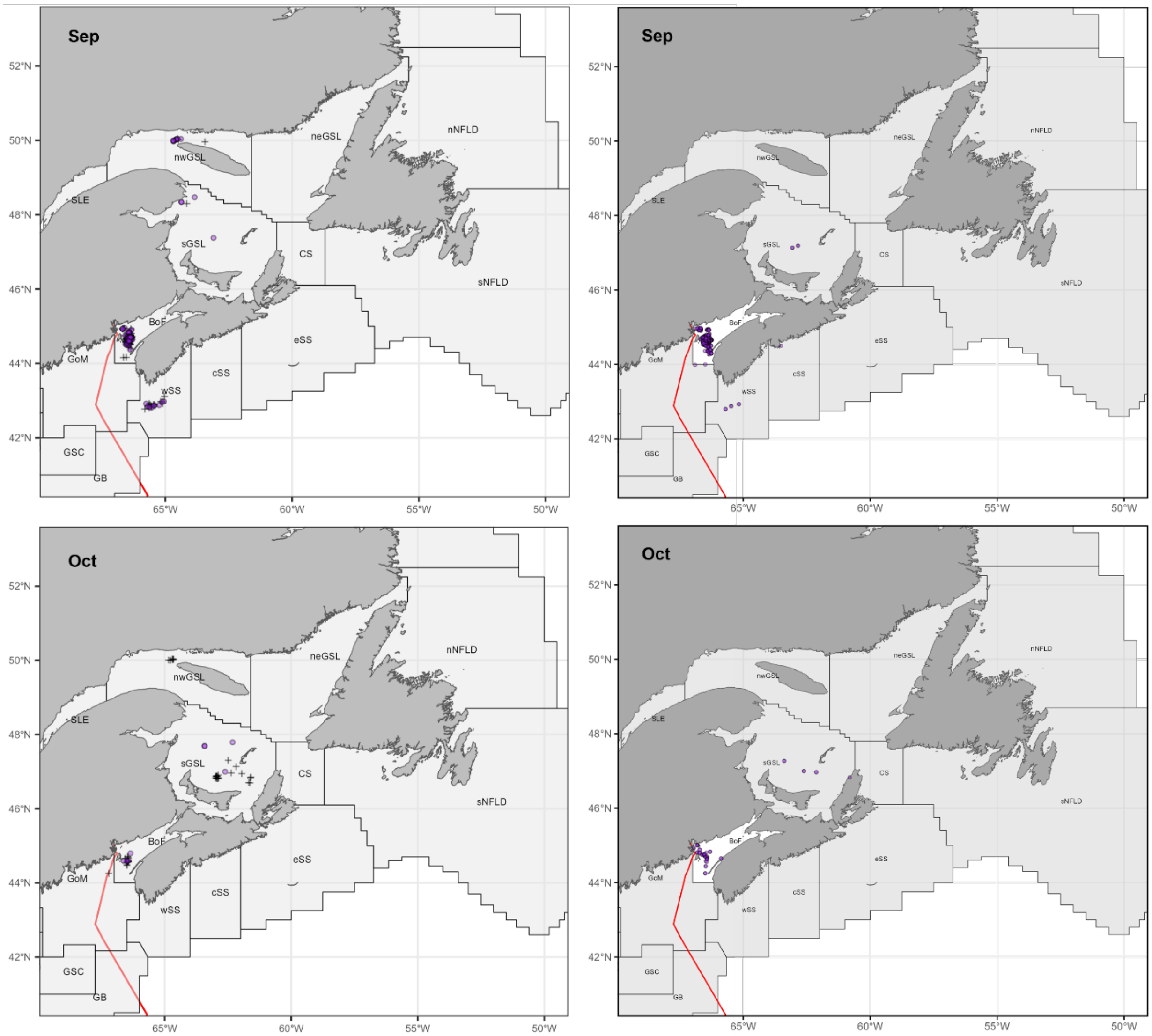

*Figure 38: Distribution of monthly (September and October) occurrence of individual North Atlantic right whale observations of pregnant females (i.e., **gestation**; left column; see Appendix 4) and mother-calf pair associations (i.e., **rearing, socialization, visible nursing** behaviour; right column; see Appendix 4) from 1990-2022. The location of pregnant females is represented by circles for Birth Year-1 and grey plus signs for Birth Year-2 to account for pregnant (Y-1) and possibly pregnant (Y-2). Canadian areas and Exclusive Economic Zone Canada/United States of America border (red line) identified. NOTE 1: White study area polygons in the mother-calf pair associations represent areas where there were 30 or more sightings with associated contextual data. The number of observations within and across areas reflects the **minimum** occurrence, due to areas and/or months without survey effort and/or disparity in survey effort amongst areas and months, and the natural limitations in observing 'interpretable' behaviors. NOTE 2: The extent of the map is reduced to better visualize the data, no occurrences were recorded off Labrador or in the Flemish Cap.*

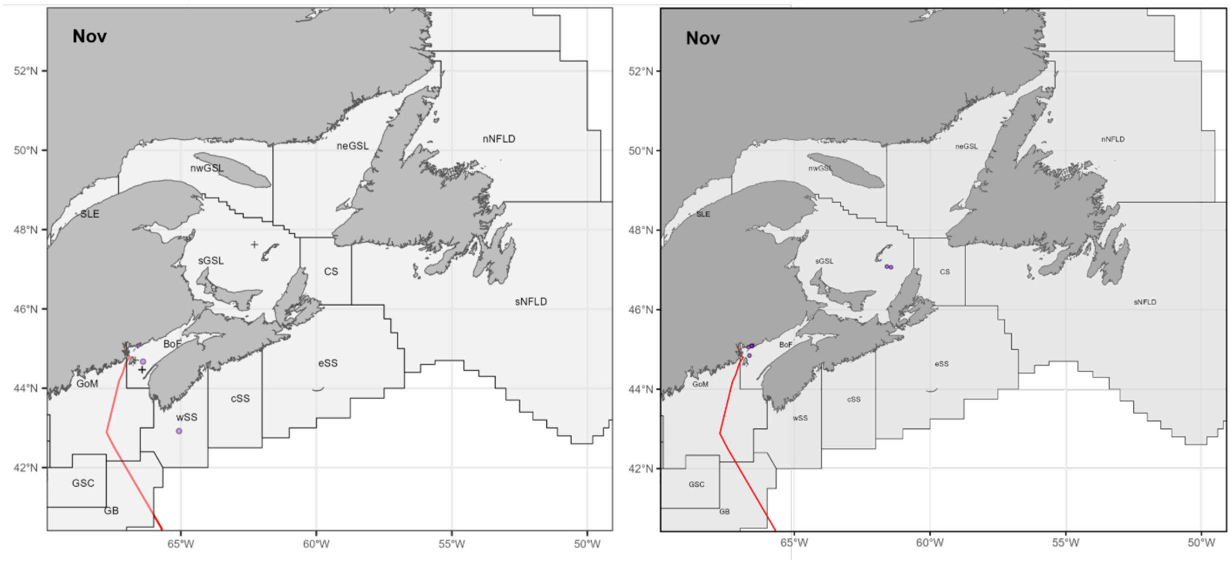

*Figure 39: Distribution of monthly (November) occurrence of individual North Atlantic right whale observations of pregnant females (i.e., **gestation**; left column; see Appendix 4) and mother-calf pair associations (i.e**., rearing, socialization, visible nursing behaviour**; right column; see Appendix 4) from 1990-2022. The location of pregnant females is represented by circles for Birth Year-1 and grey plus signs for Birth Year-2 to account for pregnant (Y-1) and possibly pregnant (Y-2). Canadian areas and Exclusive Economic Zone Canada/United States of America border (red line) identified. NOTE 1: White study area polygons in the mother-calf pair associations represent areas where there were 30 or more sightings with associated contextual data. The number of observations within and across areas reflects the **minimum** occurrence, due to areas and/or months without survey effort and/or disparity in survey effort amongst areas and months, and the natural limitations in observing 'interpretable' behaviors. NOTE 2: The extent of the map is reduced to better visualize the data, no occurrences were recorded off Labrador or in the Flemish Cap.*

Beyond a prey source, other habitat features and/or attributes specific to nursery habitats include: unimpeded space to successfully nurse/suckle, water and air quality to not cause adverse affects, an acoustic environment that will not impede use of the habitat, and a limited presence or total absence of potential predators.

Socializing and Reproduction

It is often difficult to describe marine mammal social interactions because they are rarely observed in the wild. One notable exception is the extensive sea-surface observations of NARW social and/or sexual interactions, (i.e., SAGs). These behaviours were observed from May through December in the BoF, wSS, and sGSL with occasional observations in nwGSL, GoM, GB, and CS (Figures 40-41; Appendix 4).

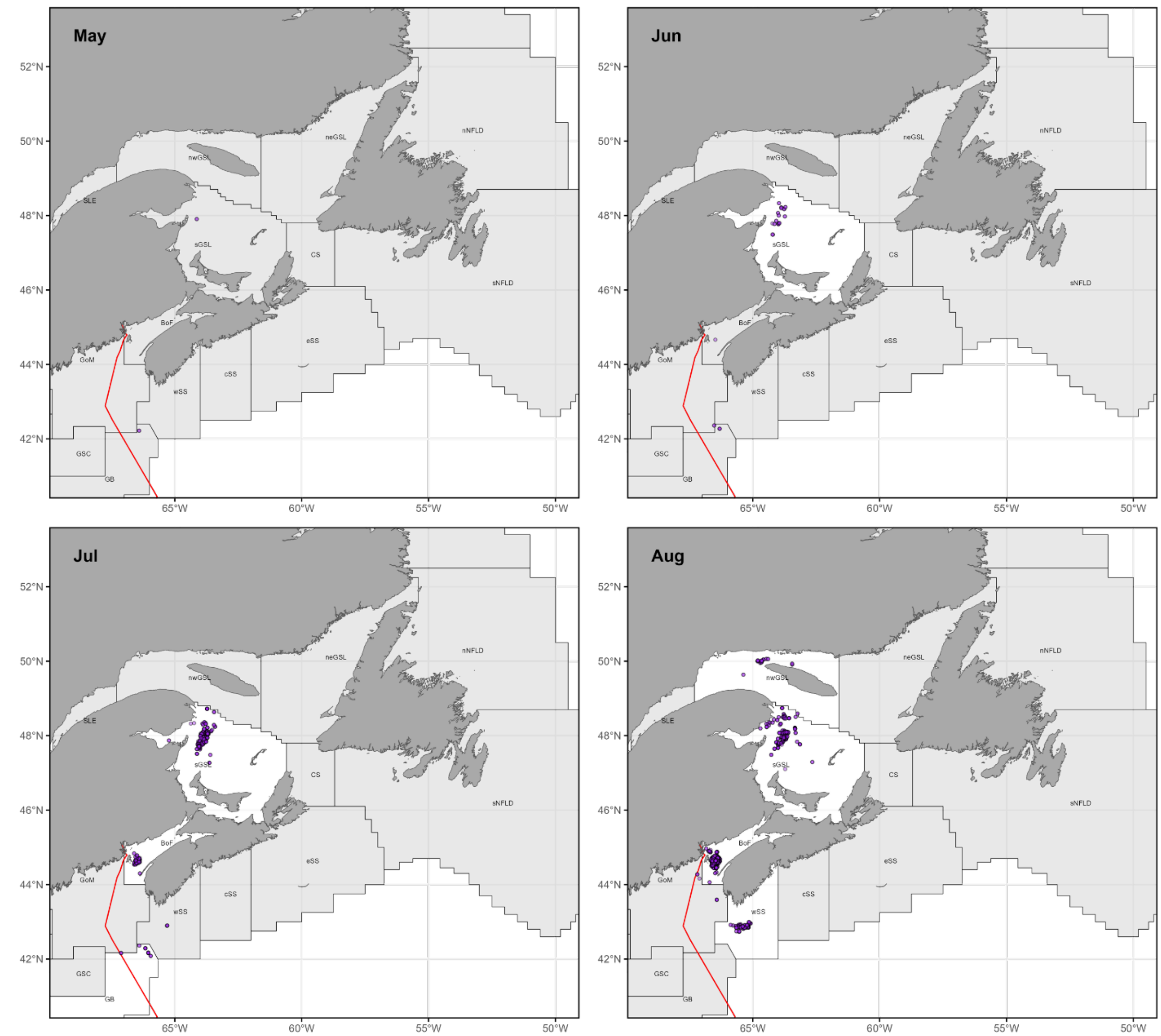

*Figure 40: Distribution of monthly (May, June, July, and August) occurrence of individual North Atlantic right whale observations in Surface Active Groups (SAG; i.e., **social and reproductive** behaviour; see Appendix 4) from 1990-2021. Canadian areas and Exclusive Economic Zone Canada/United States of America border (red line) identified. NOTE 1: White study area polygons represent areas where there were 30 or more sightings with associated contextual data. The number of observations within and across areas reflects the **minimum** occurrence, due to areas and/or months without survey effort and/or disparity in survey effort amongst areas and months, and the natural limitations in observing 'interpretable' behaviors. NOTE 2: The extent of the map is reduced to better visualize the data, no occurrences were recorded off Labrador or in the Flemish Cap.*

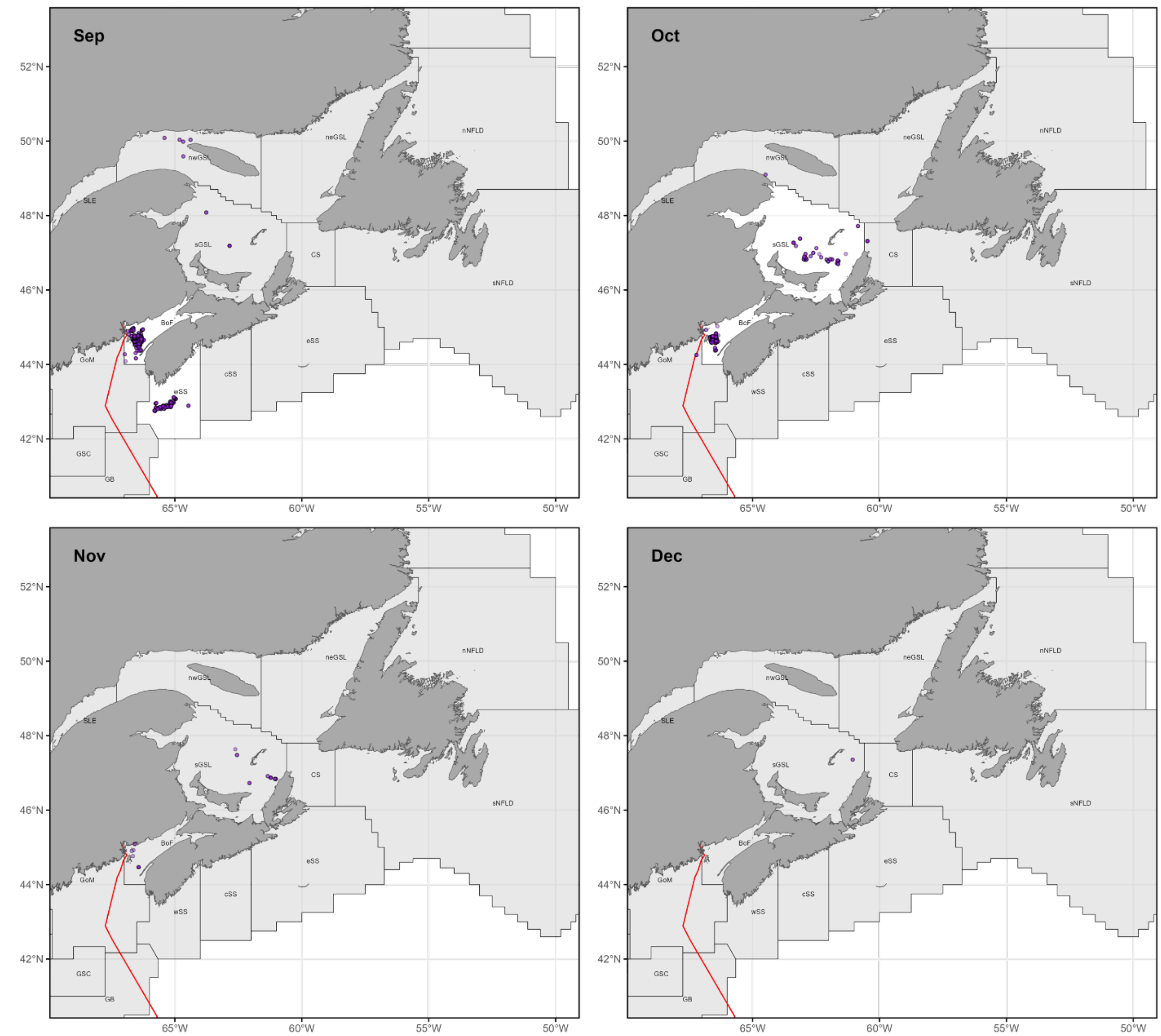

Figure 41: Distribution of monthly (September, October, November, and December) occurrence of individual North Atlantic right whale observations in Surface Active Groups (SAG; i.e., ***social and reproductive*** *behaviour; see Appendix 4) from 1990-2021. Canadian areas and Exclusive Economic Zone Canada/United States of America border (red line) identified NOTE 1: White study area polygons represent areas where there were 30 or more sightings with associated contextual data. The number of observations within and across areas reflects the* ***minimum*** *occurrence, due to areas and/or months without survey effort and/or disparity in survey effort amongst areas and months, and the natural limitations in observing 'interpretable' behaviors. NOTE 2: The extent of the map is reduced to better visualize the data, no occurrences were recorded off Labrador or in the Flemish Cap.*

The extent of habitat requirements for these specific behaviours are largely unknown and possibly not bound to specific habitat features or attributes as these are ubiquitous amongst habitats and throughout the year (Kraus and Hatch 2001; Kraus et al. 2007). However, particularly important attributes would include: unimpeded space, environmental sound levels low enough not to impact social communication, and access to conspecifics (Parks 2003; Brown and Sironi 2023).

Observed shift in habitat use between 2010 and 2021

The shift in habitat uses from the identified southern Canadian critical habitats to the GSL in the 2010s is also discernible from the supplemental data presented herein (Figure 42). The functional behaviours, discerned from observations and contextual data, appear consistent between the BoF and the sGSL, pre- and following the distributional shift. Subsequent to 2010 there are less observations of rearing/nursing, however this may also be a result of survey effort, as some vessel-based surveys shifted their efforts from the BoF into the sGSL.

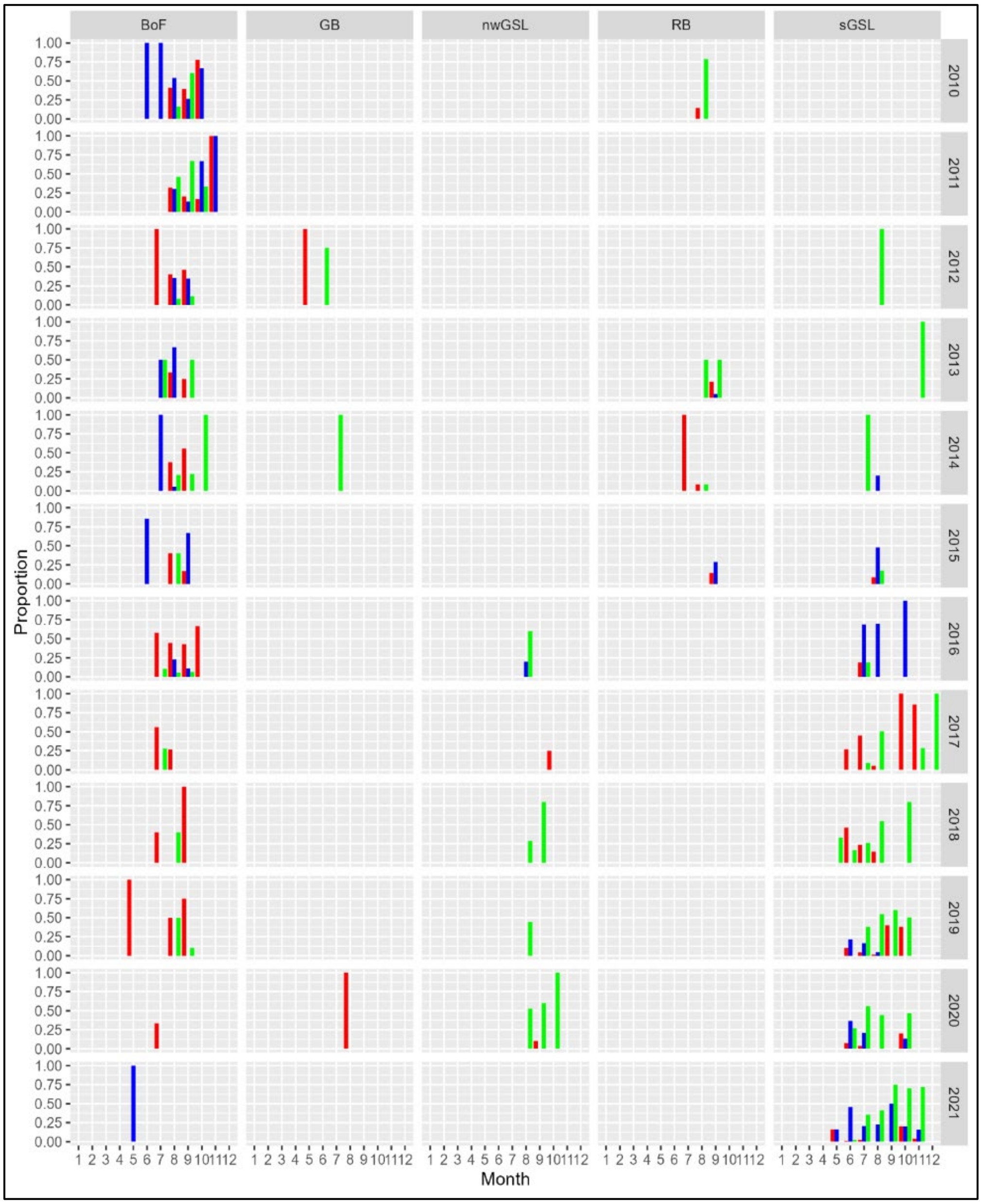

Figure 42: Seasonal extent (May to November [1 in December 2017]) of observed functional behaviours (red; foraging, blue; rearing/nursing, and green; social/reproduction; see Appendix 4) observed within the last decade (2010-2021) in the five areas (within the Canadian Exclusive Economic Zone) with highest number of observations. Full summary of observation numbers are in Appendix 4. NOTE: Number of observations within and amongst areas represents ***minimum*** *occurrence as a result of differences in survey effort and inherent reduced ability of observing 'interpretable' behaviours.*

FEATURES AND ATTRIBUTES

NARWs occur across a broad spectrum of environmental conditions, which include currents, stratification, mixed waters, fronts, and varying seawater temperatures and salinities. However, description of important habitats indicate that their presence in Canadian waters is largely driven by environmental factors that affect prey availability and aggregation, although other non-prey-related influences also play a role (e.g. Davies et al. 2015). As such, key habitat attributes vital to the function(s) of NARWs are broadly summarized by important biophysical features. Future research is needed, both within and beyond the areas outlined in this document, to further characterize key habitat features, either qualitatively or quantitatively, that could support monitoring efforts and help identify changes that may impact the recovery of the NARW.

Table 1: General description of the biophysical features and associated attributes supporting identified life-cycle functions of the North Atlantic right whale (NARW) in eastern Canadian waters. 'All' life stages include: Adult females and males, juveniles and calves. Appendix 3 provides additional habitat details relevant to NARWs at specific time periods and locations, as identified in previously published literature.

Life Stage	Function(s)	Feature(s)	Attributes
All	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing Social/ Reproduction Movement/ Migration	Prey supply	Prey availability at depths shallower than maximum NARW foraging depth. Abundant, sufficiently large and energy-rich prey with limited avoidance capabilities to meet NARW biological requirements. A minimum zooplankton energy density threshold for NARWs to feed. Persistent patches of prey that meet daily energy requirements of all life stages of NARWs, such as adult males and resting females (~1500-1900 MJ d^{-1}), pregnant females (~1855-2090 MJ d^{-1}), and including the most energy demanding life stages lactating females (~4120-4233 MJ d^{-1}), and developing juveniles. Dominance of large lipid rich copepods, especially *Calanus* spp. Other zooplankton prey includes smaller copepods with less caloric value per individual (e.g., *Pseudocalanus* spp., *Centropages* spp.) and potentially euphausiids.

Life Stage	Function(s)	Feature(s)	Attributes
All	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Marine environment	Presence of a local or proximate source of prey. Environmental, oceanographic, and bathymetric conditions to supply, support and aggregate high concentrations of prey at depths shallower than maximum NARW foraging depth: upwelling or downwelling zones and localized interactions of ocean currents with coastline or bathymetric features. Environmental, oceanographic, and bathymetric cues for movement and migration.
Male and female juveniles and calves	Rearing/ Nursing/ Socialization	Marine environment	Limited presence or total absence of potential predators including killer whales and white sharks.
All	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Movement/ Migration	Bathymetric features i.e., bank, basin, canyon, continental shelf, continental slope/ ledge, seamount	Bathymetric features to retain and aggregate prey species at depths shallower than maximum NARW foraging depth: localized interactions of ocean currents with coastline or bathymetric features and prey-retaining basins or valleys providing habitat stability. Bathymetric features providing migratory cues (e.g., continental shelf break).
All	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Water column	Chemical, physical, and biological characteristics of the water column to supply, support, and aggregate high concentrations of prey and not result in loss of function. Prey availability at depths shallower than maximum NARW foraging depth. Water depth < 350 m to include recorded maximum NARW dive depth (i.e., 306 m).

Life Stage	Function(s)	Feature(s)	Attributes
All	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Physical space and Corridor	Physical space, including the vertical and horizontal planes of the water column, to allow animals to move freely and unimpeded by physical obstructions and not alter behavioural functions at and below the surface. Habitat connectivity to successfully immigrate, emigrate, and facilitate seasonal movements in and out of known habitats.
All	Foraging/ Feeding Rearing/ Nursing/ SocializationSocial/ Reproduction Movement/ Migration	Acoustic environment	Ambient sound levels ensuring integrity of acoustic space within the 20 Hz – 22 kHz frequency band. Ambient sound levels that allow efficient acoustic social communication and do not impede use of habitat for behavioural functions.
All	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Water quality and Air quality	Suitable chemical, physical, and biological water quality characteristics to sustain prey species. Water and air quality to not cause adverse health effects or result in loss of function.

QUANTITY AND QUALITY OF HABITAT

We are unable to quantify the total amount of habitat necessary for the NARW to complete their annual cycle. Spatiotemporal variation and uncertainty associated with prey and foraging energetics, and composition and density of various available prey, as well as subsequent effects of variability in prey consumption on body condition and vital rates preclude this exercise at this time.

LOOK INTO THE FUTURE: AVAILABILITY OF SUITABLE HABITAT IN CANADA

NARW foraging habitats, and their prey assemblages, are, and will be, vulnerable to ongoing and/or future changes in environmental conditions. Characterizing the processes that drive NARW prey distribution and dynamics is crucial. Variations in environmental conditions and climate change, along with species-specific responses of *Calanus* spp. to these changes, could impact the resilience and suitability of identified potential NARW foraging habitats into the future (Johnson et al. 2024; Plourde et al. 2024). Lehoux et al. (2024) combined SDMs and regional climate ocean simulations models to predict patterns of change in future foraging conditions in eastern Canadian waters (Figure 43).

Temperature increases in both surface and deep Laurentian Channel waters, as well as changes in seasonal sea ice and the timing of the spring bloom could impact *Calanus* spp. in the GSL (Johnson et al. 2024). However, the diversity and variable phenology of *Calanus* spp. in the GSL could buffer the impact of environmental and circulation changes possibly making NARW feeding habitat in the GSL more resilient to climatic changes compared to the *C. finmarchicus* dominated NARW feeding habitats on the SS, BoF and in the northern USA (Johnson et al. 2024; Lehoux et al. 2024).

Results from end-of-century projections, assuming no major changes in oceanographic conditions, ultimately predict a decline of total *Calanus* spp. biomass over the 21st century across eastern Canadian waters (Lehoux et al. 2024). Foraging conditions in the southern range of Canadian habitats are expected to deteriorate at a higher rate than in the northern regions. Specifically, the *Calanus* spp. biomass is predicted to decreases by 60% towards the end of the century (i.e., 2080-2089) compared to the 2000-2009 levels in the BoF, northeast GoM and wSS areas, and by 40%, 35%, and 25% in the GSL, eSS and southern Newfoundland, respectively (Figure 43; Lehoux et al. 2024). Lehoux et al. (2024) caution that these predictions are made assuming only modest changes in environmental conditions and the impact of drastic changes in major habitat features such as the Labrador Current are highly unpredictable but would be assumed to alter NARW habitats.

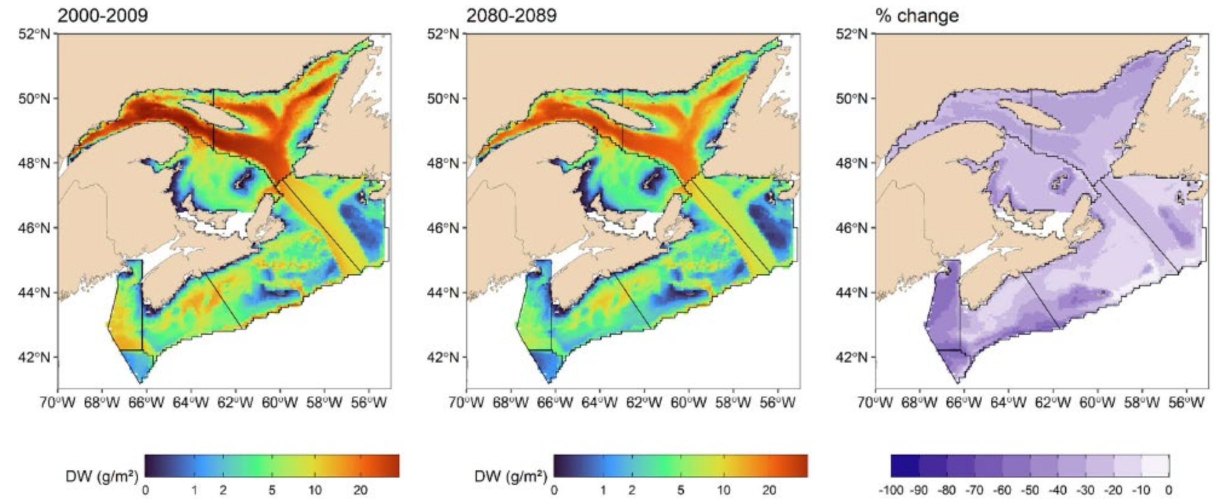

Figure 43: Change in total Calanus predicted biomass between 2080-2089 and 2000-2009 (April-October). Black lines: boundaries of regions used to report results (Lehoux et al. 2024).

ACTIVITIES LIKELY TO DESTROY IMPORTANT HABITATS

The marine environment has changed considerably over the last century largely as a result of industrialization and urbanization. Anthropogenic activities identified herein are not exhaustive but rather examples of activities that could result in NARWs losing functional use of important habitat. These activities include, but are not limited to: fishing activities, vessel traffic, reductions in prey availability or accessibility, as well as acoustic disturbances due to noise pollution, environmental contamination, and physical disturbances (Table 2). The activities described below are consistent with the threats to the species identified in the NARW threats assessment (Vanderlaan et al. *In prep.*[2]).

FISHING ACTIVITIES

Fixed-gear fisheries intrinsically impact the amount of physical space in the water column and corridors, important habitat features, by reducing the amount of unimpeded space for movement, migration, foraging, feeding, gestation, rearing, growth, nursery, socialization, socializing, and reproduction functions. Traditional pot and trap fixed-gear has vertical rope components that connect pots/traps on the sea floor to a surface buoy. Certain fisheries, such as American lobster (*Homarus americanus*), use traps in a trawl configuration requiring ground lines to connect multiple pots or traps, as opposed to some fisheries that use a single trap for every vertical line to a surface buoy.

The fishing landscape across management regions in Canada is complex. During the period of 2021-2023, there was at least one fixed-gear fishery open in every month (DFO unpublished data), however the density of gear throughout Canadian waters varies across space and time. In the GSL during 2018 there were approximately 760 license holders in the snow crab fisheries with a maximum of 150 traps, potentially representing 100,000 traps being fished over the season (Cole et al. 2021). A map of fixed gear landings representative of fishing intensity in

[2] Vanderlaan, A.S.M., Lang, S.L.C., Sanchez, M., Murphy, M.J., Pisano, O.M., Christie, K. Threat Assessment for the Critically Endangered North Atlantic Right Whale (*Eubalaena glacialis*). DFO Can. Sci. Advis. Sec. Res. Doc. In preparation.

eastern Canadian waters for the period 2012-2021, demonstrates the high level of fixed gear fishing throughout several areas where NARWs are known to aggregate or transit through during migration, including wSS, eSS, sGSL, nwGSL, Placentia Bay, and east of St. John's, NL along the shelf break (Vanderlaan et al. *In prep*.[2], Figure 8 in paper). Much of the designated important habitat for NARWs is impeded by fishing activities.

Although there is no existing commercial fishery for zooplankton in eastern Canadian waters, there are fisheries for the commercial harvest of *C. finmarchicus* to supply the aquaculture feed industry in Norway. Grimaldo and Gjøsund (2012) describe trials that reported catch rates of up to two tons dried weight per hour. In the Maritimes Region on the SS, there have been previous proposals for experimental krill fisheries (DFO 1996). Any future proposal for such a fishery in eastern Canadian waters should take into consideration the potential destruction of NARW habitat by reducing prey availability that is required to support the population.

VESSEL TRAFFIC

There is substantial overlap in areas of observed NARW aggregations and high shipping and vessel activity (Vanderlaan et al. 2008); however, some conservation initiatives have reduced co-occurrence in the GMB and RB Critical Habitats (Vanderlaan et al. 2008; Vanderlaan and Taggart 2009). A density mapping study that examined Automatic Identification System (AIS) data from 2019 illustrates the magnitude of traffic in eastern Canada (Veinot et al. 2023). The threat of vessel traffic geographic extent was assessed by Vanderlaan et al. (*In prep*.[2]) as extensive occupying 71-100% of NARW's habitat. Areas into and out of major ports, such as Saint John, New Brunswick (NB) in the BoF, Halifax (NS) on the SS, Belledune in the Chaleur Bay, and the SLE ports, all show high vessel density. There is also significant traffic in the CS, as it is the main entry point into the GSL, and it accommodates a daily ferry route between Cape Breton, NS and NL. The CS is a migratory corridor between the BoF and RB and the sGSL and nwGSL which are now identified as important habitats. The important habitat in sGSL and nwGSL include the Honguedo Strait, another migratory corridor, along which the main commercial shipping channel passes. The other major ports in NL also show high vessel traffic, including into and out of Placentia Bay and St John's, NL, in addition to areas close to shore around the Avalon Peninsula, NL. Although there is limited survey effort and evidence of NARW presence in NL (Lawson et al. 2025), the information presented in this document illustrates the future potential importance of these areas as suitable habitat for NARWs.

Recent dynamic mapping examples have illustrated the issue of shipping and vessel activity reducing available habitat space for movement and foraging. Bedriñana-Romano et al. (2021) published an animation as part of their work that shows a tagged blue whale in Chile dodging ship traffic in a busy area that they utilize for feeding. The National Oceanic and Atmospheric Administration have a similar visualization for NARWs (Figure 44; NOAA 2024b). Vessel traffic could obstruct and limit the space available for NARWs to perform their functional behaviours.

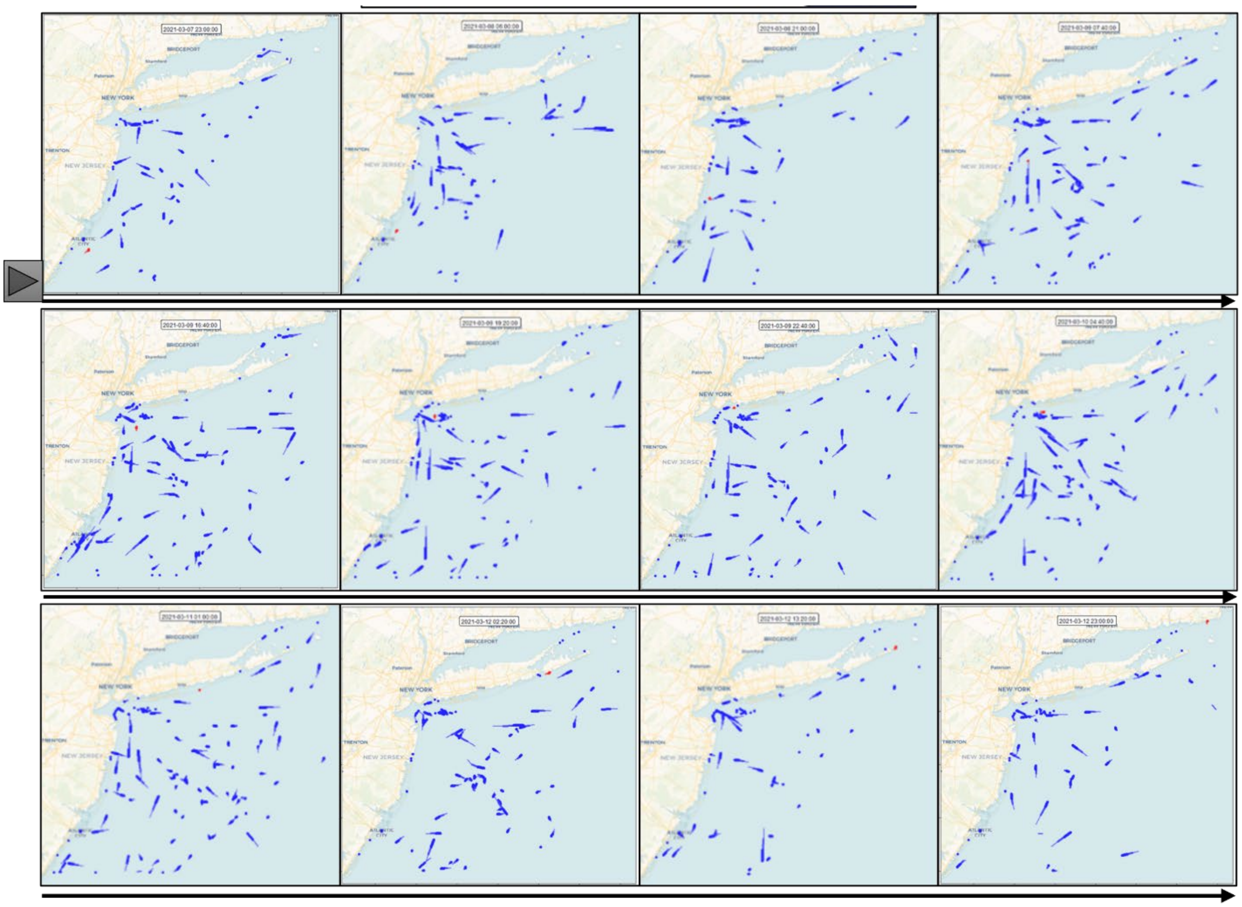

Figure 44: Movements of a telemetry-tagged juvenile North Atlantic right whale (NARW) off the coast of the United States of America in March 2021. Panels are time lapse images from the National Oceanic and Atmospheric Administration NARW visualization video (NOAA 2024b). The NARW (red dot) is initially off the coast of Virginia/North Carolina (top left) travelling north to Massachusetts (bottom right) among heavy vessel (blue streak) traffic moving into and out of a major port.

INTRODUCTION OF UNDERWATER NOISE

NARWs communicate in low frequency ranges that are similar to most coastal anthropogenic noise sources. Noise pollution has been shown to reduce the distance over which the whales can communicate (Hatch et al. 2012; Cholewiak et al. 2018; Matthews and Park 2021), as well as contribute to changes in fundamental frequency, and call amplitude (Parks et al. 2007; Parks et al. 2009; Park et al. 2011b; Parks et al. 2016). Although NARWs may be able to adapt to higher background noise levels, there are physical limitations to compensate for the loss of communication space that is vital to social interactions (Parks and Tyack 2005; Parks et al. 2007; Parks et al. 2011b; Pirotta et al. 2023).

The levels of anthropogenic noise in several environments have been described as persistent and pervasive noisy soundscapes impacting marine life (e.g., Nowacek et al. 2007; Clark et al. 2009; Simard et al. 2010; Aulanier et al. 2016; Gomez et al. 2016). Although there are many anthropogenic sound inputs, according to Marotte and Wright et al. (2022) the top three contributors to anthropogenic noise of concern in Canadian waters are commercial shipping, seismic air guns, and military active sonars. Shipping activity is considered the largest contributor to noise in the urban ocean environment (Simard et al. 2014; Gervaise et al. 2015; Williams et al. 2015). In some areas of the eastern USA seaboard, exposure levels beyond human thresholds defined by the Occupational Safety and Health Administration have been recorded (Park et al. 2007).

Acoustic disturbances can lead to the destruction or avoidance of habitat due to an increase in ambient noise levels; for example, Erbe et al. (2019) found evidence of area avoidance by marine mammals due to high anthropogenic noise. Johnston and Painter (2024) modelled how soundscapes could influence the migration paths of baleen whales by systematically addressing three possible outcomes of higher noise: reduced communication space, reduced goal-targeting information, and increased triggering of an explicit reorientation response. The model predicted the various levels of impact wherein: diminished communication space can lead to greater solitude and slower migration, the loss of information can lead to increased confusion and off-course drifting, and loud noises can lead to a strong noise avoidance to the point that routes become blocked (Johnston and Painter 2024).

In eastern Canadian waters, marine soundscapes have been described in the GSL from the St. Lawrence Seaway into the SLE. Much of this work was related to categorizing the changes and impacts to the endangered SLE beluga (*Delphineptarus leucas*) and the blue whale (*Balaenoptera musculus;* Gervaise et al. 2012; Simard et al. 2014; Aulanier et al. 2016; Lesage 2021). Given their observed distribution in eastern Canada, NARWs would be exposed to the same noisy soundscape as the beluga and blue whales while migrating in the St. Lawrence Seaway as well as moving amongst habitats in the GSL (i.e., nGSL and sGSL). A novel, publicly available tool, the Ocean Soundscape Atlas, was developed to visualize underwater noise in the GSL and into the CS (UQAR 2024; Figure 45). These examples of the interactive maps from the Ocean Soundscape Atlas highlight the differences in the acoustic habitats NARWs frequent to complete vital functions while migrating into and out of the GSL as well as during their residency from April to November.

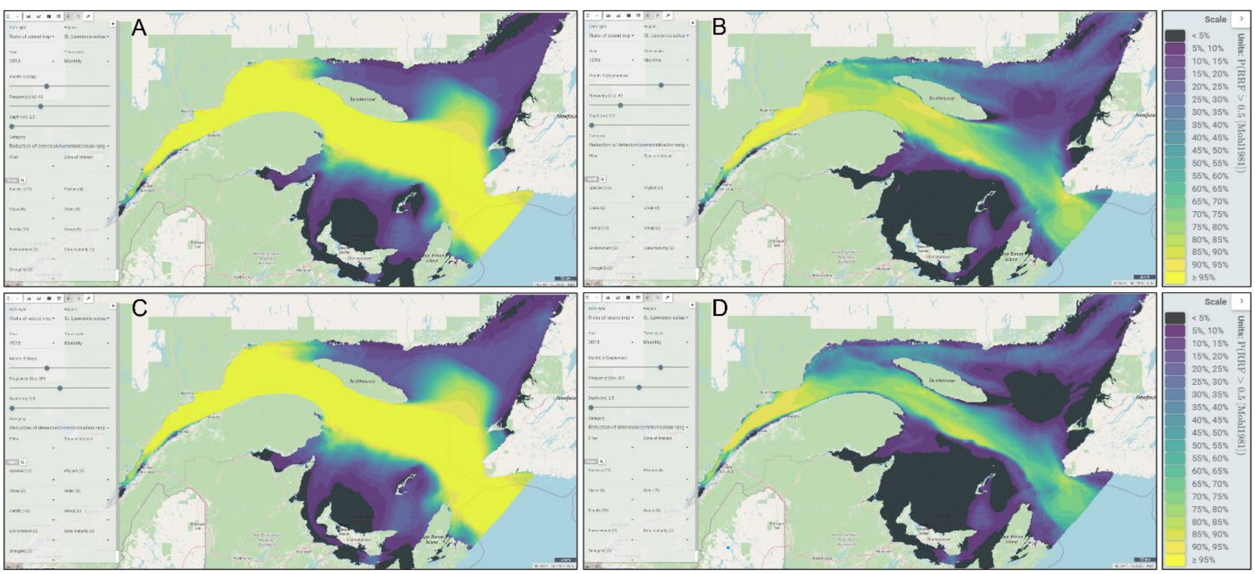

Figure 45: Maps from the [Ocean Soundscape Atlas] depicting the 2018 monthly probability that shipping-noise addition to ambient noise levels halves the sound detection or recognition range (Aulanier et al. *2017; Gervaise* et al. *2012; Møhl 1981; NRC 2003). This probability can be used as a proxy for NARW-upcall masking due to shipping noise. The figures on the left show the variation of the masking proxy during the season of NARW-presence in the GSL in May (A and C) and, on the right, in September (B and D). The upper figures show the variation of the masking proxy across the NARW-upcall band of 63 Hz (A and B) and lower figures of 200 Hz (C and D).*

Model outputs from the Soundscape Atlas demonstrate that, during the early season when NARWs are migrating into the GSL, there is a greater than 95% risk that shipping noise, combined with natural ambient noise, reduces the range of acoustic transmission by half. This risk applies across the whole the Laurentian Chanel and spans the full NARW-upcall frequency band (Figure 45A; May 2018, 63 Hz and Figure 45C; May 2018, 200 Hz). This would indicate an increase in NARW-upcall masking and a reduction of NARW communication space, but also, a decrease in the NARW-detection performances of underwater passive acoustic systems. The model outputs also indicate that during the summer season, the risk that shipping noise halves acoustic transmission ranges becomes lower, especially in the Shediac Valley where most of the NARWs are observed and where the risk drops below 25% across the whole NARW-upcall band (Figure 45B; September 2018, 63 Hz and Figure 45D; September 2018, 200 Hz).

The modelling of underwater acoustic environments, as well as the determination of the lethal and sub-lethal impacts from different noise sources on cetaceans are beyond the scope of this synthesis; however, see Vanderlaan et al. (*In prep*.[2]) for more information on the impacts of various anthropogenic noises on NARWs.

INDUSTRIAL ACTIVITIES

Industrial activities span a diverse range of both land- and marine-based sources, such as production factories, offshore drilling platforms, and waste management facilities. The types of activities conducted by these sources can lead to the input of pollutants into the air and water, which can lead to the destruction of suitable habitat for both NARWs and their prey, and can result in potential long-term negative health effects.

Vanderlaan et al. (*In prep*.[2]) examined a few specific threats to NARWs related to industrial activities. However, they did not examine the effects on NARW prey species, an essential component of important habitat.

Persistent organic pollutants (POPs) deposited in the marine environment can lead to bioaccumulation in the food web, which begins with intake by zooplankton such as the *Calanus* spp. (Hallanger et al. 2011). Microplastics, another form of pollutant resulting from industrial activity, can lead to the destruction of habitat by reducing prey quality and quantity. In a review of available studies, Botterell et al. (2019) summarize the effects of microplastics on prey, which can include obstructed feeding, decreased fecundity, reduced rate of growth and development, and increased mortality rate. The bioaccumulation of pollutants, along with a reduction in the quality of prey, will affect the quality of NARW important habitat and have direct consequences on the whales as well (Desforges et al. 2016).

Prey supply is an important feature of NARW habitat and Johnson et al. (2024), highlight the factors that can lead to low abundance, changes in the timing of the spring bloom, and other negative effects again decreasing the quality of NARW important habitat.

Industrial activity can also lead to destruction of habitat by reducing air quality, which could cause adverse health effects for prey and/or NARWs directly. Again, if prey species are affected by air pollution from industrial activities the quality of the NARW important habitat could also be impacted. It is important to note the sources of water and air pollution from industrial activities could be quite far away from NARW important habitat due to the nature of water and airborne pollutants.

WIND ENERGY DEVELOPMENT AND PRODUCTION

Wind energy production via wind farms is a new and emerging threat to NARWs. Although there are currently no offshore wind farms in eastern Canadian waters, both NS and NL launched regional assessments in collaboration with the federal government in early 2023 for their potential development (information available on the Impact Assessment Agency of Canada web portal). The importance of this activity in eastern Canadian waters is likely to increase considerably in the coming years as the climate and energy crises fuel demand for more renewable energy sources. There are already a few small-scale American wind farms that are operational, including two off southern New England, with several other projects on the horizon.

Vanderlaan et al. (*In prep.*[2]) assessed the threat risk levels related to the operational phase of wind energy production as unknown. However, wind farm construction and operation will contribute to acoustic noise pollution which will have effects on NARW important habitat.

The range of wind farm activities differ between the construction phase and the operation phase. During the construction phase, the main activities likely to destroy habitat are pile driving (noise pollution) and vessel traffic (Bailey et al. 2014). During the operation phase, vessel traffic will continue, along with some acoustic disturbance related to the operation of wind turbines and the generation of electromagnetic fields around transmitting cables. Although there is limited information regarding how these latter activities could destroy habitat, Tricas and Gill (2011) presented evidence that migration behaviour could be affected due to magneto-sensitivity of cetacean species.

Wind farm activity could also potentially lead to the alteration of habitat by changing prey distribution and availability, thereby affecting habitat quality. Similar to the prey effects referenced above with changing ocean circulations, offshore wind infrastructure could change the mixing of stratified waters, as well as impact local shelf sea dynamics (Dorrell et al. 2022). More research is required to fully understand the impacts to physical and ocean processes in the proposed areas for wind farms. Many of these gaps are highlighted in the National Academies of Sciences Engineering and Medicine (2023) report for the Nantucket Shoals region.

Table 2: Examples of activities that have, or have the potential to, affect functions, features, or attributes of habitats important to North Atlantic right whales (NARWs) through an established or anticipated Pathway of Effect (PoE). The PoE describes, if possible, how an activity is likely to destroy the habitat (Brownscombe and Smokorowski 2021). A comprehensive list of activities and associated threat were identified and assessed in the NARW threat assessment (Vanderlaan et al. *In prep.*[2]*).*

Activity	Threat	Anticipated (A) or Established (E) Pathway of Effect	Function(s) Affected	Feature(s) Affected	Attribute(s) Affected
Fishing activity e.g., use of bottom-contact fixed fishing gear with associated vertical and/or groundline rope	Fishery interaction(s)	Reduction in space to complete movement (E)	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Physical space Corridor	Physical space, including the vertical and horizontal planes of the water column, to allow animals to move freely and unimpeded by physical obstructions and not alter behavioural functions at and below the surface. Habitat connectivity to successfully immigrate, emigrate, and facilitate seasonal movements in and out of known habitats.
Fishing activity e.g., plankton harvesting	Food supply reduction (direct)	Reduction in abundance and availability of prey (A)	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing Social/ Reproduction Movement/ Migration	Marine environment Prey supply	Presence of a local or proximate source of prey. Prey availability at depths shallower than maximum NARW foraging depth. Abundant, sufficiently large and energy-rich prey with limited avoidance capabilities to meet NARW biological requirements. A minimum zooplankton energy density threshold for NARWs to feed. Persistent patches of prey that meet daily energy requirements of all life stages of NARWs, such as adult males and resting females (~1500-1900 MJ d^{-1}), pregnant females (~1855-2090 MJ d^{-1}), and including the most energy demanding life stages lactating females (~4120-4233 MJ d^{-1}), and developing juveniles. Dominance of large lipid rich copepods, especially *Calanus* spp. Other zooplankton prey includes smaller copepods with less caloric value per individual (e.g., *Pseudocalanus* spp., *Centropages* spp.) and potentially euphausiids.

Activity	Threat	Anticipated (A) or Established (E) Pathway of Effect	Function(s) Affected	Feature(s) Affected	Attribute(s) Affected
Vessel traffic in the marine environment e.g., shipping vessels, fishing vessels, cruise ships, whale watching vessels, ferries, offshore energy sector maintenance vessels, and supply vessels	Vessel presence	Reduction in space to complete movement (E)	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Physical space Corridor	Physical space, including the vertical and horizontal planes of the water column, to allow animals to move freely and unimpeded by physical obstructions and not alter behavioural functions at and below the surface. Habitat connectivity to successfully immigrate, emigrate, and facilitate seasonal movements in and out of known habitats.
Vessel traffic in the marine environment e.g., shipping vessels, fishing vessels, cruise ships, whale watching vessels, ferries, offshore energy sector maintenance vessels, and supply vessels	Vessel noise pollution	Reduction in communication space (E) e.g., masking, avoidance	Foraging/ Feeding Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Acoustic environment	Ambient sound levels ensuring integrity of acoustic space within the 20 Hz – 22 kHz frequency band. Ambient sound levels that allow efficient acoustic social communication and do not impede use of habitat for behavioural functions.
Introduction of underwater noise e.g., seismic surveys using airgun arrays, low and mid-frequency sonars, pile driving, production drilling	Noise pollution	Reduction in communication space (E) e.g., masking, avoidance	Foraging/ Feeding Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Acoustic environment	Ambient sound levels ensuring integrity of acoustic space within the 20 Hz – 22 kHz frequency band. Ambient sound levels that allow efficient acoustic social communication and do not impede use of habitat for behavioural functions.

Activity	Threat	Anticipated (A) or Established (E) Pathway of Effect	Function(s) Affected	Feature(s) Affected	Attribute(s) Affected
Introduction of underwater noise e.g., seismic surveys using airgun arrays, low and mid-frequency sonars, pile driving, production drilling	Noise pollution	Reduction in space to complete movement (A) i.e., avoidance, habitat connectivity	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Physical space Corridor	Physical space, including the vertical and horizontal planes of the water column, to allow animals to move freely and unimpeded by physical obstructions and not alter behavioural functions at and below the surface. Habitat connectivity to successfully immigrate, emigrate, and facilitate seasonal movements in and out of known habitats.
Industrial activities e.g., ocean dumping, industrial development and operation, vessel discharge	Chemical contaminants e.g., heavy metal pollution, persistent organic pollutant pollution, petroleum spills, plastic and marine debris pollution	Reduction in environmental quality (E)	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Marine environment Prey supply Water quality Air quality	Presence of a local or proximate source of prey. Abundant, sufficiently large and energy-rich prey with limited avoidance capabilities to meet NARW biological requirements. A minimum zooplankton energy density threshold for NARWs to feed. Persistent patches of prey that meet daily energy requirements of all life stages of NARWs, such as adult males and resting females (~1500-1900 MJ d^{-1}), pregnant females (~1855-2090 MJ d^{-1}), and including the most energy demanding life stages lactating females (~4120-4233 MJ d^{-1}), and developing juveniles. Dominance of large lipid rich copepods, especially *Calanus* spp. Other zooplankton prey includes smaller copepods with less caloric value per individual (e.g., *Pseudocalanus* spp., *Centropages* spp.) and potentially euphausiids. Suitable chemical, physical, and biological water quality characteristics to sustain prey species. Water and air quality to not cause adverse health effects or result in loss of function.

Activity	Threat	Anticipated (A) or Established (E) Pathway of Effect	Function(s) Affected	Feature(s) Affected	Attribute(s) Affected
Industrial activities e.g., ocean dumping, industrial development and operation, vessel discharge	Chemical contaminants e.g., heavy metal pollution, persistent organic pollutant pollution, petroleum spills, plastic and marine debris pollution	Reduction in space to complete movement (A) e.g., avoidance	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Physical space Corridor	Physical space, including the vertical and horizontal planes of the water column, to allow animals to move freely and unimpeded by physical obstructions and not alter behavioural functions at and below the surface. Habitat connectivity to successfully immigrate, emigrate, and facilitate seasonal movements in and out of known habitats.
Energy development and production e.g., development of offshore wind farms	Coastal and marine offshore development i.e., construction of industrial platforms	Reduction in environmental quality (E) e.g., disruption of localized ocean properties, changes to food supply	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Marine environment Bathymetric features Prey supply Water column Water quality Air quality	Presence of a local or proximate source of prey. Environmental, oceanographic, and bathymetric conditions to supply, support and aggregate high concentrations of prey at depths shallower than maximum NARW foraging depth: upwelling or downwelling zones and localized interactions of ocean currents with coastline or bathymetric features. Environmental, oceanographic, and bathymetric cues for movement and migration. Bathymetric features to retain and aggregate prey species at depths shallower than maximum NARW foraging depth: localized interactions of ocean currents with coastline or bathymetric features and prey-retaining basins or valleys providing habitat stability. Prey availability at depths shallower than maximum NARW foraging depth.

Activity	Threat	Anticipated (A) or Established (E) Pathway of Effect	Function(s) Affected	Feature(s) Affected	Attribute(s) Affected
					Abundant, sufficiently large and energy-rich prey with limited avoidance capabilities to meet NARW biological requirements. A minimum zooplankton energy density threshold for NARWs to feed. Persistent patches of prey that meet daily energy requirements of all life stages of NARWs, such as adult males and resting females (~1500-1900 MJ d^{-1}), pregnant females (~1855-2090 MJ d^{-1}), and including the most energy demanding life stages lactating females (~4120-4233 MJ d^{-1}), and developing juveniles. Dominance of large lipid rich copepods, especially *Calanus* spp. Other zooplankton prey includes smaller copepods with less caloric value per individual (e.g., *Pseudocalanus* spp., *Centropages* spp.) and potentially euphausiids. Chemical, physical, and biological characteristics of the water column to supply, support, and aggregate high concentrations of prey and not result in loss of function. Water depth < 350 m to include recorded maximum NARW dive depth (i.e., 306 m). Suitable chemical, physical, and biological water quality characteristics to sustain prey species. Water and air quality to not cause adverse health effects or result in loss of function.

Activity	Threat	Anticipated (A) or Established (E) Pathway of Effect	Function(s) Affected	Feature(s) Affected	Attribute(s) Affected
Energy development and production e.g., development of offshore wind farms, oil and gas platforms	Coastal and marine offshore development i.e., construction of industrial platforms	Reduction in space to complete movement (E)	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Physical space Corridor	Physical space, including the vertical and horizontal planes of the water column, to allow animals to move freely and unimpeded by physical obstructions and not alter behavioural functions at and below the surface. Habitat connectivity to successfully immigrate, emigrate, and facilitate seasonal movements in and out of known habitats.
Energy development and production e.g., operation and maintenance of offshore wind farms, petroleum drilling	Coastal and marine offshore energy production i.e., operation and maintenance	Reduction in environmental quality (A) e.g., disruption of localized ocean properties, changes to food supply	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Marine environment Bathymetric features Prey supply Water Column Water quality Air quality	Presence of a local or proximate source of prey. Environmental, oceanographic, and bathymetric conditions to supply, support and aggregate high concentrations of prey at depths shallower than maximum NARW foraging depth: upwelling or downwelling zones and localized interactions of ocean currents with coastline or bathymetric features. Environmental, oceanographic, and bathymetric cues for movement and migration. Bathymetric features to retain and aggregate prey species at depths shallower than maximum NARW foraging depth: localized interactions of ocean currents with coastline or bathymetric features and prey-retaining basins or valleys providing habitat stability. Prey availability at depths shallower than maximum NARW foraging depth. Abundant, sufficiently large and energy-rich prey with limited avoidance capabilities to meet NARW biological requirements. A minimum zooplankton energy density threshold for NARWs to feed.

Activity	Threat	Anticipated (A) or Established (E) Pathway of Effect	Function(s) Affected	Feature(s) Affected	Attribute(s) Affected
					Persistent patches of prey that meet daily energy requirements of all life stages of NARWs, such as adult males and resting females (~1500-1900 MJ d^{-1}), pregnant females (~1855-2090 MJ d^{-1}), and including the most energy demanding life stages lactating females (~4120-4233 MJ d^{-1}), and developing juveniles. Dominance of large lipid rich copepods, especially *Calanus* spp. Other zooplankton prey include smaller copepods with less caloric value per individual (e.g., *Pseudocalanus* spp., *Centropages* spp.) and potentially euphausiids. Chemical, physical, and biological characteristics of the water column to supply, support, and aggregate high concentrations of prey and not result in loss of function. Water depth < 350 m to include recorded maximum NARW dive depth (i.e., 306 m). Suitable chemical, physical, and biological water quality characteristics to sustain prey species. Water and air quality to not cause adverse health effects or result in loss of function.
Energy development and production e.g., development of offshore wind farms, oil and gas platforms, operation and maintenance of offshore wind farms, petroleum drilling	Noise pollution	Reduction in communication space (E) e.g., masking	Foraging/ Feeding Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Acoustic environment	Ambient sound levels ensuring integrity of acoustic space within the 20 Hz – 22 kHz frequency band. Ambient sound levels that allow efficient acoustic social communication and do not impede use of habitat for behavioural functions.

Activity	Threat	Anticipated (A) or Established (E) Pathway of Effect	Function(s) Affected	Feature(s) Affected	Attribute(s) Affected
Energy development and production e.g., development of offshore wind farms, oil and gas platforms, operation and maintenance of offshore wind farms, petroleum drilling	Noise pollution	Reduction in space to complete movement (A) i.e., avoidance	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Physical space Corridor	Physical space, including the vertical and horizontal planes of the water column, to allow animals to move freely and unimpeded by physical obstructions and not alter behavioural functions at and below the surface. Habitat connectivity to successfully immigrate, emigrate, and facilitate seasonal movements in and out of known habitats.

SUMMARY AND CONCLUSIONS

NARWs utilize many eastern Canadian habitats to forage, feed, rear offspring, socialize, mate, and migrate. The disruption of the important environmental features and attributes that support these vital functions, either through localized circulation variability, anthropogenic activities, or large-scale climate change, may result in the reduction or removal of suitable habitats, forcing NARWs to seek other optimal habitats. NARW distribution shifts have been documented over the last four decades in the Northwest Atlantic where NARWs passed over known high-use foraging grounds in certain years (Meyer-Gutbrod et al. 2023). The influence of cultural inheritance on NARW distribution could explain the persistence of NARWs in habitats categorized as sub-optimal or presumed abandoned, as well as recent observations in historical NARW habitats in eastern Canada (Carroll et al. 2015; Lawson et al. 2025; Moors-Murphy et al. 2025). A contemporary example is the continued NARW occupation of the BoF habitat, a known traditional feeding habitat and designated critical habitat, even during relatively sub-optimal conditions (Davies et al. 2015; Sorochan et al. 2019; Plourde et al. 2024; Moors-Murphy et al. 2025). As such, identifying the extent of important habitat should consider both the historical and contemporary observed variability in NARW occurrence in high-use areas (Mayo et al. 2018; Davies et al. 2019; Charif et al. 2020). All of these factors highlight the importance of supplementing the existing critical habitats for NARWs rather than removing them due to perceived habitat abandonment when regional and/or local conditions do not meet NARWs needs at that time.

The GoC has expanded its research, monitoring, and funding programs for the critically endangered NARW, advancing our knowledge through systemic aerial surveys, passive acoustics, habitat studies, and prey studies, among others. The data collected from these and other efforts were synthesized to evaluate the relative importance of various areas in Canadian waters for the NARW. Given the evidence provided above, areas were identified as important NARW habitat supporting the functions of movement, foraging and feeding, gestation, rearing, nursing, socialization, and socializing and reproduction, as well as migratory corridors.

Important habitats within eastern Canadian waters supporting the aforementioned critical biological functions include:

- BoF, wSS, the GoM, the northeast tip of GB, and the SS, particularly the Emerald Basin area;
- CS;
- nwGSL including the Jacques Cartier Strait and the Honguedo Strait, the Laurentian channel Strait in the neGSL and sGSL, particularly the swGSL.

Potential feeding habitats within eastern Canadian waters to support the foraging function includes:

- northeast of Anticosti Island;
- North / eastern coastal and offshore NL including the Flemish Cap and the southern edge of the Grand Banks

Changes in NARW occurrence, phenology and distribution are thought to be heavily influenced by prey abundance on the continental shelf and its environmental drivers (Woodley and Gaskin 1996; Baumgartner et al. 2003a; Jiang et al. 2007; Pendleton et al. 2009; Michaud and Taggart 2011; Davies et al. 2015; Le Corre et al. 2023; Ross et al. 2023; Johnson et al. 2024). Climate forcing, including anthropogenic climate change, influences the physical and biological oceanographic conditions on western North Atlantic shelves (Greene et al. 2013; Gonçalves

Neto et al. 2021; Lehmann et al. 2023; Mills et al. 2024) where NARWs feed (Sorochan et al. 2021a). Climate change has, and is projected to, affect prey population levels on NARW foraging grounds (Grieve et al. 2017; Record et al. 2019; Pershing and Stamiezkin 2020; Meyer-Gutbrod et al. 2021; Ross et al. 2021; Lehoux et al. 2024) with subsequent and potential impacts on the distribution, health, and calf production of NARWs (Meyer-Gutbrod et al. 2015; Rolland et al. 2016; Pirotta et al. 2023). Further environmental change resulting in the disruption of the important environmental features and attributes described here may result in the reduction of prey population levels on the SS and in the GSL (Lehoux et al. 2024). In response, NARWs may seek food elsewhere such as the identified potential feeding habitats north of Anticosti Island, in the Flemish Cap, and on parts of the Newfoundland Shelf.

AREAS OF FUTURE RESEARCH

Areas of research and monitoring that would further our understanding of whether habitat areas identified in eastern Canadian waters are sufficient for NARW recovery are included in the individual research documents provide by: Plourde et al. (2024), Johnson et al. (2024), and Lehoux et al. (2024) for prey and foraging ecology gaps; St-Pierre et al. (2024), Mosnier et al. 2025b, Simard et al. (2024), Moors-Murphy et al. (2025), and Lawson et al. (2025) for abundance, distribution, and seasonal occupancy gaps; and by Vanderlaan et al. (*In prep*.[2]) and Moore et al. (2021) for gaps in our understanding of threats to- and health impacts on NARWs. Further research in many disciplines could also provide quantitative, area-specific, values for the attributes of important habitat identified. Specific studies, grouped by research category, are summarized below; however, these do not represent the full scope of NARW research questions within the scientific community.

Prey / Foraging Ecology

A more complete understanding of the factors influencing regional *Calanus spp*. distribution, abundance, and aggregation sufficient for NARW feeding, is needed in order to reduce uncertainty in the predictions of interannual variability for important foraging habitat for NARWs. Johnson et al. (2024) highlight the need for more data collection in upstream areas of the sGSL, where abundance and spatial distribution estimates are currently made seasonally at a relatively low spatial resolution. Increasing spatiotemporal resolution of sampling stations would allow *Calanus* spp. phenology and diapause timing observations and help to better understand zooplankton dynamics. The authors also identify that there is a greater risk to sGSL foraging habitat from advective supply in spring compared to summer, and that effects of changes in upstream water column density structure on circulation and transport of *Calanus* spp. into the sGSL have not yet been assessed.

Another element of prey aggregation that could be explored is whether aggregations form at surface circulation features, such as salinity-driven fronts that are common in the Shediac Valley in spring and summer (Johnson et al. 2024). Further to this, is the question of whether NARWs in the sGSL focus their feeding efforts on predictable prey aggregations or feed more opportunistically on transient features.

Climate change and rising ocean temperatures have resulted in rapidly changing environmental conditions, such as increasing sea surface temperatures, and changes in seasonal ice dynamics and the timing of the spring bloom. More research is needed to better understand what effects these changes will have on *Calanus* spp. populations (Johnson et al. 2024).

Plourde et al. (2024) highlighted the need for more targeted survey efforts in newly identified potential foraging habitats to validate developed models and monitor their predictions:

- January through March: wGSL, Labrador, sNL, neGB, sGB, Flemish Cap;

- April through June: Northeast Channel, coastal Cape Breton, eSS, sGB, offshore eNL;
- July through September: Northeast Channel, wSS, inner shelf near coast in wNL and Lab;
- October through December: wGSL, southern eNL, northeast slope GB, Flemish Cap.

Both Plourde et al. (2024) and Lehoux et al. (2024) indicate the need for prey survey and model design methodology that accounts for the uncertainty in species identification of *C. finmarchicus* and *C. glacialis* due to the overlap in prosome length. Additionally, future prey field work is needed to describe the distribution of *C. finmarchicus* on the shelf in eNL and Labrador, due to a lack of taxonomic resolution with *C. glacialis* in previously collected data. Future studies aimed at developing long-term projections of *Calanus* spp., as was done by Lehoux et al. (2024), would benefit from greater knowledge of ocean circulation in off-shelf boundary conditions, and transport pathways between source regions (wGSL, eGSL) and the sGSL (Plourde et al. 2024).

Abundance and Distribution

St-Pierre et al. (2024) underscore the importance of having multiple sources of data, such as acoustic detections and sightings data, both survey based and opportunistic sightings, to strengthen abundance and distribution estimates. This should continue to be considered in the survey design phase of future assessments. The authors also state that PAM and survey planning should be coupled with habitat modelling to identify geographic areas with suitable NARW habitat that could be targeted during survey efforts. Statistical methodologies that would allow the combination of acoustic detections and visual sightings to build species distributions models and habitat suitability models require development; however, promising advancements in combining various types of data and model validations are underway (cf. Watson et al. 2021; Roberts et al. 2024).

Habitat modelling can be an effective way to focus monitoring and mitigation efforts. Mosnier et al. (2025b) used available information to predict spatiotemporal locations of important habitats, but highlighted the need for increased surveillance and data collection in early spring and late autumn when there has typically been less dedicated survey effort. Additionally, they suggested that water depth should be explored further as an environmental variable given their reported results.

Passive Acoustic Monitoring and Analyses

Although there have been fewer NARW sightings in and around Newfoundland compared to other emerging habitats in Canada, the body of work related to the Recovery Potential Assessment of NARWs indicates that it is likely to become increasingly important in future years. Lawson et al. (2025) have been refining and testing their Low Frequency Detection and Classification System (LFDCS) call library with specific exemplars from Newfoundland. Nevertheless, they have raised the need to continue to improve the performance of the library by examining the varying geographic characteristics of NARW upcalls.

Across all three of the regional acoustic reviews (Simard et al. 2024; Lawson et al. 2025; Moors-Murphy et al. 2025), there is a clear need for additional acoustic monitoring in the following areas:

- NL (Lawson et al. 2025): Northern Labrador as a migration corridor (particularly given detections from southeastern Greenland), Flemish Cap and Flemish Pass, tail of the Grand Banks, north-side of Cabot Strait (closer spacing to determine whether calls are missed or animals are not calling, given relatively short detection distances for upcalls [5-15 km]); more coverage of Newfoundland waters in projected suitable habitat;

- Maritimes (Moors-Murphy et al. 2025): areas adjacent to critical habitats, coast waters around Nova Scotia, eastern Scotian Shelf, and broader coverage of the Cabot Strait;
- GSL (Simard et al. 2024): northeast Anticosti Island, neGSL, Strait of Belle Isle.

Echoing areas of research identified in the abundance and distribution section above, Moors-Murphy et al. (2025) call for a renewal of visual survey efforts in historically important habitat areas to complement future PAM. This includes the areas of designated RB and GMB Critical Habitats, as well as in late autumn in other areas of the BoF.

Given that the exact timing of spring and autumn migrations via the Cabot Strait still remains largely uncertain despite the deployment of PAM recorders in this area, Moors-Murphy et al. (2025) suggest that the detection range of upcalls may be reduced in this area. Future studies should focus on conducting a thorough assessment of ambient and anthropogenic noise levels, along with detection range modelling, in this and other areas. This would help to elucidate timing for visual and acoustic surveys in this area in the future.

Threats

In the threat assessment completed by Vanderlaan et al. (*In prep*.[2]), a number of the threats that would impact NARW important habitat were assessed as "Unknown" due to gaps in information about the population level of consequences of these threats to NARWs. Furthermore, many of the threats intersect with one another and the cumulative effects of the threats were not assessed for NARWs (Vanderlaan et al. *In prep*.[2]) or their important habitat. As such, these would be important areas of future research.

Health

Moore et al. (2021; their Table 3), summarized the information required to further assess and research NARW health and recovery. Some are particularly relevant for the determination of important habitat in Canada, including an increase in survey efforts and photo identification imagery in important habitat; a better understanding of various acoustic traumas and whether or not these are reducing available habitat; establishing energetic models that involve prey that could be used to assess the quality of various habitats, and analyzing surface active group prevalence and calf presence by habitat.

While already addressed by many of the associated working papers, the importance of studies in potential areas of wind farm development in offshore Canadian waters in the short to medium-term cannot be understated. Europe and the USA have accrued a great deal of experience and research with regards to wind farm development and operation, Canada can draw upon a vast quantity of emerging recommendations and studies to inform the design and implementation of targeted studies in important habitat areas with potential for wind energy development. The publication by the National Academies of Sciences Engineering and Medicine (2023) commissioned by the US Bureau of Ocean Energy Management (BOEM) includes a number of relevant recommendations for planned studies, including:

- observational studies during all phases of wind energy development to isolate, quantify, and characterize hydrodynamic effects;
- collection of oceanographic and ecological data during all phases of development to quantify effects on prey;
- PAM during all phases of wind energy development to characterize changes in habitat use.

There has been considerable investment into NARW research in Canadian waters by the GoC, especially since the last Recovery Strategy for NARWs was developed (DFO 2014). This document is a synthesis of some of that research and was used to identify a large contiguous area as important habitat for NARWs. Further studies could refine these areas and predict future habitats to support the survival and recovery of NARWs.

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We would like to further express our deepest gratitude to Dr. Stephane Plourde, whose dedication and insightful contributions significantly advanced our understanding of North Atlantic right whale prey ecology. Stephane's passing in March 2025 is a profound loss to the scientific community. We honor his memory, and his work will continue to inspire and guide our research.

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APPENDIX 1. SPECIES AT RISK PROGRAM TERMINOLOGY

The terms used in this document are listed with definitions as provided by the Species at Risk Program internal guidelines consistent with the guiding principles provided in the Directive on the Identification of critical habitat for Aquatic Species at Risk (DFO 2015). These internal guidelines support the Science sector in the development of advice on habitat necessary for the survival or recovery of species at risk.

Table A1.1: Life Cycle Functions terms and definitions.

Term	**Definition of term**
Gestation function	The period of development during the carrying of an embryo, and later fetus, inside viviparous and ovoviviparous species
Growth function	The process of increasing in physical size
Maturation function	The process of becoming a mature adult
Foraging behaviour	A series of actions that individuals take to search for food (locating and obtaining) as well as the subsequent consumption
Feeding function	The act of consuming food
Foraging function	The act of searching for food
Movement function	A change in location made by an individual
Exploration function	Movement directed towards acquiring information about the environment
Mating function	The pairing of a male and female for the purpose of reproduction
Migration function	The regular, often cyclical, movement of a significant proportion of a population (or species) from one location to another that is prompted by factors such as changes in environmental conditions, resource availability, reproductive requirements, or the search for more suitable habitats
Nursing function	A female marine mammal feeding her young with milk
Rearing function	Supporting offspring development to maturity or self-sufficiency
Reproduction function	The process by which an organism produces (sexually or asexually) an offspring that is biologically similar to the parent organism
Resting function	A bodily state characterized by minimal functional and metabolic activities
Socialization function	Developmental processes through which individuals learn necessary behaviours such as foraging, migration, and communication
Socializing function	The action of interacting with others for the purpose of companionship

Table A1.2: Features supporting Life Cycle Functions.

Term	Definition of term
Acoustic environment	The combination of all the acoustic sources, natural and artificial, within a given area
Bank	A submerged elevation of the seafloor with a summit less than 200 m below the surface but not so high as to endanger navigation
Basin	A depression, or dip, on the seafloor, river bottom, lake bottom, etc. Typically oval or circular in shape, with sides higher than the bottom
Canyon	A narrow steep-sided valley that cuts into a continental slope or continental rise in the ocean
Continental shelf waters	Marine waters above the edge of a continent
Continental slope waters	Marine waters above the outer edge of the continental shelf and the adjacent deep ocean
Corridor	Area of habitat through which animals tend to preferentially migrate or move
Ledge	A drop-off where the depth of the bottom goes from shallow to deep in a short distance
Marine environment	Habitats distinguished by waters that have a high salt content (for example, oceans, seas, bays) seaward of the mean high-water mark.
Nursery	A habitat that enhances the growth and survival of juveniles
Physical space	Area of habitat through which animals can freely move
Prey	The availability of food sources
Seamount	Independent features that rise to at least 1000 m above the seafloor, characteristically of conical form, and do not reach the water surface
Water column	The vertical section of water from the surface to the bottom of the water body
Water quality	The condition of the water, including chemical, physical, and biological characteristics, usually with respect to its suitability for a particular purpose

APPENDIX 2. DEFINING NARW AREAS OF EASTERN CANADA

The NARWC sighting database only divided Canadian sightings into regions and area codes using crude boundaries meant to capture general areas and lacked definition north of eSS, e.g., identified as GSL or north (Figure A2(1) inset). A number of new Canadian areas were created and defined using a method that would allow modification of NARWC areas and integration into the existing NARWC databases (Figure A2.1; Table A2.1). The boundaries are defined using non-diagonal lines due to the current technological constraints of the NARWC databases. For this process, boundaries of the study areas along the shelf break generally follow the contour just beyond the 500 m isobath. The sGSL area was defined on the northern edge based on the 200 m isobath.

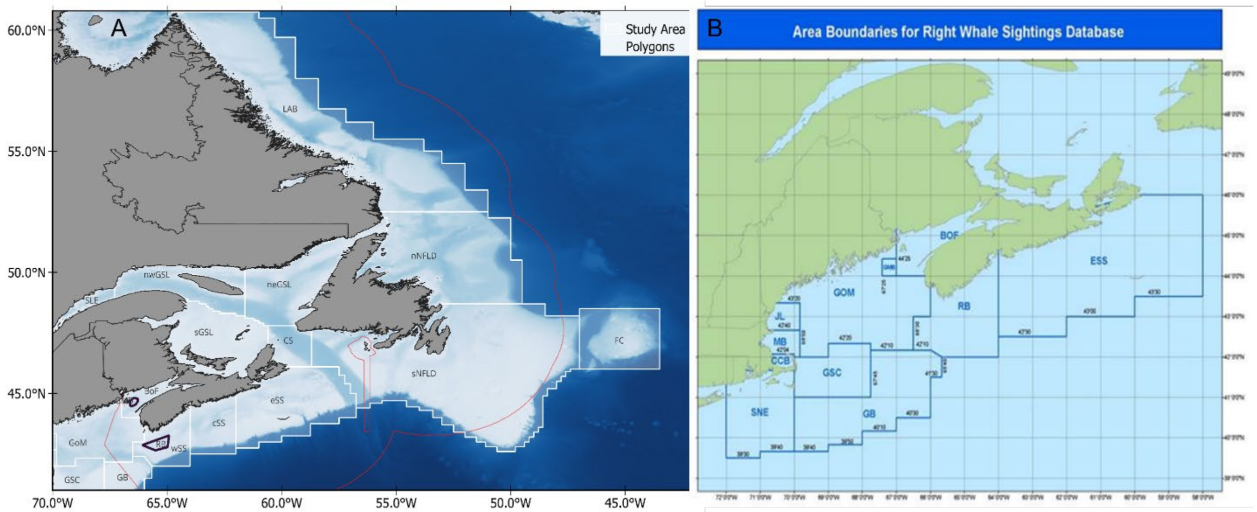

Figure A2.1: North Atlantic right whale (NARW) Canadian habitat areas expanded (A) from North Atlantic Right Whale Consortium established area boundaries in the NARW Sightings / Identification databases (B). NOTE: Within the NARW Consortium (NARWC) NARW Identification Database (B), sightings in northern Canadian extent were labelled as east and/or north (EAST/NRTH) or Gulf of St. Lawrence (GSL).

Table A2.1: Description of Canadian habitat geographic areas used herein with reference to existing North Atlantic right whale Consortium (NARWC) database areas.

Eastern Canadian Areas	Name	NARWC Area (reference)	Comment
BoF	Bay of Fundy	BoF	Entire BoF including Grand Manan Basin Critical Habitat
RB	Roseway Basin (Critical Habitat)	RB	NEW: RB Critical Habitat defined. Entire western Scotian Shelf (wSS) previously referred to as Roseway Basin
wSS	western Scotian Self	RB	NEW: wSS referred to as RB in the NARWC database area including the RB Critical Habitat area
cSS	central Scotian Shelf	cSS	NEW: Split eSS into two regions (cSS and eSS) based on available NARW data; can be combined to equal NEAQ eSS
eSS	eastern Scotian Shelf	eSS	NEW: eSS outer boundary further defined based on SS edge; can be combined to equal NEAQ eSS
GB - CAN	George's Bank	GB	Portion of GB within Canadian EEZ
GOM - CAN	Gulf of Maine	GOM/GMB	Portion of GB within Canadian EEZ. GMB was removed and is now just part of GOM
CS	Cabot Strait	GSL	NEW sub area created
neGSL	northeast Gulf of St. Lawrence	GSL	NEW sub area created
nwGSL	northwest Gulf of St. Lawrence	GSL	NEW sub area created
sGSL	southern Gulf of St. Lawrence	GSL	NEW sub area created
SLE	St. Lawrence Estuary	GSL	NEW sub area created
sNFLD	southern Newfoundland	EAST/NRTH	NEW sub area created
nNFLD	northern Newfoundland	NRTH	NEW sub area created
FC	Flemish Cap	NRTH	NEW sub area created
LAB	Labrador	NRTH	NEW sub area created

APPENDIX 3. FUNCTION, FEATURES, AND ATTRIBUTES: SUPPLEMENTAL INFORMATION

Table A3.1: Detailed habitat characteristics and unique feature attributes of Canadian areas associated with North Atlantic right whales (NARWs), as documented in published literature. This appendix table provides expanded insight and supporting references beyond the general habitat features and attributes summarized in Table 1. 'All' life stages include: Adult females and males, juveniles and calves.

Life Stage(s)	Function(s)	Feature(s)	Location	Attributes	Citation(s)
All	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing Social/ Reproduction Movement/ Migration	Prey supply	Eastern Canadian habitats	[1,2,3,7,11,23,25,26] Abundant, sufficiently large and energy-rich prey with limited avoidance capabilities to meet NARW biological requirements. [2,3,5,8,9,10,15,20,22,27] Biophysical prey concentrating mechanisms: zooplankton movement (swimming, sinking, floating) and prey aggregations at depths shallower than maximum NARW foraging depth. [4,14,17,19,20,24,26,27] Minimum zooplankton density threshold to meet daily energy needs regardless of type of the *Calanus* spp. consumed or variations in their energy content or quality. [13,18,21] Persistent patches of prey that meet daily energy requirements of all life stages of NARWs, such as adult males and resting females (~1500-1900 MJ d^{-1}), pregnant females (~1855-2090 MJ d^{-1}), and including the most energy demanding life stages lactating females (~4120-4233 MJ d^{-1}), and developing juveniles. [1,3,6,9,12,16,20,23] Dominance of large lipid rich copepods, especially *Calanus* spp. Other zooplankton prey includes smaller copepods with less caloric value per individual (e.g., *Pseudocalanus* spp., *Centropages* spp.) and potentially euphausiids. [20,27] *Calanus spp.* phenology and the timing of the	[1]Watkins and Schevill 1976; [2]Murison and Gaskin 1989; [3]Mayo and Marx 1990; [4]Woodley and Gaskin 1996; [5]Osgood and Checkley Jr 1997; [6]Mayo et al. 2001; [7]Baumgartner and Mate 2003; [8]Genin 2004; [9]DeLorenzo Costa et al. 2006; [10]Johnson et al. 2006; [11]Davies et al. 2012, [12]2013; [13]Fortune et al. 2013; [14]McKinstry et al. 2013; [15]Davies et al. 2014; [16]Johnson et al. 2017; [17]DFO 2019; [18]Plourde et al. 2019; [19]Sorochan et al. 2019; [20]Lehoux et al. 2020; [21]Gavrilchuk et al. 2021; [22]Reviewed by Sorochan et al. 2021a; [23]Johnson 2022; [24]Meyer-Gutbrod et al. 2023; [25]Sorochan et al. 2023; [26]Helenius et al. 2024; [27]Johnson et al. 2024

Life Stage(s)	Function(s)	Feature(s)	Location	Attributes	Citation(s)
				phytoplankton bloom influencing the population levels of Calanoid copepods.	
		Prey supply	GMB and BoF	[1,2,6,8,9,11] *C. finmarchicus* C5 dominates species composition, but *C. hyperboreus* and *C. glacialis* are also present. [3,4,5,10] Overall threshold density of *C. finmarchicus* CV of >1,000 individuals m^{-3}, with >10,000 individuals m^{-3} required for lactating females. [3,5,7] Discrete and highly concentrated subsurface layers of late-stage *Calanus* spp. Discrete layers of *C. finmarchicus* C5 often occur near the bottom mixed layer.	[1]Conover 1988; [2]Stone et al. 1988; [3]Murison and Gaskin 1989; [4]Woodley and Gaskin 1996; [5]Baumgartner and Mate 2003; [6]Michaud and Taggart 2007; [7]Baumgartner et al. 2017; [8]Sorochan et al. 2019; [9]Plourde et al. 2019; [10]Gavrilchuk et al. 2021; [11]Sorochan et al. 2021a
		Prey supply	RB and SS	[1,2,5,6,7,9,10,12] *C. finmarchicus* is the dominant *Calanus* species but *C. hyperboreus and C. glacialis* can contribute significantly to abundance and biomass of Calanus in spring and summer. [3,4,11] Overall threshold density of *C. finmarchicus* C5 of >1,000 individuals m^{-3}, with >10,000 individuals m^{-3} required for lactating females. [3,4,6,7,8] Discrete and highly concentrated subsurface layers of late-stage *Calanus* spp.	[1]Conover et al. 1988; [2]Stone et al. 1988; [3]Murison and Gaskin 1989; [4]Baumgartner and Mate 2003; [5]Sameoto and Herman 1990; [6]Davies et al. 2013, [7]2014; [8]Baumgartner et al. 2017; [9]Sorochan et al. 2019; [10]Plourde et al. 2019; [11]Gavrilchuk et al. 2021; [12]Sorochan et al. 2021a
		Prey supply	SLE, nwGSL, sGSL Possibly NL	[1,5] Phenology of the three *Calanus* spp. influence the timing, vertical distributions, and stage composition of their aggregations. [3,6,7,8] High foraging habitat quality when considering 'local' species composition and regional differences in late stage *Calanus* spp. size and energy content. [1,2,4] Abundance of *C. glacialis* and *C. hyperboreus* is higher than the western SS and GoM, and the contribution of *C. hyperboreus* to overall biomass of	[1]Plourde et al. 2019; [2]Sorochan et al. 2019; [3]Lehoux et al. 2020; [4]Sorochan et al. 2021a, [5]2021b; [6]Johnson et al. 2024; [7]Plourde et al. 2024 NL: [8]Lawson et al. 2025

Life Stage(s)	Function(s)	Feature(s)	Location	Attributes	Citation(s)
				Calanus spp. in spring and summer is substantially higher than on the SS. [3,6] In spring, abundance and biomass of late-stage *Calanus* spp. is dominated by *C. hyperboreus* with a transition to a *C. finmarchicus* dominated complex in summer. [6] Abundant layers of zooplankton (>500 ind m^{-3}) at depths between 80 – 100 m and highest concentrations (> 1000 ind. m^{-3}) of *Calanus spp*. typically observed between 70 – 90 m, usually near the bottom and in close proximity to the Cold Intermediate Layer.	
All	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Marine Environment Bathymetric features i.e., bank, basin, canyon, continental shelf, continental slope/ ledge, seamount) Water column Water quality Air quality	Eastern Canadian habitats	[22,25] Phytoplankton bloom, temperature, and ocean circulation that influence the population level and supply of calanoid copepods in foraging areas [1,2,3,4,5,,7,10,11,12,13,14,15,17,18,19,21,22,24] Bathymetric features to retain and aggregate prey species at depths shallower than maximum NARW foraging depth: localized interactions of ocean currents with coastline or bathymetric features and prey-retaining basins or valleys providing habitat stability. [4,6,16] Relatively shallow bottom depth (e.g., < 200 m), zones of convergent or divergent flow characterized by surface slicks or strong density gradients in (i.e., fronts). [8,9,15,23,25] Water and air quality to not cause adverse health effects or result in loss of function.	[1]Gaskin 1987; [2]Plourde and Runge 1993; [3]Epstein and Beardsley 2001; [4]Baumgartner et al. 2003a; [5]Genin 2004; [6]Baumgartner and Mate 2005; [7]Johnson et al. 2006; [8]Chen et al. 2009; [9]Lachmuth et al. 2011; [10]Meyer-Gutbrod et al. 2018, [11]2021; [12]Michaud and Taggart 2011; [13]Davies et al. 2013, [14]2014; [15]Desforges et al. 2016; [16]Baumgartner et al. 2017; [17]Plourde et al. 2019; [18]Record et al. 2019; [19]Sorochan et al. 2019, [20]2021a; [21]Ross et al. 2021; [22]Sorochan et al. 2023; [23]Johnson et al. 2024; [24]Lehoux et al. 2024; [25]Vanderlaan et al. *In prep*.[2]

Life Stage(s)	Function(s)	Feature(s)	Location	Attributes	Citation(s)
		Marine Environment Bathymetric features i.e., bank, basin, canyon, continental shelf, continental slope/ ledge, seamount) Water column Water quality	BoF, GMB	[1,10,19] Proximate sources of *Calanus* spp. to the lower BoF include the NS Coastal Current, GoM, and slope water that enters the GoM from the North East Channel. [17,18] NARW residence time linked to *Calanus* biomass levels and shifts in phytoplankton and zooplankton communities. [7,8,13,14,15] Bottom topography, tidal-driven advection, and ocean circulation are believed to contribute to accumulation of *Calanus* spp., primarily in relatively warm and salty water at depths > 100 m in summer and fall. [5] Areas of both high and low topographic variation, depths between 80 – 240 m. [5,6,7,16] Large, persistent prey patches found near the bottom or the upper surface of the bottom mixed layer (max depth 200 m) and average dive depth was 121.2 m. [9,11,12] Very strong tidal currents that interact with coastline and bottom topography to produce a highly dynamic environment. [2,3,4,5] NARW associated with stratified waters, well-mixed waters with frequent upwelling, along fronts, and in transition zones between mixed, stratified waters and/or higher SST. [3,4,5,6,15] Higher sea surface temperatures ranging between 10 to 16 °C, with an average from 12.6 °C to 13.7 °C.	[1]Corey and Milne 1987; [2]Gaskin 1987; [3]Murison and Gaskin 1989; [4]Gaskin 1991; [5]Woodley and Gaskin 1996; [6]Baumgartner and Mate 2003; [7]Baumgartner et al. 2003a, [8]2003b; [9]Johnston et al. 2005; [10]Johnson et al. 2006; [11]Aretxebaleta et al. 2008; [12]Ingram et al. 2008; [13]Michaud and Taggart 2011; [14]Davies et al. 2013, [15]2014; [16]Baumgartner et al. 2017; [17]Johnson et al. 2017; [18]Fisheries and Oceans Canada 2019; [19]Record et al. 2019

Life Stage(s)	Function(s)	Feature(s)	Location	Attributes	Citation(s)
		Marine Environment Bathymetric features i.e., bank, basin, canyon, continental shelf, continental slope/ ledge, seamount) Water column Water quality	wSS, cSS (Emerald Basin)	[1,3] Sources of *Calanus* spp. include: the GSL outflow, slope water (e.g., Labrador Slope Water) via equatorward currents that flow along the coast and shelf break. [2,6,7] Deep basins that facilitate the accumulation and retention of migratory and resident copepods (Emerald Basin = deepest basins). [5,7,9,10] Large, persistent patches found near the bottom or the upper surface of the bottom mixed layer in RB (max depth 150 m). Highest concentration of *Calanus* spp. copepods observed between 75 – 120 m and average NARW dive depth was 102.5 m. [4,8,9] Large, persistent patches found near the bottom or the upper surface of the bottom mixed layer in EB (max depth ~290 m) characterized by warm, saline slope water below 100 m, low upwelling velocity, and increased light attenuation below 200 m.	[1]Gatien 1976; [2]Sameoto and Herman 1990; Herman et al. 1991; [3]Loder et al. 1998; [4]Baumgartner et al. 2003b; [5]Baumgartner and Mate 2005; [6]Michaud and Taggart 2011; [7]Davies et al. 2013, [8]2014, [9]2015; [10]Baumgartner et al. 2017
		Marine Environment Bathymetric features i.e., bank, basin, canyon, continental shelf, continental slope/ ledge, seamount)	sGSL	[2,3,5] Gaspé Current is a biologically productive environment and important source of zooplankton to the sGSL. [1] Relatively shallow bottom depths (typically < 100 m) and topographic variation in the form of banks and valleys. [1,4,6,7,10] Shallow bottom depth contributing to aggregation and availability near the sea floor however depth may impede persistence of high concentrations in specific locations. [8,9,10,11,12] NARW are associated directly with abundant layers of zooplankton (> 500 ind m^{-3}) at depths between	[1]Loring and Nota 1973; [2]Koutitonsky and Bugden 1991; [3]Brennan et al. 2019; [4]Plourde et al. 2019; [5]Benkort et al. 2020; [6]Sorochan et al. 2021a, [7]2021b; [8]Johnson et al. 2022; [9]Sorochan et al. 2023; [10]Le Corre et al. 2023 [11]Wright et al. 2024; [12]Johnson et al. 2024

Life Stage(s)	Function(s)	Feature(s)	Location	Attributes	Citation(s)
		Water column		80 – 100 m but highest concentrations (> 1000 ind m^{-3}) of *Calanus* spp. have typically been observed between 70 – 90 m, usually near the bottom and in close proximity to the Cold Intermediate Layer.	
All	Foraging/ Feeding Gestation/ Growth Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Physical space and corridor	Eastern Canadian habitats	[1,2,3,8,14,16,17,20,22] Physical space, including the vertical and horizontal planes of the water column, to allow animals to move freely and unimpeded by physical obstructions and not alter behavioural functions at and below the surface. [1,5,6,7,8,9,10,12,13,17,18,19] Unimpeded space to complete movement and behavioural functions (i.e. density of physical obstructions). [4,6,7,8,9,11,15,20,21,22,23,24] Habitat connectivity to successfully immigrate, emigrate, and facilitate seasonal movements in and out of known feeding habitats (e.g., BoF, RB, EB, sGSL and nGSL) and other occasional feeding habitats (e.g., eastern NL).	[1]Watkins and Schevill 1976; [2]Mayo and Marx 1990; [3]Goodyear 1993; [4]Nieukirk 1993; [5]Mate et al. 1997; [6]Kenney et al. 2001; [7]Nowacek et al. 2001; [8]Baumgartner and Mate 2003, [9]2005; [10]Clark et al. 2010; [11]Vanderlaan 2010; [12]Parks et al. 2012; [13]Hain et al. 2013; [14]Nousek-McGregor et al. 2014; [15]Brillant et al. 2015; [16]Baumgartner et al. 2017; [17]van der Hoop et al. 2017; [18]Cusano et al. 2018; [19]Hamilton and Kraus 2019; [20]van der Hoop et al. 2019; [21]Simard et al. 2024; [22]Wright et al. 2024; [23]Lawson et al. 2025; [24]Moors-Murphy et al. 2025
		Physical space and corridor	SLE, nwGSL, sGSL	[1,2,3] NARWs may feed on both active and diapausing *Calanus* and can change foraging strategies (i.e., feeding throughout entire water column) throughout the season to exploit varying prey composition.	[1]Sorochan et al. 2021b; [2]Franklin et al. 2022; [3]Wright et al. 2024
All	Foraging/ Feeding Rearing/ Nursing/ Socialization Social/ Reproduction Movement/ Migration	Acoustic environment	Eastern Canadian habitats	[1,4,5,7,10,11,17,18,23,25,26] Received sound levels below a level that would impact: acoustic social communication, health parameters, navigation, or impede use of important habitat by NARWs s. [7,23] Sound perception i.e., predicted hearing range within 20 Hz to 22 kHz. [3,22,23] Sound level > than ambient noise level (e.g., 250 Hz at 10 km from source, > 80 dB re 1 $\mu Pa^2/Hz$).	[1]Kraus and Hatch 2001; [2]Nowacek et al. 2004; [3]Parks 2003; [4]Vanderlaan et al. 2003; [5]Parks and Tyack 2005; [6]Nowacek et al. 2007; [7]Parks et al. 2007; [8]Clark et al. 2009; [9]Simard et al. 2010; [10]Parks et al. 2011b; [11]Hatch et al. 2012; [12]Simard et al. 2014; [13]Williams et al. 2015; [14]Gervaise et al. 2015; [15]Aulanier et al. 2016; [16]Gomez et al. 2016; [17]Cholewiak et al. 2018; [18]Erb et al. 2019; [19]Gervaise

Life Stage(s)	Function(s)	Feature(s)	Location	Attributes	Citation(s)
				[2] NARWs do not respond solely to noise source level (e.g., NARW respond to alert signals between 133-148 dB re 1 μPa^2/Hz however, not for vessel noise in same sound source levels). [6,8,9,12,13,14,15,16,19,20,21,24,27,28,29] Anthropogenic noise in several eastern Canadian environments described as persistent and pervasive noisy soundscapes mostly within the NARW low frequency communication range.	et al. 2019a, [20]2019b; [21]Simard et al. 2019; [22]Parks et al. 2019; [23]Matthews and Parks 2021; [24]Marotte and Wright et al. 2022; [25]Johnston and Painter 2024; [26]Pirotta et al. 2023; [27]Simard et al. 2024; [28]Lawson et al. 2025; [29]Moors-Murphy et al. 2025

APPENDIX 4. DESCRIPTION OF SUPPLEMENTAL DATA

Behaviour code descriptions as provided with data exports from the NARWC Identification Catalogue, New England Aquarium (accessed, May 2023). Behaviours are separated into functional categories, which are generally described below and include the data source used. Further clarification and specific descriptions of the NARWC catalogue codes are found in Table A4.1. Table A4.4 includes a breakdown of the behaviour codes by decade (1990-2021) and areas of observation. Of note, several behaviours can be attributed to a single NARW within a sighting event (Table A4.5). For example, this means that a mother-calf pair observed feeding would be counted in both ‘rearing’ and ‘foraging’ if there were associated behaviours for each type.

FORAGING AND FEEDING

There are a variety of observable feeding behaviours that can be linked to the location in the water column (Table A4.2). Most of the observed feeding behaviours include surface and sub-surface feeding where the NARW are observed with their mouth agape. Other observable features point to bottom contact (e.g., ‘MUD’) associated with whales diving to the bottom to feed. All codes within this category, including descriptions, can be found in Table A4.2- Feeding.

GESTATION

The gestation period for NARW has generally been accepted as being in the range of roughly 12-13 months, although research on baleen steroid hormones suggests that gestation length could be between 18-24 months (N. Lysiak, pers. comm.; Hunt et al. 2016; Lysiak et al. 2018; Lysiak et al. 2023). The data used to identify when and where pregnant females were observed included: cross-referencing the annual list of new mothers (Year) and those mothers in the Identification Database in Year-1 and Year-2 to account for uncertainties in gestational length (Table A4.3).

REARING

These behaviours are exclusive of the codes used to identify foraging and are broken down by specific rearing functions: gestation, nursing, and socialization. Aside from the data required to identify gestation, the source of the data for this category is derived from the associated behaviour codes in the dataset provided (Table A4.2).

NARW calves stay with their mothers typically until the end of their birth year (Hamilton et al. 2022), with the vast majority of births occurring in southern USA waters. Nursing does occur in Canadian waters, with mothers observed in Canada as early as May, and NARW mothers nurse their calves for up to a year (Brown and Sironi 2023). There are multiple codes within the behaviour data attributed to rearing that include observed nursing events and exclude gestation (described below). A behaviour code for an observation of a mother cradling a calf (CRDLE) was excluded from this table. The only sightings in Canada with this behaviour were on July 18, 2021 in the GSL, and involved an adult male and sexually immature calf, described further by Lonati et al. (2022).

NURSING

Nursing is identified by the observation of the calf distally aligned below the mother for extended time and the mother seemingly resting at the surface (Table A4.4).

SOCIALIZATION

Socialization is surmised by the association of the mothers and calves and summarized by combining multiple behaviour codes as described in Table A4.2. Processes for socialization are described within the ‘Rearing, Nursing, and Socialization’ section of this document. In Table A4.2, the females associated with yearlings (i.e., a NARW is a yearling as of December 1 of that year), codes W/YRLG and YRLG W/MOTHER, were also added within the socialization context. However, there is only one instance of each of these in Canada, solely in the BoF in 2003 (Table A4.4).

SOCIALIZING AND REPRODUCTION

The function of SAG activity is described in the ‘Socializing and Reproduction’ section of this document (Table A4.4).

Table A4.1: Summary of total sightings with behaviour codes of interest available in the provided North Atlantic right whale Consortium Identification Database from 1990-2021 in Canadian.

Canadian Areas Only		**Time Period (years 1990-2021)**		
Total Sightings in Canadian waters	Total Sightings with applicable Behaviour	**1990-1999**	**2000-2009**	**2010-2021**
30,179	11,954	3,370	5,883	2,701

Table A4.2: Descriptions of observed North Atlantic right whale (NARW) Consortium Identification Database behaviour codes sorted by functional behaviours considered to inform NARW jabitat use in Canadian waters.

Functional Behaviour Category	**NARW Behaviour codes examined**	**Description**
Rearing (calf)/ socialization	NURS	Probable nursing
	CALF	Calf alone (separated by several hundred yards or more)
	CALF OF UNPH MOTHER	Calf with unphotographed mother
	CALF W/ OTHER(S)	Calf with whale(s) other than mother (SAG, another calf)
	CALF W/MOTHER	Calf of mother/calf pair
	CALF W/ UNPH	Calf with unphotographed whale(s)
	W/CALF	Mother of a mother/calf pair
Rearing (yearling)/ socialization	W/YRLG	Mother of mother/calf pair; whale becomes yearling Dec 1
	YRLG W/MOTHER	Yearling of mother/calf pair with mother from previous year; whale becomes yearling Dec 1
Socializing (non-reproductive social behaviour i.e., Jan-Sept sightings only)	SAG	Two or more whales rolling and touching at the surface
Reproduction or non-reproductive social behaviour	INTRO	Intromission penis insertion; applicable even if both males
	PENIS	Penis observed; only if known which whale it belongs to

Functional Behaviour Category	NARW Behaviour codes examined	Description
	SAG	Two or more whales rolling and touching at the surface
Foraging / Feeding	CO FD	Coordinated feeding; two or more whales, not in echelon
	ECH	Echelon feeding; when two or more animals swim in a tight "V" formation like geese flying
	FEED	Unspecified type of feeding; use only if data are unclear
	MUD	Mud anywhere on the body; record where
	NOD	Nodding; specific to skim feeding. The mouth remains open as the whale nods its head - presumably to flush its baleen
	SIDE FD	Feed on side; this behavior is most often detected from the air and can be combined with any of the other feeding behaviors.
	SKM FD	Skim feeding; consider it skim feeding if any part of the rostrum breaks the surface of the water.
	SUB FD	Subsurface feeding; use if the rostrum does not break the surface of the water.

Table A4.3: Summary of gestational behaviour 'observations' from 1990-2023 identified from the North Atlantic right whale (NARW) Consortium Identification Database provided cross-referenced with the list of 'ALL' mothers from 1991-2023. The full list of confirmed mothers in the population for each year (BIRTH YEAR; Y) was provided by the New England Aquarium. From this list (BIRTH YEAR), a summary of the mothers observed in Canada in their CALF YEAR (Y), PREGNANT YEAR (Y-1), PREGNANT YEAR minus 2 (Y-2). Discrepancy in the numbers in Canadian columns (three columns on the right; grey scale) should reflect, at minimum, the number of female NARW feeding in Canadian waters while pregnant (Y-1 and Y-2). Mothers may not bring their calf to Canada but may have been feeding in years previous while pregnant. The area where pregnant females were observed is summarized in Table A4.4 below.

Year (Y)	BIRTH YEAR (Y) ALL mothers observed in current year	CALF YEAR (Y) ALL mothers observed with calf **in Canadian areas** i.e., rearing	PREGNANT YEAR (Y-1) ALL females identified in BIRTH YEAR column observed in Canada in previous year i.e., gestation	PREGNANT YEAR (Y-2) ALL females identified in BIRTH YEAR column observed in Canada in two years previous i.e., gestation
1990	10	9	0	0
1991	12	10	3	0
1992	8	5	2	0

Year (Y)	BIRTH YEAR (Y) ALL mothers observed in current year	CALF YEAR (Y) ALL mothers observed with calf **in Canadian areas** i.e., rearing	PREGNANT YEAR (Y-1) ALL females identified in BIRTH YEAR column observed in Canada in previous year i.e., gestation	PREGNANT YEAR (Y-2) ALL females identified in BIRTH YEAR column observed in Canada in two years previous i.e., gestation
1993	5	4	1	0
1994	7	4	3	1
1995	3	3	3	2
1996	14	14	10	10
1997	13	11	8	9
1998	1	0	0	0
1999	4	0	0	1
2000	0	0	0	0
2001	24	20	15	16
2002	13	7	2	4
2003	18	15	11	11
2004	14	9	5	6
2005	25	16	0	5
2006	18	13	12	5
2007	20	13	7	10
2008	23	16	8	9
2009	36	20	11	9
2010	19	13	10	7
2011	18	15	4	8
2012	5	1	0	0
2013	15	2	8	3
2014	7	3	0	1
2015	12	5	4	0

Year (Y)	BIRTH YEAR (Y) ALL mothers observed in current year	CALF YEAR (Y) ALL mothers observed with calf **in Canadian areas** i.e., rearing	PREGNANT YEAR (Y-1) ALL females identified in BIRTH YEAR column observed in Canada in previous year i.e., gestation	PREGNANT YEAR (Y-2) ALL females identified in BIRTH YEAR column observed in Canada in two years previous i.e., gestation
2016	13	6	4	2
2017	5	0	0	0
2018	0	0	0	0
2019	6	4	4	4
2020	8	5	5	5
2021	18	8	10	9
2022	15	5	6	7
2023	11	4	4	5

Table A4.4: Summary of North Atlantic right whale (NARW) Consortium (NARWC) functional behaviour categories by relevant Canadian area (see Appendix 2) and decade analysed. Rearing (Nursing), Foraging and Feeding, and Social and Reproduction functional behaviour categories are summarized from the behaviour codes in the provided NARWC Identification Database and Gestation numbers are summarized by area as per Table 4.3. NOTE: The number of observations per decade are influenced by the effort in those areas during each time period, which is not taken into consideration within this analysis.

		Time Period (years 1990-2021)		
Area	**Functional Behaviour Category**	**Decade 1 (1990-1999) # sightings**	**Decade 2 (2000-2009) # sightings**	**Decade 3 (2010-2021) # sightings**
BoF	Rearing/ Socialization (Nursing)	939 (4)	2329 (166)	289 (21)
BoF	Socializing/ Reproduction	1723	2816	481
BoF	Foraging/ Feeding	646	910	433
BoF	Gestation (# of unique females)	105(25)	356(49)	17(5)
CS	Rearing/ Socialization (Nursing)	0	0	3

Area	Functional Behaviour Category	Time Period (years 1990-2021)		
		Decade 1 (1990-1999) # sightings	Decade 2 (2000-2009) # sightings	Decade 3 (2010-2021) # sightings
CS	Socializing/ Reproduction	0	0	7
CS	Foraging/ Feeding	1	0	0
CS	Gestation (# of unique females)	0(0)	0(0)	0(0)
eSS	Rearing/ Socialization (Nursing)	0	0	0
eSS	Socializing/ Reproduction	0	0	0
eSS	Foraging/ Feeding	0	0	0
eSS	Gestation (# of unique females)	0(0)	0(0)	0(0)
GB-CAN	Rearing/ Socialization (Nursing)	0	0	0
GB-CAN	Socializing/ Reproduction	2	13	23
GB-CAN	Foraging/ Feeding	2	1	40
GB-CAN	Gestation (# of unique females)	1(1)	2(2)	6(5)
GoM-CAN	Rearing/ Socialization (Nursing)	0	3 (2)	5
GoM-CAN	Socializing/ Reproduction	3	4	6
GoM-CAN	Foraging/ Feeding	1	3	7
GoM-CAN	Gestation (# of unique females)	2(1)	4(4)	2(2)

Area	Functional Behaviour Category	Time Period (years 1990-2021)		
		Decade 1 (1990-1999) # sightings	**Decade 2 (2000-2009) # sightings**	**Decade 3 (2010-2021) # sightings**
wSS	Rearing/ Socialization (Nursing)	4	2	4 (2)
wSS	Socializing/ Reproduction	204	354	34
wSS	Foraging/ Feeding	0	4	14
wSS	Gestation (# of unique females)	7(5)	18(11)	9(7)
SLE	Rearing/ Socialization (Nursing)	0	0	0
SLE	Socializing/ Reproduction	0	0	0
SLE	Foraging/ Feeding	0	0	0
SLE	Gestation (# of unique females)	0(0)	0(0)	0(0)
cSS	Rearing/ Socialization (Nursing)	0	1	0
cSS	Socializing/ Reproduction	0	0	0
cSS	Foraging/ Feeding	0	0	0
cSS	Gestation (# of unique females)	0(0)	0(0)	0(0)
nNFLD	Rearing/ Socialization (Nursing)	0	0	0
nNFLD	Socializing/ Reproduction	0	0	0
nNFLD	Foraging/ Feeding	0	0	1

Area	Functional Behaviour Category	Time Period (years 1990-2021)		
		Decade 1 (1990-1999) # sightings	**Decade 2 (2000-2009) # sightings**	**Decade 3 (2010-2021) # sightings**
nNFLD	Gestation (# of unique females)	0(0)	0(0)	0(0)
neGSL	Rearing/ Socialization (Nursing)	0	0	0
neGSL	Socializing/ Reproduction	0	0	0
neGSL	Foraging/ Feeding	0	0	0
neGSL	Gestation (# of unique females)	0(0)	0(0)	0(0)
nwGSL	Rearing/ Socialization (Nursing)	0	0	2
nwGSL	Socializing/ Reproduction	0	0	53
nwGSL	Foraging/ Feeding	0	0	2
nwGSL	Gestation (# of unique females)	0(0)	0(0)	19(3)
sGSL	Rearing/ Socialization (Nursing)	0	12	287 (56)
sGSL	Socializing/ Reproduction	3	14	901
sGSL	Foraging/ Feeding	0	0	289
sGSL	Gestation (# of unique females)	4(1)	7(2)	252(29)

Table A4.5: Summary of North Atlantic right whale (NARW) Consortium (NARWC) functional behaviour co-occurrence by relevant Canadian area. The proportion of the total number observed per decade is presented. NOTE: The number of observations and proportion per decade can be a reflection of effort in those areas during each time period, which is not taken into consideration within this analysis.

		Behavioural Function				**Time Period**		
Area	**No. of Co-occurring Functions**	**Rearing / Socialization (Nursing)**	**Socializing/ Reproduction**	**Foraging/ Feeding**	**Total Sightings**	**1990-1999**	**2000-2009**	**2010-2021**
BoF	1	FALSE	FALSE	**TRUE**	1345	40%	37%	24%
BoF	1	FALSE	**TRUE**	FALSE	4446	36%	55%	9%
BoF	1	**TRUE**	FALSE	FALSE	3043	28%	65%	7%
BoF	2	FALSE	**TRUE**	**TRUE**	344	22%	63%	15%
BoF	2	**TRUE**	FALSE	**TRUE**	285	12%	66%	22%
BoF	2	**TRUE**	**TRUE**	FALSE	215	20%	71%	9%
BoF	3	**TRUE**	**TRUE**	**TRUE**	15	13%	80%	7%
CS	1	FALSE	FALSE	**TRUE**	1	100%	0%	0%
CS	1	FALSE	**TRUE**	FALSE	7	0%	0%	100%
CS	1	**TRUE**	FALSE	FALSE	3	0%	0%	100%
GB-Can	1	FALSE	FALSE	**TRUE**	43	5%	2%	93%
GB-Can	1	FALSE	**TRUE**	FALSE	38	5%	34%	61%

Area	No. of Co-occurring Functions	Behavioural Function			Total Sightings	Time Period		
		Rearing / Socialization (Nursing)	Socializing/ Reproduction	Foraging/ Feeding		1990-1999	2000-2009	2010-2021
GoM-Can	1	FALSE	FALSE	**TRUE**	10	10%	30%	60%
GoM-Can	1	FALSE	**TRUE**	FALSE	13	23%	31%	46%
GoM-Can	1	**TRUE**	FALSE	FALSE	7	0%	43%	57%
GoM-Can	2	**TRUE**	FALSE	**TRUE**	1	0%	0%	100%
wSS	1	FALSE	**TRUE**	FALSE	591	35%	60%	6%
wSS	1	**TRUE**	FALSE	FALSE	10	40%	20%	40%
wSS	1	FALSE	FALSE	**TRUE**	17	0%	18%	82%
wSS	2	FALSE	**TRUE**	**TRUE**	1	0%	100%	0%
cSS	1	**TRUE**	FALSE	FALSE	1	0%	100%	0%
nNFLD	1	FALSE	FALSE	**TRUE**	1	0%	0%	100%
nwGSL	1	FALSE	FALSE	**TRUE**	2	0%	0%	100%
nwGSL	1	FALSE	**TRUE**	FALSE	53	0%	0%	100%
nwGSL	1	**TRUE**	FALSE	FALSE	2	0%	0%	100%
sGSL	1	FALSE	**TRUE**	FALSE	886	0%	2%	98%

Area	No. of Co-occurring Functions	Behavioural Function			Total Sightings	Time Period		
		Rearing / Socialization (Nursing)	Socializing/ Reproduction	Foraging/ Feeding		1990-1999	2000-2009	2010-2021
sGSL	1	**TRUE**	FALSE	FALSE	265	0%	5%	95%
sGSL	1	FALSE	FALSE	**TRUE**	273	0%	0%	100%
sGSL	2	FALSE	**TRUE**	**TRUE**	9	0%	0%	100%
sGSL	2	**TRUE**	FALSE	**TRUE**	7	0%	0%	100%
sGSL	2	**TRUE**	**TRUE**	FALSE	25	0%	0%	100%
sGSL	3	**TRUE**	**TRUE**	**TRUE**	2	0%	0%	100%

APPENDIX 5. DETAILS OF INDIVIDUAL NARW SIGHTING HISTORY

Table A5.1: Demographic information of example individual North Atlantic right whales (EgNo = idividual's catalog number) and their movement patterns amongst Canadian habitats within a year as depicted in Figure 28.

EgNo	Name	Demographic	Age at Year	Year	No. of areas	1st Area	2nd Area	3rd Area	4th Area	5th Area
3125	.	M	18	2019	5	sGSL (July 4 ENT, *tagged July 19-22)	CS (July 23, 24)	eSS (July 25, 26)	cSS (July 27, 28)	wSS (July 29, 30)
3191	Waldo	M	> 20	2020	3	sGSL (June 6-22)	CS (Aug 11)	nwGSL (Sept 19, Oct 1)	sGSL (Oct 26)	
3746	.	M	10	2017	3	sGSL (June 6)	CS (June 23, 25)	neGSL (July 5)		
3845	Mogul	M	11	2019	2	nNFLD (Sept 19)	sGSL (Oct 28, 29)			
1271	Dropcloth	M	> 43	2021	2	sGSL (June 20-Aug 31)	CS (Oct 13, 19)			
4040	Chiminea	F	10	2018	2	sGSL (June 6-Jul 11)	nwGSL (July 19)	sGSL (Aug 17)		
3308	Sierra	F	11	2014	3	cSS (July 22)	BoF (Aug 8)	wSS (Aug 20)		
1245	Slalom	F	35	2017	2	sGSL (July 29)	BoF (Aug 3)	sGSL (Aug 22)		
3890	Babushka	F	14	2022	2	sGSL (June 12-Aug 25)	BoF (Sept 10)			
1934	Sagamore	F	31	2020	2	sGSL (July 3,16, 2)	nwGSL (Aug 3,11)			
4523	Beaker	calf with mom	< 1	2015	3	sGSL (Aug 10, 19)	RB (Sept 17)	BoF (Sept 26)		
3157	Cascade	mom with calf	13	2014	2	CS (July 13)	BoF (July 26-Aug 18, 21)			